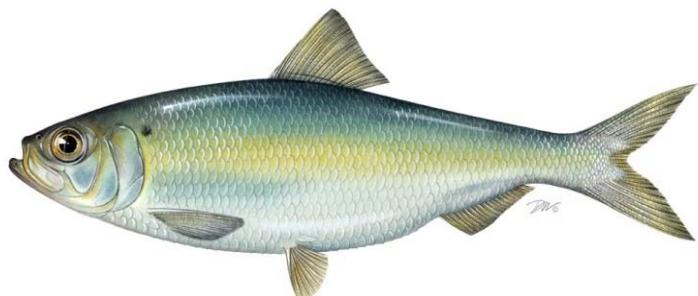


Atlantic States Marine Fisheries Commission

River Herring Stock Assessment Update *Volume II: State-Specific Reports*



August 2017



Vision: Sustainably Managing Atlantic Coastal Fisheries

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5 Status of River Herring in Maine

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Executive Summary

New England has a rich history of fishing and fishermen that capitalized on the abundant fisheries resources available to harvest in the Gulf of Maine. Anadromous fish were among the first species utilized as they ascended rivers and streams on spring spawning migrations. John Pory provided the first written accounts of river herring (alewife and blueback herring) abundance in New England in 1622 (Watts 2003). John Josellyn (1674) further documented accounts of river herring in Maine, then still part of Massachusetts, when describing harvest by two fishermen using stone weirs. Watts (2003) provides verbatim copies of historical documents regarding the importance of river herring in New England back to the 17th century. These texts provide a rich history of the utilization of river herring throughout New England. These historical accounts provide a background for many of the management and social issues related to managing river herring in New England today.

Maine retains some of the last healthy runs of river herring in New England. Maine's directed commercial fisheries are self-sustaining and all operate under sustainable fisheries management plans cooperatively developed between the municipalities that own rights to harvest the river herring resource and the State of Maine. While reported landings of Maine river herring have declined from historical levels in the 1950s. The State of Maine has made significant progress in increasing run size and populations numbers at several locations. Newly established runs in the Kennebec, Sebasticook and Penobscot rivers and Chemo, Pushaw and Webber ponds return an estimated 5.0 million fish that were not in existence during the last coast wide river herring assessment.

5.1 INTRODUCTION

Alewife and blueback herring, collectively known as river herring, are two of eleven species of anadromous fish found in Maine. Anadromous fish spend most of their life at sea and return to freshwater to spawn. River herring historically occurred in all major and minor coastal watersheds in the state (Watts 2003). The majority of adults return as first-time spawners at ages four and five. Spawning can commence as early as mid-April and typically ends by late July. Blueback herring spawn later than alewives and spawning dates are successively later as you move from west to east along Maine's coast.

Watts attributes the earliest declines in these populations to dam construction and industrial pollution, which rendered many waters unsuitable for river herring migration into freshwater spawning and nursery habitats. Protection of spawning populations of alewives began as early as the 1700s. Fish passage requirements at hydroelectric dams, a fishway construction program by the state, and restoration efforts in Maine over the past 30 years have significantly increased the amount of available spawning habitat.

River herring have supported important municipal commercial fisheries since colonial times. Prior to dam construction on the larger river systems, inland towns such as Clinton and Newport on the Sebasticook River, 80 miles inland, had exclusive rights to harvest river herring. Currently, 38 municipalities maintain exclusive rights to harvest river herring. At the January 2017 Board meeting the

Atlantic States Marine Fisheries Commission approved sustainable fisheries management plans for 22 municipalities that will continue to fish in 2017. The majority of the harvest is sold as lobster bait, though a small percentage of the landings are smoked and utilized for human consumption.

5.2 MANAGEMENT UNIT DEFINITION

Municipal boundaries are the units used to manage Maine's river herring resources in inland waters. River herring resources that migrate inland, beyond the immediate coastal waters of the state, are property of the municipality. The Maine Department of Marine Resources (DMR) and respective municipality cooperatively manage river herring resource within the management unit. The coastal area outside municipal boundaries is closed to all commercial fishing for river herring by state law.

5.3 REGULATORY HISTORY

5.3.1 Regulation History

As early as 1706, the Town of Middleborough, Massachusetts, passed laws restricting the harvest to those planting corn (Watts 2003). The number of fish allotted for harvest was in direct proportion to the amount of corn a person planted for the season. Those not planting corn were not allotted fish for that year. These early conservation measures indicate the important role river herring held during the colonial period. Through the years several laws were passed, the most significant were those related to upstream passage at the numerous mill dams that existed during that time. In Massachusetts, upstream fish passage laws began as early as 1735. From this point forward, many of the regulations dealt with partitioning the resource among user groups and fishing methods used to harvest fish. Many of these regulations and traditional uses of the resource continue today.

Beginning in 1960 and running through 1987 the State of Maine recommended a one day closed period per week to allow river herring escapement to spawning grounds. Most municipalities, though not all, instituted the one closed day per week. From 1988-1994 the state required that all municipalities have two closed days or a conservation equivalent to ensure spawning escapement. In 1995, the state required three closed days or a conservation equivalent.

5.3.2 Current Regulations

The Department of Marine Resources, along with municipalities granted the exclusive rights to harvest river herring resources, cooperatively manage the municipal fisheries. Each town must submit an annual harvesting plan to DMR for approval that includes a three-day per week escapement period or biological equivalent to insure conservation of the resource. In some instances, an escapement number is calculated and the harvester passes a specific number upstream to meet escapement goals. River herring runs not controlled by a municipality and not approved as sustainable by the ASMFC River Herring and American Shad Management Board are closed to commercial harvest.

Each run and harvest location is unique, either in seasonality, fish composition, or harvesting limitations. Some run specific management plans require continuous escapement and are more restrictive than the three day closed period. Others have closed periods shorter than the three-day requirement, but require an escapement number, irrespective of the number harvested during the season. Maine increased the weekly fishing closure from a 24-hour closure in the 1960s to 48-hour closure beginning in 1988. The closed period increased to 72-hours beginning in 1995 to protect spawning fish (Figure 5.1). Most towns operate a weir at one location on each stream and law prohibits fishing at any other location on the stream. The state landings program compiles in-river landings of river herring from

mandatory reports provided by the municipality under each municipal harvest plan or they lose exclusive fishing rights.

The state will permit twenty-two municipalities to fish for river herring in 2017. The river specific management plans require the remaining municipalities to close their runs for conservation and not harvest. There are several reasons for the state/municipal restrictions imposed on these fisheries. Many municipalities voluntarily restrict harvest to increase the numbers of fish that return in subsequent years. Some of these runs are large, but have the potential to become even larger and some suffer from lack of good upstream or downstream fish passage. The commercial fishery does not exploit the estimated 1.5 – 2.0 million river herring that return to the East Machias River or the millions of fish in the main stem of Maine's nine largest rivers.

Recreational fishermen are allowed to fish for river herring year-round but are restricted to four fishing days a week to allow river herring an opportunity to reach spawning habitats. Access to river herring populations for recreational anglers is poor and as a result, landings are low. The three day closed period required for commercial fishermen is also required for recreational anglers. The limit is 25 fish per day and gear is restricted to dip net and hook-and-line. Recreational fishermen may not fish in waters, or in waters upstream, of a municipality that owns fishing rights. Recreational fishermen are not required to report their catch. The MRIP program does sample some of these fishermen based on results queried from the database.

5.3.3 Alewife Fishing Rights (Alewife and Blueback Herring)

The Commissioner is authorized to develop, manage, or lease alewife fishing rights as follows.

- 1) River herring rights: The commissioner shall grant the right, exclusive or otherwise, to take river herring to any municipality entitled to those rights on January 1, 1974 and may grant the right to take river herring to any other municipality provided:
 - A. Any municipality that has had the right to take river herring, exclusive or otherwise, or is granted that right by the commissioner, shall take action through its legislative body and file a copy of this action with the commissioner prior to April 20th or lose that right for the remaining part of that year.
 - B. Municipal rights in existence on January 1, 1974 which are not exercised for three consecutive years shall lapse.
 - C. At its annual meeting the municipality may determine by vote:
 - (1) Whether river herring fishing will be operated by the municipality through the municipal officers or a committee.
 - (2) Whether the municipal rights to take river herring will be sold by the municipal officers or committee.
- D. Harvesting plans shall be developed as follows.
 - (1) Any municipality engaged in harvesting river herring shall submit a written harvesting plan to the commissioner prior to April 20th of each calendar year. All harvesting plans shall set forth in detail the exact conditions under which alewives may be taken, all in accordance with good conservation practices.
 - (2) The commissioner, after consultation with the appropriate municipal officers, shall approve or modify the harvesting plan as he deems necessary for the conservation of river herring and other anadromous fish, and shall file a copy of the approved plan with the clerk of the municipality.

Limitations. The following limitations apply to any grant:

- A. It shall be unlawful to take river herring from 6 a.m. each Saturday morning until 6 a.m. Sunday morning. Municipalities which make other provisions for escape of spawning river herring, which are approved by the commissioner, shall be exempt from this limit.
- B. It shall be unlawful for any municipality or purchaser or lessee of the municipal right to take river herring in any manner except as provided in the approved river herring harvesting plan.

Closed period in rivers and streams not under lease agreement. In any river or stream not managed under a lease agreement, there is a 72-hour closed period on the taking of river herring and obstruction of the watercourse to allow the free passage of fish from 6 a.m. on Thursday to 6 a.m. the following Sunday.

5.4 ASSESSMENT HISTORY

Maine has not conducted a formal coast wide assessment of its river herring resources. The length of Maine's coastline and number of watersheds that support river herring make a coast wide assessment difficult. Each water body supporting a river herring run is a separate spawning stock with adults homing to natal spawning and rearing locations. Current river herring assessments focus on individual spawning runs and river specific populations and take into account species composition, run timing, and genetic differences among stocks.

River herring assessment data and analysis include annual mortality estimates, passage counts, landings, age at length, repeat spawning and juvenile abundance. Ratios of escapement to returns 4-5 years later provided data to justify an increase or decrease harvest rates and monitor spawning success. Crecco (1990) conducted the most recent ASMFC assessment for the Damariscotta fishery. Crecco determined that the Damariscotta River alewife fishery was severely over fished. Commercial exploitation rates for the fishery ranged from 90 to 98 percent. After this assessment, the Town of Damariscotta closed the fishery for 8 years to rebuild the run. It is unclear what impact the poor condition of the fishway had on escapement and harvest.

The Damariscotta river herring run is the most studied run in Maine. Its proximity to the coast and size of the run provide large numbers of study fish for researchers. Historically the commercial catches of alewives were large compared to most Maine alewife runs. Numerous studies investigated the sex ratio of river herring returns to the fishway, parent-progeny relationships, and efficiency of the fishway for male and female alewives.

Walton's (1987) research investigating the parent-progeny relationship of alewives entering the lake to spawn. His research indicates that the number of spawning females and numbers juvenile emigrants are asymptotically related. Despite the annual variability in estimated egg deposition the numbers of juveniles produced remained relatively constant throughout the eight year study. His conclusion is that the ability of Maine's lakes to produce alewives is finite and that year class strength is established prior to juvenile emigration from spawning habitats

5.5 STOCK SPECIFIC LIFE HISTORY

5.5.1 Alewife

Adults typically enter rivers from early May to early June and swim upstream into lakes, ponds, and dead water habitats to spawn. The temperature range for spawning is 12.8-15.5 °C. Each female produces 60,000-100,000 eggs, depending upon the size of the individual fish. The majority of the surviving spent adults then make their way downstream shortly after spawning. Early spawners can be seen migrating seaward and passing later run spawners that are still migrating upriver. Eggs, which are about 1.3 mm in diameter, hatch in about three days at 22 °C and six days at 15.5 °C. The seaward migration of young generally occurs from mid-July through early December at a size range of 32-152 mm. Size at emigration depends upon the availability of feed in the lakes, the total numbers of young produced in a particular watershed, and the length of time the fish remain in the freshwater environment.

There are populations of dwarf anadromous alewives found in eastern Maine. These runs were located in ponds in the Bagaduce River. Two of these runs no longer exist. Walker Pond still has a population of dwarf alewives and their life history does vary from those of typical anadromous alewives in that the juveniles remain in nursery habitat for 16 months compare to the typical 4 months (Walton & Smith 1974).

Little is known about the life history of either alewife or blueback herring after they migrate to sea. Trawl survey data indicate that one and two year olds inhabit the coastal waters of Maine in the spring and fall. Abundance, species composition, and number at length change annually. Survey trawls at most of the 90 survey locations capture one or both of these species (Sherman 2001).

5.5.2 Blueback Herring

Blueback herring spawning requirements differ slightly from those of the alewife. Blueback herring spawn from Nova Scotia to northern Florida, but are most numerous in warmer waters from Chesapeake Bay south. Females usually reach 100% maturity by age 5 and produce 60,000-103,000 eggs, whereas males generally mature at an earlier age (ages 3-4) and smaller size than females. Once the young-of-the-year leave the rivers they over winter near the coast. After the first winter, little information about their migratory or feeding behavior is available.

There is little stock specific life history data available for individual stocks of blueback herring. In Maine, stocks of blueback herring spawn in the main stem rivers and larger tributaries. Spawning occurs in late May through July dependent on water temperature. The commercial alewife fishery does capture some blueback herring during the first week of June but the numbers are low. The occurrence of blueback herring does increase toward the end of the alewife-fishing season and continues to increase after commercial fishermen remove gear from the river. The reopening of the Sebasticook River allowed recolonization of the river in 2008 from the main stem Kennebec River. The Sebasticook River now has a blueback run of over 1-million fish. The East Machias, Orland and St. George rivers have significant blueback populations that are protected under Maines' commercial harvest regulations.

Blueback herring populations in Maine appear to be increasing in the upper regions of Maines watersheds because of fish passage and restoration efforts. The main stem Kennebec and Sebasticook Rivers support estimated populations of several million fish. The Department expects this number to grow after upstream passage is installed on the Kennebec River at three additional main stem dams.

5.5.3 Growth

The growth of juvenile alewives is dependent on the nursery and rearing habitat they occupy. Juveniles resulting from stocking pre-spawn alewives, during the same day but at different locations, exhibit different growth rates. This depends largely on the trophic level of the pond and other environmental factors. Juveniles from eutrophic or mesotrophic lakes grow larger than those from oligotrophic lakes within the same watershed. Migration from oligotrophic lakes appears to occur earlier in the season than from mesotrophic or eutrophic lakes.

Dow (1973) indicated growth of adult alewives from cold water estuaries were smaller than those found on warmer water estuaries. Investigations by Roundsefell & Stringer (1943) reported considerable inter-site variation in the size of adult anadromous alewives from different locations in Maine. This is not substantiated by research conducted by Walton & Smith (1974) who reported similar growth parameters and no significant differences in length at age for 21 coastal watersheds in Maine.

The total lengths of adult alewives returning to spawn in the Androscoggin and Sebasticook rivers range from 260 to 330 millimeters. Based on an analysis of scale ages these returns are 3 to 8 year old, though alewives in the statewide commercial fishery are as old as 9-years. The Maine – New Hampshire Trawl Survey captures alewives much smaller than the adults captured during the annual spawning runs. The majority of these alewives are young-of-the-year and consistent with length frequencies of juvenile river herring leaving nursery habitats in the spring. The trawl survey captures a small number of alewives in the 150 to 200 mm range. These fish are assumed 2-year-olds, but this has not been confirmed through scale aging techniques (Figure 5.2).

There is little data on the growth of blueback herring in Maine. Field staff samples few adults during the annual spawning run. The few samples that do occur are limited to individuals captured at the fishway on the Sebasticook River or while sampling commercial alewife runs. The Maine – New Hampshire trawl survey does capture blueback herring during the spring and fall inshore trawl surveys (Figure 5.3)

During the past several years, data collected at the Brunswick Fishway indicate that the mean total lengths of alewives ascending the show no trends (Figure 5.4). Today alewives are as large as alewives captured in non-commercial catches of years past, but year class strength can influence trends in mean length. The Sebasticook alewives show no trend for the same period (Figure 5.5). The downward trends in mean lengths observed in some states are not apparent in Maine data for these two rivers for the past several years.

5.5.4 Fecundity

For both species, age at sexual maturity is primarily ages 4-5 in the northern portion of their ranges. Blueback herring and alewife do show up in spawning runs as young as three years old. Fecundity of individual fish correlates positively to length and age. Alewife produce 60,000-103,000 eggs per season and blueback herring produce a similar amount, 60,000 to 100,000 eggs per season. Older fish are more fecund than younger fish.

5.6 HABITAT DESCRIPTIONS

Habitat requirements for spawning populations of river herring in Maine are specific to each species. Overlap observed in spawning populations of river herring in states to the south do not appear to occur in Maine. Alewife spawning occurs in ponded habitats or slow sections of river systems. Shallow eutrophic and mesotrophic lakes appear to be the best lakes and ponds for alewife spawning. Maine

does have a number of oligotrophic lakes that return alewives but the size of the juveniles emigrating from the lake tend to be small and migrations begin early in July.

In contrast, blueback herring spawn in the main channels of tidal fresh water rivers and inland streams and rivers. Typically, blueback herring spawn in fast water below locations where commercial alewife fisheries occur. There are only a few locations in Maine where blueback herring are enumerated upstream of alewife fisheries. The St. George, Kennebec, Sebasticook, East Machias and Orland rivers all support runs of blueback herring.

Access to specific habitat types, flows, or substrate, do not appear more important than access to the suite of habitat types generally found in typical coastal rivers for blueback herring or lakes and ponds for alewife. For several years, the Department documented the effects of habitat loss on the St. Croix River in eastern Maine (Figure 5.6). In 1995, the Maine Legislature passed a law resulting in a unilateral closure of the Woodland Dam and Grand Falls fishways to upstream passage of prespawn alewives into spawning habitat. The Department and Canadian fishery agencies opposed the closure of the St. Croix River based on the existing evidence that alewife caused the collapse of smallmouth bass in Spednec Lake a headpond on the river. The alewife run in the St. Croix River declined significantly and eventually collapsed. In 2000, slightly more than 5,000 fish returned to the river. Canadian fisheries agencies did stock 2,000 fish annually but the return rate was only 0.26 percent of historic levels.

5.7 RESTORATION PROGRAMS

The goal of Maine's river herring restoration activities is to provide access to all habitats that supported river herring historically. Many of these habitats are well inland of the coastal rivers that support the current river herring runs. Access to much of this habitat is still blocked by dams without upstream fish passage and other impediments. The resource agencies are making progress by installing upstream and downstream fish passage facilities, especially in the Sebasticook River watershed and smaller coastal watersheds. A significant restoration project is underway on Outlet Stream in the town of Vassalboro which will restore a run of more than one-million returns. Fish passage or dam removals at five sites on Outlet Stream will provide passage into China Lake a 3,845-acre lake that are expected to add to the growing number of fish in the Sebasticook watershed.

A recent agreement between the Department of Inland Fisheries and Wildlife and the DMR will reopen the fishway into Sheepscot Pond and increase returns to this river by sixty percent. The Sheepscot River restoration project includes one dam removal on the east branch, modification of a dam at head-of-tide to provide passage as well as a fishway into Branch Lake on the west branch.

Starting in 2010 the DMR began restoring river herring to the Penobscot River, Maine's largest river. The trap and transfer program introduced 21,556 pre-spawn river herring from the Kennebec River into three habitats (Chemo, Perch, and Mattamiscontis Ponds) in the Penobscot drainage. This trap and transfer program will continue until sufficient returns to the Penobscot permit transfers of fish from sources within the Penobscot basin. Since the 2010, the Department made significant progress in recolonizing Chemo, Perch, Mattamiscontis and several other lakes and ponds. Pushaw Lake and additional waters are currently under restoration with the goal of initiating a commercial harvest.

In 1965 Maine initiated the restoration of alewives in the St. Croix River when Denil fishways were installed at the Woodland dam (2nd dam) and the Grand Falls dam (3rd dam) on the mainstem river. A fishway previously installed in the Vanceboro dam at the outlet of Spednic Lake in 1963 on the New Brunswick side of the river worked well. However, the poorly functioning fishway on the New Brunswick

shore that was operational at the Milltown dam (1st dam) in the 1960's and 1970's was replaced in 1981 with a more efficient Pool and Chute fishway. The alewife run increased dramatically four years after the Milltown fishway became fully functional in 1982 and peaked at 2.6 million fish in 1987. Coincident with the increase in the alewife population, the smallmouth bass fishery in Spednic Lake declined. Following complaints of poor smallmouth bass fishing from local guides and sporting camps at Spednic Lake in Washington County, the Department of Inland Fisheries & Wildlife undertook a cooperative study with the New Brunswick Department of Natural Resources to determine the cause for the decline in the smallmouth bass population. Although it was not possible to establish that the increase in the alewife run affected the smallmouth bass fishery, it was postulated that the large influx of alewives through the Vanceboro Dam, coupled with a lake drawdown of 9-14 feet, may have resulted in loss of young fry bass habitat (Maine Rivers 2006). This also may have increased competition for food and habitat which lead to poor bass fry survival over several successive years (Maine Rivers 2006). In response to the smallmouth bass decline, the St. Croix River Fisheries Steering Committee agreed to block the Vanceboro fishway during the alewife run and requested that Georgia Pacific Company revise its water management plan on the St. Croix watershed in order to minimize the impacts of water drawdown on young bass. Georgia Pacific agreed and closed the Vanceboro fishway beginning in 1988, which has resulted in the collapse of the alewife run in the St. Croix River.

In an effort to reach a compromise, the St. Croix River Fisheries Steering Committee drafted a Memorandum of Understanding that would allow for the controlled escapement of up to 90,000 alewives through the Grand Falls fishway into the waters below West Grand Lake and Spednic Lake. A bill was introduced in the Maine Legislature in 2001 (L.D. 365) that would allow the Woodland and Grand Falls fishways to reopen but the bill was defeated. The Maine signatories did not sign or implement the Memorandum of Understanding. The alewife run in the St. Croix River reached a new low in 2002. Canadian fisheries staff counted only 900 alewives at the Milltown fishway. The Canadian Department of Fisheries and Oceans transported 807 of the 900 alewives to the Woodland headpond in an effort to save the run from extinction.

St Croix Update: In 2013 the Maine Legislature reversed its decision and allowed river herring to pass into a larger portion of the watershed beginning in 2014. The DMR anticipates a positive response in run size within the next decade. The DMR is working with state, federal resource agencies and NGOs to assess the aging fish passage facilities at the Milltown, Woodland and Grand Falls dams to maximize access to historic spawning habitats on the St. Croix River.

A well-established trap and truck program maintains historic runs that do not have upstream passage until resource agencies achieve permanent passage. The number of river alewife stocked varies based on available habitat and access to broodstock. The annual stocking goal of the restoration projects range from a few hundred fish to 200,000 fish, with most stocked in the Androscoggin and Kennebec watersheds. These locations do not have upstream passage and require transport of spawning fish around existing barriers. The stocking program on the Sebasticook changed in 2009 with the removal of an existing hydropower dam and upstream passage on all dams on the main stem of the Sebasticook. In 2009 stocking numbers dropped by 150,000 fish. During the 2010 stocking season Maine fisheries staff targeted 63 spawning habitats into which 323,180 pre-spawn river herring would be released. The number of stocking programs continues to decline as the number of permanent fish passages increase throughout Maine.

5.7.1 Restoration Objective(s) and/or Targets

Dam construction during the last century isolated many of the inland waters currently stocked with alewives. The historical significance of anadromous fish to these waters was eventually lost, and freshwater fish communities, especially recreationally important game fish, began dominating these habitats. The goal of the DMR restoration program is to recolonize habitat historically available to river herring within the state of Maine and maintain a sustainable commercial and recreational river herring harvest.

The interim restoration-stocking target for inland spawning habitats is six fish per surface acre for inland lakes and ponds locations stocked by truck. The State of Maine established this stocking rate during a 10-year study conducted by MDMR, Maine Department of Environmental Protection and Maine Inland Fisheries and Wildlife (Kircheis 2002). The goal of the study was to quantify the effects of a spawning population of alewife on the resident fish species and zooplankton community within inland waters. A stocking rate of six fish per surface acre of lake or pond habitat showed no negative effects for growth rates of resident fresh water fish species. The DMR observes this stocking rate for all truck-stocked locations. It is important to note that the initial stocking rate for this study was arbitrary and the stocking density could be higher and still not demonstrate significant negative impacts to resident fish species.

The state manages coastal runs for free passage and does not restrict these waters to the six fish per acre limit. All fishways that provide upstream passage for alewives are free passage, even those that provide access to habitats once stocked by truck. The management threshold for these locations is a return rate of 235 fish per acre with 35 fish per acre escapement into spawning habitat.

The DMR management program for alewives initially focused on providing, or improving, fish passage on smaller coastal drainages. Since 1969, DMR has installed 17 fishways and maintains 19 others from Cumberland to Washington County. It also assists in the operation and maintenance of 12 non-hydro dams owned by other public entities. With the advent of better water quality in the larger river systems, DMR has actively sought installation of fish passage in hydroelectric dams licensed by the Federal Energy Regulatory Commission.

The DMR is actively involved in the restoration of anadromous fish to the Androscoggin and Kennebec rivers. Since 1983 the DMR has operated the vertical slot fishway in the Brunswick dam located at the head-of-tide on the Androscoggin River. The construction of fish lifts at the next two up-stream dams, Pejepscot and Worumbo, allows passage of anadromous fish to Lewiston Falls. The majority of alewife habitat is located in the lakes and ponds in the Sabattus and Little Androscoggin rivers. These ponds are not currently accessible due to FERC licensed hydropower dams without upstream fish passage. The DMR has transported alewives to ponds in these two drainages annually since 1983. The number stocked fluctuates widely over the years and relates to the amount and location of habitat stocked in previous years (Figure 5.7).

The DMR implemented a restoration plan for alewives in the Kennebec River watershed above Augusta in 1986 through an agreement with the majority of hydroelectric dam owners in the watershed. The agreement called for the stocking of alewives in the program's initial years to build up the population size, with eventual fish passage later. The original agreement was modified in 1998 and incorporated into the Kennebec River Settlement Accord which resulted in the removal of the Edwards Dam in 1999. The new agreement continued funding for the anadromous fish restoration program and established new dates for fish passage. The alewife restoration program in the Kennebec River focused on stocking

lakes and ponds in the Sebasticook River watershed and Seven Mile Stream drainage. Many of these habitats now have permanent fish passage and contribute significantly to the river herring runs on the Kennebec and Sebasticook rivers.

Fish passage on the Saco River became available in 1993 when Central Maine Power built fish passage facilities at the Cataract dam located at head-of-tide (dam and passage facilities now owned and operated by Florida Power and Light). The amount of habitat for alewives is limited in the Saco River drainage, but a remnant of the former run continues as the result of a trap and truck effort to the Skelton Dam headpond by the dam's owners. Passage became available at Skelton in 2002 with the installation of an inclined fish lift by Florida Power and Light.

5.7.2 Hatchery Evaluation

There are no hatcheries in Maine raising juvenile river herring for current restoration programs. The high costs of developing and supporting a long-term hatchery program prevent the state from exploring a hatchery program as an option for restoring river herring runs in Maine.

5.7.3 Fish Passage efficiency

The goal for fish passage efficiency at hydropower dams is 100 percent depending on environmental conditions. In reality, many of the upstream fish passage facilities are well below this goal. Upstream efficiency studies are routinely part of FERC licensing requirements and conducted with oversight from the state resource agencies. River herring passage efficiency at state or town owned coastal fishways or those leading into lakes and ponds are not routinely assessed. Run counts and biological data are collected at these sites to assure that these facilities are passing fish and meeting passage goals. In recent years rock-ramp or nature-like fishways have become increasingly popular for passing river herring. Their ability to maintain water levels, aesthetic features and excellent upstream passage make these fishway types a good fit for a number of passage locations.

5.7.4 Trap and transport

State resource agencies use trap and transport to maintain or rebuild extirpated runs along the Maine coast. Trap and transport also provides passage around dams without fishways and enhances runs with poor upstream passage. The trap and transfer programs stock 100,000 to 200,000 fish annually into spawning habitats that do not have upstream fish passage. As the number of upstream fish passages increase the need to truck fish decreases, allowing more time for biological assessment.

5.8 AGE

The maximum age for alewife and blueback herring in Maine is nine years (Libby 1980, Walton 1983). These ages are from river herring captured in commercial fisheries conducted in the 1970s and 1980s and still occur in the commercial fisheries conducted in 2016. Walton and Libby used ageing techniques developed by Marcy 1969, Rothschild 1963, and Norden 1967. As of 2000 in addition to Marcy, Rothschild and Norden fisheries staff also refer to Cating (1950), Marcy (1969), and Rothschild (1963) to determine the age of returning river herring. The method developed by Cating for American shad, may not be suitable for river herring and staff use caution when using the methodology developed by Cating. Maine does not have a reference set of known age fish used to validate scale ages using Cating's method.

5.9 FISHERY DESCRIPTIONS

The predominant Maine river herring fisheries are directed fisheries located at head-of-tide or above. The municipality that owns the fishing rights and the State of Maine manage these fisheries cooperatively. Traditionally the town owning the rights leases the rights to an individual fisherman or hires a fisherman to harvest the run for the town. These fisheries operate under a population and site-specific management plans that maintain and conserve spawning stock biomass.

Commercial fisherman are prohibited from targeting river herring in coastal waters using seines, weirs, gill nets or fish traps. The coastal fisheries for lobster bait ended in 2012 with the AMSFC moratorium on directed fisheries that could not meet sustainability guidelines. Our current knowledge of mixed stocks in coastal waters makes an assessment of the fishery and subsequent determination of sustainability impossible.

There are few recreational anglers fishing for river herring in the state of Maine. Access to most fishable locations are within municipalities that hold exclusive harvest rights. Where recreational anglers have access to river herring the daily limit is 25 fish taken by dip net or rod and reel.

5.9.1 Commercial fisheries

The municipal river herring fisheries conducted in Maine rivers are site specific and all commercial runs are unique in terms of species composition, run size, and harvest location. The harvest methods and local control of these fisheries make comparing the runs difficult. Four municipal commercial runs dominate the commercial landings for the State of Maine. These fisheries occur on small coastal river systems, some with limited spawning and nursery habitat. Despite the unique character of the runs in Maine, commercial catches have declined compared to historic levels of harvest (Figure 5.8)

The commercial harvesters are required to collect biological data from commercial catches. In addition, there is mandatory reporting of annual landings for each commercial fishery operated by a municipality. Funding and personnel limitations do not allow state resource management agencies an opportunity to collect this information. In 2008, MDMR asked all commercial fishermen to voluntarily collect scale samples from the commercial catches to determine the age structure and repeat spawning of fish returning to natal streams. The majority of commercial fishermen did collect samples, but there were some fishermen who did not participate. These data are in the Maine Sustainable Harvest Plan provided to the American shad and River Herring Technical Committee. During the preparation of this plan, additional age data from the 1942 report “Restoration and Management of the New England Alewife Fisheries with Special Reference to Maine” by Rounsfell and Stringer (1943) were discovered.

Libby (1982) sampled the commercial alewife fishery at Damariscotta Lake in 1980 and found that the mean total lengths of alewives during that year for both sexes were larger than those observed today at the Brunswick and Sebasticook river fishways (Table 5.1, 3.2, and 3.3).

Damariscotta Lake

The Damariscotta fishery is one of the most studied in Maine. Local residents built the fishway in 1803 and modified several times over the last 200 years. Modifications to the free stone masonry structure were to repair damage or improve passage and modify holding pools. Still the efficiency of this fishway varied and its ability to pass larger female river herring was studied by Libby (1981). He concluded the male to female ratio of the commercial catch at the base of the fishway, compared to the ratio of

alewives entering the lake favored males and directly relates to the efficiency of the fishway and its length. The ratios of males to females entering the lake were as high a 4:1 during the run.

In the early 2000s an assessment of the fishway by the U.S. Fish & Wildlife Service indicated the need to modify and/or repair four sections of the fishway. The 150-meter stone pool and chute fishway that historically passed river herring into spawning habitat at Damariscotta Lake was replaced with a concrete pool and weir fishway. The elevation of the 1,781-hectare lake is 16 meters above mean high tide. A multi-year project commenced to completely rebuild the fishway. The fishway rebuild occurred over four years and the Department observed an immediate improvement in passage efficiency. Since the completion of the project annual runs as high as 1-million fish have ascended the fishway.

Harvesters trap fish in a side channel at the base of the fishway that provides supplemental attraction water. The commercial fishery operates four days a week during the duration of the run and unobstructed upstream passage is available all season. The towns of Newcastle and Nobleboro monitor the numbers of fish entering the lake. The number of fish entering the lake are counted during a ten minute period each hour and expanded to the hours of operation (Figure 5.9).

St. George River

The St. George River fishery is located at head-of-tide in the St. George River. An extensive weir system closes the river to all upstream passage. The weir is not placed in the river until May 15th and after a significant number of fish have passed upstream. The weir operates five days a week and is open 2 days a week to allow upstream passage for spawning fish. Spawning escapement is not monitored, but assumed to be two fifths of the annual run. Due to the expanse of the weir, environmental conditions, especially river flows during the spring, affect the harvest. The weir frequently lifts off bottom and breaches due to accumulated debris on the weir mesh.

Harvesters hold live river herring in a trap at the head of the weir prior to sale. Fish that are not sold can be released alive to continue their migration upstream to spawn. The St. George fishery is one of three fisheries that also include blueback herring. Alewives as old as nine and blueback herring as old as eight were sampled from this fishery in 2016 and regularly produces some of the oldest fish found in any of Maine's river herring runs.

The St. George run remains one of the most intensively fished runs in Maine (Figure 5.10). Seven ponds within the watershed provide spawning and nursery habitat. The amount of habitat available to alewife increased in 2003 with the construction of a rock ramp fishway at Sennebec Lake. Restoration efforts in the watershed continue. The DMR plans to construct upstream passage into several lakes and ponds in the watershed in the future.

Union River

The Town of Ellsworth maintains the Union River fishery by stocking adult alewives above the hydropower dam at head-of-tide. There is no free passage or upstream fish passage facility required at the hydropower station. The FERC license requires transporting river herring around the dam by Brookfield Renewable, LLC the dam owners. The annual stocking rate (from 2015 forward) is 315,000 fish from the commercial run during the harvest. The Union River is one of three commercially harvested resources with known escapement numbers.

The fishery on the Union River is relatively new and provides a large number of alewives for commercial use, primarily lobster bait (Figure 5.11). The Union River fishery is unique because of known escapement rates. The resource agencies can manipulate these rates and correlate them directly to harvest to determine the effects of escapement on returns. As with most other directed alewife fisheries in Maine, water flows influence the number of fish that are available to commercial harvesters. This was evident in 2005 when extreme high flows prevented alewives from reaching commercial fishing locations and destroyed commercial fishing gear.

Orland River

The Orland River fishery operates four days a week, allowing a three-day escapement period per week (Figure 5.12). Two Alaska Step Pass fishways provide upstream fish passage into a series of lakes that support spawning. In addition to the alewife run there is a significant blueback herring run that occurs on the Orland River. The commercial harvest ends prior to the majority of these fish reaching spawning locations and escapes the fishery. The fishery occurs at head of tide and like most river herring fisheries, high water and fluctuations in flows affect run timing and strength.

Ocean, Coastal, and In-river Fisheries

For decades, pressure has increased in the coastal zone to catch pelagic fish species as bait for the Maine lobster fishery. Most of the fisheries focused on Atlantic herring or menhaden that could be caught in large numbers with mobile gear. There are no directed river herring fisheries in main stem rivers below head of tide. The same is true in the coastal and ocean regions under the jurisdiction of the State of Maine. There is a strict 5% river herring bycatch tolerance for all vessel participating in these coastal and ocean fisheries and landing in Maine. All fishermen are required to report landings if they have a permit to harvest Atlantic herring and after January 1, 2011 fishermen must purchase a Pelagic License and meet mandatory reporting requirements. For many years the NMFS and State of Maine landings program attempted to record commercial river herring landings in the Atlantic herring fishery and bait gillnet fishery. However, the State of Maine did not require mandatory reporting for these fisheries prior to 2002 (Table 5.4, 3Table 5.5, Table 5.6).

5.9.2 Bycatch Losses

The data collected to determine bycatch losses come from Vessel Trip Reports (VTR) required for all federally permitted fishing vessels. The weight of bycatch is often estimated by fishermen and not an accurate weight or number. There is no means to verify these catch weights or determine the amount of under-reporting or misidentification of species reported.

River herring bycatch occurs in all small mesh fisheries conducted along Maine's coast. Bycatch by weight inside Maine territorial waters among the small mesh otter trawl fisheries is low, based on sea-sample data collected from these fisheries in past years and time of year when these fisheries occur (Table 5.7 and Table 5.8). The small mesh fisheries with the highest bycatch target whiting and had targeted northern shrimp during the fall and winter respectively. Bycatch is limited to juvenile fish and is small compared to the catch numbers of the target species. The mid-water trawls do catch river herring, though there is not enough observer coverage to determine how much, or where, this bycatch occurs. This is a current concern to many researchers trying to rebuild stocks of Alosines.

5.9.3 Recreational Fisheries

There are not a large number of recreational anglers pursuing river herring in Maine. In Maine there is no survey or mandatory reporting required of recreation fishermen. The MRIP survey does indicate that recreational fishermen fishing for river herring were interviewed while fishing for river herring in Maine. Based on MRIP recreational catches are low with high PSE values.

5.10 FISHERY-INDEPENDENT SURVEYS

5.10.1 Adult Catch Data

Fishery independent adult catch data is limited to biological data collected at three state operated fishways, volunteer efforts to collect biological information because of Amendment 2 and the Maine-New Hampshire Inshore Trawl Survey. State fisheries personnel collect biological samples throughout the run on the Androscoggin, Kennebec and Sebasticook rivers. Data include weight-length, species composition, scale samples, and intermittent gonad weights. In addition to biological data, staff collects run counts, trap and transfer numbers, and species community data. When several species of anadromous fish are present samplers will separate species of river herring and collect sample information.

An increasing number of volunteers and conservation groups are collecting limited data on several non-commercial river herring runs. These data are collected at additional locations to assess changes made to upstream passage facilities, collect biological data to start a commercial fishery, or monitor run size. These changes typically occur at fishways that lead to upstream spawning and nursery habitats. Data collection occurs for one or more years depending on historic data and the need to acquire additional data to assess any changes in these populations.

The Maine-New Hampshire Inshore Trawl Survey provides data from the near shore coastal areas of Maine and New Hampshire to the Massachusetts boarder. The trawl survey occurs semi-annually in the spring and in the fall. The survey samples 90 stations randomized over towable bottom within five survey strata. The time series for the trawl survey is extensive and becomes more valuable as the number of sample points increase. The trawl survey data has supported the last two river herring assessment updates.

5.10.2 Age Composition

Collection of age data occurs at fish passage facilities on the Androscoggin, Kennebec and Sebasticook rivers. Data collection started at the newly constructed Lockwood fishway on the main stem Kennebec River in 2005. Staff collects a limited number of samples annually throughout the duration of these river herring runs. Since 2008, all directed commercial fisheries are required to collect scale samples that provide age and repeat spawning data for each run respectively. In addition, a number of volunteer and conservation groups are collecting scale data on non-commercial runs in hope of restoring these runs.

Age composition for alewives in the commercial catches run from 3 years to 9 years. The majority of the first time spawning fish are 4 to 5 years old and typically make up the majority of the annual run. Blueback herring ages range from 2 years to 8 years old with the majority being 4 to 5 years old fish. Because so few bluebacks are harvested there may be older fish that are not being sampled.

5.10.3 Androscoggin River

Androscoggin River alewife age data exists for most years from 1983 through 2016. The anadromous fish restoration program on the Androscoggin River began in 1983 when Central Maine Power Company constructed upstream fish passage at the head-of-tide. The age structure of returning adult alewives does not appear to change significantly between years. Data collected during the early years of the restoration project are similar to data collected for the past three-year period (Table 5.9).

There is no commercial fishery conducted on the Androscoggin River. However, there are a number of hydropower dams between head-of-tide and spawning and nursery habitat. Three hydropower dams exist on the main stem Androscoggin River and four on the Little Androscoggin River. The role these hydropower stations have on the age structure is unknown, though assumed to significantly impact survival of downstream adult migration.

5.10.4 Sebasticook River

The Sebasticook River is a major tributary to the Kennebec River that historically produced large runs of anadromous fish. Removal of Edwards' Dam at the head-of-tide in Augusta, Maine, in 1999, opened several miles of river to free passage for all anadromous fish species. After removal of Edwards, the Ft. Halifax Dam, located on the Sebasticook River, became an obstacle to upstream passage. Trap and transfer operations moved from Edwards Dam to Ft. Halifax. For a short period, an intense river herring fishery existed below the Ft. Halifax Dam. The fishery peaked in 2005 with several thousand fish harvested, but much of this harvest was unrecorded. The effect of this harvest is apparent in the ages of alewife sampled in 2003 (Table 5.10)

Biological sampling began at Ft. Halifax in 2000. Like the Androscoggin biological data collection, these biological data are a mix of several different stocks of alewives that use the Sebasticook River to access spawning habitat upstream. When fisheries staff collects biological samples, the stock of origin is unknown. These data do provide a reasonable estimate of some biological parameters but may not be representative of a particular run or stock. The dam owner removed Fort Halifax dam in 2008 instead of building a fishway. The Benton Falls hydropower dam located 6 miles upstream of the Fort Halifax site is now the first barrier on the river. There is fish passage at Benton and Burnham that provide upstream passage into a number of spawning habitats upstream. Since 2008 a significant increase in blueback herring and alewife have occurred in the Sebasticook River. Counts in 2016 indicate more than 1-million blueback herring passed upstream.

5.10.5 Juvenile Catch Data

The State of Maine conducts an annual juvenile alosine survey for six Maine rivers including Merrymeeting Bay. This survey samples for all juvenile alosines managed by the state resource agencies. The survey began in 1979, covering 17 fixed stations as well as data from a separate juvenile striped bass survey designed to assess the numbers of juvenile striped bass in the lower Kennebec River. The Juvenile Alosine Survey for the Kennebec/Androscoggin estuary monitors the abundance of juvenile alosines at 14 permanent sampling sites. Four sites are on the upper Kennebec River, three on the Androscoggin River, four on Merrymeeting Bay, one each on the Cathance, Abadagasset, and Eastern rivers. These sites are in the tidal freshwater portion of the estuary. Since 1994, MDMR added six additional sites in the lower salinity-stratified portion of the Kennebec River.

The sampling protocol for all stations is similar to that used in the juvenile shad-sampling program on the Connecticut River. Field staff samples each site once every other week from July to the end of September. The goal is to sample each site six times during the season. Field staff collects samples with a beach seine within three hours of high slack water. The seine is made of 6.35 mm stretch mesh nylon, measures 17 m long and 1.8m deep with a 1.8 m x 1.8 m bag at its center. One person holds an end of the seine stationary at the land/water interface, and the boat operator tows the opposite end perpendicular to shore. After the net fully extends, the boat operator tows the seine in an upriver arc and pulls the net ashore. The net samples an area of approximately 220 m². Staff sort and process the catch in the field.

The number of adult blueback herring spawning in Maine rivers is difficult to assess. These fish are limited to the main stems of rivers below the first upstream obstruction, typically a dam. Although some dams do have upstream passage facilities, blueback herring are reluctant to use these passages. Blueback herring rarely use the Brunswick fishway, though fishway staff observes large numbers of blueback herring spawning directly below the fishway in the tailrace.

The survey does not do as good a job of indicting the spawning success of alewife. Little if any spawning occurs in Merrymeeting Bay or the lower portion of Maine tidal rivers. Alewives are likely captured in the bay as they rest and feed along their downstream migration routes. A number of environmental factors may influence number of alewives in the bay at a given time. High water levels that facilitate downstream passage and colder water temperatures, believed to trigger downstream migration, may increase the number of juveniles in the bay at a given time.

5.11 ASSESSMENT APPROACH(S) AND RESULTS

Little formal assessment of any of Maine's river herring resources have occurred during the past several decades. Crecco and Gibson (1990) did conduct a formal assessment of the Damariscotta Lake run and indicated that the run was severely over fished. Crecco used the Shepherd Stock Recruitment model to estimate maximum sustainable yield, annual fishing rate at MSY, and project harvest levels that would cause collapse of the fishery. Crecco concluded that the Damariscotta run was harvested at levels that indicated stock recruitment failure was apparent.

Maine and ASMFC fisheries staff completed a comprehensive, though less detailed, assessment of several Maine river herring runs in 2010 and 2015 to meet the Amendment 2 to the American Shad and River Herring Plan. These analyzes used a number of biological datasets, harvest rates, and escapement rates to estimate population size and composition for each commercial and some non-commercial river herring runs in Maine. For most commercial fisheries the biological datasets are short, beginning in 2008 through the present. Reported harvest and estimated escapement provide a longer time series of data, many runs having data through the 1950s.

5.11.1 Spawning Stock

Data from adult fisheries independent surveys indicate that the number and weights of alewife are trending upward or are stable for the past several years (Figure 5.13 and Figure 5.14). The trends of blueback herring in the survey indicate variable catch numbers and catch weights during the past several years with no apparent trend (Figure 5.15 and Figure 5.16).

5.11.2 Trends in Age

Analysis of alewife scale samples collected from the Androscoggin and Sebasticook rivers indicates that returning fish are most often 4-5 years old. Blueback herring are predominately 3 to 5 years old. The numbers of river herring older than six years represent a small proportion of the adults sampled. This is an apparent shift in the age structure for all Maine river herring runs, commercial and non-commercial from the mid-1980s, but similar to length data collected in the 1940s. Scale samples collected from 15 commercial fisheries in 2008 had few river herring over 6 years of age. While commercial catches in the 1980s commonly had fish as old as 8 years of age. Since 2010 larger number of older fish do appear in the samples collected, but still remain a small percentage of the fish sampled.

5.11.3 Juvenile Stock

Results of the annual juvenile alosine survey indicate that annual production of alewife and blueback herring within the sample area and migration timing through the sites vary widely year-to-year (Table 5.11 and Table 5.12; Figure 5.17 and Figure 5.18). Prior to 1992, the number of blueback herring captured were low and sporadic, occurring only occasionally during the sample season. The survey time series for both species does indicate a stable or slightly increasing population. The juvenile survey results are a better indication of annual blueback herring spawning success.

5.12 BENCHMARKS

There are no previous benchmarks established for the Maine river herring fisheries other than Crecco's estimation of Z (3.22), u (0.891), and F (2.20) for the Damariscotta fishery in the 1970s. Estimates of Z for most of the river herring fisheries are not as high as the value Crecco observed in the 1970s.

5.12.1 Total Mortality

Prior to 2008, limited biological data were collected from the Maine municipal river herring fisheries. However, researchers did collect data during studies conducted at Damariscotta Lake in the late 1970s. Currently DMR staff collects age data on the Androscoggin, Kennebec and Sebasticook rivers while monitoring upstream fish passage. These data are used to calculate the total mortality (Z) for alewife runs from these rivers, with total mortality calculated separately by sex for each year and river system.

Since the inception of Amendment 2 in 2008, DMR has requested that commercial harvesters, volunteer and conservation groups collect scale samples from commercial and non-commercial river herring runs along the Maine coast. In 2016 harvesters and conservation groups collected scale samples from 33 runs. Commercial fishing occurs on some runs while others remain closed for conservation or were not fished within the past five years.

The DMR asked harvesters and others to collect samples from 25 fish every week during the duration of the run. Most harvesters fishing commercial runs were able to provide the number of scale samples requested. Commercial harvesters also volunteered to provide coverage at locations that are temporarily closed or have been closed for several years. The number of scale samples collected from runs that are temporarily closed, or closed for more than five years, were typically less than the number requested (Table 5.13).

Commercial river herring fisherman began collecting scale samples from catches of river herring returning to natal rivers to spawn. These samples provide a basis to estimate total mortality for all the

runs fished in Maine. Fisherman continue to collect scale samples under the direction of the DMR and as part of the municipal harvest plans. In addition, a number of volunteer and conservation groups have collected data from non-commercial streams.

Calculation of total mortality estimates occurred for all runs regardless of the number of samples collected. All sample locations that had corresponding sex data are included in the combined Z-estimates in each figure. Heinke and Chapman-Robson methods were used to obtain Z-estimates. We used these methods because of the limitations of the number of age data classes that the Catch-Curve method requires for the analysis (Figure 5.25, Figure 5.26, Figure 5.27, and Figure 5.28).

The Department explored several methods to estimate Z, including Catch Curve, Heinecke, and Chapman-Robson. Each of these has advantages when working with limited data sets. The Catch Curve was most restrictive, needing a number of age-classes in order to conduct the analysis. The Chapman-Robson method addresses biases present in the Catch Curve analysis and is used as a standard in the 2015 update.

Age data analyzed from scale samples collected since the inception of the Sebasticook River run reflect, in part, the high fishing pressure exerted on this population from 2002 through 2005 (Figure 5.19, Figure 5.20) Fishing regulations allowed unrestricted access to these fisheries resources during this period. DMR assumed management of this resource from the Department of Inland Fisheries and Wildlife in 2007. Limited commercial fishing started in 2009 on the Sebasticook River after fishing rights were transferred to the Town of Benton. The annual mortality estimates for males and females differ at this location. The reasons for these differences are not clear. The Sebasticook River was a source of broodstock for a number of restoration projects east of the Kennebec River, but with increased passage these fish are no longer needed as brood stock. The Sebasticook River run ranges between 2.5 and 3.5 million fish annually and comprised of both alewife and blueback herring..

The age data presented in this analysis are from scale samples collected at the Brunswick Fishway since it opened in 1983. Much of the raw data are no longer available for analysis, but all available data contributed in calculating the Z-estimates (Figure 5.21 and Figure 5.22). Trend lines fitted to the male Z-estimates were flat for the years of data that were available and the Z-estimates for females indicated a slight upward trend. The Androscoggin River alewife run is small compared to the Sebasticook run. The annual run averages 52,000 individuals. There is not a commercial fishery on the Androscoggin River.

Z-estimates calculated using the Beverton-Holt model were compared to the Catch-Curve, Heinke, and Chapman-Robson models. The Beverton-Holt trends are similar for the Androscoggin and Sebasticook rivers, and indicate decreasing Z-estimates for both sexes of alewives for the period 2010 – 2016 (Figure 5.23 and Figure 5.24).

5.13 CONCLUSIONS AND RECOMMENDATIONS

Maine commercial river herring landings are down when compared to levels of reported harvest in the 1950s though commercial river herring landings are not an accurate measure of Maine's current river herring stocks. The majority of the river herring fisheries in Maine are closed to directed commercial harvest as a conservation measure. River herring in the main stem of nine of the state's nine largest rivers are not exploited by commercial fishermen.

The directed commercial fisheries at some locations have declined but the causes for the declining landings are not clear. These declines are likely the cause of a number of factors including

environmental conditions, bycatch, habitat degradation, predation, and lack of adequate upstream and downstream fish passage. The same trends appear at locations where the stock is not commercially fished. Currently all directed fisheries continue to maintain self-sustaining fisheries for river specific stocks.

Bycatch of juvenile river herring in coastal waters appears to have decreased during the past several years. This decrease in catch is a combination of eliminating directed river herring in the coastal areas and bycatch in other small mesh fisheries inside and outside three-miles of Maine's coast. Bycatch and directed river herring landings are self-reported and may not accurately reflect the number river herring captured or discarded. In 2011, a commercial fishing license is required for anyone who fishes for any pelagic species using any gear type. This license creates a database of small mesh gear fisherman for a proposed bycatch sampling program in Maine coastal waters. The bycatch sampling program will focus on Alosines, alewife, blueback herring, and American shad captured as bycatch in the Atlantic herring, Atlantic Mackerel, and Atlantic menhaden fishery.

The DMR maintains a number of non-commercial runs through stocking while the state resource agencies pursue upstream and downstream passage into historic spawning habitats. None of the directed fisheries are stocked with spawning fish and all are expected to maintain self-sustaining populations through implementation of their management plans. Management of directed river herring fisheries in Maine incorporate management actions to conserve populations of spawning fish through gear restrictions, closed seasons, and fishing area closures. These management actions are enforced through the Maine Marine Patrol and law enforcement action at the local level. Management plans exist for all municipally owned directed fisheries, each approved by DMR.

During the 2016 fishing season fisheries staff monitored the majority of the directed fisheries and collected biological data. These data provide information for a comprehensive stock assessment for runs that are actively fished and affected by directed fishing effort. Biological data collection is difficult because of the geographic area over which these fisheries occur, the number of fishing locations and limited personnel resources. Increased sampling is important to effectively manage the existing resources and assess the effectiveness of current management actions.

The limited data that are available indicate that the current population of river herring in Maine is stable at current level and in some instances increasing. Mortality estimates for the Androscoggin and Sebasticook rivers are lower than those calculated by Crecco in the 1980s. Juvenile index survey data indicate increasing populations of blueback and alewife in Merrymeeting Bay. Analysis of mean length and weight data indicate variable trends in weights and lengths at those locations where sampling does occur.

5.13.1 Recommendations

1. Increase sampling of stock specific runs that support directed commercial fisheries.
2. Increase upstream and downstream fish passage into historical spawning and nursery habitats.
3. Quantify bycatch of river herring in ocean fisheries, especially within three miles of the coast.

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Table 5.1 Mean Total Lengths of Fishery Dependent Catches at the Damariscotta Fishway

| Date | Number Sampled | Mean Total Length (mm) | | | |
|-----------|----------------|------------------------|-----|---------|-----|
| | | Males | SE | Females | SE |
| 5/6/1980 | 50 | 305.5 | 1.7 | 316.2 | 2.2 |
| 5/8/1980 | 50 | 300.4 | 1.8 | 316.6 | 1.6 |
| 5/12/1980 | 50 | 305.2 | 1.7 | 310.2 | 2.0 |
| 5/14/1980 | 50 | 304.1 | 1.6 | 315.4 | 2.3 |
| 5/16/1980 | 37 | 304.4 | 1.6 | 312.9 | 2.2 |
| 5/18/1980 | 50 | 301.6 | 1.8 | 308.5 | 1.6 |
| 5/20/1980 | 50 | 299.9 | 1.5 | 311.0 | 1.4 |
| 5/22/1980 | 50 | 302.0 | 1.4 | 309.0 | 1.8 |
| 5/24/1980 | 50 | 292.7 | 1.8 | 302.0 | 1.7 |
| 5/26/1980 | 50 | 299.3 | 1.5 | 308.3 | 1.8 |
| 5/28/1980 | 50 | 296.3 | 1.7 | 305.9 | 2.5 |
| 5/30/1980 | 50 | 295.7 | 1.7 | 304.2 | 1.8 |
| 6/1/1980 | 45 | 298.0 | 1.9 | 307.7 | 2.2 |
| 6/3/1980 | 44 | 293.4 | 2.2 | 307.2 | 2.3 |
| 6/5/1980 | 35 | 299.0 | 2.7 | 305.3 | 2.4 |

Table 5.2 Mean Total Lengths of Fishery Independent Catches at the Brunswick Fishway.

| Date | Number Sampled | Mean Total Length (mm) | | | |
|-----------|----------------|------------------------|----|---------|----|
| | | Males | SE | Females | SE |
| 5/13/2008 | 50 | 268.1 | | 287.1 | |
| 5/17/2008 | 50 | 270.6 | | 281.4 | |
| 5/21/2008 | 50 | 256.0 | | 267.7 | |
| 6/4/2008 | 50 | 267.9 | | 279.0 | |

| Date | Number Sampled | Mean Total Length (mm) | | | |
|-----------|----------------|------------------------|----|---------|----|
| | | Males | SE | Females | SE |
| 5/12/2016 | 50 | 289.8 | | 303.4 | |
| 5/18/2016 | 50 | 278.4 | | 285.2 | |
| 5/25/2016 | 50 | 282.4 | | 280.6 | |
| 6/1/2016 | 50 | 271.0 | | 280.1 | |

Table 5.3 Mean Total Lengths of Fishery Independent Catches at the Sebasticook Fishway.

| Date | Number Sampled | Mean Total Length (mm) | | | |
|-----------|----------------|------------------------|----|---------|----|
| | | Males | SE | Females | SE |
| 5/9/2007 | 100 | 282.1 | | 290.2 | |
| 5/13/2007 | 100 | 267.5 | | 280.9 | |
| 5/14/2007 | 100 | 277.2 | | 281.5 | |
| 5/16/2007 | 100 | 278.9 | | 282.6 | |
| 5/21/2007 | 100 | 276.6 | | 287.4 | |
| 5/24/2007 | 100 | 273.8 | | 278.6 | |
| 5/26/2007 | 100 | 265.3 | | 274.4 | |
| 5/28/2007 | 100 | 271.7 | | 277.8 | |
| 6/6/2007 | 98 | 255.3 | | 266.2 | |

Table 5.4 Combined Direct and Non-Direct Ocean, Coastal, In-River Alewife Harvest.

| Ocean / Coastal Commercial Harvest (Kg) | | | | | | | | | |
|---|----------|--------------|-------------|------|--------------|-------------|----------------|--------------|-------------|
| | Gill net | | | Weir | | | Pound/Trap net | | |
| | N | Total weight | Mean weight | N | Total weight | Mean weight | N | Total weight | Mean weight |
| 2002 | 22 | 1,887 | 86 | 1 | 5 | 10 | | 0 | |
| 2003 | 22 | 2,754 | 125 | | 0 | | 2 | 23 | 11 |
| 2004 | 30 | 5,599 | 187 | 1 | 9,923 | 9,923 | 5 | 68 | 14 |
| 2005 | 32 | 1,194 | 37 | 12 | 1,580 | 132 | | 0 | |
| 2006 | 20 | 591 | 30 | 1 | 9,450 | 9,450 | 30 | 3,771 | 126 |
| 2007 | 30 | 254 | 8 | 1 | 0 | 0 | 1 | 3 | 3 |
| 2008 | 56 | 66 | 1 | | 0 | | 20 | 3,464 | 173 |
| 2009 | 37 | 617 | 17 | | 0 | | 36 | 4,526 | 126 |
| 2010 | 32 | 986 | 31 | | | | 18 | 4,382 | 243 |
| 2011 | 1 | 213 | 213 | 1 | 145,640 | 145,640 | 10 | 435,874 | 43,587 |
| 2012 | 0 | 0 | 0 | 1 | 126,150 | 126,150 | 10 | 633,692 | 63,369 |
| 2013 | 2 | 513 | 257 | 1 | 70,100 | 70,100 | 2 | 17,220 | 8,610 |
| 2014 | 0 | 0 | 0 | 1 | 175,840 | 175,840 | 11 | 440,910 | 40,083 |
| 2015* | 1 | 6 | 6 | 1 | 44,600 | 44,600 | 2 | 63,998 | 31,999 |

*preliminary data

| | Unknown Gear Type | | Other Gear(cast net, dip net) | | | Total | | | |
|-------|-------------------|--------------|-------------------------------|----|--------------|-------------|-----|--------------|-------------|
| | N | Total weight | Mean weight | N | Total weight | Mean weight | N | Total weight | Mean weight |
| 2002 | | 9 | | | 0 | | 23 | 1,900 | 83 |
| 2003 | | 149 | | | 0 | | 24 | 2,925 | 122 |
| 2004 | | 106 | | 6 | 250 | 93 | 42 | 15,945 | 380 |
| 2005 | | 35 | | | 0 | | 44 | 2,808 | 64 |
| 2006 | | 62 | | 14 | 253 | 40 | 65 | 14,127 | 217 |
| 2007 | | 81 | | | 0 | | 32 | 4,349 | 136 |
| 2008 | | 0 | | 33 | 5,724 | 173 | 109 | 9,254 | 85 |
| 2009 | | 0 | | 1 | 315 | 700 | 74 | 5,457 | 74 |
| 2010 | | 0 | | 12 | 358,661 | 29,888 | 62 | 364,084 | 5,872 |
| 2011 | | 0 | | 16 | 740,635 | 46,290 | 28 | 1,322,438 | 47,230 |
| 2012 | | 0 | | 1 | 6 | 0 | 12 | 759,848 | 63,321 |
| 2013 | | 0 | | 23 | 851,191 | 37,008 | 28 | 941,354 | 33,620 |
| 2014 | | 0 | | 17 | 673,433 | 39,614 | 29 | 1,290,183 | 44,489 |
| 2015* | | 0 | | 10 | 255,934 | 25,593 | 14 | 445,573 | 31,827 |

*preliminary data

Table 5.5 Direct and Non-Direct Ocean / Coastal Blueback Herring Harvest.

| Blueback Herring Ocean / Coastal Commercial Harvest (Kg) | | | | | | | | | |
|--|----------|--------------|-------------|------|--------------|-------------|----------------|--------------|-------------|
| | Gill net | | | Weir | | | Pound/Trap net | | |
| | N | Total weight | Mean weight | N | Total weight | Mean weight | N | Total weight | Mean weight |
| 2002 | 22 | 0 | 0 | 5 | 450 | 90 | 5 | 275 | 55 |
| 2003 | 22 | 203 | 9 | | | | 30 | 1,024 | 34 |
| 2004 | 30 | 135 | 5 | | | | 12 | 464 | 39 |
| 2005 | 32 | 101 | 3 | | | | 20 | 662 | 33 |
| 2006 | 20 | 149 | 7 | | | | 16 | 640 | 40 |
| 2007 | 30 | 596 | 20 | 6 | 262 | 44 | 23 | 3,066 | 133 |
| 2008 | 56 | 2,091 | 37 | 3 | 1,329 | 443 | 18 | 195 | 11 |
| 2009 | 37 | 435 | 12 | 2 | 124 | 62 | 38 | 6,590 | 173 |
| 2010 | 32 | | | | | | 26 | 26,470 | 1,018 |
| 2011 | 0 | 0 | 0 | 1 | 36,660 | 36,660 | 5 | 17,983 | 3,597 |
| 2012 | 0 | 0 | 0 | 1 | 42,050 | 42,050 | 3 | 1,931 | 644 |
| 2013 | 0 | 0 | 0 | 1 | 73,600 | 73,600 | 1 | 690 | 690 |
| 2014 | 0 | 0 | 0 | 1 | 43,960 | 43,960 | 2 | 81 | 41 |
| 2015* | 0 | 0 | 0 | 1 | 133,800 | 133,800 | 0 | 0 | 0 |

*preliminary data

| | Otter Trawl | | | Other Gear(cast net, dip net) | | | Total | | |
|-------|-------------|--------------|-------------|-------------------------------|--------------|-------------|-------|--------------|-------------|
| | N | Total weight | Mean weight | N | Total weight | Mean weight | N | Total weight | Mean weight |
| 2002 | 3 | 203 | 68 | | 295 | | 35 | 1,223 | 35 |
| 2003 | | 0 | | | | | 52 | 1,226 | 24 |
| 2004 | | 0 | | | | | 42 | 599 | 14 |
| 2005 | | 0 | | | | | 52 | 763 | 15 |
| 2006 | 3 | 2,093 | 698 | | 2,109 | | 39 | 4,990 | 128 |
| 2007 | | | | | | | 59 | 3,924 | 67 |
| 2008 | | | | | | | 77 | 3,615 | 47 |
| 2009 | | | | | | | 77 | 7,149 | 93 |
| 2010 | | | | | | | 58 | 26,470 | 456 |
| 2011 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 54,643 | 9,107 |
| 2012 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 43,981 | 10,995 |
| 2013 | 0 | 0 | 0 | 4 | 1,899 | 475 | 6 | 76,189 | 12,698 |
| 2014 | 1 | 9 | 9 | 0 | 0 | 0 | 4 | 44,050 | 11,013 |
| 2015* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 133,800 | 133,800 |

*preliminary data

Table 5.6 Bait Gill Net Permit Holders and Active Participants.

| Bait Gill Net Fishery | | | | | |
|------------------------------|----------------|----------------|------------------|--------------|-----------|
| Permit Holders | Active Permits | Number of Nets | Sq. Yards of Net | Hours Fished | |
| 2002 | 92 | 22 | unknown | unknown | unlimited |
| 2003 | 340 | 22 | unknown | unknown | unlimited |
| 2004 | 286 | 30 | unknown | unknown | unlimited |
| 2005 | 284 | 32 | unknown | unknown | unlimited |
| 2006 | 258 | 20 | unknown | unknown | unlimited |
| 2007 | 299 | 30 | unknown | unknown | unlimited |
| 2008 | 370 | 56 | unknown | unknown | unlimited |
| 2009 | 378 | 37 | unknown | unknown | unlimited |
| 2010 | 269 | - | unknown | unknown | unlimited |
| 2011 | 283 | 1 | unknown | unknown | unlimited |
| 2012 | 259 | - | unknown | unknown | unlimited |
| 2013 | 222 | 2 | unknown | unknown | unlimited |
| 2014 | 189 | - | unknown | unknown | unlimited |
| 2015 | 173 | 1 | unknown | unknown | unlimited |

In 2011 the Bait Gill Net Permit was discontinued and replaced with the Pelagic Fisheries license. Any individual that catches pelagic species in state waters is required to purchase this license and report landings. Bait Gill Net fishermen are required to report under the new Pelagic License.

Table 5.7 Alewife Bycatch Maine Otter Trawl Fisheries.

| Alewife Bycatch in Otter Trawl Fisheries (VTR data) | | | |
|---|---------------------------------------|------------------------------|----------------------|
| Year | Total Effort Effort (hours fished) | Total Catch Reported (Kg) | CPUE hours fished |
| 2002 | 52 | 9 | 0.2 |
| 2003 | 200 | 150 | 0.7 |
| 2004 | 228 | 107 | 0.5 |
| 2005 | 195 | 35 | 0.2 |
| 2006 | 242 | 62 | 0.3 |
| 2007 | 305 | 0 | 0.0 |
| 2008 | 108 | 0 | 0.0 |
| 2009 | 165 | 0 | 0.0 |
| 2010 | 24 | 0 | 0.0 |
| 2011 | 19.16 | 0 | 0.0 |
| 2012 | 11.74 | 0 | 0.0 |
| 2013 | 23.97 | 0 | 0.0 |
| 2014 | 0 | 0 | 0.0 |
| 2015* | 0 | 0 | 0.0 |

* Preliminary data

Table 5.8 Blueback Herring Bycatch Maine Otter Trawl Fisheries.

Blueback Herring Bycatch in Otter Trawl Fisheries (VTR data)

| Year | Total Effort (hours fished) | Total Catch Reported (Kg) | CPUE (hours fished) |
|-------|--------------------------------|------------------------------|------------------------|
| 2002 | 3 | 293 | 250.0 |
| 2003 | 0 | 0 | 0 |
| 2004 | 0 | 0 | 0 |
| 2005 | 3 | 1 | 0.8 |
| 2006 | 6 | 2,093 | 775.0 |
| 2007 | 0 | 0 | 0 |
| 2008 | 0 | 0 | 0 |
| 2009 | 0 | 0 | 0 |
| 2010 | 0 | 0 | 0 |
| 2011 | 0 | 0 | 0 |
| 2012 | 0 | 0 | 0 |
| 2013 | 0 | 0 | 0 |
| 2014 | 0 | 0 | 0 |
| 2015* | 0 | 0 | 0 |

*Preliminary data

Table 5.9 Alewife Age Structure from Samples Collected at the Brunswick Fishway.

Androscoggin River - Brunswick Fishway

| | 2016 | | 2015 | | 2014 | | 1995 | | 1994 | | 1993 | |
|-------|-------|---------|-------|---------|-------|---------|-------|---------|-------|---------|-------|---------|
| | Males | Females |
| Age 3 | 13 | 12 | | | 4 | 2 | 3 | 2 | 0 | 0 | 33 | 6 |
| Age 4 | 66 | 47 | | | 23 | 9 | 36 | 38 | 48 | 45 | 19 | 12 |
| Age 5 | 30 | 20 | | | 2 | 8 | 6 | 26 | 25 | 20 | 14 | 7 |
| Age 6 | 9 | 2 | | | 0 | 2 | 0 | 11 | 1 | 2 | 4 | 7 |
| Age 7 | 1 | 2 | | | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |

Table 5.10 Alewife Age Structure from Samples Collected at the Ft. Halifax and Benton Fishways.

Sebasticook River - Ft. Halifax Fishway

| | 2016 | | 2015 | | 2014 | | 2003 | | 2002 | | 2001 | |
|-------|-------|---------|-------|---------|-------|---------|-------|---------|-------|---------|-------|---------|
| | Males | Females |
| Age 3 | | | 8 | 1 | 0 | 2 | 42 | 34 | 21 | 15 | 6 | 0 |
| Age 4 | | | 23 | 20 | 8 | 14 | 20 | 26 | 65 | 53 | 65 | 44 |
| Age 5 | | | 6 | 4 | 6 | 5 | 8 | 11 | 29 | 28 | 21 | 10 |
| Age 6 | | | 0 | 1 | 3 | 3 | 0 | 0 | 6 | 4 | 3 | 2 |
| Age 7 | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 |

Table 5.11 Juvenile Alosine Survey - Alewife.

Alewife

| Year | Sample Size | Total Catch | Arithmetic Mean | | Geometric Mean | | |
|------|-------------|-------------|-----------------|-------|----------------|------|-------|
| | | | Mean | SE | Mean | LCI | UCI |
| 1979 | 45 | 197 | 4.38 | 14.05 | 4.51 | 0.64 | 17.50 |
| 1980 | 57 | 338 | 5.93 | 6.56 | 1.64 | 0.48 | 3.70 |
| 1981 | 58 | 153 | 2.64 | 2.95 | 0.74 | 0.17 | 1.59 |
| 1982 | 59 | 137 | 2.32 | 5.72 | 0.90 | 0.12 | 2.22 |
| 1983 | 53 | 5,309 | 100.17 | 39.97 | 3.18 | 1.53 | 5.91 |
| 1984 | 45 | 696 | 15.47 | 5.31 | 0.94 | 0.40 | 1.70 |
| 1985 | 42 | 287 | 6.83 | 2.38 | 0.89 | 0.40 | 1.55 |
| 1986 | 62 | 404 | 6.52 | 1.52 | 1.43 | 0.84 | 2.21 |
| 1987 | 60 | 1,294 | 21.57 | 5.38 | 2.33 | 1.33 | 3.74 |
| 1988 | 100 | 2,200 | 22.00 | 8.47 | 2.11 | 1.33 | 3.16 |
| 1989 | 92 | 1,741 | 18.92 | 4.40 | 2.46 | 1.51 | 3.76 |
| 1990 | 98 | 2,047 | 20.89 | 9.07 | 1.57 | 0.90 | 2.49 |
| 1991 | 88 | 3,979 | 45.22 | 27.32 | 2.40 | 1.34 | 3.94 |
| 1992 | 79 | 3,123 | 39.53 | 15.05 | 2.85 | 1.57 | 4.78 |
| 1993 | 76 | 1,386 | 18.24 | 6.12 | 2.16 | 1.17 | 3.60 |
| 1994 | 93 | 667 | 7.17 | 1.70 | 1.80 | 1.16 | 2.63 |
| 1995 | 110 | 3,351 | 30.46 | 8.54 | 4.43 | 2.89 | 6.56 |
| 1996 | 89 | 1,150 | 12.92 | 4.37 | 1.38 | 0.75 | 2.22 |
| 1997 | 110 | 1,754 | 15.95 | 5.50 | 1.79 | 1.10 | 2.72 |
| 1998 | 112 | 1,565 | 13.97 | 9.45 | 1.04 | 0.60 | 1.60 |
| 1999 | 108 | 4,325 | 40.05 | 13.96 | 2.44 | 1.44 | 3.87 |
| 2000 | 111 | 20,885 | 188.15 | 53.83 | 5.64 | 3.30 | 9.25 |
| 2001 | 129 | 2,344 | 18.17 | 5.36 | 1.47 | 0.88 | 2.24 |
| 2002 | 127 | 1,430 | 11.26 | 2.94 | 1.75 | 1.14 | 2.54 |
| 2003 | 114 | 4,664 | 40.91 | 16.29 | 2.34 | 1.42 | 3.62 |
| 2004 | 105 | 2,769 | 26.37 | 7.71 | 3.45 | 2.18 | 5.22 |
| 2005 | 112 | 1,238 | 11.05 | 3.45 | 1.17 | 0.67 | 1.82 |
| 2006 | 120 | 3,795 | 31.63 | 11.83 | 1.88 | 1.06 | 3.03 |
| 2007 | 119 | 1,211 | 10.18 | 3.41 | 1.24 | 0.72 | 1.92 |
| 2008 | 104 | 1,267 | 12.18 | 3.97 | 1.02 | 0.55 | 1.62 |
| 2009 | 111 | 857 | 7.72 | 2.10 | 1.39 | 0.86 | 2.06 |
| 2010 | 114 | 3,889 | 35.04 | 19.77 | 2.03 | 1.23 | 3.11 |
| 2011 | 117 | 1,338 | 12.05 | 3.92 | 1.19 | 0.69 | 1.83 |
| 2012 | 118 | 2,521 | 22.71 | 14.89 | 1.01 | 0.56 | 1.59 |
| 2013 | 120 | 4,087 | 36.82 | 19.10 | 1.71 | 1.01 | 2.65 |
| 2014 | 120 | 2,055 | 18.51 | 5.77 | 1.47 | 0.85 | 2.28 |
| 2015 | 112 | 3,502 | 31.55 | 7.55 | 3.55 | 2.26 | 5.34 |

Table 5.12 Juvenile Alosine Survey – Blueback Herring

| Blueback Herring | | Total Catch | Arithmetic | | Geometric | | |
|------------------|-------------|-------------|------------|-------|-----------|-------|------|
| Year | Sample Size | | Mean | SE | Mean | LCI | UCI |
| 1979 | 45 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1980 | 57 | 1 | 0.02 | 0.04 | 0.01 | -0.02 | 0.03 |
| 1981 | 58 | 31 | 0.53 | 0.50 | 0.08 | -0.06 | 0.25 |
| 1982 | 59 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1983 | 53 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1984 | 45 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1985 | 42 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1986 | 62 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1987 | 60 | 25 | 0.42 | 0.26 | 0.05 | -0.02 | 0.13 |
| 1988 | 100 | 13 | 0.13 | 0.10 | 0.03 | -0.02 | 0.08 |
| 1989 | 92 | 9 | 0.10 | 0.07 | 0.03 | -0.01 | 0.07 |
| 1990 | 98 | 4 | 0.04 | 0.03 | 0.02 | -0.01 | 0.05 |
| 1991 | 88 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1992 | 79 | 1,079 | 13.66 | 7.48 | 0.58 | 0.20 | 1.09 |
| 1993 | 76 | 47 | 0.62 | 0.62 | 0.05 | -0.05 | 0.16 |
| 1994 | 93 | 289 | 3.11 | 1.32 | 0.38 | 0.15 | 0.66 |
| 1995 | 110 | 1,402 | 12.75 | 3.18 | 1.99 | 1.23 | 3.01 |
| 1996 | 93 | 620 | 6.67 | 5.93 | 0.30 | 0.09 | 0.55 |
| 1997 | 110 | 598 | 5.44 | 3.79 | 0.49 | 0.24 | 0.79 |
| 1998 | 112 | 562 | 5.02 | 2.07 | 0.69 | 0.38 | 1.08 |
| 1999 | 108 | 982 | 9.09 | 3.50 | 0.73 | 0.35 | 1.21 |
| 2000 | 111 | 1,086 | 9.78 | 9.46 | 0.15 | -0.01 | 0.32 |
| 2001 | 129 | 273 | 2.12 | 0.90 | 0.30 | 0.13 | 0.50 |
| 2002 | 127 | 1,489 | 11.72 | 4.22 | 1.00 | 0.56 | 1.56 |
| 2003 | 114 | 1,697 | 14.89 | 7.79 | 0.90 | 0.47 | 1.44 |
| 2004 | 105 | 3,020 | 28.76 | 8.33 | 1.69 | 0.91 | 2.80 |
| 2005 | 112 | 1,526 | 13.63 | 5.71 | 0.65 | 0.29 | 1.11 |
| 2006 | 110 | 2,541 | 23.10 | 14.86 | 0.68 | 0.30 | 1.16 |
| 2007 | 113 | 1,218 | 10.78 | 7.80 | 0.48 | 0.21 | 0.82 |
| 2008 | 104 | 244 | 2.35 | 1.21 | 0.37 | 0.17 | 0.60 |
| 2009 | 111 | 66 | 0.69 | 0.37 | 0.15 | 0.05 | 0.27 |
| 2010 | 114 | 122 | 1.07 | 0.49 | 0.27 | 0.12 | 0.43 |
| 2011 | 117 | 184 | 1.57 | 0.60 | 0.29 | 0.12 | 0.49 |
| 2012 | 118 | 305 | 2.58 | 1.78 | 0.26 | 0.09 | 0.45 |
| 2013 | 120 | 331 | 2.76 | 1.04 | 0.46 | 0.23 | 0.74 |
| 2014 | 120 | 1,355 | 11.29 | 5.13 | 0.57 | 0.25 | 0.98 |
| 2015 | 112 | 51 | 0.46 | 0.25 | 0.14 | 0.04 | 0.24 |

Table 5.13 Alewife Run Locations Where Commercial Harvesters Collected Scales for Aging in 2008, 2010, 2016.

| Run Location | Commercial Fishery | 2008 | 2010 | 2016 |
|--------------------|--------------------|------|------|------|
| Saco River | N | | X | |
| Presumpscot River | N | | X | X |
| Winnegance Lake | Y | | X | X |
| Dresden Mills | Y | X | X | X |
| Sewall Pond | N | X | X | X |
| Nequassett Lake | y | X | X | X |
| Androscoggin | N | X | X | X |
| Vassalboro | Y | | X | X |
| Benton | Y | | X | X |
| Sheepscot River | Y | | X | X |
| Dyer River | Y | | X | X |
| Damariscotta River | Y | | X | X |
| Medomak River | N | | X | X |
| Warren | Y | | X | X |
| Souadabscook River | N | | X | |
| Chemo Pond | N | | X | X |
| Orland | Y | | X | X |
| Union River | Y | | X | X |
| Wights Pond | N | | | X |
| Pierce Pond | N | | | X |
| Walker Pond | N | | | X |
| Somes Pond | N | | X | X |
| Seal Cove Pond | N | | | X |
| Grist Mill Stream | Y | X | X | X |
| Flanders Stream | Y | X | | X |
| Patten Pond | Y | X | X | X |
| Card Mill Stream | N | X | | X |
| Gouldsboro | Y | X | X | X |
| Pembroke | Y | | X | X |
| Cherryfield | Y | | X | X |
| Pleasant River | N | | | X |
| East Machias | Y | | X | X |
| Crawford Lake | N | | | X |
| Dennysville | N | | X | X |
| Pembroke | N | | | X |
| Perry | Y | | X | X |
| St. Croix River | N | | | X |

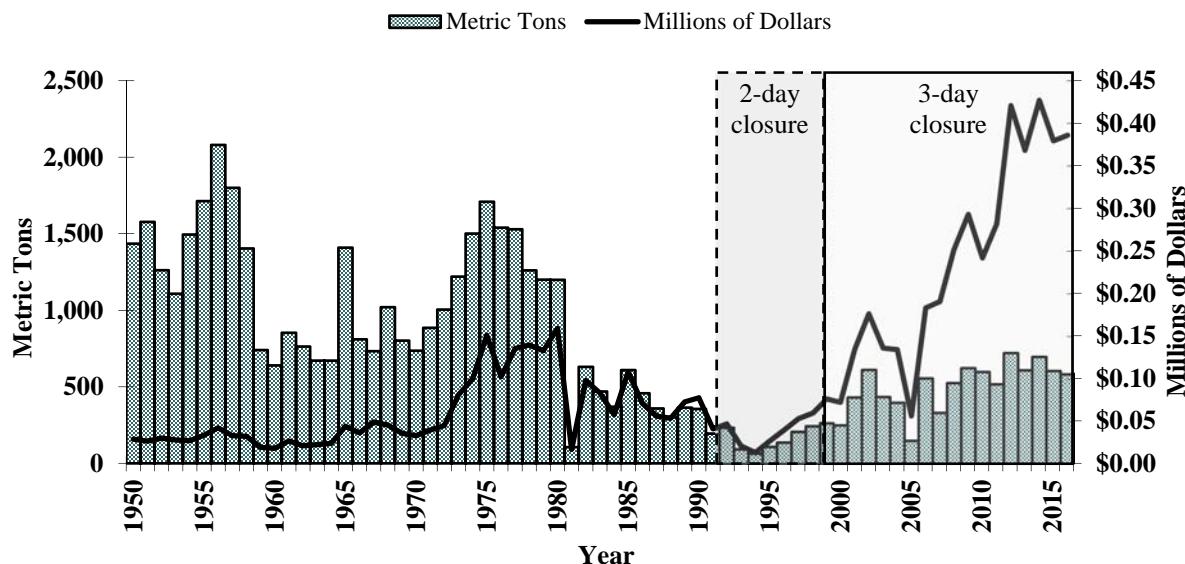


Figure 5.1 State of Maine Alewife Landings.

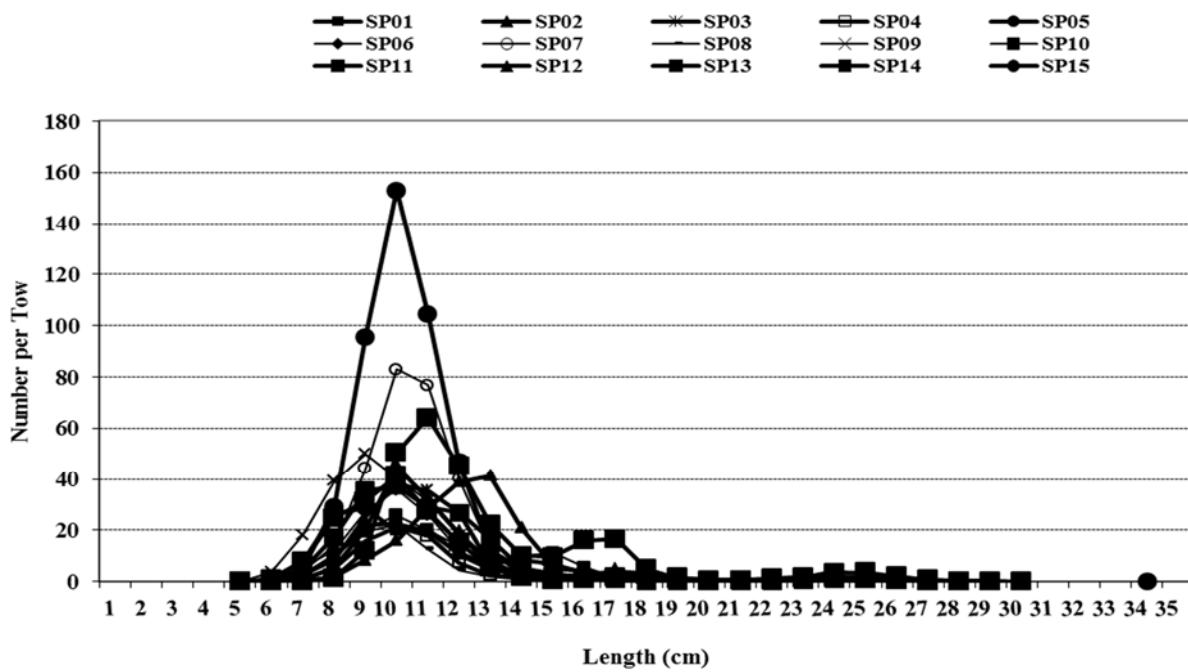


Figure 5.2 Length Frequency of Alewife Captured During the 2001 – 2015 Spring Inshore Trawl Survey.

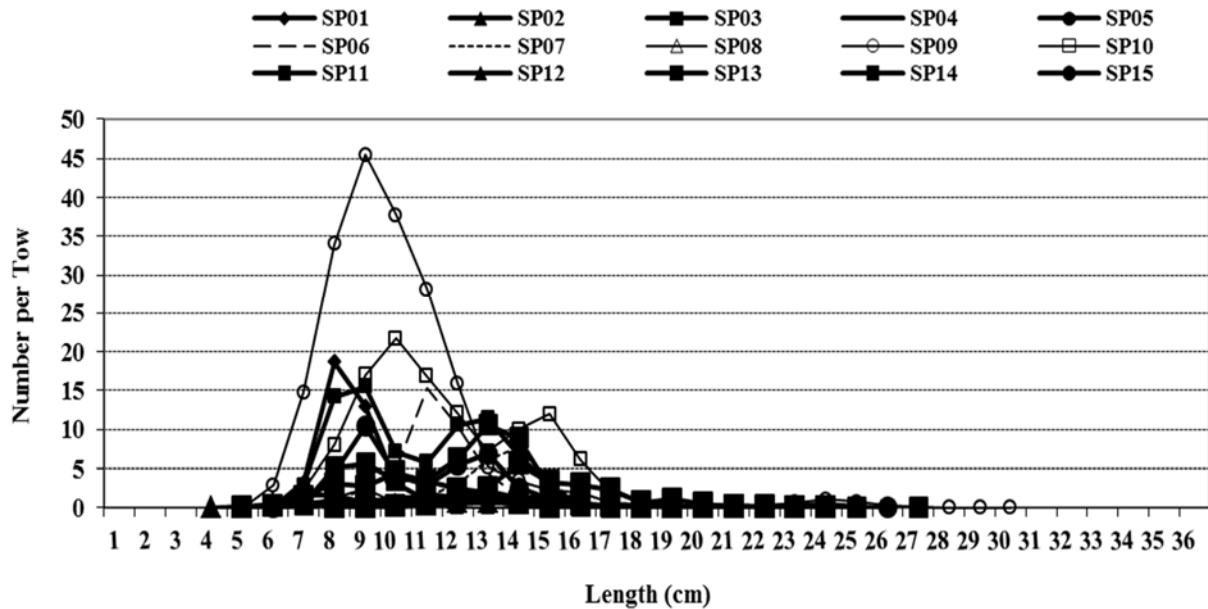


Figure 5.3 Length Frequency of Blueback Herring Captured During the 2001 – 2015 Maine-New Hampshire Spring Trawl Survey.

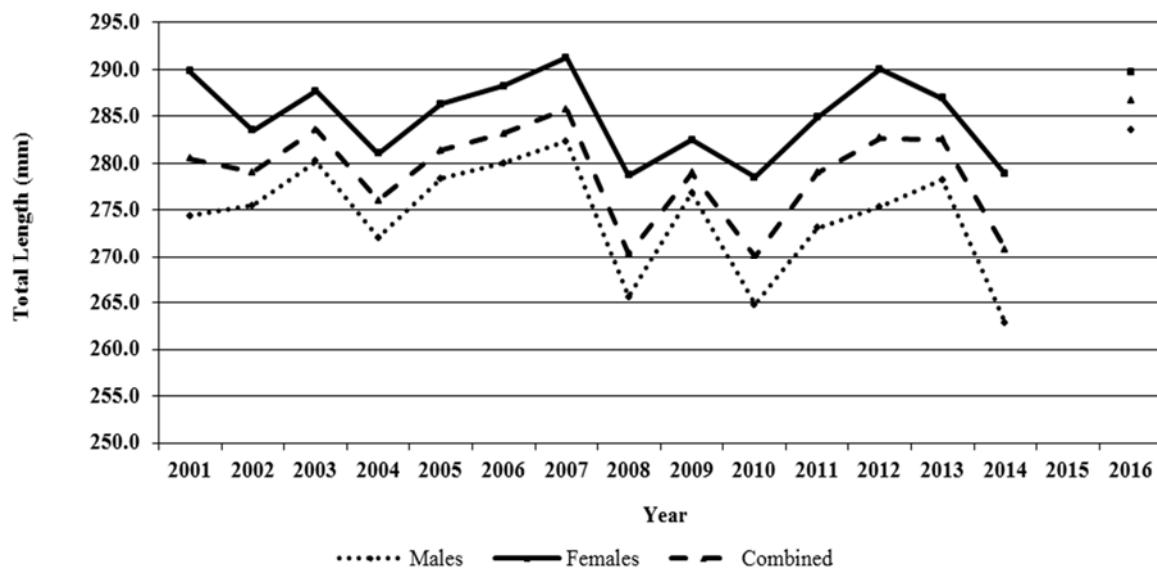


Figure 5.4 Mean Total Lengths of Alewives Sampled at the Brunswick Fishway.

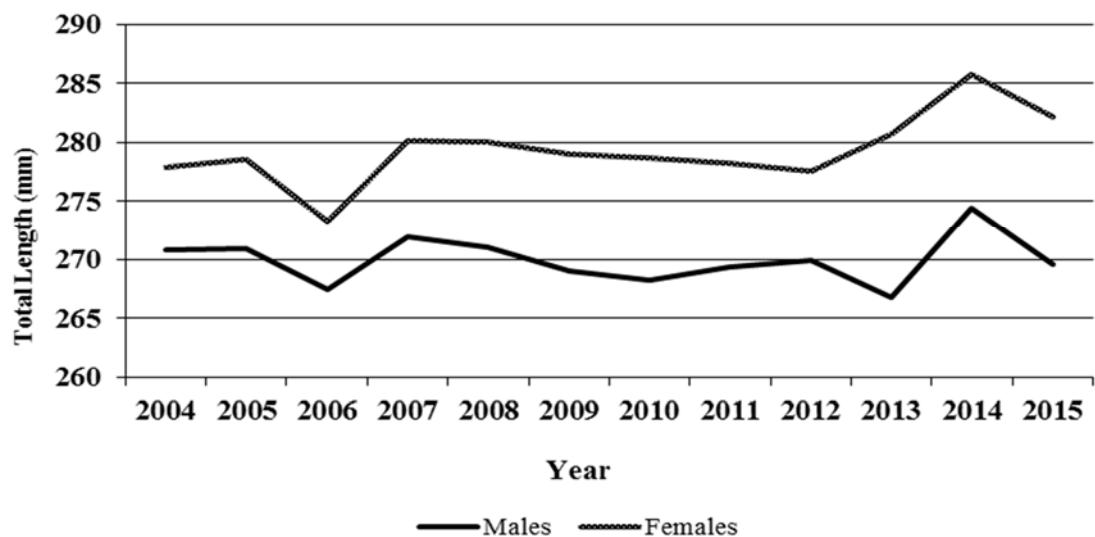


Figure 5.5 Mean Total Lengths of Alewives Sampled at the Sebasticook Fishway.

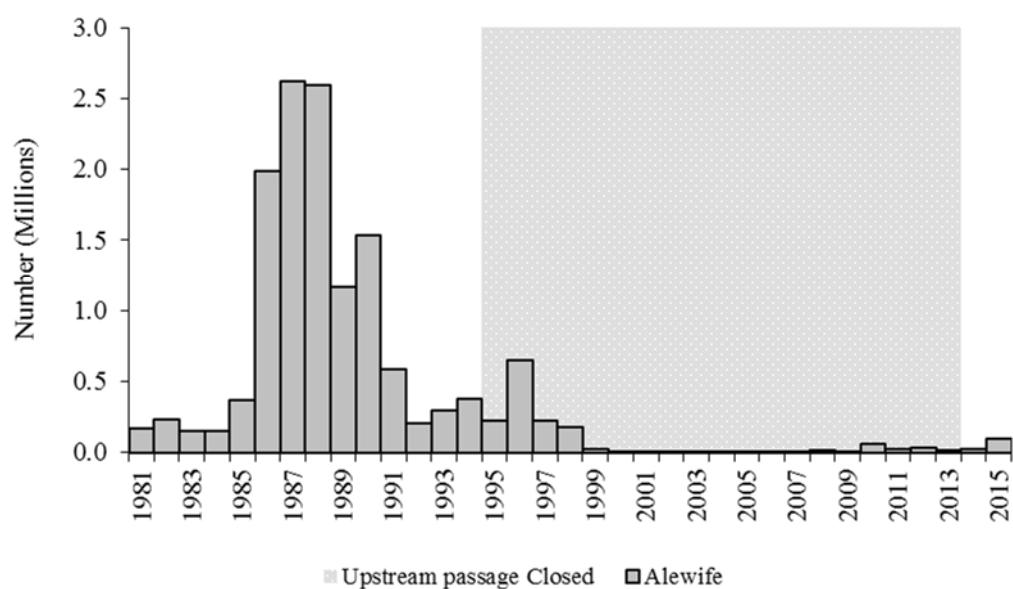


Figure 5.6 Number of river herring counted at Milltown Fishway on the St. Croix River from 1981-2015.

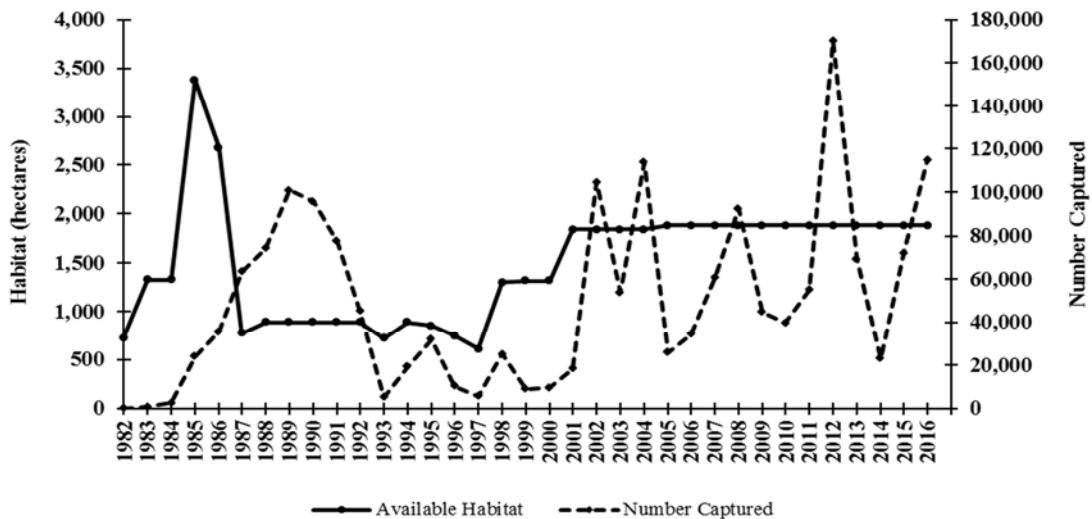


Figure 5.7 Adult River Herring Run Size and Habitat Availability - Androscoggin River Watershed, 1982-2015.

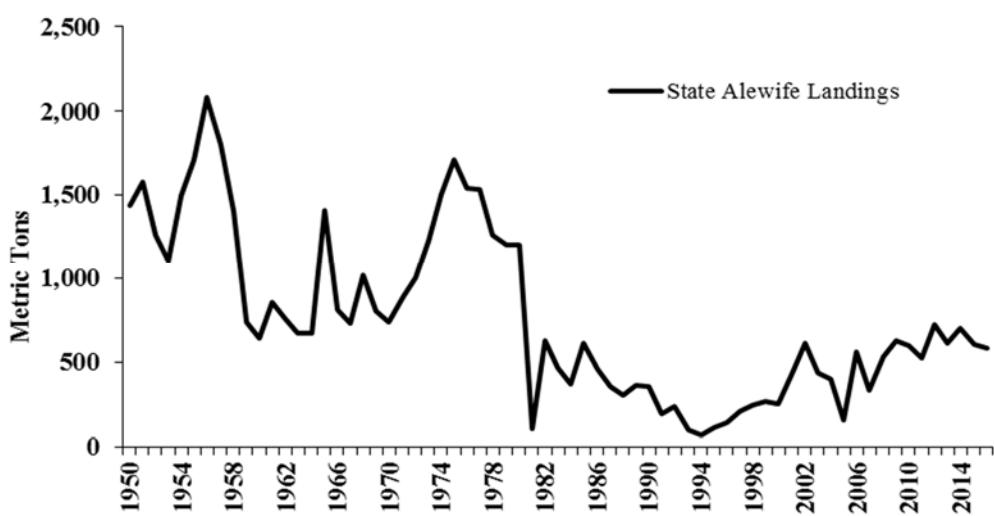


Figure 5.8 Maine Commercial Alewife Harvest.

Damariscotta Lake

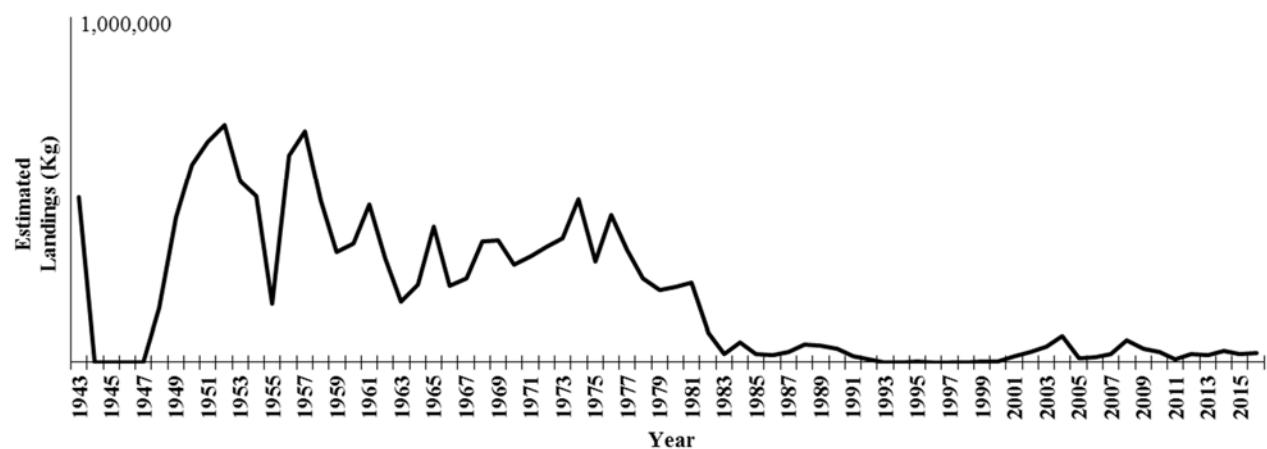


Figure 5.9 Damariscotta Lake Alewife Commercial Harvest

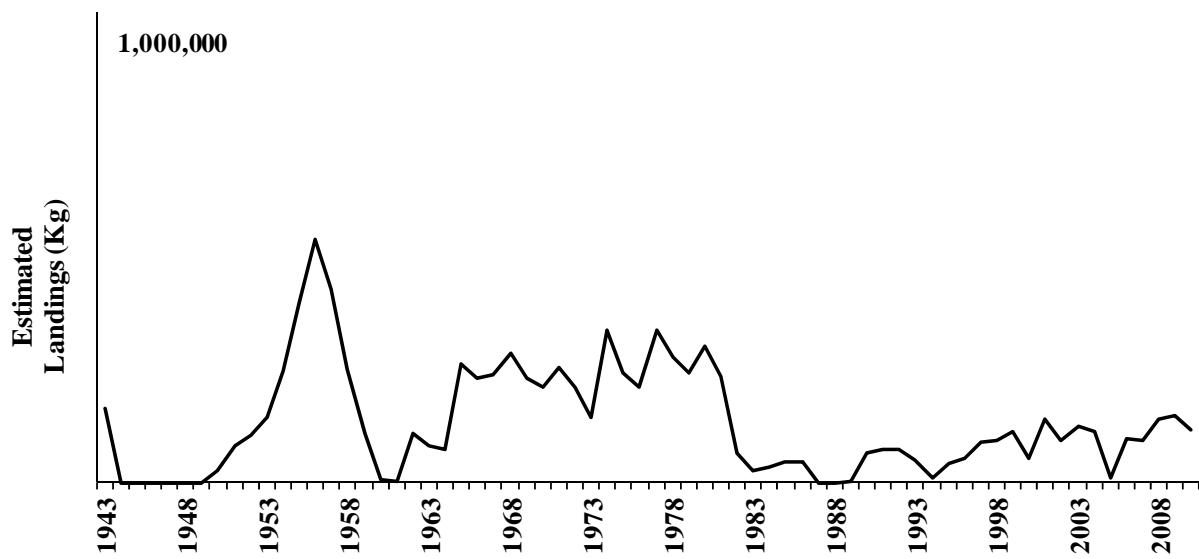


Figure 5.10 St. George Commercial River Herring Harvest

Union River

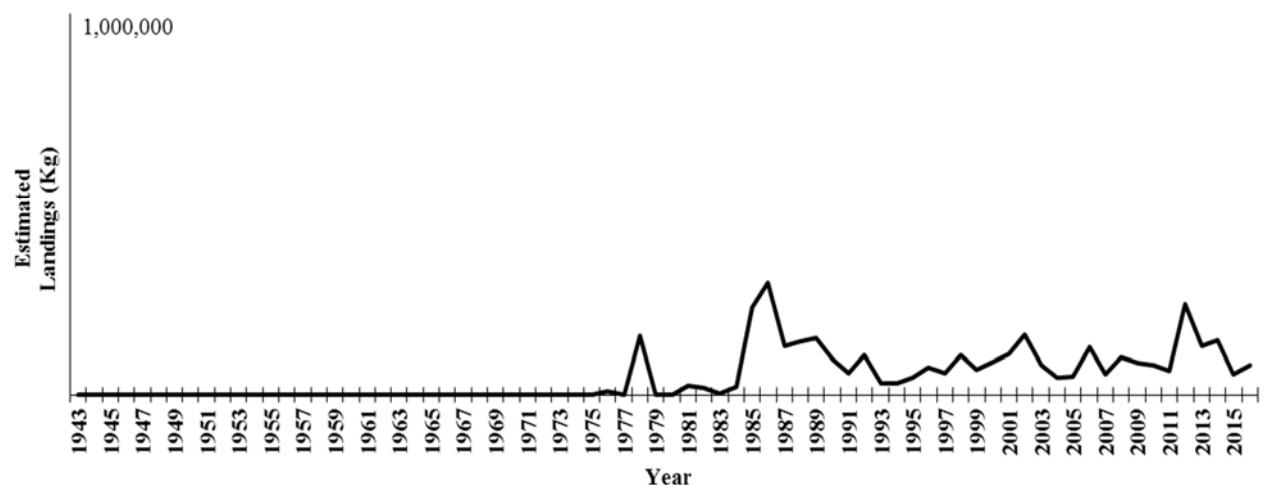


Figure 5.11 Union River Commercial Alewife Harvest

Orland River

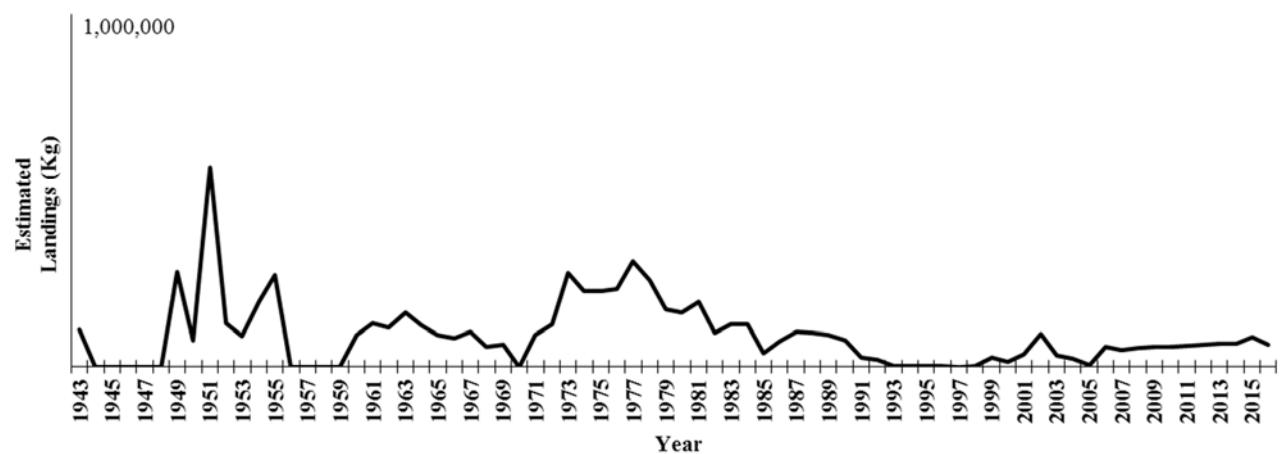


Figure 5.12 Orland Commercial River Herring Harvest

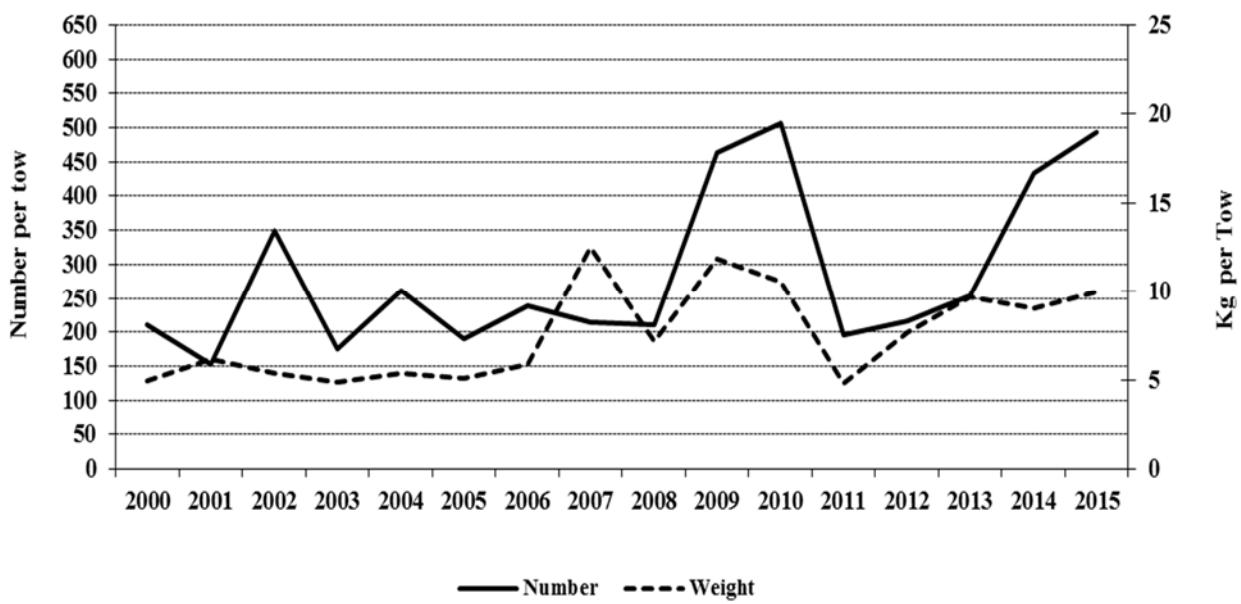


Figure 5.13 Total Number and Weight of Alewife Captured During the Fall Maine-New Hampshire Trawl Survey.

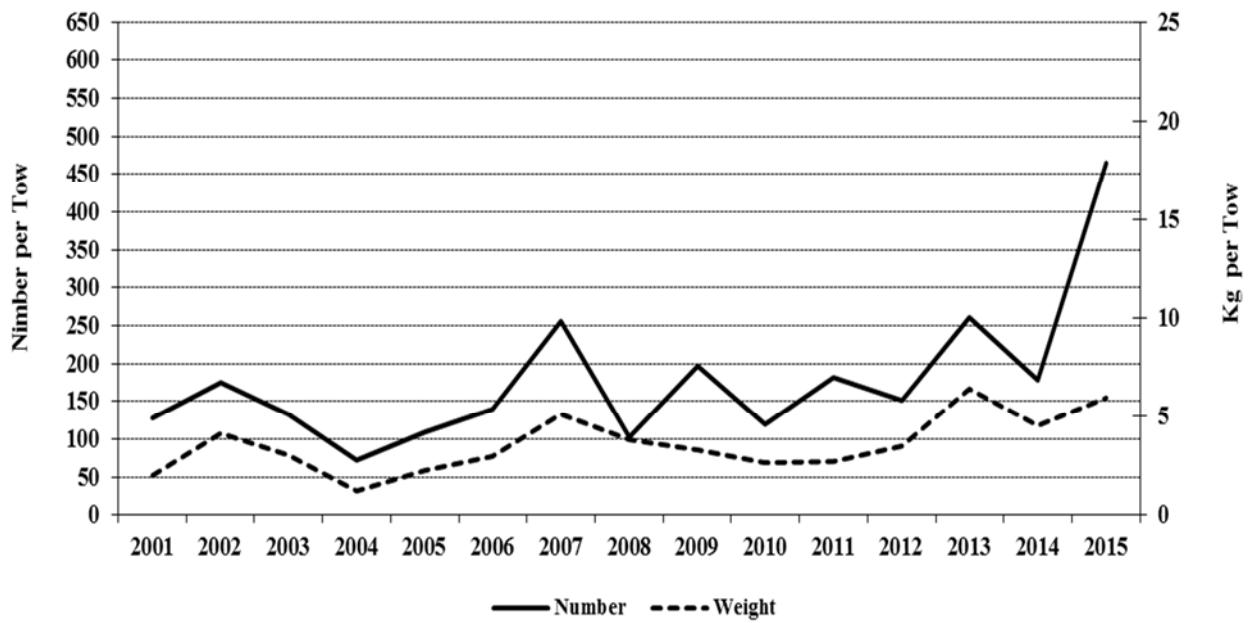


Figure 5.14 Total Number and Weight of Alewife Captured During the Spring Maine-New Hampshire Trawl Survey.

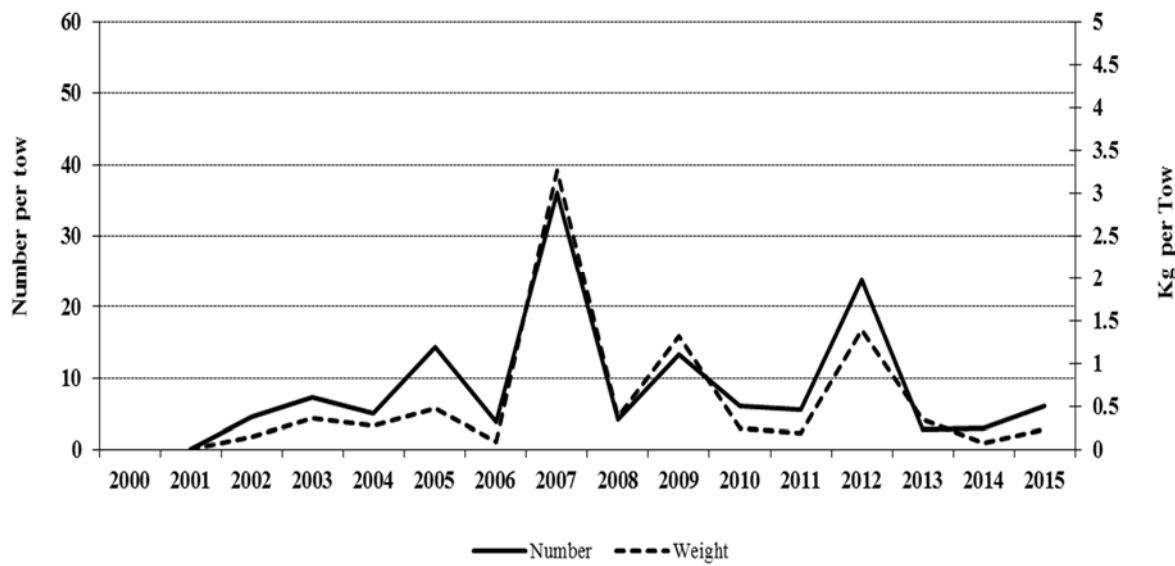


Figure 5.15 Total Number and Weight of Blueback Herring Captured During the Fall Maine-New Hampshire Trawl Survey.

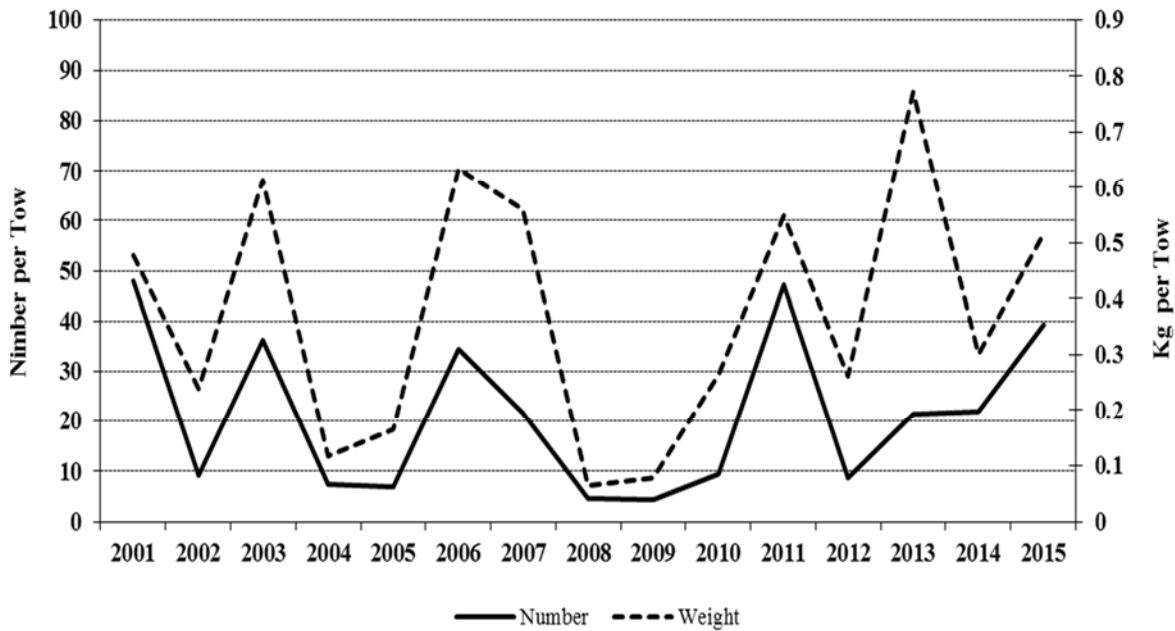


Figure 5.16 Total Number and Weight of Blueback Herring Captured During the Spring Maine-New Hampshire Trawl Survey.

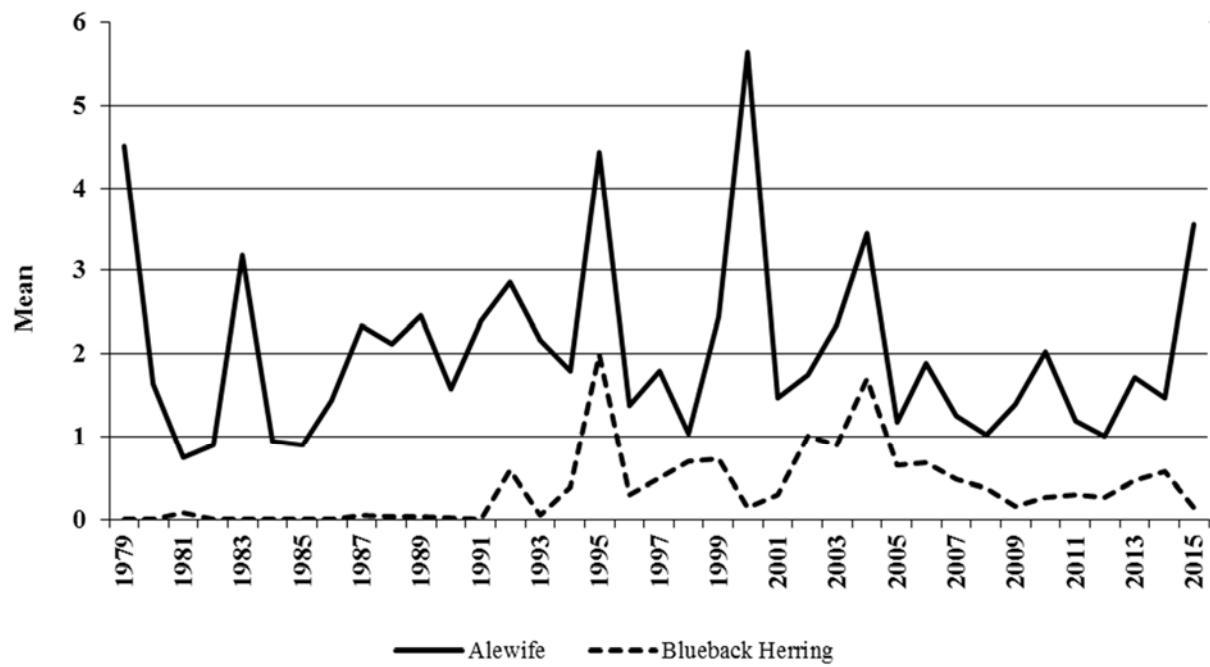


Figure 5.17 Geometric Means for Merrymeeting Bay – Alewife and Blueback Herring

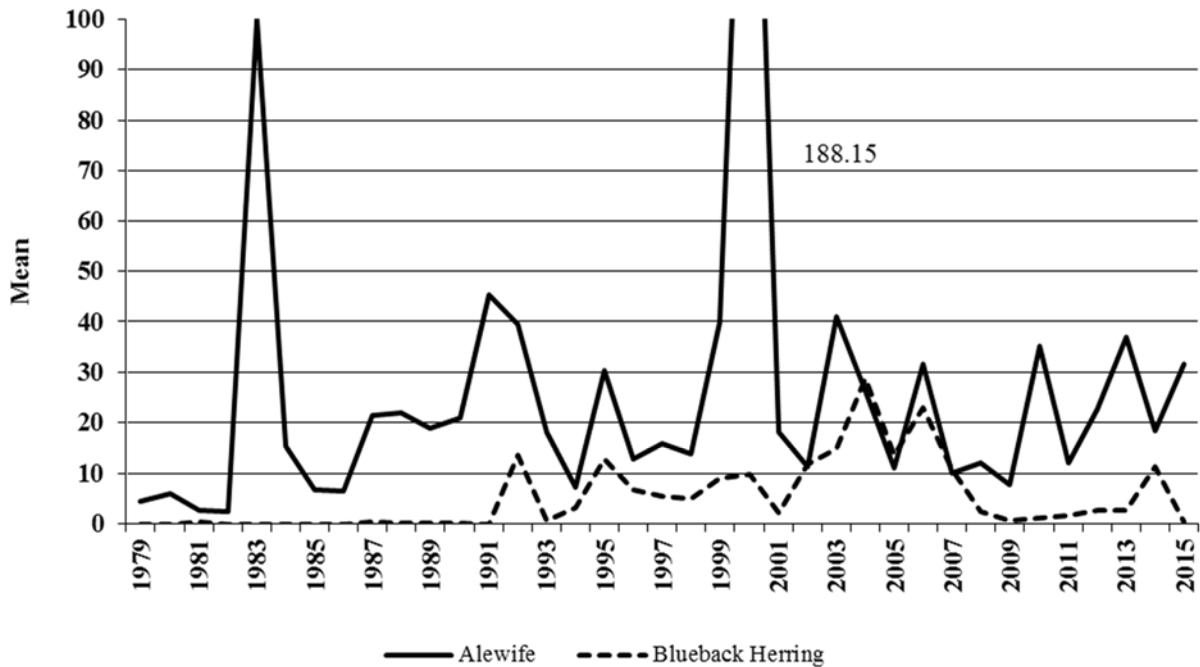


Figure 5.18 Arithmetic Means for Merrymeeting Bay – Alewife and Blueback Herring.

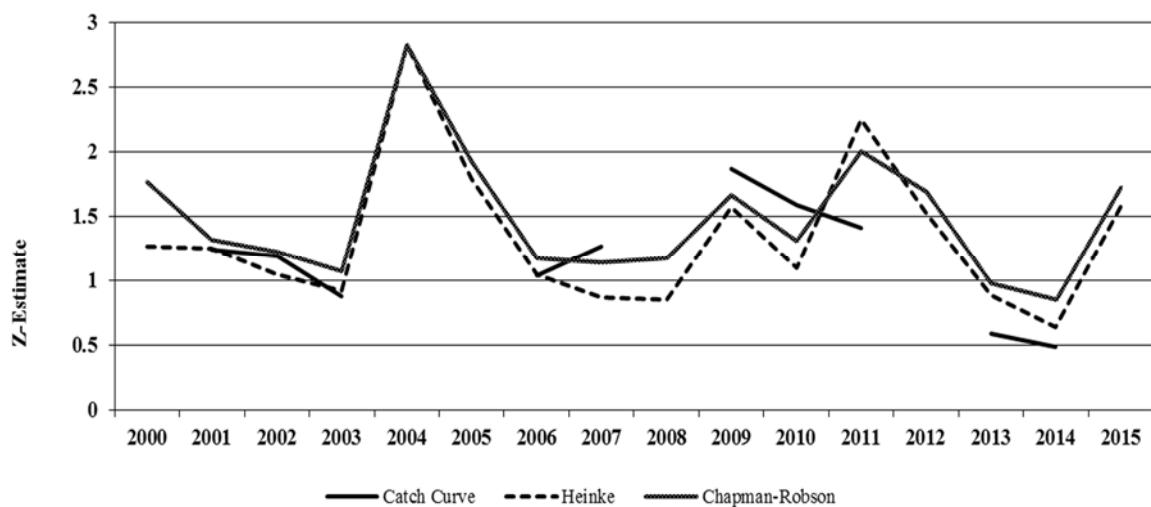


Figure 5.19 Male Alewife Z Estimates for the Sebasticook River at Ft. Halifax and Benton Falls.

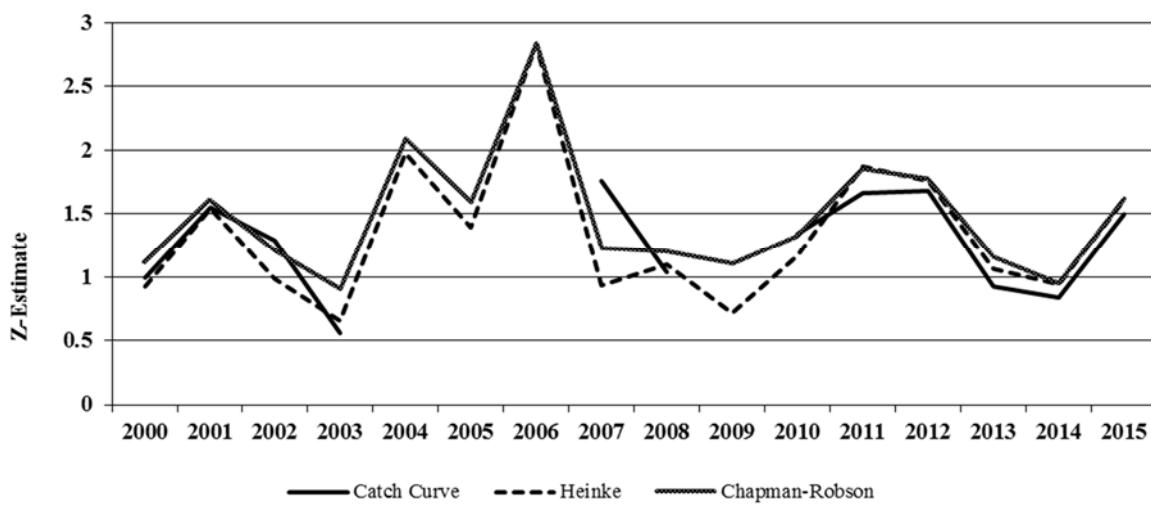


Figure 5.20 Female Alewife Z Estimates for the Sebasticook River at Ft. Halifax and Benton Falls.

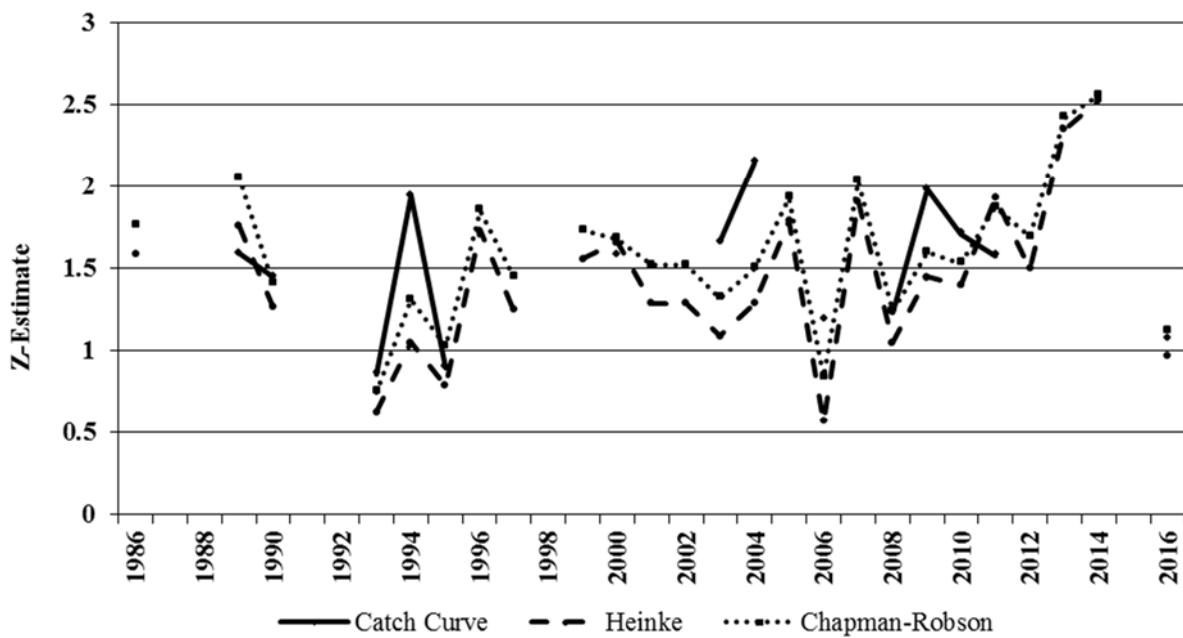


Figure 5.21 Male Alewife Z Estimates for the Androscoggin River at the Brunswick Fishway.

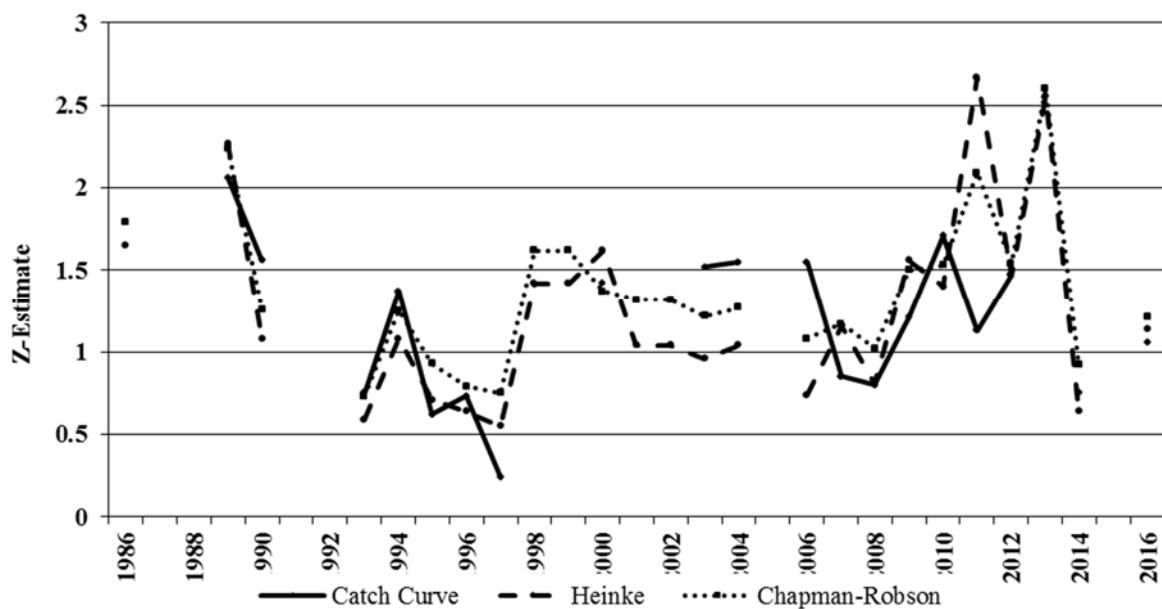


Figure 5.22 Female Alewife Z Estimates for the Androscoggin River at the Brunswick Fishway.

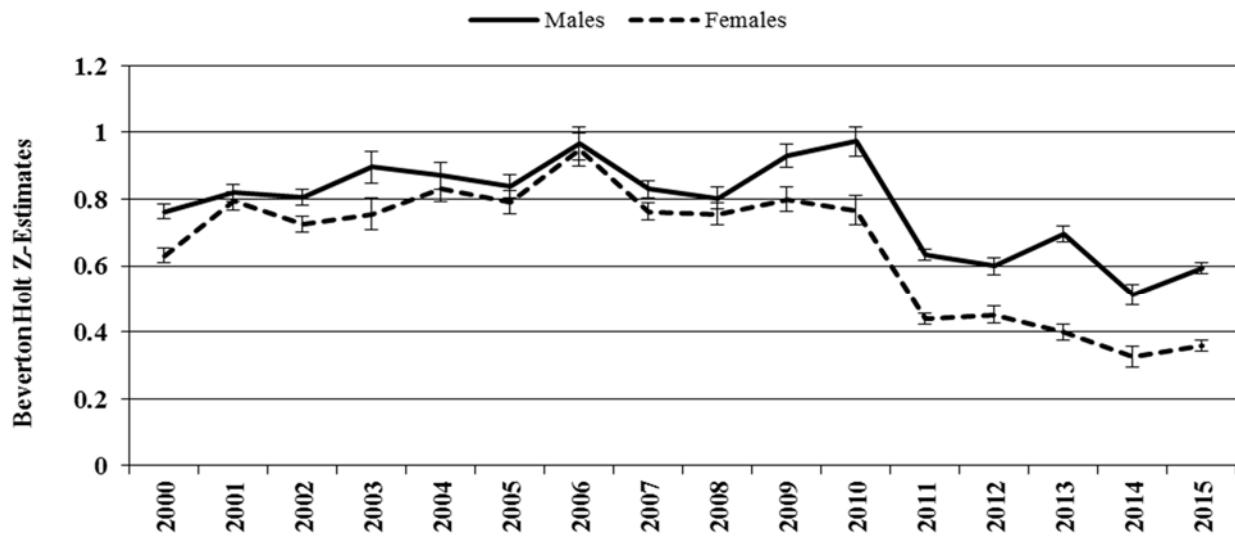


Figure 5.23 Male and Female Alewife Z Estimates for the Sebasticook River using Beverton-Holt.

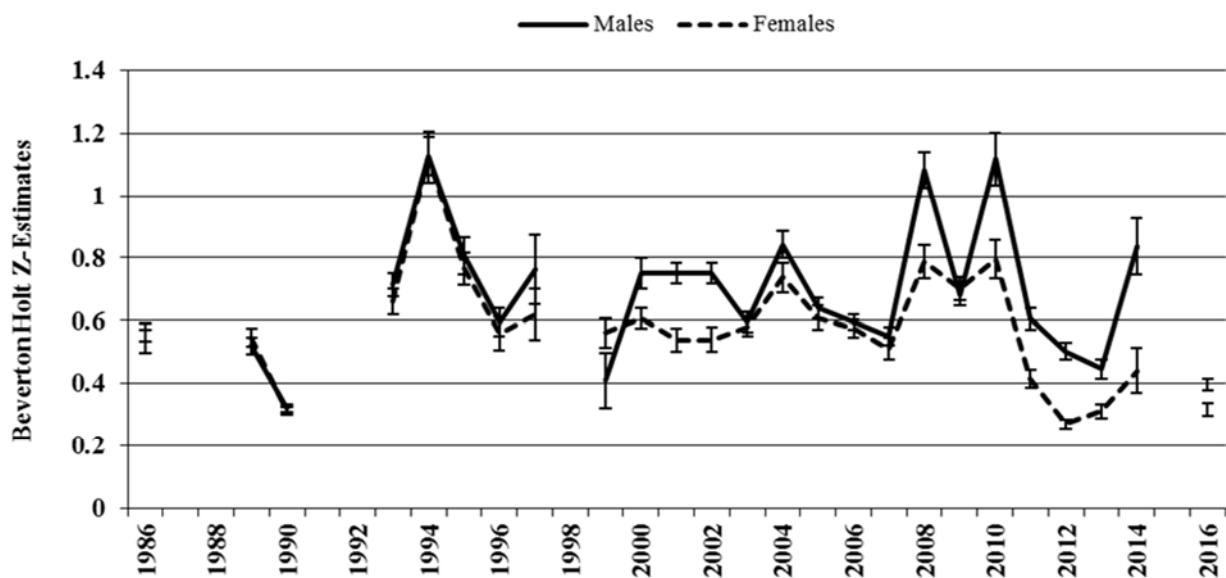


Figure 5.24 Male and Female Alewife Z-Estimates for the Androscoggin River using Beverton-Holt

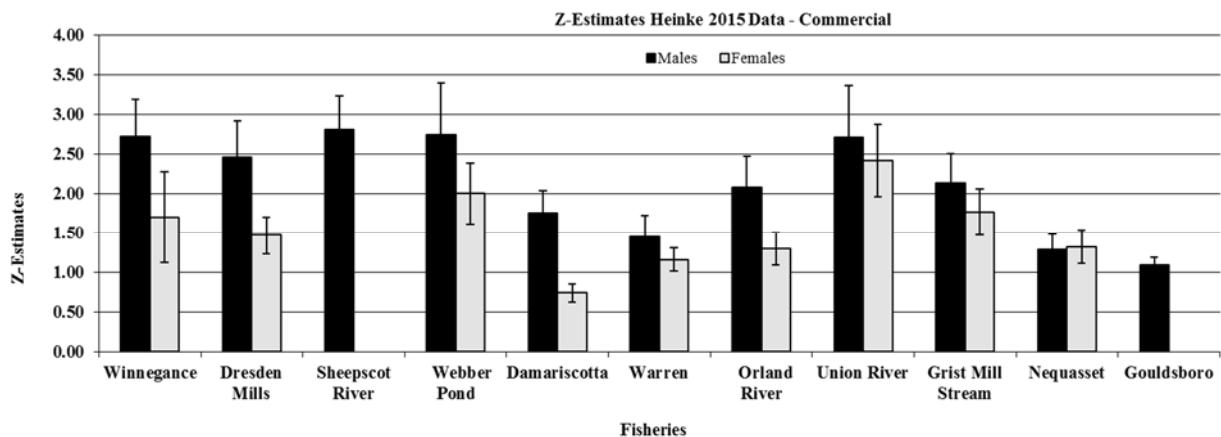


Figure 5.25 Male and female Z-estimates (Heinke) of Alewife Captured at Eleven Commercial Runs in 2015.

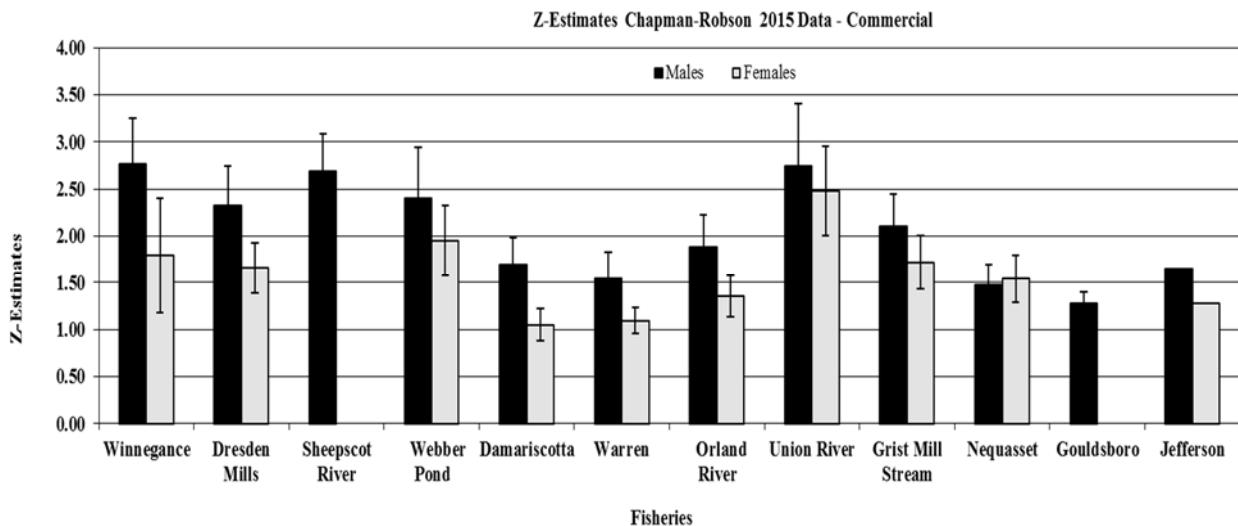


Figure 5.26 Male and female Z-estimates (Chapman-Robson) of Alewife Captured at Twelve Commercial Runs in 2015.

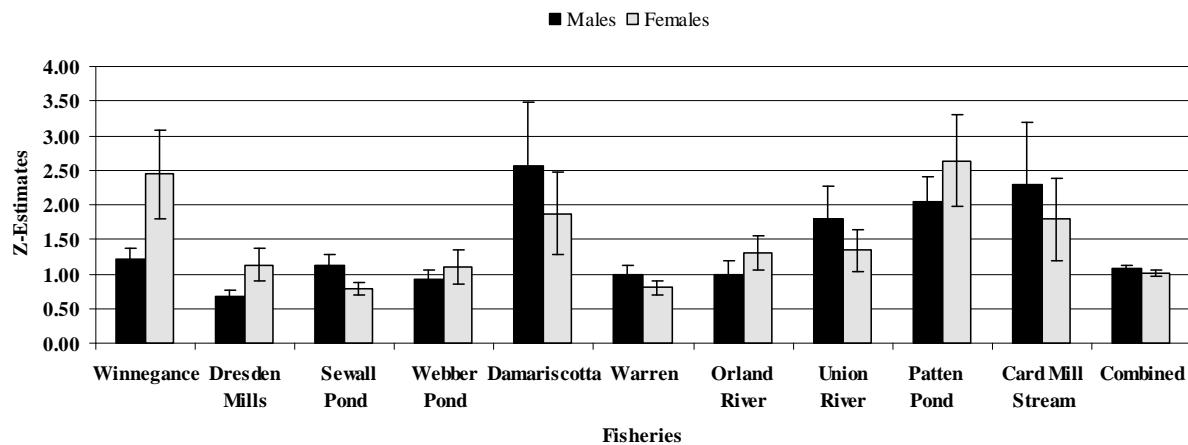


Figure 5.27 Male and female Z-estimates (Heinke) of Alewife Captured at Ten Commercial and Non-Commercial Runs in 2009.

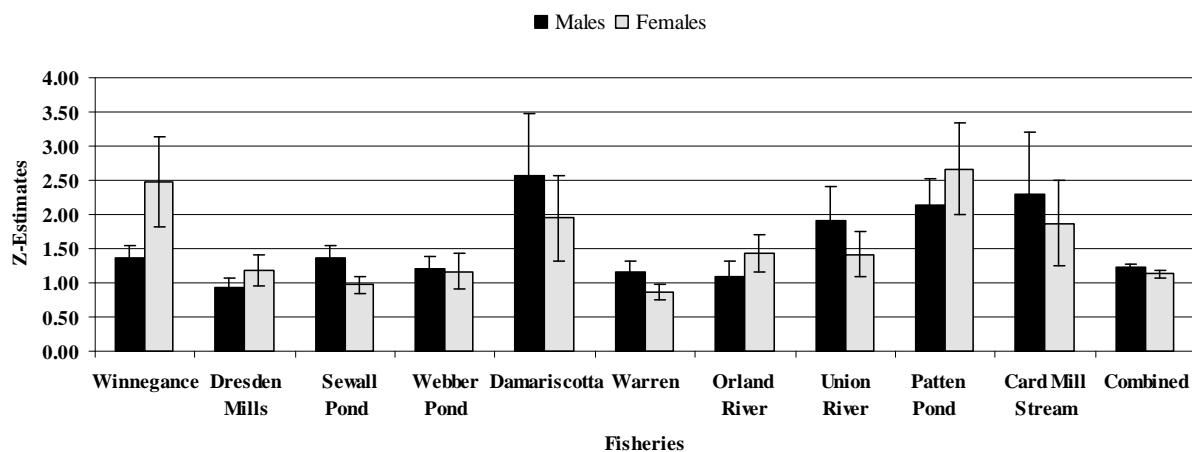


Figure 5.28 Male and female Z-estimates (Chapman-Robson) of Alewife Captured at Ten Commercial and Non-Commercial Runs in 2009.

6 Status of River Herring in New Hampshire

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6.1. INTRODUCTION

New Hampshire's coastal rivers once supported abundant runs of anadromous fish including river herring (alewife and blueback herring) (Figure 6.1), American shad, and Atlantic salmon (Jackson 1944). These and other diadromous species have been denied access to historical freshwater spawning habitat since the construction of milldams as early as the 1600s but more dramatically during the nineteenth century textile boom in most New Hampshire coastal rivers (Figure 6.2). Barriers eliminated American shad and Atlantic salmon populations, but river herring only declined in numbers because they utilized small areas of freshwater at the base of dams during spring runoffs for spawning.

Restoration of diadromous fish populations in New Hampshire began with construction of fishways in the late 1950s and continued through the early 1970s by the New Hampshire Fish and Game Department (NHFGD) in the Exeter, Lamprey, Winnicut, Oyster, and Cocheco rivers in the Great Bay Estuary (Figure 6.3, Figure 6.4, Figure 6.5, Figure 6.6, Figure 6.7) and the Taylor River in the Hampton-Seabrook Estuary (Figure 6.8). These fishways re-opened acres of freshwater spawning and nursery habitat for river herring, American shad, and other diadromous fish.

6.2. MANAGEMENT UNIT DEFINITION

NHFGD manages the river herring populations within state waters. Primarily river herring are intercepted for biological sampling and enumerated at Department owned fish ladders at the head-of-tide dams for management purposes. Individual river herring spawning runs in the Exeter (Squamscott), Lamprey, Winnicut, Oyster, Cocheco, and Taylor Rivers were evaluated independently in this report as units of the State's river herring stock.

6.2.1. Exeter/Squamscott River

The Exeter River drains an area of 326 square km in southern New Hampshire (Figure 6.3). The river flows east and north from the Town of Chester to the Town of Exeter. It empties into Great Bay northeast of Exeter. The head-of-tide occurs at the Town of Exeter and the saltwater portion of the river is called the Squamscott River.

The two lowermost dams on the main stem Exeter River are the Great Dam in Exeter at river kilometer (rkm) 10.6 and the Pickpocket Dam at rkm 22.4 (each 4.6 km high). The next barrier above Pickpocket Dam is a set of natural falls at rkm 32.9. NHFGD constructed upstream fish passage facilities (Denil fishways) on both dams from 1969 to 1971 for anadromous fish, funded in part by the U.S. Fish and Wildlife Service (USFWS). Fish ladder improvements occurred in 1994 and 1999 and a fish trap was constructed at the upriver end of the Great Dam fish ladder. There are no downstream fish passage facilities on either dam so emigrating adults and juveniles pass over the spillway when river flows allow. There are approximately one hundred meters of fresh water that occurs between head-of-tide and the

Great Dam caused by an elevated ledge that prevents saltwater incursion. River herring have been observed below the Great Dam and have the ability to spawn in this area. Most spawning and rearing habitat occurs above the dam. Periodic water quality monitoring has recorded declines in dissolved oxygen (DO) between the two dams for some years since 1995 (Smith *et al.* 2005; Langan 1995).

6.2.2. Lamprey River

The Lamprey River flows 97 km through southern New Hampshire to the Town of Newmarket where it becomes tidal and enters the Great Bay estuary just north of the mouth of the Squamscott River. The Lamprey River watershed is shown in Figure 6.4. The Macallen Dam, located at rkm 3.2 in Newmarket, is the lowermost head-of-tide dam (8.2 m high) on the Lamprey River. Fish passage is provided by a Denil fish ladder constructed from 1969 to 1970 for anadromous fish by NHFGD, funded in part by the USFWS. There are no downstream passage facilities at the Macallen Dam and emigrating juveniles and adults must pass over the spillway. Fish kills have not been observed below the first dam suggesting that adults and juveniles emigrate with limited mortality. The Wiswall Dam (3.4 m high) is located 5.6 km above the Macallen Dam and has a Denil fish ladder constructed in 2012 by the Town of Durham and operated by NHFGD. The passage at Wiswall Dam provides access to an additional 12.6 km of spawning habitat. Downstream migration at Wiswall Dam is provided by a stop log bay within the spillway that is opened during the fish migration season.

6.2.3. Winnicut River

The Winnicut River drains a watershed of 36.8 square km in southeast New Hampshire (Figure 6.5). It originates in the town of North Hampton and flows north through Greenland where it empties into Great Bay. The last remaining dam on the main stem of the river, located at the head-of-tide at approximately 3.2 rkm, was removed in 2009. A run-of-river fish passage structure was constructed in 2011 to enhance passage of river herring through the constriction of the river caused by the Route 33 Highway Bridge approximately 100 feet above the former dam.

6.2.4. Oyster River

The Oyster River drains a watershed of 27.5 km through southeast New Hampshire (Figure 6.6). It begins in Barrington and flows southeast to Lee, then flows east-southeast through Durham where it empties into Little Bay. The first dam exists at the head of tide just west of NH Route 108 at rkm 4.8. The spillway length is 42.7 m and a height of 3 m. A Denil fish ladder was constructed at this dam around 1975. The next barrier to fish passage is a dam at about rkm 7.7.

6.2.5. Cocheco River

The Cocheco River flows 48 km southeast through southern New Hampshire to Dover where it joins the Salmon Falls River to form the Piscataqua River (Figure 6.7). The lowermost dam (4.6 m high, built on a natural ledge for a total height of 8 – 10 m) on the Cocheco River is within the City of Dover at the head of tide, at rkm 5.5. A Denil fish ladder was constructed at the dam in 1969 to 1970 for anadromous fish by NHFGD, funded in part by the USFWS. The next barrier is a set of natural falls located at rkm 9.5.

The City of Dover currently owns the dam and leases the attached hydroelectric facility to Southern New Hampshire Hydroelectric Development Corporation (SNHHDC). The Federal Energy Regulatory Commission (FERC) requires SNHHDC to provide downstream fish passage and utilize a grating system

to prevent small fish from passing through the turbines. The downstream passage system is a 24" PVC tube emptying in a plunge pool below the dam. This system passes emigrating diadromous species when operating efficiently. Emigrating juvenile and adult river herring must either pass over the dam if flows allow, travel through the downstream migration tube, or move through the turbines at the hydroelectric facility if they can pass through the grating system.

6.2.6. Taylor River

The Taylor River is located in southeastern New Hampshire and is about 17.1 km long (Figure 6.8). The river begins on the border between Hampton Falls and Kensington, New Hampshire. It flows north, east, then southeast through Hampton Falls where it meets tide water at Interstate 95. The lowermost 6.4 km of the river forms the boundary between Hampton and Hampton Falls. The first dam is located at rkm 5.1. There is a Denil fish ladder at this head-of-tide dam that was constructed in the late 1960s. Due to a severely diminished spawning run and lack of a sampling trap at the Taylor River the NHFG decided to discontinue daily monitoring. Beginning in 2015, the Taylor River fish ladder was opened to allow for diadromous fish passage, but was only monitored on a weekly basis. Daily monitoring activities will not be continued until further evidence of a river herring spawning run is observed. The next dam is a barrier to further fish passage and is located at rkm 6.9.

6.3. REGULATORY HISTORY

The regulatory history of river herring in New Hampshire state waters (inland and 0-3 miles) began in 1967. With the establishment of a permit and reporting requirement for residents or nonresidents utilizing a seine, net, or weir for the taking of river herring. In 1987, the taking of river herring in state waters on Wednesdays by any method was prohibited. New regulations were instituted in 2005 closing a large section of tidal waters in the Taylor River and restricting harvest days in the Squamscott River in Exeter. In 2012 the Oyster River and its tributaries were closed to the taking of river herring from the head-of-tide dam downstream to its mouth at Great Bay. The new regulations were intended to allow more river herring returns to the Exeter, Taylor, and Oyster river fishways.

The current regulations are:

Fis 603.01 River Herring.

- (a) No person shall take river herring, alewives (*Alosa pseudoharengus*) and bluebacks (*Alosa aestivalis*) from the waters of the state, by any method, between sunrise Wednesday and sunrise Thursday of any week.
- (b) Any trap or weir used during the period specified in paragraph (a) above, shall be constructed so as to allow total escapement of all river herring.
- (c) Any river herring taken by any method during the period specified in paragraph (a) shall be immediately released back into the waters from which it was taken.

Fis 604.03 Taylor River. The Taylor River from the railroad bridge to the head of tide dam in Hampton shall be closed to the taking river herring by netting of any method.

Fis 604.04 Squamscott River.

(a) During April, May and June the taking of river herring in the Squamscott River and its tributaries from the Rt. 108 Bridge to the Great Dam in Exeter shall be subject to the following:

- (1) Open to the taking of river herring by netting of any method only on Saturdays and Mondays;
- (2) The daily limit shall be one tote per person. "Tote" means a fish box or container measuring 31.5"x 18" x 11.5"; and
- (3) The tote shall have the harvester's coastal harvest permit number plainly visible on the outside of the tote.

Fis 604.05 Oyster River. The Oyster River and its tributaries shall be closed to the taking of river herring by any method from the head-of-tide dam at Mill Pond in Durham, 43°07'51.23"N, 70°55'08.20"W and 43°07'50.31"N, 70°55'08.04"W, downstream to the river mouth at Wagon Hill Farm and Durham Point, a line extending from 43°07'31.87"N, 70°52'17.67"W to 43°07'20.18"N, 70°52'19.16"W.

6.4. ASSESSMENT HISTORY

New Hampshire has not conducted a formal river herring stock assessment, but did provide data for the 2012 coastwide benchmark stock assessment.

6.5. GENERAL LIFE HISTORY

Both alewives and blueback herring are found in the coastal rivers and streams of New Hampshire. Alewives spawn from late-April to late-May when water temperatures have reached a minimum of 9°C. Blueback herring typically spawn from early-May until the end of June when temperatures have reached 16°C. Typically alewives spawn in the slack water areas of rivers and impoundments while blueback herring prefer faster moving water in rivers and streams. After utilizing the freshwater as nursery habitat during summer months, the juveniles typically emigrate to the ocean from late-August through October. The majority of returning adult river herring are between the ages of 3 and 5 years old.

6.5.1. Growth

From 1990 to 2015, the NHFGD has collected length, sex, species, and age data from fish ladders during the spring spawning migrations (see section 6.8) in coastal river systems. Von Bertalanffy growth curves for total length at age for male and female river herring are presented in Figure 6.10.

6.6. HABITAT DESCRIPTIONS

As stated in Atlantic States Marine Fisheries Commission's Amendment 1 of the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 1999), habitats used by alewives include spawning sites and nursery areas in coastal rivers, which are primarily freshwater portions of rivers and their associated bays and estuaries. In addition to spawning and nursery areas, adult habitats also consist of the near shore ocean. These habitats are distributed along the East Coast from the Bay of Fundy, Canada to Florida. Use of these habitats by migratory alewives may increase or diminish as the size of the population changes.

New Hampshire's coastal area contains two major estuaries with the Great Bay Estuary System being the largest. The Great Bay Estuary includes seven small to moderate size rivers with most flowing into a large embayment (Great Bay and Little Bay) before draining into a narrow, 15 km long opening to the sea via the Piscataqua River. The following is a description of each river in the estuary.

Cocheco River

The Cocheco River flows 48 km southeast through southern New Hampshire to Dover where it joins the Salmon Falls River to form the Piscataqua River. The Piscataqua River flows approximately 20 km to the sea. The Cocheco River drains a watershed of 479 square km. The lowermost dam (4.6m high, built on a natural ledge for a total height of 8-10 m) on the Cocheco River is within the City of Dover, at rkm 5.5. This dam impounds an area of 20 acres. A Denil fish ladder which provides access to approximately 49 acres of potential spawning habitat was constructed at the dam in 1969 to 1970 for anadromous fish by NHFGD, the owner also maintains a downstream migration structure which was replaced for increased efficiency in 2010. The downstream passage system is a PVC tube emptying in a plunge pool below the dam. The next barrier is a set of natural falls located at rkm 9.5. During certain flow conditions there is the potential that river herring can ascend this natural falls and continue migrating upriver a distance of 1.5 km to the Watson Dam in Dover, NH. There is no fish ladder at this dam, but a downstream migration pipe is provided by the hydroelectric facility. Currently there are no concerns with the passage efficiency of the existing fish ladder or the water quality throughout the spawning and emigration season in the Cocheco River. No spawning activity has been observed below the dam.

Lamprey River

The Lamprey River flows 97 km through southern New Hampshire to the Town of Newmarket where it becomes tidal and enters the Great Bay Estuary just north of the mouth of the Exeter River. The mouth of the Lamprey River in Great Bay is approximately 27 km inland from the Atlantic coast. The Lamprey River watershed drains an area of 549 square km. It is the largest watershed that empties directly into The Great Bay. The Macallen Dam, located at rkm 3.2 in Newmarket, is the lowermost head-of-tide dam (8.2 m high) on the Lamprey River. A Denil fish ladder constructed from 1969 to 1970 for anadromous fish by NHFGD allows access to 120 acres of potential spawning habitat. The Wiswall Dam (3.4 m high) is located 5.6 km upstream of the Macallen Dam. Construction of a Denil fish ladder was completed in 2012. This fish provides access to another 12.6 km of habitat. There are no downstream passage facilities at the Macallen Dam and emigrating juveniles and adults must pass over the spillway. Fish kills have not been observed below the first dam suggesting that adults emigrate with limited mortality. Downstream passage is provided at Wiswall Dam via a stop log bay within the spillway. Stop logs are removed during the fish migration season to provide passage for both adult and juvenile river herring.

The run of river herring through the fishway each year tends to be mostly alewives. However, each spring towards the end of the annual migration a large number of blueback herring congregate just below the Macallen Dam. A small number of these blueback herring ascend the fishway, but the vast majority of them spawn below the dam. The area they spawn in is approximately 0.40 acre in size. Above the Macallen Dam there is a variety of spawning habitat available for both alewives and blueback herring with no observed water quality issues, so it is unclear why most bluebacks spawn below the fishway/dam.

Oyster River

The Oyster River begins in the town of Barrington, NH. The size of the Oyster River watershed is approximately 67 square km. The Oyster flows southeasterly approximately 27.5 km through the towns of Lee and Durham on its way to Little Bay in the Great Bay Estuary. The mouth of the Oyster River lies approximately 19 km from the Atlantic Ocean. The head-of-tide dam occurs at rkm 4.8 in Durham, NH. There is a Denil fish ladder at this dam that was constructed in 1975. This fish ladder provides access to approximately 24 acres of potential spawning habitat. The next dam on the Oyster River occurs at rkm 7.7 and is a barrier to river herring passage.

The numbers of river herring returning to the Oyster River fishway have been decreasing since the mid 1990's. One possible explanation for the decline is diminishing water quality in the Mill Pond impoundment above the head-of-tide dam. Increasing eutrophication has been observed by NHFGD staff over the past several years. Due to this eutrophication oxygen levels could be critically low while juvenile river herring are utilizing the impoundment as nursery habitat. In addition, the Oyster River is used as a municipal water supply. In years when flows are below average very little water is observed flowing over the spillway of the head-of-tide dam. River herring can only emigrate from this impoundment over the spillway and thus become "trapped" in water with diminishing quality in years with lower river discharge. In response to the diminishing river herring returns the Oyster River and its tributaries were closed to taking of all river herring in 2012.

Squamscott/Exeter River

The Exeter River drains an area of 326 square km in southern New Hampshire. The River flows east and north from the Town of Chester to the Town of Exeter. It empties into Great Bay northeast of Exeter. The head-of-tide occurs at the Town of Exeter and the saltwater portion of the river is called the Squamscott River. The two lowermost dams on the main stem Exeter River are the Great Dam in Exeter at river kilometer (rkm) 10.6 and the Pickpocket Dam at rkm 22.4 (each 4.6 km high). Both dams have a Denil fish ladder, providing access to approximately 62 acres of potential spawning habitat. The next barrier above Pickpocket Dam is a set of natural falls at rkm 32.9. The mouth of the Exeter River (Squamscott) in Great Bay lies approximately 27.4 km inland from the sea. During summer 2016 the Great Dam and associated fish ladder were removed. Beginning in spring 2017 river herring will be enumerated and sampled at the Pickpocket fish ladder.

The Exeter River is the only river monitored by the NHFGD that has available fresh water spawning habitat located below the fishway. The NHFGD constructed upstream fish passage facilities (Denil fishways) on both dams from 1969 to 1971 for anadromous fish. Fish ladder improvements occurred in 1994 and 1999 at the Great Dam fishway. A fish trap was constructed at the upriver end of the fish ladder. In addition, improvements were made in the vicinity of the ladder entrance to enhance attraction flow during normal river flow conditions. Despite the recent work to improve fish passage efficiency of the fish ladder at Great Dam, the vast majority of river herring choose to spawn below the fish ladder in an approximately 0.50 acre area of fresh water that occurs between head-of-tide and the Great Dam caused by an elevated ledge that prevents saltwater incursion. River herring gather in very large numbers below the Great Dam and spawning has been observed. These observations combined with relatively high levels of documented harvest occurring each year below the first dam and the inefficiency of the fish ladder in passing river herring indicates that spawning success in this river is much higher than indicated by fish passage numbers through the fish ladder.

There are no downstream fish passage facilities on either dam so emigrating adults and juveniles pass over the spillway when river flows allow. There are no hydroelectric operations at either fishway, however, at the Great Dam there is a condominium complex that utilizes a small amount of water from the penstock for cooling of their heating and air conditioning system. This minimal flow through the penstock does not have an impact on emigrating river herring. In addition, poor water quality has been documented in the critical nursery habitat above Great Dam. Periodic water quality monitoring has recorded low levels of dissolved oxygen (DO) between the two dams in some years since 1995 (Smith et al. 2005; Langan 1995).

Other Rivers Within the Great Bay Estuary:

There are three other major rivers in the Great Bay Estuary that are not monitored regularly by NHFGD staff. They are the Winnicut, Bellamy and Salmon Falls Rivers. The rivers range in length from 14.6 km for the Winnicut to 61 km for the Salmon Falls. Watershed sizes range from approximately 855 square km for the Salmon Falls to 45.3 square km for the Winnicut River.

The Winnicut River flows directly into Great Bay in Greenland, NH. The NHFGD operated a Canada step weir fish passage from approximately 1957 until 2009 on the Winnicut. During the summer of 2009 the fish ladder and associated NHFGD owned dam were removed to restore anadromous fish habitat. The dam removal drained a 34 acre impoundment and the Winnicut River became the only major tributary to Great Bay with no man-made barriers along its entire length.

The Bellamy River enters the Great Bay Estuary at Little Bay in Dover, NH. A partially breached timber crib dam at the head-of-tide at rkm 6.9 was removed to restore anadromous fish habitat in 2004. Since the removal NHFGD staff has observed large numbers of river herring below the next dam approximately 0.6 km upstream. Removal of the next two dams on the Bellamy River is in the planning stages currently.

The Salmon Falls River joins the Cocheco River to form the Piscataqua River within the Great Bay Estuary. The head-of-tide dam is located at approximately rkm 6.7. A Denil fish ladder has been operated at this dam since 2002. The Salmon Falls River is a border river between the states of Maine and New Hampshire and the fish ladder and associated hydroelectric facility are on the Maine side in the town of South Berwick. The hydroelectric operator is responsible for operation and maintenance of the fish ladder with technical guidance by both NHFGD and Maine Division of Marine Resources. The Denil fish ladder at the head-of-tide dam provides river herring access to a 58 acre impoundment.

6.6.1. Habitat Quality

Dams and natural barriers restrict potential available spawning and nursery habitat in New Hampshire coastal rivers for river herring. Anthropogenic changes to these river systems can further affect habitat (e.g., increased development, increased impervious surfaces, and increased water withdrawals). These may have affected all six river systems, but their effects are the most dramatic in the Exeter and Taylor Rivers. Currently, several New Hampshire state agencies are working with the Town of Exeter on instream flows and water withdrawal for water resources. These factors have affected the downstream emigration of both adult and juvenile river herring with both barrier concerns and water quality issues. These issues came to New Hampshire's attention when low DO levels were monitored in 1995 by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) that indicated low levels of dissolved oxygen between two and five mg per liter in impoundment reaches of the Exeter

River (Rich Langan, unpublished data). The 2016 removal of Great Dam in Exeter should greatly improve water quality in the Exeter River.

6.6.2. Habitat Loss

Once dams are built (with fish passage) or removed, habitat for the two species of river herring can change composition. Therefore habitat loss for one species may benefit the other depending upon whether an impoundment has been developed or a riverine system has been restored. As impoundments degrade due to anthropogenic reasons and become more eutrophic over time habitat continues to be lost.

6.6.3. Habitat Alterations

Fish passage over dams continues to be a problem in New Hampshire where 3,074 active dams have been recorded throughout the state with less than 30 known fish passage systems. New Hampshire Fish and Game has been working with the Department of Environmental Services (DES), and other state and federal agencies to address dam removal projects through the New Hampshire River Restoration Program (RRTF). To date there have been 27 dams completely removed and two partially breached under the RRTF program since 2001, several of which have benefitted diadromous species. The DES continues to work with municipalities with in-stream flow rules for water withdrawals for municipal use.

6.7. RESTORATION PROGRAMS

Restoration activities for river herring in New Hampshire river systems have included constructing and improving upstream passage facilities at dams; stocking of adult fish into historic and viable spawning reaches; removing dams; and improving water quality in spawning and rearing reaches. From 1984 to 2015 approximately 55,600 adult river herring have been stocked in coastal rivers of New Hampshire (Table 6.2). The transfers that occurred were either in-basin transfers to increase spawning habitat or out-of-basin transfers to help supplement spawning runs in rivers with lower return numbers.

Restoration of diadromous fish populations began with construction of fishways from the late 1950s to the early 1970s by the NHFGD in the Cocheco, Exeter, Oyster, Lamprey, Taylor, and Winnicut rivers. These fishways re-opened acres of freshwater spawning and nursery habitat for river herring, American shad, and other diadromous fish. Since that time, modifications have been made to the Exeter River fish ladder to improve the effectiveness at passing alosines and a holding trap was constructed to facilitate monitoring of spawning fish through enumeration and collection of biological data. The last remaining dam on the main stem of the Winnicut River was removed by the NHFGD and DES in 2009. Construction of a Denil fish ladder was completed in early 2012 on Wiswall Dam in Durham. Wiswall Dam is the second dam on the Lamprey River.

6.7.1. Restoration Objective

The restoration target for New Hampshire's river herring is to return rivers populations to levels of abundance that will enable the full utilization of available and/or historical spawning habitat.

6.7.2. Fish Passage Efficiency

New Hampshire has not conducted specific fish passage efficiency studies on the seven fish ladders in coastal rivers.

6.8. AGE

The maximum age for alewife and blueback herring in New Hampshire has been recorded at nine years. Biological samples consisting of length measurements, sex and species determination, and scale samples, used for age determination, are collected from river herring at most fishways annually. Prior to 2009, the biological sampling target for river herring was to obtain three separate samples, one sample taken at each division of the spawning run (beginning, middle, end). Each individual sample attempted to gather approximately 150 length measurements (total length in millimeters) and sex determinations. Scale samples were taken from approximately 50 fish per sample when available. Years in which the target sampling level were reached, resulted in 450 randomly selected sex/length determinations as well as 150 scales for determination of age, sex, and species for each river. Beginning in 2009, scale samples are taken by grouping river herring by species and sex into one centimeter increments (Bins). The returning river herring are sampled throughout the spawning run, in an attempt to obtain a target sampling level of five fish within each bin for each sex and each species.

All allosine scale samples are cleaned, mounted between glass slides, and aged using an overhead scale projector via methods described by Marcy (1969). Prior to 2009, scale samples were also used for species determination for river herring (i.e. alewife or blueback herring) using methods described by MacLellan et al. (1981). Two or more readers independently aged all scales. Beginning in 2009, the bin sampling method controlled the distribution of species in the scale samples; therefore a field species determination of all individuals was incorporated into the 150 random length samples taken during the beginning, middle, and end of the run to determine species distribution within each river.

6.9. FISHERY DESCRIPTIONS

Historically, river herring have been the most prevalent anadromous fishes harvested in New Hampshire and sold as food, fertilizer, bait for commercial or recreational fisheries, and even the scales were utilized for the production of artificial pearls. More recently river herring fisheries have utilized the harvest as bait for commercial and recreational fisheries solely. New Hampshire monitors in-state river herring fisheries through the Coastal Harvest Reporting Program and the National Marine Fisheries Service monitors commercial landings of river herring in New Hampshire through either vessel trip reports or dealer reports from federally permitted vessels or dealers. However, due to the large volume herring fisheries, there is likely an incomplete accounting of river herring as part of the bycatch in the herring fishery.

New Hampshire's Sustainable Fishery Management Plan (SFMP) for river herring was first approved by ASMFC in 2011. The SFMP was re-submitted in 2015 with recent data and the existing management measures—ASMFC approved the 2015 SFMP. The SFMP has two separate targets, one fishery-dependent and one fishery-independent. The fishery-dependent target will be a harvest level that results in a harvest percentage (exploitation rate) that does not exceed 20% in the 'Great Bay Indicator Stock', providing an 80% escapement level. Specifically, a three year running average of the total annual river herring harvest from throughout Great Bay Estuary will be compared to a three year running average of minimum annual counts of spawning river herring returns documented via fish ladder counts on four rivers in Great Bay Estuary plus annual harvest of river herring throughout the estuary system. The fishery-dependent target has not been exceeded since its implementation.

The New Hampshire fishery-independent target for river herring returns is 350 fish per acre of available spawning habitat. This currently equates to a return of 72,450 fish. This target is slightly above 50% of

the mean annual river herring return to the Great Bay Estuary since 1990. As of 2017, the fishery-independent target has been reached each year since implementation.

6.9.1. Commercial Fisheries

In 1896 reported river herring catches totaled 293,671 pounds for New Hampshire streams (Bigelow and Schroeder 1953). Most of the current New Hampshire commercial landings of river herring are from vessels fishing in the EEZ. Landings peaked in 1977 at 210,000 pounds and have dropped ever since (Table 6.3; Figure 6.9. Commercial landings (in pounds) of river herring in New Hampshire.). The river herring caught in ocean waters were most likely of mixed stock origin. The very limited harvest of river herring in state waters is primarily for personal use such as lobster or recreational fishing bait. These landings are primarily made through netting activities of state-permitted coastal netters. All individuals participating in netting of river herring with the state are required to annually submit reports of both fishing effort and harvest weight or numbers of river herring taken. The following is a description of the river herring fishery.

Cocheco River

The river herring fishery in the Cocheco River is very sporadic with very few fish harvested over the course of the last several years. Total annual in-river harvest has ranged from zero fish to approximately 550 fish. Harvesters typically fish with cast nets, dip nets, or gill nets. The Cocheco River is closed to fishing from the fish ladder at the lowermost dam to the Washington Street Bridge approximately 200 m downstream. Most of the river herring harvest occurs from the downstream side of the Washington Street Bridge to a distance approximately 0.50 km downstream. In addition, there is a popular striped bass fishery that occurs along this stretch of river. Recreational anglers “snag” river herring to be used as live striped bass bait.

Lamprey River

The river herring harvest at the Lamprey River in recent years has been very low, usually less than 2,000 fish per year. The fishing activity is very sporadic. Landings are reported using a variety of methods including: cast net, gill net, dip net, and weir. Primarily the harvest occurs from approximately 70 m downstream of Macallen Dam to a distance of 0.50 km downstream. There is one weir fisherman that maintains his netting permit but does not consistently fish the weir. It is worth noting that each spring there is a very popular striped bass fishery that occurs within 0.33 km downstream of Macallen Dam. Striped bass anglers “snag” river herring to use as live bait.

Oyster River

There is typically very little river herring harvest that occurs in the Oyster River, usually less than 800 fish per year. The limited harvest that occurs is via dip net, cast net, or gill net. The Oyster River has very few locations where capturing river herring can be done efficiently. Due to this, harvest can occur sporadically anywhere along the tidal portion of the river. In response to diminishing returns of river herring to the Oyster River fish ladder the river was closed to the taking of river herring by any method beginning in 2012.

Squamscott/Exeter River

The river herring fishery that occurs at the Exeter River is conducted to harvest river herring for personal use as bait in fisheries for lobster and striped bass. The majority of the fishing occurs approximately 125 meters downstream of The Great Dam just to the northwest of the String Bridge. There is an elevated ledge under the String Bridge where migrating river herring gather in numbers waiting to ascend the falls. This is the area the harvesters focus their efforts. The gear types utilized by harvesters include; cast nets, gill nets, dip nets, and wire baskets. Despite being legally limited to just a two day fishery and a one tote per day per angler limit, the Exeter River can still account for as much as 90% of the total New Hampshire harvest for river herring.

In 2005, following a number of years of increased harvest in the Squamscott/Exeter River, NHFGD implemented major changes to rules for river herring and shad in this river in order to reduce the harvest levels. These changes included implementing a one tote harvest limit per day and increasing the escapement days from one day per week to 5 days per week. Harvest levels since 2005 have been reduced by at least 50% of the levels observed in 1998 and many prior years (Table 6.3) and estimates of instantaneous mortality from 2006 to 2009 have been some of the lowest in the time series.

Other Rivers within the Great Bay Estuary:

The Bellamy, Winnicut, and Salmon Falls Rivers have a very sporadic harvest ranging from 0 fish to as many as 2,548 fish at the Salmon Falls in 1999. The combined harvest from all three rivers ranges from as few as 111 fish in 1992 to 3,127 in 1999. Like many other New Hampshire coastal rivers it is very difficult to capture river herring efficiently at these locations so harvest can occur anywhere along the tidal portion. However, in the Bellamy River some harvest does occur within the fresh water reach of the river just above the head-of-tide. Typically gill nets, cast nets, and dip nets are used to harvest river herring at these locations.

6.9.2. Recreational Fisheries

There is a very limited recreational fishery for river herring at head-of-tide dams on some of New Hampshire's coastal rivers. This recreational fishery mainly occurs on the Squamscott, Cocheco, and Lamprey Rivers. Harvesters catch river herring with various forms of nets, traps, or snagging with hook and line for the purpose of striped bass bait.

6.9.3. Bycatch

Bycatch of river herring likely occurs in commercial fisheries targeting other species. At this time New Hampshire does not evaluate the number of river herring that are caught as bycatch from commercial fisheries within the EEZ landing in New Hampshire. Sea sampling surveys conducted by the NHFGD in the mid-1990s showed river herring bycatch comprised less than 5% of the total catch.

6.10. FISHERY-INDEPENDENT SURVEYS

Two fishery-independent surveys are conducted in New Hampshire to monitor river herring. Each spring or early summer (April through June) NHFGD operates seven fish ladders along coastal rivers to enumerate and monitor migrating diadromous species, described below. In addition to monitoring adult migration of river herring, NHFGD conducts a seine survey in the Great Bay and Hampton-Seabrook

estuaries for juvenile finfish that provides an index of relative abundance for a variety of species including alewives and blueback herring.

6.10.1. Adult Catch Data

Seven fish ladders on six coastal New Hampshire rivers (Cocheco, Exeter, Lamprey, Oyster, Winnicut, and Taylor rivers) are operated from early April to mid-July, to allow for the passage of American shad, river herring, and other diadromous fish to historical spawning and nursery areas. The number of fish passing through the fishways are either enumerated by hand or estimated by the use of Smith-Root Model 1101 electronic fish counters. Counts recorded by the electronic fish counters are adjusted by daily calibration counts consisting of a minimum of ten one-minute counts. During daily visits, fish ladders and electronic counting devices are examined to assure of proper operation.

6.10.2. Juvenile Catch Data

A beach seine survey is conducted annually on a monthly basis from June to November at 15 fixed stations in New Hampshire's estuaries. Four of these stations are located in the Hampton-Seabrook Estuary and 11 are located in the Great Bay Estuary. Within the Great Bay Estuary, three stations are located in Little Harbor, three stations are located in the middle to upper Piscataqua River, and five stations are located in Little Bay/Great Bay area.

Beach seine hauls are conducted by boat using a 30.5 m long by 1.8 m high bag seine with 6.4 mm mesh deployed 10 - 15 m from the beach. A single seine haul is made at each station during the months of June through November. Seine hauls are all conducted during daylight hours and constrained to the period of approximately two hours before to two hours after low tide. Seines are set into the current and, at most stations, in water depths less than six feet to prevent the foot rope of the net from coming off the bottom. With each seine haul, surface salinity (ppt) and temperature ($^{\circ}\text{C}$) are measured and substrate type at the station is observed and recorded.

All fish captured are identified to the lowest possible taxon (species level is the target) and enumerated. All finfish captured are measured, total length to the nearest millimeter up to a maximum of 25 individuals per species per seine haul sample. The primary species of interest are winter flounder, rainbow smelt, river herring, American shad, and Atlantic silverside. In addition, if the following invertebrate species of special interest are captured, they are identified and enumerated: rock crab, Jonah crab, green crab, horseshoe crab, American lobster, and Asian shore crab.

An annual index of relative abundance is determined using the geometric mean catch-per-seine-haul. This relative annual index can be used to determine successful occurrence of river herring spawning activity between years. However, due to the estuary-wide design and limited sampling rate in close proximity to monitored rivers during times of peak juvenile river herring emigration in the late summer/fall months these indices should be used conservatively.

6.11. ASSESSMENT APPROACHES AND RESULTS

6.11.1. Trends in Run Size

New Hampshire has seen a general increase in returns to fish ladders in the last ten years. The Cocheco and Lamprey Rivers generally have the highest number of returning river herring each spring. Returns to these rivers have exceeded 40,000 fish on several occasions (Table 6.1). The Oyster River spawning population has

been declining since the early 1990s. The run has decreased from 157,000 fish in 1992 to approximately 1,800 fish in 2015. The Winnicut River monitored spawning run has been generally increasing since 1998; 219 river herring in 1998 and 8,300 river herring in 2008. The Winnicut River Dam and associated fish ladder were removed in 2009. Monitoring of the spawning run in the Winnicut River was hindered in 2010, but a run-of-river fish passage structure was completed early in 2011. Unfortunately the passage structure is ineffective at passing herring and a solution is forthcoming. The Exeter and Taylor Rivers have declining river runs as well. In recent years the Taylor has had so few fish returning that the NHFGD discontinued daily monitoring in 2015. The Exeter River monitored spawning returns are typically less than 1,000 fish each year, however a return of 5,500 occurred in 2015.

Fish ladder counts in some rivers should be classified as minimum estimates of spawning river herring. For example, large numbers of blueback herring are often observed below the ladders in the Lamprey, Cocheco, and Exeter Rivers in late May but do not ascend the ladders. Despite a recent increasing trend, returns are still lower than those experienced during the 1980's to early 1990's. Several factors may be contributing to this. High flows before and during the runs in some years may have influenced the decline in returns in monitored rivers. The passage inefficiency of fish ladders created by unusually high river flow levels, in turn reduces the annual return enumerations in those years. An example of strong control by environmental conditions occurred in 2005, 2006, and 2007 when New Hampshire coastal rivers experienced flood conditions that reached "100 year flood" levels in 2006 and 2007. During years where persistent high river velocity exists in all coastal rivers in the state, many river herring are unable to reach or successfully ascend the fish ladders monitored by the Department. In 2005, above average precipitation levels later in the spawning run reduced blueback returns specifically, which for runs comprised largely of bluebacks, such as the Oyster River, resulted in lowered total annual run sizes. The passage inefficiency of fish ladders created by unusually high river flow levels, in turn reduces the annual return enumerations in those years. River flows in most years since 2007 have been more favorable to fish passage. Other factors affecting returns include; poor water quality affecting survival of young-of-the-year (low DO during summer months, downstream passage problems, water withdrawals by the local municipalities, and drought conditions in some years).

6.11.2. Trends in Length

Total lengths for river herring monitored in New Hampshire coastal rivers ranged from 200 mm to 370 mm in all rivers combined (Table 6.4, Table 6.5, and Table 6.6). The mean length of males varied annually (Table 6.7, Table 6.8, and Table 6.9; Figure 6.11), ranging from 247 mm to 292 mm. Mean length of females ranged from 263 mm to 306 mm. In general, fish returning to the Oyster River had the shortest mean lengths while those returning to the Lamprey River had the longest. This is likely due to the predominance of blueback herring returning to the Oyster River while alewives dominate the monitored spawning runs in the Lamprey River. In most years there are slightly higher percentages of males returning than females.

6.11.3. Trends in Age

The river herring returning to the New Hampshire coastal fish ladders ranged in age from three to nine years old. The majority of alewife returns ranged from age four to six and blueback herring from age three to five (Table 6.10, Table 6.11, and Table 6.12; Figure 6.12). Species were not determined during ageing of scales in 1990.

6.11.4. Trends in Length at Age

Mean total length at age of river herring returning to New Hampshire coastal rivers has decreased over time since 1992 (Figure 6.13, Figure 6.14). Table 6.13, Table 6.14, and Table 6.15 show river specific river herring

mean length at age information. Reasons may be degrading impoundments affecting early growth, various environmental factors such as droughts or floods that have affected either immigration or emigration pathways affecting river specific populations as a whole, selective predation, or other stressors that affect growth potential.

6.11.5. Trends in Repeat Spawning

The percentages of repeat spawning fish are determined by the presence or absence of spawning checks observed during the ageing process of collected river herring scales (Table 6.16, Table 6.17, and Table 6.18). River herring were determined to have repeated spawning up to four times in New Hampshire rivers, with the percentage of single year repeat spawning fish as high as 45% in some years.

6.11.6. Juvenile Abundance

The highest relative abundance for juvenile blueback herring as measured by the geometric mean catch per seine haul, occurred in 1999 when nearly 12,000 were captured (Table 6.19). Peaks in relative abundance for alewives occurred in 2002, 2003, and in 2006. The indices, in general, are very low for juvenile alewives. In contrast, blueback herring are one of the more commonly captured species at some stations in certain years.

6.11.7. Total Mortality

The methods used to evaluate total mortality were: Chapman-Robson, Heinecke, and Catch Curve analysis. The analysis calculated total instantaneous mortality (Z) rates and standard errors using ages from spawning river herring returning to the fishways on the Cocheco, Lamprey, Oyster, Winnicut, and Exeter rivers (Table 6.20; Figure 6.15). The catch curve analysis was the most restrictive and did not calculate mortality at times due to the small span of age classes in some rivers and/or years. However, the Chapman-Robson and Heinecke method addressed these biases if sample size included more than one age and the fish aged were greater than the determined fully recruitment age. Both the Chapman-Robson and Heinecke Z estimates essentially followed the same trend pattern over the time series for each river evaluated.

The Cocheco River has both species that utilized the fish ladder. Mortality estimates indicate peak mortality in the early 1990's then generally stabilizing from the late 1990's to the mid-2000's within ranges between 0.5 and 1.5. An increase in mortality started in 2005 for male alewives female alewives have experienced a decreasing trend since 2006. Male blueback herring mortality rates in the Cocheco River remained relatively stable since 2000 however female blueback herring mortality rates declined dramatically between 2003 and 2007 but appear to experiencing an upward trend again in 2008.

The Lamprey River primarily has alewives that negotiate the fish ladder. Very few blueback herring have been sampled from the exit of the fish ladder; they primarily spawn below the dam, therefore are not included in the analysis for the mortality rate in the Lamprey River. The mortality estimates for the alewives range from approximately 0.5 to 2.0. Both sexes follow the general mortality trend but not necessarily within the same year.

The Exeter River has both species that utilize the fish ladder however there is available spawning freshwater habitat below the dam that is utilized by river herring. Issues affecting total mortality may include downstream fish passage of juvenile and post spawned adults inhibited by water withdrawals and low flows coupled with low summer dissolved oxygen levels in impoundments above the dams.

Despite the recent work to improve fish passage efficiency of the fish ladder at Great Dam, the vast majority of river herring choose to spawn below the fish ladder in an approximately 0.50 acre area of fresh water that occurs between head-of-tide and the Great Dam caused by an elevated ledge that prevents saltwater incursion. River herring gather in very large numbers below the Great Dam and spawning has been observed. These observations combined with relatively high levels of documented harvest occurring each year below the first dam and the inefficiency of the fish ladder in passing river herring indicates that escapement to spawn in this river is much higher than measured by the number of river herring passing up river through the fish ladder. This lowers the confidence of mortality rates for the Exeter River calculated using passage numbers. However, mortality estimates ranged from 0.01 to 1.7 between the two species and sexes throughout the years and appear to be on a general decline. Fishing by nets on pre-spawned adults may have contributed to a higher mortality prior to 2005 when regulations were imposed to restrict harvest.

The Winnicut River fish ladder was a Canadian step-weir design which was not effective for passing river herring however renovations in 1997 and 2002 allowed more successful passage by river herring. As a result sampling has been more consistent since 1998 but sample size has been low in some years (Table 6.1) which may affect the reliability of mortality estimates. The mortality estimates have ranged from approximately 0.2 to 2.4 since 1998, however the mortality trend is erratic for male and females between the two species. Along with the lack of confidence in mortality estimates due to low sample size, other mortality issues could be due to emigration escapement issues and fluctuations in a developing population as it reaches river carrying capacity.

The Oyster River fish ladder primarily passes blueback herring and very little alewives. The few alewives have not been included within the mortality estimates. The mortality estimates have ranged from 0.24 to greater than 2.0 between 1992 and 2008. Both sexes have experienced similar trends in mortality but not necessarily within the same years. The dissolved oxygen within the Oyster River impoundment has been recently recorded to have levels below 5 mg/l, again likely affecting adult recruitment.

Sampling has been too erratic in the Taylor River to calculate a mortality estimate with any measure of confidence due to the design of the fish ladder and level of sampling.

6.12. BENCHMARKS

6.12.1. Data and Methods

Size at age data from the river systems in general only represent mature fish. We used the length-at-age data collected by the NMFS trawl survey (1973-1986) to estimate length-at-age for immature fish and used length-weight data from ChesMMAP and the Cooperative Winter Tagging Cruise (2008-2010) to convert those lengths-at-age to weight-at-age.

The length-weight relationship developed from the ChesMMAP and Cooperative Winter Tagging Cruise data was used to convert NH's length-at-age estimates to weight-at-age for the spawning stock biomass per recruit estimates.

Repeat spawner marks were used to develop maturity schedules for each species.

Two values of natural mortality were used: 0.3 and 0.7.

Fishing mortality and natural mortality were assumed to occur consistently throughout the year, so the fraction of both that elapsed before spawning was estimated based on the month with the highest run counts (if available) or landings, and was set at 0.33 for both species.

Fishing selectivity was assumed 1 for all ages. Fishing mortality in this analysis was assumed to represent both directed in-river fishing on mature adults and incidental catch of juveniles in the ocean, as well as other sources of mortality, such as passage mortality and increased predation.

The Yield-Per-Recruit Program (v. 2.7.2) from the NMFS Toolbox was used to develop spawning stock biomass per recruit reference points. The YPR program is an implementation of the Thompson-Bell per-recruit model. The maximum age for each river was the oldest age for which biological data were available; it was assumed to represent a plus group with 11 being the oldest age in the plus group for both species.

6.12.2. Results

The SPR benchmarks were sensitive to assumptions about M, which is difficult to estimate empirically for these species.

Estimates of Z in recent years for NH rivers were at or near the Z benchmarks. Only male blueback herring in the Oyster River and male alewife and female blueback herring in the Winnicut River exceeded all Z benchmarks (Table 6.21, Table 6.21).

6.13. CONCLUSIONS AND RECOMMENDATIONS

New Hampshire rivers were severely impacted over the past several centuries, negatively affecting anadromous species. Dams, fishing, and poor water quality are among the many obstacles that river herring have faced. Restoration efforts should continue with focus on the following strategies for New Hampshire coastal rivers targeted for restoration:

1. Continue efforts to monitor and improve water quality.
2. Continue transfers of spawning adult river herring from donor rivers to increase available spawning habitat and augment declining runs in other rivers.
3. Continue work to install upstream and downstream fish passage or remove dams in coastal rivers.
4. Continue to monitor returns of spawning adult river herring to fish ladders.
5. Efforts should be made to identify and reduce all sources of mortality whether during ocean residency or in-river.

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Table 6.1 Numbers of river herring returning to fishways on coastal New Hampshire rivers.

| Year | Cocheco River | Exeter River | Oyster River | Lamprey River | Taylor River | Winnicut River | Annual Total |
|------|---------------|--------------|--------------|---------------|--------------|---------------------|--------------|
| 1972 | | | | 2,528 | | + | 2,528 |
| 1973 | | | | 1,380 | | + | 1,380 |
| 1974 | | | | 1,627 | | + | 1,627 |
| 1975 | | 2,639 | | 2,882 | | + | 5,521 |
| 1976 | 9,500 | | 11,777 | 3,951 | 450,000 | + | 475,228 |
| 1977 | 29,500 | | 359 | 11,256 | | 2,700 ⁺⁺ | 43,815 |
| 1978 | 1,925 | 205 | 419 | 20,461 | 168,256 | 3,229 ⁺⁺ | 194,495 |
| 1979 | 586 | 186 | 496 | 23,747 | 375,302 | 3,410 ⁺⁺ | 403,727 |
| 1980 | 7,713 | 2,516 | 2,921 | 26,512 | 205,420 | 4,393 ⁺⁺ | 249,475 |
| 1981 | 6,559 | 15,626 | 5,099 | 50,226 | 94,060 | 2,316 ⁺⁺ | 173,886 |
| 1982 | 4,129 | 542 | 6,563 | 66,189 | 126,182 | 2,500 ⁺⁺ | 206,105 |
| 1983 | 968 | 1 | 8,866 | 54,546 | 151,100 | + | 215,481 |
| 1984 | 477 | | 5,179 | 40,213 | 45,600 | + | 91,469 |
| 1985 | 974 | | 4,116 | 54,365 | 108,201 | + | 167,656 |
| 1986 | 2,612 | 1,125 | 93,024 | 46,623 | 117,000 | 1,000 ⁺⁺ | 261,384 |
| 1987 | 3,557 | 220 | 57,745 | 45,895 | 63,514 | + | 170,931 |
| 1988 | 3,915 | | 73,866 | 31,897 | 30,297 | + | 139,975 |
| 1989 | 18,455 | | 38,925 | 26,149 | 41,395 | + | 124,924 |
| 1990 | 31,697 | | 154,588 | 25,457 | 27,210 | + | 238,952 |
| 1991 | 25,753 | 313 | 151,975 | 29,871 | 46,392 | + | 254,304 |
| 1992 | 72,491 | 537 | 157,024 | 16,511 | 49,108 | + | 295,671 |
| 1993 | 40,372 | 278 | 73,788 | 25,289 | 84,859 | + | 224,586 |
| 1994 | 33,140 | * | 91,974 | 14,119 | 42,164 | + | 181,397 |
| 1995 | 79,385 | 592 | 82,895 | 15,904 | 14,757 | + | 193,533 |
| 1996 | 32,767 | 248 | 82,362 | 11,200 | 10,113 | + | 136,690 |
| 1997 | 31,182 | 1,302 | 57,920 | 22,236 | 20,420 | + | 133,060 |
| 1998 | 25,277 | 392 | 85,116 | 15,947 | 11,979 | 219 | 138,930 |
| 1999 | 16,679 | 2,821 | 88,063 | 20,067 | 25,197 | 305 | 153,132 |
| 2000 | 30,938 | 533 | 70,873 | 25,678 | 44,010 | 528 | 172,560 |
| 2001 | 46,590 | 6,703 | 66,989 | 39,330 | 7,065 | 1,118 | 167,795 |
| 2002 | 62,472 | 3,341 | 58,179 | 58,065 | 5,829 | 7,041 | 194,927 |
| 2003 | 71,199 | 71 | 51,536 | 64,486 | 1,397 | 5,427 | 194,116 |
| 2004 | 47,934 | 83 | 52,934 | 66,333 | 1,055 | 8,044 | 176,383 |
| 2005 | 16,446 | 66 | 12,882 | 40,026 | 233 | 2,703 | 72,356 |
| 2006 | 4,318 | 16 | 6,035 | 23,471 | 147 | 822 | 34,809 |
| 2007 | 15,815 | 40 | 17,421 | 55,225 | 217** | 7,543 | 96,261 |
| 2008 | 30,686 | 168 | 20,780 | 36,247 | 976 | 8,359 | 97,214 |
| 2009 | 36,165 | 513 | 11,661 | 42,425 | * | 4,974 | 95,737 |
| 2010 | 32,654 | 69 | 19,006 | 33,327 | 675 | 576 ⁺⁺⁺ | 86,307 |
| 2011 | 43,090 | 256 | 4,755 | 50,447 | 59 | 72 ⁺⁺⁺ | 99,338 |
| 2012 | 27,608 | 378 | 2,573 | 86,862 | 92 | 5 ⁺⁺⁺ | 117,518 |
| 2013 | 18,337 | 588 | 7,149 | 79,408 | 128 | 0 | 105,610 |
| 2014 | 29,968 | 789 | 4,227 | 84,868 | 57 | 0 | 119,909 |
| 2015 | 64,456 | 5,562 | 1,803 | 69,843 | * | 0 | 141,664 |

* - Swim through operation.

** -Due to fish counter malfunction there was up to two weeks where passing fish were not enumerated.

+ - Fishway unable to pass fish until modifications in 1997.

++ - Fish netted below and hand passed over Winnicut River dam.

+++ - Minimum estimate based on time counts, fishway/dam removed in fall 2009.

Table 6.2 Numbers of river herring stocked in coastal New Hampshire rivers from 1984 - 2015.

| Year | Cocheco River System | Winnicut River | Exeter River | Lamprey River System | Salmon Falls River |
|------|----------------------|----------------|--------------|----------------------|--------------------|
| 1984 | 5,000 | | | | |
| 1985 | 500 | | | | |
| 1986 | 2,000 | | | | |
| 1987 | 2,125 | | | | |
| 1988 | 2,000 | | | | |
| 1989 | | | | | |
| 1990 | 2,000 | | | | |
| 1991 | 1,700 | | | | |
| 1992 | 1,300 | | | | |
| 1993 | | | | | |
| 1994 | 365 ^a | | | 320 ^a | 220 |
| 1995 | 1,400 ^a | | 125 | 3,230 ^b | 250 |
| 1996 | 750 ^a | | | 2,100 ^a | 200 |
| 1997 | 950 ^a | | | 2,000 ^a | 300 |
| 1998 | 1,000 ^a | 300 | | 1,975 ^a | 240 |
| 1999 | 990 ^a | 200 | | 2,020 ^a | 200 |
| 2000 | 1,000 ^a | 430 | | 2,020 ^a | 320 |
| 2001 | 1,000 ^a | | | 2,000 ^a | 200 |
| 2002 | 1,000 ^a | | | 1,900 ^a | |
| 2003 | 1,100 ^a | | | 2,000 ^a | |
| 2004 | 1,050 ^a | | 100 | 2,000 ^b | |
| 2005 | 1,000 ^a | | 200 | 2,000 ^b | |
| 2006 | 1,000 ^a | | 40 | 200 ^b | |
| 2007 | 900 ^a | | 175 | 2,000 ^b | |
| 2008 | 1,000 ^a | | 250 | 2,000 ^b | |
| 2009 | 500 ^a | | 250 | 750 ^b | |
| 2010 | 1,000 ^a | | | 750 ^b | |
| 2011 | 2,000 ^a | 200 | 659 | 2,145 ^a | |
| 2012 | 1,000 ^a | | | 1,000 ^a | |
| 2013 | 480 ^a | | | | |
| 2014 | | | | | |
| 2015 | 1,000 ^a | 250 | | 1,500 ^a | |

^a - In-river transfer.

^b - Combination of in-river and out-of-basin transfers.

Table 6.3 Reported ocean commercial landings (kg) of river herring in New Hampshire from the NMFS, 1957-2015.

| Year | Species* | Metric Tons | Pounds | \$ |
|-------------|---------------|-------------|-----------|--------|
| 1957 | River Herring | 34 | 75,000 | 750 |
| 1958 | River Herring | 27.2 | 60,000 | 600 |
| 1959 | River Herring | 36.3 | 80,000 | 800 |
| 1960 | River Herring | 43.1 | 95,000 | 1,000 |
| 1961 | River Herring | 45.4 | 100,000 | 1,000 |
| 1962 | River Herring | 56.7 | 125,000 | 1,250 |
| 1963 | River Herring | 68 | 150,000 | 1,500 |
| 1964 | River Herring | 34 | 75,000 | 1,125 |
| 1965 | River Herring | 56.7 | 125,000 | 1,875 |
| 1966 | River Herring | 34 | 75,000 | 1,125 |
| 1967 | River Herring | 29.5 | 65,000 | 1,650 |
| 1968 | River Herring | 18.4 | 40,600 | 1,043 |
| 1969 | River Herring | 17 | 37,500 | 1,081 |
| 1970 | River Herring | 14.1 | 31,000 | 930 |
| 1971 | River Herring | 11.3 | 25,000 | 750 |
| 1972 | River Herring | 10.9 | 24,000 | 800 |
| 1973 | River Herring | 9.8 | 21,500 | 944 |
| 1977 | River Herring | 95.3 | 210,000 | 7,518 |
| 1978 | River Herring | 74.8 | 165,000 | 8,200 |
| 1982 | River Herring | 51.9 | 114,500 | 7,400 |
| 1983 | River Herring | 52.3 | 115,216 | 10,730 |
| 1984 | River Herring | 40.8 | 90,000 | 6,300 |
| 1985 | River Herring | 27.8 | 61,300 | 7,128 |
| 1986 | River Herring | 12.2 | 26,990 | 2,275 |
| 1987 | River Herring | 8.9 | 19,550 | 2,346 |
| 1988 | River Herring | 5.5 | 12,087 | 5,440 |
| 1989 | River Herring | 5.1 | 11,200 | 5,478 |
| 1992 | River Herring | 4.4 | 9,802 | 4,900 |
| 1993 | River Herring | 1.2 | 2,676 | 576 |
| 1998 | River Herring | 11.8 | 25,994 | 3,795 |
| 2008 | River Herring | 3.7 | 8,137 | 1,839 |
| 2009 | River Herring | 4.3 | 9,443 | 1,761 |
| 2010 | River Herring | 3.4 | 7,466 | * |
| 2011 | River Herring | 1.9 | 4,094 | * |
| 2012 | River Herring | 1.2 | 2,681 | * |
| 2013 | River Herring | 2.0 | 4,420 | * |
| 2014 | River Herring | 2.6 | 5,737 | * |
| 2015 | River Herring | 3.4 | 7,566 | * |
| GRAND TOTAL | | 960.9 | 2,118,459 | 93,909 |

*- River herring harvested by NH coastal harvesters for personnel use

Table 6.4 Length frequency of river herring returning to New Hampshire rivers, 1994-2015.

| Length (cm) | Cocheco River – Combined Species | | | | | | | | | | | | | | | | | | | | | |
|----------------|----------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 199 4 | 199 5 | 199 6 | 199 7 | 199 8 | 199 9 | 200 0 | 200 1 | 200 2 | 200 3 | 200 4 | 200 5 | 200 6 | 200 7 | 200 8 | 200 9 | 201 0 | 201 1 | 201 2 | 201 3 | 201 4 | 201 5 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 3 | 0 | 1 | 11 | 5 | 0 | 3 | 2 | 19 | 1 | 3 | 0 | 0 | 1 | 14 | 5 | 8 | 0 | 0 | 4 | 7 | 1 |
| 24 | 15 | 1 | 2 | 63 | 19 | 4 | 25 | 0 | 39 | 15 | 6 | 0 | 8 | 19 | 28 | 12 | 23 | 5 | 1 | 37 | 28 | 2 |
| 25 | 16 | 4 | 10 | 83 | 43 | 24 | 49 | 23 | 43 | 34 | 20 | 10 | 23 | 50 | 55 | 32 | 67 | 22 | 0 | 94 | 86 | 22 |
| 26 | 44 | 18 | 22 | 97 | 105 | 75 | 90 | 56 | 54 | 71 | 55 | 30 | 31 | 86 | 99 | 75 | 73 | 57 | 7 | 106 | 123 | 44 |
| 27 | 35 | 29 | 39 | 60 | 132 | 98 | 115 | 120 | 58 | 125 | 94 | 58 | 34 | 111 | 103 | 139 | 74 | 134 | 30 | 47 | 118 | 113 |
| 28 | 17 | 45 | 50 | 39 | 97 | 125 | 55 | 123 | 76 | 120 | 88 | 62 | 59 | 103 | 87 | 110 | 77 | 121 | 108 | 37 | 99 | 118 |
| 29 | 9 | 30 | 53 | 40 | 40 | 79 | 52 | 69 | 75 | 60 | 86 | 97 | 70 | 48 | 41 | 63 | 67 | 66 | 147 | 26 | 46 | 100 |
| 30 | 2 | 11 | 30 | 33 | 13 | 47 | 43 | 48 | 64 | 16 | 60 | 62 | 49 | 18 | 19 | 13 | 46 | 28 | 115 | 64 | 40 | 38 |
| 31 | 1 | 1 | 14 | 19 | 12 | 0 | 18 | 13 | 20 | 10 | 26 | 20 | 14 | 12 | 3 | 5 | 11 | 14 | 34 | 27 | 27 | 10 |
| 32 | 0 | 1 | 2 | 6 | 5 | 3 | 5 | 3 | 5 | 2 | 7 | 6 | 10 | 6 | 0 | 2 | 2 | 3 | 7 | 8 | 19 | 1 |
| 33 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 5 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 35 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 142 | 140 | 224 | 452 | 475 | 458 | 455 | 458 | 453 | 454 | 450 | 347 | 300 | 457 | 454 | 456 | 450 | 450 | 450 | 600 | 450 | |

Table 6.4 Continued.

| Length (cm) | Exeter River– Combined Species | | | | | | | | | | | | | | | | | | | | | |
|-------------|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 22 | 0 | 0 | 0 | 2 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | |
| 23 | 0 | 0 | 0 | 42 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 2 | 0 | 0 | 4 | 0 | 2 | 0 | |
| 24 | 0 | 1 | 0 | 233 | 22 | 11 | 4 | 0 | 6 | 1 | 0 | 0 | 0 | 3 | 7 | 3 | 4 | 4 | 2 | 11 | 23 | |
| 25 | 0 | 11 | 0 | 251 | 66 | 50 | 21 | 11 | 18 | 1 | 1 | 4 | 0 | 6 | 21 | 11 | 11 | 28 | 2 | 45 | 37 | |
| 26 | 0 | 27 | 0 | 158 | 86 | 120 | 65 | 66 | 31 | 2 | 11 | 9 | 1 | 7 | 37 | 45 | 14 | 66 | 8 | 104 | 61 | |
| 27 | 0 | 43 | 2 | 164 | 95 | 120 | 73 | 124 | 37 | 14 | 29 | 24 | 2 | 7 | 55 | 129 | 8 | 70 | 27 | 110 | 85 | |
| 28 | 0 | 38 | 11 | 126 | 69 | 62 | 61 | 129 | 36 | 27 | 19 | 15 | 7 | 9 | 29 | 99 | 5 | 47 | 46 | 59 | 82 | |
| 29 | 0 | 19 | 6 | 67 | 33 | 24 | 24 | 91 | 25 | 15 | 13 | 15 | 4 | 4 | 12 | 38 | 3 | 10 | 56 | 22 | 56 | |
| 30 | 0 | 6 | 2 | 24 | 7 | 6 | 8 | 26 | 6 | 4 | 3 | 4 | 1 | 1 | 2 | 9 | 2 | 2 | 26 | 8 | 22 | |
| 31 | 0 | 1 | 0 | 5 | 4 | 2 | 2 | 5 | 1 | 1 | 2 | 1 | 0 | 1 | 2 | 2 | 1 | 0 | 9 | 3 | 7 | |
| 32 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 2 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 2 | |
| 33 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | * | 147 | 22 | 1075 | 386 | 403 | 259 | 454 | 160 | 67 | 78 | 77 | 16 | 40 | 168 | 336 | 48 | 233 | 179 | 366 | 375 | 450 |

*- Due to damage to fish trap, fishway became a swim through operation

Table 6.4 Continued.

| Length (cm) | Lamprey River– Combined Species | | | | | | | | | | | | | | | | | | | | | |
|----------------|---------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 24 | 1 | 1 | 0 | 2 | 3 | 2 | 6 | 0 | 0 | 0 | 6 | 1 | 4 | 20 | 5 | 2 | 23 | 6 | 2 | 6 | 3 | 1 |
| 25 | 12 | 1 | 3 | 11 | 18 | 21 | 36 | 7 | 5 | 31 | 19 | 2 | 13 | 31 | 40 | 13 | 56 | 42 | 9 | 25 | 31 | 19 |
| 26 | 18 | 15 | 13 | 37 | 50 | 66 | 72 | 31 | 20 | 54 | 49 | 21 | 18 | 27 | 90 | 35 | 66 | 87 | 19 | 81 | 74 | 55 |
| 27 | 48 | 32 | 14 | 45 | 71 | 100 | 128 | 78 | 37 | 54 | 100 | 49 | 18 | 44 | 128 | 99 | 29 | 119 | 54 | 69 | 67 | 100 |
| 28 | 31 | 43 | 38 | 35 | 80 | 97 | 150 | 113 | 68 | 91 | 88 | 98 | 47 | 70 | 80 | 144 | 42 | 77 | 91 | 58 | 75 | 81 |
| 29 | 19 | 31 | 33 | 56 | 58 | 99 | 92 | 118 | 107 | 78 | 59 | 94 | 78 | 66 | 60 | 100 | 62 | 49 | 136 | 66 | 66 | 81 |
| 30 | 9 | 12 | 17 | 60 | 34 | 45 | 79 | 71 | 103 | 77 | 65 | 83 | 79 | 60 | 26 | 37 | 53 | 43 | 90 | 75 | 48 | 50 |
| 31 | 1 | 5 | 8 | 47 | 18 | 13 | 30 | 25 | 79 | 39 | 46 | 32 | 52 | 48 | 18 | 13 | 24 | 20 | 42 | 53 | 51 | 37 |
| 32 | 2 | 2 | 1 | 9 | 6 | 7 | 11 | 7 | 30 | 19 | 11 | 16 | 16 | 30 | 3 | 5 | 12 | 4 | 6 | 15 | 24 | 18 |
| 33 | 0 | 0 | 0 | 2 | 1 | 3 | 3 | 2 | 7 | 4 | 6 | 6 | 6 | 12 | 3 | 1 | 1 | 2 | 0 | 1 | 9 | 7 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 4 | 0 | 1 | 2 | 0 | 2 | 1 | 0 | 1 | 0 | 1 | 1 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 141 | 142 | 127 | 304 | 339 | 453 | 608 | 452 | 459 | 449 | 453 | 402 | 333 | 411 | 453 | 451 | 369 | 450 | 450 | 449 | 450 | |

Table 6.4 Continued.

| Length (cm) | Oyster River– Combined Species | | | | | | | | | | | | | | | | | | | | | |
|----------------|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 0 | 1 | 0 | 1 | 7 | 8 | 1 | 11 | 0 | 0 | 3 | 27 | 0 | 0 | 0 |
| 23 | 7 | 0 | 3 | 11 | 15 | 4 | 4 | 1 | 15 | 0 | 5 | 17 | 49 | 31 | 98 | 13 | 8 | 26 | 43 | 6 | 4 | 0 |
| 24 | 19 | 0 | 12 | 72 | 46 | 20 | 33 | 6 | 123 | 42 | 31 | 40 | 136 | 98 | 99 | 91 | 71 | 84 | 36 | 49 | 38 | 3 |
| 25 | 28 | 27 | 29 | 74 | 91 | 105 | 78 | 41 | 86 | 107 | 85 | 63 | 106 | 106 | 83 | 120 | 171 | 86 | 83 | 146 | 78 | 39 |
| 26 | 24 | 43 | 46 | 113 | 137 | 147 | 112 | 116 | 75 | 136 | 133 | 90 | 53 | 126 | 87 | 46 | 126 | 92 | 93 | 128 | 112 | 139 |
| 27 | 23 | 33 | 24 | 93 | 109 | 111 | 111 | 130 | 96 | 87 | 110 | 71 | 49 | 62 | 49 | 19 | 60 | 88 | 81 | 79 | 106 | 125 |
| 28 | 20 | 16 | 17 | 62 | 60 | 52 | 69 | 98 | 46 | 40 | 53 | 44 | 26 | 20 | 22 | 7 | 17 | 43 | 56 | 33 | 56 | 82 |
| 29 | 13 | 10 | 1 | 16 | 38 | 11 | 30 | 42 | 29 | 28 | 28 | 11 | 19 | 7 | 2 | 3 | 3 | 22 | 16 | 8 | 34 | 38 |
| 30 | 4 | 14 | 1 | 4 | 5 | 2 | 6 | 12 | 3 | 6 | 5 | 0 | 2 | 2 | 2 | 0 | 0 | 5 | 12 | 1 | 16 | 16 |
| 31 | 0 | 1 | 0 | 3 | 3 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 5 | 8 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 33 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 138 | 150 | 133 | 448 | 506 | 453 | 446 | 449 | 474 | 447 | 452 | 343 | 448 | 453 | 453 | 299 | 457 | 450 | 450 | 450 | 450 | 450 |

Table 6.4 Continued.

| Length (cm) | Winnicut River– Combined Species | | | | | | | | | | | | | | | | | | | | | |
|----------------|----------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 2 | 26 | 0 | 2 | 1 | 1 | 26 | 5 | 7 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 3 | 6 | 87 | 6 | 25 | 32 | 13 | 74 | 30 | 35 | 29 | 47 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 23 | 36 | 98 | 50 | 109 | 138 | 59 | 65 | 31 | 75 | 64 | 91 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 0 | 26 | 70 | 107 | 119 | 145 | 127 | 116 | 64 | 16 | 135 | 98 | 98 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 16 | 64 | 62 | 126 | 90 | 99 | 149 | 46 | 14 | 106 | 128 | 88 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 6 | 26 | 43 | 91 | 49 | 37 | 80 | 38 | 11 | 52 | 75 | 62 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 3 | 9 | 17 | 57 | 22 | 7 | 29 | 19 | 6 | 18 | 37 | 42 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | 0 | 0 | 1 | 2 | 7 | 13 | 7 | 2 | 5 | 4 | 7 | 8 | 15 | 18 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 3 | 1 | 0 | 0 | 1 | 7 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | *0 | *0 | *0 | *0 | 79 | 218 | 450 | 464 | 453 | 444 | 453 | 343 | 124 | 443 | 457 | 452 | ^0 | ^0 | ^0 | ^0 | ^0 | ^0 |

*- Fishway unable to pass fish.

^-Fishway and dam removed Summer 2009

Table 6.4 Continued.

| Length (cm) | Taylor River– Combined Species | | | | | | | | | | | | | | | | | | | | | |
|----------------|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 7 | 14 | 2 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 35 | 29 | 6 | 0 | 0 | 0 | 20 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 0 | 33 | 45 | 58 | 0 | 0 | 0 | 19 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 16 | 49 | 70 | 0 | 3 | 0 | 12 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 18 | 25 | 66 | 0 | 7 | 0 | 8 | 2 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 9 | 11 | 33 | 0 | 7 | 0 | 10 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | 0 | 0 | 5 | 3 | 8 | 0 | 8 | 0 | 6 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | *0 | *0 | *0 | *0 | 125 | 181 | 247 | 0 | 26 | 0 | 80 | 14 | 0 | 18 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | ^0 |

* -data not available for selected year

^-No fish sampled, ASMFC removed NHFGD monitoring requirement

Table 6.5 Length frequency of alewife river herring returning to New Hampshire rivers, 1994-2015.

| Length (cm) | Cocheco River - Alewife | | | | | | | | | | | | | | | | | | | | | | |
|----------------|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 23 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 7 | 1 |
| 24 | 4 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 7 | 5 | 1 | 34 | 28 | 2 |
| 25 | 8 | 1 | 3 | 11 | 0 | 2 | 1 | 0 | 1 | 2 | 0 | 1 | 3 | 0 | 3 | 9 | 20 | 22 | 0 | 92 | 85 | 22 | |
| 26 | 27 | 2 | 15 | 9 | 10 | 4 | 11 | 3 | 7 | 4 | 3 | 6 | 5 | 2 | 15 | 14 | 24 | 57 | 7 | 106 | 123 | 44 | |
| 27 | 37 | 11 | 22 | 9 | 27 | 20 | 25 | 20 | 10 | 29 | 14 | 16 | 5 | 13 | 26 | 21 | 18 | 134 | 30 | 47 | 117 | 113 | |
| 28 | 26 | 34 | 33 | 8 | 44 | 29 | 26 | 30 | 22 | 36 | 20 | 27 | 13 | 27 | 26 | 18 | 16 | 121 | 108 | 37 | 99 | 118 | |
| 29 | 10 | 41 | 47 | 7 | 15 | 37 | 18 | 34 | 21 | 25 | 28 | 28 | 22 | 21 | 17 | 17 | 7 | 66 | 147 | 26 | 46 | 100 | |
| 30 | 5 | 17 | 39 | 11 | 9 | 10 | 18 | 19 | 21 | 8 | 21 | 24 | 18 | 12 | 8 | 5 | 3 | 28 | 115 | 64 | 40 | 38 | |
| 31 | 2 | 4 | 25 | 8 | 5 | 6 | 7 | 8 | 7 | 4 | 13 | 10 | 8 | 8 | 2 | 1 | 0 | 14 | 34 | 27 | 27 | 10 | |
| 32 | 0 | 1 | 3 | 2 | 3 | 2 | 0 | 3 | 3 | 3 | 2 | 7 | 1 | 4 | 0 | 0 | 0 | 3 | 7 | 8 | 19 | 1 | |
| 33 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | 0 | |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 119 | 112 | 190 | 70 | 115 | 111 | 106 | 117 | 93 | 111 | 102 | 120 | 77 | 92 | 98 | 88 | 96 | 450 | 450 | 445 | 598 | 450 | |

Table 6.5 Continued.

| Length (cm) | Exeter River - Alewife | | | | | | | | | | | | | | | | | | | | | |
|----------------|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 4 | 0 | 2 | 0 | 0 |
| 24 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 4 | 1 | 11 | 7 | 0 |
| 25 | 0 | 0 | 0 | 7 | 5 | 3 | 3 | 0 | 0 | 0 | 0 | 2 | 0 | 4 | 7 | 3 | 8 | 28 | 2 | 45 | 24 | 17 |
| 26 | 0 | 11 | 0 | 14 | 8 | 13 | 9 | 1 | 6 | 1 | 0 | 4 | 1 | 9 | 27 | 20 | 5 | 66 | 8 | 104 | 59 | 69 |
| 27 | 0 | 27 | 2 | 19 | 18 | 41 | 29 | 6 | 11 | 7 | 10 | 14 | 2 | 7 | 33 | 73 | 5 | 70 | 27 | 110 | 83 | 98 |
| 28 | 0 | 48 | 8 | 29 | 33 | 20 | 29 | 18 | 19 | 16 | 15 | 17 | 1 | 9 | 43 | 131 | 3 | 47 | 46 | 59 | 82 | 58 |
| 29 | 0 | 24 | 5 | 21 | 18 | 15 | 17 | 20 | 11 | 20 | 12 | 16 | 7 | 6 | 18 | 58 | 2 | 10 | 56 | 22 | 56 | 41 |
| 30 | 0 | 11 | 3 | 14 | 5 | 6 | 6 | 10 | 5 | 5 | 3 | 4 | 4 | 2 | 3 | 17 | 0 | 2 | 26 | 8 | 22 | 31 |
| 31 | 0 | 5 | 1 | 3 | 4 | 2 | 1 | 1 | 0 | 3 | 3 | 2 | 0 | 1 | 1 | 4 | 1 | 0 | 9 | 3 | 7 | 9 |
| 32 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 2 | 2 |
| 33 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | * | 127 | 20 | 111 | 92 | 105 | 94 | 56 | 52 | 54 | 44 | 64 | 16 | 40 | 134 | 307 | 26 | 233 | 178 | 366 | 311 | 325 |

*- Due to damage to fish trap, fishway became a swim through operation

Table 6.5 Continued.

| Length (cm) | Lamprey River - Alewife | | | | | | | | | | | | | | | | | | | | | |
|-------------|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 6 | 2 | 6 | 3 | 1 |
| 25 | 9 | 2 | 2 | 1 | 6 | 6 | 5 | 0 | 1 | 2 | 6 | 1 | 5 | 5 | 5 | 1 | 6 | 42 | 9 | 25 | 31 | 19 |
| 26 | 12 | 1 | 8 | 9 | 22 | 8 | 17 | 5 | 3 | 20 | 13 | 4 | 9 | 7 | 17 | 6 | 14 | 87 | 19 | 81 | 74 | 55 |
| 27 | 30 | 22 | 12 | 11 | 27 | 27 | 30 | 12 | 12 | 13 | 22 | 9 | 11 | 10 | 39 | 24 | 10 | 119 | 54 | 69 | 67 | 100 |
| 28 | 47 | 32 | 25 | 10 | 30 | 35 | 36 | 39 | 18 | 22 | 37 | 24 | 6 | 18 | 24 | 45 | 3 | 77 | 91 | 58 | 75 | 81 |
| 29 | 25 | 36 | 41 | 13 | 28 | 27 | 47 | 40 | 28 | 26 | 32 | 38 | 23 | 27 | 31 | 32 | 1 | 49 | 136 | 66 | 66 | 81 |
| 30 | 12 | 14 | 24 | 30 | 16 | 22 | 27 | 30 | 35 | 28 | 19 | 24 | 31 | 30 | 13 | 26 | 0 | 43 | 90 | 75 | 48 | 50 |
| 31 | 4 | 8 | 10 | 14 | 5 | 11 | 23 | 12 | 23 | 12 | 23 | 20 | 24 | 18 | 9 | 7 | 1 | 20 | 42 | 53 | 51 | 37 |
| 32 | 1 | 3 | 5 | 4 | 0 | 3 | 7 | 6 | 12 | 13 | 5 | 4 | 9 | 11 | 5 | 3 | 0 | 4 | 6 | 15 | 24 | 18 |
| 33 | 1 | 1 | 1 | 1 | 0 | 1 | 2 | 1 | 5 | 3 | 3 | 3 | 4 | 9 | 0 | 1 | 0 | 2 | 0 | 1 | 9 | 7 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 2 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 141 | 119 | 128 | 94 | 135 | 141 | 195 | 145 | 139 | 140 | 162 | 128 | 122 | 140 | 143 | 145 | 37 | 450 | 450 | 450 | 449 | 450 |

Table 6.5 Continued.

| Length (cm) | Oyster River - Alewife | | | | | | | | | | | | | | | | | | | | | |
|-------------|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 0 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 3 | 7 | 2 |
| 25 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 16 | 10 | 11 | 29 | 3 | 10 |
| 26 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 13 | 24 | 13 | 52 | 17 | 38 |
| 27 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 15 | 55 | 17 | 62 | 15 |
| 28 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 5 | 32 | 12 | 26 | 28 |
| 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 20 | 12 | 7 | 28 | 20 |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 5 | 12 | 1 | 13 |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 5 | 7 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 8 | 5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 4 | 15 | 54 | 149 | 83 | 185 | 112 | 163 |

Table 6.5 Continued.

| Length (cm) | Winnicut River - Alewife | | | | | | | | | | | | | | | | | | | | | |
|-------------|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 16 | 5 | 8 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 1 | 4 | 8 | 8 | 5 | 11 | 4 | 21 | 7 | 19 | 8 | 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 0 | 0 | 17 | 4 | 19 | 21 | 17 | 11 | 14 | 5 | 25 | 14 | 17 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 1 | 21 | 3 | 25 | 23 | 24 | 34 | 16 | 1 | 40 | 37 | 18 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 2 | 11 | 3 | 21 | 17 | 11 | 29 | 17 | 3 | 24 | 37 | 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 1 | 10 | 2 | 11 | 6 | 6 | 9 | 5 | 3 | 9 | 21 | 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 5 | 1 | 4 | 2 | 3 | 7 | 9 | 17 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 3 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | *0 | *0 | *0 | *0 | 5 | 67 | 21 | 87 | 79 | 70 | 92 | 100 | 32 | 139 | 134 | 116 | ^0 | ^0 | ^0 | ^0 | ^0 | ^0 |

*- Fishway unable to pass fish.

^-Fishway and dam removed Summer 2009

Table 6.5 Continued.

| Length (cm) | Taylor River - Alewife | | | | | | | | | | | | | | | | | | | | | |
|-------------|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | *0 | *0 | *0 | *0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ^0 |

* data not available for selected year

^-No fish sampled, ASMFC removed NHFGD monitoring requirement

Table 6.6 Length frequency of blueback river herring returning to New Hampshire rivers, 1994-2015.

| Length (cm) | Cocheco River - Blueback | | | | | | | | | | | | | | | | | | | | | |
|-------------|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 7 | 0 | 0 | 0 | 0 | 0 |
| 24 | 4 | 0 | 0 | 8 | 3 | 0 | 2 | 0 | 10 | 0 | 0 | 0 | 1 | 1 | 7 | 0 | 10 | 0 | 0 | 3 | 0 | 0 |
| 25 | 10 | 0 | 8 | 18 | 15 | 0 | 6 | 1 | 14 | 7 | 0 | 0 | 0 | 17 | 9 | 0 | 26 | 0 | 0 | 2 | 1 | 0 |
| 26 | 1 | 8 | 5 | 20 | 14 | 9 | 9 | 5 | 7 | 11 | 7 | 3 | 2 | 18 | 13 | 0 | 8 | 0 | 0 | 0 | 0 | 0 |
| 27 | 4 | 8 | 14 | 10 | 15 | 16 | 4 | 8 | 6 | 5 | 7 | 2 | 1 | 21 | 8 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 28 | 2 | 4 | 8 | 10 | 6 | 4 | 2 | 11 | 7 | 2 | 1 | 0 | 2 | 5 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 1 | 3 | 4 | 5 | 1 | 0 | 2 | 0 | 5 | 0 | 2 | 0 | 2 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 23 | 25 | 42 | 75 | 54 | 29 | 25 | 25 | 53 | 25 | 17 | 5 | 8 | 67 | 48 | 2 | 53 | 0 | 0 | 5 | 2 | 0 |

Table 6.6 Continued.

| Length (cm) | Exeter River - Blueback | | | | | | | | | | | | | | | | | | | | | |
|-------------|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 22 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 16 |
| 25 | 0 | 5 | 0 | 40 | 23 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 2 | 1 | 0 | 0 | 0 | 13 | 33 |
| 26 | 0 | 11 | 0 | 34 | 31 | 15 | 1 | 9 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 2 | 58 |
| 27 | 0 | 9 | 0 | 27 | 16 | 22 | 0 | 26 | 1 | 0 | 6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 24 |
| 28 | 0 | 14 | 0 | 25 | 4 | 7 | 1 | 20 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| 29 | 0 | 12 | 1 | 11 | 3 | 2 | 0 | 16 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 30 | 0 | 7 | 1 | 1 | 0 | 0 | 1 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | *0 | 61 | 2 | 161 | 80 | 51 | 3 | 85 | 2 | 1 | 13 | 0 | 0 | 0 | 12 | 6 | 1 | 0 | 1 | 0 | 33 | 125 |

*- Due to damage to fish trap, fishway became a swim through operation

Table 6.6 Continued.

| Length (cm) | Lamprey River - Blueback | | | | | | | | | | | | | | | | | | | | | |
|-------------|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 1 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 5 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 13 | 0 | 2 | 0 | 19 | 0 | 0 | 0 | 3 | 0 | 0 | 2 | 11 | 0 | 1 | 32 | 0 | 0 | 0 | 0 | 0 |

Table 6.6 Continued.

| Length (cm) | Oyster River - Blueback | | | | | | | | | | | | | | | | | | | | | |
|-------------|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 3 | 27 | 0 | 0 | 0 |
| 23 | 4 | 0 | 2 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 8 | 3 | 16 | 0 | 8 | 26 | 41 | 5 | 4 | 0 |
| 24 | 15 | 1 | 5 | 15 | 8 | 4 | 5 | 1 | 11 | 5 | 5 | 20 | 23 | 30 | 43 | 13 | 66 | 82 | 33 | 42 | 36 | 3 |
| 25 | 30 | 10 | 23 | 24 | 16 | 13 | 17 | 6 | 43 | 23 | 19 | 11 | 38 | 35 | 25 | 33 | 153 | 76 | 72 | 117 | 75 | 29 |
| 26 | 28 | 39 | 37 | 36 | 34 | 39 | 30 | 25 | 21 | 53 | 30 | 28 | 25 | 45 | 29 | 22 | 112 | 68 | 80 | 76 | 95 | 101 |
| 27 | 24 | 32 | 31 | 35 | 33 | 44 | 51 | 48 | 30 | 32 | 39 | 22 | 11 | 37 | 20 | 10 | 44 | 33 | 64 | 17 | 91 | 82 |
| 28 | 18 | 16 | 25 | 15 | 35 | 34 | 21 | 41 | 21 | 15 | 23 | 31 | 19 | 20 | 9 | 7 | 12 | 11 | 44 | 7 | 28 | 46 |
| 29 | 20 | 10 | 4 | 15 | 17 | 8 | 17 | 14 | 11 | 15 | 9 | 9 | 13 | 8 | 2 | 1 | 3 | 2 | 4 | 1 | 6 | 18 |
| 30 | 8 | 8 | 0 | 5 | 6 | 2 | 2 | 8 | 2 | 5 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 7 |
| 31 | 0 | 3 | 1 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 32 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 147 | 120 | 128 | 150 | 151 | 145 | 143 | 144 | 141 | 149 | 128 | 126 | 141 | 179 | 145 | 86 | 398 | 301 | 367 | 265 | 338 | 287 |

Table 6.6 Continued.

| Length (cm) | Winnicut River - Blueback | | | | | | | | | | | | | | | | | | | | | |
|-------------|---------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 1 | 3 | 17 | 0 | 1 | 3 | 1 | 4 | 12 | 4 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 13 | 8 | 28 | 2 | 9 | 15 | 5 | 16 | 16 | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 0 | 27 | 16 | 40 | 14 | 29 | 21 | 13 | 10 | 16 | 6 | 1 | 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 18 | 24 | 28 | 12 | 14 | 21 | 9 | 10 | 15 | 7 | 6 | 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 9 | 13 | 21 | 15 | 8 | 14 | 10 | 5 | 4 | 3 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 2 | 3 | 14 | 10 | 5 | 2 | 6 | 6 | 4 | 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 5 | 2 | 1 | 0 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | *0 | *0 | *0 | *0 | 74 | 69 | 157 | 59 | 68 | 77 | 44 | 52 | 73 | 30 | 16 | 33 | ^0 | ^0 | ^0 | ^0 | ^0 | ^0 |

*- Fishway unable to pass fish.

^-Fishway and dam removed Summer 2009

Table 6.6 Continued.

| Length (cm) | Taylor River - Blueback | | | | | | | | | | | | | | | | | | | | | |
|-------------|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 21 | 12 | 2 | 0 | 1 | 0 | 8 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 0 | 35 | 11 | 8 | 0 | 0 | 0 | 19 | 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 22 | 18 | 28 | 0 | 1 | 0 | 13 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 16 | 12 | 29 | 0 | 3 | 0 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 10 | 5 | 19 | 0 | 11 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | 0 | 0 | 4 | 3 | 9 | 0 | 11 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 0 | 0 | 0 | 4 | 2 | 2 | 0 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | *0 | *0 | *0 | *0 | 115 | 67 | 97 | 0 | 30 | 0 | 67 | 14 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | ^0 |

* data not available for selected year

^A-No fish sampled, ASMFC removed NHFGD monitoring requirement

Table 6.7 Percent of male and female river herring, mean total length (mm), and total sampled river herring during spawning returns to the first dam on the Cocheco, Exeter, Oyster, Lamprey, Taylor, and Winnicut rivers, New Hampshire, 1994-2015.

| | Cocheco River– Combined Species | | | | | Exeter River– Combined Species | | | | | Oyster River– Combined Species | | | | |
|------|---------------------------------|--------|-------------|--------|-------|--------------------------------|--------|-------------|--------|-------|--------------------------------|--------|-------------|--------|-------|
| | % | | Mean Length | | Total | % | | Mean Length | | Total | % | | Mean Length | | Total |
| Year | Male | Female | Male | Female | N | Male | Female | Male | Female | N | Male | Female | Male | Female | N |
| 1994 | 56.5 | 44.5 | 274 | 274 | 462 | * | * | * | * | * | 63.2 | 36.8 | 262 | 277 | 450 |
| 1995 | 48.8 | 51.2 | 279 | 287 | 450 | 66.5 | 33.5 | 271 | 284 | 520 | 53.0 | 47.0 | 264 | 277 | 450 |
| 1996 | 50.7 | 49.3 | 282 | 290 | 402 | 54.8 | 45.2 | 278 | 284 | 221 | 61.4 | 38.6 | 258 | 270 | 446 |
| 1997 | 63.7 | 36.3 | 267 | 278 | 452 | 59.2 | 40.8 | 262 | 266 | 1075 | 60.7 | 39.3 | 261 | 272 | 448 |
| 1998 | 52.4 | 47.6 | 271 | 280 | 475 | 64.5 | 35.5 | 268 | 278 | 386 | 48.2 | 51.8 | 261 | 273 | 506 |
| 1999 | 52.4 | 47.6 | 277 | 288 | 458 | 65.8 | 34.2 | 267 | 278 | 403 | 57.4 | 42.6 | 261 | 273 | 453 |
| 2000 | 61.5 | 38.5 | 272 | 285 | 455 | 66.0 | 34.0 | 273 | 280 | 259 | 59.0 | 41.0 | 263 | 277 | 446 |
| 2001 | 54.1 | 45.9 | 278 | 286 | 458 | 59.7 | 40.3 | 277 | 288 | 454 | 60.8 | 39.2 | 269 | 283 | 449 |
| 2002 | 59.6 | 40.4 | 273 | 287 | 453 | 63.1 | 36.9 | 272 | 282 | 160 | 69.0 | 31.0 | 259 | 270 | 474 |
| 2003 | 49.3 | 50.7 | 275 | 280 | 454 | 62.7 | 37.3 | 283 | 291 | 67 | 51.7 | 48.3 | 260 | 272 | 447 |
| 2004 | 42.4 | 57.6 | 282 | 288 | 450 | 57.7 | 42.3 | 277 | 286 | 78 | 58.0 | 42.0 | 263 | 275 | 452 |
| 2005 | 50.4 | 49.6 | 285 | 294 | 347 | 66.2 | 33.8 | 278 | 289 | 77 | 60.5 | 39.5 | 257 | 273 | 343 |
| 2006 | 60.0 | 40.0 | 281 | 295 | 300 | 43.8 | 56.2 | 281 | 295 | 16 | 79.1 | 20.9 | 251 | 273 | 448 |
| 2007 | 62.8 | 37.2 | 272 | 285 | 457 | 60.0 | 40.0 | 268 | 283 | 40 | 64.7 | 35.3 | 254 | 267 | 453 |
| 2008 | 59.0 | 41.0 | 266 | 279 | 454 | 58.3 | 41.7 | 268 | 278 | 168 | 65.8 | 34.2 | 248 | 263 | 453 |
| 2009 | 58.3 | 41.7 | 273 | 282 | 456 | 56.3 | 43.8 | 276 | 283 | 336 | 76.6 | 23.4 | 251 | 265 | 299 |
| 2010 | 66.7 | 33.3 | 275 | 278 | 450 | 60.4 | 39.6 | 263 | 277 | 48 | 66.3 | 33.7 | 256 | 266 | 457 |
| 2011 | 56.7 | 43.3 | 276 | 287 | 354 | 64.4 | 35.6 | 267 | 279 | 230 | 56.9 | 42.9 | 258 | 269 | 149 |
| 2012 | 47.8 | 52.2 | 290 | 299 | 320 | 40.2 | 58.7 | 283 | 294 | 328 | 50.4 | 49.6 | 252 | 273 | 454 |
| 2013 | 54.9 | 44.9 | 271 | 279 | 452 | 62.8 | 37.2 | 268 | 279 | 364 | 57.8 | 42.2 | 259 | 267 | 604 |
| 2014 | 55.2 | 44.7 | 272 | 284 | 587 | 66.1 | 33.9 | 273 | 285 | 375 | 49.8 | 50.2 | 263 | 277 | 337 |
| 2015 | 53.2 | 46.8 | 279 | 290 | 450 | 71.1 | 28.9 | 267 | 279 | 450 | 59.2 | 40.8 | 271 | 282 | 450 |

*-Sampling did not occur.

Table 6.7 Continued.

| | Lamprey River– Combined Species | | | | | Taylor River– Combined Species | | | | | Winnicut River– Combined Species | | | | |
|------|---------------------------------|--------|-------------|--------|-------|--------------------------------|--------|-------------|--------|-------|----------------------------------|--------|-------------|--------|-------|
| | % | | Mean Length | | Total | % | | Mean Length | | Total | % | | Mean Length | | Total |
| Year | Male | Female | Male | Female | N | Male | Female | Male | Female | N | Male | Female | Male | Female | N |
| 1994 | 51.9 | 48.1 | 274 | 281 | 447 | * | * | * | * | * | * | * | * | * | * |
| 1995 | 52.6 | 47.4 | 279 | 293 | 450 | * | * | * | * | * | * | * | * | * | * |
| 1996 | 51.0 | 49.0 | 281 | 294 | 398 | * | * | * | * | * | * | * | * | * | * |
| 1997 | 46.7 | 53.3 | 284 | 297 | 304 | * | * | * | * | * | * | * | * | * | * |
| 1998 | 56.3 | 43.7 | 279 | 289 | 339 | 70.4 | 29.6 | 253 | 274 | 125 | 84.8 | 15.2 | 254 | 271 | 79 |
| 1999 | 52.3 | 47.7 | 279 | 289 | 453 | 61.9 | 38.1 | 253 | 269 | 181 | 82.6 | 17.4 | 257 | 271 | 218 |
| 2000 | 52.3 | 47.7 | 279 | 290 | 608 | 44.9 | 55.1 | 261 | 274 | 247 | 79.8 | 20.2 | 248 | 265 | 450 |
| 2001 | 58.2 | 41.8 | 286 | 294 | 452 | * | * | * | * | * | 71.8 | 28.2 | 262 | 273 | 464 |
| 2002 | 58.2 | 41.8 | 292 | 306 | 459 | 38.5 | 61.5 | 269 | 288 | 26 | 73.7 | 26.3 | 255 | 265 | 453 |
| 2003 | 57.2 | 42.8 | 284 | 296 | 449 | * | * | * | * | * | 85.4 | 14.6 | 253 | 264 | 444 |
| 2004 | 53.0 | 47.0 | 285 | 290 | 453 | 63.8 | 36.2 | 255 | 275 | 80 | 79.0 | 21.0 | 260 | 269 | 453 |
| 2005 | 57.2 | 42.8 | 290 | 298 | 402 | 71.4 | 28.6 | 256 | 263 | 14 | 78.4 | 21.6 | 247 | 266 | 343 |
| 2006 | 55.3 | 44.7 | 289 | 303 | 333 | * | * | * | * | * | 89.5 | 10.5 | 251 | 264 | 124 |
| 2007 | 59.6 | 40.4 | 282 | 303 | 411 | 61.1 | 38.9 | 287 | 279 | 18 | 88.0 | 12.0 | 257 | 270 | 443 |
| 2008 | 47.5 | 52.5 | 274 | 283 | 453 | * | * | * | * | * | 81.4 | 18.6 | 259 | 274 | 457 |
| 2009 | 60.3 | 39.7 | 282 | 291 | 451 | * | * | * | * | * | 82.1 | 17.9 | 256 | 277 | 452 |
| 2010 | 60.7 | 39.3 | 272 | 296 | 369 | * | * | * | * | * | * | * | * | * | * |
| 2011 | 56.2 | 43.8 | 274 | 286 | 450 | * | * | * | * | * | * | * | * | * | * |
| 2012 | 55.1 | 44.9 | 287 | 298 | 470 | * | * | * | * | * | * | * | * | * | * |
| 2013 | 50.2 | 49.8 | 280 | 293 | 756 | * | * | * | * | * | * | * | * | * | * |
| 2014 | 52.3 | 47.7 | 283 | 292 | 450 | * | * | * | * | * | * | * | * | * | * |
| 2015 | 54.7 | 45.3 | 288 | 302 | 450 | * | * | * | * | * | * | * | * | * | * |

*-Sampling did not occur.

Table 6.8 Percent of male and female alewife river herring, mean total length (mm), and total sampled river herring during spawning returns to the first dam on the Cocheco, Exeter, Oyster, Lamprey, Taylor, and Winnicut rivers, New Hampshire, 1994-2015.

| | Cocheco River - Alewife | | | | | Exeter River - Alewife | | | | | Oyster River - Alewife | | | | |
|------|-------------------------|-------|-------------------------------|-----|------------|------------------------|-------|-------------------------------|-----|------------|------------------------|-------|-------------------------------|-----|------------|
| | % Year | | Mean Length Male Female | | Total N | % Male Female | | Mean Length Male Female | | Total N | % Male Female | | Mean Length Male Female | | Total N |
| 1994 | 58.0% | 42.0% | 268 | 274 | 119 | * | * | * | * | * | + | + | + | + | 0 |
| 1995 | 50.9% | 49.1% | 282 | 289 | 112 | 64.6% | 35.4% | 277 | 288 | 127 | 50.0% | 50.0% | 261 | 270 | 8 |
| 1996 | 52.1% | 47.9% | 283 | 293 | 190 | 60.0% | 40.0% | 283 | 296 | 20 | 80.0% | 20.0% | 267 | 283 | 5 |
| 1997 | 75.7% | 24.3% | 276 | 291 | 70 | 64.9% | 35.1% | 275 | 286 | 111 | + | + | + | + | 0 |
| 1998 | 53.0% | 47.0% | 277 | 287 | 115 | 58.7% | 41.3% | 276 | 279 | 92 | + | + | + | + | 0 |
| 1999 | 52.3% | 47.7% | 280 | 290 | 111 | 64.8% | 35.2% | 272 | 277 | 105 | + | + | + | + | 0 |
| 2000 | 56.6% | 43.4% | 279 | 287 | 106 | 71.3% | 28.7% | 275 | 283 | 94 | + | + | + | + | 0 |
| 2001 | 45.3% | 54.7% | 280 | 292 | 117 | 71.4% | 28.6% | 283 | 291 | 56 | + | + | + | + | 0 |
| 2002 | 61.3% | 38.7% | 284 | 293 | 93 | 63.5% | 36.5% | 277 | 284 | 52 | 100.0% | 0.0% | 290 | 0 | 1 |
| 2003 | 39.6% | 60.4% | 279 | 284 | 111 | 61.1% | 38.9% | 283 | 293 | 54 | + | + | + | + | 0 |
| 2004 | 44.1% | 55.9% | 286 | 292 | 102 | 63.6% | 36.4% | 279 | 293 | 44 | 33.3% | 66.7% | 281 | 284 | 3 |
| 2005 | 48.3% | 51.7% | 283 | 294 | 120 | 65.6% | 34.4% | 277 | 289 | 64 | + | + | + | + | 0 |
| 2006 | 64.9% | 35.1% | 284 | 296 | 77 | 43.8% | 56.3% | 281 | 295 | 16 | + | + | + | + | 0 |
| 2007 | 49.5% | 49.5% | 283 | 295 | 93 | 60.0% | 40.0% | 268 | 283 | 40 | + | + | + | + | 0 |
| 2008 | 58.2% | 41.8% | 273 | 281 | 98 | 60.4% | 39.6% | 269 | 280 | 134 | 75.0% | 25.0% | 271 | 268 | 4 |
| 2009 | 51.1% | 48.9% | 271 | 283 | 184 | 58.3% | 41.7% | 276 | 283 | 307 | 68.8% | 31.3% | 259 | 269 | 16 |
| 2010 | 48.6% | 51.4% | 283 | 294 | 72 | 50.0% | 50.0% | 265 | 280 | 32 | 72.7% | 27.3% | 256 | 282 | 22 |
| 2011 | 52.0% | 48.0% | 274 | 292 | 75 | 58.7% | 41.3% | 267 | 280 | 63 | 54.8% | 45.2% | 271 | 285 | 62 |
| 2012 | 46.0% | 50.8% | 287 | 299 | 63 | 45.8% | 54.2% | 279 | 294 | 59 | 48.0% | 52.0% | 268 | 279 | 50 |
| 2013 | 50.6% | 49.4% | 279 | 291 | 87 | 48.6% | 51.4% | 274 | 283 | 70 | 47.7% | 52.3% | 266 | 279 | 65 |
| 2014 | 48.1% | 51.9% | 280 | 291 | 106 | 51.4% | 48.6% | 280 | 288 | 70 | 46.0% | 54.0% | 282 | 296 | 50 |
| 2015 | 48.8% | 51.3% | 283 | 293 | 80 | 50.8% | 50.8% | 280 | 292 | 63 | 49.2% | 50.8% | 280 | 290 | 59 |

*-Sampling did not occur.

+-Sampling occurred but no alewife encountered in run.

Table 6.8 Continued.

| | Lamprey River - Alewife | | | | | Taylor River - Alewife | | | | | Winnicut River - Alewife | | | | |
|------|-------------------------|--------|---------------------|--------|-----------------|------------------------|--------|-----------------------|--------|------------|--------------------------|--------|-----------------------|--------|------------|
| | % Year | | Mean Length Male | | Total Female | % Male | | Mean Length Female | | Total N | % Male | | Mean Length Female | | Total N |
| Year | Male | Female | Male | Female | N | Male | Female | Male | Female | N | Male | Female | Male | Female | N |
| 1994 | 55.3% | 44.7% | 274 | 284 | 141 | * | * | * | * | * | * | * | * | * | * |
| 1995 | 46.2% | 53.8% | 278 | 292 | 119 | * | * | * | * | * | * | * | * | * | * |
| 1996 | 51.6% | 48.4% | 283 | 293 | 128 | * | * | * | * | * | * | * | * | * | * |
| 1997 | 51.1% | 48.9% | 286 | 294 | 94 | * | * | * | * | * | * | * | * | * | * |
| 1998 | 58.5% | 41.5% | 275 | 285 | 135 | 66.7% | 33.3% | 260 | 286 | 3 | 80.0% | 20.0% | 261 | 267 | 5 |
| 1999 | 48.9% | 51.1% | 277 | 290 | 141 | + | + | + | + | 0 | 77.6% | 22.4% | 259 | 272 | 67 |
| 2000 | 52.3% | 47.7% | 282 | 291 | 195 | + | + | + | + | 0 | 66.7% | 33.3% | 245 | 264 | 21 |
| 2001 | 56.6% | 43.4% | 287 | 293 | 145 | * | * | * | * | * | 73.6% | 26.4% | 259 | 268 | 87 |
| 2002 | 59.7% | 40.3% | 290 | 305 | 139 | + | + | + | + | 0 | 83.5% | 16.5% | 259 | 276 | 79 |
| 2003 | 64.3% | 35.7% | 285 | 296 | 140 | * | * | * | * | * | 88.6% | 11.4% | 255 | 272 | 70 |
| 2004 | 53.1% | 46.9% | 283 | 292 | 162 | 100.0% | 0.0% | 251 | 0 | 1 | 77.2% | 22.8% | 263 | 269 | 92 |
| 2005 | 53.1% | 46.9% | 287 | 297 | 128 | + | + | + | + | 0 | 81.0% | 19.0% | 245 | 265 | 100 |
| 2006 | 50.0% | 50.0% | 285 | 301 | 122 | * | * | * | * | * | 93.8% | 6.3% | 254 | 279 | 32 |
| 2007 | 59.3% | 40.7% | 285 | 307 | 140 | 57.9% | 42.1% | 287 | 281 | 19 | 84.2% | 15.8% | 258 | 273 | 139 |
| 2008 | 42.7% | 57.3% | 276 | 285 | 143 | + | + | + | + | 0 | 79.9% | 20.1% | 264 | 273 | 134 |
| 2009 | 54.8% | 45.2% | 282 | 291 | 197 | * | * | * | * | * | 66.9% | 33.1% | 260 | 277 | 166 |
| 2010 | 45.7% | 54.3% | 279 | 294 | 81 | * | * | * | * | * | * | * | * | * | * |
| 2011 | 47.6% | 51.2% | 280 | 290 | 84 | * | * | * | * | * | * | * | * | * | * |
| 2012 | 48.1% | 51.9% | 282 | 290 | 79 | * | * | * | * | * | * | * | * | * | * |
| 2013 | 50.0% | 50.0% | 279 | 291 | 82 | * | * | * | * | * | * | * | * | * | * |
| 2014 | 49.5% | 50.5% | 285 | 295 | 101 | * | * | * | * | * | * | * | * | * | * |
| 2015 | 49.4% | 50.6% | 288 | 298 | 83 | * | * | * | * | * | * | * | * | * | * |

*-Sampling did not occur.

+-Sampling occurred but no alewife encountered in run.

Table 6.9 Percent of male and female blueback river herring, mean total length (mm), and total sampled river herring during spawning returns to the first dam on the Cocheco, Exeter, Oyster, Lamprey, Taylor, and Winnicut rivers, New Hampshire, 1994-2015.

| | Cocheco River - Blueback | | | | | Exeter River - Blueback | | | | | Oyster River - Blueback | | | | |
|------|--------------------------|--------|-------------|--------|-------|-------------------------|--------|-------------|--------|-------|-------------------------|--------|-------------|--------|-------|
| | % | | Mean Length | | Total | % | | Mean Length | | Total | % | | Mean Length | | Total |
| Year | Male | Female | Male | Female | N | Male | Female | Male | Female | N | Male | Female | Male | Female | N |
| 1994 | 69.6% | 30.4% | 251 | 259 | 23 | * | * | * | * | * | 68.0% | 32.0% | 260 | 276 | 147 |
| 1995 | 24.0% | 76.0% | 269 | 274 | 25 | 67.2% | 32.8% | 272 | 292 | 61 | 52.5% | 47.5% | 266 | 277 | 120 |
| 1996 | 50.0% | 50.0% | 265 | 277 | 42 | 100.0% | 0.0% | 294 | | 2 | 57.0% | 43.0% | 260 | 269 | 128 |
| 1997 | 58.7% | 41.3% | 257 | 268 | 75 | 85.7% | 14.3% | 260 | 272 | 161 | 66.7% | 33.3% | 261 | 275 | 150 |
| 1998 | 59.3% | 40.7% | 258 | 267 | 54 | 77.5% | 22.5% | 257 | 277 | 80 | 47.0% | 53.0% | 264 | 275 | 151 |
| 1999 | 65.5% | 34.5% | 265 | 270 | 29 | 72.5% | 27.5% | 263 | 274 | 51 | 57.2% | 42.8% | 263 | 274 | 145 |
| 2000 | 76.0% | 24.0% | 258 | 271 | 25 | 100.0% | 0.0% | 278 | | 3 | 62.2% | 37.8% | 263 | 277 | 143 |
| 2001 | 52.0% | 48.0% | 267 | 273 | 25 | 55.3% | 44.7% | 272 | 288 | 85 | 58.3% | 40.3% | 268 | 282 | 144 |
| 2002 | 71.7% | 28.3% | 255 | 267 | 53 | 50.0% | 50.0% | 266 | 286 | 2 | 73.8% | 26.2% | 260 | 271 | 141 |
| 2003 | 52.0% | 48.0% | 256 | 265 | 25 | 100.0% | 0.0% | 249 | | 1 | 56.4% | 43.6% | 261 | 273 | 149 |
| 2004 | 41.2% | 58.8% | 263 | 273 | 17 | 69.2% | 30.8% | 268 | 274 | 13 | 59.4% | 40.6% | 263 | 273 | 128 |
| 2005 | 80.0% | 20.0% | 262 | 263 | 5 | + | + | + | + | 0 | 61.9% | 37.3% | 255 | 276 | 126 |
| 2006 | 62.5% | 37.5% | 263 | 282 | 8 | + | + | + | + | 0 | 74.5% | 24.1% | 254 | 277 | 141 |
| 2007 | 70.1% | 29.9% | 260 | 269 | 67 | + | + | + | + | 0 | 59.2% | 40.8% | 254 | 267 | 179 |
| 2008 | 64.6% | 35.4% | 250 | 272 | 48 | 58.3% | 41.7% | 248 | 271 | 12 | 71.0% | 29.0% | 247 | 261 | 145 |
| 2009 | 50.0% | 50.0% | 234 | 282 | 2 | 100.0% | 0.0% | 255 | | 6 | 66.4% | 33.6% | 253 | 267 | 119 |
| 2010 | 79.2% | 20.8% | 252 | 249 | 53 | 100.0% | 0.0% | 259 | | 1 | 66.1% | 33.9% | 256 | 264 | 398 |
| 2011 | + | + | + | + | 0 | 100.0% | 0.0% | 268 | | 1 | 46.8% | 53.2% | 250 | 266 | 62 |
| 2012 | + | + | + | + | 0 | + | + | + | + | 0 | 53.2% | 46.8% | 254 | 268 | 62 |
| 2013 | 80.0% | 20.0% | 247 | 258 | 5 | + | + | + | + | 0 | 41.7% | 58.3% | 254 | 266 | 60 |
| 2014 | 0.0% | 100.0% | | 264 | 2 | 78.8% | 21.2% | 249 | 257 | 33 | 53.1% | 46.9% | 259 | 276 | 64 |
| 2015 | + | + | + | + | 0 | 51.2% | 48.8% | 265 | 274 | 41 | 41.5% | 58.5% | 273 | 282 | 53 |

*-Sampling did not occur.

+-Sampling occurred but no blueback encountered in run.

Table 6.9 Continued.

| | Lamprey River - Blueback | | | | | Taylor River - Blueback | | | | | Winnicut River - Blueback | | | | |
|------|--------------------------|--------|----------------------------|--------|---------|-------------------------|--------|----------------------------|--------|---------|---------------------------|--------|----------------------------|--------|---------|
| | % Year | | Mean Length Male Female | | Total N | % Male Female | | Mean Length Male Female | | Total N | % Male Female | | Mean Length Male Female | | Total N |
| Year | Male | Female | Male | Female | N | Male | Female | Male | Female | N | Male | Female | Male | Female | N |
| 1994 | + | + | + | + | 0 | * | * | * | * | * | * | * | * | * | * |
| 1995 | 38.5% | 61.5% | 288 | 292 | 13 | * | * | * | * | * | * | * | * | * | * |
| 1996 | + | + | + | + | 0 | * | * | * | * | * | * | * | * | * | * |
| 1997 | 0.0% | 100.0% | | 282 | 2 | * | * | * | * | * | * | * | * | * | * |
| 1998 | + | + | + | + | 0 | 73.0% | 27.0% | 253 | 271 | 115 | 85.1% | 14.9% | 254 | 271 | 74 |
| 1999 | 47.4% | 52.6% | 253 | 265 | 19 | 67.2% | 32.8% | 253 | 272 | 67 | 88.4% | 11.6% | 256 | 267 | 69 |
| 2000 | + | + | + | + | 0 | 48.5% | 51.5% | 262 | 274 | 97 | 72.0% | 28.0% | 249 | 265 | 157 |
| 2001 | + | + | + | + | 0 | * | * | * | * | * | 78.0% | 22.0% | 262 | 279 | 59 |
| 2002 | + | + | + | + | 0 | 33.3% | 66.7% | 268 | 288 | 30 | 75.0% | 25.0% | 253 | 263 | 68 |
| 2003 | 100.0% | 0.0% | 264 | | 3 | * | * | * | * | * | 85.7% | 14.3% | 254 | 258 | 77 |
| 2004 | + | + | + | + | 0 | 58.2% | 41.8% | 254 | 273 | 67 | 79.5% | 20.5% | 256 | 269 | 44 |
| 2005 | + | + | + | + | 0 | 71.4% | 28.6% | 256 | 263 | 14 | 80.8% | 19.2% | 249 | 267 | 52 |
| 2006 | 100.0% | 0.0% | 256 | | 2 | * | * | * | * | * | 84.9% | 15.1% | 247 | 257 | 73 |
| 2007 | 63.6% | 36.4% | 262 | 271 | 11 | + | + | + | + | 0 | 83.3% | 16.7% | 254 | 266 | 30 |
| 2008 | + | + | + | + | 0 | 100.0% | 0.0% | 239 | | 7 | 87.5% | 12.5% | 260 | 278 | 16 |
| 2009 | 75.0% | 25.0% | 255 | 251 | 4 | * | * | * | * | * | 65.1% | 34.9% | 252 | 265 | 43 |
| 2010 | 90.6% | 9.4% | 256 | 268 | 32 | * | * | * | * | * | * | * | * | * | * |
| 2011 | + | + | + | + | 0 | * | * | * | * | * | * | * | * | * | * |
| 2012 | + | + | + | + | 0 | * | * | * | * | * | * | * | * | * | * |
| 2013 | + | + | + | + | 0 | * | * | * | * | * | * | * | * | * | * |
| 2014 | + | + | + | + | 0 | * | * | * | * | * | * | * | * | * | * |
| 2015 | + | + | + | + | 0 | * | * | * | * | * | * | * | * | * | * |

*-Sampling did not occur.

+-Sampling occurred but no blueback encountered in run.

Table 6.10 Number-at-age of river herring collected from the coastal rivers of New Hampshire, 1994-2015.

| Cocheco River– Combined Species | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 3 | 69 | 19 | 45 | 45 | 29 | 6 | 61 | 20 | 17 | 6 | 1 | 2 | 0 | 0 | 6 | 13 | 5 | 2 | 1 | 3 | 1 | 4 |
| 4 | 61 | 74 | 78 | 49 | 65 | 62 | 36 | 61 | 54 | 89 | 15 | 29 | 13 | 31 | 27 | 75 | 13 | 16 | 16 | 38 | 26 | 24 |
| 5 | 10 | 42 | 63 | 34 | 50 | 47 | 27 | 43 | 45 | 29 | 69 | 47 | 21 | 55 | 57 | 48 | 28 | 32 | 19 | 16 | 36 | 23 |
| 6 | 0 | 2 | 35 | 14 | 15 | 20 | 7 | 9 | 24 | 7 | 26 | 46 | 25 | 54 | 44 | 42 | 19 | 19 | 17 | 13 | 20 | 18 |
| 7+ | 0 | 0 | 2 | 3 | 10 | 5 | 0 | 9 | 6 | 5 | 8 | 1 | 26 | 19 | 12 | 8 | 7 | 6 | 10 | 1 | 25 | 11 |
| Total | 140 | 137 | 223 | 145 | 169 | 140 | 131 | 142 | 146 | 136 | 119 | 125 | 85 | 159 | 146 | 186 | 72 | 75 | 63 | 91 | 108 | 81 |

| Exeter River– Combined Species | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 3 | * | 70 | 6 | 82 | 69 | 23 | 53 | 8 | 2 | 2 | 0 | 2 | 0 | 3 | 21 | 3 | 6 | 6 | 1 | 5 | 4 | 1 |
| 4 | * | 94 | 11 | 112 | 44 | 88 | 37 | 45 | 15 | 30 | 6 | 25 | 1 | 9 | 62 | 147 | 17 | 24 | 13 | 29 | 44 | 61 |
| 5 | * | 17 | 5 | 52 | 37 | 38 | 5 | 47 | 27 | 14 | 31 | 26 | 6 | 15 | 44 | 119 | 12 | 27 | 30 | 19 | 35 | 28 |
| 6 | * | 4 | 0 | 22 | 16 | 7 | 2 | 31 | 10 | 6 | 18 | 8 | 4 | 11 | 16 | 39 | 3 | 6 | 12 | 10 | 15 | 13 |
| 7+ | * | 0 | 0 | 4 | 6 | 0 | 0 | 10 | 0 | 3 | 2 | 3 | 5 | 2 | 3 | 5 | 0 | 1 | 3 | 7 | 5 | 1 |
| Total | * | 185 | 22 | 272 | 172 | 156 | 97 | 141 | 54 | 55 | 57 | 64 | 16 | 40 | 146 | 313 | 38 | 64 | 59 | 70 | 103 | 104 |

| Oyster River– Combined Species | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 3 | 65 | 33 | 32 | 64 | 36 | 44 | 61 | 21 | 12 | 32 | 20 | 22 | 6 | 9 | 46 | 33 | 29 | 51 | 12 | 16 | 4 | 3 |
| 4 | 48 | 68 | 61 | 50 | 58 | 84 | 56 | 48 | 54 | 62 | 17 | 38 | 46 | 71 | 48 | 64 | 23 | 43 | 40 | 70 | 32 | 46 |
| 5 | 23 | 25 | 37 | 28 | 44 | 15 | 25 | 39 | 37 | 43 | 69 | 45 | 46 | 68 | 38 | 22 | 32 | 21 | 38 | 22 | 60 | 38 |
| 6 | 4 | 2 | 3 | 7 | 11 | 2 | 1 | 24 | 28 | 7 | 21 | 20 | 32 | 22 | 11 | 13 | 10 | 6 | 17 | 13 | 14 | 21 |
| 7+ | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 10 | 11 | 5 | 4 | 0 | 9 | 9 | 6 | 3 | 6 | 3 | 5 | 4 | 4 | 4 |
| Total | 140 | 128 | 133 | 150 | 151 | 145 | 143 | 142 | 142 | 149 | 131 | 125 | 139 | 179 | 149 | 135 | 100 | 124 | 112 | 125 | 114 | 112 |

Table 6.10 Continued.

| Lamprey River– Combined Species | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| 3 | 48 | 26 | 26 | 15 | 18 | 15 | 50 | 11 | 3 | 8 | 7 | 0 | 3 | 2 | 9 | 6 | 10 | 5 | 1 | 4^ | 4 | 2 | |
| 4 | 68 | 74 | 60 | 18 | 30 | 44 | 68 | 49 | 28 | 53 | 26 | 25 | 13 | 21 | 25 | 44 | 21 | 25 | 24 | 28 | 29 | 27 | |
| 5 | 19 | 31 | 35 | 35 | 46 | 53 | 44 | 52 | 39 | 41 | 63 | 55 | 42 | 42 | 52 | 79 | 27 | 34 | 30 | 13 | 27 | 22 | |
| 6 | 5 | 1 | 5 | 24 | 31 | 35 | 26 | 26 | 42 | 17 | 45 | 44 | 36 | 54 | 37 | 60 | 25 | 15 | 16 | 24 | 25 | 15 | |
| 7+ | 1 | 0 | 0 | 4 | 10 | 13 | 7 | 7 | 27 | 24 | 21 | 4 | 30 | 32 | 20 | 12 | 9 | 5 | 8 | 13 | 16 | 17 | |
| Total | 141 | 132 | 126 | 96 | 135 | 160 | 195 | 145 | 139 | 143 | 162 | 128 | 124 | 151 | 143 | 201 | 92 | 84 | 79 | 82 | 101 | 83 | |

| Taylor River– Combined Species | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | | |
| 3 | * | * | * | * | 49 | 48 | 31 | * | 1 | * | 22 | 1 | * | 0 | 3 | * | * | * | * | * | * | * | * | |
| 4 | * | * | * | * | 33 | 10 | 47 | * | 1 | * | 19 | 13 | * | 1 | 4 | * | * | * | * | * | * | * | * | |
| 5 | * | * | * | * | 24 | 4 | 14 | * | 6 | * | 15 | 0 | * | 10 | 0 | * | * | * | * | * | * | * | * | |
| 6 | * | * | * | * | 6 | 5 | 5 | * | 16 | * | 7 | 0 | * | 6 | 0 | * | * | * | * | * | * | * | * | |
| 7+ | * | * | * | * | 6 | 0 | 0 | * | 6 | * | 5 | 0 | * | 2 | 0 | * | * | * | * | * | * | * | * | |
| Total | * | * | * | * | 118 | 67 | 97 | * | 30 | * | 68 | 14 | * | 19 | 7 | * | * | * | * | * | * | * | * | |

| Winnicut River– Combined Species | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | | |
| 3 | * | * | * | * | 45 | 44 | 60 | 42 | 29 | 36 | 3 | 48 | 9 | 5 | 5 | 30 | * | * | * | * | * | * | * | |
| 4 | * | * | * | * | 24 | 69 | 70 | 64 | 61 | 88 | 58 | 52 | 41 | 56 | 29 | 65 | * | * | * | * | * | * | * | |
| 5 | * | * | * | * | 4 | 19 | 30 | 25 | 30 | 21 | 66 | 38 | 34 | 60 | 71 | 40 | * | * | * | * | * | * | * | |
| 6 | * | * | * | * | 4 | 4 | 16 | 14 | 21 | 2 | 7 | 13 | 16 | 32 | 37 | 49 | * | * | * | * | * | * | * | |
| 7+ | * | * | * | * | 2 | 0 | 2 | 1 | 6 | 0 | 2 | 1 | 5 | 16 | 8 | 25 | * | * | * | * | * | * | * | |
| Total | * | * | * | * | 79 | 136 | 178 | 146 | 147 | 147 | 136 | 152 | 105 | 169 | 150 | 209 | * | * | * | * | * | * | * | |

* data not available for selected year

Table 6.11 Number-at-age of alewife river herring collected from the coastal rivers of New Hampshire, 1994-2015.

| Cocheco River - Alewife | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| 3 | 52 | 10 | 37 | 18 | 11 | 1 | 48 | 14 | 3 | 4 | 1 | 2 | 0 | 0 | 0 | 13 | 5 | 1 | 1 | 1 | 1 | 4 | |
| 4 | 57 | 60 | 61 | 15 | 38 | 45 | 26 | 52 | 29 | 72 | 10 | 28 | 9 | 7 | 18 | 74 | 13 | 20 | 16 | 35 | 25 | 24 | |
| 5 | 10 | 40 | 51 | 23 | 42 | 40 | 25 | 36 | 33 | 26 | 57 | 43 | 19 | 29 | 37 | 48 | 28 | 26 | 19 | 16 | 36 | 23 | |
| 6 | 0 | 2 | 31 | 12 | 14 | 20 | 7 | 7 | 22 | 5 | 26 | 46 | 25 | 39 | 33 | 41 | 19 | 16 | 17 | 13 | 19 | 18 | |
| 7+ | 0 | 0 | 1 | 2 | 10 | 5 | 0 | 8 | 6 | 4 | 8 | 1 | 24 | 18 | 10 | 8 | 7 | 12 | 10 | 21 | 25 | 11 | |
| Total | 119 | 112 | 181 | 70 | 115 | 111 | 106 | 117 | 93 | 111 | 102 | 120 | 77 | 93 | 98 | 184 | 72 | 75 | 63 | 66 | 106 | 80 | |

| Exeter River – Alewife | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | | |
| 3 | * | 44 | 5 | 24 | 20 | 12 | 52 | 2 | 2 | 1 | 0 | 2 | 0 | 3 | 17 | 0 | 4 | 13 | 1 | 5 | 0 | 1 | | |
| 4 | * | 68 | 11 | 55 | 23 | 51 | 36 | 16 | 14 | 30 | 2 | 25 | 1 | 9 | 57 | 146 | 15 | 21 | 13 | 29 | 23 | 34 | | |
| 5 | * | 11 | 4 | 21 | 30 | 35 | 4 | 29 | 26 | 14 | 23 | 26 | 6 | 15 | 44 | 118 | 11 | 21 | 30 | 19 | 28 | 16 | | |
| 6 | * | 1 | 0 | 7 | 14 | 7 | 2 | 8 | 10 | 6 | 17 | 8 | 4 | 11 | 14 | 39 | 2 | 8 | 12 | 10 | 14 | 11 | | |
| 7+ | * | 0 | 0 | 4 | 5 | 0 | 0 | 1 | 0 | 3 | 2 | 3 | 5 | 2 | 2 | 4 | 0 | 0 | 3 | 7 | 5 | 1 | | |
| Total | * | 124 | 20 | 111 | 92 | 105 | 94 | 56 | 52 | 54 | 44 | 64 | 16 | 40 | 134 | 307 | 32 | 63 | 59 | 70 | 70 | 63 | | |

| Oyster River – Alewife | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | | |
| 3 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 2 | 5 | 2 | 4 | 1 | 0 | | |
| 4 | 0 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 13 | 18 | 17 | 34 | 7 | 25 | | |
| 5 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 3 | 30 | 14 | 14 | 29 | 21 | | |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 8 | 13 | 9 | 10 | 10 | | |
| 7+ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 3 | 2 | 1 | 4 | 4 | 3 | 3 | | |
| Total | 0 | 8 | 5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 4 | 16 | 22 | 62 | 50 | 65 | 50 | 59 | | |

Table 6.11 Continued.

| Lamprey River – Alewife | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| 3 | 48 | 25 | 26 | 15 | 18 | 3 | 50 | 11 | 3 | 8 | 7 | 0 | 2 | 0 | 9 | 4 | 9 | 0 | 1 | 3 | 4 | 2 | |
| 4 | 68 | 65 | 60 | 17 | 30 | 38 | 68 | 49 | 28 | 53 | 26 | 25 | 13 | 19 | 25 | 44 | 16 | 20 | 24 | 28 | 29 | 27 | |
| 5 | 19 | 28 | 35 | 35 | 46 | 52 | 44 | 52 | 39 | 38 | 63 | 55 | 41 | 38 | 52 | 78 | 25 | 23 | 30 | 13 | 27 | 22 | |
| 6 | 5 | 1 | 5 | 23 | 31 | 35 | 26 | 26 | 42 | 17 | 45 | 44 | 36 | 52 | 37 | 59 | 24 | 23 | 16 | 24 | 25 | 15 | |
| 7+ | 1 | 0 | 0 | 4 | 10 | 13 | 7 | 7 | 27 | 24 | 21 | 4 | 30 | 31 | 20 | 12 | 7 | 18 | 8 | 13 | 16 | 17 | |
| Total | 141 | 119 | 126 | 94 | 135 | 141 | 195 | 145 | 139 | 140 | 162 | 128 | 122 | 140 | 143 | 197 | 81 | 84 | 79 | 81 | 101 | 83 | |

| Taylor River – Alewife | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | | |
| 3 | * | * | * | * | 0 | 0 | 0 | * | 0 | * | 0 | 0 | * | 0 | 0 | * | * | * | * | * | * | * | * | |
| 4 | * | * | * | * | 2 | 0 | 0 | * | 0 | * | 0 | 0 | * | 1 | 0 | * | * | * | * | * | * | * | * | |
| 5 | * | * | * | * | 0 | 0 | 0 | * | 0 | * | 1 | 0 | * | 10 | 0 | * | * | * | * | * | * | * | * | |
| 6 | * | * | * | * | 0 | 0 | 0 | * | 0 | * | 0 | 0 | * | 6 | 0 | * | * | * | * | * | * | * | * | |
| 7+ | * | * | * | * | 1 | 0 | 0 | * | 0 | * | 0 | 0 | * | 2 | 0 | * | * | * | * | * | * | * | * | |
| Total | * | * | * | * | 3 | 0 | 0 | * | 0 | * | 1 | 0 | * | 19 | 0 | * | * | * | * | * | * | * | * | |

| Winnicut River – Alewife | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | | |
| 3 | * | * | * | * | 1 | 12 | 9 | 28 | 18 | 20 | 2 | 34 | 4 | 5 | 3 | 21 | * | * | * | * | * | * | * | |
| 4 | * | * | * | * | 3 | 38 | 7 | 41 | 23 | 40 | 36 | 31 | 9 | 45 | 24 | 35 | * | * | * | * | * | * | * | |
| 5 | * | * | * | * | 0 | 13 | 2 | 9 | 18 | 9 | 47 | 24 | 9 | 51 | 66 | 37 | * | * | * | * | * | * | * | |
| 6 | * | * | * | * | 1 | 4 | 2 | 9 | 15 | 1 | 5 | 10 | 7 | 24 | 33 | 49 | * | * | * | * | * | * | * | |
| 7+ | * | * | * | * | 0 | 0 | 1 | 0 | 5 | 0 | 2 | 1 | 3 | 14 | 8 | 24 | * | * | * | * | * | * | * | |
| Total | * | * | * | * | 5 | 67 | 21 | 87 | 79 | 70 | 92 | 100 | 32 | 139 | 134 | 166 | * | * | * | * | * | * | * | |

* data not available for selected year

Table 6.12 Number-at-age of blueback river herring collected from the coastal rivers of New Hampshire, 1994-2015.

| Cocheco River - Blueback | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| 3 | 17 | 9 | 8 | 27 | 18 | 5 | 13 | 6 | 14 | 2 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | |
| 4 | 4 | 14 | 17 | 34 | 27 | 17 | 10 | 9 | 25 | 17 | 5 | 1 | 4 | 24 | 9 | 1 | 0 | 0 | 0 | 3 | 1 | 0 | |
| 5 | 0 | 2 | 12 | 11 | 8 | 7 | 2 | 7 | 12 | 3 | 12 | 4 | 2 | 27 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 6 | 0 | 0 | 4 | 2 | 1 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 15 | 11 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | |
| 7+ | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 21 | 25 | 42 | 75 | 54 | 29 | 25 | 25 | 53 | 25 | 17 | 5 | 8 | 67 | 48 | 2 | 0 | 0 | 0 | 5 | 2 | 0 | |

| Exeter River – Blueback | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | | |
| 3 | * | 26 | 1 | 58 | 49 | 11 | 1 | 6 | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 3 | 2 | 0 | 0 | 0 | 4 | 0 | | |
| 4 | * | 26 | 0 | 57 | 21 | 37 | 1 | 29 | 1 | 0 | 4 | 0 | 0 | 0 | 5 | 1 | 2 | 0 | 0 | 0 | 21 | 27 | | |
| 5 | * | 6 | 1 | 31 | 7 | 3 | 1 | 18 | 1 | 0 | 8 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 7 | 12 | | |
| 6 | * | 3 | 0 | 15 | 2 | 0 | 0 | 23 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | | |
| 7+ | * | 0 | 0 | 0 | 1 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Total | * | 61 | 2 | 161 | 80 | 51 | 3 | 85 | 2 | 1 | 13 | 0 | 0 | 0 | 12 | 6 | 6 | 1 | 0 | 0 | 33 | 41 | | |

| Oyster River – Blueback | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|--|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | | |
| 3 | 65 | 30 | 31 | 64 | 36 | 44 | 61 | 21 | 12 | 32 | 20 | 22 | 6 | 9 | 45 | 30 | 27 | 25 | 10 | 12 | 3 | 3 | | |
| 4 | 48 | 63 | 58 | 50 | 58 | 84 | 56 | 49 | 54 | 62 | 17 | 39 | 48 | 71 | 48 | 58 | 10 | 21 | 23 | 36 | 25 | 21 | | |
| 5 | 23 | 25 | 36 | 28 | 44 | 15 | 25 | 39 | 36 | 43 | 67 | 45 | 46 | 68 | 36 | 20 | 29 | 9 | 24 | 8 | 31 | 17 | | |
| 6 | 4 | 2 | 3 | 7 | 11 | 2 | 1 | 25 | 28 | 7 | 21 | 20 | 32 | 22 | 11 | 11 | 8 | 5 | 4 | 4 | 4 | 11 | | |
| 7+ | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 10 | 11 | 5 | 3 | 0 | 9 | 9 | 5 | 0 | 4 | 2 | 1 | 0 | 1 | 1 | | |
| Total | 140 | 120 | 128 | 150 | 151 | 145 | 143 | 144 | 141 | 149 | 128 | 126 | 141 | 179 | 145 | 119 | 78 | 62 | 62 | 60 | 64 | 53 | | |

Table 6.12 Continued.

| Lamprey River – Blueback | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 3 | 0 | 1 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 9 | 0 | 1 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 4 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7+ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 13 | 0 | 2 | 0 | 19 | 0 | 0 | 0 | 3 | 0 | 0 | 2 | 11 | 0 | 4 | 11 | 0 | 0 | 0 | 0 | 0 |

| Taylor River – Blueback | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 3 | * | * | * | * | 49 | 48 | 31 | * | 1 | * | 22 | 1 | * | 0 | 3 | * | * | * | * | * | * | * |
| 4 | * | * | * | * | 31 | 10 | 47 | * | 1 | * | 19 | 13 | * | 0 | 4 | * | * | * | * | * | * | * |
| 5 | * | * | * | * | 24 | 4 | 14 | * | 6 | * | 14 | 0 | * | 0 | 0 | * | * | * | * | * | * | * |
| 6 | * | * | * | * | 6 | 5 | 5 | * | 16 | * | 7 | 0 | * | 0 | 0 | * | * | * | * | * | * | * |
| 7+ | * | * | * | * | 5 | 0 | 0 | * | 6 | * | 5 | 0 | * | 0 | 0 | * | * | * | * | * | * | * |
| Total | * | * | * | * | 115 | 67 | 97 | * | 30 | * | 67 | 14 | * | 0 | 7 | * | * | * | * | * | * | * |

| Winnicut River – Blueback | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Age | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 3 | * | * | * | * | 44 | 32 | 51 | 14 | 11 | 16 | 1 | 14 | 5 | 0 | 2 | 9 | * | * | * | * | * | * |
| 4 | * | * | * | * | 21 | 31 | 63 | 23 | 38 | 48 | 22 | 21 | 32 | 11 | 5 | 30 | * | * | * | * | * | * |
| 5 | * | * | * | * | 4 | 6 | 28 | 16 | 12 | 12 | 19 | 14 | 25 | 9 | 5 | 3 | * | * | * | * | * | * |
| 6 | * | * | * | * | 3 | 0 | 14 | 5 | 6 | 1 | 2 | 3 | 9 | 8 | 4 | 0 | * | * | * | * | * | * |
| 7+ | * | * | * | * | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 2 | 0 | 1 | * | * | * | * | * | * |
| Total | * | * | * | * | 74 | 69 | 157 | 59 | 68 | 77 | 44 | 52 | 73 | 30 | 16 | 43 | * | * | * | * | * | * |

* data not available for selected year

Table 6.13 Mean total length-at-age (TL, mm) of river herring returning to New Hampshire rivers, 1992-2015.

| Cocheco River– Combined Species | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 280 | 249 | 260 | 268 | 272 | 253 | 258 | 258 | 268 | 271 | 248 | 262 | 266 | 258 | | | 236 | 249 | 255 | 246 | 244 | 245 | 245 | 266 | |
| 4 | 284 | 267 | 273 | 282 | 282 | 262 | 269 | 273 | 277 | 280 | 266 | 274 | 274 | 273 | 265 | 261 | 257 | 266 | 273 | 263 | 284 | 261 | 255 | 270 | |
| 5 | 314 | 284 | 292 | 290 | 292 | 286 | 280 | 284 | 295 | 288 | 284 | 285 | 282 | 284 | 280 | 268 | 271 | 281 | 293 | 273 | 283 | 285 | 279 | 281 | |
| 6 | 322 | 300 | | 307 | 296 | 305 | 293 | 294 | 304 | 292 | 300 | 294 | 300 | 300 | 291 | 285 | 277 | 292 | 297 | 301 | 301 | 303 | 296 | 302 | |
| 7+ | 328 | | | | 311 | 309 | 314 | 314 | | 309 | 306 | 305 | 311 | 315 | 298 | 312 | 290 | 312 | 306 | 311 | 317 | 313 | 318 | 325 | |

| Exeter River– Combined Species | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 274 | | * | 271 | 285 | 253 | 257 | 259 | 270 | 272 | 266 | 252 | | 236 | | 245 | 252 | 250 | 253 | 255 | 244 | 253 | 246 | 265 | |
| 4 | 283 | 264 | * | 283 | 285 | 268 | 270 | 269 | 283 | 274 | 273 | 283 | 271 | 272 | 273 | 261 | 270 | 275 | 265 | 268 | 276 | 263 | 260 | 271 | |
| 5 | 290 | 279 | * | 296 | 300 | 282 | 280 | 279 | 293 | 285 | 281 | 289 | 277 | 283 | 284 | 271 | 279 | 280 | 285 | 281 | 287 | 283 | 278 | 285 | |
| 6 | 302 | 298 | * | 317 | | 289 | 288 | 297 | 306 | 287 | 287 | 295 | 288 | 301 | 285 | 289 | 282 | 286 | 290 | 285 | 295 | 304 | 293 | 300 | |
| 7+ | 292 | 319 | * | | | 315 | 312 | | | 287 | | 314 | 311 | 322 | 300 | 306 | 310 | 291 | | | 317 | 309 | 317 | 328 | |

| Oyster River– Combined Species | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 267 | 242 | 253 | 262 | 257 | 255 | 254 | 258 | 261 | 260 | 250 | 254 | 249 | 241 | 235 | 243 | 238 | 249 | 250 | 245 | 238 | 246 | 249 | 258 | |
| 4 | 277 | 264 | 273 | 270 | 265 | 267 | 269 | 269 | 271 | 271 | 252 | 261 | 264 | 256 | 245 | 250 | 248 | 255 | 260 | 263 | 255 | 261 | 264 | 272 | |
| 5 | 288 | 278 | 288 | 283 | 269 | 280 | 278 | 281 | 280 | 276 | 268 | 275 | 270 | 272 | 258 | 264 | 262 | 269 | 269 | 280 | 274 | 279 | 279 | 288 | |
| 6 | 303 | 289 | 293 | 308 | 274 | 292 | 293 | 296 | 281 | 281 | 276 | 286 | 276 | 280 | 277 | 271 | 273 | 275 | 274 | 293 | 288 | 294 | 294 | 290 | |
| 7+ | 318 | | | | | 318 | 307 | | | 287 | 284 | 298 | 290 | | 291 | 288 | 281 | 286 | 282 | 285 | 291 | 311 | 308 | 305 | |

Table 6.13 Continued.

| Lamprey River– Combined Species | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 283 | | 269 | 274 | 278 | 263 | 261 | 253 | 273 | 272 | 262 | 264 | 259 | | 247 | 247 | 261 | 250 | 254 | | 256 | 250 | 252 | 255 | |
| 4 | 293 | 274 | 279 | 285 | 287 | 274 | 266 | 268 | 281 | 282 | 279 | 276 | 271 | 273 | 261 | 268 | 269 | 272 | 261 | 258 | 267 | 263 | 268 | 271 | |
| 5 | 302 | 283 | 292 | 297 | 296 | 296 | 281 | 281 | 295 | 292 | 294 | 288 | 284 | 290 | 285 | 279 | 277 | 285 | 288 | 275 | 285 | 287 | 285 | 295 | |
| 6 | 320 | 301 | 308 | 314 | 300 | 305 | 292 | 296 | 304 | 299 | 304 | 298 | 294 | 301 | 302 | 299 | 287 | 295 | 303 | 294 | 304 | 301 | 307 | 302 | |
| 7+ | 321 | | 329 | | | 316 | 304 | 312 | 312 | 306 | 311 | 319 | 313 | 324 | 310 | 313 | 305 | 307 | 309 | 314 | 318 | 314 | 321 | 321 | |

| Taylor River– Combined Species | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | * | 251 | * | * | * | * | 246 | 253 | 263 | * | 236 | * | 247 | 253 | * | | 241 | * | * | * | * | * | * | * | * |
| 4 | * | 265 | * | * | * | * | 255 | 266 | 267 | * | 266 | * | 258 | 258 | * | 264 | 238 | * | * | * | * | * | * | * | * |
| 5 | * | 279 | * | * | * | * | 272 | 282 | 274 | * | 275 | * | 267 | | * | 276 | | * | * | * | * | * | * | * | * |
| 6 | * | 295 | * | * | * | * | 284 | 294 | 291 | * | 284 | * | 281 | | * | 295 | | * | * | * | * | * | * | * | * |
| 7+ | * | 309 | * | * | * | * | 296 | | | * | 291 | * | 296 | | * | 308 | | * | * | * | * | * | * | * | * |

| Winnicut River– Combined Species | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | * | * | * | * | * | * | 249 | 250 | 239 | 254 | 250 | 247 | 232 | 233 | 229 | 239 | 235 | 237 | * | * | * | * | * | * | * |
| 4 | * | * | * | * | * | * | 260 | 261 | 253 | 262 | 252 | 256 | 258 | 248 | 242 | 247 | 254 | 254 | * | * | * | * | * | * | * |
| 5 | * | * | * | * | * | * | 271 | 273 | 269 | 272 | 266 | 269 | 266 | 268 | 252 | 258 | 263 | 265 | * | * | * | * | * | * | * |
| 6 | * | * | * | * | * | * | 285 | 289 | 274 | 281 | 272 | 280 | 274 | 268 | 275 | 270 | 278 | 279 | * | * | * | * | * | * | * |
| 7+ | * | * | * | * | * | * | 303 | | 289 | 268 | 291 | | 277 | 263 | 281 | 292 | 287 | 289 | * | * | * | * | * | * | * |

*data not available for selected year

Table 6.14 Mean total length-at-age (TL, mm) of alewife river herring returning to New Hampshire rivers, 1992-2015.

| Cocheco River - Alewife | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 285 | 249 | 263 | 272 | 274 | 261 | 267 | 250 | 273 | 274 | 262 | 265 | 266 | 258 | | | | 249 | 255 | 246 | 244 | 248 | 245 | 266 | |
| 4 | 288 | 271 | 273 | 283 | 286 | 262 | 273 | 276 | 280 | 281 | 275 | 277 | 279 | 273 | 266 | 273 | 262 | 266 | 273 | 263 | 284 | 262 | 255 | 270 | |
| 5 | 316 | 291 | 292 | 290 | 296 | 289 | 281 | 287 | 297 | 291 | 288 | 287 | 284 | 286 | 281 | 276 | 276 | 281 | 293 | 273 | 283 | 285 | 279 | 281 | |
| 6 | 322 | 302 | | 307 | 298 | 308 | 294 | 294 | 304 | 297 | 301 | 306 | 300 | 300 | 291 | 288 | 280 | 292 | 297 | 301 | 301 | 303 | 297 | 302 | |
| 7+ | 328 | | | | 325 | 305 | 314 | 314 | | 313 | 306 | 312 | 311 | 315 | 299 | 314 | 294 | 312 | 306 | 312 | 317 | 312 | 318 | 325 | |

| Exeter River-Alewife | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 279 | | * | 274 | 284 | 261 | 260 | 258 | 270 | 282 | 266 | 255 | | 236 | | 245 | 255 | | 256 | 255 | 244 | 253 | | 265 | |
| 4 | 284 | 262 | * | 283 | 285 | 276 | 275 | 270 | 283 | 280 | 274 | 283 | 276 | 272 | 273 | 261 | 272 | 276 | 265 | 268 | 276 | 263 | 266 | 274 | |
| 5 | 292 | 282 | * | 296 | 302 | 292 | 280 | 280 | 292 | 287 | 281 | 289 | 279 | 283 | 284 | 271 | 279 | 280 | 284 | 282 | 287 | 283 | 286 | 296 | |
| 6 | 304 | 302 | * | 305 | | 299 | 289 | 297 | 306 | 289 | 287 | 294 | 289 | 301 | 284 | 289 | 282 | 286 | 304 | 285 | 295 | 304 | 296 | 305 | |
| 7+ | | 329 | * | | | 315 | 307 | | | 298 | | 314 | 311 | 322 | 300 | 306 | 308 | 297 | | | 317 | 309 | 317 | 328 | |

| Oyster River - Alewife | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 272 | | | 262 | 278 | | | | | | | | | | | | | 231 | 250 | 276 | 258 | 246 | 248 | 265 | |
| 4 | 281 | | | 268 | 269 | | | | | | | | | | | | | 255 | 257 | 267 | 253 | 261 | 278 | 273 | |
| 5 | 298 | | | | 266 | | | | | | | 290 | | 284 | | | | 274 | 264 | 258 | 281 | 283 | 288 | 290 | |
| 6 | 297 | | | | | | | | | | | | | | | | | 261 | 276 | 296 | 288 | 296 | 296 | 297 | |
| 7+ | 324 | | | | | | | | | | | | | | 281 | | | 303 | 286 | 278 | 281 | 293 | 311 | 313 | 307 |

Table 6.14 Continued.

| Lamprey River - Alewife | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 283 | | 269 | 274 | 278 | 263 | 261 | 249 | 273 | 272 | 262 | 264 | 259 | | 250 | | 261 | 252 | 254 | | 256 | 250 | 252 | 255 | |
| 4 | 293 | 274 | 279 | 284 | 287 | 275 | 266 | 268 | 281 | 282 | 279 | 276 | 271 | 273 | 261 | 269 | 269 | 272 | 260 | 258 | 267 | 263 | 268 | 271 | |
| 5 | 302 | 282 | 292 | 297 | 296 | 296 | 281 | 281 | 295 | 292 | 294 | 290 | 284 | 290 | 286 | 280 | 277 | 285 | 290 | 275 | 285 | 287 | 285 | 295 | |
| 6 | 320 | 301 | 308 | 314 | 300 | 305 | 292 | 296 | 304 | 299 | 304 | 298 | 294 | 301 | 302 | 300 | 287 | 295 | 304 | 294 | 304 | 301 | 307 | 302 | |
| 7+ | 321 | | 329 | | | 316 | 304 | 312 | 312 | 306 | 311 | 319 | 313 | 324 | 310 | 314 | 305 | 307 | 322 | 314 | 318 | 314 | 321 | 321 | |

| Taylor River - Alewife | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | * | 256 | * | * | * | * | | | | * | | * | | | * | | | * | * | * | * | * | * | * | * |
| 4 | * | 260 | * | * | * | * | 260 | | | * | | * | | | * | 264 | | * | * | * | * | * | * | * | * |
| 5 | * | 279 | * | * | * | * | | | | * | | * | | 251 | | * | 276 | | * | * | * | * | * | * | * |
| 6 | * | | * | * | * | * | | | | * | | * | | | * | 295 | | * | * | * | * | * | * | * | * |
| 7+ | * | | * | * | * | * | 286 | | | * | | * | | | * | 308 | | * | * | * | * | * | * | * | * |

| Winnicut River - Alewife | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | * | * | * | * | * | * | 244 | 249 | 240 | 254 | 251 | 248 | 234 | 231 | 227 | 239 | 233 | 234 | * | * | * | * | * | * | * |
| 4 | * | * | * | * | * | * | 263 | 259 | 252 | 261 | 254 | 259 | 260 | 247 | 243 | 248 | 254 | 250 | * | * | * | * | * | * | * |
| 5 | * | * | * | * | * | * | | 273 | 264 | 270 | 265 | 269 | 266 | 268 | 251 | 258 | 263 | 265 | * | * | * | * | * | * | * |
| 6 | * | * | * | * | * | * | 277 | 288 | 276 | 278 | 271 | 290 | 277 | 269 | 284 | 271 | 278 | 279 | * | * | * | * | * | * | * |
| 7+ | * | * | * | * | * | * | | | 282 | | 294 | | 276 | 263 | 281 | 292 | 286 | 290 | * | * | * | * | * | * | * |

*data not available for selected year

Table 6.15 Mean total length-at-age (TL, mm) of blueback river herring returning to New Hampshire rivers, 1992-2015.

| Cocheco River – Blueback | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 273 | | 252 | 264 | 262 | 248 | 252 | 260 | 252 | 262 | 245 | 255 | | | | | 236 | | | | | 244 | | | |
| 4 | 277 | 263 | 268 | 275 | 266 | 262 | 264 | 267 | 268 | 273 | 256 | 260 | 264 | 258 | 262 | 257 | 247 | 234 | | | | 253 | 254 | | |
| 5 | 299 | 277 | | 294 | 276 | 282 | 274 | 270 | 278 | 270 | 273 | 261 | 271 | 263 | 274 | 259 | 262 | | | | | | | | |
| 6 | 322 | 292 | | | 282 | 288 | 287 | | | 277 | 290 | 266 | | | | 277 | 268 | 282 | | | | | 273 | | |
| 7+ | | | | | 297 | 318 | | | 280 | | 277 | | | 286 | 292 | 272 | | | | | | | | | |

| Exeter River – Blueback | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 264 | | * | 267 | 292 | 249 | 255 | 261 | 255 | 268 | | 249 | | | | | 239 | 250 | 244 | | | | 246 | | |
| 4 | 276 | 268 | * | 281 | | 260 | 265 | 267 | 282 | 271 | 266 | | 268 | | | | 254 | 251 | 264 | | | | 252 | 267 | |
| 5 | 283 | 277 | * | 294 | 295 | 276 | 278 | 271 | 298 | 281 | 286 | | 270 | | | | 260 | 301 | | | | | 248 | 272 | |
| 6 | 297 | 292 | * | 321 | | 284 | 279 | | | 287 | | | 275 | | | | 276 | | 262 | | | | 264 | 276 | |
| 7+ | 292 | 308 | * | | | | 334 | | | 286 | | | | | | | 312 | 270 | | | | | | | |

| Oyster River – Blueback | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 267 | 242 | 253 | 262 | 256 | 255 | 254 | 258 | 261 | 260 | 250 | 254 | 249 | 241 | 234 | 243 | 238 | 248 | 248 | 242 | 237 | 246 | 243 | 258 | |
| 4 | 276 | 264 | 273 | 270 | 265 | 267 | 269 | 269 | 271 | 270 | 252 | 261 | 264 | 256 | 245 | 250 | 248 | 255 | 264 | 260 | 256 | 261 | 261 | 271 | |
| 5 | 287 | 278 | 288 | 283 | 269 | 280 | 278 | 281 | 280 | 276 | 268 | 275 | 269 | 272 | 258 | 264 | 261 | 269 | 270 | 276 | 269 | 271 | 271 | 286 | |
| 6 | 304 | 290 | 293 | 308 | 274 | 292 | 293 | 296 | 281 | 281 | 276 | 286 | 276 | 280 | 277 | 271 | 273 | 277 | 273 | 288 | 288 | 290 | 288 | 284 | |
| 7+ | 316 | | | | | 318 | 306 | | | 287 | 284 | 298 | 292 | | 291 | 288 | 276 | | 284 | 287 | 284 | | 292 | 299 | |

Table 6.15 Continued.

| Lamprey River – Blueback | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | 279 | | | | 254 | | | | | | | 241 | 247 | | 245 | 257 | | | | | |
| 4 | 280 | | | | 287 | | 253 | | 270 | | | | | | | | 262 | | 262 | | | | | | |
| 5 | | 288 | | 304 | | | | 250 | | | | 264 | | | 271 | 267 | | 258 | 265 | | | | | | |
| 6 | | | | | | | 312 | | | | | | | | | | 279 | | 269 | 263 | | | | | |
| 7+ | | | | | | | | | | | | | | | | | 272 | | 260 | | | | | | |

| Taylor River – Blueback | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | * | 248 | * | * | * | * | 246 | 252 | 263 | * | 236 | * | 247 | 253 | * | | 241 | * | * | * | * | * | * | * | |
| 4 | * | 264 | * | * | * | * | 255 | 266 | 267 | * | 266 | * | 258 | 258 | * | | 238 | * | * | * | * | * | * | * | |
| 5 | * | 279 | * | * | * | * | 272 | 282 | 274 | * | 275 | * | 268 | | * | | * | * | * | * | * | * | * | * | |
| 6 | * | 295 | * | * | * | * | 284 | 294 | 291 | * | 284 | * | 281 | | * | | * | * | * | * | * | * | * | * | |
| 7+ | * | 309 | * | * | * | * | 298 | | | * | 290 | * | 296 | | * | | * | * | * | * | * | * | * | * | |

| Winnicut River – Blueback | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Mean Length (mm) at Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| Year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Age | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | * | * | * | * | * | * | 249 | 250 | 239 | 255 | 247 | 245 | 230 | 239 | 230 | | 239 | 245 | * | * | * | * | * | * | |
| 4 | * | * | * | * | * | * | 260 | 262 | 253 | 263 | 251 | 254 | 256 | 249 | 242 | 241 | 256 | 259 | * | * | * | * | * | * | |
| 5 | * | * | * | * | * | * | 271 | 274 | 269 | 273 | 267 | 268 | 264 | 270 | 252 | 254 | 266 | 262 | * | * | * | * | * | * | |
| 6 | * | * | * | * | * | * | 287 | | 274 | 285 | 274 | 270 | 267 | 266 | 269 | 270 | 276 | | * | * | * | * | * | * | |
| 7+ | * | * | * | * | * | * | 303 | | 296 | 268 | 276 | | | | | | 281 | 292 | | 287 | * | * | * | * | |

*data not available for selected year

Table 6.16 Distribution of repeat spawning frequency of river herring returning to New Hampshire rivers, from scale samples aged between 2000 and 2015.

| Cocheco River - Combined Species | | | | | | |
|----------------------------------|------|------|------|------|------|---------|
| Year | % r0 | % r1 | % r2 | % r3 | % r4 | Total N |
| 2000 | 66% | 15% | 18% | 1% | 0% | 131 |
| 2001 | 57% | 33% | 6% | 2% | 1% | 142 |
| 2002 | 63% | 25% | 12% | 0% | 0% | 146 |
| 2003 | 71% | 16% | 10% | 3% | 0% | 136 |
| 2004 | 34% | 45% | 18% | 3% | 0% | 119 |
| 2005 | 47% | 29% | 18% | 6% | 0% | 125 |
| 2006 | 53% | 24% | 13% | 8% | 2% | 85 |
| 2007 | 69% | 17% | 9% | 4% | 1% | 160 |
| 2008 | 68% | 26% | 6% | 0% | 0% | 146 |
| 2009 | 78% | 21% | 1% | 0% | 0% | 90 |
| 2010 | 35% | 35% | 29% | 1% | 0% | 72 |
| 2011 | 64% | 21% | 12% | 9% | 0% | 75 |
| 2012 | 41% | 40% | 16% | 2% | 2% | 63 |
| 2013 | 53% | 23% | 15% | 8% | 0% | 93 |
| 2014 | 44% | 27% | 19% | 11% | 0% | 108 |
| 2015 | 62% | 19% | 7% | 10% | 1% | 81 |

| Exeter River - Combined Species | | | | | | |
|---------------------------------|------|------|------|------|------|---------|
| Year | % r0 | % r1 | % r2 | % r3 | % r4 | Total N |
| 2000 | 90% | 8% | 2% | 0% | 0% | 97 |
| 2001 | 48% | 33% | 16% | 3% | 0% | 141 |
| 2002 | 80% | 13% | 7% | 0% | 0% | 54 |
| 2003 | 62% | 25% | 13% | 0% | 0% | 55 |
| 2004 | 58% | 26% | 14% | 2% | 0% | 57 |
| 2005 | 78% | 16% | 3% | 3% | 0% | 64 |
| 2006 | 63% | 31% | 6% | 0% | 0% | 16 |
| 2007 | 83% | 15% | 3% | 0% | 0% | 40 |
| 2008 | 90% | 8% | 2% | 1% | 0% | 146 |
| 2009 | 88% | 11% | 1% | 0% | 0% | 314 |
| 2010 | 76% | 21% | 0% | 3% | 0% | 38 |
| 2011 | 89% | 11% | 0% | 0% | 0% | 64 |
| 2012 | 66% | 25% | 8% | 0% | 0% | 59 |
| 2013 | 71% | 20% | 9% | 0% | 0% | 70 |
| 2014 | 64% | 30% | 5% | 1% | 0% | 103 |
| 2015 | 66% | 25% | 8% | 1% | 0% | 104 |

Table 6.16 Continued

| Year | Oyster River - Combined Species | | | | | Total N |
|------|---------------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | 66% | 26% | 7% | 2% | 0% | 145 |
| 2001 | 36% | 42% | 16% | 5% | 1% | 146 |
| 2002 | 63% | 17% | 15% | 4% | 0% | 142 |
| 2003 | 49% | 32% | 16% | 3% | 0% | 149 |
| 2004 | 32% | 25% | 34% | 8% | 1% | 131 |
| 2005 | 50% | 35% | 14% | 1% | 0% | 126 |
| 2006 | 57% | 24% | 13% | 6% | 0% | 141 |
| 2007 | 62% | 28% | 7% | 3% | 0% | 179 |
| 2008 | 72% | 17% | 7% | 3% | 0% | 149 |
| 2009 | 59% | 35% | 6% | 0% | 0% | 101 |
| 2010 | 53% | 24% | 18% | 5% | 0% | 100 |
| 2011 | 73% | 38% | 9% | 4% | 0% | 124 |
| 2012 | 60% | 31% | 17% | 3% | 1% | 112 |
| 2013 | 81% | 12% | 6% | 0% | 0% | 126 |
| 2014 | 33% | 60% | 6% | 1% | 0% | 114 |
| 2015 | 47% | 29% | 18% | 4% | 1% | 112 |

| Year | Lamprey River - Combined Species | | | | | Total N |
|------|----------------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | 54% | 26% | 17% | 3% | 1% | 195 |
| 2001 | 41% | 45% | 10% | 3% | 0% | 145 |
| 2002 | 37% | 29% | 29% | 5% | 0% | 139 |
| 2003 | 48% | 27% | 20% | 6% | 0% | 143 |
| 2004 | 45% | 27% | 20% | 7% | 1% | 162 |
| 2005 | 48% | 36% | 14% | 2% | 0% | 128 |
| 2006 | 41% | 34% | 19% | 6% | 0% | 124 |
| 2007 | 43% | 27% | 22% | 6% | 2% | 151 |
| 2008 | 67% | 20% | 8% | 3% | 1% | 143 |
| 2009 | 50% | 40% | 9% | 1% | 0% | 146 |
| 2010 | 36% | 39% | 20% | 5% | 0% | 92 |
| 2011 | 52% | 21% | 15% | 11% | 0% | 84 |
| 2012 | 54% | 33% | 10% | 3% | 0% | 79 |
| 2013 | 46% | 30% | 18% | 5% | 0% | 82 |
| 2014 | 43% | 40% | 13% | 4% | 1% | 101 |
| 2015 | 42% | 25% | 22% | 11% | 0% | 83 |

Table 6.16 Continued

| Year | Taylor River - Combined Species | | | | | |
|------|---------------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | Total N |
| 2000 | 69% | 28% | 2% | 1% | 0% | 97 |
| 2001 | * | * | * | * | * | * |
| 2002 | 7% | 40% | 47% | 7% | 0% | 30 |
| 2003 | * | * | * | * | * | * |
| 2004 | 71% | 15% | 10% | 4% | 0% | 68 |
| 2005 | 93% | 7% | 0% | 0% | 0% | 14 |
| 2006 | * | * | * | * | * | * |
| 2007 | 68% | 26% | 5% | 0% | 0% | 19 |
| 2008 | 100% | 0% | 0% | 0% | 0% | 7 |
| 2009 | * | * | * | * | * | * |
| 2010 | * | * | * | * | * | * |
| 2011 | * | * | * | * | * | * |
| 2012 | * | * | * | * | * | * |
| 2013 | * | * | * | * | * | * |
| 2014 | * | * | * | * | * | * |
| 2015 | * | * | * | * | * | * |

| Year | Winnicut River - Combined Species | | | | | |
|------|-----------------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | Total N |
| 2000 | 77% | 11% | 9% | 3% | 0% | 179 |
| 2001 | 57% | 33% | 9% | 1% | 0% | 146 |
| 2002 | 67% | 12% | 18% | 3% | 0% | 147 |
| 2003 | 63% | 34% | 3% | 0% | 0% | 147 |
| 2004 | 36% | 44% | 18% | 1% | 0% | 136 |
| 2005 | 66% | 24% | 9% | 1% | 0% | 152 |
| 2006 | 70% | 24% | 4% | 3% | 0% | 105 |
| 2007 | 38% | 40% | 14% | 7% | 1% | 169 |
| 2008 | 36% | 33% | 26% | 3% | 1% | 150 |
| 2009 | 54% | 23% | 16% | 6% | 0% | 149 |
| 2010 | * | * | * | * | * | * |
| 2011 | * | * | * | * | * | * |
| 2012 | * | * | * | * | * | * |
| 2013 | * | * | * | * | * | * |
| 2014 | * | * | * | * | * | * |
| 2015 | * | * | * | * | * | * |

*-Sampling did not occur.

+-Sampling occurred but no alewife encountered in run.

Table 6.17 Distribution of repeat spawning frequency of alewife river herring returning to New Hampshire rivers, from scale samples aged between 2000 and 2015.

| Cocheco River - Alewife | | | | | | |
|-------------------------|------|------|------|------|------|---------|
| Year | % r0 | % r1 | % r2 | % r3 | % r4 | Total N |
| 2000 | 68% | 11% | 20% | 1% | 0% | 106 |
| 2001 | 56% | 34% | 6% | 3% | 1% | 117 |
| 2002 | 54% | 33% | 13% | 0% | 0% | 93 |
| 2003 | 69% | 17% | 12% | 2% | 0% | 111 |
| 2004 | 30% | 46% | 20% | 4% | 0% | 102 |
| 2005 | 46% | 29% | 18% | 7% | 0% | 120 |
| 2006 | 49% | 25% | 14% | 9% | 3% | 77 |
| 2007 | 69% | 15% | 8% | 8% | 1% | 93 |
| 2008 | 70% | 27% | 3% | 0% | 0% | 98 |
| 2009 | 78% | 20% | 1% | 0% | 0% | 88 |
| 2010 | 35% | 35% | 29% | 1% | 0% | 72 |
| 2011 | 57% | 21% | 12% | 9% | 0% | 75 |
| 2012 | 41% | 40% | 16% | 2% | 2% | 63 |
| 2013 | 51% | 24% | 16% | 8% | 0% | 87 |
| 2014 | 43% | 27% | 18% | 11% | 0% | 106 |
| 2015 | 63% | 19% | 8% | 10% | 1% | 80 |

| Exeter River - Alewife | | | | | | |
|------------------------|------|------|------|------|------|---------|
| Year | % r0 | % r1 | % r2 | % r3 | % r4 | Total N |
| 2000 | 89% | 9% | 2% | 0% | 0% | 94 |
| 2001 | 63% | 36% | 2% | 0% | 0% | 56 |
| 2002 | 81% | 13% | 6% | 0% | 0% | 52 |
| 2003 | 61% | 26% | 13% | 0% | 0% | 54 |
| 2004 | 64% | 23% | 11% | 2% | 0% | 44 |
| 2005 | 78% | 16% | 3% | 3% | 0% | 64 |
| 2006 | 63% | 31% | 6% | 0% | 0% | 16 |
| 2007 | 83% | 15% | 3% | 0% | 0% | 40 |
| 2008 | 91% | 8% | 1% | 0% | 0% | 134 |
| 2009 | 88% | 11% | 1% | 0% | 0% | 307 |
| 2010 | 81% | 19% | 0% | 0% | 0% | 32 |
| 2011 | 89% | 11% | 0% | 0% | 0% | 63 |
| 2012 | 66% | 25% | 8% | 0% | 0% | 59 |
| 2013 | 71% | 20% | 9% | 0% | 0% | 70 |
| 2014 | 51% | 40% | 7% | 1% | 0% | 70 |
| 2015 | 73% | 14% | 11% | 2% | 0% | 63 |

Table 6.17 Continued.

| Year | Oyster River - Alewife | | | | | Total N |
|------|------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | | | | | | + |
| 2001 | | | | | | + |
| 2002 | 0% | 100% | 0% | 0% | 0% | 1 |
| 2003 | | | | | | + |
| 2004 | 100% | 0% | 0% | 0% | 0% | 3 |
| 2005 | | | | | | + |
| 2006 | | | | | | + |
| 2007 | | | | | | + |
| 2008 | 50% | 25% | 0% | 25% | 0% | 4 |
| 2009 | 40% | 33% | 27% | 0% | 0% | 15 |
| 2010 | 73% | 14% | 5% | 9% | 0% | 22 |
| 2011 | 65% | 26% | 6% | 3% | 0% | 62 |
| 2012 | 66% | 16% | 14% | 1% | 1% | 50 |
| 2013 | 83% | 11% | 6% | 0% | 0% | 65 |
| 2014 | 36% | 56% | 8% | 0% | 0% | 50 |
| 2015 | 61% | 29% | 7% | 2% | 2% | 59 |

| Year | Lamprey River - Alewife | | | | | Total N |
|------|-------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | 54% | 26% | 17% | 3% | 1% | 195 |
| 2001 | 41% | 45% | 10% | 3% | 0% | 145 |
| 2002 | 37% | 29% | 29% | 5% | 0% | 139 |
| 2003 | 49% | 26% | 19% | 6% | 0% | 140 |
| 2004 | 45% | 27% | 20% | 7% | 1% | 162 |
| 2005 | 48% | 36% | 14% | 2% | 0% | 128 |
| 2006 | 40% | 34% | 20% | 6% | 0% | 122 |
| 2007 | 43% | 26% | 22% | 6% | 2% | 140 |
| 2008 | 67% | 20% | 8% | 3% | 1% | 143 |
| 2009 | 50% | 41% | 8% | 1% | 0% | 145 |
| 2010 | 37% | 38% | 20% | 5% | 0% | 81 |
| 2011 | 52% | 21% | 15% | 11% | 0% | 84 |
| 2012 | 54% | 33% | 10% | 3% | 0% | 79 |
| 2013 | 46% | 30% | 18% | 5% | 0% | 82 |
| 2014 | 43% | 40% | 13% | 4% | 1% | 101 |
| 2015 | 42% | 25% | 22% | 11% | 0% | 83 |

*-Sampling did not occur.

+-Sampling occurred but no alewife encountered in run.

Table 6.17 Continued.

| Year | Taylor River - Alewife | | | | | Total N |
|------|------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | | | | | | + |
| 2001 | * | * | * | * | * | * |
| 2002 | | | | | | + |
| 2003 | * | * | * | * | * | * |
| 2004 | 100% | 0% | 0% | 0% | 0% | 1 |
| 2005 | | | | | | + |
| 2006 | * | * | * | * | * | * |
| 2007 | 68% | 26% | 5% | 0% | 0% | 19 |
| 2008 | | | | | | + |
| 2009 | * | * | * | * | * | * |
| 2010 | * | * | * | * | * | * |
| 2011 | * | * | * | * | * | * |
| 2012 | * | * | * | * | * | * |
| 2013 | * | * | * | * | * | * |
| 2014 | * | * | * | * | * | * |
| 2015 | * | * | * | * | * | * |

| Year | Winnicut River - Alewife | | | | | Total N |
|------|--------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | 76% | 0% | 19% | 5% | 0% | 21 |
| 2001 | 55% | 36% | 7% | 2% | 0% | 87 |
| 2002 | 59% | 13% | 22% | 5% | 0% | 79 |
| 2003 | 64% | 31% | 4% | 0% | 0% | 70 |
| 2004 | 34% | 45% | 20% | 2% | 0% | 92 |
| 2005 | 60% | 28% | 11% | 1% | 0% | 100 |
| 2006 | 63% | 31% | 0% | 6% | 0% | 32 |
| 2007 | 38% | 40% | 14% | 8% | 0% | 139 |
| 2008 | 35% | 34% | 26% | 4% | 1% | 134 |
| 2009 | 45% | 27% | 21% | 8% | 0% | 116 |
| 2010 | * | * | * | * | * | * |
| 2011 | * | * | * | * | * | * |
| 2012 | * | * | * | * | * | * |
| 2013 | * | * | * | * | * | * |
| 2014 | * | * | * | * | * | * |
| 2015 | * | * | * | * | * | * |

**-Sampling did not occur.*

+-Sampling occurred but no alewife encountered in run.

Table 6.18 Distribution of repeat spawning frequency of blueback river herring returning to New Hampshire rivers, from scale samples aged between 2000 and 2015.

| Year | Cocheco River - Blueback | | | | | Total N |
|------|--------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | 56% | 32% | 12% | 0% | 0% | 25 |
| 2001 | 60% | 28% | 8% | 0% | 4% | 25 |
| 2002 | 79% | 11% | 9% | 0% | 0% | 53 |
| 2003 | 76% | 12% | 4% | 8% | 0% | 25 |
| 2004 | 59% | 35% | 6% | 0% | 0% | 17 |
| 2005 | 80% | 20% | 0% | 0% | 0% | 5 |
| 2006 | 88% | 13% | 0% | 0% | 0% | 8 |
| 2007 | 69% | 19% | 12% | 0% | 0% | 67 |
| 2008 | 63% | 25% | 13% | 0% | 0% | 48 |
| 2009 | 50% | 50% | 0% | 0% | 0% | 2 |
| 2010 | | | | | | + |
| 2011 | | | | | | + |
| 2012 | | | | | | + |
| 2013 | 100% | 0% | 0% | 0% | 0% | 5 |
| 2014 | 50% | 0% | 50% | 0% | 0% | 2 |
| 2015 | | | | | | + |

| Year | Exeter River - Blueback | | | | | Total N |
|------|-------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | 100% | 0% | 0% | 0% | 0% | 3 |
| 2001 | 39% | 32% | 25% | 5% | 0% | 85 |
| 2002 | 50% | 0% | 50% | 0% | 0% | 2 |
| 2003 | 100% | 0% | 0% | 0% | 0% | 1 |
| 2004 | 38% | 38% | 23% | 0% | 0% | 13 |
| 2005 | | | | | | + |
| 2006 | | | | | | + |
| 2007 | | | | | | + |
| 2008 | 75% | 0% | 17% | 8% | 0% | 12 |
| 2009 | 50% | 50% | 0% | 0% | 0% | 6 |
| 2010 | 50% | 33% | 0% | 17% | 0% | 6 |
| 2011 | 100% | 0% | 0% | 0% | 0% | 1 |
| 2012 | | | | | | + |
| 2013 | | | | | | + |
| 2014 | 91% | 9% | 0% | 0% | 0% | 33 |
| 2015 | 56% | 41% | 2% | 0% | 0% | 41 |

*-Sampling did not occur.

+-Sampling occurred but no blueback encountered in run.

Table 6.18 Continued.

| Year | Oyster River - Blueback | | | | | Total N |
|------|-------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | 65% | 26% | 7% | 2% | 0% | 143 |
| 2001 | 35% | 43% | 15% | 6% | 1% | 144 |
| 2002 | 64% | 16% | 16% | 4% | 0% | 141 |
| 2003 | 49% | 32% | 16% | 3% | 0% | 149 |
| 2004 | 30% | 26% | 34% | 9% | 1% | 128 |
| 2005 | 50% | 35% | 14% | 1% | 0% | 126 |
| 2006 | 57% | 24% | 13% | 6% | 0% | 141 |
| 2007 | 62% | 28% | 7% | 3% | 0% | 179 |
| 2008 | 72% | 17% | 8% | 3% | 0% | 145 |
| 2009 | 63% | 35% | 2% | 0% | 0% | 86 |
| 2010 | 47% | 27% | 22% | 4% | 0% | 78 |
| 2011 | 53% | 35% | 8% | 3% | 0% | 62 |
| 2012 | 44% | 37% | 16% | 3% | 0% | 62 |
| 2013 | 80% | 13% | 7% | 0% | 0% | 60 |
| 2014 | 31% | 63% | 5% | 2% | 0% | 64 |
| 2015 | 32% | 30% | 30% | 8% | 0% | 53 |

| Year | Lamprey River - Blueback | | | | | Total N |
|------|--------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | | | | | | + |
| 2001 | | | | | | + |
| 2002 | | | | | | + |
| 2003 | 0% | 33% | 67% | 0% | 0% | 3 |
| 2004 | | | | | | + |
| 2005 | | | | | | + |
| 2006 | 100% | 0% | 0% | 0% | 0% | 2 |
| 2007 | 45% | 36% | 18% | 0% | 0% | 11 |
| 2008 | | | | | | + |
| 2009 | 0% | 0% | 100% | 0% | 0% | 1 |
| 2010 | 27% | 45% | 18% | 9% | 0% | 11 |
| 2011 | | | | | | + |
| 2012 | | | | | | + |
| 2013 | | | | | | + |
| 2014 | | | | | | + |
| 2015 | | | | | | + |

*-Sampling did not occur.

+-Sampling occurred but no blueback encountered in run.

Table 6.18 Continued.

| Year | Taylor River - Blueback | | | | | Total N |
|------|-------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | 69% | 28% | 2% | 1% | 0% | 97 |
| 2001 | * | * | * | * | * | * |
| 2002 | 7% | 40% | 47% | 7% | 0% | 30 |
| 2003 | * | * | * | * | * | * |
| 2004 | 70% | 15% | 10% | 4% | 0% | 67 |
| 2005 | 93% | 7% | 0% | 0% | 0% | 14 |
| 2006 | * | * | * | * | * | * |
| 2007 | | | | | | + |
| 2008 | 100% | 0% | 0% | 0% | 0% | 7 |
| 2009 | * | * | * | * | * | * |
| 2010 | * | * | * | * | * | * |
| 2011 | * | * | * | * | * | * |
| 2012 | * | * | * | * | * | * |
| 2013 | * | * | * | * | * | * |
| 2014 | * | * | * | * | * | * |
| 2015 | * | * | * | * | * | * |

| Year | Winnicut River - Blueback | | | | | Total N |
|------|---------------------------|------|------|------|------|---------|
| | % r0 | % r1 | % r2 | % r3 | % r4 | |
| 2000 | 76% | 13% | 8% | 3% | 0% | 157 |
| 2001 | 59% | 29% | 12% | 0% | 0% | 59 |
| 2002 | 76% | 10% | 13% | 0% | 0% | 68 |
| 2003 | 61% | 36% | 3% | 0% | 0% | 77 |
| 2004 | 41% | 43% | 16% | 0% | 0% | 44 |
| 2005 | 79% | 17% | 4% | 0% | 0% | 52 |
| 2006 | 73% | 21% | 5% | 1% | 0% | 73 |
| 2007 | 40% | 40% | 13% | 3% | 3% | 30 |
| 2008 | 44% | 31% | 25% | 0% | 0% | 16 |
| 2009 | 88% | 12% | 0% | 0% | 0% | 33 |
| 2010 | * | * | * | * | * | * |
| 2011 | * | * | * | * | * | * |
| 2012 | * | * | * | * | * | * |
| 2013 | * | * | * | * | * | * |
| 2014 | * | * | * | * | * | * |
| 2015 | * | * | * | * | * | * |

*-Sampling did not occur.

+Sampling occurred but no blueback encountered in run.

Table 6.19 Annual juvenile abundance index of river herring seined in Great Bay Estuary, New Hampshire, 1997-2015.

| Year | Alewife Catch | Alewife Arithmetic Mean | Alewife Geometric Mean | Blueback Catch | Blueback Arithmetic Mean | Blueback Geometric Mean |
|------|---------------|-------------------------|------------------------|----------------|--------------------------|-------------------------|
| 1997 | 16 | 0.18 | 0.07 | 295 | 3.31 | 0.49 |
| 1998 | 14 | 0.16 | 0.04 | 1821 | 20.23 | 0.66 |
| 1999 | 660 | 7.33 | 0.27 | 11838 | 131.53 | 0.97 |
| 2000 | 71 | 0.79 | 0.26 | 5092 | 56.58 | 0.74 |
| 2001 | 119 | 1.24 | 0.13 | 1476 | 15.38 | 0.88 |
| 2002 | 164 | 1.82 | 0.34 | 261 | 2.90 | 0.26 |
| 2003 | 899 | 9.99 | 0.32 | 1812 | 20.13 | 0.76 |
| 2004 | 35 | 0.39 | 0.14 | 124 | 1.38 | 0.22 |
| 2005 | 29 | 0.32 | 0.11 | 2146 | 23.84 | 0.35 |
| 2006 | 1471 | 16.34 | 0.32 | 432 | 4.80 | 0.42 |
| 2007 | 203 | 2.26 | 0.21 | 1503 | 16.70 | 0.50 |
| 2008 | 39 | 0.43 | 0.15 | 37 | 0.41 | 0.13 |
| 2009 | 32 | 0.36 | 0.10 | 182 | 2.02 | 0.20 |
| 2010 | 14 | 0.16 | 0.08 | 79 | 0.88 | 0.17 |
| 2011 | 21 | 0.24 | 0.08 | 7 | 0.07 | 0.05 |
| 2012 | 6 | 0.07 | 0.02 | 29 | 0.32 | 0.08 |
| 2013 | 739 | 8.21 | 0.23 | 6 | 0.07 | 0.04 |
| 2014 | 8 | 0.09 | 0.05 | 46 | 0.51 | 0.14 |
| 2015 | 117 | 1.30 | 0.31 | 19 | 0.21 | 0.06 |

Table 6.20 Estimates of total instantaneous mortality (Z) with standard errors for river herring in coastal New Hampshire rivers, using Chapman-Robson, Heinecke, and catch curve methods based on age, separated by species and sex, 1990-2015.

| Cocheco River | | | Chapman-Robson | | Heinecke | | Catch Curve | |
|---------------|--------|------|----------------|-------|------------|-------|-------------|-------|
| Species | Sex | Year | Z estimate | SE | Z estimate | SE | Z estimate | SE |
| Alewives | Male | 1992 | 0.84 | 0.138 | 0.57 | 0.093 | 0.44 | 0.184 |
| Alewives | Male | 1993 | 1.49 | 0.233 | 1.25 | 0.191 | * | * |
| Alewives | Male | 1994 | 2.30 | 0.468 | 2.22 | 0.446 | * | * |
| Alewives | Male | 1995 | 1.19 | 0.176 | 0.89 | 0.128 | 1.70 | 0.748 |
| Alewives | Male | 1996 | 0.84 | 0.103 | 0.63 | 0.075 | 0.39 | 0.019 |
| Alewives | Male | 1997 | 1.22 | 0.260 | 1.14 | 0.240 | 1.07 | 0.017 |
| Alewives | Male | 1998 | 1.87 | 0.370 | 2.14 | 0.441 | 1.35 | 0.782 |
| Alewives | Male | 1999 | 0.82 | 0.112 | 0.64 | 0.086 | 1.02 | 0.357 |
| Alewives | Male | 2000 | 0.84 | 0.111 | 0.76 | 0.101 | 0.73 | 0.138 |
| Alewives | Male | 2001 | 1.03 | 0.159 | 0.83 | 0.126 | 1.05 | 0.455 |
| Alewives | Male | 2002 | 0.71 | 0.099 | 0.49 | 0.068 | 0.83 | 0.155 |
| Alewives | Male | 2003 | 0.95 | 0.152 | 0.74 | 0.117 | 0.93 | 0.276 |
| Alewives | Male | 2004 | 1.28 | 0.217 | 1.05 | 0.174 | 1.11 | 0.146 |
| Alewives | Male | 2005 | 1.06 | 0.183 | 0.72 | 0.121 | 1.47 | 0.786 |
| Alewives | Male | 2006 | 1.85 | 0.514 | 1.73 | 0.475 | * | * |
| Alewives | Male | 2007 | 1.19 | 0.258 | 1.39 | 0.306 | 0.75 | 0.834 |
| Alewives | Male | 2008 | 1.82 | 0.402 | 1.69 | 0.364 | * | * |
| Alewives | Male | 2009 | 0.86 | 0.097 | 0.72 | 0.080 | 0.96 | 0.269 |
| Alewives | Male | 2010 | 1.00 | 0.208 | 0.82 | 0.169 | 1.01 | 0.288 |
| Alewives | Male | 2011 | 0.96 | 0.198 | 0.82 | 0.169 | 0.63 | 0.039 |
| Alewives | Male | 2012 | 0.9 | 0.195 | 0.65 | 0.138 | 0.65 | 0.259 |
| Alewives | Male | 2013 | 0.6 | 0.094 | 0.56 | 0.087 | 0.19 | 0.185 |
| Alewives | Male | 2014 | 0.67 | 0.109 | 0.57 | 0.093 | 0.41 | 0.152 |
| Alewives | Male | 2015 | 0.93 | 0.185 | 0.73 | 0.144 | 0.95 | 0.165 |
| Alewives | Female | 1992 | 1.95 | 0.520 | 1.85 | 0.486 | * | * |
| Alewives | Female | 1993 | 1.49 | 0.262 | 1.27 | 0.216 | * | * |
| Alewives | Female | 1994 | 1.76 | 0.365 | 1.61 | 0.327 | * | * |
| Alewives | Female | 1995 | 1.19 | 0.176 | 0.89 | 0.128 | 1.70 | 0.748 |
| Alewives | Female | 1996 | 1.24 | 0.196 | 0.97 | 0.151 | 1.67 | 0.639 |
| Alewives | Female | 1997 | ** | ** | ** | ** | ** | ** |
| Alewives | Female | 1998 | 0.55 | 0.081 | 0.36 | 0.054 | 0.46 | 0.132 |
| Alewives | Female | 1999 | 1.06 | 0.188 | 1.07 | 0.190 | 0.87 | 0.206 |
| Alewives | Female | 2000 | 0.62 | 0.093 | 0.43 | 0.064 | 0.40 | 0.201 |
| Alewives | Female | 2001 | 0.76 | 0.103 | 0.61 | 0.082 | 0.56 | 0.149 |
| Alewives | Female | 2002 | 0.95 | 0.187 | 0.69 | 0.134 | 0.77 | 0.305 |
| Alewives | Female | 2003 | 1.33 | 0.177 | 1.47 | 0.199 | 1.01 | 0.169 |
| Alewives | Female | 2004 | 1.02 | 0.150 | 0.94 | 0.136 | 1.11 | 0.166 |
| Alewives | Female | 2006 | 1.14 | 0.283 | 0.94 | 0.231 | 1.20 | 0.342 |
| Alewives | Female | 2007 | 1.02 | 0.186 | 1.01 | 0.184 | 0.97 | 0.107 |
| Alewives | Female | 2008 | 0.96 | 0.169 | 0.78 | 0.136 | 0.67 | 0.070 |
| Alewives | Female | 2009 | 0.65 | 0.071 | 0.44 | 0.048 | 0.49 | 0.224 |
| Alewives | Female | 2010 | 0.88 | 0.168 | 0.66 | 0.125 | 0.51 | 0.103 |
| Alewives | Female | 2011 | 0.71 | 0.135 | 0.53 | 0.1 | 0.58 | 0.135 |
| Alewives | Female | 2012 | 0.53 | 0.095 | 0.37 | 0.067 | 0.39 | 0.088 |
| Alewives | Female | 2013 | 0.57 | 0.088 | 0.5 | 0.078 | 0.16 | 0.259 |

Table 6.20 Continued.

| Cocheco River | | | Chapman-Robson | | Heinecke | | Catch Curve | |
|---------------|--------|------|----------------|---------|----------|-------|-------------|---------|
| Species | Sex | Year | Z estimate | Species | Sex | Year | Z estimate | Species |
| Alewifes | Female | 2014 | 0.72 | 0.115 | 0.62 | 0.099 | 0.46 | 0.067 |
| Alewifes | Female | 2015 | 0.54 | 0.088 | 0.44 | 0.072 | 0.33 | 0.054 |
| Blueback | Male | 1992 | 1.56 | 0.430 | 1.67 | 0.469 | 1.28 | 0.340 |
| Blueback | Male | 1993 | 2.60 | 0.667 | 2.56 | 0.653 | * | * |
| Blueback | Male | 1994 | 2.01 | 0.634 | 1.95 | 0.606 | * | * |
| Blueback | Male | 1996 | 0.94 | 0.251 | 0.92 | 0.245 | 0.55 | 0.317 |
| Blueback | Male | 1997 | 1.79 | 0.400 | 1.65 | 0.361 | * | * |
| Blueback | Male | 1998 | 1.39 | 0.344 | 1.15 | 0.279 | * | * |
| Blueback | Male | 1999 | 1.56 | 0.430 | 1.39 | 0.375 | * | * |
| Blueback | Male | 2000 | 1.03 | 0.247 | 0.75 | 0.175 | 1.15 | 0.536 |
| Blueback | Male | 2001 | 0.98 | 0.417 | 1.10 | 0.471 | 0.69 | 0.400 |
| Blueback | Male | 2002 | 1.13 | 0.233 | 0.96 | 0.195 | 1.04 | 0.200 |
| Blueback | Male | 2003 | 0.98 | 0.308 | 1.30 | 0.420 | 0.62 | 0.360 |
| Blueback | Male | 2004 | ** | ** | ** | ** | ** | ** |
| Blueback | Male | 2005 | ** | ** | ** | ** | ** | ** |
| Blueback | Male | 2006 | 1.10 | 0.516 | 0.92 | 0.424 | * | * |
| Blueback | Male | 2007 | 1.34 | 0.255 | 1.16 | 0.217 | 1.55 | 0.376 |
| Blueback | Male | 2008 | 1.30 | 0.338 | 1.22 | 0.316 | 1.24 | 0.083 |
| Blueback | Male | 2009 | ** | ** | ** | ** | ** | ** |
| Blueback | Male | 2010 | ** | ** | ** | ** | ** | ** |
| Blueback | Male | 2011 | ** | ** | ** | ** | ** | ** |
| Blueback | Male | 2012 | ** | ** | ** | ** | ** | ** |
| Blueback | Male | 2013 | ** | ** | ** | ** | ** | ** |
| Blueback | Male | 2014 | ** | ** | ** | ** | ** | ** |
| Blueback | Male | 2015 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 1992 | 1.47 | 0.483 | 1.30 | 0.420 | * | * |
| Blueback | Female | 1993 | 1.73 | 0.364 | 1.58 | 0.324 | * | * |
| Blueback | Female | 1994 | 1.39 | 0.567 | 1.25 | 0.505 | * | * |
| Blueback | Female | 1995 | 1.87 | 0.623 | 1.79 | 0.589 | * | * |
| Blueback | Female | 1996 | 1.47 | 0.483 | 1.70 | 0.579 | 1.10 | 0.634 |
| Blueback | Female | 1997 | 0.96 | 0.213 | 0.89 | 0.197 | 0.88 | 0.053 |
| Blueback | Female | 1998 | 1.61 | 0.434 | 1.73 | 0.475 | 1.32 | 0.362 |
| Blueback | Female | 1999 | 1.20 | 0.452 | 0.98 | 0.361 | * | * |
| Blueback | Female | 2000 | 0.81 | 0.340 | 0.69 | 0.289 | 0.55 | 0.083 |
| Blueback | Female | 2001 | 1.03 | 0.340 | 0.92 | 0.300 | 0.90 | 0.117 |
| Blueback | Female | 2002 | 1.39 | 0.416 | 1.18 | 0.346 | * | * |
| Blueback | Female | 2003 | 1.32 | 0.410 | 1.39 | 0.433 | 1.10 | 0.234 |
| Blueback | Female | 2004 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2005 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2006 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2007 | 0.75 | 0.172 | 0.60 | 0.136 | 0.20 | 0.222 |
| Blueback | Female | 2008 | 0.98 | 0.255 | 0.69 | 0.177 | 1.04 | 0.523 |
| Blueback | Female | 2009 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2010 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2011 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2012 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2013 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2014 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2015 | ** | ** | ** | ** | ** | ** |

Table 6.20 Continued.

| Lamprey River | | | Chapman-Robson | | Heinecke | | Catch Curve | |
|---------------|--------|------|----------------|-------|----------|-------|-------------|-------|
| Species | Sex | Year | Z estimate | SE | Z | SE | Z | SE |
| Alewives | Male | 1990 | 1.61 | 0.596 | 1.50 | 0.550 | * | * |
| Alewives | Male | 1991 | ** | ** | ** | ** | ** | ** |
| Alewives | Male | 1992 | 1.23 | 0.182 | 1.24 | 0.184 | 1.05 | 0.247 |
| Alewives | Male | 1993 | 1.95 | 0.290 | 1.81 | 0.264 | * | * |
| Alewives | Male | 1994 | 1.74 | 0.284 | 1.67 | 0.271 | 1.83 | 0.143 |
| Alewives | Male | 1995 | 1.88 | 0.344 | 1.74 | 0.312 | * | * |
| Alewives | Male | 1996 | 1.25 | 0.182 | 1.08 | 0.156 | 1.23 | 0.220 |
| Alewives | Male | 1997 | 1.10 | 0.207 | 0.87 | 0.161 | 1.10 | 0.350 |
| Alewives | Male | 1998 | 1.05 | 0.156 | 0.85 | 0.125 | 0.86 | 0.174 |
| Alewives | Male | 1999 | 0.73 | 0.092 | 0.50 | 0.062 | 0.70 | 0.229 |
| Alewives | Male | 2000 | 0.84 | 0.100 | 0.71 | 0.083 | 0.81 | 0.158 |
| Alewives | Male | 2001 | 0.71 | 0.084 | 0.51 | 0.060 | 0.85 | 0.157 |
| Alewives | Male | 2002 | 1.41 | 0.248 | 1.15 | 0.198 | * | * |
| Alewives | Male | 2003 | 0.69 | 0.077 | 0.57 | 0.063 | 0.39 | 0.155 |
| Alewives | Male | 2004 | 0.86 | 0.110 | 0.68 | 0.086 | 0.81 | 0.107 |
| Alewives | Male | 2005 | 1.10 | 0.162 | 0.75 | 0.108 | 1.65 | 0.859 |
| Alewives | Male | 2006 | 0.83 | 0.121 | 0.65 | 0.094 | 0.92 | 0.164 |
| Alewives | Male | 2007 | 1.13 | 0.187 | 1.07 | 0.176 | 1.02 | 0.411 |
| Alewives | Male | 2008 | 1.73 | 0.364 | 1.76 | 0.370 | 1.59 | 0.117 |
| Alewives | Male | 2009 | 1.09 | 0.128 | 0.86 | 0.099 | 1.02 | 0.301 |
| Alewives | Male | 2010 | 1.05 | 0.219 | 0.73 | 0.150 | 1.28 | 0.644 |
| Alewives | Male | 2011 | 0.73 | 0.139 | 0.53 | 0.1 | 0.61 | 0.118 |
| Alewives | Male | 2012 | 1 | 0.208 | 0.92 | 0.19 | 0.66 | 0.147 |
| Alewives | Male | 2013 | 0.55 | 0.09 | 0.46 | 0.075 | 0.51 | 0.245 |
| Alewives | Male | 2014 | 0.85 | 0.155 | 0.63 | 0.114 | 0.46 | 0.085 |
| Alewives | Male | 2015 | 0.77 | 0.147 | 0.59 | 0.112 | 0.81 | 0.245 |
| Alewives | Female | 1990 | ** | ** | ** | ** | ** | ** |
| Alewives | Female | 1991 | ** | ** | ** | ** | ** | ** |
| Alewives | Female | 1992 | 1.08 | 0.171 | 0.89 | 0.139 | 0.94 | 0.183 |
| Alewives | Female | 1993 | 1.56 | 0.244 | 1.35 | 0.205 | * | * |
| Alewives | Female | 1994 | 1.10 | 0.172 | 1.03 | 0.161 | 1.11 | 0.070 |
| Alewives | Female | 1995 | 1.20 | 0.173 | 0.90 | 0.126 | 1.73 | 0.757 |
| Alewives | Female | 1996 | 1.07 | 0.164 | 0.76 | 0.113 | 1.26 | 0.600 |
| Alewives | Female | 1997 | 1.06 | 0.199 | 0.79 | 0.147 | 1.07 | 0.417 |
| Alewives | Female | 1998 | 0.86 | 0.144 | 0.64 | 0.106 | 0.82 | 0.189 |
| Alewives | Female | 1999 | 0.85 | 0.113 | 0.66 | 0.087 | 0.79 | 0.110 |
| Alewives | Female | 2000 | 0.76 | 0.093 | 0.56 | 0.068 | 0.66 | 0.146 |
| Alewives | Female | 2001 | 1.28 | 0.217 | 1.05 | 0.174 | 1.63 | 0.540 |
| Alewives | Female | 2002 | 0.71 | 0.103 | 0.48 | 0.068 | 0.90 | 0.430 |
| Alewives | Female | 2003 | 0.57 | 0.082 | 0.43 | 0.061 | 0.47 | 0.142 |
| Alewives | Female | 2004 | 0.85 | 0.110 | 0.66 | 0.084 | 0.75 | 0.141 |
| Alewives | Female | 2005 | 1.01 | 0.147 | 0.77 | 0.110 | 1.10 | 0.485 |
| Alewives | Female | 2006 | 0.87 | 0.142 | 0.64 | 0.104 | 0.50 | 0.112 |
| Alewives | Female | 2007 | 1.02 | 0.165 | 0.90 | 0.144 | 1.08 | 0.103 |
| Alewives | Female | 2008 | 0.87 | 0.113 | 0.81 | 0.105 | 0.86 | 0.246 |
| Alewives | Female | 2009 | 0.95 | 0.118 | 0.62 | 0.076 | 0.84 | 0.465 |
| Alewives | Female | 2010 | 1.39 | 0.344 | 1.15 | 0.279 | * | * |
| Alewives | Female | 2011 | 0.97 | 0.206 | 0.78 | 0.163 | 0.73 | 0.143 |
| Alewives | Female | 2012 | 0.91 | 0.174 | 0.73 | 0.138 | 0.93 | 0.127 |
| Alewives | Female | 2013 | 0.58 | 0.092 | 0.43 | 0.069 | 0.21 | 0.147 |
| Alewives | Female | 2014 | 0.52 | 0.074 | 0.35 | 0.049 | 0.38 | 0.115 |
| Alewives | Female | 2015 | 1.14 | 0.283 | 1.1 | 0.272 | 0.9 | 0.117 |

Table 6.20 Continued.

| Oyster River | | | Chapman-Robson | | Heinecke | | Catch Curve | |
|--------------|--------|------|----------------|-------|----------|-------|-------------|-------|
| species | sex | year | estimate | SE | estimate | SE | estimate | SE |
| Blueback | Male | 1992 | 0.67 | 0.080 | 0.48 | 0.056 | 0.41 | 0.080 |
| Blueback | Male | 1993 | 2.04 | 0.349 | 1.93 | 0.323 | * | * |
| Blueback | Male | 1994 | 1.01 | 0.109 | 0.82 | 0.087 | 1.30 | 0.281 |
| Blueback | Male | 1995 | 1.51 | 0.242 | 1.29 | 0.201 | * | * |
| Blueback | Male | 1996 | 1.17 | 0.175 | 0.92 | 0.134 | 1.35 | 0.487 |
| Blueback | Male | 1997 | 0.79 | 0.081 | 0.58 | 0.059 | 0.78 | 0.200 |
| Blueback | Male | 1998 | 0.64 | 0.077 | 0.41 | 0.049 | 0.47 | 0.234 |
| Blueback | Male | 1999 | 2.11 | 0.351 | 2.01 | 0.327 | * | * |
| Blueback | Male | 2000 | 0.93 | 0.103 | 0.64 | 0.069 | 0.72 | 0.341 |
| Blueback | Male | 2001 | 0.77 | 0.094 | 0.58 | 0.071 | 0.73 | 0.214 |
| Blueback | Male | 2002 | 0.73 | 0.078 | 0.60 | 0.063 | 0.53 | 0.066 |
| Blueback | Male | 2003 | 1.14 | 0.149 | 0.92 | 0.118 | 1.34 | 0.260 |
| Blueback | Male | 2004 | 1.59 | 0.255 | 1.47 | 0.232 | 1.81 | 0.287 |
| Blueback | Male | 2005 | 0.99 | 0.137 | 0.71 | 0.096 | 0.88 | 0.374 |
| Blueback | Male | 2006 | 0.83 | 0.086 | 0.61 | 0.062 | 1.19 | 0.455 |
| Blueback | Male | 2007 | 0.89 | 0.093 | 0.70 | 0.073 | 0.93 | 0.165 |
| Blueback | Male | 2008 | 0.67 | 0.067 | 0.51 | 0.051 | 0.72 | 0.114 |
| Blueback | Male | 2009 | 1.21 | 0.173 | 1.30 | 0.188 | 0.80 | 0.542 |
| Blueback | Male | 2010 | 0.62 | 0.101 | 0.57 | 0.093 | 0.51 | 0.119 |
| Blueback | Male | 2011 | 0.91 | 0.174 | 0.8 | 0.153 | 0.9 | 0.12 |
| Blueback | Male | 2012 | 1.1 | 0.231 | 0.73 | 0.15 | * | * |
| Blueback | Male | 2013 | 2.2 | 0.647 | 2.14 | 0.624 | * | * |
| Blueback | Male | 2014 | 2.83 | 0.941 | 2.83 | 0.941 | * | * |
| Blueback | Male | 2015 | 0.72 | 0.156 | 0.53 | 0.113 | 0.13 | 0.162 |
| Blueback | Female | 1992 | 0.60 | 0.091 | 0.76 | 0.116 | 0.47 | 0.169 |
| Blueback | Female | 1993 | 1.64 | 0.257 | 1.45 | 0.221 | * | * |
| Blueback | Female | 1994 | 1.01 | 0.180 | 0.75 | 0.132 | 0.90 | 0.329 |
| Blueback | Female | 1995 | 1.29 | 0.210 | 1.12 | 0.180 | 1.34 | 0.263 |
| Blueback | Female | 1996 | 1.19 | 0.185 | 0.91 | 0.137 | 1.67 | 0.707 |
| Blueback | Female | 1997 | 0.69 | 0.100 | 0.51 | 0.073 | 0.77 | 0.126 |
| Blueback | Female | 1998 | 0.97 | 0.122 | 0.79 | 0.098 | 1.01 | 0.126 |
| Blueback | Female | 1999 | 1.61 | 0.256 | 1.59 | 0.252 | 1.49 | 0.057 |
| Blueback | Female | 2000 | 1.10 | 0.195 | 0.78 | 0.136 | 1.47 | 0.714 |
| Blueback | Female | 2001 | 0.89 | 0.158 | 0.75 | 0.132 | 0.47 | 0.128 |
| Blueback | Female | 2002 | 0.63 | 0.107 | 0.41 | 0.068 | 0.43 | 0.193 |
| Blueback | Female | 2003 | 0.79 | 0.113 | 0.58 | 0.082 | 0.66 | 0.171 |
| Blueback | Female | 2004 | 1.34 | 0.219 | 1.20 | 0.194 | 1.35 | 0.202 |
| Blueback | Female | 2005 | 1.22 | 0.214 | 0.90 | 0.154 | * | * |
| Blueback | Female | 2006 | 0.76 | 0.136 | 0.50 | 0.088 | 0.24 | 0.094 |
| Blueback | Female | 2007 | 1.22 | 0.181 | 1.22 | 0.182 | 0.90 | 0.283 |
| Blueback | Female | 2008 | 0.80 | 0.134 | 0.59 | 0.098 | 0.91 | 0.274 |
| Blueback | Female | 2009 | 1.01 | 0.180 | 0.75 | 0.132 | 0.90 | 0.329 |
| Blueback | Female | 2010 | 1.33 | 0.280 | 1.31 | 0.276 | 1.13 | 0.121 |
| Blueback | Female | 2011 | 0.79 | 0.166 | 0.78 | 0.163 | 0.58 | 0.095 |
| Blueback | Female | 2012 | 1.3 | 0.338 | 1.22 | 0.316 | 1.24 | 0.083 |
| Blueback | Female | 2013 | 1.15 | 0.217 | 1.13 | 0.214 | 0.83 | 0.245 |
| Blueback | Female | 2014 | 1.53 | 0.385 | 1.56 | 0.395 | 1.35 | 0.147 |
| Blueback | Female | 2015 | 0.8 | 0.155 | 0.56 | 0.107 | 0.85 | 0.209 |

Table 6.20 Continued.

| Winnicut River | | | Chapman-Robson | | Heinecke | | Catch Curve | |
|----------------|--------|------|----------------|-------|----------|-------|-------------|--------|
| species | sex | year | estimate | SE | estimate | SE | estimate | SE |
| Alewives | Male | 1998 | 1.1 | 0.667 | 1.1 | 0.667 | * | * |
| Alewives | Male | 1999 | 1.47 | 0.25 | 1.41 | 0.239 | 1.37 | 0.009 |
| Alewives | Male | 2000 | 0.89 | 0.247 | 0.85 | 0.233 | 0.76 | 0.183 |
| Alewives | Male | 2001 | 1.25 | 0.197 | 1.34 | 0.213 | 0.87 | 0.501 |
| Alewives | Male | 2002 | 0.7 | 0.102 | 0.58 | 0.083 | 0.74 | 0.242 |
| Alewives | Male | 2003 | 1.95 | 0.346 | 1.82 | 0.316 | * | * |
| Alewives | Male | 2004 | 2.37 | 0.47 | 2.30 | 0.450 | * | * |
| Alewives | Male | 2005 | 0.69 | 0.079 | 0.48 | 0.054 | 0.86 | 0.182 |
| Alewives | Male | 2006 | 0.62 | 0.124 | 0.42 | 0.084 | 0.36 | 0.092 |
| Alewives | Male | 2007 | 1.00 | 0.123 | 0.94 | 0.115 | 0.90 | 0.013 |
| Alewives | Male | 2008 | 1.16 | 0.134 | 1.00 | 0.113 | 1.12 | 0.246 |
| Alewives | Male | 2009 | 1.45 | 0.249 | 1.29 | 0.219 | 1.68 | 0.357 |
| Alewives | Female | 1999 | 0.89 | 0.247 | 0.69 | 0.189 | 0.63 | 0.167 |
| Alewives | Female | 2000 | 0.61 | 0.251 | 0.69 | 0.289 | 0.33 | 0.190 |
| Alewives | Female | 2001 | 0.69 | 0.147 | 0.57 | 0.121 | 0.45 | 0.110 |
| Alewives | Female | 2002 | 0.75 | 0.244 | 0.69 | 0.224 | 0.59 | 0.144 |
| Alewives | Female | 2003 | 0.92 | 0.359 | 0.85 | 0.330 | 0.69 | <0.001 |
| Alewives | Female | 2004 | 1.28 | 0.366 | 1.54 | 0.454 | 0.85 | 0.892 |
| Alewives | Female | 2005 | 1.16 | 0.355 | 0.88 | 0.261 | * | * |
| Alewives | Female | 2007 | 0.73 | 0.18 | 0.53 | 0.130 | 0.65 | 0.150 |
| Alewives | Female | 2008 | 0.86 | 0.186 | 0.83 | 0.179 | 0.67 | 0.158 |
| Alewives | Female | 2009 | 0.99 | 0.179 | 0.93 | 0.168 | 0.60 | 0.259 |
| Blueback | Male | 1998 | 1.12 | 0.149 | 1.05 | 0.139 | 1.03 | 0.164 |
| Blueback | Male | 1999 | 0.98 | 0.131 | 0.71 | 0.093 | 0.82 | 0.326 |
| Blueback | Male | 2000 | 1.06 | 0.134 | 1.02 | 0.128 | 1.19 | 0.238 |
| Blueback | Male | 2001 | 1.06 | 0.193 | 0.93 | 0.168 | 1.06 | 0.130 |
| Blueback | Male | 2002 | 1.22 | 0.196 | 1.22 | 0.195 | 1.14 | 0.024 |
| Blueback | Male | 2003 | 1.71 | 0.27 | 1.63 | 0.254 | 1.86 | 0.197 |
| Blueback | Male | 2004 | 1.16 | 0.211 | 0.82 | 0.144 | * | * |
| Blueback | Male | 2005 | 1.27 | 0.251 | 1.17 | 0.230 | 1.15 | 0.059 |
| Blueback | Male | 2006 | 0.87 | 0.118 | 0.66 | 0.088 | 0.90 | 0.160 |
| Blueback | Male | 2007 | 0.69 | 0.141 | 0.51 | 0.103 | 0.69 | 0.299 |
| Blueback | Male | 2008 | 1.39 | 0.567 | 1.25 | 0.505 | * | * |
| Blueback | Male | 2009 | 2.35 | 0.656 | 2.30 | 0.636 | * | * |
| Blueback | Female | 1998 | 0.63 | 0.226 | 0.69 | 0.250 | 0.35 | 0.268 |
| Blueback | Female | 1999 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2000 | 0.94 | 0.161 | 0.72 | 0.121 | 0.67 | 0.166 |
| Blueback | Female | 2001 | 1.30 | 0.464 | 1.10 | 0.385 | * | * |
| Blueback | Female | 2002 | 0.85 | 0.242 | 0.77 | 0.220 | 0.42 | 0.245 |
| Blueback | Female | 2003 | 1.39 | 0.474 | 1.20 | 0.404 | * | * |
| Blueback | Female | 2004 | 1.25 | 0.546 | 1.10 | 0.471 | * | * |
| Blueback | Female | 2005 | 2.08 | 0.875 | 2.08 | 0.875 | * | * |
| Blueback | Female | 2006 | 1.25 | 0.546 | 1.10 | 0.471 | * | * |
| Blueback | Female | 2007 | 0.69 | 0.354 | 0.69 | 0.354 | 0.20 | 0.172 |
| Blueback | Female | 2008 | ** | ** | ** | ** | ** | ** |
| Blueback | Female | 2009 | 1.67 | 0.501 | 1.95 | 0.606 | 0.71 | 0.615 |

Table 6.20 Continued.

| Exeter River*** | | Chapman-Robson | | Heinecke | | Catch Curve | |
|-----------------|------|----------------|-------|------------|-------|-------------|-------|
| Species | Year | Z estimate | SE | Z estimate | SE | Z estimate | SE |
| River Herring | 1991 | 1.02 | 0.113 | 0.92 | 0.100 | 1.05 | 0.066 |
| River Herring | 1992 | 1.01 | 0.091 | 0.85 | 0.076 | 1.19 | 0.223 |
| River Herring | 1993 | 1.37 | 0.162 | 1.24 | 0.145 | 1.35 | 0.152 |
| River Herring | 1994 | No Sampling | | | | | |
| River Herring | 1995 | 1.72 | 0.180 | 1.70 | 0.178 | 1.58 | 0.076 |
| River Herring | 1996 | 1.39 | 0.375 | 1.16 | 0.307 | * | * |
| River Herring | 1997 | 1.01 | 0.077 | 0.89 | 0.067 | 1.09 | 0.157 |
| River Herring | 1998 | 0.64 | 0.050 | 0.51 | 0.040 | 0.59 | 0.093 |
| River Herring | 1999 | 1.26 | 0.116 | 1.07 | 0.097 | 1.27 | 0.261 |
| River Herring | 2000 | 1.03 | 0.110 | 0.79 | 0.082 | 1.18 | 0.212 |
| River Herring | 2001 | 0.98 | 0.109 | 0.76 | 0.083 | 1.28 | 0.282 |
| River Herring | 2002 | 1.53 | 0.276 | 1.31 | 0.231 | * | * |
| River Herring | 2003 | 0.91 | 0.129 | 0.83 | 0.118 | 0.78 | 0.020 |
| River Herring | 2004 | 1.19 | 0.176 | 0.94 | 0.136 | 1.37 | 0.477 |
| River Herring | 2005 | 1.27 | 0.224 | 1.21 | 0.212 | 1.08 | 0.057 |
| River Herring | 2006 | 0.69 | 0.183 | 0.51 | 0.133 | 0.09 | 0.181 |
| River Herring | 2007 | 0.99 | 0.195 | 0.77 | 0.149 | 1.05 | 0.321 |
| River Herring | 2008 | 0.89 | 0.083 | 0.69 | 0.062 | 1.13 | 0.159 |
| River Herring | 2009 | 0.90 | 0.053 | 0.65 | 0.037 | 1.13 | 0.290 |
| River Herring | 2010 | 1.00 | 0.185 | 0.76 | 0.137 | 0.87 | 0.300 |
| River Herring | 2011 | 1.53 | 0.308 | 1.32 | 0.259 | NA | NA |
| River Herring | 2012 | 1.2 | 0.19 | 1.1 | 0.172 | 1.2 | 0.144 |
| River Herring | 2013 | 0.73 | 0.092 | 0.59 | 0.074 | 0.49 | 0.037 |
| River Herring | 2014 | 0.8 | 0.083 | 0.59 | 0.06 | 0.74 | 0.14 |
| River Herring | 2015 | 1.03 | 0.106 | 0.9 | 0.091 | 1.31 | 0.31 |

*- No Z estimate due to less than three ages to assess.

**- No Z estimates due to extremely low sample size, no species differentiation, or ages below fully recruited age.

Table 6.21 Spawner-per-recruit Z benchmarks for New Hampshire and 2009 estimates of Z by river system

| River | Species | Sex | Z_{2009} | Benchmark | | | |
|----------|----------|--------|------------|-----------------|-----------------|-----------------|-----------------|
| | | | | Z40% (M=0.3) | Z20% (M=0.3) | Z40% (M=0.7) | Z20% (M=0.7) |
| Cocheco | Alewife | Male | 0.86 | 0.46 | 0.60 | 0.92 | 1.11 |
| Cocheco | Alewife | Female | 0.65 | 0.46 | 0.60 | 0.92 | 1.11 |
| Lamprey | Alewife | Male | 1.09 | 0.46 | 0.60 | 0.92 | 1.11 |
| Oyster | Blueback | Male | 1.21 | 0.48 | 0.64 | 0.95 | 1.15 |
| Oyster | Blueback | Female | 1.01 | 0.48 | 0.64 | 0.95 | 1.15 |
| Winnicut | Alewife | Male | 1.45 | 0.46 | 0.60 | 0.92 | 1.11 |
| Winnicut | Alewife | Female | 0.99 | 0.46 | 0.60 | 0.92 | 1.11 |
| Winnicut | Blueback | Female | 1.67 | 0.48 | 0.64 | 0.95 | 1.15 |

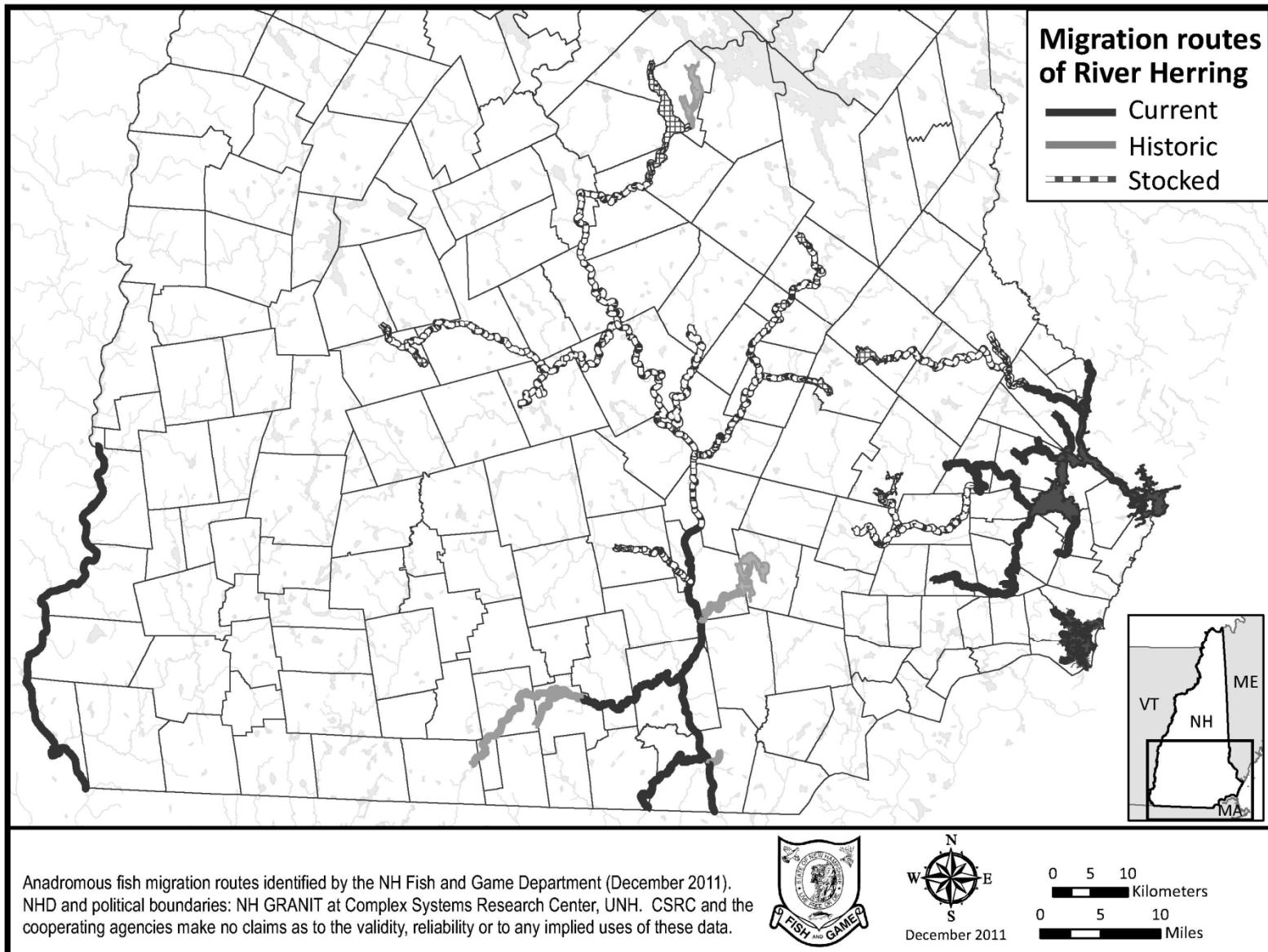


Figure 6.1 Map of New Hampshire's river herring migration routes (historic, current and stocked fish).

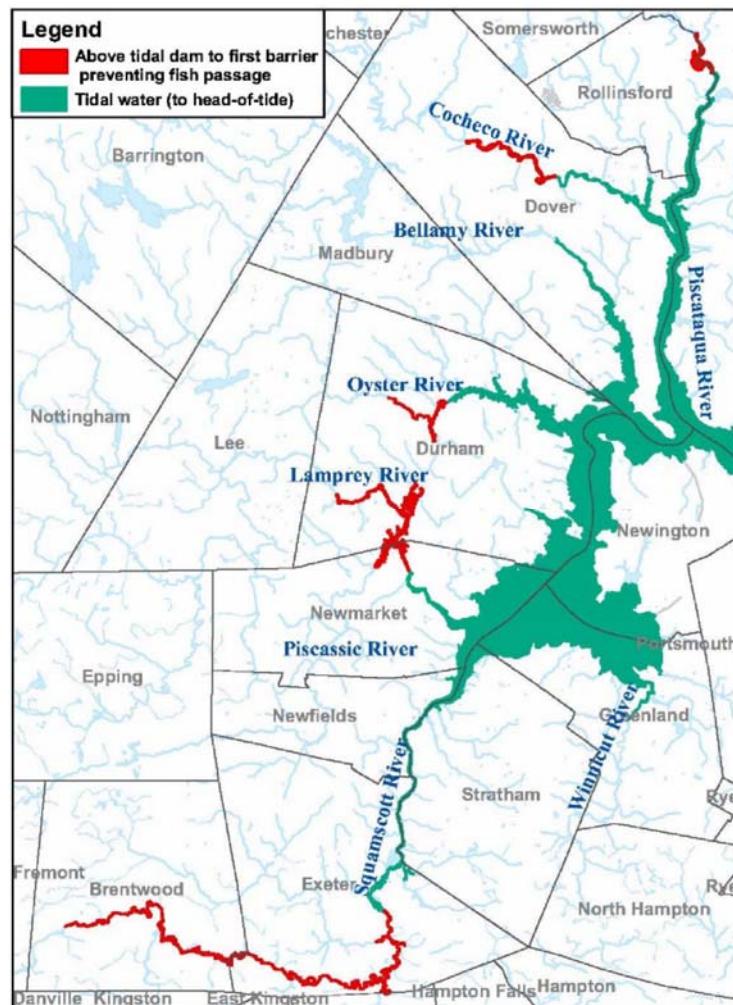


Figure 6.2 Great Bay Estuary rivers with fish passage and available anadromous spawning and rearing habitat.

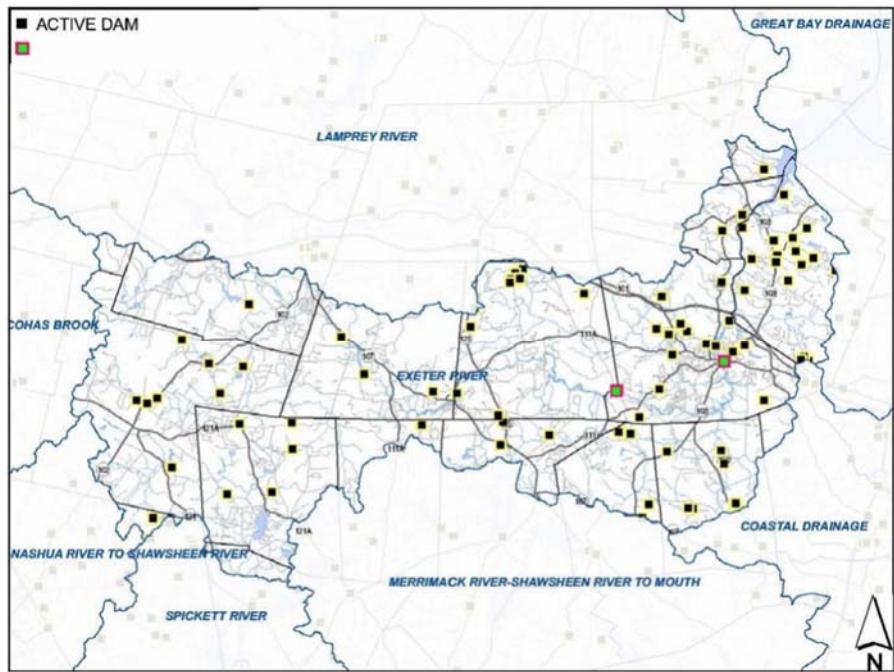


Figure 6.3 Exeter River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

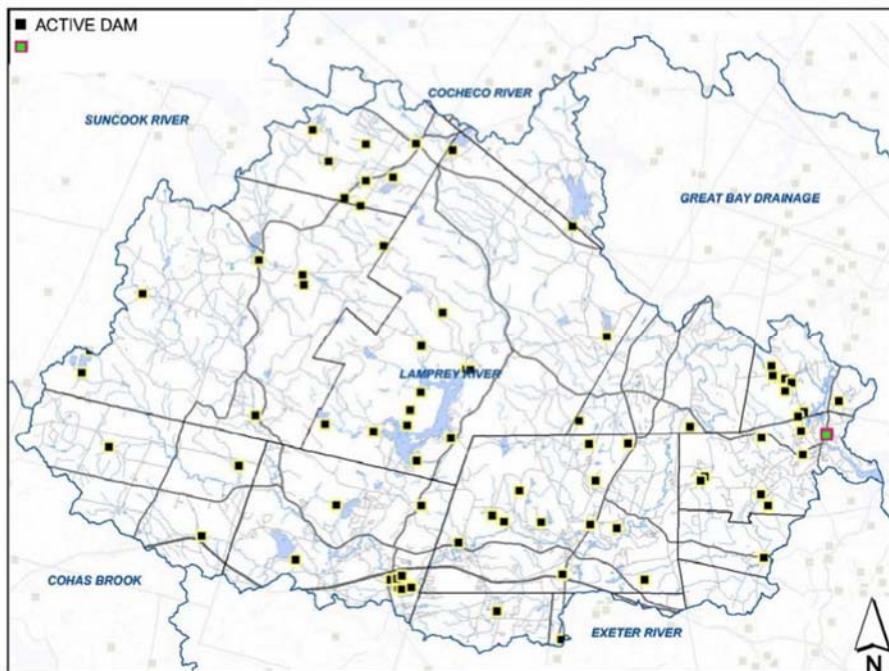


Figure 6.4 Lamprey River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

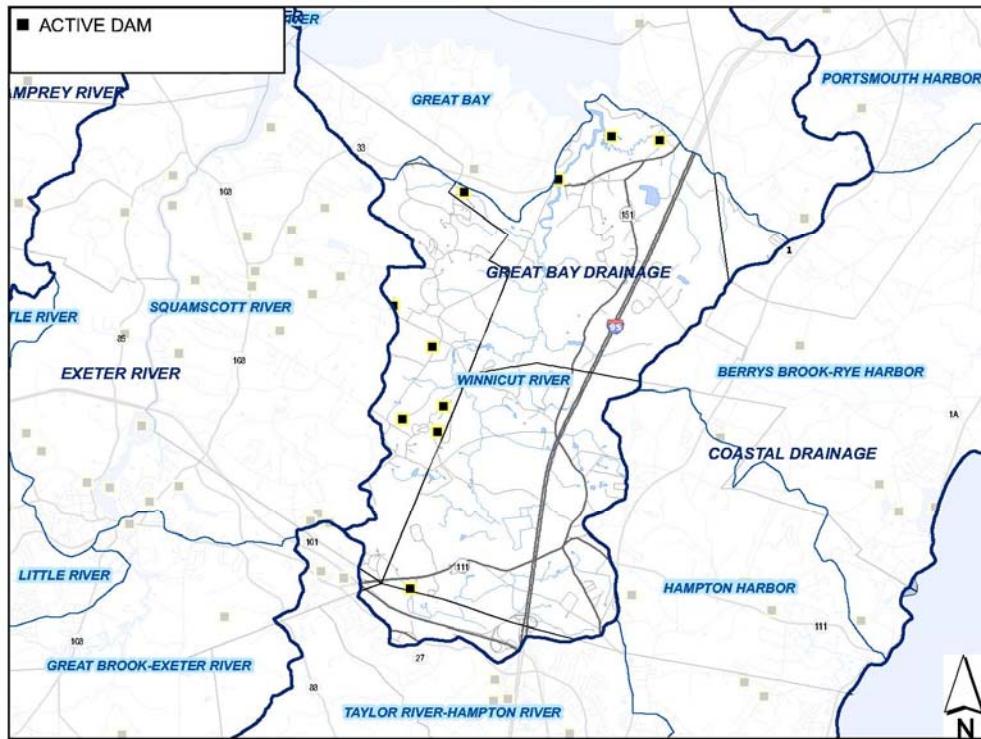


Figure 6.5 Winnicut River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

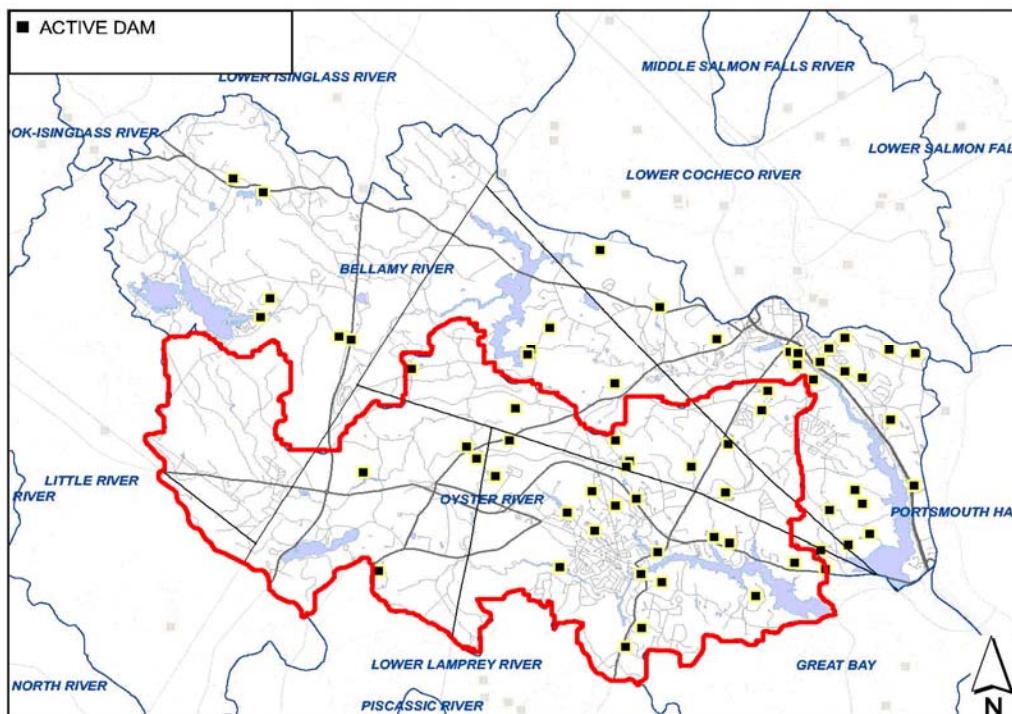


Figure 6.6 Oyster River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

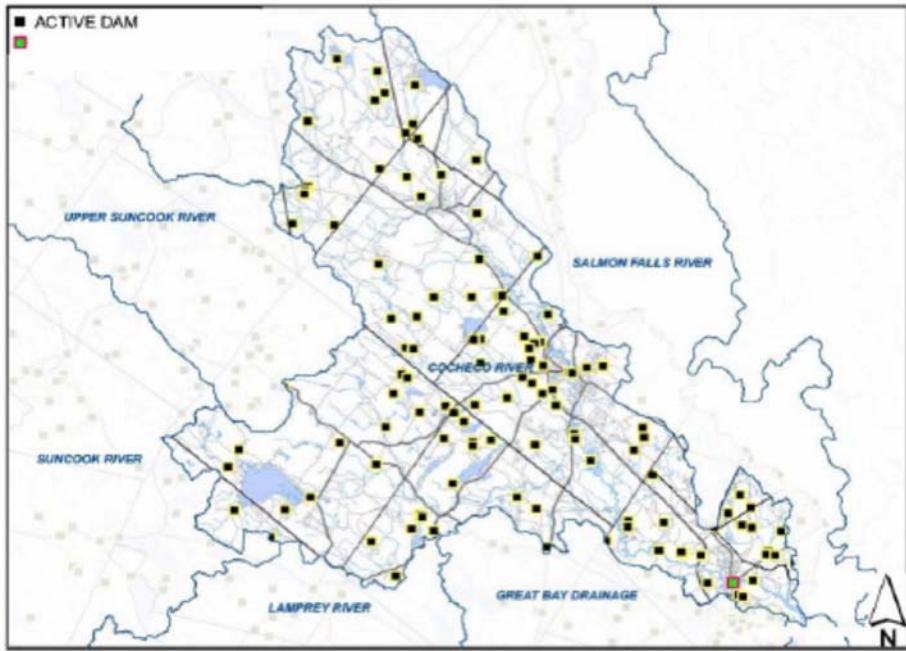


Figure 6.7 Cocheco River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

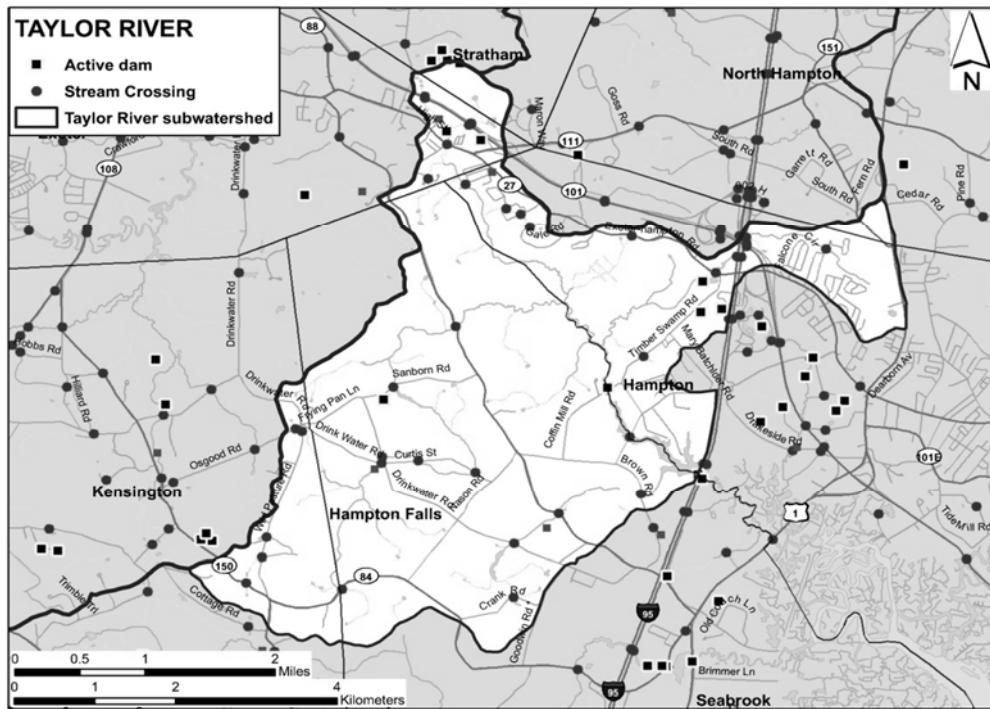


Figure 6.8 Taylor River watershed dams and fish passage, Hampton-Seabrook Estuary, New Hampshire.

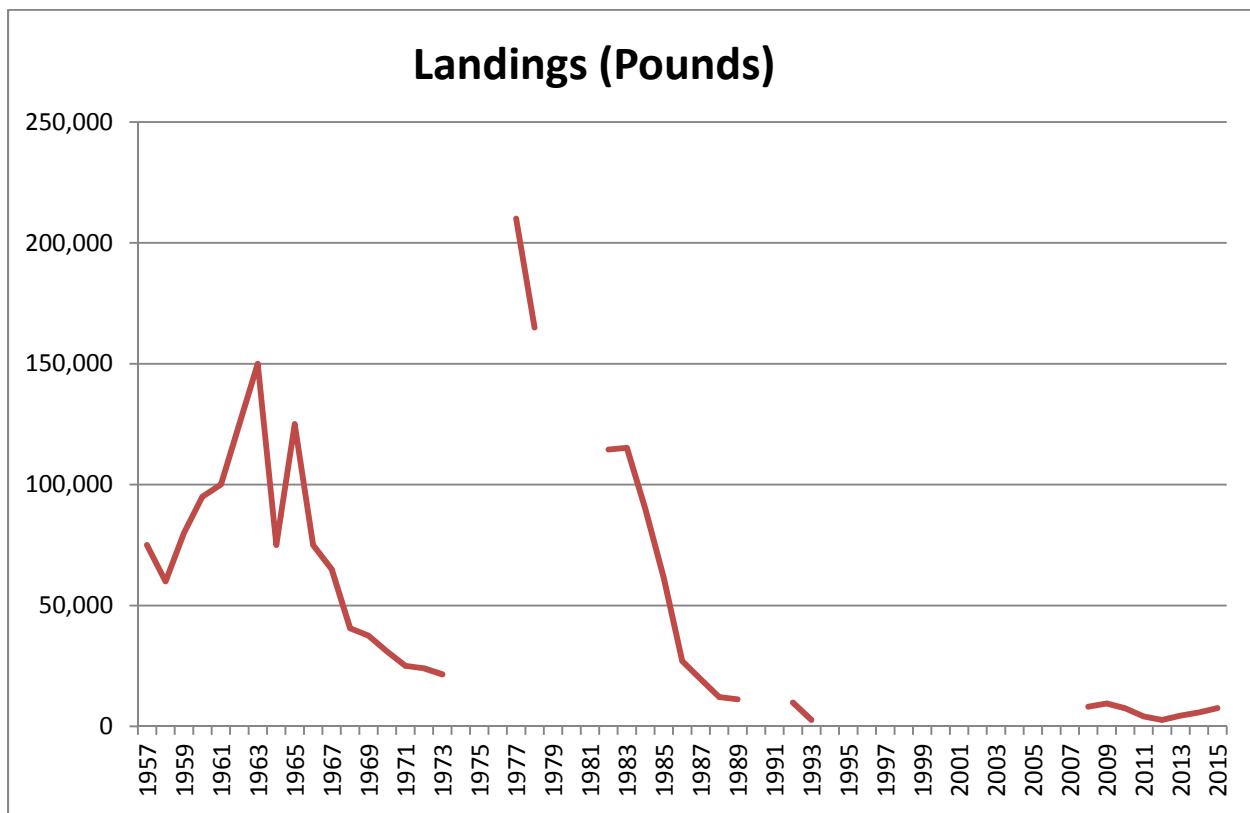


Figure 6.9. Commercial landings (in pounds) of river herring in New Hampshire.

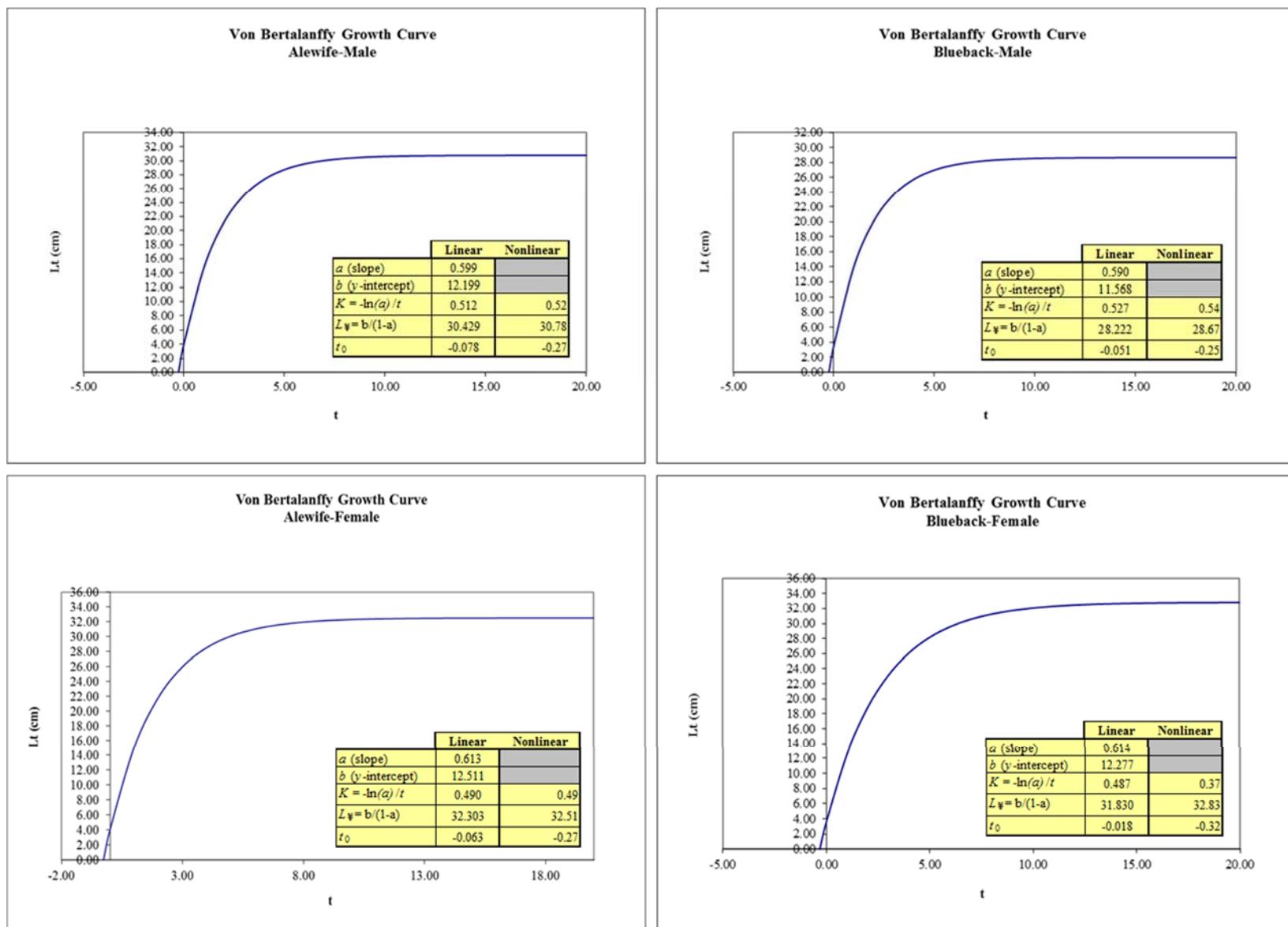
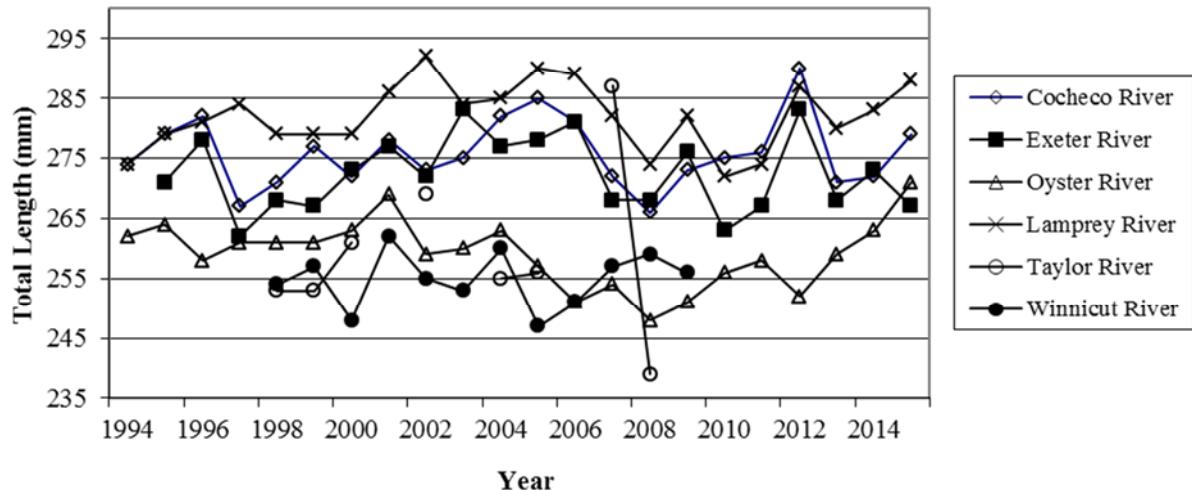


Figure 6.10 Von Bertalanffy growth curves for male and female river herring from New Hampshire rivers.

Mean total length of male river herring returning to NH coastal rivers, 1994-2015



Mean total length of female river herring returning to NH coastal rivers, 1994-2015

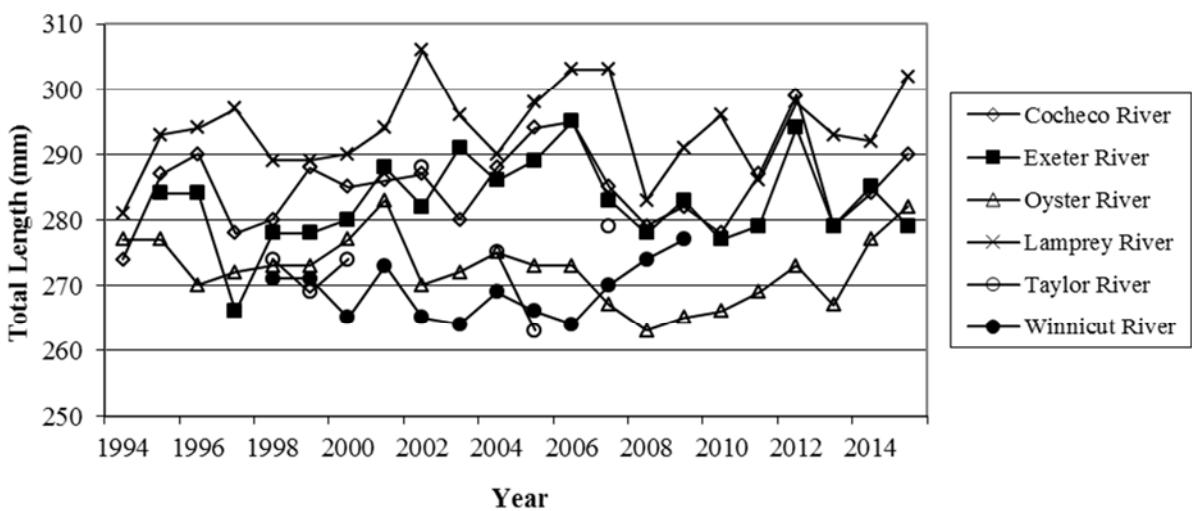


Figure 6.11 Mean total length (mm) of male and female river herring returning to the coastal rivers of New Hampshire, 1994-2015.

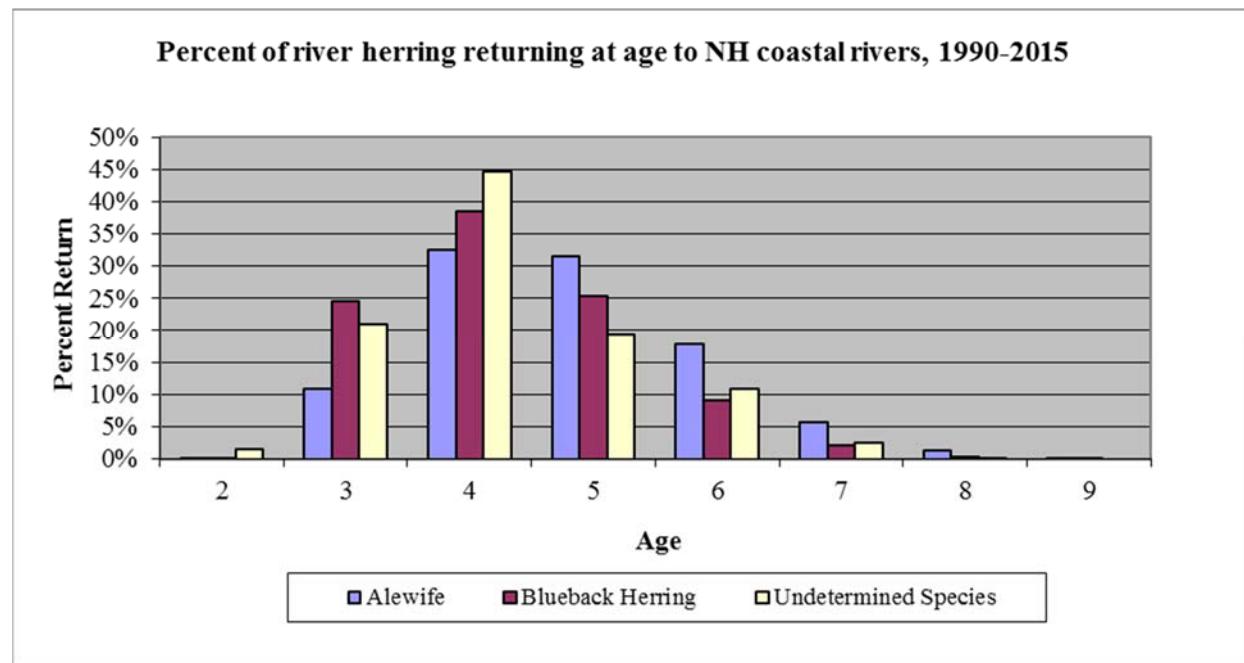


Figure 6.12 Percent of river herring returning at age to New Hampshire coastal rivers, 1990-2015.

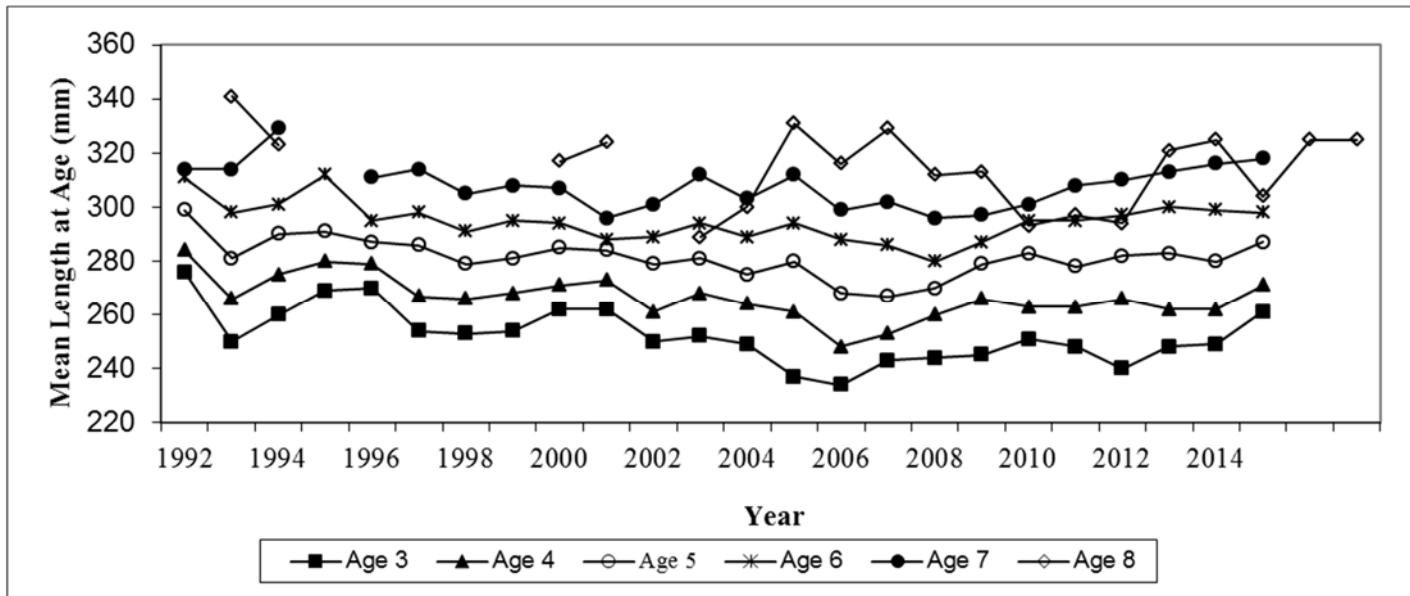


Figure 6.13 Mean length at age for river herring returns to New Hampshire coastal rivers, 1992 - 2015.

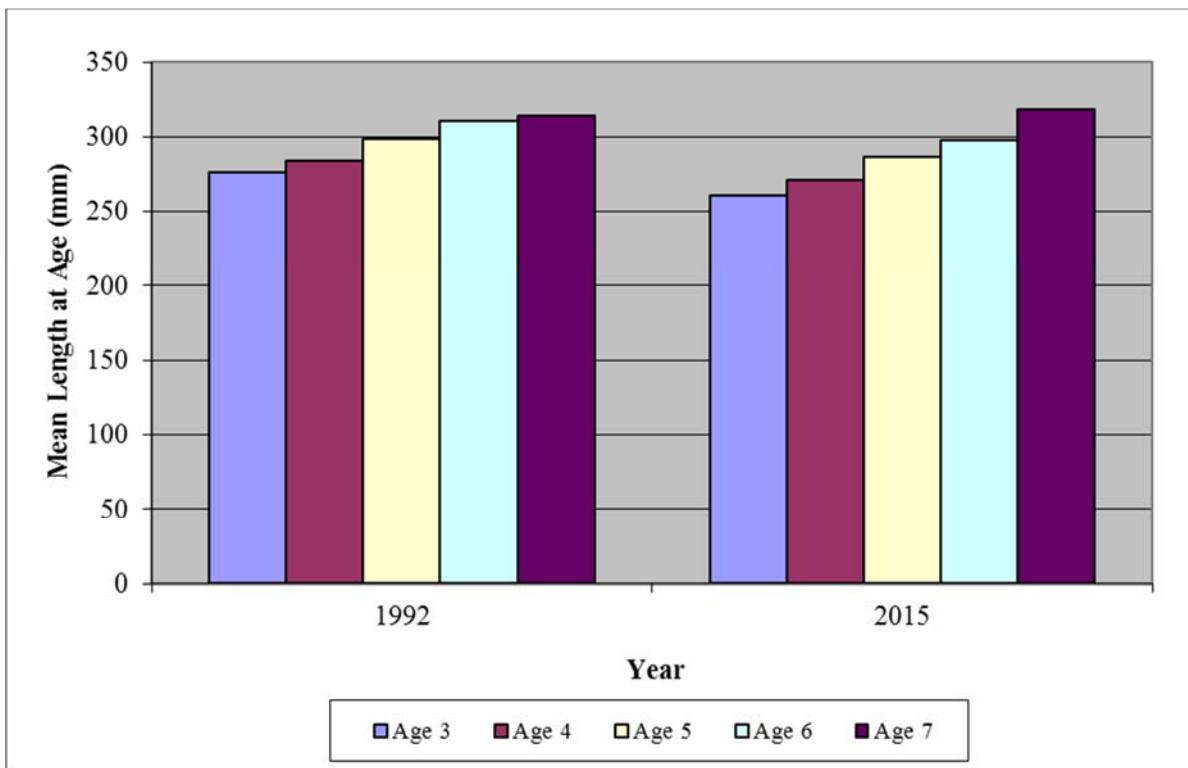


Figure 6.14 Mean length at age differences between 1992 and 2015 of river herring returning to New Hampshire coastal rivers.

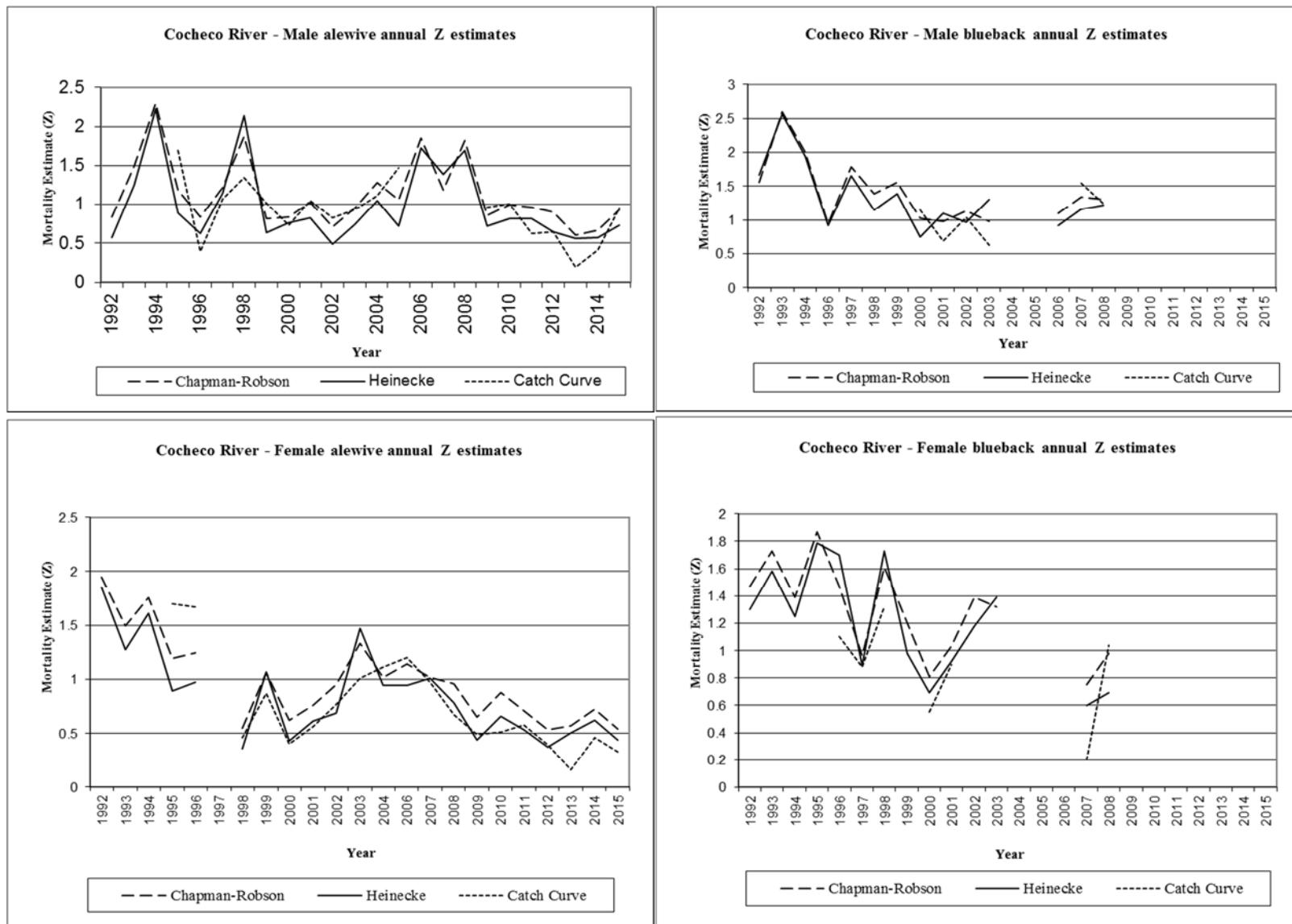


Figure 6.15 Estimates of total instantaneous mortality (Z) for river herring in coastal New Hampshire rivers, using Chapman-Robson, Heinecke, and catch curve methods based on age, separated by species and sex, 1990-2015.

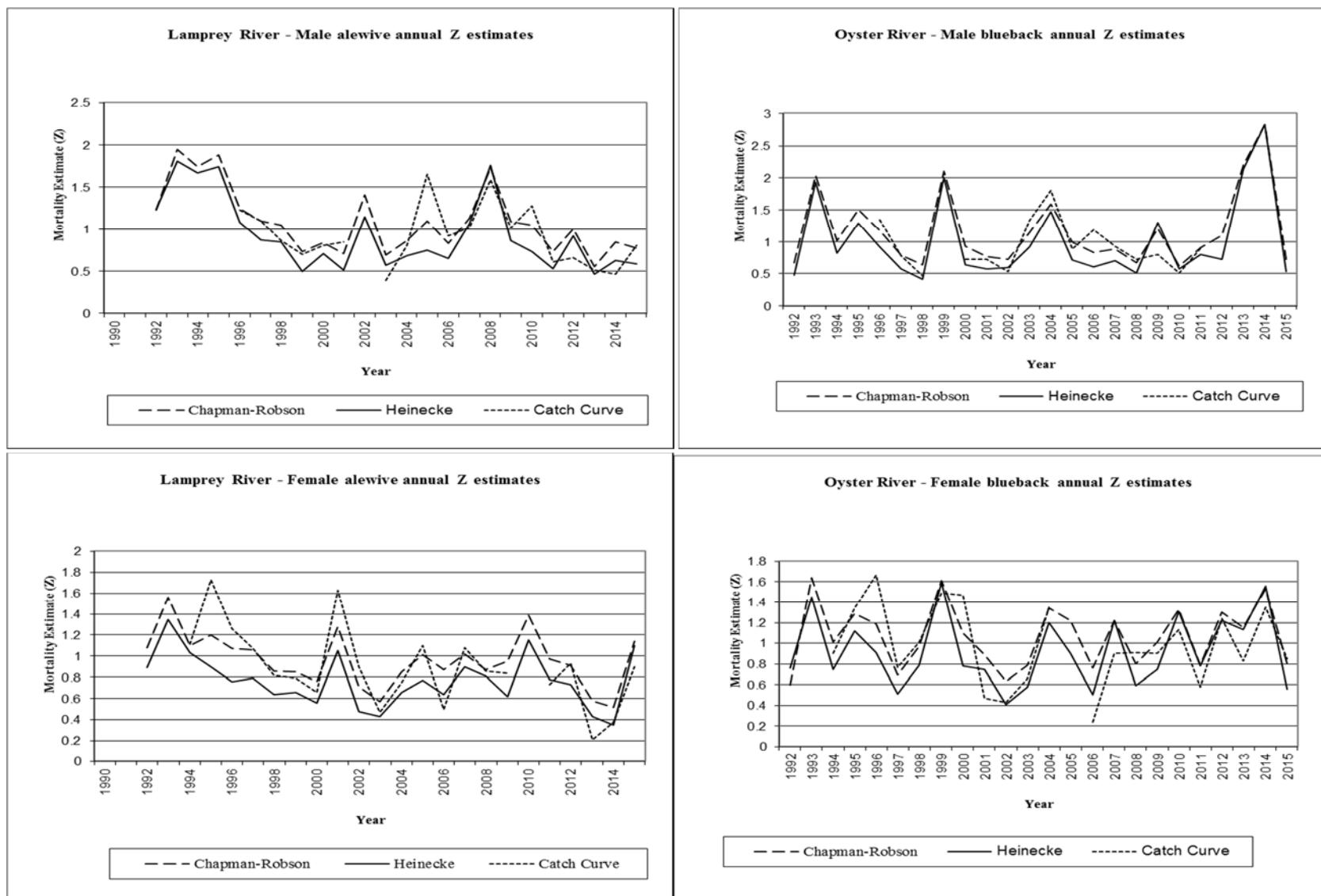


Figure 6.15 Continued.

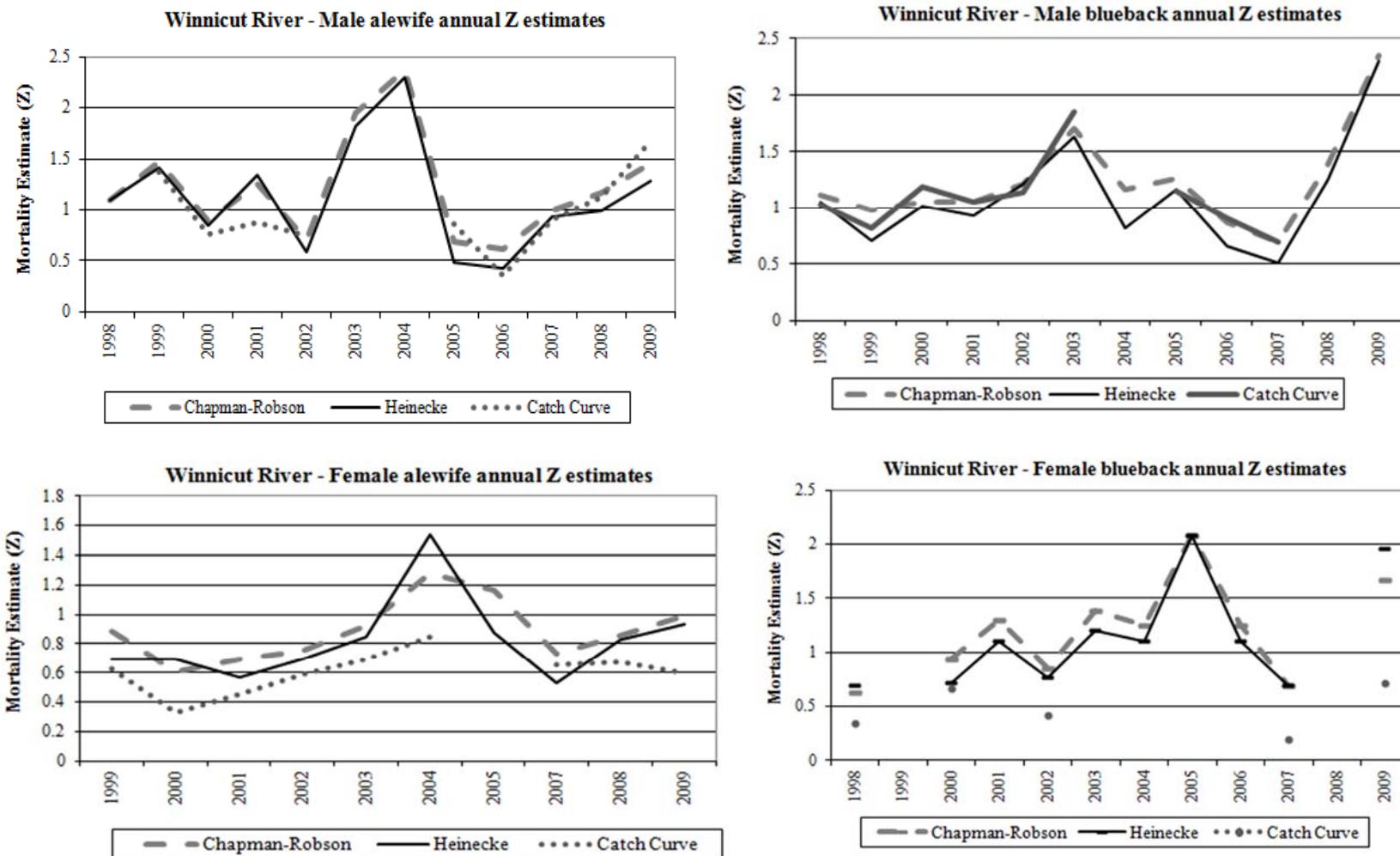
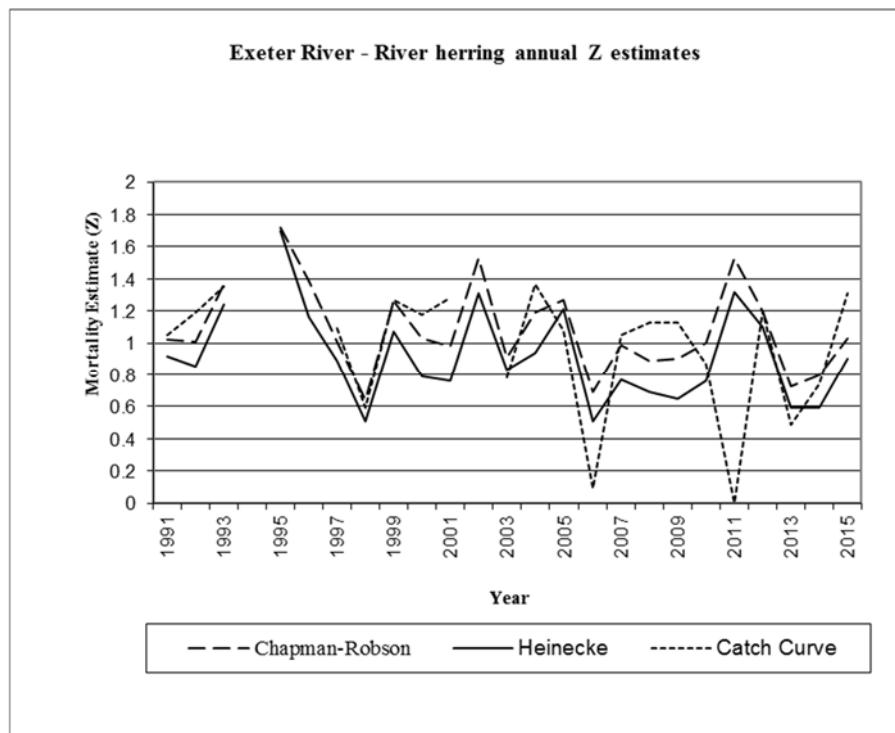


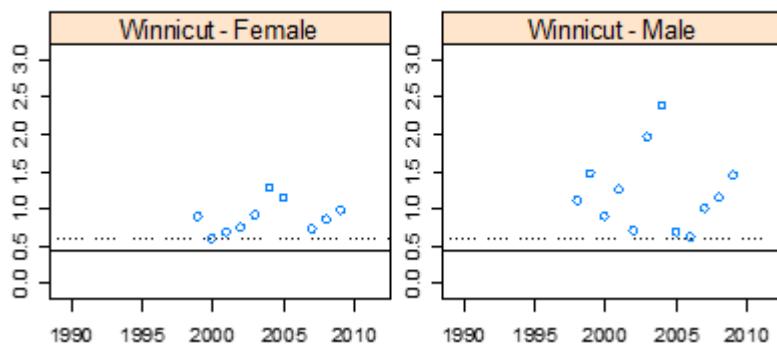
Figure 6.15 Continued.



*Due to low sample size Z estimates were not conducted between species or sex.

Figure 6.15 Continued

NH Alewife (M=0.3)



NH Alewife (M=0.7)

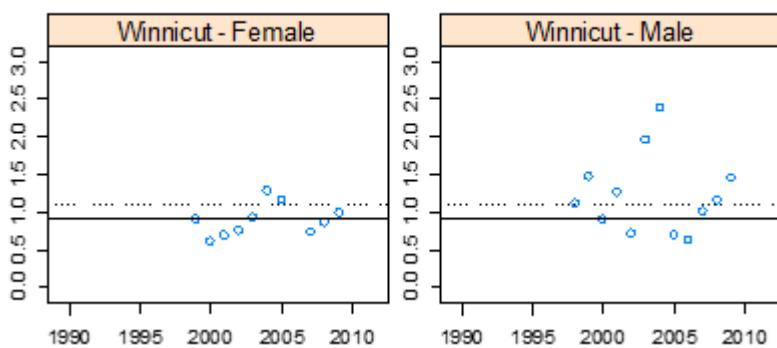


Figure 6.16 Empirical estimates of Z for NH alewife by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

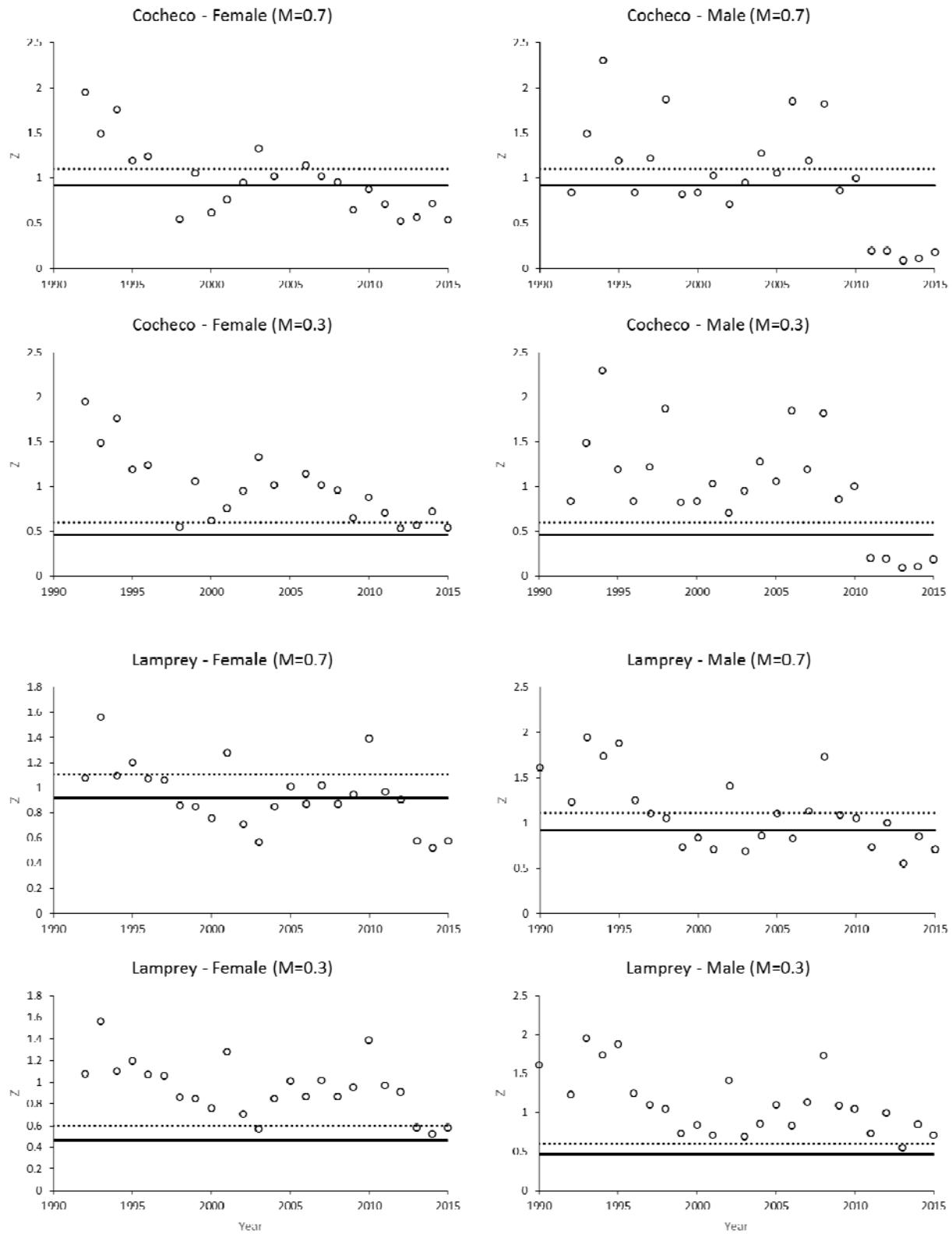
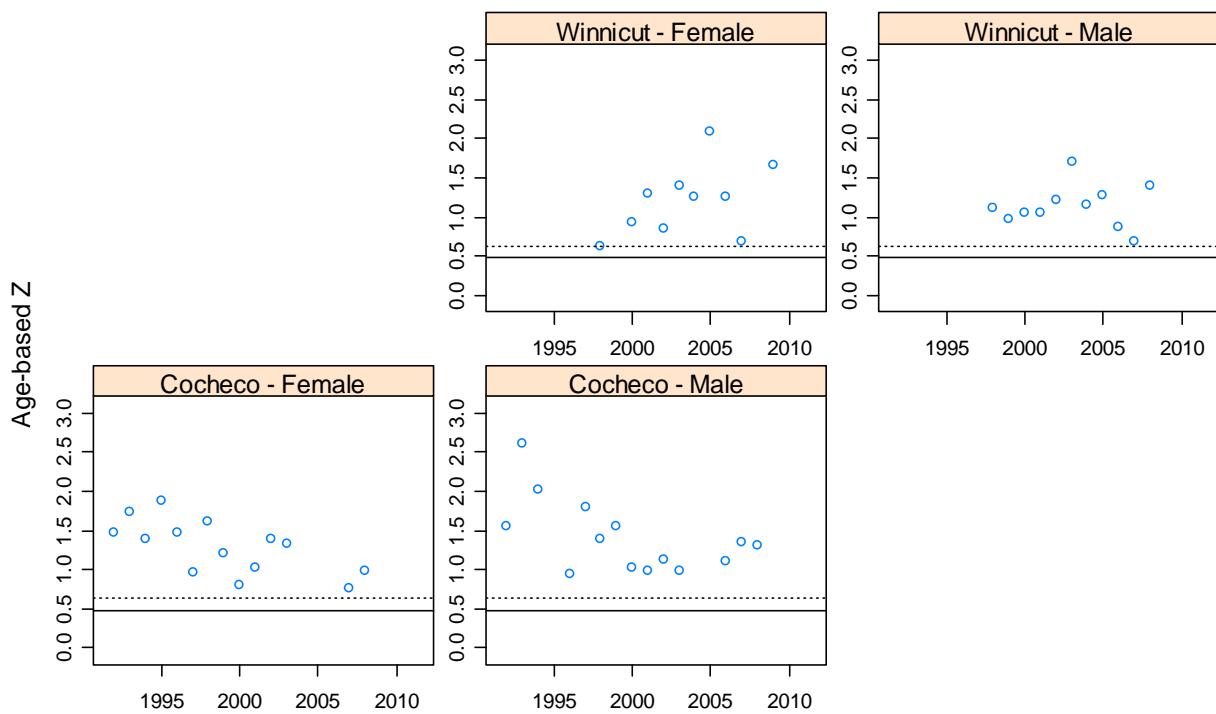


Figure 6.16 Continued

NH Blueback Herring ($M=0.3$)



NH Blueback Herring ($M=0.7$)

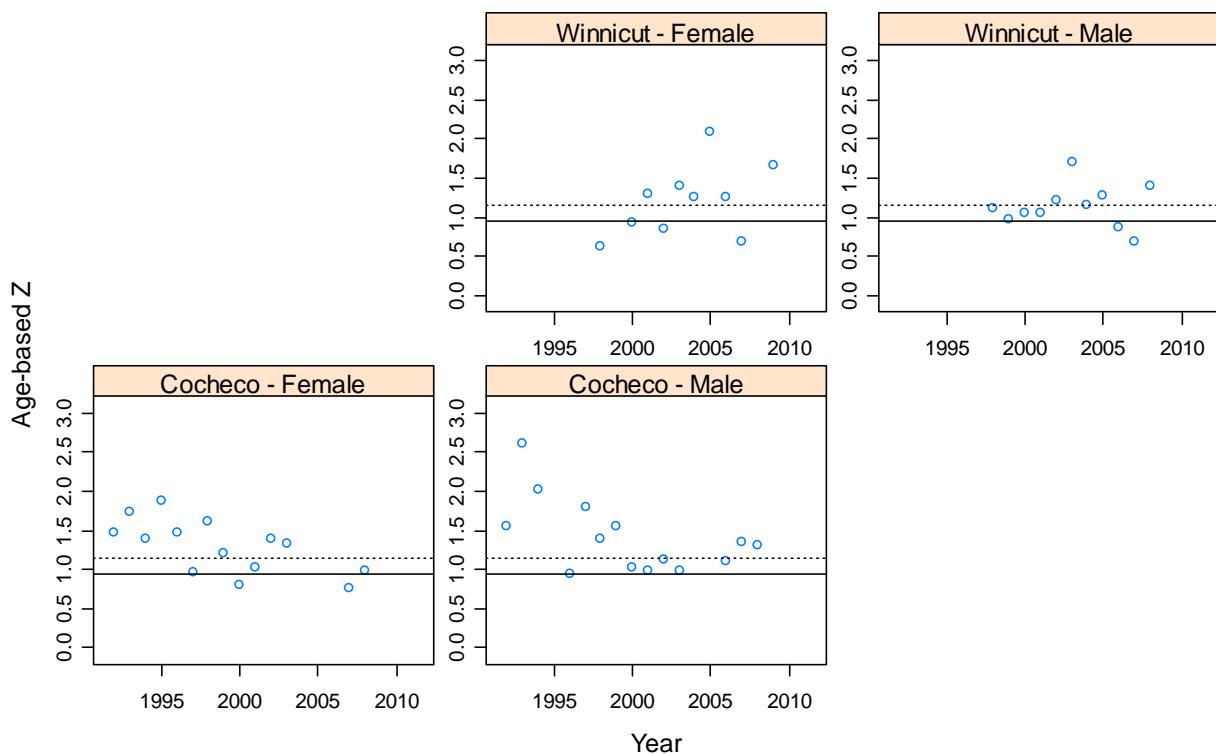


Figure 6.17: Empirical estimates of Z for NH blueback herring by river for different values of M . Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

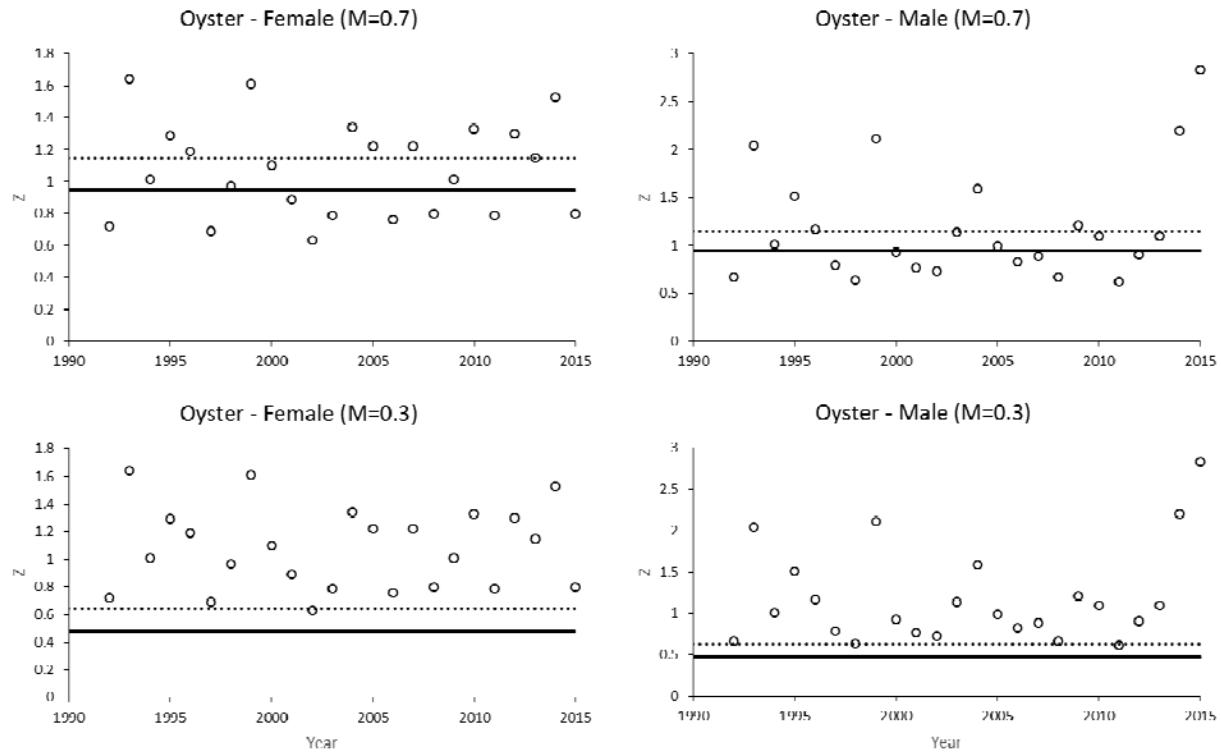


Figure 6.17 Continued

7 Status of River Herring in Massachusetts

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Executive Summary

Data on abundance, size structure and age composition were used to assess the current status of alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) in Massachusetts rivers. Count data for three rivers (Parker River, Monument River and Mattapoisett River) indicated a precipitous decline in alewife abundance after 2000. A strong decline was not observed in the Nemasket River, but average passage count after 2004 (587,000 fish) was about half of the average passage count prior to 2004 (1.04 million fish). Abundance has increased slowly in each river since about 2006-2008. A decline in the Monument River run size of blueback herring was not observed until after 2004 and total run size remains low. Size data from the Monument River and Stony Brook showed that the average total lengths of alewife and blueback herring have declined by about 20-25 mm over time. The current maximum age of both species is 1-2 years less than the maximum age observed during 1985-1987. The proportions of alewives that were repeat spawners in the Monument River declined in recent years by 64% or more compared to data from 1986-1987. In other rivers, proportions of repeated spawners as high as 0.54 (Charles River) were observed, but most estimates were below 0.30 in recent years. Similar reductions in proportions of repeat spawners were observed for blueback herring in the Monument River.

7.1. INTRODUCTION

In Massachusetts, more than 100 coastal rivers and streams are home to the anadromous alewife (*Alosa pseudoharengus*) and blueback (*Alosa aestivalis*) herring. Known colloquially as “river herring”, these fishes are ecologically-important because they are forage for many marine and freshwater fish predators such as striped bass (*Morone saxatilis*), cod (*Gadus morhua*), and yellow perch (*Perca flavescens*) as well as birds (Loesch, 1987). In addition, they are a key link in the transfer of nutrients between freshwater and marine systems (Mullen et al., 1986). River herring provide recreational and cultural benefits to citizens who value them for food and bait.

In the early to mid-2000s, river herring abundance in several runs throughout Massachusetts declined to historical low levels. The declines prompted the Massachusetts Division of Marine Fisheries (DMF) to establish in 2005 a three-year moratorium on the sale and harvest of river herring throughout the state, which has been extended to the present day. Since the harvest ban, river herring abundance has increased in many runs throughout coastal Massachusetts, but remains depressed in others. This report summarizes historical and current data on abundance, population characteristics, and mortality of river herring for the determination of the status of the stocks.

7.2. MANAGEMENT UNIT DEFINITION

River herring runs in Massachusetts are managed directly by DMF or by Town governments that have local control management plans approved by DMF.

7.3. FISHERY REGULATIONS

Currently, the Commonwealth of Massachusetts is in the 12th year of a harvest moratorium for river herring. Starting with the 2006 season, the moratorium was scheduled to expire on January 1, 2009, but lack of recovery prompted an extension of the moratorium through 2011. The Massachusetts Marine Fisheries Advisory Commission approved in November of 2008 the following regulations on the Harvest, Possession and Sale of River Herring in the Commonwealth, 322-CMR Section 6:17:

Purpose. 322 CMR 6.00 is promulgated to establish consistent state management of river herring fisheries.

Definitions.

- (a) "River Herring" means those species of fish known as alewives (*Alosa pseudoharengus*) and bluebacks (*Alosa aestivalis*).
 - (b) "Batch" means all fish in any separate container.
 - (c) "Container" means any box, tote, bag, bucket or other receptacle containing loose fish which may be separated from the entire load or shipment.
 - (3) Taking and Possession of River Herring in Waters under the Jurisdiction of the Commonwealth. It shall be unlawful for any person to harvest, possess or sell river herring in the Commonwealth or in the waters under the jurisdiction of the Commonwealth.
- Exceptions. The Director may authorize the harvest and possession of river herring from a particular spawning run for personal use based on documentation that the spawning run from which herring are harvested is not depleted.
- Tolerance for bait fisheries. No person shall possess any batch of fish where more than 5% of the total is comprised of river herring species by count.
- (6) Expiration. These measures shall expire on January 1, 2012. (*updated and current*)

7.4. ASSESSMENT HISTORY

No assessments of river herring populations in Massachusetts were conducted prior to the present effort that used 2004-2010 data. Three major efforts have been made by the Division of Marine Fisheries (and predecessor agency) to survey the presence and status of river herring runs and in the last century (Belding 1921; Reback et al. 1972; and Reback et al. 2004-5). These surveys provide valuable information on the presence of runs, fish passage, and fisheries, but did not attempt to quantify population abundance.

7.5. GENERAL LIFE HISTORY

Both blueback herring and alewives are found in many coastal stream systems in Massachusetts. While both species are capable of spawning in a variety of freshwater environments in Massachusetts, bluebacks typically spawn in more riverine areas, while alewives tend to spawn in more lacustrine (ponds and lakes) areas. Alewives begin to spawn in late March to mid-May when water temperatures reach about 10.5°C, but they have been observed in Massachusetts streams as early as February and, in one instance, January. Bluebacks begin to spawn later in the spring (late April through June) when water temperatures reach about 13.9°C. Blueback eggs are semi-buoyant and tend to drift with the current while alewife eggs will remain in contact with the substrate. After utilizing the freshwater habitat for a nursery area juvenile herring begin their migration to the ocean in late June to early July (Gahagan et al. 2010). Peak migration occurs in September on Cape Cod (Kosa and Mather, 2001; Yako et al., 2002) and it continues through December. Once in the marine environment, river herring feed on zooplankton such as microcrustaceans, fish eggs and fish larvae (Munroe, 2002). Maturity occurs between 2 to 5 years of age and the fish return to their natal streams utilizing their olfactory sense to guide them to home waters.

7.6. HABITAT DESCRIPTIONS

With over 100 river herring runs in Massachusetts there is a wide range of habitat types used by anadromous alewife and blueback herring. Many habitats have been altered from natural states by watershed development and dam construction. The typical alewife run has a corridor of migratory habitat that transitions from intertidal to freshwater river and leads to a freshwater pond used for spawning and nursery habitat. Other habitats used by alewife include man-made ponds, large reservoirs, brackish tidal ponds, and main stem rivers. Blueback herring can use the same habitat types as alewife but show a tendency to favor lotic environments. The Division of Marine Fisheries has an ongoing investigation to assess the suitability of river herring spawning and nursery habitats (Chase 2010) that will contribute additional information on water quality and habitat requirements.

7.7. RESTORATION PROGRAMS

Massachusetts' statutes direct the Division of Marine Fisheries to work with Towns to sustain river herring runs, manage fisheries and provide fish passage. The Division of Marine Fisheries has maintained a fishway crew since 1934. This ongoing program has focused on sustaining and restoring passageways for adult river herring migration and juvenile herring emigration. The present program continues this tradition with additional efforts aimed at collaborative projects, spawning and nursery habitat restoration and other diadromous fish species.

7.8. AGE

Age samples have been recorded in the Monument River since 1980. Outside of the Monument River few efforts were made to age river herring in Massachusetts until the present assessment for 2004-2015. All available river herring age data in Massachusetts are summarized in the following sections.

7.9. FISHERY DESCRIPTIONS

7.9.1. Commercial Fishery

Historically, river herring were one of the most valuable anadromous fishes harvested commercially in Massachusetts and sold as food or commercial bait (Belding, 1921). Prior to the 1950s, annual landings were 5 million pound or less (Appendix Table 1; Figure 7.1). Landings increased dramatically during the late 50s-early 60s (peak: 33 million pounds in 1958) as foreign fleets, using purse seines, exploited herring on Georges Bank (Appendix Table 1; Figure 7.1). By the early-1980s, after the establishment of the exclusive economic zone, river herring landings became a small fraction of the historical highs with most harvest occurring in spawning runs. Regulation of harvest limits in 1989 (25 fish/day) by the Commonwealth of Massachusetts restricted landings further and by 1994, there was little river herring sold commercially at fish houses (Appendix Table 1; Figure 7.1). Since 2005, there has been a moratorium on the possession and sale of river herring in Massachusetts.

The landings data reported by NMFS are underestimated because of poor or no record-keeping of harvest by towns with herring runs. Since the 1980s, DMF has collected annual harvest data from the towns of Middleboro, Bourne, and Mattapoisett with herring runs on the Nemasket River, Monument River and Mattapoisett River, respectively (Figure 7.2).

7.9.2. Bycatch in Commercial Fisheries

The issue of river herring bycatch has received much attention recently. Bycatch of river herring does occur in commercial fisheries that are targeting other species. Quantification of this take is difficult to estimate and efforts are being made to improve monitoring and reporting of this source of mortality. The commercial mid-water trawl, pair trawls, bottom trawl and purse seine fisheries for Atlantic herring are a point of focus. Cieri et al. (2008) reported that bycatch of river herring from the Atlantic herring fishery ranged from 171,973 pounds to 1.68 million pounds during 2005-2007. Catch caps were created for mid-water trawl and bottom trawl fishermen pursuing Atlantic herring and Atlantic mackerel in 2014. Periodic reports of by-catch are also received from the long fin and short fin squid, whiting, and northern shrimp fisheries as well as menhaden bait fisheries. Reports are often anecdotal and not well documented. In addition small numbers of illegal harvest (poaching) are usually reported to the MA Environmental Police each spring. These types of losses contribute to the total mortality of alewife and blueback herring but the actual extent and amount is poorly known at this time. In the Atlantic herring fishery, only 5% of the total landings are allowed to contain river herring as bycatch. In response to these bycatch issues, in 2008, DMF initiated a comprehensive monitoring program for river herring bycatch in the Atlantic herring fishery. In 2010 DMF, SMAST, and the mid-water trawl fleet created a collaborative River Herring Bycatch Avoidance Program (RHBA), with a goal of reducing at-sea bycatch by 50%. A subsequent RHBA was created with small-mesh bottom trawl herring fishermen in late 2011. Recently, a comprehensive evaluation of the first four full years of the mid-water trawl RHBA (2011-2014) found that the RHBA program coincided with a 58% reduction in bycatch from the previous four year period (2007-2010), with the overall fishery bycatch rate being reduced by 21% (Bethoney et al. In Press).

7.9.3. Recreational Fishery

Historically, river herring were commonly harvested for food in coastal towns in Massachusetts. Recreational use in recent decades was mainly for bait in the striped bass fishery. The discontinued Marine Recreational Fisheries Statistics Survey (MRFSS) estimated of the numbers of river herring

harvested and released by anglers in Massachusetts are very imprecise and show little trend (Appendix Table 2). Since spring of 2005, there has been no recreational (bait) fishery for alewife and/or blueback herring allowed in the Commonwealth of Massachusetts.

7.9.4. Subsistence Fishery

The only subsistence river herring fishery currently conducted within Massachusetts is under a Memorandum of Understanding (MOU) between the Commonwealth and the federally recognized Mashpee Wampanoag Indian Tribe on Cape Cod. This understanding recognizes the Tribe's aboriginal fishing rights and allows harvesting of river herring by Tribal members which is regulated by the Tribe pursuant to the Tribe's regulatory authority. Reported harvests were provided to DMF for 2010-2013 and ranged from about 1,200 fish to 3,500 fish per year, with removals coming from several rivers. No reporting has occurred since 2013.

7.9.5. Stocking Efforts

DMF conducts a trap and transport stocking program for alewife and blueback herring. The three major objectives are to: 1) maintain and enhance existing populations, 2) restore historically important populations and 3) create new populations where feasible. Stocking of gravid river herring where river access has been provided or improved is generally conducted for three or more consecutive years per system. Prior to the moratorium the program transported between 30,000 and 50,000 fish per year into ten to fifteen different systems. A DMF stocking protocol was developed and implemented in 2013 that provided criteria for stocking decisions and a focus to allow remnant populations present at restoration sites to naturally re-colonize habitat prior to the introduction of donor stock genetics. The protocol has reduced stocking activity with most recent efforts occurring with-in drainage, moving fish upstream past multiple obstructions to the headwater spawning habitat.

7.10. FISHERIES-INDEPENDENT MONITORING

Data on alewife and blueback herring in Massachusetts come from mostly historical and/or current work conducted by DMF, academic and federal scientists, and local citizen groups interested in protecting river herring resources. Figure 7.3 shows the rivers and locations for which fisheries-independent data are available. In this document, "passage" estimates are considered herring counts that, when added to the harvest estimates, may not produce the total amount of herring in the river system because the count location is situated above viable spawning habitat of river herring (e.g., Nemasket River). "Escapement" estimates are considered herring counts that, when added to harvest estimates, produce the total amount of river herring in the system because the harvest and count locations are situated close to the river mouth (e.g., Monument River). In 2013, DMF began using otoliths rather than scales to age river herring. All scales are now archived, with the exception of Monument alewife, which are still processed to generate repeat spawning rate estimates. The following gives a brief description of data available:

Acushnet River (New Bedford) - Since 2005, DMF has conducted a census of river herring entering the spawning ground using a fish trap. Simultaneous estimation of passage by using an electronic counter began in 2008, and video counting was attempted in 2008. DMF has also collected biological samples from dead fish, but samples were non-random and sample sizes were too small to use in this assessment. This location monitors the herring run response to fish passage restoration.

Agawam River (Wareham) - The town of Wareham has been estimating combined passage using an electronic counter since 2006. Biological data are available from only 1991.

Back River (Weymouth) - The town of Weymouth's herring warden provides a "relative" passage estimate from his daily observations of run activity. No statistically-valid design is used. In 2007, DMF characterized the alewife population under an NOAA Anadromous Fish Conservation Act grant. DMF collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River below). DMF resumed collecting biological data and installed a SR-1601 Electronic Resistivity Counter in 2015.

Bound Brook (Scituate) - The North and South Rivers Watershed Association began passage counts using visual estimation in 2010. No statistical design was used. There are no biological data available.

Charles River (Boston) - The University of Massachusetts with assistance of DMF conducted video counts in 2008 and 2009. DMF conducted video counts in 2013 and 2014. Biological data are available from 1985, 1993, 2013, and 2014.

Connecticut River (Holyoke) - Fishlift counts have been made at the Holyoke Dam since 1967 for blueback herring by the US Fish and Wildlife Service. The numbers are used by the State of Connecticut in their river herring assessment; therefore, the information is not discussed herein to avoid duplication of effort.

Coonamessett River (Falmouth) - Falmouth Department of Natural Resources has been estimating passage using visual estimation since 2005. There are no biological data available.

Herring Brook, First (Scituate) - The North and South Rivers Watershed Association conducted passage counts using visual estimation in 2005-2006. No statistical design was used. There are no biological data available.

Herring Brook, Second (Norwell) - The North and South Rivers Watershed Association conducted passage counts using visual estimation in 2005-2006. No statistical design was used. There are no biological data available.

Herring Brook, Third (Norwell/Hanover) - The North and South Rivers Watershed Association conducted passage counts using visual estimation in 2003, and 2005-2006. No statistical design was used. There are no biological data available.

Herring River (Wellfleet) - The Association to Preserve Cape Cod has been estimating passage numbers using visual counting since 2007. There are no biological data available.

Herring River (Harwich) - The Association to Preserve Cape Cod has been estimating passage numbers using visual counting since 2007. DMF began collecting biological data and installed a SR-1601 Electronic Resistivity Counter in 2016.

Ipswich River (Ipswich) - The Ipswich Watershed Association has been estimating passage using visual counting since 2000. They've attempted to use the statistical design of Rideout et al. (1979) but prior to 2005, effort was not sufficient to provide reliable estimates. In 2006-2008, DMF also made census counts by using a fish trap. There are no biological data available.

Jones River (Kingston) - The Jones River Watershed Association has been conducting passage counts using visual estimation since 2005. There are no biological data available. No statistically-valid design was used.

Little River (Gloucester) - Massachusetts Audubon made passage counts using visual estimation during 2000-2002, 2005, and 2009. There are no biological data available. No statistically-valid design was used.

Marston-Mills River (Marston-Mills) - Starting in 2007, a local watershed group provides visual counts of combined herring passage at Mill Pond dam in the Marston-Mills River. They use a stratified random design. There are no historical or current data on population characteristics.

Mattapoisett River (Mattapoisett) - Since 1988, Alewives Anonymous has provided passage counts of alewife using an electronic fish counter. Harvest data are also provided. In 1995, 2006 and 2007, DMF collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River below).

Merrimack River (Lawrence) - The number of herring lifted at the Essex and Pawtucket Dam fishlifts since 1983 are provided by the US Fish and Wildlife Service. In 2014, DMF began collecting 100 herring a week from the Essex Dam fish lift to biologically characterize this population.

Monument River (Bournedale) - DMF has been scientifically monitoring the abundance, sex composition, length structure, age composition and removals of alewife and blueback herring in the Monument River since the early 1980s (Churchill, 1981; O'Hara, 1980; Brady, 1987a, b). Prior to 1985, abundance was estimated by using visual counts following the statistical design of Rideout et al. (1979). Since 1985, escapement has been estimated by using a Smith-Root electronic fish counter that is calibrated daily. Fish entering the system are sampled weekly by using a dipnet. Ages are determined from otoliths and scales are used to identify repeat spawners and are also aged using the criteria of Rothschild (1963), Marcy (1969) and Kornegay (1977). Fish samples are used to apportion abundance into species- and sex-specific estimates (Brady, 1987). In the past, DMF often used herring from this river as donor stock to other river systems. All numbers transported are added to harvest recorded by the Bournedale fish warden to get total number of removals. Scale ages are only available for 1984-1987, 1993, and 1995-present. Since the counting location is not far above the catchment basin where herring are removed, and both are close to the river mouth, the total run size is estimated by adding escapement counts to removal numbers.

Mystic River (Boston) - DMF has collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations since 2004 (see Monument River above). Beginning in 2012, the Mystic River Watershed Association began a visual count estimate using the statistical method of Nelson (2006).

Nemasket River (Middleboro) - Since 1996, the town of Middleboro has provided visual counts of alewife passage at the fishway off Wareham Street (river mile 7.5). The statistical design of Rideout et al. (1979) is used. Since 2004, DMF has characterized the alewife and blueback populations under an NOAA Anadromous Fish Conservation Act grant. DMF has collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River above).*Parker River (Newbury)* - Students and researchers at the University of Massachusetts, Amherst conducted several studies during the 1970s that provide information on juvenile and adult population characteristics,

abundance and migration of alewives (Beltz, 1975; Cohen, 1976; Cole et al., 1976; Cole et al., 1978; Huber, 1974; Jimenez, 1978; Libey, 1976; Mayo, 1974; Rideout et al., 1979). Since 1997, the Parker River Clean Water Association has been estimating passage numbers at the first dam using visual counting and the statistical design of Nelson (2006). In 2014, DMF installed a video system to better estimate passage at the first dam. Due to high flood waters of 2005 and 2006, a weir failed, making it difficult for alewives to pass. The weirs were repaired in the summer of 2013 and additional modifications were made to the fishway in 2014. Passage counts between 2005 and 2014 may have been biased. Since 2012, DMF has collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River above).

Pilgrim Lake (Orleans) - The Association to Preserve Cape Cod has provided abundance estimates of alewife passage using visual counting and a stratified random design since 2008.

Quashnet River (Falmouth/Mashpee) - In 2004, DMF characterized the alewife population under an NOAA Anadromous Fish Conservation Act grant. DMF collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River above). There are no estimates of passage numbers available.

Sippican River (Wareham) - Alewives Anonymous made electronic census counts of alewife passage in 1995-2002 and 2006. There are no biological data available.

South River (Marshfield) - The North and South Rivers Watershed Association conducted passage counts using visual estimation in 2006, 2008 and 2010. No statistical design was used. There are no biological data available.

Stony Brook (Brewster) - The Association to Preserve Cape Cod has provided estimates of alewife passage numbers at the lower Mill Pond dam using visual counting and a stratified random design since 2007. In 2004, DMF characterized the alewife population under an NOAA Anadromous Fish Conservation Act grant. DMF collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River above). Mr. George A. Kurlycheck, a Middle School teacher in Harwich, collected average size data on alewife (sexes combined) from 1978-2001.

Town Brook (Plymouth) - DMF has collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations since 2004 (see Monument River above). The town of Plymouth, University of Massachusetts, and DMF have made visual counts since 2008 and video counts were made in 2008 and 2009.

Town River (Bridgewater) - The town of Bridgewater has made combined electronic passage counts of river herring (species combined) since 2000. There are no biological data available.

Trunk River (Falmouth) - Falmouth Department of Natural Resources has been estimating passage since 2008. No statistical design is used. There are no biological data available.

Wankinco River (Wareham) - The town of Wareham has made combined electronic passage counts since 2007. There are no biological data available.

7.10.1. Trends in Run Size

The river estimates of passage counts and total run size used in this assessment came from the Mattapoisett River, Monument River, Nemasket River, Parker River, and Town River (Appendix Table 3; Figure 7.4). Some river estimates were deemed limited and not used for this assessment because 1) lack of statistical design (e.g., Back River), 2) non-reflectance of natural abundance trends (e.g., Merrimack River), or 3) shortness of time series (e.g., Marston-Mills River, Stony Brook, and Town Brook).

Mattapoisett River

Alewife - Passage estimates of alewife showed increasing trends in numbers from 22,000 fish in 1988 to 130,000 fish in 2000 (Appendix Table 3; Figure 7.4). Passage estimates dropped precipitously through 2004 to 5,385 fish. Passage size has increased gradually to 55,429 fish in 2014 (Appendix Table 3; Figure 7.4).

Monument River

Alewife - A fluctuating, but increasing trend in total run size was evident from 1980 to 2000, peaking at about 597,937 fish (Appendix Table 3; Figure 7.4). Thereafter, it dropped precipitously through 2002 to 182,031 fish, and then continued to decline through 2006 to the lowest level observed in the time series (52,472 fish). Alewife abundance has increased gradually since 2007 to an average of about 131,448 fish, with run counts exceeding 200,000 individuals in 2014 and 2015. (Appendix Table 3; Figure 7.4).

Blueback - Total run size was highest during 1980-1991, averaging about 64,800 fish. Abundance was lower on average (41,000 fish) during 1992-2002 and it began to decline in 2003 to 8,140 fish in 2007 (Appendix Table 3; Figure 7.4). Abundance increased to 18,532 and 30,356 fish in 2008 and 2009, respectively, but dropped to 9,358 fish in 2010 (Appendix Table 3; Figure 7.4). Since 2010, abundance has fluctuated between 13,632 (2011) and 101,863 (2013) herring.

Nemasket River

Alewife - Passage numbers of alewife have fluctuated considerably since 1996 (Appendix Table 3; Figure 7.4). Passage numbers averaged 720,000 fish prior to 2002, but following the peak (1.4 million fish), numbers declined through 2005 to 226,000 fish. Since 2007, numbers have increased to 565,000 fish on average (Appendix Table 3; Figure 7.4).

Parker River

Alewife - Passage counts of alewives and blueback herring fluctuated considerably during the 1970s, peaking at 38,163 fish in 1973 and then declining to an average of 11,256 fish between 1976-1978. Passage counts were as high as 7,894 fish in 2000, exceeding the 1977 estimate of 6,654 fish, but declined to low levels by 2005 (Appendix Table 3; Figure 7.4). Since 2008, passage numbers have increased. It is very likely that passage conditions obscure population trends at this site.

Town River

Alewife/Blueback - Passage numbers of alewife and blueback herring (combined) have fluctuated considerably since 2000 (Appendix Table 3; Figure 7.4). Passage numbers were as high 310,000 fish

in 2003. In most years, however, passage numbers averaged only 32,149 fish (Appendix Table 3; Figure 7.4). During the period 2012-2014, passage and counts at Town River were affected by extreme low flows, dam and fishway degradation, and counter failures, making counts for those years inaccurate or non-reflective of abundance trends.

7.10.2. Trends in Size Structure

Raw length frequencies available for each river, species and sex are shown in Appendix Tables 4-5, and summary statistics for the length distributions are shown in Appendix Tables 6-7. Males of each species are smaller in length than females of the same species, and blueback herring are smaller in length than alewives. Comparison of average sizes among rivers showed that alewives collected in the Monument River, Mystic River, Quashnet River, Stony Brook, and Town Brook were about 10-30 mm smaller than alewives collected in the Back, Mattapoisett, Parker, and Nemasket rivers (Appendix Tables 6 and 7). Mean total length of both species and sexes from the Monument River declined from 1984 through the mid-1990s (Appendix Table 7; Figure 7.5). Female and male alewives and blueback herring sampled during 2011-2015 were about 20-25 mm smaller, on average, than alewives and blueback herring of the same sex sampled during 1984-1987 (Appendix Table 7). Mean total length of alewife (sexes combined) in Stony Brook showed a similar decline over time (Figure 7.5).

7.10.3 Trends in Age

Any available age data regardless of the length of the time series were used in this assessment. Raw data are presented in Appendix Tables 8 and 9. Mean age is presented in Appendix Table 10.

Agawam River

Alewife - Age samples (n=71 for females; n=86 for males) were available from 1991. The youngest and oldest alewives observed on the run were ages 3 and 7, respectively, for females and ages 3 and 6, respectively, for males (Appendix Table 8; Figure 7.6). Mean ages for female and male alewife in 1991 were 4.6 and 4.3 years, respectively (Appendix Table 10).

Blueback - Age samples (n=6 for females; n=7 for males) were available from 1991. These sample sizes were too small to provide accurate observation mean sizes, gender differences and the youngest and oldest ages of blueback herring in the run. (Appendix Table 10).

Back River

Alewife - Age samples (n=210 for females; n=228 for males) were available from 2007 for alewife only. The youngest and oldest alewives observed in the run were ages 3 and 8, respectively, for females and ages 3 and 7, respectively, for males (Appendix Table 8; Figure 7.6). Mean ages for female and male alewife in 2007 were 4.2 and 4.0 years, respectively (Appendix Table 10).

Charles River

Alewife - Age samples were available from 2013-2014 for alewife. The youngest and oldest alewives observed in the run were ages 3 and 6, respectively, for both females and males (Appendix Table 8; Figure 7.6). Mean ages for female and male alewife in 2007 were 4.2 and 4.0 years, respectively (Appendix Table 10).

Blueback - Age samples were available from 1985-1993 and 2012-2014. The youngest and oldest alewives observed in the run were ages 2 and 10, respectively, for females and ages 2 and 7, respectively, for males (Appendix Table 8). Mean ages for female and male alewife were 5.2 and 4.4 years in 1985, respectively, and 4.8 and 4.0 in 1993 (Appendix Table 10).

Mattapoisett River

Alewife - Age samples were available from 1995 and 2006. The youngest and oldest alewives observed in the run were ages 3 and 7, respectively, for females and 3 and 6, respectively, for males (Appendix Table 8; Figure 7.6). Mean ages for female and male alewife were 4.8 and 4.4, respectively, in 1995 and 3.9 and 3.7 years, respectively, in 2006 (Appendix Table 10) indicating a possible decline between the two years.

Monument River

Alewife - The earliest time series (1985-1987) of age composition data come from Brady (1987a). The youngest and oldest individuals observed in the run during 1985-1987 were age 3 and 8 for females, and age 3 and 7 for males, respectively (Appendix Table 9). Ages 4-5 were the most abundant age-classes in the spawning run. From 1993-2015, the youngest and oldest individuals observed on the run were age 2 and 8 for both sexes, respectively, although ages older than 6 were observed infrequently (Appendix Table 9). Ages 4 and 5 were the most abundant age-classes. Comparison of the age compositions between 1984-1987 and later years indicated that the maximum age of male and female alewife has decreased by one to two years. Comparison of mean ages during 1985-1987 to mean ages during 1993-2015 indicated a decline in mean age over time (Appendix Table 10; Figure 7.7).

Blueback - The earliest time series (1985-1987) of age composition data come from Brady (1987b). The youngest and oldest individuals of both sexes observed in the run during 1985-1987 were age 3 and 7, respectively (Appendix Table 9). Ages 4-5 were the most abundant age-classes in the spawning run. From 1993-2015, the youngest and oldest individuals observed on the run were age 3 and 6, respectively, for both sexes, except in 1997 and 2008 (Appendix Table 9). Ages 4 and 5 were the most abundant age-classes. Comparison of the age compositions over time indicated that the maximum age of male and female alewife has decreased by one to two years. Comparison of mean ages during 1985-1987 to mean ages during 1993-2015 indicated a decline in mean age over time (Appendix Table 10; Figure 7.7).

Mystic River

Alewife - Age compositions of both sexes of alewife from 2004-2015 were composed of ages 2-9 with peak numbers occurring mostly at ages 4 and 5 (Appendix Table 8). Mean age ranged from 3.9 to 4.7 years for females and from 3.5 to 4.3 years for males (Appendix Table 10).

Blueback - Age samples for blueback herring were available from 2005-2015. The youngest and oldest individuals of both sexes observed in the run were age 2 and 8, respectively (Appendix Table 8). Ages 4 and 5 were the most abundant age-classes. Mean age ranged from 3.2 to 4.5 years for females and from 3.2 to 3.8 years for males (Appendix Table 10).

Nemasket River

Alewife - The youngest and oldest individuals observed in the run during 2004-2015 were age 3 and 8, respectively for females and age 2 and 8, respectively for males (Appendix Table 8). Ages 4-5 were the most abundant age-classes. Mean age ranged from 3.4 to 5.3 years for females, and from 4.9 to 3.3 years for males (Appendix Table 10).

Parker River

Alewife - The earliest time series (1971-1978) of age composition data come from studies of alewife by Cole et al. (1976), Cole et al. (1978), and Mayo (1974). In this period, the youngest and oldest alewives of both sexes observed in the run were age 3 and 9, respectively. Ages 4-6 were the most abundant age-classes in the spawning run, although ages 7-8 were common. Average age from 1971-1978 ranged from 4.3 to 6.0 years for females, and from 4.0 to 5.7 for males (Appendix Table 10). The time series begun in 2011 suggests that the age structure of alewife in the Parker River has become more truncated. The youngest and oldest female alewife observed between 2011-2015 were age 3 and 7, respectively. The youngest and oldest males were age 2 and 8, respectively. For both sexes ages 3-5 were the most abundant age-classes with few older fish (Appendix Table 8). Average age from 2011-2014 ranged from 3.6 to 4.5 for females and 3.4 to 4.3 for males (Appendix Table 10).

Blueback - Age samples for blueback herring were available from 2011-2015. The youngest and oldest females observed between 2011-2015 were age 3 and 7, respectively. The youngest and oldest males were age 2 and 6, respectively. For both sexes ages 3-5 were the most abundant age-classes with occasional older fish (Appendix Table 8). Average age from 2011-2014 ranged from 3.2 to 4.1 for females and 3.2 to 3.9 for males (Appendix Table 10).

Quashnet River

Alewife - During 2004, the youngest and oldest individuals observed in the run were age 3 and 5 for both sexes, respectively (Appendix Table 8). Age 4 was the most abundant age-class. Mean ages for female and male alewife in 2004 were 4.3 and 3.9 years, respectively (Appendix Table 10).

Blueback - No description of the age composition is made because only 8 individuals were aged (Appendix Table 8).

Stony Brook

Alewife - During 2004, the youngest and oldest individuals observed in the run were age 3 and 7 for females, and age 3 and 6 for males, respectively (Appendix Table 8). Ages 4-5 were the most abundant age-classes. Mean ages for female and male alewife in 2004 were 4.5 and 4.1, respectively (Appendix Table 10).

Town Brook

Alewife - The youngest and oldest individuals observed in the run during 2004-2015 were age 3 and 8 for females and age 2 and 7 for males, respectively (Appendix Table 9). Age 4 was the most abundant age-class for both sexes. Mean age ranged from 3.7 to 4.9 years for females and from 3.4 to 4.6 years for males (Appendix Table 10).

Blueback - No description of the age composition is made because only 10 were aged.

7.10.4. Trends in Mean Length-At-Age

Mean length-at-age data for alewife and blueback herring from the Monument River were plotted by sex and year to determine if changes in growth have occurred over time (Figure 7.8). Unfortunately, data from 1984-1987 were not available for historical comparison. Mean length-at-age of alewife for ages 3-5 of both sexes has gone through several declines and increases over the 23 year time series. Mean lengths plateaued during 2012-2014 and decreased in 2015 (Figure 7.8). Mean length-at-age for blueback herring has varied without trend (Figure 7.8).

7.10.5. Trends in Proportions and Repeat Spawners

The frequencies of new and repeat spawners determined by reading spawning checks on scales are listed in Appendix Table 11 and 12 by species, river, sex and year. The proportions that repeat spawners comprised the total samples are given in Table 7.1. After 2013, repeat spawning frequency was determined for Monument River alewife only.

Agawam River

Alewife - The proportion of repeat spawners for female and male alewife in 1991 was 0.11 and 0.10, respectively (Table 7.1).

Blueback - The proportions of repeat spawners for female and male blueback herring were not calculated due to small sample size (Table 7.1).

Back River

Alewife - The proportion of repeat spawners for both sexes was 0.11 in 2007 (Table 7.1).

Charles River

Blueback - The proportions of repeat spawners for female blueback herring were 0.54 in 1985, 0.44 in 1993, 0.36 in 2012, and 0.14 in 2013. For males, the proportions were 0.49 in 1985, 0.25 in 1993, 0.14 in 2012, and 0.13 in 2013 (Table 7.1). Data for both sexes indicate a possible decline in the fraction of repeat spawners.

Mattapoisett River

Alewife - The proportions of repeat spawners for female alewife were 0.33 in 1995 and 0.04 in 2007. For males, the proportions were 0.19 in 1995 and 0.03 in 2007 (Table 7.1). Data for both sexes indicate a possible decline in the fraction of repeat spawners.

Monument River

Alewife - The earliest time series (1986-1987) of repeat spawner data come from Brady (1987a). During 1986-1987, the estimated proportions of repeat spawners for females ranged from 0.44 to 0.45, and those for males ranged from 0.39 to 0.41 (Table 7.1). From 1993-2015, proportions of

repeat spawners ranged from 0.01-0.41, but most were ≤ 0.29 . Since 2003, the proportions of repeat spawners have been ≤ 0.19 .

Blueback - The earliest time series (1986-1987) of repeat spawner data come from Brady (1987b). During 1986-1987, the estimated proportions of repeat spawners for females ranged from 0.38 to 0.39, and those for males ranged from 0.20 to 0.22 (Table 7.1). From 1993-2013, proportions of repeat spawners ranged from 0.00-0.27, but most were ≤ 0.20 . Since 2003, the proportions of repeat spawners have been ≤ 0.14 .

Mystic River

Alewife - The estimated proportions of repeat spawners for female and male alewife varied without trend (range: 0.0 in 2006 to 0.46 in 2012 for females; 0.0 in 2006 to 0.34 in 2012 for males) (Table 7.1).

Blueback - The estimated proportions of repeat spawners for female and male blueback herring varied without trend (range: 0.03 in 2005 to 0.52 in 2012 for females; 0.06 in 2005 to 0.49 in 2012 for males) (Table 7.1).

Nemasket River

Alewife - The estimated proportions of repeat spawners for females and males were high in 2004 (0.43 for females; 0.44 for males) but declined thereafter to ≤ 0.30 for females and ≤ 0.29 for males (Table 7.1).

Quashnet River

Alewife - The estimated proportions of repeat spawners for both sexes were ≤ 0.07 in 2004 (Table 7.1).

Blueback - No estimates of proportions of repeat spawners were produced because of low sample sizes (Table 7.1).

Stony Brook

Alewife - The estimated proportions of repeat spawners for both sexes were ≤ 0.21 in 2004 (Table 7.1).

Town Brook

Alewife - The estimated proportions of repeat spawners for female and male alewife were low (≤ 0.17) prior to 2007, but increased above 0.17 thereafter (Table 7.1).

Blueback - No estimates of proportions of repeat spawners were produced because of low sample sizes (Table 7.1).

7.10.6. Trends in Total Instantaneous Mortality Rates

The Chapman-Robson survival estimator (Chapman and Robson, 1960; Murphy, 1997) was applied to the annual age frequency data to generate estimates of survival rate (S) for each species, sex and year. Total instantaneous mortality rate (Z) was estimated by the natural-log transformation of S . For age data, the first age-at-full recruitment was the age with the highest frequency. Only Z estimates made from data with three or more age-classes (including first fully-recruited age) were deemed valid.

Estimates of Z from the age data by species and sex are given in Appendix Table 13 and are plotted in Figures 7.9 and 7.10. Although Z estimates were made for alewife and blueback herring from several rivers, long time series of Z estimates from which change could be detected were available only from the Monument River. Estimates for each river are summarized below:

Agawam River

Alewife – The Z estimates for females and males in 1991 were 0.96 and 1.18, respectively. (Appendix Table 13; Figure 7.9).

Blueback – The Z estimate for females in 1991 0.81. The Z estimate for males in 1991 was not valid (Appendix Table 13; Figure 7.10).

Back River

Alewife - The Z estimates for females and males in 2007 were 1.24 and 1.64, respectively. (Appendix Table 13; Figure 7.9).

Charles River

Blueback - The Z estimates for females and males in 1985 were 0.67 and 0.96, respectively. (Appendix Table 13; Figure 7.10). In 1993, the Z estimates were 1.19 for females and 1.05 for males (Appendix Table 13; Figure 7.10). From 2012-2014, Z estimates for females ranged from 0.81 (2012) to 1.31 (2014), while those for males ranged from 0.84 (2013) to 1.41 (2014) (Appendix Table 13; Figure 7.10).

Mattapoisett River

Alewife - Z estimates for females and males in 1995 were 0.72 and 0.94, . During 2006-2007, a Z estimate was only available for females in 2007 and was 1.1 (Appendix Table 13; Figure 7.10).

Monument River

Alewife - For 1985-1987, Z estimates from age frequency data ranged from 0.76 (1987) to 1.04 (1985) for females and from 0.84 (1987) to 1.03 (1986) for males (Appendix Table 13; Figure 7.9). For 1993-2015, Z estimates from age frequency data ranged from 0.87 (1993) to 2.4 (2014) for females and from 1.02 (1993) to 1.99 (2011) for males. Age structure was too truncated for females in 2015 and for males in 2014 and 2015 to provide valid estimates (Appendix Table 13). Comparison of Z estimates showed an increase in total mortality over the time series for both sexes (Figure 7.9).

Blueback - For 1985-1987, Z estimates from age frequency data ranged from 0.98 (1985) to 1.49 (1986) for females and from 1.06 (1987) to 1.27 (1985) for males (Appendix Table 13; Figure 7.10). For 1993-2015, Z estimates from age frequency data ranged from 0.75 (1993) to 1.93 (2015) for females and from 0.76 (2001) to 2.12 (2015) for males (Appendix Table 13; Figure 7.10). Comparison of Z estimates from age and repeat spawner data showed no trend in total mortality over the time series for both sexes, although the most recent two years have been among the highest values (Figure 7.10).

Mystic River

Alewife - Z estimates for females during 2004-2015 ranged from 0.93 (2015) to 1.58 (2004) (Appendix Table 13; Figure 7.9). For males, Z estimates during 2004-2015 ranged from 0.88 (2005) to 2.23 (2007)(Appendix Table 13; Figure 7.9).

Blueback - Z estimates for females during 2004-2015 ranged from 0.86 (2008) to 2.25 (2011) (Appendix Table 13; Figure 7.10). For males, Z estimates during 2004-2015 ranged from 0.83 (2012) to 1.99 (2015)(Appendix Table 13; Figure 7.10).

Nemasket River

Alewife - Z estimates for females during 2004-2015 ranged from 0.95 (2010) to 2.31 (2014) (Appendix Table 14; Figure 7.9). For males, Z estimates during 2004-2015 ranged from 0.93 (2009) to 2.13 (2015) (Appendix Table 13; Figure 7.9).

Stony Brook

Alewife - Z estimates for Stony Brook alewife were only available in 2004. The Z estimates were 1.96 for females (Appendix Table 13; Figure 7.9) and 1.3 for males (Appendix Table 13; Figure 7.9).

Town Brook

Alewife - Z estimates for females during 2004-2010 ranged from 0.84 (2010) to 2.16 (2015) (Appendix Table 13; Figure 7.9). For males, Z estimates during 2004-2015 ranged from 0.87 (2009) to 1.93 (2015)(Appendix Table 13; Figure 7.9).

7.10.7. Trends in Age-1 Indices of Relative Abundance

Relative indices of age-1 abundance for alewife and blueback herring from the DMF trawl survey are shown in Figure 7.11 for areas north and south of Cape Cod. Indices of relative abundance of alewife fluctuated without trends during 1978-2015 and were generally lower south of Cape Cod.

7.11. CONCLUSIONS AND RECOMMENDATIONS

The following is a short list of many potential causes of the changes in abundance, population characteristics and dynamics of alewife and blueback herring in Massachusetts acting singly or synergistically:

Environmental Changes - Changes in weather as a result of climate change can impact many aspects of the alewife and blueback life stages. Changes in rainfall patterns could affect the food production in

the nursery areas and cause higher mortality of juveniles as competition for limited zooplankton resources is believed a major factor affecting survival and growth of juveniles (Walton 1983). Such changes can cause shifts in the carrying capacity of a nursery ground and ultimately affect recruitment. Another potential impact of changes in rainfall is on the migration patterns of juvenile herring. It is believed that drops in temperature and rainfall events cue juveniles to move out of Massachusetts river systems in fall (Kosa and Mather, 2001; Yako et al., 2002). Decreases in rainfall during their peak migration in fall may inhibit migration and increase potential mortality.

Predation - It is possible that the increase in total mortality observed after 1999 and decrease in size of herring over time are the result of selective predation by increasing populations of striped bass (*Morone saxatilis*), cormorants (*Phalacrocorax auritus*), spiny dogfish (*Squalus acanthias*), seals (*Phoca vitulina*) and other species of fish and wildlife that have apparently prospered as river herring have declined.

Bycatch in Fisheries - It is possible that bycatch in several fisheries for small pelagic fish off the Massachusetts coast may be contributing to increases in total mortality in some herring runs. More information is needed on the impact of ocean bycatch. Since 2010, DMF has sampled portside landings of small mesh fisheries in New England to better understand the potential impacts of bycatch (Bethoney et al. 2013, Bethoney et al. 2014). Assessments of stock unit catch composition and amounts indicate that bycatch is likely not uniform across the species' range, but focused on certain geographic areas (Hasselman et al. 2016).

Legal Bait Harvesting and Poaching - Although not well quantified, anecdotally, there was a tremendous increase in unreported harvest of river herring both legally and illegally from the spawning runs primarily for use as bait in the recreational striped bass fishery. This occurred 6-7 years prior to the moratorium in concurrence with the rebuilding of the striped bass stocks. Prior to that surge in use of river herring for striped bass bait, there was similar unreported harvest of river herring for lobster bait that may not have been widespread as the striped bass bait harvest but at times caused large removals from individual runs.

Watershed Alterations - Many watersheds in Massachusetts continue to be degraded by stormwater impacts, eutrophication, and water withdrawals and other hydrologic disruption related to coastal development. Such conditions may affect the passage and spawning of adults and survival of young. Since 2008, DMF has been assessing the status and impairment of individual river herring spawning and nursery habitats with standard sampling protocols (Chase 2010).

Acknowledgements

Funding for this effort was provided by the Massachusetts Division of Marine Fisheries and Sportfish Restoration Funds Grant F-57-R. Thanks are due to current and past staff of the Diadromous Fish Biology and Management Project for collecting and processing field samples and to current and past members of the MDMF Age and Growth Laboratory for ageing scales and otoliths. Our appreciation is also expressed for the dedication of Town herring wardens and the many citizen volunteers who have contributed to river herring counts and stewardship in Massachusetts.

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| River | 1986 | 1987 | 1991 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
|--------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Agawam | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Back | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mattapoisett | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monument | 0.45 | 0.44 | | | | | | | | | | | | | | | | | | | | | | | | |
| Mystic | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nemasket | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Quashnet | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Stony | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Town | | | | | | | | | | | | | | | | | | | | | | | | | | |

Male

| River | 1986 | 1987 | 1991 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
|--------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| Agawam | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Back | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mattapoisett | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monument | 0.39 | 0.41 | | | | | | | | | | | | | | | | | | | | | | | | |
| Mystic | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nemasket | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Quashnet | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Stony | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Town | | | | | | | | | | | | | | | | | | | | | | | | | | |

Blueback
Female

| River | 1985 | 1986 | 1987 | 1991 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Agawam | | | * | | | | | | | | | | | | | | | | | | | | | | | |
| Charles | 0.54 | | 0.44 | | | | | | | | | | | | | | | | | | | | | | | |
| Monument | 0.38 | 0.39 | | 0.18 | 0.11 | 0.06 | 0.17 | 0.00 | 0.20 | 0.00 | 0.00 | 0.08 | 0.03 | 0.08 | 0.05 | 0.14 | 0.01 | 0.06 | 0.05 | 0.01 | 0.06 | 0.12 | 0.06 | | | |
| Mystic | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Quashnet | | | | | | | | | | | | | | | | | * | | | | | | | | | |
| Town | | | | | | | | | | | | | | | | | * | | | | | | | | | |

Male

| River | 1985 | 1986 | 1987 | 1991 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Agawam | | * | | | | | | | | | | | | | | | | | | | | | | | | |
| Charles | 0.49 | | 0.25 | | | | | | | | | | | | | | | | | | | | | | | |
| Monument | 0.22 | 0.20 | | 0.13 | 0.06 | 0.17 | 0.00 | 0.27 | 0.10 | 0.00 | 0.02 | 0.14 | 0.03 | 0.02 | 0.08 | 0.14 | 0.06 | 0.06 | 0.04 | 0.01 | 0.07 | 0.15 | 0.04 | | | |
| Mystic | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Quashnet | | | | | | | | | | | | | | | | | * | | | | | | | | | |
| Town | | | | | | | | | | | | | | | | | * | | | | | | | | | |

Table 7.1. Proportion of repeat spawners in alewife and blueback herring samples by sex, river and year. *=not calculated due to small sample size.

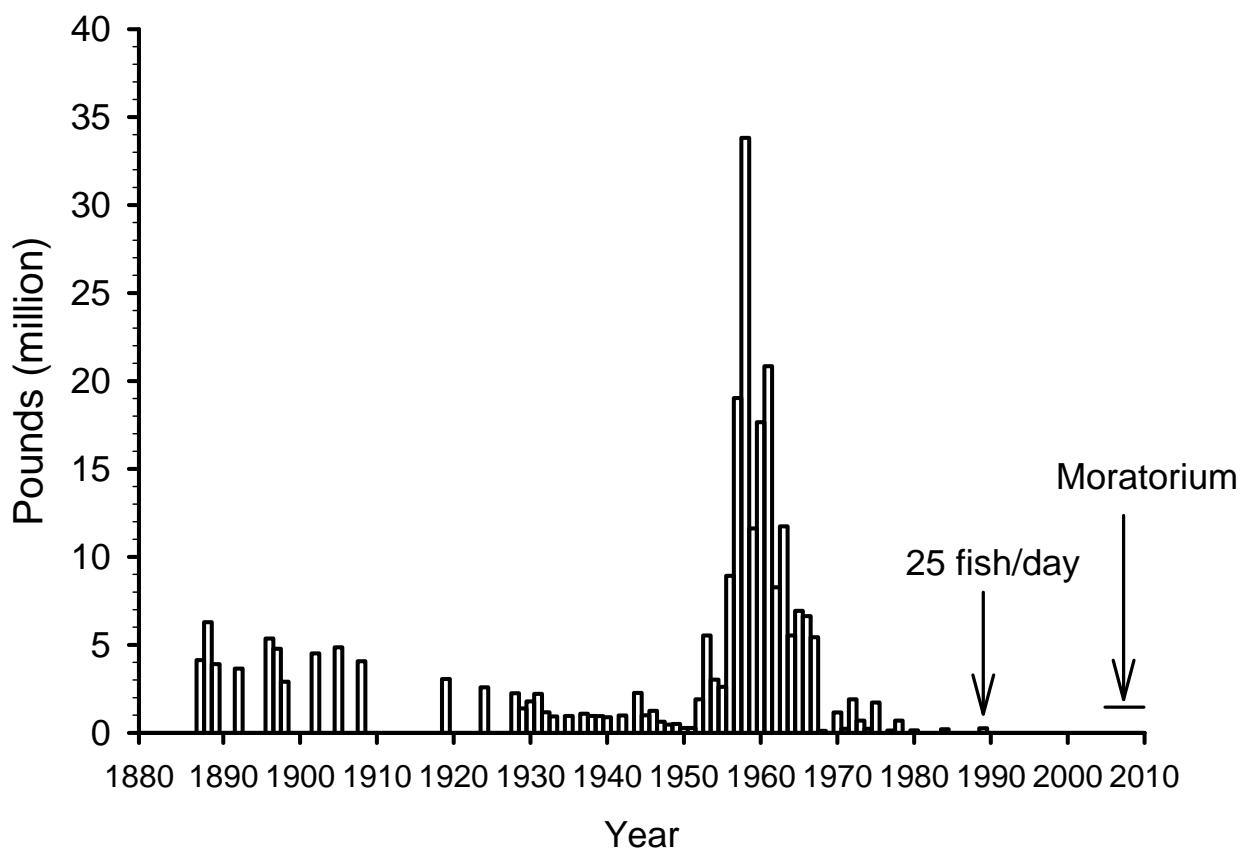


Figure 7. 1. Massachusetts commercial landings of river herring, 1887-2010.

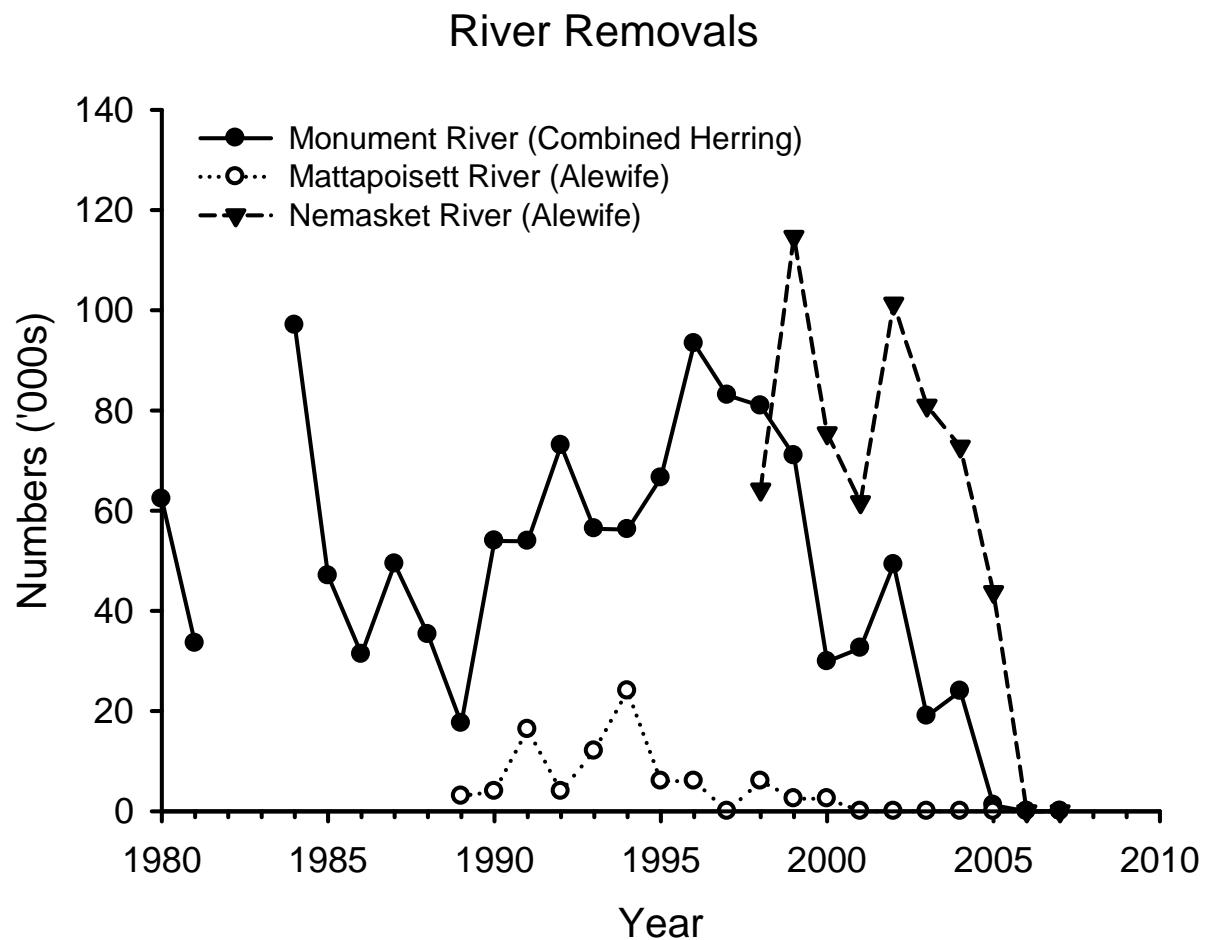


Figure 7.2. Number of fish removed (for bait, stocking, or scientific samples) from three Massachusetts rivers, 1980-2010.



Figure 7.3. Massachusetts rivers for which historical and/or current data on river herring are available.

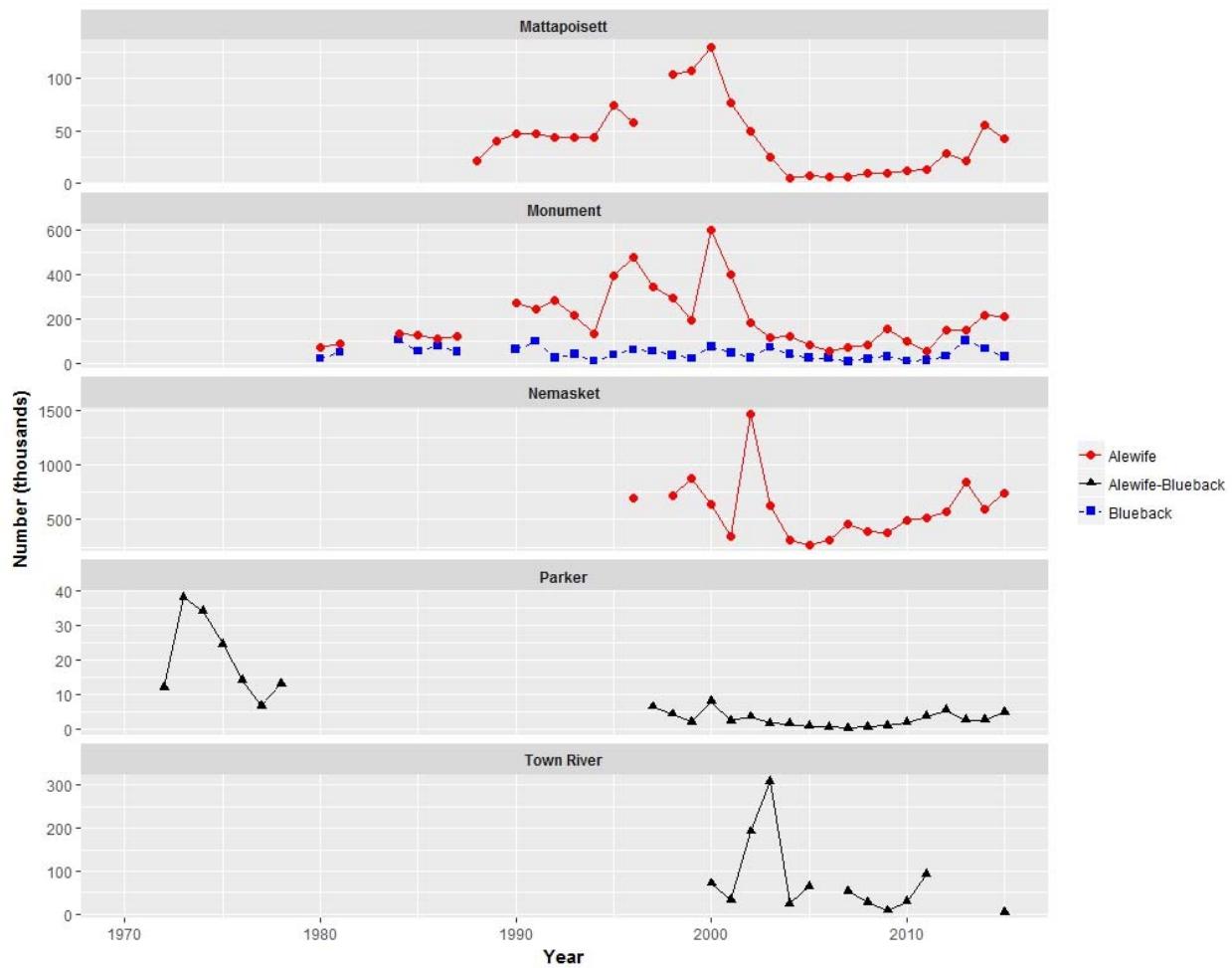


Figure 7.4. Passage and total run size counts for alewife and blueback herring in five Massachusetts Rivers.

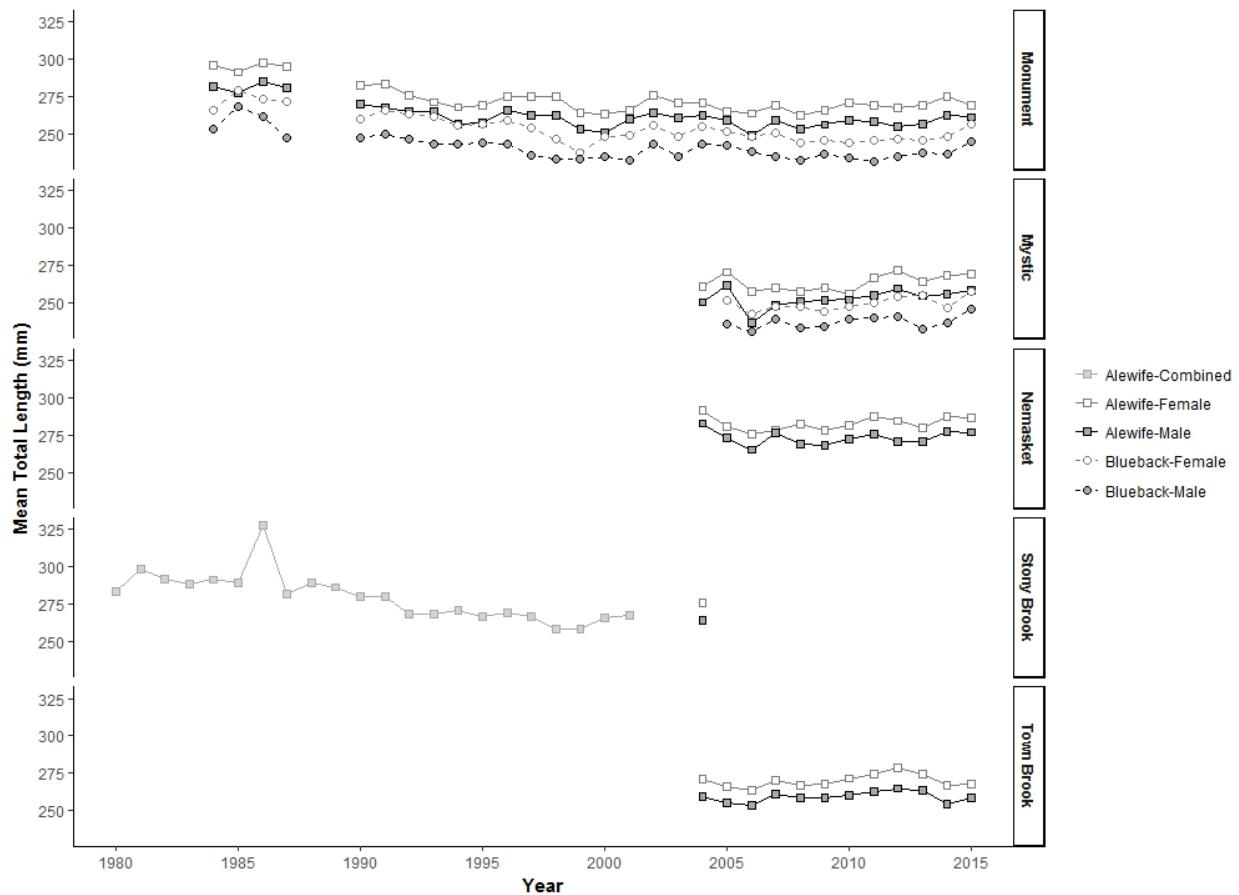


Figure 7.5. Mean total lengths of alewife and blueback herring in the Monument River, Mystic River, Nemasket River, Stony Brook, and Town Brook, 1978-2015.

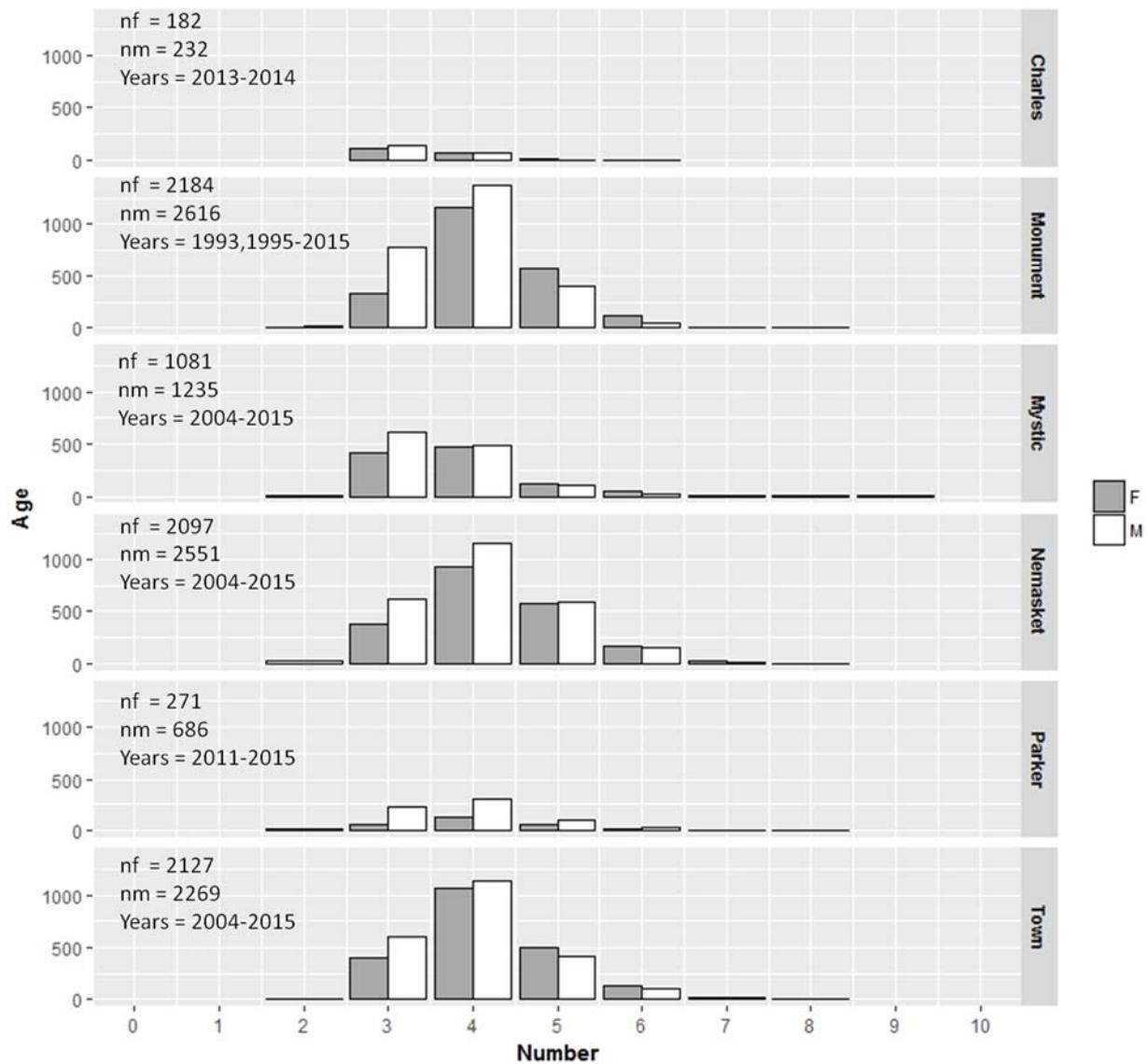


Figure 7.6. Age structure of alewife and blueback herring by sex (female: dark grey bars; male: white bars) in Massachusetts rivers from sampling, 2004-2015. *nf* is female sample size and *nm* is male sample size. Rivers with new data collected between assessments were included.

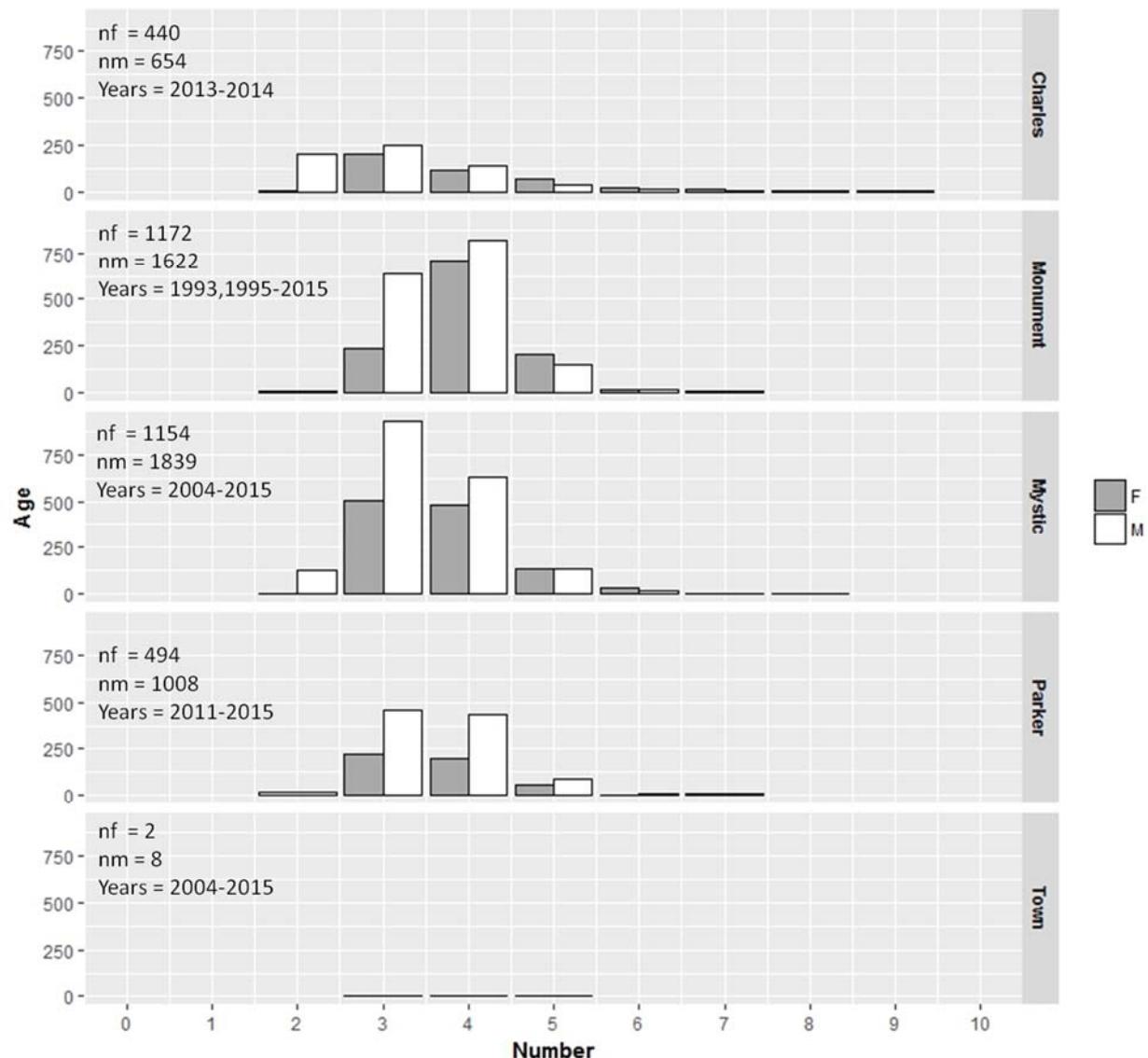


Figure 7.6. Continued.

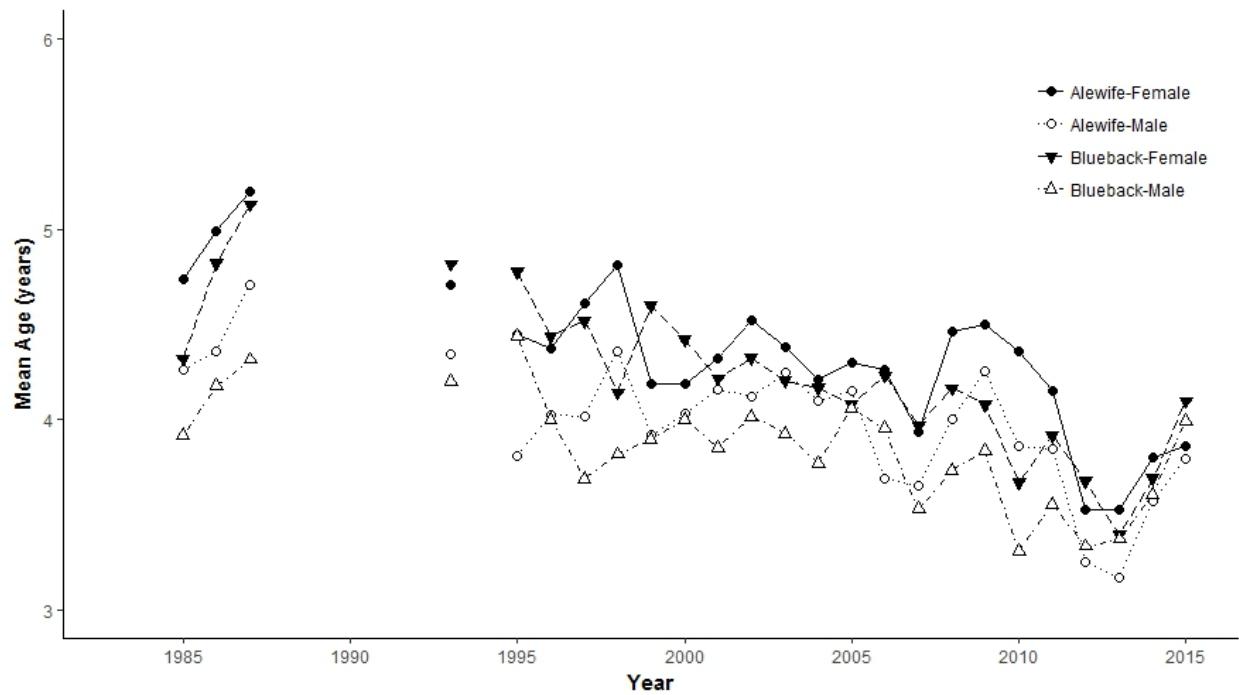


Figure 7.7. Mean age of Monument River alewife and blueback herring by sex, 1985-2015.

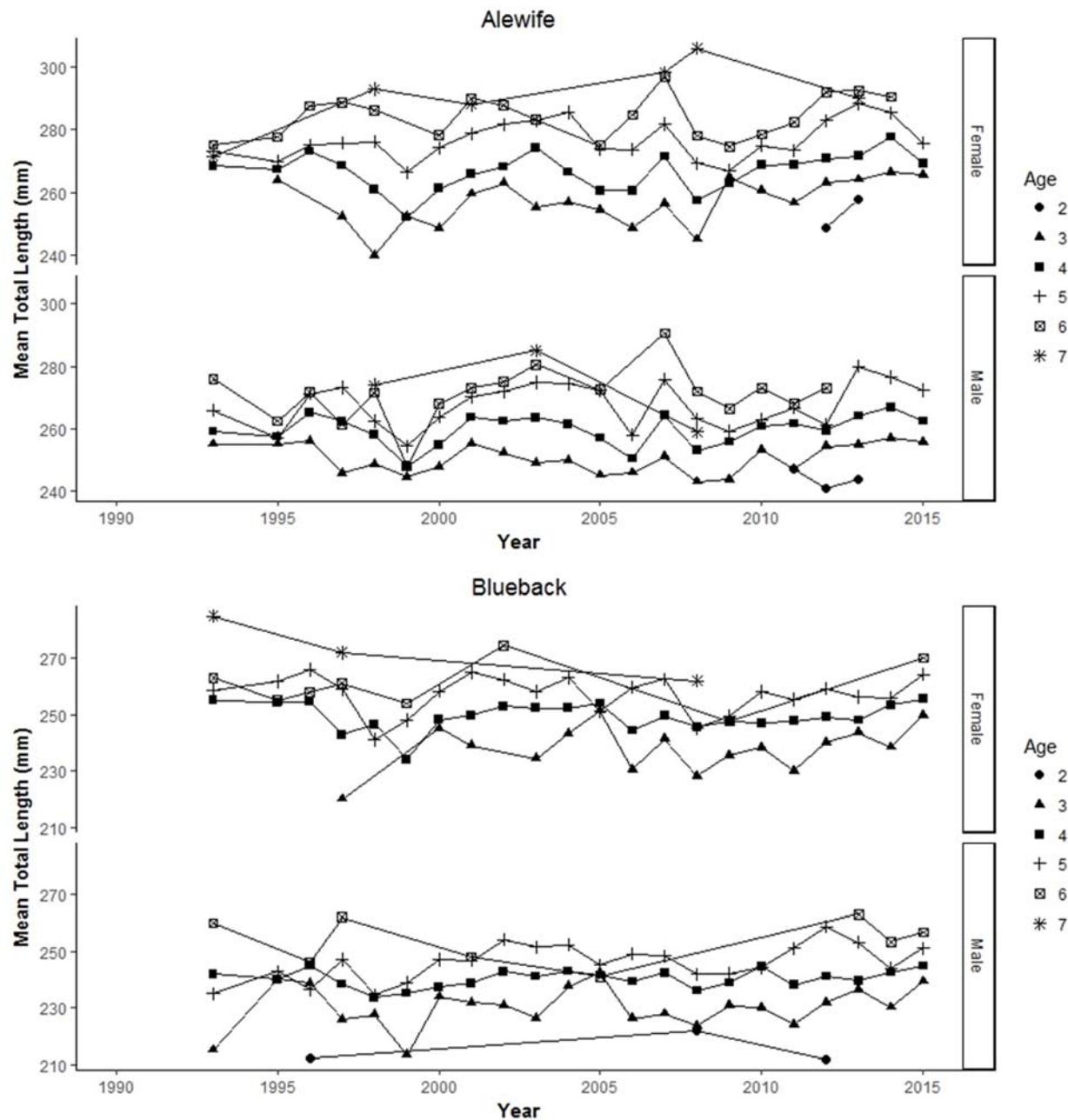


Figure 7.8. Mean length-at-age of alewife and blueback herring by year and sex for the Monument River, 1990-2015.

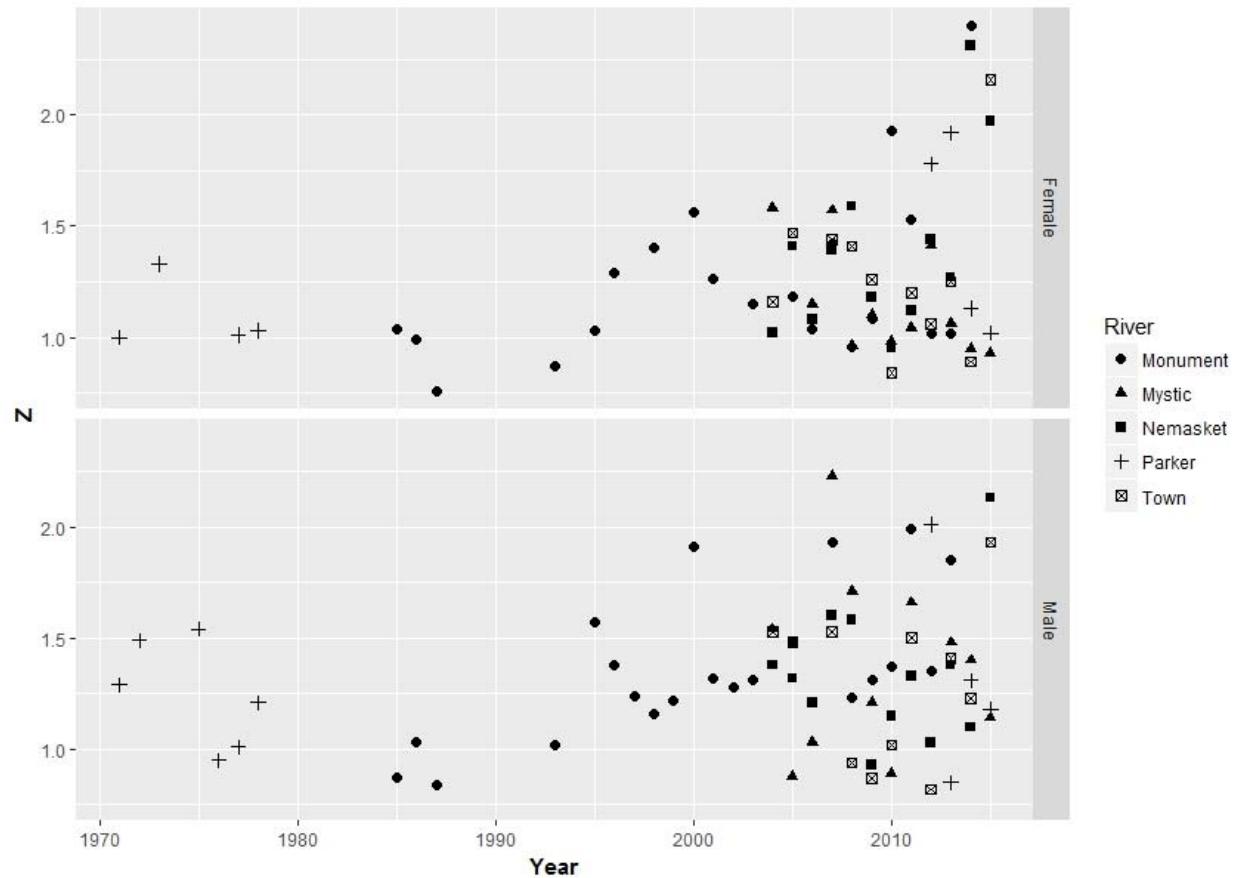


Figure 7.9. Estimates of total instantaneous mortality (Z) from age data for alewife in several Massachusetts rivers, 1985-2015. The Chapman-Robson survival estimator was applied to age frequency data.

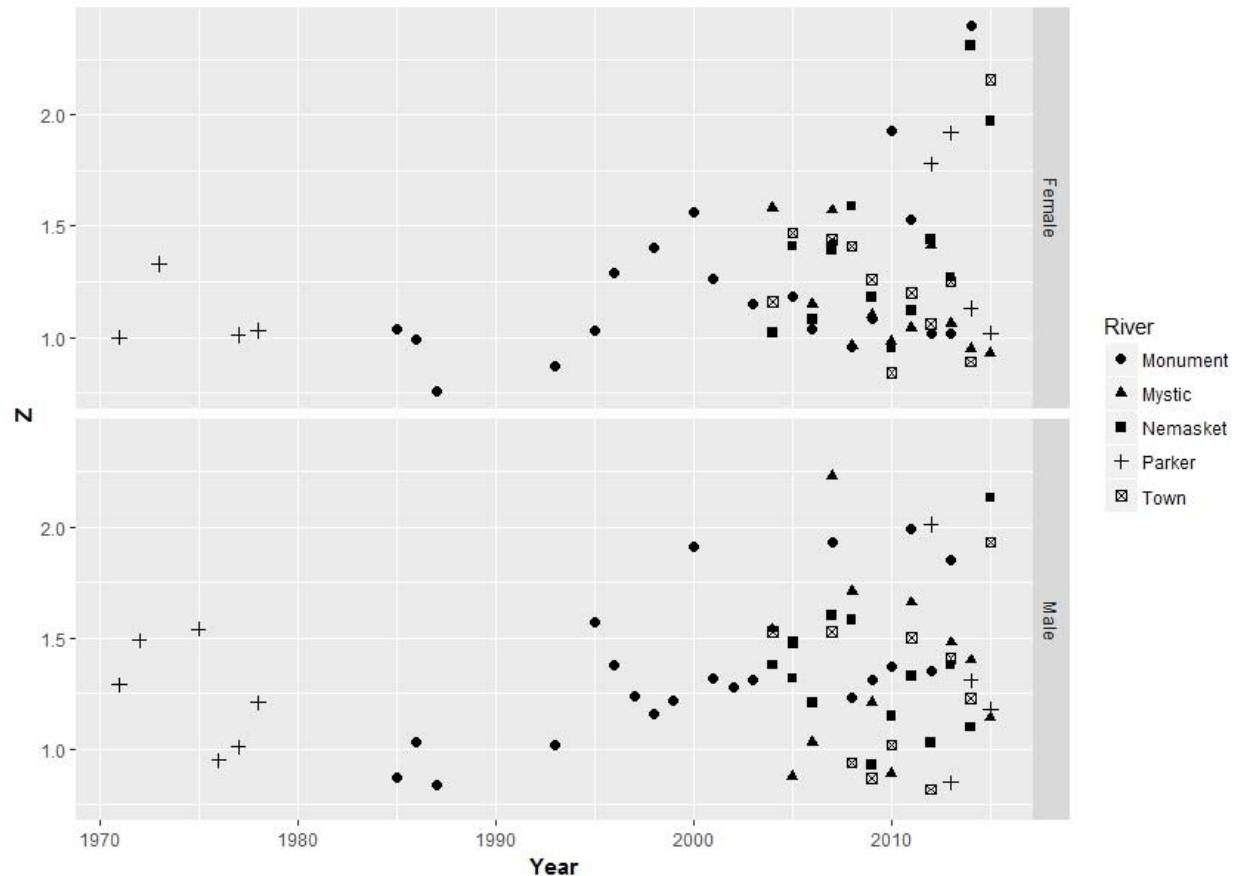


Figure 7.10. Estimates of total instantaneous mortality (Z) from age data for blueback herring in several Massachusetts rivers, 1985-2015. The Chapman-Robson survival estimator was applied to age frequency data.

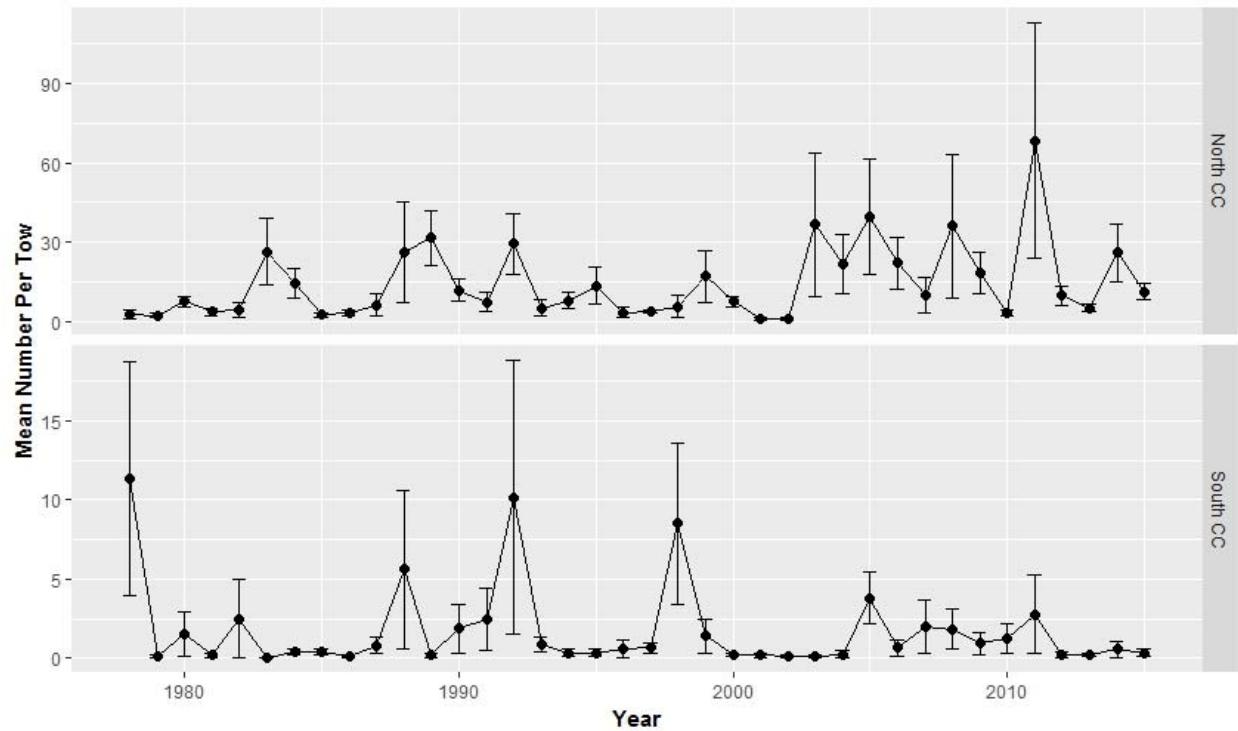


Figure 7.11. Indices of relative abundance (stratified mean number per tow) for age-1 alewife and blueback herring north and south of Cape Cod from the spring Massachusetts inshore bottom trawl survey, 1978-2015. Whiskers are +/- 1 standard error.

Appendix Table 7.1. Commercial landings (pounds) of river herring in Massachusetts by gear type, 1887-2007. Source: National Marine Fisheries Service and ASMFC (1985).

| Commercial Landings | | | | | | | | | | | |
|---------------------|---------|-------------|------------|----------|---------|-------------|----------|--------|-----------|--------------|-----------|
| Year | Dip Net | Purse Seine | Float Trap | Fyke Net | Gillnet | Beach Seine | Lift Net | Trawls | Pound Net | Unknown Gear | Total |
| 1887 | | | | | | | | | | 4,130,000 | 4,130,000 |
| 1888 | | | | | | | | | | 6,292,000 | 6,292,000 |
| 1889 | | | | | | | | | | 3,911,000 | 3,911,000 |
| 1890 | | | | | | | | | | - | - |
| 1891 | | | | | | | | | | - | - |
| 1892 | | | | | | | | | | 3,651,000 | 3,651,000 |
| 1893 | | | | | | | | | | - | - |
| 1894 | | | | | | | | | | - | - |
| 1895 | | | | | | | | | | - | - |
| 1896 | | | | | | | | | | 5,356,000 | 5,356,000 |
| 1897 | | | | | | | | | | 4,779,000 | 4,779,000 |
| 1898 | | | | | | | | | | 2,900,000 | 2,900,000 |
| 1899 | | | | | | | | | | - | - |
| 1900 | | | | | | | | | | - | - |
| 1901 | | | | | | | | | | - | - |
| 1902 | | | | | | | | | | 4,517,000 | 4,517,000 |
| 1903 | | | | | | | | | | - | - |
| 1904 | | | | | | | | | | - | - |
| 1905 | | | | | | | | | | 4,861,000 | 4,861,000 |
| 1906 | | | | | | | | | | - | - |
| 1907 | | | | | | | | | | - | - |
| 1908 | | | | | | | | | | 4,062,000 | 4,062,000 |
| 1909 | | | | | | | | | | - | - |
| 1910 | | | | | | | | | | - | - |
| 1911 | | | | | | | | | | - | - |
| 1912 | | | | | | | | | | - | - |
| 1913 | | | | | | | | | | - | - |
| 1914 | | | | | | | | | | - | - |
| 1915 | | | | | | | | | | - | - |
| 1916 | | | | | | | | | | - | - |
| 1917 | | | | | | | | | | - | - |
| 1918 | | | | | | | | | | - | - |
| 1919 | | | | | | | | | | 3,064,000 | 3,064,000 |
| 1920 | | | | | | | | | | - | - |

Appendix Table 7.1 cont.

Commercial Landings

| Year | Dip Net | Purse Seine | Float Trap | Fyke Net | Gillnet | Beach Seine | Lift Net | Trawls | Pound Net | Unknown Gear | Total |
|------|---------|-------------|------------|----------|---------|-------------|----------|--------|-----------|--------------|-----------|
| 1921 | | | | | | | | | | - | - |
| 1922 | | | | | | | | | | - | - |
| 1923 | | | | | | | | | | - | - |
| 1924 | | | | | | | | | | 2,593,000 | 2,593,000 |
| 1925 | | | | | | | | | | - | - |
| 1926 | | | | | | | | | | - | - |
| 1927 | | | | | | | | | | - | - |
| 1928 | | | | | | | | | | 2,248,000 | 2,248,000 |
| 1929 | | | | | | | | | | 1,386,000 | 1,386,000 |
| 1930 | | | | | | | | | | 1,790,000 | 1,790,000 |
| 1931 | | | | | | | | | | 2,212,000 | 2,212,000 |
| 1932 | | | | | | | | | | 1,164,000 | 1,164,000 |
| 1933 | | | | | | | | | | 923,000 | 923,000 |
| 1934 | | | | | | | | | | - | - |
| 1935 | | | | | | | | | | 959,000 | 959,000 |
| 1936 | | | | | | | | | | - | - |
| 1937 | | | | | | | | | | 1,086,000 | 1,086,000 |
| 1938 | | | | | | | | | | 958,000 | 958,000 |
| 1939 | | | | | | | | | | 946,000 | 946,000 |
| 1940 | | | | | | | | | | 879,000 | 879,000 |
| 1941 | | | | | | | | | | - | - |
| 1942 | | | | | | | | | | 984,000 | 984,000 |
| 1943 | | | | | | | | | | - | - |
| 1944 | | | | | | | | | | 2,266,000 | 2,266,000 |
| 1945 | | | | | | | | | | 988,000 | 988,000 |
| 1946 | | | | | | | | | | 1,249,000 | 1,249,000 |
| 1947 | | | | | | | | | | 633,000 | 633,000 |
| 1948 | | | | | | | | | | 468,000 | 468,000 |
| 1949 | | | | | | | | | | 502,000 | 502,000 |
| 1950 | 0 | 25,100 | 300 | 0 | 0 | 244,500 | 0 | 0 | 0 | 0 | 269,900 |
| 1951 | 0 | 42,300 | 3,700 | 0 | 0 | 230,000 | 0 | 0 | 0 | 0 | 276,000 |
| 1952 | 0 | 87,000 | 12,700 | 0 | 0 | 1,804,000 | 0 | 500 | 0 | 500 | 1,904,700 |
| 1953 | 0 | 4,538,200 | 240,100 | 0 | 0 | 751,600 | 0 | 4,800 | 0 | 0 | 5,534,700 |
| 1954 | 0 | 2,843,000 | 54,000 | 0 | 0 | 119,500 | 0 | 3,700 | 0 | 0 | 3,020,200 |
| 1955 | 0 | 1,869,800 | 75,600 | 0 | 400 | 675,300 | 0 | 0 | 0 | 0 | 2,621,100 |

Appendix Table 7.1 cont.

Commercial Landings

| Year | Dip Net | Purse Seine | Float Trap | Fyke Net | Gillnet | Beach Seine | Lift Net | Trawls | Pound Net | Unknown Gear | Total |
|------|---------|-------------|------------|----------|---------|-------------|----------|-----------|-----------|--------------|------------|
| 1956 | 0 | 8,752,500 | 77,000 | 0 | 0 | 92,000 | 0 | 0 | 0 | 0 | 8,921,500 |
| 1957 | 14,800 | 16,439,200 | 54,000 | 0 | 0 | 140,000 | 0 | 2,379,100 | 0 | 0 | 19,027,100 |
| 1958 | 16,200 | 32,482,400 | 106,800 | 0 | 0 | 1,167,000 | 0 | 42,300 | 0 | 0 | 33,814,700 |
| 1959 | 30,000 | 9,729,400 | 27,500 | 0 | 0 | 1,711,200 | 0 | 105,700 | 14,200 | 0 | 11,618,000 |
| 1960 | 0 | 16,151,300 | 26,900 | 0 | 0 | 1,387,900 | 0 | 0 | 85,000 | 0 | 17,651,100 |
| 1961 | 0 | 19,107,600 | 0 | 0 | 0 | 1,230,600 | 500,000 | 0 | 0 | 0 | 20,838,200 |
| 1962 | 0 | 6,123,200 | 0 | 0 | 0 | 2,150,000 | 0 | 2,500 | 0 | 0 | 8,275,700 |
| 1963 | 40,000 | 10,882,200 | 0 | 0 | 0 | 798,300 | 0 | 13,000 | 1,600 | 0 | 11,735,100 |
| 1964 | 339,900 | 3,998,600 | 0 | 0 | 0 | 1,190,300 | 0 | 0 | 0 | 0 | 5,528,800 |
| 1965 | 66,200 | 6,332,200 | 0 | 0 | 0 | 532,900 | 0 | 0 | 4,000 | 0 | 6,935,300 |
| 1966 | 90,100 | 6,106,400 | 0 | 0 | 0 | 436,700 | 0 | 0 | 0 | 0 | 6,633,200 |
| 1967 | 95,000 | 5,105,800 | 3,100 | 0 | 0 | 228,000 | 0 | 0 | 0 | 0 | 5,431,900 |
| 1968 | 14,200 | 0 | 0 | 0 | 0 | 102,500 | 0 | 0 | 0 | 0 | 116,700 |
| 1969 | 0 | 0 | 0 | 0 | 0 | 100,000 | 0 | 0 | 0 | 0 | 100,000 |
| 1970 | 0 | 813,600 | 0 | 0 | 0 | 100,000 | 0 | 242,700 | 0 | 0 | 1,156,300 |
| 1971 | 0 | 44,600 | 500 | 0 | 0 | 143,200 | 0 | 34,000 | 0 | 0 | 222,300 |
| 1972 | 38,800 | 1,171,700 | 700 | 0 | 0 | 128,500 | 0 | 567,700 | 0 | 0 | 1,907,400 |
| 1973 | 32,500 | 518,200 | 7,400 | 0 | 0 | 106,000 | 0 | 31,300 | 0 | 0 | 695,400 |
| 1974 | 175,300 | 0 | 2,500 | 0 | 0 | 0 | 0 | 50,700 | 0 | 0 | 228,500 |
| 1975 | 37,800 | 1,631,900 | 17,200 | 0 | 0 | 30,000 | 0 | 0 | 0 | 0 | 1,716,900 |
| 1976 | 6,400 | 0 | 0 | 0 | 0 | 38,500 | 0 | 0 | 0 | 0 | 44,900 |
| 1977 | 0 | 18,000 | 1,500 | 0 | 0 | 50,000 | 0 | 62300 | 0 | 0 | 131,800 |
| 1978 | 0 | 619,700 | 0 | 0 | 0 | 81,000 | 0 | 600 | 0 | 0 | 701,300 |
| 1979 | 0 | 0 | 0 | 0 | 0 | 52,000 | 0 | 300 | 0 | 0 | 52,300 |
| 1980 | 45,000 | 0 | 0 | 0 | 0 | 99,000 | 0 | 0 | 0 | 0 | 144,000 |
| 1981 | 36,300 | 0 | 0 | 0 | 0 | 47,700 | 0 | 0 | 0 | 0 | 84,000 |
| 1982 | 28,000 | 0 | 0 | 0 | 0 | 25,500 | 0 | 0 | 0 | 0 | 53,500 |
| 1983 | 13,000 | 0 | 0 | 0 | 0 | 80,000 | 0 | 100 | 0 | 0 | 93,100 |
| 1984 | 37,700 | 110,800 | 0 | 500 | 0 | 45,000 | 0 | 100 | 0 | 0 | 194,100 |
| 1985 | 35,200 | 0 | 0 | 400 | 0 | 11,000 | 0 | 0 | 0 | 0 | 46,600 |
| 1986 | 23,900 | 0 | 0 | 0 | 0 | 8,500 | 0 | 0 | 0 | 0 | 32,400 |
| 1987 | 24,000 | 0 | 0 | 0 | 0 | 8,500 | 0 | 0 | 0 | 0 | 32,500 |
| 1988 | 35,580 | 0 | 0 | 0 | 0 | 7,000 | 0 | 0 | 0 | 0 | 42,580 |
| 1989 | 14,200 | 237,500 | 0 | 0 | 0 | 4,000 | 0 | 0 | 0 | 0 | 255,700 |
| 1990 | 18,200 | 0 | 0 | 0 | 0 | 2,500 | 0 | 0 | 0 | 0 | 20,700 |

Appendix Table 7.1 cont.

Commercial Landings

| Year | Dip Net | Purse Seine | Float Trap | Fyke Net | Gillnet | Beach Seine | Lift Net | Trawls | Pound Net | Unknown Gear | Total |
|------|---------|-------------|------------|----------|---------|-------------|----------|--------|-----------|--------------|--------|
| 1991 | 17,800 | 0 | 0 | 0 | 0 | 2,500 | 0 | 0 | 0 | 0 | 20,300 |
| 1992 | 16,200 | 0 | 0 | 0 | 0 | 2,500 | 0 | 0 | 0 | 0 | 18,700 |
| 1993 | 16,400 | 0 | 0 | 0 | 0 | 2,500 | 0 | 0 | 0 | 0 | 18,900 |
| 1994 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1995 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1996 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 180 | 0 | 0 | 180 |
| 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1999 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2002 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 89 | 0 | 89 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2008 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2009 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2010 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2011 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix Table 7.2. Marine Recreational Fisheries Statistics Survey estimates of numbers and associated statistics of river herring (alewife and blueback) harvested and released in Massachusetts by the recreational anglers.

| MRFSS Estimates of Harvest and Releases Numbers of Fish in Massachusetts | | | | | | | | | | | | | |
|--|-------------|-------|----------|----------|---------|-------|------|-------------|--------|----------|--------|---------|--------|
| Alewife | | | | Blueback | | | | | | | | | |
| Year | Total Catch | SE | Releases | SE | Harvest | SE | Year | Total Catch | SE | Releases | SE | Harvest | SE |
| 1982 | | | | | | | 1982 | | | | | | |
| 1983 | 81 | 81 | 81 | 81 | 0 | 0 | 1983 | | | | | | |
| 1984 | | | | | | | 1984 | | | | | | |
| 1985 | | | | | | | 1985 | | | | | | |
| 1986 | 32,506 | 20424 | 0 | 0 | 32,506 | 20424 | 1986 | 804 | 804 | 0 | 0 | 804 | 804 |
| 1987 | | | | | | | 1987 | 83,281 | 66,261 | 20,163 | 20,163 | 63,118 | 63,118 |
| 1988 | | | | | | | 1988 | | | | | | |
| 1989 | | | | | | | 1989 | 639 | 295 | 0 | 0 | 639 | 295 |
| 1990 | | | | | | | 1990 | 5,632 | 3,274 | 5,632 | 3,274 | 0 | 0 |
| 1991 | | | | | | | 1991 | 562 | 413 | 0 | 0 | 562 | 413 |
| 1992 | 9,411 | 9411 | 0 | 0 | 9,411 | 9411 | 1992 | | | | | | |
| 1993 | | | | | | | 1993 | 5,707 | 2,219 | 1,182 | 1,182 | 4,525 | 1,878 |
| 1994 | | | | | | | 1994 | 1,246 | 747 | 0 | 0 | 1,246 | 747 |
| 1995 | | | | | | | 1995 | 352 | 350 | 0 | 0 | 352 | 350 |
| 1996 | | | | | | | 1996 | 5,504 | 3,904 | 0 | 0 | 5,504 | 3,904 |
| 1997 | | | | | | | 1997 | 9,496 | 6,440 | 0 | 0 | 9,496 | 6,440 |
| 1998 | | | | | | | 1998 | 739 | 739 | 739 | 739 | 0 | 0 |
| 1999 | | | | | | | 1999 | | | | | | |
| 2000 | | | | | | | 2000 | | | | | | |
| 2001 | 2,124 | 1651 | 0 | 0 | 2,124 | 1651 | 2001 | | | | | | |
| 2002 | | | | | | | 2002 | | | | | | |
| 2003 | | | | | | | 2003 | 75,752 | 41,962 | 19,392 | 13,837 | 56,360 | 39,614 |
| 2004 | 237,564 | 85369 | 0 | 0 | 237,564 | 85369 | 2004 | | | | | | |
| 2005 | | | | | | | 2005 | 11,657 | 11,657 | 0 | 0 | 11,657 | 11,657 |
| 2006 | | | | | | | 2006 | | | | | | |
| 2007 | | | | | | | 2007 | 1,191 | 1,191 | 1,191 | 1,191 | 0 | 0 |
| 2008 | | | | | | | 2008 | 18,543 | 15,360 | 18,543 | 15,360 | 0 | 0 |
| 2009 | | | | | | | 2009 | | | | | | |

Appendix Table 7.3. Passage, total and removal numbers of river herring from select Massachusetts rivers.

| Mattapoisett River | | | Monument River | | | Nemasket River | | | |
|--------------------|---------|----------|----------------|-------------|-------------|----------------|------|-----------|----------|
| Alewife | | Removals | Year | Blueback | Alewife | Combined | Year | Alewife | |
| Year | Passage | s | | Total Count | Total Count | Removals | | Passage | Removals |
| 1972 | | | 1972 | | | | 1972 | | |
| 1973 | | | 1973 | | | | 1973 | | |
| 1974 | | | 1974 | | | | 1974 | | |
| 1975 | | | 1975 | | | | 1975 | | |
| 1976 | | | 1976 | | | | 1976 | | |
| 1977 | | | 1977 | | | | 1977 | | |
| 1978 | | | 1978 | | | | 1978 | | |
| 1979 | | | 1979 | | | | 1979 | | |
| 1980 | 20,357 | | 1980 | 20,357 | 70,736 | 62,280 | 1980 | | |
| 1981 | 49,483 | | 1981 | 49,483 | 85,796 | 33,480 | 1981 | | |
| 1982 | | | 1982 | | | | 1982 | | |
| 1983 | | | 1983 | | | | 1983 | | |
| 1984 | 104,645 | | 1984 | 104,645 | 130,709 | 97,000 | 1984 | | |
| 1985 | 53,715 | | 1985 | 53,715 | 124,316 | 47,000 | 1985 | | |
| 1986 | 75,734 | | 1986 | 75,734 | 110,803 | 31,320 | 1986 | | |
| 1987 | 52,686 | | 1987 | 52,686 | 122,935 | 49,350 | 1987 | | |
| 1988 | 22,000 | 0 | 1988 | | | 35,280 | 1988 | | |
| 1989 | 40,000 | 3,000 | 1989 | | | 17,520 | 1989 | | |
| 1990 | 47,000 | 3,960 | 1990 | 62,397 | 269,502 | 53,950 | 1990 | | |
| 1991 | 47,000 | 16,320 | 1991 | 99,646 | 245,151 | 53,880 | 1991 | | |
| 1992 | 44,000 | 3,960 | 1992 | 24,017 | 280,001 | 73,002 | 1992 | | |
| 1993 | 44,000 | 12,000 | 1993 | 39,117 | 213,249 | 56,380 | 1993 | | |
| 1994 | 44,000 | 24,000 | 1994 | 9,665 | 134,590 | 56,210 | 1994 | | |
| 1995 | 75,000 | 6,000 | 1995 | 37,912 | 395,201 | 66,513 | 1995 | | |
| 1996 | 58,000 | 6,000 | 1996 | 59,008 | 477,432 | 93,339 | 1996 | 696,666 | |
| 1997 | | | 1997 | 53,855 | 345,074 | 83,045 | 1997 | | |
| 1998 | 104,000 | 6,000 | 1998 | 36,210 | 292,970 | 80,881 | 1998 | 651,441 | 64,200 |
| 1999 | 107,000 | 2,500 | 1999 | 21,754 | 191,516 | 70,973 | 1999 | 766,894 | 114,832 |
| 2000 | 130,000 | 2,500 | 2000 | 73,902 | 597,937 | 29,859 | 2000 | 560,986 | 75,426 |
| 2001 | 77,000 | 0 | 2001 | 46,478 | 400,422 | 32,552 | 2001 | 284,498 | 61,668 |
| 2002 | 50,000 | 0 | 2002 | 25,530 | 182,031 | 49,211 | 2002 | 1,361,691 | 101,302 |
| 2003 | 25,000 | 0 | 2003 | 70,181 | 116,718 | 18,990 | 2003 | 548,835 | 80,971 |
| 2004 | 5,385 | 0 | 2004 | 39,802 | 121,184 | 23,954 | 2004 | 244,832 | 72,763 |
| 2005 | 8,000 | 0 | 2005 | 22,944 | 79,483 | 1,192 | 2005 | 225,904 | 43,741 |
| 2006 | 6,270 | 0 | 2006 | 22,192 | 52,472 | 0 | 2006 | 313,242 | 0 |
| 2007 | 6,011 | 0 | 2007 | 8,140 | 69,385 | 0 | 2007 | 462,000 | 0 |
| 2008 | 9,987 | 0 | 2008 | 18,532 | 84,196 | 0 | 2008 | 392,451 | 0 |
| 2009 | 10,356 | 0 | 2009 | 30,536 | 154,532 | 0 | 2009 | 383,338 | 0 |
| 2010 | 12,319 | 0 | 2010 | 9,358 | 96,355 | 0 | 2010 | 489,931 | 0 |
| 2011 | 12,857 | 0 | 2011 | 13,632 | 55,009 | 0 | 2011 | 512,139 | 0 |
| 2012 | 28,447 | 0 | 2012 | 32,145 | 147,937 | 0 | 2012 | 567,952 | 0 |
| 2013 | 21,613 | 0 | 2013 | 101,863 | 151,008 | 0 | 2013 | 840,033 | 0 |
| 2014 | 55,429 | 0 | 2014 | 64,595 | 213,539 | 0 | 2014 | 590,105 | 0 |
| 2015 | 42,332 | 0 | 2015 | 29,305 | 211,067 | 0 | 2015 | 741,048 | 0 |

Appendix Table 7.3 cont.

| Year | Parker River | Marston-Mills | Stony Brook | Agawam | Wankinco | Sippican | Town River | Pilgrim Lake | Herring R. (Hawwich) | Herring R. (Wellfleet) |
|------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|-----------------|----------------------|------------------------|
| | Combined Passage | Alewife Passage | Combined Passage | Combined Passage |
| 1972 | 12,097 | | | | | | | | | |
| 1973 | 38,163 | | | | | | | | | |
| 1974 | 34,163 | | | | | | | | | |
| 1975 | 24,539 | | | | | | | | | |
| 1976 | 13,998 | | | | | | | | | |
| 1977 | 6,654 | | | | | | | | | |
| 1978 | 13,116 | | | | | | | | | |
| 1979 | | | | | | | | | | |
| 1980 | | | | | | | | | | |
| 1981 | | | | | | | | | | |
| 1982 | | | | | | | | | | |
| 1983 | | | | | | | | | | |
| 1984 | | | | | | | | | | |
| 1985 | | | | | | | | | | |
| 1986 | | | | | | | | | | |
| 1987 | | | | | | | | | | |
| 1988 | | | | | | | | | | |
| 1989 | | | | | | | | | | |
| 1990 | | | | | | | | | | |
| 1991 | | | | | | | | | | |
| 1992 | | | | | | | | | | |
| 1993 | | | | | | | | | | |
| 1994 | | | | | | | | | | |
| 1995 | | | | | | 326 | | | | |
| 1996 | | | | | | 680 | | | | |
| 1997 | 6,396 | | | | | 610 | | | | |
| 1998 | 4,242 | | | | | 671 | | | | |
| 1999 | 7,965 | | | | | | | | | |
| 2000 | 7,894 | | | | | | 959 | 72,000 | | |
| 2001 | 2,244 | | | | | | 558 | 33,000 | | |
| 2002 | 3,500 | | | | | | 359 | 193,069 | | |
| 2003 | 1,500 | | | | | | | 310,000 | | |
| 2004 | 1,447 | | | | | | | 25,000 | | |
| 2005 | 747 | | | | | | | 65,826 | | |
| 2006 | 500 | 6482 | | 53,173 | | | 89 | | | |
| 2007 | 60 | 15,136 | 30,252 | 100,473 | 2,788 | | | 53,315 | | |
| 2008 | 485 | 43,948 | 33,383 | 30,429 | 8,246 | | | 27,783 | 1,847 | |
| 2009 | 800 | 11,668 | 19,197 | 36,354 | 6,539 | | | 8,596 | 1,090 | 19,336 |
| 2010 | 1,800 | 4,174 | 71,026 | 30,057 | 10,665 | | | 29,465 | 1,461 | 41,254 |
| 2011 | 3,624 | 494 | 37,091 | 19,064 | 10,442 | | | 93,312 | 1,370 | 10,466 |
| 2012 | 5,416 | 87,308 | 41,028 | 73,186 | 24,764 | | | | 5,931 | 101,624 |
| 2013 | 2,500 | 56,987 | 153,262 | 33,637 | 8,734 | | | | 3,001 | 91,167 |
| 2014 | 2,491 | 47,006 | 271,364 | 48,873 | 18,625 | | | | 4,202 | 247,894 |
| 2015 | 4,911 | 23,840 | 251,530 | 24,398 | 14,170 | | | 5,427 | 4,245 | 127,860 |
| | | | | | | | | | | 18,025 |

Counter performance
and fishway issues
in 2012-2014

Appendix Table 7.4. Length frequencies of alewife and blueback herring from various rivers by sex and year. Length intervals are 10-mm total length bins with the label equal to the lower limit of the bin.

| Alewife | | | | | | | | | | | | | | |
|------------|------|---|------|---|------|---|------|-----|------|---|------|---|------|---|
| Back River | | | | | | | | | | | | | | |
| TL mm | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | 2010 | |
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| 190 | | | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | | | |
| 210 | | | | | | | | | | | | | | |
| 220 | | | | | | | | | | | | | | |
| 230 | | | | | | | | | | | | | | |
| 240 | | | | | | | 1 | 5 | | | | | | |
| 250 | | | | | | | 19 | 16 | | | | | | |
| 260 | | | | | | | 59 | 57 | | | | | | |
| 270 | | | | | | | 78 | 64 | | | | | | |
| 280 | | | | | | | 54 | 48 | | | | | | |
| 290 | | | | | | | 15 | 15 | | | | | | |
| 300 | | | | | | | 2 | 5 | | | | | | |
| 310 | | | | | | | | | | | | | | |
| 320 | | | | | | | | | | | | | | |
| 330 | | | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | | | |
| Total | 0 | 0 | 0 | 0 | 0 | 0 | 228 | 211 | 0 | 0 | 0 | 0 | 0 | 0 |

| Mattapoisett River | | | | | | | | | | | | | | | | |
|--------------------|------|----|------|---|------|---|------|----|------|----|------|---|------|---|------|---|
| TL mm | 1995 | | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | 2010 | |
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| 190 | | | | | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | | | | | |
| 210 | | | | | | | | | | | | | | | | |
| 220 | | | | | | | | | | | | | | | | 1 |
| 230 | | | | | | | | | | | | | | | | |
| 240 | 1 | | | | | | | | | | | | | | | |
| 250 | 4 | | | | | | | | | | | | | | | |
| 260 | 12 | 5 | | | | | | | | | | | | | | |
| 270 | 19 | 8 | | | | | | | | | | | | | | |
| 280 | 7 | 6 | | | | | | | | | | | | | | |
| 290 | 8 | 18 | | | | | | | | | | | | | | |
| 300 | 2 | 7 | | | | | | | | | | | | | | |
| 310 | 1 | 6 | | | | | | | | | | | | | | |
| 320 | | | | | | | | | | | | | | | | |
| 330 | | | | | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | | | | | |
| Total | 54 | 50 | 0 | 0 | 0 | 0 | 35 | 24 | 14 | 24 | 0 | 0 | 0 | 0 | 0 | 0 |

| Quashnet River | | | | | | | | | | | | | | | | |
|----------------|------|----|------|---|------|---|------|---|------|---|------|---|------|---|---|---|
| TL mm | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | 2010 | | | |
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | | |
| 190 | | | | | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | | | | | |
| 210 | | | | | | | | | | | | | | | | |
| 220 | | | | | | | | | | | | | | | | |
| 230 | 2 | 1 | | | | | | | | | | | | | | |
| 240 | 11 | 2 | | | | | | | | | | | | | | |
| 250 | 20 | 13 | | | | | | | | | | | | | | |
| 260 | 18 | 21 | | | | | | | | | | | | | | |
| 270 | 11 | 26 | | | | | | | | | | | | | | |
| 280 | 4 | 20 | | | | | | | | | | | | | | |
| 290 | | 4 | | | | | | | | | | | | | | |
| 300 | | | | | | | | | | | | | | | | |
| 310 | | | | | | | | | | | | | | | | |
| 320 | | | | | | | | | | | | | | | | |
| 330 | | | | | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | | | | | |
| Total | 66 | 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Stony Brook | | | | | | | | | | | | | | | | |
|-------------|------|----|------|---|------|---|------|---|------|---|------|---|------|---|---|---|
| TL mm | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | 2010 | | | |
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | | |
| 190 | | | | | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | | | | | |
| 210 | | | | | | | | | | | | | | | | |
| 220 | | | | | | | | | | | | | | | | |
| 230 | 2 | 1 | | | | | | | | | | | | | | |
| 240 | 14 | 3 | | | | | | | | | | | | | | |
| 250 | 23 | 6 | | | | | | | | | | | | | | |
| 260 | 34 | 12 | | | | | | | | | | | | | | |
| 270 | 30 | 36 | | | | | | | | | | | | | | |
| 280 | 13 | 24 | | | | | | | | | | | | | | |
| 290 | 1 | 14 | | | | | | | | | | | | | | |
| 300 | | 1 | | | | | | | | | | | | | | |
| 310 | | | | | | | | | | | | | | | | |
| 320 | | | | | | | | | | | | | | | | |
| 330 | | | | | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | | | | | |
| Total | 117 | 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix Table 7.4 cont.

| Alewife | | | | | | | | | | | | | | | | | | | | | | | | |
|------------|------|----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|-----|-----|
| Town Brook | | | | | | | | | | | | | | | | | | | | | | | | |
| TL mm | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | | |
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | | |
| 190 | | | | | | | | | | | | | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | | | | | | | | | | | | | |
| 210 | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| 220 | 1 | | 3 | 1 | 5 | | | | 1 | | 3 | 1 | 1 | | | | | | | | | | | |
| 230 | 5 | 2 | 8 | 3 | 10 | 4 | 9 | 2 | 10 | 3 | 13 | 1 | 6 | 1 | 3 | 1 | 5 | 1 | 2 | 2 | 21 | 8 | 2 | |
| 240 | 12 | 1 | 33 | 9 | 27 | 12 | 43 | 6 | 43 | 16 | 35 | 14 | 45 | 4 | 18 | 3 | 15 | 3 | 21 | 5 | 40 | 13 | 31 | 5 |
| 250 | 16 | 12 | 62 | 32 | 50 | 23 | 74 | 32 | 83 | 35 | 82 | 42 | 85 | 25 | 39 | 11 | 46 | 16 | 37 | 17 | 55 | 41 | 102 | 53 |
| 260 | 25 | 20 | 30 | 44 | 34 | 46 | 108 | 78 | 70 | 74 | 70 | 56 | 85 | 64 | 74 | 42 | 35 | 27 | 65 | 42 | 33 | 47 | 63 | 90 |
| 270 | 22 | 40 | 14 | 31 | 11 | 36 | 60 | 73 | 31 | 49 | 37 | 63 | 44 | 79 | 34 | 69 | 47 | 40 | 30 | 46 | 18 | 45 | 25 | 72 |
| 280 | 3 | 16 | 4 | 13 | 5 | 15 | 40 | 12 | 20 | 7 | 22 | 9 | 38 | 8 | 38 | 23 | 60 | 15 | 40 | 4 | 18 | 9 | 24 | |
| 290 | 3 | | 9 | | 2 | | 14 | 4 | 6 | 11 | 3 | 14 | 3 | 12 | 4 | 24 | 4 | 16 | 1 | 9 | 2 | 9 | | |
| 300 | 1 | | 1 | | 1 | | | | 3 | 3 | 2 | | 2 | | 1 | 15 | 1 | 8 | 1 | 1 | | | | |
| 310 | | | | | | | 1 | | | | 1 | | | | 1 | 1 | 1 | | | | | | | |
| 320 | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| 330 | | | | | | | | | | | | | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | 85 | 95 | 154 | 143 | 137 | 128 | 310 | 246 | 257 | 207 | 245 | 212 | 278 | 227 | 179 | 179 | 175 | 188 | 175 | 175 | 174 | 174 | 243 | 255 |

| Agawam | | | | | | | | | | | | |
|--------|----|----|---|---|---|---|---|---|---|---|---|---|
| 1991 | | | | | | | | | | | | |
| TL mm | M | | F | | | | | | | | | |
| | M | F | M | F | M | F | M | F | M | F | M | F |
| 190 | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | |
| 210 | | | | | | | | | | | | |
| 220 | | | | | | | | | | | | |
| 230 | | | | | | | | | | | | |
| 240 | | | | | | | | | | | | |
| 250 | | | | | | | | | | | | |
| 260 | | | | | | | | | | | | |
| 270 | | | | | | | | | | | | |
| 280 | | | | | | | | | | | | |
| 290 | | | | | | | | | | | | |
| 300 | | | | | | | | | | | | |
| 310 | | | | | | | | | | | | |
| 320 | | | | | | | | | | | | |
| 330 | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | |
| Total | 86 | 71 | | | | | | | | | | |

| Parker | | | | | | | | | | | | |
|--------|------|----|------|----|------|----|------|----|------|----|---|---|
| River | | | | | | | | | | | | |
| TL mm | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | | |
| | M | F | M | F | M | F | M | F | M | F | M | F |
| 190 | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | |
| 210 | | | | | | | | | | | | |
| 220 | | | | | | | | | | | | |
| 230 | 1 | | 12 | 1 | 2 | | 1 | | | | | |
| 240 | 3 | 2 | 22 | 2 | 23 | 3 | 14 | 3 | 1 | | | |
| 250 | 4 | | 35 | 6 | 50 | 5 | 17 | 6 | 8 | | | |
| 260 | 2 | 2 | 53 | 8 | 70 | 11 | 29 | 10 | 41 | 4 | | |
| 270 | 1 | 1 | 36 | 22 | 62 | 19 | 55 | 15 | 41 | 7 | | |
| 280 | 10 | 26 | 32 | 18 | 39 | 19 | 41 | 5 | | | | |
| 290 | 1 | 9 | 11 | 10 | 14 | 20 | 18 | 4 | | | | |
| 300 | | 2 | 1 | 7 | 3 | 12 | 5 | 3 | | | | |
| 310 | | | | 2 | 1 | 7 | 1 | 1 | | | | |
| 320 | | | | | | | | | | | | |
| 330 | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | |
| Total | 11 | 5 | 172 | 76 | 252 | 75 | 173 | 92 | 156 | 24 | | |

Appendix Table 7.4 cont.

**Alewife
Mystic River**

| TL mm | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | |
|-------|------|----|------|----|------|----|------|-----|------|----|------|----|------|----|------|-----|------|-----|------|-----|------|-----|------|-----|
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| 190 | | | | | | | | | | | | | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | | | | | | | | | | | | | |
| 210 | 1 | | | | 6 | | | | | 1 | | | | | | | | | | | | | | |
| 220 | 7 | | 1 | 3 | 6 | 2 | 1 | 1 | 2 | | | | | | | | 1 | | | | 1 | | | |
| 230 | 16 | 8 | 2 | 3 | 2 | 29 | 6 | 21 | 7 | 6 | 3 | 1 | 8 | 10 | 19 | | | | | 7 | 1 | 3 | | |
| 240 | 10 | 6 | | 9 | 7 | 44 | 28 | 28 | 8 | 13 | 8 | 7 | 8 | 48 | 9 | 20 | 11 | 74 | 1 | 38 | 13 | 22 | 9 | |
| 250 | 12 | 8 | 3 | 2 | 1 | 5 | 35 | 36 | 25 | 11 | 27 | 22 | 2 | 10 | 73 | 35 | 52 | 14 | 84 | 26 | 46 | 24 | 60 | 30 |
| 260 | 12 | 15 | 2 | 2 | 2 | 7 | 10 | 26 | 28 | 14 | 13 | 15 | 2 | 7 | 48 | 29 | 53 | 34 | 46 | 66 | 27 | 29 | 37 | 47 |
| 270 | 9 | 15 | 2 | 4 | | 7 | 12 | 21 | 3 | 9 | 1 | 12 | 2 | | 14 | 23 | 32 | 40 | 28 | 42 | 18 | 35 | 21 | 56 |
| 280 | 3 | 4 | | 2 | | 1 | 3 | 10 | 1 | | 4 | | | 1 | 17 | 6 | 32 | 8 | 35 | 3 | 16 | 4 | 18 | |
| 290 | 1 | | | | | 3 | | | 2 | | | | | | 5 | | 9 | | 16 | 2 | 8 | | 7 | |
| 300 | | 1 | 1 | | | | 2 | | 1 | | 1 | | | 4 | | | 2 | | 7 | | 2 | | 4 | |
| 310 | | | | | | | | | | | | | | | | | | | 7 | | | | | |
| 320 | | | | | | | | | | | | | | | | | | | | | | | | |
| 330 | | | | | | | | | | | | | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | 71 | 56 | 10 | 12 | 24 | 29 | 139 | 134 | 108 | 53 | 62 | 65 | 14 | 26 | 192 | 122 | 174 | 142 | 259 | 200 | 142 | 130 | 147 | 171 |

Nemasket River

| TL mm | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | |
|-------|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| 190 | | | | | | | | | | | | | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | | | | | | | | | | | | | |
| 210 | | | | | | | | | | | | | | | | | | | | | | | | |
| 220 | | | | | | | | | | | | | | | | | | | | | | | | |
| 230 | | 1 | | 1 | | | | | | | | | | | | 1 | | | | | | | | 1 |
| 240 | 1 | 6 | 2 | 19 | 1 | 1 | 14 | | 4 | 1 | 2 | | 5 | | | 10 | | 7 | | 1 | | | | |
| 250 | 10 | 1 | 25 | 7 | 51 | 9 | 21 | 15 | 47 | 9 | 74 | 7 | 29 | 8 | 24 | 3 | 30 | 1 | 25 | 2 | 19 | 3 | 19 | 4 |
| 260 | 20 | 9 | 30 | 21 | 59 | 35 | 84 | 51 | 76 | 17 | 106 | 30 | 81 | 27 | 50 | 15 | 79 | 22 | 94 | 27 | 59 | 7 | 55 | 12 |
| 270 | 23 | 16 | 40 | 40 | 40 | 43 | 131 | 76 | 64 | 66 | 77 | 72 | 96 | 62 | 96 | 28 | 55 | 35 | 102 | 87 | 92 | 49 | 91 | 52 |
| 280 | 35 | 31 | 19 | 25 | 18 | 19 | 96 | 67 | 39 | 67 | 40 | 51 | 51 | 78 | 79 | 79 | 37 | 41 | 48 | 66 | 108 | 77 | 69 | 77 |
| 290 | 34 | 28 | 17 | 19 | 6 | 14 | 45 | 29 | 17 | 33 | 11 | 23 | 15 | 45 | 27 | 67 | 16 | 36 | 7 | 23 | 39 | 62 | 33 | 65 |
| 300 | 14 | 29 | 9 | 10 | 2 | 2 | 14 | 14 | 1 | 15 | 1 | 6 | 1 | 5 | 1 | 24 | 2 | 14 | 1 | 7 | 6 | 34 | 7 | 32 |
| 310 | 2 | 11 | | 6 | 1 | 4 | | | 2 | | 5 | | 1 | | 6 | | | 4 | | 1 | | 3 | 1 | 5 |
| 320 | 2 | | | | 1 | 1 | | | 1 | | | | | | | | 1 | | | | | | | |
| 330 | | | | | | | | | | | | | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | 139 | 127 | 147 | 130 | 197 | 127 | 394 | 255 | 259 | 213 | 313 | 191 | 276 | 231 | 283 | 220 | 229 | 154 | 284 | 213 | 324 | 236 | 276 | 247 |

Appendix Table 7.4 cont.

Blueback

Town Brook

Quashnet River

Mystic River

| | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | |
|-------|------|----|------|----|------|----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|----|---|
| TL mm | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | |
| 190 | | | | | 1 | | | | 3 | | | | | | 2 | | | | | | | | | | |
| 200 | | | | 2 | | | 1 | | 2 | | 6 | | 8 | | | | 5 | | | 2 | | 6 | | | |
| 210 | | | | | 17 | | 1 | | 8 | | 21 | | | 3 | | 3 | | | 13 | | 40 | | 5 | | 2 |
| 220 | | 14 | 2 | 41 | | | 36 | 8 | 43 | 4 | 49 | 3 | 37 | 1 | 23 | 4 | 18 | 1 | 34 | 1 | 41 | | | 0 | |
| 230 | | 22 | 11 | 37 | 5 | 97 | 50 | 50 | 4 | 145 | 37 | 112 | 25 | 91 | 20 | 44 | 8 | 28 | 6 | 129 | 39 | 13 | | | |
| 240 | | 14 | 13 | 28 | 16 | 70 | 64 | 28 | 5 | 87 | 74 | 105 | 43 | 122 | 40 | 52 | 28 | 46 | 15 | 66 | 85 | 53 | 7 | | |
| 250 | | 5 | 18 | 3 | 8 | 31 | 60 | 14 | 10 | 19 | 29 | 27 | 38 | 44 | 59 | 38 | 36 | 22 | 43 | 17 | 26 | 32 | 36 | | |
| 260 | | 2 | 13 | 1 | 3 | 5 | 25 | 3 | 5 | 1 | 6 | 3 | 10 | 6 | 19 | 9 | 29 | 4 | 14 | 1 | 11 | 2 | 25 | | |
| 270 | | | | 3 | | 1 | 1 | 7 | 2 | | | | | 1 | | 4 | | 2 | 12 | 1 | 9 | 2 | 9 | 3 | |
| 280 | | | | | | | 3 | | | | | | | | | | | | | | 2 | | | 3 | |
| 290 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 300 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 310 | | | | 5 | | | | | | | | | | | | | | | | | | | | | |
| 320 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 330 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 340 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | 0 | 0 | 59 | 65 | 129 | 33 | 243 | 217 | 157 | 28 | 330 | 149 | 287 | 118 | 296 | 146 | 178 | 114 | 181 | 90 | 261 | 173 | 102 | 71 | |

Appendix Table 7.4 cont.

| Blueback | | | | | | | | | | | |
|--------------|------|----|------|----|------|-----|------|-----|------|-----|----|
| Parker River | | | | | | | | | | | |
| TL mm | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | |
| | M | F | M | F | M | F | M | F | M | F | |
| 190 | | | | | | | | | | | |
| 200 | | | | | | | | | | | |
| 210 | | | | | 3 | | | | | | |
| 220 | 2 | 4 | | | 7 | | 2 | | | | |
| 230 | 23 | | 11 | | 9 | 1 | 32 | 1 | 1 | | |
| 240 | 77 | 5 | 39 | 2 | 57 | 10 | 108 | 39 | 36 | | |
| 250 | 61 | 16 | 92 | 9 | 98 | 27 | 92 | 57 | 120 | 21 | |
| 260 | 20 | 9 | 57 | 34 | 60 | 39 | 30 | 28 | 71 | 38 | |
| 270 | 1 | 4 | 9 | 23 | 18 | 28 | 5 | 12 | 33 | 29 | |
| 280 | | | | | 7 | 3 | 21 | 2 | 8 | 2 | 20 |
| 290 | | | | | | | | | | | 4 |
| 300 | | | | | | | | | | | |
| 310 | | | | | | | | | | | |
| 320 | | | | | | | | | | | |
| 330 | | | | | | | | | | | |
| 340 | | | | | | | | | | | |
| Total | 184 | 34 | 212 | 75 | 255 | 129 | 271 | 145 | 263 | 112 | |

| Agawam | | | | | | | | | | | |
|--------|------|---|------|----|------|----|------|----|------|-----|--|
| TL mm | 1991 | | 1985 | | 1993 | | 2012 | | 2013 | | |
| | M | F | M | F | M | F | M | F | M | F | |
| 190 | | | | | | | | | | | |
| 200 | | | | | | | 3 | 10 | 12 | | |
| 210 | | | | | | | 10 | 3 | 39 | 103 | |
| 220 | 2 | | | | | | 16 | 1 | 104 | 2 | |
| 230 | 2 | 1 | 3 | | | | 7 | 5 | 73 | 7 | |
| 240 | | | | | 16 | 2 | 8 | 4 | 40 | 8 | |
| 250 | 1 | | 19 | 10 | 7 | | 9 | 13 | 15 | 46 | |
| 260 | 2 | 3 | 16 | 20 | 5 | | 16 | 5 | 7 | 9 | |
| 270 | | 2 | 8 | 11 | 4 | | 15 | 1 | 5 | 1 | |
| 280 | | | 1 | 14 | 1 | | 9 | | 1 | 2 | |
| 290 | | | | | | | | | 2 | | |
| 300 | | | | | | | 7 | | 4 | | |
| 310 | | | | | | | 3 | | | | |
| 320 | | | | | | | 1 | | | | |
| 330 | | | | | | | 1 | | | | |
| 340 | | | | | | | 1 | | | | |
| Total | 7 | 6 | 63 | 70 | 61 | 68 | | | | | |

| Charles | | | | | | | | | | | |
|---------|------|-----|------|-----|------|---|------|----|------|-----|--|
| TL mm | 1991 | | 1985 | | 1993 | | 2012 | | 2013 | | |
| | M | F | M | F | M | F | M | F | M | F | |
| 190 | | | | | | | | | | | |
| 200 | | | | | | | 3 | 10 | 12 | | |
| 210 | | | | | | | 10 | 3 | 39 | 103 | |
| 220 | 2 | | | | | | 16 | 1 | 104 | 2 | |
| 230 | 2 | 1 | 3 | | | | 7 | 5 | 73 | 7 | |
| 240 | | | | | 16 | 2 | 8 | 4 | 40 | 8 | |
| 250 | 1 | | 19 | 10 | 7 | | 9 | 13 | 15 | 46 | |
| 260 | 2 | 3 | 16 | 20 | 5 | | 16 | 5 | 7 | 9 | |
| 270 | | 2 | 8 | 11 | 4 | | 15 | 1 | 5 | 1 | |
| 280 | | | 1 | 14 | 1 | | 9 | | 1 | 2 | |
| 290 | | | | | | | 2 | | | | |
| 300 | | | | | | | 7 | | 4 | | |
| 310 | | | | | | | 3 | | | | |
| 320 | | | | | | | 1 | | | | |
| 330 | | | | | | | 1 | | | | |
| 340 | | | | | | | 1 | | | | |
| Total | 444 | 112 | 180 | 147 | 2 | 0 | | | | | |

| Nemasket | | | | | | | | | | | |
|----------|------|-----|------|-----|------|---|------|----|------|-----|--|
| TL mm | 1991 | | 1985 | | 1993 | | 2012 | | 2013 | | |
| | M | F | M | F | M | F | M | F | M | F | |
| 190 | | | | | | | | | | | |
| 200 | | | | | | | 3 | 10 | 12 | | |
| 210 | | | | | | | 10 | 3 | 39 | 103 | |
| 220 | 2 | | | | | | 16 | 1 | 104 | 2 | |
| 230 | 2 | 1 | 3 | | | | 7 | 5 | 73 | 7 | |
| 240 | | | | | 16 | 2 | 8 | 4 | 40 | 8 | |
| 250 | 1 | | 19 | 10 | 7 | | 9 | 13 | 15 | 46 | |
| 260 | 2 | 3 | 16 | 20 | 5 | | 16 | 5 | 7 | 9 | |
| 270 | | 2 | 8 | 11 | 4 | | 15 | 1 | 5 | 1 | |
| 280 | | | 1 | 14 | 1 | | 9 | | 1 | 2 | |
| 290 | | | | | | | 2 | | | | |
| 300 | | | | | | | 7 | | 4 | | |
| 310 | | | | | | | 3 | | | | |
| 320 | | | | | | | 1 | | | | |
| 330 | | | | | | | 1 | | | | |
| 340 | | | | | | | 1 | | | | |
| Total | 444 | 112 | 180 | 147 | 2 | 0 | | | | | |

Appendix Table 7.5. Length frequencies of alewife and blueback herring by sex and year from the Monument River. Length bins are +/- 2.5 mm total length around the midpoint shown.

| Alewife Male | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Total Length (mm) | | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 205 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 210 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 215 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 220 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 225 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 230 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 235 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 240 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 245 | 1 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 250 | 1 | 2 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 255 | 4 | 4 | 2 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 260 | 5 | 6 | 3 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 265 | 8 | 9 | 8 | 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 270 | 11 | 6 | 7 | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 275 | 14 | 7 | 4 | 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 280 | 14 | 8 | 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 285 | 10 | 10 | 14 | 17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 290 | 16 | 9 | 5 | 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 295 | 14 | 4 | 16 | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 300 | 8 | 2 | 8 | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 305 | 2 | 1 | 3 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 310 | 2 | 6 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 315 | 3 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 320 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 325 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 330 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | 96 | 83 | 83 | 99 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Alewife Female | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total Length (mm) | | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 205 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 210 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 215 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 220 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 225 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 230 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 235 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 240 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 245 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 250 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 255 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 260 | 3 | 4 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 265 | 4 | 6 | 11 | 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 270 | 3 | 2 | 4 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 275 | 10 | 18 | 14 | 16 | 15 | 11 | 23 | 25 | 11 | 9 | 18 | 16 | 17 | 10 | 12 | 14 | 3 | 29 | 30 | 28 | 26 | 12 | 22 | 30 | | | | | | | | | |
| 280 | 10 | 13 | 9 | 18 | 20 | 18 | 14 | 14 | 12 | 23 | 25 | 9 | 7 | 10 | 5 | 23 | 7 | 5 | 6 | 14 | 17 | 11 | 39 | 15 | 12 | 3 | 20 | 15 | | | | | |
| 285 | 11 | 12 | 5 | 22 | 23 | 13 | 9 | 7 | 8 | 9 | 18 | 23 | 10 | 2 | 3 | 8 | 13 | 3 | 8 | 3 | 1 | 15 | 7 | 6 | 17 | 11 | 4 | 5 | 21 | 7 | | | |
| 290 | 14 | 14 | 10 | 7 | 22 | 19 | 6 | 3 | 4 | 3 | 5 | 14 | 7 | 1 | 10 | 1 | 4 | 2 | 3 | 2 | 5 | 2 | 4 | 4 | 4 | 15 | 3 | | | | | | |
| 295 | 18 | 20 | 13 | 9 | 10 | 19 | 4 | 1 | 4 | 7 | 5 | 7 | 1 | 1 | 5 | 1 | 2 | 2 | 4 | 1 | 1 | 1 | 3 | 1 | 6 | 3 | | | | | | | |
| 300 | 20 | 13 | 5 | 13 | 9 | 13 | 4 | 1 | 1 | 4 | 5 | 4 | 1 | 1 | 2 | 1 | 2 | 1 | 4 | 1 | 1 | 2 | 1 | 1 | 3 | 1 | 6 | 3 | | | | | |
| 305 | 17 | 8 | 11 | 8 | 3 | 8 | 1 | 1 | 1 | 2 | 2 | 2 | | | | | | | | | | | | | | | | | | | | | |
| 310 | 11 | 7 | 12 | 5 | 4 | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 315 | 11 | 3 | 5 | 12 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 320 | 1 | 1 | 3 | 6 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 325 | 1 | 1 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 330 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 335 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 340 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | 127 | 104 | 87 | 118 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 135 | 161 | 97 | 92 | 122 | 92 | 137 | 174 | 90 | 79 | 117 | 99 | 108 | 44 | 72 | 66 | 58 | 185 | 194 | 157 | 216 | 125 | 110 | 63 | 151 | 145 | | | | | | | |

Appendix Table 7.5 cont.

Appendix Table 7.6. Sample size (n), mean, and standard deviation (SD) of total length distributions of alewife and blueback herrings by sex collected in nine rivers, 1985-2015.

Alewife - Females

| | Agawam | | | Back | | | Mattapoisett | | | Mystic | | | Nemasket | | | Parker | | | Quashnet | | | Stony Brook | | | Town Brook | | | |
|------|--------|-------|--------|------|---|--------|--------------|---|--------|--------|---|--------|----------|---|--------|--------|---|--------|----------|---|--------|-------------|---|--------|------------|---|--------|--|
| | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | |
| | SD | | | SD | | | SD | | | SD | | | SD | | | SD | | | SD | | | SD | | | SD | | | |
| 1991 | 71 | 282.2 | 11.88 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1995 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2004 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2005 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2006 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2007 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2008 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2009 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2011 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2013 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2014 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2015 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Alewife - Males

| | Agawam | | | Back | | | Mattapoisett | | | Mystic | | | Nemasket | | | Parker | | | Quashnet | | | Stony Brook | | | Town Brook | | | |
|------|--------|-------|--------|------|---|--------|--------------|---|--------|--------|---|--------|----------|---|--------|--------|---|--------|----------|---|--------|-------------|---|--------|------------|---|--------|--|
| | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | Mean | n | Length | |
| | SD | | | SD | | | SD | | | SD | | | SD | | | SD | | | SD | | | SD | | | SD | | | |
| 1991 | 86 | 269.8 | 13.63 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1995 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2004 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2005 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2006 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2007 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2008 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2009 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2010 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2011 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2013 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2014 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2015 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Appendix Table 7.6 cont.

| Agawam | | | Charles | | | Mystic | | | Blueback - Females | | | Nemasket | | | Parker | | | Quashnet | | | Town Brook | | |
|------------------|-----------|--------------|---------|-----------|--------------|--------|-----------|--------------|--------------------|-----------|--------------|----------|-----------|--------------|----------|-----------|--------------|------------|-----------|--------------|------------|--|--|
| | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | | |
| 1985 | | | | 70 | 276.8 | 20.58 | | | | | | | | | | | | | | | | | |
| 1991 | 6 | 262.3 | 16.71 | | | | | | | | | | | | | | | | | | | | |
| 1993 | | | | 68 | 264.1 | 20.18 | | | | | | | | | | | | | | | | | |
| 2004 | | | | | | | 61 | 251.5 | 14.31 | | | | | | | | | | | | | | |
| 2005 | | | | | | | 38 | 242.8 | 13.99 | | | | | | | | | | | | | | |
| 2006 | | | | | | | 217 | 248.0 | 11.77 | | | | | | | | | | | | | | |
| 2007 | | | | | | | 28 | 247.4 | 12.70 | | | | | | | | | | | | | | |
| 2008 | | | | | | | 150 | 244.2 | 7.76 | | | | | | | | | | | | | | |
| 2009 | | | | | | | 118 | 247.6 | 9.48 | | | | | | | | | | | | | | |
| 2010 | | | | | | | 146 | 250.5 | 10.54 | | | | | | 34 | 258.4 | 8.59 | | | | | | |
| 2011 | | | | 45 | 252.3 | 13.16 | 114 | 254.4 | 10.96 | | | | | | 75 | 267.9 | 9.28 | | | | | | |
| 2012 | | | | 112 | 253.7 | 10.91 | 90 | 255.1 | 11.41 | | | | | | 129 | 266.6 | 12.22 | | | | | | |
| 2013 | | | | 147 | 252.8 | 11.52 | 173 | 246.9 | 10.93 | | | | | | 145 | 256.5 | 11.34 | | | | | | |
| 2014 | | | | | | | 71 | 258.0 | 7.12 | | | | | | 112 | 269.3 | 10.42 | | | | | | |
| 2015 | | | | | | | | | | | | | | | | | | | | | | | |
| Blueback - Males | | | | | | | | | | | | | | | | | | | | | | | |
| Agawam | | | Charles | | | Mystic | | | Nemasket | | | Parker | | | Quashnet | | | Town Brook | | | | | |
| | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | Mean n | Length SD | | | |
| 1985 | | | | 63 | 256.7 | 11.81 | | | | | | | | | | | | | | | | | |
| 1991 | 7 | 242.9 | 17.61 | | | | | | | | | | | | | | | | | | | | |
| 1993 | | | | 61 | 235.8 | 20.30 | | | | | | | | | | | | | | | | | |
| 2004 | | | | | | | 58 | 236.1 | 10.59 | | | | | | 2 | 232.5 | 6.36 | | | | | | |
| 2005 | | | | | | | 131 | 230.6 | 11.20 | | | | | | | | | | | | | | |
| 2006 | | | | | | | 243 | 239.0 | 10.04 | | | | | | | | | | | | | | |
| 2007 | | | | | | | 157 | 233.4 | 14.05 | | | | | | | | | | | | | | |
| 2008 | | | | | | | 333 | 234.7 | 10.42 | | | | | | | | | | | | | | |
| 2009 | | | | | | | 287 | 238.9 | 8.74 | | | | | | | | | | | | | | |
| 2010 | | | | | | | 296 | 240.3 | 11.06 | | | | | | 184 | 248.2 | 8.64 | | | | | | |
| 2011 | | | | 285 | 230.4 | 12.06 | 178 | 240.8 | 13.54 | | | | | | 212 | 254.3 | 9.61 | | | | | | |
| 2012 | | | | 444 | 231.9 | 14.27 | 181 | 232.7 | 15.33 | | | | | | 255 | 254.1 | 11.62 | | | | | | |
| 2013 | | | | 180 | 243.1 | 9.86 | 261 | 236.6 | 8.98 | | | | | | 271 | 249.5 | 9.67 | | | | | | |
| 2014 | | | | | | | 102 | 246.1 | 7.28 | | | | | | 263 | 258.4 | 8.61 | | | | | | |
| 2015 | | | | | | | | | | | | | | | | | | | | | | | |

Appendix Table 7.7. Sample size (n), mean, and standard deviation (SD) of total length distributions of alewife and blueback herrings by sex collected in the Monument River, 1984-2010.

| Monument River | | | | | | | | | | |
|----------------|---------|-------------|-------|------|-------------|------------------|--------|-------------|-------|-------|
| | Alewife | | | | | Blueback Herring | | | | |
| Year | Female | | | Male | | Year | Female | | | |
| | n | Mean Length | SD | n | Mean Length | SD | n | Mean Length | SD | |
| 1984 | 127 | 295.6 | 13.17 | 96 | 281.3 | 14.85 | 1984 | 101 | 265.9 | 16.17 |
| 1985 | 104 | 291.3 | 12.80 | 83 | 277.8 | 16.72 | 1985 | 55 | 279.4 | 14.59 |
| 1986 | 87 | 297.5 | 16.51 | 83 | 284.6 | 15.34 | 1986 | 43 | 272.9 | 12.87 |
| 1987 | 118 | 295.1 | 16.30 | 99 | 281.1 | 14.25 | 1987 | 35 | 271.7 | 17.32 |
| 1988 | | | | | | | 1988 | | | |
| 1989 | | | | | | | 1989 | | | |
| 1990 | 135 | 282.1 | 14.27 | 124 | 270.0 | 13.87 | 1990 | 71 | 259.7 | 11.65 |
| 1991 | 161 | 283.4 | 15.49 | 205 | 267.6 | 13.34 | 1991 | 63 | 265.9 | 16.00 |
| 1992 | 97 | 275.5 | 12.54 | 93 | 265.2 | 11.69 | 1992 | 14 | 263.2 | 13.67 |
| 1993 | 92 | 271.2 | 10.36 | 79 | 264.7 | 11.28 | 1993 | 13 | 261.9 | 11.09 |
| 1994 | 122 | 267.8 | 14.55 | 139 | 256.2 | 12.65 | 1994 | 26 | 255.6 | 15.90 |
| 1995 | 92 | 269.2 | 12.45 | 123 | 257.4 | 8.99 | 1995 | 21 | 256.4 | 9.24 |
| 1996 | 137 | 274.6 | 11.95 | 197 | 265.8 | 10.48 | 1996 | 20 | 259.0 | 11.19 |
| 1997 | 174 | 274.9 | 12.77 | 197 | 262.7 | 13.97 | 1997 | 100 | 254.1 | 14.40 |
| 1998 | 90 | 274.8 | 15.27 | 101 | 262.3 | 12.42 | 1998 | 18 | 246.7 | 6.18 |
| 1999 | 79 | 263.9 | 12.78 | 131 | 253.5 | 10.44 | 1999 | 4 | 237.5 | 17.56 |
| 2000 | 117 | 263.5 | 12.02 | 132 | 251.1 | 10.58 | 2000 | 20 | 248.5 | 8.75 |
| 2001 | 99 | 265.5 | 13.01 | 112 | 259.7 | 10.22 | 2001 | 28 | 248.8 | 11.83 |
| 2002 | 108 | 275.4 | 12.72 | 133 | 264.2 | 11.62 | 2002 | 43 | 255.7 | 11.10 |
| 2003 | 44 | 270.5 | 11.35 | 45 | 260.7 | 10.80 | 2003 | 70 | 248.1 | 10.01 |
| 2004 | 72 | 270.8 | 11.59 | 95 | 262.4 | 11.17 | 2004 | 49 | 254.8 | 10.71 |
| 2005 | 66 | 265.1 | 10.73 | 82 | 259.2 | 11.17 | 2005 | 40 | 251.9 | 11.82 |
| 2006 | 58 | 263.7 | 14.04 | 61 | 249.4 | 7.89 | 2006 | 56 | 247.9 | 12.31 |
| 2007 | 185 | 269.1 | 12.88 | 220 | 259.4 | 11.41 | 2007 | 69 | 250.3 | 10.04 |
| 2008 | 194 | 262.6 | 13.75 | 286 | 253.0 | 12.23 | 2008 | 67 | 244.1 | 9.52 |
| 2009 | 157 | 265.5 | 9.54 | 158 | 256.2 | 10.23 | 2009 | 80 | 246.0 | 8.07 |
| 2010 | 216 | 270.7 | 10.70 | 264 | 259.4 | 10.84 | 2010 | 67 | 244.3 | 9.66 |
| 2011 | 125 | 269.1 | 11.20 | 158 | 258.4 | 12.37 | 2011 | 98 | 245.6 | 12.72 |
| 2012 | 110 | 267.7 | 11.61 | 152 | 254.9 | 10.46 | 2012 | 78 | 246.3 | 9.79 |
| 2013 | 63 | 269.4 | 11.96 | 99 | 256.6 | 10.88 | 2013 | 93 | 245.5 | 8.02 |
| 2014 | 151 | 274.7 | 12.47 | 237 | 262.6 | 11.36 | 2014 | 108 | 248.6 | 10.03 |
| 2015 | 145 | 269.1 | 9.78 | 128 | 261.2 | 9.18 | 2015 | 133 | 256.5 | 8.94 |

Appendix Table 7.8. Age composition of alewife and blueback herring from Massachusetts rivers, 2004-2015.

Alewife

| Age | Back River | | | | | | | | | | | | |
|-------|------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | Female | | | | | Male | | | | | | | |
| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 36 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 119 | 0 | 0 | 0 | 0 | 0 | 152 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 35 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 210 | 0 | 0 | 0 | 0 | 0 | 228 | 0 | 0 | 0 |

| Age | Quashnet River | | | | | | | | | | | | |
|-------|----------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | Female | | | | | Male | | | | | | | |
| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 |
| 4 | 61 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 |
| 5 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 85 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 65 | 0 | 0 | 0 | 0 |

| Age | Mattapoisett River | | | | | | | | | | | | | | | |
|-------|--------------------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|---|
| | Female | | | | | Male | | | | | | | | | | |
| 1995 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 1995 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 4 | 0 | 0 | 9 | 0 | 0 | 0 | 9 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 |
| 4 | 20 | 0 | 0 | 9 | 0 | 0 | 0 | 26 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 |
| 5 | 13 | 0 | 0 | 5 | 0 | 0 | 0 | 10 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| 6 | 9 | 0 | 0 | 1 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 50 | 0 | 0 | 24 | 0 | 0 | 0 | 54 | 0 | 0 | 35 | 0 | 0 | 0 | 0 | 0 |
| | 4.78 | | | | 4.352 | | | | | | | | | | | |

| Age | Stony Brook | | | | | | | | | | | | | | |
|-------|-------------|------|------|------|------|------|------|------|------|------|------|------|------|---|---|
| | Female | | | | | Male | | | | | | | | | |
| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | | |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 0 | 0 | 0 | 0 | 0 |
| 4 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 0 | 0 | 0 | 0 | 0 |
| 5 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 0 | 0 | 0 | 0 | 0 |
| 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 116 | 0 | 0 | 0 | 0 | 0 |

| Age | Mystic River | | | | | | | | | | | | | | | | | | | |
|-------|--------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|----|-----|
| | Female | | | | | Male | | | | | | | | | | | | | | |
| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | | |
| 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 6 | 2 | 1 | 0 | |
| 3 | 4 | 0 | 1 | 37 | 10 | 4 | 14 | 39 | 35 | 124 | 64 | 83 | 25 | 2 | 6 | 57 | 39 | 5 | 9 | |
| 4 | 40 | 5 | 9 | 75 | 25 | 30 | 9 | 58 | 80 | 21 | 56 | 67 | 34 | 4 | 3 | 68 | 56 | 35 | 2 | |
| 5 | 9 | 6 | 4 | 7 | 10 | 18 | 3 | 8 | 19 | 19 | 6 | 17 | 10 | 3 | 1 | 7 | 11 | 14 | 2 | |
| 6 | 2 | 1 | 1 | 5 | 8 | 4 | 0 | 14 | 6 | 4 | 3 | 3 | 1 | 1 | 0 | 1 | 2 | 4 | 1 | |
| 7 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 56 | 12 | 15 | 126 | 53 | 56 | 26 | 122 | 142 | 171 | 130 | 171 | 71 | 10 | 10 | 133 | 108 | 58 | 14 | 192 |

Appendix Table 7.8 cont.

| Age | Town Brook | | | | | | | | | | | | Male | | | | | | | | | | | | |
|-------|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|
| | Female | | | | | | | | | | | | Male | | | | | | | | | | | | |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 |
| 3 | 5 | 20 | 25 | 27 | 4 | 2 | 20 | 18 | 49 | 59 | 93 | 72 | 17 | 16 | 45 | 61 | 24 | 10 | 47 | 25 | 73 | 72 | 127 | 88 | |
| 4 | 52 | 79 | 75 | 164 | 81 | 65 | 69 | 108 | 78 | 81 | 49 | 168 | 50 | 104 | 80 | 190 | 113 | 91 | 73 | 116 | 71 | 77 | 30 | 137 | |
| 5 | 35 | 26 | 26 | 38 | 89 | 75 | 63 | 39 | 50 | 24 | 26 | 11 | 14 | 27 | 11 | 45 | 94 | 74 | 47 | 33 | 28 | 16 | 11 | 9 | |
| 6 | 1 | 3 | 0 | 13 | 28 | 27 | 25 | 12 | 10 | 11 | 5 | 5 | 2 | 5 | 0 | 10 | 24 | 27 | 12 | 4 | 2 | 5 | 5 | 7 | |
| 7 | 1 | 1 | 0 | 0 | 4 | 8 | 2 | 2 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 2 | 4 | 1 | 1 | 1 | 2 | 1 | 1 | |
| 8 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 94 | 129 | 126 | 242 | 206 | 177 | 179 | 179 | 188 | 175 | 174 | 257 | 83 | 153 | 136 | 307 | 257 | 206 | 180 | 179 | 175 | 175 | 174 | 244 | |

| Parker River | | | | | | | | | | | |
|--------------|--------|------|------|------|------|------|------|------|------|------|--|
| Age | Female | | | | | Male | | | | | |
| | 2011 | 2012 | 2013 | 2014 | 2015 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 1 | |
| 3 | 2 | 16 | 23 | 23 | 0 | 7 | 69 | 87 | 56 | 11 | |
| 4 | 3 | 53 | 22 | 42 | 14 | 4 | 82 | 47 | 82 | 97 | |
| 5 | 0 | 4 | 27 | 20 | 7 | 0 | 7 | 37 | 27 | 34 | |
| 6 | 0 | 1 | 1 | 6 | 3 | 0 | 2 | 3 | 8 | 11 | |
| 7 | 0 | 2 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| Total | 5 | 76 | 75 | 91 | 24 | 11 | 172 | 174 | 173 | 155 | |

| Agawam | | | Charles | | | |
|--------|--------|------|---------|------|------|------|
| | Female | | Female | | Male | |
| Age | 1991 | 1991 | 2013 | 2014 | 2013 | 2014 |
| 2 | 0 | | 2 | 0 | 0 | 0 |
| 3 | 1 | 6 | 3 | 89 | 16 | 130 |
| 4 | 35 | 49 | 4 | 12 | 51 | 25 |
| 5 | 28 | 27 | 5 | 6 | 5 | 2 |
| 6 | 6 | 4 | 6 | 1 | 2 | 2 |
| 7 | 1 | 0 | 7 | 0 | 0 | 0 |
| 8 | 0 | 0 | 8 | 0 | 0 | 0 |
| Total | 71 | 86 | Total | 108 | 74 | 159 |

Appendix Table 7.8 cont.

Blueback

| Age | Mystic River | | | | | | | | | | | | Male | | | | | | | | | | | | |
|-------|--------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|
| | Female | | | | | | | | | | | | Male | | | | | | | | | | | | |
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 22 | 1 | 5 | 13 | 72 | 7 | 2 |
| 3 | 0 | 3 | 2 | 62 | 4 | 75 | 71 | 17 | 34 | 60 | 148 | 26 | 0 | 18 | 42 | 81 | 55 | 207 | 135 | 51 | 78 | 82 | 147 | 33 | |
| 4 | 0 | 32 | 18 | 94 | 12 | 49 | 44 | 115 | 47 | 10 | 16 | 44 | 0 | 22 | 58 | 125 | 67 | 54 | 41 | 121 | 52 | 14 | 20 | 55 | |
| 5 | 0 | 3 | 9 | 49 | 8 | 9 | 2 | 13 | 30 | 9 | 6 | 1 | 0 | 2 | 10 | 30 | 23 | 15 | 2 | 6 | 31 | 4 | 0 | 8 | |
| 6 | 0 | 2 | 2 | 7 | 3 | 3 | 1 | 1 | 3 | 6 | 2 | 0 | 0 | 0 | 0 | 1 | 6 | 2 | 0 | 0 | 4 | 7 | 0 | 0 | |
| 7 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | |
| Total | 0 | 40 | 31 | 213 | 28 | 136 | 118 | 146 | 114 | 90 | 172 | 71 | 0 | 42 | 110 | 237 | 157 | 300 | 180 | 183 | 178 | 180 | 174 | 99 | |

Town Brook

| Age | Female | | | | | | Male | | | | | | | | | | | | Male | | | | | |
|-------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 2004 | | | 2005 | | | 2006 | | | 2007 | | | 2008 | | | 2009 | | | 2010 | | | 2015 | | |
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2015 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2015 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2015 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Parker River

| Age | Female | | | | | | Male | | | | | | | | | | | | Male | | | | | | | | |
|-------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|--|
| | 2011 | | | 2012 | | | 2013 | | | 2014 | | | 2015 | | | 2011 | | | 2012 | | | 2013 | | | 2014 | | |
| | 2011 | 2012 | 2013 | 2014 | 2015 | 2011 | 2012 | 2013 | 2014 | 2015 | 2011 | 2012 | 2013 | 2014 | 2015 | 2011 | 2012 | 2013 | 2014 | 2015 | 2011 | 2012 | 2013 | 2014 | 2015 | | |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 3 | 20 | 9 | 67 | 116 | 9 | 125 | 53 | 90 | 146 | 47 | 50 | 138 | 22 | 26 | 197 | 5 | 10 | 38 | 3 | 7 | 8 | 15 | 48 | 2 | 16 | | |
| 4 | 13 | 54 | 17 | 25 | 93 | 5 | 1 | 38 | 3 | 7 | 6 | 0 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 2 | 2 | 0 | 0 | | | |
| 5 | 1 | 0 | 2 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| 7 | 0 | 2 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Total | 34 | 75 | 129 | 145 | 111 | 184 | 212 | 175 | 175 | 262 | | | | | | | | | | | | | | | | | |

Quashnet River

| Age | Female | | | | | | Male | | | | | | | | | | | | Male | | | | | |
|-------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 2004 | | | 2005 | | | 2006 | | | 2007 | | | 2008 | | | 2009 | | | 2010 | | | 2004 | | |
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Agawam

| Age | Female | | Male | |
|-------|--------|------|------|------|
| | 1991 | 1991 | 1991 | 1991 |
| 2 | 0 | 0 | 0 | 0 |
| 3 | 0 | 1 | 1 | 1 |
| 4 | 3 | 2 | 2 | 2 |
| 5 | 2 | 2 | 2 | 2 |
| 6 | 1 | 2 | 2 | 2 |
| 7 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 |
| Total | 6 | 7 | 7 | 7 |

Charles</

Appendix Table 7.9. Age composition of alewife and blueback herring from the Monument River, 1985-2010.

Alewife

Female

| Age | 1985 | 1986 | 1987 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|---|
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 |
| 3 | 7 | 2 | 1 | 0 | 5 | 0 | 2 | 1 | 6 | 6 | 5 | 8 | 3 | 2 | 6 | 10 | 52 | 18 | 1 | 30 | 12 | 64 | 39 | 34 | 27 | |
| 4 | 28 | 29 | 38 | 24 | 43 | 60 | 20 | 29 | 18 | 77 | 60 | 35 | 34 | 53 | 35 | 26 | 97 | 89 | 80 | 61 | 87 | 29 | 12 | 84 | 111 | |
| 5 | 29 | 30 | 32 | 19 | 17 | 23 | 22 | 35 | 13 | 18 | 24 | 45 | 17 | 17 | 24 | 17 | 22 | 69 | 48 | 83 | 21 | 14 | 2 | 5 | 7 | |
| 6 | 5 | 19 | 20 | 7 | 11 | 5 | 5 | 14 | 0 | 4 | 4 | 6 | 4 | 0 | 1 | 4 | 3 | 16 | 12 | 6 | 5 | 1 | 4 | 2 | 0 | |
| 7 | 4 | 5 | 15 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| 8 | 3 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 76 | 86 | 110 | 51 | 76 | 88 | 49 | 80 | 37 | 105 | 94 | 94 | 58 | 72 | 66 | 57 | 178 | 194 | 141 | 180 | 125 | 110 | 59 | 125 | 145 | |

Male

| Age | 1985 | 1986 | 1987 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 11 | 1 | 0 | 0 |
| 3 | 17 | 10 | 2 | 6 | 34 | 25 | 16 | 6 | 17 | 13 | 16 | 23 | 6 | 6 | 9 | 24 | 93 | 83 | 11 | 64 | 40 | 100 | 80 | 78 | 29 |
| 4 | 26 | 40 | 39 | 21 | 48 | 59 | 30 | 56 | 20 | 83 | 60 | 62 | 44 | 71 | 54 | 32 | 100 | 129 | 88 | 77 | 100 | 34 | 16 | 92 | 96 |
| 5 | 12 | 27 | 34 | 13 | 12 | 22 | 9 | 25 | 11 | 15 | 29 | 36 | 16 | 15 | 17 | 5 | 16 | 65 | 30 | 37 | 12 | 6 | 1 | 4 | 3 |
| 6 | 8 | 5 | 13 | 4 | 2 | 3 | 4 | 6 | 1 | 1 | 2 | 1 | 2 | 0 | 2 | 0 | 2 | 8 | 8 | 1 | 3 | 1 | 0 | 0 | 0 |
| 7 | 2 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 65 | 83 | 90 | 44 | 96 | 109 | 59 | 94 | 49 | 112 | 107 | 122 | 69 | 92 | 82 | 61 | 211 | 286 | 137 | 179 | 156 | 152 | 98 | 174 | 128 |

Blueback

Female

| Age | 1985 | 1986 | 1987 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 9 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 5 | 5 | 11 | 5 | 11 | 7 | 13 | 30 | 15 | 33 | 60 | 28 | 8 | |
| 4 | 22 | 14 | 1 | 5 | 7 | 10 | 30 | 12 | 3 | 9 | 14 | 29 | 44 | 30 | 14 | 33 | 48 | 46 | 45 | 29 | 76 | 37 | 29 | 55 | 105 |
| 5 | 19 | 19 | 16 | 4 | 8 | 5 | 16 | 2 | 1 | 9 | 7 | 9 | 19 | 13 | 14 | 18 | 9 | 12 | 13 | 8 | 7 | 8 | 4 | 2 | 19 |
| 6 | 2 | 5 | 7 | 1 | 3 | 1 | 3 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7 | 1 | 1 | 3 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 53 | 39 | 31 | 11 | 18 | 16 | 52 | 14 | 5 | 19 | 23 | 40 | 68 | 48 | 39 | 56 | 68 | 67 | 74 | 67 | 98 | 78 | 93 | 85 | 133 |

Male

| Age | 1985 | 1986 | 1987 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 3 | 12 | 5 | 8 | 1 | 1 | 6 | 25 | 4 | 5 | 6 | 17 | 9 | 13 | 14 | 8 | 14 | 44 | 22 | 31 | 60 | 58 | 79 | 115 | 85 | 23 |
| 4 | 17 | 32 | 31 | 11 | 7 | 11 | 27 | 5 | 22 | 16 | 14 | 40 | 48 | 31 | 33 | 40 | 31 | 44 | 37 | 15 | 70 | 34 | 54 | 86 | 144 |
| 5 | 5 | 14 | 16 | 2 | 8 | 4 | 5 | 2 | 2 | 6 | 9 | 10 | 8 | 3 | 9 | 11 | 6 | 5 | 17 | 5 | 1 | 4 | 4 | 8 | 16 |
| 6 | 2 | 0 | 4 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 3 |
| 7 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 36 | 51 | 60 | 15 | 16 | 24 | 58 | 11 | 29 | 28 | 41 | 59 | 69 | 48 | 51 | 65 | 81 | 72 | 85 | 80 | 129 | 119 | 174 | 182 | 186 |

Appendix Table 7.10. Average age (years) of alewife and blueback herring collected by sex, river and year. *=not calculated due to small sample size.

| River | Alewife Female | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------|-------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1985 | 1986 | 1987 | 1991 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Agawam | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Back | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Charles | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Mattapoisett | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Monument | - | - | - | - | - | - | - | - | 4.7 | 5.0 | 5.2 | - | 4.7 | 4.4 | 4.4 | 4.6 | 4.8 | 4.2 | 4.2 | 4.3 | 4.5 | 4.4 | 4.2 | 4.3 | 4.3 | 3.9 | 4.5 | 4.5 | 4.4 | 4.2 | 3.5 | 3.5 | 3.8 | 3.9 |
| Mystic | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Nemasket | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Parker | 6.0 | 5.2 | 4.3 | 4.5 | 5.3 | 5.7 | 5.1 | 4.4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Quashnet | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Stony Brook | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Town Brook | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Male | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| River | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1985 | 1986 | 1987 | 1991 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Agawam | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Back | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Charles | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Mattapoisett | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Monument | - | - | - | - | - | - | - | - | 4.3 | 4.4 | 4.7 | - | 4.3 | 3.8 | 4.0 | 4.0 | 4.4 | 3.9 | 4.0 | 4.2 | 4.1 | 4.2 | 4.1 | 3.7 | 3.7 | 4.0 | 4.3 | 3.9 | 3.8 | 3.3 | 3.2 | 3.6 | 3.8 | |
| Mystic | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Nemasket | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Parker | 5.7 | 4.2 | 4.0 | 4.5 | 5.0 | 5.4 | 5.1 | 4.4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Quashnet | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Stony Brook | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Town Brook | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Blueback Female | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| River | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1985 | 1986 | 1987 | 1991 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Agawam | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Charles | - | - | - | - | - | - | - | - | 5.2 | - | - | 4.8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Monument | - | - | - | - | - | - | - | - | 4.3 | 4.8 | 5.1 | - | 4.8 | 4.8 | 4.4 | 4.5 | 4.1 | 4.6 | 4.4 | 4.2 | 4.3 | 4.2 | 4.2 | 4.1 | 4.2 | 4.0 | 4.2 | 4.1 | 3.7 | 3.9 | 3.4 | - | | |
| Mystic | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Parker | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Quashnet | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Town Brook | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Male | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| River | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1985 | 1986 | 1987 | 1991 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Agawam | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Charles | - | - | - | - | - | - | - | - | 4.4 | - | - | 4.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Monument | - | - | - | - | - | - | - | - | 3.9 | 4.2 | 4.3 | - | 4.2 | 4.4 | 4.0 | 3.7 | 3.8 | 3.9 | 4.0 | 3.9 | 4.0 | 3.8 | 4.1 | 4.0 | 3.5 | 3.7 | 3.8 | 3.2 | 3.6 | 4.0 | | | | |
| Mystic | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Parker | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Quashnet | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |
| Town Brook | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | | |

Appendix Table 7.11. Repeat spawner frequencies for alewife and blueback herring by river, sex and year. 0 = new spawner, 1=second-time spawner, 2= third-time spawner, etc.

| Alewife | | | | | | | | | | | | | | | | |
|--------------------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Back River | | | | | | | | | | | | | | | | |
| RPS | Female | | | | | | | Male | | | | | | | | |
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | | |
| 0 | 0 | 0 | 0 | 186 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 202 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 210 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 228 | 0 | 0 | 0 | 0 |
| Mattapoisett River | | | | | | | | | | | | | | | | |
| RPS | Female | | | | | | | Male | | | | | | | | |
| | 1995 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 1995 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| 0 | 33 | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 44 | 0 | 0 | 34 | 0 | 0 | 0 | 0 |
| 1 | 14 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 49 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 54 | 0 | 0 | 35 | 0 | 0 | 0 | 0 |
| Quashnet River | | | | | | | | | | | | | | | | |
| RPS | Female | | | | | | | Male | | | | | | | | |
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | | |
| 0 | 79 | 0 | 0 | 0 | 0 | 0 | 0 | 62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 85 | 0 | 0 | | | | | 65 | 0 | 0 | | | | | | |
| Stony Brook | | | | | | | | | | | | | | | | |
| RPS | Female | | | | | | | Male | | | | | | | | |
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | | |
| 0 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 97 | 0 | 0 | 0 | 0 | 0 | 0 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix Table 7.11 cont.

Alewife

Mystic River

| RPS | Female | | | | | | | | | | Male | | | | | | | | | |
|-------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| 0 | 36 | 11 | 15 | 110 | 40 | 40 | 22 | 79 | 76 | 134 | 48 | 7 | 10 | 125 | 91 | 46 | 12 | 149 | 115 | 147 |
| 1 | 18 | 0 | 0 | 12 | 7 | 14 | 3 | 24 | 50 | 27 | 19 | 3 | 0 | 7 | 16 | 10 | 2 | 39 | 53 | 21 |
| 2 | 1 | 1 | 0 | 3 | 5 | 2 | 1 | 12 | 12 | 7 | 4 | 0 | 0 | 2 | 0 | 2 | 0 | 4 | 6 | 7 |
| 3 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 56 | 12 | 15 | 126 | 53 | 56 | 26 | 26 | 26 | 26 | 71 | 10 | 10 | 134 | 108 | 58 | 14 | 192 | 174 | 175 |

Alewife

Nemasket River

| RPS | Female | | | | | | | | | | Male | | | | | | | | | |
|-------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| 0 | 70 | 98 | 112 | 218 | 167 | 103 | 146 | 131 | 124 | 142 | 78 | 104 | 176 | 347 | 207 | 208 | 159 | 134 | 148 | 136 |
| 1 | 31 | 24 | 11 | 30 | 37 | 42 | 35 | 44 | 26 | 28 | 34 | 30 | 15 | 47 | 43 | 38 | 25 | 45 | 20 | 33 |
| 2 | 21 | 5 | 1 | 3 | 8 | 3 | 8 | 3 | 2 | 1 | 24 | 8 | 3 | 0 | 9 | 4 | 5 | 3 | 6 | 3 |
| 3 | 1 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 3 | 4 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 0 |
| Total | 123 | 129 | 124 | 252 | 213 | 148 | 189 | 178 | 154 | 171 | 139 | 146 | 195 | 394 | 259 | 252 | 189 | 182 | 175 | 172 |

Town Brook

| RPS | Female | | | | | | | | | | Male | | | | | | | | | |
|-------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| 0 | 81 | 110 | 116 | 202 | 146 | 122 | 142 | 138 | 119 | 124 | 69 | 134 | 130 | 237 | 174 | 140 | 150 | 135 | 127 | 121 |
| 1 | 11 | 18 | 10 | 37 | 50 | 50 | 30 | 34 | 50 | 38 | 13 | 17 | 6 | 64 | 70 | 58 | 21 | 38 | 37 | 46 |
| 2 | 0 | 2 | 0 | 3 | 11 | 5 | 7 | 7 | 17 | 12 | 1 | 2 | 0 | 6 | 13 | 6 | 9 | 6 | 10 | 6 |
| 3 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 2 |
| Total | 94 | 130 | 126 | 243 | 207 | 177 | 179 | 179 | 188 | 175 | 83 | 153 | 136 | 307 | 257 | 206 | 180 | 179 | 175 | 175 |

Agawam

Fem Male

| RPSS | 1991 | 1991 |
|-------|------|------|
| 0 | 63 | 77 |
| 1 | 6 | 9 |
| 2 | 2 | 0 |
| 3 | 0 | 0 |
| Total | 71 | 86 |

Appendix Table 7.11 cont.

Blueback

Mystic River

| RPS | Females | | | | | | | Males | | | | | | | | | | | | | |
|-------|---------|------|------|-------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | |
| 0 | 0 | 36 | 26 | 180 | 18 | 120 | 100 | 115 | 55 | 74 | 0 | 33 | 87 | 195 | 114 | 262 | 156 | 147 | 91 | 162 | |
| 1 | 0 | 0 | 3 | 27 | 6 | 15 | 17 | 29 | 54 | 11 | 0 | 2 | 23 | 37 | 34 | 37 | 22 | 36 | 73 | 10 | |
| 2 | 0 | 1 | 2 | 6 | 3 | 1 | 1 | 2 | 4 | 5 | 0 | 0 | 0 | 5 | 7 | 2 | 1 | 0 | 14 | 8 | |
| 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | |
| Total | 0 | 37 | 31 | 213 | 28 | 136 | 118 | 146 | 114 | 90 | 0 | 35 | 110 | 237 | 157 | 301 | 179 | 183 | 178 | 180 | |
| | | | | 0.027 | | | | | | | | | | | | | | | | | |

Quashnet River

| RPS | Females | | | | | | | Males | | | | | | | | | | | | | |
|-------|---------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 0 | | | | | | | | | | | | | | | | | |

Town Brook

| RPS | Females | | | | | | | Males | | | | | | | | | | | | | |
|-------|---------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | | | | | | | |

| RPS | Agawam | |
|-------|--------|------|
| | Fem | Male |
| 0 | 6 | 7 |
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 0 | 0 |
| Total | 6 | 7 |

| RPS | Charles | | | | | | | | |
|-----|---------|------|------|------|------|------|------|------|--|
| | Female | | | Male | | | | | |
| | 1985 | 1993 | 2012 | 2013 | 1985 | 1993 | 2012 | 2013 | |
| 0 | 32 | 37 | 29 | 96 | 32 | 47 | 151 | 152 | |
| 1 | 18 | 18 | 13 | 12 | 21 | 10 | 23 | 17 | |
| 2 | 10 | 11 | 2 | 3 | 10 | 4 | 1 | 5 | |
| 3 | 3 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | |
| 4 | 7 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | |

Appendix Table 7.12. Repeat spawner frequencies for alewife and blueback herring from the Monument River by sex and year. 0 = new spawner, 1=second-time spawner, 2= third-time spawner, etc.

Alewife

| RPS | Female | | | | | | | | | | | | | | | | | | | | | | | |
|-------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1986 | 1987 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 0 | 47 | 62 | 41 | 70 | 72 | 35 | 47 | 33 | 97 | 81 | 67 | 51 | 71 | 61 | 49 | 163 | 165 | 122 | 156 | 105 | 97 | 52 | 109 | 136 |
| 1 | 25 | 26 | 9 | 4 | 14 | 9 | 28 | 4 | 7 | 10 | 24 | 3 | 1 | 5 | 8 | 12 | 26 | 17 | 17 | 19 | 11 | 5 | 15 | 8 |
| 2 | 12 | 17 | 1 | 2 | 2 | 5 | 5 | 0 | 1 | 3 | 3 | 4 | 0 | 0 | 1 | 3 | 3 | 2 | 7 | 1 | 2 | 2 | 0 | 1 |
| 3 | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Total | 86 | 110 | 51 | 76 | 88 | 49 | 80 | 37 | 105 | 94 | 94 | 58 | 72 | 66 | 58 | 178 | 194 | 141 | 180 | 125 | 110 | 59 | 125 | 145 |

Male

| RPS | Male | | | | | | | | | | | | | | | | | | | | | | | |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|
| | 1986 | 1987 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2009 | 2009 | 2009 | 2009 | 2009 | |
| 0 | 51 | 53 | 34 | 91 | 83 | 46 | 67 | 43 | 101 | 88 | 84 | 56 | 87 | 79 | 58 | 198 | 250 | 123 | 167 | 142 | 143 | 94 | 155 | 122 |
| 1 | 24 | 27 | 9 | 4 | 26 | 8 | 22 | 6 | 10 | 18 | 34 | 10 | 5 | 3 | 3 | 13 | 34 | 14 | 11 | 13 | 9 | 4 | 18 | 6 |
| 2 | 8 | 9 | 1 | 1 | 0 | 5 | 5 | 0 | 1 | 1 | 3 | 3 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 83 | 90 | 44 | 96 | 109 | 59 | 94 | 49 | 112 | 107 | 122 | 69 | 93 | 82 | 61 | 211 | 286 | 137 | 179 | 156 | 152 | 98 | 174 | 128 |

Blueback

| RPS | Female | | | | | | | | | | | | | | | | | | | | | | | |
|-------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1986 | 1987 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 0 | 24 | 19 | 9 | 16 | 15 | 43 | 14 | 4 | 19 | 23 | 37 | 66 | 46 | 37 | 48 | 67 | 63 | 70 | 66 | 92 | 69 | 87 | 0 | 0 |
| 1 | 12 | 7 | 1 | 2 | 1 | 9 | 0 | 1 | 0 | 0 | 3 | 2 | 2 | 2 | 8 | 1 | 4 | 4 | 1 | 6 | 9 | 6 | 0 | 0 |
| 2 | 2 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 39 | 31 | 11 | 18 | 16 | 52 | 14 | 5 | 19 | 23 | 40 | 68 | 48 | 39 | 56 | 68 | 67 | 74 | 67 | 98 | 78 | 93 | 0 | 0 |

Male

| RPS | Male | | | | | | | | | | | | | | | | | | | | | | | |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1986 | 1987 | 1993 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 0 | 40 | 48 | 13 | 15 | 20 | 58 | 8 | 26 | 28 | 40 | 51 | 67 | 45 | 48 | 56 | 76 | 68 | 82 | 79 | 120 | 101 | 167 | 0 | 0 |
| 1 | 10 | 9 | 1 | 1 | 4 | 0 | 3 | 3 | 0 | 1 | 8 | 2 | 3 | 3 | 9 | 5 | 4 | 3 | 1 | 9 | 18 | 7 | 0 | 0 |
| 2 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 51 | 60 | 15 | 16 | 24 | 58 | 11 | 29 | 28 | 41 | 59 | 69 | 48 | 51 | 65 | 81 | 72 | 85 | 80 | 129 | 119 | 174 | 0 | 0 |

Appendix Table 7.13. Yearly estimates of instantaneous total mortality (Z) from age-repeat spawner frequency and length data for alewives and blueback herring from Massachusetts Rivers by sex. *=not calculated due to small sample size.

Alewife
Females

Chapman-Robson Z Estimates (Age Data)

| Year | Agawam | Back | Mattapoisett | Monument | Mystic | Nemasket | Parker | Stony | Town |
|------|--------|------|--------------|----------|--------|----------|--------|-------|------|
| 1971 | | | | | | | 1.00 | | |
| 1972 | | | | | | | | | |
| 1973 | | | | | | | 1.33 | | |
| 1974 | | | | | | | | | |
| 1975 | | | | | | | | | |
| 1976 | | | | | | | | | |
| 1977 | | | | | | | 1.01 | | |
| 1978 | | | | | | | 1.03 | | |
| 1979 | | | | | | | | | |
| 1980 | | | | | | | | | |
| 1981 | | | | | | | | | |
| 1982 | | | | | | | | | |
| 1983 | | | | | | | | | |
| 1984 | | | | | | | | | |
| 1985 | | | | | 1.04 | | | | |
| 1986 | | | | | 0.99 | | | | |
| 1987 | | | | | 0.76 | | | | |
| 1988 | | | | | | | | | |
| 1989 | | | | | | | | | |
| 1990 | | | | | | | | | |
| 1991 | 0.96 | | | | | | | | |
| 1992 | | | | | | | | | |
| 1993 | | | | | 0.87 | | | | |
| 1994 | | | | | | | | | |
| 1995 | | | | 0.72 | 1.03 | | | | |
| 1996 | | | | | 1.29 | | | | |
| 1997 | | | | | | | | | |
| 1998 | | | | | 1.4 | | | | |
| 1999 | | | | | | | | | |
| 2000 | | | | | 1.56 | | | | |
| 2001 | | | | | 1.26 | | | | |
| 2002 | | | | | | | | | |
| 2003 | | | | | 1.15 | | | | |
| 2004 | | | | | | 1.58 | 1.02 | | 1.16 |
| 2005 | | | | | 1.18 | | 1.41 | | 1.47 |
| 2006 | | | | 1.1 | 1.04 | 1.15 | 1.08 | | |
| 2007 | | | | | 1.42 | 1.57 | 1.39 | | 1.44 |
| 2008 | | | | | 0.96 | 0.96 | 1.59 | | 1.41 |
| 2009 | | | | | 1.08 | 1.1 | 1.18 | | 1.26 |
| 2010 | | | | | 1.93 | 0.98 | 0.95 | | 0.84 |
| 2011 | | | | | 1.53 | 1.04 | 1.12 | | 1.2 |
| 2012 | | | | | 1.02 | 1.41 | 1.44 | 1.78 | 1.06 |
| 2013 | | | | | 1.02 | 1.06 | 1.27 | 1.92 | 1.25 |
| 2014 | | | | | 2.4 | 0.95 | 2.31 | 1.13 | 0.89 |
| 2015 | | | | | * | 0.93 | 1.97 | 1.02 | 2.16 |

Appendix Table 13 cont.

Alewife
Males

Chapman-Robson Z Estimates (Age Data)

| Year | Agawam | Back | Mattapoisett | Monument | Mystic | Nemasket | Parker | Stony | Town |
|------|--------|------|--------------|----------|--------|----------|--------|-------|------|
| 1971 | | | | | | | 1.29 | | |
| 1972 | | | | | | | 1.49 | | |
| 1973 | | | | | | | | | |
| 1974 | | | | | | | | | |
| 1975 | | | | | | | 1.54 | | |
| 1976 | | | | | | | 0.95 | | |
| 1977 | | | | | | | 1.01 | | |
| 1978 | | | | | | | 1.21 | | |
| 1979 | | | | | | | | | |
| 1980 | | | | | | | | | |
| 1981 | | | | | | | | | |
| 1982 | | | | | | | | | |
| 1983 | | | | | | | | | |
| 1984 | | | | | | | | | |
| 1985 | | | | | 0.87 | | | | |
| 1986 | | | | | 1.03 | | | | |
| 1987 | | | | | 0.84 | | | | |
| 1988 | | | | | | | | | |
| 1989 | | | | | | | | | |
| 1990 | | | | | | | | | |
| 1991 | 1.18 | | | | | | | | |
| 1992 | | | | | | | | | |
| 1993 | | | | | 1.02 | | | | |
| 1994 | | | | | | | | | |
| 1995 | | | 0.94 | | 1.57 | | | | |
| 1996 | | | | | 1.38 | | | | |
| 1997 | | | | | 1.24 | | | | |
| 1998 | | | | | 1.16 | | | | |
| 1999 | | | | | 1.22 | | | | |
| 2000 | | | | | 1.91 | | | | |
| 2001 | | | | | 1.32 | | | | |
| 2002 | | | | | 1.28 | | | | |
| 2003 | | | | | 1.31 | | | | |
| 2004 | | | | | | 1.54 | 1.38 | 1.3 | 1.53 |
| 2005 | | | | | 1.48 | 0.88 | 1.32 | | 1.48 |
| 2006 | | | | | | 1.03 | 1.21 | | |
| 2007 | | 1.64 | | | 1.93 | 2.23 | 1.6 | | 1.53 |
| 2008 | | | | | 1.23 | 1.71 | 1.58 | | 0.94 |
| 2009 | | | | | 1.31 | 1.21 | 0.93 | | 0.87 |
| 2010 | | | | | 1.37 | 0.89 | 1.15 | | 1.02 |
| 2011 | | | | | 1.99 | 1.66 | 1.33 | | 1.5 |
| 2012 | | | | | 1.35 | * | 1.03 | 2.01 | 0.82 |
| 2013 | | | | | 1.85 | 1.48 | 1.38 | 0.85 | 1.41 |
| 2014 | | | | | * | 1.4 | 1.1 | 1.31 | 1.23 |
| 2015 | | | | | * | 1.14 | 2.13 | 1.18 | 1.93 |

Appendix Table 13 cont.

| Blueback Females | | | | | | Blueback Males | | | | |
|---------------------------------------|--------|---------|----------|--------|--------|---------------------------------------|---------|----------|--------|--------|
| Chapman-Robson Z Estimates (Age Data) | | | | | | Chapman-Robson Z Estimates (Age Data) | | | | |
| Year | Agawam | Charles | Monument | Mystic | Parker | Year | Charles | Monument | Mystic | Parker |
| 1971 | | | | | | 1971 | | | | |
| 1972 | | | | | | 1972 | | | | |
| 1973 | | | | | | 1973 | | | | |
| 1974 | | | | | | 1974 | | | | |
| 1975 | | | | | | 1975 | | | | |
| 1976 | | | | | | 1976 | | | | |
| 1977 | | | | | | 1977 | | | | |
| 1978 | | | | | | 1978 | | | | |
| 1979 | | | | | | 1979 | | | | |
| 1980 | | | | | | 1980 | | | | |
| 1981 | | | | | | 1981 | | | | |
| 1982 | | | | | | 1982 | | | | |
| 1983 | | | | | | 1983 | | | | |
| 1984 | | | | | | 1984 | | | | |
| 1985 | | 0.67 | | 0.98 | | 1985 | 0.96 | | 1.27 | |
| 1986 | | | | 1.49 | | 1986 | | | | |
| 1987 | | | | 1.07 | | 1987 | | | 1.06 | |
| 1988 | | | | | | 1988 | | | | |
| 1989 | | | | | | 1989 | | | | |
| 1990 | | | | | | 1990 | | | | |
| 1991 | 0.81 | | | | | 1991 | | | | |
| 1992 | | | | | | 1992 | | | | |
| 1993 | | 1.19 | | 0.75 | | 1993 | 1.05 | | 1.45 | |
| 1994 | | | | | | 1994 | | | | |
| 1995 | | | | | | 1995 | | | | |
| 1996 | | | | 1.15 | | 1996 | | | 1.1 | |
| 1997 | | | | 1.02 | | 1997 | | | 1.72 | |
| 1998 | | | | | | 1998 | | | | |
| 1999 | | | | 0.85 | | 1999 | | | | |
| 2000 | | | | | | 2000 | | | | |
| 2001 | | | | | | 2001 | | | 0.76 | |
| 2002 | | | | 1.39 | | 2002 | | | | |
| 2003 | | | | | | 2003 | | | | |
| 2004 | | | | | | 2004 | | | | |
| 2005 | | | | | 1.82 | 2005 | | | 1.54 | |
| 2006 | | | | | 1.15 | 2006 | | | | |
| 2007 | | | | | 1.19 | 2007 | 1.05 | | 1.77 | |
| 2008 | | | | 1.54 | 0.86 | 2008 | | | 1.26 | |
| 2009 | | | | 1.43 | 1.02 | 2009 | | | 1.39 | |
| 2010 | | | | 0.9 | 1.19 | 2010 | | | 1.43 | 1.55 |
| 2011 | | | | | 2.25 | 2011 | * | * | * | 1.3 |
| 2012 | | 0.81 | | * | 1.16 | 2012 | 1.07 | 1.32 | 0.83 | 2.3 |
| 2013 | | 1.23 | | 1.25 | 0.99 | 2013 | 0.84 | 1.3 | 1.13 | 0.82 |
| 2014 | | 1.31 | | * | 1.8 | 2014 | 1.41 | 2.06 | * | 1.76 |
| 2015 | | | | 1.93 | * | 2015 | * | 2.12 | 1.99 | 2.46 |

8 Status of River Herring in Rhode Island

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Executive Summary

Major declines in river herring run sizes occurred at Gilbert Stuart and Nonquit during 2000 to 2005. These declines were followed by increasing trends from 2006 to 2014 until 2015 when the majority of Rhode Island's river herring runs decreased. Gilbert Stuart river herring spawning stock size drastically decreased each year from 290,814 in 2000 to a low of 7,776 fish in 2005. Between 2010 and 2014 the average run size was 95,267 and in 2015 decreased to 11,135. Likewise, Nonquit run size decreased from 185,524 fish in 2000 to a low of 25,417 in 2004. Between 2010 and 2014 the average run size was 50,567 and in 2015 decreased to 32,330. Likewise mortality rates and percentage of repeat spawners showed some improvement until 2015. Mortality rates (Z) decreased for both sites prior to 2015, and percentage of repeat spawners increased until 2015. All of Rhode Island's runs decreased in 2015, therefore Rhode Island continued with the statewide closure imposed in 2006, on the harvest of river herring (alewives and bluebacks) in fresh and marine waters.

8.1. INTRODUCTION

In Rhode Island, the Division of Fish and Wildlife currently manages 21 river herring runs and operates and maintains 26 fishways on 11 of the systems. These systems include small brooks and streams to large rivers and impoundments. Since the 1960s, the Division of Fish and Wildlife has worked toward restoring anadromous fish to Rhode Island. These efforts include partnering with various organizations on anadromous habitat restoration projects, conducting anadromous fish stocking, monitoring anadromous fish populations throughout the state, providing seasonal adjustments and maintenance to existing fishways, and setting harvest regulations.

The two Rhode Island systems with the most complete quantitative data sets on river herring are the Gilbert Stuart and Nonquit. Available data include spawning stock size, length at age, mortality rates, proportion of repeat spawning and juvenile abundance indices. Gilbert Stuart has an Alaskan steeppass fishway which provides access to 68 acres of nursery and spawning habitat. Gilbert Stuart Pond empties into the Narrow River and discharges into the Atlantic Ocean (Figure 8.1). River herring at Gilbert Stuart have been monitored by the Division of Fish and Wildlife since 1980. Nonquit has a Denil fishway which provides access to 202 acres of nursery and spawning habitat. Nonquit Pond spills into Almy Brook which joins the Sakonnet River and empties into the Atlantic Ocean (Figure 8.2). Nonquit River herring stocks have been monitored since 1999.

In addition, to assessing the status of the Gilbert Stuart and Nonquit stocks, this report will summarize spawning stock size results from Buckeye Brook, JAI results from the Pawcatuck River seine survey, and river herring data collected from three marine fishery-independent surveys.

8.2. MANAGEMENT UNIT DEFINITION

The Rhode Island Department of Environmental Management (RIDEM) has management authority over river herring (alewives and bluebacks) occurring in the state's fresh and marine waters [RI Gen. Laws].

8.3. REGULATORY HISTORY

Currently there is a moratorium on harvest of river herring (alewives and bluebacks) in Rhode Island's fresh and marine waters (RIDFW Reg; RIMF Reg.). Due to drastic declines in spawning stock size beginning in 2001, Rhode Island passed regulations in March 2006 for the complete closure. Prior to 1998, the freshwater daily river herring limit was 12 fish per day and closed Sunday, Monday, and Tuesday. There were no regulations for marine waters. In 1998 the daily freshwater limit was increased to 24 fish per day with the same closed days, and then decreased to 12 fish per day in 2005. The 2006 closure marked the first time there were reciprocal regulations for Rhode Island marine and fresh waters. The marine and freshwater closure continued through 2015 and is planned for 2016. Table 8.1 summarizes current and past Rhode Island river herring regulations.

8.4. ASSESSMENT HISTORY

In the 2012 ASMFC Stock Assessment Report No.12-02 the two Rhode Island systems assessed were Gilbert Stuart and Nonquit. The assessment showed Gilbert Stuart and Nonquit run sizes decreased between 2001 and 2005 and the declines were followed by increasing trends from 2006 to 2010. Prior to 2012, the last formal assessment was prepared by Crecco and Gibson in 1990. The Rhode Island system assessed in the report was the Annaquatic River which in the 1970s had a spawning stock size over 300,000 (Durbin 1979). At the time of the assessment, the status of the river herring population was partially exploited with no trend in stock condition. Currently, only presence/absence data are recorded at the Annaquatic River, therefore this system will not be covered in this report.

8.5. STOCK-SPECIFIC LIFE HISTORY

Gilbert Stuart and Nonquit river herring stocks are iteroparous and predominately alewives. Between 2000 and 2005, weekly species identification results showed Rhode Island's spring returns were 100% alewives. Since 2005, species identification at both sites has been over 95% alewives. Gilbert Stuart river herring were used as Rhode Island's main broodstock source between 1966 and 1978 to stock into the Annaquatic, Hunt, and Pawcatuck rivers. Gilbert Stuart was again used as a broodstock source between 1999 and 2004, and sparingly in years following due to the drastic declines in run size in 2004. Both the Gilbert Stuart and Nonquit systems were stock between 1990 and 1993 with alewife broodstock from Massachusetts systems.

8.6. HABITAT DESCRIPTION

Gilbert Stuart has an Alaskan steeppass fishway which provides access to 68 acres of nursery and spawning habitat. Gilbert Stuart Pond empties into the Narrow River and discharges into the Atlantic Ocean (Figure 8.1). Nonquit has a Denil fishway which provides access to 202 acres of nursery and spawning habitat. Nonquit Pond spills into Almy Brook which joins the Sakonnet River and empties into the Atlantic Ocean (Figure 8.2). Buckeye Brook is a natural free flowing system that provides access to 91 acres of spawning habitat in Warwick and Spring Green Ponds. Buckeye Brook empties into Narragansett Bay. The Pawcatuck River is a riverine system and currently has two Denil fishways which

provide access to miles of riverine habitat, Watchaug Pond (573 acres), and Chapman Pond (164 acres). In addition to a river herring run, the Pawcatuck River is also managed for American shad.

8.7. RESTORATION PROGRAMS

8.7.1. Recovery Target

The state of Rhode Island has informally adopted a recovery target of greater than 50% of the spawning stock size estimated by Gibson (1984). Target goals for spawning stock size at Buckeye Brook, Gilbert Stuart and Nonquit are shown in Table 8.3. The estimates are calculated based on habitat size and are used as indicators to predict the spawning stock size potential of restored habitat or strength of existing runs.

8.7.2. Restoration Objectives

The Rhode Island Division of Fish and Wildlife is partnering with many government agencies, NGO's, and private entities on a wide variety of anadromous habitat restoration projects throughout the state. Projects include constructing new fishways, culvert modifications, and dam removals to enhance spawning and nursery habitat. Since the last assessment fish passage projects have been completed on the Pawcatuck, Pawtuxet, Ten Mile and Woonasquatucket Rivers. Currently several fish passage projects are proposed or currently being implemented on the Blackstone River, Pawcatuck River, and Factory Brook (Edwards 2015; Erkan 2002).

8.7.3. Stocking Efforts

Stocking has been important to Rhode Island's river herring restoration efforts (Table 8.2). Each year trap and transport is conducted utilizing out-of-state and in-state broodstock sources to supplement existing runs or restore extirpated systems that have been restored. Gilbert Stuart was Rhode Island's only broodstock source for river herring between 1966 and 1972, and today is still an important source. Nonquit has not been utilized as a broodstock source, but was considered in 2001, prior to the drastic decrease in spawning stock size. Between 1990 and 1993, both Gilbert Stuart and Nonquit received supplemental stockings from the Agwam and Bourne rivers located in Massachusetts. Since 2001 it has become increasingly difficult to obtain available out-of state and in-state broodstock sources, due to the declines in river herring run sizes.

8.7.4. Fish Passage

The Alaskan steeppass at Gilbert Stuart has been the primary survey site for monitoring adult river herring since 1981. The eight foot obstruction at the Gilbert Stuart Birthplace, is a dam with various water control structures serving the historic grist mill (Erkan 2002). In 2000, the fishway passed over 290,000 fish and in recent years estimates of one thousand fish per hour have been observed (Edwards 2015). The Denil fishway at Nonquit has been the primary survey site for monitoring adult river herring since 1999. The seven foot obstruction is owned by the City of Newport Water Company and the impoundment is used as a secondary water supply (Erkan 2002). In 1999, the fishway passed over 230,000 fish (Edwards 2015). Buckeye Brook is a free-flowing system and river herring migrate to Warwick Pond without obstruction. The connection between Warwick Pond and Spring Green Pond passes through the T.F Green Airport property.

8.8. AGE

Scale samples collected from Rhode Island Division of Fish and Wildlife's anadromous fish sampling projects at Gilbert Stuart and Nonquit were pressed between glass slides and analyzed by techniques described in Rothschild (1963) and Marcy (1969). The age of each fish and number of spawning marks were recorded. Regenerated scales are not considered reliable for ageing. Two groups have carried out most of the ageing work for river herring. Biologists from both groups have worked together to ensure consistency of methodology in the collection, processing, and age determination of scale samples. Approximately 150 scale samples are collected throughout the spring run at Gilbert Stuart and Nonquit. For both sites, the typical ages for males are 3 and 4, and females are typically ages 4 and 5 (Table 8.6, Table 8.7, Table 8.11, Table 8.12). Age-two males and age seven females were the minimum and maximum ages observed between 2011 and 2015.

8.9. FISHERIES-DEPENDENT MONITORING

8.9.1. Commercial Fisheries

Rhode Island commercial landings are shown in Table 8.14 (NMFS, Fisheries Statistics Division, Silver Spring, MD, personal communication). The river herring fishery was an inshore fishery and landings occurred throughout the late 1800's in New England waters (NMFS 1989). Oviatt et al. (2003) estimated over 1,100,000 kg ww of alewives were landed at Rhode Island ports in 1880, which is a substantial increase compared with the reported Rhode Island river herring commercial landings of zero in 1960 (NMFS 2010). The majority of the river herring landings between 1950 and 1980 were from seine hauls and trap net fisheries. The trap net fishery was the predominate source of landings throughout the 1990's. The reported landings have been zero or negligible since 1987. In March 2006, Rhode Island passed the moratorium on the harvest of river herring (alewives and blueback herring) in marine and freshwaters of the state.

8.9.2. Recreational Fisheries

No recreational data are available.

8.9.3. Bycatch Estimates

Bycatch is known to take place in the Atlantic herring bait fisheries, however no bycatch data is available.

8.9.4. Subsistence Fishery

No subsistence fishery data is available.

8.9.5. Characterization of Other Losses

No data is available.

8.10. FISHERIES-INDEPENDENT MONITORING

8.10.1. Spawning Stock Surveys

Each spring river herring spawning stock size is estimated using electronic fish counters or direct count methods on several Rhode Island river systems. The anadromous life history of river herring allows for a unique sampling and monitoring opportunity when they return to their native freshwater systems to spawn. In addition to estimating run sizes, a representative sample of river herring from Gilbert Stuart and Nonquit were sampled for biological data. River herring were sampled and measured for length, weight, and scale samples taken for age analysis. Approximately 50 alewives were sampled three times throughout each spring migration. Gilbert Stuart has a break in the biological data time series between 1993 and 2000; however spawning stock size was estimated during those years. Mortality rates (Z) are estimated by a percentage of repeat spawners method (Crecco and Gibson 1988).

Gilbert Stuart

The Division has estimated spawning stock size since 1981 using electronic fish counters or direct count methods. River herring were sampled for biological data during two time periods. The first sampling period was between 1980 and 1992, and the second from 2000 to present. The break in the biological data time series between 1993 and 1999 was due to changes in staff, but spawning stock size estimates were continued during this time period. Due to low run size, data could not be collected in 2015 following numerous attempts to sample fish.

Nonquit

The Division has estimated spawning stock size at Nonquit since 1999 using a solar operated electronic fish counter. The only known data, which included run size estimates, were collected in 1976 and reported as 80,000 fish (Lynch 1976). River herring were sampled for biological data since 2000, except for in 2010 when river herring were unable to be captured after numerous attempts.

Buckeye Brook

The Buckeye Brook Coalition and Division partnered in 2003 to initiate a direct count program utilizing volunteers (Puriton 2000; Stevenson 1997). River herring have not been sampled for biological data, nor have JAI's been performed at Buckeye Brook.

Pawcatuck River

A fishway trap is installed and operated each spring to monitor American shad returns. The increased number of river herring compared to American shad and high water volume make utilizing the fishway trap unfeasible for estimating river herring run size. Direct count techniques have failed, due to visibility and electronic counters are not efficient at the site. Since 2006, in addition to observations (presence/absence) the Division has initiated a four factor ranking system in which personnel estimate the number of herring in the trap and fishway each day the trap is checked for American shad. In addition, video techniques should assist in estimating the Pawcatuck River run size in the future.

Annaquatucket River and remaining RI herring runs

At other Rhode Island river herring systems, the Division conducts periodic qualitative analysis which consists of determining the presence and absence of adult and juvenile river herring. Methods include random net surveys, visual observations and electrofishing to determine spawning success. The Annaquatucket River experienced a complete collapse during the 1990's which may have resulted from other factors unrelated to the factors responsible for the recent decline.

8.10.2. Ocean Trawl Survey Indices

The Marine Division of Rhode Island Fish and Wildlife conducts a trawl survey, a Narragansett Bay seine survey, and coastal pond seine survey. The marine surveys are conducted in Narragansett Bay, Block Island Sound and surrounding coastal ponds. All three surveys collect river herring numbers and length frequency data.

Trawl Survey

The methodology used in the allocation of sampling stations employs both random and fixed station allocation. Fixed station allocation began in 1988 in Rhode Island and Block Island Sounds. This was based on the frequency of replicate stations selected per depth stratum since 1979. With the addition of the Narragansett Bay monthly segment which started in 1990, an allocation system of 13 fixed stations was employed. Sampling stations were established by dividing Narragansett Bay into a grid of cells. The seasonal trawl survey is conducted in the spring and fall of each year. Usually 42 stations are sampled each season; however this number has ranged from 26 to 72 over the survey time series. The stations sampled in Narragansett Bay during the seasonal segment are a combination of fixed and random sites. Thirteen fixed during the monthly portion and 26, (14 of which are randomly selected) during the seasonal portion. The random sites are randomly selected from a predefined grid. All stations sampled in Rhode Island and Block Island Sounds are fixed.

Depth Stratum Identification:

| Area | Stratum | Area nm ² | Depth Range (m) |
|--------------------|---------|----------------------|-----------------|
| Narragansett Bay | 1 | 15.50 | <=6.09 |
| | 2 | 51.00 | >=6.09 |
| Rhode Island Sound | 3 | 0.25 | <=9.14 |
| | 4 | 2.25 | 9.14 – 18.28 |
| | 5 | 13.5 | 18.28 – 27.43 |
| | 6 | 9.75 | >=27.43 |

| | | | |
|--------------------|----|-------|---------------|
| Block Island Sound | 7 | 3.50 | <=9.14 |
| | 8 | 10.50 | 9.14 – 18.28 |
| | 9 | 11.50 | 18.28 – 27.43 |
| | 10 | 12.25 | 27.43 – 36.57 |
| | 11 | 4.00 | >=36.57 |

At each station, an otter trawl equipped with a $\frac{1}{4}$ inch liner is towed for twenty minutes covering .83 nautical miles. Data on wind direction and speed, sea condition, air temperature and cloud cover as well as surface and bottom water temperatures, are recorded at each station. Catch is sorted by species. Length (cm/mm) is recorded for all finfish, skates, squid, scallops, lobster, blue crabs and horseshoe crabs. Similarly, weights (gm/kg) and number are recorded for each species (Lynch 2007). The survey is a random / fixed stratified trawl survey that operates throughout state waters. Adults and juveniles are collected (Olszewski 2015).

Narragansett Bay Seine Survey

Since 1988, eighteen stations have been sampled monthly from June through October. The survey is a fixed station seine survey using a 200ft seine net that samples throughout Narragansett Bay. Predominately juveniles are collected (McNamee 2015).

Coastal Pond Seine Survey

Since 1992, twelve stations have been sampled monthly from May through November. The survey is a fixed station seine survey using a 160 ft seine net that takes place in Rhode Island's coastal ponds. The majority of the samples collected are juveniles but occasionally adults are captured and reported with the length frequency data (Lake 2015).

8.10.3. Juvenile Abundance Indices

Gilbert Stuart

Between 1988 and 1996 a trapnet was installed during the fall to capture juveniles exiting the freshwater impoundment. The trapnet was connected to the exit of the Alaskan steeppass fishway, therefore trapped fish endured high velocities of water. Due to high juvenile mortality the JAI was discontinued in 1996. During the 2007 season a different style trapnet, which prevents juvenile mortality was utilized. This weir based trap located 200 yards below the fishway allows trapped out-migrating juveniles a safe holding pen. The trap is set for one hour and juveniles are enumerated and length measurements are collected.

Nonquit

Since 2001 a trapnet was installed weekly each fall in the Denil fishway. The trap is placed in slots located at the front of the turning pool, and juveniles are captured as they exit the freshwater impoundment and held in the turning pool.

Pawcatuck River

Seine survey conducted weekly each fall since 1988 at five fixed stations in the lower Pawcatuck River (O'Brien 1986). Majority of the samples collected are juveniles but occasionally age one river herring are captured and reported with the length frequency data.

Remaining Rhode Island Runs

Periodic qualitative analysis which consists of determining the presence and absence of adult and juvenile river herring is selected Rhode Island systems. Methods include random net surveys, visual observations and electrofishing to determine spawning success.

8.11. ASSESSMENT APPROACHES AND RESULTS

8.11.1. Trends in Spawning Stock Size

Rhode Island river herring spawning stock sizes drastically decreased from 2000 to 2004. Since the statewide closure in 2006, the run sizes have increased but are still well below the run sizes estimated between 1999 and 2002 (Table 8.15; Figure 8.).

Gilbert Stuart

Between 1998 and 2001, the Gilbert Stuart stock displayed a stable trend and passed over one million herring. The annual mean spawning stock size during this period was 266,853. After 2001, the run declined to a low of 7,776 in 2005 (Table 8.15; Figure 8.). Since the closure in 2006, the spawning stock size has increased but was still substantially below the annual mean for the 1998 through 2001 time frame. The Gilbert Stuart run size has been below the predicted target population size of 64,000 since 2003, until the 2010 river herring run size was estimated at 110,000 (Table 8.3).

Nonquit

When the current time series began in 1999 the run size was estimated at 230,853 fish (Table 8.15; Figure 8. After 1999, the run size declined to a low of 25,417 fish in 2004. As with Gilbert Stuart, the Nonquit run size drastically decreased between 2002 and 2005. Since the closure in 2006, the spawning stock size has increased but was still substantially below 1999 returns, with the exception of 2008 when the run size reached 224,000. The Nonquit run size was below the predicted target population size of 138,000 each year since 2000, with the exception of 2008 (Table 8.3).

8.11.2. Trends in Length

Annual mean fork length results for the past two segments were less for both males and females for river herring sampled at Gilbert Stuart between 2000-2010 and 2011-2015, as compared with results from fish sampled between 1980 and 1992 (Table 8.4 and Table 8.5). The last mean lengths reported for Nonquit were in 1976 and since 2000 the Nonquit mean lengths were below those previously reported (Lynch 1976, Table 8.9; Table 8.10; Figure 8.4).

8.11.3. Trends in Age

Pooled age data (1980-1992) at Gilbert Stuart showed fifteen percent of the river herring sampled was ages 6, 7 or 8 (Gibson 1992). Annual mean age for both males and females has decreased since 1980 (Figure 8.4). Age data from 2003 to present show no age 8 river herring and a decrease in percentages of 6 and 7 year olds sampled at Gilbert Stuart.

Table 8.6 and Table 8.7 show number and percent at age for males and females sampled at Gilbert Stuart.

Table 8.12 show the number and percent at age for males and females sampled at Nonquit. Mean age for males and females in the Nonquit has remained stable from 2000 to present (Figure 8.5).

8.11.4. Trends in Length at Age

River herring from Gilbert Stuart and Nonquit have displayed a decrease in length at age over time (Table 8.4). Since 2000, the mean length at ages recorded for Gilbert Stuart, were consistently lower for all age classes than reported in 1992 (Gibson 1992). Mean fork length at age for males and females at Gilbert Stuart is shown in Tables 8.4 and 8.5. Age results at Nonquit show the same decrease in percentages of 6 and 7 year olds sampled as compared from fish sampled at Gilbert Stuart between 1984 and 1992. Mean fork length at age for males and females at Nonquit is shown in Tables 8.9 and 8.10.

8.11.5. Trends in Proportion of Repeat Spawners

Percent repeat spawning at Gilbert Stuart and Nonquit decreased between 2000 and 2007, but have improved since 2007. Historical percentages for Nonquit were lacking, but historic percentages were available for Gilbert Stuart. Pooled estimates (1983-1992) resulted in a repeat spawning value of 42 % (Gibson 1992). The five year average (2003-2007) for Gilbert Stuart and Nonquit was 8.9% and 6.8%, respectively. Since the closure in 2006 the percentage of repeat spawners has increased at both locations, but compared to the historic data (1984-1992) the percentage of repeat spawning has decreased for both sites (Figure 8.). The three year average for this segment for Gilbert Stuart and Nonquit were 18.7% and 24.2%, respectively. This showed the percentage of repeat spawners continued to increase compared to the three year average (2008-2010) following the closure for Gilbert Stuart at 12.5% and Nonquit at 17.9%.

8.11.6. Total Mortality (Z) Estimates

The instantaneous mortality (Z) rates were calculated using the repeat spawning method (Crecco and Gibson 1988). Results are presented in Figure 8. Mortality rates substantially increased between 2003 and 2005. Both sites displayed the highest mortality rates in 2004 with Z values estimated at 3.9 for Gilbert Stuart and 4.1 for Nonquit. Historical mortality rate data for Nonquit was lacking, but historic data was available for Gilbert Stuart. Pooled estimates (1984-1992) utilizing the repeat spawning method resulted in a Z value of 1.2 (Gibson 1992). Gilbert Stuart and Nonquit mortality rates increased between 1992 and 2007, but following the closure, mortality rates for both sites had decreased. The exception was Gilbert Stuart in 2015 when results showed low run size and a mortality rate over 4.0.

8.11.7. Trends in Juvenile Abundance

Relative abundance indices in juveniles from the trawl survey are shown in Figure 8., and expressed in mean number per tow. Length frequency results are shown in Table 8.16 (Olszewski 2015). The trawl survey river herring indices decreased beginning in 2002 and have increased since 2010. The timing of this decrease coincides with the drastic decline in RI river herring spawning stock sizes. Relative abundance indices of juveniles from the Narragansett Bay Seine Survey are shown in Figure 8., and expressed in mean number per seine haul. Relative abundance indices of juveniles from the Coastal Pond Seine Survey are shown in Figure 8., and expressed in mean number per seine haul. Majority of the samples collected are juveniles but occasionally adults are captured and reported with the length frequency data (Lake 2015). Relative abundance indices for juveniles in the Gilbert Stuart River are shown in Table 8.17, and expressed in mean number per one hour trap set. Relative abundance indices for juveniles in the Nonquit River are shown in Table 8.17, and expressed in mean number per one hour trap set. The juvenile abundance indices from the Gilbert Stuart and Nonquit trap showed no correlation with the spawning stock size estimates for either system. Relative abundance indices for juveniles in the Pawcatuck River are shown in Table 8.18, and expressed in mean number per seine haul. The Pawcatuck River seine survey abundance indices for river herring have decreased since 2004 and have continued to remain low.

8.12. BENCHMARKS

The state of Rhode Island has informally adopted a recovery target for river herring run sizes of greater than 50% of the predicted spawning stock sizes based on available habitat, estimated by Gibson (1984). Target goals for spawning stock size at Buckeye Brook (39,461), Gilbert Stuart (32,150) and Nonquit (69,124) are shown in Table 8.3. In addition, Rhode Island has informally adopted a Z benchmark value of less than 2.5 using the percentage of repeat spawner technique (Crecco and Gibson 1988) and a percentage of repeat spawning benchmark of greater than 10 percent.

8.13. CONCLUSIONS AND RECOMMENDATIONS

Between 2000 and 2006, Rhode Island river herring stocks experienced sharp declines in spawning stock size, increases in mortality rates (Z) and decreases in percentage of repeat spawners causing Rhode Island to impose a statewide closure in 2006 to the harvest of river herring in fresh and marine waters. Since the closure in 2006, Rhode Island's run sizes increased until 2015. The majority of the run sizes in 2015 drastically decreased. Between 2010 and 2014, the Gilbert Stuart five year average was 95,267 and the run size decreased to 11,135 in 2015. The Nonquit five year average was 50,567 and decreased to 32,330 in 2015 (Figure 8.). In addition, prior to 2015, Gilbert Stuart and Nonquit showed decreases in mortality rates and increases in the percentage of repeat spawners. Truncated age structures remained the same.

Recent results prior to 2015 show there has been some improvement since the closure, but current run sizes are still well below the estimated run sizes (1999-2001) recorded prior to the decline (Table 8.15). Gilbert Stuart and Buckeye Brook exceeded the recovery target for river herring run sizes from 2011 to 2014, but were below the target in 2015. During the same timeframe (2011-2015), Nonquit only exceeded the target value in 2014. Likewise mortality rates (Z) and percentage of repeat spawners has shown some improvement (Figure 8.9 and Figure 8.10). Between 2011 and 2015, Gilbert Stuart and Nonquit mortality rates were below the target value of 2.5 with the exception of Gilbert Stuart in 2015

which displayed a value of 4.1. Likewise both sites displayed higher percentage of repeat spawner values than the target value of 10 percent, except for in 2012, when Nonquit displayed a value of 8.2.

The decrease in river herring run sizes between 2002 and 2005 warranted drastic regulatory changes in which the Rhode Island moratorium was imposed in March 2006. The moratorium is still in place and will continue through 2017. Reasons for the drastic declines in Rhode Island river herring run sizes may be related to a combination of factors which may have affected river herring stocks prior to the closure. Some theories include degradation of spawning and nursery habitat, an increase in predator populations, and overfishing. Degradation of spawning habitat could be the result of changes in water quality in the freshwater systems affecting egg development or juvenile mortality. Predator population increases in certain sportfish and bird species, may have been affecting river herring stocks. Overfishing may have been a result of an increase in the in-river fishery, an unregulated marine fishery in Rhode Island marine waters prior to 2006, or an ocean by-catch fishery intercepting Rhode Island river herring stocks during seasonal migrations.

In summary, Rhode Island's best available results are from river herring data collected at Gilbert Stuart and Nonquit. The Buckeye Brook spawning stock size estimates, Pawcatuck River JAI data, and results from the marine surveys are additional valued data sets. Gilbert Stuart and Nonquit have the best available quantitative data sets and the longest run size time series. In the past the Division has used the results from these two systems to gauge river herring stocks throughout the state and make recommendations for regulatory changes. The JAI time series is short for both systems, but if continued could provide useful information in the future. The Buckeye Brook spawning stock size estimates are available, and will continue in the future. River herring have not been sampled for biological data and no JAI's have been conducted. The Pawcatuck River spawning stock size estimates are still being developed, therefore not included in this report. Sampling for biological characteristics has occurred but is incomplete therefore not included. Pawcatuck River seine survey is available and there is a long time series, but there are not any accurate spawning stock size estimates available to compare with. The seine survey is used for American shad monitoring and therefore the river herring results were included in this report. Marine trawl and seine surveys offer long time series which provide catch indices and length frequency data. Results may be useful for tuning other models or indexing the broader river herring populations in state waters (mixed-ocean stocks). In addition, the Division is continuing to develop qualitative and quantitative assessments at remaining river herring runs throughout the state.

Future monitoring recommendations include:

- 1) Mandatory - Continue spawning stock size monitoring at Gilbert Stuart, Nonquit and Buckeye Brook to extend the existing time series and evaluate the stock status. Continue sampling river herring for biological data at Gilbert Stuart, Nonquit, and Pawcatuck River to determine age composition, growth rates, percent repeat spawning, and mortality rates. Continue JAI survey at Gilbert Stuart, Nonquit, and the Pawcatuck River to extend the existing time series. Begin utilizing video technology for estimating run sizes on the Pawcatuck, Saugatucket, and Ten Mile River.
- 2) Recommended - Initiate JAI survey and adult biological sampling at Buckeye Brook. Continue modifying the four-factor system to estimate the Pawcatuck River herring run size. Continue collecting river herring data from the three marine surveys. Continue monitoring success of stocking program by various sampling methods to determine spawning success.

3) Desired- As new river systems are restored and river herring populations become established, set up monitoring projects to determine spawning stock size, biological characteristics, and juvenile abundance indices.

Towards a river herring restoration goal and stock recovery, the Rhode Island Division of Fish and Wildlife will continue to monitor runs throughout the state, transplant adult broodstock into extirpated or restored systems, work with partners on numerous fish passage projects, and represent the state at regional meetings.

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Table 8.1 Rhode Island river herring regulation change summary.

| Year | Regulation Change |
|---------------|--|
| Prior to 1998 | 12 fish bag limit per person per day |
| 1998 | Part II freshwater regulations – Increased bag limit to 24 fish per person per day |
| 2002 | Part II freshwater regulations – Changed the freshwater/saltwater boundary at Nonquit pond |
| 2004 | Part II freshwater regulations – Closed Prince Pond to harvest and reduced bag limit to 12 fish per person per day in Hardig and Buckeye Brook |
| 2005 | Part II freshwater regulations – Reduced bag limit to 12 fish per person per day statewide |
| 2006 | Part II RI freshwater regulations – Imposed moratorium in all fresh water systems; Part 7.20 RI marine regulations – Imposed moratorium in all state marine waters |

Table 8.2 Alewife broodstock stocking summary.

| Date | Location Stocked | Number | Date | Location Stocked | Number |
|-----------|-------------------------|--------|-----------|--------------------------|--------|
| 4/12/2001 | Bellville | 2,500 | 4/21/2008 | Woonasquatucket | 600 |
| 4/12/2001 | Echo Lake | 2,500 | 4/22/2008 | Echo Lake | 700 |
| 4/24/2001 | Prince Pond | 600 | 4/22/2008 | Brickyard Pond | 300 |
| 4/25/2001 | Crossmills, Charlestown | 1,200 | 4/23/2008 | Turner Reservoir | 1,000 |
| 5/2/2001 | Warwick Pond, Warwick | 1,000 | 5/5/2008 | Woonasquatucket | 600 |
| 5/4/2001 | Crossmills, Charlestown | 1,100 | 5/7/2008 | Blackstone | 500 |
| 5/4/2001 | Hamilton Reservoir | 1,100 | 2008 | Omega-volunteers lifting | 3,000 |
| 4/9/2002 | Echo Lake | 2,500 | 4/15/2009 | Indian Lake | 1,000 |
| 4/11/2002 | Bellville | 2,500 | 4/17/2009 | Echo Lake | 500 |
| 4/16/2002 | Crossmills, Charlestown | 600 | 4/17/2009 | Brickyard Pond | 500 |
| 4/17/2002 | Chapmans | 1,000 | 4/22/2009 | Turner Reservoir | 1,000 |
| 4/17/2002 | Crossmills, Charlestown | 1,500 | 2009 | Omega-volunteers lifting | 800 |
| 4/18/2002 | Prince Pond | 1,000 | 4/14/2010 | Indian Lake | 1,000 |
| 4/19/2002 | Turner Reservoir | 1,500 | 4/15/2010 | Turner Reservoir | 1,000 |
| 4/22/2002 | Watchaug Pond | 250 | 4/16/2010 | Kickemuit | 1,000 |
| 4/23/2002 | Wesquage | 500 | 2011 | Ten-mile | 1,000 |
| 4/23/2002 | Wordon's Pond | 500 | 2011 | Kickemuit | 1,000 |
| 4/26/2002 | Turner Reservoir | 1,500 | 2011 | Indian Lake | 1,300 |
| 5/1/2002 | Wesquage | 600 | 2011 | Watchaug Pond | 300 |
| 4/15/2003 | Turner Reservoir | 1,200 | 2011 | Woonasquatucket | 600 |
| 4/17/2003 | Turner Reservoir | 2,250 | 4/9/2012 | Kickemuit | 1,000 |
| 4/16/2003 | Echo Lake | 2,500 | 4/9/2012 | Blackstone | 1,000 |
| 4/22/2003 | Factory Pond | 2,500 | 4/10/2012 | Worden Pond | 700 |
| 4/24/2003 | Belleville | 2,500 | 4/10/2012 | Woonasquatucket A.Mills | 1,000 |
| 4/28/2003 | Wesquage | 1,000 | 4/11/2012 | Worden Pond | 900 |
| 4/29/2003 | Prince Pond | 700 | 4/12/2012 | Pawtuxet River | 1,000 |
| 5/1/2003 | Chapmans | 200 | 4/12/2012 | Watchaug Pond | 1,450 |
| 5/6/2003 | Crossmills, Charlestown | 800 | 4/16/2012 | Worden Pond | 1,400 |
| 5/8/2003 | Warwick Pond, Warwick | 750 | 4/16/2012 | Watchaug Pond | 1,600 |
| 4/15/2004 | Turner Reservoir | 1,500 | 4/17/2012 | Hunts River | 1,000 |
| 4/20/2004 | Turner Reservoir | 1,500 | 4/17/2012 | Chapman Pond | 1,000 |
| 4/13/2004 | Echo Lake | 2,300 | 4/18/2012 | Blackstone | 250 |
| 4/13/2004 | Prince Pond | 200 | 4/24/2012 | Blackstone | 1,000 |
| 4/15/2004 | Belleville | 2,500 | 4/9/2013 | Worden Pond | 1,300 |
| 4/20/2004 | Indian Lake | 2,500 | 4/10/2013 | Worden Pond | 1,410 |
| 4/21/2004 | Warwick Pond, Warwick | 750 | 4/10/2013 | Turner Reservoir | 1,000 |
| 4/22/2004 | Crossmills, Charlestown | 750 | 4/11/2013 | Kickemuit | 1,000 |
| 4/23/2004 | Crossmills, Charlestown | 500 | 4/15/2013 | Worden Pond | 230 |
| 4/23/2004 | Factory Pond | 1,500 | 4/17/2013 | Pawtuxet River | 1,000 |
| 4/28/2004 | Wordon's Pond | 1,000 | 4/17/2013 | Watchaug Pond | 1,400 |
| 4/28/2004 | Wesquage | 400 | 4/18/2013 | Pawtuxet River | 1,000 |
| 4/20/2005 | Brickyard Pond | 1,000 | 4/18/2013 | Watchaug Pond | 700 |
| 4/20/2005 | Echo Lake | 660 | 4/22/2013 | Watchaug Pond | 400 |
| 4/21/2005 | Belleville | 1,660 | 4/25/2013 | Woonasquatucket | 1,000 |
| 4/18/2005 | Prince Pond | 200 | 4/25/2013 | Belleville | 700 |
| 4/19/2005 | Factory Pond | 1,000 | 4/25/2013 | Secret Lake | 300 |
| 4/22/2005 | Crossmills, Charlestown | 600 | 4/14/2014 | Worden Pond | 1,500 |
| 4/25/2005 | Wesquage | 250 | 4/14/2014 | Watchaug Pond | 1,400 |
| 4/29/2005 | Wesquage | 200 | 4/15/2014 | Turner Reservoir | 1,000 |
| 4/26/2005 | Turner Reservoir | 1,000 | 4/15/2014 | Worden Pond | 1,300 |
| 4/13/2006 | Echo Lake | 500 | 4/17/2014 | Kickemuit | 1,000 |
| 4/13/2006 | Brickyard Pond | 500 | 4/21/2014 | Watchaug Pond | 400 |
| 4/14/2006 | Factory Pond | 1,000 | 4/22/2014 | Factory Pond | 1,100 |
| 4/18/2006 | Belleville | 700 | 4/23/2014 | Pawtuxet River | 1,000 |
| 4/21/2006 | Indian Lake | 1,000 | 4/29/2014 | Woonasquatucket | 1,000 |
| 4/28/2006 | Crossmills, Charlestown | 350 | 4/16/2015 | Kickemuit | 1,000 |
| 4/28/2006 | Wesquage | 350 | 4/21/2015 | Turner Reservoir | 1,000 |
| 4/17/2007 | Echo Lake | 300 | 4/22/2015 | Pawtuxet River | 1,000 |
| 4/17/2007 | Brickyard Pond | 300 | 4/23/2015 | Woonasquatucket | 1,000 |
| 4/23/2007 | Indian Lake | 1,400 | 4/27/2015 | Worden Pond | 750 |
| 4/24/2007 | Kickemuit | 200 | 4/29/2015 | Pawtuxet River | 1,000 |
| 4/24/2007 | Kickemuit | 100 | 4/30/2015 | Potowamut | 1,000 |
| 4/15/2008 | Indian Lake | 1,000 | 5/1/2015 | Watchaug Pond | 400 |
| 4/18/2008 | Kickemuit | 350 | | | |

Table 8.3 River herring spawning stock size estimates based on habitat size (Gibson 1984).

| Location | Estimated Spawning Stock Size | Actual 2004-2007 Mean Spawning Stock Size | Actual 2008-2010 Mean Spawning Stock Size | Actual 2013-2015 Mean Spawning Stock Size |
|---------------------------|-------------------------------|---|---|---|
| Gilbert Stuart | | | | |
| Habitat Size 68 acres | 64,306 | 20,440 | 67,921 | 68,261 |
| Nonquit | | | | |
| Habitat Size 202 acres | 138,248 | 50,473 | 104,288 | 52,131 |
| Buckeye Brook | | | | |
| Habitat Size 91 acres | 78,923 | 12,933 | 24,875 | 35,946 |

Table 8.4 Mean fork length (mm) at age for female river herring sampled at Gilbert Stuart.

| Year | Mean Fork Length-at-Age | | | | | | | Annual Mean FL |
|------|-------------------------|-------|-------|---------------------------|-------|-------|----------------------|-------------------|
| | 2 | 3 | 4 | 5 | 6 | 7 | N | |
| 1984 | 221.8 | 165.7 | 292.3 | 309.7 | 321.4 | 333.0 | 138.0 | 265.7 |
| 1985 | 232.4 | 271.3 | 296.9 | 307.3 | 323.0 | 334.5 | 35.0 | 266.5 |
| 1986 | | | 302.8 | 304.5 | 320.4 | 326.3 | 74.0 | 273.3 |
| 1987 | | | | | | | | |
| 1988 | 240.0 | 269.0 | 284.0 | 311.0 | 317.0 | 331.0 | 81.0 | 260.2 |
| 1989 | | 273.0 | 286.0 | 299.0 | 318.0 | 324.0 | 115.0 | 256.3 |
| 1990 | | | 286.0 | 293.0 | 308.0 | | 17.0 | 259.6 |
| 1991 | | | | <i>Data Not Available</i> | | | 42.0 | 250.0 |
| 1992 | | 259.9 | 271.9 | 302.6 | 311.4 | 320.0 | <i>Not Available</i> | 249.1 |
| 1993 | | | | | | | | |
| 1994 | | | | | | | | |
| 1995 | | | | | | | | |
| 1996 | | | | | | | | |
| 1997 | | | | | | | | |
| 1998 | | | | | | | | |
| 1999 | | | | | | | | |
| 2000 | | 229.8 | 241.4 | 245.5 | 260.0 | | 58.0 | 242.2 |
| 2001 | 224.5 | 233.3 | 241.6 | 244.4 | 252.0 | | 47.0 | 251.8 |
| 2002 | | 237.7 | 246.8 | 249.0 | 260.5 | | 42.0 | 255.9 |
| 2003 | | 242.0 | 250.8 | 255.3 | 263.3 | | 29.0 | 254.7 |
| 2004 | | 215.0 | 237.0 | 242.0 | 257.0 | | 66.0 | 231.6 |
| 2005 | | 212.0 | 233.0 | 251.0 | 241.0 | | 82.0 | 239.0 |
| 2006 | | 227.0 | 237.0 | 255.0 | 262.0 | | 32.0 | 243.0 |
| 2007 | | | 239.0 | 244.0 | 278.0 | | 39.0 | 242.3 |
| 2008 | | | 228.0 | 244.0 | 254.0 | 270.0 | 43.0 | 240.4 |
| 2009 | | | 233.0 | 239.0 | 237.0 | | 30.0 | 234.5 |
| 2010 | | 207.0 | 326.0 | 237.0 | 242.0 | | 24.0 | 231.9 |
| 2011 | | 234.0 | 240.9 | 248.7 | 256.1 | | 62.0 | 246.3 |
| 2012 | | | 239.3 | 253.0 | 270.0 | | 17.0 | 246.8 |
| 2013 | | 230.0 | 240.1 | 251.2 | 267.3 | 270.0 | 30.0 | 247.7 |
| 2014 | | | 241.3 | 255.1 | 258.0 | | 26.0 | 247.9 |
| 2015 | | | | <i>Data Not Available</i> | | | | |

Table 8.5 Mean fork length (mm) at age for male river herring sampled at Gilbert Stuart.

| Year | Mean Fork Length-at-Age | | | | | | | Annual Mean FL |
|------|-------------------------|-------|-------|--------------------|-------|-------|---------------|-------------------|
| | 2 | 3 | 4 | 5 | 6 | 7 | N | |
| 1984 | 224.2 | 264.9 | 287.4 | 297.6 | | | 75.0 | 251.5 |
| 1985 | 224.4 | 260.9 | 279.4 | 295.0 | 305.3 | | 41.0 | 252.3 |
| 1986 | | 261.0 | 287.3 | 292.0 | 301.5 | | 43.0 | 256.2 |
| 1987 | | | | | | | | |
| 1988 | 238.0 | 262.0 | 278.0 | 299.0 | 310.0 | | 122.0 | 236.0 |
| 1989 | | 263.0 | 278.0 | 288.0 | 317.0 | 318.0 | 111.0 | 250.9 |
| 1990 | | | 283.0 | 291.0 | | | 15.0 | 252.2 |
| 1991 | | | | Data Not Available | | | 89.0 | 231.9 |
| | | | | | | | Not Available | |
| 1992 | 239.5 | 251.3 | 268.1 | 291.3 | 302.5 | | | 226.6 |
| 1993 | | | | | | | | |
| 1994 | | | | | | | | |
| 1995 | | | | | | | | |
| 1996 | | | | | | | | |
| 1997 | | | | | | | | |
| 1998 | | | | | | | | |
| 1999 | | | | | | | | |
| 2000 | | 220.9 | 235.1 | 231.3 | | | 43.0 | 232.3 |
| 2001 | | 231.0 | 246.5 | 254.1 | 253.3 | | 101.0 | 241.2 |
| 2002 | 222.8 | 230.1 | 238.1 | 244.2 | | | 99.0 | 234.3 |
| 2003 | | 231.7 | 241.2 | 248.1 | 245.0 | | 75.0 | 239.5 |
| 2004 | 206.0 | 219.0 | 233.0 | 240.0 | | | 53.0 | 224.6 |
| 2005 | 211.0 | 215.0 | 232.0 | 233.0 | | | 42.0 | 224.9 |
| 2006 | 209.0 | 221.0 | 224.0 | 241.0 | 245.0 | | 100.0 | 225.8 |
| 2007 | | 220.0 | 227.0 | 234.0 | | | 110.0 | 225.8 |
| 2008 | | 216.0 | 227.0 | 236.0 | 237.0 | | 94.0 | 225.8 |
| 2009 | 201.0 | 208.0 | 227.0 | 235.0 | 226.0 | | 67.0 | 228.9 |
| 2010 | 216.0 | 221.0 | 226.0 | 231.0 | | | 85.0 | 223.8 |
| 2011 | 202.0 | 222.4 | 232.1 | 237.8 | | | 171.0 | 230.1 |
| 2012 | | 222.0 | 231.0 | 239.7 | 245.0 | | 28.0 | 231.1 |
| 2013 | 219.0 | 223.7 | 230.2 | 239.0 | | | 29.0 | 229.4 |
| 2014 | | 234.0 | 237.4 | 244.4 | | | 54.0 | 238.2 |
| 2015 | | | | Data Not Available | | | | |

Table 8.6 Number and percent at age for female river herring sampled at Gilbert Stuart.

| Year | Number-at-Age | | | | | | | Percent-at-Age | | | | | | |
|------|---------------|----|----|----|----|-----|-------|----------------|-------|-------|-------|-------|-------|------|
| | | | | | | | | Mean Age | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | Total | | 2 | 3 | 4 | 5 | 6 | 7 |
| 1984 | 12 | 70 | 40 | 15 | 1 | 138 | 4.4 | 0.0% | 8.7% | 50.7% | 29.0% | 10.9% | 0.7% | |
| 1985 | 6 | 17 | 4 | 6 | 2 | 35 | 4.5 | 0.0% | 17.1% | 48.6% | 11.4% | 17.1% | 5.7% | |
| 1986 | | 13 | 35 | 18 | 7 | 73 | 5.3 | 0.0% | 0.0% | 17.8% | 47.9% | 24.7% | 9.6% | |
| 1987 | | | | | | | | | | | | | | |
| 1988 | 1 | 27 | 9 | 22 | 17 | 5 | 81 | 4.5 | 1.2% | 33.3% | 11.1% | 27.2% | 21.0% | 6.2% |
| 1989 | | 6 | 60 | 39 | 7 | 2 | 114 | 4.5 | 0.0% | 5.3% | 52.6% | 34.2% | 6.1% | 1.8% |
| 1990 | | | 8 | 9 | | | 17 | 4.5 | 0.0% | 0.0% | 47.1% | 52.9% | 0.0% | 0.0% |
| 1991 | | | | | | | | | | | | | | |
| 1992 | | | | | | | | | | | | | | |
| 1993 | | | | | | | | | | | | | | |
| 1994 | | | | | | | | | | | | | | |
| 1995 | | | | | | | | | | | | | | |
| 1996 | | | | | | | | | | | | | | |
| 1997 | | | | | | | | | | | | | | |
| 1998 | | | | | | | | | | | | | | |
| 1999 | | | | | | | | | | | | | | |
| 2000 | 5 | 34 | 17 | 2 | | 58 | 4.3 | 0.0% | 8.6% | 58.6% | 29.3% | 3.4% | 0.0% | |
| 2001 | 1 | 11 | 32 | 3 | | 47 | 4.8 | 0.0% | 2.1% | 23.4% | 68.1% | 6.4% | 0.0% | |
| 2002 | 11 | 13 | 14 | 4 | | 42 | 4.3 | 0.0% | 26.2% | 31.0% | 33.3% | 9.5% | 0.0% | |
| 2003 | 1 | 17 | 7 | 4 | | 29 | 4.5 | 0.0% | 3.4% | 58.6% | 24.1% | 13.8% | 0.0% | |
| 2004 | 11 | 37 | 17 | 1 | | 66 | 4.1 | 0.0% | 16.7% | 56.1% | 25.8% | 1.5% | 0.0% | |
| 2005 | 19 | 9 | 18 | 36 | | 82 | 4.9 | 0.0% | 23.2% | 11.0% | 22.0% | 43.9% | 0.0% | |
| 2006 | 9 | 7 | 10 | 6 | | 32 | 4.4 | 0.0% | 28.1% | 21.9% | 31.3% | 18.8% | 0.0% | |
| 2007 | | 30 | 8 | 1 | | 39 | 4.3 | 0.0% | 0.0% | 76.9% | 20.5% | 2.6% | 0.0% | |
| 2008 | | 16 | 23 | 3 | 1 | 43 | 4.7 | 0.0% | 0.0% | 37.2% | 53.5% | 7.0% | 2.3% | |
| 2009 | | | 16 | 13 | 1 | 30 | 4.5 | 0.0% | 0.0% | 53.3% | 43.3% | 3.3% | 0.0% | |
| 2010 | 1 | 10 | 12 | 1 | | 24 | 4.5 | 0.0% | 4.2% | 41.7% | 50.0% | 4.2% | 0.0% | |
| 2011 | 0 | 1 | 25 | 28 | 8 | 0 | 62 | 4.7 | 0.0% | 1.6% | 40.3% | 45.2% | 12.9% | 0.0% |
| 2012 | 0 | 0 | 9 | 7 | 1 | 0 | 17 | 4.5 | 0.0% | 0.0% | 52.9% | 41.2% | 5.9% | 0.0% |
| 2013 | 0 | 1 | 15 | 9 | 4 | 1 | 30 | 4.6 | 0.0% | 3.3% | 50.0% | 30.0% | 13.3% | 3.3% |
| 2014 | 0 | 0 | 14 | 10 | 2 | 0 | 26 | 4.5 | 0.0% | 0.0% | 53.8% | 38.5% | 7.7% | 0.0% |
| 2015 | | | | | | | | | | | | | | |

Table 8.7 Number and percent at age for male river herring sampled at Gilbert Stuart.

| Year | Number-at-Age | | | | | | | Percent-at-Age | | | | | | |
|------|---------------|----|-----|----|---|---|-------|----------------|-------|-------|-------|-------|-------|------|
| | | | | | | | | Mean Age | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | Total | | 2 | 3 | 4 | 5 | 6 | 7 |
| 1984 | 3 | 17 | 41 | 14 | | | 75 | 3.1 | 4.0% | 22.7% | 54.7% | 18.7% | 0.0% | 0.0% |
| 1985 | | 17 | 9 | 12 | 3 | | 41 | 4.0 | 0.0% | 41.5% | 22.0% | 58.5% | 7.3% | 0.0% |
| 1986 | 2 | 6 | 24 | 11 | | | 43 | 5.0 | 0.0% | 4.7% | 14.0% | 55.8% | 25.6% | 0.0% |
| 1987 | | | | | | | | | | | | | | |
| 1988 | 2 | 90 | 13 | 10 | 7 | | 122 | 3.4 | 1.6% | 73.8% | 10.7% | 8.2% | 5.7% | 0.0% |
| 1989 | | 16 | 70 | 22 | 1 | 2 | 111 | 3.3 | 0.0% | 14.4% | 63.1% | 19.8% | 0.9% | 1.8% |
| 1990 | | | 2 | 10 | 3 | | 15 | 5.1 | 0.0% | 0.0% | 13.3% | 66.7% | 20.0% | 0.0% |
| 1991 | | | | | | | | | | | | | | |
| 1992 | | | | | | | | | | | | | | |
| 1993 | | | | | | | | | | | | | | |
| 1994 | | | | | | | | | | | | | | |
| 1995 | | | | | | | | | | | | | | |
| 1996 | | | | | | | | | | | | | | |
| 1997 | | | | | | | | | | | | | | |
| 1998 | | | | | | | | | | | | | | |
| 1999 | | | | | | | | | | | | | | |
| 2000 | | 7 | 30 | 6 | | | 43 | 4.0 | 0.0% | 16.3% | 69.8% | 14.0% | 0.0% | 0.0% |
| 2001 | 2 | 16 | 52 | 30 | 1 | | 101 | 4.1 | 2.0% | 15.8% | 51.5% | 29.7% | 1.0% | 0.0% |
| 2002 | 4 | 49 | 33 | 13 | | | 99 | 3.6 | 4.0% | 49.5% | 33.3% | 13.1% | 0.0% | 0.0% |
| 2003 | 20 | 45 | 9 | 1 | | | 75 | 3.9 | 0.0% | 26.7% | 60.0% | 12.0% | 1.3% | 0.0% |
| 2004 | 7 | 20 | 22 | 4 | | | 53 | 3.4 | 13.2% | 37.7% | 41.5% | 7.5% | 0.0% | 0.0% |
| 2005 | 2 | 8 | 6 | 26 | | | 42 | 3.9 | 4.8% | 19.0% | 14.3% | 61.9% | 0.0% | 0.0% |
| 2006 | 3 | 28 | 52 | 16 | 1 | | 100 | 3.8 | 3.0% | 28.0% | 52.0% | 16.0% | 1.0% | 0.0% |
| 2007 | 28 | 71 | 11 | | | | 110 | 3.9 | 25.5% | 64.5% | 10.0% | 10.0% | 0.0% | 0.0% |
| 2008 | 26 | 44 | 23 | 1 | | | 94 | 4.0 | 0.0% | 27.7% | 46.8% | 24.5% | 1.1% | 0.0% |
| 2009 | 1 | 4 | 42 | 19 | 1 | | 67 | 4.2 | 1.5% | 6.0% | 62.7% | 28.4% | 1.5% | 0.0% |
| 2010 | 5 | 30 | 42 | 8 | | | 85 | 3.6 | 5.9% | 35.3% | 49.4% | 9.4% | 0.0% | 0.0% |
| 2011 | 4 | 35 | 111 | 21 | 0 | 0 | 171 | 3.9 | 2.3% | 20.5% | 64.9% | 12.3% | 0.0% | 0.0% |
| 2012 | 0 | 8 | 12 | 7 | 1 | 0 | 28 | 4.0 | 0.0% | 28.6% | 42.9% | 25.0% | 3.6% | 0.0% |
| 2013 | 1 | 7 | 17 | 4 | 0 | 0 | 29 | 3.8 | 3.4% | 24.1% | 58.6% | 13.8% | 0.0% | 0.0% |
| 2014 | 0 | 3 | 43 | 8 | 0 | 0 | 54 | 4.1 | 0.0% | 5.6% | 79.6% | 14.8% | 0.0% | 0.0% |
| 2015 | | | | | | | | | | | | | | |

Table 8.8 Summary of Gilbert Stuart river herring data between 1980 and 2015.

| Year | Population Size | N Sampled | Sex Ratio (% Female) | Mean Age (Male) | Mean Age (Female) | Mean Length (Male) | Mean Length (Female) | Percent Repeat Spawner |
|------|-----------------|-----------|-------------------------|--------------------|----------------------|-----------------------|-------------------------|------------------------------|
| 1980 | 54,042 | | 58.9 | 4.93 | 5.09 | 261.0 | 272.0 | |
| 1981 | 64,297 | | 42.6 | 4.71 | 4.98 | 252.9 | 265.8 | |
| 1982 | 88,194 | | 24.0 | 4.50 | 4.97 | 255.8 | 272.0 | |
| 1983 | 68,919 | | 57.8 | 4.26 | 4.62 | 244.2 | 264.0 | |
| 1984 | 52,873 | 213 | 64.8 | 3.13 | 4.46 | 251.5 | 265.7 | 22.0 |
| 1985 | 56,224 | 76 | 46.0 | 4.02 | 4.45 | 252.3 | 266.5 | 28.9 |
| 1986 | 51,986 | 107 | 43.9 | 5.02 | 5.26 | 256.2 | 273.3 | 66.7 |
| 1987 | 50,893 | | | 4.16 | 5.29 | 275.8 | 304.4 | 66.7 |
| 1988 | 74,324 | 203 | 39.9 | 3.43 | 4.52 | 236.0 | 260.2 | 32.5 |
| 1989 | 89,577 | 226 | 50.9 | 3.33 | 4.46 | 250.9 | 256.3 | 28.3 |
| 1990 | 11,009 | 32 | 53.1 | 5.07 | 4.53 | 252.2 | 259.6 | 50.0 |
| 1991 | 21,540 | 131 | 32.1 | 3.37 | 3.97 | 231.9 | 250.0 | 23.3 |
| 1992 | 32,384 | | | 3.52 | 4.56 | 226.6 | 249.1 | 26.3 |
| 1999 | 259,336 | | | | | | | |
| 2000 | 290,814 | 101 | 57.4 | 3.98 | 4.28 | 232.3 | 242.2 | 18.8 |
| 2001 | 254,948 | 148 | 31.8 | 4.12 | 4.79 | 313.5 | 251.8 | 20.3 |
| 2002 | 152,056 | 141 | 29.8 | 3.56 | 4.26 | 234.3 | 255.9 | 17.0 |
| 2003 | 67,172 | 104 | 27.9 | 3.88 | 4.48 | 239.5 | 254.7 | 7.7 |
| 2004 | 16,960 | 119 | 55.5 | 3.43 | 4.12 | 224.6 | 231.6 | 8.4 |
| 2005 | 7,776 | 124 | 66.1 | 3.90 | 4.87 | 224.9 | 239.0 | 5.0 |
| 2006 | 21,600 | 132 | 24.2 | 3.84 | 4.41 | 225.8 | 243.0 | 15.9 |
| 2007 | 36,864 | 149 | 26.2 | 3.86 | 4.26 | 225.8 | 242.3 | 7.4 |
| 2008 | 58,640 | 137 | 31.4 | 3.99 | 4.74 | 225.8 | 240.4 | 19.9 |
| 2009 | 34,835 | 97 | 30.9 | 4.22 | 4.50 | 228.9 | 234.5 | 10.3 |
| 2010 | 110,287 | 109 | 22.0 | 3.62 | 4.54 | 223.8 | 231.9 | 7.3 |
| 2011 | 64,500 | 223 | 26.7 | 3.87 | 4.69 | 230.1 | 246.3 | 16.4 |
| 2012 | 107,901 | 45 | 37.8 | 4.04 | 4.53 | 231.1 | 246.8 | 15.6 |
| 2013 | 91,240 | 59 | 50.9 | 3.83 | 4.63 | 229.4 | 247.7 | 25.4 |
| 2014 | 102,408 | 80 | 32.5 | 4.09 | 4.54 | 238.2 | 247.9 | 15.0 |
| 2015 | 11,135 | | | | | | | |

Table 8.9 Mean fork length (mm) at age for female river herring sampled at Nonquit.

| Year | Mean Fork Length-at-Age | | | | | | Annual Mean FL |
|------|--|-------|-------|-------|-------|-------|-------------------|
| | 2 | 3 | 4 | 5 | 6 | 7 | |
| 2000 | | 227.2 | 237.8 | 244.2 | 244.8 | | 66.0 239.0 |
| 2001 | | 238.5 | 246.0 | 250.8 | 256.5 | | 79.0 248.0 |
| 2002 | | 237.7 | 246.8 | 249.0 | 260.5 | | 71.0 248.0 |
| 2003 | | 242.0 | 250.8 | 255.3 | 263.3 | | 79.0 252.3 |
| 2004 | | 228.0 | 245.9 | 256.4 | 260.7 | | 54.0 234.6 |
| 2005 | | 219.0 | 228.0 | 237.0 | 243.0 | | 92.0 230.9 |
| 2006 | | | 221.0 | 234.0 | 237.0 | | 46.0 231.2 |
| 2007 | | 228.0 | 242.0 | 244.0 | 253.0 | | 55.0 242.1 |
| 2008 | | 227.0 | 235.0 | 241.0 | 244.0 | | 64.0 238.9 |
| 2009 | | 222.0 | 230.0 | 241.0 | 244.0 | 248.0 | 61.0 235.9 |
| 2010 | <i>No Data Available: No Sampling Done</i> | | | | | | |
| 2011 | | | 237.5 | 247.0 | 252.8 | 252.5 | 31.0 243.7 |
| 2012 | | 225.7 | 235.1 | 244.8 | 251.3 | 263.0 | 57.0 239.4 |
| 2013 | | 235.0 | 247.7 | 252.8 | 263.0 | 260.0 | 25.0 251.9 |
| 2014 | | | 246.1 | 253.5 | 270.1 | | 67.0 251.5 |
| 2015 | | | 244.5 | 259.0 | 263.3 | | 44.0 257.1 |

Table 8.10 Mean fork length (mm) at age for male river herring sampled at Nonquit.

| Year | Mean Fork Length-at-Age | | | | | | | Annual Mean FL |
|------|-------------------------|--|-------|-------|-------|-------|------|-------------------|
| | 2 | 3 | 4 | 5 | 6 | 7 | N | |
| 2000 | | 226.6 | 233.1 | 241.7 | | | 77.0 | 231.0 |
| 2001 | 223.5 | 233.6 | 240.0 | 243.4 | 251.0 | | 76.0 | 238.0 |
| 2002 | 223.8 | 233.8 | 237.8 | 241.8 | | | 74.0 | 235.0 |
| 2003 | | 233.2 | 241.4 | 246.1 | | | 64.0 | 238.6 |
| 2004 | | 234.7 | 240.6 | 244.5 | | | 74.0 | 224.7 |
| 2005 | 208.0 | 214.0 | 232.0 | 229.0 | | | 50.0 | 221.8 |
| 2006 | 210.0 | 220.0 | 222.0 | 236.0 | 242.0 | | 97.0 | 221.8 |
| 2007 | | 221.0 | 230.0 | 235.0 | 234.0 | | 85.0 | 229.1 |
| 2008 | | 215.0 | 223.0 | 228.0 | 236.0 | | 85.0 | 223.5 |
| 2009 | | 217.0 | 225.0 | 230.0 | 237.0 | 232.0 | 74.0 | 226.1 |
| 2010 | | <i>No Data Available: No Sampling Done</i> | | | | | | |
| 2011 | | 226.0 | 232.5 | 241.0 | 237.0 | | 44.0 | 234.7 |
| 2012 | | 217.4 | 228.4 | 237.2 | 245.5 | | 90.0 | 230.1 |
| 2013 | 209.0 | 230.8 | 233.9 | 239.9 | | | 49.0 | 233.4 |
| 2014 | | 232.0 | 239.0 | 249.7 | | | 77.0 | 240.6 |
| 2015 | | | 242.1 | 245.8 | 247.0 | | 43.0 | 244.0 |

Table 8.11 Number and percent at age for female river herring sampled at Nonquit.

| Year | Number-at-Age | | | | | | | Percent-at-Age | | | | | | |
|------|--|----|----|----|---|---|-------|----------------|------|-------|-------|-------|-------|------|
| | | | | | | | | Mean Age | 2 | 3 | 4 | 5 | 6 | 7 |
| | 2 | 3 | 4 | 5 | 6 | 7 | Total | | | | | | | |
| 2000 | 9 | 39 | 13 | 5 | | | 66 | 4.21 | 0.0% | 13.6% | 59.1% | 19.7% | 7.6% | 0.0% |
| 2001 | 6 | 42 | 25 | 6 | | | 79 | 4.39 | 0.0% | 7.6% | 53.2% | 31.6% | 7.6% | 0.0% |
| 2002 | 7 | 33 | 25 | 6 | | | 71 | 4.42 | 0.0% | 9.9% | 46.5% | 35.2% | 8.5% | 0.0% |
| 2003 | 1 | 33 | 37 | 8 | | | 79 | 4.66 | 0.0% | 1.3% | 41.8% | 46.8% | 10.1% | 0.0% |
| 2004 | 2 | 33 | 16 | 3 | | | 54 | 4.37 | 0.0% | 3.7% | 61.1% | 29.6% | 5.6% | 0.0% |
| 2005 | 12 | 14 | 32 | 34 | | | 92 | 4.96 | 0.0% | 13.0% | 15.2% | 34.8% | 37.0% | 0.0% |
| 2006 | 12 | 25 | 9 | | | | 46 | 3.93 | 0.0% | 26.1% | 54.3% | 19.6% | 0.0% | 0.0% |
| 2007 | 2 | 41 | 10 | 2 | | | 55 | 4.22 | 0.0% | 3.6% | 74.5% | 18.2% | 3.6% | 0.0% |
| 2008 | 2 | 18 | 32 | 12 | | | 64 | 4.84 | 0.0% | 3.1% | 28.1% | 50.0% | 18.8% | 0.0% |
| 2009 | 3 | 25 | 25 | 6 | 2 | | 61 | 4.66 | 0.0% | 4.9% | 41.0% | 41.0% | 9.8% | 3.3% |
| 2010 | <i>No Data Available: No Sampling Done</i> | | | | | | | | | | | | | |
| 2011 | 0 | 15 | 9 | 5 | 2 | | 31 | 4.81 | 0.0% | 0.0% | 48.4% | 29.0% | 16.1% | 6.5% |
| 2012 | 3 | 33 | 12 | 8 | 1 | | 57 | 4.49 | 0.0% | 5.3% | 57.9% | 21.1% | 14.0% | 1.8% |
| 2013 | 2 | 7 | 11 | 4 | 1 | | 25 | 4.80 | 0.0% | 8.0% | 28.0% | 44.0% | 16.0% | 4.0% |
| 2014 | 0 | 34 | 26 | 7 | 0 | | 67 | 4.60 | 0.0% | 0.0% | 50.7% | 38.8% | 10.4% | 0.0% |
| 2015 | 0 | 8 | 29 | 7 | 0 | | 44 | 4.98 | 0.0% | 0.0% | 18.2% | 65.9% | 15.9% | 0.0% |

Table 8.12 Number and percent at age for male river herring sampled at Nonquit.

| Year | Number-at-Age | | | | | | | Mean Age | Percent-at-Age | | | | | | |
|------|--|----|----|----|---|---|-------|----------|----------------|-------|-------|-------|------|------|--|
| | 2 | 3 | 4 | 5 | 6 | 7 | Total | | 2 | 3 | 4 | 5 | 6 | 7 | |
| 2000 | | 31 | 39 | 7 | | | 77 | 3.69 | 0.0% | 40.3% | 50.6% | 9.1% | 0.0% | 0.0% | |
| 2001 | 2 | 21 | 44 | 8 | 1 | | 76 | 3.80 | 2.6% | 27.6% | 57.9% | 10.5% | 1.3% | 0.0% | |
| 2002 | 6 | 32 | 31 | 5 | | | 74 | 3.47 | 8.1% | 43.2% | 41.9% | 6.8% | 0.0% | 0.0% | |
| 2003 | | 22 | 33 | 9 | | | 64 | 3.80 | 34.4% | 51.6% | 51.6% | 14.1% | 0.0% | 0.0% | |
| 2004 | | 27 | 41 | 6 | | | 74 | 3.72 | 36.5% | 55.4% | 55.4% | 8.1% | 0.0% | 0.0% | |
| 2005 | 5 | 9 | 6 | 30 | | | 50 | 4.22 | 10.0% | 18.0% | 12.0% | 60.0% | 0.0% | 0.0% | |
| 2006 | 2 | 50 | 37 | 7 | 1 | | 97 | 3.54 | 2.1% | 51.5% | 38.1% | 7.2% | 1.0% | 0.0% | |
| 2007 | | 13 | 58 | 11 | 3 | | 85 | 4.05 | 0.0% | 15.3% | 68.2% | 12.9% | 3.5% | 0.0% | |
| 2008 | | 13 | 50 | 17 | 5 | | 85 | 4.16 | 0.0% | 15.3% | 58.8% | 20.0% | 5.9% | 0.0% | |
| 2009 | | 8 | 40 | 23 | 2 | 1 | 74 | 4.30 | 0.0% | 10.8% | 54.1% | 31.1% | 2.7% | 1.4% | |
| 2010 | <i>No Data Available: No Sampling Done</i> | | | | | | | | | | | | | | |
| 2011 | 0 | 5 | 23 | 15 | 1 | 0 | 44 | 4.27 | 0.0% | 11.4% | 52.3% | 34.1% | 2.3% | 0.0% | |
| 2012 | 0 | 9 | 56 | 21 | 4 | 0 | 90 | 4.22 | 0.0% | 10.0% | 62.2% | 23.3% | 4.4% | 0.0% | |
| 2013 | 2 | 8 | 31 | 8 | 0 | 0 | 49 | 3.92 | 4.1% | 16.3% | 63.3% | 16.3% | 0.0% | 0.0% | |
| 2014 | 0 | 10 | 49 | 18 | 0 | 0 | 77 | 4.10 | 0.0% | 13.0% | 63.6% | 23.4% | 0.0% | 0.0% | |
| 2015 | 0 | 0 | 22 | 19 | 2 | 0 | 43 | 4.53 | 0.0% | 0.0% | 51.2% | 44.2% | 4.7% | 0.0% | |

Table 8.13 Summary of Nonquit river herring data sampled from 2000-2015.

| Year | Population Size | N Sampled | Sex Ratio (% Female) | Mean Age (Male) | Mean Age (Female) | Mean Length (Male) | Mean Length (Female) | Percent Repeat Spawner |
|------|-----------------|-----------|----------------------|-----------------|-------------------|--------------------|----------------------|------------------------|
| 2000 | 185,524 | 143 | 46.2 | 3.69 | 4.21 | 231.0 | 239.0 | 14.0 |
| 2001 | 129,518 | 155 | 51.0 | 3.80 | 4.39 | 238.0 | 248.0 | 10.3 |
| 2002 | 97,444 | 145 | 49.0 | 3.47 | 4.42 | 235.0 | 248.0 | 9.0 |
| 2003 | 74,998 | 143 | 55.2 | 3.80 | 4.66 | 238.6 | 252.3 | 15.4 |
| 2004 | 25,417 | 128 | 42.2 | 3.72 | 4.37 | 224.7 | 234.6 | 4.7 |
| 2005 | 42,192 | 142 | 64.8 | 4.22 | 4.96 | 221.8 | 230.9 | 6.4 |
| 2006 | 74,902 | 143 | 32.2 | 3.54 | 3.93 | 221.8 | 231.2 | 2.1 |
| 2007 | 59,380 | 140 | 39.3 | 4.05 | 4.22 | 229.1 | 242.1 | 5.3 |
| 2008 | 224,506 | 149 | 43.0 | 4.16 | 4.84 | 223.5 | 238.9 | 18.8 |
| 2009 | 49,841 | 135 | 45.2 | 4.30 | 4.66 | 226.1 | 235.9 | 17.0 |
| 2010 | 38,516 | No Data | | | | | | |
| 2011 | 30,126 | 75 | 40.8 | 4.27 | 4.81 | 234.7 | 243.7 | 17.1 |
| 2012 | 60,132 | 147 | 38.8 | 4.22 | 4.49 | 230.1 | 239.4 | 8.2 |
| 2013 | 52,563 | 74 | 33.8 | 3.92 | 4.80 | 233.4 | 251.9 | 24.3 |
| 2014 | 71,501 | 144 | 46.5 | 4.10 | 4.60 | 240.6 | 251.5 | 14.6 |
| 2015 | 32,330 | 87 | 57.1 | 4.53 | 4.98 | 244.0 | 257.1 | 33.8 |

Table 8.14 NMFS reported river herring commercial landings (1950-2010).

| Year | Haul seines | Pound net | Fyke & Hoop nets | Trawl | Hand Lines | Fish Pots | Total (pounds) | Total (kg) |
|------|-------------|-----------|------------------|--------|------------|-----------|------------------------------|------------|
| 1950 | 157,000 | 155,100 | | | | | 312,100 | 141,542 |
| 1951 | 104,300 | 801,500 | | | | | 905,800 | 410,794 |
| 1952 | 163,000 | 17,300 | | 600 | | | 180,900 | 82,041 |
| 1953 | 184,300 | 31,300 | | 700 | | | 216,300 | 98,095 |
| 1954 | 13,400 | 3,200 | | 400 | | | 17,000 | 7,710 |
| 1955 | 2,400 | 43,700 | | | | | 46,100 | 20,907 |
| 1956 | 54,500 | | | | | | 54,500 | 24,717 |
| 1957 | 29,300 | | | | | | 29,300 | 13,288 |
| 1958 | | 11,400 | | | | | 11,400 | 5,170 |
| 1959 | 301,300 | | 39,300 | | | | 340,600 | 154,467 |
| 1960 | | | | | | | 0 | 0 |
| 1961 | | | | | | | 0 | 0 |
| 1962 | | | | | | | 0 | 0 |
| 1963 | 112,000 | 17,300 | | | | | 129,300 | 58,639 |
| 1964 | 140,000 | | | | | | 140,000 | 63,492 |
| 1965 | 210,000 | | | | | | 210,000 | 95,238 |
| 1966 | 189,000 | 3,500 | | | | | 192,500 | 87,302 |
| 1967 | 175,000 | 10,500 | | | | | 185,500 | 84,127 |
| 1968 | 168,000 | 22,000 | | | | | 190,000 | 86,168 |
| 1969 | 196,000 | 18,900 | | | | | 214,900 | 97,460 |
| 1970 | 102,200 | 23,800 | | 17,600 | | | 143,600 | 65,125 |
| 1971 | 52,500 | | | 100 | | | 52,600 | 23,855 |
| 1972 | 34,000 | | | | | | 34,000 | 15,420 |
| 1973 | 15,100 | | | | | | 15,100 | 6,848 |
| 1974 | 34,000 | 2,000 | | | 100 | | 36,100 | 16,372 |
| 1975 | 35,500 | 6,000 | | | | | 41,500 | 18,821 |
| 1976 | 31,200 | 2,800 | | | | | 34,000 | 15,420 |
| 1977 | 32,500 | 2,800 | | | | | 35,300 | 16,009 |
| 1978 | 24,000 | 2,200 | | | | | 26,200 | 11,882 |
| 1979 | 5,500 | 6,200 | | | | | 11,700 | 5,306 |
| 1980 | 5,000 | 2,400 | | | | | 7,400 | 3,356 |
| 1981 | | | | | | | 0 | 0 |
| 1982 | | 4,800 | | | | | 4,800 | 2,177 |
| 1983 | | 6,100 | | | | | 6,100 | 2,766 |
| 1984 | | 900 | | | | | 900 | 408 |
| 1985 | | 400 | | | | | 400 | 181 |
| 1986 | | | | | | | 0 | 0 |
| 1987 | | 2,600 | | | | | 2,600 | 1,179 |
| 1988 | | | | | | | 0 | 0 |
| 1989 | | | | | | | 0 | 0 |
| 1990 | | | | | | | 0 | 0 |
| 1991 | | | | | | | 0 | 0 |
| 1992 | | | | | | | 0 | 0 |
| 1993 | | | | | | | 0 | 0 |
| 1994 | | | | | | | 0 | 0 |
| 1995 | | | 400 | | 3 | | 403 | 183 |
| 1996 | | 750 | | | | | 750 | 340 |
| 1997 | | | | | | | 0 | 0 |
| 1998 | | | | | | | 0 | 0 |
| 1999 | | | | | | | 0 | 0 |
| 2000 | | | 574 | | | | 574 | 260 |
| 2001 | | | | | | | 0 | 0 |
| 2002 | | | | 12 | | | 12 | 5 |
| 2003 | | | | | | | <i>Moratorium After 2002</i> | |

Table 8.15 Spawning stock size estimates for river herring at Gilbert Stuart, Nonquit and Buckeye Brook.

| Gilbert Stuart | | Nonquit | | Buckeye Brook | |
|----------------|----------|---------|----------|---------------|----------|
| Year | Alewives | Year | Alewives | Year | Alewives |
| 1981 | 64,297 | | | | |
| 1982 | 88,194 | | | | |
| 1983 | 68,919 | | | | |
| 1984 | 17,337 | | | | |
| 1985 | 16,492 | | | | |
| 1986 | 48,011 | | | | |
| 1987 | 50,893 | | | | |
| 1988 | 74,324 | | | | |
| 1989 | 89,577 | | | | |
| 1990 | 11,009 | | | | |
| 1991 | 21,540 | | | | |
| 1992 | 32,384 | | | | |
| 1993 | 21,754 | | | | |
| 1994 | 43,342 | | | | |
| 1995 | 95,331 | | | | |
| 1996 | 70,904 | | | | |
| 1997 | 122,720 | | | | |
| 1998 | 262,315 | | | | |
| 1999 | 259,336 | 1999 | 230,853 | | |
| 2000 | 290,814 | 2000 | 185,524 | | |
| 2001 | 254,948 | 2001 | 129,518 | | |
| 2002 | 152,056 | 2002 | 97,444 | | |
| 2003 | 67,172 | 2003 | 74,998 | 2003 | 38,949 |
| 2004 | 15,376 | 2004 | 25,417 | 2004 | 5,010 |
| 2005 | 7,776 | 2005 | 42,192 | 2005 | 18,707 |
| 2006 | 21,744 | 2006 | 74,902 | 2006 | 9,428 |
| 2007 | 36,864 | 2007 | 59,380 | 2007 | 18,587 |
| 2008 | 58,640 | 2008 | 224,506 | 2008 | 34,629 |
| 2009 | 34,835 | 2009 | 49,841 | 2009 | 31,697 |
| 2010 | 110,287 | 2010 | 38,516 | 2010 | 8,299 |
| 2011 | 64,500 | 2011 | 30,126 | 2011 | 50,517 |
| 2012 | 107,901 | 2012 | 60,132 | 2012 | 90,625 |
| 2013 | 91,240 | 2013 | 52,563 | 2013 | 45,244 |
| 2014 | 102,408 | 2014 | 71,501 | 2014 | 47,263 |
| 2015 | 11,135 | 2015 | 32,330 | 2015 | 15,333 |

Table 8.16 Trawl survey length frequency data collected for river herring (1996-2015).

| Length | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 2 | | | 1 | | | | | | | | | | | 1 | | | | | | |
| 3 | 11 | | 9 | 11 | | 1 | | | | | | | | 1 | | | | | | |
| 4 | 114 | 3 | 7 | 19 | 14 | 19 | | 49 | 46 | 7 | 1 | | 36 | 119 | 20 | | | | | |
| 5 | 243 | 7 | 24 | 36 | 29 | 51 | | 197 | | 2 | 66 | | 33 | 48 | 57 | 20 | 1 | | 2 | |
| 6 | 122 | 6 | 3 | 65 | 97 | 7 | 4 | 59 | | | 4 | | 1 | 1 | 5 | 30 | 27 | 20 | 146 | |
| 7 | 12 | 7 | | 54 | 20 | 1 | 1 | 10 | | | 1 | | 2 | 9 | 237 | 449 | 3 | 120 | 1 | |
| 8 | 6 | 8 | | 16 | 3 | 1 | | | | | | | 3 | 13 | 745 | 1059 | 2 | 39 | 2 | |
| 9 | 2 | 6 | | 1 | 4 | | | | | | | | | 5 | 709 | 646 | 20 | 183 | 6 | |
| 10 | 1 | 1 | | 1 | | | | | | | | 1 | | 2 | 411 | 507 | 21 | 208 | 105 | |
| 11 | | | | 2 | | 1 | | | | | | | | | 986 | 782 | 3 | 354 | 1169 | |
| 12 | | | | 1 | | | | | | | | | | | 1481 | 898 | 42 | 451 | 1433 | |
| 13 | | | | | | | | | | | | | | | 1823 | 2242 | 88 | 373 | 988 | |
| 14 | | | | | | | | | | | | | | | 1188 | 3698 | 99 | 392 | 220 | |
| 15 | | 1 | | | | | | | | | | | | | 550 | 902 | 51 | 122 | 26 | |
| 16 | | | | | | | | | | | | | | | 262 | 219 | 20 | 4 | 1 | |
| 17 | | | | | | | | | | | | | | | 126 | 108 | 2 | 2 | 2 | |
| 18 | | | | | | | | | | | | | | | 22 | 73 | 7 | 1 | 11 | |
| 19 | | | | | | | | | | | | | | | 23 | 41 | 1 | 1 | 1 | |
| 20 | | | | | | | | | | | | | | | 22 | 54 | | | | |
| 21 | | 6 | | | | | | | | | | | | | 11 | 22 | | 1 | 1 | |
| 22 | | 17 | | | | | | | | | | | | | 16 | 24 | | 1 | 1 | |
| 23 | 1 | 29 | | | | | | | | | | | | | 19 | 60 | | | | |
| 24 | 3 | 27 | | | | | | | | | | | | | 10 | 33 | | 1 | | |
| 25 | 4 | 8 | | | | | | | | | | | | | 9 | 10 | | 1 | | |
| 26 | | 5 | | | | | | | | | | | | | 4 | 3 | | | | |

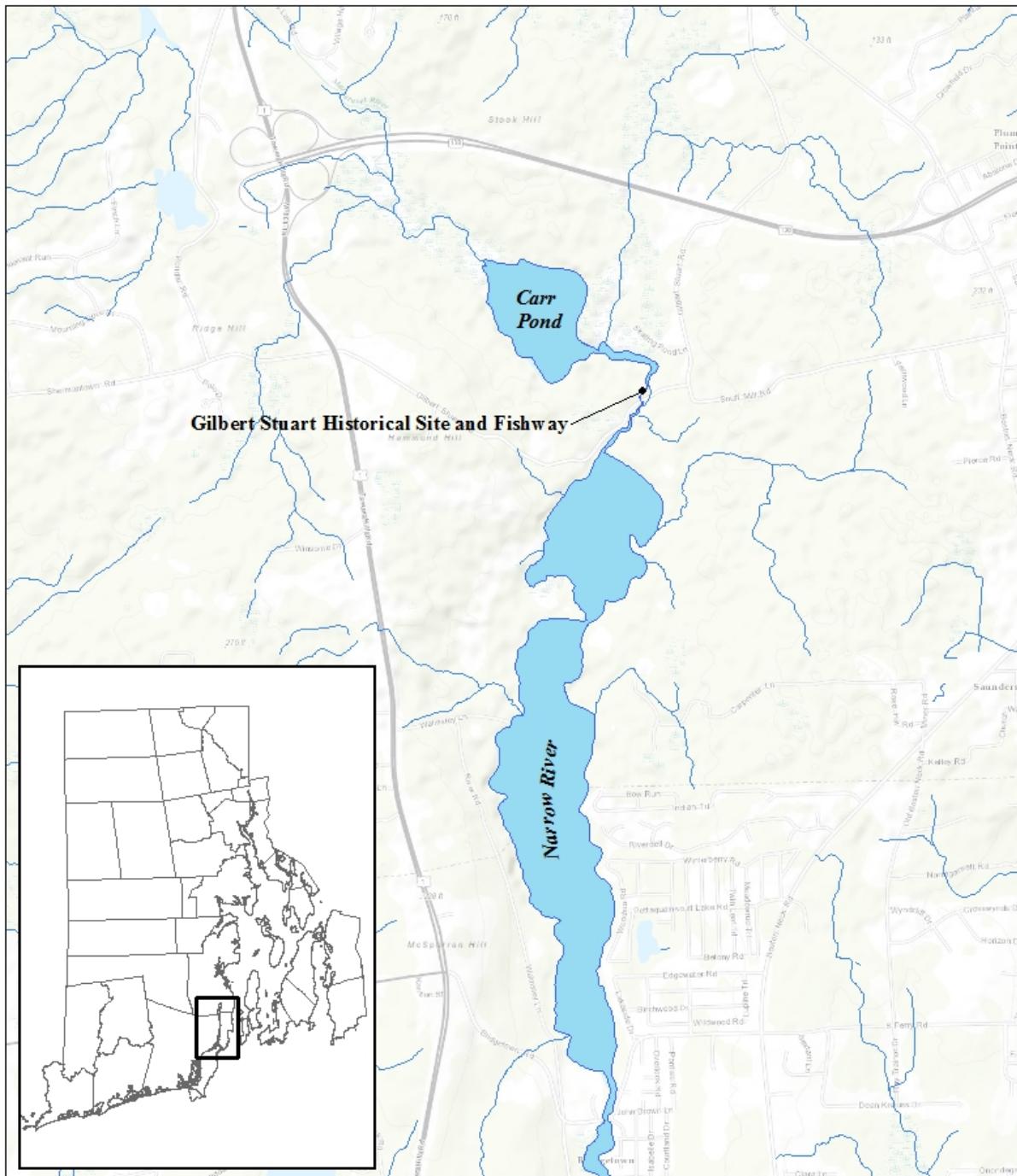
Table 8.17 Gilbert Stuart and Nonquit juvenile river herring mean catch rates.

| Gilbert Stuart | Catch/Hr | SE |
|----------------|----------|--------|
| 1988 | 112.07 | 46.81 |
| 1989 | 79.13 | 40.26 |
| 1990 | 152.25 | 71.34 |
| 1991 | 163.3 | 59.5 |
| 1992 | 343.3 | 125.3 |
| 2007 | 94.9 | 86.5 |
| 2008 | 97.25 | 75.54 |
| 2009 | 6.6 | 4.47 |
| 2010 | 10.89 | 6.79 |
| 2011 | 12.11 | 8.84 |
| 2012 | 16.53 | 9.78 |
| 2013 | 1.53 | 1.45 |
| 2014 | 189.81 | 90.28 |
| 2015 | 223.96 | 137.38 |

| Nonquit | Catch/Hr | SE |
|---------|-----------|-----------|
| 2001 | 161.25 | 83.4 |
| 2002 | 66.57 | 7.9 |
| 2003 | 415.04 | 242.58 |
| 2004 | 2,110.33 | 1,906.33 |
| 2005 | 887.91 | 451.73 |
| 2006 | 62.39 | 40.8 |
| 2007 | 110.15 | 71.49 |
| 2008 | 2,219.58 | 1,954.64 |
| 2009 | 40.67 | 9.59 |
| 2010 | 31.87 | 25.57 |
| 2011 | 578.32 | 485.64 |
| 2012 | 400.65 | 410.36 |
| 2013 | 32.35 | 33.35 |
| 2014 | 40,293.90 | 39,979.90 |
| 2015 | 265 | 234.93 |

Table 8.18 Pawcatuck River JAI results for river herring (1993-2010).

| Year | Number of Hauls | Number of Fish | Geometric Mean YOY | LL 95%CL | UL 95%CL | Zero Hauls | Arithmetic Mean | SE |
|------|-----------------|----------------|--------------------|----------|----------|------------|-----------------|-------|
| 1993 | 35 | 520 | 0.37 | -0.05 | 0.97 | 28 | 7.09 | 1.23 |
| 1994 | 25 | 43 | 0.31 | -0.07 | 0.85 | 22 | 1.72 | 1.34 |
| 1995 | 30 | 240 | 0.9 | 0.14 | 2.17 | 23 | 8 | 4.21 |
| 1996 | 30 | 145 | 0.31 | -0.08 | 0.87 | 26 | 4.83 | 4.6 |
| 1997 | 40 | 5 | 0.08 | -0.02 | 0.18 | 35 | 0.13 | 0.09 |
| 1998 | 55 | 1122 | 1.51 | 0.63 | 2.87 | 36 | 20.4 | 12.57 |
| 1999 | 45 | 10 | 0.18 | 0.05 | 0.32 | 38 | 0.43 | 0.09 |
| 2000 | 65 | 527 | 2.03 | 1.2 | 3.17 | 27 | 8.11 | 1.01 |
| 2001 | 65 | 35 | 0.21 | 0.06 | 0.39 | 56 | 0.54 | 0.23 |
| 2002 | 50 | 500 | 2.34 | 1.3 | 3.86 | 19 | 19.61 | 10.47 |
| 2003 | 54 | 226 | 0.67 | 0.24 | 1.24 | 41 | 4.19 | 2.13 |
| 2004 | 60 | 533 | 1.43 | 0.68 | 2.5 | 37 | 8.88 | 4.09 |
| 2005 | 57 | 27 | 0.08 | -0.04 | 0.22 | 54 | 0.47 | 0.44 |
| 2006 | 67 | 184 | 0.27 | 0.03 | 0.55 | 60 | 2.75 | 2.02 |
| 2007 | 70 | 186 | 0.3 | 0.05 | 0.61 | 62 | 2.66 | 1.44 |
| 2008 | 60 | 10 | 0.08 | -0.01 | 0.17 | 56 | 0.17 | 0.11 |
| 2009 | 60 | 0 | 0 | 0 | 0 | 60 | 0 | 0 |
| 2010 | 55 | 17 | 0.15 | 0.03 | 0.28 | 48 | 0.309 | 0.15 |
| 2011 | 60 | 12 | 0.067 | -0.026 | 0.169 | 58 | 0.2 | 0.13 |
| 2012 | 70 | 11 | 0.05 | -0.026 | 0.122 | 68 | 0.16 | 0.14 |
| 2013 | 70 | 81 | 0.13 | -0.13 | 0.31 | 66 | 1.16 | 0.14 |
| 2014 | 65 | 141 | 0.29 | 0.054 | 0.58 | 56 | 2.17 | 1.29 |
| 2015 | 60 | 205 | 0.74 | 0.31 | 1.31 | 45 | 3.42 | 1.12 |



| | | | |
|---|---|---|--|
| Rhode Island Department of Environmental Management | Status of Rhode Island River Herring Stocks through 2015 | 1 inch = 2,000 feet 0 0.125 0.25 0.5 Miles | |
|---|---|---|--|

Figure 8.1 Gilbert Stuart Fishway, North Kingstown, Rhode Island

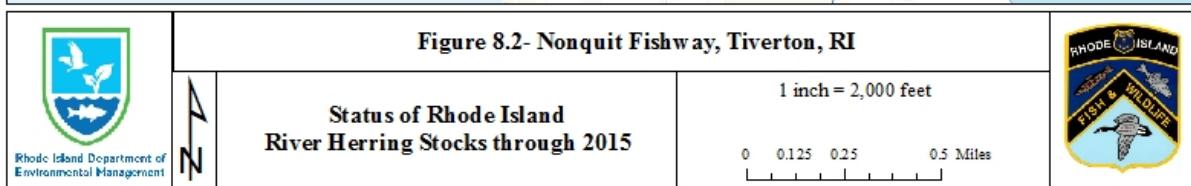
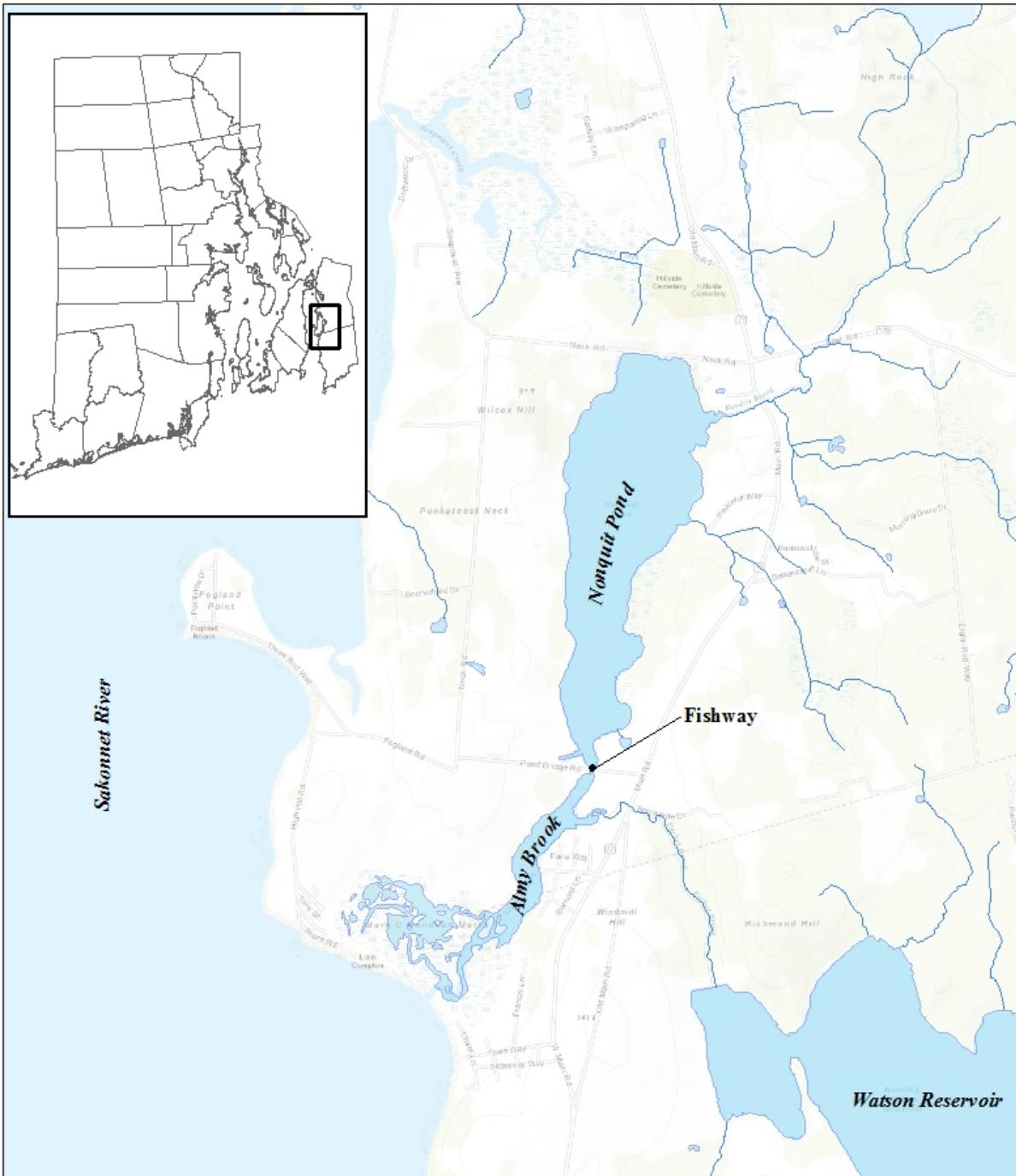


Figure 8.2 Nonquit Fishway, Tiverton, Rhode Island

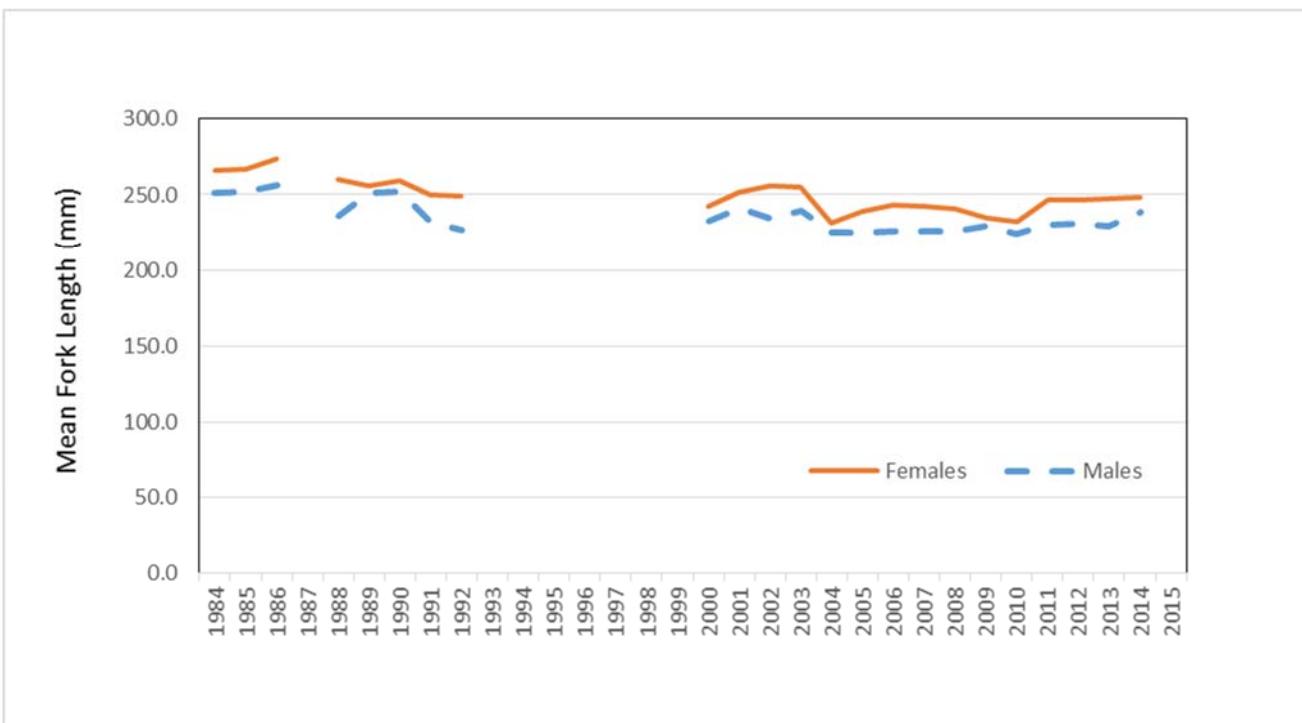


Figure 8.3 Annual mean fork length (mm) for river herring sampled at Gilbert Stuart.

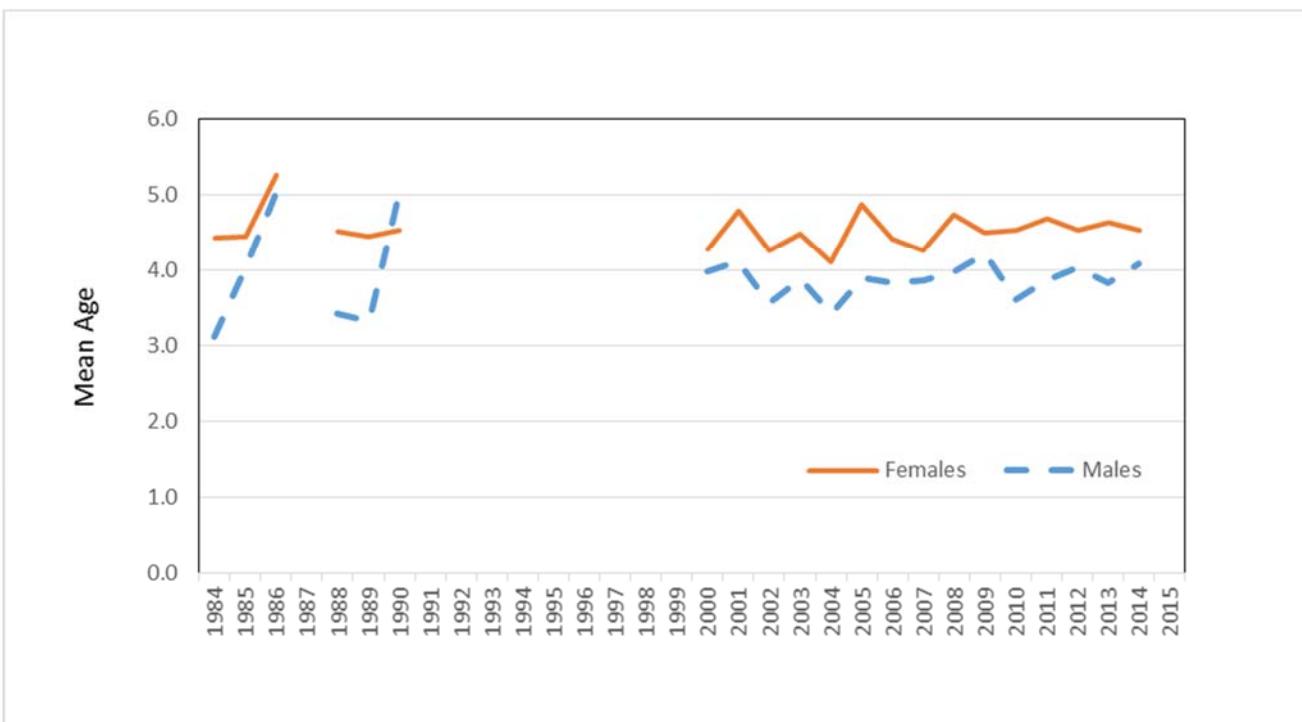


Figure 8.4 Annual mean age for river herring sampled at Gilbert Stuart.

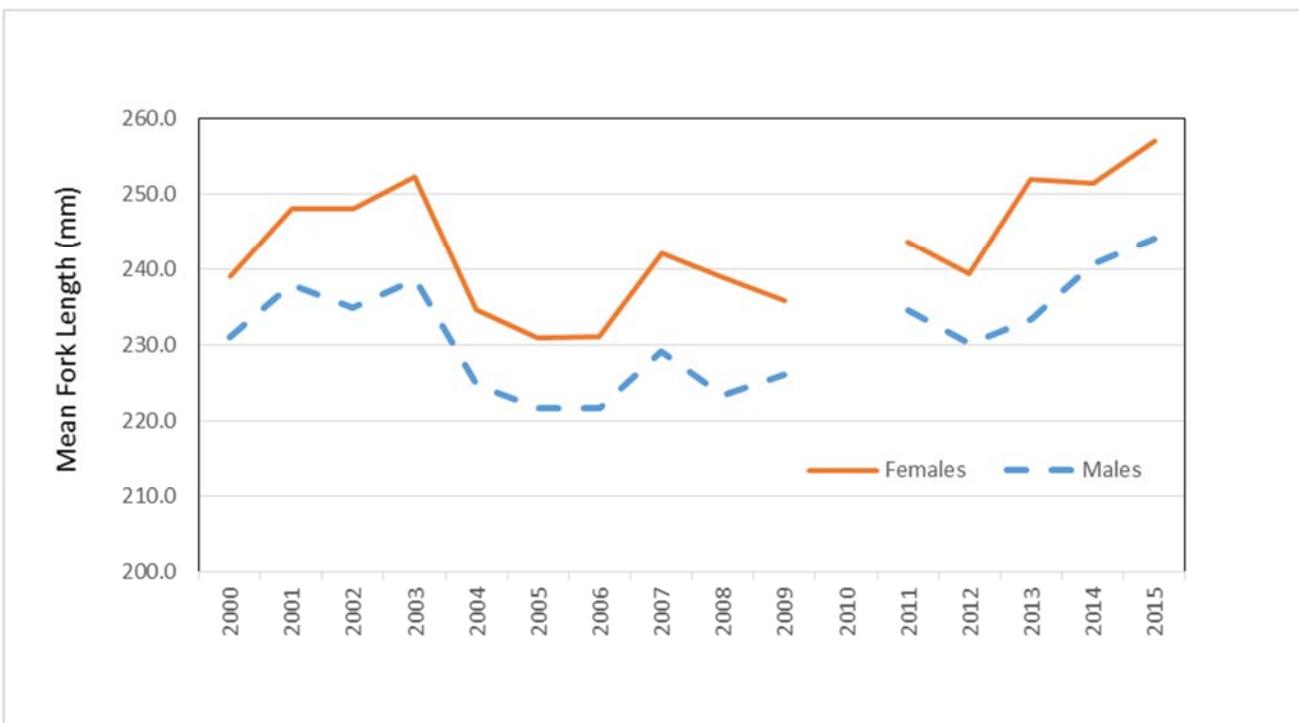


Figure 8.5 Annual mean fork length (mm) for river herring sampled at Nonquit.

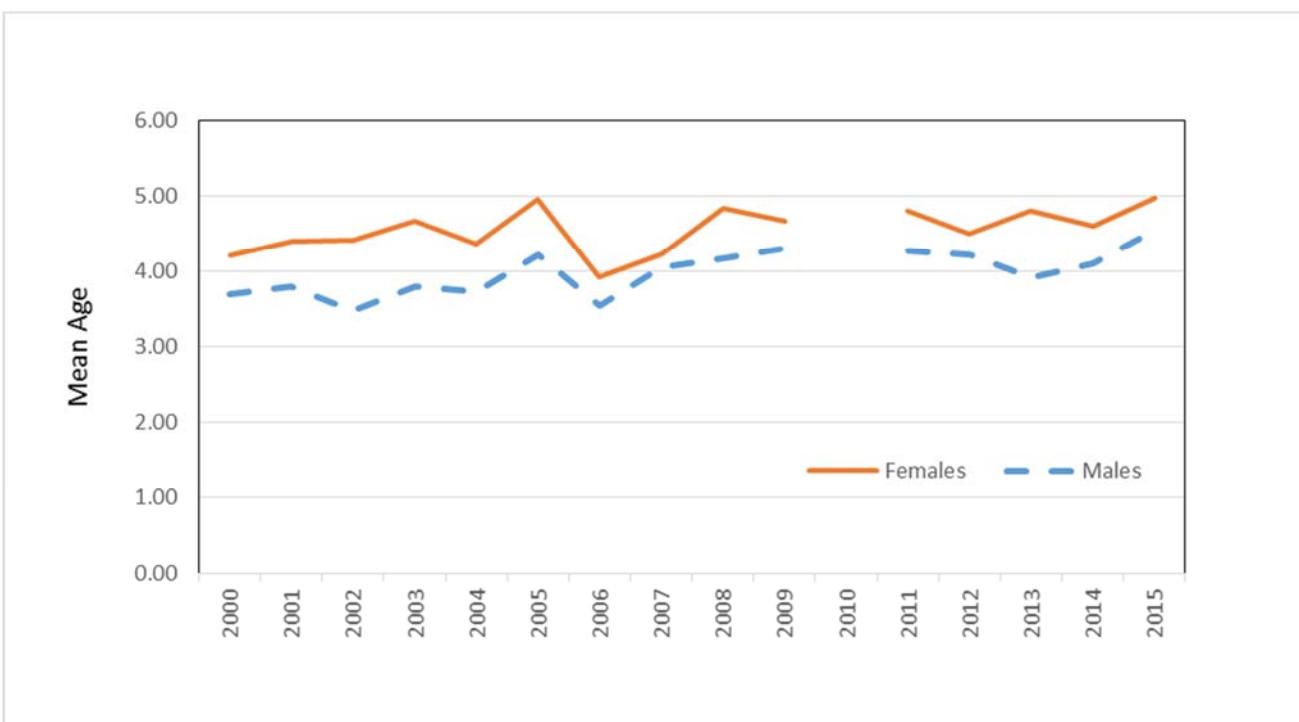


Figure 8.6 Annual mean age for river herring sampled at Nonquit.

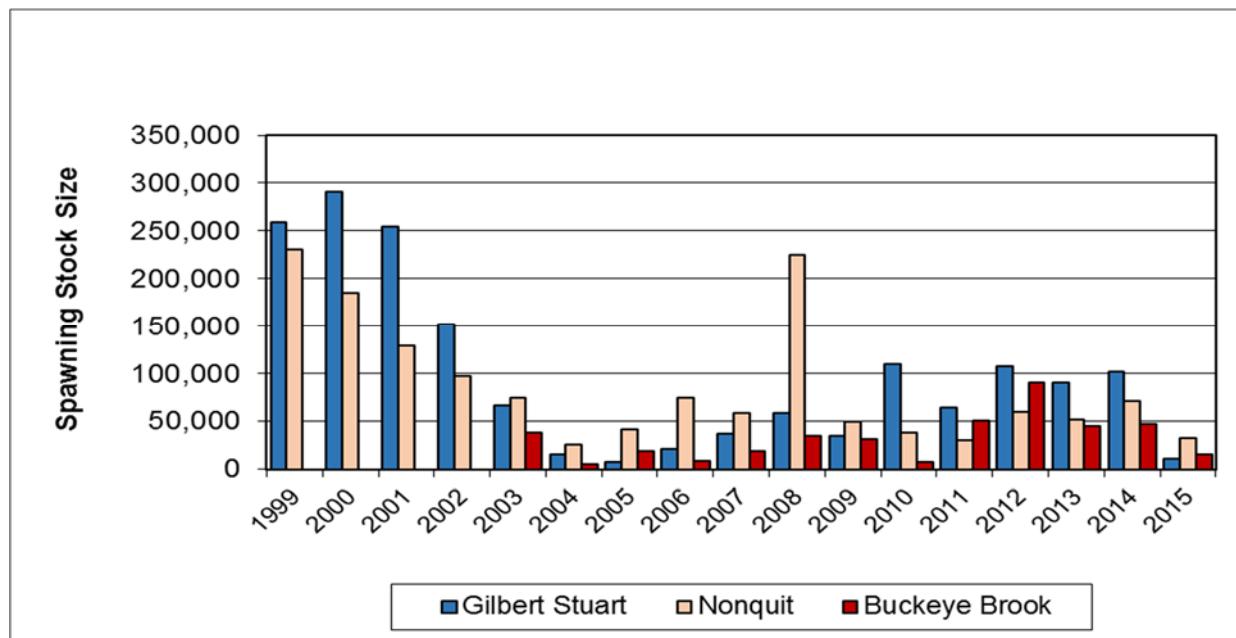


Figure 8.7 Spawning stock size estimates for Gilbert Stuart, Nonquit and Buckeye Brook.

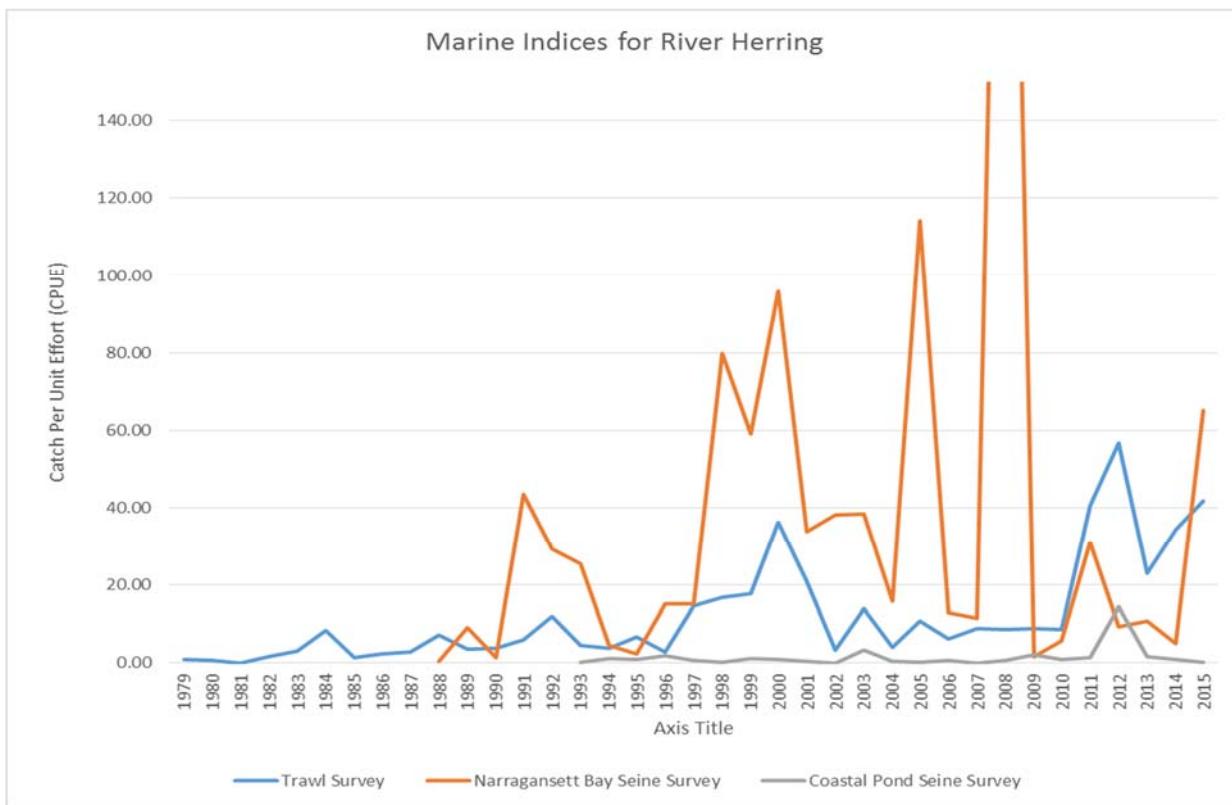


Figure 8.8 Marine Survey Indices-Annual mean river herring catch per tow or seine haul (arithmetic mean)

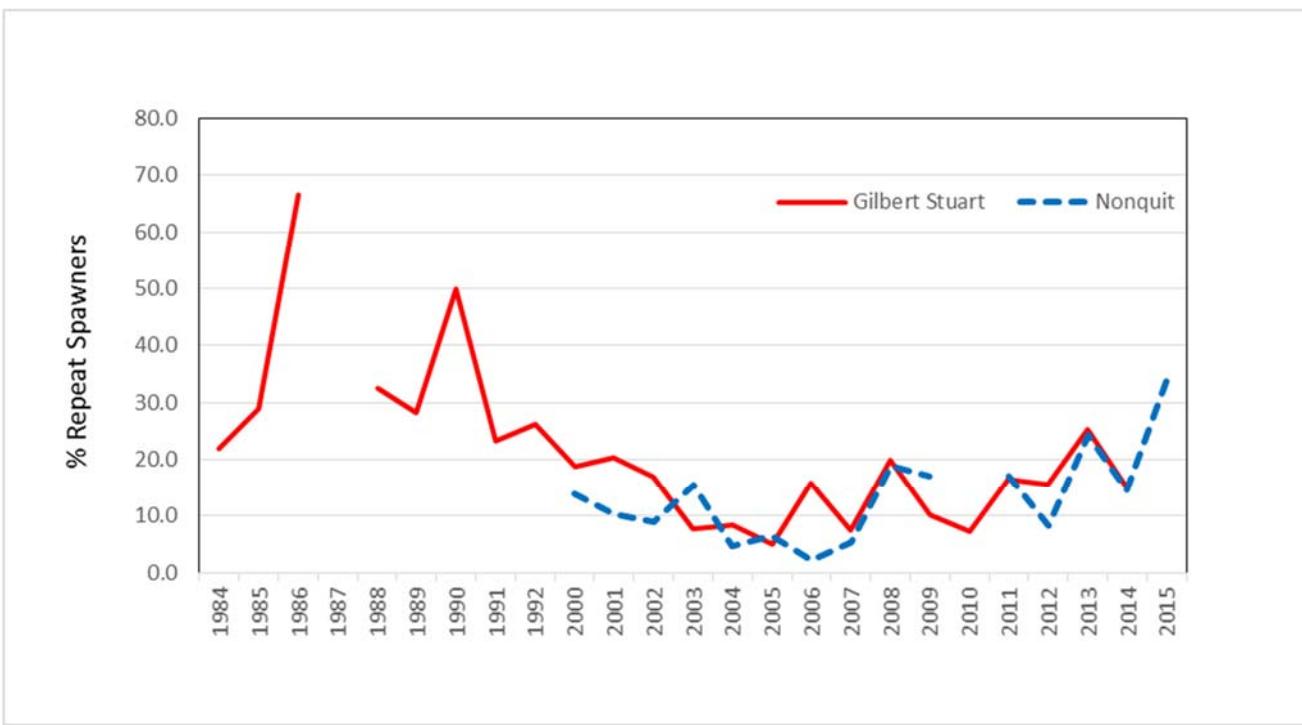


Figure 8.9 Percent repeat spawning for river herring sampled at Gilbert Stuart and Nonquit.

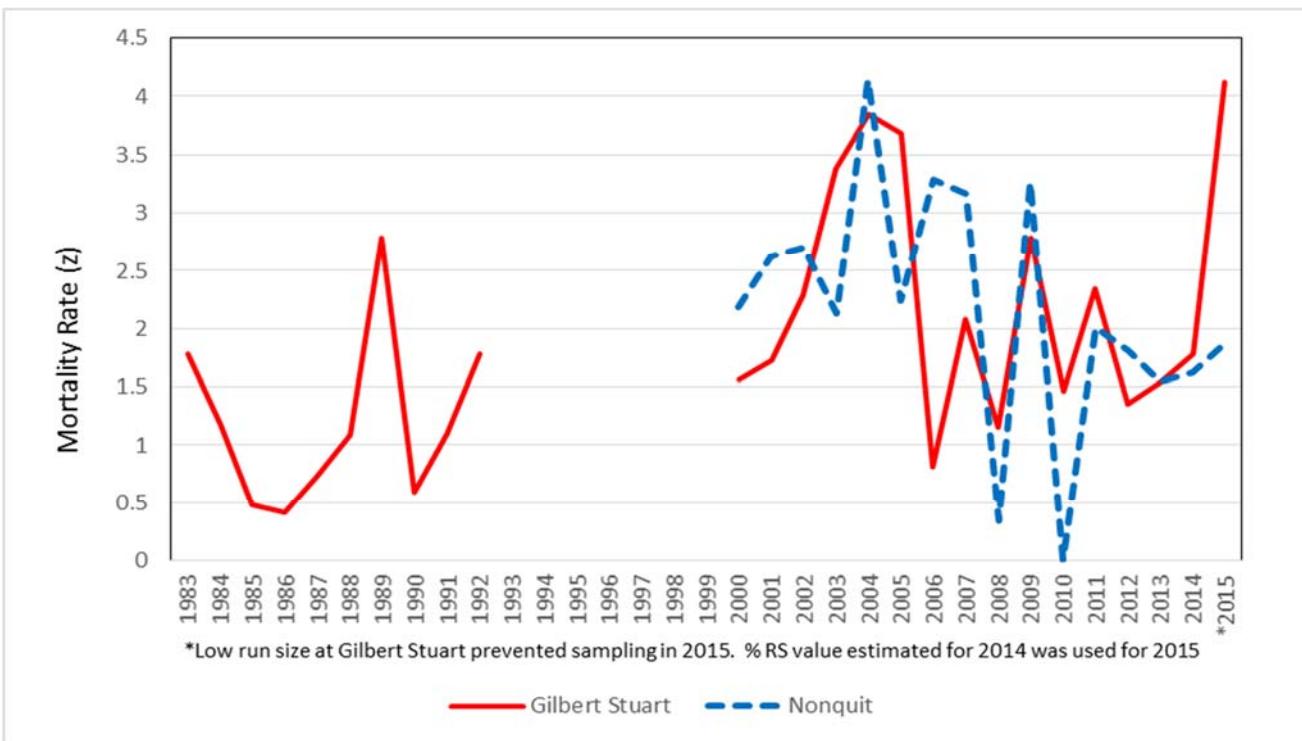


Figure 8.10 Total Mortality Rate (Z) for river herring sampled at Gilbert Stuart and Nonquit.

9 Status of River Herring in Connecticut

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Executive Summary

A statewide moratorium on the take of anadromous river herring (blueback herring, *Alosa aestivalis*, and alewife, *Alosa pseudoharengus*) in Connecticut waters, has been in effect since 2002. Commercial river herring fisheries historically occurred primarily in the Connecticut River, but effort quickly declined after the 1960s. Recreational fisheries, thought mostly to be for bait use, have never been quantified. Adult blueback herring lift counts at the Connecticut River Holyoke Dam reached peak levels in 1985, experienced drastic declines in the 1990s, and have remained at low levels to date. Investigations of the decline during the 1990s, demonstrated statistically and empirically that striped bass population increases, and attendant increases in predation, were a likely contributing factor to the decline of Connecticut River blueback herring (Davis et al. 2012; Davis 2016; Savoy and Crecco 2004).

Connecticut River alosine juvenile production has been monitored by the Connecticut Department of Energy and Environmental Protection (CT DEEP) since 1978. Despite the fact that there have been less than 2,000 adult blueback herring passed annually at Holyoke Dam fish lift since 1993, there have still been some moderate to strong blueback juvenile index (JI) values that have ranked in the top 20 of the index time series. This includes an unexpectedly strong 2010 blueback JI geometric mean value of 12.8, when less than 100 adults were passed at the Holyoke lift. Juvenile indices comparable to the 2010 index value were also produced in 1981, 1984 and 1992 when counts at the fish lift ranged from 300,000 to 480,000. This suggests that the blueback production within the lower river has been able to sustain the stock, albeit, at lower population levels. Despite the statewide landings closure, adult blueback stock size in the upper river has shown no sign of recovery.

Adult alewife abundance has not been monitored in the main stem of the Connecticut River. Passage counts of adult river herring are collected within several Connecticut tributaries by the CT DEEP Diadromous Fisheries Project. Alewife counts at Bride Lake in East Lyme Connecticut have fluctuated since 2003 and produced the highest counts of adult alewives in 2012 and 2013. Alewife and blueback herring relative abundance of mixed stocks age 1+ are documented by the Long Island Sound Trawl Survey (LISTS) and have had variable trends. Additional fishery independent monitoring occurs within other rivers and streams throughout the state, however, there is not yet sufficient data to conduct a formal assessment on any of these systems. Fish restoration and habitat improvement projects are ongoing in an effort to provide river herring access to historical spawning habitats.

9.1. INTRODUCTION

Historically, Connecticut had both commercial and recreational river herring fisheries that were collectively reported as alewives. While there are no reliable historical population estimates, annual anecdotal observations of the fishery were typically reported in the local newspapers. These anecdotes described the widely fluctuating trends of commercial catches in any given year, as ranging from "scarce" to "plentiful" (Hartford Courant 1906; Hartford Courant 1915).

While Connecticut has numerous river herring runs throughout the state, there is little continuous, long-term data on stocks. The annual Connecticut River adult blueback herring counts at the Holyoke Fish lift have been widely circulated, but were only representative of adult blueback herring that migrate beyond the Holyoke Dam at river kilometer 139. CT DEEP has monitored Connecticut River juvenile American shad and blueback herring abundance since 1978. There also are some more recent monitoring efforts which focus on obtaining adult counts at several fishways throughout the state (Gephard et al 2016). The US Fish and Wildlife Service Connecticut River Fish and Wildlife Conservation office (CRFWCO) initiated an electrofishing survey in 2013 for Connecticut River adult alewife and blueback herring (Sprankle 2016). The CRFWCO has also initiated discussions on coordinating juvenile studies in the Massachusetts portion of the river.

9.2. MANAGEMENT UNIT DEFINITION

The Connecticut Department of Energy and Environmental Protection manages river herring populations located within Connecticut state waters. The demarcation line between the marine and inland districts typically occurs at the first bridge upstream from the river mouth or cove unless otherwise specified. The moratorium for river herring is in effect for all state waters. Long Island Sound is jointly managed by Connecticut and New York.

9.3. REGULATORY HISTORY

9.3.1 Commercial Fishery

From 2002 to present there has been a statewide moratorium on commercial and recreational take of anadromous blueback herring and alewife. Under emergency declaration authority of section 26-102 of the Connecticut General Statutes, the commercial or recreation taking of migratory alewives and blueback herring is prohibited from all marine waters and most inland waters. This prohibition is determined on an annual basis.

Historically, Connecticut's river herring commercial fisheries were not heavily regulated. Regulations placed on the commercial river herring fishery, such as restrictions in coves and tributaries, were typically put into place to protect other species. Most of the focus of alosine regulations were for the American shad fishery, which at one time was one of the most important commercial species in the state (Blake and Smith 1984).

Connecticut has three major rivers (Connecticut, Housatonic and Thames) and several smaller rivers and coastal streams (Figure 9.1). While river herring fisheries likely occurred in all of these systems, the bulk of Connecticut's river herring fisheries occurred in the Connecticut River (Blake and Smith 1984). Regulatory jurisdictions of the fisheries were divided into marine and freshwater districts.

During the early 19th century, Connecticut regulations applied penalties for preventing fish migration. Laws were enacted prohibiting constructing dams unless there was a proper opening for fish to pass from April through June. Any obstructions created to catch fish near a dam in the river during spring migration would result in a fine. Rest days prohibited seining and scoop netting in the Shetucket River below the junction with the Quinebaug (Thames River Watershed) during designated nights in the spring. Seining was prohibited at the mouth of Housatonic River during the spring (Goodrick *et al.* 1821). No weirs or other obstructions, were allowed across Bride Brook outlet in East Lyme, between

sunset on Saturday and sunrise on the following Friday from late March early May (Connecticut General Assembly, 1900). In the mid-20th century, Connecticut state statutes identified specific coves within the Connecticut River prohibiting the use of seines and fyke nets during spring anadromous spawning runs.

Haul seine was the primary gear for commercial river herring fisheries in the Connecticut River. Use of haul seines eventually phased out in the 1980s (Table 9.). Since the 1990s, there were landings reported using gill nets and trawls.

9.3.2 Recreational Fishery

Prior to the statewide fishery moratorium in 2002, the recreational limit for both inland and marine waters was 25 blueback herring or alewife, in aggregate, per person per day, for personal use purposes. Land locked alewives from specific lakes were allowed to be taken recreationally by angling and scoop net. There is no historical data on catch and effort in the river herring recreational fishery. Catches were most likely used for bait purposes, but no attempt has been made to determine the magnitude of these fisheries in Connecticut.

9.4. ASSESSMENT HISTORY

The first coastwide river herring stock assessment was conducted in 1990 (ASMFC) by Crecco and Gibson. Connecticut River blueback herring was one of the 15 stocks on the coast analyzed using long-term commercial catch & effort, fishing mortality, and relative population abundance data to estimate maximum sustainable yield (MSY), annual fishing rates at MSY (u_{msy}) and annual fishing rates at stock collapse (u_{col}) to determine whether trends were consistent with overfishing. Based on the analyses, five of the 15 river herring stocks (St. John blueback and alewife, Damariscotta, Potomac and Chowan River alewife) had been overfished. The shape of the stock recruitment curve ($r^2=0.59$) for Connecticut River blueback herring showed that recruitment levels rose to a maximum at low to intermediate spawning stock sizes and then declined slightly thereafter at higher spawning stock levels. Fishing rates ($u<0.3$) were very low for the Connecticut River because at that point, in-river directed fisheries no longer existed. The conclusion of the 1990 assessment was that the blueback herring stock in the Connecticut River was partially exploited and not overfished.

When the second stock assessment was completed in 2012 (ASMFC), Connecticut's river herring commercial and recreational fisheries had been closed for a decade and the adult blueback herring counts at the Holyoke Dam were no longer a meaningful index of abundance. State alewife stocks have never been included in a formal stock assessment, but there were some fishway counts initiated after the state harvest closure that were provided for the assessment to be included for coastwide trend analysis. Statistical and empirical evidence linked the blueback herring stock collapse in the Connecticut River to striped bass predation. The rise in abundance due to the successful rebuilding of the striped bass population was coincident with the decline of blueback herring in the river (Savoy and Crecco 2004).

9.5. STOCK SPECIFIC LIFE HISTORY

9.5.1. Growth

Marcy's age study (1969) of blueback herring and alewife reported mean lengths-at-age ranging from 283.7mm-324.8mm for female alewives ages 4-8 and from 264.6mm-300.7mm for male alewives ages 4-7. Blueback herring mean lengths ranged from 261.3mm-310.9mm for females ages 4-7, and 258.0mm to 298.1mm for males ages 4 to 7.

A more recent study of blueback herring in the Connecticut River (Davis 2016) suggests that mean length-at-age may have decreased since the 1960s: for instance, mean length of age-4 blueback herring (sex-aggregated) during 2005-07 ranged from 245-253 mm vs. 267 mm for male and 277 mm for female blueback herring during the 1960s (Davis 2016; Marcy 1969). A more recent study of alewife at Bride Brook (the same run studied by Marcy) did not provide indications of similar decadal shifts in growth for this population (Davis et al. 2009).

9.5.2. Reproduction

Blueback herring have an extended spawning season in Connecticut waters. Loesch (1968), detected blueback herring in Connecticut in mid-April when water temperatures were around 8 degrees C. The highest abundance near spawning areas occurred during the latter half of June and early July. Smaller spawning groups historically have been observed from mid-May to mid-July (Loesch and Lund 1977). Blueback herring choose spawning sites with swift flow and hard substrate and avoided shallow areas. While parts of the spawning season for the alewife and blueback herring overlap, the two species were observed spatially isolated by selecting different spawning sites. Alewife spawning migrations in Connecticut start as early as the beginning of March and continue in some rivers until mid-June. In an examination of alewife spawning behavior in Bride Lake from 1966-1969, alewives immigrated in March when water temperatures were 4 or 5 deg C and alewives stopped entering Bride Lake in early June when water temperatures were 19-20 degrees. Alewives were observed on the spawning grounds for 3-82 days (Kissil 1974).

9.5.3. Maturity

Marcy (1969) examined Alewife scales from the Connecticut River and Bride Brook, and blueback herring scales from the Connecticut and Thames Rivers. Alewives reached a maximum age of 8, while bluebacks reached a maximum age of 7. The majority of alewives in the spawning run were ages 5 and 6. Majority of male alewives initially spawned at age 4 (68%) and the rest at age 5. Majority of female alewives (68%) initially spawned at age 5. Forty seven percent of male bluebacks spawned first for the first time at age 3 and 50% at age 4. Seventy five percent of female bluebacks initially spawned at age 4 and 16% at age 5.

More recent studies of Connecticut river herring populations suggest shifts towards earlier age-at-maturity. A study of the Bride Brook alewife run in the early-mid 2000s revealed that the majority of spawners were age 3, with fish as young as age 2 participating in the run; Marcy (1969) reported no fish younger than age 4 in this run during the 1960s (Davis et al. 2009). A similar study of the Connecticut River blueback herring run in the mid-2000s documented runs dominated by age-3 and age-4 fish in most study years (with fish as young as age-2 collected), whereas Marcy (1969) reported that approximately 85% of blueback herring collected from the Connecticut and Thames River in the 1960s were age-5 or older and fish younger than age-4 were rare (Davis 2016).

9.5.4. Fecundity

Previous studies of the variation in estimated egg counts for individual Connecticut River blueback herring ranged from 45,800 (238-mm fish) to 349,700 (310-mm fish). (Loesch and Lund 1977). A more recent study of river herring reproductive dynamics (Ganias et al. 2015), using alewives collected from the Bride Lake run, demonstrated that anadromous alewives are batch spawners with indeterminate fecundity – meaning that they can develop and spawn batches of oocytes during the spawning season, and therefore previous estimates of oocyte production that assumed determinate fecundity (e.g. Loesch and Lund) are likely underestimates of annual capacity for oocyte production. Therefore, accurate assessments of annual oocyte production by river herring will require additional information on within-season reproductive dynamics (e.g. frequency of batch production and duration on the spawning grounds) and cannot rely only on enumeration of oocytes in pre-spawn fish (Ganias et al. 2015).

9.6. HABITAT DESCRIPTION

The Connecticut River is the largest river in New England and flows 410 miles from the Canadian border to Long Island Sound. Historically, river herring could be found in all three of Connecticut's major watersheds (the Connecticut, Housatonic, and Thames Rivers) (Figure 9.1) as well as most of the coastal rivers and streams across the State. Blueback herring are more abundant in the larger rivers of the state and have been known to ascend the Connecticut River nearly 200 miles (Gephard and McMenemy 2004). Blueback herring also enter the smaller coastal streams in the state, but less often than alewives and typically are thought to be more common in the western end of the state.

In the 1700s, Connecticut River American shad and herring were so abundant that anyone who consumed shad was looked down upon. The river falls were great places for fishing. Shad and herring were barreled, salted and exported. According to Judd (1905), during this era before dam construction it was not necessary to regulate fisheries. The first dam at South Hadley around 1795 and the dam at Turners Falls heavily impacted anadromous fish. Accounts of fisheries at the falls were described as the best fishing in springtime and shad were caught in seines and with scoop nets below the falls. Boats fished near the falls and collected shad by scoop net and could collect several thousand fish in a day. Shad were so abundant that it was said that oars would strike the fish while paddling across the river.

Connecticut's river herring runs during the late 18th and early 19th century were greatly affected by settlement and industrialization which ultimately led to impacts from deforestation, dam construction and water pollution. More recently, river herring populations have benefitted from water quality improvement, declines in commercial fishing effort, as well as ongoing restoration of access to spawning habitat through fish passage projects. Barrier dams are identified as one of the greatest threats to river herring populations in the freshwater environment. There are over 500 dams within the historic range of river herring in Connecticut.

9.6.1. Habitat Water Quality

The Connecticut River, once famously referred to as “New England’s most beautifully landscaped sewer,” has a long history of poor water quality due to heavy industrial expansion of textiles, heavy metal processing, logging and sewage. Natural disasters such as hurricanes, droughts and flooding events have also had large impacts on the water quality of the river. Connecticut has been progressive in the development of water quality management following some the dismal times of heavily polluted waters. Connecticut’s Clean Water Act (1967) was developed 5 years ahead of the Federal Clean Water Act of 1972.

From the 19th century up until the development of Connecticut's Clean Water Act, untreated or minimally treated waste discharge caused water quality issues in the Connecticut River. Concentrations of dissolved oxygen in the Connecticut River below the Holyoke Dam were measured close to zero during the mid 1960s and early 1970s.

Legislative interest in water pollution dates back as far as 1887 when the Connecticut General Assembly authorized the formation of a sewer study commission to investigate sewage disposal. The commission report in 1889 recommended the State find ways to stop further pollution. A Legislative study commission was created in 1913 to investigate factory wastes and, again, in 1921 to investigate solutions to eliminate pollution. In 1925 laws were enacted to create a State Water Commission, but the commission had few resources and a lack of direct regulatory authority. The State and Federal Clean Water Acts resulted in several downward trends in pollutants and increasing trends in dissolved oxygen. Downward trends in sulfate concentrations likely are attributable to reductions in sulfur dioxide emissions mandated by the Clean Air Act of 1970. Water quality challenges for the Connecticut River still remain and include: reducing nitrogen loads from point and nonpoint sources, reducing bacteria and other contaminant concentrations in storm water runoff, and separating storm water and sanitary sewers at some locations to prevent combined sewer overflows (Mullaney, J.R. 2004). Microplastics are a recent pollution issue, and while they are known to be a threat to the marine and aquatic life that consume them, their impact on fish health is largely unknown. Both the federal government and the state of Connecticut have passed legislation to phase out the use of plastic microbeads from cosmetic products.

9.6.2. Habitat Alterations

Connecticut River

One of the most significant impacts to anadromous fish habitat in Connecticut, was the construction of dams. The Connecticut River was the first river in the country to be improved by canals, with the construction of locks at South Hadley Falls in 1795, which enabled traffic on the Connecticut River to move past the 40 foot falls at South Hadley. Shad and salmon stocks began to show signs of depletion after the construction of Turners Falls Dam in 1798. A timber dam constructed at South Hadley falls was completed in 1849, although a smaller version of a dam was built during construction of the canals and was maintained and enlarged 3 to 4 times with a wing dam in place until the construction of the timber dam (Kirtland, 1897). The dams caused immediate declines to anadromous fish populations.

The first type of fish passage at Holyoke was attempted in 1873 and was unsuccessful at passing shad. In 1900 the present form of the dam was constructed and in 1940 a second attempt was made to construct a fishway, which was also unsuccessful. In 1949 the Holyoke Water Power Company was granted a license to construct a new power plant. A stipulation was for the power company to build fish passage. The finished product was completed in 1952, but was ineffective and replaced by a fish elevator in 1955 (Henry 1976). Daily counts of American shad lifted have been made annually from 1955 to 2015 (Watson 1970; Moffit *et al.* 1982; Leggett *et al.* 2004). Major technological improvements in the Holyoke lift have been made in 1969, 1975 and 1976 (Henry 1976) which resulted in increased annual passage rates (mean number/lift day) of American shad. After 1976 no further improvements in the fish lift were made until 2005. Improvements in 2005 include new tailrace lift tower, bucket and hoist, new spillway lift tower, bucket and hoist, redesigned spillway entrance gallery and crowder, a wider exit flume, a new shad trap and truck facility, a new counting room and second counting window (Slater 2016). As part of a settlement agreement, Holyoke Gas and Electric was required to incorporate

downstream fish passage measures. The new downstream facility was constructed in 2015 and opened for operation as of April 2016 (Sprankle 2016).

The Enfield Dam (RKM 110), was constructed around 1829 to avoid the rapids and to divert water to the Windsor Locks Canal. The dam was a wooden crib structure nearly 1,500 feet in length. The low-head dam was often submerged during high flows in the spring and became an obstruction to fish migration only during low flows. The dam fell into disrepair in the late 1970s and is now breached and no longer an impediment to anadromous fish migration (Leggett *et al.* 2004).

Thames River

The Greeneville Dam was built on the Thames River in 1829 to provide grist and paper mills with water (US Census Office 1880). Norwich Public utilities completed construction of a fish lift elevator in 1996 to pass fish above the dam. Daily anadromous fish counts at the fish lift (Table 9.1) are reported to CT DEEP by Norwich Public Utilities.

Housatonic River

The Derby dam, the first dam of the Housatonic River was completed in 1868 (Leffel 1874). The Stevenson Dam, bordering Monroe and Oxford, is the largest of the five Connecticut Light & Power hydroelectric dams on the Housatonic River (HVA 1999).

Bride Lake

Historically, Bride Brook supported one of the largest alewife runs amongst Connecticut coastal streams. However, registered ground water diversions from nearby public water supply wells contribute to dry stream conditions in the brook just downstream of Bride Lake, significantly decreasing the viability of this alewife breeding ground. (Gephard *et al.* 2000). Replacement of an entrance culvert coincides with increases in adult alewife entering the lake over recent years (Table 9.1).

9.6.3. Habitat Loss

Connecticut's river herring runs during the late 18th and early 19th century were greatly impacted by settlement and industrialization which resulted in deforestation, dam construction and water pollution. Since then, river herring populations have benefitted from water quality improvement, declines in commercial fishing effort, as well as ongoing restoration of access to spawning habitat through fish passage projects. The CT DEEP Diadromous program's restoration efforts have focused on increasing fish passage and transplanting river herring. Barrier dams are identified as one of the greatest threats to river herring populations in the freshwater environment. There are over 500 dams within the historic range of river herring in Connecticut. Access to habitat previously blocked has been restored through construction of fishways and dam removal, providing more spawning habitat to increase production. Since 1990, 11 dams have been removed and 53 fishways have been constructed throughout the state with more projects being completed each year.

9.7. RESTORATION

9.7.1. Objective/Target

The CT DEEP Diadromous program, is responsible for the enhancement and restoration of diadromous fish in Connecticut. Efforts have focused on increasing access to fish habitat through increasing fish passage, removing dams, and transplanting river herring from donor streams to streams that historically had river herring. Pre-spawned adults are also transplanted from healthy runs to streams where the run requires rebuilding. In 2016, DEEP staff operated and maintained nine State-owned fishways and assisted partners with the operation and maintenance of another 52 fishways in the state (Gephard *et. al* 2016).

The Connecticut River watershed spans across 4 states which includes Connecticut, Massachusetts, New Hampshire and Vermont. The Connecticut River Anadromous Fish Restoration Program is a cooperative interjurisdictional management effort that began in 1967. In 1983 an interstate compact relating to the restoration of Atlantic salmon and diadromous fish was created including the four states located in the Connecticut River watershed, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (Public Law 98-138). While the initial focus of the compact was Atlantic salmon, the Connecticut River Atlantic Salmon Commission (CRASC) also works on diadromous fish recovery and restoration. Goals outlined in the CRASC River herring management plan include increasing passage through upstream barriers, maximizing outmigrating juvenile survival, and enhancing and restoring habitat in the Connecticut River Basin (CRASC 2004).

The US Fish and Wildlife Service Connecticut River Fish and Wildlife Conservation Office (CRFWCO) works with CT DEEP and CRASC to coordinate and participate in population assessment and restoration activities in the Connecticut River Basin. Ongoing river herring data assessments conducted by CRFWCO, include a river herring electrofishing survey and truck and transport of blueback herring (Sprankle, 2016)

9.8. AGE

Several studies have examined age structure of Connecticut's river herring populations, but unfortunately, there is not a continuous time series of data. Loesch and Lund (1977) reported age structure and mean length, by sex, for blueback herring collected from 1966 to 1968. Ages ranged from 3 to 7 for both sexes. During 1966 and 1967, Marcy (1969) examined age structure from CT River alewives and blueback herring, Bride Brook alewives, and Thames River blueback herring. Alewives reached a maximum age of 8 years, while blueback herring reached seven years. Bride Brook alewives were predominately 5 and 6 years old, while blueback herring were predominately ages 3 and 4.

More recent examination of the Bride Brook alewife age structure demonstrated a decrease in mean age and size of spawners, as well as decreased rates of repeat spawning relative to the 1960s (Davis and Schultz 2009). A Connecticut River blueback herring study conducted from 2005 to 2007 documented truncation of age structure, a decrease in average length and a decrease in the rate of repeat spawning relative to the 1960s (Davis 2016).

The CT DEEP diadromous program collects biological samples from the Bride Lake alewife spawning run. It is anticipated that there will be a 10 year age structure time series for Bride Lake that can be included in the next benchmark assessment

The USFWS CRFWCO collects biological samples from blueback herring and alewives collected during their CT River electrofishing survey. This time series does not meet the minimum 10 year cutoff recommended by the SAS for assessment. Data will be presented in the next benchmark assessment.

9.9. FISHERIES DESCRIPTIONS

9.9.1. Commercial Fishery

Currently there are no directed commercial or recreational fisheries in Connecticut. Although commercial fishermen on the Connecticut River have reported their annual catches to the State of Connecticut since 1890, this information may not be reliable to determine fluctuations in abundance. In early years, license data did not include catch effort (Smith et al. 1989). Better documentation of landings started in 1975 when all lobster pot and otter trawl fishermen licensed by the State of Connecticut were required to report their monthly catch by species in monthly logbooks. From 1981 to 1995, all haul seine and gillnet commercial fishermen licensed in Connecticut were also required to report their annual landings and fishing effort to the State by September of following year. After 1995, all gillnet and haul seine fishermen were required to report their landings in the monthly logbook system. Because of the difficulty of differentiating blueback herring from alewife, commercial landings reported for most years were not separated by species.

River herring contributed a low percentage to total commercial finfish landings and landings of all species including shellfish in Connecticut. River herring were harvested primarily by haul seine with 2-6% harvested by gillnet (Table 9.). Commercial fishing for river herring occurred predominately in the Connecticut River and was used mostly for lobster bait and bait for game fishing. During the 1950s they were used as industrial fish, being reduced to fish meal. Two peak periods in the recorded historical landings occurred from 1892-1908 and 1950-1955. During these periods annual landings exceeded 500,000 pounds. A record landing of 1.94 million pounds occurred in 1950 (Blake and Smith 1984). Landings generally remained at less than 100,000 pounds since 1960. The majority of the river herring landings from the ocean in the mid-1980s to the mid-1990s were taken within Long Island Sound with a little over 20% occurring in the Atlantic Ocean and from Block Island Sound. Landings in the 1990s dwindled to a few thousand pounds except for two years of large landings in 1995 and 2000 which were attributed to catches in Block Island Sound and the Exclusive Economic Zone (EEZ) (Figure 9.2).

9.9.2. Recreational Fishery

There was a directed recreational fishery in the Connecticut River system for use of live bait in the striped bass fishery in the river and for marine fisheries in Long Island Sound. Harvested primarily by scoop or dip netting, pressure on river herring was likely higher in rivers with the strongest runs. The magnitude of the recreational harvest has never been estimated (Savoy and Crecco 2004).

9.9.3. Bycatch Estimates

Connecticut commercial fishermen are required to submit monthly logbook reports detailing their catch. There have been no reports of river herring in logbooks since the statewide moratorium was implemented. Species-specific river herring incidental catch estimates by gear type and region collected through the Northeast Fisheries Observer Program, are presented in the coastwide assessment volume of this update.

9.10. FISHERIES INDEPENDENT MONITORING

9.10.1. Juvenile Surveys

A long (1979-2016) time series of juvenile blueback herring relative abundance has been established in the Connecticut River (Table 9., Figure 9.5). The average juvenile indices (JI) were expressed as the geometric mean catch per seine haul from 7 stations located between Essex, CT (river km 10) and Holyoke, MA (river km 139) (Marcy 1976). Each year this beach seine survey has been conducted weekly during the months of July through October. One seine haul is made at each station using a 30.5m bag seine (Crecco et al. 1981; Marcy 1976). Although some juvenile alewife remain in the lower river throughout summer and fall when the survey is conducted (Crecco et al. 1981), few are taken in the seine. Loesch (1987) reported juvenile alewife are distributed mainly in deeper (> 5 m) water and are less susceptible than juvenile blueback herring and shad to the beach seine.

9.10.2. Spawning Stock Surveys

Holyoke Lift Counts - Counts of blueback herring lifted at the Holyoke dam on the Connecticut River (rkm 139) are collected annually by the Massachusetts Division of Fisheries and Wildlife. The Holyoke lift counts were used as a proxy of adult blueback herring abundance during the 1980s and early 1990s. When the lift numbers rapidly declined and stayed at low levels, they became non-informative as an indicator of adult blueback abundance for the Connecticut River system.

Fishway counts – Fishway counts are monitored by CT DEEP Diadromous Fisheries Project. Counts of river herring at several fishways are available to monitor population trends. Additionally, Bride Brook (East Lyme, CT), lacks a fishway, but has a counting weir which allows enumeration of the run prior to the fish entering the lake.

Some of the fishway counts provided to the SAS for trend analysis are used by CT DEEP as index sites for river herring. The sites selected should be free of influence, human or artificial, that affect the number of herring that are counted. In most cases, Connecticut fishways are effective at passing river herring in the same manner and same efficiency, year-after-year. Therefore, changes in counts are more likely to reflect true run abundance. However, at the Rainbow Dam Fishway (Farmington River) and the Kinneytown Dam Fishway (Naugatuck River), this is not the case. At Rainbow Dam, there is a vertical slot fishway that does not effectively pass river herring. There are years when the tailrace below the dam appears full of blueback herring, with an estimated tens of thousands of fish observed, yet only two or three individual fish are passed. Because of the design of the Rainbow fishway, the counts are not representative of run abundance. At the Kinneytown Dam fishway, river herring seem to use the Denil fishway when they find it. However, almost on an annual basis the dam's flashboards fail and large amounts of water pass over the spillway and attract migrant fish away from the fishway and toward a long bypass reach under the spillway. Often, fewer than 10 river herring are passed in the fishway, yet there are thousands of river herring observed under the spillway. The fishway counts are not representative of run abundance. Because of the discrepancies between observed river herring presences and fishway counts, we chose to withdraw both of these datasets from the stock assessment update (S Gephard, personal communication).

Long Island Sound Trawl Survey (LISTS) – The LISTS has been conducted annually throughout Long Island Sound since 1984 and has documented age 1+ alosines. Alosines collected in the survey have emigrated from their natal rivers. There are small numbers of adults collected as well as alosines that remain in Long Island Sound for 1 or 2 years before they join coastal migratory stocks (Savoy and Crecco 2004).

Relative abundance is expressed as the annual geometric mean catch per tow (Gottschall et al. 2011). Length frequencies (cm, FL) of all finfishes including blueback herring and alewife have been monitored by LISTS annually from 1989 to 2010 (Table 9.4-Table 9.7). The trawl survey employs a Sound-wide stratified random design with four depth strata and three bottom substrate types. Forty stations are usually sampled monthly during spring (April-June) and fall (September-October) for a total of 200 samples each year. Most (90%) of the trawl strata from the CT DEEP trawl survey are located in the central (west of the Connecticut River) and western basins of LIS. Marcy (1969) suggested that many juveniles (age 1+) spend their first winter close to the mouth of their natal river due to their presence in the lower portion of the Connecticut River in early spring.

9.11. ASSESSMENT APPROACHES AND RESULTS

9.11.1. Trends in Run Size

River herring runs appeared to be abundant and stable during the 1970s and 1980s (Crecco and Gibson 1990). A large decrease in numbers of blueback herring lifted over the Holyoke Dam (rkm 139) in the 1990s was well documented and widely reported. A similar decline in American shad also took place in the Connecticut River. Several hypotheses were examined and strong statistical and empirical evidence was shown to support striped bass predation as a contributing factor to the decline of alosines in the Connecticut River (Davis et al. 2012; Davis 2016; Savoy and Crecco 2004).

The Holyoke fish lift was the only long-term source of adult blueback herring counts. More than 630,000 blueback herring were counted at the fish lift in 1985. However, the number counted at the lift had decreased to less than 1,000 fish being passed on an annual basis since 2004 (Table 9.1, Figure 9.3). A shorter time series of alewife abundance shows fluctuation in the numbers of fish entering Bride Lake with a peak count occurring in 2013 (Table 9.1, Figure 9.4). The LISTS survey has mixed age classes and does not show a definitive trend in abundance partially because those collections of river herring are a mixture from of different stocks from several rivers and streams (Figures 9.6, Figure 9.7). Alewife catches in the LISTS survey are typically higher than blueback herring.

Unlike American shad, there is no direct Connecticut River population estimate for adult blueback herring. Prior to 1996, the total number of adult blueback herring passed annually at the Holyoke Dam fish lift (Savoy and Crecco 2004) was assumed to be an informative index of river-wide stock size (Table 9.1; Figure 9.4). No adult alewife have been counted at the Holyoke fish lift because alewife spawn mainly in the lower river (Marcy 1969). When lift numbers of adult blueback herring fell below 1,000 fish per year from 2004 to 2016, it became increasingly evident that annual counts at Holyoke overstated the decline in river-wide stock abundance. The passage of 21 to 976 blueback herring per year from 2004 to 2010 would suggest that the river-wide stock had declined by 99% since about 1990 (Table 9.1, Figure 9.3). It is unlikely that a 99% drop in stock since 1990 could have produced measurable juvenile production as indicated from 2004 to 2016 (Table 9., Figure 9.5). The use of annual blueback lift data to monitor river-wide trends in abundance became even less reasonable in 2010, when a large 2010 juvenile index emerged when only 76 adult blueback herring were passed at the Holyoke fish lift (Table 9.).

Fishway counts and fish counter data collected over the past ten years vary by river system. Large inland fishways on the Connecticut and Shetucket have low counts of river herring. Annual passage at the Greeneville Dam fishlift on the Shetucket River has varied from 13 to 800 bluebacks and 129 to 2,422 alewives. Bride Brook is one of the more consistently monitored coastal systems, where a stable

trend of alewife returns has been seen since 2002, with increased counts of 287,000 and 354,000 in 2012 and 2013, respectively.

9.11.2. Trends in Size Structure

Connecticut does not have continuous long term length frequency data on adult river herring. Annual river herring length frequencies collected by the Long Island Sound Trawl Survey are comprised of multiple age classes (primarily sub-adults) of river herring from NY and CT waters. Natal river origin of river herring collected by LISTS is unknown. The LISTS length frequencies of blueback herring and alewife have been monitored annually from 1989 to 2010 (Table 9.4, Table 9.5, Table 9.6, Table 9.7). The CT DEEP Diadromous Fisheries Project collects annual length frequency data for alewives at Bride Brook that will be presented in the next benchmark stock assessment. Since 2013, The CRFWCO collects length frequency data from adult blueback herring and alewives captured during their electrofishing. This data will be presented in the next assessment when the duration reaches the 10 year duration as recommended by the SAS. Additional short-term studies in the CT River have documented the decline in mean length at age, truncation of age structure and decline in rate of repeat spawners for Connecticut River blueback herring and Bride Lake alewives (Davis 2016; Davis and Schultz 2009).

9.11.3. Trends in Age Composition

Truncation of age structure has been documented for Connecticut River blueback herring (Davis 2016) and Bride Lake alewife (Davis and Schultz 2009). There are no long-term data sets available on age structure of Connecticut river herring stocks.

9.11.4. Trends in Proportion of Repeat Spawner

Reductions in frequency of repeat-spawning has been documented for Connecticut River blueback herring (Davis 2016) and Bride Lake alewife (Davis and Schultz 2009). There are no long-term data sets available on repeat spawning frequencies in Connecticut river herring stocks.

9.11.5. Trends in Z

Mortality rates were not calculated. Length frequencies and age structure data is being collected, but the time series do not meet the 10 year mark needed to be included in this assessment update.

9.11.6. Fishing Mortality

There are no directed commercial or recreational fisheries in Connecticut.

9.11.7. Trends in Age – 1 Indices of Relative Abundance

Juvenile blueback herring production was high and relatively stable from 1978 to about 1997, but juvenile indices dropped thereafter and remained relatively low from 1998 through 2009. The juvenile index in 2010 was unexpectedly strong, being the highest in the time series since 1994. There are 5 juvenile index values that have ranked in the top 20 since the stock decline at the Holyoke lift. The unexpectedly strong 2010 blueback JI value of 12.8 occurred when less than 100 adults were passed at the Holyoke lift. It is interesting to note that comparable juvenile index values were also produced in 1981, 1984 and 1992 when the counts at the lift ranged from 300,000 to 480,000. This suggests that the blueback production within the lower river is still able to sustain the stock.

9.11.8. Potential Sources of Increased Mortality

Sources of mortality to river herring that exist outside of their natal systems are addressed in the coastwide assessment volume of this update. While most streams and rivers have no information on mortality available, there are sources within the Connecticut River that have been examined.

Striped bass abundance in Connecticut waters and along the Atlantic coast had risen since 1995 to record high levels (ASMFC 2007) coincident with the decline of blueback herring in the Connecticut River. Unlike many other marine finfish predators, adult (> 70 cm) striped bass have the ability to move into freshwater and have been sampled in large and increasing numbers well above the salt wedge in the Connecticut River since 1993 (Davis et al. 2012; Davis 2016; Savoy 1995).

A study of striped bass abundance, size structure, and food habits conducted in the Connecticut River from May-June of 2005-08 demonstrated that striped bass predation was a likely contributor to the decline of the Connecticut River blueback herring run to Holyoke Dam during the 1990s, and is also likely continuing to suppress blueback herring production in the upper river. The study estimated that during the mid-2000s, approximately 125,000 striped bass >30 cm were present in the 64 km river stretch between Wethersfield, CT and the Holyoke Dam during the spring migration season, and that this migratory contingent of striped bass consumed approximately 400,000 (90% CI 200,000-800,000) adult blueback herring annually (Davis et al. 2012; Davis 2016).

9.12. BENCHMARKS

No benchmarks were established for Connecticut.

9.13. CONCLUSIONS AND RECOMMENDATIONS

Fishing mortality rates for river herring in Connecticut waters have been negligible in recent history as Connecticut has had a moratorium on harvest since 2002. The Connecticut River blueback herring population below the Holyoke Dam is of unknown size. Despite the lack of adults passed at the Holyoke Dam, there continues to be stable juvenile blueback production in recent years with index values comparable to values produced with passage of several hundred thousand of fish at the lift. It is unknown as to whether or not the peak values of passage at the Holyoke Dam are a sustainable population for the Connecticut River above Holyoke since there is not enough historical data to estimate population size. Anadromous fish had no access above the Holyoke Dam from 1849-1955. Over 60% of the annual lift values since 1975 have remained below 50,000. The decrease in blueback herring adults documented at the Holyoke lift during the 1990s could not be attributed to directed fisheries in Connecticut since there were no longer commercial fisheries in state waters targeting river herring.

Recent studies of alewife and blueback herring runs in Connecticut suggest that in recent decades river herring runs have experienced a truncation in age structure, reduced size and age of spawners, and decreased rates of repeat spawning. These changes have likely produced a reduction in the resilience of river herring populations, as reduced size and age of spawners likely translates to lower annual reproductive outputs; further, the reduced number of age classes within runs exacerbates the impact of poor year classes.

The LISTS mixed stock indices for age 1+ river herring in Connecticut has been variable. Since the benchmark assessment alewife appear to be more available to the trawl. Mixed age alewife indices from LISTS shows a fluctuating but increasing trend since 1984.

We recommend the continuation of surveys on the Connecticut River and Bride Lake. Catch effort data and biological samples from these surveys should reach sufficient length to be included in the next benchmark stock assessment.

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Table 9.1 Annual River Herring fishway passage counts Holyoke=CT River, Greeneville=Thames River,
Bride Brook=Bride Lake.

| Year | Fishway | BBH | Fishway | ALW | BBH | Fishway | ALW |
|------|---------|---------|-------------|-------|-----|-------------|---------|
| 1966 | | | | | | Bride Brook | 184,151 |
| 1967 | | | | | | Bride Brook | 140,203 |
| 1968 | | | | | | | |
| 1969 | | | | | | | |
| 1970 | | | | | | | |
| 1971 | | | | | | | |
| 1972 | | | | | | | |
| 1973 | | | | | | | |
| 1974 | | | | | | | |
| 1975 | Holyoke | 1,600 | | | | | |
| 1976 | Holyoke | 4,745 | | | | | |
| 1977 | Holyoke | 32,492 | | | | | |
| 1978 | Holyoke | 40,765 | | | | | |
| 1979 | Holyoke | 39,895 | | | | | |
| 1980 | Holyoke | 197,950 | | | | | |
| 1981 | Holyoke | 419,734 | | | | | |
| 1982 | Holyoke | 586,808 | | | | | |
| 1983 | Holyoke | 454,247 | | | | | |
| 1984 | Holyoke | 482,954 | | | | | |
| 1985 | Holyoke | 632,255 | | | | | |
| 1986 | Holyoke | 517,521 | | | | | |
| 1987 | Holyoke | 358,607 | | | | | |
| 1988 | Holyoke | 343,361 | | | | | |
| 1989 | Holyoke | 286,537 | | | | | |
| 1990 | Holyoke | 392,157 | | | | | |
| 1991 | Holyoke | 412,344 | | | | | |
| 1992 | Holyoke | 312,863 | | | | | |
| 1993 | Holyoke | 103,465 | | | | | |
| 1994 | Holyoke | 31,843 | | | | | |
| 1995 | Holyoke | 112,124 | | | | | |
| 1996 | Holyoke | 55,011 | Greeneville | 129 | 13 | | |
| 1997 | Holyoke | 63,945 | Greeneville | 142 | 808 | | |
| 1998 | Holyoke | 11,146 | Greeneville | 337 | 137 | | |
| 1999 | Holyoke | 2,699 | Greeneville | 3,722 | 464 | | |
| 2000 | Holyoke | 10,587 | Greeneville | 480 | 29 | | |
| 2001 | Holyoke | 10,602 | Greeneville | 702 | 187 | | |
| 2002 | Holyoke | 1,939 | Greeneville | 2,288 | 14 | | |
| 2003 | Holyoke | 1,392 | Greeneville | 335 | 216 | Bride Brook | 117,158 |
| 2004 | Holyoke | 151 | Greeneville | 329 | 2 | Bride Brook | 81,350 |
| 2005 | Holyoke | 534 | Greeneville | 592 | 5 | Bride Brook | 68,757 |
| 2006 | Holyoke | 21 | Greeneville | 2,412 | 9 | Bride Brook | 129,114 |
| 2007 | Holyoke | 75 | Greeneville | 2,422 | 0 | Bride Brook | 66,975 |
| 2008 | Holyoke | 84 | Greeneville | 535 | 0 | Bride Brook | 73,268 |
| 2009 | Holyoke | 39 | Greeneville | 190 | 0 | Bride Brook | 74,774 |
| 2010 | Holyoke | 76 | Greeneville | 90 | 0 | Bride Brook | 164,149 |
| 2011 | Holyoke | 138 | Greeneville | 362 | 0 | Bride Brook | 196,996 |
| 2012 | Holyoke | 39 | Greeneville | 244 | 1 | Bride Brook | 287,003 |
| 2013 | Holyoke | 976 | Greeneville | 713 | 24 | Bride Brook | 354,862 |
| 2014 | Holyoke | 647 | Greeneville | 794 | 297 | Bride Brook | 260,926 |
| 2015 | Holyoke | 87 | Greeneville | 502 | 10 | Bride Brook | 218,076 |
| 2016 | Holyoke | 137 | Greeneville | 1,456 | 114 | Bride Brook | 148,596 |

Table 9.2 River herring NMFS landings by gear for Connecticut from NMFS Commercial Fisheries Statistics. DN=Dip Nets, Common, ENGU=Entangling Nets (Gill) UNSP, FHN=Fyke and Hoop nets, Fish, GNDO=Gill Nets, Drift, other, GNDS=Gill Nets, Drift, Shad, GNO=Gill Nets, Other, GNS=Gill Nets, Salmon, GN=Gill Nets, Stake, HSB=Haul Seine, Beach, LHO=Lines Hand, Other, NC=Not Coded, OTBF= Otter Trawl Bottom, Fish, PU=Pots, Unclassified, PNO=Pound Nets, Other, TU=Trawls, unspecified, PNF=Pound Nets, Fish.

| Year | DN | EN | FHN | GNDO | GNDS | GNO | GNS | GN | HSB | LHO | NC | OTBF | PU | PNO | TU | PNF | Total |
|-------------|-----------|-----------|------------|-------------|-------------|------------|------------|-----------|------------|------------|-----------|-------------|-----------|------------|-----------|------------|--------------|
| 1950 | | | 600 | 200 | | | | | 1,947,100 | | | | | | | | 1,947,900 |
| 1951 | | | | 7,000 | | | | | 482,900 | | | | | | | | 489,900 |
| 1952 | | 100 | | | | | | | 758,100 | | | | 1,300 | 302,000 | | | 1,061,500 |
| 1953 | | | | 4,200 | | | | | 328,500 | | | 100 | | 7,500 | | | 340,300 |
| 1954 | | | | 2,000 | | | | | 970,700 | | | | | | | | 972,700 |
| 1955 | | | | 600 | | | | | 889,700 | | | | | | | | 890,300 |
| 1956 | 1,000 | | 1,200 | 37,000 | | | | | 40,200 | | | | | | | | 79,400 |
| 1957 | | | | 600 | | | | | 62,600 | | | | 100 | | | | 63,300 |
| 1958 | 2,400 | | | | | | | | 7,100 | | | | | | | | 9,500 |
| 1959 | 2,400 | | 1,100 | | | | | | 4,000 | | | | 300 | | | | 7,800 |
| 1960 | 2,400 | | 1,000 | 12,000 | | | | | 2,600 | | | | 2,000 | | | | 20,000 |
| 1961 | 1,800 | | | | | 1,000 | | | 200 | | | | | 3,000 | | | 6,000 |
| 1962 | 6,000 | | | | | | 7,000 | | 6,000 | | | | | | | | 19,000 |
| 1963 | 2,000 | | | | | | | | 1,400 | | | | | | | | 3,400 |
| 1964 | 600 | | | | | | | | 12,700 | | 1,500 | | | | | | 14,800 |
| 1965 | 2,400 | | | | | | | | 16,700 | | 5,000 | | | | | | 24,100 |
| 1966 | 2,900 | | | 100 | | | | | 1,600 | | 2,000 | | | | | | 6,600 |
| 1967 | 2,900 | | | 16,000 | | | | | 2,300 | | 2,200 | | | | | | 23,400 |
| 1968 | 3,600 | | | | | | | | 23,300 | | 5,900 | | | | | | 32,800 |
| 1969 | 2,100 | | | 600 | | | | | 6,900 | | 1,000 | | | | | | 10,600 |
| 1970 | 15,400 | | | 400 | | | | | 13,900 | | 92,600 | | | | | | 122,300 |
| 1971 | 5,800 | | | 4,900 | | | | | 12,400 | | 1,900 | | | | | | 25,000 |
| 1972 | 7,600 | | 1,400 | 1,900 | | 400 | | | 11,500 | | | | | | | | 22,800 |
| 1973 | | 1,800 | 2,000 | 3,000 | 4,000 | | | | 3,500 | | | | | | | | 14,300 |
| 1974 | 13,600 | | | 2,900 | | | | | 500 | | | | | | | | 17,000 |
| 1975 | | 1,200 | 4,000 | | | | | | 20,000 | | | | | | | | 25,200 |
| 1976 | 1,600 | | | 4,200 | | | | | 61,100 | 200 | | | | | | | 67,100 |
| 1977 | | 100 | | | | | | | 61,200 | | | | | | | | 61,300 |
| 1978 | 500 | | | 900 | | | | | 37,400 | 1,000 | | | | | | | 39,800 |

Table 9.2 Continued

| Year | DN | EN | FHN | GNDO | GNDS | GNO | GNS | GN | HSB | LHO | NC | OTBF | PU | PNO | TU | PNF | Total |
|-------------|-----------|-----------|------------|-------------|-------------|------------|------------|-----------|------------|------------|-----------|-------------|-----------|------------|-----------|------------|--------------|
| 1979 | | | | 2,200 | | | | | 59,000 | 500 | | 1,000 | | | | | 62,700 |
| 1980 | | | | 1,100 | | | | | 54,000 | | | 0 | | | | | 55,100 |
| 1981 | | | | 3,200 | | | | | 49,200 | 0 | | | | | | | 52,700 |
| 1982 | 400 | | | 2,000 | | | | | 39,300 | 0 | | 100 | | | | | 41,800 |
| 1983 | 500 | | | 2,100 | | | | | 34,700 | | | 200 | | | | | 37,500 |
| 1984 | | | | 1,200 | | | | | 30,700 | | | 500 | | | | | 32,400 |
| 1985 | 3,400 | | | 1,100 | | | | | 33,600 | | | 800 | | | | | 38,900 |
| 1986 | | | | 7,700 | | | | | 32,200 | 200 | | | | | | | 40,100 |
| 1987 | 500 | | 900 | 900 | | | | | 19,000 | | | 100 | | | | | 21,400 |
| 1988 | 1,100 | | | 200 | | | | | 100 | 300 | | 400 | | | | | 2,100 |
| 1989 | 200 | | | 300 | | | | | 500 | | | 600 | | | | | 1,600 |
| 1990 | | | 150 | 800 | | | | | | 200 | | | | | | | 1,150 |
| 1991 | | | 200 | 800 | | | | | | 200 | | | | | | | 1,200 |
| 1992 | 300 | | 300 | 2,300 | | | | | 300 | | | | | | | | 3,200 |
| 1993 | | | | 1,090 | | | | | | 1,350 | | | | | | | 2,440 |
| 1994 | | | | | | | | | | | 2,000 | | | | | | 2,000 |
| 1995 | | | | | | | | | | | 14,044 | | | | | | 14,044 |
| 1996 | | | | 184 | | | | | 68 | | | | | | | | 252 |
| 1997 | | | | | | | | | | | | | | | | | 0 |
| 1998 | | | | | | | | | | | | | | | | | 0 |
| 1999 | | | | | | | | | | | | 102,060 | | | | | 102,060 |
| 2000 | | | | | | | | | 700 | | | 74,990 | | | | 2,295 | 77,985 |
| 2001 | | | | | | | | | 20 | | | | | | | | 20 |

Table 9.3 Annual blueback herring juvenile abundance index for the Connecticut River expressed as arithmetic and geometric mean catch per unit effort, 1979-2015.

| Year | GM CPUE |
|------|------------|
| 1979 | 24.8 |
| 1980 | 26.75 |
| 1981 | 11.49 |
| 1982 | 6.09 |
| 1983 | 16.47 |
| 1984 | 11.57 |
| 1985 | 18.23 |
| 1986 | 13.61 |
| 1987 | 21.58 |
| 1988 | 17.04 |
| 1989 | 7.52 |
| 1990 | 14.41 |
| 1991 | 13.33 |
| 1992 | 10.19 |
| 1993 | 14.43 |
| 1994 | 13.92 |
| 1995 | 5.03 |
| 1996 | 5.91 |
| 1997 | 10.28 |
| 1998 | 4.39 |
| 1999 | 5.57 |
| 2000 | 4.17 |
| 2001 | 3.83 |
| 2002 | 3.95 |
| 2003 | 5.88 |
| 2004 | 2.36 |
| 2005 | 4.1 |
| 2006 | 3.5 |
| 2007 | 6.61 |
| 2008 | 2.2 |
| 2009 | 1.77 |
| 2010 | 12.82 |
| 2011 | 2.93 |
| 2012 | 2.22 |
| 2013 | 6.89 |
| 2014 | 3.69 |
| 2015 | 8.63 |

Table 9.4 Long Island Sound Trawl Survey Alewife Spring Length Frequencies, 1989-2015.

| length | Spring | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|--------|------|------|------|------|-------|------|-------|------|------|-------|-------|------|------|------|------|------|------|-------|------|-------|------|------|------|------|------|------|
| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| 7 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 4 | 0 | 2 | 1 | 0 | 0 | 0 | 3 |
| 8 | 0 | 0 | 0 | 0 | 18 | 3 | 3 | 0 | 0 | 0 | 2 | 9 | 16 | 0 | 3 | 1 | 2 | 0 | 0 | 4 | 1 | 10 | 0 | 1 | 3 | 2 | 12 |
| 9 | 0 | 0 | 2 | 0 | 15 | 9 | 6 | 1 | 6 | 0 | 6 | 21 | 32 | 1 | 18 | 6 | 16 | 0 | 0 | 4 | 6 | 10 | 0 | 3 | 7 | 5 | 11 |
| 10 | 0 | 0 | 0 | 1 | 11 | 19 | 18 | 2 | 22 | 7 | 6 | 28 | 23 | 5 | 32 | 55 | 32 | 0 | 8 | 5 | 11 | 23 | 5 | 6 | 16 | 7 | 16 |
| 11 | 0 | 0 | 5 | 4 | 10 | 44 | 11 | 2 | 64 | 11 | 20 | 52 | 14 | 6 | 27 | 87 | 26 | 29 | 13 | 32 | 10 | 9 | 22 | 8 | 11 | 16 | 13 |
| 12 | 6 | 0 | 4 | 7 | 6 | 83 | 17 | 8 | 127 | 12 | 32 | 43 | 5 | 29 | 25 | 100 | 55 | 44 | 34 | 131 | 17 | 6 | 54 | 27 | 19 | 15 | 7 |
| 13 | 1 | 0 | 4 | 4 | 47 | 122 | 48 | 16 | 63 | 44 | 42 | 99 | 4 | 70 | 11 | 83 | 61 | 15 | 38 | 193 | 24 | 12 | 48 | 98 | 18 | 24 | 6 |
| 14 | 0 | 0 | 9 | 7 | 77 | 172 | 35 | 26 | 69 | 61 | 56 | 234 | 7 | 139 | 28 | 63 | 37 | 9 | 37 | 178 | 51 | 6 | 50 | 187 | 14 | 33 | 6 |
| 15 | 3 | 0 | 8 | 5 | 68 | 140 | 54 | 32 | 56 | 51 | 120 | 334 | 6 | 157 | 25 | 33 | 50 | 49 | 85 | 86 | 101 | 8 | 59 | 123 | 12 | 48 | 7 |
| 16 | 2 | 0 | 8 | 5 | 84 | 159 | 38 | 86 | 44 | 50 | 144 | 320 | 4 | 86 | 26 | 31 | 74 | 25 | 128 | 46 | 106 | 7 | 37 | 56 | 5 | 53 | 5 |
| 17 | 5 | 4 | 4 | 16 | 63 | 108 | 32 | 203 | 28 | 34 | 330 | 85 | 5 | 82 | 21 | 33 | 73 | 78 | 161 | 47 | 142 | 5 | 7 | 27 | 10 | 16 | 5 |
| 18 | 4 | 4 | 9 | 8 | 59 | 81 | 7 | 254 | 32 | 22 | 136 | 15 | 4 | 15 | 19 | 18 | 71 | 93 | 182 | 25 | 196 | 2 | 11 | 17 | 21 | 30 | 5 |
| 19 | 6 | 7 | 7 | 2 | 37 | 33 | 7 | 180 | 9 | 11 | 99 | 20 | 3 | 6 | 26 | 42 | 59 | 86 | 122 | 49 | 215 | 7 | 11 | 24 | 22 | 24 | 9 |
| 20 | 3 | 1 | 7 | 2 | 27 | 24 | 10 | 161 | 17 | 17 | 82 | 22 | 9 | 17 | 13 | 30 | 26 | 76 | 105 | 38 | 137 | 7 | 9 | 19 | 10 | 50 | 3 |
| 21 | 1 | 0 | 3 | 1 | 13 | 17 | 14 | 107 | 34 | 22 | 72 | 27 | 12 | 28 | 22 | 50 | 21 | 40 | 71 | 21 | 53 | 18 | 9 | 18 | 28 | 58 | 9 |
| 22 | 4 | 2 | 8 | 2 | 10 | 26 | 12 | 103 | 48 | 18 | 47 | 41 | 18 | 46 | 25 | 48 | 18 | 18 | 41 | 14 | 29 | 22 | 10 | 24 | 34 | 25 | 20 |
| 23 | 5 | 1 | 8 | 6 | 3 | 12 | 12 | 76 | 44 | 16 | 47 | 90 | 36 | 63 | 40 | 36 | 7 | 5 | 28 | 16 | 13 | 12 | 16 | 27 | 39 | 8 | 17 |
| 24 | 7 | 0 | 3 | 2 | 1 | 12 | 7 | 34 | 28 | 14 | 21 | 58 | 45 | 49 | 42 | 13 | 6 | 1 | 10 | 7 | 14 | 4 | 7 | 18 | 15 | 18 | 12 |
| 25 | 3 | 2 | 1 | 0 | 3 | 5 | 2 | 9 | 9 | 2 | 11 | 11 | 23 | 12 | 29 | 11 | 3 | 1 | 3 | 0 | 11 | 2 | 4 | 11 | 4 | 12 | 10 |
| 26 | 1 | 0 | 1 | 2 | 1 | 5 | 1 | 3 | 1 | 2 | 2 | 1 | 5 | 7 | 17 | 5 | 2 | 0 | 2 | 0 | 1 | 0 | 2 | 3 | 3 | 4 | 7 |
| 27 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 28 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 29 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 32 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 56 | 21 | 93 | 74 | 556 | 1,076 | 334 | 1,304 | 701 | 395 | 1,275 | 1,515 | 274 | 820 | 452 | 749 | 642 | 569 | 1,068 | 901 | 1,138 | 172 | 364 | 698 | 291 | 449 | 185 |

Table 9.5 Long Island Sound Trawl Survey Alewife Fall Length Frequencies, 1989-2015.

| length | Fall | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | - | 0 | 0 | 0 | 0 | |
| 9 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 6 | 1 | 1 | 0 | 1 | 0 | 3 | 2 | 0 | - | 1 | 0 | 0 | 1 | |
| 10 | 0 | 0 | 0 | 0 | 5 | 1 | 4 | 1 | 1 | 0 | 1 | 4 | 23 | 0 | 7 | 1 | 7 | 0 | 8 | 2 | 1 | - | 1 | 0 | 0 | 2 | |
| 11 | 0 | 0 | 0 | 0 | 27 | 30 | 5 | 5 | 6 | 1 | 3 | 5 | 59 | 0 | 33 | 6 | 14 | 0 | 22 | 1 | 2 | - | 9 | 0 | 8 | 0 | |
| 12 | 0 | 0 | 0 | 1 | 120 | 82 | 9 | 25 | 12 | 9 | 6 | 9 | 86 | 4 | 64 | 7 | 8 | 0 | 44 | 0 | 2 | - | 22 | 2 | 14 | 7 | |
| 13 | 0 | 0 | 3 | 0 | 88 | 84 | 14 | 21 | 21 | 7 | 9 | 17 | 72 | 0 | 4 | 12 | 17 | 0 | 87 | 5 | 10 | - | 14 | 3 | 16 | 27 | |
| 14 | 0 | 0 | 2 | 4 | 16 | 36 | 11 | 30 | 31 | 0 | 11 | 10 | 23 | 3 | 3 | 16 | 15 | 0 | 134 | 14 | 10 | - | 22 | 0 | 34 | 48 | |
| 15 | 0 | 0 | 1 | 8 | 21 | 31 | 0 | 9 | 53 | 0 | 5 | 8 | 24 | 3 | 5 | 28 | 15 | 2 | 118 | 4 | 8 | - | 28 | 2 | 6 | 12 | |
| 16 | 3 | 0 | 3 | 10 | 53 | 14 | 4 | 1 | 110 | 1 | 25 | 2 | 36 | 17 | 20 | 30 | 12 | 4 | 31 | 0 | 1 | - | 14 | 1 | 2 | 4 | |
| 17 | 2 | 0 | 0 | 12 | 25 | 33 | 1 | 2 | 194 | 4 | 34 | 0 | 27 | 8 | 19 | 12 | 3 | 0 | 8 | 3 | 1 | - | 19 | 2 | 2 | 0 | |
| 18 | 3 | 0 | 0 | 9 | 13 | 24 | 1 | 1 | 62 | 3 | 11 | 1 | 5 | 0 | 0 | 1 | 5 | 0 | 6 | 0 | 1 | - | 17 | 0 | 0 | 2 | |
| 19 | 0 | 0 | 0 | 2 | 1 | 11 | 0 | 0 | 0 | 1 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 1 | 0 | - | 1 | 0 | 1 | 0 | |
| 20 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | - | 0 | 0 | 0 | 0 | |
| 21 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | |
| 22 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | |
| 23 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 1 | |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | |
| 25 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | |
| Total | 8 | 1 | 9 | 46 | 377 | 354 | 50 | 95 | 492 | 27 | 117 | 58 | 364 | 38 | 156 | 113 | 98 | 6 | 468 | 33 | 37 | 0 | 148 | 10 | 83 | 104 | 301 |

Table 9.6 Long Island Sound Trawl Survey Blueback Spring Length Frequencies, 1989-2015.

| length | Spring | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|----|
| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 | | |
| 7 | 0 | 0 | 0 | 2 | 0 | 2 | 7 | 2 | 0 | 0 | 2 | 0 | 4 | 1 | 0 | 3 | 2 | 1 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 5 | 1 | 17 |
| 8 | 0 | 0 | 3 | 0 | 2 | 76 | 20 | 4 | 0 | 5 | 0 | 10 | 7 | 12 | 7 | 9 | 8 | 1 | 0 | 8 | 0 | 1 | 0 | 0 | 9 | 8 | 30 | |
| 9 | 0 | 0 | 2 | 0 | 3 | 114 | 11 | 5 | 21 | 15 | 0 | 14 | 5 | 9 | 23 | 23 | 14 | 8 | 1 | 11 | 7 | 4 | 3 | 3 | 9 | 3 | 24 | |
| 10 | 0 | 0 | 5 | 10 | 7 | 74 | 9 | 19 | 45 | 45 | 0 | 18 | 2 | 9 | 26 | 47 | 6 | 23 | 9 | 14 | 19 | 19 | 5 | 18 | 5 | 1 | 32 | |
| 11 | 0 | 0 | 3 | 4 | 9 | 41 | 9 | 10 | 258 | 48 | 0 | 28 | 1 | 6 | 11 | 39 | 10 | 2 | 3 | 12 | 25 | 38 | 9 | 12 | 8 | 2 | 29 | |
| 12 | 3 | 0 | 5 | 0 | 2 | 9 | 5 | 3 | 4 | 16 | 0 | 18 | 2 | 3 | 4 | 20 | 12 | 0 | 5 | 2 | 27 | 8 | 3 | 5 | 1 | 2 | 10 | |
| 13 | 0 | 0 | 0 | 4 | 0 | 13 | 5 | 2 | 0 | 2 | 0 | 12 | 1 | 1 | 1 | 12 | 3 | 1 | 3 | 4 | 17 | 10 | 6 | 1 | 1 | 0 | 3 | |
| 14 | 0 | 0 | 0 | 15 | 0 | 5 | 3 | 1 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 7 | 0 | 1 | 1 | 5 | 4 | 2 | 0 | 0 | 0 | 0 | |
| 15 | 0 | 0 | 1 | 27 | 1 | 3 | 4 | 7 | 0 | 0 | 1 | 2 | 0 | 4 | 0 | 0 | 8 | 1 | 2 | 2 | 9 | 1 | 0 | 0 | 0 | 0 | | |
| 16 | 0 | 0 | 0 | 65 | 0 | 8 | 3 | 7 | 0 | 3 | 5 | 1 | 1 | 1 | 4 | 4 | 13 | 2 | 23 | 1 | 30 | 4 | 2 | 2 | 7 | 0 | 0 | |
| 17 | 0 | 0 | 1 | 11 | 3 | 9 | 1 | 10 | 4 | 0 | 5 | 3 | 10 | 7 | 4 | 4 | 11 | 2 | 37 | 7 | 64 | 2 | 12 | 2 | 5 | 6 | 0 | |
| 18 | 0 | 1 | 0 | 2 | 0 | 3 | 0 | 4 | 2 | 0 | 0 | 5 | 15 | 2 | 3 | 3 | 1 | 2 | 7 | 3 | 49 | 1 | 3 | 2 | 3 | 11 | 1 | |
| 19 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 3 | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 3 | 2 | 1 | 3 | 2 | 17 | 2 | 1 | 0 | 1 | 4 | 0 | |
| 20 | 0 | 0 | 0 | 4 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 5 | 2 | 0 | 1 | 2 | 0 | 1 | 0 | 1 | 3 | 0 | |
| 21 | 2 | 1 | 2 | 0 | 0 | 1 | 1 | 3 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 3 | 2 | 3 | 2 | 0 | 1 | 1 | 0 | 0 | 7 | 2 | 1 | |
| 22 | 1 | 0 | 0 | 1 | 0 | 3 | 0 | 4 | 0 | 1 | 0 | 3 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 5 | 2 | 0 | |
| 23 | 0 | 0 | 3 | 2 | 0 | 3 | 2 | 3 | 1 | 0 | 0 | 5 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | |
| 24 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | |
| 25 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 26 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Total | 6 | 3 | 29 | 147 | 30 | 373 | 83 | 90 | 338 | 140 | 11 | 136 | 52 | 56 | 89 | 173 | 104 | 49 | 101 | 71 | 272 | 102 | 47 | 45 | 68 | 47 | 153 | |

Table 9.7 Long Island Sound Trawl Survey Blueback Fall Length Frequencies, 1989-2015.

| length | Fall | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 3 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | - | 0 | 0 | 0 | |
| 10 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 8 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 1 | |
| 11 | 0 | 0 | 0 | 0 | 3 | 13 | 4 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 1 | |
| 12 | 0 | 0 | 3 | 9 | 8 | 227 | 14 | 0 | 12 | 1 | 1 | 0 | 7 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 1 | |
| 13 | 38 | 1 | 4 | 11 | 24 | 225 | 48 | 0 | 117 | 18 | 0 | 0 | 36 | 2 | 0 | 15 | 2 | 2 | 0 | 0 | - | 0 | 1 | 0 | 1 | 0 | |
| 14 | 77 | 0 | 1 | 6 | 18 | 247 | 40 | 1 | 111 | 28 | 1 | 0 | 117 | 7 | 0 | 17 | 3 | 8 | 1 | 1 | 3 | - | 4 | 0 | 0 | 2 | 26 |
| 15 | 24 | 0 | 0 | 1 | 20 | 94 | 3 | 3 | 34 | 16 | 0 | 3 | 52 | 3 | 4 | 6 | 2 | 4 | 14 | 2 | 5 | - | 9 | 0 | 0 | 3 | 60 |
| 16 | 0 | 0 | 0 | 0 | 2 | 14 | 0 | 0 | 5 | 2 | 1 | 10 | 0 | 4 | 0 | 0 | 0 | 31 | 0 | 2 | - | 9 | 0 | 0 | 1 | 6 | |
| 17 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 7 | 0 | 1 | - | 3 | 0 | 0 | 2 | 0 | |
| 18 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 20 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 22 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 24 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| 25 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | |
| Total | 140 | 2 | 9 | 27 | 76 | 827 | 172 | 7 | 292 | 72 | 8 | 8 | 227 | 12 | 9 | 42 | 8 | 14 | 55 | 3 | 18 | 0 | 25 | 1 | 0 | 10 | 94 |

Table 9.8. LISTS spring and fall alewife indices of abundance, 1984-2015.

| Year | Alewife Spring | Alewife Fall |
|-------------|-----------------------|---------------------|
| 1984 | 0.43 | 0.42 |
| 1985 | 0.10 | 0.01 |
| 1986 | 0.66 | 0.05 |
| 1987 | 1.00 | 0.04 |
| 1988 | 0.47 | 0.19 |
| 1989 | 0.72 | 0.16 |
| 1990 | 0.54 | 0.11 |
| 1991 | 0.39 | 0.07 |
| 1992 | 0.39 | 0.19 |
| 1993 | 0.84 | 0.40 |
| 1994 | 1.83 | 0.66 |
| 1995 | 0.96 | 0.16 |
| 1996 | 2.18 | 0.24 |
| 1997 | 1.44 | 1.23 |
| 1998 | 1.11 | 0.11 |
| 1999 | 1.89 | 0.42 |
| 2000 | 1.53 | 0.25 |
| 2001 | 0.75 | 0.55 |
| 2002 | 0.95 | 0.22 |
| 2003 | 1.14 | 0.58 |
| 2004 | 1.86 | 0.26 |
| 2005 | 1.30 | 0.43 |
| 2006 | 0.78 | 0.05 |
| 2007 | 1.62 | 0.95 |
| 2008 | 1.32 | 0.42 |
| 2009 | 1.04 | 0.18 |
| 2010 | 1.29 | |
| 2011 | 0.94 | 0.43 |
| 2012 | 0.77 | 0.07 |
| 2013 | 1.06 | 0.40 |
| 2014 | 0.88 | 0.18 |
| 2015 | 0.77 | 0.64 |

Table 9.8. LISTS spring and fall blueback herring indices of abundance, 1984-2015.

| Year | Blueback Fall* | Blueback Spring |
|-------------|-----------------------|------------------------|
| 1984 | 0.38 | 5.42 |
| 1985 | 0.16 | 0.30 |
| 1986 | 0.07 | 0.34 |
| 1987 | 0.13 | 0.14 |
| 1988 | 0.53 | 0.03 |
| 1989 | 0.34 | 0.05 |
| 1990 | 0.10 | 0.08 |
| 1991 | 0.04 | 0.11 |
| 1992 | 0.08 | 0.20 |
| 1993 | 0.11 | 0.08 |
| 1994 | 0.93 | 0.55 |
| 1995 | 0.27 | 0.29 |
| 1996 | 0.05 | 0.28 |
| 1997 | 0.75 | 0.25 |
| 1998 | 0.16 | 0.15 |
| 1999 | 0.06 | 0.02 |
| 2000 | 0.06 | 0.37 |
| 2001 | 0.20 | 0.19 |
| 2002 | 0.06 | 0.15 |
| 2003 | 0.10 | 0.27 |
| 2004 | 0.09 | 0.46 |
| 2005 | 0.06 | 0.33 |
| 2006 | 0.15 | 0.13 |
| 2007 | 0.24 | 0.29 |
| 2008 | 0.05 | 0.21 |
| 2009 | 0.09 | 0.43 |
| 2010 | | 0.37 |
| 2011 | 0.08 | 0.14 |
| 2012 | 0.01 | 0.13 |
| 2013 | 0.00 | 0.26 |
| 2014 | 0.04 | 0.15 |
| 2015 | 0.17 | 0.42 |



Figure 9.1 Map of Connecticut's 3 major rivers (Connecticut, Housatonic, Thames) and Long Island Sound.

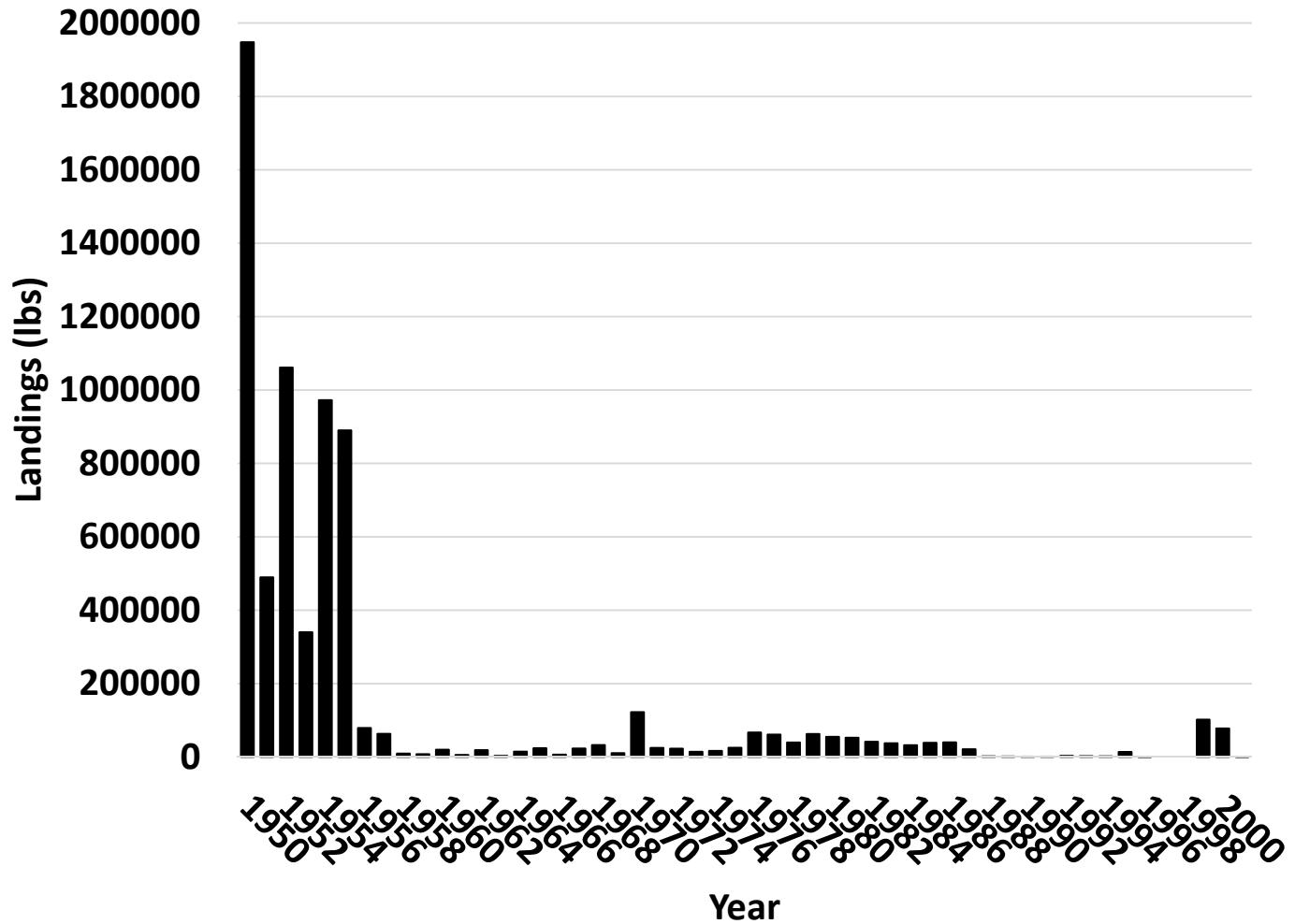


Figure 9.2 Connecticut Commercial landings (lbs.) reported to NMFS 1950-2001.

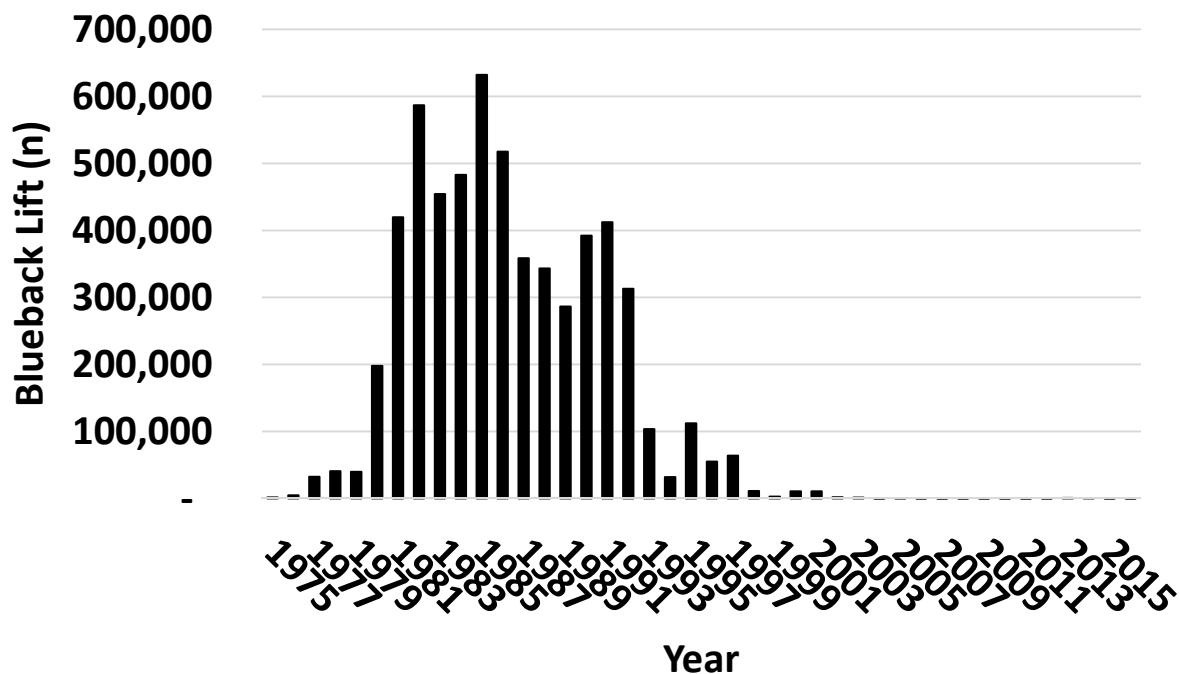


Figure 9.3 Number of blueback herring lifted at the Holyoke Dam, 1975-2016.

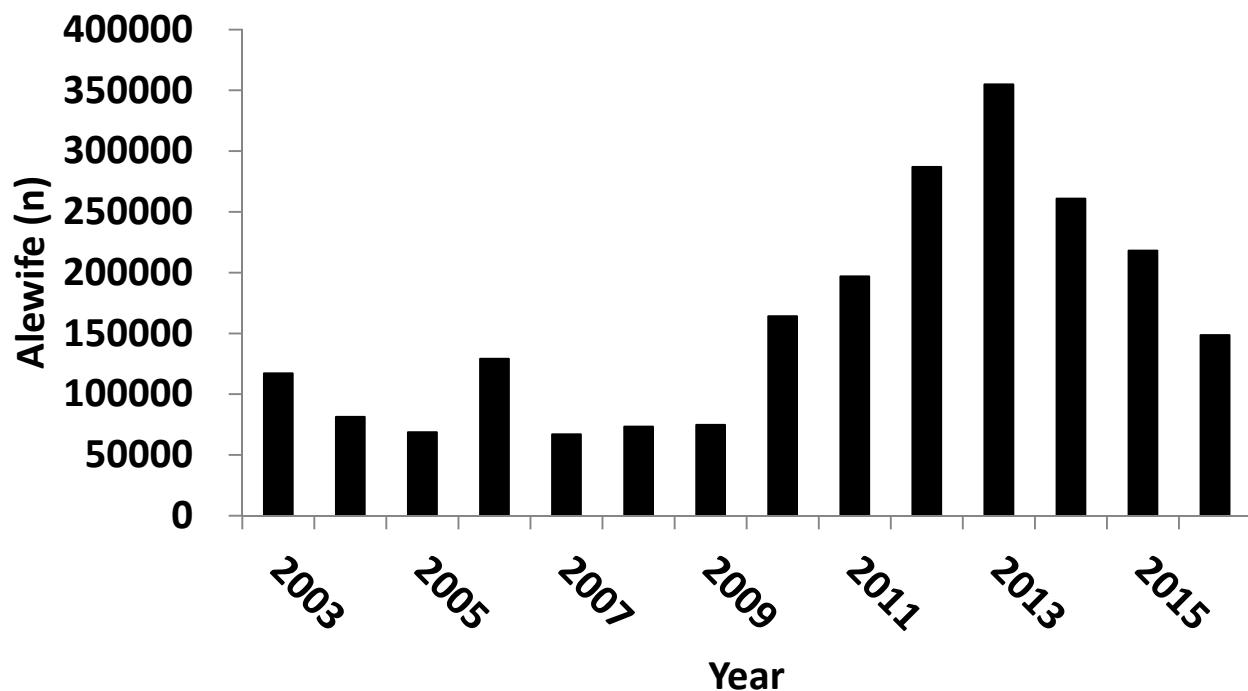


Figure 9.4 Number of alewives passed at Bride Brook, 2003-2016.

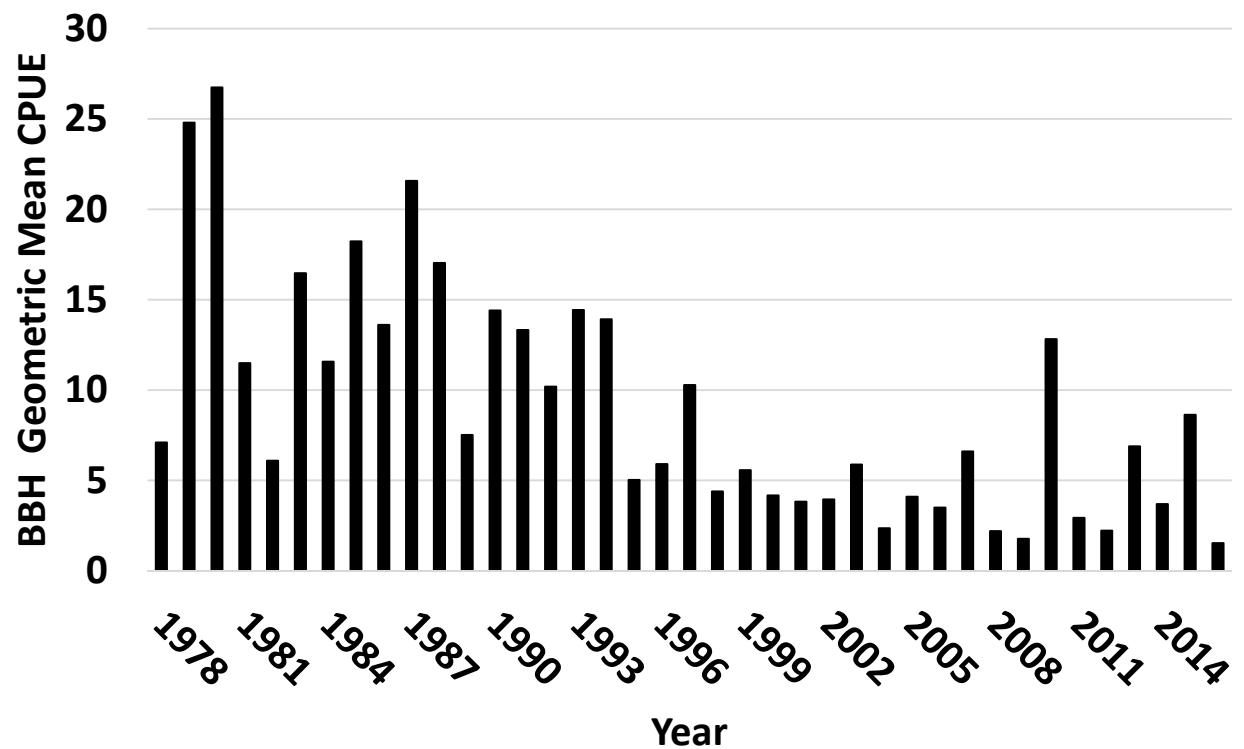


Figure 9.5. CT River juvenile blueback herring indices, 1979-2016.

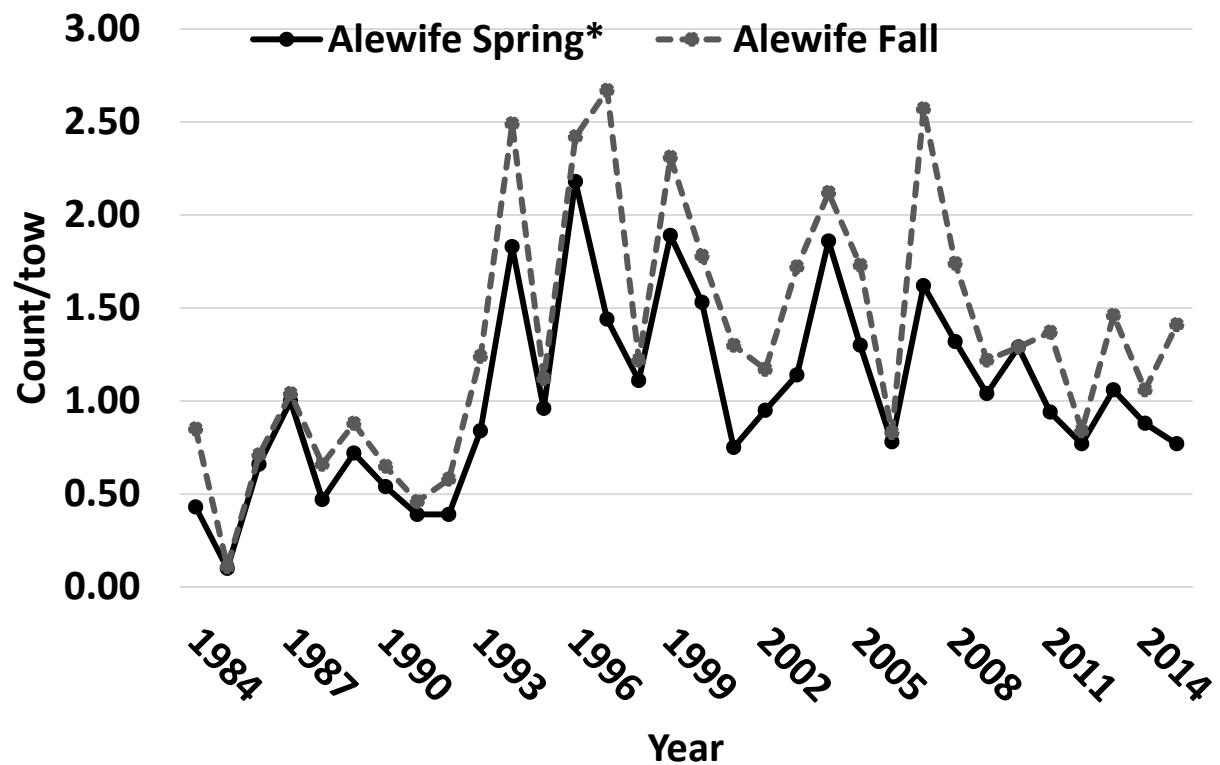


Figure 9.6 Long Island Sound Trawl Survey Alewife spring and fall geometric mean per tow, 1984-2015.

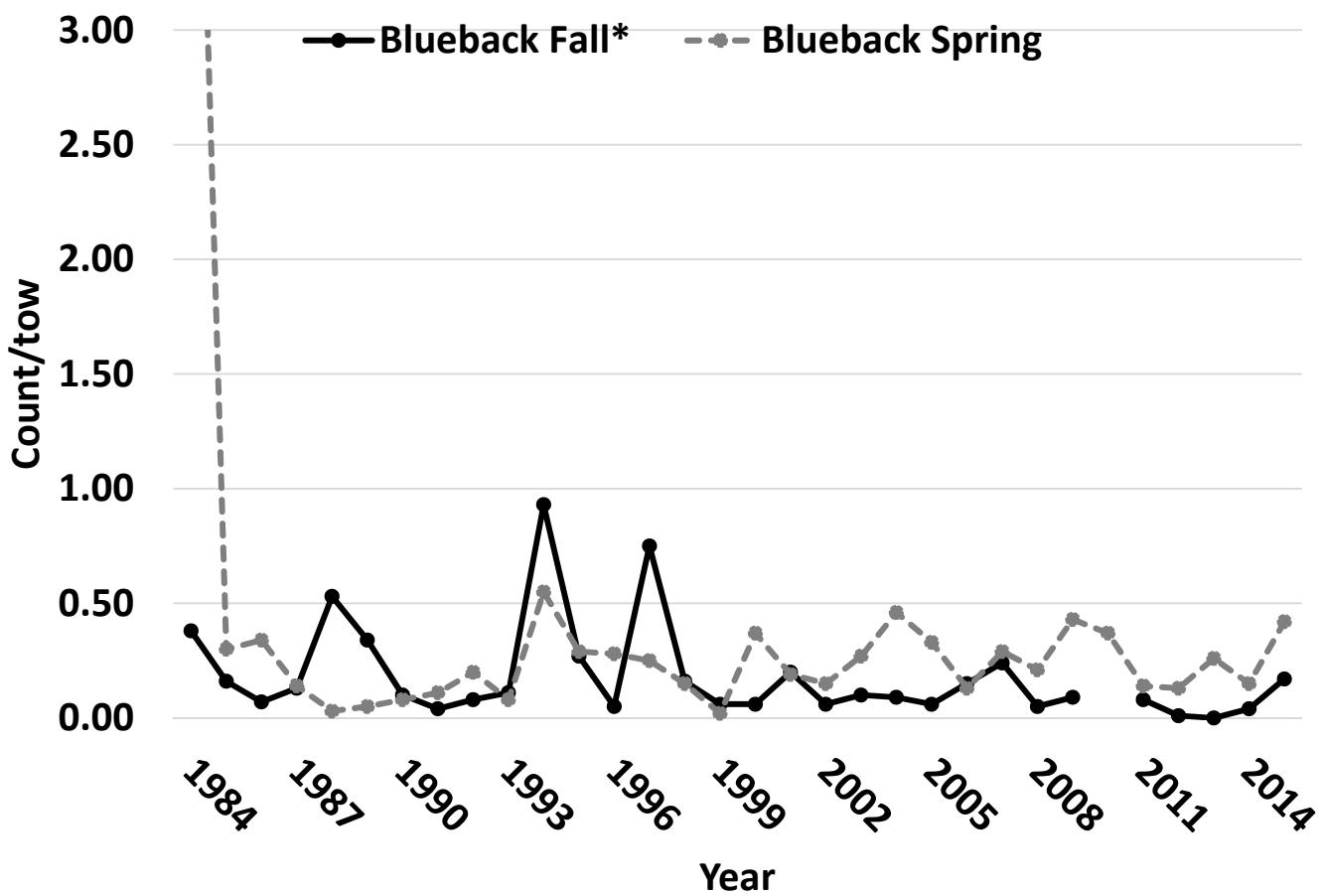


Figure 9.7 Long Island Sound Trawl Survey river herring spring and fall geometric mean per tow, 1984-2015. Note: the 1984 value (not shown on axis) is 5.4.

10 Status of River Herring in New York

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10.1. INTRODUCTION

The fisheries that existed back in colonial days in the Hudson Valley of New York undoubtedly included river herring among the many species harvested. River herring, comprised of both alewife (*Alosa pseudoharengus*), and blueback herring (*Alosa aestivalis*) were among the fish mentioned by early explorers and colonists – the French Jesuits, Dutch and English. Archaeological digs along the Hudson in Native American middens indicates that the fishery resources in the river provided an important food source to them.

Written records of the Hudson's river herring fishery were over-shadowed by the shad fishery. Records for herring begin in the early 1900s and follow a path of increased landing through the years of WWII followed by a quick dramatic decline to the mid-1960s. Since then harvest remained relatively low. Just as for American shad, factors, other than fishing, contributed to keeping the population low: habitat destruction (filling of shallow water spawning habitat) and water quality problems associated with pollution, creating dissolved oxygen blocks in major portions of the river (Albany and New York City).

In this chapter, we summarize the history and characteristics of the Hudson stock of river herring, provide abundance trends, describe possible benchmarks, and make recommendations for the stock.

10.2 MANAGEMENT UNIT

The management unit for river herring stocks in New York State comprises three sub-units. All units extend throughout the stock's range on the Atlantic coast.

- The largest consists of the Hudson River Estuary from the Verrazano Narrows at New York City to the Federal Dam at Troy including numerous tributary streams (Figure 1).
- The second is made up of all Long Island streams that flow into waters surrounding Long Island and streams on the New York mainland (Bronx and Westchester Counties) that flow into the East River and/or Long Island Sound (Figure 2).
- The third subunit consists of the non-tidal Delaware River and tributaries upriver of Port Jervis

10.3 REGULATORY HISTORY

During the 19th century, regulating fisheries within New York waters was the sole responsibility of the state. In 1868, in response to an apparent decline in American shad, the New York State legislature implemented fishing net restrictions, an escapement (net free) period and a season to control fishing on the Hudson. It is likely that these restrictions (season and net use) also affected the take of river herring, as all three Alosines (American shad [*Alosa sapidissima*], alewife and blueback herring) occurred in the

river at the same time. Prior to 2013, take of river herring in New York remained relatively unregulated. Most restrictions concerned the use of gear to take fish, with no limits on take for either recreational or commercial use.

In response to Amendment 2 New York State proposed, and ASMFC approved, the 2012 Sustainable Fishery Management Plan (SFMP) for New York River Herring Stocks (Hattala et al. 2011a). This SFMP included an experimental five year restricted fishery in the Hudson River, a partial fishery closure in tributaries, a moratorium for all non-Hudson waters, and annual stock monitoring in the Hudson River. Monitoring included young of year indices, and for adults: age and length characteristics, mortality estimators, and commercial fishing catch per unit effort (CPUE). The sustainability target for both species was set using the young-of-year indices. The sustainability target value was defined as the 25th percentile of the time series, such that three consecutive years with index values below this target would trigger management action. From 2012-2016, the indices did not fall below the target for three consecutive years for either species.

In 2017, New York State submitted a an update to the 2012 SFMP (Hattala et al. 2011a), which proposed a continuation of the moratorium in non-Hudson waters, a restricted fishery in the Hudson River, annual stock monitoring, and sustainability target described in the original SFMP. This update was approved by the ASMFC Management Board in February 2017 (Eakin et al. 2017).

10.4 ASSESSMENT HISTORY

The first ASMFC assessment of the coast-wide river herring stocks occurred in 1990 (Crecco and Gibson 1990). New York stocks were not included in this analysis.

A second, benchmark ASMFC assessment took place in 2012 (ASMFC 2012). Data for Hudson River stocks of both species were inconsistent. Total lengths were decreasing, while commercial CPUE's were increasing. The young-of-year indices were extremely erratic, potentially indicating instability in the system. As a result of these conflicting stock indicators, the Hudson River stocks for both species were classified as depleted but stable, warranting a reduced commercial and recreational fishery rather than a moratorium.

10.5 STOCK SPECIFIC LIFE HISTORY

Hudson River and tributaries

River herring in the Hudson River spawn in the spring. Alewives are the first to enter the estuary, arriving as early as mid-March and spawning through mid-May. Blueback herring arrive slightly later, generally in April and spawn into early June (Hattala et al. 2011b; Eakin, Cornell University, unpublished data). River herring spawn in the entire freshwater portion of the Hudson and its tributaries up to the first impassable barrier. Adults of both species spawn in Hudson River tributaries, but also spawn in shallow waters of the main-stem Hudson. The nursery area for river herring includes the spawning reach and extends south to Newburgh Bay (rkm 90) encompassing the freshwater portion of the estuary.

Some river herring migrate upstream of the Federal Dam through the Champlain and Erie Canal lock systems. We do not know: 1) if a significant number of river herring move upstream of the dam relative to the entire Hudson River spawning population 2) how many post-spawn adult river herring survive their return trip out of the canal system or 3) if the juvenile herring are able to survive and return to the Hudson River below the Federal Dam. Construction of passage on the Federal Dam will facilitate upstream and downstream migration.

Adults of both species initially enter the Hudson tributaries, but also spawn in the shallow waters of the main stem Hudson. Alewife prefer to spawn over gravel, sand and stone in back water and eddies whereas bluebacks tend to spawn in fast moving water over a hard bottom. Herring spawn in the entire freshwater portion of the Hudson and its tributaries up to the first impassable barrier for approximately six to ten weeks. Once spawning ends, most fish quickly return to ocean waters.

A portion of the Hudson's blueback herring stock are known to move as far inland as Rome NY (439 km inland), via the Erie Canal and Mohawk River. Blueback herring access the canal via the Troy Lock and the Waterford flight (series of locks into the Mohawk river/Erie Canal, see description in Section 10.6). The canal system opens in New York on or about May 1st. Because of this late opening, most alewives are already spawning. Many blueback have yet to spawn and congregate below the lock at Troy to move into the canal system.

Long Island, Bronx and Westchester Counties

The herring runs in streams on Long Island are comprised almost exclusively of alewife (B. Young, NYSDEC retired, personal communication). Most streams are relatively short runs to the ocean from either head ponds (created by dammed streams) or deeper kettle-hole lakes. Either can be fed by a combination of groundwater, run-off or area springs. Spawning occurs in April through May in the tidal freshwater streams below most of the barriers. Passage for spawning adults into the head ponds or kettle lakes occurs on just a few streams.

Little is known about runs in the Bronx and Westchester County streams. We have no record of river herring in any of the streams in southern Westchester County. In the Bronx River (Bronx County) alewives were introduced to this river in 2006 and 2008 and some adult fish returned in 2009 (Jackman and Ruzicka 2009). Monitoring of this run is in its early stages.

Delaware River

River herring in the New York portion of the Delaware River are very rare. While there have been individual young-of-year (YOY) fish occasionally found (Horwitz et al 2014), we have no record of any fishing effort for either species.

10.5.1 AGE

There are several historical sampling efforts that report age data for spawning adult river herring in the Hudson River watershed. A blueback herring study, conducted in 1989 and 1990, collected data on length and scales for aging from fish in the upper Hudson Estuary and the Mohawk River, a major tributary of the Hudson. Additional length and age data for both species came from the 1936 Biological Survey of the lower Hudson River watershed (Greeley 1937) and a 1999-2001 state-contracted survey conducted by Normandeau Associates, Inc. (NAI 2008) on the Hudson River and its tributaries. In 2012 New York established the river herring spawning stock survey. The objectives of the survey were to evaluate species, size, age, and sex composition of spawning river herring. Table 1 lists the number at age by survey, species, and sex.

Unfortunately, aging techniques have varied among these studies. The 1989-90 study used Cating's (1954) technique, developed for aging American shad scales. NAI (2008) developed their own aging criteria after noting many discrepancies on annuli placement compared to the Cating shad technique. It is not known what criteria Greeley used to age the few fish reported from the 1936 Biological Survey.

Current NYSDEC protocols were developed through training sessions and workshops with aging experts along the coast (see ASMFC 2014). The revised protocol can be found in Appendix 2 of the 2017 SFMP (Eakin et al. 2017). With no overlap among the agers, the use of different sampling gears, and no uniform aging protocols among the surveys, any comparison of ages or lengths at age across surveys and years should be done with extreme caution.

10.5.2 GROWTH

Growth characteristics of river herring were estimated using the Von Bertalanffy and Gompertz Growth models (Ricker 1975). Both models use the annual age and associated lengths and weights of aged samples from the fishery independent surveys described above in Section 10.5.1. In all calculations, the same young-of-year values were used to anchor the models. These values came from samples from the NYSDEC Alosine Beach Seine Survey. Resulting estimates for each survey and time period are found in Table 2 for Von Bertalanffy growth and Table 3 for Gompertz growth. Though these estimates may provide a snapshot of the growth characteristics of each species, they should be used with caution, as they can be highly influenced by sample size, aging protocol, inter-year class variation and changes in fishing mortality. It is anticipated that with a longer time series (5-10 more years) of ages, lengths, and weights collected in the current sampling strategy and aged with current aging methodologies, will come more robust growth estimates and associated error values for the existing fishery.

10.5.4 REPRODUCTION

Spawning begins in the Hudson Estuary in April for alewife when water temperatures reach 10-11°C. It continues through early May; blueback spawn when water temperatures reach about 14°C and cease spawning by early June (Smith 1985). The rate of post-spawning mortality is unknown for either species.

10.5.5 MATURITY SCHEDULE

The spawning stock survey (2012-present) is the most consistent dataset to evaluate maturity for both species. From these data, maturity was estimated from age at first spawn, subtracting the number of spawning marks from the age of each fish. Maturity schedule is presented as percent mature at age present in the river for each species and sex. As with growth rates, annual variations in recruitment and fishing mortality have significant impacts on maturity schedules. To address these potential problems, we will compare inter-annual maturity estimates with those calculated by year class once enough long-term age and spawning mark data are available.

Age data from 2012-2015 (see Figure 3) indicate that alewife herring primarily begin to spawn at age three and are fully mature by age five. Blueback herring begin to spawn at age two and the majority reach full maturity by age four.

10.5.6 FECUNDITY

Limburg and Blackburn (2003) performed a fecundity and condition analysis for blueback herring collected during a large river herring study conducted by the Normandeau Associates, Inc. (NAI 2008) from 1999 to 2001. NAI collected fish from the lower Hudson River's Tappan Zee (rkm 40) to Lock 17 at Little Falls in the Mohawk River (rkm 382). A total of 169 females and 75 males were examined.

The blueback herring of the Hudson and Mohawk Rivers embark on a long and complex spawning run. Condition, measured as a Gonadosomatic Index (GSI), levels decreased in both males (30%) and females (26%) as fish stayed longer and swam further up river. Feeding was documented in blueback herring and

likely supplemented energy loss due to migration. Total fecundity varied with “age” (as determined from otoliths by Limburg and Blackburn) and ranged from 3,993 to 177,948 for “green” (ripe) fish. Estimated egg standing crop was 98,870 eggs (256 mm length-standardization of “green” fish). This number is low compared to other similar estimates from Canada, the Connecticut and Altamaha Rivers. The identification of multiple size modes of eggs indicate batch spawning in blueback herring, similar to that seen in American shad (Olney and McBride 2003).

Limburg and Blackburn (2003) also stated that fecundity was positively related to fish aged three to six, with wide confidence intervals. However, a lack of relationship with length was most likely the result of the selectivity of the gill net sampling gear. It is also possible that some ages derived from otoliths were not correct since accuracy of ageing river herring by otoliths has not been verified.

10.6 HABITAT DESCRIPTION

10.6.1 SPAWNING AND NURSERY HABITAT

Hudson River Estuary

The Hudson River flows from Lake Tear of the Clouds in the Adirondacks to the Battery in New York City. It is influenced by tides to the Federal Dam in Troy, 245 km from the Battery (Figure 1). The salt front moves, depending on freshwater inputs from Hudson River tributaries and tidal flow, and generally varies in location from Tappan Zee (rkm 45) to Newburgh (rkm 95). The river includes two major estuarine bays: Haverstraw Bay (rkm 55) and Tappan Zee Bay (rkm 45). These bays are mainly shallow water less than four meters deep where the river extends up to five and a half kilometers from shore to shore. The river also includes a narrow and deep section, the Hudson Highlands, where the river is less than one kilometer wide and over 30 meters deep (Stanne et al., 2007).

The Hudson River below the Federal Dam at Troy has approximately 68 primary tributaries, most of which provide some spawning habitat for river herring (Schmidt and Cooper 1996). The largest of these tributaries is the Mohawk River, which enters the Hudson two kilometers north of the Troy Dam. Diadromous fish access to the Mohawk River, and portions of the non-tidal Hudson above the Federal Dam, is possible only through the Erie Canal and Champlain lock system. Fish passage for migratory species at the Troy dam is required by a 2009 FERC relicensing settlement agreement and is in the design phase. Other major tributaries of the Hudson River, all in the estuary, include the Croton River, Wappingers Creek, Rondout Creek, Esopus creek, Catskill Creek, and Stockport Creek.

Long Island, Bronx, and Westchester County

Freshwater tributaries in the New York portion of the Atlantic Ocean and Long Island Sound watershed are also important for New York river herring (Figure 2). This watershed drains most of the New York City Metropolitan Area, all of Long Island, and portions of Westchester County. The Atlantic Ocean coastline extends 189 kilometers from Rockaway Point to Montauk Point. The watershed includes 840 kilometers of freshwater rivers and streams.

The herring runs in streams on Long Island are comprised almost exclusively of alewife (B. Young, NYSDEC retired, personal communication). Most streams are relatively short runs to saltwater from either head ponds (created by dammed streams) or deeper kettle-hole lakes. Either can be fed by a combination of groundwater, run-off, or area springs. Spawning occurs mid-March through May in the tidal freshwater below most of the barriers. Natural passage for spawning adults into the head ponds or kettle lakes is present in very few streams.

There have been limited efforts to understand river herring runs on Long Island since 1995. Several known runs of alewives on Long Island occur in East Hampton, Southampton, Riverhead and Brookhaven. With the advent of a more aggressive restoration effort in Riverhead on the Peconic River other runs have come to light. Since 2006, an annual volunteer alewife spawning run survey has been conducted. This volunteer effort predominantly documents the presence or absence of alewives in Long Island coastal streams. In 2010, a volunteer investigation was initiated to quantify the Peconic River alewife run. Size and sex data have been collected annually since 2011. A first order estimate of the Peconic River spawning run size has been attempted since 2010; attempts have been made to improve these observations with video counts. These efforts have been undertaken to understand the Long Island coastal streams and to improve the runs that exist there.

10.6.2 HABITAT LOSS AND ALTERATION

Hudson River Estuary

Hudson River tributaries provide important habitat to both migrating and resident fishes, as well as other wildlife. Barriers to upstream and downstream movement exist in tributaries to the Hudson River, many of them in relatively short distance upstream from the confluence with the Hudson River. While many of these barriers are natural features, such as waterfalls and ledges, there exist numerous anthropogenic barriers, including dams (some opportunistically built on top of existing natural barriers), undersize and improperly positioned culverts, and undersized bridges. Thus, many opportunities exist to remove man-made barriers in order to restore historical upstream and downstream access to important habitats for both diadromous and resident fishes. Based on NOAA's 2009-2014 evaluation of 67 lower Hudson tributaries, the first barrier upstream from the Hudson are man-made on 27 tributaries, while 37 are natural and three are undetermined (Alderson and Rosman 2014). After further assessment to consider where barrier removal is practical and beneficial to river herring, this research estimated that 56 tributary kilometers have the potential to be opened to river herring via the removal of 27 barriers on 14 tributaries. The largest gains in total stream miles can be found on the following five tributaries: Claverack, Croton, Moodna, Rondout, and Sparkill Creeks. Restoration opportunities on these five tributaries could enhance access to river herring habitat for an estimated 35.8 kilometers. Removal of man-made barriers in the Hudson River Estuary is a high priority because of the potential for habitat gains and the perceived limitation of number of opportunities for large-scale restoration.

The introduction of zebra mussels in the Hudson in 1991, and their subsequent explosive growth in the river, quickly caused pervasive changes in the phytoplankton (80% drop) and micro- and macrozooplankton (76% and 50% drop respectively) communities (Caraco et al. 1997). Water clarity improved dramatically (up by 45%) and shallow water zoobenthos increased by 10%. Given these massive changes, Strayer et al. (2004) explored potential effects of zebra mussel impact on YOY fish species. Most telling was a decrease in observed growth rates and abundance of YOY fishes, including open-water species such as alewife and blueback herring. A decade later, Strayer et al. (2014), reporting on the improvement in zooplankton and macrobenthos inhabiting deep water indicated that abundance of juvenile alewives increased during the late zebra mussel invasion period while post-yolk sac larval abundance did not. The abundance of post-yolk sac and juvenile American shad and post-yolk sac river herring declined during the early to later zebra mussel invasion period. It is not yet clear how this constraint affects annual survival and subsequent recruitment.

Another factor that is not well researched or understood is the potential barriers posed by the railroads along both the east and west sides of the Hudson River. Tributaries once flowed freely, with

unobstructed hydraulics, from the upland valley to the wide estuary. While these connections still exist, they are much different today than they were historically. Tributaries are forced through bridge and culvert constrictions under the tracks as they make their way to the Hudson River. The impact of this funneling effect on access from the Hudson into tidal tributary mouths is not well understood.

Long Island, Bronx, and Westchester County

Most streams on Long Island and in Westchester County were impacted by human use as the population expanded. Many streams were blocked off with dams to create head ponds, initially used to contain water for power or irrigation purposes for agriculture. The dams remain; only a few with passage facilities. Many streams were also negatively affected by the construction of highways, with installations of culverts or other water diversions which impact immigrating fishes.

10.7 HABITAT RESTORATION

Hudson River Estuary

The Hudson River Estuary Habitat Restoration Plan (Miller 2013) has identified a number of river and tributary restoration activities that will benefit river herring, including barrier mitigation and side channel restoration. Recent research has highlighted important barrier removal opportunities for river herring habitat in the Hudson River Estuary (Alderson and Rosman, 2014). Mitigation of these barriers is an important priority for many researchers, non-profits, and local governments in the estuary, and features prominently in the Hudson River Estuary Program's Action Agenda 2015-2020 (2015).

In May 2016, the first dam upstream of the confluence with the Hudson River was removed from the Wynants Kill, a relatively small tributary in Troy, NY, downstream of the Federal Dam. Within days of the May 2016 removal, hundreds of herring moved past the former dam location into upstream habitat. Subsequent sampling efforts yielded river herring eggs, providing evidence that river herring were actively spawning in the newly available habitat. This dam removal will provide an additional half kilometer of spawning habitat for river herring that has not been available for 85 years.

There are also a number of side-channel restoration projects under development that will improve habitat for river herring in the estuary. Side channels within the river bed provide important shallow water and intertidal habitats that are isolated from the higher energy regime of the main channel. These side channels historically occurred in the northern third of the estuary as part of a braided river-channel system dominated by vegetated shallows and intertidal wetlands. These habitats were destroyed on a large scale in the early twentieth century, particularly in the upper estuary, as a result of dredge and fill activities associated with construction of the federal navigation channel.

Gay's Point (rkm 196) has been identified as a potentially suitable location for side channel creation. The site consists of an artificially created tidal embayment that is separated from the main river channel by dredge spoils. Contiguous backwaters, such as those at Gay's Point, typically have lower current velocities, greater sediment deposition resulting in finer substrates, higher water temperatures, and lower dissolved oxygen levels than side channels with relatively unimpeded flow. Increasing tidal flow through the embayment at Gay's Point is anticipated to improve water quality, provide coarser-grained bed materials, and ultimately create more productive spawning, nursery, and foraging habitat for river herring. This project is currently under way and is being overseen by the New York State Department of Environmental Conservation.

Long Island, Bronx, and Westchester County

Initial barrier mitigation to benefit river herring was summarized in the last SFMP, and included restoration of herring runs on the Carmans and Peconic Rivers (Hattala et al. 2011a), and rudimentary fish passage at Beaver Lake, Oyster Bay. Since 2011, additional completed barrier mitigation projects that benefit alewife include the installation of passage devices at five locations (Canaan Lake, Brookhaven; Twin Ponds, Centerport; Argyle Lake, Babylon; Udall's Mill Pond, Saddle Rock; and Massapequa Creek, Massapequa); a box culvert modification at Alewife creek, Southampton; and a dam removals at Harrison Pond in Smithtown and at Sunken Meadow. Additionally, the installation of fish passage devices on the Bronx River and at the Edwards Avenue dam in Riverhead may provide additional spawning habitat once further barriers have been mitigated.

Barrier mitigation remains a priority for a number of environmental groups and local, state, and federal agencies. We are aware of at least six additional projects that are likely to occur in the next five years.

10.8 FISHERY DESCRIPTION

Historical fisheries for river herring in New York State waters occurred in the Hudson River Estuary and tributaries, some streams on Long Island, and as bycatch in commercial fisheries in marine waters around Long Island. The herring taken in the bycatch ocean fishery were of unknown mixed stock origin. Currently, the Hudson River Estuary fishery is the only remaining fishery in New York. Current commercial and recreational fishing restrictions for the Hudson Estuary are listed in Appendix 1.

10.8.1 FISHERY DEPENDENT - COMMERCIAL

Hudson River Estuary

Anecdotal reports indicate that herring played a small part in the historical commercial fishing industry in the Hudson River. The current commercial fishery in the Hudson River exploits the spawning migration of both alewife and blueback herring. River herring may be commercially caught in the Hudson River from March 15th to June 15th, dates inclusive. The primary use of commercially caught herring is for bait in the recreational striped bass fishery. An annual commercial Hudson River permit allows use of the following gears: gill nets, scoop/dip/scap nets, seines, fyke nets, and trap nets. Permit holders are required to report effort and harvest to the Department. In response to Amendment 2, more stringent regulations were put into place in 2013. Highlights include the closure of tributaries to nets, net size restrictions for scap nets, and monthly reporting (Appendix 1).

Fishing effort and commercial gear use has historically been different south of the Bear Mountain Bridge (rkm 75) than in the northern reaches. This is roughly the location of the salt front in the spring. As such, this bridge is used as a demarcation for gear use. The fishery below the Bear Mountain Bridge intercepts fish moving to freshwater spawning areas, while the fishery north of the bridge targets river herring in their spawning aggregation areas.

The intercept fishery is a fixed gill net fishery that occurs in the main-stem river from rkm 40 to rkm 75 (Piermont to Bear Mountain Bridge, Figure 1). In this stretch, the river is fairly expansive (up to 5.5 km) with wide, deep-water (~ six to eight m) shoals bordering the channel. Most fishers in this portion of the fishery choose specific locations within these shoals and sample in the same locations each year. The fishermen generally fish these nets from 12-24 hours per trip. Since 2013, an average of 22 active fishers annually participated in this lower river fixed gill net fishery. Nets are 7.6 to 91 m long, with meshes ranging from 4.4 to 8.9 cm stretch.

Fishermen in the freshwater portion of the fishery, above Bear Mountain Bridge, use drift gill nets to sample the main-stem of the Hudson River. This gear is used up to rkm 225 (Castleton) where the river is much narrower (1.6 to 2 km wide). Since 2013, an average of 49 fishers annually participate in this mid river gill net fishery. Nets range in length from 6 to 183 m with mesh size ranges from 3.8 to 8.9 cm stretch. These nets must be tended at all times, and most are fished for less than two hours per trip. Though restricted from use in the 2013 regulation changes, commercial reports indicate fixed gill nets have been used in roughly 19% of gill net trips above Bear Mountain since 2013.

Scap nets (also known as lift and/or dip nets) are the other major gear used in the freshwater river herring fishery. Prior to 2013, this gear was primarily used in the major river herring spawning tributaries. The current scap/lift net fishery occurs in main-stem river from roughly rkm 90 to rkm 228 (Cornwall-on-Hudson to Port of Albany). Scap/lift nets range in size from 0.28 to 59.7 m². On average, 31 fishers have annually reported the use of this gear type since 2013.

It is important to note that many commercial permit holders are recreational anglers taking river herring for personal use as bait or food. From 2013 to 2015, an average of 156 gill nets and 121 scap nets permits were sold annually. According to the required annual reports, however, only 35% of the permittees actively fished in those three years (Table 4), and of those that used the commercial gears, roughly half of gill net users and the majority of scap net users reported catches as taken for “personal use” or “personal bait” (Figure 4).

10.8.2 Commercial Landings and License Reporting

Recorded landings of river herring in New York State began in the early 1900s (Table 9 and Figure 5). Anecdotal reports indicate that herring only played a small part in the historic commercial fishing industry in the Hudson River. Total New York commercial landings for river herring include all herring caught in all gears and for both marine and inland waters. Several different time series of data are reported in Table 9, including several state sources, National Marine Fisheries Service (NMFS), and more currently Atlantic Coastal Cooperative Statistics Program (ACCSP). NMFS data do not specify river or ocean source(s) and landings are often reported as either alewife or blueback herring, but not both in a given year. It is unlikely that only one species was caught. From 1995 to the present, the Department has summarized landings and fishing effort information from mandatory state catch reports required for Hudson River marine permits. Full compliance for this reporting started in 2000. All Hudson River data are sent to NMFS and ACCSP for incorporation into the national databases.

Because of the discrepancies among the data series and the lack of information to assign the landings to a specific water body source, only the highest value from all sources is shown in Figure 5. This method limits double counting. Several peaks occur during the time period. The first peak was in the early 1900's (501,438 pounds) followed by a lull until the period prior to World War II when landings peaked a second time in 1935 (274,405 pounds). Post WW II there was another period of low landings until a final peak in 1982 (229,201 pounds). Combined ocean and river landings in New York waters has remained relatively low, with some data gaps, during the rest of the 1980s through present. In 1966, roughly 4.2 million pounds were landed (omitted on Figure 5), followed by a series of years of low landings with another peak in 1982. Landings were low, with some data gaps during the rest of the 1980s through present.

Hudson River Landings

Since 1995, landings are separated between the Hudson and other waters (Table 9). However due to optional participation and minimal enforcement of commercial reporting, any in-river reporting from 1995-1999 is unreliable. It is likely that additional effort was shifted to river herring catches during this time-period than is reported. Moving forward, analyses on in-river landings begin in 2000.

The primary outlet for harvest taken by commercial Hudson River permits is for the in-river bait industry. From 2000 to 2012, nearly all reported commercial river herring landings were split between scap/lift nets (~49% of the catch) and gill nets (~16% drift and ~35% fixed) (Figure 6). From 2000 to 2012, combined landings averaged 15,061 pounds, peaking in 2002 at 20,346 pounds. Post regulation change in 2013, landings declined to roughly 45% of the average from 2000 through 2012. Scap nets accounted for the largest portion of this decline. This is a result of the ban on nets from tributaries, where most commercial scap netting occurred. As the demand for bait has probably not diminished, we expected an increase in landings for the other gears. Though there was a slight increase in drift gill net landings, a big portion of this missing harvest has likely shifted to non-commercial gears, such as hook and line, cast nets, and small scap nets. These personal use gears do not have a mandatory reporting requirement.

10.8.3 Commercial Discards

Hudson River fishery discard rate

From 1996 to 2010, river herring were not reported as discards on any mandatory reports targeting herring. Some minimal discards were reported after 2011, but these have been less than 1% of total catch (see values in black in Figure 4).

Mixed stock ocean fisheries

Level of discard and discard rate is unknown.

10.8.4 Commercial Catch Rates

10.8.4.1 Hudson River Catch Rates - Mandatory reports

Relative abundance of river herring is tracked through catch per unit effort (CPUE) statistics of fish taken from the targeted river herring commercial fishery in the estuary. All commercial fishers fill out monthly mandatory reports. Reports include catch, discards, gear, effort, and fishing location for each trip. CPUEs are calculated as total catch divided by total effort (square yards of net * hours fished), separately by gear type (fixed gill nets, drift gill nets, and scap nets). Annual mean CPUEs are summarized differently based on the location of fishing effort.

Above the Bear Mountain Bridge (rkm 75 in Figure 1) and within the spawning reach, drift gill nets and scap nets are the primary gears. In this section of river, fishermen catch fish that are either staging or moving into areas to spawn. Gears are generally not deployed until fish are present. CPUEs for gears above the Bear Mountain Bridge are calculated as total annual catch/total annual effort. Below the Bear Mountain Bridge (rkm 75) and thus below the spawning reach, fixed gill nets are the primary commercial gear. In this section, nets are fished in roughly the same location each year by a consistent group of fishermen. These fishermen capture fish moving upriver to spawning locations and run size is determined by number (density) of spawners each week as well as duration (number of weeks) of the run. Annual CPUEs in this reach are calculated as the sum of weekly CPUEs to best capture the periodicity of run. Annual efforts and CPUEs for the main commercial river herring gears are shown in

Figure 7. Values for drift gill and scap net values in Figure 7 are only for trips above rkm 75, while fixed gill net values are only for trips made below rkm 75.

As shown in Part A of Figure 7, drift gill net CPUEs have increased steadily since 2000, with efforts declining since 2006. Annual drift gill net trips by river section above the Bear Mountain Bridge are shown in Table 10. On average, 74% of drift gill net trips take place in the Saugerties and Catskill reaches. Based on historical information on spawning (Schmidt et al. 1994; Schmidt and Lake 2000) as well as the recent results from the fishery independent survey described in Section 10.10.2 below, these sections make up a small portion of the habitat available for spawning. In addition, there are two significant stretches of river where gill net use is prohibited. Due to the opportunistic nature of the upriver fishery (fishermen only fish when river herring are present), as well as the large amount of variability in effort within the freshwater spawning reach, this dataset is not reliable to track annual abundance.

Annual scap net CPUEs and efforts are shown in Part B of Figure 7. Efforts were relatively steady through 2012, but dropped dramatically in 2013 when net use became illegal in tributaries. Scap net CPUEs declined from 2000 to 2007, and have increased from 2007 to present. Due to significant changes in the fishery due to regulation changes, CPUEs from this commercial gear are not reliable to monitor changes in relative abundance.

Part C of Figure 7 shows effort and CPUEs for the lower river fixed gill net fishery. Effort in this fishery has decreased steadily since 2000, but the annual sum of weekly CPUEs has been increasing since 2010. Because most river herring must pass through this fishery on the way to freshwater spawning reaches and tributaries, it has the best chance at sampling the entirety of the spawning stocks of both species. As such, these CPUEs likely provide the best abundance indicator of the three main commercial gears and are best suited for trend analysis.

10.8.4.2 *Hudson River Commercial Monitoring Program*

Catch Rates

Until the mid-1990s, the Department's commercial fishery monitoring program was directed at the American shad gill net fishery, a culturally historic and economically important fishery. We expanded monitoring to the river herring fishery in 1996, but remain limited by available manpower and the ability to connect with the fishers. Monitoring focuses on the lower river fixed gill net fishery since we considered it to be a better measure of annual abundance trends (see section above).

While onboard commercial fishing vessels, technicians record numbers of fish caught, gear type and size, fishing time, and location. Scale samples, lengths and weights are taken from a subsample of the fisher's catch. CPUE is based on gear type and location and is calculated by the method used for summarizing mandatory report data.

Since 1996, staff monitored 122 trips targeting river herring. Annually, these trips were sporadic and sample sizes were low, from zero to 20 trips per year (Table 11). Because of minimal sample size, the resulting CPUE is potentially unreliable for tracking relative abundance. However, as shown in Figure 8, the commercial monitoring CPUE for fixed gill nets in the lower river follows the same trend as the lower river CPUE from the same gear in mandatory commercial catch reports (correlation value 0.81, $p < 0.001$). This is indicative that our monitoring efforts capture trends in the reported fishery. With

increased sample sizes for commercial monitoring, we expect this relationship to improve. In addition, active monitoring provides the only data on catch composition of commercial harvest.

Catch Composition, Size and Age Structure

Catch composition in the fixed gill net fishery varies annually, most likely due to small sample sizes and when the samples occurred (early or late in the run) (Table 12). Annual observed landings ranged from 44 to 2,450 fish, with alewives observed more often than blueback herring. The sex ratio of alewives was nearly equal (~ 50:50) in all years; however, female blueback herring were observed more often than male blueback herring most likely due to the size selectivity of gill nets fished and timing of fishery.

Mean lengths and weights of dockside subsamples are shown in Figure 9. Though sample sizes are relatively low for certain years, there is an increasing trend in length and weight for both species since 2010. This trend is similar to that observed for both species in the spawning stock survey (**Section 10.10.4**).

Age data for samples collected during the commercial monitoring program were processed and analyzed in the methods described in Appendix 2 of the 2017 NY river herring SFMP (Eakin et al. 2017). Ages were estimated for a subsample of the scale samples in 2012 and we used an age length frequency table from these data to estimate ages for the remaining scale and length samples from the 2012 commercial fishery. Mean length at age for 2012 commercial samples were then compared to the mean length at age for fish taken in the Fishery Independent survey in 2012 (Figure 10). As there was little deviation in mean length at age for both species among the surveys, we used the annual age-length keys derived from samples collected during the Fishery Independent Survey to estimate the respective year's commercial fishery age structure from 2013-2015.

Table 13 displays the age structure for dockside samples taken from 2012 to 2015. Mean age for sexes of both species is trending upward, which corresponds with the increase in mean lengths during the same time period as well as the increasing trend in the fishery independent age dataset described in Section 10.10.4.

10.8.5 Mixed Stock and Ocean Fishery Catch Rates

Proportion of Hudson River herring caught as ocean fishery by-catch is unknown.

Quantifying the impact of bycatch and incidental fisheries on Hudson River herring remains difficult. Two Federal councils have identified alternatives to reduce catch of river herring in their Fishery Management Plans (FMP). The Mid Atlantic Fisheries Management Council's (MAFMC) Amendment 14 of the Atlantic Mackerel, Squid and Butterfish FMP and the New England Fishery Management Council's (NEFMC) Amendment 5 to the Atlantic herring FMP both identified shad and river herring as incidental catch in these directed fisheries and acknowledged the need to minimize catch of shad and river herring. Both of these plans, through the amendments identified above and subsequent framework adjustments:

- Implemented more effective monitoring of river herring and American shad catch at sea
- Established catch caps for river herring and American shad
- Identified catch triggers and closure areas

Fishery observer data are used to estimate and monitor the river herring and American shad captured by Atlantic herring and Atlantic mackerel vessels that land more than three metric tons (mt) per trip

using methodology developed by the Greater Atlantic Regional Fisheries Office (GARFO), of the NOAA Fisheries. River herring and American shad bycatch and bycatch quotas are presented in Table 5 and Table 6.

While the data in Table 5 and Table 6 provide us with an estimate of the incidental catch of river herring and American shad in these fisheries, it does not identify the bycatch by species. However, Amendment 14 of the Mackerel, Squid and Butterfish FMP does present species-specific data by region and fleet from earlier years (Table 7). Observed annual alewife catch between 1989 and 2010 ranged from 2.7 mt to 484 mt with an annual average of 119 mt. Observed annual blueback herring catch between 1989 and 2010 ranged from 19.6 mt to 1,803 mt with an annual average of 290 mt. In some years, large portions of the incidental catch was not identified to species. If the same annual proportion of river herring composition is applied from the known catch to the unknown catch, the total estimated river herring catch in the period 1989-2010 ranged from 42.8 mt to 2,313 mt with an annual average of 499 mt.

Data were only located that distinguished catch by species for the time period 1989-2010. More recent data present incidental harvest data by fishery, but do not distinguish among species. In order to get a general sense of the magnitude of potential harvest from these fisheries (Table 8), the average proportion of known harvest that was river herring from the historic data (80%, from Table 7) is applied to the combined river herring and American shad catch. Unfortunately, it is impossible to determine which river herring stock(s) were affected by the harvest from these mixed stock fisheries. Directed and incidental harvest from New York waters are shown in Figure 5.

10.9 FISHERY DEPENDENT – RECREATIONAL

Hudson River Estuary

The recreational river herring fishery exists throughout the main-stem Hudson River, and its tributaries including those in the tidal section and above the Troy Dam (Mohawk River). Some recreational herring fishers use their catch as food (smoking/pickling). However, the recreational river herring fishery is driven primarily by the need for bait in the recreational striped bass fishery.

In concert with the change in commercial regulations in 2013, new regulations were put into place for the recreational fishery in response to Amendment 2. Regulations for recreational take are found in Table B of Appendix 1. The most significant changes were creel limit of 10 fish per day or 50 fish per boat, as well as the prohibition of personal net use in tributaries. All 2013 changes are denoted in bold in Table B.

The magnitude of the recreational fishery for river herring is unknown for most years. NYSDEC contracted with Normandeau Associates, Inc. (NAI) to conduct creel surveys on the Hudson River in 2001 and 2005 (NAI 2003 and 2007). Estimated catch of river herring in 2001 was 34,777 fish with a 35.2% retention rate. When the 2001 data were analyzed, NAI found that the total catch and harvest of herring was underestimated due to the angler interview methods. In the 2001 survey, herring caught by fishers targeting striped bass were only considered incidental catch, and not always included in herring total catch and harvest data. Fishers were actually targeting herring and striped bass simultaneously. Corrections were made to the interview process for the 2005 survey and estimated catch increased substantially to 152,117 herring (Table 14). Catch rates from 2001 survey were also adjusted using the 2005 survey data. The adjusted catch rose to 93,157 fish.

River herring use by striped bass anglers can also be evaluated using data obtained from our Cooperative Angler Program (CAP). The CAP was designed to gather data from recreational striped bass

anglers through voluntary trip reports. Volunteer anglers log information for each striped bass fishing trip including fishing time, location, bait use, fish caught, length, weight, and bycatch. From 2006 through 2015, volunteer anglers were asked to provide specific information about river herring bait use. Due to the difficulties associated with differentiating between alewife and blueback herring, anglers were only asked to report the catch as river herring. The annual proportion of angler days where river herring was used for bait ranged from 25% (2007) to 57 % (2013) with a mean of 46%. The proportion of river herring used by anglers that were caught rather than purchased increased through the time period (Table 14). River herring caught per trip varied from 1.6 to 6.7 with the highest values in the last three years. Herring purchased per trip ranged from 0.63 to 1.7.

The most recent creel information and the CAP trips were combined in an attempt to estimate the current recreational river herring harvest. Annual numbers of striped bass trips taking place after 2007 were calculated as the 2007 creel estimate (Connelly and Brown 2009) multiplied by the ratio of CAP trips in the year of interest to the number of 2007 CAP trips. This value was then multiplied by the annual proportion of angler trips using herring in the CAP, and multiplied again by the number of herring caught or purchased per trip in the CAP. Estimates of river herring use by striped bass anglers ranged from 78,491 fish in 2007 to 386,915 fish in 2015 with an increasing trend of herring use from 2006 to 2015. To put potential recreational herring harvest in context, the average estimated annual recreational harvest from 2013-2015 was 312,036 herring. During the same time period, counts from Black Creek, a small tributary to the Hudson with approximately 1.8 km of available spawning habitat, averaged 409,233 alewives (roughly 139,000 pounds) annually (see Table 15 and *In-stream Fish Counter* in Section 10.10.2 below). Black Creek is only one of the 68 primary tributaries to the Hudson River.

This analysis should be interpreted with caution and viewed only as potential recreational river herring harvest scenarios. It should also be noted that these estimates are derived from a group of dedicated striped bass anglers who presumably exert more effort than a typical angler and thus we view these estimates as the maximum potential recreational herring harvest. Until a creel survey can be conducted, this is the Department's best estimate of recreational herring harvest.

The number of river herring taken from the Hudson River and tributaries for personal use as food by recreational anglers is unknown but expected to be minimal.

Long Island, Bronx and Westchester Counties

As of 2013, recreational river herring fisheries have been closed in the marine and coastal district of NY.

10.10 FISHERY INDEPENDENT SURVEYS

10.10.1 SPAWNING STOCK SURVEYS

Several surveys have sampled the alewife and blueback herring spawning stocks, or production, portion of the population. These are the fish which have escaped from coastal and in-river commercial fisheries. Spawning stock data for river herring in the Hudson River is available from several sources: a New York Conservation Department historical report, a variety of NYSDEC surveys, and a large scale survey contracted to Normandeau Associates, Inc. (NAI 2008).

10.10.2 New York State Surveys

The New York State Conservation Department, predecessor of the current NYSDEC, conducted a

biological survey of all state natural resources during the 1930s. The Hudson watershed was sampled in 1936 (Greeley 1937). Number, mean length, and weight for both sexes of blueback herring ('summer' herring) and alewife are reported in the top rows of Table 16 and Table 17; sample size is very small.

NYSDEC river herring data are from several surveys (Table 18). The longest dataset (1975-2000) is from an annual survey of chemical contaminants in fish that targeted multiple species within the Hudson River estuary. Sample size varied among years. In most years, length data were recorded for a sub sample of the total collected. The NYSDEC also conducted a short, two year survey in 1989 and 1990, to examine the population characteristics of blueback herring in the Hudson and the Mohawk River, the Hudson's largest tributary.

From 1985 to the present, the NYSDEC Hudson River Fisheries Unit (HRFU) has conducted an annual American shad and striped bass spawning stock survey. One component of this survey uses electro-fishing gear to collect large numbers of striped bass for tagging; herring are incidental catch. The major gear used for the spawning stock survey is a 154 m or 305 m haul seine, fished at beaches located throughout the spawning area for shad and striped bass. The 10.2 cm stretch mesh in these nets was specifically designed to catch shad and striped bass, but to let smaller river herring escape. However, some large (> 280mm) herring were occasionally caught in these gears. Sampling occurs between Hudson River km 145 and km 232 from late April through early June.

In 1987, the Department added river herring sampling to the existing American shad and striped bass spawning stock survey. Sampling occurred sporadically and when time allowed. From 1987 to 1990, two small mesh (9.5 mm) beach seines (30.5m and 61m) were used with limited success. In 1998, the Department specifically designed a small haul seine (91 m) with an appropriate mesh size (5.1 cm) to target river herring. Similar to the gear design for the American shad and striped bass seine survey to minimize size and age bias (Kahnle et al. 1988), the Department designed the herring seine to capture all sizes present with the least amount of bias. The current herring haul seine design consists of two 46 m long by 3.7 m deep wings attached to a round, center-located bag measuring 1.2 meters in diameter and 3.7 m long. The entire net is 5.08 cm stretch mesh made of twisted nylon twine. The top float line includes fixed foam floats every 0.6 m and fixed chains to the lead line (bottom of seine) every 0.75 m.

To meet the requirements outlined in Amendment 2 (ASMFC 2009) for the mandatory fishery-independent monitoring programs, in 2012 New York established the river herring spawning stock survey. The objectives of the survey were to evaluate species, size, and sex composition of spawning river herring; and then develop the methodology to use the gear to perform an annual assessment of the Hudson River's river herring spawning stock. The sampling target was four sample days per week (March 15 to June 15). A minimum of five beaches were sampled each day, and results were used to evaluate sample sites for future sampling use as well as collect spawning adult river herring in the area.

In 2012, sampling sites ranged from Tappan Zee (rkm 45) to Albany (rkm 232) (Figure 1). Despite much effort in 2012, no river herring were caught in the southern part of the river from Poughkeepsie south to the Tappan Zee. These areas were dropped in 2013, and the sampling area was pared to the mid and upper river sections where river herring were most readily caught. Currently, each sampling day of the week focuses on one river reach from Kingston (rkm 136) to Albany (rkm 232) (Figure 1). Reaches are broken down as follows: Kingston (rkm 136-169), Catskill (rkm 170-190), Coxsackie (rkm 191-213), and Albany (rkm 214-232). Initially, sites were randomly selected from a map of all known beaches within the Hudson River Estuary. After scouting, sites were removed if they no longer had beaches or had major sampling obstructions. Current sampling focuses on 15 fixed sites spread throughout the four

reaches. Table 19 lists sampling efforts and catches per river section from 2012-2015. After each haul, technicians examine each fish for species, gender, and spawning condition. A subsample of ten fish are sampled of each gender and species for total length, weight and scale samples are removed. When possible, 30 extra fish are measured from each sex and species for each sampling event. All other incidental catch is tallied by species.

In-stream Fish Counter

In 2013, a pilot study was initiated using an in-stream fish counter in Black Creek. Black Creek is a small tributary located at rkm 135, just south of Kingston, NY and has a known river herring spawning run. The primary objective was to determine if a fish counting device was an appropriate method to collect absolute abundance data for river herring in small tributaries. The secondary objectives were to identify when river herring migrate into tributaries and identify parameters that may influence those migrations (i.e. moon phase, water level, water temperatures).

The study design consisted of a stream wide weir to guide river herring through a Smith Root SR-1601® multichannel fish counter. NYSDEC staff built the counting head using four inch PVC tubes stacked in two rows of four, forcing fish through one of eight individual counting tubes (Figure 11). The counter was installed at the end of March each year and remained in place until the end of May. The location of the counter is close to the head of tide. Staff attempted to visit the counter on a daily basis. During site visits, technicians recorded fish counts on the counter system, along with any applicable environmental observations, such as weather conditions, temperature, and water level. Once the daily count was recorded, the counter was reset to zero. To compare potential diel patterns, multiple visits were made during the same day. In 2013, a trap was incorporated into the design of the weir to help determine species composition of the fish passing through the counter and assess the accuracy of the electronic counter. This trap was attached to the counter exit directly up stream of the weir. The trap was closed on five occasions at various times throughout the run in 2013. It was hoped that these trapping results could be used as a correction factor to the final count data; however, it was very difficult to capture every fish in the trap due to the stream substrate as well as impaired visibility. At this time there is no accurate correction factor for the counts. To address this in 2014, a video camera system was used to verify counts and create an accurate correction factor. Staff are currently analyzing video footage.

Monitoring of Black Creek has continued on an annual basis since 2013 and annual count data are reported in Table 15. Historic evidence shows the spawning run in Black Creek to be exclusively made up of alewife (Schmidt and Lake 2000). This has been verified in all years of monitoring, as all mortalities and all live captured river herring at or near the weir were identified as alewife. The annual count data from Black Creek is used as ancillary data to support trends identified in the relative abundance indices described in section 10.10.2 and provide a reference for landings in the commercial and recreational fisheries.

10.10.3 Normandeau (State Contracted) Survey

During the period when the NYSDEC was trying to target river herring in their sampling programs, Normandeau Associates Incorporated (NAI 2008) was contracted to survey river herring throughout the Hudson River and its tributaries, including the Mohawk River from 1999-2001. The primary study objective was to determine the best method available to easily characterize the spawning stock over a broad geographic area. Over the three year period, they used many combinations of gear in the various sampling areas (Hudson, tributaries and Mohawk). The most prevalent gear used was gill nets chosen for

their mobility and need for small field crews. Scap and cast nets were predominantly used in the tributaries.

A number of difficulties were identified. Not all gears worked equally well both temporally and spatially in the different sampling areas (Hudson, small tributaries and Mohawk). Data from the NAI study were limited by the high selectivity of the gill net gears, inconsistent use of different gill net mesh sizes among years, and lack of comparability of gear uses in the Hudson (gill nets) to that used in the tributaries (angling, scap or cast nets). No one gear could capture both species well, as well as both sexes and sizes of fish in relatively unbiased proportions. Data are presented but should be interpreted with caution due to the selectivity issues that could not be adjusted for. Sample size varied greatly between areas, attributed to gear used (Table 20). Alewives were caught primarily in the tributaries using scap/lift nets, biased heavily to males; fewer alewives were caught by gill nets in the main river. No alewives were found to use the Mohawk. Blueback herring were primarily caught in the main stem Hudson River followed by Mohawk River; few were caught in the estuary tributaries, especially in 2000 and 2001 (Table 20). It is not clear if this was attributed to gear or actual effort expended in the different areas.

NAI (2008) also developed its own aging technique. They began with the aging technique of Cating (1954) developed for American shad, then noted differences in the structure of the scale, and developed their own technique for aging herring. It is not clear if the aging and spawning mark identification techniques for the NAI data is similar to those used to age other data presented in this report; therefore, comparisons should be made with extreme caution and NAI results are not included in trend analyses.

10.10.4 Catch, Size and Age Distribution

Normandeau Survey

Due to the potential size and sex biases listed above, results from the Normandeau Survey are not included in this update. For reference, they can be found in the original benchmark assessment.

NYSDEC spawning stock surveys

Prior to 2012, the intermittent effort (n-hauls) expended to catch river herring resulted in relatively low and variable catches (Table 18). However, with the focused survey, catches and hauls have increased greatly from 2012 to present.

Since 2012, alewife catches have been on average 73.6% males and 26.4% females (Figure 12). The high ratio of male alewives may indicate a possible sex bias in the sampling technique for alewives. It is suspected that males either remain out in the main river close to shore whereas most female alewives could be further offshore, unavailable to gears or they could be staging near tributary entrances. Mid-Hudson tributary sampling conducted by Schmidt and Lake (2000), and the Black Creek counter study (**Section 10.10.2**) resulted in more equal sex ratios. Sex ratios of blueback herring have been more even. On average, blueback herring consisted of 44.6% males and 55.4% females (Figure 12). Bluebacks may be more susceptible to the hauls seine gear because they prefer to spawn in shallow shoals of the main-stem river.

Mean total length and weight of fish was calculated when adequate sample sizes occurred. Prior to 2012, fishery dependent sample sizes were relatively low each year, limiting the usefulness of these data for trend analysis (Tables 16 and 17). In the prior assessment, n of 34 per year was used as the cutoff for inclusion in the analysis based on the method described by Lynch and Kim (2010). This was reevaluated for the update and a different method for selecting historical lengths was used. To determine which

historical years to include in the analyses, sample size requirements were calculated using the following equation (Zar 1999):

$$(Equation\ 1) \quad n = \frac{s^2}{\delta^2} (Z_{\alpha(2)} + Z_{\beta(1)})^2$$

where s^2 = variance observed for all years

δ = minimum detectable change

$Z_{\alpha(2)}$ = critical value for an α (two-sided) at 95% confidence = 1.96

$Z_{\beta(1)}$ = critical value for an β (one-sided) at 80% confidence = 0.84

This equation provides the sample size required to detect a minimum detectable difference between means of different years. Table 21 lists the calculations using Equation 1 for several levels of precision values by species and sex. For length comparisons, the sample sizes required to detect five mm differences in length by sex and species are used and resulting years to include in the analysis are shaded in gray on Tables 16 and 17. Note that since 2012, sample sizes are adequate to detect a 2.5 mm change in mean lengths in a comparison between years.

The overall trends in mean length for all combinations of species and sex show a ‘U-Shaped’ pattern with a decline in mean length until roughly 2011 and then an increase to present (Figure 13). Further analysis is provided below in **Section 10.11.2**. The extreme variances observed for sample weights (Table 16 and Table 17) led to very poor precision in estimating differences in annual means, and will not be examined further.

Through training sessions and workshops with aging experts such as the Massachusetts Division of Marine Fisheries and other Atlantic Coast agencies (ASMFC 2014), HRFU biologists developed criteria for determining what constitutes an annulus and spawning mark in Hudson River fish. (Details in Appendix 2). Prior accepted aging methods such as Cating (1954, previously used for American shad) or Marcy (1969, used for river herring) were not used due to their reliance on transverse grooves to estimate annuli location. This protocol has been used since 2012.

Scale selection and preparation protocols were also changed in 2012. For each catch event, scale samples were removed from a subset of ten individuals of each sex and species. Scales were removed from the left side of the fish directly below the dorsal fin above the midline (Rothschild 1963; Marcy 1969; Hattala 1999) and placed in an individually identified envelope. In the lab, technicians numbered scale envelopes and entered the samples into a database along with the associated sampling program (fishery independent or dependent) data: gear type, species, sex, and length. Due to the large number of age-samples per year since 2012, staff used the Ketchen (1950) method of selecting a stratified sub-sample of fixed numbers of fish aged per 10 mm length bin. In 2012 and 2013, scale samples were separated by sampling program, species, and sex; and then thirty fish were randomly selected per 10 mm length bin. All fish were aged when there were fewer than 30 fish in a length bin. Due to time restraints and based on new literature (Coggins et al. 2013), staff have aged 15 fish per length bin since 2014. The sub-sample of aged fish were used to develop annual age-length keys for each species and sex (Loesch 1987; Devries and Frie 1996; Davis and Schultz 2009). Sex-specific age-length keys were then used to estimate numbers at age of each sex and species for the entire sample for each year. The resulting estimated numbers at age were used to calculate mean length at age as well as mortality estimates reported in the *Trends in Instantaneous Mortality* section below.

Prior to 2012, sampling was intermittent (Table 18) and no aging was performed on scale samples removed from river herring. However, beginning in 2009, scales were analyzed for number of spawning marks. Age and repeat spawn data are shown in Table 22 and Table 23 for comparison. These data were also used in trend analysis (see **Sections 10.11.3** and **10.11.4** below). Focused sampling on the spawning stock began in 2012, and since that time 4,712 scales samples were taken from alewives and ages were assigned to a stratified random subsample of 1,122 of those samples. Female alewives ranged from age two to nine (Table 22) with zero to five repeat spawn marks and ranged from 68% to 36% virgin fish (Table 23). Since 2012, mean age of female alewives has been stable to slightly increasing. Male alewives ranged two to eight years of age (Table 22) with zero to five repeat spawn marks (Table 23). Male alewives ranged from 82% to 51% virgin fish. Mean age and of male alewives has been stable to slightly increasing since 2012.

From 2012 to 2015, staff removed 2,673 scale samples from blueback herring and assigned ages to 847 of those samples. Female blueback ages ranged from three to seven (Table 22) with zero to three repeat spawn marks (Table 23). Female bluebacks ranged from 79% to 52% virgin fish. Mean age of female blueback herring has remained stable without a trend since 2012. Male bluebacks ranged in age from two to six (Table 22) with zero to three repeat spawn marks and ranged from 92% to 59% virgin fish (Table 23).

Alewife males and females are on average larger than blueback males and females of the same age. Max total lengths and mean length at age of both species are near those reported in Greeley 1937 (Tables 16 and 17). Since 2012, mean length at age for both species across all ages has been either stable or increasing with the majority increasing (Figure 14). Along with increasing mean length at age, the overall age structure for both species has expanded (Figure 15) with increased repeat spawning occurrence (Figure 16). The expanded age structure and increased occurrence of repeat spawning marks in 2014 and 2015 suggests a higher survival rate during both post-spawn emigration and during ocean residency.

10.10.5 VOLUNTEER AND OTHER RIVER HERRING MONITORING

The South Shore Estuary Reserve Diadromous Fish Workgroup (SSER), in partnership with the Seatuck Environmental Association, have been incorporating citizen volunteers in the collection of data on temporal variation and physical characteristics associated with spawning of river herring in tributaries. These data were not provided by the fishery dependent and independent sample programs discussed above. The volunteer programs also bring public awareness to environmentally important issues.

Long Island Streams

The SSER began a volunteer survey of alewife spawning runs on the south shore of Long Island in 2006. The survey has been organized by the Seatuck Environmental Association, in cooperation with the SSER, as of 2008. The survey is designed to identify alewife spawning in support of diadromous fish restoration projects. The survey also evaluates current fish passage projects (i.e. Carmans River fish ladder), and sets a baseline of known spawning runs. Data were available for surveys in 2006 – 2008. Monitoring occurred on six to nine targeted streams annually, with volunteer participation ranging from 24 to 68 individuals. Monitoring takes place from March through May. Alewife were seen as early as March 5 (2006) and as late as May 31 (2008). Data indicated that alewife use multiple streams in low numbers. It is not clear whether each stream supports a spawning population since total sightings were very low. The Carmans and Swan Rivers showed the most alewife activity and likely support yearly spawning migrations. The first permanent fish ladder on Long Island was installed in 2008 on the Carmans River. Information

gathered during this study will aid in future construction of additional fish passage (Kritzer et al. 2007a, 2007b, Hughes and O'Reilly 2008). Byron Young continues to monitor alewife, mostly in the Peconic River. In 2016, the Peconic run was above average. Fish were first observed on March 2, and last observed on May 16, representing a nearly 10 week spawning season (B. Young, retired, NYS Department of Environmental Conservation, personal communication).

In addition to the SSER, other interested individuals have also monitored Long Island runs (see Appendix Table A). Anecdotal data provides valuable information on tracking existing in-stream conditions, whether streams hold active or suspected runs, interaction with human land uses, and suggestions for improvement (L. Penney, Town of East Hampton, personal communication). A rock ramp was constructed around the first barrier to migration on the Peconic River in early 2010 (B. Young, retired, NYS Department of Environmental Conservation, personal communication). The Seatuck Environmental Association set up an automated video counting apparatus at the upriver end of this ramp. Data are still being analyzed. A video can be viewed on their website at <https://www.seatuck.org/index.php/fish-counting>

The Department has conducted a similar river herring volunteer monitoring program annually since 2008 for tributaries of the Hudson River Estuary (Hattala et al. 2011b). We designed this project to gather presence-absence and temporal information about river herring spawning runs from the lower, middle, and upper tributaries of the estuary. Between nine and 11 tributaries were monitored annually by 70 to 213 volunteers in 2008, 2009, and 2010. Herring were seen as early as 31 March and as late as 1 June. River herring were observed in all but one of the tributaries. However, several tributaries with known strong historical runs had very few sightings. Water temperature seemed to be the most important factor determining when herring began to run up a given tributary. Sightings of herring were most common at water temperature above 50 degrees F. Tributaries in the middle part of the estuary warmed the fastest each spring and generally had the earliest runs.

10.10.6 YOUNG-OF-THE-YEAR ABUNDANCE

Since 1980, the Department has produced an annual measure of relative abundance of YOY alewife and blueback herring in the Hudson River Estuary. Although the program was designed to sample YOY American shad, it also provides data on the two river herring species. Blueback herring appear more commonly than alewife throughout the time series. In the first four years of the program, sampling occurred river-wide (rkm 0-252), bi-weekly from August through October, beginning after the peak in YOY abundance occurred. The sampling program was altered in 1984 to concentrate in the freshwater middle and upper portions of the estuary (rkm 88-225), the major nursery area for young American shad and river herring. Timing of sampling was changed to begin in late June or early July and continue biweekly through late October each year. Gear is a 30.5 m by 3.1 m beach seine of 6.4 mm stretch mesh. Collections are made during the day at 28 fixed sites in nearshore habitats spanning four reaches of the freshwater portion of the river. Catch per unit effort is expressed as the annual geometric mean of fish per seine haul for Julian weeks 26 through 42 (July through October). This period encompasses the major peak of use in the middle and upper estuary.

Other indices are available from the Hudson River generating (HRG) companies Long River Monitoring Program (ASA 2017). The HRG sampling program includes a river-wide beach seine survey and an off shore fall shoal survey (sampling open water areas over the channel and shoals). The HRG beach seine survey (BSS) randomly samples beaches in thirteen river segments spread out the entire 246 km of the Hudson River. Sampling is more highly concentrated in the brackish water portion of the Hudson, as the

survey was designed to sample for young of the year striped bass. The BSS began in August for most years of the survey (1974 through 1997), but is now similar in timing to NYSDEC survey running from July through October. The seine used is similar to the NYSDEC YOY program, except that the stretch mesh size is slightly larger (9.5 mm rather than 4 mm). Catch per unit effort for the BSS survey is expressed as a weighted mean CPUE of samples taken between Julian week 33 and Julian week 40. The fall shoals survey (FSS) uses a beam trawl and samples the same river reaches as the BSS. However, it samples at night in the open water (channel sections) of the river. The CPUE for the FSS survey is expressed as a weighted mean density of samples taken between Julian week 33 and Julian week 40.

CHGE et al. (1999) indicated that neither the BSS nor the FSS samples river herring well, as herring tend to move on and off shore on a periodic cycle. Blueback herring tend to move offshore at night and distribute themselves near the surface of the water; alewives tend to move on shore at night. The “best” herring indices were calculated from FSS samples because the channel stratum represents a larger fraction of the total river habitat than the shore zone. Summary data for the HRG and NYSDEC surveys are found in Table 24.

From 1980 to 1998, the Department’s geometric mean YOY annual index for alewife was low, with only one year (1991) having over one fish per haul. Since 1998, the index has generally increased through 2012, and has been stable at roughly one fish per haul since 2013 (Figure 17).

From 1980 through 1994, the Department’s geometric mean YOY annual index for blueback herring averaged about 24 fish per haul, with only one year (1981) dropping below 10 fish per haul (Figure 18). After 1994, the mean dropped to around 17 fish per haul. The largest index value for the time series occurred in 2014, which was just over 50 fish per haul.

The underlying reason for the wide inter-annual variation in YOY river herring indices is not clear. The increased inter-annual variation in relative abundance indices of both species may indicate a change in overall stability in the system. Further investigation into temporal and environmental variables that may contribute to this high variability is necessary. By the time of the next benchmark stock assessment, staff will evaluate different standardized models to best account for the influence of covariates, such as salinity, water temperature, time of day, and sampling week on YOY catches.

10.10.7 ENTRAINMENT AND IMPINGEMENT ESTIMATES

A river-wide ichthyoplankton survey occurs annually in the Hudson River Estuary, conducted by consultants under contract with the Hudson River Generating companies. In order better define impacts of the once-through cooling systems on fish, estimates of mortality on various ichthyoplankton life stages were calculated using two models, the Empirical Transport Model and the Conditional Entrainment Mortality Rate (CEMR) model. Detailed methodology for both models can be found in CHG&E et al. (1999).

Estimates of mortality are expressed as conditional entrainment and impingement mortality rates, or the percent reduction in a year-class that would be due to mortality from entrainment and/or impingement through once-through cooling water systems if no other causes of mortality operated. Losses for the Hudson River Estuary can occur at one major office complex air conditioning unit, two nuclear power plants, one waste-fuel power plant, and five fossil-fuel power plants located throughout the Hudson Valley above New York City. CEMR at these facilities combined has ranged from 9 to 42 percent for alewife and 8 to 41 percent for blueback herring during the period 1974 to 1997 (Table 25).

Estimates have not been made for years since 1997.

10.11 ASSESSMENT APPROACH AND RESULTS

We used an index based approach to assessing status of river herring in the Hudson River. Although data were available to set a benchmark for fishing or total mortality using a biomass per recruit approach, we judged that available techniques for measuring stock specific mortality rates were not adequate. Moreover, approaches using loss estimates to the stock required information on stock specific ocean losses and these data were not available.

10.11.1 TRENDS IN RUN SIZE

As described above in section 10.8.4 Hudson River catch rates, annual CPUE is calculated differently for the two component fisheries in the river. The gear of choice for an abundance index is the fixed gill nets below the Bear Mountain Bridge. This gear operates as an intercept fishery, capturing fish on their emigration into the river before they reach their spawning areas. We only use data from 2000 to 2015, when mandatory reporting was enforced. CPUE for this gear declined slightly from 2000 to about 2006 then has gradually increased to present (Figure 19). For all years, 2000 to 2015, there is a significant increasing trend (Mann-Kendall: $\tau = 0.417$; $p = 0.027$).

10.11.2 TRENDS IN SIZE STRUCTURE

The shaded values in Tables 16 and 17 represent the years included in the trend analysis for each combination of species and sex.

Twelve of the 27 years (1980 to 2015) were used in the trend analysis for alewife males. There is no significant trend (Mann-Kendall: $\tau = 0.061$; $p = 0.84$) when examining all years (Figure 13). However, as was determined in the last assessment, there was a declining trend from years up to 2010. This trend was strong but not significant (Mann-Kendall: $\tau = -0.52$; $p = 0.13$). Since the last assessment, there is an increasing trend in mean length. As with the previous stanza, this trend is strong but not quite significant (Mann-Kendall: $\tau = 0.73$; $p = 0.06$). Seven of 27 years were used to investigate trends in mean lengths of alewife females. As with males, there was no significant trend over all years, but there was a strong increasing trend since the last assessment (Figure 13).

Ten of 25 years of length data were used to examine trends in mean lengths of male blueback herring. There is a weak decreasing trend from 1989-2015 (Figure 13). Splitting the time series at 2010 (the final year of data used in the last assessment), results in a strong decreasing trend from 1989 to 2010 and an equally strong increasing trend from 2010 to 2015. Neither trend is significant. The same overall patterns are observed using the subset of female blueback herring mean lengths: a slight overall decline from 1989 to present, a stronger declining trend until 2010, followed by a strong (and in this case significant) increasing trend from 2010-2015.

In all combinations of species and sex, there is a ‘U-Shaped’ pattern to the mean lengths, with the post-assessment trends largely driven by 2014 and 2015. These values coincide with commercial and recreational regulation changes in the river, as well as the onset of the bycatch avoidance system in the fisheries occurring in the mid-Atlantic and further north. These patterns could reflect increased survivorship, but are better evaluated in the next three sections.

10.11.3 TRENDS IN AGE COMPOSITION

As described above in Section 10.5.1, many scale samples from NYSDEC surveys remain un-aged or were aged using differing protocols. In the previous assessment, ages from these fish were determined through length at age keys from datasets provided by Maine, Massachusetts, and Maryland. Annual estimated age structures resulted in some similarities, but also major differences resulting in speculative trend analyses. For this update, there is major concern in using the previous method based on the wide assumptions that must be made regarding the stock specific characteristics for each species. Moving forward, only ages from the current spawning stock survey and aging protocols are used (2012-2015). Although four years of comparable data are not enough for meaningful analysis, there are notable changes in mean age from 2012 to present (Table 22). As expected from the length analysis, the mean age has generally increased in all but blueback herring males.

Coupled with the increases in mean length at age are changing annual proportions at age (Figure 15). There is an increasing trend in higher proportions of older age fish in 2014 and 2015, the largest change appears to be in alewife females and the smallest change is with blueback males. Also of note for blueback males, there were very few two year olds in the 2015 sample. This, along with the decreasing proportions of younger fish for all combinations of sex and species, could signify a problem with recruitment; however it could also be influenced by a large year class coming through. Either way, these proportions at age should continue to be monitored and will be useful with a longer time series of ages.

10.11.4 TRENDS IN PROPORTION OF REPEAT SPAWNERS

No trend analysis of repeat spawn data was done on in the previous assessment due to minimal years of recent data. Since the 2011 assessment, we have seven consecutive years of repeat spawn data from 2009 to 2015 (Figure 16). A very similar trend is observed for annual proportions of repeat spawn data for all but blueback males: a relatively stable pattern through 2013 followed by a shift in larger proportions of multiple repeat spawn marks in 2014 and 2015. Blueback males also had the same increase in 2014 and 2015; however, there was a decreasing trend in spawn mark proportions from 2009 to 2013. As with the shift in older fish in recent years, these trends may indicate a recruitment issue; however, they also suggest a higher survival rate during both post-spawn emigration and ocean residency.

10.11.5 TRENDS IN TOTAL INSTANTANEOUS MORTALITY

In the previous assessment, the variation in annual age structure, generated by the ME, MA and MD length-age keys, translated into a wide variation in estimates of total mortality when age-based estimation methods (Chapman and Robson 1960) were used. Due to the wide assumptions made using age-length keys from other stocks, trends in the mortality rates varied among species, sexes and methods. As an alternative, mortality estimates were made using the Beverton-Holt length-based method (Gedamke and Hoenig 2006), using growth parameters for length from a very small sample size of river herring capture in 1936. The authors noted issues with the 1936 dataset as well as some of the inputs, especially the arbitrary assignment of length at full recruitment and the sensitivity of L_{∞} on the results. In addition, they acknowledged the assumption that the stock is in equilibrium, was not met. For these reasons, these results are not replicated in this update, instead only current estimates of instantaneous mortality rates are analyzed.

Total instantaneous mortality rates were calculated on an annual basis since 2012 for age data and 2009 for repeat spawn data using a bias-correction Chapman and Robson mortality estimator described in Smith et al. (2012). To be consistent with the methods used in the 2012 Benchmark Stock Assessment

for River Herring, the age of full recruitment was the age of highest abundance and there had to be at least three ages or spawning marks to be included in the respective analyses (ASMFC 2012).

Mortality estimates for both species were calculated using age and repeat spawn data independently. Mortality derived from age data for alewives declined or remained stable from 2012-2014 (Table 22). In 2015, estimates for both sexes of alewives increased; however, we feel that this increase is due to a large year class moving through the fishery resulting in over dispersion of older fish, and is further compounded by fewer age three and age four fish observed in 2015.

Blueback herring age based mortality estimates have been stable since 2012 for both sexes with a slight increase in 2015 (Table 22). Since 2012, both sexes of blueback herring have been comprised of primarily three and four year old fish. Despite blueback herring being dominated by two year classes, a few older fish with increased occurrences of repeat spawning marks are beginning to appear in the fishery (Figure 16).

Mortality estimates were derived from repeat spawning data since 2009 and follow the same trends as mortality estimates derived from age data, with the only exception in 2015 (Table 23). In 2015, alewife and female blueback mortality estimates derived from age data were higher than those derived from repeat spawn data. This is due to increase repeat spawn occurrence and a reduction in the number of virgin fish.

Mortality estimates derived from repeat spawn data for both sexes of alewives slightly increased from 2009-2011 and since declined (Table 23). Female blueback herring mortality estimates were stable from 2009-2012. Male blueback herring mortality estimates increased from 2009-2012. From 2012-present both sexes of blueback herring mortality estimates derived from repeat spawn data have declined.

In most instances, the mortality estimates based on spawning marks were higher than those calculated from ages. This may be a result of the age based method using the most abundant number at age as age at full recruitment. In doing so, we may include ages of the population that may not actually be fully recruited. Once an adequate data set is available for age based mortality estimates, we will compare long-term trends between the two methods. This will identify any potential discrepancies in our mortality estimation methods.

10.11.6 TRENDS IN AGE 0 INDICES OF RELATIVE ABUNDANCE

Alewife: Based on the NYSDEC Alosine Beach Seine Survey, the Hudson River stock of alewife has been erratically increasing over the entire times series. The trend is positive and significant (Mann-Kendall: tau = 0.408; p < 0.001; Figure 20). The HRG surveys indicate minimal trends across their respective sampling periods.

Blueback herring: Unlike alewife, NYSDEC Alosine Beach Seine Survey data for bluebacks indicate a decreasing, non-significant trend, but significant decreasing trends for the HRG beach seine survey and fall shoal survey (Figure 20). In all three surveys, the blueback YOY trends have been erratic but stable for the last 20 years.

The underlying reason for the wide inter-annual variation in all three YOY river herring indices is not clear. The increased inter-annual variation since the 1990s may indicate a change in overall stability in the system. Further investigation into temporal and environmental variables that may contribute to this

high variability is necessary. By the next benchmark assessment NYSDEC staff will evaluate different standardized models to best account for the influence of covariates, such as salinity, water temperature, and sampling week on YOY catches in all three surveys.

10.12 BENCHMARKS

Stock assessments often set benchmarks for juvenile production and characteristics of the adult stock to prevent over-fishing. Setting mortality benchmarks for the Hudson River stocks has been problematic. In the sections above we raised issues and uncertainties associated with calculating current total mortality estimates. By continuing current sampling methodologies on the spawning stock and using consistent aging methods, mortality estimates may be useful in the future. Until then we choose to use other stock indicators.

10.12.1 JUVENILE INDICES

The recently approved 2017 NY SFMP for river herring set a sustainability target for juvenile indices using NYSDEC seine data from the time period of 1983 through 2015 for both species. It defines a more conservative definition of juvenile recruitment failure than described in section 3.1.1.2 of Amendment 2 to the ASMFC Interstate Fisheries Management Plan for Shad and River herring (ASMFC 2009). Amendment 2's definition is that recruitment failure occurs when three consecutive juvenile index values are lower than 90% of all the values obtained in the base period. This plan was more conservative using a 75% cut off level. The resulting sustainability target value is the 25th percentile of the time series, such that three consecutive years with index values below this target would trigger management action. The target for alewife is 0.37 (Figure 17) and the target for blueback herring is 7.53 (Figure18).

The plan states New York State will take immediate corrective action if the recruitment failure limit is met for three consecutive years. Potential management actions may include but are not limited to: area closures, gear restrictions, and permit fee restructuring. Corrective actions will remain in place until the juvenile index value is above the juvenile recruitment failure level set in Amendment 2 to the ASMFC Interstate Fisheries Management Plan for Shad and River herring for three consecutive years.

There are several measures of stock condition of Hudson River herring that can be used to monitor relative change among years. However, these measures have limitations (described below) that currently preclude their use as targets. These include mean length in fishery independent samples, catch per unit effort (CPUE) in the reported commercial harvest, age structure, and proportion of repeat spawning marks. We propose to monitor these measures during the fishery and use them in concert with the sustainability target to evaluate consequences of a continued fishery.

10.12.2 MEAN LENGTH AND MEAN AGE

Mean total length and mean age reflects age structure of the populations and thus some combination of recruitment and level of total mortality. Mean total length and mean age of both river herring species in the Hudson River system have been increasing since sampling efforts increased and became consistent in 2012. Max total lengths and mean length at age of both species are approaching or have exceeded those reported in Greeley (1937). The increases in mean length and mean age are indicative of reduced mortality both within river and during their ocean residency. However, the ocean bycatch fishery is a large unknown and not solely controlled by New York State to effect a change. We propose to continue monitoring mean total length and mean age during the proposed fishery, with specific investigation of mean length at age as a benchmark once more age data are available.

10.12.3 CATCH PER UNIT EFFORT IN COMMERCIAL REPORTS

CPUEs calculated from the reported harvest as well as commercial monitoring efforts reflect general trends in abundance. However, annual values can be influenced by changes in reporting rate in reported harvest and thus reported CPUE should be used as a target at this time. The small sample sizes of commercial monitoring trips precludes the use of annual CPUEs as a target as well. However, with a longer time series of age data as well as an increase in monitoring trips, staff will validate the commercial CPUEs with YOY relative abundance indices following methods described by Hattala and Kahnle (2007).

10.12.4 AGE STRUCTURE, REPEAT SPAWNING, AND TOTAL MORTALITY

The current spawning stock survey will continue into the near future. Thus, age frequencies, frequency of repeat spawning and total mortality (Z) will continue to be consistently monitored. Once an adequate time series of data is collected, a mortality based benchmark will be developed and used as a sustainability target in future sustainable fishery management plans.

10.13 CONCLUSIONS AND RECOMMENDATIONS

The New York stock of river herring is much reduced from historic levels. In the 2011 Benchmark Stock Assessment, it was determined mean lengths and weights of both river herring species were significantly declining since the early 1980's. Conversely, recruitment of both species was considered erratic but stable, with a slight increasing trend in alewife YOY and a slight decreasing trend in YOY blueback herring. Neither trend in YOY abundance was significant. Taking into account these conflicting trends, along with the upsurge in herring use as bait for the recreational striped bass fishery, NY managers asserted the stocks needed to be managed with caution until further data were collected. They made the following recommendations:

- Restrict directed recreational and commercial fisheries that could potentially affect New York stocks to curtail further decline. Close river herring fishing on Long Island and the Bronx and south shore of Westchester County due to lack of data on stock condition.
- Hudson River and tributaries: Continue fishery independent young of year and spawning stock surveys; and fishery dependent monitoring: CPUE and biological characteristics of catch.
- Long Island, Bronx and south shore of Westchester County: Encourage development of monitoring programs for selected runs.
- Identify and control bycatch from fisheries outside of New York such as the Atlantic herring and mackerel fisheries and inshore small mesh fisheries.

Since the last stock assessment, NY addressed several of these recommendations. In an approved 2012 Sustainable Fishery Management Plan (SFMP) for river herring, NY laid out increased restrictions to the recreational and commercial fisheries which were implemented in 2013 (Appendix 1). Highlights included net size restrictions, a closure of net use in Hudson River tributaries during the spawning season, a recreational possession limit and a moratorium on all other New York waters. In addition, the SFMP laid the groundwork for a river herring spawning stock survey beginning in 2012, which has since provided the consistent sampling and aging methodologies required to better evaluate trends in the Hudson stock. Along with an improved spawning stock survey, more effort was made to monitor commercial trips to obtain better representative samples of commercial harvest characteristics throughout the river. From 2012-2016, both sampling programs provided the necessary data as evidence to continue the fishery in 2017. In spring of 2017, NY submitted and ASMFC approved a new

five-year SFMP, with minimal changes from the first plan. In this document, NY pledged to continue the extensive sampling and aging of river herring that will provide more robust targets for the next Benchmark Assessment as well as a potential 2022 five-year SFMP.

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Table 1. Age structure of alewife and blueback herring from spawning stock sampling in the Hudson River Estuary and the Mohawk River.

| Year | Age | | | | | | | | | | | | | n | Mean Age |
|---|-----|-----|-----|------|-----|-----|----|----|----|----|----|----|------|------|----------|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | | | |
| Alewife Male | | | | | | | | | | | | | | | |
| 1936 | 2 | 6 | 1 | 2 | | | | | | | | | 11 | 3.27 | |
| 1999 | | 16 | 108 | 240 | 149 | 34 | 10 | | | | | | 557 | 5.19 | |
| 2000 | | 2 | 179 | 312 | 233 | 109 | 17 | 4 | 2 | | | | 858 | 5.40 | |
| 2001 | 14 | 212 | 196 | 105 | 14 | 2 | 20 | | | | | | 563 | 3.96 | |
| 2012 | 27 | 385 | 726 | 308 | 91 | 21 | 2 | | | | | | 1559 | 4.08 | |
| 2013 | | 615 | 782 | 276 | 48 | 15 | 1 | | | | | | 1737 | 3.89 | |
| 2014 | 1 | 372 | 933 | 1233 | 61 | 18 | 29 | | | | | | 2647 | 4.43 | |
| 2015 | | 105 | 430 | 544 | 203 | 12 | 8 | | | | | | 1302 | 4.70 | |
| Alewife Female | | | | | | | | | | | | | | | |
| 1936 | | 4 | 6 | 3 | | | | | | | | | 13 | 3.92 | |
| 1999 | | 1 | 5 | 26 | 41 | 20 | 7 | | | | | | 100 | 5.95 | |
| 2000 | | | 15 | 187 | 177 | 101 | 58 | 27 | 5 | | | | 570 | 6.18 | |
| 2001 | | | 18 | 99 | 38 | 10 | 3 | 1 | | | | | 169 | 6.31 | |
| 2012 | 5 | 76 | 210 | 175 | 32 | 11 | 7 | 2 | | | | | 518 | 4.44 | |
| 2013 | | 148 | 275 | 84 | 58 | 17 | 12 | 1 | | | | | 596 | 4.26 | |
| 2014 | | 83 | 537 | 383 | 137 | 75 | 27 | 5 | | | | | 1247 | 4.75 | |
| 2015 | | 56 | 179 | 372 | 114 | 30 | 8 | | | | | | 759 | 4.87 | |
| Blueback Herring Male | | | | | | | | | | | | | | | |
| 1936 | | | 1 | 2 | 1 | | | | | | | | 4 | 5.00 | |
| 1989 | | 44 | 164 | 74 | 5 | 1 | | | | | | | 288 | 4.15 | |
| 1990 | 8 | 143 | 100 | 41 | 7 | | | | | | | | 299 | 3.65 | |
| 1999 | 23 | 143 | 285 | 250 | 131 | 40 | 11 | 1 | | | | | 884 | 4.56 | |
| 2000 | | 57 | 354 | 253 | 94 | 26 | 5 | 1 | | | | | 790 | 4.62 | |
| 2001 | | 15 | 169 | 176 | 97 | 23 | 6 | | | | | | 486 | 4.92 | |
| 2012 | 64 | 157 | 89 | 16 | 3 | | | | | | | | 329 | 3.20 | |
| 2013 | 34 | 483 | 209 | 44 | 17 | | | | | | | | 787 | 3.40 | |
| 2014 | 83 | 308 | 205 | 51 | 1 | | | | | | | | 649 | 3.35 | |
| 2015 | 3 | 412 | 168 | 44 | 3 | | | | | | | | 630 | 3.42 | |
| Blueback Herring Female | | | | | | | | | | | | | | | |
| 1936 | | 4 | 15 | 13 | 4 | | | | | | | | 36 | 4.47 | |
| 1989 | | 31 | 182 | 77 | 7 | | | | | | | | 297 | 4.20 | |
| 1990 | 6 | 86 | 102 | 52 | 8 | | | | | | | | 254 | 3.88 | |
| 1999 | 1 | 39 | 223 | 312 | 189 | 63 | 16 | 3 | | | | | 846 | 5.08 | |
| 2000 | | 21 | 231 | 336 | 197 | 48 | 28 | 17 | 8 | 2 | | | 888 | 5.25 | |
| 2001 | | 4 | 66 | 135 | 176 | 44 | 12 | 4 | | | | 1 | 442 | 5.57 | |
| 2012 | | 152 | 168 | 61 | 4 | | | | | | | | 385 | 3.78 | |
| 2013 | 1 | 364 | 203 | 97 | 21 | 1 | | | | | | | 687 | 3.67 | |
| 2014 | 7 | 320 | 274 | 77 | 36 | 9 | | | | | | | 723 | 3.78 | |
| 2015 | | 248 | 262 | 162 | 36 | 9 | | | | | | | 716 | 4.02 | |
| Survey notes: | | | | | | | | | | | | | | | |
| 1936: Greeley (1937) - unknown gear; unknown aging method | | | | | | | | | | | | | | | |
| 1989-90: NYSDEC - electrofishing; unknown scale aging method (likely Cating) | | | | | | | | | | | | | | | |
| 1999-2001: Normandeau Associates - various gears, size and sex selective; scale aging (modified Cating) | | | | | | | | | | | | | | | |
| 2012-2015: NYSDEC - electrofishing and seining; MA DMF based scale aging method (ASMFC workshop) | | | | | | | | | | | | | | | |

Table 2. Von Bertalanffy growth estimates using spawning stock data from the Hudson River Estuary and the Mohawk River.

| Alewife | | | | | |
|------------------|-----|-----|---------|-------|--------|
| Survey | sex | n | Linf | K | t0 |
| 1936 Greeley | m | 8 | 317.910 | 0.489 | -0.139 |
| | f | 9 | 344.003 | 0.421 | -0.180 |
| 1999-2001 NAI | m | 366 | 278.184 | 0.482 | -0.326 |
| | f | 376 | 297.919 | 0.382 | -0.492 |
| 2012-2015 NYSDEC | m | 571 | 290.788 | 0.547 | -0.166 |
| | f | 551 | 305.150 | 0.52 | -0.168 |
| Blueback herring | | | | | |
| Survey | sex | n | Linf | K | t0 |
| 1936 Greeley | m | 4 | 337.408 | 0.453 | -0.052 |
| | f | 4 | 343.127 | 0.442 | -0.055 |
| 1989-1990 NYSDEC | m | 587 | 269.189 | 0.750 | 0.088 |
| | f | 551 | 284.457 | 0.695 | 0.089 |
| 1999-2001 NAI | m | 449 | 284.624 | 0.497 | -0.198 |
| | f | 668 | 284.624 | 0.497 | -0.198 |
| 2012-2015 NYSDEC | m | 402 | 266.138 | 0.817 | 0.115 |
| | f | 445 | 272.300 | 0.902 | 0.197 |

Table 3. Gompertz growth estimates using spawning stock data from the Hudson River Estuary and the Mohawk River.

| Alewife | | | | | |
|------------------|-----|-----|---------|--------|--------|
| Survey | sex | n | Wo | G | sg |
| 1936 Greeley | m | 6 | 0.000 | 13.655 | 1.782 |
| | f | 8 | 0.012 | 9.943 | 1.383 |
| 1999-2001 NAI | m | 152 | 2.030 | 4.553 | 0.635 |
| | f | 96 | 3.101 | 4.428 | 0.494 |
| 2012-2015 NYSDEC | m | 548 | 0.00032 | 13.291 | 1.0634 |
| | f | 536 | 0.000 | 13.446 | 0.997 |
| Blueback herring | | | | | |
| Survey | sex | n | Linf | K | t0 |
| 1936 Greeley | m | 4 | 0.001 | 12.98 | 1.439 |
| | f | 4 | 0.625 | 6.377 | 0.747 |
| 1989-1990 NYSDEC | m | 583 | 0.379 | 5.980 | 0.998 |
| | f | 547 | 0.542 | 5.846 | 0.941 |
| 1999-2001 NAI | m | 82 | 1.417 | 4.827 | 0.647 |
| | f | 130 | 1.784 | 4.731 | 0.609 |
| 2012-2015 NYSDEC | m | 394 | 0.737 | 5.255 | 0.995 |
| | f | 428 | 2.540 | 4.390 | 0.651 |

Table 4. Recent records of type of commercial licenses sold for the New York portions of the Hudson River Estuary.

| Year | Gill Nets | | | Scap Nets | | Gill net | | Scap Net | |
|------|--------------|----------|-----------------------------|-------------------|-----------------|-----------------------------------|----------------|-----------------------------------|----------------|
| | Shad/herring | | Total GN permits sold | N-Fishers sold | Permits sold | N-Fishers reporting herring | % Reporting | N-Fishers reporting herring | % Reporting |
| | N-Fishers | Gill Net | | | | Gill Net | | Gill Net | |
| 1995 | 112 | 47 | 75 | 122 | 2 | 2 | 5 | 2 | 100% |
| 1996 | 134 | 54 | 88 | 142 | 2 | 2 | 4 | 2 | 100% |
| 1997 | 112 | 45 | 74 | 119 | 35 | 35 | 22 | 24 | 69% |
| 1998 | 140 | 65 | 119 | 184 | 46 | 46 | 33 | 33 | 72% |
| 1999 | 145 | 77 | 68 | 145 | 31 | 31 | 40 | 20 | 65% |
| 2000 | 223 | 108 | 123 | 231 | 443 | 449 | 67 | 124 | 28% |
| 2001 | 190 | 87 | 83 | 170 | 345 | 348 | 67 | 127 | 37% |
| 2002 | 232 | 141 | 120 | 261 | 291 | 338 | 87 | 113 | 39% |
| 2003 | 238 | 144 | 106 | 250 | 237 | 278 | 96 | 115 | 49% |
| 2004 | 275 | 160 | 127 | 287 | 245 | 291 | 89 | 106 | 43% |
| 2005 | 255 | 162 | 111 | 273 | 215 | 255 | 68 | 80 | 37% |
| 2006 | 290 | 179 | 129 | 308 | 229 | 273 | 92 | 87 | 38% |
| 2007 | 290 | 178 | 130 | 308 | 201 | 244 | 87 | 75 | 37% |
| 2008 | 277 | 173 | 119 | 292 | 182 | 219 | 78 | 85 | 47% |
| 2009 | 254 | 159 | 108 | 267 | 168 | 199 | 76 | 78 | 46% |
| 2010 | 181 | 0 | 185 | 185 | 161 | 190 | 74 | 73 | 45% |
| 2011 | 177 | 0 | 181 | 181 | 144 | 164 | 62 | 61 | 42% |
| 2012 | 154 | 0 | 155 | 155 | 128 | 151 | 66 | 51 | 40% |
| 2013 | 157 | 0 | 166 | 166 | 112 | 127 | 77 | 33 | 29% |
| 2014 | 150 | 0 | 152 | 152 | 109 | 124 | 47 | 27 | 25% |
| 2015 | 148 | 0 | 150 | 150 | 96 | 112 | 58 | 33 | 34% |

Table 5. River herring and American shad catch in metric tons (mt) by Atlantic Mackerel and Atlantic herring vessels, 2014 -2015. Data summarized by NMFS from vessels via the Vessel Monitoring System (VMS), the Vessel Trip Report System (VTR), Dealer Reports, and the Northeast Fisheries Observer Program.

| Estimated river herring/shad catch (mt) | 2014 | 2015 |
|--|-------------|-------------|
| Atlantic mackerel vessels | 6.42 | 12.87 |
| Atlantic herring vessels - ALL | na | 176.5 |
| Atlantic herring: GOM Mid-water trawl | na | 11.1 |
| Atlantic herring: Cape Cod Mid-water trawl | na | 0.7 |
| Atlantic herring: Southern New England bottom trawl | na | 100.7 |
| Atlantic herring: Southern New England mid-water trawl | na | 64 |

Table 6. River herring and American shad quotas for Atlantic Mackerel and Atlantic herring vessels, 2014-2015, and anticipated quota for Atlantic herring vessels 2016-2018.

| Annual harvest cap for river herring/shad (mt) | 2014 | 2015 | 2016-18 (proposed) |
|--|-------------|-------------|---------------------------|
| Atlantic mackerel vessels | 236 | 89 | 82 |
| Atlantic herring vessels - ALL | 312 | 312 | 361 |
| Atlantic herring: GOM Mid-water trawl | 86 | 86 | 76.7 |
| Atlantic herring: Cape Cod Mid-water trawl | 13 | 13 | 32.4 |
| Atlantic herring: Southern New England bottom trawl | 89 | 89 | 122.3 |
| Atlantic herring: Southern New England mid-water trawl | 124 | 124 | 129.6 |

Table 7. Species-specific total annual incidental catch (mt) across all fleets and regions. Midwater trawl estimates were only included beginning in 2005. Modified from Amendment 14 of the Atlantic Mackerel, Squid and Butterfish Fishery Management Plan for the Mid Atlantic Fishery Management Council.

| Year | ALEWIFE Catch (mt) | AMERICAN SHAD Catch (mt) | BLUEBACK HERRING Catch (mt) | Unknown Catch (mt) | HICKORY SHAD Catch (mt) | Total Catch (mt) | Total identified catch (mt) | Proportion of known catch that is River Herring | Estimated unknown catch that is River Herring (mt) | Total estimated River Herring catch (mt) |
|---------|-----------------------|--------------------------------|-----------------------------------|--------------------------|-------------------------------|------------------------|-----------------------------------|--|--|--|
| 1989 | 20.4 | 58.9 | 19.6 | 7.1 | 0.0 | 106.0 | 98.9 | 0.40 | 2.9 | 42.8 |
| 1990 | 55.3 | 25.8 | 78.9 | 331.3 | 0.0 | 491.4 | 160.1 | 0.84 | 277.9 | 412.2 |
| 1991 | 68.2 | 104.3 | 115.4 | 110.5 | 39.4 | 437.7 | 327.3 | 0.56 | 62.0 | 245.6 |
| 1992 | 30.6 | 79.8 | 458.2 | 387.5 | 0.0 | 956.1 | 568.5 | 0.86 | 333.1 | 821.9 |
| 1993 | 40.5 | 51.0 | 210.6 | 18.6 | 0.0 | 320.6 | 302.0 | 0.83 | 15.5 | 266.5 |
| 1994 | 5.5 | 70.3 | 40.2 | 9.8 | 0.2 | 126.0 | 116.2 | 0.39 | 3.8 | 49.5 |
| 1995 | 6.4 | 17.2 | 213.5 | 51.9 | 0.0 | 288.9 | 237.1 | 0.93 | 48.1 | 268.0 |
| 1996 | 482.0 | 40.0 | 1803.4 | 28.7 | 26.6 | 2380.8 | 2352.1 | 0.97 | 27.9 | 2313.3 |
| 1997 | 41.3 | 37.0 | 982.0 | 67.6 | 18.3 | 1146.2 | 1078.6 | 0.95 | 64.1 | 1087.4 |
| 1998 | 80.9 | 55.3 | 49.3 | 0.4 | 39.2 | 225.1 | 224.7 | 0.58 | 0.2 | 130.4 |
| 1999 | 3.9 | 15.7 | 206.7 | 128.8 | 56.8 | 411.8 | 283.0 | 0.74 | 95.8 | 306.3 |
| 2000 | 28.4 | 74.4 | 55.5 | 22.0 | 0.1 | 180.2 | 158.3 | 0.53 | 11.6 | 95.5 |
| 2001 | 93.0 | 61.9 | 120.1 | 2.1 | 80.6 | 357.8 | 355.7 | 0.60 | 1.3 | 214.4 |
| 2002 | 2.7 | 24.1 | 173.2 | 76.5 | 1.4 | 277.9 | 201.4 | 0.87 | 66.8 | 242.8 |
| 2003 | 248.4 | 21.4 | 332.5 | 15.3 | 14.3 | 631.9 | 616.6 | 0.94 | 14.4 | 595.3 |
| 2004 | 99.7 | 18.2 | 81.5 | 176.7 | 35.0 | 411.2 | 234.5 | 0.77 | 136.6 | 317.9 |
| 2005 | 347.4 | 78.2 | 220.0 | 7.2 | 19.4 | 672.3 | 665.1 | 0.85 | 6.1 | 573.6 |
| 2006 | 57.6 | 29.3 | 187.5 | 232.0 | 13.4 | 519.8 | 287.7 | 0.85 | 197.6 | 442.7 |
| 2007 | 484.0 | 55.1 | 180.1 | 105.3 | 4.8 | 829.3 | 724.0 | 0.92 | 96.6 | 760.8 |
| 2008 | 145.0 | 52.4 | 526.6 | 328.0 | 7.8 | 1059.8 | 731.8 | 0.92 | 301.0 | 972.6 |
| 2009 | 158.7 | 59.5 | 202.0 | 180.1 | 10.9 | 611.2 | 431.1 | 0.84 | 150.6 | 511.3 |
| 2010 | 118.5 | 46.1 | 125.0 | 86.5 | 1.1 | 377.3 | 290.8 | 0.84 | 72.4 | 316.0 |
| Average | 119.0 | 48.9 | 290.1 | 107.9 | 16.8 | 582.7 | 474.8 | 0.80 | 90.3 | 499.4 |

Table 8. Estimated river herring harvest (mt), based on average rate of known river herring bycatch 1989-2010 applied to actual harvest in 2014-15.

| Estimated American shad catch (mt) | 2014 | 2015 |
|--|-------------|-------------|
| Atlantic mackerel vessels | 5.14 | 10.30 |
| Atlantic herring vessels - ALL | na | 141.20 |
| Atlantic herring: GOM Mid-water trawl | na | 8.88 |
| Atlantic herring: Cape Cod Mid-water trawl | na | 0.56 |
| Atlantic herring: Southern New England bottom trawl | na | 80.56 |
| Atlantic herring: Southern New England mid-water trawl | na | 51.20 |

Table 9. New York River river herring landings- all numbers are in kg, unless indicated

| Year | River herring (max value) | NYSDEC catch summary data | | | NMFS website | | | | ACCSP database non-confidential | | | | | | |
|------|---------------------------------|--|---|-------|--------------|--------|----------------------|---------|------------------------------------|-----------------|---------|---------------------|-------------------|-----------------|-----------------|
| | | Ocean and River Sheppard ^a | Dept. Annual reports ^b | Ibs | kgs | number | HERRING, BLUEBACK | ALEWIFE | "HERRINGS" | TOTAL Pounds | Alewife | Blueback herring | River herrings | Herring, unc | TOTAL Pounds |
| 1900 | | | | | | | | | | | | | | | |
| 1901 | | | | | | | | | | | | | | | |
| 1902 | | | | | | | | | | | | | | | |
| 1903 | | | | | | | | | | | | | | | |
| 1904 | 501438 | | 501438 | | | | | | | | | | | | |
| 1905 | 277225 | | 277225 | | | | | | | | | | | | |
| 1906 | | | | | | | | | | | | | | | |
| 1907 | | | | | | | | | | | | | | | |
| 1908 | 81211 | | 81211 | | | | | | | | | | | | |
| 1909 | 111334 | | 111334 | | | | | | | | | | | | |
| 1910 | | | | | | | | | | | | | | | |
| 1911 | | | | | | | | | | | | | | | |
| 1912 | | | | | | | | | | | | | | | |
| 1913 | 92175 | 92175 | 92175 | | | | | | | | | | | | |
| 1914 | | | | | | | | | | | | | | | |
| 1915 | | | | | | | | | | | | | | | |
| 1916 | 21762 | | 21762 | | | | | | | | | | | | |
| 1917 | 49935 | 49935 | 49935 | | | | | | | | | | | | |
| 1918 | 88224 | 88224 | 88224 | | | | | | | | | | | | |
| 1919 | | | | | | | | | | | | | | | |
| 1920 | 101850 | | 101850 | | | | | | | | | | | | |
| 1921 | 10852 | | 10852 | | | | | | | | | | | | |
| 1922 | 73431 | 73431 | 73431 | | | | | | | | | | | | |
| 1923 | 50747 | | | | | | | | | | | | | | |
| 1924 | 56620 | | | | | | | | | | | | | | |
| 1925 | 92188 | 92188 | 92188 | | | | | | | | | | | | |
| 1926 | 131535 | | 131535 | | | | | | | | | | | | |
| 1927 | 140094 | | 140094 | | | | | | | | | | | | |
| 1928 | 178819 | | 178819 | | | | | | | | | | | | |
| 1929 | 146835 | 146835 | 146835 | | | | | | | | | | | | |
| 1930 | 138504 | 138504 | 138504 | | | | | | | | | | | | |
| 1931 | 185707 | 185707 | 185707 | | | | | | | | | | | | |
| 1932 | 91432 | 91432 | 91432 | | | | | | | | | | | | |
| 1933 | 174969 | 174969 | 174969 | | | | | | | | | | | | |
| 1934 | 196848 | 196848 | 196848 | | | | | | | | | | | | |
| 1935 | 274405 | 274405 | 274405 | | | | | | | | | | | | |
| 1936 | 208282 | 208282 | 208282 | | | | | | | | | | | | |
| 1937 | 227865 | 227865 | 227865 | | | | | | | | | | | | |
| 1938 | 244521 | 244521 | 244521 | | | | | | | | | | | | |
| 1939 | 198806 | 198806 | 198806 | | | | | | | | | | | | |
| 1940 | 173453 | 173453 | 173453 | | | | | | | | | | | | |
| 1941 | 222975 | 222975 | 222975 | | | | | | | | | | | | |
| 1942 | 150422 | | 150422 | | | | | | | | | | | | |
| 1943 | 169056 | 169056 | 169056 | | | | | | | | | | | | |
| 1944 | 157644 | 157644 | 157644 | | | | | | | | | | | | |
| 1945 | 123619 | 123619 | 123619 | | | | | | | | | | | | |
| 1946 | 131302 | 131302 | 131302 | | | | | | | | | | | | |
| 1947 | 106189 | 106189 | 106189 | | | | | | | | | | | | |
| 1948 | 90468 | 90468 | 90468 | | | | | | | | | | | | |
| 1949 | 99768 | | 99768 | | | | | | | | | | | | |
| 1950 | 103700 | | 103258 | | | | 103700 | | 103700 | 103700 | | | 103700 | | |
| 1951 | 74800 | | 68987 | | | | 74800 | | 74800 | 74600 | | | 74600 | | |
| 1952 | 90300 | | 88501 | 88501 | | | 90300 | | 90300 | 90300 | | | 90300 | | |
| 1953 | 70753 | | 70753 | 70753 | | | 57200 | | 57200 | 56800 | | | 56800 | | |
| 1954 | 83500 | | | | | | 83500 | | 83500 | 83500 | | | 83500 | | |
| 1955 | 102000 | 12400 | 12400 | | | | 102000 | | 102000 | 102000 | | | 102000 | | |
| 1956 | 67904 | 67904 | 67904 | | | | 67800 | | 67800 | 67800 | | | 67800 | | |
| 1957 | 56300 | 56100 | 56100 | | | | 56300 | | 56300 | 56100 | | | 56100 | | |
| 1958 | 66100 | 66100 | 66100 | | | | 66100 | | 66100 | 66100 | | | 66100 | | |
| 1959 | 45600 | 45600 | 45600 | | | | 45600 | | 45600 | 45600 | | | 45600 | | |
| 1960 | 38200 | 38200 | 38200 | | | | 38200 | | 38200 | 38200 | | | 38200 | | |
| 1961 | 33800 | 33800 | 33800 | | | | 33800 | | 33800 | 33800 | | | 33800 | | |
| 1962 | 38200 | 38200 | 38200 | | | | 38200 | | 38200 | 38200 | | | 38200 | | |
| 1963 | 32300 | 32300 | 32300 | | | | 32300 | | 32300 | 32300 | | | 32300 | | |
| 1964 | 37000 | 37000 | 37000 | | | | 37000 | | 37000 | 37000 | | | 37000 | | |
| 1965 | 23600 | 23600 | 300 | | | | 23600 | | 23600 | 23600 | | | 23600 | | |
| 1966 | 4188000^d | 24500 | 0 | | | | 4188000 | | 4188000 | 4188000 | | | 4188000 | | |
| 1967 | 4400 | 4400 | 350 | | | | 4400 | | 4400 | 4400 | | | 4400 | | |
| 1968 | 7000 | 7000 | 352 | | | | 7000 | | 7000 | 7000 | | | 7000 | | |
| 1969 | 9200 | 9200 | 150 | | | | 9200 | | 9200 | 9200 | | | 9200 | | |
| 1970 | 11000 | 9400 | 35 | | | | 11000 | | 11000 | 11000 | | | 11000 | | |
| 1971 | 68 | | 68 | | | | | | | | | | | | |
| 1972 | 400 | | 102 | | | | 400 | | 400 | 400 | | | 400 | | |
| 1973 | 21600 | 2000 | 252 | | | | 21600 | | 21600 | 21600 | | | 21600 | | |
| 1974 | 16900 | 16900 | 4 | | | | 15400 | | 15400 | 15400 | | | 15400 | | |
| 1975 | 15300 | | 500 | | | | 15300 | | 15300 | 15300 | | | 15300 | | |

Table 9. (cont'd) New York River river herring landings- all numbers are in kg, unless indicated.

| Year | River herring (max value) | NYSDEC catch summary data | | | NMFS website | | | | ACCS database non-confidential | | | | |
|------|------------------------------|---------------------------|-------|-------------------|----------------------|---------|------------|-----------------|-----------------------------------|---------------------|-------------------|-----------------|-----------------|
| | | Ocean and River | | Hudson River ONLY | HERRING, BLUEBACK | ALEWIFE | "HERRINGS" | TOTAL Pounds | Alewife | Blueback herring | River herrings | Herring, unc | TOTAL Pounds |
| 1976 | 1500 | | | | | 1500 | | 1500 | | 1500 | | | 1500 |
| 1977 | 6000 | | | | | 6000 | | 6000 | | 6000 | | | 6000 |
| 1978 | 700 | | | | | 700 | | 700 | | 700 | | | 700 |
| 1979 | 1000 | | | | | 1000 | | 1000 | | 1000 | | | 1000 |
| 1980 | 900 | | | | | 900 | | 900 | | 900 | | | 900 |
| 1981 | 64900 | | | | | 64900 | | 64900 | | 64900 | | | 64900 |
| 1982 | 229200 | | | | | 229200 | | 229200 | | 229200 | | | 229200 |
| 1983 | 24700 | | | | | 24700 | | 24700 | | 24700 | | | 24700 |
| 1984 | 4200 | | | | | 4200 | | 4200 | | 4200 | | | 4200 |
| 1985 | 150 | | | | | 150 | | 150 | | 150 | | | 150 |
| 1986 | 2900 | | | | | 2900 | | 2900 | | 2900 | | | 2900 |
| 1987 | 2765 | | | | | 2765 | | 2765 | | 2765 | | | 2765 |
| 1988 | 100 | | | | | 100 | | 100 | | 100 | | | 100 |
| 1989 | 500 | | | | | 500 | | 500 | | 500 | | | 500 |
| 1990 | 0 | | | | | | | | | | | | |
| 1991 | 0 | | | | | | | | | | | | |
| 1992 | 0 | | | | | | | | | | | | |
| 1993 | 0 | | | | | | | | | | | | |
| 1994 | 0 | | | | | | | | | | | | |
| 1995 | 50864 | | 511 | 232 | 1163 | | | | | | | 50864 | 50864 |
| 1996 | 82255 | | 566 | 257 | 1187 | | | | | | | 82255 | 82255 |
| 1997 | 69318 | | 3166 | 1436 | 7241 | | | | | | | 69318 | 69318 |
| 1998 | 88505 | | 6247 | 2834 | 14241 | 4867 | 58 | 4925 | | 4867 | | 83638 | 88505 |
| 1999 | 74446 | | 3319 | 1506 | 7553 | | | | | | | 74446 | 74446 |
| 2000 | 58377 | | 16861 | 7648 | 38613 | 490 | | 490 | | | | 58377 | 58377 |
| 2001 | 23491 | | 19607 | 8894 | 43537 | 3235 | | 3235 | | | | 23491 | 23491 |
| 2002 | 31778 | | 20346 | 9229 | 46269 | 474 | | 474 | | 390 | | 31388 | 31778 |
| 2003 | 53288 | | 19644 | 8910 | 44811 | 20467 | | 20467 | | 20467 | | 32821 | 53288 |
| 2004 | 16435 | | 16435 | 7455 | 37816 | 14446 | | 14446 | | 688 | | 11721 | 12409 |
| 2005 | 13509 | | 13509 | 6128 | 31948 | 5791 | | 5791 | | 2463 | | 259 | 2722 |
| 2006 | 20046 | | 10011 | 4541 | 25144 | 11111 | | 8935 | 20046 | 9835 | | 6424 | 16259 |
| 2007 | 30205 | | 13902 | 6306 | 35953 | 28159 | 24 | 2022 | 30205 | 24 | 11992 | 13843 | 25859 |
| 2008 | 24756 | | 13146 | 5963 | 35612 | 20956 | 99 | 3701 | 24756 | 99 | 4 | 13044 | 13147 |
| 2009 | 12804 | | 11832 | 5367 | 32700 | 11747 | 83 | 974 | 12804 | 82 | 224 | 11525 | 11831 |
| 2010 | 14024 | | 12769 | 5792 | 36848 | 12667 | 101 | 1256 | 14024 | 101 | 51 | 12618 | 12770 |
| 2011 | 25334 | | 10380 | 4708 | 31713 | 25334 | | | 25334 | | | 10370 | 10370 |
| 2012 | 21846 | | 17346 | 7868 | 48215 | 17564 | | 4282 | 21846 | | 257 | 17463 | 20875 |
| 2013 | 7545 | | 7545 | 3365 | 24724 | 3233 | | | 3233 | | 2038 | 892 | 2930 |
| 2014 | 7127 | | 7127 | 3233 | 20791 | 6755 | | 68 | 6823 | | 254 | | 254 |
| 2015 | 5914 | | 5914 | 2683 | 15635 | | | | | | 367 | | 367 |

a Sheppard 1976

b NYSDEC Annual Reports - Historic annual reports

c NYSDEC License Reports - Mandatory commercial license reporting system: pounds and/or numbers estimated

d Max value was 418800 from NMFS report, removed from Landings Figure

Table 10. Drift gill net trips by river section above Bear Mountain Bridge (rkm 75). From mandatory commercial reports stating mesh less than or equal to 3.5" stretch mesh. Note: Kingston Flats rkm's are not exclusive and trip rkm's are based on fishermen descriptions, so any rkm 148-149 trips are moved to the Kingston reach and rkm 154-155 trips are listed with the Saugerties reach.

| | West Point rkm 75 - 89 | Cornwall rkm 90 - 98 | Poughkeepsie rkm 99 - 122 | Hyde Park rkm 123 - 135 | Kingston rkm 138 - 147 | Kingston Flats rkm 148 - 155 | Saugerties rkm 156 - 171 | Catskill rm 172 - 200 | Coxsackie rkm 201 - 216 | Albany rkm 217 - 245 |
|------|---------------------------|-------------------------|------------------------------|----------------------------|---------------------------|-------------------------------------|-----------------------------|--------------------------|----------------------------|-------------------------------------|
| 2000 | | | 2 | | 3 | | 104 | 88 | 2 | |
| 2001 | | | 1 | 7 | 3 | | 31 | 120 | 5 | |
| 2002 | | 5 | 3 | 5 | 14 | | 37 | 168 | 6 | |
| 2003 | | | | 8 | 10 | | 59 | 184 | 14 | |
| 2004 | | 2 | | 8 | 3 | | 37 | 188 | 20 | |
| 2005 | | | | 1 | 12 | | 60 | 145 | 17 | |
| 2006 | | | 1 | 10 | 16 | | 69 | 87 | 25 | |
| 2007 | | 1 | 11 | 13 | 32 | Area closed to gill nets | 57 | 62 | 19 | Area closed to gill nets |
| 2008 | | | | 4 | 24 | | 49 | 67 | 13 | |
| 2009 | | | 11 | | 17 | | 64 | 45 | 11 | |
| 2010 | | | 12 | 3 | 26 | | 28 | 38 | 11 | |
| 2011 | | | 10 | 1 | 10 | | 22 | 33 | 1 | |
| 2012 | | | 20 | 1 | 34 | | 34 | 33 | 3 | |
| 2013 | 8 | 13 | | | 58 | | 82 | 88 | 11 | |
| 2014 | 6 | 6 | | | 69 | | 58 | 54 | 8 | |
| 2015 | 10 | 14 | | | 25 | | 44 | 68 | 12 | |
| Mean | 0.0 | 5.3 | 8.7 | 5.5 | 22.3 | 0 | 52.2 | 91.8 | 11.1 | 0 |
| % | 0% | 3% | 4% | 3% | 11% | 0% | 27% | 47% | 6% | 0% |

Table 11. Number of river herring monitoring trips and catch per unit effort (CPUE) in the Hudson River commercial gill net fishery from 1996 through 2015.

| YEAR | Fixed gill nets below Bear Mtn Bridge | | | | | Drift gill nets | | | |
|------|---------------------------------------|---------|-------|-------------|--------------------|-----------------|---------|-------|-------------|
| | Trips | Effort^ | Catch | Annual CPUE | Sum of Weekly CPUE | Trips | Effort^ | Catch | Annual CPUE |
| 1996 | 0 | | | | | 1 | 91 | 43 | 0.472 |
| 1997 | 5 | 6830.6 | 208 | 0.030 | 0.055 | 0 | | | |
| 1998 | 0 | | | | | 0 | | | |
| 1999 | 4 | 11372.2 | 421 | 0.037 | 0.065 | 0 | | | |
| 2000 | 5 | 15650.0 | 545 | 0.035 | 0.126 | 1 | 160 | 7 | 0.044 |
| 2001 | 7 | 26688.9 | 1221 | 0.046 | 0.276 | 0 | | | |
| 2002 | 8 | 32222.2 | 1328 | 0.041 | 0.230 | 0 | | | |
| 2003 | 2 | 4800.0 | 171 | 0.036 | 0.071 | 0 | | | |
| 2004 | 11 | 41164.4 | 1826 | 0.044 | 0.230 | 0 | | | |
| 2005 | 1 | 9600.0 | 428 | 0.045 | 0.045 | 0 | | | |
| 2006 | 2 | 5591.1 | 246 | 0.044 | 0.044 | 1 | 378 | 0 | 0.000 |
| 2007 | 4 | 25777.8 | 299 | 0.012 | 0.055 | 2 | 4767 | 36 | 0.008 |
| 2008 | 0 | | | | | 0 | | | |
| 2009 | 3 | 19266.7 | 468 | 0.024 | 0.045 | 0 | | | |
| 2010 | 1 | 4326.7 | 154 | 0.036 | 0.036 | 0 | | | |
| 2011 | 4 | 6531.6 | 329 | 0.050 | 0.150 | 0 | | | |
| 2012 | 20 | 50916.4 | 1066 | 0.021 | 0.154 | 6 | 7013 | 560 | 0.080 |
| 2013 | 4 | 10719.8 | 1382 | 0.129 | 0.419 | 1 | 178 | 112 | 0.630 |
| 2014 | 7 | 14612.8 | 2161 | 0.148 | 0.605 | 1 | 2843 | 289 | 0.102 |
| 2015 | 5 | 8435.0 | 605 | 0.072 | 0.176 | 1 | 637 | 197 | 0.309 |

^Sq yd net area * hours

Table 12. Observed landings and dockside subsamples for commercial river herring trips made in the Hudson River Estuary for 2001 through 2015.

| Year | N of trips | On-board Observations of Commercial Trips | | | | | | | | | | | | | | Total | Percent | | | |
|------|------------|---|-----|-----------|------|------|------------------|-----|------|------|--------|------------------------------|-----|-----|------|-------|---------|---------|----------|---------|
| | | Alewife | | | | | Blueback herring | | | | | Unidentified "river herring" | | | | | | | | |
| | | Number | | Sex ratio | | M | F | U | M | F | Number | Sex ratio | M | F | U | M | F | Alewife | Blueback | Unknown |
| 2001 | 7 | 192 | 178 | 851 | 0.52 | 0.48 | | | | | | | | | | | 1,221 | 100% | 0% | 0% |
| 2002 | 8 | | | 43 | | | 19 | 41 | 1225 | 0.32 | 0.68 | | | | | | 1,328 | 3% | 97% | 0% |
| 2003 | 2 | | | 171 | | | | | | | | | | | | | 171 | 100% | 0% | 0% |
| 2004 | 11 | 124 | 168 | 8 | 0.42 | 0.58 | 5 | 6 | | 0.45 | 0.55 | 500 | 796 | 297 | 0.39 | 0.61 | 1,904 | 16% | 1% | 84% |
| 2005 | 1 | | | 428 | | | | | | | | | | | | | 456 | 94% | 0% | 6% |
| 2006 | 3 | | | 1 | | | | | 246 | | | | | | | | 247 | 0% | 100% | 0% |
| 2007 | 6 | | | 14 | | | | | 53 | | | | | | | | 335 | 4% | 16% | 80% |
| 2008 | 0 | | | | | | | | | | 44 | | | | | | 44 | 0% | 0% | 100% |
| 2009 | 3 | 187 | 179 | 4 | 0.51 | 0.49 | 37 | 61 | | 0.38 | 0.62 | | | | | | 468 | 79% | 21% | 0% |
| 2010 | 1 | 23 | 28 | 1 | 0.45 | 0.55 | 11 | 88 | 3 | 0.11 | 0.89 | | | | | | 154 | 34% | 66% | 0% |
| 2011 | 4 | 163 | 148 | 0 | 0.52 | 0.48 | 3 | 5 | | 0.38 | 0.63 | | | | | | 329 | 95% | 2% | 3% |
| 2012 | 26 | 439 | 568 | 121 | 0.44 | 0.56 | 54 | 70 | 68 | 0.44 | 0.56 | | 383 | | | | 1,703 | 66% | 11% | 22% |
| 2013 | 5 | 615 | 586 | 1 | 0.51 | 0.49 | 98 | 305 | | 0.24 | 0.76 | | | | | | 1,605 | 75% | 25% | 0% |
| 2014 | 8 | 750 | 830 | 5 | 0.47 | 0.53 | 236 | 629 | | 0.27 | 0.73 | | | | | | 2,450 | 65% | 35% | 0% |
| 2015 | 6 | 202 | 291 | 12 | 0.41 | 0.59 | 77 | 185 | | 0.29 | 0.71 | | 35 | | | | 802 | 63% | 33% | 4% |

Table 13. Age structure of river herring samples from the commercial fishery. 2012 commercial scale samples were aged; 2013-2015 ages were estimated using age-length keys derived from fishery independent samples.

| | Age | | | | | | | | | Total | Mean Age |
|-------------------------|-----|----|-----|-----|----|----|---|---|-----|-------|----------|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | |
| Alewife Male | | | | | | | | | | | |
| 2012 | 4 | 71 | 110 | 37 | 4 | 5 | | | 231 | 3.91 | |
| 2013 | | 26 | 37 | 15 | 3 | 1 | | | 83 | 3.97 | |
| 2014 | | 32 | 82 | 102 | 2 | 1 | 1 | | 221 | 4.37 | |
| 2015 | | 4 | 42 | 53 | 18 | 1 | 1 | | 118 | 4.77 | |
| Alewife Female | | | | | | | | | | | |
| 2012 | 1 | 30 | 155 | 121 | 25 | 11 | 2 | 1 | 346 | 4.54 | |
| 2013 | | 19 | 39 | 12 | 5 | 1 | | | 76 | 4.07 | |
| 2014 | | 23 | 106 | 62 | 18 | 11 | 3 | 2 | 225 | 4.58 | |
| 2015 | | 14 | 41 | 67 | 18 | 4 | 1 | | 146 | 4.73 | |
| Blueback herring Male | | | | | | | | | | | |
| 2012 | 2 | 18 | 40 | 11 | 3 | | | | 75 | 3.94 | |
| 2013 | 0.2 | 10 | 9 | 4 | 2 | | | | 25 | 3.91 | |
| 2014 | 0.3 | 17 | 55 | 25 | 2 | | | | 99 | 4.11 | |
| 2015 | 7 | 8 | 17 | 1 | | | | | 33 | 4.35 | |
| Blueback herring Female | | | | | | | | | | | |
| 2012 | | 32 | 68 | 34 | 2 | 2 | | | 137 | 4.09 | |
| 2013 | | 13 | 11 | 6 | 2 | 1 | | | 32 | 3.92 | |
| 2014 | | 26 | 63 | 23 | 13 | 5 | | | 130 | 4.29 | |
| 2015 | | 6 | 16 | 16 | 4 | 1 | | | 43 | 4.53 | |

Table 14. Estimated recreational use and take of river herring by Hudson River anglers.

| Herring Use* | | | | | | | | | |
|---------------------------------|--|---------------------|------------------|-----------------|-------------------|---------------------------------------|----------------------|-------------------------------|-----------------------|
| Year | % of all CAP Trips using herring as bait | N-SB Trips using RH | N bough t / trip | N caught / trip | Total RH use/trip | % change in annual effort of CAP data | Estimated SB trips** | Trips using herring as bait** | Estimated Herring Use |
| 2001 | | | | | | | 53,988 | 39,500 | 93,157** |
| 2005 | 89% | | | | | | 72,568 | 64,500 | 152,117** |
| Cooperative Angler Program Data | | | | | | | | | |
| 2006 | 48% | 263 | 1.47 | 2.57 | 4.04 | | | | |
| 2007 | 25% | 335 | 1.66 | 1.80 | 3.46 | | 90,742 | 22,685 | 78,491*** |
| 2008 | 33% | 474 | 0.86 | 1.64 | 2.50 | +21% | 109,557 | 36,154 | 84,969*** |
| 2009 | 35% | 508 | 0.63 | 3.80 | 4.43 | +9% | 98,739 | 34,559 | 148,303*** |
| 2010 | 52% | 532 | 0.67 | 4.80 | 5.48 | +1 | 91,513 | 47,587 | 258,150*** |
| 2011 | 48% | 885 | 0.71 | 4.35 | 5.06 | +14% | 103,532 | 49,695 | 251,285*** |
| 2012 | 53% | 749 | 1.10 | 4.76 | 5.86 | -1% | 89,735 | 47,650 | 278,627*** |
| 2013 | 57% | 611 | 1.04 | 5.23 | 6.27 | -11% | 80,703 | 46,001 | 288,579*** |
| 2014 | 55% | 512 | 0.74 | 5.30 | 6.04 | -14% | 78,438 | 43,141 | 260,613*** |
| 2015 | 54% | 571 | 0.66 | 6.04 | 6.70 | +18% | 106,961 | 57,759 | 386,915*** |

*Data from NYSDEC - HRFU Cooperative Angler Program (unpublished data)

**Creel survey data: NAI 2003, NAI 2007; 2001 estimated use modified using 2005 RH use per trip* 2001 trips using herring as bait; From 2008 to 2015 estimated using the percent change in annual effort of the CAP data*2007 SB trips from NYSDEC statewide angler survey

***Estimate calculated from the average RH/trip (CAP) and Estimated SB trips from 2007 NYSDEC statewide angler survey adjusted annually using the percent change in effort from CAP data

Table 15. Annual daily count data from Black Creek and commercial and estimated recreational herring harvest.

| Black Creek Daily Alewife Count Data | | | | | | | Hudson River Harvest | | | |
|--------------------------------------|-----|-------|----------|----------|---------|--------------|----------------------|----------------------|-------------------------|---------|
| | Min | Max | Mean | SD | SE | Total Counts | n (days)* | Commercial Harvest** | Recreational Harvest*** | Total |
| 2013 | 25 | 40571 | 4380.53 | 7710.69 | 1124.72 | 205,885 | 47 | 24,612 | 288,579 | 313,191 |
| 2014 | 294 | 58416 | 18458.75 | 13206.45 | 2334.59 | 590,680 | 32 | 20,805 | 260,613 | 281,418 |
| 2015 | 26 | 45186 | 13064.74 | 12146.56 | 2114.45 | 431,136 | 33 | 15,634 | 386,915 | 402,549 |

*Number of days count data were recorded

**Number harvested of combined river herring species from Hudson River commercial reports

***Estimated harvest numbers of combined river herring species derived from CAP data and 2007 NYSDEC statewide angler survey

Table 16. Mean total length and weight of alewives collected during spawning stock sampling in the Hudson River Estuary

| Year | Alewife - Male | | | | | | | | | | Alewife - Female | | | | | | | | | |
|------|----------------|-----|-----|-------|------|--------|-----|-----|-------|------|------------------|-----|-----|-------|------|--------|-----|-----|-------|------|
| | TL | | | | | Weight | | | | | TL | | | | | Weight | | | | |
| | N | Max | Min | Mean | STD | N | Max | Min | Mean | STD | N | Max | Min | Mean | STD | N | Max | Min | Mean | STD |
| 1936 | 8 | 291 | 270 | 282.9 | 7.8 | 6 | 227 | 184 | 210.3 | 16.6 | 9 | 324 | 288 | 302.7 | 12.3 | 8 | 340 | 198 | 241.3 | 43.9 |
| 1975 | | | | | | | | | | | | | | | | | | | | |
| 1976 | | | | | | | | | | | | | | | | | | | | |
| 1977 | | | | | | | | | | | | | | | | | | | | |
| 1978 | | | | | | | | | | | | | | | | | | | | |
| 1979 | | | | | | | | | | | | | | | | | | | | |
| 1980 | 1 | 298 | 298 | 298.0 | | 1 | 249 | 249 | 249.0 | | 1 | 315 | 315 | 315.0 | | 1 | 318 | 318 | 318.0 | |
| 1981 | 2 | 291 | 272 | 281.5 | 13.4 | 2 | 216 | 179 | 197.4 | 26.2 | 1 | 292 | 292 | 292.0 | | 1 | 222 | 222 | 222.0 | |
| 1982 | | | | | | | | | | | 1 | 310 | 310 | 310.0 | | 1 | 275 | 275 | 275.0 | |
| 1983 | | | | | | | | | | | | | | | | | | | | |
| 1984 | 1 | 267 | 267 | 267.0 | | 1 | 168 | 168 | 168.0 | | 1 | 264 | 264 | 264.0 | | 1 | 222 | 222 | 222.0 | |
| 1985 | 7 | 312 | 249 | 286.4 | 22.7 | 7 | 281 | 145 | 220.7 | 49.0 | 3 | 320 | 312 | 316.7 | 4.2 | 3 | 295 | 272 | 281.3 | 12.1 |
| 1986 | | | | | | | | | | | | | | | | | | | | |
| 1987 | 26 | 302 | 266 | 279.2 | 8.9 | 22 | 260 | 160 | 217.3 | 35.3 | 28 | 353 | 276 | 302.6 | 14.8 | 26 | 410 | 200 | 268.1 | 55.9 |
| 1988 | | | | | | | | | | | | | | | | | | | | |
| 1989 | | | | | | | | | | | | | | | | | | | | |
| 1990 | 89 | 296 | 239 | 267.5 | 14.9 | 87 | 270 | 100 | 178.2 | 35.7 | 7 | 327 | 255 | 284.7 | 22.8 | 7 | 310 | 180 | 218.6 | 54.9 |
| 1991 | 17 | 290 | 234 | 265.0 | 15.7 | 16 | 200 | 100 | 147.5 | 30.7 | 5 | 290 | 266 | 273.2 | 9.7 | 5 | 210 | 150 | 172.0 | 23.9 |
| 1992 | 12 | 286 | 236 | 269.7 | 15.3 | 12 | 220 | 110 | 176.7 | 29.6 | 23 | 306 | 240 | 278.4 | 16.6 | 23 | 290 | 120 | 189.1 | 46.8 |
| 1993 | 17 | 299 | 246 | 268.2 | 13.8 | 14 | 205 | 120 | 159.6 | 18.5 | 5 | 300 | 258 | 278.4 | 16.6 | 5 | 220 | 150 | 178.0 | 30.3 |
| 1994 | | | | | | | | | | | | | | | | | | | | |
| 1995 | 1 | 252 | 252 | 252.0 | | 1 | 140 | 140 | 140.0 | | 1 | 274 | 274 | 274.0 | | 1 | 200 | 200 | 200.0 | |
| 1996 | | | | | | | | | | | | | | | | | | | | |
| 1997 | 2 | 287 | 230 | 258.5 | 40.3 | 2 | 200 | 120 | 160.0 | 56.6 | 8 | 310 | 262 | 280.5 | 15.4 | 8 | 240 | 140 | 185.0 | 31.6 |
| 1998 | 33 | 277 | 237 | 255.9 | 9.9 | 33 | 180 | 120 | 145.2 | 19.4 | 6 | 292 | 251 | 266.2 | 13.7 | 6 | 240 | 160 | 173.3 | 32.7 |
| 1999 | 7 | 261 | 228 | 245.6 | 12.8 | 6 | 140 | 50 | 73.3 | 34.4 | 4 | 283 | 258 | 271.0 | 10.9 | 4 | 220 | 40 | 106.3 | 79.1 |
| 2000 | | | | | | | | | | | | | | | | | | | | |
| 2001 | 399 | 300 | 210 | 262.7 | 13.2 | | | | | | 123 | 304 | 229 | 272.4 | 12.9 | | | | | |
| 2002 | | | | | | | | | | | | | | | | | | | | |
| 2003 | 265 | 305 | 222 | 262.9 | 13.7 | 166 | 220 | 50 | 148.7 | 38.6 | 139 | 310 | 172 | 272.0 | 18.3 | 85 | 280 | 100 | 161.4 | 40.3 |
| 2004 | | | | | | | | | | | | | | | | | | | | |
| 2005 | 96 | 280 | 231 | 252.0 | 10.2 | 88 | 200 | 80 | 143.2 | 30.0 | 16 | 291 | 235 | 263.0 | 16.2 | 13 | 180 | 80 | 123.1 | 31.5 |
| 2006 | 16 | 260 | 220 | 238.4 | 8.3 | 12 | 180 | 80 | 114.6 | 24.8 | 10 | 283 | 239 | 255.3 | 12.6 | 8 | 280 | 80 | 155.6 | 60.8 |
| 2007 | 47 | 290 | 219 | 251.6 | 12.6 | 47 | 220 | 80 | 140.6 | 30.7 | 5 | 273 | 240 | 257.8 | 12.2 | 5 | 180 | 120 | 148.0 | 22.8 |
| 2008 | 202 | 285 | 215 | 243.7 | 12.1 | 188 | 260 | 60 | 158.0 | 38.3 | 55 | 305 | 225 | 264.5 | 18.3 | 55 | 380 | 120 | 208.4 | 53.2 |
| 2009 | 460 | 290 | 214 | 255.5 | 10.8 | 221 | 220 | 80 | 162.6 | 27.6 | 85 | 300 | 230 | 267.6 | 12.1 | 41 | 280 | 140 | 205.9 | 32.0 |
| 2010 | 272 | 295 | 221 | 253.0 | 13.2 | 115 | 250 | 80 | 155.7 | 31.6 | 87 | 325 | 237 | 271.0 | 18.4 | 73 | 300 | 110 | 193.3 | 45.0 |
| 2011 | 105 | 283 | 222 | 249.4 | 11.5 | 74 | 206 | 85 | 138.6 | 28.4 | 102 | 300 | 230 | 265.5 | 14.9 | 53 | 260 | 92 | 173.0 | 39.0 |
| 2012 | 1574 | 296 | 216 | 258.4 | 12.9 | 960 | 250 | 80 | 156.4 | 30.2 | 525 | 321 | 233 | 272.1 | 14.9 | 355 | 360 | 100 | 180.8 | 45.4 |
| 2013 | 1742 | 294 | 211 | 255.1 | 11.1 | 682 | 220 | 65 | 130.6 | 26.7 | 598 | 318 | 228 | 268.1 | 16.0 | 344 | 300 | 90 | 163.0 | 42.0 |
| 2014 | 2647 | 305 | 222 | 266.3 | 13.3 | 855 | 260 | 50 | 154.1 | 39.3 | 1248 | 320 | 227 | 279.6 | 14.1 | 520 | 330 | 60 | 183.1 | 46.7 |
| 2015 | 1303 | 310 | 221 | 268.2 | 15.3 | 508 | 295 | 80 | 168.1 | 38.1 | 759 | 322 | 245 | 283.3 | 14.7 | 361 | 335 | 115 | 208.5 | 42.7 |

*Fish 170 mm or greater; collected using electrofishing, herring haul seine, and beach seine gears

Best values for length/weight analysis

Table 17. Mean total length and weight of blueback herring collected during spawning stock sampling in the Hudson River Estuary

| Year | Blueback herring - Male | | | | | | | | | | Blueback herring - Female | | | | | | | | | | |
|------|-------------------------|-----|-----|-------|------|--------|-----|-----|-------|------|---------------------------|-----|-----|-------|------|--------|-----|-----|-------|------|--|
| | TL | | | | | Weight | | | | | TL | | | | | Weight | | | | | |
| | N | Max | Min | Mean | STD | N | Max | Min | Mean | STD | N | Max | Min | Mean | STD | N | Max | Min | Mean | STD | |
| 1936 | 4 | 290 | 310 | 299.0 | 8.5 | 4 | 255 | 213 | 244.5 | 21.3 | 4 | 266 | 321 | 294.0 | 22.5 | 4 | 369 | 206 | 279.2 | 67.6 | |
| 1975 | | | | | | | | | | | | | | | | | | | | | |
| 1976 | | | | | | | | | | | 2 | 330 | 330 | 330.0 | 0.0 | | | | | | |
| 1977 | | | | | | | | | | | | | | | | | | | | | |
| 1978 | | | | | | | | | | | | | | | | | | | | | |
| 1979 | | | | | | | | | | | | | | | | | | | | | |
| 1980 | | | | | | | | | | | | | | | | | | | | | |
| 1981 | 1 | 284 | 284 | 284.0 | | 1 | 194 | 194 | 194.0 | | 1 | 289 | 289 | 289.0 | | 1 | 228 | 228 | 227.6 | | |
| 1982 | 2 | 290 | 268 | 278.9 | 15.3 | 2 | 219 | 184 | 201.7 | 24.5 | 2 | 300 | 286 | 292.8 | 10.2 | 2 | 253 | 213 | 232.6 | 28.1 | |
| 1983 | | | | | | | | | | | | | | | | | | | | | |
| 1984 | 16 | 282 | 231 | 259.9 | 16.6 | 16 | 213 | 132 | 160.0 | 26.1 | 12 | 300 | 251 | 274.8 | 15.7 | 12 | 327 | 145 | 212.3 | 50.5 | |
| 1985 | 11 | 304 | 245 | 271.0 | 18.0 | 11 | 231 | 136 | 172.6 | 30.7 | 10 | 329 | 267 | 284.1 | 18.0 | 10 | 295 | 159 | 198.2 | 38.7 | |
| 1986 | | | | | | | | | | | | | | | | | | | | | |
| 1987 | 21 | 294 | 243 | 268.0 | 14.0 | 10 | 310 | 140 | 205.0 | 42.5 | 36 | 340 | 235 | 283.7 | 21.4 | 24 | 400 | 120 | 242.1 | 59.6 | |
| 1988 | | | | | | | | | | | | | | | | | | | | | |
| 1989 | 316 | 285 | 219 | 256.1 | 9.0 | 316 | 204 | 75 | 136.0 | 15.9 | 317 | 305 | 228 | 265.9 | 10.6 | 316 | 275 | 100 | 159.6 | 22.9 | |
| 1990 | 345 | 287 | 195 | 246.5 | 15.1 | 340 | 225 | 70 | 121.3 | 26.8 | 283 | 314 | 228 | 263.5 | 16.5 | 279 | 280 | 88 | 163.7 | 37.3 | |
| 1991 | 6 | 262 | 225 | 246.5 | 15.0 | 6 | 180 | 100 | 128.3 | 28.6 | 11 | 286 | 241 | 261.2 | 14.9 | 10 | 220 | 100 | 145.0 | 46.5 | |
| 1992 | 112 | 295 | 215 | 250.5 | 15.0 | 99 | 260 | 80 | 142.6 | 38.0 | 129 | 324 | 228 | 272.9 | 21.3 | 110 | 380 | 100 | 187.7 | 52.8 | |
| 1993 | 1 | 243 | 243 | 243.0 | | 1 | 130 | 130 | 130.0 | | 1 | 255 | 255 | 255.0 | | 1 | 160 | 160 | 160.0 | | |
| 1994 | | | | | | | | | | | | | | | | | | | | | |
| 1995 | | | | | | | | | | | | | | | | | | | | | |
| 1996 | | | | | | | | | | | | | | | | 1 | 290 | 290 | 290.0 | | |
| 1997 | | | | | | | | | | | | | | | | | | | | | |
| 1998 | 1 | 230 | 230 | 230.0 | | 1 | 100 | 100 | 100.0 | | | | | | | | | | | | |
| 1999 | 20 | 286 | 225 | 251.0 | 19.0 | 18 | 220 | 50 | 135.6 | 45.1 | 20 | 314 | 225 | 275.4 | 19.3 | 19 | 260 | 100 | 183.7 | 35.8 | |
| 2000 | | | | | | | | | | | | | | | | | | | | | |
| 2001 | 2 | 267 | 235 | 251.0 | 22.6 | | | | | | | | | | | 3 | 280 | 257 | 267.3 | 11.7 | |
| 2002 | | | | | | | | | | | | | | | | | | | | | |
| 2003 | 4 | 267 | 240 | 254.0 | 14.5 | 4 | 180 | 100 | 130.0 | 34.6 | 3 | 283 | 252 | 268.7 | 15.6 | 2 | 120 | 120 | 120.0 | 0.0 | |
| 2004 | 6 | 263 | 234 | 246.2 | 11.9 | 1 | 240 | 240 | 240.0 | | 4 | 268 | 242 | 252.0 | 11.4 | | | | | | |
| 2005 | 21 | 266 | 228 | 246.4 | 10.8 | 16 | 220 | 80 | 108.8 | 36.5 | 16 | 263 | 231 | 245.0 | 9.3 | 13 | 120 | 70 | 98.5 | 18.2 | |
| 2006 | 2 | 256 | 249 | 252.5 | 4.9 | 2 | 140 | 120 | 130.0 | 14.1 | 1 | 245 | 245 | 245.0 | | 1 | 160 | 160 | 160.0 | | |
| 2007 | | | | | | | | | | | | | | | | | | | | | |
| 2008 | 13 | 253 | 226 | 236.6 | 7.6 | 13 | 180 | 120 | 130.8 | 19.3 | 8 | 260 | 227 | 245.8 | 10.4 | 8 | 200 | 120 | 148.8 | 24.7 | |
| 2009 | 108 | 268 | 197 | 243.9 | 13.7 | 54 | 200 | 60 | 108.8 | 35.1 | 112 | 275 | 206 | 253.7 | 9.0 | 54 | 160 | 70 | 128.6 | 18.6 | |
| 2010 | 62 | 265 | 202 | 237.8 | 12.1 | 46 | 180 | 70 | 115.6 | 23.7 | 50 | 276 | 215 | 250.3 | 11.5 | 44 | 210 | 100 | 144.6 | 25.1 | |
| 2011 | 85 | 264 | 212 | 233.0 | 11.6 | 48 | 160 | 74 | 107.8 | 20.1 | 117 | 280 | 210 | 243.8 | 14.6 | 75 | 178 | 80 | 121.9 | 21.9 | |
| 2012 | 333 | 273 | 200 | 238.3 | 13.8 | 171 | 185 | 60 | 106.8 | 23.4 | 392 | 299 | 229 | 255.1 | 11.6 | 186 | 215 | 70 | 129.2 | 26.8 | |
| 2013 | 786 | 275 | 205 | 246.6 | 9.7 | 279 | 185 | 40 | 108.6 | 24.6 | 688 | 297 | 213 | 257.6 | 11.1 | 293 | 250 | 75 | 134.5 | 30.5 | |
| 2014 | 650 | 287 | 203 | 243.4 | 13.4 | 289 | 200 | 30 | 101.5 | 27.1 | 723 | 301 | 214 | 259.0 | 14.6 | 305 | 290 | 45 | 136.6 | 40.0 | |
| 2015 | 653 | 290 | 220 | 249.9 | 8.5 | 270 | 205 | 90 | 125.6 | 17.9 | 742 | 303 | 234 | 262.7 | 12.5 | 310 | 265 | 90 | 156.3 | 31.6 | |

*Fish 170 mm or greater; collected using electrofishing, herring haul seine, and beach seine gears

Best values for length/weight analysis

Table 18. Annual catch and effort (n-hauls) for alewife and blueback herring.

| Year | Annual Effort (N-hauls & Efish events) | Weeks sampled | Annual Catch (Alewife) | Annual Catch (Blueback) |
|------------------------|--|------------------|------------------------------|-------------------------------|
| Historical survey data | | | | |
| 1975 | 2 | 2 | 0 | 4 |
| 1976 | 3 | 2 | 0 | 3 |
| 1977 | 1 | 1 | 2 | 0 |
| 1978 | 0 | 0 | 0 | 0 |
| 1979 | 4 | 3 | 69 | 30 |
| 1980 | 3 | 3 | 4 | 1 |
| 1981 | 3 | 2 | 5 | 2 |
| 1982 | 3 | 3 | 3 | 4 |
| 1983 | 2 | 1 | 1 | 3 |
| 1984 | 3 | 3 | 5 | 28 |
| 1985 | 2 | 2 | 19 | 21 |
| 1986 | 0 | 0 | 0 | 0 |
| 1987 | 5 | 3 | 461 | 1626 |
| 1988 | 1 | 1 | 0 | 0 |
| 1989 | 9 | 4 | 98 | 633 |
| 1990 | 18 | 7 | 252 | 771 |
| 1991 | 2 | 2 | 22 | 17 |
| 1992 | 7 | 3 | 35 | 247 |
| 1993 | 4 | 2 | 37 | 17 |
| 1994 | 0 | 0 | 0 | 0 |
| 1995 | 2 | 2 | 2 | 0 |
| 1996 | 1 | 1 | 0 | 1 |
| 1997 | 1 | 1 | 10 | 0 |
| 1998 | 1 | 1 | 39 | 1 |
| 1999 | 6 | 3 | 12 | 43 |
| 2000 | 2 | 1 | 0 | 0 |
| 2001 | 13 | 3 | 1426 | 33 |
| 2002 | 0 | 0 | 0 | 0 |
| 2003 | 16 | 4 | 417 | 7 |
| 2004 | 3 | 2 | 0 | 10 |
| 2005 | 13 | 4 | 120 | 41 |
| 2006 | 5 | 2 | 27 | 3 |
| 2007 | 6 | 4 | 53 | 0 |
| 2008 | 15 | 4 | 262 | 21 |
| 2009 | 22 | 5 | 660 | 278 |
| 2010 | 63 | 7 | 342 | 117 |
| 2011 | 28 | 6 | 208 | 204 |
| Current survey data | | | | |
| 2012 | 167 | 15 | 2168 | 1314 |
| 2013 | 119 | 11 | 4870 | 4056 |
| 2014 | 114 | 10 | 11231 | 3054 |
| 2015 | 110 | 8 | 4328 | 3080 |

*Only includes hauls when gear performed well without any major issues i.e. no hangs, rips in net, or lifting of the lead line

Table 19. Sampling efforts (n-hauls) and catches per river section from 2012-15.

| River section | 2012 | | | 2013 | | | 2014 | | | 2015 | | |
|-------------------|---------|---------|------------------|---------|---------|------------------|---------|---------|------------------|---------|---------|------------------|
| | N-sites | N-hauls | N-herring caught |
| Albany | 6 | 37 | 1978 | 3 | 21 | 4273 | 3 | 26 | 3440 | 3 | 21 | 2247 |
| Catskill | 14 | 52 | 529 | 9 | 38 | 1639 | 7 | 30 | 3118 | 5 | 33 | 1851 |
| Coxsackie | 15 | 47 | 477 | 10 | 34 | 2269 | 5 | 30 | 5908 | 5 | 33 | 2113 |
| Kingston | 14 | 46 | 468 | 6 | 32 | 787 | 5 | 36 | 1898 | 4 | 32 | 1178 |
| Newburgh | 4 | 11 | - | - | - | - | - | - | - | - | - | - |
| Poughkeepsie | 14 | 3 | 1 | - | - | - | - | - | - | - | - | - |
| IndianPoint | 5 | 6 | - | - | - | - | - | - | - | - | - | - |
| Croton-Haverstraw | 3 | 10 | - | - | - | - | - | - | - | - | - | - |
| TappanZee | 6 | 6 | - | - | - | - | - | - | - | - | - | - |
| Totals | 81 | 218 | 3453 | 28 | 125 | 8968 | 20 | 122 | 14364 | 17 | 119 | 7389 |

Table 20. Catch composition of river herring caught during the 1999-2001 survey* in the Hudson River and its tributaries, including the Mohawk River.

| Year | Geographic Region | Alewife | | | Blueback Herring | | | Total** | | |
|------------------------|--------------------|-------------|-------------|--------------|------------------|-------------|--------------|-------------|--------------|--------------|
| | | Female | Male | Total | Female | Male | Total | Female | Male | Total |
| 1999 | Hudson River | 195 | 89 | 335 | 187 | 56 | 262 | 382 | 145 | 597 |
| | Hudson River Above | | | | | | | | | |
| | Troy | 22 | 31 | 57 | 22 | 13 | 37 | 44 | 44 | 94 |
| | Hudson River | | | | | | | | | |
| | Tributaries | 136 | 1612 | 1758 | 84 | 272 | 358 | 220 | 1884 | 2116 |
| | Mohawk River | | | | 2739 | 3988 | 7083 | 2739 | 3988 | 7083 |
| | Total | 353 | 1732 | 2150 | 3032 | 4329 | 7740 | 3385 | 6061 | 9890 |
| 2000 | Hudson River | 664 | 602 | 1317 | 1134 | 600 | 1784 | 1798 | 1202 | 3101 |
| | Hudson River Above | | | | | | | | | |
| | Troy | 21 | 6 | 27 | 120 | 56 | 183 | 141 | 62 | 210 |
| | Hudson River | | | | | | | | | |
| | Tributaries | 171 | 3046 | 3246 | 18 | 56 | 75 | 189 | 3102 | 3321 |
| | Mohawk River | | | | 636 | 678 | 1372 | 636 | 678 | 1372 |
| | Total | 856 | 3654 | 4590 | 1908 | 1390 | 3414 | 2764 | 5044 | 8004 |
| 2001 | Hudson River | 554 | 607 | 1213 | 1312 | 1051 | 2471 | 1866 | 1658 | 3684 |
| | Hudson River Above | | | | | | | | | |
| | Troy | 9 | 6 | 15 | 134 | 75 | 213 | 143 | 81 | 228 |
| | Hudson River | | | | | | | | | |
| | Tributaries | 286 | 1880 | 2185 | 27 | 16 | 44 | 313 | 1896 | 2229 |
| | Mohawk River | | | | 1172 | 1086 | 2379 | 1172 | 1086 | 2379 |
| | Total | 849 | 2493 | 3413 | 2645 | 2228 | 5107 | 3494 | 4721 | 8520 |
| TOTAL ALL YEARS | | 2058 | 7879 | 10153 | 7585 | 7947 | 16261 | 9643 | 15826 | 26414 |

* NAI 2008, Vol. 1, Table 5.1

** Total includes herring of undetermined sex

Table 21. Minimum sample sizes required to detect a difference in mean length from Equation 1. Bolded values were used in trend analyses.

| Species | Sex | minimum samples sizes | | |
|----------|--------|-----------------------|-------|------|
| | | 5mm | 2.5mm | 1mm |
| Blueback | male | 56 | 222 | 1387 |
| Blueback | female | 70 | 278 | 1732 |
| Alewife | male | 73 | 291 | 1817 |
| Alewife | female | 92 | 367 | 2293 |

Table 22. Age and Z estimates (Chapman-Robson) of river herring caught during NYSDEC spawning stock surveys. 1989-1990: electrofishing in Mohawk R/lock 9 to Troy Dam; 2009-2015: Hudson River only-Haul Seine and Electrofishing.

| Year | Age | | | | | | | | | n | Mean Age | Instantaneous mortality (Z)* |
|-------------------------|-----|-----|-----|------|-----|----|----|---|------|------|----------|------------------------------|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | | |
| Alewife Male | | | | | | | | | | | | |
| 2012 | 27 | 385 | 726 | 308 | 91 | 21 | 2 | | 1559 | 4.08 | 1.12 | |
| 2013 | | 615 | 782 | 276 | 48 | 15 | 1 | | 1737 | 3.89 | 1.30 | |
| 2014 | 1 | 372 | 933 | 1233 | 61 | 18 | 29 | | 2647 | 4.43 | 0.91 | |
| 2015 | | 105 | 430 | 544 | 203 | 12 | 8 | | 1302 | 4.70 | 1.40 | |
| Alewife Female | | | | | | | | | | | | |
| 2012 | 5 | 76 | 210 | 175 | 32 | 11 | 7 | 2 | 518 | 4.44 | 0.88 | |
| 2013 | | 148 | 275 | 84 | 58 | 17 | 12 | 1 | 596 | 4.26 | 0.90 | |
| 2014 | | 83 | 537 | 383 | 137 | 75 | 27 | 5 | 1247 | 4.75 | 0.76 | |
| 2015 | | 56 | 179 | 372 | 114 | 30 | 8 | | 759 | 4.87 | 1.29 | |
| Blueback Herring Male | | | | | | | | | | | | |
| 1989 | | 44 | 164 | 74 | 5 | 1 | | | 288 | 4.15 | 1.32 | |
| 1990 | 8 | 143 | 100 | 41 | 7 | | | | 299 | 3.65 | 0.88 | |
| 2012 | 64 | 157 | 89 | 16 | 3 | | | | 329 | 3.20 | 1.10 | |
| 2013 | 34 | 483 | 209 | 44 | 17 | | | | 787 | 3.40 | 1.15 | |
| 2014 | 83 | 308 | 205 | 51 | 1 | | | | 649 | 3.35 | 1.03 | |
| 2015 | 3 | 412 | 168 | 44 | 3 | | | | 630 | 3.42 | 1.21 | |
| Blueback Herring Female | | | | | | | | | | | | |
| 1989 | | 31 | 182 | 77 | 7 | | | | 297 | 4.20 | 1.36 | |
| 1990 | 6 | 86 | 102 | 52 | 8 | | | | 254 | 3.88 | 1.20 | |
| 2012 | | 152 | 168 | 61 | 4 | | | | 385 | 3.78 | 0.82 | |
| 2013 | 1 | 364 | 203 | 97 | 21 | 1 | | | 687 | 3.67 | 0.91 | |
| 2014 | 7 | 320 | 274 | 77 | 36 | 9 | | | 723 | 3.78 | 0.81 | |
| 2015 | | 248 | 262 | 162 | 36 | 9 | | | 716 | 4.02 | 1.02 | |

*Z estimates derived from bias-corrected Chapman-Robson mortality estimator as described in Smith et al. 2012 using the age at most abundance as the age at full recruitment.

Table 23. Percent repeat spawner and Z estimates of river herring caught in NYSDEC spawning stock surveys. 1989-1990: electrofishing in Mohawk R/lock 9 to Troy Dam; 2009-2015: Hudson River only-Haul Seine and Electrofishing.

| Year | Repeat spawn marks | | | | | | n | Mean RS | % Virgin | % Repeat | Instantaneous mortality (Z)* |
|-------------------------|--------------------|----|----|----|---|---|-----|---------|----------|----------|------------------------------|
| | 0 | 1 | 2 | 3 | 4 | 5 | | | | | |
| Alewife Male | | | | | | | | | | | |
| 2009 | 229 | 65 | 12 | 0 | | | 306 | 0.29 | 75% | 25% | 1.48 |
| 2010 | 165 | 28 | 11 | 2 | | | 206 | 0.27 | 80% | 20% | 1.53 |
| 2011 | 101 | 18 | 2 | 1 | 1 | | 123 | 0.24 | 82% | 18% | 1.62 |
| 2012 | 138 | 35 | 19 | 1 | | | 193 | 0.39 | 72% | 28% | 1.25 |
| 2013 | 150 | 23 | 13 | 2 | | | 188 | 0.29 | 80% | 20% | 1.50 |
| 2014 | 52 | 19 | 7 | 4 | 2 | | 84 | 0.63 | 62% | 38% | 0.93 |
| 2015 | 54 | 19 | 25 | 6 | 1 | 1 | 106 | 0.91 | 51% | 49% | 0.73 |
| Alewife Female | | | | | | | | | | | |
| 2009 | 70 | 41 | 9 | 1 | | | 121 | 0.51 | 58% | 42% | 1.07 |
| 2010 | 51 | 32 | 15 | 2 | 1 | | 101 | 0.71 | 50% | 50% | 0.86 |
| 2011 | 84 | 25 | 12 | 2 | | | 123 | 0.45 | 68% | 32% | 1.16 |
| 2012 | 124 | 36 | 17 | 5 | 3 | | 185 | 0.52 | 67% | 33% | 1.06 |
| 2013 | 116 | 39 | 24 | 9 | 8 | | 196 | 0.74 | 59% | 41% | 0.84 |
| 2014 | 42 | 13 | 10 | 10 | 4 | 2 | 81 | 1.10 | 52% | 48% | 0.64 |
| 2015 | 32 | 25 | 20 | 8 | 4 | | 89 | 1.18 | 36% | 64% | 0.59 |
| Blueback herring Male | | | | | | | | | | | |
| 1989 | 187 | 83 | 18 | | | | 288 | 0.41 | 65% | 35% | 1.22 |
| 1990 | 235 | 46 | 18 | | | | 299 | 0.27 | 79% | 21% | 1.52 |
| 2009 | 38 | 24 | 2 | | | | 64 | 0.44 | 59% | 41% | 1.16 |
| 2010 | 63 | 12 | 4 | | | | 79 | 0.25 | 80% | 20% | 1.55 |
| 2011 | 66 | 12 | 1 | | | | 79 | 0.18 | 84% | 16% | 1.83 |
| 2012 | 294 | 28 | 7 | | | | 329 | 0.13 | 89% | 11% | 2.22 |
| 2013 | 118 | 7 | 2 | 1 | | | 128 | 0.11 | 92% | 8% | 2.25 |
| 2014 | 57 | 9 | 4 | 1 | | | 71 | 0.28 | 80% | 20% | 1.47 |
| 2015 | 48 | 9 | 7 | | | | 64 | 0.36 | 75% | 25% | 1.29 |
| Blueback herring Female | | | | | | | | | | | |
| 1989 | 224 | 66 | 7 | | | | 297 | 0.27 | 75% | 25% | 1.54 |
| 1990 | 200 | 44 | 10 | | | | 254 | 0.25 | 79% | 21% | 1.59 |
| 2009 | 44 | 12 | 3 | | | | 59 | 0.31 | 75% | 25% | 1.40 |
| 2010 | 46 | 16 | 4 | | | | 66 | 0.36 | 70% | 30% | 1.28 |
| 2011 | 80 | 26 | 5 | 1 | | | 112 | 0.35 | 71% | 29% | 1.33 |
| 2012 | 107 | 26 | 2 | 1 | | | 136 | 0.24 | 79% | 21% | 1.60 |
| 2013 | 121 | 19 | 11 | 4 | | | 155 | 0.34 | 78% | 22% | 1.35 |
| 2014 | 48 | 10 | 12 | 4 | | | 74 | 0.62 | 65% | 35% | 0.94 |
| 2015 | 41 | 21 | 13 | 4 | | | 79 | 0.75 | 52% | 48% | 0.83 |

*Z estimates derived from bias-corrected Chapman-Robson mortality estimator as described in Smith et al. 2012 using the age at most abundance as the age at full recruitment.

Table 24. NYSDEC and HRG young-of-year Alewife indices. NYSDEC index is a geometric mean CPUE for all hauls between Julian weeks 26 and 42. The HRG BSS index is a weighted arithmetic mean CPUE for weeks 33 to 40. The HRG FSS index is a weighted mean density for the channel strata for weeks 33-40.

| Year | Alewife | | | | | | Blueback Herring | | | | | |
|------|--------------------|------|-----------------------|------|-----------------|------|--------------------|------|-----------------------|-------|-----------------|-------|
| | NYSDEC Beach Seine | | HRG Beach Seine (BSS) | | HRG Trawl (FSS) | | NYSDEC Beach Seine | | HRG Beach Seine (BSS) | | HRG Trawl (FSS) | |
| | CPUE | SE | CPUE | SE | Density | SE | CPUE | SE | CPUE | SE | Density | SE |
| 1974 | | | 2.92 | 0.44 | | | | | 23.51 | 3.39 | | |
| 1975 | | | 2.47 | 0.40 | | | | | 69.66 | 9.49 | | |
| 1976 | | | 2.40 | 0.63 | | | | | 155.55 | 23.84 | | |
| 1977 | | | 4.18 | 0.61 | | | | | 219.37 | 26.38 | | |
| 1978 | | | 5.49 | 0.97 | | | | | 229.19 | 44.49 | | |
| 1979 | | | 1.35 | 0.23 | 0.20 | 0.08 | | | 54.45 | 8.32 | 3.70 | 0.75 |
| 1980 | 0.25 | 0.13 | 0.50 | 0.16 | 0.69 | 0.35 | 12.02 | 0.53 | 100.84 | 53.80 | 2.61 | 0.75 |
| 1981 | 0.23 | 0.18 | 4.15 | 0.94 | 0.63 | 0.21 | 7.18 | 0.69 | 181.93 | 72.90 | 21.20 | 5.86 |
| 1982 | 0.61 | 0.19 | 0.79 | 0.24 | 0.28 | 0.08 | 15.87 | 0.60 | 121.72 | 31.43 | 10.33 | 2.06 |
| 1983 | 0.37 | 0.06 | 1.79 | 0.27 | 0.19 | 0.07 | 35.51 | 0.19 | 190.86 | 41.85 | 6.08 | 1.07 |
| 1984 | 0.05 | 0.02 | 0.49 | 0.14 | 0.21 | 0.13 | 11.26 | 0.20 | 22.66 | 5.41 | 20.39 | 3.67 |
| 1985 | 0.60 | 0.07 | 0.74 | 0.17 | 0.93 | 0.41 | 21.00 | 0.18 | 18.82 | 3.90 | 17.42 | 4.58 |
| 1986 | 0.21 | 0.04 | 0.83 | 0.51 | 0.26 | 0.08 | 17.11 | 0.16 | 14.10 | 4.41 | 6.48 | 1.38 |
| 1987 | 0.33 | 0.07 | 0.65 | 0.12 | 0.52 | 0.27 | 35.19 | 0.21 | 69.80 | 15.69 | 25.61 | 12.36 |
| 1988 | 0.32 | 0.05 | 0.42 | 0.09 | 0.27 | 0.13 | 43.32 | 0.16 | 47.41 | 14.02 | 26.69 | 4.30 |
| 1989 | 0.17 | 0.03 | 0.16 | 0.04 | 0.23 | 0.07 | 16.78 | 0.17 | 35.88 | 8.09 | 16.83 | 5.41 |
| 1990 | 0.57 | 0.07 | 1.05 | 0.17 | 0.35 | 0.14 | 44.33 | 0.19 | 97.85 | 13.97 | 29.69 | 10.64 |
| 1991 | 1.04 | 0.09 | 3.47 | 0.57 | 0.33 | 0.12 | 24.25 | 0.17 | 47.44 | 11.06 | 12.65 | 1.47 |
| 1992 | 0.29 | 0.04 | 0.30 | 0.12 | 0.17 | 0.08 | 13.95 | 0.15 | 31.10 | 6.53 | 15.52 | 3.87 |
| 1993 | 0.46 | 0.06 | 0.54 | 0.16 | 0.23 | 0.08 | 29.28 | 0.17 | 35.23 | 5.52 | 7.72 | 1.59 |
| 1994 | 0.72 | 0.07 | 1.40 | 0.34 | 0.12 | 0.06 | 27.47 | 0.19 | 88.84 | 13.78 | 5.77 | 1.90 |
| 1995 | 0.46 | 0.06 | 1.14 | 0.35 | 0.11 | 0.03 | 6.52 | 0.14 | 38.18 | 23.30 | 1.27 | 0.42 |
| 1996 | 0.39 | 0.06 | 0.10 | 0.04 | 0.49 | 0.15 | 21.39 | 0.15 | 36.71 | 17.55 | 50.16 | 15.89 |
| 1997 | 0.50 | 0.06 | 2.26 | 0.44 | 0.32 | 0.10 | 15.60 | 0.17 | 162.11 | 35.44 | 7.30 | 1.43 |
| 1998 | 0.16 | 0.03 | 0.21 | 0.15 | 0.03 | 0.02 | 1.45 | 0.11 | 1.28 | 0.31 | 0.03 | 0.03 |
| 1999 | 2.94 | 0.11 | 4.53 | 1.07 | 0.70 | 0.17 | 34.58 | 0.16 | 58.67 | 17.79 | 2.07 | 0.78 |
| 2000 | 0.69 | 0.07 | 0.60 | 0.32 | 0.20 | 0.08 | 10.79 | 0.13 | 25.98 | 14.98 | 2.68 | 1.16 |
| 2001 | 2.11 | 0.10 | 2.73 | 0.78 | 0.87 | 0.72 | 43.84 | 0.17 | 57.61 | 11.40 | 5.85 | 5.00 |
| 2002 | 1.13 | 0.09 | 0.58 | 0.10 | 0.02 | 0.01 | 2.83 | 0.13 | 12.63 | 5.77 | 0.80 | 0.55 |
| 2003 | 0.74 | 0.06 | 3.39 | 0.90 | 0.29 | 0.12 | 17.10 | 0.16 | 119.20 | 27.39 | 5.92 | 1.89 |
| 2004 | 0.50 | 0.05 | 1.27 | 0.36 | 0.10 | 0.04 | 7.52 | 0.15 | 49.56 | 11.71 | 1.52 | 0.35 |
| 2005 | 1.43 | 0.09 | 5.29 | 1.23 | 0.34 | 0.09 | 26.41 | 0.16 | 65.86 | 20.09 | 2.33 | 1.05 |
| 2006 | 0.58 | 0.07 | 0.80 | 0.44 | 0.04 | 0.02 | 2.41 | 0.11 | 8.28 | 3.44 | 0.53 | 0.15 |
| 2007 | 4.56 | 0.13 | 6.69 | 2.00 | 1.87 | 1.14 | 33.22 | 0.16 | 71.60 | 9.05 | 5.24 | 0.91 |
| 2008 | 2.28 | 0.11 | 3.89 | 1.00 | 0.80 | 0.54 | 17.03 | 0.16 | 39.99 | 8.85 | 5.56 | 1.35 |
| 2009 | 0.45 | 0.06 | 1.37 | 0.47 | 0.04 | 0.03 | 2.80 | 0.12 | 3.88 | 1.14 | 0.87 | 0.25 |
| 2010 | 2.92 | 0.12 | 7.28 | 2.21 | 0.80 | 0.34 | 15.48 | 0.16 | 66.64 | 20.06 | 4.00 | 2.11 |
| 2011 | 0.95 | 0.08 | 1.79 | 0.36 | 0.31 | 0.11 | 15.89 | 0.17 | 41.62 | 6.29 | 13.63 | 1.96 |
| 2012 | 0.36 | 0.06 | 0.25 | 0.09 | 0.15 | 0.06 | 6.03 | 0.15 | 34.66 | 10.55 | 4.32 | 1.43 |
| 2013 | 1.00 | 0.09 | 0.25 | 0.09 | 0.04 | 0.03 | 0.60 | 0.07 | 0.78 | 0.45 | 0.02 | 0.02 |
| 2014 | 0.93 | 0.09 | 0.53 | 0.14 | 1.15 | 0.26 | 52.22 | 0.15 | 74.18 | 21.59 | 27.21 | 9.10 |
| 2015 | 1.07 | 0.10 | 3.01 | 0.60 | 1.25 | 0.34 | 7.53 | 0.14 | 46.78 | 8.69 | 2.86 | 0.75 |

Table 25. Annual estimates of alewife and blueback herring American shad conditional entrainment and impingement mortality rates from water withdrawals* at power generating and other cooling systems on the Hudson River. (CHGE et al. 1999)

| Year | Alewife | | | Blueback herring | | |
|------|-------------|-------------|-------|------------------|-------------|-------|
| | Entrainment | Impingement | Total | Entrainment | Impingement | Total |
| 1974 | 27.19 | 1.44 | 28.63 | 27.19 | 0.36 | 27.55 |
| 1975 | 40.67 | 1.44 | 42.11 | 40.67 | 0.36 | 41.03 |
| 1976 | 31.10 | 1.44 | 32.54 | 31.10 | 0.36 | 31.46 |
| 1977 | 32.99 | 1.44 | 34.43 | 32.99 | 0.36 | 33.35 |
| 1978 | 27.50 | 1.44 | 28.94 | 27.50 | 0.36 | 27.86 |
| 1979 | 27.42 | 1.44 | 28.86 | 27.42 | 0.36 | 27.78 |
| 1980 | 24.71 | 1.44 | 26.15 | 24.71 | 0.36 | 25.07 |
| 1981 | 11.98 | 1.44 | 13.42 | 11.98 | 0.36 | 12.34 |
| 1982 | 9.74 | 1.44 | 11.18 | 9.74 | 0.36 | 10.10 |
| 1983 | 21.22 | 1.44 | 22.66 | 21.22 | 0.36 | 21.58 |
| 1984 | 24.80 | 1.44 | 26.24 | 24.80 | 0.36 | 25.16 |
| 1985 | 14.68 | 1.59 | 16.27 | 14.68 | 0.40 | 15.08 |
| 1986 | 10.09 | 1.89 | 11.98 | 10.09 | 0.70 | 10.79 |
| 1987 | 32.36 | 1.40 | 33.76 | 32.36 | 0.30 | 32.66 |
| 1988 | 24.12 | 1.10 | 25.22 | 24.12 | 0.20 | 24.32 |
| 1989 | 32.67 | 1.20 | 33.87 | 32.67 | 0.20 | 32.87 |
| 1990 | 29.65 | 1.44 | 31.09 | 29.65 | 0.36 | 30.01 |
| 1991 | 21.63 | 1.44 | 23.07 | 21.63 | 0.36 | 21.99 |
| 1992 | 39.45 | 1.44 | 40.89 | 39.45 | 0.36 | 39.81 |
| 1993 | 11.24 | 1.44 | 12.68 | 11.24 | 0.36 | 11.60 |
| 1994 | 17.03 | 1.44 | 18.47 | 17.03 | 0.36 | 17.39 |
| 1995 | 14.34 | 1.44 | 15.78 | 14.34 | 0.36 | 14.70 |
| 1996 | 7.69 | 1.44 | 9.13 | 7.69 | 0.36 | 8.05 |
| 1997 | 22.36 | 1.44 | 23.80 | 22.36 | 0.36 | 22.72 |

*For Bowline Point, Indian Point, Roseton, Danskammer, Lovett, Empire State Plaza, Albany Steam Station, Westchester Resco

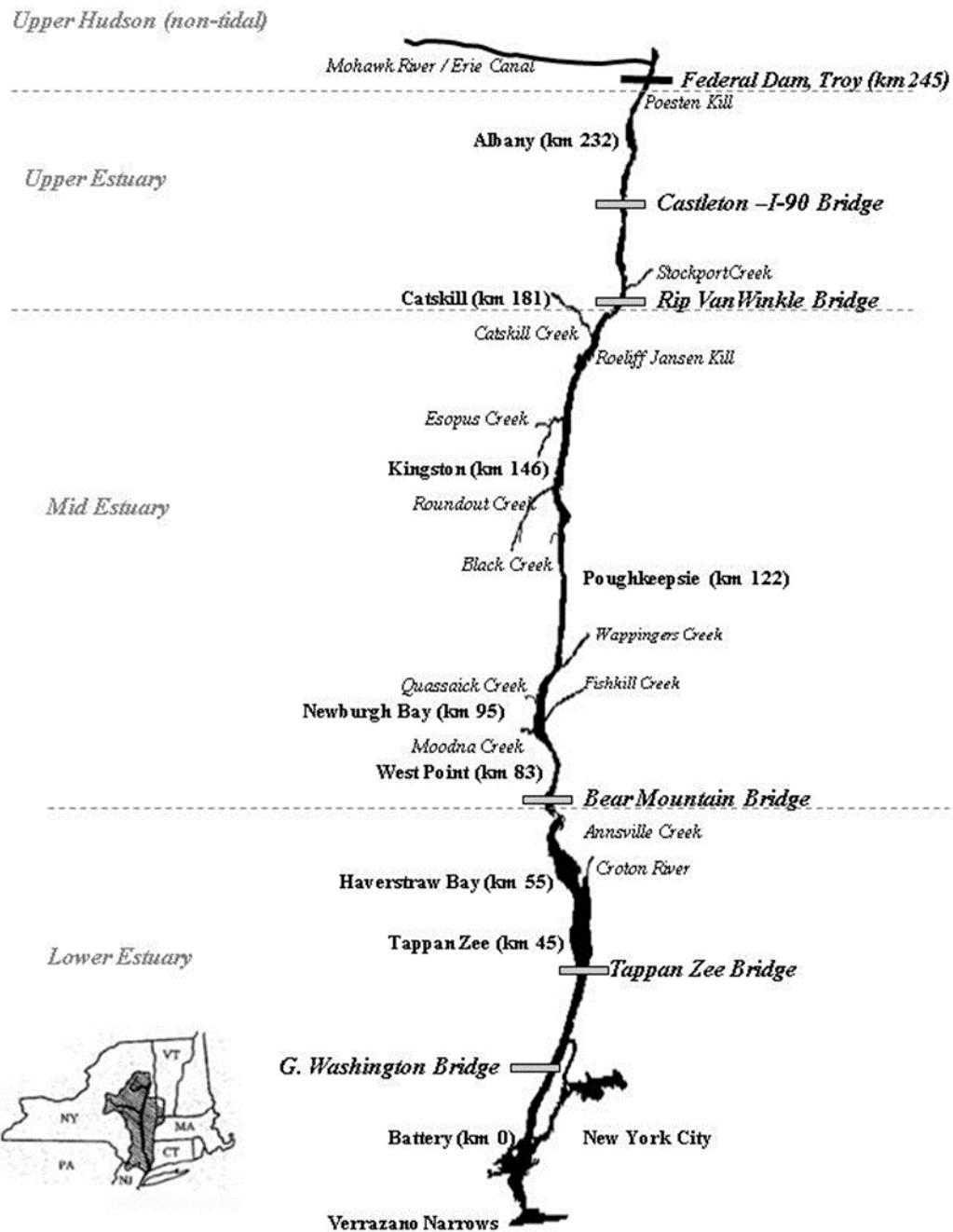


Figure 1. Hudson River Estuary with major spawning tributaries for river herring.

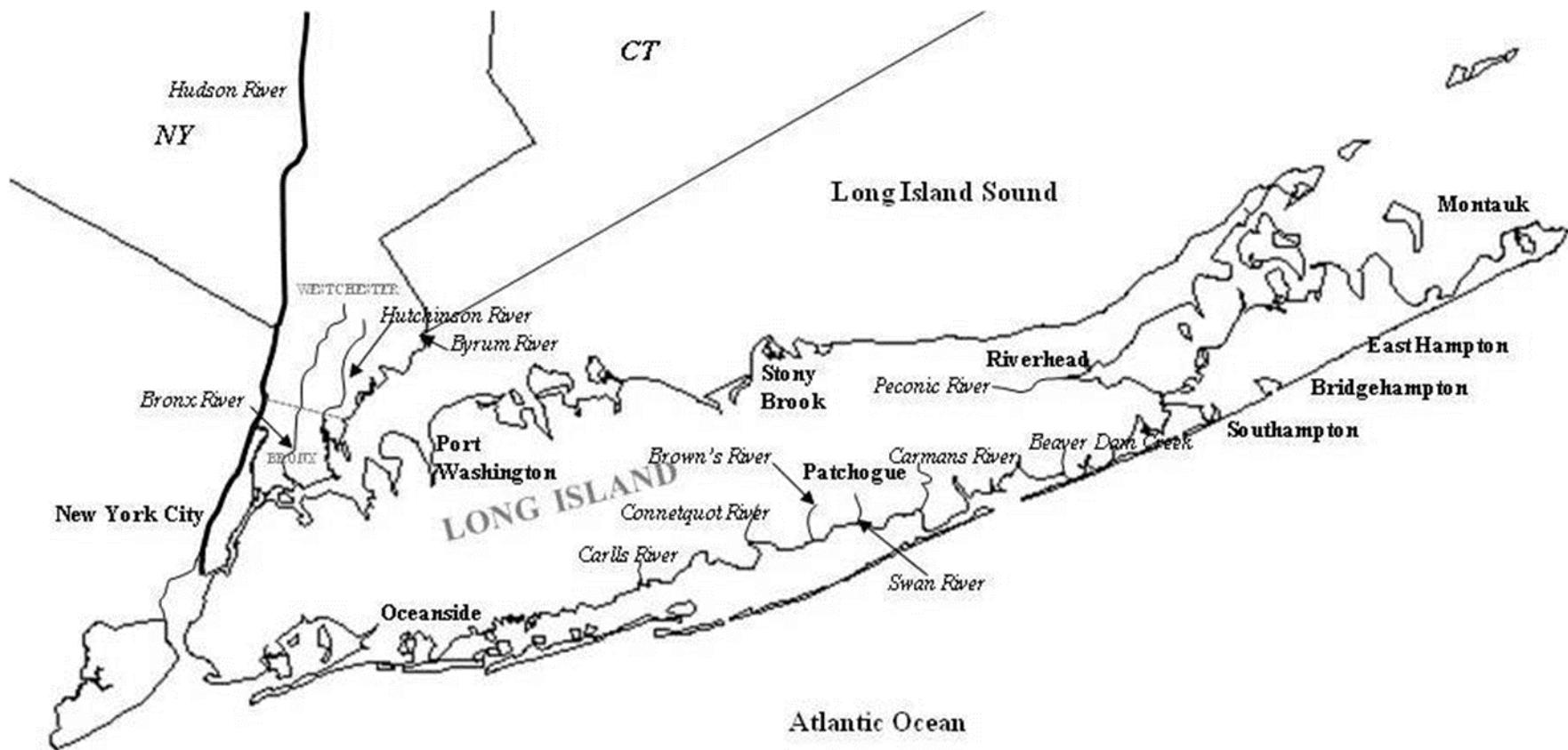


Figure 2. Long Island, Bronx and Westchester Counties, New York, with some river herring (primarily alewife) spawning streams identified.

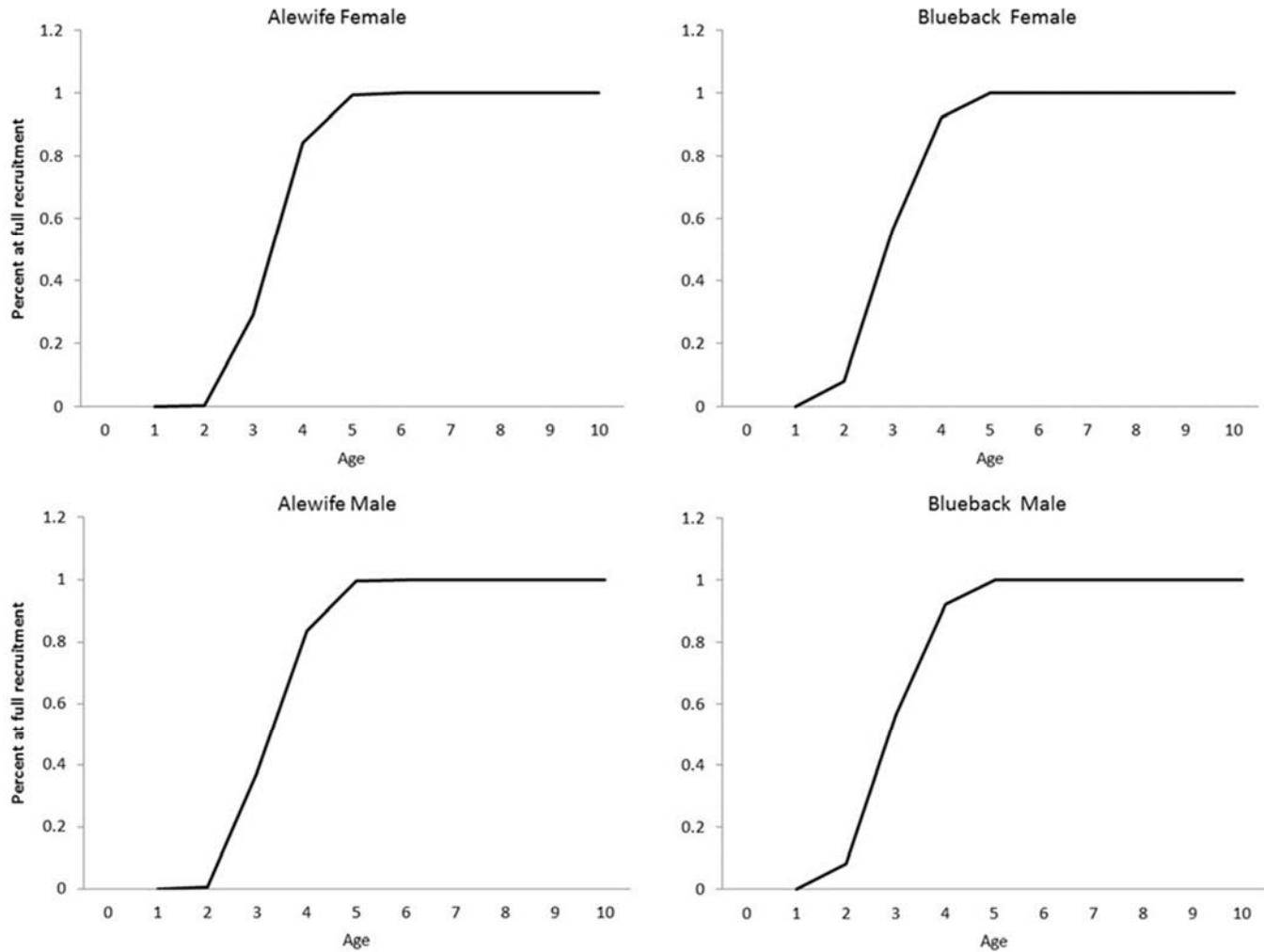


Figure 3. Maturity schedule for alewife and blueback herring derived from 2012-15 age data.

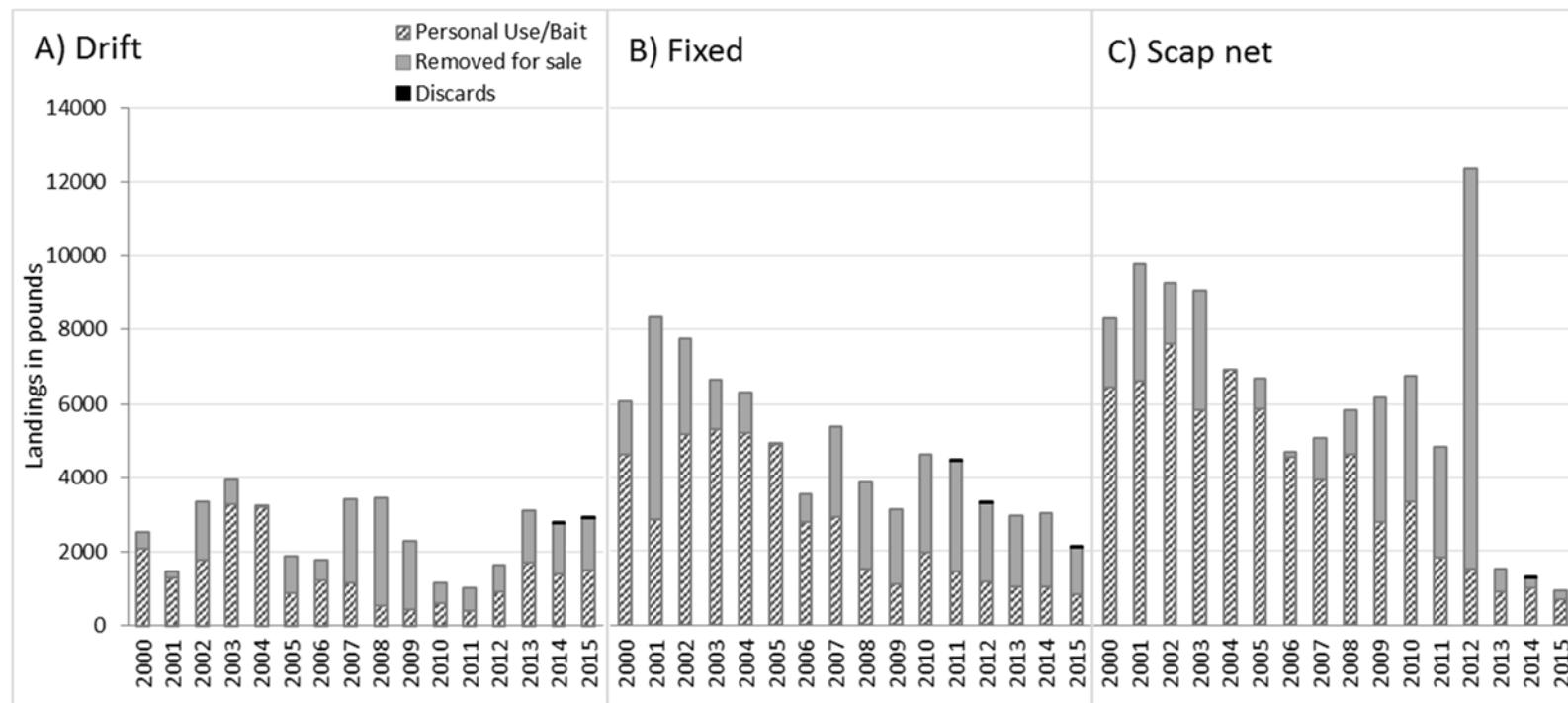


Figure 4. Dispositions of commercially caught river herring as reported in mandatory trip reports. Note very minimal discards in black.

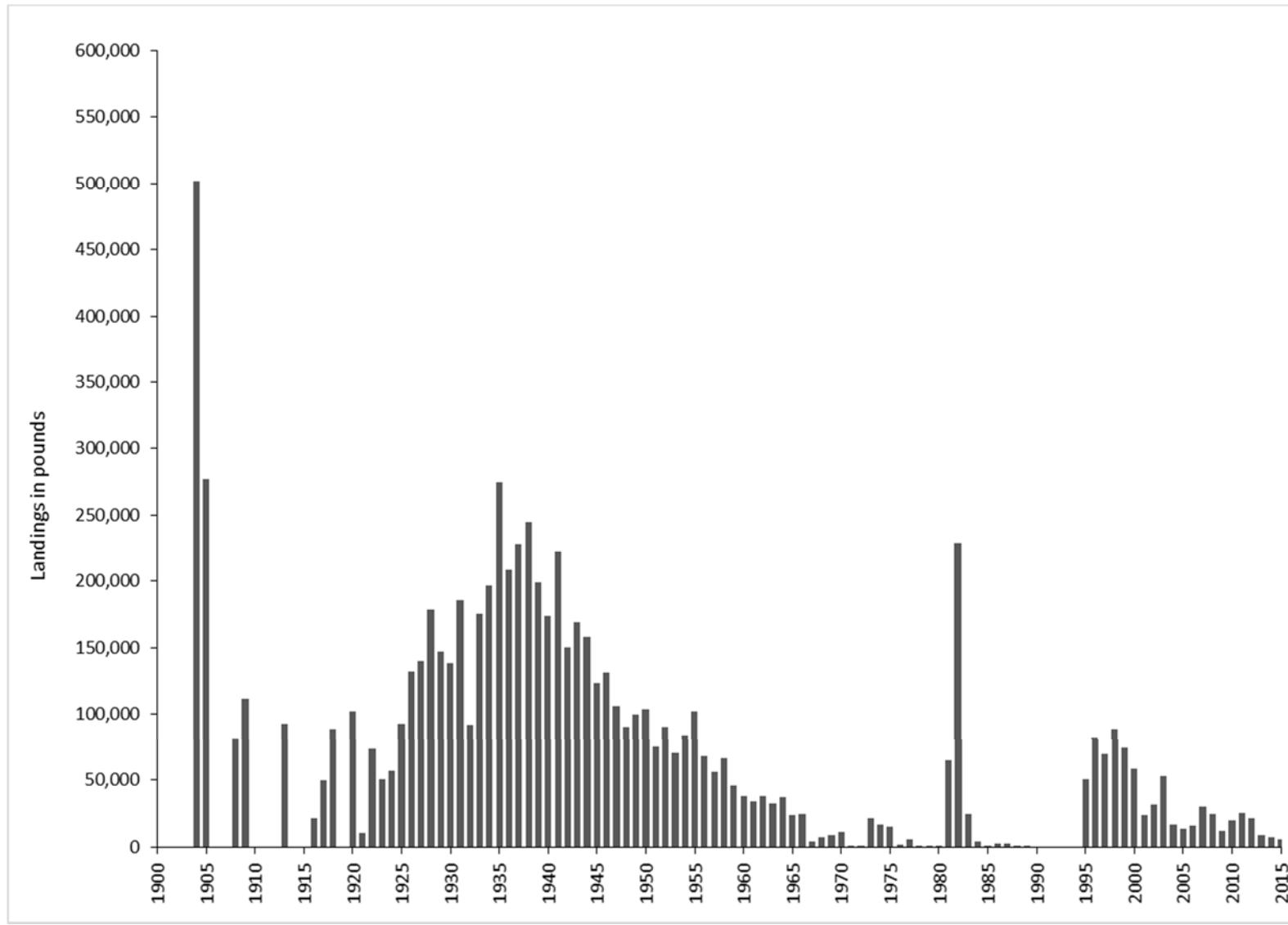


Figure 5. Pounds of river herring landed in New York waters. 1966 data point not included (see text).

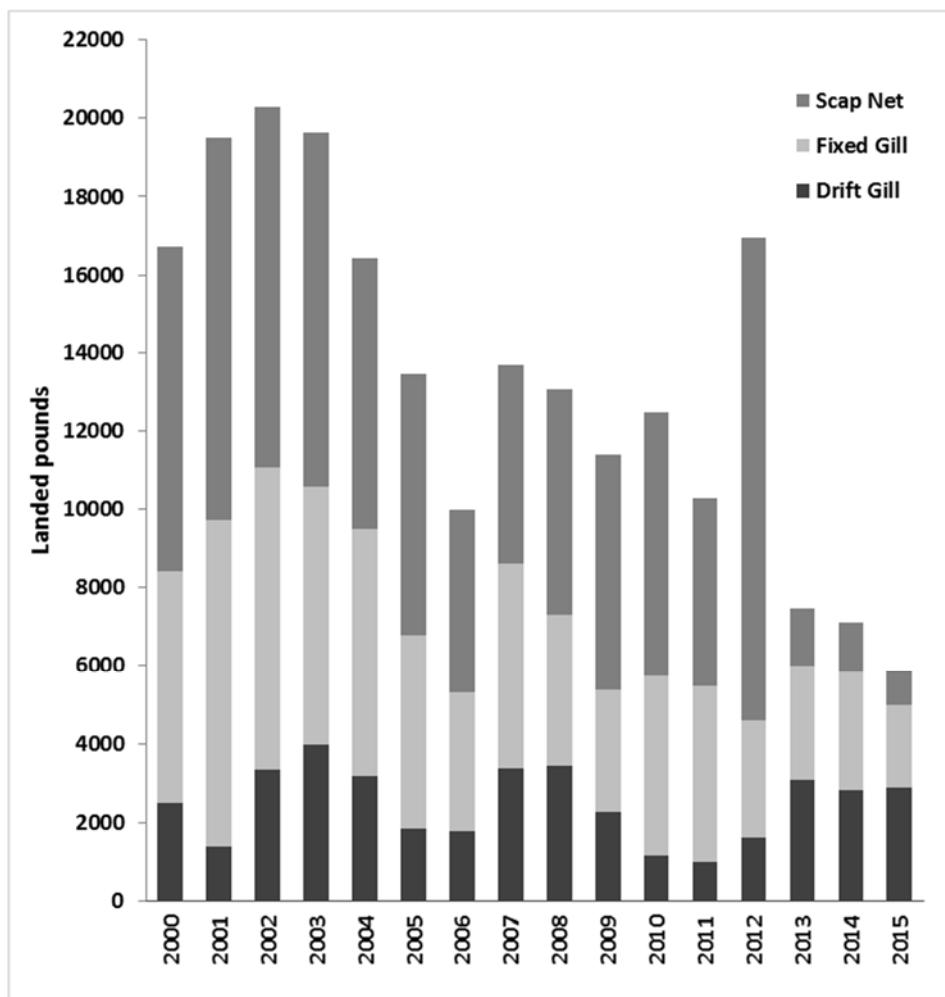


Figure 6. Annual total landed pounds of river herring separated by gear type. Catch includes targeted river herring trips only.

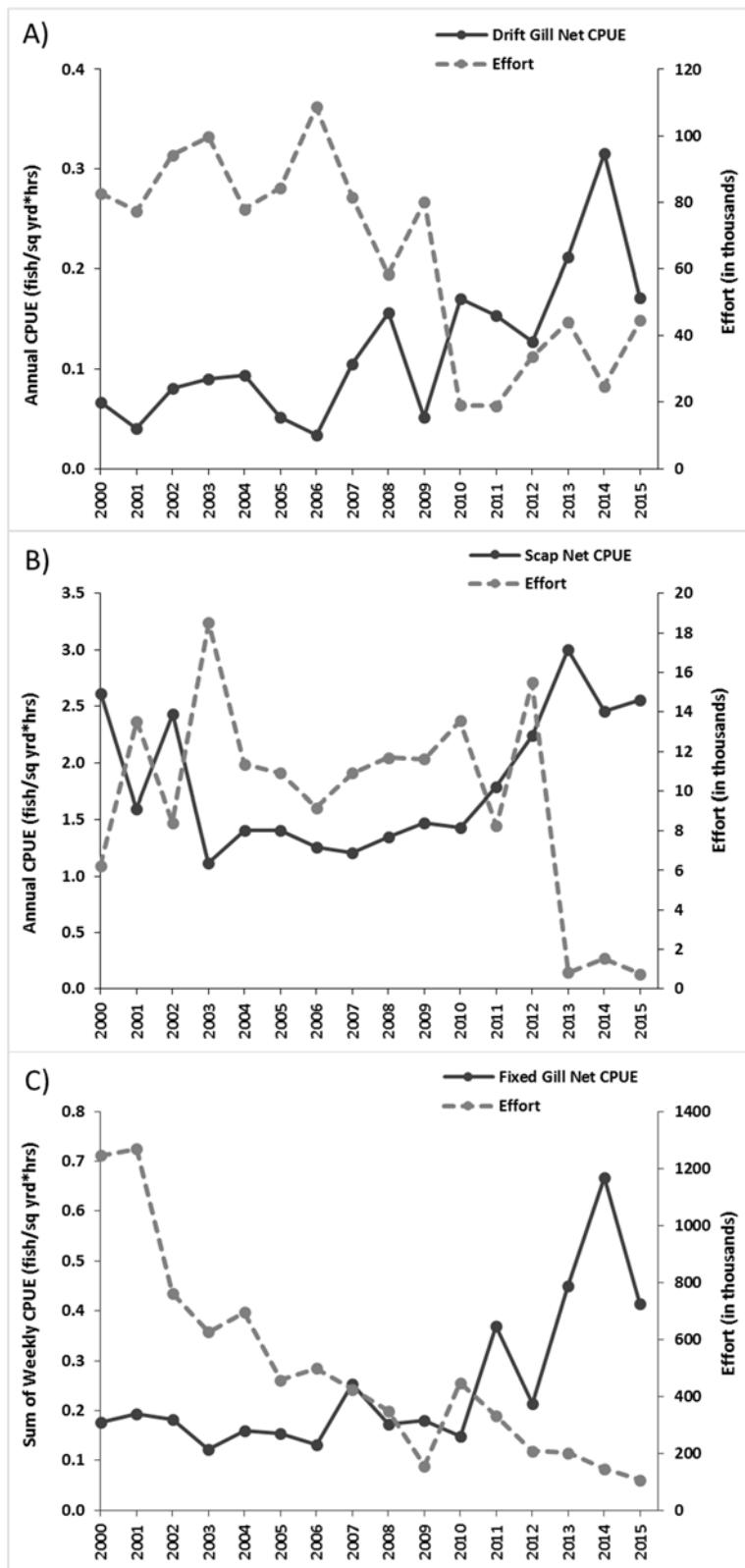


Figure 7. Efforts (sq yd net area * hours) and CPUEs from mandatory commercial reports. A) Drift gill net fishery above rkm 75; CPUE is total catch/total effort. B) Scap net fishery above rkm 75; CPUE is total catch/total effort. C) Fixed gill net fishery below rkm 75; CPUE is the sum of weekly catch/weekly effort.

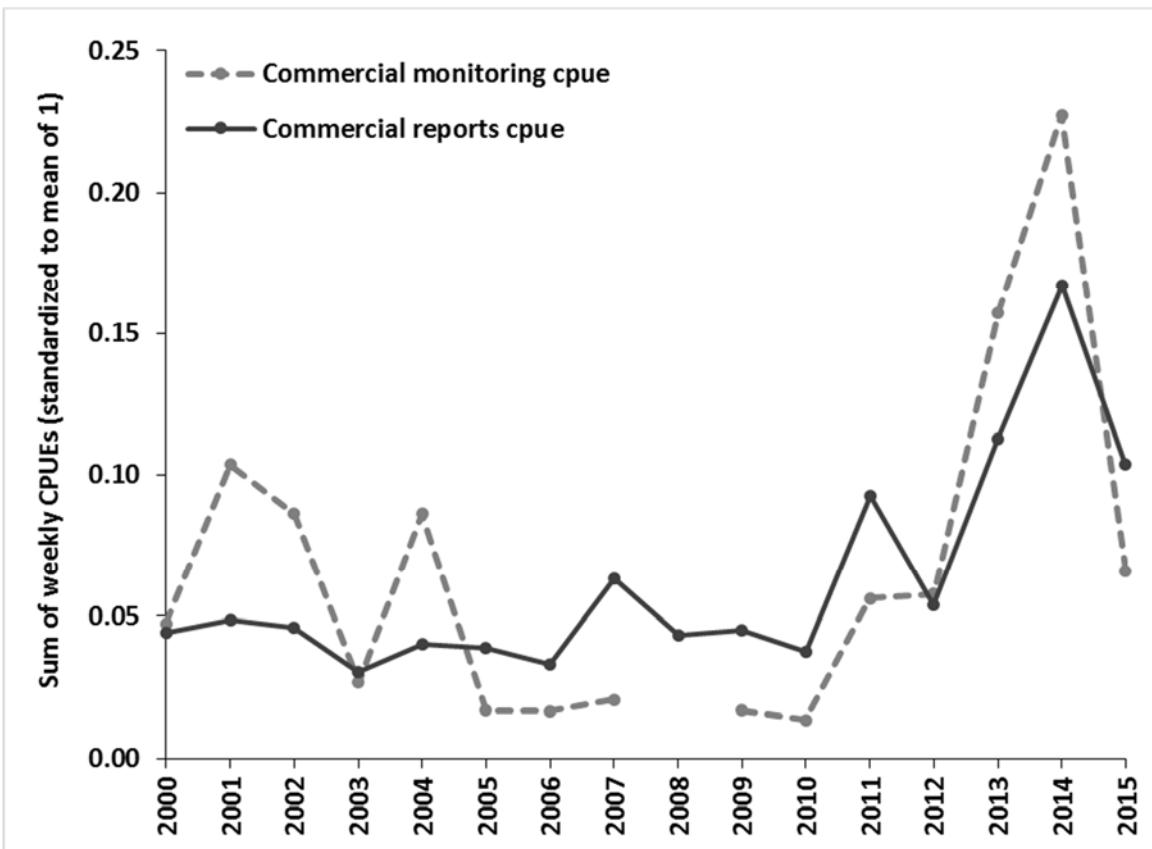


Figure 8. Comparison of the sum of weekly CPUEs calculated from commercial monitoring and mandatory commercial reports of the fixed gill net fishery below the Bear Mountain Bridge (rmk 75). Values are standardized to a mean of 1.

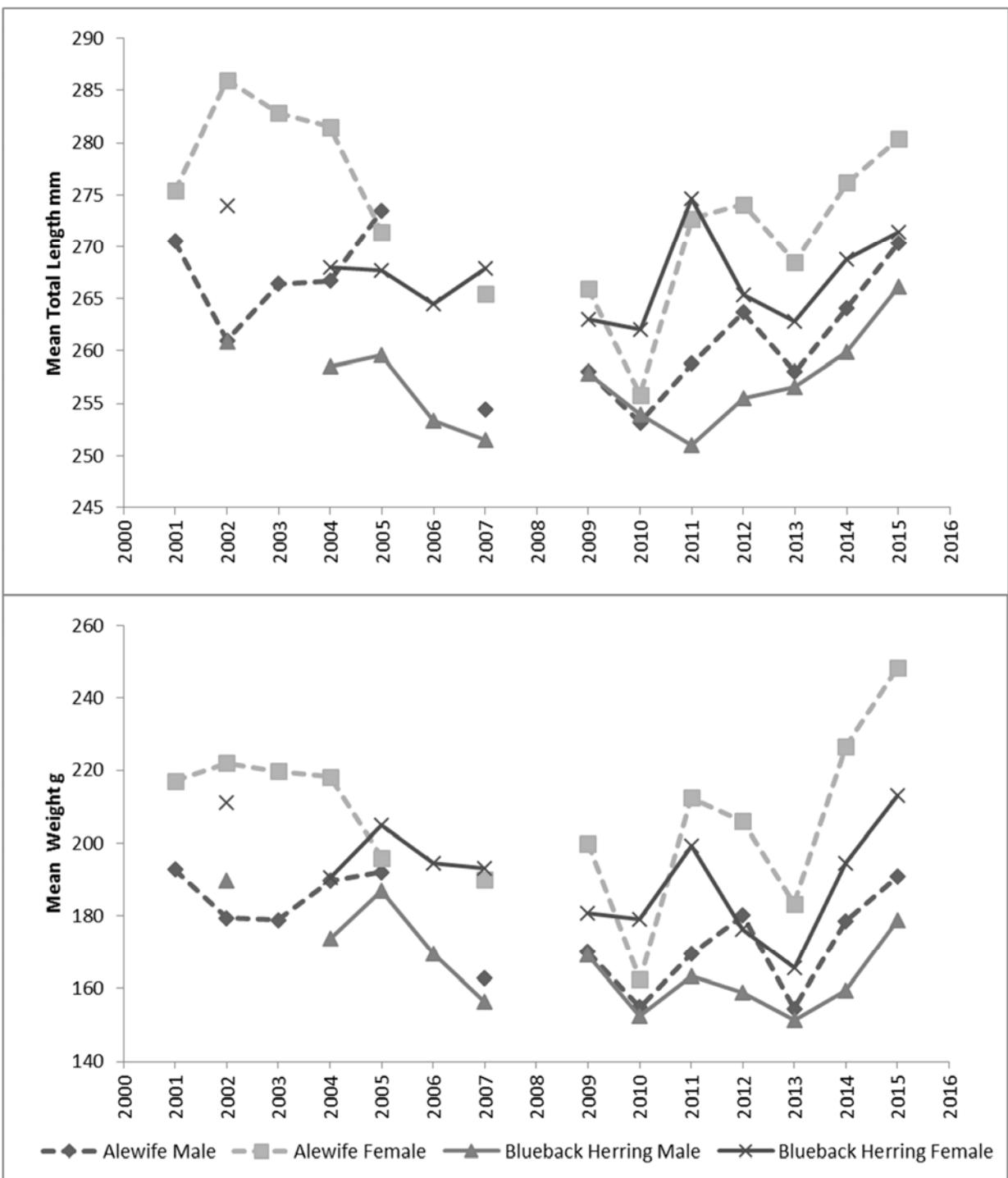


Figure 9. Mean length and weight of river herring collected in fishery dependent sampling in the commercial fishery in the Hudson River.

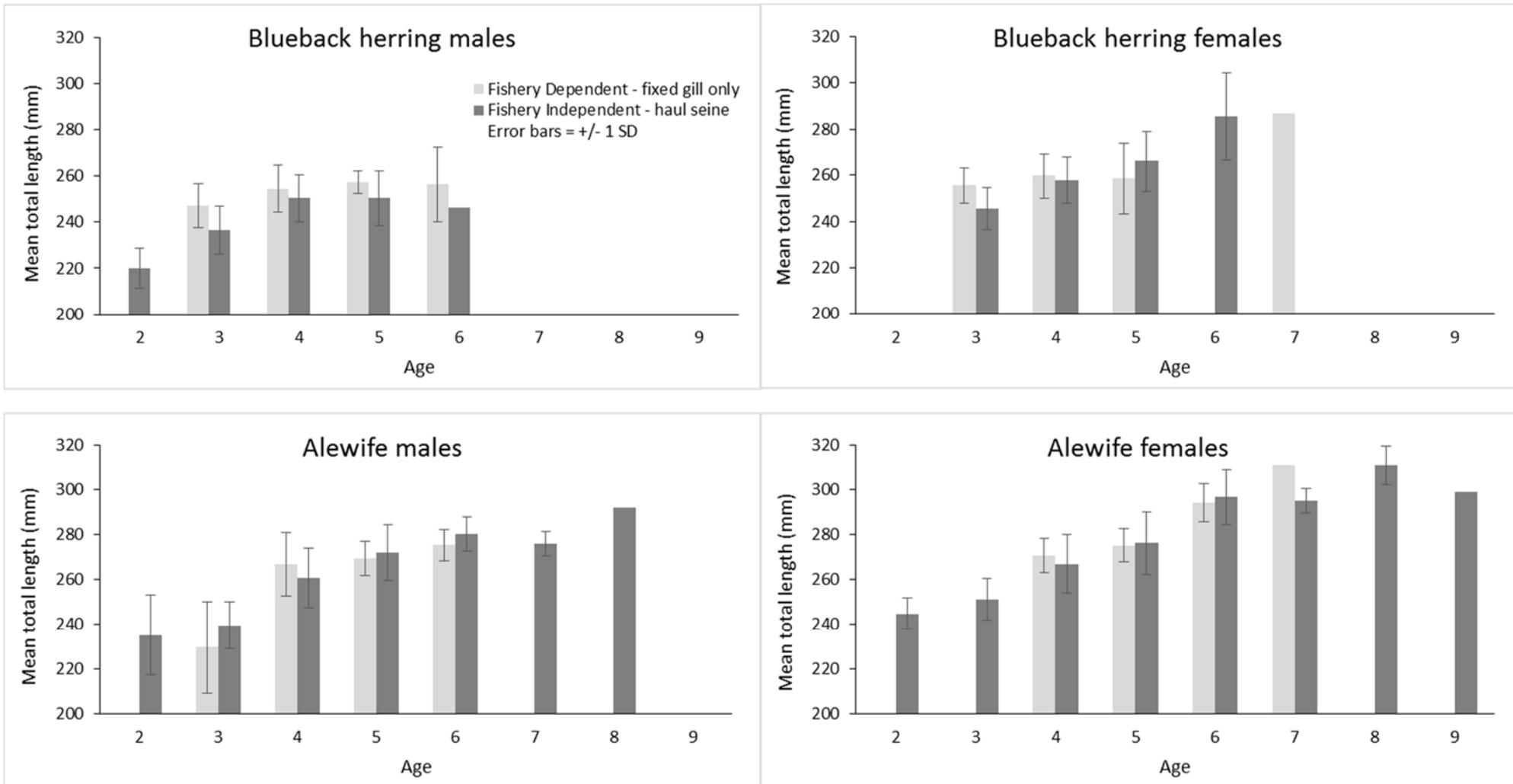


Figure 10. Comparison of length at age of river herring sampled in the lower-river fixed gill net commercial fishery versus the fishery independent survey.



Figure 11. Top: Front view of the counter head that consists of eight four inch PVC tubes fitted with three stainless steel clamps, acting as sensors that measure water conductivity. Bottom left: View of fish counter head during construction. Bottom right: View of in-stream weir and fish counter.

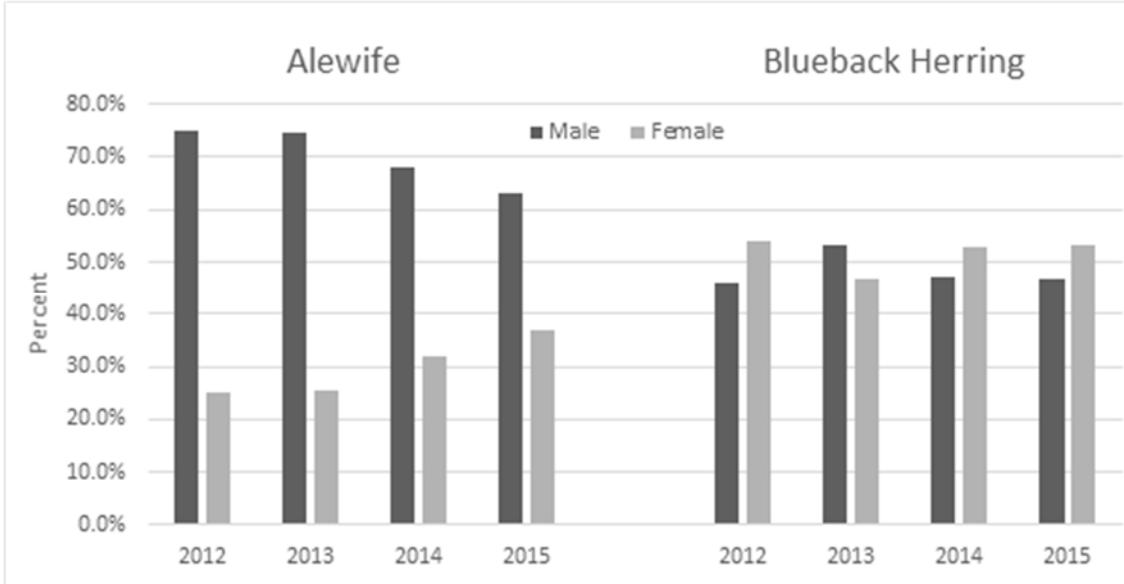
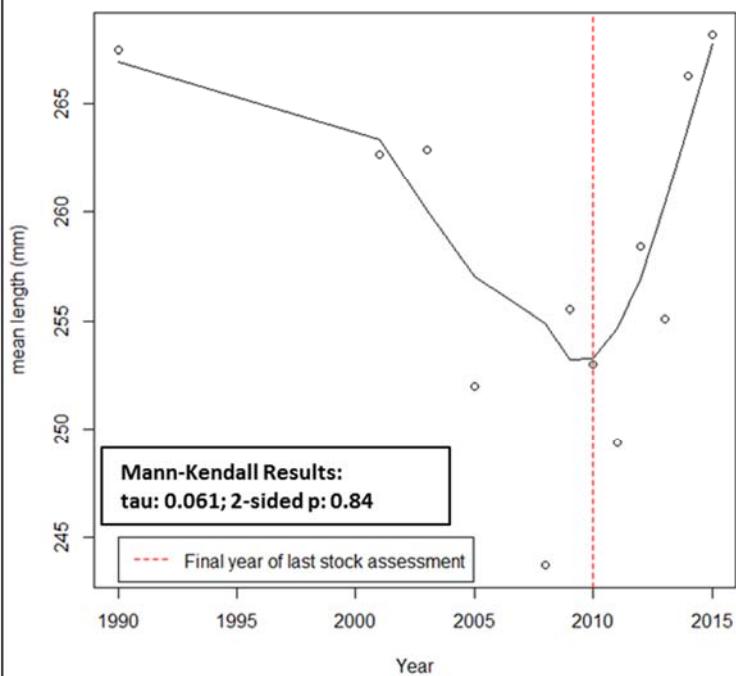
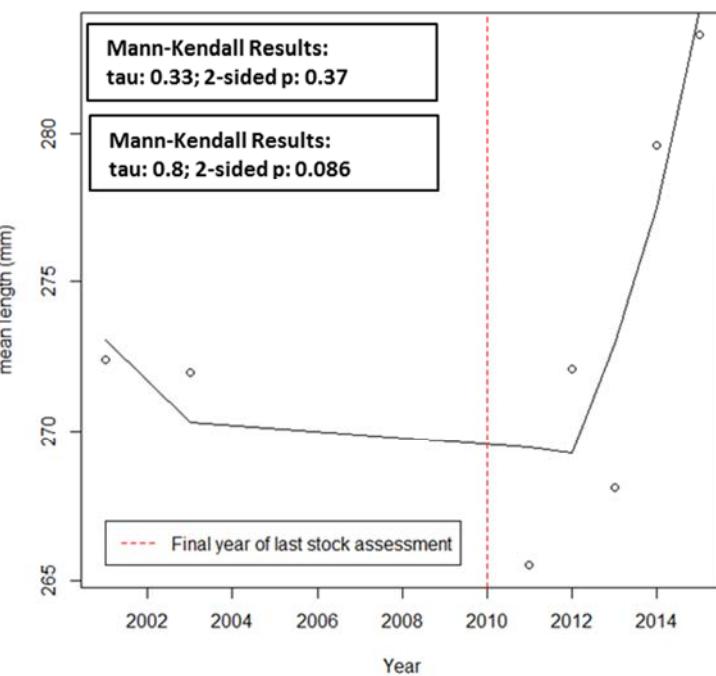


Figure 12. Annual sex ratios from river herring collected during the fisheries independent survey.

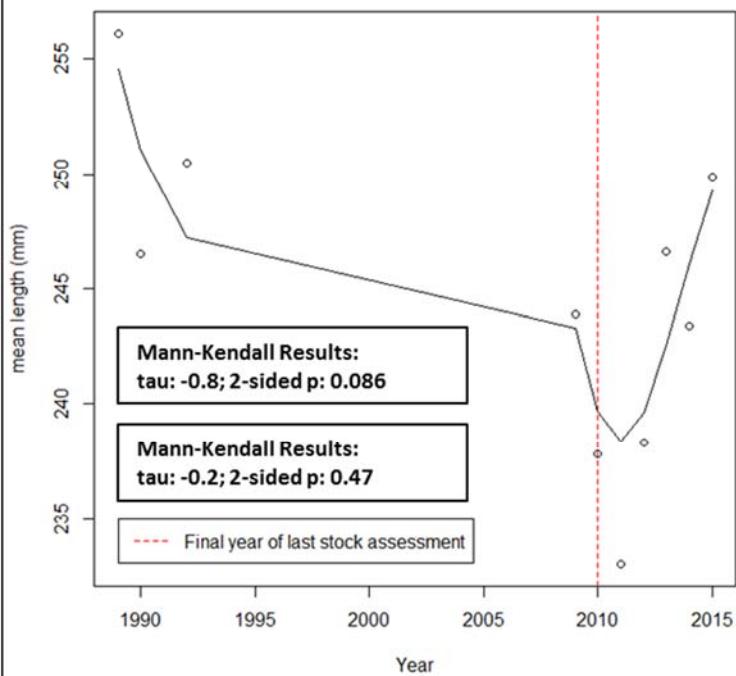
1990-2015: Trends in FI male alewife lengths (mm) - n > 72



2001-2015: Trends in FI female alewife lengths (mm) - n > 91



1989-2015: Trends in FI male blueback lengths (mm) - n > 55



1989-2015: Trends in FI female blueback lengths (mm) - n > 69

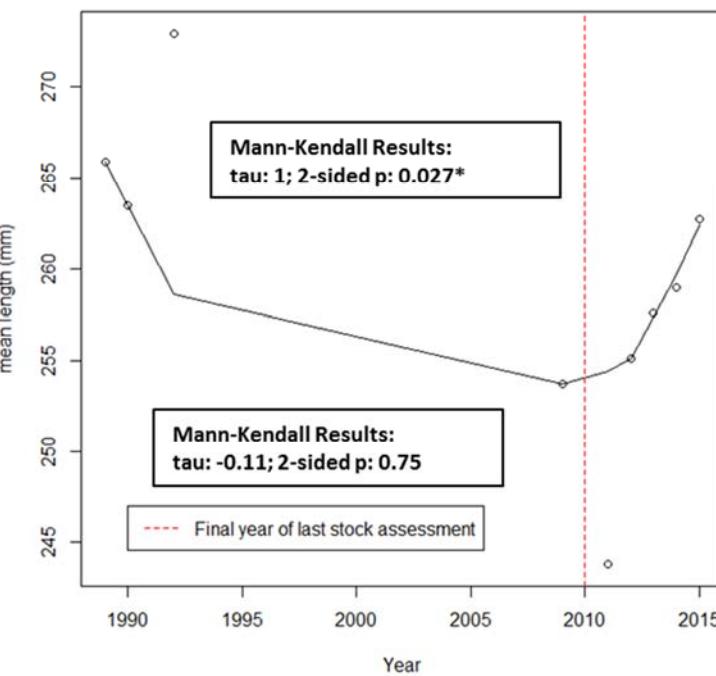


Figure 13. Trends in mean length for river herring by sex and species. Black lines are lowess smoothers (Cleveland 1981) and the red dotted lines indicate the terminal year for data included in the benchmark stock assessment.

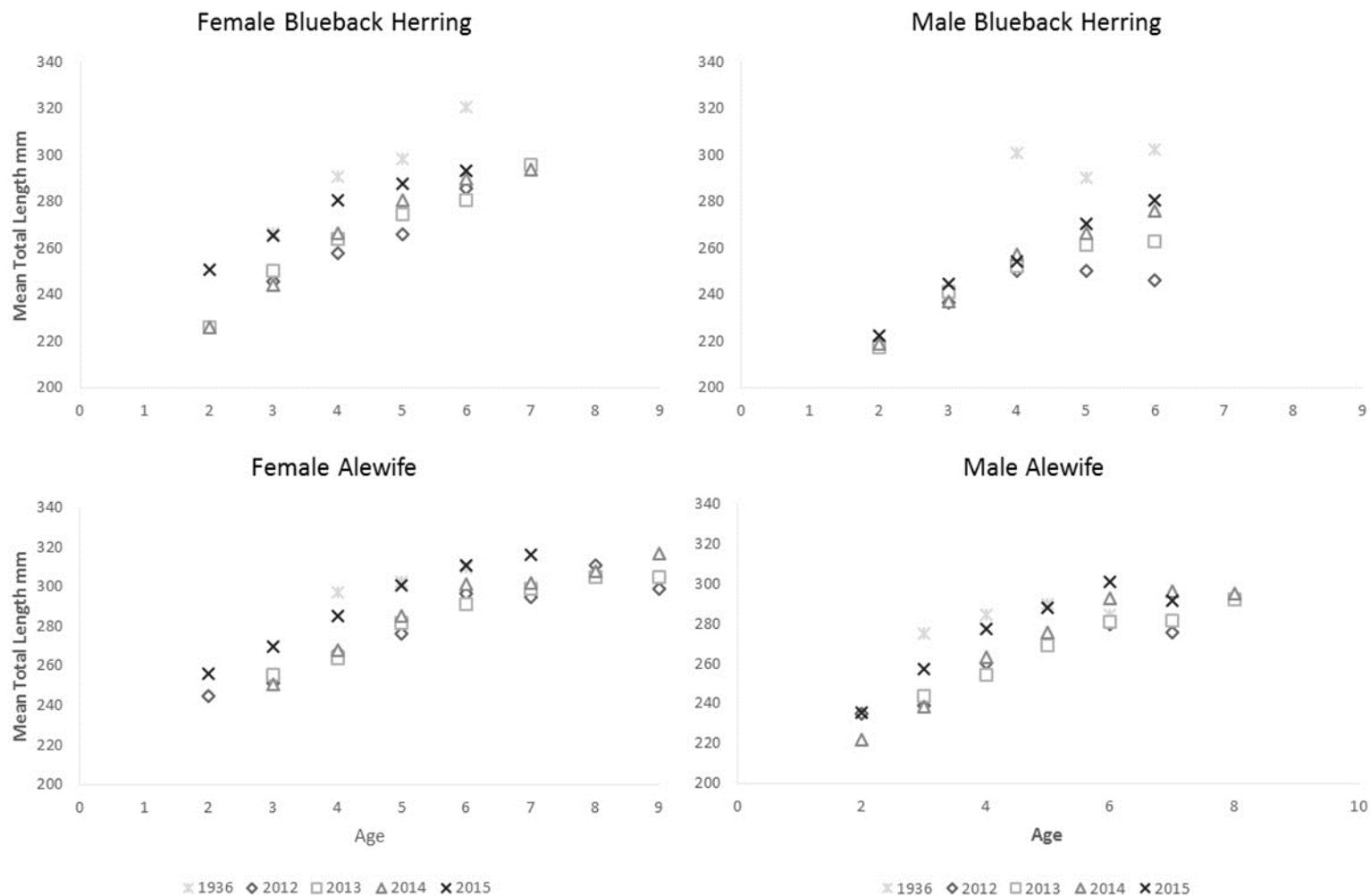


Figure 14. Mean length at age for river herring from fisheries independent sampling.

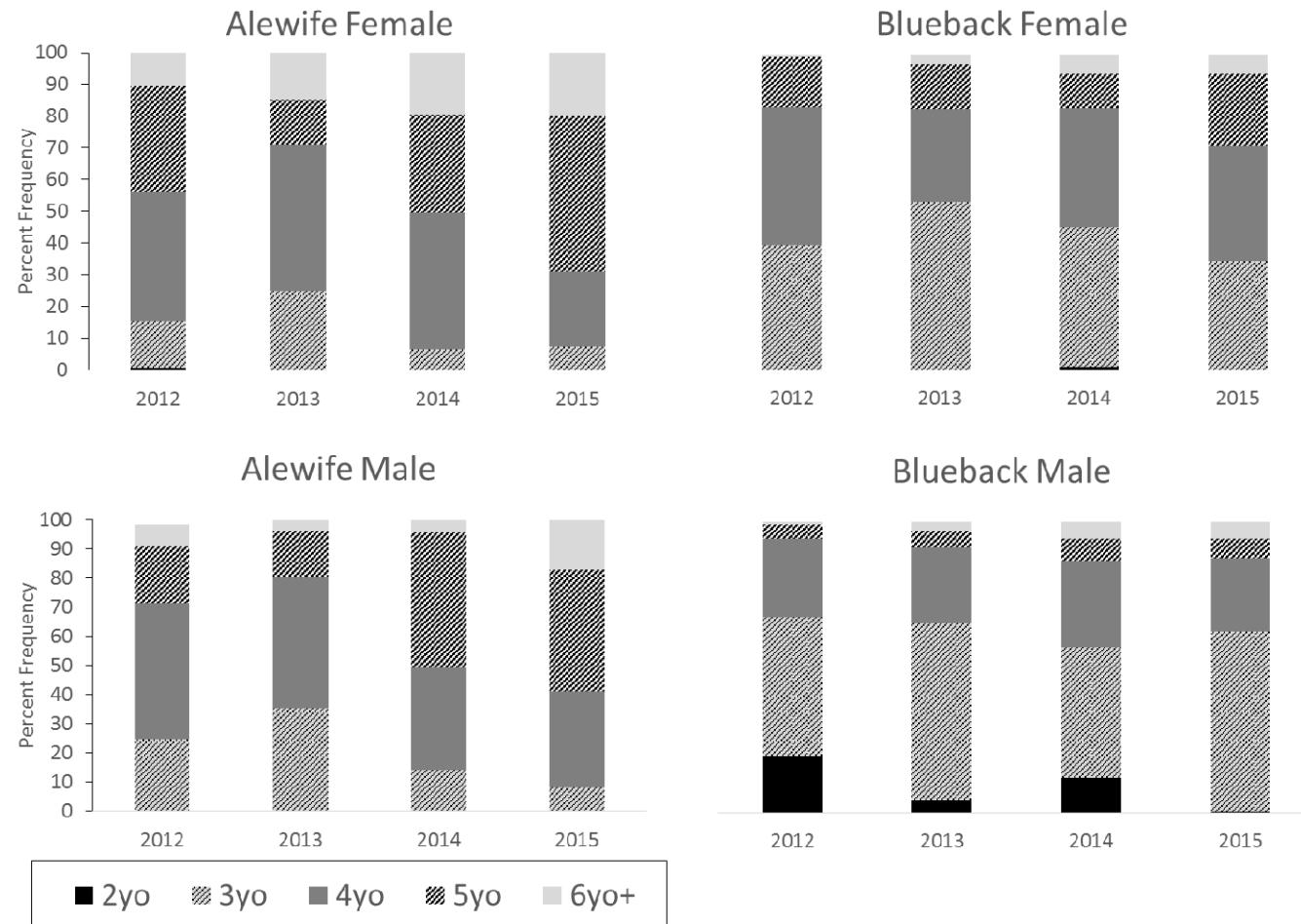


Figure 15. Proportion at age for both species of river herring collected during fisheries independent sampling.

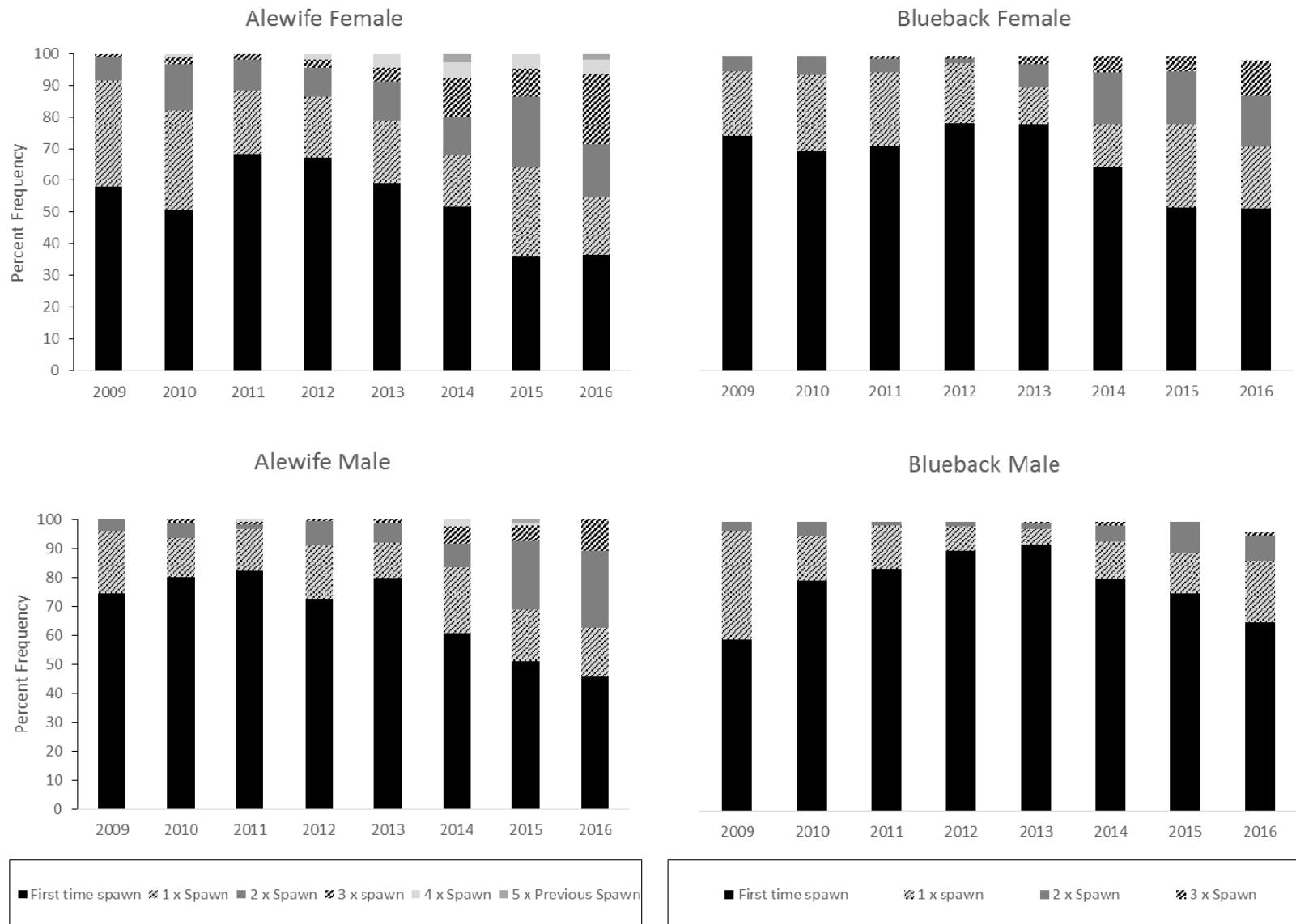


Figure 16. Frequency of repeat spawning occurrence for both species of river herring collected during fisheries independent sampling.

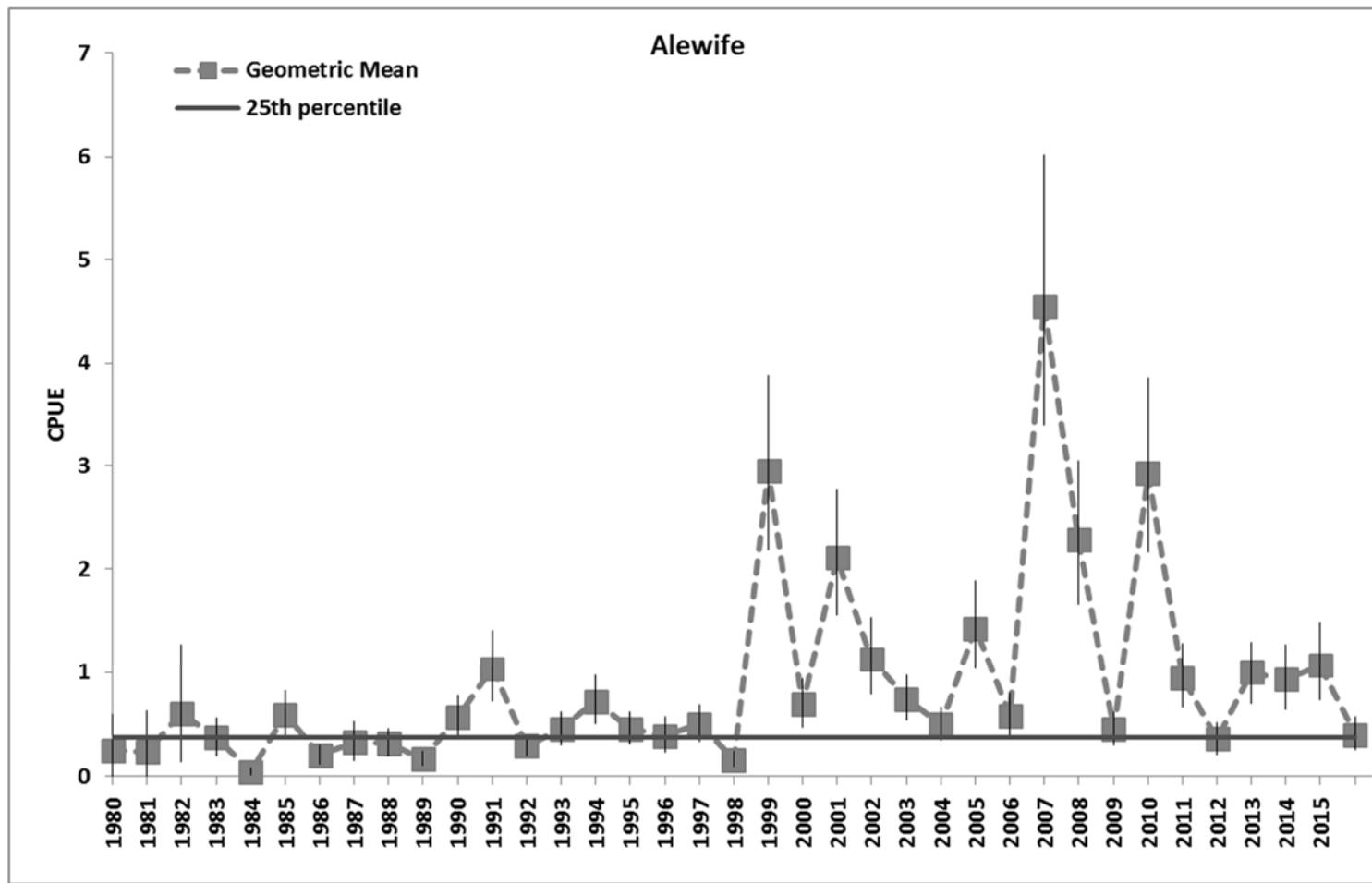


Figure 17. NYSDEC Young-of-year Alewife Index of Abundance. Solid line is the 25th percentile of the values from 1983-2015.

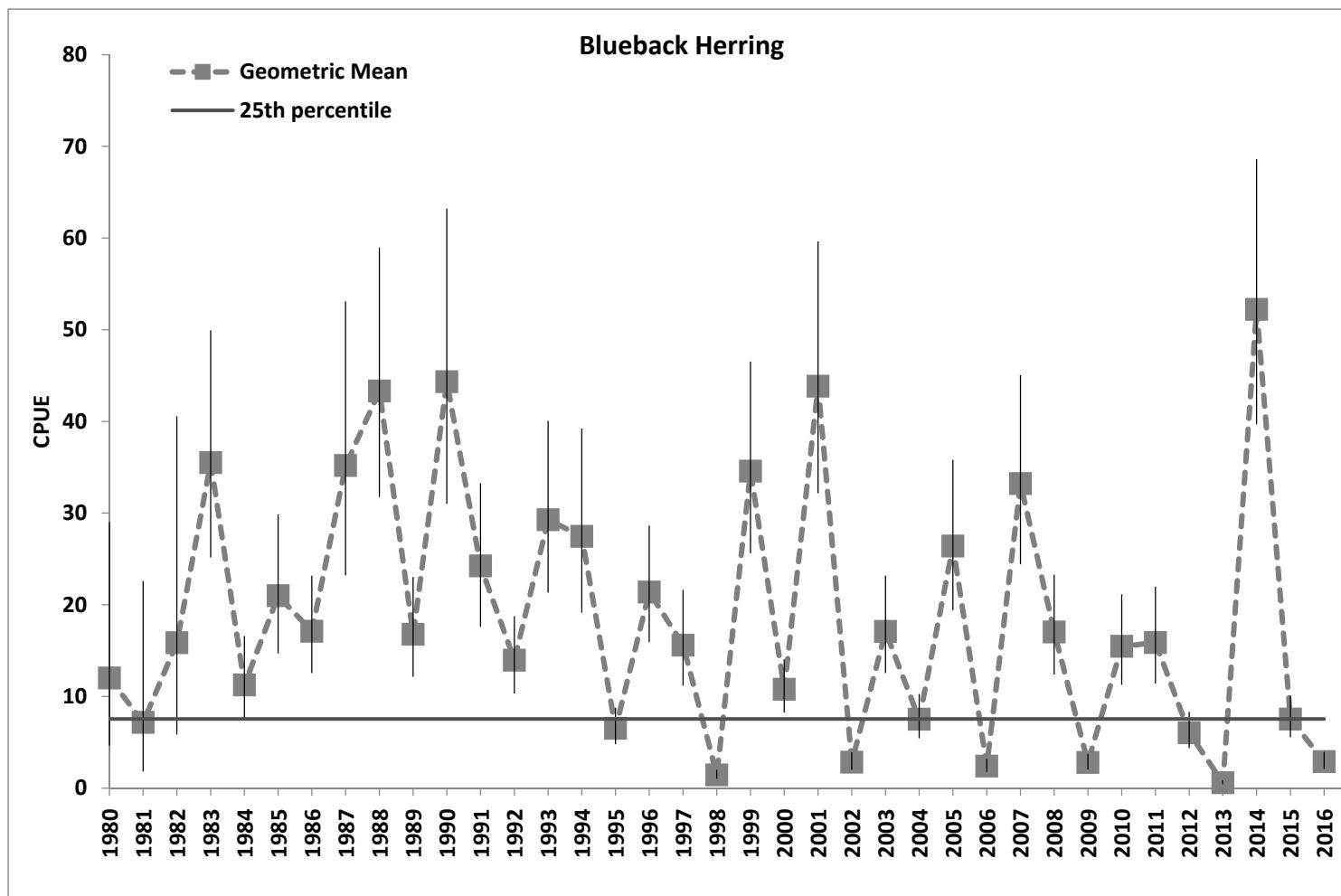


Figure 18. NYSDEC Young-of-year blueback herring index of abundance. Solid line is the 25th percentile of the values from 1983-2015.

Commercial Reporting CPUE: Fixed Gill Nets below Bear Mt. Bridge

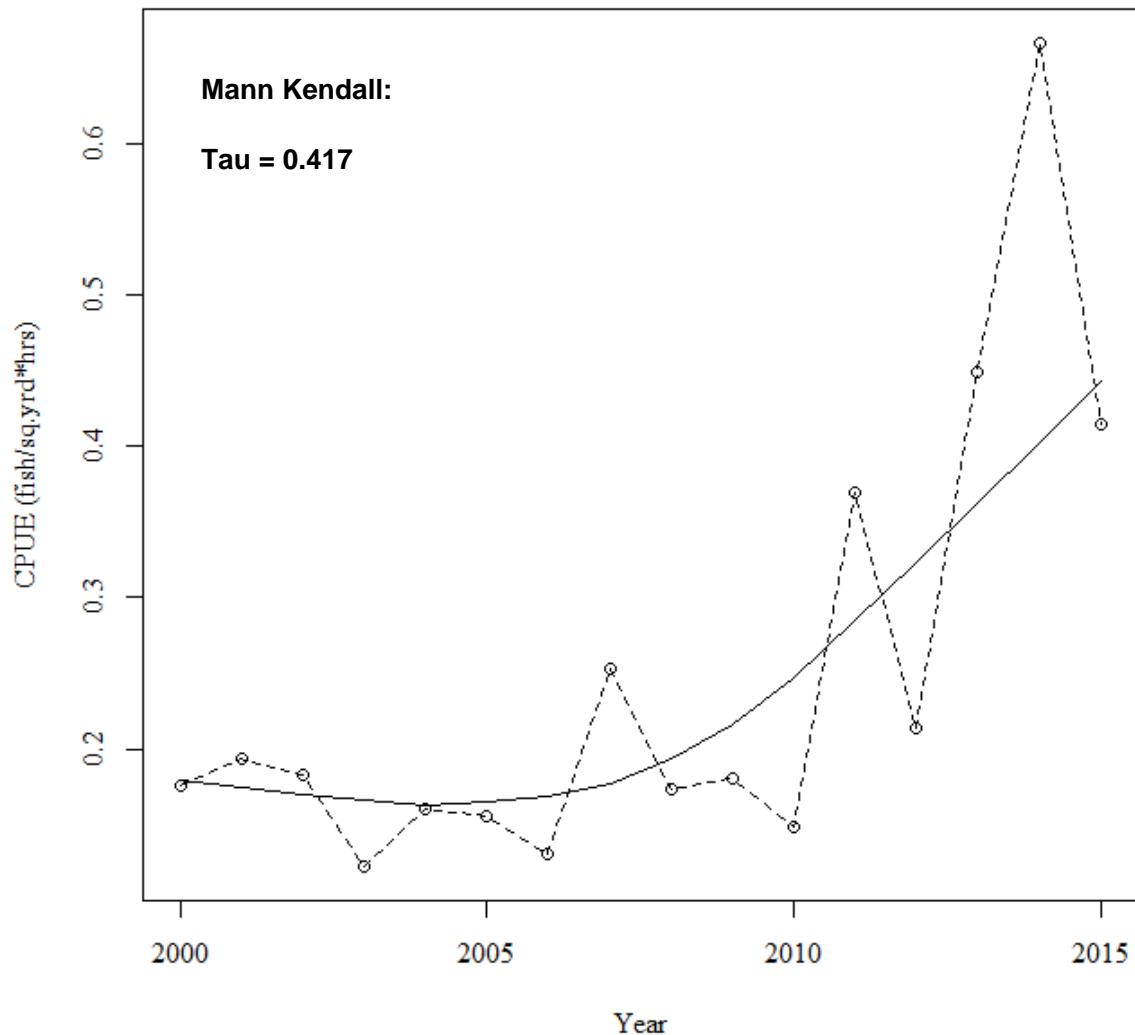


Figure 19. Trend analysis for CPUEs of commercial fixed gill net fishermen below Bear Mountain Bridge. CPUE is calculated as the sum of weekly CPUEs.

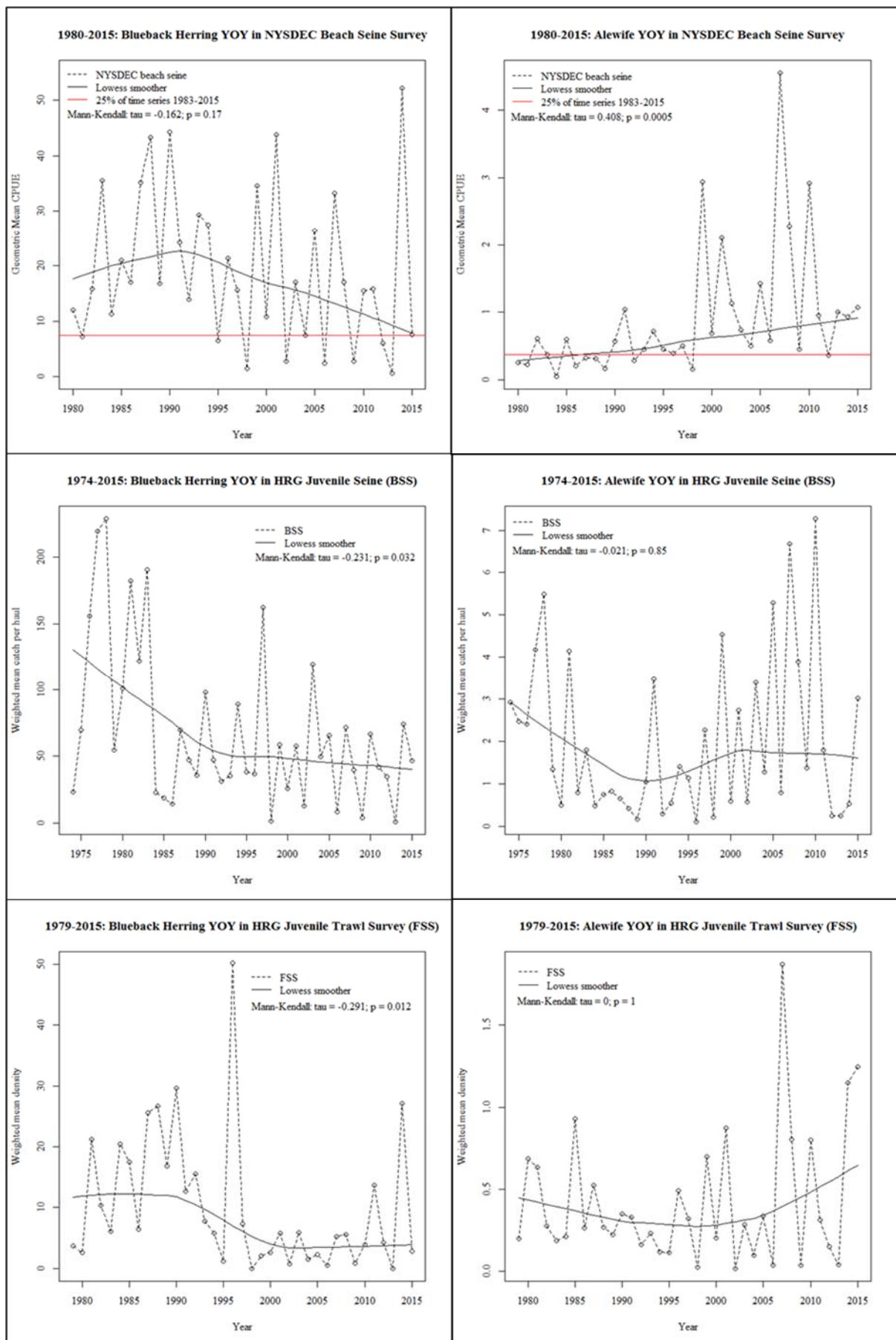


Figure 20. Trend analysis for Hudson River YOY surveys.

Appendix

Table A. Summary of historical and current commercial fishery regulations for alewife and blueback herring in New York State (2013 regulation changes in bold).

| Regulation | 2013 to Present | Regulation link |
|--|---|---|
| Season | Mar 15 – Jun 15 | 6 CRR-NY 36.3 (a) |
| Creel/ catch limits | None | |
| Commercial Gear (Marine permit) | Gill nets as commercial gear <ul style="list-style-type: none"> - 600 ft or less - 3.5 in stretch mesh or smaller - No fishing at night in HR above Bear Mt Bridge - Drift gill nets only allowable gill nets above Bear Mt Bridge - Gill nets above Bear Mt Bridge must be tended at all times | 6 CRR-NY 36.3 (c) 6 CRR-NY 36.3 (b) 6 CRR-NY 36.3 (3)(i) 6 CRR-NY 36.3 (7) 6 CRR-NY 36.3 (2)(iv) 6 CRR-NY 36.3 (5) |
| | Seine as commercial gear <ul style="list-style-type: none"> - No size restrictions below Castleton/I90 | 6 CRR-NY 36.3 (c) |
| | Scoop/Dip/Scap net as commercial gear <ul style="list-style-type: none"> - 10' x 10' maximum | 6 CRR-NY 36.3 (c) |
| | Fyke/hoop/trap nets as commercial gear <ul style="list-style-type: none"> - No size restrictions | 6 CRR-NY 36.3 (c) |
| Commercial Gear (Bait license) | Cast Net as bait collection gear <ul style="list-style-type: none"> - 10 ft maximum diameter | <i>To find the law click here, on ENV, find Article 11, click on Title 13, click ECL 11-1315</i> |
| Closed areas | No gill nets above I90 - Castleton Bridge | 6 CRR-NY 36.3 (2)(ii) |
| | No nets on Kingston Flats | 6 CRR-NY 36.3 (2)(i) |
| | No nets in any tributary (including Mohawk River) | 6 CRR-NY 36.3 (2)(i) |
| | All other waters of NY State closed to the take of anadromous river herring | 6 CRR-NY 40.1(i) |
| Escapement (no fishing days) | 36 hr lift period for all commercial gears Friday 6AM – Saturday 6PM | 6 CRR-NY 36.3 (4) |
| Marine Permit Fees (established 1911) | Gill net \$0.05/foot | 6 CRR-NY 35.1 |
| | Scap net <10 sq ft \$1.00 | |
| | Seine \$0.05/foot | |
| | Trap nets \$3 to \$10 | |
| | Fyke net \$1 to \$2 | |

Table A (continued). Summary of historical and current commercial fishery regulations for alewife and blueback herring in New York State (2013 regulation changes in bold).

| Marine Permit Reporting | Mandatory daily catch & effort; Vessel Trip Reports (VTRs) due monthly | 6 CRR-NY 36.1 (a)(1) |
|-------------------------|--|---|
| Transport and sale | <ul style="list-style-type: none"> - Commercially caught anadromous river herring must be sold and used in the Hudson River and tributaries to first impassable barrier and within the transport corridor - May also be sold or transferred to locations in the Marine District - Transport within DEC Reg. 3 requires a bait transport permit - Retail sale of live and frozen anadromous river herring requires <ul style="list-style-type: none"> o Fish health certification on premises o Receipt to purchaser (valid for 10 days) - Retail sale of dead packaged anadromous river herring requires <ul style="list-style-type: none"> o Preservation other than freezing o Each package must be labeled with <ul style="list-style-type: none"> ▪ Name of packager-processor ▪ Name of fish species ▪ Quantity of fish ▪ Means of preservation | 6 CRR-NY 35.3 (d) 6 CRR-NY 35.3 (c)(1) 6 CRR-NY 35.3 (c)(2) 6 CRR-NY 35.3 (c)(3)(ii) 6 CRR-NY 35.3 (c)(3)(iii)(a) 6 CRR-NY 35.3 (c)(4) |

Table B. Summary of historical and current recreational fishery regulations for alewife and blueback herring in New York State (2013 regulation changes in bold).

| Regulation | 2013 to Present | Regulation link |
|--|--|--|
| Season | Mar 15 – Jun 15 | 6 CRR-NY 10.10 (c)(2) |
| Creel/ catch limits (personal use) | 10 per day per angler or a maximum boat limit of 50 per day for a group of boat anglers (whichever is lower) | 6 CRR-NY 10.10 (c)(2) |
| Creel/ catch limits (party or charter) | <ul style="list-style-type: none"> - 10 per day per angler or a maximum boat limit of 50 per day for a group of boat anglers (whichever is lower) - Operator of party or charter north of Tappan Zee bridge may possess anadromous river herring in excess of individual recreational possession limit as long as <ul style="list-style-type: none"> ○ Register with Hudson River Fisheries Unit ○ Must display a valid Hudson River herring decal on port side of vessel | 6 CRR-NY 10.10 (c)(4)(i) 6 CRR-NY 10.10 (c)(4)(ii) 6 CRR-NY 10.10 (c)(4)(iii) 6 CRR-NY 10.10 (c)(4)(iii)(c) |
| Recreational gear (personal use) | Angling | 6 CRR-NY 10.10 (c)(2) |
| | Seine – not exceeding 36 square feet | 6 CRR-NY 10.10 (c)(3)(ii)(e) |
| | Scap net – <ul style="list-style-type: none"> - Not exceeding 16 square feet - Only one net | 6 CRR-NY 10.10 (c)(3)(ii)(d) 6 CRR-NY 10.10 (c)(3)(ii)(b) |
| | Dip/Scoop – <ul style="list-style-type: none"> - Not exceeding 14 inches in diameter or 13 inches by 13 inches square - Only one net | 6 CRR-NY 10.10 (c)(3)(ii)(c) 6 CRR-NY 10.10 (c)(3)(ii)(b) |
| | Cast net – not exceeding 10 feet in diameter | 6 CRR-NY 10.10 (c)(3)(ii)(f) |
| Closed areas | <ul style="list-style-type: none"> - No nets in any Hudson River tributary (including Mohawk R) <ul style="list-style-type: none"> ○ Nets must be stowed prior to entering a tributary - All other waters of NY State closed to the take of anadromous river herring | 6 CRR-NY 10.10 (c)(3)(i) 6 CRR-NY 10.10 (c)(3)(iii) 6 CRR-NY 10.10 (c)(2) 6 CRR-NY 40.1(f) |
| Transport restrictions | Herring taken in the Hudson River and tributaries (up to first impassable barrier) for personal use: <ul style="list-style-type: none"> - May only be used in the Hudson River and tributaries up to first impassable barrier - May only transported overland within the transportation corridor | 6 CRR-NY 10.1 (f)(3)(iii) 6 CRR-NY 10.1 (f)(3)(iii)(c) |
| Escapement (no fishing days) | None | |
| License | Marine Registry | 6 CRR-NY 10.10 (c)(1)(i) |
| Reporting | None | |

11 Status of River Herring in New Jersey

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11.1 INTRODUCTION

In this report, river herring refers collectively to alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*). The river herring data presented within this report focuses on the coastal waters off of New Jersey. Data on river herring occurring within the Delaware River Drainage Basin (Basin) can be found in Section 12. Coastal areas are monitored through New Jersey's Stock Assessment Trawl Survey and the sampling area includes the near shore waters from the entrance of New York Harbor south, to the entrance of the Delaware Bay (Figure 11.1). The Raritan River fish ladder is located at the Island Farm weir just downriver of the Millstone-Raritan river confluence.

11.2 MANAGEMENT UNIT DEFINITION

New Jersey Division of Fish and Wildlife manages river herring populations occurring within New Jersey's sections of the Basin and the coastal waters from Cape May Point to Sandy Hook including Raritan Bay and River.

11.3 REGULATORY HISTORY

11.3.1 Commercial Fishery

As of January 1, 2012 landings of river herring in New Jersey have been prohibited. These regulations are in compliance with the Atlantic States Marine Fisheries Commission Amendment 2 to the Fisheries Management Plan for Shad and River herring.

Historically, no specific regulations have been adopted to reduce or restrict commercial landings of river herring in New Jersey, however there have been regulations which limited commercial fishing effort and had a direct impact on catch. New Jersey adopted general regulations that apply to the commercial fishery such as limited entry, limitations on the amount of gear, and gear restrictions in defined areas. Note these restrictions apply to all New Jersey waters and not just the coastal jurisdiction, unless otherwise noted. These restrictions included but were not limited to:

1. From November 1 to April 30, only haul seines with a mesh size $\geq 2 \frac{3}{4}$ inch stretch and with a maximum length of 420 feet can be used in the Delaware River. This is currently limited to one commercial fishery based in Lambertville and rarely harvests river herring,
2. From February 1 through December 15, gill nets may be used in Delaware Bay and River. From February 12 through May 15, the maximum net length allowed is 2400 feet; from May 16 through December 15, the maximum net length is 1200 feet,
3. Gill net small mesh exemption permit (GNSMEP) allows fishers to use gill nets between 2.75 inch stretched mesh to 3.25 inch stretched mesh within two nautical miles of the mean high water line between sunrise and sunset. Holders of these permits are required to report all landings and any weakfish discards.

4. Pound nets are allowed all year in Ocean waters and Sandy Hook/Raritan Bay. In Delaware Bay, pound nets are allowed only during February 15 to May 15

11.3.2 Recreational Fishery

As of January 1, 2012, the recreational fishery has been closed

Historically, the recreational fishery for river herring was very small with few participants and low retention rates. Those herring that were landed were typically frozen for bait, pickled, harvested for their roe, and other traditional uses. Recreational gear included hook and line, dip net, bait seine, cast net, and umbrella net.

Harvest of landlocked freshwater populations of river herring is permitted year round on lakes in select counties in New Jersey for bait purposes. Anglers are restricted to 35 fish per day with a six inch maximum size limit. Any unused herring must be returned to the water upon conclusion of the angler's fishing trip. Herring may not be transported away from the shoreline of these lakes by any mechanism. They may not be sold.

11.4 ASSESSMENT HISTORY

No stock assessments have been completed on river herring populations in New Jersey's coastal rivers and streams.

11.5 STOCK SPECIFIC LIFE HISTORY

Adult alewife and blueback herring will typically enter New Jersey streams to spawn beginning in early February. Peak spawning activity occurs during mid-April through May. Post-spawned adults will return to the ocean by mid-June. Larvae will hatch and juvenile will maintain freshwater residence through mid-November, although juvenile emigration can occur as early as July. Mature adults will return to their natal streams to spawn.

11.6 HABITAT DESCRIPTION

Many of New Jersey's rivers and streams contained spawning runs of river herring until pollution, overfishing and dams restricted the population and destroyed spawning habitat. It is estimated from 1953 to 1973, 61,678 acres of coastal wetlands and uncounted acreage of adjacent transitional wetlands were lost to filling and diking in New Jersey (Ferrigno et al 1973). Field investigations during the early to mid-1970s confirmed 132 river herring spawning runs (108 alewife and 24 blueback) in rivers and streams that were continuous with the marine environment (Zich 1977). The majority of these runs were river herring. Zich concluded that nine herring runs had already become extinct.

Also during these field investigations, 83 constructed barriers were found on streams where herring runs were reported or confirmed. These barriers were assessed to be blocking or limiting fish passage and therefore reducing spawning habitat. There is no current estimate as to whether or not this number has changed significantly since that time. Recent efforts have been undertaken to restore river herring runs in some of these systems by removing dams, installing fish ladders and/or trap and transport.

11.7 RESTORATION PROGRAMS

Restoration programs for river herring in New Jersey have been limited to the installation of fish ladders and occasional minor trap and transport programs or dam removal. The total amount of freshwater habitat

opened up through these efforts has not been calculated. The only usable data available is from PSEG and represents fish ladder monitoring for both Delaware and New Jersey through 2016.

11.8 AGE

No age data has been reported for New Jersey. Otoliths have been collected during the January and April Ocean Stock Assessment trawls since 2009. Processing and aging of these samples will be completed as funding becomes available.

11.9 FISHERY DESCRIPTION

11.9.1 Commercial Fishery

New Jersey river herring landing estimates were obtained from two sources (Table 11.1; Figure 11.2). The NMFS estimates (1950 to 2009) are for the entire state, while mandatory logbooks of the GNSMEP (2000 to 2015) are from Delaware Bay. The average reported NMFS landings for the time period is estimated at 8,180 pounds. There are no estimates of underreporting, however it is assumed that the current data for river herring is underreported since some landings may be categorized as bait.

11.9.2 Recreational Fishery

Recreational surveys within the coastal jurisdictions have not been conducted.

11.9.3 Characterization of Other Losses

There are potential unknown sources of mortality from power plant intakes, commercial discards, and landings categorized as “bait”. Many of these could be significant according to some data points.

11.10 FISHERY-INDEPENDENT SURVEYS

11.10.1 Coastal waters

Ocean Trawl Survey

The New Jersey Ocean Trawl Survey is a multispecies survey that started in August 1988 and samples the near shore waters from the entrance of New York Harbor south, to the entrance of the Delaware Bay five times a year (January, April, June, August and October). There are 15 strata with five strata assigned to three different depth regimes; inshore (3 to 5 fathoms), mid-shore (5 to 10 fathoms), and off-shore (10 to 15 fathoms). Station allocation and location is random and stratified by strata size (Figure 11.1).

The survey net is a two-seam trawl with forward netting of 4.7 inch stretch mesh and rear netting of 3.1 inches stretch mesh. The codend is 3.0 inches stretch mesh and is lined with a 0.25 inch bar mesh liner. Each trawl is 20 minutes long and at the end of each tow, the total weight of each species is measured in kg and the length of all individuals, or a representative sample by weight for large catches, is measured to the nearest cm. A series of water quality parameters, such as surface and bottom salinity, temperature and dissolved oxygen, are also recorded at the start of each tow. New Jersey began collecting otoliths and other biological data in 2009 to develop age at length keys for both species. Processing and aging of these samples will be completed as funding becomes available.

River Herring Adult and Juvenile Abundance Survey

In 2015 the state of New Jersey began a river herring adult and juvenile abundance survey on the Great Egg Harbor River which has been known to have historical river herring populations. Gillnetting is performed once a week at two locations on the river representing brackish and freshwater environments. Adult river herring moving into spawning areas are collected by use of anchored sinking gill nets that measuring 141' x 6' x 3" and 171' x 6' x 3" stretch mesh set for 90 minutes. River herring collected are measured by fork and total length and are inspected for sex and ripeness. Water chemistry data (water temperature, salinity, dissolved oxygen, and pH) as well as atmospheric conditions (tidal stage, weather, wind directions and speed, cloud cover, moon phase, and air temperature) were recorded.

In the summer and fall juvenile river herring are collected at 7 sites along the river representing freshwater and estuarine environments utilizing a 100' x 6' x ¼ mesh bagged beach seine bi-weekly. Water chemistry data (water temperature, salinity, dissolved oxygen, and pH) as well as atmospheric conditions (air temperature, cloud cover and moon phase) were recorded. A total of 30 alewife and 30 blueback herring were subsampled from each haul and measured to fork length. All remaining alewife and blueback were counted and released.

This project is anticipated to continue as long as funding is available. As a longer time series is established, indices of abundance will be calculated to track adult returns and spawning success within the Great Egg Harbor River.

Raritan River Fish Passage

The Raritan River, which empties into Raritan/Sandy Hook Bay, historically supported a spawning run of river herring. A dam constructed at the confluence of the Millstone and Raritan rivers was equipped with a fish ladder that included an underwater viewing room. Data is available for 1996 to 2005 (except for 2000 and 2004) and 2011 to 2012. A CPUE was developed as the number of fish counted per day. Confidence that all herring are counted is low.

11.11 ASSESSMENT APPROACHES AND RESULTS

The purpose of this report is to assess the stock status of the New Jersey's coastal populations of blueback herring and alewife. It is obvious from historical data and anecdotal information that river herring populations statewide were much larger in the past and have declined drastically since the robust numbers of the late 1800s. The only data available for assessment is data from New Jersey's Ocean Trawl Survey and a fish ladder index from the Raritan River. The River Herring Adult and Juvenile Abundance Survey in the Great Egg Harbor River may prove to be a source of useable data in the future.

11.12 TRENDS IN SPAWNING STOCK SIZE

The majority of river herring are captured during the January and April trawls of the Ocean Trawl Survey so only those months are used for the geometric mean (Table 11.2; Figure 11.3). The trawl index for blueback herring showed a declining trend from 1993 to 2004 but has shown an increasing trend ever since. This includes the highest index of the time series in 2008. Since the previous stock assessment report there was a precipitous drop in the index in 2010 with an immediate recovery to the time series average in the following years. The alewife index has varied without much of a trend since the beginning, although there has been a slight increase since 2000 with a similar drop off in CPUE in 2010 and subsequent increase, although not as dramatic as in the case of bluebacks.

The Raritan fish ladder data is a very short term data set that was discontinued in 2005 and reinitiated for the 2011 and 2012 spring spawning runs. Regardless, the data showed a decreasing trend from 1997 to 2005 (Table 11.3; Figure 11.5).

The intermittent time series and uncertainty in count accuracy leaves this survey with little utility for management purposes.

11.13 BENCHMARKS

No benchmarks were developed for the coastal waters of New Jersey.

11.14 CONCLUSIONS AND RECOMMENDATIONS

Data for stock assessment of New Jersey's coastal rivers and streams is virtually non-existent. Additional data for New Jersey's portion of the Delaware Basin can be found in section 12. There are only two sources of river herring data from New Jersey's coastal waters, only one of which is currently ongoing._ The Ocean Trawl survey, which collects fishery independent data of mixed coastal stocks, showed an increase in blueback herring in recent years and a slight increasing trend for alewife since 2002. In contrast, the short data set from the Raritan fish ladder showed an overall decreasing trend. With so little data available, it is not possible to determine an accurate state of river herring stocks in New Jersey's coastal waters. It would be beneficial to undertake a more rigorous investigation of the population dynamics of these species within and outside the New Jersey coast.

For the New Jersey coast, this would include:

- Additional information on commercial and recreational landings
- Improved assessment of river herring adults at all fish ladder installations
- Improved assessment of river herring production in targeted tributaries
- Predator-prey relationships especially with striped bass, bluefish and white perch for yoy and striped bass, weakfish, bluefish, spiny dogfish for adults
- Habitat evaluations
- Development of age-length keys from samples collected during the Ocean Trawl Survey
- Revisit Raritan Bay fish ladder survey data

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Table 11.1 New Jersey commercial river herring (alewife and blueback herring) landings, in pounds: 1950 – 2015. NMFS landings are statewide; Logs are from the Delaware Basin.

| Year | NMFS | Logs | Year | NMFS | Logs |
|------|--------|------|------|--------|-------|
| 1950 | 29,000 | - | 1983 | 2,200 | - |
| 1951 | 7,200 | - | 1984 | 3,100 | - |
| 1952 | 600 | - | 1985 | 4,800 | - |
| 1953 | 8,600 | - | 1986 | 4,200 | - |
| 1954 | 0 | - | 1987 | 5,200 | - |
| 1955 | 22,900 | - | 1988 | 700 | - |
| 1956 | 22,300 | - | 1989 | 800 | - |
| 1957 | 8,100 | - | 1990 | 42,494 | - |
| 1958 | 1,400 | - | 1991 | 9,994 | - |
| 1959 | 2,200 | - | 1992 | 3,069 | - |
| 1960 | 3,000 | - | 1993 | 2,659 | - |
| 1961 | 16,500 | - | 1994 | 328 | - |
| 1962 | 20,300 | - | 1995 | 795 | - |
| 1963 | 3,400 | - | 1996 | 4,449 | - |
| 1964 | 14,200 | - | 1997 | 4,515 | 9,221 |
| 1965 | 21,500 | - | 1998 | 7,371 | 2,430 |
| 1966 | 12,400 | - | 1999 | 1,377 | 3,880 |
| 1967 | 9,000 | - | 2000 | 0 | 5,410 |
| 1968 | 8,400 | - | 2001 | 1,034 | 1,900 |
| 1969 | 5,100 | - | 2002 | 3,366 | 552 |
| 1970 | 7,500 | - | 2003 | 228 | 2,127 |
| 1971 | 9,500 | - | 2004 | 2,548 | 3,192 |
| 1972 | 14,700 | - | 2005 | 1,079 | 2,402 |
| 1973 | 7,000 | - | 2006 | 469 | 2,793 |
| 1974 | 10,600 | - | 2007 | 0 | - |
| 1975 | 9,300 | - | 2008 | 631 | 1,551 |
| 1976 | 11,300 | - | 2009 | 0 | 177 |
| 1977 | 10,600 | - | 2010 | 1,004 | 409 |
| 1978 | 2,400 | - | 2011 | | 1,634 |
| 1979 | 6,600 | - | 2012 | | 18 |
| 1980 | 18,600 | - | 2013 | | 0 |
| 1981 | 13,800 | - | 2014 | | 1 |
| 1982 | 13,600 | - | 2015 | | 0 |
| | | | Avg | 7,541 | 2,094 |

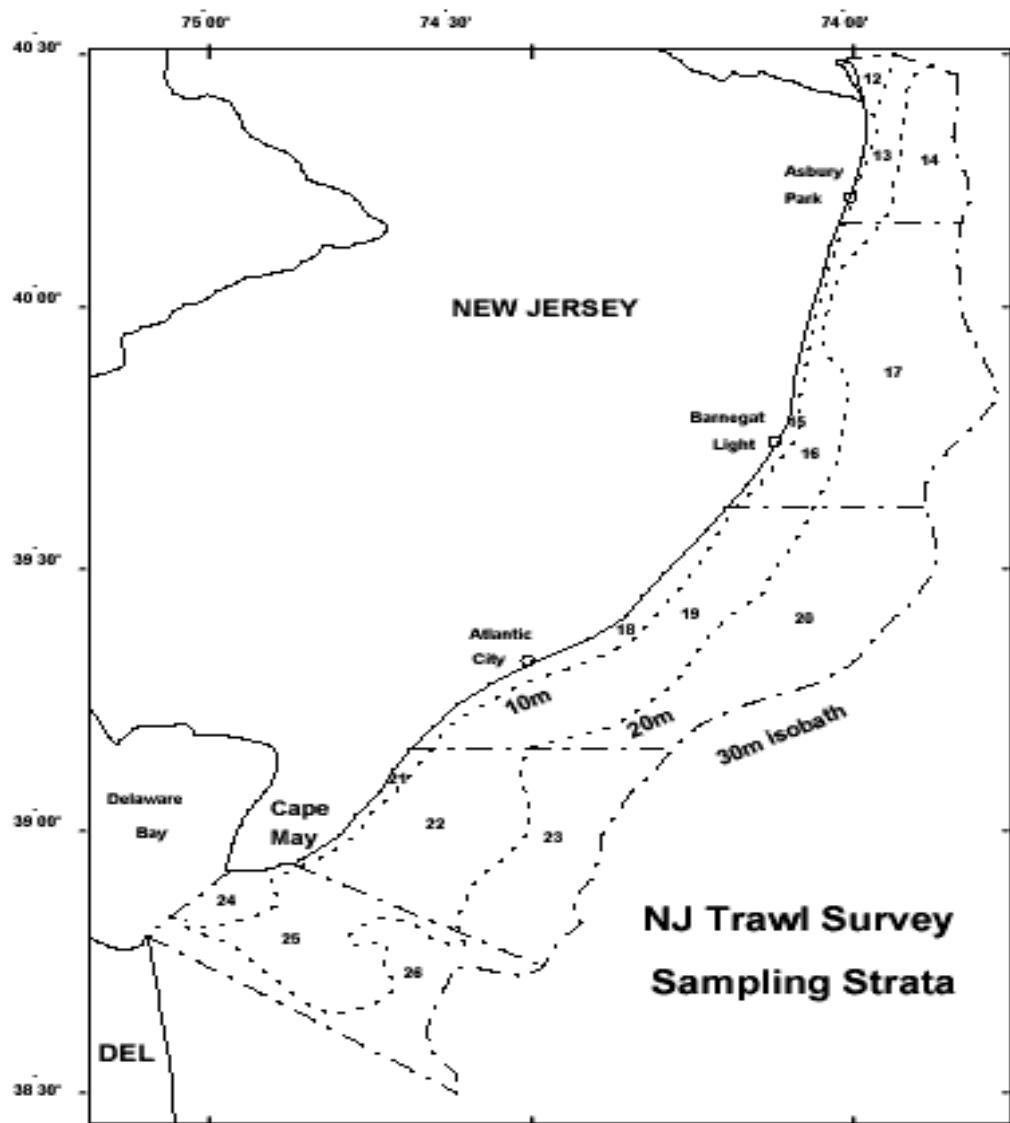
Table 11.2 Ocean Trawl Survey river herring geometric mean per tow: 1989-2015

| Year | Blueback | Alewife |
|-------------|-----------------|----------------|
| 1989 | 4.45 | 3.01 |
| 1990 | 2.36 | 2.57 |
| 1991 | 3.42 | 5.01 |
| 1992 | 4.73 | 2.85 |
| 1993 | 4.34 | 7.03 |
| 1994 | 5.32 | 2.82 |
| 1995 | 3.20 | 5.01 |
| 1996 | 2.75 | 8.23 |
| 1997 | 4.01 | 3.97 |
| 1998 | 3.43 | 30.08 |
| 1999 | 4.26 | 11.85 |
| 2000 | 2.76 | 1.76 |
| 2001 | 2.30 | 1.79 |
| 2002 | 2.83 | 2.39 |
| 2003 | 4.42 | 4.69 |
| 2004 | 4.34 | 4.67 |
| 2005 | 4.51 | 3.92 |
| 2006 | 6.03 | 2.44 |
| 2007 | 4.70 | 4.63 |
| 2008 | 8.77 | 5.71 |
| 2009 | 6.21 | 4.89 |
| 2010 | 1.39 | 0.48 |
| 2011 | 2.07 | 2.02 |
| 2012 | 4.80 | 2.85 |
| 2013 | 4.22 | 2.20 |
| 2014 | 3.91 | 1.80 |
| 2015 | 4.60 | 2.74 |
| AVG | 4.08 | 4.87 |

Table 11.3 Raritan River Island Farm Weir fish ladder viewing CPUE (Herring per Day): 1996-2005, 2011-2012

| Year | CPUE | Year | CPUE |
|------|------|------------|-------------|
| 1996 | 0.00 | 2002 | 0.29 |
| 1997 | 1.70 | 2003 | 0.15 |
| 1998 | 0.16 | 2004 | - |
| 1999 | 0.55 | 2005 | 0.00 |
| 2000 | - | 2011 | 1.45 |
| 2001 | 0.82 | 2012 | 0.35 |
| | | AVG | 0.55 |

Figure 11.1 New Jersey Ocean Trawl Survey area: 2015



* Strata correspond to those of the National Marine Fisheries Service's spring and fall groundfish surveys

Figure 11.2 New Jersey Reported Commercial Landings 1950-2015

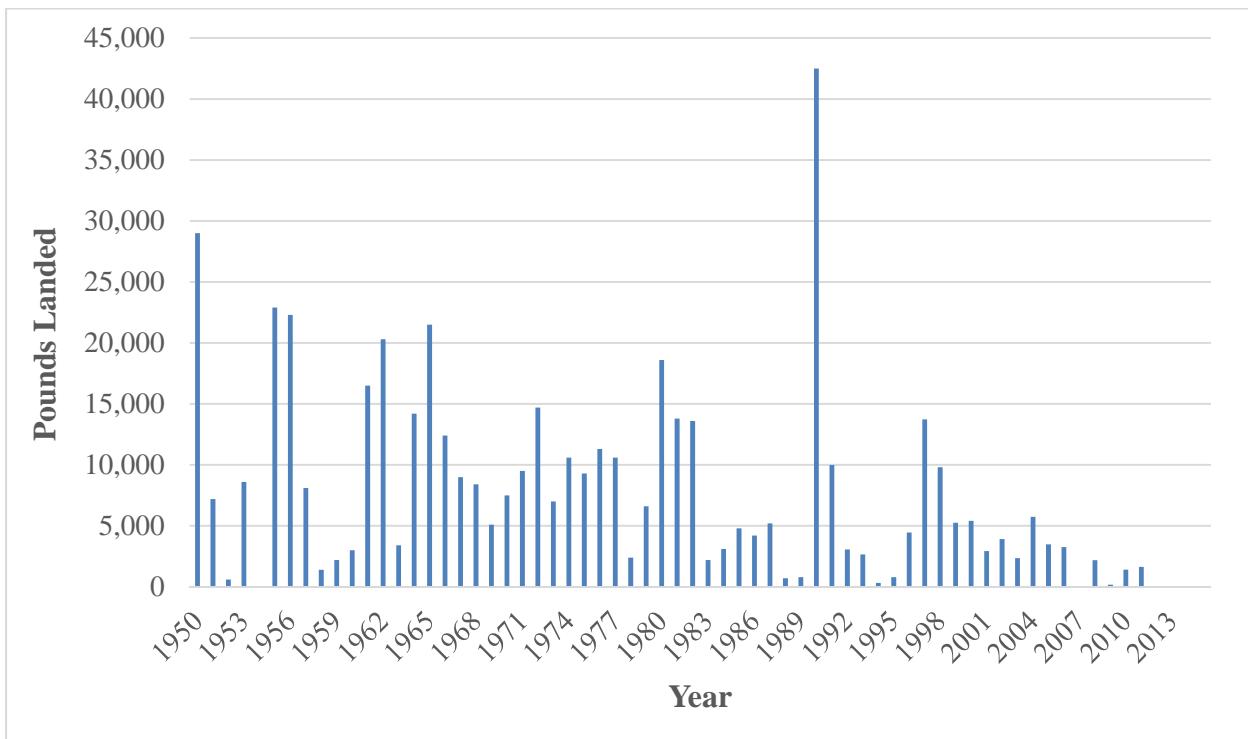


Figure 11.3 Ocean Trawl Survey river herring geometric mean per tow: 1989-2010

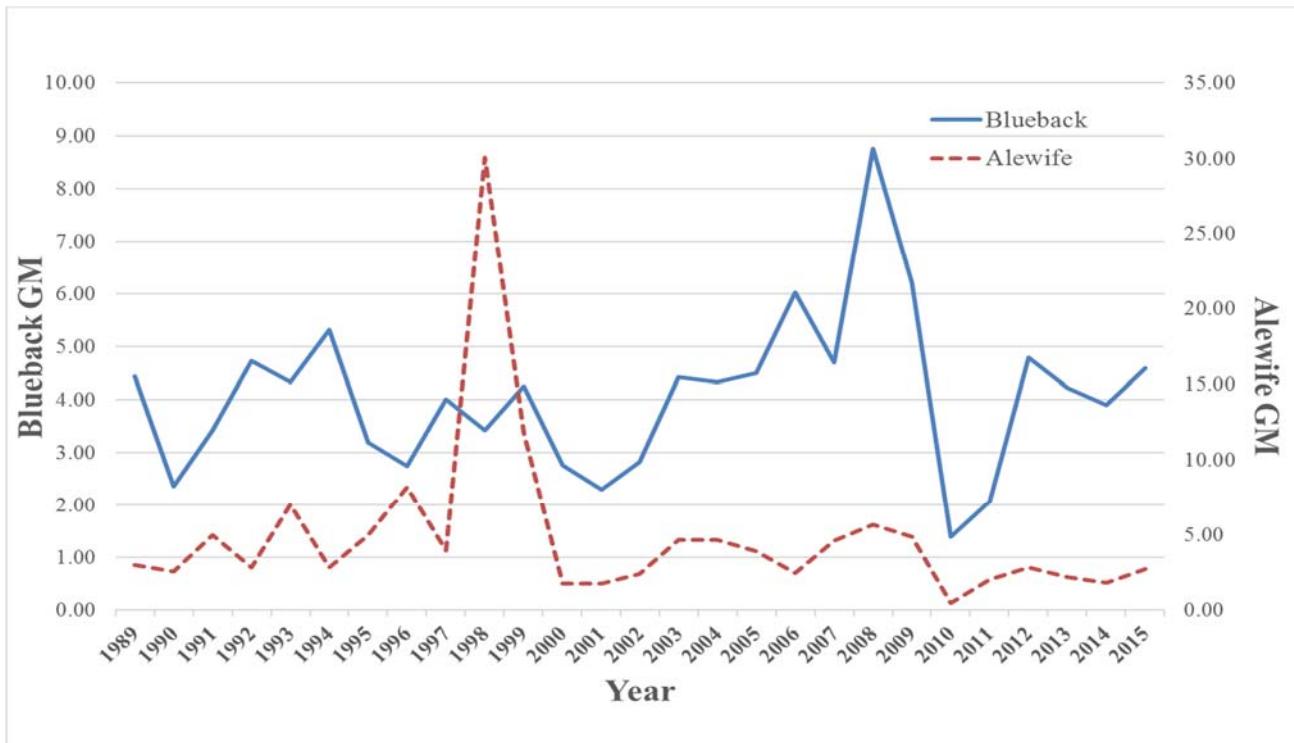


Figure 11.4 Ocean Trawl Survey percent length frequencies: 1989-2015

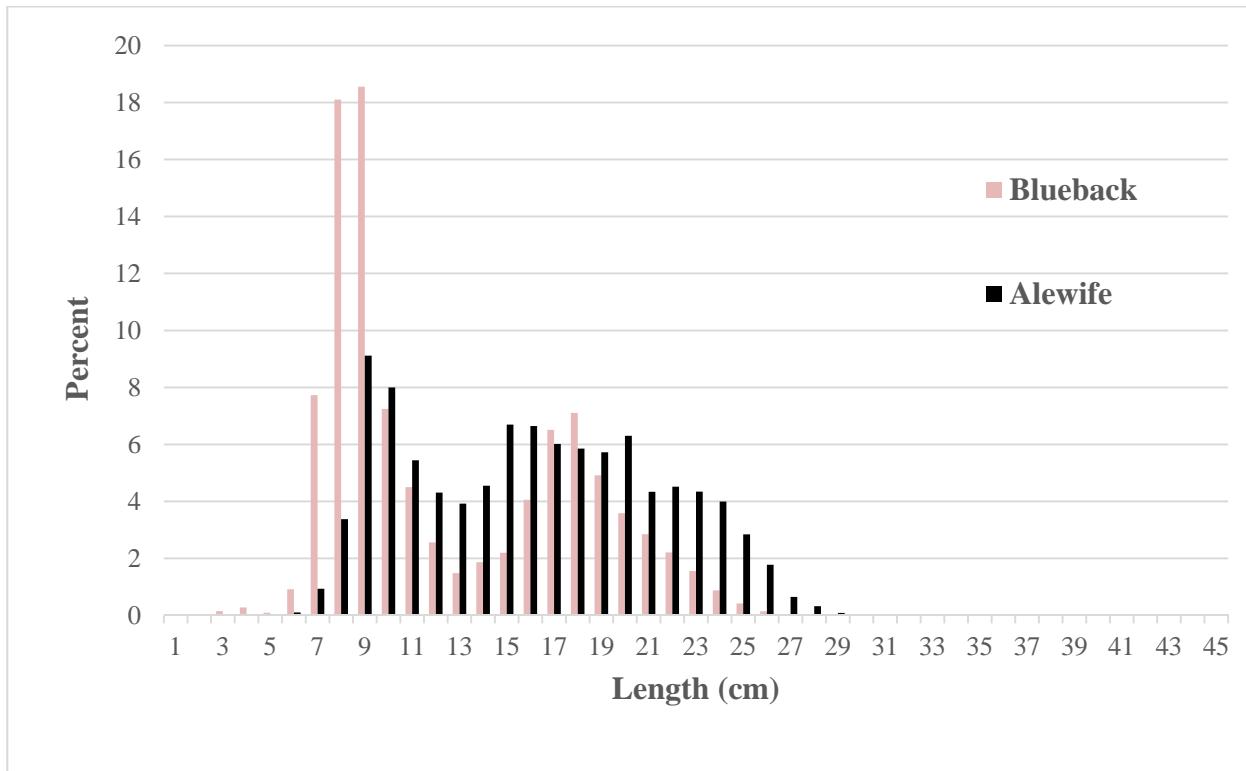
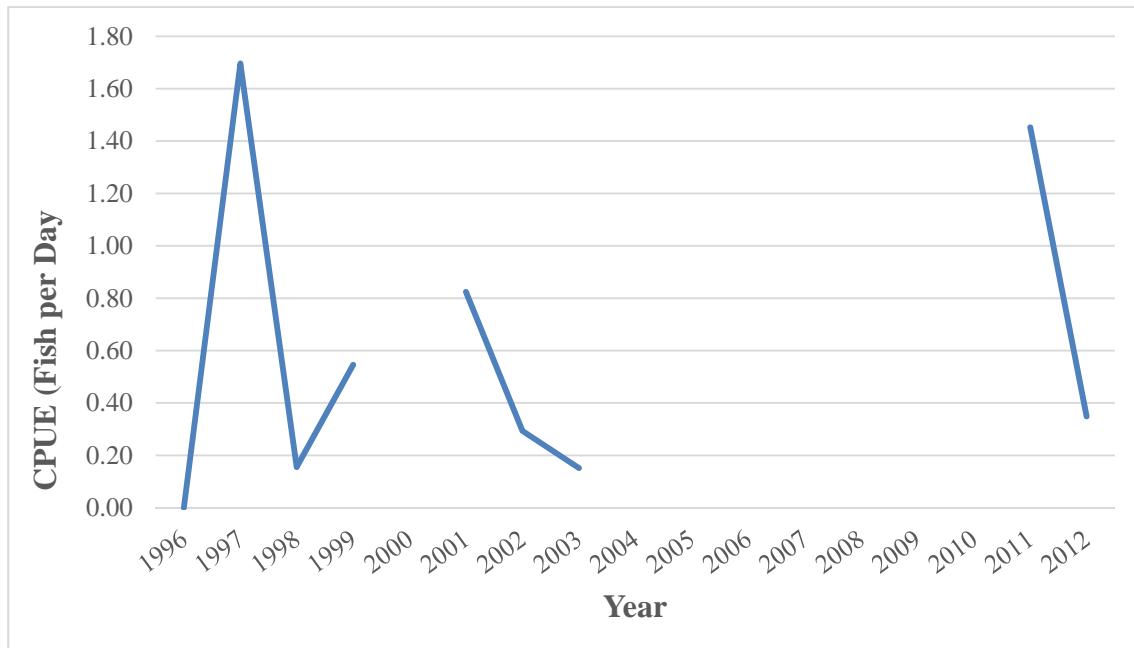


Figure 11.5 Raritan River Island Farm Weir fish ladder viewing CPUE (1996-2005, 2011-2012).



12 Status of River Herring in Delaware River and Bay

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12.1. INTRODUCTION

River herring populations in the state of Delaware, Pennsylvania and New Jersey consist of two species, alewife and the blueback herring. Both species occur throughout the Delaware River and Bay (Basin).

During the early 1900s the volume of herring in the Delaware River was so great that they often flipped onto the creek banks of the river each spring. The decline of river herring in the Basin began in the 1940's due to heavy organic loads around Philadelphia, Pennsylvania which caused severe declines in dissolved oxygen (DO). The ensuing "DO blocks" made parts of the lower Delaware River uninhabitable for fish during the warmer months of the year (Sykes and Lehman 1957). The contamination continued to worsen to such a degree that by 1951 it was advised that no one should go into the water. During the 1940s, commercial herring fisheries were mainly limited to the lower reaches of the River and Bay below Pennsylvania. By 1950, the urban reach of the Delaware River was one of the most polluted stretches of river in the world.

A remnant of the herring runs in the upper Basin survived by migrating upstream early in the season, when water temperatures were low and flows were high, before low DO ensued. These fish, because of their early arrival, migrated farther up the Delaware to spawn. Runs in the lower Basin survived by spawning below the DO block. Out-migrating juveniles survived by moving downriver late in the season during high flows and low temperatures, thus avoiding the low oxygen waters present around Philadelphia earlier in the fall. Pollution continued to be a major factor until passage of the Federal Clean Water Act in 1972. This Act was instrumental in the elimination of the pollution block in the region around Philadelphia.

12.2. MANAGEMENT UNIT DEFINITION

The Delaware River Drainage Basin consists of the Delaware River, including the East and West branches above Hancock, New York, and its tributaries to the mouth of Delaware Bay, encompassing some 13,539 square miles and 216 tributaries. The Basin includes the states of Delaware, New Jersey, New York, and

Pennsylvania. Management authority lies with the New York Department of Environmental Conservation (NYDEC), Pennsylvania Fish and Boat Commission (PFBC), New Jersey Division of Fish and Wildlife (NJDFW) and Delaware Division of Fish and Wildlife (DFW)

The main-stem of the Delaware River is the longest un-dammed river east of the Mississippi and stretches for 330 miles. There are individual runs of river herring in nearly all of Delaware Basin's larger streams and rivers to at least river-mile 155. The Delaware River north of Port Jervis, NY is a shared water body between the states of New York and Pennsylvania. River herring have not been documented to occur in this section of the Delaware River and will not be discussed in this chapter.

12.3. REGULATORY HISTORY

12.3.1. Commercial Fishery

As of January 1, 2012 landings of river herring in systems without an approved sustainable fisheries management plan are prohibited. These regulations are in compliance with the Atlantic States Marine Fisheries Commission Amendment 2 to the Fisheries Management Plan for Shad and River herring.

As of January 1, 2012 the commercial fishery in Delaware, New Jersey and Pennsylvania waters has been closed. No harvest of river herring is permitted.

Within Delaware's waters of the Basin, DFW restrictions historically included:

1. The spring gill net season is from February 15- May 31, and the fall season for any remaining quota not caught in the spring season extends from November 15-December 31.
2. Drift gill nets only from February 15-February 28 with a stretch mesh > 4" and from May 10-May 31.
3. Drift gill nets are prohibited from Saturday through 1600 hours Sunday or on legal state holidays from May 10 through September 30.
4. No fixed gill net more than one-half nautical mile from the beach of the Delaware River and Bay to the north of Beach Plum Island Nature Preserve between and including May 11 and September 30, and no more than 200 feet of net from May 11 through September 30.
5. No fixed gill nets from May 10 through September 30 in Delaware Bay.
6. The use of any type of net within 300 feet of any dam is prohibited on any tributary.
7. The striped bass spawning grounds which include the Nanticoke, Delaware River and C&D Canal are closed to all gill nets from April 1 to May 31.

Within New Jersey's waters of the Basin, NJDFW restrictions historically included:

1. From November 1 to April 30, only haul seines with a mesh size $\geq 2 \frac{3}{4}$ inch stretch and with a maximum length of 420 feet can be used in the Delaware River. This is currently limited to one commercial fishery based in Lambertville and rarely harvests river herring,
2. From February 1 through December 15, gill nets may be used in Delaware Bay and River. From February 12 through May 15, the maximum net length allowed is 2400 feet; from May 16 through December 15, the maximum net length is 1200 feet,

3. Gill net small mesh exemption permit (GNSMEP) allows fishers to use gill nets between 2.75 inch stretched mesh to 3.25 inch stretched mesh within two nautical miles of the mean high water line between sunrise and sunset. Holders of these permits are required to report all landings and any weakfish discards.
4. Pound nets are allowed all year in Ocean waters and Sandy Hook/Raritan Bay. In Delaware Bay, pound nets are allowed only during February 15 to May 15

A robust commercial river herring fishery existed near Philadelphia in the late 1800's and early 1900's. This fishery was eliminated by the "DO block" in the mid 1900's. No commercial fishery has existed for river herring within New York's shared portion of the Delaware River

12.3.2. Recreational Fishery

Historically, the recreational fishery for river herring was very small with few participants and low retention rates. Those herring that were landed were typically frozen for bait, pickled, kept for their roe or other traditional uses.

As of January 1, 2012 the recreational fishery in Delaware, New Jersey and Pennsylvania waters has been closed. No harvest of river herring is permitted.

Delaware

In the Delaware portion of the Basin, the recreational fishery took place at the various low-head dams that form mill ponds on the majority of Delaware's tidal rivers where herring concentrated during the spring spawning season. Some recreational fishermen used hook and line, but most herring were landed using lift nets (umbrella nets) or dip nets at the peak of the run. Prior to 2005, no recreational limit for river herring existed in the State of Delaware. The catch and effort for river herring increased as striped bass stocks rebounded and the popularity of using live river herring for bait escalated. In an effort to prevent over exploitation of these small herring runs, a 25 fish per day limit was adopted in 2005. The popularity of this fishery continued to increase and consequently a 10 fish per day possession limit was adopted in spring of 2008 to help conserve remaining spawning stocks and to prevent stock-piling fish in net pens or live cars. In addition, in 2008, Delaware's General Assembly approved legislation that prohibits the use of any net by any fisherman within 300 feet of any dam on any tidal tributary. The 10 fish possession limit and the prohibited use of any net immediately below any dam greatly reduced both catch and effort by forcing recreational fishermen to use only hook and line and to limit landings to the possession limit. **As of January 1, 2012 the recreational fishery in Delaware waters has been closed. No harvest of river herring is permitted.**

New Jersey

Historically, the recreational fishery for river herring was very small with few participants and low retention rates. Those herring that were landed were typically frozen for bait, pickled, harvested for their roe, and other traditional uses. In the freshwater areas of New Jersey, the limit was historically 10 fish per angler per day, while the marine section was 35 fish. Recreational gear included hook and line, dip net, bait seine, cast net, and umbrella net. **As of January 1, 2012 the recreational fishery in New Jersey waters has been closed. No harvest of river herring is permitted.**

Pennsylvania

Historically, the sport fishery for river herring in Pennsylvania was almost exclusively a bait fishery which was limited to hook and line fishing, open year-round, with no minimum length limit. Since the mid-1980's, the daily creel limit for river herring in the Delaware River and Estuary was a total of 35 fish. Beginning in 2010, the Pennsylvania Fish and Boat Commission adopted regulations in coordination with New Jersey and later coordinated with New York reducing the daily creel limit from the historic limit to a limit of 10 river herring from the confluence of the East and West Branches downriver to the Commodore Barry Bridge. The remaining 2.9 river miles below the Commodore Barry Bridge remained at the historic daily limit of 35 herring, in cooperation with New Jersey's Marine Council. **As of January 1, 2012 the recreational fishery in Pennsylvania waters has been closed. No harvest of river herring is permitted.**

12.4. ASSESSMENT HISTORY

In 2012 a river herring benchmark stock assessment was completed and found that of the 52 stocks of alewife and blueback herring assessed, 23 were depleted relative to historic levels, one was increasing, and the status of 28 stocks could not be determined because the time-series of available data was too short. Estimates of abundance and fishing mortality could not be developed due to lack of data. The "depleted" determination was used instead of "overfished" and "overfishing" to indicate factors other than fishing have contributed to the overall population decline, including habitat loss, predation and climate change (ASMFC 2012).

12.5. STOCK SPECIFIC LIFE HISTORY

Adult alewife and blueback herring will typically enter the Basin to spawn beginning in early February. Peak activity for alewife occurs during April and the beginning of May, while peak spawning activity for blueback typically occurs during April and through the end of May. The adults emigrate downstream soon after spawning although a minority remains in the ponds through the summer. Larvae will hatch and juvenile will maintain freshwater residence through November, although juvenile emigration can occur as early as the water temperatures decline through the fall. Once mature, adults will return to their natal streams to spawn.

12.6. HABITAT DESCRIPTION

Many of the Basin tributaries contained spawning runs of river herring until pollution, overfishing, and dams restricted the population and destroyed spawning habitat.

On the Delaware side of the Basin all of the major tributaries contained spawning runs of river herring through 1990. At that time, there were 13 tidal streams that had either confirmed runs from a variety of adult and juvenile monitoring activities, or the collection of eggs and early life stages during the spring spawning season. All of the tidal streams have reduced amounts of available spawning habitat due to the construction of low-head dams that formed mill ponds dating to the 1800's or earlier 1900's. No new dams have been constructed since the 1960's that interfere with river herring spawning. Although all of Delaware's tidal rivers have been dammed to some extent, there was some suitable spawning and nursery habitat available in each system to sustain at least a remnant spawning stock. All of the tidal streams are relatively short in length, resulting in a fairly steep salinity gradient, especially in those rivers that terminate in the lower Bay where the ambient salinity is high. Subsequently, all spawning is usually restricted to a short distance of freshwater near the dam and immediately downstream. In northern Delaware, where springtime salinities in the adjacent Delaware River are very low, the spawning areas are more dispersed, and eggs and larvae are found throughout much of each system. The Christina River is the longest of the

Delaware tidal tributaries and is approximately 15 miles from the Bay to the first dam. Age-0 River herring use these tributaries for nursery habitat from spring through early fall and then migrate to the mainstem Delaware River and Bay. Those adults (typically blueback herring) that use the ladders generally do so during the peak of the run and all spawning occurs in the impoundment; no movement into upstream tributary streams has been documented. The adults emigrate downstream soon after spawning although a minority remains in the ponds through the summer. The ladders are kept opened for a period of time throughout the summer and fall to allow the juvenile year class that generally congregates in the deeper waters near the dam to leave the system via the ladder, rather than swimming over the face of the dam.

On the New Jersey side of the Basin, it is estimated from 1953 to 1973, 61,678 acres of coastal wetlands and uncounted acreage of adjacent transitional wetlands were lost to filling and diking (Ferrigno et al 1973). Field investigations during the early to mid-1970s confirmed 132 river herring spawning runs (108 alewife and 24 blueback) in rivers and streams that were contiguous with the marine environment (Zich 1977). Zich concluded that nine herring runs had already become extinct. Also during these field investigations, 83 constructed barriers were found on streams where herring runs were reported or confirmed. These barriers were assessed to be blocking or limiting fish passage and therefore reducing spawning habitat. There is no current estimate as to whether or not this number has changed significantly since that time. Recent efforts have been undertaken to restore river herring runs in some of these systems by removing dams, installing fish ladders and/or trap and transport.

12.7. RESTORATION PROGRAMS

Efforts in Delaware and New Jersey have been undertaken to restore river herring runs in some of these systems by installing fish ladders. Twelve tidal streams located within the Delaware River/Bay watershed have fish ladders installed (eight in Delaware and four in New Jersey) at the first upstream dam to allow for river herring passage into the non-tidal impoundments above the dams. The fish ladders are all of Alaskan Steeppass design and are operated to allow for increased spawning activity and nursery habitat. All of the ladders have been monitored at some level to determine passage rates and develop species use following construction. All fish using the ladder were trapped in a fish ladder exit trap, identified, counted and released. Only target species were released into the impoundment. A target passage rate of 5 adults per surface acre was established for all ladders as a threshold for successful river herring passage. Once the target rate was achieved, annual monitoring was suspended. Annual monitoring has continued at those ladders that have not met the 5 fish per surface acre target. Some engineering modifications to the entrance to the ladders have been done to enhance passage. Monitoring at the ladders was discontinued at those sites that achieved their target for two consecutive years to avoid potentially impacting spawning behavior. Monitoring resumes at these sites every third year to determine trends in abundance and continued use. A supplemental stocking program for river herring was initiated in some impoundments as part of their restoration efforts (Table 12.5). This stocking element was dependent on the availability of adult river herring in hopes of increasing spawning run size in subsequent years. No stocking has occurred since 2004 due to the limited availability of adult herring for trap and transfer.

Within Pennsylvania, restoration efforts have also focused on dam removal and installation of fish passage. Fishways have been constructed in the Schuylkill River at Fairmount Dam (rebuilt in 2008), Flat Rock Dam (2007), Norristown Dam (2007), and Black Rock Dam (2009), which, along with dam removals have opened up 100 river miles to migratory fish. Fishways have been built on the Lehigh River at Easton Dam (rebuilt in 2001), Chain Dam (rebuilt in 2001), and Hamilton Street Dam (1983), opening up 24 river miles to migratory fish. Dam removals have occurred in Ridley Creek (2 dams), Chester Creek (2 dams), Neshaminy Creek (2 dams), Darby Creek (4 dams, 10.5 miles opened), and Pennypack Creek (7 dams, 22 miles opened).

12.8. AGE

No age data has been reported from the Delaware Basin.

12.9. FISHERY DESCRIPTION

Fisheries data, with some exceptions, is reported and compiled by state. **As of January 1, 2012 there has been no commercial fishery within Pennsylvania, New Jersey, and Delaware waters.**

12.9.1. Commercial Fishery

Delaware

Delaware's commercial landings were determined annually from mandatory commercial catch reports under the provisions enacted by the Delaware General Assembly in 1984. Every fisherman holding a commercial food-fishing license was required to submit a monthly report specifying what general area gear was deployed at within the estuary, the type and amount of fishing gear deployed, and the pounds landed of each species taken for each day fished. The reported commercial gill net landings and the kilograms of fish landed per meter of gill net for Delaware's portion of the Delaware Estuary are found in Table 12.1 and Figure 12.3. The effort data reflects days that fishermen actually landed river herring and does not account for days when the species was not landed.

The commercial fishery for river herring was relatively small but highly variable in Delaware, ranging from 500 lbs to 36,000 lbs annually since 1985. Commercial landings occurred from February through May with peak landings in March and April. Landings occurred from all of the broader regional areas of Delaware but the Nanticoke River has traditionally yielded the majority of landings and it also has the largest herring runs of any of the tidal streams in the state (see Section 13 for more information on the fishery in the Nanticoke River). Both species are represented in the catch but the majority is probably blueback herring based on observations of relative abundance and temporal distributions within state waters.

Adult river herring in Delaware have not been sampled for any biological characteristics such as size, sex, and age structure or species composition. In the past there has been concern over the misidentification of river herring by commercial watermen in the Delaware Estuary. Analysis of past data has resulted in a cutoff date of June 1 for reported herring landings. Landings were reported monthly until 1989, after which they were reported on a daily basis. There has been no commercial fishery for river herring in Delaware since 2011, when the total estimated dockside value for all species landed was \$1.3 million with river herring contributing \$682 to that total value.

New Jersey

New Jersey river herring landing estimates were obtained from two sources (Table 12.5 and 12.8). The NMFS estimates (1950 to 2010) are for the entire state, while mandatory logbooks of the GNSMEP (2000 to 2015) are from Delaware Bay. The average reported NMFS landings for the time period is estimated at 7,541 pounds. There are no estimates of underreporting, however it is assumed that the current data for river herring is underreported since some landings may be categorized as bait.

The GNSMEP is primarily directed towards white perch and other species with river herring being a harvestable bycatch when they could still legally be harvested. The gear is not standardized and therefore the data should only be used for potential trends and not absolute numbers. Harvest was only categorized as herring and could include some Atlantic herring landings. A CPUE developed for this data shows a declining trend since 2000 (Table 12.1 and 12.8).

12.9.2. Recreational Fishery

As of January 1, 2012 there has been no recreational fishery within Pennsylvania, New Jersey, and Delaware.

Delaware

There are over 500 ‘recreational’ gill net permits issued to Delaware fishermen. The permit stipulates that a fisherman is entitled to set up to 200 feet of anchored or fixed gill net with a minimum mesh size of 3.25 inches. Many commercial crabbers hold these permits which allow them to catch bait, primarily Atlantic menhaden. River herring were also reported as discards from this fishery but were highly variable ranging from 6 fish per year to over 1,000. All recreational gill net fishermen abided by the same seasons, size and creel limits for foodfish that applied to recreational anglers except the harvest of certain species (such as striped bass) was not allowed. From 1996 through 2003 annual total harvest estimates ranged from 4,400 fish in 1996 to 297 in 2002 (Table 12.2). The number of river herring harvested per trip declined steadily from 1998 through 2004 (Table 12.2). **As of January 1, 2012 the recreational fishery in Delaware waters has been closed. No harvest of river herring is currently permitted.**

New Jersey

The only survey of the recreational fishery for river herring within the Delaware Basin was an access point survey in conjunction with an aerial effort survey conducted by Versar, Inc. during 2002 (Volstad et al 2003). The study area included all tidal and non-tidal waters from the Delaware Memorial Bridge to Downsville, NY.

A total of 7,553 river herring were estimated to be caught and 4,916 were harvested by recreational anglers in the Delaware River for 2002. Angler catch rate was estimated 0.0189 per angler hour and the harvest rate was estimated at 0.0123 per angler hour.

12.9.3. Subsistence Fishing

There is no known or recorded subsistence fishery for river herring within the Basin.

12.9.4. Characterization of Other Losses

There are many potential unknown sources of mortality from power plant intakes, commercial discards, and landings categorized as “bait”. Many of these could be significant.

12.10. FISHERY-INDEPENDENT SURVEYS

12.10.1. Spawning Stock Surveys

The Delaware Estuary is monitored annually by DFW to document the relative abundance and distribution of a number of important finfish species. A 30-foot bottom trawl was used to sample nine fixed stations in the Delaware Bay from March through December (Greco 2015). Tow duration was 20 minutes with a minimum tow time of 10 minutes required for the data to be considered valid. A global positioning system (GPS) was used to determine exact vessel position at the start and conclusion of each tow. Odometer readings from the GPS unit were used to determine distance towed (nautical miles). Adult densities were calculated for blueback herring and alewife by dividing the number of individuals for a species by the distance towed (N/NM) at each station sampled, then calculating arithmetic means and standard errors in the typical fashion.

Length frequencies have been determined for blueback herring (Figure 12.9) and alewife (Figure 12.10) resulting from collections during the adult finfish surveys conducted on the Delaware Bay. Species represented by less than 50 individuals were measured for fork length to the nearest half-centimeter. Species with more than fifty individuals were randomly sub-sampled (50 measurements) for length with the remainder being enumerated for each tow.

One of the area utilities Public Service Electric and Gas (PSEG) constructed and maintained fish ladders on Delaware River Estuary tributaries for spawning run restoration of alewife and blueback herring (Table 12.3). Alaska Steeppass fish ladders have been installed at twelve sites: Sunset Lake, Stewart Lake, Newton Lake, and Cooper River Lake in New Jersey, and Noxontown Pond, Silver Lake (Dover), Silver Lake (Milford), McGinnis Pond, Coursey Pond, McColley Pond, Garrisons Lake and Moores Lake in Delaware. Adult passage monitoring typically occurred from March to early June. Sampling was performed using a fish ladder exit trap net. Sites were not sampled every year. Sampling was stopped when a fish ladder consistently passed adult herring, to avoid potentially impacting spawning behavior.

12.10.2. Juvenile Surveys

The Delaware Estuary is monitored annually by DFW to document the relative abundance and distribution of a number of important juvenile finfish species encountered in the estuary from April through October at 38 fixed stations using a 16' trawl seine. Tow duration was 10 minutes for the 16-foot trawl survey. A global positioning system (GPS) was used to determine exact vessel position at the start and conclusion of each tow. Odometer readings from the GPS unit were used to determine distance towed (nautical miles). JAIs were determined for yoy and age 1 blueback herring and alewife resulting from collections during juvenile finfish surveys. Fish densities were calculated by dividing the number of individuals for a species by the distance towed (No/NM) at each station sampled, then arithmetic means and standard errors were calculated. Length frequencies have been determined for blueback herring and alewife resulting from collections during juvenile finfish surveys conducted on the Delaware River and Delaware Bay. A representative subsample of 30 juvenile specimens per species was measured for fork length to the nearest millimeter; the remainder were enumerated.

Another juvenile survey includes the use of a 150' haul seine is used to generate juvenile indices of abundance for the Christina River, a tributary of the Delaware River (Park, I. A. 2015). Haul seine sampling was fully implemented in 2014 and continued annually to assess reproduction and recruitment of all alosines. Sampling in 2015 was conducted biweekly at five locations on the Christina River from July through the first week of November during ebb or slack tides. All captured fish were identified to species and enumerated.

The reproductive success of YOY river herring was assessed, prior to assumed out-migration, in Delaware ponds using a boat-mounted pulsed-DC electrofisher by DFW staff during 1995-96 and from 2000 to the present (Stetzar 2015). Fall samples were obtained to determine spawning success, recruitment and relative abundance between impoundments. Most of these impoundments are small, averaging less than 64 acres, and the entire pond can be surveyed relatively quickly. Young river herring are either counted individually or size of the schools is estimated. Subsamples are taken to determine species composition and size ranges. The CPUE was calculated using the total river herring observed which included estimates of larger schools. Estimates of total production are not determined. Careful analysis of the juvenile electrofishing data is warranted since not all impoundments were equally sampled throughout the time period. This work was discontinued in February of 2014.

PSEG also conducted electrofishing twice a month from September through November to gauge juvenile river herring presence and relative abundance at the impoundments discussed earlier in this document

(Table 12.6). Fish were counted each time the foot switch was pressed. The count of small numbers of fish was an exact count. Estimates of larger numbers of fish were made in 10, 25, 50, 100, 150, and 200 fish increments. Sampling frequency and locations varied. Additionally, when herring were encountered in considerable numbers, electroshocking was briefly interrupted to limit the stress on fish. The survey was discontinued in 2005.

New Jersey has conducted a juvenile abundance survey for striped bass in the Delaware River from Trenton to Artificial Island since 1980. The program utilizes a 100-foot bagless beach seine during the months of August, September, and October at representative stations. A juvenile abundance index (JAI) is calculated for alewife and blueback herring using a geometric mean. Since river herring are not collected at all stations, those farthest downriver stations (below the Delaware Memorial Bridges) have been removed from analysis to give a more accurate picture of juvenile production in the lower Delaware River. Length frequencies of juvenile blueback herring and alewife have been determined from collections since 2002 (Table 12.9). A representative subsample of 30 juvenile specimens per species was measured for fork length to the nearest half centimeter; the remainder was enumerated. No trends were discernible from this time series of data.

12.11. ASSESSMENT APPROACHES AND RESULTS

The purpose of this report is to document and update the stock status of river herring in the Delaware River and Estuary. It is obvious from historical data and anecdotal information that river herring populations were much larger in the past and have declined drastically since the late 1800s.

12.11.1. Spawning Stock Abundance

Adult river herring commercial landings were typically the result of bycatch from other fisheries like the white perch fishery. Overall landings data in both New Jersey and Delaware showed that landings have declined in the years prior to the basin wide harvest moratorium. The best indicator of the commercial fishery was the CPUE from mandatory commercial catch reports. In Delaware, the commercial CPUE for the Delaware Estuary declined since the mid-1990s and the lowest CPUE in the time series for the Delaware River occurred in 2010. The New Jersey commercial CPUE, except for 2000, decreased since 1997 up until the harvest moratorium. The recreational gill net CPUE for Delaware peaked in 1998 with no data between 2004- 2006, then a slight incline with data collected in 2007. The declines seen in the commercial and recreational data could be a result of declining stocks, declining effort, or regulatory changes.

Adult data from Delaware's finfish trawl survey indicate the greatest recent increase in alewife abundance occurred from 1996-1998 (Figure 12.8). After 1998 alewife relative abundance decreased and has remained at substantially depressed levels since 2002, however since 2008 alewife levels have been trending somewhat upwards (Figure 12.8). Blueback herring varied without trend throughout the 1990's prior to good year classes in 1999 and 2000. Blueback herring abundance has trended downward from 2001-2003 and has remained stable at low levels without trend since 2003.

The aggregate PSEG fish ladder passage CPUE (#/Hr) has trended downward since 1996 in Delaware and New Jersey ponds (Table 12.4). This index has declined throughout the time series from the highest value of 0.5 in 1996 to the lowest value of 0.001 in 2014 (PSEG 2015). Blueback herring have been the primary users of the fish ladders and river herring runs in the Basin are dominated by blueback herring overall. Alewife use of the ladders increases slightly in the northern part of the Basin. These numbers need to be considered with certain caveats however. For blueback herring, ladders that had high usage are no longer sampled every year. Likewise, newer ladders have yet to see any significant usage but are monitored 24

hours per day. The increase in alewife usage comes mainly from the Sunset Lake (NJ) fish ladder where restoration seems to be going well for alewife while all other fish ladders have yet to see the same results.

12.11.2. Juvenile Abundance

The annual abundance (geometric mean catch per tow) from 16-foot otter trawl sampling for YOY alewife in the Delaware River and Bay varied without trend throughout the time series with peak years in 1996, 2000, 2003, 2007, and 2015 (Figure 12.13). However, the time series does demonstrate improvement since 2012. The Age 1 alewife index declined since the highest value was reached in 1997 (Figure 12.15). The YOY index for blueback herring increased slightly from 1990 through 2003, but substantial declines were noted since then (Figure 12.14). The Age 1 blueback herring index has varied substantially since 1991 with no discernible trend (Figure 12.16). It is unknown if these changes in the trawl index are actual trends or more a function of gear inefficiency. A bottom trawl is not the most efficient gear for capturing alosines, and can result in low sample numbers. Environmental conditions may have also played a factor in the number of river herring captured.

In 2015, the annual abundance (geometric mean catch per haul) of river herring from haul seining on the Christina River was 2.11 for alewife and 1.34 for blueback herring. The geometric mean increased substantially from 2014 for both species (Table 12.10).

The PSEG electrofishing survey for YOY alewife fluctuates wildly but shows an increasing trend. The blueback herring index shows an increasing trend from 1996 to 2001 before declining through 2005 when sampling was discontinued (PSEG 2009).

Overall CPUE (catch per minute) of YOY river herring collected during electrofishing efforts throughout seven Delaware impoundments by DFW staff exhibited the highest values in 1999, 2004 and 2007. However, the overall CPUE is often driven by a single pond's catch and does not represent an overall trend in use or reproductive success. For example the 1999 and 2004 CPUE were driven by high numbers sampled primarily in one pond (Wagamon's Pond). The 2007 value was driven by a high number of river herring caught in McColley Pond as well. This work was discontinued in February of 2014.

Juvenile production was very low for both species in the early years of the NJDFW striped bass survey (Table 12.9). Since that time, the blueback herring index was varied with a fairly steady increase in blueback herring production from 1980 through the first real high year class in 1993. From 1993 through 2001, the survey included two additional large year classes (1996 and 2001) with some production years below average. Since 2001 the production of blueback herring has decreased. Abundance of YOY alewife has fluctuated without trend with years of high abundance (1988, 1996, 2001 and 2005) mixed with years of low abundance (1992, 1998, 2002, and 2006, and 2008-2015). More recent alewife trends are similar to blueback herring, although 2007 was considered a good year. It should be noted that environmental conditions in 2002 (drought) and 2006 (floods) were not conducive for good spawning or survival of either species.

12.12. BENCHMARKS

No benchmarks were developed at this time for river herring fisheries in the Basin.

12.13. CONCLUSIONS AND RECOMMENDATIONS

The data that is presented here is a stock status report update of the original stock status report of 2008, and is not intended as a full assessment of river herring within the Delaware River Basin. Additional assessment techniques and data should be used in an attempt to determine why these stocks have

declined in recent years. This would include comparisons to data from other east coast river systems, predation, fishing mortality estimates if available, and offshore harvest and discards.

Overall river herring landings in the Delaware Basin have declined since 1992. Although fish passage may have been considered fair to good in some years, reproduction in these freshwater impoundments has been poor overall. The installation of fish ladders in Delaware ponds have resulted in little success and it appears that to date this effort has been ineffective in restoring river herring populations. However, alewives in New Jersey have increased in recent years due to an increase in passage at the Sunset lake fish ladder.

The overall assessment of data from these stocks suggest stocks have declined since the beginning of data collection. There are no estimates of mortality for the Delaware Basin stocks of river herring so it is not possible to determine the cause or causes of this decline. In order to update our current understanding of the population dynamics associated with both species of river herring within the Delaware River Basin, the following research areas should be further considered, including, but not limited to:

- Improved assessment of river herring adults at all fish ladder installations such as tagging studies below the ladders to estimate population numbers and ladder passage rates.
- Evaluation of fish ladders to determine the effectiveness of attraction flow at each ladder, with priority given to those ladders that are under performing.
- Improved assessment of river herring production in targeted tributaries within the basin.
- Predator-prey relationships especially with striped bass, bluefish and white perch for yoy and striped bass, weakfish, bluefish, spiny dogfish for adults require evaluation.
- Habitat condition and usage continue to require evaluation and consistent monitoring.

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Table 12.1 Delaware Estuary Gill Net Landings and CPUE. Discontinued after 2011. (Source: DE DFW).

| Year | Kgs Landed | CPUE (kgs/net meter) |
|-------|--------------|----------------------|
| 1985 | 2158 | 0.044 |
| 1986 | 643 | 0.015 |
| 1987 | 496 | 0.010 |
| 1988 | 1263 | 0.009 |
| 1989 | 1560 | 0.112 |
| 1990 | 746 | 0.046 |
| 1991 | 3305 | 0.070 |
| 1992 | 307 | 0.018 |
| 1993 | 2568 | 0.102 |
| 1994 | 170 | 0.043 |
| 1995 | 110 | 0.019 |
| 1996 | 679 | 0.071 |
| 1997 | 44 | 0.014 |
| 1998 | 181 | 0.017 |
| 1999 | 128 | 0.042 |
| 2000 | 223 | 0.028 |
| 2001 | 562 | 0.053 |
| 2002 | 38 | 0.012 |
| 2003 | 196 | 0.029 |
| 2004 | 231 | 0.023 |
| 2005 | 8 | 0.003 |
| 2006 | 579 | 0.016 |
| 2007 | 85 | 0.005 |
| 2008 | 886 | 0.064 |
| 2009* | Confidential | |
| 2010* | Confidential | |
| 2011 | 341 | 0.362 |

Table 12.2 Recreational fishery for river herring in Delaware, 1996 – 2003, and 2007. (Source DE DFW).

| Year | Harvested N | Released Alive N | Total N | # of Fishers | Effort Trips | Net Yard Days | Catch per Trip | Harvest per Trip |
|------|----------------|---------------------|------------|-----------------|-----------------|------------------|----------------------|------------------------|
| 1996 | 4399 | . | 4399 | 391 | 3,808 | 196,381 | 1.16 | 1.16 |
| 1997 | 2247 | . | 2247 | 274 | 2,291 | 111,659 | 0.98 | 0.98 |
| 1998 | 2835 | . | 2835 | 269 | 1,161 | 55,453 | 2.44 | 2.44 |
| 1999 | 460 | 14 | 474 | 27 | 948 | 49,342 | 0.50 | 0.49 |
| 2000 | 1134 | 6 | 1140 | 197 | 1,560 | 84,396 | 0.73 | 0.73 |
| 2001 | 502 | 1028 | 1530 | 198 | 1,686 | 82,301 | 0.91 | 0.30 |
| 2002 | 297 | 48 | 345 | 179 | 1,615 | 83,022 | 0.21 | 0.18 |
| 2003 | 370 | 43 | 413 | 173 | 1,390 | 65,779 | 0.30 | 0.27 |
| 2004 | No Data | . | . | . | . | . | . | . |
| 2005 | No Data | . | . | . | . | . | . | . |
| 2006 | No Data | . | . | . | . | . | . | . |
| 2007 | 341 | 495 | 836 | 144 | 878 | 43,096 | 0.95 | 0.39 |

Table 12.3 Fish ladder information from PSEG

| | Ladder Date | Size (acres) | Length (miles) | Perimeter (miles) | Lake Watershed (acres) |
|-----------------------|-------------|--------------|----------------|-------------------|------------------------|
| New Jersey | | | | | |
| Cooper River Lake | 1998 | 190 | 4.53 | 9.57 | 23,680 |
| Newtown Lake | 2004 | 41 | 2.87 | 6.03 | 2,332 |
| Stewart Lake | 2004 | 38 | 1.17 | 4.39 | 2,897 |
| Sunset Lake | 1997 | 94 | 0.67 | 2.1 | 29,248 |
| | | | | | |
| Delaware | | | | | |
| Coursey Pond | 1997 | 58 | 0.72 | 2.48 | 14,579 |
| Garrison Lake | 1999 | 86 | 0.76 | 2.19 | 10,752 |
| McColley Pond | 1996 | 49 | 1.14 | 3.34 | 6,080 |
| McGuiness Pond | 1996 | 31 | 0.76 | 2.16 | 7,040 |
| Moores Lake | 1999 | 27 | 0.76 | 1.87 | 11,776 |
| Noxontown Pond | 2004 | 162 | 1.99 | 7.03 | 6,110 |
| Silver Lake (Dover) | 1996 | 171 | 1.71 | 4.52 | 20,480 |
| Silver Lake (Milford) | 2004 | 27 | 0.49 | 1.56 | 17,326 |

Table 12.4 PSEG river herring fish passage CPUE for Delaware and New Jersey Ponds. Source: NJ DFW.

| Year | Effort | BB | AW |
|------|----------|-------|-------|
| 1996 | 239 | 0.490 | 0.013 |
| 1997 | 593 | 0.312 | 0.002 |
| 1998 | 3501 | 0.196 | 0.006 |
| 1999 | 7384 | 0.176 | 0.031 |
| 2000 | 12242 | 0.118 | 0.007 |
| 2001 | 14684 | 0.134 | 0.006 |
| 2002 | 14552 | 0.181 | 0.019 |
| 2003 | 14928 | 0.059 | 0.013 |
| 2004 | 17679 | 0.065 | 0.054 |
| 2005 | 16053 | 0.022 | 0.002 |
| 2006 | 12232 | 0.016 | 0.002 |
| 2007 | 13102.67 | 0.008 | 0.025 |
| 2008 | 17986.61 | 0.138 | 0.010 |
| 2009 | 19941.96 | 0.010 | 0.028 |
| 2010 | 13165 | 0.010 | 0.060 |
| 2011 | 14019.87 | 0.025 | 0.051 |
| 2012 | 20469.38 | 0.039 | 0.008 |
| 2013 | 16347.98 | 0.007 | 0.000 |
| 2014 | 12111 | 0.001 | 0.001 |
| 2015 | 0 | - | - |
| 2016 | 22567 | 0.117 | 0.005 |

Table 12.5 PSEG river herring stocking for Delaware and NJ Ponds (1996-2004). Discontinued after 2004.
Source: NJ DFW.

| Bluebacks | | | | | | | | | | |
|------------------------|------|------|-------|-------|------|-------|------|------|------|-------|
| Impoundment | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | Total |
| Cooper River Lake (NJ) | N/A | N/A | 766 | 1,069 | 964 | 1,071 | 840 | 197 | 0 | 4,907 |
| Coursey Pond | N/A | 0 | 156 | 0 | 0 | 0 | 0 | 0 | 0 | 156 |
| Garrison's Lake | N/A | N/A | N/A | 318 | 48 | 473 | 432 | 0 | 17 | 1,288 |
| McColley Pond | 8 | 0 | 7 | 11 | 0 | 0 | 0 | 0 | 0 | 26 |
| McGinnis Pond | 32 | 0 | 211 | 166 | 0 | 241 | 0 | 22 | 11 | 683 |
| Moore's Lake | N/A | N/A | N/A | 271 | 70 | 0 | 0 | 0 | 0 | 341 |
| Newton Lake (NJ) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Noxontown Pond | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 23 | 23 |
| Silver Lake (Dover) | 84 | 0 | 713 | 687 | 419 | 993 | 865 | 201 | 0 | 3,962 |
| Silver Lake (Milford) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Stewart Lake (NJ) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Sunset Lake (NJ) | N/A | 50 | 1,045 | 892 | 430 | 1,337 | 756 | 969 | 126 | 5,605 |
| Alewife | | | | | | | | | | |
| Impoundment | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | Total |
| Cooper River Lake (NJ) | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coursey Pond | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Garrison's Lake | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| McColley Pond | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| McGinnis Pond | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 |
| Moore's Lake | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Newton Lake (NJ) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Noxontown Pond | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0 | 0 |
| Silver Lake (Dover) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Silver Lake (Milford) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Stewart Lake (NJ) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Sunset Lake (NJ) | N/A | 0 | 0 | 3 | 71 | 0 | 254 | 0 | 0 | 328 |

Table 12.6 PSEG river herring electrofishing CPUE for Delaware and New Jersey Ponds. Discontinued after 2005 Source: NJ DFW.

| Year | Effort | Blueback | Alewife |
|------|--------|----------|---------|
| 1996 | 707.4 | 0.062 | 0.000 |
| 1997 | 470.8 | 0.520 | 0.002 |
| 1998 | 618.6 | 4.470 | 0.000 |
| 1999 | 493.6 | 26.244 | 0.063 |
| 2000 | 433.1 | 12.136 | 0.028 |
| 2001 | 499.5 | 49.215 | 0.212 |
| 2002 | 434.9 | 8.533 | 0.000 |
| 2003 | 433.9 | 15.266 | 0.364 |
| 2004 | 720 | 5.819 | 0.013 |
| 2005 | 720 | 6.639 | 0.554 |

Table 12.7 New Jersey commercial river herring (alewife and blueback herring) landings, in pounds (1950 – 2015). NMFS landings are statewide; Logs are from the Delaware Basin. Source: NJ DFW.

| Year | NMFS | Logs | Year | NMFS | Logs |
|------|--------|------|------|--------|-------|
| 1950 | 29,000 | - | 1983 | 2,200 | - |
| 1951 | 7,200 | - | 1984 | 3,100 | - |
| 1952 | 600 | - | 1985 | 4,800 | - |
| 1953 | 8,600 | - | 1986 | 4,200 | - |
| 1954 | 0 | - | 1987 | 5,200 | - |
| 1955 | 22,900 | - | 1988 | 700 | - |
| 1956 | 22,300 | - | 1989 | 800 | - |
| 1957 | 8,100 | - | 1990 | 42,494 | - |
| 1958 | 1,400 | - | 1991 | 9,994 | - |
| 1959 | 2,200 | - | 1992 | 3,069 | - |
| 1960 | 3,000 | - | 1993 | 2,659 | - |
| 1961 | 16,500 | - | 1994 | 328 | - |
| 1962 | 20,300 | - | 1995 | 795 | - |
| 1963 | 3,400 | - | 1996 | 4,449 | - |
| 1964 | 14,200 | - | 1997 | 4,515 | 9,221 |
| 1965 | 21,500 | - | 1998 | 7,371 | 2,430 |
| 1966 | 12,400 | - | 1999 | 1,377 | 3,880 |
| 1967 | 9,000 | - | 2000 | 0 | 5,410 |
| 1968 | 8,400 | - | 2001 | 1,034 | 1,900 |
| 1969 | 5,100 | - | 2002 | 3,366 | 552 |
| 1970 | 7,500 | - | 2003 | 228 | 2,127 |
| 1971 | 9,500 | - | 2004 | 2,548 | 3,192 |
| 1972 | 14,700 | - | 2005 | 1,079 | 2,402 |
| 1973 | 7,000 | - | 2006 | 469 | 2,793 |
| 1974 | 10,600 | - | 2007 | 0 | - |
| 1975 | 9,300 | - | 2008 | 631 | 1,551 |
| 1976 | 11,300 | - | 2009 | 0 | 177 |
| 1977 | 10,600 | - | 2010 | 1,004 | 409 |
| 1978 | 2,400 | - | 2011 | | 1,634 |
| 1979 | 6,600 | - | 2012 | | 18 |
| 1980 | 18,600 | - | 2013 | | 0 |
| 1981 | 13,800 | - | 2014 | | 1 |
| 1982 | 13,600 | - | 2015 | | 0 |
| | | | Avg | 7,541 | 2,094 |

Table 12.8 New Jersey Commercial CPUE for Delaware Bay (1997-2015). Source: NJ DFW.

| Year | Hr*Ft/100 | Lbs | CPUE |
|-------------|------------------|------------|-------------|
| 1997 | 15,248 | 9,221 | 0.60 |
| 1998 | 8,100 | 2,430 | 0.30 |
| 1999 | 22,608 | 3,880 | 0.17 |
| 2000 | 6,846 | 5,410 | 0.79 |
| 2001 | 12,696 | 1,900 | 0.15 |
| 2002 | 17,872 | 552 | 0.03 |
| 2003 | 12,160 | 2,127 | 0.17 |
| 2004 | 43,348 | 3,192 | 0.07 |
| 2005 | 40,176 | 2,402 | 0.06 |
| 2006 | 45,288 | 2,793 | 0.06 |
| 2007 | - | - | - |
| 2008 | 49,176 | 1,551 | 0.03 |
| 2009 | 29,808 | 177 | 0.01 |
| 2010 | 26,688 | 409 | 0.02 |
| 2011 | 43,992 | 1,634 | 0.04 |
| 2012 | 49,884 | 18 | 0.00 |
| 2013 | 0 | 0 | 0.00 |
| 2014 | 144 | 1 | 0.01 |
| 2015 | 0 | 0 | 0.00 |

Table 12.9 Delaware River index of relative abundance, geometric mean, for juvenile river herring collected during New Jersey's striped bass young of year survey (1980-2015). Source: NJ DFW.

| YEAR | Alewife | Rank | Blueback | Rank |
|------------------|-------------|------|-------------|------|
| 1980 | 0.00 | 32 | 30.30 | 2 |
| 1981 | 0.00 | 32 | 0.26 | 35 |
| 1982 | 0.10 | 22 | 3.19 | 25 |
| 1983 | 0.28 | 11 | 46.15 | 1 |
| 1984 | 0.00 | 32 | 16.99 | 8 |
| 1985 | 0.06 | 25 | 7.17 | 17 |
| 1986 | 0.52 | 6 | 18.13 | 6 |
| 1987 | 0.23 | 15 | 10.72 | 10 |
| 1988 | 3.17 | 1 | 9.03 | 13 |
| 1989 | 0.26 | 13 | 17.90 | 7 |
| 1990 | 0.26 | 12 | 4.63 | 21 |
| 1991 | 0.47 | 7 | 9.84 | 11 |
| 1992 | 0.03 | 27 | 6.91 | 18 |
| 1993 | 0.35 | 9 | 19.78 | 5 |
| 1994 | 0.19 | 17 | 2.38 | 28 |
| 1995 | 0.11 | 21 | 1.84 | 29 |
| 1996 | 1.96 | 2 | 24.97 | 4 |
| 1997 | 0.15 | 19 | 2.58 | 27 |
| 1998 | 0.03 | 28 | 4.36 | 22 |
| 1999 | 0.41 | 8 | 5.34 | 20 |
| 2000 | 0.14 | 20 | 12.33 | 9 |
| 2001 | 0.83 | 4 | 26.33 | 3 |
| 2002 | 0.00 | 32 | 0.62 | 33 |
| 2003 | 0.30 | 10 | 7.50 | 16 |
| 2004 | 0.24 | 14 | 8.15 | 14 |
| 2005 | 0.95 | 3 | 9.79 | 12 |
| 2006 | 0.00 | 32 | 0.15 | 36 |
| 2007 | 0.52 | 5 | 4.29 | 23 |
| 2008 | 0.01 | 29 | 1.37 | 30 |
| 2009 | 0.06 | 24 | 3.55 | 24 |
| 2010 | 0.05 | 26 | 1.37 | 31 |
| 2011 | 0.19 | 16 | 7.97 | 15 |
| 2012 | 0.01 | 31 | 0.42 | 34 |
| 2013 | 0.01 | 30 | 1.21 | 32 |
| 2014 | 0.18 | 18 | 5.46 | 19 |
| 2015 | 0.10 | 23 | 2.76 | 26 |
| | | | | |
| 1980-2015 | 0.34 | | 9.33 | |
| 2006-2015 | 0.30 | | 2.85 | |
| 2011-2015 | 0.13 | | 3.56 | |

Table 12.10 The geometric mean number taken per haul of river herring (2014-2015). Source: DE DFW.

| Year | Alewife | Blueback herring |
|------|---------|------------------|
| 2014 | 0.02 | 0.61 |
| 2015 | 2.11 | 1.34 |

Delaware River Basin

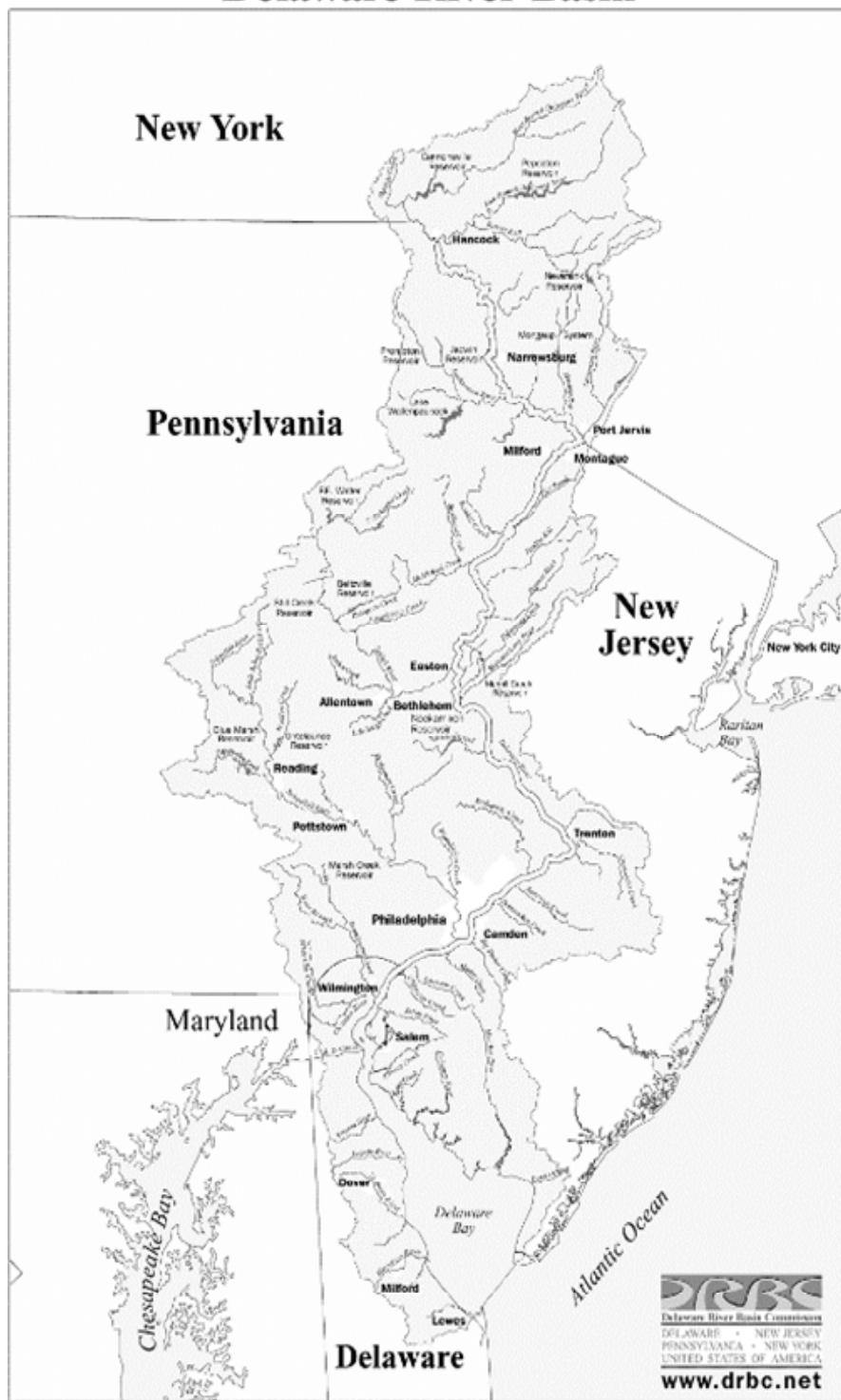


Figure 12.1 Map of the Delaware River/Bay Watershed.

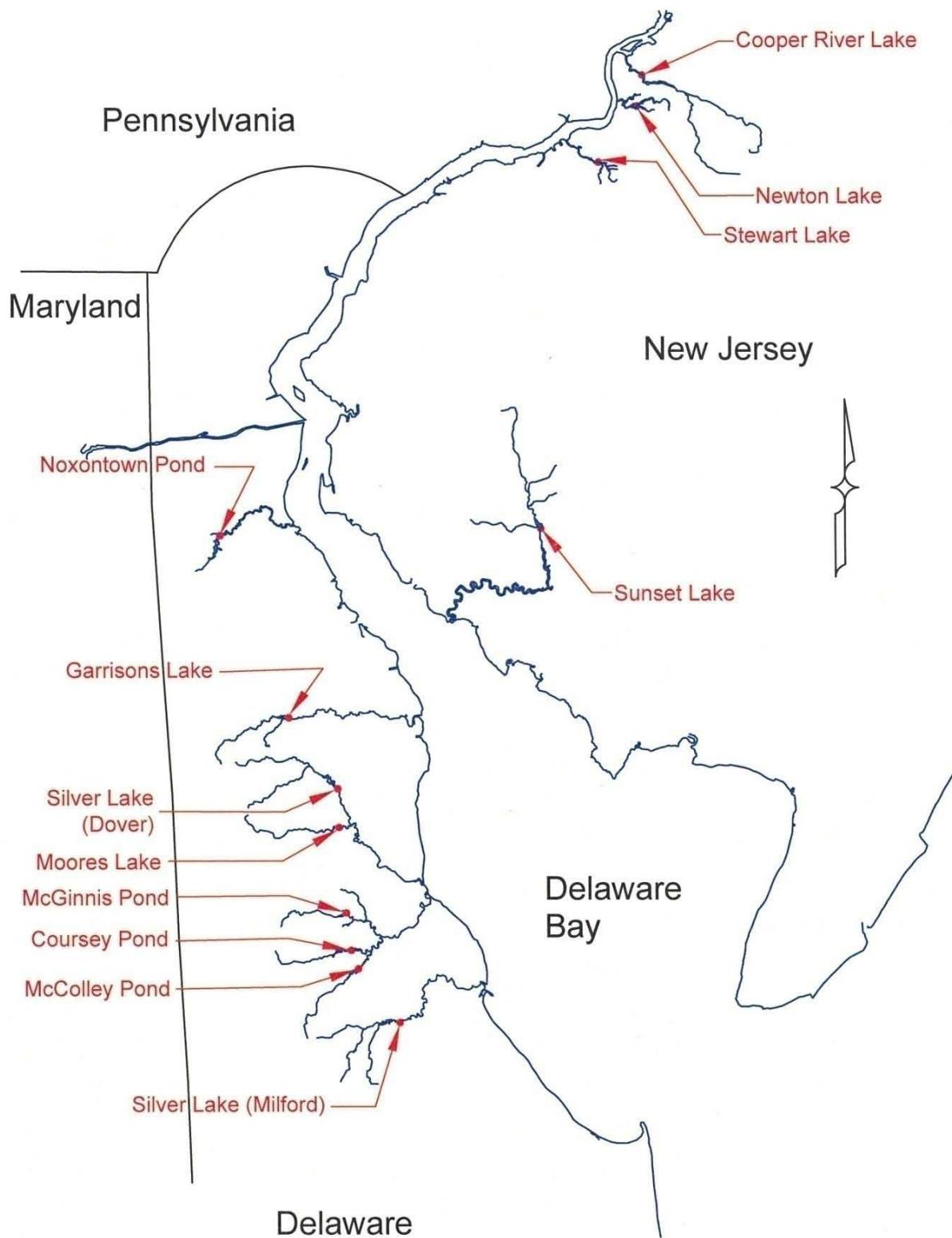


Figure 12.2 Locations of PSEG fish ladders within the Delaware River Basin (2009).

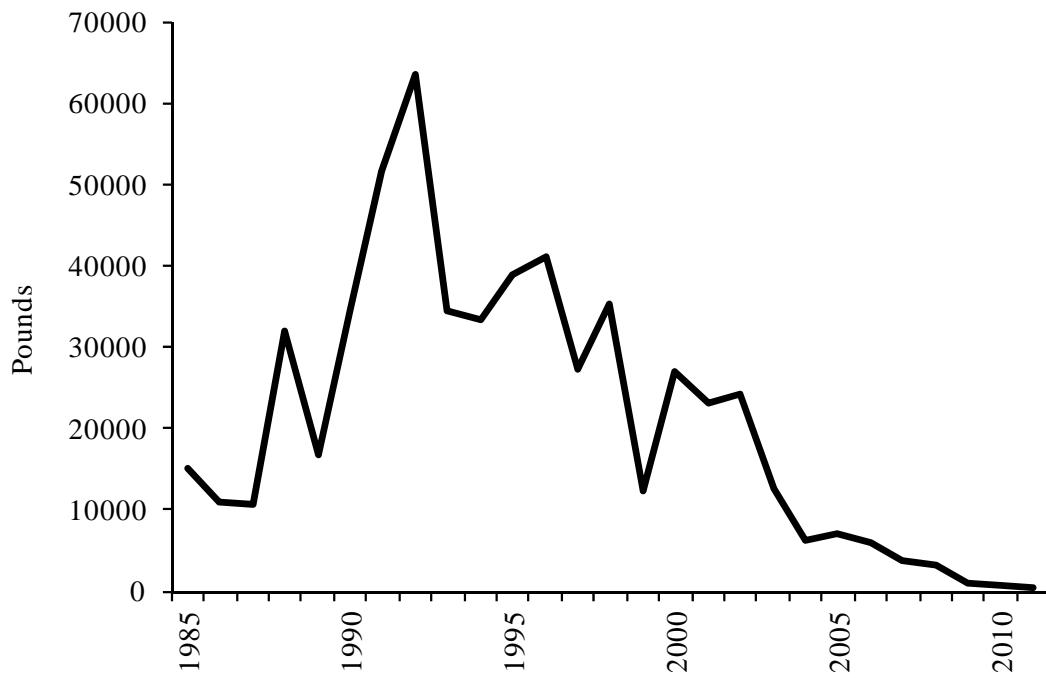


Figure 12.3 The reported **statewide** river herring commercial landings for Delaware, all gears combined. Discontinued after 2011. Source: DE DFW

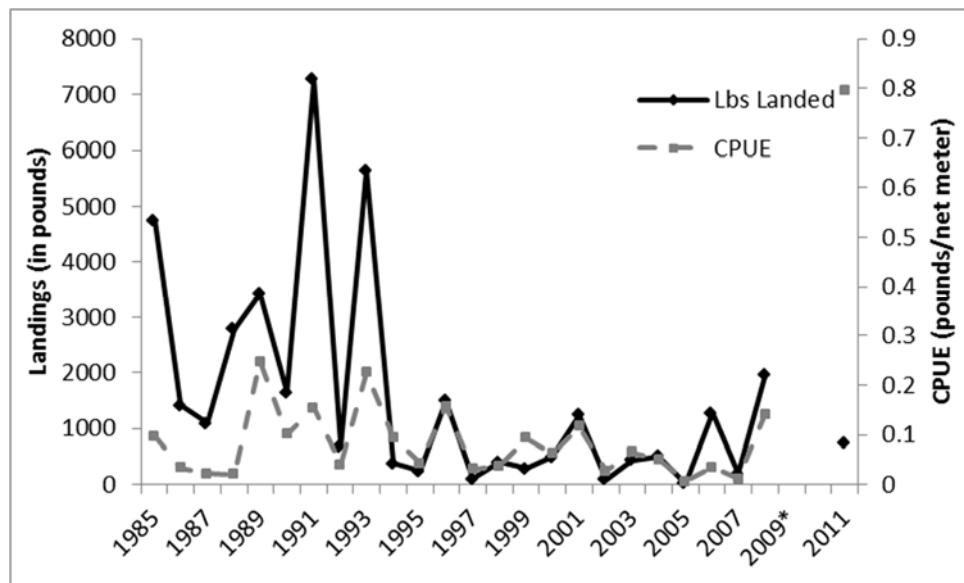


Figure 12.4 The reported commercial gill net landings and the pounds of fish landed per meter of gill net for Delaware's portion of the **Delaware Estuary**. * Data from 2009 and 2010 are confidential. Discontinued after 2011. Source: DE DFW

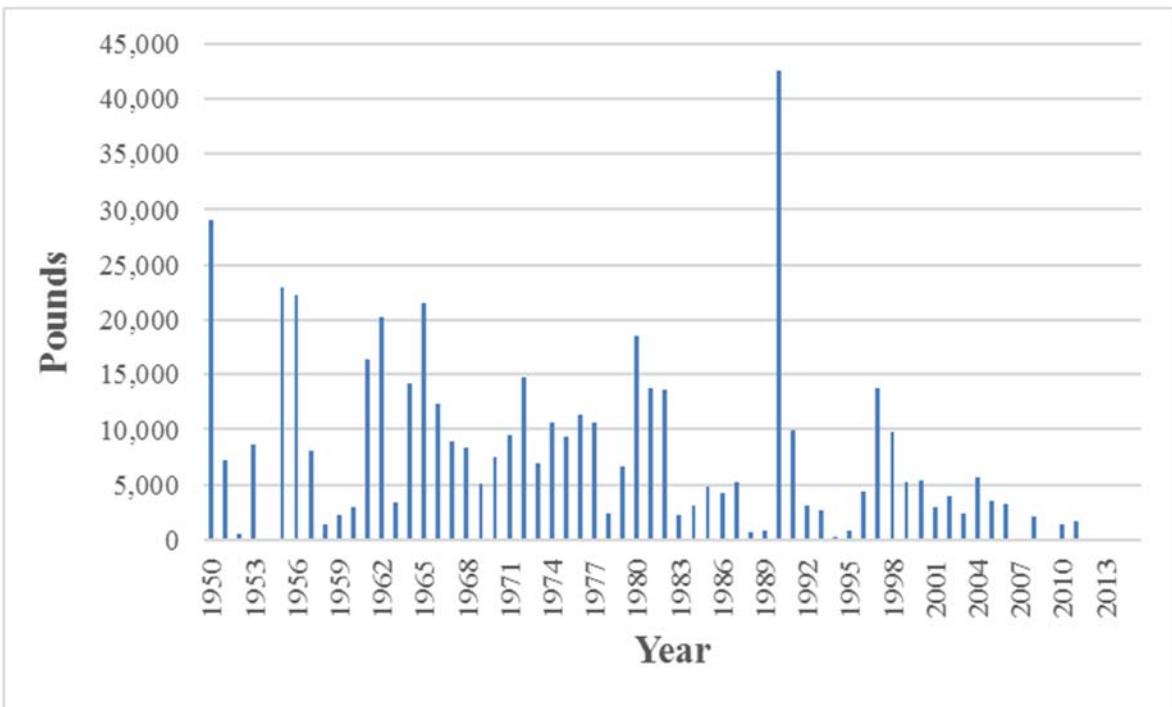


Figure 12.5 New Jersey Reported Commercial Landings (1950-2015). Source: NJ DFW

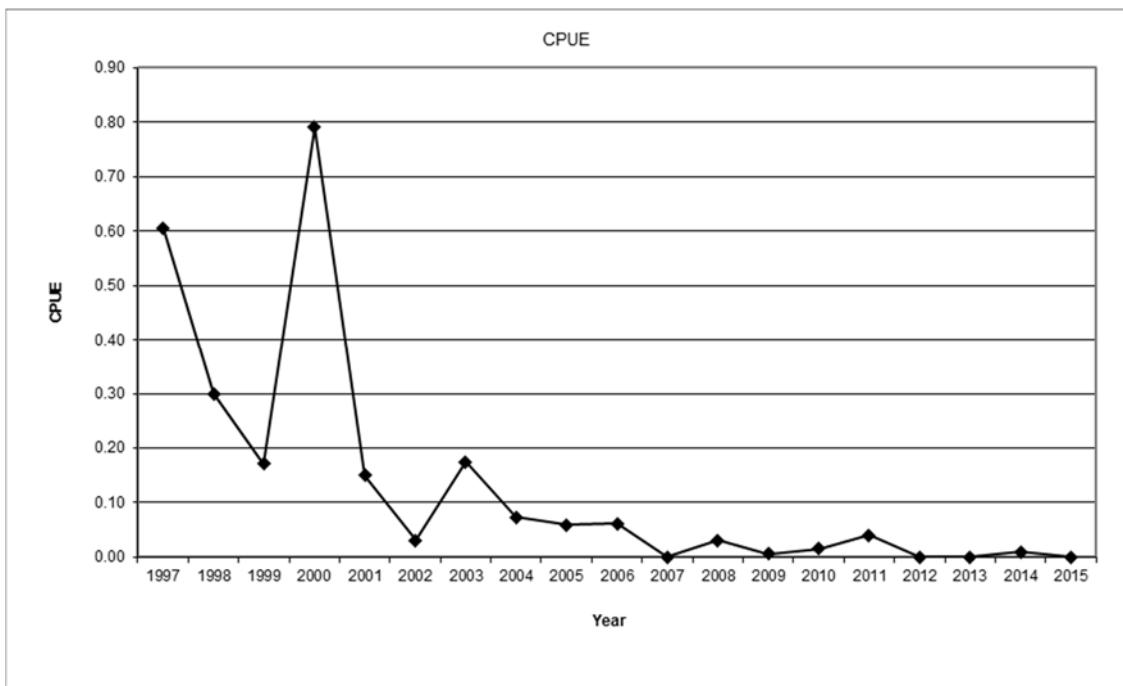


Figure 12.6 New Jersey Commercial CPUE for lower Delaware Bay (1997-2015). Harvest is bycatch in small mesh weakfish/perch fisheries during February to May. Source: NJ DFW

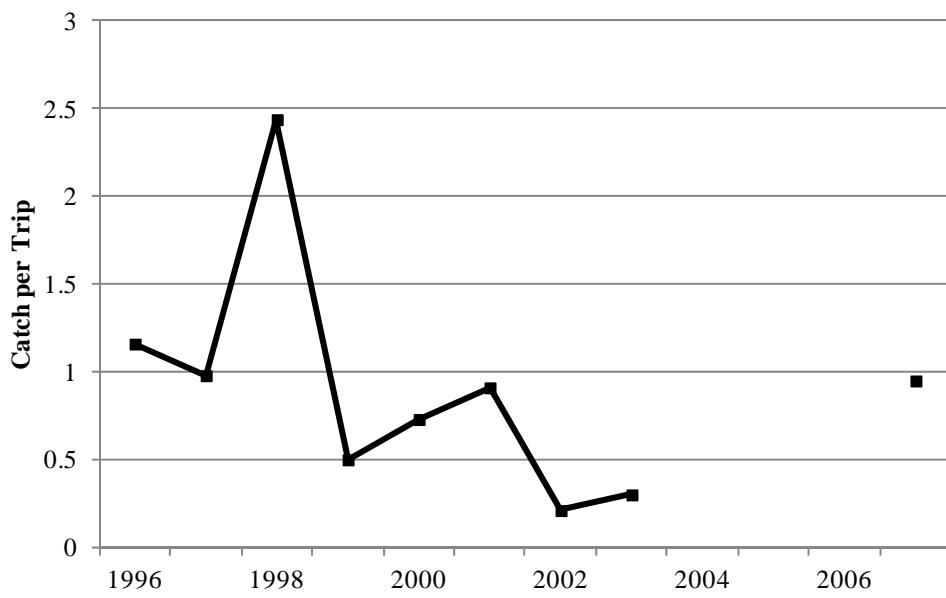


Figure 12.7 The recreational gill net fishery annual catch per trip for river herring in Delaware (1996 – 2003 and 2007). Source: DE DFW

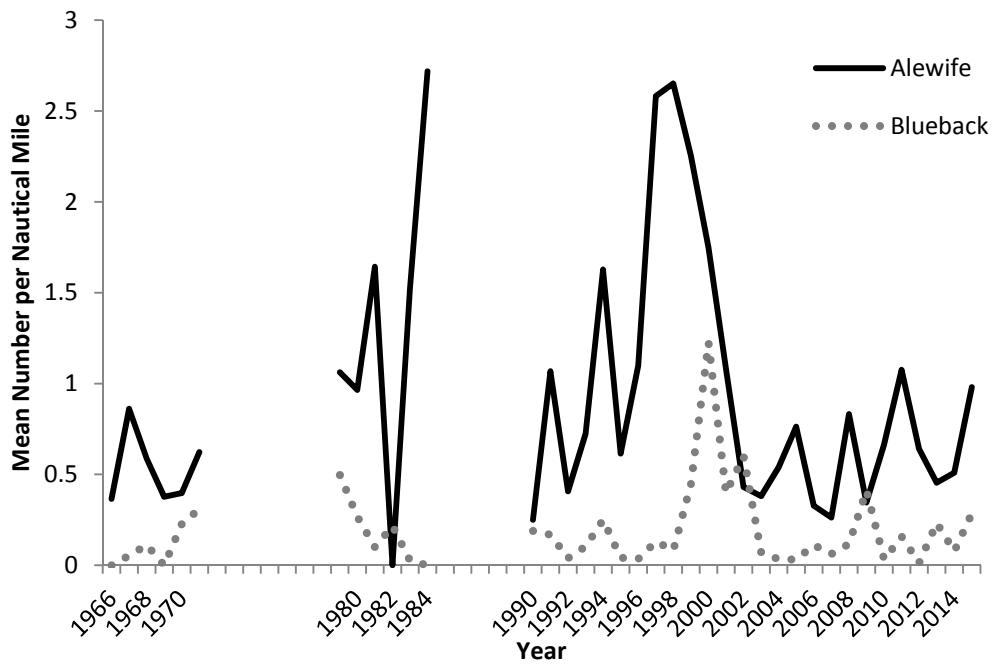


Figure 12.8 Adult River Herring indices for the Delaware Bay 30 foot trawl: 1966 – 2015. There is no data for 1972-1978 and 1985-1989. Source: DE DFW.

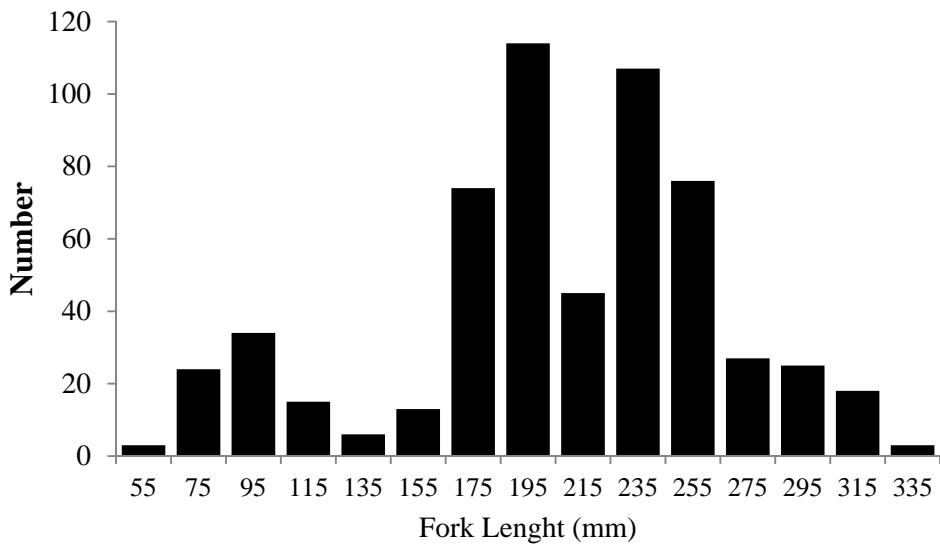


Figure 12.9 Adult Blueback Herring length frequencies for the Delaware River/Bay 30 foot trawl: 1966 – 2015. There was no data for 1972-1978 and 1985-1989. Source: DE DFW.

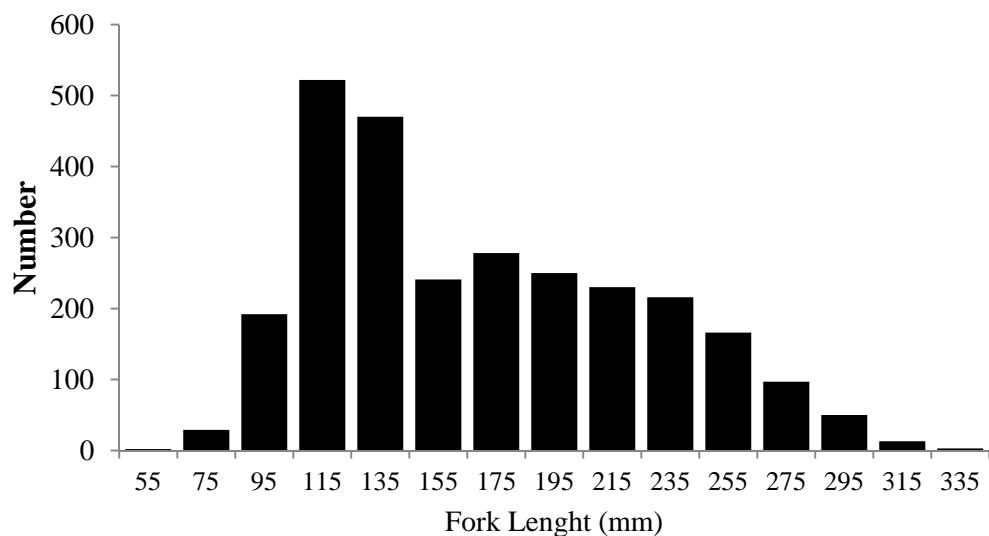


Figure 12.10 Adult Alewife length frequencies for the Delaware River/Bay 30 foot trawl: 1966 – 2015. There was no data for 1972-1978 and 1985-1989. Source: DE DFW.

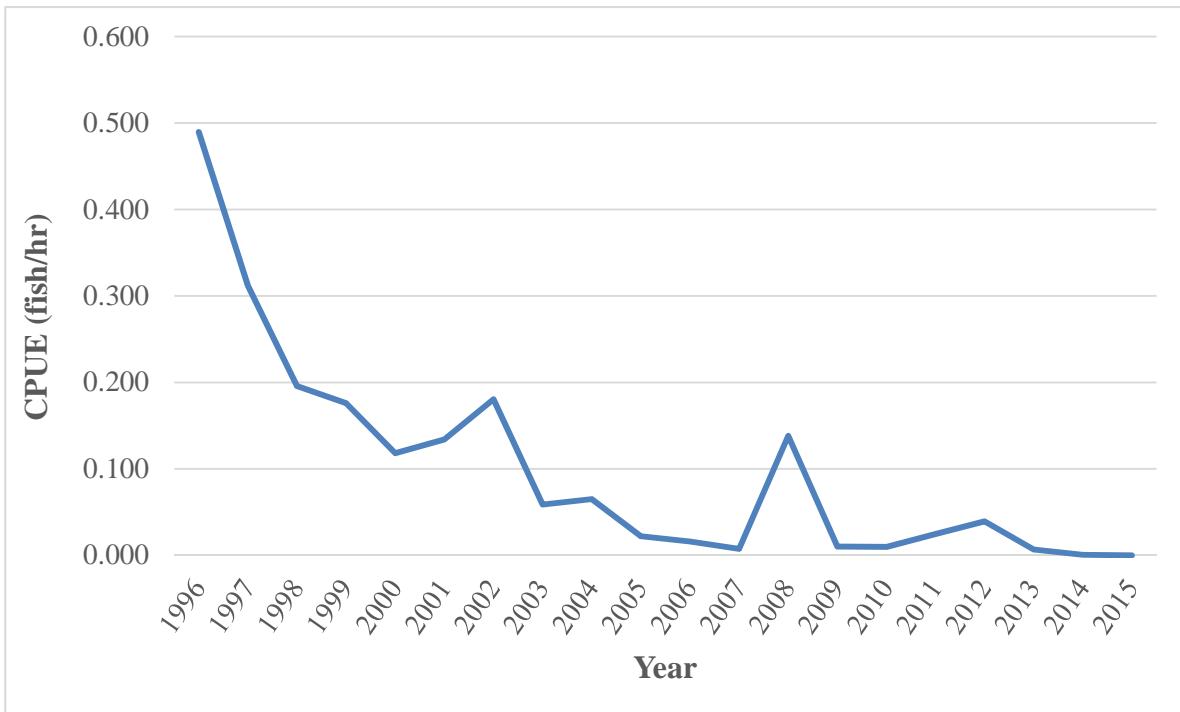


Figure 12.11 PSEG blueback herring fish passage CPUE (fish per hour) for Delaware and New Jersey Ponds.
Source: NJ DFW.

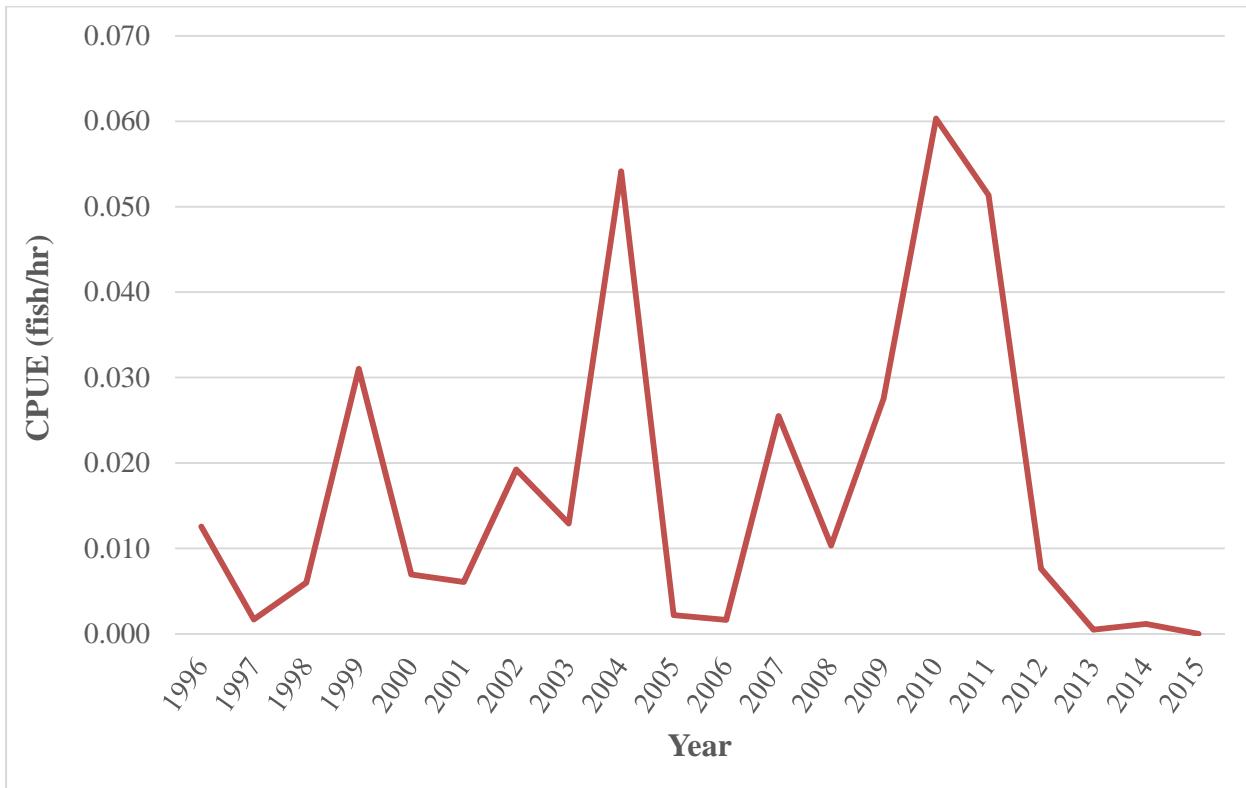


Figure 12.12 PSEG alewife fish passage CPUE (fish per hour) for Delaware and New Jersey Ponds. Source: DE DFW.

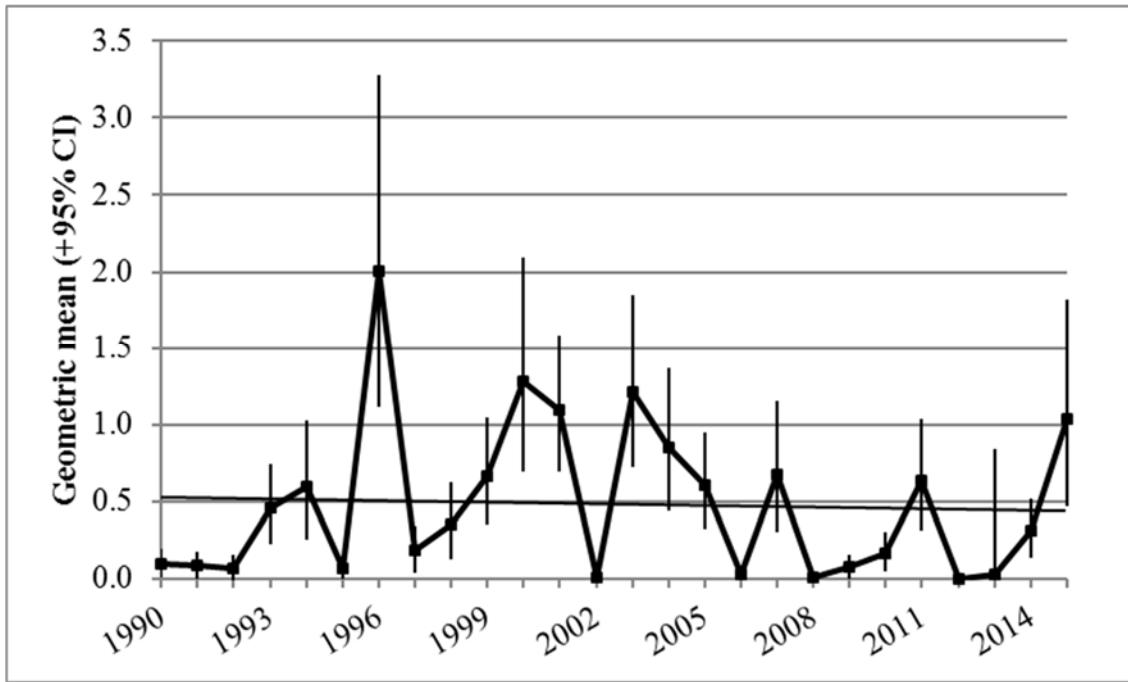


Figure 12.13. Annual YOY alewife relative abundance index (geometric mean catch per tow) and trend from the 16 foot otter trawl survey in the Delaware Estuary. Source: DE DFW.

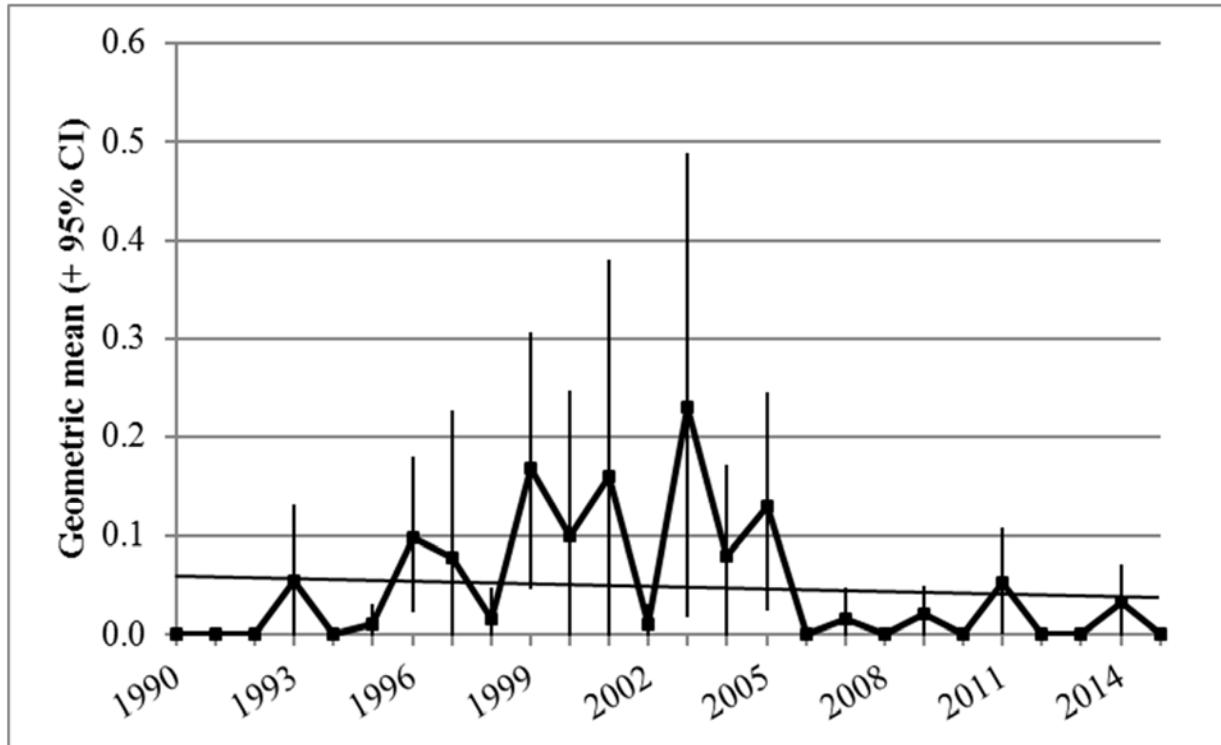


Figure 12.14. Annual YOY blueback herring relative abundance index (geometric mean catch per tow) and trend from the 16 foot otter trawl survey in the Delaware Estuary. Source: DE DFW.

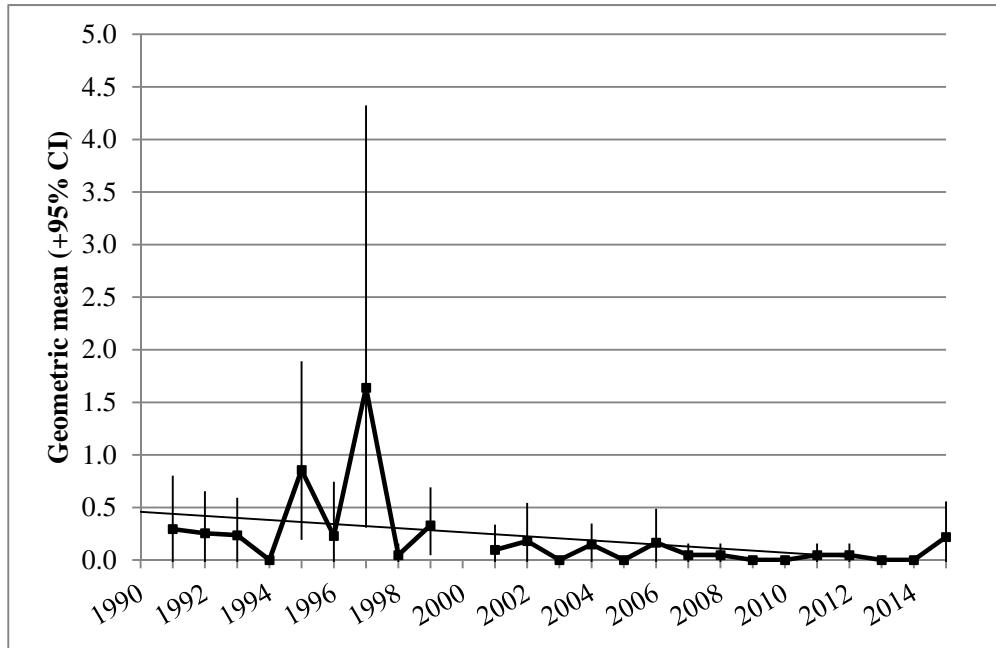


Figure 12.15 Annual Age 1 alewife relative abundance index (geometric mean catch per tow) from the 16-foot otter trawl survey in the Delaware Estuary. The 2000 age 1 annual abundance estimate was not available due to sampling missed in April of that year. Source: DE DFW.

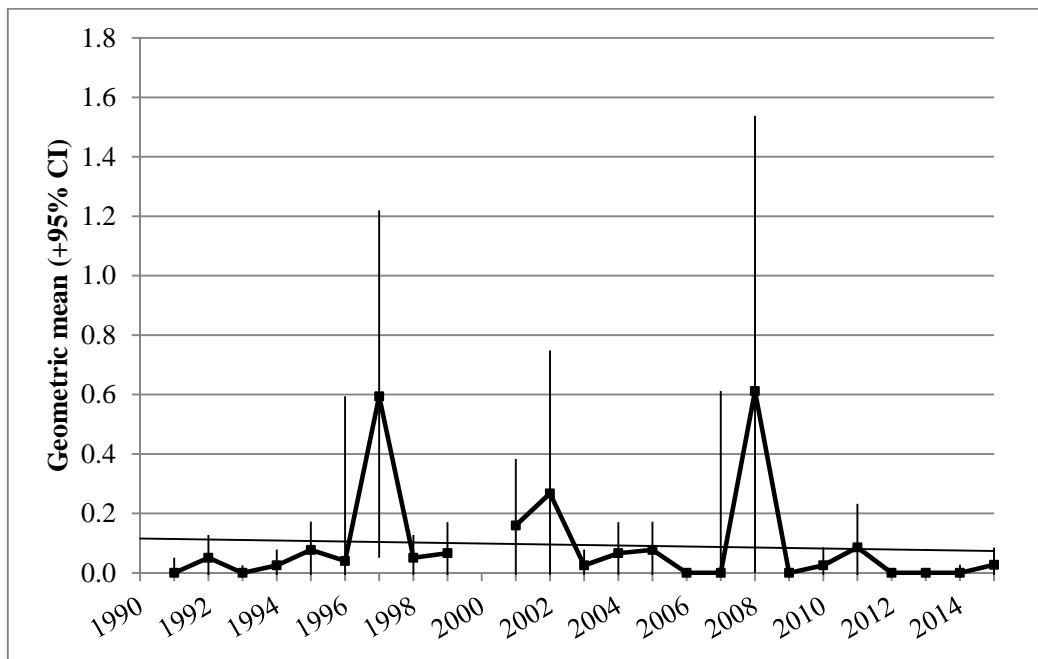


Figure 12.16 Annual age 1 blueback herring relative abundance indices (geometric mean catch per tow) from the 16 foot otter trawl survey in the Delaware Estuary. The 2000 age 1 annual abundance estimate was not available due to sampling missed in April of that year. Source: DE DFW.

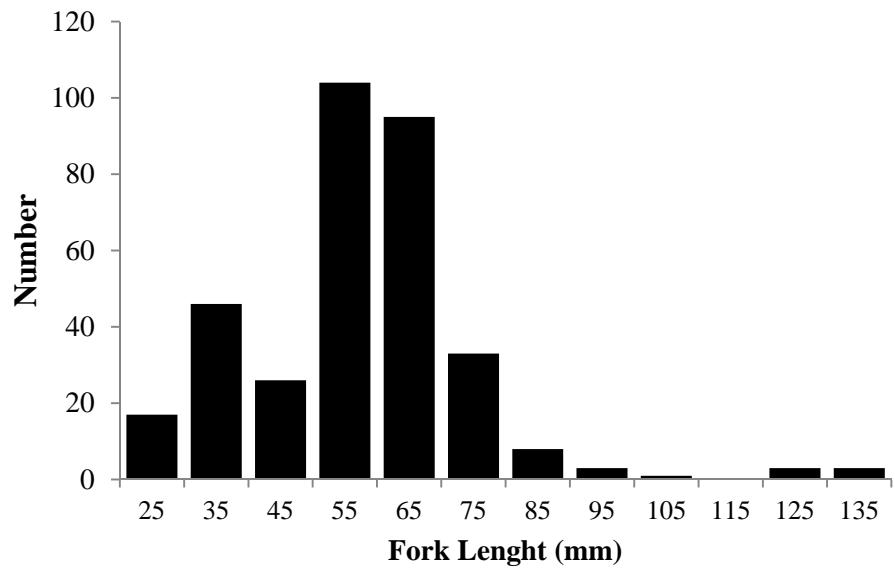


Figure 12.17 Delaware River length frequencies for YOY blueback herring collected during Delaware's 16 foot otter trawl survey in the Delaware Estuary from 1981-2015. Source: DE DFW.

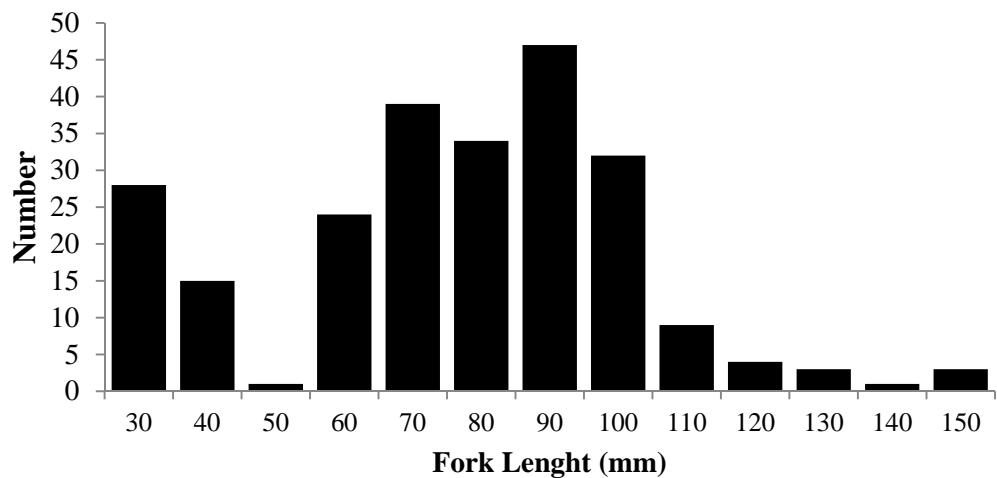


Figure 12.18 Delaware River length frequencies for Age 1 blueback herring collected during Delaware's 16 foot trawl survey in the Delaware Estuary from 1981-2015. Source: DE DFW.

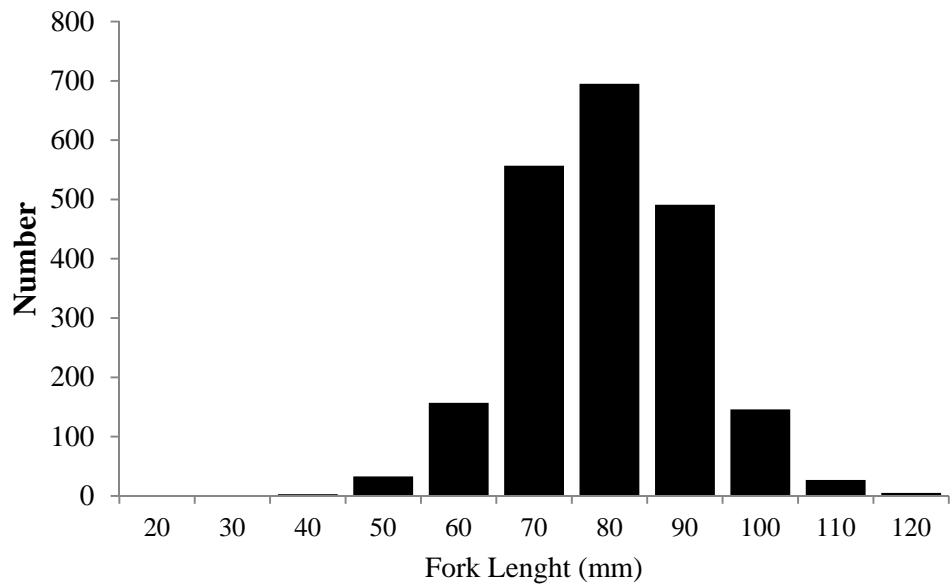


Figure 12.19 Delaware River length frequencies for YOY alewife collected during Delaware's 16 foot trawl survey in the Delaware Estuary from 1981-2015. Source: DE DFW.

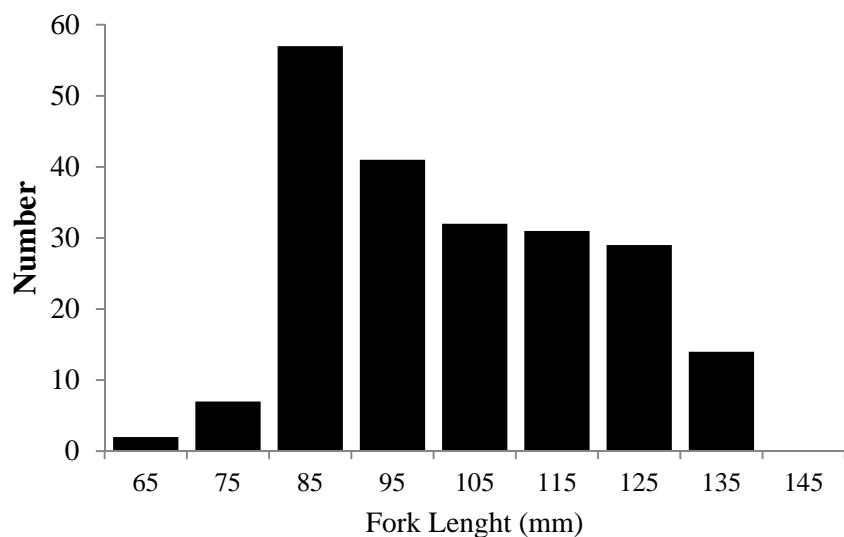


Figure 12.20 Delaware River length frequencies for Age 1 alewife collected during Delaware's 16 foot trawl survey in the Delaware Estuary from 1981-2015. Source: DE DFW.

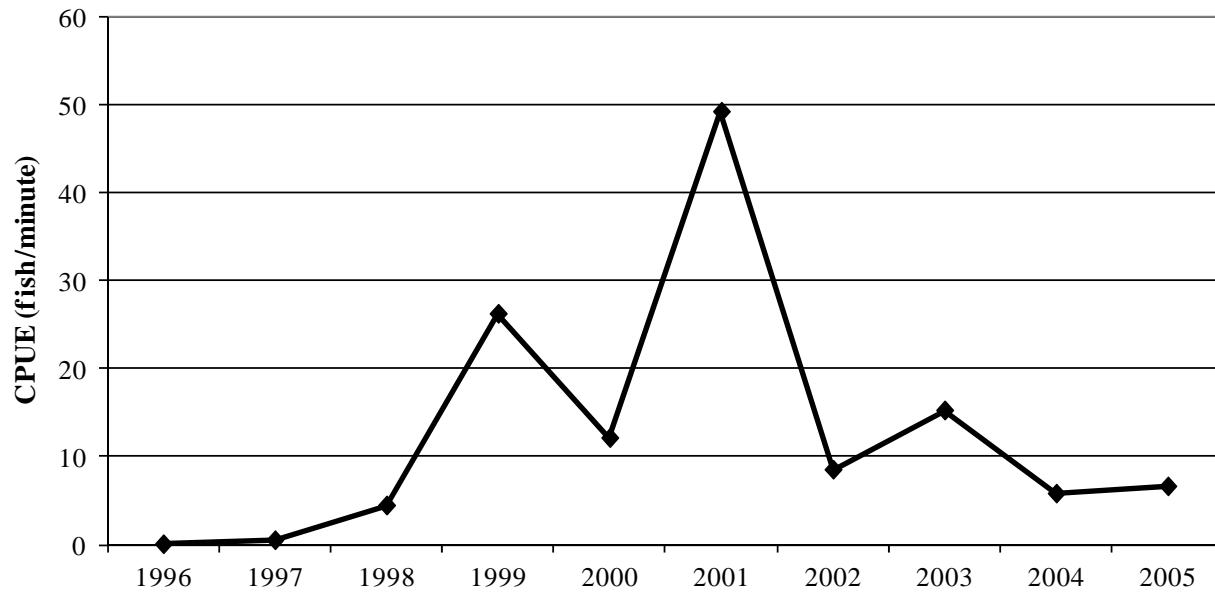


Figure 12.21 PSEG blueback herring electrofishing CPUE for Delaware and New Jersey Ponds (1996 – 2005). Discontinued after 2005. Source: NJ DFW.

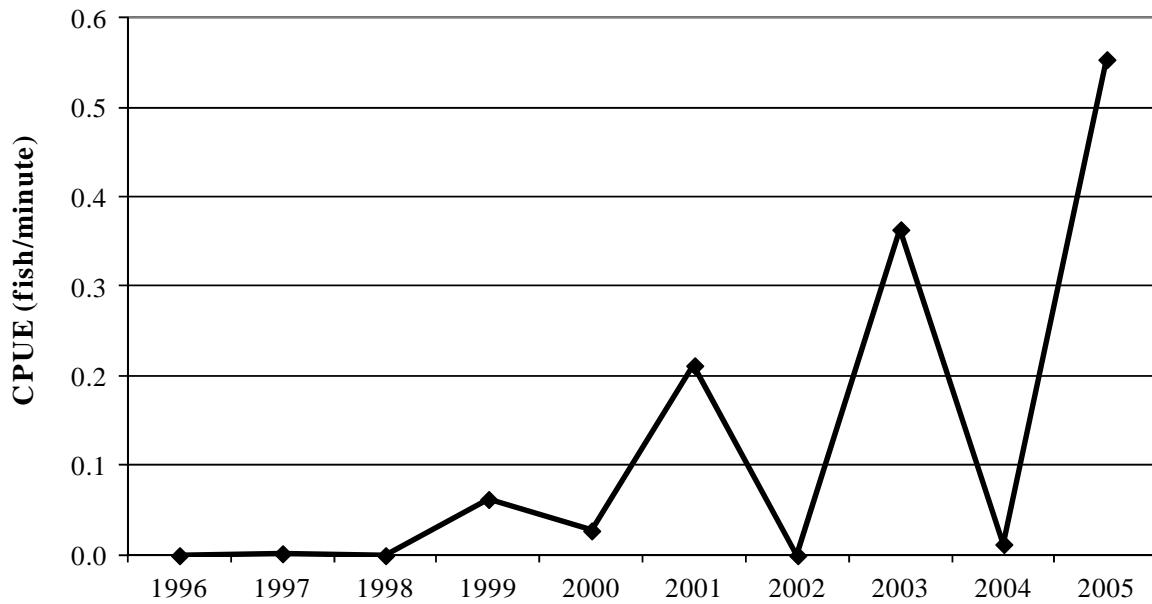


Figure 12.22 PSEG alewife electrofishing CPUE for Delaware and New Jersey Ponds (1996 – 2005). Discontinued after 2005. Source: NJ DFW.

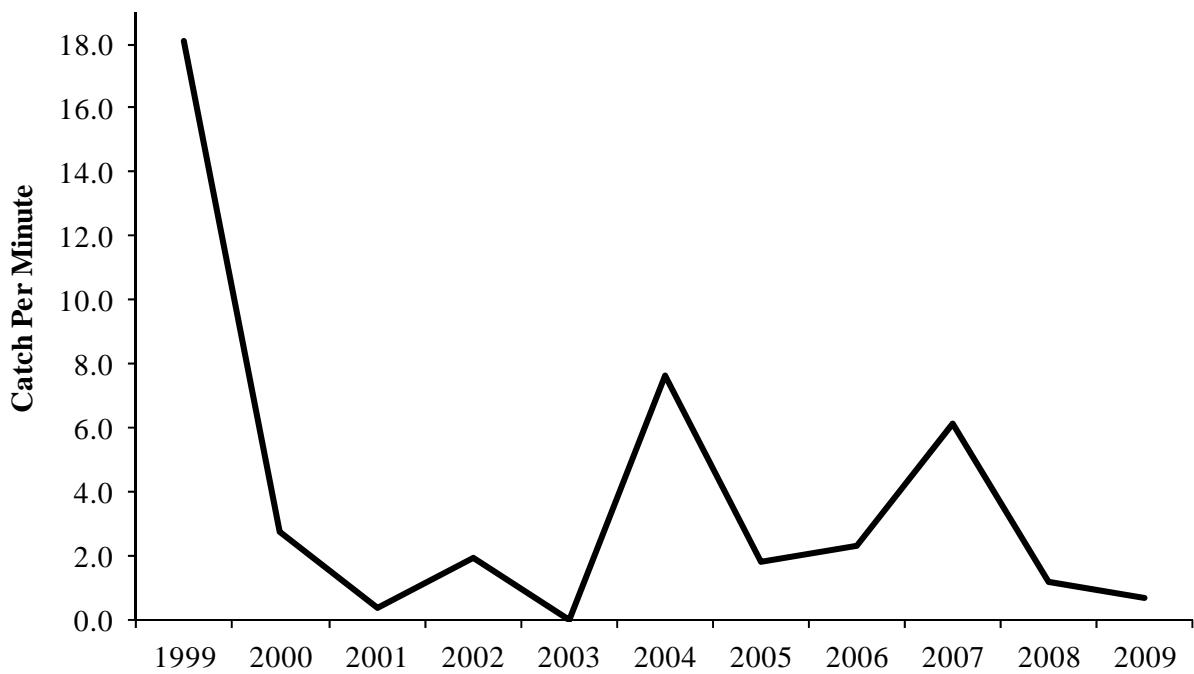


Figure 12.23 Overall CPUE (catch per minute) of YOY river herring collected during electrofishing at seven Delaware impoundments equipped with Alaskan Steeppass fish ladders, 1999-2009. Each pond was not sampled annually. These values reflect an aggregate CPUE calculated from those ponds sampled during that specific year. Source: DE DFW.

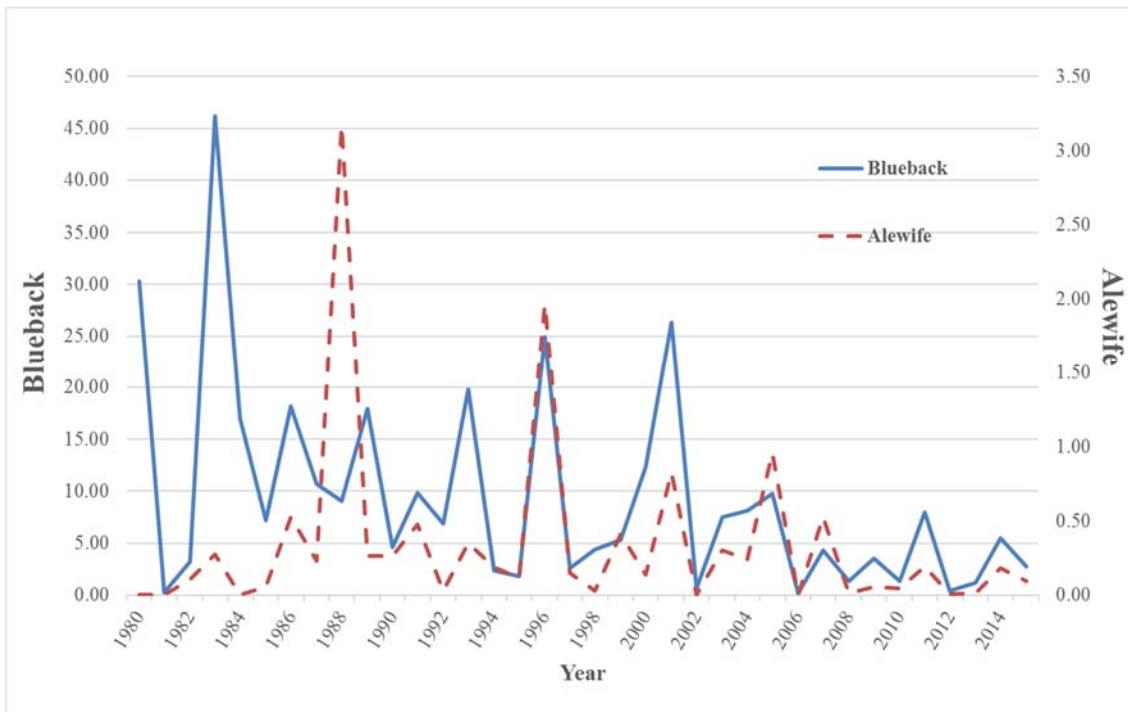


Figure 12.24 Delaware River index of relative abundance, geometric mean, for juvenile river herring collected during New Jersey's striped bass young of year survey (1980-2015). Source: NJ DFW.

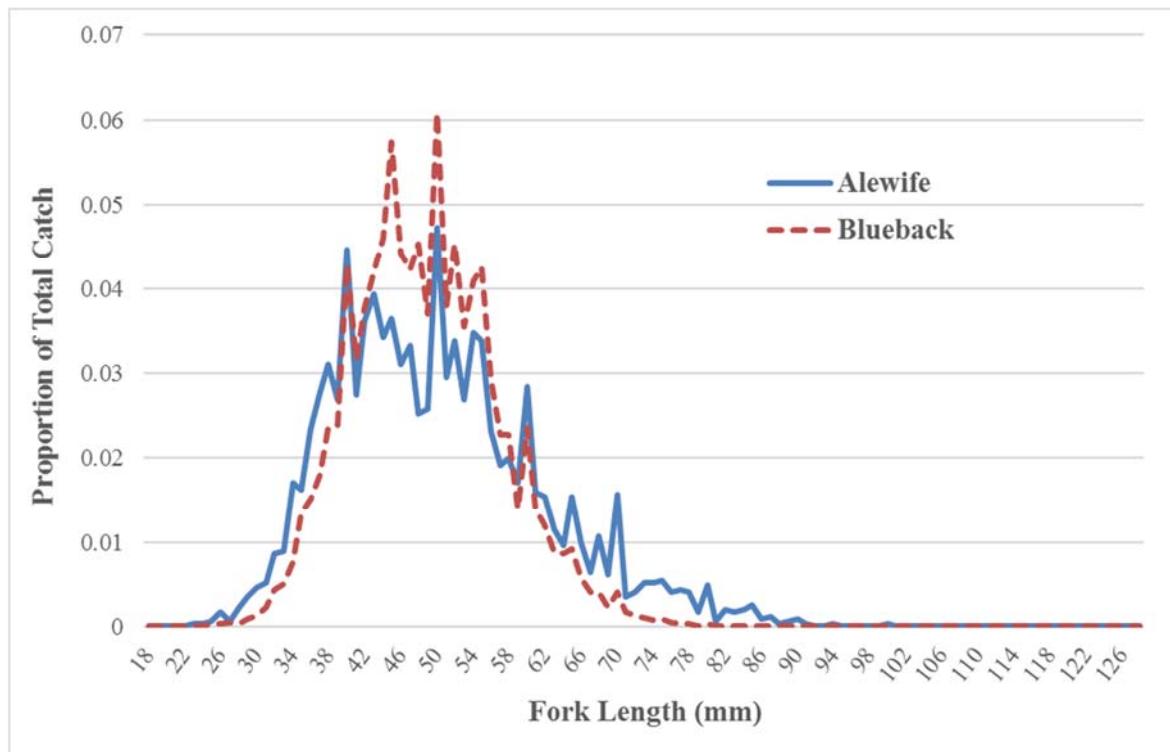


Figure 12.25 Delaware River juvenile river herring (alewife and blueback herring) length frequency (proportion at length) collected during New Jersey's striped bass young of year survey (2000-2015). Source: NJ DFW.

13 Status of River Herring in Maryland and the Upper Chesapeake Bay

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13.1. INTRODUCTION

Alewife and blueback herring are synonymous with the term river herring. Both species historically occur in significant numbers in the Chesapeake Bay with pre-spawn alewife herring appearing in the tributaries during late February followed by blueback herring in April. Evidence suggests that Native Americans depended partially on fish for food and caught shad and herring in large quantities long before European colonists arrived in North America (Meehan, 1897; Gay, 1892). Herring were likely caught for subsistence since colonial days, Radoff (1971) noted that herring were first exported from Maryland in 1753 but the fishery was more local and seasonal because salt was limited.

Documented landings from Maryland's portion of the Chesapeake Bay and tributaries date back to the 1800's. This serves as one of the best sources of data for river herring in the Upper Chesapeake Bay. Commercial landings are also available from Delaware's portion of the Nanticoke River. The fishery in this area was an important local resource for commercial fishermen in the past. The commercial and recreational fisheries in the Upper Chesapeake Bay were closed in 2012.

13.2. Management Unit Definition

In general, since most river herring in the Chesapeake Bay will return to their natal rivers to spawn, each river is considered a separate stock. The Maryland portion of the Chesapeake Bay begins at the Virginia line, at the mouth of the Pocomoke River, and continues north, ending at the Susquehanna Flats.

While distinct geographic areas divide the Chesapeake Bay into two or three zones, the divisions were not consistent in the literature. The Upper Chesapeake Bay area designated for this assessment is defined as the area from the Susquehanna River to the Nanticoke River and analyzes data from Maryland, Pennsylvania and Delaware. The management authorities in the Upper Chesapeake Bay include the Maryland Department of Natural Resources (MD DNR), the Delaware Division of Fish and Wildlife (DFW) and the Pennsylvania Fish and Boat Commission (PFBC).

There are a few minor tributaries of the Bay on Maryland's western shore that have small runs of river herring, but the two major Chesapeake Bay tributaries in the Upper Chesapeake are the Susquehanna and Nanticoke Rivers. The Susquehanna River watershed is located in Maryland, Pennsylvania and New York;

however the New York portion will not be discussed in this report because river herring cannot access this portion. The Nanticoke River watershed originates in southwest Delaware and flows through Maryland before emptying into the Chesapeake Bay along Maryland's eastern shore. In addition to the mainstem of the Nanticoke River, herring runs primarily occur in Deep Creek and Broad Creek, two main tributaries to the Nanticoke River in Delaware.

13.3. Regulatory History

Since the Upper Chesapeake Bay is under the jurisdiction of four separate states, there have been differing regulations pertaining to river herring within the Bay. As of January 1, 2012 landings of river herring in systems without an approved sustainable fisheries management plan are prohibited. These regulations are in compliance with the Atlantic States Marine Fisheries Commission Amendment 2 to the Fisheries Management Plan for Shad and River herring (2009). Regulations below may apply state-wide unless otherwise noted.

13.3.1. Commercial

Maryland

Maryland's commercial river herring fishery historically has been seasonally restricted, closed from June 5th to Jan 1st of the next year. Since migrations occur in the spring, this law has little, if any, management consequences. Up until 2005, it was primarily a directed fishery using drift gill nets with meshes ranging from 3 ½ to 3 ¼ inches. A limited pound and fyke net bycatch fishery also existed. After 2005, the directed fishery reported few fish and little effort, and many commercial gill netters no longer targeted river herring. A directed commercial river herring fishery developed in 2006 in a select Chesapeake Bay tributary (based on landing records) and was the result of new spring regulations allowing river herring as live bait to target striped bass in the upper Chesapeake Bay. There were no state limits on total river herring catch or the amount of gear utilized. Individual rivers may have distinct gill net area restrictions. As of January 1, 2012 possession of river herring is prohibited in Maryland.

Delaware

No specific regulations were ever adopted to reduce or restrict commercial landings of river herring, however there are regulations that applied to the commercial fishery that limited commercial fishing effort and have a direct impact on catch and effort. In Delaware, these restrictions include a limited entry license system, limitations on the amount of gear allowed to be fished, and season and area closures. Examples include:

1. Drift nets are prohibited from Saturday through 1600 hours Sunday.
2. No fixed gill nets from January 1 through May 31, and not more than 200 feet of net from June through September in the Delaware River.
3. No fixed gill nets from May 10 through September 30 in Delaware Bay.
4. The use of any type of net within 300 feet of any dam is prohibited on any tributary.
5. The striped bass spawning grounds which include the Nanticoke , Delaware River and C&D Canal are closed to all gill nets from April 1 to May 31

Additionally, since 1985, every fisherman holding a commercial food-fishing license was required to submit a monthly report specifying where he fished, the type and amount of fishing gear deployed, and the pounds landed of each species taken for each day fished. Those herring that were landed were typically frozen for bait, pickled, kept for their roe and other traditional uses. As of January 1, 2012 possession of river herring are prohibited in Delaware.

Pennsylvania

Harvest of river herring is prohibited in Pennsylvania waters of the Susquehanna River.

13.3.2. Recreational

Maryland

Maryland's recreational river herring fishery historically was seasonally restricted, closed from June 5th to Jan 1st of the next year. There were no size or creel limits on river herring. Maryland has no recreational landings data. Limited data indicated that catches were minimal but there may be small incidental catches of river herring used for striped bass bait that are not documented. Historically, anglers used dip nets to catch river herring and very few herring were caught by hook and line, usually when fishing for other species. Dip nets may not be used within 50 yards of the mouth of any river or tributary or the base of a dam and may not be used in any waters of the state stocked with trout. In non-tidal waters an individual can only use hook and line to take herring. Dip nets may not be used in the Susquehanna River upstream of Deer Creek. Nets, other than a landing net, cannot be used in Deer Creek. As of January 1, 2012 the recreational fishery was closed.

Delaware

The recreational fishery in Delaware often occurred at the various low-head dams that form mill ponds on the many of Delaware's tidal rivers where herring concentrated during the spring spawning season. Recreational fishermen used hook and line and t lift nets (umbrella nets) or dip nets during the peak of the run to catch herring. Prior to 2005, no recreational limit for river herring existed in the State of Delaware. Anecdotal reports indicated the catch and effort for river herring has increasing as striped bass stocks rebounded and the popularity of using live river herring for bait escalated. In an effort to prevent over exploitation of these small herring runs, a 25-fish limit was adopted in 2005. The popularity of this fishery continued to increase and consequently a 10-fish possession limit was adopted in spring of 2008 to help conserve remaining spawning stocks and to prevent "stock-piling" in net pens or live cars. In addition during 2008, Delaware's General Assembly approved legislation that prohibits the use of any net by any fisherman within 300 feet of any dam on any tidal tributary. The 10-fish possession limit and the prohibited use of any net immediately below any dam greatly reduce both catch and effort by forcing recreational fishermen to use only hook and line and to limit landings to the possession limit. As of January 1, 2012 the recreational fishery was closed.

Pennsylvania

There has been no sport fishery for river herring in Pennsylvania waters of the Susquehanna River since the 1920's when the Conowingo Dam was built. As of January 1, 2012 the recreational fishery was closed.

13.4. Assessment History

River herring assessments in Maryland waters have been conducted sporadically during the last fifty years, and were generally regionally specific. The most comprehensive collection of data by Mowrer et al (1984) summarized river-specific data and stock status of river herring. This study concluded that:

- Commercial landings had declined since the 1930's and was due to exploitation
- Recreational river herring fishery in the 1980s was less than 1% of the reported commercial landings
- Stock levels were at historically low levels

Mowrer et al (1984) also provided a 1980 population estimate of 57,628 blueback herring in the Susquehanna River. In the Choptank River, a tributary of the Chesapeake Bay on the Delmarva Peninsula, he estimated river herring (species combined) abundance of 570,543 in 1972 and 305,794 in 1973 (Speir et al. 2008). Ogburn et al. (2016) estimated run counts of alewife and blueback herring in the Choptank River using DIDSON technology paired with weekly electrofishing. This study, which occurred just upstream of where abundance was estimated in 1972 and 1973, estimated the run count in 2014 of alewife herring at $581,275 \pm 31,970$ and $726,450 \pm 39,955$ for blueback herring.

The Nanticoke River was included in the 1990 ASMFC coastwide stock assessments of river herring from selected Atlantic coast rivers (ASMFC 1990). Nanticoke River alewife were not overfished ($u < u_{msy}$) but have experienced a stock decline in recent years. The current or historical u values for Nanticoke alewife were within 75% of the u_{msy} levels, and therefore were considered by the criteria to be fully exploited. Abundance from these river herring stocks has exhibited a significant decline in recent years. The Nanticoke River blueback herring were considered to be partially exploited, since the current and historical fishing rates for these stocks were less than 75% of the river-specific u_{msy} levels.

Of the 15 river herring stocks examined in the 2012 ASMFC coastwide stock assessment, nine stocks were judged by the criteria to be either overfished ($u > u_{msy}$) or severely depleted (ASMFC 2012). These overfished stocks were confined to the northern and mid-southern end of the geographic range for river herring and included the Nanticoke stock of alewife. There are substantial weir fisheries on the river herring stocks within the north and south, whereas river herring from mid-southern rivers, such as the Nanticoke, were harvested primarily by pound nets that were set in or just outside these river systems (ASMFC 1985).

13.5. Stock-Specific Life History

Alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) are anadromous clupeids and members of the herring family which include the two shad species. These two species collectively known as river herring, mature between two and five years of age in the Chesapeake Bay, and peak catch-at-age is from four to six years. Some fish may return to spawn for four consecutive years (repeat spawning; Sadzinski and Jarzynski. 2007). Hatching occurs one week after fertilization. Young-of-the-year begin leaving the Chesapeake Bay in late fall. Juveniles remain in the ocean until sexual maturity, most returning to their natal rivers to spawn. There appears to be annual overwintering of both species of herring in the Chesapeake (Dovel 1971 and Carter 1973).

13.5.1. Growth

Dovel (1971) estimated young-of-the-year growth rates for blueback herring at six months old to be 65.0 mm total length (TL) with an estimated hatching date of 15 April. One-year old TL was estimated to be 80.0 mm. Preliminary review of the literature has not revealed adult river herring growth studies in the Chesapeake Bay.

Mowrer et. al 1980 also estimated young-of-the-year growth from beach seine samples and noted the larger size of alewife as compared to blueback herring; however both species were comparable in length by September. Their growth curves quickly flattened, indicating outward migration of larger fish.

13.5.2. Maturity Schedule

Using Speir and Mowrer's (1987) maturity schedule calculation, 84% of male alewife and 100% of male blueback herring were mature by age 4 in 2010. The percentages of female alewife and blueback herring mature by age 4 in 2010 were 66% and 93%, respectively.

13.5.3. Natural Reproduction

Dovel (1971) collected egg and larval fish throughout the Chesapeake Bay in the late 1960's and early 1970's and noted significant numbers of *Alosa* species in his samples, including river herring.

O'Dell et al (1984) surveyed anadromous fish species in Maryland streams from 1979-1982. They concluded that river herring successfully spawned in each major river system through the capture of pre-spawned adults and later by fertilized eggs or larval fish. Natural reproduction of river herring did occur in all major tributaries and likely still occurs in every major river system.

13.6. Habitat Descriptions

Carter et. al (1982) surveyed more than 700 streams in Maryland from 1970 to 1980 and documented anadromous species in 323 of these streams. The report defines spawning and nursery areas by river system and is species specific. Natural or man-made barriers to migration were also noted. Based on his data and juvenile indices, river herring were a prolific species in Maryland tributaries and spawning and nursery habitat was not limiting.

The first major hydroelectric plant on the Susquehanna River was constructed at York Haven, PA (river km 90) in 1904. In 1910, Holtwood Dam (river km 39) was built with two fishways that were later shown to be ineffective. Commercial fishing continued below Holtwood until 1924 (Kotkas and Robbins 1977) but soon disappeared because of the absence of American shad. Conowingo Dam (river km 16) was constructed in 1928 and Safe Harbor Dam (river km 52) was completed in 1931. These dams permanently cut off river herring from their historical spawning areas in the Susquehanna River until 1972 when the Conowingo Dam was retrofitted with a fish elevator and fish were trucked above the upper most mainstream dam.

The Nanticoke River is a major tributary of the Chesapeake Bay. It begins in Delaware and flows 64 miles, including 37 miles through Maryland, before emptying into the Bay. It is a free-flowing river originating near Greenwood, Delaware. Delaware Division of Fish and Wildlife staff reported river herring caught by recreational anglers as far upstream as Bridgeville, Delaware. River herring spawn within two primary tributaries that flow into the Nanticoke River within Delaware boundaries as well. Deep Creek begins at the dam below Concord Pond and flows into the Nanticoke proper at Seaford, DE. Broad Creek extends from the dam below Records Pond in Laurel, DE and flows into the mainstem of the Nanticoke just upstream of the Maryland state line. Although the dams on Deep Creek and Broad Creek inhibit upstream passage,

there is sufficient spawning habitat below the structures to maintain a stable run. Smaller tributaries, many of which are tidal freshwater, also contribute to the total amount of spawning and rearing habitat available. These tributaries include Marshyhope Creek and Barren Creek on the Maryland side.

13.7. Restoration Programs

There are no dedicated restoration programs for river herring in the Upper Chesapeake Bay. There has been some experimental stocking in select rivers, but numbers of larval fish stocked (less than 500,000) were likely not significant enough to impact the stock and stocking was not consistent over time. Stocking was primarily done as mitigation for construction projects and to evaluate fish passage effectiveness. No evaluation of stocked fish survival or how the stocking contributed to populations was conducted. Adult river herring were captured from the west fish lift at Conowingo Dam, transported upstream and stocked in Pennsylvania waters during 1990 to 2001.

As part of the Chesapeake 2000 Agreement, several fish passage commitments were developed that are important for anadromous fish, especially shad and river herring. The commitments include: 1) identify the final initiatives necessary to achieve the existing goal of restoring fish passage to more than 1,357 miles of currently blocked river habitat and establish a monitoring program to assess outcomes; 2) set a new goal with implementation schedules for additional migratory and resident fish passages; 3) determine tributary-specific target population sizes; and, 4) revise fish management plans. The fish passage goal was met at the end of 2004 with approximately 1,400 miles of habitat reopened for anadromous fish. A new goal was established in 2005. To date, MDNR's Fish Passage Program has completed 79 projects, reopening a total 457 miles of upstream spawning habitat in Maryland since 2005. The current goal is to expand to 3,500 miles (Bay wide) by 2025. MD DNR Fish Passage is making progress towards the removal of Bloede Dam on the Patapsco River. An ecosystem-based management plan for alosines was developed and includes population and habitat strategies.

On the Susquehanna River, the Policy Committee of the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) approved an "Alosine Management and Restoration Plan for the Susquehanna River Basin" in 2010. The restoration goal is:

"By 2025, produce self-sustaining annual populations of 2 million American shad and 5 million river herring, reproducing in the free-flowing Susquehanna River above York Haven Dam, and in suitable tributaries, and provide 500,000 angling days annually throughout the Basin for these species."

13.7.1. Upstream Fish Passage Efficiency

Fishway counts at the four dams along the Susquehanna River (from south to north: Conowingo (MD), Holtwood (PA), Safe Harbor (PA) and York Haven (PA)) are provided in Tables 13.1 and 13.2. River herring passage was episodic prior to 2002 and has plummeted since then. The fish lifts at Conowingo, the lower most dam, target operation and attraction flow for American shad passage, which likely excludes river herring. Operation of these lifts begins in April annually, and therefore misses the peak of the alewife run in most years.

Few river herring have passed upstream of Holtwood Dam except in 2000 and 2001 when river herring were transported to the Conestoga River, a tributary of the Susquehanna River. The transported river herring left the Conestoga River and moved up the mainstem Susquehanna River and were observed at the Safe Harbor Dam. In 2001, transports to the Conestoga River included 2,983 blueback herring in 2000 and 4,200 blueback herring and 1,820 alewives. Other reports of alewife upstream of Holtwood Dam are largely

attributed to movement of individuals from landlocked populations in several lakes in the drainage. Transport of river herring above Holtwood Dam ceased in 2001, when the East Fish Lift at Conowingo Dam became an automated flow through system.

The operating license for Conowingo Dam expired in 2014. Exelon Generation, LLC has been operating the dam under a temporary license while a new is being reviewed by the Federal Energy Regulatory Commission (FERC), resource agencies for Maryland and Pennsylvania and US Fish and Wildlife Service.

The US Fish and Wildlife Service and Exelon Generation, LLC signed a settlement agreement in April 2016 which will allow for adaptive management and fish passage improvements geared towards migratory fish restoration at Conowingo Dam (over the term of its next FERC Operating License). Initial improvements will encompass: enhanced attraction flows for the East Fish Lift, reduction in fish lift cycle time and added capacity; tailrace modifications (zone of passage) for river herring; a Trap and Transport program to move adult shad and river herring from below Conowingo to above York Haven Dam; fish passage efficiency target of 85% substantiated through radio telemetry monitoring every five years through the term of the FERC operating license; along with other operational and structural modifications should performance targets not be met.

Fish passage improvements at the Holtwood Hydroelectric Station (i.e. construction of zones of passage in the tailrace and spillway, dedicated attraction water flow to spillway, increased attraction flow and replacement of flashboards with Obermeyer crest gates) were near completion prior to the 2015 spring passage season. The 401 Water Quality Certification at the York Haven Hydroelectric Project, requires the construction of a nature-like fishway along the main dam to be constructed by 2021. The planning and design phases of the nature-like fishway were well underway in 2015, with several pre-permit application meetings being held.

Smaller fish ladders have been installed on a number of dams throughout the Upper Chesapeake Bay region allowing river herring to pass, but fish counts and efficiency have not been assessed for any of these structures.

13.8. Age

MD DNR has collected scale samples from river herring through fishery dependent sampling in the Nanticoke River since 1989 and the North East River since 2013. Scales were removed below the insertion of the dorsal fin. A minimum of four scales per fish were cleaned, mounted between two glass slides and read for age and spawning history using a Bell and Howell MT-609 microfiche reader. The scale edge was counted as a year-mark since it was assumed that each fish had completed a full year's growth at the time of capture. Annuli were identified using Cating's (1953) method and the same reader aged river herring in Maryland from 1989 - 2010. Since 2010, two new readers began ageing river herring from Maryland one beginning in 2011, and the other in 2014. Following the recommendation from the "2013 River Herring Ageing Workshop" (ASMFC 2014), ages have been assigned to river herring utilizing the methods outlined in "Massachusetts Division of Marine Fisheries Age and Growth Laboratory: Fish Aging Protocols" (Elzey et al., 2015). The number of repeat spawning marks, defined as the freshwater spawning mark on the scale was recorded for each fish.

Since 2011, the PFBC and MD DNR, through their membership in the SRAFRC and contracts with the contractor responsible for operating the west fish lift and American Shad tank spawning operation at Conowingo Dam, requested that the first 50 river herring of each species be sampled for biological data collection (i.e. length, weight, scales and otoliths), annually. Additionally, one of every 25th additional river herring species collected will also be sacrificed for biological data collection. Age determinations of any

collected river herring were made by the PFBC following the “Massachusetts Division of Marine Fisheries Age and Growth Laboratory: Fish Aging Protocols” (Elzey et al., 2015). However, the identification of repeat spawning marks were not identified due to the inexperienced nature of the scale reader

13.9. Fishery Descriptions

13.9.1. Commercial Fisheries

Prior to the 2012 stock assessment, river herring populations had declined to such low levels that most commercial fishermen were no longer targeting them, but instead caught them as bycatch while targeting white perch. Maryland enacted a moratorium on river herring that took effect January 1, 2012.

Maryland

Evidence suggests that Native Americans depended partially on fish for food and caught shad and herring in large quantities long before European colonists arrived in North America (Meehan, 1897; Gay, 1892). The earliest commercial fisheries were initiated in the late 1800s and with the introduction of the pound net into Maryland waters, herring catches likely peaked. During the 20th century, pound and fyke nets were extensively used to catch river herring. After the 1980's the fishery was in decline and it evolved more into a bycatch fishery. In addition, commercial fishermen could target river herring on their spawning grounds using small mesh gill nets. The commercial river herring landings for the Nanticoke River showed declines while the fishery was monitored from 1989-2011. The commercial fishery has been closed since January 1, 2012.

Delaware

Commercial Landings and Catch Rates

Since 1985, Delaware's commercial landings were determined annually from mandatory commercial catch reports. Landings occur from all of the broader regional areas of Delaware but the upper Nanticoke River has traditionally yielded the majority of landings and it also has the largest herring runs of any of the tidal streams in the state. In 2010, 84% of river herring landings reported in Delaware came from the Nanticoke. Commercial landings occurred from January through May with peak landings occurring in March. Both species are represented in the catch but the majority is probably blueback herring based on observations of relative abundance and temporal distributions within state waters. Additional sampling is not performed.

In Delaware's portion of the Nanticoke River the CPUE has been in decline since the mid 1990's and the lowest CPUE in the time series occurred in 2010 (Table 13.3). The effort data reflects days that fishermen actually landed river herring and does not account for days when the species was not landed.

13.9.2. Recreational Fisheries

Maryland

MD DNR has conducted a roving creel survey below Conowingo Dam on the Susquehanna River since 2001. In general, few anglers (less than one percent) target river herring in the spring because most anglers are targeting American or hickory shad and walleye. In most river systems, river herring are not targeted and are caught as bycatch.

Delaware

There are over 500 ‘recreational’ gill net permits issued to Delaware fishermen statewide. Mostly commercial crabbers hold these permits which allow them to catch bait, primarily Atlantic menhaden. River herring were also reported as discards from this fishery but were highly variable ranging from 6 fish per year to over 1,000. From 1996 through 2003 annual total harvest estimates ranged from 4,400 fish in 1996 to 297 in 2002 (Table 13.4).

13.9.3. Subsistence Fisheries

Herring were likely caught for subsistence since colonial days Radoff (1971) noted that herring were first exported from Maryland in 1753 but the fishery was more local and seasonal because salt was limited. No additional information on subsistence fishing is available.

13.9.4. Bycatch Losses

Bycatch losses were typically minimal because the commercial fisheries were allowed to harvest and land river herring. As of January 1, 2012 no landings of river herring are allowed in Maryland or Delaware. Currently, there are no means for reporting river herring bycatch in the Maryland reporting system.

Bycatch Monitoring

River herring are captured as bycatch primarily in the spring pound and fyke net commercial fishery targeting perch and catfish species. This fishery occurs in the Chesapeake Bay and various Maryland tributaries in the spring. Maryland was monitoring this fishery in the Nanticoke River prior to the moratorium on river herring, and following the moratorium has continued to sample river herring as bycatch from this fishery.

Alewife and blueback herring in Maryland’s portion of the Nanticoke River were collected from commercial pound nets and fyke nets, and the number of nets and locations were fished at the discretion of the commercial watermen. These nets were generally sampled at least one to two times per week from early March to late April. Fish were sorted according to species and transferred to the survey boat for processing. Monitoring began in 1989, when it was still legal for commercial fishermen to harvest river herring, but has continued since the fishery closed as bycatch monitoring. In 2015, there was extensive ice coverage late into the spring on the Nanticoke River that prohibited commercial fishermen from setting their gear, therefore analyses utilizing data from this monitoring have a terminal year of 2014.

A minimum of ten alewife and ten blueback herring selected at random from unculled commercial catches were counted, sexed, fork length measured and scales removed for age analysis. The total number of herring harvested was estimated by multiplying the number of bushels harvested by the number of fish per bushel from sampled nets on that particular day or by direct counts.

Beginning in 2014, if random scale samples taken during the sampling season exceeded 300 samples per species, then a randomly chosen subset of 300 scales were aged. Ages were then assigned to the total catch using an age length key. This was a necessary change to accommodate large catches and limited available staff time for processing.

13.9.5. Other Losses

Prior to the moratorium, herring were used as bait in eel and crab pots in Maryland. Some of the herring used as bait were females that had their roe removed for market. As of January 1, 2012 possession of river

herring is not be allowed in Maryland, unless a bill of sale is provided from a state with a river herring fishery.

13.10. Fishery-Independent Surveys

13.10.1. Adult Catch Data

Fishery-independent data for river herring comes from the fish lifts at Conowingo Dam in the Susquehanna River and a multi-panel anchored gill net survey in the North East River. There are two lifts (west and east) operating at the lowest dam on the Susquehanna River. The lifts are operated to give priority to American shad passage and may exclude other species, including river herring. The two fish lifts are operated each spring beginning in April, which may eliminate alewife herring because their peak spawning period is likely prior to the opening of the lifts.

The west fish lift at Conowingo Dam has been used to monitor adult abundance since 1972. This lift operates in the traditional manner except that fish collected are dumped into a large steel trough where the catch is hand sorted by biologists. Target species are enumerated, sampled and then released back into the Conowingo Dam tailrace, used for tank-spawning, or transported upstream, as dictated by restoration plan requirements. Since 2011, the operators of the west fish lift have been instructed to collect the first 50 river herring of each species, followed by one of every 25th additional river herring species collected.

The Conowingo east fish lift is constructed with a viewing window where a trained biologist counts all fish species as they exit the fishway and enter the upstream reservoir. This lift has been operating since 1991 but prior to 1997, fish were manually trucked upriver. It is also worth noting that flows have been increased since the late 1990's to maximize American shad catches in the east lift, which may decrease river herring catches.

MD DNR has conducted a gill net survey targeting river herring in the North East River since 2013. A multi-panel sinking monofilament gill net is set perpendicular to the channel at four randomly chosen sites once a week for 10 weeks in mid-March to mid-May. For the 2013 and 2014 sampling years, the gill net had three separate panels each 100ft x 6ft with mesh sizes of 2 ½, 2 ¾, and 3". In 2015, the 3" mesh panel was replaced with a 2 ¼" mesh panel, as there was evidence the current mesh size selection was not successful in capturing smaller sized blueback herring. Four sites are randomly chosen for each day, along with four alternate sites, from a grid of 1000ft x 1000ft squares overlaid on a map of the North East River. Determination of whether to set the net shallow or deep is also randomly chosen. The net is soaked for 30 min at each site prior to retrieval. All fish are identified and enumerated to species per gill net mesh size. All alewife and blueback herring are sexed and measured to the nearest mm FL and TL. Scales are taken from a subsample of alewife and blueback herring per panel (i.e. first 20 fish encountered of each species per panel) to determine age and spawning history.

The North East River Gill Net Survey is successful in capturing a relative sample of both alewife and blueback herring spawning stock in the North East River. This survey captures the weekly temporal differences in these species spawning runs, and provides a relative index of abundance. Since this survey has a short-time series and was not initiated prior to the previous assessment, the group determined it would not be used for determining stock status at this time.

13.10.2. Juvenile Catch Data

Maryland's river herring juvenile indices are derived annually from seine sampling at 22 fixed stations within the Chesapeake Bay. A 30.5-m x 1.24-m bagless beach seine of untreated 6.4-mm bar mesh was set

by hand. One end was held on shore. The other was fully stretched perpendicular from the beach and swept with the current (Durell et. al 2007).

Stations have been sampled continuously since 1954, with changes in some station locations (see <http://dnr.maryland.gov/fisheries/PublishingImages/sitemap.jpg>). They are divided among four of the major spawning and nursery areas: seven each in the Potomac River and Head of Bay areas and four each in the Nanticoke and Choptank Rivers. Sampling is monthly, with rounds occurring during July, August, and September.

Replicate seine hauls, a minimum of thirty minutes apart, are taken at each site on each sample round. This produces a total of 132 samples from which bay-wide means are calculated. In 1962, stations were standardized and a second sample round was added for a total of 88 samples. A third sample round, added in 1966, increased sample size to 132. Auxiliary stations have been sampled on an inconsistent basis and are not included in survey indices.

A 150' haul seine is used to generate juvenile indices of abundance for the upper Nanticoke River stock in Delaware (Moore 2015). Haul seine sampling was initiated in 1999 and continued annually to assess reproduction and recruitment of all alosines. Sampling in 2015 was conducted at four locations using a haul seine from July-October. Samples were obtained once every two weeks at ebb or low slack tide. The geometric mean was calculated using the number taken per haul and utilized as an index of relative abundance for each species. Alosine samples with more than 90 individuals per species were randomly sub-sampled for lengths with the remainder being enumerated.

13.11. Assessment Approaches and Results

13.11.1. Spawning Stock Abundance

As was described in Section 13.9, commercial landings in the Upper Chesapeake Bay decline leading up to the moratorium. Alewife geometric mean CPUEs for the lower Nanticoke River have varied without trend, while those for blueback herring have significantly decreased (Figure 13.1 and 13.2, respectively). River herring lift catches at the Conowingo Dam (Tables 13.1 and 13.2) were erratic for the time series. Flows have been increased in recent years to encourage American shad to use the lift. Although high flow precludes river herring usage of the lifts this may not explain the wide range of annual values.

13.11.2. Juvenile Abundance

Beach seine sampling conducted by MD DNR since 1959 in the lower Nanticoke has fluctuated without trend for both alewife and blueback herring (Figure 13.5 and 13.6). The highest index value in a decade was recorded for blueback herring in 2011 (0.98), followed by the 2015 index (0.82), although both were still below the time-series mean (1.09). The highest alewife index value in a decade was recorded in 2010 (0.80), followed by the 2015 index (0.60), and both were above the time-series mean (0.36).

Haul seine sampling conducted in the Upper Nanticoke River by DFW has seen no long-term trend from 1999-2015 in juvenile blueback herring relative abundance. However, juvenile blueback herring relative abundance decreased to the sixth highest value in the 17-year time series during 2015 (Figure 13.7). Length frequency data of YOY river herring collected from the DFW haul seine survey indicated 60 mm was the most abundant size class for blueback herring and 70 mm was the most abundant size class for alewife (Figure 13.3 and 13.4). Anecdotal information from Delaware electrofishing surveys indicated the majority of river herring in the upper Nanticoke system consisted of blueback herring. As a result, alewife relative abundance has been calculated from small sample sizes. No long-term trend for alewife relative abundance

has been observed from 1999–2015 however the 2015 alewife geometric mean CPUE was the highest in the time series (Figure 13.8).

Baywide juvenile alewife and blueback herring indices are presented in Figure 13.9 and 13.10, respectively.

13.11.3. Trends in Mean Age and Length

The river herring data for Maryland is based on the bycatch monitoring in the lower Nanticoke River. Sample bias is likely minimum because of the very small mesh sizes used in both the pound and fyke nets (1.5 inch stretched mesh). Therefore, changes in mean age and length of fish over time is likely due to population changes, especially since the same gear and mesh sizes have been used during our sampling efforts.

Data from MD DNR indicated that in the recent years, fewer fish over the age of 7 for both alewife and blueback herring have been observed (Tables 13.5 and 13.6, respectively). Mean length has declined over the time series for blueback herring, and varies without trend for alewife (Figure 13.11). Age four and five fish were most prevalent in the samples, but river herring were generally not fully recruited to the spawning population until age five. Number of alewife and blueback herring sampled by sex and age class from bycatch monitoring in the lower Nanticoke River is presented in Tables 13.6 and 13.7 respectively. Mean length-at-age for alewife and blueback herring sampled from the Nanticoke River is presented in Tables 13.7 and 13.8 respectively.

River herring data from the West Fish Lift collections at Conowingo Dam is likely biased, as sampling begins in mid-April or early May, following the peak spawning periods for alewife. Further, operations of the West Fish Lift, like the East Lift, have traditionally been operated at flows to maximize American Shad catch/passage, thereby further hindering river herring catch. However, between 2012 and 2015, 85 blueback herring were collected at the West Fish Lift, in addition to 43 alewife between 2014 and 2015. Catch-by-age data are presented in Tables 13.9 (alewife) and 13.10 (blueback herring). Tables 13.11 and 13.12 summarize mean length at age for alewife and blueback herring, respectively.

13.11.4. Trends in Repeat Spawning

The arcsine-transformed proportion of alewife repeat spawners (sexes combined) from bycatch monitoring in the lower Nanticoke River indicated no trend (1989–2014; $r^2 = 0.078$ $P = 0.18$), while blueback herring repeat spawning showed a decreasing trend (1989–2014; $r^2 = 0.63$, $P < 0.001$; Figure 13.12).

13.11.5. Trends in Z-Estimates

Total instantaneous mortalities (Z) were estimated from bycatch monitoring in the lower Nanticoke River by the Chapman-Robson method utilizing age data (Citation needed). Following methodology from the previous assessment, the first age-at-full recruitment was the age with the highest frequency and estimates were only made when data was available from three or more age-classes (including first fully-recruited age). Mortality rates for alewife and blueback herring by sex are presented in Figures 13.13 and 13.14, respectively.

13.12. BENCHMARKS

No benchmarks have been developed for Maryland at this time.

CONCLUSIONS

Commercial landings in Maryland and Delaware showed a decline leading up to a moratorium being established in 2012. The expectation is that this regulatory change will help protect the remaining spawning populations and aid in reversing the declining trend in river herring abundance.

Maryland's best estimate of adult relative abundance comes from the Nanticoke River and shows that both alewife and blueback herring populations have remained low for the time series, and blueback herring have continued to decline following the closure of the fishery. In general, ages four and five were the most prevalent fish in adult samples from pound and fyke nets on the Nanticoke River, but river herring were generally not fully recruited to the spawning population until age five, as shown with the freshwater spawning mark not present on all five year-old fish. Fewer older aged fish (>7 years) have been observed for both alewife and blueback herring from the Nanticoke River, and mean length of blueback herring from this system has continued to decline.

In the recent years, juvenile alewife abundance has shown a slight increasing trend in the upper Nanticoke with the highest value of the time series observed in 2015. Blueback herring juvenile relative abundance decreased slightly from the 2014 value to the sixth highest value of the 17-year time series during 2015.

Data from the Conowingo Dam fish lifts on the Susquehanna River are highly influenced by flow and likely do not reflect the abundance of river herring in the system. Therefore, trends in abundance for this system are relatively unknown.

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Table 13.1. Blueback herring passage at Susquehanna River Dams.

| Year | Conowingo (rm 10.0) | Holtwood (rm 24.6) | Safe Harbor (rm 32.2) | York Haven (rm 56.1) |
|-------|------------------------|------------------------|--------------------------|-------------------------|
| 1997 | 242,815 | 1,042 | 534 | no fishway |
| 1998 | 700 | 62 | 20 | no fishway |
| 1999 | 130,625 | 73 | 30 | no fishway |
| 2000 | 14,963 | 27 | 816 | 0 |
| 2001 | 284,921 | 1,300 | 710 | 4 |
| 2002 | 2,037 | 13 | 0 | 0 |
| 2003 | 530 | 3 | 0 | 0 |
| 2004 | 101 | 0 | 0 | 0 |
| 2005 | 4 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0 |
| 2007 | 460 | 0 | 0 | 0 |
| 2008 | 1 | 0 | 0 | 0 |
| 2009 | 71 | 0 | 0 | 0 |
| 2010 | 4 | 0 | 0 | 0 |
| 2011 | 17 | 0 | 0 | 0 |
| 2012 | 25 | 0 | 0 | 0 |
| 2013 | 7 | 0 | 0 | 0 |
| 2014 | 25 | 0 | 0 | 0 |
| 2015 | 3 | 0 | 0 | 0 |
| Total | 677,309 | 2,520 | 1,290 | 4 |

Table 13.2. Alewife passage at Susquehanna River Dams.

| | Conowingo (rm 10.0) | Holtwood (rm 24.6) | Safe Harbor (rm 32.2) | York Haven (rm 56.1) |
|-------|------------------------|------------------------|--------------------------|-------------------------|
| Year | | | | |
| 1997 | 63 | 0 | 0 | no fishway |
| 1998 | 6 | 0 | 0 | no fishway |
| 1999 | 14 | 1 | 1 | no fishway |
| 2000 | 2 | 0 | 0 | 2 |
| 2001 | 7,458 | 1 | 0 | 0 |
| 2002 | 74 | 0 | 0 | 1 |
| 2003 | 21 | 2 | 0 | 0 |
| 2004 | 89 | 2 | 1 | 0 |
| 2005 | 0 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0 |
| 2007 | 429 | 0 | 0 | 0 |
| 2008 | 4 | 0 | 0 | 0 |
| 2009 | 160 | 1* | 0 | 0 |
| 2010 | 1 | 0 | 0 | 0 |
| 2011 | 2 | 0 | 0 | 0 |
| 2012 | 27 | 0 | 0 | 0 |
| 2013 | 0 | 0 | 0 | 0 |
| 2014 | 111 | 0 | 0 | 0 |
| 2015 | 10 | 0 | 0 | 0 |
| Total | 8,471 | 6 | 2 | 3 |

* Landlocked populations of alewives are present in Susquehanna River Basin impoundments and some of those recorded at the fishways may not be anadromous in origin.

Table 13.3 Nanticoke River Gill Net Landings and CPUE

| <u>Year</u> | <u>Kgs Landed</u> | <u>CPUE (kgs/ net meter)</u> |
|-------------|-------------------|------------------------------|
| 1985 | 1271 | 0.165 |
| 1986 | 1862 | 0.162 |
| 1987 | 1759 | 0.163 |
| 1988 | 5901 | 0.175 |
| 1989 | 1706 | 0.097 |
| 1990 | 6818 | 0.315 |
| 1991 | 6824 | 0.458 |
| 1992 | 13495 | 0.410 |
| 1993 | 4541 | 0.211 |
| 1994 | 6950 | 0.547 |
| 1995 | 8056 | 0.800 |
| 1996 | 8378 | 0.810 |
| 1997 | 5445 | 0.282 |
| 1998 | 7627 | 0.397 |
| 1999 | 2490 | 0.089 |
| 2000 | 5188 | 0.133 |
| 2001* | | confidential |
| 2002* | | confidential |
| 2003* | | confidential |
| 2004* | | confidential |
| 2005* | | confidential |
| 2006* | | confidential |
| 2007* | | confidential |
| 2008* | | confidential |
| 2009* | | confidential |
| 2010* | | confidential |

Table 13.4 Recreational fishery for river herring in Delaware (statewide).

| <u>Year</u> | Harvested <u>N</u> | Released Alive <u>N</u> | Total <u>N</u> | # of Fishers | Effort | Net Yard <u>Days</u> | Catch per <u>Trip</u> | Harvest per <u>Trip</u> |
|-------------|-----------------------|----------------------------|-------------------|-----------------|--------------|-------------------------|-----------------------------|-------------------------------|
| | | | | | <u>Trips</u> | <u>Days</u> | | |
| 1996 | 4399 | . | 4399 | 391 | 3,808 | 196,381 | 1.16 | 1.16 |
| 1997 | 2247 | . | 2247 | 274 | 2,291 | 111,659 | 0.98 | 0.98 |
| 1998 | 2835 | . | 2835 | 269 | 1,161 | 55,453 | 2.44 | 2.44 |
| 1999 | 460 | 14 | 474 | 27 | 948 | 49,342 | 0.50 | 0.49 |
| 2000 | 1134 | 6 | 1140 | 197 | 1,560 | 84,396 | 0.73 | 0.73 |
| 2001 | 502 | 1028 | 1530 | 198 | 1,686 | 82,301 | 0.91 | 0.30 |
| 2002 | 297 | 48 | 345 | 179 | 1,615 | 83,022 | 0.21 | 0.18 |
| 2003 | 370 | 43 | 413 | 173 | 1,390 | 65,779 | 0.30 | 0.27 |
| 2004 | No Data | . | . | . | . | . | . | . |
| 2005 | No Data | . | . | . | . | . | . | . |
| 2006 | No Data | . | . | . | . | . | . | . |
| 2007 | 341 | 495 | 836 | 144 | 878 | 43,096 | 0.95 | 0.39 |

Table 13.5 Annual catch-by-age and sex for alewife herring sampled from the Nanticoke River, 1989-2014.

| Year | Males | | | | | | | | | | |
|------|--------------|-----|-----|----|----|---|---|---|----|----|--|
| | Catch-by-Age | | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
| 1989 | 14 | 76 | 79 | 20 | 3 | | | | | | |
| 1990 | 53 | 94 | 142 | 75 | 12 | 1 | | | | | |
| 1991 | 18 | 249 | 123 | 54 | 12 | 1 | | | | | |
| 1992 | 29 | 99 | 135 | 27 | 6 | | | | | | |
| 1993 | 15 | 73 | 93 | 48 | 7 | 1 | | | | | |
| 1994 | 29 | 77 | 94 | 31 | 7 | | | | | | |
| 1995 | 8 | 18 | 10 | 6 | 2 | | | | | | |
| 1996 | 1 | 62 | 81 | 40 | 11 | 1 | | | | | |
| 1997 | 18 | 53 | 32 | 5 | 0 | 1 | | | | | |
| 1998 | 9 | 52 | 27 | 11 | 2 | | | | | | |
| 1999 | 21 | 36 | 53 | 39 | 5 | | | | | | |
| 2000 | 13 | 72 | 19 | 1 | | | | | | | |
| 2001 | 16 | 48 | 40 | 2 | | | | | | | |
| 2002 | 5 | 42 | 48 | 26 | 4 | | | | | | |
| 2003 | 5 | 19 | 24 | 16 | 1 | | | | | | |
| 2004 | 12 | 37 | 22 | 11 | 3 | | | | | | |
| 2005 | 6 | 39 | 19 | 5 | 1 | | | | | | |
| 2006 | 4 | 13 | 22 | 11 | | | | | | | |
| 2007 | 13 | 49 | 19 | 7 | | | | | | | |
| 2008 | 5 | 24 | 26 | 10 | 1 | | | | | | |
| 2009 | 5 | 33 | 15 | 5 | | | | | | | |
| 2010 | 2 | 14 | 4 | 5 | | | | | | | |
| 2011 | 6 | 18 | 14 | 11 | | | | | | | |
| 2012 | 12 | 24 | 21 | 8 | | | | | | | |
| 2013 | 5 | 12 | 17 | 8 | 1 | | | | | | |
| 2014 | 3 | 59 | 61 | 14 | 1 | | | | | | |

Table 13.5 Continued

Females

| Year | Catch-by-Age | | | | | | | | | |
|------|--------------|----|-----|-----|-----|----|----|---|----|----|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1989 | | 6 | 85 | 87 | 50 | 13 | 2 | | | |
| 1990 | | 12 | 78 | 141 | 93 | 26 | 21 | 1 | | |
| 1991 | | 8 | 158 | 102 | 77 | 35 | 7 | 6 | | |
| 1992 | | 13 | 116 | 244 | 70 | 30 | 7 | 2 | | |
| 1993 | | 1 | 78 | 151 | 129 | 30 | 11 | | | |
| 1994 | | 8 | 75 | 135 | 90 | 34 | 3 | | | |
| 1995 | | 4 | 23 | 12 | 15 | 11 | | | | |
| 1996 | | 25 | 61 | 68 | 28 | 19 | 7 | 1 | | |
| 1997 | | 6 | 67 | 48 | 19 | 3 | 4 | | | |
| 1998 | | 2 | 69 | 65 | 28 | 5 | 0 | 1 | | |
| 1999 | | 7 | 31 | 75 | 48 | 1 | 1 | | | |
| 2000 | | 2 | 62 | 30 | 23 | 6 | | | | |
| 2001 | | 1 | 38 | 62 | 24 | 7 | 1 | | | |
| 2002 | | 1 | 21 | 54 | 75 | 19 | 2 | | | |
| 2003 | | 2 | 13 | 35 | 43 | 10 | | | | |
| 2004 | | | 26 | 40 | 31 | 15 | 6 | | | |
| 2005 | | | 28 | 24 | 27 | 17 | 3 | | | |
| 2006 | | 2 | 15 | 56 | 24 | 4 | 4 | | | |
| 2007 | | 2 | 38 | 40 | 35 | 12 | 3 | | | |
| 2008 | | 2 | 26 | 56 | 17 | 13 | 2 | 1 | | |
| 2009 | | 4 | 50 | 61 | 33 | 10 | | | | |
| 2010 | | | 5 | 19 | 16 | 4 | | | | |
| 2011 | | 2 | 48 | 37 | 35 | 9 | 2 | | | |
| 2012 | | 8 | 22 | 34 | 27 | 10 | | | | |
| 2013 | | 3 | 19 | 31 | 20 | 11 | 1 | | | |
| 2014 | | 2 | 35 | 84 | 20 | 3 | 1 | | | |

Table 13.6 Annual catch-by-age and sex for blueback herring sampled from the Nanticoke River, 1989-2014.

Males

| Year | Catch-by-Age | | | | | | | | | |
|------|--------------|----|-----|-----|-----|----|----|----|----|--|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| 1989 | | 10 | 110 | 122 | 76 | 15 | 6 | 1 | | |
| 1990 | | 15 | 69 | 131 | 110 | 79 | 29 | 11 | | |
| 1991 | | 11 | 101 | 82 | 101 | 54 | 19 | 2 | 1 | |
| 1992 | | 10 | 43 | 54 | 49 | 36 | 14 | 4 | | |
| 1993 | | 5 | 39 | 74 | 73 | 40 | 15 | 3 | | |
| 1994 | | 24 | 91 | 102 | 41 | 9 | | | | |
| 1995 | | 2 | 13 | 11 | 10 | 4 | | | | |
| 1996 | 1 | 13 | 67 | 63 | 12 | 1 | 2 | | | |
| 1997 | | 10 | 18 | 53 | 82 | 11 | 2 | | | |
| 1998 | | 7 | 22 | 23 | 22 | 15 | | | | |
| 1999 | | 7 | 14 | 20 | 14 | 3 | | | | |
| 2000 | | 8 | 59 | 31 | 10 | 5 | | | | |
| 2001 | | 7 | 23 | 17 | 4 | | | | | |
| 2002 | | 8 | 24 | 25 | 7 | | | | | |
| 2003 | | 2 | 17 | 27 | 12 | | | | | |
| 2004 | | 16 | 29 | 19 | 4 | 1 | | | | |
| 2005 | | 3 | 3 | 2 | 0 | | | | | |
| 2006 | | 1 | 6 | 15 | 3 | 1 | | | | |
| 2007 | | 11 | 17 | 7 | 1 | | | | | |
| 2008 | | 5 | 19 | 11 | | | | | | |
| 2009 | | 9 | 17 | 5 | | | | | | |
| 2010 | | 2 | 8 | 0 | 1 | | | | | |
| 2011 | | 8 | 30 | 13 | 5 | | | | | |
| 2012 | 1 | 14 | 30 | 19 | 4 | | | | | |
| 2013 | | 4 | 22 | 17 | 11 | 1 | | | | |
| 2014 | | 21 | 75 | 38 | 5 | 1 | | | | |

Table 13.6 Continued

Females

| Year | Catch-by-Age | | | | | | | | | |
|------|--------------|----|-----|-----|-----|----|----|----|----|--|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| 1989 | | 3 | 112 | 126 | 76 | 37 | 6 | 1 | | |
| 1990 | | 0 | 43 | 78 | 75 | 64 | 18 | 5 | 4 | |
| 1991 | | 6 | 76 | 68 | 106 | 54 | 24 | 14 | | |
| 1992 | | 2 | 34 | 44 | 50 | 31 | 20 | 5 | | |
| 1993 | | 1 | 29 | 90 | 72 | 43 | 18 | 6 | 1 | |
| 1994 | | 3 | 42 | 70 | 46 | 19 | 4 | 1 | | |
| 1995 | | 3 | 11 | 7 | 5 | 1 | 3 | | | |
| 1996 | | 2 | 57 | 63 | 24 | 3 | 3 | | | |
| 1997 | | 3 | 33 | 50 | 67 | 14 | 3 | 1 | | |
| 1998 | | 0 | 38 | 39 | 41 | 22 | 3 | | | |
| 1999 | | 1 | 9 | 36 | 14 | 5 | | | | |
| 2000 | | 4 | 41 | 20 | 11 | 7 | 2 | | | |
| 2001 | | 1 | 24 | 20 | 7 | 2 | | | | |
| 2002 | | 1 | 27 | 41 | 15 | 1 | | | | |
| 2003 | | 1 | 22 | 26 | 15 | 5 | 1 | | | |
| 2004 | | 0 | 20 | 25 | 8 | 9 | 1 | | | |
| 2005 | | 1 | 6 | 1 | 2 | | | | | |
| 2006 | | 1 | 13 | 22 | 6 | | | | | |
| 2007 | | 8 | 13 | 11 | 4 | 2 | | | | |
| 2008 | | 3 | 23 | 14 | 3 | 3 | 1 | | | |
| 2009 | | 5 | 20 | 8 | 1 | 1 | | | | |
| 2010 | | | 7 | 6 | 2 | | | | | |
| 2011 | | 1 | 37 | 20 | 7 | 1 | | | | |
| 2012 | | 6 | 21 | 31 | 7 | 3 | | | | |
| 2013 | | 1 | 11 | 7 | 4 | 1 | 3 | | | |
| 2014 | | 15 | 45 | 47 | 13 | 1 | | | | |

Table 13.7 Mean length-at-age by sex for alewife herring sampled from the Nanticoke River, 1989-2010.

| Year | Males | | | | | | | | | |
|------|-------|-----|-----|-----|-----|-----|-----|---|----|----|
| | Age | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1989 | | 230 | 236 | 243 | 256 | 261 | | | | |
| 1990 | | 221 | 231 | 244 | 250 | 263 | 264 | | | |
| 1991 | | 224 | 234 | 240 | 251 | 260 | 243 | | | |
| 1992 | | 216 | 228 | 238 | 247 | 254 | | | | |
| 1993 | | 208 | 225 | 239 | 246 | 248 | 246 | | | |
| 1994 | | 207 | 219 | 231 | 239 | 246 | | | | |
| 1995 | | 214 | 226 | 238 | 246 | 251 | 244 | | | |
| 1996 | 212 | 219 | 228 | 238 | 242 | 263 | | | | |
| 1997 | | 213 | 228 | 233 | 240 | | 252 | | | |
| 1998 | | 217 | 225 | 238 | 243 | 254 | | | | |
| 1999 | | 211 | 222 | 233 | 238 | 244 | | | | |
| 2000 | | 220 | 228 | 238 | 258 | | | | | |
| 2001 | | 225 | 234 | 240 | 247 | | | | | |
| 2002 | | 225 | 233 | 241 | 244 | 248 | | | | |
| 2003 | | 228 | 239 | 245 | 251 | | | | | |
| 2004 | | 228 | 242 | 251 | 250 | | | | | |
| 2005 | | 214 | 226 | 236 | 252 | 252 | | | | |
| 2006 | | 219 | 223 | 235 | 242 | | | | | |
| 2007 | | 219 | 227 | 235 | 248 | | | | | |
| 2008 | | 216 | 217 | 229 | 235 | 278 | | | | |
| 2009 | | 221 | 224 | 231 | 241 | | | | | |
| 2010 | | 221 | 224 | 232 | 248 | | | | | |
| 2011 | | 215 | 230 | 233 | 244 | | | | | |
| 2012 | | 215 | 217 | 230 | 242 | | | | | |
| 2013 | | 204 | 222 | 232 | 243 | 245 | | | | |
| 2014 | | 222 | 222 | 229 | 240 | 230 | | | | |

Table 13.7 Continued.

Females

| Year | Age | | | | | | | | | |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1989 | | 229 | 244 | 253 | 267 | 277 | 286 | | | |
| 1990 | | 225 | 238 | 253 | 261 | 274 | 283 | 286 | | |
| 1991 | | 227 | 243 | 251 | 263 | 270 | 273 | 286 | | |
| 1992 | | 223 | 240 | 248 | 256 | 265 | 276 | 279 | | |
| 1993 | | 225 | 233 | 247 | 256 | 265 | 277 | | | |
| 1994 | | 219 | 228 | 243 | 254 | 258 | 270 | | | |
| 1995 | | 221 | 235 | 252 | 263 | 268 | 274 | | 280 | |
| 1996 | | 219 | 231 | 250 | 257 | 267 | 268 | 260 | | |
| 1997 | | 228 | 234 | 242 | 253 | 267 | 271 | | | |
| 1998 | | 224 | 235 | 245 | 255 | 264 | | 277 | | |
| 1999 | | 220 | 229 | 242 | 250 | 260 | 272 | | | |
| 2000 | | 237 | 237 | 250 | 257 | 270 | | | | |
| 2001 | | 239 | 243 | 249 | 256 | 266 | 270 | | | |
| 2002 | | 226 | 238 | 248 | 255 | 260 | 263 | | | |
| 2003 | | 240 | 239 | 250 | 260 | 263 | | | | |
| 2004 | | 235 | 249 | 259 | 262 | 270 | | | | |
| 2005 | | | 233 | 243 | 257 | 267 | 272 | | | |
| 2006 | | 228 | 240 | 247 | 256 | 264 | 277 | | | |
| 2007 | | 220 | 236 | 247 | 256 | 265 | 269 | | | |
| 2008 | | 217 | 231 | 238 | 248 | 256 | 276 | 279 | | |
| 2009 | | 215 | 231 | 242 | 252 | 261 | | | | |
| 2010 | | | 234 | 245 | 257 | 251 | | | | |
| 2011 | | 226 | 241 | 247 | 255 | 266 | 275 | | | |
| 2012 | | 218 | 233 | 249 | 260 | 263 | | | | |
| 2013 | | 233 | 232 | 240 | 249 | 262 | 269 | | | |
| 2014 | | 233 | 229 | 240 | 253 | 263 | 263 | | | |

Table 13.8 Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2014.

Males

| Year | Age | | | | | | | | | |
|------|-----|-----|-----|-----|-----|-----|-----|-----|----|--|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| 1989 | | 218 | 227 | 234 | 245 | 259 | 262 | 279 | | |
| 1990 | | 218 | 232 | 239 | 249 | 258 | 263 | 270 | | |
| 1991 | | 217 | 229 | 237 | 247 | 258 | 260 | 273 | | |
| 1992 | | 212 | 224 | 235 | 245 | 251 | 260 | 256 | | |
| 1993 | | 205 | 224 | 237 | 247 | 256 | 262 | 261 | | |
| 1994 | | 213 | 223 | 238 | 250 | 256 | | | | |
| 1995 | | 220 | 226 | 233 | 247 | 256 | | | | |
| 1996 | 205 | 219 | 230 | 240 | 244 | 270 | 261 | | | |
| 1997 | | 212 | 225 | 238 | 241 | 247 | 257 | | | |
| 1998 | | 212 | 225 | 233 | 245 | 253 | | | | |
| 1999 | | 200 | 222 | 232 | 239 | 251 | | | | |
| 2000 | | 219 | 225 | 235 | 246 | 249 | | | | |
| 2001 | | 218 | 231 | 235 | 250 | | | | | |
| 2002 | | 217 | 229 | 234 | 243 | | | | | |
| 2003 | 215 | 230 | 240 | 238 | | | | | | |
| 2004 | 216 | 231 | 234 | 245 | 250 | | | | | |
| 2005 | | 222 | 226 | 238 | | | | | | |
| 2006 | | 209 | 224 | 235 | 236 | 270 | | | | |
| 2007 | | 207 | 221 | 227 | 266 | | | | | |
| 2008 | | 206 | 216 | 220 | | | | | | |
| 2009 | | 214 | 219 | 231 | | | | | | |
| 2010 | | 219 | 227 | | 228 | | | | | |
| 2011 | | 206 | 220 | 226 | 234 | | | | | |
| 2012 | 212 | 208 | 217 | 228 | 229 | | | | | |
| 2013 | | 216 | 222 | 225 | 231 | 226 | | | | |
| 2014 | | 214 | 226 | 232 | 239 | 236 | | | | |

Table 13.8 Continued.

Females

| Year | Age | | | | | | | | | |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| 1989 | | 227 | 236 | 244 | 257 | 271 | 279 | 297 | | |
| 1990 | | | 241 | 252 | 262 | 271 | 281 | 286 | 291 | |
| 1991 | | 228 | 238 | 251 | 260 | 264 | 273 | 285 | | |
| 1992 | | 230 | 230 | 250 | 260 | 264 | 272 | 281 | | |
| 1993 | | 220 | 236 | 246 | 259 | 269 | 277 | 290 | 296 | |
| 1994 | | 215 | 226 | 245 | 260 | 272 | 282 | 277 | | |
| 1995 | | 228 | 235 | 248 | 260 | 264 | 270 | | | |
| 1996 | | 218 | 238 | 249 | 257 | 275 | 278 | | | |
| 1997 | | 226 | 242 | 247 | 254 | 268 | 276 | 290 | | |
| 1998 | | | 233 | 246 | 257 | 265 | 281 | | | |
| 1999 | | 219 | 236 | 244 | 253 | 273 | | | | |
| 2000 | | 227 | 231 | 243 | 260 | 269 | 275 | | | |
| 2001 | | 219 | 242 | 248 | 260 | 273 | | | | |
| 2002 | | 220 | 235 | 246 | 257 | 260 | | | | |
| 2003 | 224 | 235 | 248 | 252 | 264 | 283 | | | | |
| 2004 | | 236 | 245 | 254 | 262 | 262 | | | | |
| 2005 | | 241 | 236 | 248 | 264 | | | | | |
| 2006 | | 204 | 235 | 242 | 246 | | | | | |
| 2007 | | 217 | 221 | 246 | 247 | 266 | | | | |
| 2008 | | 213 | 227 | 234 | 252 | 251 | 261 | | | |
| 2009 | | 227 | 232 | 242 | 260 | 278 | | | | |
| 2010 | | | 243 | 238 | 247 | | | | | |
| 2011 | | 201 | 240 | 238 | 251 | 262 | | | | |
| 2012 | | 213 | 230 | 243 | 250 | 256 | | | | |
| 2013 | | 232 | 226 | 240 | 244 | 233 | 256 | | | |
| 2014 | | 217 | 232 | 245 | 256 | 275 | | | | |

Table 13.9 Annual catch-by-age and sex for alewife herring sampled from the West Fish Lift, Conowingo Dam, Susquehanna River, 2014 - 2015.

| Year | Males | | | | | | | | | |
|------|--------------|---|---|---|---|---|---|---|----|----|
| | Catch-by-Age | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 2014 | | 6 | | 1 | | | | | | |
| 2015 | | 1 | 9 | 7 | 1 | | | | | |

| Year | Females | | | | | | | | | |
|------|--------------|---|---|---|---|---|---|---|----|----|
| | Catch-by-Age | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 2014 | | 4 | 2 | | | | | | | |
| 2015 | | | 5 | 7 | | | | | | |

Table 13.10 Annual catch-by-age and sex for blueback herring sampled from the West Fish Lift, Conowingo Dam, Susquehanna River, 2012 - 2015.

| Year | Males | | | | | | | | | |
|------|--------------|----|----|---|---|---|---|---|----|----|
| | Catch-by-Age | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 2012 | | 4 | 3 | | | | | | | |
| 2013 | | | 1 | 1 | | | | | | |
| 2014 | | 12 | 29 | 8 | 2 | 1 | | | | |
| 2015 | | 3 | 6 | 4 | | | | | | |

| Year | Females | | | | | | | | | |
|------|--------------|---|---|---|---|---|---|---|----|----|
| | Catch-by-Age | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 2012 | | | 2 | | | | | | | |
| 2013 | | | | | | | | | | |
| 2014 | | | 4 | 1 | | | | | | |
| 2015 | 1 | 1 | 1 | 1 | | | | | | |

Table 13.11 Mean length-at-age by sex for alewife herring sampled from the West Fish Lift, Conowingo Dam, Susquehanna River, 2014 - 2015.

| Year | Males | | | | | | | | | |
|------|--------------------|-----|-----|-----|-----|---|---|---|----|----|
| | Mean Length at Age | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 2014 | | 255 | | 278 | | | | | | |
| 2015 | | 259 | 266 | 264 | 260 | | | | | |

| Year | Females | | | | | | | | | |
|------|--------------------|-----|-----|-----|---|---|---|---|----|----|
| | Mean Length at Age | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 2014 | | 263 | 287 | | | | | | | |
| 2015 | | | 268 | 279 | | | | | | |

Table 13.12 Mean length-at-age by sex for blueback herring sampled from the West Fish Lift, Conowingo Dam, Susquehanna River, 2012 - 2015.

| Year | Males | | | | | | | | | |
|------|--------------------|-----|-----|-----|-----|-----|---|---|----|----|
| | Mean Length at Age | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 2012 | | 231 | 249 | | | | | | | |
| 2013 | | | 254 | 250 | | | | | | |
| 2014 | | 237 | 253 | 262 | 260 | 292 | | | | |
| 2015 | | 252 | 252 | 264 | | | | | | |

| Year | Females | | | | | | | | | |
|------|--------------------|-----|-----|-----|-----|---|---|---|----|----|
| | Mean Length at Age | | | | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 2012 | | | 255 | | | | | | | |
| 2013 | | | | | | | | | | |
| 2014 | | | 264 | 273 | | | | | | |
| 2015 | | 251 | 272 | 284 | 280 | | | | | |

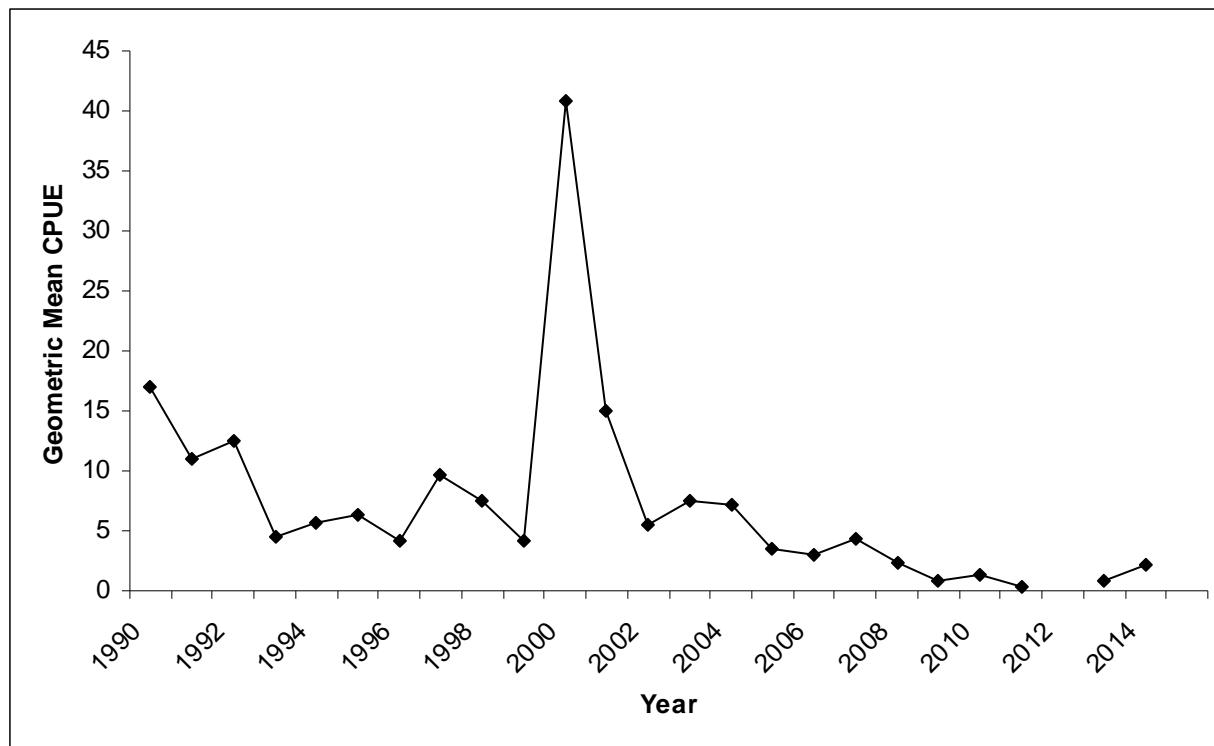


Figure 13.1 Geometric mean CPUEs of adult alewife herring from the Nanticoke River fyke nets, 1989-2014.

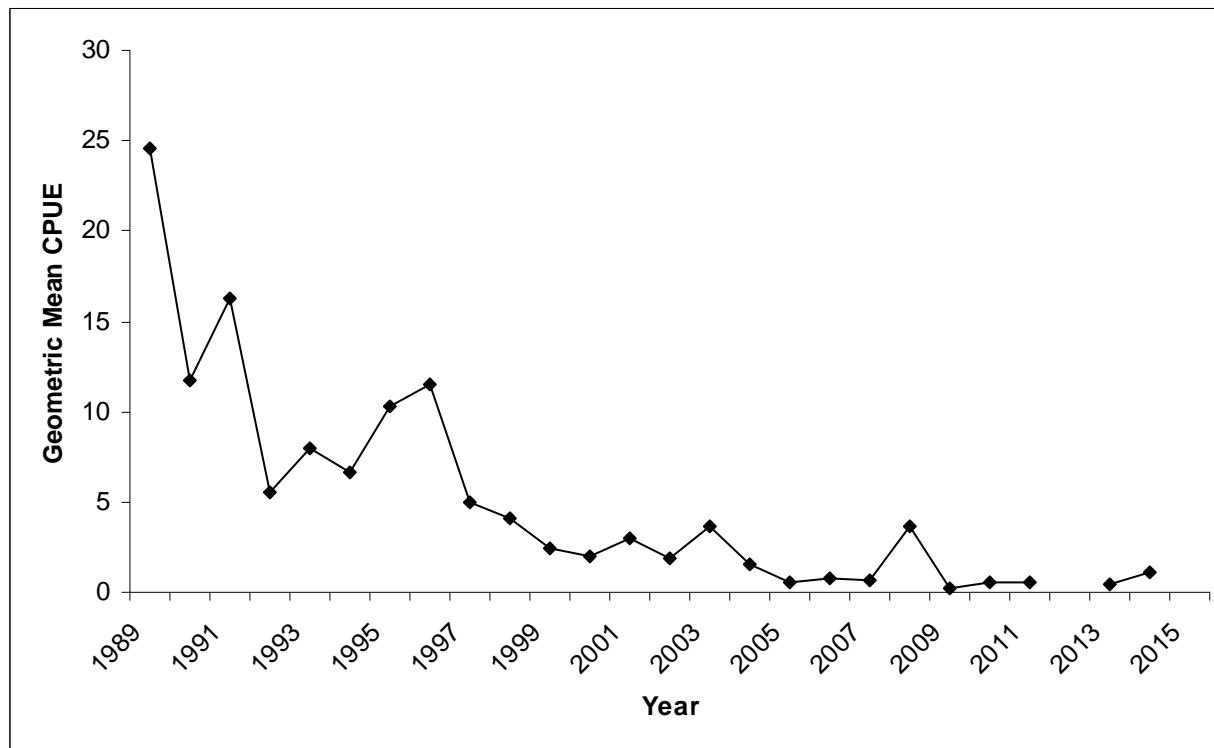


Figure 13.2 Geometric mean CPUEs of blueback herring from the Nanticoke River fyke nets, 1989-2014.

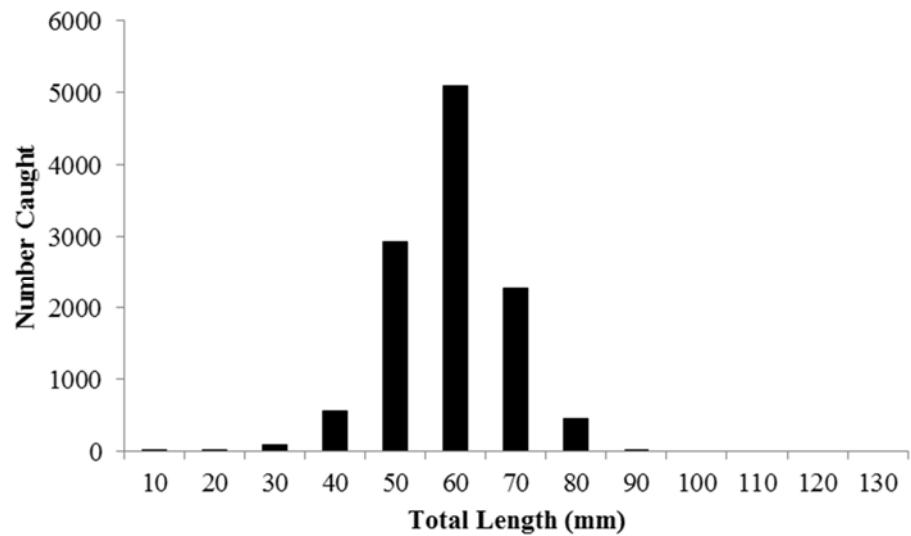


Figure 13.3 Length frequency of YOY blueback herring from the haul seine survey on the Nanticoke River in Delaware 1999-2015.

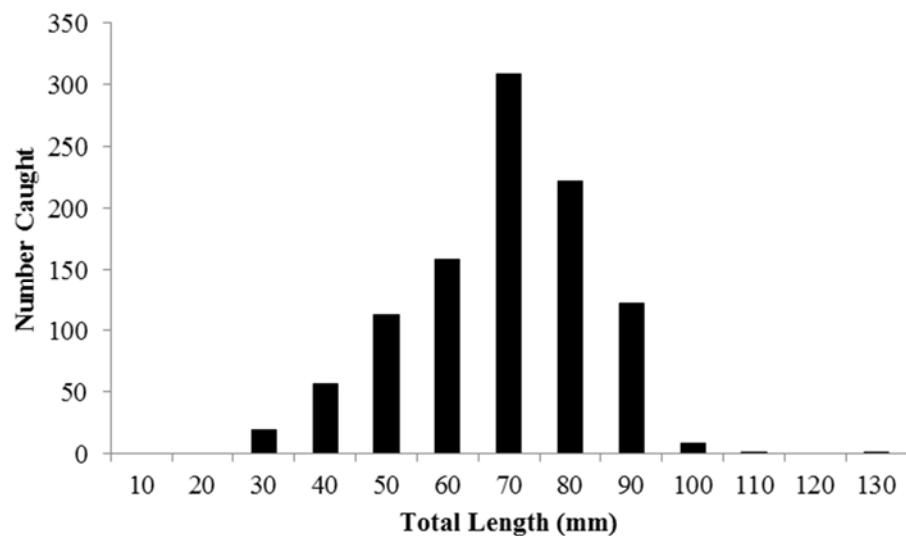


Figure 13.4 Length frequency of YOY alewife from the haul seine survey on the Nanticoke River in Delaware 1999-2015.

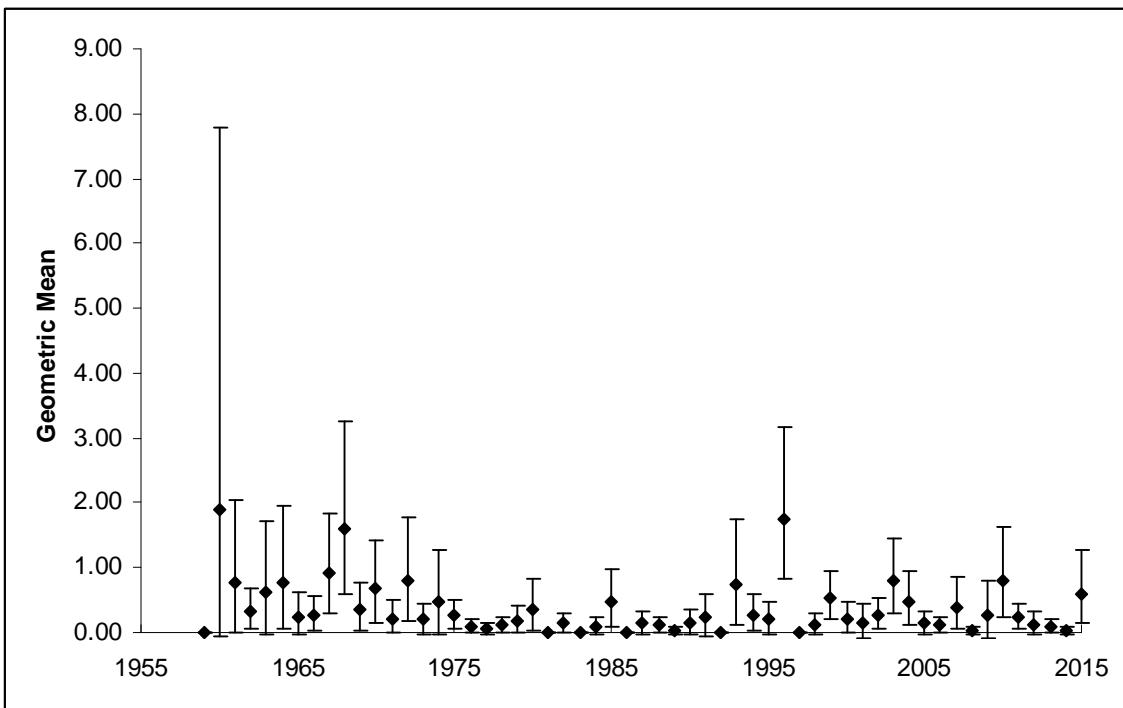


Figure 13.5 Nanticoke River juvenile alewife herring geometric mean CPUEs with 95% confidence intervals, 1959-2015.

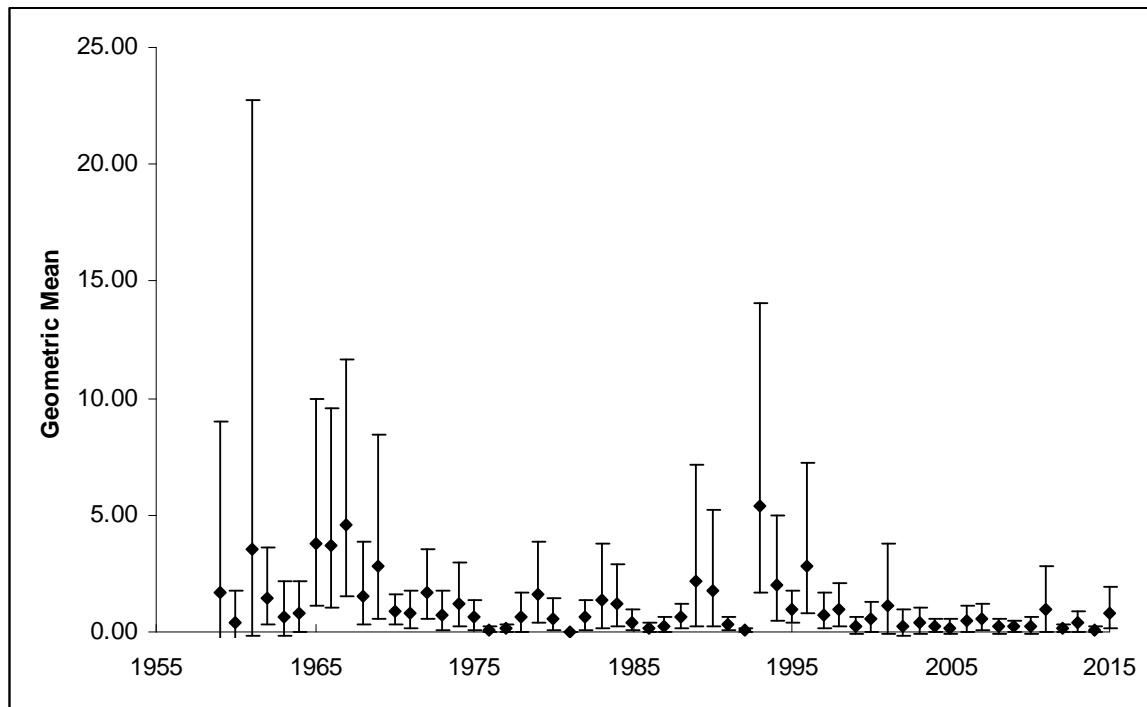


Figure 13.6 Nanticoke River juvenile blueback herring geometric mean CPUEs with 95% confidence intervals, 1959-2015.

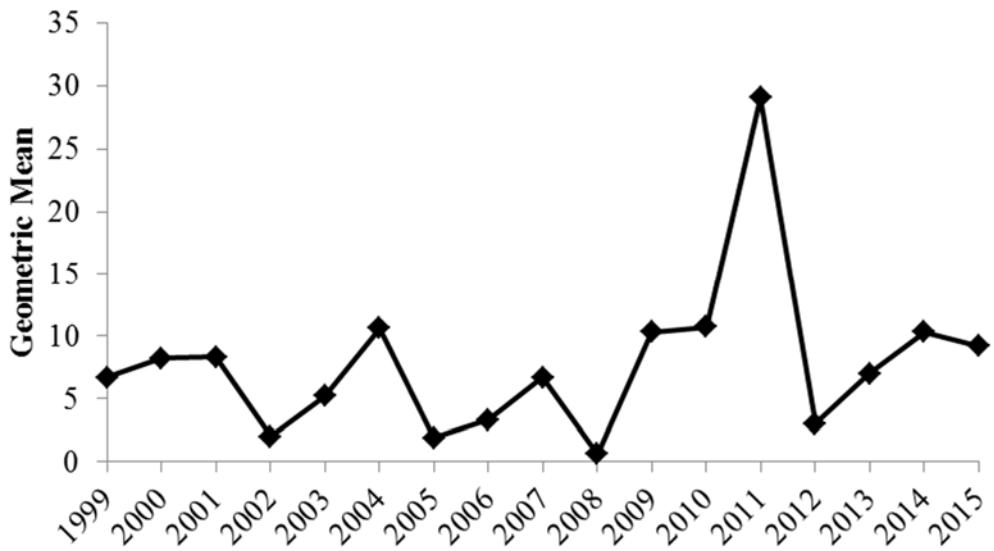


Figure 13.7 The geometric mean for juvenile blueback herring caught with the haul seine from the upper Nanticoke River and Broad Creek from 1999 through 2015.

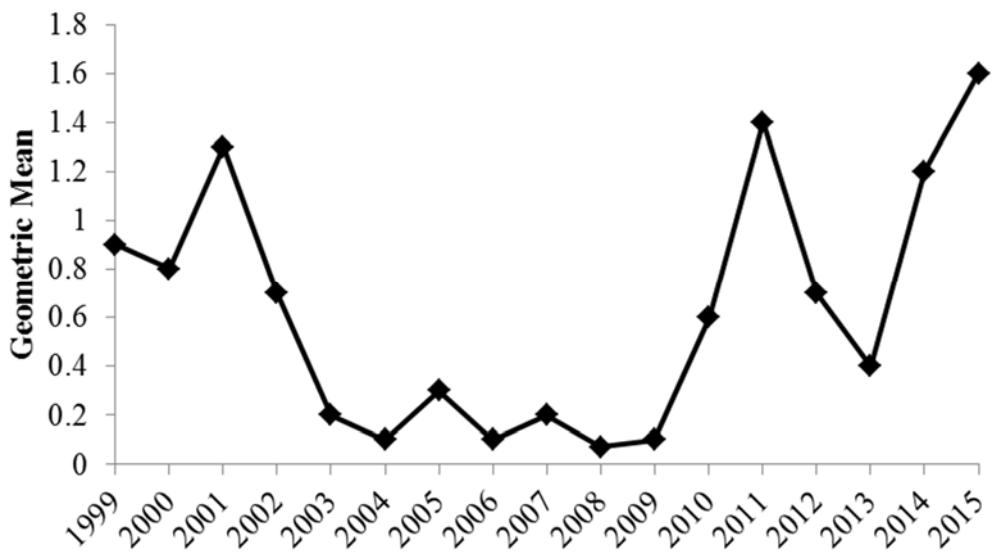


Figure 13.8 The geometric mean for juvenile alewife caught with the haul seine from the upper Nanticoke River and Broad Creek from 1999 through 2015.

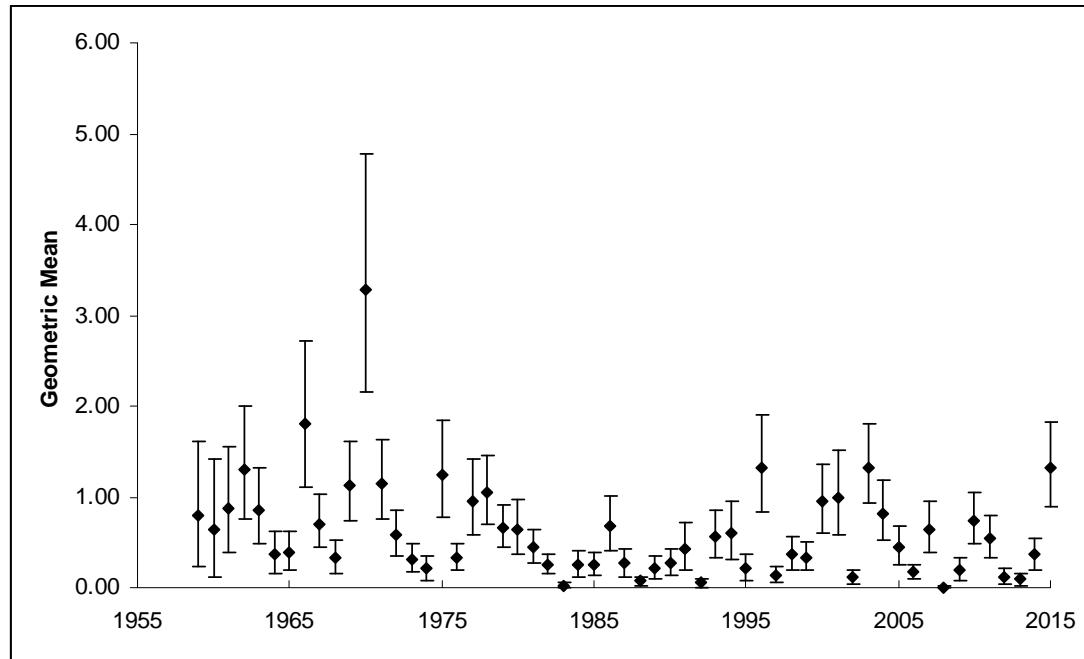


Figure 13.9 Baywide juvenile alewife herring geometric mean CPUEs with 95% confidence intervals, 1959-2015.

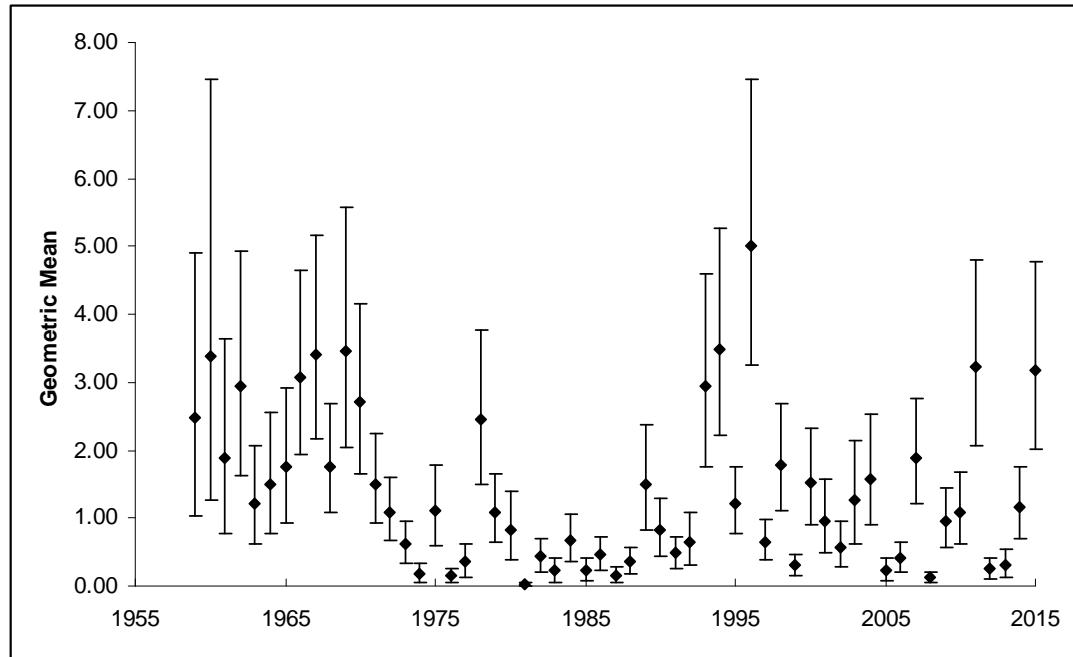


Figure 13.10 Baywide juvenile blueback herring geometric mean CPUEs with 95% confidence intervals, 1959-2015.

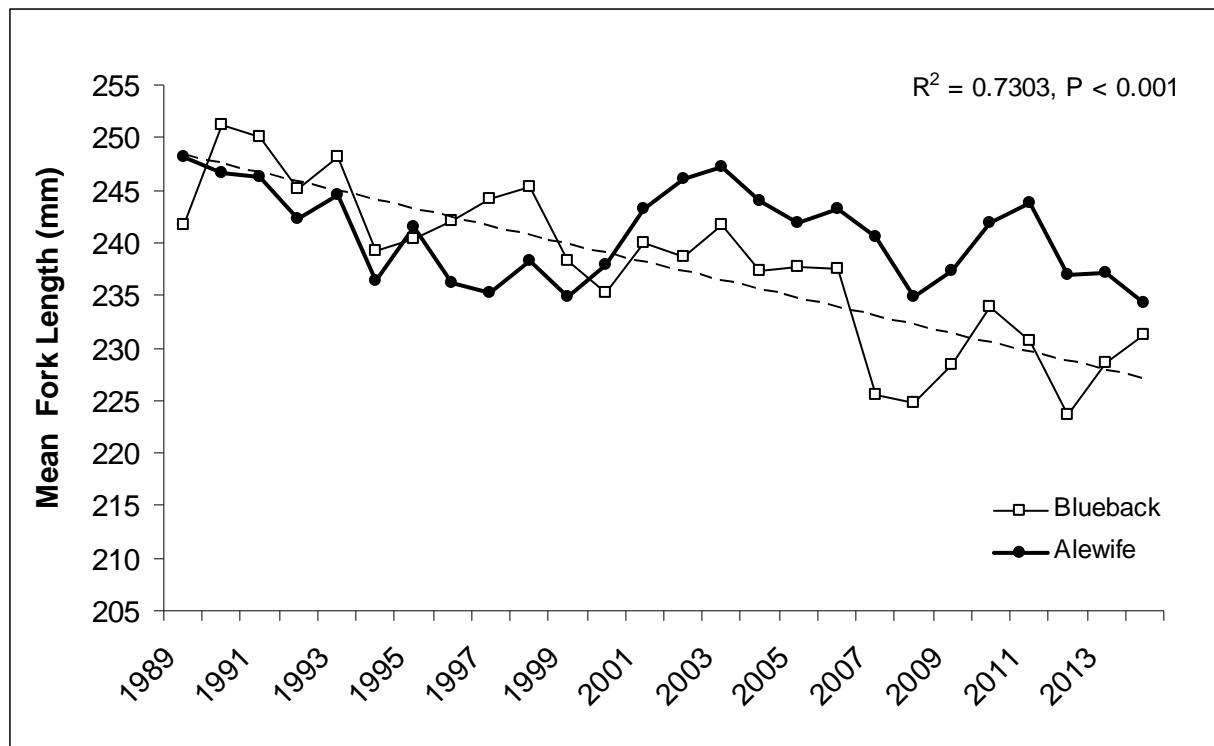


Figure 13.11 Mean length (FL mm) of adult alewife and blueback herring from the Nanticoke River, 1989-2014.

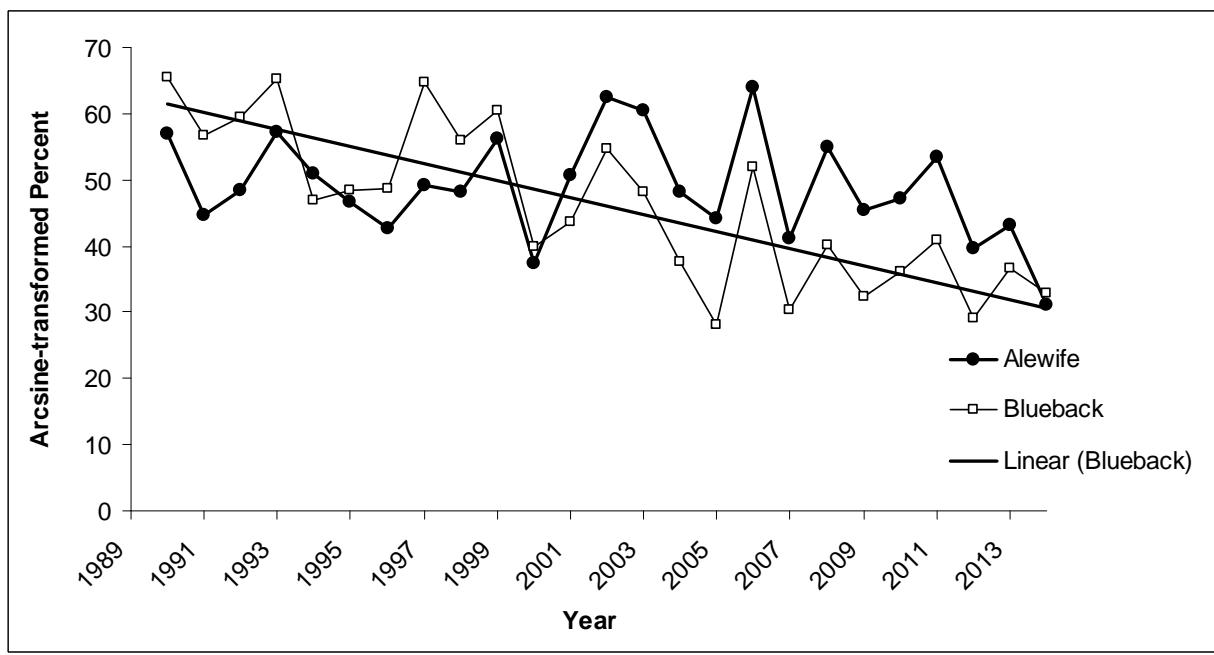


Figure 13.12 Trends in the arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes combined) from the Nanticoke River, 1989-2014.

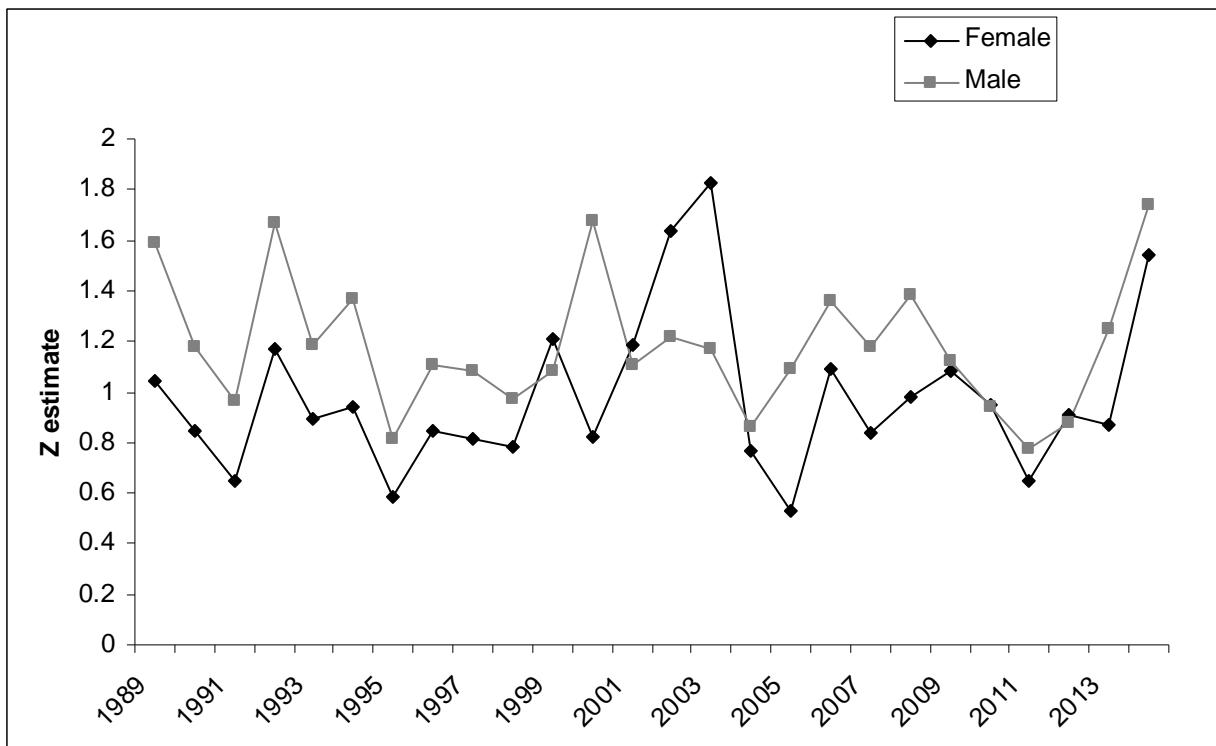


Figure 13.13 Alewife mortality rates for males and females from the Nanticoke River, 1989-2014.

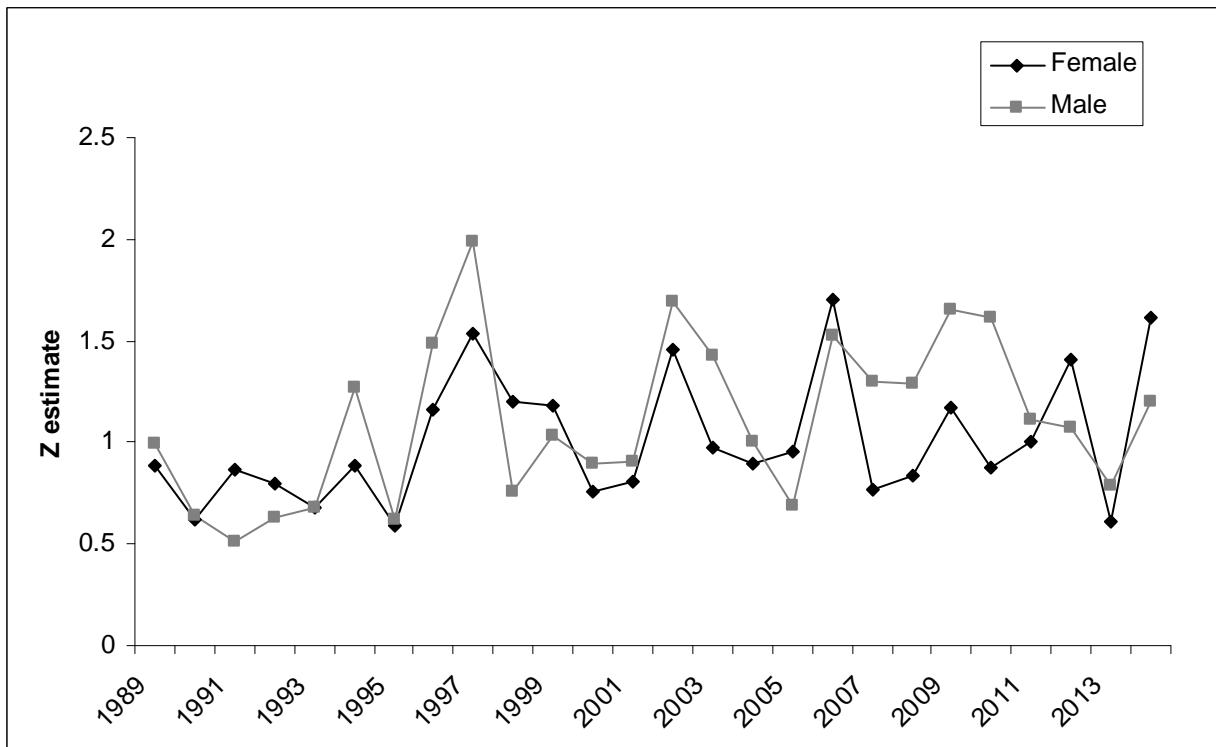


Figure 13.14 Blueback herring mortality rates for males and females from the Nanticoke River, 1989-2014.

14 Status of River Herring in the Potomac River

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Executive Summary

The following report will give a brief overview of the work done by the District Department of Energy and Environment (DOEE) and the Potomac River Fisheries Commission (PRFC) as it relates to river herring (alewife and blueback herring) management and monitoring. PRFC manages and tracks commercial landings of river herring in the Potomac River. In 2010, the commercial harvest of river herring was closed to all gear with the exception of a limited pound net by-catch of 50 pounds per fishermen per day, and a moratorium was established on river herring for recreational and charter fishing. In 2012, all commercial fisheries were closed to the taking and/or possession of river herring. Surveys conducted by DOEE include fisheries independent electrofishing for adults and seining and push net sampling for juveniles. There has been a drastic decline in CPUE of alewife and blueback herring in the DDOE adult electrofishing survey from the late 1990s to early 2000s. However, size structure trends from the electrofishing survey have remained relatively stable from 2005-2016. Maryland Department of Natural Resources (MD DNR) conducts a juvenile survey in the Potomac River, and a striped bass spawning stock survey which encounters river herring. The population of blueback herring appears to be more abundant in the Potomac River than alewife herring.

14.1 INTRODUCTION

River herring (*Alosa pseudoharengus* and *Alosa aestivalis*) are important anadromous species that frequent the waters of the Potomac River. There was a significant abundance of river herring caught in the Potomac River from the Colonial Period through the 19th Century. Historically, the primary gear for harvesting river herring in the Potomac River was the haul seine. The large haul seine fisheries of the 18th and 19th centuries are now gone and replaced today by much smaller, shorter seines (2,400 ft. maximum).

Sexually mature river herring return each spring to spawn in the Potomac River. Locally and historically, the "herring run" was an anticipated fishing event as eager anglers, birds, and other opportunists took advantage of these nutrient rich visitors. Adult herring are normally present in the Potomac River for about three months each year from March through May. In addition to the annual run of adult river herring, the juveniles that were spawned use the region as a nursery to grow and develop. Each year clouds of juvenile river herring consume zooplankton during the summer months before migrating out of our region by autumn.

River herring are monitored by DOEE and MD DNR each year to assess the status of the local populations and determine how that may affect the overall coastal stock. Because of the two distinct life stages (adult and juvenile) that are represented in the Potomac River, sampling efforts are designed to target each group specifically. Data is analyzed annually and compared by year to determine significant trends in population structure and size.

14.2 DEFINITION OF MANAGEMENT UNITS

The low water mark of the southern shore Potomac River, exclusive of the tributaries, is the boundary line between the states of Maryland and Virginia, with Maryland being the owner of the river. Maryland and Virginia first entered into a compact in 1785 (before the adoption of the U.S. Constitution) to regulate, among other things, the fisheries of the Potomac. After the adoption of the U.S. Constitution and the formation of a Federal Government, Maryland ceded the area, including that part of the Potomac River, which is now the District of Columbia.

There are five fishery management authorities on the Potomac River. The Potomac River Fisheries Commission (PRFC) is the Maryland / Virginia bi-state Commission with fisheries management authority for the main stem of the river, exclusive of the tributaries on either side, from the Chesapeake Bay to the southern Maryland / District of Columbia boundary line; the District Department of Energy and Environment (DOEE) with authority for the Potomac River to the Virginia shore and other waters within D.C.; the Maryland Department of Natural Resources (MD DNR) with authority for the tributaries of the Potomac on the Maryland side of the river and the fluvial portion of the river upstream of D.C.; the Virginia Marine Resources Commission (VMRC) with authority for commercial fisheries in all tidal Virginia tributaries and for recreational fisheries in the saltwater portions of the tidal Virginia tributaries below the Route 301 Bridge; and the Virginia Department of Game and Inland Fisheries (VDGIF) with authority for recreational fisheries in the freshwater portions on the Virginia tributaries. Additionally the Federal government controls much of the shoreline, and therefore access, of the Potomac through several military bases and the National Park Service.

14.3 REGULATORY HISTORY

During colonial times, the fisheries were essentially unregulated. In 1785 Maryland and Virginia adopted a compact to regulate the fisheries by requiring all fishery laws for the Potomac River to be enacted jointly by the legislatures of both states. In 1963 the PRFC was created and charged with the establishment and maintenance of a program to conserve and improve fishery resources. While PRFC has never had any specific regulations regarding river herring, there have been prohibitions against certain gears such as purse nets, trawls, trammel nets, troll nets, or drag nets have been in place which has limited commercial harvest of river herring such that river herring harvest in the Potomac is almost exclusively taken by pound nets. The District of Columbia does not allow commercial harvest of river herring from their portion of the Potomac River.

The pound net fishery shifted from a shad and herring fishery in the 1960's and early 1970's, when those species began declining, to primarily a menhaden fishery in the late 1970's and early 1980's. The deep water in-line pound nets were replaced by shallow water singly-set pound nets, and as a result shad and river herring became by-catch species in pound nets. The PRFC adopted a commercial fishery moratorium for river herring in 2010, with a minimal by-catch provision of 50 pounds per licensee per day for pound nets. A pound net by-catch provision was put in place to enable monitoring of river herring runs. In 2012, all fisheries were closed to the taking and/or possession of river herring. The PRFC now has no commercial or recreational fisheries for river herring.

The PRFC adopted the mandatory use of fish cull panels in all pound nets in the Potomac River, effective January 1, 2011. Fish cull panels are specially designed and manufactured by-catch reduction devices that have been tested and used (prior to 2011) voluntarily in Potomac River pound nets. They were effective in the safe release of sublegal flounder, weakfish, spot, croaker and bluefish when installed in the bottom corners of the sides of the pound nets. The regulation requires that four panels be installed in the bottom corners of the upriver and downriver sides of the net, and two additional panels be installed closer to the surface for the purpose of releasing river herring. It is expected that this conservation measure will greatly reduce the by-catch of small fish in pound nets.

Prior to 2010, no river herring were reported as discarded because it was an open fishery and the fishermen kept their entire catch. The fishermen are now adding data for the discard/release of river herring, and in 2015 there were 715 pounds of river herring that were reported as discarded. However, an unknown amount of river herring are released each year from pound nets as a result of the mandatory use of the fish cull panels.

The Potomac River recreational fishery for river herring under the jurisdiction of PRFC was closed in 2010 in the main stem of the river below the District of Columbia. Recreational anglers have historically been permitted to harvest river herring within the District of Columbia's portion of the Potomac River by way of hook and line fishing, dip netting, and snagging, with no size or creel limit. As of January 1, 2012 recreational harvest of river herring was prohibited within the District's waters.

Note that the PRFC regulates and records harvest for only the main stem of the river, while the tributaries on either side are under Maryland or Virginia jurisdiction. Harvest records for alewife and blueback herring in the Potomac River have been historically combined as river herring.

14.4 ASSESSMENT HISTORY

A stock assessment on selected river herring stock was conducted in 1990 by ASMFC. This assessment included both alewife and blueback herring populations in the Potomac River. Stock-recruitment (S-R) analyses were originally planned for the Potomac River, but the river herring S-R data were considered to be unreliable because recruitment estimates were either missing for certain years, were of unacceptably short duration (<15 years), or yielded imprecise and implausible S-R parameters.

The assessment found that Potomac River alewife populations were or were being overfished ($u > u_{msy}$ or u_{coll}) to the extent that recruitment failure was apparent in the late 1980's. The Potomac River blueback herring stocks were not overfished ($u < u_{msy}$) but were experiencing a stock decline. The 1990 or historical u values for Potomac River blueback herring were within 75% of the u_{msy} levels, and therefore were considered by the criteria to be fully exploited. The time series of alewife and blueback herring abundance exhibited a pronounced downward trend during the 1980's which is consistent with excessive fishing mortality.

The assessment also concluded that the highest fishing mortality rates ($u > 0.60$) on river herring occurred mainly near the northern (St. John and Damariscotta Rivers) and southern (Potomac, Rappahannock, Chowan Rivers) end of the distribution, where there are directed riverine fisheries. In order to rebuild the spawning population and stabilize recruitment in these river herring stocks, additional conservation measures were recommended to be imposed to reduce the fishing mortality rates below the u_{msy} levels. The results strongly suggested that heavy fishing pressure by the states of Maine, Virginia and North Carolina is primarily responsible for the continued decline of river herring stocks in the Damariscotta, Potomac, Rappahannock and Chowan Rivers.

14.5 STOCK-SPECIFIC LIFE HISTORY

Alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) are anadromous clupeids. Adult river herring usually appear in the Potomac River waters in March, and spawn through May. Approximately 44 to 65 percent of blueback herring in Chesapeake Bay tributaries are repeat spawners (Joseph and Davis 1965), as well as 30 to 72 percent of alewife (Weinrich et al. 1987; Howell et al. 1990). Alewife usually spawn three to four weeks earlier than blueback herring, giving juvenile alewife a relative size advantage over juvenile blueback herring, and thus access to a larger variety of prey (Jessop 1990); however, there may be considerable overlap in the spawning period (Loesch 1987). Hatching usually occurs within three to five days after fertilization (Edsall 1970). In addition to the annual run of adult river herring, the juveniles that were spawned use this tidal freshwater area as a nursery to grow and develop (Warriner et al. 1970). Michael Odom (U.S. Fish and Wildlife Service, personal communication) has observed that in the Potomac River, juvenile blueback herring are found in the pelagic main channel portion of tidal waters, while American shad juveniles seek shallower nearshore flats adjacent to and among SAV beds. Juvenile river herring in the Potomac River are abundant at the surface during daylight in the summer; however they shift to mid-water and bottom depths in the fall until they begin their seaward migration in November (Warriner et al. 1970). There appears to be some overwintering annually of both species of herring in the Chesapeake Bay (Dovel 1971; Hildebrand 1963).

14.6 HABITAT DESCRIPTION

The Potomac River is a major tributary of the Chesapeake Bay, the area of its watershed ranking fourth on the East Coast (Figure 14.1). The estuary extends 113 miles from its mouth to the head of tide. On the outskirts of the District of Columbia at Little Falls, a low head dam for water withdrawal has a fish passage facility that allows river herring to extend their spawning range an additional 10 to 12 miles upstream to Great Falls, a natural barrier to all anadromous species. Alosine fishes (American shad, hickory shad, alewife, and blueback herring) utilize that reach of the Potomac extending from Ragged Point to the fall line near Washington, D.C. (Warriner et al. 1970; Lippson and Moran 1974). The primary spawning grounds of alosine fishes include mainstream and tributaries from Mathias Point to the fall line. River herring also utilize the freshwater portions of downriver tributary streams in Maryland and Virginia as spawning sites.

Within District of Columbia, spawning herring are typically found congregating adjacent to man-made sea walls and rip rap barriers which account for much of the shoreline habitat. They can also be found "staging" in deeper holes and pools prior to significant rain events which trigger upstream migration and subsequent spawning. The larvae and juveniles spread throughout the tidal freshwater portion of the estuary (Warriner et al., 1970) and remain there until water temperatures drop in the fall; at that time they proceed seaward. Juvenile river herring tend to remain in clusters or schools moving along various types of shoreline cover, SAV beds, and open water.

Within the District of Columbia, there have been no significant losses of habitat over the past twenty years while potential habitat has been made available in Rock Creek. In 2007, DOEE installed a fish ladder at Pierce Mill in Rock Creek in conjunction with the removal of all of the remaining man-made obstructions to fish passage. These habitat improvements were designed to expand potential spawning habitat for river herring and other anadromous species. Electrofishing efforts in Rock Creek have been expanded to include this additional habitat, but have so far failed to confirm the utilization of the fish ladder by river herring.

14.7 RESTORATION

DOEE and PRFC currently have no restoration programs for river herring.

14.8 AGE

PRFC provided a bushel sample of pound net caught river herring to the Chesapeake Biological Laboratory for age analyses in 2011 and 2013. Results included in appendix. DOEE currently has no age data for river herring.

14.9 FISHERY DESCRIPTIONS

14.9.1 Commercial Permits

In 1964, the first year that the PRFC collected harvest data, there were 138 pound nets licensed. Pound net licenses have fluctuated from a high of 181 in 1969 to a low of 69 in 1974. The pound net fishery shifted from a shad and river herring fishery in the 1960's and early 1970's, when those species began declining, to primarily a menhaden fishery in the late 1970's and early 1980's with shad and river herring as bycatch species. After Maryland and Virginia established limited entry fisheries in the 1990's, the PRFC responded to industry's request and capped the Potomac River pound net fishery at 100 licenses in 1995. The 100 pound net licenses are held by 18 fishermen in 2017, and the PRFC only requires that one net be set; consequently the number of pound nets being fished in the Potomac is at a very low level.

14.9.2 Commercial Landings

With the total moratorium in place in 2012, the only reports of river herring are discards or releases.

14.9.3 Recreational Fishery

As of January 1, 2010 recreational landings were prohibited in the Potomac River water's under the jurisdiction of PRFC. As of January 1, 2012 recreational landings were prohibited in the Potomac River water's under the jurisdiction of the DOEE.

14.10 FISHERY INDEPENDENT SURVEYS

The DOEE Fisheries Research Branch conducts three main surveys in which river herring are regularly encountered. These surveys include boat electrofishing, seining, and push net.

MD DNR conducts an annual juvenile survey for YOY in the Potomac River, and a spring striped bass spawning stock survey in which river herring are encountered.

14.10.1 Spawning Stock Survey

A standardized electrofishing survey is conducted throughout the District of Columbia's waters from March–November. This survey is conducted on a monthly basis at eight standard sites located throughout the District's jurisdiction. Four alternate sites were added in 1995; alternate sites are only visited every other month during May–November. Transects are run at each site for 600 seconds with 2 repetitions conducted at each site. This survey targets all species of fish located in the District and allows biologist to track population trends of both resident and anadromous fish species occurring in the District. In the spring, typically from April – June, adult river herring appear in this survey. The data collected from the herring include species and the length and sex of each herring netted. For large samples, data from 50 fish are recorded and the remaining fish are counted. The DOEE uses this survey to monitor trends in run sizes and the size structure of adults. CPUE is calculated by number of fish captured per hours of shock time; because the survey is conducted March – November only the data collected from March-June is used for the calculation of the adult herring CPUE (Table 14.3).

MDNR has conducted a spring striped bass spawning stock survey since 1959 in which river herring are encountered. The survey occurs above the Rt. 301 Bridge and the samples are collected using a drift gill net (Figures 14.6 and 14.7).

14.10.2 Juvenile Surveys

A beach seining survey was initiated by DOEE in 1990. During June through October, a single haul is made at each of six fixed locations. Prior to 2010, sampling sites were visited once a month; as of 2010, the frequency of visits to the sites was increased to twice a month. This survey targets all YOY finfish occurring within the District of Columbia. The data that are recorded includes species and length. For large samples, data from 50 fish are recorded and the remaining fish are counted. Juvenile river herring show up in this survey typically from June – October.

The push net survey is conducted in the District of Columbia's Potomac River waters from July to September. This survey has been in effect from 2005 – present. The push net consists of a 4'x 3' frame with a 1/8" mesh bag attached. The frame pivots out over the bow of the boat and the net is then allowed to skim just below the surface of the water. A total of six fixed transects are run. The boat is kept at a constant speed of five mph for 10 min. Each site is sampled once a week for 11 consecutive weeks. This survey is designed to capture YOY alosine species. When samples are examined all fish are identified to species and counted; lengths are taken from a subset of 50 individuals.

A previous push net juvenile survey was conducted by the Interstate Commission on the Potomac River Basin (ICPRB) and U.S. Fish and Wildlife Service (USFWS) from 1997 to 2002. This survey was generally upstream of the area of the river sampled by the MDNR YOY survey (described below). The purpose of the USFWS survey was to capture juvenile American shad to determine proportion of hatchery fish. Identification of river herring to species was not done by technicians all of the time, but blueback herring were encountered. Data from 1997 is not considered reliable because the sampling protocol and sites had not been standardized. Additionally data from 2002 was not processed. Funding for the ICPRB/USFWS survey ended in 2002.

MDNR has been annually sampling for juvenile/YOY river herring within the Chesapeake Bay since 1959. Durell and Weedon (2015) described the sampling protocol. Seine sampling occurs at 22 fixed stations using a 30.5 x 1.24 meter bagless beach seine of untreated 6.4 mm bar mesh which is set by hand. One end is held on shore while the other is fully stretched perpendicular from the beach and swept with the current. Stations have been sampled continuously since 1954, with changes in some station locations. The sampling is divided among four of the major spawning and nursery areas: seven each in the Potomac River and Head of Bay areas and four each in the Nanticoke and Choptank Rivers. Sampling is monthly, with rounds occurring during July, August, and September. Replicate seine hauls, a minimum of thirty minutes apart, are taken at each site on each sample round. This produces a total of 132 samples from which bay-wide means are calculated. In 1962, stations were standardized and a second sample round was added for a total of 88 samples. A third sample round, added in 1966, increased sample size to 132. Auxiliary stations have been sampled on an inconsistent basis and are not included in survey indices. The river herring juvenile indices for the Potomac River are derived from the MDNR juvenile survey (Figures 14.8 and 14.9).

14.11 ASSESSMENT APPROACHES AND RESULTS

There is very little data available to conduct an assessment of the population of river herring in the Potomac River.

14.11.1 Trends in Spawning Stock

Trends in spawning stock can be observed in data collected from the electrofishing survey in which a CPUE is generated. CPUE (fish captured per hour of shock time) indices derived from this survey show a drastic decline for both alewife and blueback herring from the late 1990s to early 2000s (Figure 14.3).

14.11.2 Trends in Length

The electrofishing survey provides data to observe trends in size structure of adult river herring. Size structure trends have remained relatively stable from 2005-2016; however data prior to 2005 is unavailable. During this time period average annual adult alewife lengths were between 259 and 270 mm for males and 283 to 290 for females. For blueback herring, average annual adult lengths were between 239 and 251mm for males and 258 and 270 mm for females.

Limited data is available from the pound net sample analyses conducted at CBL in 2011 and 2013 (See appendix).

14.11.3 Trends in Juvenile Abundance

The beach seining and push net surveys conducted by DOEE provide relative abundance data for juvenile river herring. Due to the differences in survey design and species identification it is difficult to draw trends between the USFWS/ICPRF and DOEE push net surveys. Geometric means (average number of fish per haul) derived from the beach seining survey show a dramatic decline in alewife numbers from the early 1990's until present day. By comparison, geometric means derived for blueback herring appear to have followed a cyclical pattern since 1994 (Figure 14.4). The push net survey show similar trends for both alewife and blueback. Since 2005, when the push net survey was started, the geometric means seem to follow a cyclical pattern (Figure 14.5).

The MD DNR juvenile/YOY river herring survey catches blueback herring in higher proportions. The 2016 geometric mean CPUE for alewife was 0.00, a decrease from the 0.24 value in 2015. The 2016 geometric mean CPUE for blueback was 0.17, compared to 4.00 in 2015. There are no apparent trends in the YOY indices. The geometric mean CPUEs for the Potomac River YOY alewife and blueback herring are presented in Figures 14.8 and 14.9.

14.11.4 Trends in Sex

Trends in sex are available from the DDOE electrofishing survey. In the DOEE electrofishing survey male alewives have consistently occurred more frequently than females, while there is no apparent trend for blueback herring.

Limited data is available from the pound net sample analyses conducted at CBL in 2011 and 2013 (See appendix).

14.11.5 Trends in Age

Limited data is available from the pound net sample analyses conducted at CBL in 2011 and 2013 (See appendix).

14.11.6 Trends in Repeat Spawning

No data is available for trends in proportion of repeat spawners.

14.11.7 Trends in Mortality

No data is available for trends in mortality.

14.12 BENCHMARKS

There are no benchmarks established for river herring fisheries in the Potomac River.

14.13 CONCLUSIONS

The YOY indices have fluctuated widely without trend. The population of blueback herring appears to be more abundant in the Potomac River than alewife herring.

PRFC and DOEE recognize that invasive species such as blue catfish potentially pose a threat to the river herring populations within the Potomac River. DOEE is currently establishing sampling protocol to investigate blue catfish populations and diet within the waters of the District of Columbia. PRFC has encouraged more commercial fishing to target blue catfish and the market for blue catfish has become stronger, especially in Maryland.

The PRFC and DOEE will continue to use surveys and YOY indices to track relative health of the river herring stock. The PRFC and DOEE will continue to communicate with the other management authorities on the Potomac River for additional data that may become available for the assessment of river herring.

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Table 14.1 Commercial Landings of River Herring in the Potomac River. A moratorium on the harvest of river herring was enacted in 2010, except for the limited pound net by-catch* of 50 lbs per day. A total moratorium was established in 2012. Source: PRFC.

| Year | Landings | Year | Landings |
|------|------------|------|-----------|
| 1960 | 5,788,600 | 1986 | 1,198,669 |
| 1961 | 6,234,900 | 1987 | 1,164,854 |
| 1962 | 11,013,600 | 1988 | 182,656 |
| 1963 | 8,037,800 | 1989 | 97,047 |
| 1964 | 8,162,444 | 1990 | 49,734 |
| 1965 | 9,959,891 | 1991 | 365,966 |
| 1966 | 11,127,487 | 1992 | 162,885 |
| 1967 | 8,580,234 | 1993 | 144,752 |
| 1968 | 7,477,581 | 1994 | 80,258 |
| 1969 | 3,433,438 | 1995 | 113,504 |
| 1970 | 6,184,858 | 1996 | 80,447 |
| 1971 | 5,858,125 | 1997 | 59,949 |
| 1972 | 5,720,951 | 1998 | 18,501 |
| 1973 | 2,005,057 | 1999 | 26,656 |
| 1974 | 3,529,221 | 2000 | 33,370 |
| 1975 | 5,758,824 | 2001 | 35,723 |
| 1976 | 1,308,222 | 2002 | 55,086 |
| 1977 | 473,531 | 2003 | 20,132 |
| 1978 | 1,467,743 | 2004 | 19,739 |
| 1979 | 997,360 | 2005 | 8,507 |
| 1980 | 1,686,203 | 2006 | 6,819 |
| 1981 | 84,143 | 2007 | 6,011 |
| 1982 | 493,039 | 2008 | 5,476 |
| 1983 | 1,728,810 | 2009 | 8,925 |
| 1984 | 899,275 | 2010 | 898* |
| 1985 | 261,675 | 2011 | 1,672* |

Table 14.2 Adult alewife and blueback herring length frequency caught by electrofishing by year in Potomac River. Source: DOEE.

| Blueback herring - male | | | | | | | | | | | | Blueback herring - female | | | | | | | | | | | | |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|---------------------------|------|------|------|------|------|------|------|------|------|------|----|----|
| Bin | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | | |
| <200 | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| 200-209 | | | | | | | | | | | | | | | | | | | | | | | | |
| 210-219 | 1 | | | | | | | 1 | | | | | | | | | | | | | | | | |
| 220-229 | 5 | 3 | 1 | | | 5 | 7 | | 2 | | 1 | | | | | | | | | | | | | |
| 230-239 | 25 | 24 | 3 | 3 | 10 | 5 | 22 | 11 | 25 | 21 | 13 | | | | | | | 1 | 1 | | 1 | | | |
| 240-249 | 18 | 49 | 9 | 14 | 22 | 12 | 8 | 45 | 7 | 96 | 67 | | | 2 | | 3 | 2 | 1 | 2 | 2 | 6 | 4 | 5 | |
| 250-259 | 18 | 51 | 22 | 26 | 22 | 20 | 6 | 34 | 35 | 83 | 143 | | | 6 | 4 | 7 | 3 | 8 | | 8 | 3 | 8 | 4 | |
| 260-269 | 18 | 27 | 19 | 22 | 11 | 7 | 1 | 3 | 22 | 55 | 77 | | | 15 | 21 | 20 | 1 | 7 | | 16 | 11 | 15 | 13 | |
| 270-279 | 4 | 8 | 12 | 4 | 6 | 1 | | | 3 | 11 | 15 | | | 8 | 34 | 25 | 4 | 6 | | 4 | 12 | 9 | 15 | |
| 280-289 | 2 | 1 | 6 | 1 | | | | | 1 | 2 | 2 | | | 1 | 5 | 11 | 14 | 2 | 2 | | 4 | 5 | 8 | |
| 290-299 | | | 1 | | | | | | | | | | | | 4 | 3 | 9 | | 1 | | | | 1 | 2 |
| 300-309 | | | | | | | | | | | | | | | | 4 | 1 | | | | | | | 3 |
| 310-319 | | | | | | | | | | | | | | | | | | | | | | | | |
| 320-329 | | | | | | | | | | | | | | | | | | | | | | | | |
| 330-339 | | | | | | | | | | | | | | | | | | | | | | | | |
| 340-349 | | | | | | | | | | | | | | | | | | | | | | | | |
| >350 | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | 91 | 163 | 73 | 70 | 71 | 50 | 44 | 94 | 95 | 268 | 319 | | | 1 | 40 | 77 | 79 | 12 | 26 | 3 | 30 | 37 | 42 | 50 |

Table 14.2 Continued Adult alewife and blueback herring length frequency caught by electrofishing by year in Potomac River. Source: DOEE.

| Alewife - male | | | | | | | | | | | Alewife - female | | | | | | | | | | | |
|----------------|------|------|------|------|------|------|------|------|------|------|------------------|------|------|------|------|------|------|------|------|------|------|------|
| Bin | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| <200 | | | | | | 1 | 1 | | | | 7 | | | | | | | | | | | |
| 200-209 | | | | | | | | | | | | | | | | | | | | | | |
| 210-219 | | | | | | | | | | | | | | | | | | | | | | |
| 220-229 | | | | | | 2 | 3 | | | | 3 | | | | | | | | | | | |
| 230-239 | | | 1 | | 9 | 10 | 9 | | 14 | | 21 | | | | | | | | | | | |
| 240-249 | 2 | 6 | 1 | 3 | 19 | 36 | 32 | 7 | 22 | 1 | 51 | | | | | 1 | 2 | 2 | | | | 3 |
| 250-259 | 2 | 11 | 5 | 4 | 20 | 77 | 14 | 14 | 31 | 15 | 59 | | | | | 1 | 1 | 1 | | | | 1 |
| 260-269 | 5 | 13 | 5 | 10 | 14 | 37 | 24 | 17 | 24 | 20 | 96 | | | | | 4 | 2 | | 6 | 9 | 3 | 11 |
| 270-279 | 17 | 24 | 2 | 13 | 11 | 17 | 9 | 10 | 23 | 17 | 54 | | | | | 2 | 4 | | 1 | 8 | 7 | 1 |
| 280-289 | 22 | 9 | 3 | 15 | 6 | 2 | | 1 | 5 | 8 | 12 | | | | | 3 | 6 | 2 | 2 | 8 | 3 | 12 |
| 290-299 | 8 | 2 | 2 | 2 | 6 | 2 | 1 | 1 | | 1 | 6 | | | | | 3 | 3 | 1 | 5 | 7 | 2 | 4 |
| 300-309 | 2 | | | 1 | | | 1 | 1 | | 1 | 2 | | | | | 2 | 6 | | 1 | 3 | | 7 |
| 310-319 | | | | 1 | | | | | | | | | | | | 5 | 2 | | 6 | | | 1 |
| 320-329 | | | | | | | | | | | | | | | | | | 1 | | 1 | | 2 |
| 330-339 | | | | | | | | | | | | | | | | | | | | | | |
| 340-349 | | | | | | | | | | | | | | | | | | | | | | |
| >350 | | | | | | | | | | | | | | | | | | | | | | |
| Total | 58 | 65 | 19 | 49 | 85 | 184 | 94 | 51 | 119 | 63 | 311 | | | | | 16 | 26 | 7 | 15 | 36 | 28 | 25 |
| | | | | | | | | | | | | | | | | | | | | | | 74 |
| | | | | | | | | | | | | | | | | | | | | | | 15 |
| | | | | | | | | | | | | | | | | | | | | | | 24 |
| | | | | | | | | | | | | | | | | | | | | | | 34 |

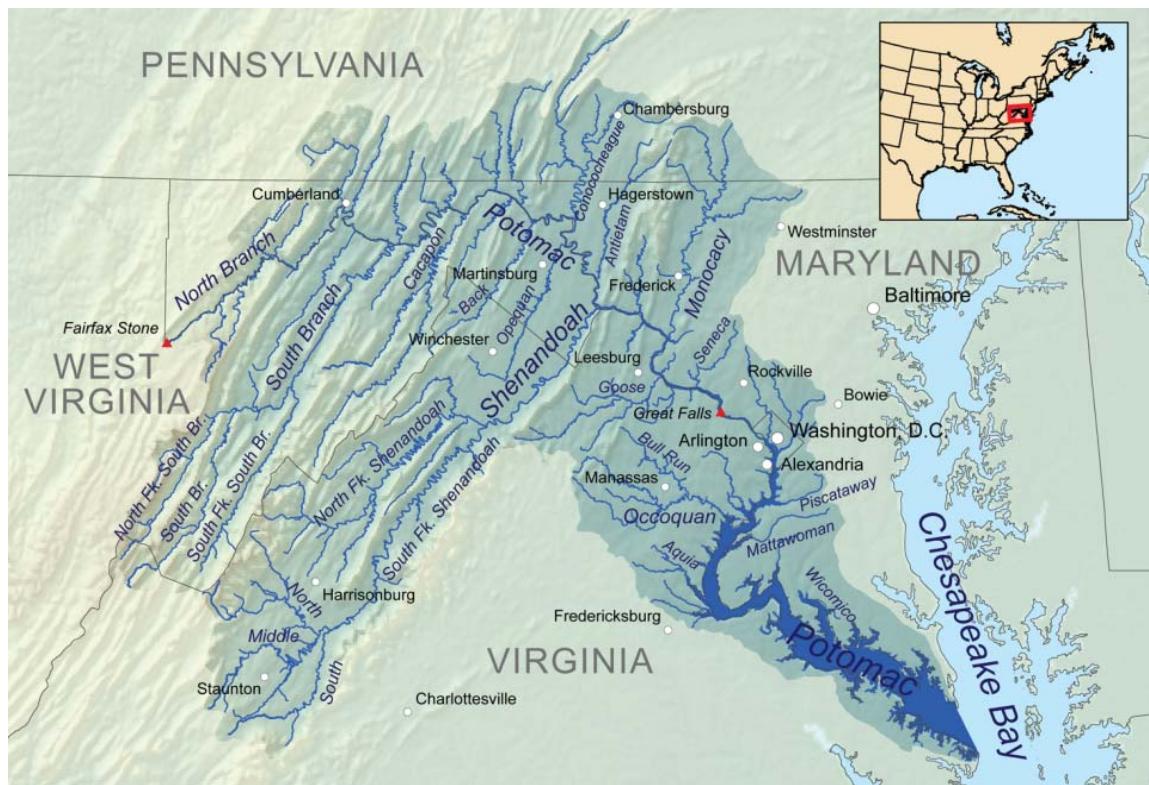


Figure 14.1 The Potomac River Basin.

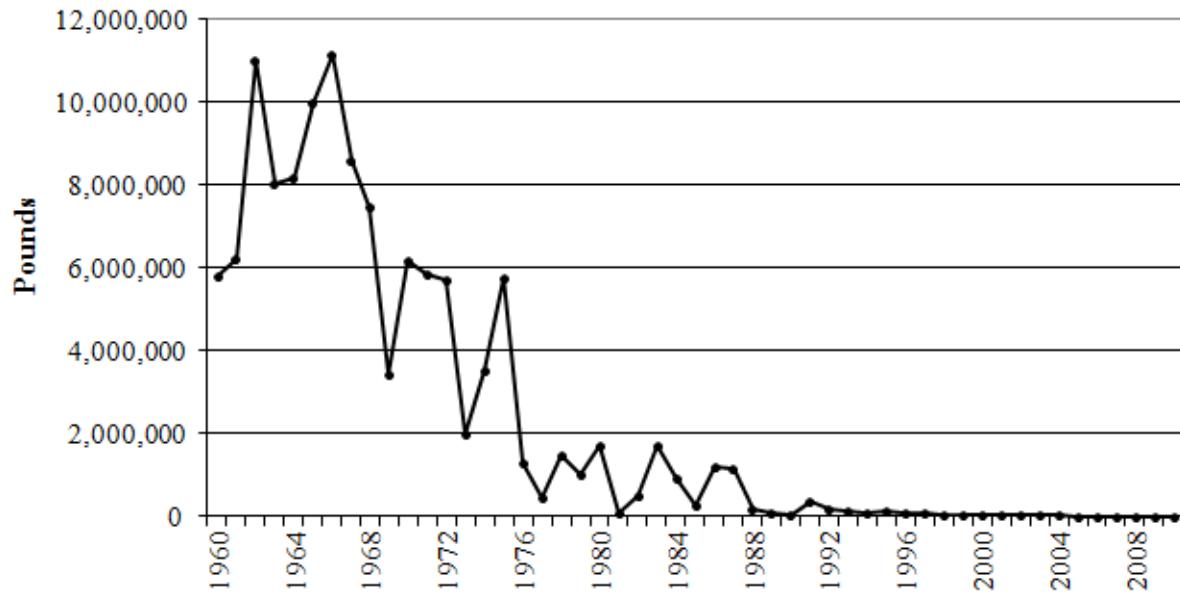


Figure 14.2 River Herring Harvested (pounds) in the Potomac River from 1960 – 2010. Source: PRFC

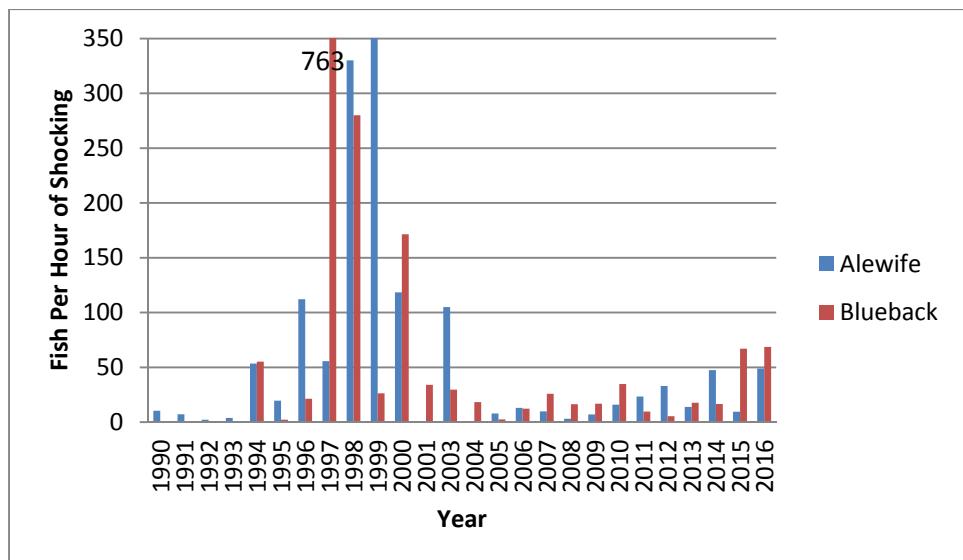


Figure 14.3 CPUE (fish per hour of shocking) of adult alewife and blueback herring during boat electrofishing survey in the Potomac River, 1990-2016. Source: DOEE.

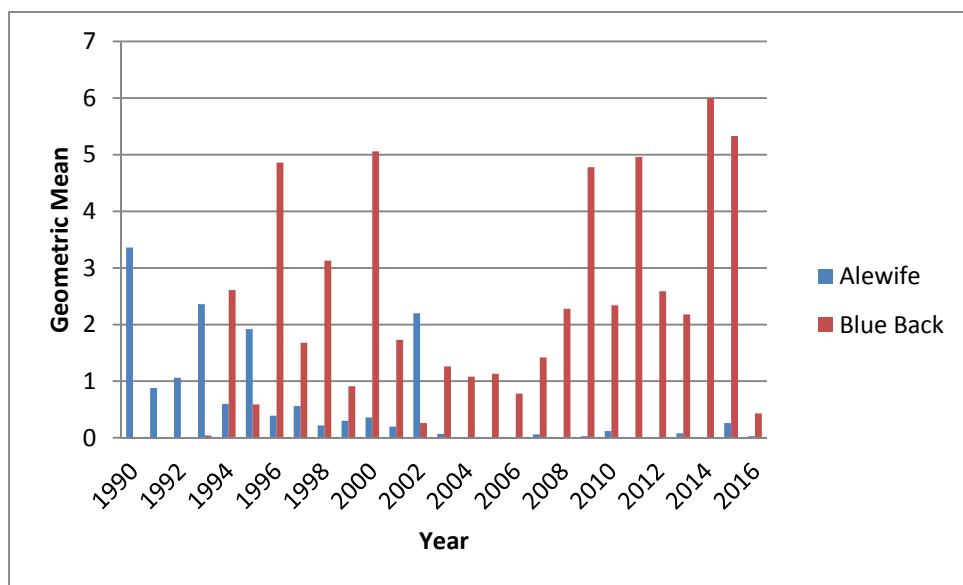


Figure 14.4 Geometric mean (average number of fish per haul) of YOY alewife and blueback herring caught during 100ft beach seining survey, 1990-2016

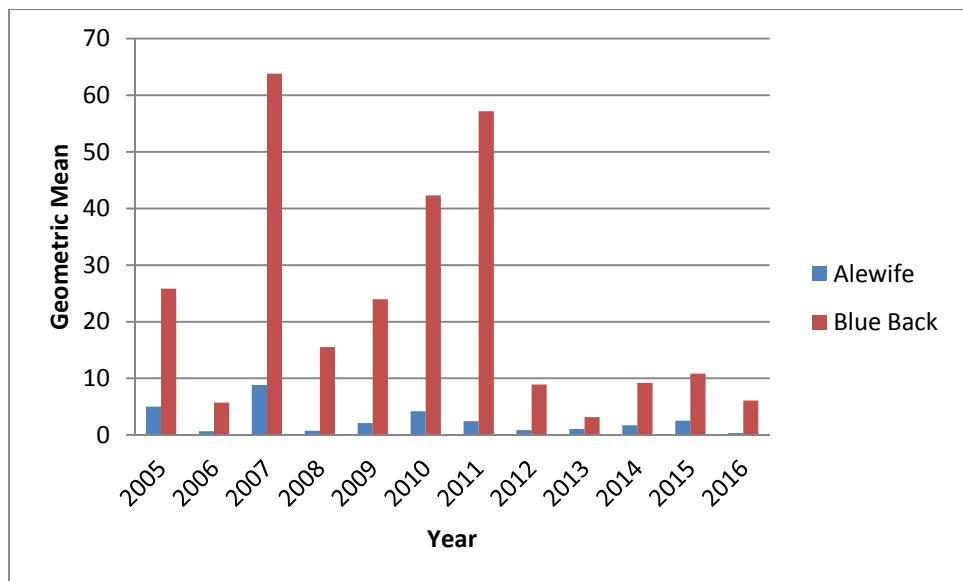


Figure 14.5 Geometric mean (average number of fish per haul) of YOY alewife and blueback herring caught during 10 minute push net survey, 2005-2016.

Effort corrected catch of blueback herring on the Potomac River during the MD DNR striped bass spawning stock survey. CPUE is standardized as the number of fish caught per 1000 square yards of drift gill net per hour.

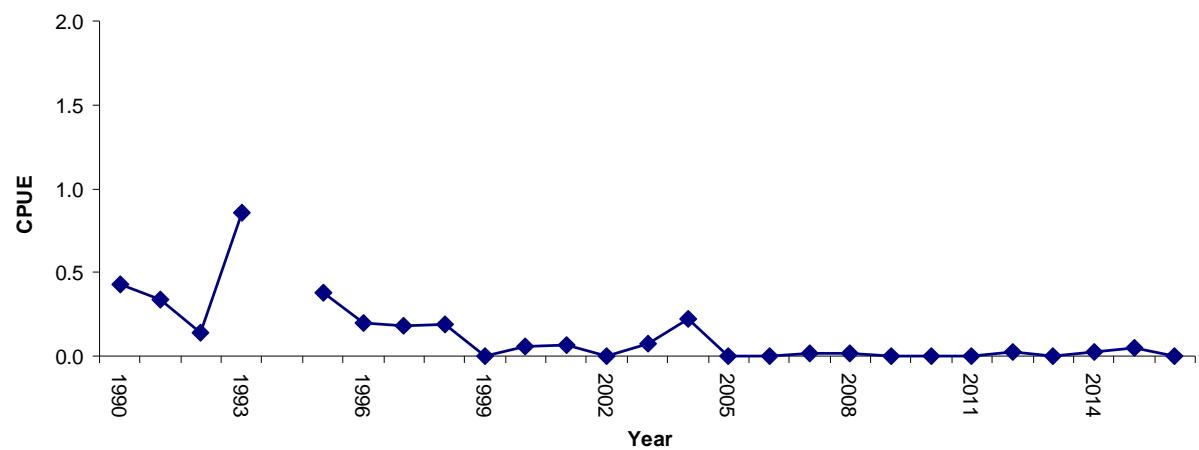


Figure 14.6 MD DNR striped bass spawning survey

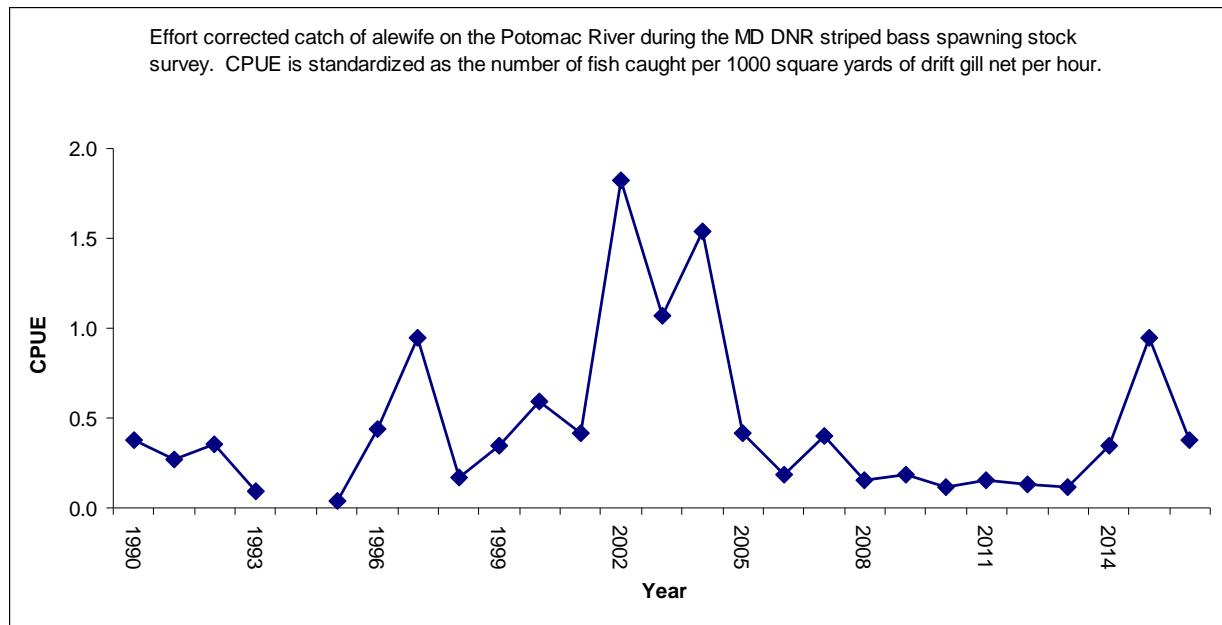


Figure 14.7 MD DNR striped bass spawning survey

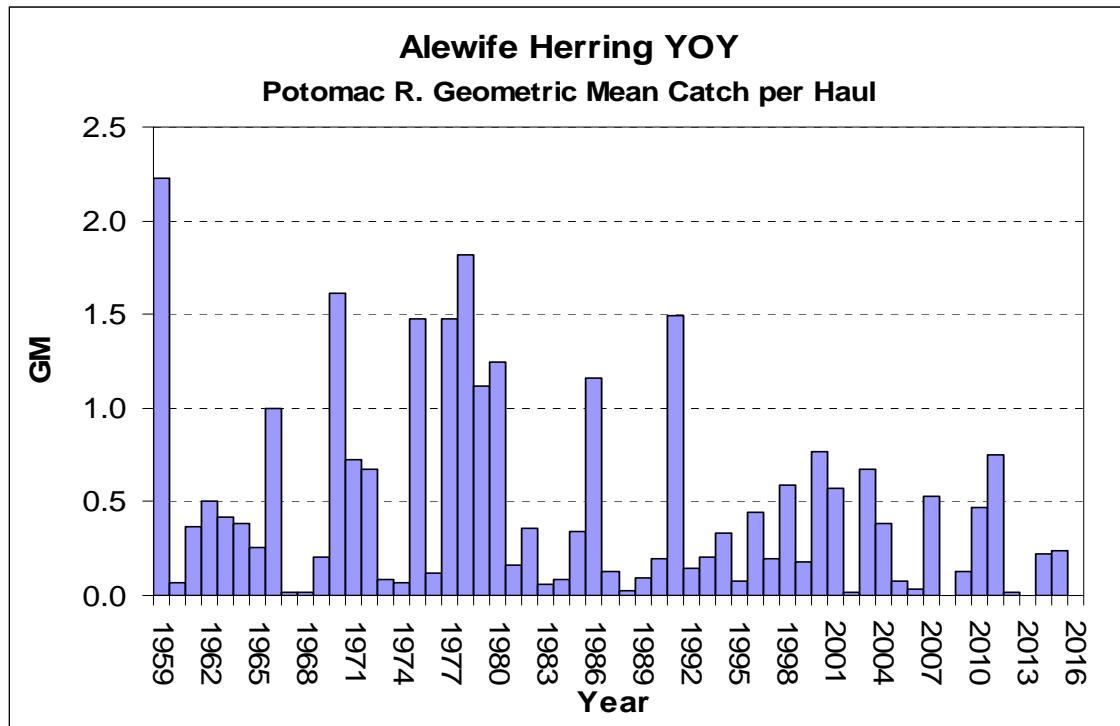


Figure 14.8 Juvenile alewife geometric mean (catch per haul) in the Potomac River (1959 – 2017).
Source: Maryland Department of Natural Resources.

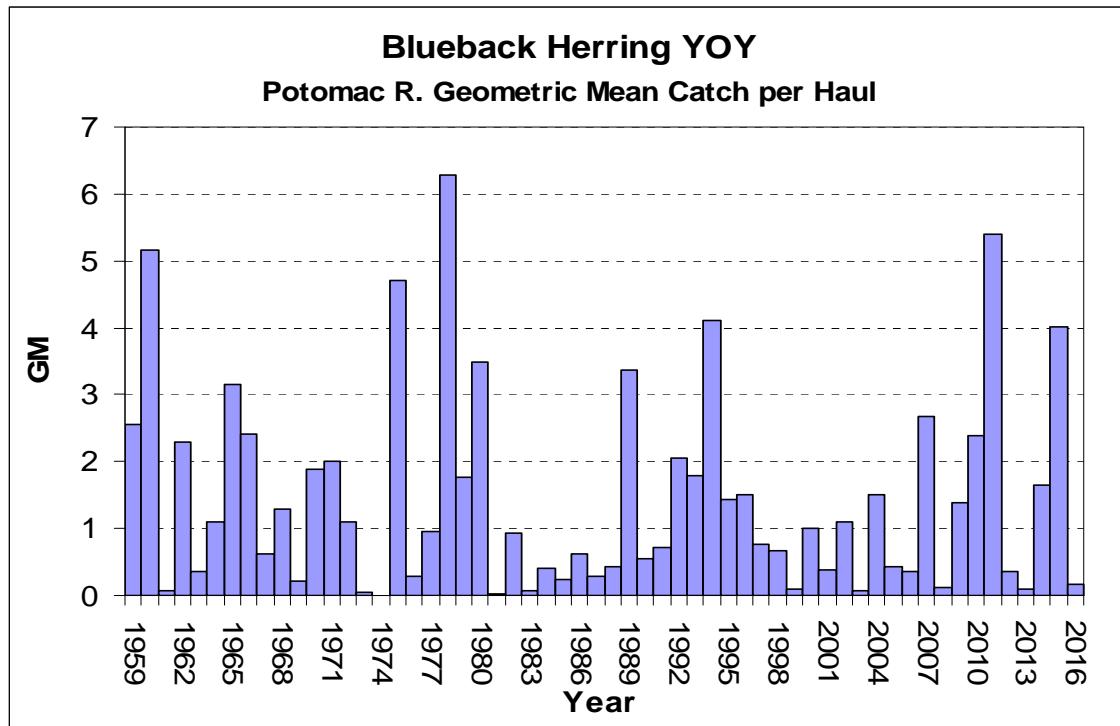


Figure 14.9 Juvenile blueback herring geometric mean (catch per haul) in the Potomac River (1959 – 2017). Source: Maryland Department of Natural Resources.

APPENDIX

Ref. No. [UMCES]CBL-11-040

The Biological Characteristics of River Herring Caught in Potomac River Pound Nets

Final Report Submitted to:
Potomac River Fisheries Commission

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Technical Report Series No. TS-625-11 of the University of Maryland Center for Environmental Science.

1. Background.

River herring is a term used to describe two similar congeneric species of fish, blueback herring (*Alosa aestivalis*) and alewives (*Alosa pseudoharengus*). These two species display anadromous behavior, meaning that they live as adults in estuarine and ocean habitats but migrate to spawn in freshwater rivers. These two species will migrate into tributaries of the Chesapeake Bay to spawn each spring. Alewives may spawn a few weeks earlier than blueback herring in areas where they overlap (Jones et al. 1978). Upon spawning, adults will leave freshwater rivers and return to estuarine and ocean habitats (Jones et al. 1978). Eggs hatch in freshwater and larvae and juveniles spend the first year of their lives in fresh and brackish waters (Hildebrand 1963, Street et al. 1975). As adults, they feed primarily on zooplankton (Janssen and Brant 1981). They are preyed upon by a variety of other species and may play an important role in food web dynamics (Blackwell et al. 1997, Bowen and Harrison 1996, Buckel and Conover 1997, Buckel et al. 1999, Dew 1988). Historically, they supported large, valuable fisheries, but catches have declined significantly as damming of rivers has blocked access to spawning habitat.

Blueback herring range from Nova Scotia to Florida (Hildebrand 1963, Scott and Crossman 1973), whereas alewives range from Labrador to South Carolina (Berry 1964, Winters 1973). In areas where their ranges overlap, such as the mid-Atlantic Bight and Chesapeake Bay, these schooling species are often found together (Raney and Massman 1953, O'Dell and Mowrer 1984). They can be difficult to distinguish without close examination. There are several distinguishing characteristics between the two species. Blueback herring have a dusky, mottled peritoneum (the lining of the body cavity), while alewives have a pale, pink colored peritoneum. They are also distinguished by the diameter of the eye, which is significantly larger for alewives (Murdy et al. 1997).

Here we report the results of sampling of migrating river herring from the Potomac River in spring 2011 to determine the distribution and characteristics of both species.

2. Methods.

Fish were collected from Potomac River pound nets in May and delivered fresh, on-ice to the Chesapeake Biological Laboratory where they were frozen for future dissection and analysis. Fish were thawed in batches, weighed to the nearest 0.01 g. and measured for total length and fork length to the nearest 1 mm. Total length is a measure of the fish from snout to the end of the tail. Fork length is a measure of the fish from the snout to the shortest of the tail fin rays (the fork in the tail). Total length is preferred, but may not always be a representative measure of fish length because the longest fin rays may be subject to damage.

Fish were then dissected by making an incision from the anal pore to the pectoral fins in order to examine the body cavity. The peritoneum was visually inspected to determine the species of fish (Murdy et al. 1997). The gonads were then visually inspected to determine the sex of the fish. The next incision was made by removing the fish's head along the operculum followed by turning the head so that it was oriented with the snout vertically upwards. An incision was then made into the skull that was along a tangent following the upper portion of the eye socket. This sufficed to open the skull of the fish so that sagittal otoliths could be removed. Fish have two sagittal otoliths which can be prepared in a way that will show annual growth rings. Otoliths were rinsed and placed in a labeled vial for future ageing analysis.

Otoliths were aged using standard procedures (Secor et al. 1991). Briefly, otoliths were mounted in a clear epoxy resin (Epoxyfix, Struers Company, www.struers.com). First, a layer of epoxy was poured into a

tray of molds such that each mold was filled approximately half way. After the epoxy was allowed to cure, otoliths were placed into the molds and then covered with another layer of epoxy which was then allowed to cure for 24 hours. The embedded otoliths were then removed from the molds and thin-sectioned using a low-speed diamond wafering saw (South Bay Technology, www.southbaytech.com). The saw was outfitted with 2 parallel blades with a .3mm thick aluminum spacer between them. The embedded otolith was oriented in a manner that would allow for a transverse section and aligned so that the core of the otolith was lined up with the spacer between the two blades. The thin-section was then mounted on a microscope slide using crystal bond as a mounting medium. The slide was placed under a standard bright field compound microscope and annuli were counted and recorded. Each otolith was read by two readers on two separate occasions. If the readers disagreed by more than two years, then that otolith was considered unreadable and removed from the analysis.

Disagreements in ageing may be a result of improper alignment of the otolith before sectioning or poor transmission of light through the thin-section. Additionally, these species may have marks that appear on their otoliths as a result of spawning events. These marks are often different in appearance and out of pattern relative to the annular marks, so care was taken to avoid counting these bands.

3. Results.

A total of 143 fish were sampled. 12 (8.3%) were identified as alewives and the remaining 131 were identified as blueback herring. All fish appeared to be gravid adults and preparing to spawn. 74 of the 131(56%) blueback herring were male, while 57 (44%) were female. Among the 12 alewives, 8 (66%) were male and 4 (33%) were female. Table 1 displays the size characteristics of the fish that were sampled. The alewives were slightly larger than the blueback herring. There were minimal differences in size between males and females.

A frequency distribution of the total lengths for both species reveals that blueback herring sampled lengths approximate a normal distribution except that there were two modes in the length distributions at 245 and 265mm (Figure 1). This same feature is found when looking at males and females separately (Figure 2). The distribution of sizes amongst males and females is very similar, except that females were encountered in a narrower range of sizes than males. The length and weight relationship for blueback herring is shown in Figure 3. There was no difference in the relationship ($p=.7468$) between male and females as tested by Analysis of Covariance using SAS (SAS version 9.2, Cary, NC). The model for this relationship is:

$$\text{Log}_{10}(\text{Total Length}) = 0.258(\text{Log}_{10}(\text{Weight}))+1.841$$

We note that alewives were not found in sufficiently high enough numbers to make any size- and sex-based inferences.

Otoliths were recovered and aged from 104 of the 143 fish. In 12 instances, readers disagreed on age while in 27 instances otoliths were not recovered or broken during dissection. The length at age for both species was consistent with previous studies (Joseph and Davis 1965, Pardue 1983) that examined fish from the mid-Atlantic region and Chesapeake Bay. Figure 4 shows the length at age for both species. Larger fish tended to be older, although there was a substantial amount of variation in length at age. Age 7 fish were the most common followed by Age 6 and Age 8. The younger age-classes are not well represented, but age of first spawning in these species is variable, as previous research has shown that less than 50% of age 4 fish may spawn.

Figure 5 shows the data for just blueback herring with each sex displayed separately. There is no difference in the relationship between length at age between males and females. As tested by ANCOVA. When examining the distribution of ages between species and sexes, the median age was 7 for both species and both sexes of blueback herring. The distribution of ages approximates a normal distribution around this age, with a minimum age of 4 for male blueback herring, 5 for female blueback herring, and 6 for alewives. The maximum ages recorded were 9 for alewives and 10 for both sexes of blueback herring.

4. Discussion.

The biological characteristics of blueback herring and alewives caught in Potomac River pound nets agrees with previous research on these species. Their migratory and spawning behavior indicate that these fish were moving into the Chesapeake Bay and Potomac River in advance of their spawning season. These fish were gravid and appeared ready to spawn. The difference in relative abundance between the species, with blueback herring representing the majority of fish encountered, has been previously documented in the Chesapeake Bay and mid-Atlantic regions (Joseph and Davis 1965), and also may be related to differences in the time of spawning between these two species.

Previous studies of spawning-aged river herring in this region (Joseph and Davis 1965, Street et al. 1975, O'Dell and Mowrer 1984) found fish of spawning age from 3 to 8 years old. This study found fish that were from 4 to 9 years of age with the majority of fish being 6 to 8 years of age. It is difficult to say if these changes are a reflection of the population or if there are artifacts in the spatial and temporal differences the sampling methods between studies. O'Dell and Mowrer (1984) found that blueback herring ages 5, 6, and 7 comprised 96% of the blueback herring spawning population as opposed to 57% in this study where there were significant numbers of 8 and 9 year old fish. River herring spawning migration behavior is not the same between species and sexes so a shift in sampling relative to the spawning run will result in a different portion of the population being characterized. This may influence the age, sex, and species composition of the sampled fish.

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Table 1. Summary of morphometric information on river herrings collected in the Potomac River in 2011.

| | Blueback Herring | | Alewife | |
|---------------------------|------------------|--------|---------|--------|
| | Male | Female | Male | Female |
| Number | 74 | 57 | 8 | 4 |
| Average Total Length (mm) | 254.0 | 250.6 | 264.1 | 266.0 |
| Maximum Total Length (mm) | 285 | 275 | 306 | 283 |
| Minimum Total Length (mm) | 214 | 223 | 242 | 245 |
| Average Fork Length (mm) | 225.7 | 222.4 | 234.9 | 234.8 |
| Maximum Fork Length (mm) | 263 | 246 | 260 | 247 |
| Minimum Fork Length (mm) | 188 | 198 | 219 | 215 |
| Average Weight (g) | 145.2 | 136.5 | 172.7 | 175.9 |
| Maximum Weight (g) | 196.4 | 203.7 | 266.6 | 223.9 |
| Minimum Weight (g) | 77.8 | 96.1 | 124.9 | 144.4 |

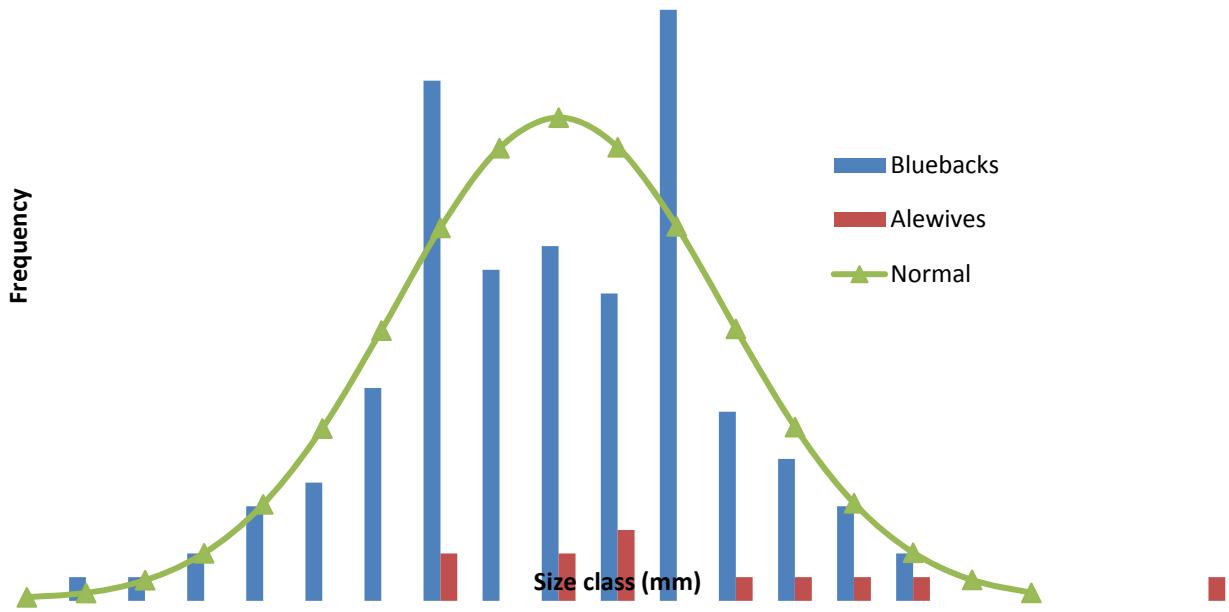


Figure 1. Size frequency distribution of blueback herring (blue) and alewife (red). A normal distribution of the predicted length frequency given the mean and variance is shown in green.

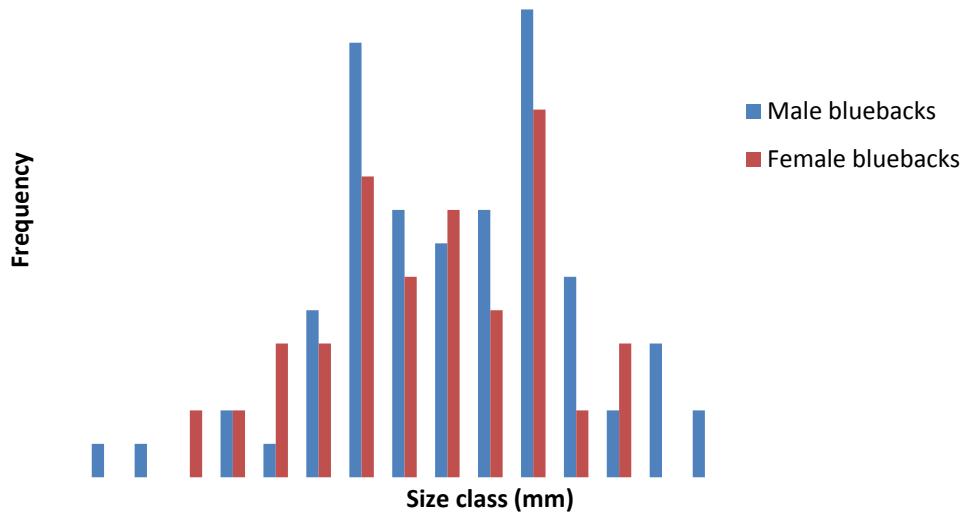


Figure 2. Size frequency distribution of male (blue) and female (red) blueback herring.

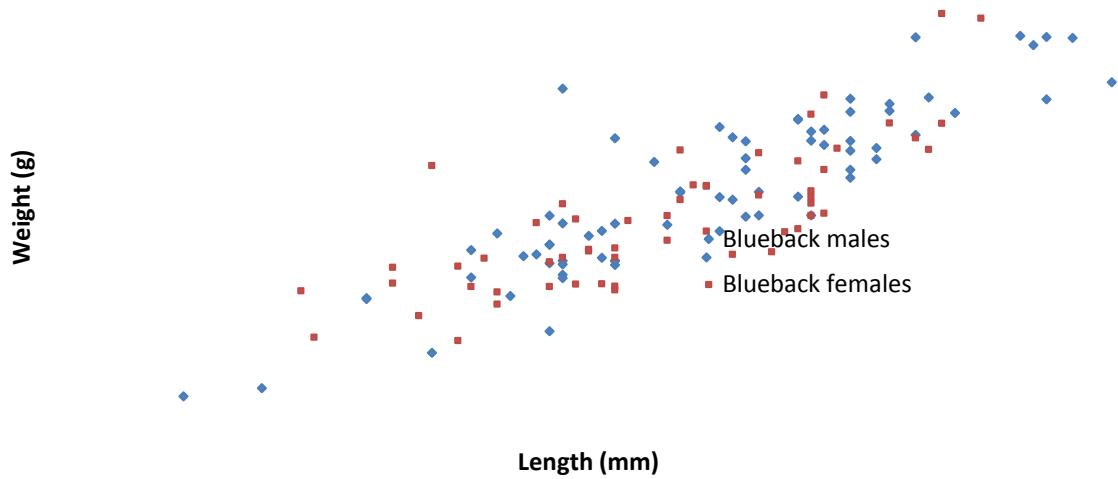


Figure 3. Length weight relationship of blueback herring. Males are show in blue. Females are shown in red.

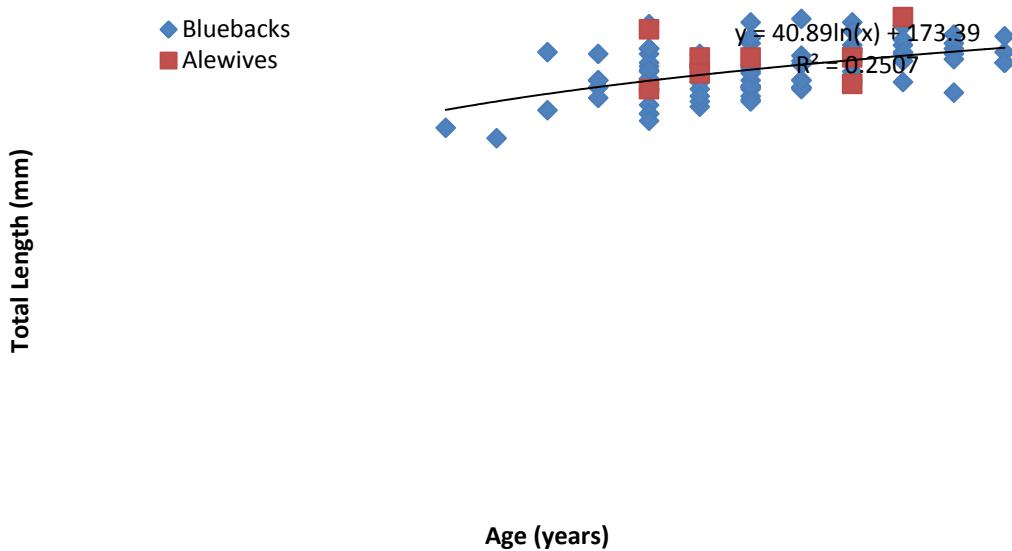


Figure 4. Total length at age for blueback herring (blue) and alewives (red).

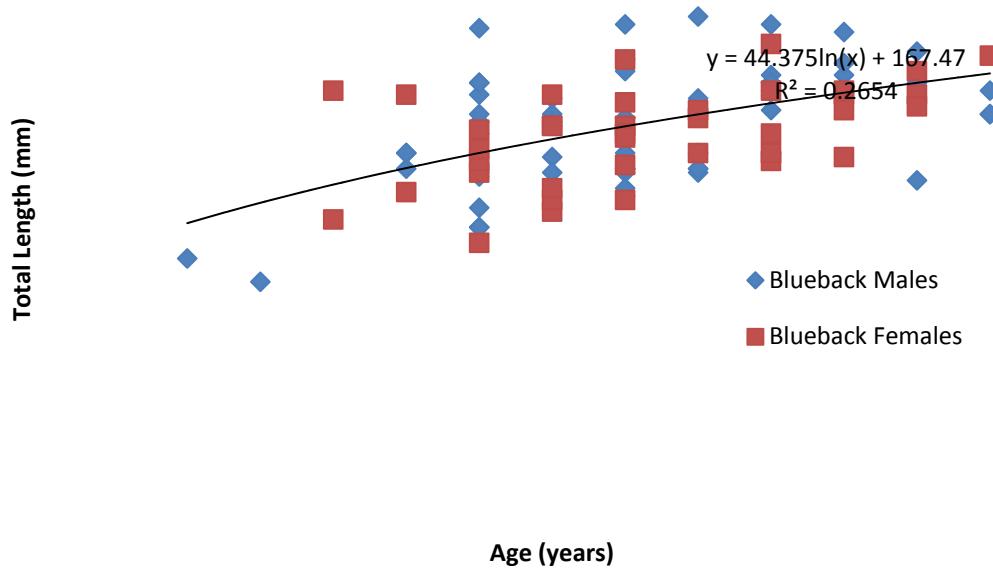


Figure 5. Total length at age for blueback herring by sex. Males are show in blue. Females in red.

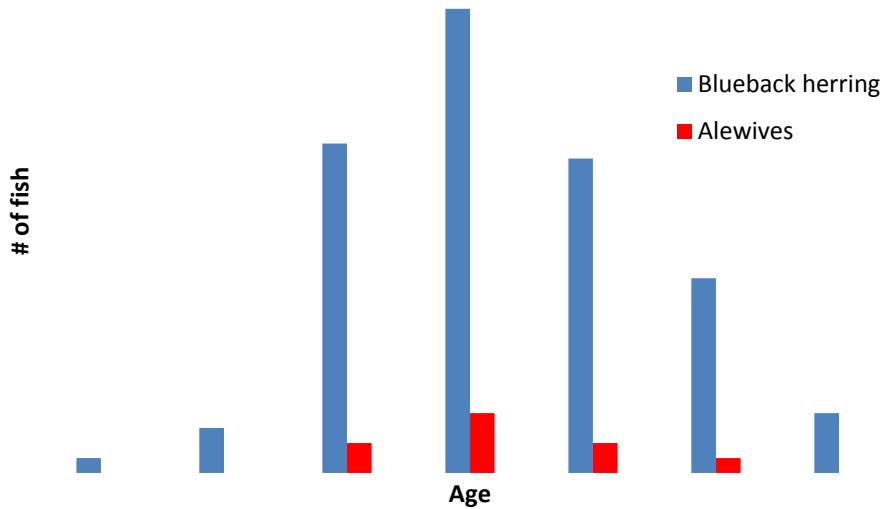


Figure 6. Frequency distribution of ages for blueback herring (blue) and alewives (red).

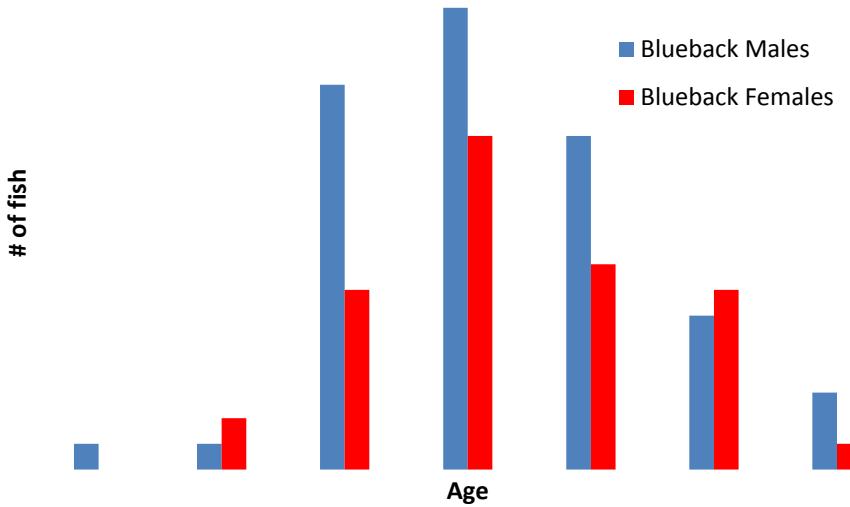


Figure 7. Frequency distribution of ages for blueback herring by sex. Males are shown in blue. Females are shown in red.

The Biological Characteristics of River Herring Caught in Potomac River Pound Nets, 2013

Final Report Submitted to:
Potomac River Fisheries Commission

by

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August 2013

Technical Report Series No.TS-649-13 of the University of Maryland Center for Environmental Science.

1. Background.

River herring is a term used to describe two similar congeneric species of fish, blueback herring (*Alosa aestivalis*) and alewives (*Alosa pseudoharengus*). These two species display anadromous behavior, meaning that they live as adults in estuarine and ocean habitats but migrate to spawn in freshwater rivers. These two species will migrate into tributaries of the Chesapeake Bay to spawn each spring. Alewives may spawn a few weeks earlier than blueback herring in areas where they overlap (Jones et al. 1978). Upon spawning, adults will leave freshwater rivers and return to estuarine and ocean habitats (Jones et al. 1978). Eggs hatch in freshwater and larvae and juveniles spend the first year of their lives in fresh and brackish waters (Hildebrand 1963, Street et al. 1975). As adults, they feed primarily on zooplankton (Janssen and Brant 1981). They are preyed upon by a variety of other species and may play an important role in food web dynamics (Blackwell et al. 1997, Bowen and Harrison 1996, Buckel and Conover 1997, Buckel et al. 1999, Dew 1988). Historically, they supported large, valuable fisheries, but catches have declined significantly as damming of rivers has blocked access to spawning habitat.

Blueback herring range from Nova Scotia to Florida (Hildebrand 1963, Scott and Crossman 1973), whereas alewives range from Labrador to South Carolina (Berry 1964, Winters 1973). In areas where their ranges overlap, such as the mid-Atlantic Bight and Chesapeake Bay, these schooling species are often found together (Raney and Massman 1953, O'Dell and Mowrer 1984). They can be difficult to distinguish without close examination. There are several distinguishing characteristics between the two species. Blueback herring have a dusky, mottled peritoneum (the lining of the body cavity), while alewives have a pale, pink colored peritoneum. They are also distinguished by the diameter of the eye, which is significantly larger for alewives (Murdy et al. 1997).

Here we report the results of sampling of migrating river herring from the Potomac River in spring 2013 to determine the distribution and characteristics of both species. This work replicates analyses of river herrings in the Potomac River conducted in 2011 (Loewenstein et al. 2011).

2. Methods.

Fish were collected from Potomac River pound nets in May and delivered fresh, on-ice to the Chesapeake Biological Laboratory where they were frozen for future dissection and analysis. Fish were thawed in batches, weighed to the nearest 0.01 g. and measured for total length and fork length to the nearest 1 mm. Total length is a measure of the fish from snout to the end of the tail. Fork length is a measure of the fish from the snout to the shortest of the tail fin rays (the fork in the tail). Total length is preferred, but may not always be a representative measure of fish length because the longest fin rays may be subject to damage.

Fish were then dissected by making an incision from the anal pore to the pectoral fins in order to examine the body cavity. The peritoneum was visually inspected to determine the species of fish (Murdy et al. 1997). The gonads were then visually inspected to determine the sex of the fish. The next incision was made by removing the fish's head along the operculum followed by turning the head so that it was oriented with the snout vertically upwards. An incision was then made into the skull that was along a tangent following the upper portion of the eye socket. This sufficed to open the skull of the fish so that sagittal otoliths could be removed. Fish have two sagittal otoliths which can be prepared in a

way that will show annual growth rings. Otoliths were rinsed and placed in a labeled vial for future ageing analysis.

Otoliths were aged using standard procedures (Secor et al. 1991). Briefly, otoliths were mounted in a clear epoxy resin (Epoxyfix, Struers Company, www.struers.com). First, a layer of epoxy was poured into a tray of molds such that each mold was filled approximately half way. After the epoxy was allowed to cure, otoliths were placed into the molds and then covered with another layer of epoxy which was then allowed to cure for 24 hours. The embedded otoliths were then removed from the molds and thin-sectioned using a low-speed diamond wafering saw (South Bay Technology, www.southbaytech.com). The saw was outfitted with 2 parallel blades with a .3mm thick aluminum spacer between them. The embedded otolith was oriented in a manner that would allow for a transverse section and aligned so that the core of the otolith was in line with the spacer between the two blades. The thin-section was then mounted on a microscope slide using crystal bond as a mounting medium. The slide was placed under a standard bright field compound microscope and annuli were counted and recorded. Each otolith was read by two readers on two separate occasions. If the readers disagreed by more than two years, then that otolith was considered unreadable and removed from the analysis. Disagreements in ageing may be a result of improper alignment of the otolith before sectioning or poor transmission of light through the thin-section. Additionally, these species may have marks that appear on their otoliths as a result of spawning events. These marks are often different in appearance and out of pattern relative to the annular marks, so care was taken to avoid counting these bands.

3. Results.

A total of 229 fish were sampled. 29 (12.6%) were identified as alewives and the remaining 200 were identified as blueback herring. All but 3 of the fish (blue back herring, sex undetermined, 183-187mm TL) appeared to be gravid adults and preparing to spawn. 96 (48%) blueback herring were male, while 101 (51%) were female. Among the 29 alewives, 8 (28%) were male and 21 (72%) were female. Table 1 displays the size characteristics of the fish that were sampled. The alewives were slightly larger than the blueback herring. Blueback herring and alewife females were longer than their male counter parts.

A frequency distribution of the total lengths for both species reveals that blueback herring sampled lengths approximate a normal distribution except that there were two modes in the length distributions at 245 and 265mm (Figure 1). This same feature corresponds with the different sizes that were observed between sexes (Figure 2). Alewives, although fewer in number, appear to have a similar pattern of sizes between sexes with modes of 260mm and 270mm for males and females, respectively (Figure 3). The length and weight relationship for blueback herring and alewives is shown in Figure 4. It should be noted that lower end of this relationship is represented primarily by male blueback herring and that the higher end of this relationship is represented primarily by female blueback herring.

Otoliths were randomly selected and aged from 62 of the 229 fish. The length at age for both species was consistent with previous studies (Joseph and Davis 1965, Pardue 1983) that examined fish from the mid-Atlantic region and Chesapeake Bay. Figure 5 shows the length at age for both species. Larger fish tended to be older, although there was a substantial amount of variation in length at age. The younger age-classes were not well represented, but age of first spawning in these species is variable, as previous research has shown that less than 50% of age 4 fish may spawn.

Figure 5 shows the data for length at age data for blueback herring with each sex and alewives in aggregate. Age 6 fish were the most common followed by Age 7. There is no difference in the

relationship between length at age between male and female blueback herring as tested by ANCOVA. Upon examining the distribution of ages between species and sexes, the median age was 6 for both sexes of blueback herring and age 8 for alewives (Figure 6). The maximum ages recorded were 11 for alewives and for both sexes of blueback herring.

4. Discussion.

The biological characteristics of blueback herring and alewives caught in Potomac River pound nets agrees with previous research on these species. Their migratory and spawning behavior indicate that these fish were moving into the Chesapeake Bay and Potomac River in advance of their spawning season. These fish were gravid and appeared to be preparing to spawn. The difference in relative abundance between the species, with blueback herring representing the majority of fish encountered, has been previously documented in the Chesapeake Bay and mid-Atlantic regions (Joseph and Davis 1965), and also may be related to differences in the time of spawning between these two species.

In analyses of fish collected in the Potomac River, Loewenstein et al. (2011) reported that 12% of 143 river herrings sampled were alewife, with the remainder being blueback herring. Blueback herring sampled varied from 214-285 mm TL and alewife varied from 242-306 mm TL. All sampled fish appeared to be gravid adults preparing to spawn. The modal age of both species in the sample was 7 years. Blueback herring varied in age from 4-10 years and alewife from 6-9 years. The proportion of the overall river herring abundance comprised by alewife remained unchanged from 2011 in this year's sample at 12%. Size and age information for river herrings collected this year were very similar. Blueback herring sizes were more variable (172-314 mm TL) and alewife appeared slightly smaller (235-295 mm TL) this year compared to 2011. Age composition was also similar among the two years, with both blueback herring and alewife in the sample varying from 4-11 years

Previous studies of spawning-aged river herring in this region (Joseph and Davis 1965, Street et al. 1975, O'Dell and Mowrer 1984) found fish of spawning age from 3 to 8 years old. This study found fish that were from 4 to 11 years of age with the majority of fish being 6 to 8 years of age. It is difficult to say if these changes are a reflection of the population or if there are artifacts in the spatial and temporal differences of the sampling methods between studies. O'Dell and Mowrer (1984) found that blueback herring ages 5, 6, and 7 comprised 96% of the blueback herring spawning population as opposed to 58% in this study where there were significant numbers of 8 and 9 year old fish. River herring spawning migration behavior is not the same between species and sexes so a shift in sampling relative to the spawning run will result in a different portion of the population being characterized. This may influence the age, sex, and species composition of the sampled fish.

Overall, our results indicate that alewife collected in pound nets in the Potomac River remains a small proportion of the total river herring catch, and that the biological characteristics of both species in the catch suggest the fishery is removing mature adult fish capable of spawning.

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Table 1. Summary of morphometric information on river herrings collected in the Potomac River in 2013.

| | Blueback Herring | | Alewife | |
|---------------------------|------------------|--------|---------|--------|
| | Male | Female | Male | Female |
| Number | 96 | 101 | 8 | 21 |
| Average Total Length (mm) | 246.5 | 258.0 | 258.5 | 266.2 |
| Maximum Total Length (mm) | 314 | 290 | 285 | 295 |
| Minimum Total Length (mm) | 227 | 172 | 243 | 235 |
| Average Fork Length (mm) | 216.8 | 226.8 | 227.8 | 234.2 |
| Maximum Fork Length (mm) | 270 | 257 | 251 | 263 |
| Minimum Fork Length (mm) | 200 | 151 | 215 | 204 |
| Average Weight (g) | 131.7 | 160.4 | 155.1 | 171.4 |
| Maximum Weight (g) | 256.6 | 241.2 | 215.5 | 237.6 |
| Minimum Weight (g) | 101.2 | 35.3 | 131.3 | 107.2 |

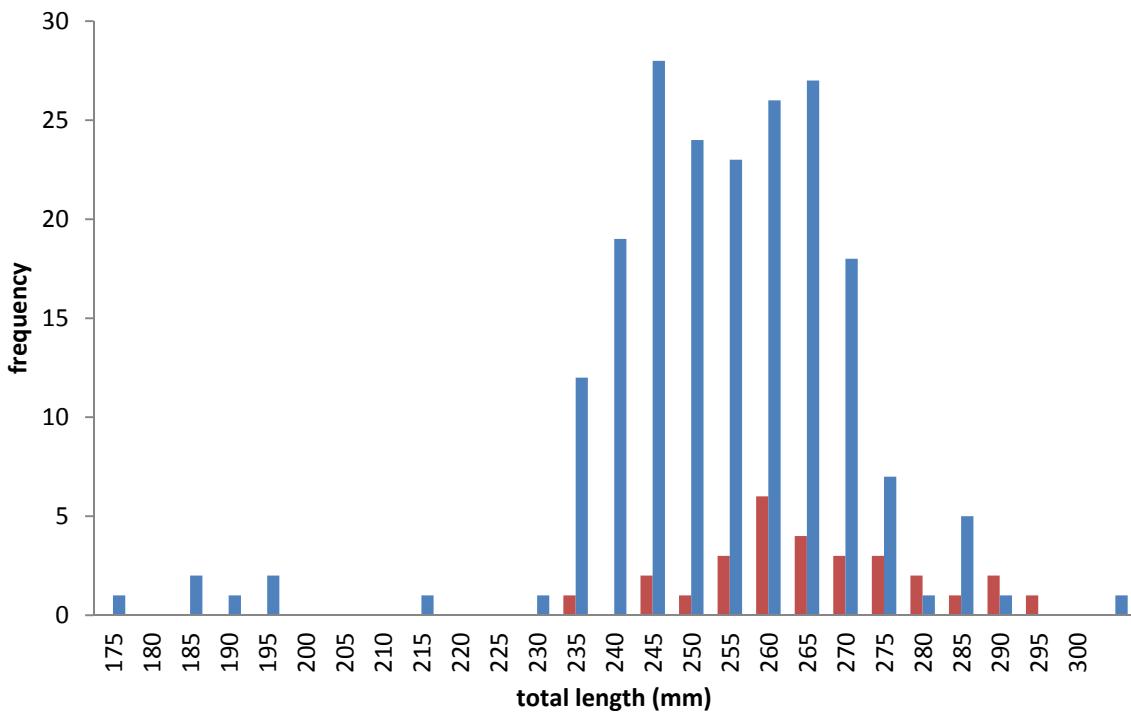


Figure 1. Size frequency distribution of blueback herring (blue) and alewife (red).

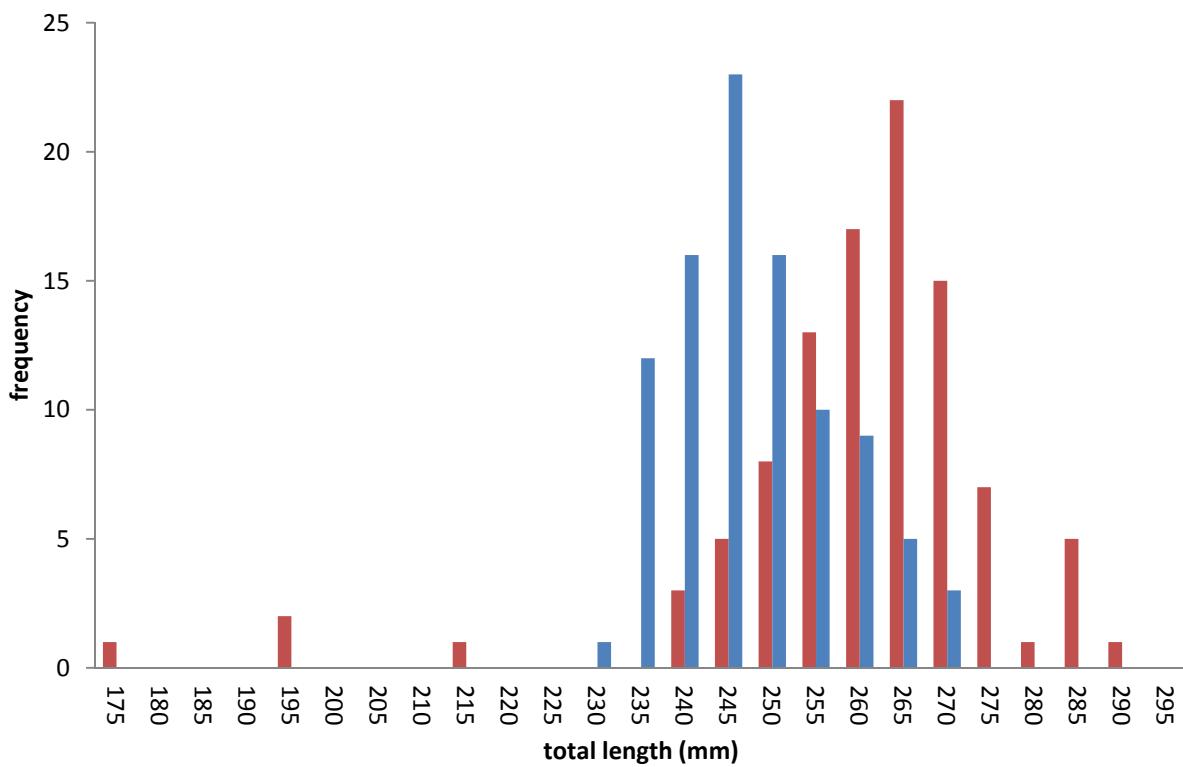


Figure 2. Size frequency distribution of male (blue) and female (red) blueback herring.

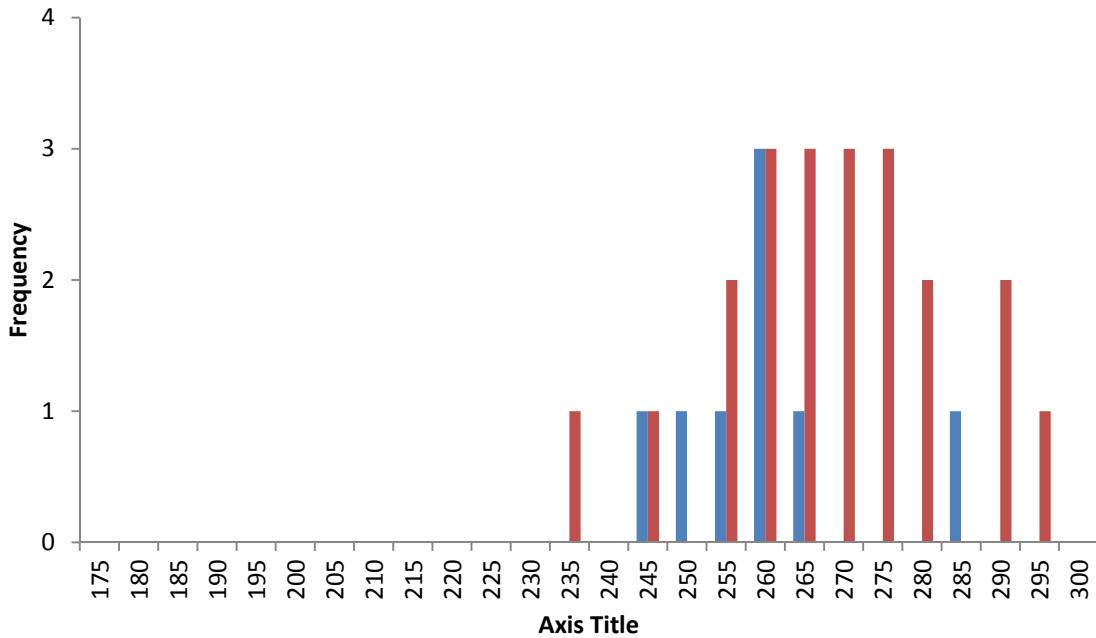


Figure 3. Size frequency distribution of male (blue) and female (red) alewives.

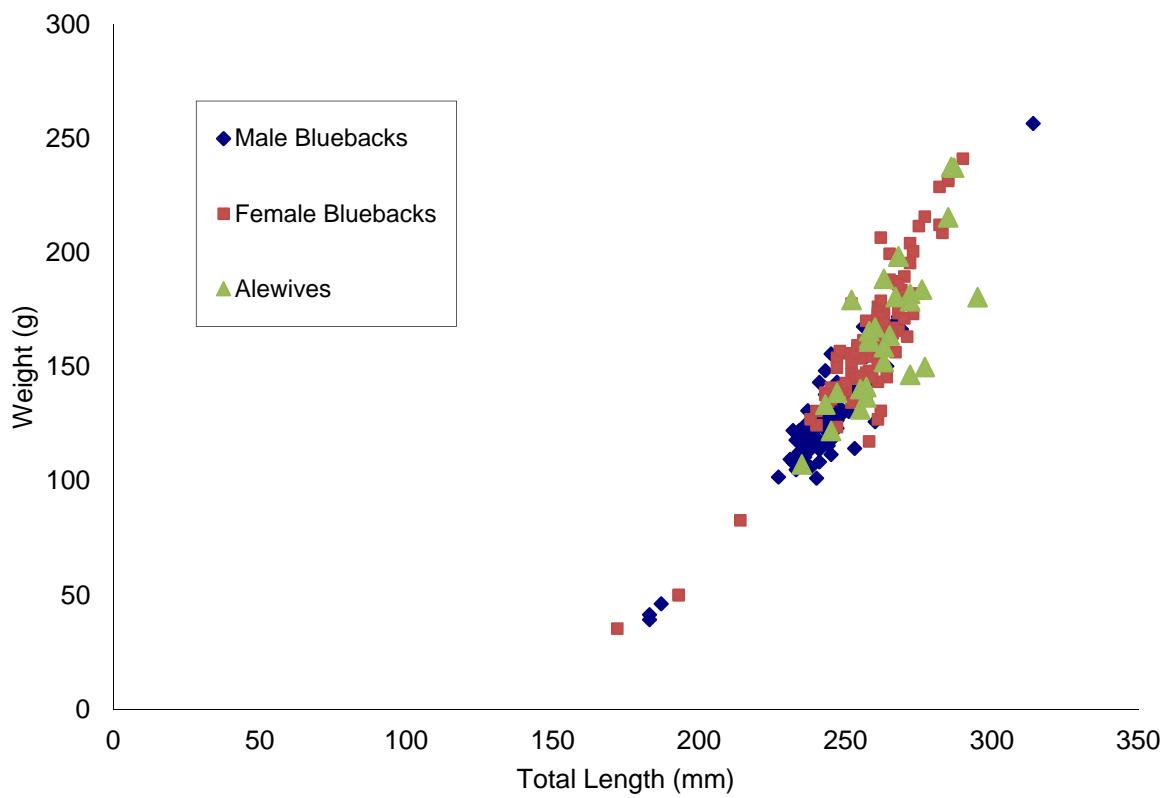


Figure 4. Length weight relationship for male blueback herring shown in blue, female blueback herring shown in red, and alewives shown in green.

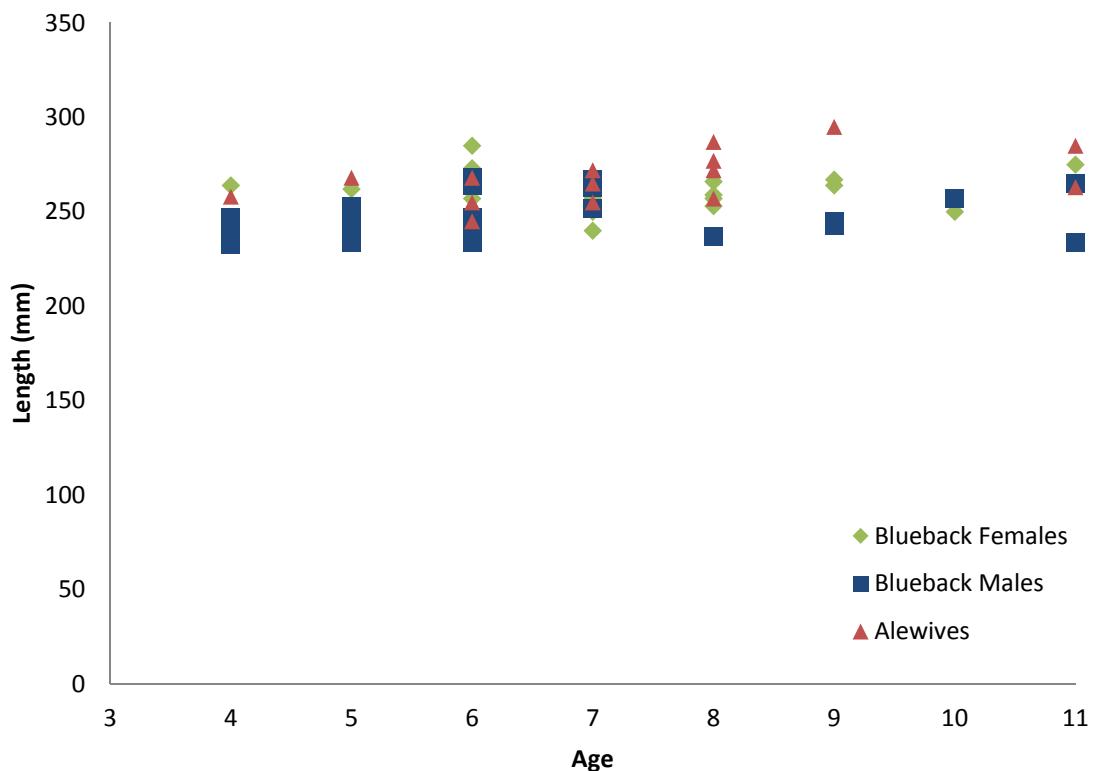


Figure 5. Total length at age for alewives (red) and blueback herring by sex (females in green, males in blue).

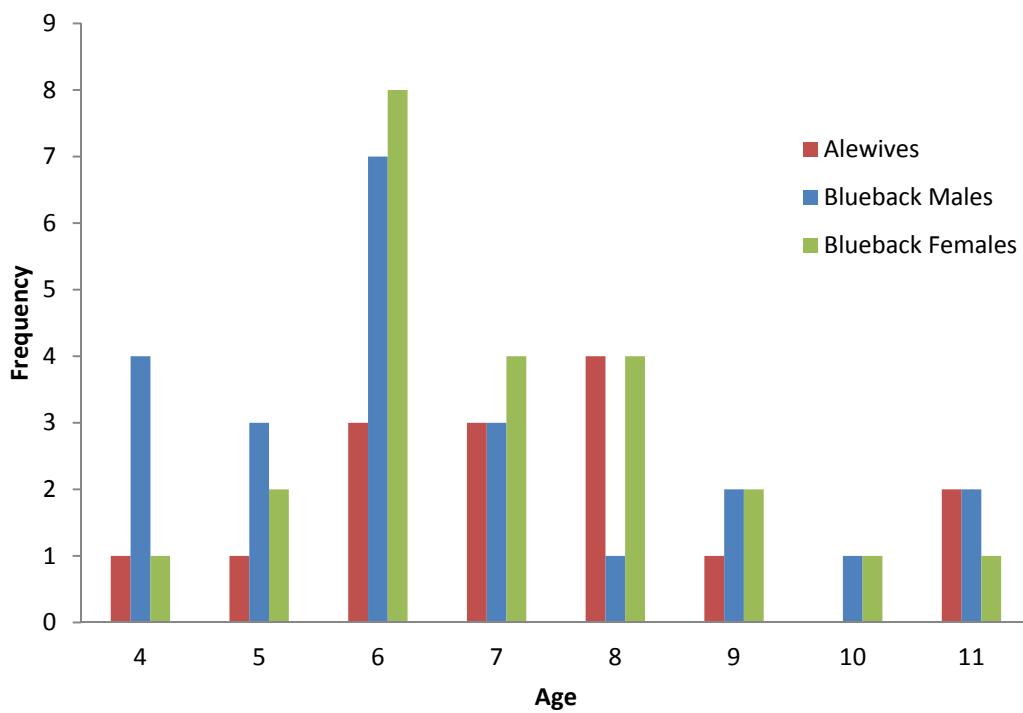


Figure 6. Frequency distribution of ages for alewives (green), blueback herring males (blue) and blueback herring females (green).

15 Status of River Herring in Virginia

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Updated June 2017 by Eric J. Hilton

Executive Summary

River herring currently occur in all of Virginia's major rivers (Figure 15.1) and have been exploited by fisheries for a long time in Virginia. Since 1994, the majority of commercial harvest of river herring from Virginia waters has been attributed to the main stem of the Chesapeake Bay, averaging over 35 thousand kilograms (alewives and blueback herring combined) a year from 1994 through 2010. Gill nets were responsible for nearly 82% of the commercial harvest of river herring from the Chesapeake Bay during this time period. The gill net harvests are likely composed of mixed spawning runs of river herring migrating to Virginia and Maryland systems. Fisheries-independent sampling of juvenile abundance depicts considerable annual variability and show little trend over the available time series. However, there are no data on juvenile abundance during the 1950s to 1970s when landings were higher and spawning runs were presumably stronger. The available data reported here are insufficient to quantitatively assess the current status of alewives and blueback herring in the James, York, and Rappahannock rivers.

The collapse of Virginia's commercial river herring fishery in the late 1970s reflects the same trend that has been observed for river herring landings along the U.S. east coast (Schmidt et al. 2003). This pattern has also been reported for Virginia's stocks of American shad during the same time period (ASMFC 2007). In the case of American shad, the VMRC imposed a ban on fishing in the Chesapeake Bay and its tributaries in 1994 in response to declining harvest. The 2007 ASMFC shad stock assessment confirmed that the 1994 ban on fishing was an appropriate action that has led to some recovery in the York River system (ASMFC 2007). Due in part to lack of available data to address the question of sustainability of river herring stocks in Virginia, and in order to comply with ASMFC Amendment 2 to for Shad and River Herring (ASMFC 2009), the VMRC implemented a ban on the possession of alewife and blueback herring that began on January 1, 2012.

INTRODUCTION

Assessment of alewife and blueback herring stocks is performed on a river-specific basis; each natal river is considered a unit stock. In Virginia, the majority of data available for river herring come from the James, York, and Rappahannock rivers (an assessment of river herring occurring in the Potomac River can be found elsewhere in this report). The stocks occurring in these river systems are the focus of this chapter.

15.1 DESCRIPTION OF MANAGEMENT UNIT(S)

Virginia's Department of Game and Inland Fisheries (VDGIF) is responsible for the management of fishery resources in the state's inland waters. The Virginia Marine Resources Commission (VMRC) oversees the management of resources in the state's marine waters.

15.2 REGULATORY HISTORY

The conservation and management of Virginia's river herring stocks dates back to colonial times. Loesch and Atran (1994) provide a brief historical overview of *Alosa* fisheries management in Virginia.

As of January 1, 2008, possession of alewives and blueback herring is prohibited on rivers draining into North Carolina (VMRC Regulation 4 VAC 15-320-25). Those rivers include the Meherrin River, Nottoway River, Blackwater River (Chowan Drainage), North Landing and Northwest rivers, and their tributaries plus Back Bay. On June 28, 2011, the VMRC voted to implement a ban on the possession of alewives and blueback herring in state waters; this ban became effective January 1, 2012 (VMRC Regulation 4 VAC-20-1260-30). The ban was enacted due to the collapse of the fishery over the last four decades and in order to comply with Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2009).

In evaluating Virginia's fisheries for river herring, it is important to note that the ocean fishery is a mixed-stock fishery, comprising river herring from different river systems. As such, river herring landed in Virginia have not necessarily originated in Virginia waters. The proportion of river herring from Virginia harvested from anywhere along the coast is currently unknown.

15.3 ASSESSMENT HISTORY

During 1966 through 1988, the Virginia Institute of Marine Science (VIMS) collected biological samples from Virginia's inshore alosine fishery as part of their annual assessment of the structure of adult alosine populations in the fishery. See sections 15.10.2–15.10.5, this report, for updated analyses of these data.

Tsimenides (1970) estimated total mortality of alewives using scales sampled from pound nets in the Rappahannock River during 1965 through 1969. The estimate of annual discrete total mortality rate (A) for male alewives was 0.594 and for females the estimate was 0.556. The male estimate of discrete total mortality ($A = 0.594$) corresponds to an instantaneous total mortality rate (Z) of 0.901. The estimate of discrete total mortality for female alewives ($A = 0.556$) corresponds to Z equal to 0.812.

A formal assessment of the alewife and blueback herring stocks occurring in the Rappahannock River was performed in 1990 as part of an assessment of multiple river herring stocks along the Atlantic Coast (Crecco and Gibson 1990). Stock status was assessed by comparing the annual discrete fishing mortality rate (u) at the time of the assessment to the river- and stock-specific annual discrete fishing mortality

rate that produces maximum sustainable yield (u_{MSY}). The instantaneous natural mortality rate (M) was assumed equal to 1.0 based on a maximum age of 9 years. This value was assumed for all river herring stocks along the coast and was assumed constant for all adult age groups (ages 3–8). That instantaneous value of M ($M = 1.0$) corresponds to a discrete natural mortality rate (m) of 0.63. Estimated u was 0.37 for alewives and 0.42 for blueback herring based on data collected from 1980 through 1985. The estimated value of u_{MSY} was 0.62 for alewives and 0.67 for blueback herring. Both the alewife and blueback herring stocks were considered partially exploited because the estimate u for each stock was less than 75% of the respective u_{MSY} . The stock condition of the Rappahannock River alewife stock was defined as severely depleted due to a substantial decline in recruitment.

15.4 STOCK SPECIFIC LIFE HISTORY

River herring (alewife, *Alosa pseudoharengus* and blueback herring, *A. aestivalis*) are anadromous, highly migratory, schooling, pelagic fishes that spend most of the annual cycle at sea but enter Virginia's rivers and streams to spawn during late winter and spring. Alewives migrate earlier than other alosine fishes (blueback herring, American shad, hickory shad) and spawn at lower temperatures (Schmidt et al. 2003), thereby being the first anadromous species available for harvest each year in Virginia. The flesh of river herring is consumed usually as a smoked, salted, or fresh product. The ripe ovaries (roes) of females are highly prized. The annual spring spawning run of river herring and American shad is an important cultural and culinary event in Virginia and their traditional fisheries have cultural significance. In addition to human consumption, river herring are the prey of striped bass, blue catfish, longnose gar, and other predators encountered along the migratory route. A comprehensive review of river herring biology and their ecological services is presented by Munroe (2002).

The species are distinct and can be distinguished by cutting the abdomen and examining the pigmentation of the peritoneum—the membrane that lines the abdominal cavity. In alewives, the peritoneum is pale or white; in blueback herring, the peritoneum is sooty dark or black. This dissection is not a routine procedure in most commercial fisheries. When fresh specimens of both species are in hand, the alewife has a much larger eye and is deeper bodied than the blueback herring. Despite these clear differences, the species are often misidentified and mixed in fishery statistics. To further complicate assessments of abundance and stock status, river herrings can be confused with young American shad, hickory shad, Atlantic menhaden, Atlantic herring, and other similar species. Scientists suspect that these species are often misidentified and mixed in reports of harvest and landings.

15.5 HABITAT DESCRIPTION

In Virginia, river herring are found in the Chesapeake Bay and its major tributaries, including the Potomac, Rappahannock, York, and James rivers, as well as smaller tributaries and other coastal habitats (e.g., along the Delmarva peninsula). Additionally, both alewife and/or blueback herring are found in certain rivers in Virginia that drain to North Carolina, including the Meherrin River, Nottoway River, Blackwater River (Chowan Drainage), North Landing and Northwest rivers, and their tributaries plus Back Bay. Both species have been introduced into landlocked reservoirs in Virginia; a reproducing population of blueback herring occurs in Kerr Reservoir, and reproducing populations of alewife are found in at least Smith Mountain Lake, Leesville Reservoir, Clayton Lake, and Bluestone Reservoir (Desfosse et al., 1994). The Potomac Rivers and those of North Carolina are described elsewhere in this assessment; here we focus on the major western tributaries of the Chesapeake Bay.

15.5.1 James River

The James River forms at the junction of Cowpasture and Jackson rivers (rkm 580), and its drainage is the largest watershed in Virginia, totaling 26,164 km² (Jenkins and Burkhead, 1994). Average annual spring discharge on the James River is 294.2 m³/s (Tuckey 2009). Prior to damming, which began in the colonial period, shad and river herring were reported to reach these headwaters and far into the major tributaries of the James River (Loesch and Atran, 1994). The two primary tributaries of the James River below the fall line at Richmond are the Appomattox River, which joins at the city of Hopewell (rkm 112), and the Chickahominy River, which joins at rkm 65. The extent of salt water is variable, but brackish conditions are observed as far up as the mouth of the Chickahominy River on a seasonal basis. Tidal water reaches Boshers Dam in Richmond (rkm 182). Numerous dams on the James River and its tributaries have historically blocked migration of fishes. Between 1989 and 1993 three dams below the fall line were breached or notched, extending available habitat to the base of Boshers Dam. A fish passage was installed in Boshers Dam in 1999, reopening 221 km of the upper James River and 322 km of its tributaries to river herring and other anadromous fishes; the next dam of the mainstem is at Lynchburg, VA (Weaver et al., 2003). The first existing dam on the Appomattox River is at rkm 17; and that on the Chickahominy is Walkers Dam at rkm 35 (with a fish passage rebuilt in 1989). A number of additional dam removal and fishway construction projects have occurred on several smaller creeks and streams in the James River drainage as well (<http://www.dgif.virginia.gov/fishing/fish-passage/>).

15.5.2 York River System

The York River system includes the Mattaponi and Pamunkey rivers, which merge at West Point, VA, to form the York River (53 rkm). This is the smallest of the three western tributary systems, with a watershed of 6,892 km² (Jenkins and Burkhead, 1994); the Pamunkey drainage is larger and has greater average spring discharge than that of the Mattaponi (3,768 km² and 47.5 m³/s vs. 2,274 km²; 27.2 m³/s, Bilcovic 2000). Tidal propagation extends to approximately 67 rkm in the Mattaponi and 97 rkm in the Pamunkey (i.e., approximately 120 km and 150 km, respectively, from the mouth of the York River; Lin and Kuo, 2001). The extent of the salt intrusion varies by season, but moderate salinity values (>2 ppt) are often observed in lower portions of these rivers. The Mattaponi, Pamunkey, and York rivers are all undammed.

15.5.3 Rappahannock River

The Rappahannock River, which is approximately 195 km in length (172 km is tidal; 118 is salt water), has its headwaters in the piedmont and is fed by the Rapidan River. The Rappahannock watershed encompasses a total of 7,032 km² (Jenkins and Burkhead, 1994), and the average annual discharge at the fall line is 45 m³/s (O'Connell and Angermeier 1997). The Rappahannock River was dammed until 2004, when the Embrey Dam, built in 1855 at Fredericksburg (rkm 250), was breached. Removal of the dam opened 170 km of potential habitat for migratory fishes, such as river herring. The Embrey Dam was the last remaining dam on the Rappahannock. A fish passage was installed on the Orange Dam on the Rapidan River (<http://www.dgif.virginia.gov/fishing/fish-passage/>). An estimated 125 tributaries of the Rappahannock River are potentially used by alosines (O'Connell and Angermeier 1997).

15.6 RESTORATION PROGRAMS

Since 2005, Virginia Commonwealth University (VCU) and USFWS's Harrison Lake National Fish Hatchery have conducted a river herring restoration program focused on Kimages Creek, a small tributary of the James River (VCU Rice Center, Charles City County, VA). Historically, Kimages Creek supported a river

herring run but was impounded at the mouth in 1928. Remnants of the run persisted below the dam into the 1970s. VCU collected broodstock from several locations, including Herring Creek, Wards Creek, and the James River, and USFWS staff at Harriots Lake National Fish Hatchery reared and OTC-marked the larvae, which were stocked into Kimages Creek. An informal target of 1M larvae (mostly blueback herring but some alewife) annually up to Spring 2011. From 2008 through 2011 limited monitoring for returning adults has recovered approximately 10 OTC-marked, reproductive adults in Kimages Creek. However, there are no funds to formally continue any dedicated restoration at this time. In December 2010, VCU, The Nature Conservancy and American Rivers re-established fish passage into a restored tidal Kimages Creek by removing 200 feet of the earthen dam at the Rice Center.

The Virginia Department of Game and Inland Fisheries (VDGIF) has been working to restore access to two major river systems (the James and Rappahannock rivers), and their tributaries as part of a restoration effort for all anadromous species. Most of these projects have taken place over the past two decades.

15.7 AGE

Fisheries dependent sampling for scales was conducted from 1966 through 1978, and for otoliths from 1975 through 1988. In this assessment, data from the following reports were used: Davis et al. 1970, 1971, 1972; Hoagman et al. 1973, 1974; Hoagman and Kriete 1975; Loesch and Kriete 1976, 1980–1984; Johnson et al. 1978; Loesch et al. 1977, 1981, 1985, 1986; Blumberg and Loesch 1988, 1989. Since 2015, otoliths have been sampled from the VIMS adult spawning stock survey in the Chickahominy River.

15.8 FISHERIES DESCRIPTIONS

Since 2003 (until the moratorium in January 2012), commercial fishing for river herring in Virginia takes place primarily in marine and estuarine waters. The major gears are gill nets and pound nets, with some ancillary use of haul seines, fyke nets, and other gears. The other category includes common dip nets, hand lines, and pots, based on VMRC reporting records. Recreational anglers fish for river herring primarily in upstream areas using hook and line, recreational gill nets, and dip nets. A brief history of Virginia's *Alosa* fisheries can be found in Loesch and Atran (1994).

15.8.1 Fisheries-Dependent

15.8.1.1 Commercial Fisheries Reporting

The VMRC's commercial fisheries records include information on both commercial harvest (fish caught and kept from an area) and landings (fish offloaded at a dock) of marine species in Virginia. The VMRC began collecting voluntary reports (monthly) of commercial landings from seafood buyers in 1973. A mandatory harvester reporting system was initiated in 1993 and collects trip-level data on harvest and landings within Virginia waters. Data collected from the mandatory reporting program are considered reliable starting in 1994, the year after the pilot year of program. The Potomac River Fisheries Commission (PRFC) has provided information on fish caught in their jurisdiction and landed in Virginia since 1973. Records of fish harvested from federal waters and landed in Virginia have been provided by the NMFS and its predecessors since 1929 (NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).

Estimates of commercial landings for river herring prior to the start of the mandatory harvester reporting program should be interpreted with care. A significant portion of the river herring catch has

been used for oil, meal, and crab bait (Joseph and Davis 1965). Prior to 1993, most of that catch was not recorded since data collection programs primarily considered food fish. The mandatory harvester program does, however, allow the reporting of landings as “bait” with no identification to species. As such, some true river landings may be reported as bait and therefore not classified as river herring in the data (VMRC, Fisheries Management Division, pers. comm.). Another issue is that the river herring species were not differentiated in the landings records prior to VMRC’s mandatory harvester reporting program—historic landings recorded as alewives include both alewives and river herring (e.g., U.S. Bureau of Fisheries 1941). Data obtained from the VMRC’s mandatory reporting program suggest alewives continue to make up the majority (~98%) of Virginia’s commercial river herring landings. However, available biological samples from the commercial fisheries suggest the proportion of alewives in the commercial landings is not that excessive or, at least, did not dominate the landings to that degree in the past. It is likely that at least a portion of the blueback herring landings continue to be reported as alewives. There is also concern that some commercial landings reported as alewives are, in fact, Atlantic menhaden (VMRC, Fisheries Management Division, pers. comm.). This may be reflected in river herring landings being reported in all months of the year and in gill nets that are harvesting larger fish, like striped bass, which has an eighteen inch minimum size.

Annual commercial landings were available for intermittent years from 1880 through 1925 and were available for all years beginning in 1929 (Table 15.1). Available historical commercial landings data for river herring in Virginia depict an active and productive fishery in the period 1950–1970 with total landings exceeding 14 million kilograms in some years (Figure 15.2). The time series of commercial landings suggest several periods of declining landings (during the 1930s; during the mid-1950s to early 1960s) followed by periods of increased landings. A steep decline in Virginia’s landings in the late 1970s was followed by an apparent collapse of the fishery.

Since 1994 (VMRC mandatory harvester reporting), commercial harvest of river herring from Virginia waters ranged from 9.5 thousand kilograms to 118 thousand kilograms from 1994 through 2010 (Figure 15.3). Most of the commercial harvest since 1994 (55%) has been reported from the main stem of the Chesapeake Bay (Figure 15.4). The James (8.43%), York (16.7%), and Rappahannock (10.4%) rivers combined account for about 35% of the commercial harvest. The majority of Virginia’s commercial river herring harvest has been taken by gill nets (Figure 15.5).

Annual commercial fishery harvest rates for alewives were calculated for 1994 to 2010 for selected Virginia water bodies. Harvest rates were calculated for gill nets—the major commercial gear for the time period. Annual harvest rates were computed as ratio estimators by dividing commercial harvest (kilograms) by the number of fishing trips for each water body (Pollock et al. 1994). Only fishing trips with positive harvest of alewives were included in the calculations; information on unsuccessful trips were not available. Annual harvest rates have been variable in the James, York, and Rappahannock rivers (Figure 15.6). Harvest rates in the James River have been variable over the time series. Gill-net harvest rates in the York River were relatively low through 2002 and have been variable, but generally increasing, over the rest of the time series. In the Rappahannock River, a three-year period of relatively higher rates occurred from 2002 to 2004. A small peak occurred in 2000, and there is evidence of another peak in 2010, but there is no obvious trend in harvest rates over time in the Rappahannock.

The commercial fishery for river herring was closed in 2012, and therefore there no longer is commercial reporting data available.

15.8.1.2 Voluntary Logbooks from an Individual

The VIMS obtained voluntary logbooks of one commercial river herring fisherman. The fisherman and his father fish the upper Rappahannock River above Port Royal, Virginia with drift gill nets and recorded their annual catches of river herring from 1995 through 2008. It was not possible to estimate precise catch rates from these records since the logbooks do not indicate the number of nets fished each day or the catch associated with each net. In addition, mesh sizes, lengths of nets, and the daily number of sets may have changed during the time period. The logbooks show that the total catch of river herring has been generally proportional to the number of days fished each year (Figure 15.7). The highest levels of catch and effort occurred from 1999 through 2002. In this period, the fisherman landed from nearly 4,000 to almost 6,000 fish each year from the Rappahannock River. Since 2002, catches have declined considerably. The fisherman reported to VIMS scientists that he had reduced effort later in this time series because fewer river herring were available. Digitization of these data has recently been completed and any further potential analysis is being investigated.

15.8.1.3 Biological Sampling

15.8.1.3.1 VMRC Biological Sampling Program

The VMRC Biological Sampling Program was initiated in 1989 to collect fisheries-dependent biological information to support assessment and management activity within the state and coast-wide. There are currently twenty-one species targeted for sampling in the program; non-target species, such as alewives and blueback herring, are sampled based on availability and staff time. When river herring are available for sampling, samples are identified to species, measured for total length (TL), and individual weights are taken for most samples. The fork length and sex of most samples is also recorded. River herring have been available for sampling from Virginia's commercial fishery in all years since the program's inception, except for 2009 and 2010. The samples were considered insufficient for characterizing the species composition of the commercial landings (J. Cimino, VMRC, pers. comm.).

The lengths of male alewives sampled from Virginia's commercial landings between 1989 and 2008 ranged between 210 and 390 mm TL and demonstrate a mode at 270 mm TL (Figure 15.8). Female alewives sampled from the commercial fishery exhibited a mode at 290 mm TL and ranged between 150 and 390 mm TL. Similar to the alewife samples, the female blueback herrings sampled from the commercial landings tended to be larger than the males (Figure 15.9). Male blueback herring ranged between 210 and 380 mm TL while females ranged between 180 and 350 mm TL. Male and female blueback herring demonstrated modes at 250 mm TL and 270 mm TL, respectively.

The average length of alewives sampled from Virginia's commercial fishery ranged from 258 to 297 mm TL per year between 1989 and 2008 (Figure 15.10). The annual average length of blueback herring samples ranged between 252 and 284 mm TL. The average annual length of both species shows an overall declining trend over the time series. The average individual weight of alewife commercial samples ranged between 161 and 276 g per year and blueback herring samples ranged between 121 and 219 g per year in individual weight (Figure 15.11). Like average length, the average individual weight of both alewives and blueback herring demonstrate a decrease over time.

15.8.1.3.2 VIMS Assessment of Virginia's Inshore Alosine Fishery (Historic Samples)

The VIMS collected biological samples from Virginia's commercial fishery from 1966 to 1988 as part of their annual assessment of the structure of adult alosine populations in Virginia's inshore alosine fishery.

Adult alosines were randomly sampled from the commercial fishery—primarily pound nets—over the duration of the spring spawning run. The majority of samples were collected from the James, York, Rappahannock, and Potomac rivers. The Potomac River samples are not included in this report. Individual samples were identified to species, measured for fork length (FL), weighed, and sexed. Structures were also removed and processed for ageing. Scales were collected during 1966 through 1978, and otoliths were collected during 1975 through 1988. In this assessment, data from the following reports were used: Davis et al. 1970, 1971, 1972; Hoagman et al. 1973, 1974; Hoagman and Kriete 1975; Loesch and Kriete 1976, 1980–1984; Johnson et al. 1978; Loesch et al. 1977, 1981, 1985, 1986; Blumberg and Loesch 1988, 1989. Refer to one of the cited reports for a more detailed description of this monitoring program. Also note that most of those data were not available in raw form.

The numbers of each species sampled were summarized by year to evaluate the species composition of Virginia's commercial river herring landings (see also section 15.9.1, this report). During the earliest years of the program (1967–1972), alewives composed the majority of the commercial landings, except in 1971 when nearly equal quantities of alewives and blueback herring were sampled (Table 15.2). The proportion of blueback herring sampled exceeded that of alewives beginning in 1973 and gradually increased through 1981; in 1981, 92% of the commercial samples were identified as blueback herring. The proportion of blueback herring then decreased but remained higher than that of alewives through 1988, the last year of the monitoring program.

The ages of alewives sampled from commercial harvest in the James River ranged from 3 to 9 years (Figure 15.12). Alewives age 4 and 5 dominated the James River commercial samples. In the Rappahannock River, alewives ranged in age from 2 to 9 in the commercial harvest (Figure 15.13). The age-frequency distributions demonstrate that the 1963, 1966, 1981, and 1982 year-classes of alewives were relatively strong in the Rappahannock River. Where both scale and otoliths ages were available, the pattern in the proportion of alewives at age is similar between the two structures, and there is no evidence of consistent over- or under-ageing by either structure. Alewives collected from the York River commercial fishery harvest ranged in age from 3 to 13 years and the majority of samples were 4- and 5-years-old (Figure 15.14). The York River age compositions suggest the 1982 year-class of resident alewives was relatively strong.

Blueback herring sampled from the James River commercial harvest were primarily age 4 and 5 in most years and ranged in age from 3 to 9 years (Figure 15.15). Blueback herring age 3 to 13 were observed in the commercial harvest samples from the Rappahannock River (Figure 15.16). The age-frequency distributions show that the 1966, 1970, 1971, 1975, 1978, and 1979 year-classes of blueback herring in the Rappahannock River were relatively strong. As with the alewife samples from the Rappahannock River, the age compositions of blueback herring based on scales were similar to those based on otoliths, and there is no evidence of consistent over- or under-ageing by either structure. The blueback herring samples from the Rappahannock River commercial harvest were dominated by 4- and 5-year-old fish from 1966 to 1975 and show increasing dominance of 5- and 6-year-olds from 1976 through 1988. In the York River, blueback herring ranged in age from 3 to 13 in the commercial harvest (Figure 15.17). The majority of blueback herring sampled from the York River commercial harvest were 4- to 6-years-old. The 1975, 1978, 1981 year-classes of blueback herring in the York River appeared to be relatively strong.

The spawning frequency data show that male and female alewives sampled from commercial harvest in the James River spawned as many as six times (Figure 15.18). In three of the four years for which data were available, the majority of male alewives sampled from the James River had spawned at least once while the majority of female alewives sampled had not yet spawned. The limited data available

characterizing spawning frequencies at age suggest most of the alewives in the James River that have spawned once are 5- or 6-years-old (Table 15.3). In the York River, male alewives spawned as many as five times, and females experienced as many as six spawning events (Figure 15.19). First-time spawners were 4- to 6-years-old (Table 15.3). The blueback herring spawning frequency data collected from the James River commercial harvest show that males spawned as many as six times, and females spawned as many as five times (Figure 15.20). In all years for which data were available, the majority of female blueback herring collected from the James River were virgin spawners. Most of the blueback herring sampled from the James River that spawned once were age 6 (Table 15.4). Both male and female blueback herring spawned as many as six times based on samples collected from commercial harvest in the York River (Figure 15.21). Similar to the James River, the majority of first-time spawners in the York River were 6-years-old (Table 15.4).

15.8.1.4 Recreational Fisheries Monitoring

The NMFS Marine Recreational Fishery Statistics Survey (MRFSS) is the primary source of marine recreational fisheries statistics for Virginia. The MRFSS program utilizes telephone surveys, angler-intercept surveys, and at-sea headboat sampling (begun in 2005) to estimate recreational fisheries statistics. The MRFSS raw data files demonstrate that alewives and blueback herring were rarely encountered during surveys of Virginia's recreational anglers. During 1981 through 2010, a total of 206 alewives and 51 blueback herring were encountered in the angler-intercept survey in Virginia. Additionally, one blueback herring was encountered during the MRFSS at-sea headboat survey. These observations occurred in only six years over the available survey time series (1981–2010); recreational statistics of alewives and blueback herring could only be derived for those years where samples were recorded. The limited availability of samples resulted in low precision (high proportional standard error) of the estimates that could be computed. As such, the MRFSS estimates of Virginia's recreational alewife and blueback herring catches are not considered reliable or representative and so are not presented here.

Estimates of recreational catch and effort from non-marine waters are not available, though river herring is a popular recreational species in Virginia's inland waters.

15.9 FISHERIES INDEPENDENT SURVEYS

15.9.1 VDGIF Electrofishing Surveys, 1994–present

The VDGIF has conducted electrofishing surveys for American shad and river herring in the Rappahannock River near Route 1 and in the James River near the Manchester Bridge in downtown Richmond. Sampling is conducted weekly at both locations. The total number of each species collected and the sex of each individual in a sample is recorded. Individual weights and total lengths are collected from a subsample per sampling date at each station.

The Route 1 sampling station starts at the very head of tide (the tidal/non-tidal interface) approximately 1.5 miles downstream of the Embrey Dam and extends downstream several hundred meters (900 seconds of boat electrofishing effort). This area was essentially unchanged by the dam removal in 2004 and represents the most consistently sampled site by the VDGIF on the river. Alewives are observed at the Rappahannock stations in March and April of each year. Blueback herring can be found in April through early June; the two species usually co-occur in April only.

Three of the four stations (Manchester 1, 2, and 4) in the James River start at the very head of tide just downstream of the last riffle/rapids and extend downstream to the 14th Street Bridge (300–500 seconds of electrofishing effort each). The Manchester 5 sampling station starts at Interstate 95 and extends downstream along the bank (500 seconds of electrofishing effort). Alewives appear in March and April at the Manchester Bridge sampling sites on the James River. Blueback herring occur at this site in April, May, and early June.

Annual cumulative catch rates were computed for the Rappahannock River (Route 1 sampling station) for 2000 to 2010 and for the James River (Manchester stations 1, 2, 4, and 5 combined) for 2002 to 2010. The years used represent the most consistent, continuous time series for each location. Catch rates were calculated as the average number of fish collected per minute of electrofishing. In the Rappahannock River, peak catch rates of blueback herring occurred in 2001 (Figure 15.22). In some years, blueback herring were not collected in the survey. Peak catch rates of alewives occurred in 2004 and 2005. In the James River, blueback herring have dominated the catch (Figure 15.23). The 2012 catch rate for blueback herring in the James River was the highest in the time series. The catch rates show a low relative abundance of alewives in the James River relative to the Rappahannock (Figure 15.22 and Figure 15.23).

15.9.2 VIMS Experimental Anchor Gill-Net Survey, 1991–2013

The VIMS performs an annual striped bass spawning stock survey in the James and Rappahannock rivers using multi-mesh anchored gill nets. Adult river herring are encountered in the Rappahannock River, but river herring are rarely observed in the James River samples. The gear is set twice a week from late March through early May, and soak time is twenty-four hours for each set. Although the peak of the blueback herring run takes place during the duration of the survey, a significant portion of the alewife migration occurs before late March and may be missed.

Indices of relative abundance based on observations from the Rappahannock River were calculated as the arithmetic average number of fish per day for alewives and blueback herring. The index for alewives has maintained relatively low levels with no obvious trend over the time series (Figure 15.24). The blueback herring index declined from the beginning of the time series through 1994 and increased to the time series peak in 1995. The index then decreased and has remained at relatively low levels through the present. Between 2010 and 2013, only a single river herring was encountered on the James (in 2012; species not recorded). On the Rappahannock, a total of 39 river herring were encountered in this time period (2010, 10; 2011, 0; 2012, 11; and 2013, 18). Counts of river herring encountered in this program ceased in 2013.

15.9.3 VIMS Juvenile Fish and Blue Crab Trawl Survey, 1979–present

The VIMS Juvenile Fish and Blue Crab Trawl Survey monitors the distribution and abundance of important finfish and invertebrate species occurring in the Chesapeake Bay. The survey sites and sampling frequency have not been consistent throughout the history of the survey (Tuckey and Fabrizio 2010). The survey currently employs a mixed design, incorporating both stratified random sites and fixed (historical mid-channel) sites. The stratification system is based on depth and latitudinal regions in the bay (random stations), or depth and longitudinal regions in the tributaries (random and fixed stations).

Annual juvenile abundance indices (JAIs) for young-of-year alewives and blueback herring were computed as random stratified geometric average number of fish per standard tow. The indices series start in 1996 because that is the year when random stations were added to the survey. The JAIs for both

species were calculated based on data collected in December through March and fish less than or equal to 110 mm. Indices were calculated for the James, York, and Rappahannock rivers separately. The relative abundance of juvenile alewives was variable without trend for each river (Figure 15.25). Similar to the alewife JAIs, the JAIs for blueback herring varied without trend for each of the three rivers (Figure 15.26). Variability about the annual JAIs values is fairly high for both species, especially for the Rappahannock River (Figure 15.25 Figure 15.26).

15.9.4 VIMS Juvenile Striped Bass Seine Survey, 1967–present (gap 1974–1979)

The VIMS Juvenile Striped Bass Seine Survey tracks trends in the annual year-class strength of striped bass in the spawning and nursery areas of the lower Chesapeake Bay. JAIs for alewives and blueback herring were calculated as the geometric average number of fish per seine set for the James, York, and Rappahannock rivers separately. The indices series start in 1989 because the number of sites sampled (~109) became consistent in that year. The JAIs for both species were calculated based on data collected in July through September using only data from sites where each species can be expected to be captured. All sampling sites are fixed in location. The JAI for alewife (Figure 15.27) has been consistently lower than the blueback herring JAI (Figure 15.28) in all three rivers. There are no obvious trends in the JAI time series for either of the species, and variability about the annual estimates has been fairly high (Figure 15.27Figure 15.28). Indexes of juvenile abundance based on the seine survey data are variable, but are almost always higher for blueback herring than for alewife, and the Rappahannock River most often shows the highest abundance for both species. No measurable recruitment of alewife was seen in the James River in 1989-1992, 1995, 1999-2003, 2008, and 2011-2012, and in the York River in 1990-1993, 1995, 1998-2000, 2006-2009, and 2012-2014. In the Rappahannock River, indexes of juvenile alewife abundance have been relatively low (e.g., <0.1) in many years (1990-1992, 1995, 2002, 2004-2006, 2008, 2012), but there has always been measureable recruitment throughout the time series. The only instances of no measurable recruitment of blueback herring within the time series occurred in the York River, and in the years 1990, 1992-1993, 1995, 1998-1999, 2002, 2005-2006, 2009, 2012-2013.

15.9.5 VIMS Juvenile Shad-River Herring Push-Net Survey, 1979–2002 (gap 1988–1990)

The VIMS Push-Net Survey, initiated in 1979, was an evening push-net survey of the York River system that targeted American shad. The survey was discontinued in 2002. Sampling in the Mattaponi and Pamunkey rivers was typically conducted from mid-May through August or until the catch of American shad was zero. The survey was temporarily halted following the 1987 sampling year. Sampling resumed again in 1991, though there were changes to the sampling design and methodology. Wilhite et al. (2003) examined the sampling strategies employed in this survey and concluded that data collected before and after the interruption in sampling (1979–1987; 1991–2002) should be considered separate data series and not compared since the collection methods differed substantially in each period. The survey data were used to calculate JAIs for alewives and blueback herring as the geometric average number of fish per standard set. Juvenile indices were calculated for both the Mattaponi and Pamunkey rivers. The majority of alewives and blueback herring caught in the survey were between 27 and 70 millimeters in length. The JAI values for alewives have been lower than that for blueback herring in both tributaries throughout the time series (Table 15.5); however, catchability of alewives and blueback herring by the push net may differ, accounting for these patterns (Loesch et al. 1982).

15.9.6 VIMS American Shad Monitoring Program, 1998–present

Few alewife or river herring are encountered in the VIMS American Shad Monitoring Program in the Rappahannock, York, and James rivers (<70 individuals of both species in all rivers combined over the history of the program) due to specificity of the gear used for the larger species, American shad (this program mimics the historical commercial American shad fishery, which targeted female American shad). Therefore, no trends or inference on alewife and river herring can be drawn from these data, and they are not included in the assessment.

15.9.7 VIMS River Herring Adult Relative Abundance Monitoring Program, 2015–present

In response to the moratorium for river herring enacted in 2012, an annual adult spawning stock monitoring program gill net was established in 2015 on the Chickahominy River, a major tributary of the James River and the location of a historical fishery for river herring; in 2016 this survey was expanded to include sampling on the Rappahannock River. Each week, generally from February to May, nets are fished on two succeeding days (two 24-h sets). All herring are counted and returned to the lab for collection of length, weight, and sex data; otoliths are removed to age the fishes; mortality is calculated. Blueback herring had a marked increase in abundance in the Chickahominy over the three years of sampling, whereas alewife experienced a significant decrease in 2016, with a subsequent increase in 2017. Because the time series only began in 2015, data are not presented herein, but these will be available for future stock assessments.

15.9.8 VIMS River Herring Juvenile Sampling, 2014–present

In 2014, a nighttime surface trawl survey was established to target juvenile alewife and blueback herring in the Chickahominy River. This survey employs a mamou trawl, which is a 6.7 m x 1.8 m floating surface trawl constructed of 35 mm high density polyethylene netting. Sampling occurs between June and September. During each cruise, three stations are randomly chosen within each of four adjacent 9.3 river km long blocks. Stations are designated at every 1.9 river km, beginning approximately 1.2 km (c. 2 miles) below Walker's Dam and ending at the river mouth. Night time sampling is conducted when juvenile *Alosa* spp. are most susceptible to surface trawling (Loesch et al. 1982). Each tow lasts 5 minutes and is conducted along the central axis of the river channel. Alewife and blueback herring caught at each station are identified and counted. Ten randomly selected individuals of each species from each station are measured and weighed. The geometric mean of the catch per tow is calculated for each cruise and the season (i.e., a seasonal catch index). Blueback herring dominate the catches. In 2016, for instance, total catches of alewife = 31 whereas total blueback herring catches = 30,951. Because the time series only began in 2014, data are not presented herein, but will be available for future stock assessments.

15.10 ASSESSMENT APPROACHES AND RESULTS

15.10.1 Trends in Relative Abundance

The indices of relative abundance for adult and juvenile river herring were tested for overall temporal trends and were compared to evaluate whether there was consistency in temporal trends among the indices. Only indices derived from the fishery-independent surveys were considered because the fishery-dependent harvest rate indices have not been corrected for changes in efficiency over time, only include records of positive tows, and would reflect trends in fished areas only. Indices derived from the VIMS Push-Net Survey were not included in the analyses because that survey was discontinued in 2002.

The Mann-Kendall test was applied to quantitatively evaluate the overall trend in relative abundance of alewives and blueback herring, by species, life stage, river, and survey. The Mann-Kendall test is a non-parametric test for monotonic trend in time-ordered data and allows for both missing observations and ties (Gilbert 1987). Trends were considered statistically significant at $\alpha = 0.05$. Spearman's rank-order correlation coefficient, ρ , was calculated to measure the degree of linear association between indices. Spearman's rank-order correlation is a non-parametric test for determining if there is an association between two variables. Indices were considered significantly correlated at $\rho = 0.05$. Comparisons were made by species and life stage.

The temporal trend of eighteen fishery-independent survey indices was evaluated using the Mann-Kendall test. Statistically significant trends were detected in two indices (Table 15.6). The indices of relative abundance of adult alewives and adult blueback herring in the Rappahannock River derived from the VIMS Experimental Anchor Gill-Net Survey (Figure 15.24) were found to have significantly decreasing trends over the time series until 2010 (alewives: $S = -74$, $P = 0.0176$; blueback herring: $S = -141$, $P = 5.50E-06$); because the collection of herring data after this time period was pooled (i.e., not separated by species) and ceased in 2013, analyses were not updated in June 2017. Statistically significant trends were not found in any of the other indices evaluated.

There were no statistically significant correlations detected among the adult indices of relative abundance for either species (Table 15.7). The indices of alewife juvenile abundance in the York River derived from the VIMS Juvenile Striped Bass Seine Survey and the VIMS Juvenile Fish and Blue Crab Trawl Survey were found to be significantly and positively correlated ($\rho = 0.665$, $P = 0.00680$). Indices of blueback herring juvenile abundance derived from the VIMS Juvenile Striped Bass Seine Survey were significantly and positively correlated between the James and Rappahannock rivers ($\rho = 0.712$, $P = 0.000200$), James and York rivers ($\rho = 0.478$, $P = 0.0246$), and York and Rappahannock ($\rho = 0.560$, $P = 0.00670$; Table 15.8).

15.10.2 Temporal Trends in Size

Size data available from the VIMS inshore alosine fishery sampling were compared to data available from the VMRC's Biological Sampling Program to evaluate trends in average size over time. The historic VIMS sampling program measured lengths in terms of fork lengths; length data from the VMRC were converted to fork lengths for consistency. Size data from the historical VIMS report were only available in summarized form and were typically reported as annual averages for the major tributaries of the Chesapeake Bay. Additionally, the historical VIMS data were primarily collected from commercial pound nets. Pound net samples collected by the VMRC were examined and it was found that only samples collected from the Rappahannock River could provide enough years to include in the evaluation. Note that the comparison may be confounded by the fact that the VIMS sampling only occurred during the spring spawning run and the VMRC sampling can occur anytime during the year when landings are available for sampling.

The Mann-Kendall test was performed to quantitatively evaluate the time-series trend in average length and weight for alewives and blueback herring, by sex. Trends were considered statistically significant at $\alpha = 0.05$.

The average length of male alewives ranged from 125 to 228 mm FL per year and the average lengths of females ranged from 160 to 294 mm FL per year (Figure 15.29). The average weight of male alewives ranged between 224 and 250 g per year while the average weight of females ranged between 236 and

265 g per year (Figure 15.30). The Mann-Kendall test detected statistically significant decreasing trends over time for the average length and weight of both male and female alewives sampled from the Rappahannock River commercial pound net fishery (Table 15.9).

There were only three years (2004, 2007, and 2008) during the recent time period in which blueback herring were available for sampling from commercial pound nets in the Rappahannock River. Despite the limited data from recent years, the annual average lengths of male and female blueback herring show evidence of an overall declining trend over time (Figure 15.31). The Mann-Kendall test found the declining trend in average length of male and female blueback herring to be statistically significant (Table 15.9). The average weight of male blueback herring ranged from 213 to 251 g per year and the average weight of females ranged from 231 to 259 g per year (Figure 15.32). No significant trends were detected in the average weight of blueback herring over time (Table 15.9).

15.10.3 Sex Ratio

Sex ratios for river herring were calculated using the data available from the VIMS sampling of Virginia's inshore alosine fishery. Samples collected by the VMRC's Biological Sampling Program were considered insufficient for calculating sex ratios (J. Cimino, VMRC, pers. comm.) and would not be comparable to the VIMS historical data because the VMRC sampling can occur throughout the year while the VIMS only sampled during the spring spawning run.

Sex ratios were computed for each species by year for the James, York, and Rappahannock rivers. The χ^2 goodness-of-fit test with Yate's correction for continuity was applied to test whether the observed sex ratios departed from a 1:1 (male: female) ratio (Zar 1999).

The sex ratio (male: female) for alewives sampled from the James River ranged from 1.1 (52% male) to 3.9 (79% male) between 1967 and 1980 (Table 15.10). Male alewives were encountered more frequently than females in all the years data were available from the James River (1967–1980). The χ^2 goodness-of-fit indicated that most of the sex ratios for alewives sampled from the James River significantly deviated from a 1:1 ratio ($P < 0.05$), in favor of males. In the York River, the sex ratio of alewives ranged from 0.53 (35% male) to 1.6 (62% male) and demonstrated an overall decrease over the time series (1967–1988). In most years, the sex ratios of alewives collected from the commercial fishery in the York River were not statistically different from a 1:1 ratio ($P \geq 0.05$). Male alewives dominated the Rappahannock River samples in most years of the available time series. Sex ratios of alewives in the Rappahannock River ranged between 0.55 (35% male) and 1.8 (65% male).

The proportion of male blueback herring sampled from the James River fishery was found to be significantly larger ($P < 0.05$) than the proportion of females sampled in all but one of the years samples were available (Table 15.11). The sex ratio of James River blueback herring ranged from 1.2 (54% male) to 5.1 (84% male) between 1967 and 1980. Blueback herring collected from the York River exhibited sex ratios ranging from 0.58 (37% male) to 1.7 (63% male). In the Rappahannock River, blueback herring sex ratios ranged between 0.73 (42% male) and 2.0 (67% male) and were dominated by males in most years.

15.10.4 Spawning Frequency

Data characterizing the spawning frequency of river herring were available for a limited number of years from the James (1967–1970) and York (1967, 1969–1970) rivers. The data were collected by the VIMS inshore alosine fishery sampling program. Repeat spawner rates were calculated by dividing the number

of sampled fish with one or more spawning marks by the total number of fish sampled and multiplying the resulting quotient by 100. Rates were calculated by species, sex, and year for each river.

The percentage of male alewives that previously spawned at least one time was nearly 50% or greater for samples collected from the James River commercial fishery (Table 15.12). Repeat spawning rates of female alewives sampled from the James River ranged between 42% and 83%. Alewives in the commercial fishery samples from the York River exhibited repeat spawning rates ranging from 46% to 70%. Female alewives sampled from the York River exceeded 50% in all three of the years for which data were available.

Repeat spawning rates for blueback herring sampled from commercial harvest in the James River ranged from 36% to 82% (Table 15.13). The proportion of females in the James River that previously spawned ranged between 33% and 73% among the years when data were available. In the York River, repeat spawner rates were 60% or greater for male blueback herring sampled from the fishery. Female blueback herring repeat spawner rates in the York River ranged from 50 to 72%.

15.10.5 Mortality

Age data collected from Virginia's inshore alosine fishery by the VIMS were used to derive catch curves in order to estimate instantaneous total mortality rates (Z). The age data obtained from the historical VIMS reports were sometimes presented in terms of proportion at age without additional information on sample size. This prevents the calculation of standard error for Z estimates so catch curves were not calculated for years when sample size information was not available. Additionally, the available data were insufficient to calculate longitudinal catch curves. Though longitudinal catch curves are generally preferred, age composition data were not available for a sufficient number of consecutive years to follow cohorts through time. Instead, cross-sectional catch curves, which are based on the estimated abundance of successive age classes within a particular year, were computed for each species by water body, ageing structure, and year based on availability of data. The data used were collected during the mid-1970s through the late 1980s.

Catch curves were computed using the method of Robson and Chapman (1961). Both alewives and blueback herring were considered fully recruited to the gear at age 4 years. Catch curves were only applied to age compositions that had samples for the assumed age at full recruitment and at least three older ages.

Estimates of annual Z s for alewives ranged from a low of 0.44 to a high of 1.8 among all computed estimates (Table 15.14). Annual Z s were highest in the Rappahannock River for most years. Alewife samples from the James River yielded the lowest estimates of Z . Blueback herring total mortality estimates ranged between 0.32 and 2.0 (Table 15.15). Estimates of blueback herring Z s were generally similar among the three rivers.

15.11 BENCHMARKS

The available data for alewives and blueback herring in the James, York, and Rappahannock rivers were considered insufficient to perform a reliable assessment of the status of these stocks. The data were also considered inadequate for developing benchmarks.

15.12 CONCLUSIONS AND RECOMMENDATIONS

15.12.1 Management Actions and Outcomes

On June 28, 2011, the VMRC voted to implement a ban on the possession of alewives and blueback herring in state waters; the ban became effective January 1, 2012. The ban was enacted due to the collapse of the fishery over the last four decades and in order to comply with Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2009). The outcome of the moratorium means the loss of harvest information. Additionally, as in the case of American shad in Virginia, a ban on possession of river herrings will not reduce removals by pound nets and some other gears, rendering discards of river herring as unreported.

It would be prudent to initiate an observer program for pound nets in the Chesapeake Bay to obtain information on patterns of species-specific exploitation (catch rates, temporal and spatial trends in catch). This program also would provide materials for biological characterization of the catch and could produce more reliable information of relative abundance of each species. Biological data are collected (2014-present) from a subsample of bycatch of river herring from poundnets by VIMS scientists, but this is not a formal observer program intended to calculate rates of exploitation.

15.12.2 Research Recommendations

- Develop and implement program for sampling commercial landings classified as “bait” in order to evaluate the relative importance of river herring (and other species) in the bait landings
- Estimate magnitude of by-catch and discards in state and ocean waters; estimate associated mortality
- Initiate an observer program for pound nets in the Chesapeake Bay to obtain information on patterns of species-specific exploitation
- Develop studies to estimate stock-specific (river-specific) estimates of natural mortality
- Develop restoration benchmarks for river herring species
- Develop studies to estimate contribution of Virginia stocks to ocean fisheries by-catch
- Develop a fish passage facility monitoring plan to estimate stock size at, and upstream of, dams with fishways and to track population trends
- Use existing creel surveys in rivers to estimate incidental catch of river herring by recreational anglers

15.12.3 Summary

The available data reported here are insufficient to quantitatively assess the current status of alewives and blueback herring in the James, York, and Rappahannock rivers. The most recent comprehensive assessment of river herring stocks examined long-term datasets from large rivers along the U.S. east coast (including the Hudson, Connecticut, Delaware, and Chowan rivers) and concluded that both river herring species in these systems showed signs of overexploitation including reductions in average age,

decreases in the percent of repeat spawning, declines in recruitment, and decreases in adult abundance (Schmidt et al. 2003). With the exception of the juvenile abundance surveys, such long-term data are not currently available for Virginia. The analysis of sex ratios and spawning frequency and estimation of mortality rates were based on historical data and not informative about the status of the population in recent years. The recent (2015) initiation of directed adult river herring monitoring program conducted in the Chickahominy and Rappahannock rivers was designed to fill this void.

Based on the results of fishery-independent sampling that depicts the presence of both species of river herring, there is strong evidence that commercial harvest data since 1994 are not an accurate depiction of the species composition of the catch in Virginia. Schmidt et al. (2003) emphasized that alewife and blueback herring should be managed separately. The species are likely misidentified in Virginia reported harvest and landings and this fact significantly diminishes our understanding of their exploitation.

River herring have been exploited by fisheries for a long time in Virginia. Since 1994 (until 2012, when a moratorium became effective), the majority of commercial harvest of river herring from Virginia waters has been attributed to the main stem of the Chesapeake Bay, averaging over 35 thousand kilograms (alewives and blueback herring combined) a year from 1994 through 2010. Gill nets were responsible for nearly 82% of the commercial harvest of river herring from the Chesapeake Bay during this time period. The gill net harvests are likely composed of mixed spawning runs of river herring migrating to Virginia and Maryland systems.

Interviews with one fisherman and examination of his voluntary logbook data suggest that the strength of the spawning run of river herring has declined in the Rappahannock River since 1995. This observation is supported by the VIMS multi-mesh anchored gill-net survey—the longest available fisheries-independent time series of adult river herring occurring in the Rappahannock River (1991–present)—and the commercial harvest rate estimates of gill nets in the river.

Fisheries-independent sampling and commercial harvest reveal that river herring occur in all of Virginia's major rivers. Abundance indices of juveniles depict considerable annual variability and show little trend over the available time series. However, there are no data on juvenile abundance during the 1950s to 1970s when landings were higher and spawning runs were presumably stronger. Additionally, the results of the correlation analyses suggest little consistency among the fishery-independent survey indices of relative abundance.

The collapse of Virginia's commercial river herring fishery in the late 1970s (Figure 15.2) reflects the same trend that has been observed for river herring landings along the U.S. east coast (Schmidt et al. 2003). This pattern has also been reported for Virginia's stocks of American shad during the same time period (ASMFC 2007). In the case of American shad, the VMRC imposed a ban on fishing in the Chesapeake Bay and its tributaries in 1994 in response to declining harvest (4 VAC 20-530 et seq.). At the time, fisheries-independent data were insufficient to assess the stocks and there were no existing monitoring programs to evaluate stock status. Subsequent research and the recent ASMFC stock assessment have confirmed that the 1994 ban on fishing was an appropriate action (ASMFC 2007). Due in part to lack of available data to address the question of sustainability of river herring stocks in Virginia, and in order to comply with ASMFC Amendment 2 to for Shad and River Herring (ASMFC 2009), the VMRC implemented a ban on the possession of alewife and blueback herring that began January 1, 2012 (VMRC Regulation 4 VAC-20-1260-30).

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Table 15.1 Annual commercial landings (kilograms) of river herring in Virginia, 1880–2010. Note that estimates are not available for all years prior to 1929.

| Year | Commercial Landings (kilograms) |
|------|------------------------------------|------|------------------------------------|------|------------------------------------|------|------------------------------------|
| 1880 | 3,141,127 | 1938 | 8,024,497 | 1963 | 11,832,137 | 1987 | 355,052 |
| 1887 | 1,996,713 | 1939 | 6,727,137 | 1964 | 12,083,699 | 1988 | 324,152 |
| 1888 | 2,927,031 | 1940 | 5,186,057 | 1965 | 16,420,178 | 1989 | 296,023 |
| 1890 | 4,827,129 | 1941 | 5,420,882 | 1966 | 12,943,166 | 1990 | 227,311 |
| 1891 | 4,995,412 | 1942 | 4,199,312 | 1967 | 12,749,300 | 1991 | 319,583 |
| 1896 | 5,532,919 | 1944 | 8,092,450 | 1968 | 14,659,831 | 1992 | 483,977 |
| 1897 | 6,209,679 | 1945 | 6,631,111 | 1969 | 13,809,935 | 1993 | 160,032 |
| 1901 | 6,311,283 | 1946 | 5,455,944 | 1970 | 8,638,847 | 1994 | 81,063 |
| 1904 | 6,624,262 | 1947 | 10,057,593 | 1971 | 4,657,531 | 1995 | 109,040 |
| 1908 | 17,184,345 | 1948 | 8,783,634 | 1972 | 4,740,403 | 1996 | 64,405 |
| 1909 | 12,599,887 | 1949 | 9,980,346 | 1973 | 4,204,317 | 1997 | 64,929 |
| 1915 | 7,281,971 | 1950 | 13,018,870 | 1974 | 6,051,813 | 1998 | 21,792 |
| 1920 | 7,559,116 | 1951 | 14,788,924 | 1975 | 5,152,585 | 1999 | 23,353 |
| 1921 | 8,542,958 | 1952 | 13,082,056 | 1976 | 1,922,171 | 2000 | 17,671 |
| 1925 | 8,123,838 | 1953 | 10,875,329 | 1977 | 630,527 | 2001 | 28,574 |
| 1929 | 5,701,681 | 1954 | 12,668,879 | 1978 | 965,278 | 2002 | 120,517 |
| 1930 | 6,979,433 | 1955 | 9,907,635 | 1979 | 766,000 | 2003 | 103,416 |
| 1931 | 7,819,510 | 1956 | 10,027,338 | 1980 | 537,138 | 2004 | 101,798 |
| 1932 | 6,283,384 | 1957 | 8,508,303 | 1981 | 235,650 | 2005 | 44,053 |
| 1933 | 8,698,743 | 1958 | 8,328,544 | 1982 | 593,023 | 2006 | 23,695 |
| 1934 | 2,651,791 | 1959 | 7,913,825 | 1983 | 833,550 | 2007 | 47,884 |
| 1935 | 4,977,767 | 1960 | 7,014,351 | 1984 | 570,220 | 2008 | 72,854 |
| 1936 | 3,941,128 | 1961 | 7,042,383 | 1985 | 195,956 | 2009 | 88,835 |
| 1937 | 6,833,051 | 1962 | 11,092,056 | 1986 | 343,824 | 2010 | 78,264 |

Table 15.2 Species composition (%) of river herring sampled from commercial harvest in the James, York, and Rappahannock rivers, 1967–1988.

| Year | n | Alewife | Blueback Herring |
|-------------|----------|----------------|-------------------------|
| 1967 | 1,419 | 56.1 | 43.9 |
| 1968 | 718 | 55.7 | 44.3 |
| 1969 | 1,090 | 60.2 | 39.8 |
| 1970 | 978 | 80.0 | 20.0 |
| 1971 | 875 | 49.1 | 50.9 |
| 1972 | 736 | 60.0 | 40.0 |
| 1973 | 865 | 38.5 | 61.5 |
| 1974 | 2,498 | 42.4 | 57.6 |
| 1975 | 4,846 | 38.7 | 61.3 |
| 1976 | 4,110 | 44.2 | 55.8 |
| 1977 | 4,860 | 34.0 | 66.0 |
| 1978 | 3,066 | 25.3 | 74.7 |
| 1979 | 2,113 | 22.2 | 77.8 |
| 1980 | 2,050 | 22.8 | 77.2 |
| 1981 | 2,168 | 8.03 | 92.0 |
| 1982 | 1,703 | 13.4 | 86.6 |
| 1983 | 2,327 | 42.2 | 57.8 |
| 1984 | 2,098 | 30.9 | 69.1 |
| 1985 | 2,452 | 44.5 | 55.5 |
| 1986 | 1,911 | 26.5 | 73.5 |
| 1987 | 1,283 | 36.9 | 63.1 |
| 1988 | 1,159 | 37.0 | 63.0 |

Table 15.3 Percent at age by number of spawning marks for alewives sampled from Virginia's commercial harvest. (Source: Loesch et al. 1977)

| Water Body | Year | n | Number Spawn Marks | Percent at Age | | | | | | | |
|--------------|------|-----|--------------------------|----------------|------|------|------|------|-----|----|----|
| | | | | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| James | 1977 | 43 | 0 | 9.30 | 83.7 | 6.98 | | | | | |
| | 1977 | 25 | 1 | | 36.0 | 64.0 | | | | | |
| | 1977 | 5 | 2 | | | 40.0 | 60.0 | | | | |
| | 1977 | 2 | 3 | | | | 100 | | | | |
| York | 1977 | 106 | 0 | 17.0 | 74.5 | 8.49 | | | | | |
| | 1977 | 41 | 1 | 2.44 | 36.6 | 58.5 | 2.44 | | | | |
| | 1977 | 5 | 2 | | | 60.0 | 40.0 | | | | |
| Rappahannock | 1977 | 305 | 0 | 4.92 | 54.8 | 38.4 | 1.97 | | | | |
| | 1977 | 194 | 1 | | 29.4 | 66.0 | 4.64 | | | | |
| | 1977 | 20 | 2 | | | 50.0 | 50.0 | | | | |
| | 1977 | 3 | 3 | | | | 66.7 | 33.3 | | | |
| | 1977 | 2 | 4 | | | | | | 100 | | |

Table 15.4 Percent at age by number of spawning marks for blueback herring sampled from Virginia's commercial harvest. (Source: 1965-1966 data—Davis et al. 1970; 1977 data—Loesch et al. 1977)

| Water Body | Year | n | Number Spawn Marks | Percent at Age | | | | | | | |
|--------------|-----------|-----|--------------------------|----------------|------|------|-------|-------|------|------|----|
| | | | | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| James | 1977 | 138 | 0 | 3.62 | 55.8 | 39.1 | 0.725 | 0.725 | | | |
| | 1977 | 92 | 1 | 2.17 | 15.2 | 82.6 | | | | | |
| | 1977 | 21 | 2 | | 4.76 | 52.4 | 42.9 | | | | |
| | 1977 | 7 | 3 | | | | 85.7 | 14.3 | | | |
| | 1977 | 1 | 4 | | | | | 100 | | | |
| | 1977 | 1 | 5 | | 100 | | | | | | |
| York | 1977 | 129 | 0 | 0.775 | 52.7 | 44.2 | 2.33 | | | | |
| | 1977 | 89 | 1 | | 10.1 | 83.1 | 6.74 | | | | |
| | 1977 | 29 | 2 | | | 72.4 | 27.6 | | | | |
| | 1977 | 9 | 3 | | | | 100 | | | | |
| Rappahannock | 1965–1966 | 162 | 0 | 23.5 | 48.1 | 25.3 | 3.09 | | | | |
| | 1965–1966 | 98 | 1 | | 8.16 | 66.3 | 24.5 | 1.02 | | | |
| | 1965–1966 | 40 | 2 | | | 22.5 | 65.0 | 10.0 | 2.50 | | |
| | 1965–1966 | 17 | 3 | | | | 29.4 | 47.1 | 17.6 | 5.88 | |
| | 1965–1966 | 2 | 4 | | | | | 50.0 | 50.0 | | |
| | 1965–1966 | 1 | 5 | | | | | | | 100 | |
| | 1977 | 240 | 0 | 3.75 | 56.7 | 38.3 | 1.25 | | | | |
| | 1977 | 202 | 1 | 1.49 | 32.7 | 65.3 | 0.495 | | | | |
| | 1977 | 34 | 2 | | 2.94 | 67.6 | 29.4 | | | | |
| | 1977 | 6 | 3 | | | | 100 | | | | |

Table 15.5 Annual JAIs (geometric average number per set) of alewives and blueback herring collected from the Mattaponi and Pamunkey rivers by the VIMS Push-Net Survey, 1979–2002. The push-net survey was not conducted in 1988, 1989, and 1990.

| Year | Mattaponi River | | Pamunkey River | |
|-------------|-----------------|------------------|----------------------|----------------------|
| | Alewife | Blueback Herring | Alewife | Blueback Herring |
| 1979 | 0.6 | 9.7 | 1.3 | 31.7 |
| 1980 | 0.6 | 2.1 | 0.6 | 32.7 |
| 1981 | 1.1 | 0.6 | 1.2 | 5 |
| 1982 | 11 | 40.2 | 5.2 | 124.2 |
| 1983 | 1.5 | 2.3 | 1.3 | 28.7 |
| 1984 | 7 | 8.7 | 0.4 | 13.9 |
| 1985 | 7.2 | 27.6 | 3.1 | 25 |
| 1986 | 2.6 | 2.6 | 2.7 | 19.4 |
| 1987 | 0.3 | 2 | 0.4 | 52.2 |
| 1988 | | | | |
| 1989 | | | | |
| 1990 | | | | |
| 1991 | 0.1 | 2.1 | 0.1 | 5 |
| 1992 | 0 | 0.04 | 0 | 0.01 |
| 1993 | 0.1 | 2.2 | 0.03 | 0.8 |
| 1994 | 2.3 | 10.8 | 1.5 | 33.7 |
| 1995 | 0.02 | 0.1 | 0.01 | 2 |
| 1996 | 4 | 12.8 | 2.1 | 28.5 |
| 1997 | 1.9 | 6.5 | 0.1 | 9.8 |
| 1998 | 1.06 | 21.05 | 0.12 | 5.7 |
| 1999 | 0.63 | 7.93 | no data ¹ | no data ¹ |
| 2000 | 1.27 | 5.37 | 0.34 | 9.24 |
| 2001 | 2.23 | 5.39 | 0.66 | 5.39 |
| 2002 | 3.32 | 5.36 | 0.41 | 2.14 |

¹ Data collected from the Pamunkey River by the VIMS push-net survey in 1999 are missing or not available.

Table 15.6 Results of the Mann-Kendall test for temporal trends in relative abundance of alewives and blueback herring sampled from fishery-independent surveys. The number of years for which data were available is represented by *n*, *S* is the Mann-Kendall test statistic, and *P* is the two-tailed probability. Trend indicates the direction of the trend if a statistically significant temporal trend was detected ($\alpha = 0.05$); NS = not significant.

| Species | Life Stage | River | Survey | n | S | P | Trend |
|------------------|-------------------|--------------|----------------|----------|----------|----------|--------------|
| Alewife | Adult | James | Electrofishing | 9 | 3 | 0.831 | NS |
| | | Rappahannock | Electrofishing | 11 | 1 | 1.00 | NS |
| | | Rappahannock | Gill Net | 20 | -74 | 0.0176 | ☒ |
| | Juvenile | James | Seine | 22 | 62 | 0.0580 | NS |
| | | James | Trawl | 15 | 15 | 0.488 | NS |
| | | York | Seine | 22 | 8 | 0.828 | NS |
| | | York | Trawl | 15 | 7 | 0.767 | NS |
| | | Rappahannock | Seine | 22 | -3 | 0.955 | NS |
| | | Rappahannock | Trawl | 15 | -31 | 0.138 | NS |
| Blueback Herring | Adult | James | Electrofishing | 9 | -2 | 0.919 | NS |
| | | Rappahannock | Electrofishing | 11 | -4 | 0.813 | NS |
| | | Rappahannock | Gill Net | 20 | -141 | 5.50E-06 | ☒ |
| | Juvenile | James | Seine | 22 | -46 | 0.203 | NS |
| | | James | Trawl | 15 | -1 | 1.00 | NS |
| | | York | Seine | 22 | 8 | 0.835 | NS |
| | | York | Trawl | 15 | 1 | 1.00 | NS |
| | | Rappahannock | Seine | 22 | -34 | 0.352 | NS |
| | | Rappahannock | Trawl | 15 | 25 | 0.235 | NS |

Table 15.7 Spearman's rank-order correlation between indices of adult relative abundance for (A) alewives and (B) blueback herring. *P*-values are shown in parentheses. Values of ρ that are statistically significant are formatted in **bold** font.

(A) Alewife

| | James— Electrofishing | Rappahannock— Electrofishing |
|--|--------------------------|---------------------------------|
| Rappahannock— Electrofishing) | 0.136 (0.728) | |
| Rappahannock— Gill Net | -0.272 (0.478) | -0.0228 (0.947) |

(B) Blueback Herring

| | James— Electrofishing | Rappahannock— Electrofishing |
|--|--------------------------|---------------------------------|
| Rappahannock— Electrofishing) | 0.176 (0.651) | |
| Rappahannock— Gill Net | 0.109 (0.781) | 0.290 (0.388) |

Table 15.8 Spearman's rank-order correlation between indices of juvenile relative abundance for (A) alewives and (B) blueback herring. *P*-values are shown in parentheses. Values of ρ that are statistically significant are formatted in **bold** font.

(A) Alewife

| | James—Seine | James—Trawl | Rappahannock—Seine | Rappahannock—Trawl | York—Seine |
|---------------------------|---------------|---------------|--------------------|--------------------|------------------------|
| James—Trawl | 0.336 (0.221) | | | | |
| Rappahannock—Seine | | 0.135 (0.548) | 0.267 (0.336) | | |
| Rappahannock—Trawl | | 0.143 (0.610) | -0.329 (0.232) | 0.210 (0.453) | |
| York—Seine | | 0.106 (0.638) | -0.0302 (0.915) | 0.533 (0.107) | 0.299 (0.280) |
| York—Trawl | | 0.198 (0.479) | 0.111 (0.694) | -0.124 (0.660) | 0.161 (0.567) |
| | | | | | 0.665 (0.00680) |

(B) Blueback Herring

| | James—Seine | James—Trawl | Rappahannock—Seine | Rappahannock—Trawl | York—Seine |
|---------------------------|-------------------------|----------------|------------------------|--------------------|-----------------|
| James—Trawl | 0.397 (0.143) | | | | |
| Rappahannock—Seine | 0.712 (0.000200) | 0.445 (0.0965) | | | |
| Rappahannock—Trawl | -0.0232 (0.934) | 0.0571 (0.840) | -0.261 (0.348) | | |
| York—Seine | 0.478 (0.0246) | 0.457 (0.0865) | 0.560 (0.00670) | -0.127 (0.651) | |
| York—Trawl | -0.107 (0.704) | 0.339 (0.216) | 0.141 (0.616) | 0.368 (0.177) | -0.0572 (0.840) |

Table 15.9 Results of the Mann-Kendall test for temporal trends in sex-specific average length and weight of alewives and blueback herring sampled from commercial pound nets in the Rappahannock River. The number of years for which data were available is represented by *n*, *S* is the Mann-Kendall test statistic, and *P* is the two-tailed probability. Trend indicates the direction of the trend if a statistically significant temporal trend was detected ($\alpha = 0.05$); NS = not significant.

| Species | Data | Sex | n | S | P | Trend |
|------------------|-------------|------------|----------|----------|----------|--------------|
| Alewife | Length | Male | 26 | -90 | 0.0497 | ? |
| | | Female | 26 | -127 | 0.00548 | ? |
| | Weight | Male | 29 | -154 | 0.00409 | ? |
| | | Female | 29 | -137 | 0.0107 | ? |
| Blueback Herring | Length | Male | 23 | -99 | 0.00965 | ? |
| | | Female | 23 | -108 | 0.00470 | ? |
| | Weight | Male | 23 | -65 | 0.0908 | NS |
| | | Female | 25 | -69 | 0.112 | NS |

Table 15.10 Calculated sex ratios (male: female), sample sizes (n), χ^2 values (Yate's corrected), and probabilities (P) that the sex ratio for alewives is 1:1 based on historical sampling of the commercial fishery. Statistically significant sex ratios are formatted in bold.

| Water Body | Year | n | Sex Ratio | χ^2 | P |
|--------------|------|-------|-------------|----------|---------|
| James | 1967 | 372 | 3.2 | 102 | < 0.001 |
| | 1968 | 400 | 1.1 | 0.723 | 0.395 |
| | 1969 | 344 | 1.2 | 3.56 | 0.0592 |
| | 1970 | 367 | 3.4 | 107 | < 0.001 |
| | 1974 | 551 | 3.9 | 191 | < 0.001 |
| | 1975 | 459 | 3.1 | 119 | < 0.001 |
| | 1977 | 189 | 2.4 | 30.6 | < 0.001 |
| | 1978 | 148 | 1.9 | 13.7 | < 0.001 |
| | 1979 | 112 | 2.0 | 12.2 | < 0.001 |
| | 1980 | 151 | 1.5 | 5.96 | 0.0146 |
| York | 1967 | 424 | 1.6 | 23.1 | < 0.001 |
| | 1969 | 312 | 0.82 | 2.70 | 0.101 |
| | 1970 | 415 | 0.80 | 5.10 | 0.0239 |
| | 1974 | 139 | 1.6 | 6.47 | 0.0109 |
| | 1975 | 211 | 1.2 | 1.54 | 0.215 |
| | 1976 | 280 | 0.84 | 1.89 | 0.169 |
| | 1977 | 291 | 1.2 | 3.09 | 0.0786 |
| | 1978 | 203 | 1.3 | 3.33 | 0.0680 |
| | 1979 | 48 | 0.78 | 0.521 | 0.470 |
| | 1980 | 114 | 0.87 | 0.430 | 0.512 |
| | 1981 | 89 | 0.59 | 5.44 | 0.0197 |
| | 1982 | 78 | 0.95 | 0.0128 | 0.910 |
| | 1983 | 84 | 0.68 | 2.68 | 0.102 |
| | 1984 | 82 | 0.64 | 3.52 | 0.0605 |
| | 1985 | 352 | 1.0 | 0.0256 | 0.873 |
| Rappahannock | 1974 | 369 | 1.2 | 3.91 | 0.0479 |
| | 1975 | 1,206 | 1.0 | 0.000829 | 0.977 |
| | 1976 | 1,537 | 1.2 | 7.87 | 0.00502 |
| | 1977 | 1,171 | 1.4 | 34.8 | < 0.001 |
| | 1978 | 425 | 1.3 | 7.92 | 0.00490 |
| | 1979 | 309 | 0.94 | 0.207 | 0.649 |
| | 1980 | 202 | 1.1 | 0.401 | 0.527 |
| | 1981 | 85 | 0.55 | 6.78 | 0.00924 |
| | 1982 | 151 | 1.8 | 12.8 | < 0.001 |
| | 1983 | 897 | 0.86 | 4.86 | 0.0275 |
| | 1984 | 567 | 1.0 | 0.0635 | 0.801 |
| | 1985 | 738 | 1.2 | 8.03 | 0.00459 |
| | 1986 | 431 | 0.99 | 0.00928 | 0.923 |
| | 1987 | 390 | 0.96 | 0.126 | 0.723 |
| | 1988 | 241 | 0.79 | 3.25 | 0.0713 |

Table 15.11 Calculated sex ratios (male: female), sample sizes (n), χ^2 values (Yate's corrected), and probabilities (P) that the sex ratio for blueback herring is 1:1 based on historical sampling of the commercial fishery. Statistically significant sex ratios are formatted in bold.

| Water Body | Year | n | Sex Ratio | χ^2 | P |
|--------------|------|-------|-------------|----------|---------|
| James | 1967 | 291 | 2.4 | 49.5 | < 0.001 |
| | 1968 | 318 | 2.2 | 46.0 | < 0.001 |
| | 1969 | 241 | 2.3 | 35.1 | < 0.001 |
| | 1970 | 177 | 5.1 | 78.7 | < 0.001 |
| | 1974 | 224 | 1.2 | 1.61 | 0.204 |
| | 1975 | 682 | 1.9 | 61.6 | < 0.001 |
| | 1977 | 586 | 1.7 | 36.9 | < 0.001 |
| | 1978 | 223 | 1.5 | 9.49 | 0.00207 |
| | 1979 | 245 | 1.3 | 4.18 | 0.0409 |
| | 1980 | 247 | 1.8 | 21.0 | < 0.001 |
| York | 1967 | 332 | 1.3 | 5.06 | 0.0244 |
| | 1969 | 193 | 1.4 | 4.66 | 0.0308 |
| | 1970 | 19 | 0.90 | 0 | 1.00 |
| | 1974 | 171 | 0.99 | 0 | 1.00 |
| | 1975 | 546 | 1.6 | 28.6 | < 0.001 |
| | 1976 | 206 | 0.82 | 1.75 | 0.186 |
| | 1977 | 777 | 1.3 | 15.6 | < 0.001 |
| | 1978 | 726 | 1.1 | 2.10 | 0.148 |
| | 1979 | 436 | 1.1 | 0.828 | 0.363 |
| | 1980 | 577 | 1.1 | 1.56 | 0.212 |
| | 1981 | 1,205 | 0.93 | 1.46 | 0.226 |
| | 1982 | 708 | 1.7 | 47.3 | < 0.001 |
| | 1983 | 826 | 0.93 | 1.02 | 0.313 |
| | 1984 | 827 | 0.58 | 58.5 | < 0.001 |
| | 1985 | 680 | 1.1 | 0.649 | 0.421 |
| Rappahannock | 1986 | 881 | 0.78 | 13.2 | < 0.001 |
| | 1987 | 515 | 1.1 | 0.280 | 0.597 |
| | 1988 | 402 | 0.86 | 2.09 | 0.148 |
| | 1974 | 489 | 1.9 | 47.2 | < 0.001 |
| | 1975 | 1,300 | 1.2 | 13.6 | < 0.001 |
| | 1976 | 2,087 | 1.5 | 90.3 | < 0.001 |
| | 1977 | 1,846 | 1.3 | 25.0 | < 0.001 |
| | 1978 | 1,341 | 0.84 | 10.4 | 0.00127 |
| | 1979 | 963 | 1.5 | 35.2 | < 0.001 |
| | 1981 | 789 | 0.83 | 6.57 | 0.0104 |
| | 1980 | 759 | 0.94 | 0.638 | 0.425 |
| | 1982 | 766 | 2.0 | 84.9 | < 0.001 |
| | 1983 | 520 | 1.1 | 2.09 | 0.148 |
| | 1984 | 622 | 1.1 | 1.75 | 0.186 |
| | 1985 | 682 | 1.3 | 13.8 | < 0.001 |
| | 1986 | 523 | 1.3 | 7.35 | 0.00671 |
| | 1987 | 295 | 1.1 | 0.488 | 0.485 |
| | 1988 | 328 | 0.73 | 7.93 | 0.00486 |

Table 15.12 Estimated rates of repeat spawning for male and female alewives sampled from the commercial fishery in the James and York rivers.

| Water Body | Year | Males | | | Females | | |
|------------|------|-------|---------|-----------|---------|---------|-----------|
| | | Total | Repeats | % Repeats | Total | Repeats | % Repeats |
| James | 1967 | 284 | 185 | 65.1 | 88 | 46 | 52.3 |
| | 1968 | 209 | 145 | 69.4 | 191 | 127 | 66.5 |
| | 1969 | 190 | 134 | 70.5 | 154 | 128 | 83.1 |
| | 1970 | 283 | 141 | 49.8 | 84 | 35 | 41.7 |
| York | 1967 | 262 | 134 | 51.1 | 162 | 92 | 56.8 |
| | 1969 | 141 | 98 | 69.5 | 171 | 135 | 78.9 |
| | 1970 | 184 | 84 | 45.7 | 231 | 123 | 53.2 |

Table 15.13 Estimated rates of repeat spawning for male and female blueback herring sampled from the commercial fishery in the James and York rivers.

| Water Body | Year | Males | | | Females | | |
|------------|------|-------|---------|-----------|---------|---------|-----------|
| | | Total | Repeats | % Repeats | Total | Repeats | % Repeats |
| James | 1967 | 206 | 115 | 55.8 | 85 | 28 | 32.9 |
| | 1968 | 220 | 130 | 59.1 | 98 | 36 | 36.7 |
| | 1969 | 167 | 137 | 82.0 | 74 | 54 | 73.0 |
| | 1970 | 148 | 53 | 35.8 | 29 | 12 | 41.4 |
| York | 1967 | 187 | 117 | 62.6 | 145 | 84 | 57.9 |
| | 1969 | 112 | 79 | 70.5 | 81 | 58 | 71.6 |
| | 1970 | 9 | 6 | 66.7 | 10 | 5 | 50.0 |

Table 15.14 Catch curve estimates of instantaneous total mortality (Z) for alewives sampled from commercial harvest in the James, York, and Rappahannock rivers.

| Water Body | Structure | Year | Z | SE[Z] |
|--------------|-----------|------|-------|-----------|
| James | Scale | 1974 | 0.846 | 0.0373 |
| | | 1975 | 1.38 | 0.0748 |
| | | 1978 | 0.502 | 0.0492 |
| | Otolith | 1979 | 1.04 | 0.162 |
| | | 1980 | 0.894 | 0.0896 |
| York | Scale | 1974 | 1.18 | 0.107 |
| | | 1975 | 1.26 | 0.102 |
| | | 1978 | 0.539 | 0.0593 |
| | Otolith | 1979 | 1.23 | 0.246 |
| | | 1980 | 0.934 | 0.105 |
| | | 1981 | 0.804 | 0.109 |
| | | 1982 | 1.16 | 0.147 |
| | | 1983 | 0.834 | 0.101 |
| | | 1984 | 0.728 | 0.0956 |
| | | 1985 | 0.791 | 0.0624 |
| | | 1986 | 0.437 | 0.0531 |
| | | 1987 | 0.488 | 0.0661 |
| | | 1988 | 0.527 | 0.0561 |
| Rappahannock | Scale | 1974 | 1.02 | 0.0558 |
| | | 1975 | 1.83 | 0.0718 |
| | | 1978 | 0.487 | 0.0291 |
| | Otolith | 1979 | 1.04 | 0.0917 |
| | | 1980 | 1.05 | 0.0892 |
| | | 1981 | 1.09 | 0.152 |
| | | 1982 | 1.42 | 0.132 |
| | | 1983 | 1.02 | 0.0506 |
| | | 1984 | 0.970 | 0.0612 |
| | | 1985 | 0.799 | 0.0460 |
| | | 1987 | 0.511 | 0.0364 |
| | | 1988 | 0.507 | 0.0461 |

Table 15.15 Catch curve estimates of instantaneous total mortality (Z) for blueback herring sampled from commercial harvest in the James, York, and Rappahannock rivers.

| Water Body | Structure | Year | Z | SE[Z] |
|--------------|-----------|------|-------|-----------|
| James | Scale | 1974 | 0.758 | 0.0546 |
| | | 1975 | 1.60 | 0.0845 |
| | | 1978 | 0.355 | 0.0326 |
| | Otolith | 1979 | 0.768 | 0.0745 |
| | | 1980 | 0.677 | 0.0631 |
| York | Scale | 1974 | 2.04 | 0.187 |
| | | 1975 | 1.31 | 0.0774 |
| | | 1978 | 0.441 | 0.0224 |
| | Otolith | 1979 | 0.958 | 0.0698 |
| | | 1980 | 0.849 | 0.0650 |
| | | 1981 | 0.674 | 0.0374 |
| | | 1982 | 0.777 | 0.0465 |
| | | 1983 | 0.481 | 0.0236 |
| | | 1984 | 0.448 | 0.0286 |
| | | 1985 | 0.419 | 0.0210 |
| | | 1987 | 0.324 | 0.0280 |
| | | 1988 | 0.428 | 0.0376 |
| | Scale | 1974 | 0.767 | 0.0360 |
| | | 1975 | 1.95 | 0.0816 |
| | | 1978 | 0.410 | 0.0137 |
| Rappahannock | Otolith | 1979 | 1.00 | 0.0536 |
| | | 1980 | 0.667 | 0.0383 |
| | | 1981 | 0.775 | 0.0410 |
| | | 1982 | 0.888 | 0.0538 |
| | | 1983 | 0.886 | 0.0607 |
| | | 1984 | 0.681 | 0.0452 |
| | | 1985 | 0.445 | 0.0256 |
| | | 1986 | 0.420 | 0.0289 |
| | | 1987 | 0.459 | 0.0381 |
| | Scale | 1988 | 0.461 | 0.0438 |

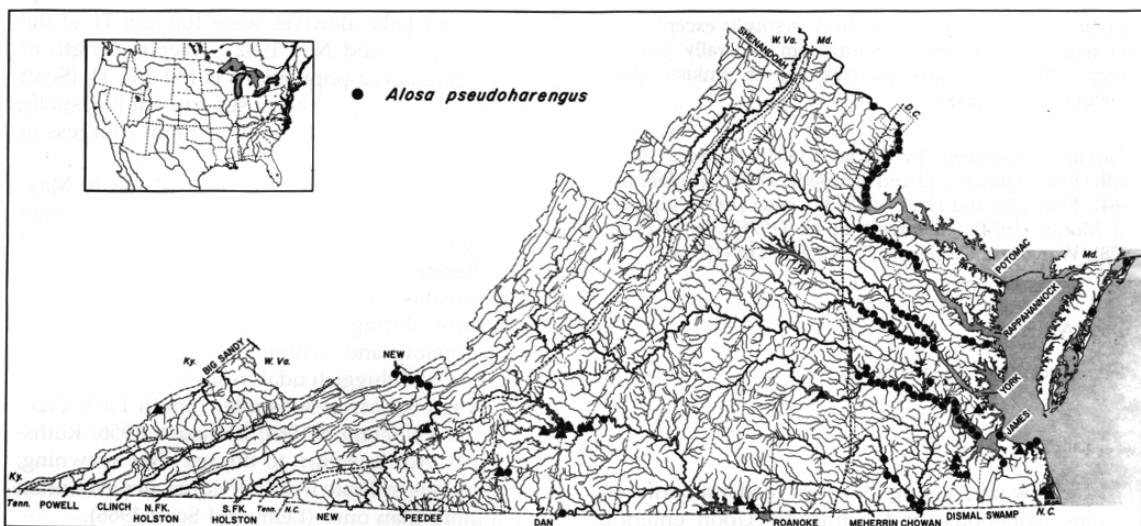
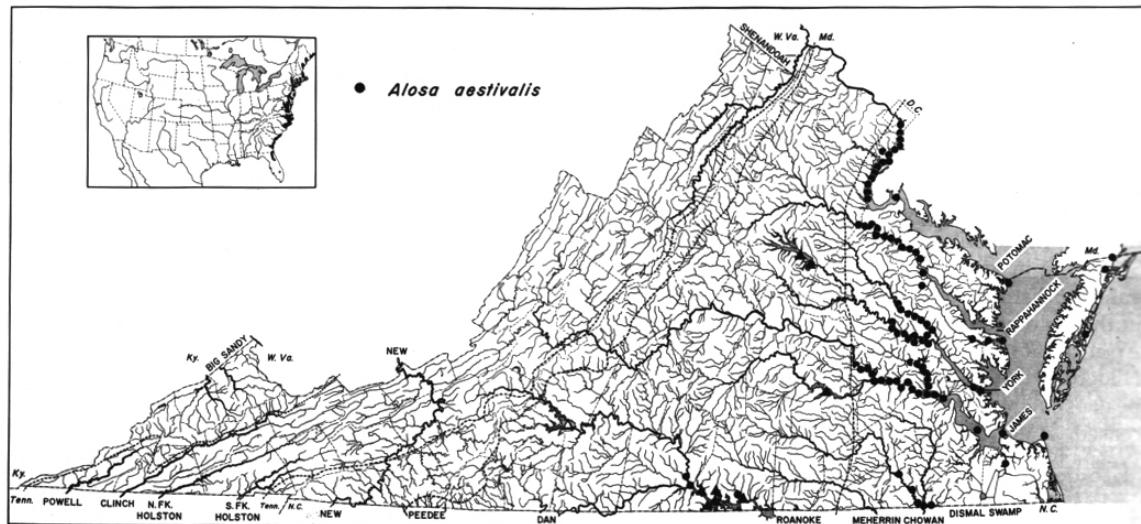


Figure 15.1 Distribution of blueback herring (top) and alewife (bottom) in Virginia. From Lee et al. 1980.

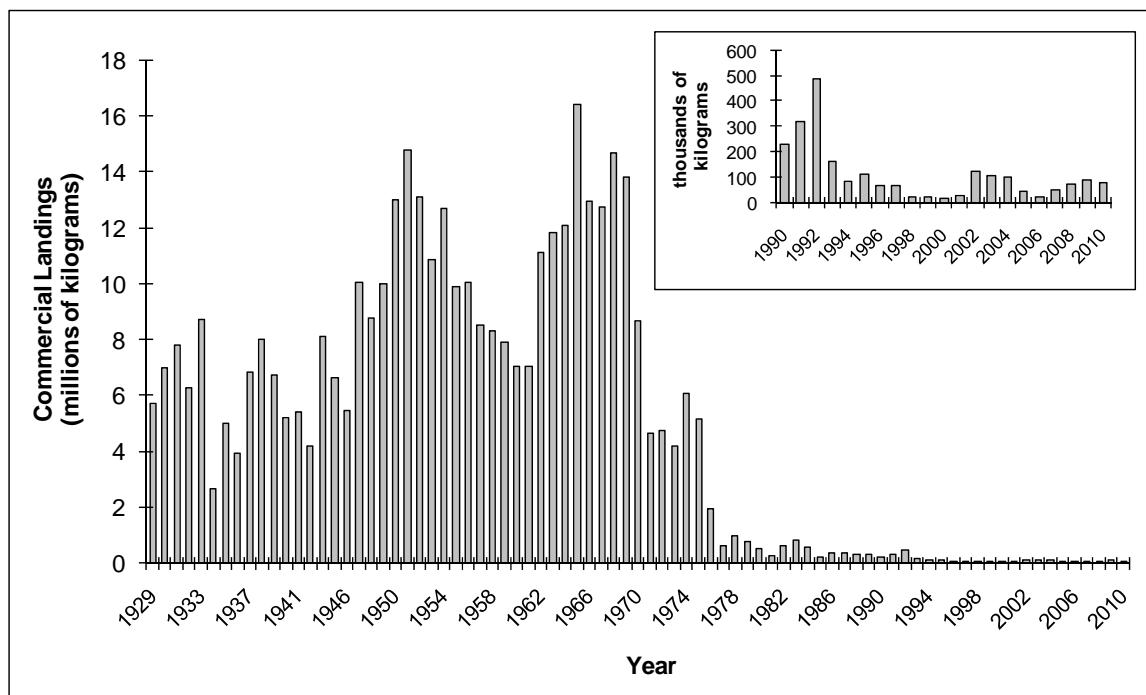


Figure 15.2 Annual commercial landings (millions of kilograms) of river herring in Virginia, 1929–2010. Inset depicts annual commercial landings (thousands of kilograms) during 1990 through 2010.

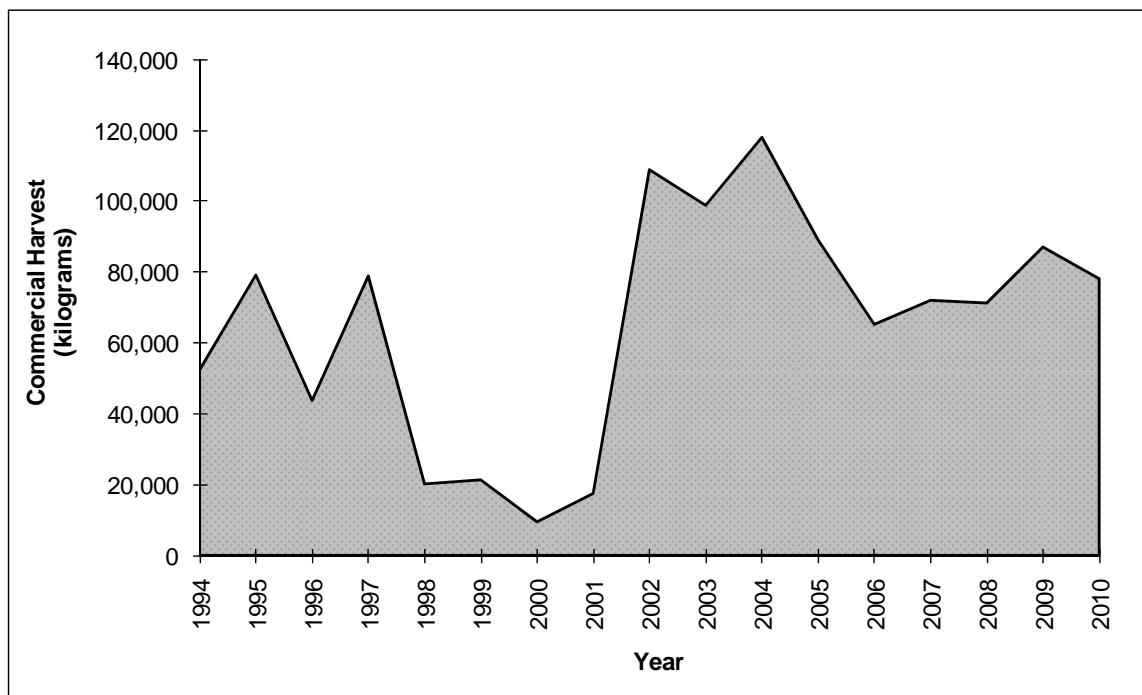


Figure 15.3 Annual commercial harvest (kilograms) of river herring from Virginia waters, 1994–2010.

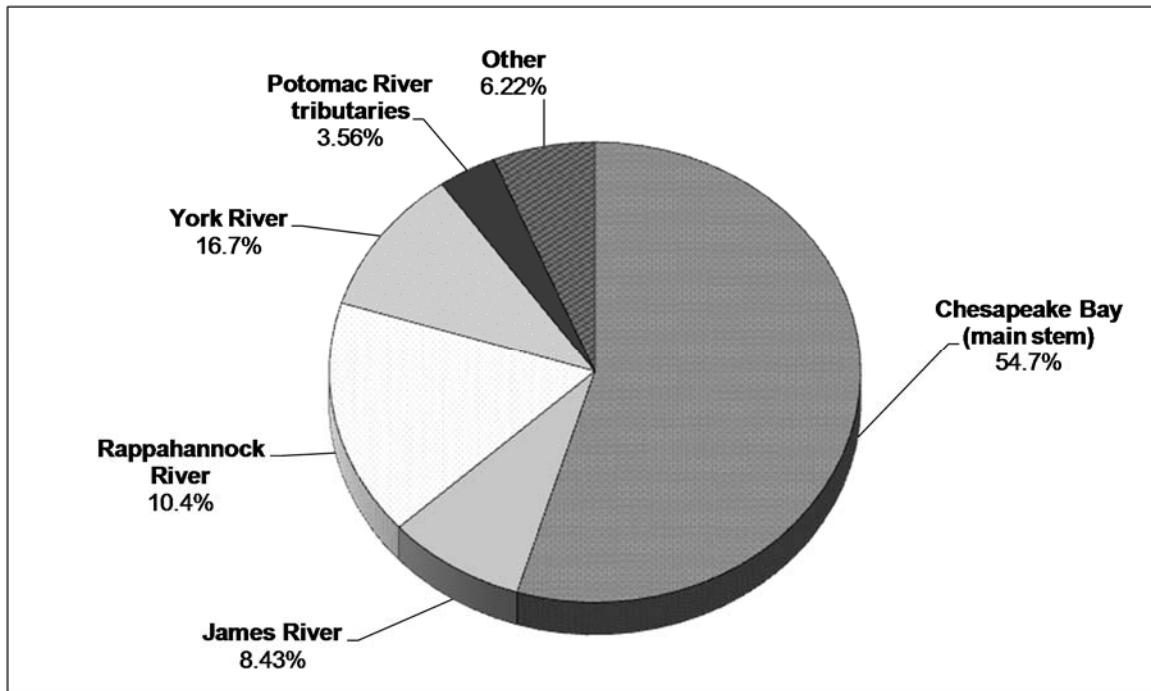


Figure 15.4 Commercial harvest (% of total kilograms) of river herring from Virginia waters, by harvest area, based on 1994–2010 average.

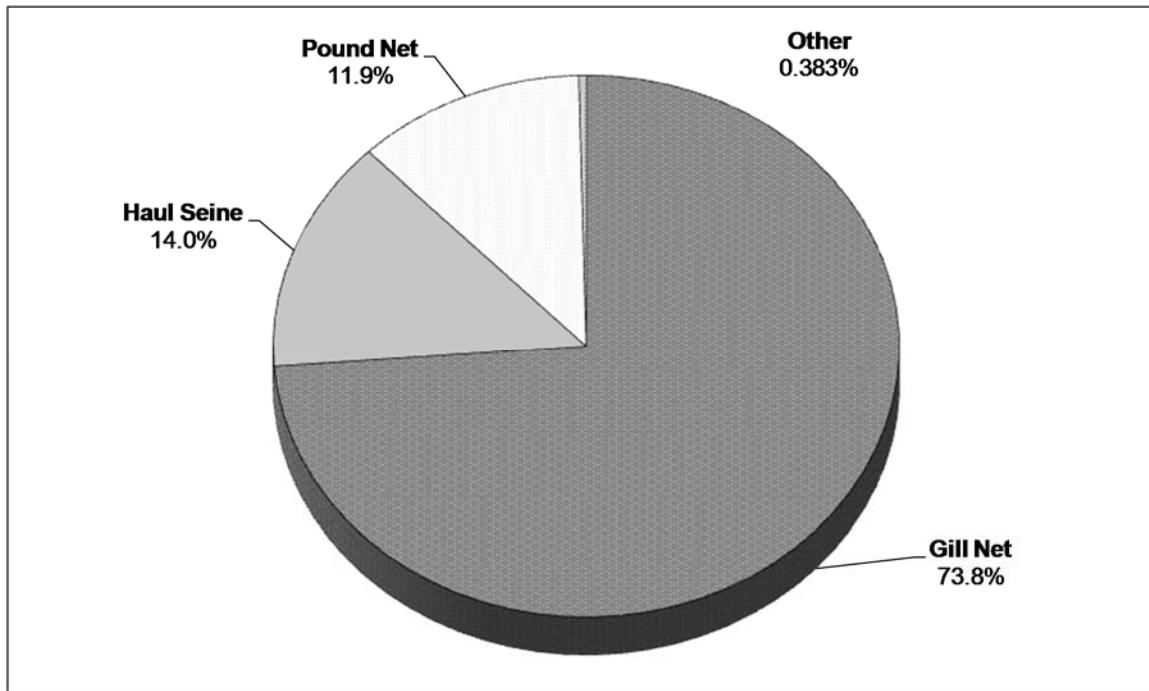


Figure 15.5 Commercial harvest (% of total kilograms) of river herring from Virginia waters, by major gear, based on 1994–2010 average.

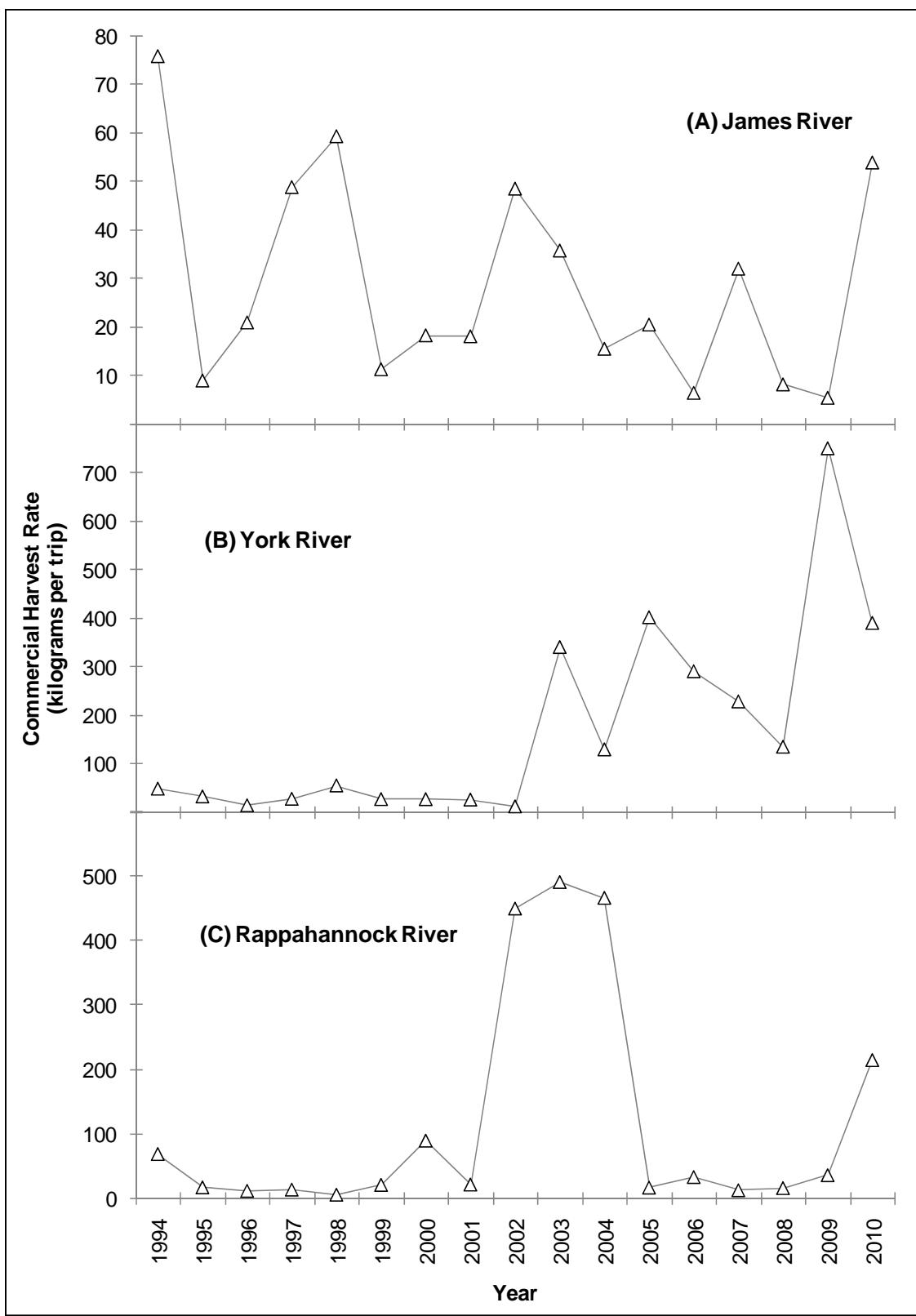


Figure 15.6 Annual commercial harvest rates (kilograms per trip) for alewives harvested by gill nets from the (A) James, (B) York, and (C) Rappahannock rivers, 1994–2010.

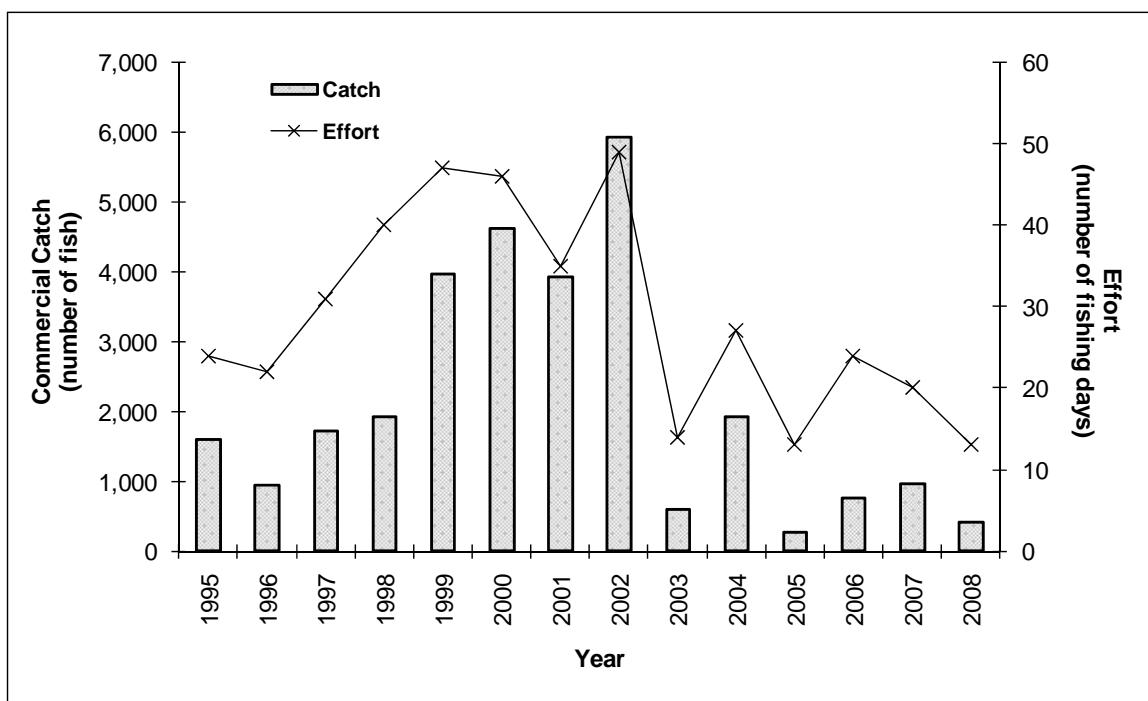


Figure 15.7 Annual commercial catch (number of fish) of river herring and effort (number of fishing days) in the upper Rappahannock River recorded in commercial logbooks, 1995–2008.

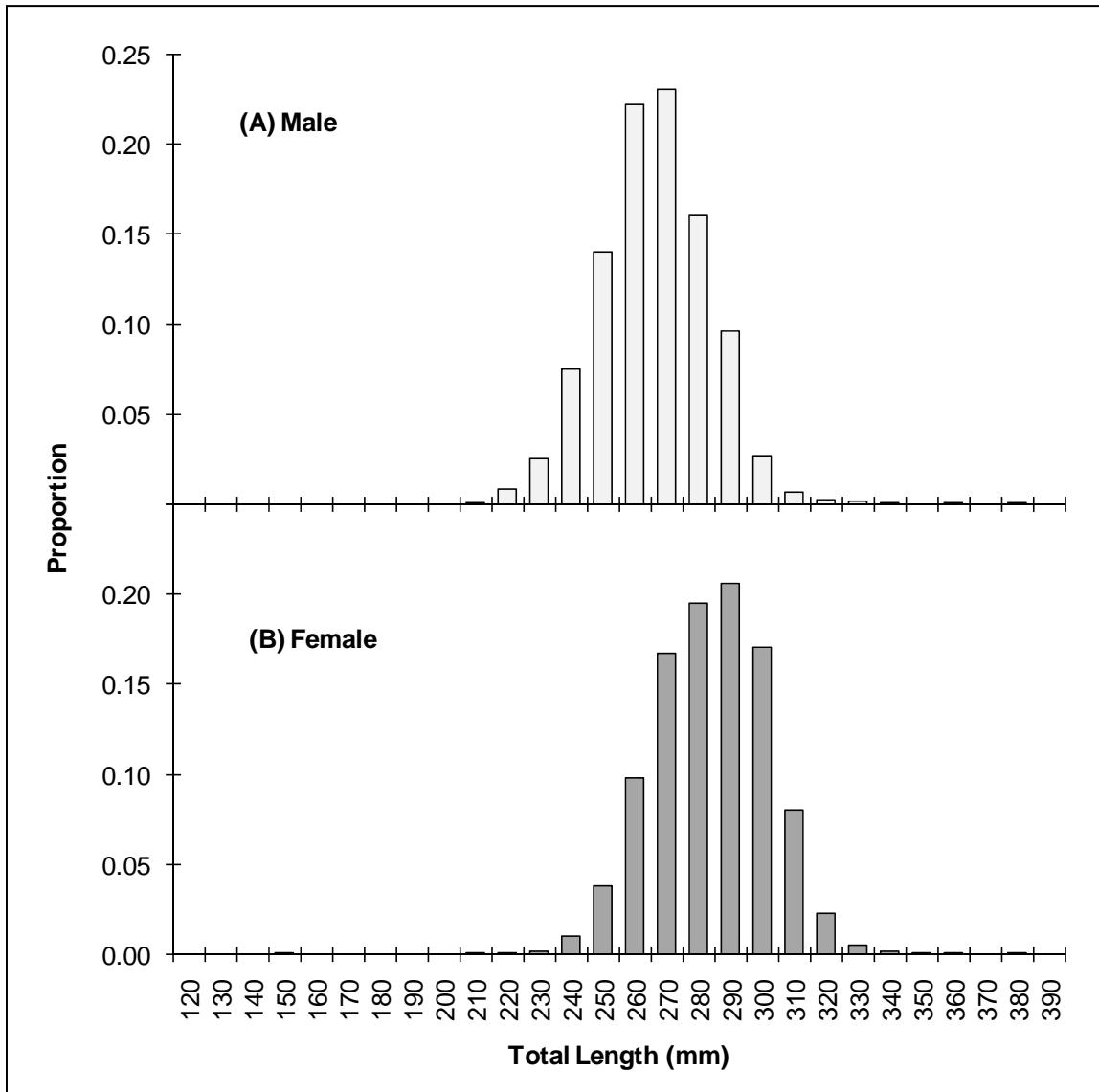


Figure 15.8 Proportion of commercial fishery samples at total length for (A) male and (B) female alewives pooled over gears, water bodies, and years, 1989–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

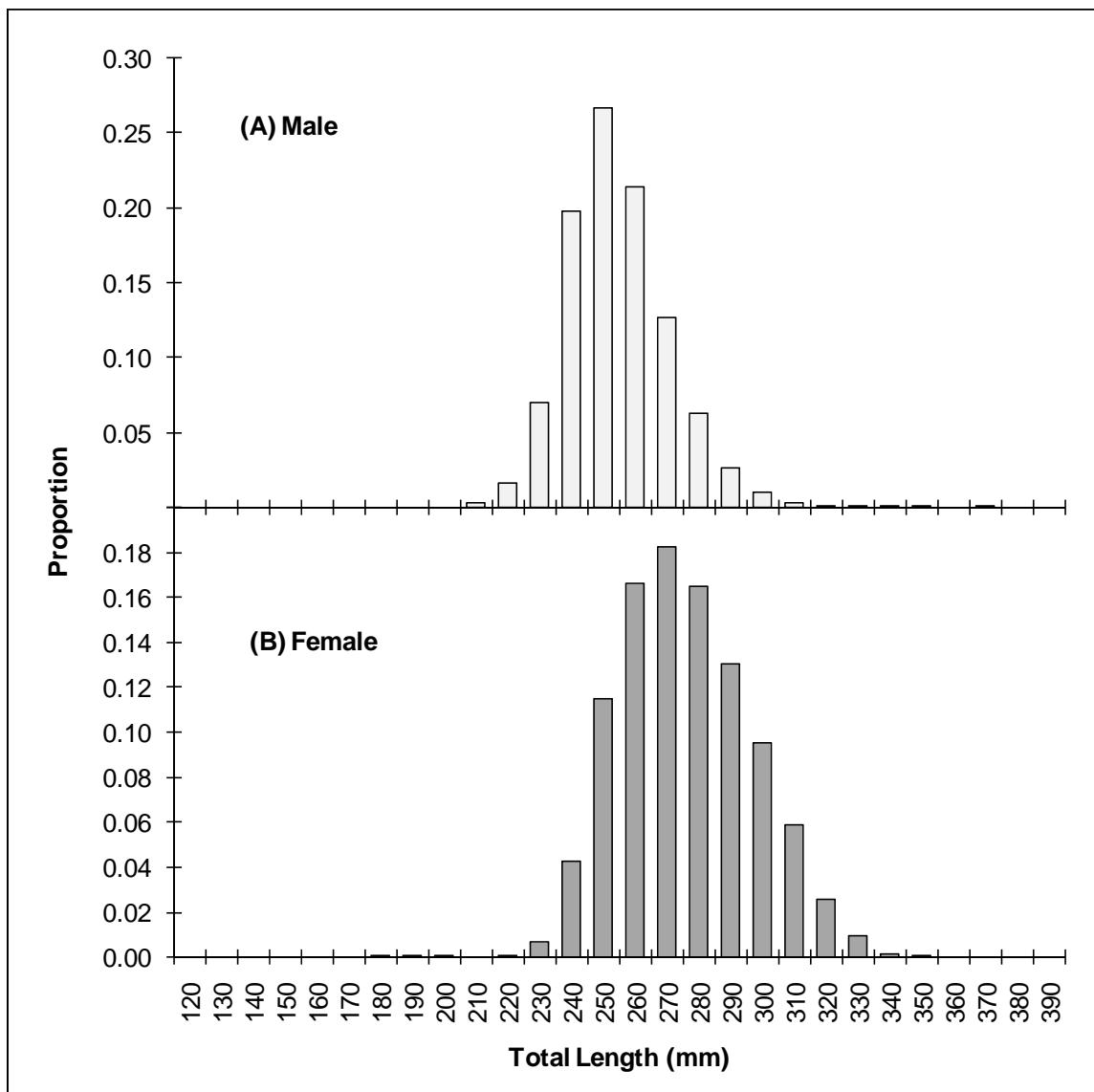


Figure 15.9 Proportion of commercial fishery samples at total length for (A) male and (B) female blueback herring pooled over gears, water bodies, and years, 1989–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

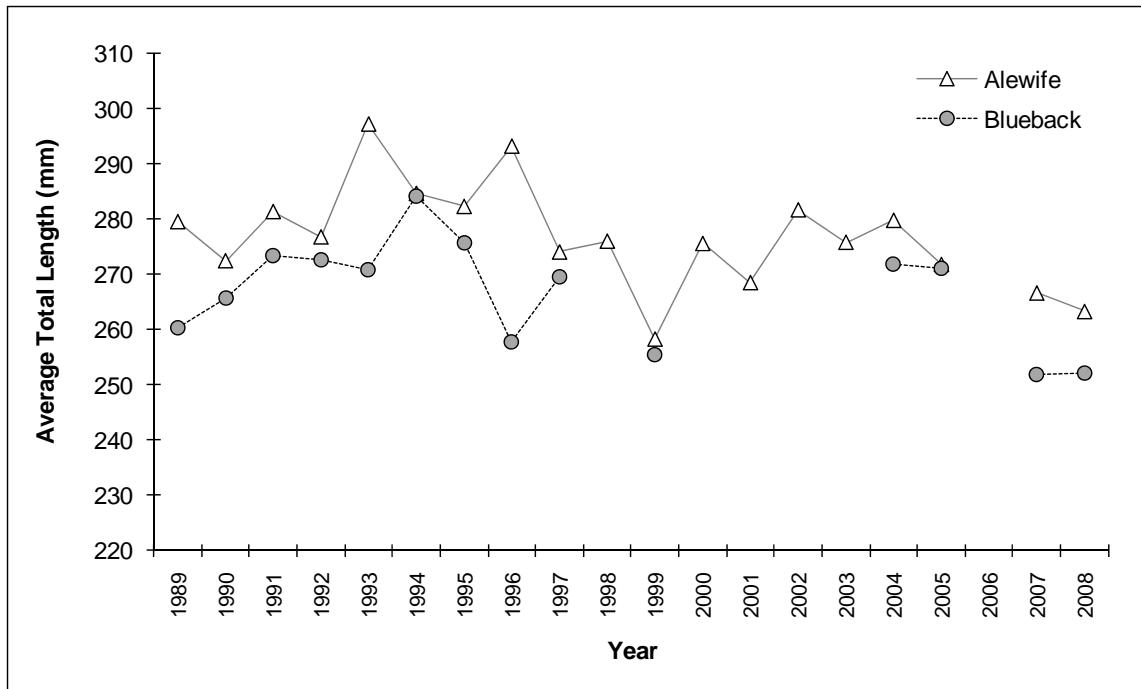


Figure 15.10 Average total length (mm) of alewives and blueback herring sampled from Virginia's commercial landings, 1989–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

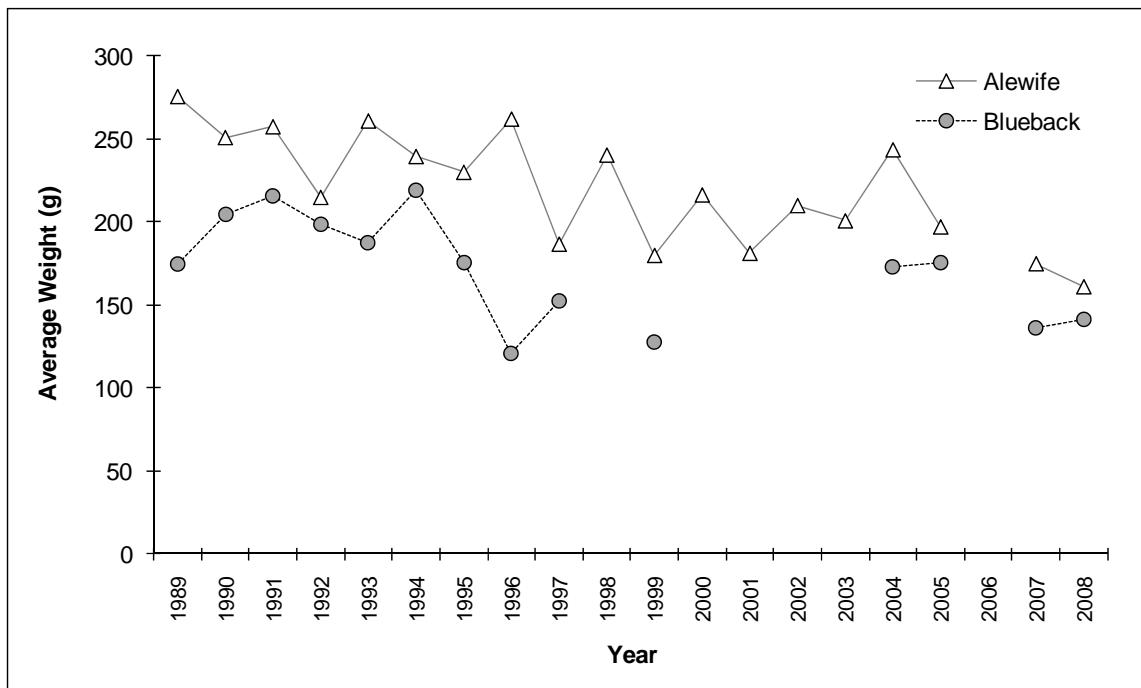


Figure 15.11 Average weight (g) of alewives and blueback herring sampled from Virginia's commercial landings, 1989–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

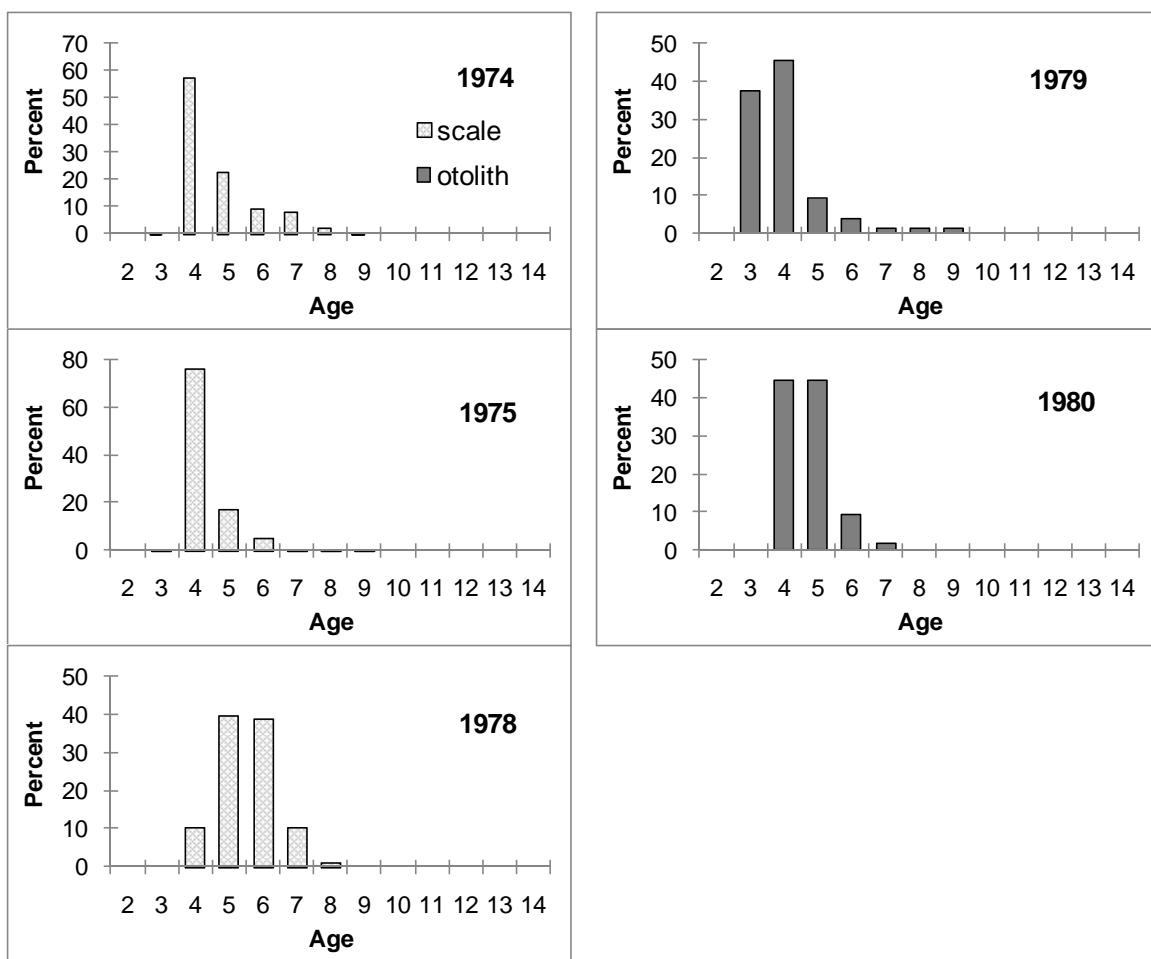


Figure 15.12 Percent at age for alewives sampled from commercial harvest in the James River, 1974–1980.

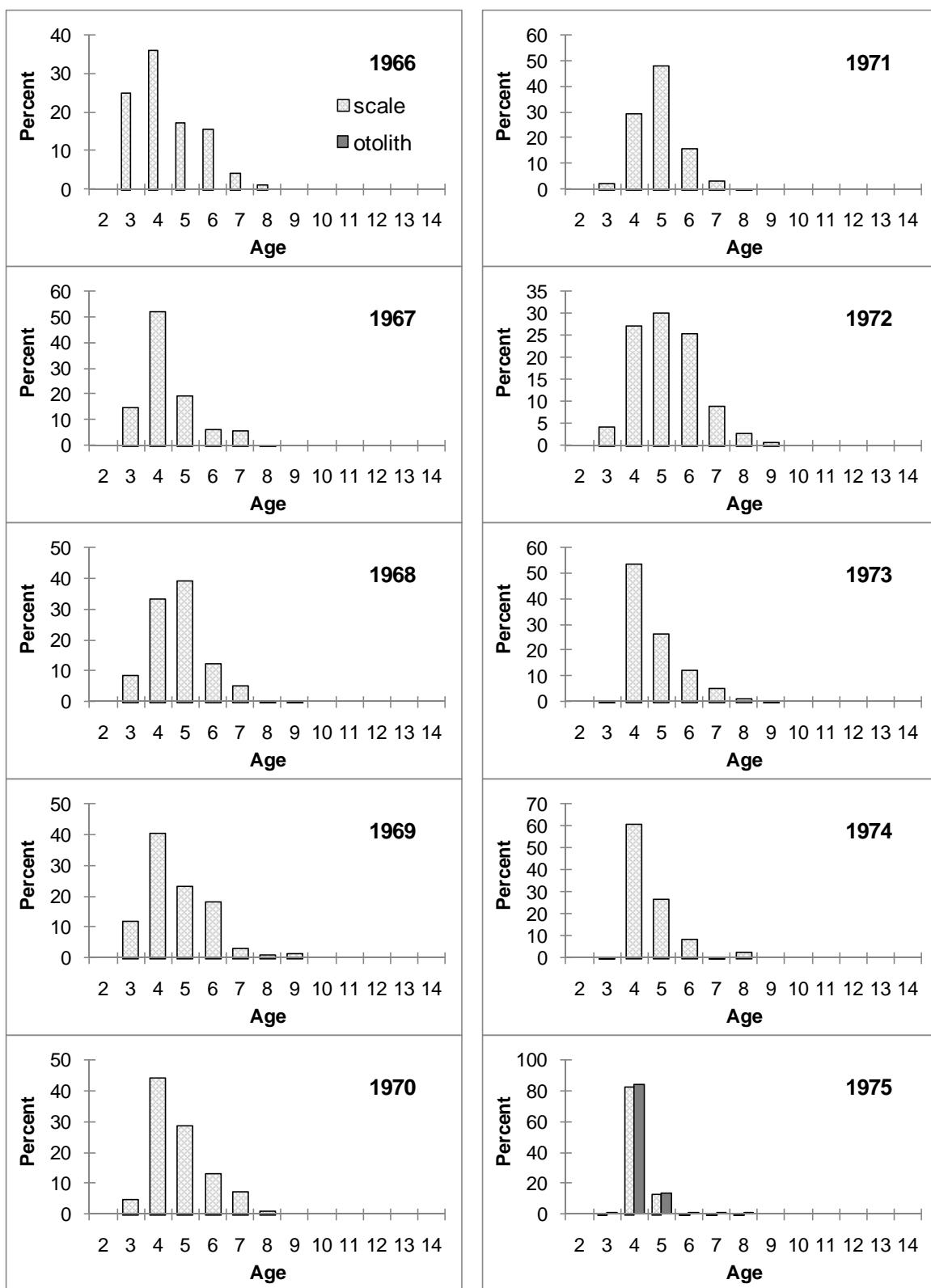


Figure 15.13 Percent at age for alewives sampled from commercial harvest in the Rappahannock River, 1966–1988.

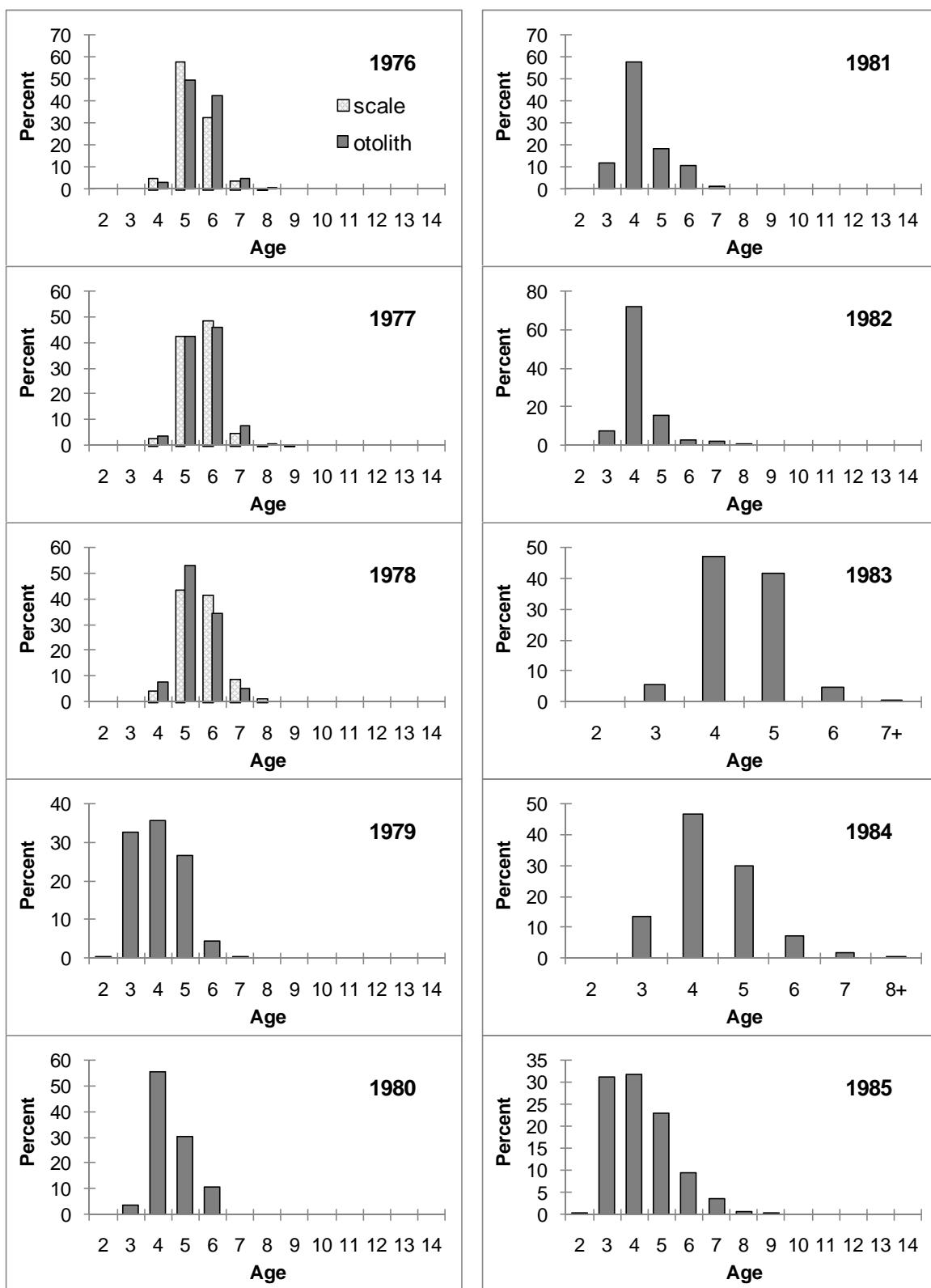


Figure 15.13. Continued.

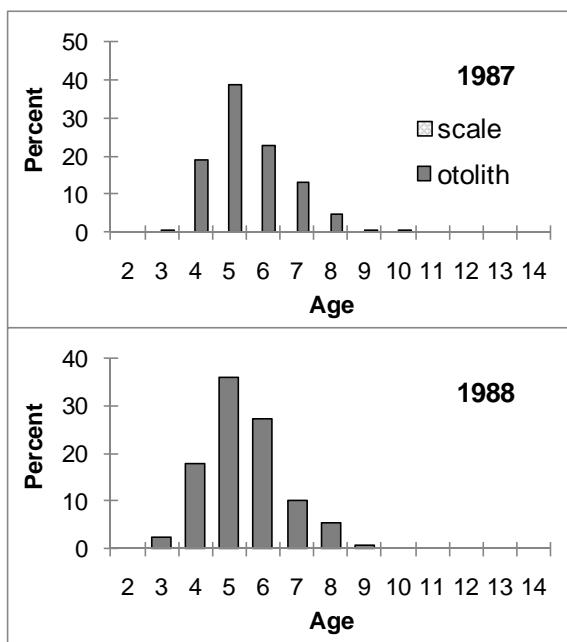


Figure 15.13. Continued.

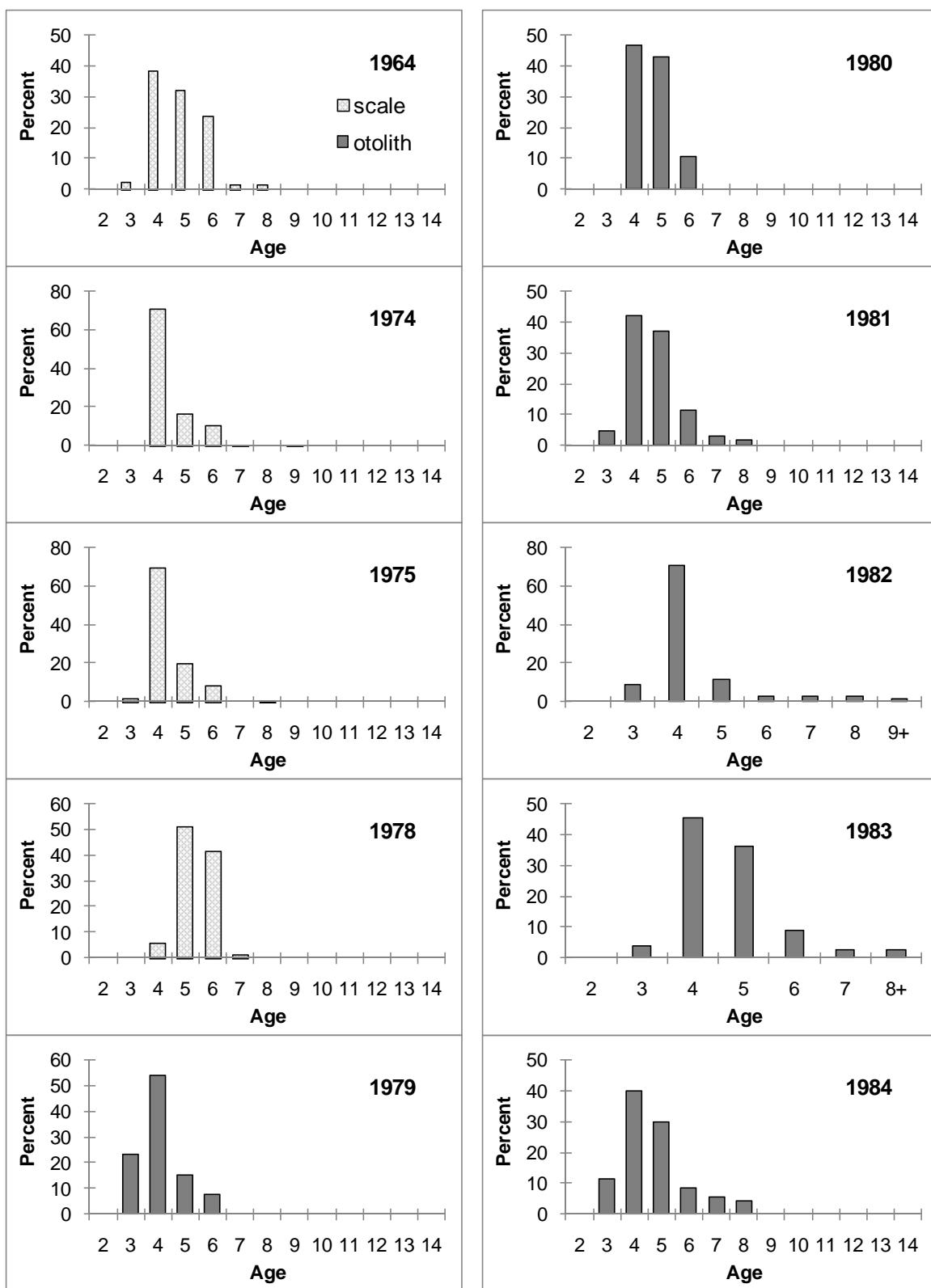


Figure 15.14 Percent at age for alewives sampled from commercial harvest in the York River, 1964–1988.

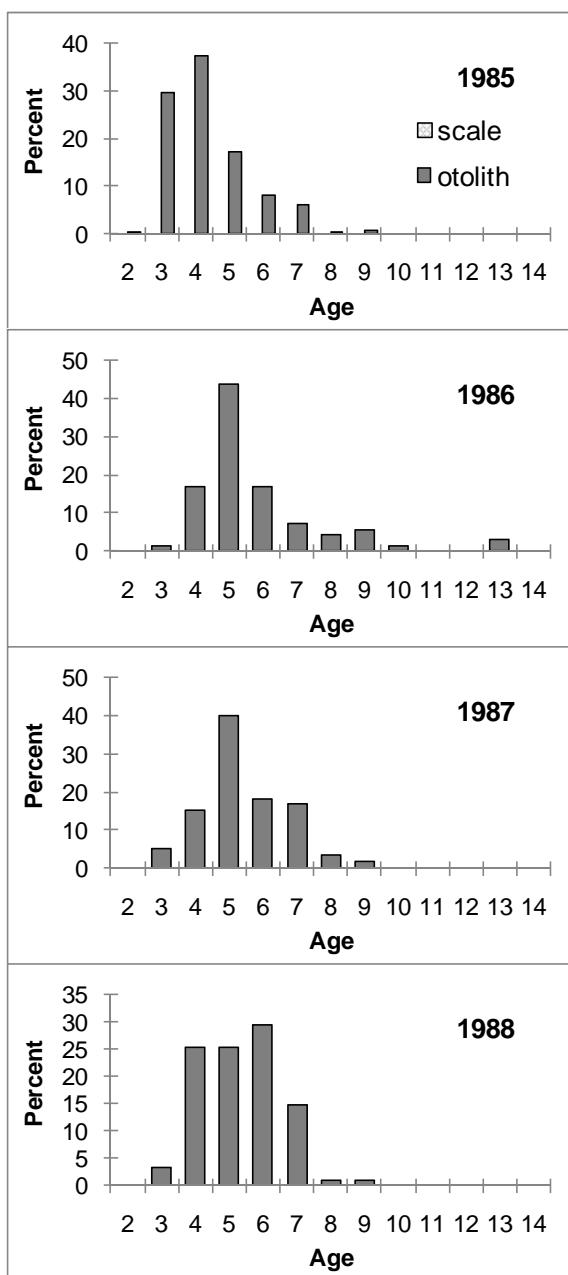


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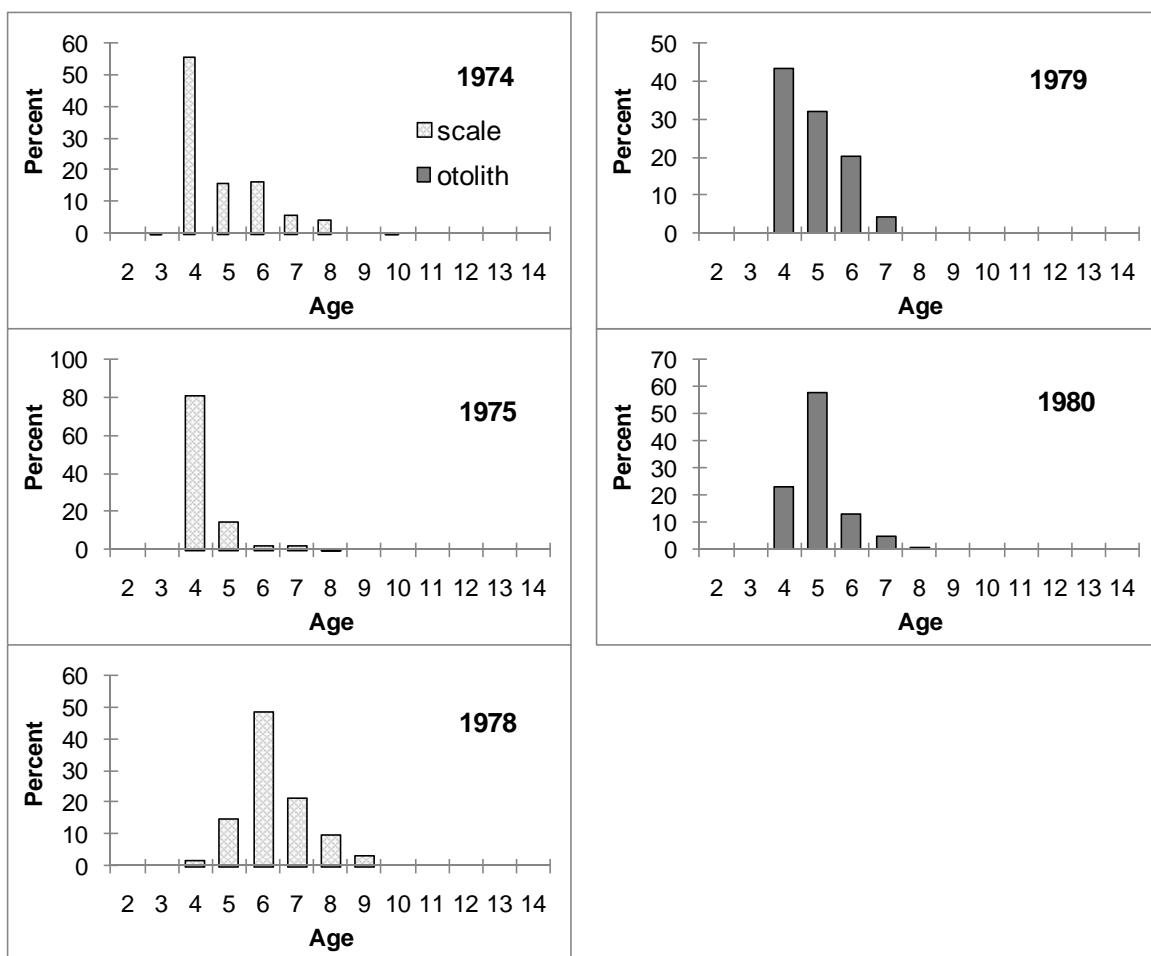


Figure 15.15 Percent at age for blueback herring sampled from commercial harvest in the James River, 1974–1980.

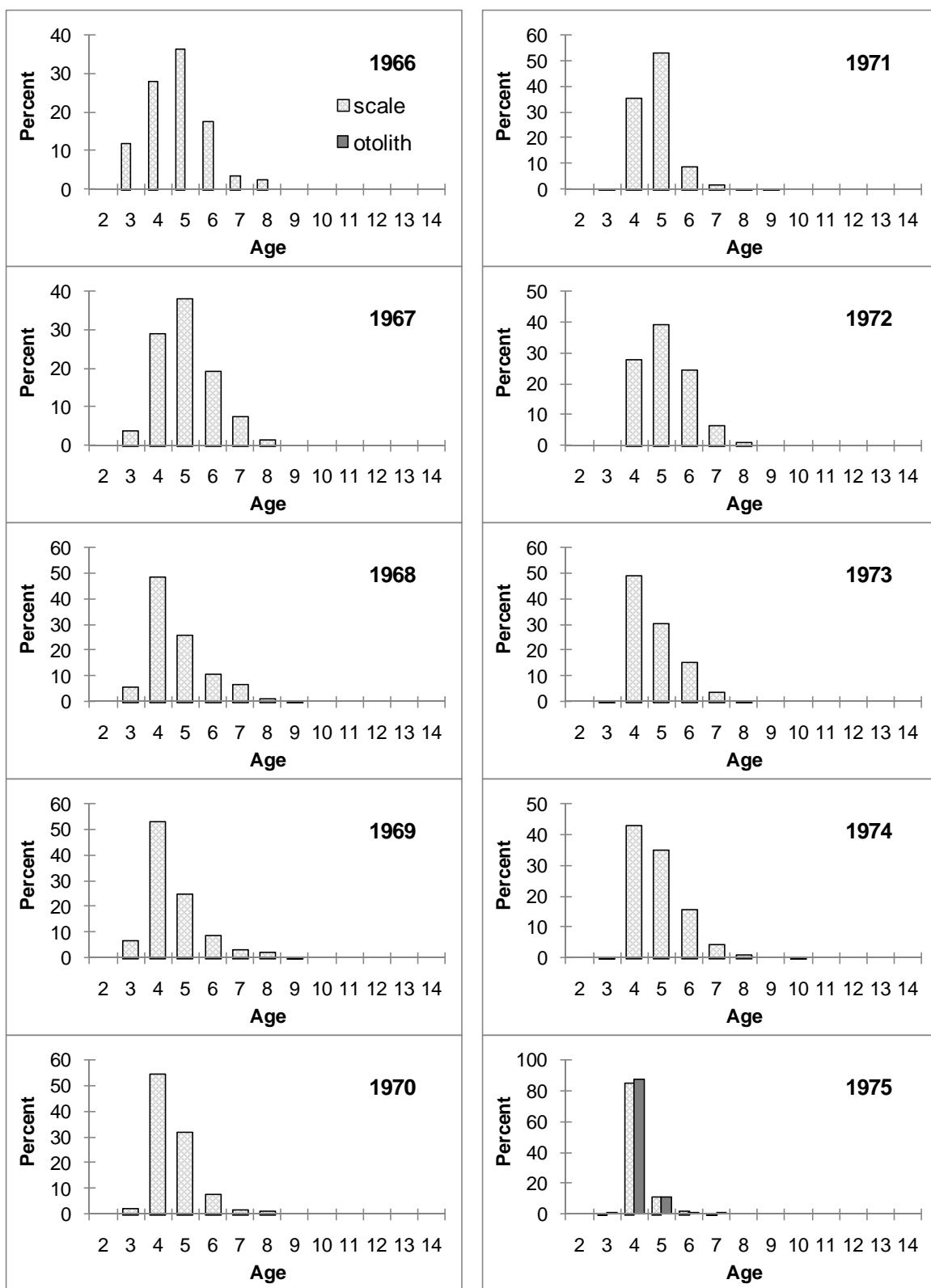


Figure 15.16 Percent at age for blueback herring sampled from commercial harvest in the Rappahannock River, 1966–1988.

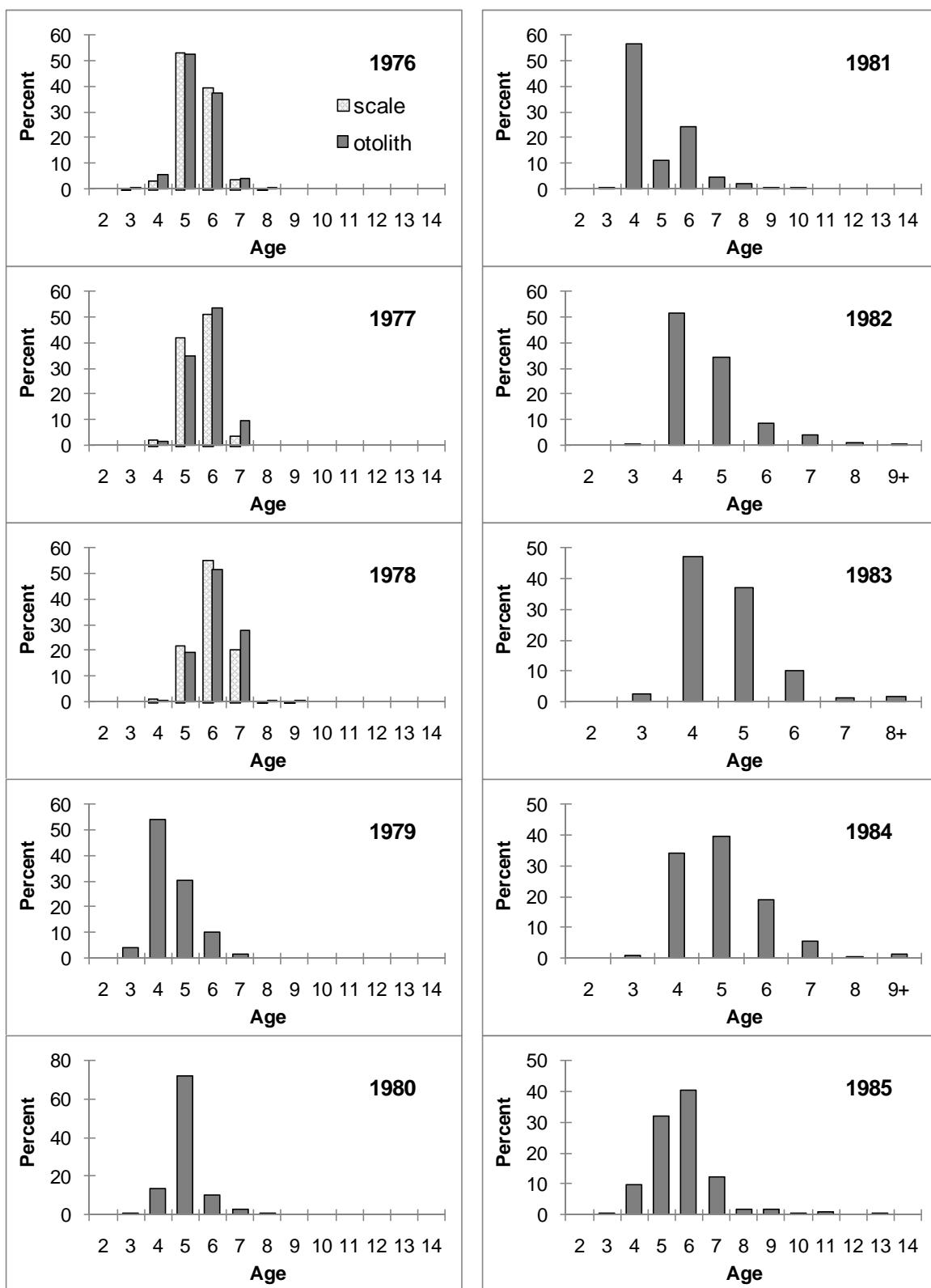


Figure 15.16. Continued.

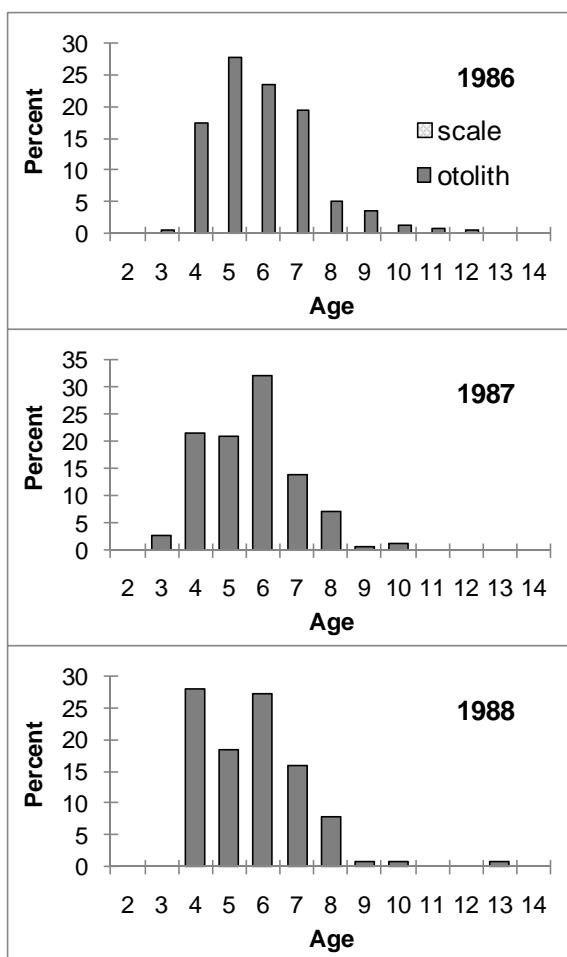


Figure 15.17 Percent at age for blueback herring sampled from commercial harvest in the York River, 1974–1988.

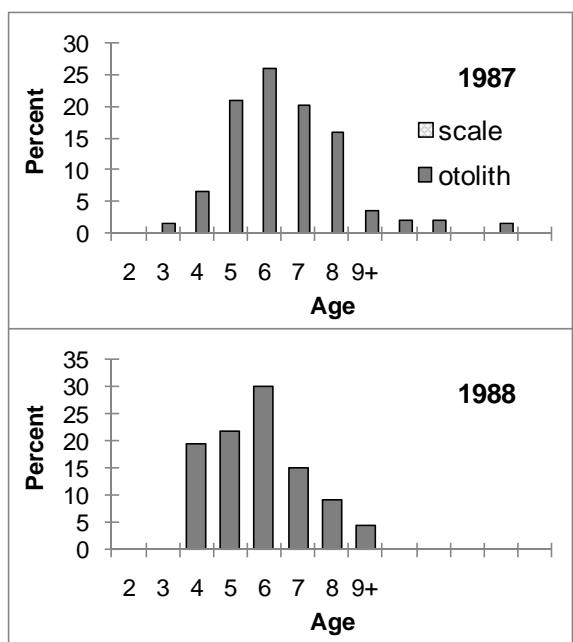


Figure 15.17. Continued.

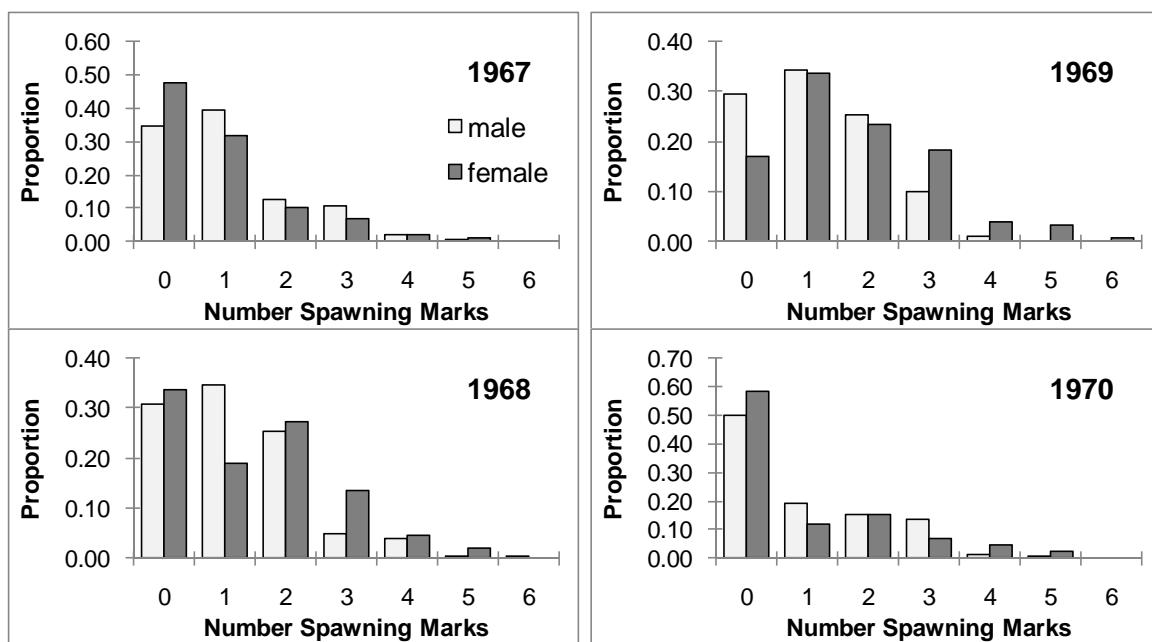


Figure 15.18 Spawning frequency of alewives sampled from commercial harvest in the James River, 1967–1970.

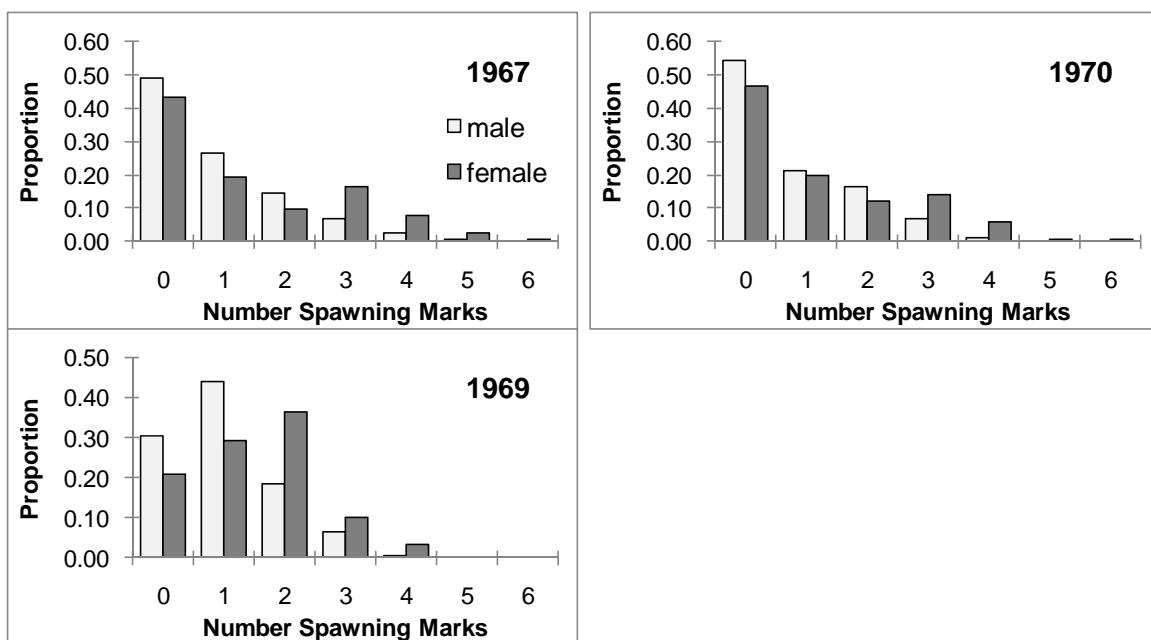


Figure 15.19 Spawning frequency of alewives sampled from commercial harvest in the York River, 1967–1970.

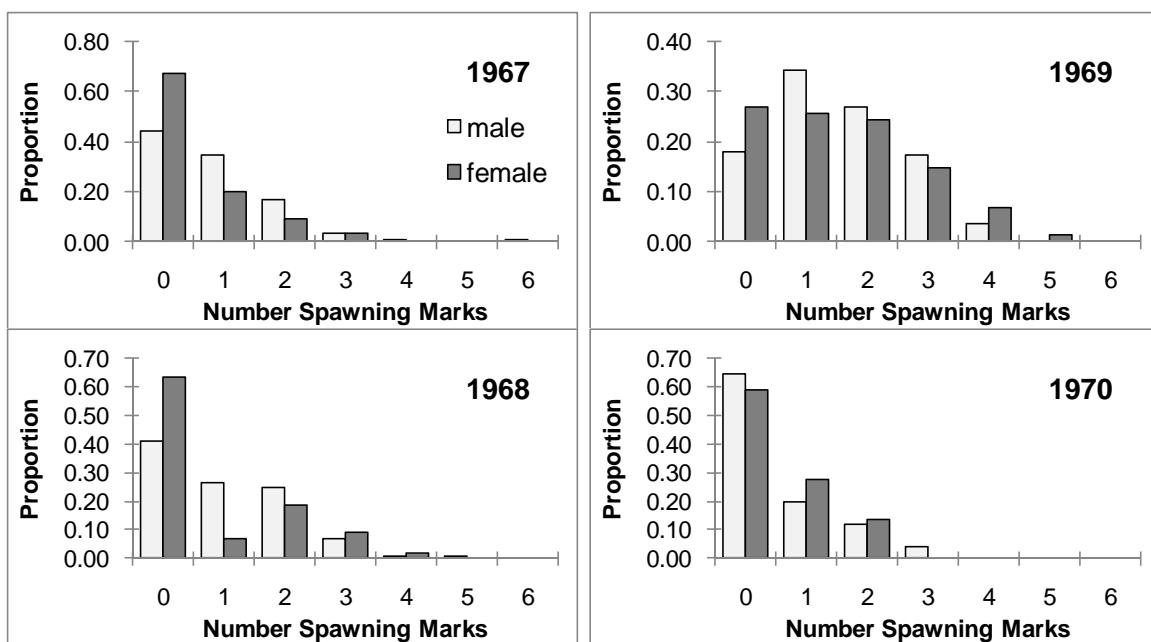


Figure 15.20 Spawning frequency of blueback herring sampled from commercial harvest in the James River, 1967–1970.

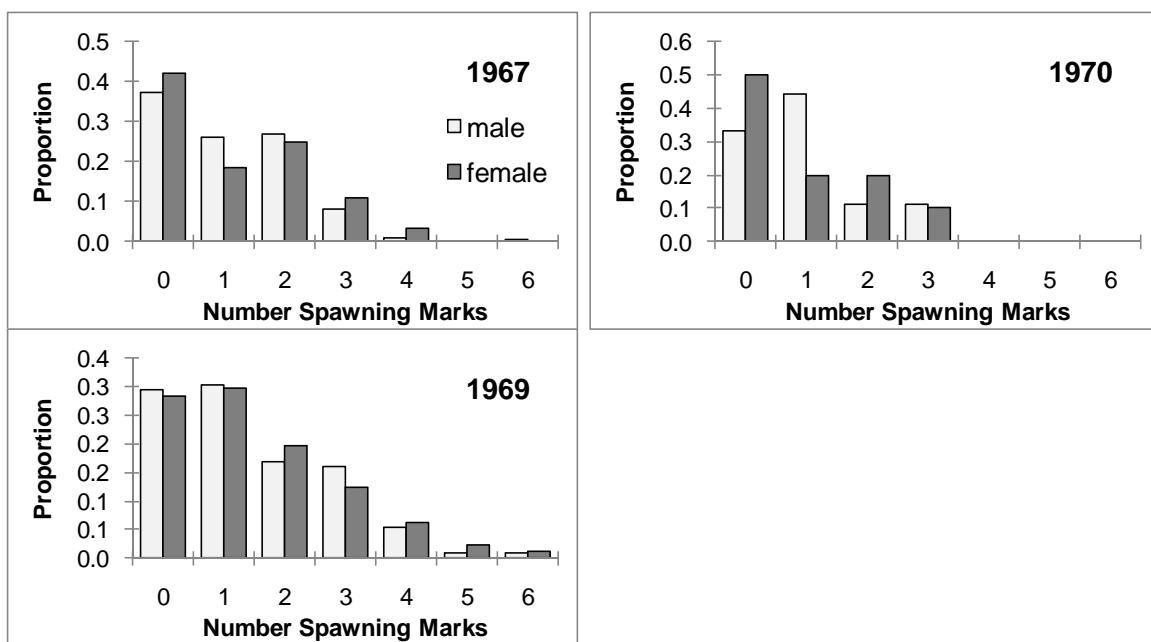


Figure 15.21 Spawning frequency of blueback herring sampled from commercial harvest in the York River, 1967–1970.

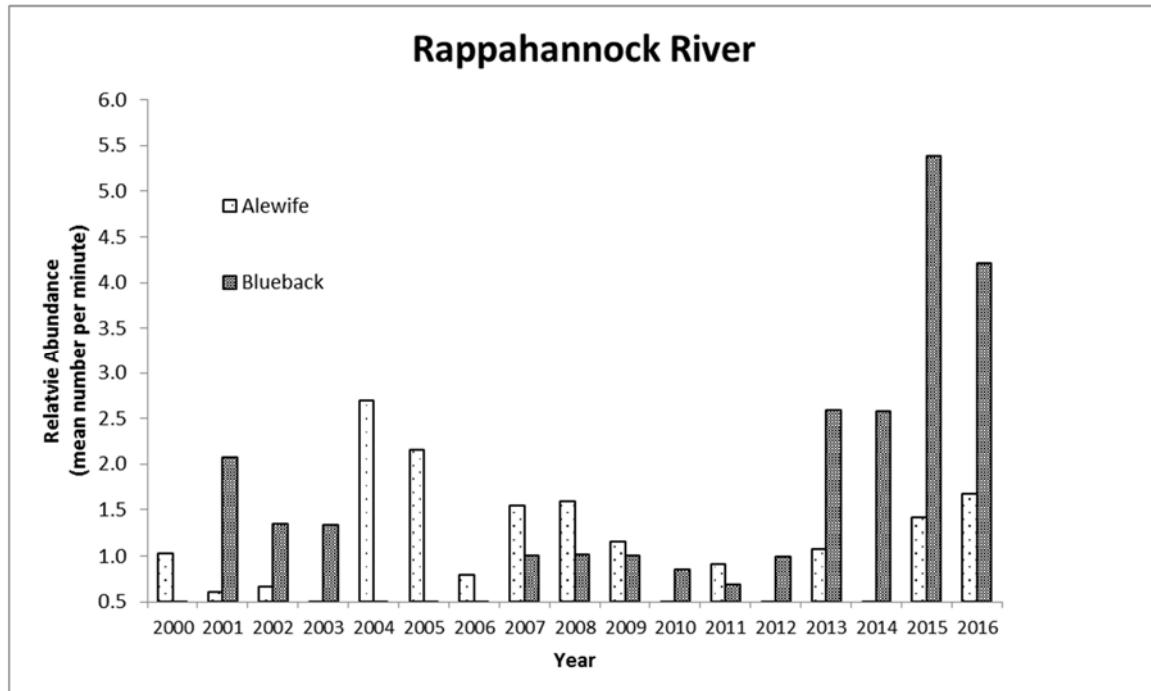


Figure 15.22 Catch rates (arithmetic average number of fish per minute) of alewives and blueback herring collected by the VDGIF's electrofishing survey of the Rappahannock River (Route 1 station), 2000–2016.

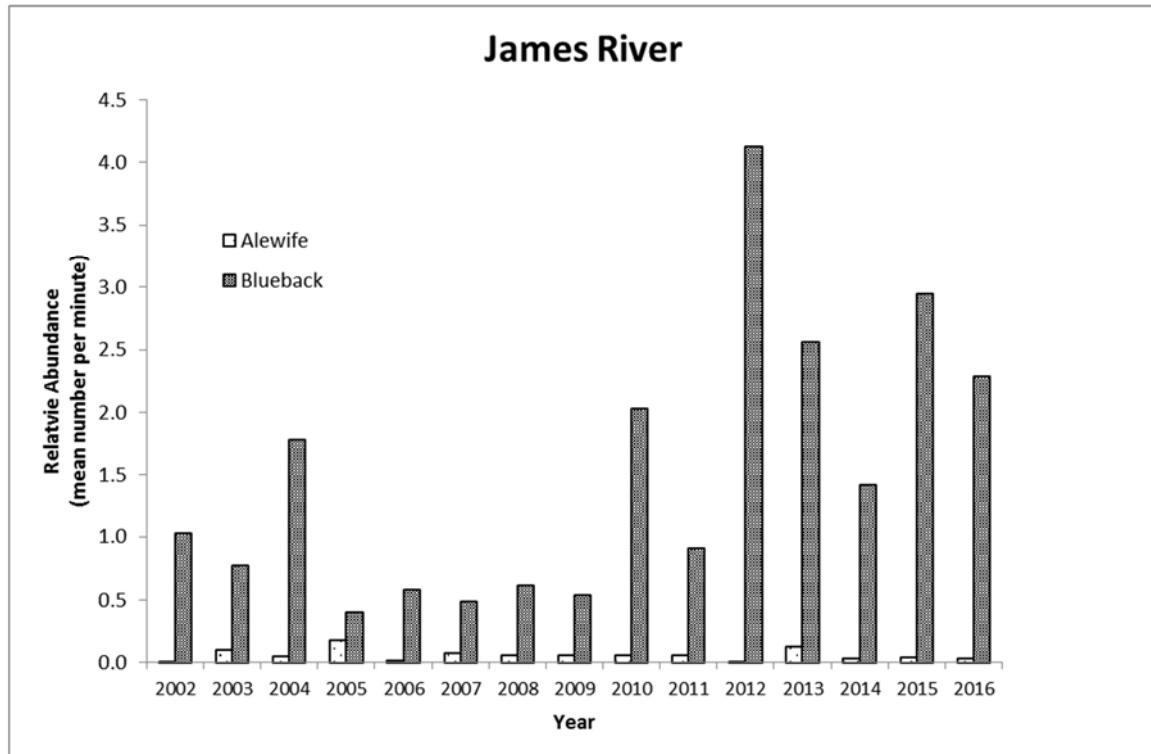


Figure 15.23 Catch rates (arithmetic average number of fish per minute) of alewives and blueback herring collected by the VDGIF's electrofishing survey of the James River (Manchester stations 1, 2, 4, and 5 combined), 2002–2016.

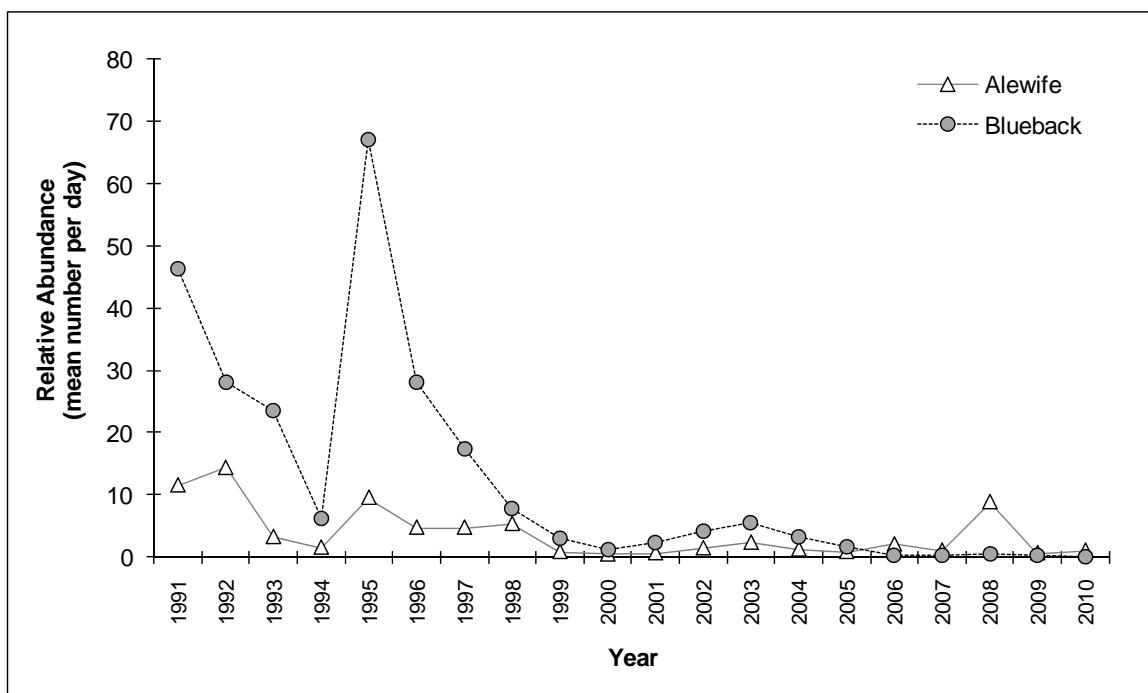


Figure 15.24 Annual relative abundance (average number per day) of adult river herring collected from the Rappahannock River by the VIMS Experimental Anchor Gill-Net Survey, 1991–2010.

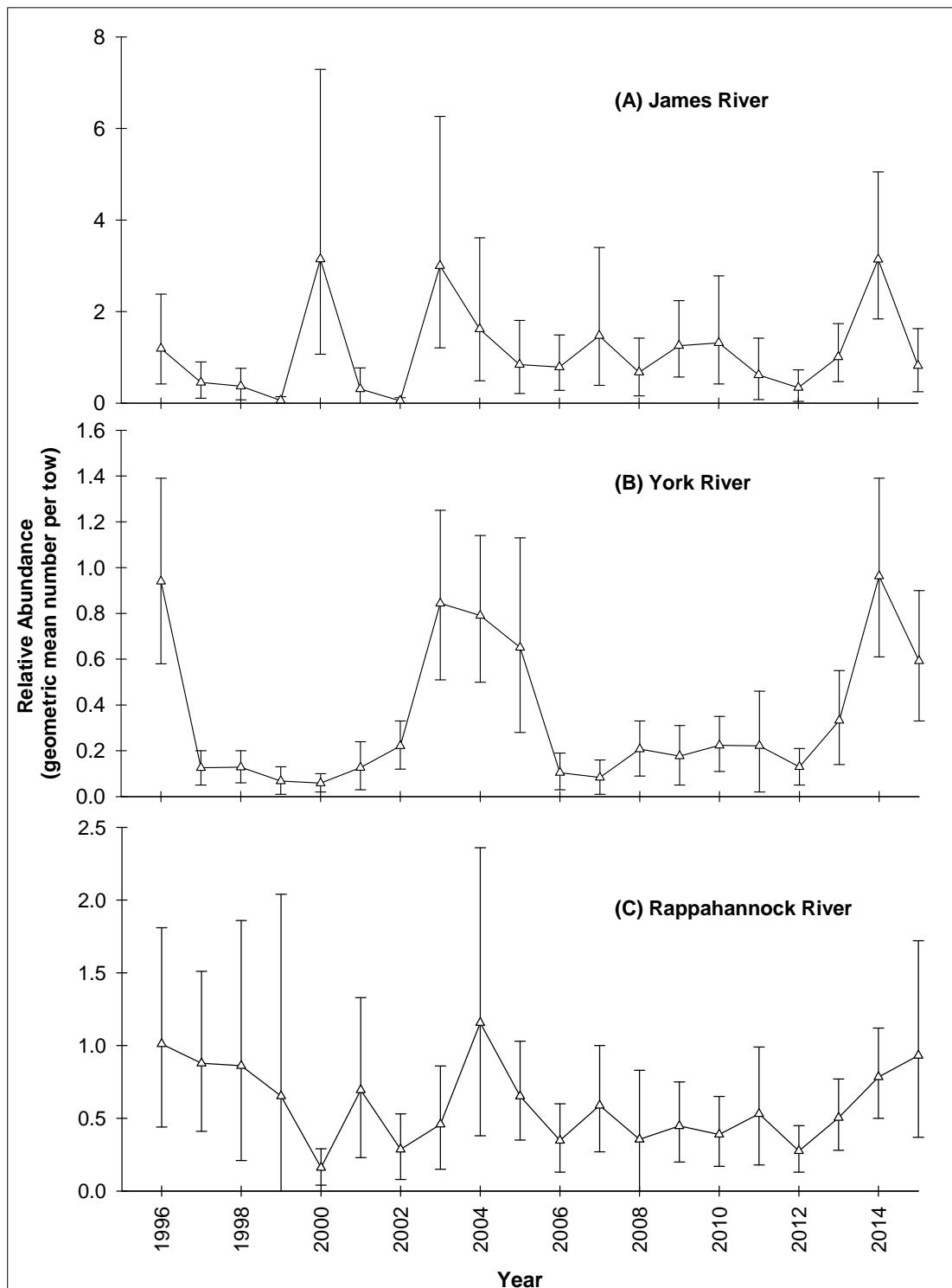


Figure 15.25 Annual JAIs (geometric average number per standard tow) for alewives collected from the (A) James, (B) York, and (C) Rappahannock rivers by the VIMS Juvenile Fish and Blue Crab Trawl Survey, 1996–2015. Error bars represent the 95% confidence intervals.

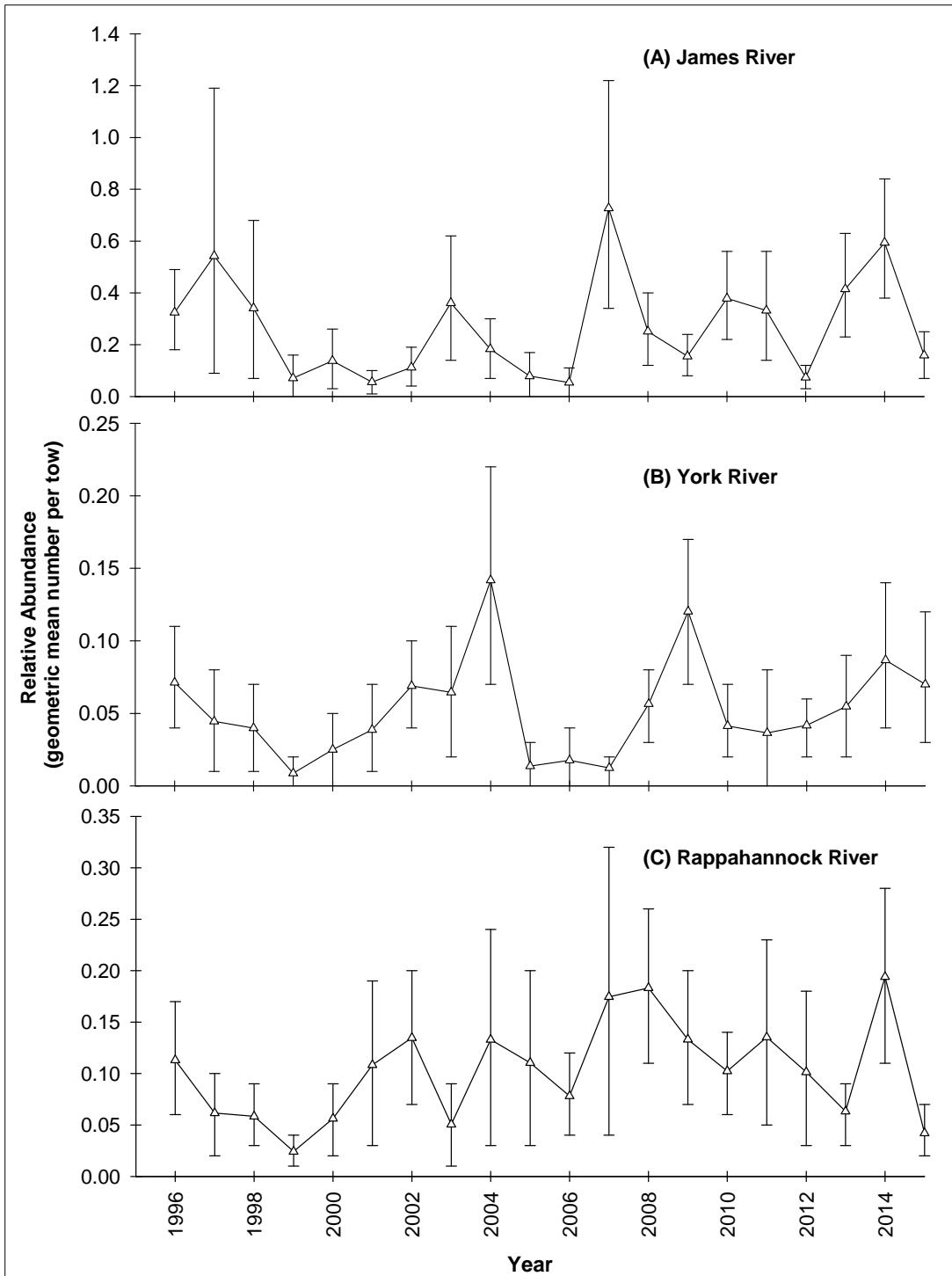


Figure 15.26 Annual JAIs (geometric average number per standard tow) for blueback herring collected from the (A) James, (B) York, and (C) Rappahannock rivers by the VIMS Juvenile Fish and Blue Crab Trawl Survey, 1996–2015. Error bars represent the 95% confidence intervals.

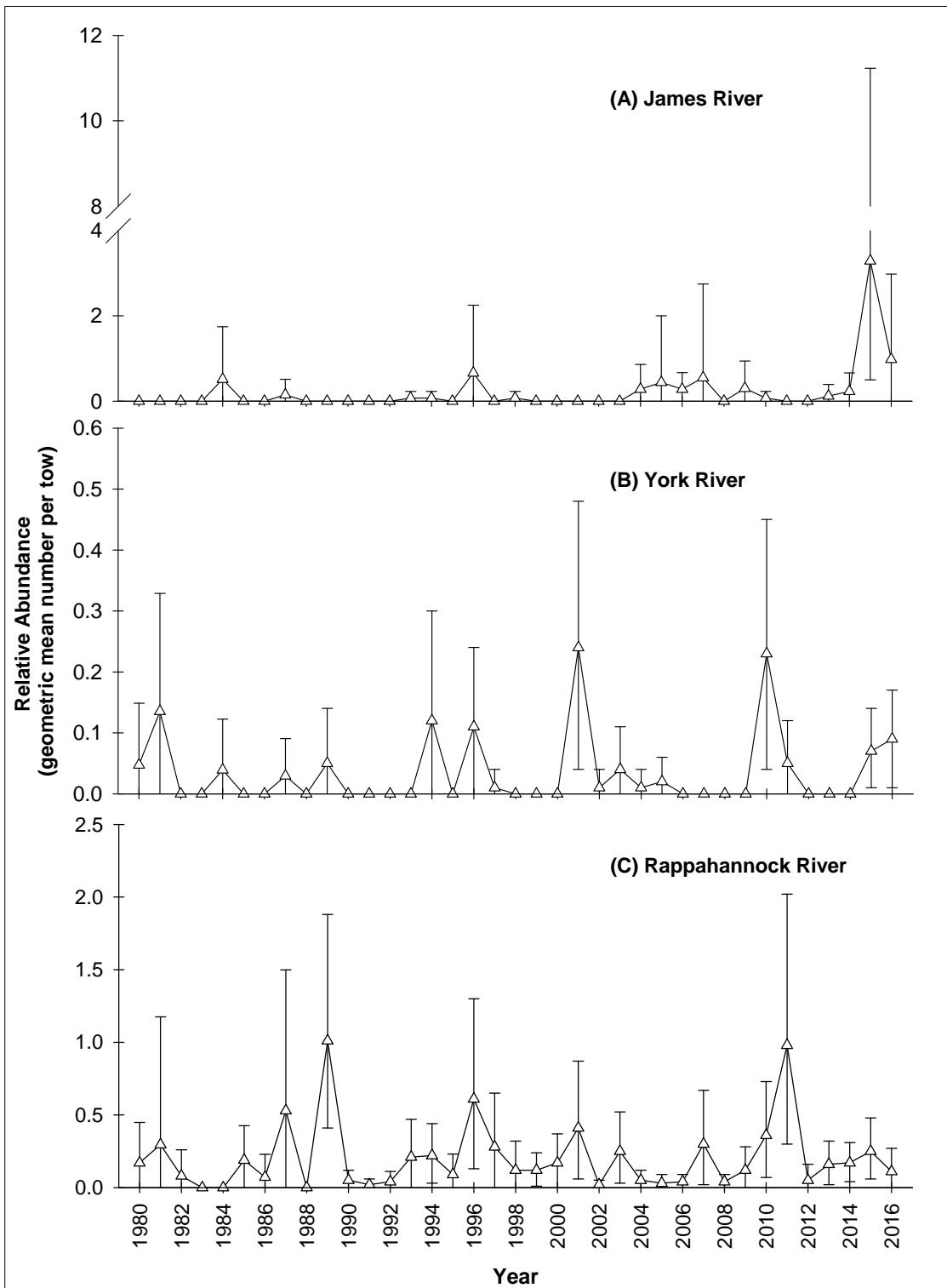


Figure 15.27 Annual JAIs (geometric average number per seine set) for alewives collected from the (A) James, (B) York, and (C) Rappahannock rivers by the VIMS Juvenile Striped Bass Seine Survey, 1989–2016. Error bars represent the 95% confidence intervals.

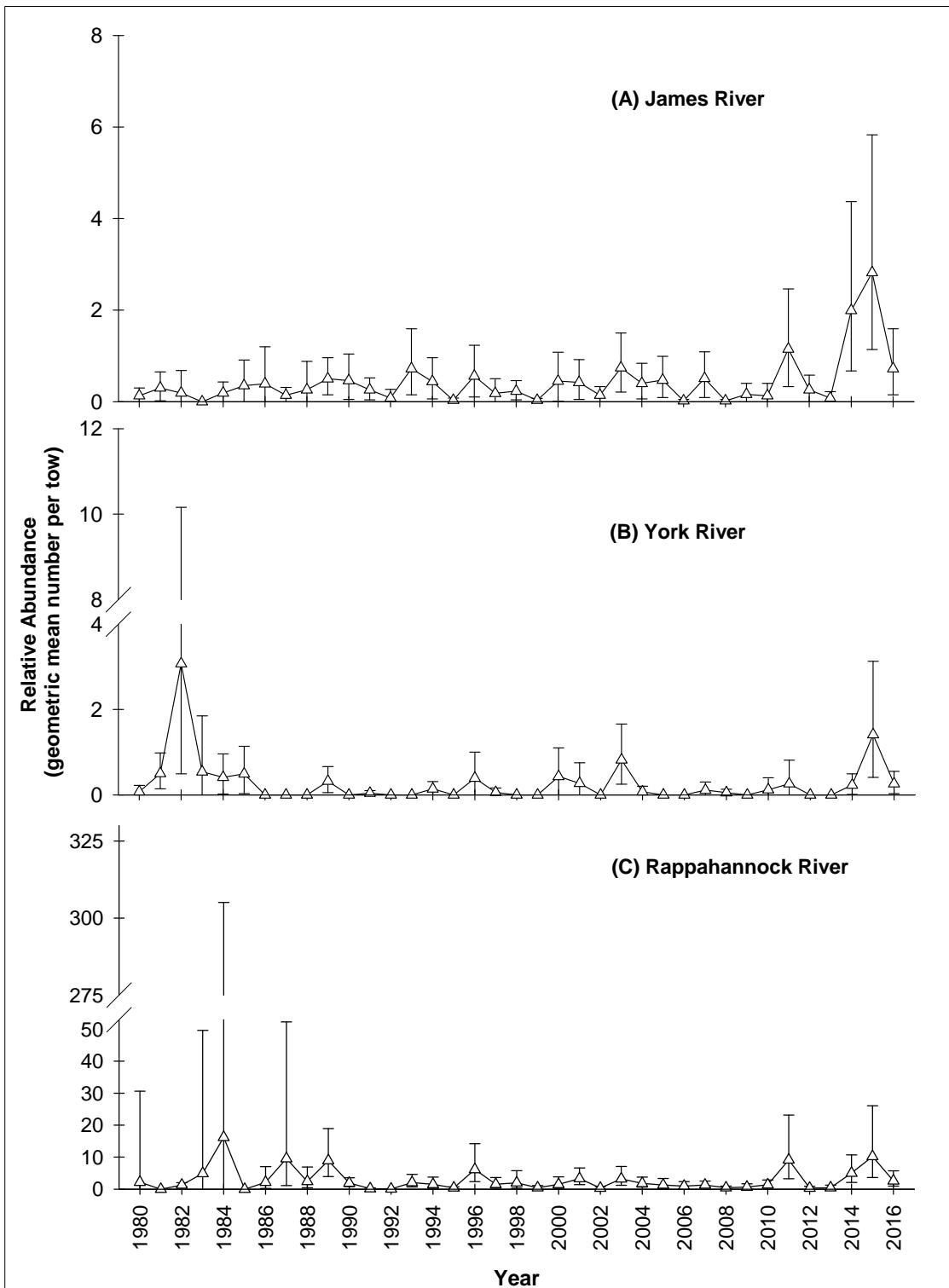


Figure 15.28 Annual JAIs (geometric average number per seine set) for blueback herring collected from the (A) James, (B) York, and (C) Rappahannock rivers by the VIMS Juvenile Striped Bass Seine Survey, 1989–2016. Error bars represent the 95% confidence intervals.

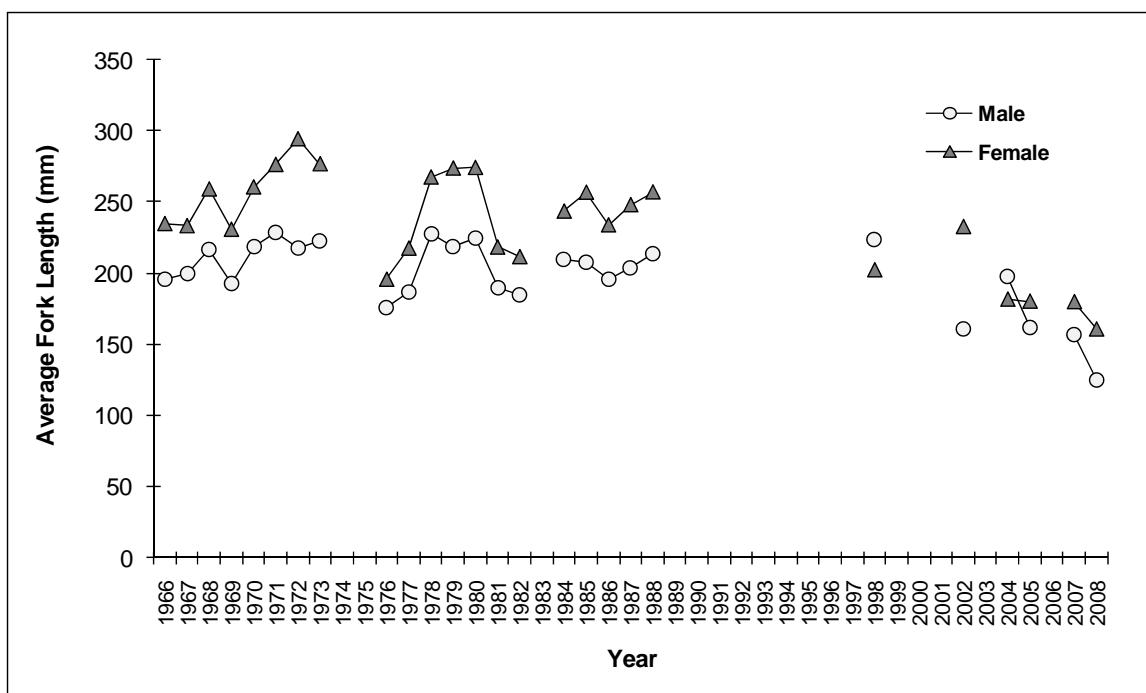


Figure 15.29 Average fork length (mm) of alewives sampled from commercial pound net harvest in the Rappahannock River, by sex, 1966–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

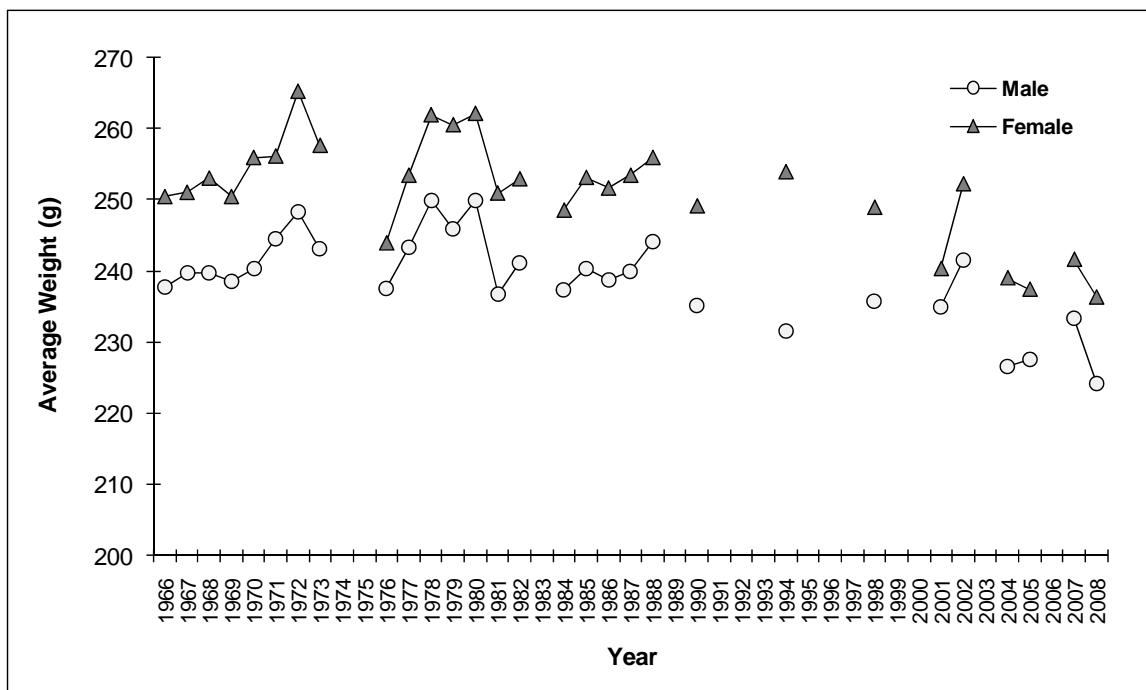


Figure 15.30 Average weight (g) of alewives sampled from commercial pound net harvest in the Rappahannock River, by sex, 1966–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

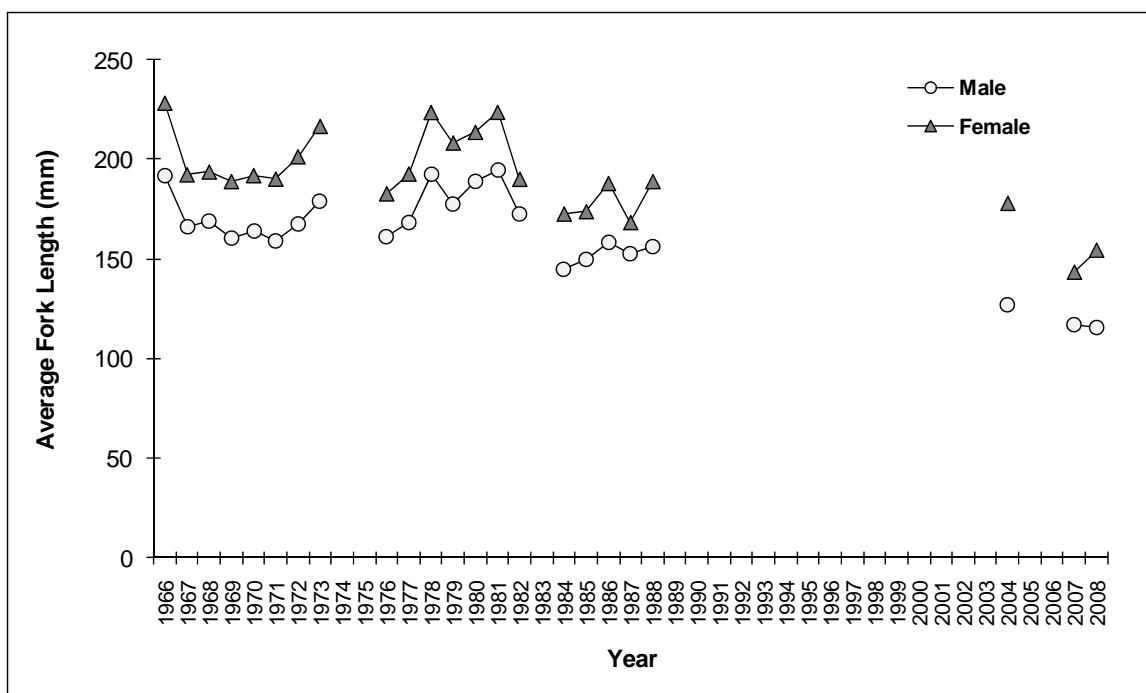


Figure 15.31 Average fork length (mm) of blueback herring sampled from commercial pound net harvest in the Rappahannock River, by sex, 1966–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

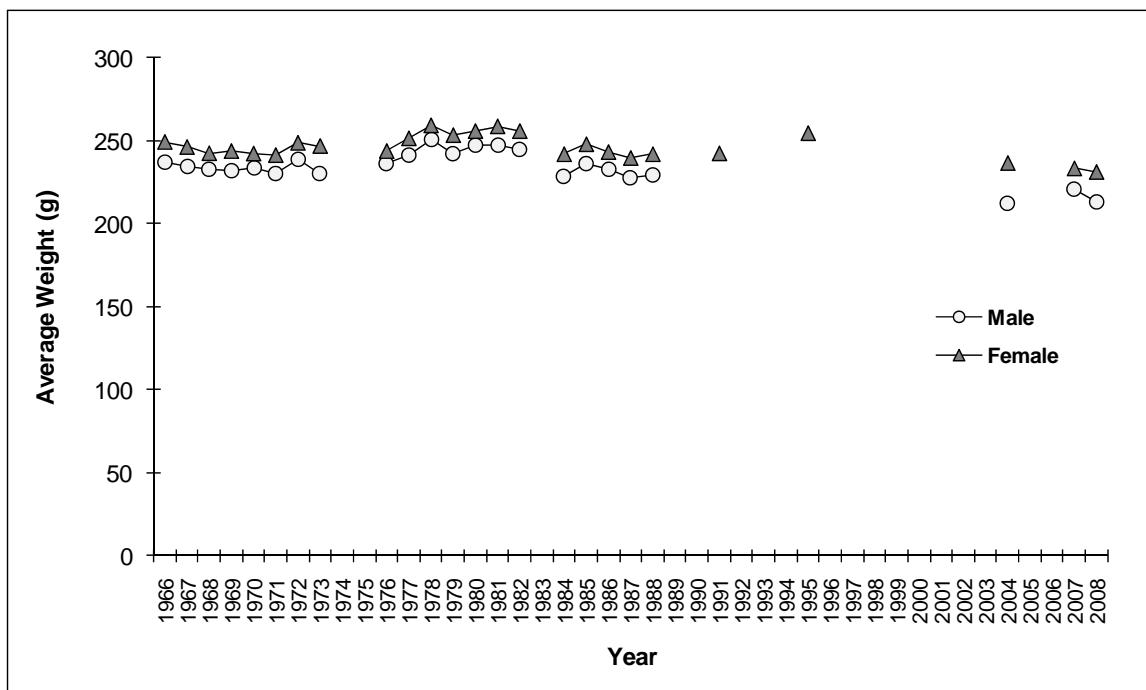


Figure 15.32 Average weight (g) of blueback herring sampled from commercial pound net harvest in the Rappahannock River, by sex, 1966–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

16 Status of River Herring in North Carolina

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Executive Summary

River herring fisheries in North Carolina's coastal sounds and rivers were once among the largest freshwater fisheries in the world. Significant declines in commercial landings and overall stock abundance began in the mid to late 1980s and continues an overall declining trend. The NC Marine Fisheries Commission (NCMFC) adopted the NC River Herring Fishery Management Plan (NCRHFMP) in 2000. The plan focused on issues pertaining to stock conditions of overfished and recruitment overfishing, habitat degradations, and research and monitoring expansion to provide assessment data and socioeconomic data. In 2007, Amendment 1 to the NCRHFMP was adopted by the NCMFC, a no harvest provision for commercial and recreational river herring fisheries in the coastal and joint waters of the state was implemented. Currently, river herring are managed under Amendment 2 to the NCRHFMP. The NCMFC adopted Amendment 2 in 2015, which eliminated the discretionary harvest season, prohibited the possession of river herring greater than six inches aboard a vessel or while engaged in fishing from the shore or a pier in all internal joint and coastal waters of North Carolina, and removed river herring from exceptions in the NCMFC mutilated finfish rule.

A forward-projecting age structured statistical catch -at -age (SCA) model for Chowan River blueback herring (*Alosa aestivalis*) was applied to the total in-river catches, age compositions, length compositions, and a fisheries independent young-of-year (YOY) index to estimate age-3 abundance, total abundance, and mortality rates. The benchmark assessment time period was 1972-2009 and this update covers 2010-2015. Exploitation rates for blueback herring in the Chowan River before the 2007 moratorium ranged as low as 0.12 in 1979 to as high as 0.85 in 1986. Exploitation averaged about 0.24 prior to 1985, increased to an average of 0.68 during 1985–1988, and averaged about 0.43 between 1989 and 2006. Since the moratorium, exploitation rates have been close to zero. Fishing mortality averaged about 0.29 prior to 1985, increased to an average of 1.1 during 1985–1988, and averaged about 0.61 between 1989 and 2006. Since the moratorium, fishing mortality has been close to zero. Blueback herring total abundance (age 3+) declined steadily from 127 million fish in 1976 to 62 million fish in 1980. Total abundance increased through 1983 to 104 million fish and then declined precipitously to 0.95 million fish in 2003 and bottomed out at approximately 0.6 million fish in 2006 and 2007. Total

abundance increased slightly from 0.6 million fish in 2007 to 9.63 million fish in 2014. Age- 3 abundance increased through 2014 to 7.5 million fish. Female SSB (spawning stock biomass) fluctuated but declined steadily from the peak of 6.5 million kilograms in 1972 to a low of 0.17 million kilograms in 1986. Female SSB increased slightly to 0.5 million kilograms through 1990, but then it declined slowly to its lowest level of 11,000 kilograms in 2005. Female SSB has been increasing since 2006 and has averaged 61,067 kilograms, peaking in 2015 at 227,333 kilograms. From the spawner-recruit data and production model, F_{MED} (level of fishing mortality where recruitment has been sufficient to balance losses to fishing mortality in half the observed years) was estimated to be 0.59. The fishing mortality rate that produces maximum sustainable yield, F_{MSY} , was 0.39 and corresponding spawning stock bass, SSB_{MSY} (the spawning stock biomass at MSY), was 1,894,382 kilograms. SSB_{MSY} was higher than the 20% of the equilibrium spawner biomass, $SSB_{20\%}$ (1,126,623 kilograms). Current female spawning stock biomass is only 12% of SSB_{MSY} . The fishing mortality rate that drives the population to extinction, F_{COL} (the fishing mortality that drives the population to extinction), was 0.9. The estimates of F_{MSY} (the fishing rates that produces maximum sustainable yield) and F_{COL} (the fishing mortality that drives the population to extinction) are considerably lower than those estimated for alewife ($F_{MSY} > 1.0$; $F_{COL} > 1.82$) in three Canadian rivers by Gibson and Myers (2003b). When comparing fishing mortality rate estimates to the derived reference points the fishing mortality exceeded all reference points several times over the time series, particularly after 1985.

Excessive exploitation and poor recruitment have led to depletion of the Chowan River blueback herring stock. Despite fishing pressure that is negligible since implementation of the 2007 no- harvest provision, the stock remains overfished as the spawning stock biomass remains less than 12% of the amount necessary to replace itself in the complete absence of fishing.

16.1. INTRODUCTION

Historically, river herring (blueback herring *Alosa aestivalis* and alewife *Alosa pseudoharengus*) supported commercial and recreational fisheries in most of North Carolina's coastal rivers. The major concentrations of river herring historically and currently are found in the Albemarle Sound and its tributaries (Figure 16.1). Due to overfishing, habitat loss and water quality degradation, river herring landings in North Carolina began to decline in the mid to late 1980's. The 2005 North Carolina River Herring Stock Assessment conducted by NCDMF indicated that river herring were overfished and that overfishing was occurring (Grist 2005). In 2006 the NC Wildlife Resources Commission (NCWRC) adopted a rule that prohibits possession of river herring six inches and greater in all inland waters of the state. In 2007 the NCMFC adopted Amendment 1 to the NCRHFMP, which prohibited commercial and recreational harvest in all coastal and joint waters of the state and set aside a 7,500 pound annual research harvest with area, season and gear restrictions. A maximum 4,000 pounds (of the 7,500 pounds) are allocated for commercial harvest and data collection in a limited fishery with quota, time and area restrictions. This fishery was approved by the ASMFC Shad & River Herring Management Board in 2011. Amendment 1 also identified four stock recovery indicators to be monitored by the NC Division of Marine Fisheries (NCDMF). The NCMFC adopted Amendment 2 to the NCRHFMP in 2015, which eliminated the discretionary harvest season, prohibited the possession of river herring greater than six inches aboard a vessel or while engaged in fishing from the shore or a pier in all, and removed river herring from exceptions in the NCMFC mutilated finfish rule. Additionally, during the development of Amendment 2 the stock recovery indicators identified in Amendment 1 were reduced from four to three, and the name was change to stock status indicators.

Although the 2000 NCRHFMP was a statewide plan, river herring data from systems outside of the Albemarle Sound area are limited. The NCDMF has conducted spawning and nursery area surveys and some age composition work for most of the coastal streams outside the Albemarle Sound area, but continuous monitoring ended over 20 years ago, as federal aid funds were decreased. Current data, other than historic landings data, do not exist for river herring outside the Albemarle Sound area. Data from the Albemarle Sound and particularly Chowan River were used to determine the 2005 and 2012 stock status of alewife and blueback herring in NC. Blueback herring was selected as the indicator species for the 2005 NC River Herring Stock Assessment and the overall development of the NCRHFMP. Key research recommendations from Amendment 1 to the NCRHFMP were to reestablish a spawning area survey in the Albemarle Sound and to expand data collection programs to other river systems in the state. Since 2008, NCDMF has conducted anadromous spawning areas surveys from January through May in the Chowan River system in conjunction with one other system in the Albemarle Sound area on a rotating basis. These surveys have provided information as to which areas currently function as productive spawning habitat. In 2016, NCDMF contracted with North Carolina State University for a 2-year study to analyze the spawning area survey collection and environmental data in order to provide estimates of habitat availability including land use change in North Carolina coastal rivers. Results of the study are due to be presented in the winter of 2018. Starting in 2006, the NCWRC began weekly boat-electrofishing surveys for adult river herring from February through April at various sample sites in various systems throughout North Carolina at locations that have a prior history of spawning adults. At the present time, NCWRC sampling occurs in the Chowan River, Tar River, Neuse River and Cape Fear River Basins. No other expansion of those data collection programs has occurred, except for the NCWRC electrofishing survey, due to lack of funds and personnel.

16.2. DESCRIPTION OF MANAGEMENT UNIT

The management of river herring in North Carolina is conducted in joint and coastal waters by the NCDMF and in inland waters by the NCWRC. The management units established in the 2000 NCRHFMP include the two species of river herring (blueback and alewife) and their fisheries throughout coastal North Carolina.

The management areas are defined as follows:

The Albemarle Sound River Herring Management Area (ASRHMA)- Albemarle Sound and all its coastal, joint and inland water tributaries; Currituck Sound; Roanoke and Croatan sounds and all their coastal, joint and inland water tributaries, including Oregon Inlet, north of a line from Roanoke Marshes Point $35^{\circ} 48.5015' \text{ N}$ $-74^{\circ} 44.1228' \text{ W}$ across to the north point of Eagles Nest Bay $35^{\circ} 44.1710' \text{ N}$ $-75^{\circ} 31.0520' \text{ W}$.

The Chowan River Herring Management Area (CRHMA)- Northwest of a line from Black Walnut Point $35^{\circ} 59.9267' \text{ N}$ $-76^{\circ} 41.0313' \text{ W}$ to Reedy Point $36^{\circ} 02.2140' \text{ N}$ $-76^{\circ} 39.3240' \text{ W}$, to the North Carolina/Virginia state line; including the Meherrin River.

16.3. REGULATORY HISTORY

From 1915-1965 various regulations including season and area closures as well as gear restrictions were implemented in the N.C. river herring fisheries. Beginning in 1995 various restrictions including season closures and total allowable catch limits were implemented.

The two management areas (ASRHMA and CRHMA) were established in the 2000 NCRHFMP and defined in North Carolina Fisheries Rules for coastal waters 2003 rule 15A NCAC 3J. 0209. An annual quota, or total allowable catch (TAC) of 300,000 pounds was established in 2000 for the ASRHMA and was allocated as follows: 200,000 pounds to the pound net fishery for the CRHMA; 67,000 pounds to the ASRHMA gill net fishery; 33,000 pounds to be allocated at the discretion of the NCDMF Director (15A NCAC 3M.0513). The same rule also granted the Director proclamation authority as it applies to blueback herring, alewife, American and hickory shad fisheries, and also established a 25 fish per person per day (blueback herring and alewife combined) recreational creel limit.

The commercial TAC was further reduced in 2006 for the ASRHMA with 65,000 pounds allocated to CRHMA pound net fishery; 35,000 pounds to the ASRHMA gill net fishery; 5,000 pounds to be allocated at the NCDMF Director discretion.

Rule 15A NCAC 3O.0503 outlines the requirements for the Albemarle Sound Management Area River Herring Dealer Permit. To purchase river herring a dealer must obtain an Albemarle Sound Management Area River Herring Dealer Permit. The permit conditions require the dealer to report landings daily to the NCDMF, and allow biological sampling of catches by NCDMF personnel.

The NCMFC through the development and approval of Amendment 1 to the NCRH FMP approved a no harvest provision for river herring, commercial and recreational, in waters under their jurisdiction in 2007. The NCMFC approved a 7,500 pound limited research set aside to be allocated at the NCDMF Director's discretion to collect data necessary for stock analysis, and to provide availability of local product for local festivals. To implement the harvest of this discretionary amount, a Discretionary Herring Fishing Permit (DHFP) was created. Individuals interested in participating had to meet the following requirements: (1) obtain a DHFP, (2) harvest only from the Joint Fishing Waters of Chowan River during the harvest period, (3) must hold a valid North Carolina Standard Commercial Fishing License (SCFL) or a Retired SCFL, and (4) participate in statistical information and data collection programs. If harvested river herring were sold they had to be sold to a licensed and permitted River Herring Dealer. The Director allocated a maximum of 4,000 pounds of the 7,500 pounds set aside for harvest in the limited fishery. Each permit holder was allocated 125-250 pounds for the four day season during Easter weekend from 2007-2010. This limited fishery has also met the requirements of Amendment 2 to the ASMFC Shad & River Herring Fisheries Management Plan and was approved by the ASMFC Shad & River Herring Management Board in 2011. In 2015, through the development and approval of Amendment 2 to the NCRHFMP the NCMFC eliminated the discretionary harvest season for river herring; prohibited the possession of river herring greater than six inches aboard a vessel or while engaged in fishing from the shore or a pier in all coastal waters (NC rule 15A NCAC 03M.0513); and removed river herring from exceptions in the NC rule 15A NCAC 03M.0101 for mutilated finfish.

Anadromous Fish Spawning Areas (AFSA) have been adopted by NCWRC and NCMFC into NC rule 15A NCAC 03R.0115 through the implementation of Amendment 1 of the NCRHFMP. These areas are designated using spawning area surveys conducted in North Carolina as well as current and future surveys that will continue to re-evaluate spawning habitat.

The NCWRC has authority over the Inland Waters of the state. Since July 1, 2006 harvest of river herring, greater than 6 inches has been prohibited in the inland waters of North Carolina's coastal systems.

16.4. ASSESSMENTS HISTORY

In 2005, an updated stock assessment was conducted by NCDMF examining both blueback herring and alewife in North Carolina, using blueback herring as the indicator species. Although blueback herring and alewife are landed in other areas of the Albemarle Sound by a variety of gears, the largest fishery was Chowan River pound nets. Catch-at-age data from the Chowan River pound net fishery were used to estimate exploitation rates and abundance from 1972 to 2003. Cohort and annual catch curves provided initial estimates of mortality, while a spreadsheet-based catch at age model incorporating a multinomial error distribution provided estimates of annual recruitment, abundance at age, and fishing mortality. Bootstrapping and log-likelihood profiling were used to evaluate the precision of model estimates.

Estimated fishing mortality for 1972 to 1994 was 0.90 for blueback herring and, except for 1995 and 1997, fishing mortality ranged from a low of 0.98 in 1998 to a high of 1.91 in 2003, with a corresponding exploitation ranging from 63% to 85%. Estimated fishing mortality for 1972 to 1994 was 0.98 for alewife and, except for 1995 and 1997, fishing mortality ranged from a low of 1.01 in 1998 to a high of 1.86 in 2002, with corresponding exploitations ranging from 64% to 85%. Chowan River blueback herring recruitment averaged 28.9 million age-3 fish per year between 1972 and 1985. However, it only averaged 552,000 fish from 1998 to 2003. Chowan River alewife recruitment averaged 7.5 million age-3 fish a year between 1972 and 1986. However, it only averaged 317,000 fish from 1998-2003.

Declines in blueback herring recruitment through the 1990s dramatically reduced SSB to 89,678 pounds in 2003. Similarly, alewife spawning stock biomass declined rapidly during the early 1990s. From 1994 to 1999, alewife SSB averaged 22,953 pounds, with a record low of 10,862 pounds in 1995. Excessive exploitation combined with poor recruitment significantly reduced abundance of both river herring species and led to much lower catches than were supported historically. Utilizing blueback herring as an indicator species, a Beverton-Holt stock-recruitment model and a stochastic recruitment model were fit and estimated model parameters were used to project population conditions under various management strategies (Grist 2005).

In 2012, a coast-wide benchmark stock assessment was conducted by the ASMFC examining both blueback herring and alewife, using blueback herring as the indicator species (ASMFC 2012). A forward-projecting age structured statistical catch-at-age model for Chowan River blueback herring was applied to the total in-river catches, age compositions, length compositions, and a fisheries independent young-of-year index to estimate age-3 abundance and mortality rates. The assessment time period was 1972-2009. Exploitation rates for blueback herring in the Chowan River before the 2007 moratorium ranged as low as 0.14 in 1979 to as high as 0.87 in 1986. Exploitation averaged about 0.28 prior to 1985, increased to an average of 0.70 during 1985–1988, and averaged about 0.40 between 1989 and 2006. Exploitation rates were close to zero in all years after the moratorium was enacted. Fishing mortality averaged about 0.34 prior to 1985, increased to an average of 1.3 during 1985–1988, and averaged about 0.56 between 1989 and 2006. Similar to exploitation rates, fishing mortality was close to zero in all years following the moratorium. Blueback herring total abundance (age 3+) declined steadily from 133 million fish in 1979 to 55 million fish in 1980. Total abundance increased through 1983 to 103 million fish and then declined precipitously to 1.1 million fish in 2002. From 2002 to 2009, total abundance averaged 1.9 million fish. Age-3 abundance peaked at 81 million fish in 1975, and declined precipitously from 1983 to 0.62 million fish in 2001. From 2002 to 2009, total abundance of age-3 fish averaged 1.0 million fish. Female SSB fluctuated but declined steadily from the peak of 5.2

million kilograms in 1972 to a low of 0.14 million kilograms in 1986. Female SSB increased slightly to 0.46 million kilograms through 1990, but then it declined slowly to its lowest level of 15,000 kilograms in 2003. Female SSB averaged about 81,000 kilograms 2004-2009.

From the spawner-recruit data and production model, F_{MED} was estimated to be 0.59. The fishing mortality rate that produces maximum sustainable yield, F_{MSY} , was 0.39 and corresponding spawning stock bass, SSB_{MSY} , was 1,955,333 kilograms. SSB_{MSY} was higher than the 20% of the equilibrium spawner biomass, $SSB_{20\%}$ (1,195,873 kilograms). Terminal year female spawning stock biomass was only 5% of SSB_{MSY} . The fishing mortality rate that drives the population to extinction, F_{COL} , was 0.91. The estimates of F_{MSY} and F_{COL} are considerably lower than those estimated for alewife ($F_{MSY} > 1.0$; $F_{COL} > 1.82$) in three Canadian rivers by Gibson and Myers (2003b). When comparing fishing mortality rate estimates to the derived reference points, fishing mortality exceeded all reference points several times over the time series, particularly after 1985.

The 2012 stock assessment indicated excessive exploitation and poor recruitment led to the depletion of the Chowan River blueback herring stock. Despite a fishing pressure that was negligible since implementation of the 2007 no-harvest provision, the stock remained overfished because the spawning stock biomass was less than 5% of the amount necessary to replace itself in the complete absence of fishing.

The 2017 Chowan River blueback herring stock assessment update report results can be found in section 16.11 of this document.

16.5. STOCK SPECIFIC LIFE HISTORY

The alewife and the blueback herring, collectively known as river herring, are anadromous members of the family Clupeidae (herrings and shads). "Anadromous" means they migrate from the ocean, enter coastal bays and sounds through inlets, and ascend into freshwater rivers and streams to spawn, traveling further upstream in wet years and remaining downstream in dry years. Surviving adults then return to the ocean after spawning. The young-of-the-year fish use rivers and estuaries as nursery grounds as they migrate downstream after hatching. After the juveniles leave the rivers and estuaries in the fall or early winter, they complete their development in the Atlantic Ocean, over the continental shelf off New England (Loesch 1987; Jenkins and Burkhead 1993). The two species occur geographically together from New Brunswick and Nova Scotia in Canada south to the northern coastal area of South Carolina. Blueback herring occur further south, to northern Florida. There are important life history differences between the two species (Loesch 1987). Alewives select slower-flowing areas for spawning, with blueback herring reported to select faster-flowing sites in areas where both species occur. In areas where both species occur, alewives generally spawn earlier. While fish are believed to return to the streams of their birth for spawning, both species readily colonize new streams or ponds and will reoccupy systems from which they have been extirpated (Loesch 1987). Both juveniles and adults respond negatively to light, in both riverine and offshore habitats, with alewives remaining deeper in the water column in both habitats (Klauda et al. 1991). Both species are important prey during all life stages for many other species of commercial and recreational importance. Both species have also been widely stocked in inland freshwater lakes and reservoirs where they live and reproduce entirely in freshwater and serve as prey for freshwater game fish.

In the collective population of river herring, the percentage of alewife and blueback herring present in major Albemarle Sound tributaries has varied based on sampling of the commercial catch (Johnson et al. 1981). For example, percent composition of alewife ranged from 4 % in 1977 to 49 % in 1979, with alewife dominating the early catches in each year. From 1989 through 1992, the percentage of alewife ranged from 14.2 to 31.2% (Winslow and Rawls 1992). The same pattern of early dominance by alewife, with subsequent later dominance by blueback herring, is evident in weekly species composition samples taken during the 1980-92 spawning runs on the Chowan and Scuppernong rivers (Winslow et al. 1983; Winslow and Rawls 1992). The fraction of alewife in the commercial catch for those years ranged from 27 to 37%.

16.6. HABITAT DESCRIPTION

River herring have historically been found in all N.C. coastal rivers and streams. The main populations of river herring are found in the Albemarle Sound and its tributaries, with smaller runs historically in the Tar, Pamlico, Neuse and Cape Fear River systems.

The Albemarle Sound system includes Albemarle, Croatan, Roanoke and Currituck Sounds and all of their tributaries. The Albemarle Sound, located in the northeastern portion of North Carolina, is a shallow estuary extending 55 miles in an east-west direction averaging 7 miles wide and 13-20 feet deep. Ten rivers drain into the Albemarle Sound which joins Pamlico Sound through Croatan and Roanoke Sounds and empties into the Atlantic Ocean via Oregon Inlet. The majority of tributaries that empty into the sound originate in extensive coastal swamps.

The Chowan River flows approximately 50 miles and is formed with the merging of Virginia's Blackwater and Nottoway rivers. It is a major tributary to the Albemarle Sound and it is the primary spawning area for river herring in North Carolina. The Chowan River empties into western Albemarle Sound. This area as well as most of the Albemarle Sound and all of its tributaries serves as a major anadromous fishery nursery area for river herring.

Anadromous spawning area surveys conducted by the NCDMF demonstrated that river herring use a wide range of habitat types for spawning, such as small, densely vegetated streams; fresh and brackish marshes; hardwood swamps; and flooded low-lying areas adjacent to both mainstem rivers and tributaries. In North Carolina, anadromous fish spawning areas are designated in NCMFC rule 15A NCAC 03R.0115 and NCWRC rule 15A NCAC 10C .0603 and include areas in most river systems.

River herring spawn in the upper reaches of North Carolinas coastal rivers and streams in the early spring. The juveniles spend most of their first year in the nearshore waters of the coastal rivers and sounds and emigrate to the ocean when water temperatures begin to cool in the fall.

16.7. RESTORATION PROGRAMS

In 2007, Amendment 1 to the NCRHFMP identified various restoration targets for the river herring stocks. Amendment 1 used the Chowan River blueback herring stock as the indicator species to establish stock recovery indicators. The plan identified stock recovery indicators that would be used to evaluate and determine recovery status of the river herring stock. The stock recovery indicators for the NCRHFMP are as follows:

Juvenile abundance – The restoration target for juvenile abundance of blueback herring is to achieve a three year moving average catch per unit of effort of at least 60.

Percent Repeat Spawners – The Chowan River blueback herring spawning stock should contain at least 10% repeat spawners (percent of the spawning stock that have spawned more than once).

Spawning Stock Biomass (SSB) – The restoration target to restore Chowan River blueback herring SSB to a minimum stock size threshold (MMST) of 4 million pounds.

Recruitment – Recruitment of age three blueback herring should be restored to a three-year moving average of at least 8 million fish.

In 2015, under Amendment 2 to the NCRHFMP, it was determined that only three of the stock recovery indicators were necessary and the recruitment indicator was dropped from the NCRHFMP. Additionally, the term stock recovery indicator was changed to stock status indicator, this term was deemed more appropriate for the restoration targets.

In addition to the above stock recovery indicators, Amendment 2 to the NCRHFMP recommended a variety of research needs and management options that address various issues such as habitat availability and degradation, predation, bycatch, critical habitat and water quality and that would contribute to the recovery of river herring stocks in North Carolina. A full description of these recommendations can be found in Amendment 2 to the NCRHFMP.

16.8. AGE

Age samples of the blueback herring and alewife catch from the Chowan River commercial pound net fishery are available from fish house sampling conducted from 1972-2006. The target sampling frequency is to collect unculled samples of at least 30 fish weekly, from at least 3 area commercial fishhouses during the fishing season.

Following the closure of the commercial river herring fisheries in North Carolina a commercial pound net survey was implemented to collect aging samples of river herring from the Chowan River. Depending on the year 3-4 commercial fishermen were contracted to fish commercial pound net sets in the Chowan River, NC during the traditional river herring commercial harvest season. All fishermen were required to obtain a weekly unculled adult sub-sample of approximately 20 pounds of river herring from their contracted pound nets. In 2009 sampling was expanded to include a visual estimate of the total daily catch of river herring in pounds from all of the pound nets set regardless of whether it was a designated contracted net or not. Adult samples were sorted to species and all individuals of each alosine species present were measured in millimeters (mm) fork length (FL) and total length (TL), weighed (kg), sexed, spawning maturity was determined, and an ageing sample was taken.

Scale samples collected for ageing were mounted between two microscope slides and read under an Eyecon 3000 microfiche reader and aged by methods similar to that in Street et al. (1975). Stratified sub-sampling, based on techniques developed by Ketchen (1950), was used to compile individuals for ageing. Samples were sorted by species, and sex, then placed in 10 mm size groups. If 15 or less samples were present in a size group, all of the samples were aged. If more than 15 samples were present in a size group, half of the fish in the group were aged. Proportions within each sex and size group were calculated and expanded to the remaining sample.

16.9. FISHERY DESCRIPTIONS

Since 2007 the commercial and recreational harvest of river herring is prohibited in all coastal and joint waters of the state. From 2007-2014 there was a 7,500 pound research set-aside harvest, with 4,000 pounds allocated for discretionary harvest to be taken over a four day period with area and gear restrictions (see section 16.3 for a complete description). The discretionary harvest season was eliminated in 2015 due to the depleted state of the river herring stocks and the lack of biological data for stock analysis and local product for area festivals obtained during the short season. The possession of river herring greater than 6 inches in the inland waters of North Carolina has been prohibited since 2006. The NCMFC complemented this rule in all internal coastal waters in 2015 under Amendment 2 to the NCRHFMP (see section 16.3).

16.9.1. Commercial Fishery

Commercial Landings

River herring have been subjected to intensive exploitation since colonial times along the Atlantic coast. The Albemarle Sound area has always been the center of the North Carolina fishery. In North Carolina, river herring were among the first fish to be exploited commercially because their oily flesh allowed them to be salt-preserved, without ice or refrigeration.

NCDMF has monitored commercial landings of river herring since 1972. Prior to 1994, commercial landings in North Carolina were acquired via a NCDMF and National Marine Fisheries Service (NMFS) Cooperative statistics program on a monthly basis from licensed seafood dealers; however, reporting at the time was not mandatory. In 1994 NCDMF implemented a mandatory commercial harvest data collection system known as the Trip Ticket Program (TTP). The Trip Ticket Program is a dealer-based reporting program that obtains a trip-level census of commercial landings in North Carolina.

The annual commercial harvest of river herring for the Albemarle Sound as well as other areas of the state is presented in Table 16.1. As mentioned previously, the Chowan River is the historical mainstay of the North Carolina river herring fishery and continued to serve in that capacity until the close of the commercial fishery statewide in 2007.

The use of pound nets revolutionized fishing in North Carolina, especially in the Albemarle Sound (Taylor 1992). Chestnut and Davis (1975) reported that 2,767 pound nets were set in North Carolina in 1927. Since the 1960s, the majority of the river herring pound nets have been set in the rivers, and the leads seldom exceeded 200 yards in length (Walburg and Nichols 1967). The Chowan River has been the center of the river herring pound net fishery, and from the late 1970s to the late 1980s the number of river herring pound nets ranged from 421 to 615 nets annually, with the amount of pound nets declining from 348 in 1989 to a low of 18 in 2009.

Gill nets, anchor and drift, have historically been utilized in the river herring fishery. The amount of gill net effort in the fishery prior to 1994 is unknown. During the 1970s, the gill net harvest of river herring accounted for approximately 15% of the total Albemarle Sound area harvest. However, from 1987 to 1994, the proportion of gill net landings increased to 24-40% of the total river herring harvest from the Albemarle Sound area. This increase may have been due to a directed fishery for roe fish. In 1986, approximately 6 million pounds were harvested in pound nets and 900,000 pounds from gill nets. During 1988, pound nets landed 2.3 million pounds and gill nets 1.5 million pounds. In contrast, 1994 totals of 425,000 pounds from pound nets and 175,000 pounds from gill nets was harvested.

Several other types of commercial gears have been used in the river herring fishery: fyke nets, fish wheels and dip nets. These gears have contributed very little to the total harvest in the Albemarle area. From 1915 through 1965, various regulations were enacted for the Albemarle Sound river herring fishery (seasons, area closures, gear restrictions).

The Albemarle Sound area accounted for 66-100% of the state's river herring harvest from 1889 to 1994. Between 1962 and 1994, the Chowan River pound net fishery contributed 43-97% of the state's total river herring landings. From 1950 to 1994, North Carolina accounted for 13.6-84.5% of the river herring landings of the Atlantic coast states.

Since the late 1800s, the areas fished and gears used to harvest river herring have remained essentially unchanged. The extent of the river herring fisheries in both the amount of gear and harvest, however, has declined significantly. The fisheries in the Albemarle Sound area are now pursued as multi-species fisheries, which are not totally dependent on river herring.

During 1995-1998, North Carolina accounted for 29-52% of the total river herring landings from the Atlantic coast. From 1999-2004, the State contributed 9-33% of the Atlantic coast river herring harvest. Landings from the Albemarle Sound area accounted for 91.6-99.8% of the state's total river herring landings during 1995-2004. The Chowan River pound net fishery contributed 60.3-76.5% of North Carolina's annual river herring harvest during 1995-1999.

Since 2000, the Chowan River pound net fishery contributed 41-66% of the state's total river herring harvest. Since 1988, regulations enacted for striped bass conservation (gill net mesh size restrictions, yardage restrictions, area closures) have impacted river herring harvest in the Albemarle Sound area. Even with these regulations, the river herring gill net fishery has accounted for a greater proportion of the overall harvest from 1995 - 1999 (21.2-38.1%). Since the 67,000 pound TAC was implemented in 2000, gill nets have accounted for 24.4-39.5% of the annual river herring landings in the Albemarle area.

From 2007 to 2014 the commercial harvest was restricted to a 7,500 pound research set aside, with a 4,000 pound maximum discretionary harvest allocation to be harvested over a four day period during the Easter holiday weekend in the Chowan River. The discretionary harvest fishery was eliminated in 2015 under Amendment 2 to the NCRHFMP (see section 16.3). Participation in the discretionary harvest fishery was limited to permitted fishermen. Landings for the research set aside season ranged from 643 pounds in 2009 to 1,765 pounds in 2010 (Table 16.2). The number of permits issued to participate in the fishery ranged from 30 in 2010 to 12 in 2013.

Commercial Catch Rates

Catch per unit effort (CPUE) for the Chowan river pound net fishery has been calculated since 1977 (Table 16.3; Figure 16.2). Catch effort was calculated by dividing the total weight (kg) by the total effort in pound net weeks (calculated as the number of pound nets fished each week summed over the entire season). Weeks were considered Sunday to Saturday and begin the first full week in January. Pound net effort was determined by an aerial survey, conducted with the assistance of the NCDMF marine patrol as well as pound net permit application data.

While the maximum number of pound nets set in any given week decreased drastically from a high of 624 in 1977 to only 36 in 2004, the total weeks fished has differed little over the years with the exception of 1997 when nets were only set for 5 weeks. Therefore, the overall decrease in total effort is due more to fewer nets set than to a reduction in the length of the fishing season. Since 2001, the

number of weeks fished increased slightly as a result of the TAC not being met, and the season remaining open longer, or nets being set earlier in the fishing season. Effort decreased considerably since the implementation of a harvest quota in 1995 and varied without trend since that time until 2006, when the moratorium was introduced.

Catch per unit effort for blueback herring and alewife from the Chowan River commercial pound net fishery declined considerably since the mid-1980s. Blueback herring CPUE increased slightly during the 1995-1999 seasons, but declined significantly after 2000. Alewife CPUE decreased considerably in 1993-1999, with slight increases in 2000 and 2001. Both CPUEs remained well below the historical levels until the close of the fishery in 2006. Following the close of the fishery, CPUE estimates from contracted pound net fishermen continued to decline for both blueback herring and alewife until 2012. From 2013-2015 CPUE estimates for both species have increased each year, with no real change in total pound nets or weeks fished. Despite this short-term increase, CPUE for both species remains much lower than historic values.

Repeat Spawners

The NCDMF has monitored repeat spawning for the Chowan River blueback herring and alewife since 1972 (Table 16.4). Percent repeat spawners for blueback herring from the Chowan River spawning stock is one of the stock recovery indicators identified in Amendment 1 to the NCRHFMP. The Chowan River blueback herring spawning stock should contain at least 10% repeat spawners (percent of the spawning stock that have spawned more than once). The percent of blueback herring repeat spawners in the pound net harvest averaged 14.8% during 1972-1982. From 1983 through 1989, the percentage of repeat spawners declined significantly, ranging from 0.6% to 6.1%. During the 1990s, blueback herring spawning repetition remained low, ranging from 1.2% (1994) to 4.7% (1993). During 2000 through 2003, a slight increase in the percentage was observed but declined again in 2004 (2.9%). Percentages increased again in 2007 and 2008 but declined again in 2009. Since, 2011 percentages have increased to levels above the restoration target. In 2015 the percent repeat spawners averaged 16.8%, the highest in a 34-year time series, showing signs that that the harvest moratorium is likely allowing increased survival of blueback herring.

The percentage of alewife repeat spawners also decreased since the 1970s, with a mean of 9.4% from 1972 through 1981. From 1988-1999, no or very small samples of alewife were obtained from the Chowan River pound net fishery, due to scarcity in the harvest. During 2001-2004, alewife samples were obtained from the pound net fishery and an increase in the percentage of repeat spawners was observed. Percent repeat spawners averaged 9.1 from 2004-2009. Alewife ages are incomplete due to significant staff turnover between 2010 and 2016. Since blueback herring were selected as the indicator species for North Carolina, staff focused on completion of blueback herring data for submittal into the stock assessment update.

Age Composition/Mean Size at Age

The age structure of blueback herring taken in the Chowan River pound net fishery has been characterized since 1972. From the 1970s to the early 1990s, sampling was conducted at up to six fish houses on a weekly basis. From 2000 through 2006, samples were obtained weekly from up to three fish houses until the season closed in 2006. Throughout the years, unculled pound net samples of at least 30 individuals each of blueback herring and alewife were obtained at least weekly during the spring. Size, age and sex composition of the harvest was determined from these samples. Samples of up to 30 fish

from each fishhouse were obtained, up to three times per week during the season, and after the season, into the second week of May. Samples in 2007 were obtained from Chowan River pound nets during the research set aside season. Samples since 2008 have been collected from the Chowan River Pound Net Survey.

The aged pound net samples were dominated by fish ages 4-6 throughout the entire time period (Appendix Table 16.3.) From 1972-1981, age 7 fish comprised 4.1 % of the aged sample annually. In recent years, age 7 fish comprised less than 1% of the aged sample, except for 2014 where age 7 fish comprised 3% of the aged sample.

Data from pound net samples for blueback herring show a decline in mean length at age since 1972 (Figure 16.3).

16.9.2. Recreational Fishery

Historically, river herring have been taken for personal consumption in every major North Carolina coastal river system. An analysis of river herring harvest by Baker (1968) indicated the majority of herring harvested by special device licensees in 1967-1968 occurred in the Chowan and Roanoke River basins. River herring were also harvested in other river basins, but American shad and hickory shad (*Alosa mediocris*) were of more importance to fishermen in those areas. Coastwide, Baker (1968) estimated that special device licensees harvested 2.9 million pounds of river herring some of which were sold. The recreational component of this total, however, is unknown. Although these fish were taken by fishermen licensed by NCWRC at that time, changes in designations of coastal/joint/inland waters, changes in jurisdictional responsibilities between NCDMF and NCWRC, and the unknown proportion of these fish which were harvested with the intent of sale precludes an estimate of the historical level of river herring harvest for personal consumption. The recreational fishery for river herring closed in 2007. It is now illegal to possess recreationally caught river herring in the coastal and joint waters of the state. It is also illegal to possess river herring greater than 6 inches from the inland waters of the state.

For the years leading up to the 2007 harvest closure, the extent of river herring harvest for personal consumption in coastal North Carolina is unknown. According to NCWRC Enforcement Officers who patrolled the inland waters of the Cape Fear, Neuse, and Tar-Pamlico river basins at that time, very few (usually none) special device licensees specifically targeting river herring were encountered in these areas, principally due to the low numbers or absence of these species. Special device licensees targeting river herring are still encountered in small tributaries of the Roanoke and Chowan rivers during the spring months of years prior to the closure, and an active recreational herring fishery persisted in tributaries to the Meherrin River. Recreational river herring fishermen are still found at small bridge crossings over tributaries to other Albemarle Sound river systems such as the Pasquotank, Perquimans, Yeopim and Scuppernong rivers. Low effort directed at river herring harvest in these areas is likely indicative of low river herring abundance.

A recreational drift net river herring fishery existed on the Roanoke River for many years. This fishery has never been fully assessed by NCDMF or NCWRC. The NCDMF initiated a pilot drift net creel survey in 1999 to characterize this fishery for development of future monitoring strategies and to provide managers with weekly reports of recreational drift net activity (participation, catch rates, species composition, net sizes, etc). Sampling was conducted in the lower river area including Williamston, Jamesville, and Plymouth. Interviews were conducted three days per week, for a total of 21 sampling days in 1999. Catches of river herring ranged from 20 to 300 fish per vessel with a mean of 106. Drift

duration ranged from 1 to 5 hours with a mean of 2.2 hours. A total of 2,764 river herring were observed in the survey. Because there was no estimate of total effort, total catch cannot be estimated.

The recreational fishery for river herring closed in 2007. It is illegal to possess recreationally caught river herring in the coastal and joint waters of the state. It is also illegal to possess river herring greater than 6 inches from the inland, coastal, and joint waters of the state.

16.10. FISHERIES INDEPENDENT SURVEYS

16.10.1. Juvenile abundance

The NCDMF began nursery area sampling for juvenile blueback herring and alewife in the Albemarle Sound area in 1972, with eleven core stations being established and sampled throughout the time period (Figure 16.4). This survey was designed to index annual relative abundance of juvenile blueback herring and alewife. Thirty-four stations were established in the western Albemarle Sound area and sampled with trawls and seines. The Carolina wing trawl was adopted as the standard trawl in place of the Cobb trawls in June 1974 (Johnson et al. 1977), and the seines continued. The 34 stations (23 trawls and 11 seines) were sampled monthly during June-October. During September, an additional 43 stations (28 trawls and 15 seines) were sampled throughout the Albemarle Sound area to determine distribution and nursery areas of anadromous species.

Seine stations were sampled with a 60 foot bag seine with $\frac{1}{4}$ inch mesh bag, with a single haul considered one catch-per-unit-of-effort (CPUE). The Carolina wing trawl had a headrope length of 26 feet, containing webbing which ranged from 4 inch stretched mesh in the wings to $\frac{1}{8}$ inch mesh tail bag. The trawl was pulled for 10 minutes, and was considered one CPUE. Samples were sorted to species, and up to 30 individuals of each alosine species present were measured to the nearest millimeter fork length (mm, FL), and all others were counted.

Based on catch consistency the seine proved to be the best sampling gear for blueback herring, and the wing trawl was the best for alewife. Due to a further reduction in federal aid funds, trawl sampling was dropped at the end of June 1984. Sampling with seines at the 11 cores stations has continued during June-October each year from 1972-present. During September, an additional 13 seine stations are sampled throughout the Albemarle Sound area to determine distribution and migration.

Juvenile abundance indices (JAI) are established for alewife and blueback herring using data from the 11 core stations sampled once per month, June-October, 1972-2015 (Figures 16.5 and 16.6). The JAI for blueback herring and alewife fluctuated over the years. The highest CPUE recorded for blueback herring was in 1973 (426.6 fish/seine); the lowest was in 1994 (0 fish/seine), part of a very low CPUE trend during 1986-2015. The average CPUE for blueback herring during 1972-2015 is 55.8 fish/seine, compared to the 63.0 fish/seine from the benchmark assessment time period, 1972-2009. The stock recovery indicator for juvenile abundance of blueback herring is to achieve a 3-year moving average catch per unit of effort of at least 60. The 3-year average based on the 2013-2015 data is 6.9.

The average CPUE for alewife during the 1972-2015 period is 2.6 fish/seine compared to the 2.4 fish/seine from the benchmark assessment time period, 1972-2009. Throughout the time series alewife numbers have not been observed in the same magnitude as blueback herring. Alewife JAI increased slightly in 2005 and 2010. In 2013, alewife numbers increased to the highest level since 1980, declined to 0 fish/seine the following year before peaking again in 2015 at 7.1 fish/seine. The current 3-year average based on the 2013-2015 data is 5.6 fish/seine.

16.10.1.1. Independent Gill Net Survey

Since 1990, NCDMF has been conducting an independent gill net survey (IGNS) throughout the Albemarle Sound area (Figure 16.7). The survey was designed for striped bass data collection. However, river herring are captured during the survey and size, age, and sex data are collected. Gill nets are set in sizes from 2.5 through 7.0 inch stretched mesh (ISM), in half-inch increments and 8.0, and 10.0 ISM are utilized.

River herring CPUE has been calculated from the IGNS throughout the Albemarle Sound area since 1991. Blueback herring and alewife CPUE from the 2.5 ISM and 3.0 ISM (combined) January-May, 1991-2015 are shown in 8. The CPUE of blueback herring has continued a general decline through 2012, the lowest value in the time series (0.86 fish/net). In 2013 the CPUE of blueback herring slightly increased before declining again in 2014, then increasing in 2015 to the highest level in the 10-year time series (5.6 fish/net). Alewife CPUE has been low for most of the time series with a general increase since 2005. CPUE has been steady from 2008-2015, except for 2012 when the CPUE dropped to 0.98 fish/net.

16.11. ASSESSMENT APPROACHES AND RESULTS

16.11.1. Statistical catch-at-age model for the Chowan River

A forward-projecting age-structured statistical catch-at-age (SCA) model for the Chowan River blueback herring stock was applied to total in-river catches, age compositions, length compositions, and a fisheries-independent young-of-year (YOY) index to estimate age-3 abundance and mortality rates. The benchmark assessment time period was 1972 to 2009. The assessment update adds the most recent 5 years of data covering the time period from 1972 to 2015.

16.11.1.1. Model Structure

The population model is aged-based and projects the population numbers-at-age by sex s forward through time given model estimates of age-3 numbers and mortality rates, assumed known values of natural mortality for immature and mature fish by age, and proportion mature-at-age. The population numbers-at-age ($N_{s,d,y,a}$) matrix has dimensions $s \times d \times y \times A-2$, where s is number of sexes, d is the number of maturity phases, y is the number of years, and A is the oldest age group (age 8+). There were six year-classes in the model, representing ages 3 through 8+.

The cohort dynamics of the model is a hybrid of the Margaree River model in Gibson and Myers (2003a). The model incorporates the immature and mature phases by sex and assumes the year begins at the start of spawning. Mature individuals of each age move into the Chowan River where they are intercepted and removed for harvest. The model assumes harvest occurs before the fish reach the spawning grounds. Biological samples for sex, and age and repeat-spawning data are collected from fishery landings. The model allows different natural mortality values for each year, age, sex, and maturity phase.

Given the above dynamics, population numbers-at-age by sex and maturity phases are calculated through time by using the cohort survival models shown in Figure 16.9. The number of age-3 bluebacks at the beginning of spawning season (R_y) are directly estimated in the model, and these estimates are partitioned into sex- (1=female; 2=male) and maturity phase- (1=immature; 2=mature) specific

estimates of age-3 abundance using sex ratio and mature proportions-at-age (derived outside of the model):

Female

Immature: $\hat{N}_{1,1,y,3} = \hat{R}_y \cdot f \cdot (1 - p_{1,y,3})$

Mature: $\hat{N}_{1,2,y,3} = \hat{R}_y \cdot f \cdot p_{1,y,3}$

Male

Immature: $\hat{N}_{2,1,y,3} = \hat{R}_y \cdot (1 - f) \cdot (1 - p_{2,y,3})$

Mature: $\hat{N}_{2,2,y,3} = \hat{R}_y \cdot (1 - f) \cdot p_{2,y,3}$

where f is the female sex ratio (proportion) and p is the proportion mature by sex s , year y , and age a . Recruitment of age-3 bluebacks (R_y) is modeled as a log-normal deviation from average recruitment:

$$\hat{R}_y = \bar{R} \cdot \exp^{\hat{e}_y}$$

where \bar{R} is the average recruitment parameter and e_y are independent and identically distributed normal random errors with mean zero and constant variance and are constrained to sum to zero over all years. This formulation differs from the original Gibson and Meyers model, which linked recruitment via a Beverton-Holt equation to log-normal deviations.

The initial population abundance-at-age for ages 4 to 8+ in 1972 for each sex and maturity phase is calculated by assuming a static stock:

Immature: $\hat{N}_{s,1,1972,a} = \hat{N}_{s,1,1972,a-1} \cdot \exp^{-M_{s,1,1972,a-1}} \cdot (1 - p_{s,1972,a})$

Mature: $\hat{N}_{s,2,1972,a} = \hat{N}_{s,2,1972,a-1} \cdot (1 - \hat{u}_{1972}) \cdot \exp^{-M_{s,2,1972,a-1}} + \hat{N}_{s,1,1972,a-1} \cdot \exp^{-M_{s,1,1972,a-1}} \cdot p_{s,1972,a}$

where M is the sex-, maturity phase-, year-, and age-specific instantaneous natural mortality rate, and u is the year-specific exploitation rate. Population abundance-at-age for ages 4 through 7 in the remaining years is calculated by:

$$\hat{N}_{s,1,y,a} = \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot (1 - p_{s,y,a})$$

Immature:

$$\hat{N}_{s,2,y,a} = \hat{N}_{s,2,y-1,a-1} \cdot (1 - \hat{u}_{y-1}) \cdot \exp^{-M_{s,2,y-1,a-1}} + \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot p_{s,y,a}$$

Mature:

The population abundance of the plus group (8+) is calculated as:

$$\hat{N}_{s,2,y,8+} = \hat{N}_{s,2,y-1,a-1} \cdot (1 - \hat{u}_{y-1}) \cdot \exp^{-M_{s,2,y-1,a-1}} + \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot p_{s,y,a} +$$

Mature:

$$\hat{N}_{s,2,y-1,8+} \cdot (1 - \hat{u}_{y-1}) \cdot \exp^{-M_{s,2,y-1,8+}}$$

Exploitation rates for each year (u_y) are estimated as individual parameters in the model.

Input values for age- and sex-specific M were calculated using the Lorenzen (1996) equation that relates body weight (in grams) to natural mortality. The grand mean of average weight-at-age of blueback herring from the pound net fishery during 1972 through 1980 was used to derive M . Natural mortality rate was assumed constant with time and among maturity phases for the base model runs. The M estimates for each sex and age were:

| | Age | | | | | |
|--------|------|------|------|------|------|------|
| | 3 | 4 | 5 | 6 | 7 | 8 |
| Female | 0.71 | 0.66 | 0.64 | 0.62 | 0.60 | 0.59 |
| Male | 0.72 | 0.70 | 0.67 | 0.64 | 0.62 | 0.61 |

The annual proportions of fish mature at each age and sex were calculated from repeat-spawner frequency data provided by the NCDMF. When data were missing in some years and ages, averaged values from surrounding cells were used to fill in missing data (Appendix Table 16.1).

Total removals of blueback herring are one set of data from which age-3 abundances and exploitation rates are estimated. Total catch in numbers was provided by NCDMF (Appendix Table 16.2). Total catch for 2007 to 2015 was estimated by using pound net catch proportions provided in 2008, average blueback landings to alewife landings ratio from years prior to 2007, and annual mean weight by

species. Given estimates of annual numbers of mature for fish at each sex and age, predicted removals-at-age is computed by:

$$\hat{C}_{y,s,a} = \hat{N}_{y,s,m,a} \hat{u}_y$$

where $C_{y,s,a}$ is the predicted in-river removals of sex (s) of age (a) during year (y). All predictions are stored in an array of dimensions $s \times y \times A-2$. Predicted catch-at-age data are then compared to the observed total catch and observed proportions of catch numbers-at-age data (sample numbers at age are provided in Appendix Table 16.3) through the equations:

Predicted Total Catch: $\hat{C}_y = \sum_s \sum_a \hat{C}_{y,s,a}$

Predicted Proportions of Catch Numbers-At-Age: $\hat{P}_{y,s,a} = \frac{\hat{C}_{y,s,a}}{\sum_a \hat{C}_{y,s,a}}$

The North Carolina YOY seine survey index for blueback herring was incorporated into the model by linking it to the recruitment estimates:

$$\hat{I}_y = \hat{q} \cdot \hat{R}_{y+3}$$

where \hat{I}_y is the predicted index of survey in year y , and q is the catchability coefficient. Based on the lagged year comparison, YOY indices from 1972 to 2015 (Appendix Table 16.4) were used to tune recruitment estimates for 1975 to 2015

Female spawning stock biomass (SSB) in year y was calculated as:

$$SSB_y = \sum_a \hat{N}_{1,2,y,a} \cdot (1 - \hat{u}_y) \cdot w_{1,2,y,a}$$

where $w_{1,2,y,a}$ is the mean weight-at-age for mature females in year y and age a . Calculated mean weights-at-age are provided in Appendix Table 16.5.

Fishing mortality rates were calculated from the estimated exploitation rates assuming a Type I fishery:

$$\hat{F}_y = -\log_e (1 - \hat{u}_y)$$

Standard errors of fishing mortality rates were derived using the delta method provided in AD Model Builder.

Lognormal errors were assumed for the total catch data and YOY index. The concentrated likelihood was weighted for variation in each observation. The generalized concentrated negative log-likelihood ($-L_l$; Parma 2002; Deriso et al. 2007) is:

$$-L_l = 0.5 * \sum_i n_i * \ln \left(\frac{\sum_i RSS_i}{\sum_i n_i} \right)$$

where n_i is the total number of observations and RSS_i is the weighted residual sum-of-squares from dataset i . Equations for the weighted residual sum-of-squares of total removals (C) and escapement numbers (E) are:

$$RSS_C = \lambda_C \sum_y \left(\frac{\log_e(C_y + 1e^{-5}) - \log_e(\hat{C}_y + 1e^{-5})}{CV_y} \right)^2$$

$$RSS_E = \lambda_E \sum_y \left(\frac{\log_e(I_y + 1e^{-5}) - \log_e(\hat{I}_y + 1e^{-5})}{CV_y} \right)^2$$

where CV_y is the coefficient of variation for the observed catch or index estimate in year y , and λ_C and λ_E are the relative weights (Parma 2002; Deriso et al. 2007). The CVs for the YOY index were high; therefore, the lambda value for total catch was set to 10 to force the model to fit the pattern in total catch since the catch values are likely more accurate.

For catch age composition data, a multinomial error distribution is assumed and the negative log-likelihood is calculated using the general equation:

$$-L_p = \lambda_p \sum_y \sum_s -n_{y,s} \sum_a (P_{y,s,a} + 1e^{-5}) \cdot \ln(\hat{P}_{y,s,a} + 1e^{-5})$$

where $n_{y,s}$ is the effective number of fish of sex s aged in year y , and $P_{y,s,a}$ is the observed proportions of catch-at-age.

Effective sample size is estimated using the iterative procedures of McAllister and Ianelli (1997). In essence, the average effective sample size for catch age (or length) composition data of each sex is calculated using the following formula:

$$\hat{n}_s = \frac{\sum_y \hat{n}_{y,s}}{d_{y,s}}$$

and \hat{n}_y is defined as:

$$\hat{n}_{y,s} = \frac{\sum_a \hat{P}_{y,s,a} (1 - \hat{P}_{y,s,a})}{\sum_a (P_{y,s,a} - \hat{P}_{y,s,a})^2}$$

where $\hat{P}_{y,s,a}$ is the predicted proportion-at-age a (or l for length data) in year y from the escapement numbers, $P_{y,s,a}$ is the observed proportion-at-age, and d_y is the number of years of data for escapement series. The average effective sample size is applied, re-calculated, and re-substituted until the average effective sample size stabilizes under equal weighting of all likelihood components.

The total log-likelihood of the model is:

$$f = -L_l - L_p$$

The total log-likelihood was estimated by the auto-differentiation routine in AD Model Builder to search for the “best” age-3 abundance estimates that minimize the total log-likelihood. AD Model Builder allows the minimization process to occur in phases. During each phase, a subset of parameters is held fixed and minimization is done over another subset of parameters until eventually all parameters have been included. In this model, the following parameters were solved over two phases:

Phase

- 1 average recruitment (log scale) and exploitation rates
- 2 catchability coefficient(s) (log scale)
- 3 recruitment deviations

Model fit for all components was checked by using standardized residual plots and root mean square errors. Standardized residuals (r) for lognormal (total catch and YOY index) were calculated as:

Total Catch:

$$r_{C,y} = \frac{\log_e(C_y + 1e^{-5}) - \log_e(\hat{C}_y + 1e^{-5})}{\sqrt{\log_e(CV_y^2 + 1)}}$$

YOY Index:

$$r_{I,y} = \frac{\log_e(I_y + 1e^{-5}) - \log_e(\hat{I}_y + 1e^{-5})}{\sqrt{\log_e(CV_y^2 + 1)}}$$

The root mean square error for total catch and the YOY index was calculated as:

| YOY Index | Total Catch |
|--|--|
| $RMSE_C = \sqrt{\frac{\sum_y r_{C,y}^2}{n}}$ | $RMSE_I = \sqrt{\frac{\sum_y r_{I,y}^2}{n}}$ |

where n is the total for Total Catch or YOY index values.

For catch age composition data, standardized residuals were derived as:

$$r_{y,s,a} = \frac{P_{y,s,a} - \hat{P}_{y,s,a}}{\sqrt{\frac{\hat{P}_{y,s,a}(1-\hat{P}_{y,s,a})}{\hat{n}_s}}}$$

where \hat{n}_s is the average effective sample size for sex s and type of data.

16.11.1.2. Reference Point Derivation

Reference points for management were derived using three analytical approaches. First, yield-per-recruit (YPR) analyses were conducted to derive $F_{0.10}$ (F where slope between two adjacent YPR values is 10% of the slope at the origin) and F_{MAX} (F at maximum yield) reference values. Second, spawning biomass-per-recruit (SPR) analysis was conducted to derive the $F_{40\%}$ and $F_{20\%}$ reference points (fishing mortality rates that reduce the spawning biomass to 40% and 20% of the maximum unfished biomass, respectively). Third, recruitment and spawning stock biomass estimates in conjunction with SPR and YPR (production model method in Gibson and Myers 2003b) were used to derive values for F_{MED} (level of fishing mortality where recruitment has been sufficient to balance losses to fishing mortality in half the observed years), F_{COL} (the fishing mortality that drives the population to extinction), F_{MSY} (the fishing rates that produces maximum sustainable yield), SSB_{MSY} (the spawning stock biomass at MSY), and $SSB_{20\%}$ (minimum threshold population size).

The YPR and SPR analyses follow the model adapted by Gibson and Myers (2003c) for alewife. For a given F , YPR is calculated as:

$$YPR_F = \sum_{a=3}^{\max a} SS_a w_a (1 - e^{-F})$$

where SS_a is given by:

$$\begin{aligned} SS_3 &= p_3 \\ SS_4 &= SS_3 e^{-M_{m,3}-F} + (1-p_3) e^{-M_{i,3}} p_4 \\ SS_5 &= SS_4 e^{-M_{m,4}-F} + (1-p_3)(1-p_4) e^{-M_{i,3}-M_{i,4}} p_5 \\ SS_6 &= SS_5 e^{-M_{m,5}-F} + (1-p_3)(1-p_4)(1-p_5) e^{-M_{i,3}-M_{i,4}-M_{i,5}} p_6 \\ SS_7 &= SS_6 e^{-M_{m,6}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6) e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}} p_7 \\ SS_8 &= SS_7 e^{-M_{m,7}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)(1-p_7) e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}-M_{i,7}} p_8 \end{aligned}$$

Where a is the age of the fish, p_a is the proportion mature at that age, $M_{m,a}$ and $M_{i,a}$ are the instantaneous natural mortality rates for mature and immature fish of age a , and w_a is the female weight at age.

Since a plus group was used in the model, one additional SS_a was calculated to match the maximum observed age (9) for female blueback:

$$SS_9 = SS_8 e^{-M_{m,8}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)(1-p_7)(1-p_8) e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}-M_{i,7}-M_{i,8}} p_8$$

Similarly, SPR is calculated as:

$$SPR_F = \sum_{a=3}^{\max a} SS_a w_a e^{-F}$$

YPR and SPR were calculated for a set of F s that ranged from 0 to 5 with an increment of 0.01. F_{MAX} was found by selecting the fishing mortality where YPR_F takes its largest value, and $F_{0.10}$ was found by selecting the fishing mortality where the marginal gain in yield was 10% that at $F = 0$. The SPR_{x%} reference points were found by selecting the fishing mortality rate where SPR_F was x% that of SPR_{F=0}. Data from 1976 were used to calculate SPR and YPR values to develop historical estimates of population quantities before the decline in abundance and changes in age structure.

F_{MED} was calculated by finding the fishing mortality rate that produced a SPR replacement line with a slope that equals the median survival ratio (median of R_y/SSB_{y-3}) from the spawner-recruitment (S-R) biomass estimates. The remaining quantities were produced using a production model based on the Beverton-Holt spawner-recruit model. A Beverton-Holt spawner-recruit model was fit externally to the age-3 recruitment numbers (R_y) and corresponding spawning stocking biomass (SSB_{y-3}). The model is:

$$R_y = \frac{aSSB_{y-3}}{1 + (aSSB_{y-3}/R_0)} e^\epsilon$$

Here, a is the slope at the origin of the spawner-recruit relationship (the maximum rate at which spawners can produce recruits at low population sizes) and R_0 is the asymptotic recruitment level which is the carrying capacity expressed as the number of fish that survive to age-3 (Gibson and Myers 2003b, 2003c). The linearized form of the model:

$$\log_e(R_y) = \log_e(a) + \log_e(SSB_{y-3}) - \log_e(1 + aSSB_{y-3}/R_0) + \varepsilon$$

was fitted to the spawner-recruitment data using non-linear least-squares regression. Only estimates of recruitment from 1978–2005 and SSB from 1975–2002 were used to estimate the S-R relationship to eliminate the influence and possible bias of the static stock abundance estimates during the first year (1972) and the retrospective bias near the terminal (see below). For a given level of F , the equilibrium spawning biomass (SSB^*) is calculated using the relationship:

$$SSB^* = \frac{(\hat{a}SPR_F - 1)\hat{R}_0}{\hat{a}}$$

The corresponding equilibrium number of recruits (R^*) is found by substituting SSB^* in the spawner-recruit model:

$$R^* = \frac{\hat{a}SSB^*}{1 + (\hat{a}SSB^*/\hat{R}_0)}$$

The equilibrium catch (C^*) is R^* multiplied by the yield-per-recruit for the given value of F :

$$C^* = R^* \cdot YPR_F$$

F_{MSY} is found by finding the fishing mortality rate that produces the maximum C^* , and SSB_{MSY} is the value of SSB^* corresponding to this fishing mortality rate. F_{COL} is the value of F where $1/SPR_{F=0} = a$. The minimum threshold population size ($SSB_{20\%}$) was calculated as 20% of the equilibrium spawner abundance in the absence of fishing:

$$SSB_{20\%} = 0.2 \frac{(\hat{a}SPR_{F=0} - 1)\hat{R}_0}{\hat{a}}$$

16.11.1.3. Model Results

Being an update, the current assessment uses female sex ratio (0.5), the effective sample sizes for females and males (35), and age-specific natural mortality rates specified in the 2012 assessment. Initial CVs used for the total catch were 0.30, and for the YOY index, the CVs estimated for the arithmetic mean were used as a proxy since the standard error for the geometric mean was not provided. As noted in the 2012 assessment, a lambda for the total catch was set of 10 to force the model match the total catch patterns. The root mean square error (RMSE) for the YOY index was 2.41.

Resulting contributions to total likelihood are listed in Table 16.5. The converged total likelihood was 4,354.45. A total of 90 parameters was estimated in the model. The resulting estimates of recruitment, exploitation rates, and catchability coefficients are given in Table 16.6. The model fit the observed total catch YOY index (Figure 16.10) and catch age composition of each sex fairly well (Figure 16.11). Exceptions for the age compositions were that the proportions of age-3 fish from 2010 to 2015 were greatly under-estimated by the model and produced very large standardized residuals (Figure 16.12). This was due to age-3 fish comprising higher proportions of sample than were observed prior to 2010.

Parameter estimates for years prior to 2006 were fairly precise ($CV<0.20$; Table 16.6), but the error in estimates increased thereafter due in part to low numbers of harvested fish.

16.11.1.4. Exploitation and Fishing Mortality Rates

Exploitation rates for blueback herring in the Chowan River before the 2007 moratorium ranged as low as 0.12 in 1979 to as high as 0.85 in 1986 (Table 16.6; Figure 16.13). Exploitation averaged about 0.24 prior to 1985, increased to an average of 0.68 during 1985–1988, and averaged about 0.43 between 1989 and 2006. Since the moratorium, exploitation rates have been close to zero. Corresponding fishing mortality rates are listed in Table 16.7 and are plotted in Figure 16.13. Fishing mortality averaged about 0.29 prior to 1985, increased to an average of 1.1 during 1985–1988, and averaged about 0.61 between 1989 and 2006. Since the moratorium, fishing mortality has been close to zero.

16.11.1.5. Population Abundance

The abundance estimates of the Chowan River blueback herring stock by sex, maturity phase, year, and age are given in Table 16.8, and total abundance by maturity state and year is given in Table 16.9. Blueback herring total abundance (age 3+) declined steadily from 157 million fish in 1976 to 62 million fish in 1980 (Table 16.9; Figure 16.13). Total abundance increased through 1983 to 104 million fish but then declined precipitously to 0.95 million fish in 2003 (Figure 16.14). After a slight increase in 2004 and 2005, total abundance declined to the lowest value of the time series (0.57 million fish) in 2006. Total abundance increased to 9.6 million fish in 2014, but declined to 5.1 million fish in 2015. Age-3 abundance peaked at 96 million fish in 1975, declined to 28.0 million fish in 1980, increased to 65 million through 1983, and then declined precipitously to its lowest value of 0.2 million fish in 2006 (Table 16.6; Figure 16.13). The model estimated that age-3 fish increased through 2014 to 7.5 million fish before decreasing to 0.4 million fish in the terminal year.

16.11.1.6. Spawning Stock Biomass

Estimates of female spawning stock biomass for blueback herring are provided in Table 16.10. Female SSB fluctuated but declined steadily from the peak of 6.5 million kilograms in 1972 to a low of 0.17 million kilograms in 1986 (Figure 16.13). Female SSB increased slightly to 0.5 million through 1990, but then it declined slowly to its lowest level of 11 thousand kilograms in 2005. The model estimated that female SSB, while still low, has been increasing since 2010 (Table 16.10; Figure 16.13).

16.11.1.7. Retrospective Analysis

In the 2012 assessment, small to moderate retrospective bias was evident in estimates of age-3 abundance, exploitation rate, female SSB, and total population abundance (Figure 16.15A). For age-3 abundance and total population abundance, the values before the terminal year were over-estimated but the terminal year estimate was consistently under-estimated. For exploitation rates and female SSB, the retrospective patterns were over- and under-estimation of the values near the terminal year, respectively.

For this update, the retrospective patterns were similar except the magnitudes of the differences were 3-4 times greater (Figure 16.15B) and indicated worsening model fit likely due to the mis-match in age composition and small catches for 2010-2015.

Small to moderate retrospective bias was evident in estimates of age-3 abundance, exploitation rate, female SSB, and total population abundance. For age-3 abundance and total population abundance, the terminal year estimate was consistently under-estimated. For exploitation rates and female SSB, the retrospective patterns were over- and under-estimation of the value, respectively.

16.12. BENCHMARKS

The fit of the Beverton-Holt stock-recruitment equation to the age-3 abundance and female SSB is shown in Figure 16.16. A plot of the residuals indicated reasonable model fit (Figure 16.16). The estimates of a and R_0 are 22.46 (SE = 3.706) and 39,346,610 fish (SE = 14,797,017), respectively. The estimate of a was precise (CV=0.16), but the estimate of R_0 was only moderately precise (CV=0.38) (Figure 16.4; Figure 16.17). Reference points generated from YPR, SPR, and the production model are shown in Table 16.11. For YPR analysis, the fishing mortality rate that maximized the yield-per-recruit, F_{max} , was greater than 5, and $F_{0.1}$ was 1.03. The fishing mortality that reduced the female spawning biomass to 40% and 20% of the level without fishing was 0.53 and 1.04, respectively.

From the spawner-recruit data and production model, F_{MED} was estimated to be 0.59 (Table 16.5; Figure 16.18). The fishing mortality rate that produces maximum sustainable yield, F_{MSY} , was 0.39 and corresponding spawning stock bass, SSB_{MSY} , was 1,894,382 kilograms. SSB_{MSY} was higher than the 20% of the equilibrium spawner biomass, $SSB_{20\%}$ (1,126,623 kilograms). Current female spawning stock biomass is only 12% of SSB_{MSY} . The fishing mortality rate that drives the population to extinction, F_{COL} , was 0.9. The relationships between the reference points from the production model are shown with the S-R data in Figure 9. The estimates of F_{MSY} and F_{COL} are considerably lower than those estimated for alewife ($F_{MSY} > 1.0$; $F_{COL} > 1.82$) in three Canadian rivers by Gibson and Myers (2003b). Historical fishing mortality rate estimates exceeded most reference points several times over the time series, particularly after 1985.

16.12.1. Sensitivity Analyses

Sensitivity analyses were not conducted because this is an update. Refer to section 16.12.1 of the 2012 stock assessment for more information.

16.12.1.1. Alternate Natural Mortality Rates

The impact of alternate estimates of age- and sex-specific natural mortality on model results were evaluated in the 2012 assessment. Refer to section 16.12.1.1 of the 2012 stock assessment for more information.

16.13. CONCLUSIONS AND RECOMMENDATIONS

The previous assessment concluded that the Chowan River blueback herring stock was not experiencing overfishing but was overfished. Amendment 1 to the NCRHFMP identified four stock recovery indicators for the Chowan River blueback herring stock: a three-year running average juvenile abundance index of greater than 60 fish per haul, a spawning population comprised of greater than 10% repeat spawners, a spawning stock biomass of greater than 4 million pounds (1.8 million kg) and a three-year running average of greater than 8 million age-3fish. Amendment 2 to the NCRHFMP removed recruitment (three-year running average of greater than 8 million age-3 fish) as a stock recovery indicator and changed the name of stock recovery indicators to stock status indicators.

Based on the 2015 fishing mortality rate and female spawning stock biomass estimates, the Chowan River blueback herring population is overfished (2015 SSB=227,333 versus $SSB_{MSY}=1.8$ million kilograms), but over-fishing is not occurring ($F=0.000$ versus $F_{MSY}=0.39$). Estimates of fishing mortality have been close to zero since the moratorium (Table 16.7, Figure 16.13). The forward-projecting statistical catch-at-age model estimates juvenile abundance as well below the target of 60 fish per haul (Figure 16.10), with no increasing pattern evident. Percentage of repeat spawners varied from 2007 through 2010, remaining below the target of 10%. Starting in 2011, there was an abrupt increase of the percentage of repeat spawners that has continued to increase annually, exceeding the target, to the highest level in 34-years of 16.8% in 2015 (Table 16.4). Female SSB has been increasing since 2010, but still remains at approximately 12% of the target of 1.8 million kilograms (Table 16.10; Figure 16.13). The factors leading to this recommendation of stock status remain largely unchanged since the 2012 stock assessment, despite a fishing pressure that is negligible. Therefore, although the stock is not currently experiencing overfishing, it remains overfished since the spawning stock biomass remains less than 12% of the amount necessary to replace itself in the complete absence of fishing.

While current research programs are recommended to continue, assessing progress towards recovery goals would be improved with additional research and surveys. Many recommendations made in the previous assessment (ASMFC 2012) and in Amendments 2 to the NCRHFMP are echoed here. Amendment 2 to the NCRHFMP identified three stock status indicators as restoration targets. Continued data collection through the Chowan River Pound Net Survey and a juvenile abundance survey to monitor these indicators are essential in determining stock status of Chowan River blueback herring. Monitoring efforts in other river basins should continue and be expanded as well.

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Table 16.1 Commercial landings in pounds of river herring in North Carolina, 1972-2006.

| Year | Atlantic Ocean | Albemarle Sound Area (excluding Chowan River) | Chowan River | Other Areas | Lb |
|--------|----------------|--|--------------|-------------|------------|
| 1972 | -- | 643,026 | 10,594,117 | 0 | 11,237,143 |
| 1973 | -- | 573,931 | 7,350,578 | 1,389 | 7,925,898 |
| 1974 | -- | 467,992 | 5,736,905 | 4,645 | 6,209,542 |
| 1975 | 2,338 | 917,723 | 5,031,756 | 250 | 5,952,067 |
| 1976 | -- | 666,584 | 5,734,776 | 0 | 6,401,360 |
| 1977 | -- | 1,102,125 | 7,418,218 | 3,470 | 8,523,813 |
| 1978 | -- | 954,939 | 5,615,113 | 37,101 | 6,607,153 |
| 1979 | 19,388 | 796,099 | 4,303,663 | 0 | 5,119,150 |
| 1980 | * | 796,237 | 5,382,954 | 39,332 | 6,218,523 |
| 1981 | 143,232 | 1,245,401 | 3,314,447 | 50,643 | 4,753,723 |
| 1982 | 7,679 | 1,872,156 | 7,459,968 | 97,900 | 9,437,703 |
| 1983 | -- | 1,453,033 | 4,405,915 | 9,384 | 5,868,332 |
| 1984 | 9,497 | 1,931,492 | 4,561,503 | 13,617 | 6,516,109 |
| 1985 | * | 2,665,334 | 8,871,391 | 11,553 | 11,548,278 |
| 1986 | 40,270 | 999,093 | 5,767,874 | 7,086 | 6,814,323 |
| 1987 | 19,279 | 838,689 | 2,334,719 | 2,288 | 3,194,975 |
| 1988 | 19,517 | 1,570,788 | 2,259,888 | 341,018 | 4,191,211 |
| 1989 | -- | 581,486 | 908,145 | 1,446 | 1,491,077 |
| 1990 | 11,073 | 433,891 | 710,849 | 1,812 | 1,157,625 |
| 1991 | -- | 372,843 | 1,202,535 | 0 | 1,575,378 |
| 1992 | 110,794 | 476,649 | 1,135,340 | 395 | 1,723,178 |
| 1993 | -- | 115,072 | 801,115 | * | 916,235 |
| 1994 | 38,834 | 211,372 | 390,852 | 3,251 | 644,309 |
| 1995** | 19,174 | 150,082 | 280,681 | 4,049 | 453,984 |
| 1996** | * | 123,725 | 404,884 | 894 | 529,503 |
| 1997** | 5,568 | 126,453 | 201,929 | 861 | 334,809 |
| 1998** | -- | 143,424 | 377,312 | 1,197 | 521,930 |
| 1999** | -- | 110,657 | 332,464 | 373 | 443,494 |
| 2000** | 599 | 140,696 | 182,658 | 8,378 | 332,336 |
| 2001** | * | 89,767 | 201,717 | 15,277 | 306,761 |
| 2002** | * | 75,736 | 92,979 | 6,145 | 174,860 |
| 2003** | * | 98,440 | 84,591 | 16,685 | 199,716 |
| 2004** | * | 107,430 | 77,177 | 3,934 | 188,542 |
| 2005** | -- | 92,688 | 157,088 | 245 | 250,021 |
| 2006** | -- | 40,590 | 67,404 | 1,249 | 109,243 |

*Denotes confidential data

**Season or TAC in ASMA

Table 16.2 Commercial landings in pounds and value of research set-aside river herring harvest in North Carolina, 2007-2014. Research set-aside harvest eliminated in 2015.

| Year | # of Permits Issued | Quota (lb/permit/period) | Harvest (lb) |
|---------|------------------------|-----------------------------|--------------|
| 2007 | 15 | 200 | 1,103 |
| 2008 | 13 | 250 | 1,292 |
| 2009 | 27 | 125 | 643 |
| 2010 | 30 | 125 | 1,765 |
| 2011 | 23 | 150 | 1,611 |
| 2012 | 18 | 150 | 678 |
| 2013 | 12 | 150 | 743 |
| 2014 | 27 | 150 | 989 |
| Average | 21 | 163 | 8,824 |
| Total | 165 | | 1,103 |

Table 16.3 Catch-per-unit effort of blueback herring and alewife in the commercial pound net fishery, Chowan River, NC.

| Year | Total PN fished | Weeks fished | Effort in PN weeks | PN BB Catch | BB CPUE | PN ALE.Catch | ALE. CPUE |
|--------|-----------------|--------------|--------------------|-------------|---------|--------------|-----------|
| 1977 | 624 | 9 | 4,854 | 7,001,059 | 1,442 | 291,711 | 60 |
| 1978 | 383 | 10 | 3,645 | 4,050,767 | 1,111 | 1,209,970 | 332 |
| 1979 | 502 | 12 | 4,996 | 2,118,907 | 424 | 2,035,813 | 407 |
| 1980 | 500 | 9 | 3,090 | 3,388,983 | 1,096 | 1,824,837 | 590 |
| 1981 | 525 | 10 | 4,120 | 2,041,319 | 495 | 1,198,870 | 291 |
| 1982 | 480 | 11 | 4,461 | 5,388,115 | 1,207 | 1,992,865 | 446 |
| 1983 | 486 | 12 | 4,895 | 2,380,261 | 486 | 1,947,488 | 398 |
| 1984 | 480 | 12 | 5,040 | 3,196,416 | 634 | 1,305,578 | 259 |
| 1985 | 421 | 12 | 3,708 | 6,845,568 | 1,846 | 1,930,802 | 520 |
| 1986 | 451 | 12 | 4,241 | 4,244,280 | 1,000 | 1,340,299 | 316 |
| 1987 | 501 | 11 | 4,969 | 1,353,601 | 272 | 980,194 | 197 |
| 1988 | 506 | 12 | 4,689 | 1,430,114 | 305 | 804,440 | 171 |
| 1989 | 348 | 9 | 3,063 | 626,222 | 204 | 281,347 | 92 |
| 1990 | 360 | 11 | 3,077 | 610,931 | 198 | 99,455 | 32 |
| 1991 | 226 | 11 | 2,037 | 720,218 | 353 | 294,174 | 144 |
| 1992 | 180 | 12 | 1,669 | 806,091 | 483 | 329,249 | 197 |
| 1993 | 197 | 11 | 1,729 | 640,092 | 370 | 160,023 | 92 |
| 1994 | 175 | 8 | 1,173 | 377,728 | 322 | 7,709 | 6 |
| 1995 | 73 | 8 | 484 | 263,163 | 543 | 5,371 | 11 |
| 1996 | 95 | 10 | 555 | 394,491 | 711 | 3,985 | 7 |
| 1997 | 102 | 5 | 461 | 190,071 | 412 | 1,920 | 4 |
| 1998 | 75 | 11 | 463 | 361,285 | 780 | 7,373 | 16 |
| 1999 | 68 | 8 | 471 | 318,495 | 676 | 6,500 | 14 |
| 2000 | 51 | 9 | 445 | 146,126 | 328 | 36,532 | 82 |
| 2001 | 63 | 7 | 385 | 136,998 | 356 | 64,470 | 167 |
| 2002 | 62 | 12 | 648 | 47,235 | 73 | 38,648 | 60 |
| 2003 | 50 | 10 | 419 | 45,326 | 108 | 35,614 | 85 |
| 2004 | 36 | 12 | 376 | 29,595 | 79 | 42,589 | 113 |
| 2005 | 41 | 15 | 447 | 148,552 | 332 | 7,424 | 16 |
| 2006 | 39 | 13 | 355 | 45,578 | 128 | 20,224 | 57 |
| 2007* | | | | | | | |
| 2008* | | | | | | | |
| 2009** | 18 | 14 | 217 | 65,763 | 303 | 23,482 | 108 |
| 2010** | 24 | 13 | 260 | 36,004 | 139 | 35,528 | 137 |
| 2011** | 26 | 14 | 286 | 28,304 | 99 | 46,181 | 162 |
| 2012** | 22 | 18 | 315 | 7,181 | 23 | 11,233 | 36 |
| 2013** | 23 | 17 | 238 | 10,136 | 43 | 17,259 | 73 |
| 2014** | 21 | 16 | 271 | 18,247 | 67 | 27,371 | 101 |
| 2015** | 23 | 18 | 253 | 18,041 | 71 | 30,719 | 121 |

* Fishery closed in 2007.

** Results based on visual estimates in contracted pound net sets from commercial fishermen in Chowan River, NC.

Table 16.4 Percentage of blueback herring and alewife repeat spawners (spawned more than once) from the Chowan River pound net fishery, 1972-2015. Alewife ages are incomplete past 2009.

| Year | Percent BB | Percent Alewife |
|-------|------------|-----------------|
| 1972 | 21.1 | 15.9 |
| 1973 | 18.3 | 13.2 |
| 1974 | 16.4 | 4.6 |
| 1975 | 3.9 | 9.3 |
| 1976 | 5.3 | 14.4 |
| 1977 | 7.3 | 4.1 |
| 1978 | 7.1 | 4.9 |
| 1979 | 20.1 | 3.3 |
| 1980 | 24.6 | 13.7 |
| 1981 | 16.2 | 9.7 |
| 1982 | 13.9 | 0.5 |
| 1983 | 1.6 | 2.5 |
| 1984 | 1.3 | 10.2 |
| 1985 | 3.3 | 0.0 |
| 1986 | 6.1 | 0.0 |
| 1987 | 3.3 | 0.7 |
| 1988 | 2.0 | 2.5 |
| 1989 | 0.6 | 0.0 |
| 1990 | 2.5 | No Samples |
| 1991 | 4.2 | 5.7 |
| 1992 | 3.7 | 12.5 |
| 1993 | 4.7 | No Samples |
| 1994 | 1.2 | No Samples |
| 1995 | 1.6 | No Samples |
| 1996 | 2.8 | No Samples |
| 1997 | 2.7 | No Samples |
| 1998 | 2.7 | No Samples |
| 1999 | 2.6 | No Samples |
| 2000 | 6.0 | 1.1 |
| 2001 | 3.1 | 5.0 |
| 2002 | 4.7 | 14.8 |
| 2003 | 5.9 | 5.4 |
| 2004 | 2.9 | 10.4 |
| 2005 | 2.1 | 12.6 |
| 2006 | 0.0 | 3.1 |
| 2007^ | 7.7 | 10.0 |
| 2008^ | 5.8 | 8.0 |
| 2009* | 1.7 | 10.5 |
| 2010* | 6.4 | |
| 2011* | 11.2 | |
| 2012* | 13.8 | |
| 2013* | 14.8 | |
| 2014* | 12.2 | |
| 2015* | 16.8 | |

[^] Based on research set aside data

*Based on samples obtained from contracted pound net sets

Table 16.5 Likelihood components with respective contributions in base model run.

Likelihood Components

| | Weight | RSS |
|---------------------|----------|---------|
| YOY Index | 1 | 171.235 |
| Total Catch | 10 | 7.64875 |
| Catch Age Comps | 1 | 4322.71 |
| Total Likelihood | | 4354.45 |
| Number of Estimates | | 90 |
| AIC | | 8888.91 |
| Catch RMSE | 0.134739 | |
| Index RMSE | 2.41498 | |

Table 16.6 Parameter estimates and associated standard deviations of base model configuration.

| Year | Age-3 Numbers | SD | CV |
|------|---------------|-----------|------|
| 1972 | 72,952,900 | 8.60E+06 | 0.12 |
| 1973 | 47,728,200 | 8.74E+06 | 0.18 |
| 1974 | 81,983,600 | 1.37E+07 | 0.17 |
| 1975 | 96,210,600 | 1.41E+07 | 0.15 |
| 1976 | 85,804,300 | 1.28E+07 | 0.15 |
| 1977 | 65,580,500 | 1.04E+07 | 0.16 |
| 1978 | 37,360,500 | 6.34E+06 | 0.17 |
| 1979 | 29,763,600 | 5.48E+06 | 0.18 |
| 1980 | 28,231,900 | 5.28E+06 | 0.19 |
| 1981 | 47,423,000 | 6.88E+06 | 0.15 |
| 1982 | 57,042,500 | 7.71E+06 | 0.14 |
| 1983 | 65,293,300 | 7.65E+06 | 0.12 |
| 1984 | 26,773,200 | 3.95E+06 | 0.15 |
| 1985 | 12,430,000 | 1.98E+06 | 0.16 |
| 1986 | 9,846,420 | 1.43E+06 | 0.15 |
| 1987 | 10,286,900 | 1.36E+06 | 0.13 |
| 1988 | 6,383,570 | 1.02E+06 | 0.16 |
| 1989 | 7,386,410 | 1.10E+06 | 0.15 |
| 1990 | 8,793,980 | 1.09E+06 | 0.12 |
| 1991 | 8,841,130 | 9.99E+05 | 0.11 |
| 1992 | 2,562,740 | 4.68E+05 | 0.18 |
| 1993 | 5,208,300 | 6.83E+05 | 0.13 |
| 1994 | 3,643,120 | 5.18E+05 | 0.14 |
| 1995 | 2,651,640 | 4.29E+05 | 0.16 |
| 1996 | 3,985,310 | 5.11E+05 | 0.13 |
| 1997 | 3,398,870 | 4.05E+05 | 0.12 |
| 1998 | 1,733,320 | 2.36E+05 | 0.14 |
| 1999 | 1,199,020 | 1.57E+05 | 0.13 |
| 2000 | 958,427 | 1.28E+05 | 0.13 |
| 2001 | 562,900 | 9.37E+04 | 0.17 |
| 2002 | 521,042 | 9.46E+04 | 0.18 |
| 2003 | 531,648 | 9.25E+04 | 0.17 |
| 2004 | 862,169 | 1.16E+05 | 0.13 |
| 2005 | 576,283 | 1.20E+05 | 0.21 |
| 2006 | 249,054 | 8.62E+04 | 0.35 |
| 2007 | 381,575 | 1.35E+05 | 0.35 |
| 2008 | 514,725 | 1.83E+05 | 0.35 |
| 2009 | 631,761 | 2.27663 | 0.36 |
| 2010 | 851,792 | 303,507 | 0.36 |
| 2011 | 1,217,180 | 440,560 | 0.36 |
| 2012 | 1,942,740 | 752,513 | 0.39 |
| 2013 | 2,826,010 | 1,213,060 | 0.43 |
| 2014 | 7,499,110 | 3,486,680 | 0.46 |
| 2015 | 427,514 | 465,579 | 1.09 |

| Year | u | SD | CV |
|------|-------|-------|------|
| 1972 | 0.218 | 0.033 | 0.15 |
| 1973 | 0.277 | 0.051 | 0.18 |
| 1974 | 0.314 | 0.061 | 0.19 |
| 1975 | 0.131 | 0.026 | 0.20 |
| 1976 | 0.187 | 0.034 | 0.18 |
| 1977 | 0.407 | 0.073 | 0.18 |
| 1978 | 0.207 | 0.038 | 0.19 |
| 1979 | 0.116 | 0.023 | 0.19 |
| 1980 | 0.270 | 0.050 | 0.19 |
| 1981 | 0.246 | 0.050 | 0.20 |
| 1982 | 0.425 | 0.067 | 0.16 |
| 1983 | 0.155 | 0.026 | 0.17 |
| 1984 | 0.203 | 0.030 | 0.15 |
| 1985 | 0.663 | 0.055 | 0.08 |
| 1986 | 0.851 | 0.047 | 0.05 |
| 1987 | 0.599 | 0.079 | 0.13 |
| 1988 | 0.613 | 0.073 | 0.12 |
| 1989 | 0.368 | 0.063 | 0.17 |
| 1990 | 0.211 | 0.034 | 0.16 |
| 1991 | 0.318 | 0.045 | 0.14 |
| 1992 | 0.387 | 0.050 | 0.13 |
| 1993 | 0.614 | 0.076 | 0.12 |
| 1994 | 0.401 | 0.058 | 0.14 |
| 1995 | 0.330 | 0.053 | 0.16 |
| 1996 | 0.478 | 0.067 | 0.14 |
| 1997 | 0.161 | 0.026 | 0.16 |
| 1998 | 0.459 | 0.055 | 0.12 |
| 1999 | 0.661 | 0.060 | 0.09 |
| 2000 | 0.504 | 0.059 | 0.12 |
| 2001 | 0.615 | 0.066 | 0.11 |
| 2002 | 0.365 | 0.061 | 0.17 |
| 2003 | 0.443 | 0.077 | 0.17 |
| 2004 | 0.216 | 0.040 | 0.19 |
| 2005 | 0.767 | 0.076 | 0.10 |
| 2006 | 0.462 | 0.105 | 0.23 |
| 2007 | 0.005 | 0.002 | 0.37 |
| 2008 | 0.007 | 0.002 | 0.37 |
| 2009 | 0.003 | 0.001 | 0.37 |
| 2010 | 0.004 | 0.002 | 0.36 |
| 2011 | 0.004 | 0.001 | 0.37 |
| 2012 | 0.002 | 0.001 | 0.37 |
| 2013 | 0.002 | 0.001 | 0.37 |
| 2014 | 0.001 | 0.001 | 0.40 |
| 2015 | 0.000 | 0.000 | 0.45 |

| q | Estimate | SD | CV |
|---|----------|----------|------|
| 1 | 2.43E-07 | 3.41E-08 | 0.14 |

Table 16.7 Derived fishing mortality values for Chowan River blueback herring.

| Year | F | SD | CV |
|------|-------|-------|------|
| 1972 | 0.245 | 0.042 | 0.17 |
| 1973 | 0.325 | 0.070 | 0.22 |
| 1974 | 0.377 | 0.089 | 0.24 |
| 1975 | 0.140 | 0.030 | 0.21 |
| 1976 | 0.207 | 0.042 | 0.20 |
| 1977 | 0.522 | 0.123 | 0.24 |
| 1978 | 0.232 | 0.048 | 0.21 |
| 1979 | 0.124 | 0.026 | 0.21 |
| 1980 | 0.315 | 0.069 | 0.22 |
| 1981 | 0.282 | 0.066 | 0.23 |
| 1982 | 0.553 | 0.116 | 0.21 |
| 1983 | 0.169 | 0.031 | 0.18 |
| 1984 | 0.227 | 0.038 | 0.17 |
| 1985 | 1.088 | 0.163 | 0.15 |
| 1986 | 1.905 | 0.313 | 0.16 |
| 1987 | 0.914 | 0.198 | 0.22 |
| 1988 | 0.950 | 0.188 | 0.20 |
| 1989 | 0.460 | 0.099 | 0.22 |
| 1990 | 0.237 | 0.043 | 0.18 |
| 1991 | 0.383 | 0.066 | 0.17 |
| 1992 | 0.489 | 0.081 | 0.17 |
| 1993 | 0.953 | 0.197 | 0.21 |
| 1994 | 0.512 | 0.096 | 0.19 |
| 1995 | 0.401 | 0.079 | 0.20 |
| 1996 | 0.650 | 0.129 | 0.20 |
| 1997 | 0.175 | 0.031 | 0.17 |
| 1998 | 0.615 | 0.101 | 0.16 |
| 1999 | 1.081 | 0.178 | 0.16 |
| 2000 | 0.702 | 0.120 | 0.17 |
| 2001 | 0.955 | 0.172 | 0.18 |
| 2002 | 0.454 | 0.096 | 0.21 |
| 2003 | 0.586 | 0.137 | 0.23 |
| 2004 | 0.243 | 0.051 | 0.21 |
| 2005 | 1.456 | 0.326 | 0.22 |
| 2006 | 0.621 | 0.195 | 0.31 |
| 2007 | 0.005 | 0.002 | 0.37 |
| 2008 | 0.007 | 0.003 | 0.37 |
| 2009 | 0.003 | 0.001 | 0.37 |
| 2010 | 0.004 | 0.002 | 0.36 |
| 2011 | 0.004 | 0.001 | 0.37 |
| 2012 | 0.002 | 0.001 | 0.37 |
| 2013 | 0.002 | 0.001 | 0.37 |
| 2014 | 0.001 | 0.001 | 0.40 |
| 2015 | 0.000 | 0.000 | 0.45 |

Table 16.8 Estimates of population abundance by sex, maturity state, year, and age.

| Year | Total | Female Immature Age | | | | | | Year | Total | Female Mature Age | | | | | |
|------|------------|---------------------------|------------|---------|----|---|----|------|------------|-------------------------|------------|------------|-----------|-----------|---------|
| | | 3 | 4 | 5 | 6 | 7 | 8+ | | | 3 | 4 | 5 | 6 | 7 | 8+ |
| 1972 | 22,365,780 | 20,426,800 | 1,918,160 | 20,820 | 0 | 0 | 0 | 1972 | 41,577,129 | 16,049,600 | 14,297,600 | 6,751,760 | 2,796,170 | 1,176,760 | 505,239 |
| 1973 | 27,089,162 | 23,577,700 | 3,474,780 | 36,682 | 0 | 0 | 0 | 1973 | 24,241,438 | 286,369 | 12,741,000 | 6,735,900 | 2,796,170 | 1,176,760 | 505,239 |
| 1974 | 43,774,342 | 40,991,800 | 2,712,500 | 70,042 | 0 | 0 | 0 | 1974 | 19,605,329 | 0 | 8,981,110 | 6,484,580 | 2,585,980 | 1,086,970 | 466,689 |
| 1975 | 48,558,500 | 47,047,000 | 1,511,500 | 0 | 0 | 0 | 0 | 1975 | 28,028,648 | 1,058,320 | 18,641,900 | 4,584,470 | 2,381,210 | 953,755 | 408,993 |
| 1976 | 48,044,550 | 42,215,700 | 5,828,850 | 0 | 0 | 0 | 0 | 1976 | 31,262,141 | 686,435 | 17,753,600 | 9,153,620 | 2,100,560 | 1,113,090 | 454,836 |
| 1977 | 46,903,989 | 32,790,200 | 14,092,700 | 21,089 | 0 | 0 | 0 | 1977 | 22,732,265 | 0 | 6,936,860 | 10,454,200 | 3,925,400 | 918,993 | 496,812 |
| 1978 | 26,223,878 | 18,493,500 | 7,657,540 | 72,838 | 0 | 0 | 0 | 1978 | 22,824,157 | 186,803 | 8,463,590 | 9,338,750 | 3,282,520 | 1,253,180 | 299,314 |
| 1979 | 16,392,903 | 14,197,300 | 2,163,940 | 31,663 | 0 | 0 | 0 | 1979 | 20,970,798 | 684,564 | 7,001,100 | 7,395,450 | 3,943,780 | 1,400,450 | 545,454 |
| 1980 | 18,016,525 | 13,988,900 | 3,971,620 | 55,922 | 83 | 0 | 0 | 1980 | 13,708,936 | 127,044 | 3,305,770 | 4,259,950 | 3,462,380 | 1,874,650 | 679,142 |
| 1981 | 29,311,859 | 23,711,500 | 5,323,240 | 277,119 | 0 | 0 | 0 | 1981 | 8,400,207 | 0 | 1,599,900 | 3,022,240 | 1,668,390 | 1,359,020 | 750,657 |
| 1982 | 32,269,540 | 28,236,000 | 4,033,540 | 0 | 0 | 0 | 0 | 1982 | 13,872,806 | 285,212 | 7,624,090 | 3,375,200 | 1,348,450 | 677,138 | 562,716 |
| 1983 | 35,255,990 | 31,993,700 | 3,262,290 | 0 | 0 | 0 | 0 | 1983 | 17,358,376 | 652,933 | 10,700,400 | 4,350,760 | 1,023,440 | 417,140 | 213,703 |
| 1984 | 17,794,930 | 12,824,400 | 4,970,530 | 0 | 0 | 0 | 0 | 1984 | 20,546,443 | 562,237 | 11,030,200 | 6,357,740 | 1,937,840 | 465,049 | 193,377 |
| 1985 | 11,227,500 | 6,215,010 | 5,012,490 | 0 | 0 | 0 | 0 | 1985 | 12,329,269 | 0 | 1,512,770 | 7,111,430 | 2,671,110 | 830,601 | 203,358 |
| 1986 | 7,051,886 | 4,923,210 | 2,071,680 | 56,996 | 0 | 0 | 0 | 1986 | 5,681,506 | 0 | 983,895 | 2,797,070 | 1,263,020 | 483,983 | 153,538 |
| 1987 | 5,741,761 | 4,891,430 | 837,482 | 12,849 | 0 | 0 | 0 | 1987 | 3,358,946 | 252,030 | 1,582,990 | 1,133,610 | 249,623 | 101,150 | 39,543 |
| 1988 | 3,749,714 | 3,191,790 | 557,924 | 0 | 0 | 0 | 0 | 1988 | 2,979,882 | 0 | 1,896,590 | 760,825 | 246,386 | 53,829 | 22,253 |
| 1989 | 3,900,135 | 3,608,260 | 291,875 | 0 | 0 | 0 | 0 | 1989 | 2,247,693 | 84,944 | 1,277,350 | 667,529 | 155,176 | 51,268 | 11,427 |
| 1990 | 3,716,828 | 3,557,170 | 159,658 | 0 | 0 | 0 | 0 | 1990 | 3,341,169 | 839,825 | 1,640,700 | 567,837 | 222,312 | 52,724 | 17,771 |
| 1991 | 3,958,120 | 3,713,280 | 244,840 | 0 | 0 | 0 | 0 | 1991 | 3,642,408 | 707,291 | 1,829,870 | 751,740 | 236,293 | 94,379 | 22,835 |
| 1992 | 1,739,037 | 1,209,610 | 529,427 | 0 | 0 | 0 | 0 | 1992 | 2,769,014 | 71,757 | 1,533,340 | 771,564 | 270,337 | 86,691 | 35,325 |
| 1993 | 2,874,112 | 2,541,650 | 325,895 | 6,567 | 0 | 0 | 0 | 1993 | 1,473,720 | 62,500 | 290,435 | 752,993 | 249,453 | 89,168 | 29,172 |
| 1994 | 2,246,860 | 1,763,270 | 483,590 | 0 | 0 | 0 | 0 | 1994 | 1,289,660 | 58,290 | 777,847 | 226,327 | 156,576 | 51,749 | 18,871 |
| 1995 | 1,600,125 | 1,299,310 | 300,815 | 0 | 0 | 0 | 0 | 1995 | 1,239,568 | 26,516 | 583,257 | 490,814 | 71,501 | 50,465 | 17,015 |
| 1996 | 2,442,927 | 1,992,660 | 447,157 | 3,110 | 0 | 0 | 0 | 1996 | 772,368 | 0 | 200,372 | 354,309 | 173,368 | 25,766 | 18,553 |
| 1997 | 1,993,304 | 1,655,250 | 335,050 | 3,004 | 0 | 0 | 0 | 1997 | 1,126,157 | 44,185 | 644,628 | 282,155 | 99,138 | 48,671 | 7,380 |
| 1998 | 1,243,380 | 866,662 | 375,159 | 1,559 | 0 | 0 | 0 | 1998 | 1,101,714 | 0 | 456,866 | 451,229 | 126,445 | 44,757 | 22,417 |
| 1999 | 810,775 | 599,511 | 210,488 | 776 | 0 | 0 | 0 | 1999 | 715,835 | 0 | 215,601 | 320,761 | 129,429 | 36,767 | 13,277 |
| 2000 | 594,871 | 479,214 | 111,414 | 4,243 | 0 | 0 | 0 | 2000 | 413,931 | 0 | 183,332 | 142,350 | 57,785 | 23,619 | 6,845 |
| 2001 | 420,266 | 280,324 | 139,712 | 230 | 0 | 0 | 0 | 2001 | 262,634 | 1,126 | 95,890 | 104,331 | 39,450 | 15,411 | 6,426 |
| 2002 | 356,306 | 260,521 | 95,785 | 0 | 0 | 0 | 0 | 2002 | 166,234 | 0 | 42,248 | 91,279 | 21,288 | 8,165 | 3,254 |
| 2003 | 371,732 | 265,824 | 105,413 | 495 | 0 | 0 | 0 | 2003 | 126,239 | 0 | 22,671 | 62,880 | 30,569 | 7,273 | 2,846 |
| 2004 | 461,073 | 412,979 | 48,094 | 0 | 0 | 0 | 0 | 2004 | 191,798 | 18,106 | 82,597 | 61,005 | 18,716 | 9,153 | 2,222 |
| 2005 | 283,201 | 259,039 | 24,162 | 0 | 0 | 0 | 0 | 2005 | 310,356 | 29,102 | 185,858 | 58,335 | 25,226 | 7,896 | 3,939 |
| 2006 | 142,994 | 124,527 | 18,467 | 0 | 0 | 0 | 0 | 2006 | 158,456 | 0 | 112,225 | 34,885 | 7,172 | 3,164 | 1,010 |
| 2007 | 192,149 | 166,558 | 25,591 | 0 | 0 | 0 | 0 | 2007 | 113,488 | 24,230 | 35,632 | 40,729 | 9,890 | 2,074 | 934 |
| 2008 | 284,473 | 257,363 | 26859 | 251 | 0 | 0 | 0 | 2008 | 125,962 | 0 | 66878 | 31296 | 21364 | 5292 | 1132 |
| 2009 | 350,804 | 315881 | 34923 | 0 | 0 | 0 | 0 | 2009 | 170,646 | 0 | 91608 | 48215 | 16523 | 11415 | 2885 |
| 2010 | 394,159 | 362012 | 32147 | 0 | 0 | 0 | 0 | 2010 | 292,760 | 63884 | 123154 | 65262 | 25350 | 8863 | 6247 |
| 2011 | 758,669 | 608588 | 149682 | 399 | 0 | 0 | 0 | 2011 | 191,858 | 0 | 59573 | 79597 | 34265 | 13579 | 4843 |
| 2012 | 1,208,581 | 971371 | 234580 | 2630 | 0 | 0 | 0 | 2012 | 237,868 | 0 | 64629 | 105414 | 42032 | 18367 | 7426 |
| 2013 | 1,788,076 | 1413000 | 362952 | 12124 | 0 | 0 | 0 | 2013 | 346,578 | 0 | 114617 | 142461 | 56869 | 22569 | 10062 |
| 2014 | 4,196,846 | 3749550 | 432101 | 15195 | 0 | 0 | 0 | 2014 | 618,450 | 0 | 262595 | 231546 | 81396 | 30545 | 12367 |
| 2015 | 1,263,677 | 213757 | 1045230 | 4690 | 0 | 0 | 0 | 2015 | 1,342,826 | 0 | 798212 | 354192 | 129949 | 43731 | 16742 |

Table 16.8. Continued.

| Male Immature Age | | | | | | | | | Male Mature Age | | | | | | | | |
|-------------------------|------------|------------|------------|--------|---|---|----|--|-----------------------|------------|------------|------------|-----------|-----------|-----------|---------|--|
| Year | Total | 3 | 4 | 5 | 6 | 7 | 8+ | | Year | Total | 3 | 4 | 5 | 6 | 7 | 8+ | |
| 1972 | 22,546,834 | 21,192,800 | 1,351,350 | 2,684 | 0 | 0 | 0 | | 1972 | 40,553,293 | 15,283,600 | 14,784,300 | 6,411,920 | 2,568,200 | 1,059,420 | 445,853 | |
| 1973 | 22,696,770 | 21,262,900 | 1,433,870 | 0 | 0 | 0 | 0 | | 1973 | 27,790,973 | 2,601,190 | 14,701,700 | 6,414,610 | 2,568,200 | 1,059,420 | 445,853 | |
| 1974 | 41,278,930 | 40,212,900 | 1,066,030 | 0 | 0 | 0 | 0 | | 1974 | 20,727,660 | 778,844 | 10,198,700 | 5,987,730 | 2,371,970 | 978,583 | 411,833 | |
| 1975 | 46,888,730 | 44,305,000 | 2,583,730 | 0 | 0 | 0 | 0 | | 1975 | 28,370,962 | 3,800,320 | 17,249,900 | 4,001,640 | 2,100,680 | 857,503 | 360,919 | |
| 1976 | 42,747,040 | 39,641,600 | 3,105,440 | 0 | 0 | 0 | 0 | | 1976 | 35,197,259 | 3,260,560 | 20,067,500 | 8,726,520 | 1,779,330 | 962,512 | 400,837 | |
| 1977 | 45,255,200 | 32,790,200 | 12,465,000 | 0 | 0 | 0 | 0 | | 1977 | 22,583,797 | 0 | 8,121,400 | 9,646,620 | 3,631,640 | 763,039 | 421,098 | |
| 1978 | 23,555,789 | 17,503,400 | 5,953,350 | 99,039 | 0 | 0 | 0 | | 1978 | 23,978,059 | 1,176,860 | 10,007,400 | 8,484,290 | 2,929,470 | 1,136,440 | 243,599 | |
| 1979 | 14,855,921 | 13,944,300 | 911,621 | 0 | 0 | 0 | 0 | | 1979 | 21,101,493 | 937,555 | 8,062,520 | 6,897,620 | 3,493,870 | 1,225,080 | 484,848 | |
| 1980 | 16,313,052 | 13,791,300 | 2,511,340 | 10,412 | 0 | 0 | 0 | | 1980 | 14,313,129 | 324,667 | 4,679,310 | 3,980,090 | 3,118,830 | 1,627,900 | 582,332 | |
| 1981 | 27,498,163 | 23,498,100 | 3,953,920 | 46,143 | 0 | 0 | 0 | | 1981 | 9,314,229 | 213,404 | 2,874,320 | 2,896,360 | 1,491,310 | 1,199,890 | 638,945 | |
| 1982 | 29,195,510 | 26,496,200 | 2,699,310 | 0 | 0 | 0 | 0 | | 1982 | 16,104,252 | 2,025,010 | 8,816,820 | 3,040,350 | 1,141,800 | 593,282 | 486,990 | |
| 1983 | 30,414,970 | 28,957,600 | 1,457,370 | 0 | 0 | 0 | 0 | | 1983 | 20,978,187 | 3,689,070 | 12,006,500 | 3,858,210 | 894,656 | 346,220 | 183,531 | |
| 1984 | 14,009,540 | 11,204,600 | 2,804,940 | 0 | 0 | 0 | 0 | | 1984 | 22,972,493 | 2,182,010 | 12,807,000 | 5,760,020 | 1,667,660 | 398,481 | 157,322 | |
| 1985 | 8,934,060 | 5,972,620 | 2,981,440 | 0 | 0 | 0 | 0 | | 1985 | 13,261,198 | 242,385 | 3,338,670 | 6,460,230 | 2,348,470 | 700,645 | 170,798 | |
| 1986 | 5,544,339 | 4,696,740 | 834,363 | 13,236 | 0 | 0 | 0 | | 1986 | 6,012,326 | 226,468 | 2,112,560 | 2,015,800 | 1,113,450 | 417,097 | 126,951 | |
| 1987 | 5,066,903 | 4,783,420 | 283,483 | 0 | 0 | 0 | 0 | | 1987 | 3,230,779 | 360,042 | 2,019,080 | 570,511 | 160,336 | 87,406 | 33,404 | |
| 1988 | 2,537,859 | 2,409,800 | 128,059 | 0 | 0 | 0 | 0 | | 1988 | 3,764,974 | 781,987 | 2,270,530 | 542,693 | 117,025 | 33,890 | 18,848 | |
| 1989 | 2,943,689 | 2,873,310 | 70,379 | 0 | 0 | 0 | 0 | | 1989 | 2,707,773 | 819,891 | 1,249,830 | 499,717 | 107,415 | 23,868 | 7,052 | |
| 1990 | 2,381,965 | 2,356,790 | 25,175 | 0 | 0 | 0 | 0 | | 1990 | 4,298,017 | 2,040,200 | 1,625,480 | 426,948 | 161,506 | 35,773 | 8,110 | |
| 1991 | 2,911,844 | 2,829,160 | 82,596 | 88 | 0 | 0 | 0 | | 1991 | 4,343,927 | 1,591,400 | 1,848,290 | 649,429 | 172,414 | 67,207 | 15,187 | |
| 1992 | 1,201,352 | 1,157,080 | 44,067 | 205 | 0 | 0 | 0 | | 1992 | 2,965,746 | 124,293 | 1,861,330 | 666,776 | 226,687 | 62,003 | 24,657 | |
| 1993 | 2,619,173 | 2,481,750 | 137,423 | 0 | 0 | 0 | 0 | | 1993 | 1,476,947 | 122,395 | 462,882 | 588,621 | 209,308 | 73,290 | 20,451 | |
| 1994 | 1,318,926 | 1,225,910 | 93,016 | 0 | 0 | 0 | 0 | | 1994 | 2,064,412 | 595,651 | 1,137,960 | 156,883 | 116,153 | 42,561 | 15,204 | |
| 1995 | 1,400,017 | 1,274,110 | 125,907 | 0 | 0 | 0 | 0 | | 1995 | 1,179,490 | 51,707 | 644,517 | 384,756 | 48,098 | 36,695 | 13,717 | |
| 1996 | 1,667,385 | 1,614,050 | 53,335 | 0 | 0 | 0 | 0 | | 1996 | 1,401,336 | 378,605 | 583,703 | 276,926 | 131,889 | 16,989 | 13,223 | |
| 1997 | 1,103,558 | 1,038,350 | 65,208 | 0 | 0 | 0 | 0 | | 1997 | 1,770,457 | 661,080 | 816,609 | 177,754 | 73,952 | 36,293 | 4,770 | |
| 1998 | 879,454 | 776,529 | 102,601 | 324 | 0 | 0 | 0 | | 1998 | 1,260,838 | 90,133 | 672,874 | 372,384 | 76,336 | 32,726 | 16,385 | |
| 1999 | 653,943 | 564,740 | 89,203 | 0 | 0 | 0 | 0 | | 1999 | 713,258 | 34,772 | 312,489 | 231,561 | 103,164 | 21,757 | 9,516 | |
| 2000 | 480,012 | 468,192 | 11,820 | 0 | 0 | 0 | 0 | | 2000 | 439,389 | 11,022 | 268,810 | 96,938 | 40,196 | 18,453 | 3,970 | |
| 2001 | 297,418 | 275,540 | 21,878 | 0 | 0 | 0 | 0 | | 2001 | 326,655 | 5,910 | 208,675 | 72,048 | 24,592 | 10,508 | 4,921 | |
| 2002 | 263,642 | 254,790 | 8,852 | 0 | 0 | 0 | 0 | | 2002 | 204,190 | 5,731 | 126,375 | 50,734 | 14,185 | 4,989 | 2,175 | |
| 2003 | 253,824 | 245,887 | 7,937 | 0 | 0 | 0 | 0 | | 2003 | 204,988 | 19,937 | 117,854 | 44,254 | 16,489 | 4,751 | 1,705 | |
| 2004 | 306,379 | 302,190 | 4,189 | 0 | 0 | 0 | 0 | | 2004 | 305,176 | 128,894 | 120,899 | 36,517 | 12,605 | 4,839 | 1,422 | |
| 2005 | 227,103 | 224,750 | 2,353 | 0 | 0 | 0 | 0 | | 2005 | 328,397 | 63,391 | 193,938 | 49,161 | 14,654 | 5,212 | 2,042 | |
| 2006 | 110,359 | 103,358 | 7,001 | 0 | 0 | 0 | 0 | | 2006 | 162,703 | 21,170 | 109,590 | 23,623 | 5,865 | 1,802 | 654 | |
| 2007 | 147,954 | 146,143 | 1,811 | 0 | 0 | 0 | 0 | | 2007 | 140,101 | 44,644 | 54,038 | 32,736 | 6,499 | 1,663 | 521 | |
| 2008 | 256,514 | 236,516 | 19,989 | 9 | 0 | 0 | 0 | | 2008 | 142,157 | 20,846 | 72,764 | 27,585 | 16,663 | 3,409 | 890 | |
| 2009 | 344,192 | 307,352 | 36,840 | 0 | 0 | 0 | 0 | | 2009 | 167,281 | 8,529 | 88,363 | 45,816 | 14,025 | 8,727 | 1,821 | |
| 2010 | 346,674 | 324,533 | 22,141 | 0 | 0 | 0 | 0 | | 2010 | 330,445 | 101,363 | 131,602 | 62,048 | 23,377 | 7,374 | 4,681 | |
| 2011 | 533,555 | 530,080 | 3,475 | 0 | 0 | 0 | 0 | | 2011 | 406,035 | 78,508 | 203,620 | 76,068 | 31,615 | 12,274 | 3,950 | |
| 2012 | 1,130,568 | 971,371 | 159,197 | 0 | 0 | 0 | 0 | | 2012 | 301,356 | 0 | 136,899 | 102,481 | 38,786 | 16,611 | 6,579 | |
| 2013 | 1,776,295 | 1,413,000 | 358,868 | 4,427 | 0 | 0 | 0 | | 2013 | 338,111 | 0 | 113,949 | 142,485 | 52,344 | 20,414 | 8,919 | |
| 2014 | 4,111,324 | 3,749,550 | 361,774 | 0 | 0 | 0 | 0 | | 2014 | 674,303 | 0 | 326,009 | 234,707 | 75,064 | 27,558 | 10,965 | |
| 2015 | 586,078 | 213,757 | 372,321 | 0 | 0 | 0 | 0 | | 2015 | 1,968,402 | 0 | 1,452,780 | 341,337 | 119,949 | 39,530 | 14,806 | |

Table 16.9 Total population abundance (number of fish 3+) estimate for the Chowan River blueback herring stock by maturity state.

| Year | Immature | Mature | Total |
|------|------------|------------|-------------|
| 1972 | 44,912,614 | 82,130,422 | 127,043,036 |
| 1973 | 49,785,932 | 52,032,411 | 101,818,343 |
| 1974 | 85,053,272 | 40,332,989 | 125,386,261 |
| 1975 | 95,447,230 | 56,399,610 | 151,846,840 |
| 1976 | 90,791,590 | 66,459,400 | 157,250,990 |
| 1977 | 92,159,189 | 45,316,062 | 137,475,251 |
| 1978 | 49,779,667 | 46,802,216 | 96,581,883 |
| 1979 | 31,248,824 | 42,072,291 | 73,321,115 |
| 1980 | 34,329,577 | 28,022,065 | 62,351,642 |
| 1981 | 56,810,022 | 17,714,436 | 74,524,458 |
| 1982 | 61,465,050 | 29,977,058 | 91,442,108 |
| 1983 | 65,670,960 | 38,336,563 | 104,007,523 |
| 1984 | 31,804,470 | 43,518,936 | 75,323,406 |
| 1985 | 20,161,560 | 25,590,467 | 45,752,027 |
| 1986 | 12,596,224 | 11,693,832 | 24,290,056 |
| 1987 | 10,808,664 | 6,589,725 | 17,398,389 |
| 1988 | 6,287,573 | 6,744,856 | 13,032,429 |
| 1989 | 6,843,824 | 4,955,466 | 11,799,290 |
| 1990 | 6,098,793 | 7,639,186 | 13,737,978 |
| 1991 | 6,869,964 | 7,986,335 | 14,856,299 |
| 1992 | 2,940,389 | 5,734,760 | 8,675,149 |
| 1993 | 5,493,285 | 2,950,667 | 8,443,953 |
| 1994 | 3,565,786 | 3,354,071 | 6,919,857 |
| 1995 | 3,000,142 | 2,419,058 | 5,419,200 |
| 1996 | 4,110,312 | 2,173,704 | 6,284,015 |
| 1997 | 3,096,863 | 2,896,614 | 5,993,477 |
| 1998 | 2,122,833 | 2,362,552 | 4,485,385 |
| 1999 | 1,464,717 | 1,429,093 | 2,893,811 |
| 2000 | 1,074,883 | 853,319 | 1,928,202 |
| 2001 | 717,684 | 589,289 | 1,306,973 |
| 2002 | 619,948 | 370,424 | 990,372 |
| 2003 | 625,556 | 331,228 | 956,784 |
| 2004 | 767,452 | 496,975 | 1,264,427 |
| 2005 | 510,304 | 638,753 | 1,149,057 |
| 2006 | 253,353 | 321,159 | 574,512 |
| 2007 | 340,103 | 253,589 | 593,693 |
| 2008 | 540,987 | 268,119 | 809,107 |
| 2009 | 694,995 | 337,927 | 1,032,922 |
| 2010 | 740,834 | 623,205 | 1,364,039 |
| 2011 | 1,292,224 | 597,893 | 1,890,117 |
| 2012 | 2,339,149 | 539,224 | 2,878,374 |
| 2013 | 3,564,371 | 684,689 | 4,249,060 |
| 2014 | 8,308,170 | 1,292,753 | 9,600,923 |
| 2015 | 1,849,755 | 3,311,229 | 5,160,983 |

Table 16.10 Estimates of female spawning stock biomass (kilograms) for the Chowan River blueback herring stock

| Year | Total | Female SSB (kg) | | | | | |
|------|---------|-----------------|---------|---------|--------|--------|--------|
| | | 3 | 4 | 5 | 6 | 7 | 8+ |
| 1972 | 6527531 | 2335420 | 2293000 | 1103950 | 485627 | 193327 | 116207 |
| 1973 | 3589943 | 30213 | 1721720 | 1022190 | 478882 | 229598 | 107340 |
| 1974 | 2800559 | 0 | 1151450 | 933634 | 420192 | 201213 | 94070 |
| 1975 | 4818669 | 134265 | 3029190 | 836572 | 490389 | 223767 | 104486 |
| 1976 | 5102914 | 81506 | 2700030 | 1563330 | 404877 | 244418 | 108753 |
| 1977 | 2858744 | 0 | 769831 | 1302870 | 552107 | 147254 | 86682 |
| 1978 | 3787339 | 21630 | 1255220 | 1555360 | 616990 | 268348 | 69791 |
| 1979 | 3919213 | 88315 | 1156850 | 1372320 | 825907 | 334119 | 141702 |
| 1980 | 2230983 | 13533 | 451038 | 652712 | 598716 | 369302 | 145682 |
| 1981 | 1519711 | 0 | 241415 | 517603 | 323499 | 270688 | 166506 |
| 1982 | 1675895 | 21322 | 841781 | 432827 | 188430 | 105136 | 86399 |
| 1983 | 2930033 | 74457 | 1663100 | 815865 | 224768 | 94079 | 57764 |
| 1984 | 2976737 | 59581 | 1485270 | 942222 | 344318 | 100046 | 45299 |
| 1985 | 783582 | 0 | 85602 | 426361 | 187135 | 64346 | 20138 |
| 1986 | 170389 | 0 | 23729 | 82033 | 40615 | 17293 | 6720 |
| 1987 | 238481 | 12831 | 103433 | 85885 | 21414 | 10258 | 4660 |
| 1988 | 192367 | 0 | 111508 | 53266 | 20585 | 4477 | 2531 |
| 1989 | 265099 | 7511 | 134731 | 88960 | 23032 | 8743 | 2122 |
| 1990 | 496277 | 108032 | 247307 | 82903 | 43510 | 10402 | 4123 |
| 1991 | 436159 | 65121 | 195932 | 111254 | 38354 | 20919 | 4579 |
| 1992 | 301522 | 6160 | 151367 | 88467 | 34809 | 14352 | 6368 |
| 1993 | 95894 | 2410 | 16800 | 49074 | 16738 | 7565 | 3307 |
| 1994 | 114382 | 4191 | 59652 | 19120 | 22514 | 5581 | 3324 |
| 1995 | 138469 | 2132 | 60170 | 53264 | 9579 | 9973 | 3351 |
| 1996 | 81622 | 0 | 19659 | 35871 | 20086 | 3160 | 2847 |
| 1997 | 187271 | 4079 | 88724 | 58489 | 20883 | 13275 | 1821 |
| 1998 | 99001 | 0 | 36301 | 40000 | 13259 | 5879 | 3562 |
| 1999 | 42132 | 0 | 11483 | 19260 | 7596 | 2470 | 1324 |
| 2000 | 34955 | 0 | 13724 | 12421 | 5271 | 2541 | 998 |
| 2001 | 19305 | 52 | 5755 | 7667 | 3491 | 1613 | 727 |
| 2002 | 19750 | 0 | 4186 | 10841 | 2975 | 1141 | 608 |
| 2003 | 11873 | 0 | 1565 | 5915 | 3199 | 729 | 466 |
| 2004 | 22943 | 1704 | 9068 | 7176 | 2789 | 1694 | 512 |
| 2005 | 11015 | 814 | 6067 | 2312 | 1117 | 434 | 270 |
| 2006 | 13395 | 0 | 9050 | 3001 | 783 | 401 | 160 |
| 2007 | 20195 | 3302 | 6238 | 7779 | 2115 | 487 | 273 |
| 2008 | 19934 | 0 | 9167 | 4973 | 4223 | 1241 | 331 |
| 2009 | 26909 | 0 | 12423 | 7692 | 3262 | 2686 | 846 |
| 2010 | 44126 | 8142 | 16677 | 10397 | 4998 | 2083 | 1829 |
| 2011 | 36756 | 0 | 10507 | 14911 | 6726 | 3193 | 1419 |
| 2012 | 40788 | 0 | 9096 | 17467 | 7720 | 4327 | 2179 |
| 2013 | 66000 | 0 | 20142 | 26742 | 10845 | 5318 | 2954 |
| 2014 | 115238 | 0 | 49567 | 39313 | 15527 | 7200 | 3631 |
| 2015 | 227333 | 0 | 122924 | 63046 | 26120 | 10321 | 4922 |

Table 16.11 Reference points derived from YPR, SPR and production model methods

| Reference Points | | |
|---------------------|--------|----------|
| | Basis | Estimate |
| Yield Per Recruit | F0.1 | 1.03 |
| | Fmax | 5 |
| Spawner Per Recruit | F40% | 0.53 |
| | F20% | 1.04 |
| Production Model | Fmed | 0.59 |
| | Fcol | 0.9 |
| | Fmsy | 0.39 |
| | SSBmsy | 1894382 |
| | SSB20% | 1126623 |



Figure 16.1 Albemarle Sound and tributaries, NC.

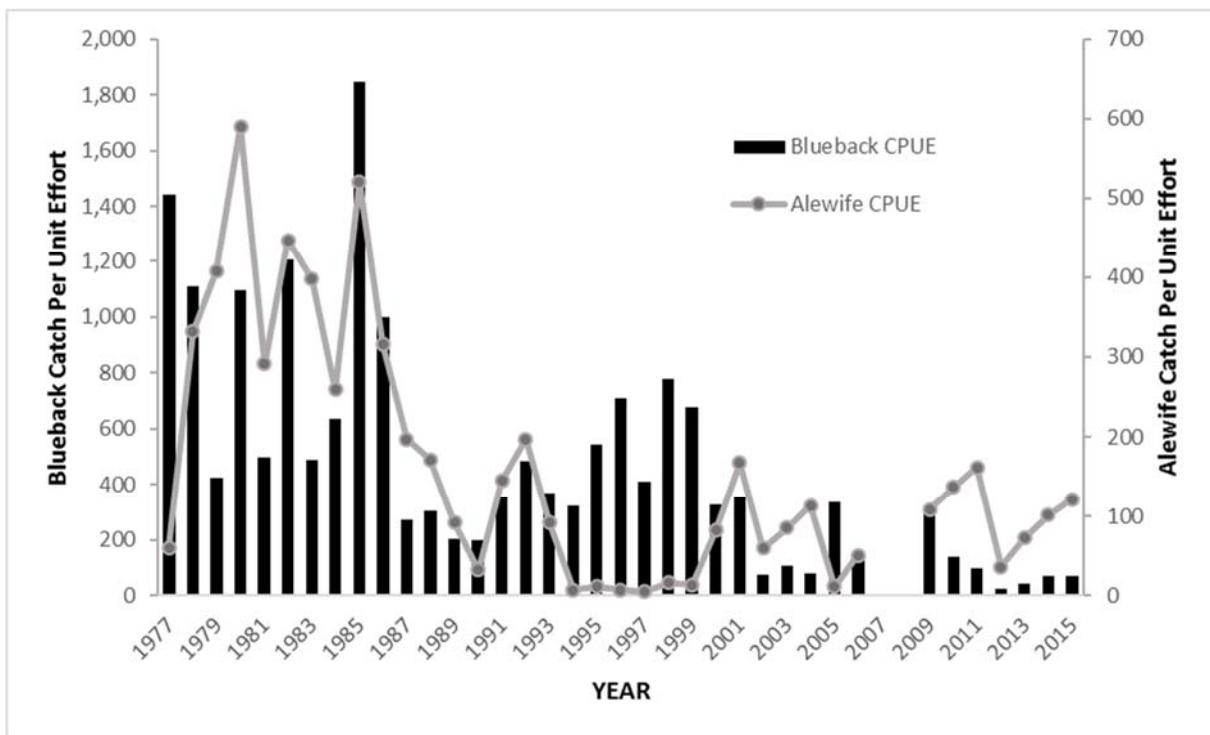
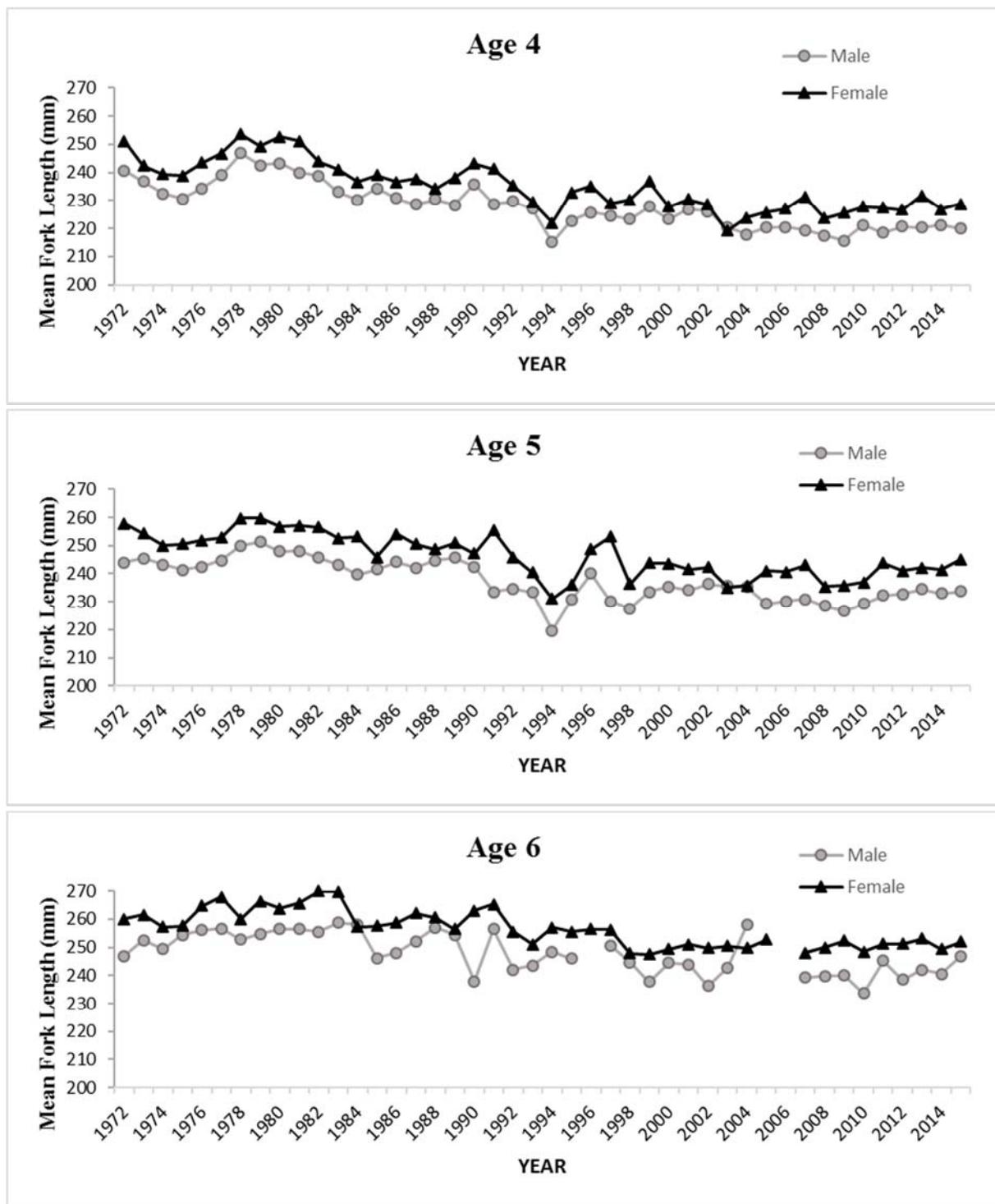


Figure 16.2 Catch per unit effort for blueback herring and alewife from the Chowan River commercial pound net fishery 1977-2015.



*2007 results based on samples collected from the research set aside harvest, April 4-7

**2008-2015 results based on samples obtained from contracted pound net sets

Figure 16.3 Mean length at age of blueback herring from the Chowan River pound net fishery, NC, 1972-2015.

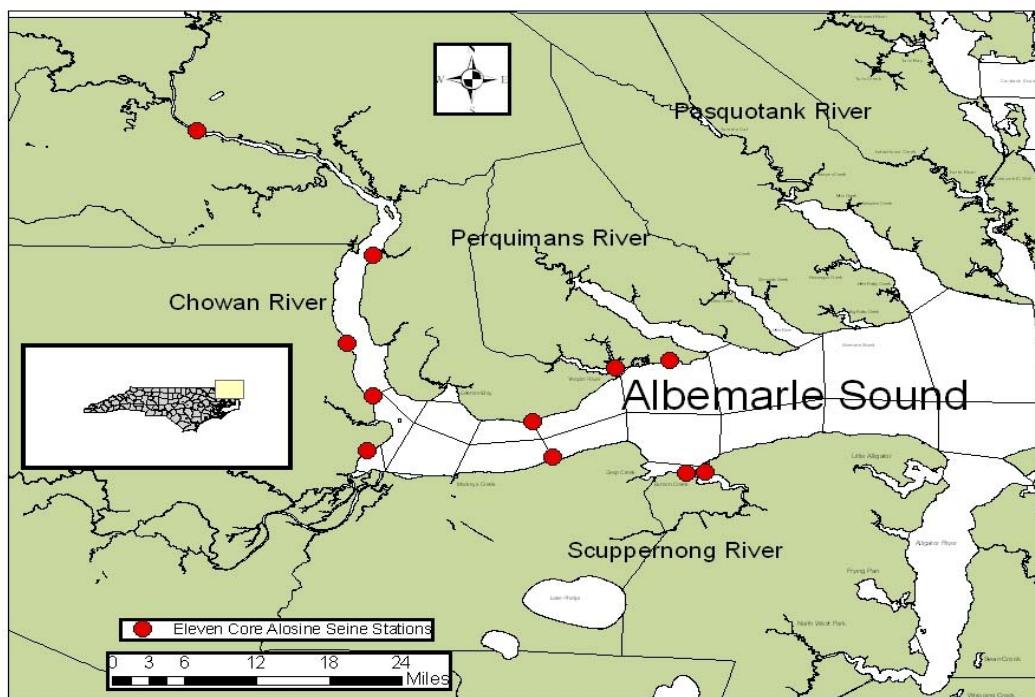


Figure 16.4 Alosine nursery area sampling sites in the Albemarle Sound area, NC 1972-2015.

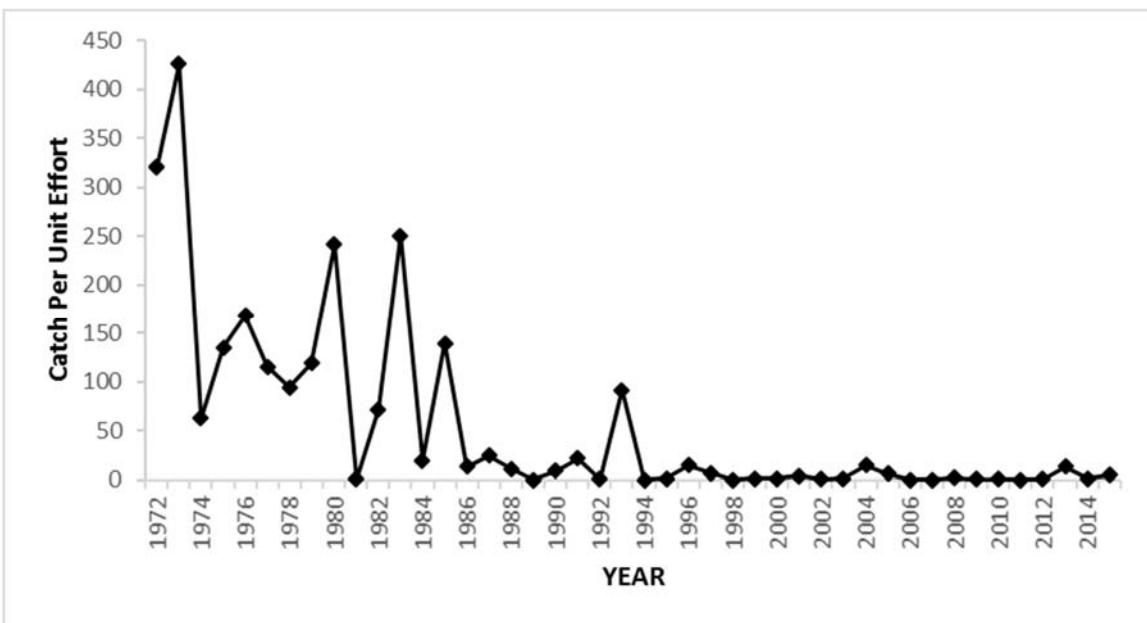


Figure 16.5 Juvenile blueback herring catch per unit effort from core seine stations, Albemarle Sound area, NC, 1972-2015.

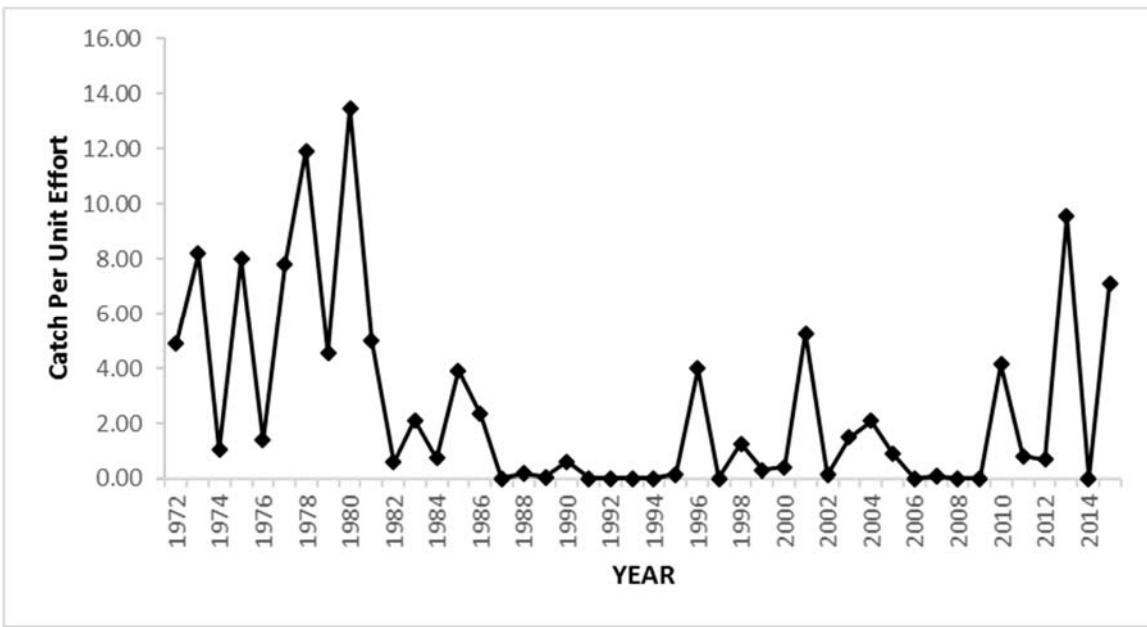


Figure 16.6 Juvenile alewife catch per unit effort from core seine stations, Albemarle Sound area, NC, 1972-2015.

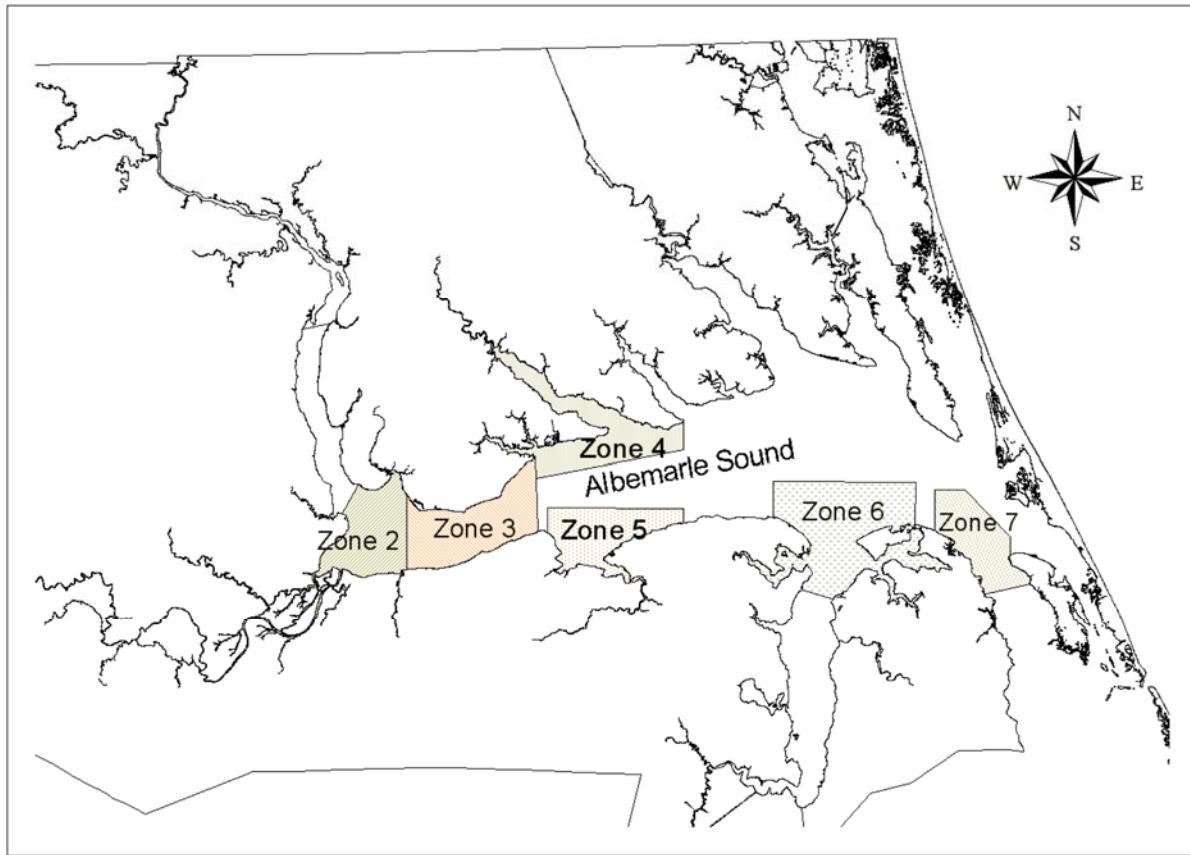


Figure 16.7 Location of sample zones for NCDMF independent gill net survey, Albemarle Sound area, 1990 – 2015.

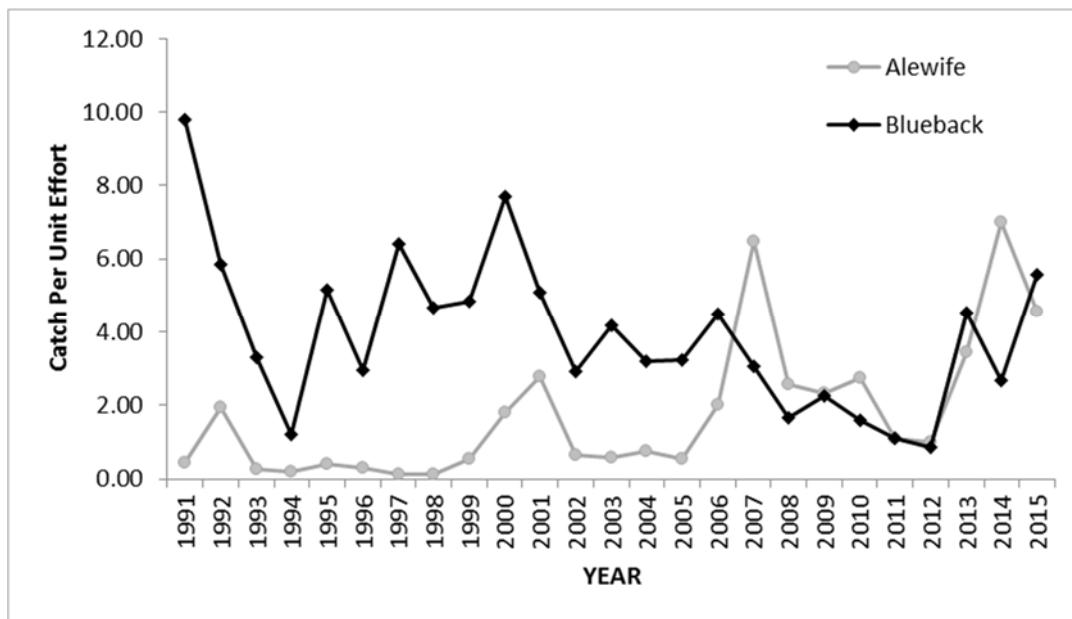


Figure 16.8 Catch per unit effort for alewife and blueback herring from the Albemarle Sound Independent Gill Net Survey, 2.5 and 3.0 ISM gill net, January-May, 1991-2015.

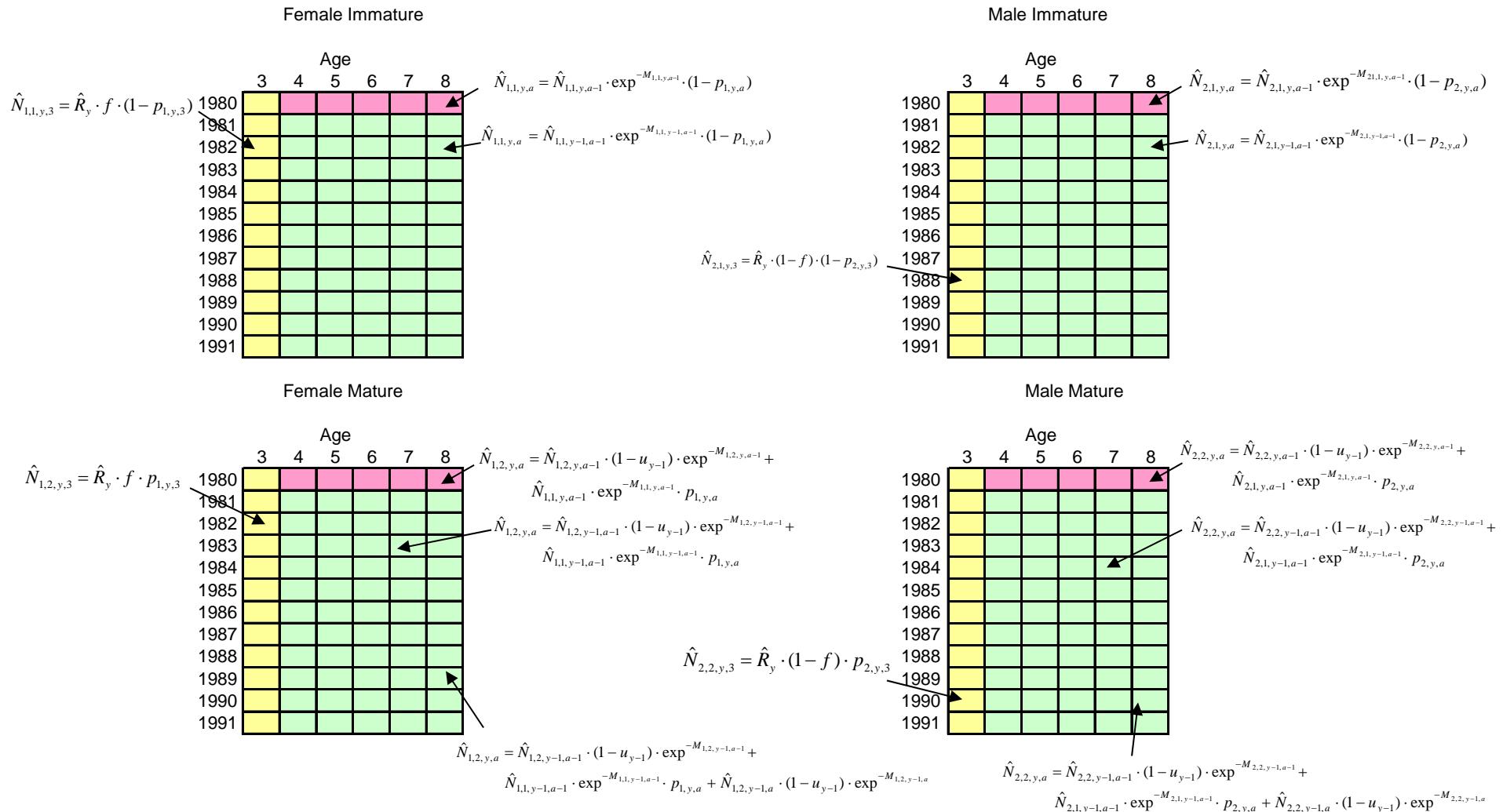


Figure 16.9 Diagram of blueback herring cohort population dynamics.

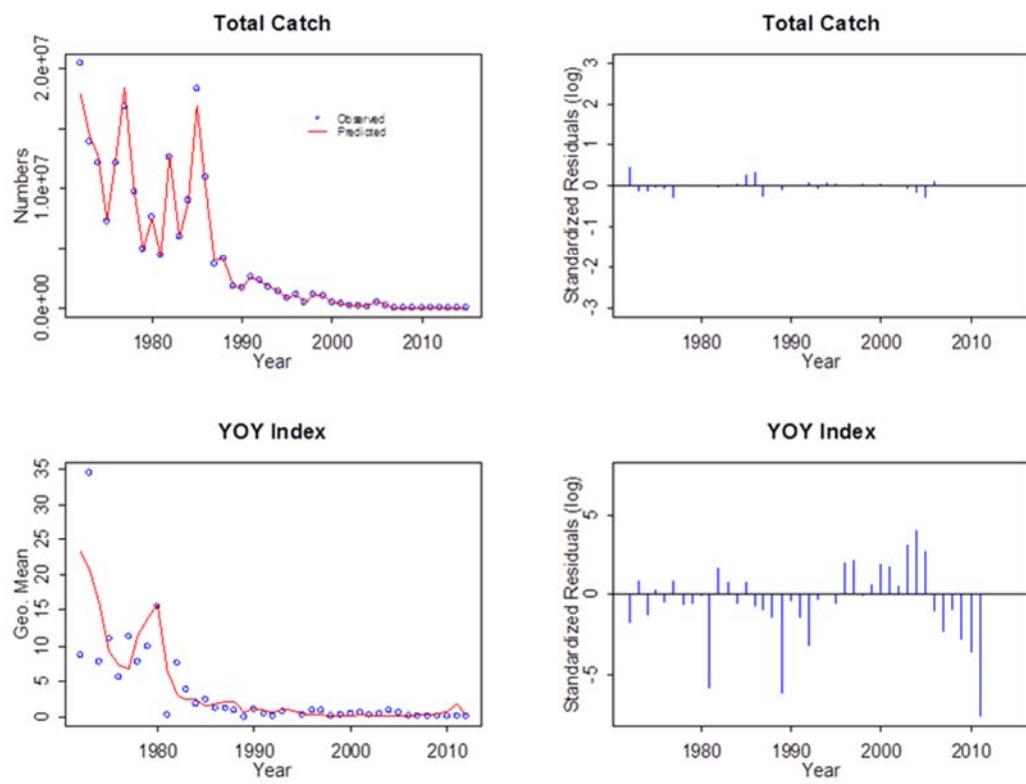


Figure 16.10 Comparison of total catch and YOY index observed and predicted values and standardized residuals for Chowan River blueback herring.

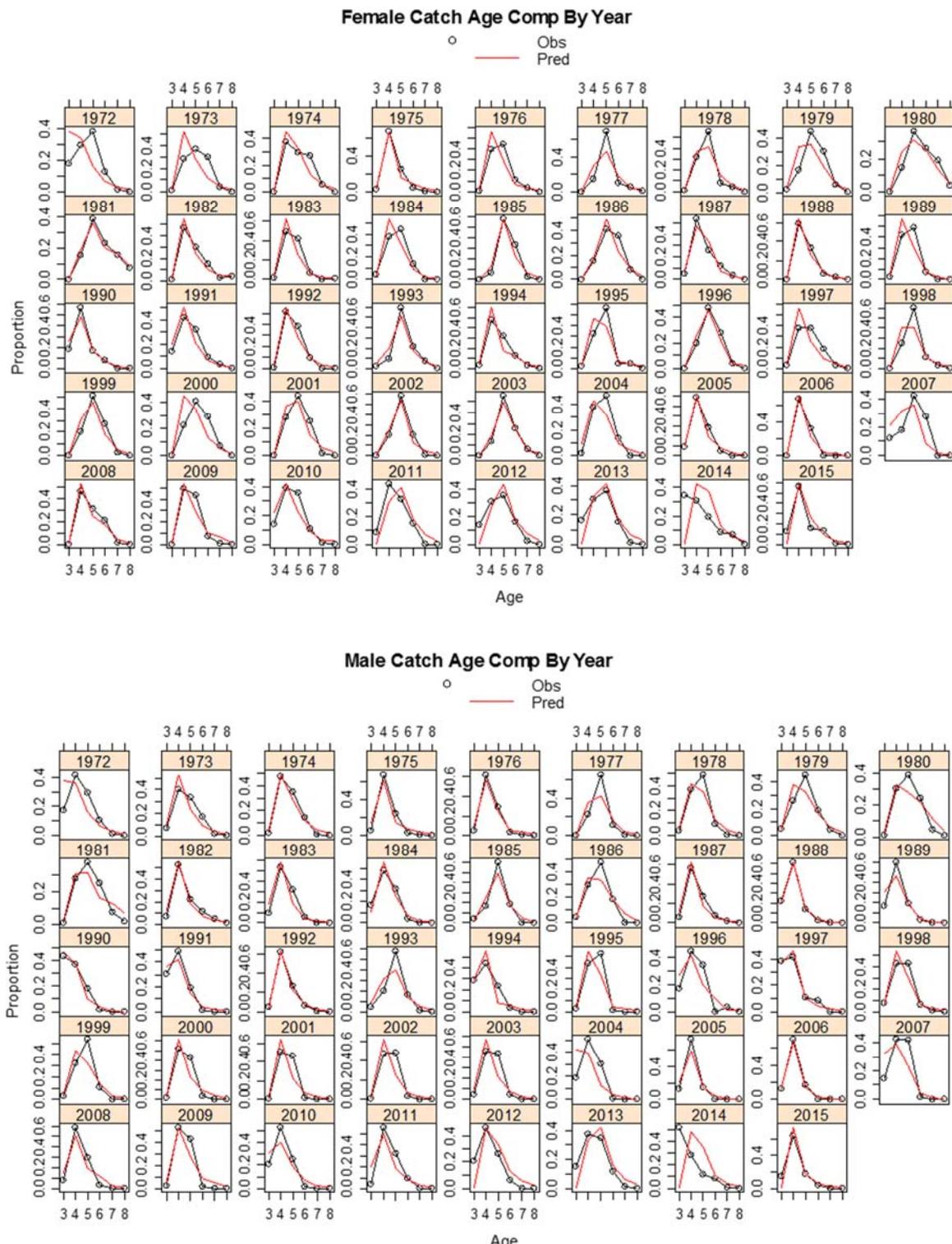
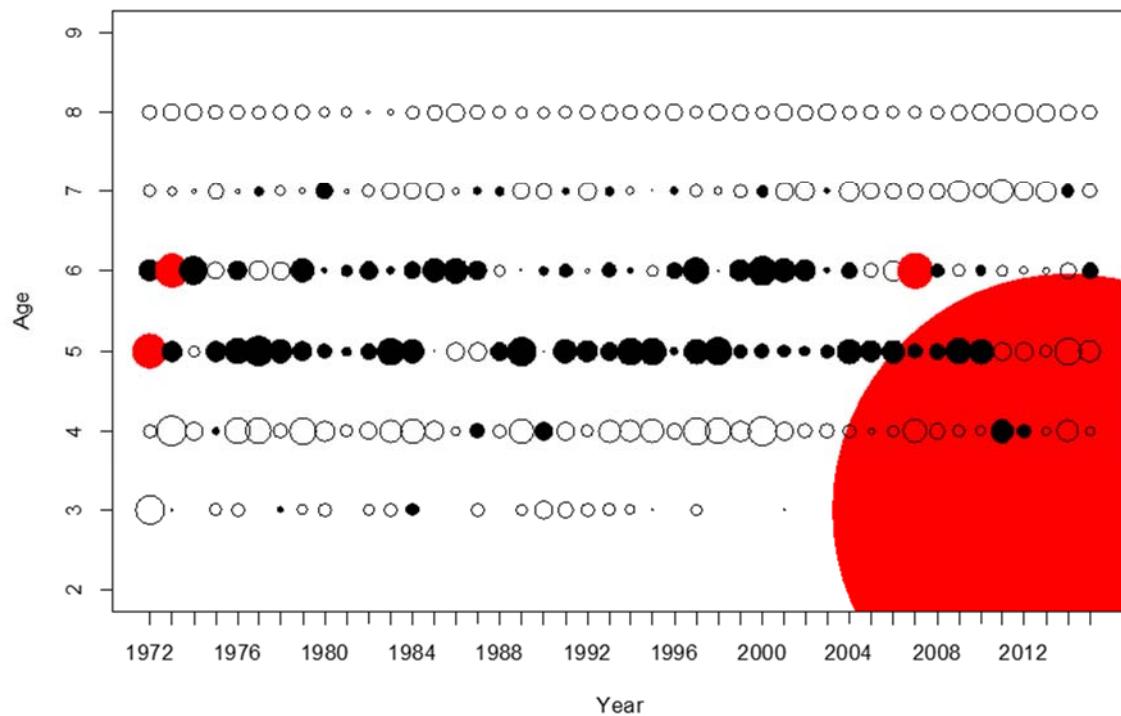


Figure 16.11 Observed and predicted catch age composition (proportions) for Chowan River blueback herring by sex, age, and year.

Female Catch Age Composition - Pearson Residuals (Solid = +, Hollow = -, Red > 3)



Male Catch Age Composition - Pearson Residuals (Solid = +, Hollow = -, Red > 3)

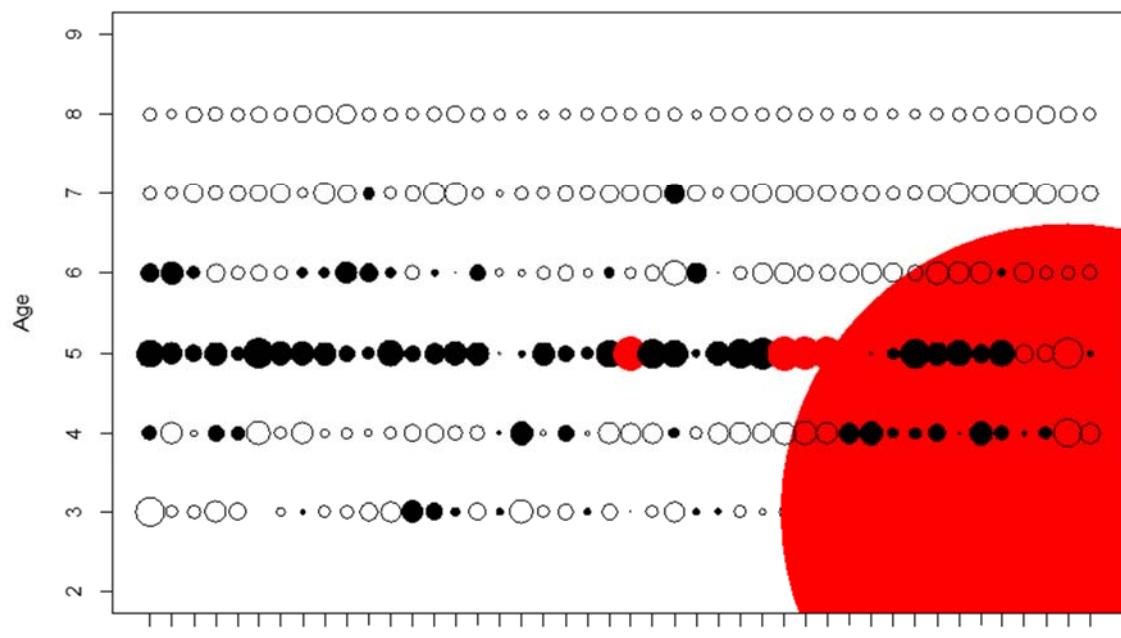


Figure 16.12 Bubble plots of standardized residuals of catch age composition by sex, year, age.

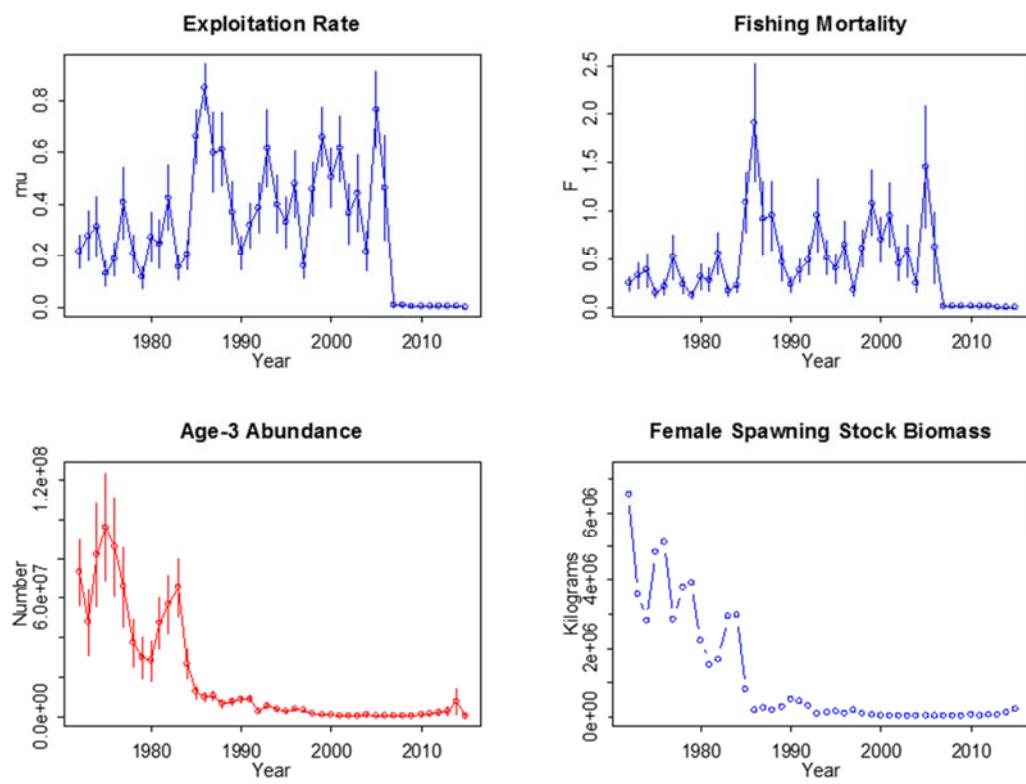


Figure 16.13 Estimates of exploitation rates, derived fishing mortality rates, recruitment (age-3 numbers), and estimates of female spawning stock biomass (in kilograms) for Chowan River blueback herring. Vertical lines, where present, represent 95% confidence intervals.

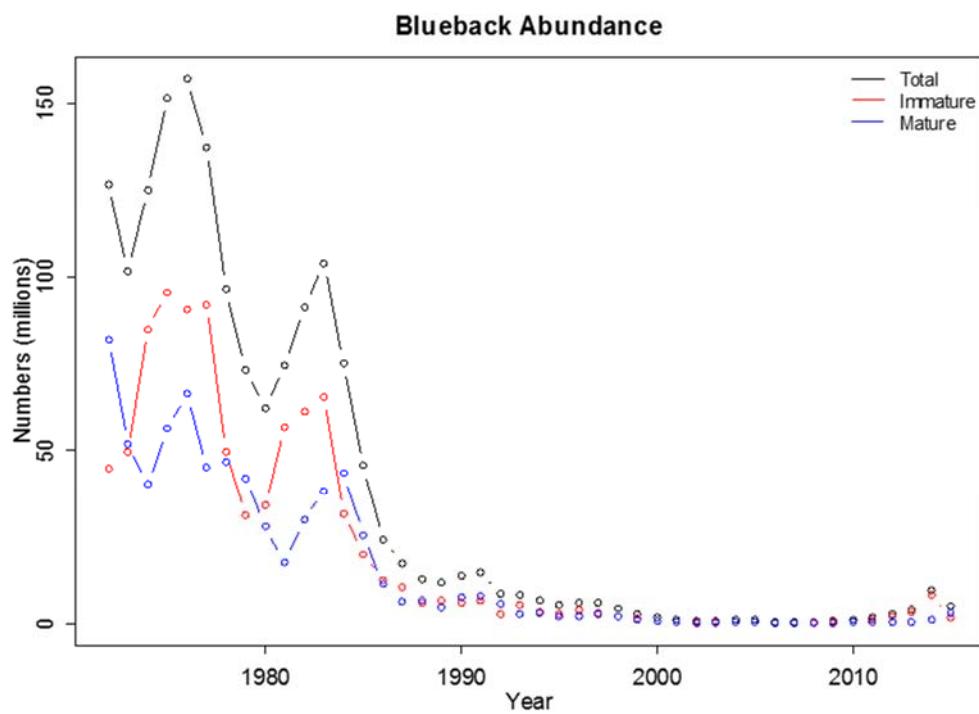


Figure 16.14 Population abundance (3+) estimates of the Chowan River blueback stock. Abundances are shown for immature and mature fish (sexes combined) and the total population.

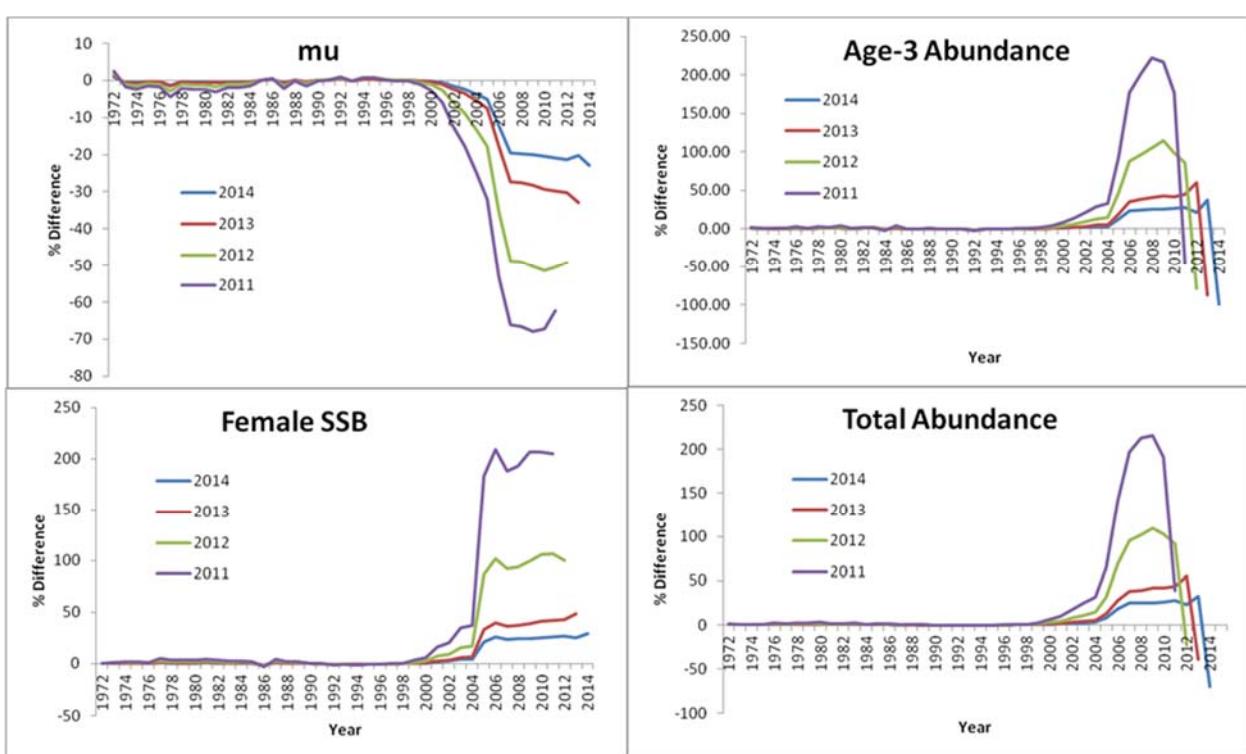
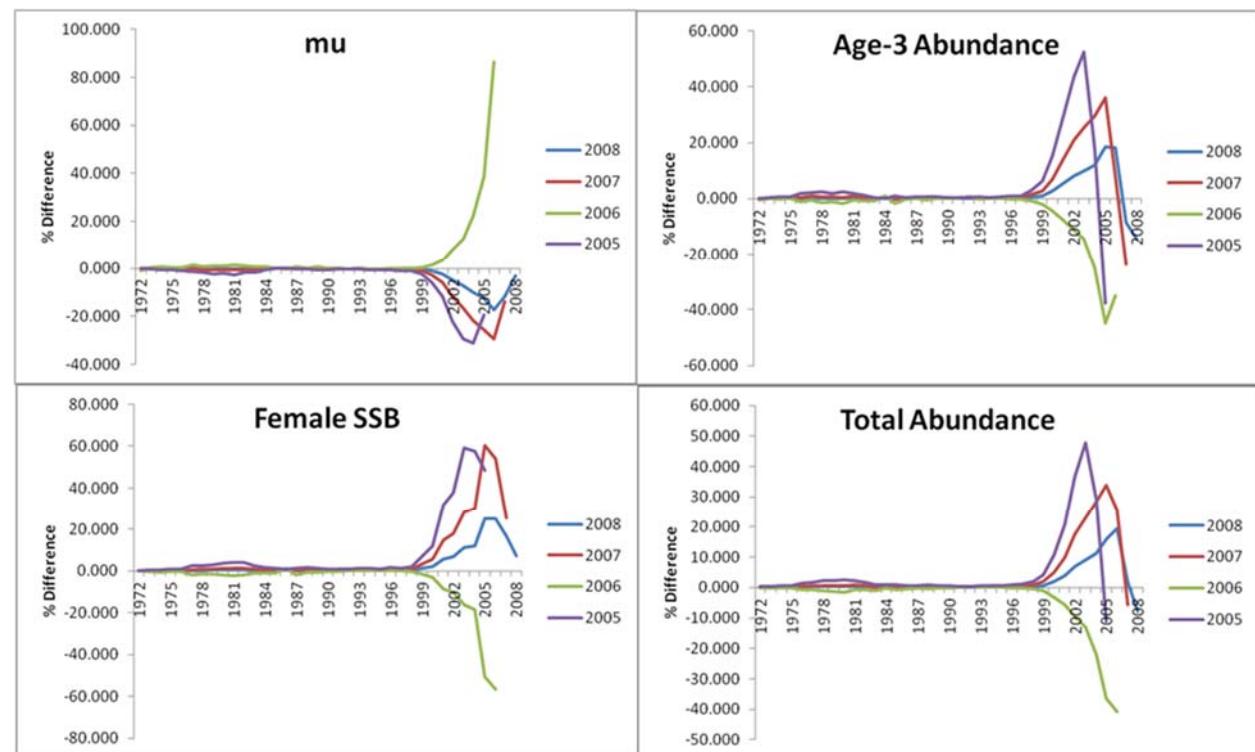


Figure 16.15 Retrospective analyses for age-3 abundance, exploitation rate, female spawning stock biomass, and total population abundance.

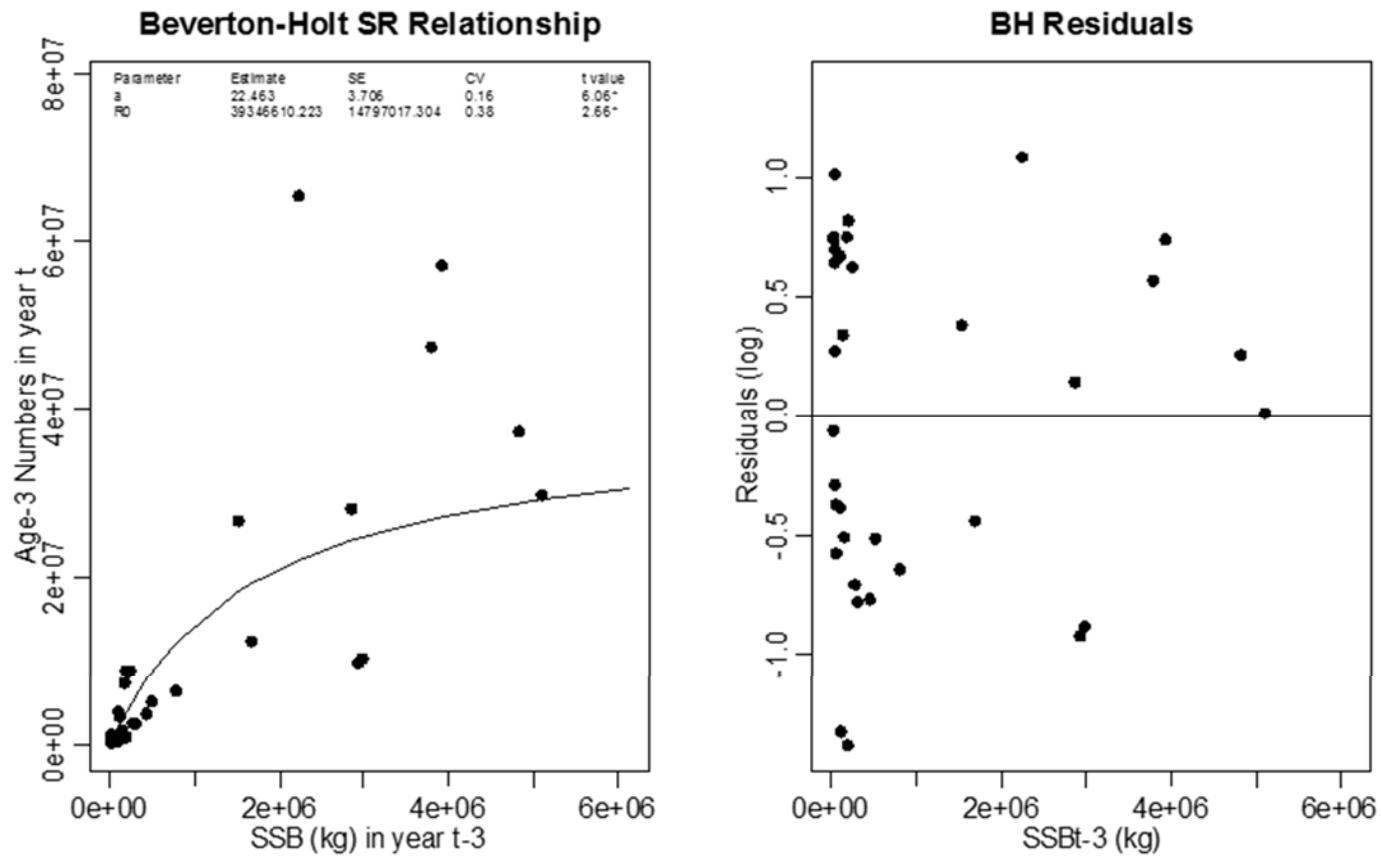


Figure 16.16 Fit of the Beverton-Holt stock-recruitment relationship to the age-3 abundance and female spawning stock biomass. Estimates of parameters a and R_0 from the Beverton-Holt equation are provided in the first graph, and residuals for the model fit are shown in the second graph.

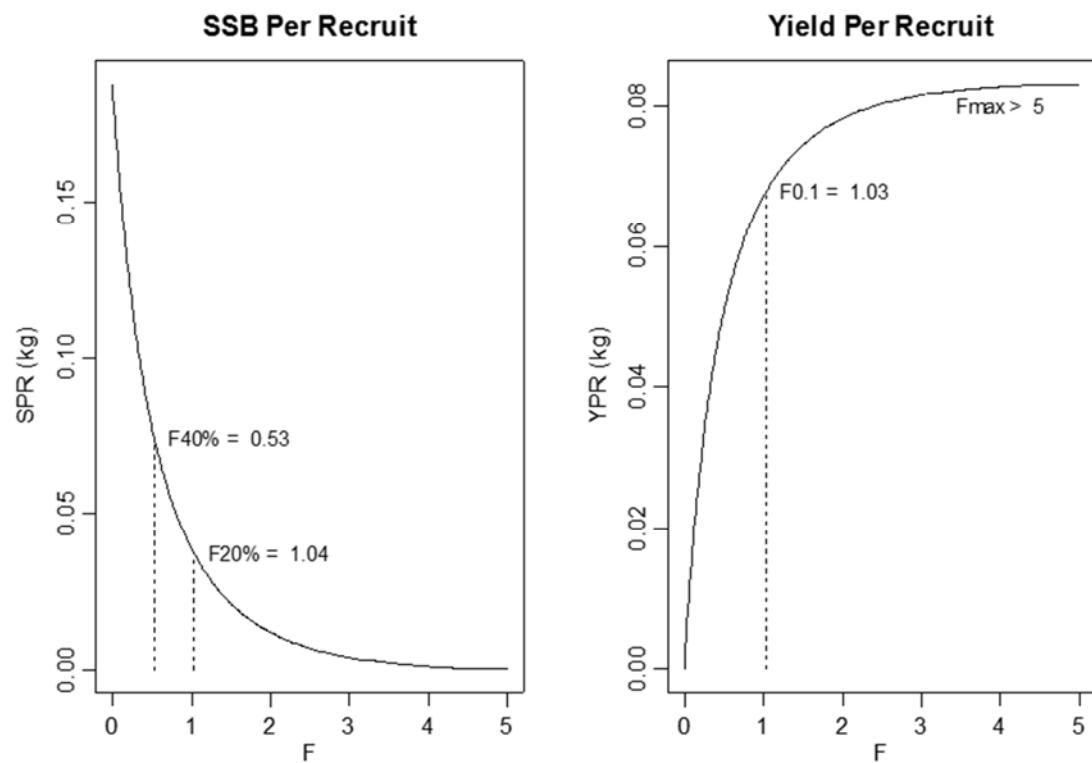


Figure 16.17 Results of spawning biomass per recruit and yield-per-recruit and analyses for the Chowan River blueback herring stock.

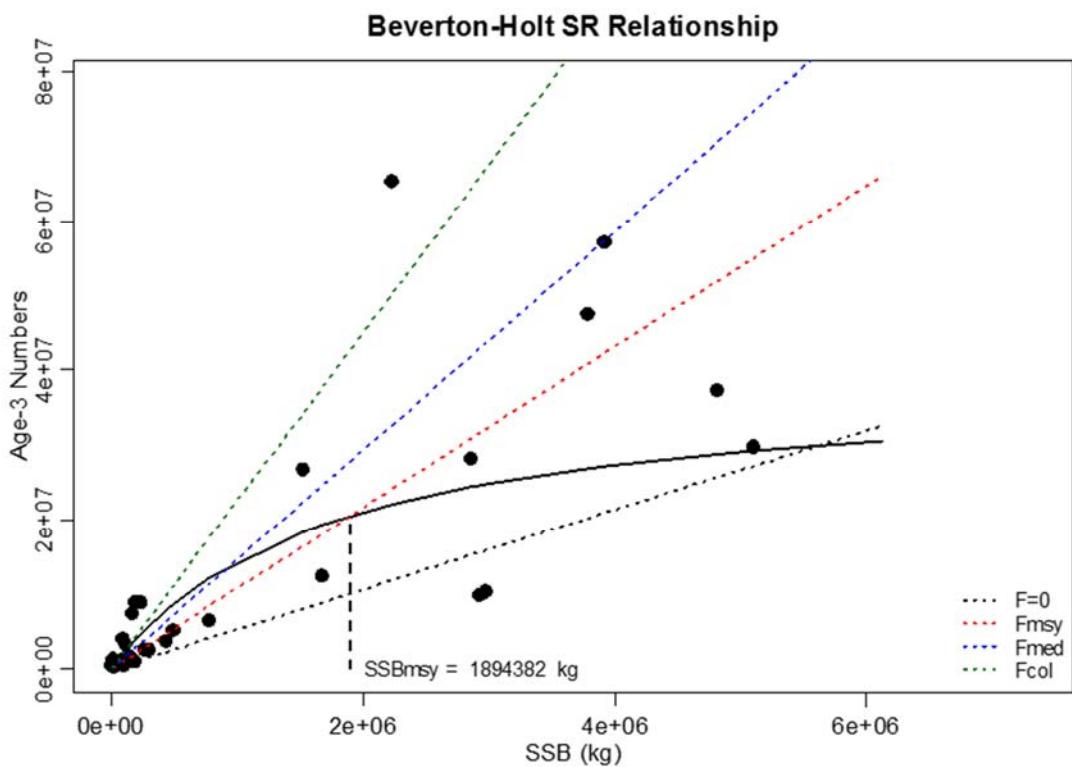


Figure 16.18 Beverton-Holt spawner-recruit model and production model reference points (see text) for the Chowan River blueback herring stock. Also shown is the replacement line in absence of fishing mortality ($F=0$).

Appendix Table 16.1. Estimates of proportion mature-at-age for female and male blueback herring in the Chowan river by year.

Female

| Year | 3 | 4 | 5 | 6 | 7 | 8 |
|------|-------|-------|-------|-------|-------|-------|
| 1972 | 0.440 | 0.809 | 0.979 | 1.000 | 1.000 | 1.000 |
| 1973 | 0.012 | 0.654 | 0.963 | 1.000 | 1.000 | 1.000 |
| 1974 | 0.000 | 0.766 | 0.961 | 1.000 | 1.000 | 1.000 |
| 1975 | 0.022 | 0.925 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1976 | 0.016 | 0.748 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1977 | 0.000 | 0.321 | 0.993 | 1.000 | 1.000 | 1.000 |
| 1978 | 0.010 | 0.525 | 0.990 | 1.000 | 1.000 | 1.000 |
| 1979 | 0.046 | 0.762 | 0.992 | 1.000 | 1.000 | 1.000 |
| 1980 | 0.009 | 0.431 | 0.950 | 0.995 | 1.000 | 1.000 |
| 1981 | 0.000 | 0.226 | 0.865 | 1.000 | 1.000 | 1.000 |
| 1982 | 0.010 | 0.654 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1983 | 0.020 | 0.765 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1984 | 0.042 | 0.684 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1985 | 0.000 | 0.205 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1986 | 0.000 | 0.322 | 0.978 | 1.000 | 1.000 | 1.000 |
| 1987 | 0.049 | 0.654 | 0.988 | 1.000 | 1.000 | 1.000 |
| 1988 | 0.000 | 0.768 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1989 | 0.023 | 0.814 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1990 | 0.191 | 0.910 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1991 | 0.160 | 0.860 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1992 | 0.056 | 0.710 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1993 | 0.024 | 0.452 | 0.976 | 1.000 | 1.000 | 1.000 |
| 1994 | 0.032 | 0.613 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1995 | 0.020 | 0.653 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1996 | 0.000 | 0.300 | 0.980 | 1.000 | 1.000 | 1.000 |
| 1997 | 0.026 | 0.658 | 0.987 | 1.000 | 1.000 | 1.000 |
| 1998 | 0.000 | 0.539 | 0.991 | 1.000 | 1.000 | 1.000 |
| 1999 | 0.000 | 0.506 | 0.996 | 1.000 | 1.000 | 1.000 |
| 2000 | 0.000 | 0.622 | 0.961 | 1.000 | 1.000 | 1.000 |
| 2001 | 0.004 | 0.407 | 0.996 | 1.000 | 1.000 | 1.000 |
| 2002 | 0.000 | 0.305 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2003 | 0.000 | 0.177 | 0.990 | 1.000 | 1.000 | 1.000 |
| 2004 | 0.042 | 0.632 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2005 | 0.101 | 0.881 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2006 | 0.000 | 0.855 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2007 | 0.127 | 0.582 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2008 | 0.000 | 0.672 | 0.981 | 1.000 | 1.000 | 1.000 |
| 2009 | 0.000 | 0.724 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2010 | 0.150 | 0.793 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2011 | 0.000 | 0.159 | 0.976 | 1.000 | 1.000 | 1.000 |
| 2012 | 0.000 | 0.216 | 0.966 | 1.000 | 1.000 | 1.000 |
| 2013 | 0.000 | 0.240 | 0.900 | 1.000 | 1.000 | 1.000 |
| 2014 | 0.000 | 0.378 | 0.919 | 1.000 | 1.000 | 1.000 |
| 2015 | 0.000 | 0.433 | 0.979 | 1.000 | 1.000 | 1.000 |

Male

| Year | 3 | 4 | 5 | 6 | 7 | 8 |
|------|-------|-------|-------|-------|-------|-------|
| 1972 | 0.419 | 0.869 | 0.996 | 1.000 | 1.000 | 1.000 |
| 1973 | 0.109 | 0.861 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1974 | 0.019 | 0.897 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1975 | 0.079 | 0.868 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1976 | 0.076 | 0.856 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1977 | 0.000 | 0.354 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1978 | 0.063 | 0.627 | 0.984 | 1.000 | 1.000 | 1.000 |
| 1979 | 0.063 | 0.893 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1980 | 0.023 | 0.630 | 0.977 | 1.000 | 1.000 | 1.000 |
| 1981 | 0.009 | 0.411 | 0.963 | 1.000 | 1.000 | 1.000 |
| 1982 | 0.071 | 0.764 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1983 | 0.113 | 0.887 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1984 | 0.163 | 0.801 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1985 | 0.039 | 0.457 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1986 | 0.046 | 0.713 | 0.991 | 1.000 | 1.000 | 1.000 |
| 1987 | 0.070 | 0.876 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1988 | 0.245 | 0.945 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1989 | 0.222 | 0.940 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1990 | 0.464 | 0.982 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1991 | 0.360 | 0.928 | 0.993 | 1.000 | 1.000 | 1.000 |
| 1992 | 0.097 | 0.968 | 0.995 | 1.000 | 1.000 | 1.000 |
| 1993 | 0.047 | 0.756 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1994 | 0.327 | 0.923 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1995 | 0.039 | 0.789 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1996 | 0.190 | 0.914 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1997 | 0.389 | 0.917 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1998 | 0.104 | 0.797 | 0.990 | 1.000 | 1.000 | 1.000 |
| 1999 | 0.058 | 0.764 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2000 | 0.023 | 0.957 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2001 | 0.021 | 0.904 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2002 | 0.022 | 0.934 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2003 | 0.075 | 0.936 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2004 | 0.299 | 0.965 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2005 | 0.220 | 0.984 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2006 | 0.170 | 0.936 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2007 | 0.234 | 0.964 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2008 | 0.081 | 0.719 | 0.990 | 1.000 | 1.000 | 1.000 |
| 2009 | 0.027 | 0.680 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2010 | 0.238 | 0.852 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2011 | 0.129 | 0.978 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2012 | 0.000 | 0.383 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2013 | 0.000 | 0.241 | 0.944 | 1.000 | 1.000 | 1.000 |
| 2014 | 0.000 | 0.474 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2015 | 0.000 | 0.796 | 1.000 | 1.000 | 1.000 | 1.000 |

Appendix Table 16.2. Estimates of total catch (in numbers) of pound nets for blueback herring in the Chowan River used in the base model run.

| Year | Numbers |
|------|------------|
| 1972 | 20,443,867 |
| 1973 | 13,918,880 |
| 1974 | 12,141,597 |
| 1975 | 7,286,423 |
| 1976 | 12,121,822 |
| 1977 | 16,831,692 |
| 1978 | 9,762,107 |
| 1979 | 4,921,229 |
| 1980 | 7,617,940 |
| 1981 | 4,360,204 |
| 1982 | 12,658,422 |
| 1983 | 5,955,402 |
| 1984 | 9,023,870 |
| 1985 | 18,364,344 |
| 1986 | 10,997,451 |
| 1987 | 3,664,782 |
| 1988 | 4,162,095 |
| 1989 | 1,772,115 |
| 1990 | 1,612,157 |
| 1991 | 2,545,614 |
| 1992 | 2,281,605 |
| 1993 | 1,763,114 |
| 1994 | 1,380,804 |
| 1995 | 814,048 |
| 1996 | 1,043,026 |
| 1997 | 468,830 |
| 1998 | 1,105,760 |
| 1999 | 948,791 |
| 2000 | 436,067 |
| 2001 | 363,260 |
| 2002 | 133,659 |
| 2003 | 143,201 |
| 2004 | 102,534 |
| 2005 | 447,376 |
| 2006 | 153,862 |
| 2007 | 1,325 |
| 2008 | 1,808 |
| 2009 | 970 |
| 2010 | 2,658 |
| 2011 | 2,125 |
| 2012 | 991 |
| 2013 | 1,051 |
| 2014 | 1,644 |
| 2015 | 10 |

Appendix Table 16.3. Number of Chowan River blueback samples from pound nets aged by sex, year, and age.

Female

| Year | 3 | 4 | 5 | 6 | 7 | 8 |
|------|----|-----|-----|----|----|----|
| 1972 | 25 | 42 | 54 | 18 | 2 | 0 |
| 1973 | 1 | 23 | 30 | 24 | 3 | 0 |
| 1974 | 0 | 29 | 23 | 21 | 4 | 0 |
| 1975 | 2 | 63 | 23 | 4 | 1 | 0 |
| 1976 | 1 | 49 | 55 | 14 | 4 | 0 |
| 1977 | 0 | 20 | 98 | 14 | 7 | 1 |
| 1978 | 1 | 31 | 55 | 8 | 4 | 0 |
| 1979 | 3 | 21 | 58 | 39 | 8 | 1 |
| 1980 | 0 | 32 | 80 | 57 | 41 | 8 |
| 1981 | 0 | 50 | 122 | 73 | 50 | 23 |
| 1982 | 1 | 49 | 31 | 15 | 3 | 4 |
| 1983 | 2 | 50 | 42 | 7 | 0 | 1 |
| 1984 | 4 | 36 | 42 | 13 | 0 | 0 |
| 1985 | 0 | 5 | 48 | 28 | 2 | 0 |
| 1986 | 0 | 14 | 37 | 32 | 7 | 0 |
| 1987 | 4 | 43 | 21 | 10 | 3 | 0 |
| 1988 | 0 | 48 | 27 | 5 | 2 | 0 |
| 1989 | 1 | 18 | 21 | 3 | 0 | 0 |
| 1990 | 16 | 51 | 15 | 7 | 0 | 0 |
| 1991 | 14 | 42 | 32 | 9 | 3 | 0 |
| 1992 | 1 | 55 | 41 | 10 | 0 | 0 |
| 1993 | 1 | 4 | 25 | 9 | 3 | 0 |
| 1994 | 1 | 15 | 10 | 4 | 1 | 0 |
| 1995 | 1 | 16 | 28 | 2 | 2 | 0 |
| 1996 | 0 | 10 | 24 | 14 | 2 | 0 |
| 1997 | 2 | 29 | 29 | 14 | 2 | 0 |
| 1998 | 0 | 131 | 321 | 60 | 17 | 0 |
| 1999 | 0 | 50 | 125 | 67 | 7 | 0 |
| 2000 | 0 | 58 | 102 | 74 | 19 | 1 |
| 2001 | 1 | 72 | 111 | 64 | 5 | 0 |
| 2002 | 0 | 29 | 82 | 29 | 1 | 0 |
| 2003 | 0 | 13 | 53 | 24 | 6 | 0 |
| 2004 | 2 | 36 | 44 | 13 | 0 | 0 |
| 2005 | 15 | 98 | 47 | 8 | 0 | 0 |
| 2006 | 0 | 37 | 18 | 0 | 0 | 0 |
| 2007 | 7 | 10 | 23 | 15 | 0 | 0 |
| 2008 | 0 | 148 | 98 | 66 | 5 | 0 |
| 2009 | 0 | 105 | 93 | 15 | 1 | 0 |
| 2010 | 30 | 83 | 76 | 22 | 2 | 0 |
| 2011 | 7 | 35 | 26 | 12 | 0 | 0 |
| 2012 | 12 | 27 | 31 | 14 | 2 | 0 |
| 2013 | 16 | 30 | 36 | 15 | 1 | 0 |
| 2014 | 25 | 22 | 14 | 6 | 5 | 0 |
| 2015 | 12 | 54 | 15 | 13 | 1 | 0 |

Male

| Year | 3 | 4 | 5 | 6 | 7 | 8 |
|------|-----|-----|-----|----|----|---|
| 1972 | 46 | 112 | 78 | 28 | 3 | 0 |
| 1973 | 16 | 93 | 76 | 38 | 5 | 2 |
| 1974 | 3 | 74 | 55 | 22 | 1 | 0 |
| 1975 | 6 | 77 | 27 | 3 | 1 | 0 |
| 1976 | 12 | 147 | 69 | 7 | 1 | 0 |
| 1977 | 0 | 39 | 115 | 20 | 1 | 0 |
| 1978 | 5 | 47 | 62 | 11 | 1 | 0 |
| 1979 | 12 | 66 | 116 | 48 | 11 | 0 |
| 1980 | 2 | 66 | 85 | 53 | 9 | 2 |
| 1981 | 3 | 97 | 131 | 87 | 25 | 7 |
| 1982 | 10 | 74 | 31 | 16 | 7 | 2 |
| 1983 | 19 | 108 | 65 | 11 | 1 | 0 |
| 1984 | 23 | 68 | 44 | 6 | 0 | 0 |
| 1985 | 5 | 22 | 76 | 24 | 0 | 0 |
| 1986 | 5 | 32 | 51 | 20 | 0 | 0 |
| 1987 | 8 | 73 | 36 | 10 | 2 | 0 |
| 1988 | 36 | 99 | 23 | 4 | 1 | 0 |
| 1989 | 20 | 70 | 23 | 4 | 0 | 0 |
| 1990 | 48 | 41 | 20 | 2 | 0 | 0 |
| 1991 | 42 | 68 | 27 | 2 | 0 | 0 |
| 1992 | 9 | 116 | 49 | 12 | 1 | 0 |
| 1993 | 4 | 17 | 50 | 14 | 1 | 0 |
| 1994 | 15 | 23 | 12 | 2 | 0 | 0 |
| 1995 | 2 | 33 | 40 | 1 | 0 | 0 |
| 1996 | 10 | 26 | 20 | 0 | 2 | 0 |
| 1997 | 14 | 15 | 4 | 3 | 0 | 0 |
| 1998 | 30 | 163 | 163 | 23 | 6 | 0 |
| 1999 | 9 | 101 | 167 | 35 | 1 | 0 |
| 2000 | 15 | 383 | 316 | 24 | 1 | 0 |
| 2001 | 3 | 170 | 155 | 7 | 0 | 0 |
| 2002 | 2 | 86 | 87 | 6 | 0 | 0 |
| 2003 | 9 | 80 | 76 | 8 | 0 | 0 |
| 2004 | 27 | 73 | 43 | 1 | 0 | 0 |
| 2005 | 16 | 89 | 18 | 0 | 0 | 0 |
| 2006 | 12 | 66 | 16 | 0 | 0 | 0 |
| 2007 | 25 | 70 | 69 | 3 | 0 | 0 |
| 2008 | 49 | 358 | 181 | 20 | 0 | 0 |
| 2009 | 7 | 174 | 142 | 5 | 0 | 0 |
| 2010 | 123 | 310 | 149 | 6 | 0 | 0 |
| 2011 | 3 | 51 | 29 | 8 | 0 | 0 |
| 2012 | 20 | 44 | 25 | 6 | 0 | 0 |
| 2013 | 17 | 42 | 39 | 13 | 1 | 0 |
| 2014 | 65 | 35 | 15 | 10 | 1 | 0 |
| 2015 | 13 | 57 | 16 | 3 | 0 | 0 |

Appendix Table 16.4. Young-of-the-year blueback herring seine index by year. -1 = not used. The 1994 value was not used because the model could not reconcile zero YOY fish.

| Year | Geo Mean |
|------|----------|
| 1972 | 8.63 |
| 1973 | 34.52 |
| 1974 | 7.70 |
| 1975 | 11.08 |
| 1976 | 5.52 |
| 1977 | 11.32 |
| 1978 | 7.76 |
| 1979 | 9.90 |
| 1980 | 15.57 |
| 1981 | 0.25 |
| 1982 | 7.58 |
| 1983 | 3.80 |
| 1984 | 1.75 |
| 1985 | 2.47 |
| 1986 | 1.16 |
| 1987 | 1.25 |
| 1988 | 0.95 |
| 1989 | 0.02 |
| 1990 | 0.99 |
| 1991 | 0.40 |
| 1992 | 0.10 |
| 1993 | 0.79 |
| 1994 | -1.00 |
| 1995 | 0.29 |
| 1996 | 0.90 |
| 1997 | 0.81 |
| 1998 | 0.13 |
| 1999 | 0.18 |
| 2000 | 0.38 |
| 2001 | 0.58 |
| 2002 | 0.19 |
| 2003 | 0.36 |
| 2004 | 0.90 |
| 2005 | 0.56 |
| 2006 | 0.09 |
| 2007 | 0.06 |
| 2008 | 0.17 |
| 2009 | 0.10 |
| 2010 | 0.09 |
| 2011 | 0.03 |
| 2012 | 0.10 |
| 2013 | 0.72 |
| 2014 | 0.15 |
| 2015 | 0.56 |

Appendix Table 16.5. Female weights-at-age (kg). Color indicates that values were estimated from observed values from other years.

| Year | 3 | 4 | 5 | 6 | 7 | 8 |
|------|------|------|------|------|------|------|
| 1972 | 0.19 | 0.20 | 0.21 | 0.22 | 0.21 | 0.29 |
| 1973 | 0.15 | 0.19 | 0.21 | 0.24 | 0.27 | 0.29 |
| 1974 | 0.15 | 0.19 | 0.21 | 0.24 | 0.27 | 0.29 |
| 1975 | 0.15 | 0.19 | 0.21 | 0.24 | 0.27 | 0.29 |
| 1976 | 0.15 | 0.19 | 0.21 | 0.24 | 0.27 | 0.29 |
| 1977 | 0.15 | 0.19 | 0.21 | 0.24 | 0.27 | 0.29 |
| 1978 | 0.15 | 0.19 | 0.21 | 0.24 | 0.27 | 0.29 |
| 1979 | 0.15 | 0.19 | 0.21 | 0.24 | 0.27 | 0.29 |
| 1980 | 0.15 | 0.19 | 0.21 | 0.24 | 0.27 | 0.29 |
| 1981 | 0.15 | 0.20 | 0.23 | 0.26 | 0.26 | 0.29 |
| 1982 | 0.13 | 0.19 | 0.22 | 0.24 | 0.27 | 0.27 |
| 1983 | 0.14 | 0.18 | 0.22 | 0.26 | 0.27 | 0.32 |
| 1984 | 0.13 | 0.17 | 0.19 | 0.22 | 0.27 | 0.29 |
| 1985 | 0.13 | 0.17 | 0.18 | 0.21 | 0.23 | 0.29 |
| 1986 | 0.13 | 0.16 | 0.20 | 0.22 | 0.24 | 0.29 |
| 1987 | 0.13 | 0.16 | 0.19 | 0.21 | 0.25 | 0.29 |
| 1988 | 0.13 | 0.15 | 0.18 | 0.22 | 0.22 | 0.29 |
| 1989 | 0.14 | 0.17 | 0.21 | 0.24 | 0.27 | 0.29 |
| 1990 | 0.16 | 0.19 | 0.18 | 0.25 | 0.25 | 0.29 |
| 1991 | 0.13 | 0.16 | 0.22 | 0.24 | 0.33 | 0.29 |
| 1992 | 0.14 | 0.16 | 0.19 | 0.21 | 0.27 | 0.29 |
| 1993 | 0.10 | 0.15 | 0.17 | 0.17 | 0.22 | 0.29 |
| 1994 | 0.12 | 0.13 | 0.14 | 0.24 | 0.18 | 0.29 |
| 1995 | 0.12 | 0.15 | 0.16 | 0.20 | 0.30 | 0.29 |
| 1996 | 0.13 | 0.19 | 0.19 | 0.22 | 0.24 | 0.29 |
| 1997 | 0.11 | 0.16 | 0.25 | 0.25 | 0.33 | 0.29 |
| 1998 | 0.12 | 0.15 | 0.16 | 0.19 | 0.24 | 0.29 |
| 1999 | 0.13 | 0.16 | 0.18 | 0.17 | 0.20 | 0.29 |
| 2000 | 0.13 | 0.15 | 0.18 | 0.18 | 0.22 | 0.29 |
| 2001 | 0.12 | 0.16 | 0.19 | 0.23 | 0.27 | 0.29 |
| 2002 | 0.13 | 0.16 | 0.19 | 0.22 | 0.22 | 0.29 |
| 2003 | 0.13 | 0.12 | 0.17 | 0.19 | 0.18 | 0.29 |
| 2004 | 0.12 | 0.14 | 0.15 | 0.19 | 0.24 | 0.29 |
| 2005 | 0.12 | 0.14 | 0.17 | 0.19 | 0.24 | 0.29 |
| 2006 | 0.13 | 0.15 | 0.16 | 0.20 | 0.24 | 0.29 |
| 2007 | 0.14 | 0.18 | 0.19 | 0.22 | 0.24 | 0.29 |
| 2008 | 0.13 | 0.14 | 0.16 | 0.20 | 0.24 | 0.29 |
| 2009 | 0.13 | 0.14 | 0.16 | 0.20 | 0.24 | 0.29 |
| 2010 | 0.13 | 0.14 | 0.16 | 0.20 | 0.24 | 0.29 |
| 2011 | 0.14 | 0.18 | 0.19 | 0.20 | 0.24 | 0.29 |
| 2012 | 0.13 | 0.14 | 0.17 | 0.18 | 0.24 | 0.29 |
| 2013 | 0.17 | 0.18 | 0.19 | 0.19 | 0.24 | 0.29 |
| 2014 | 0.16 | 0.19 | 0.17 | 0.19 | 0.24 | 0.29 |
| 2015 | 0.14 | 0.15 | 0.18 | 0.20 | 0.24 | 0.29 |

17 Status of River Herring in South Carolina

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Executive Summary

Historically, river herring (blueback herring, *Alosa aestivalis*, and alewife, *Alosa pseudoharengus*) occurred in most of South Carolina's major rivers. In recent years, there has been no evidence of alewife in South Carolina and we believe that North Carolina has become the southernmost extent of their range. All available data show that river herring landings have declined from historic levels in South Carolina. Abundance of blueback herring in the Santee and Cooper Rivers has varied widely between rivers and among years. Changes in abundance appear to have resulted from a combination of habitat alteration from flow regulation and drought, and from fishing. Abundance of blueback herring in the Cooper River was reduced in the early 1970s from apparent over fishing and following the rediversion of water from the Cooper back to the Santee River and has remained low since the mid-1980s. Blueback herring abundance in the Santee River increased following rediversion and peaked at relatively high levels through the 1990s. Droughts throughout the 2000s were thought to have negatively impacted abundance, but since then abundance has returned to a relatively moderate level throughout the 2010s. It is unlikely that fishing has affected stock abundance or age structure and we do not know if current abundance indices (CPUE, minimum population size) reflect moderate stock levels following a peak and precipitous decline or are just rebuilding stock levels following the droughts of the 2000s. Commercial harvest regulations should not be relaxed for the Santee-Cooper system. Harvest in the Cooper River and Rediversion Canal recreational fisheries appear to be minor since herring are not target species. However, we advise continuing the creel survey to monitor this fishery. As of January 1, 2012 the Santee-Cooper and Pee Dee Rivers are the only systems in South Carolina with an approved commercial and recreational sustainable fishing plan, as required under Amendment 2 to the ASMFC Shad & River Herring FMP.

17.1. INTRODUCTION

Historically, river herring (blueback herring, *Alosa aestivalis*, and alewife, *Alosa pseudoharengus*) occurred in most of South Carolina's major rivers (Figure 17.1). In recent years, there has been no evidence of alewife in South Carolina and we believe that North Carolina has become the southernmost

extent of their range. Commercial fisheries for blueback herring in South Carolina occur to a limited extent in open rivers such as Winyah Bay tributaries, but most fishing activity occurs in hydro-electric tailraces of the Santee-Cooper River system. Recreational fisheries for blueback herring exist, but only as a bycatch to the American shad fishery. Data are available to assess trends in fishery and stock status of blueback herring for the following river systems and life stages in South Carolina: Cooper River, Santee River, and the Rediversion Canal for adult herring and Winyah Bay, Waccamaw River, Santee River, Cooper River, Edisto River, and Combahee River for juveniles.

17.2. MANAGEMENT UNIT

Management of blueback herring in South Carolina is shared between the Marine Resources and Freshwater Divisions of the Department of Natural Resources (SCDNR). Management units are defined by stock and the complex of river(s) utilized. Management units include all rivers and tributaries within each area complex: Winyah Bay (Sampit, Lynches, Pee Dee, Bull Creek, Black, and Waccamaw Rivers), the Santee-Cooper Rivers complex, the Savannah River and the ACE Basin (Ashepoo-Combahee-Edisto Rivers). Detailed descriptions of these units are in Section 17.6.

17.3. REGULATORY HISTORY

The SCDNR manages commercial herring fisheries using a combination of seasons, gear restrictions, and catch limits. In 1964, commercial blueback herring fishing in Cooper River was restricted to daylight hours with a dip net not more than three feet in diameter and a limit of 100 lb (45.4 kg) per man per day. By 1969, regulations had been liberalized to allow nets with six foot diameters, fishing until ten o'clock p.m., and no limit on the harvest. Between 1966 and 1969, herring were abundant and the fishery expanded. Fishing success declined in the early 1970s and a limit of 45.4 kg of herring per man day was reimposed in 1975. Today, the commercial fishery for blueback herring has a 10 bushel daily limit (227 kg) per boat in the Cooper and Santee Rivers and the Santee-Cooper Rediversion Canal and a 250 lb (113.4 kg) per boat limit in the Santee-Cooper lakes. Seasons generally span the spawning season. All licensed fishermen have been required to report their daily catch and effort to the SCDNR since 1998. Current regulations are summarized in the Appendix.

The recreational fishery has a 1 bushel (22.7 kg) fish aggregate daily creel for blueback herring in all rivers; however very few recreational anglers target blueback herring.

17.4. ASSESSMENT HISTORY

The first ASMFC assessment of the coast-wide river herring stocks occurred in 1990 (ASMFC 1990). South Carolina stocks were not included in this analysis.

17.5. STOCK SPECIFIC LIFE HISTORY

Blueback herring of South Carolina spawn in the spring in freshwater portions of coastal rivers and streams. The best life history information comes from studies of blueback herring in the Santee-Cooper system in the central part of the state (Figure 17.2) prior to redirection of Cooper River flows to the Santee River. Spawning in these systems occurred in Lakes Moultrie and Marian and below the Pinopolis Dam on the Cooper River and the Wilson Dam on the Santee River (Bulak and Curtis 1977). Spawning was concentrated between the Pinopolis Dam (km 143) and km 77 in the Cooper River and around km 60 on the Santee River. Limited spawning also occurred in the tributaries of the Santee and Cooper Rivers and in rice fields adjacent to the Cooper River. Use of these rice fields may have declined

since rediversion and the resulting decline of Cooper River flows. Prior to rediversion, blueback herring spawned from March through early May in the Cooper River and February to April in the Santee River. Bulak and Curtis (1977) observed spawning in the Santee River at water temperatures of 12 to 20°C. River spawning below the Pinopolis and Wilson Dams was often disrupted by changes in dam discharge (Meador et al. 1984). Since rediversion, blueback herring have expanded spawning in the Santee River to the rediversion canal and spawning times in the two rivers have become more closely synchronized (Cooke and Leach 2000). Mature fish leave the spawning reaches shortly after spawning. Once in the ocean, blueback herring from the Santee River migrate widely along the Atlantic Coast. Tag returns from fish tagged in spring in the Santee River have been recaptured from as far north as the Bay of Fundy (Christie and Cooke 1987)

Meristic and enzyme studies by Christie and Cooke (1985) indicated that separate stocks of blueback herring were present in the Cooper and Santee Rivers prior to rediversion. However, the authors found evidence of straying between these two rivers and of fish from other South Carolina coastal rivers. It is likely that stocks in the Santee and Cooper rivers have mixed to a greater degree since completion of the rediversion project in 1985 and subsequent flow changes.

Young blueback herring are important forage in Lakes Moultrie and Marian (Bulak and Curtis 1978). Downriver movement of each year's juveniles starts in June and may continue through the following June (Cooke and Coale 1996). Downriver movement of adults that spawn above the dams and of young produced above the dams occurs through power turbines at all three dams, spillage over the Wilson Dam, or through the navigation locks at the Pinopolis Dam. In drought years, downriver passage declines as dam discharge declines.

Blueback herring in the Santee River are iteroparous and have been observed to spawn up to four times over their lifetime (Christie and Barwick 1984). Percent of repeat spawn has been observed as high as 31% for males and 33% for females. Male and female blueback herring can begin spawning as early as age two (Table 17.1). However, full maturity of both sexes does not occur until age six. Males generally mature at a faster rate than females.

17.6. HABITAT DESCRIPTION

Blueback herring are present in tributaries of Winyah Bay, the Santee-Cooper system, and the Savannah River. Abundance is highest in the Winyah Bay tributaries and the Santee-Cooper system. Blueback herring are at low abundance or absent from the Edisto, Ashepoo, and Combahee Rivers.



Figure 17.1 South Carolina's Major Rivers

17.6.1. Winyah Bay System

Winyah Bay extends nearly 24 km inland and has six major tributaries that have spawning runs of anadromous fish (Sampit, Lynches, Pee Dee, Bull Creek, Black, and Waccamaw). The Sampit is a small, tidal river that is navigable to about km 64. The mouth of the Black River is near the junction of the Great Pee Dee River and upper Winyah Bay and it has approximately 40 km of navigable waters. The Pee Dee River extends well into North Carolina and it is dammed at Blewett Falls, North Carolina (320 km inland) (Post *et al.* 2004). The Little Pee Dee is the largest tributary of the Pee Dee River and it extends about 96 km to the North Carolina state line. Bull Creek and Lynches River are both tributaries of the Pee Dee River. The Lynches River is navigable for over 113 km from its confluence with the Pee Dee. Bull Creek extends 24 km and borders the Waccamaw River to the south and the Great Pee Dee to the north.

17.6.2. Santee-Cooper System

The Santee River, formed by the Wateree and Congaree Rivers, was historically one of the longest river systems on the Atlantic coast. At one time, it supported spawning runs of anadromous fish to Great Falls (km 438) on the Wateree River and up to river km 602 on the Congaree River (Walburg and Nichols 1967). In 1938, the South Carolina Public Service Authority (SCPSA) initiated a large diversion project to move water from the Santee River to the Cooper River. The project included the construction of the Wilson Dam for flood control on Santee River at km 143, which created Lake Marion and the construction of Pinopolis Dam at km 77 on the Cooper River, which is a hydroelectric facility with a navigation lock (Figure 17.2). Pinopolis Dam formed Lake Moultrie (Cooke and Leach 2003). Flows were diverted from Lake Marion on the Santee River to Lake Moultrie on the Cooper River and mean annual flows in the Santee River declined from $525 \text{ m}^3/\text{s}$ to $63 \text{ m}^3/\text{s}$. When not in flood, the Santee River is a shallow, slow moving, meandering river that flows through hardwood swamps (Bulak and Curtis 1977). Discharge from the Pinopolis Dam flows 29 km through a discharge canal to its confluence with the East Branch of the Cooper River. The Cooper River downriver of the confluence receives drainage from several swamps and tributaries and is adjacent to many abandoned rice fields.

Increased flows from the Santee-Cooper Diversion Project to the Cooper River led to shoaling in Charleston Harbor, due to increased sediment loads. Consequently, starting in 1985, water was rediverted through a 15 km Rediversion Canal from Lake Moultrie to the Santee River below Lake Marion. The St. Stephen Dam was constructed 7 km up the Rediversion Canal to control flow and to provide hydro power. The Rediversion Canal diverted 75 percent of the Cooper River flow to the Santee River and increased the mean annual flow in the Santee River from $63 \text{ m}^3/\text{s}$ to $295 \text{ m}^3/\text{s}$ (Cooke and Leach 2003a). However, SCPSA has set a mean weekly discharge of $127 \text{ m}^3/\text{s}$ from the Pinopolis Dam on the Cooper River and when inflow to Lake Moultrie declines below that threshold flow to the Rediversion Canal declines. Discharge from the Wilson Dam on the Santee above the confluence with the Rediversion Canal was set at a continuous release of $14.6 \text{ m}^3/\text{s}$. The result of this water management regime is that flow to the Santee River is greater from the Rediversion Canal than from Wilson Dam except on low flow years when flow through the Rediversion Canal is reduced. Data suggested that large numbers of blueback herring which utilized the Cooper River before redirection, switched to Santee River after redirection (Cooke and Coale 1996).

17.6.3. ACE Basin (Edisto River, Combahee River, and Ashepoo River)

The lower portions of these systems comprise the ACE (Ashepoo-Combahee-Edisto) Basin National Estuarine Research Reserve. The Edisto River drains approximately $4,800 \text{ km}^2$ within the South Carolina Coastal Plain. This river is approximately 320 km long and has no dams. At approximately km 180, the North and South Forks merge forming the Edisto River proper. Anadromous fish can reach at least 161 km in the North Edisto and at least 193 km in the South Edisto on their spawning migration (Walburg and Nichols 1967). The lower 75 km of this system is tidally influenced and the lower 50 km drains substantial areas of fresh, brackish and salt marsh. The Edisto, Combahee and Ashepoo Rivers are connected for 20 km before entering the Atlantic Ocean through St. Helena Sound. The Combahee River is a black-water river about 72 km long. The Salkehatchie and Little Salkehatchie are major tributaries. There are no impoundments on the Combahee River and anadromous fish reach could reach river km 137 near Walker, South Carolina (Walburg and Nichols 1967). The Ashepoo River is the smallest of the ACE Basin Rivers and it has no obstructions to anadromous fish migration.

Increased timber harvest in the 1980s may have affected the river herring population in the ACE Basin by increasing siltation of river spawning habitat (Chris Thomason, SCDNR, personal communication).

17.6.4. Savannah River

The Savannah River is approximately 560 km long. The first barrier to upstream migration is the New Savannah Bluff Lock and Dam (NSBLD) located at Augusta, Georgia (approximately km 301). The lock at NSBLD is designed for navigation and does not provide effective fish passage. However, fish can use the navigation lock and during high flow periods, the river rises above the NSBLD allowing some fish passage. There are 43 km between NSBLD and the next dam which is the J. Strom Thurmond Dam (Billy McCord, SCDNR, personal communication). Water quality may be a problem in the Savannah since the dissolved oxygen in the lower Savannah can fall below 1.0 ppm (Billy McCord, SCDNR, personal communication).

17.7. RESTORATION PROGRAMS

17.7.1. Restoration Objectives

The U.S. Fish and Wildlife Service, the National Marine Fisheries Service (NMFS) and SCDNR developed a fish restoration plan for the Santee-Cooper River basin with proposed restoration targets (USFWS 2001). River-specific goals were not established for other systems in South Carolina.

17.7.2. Hatchery Evaluations

Larval or adult river herring are not stocked in South Carolina Rivers.

17.7.3. Fish Passage Efficiency

17.7.3.1. Santee-Cooper System

Pinopolis Dam (Cooper River)

Upriver passage at the Pinopolis Dam occurs through a tailrace canal and navigation lock. Fish passage through the lock is measured by hydro-acoustic methods that estimate annual passage of fish biomass. However, fish species is generally not known and double counting may occur as fish congregate over the hydro-acoustic array. Therefore, we did not consider annual estimates of passage biomass to be good indicators of blueback herring abundance in this system. Downriver passage may occur through the navigation lock.

St. Stephen Dam (Rediversion Canal)

The St. Stephen fish lock is located approximately mid-way on the Santee-Cooper Rediversion Canal at river kilometer 92 (Figure 17.2). Migratory fish are attracted into the entrance of the fish lock by an attraction flow. Fish are forced into the lock chamber and the chamber is then flooded to head level. A brail basket prompts the fish to swim 15 -20 m up in the water column and releases the fish into the exit channel. There they pass viewing windows before continuing on to the upper Rediversion Canal and

Santee-Cooper system. Generally, fish lock operations occur on the hour during daylight periods. Operations occur every 30 minutes when warranted by increased fish densities.

Passage efficiency at the St. Stephen Dam is unknown and likely varies among years. Poor passage efficiency was demonstrated by Cooke and Coale (1997), Cooke and Leach (2000), and Cooke and Leach (2002). Initially, high or intermittent discharges from the St. Stephen Dam on the Rediversion Canal prevented fish from entering the lock. In the 1990s, the SCPSA implemented a flow agreement to improve the fish-lock function, and a series of modifications were completed from 1995 through 2000 that may have increased the efficiency of the fish-lock. Annual variation in attraction flow, turbine discharge and water temperature in addition to fish abundance in the Rediversion Canal alter annual passage numbers of blueback herring at this facility.

The number of blueback herring that enter the Rediversion Canal from the Santee River varies among years depending on the relative flows in the Rediversion Canal and the Santee River above the canal. In moderate to high flow years, discharge of water from the St. Stephen Dam attracts fish into the Rediversion Canal. However, in low flow years when limited water is released from the St Stephen Dam, fish may bypass the Rediversion Canal and use the Santee River proper.

Fish moving downriver through the Rediversion Canal go through the turbines at the St. Stephen Dam. There have been no directed studies to determine turbine mortality on blueback herring at this facility, but it is believed that turbine strike mortality is minimal, with anecdotal information indicating that passage is more problematic for larger fish. Blueback herring appear to be more affected by pressure differential than by turbine strikes during their downstream migration at this facility (William McCord, SCNR, pers. comm.). Above Lake Marion, several impediments to migration exist on Santee River tributaries.

17.7.3.2. Wilson Dam

There are no fish passage facilities on the Wilson Dam on the Santee River although downriver passage may occur over the spillway.

17.7.3.3. Savannah River

New Savannah Bluff Lock and Dam are located at rkm 301 of the Savannah River. The dam was constructed in the 1930s as a commercial navigation lock. Currently, fish passage is possible only at flows greater than 453 m³/s when water levels above and below the dam are roughly equal. A navigation lock was used prior to 2015 for passage, however the lock is currently inoperable. When river flows do not reach 453 m³/s there is no passage above the dam.

17.8. AGE

Scale samples were used to age blueback herring using methods of Cating (1953) and Marcy (1969). Scales were taken from the left side of each herring in the area below the dorsal fin and above the lateral line. Samples were cleaned in 2% potassium hydroxide and read under a microfiche reader at a magnification of 26 x. Scale ageing was done by two independent researchers and results were not accepted until concurrence was achieved on 75 % of the age estimates for a given days sample. From 1979 to 1985, a single group of readers read scale samples, and from 2013-2015 scales have been read by two readers. Maximum age that South Carolina herring stocks can attain is unknown.

17.9. FISHERY DESCRIPTION

17.9.1. Overview

Several commercial herring fisheries occur within South Carolina. Most of the herring landed in the State over the past several decades have been taken in cast and drop net fisheries immediately below Pinopolis Dam on the Cooper River and below St. Stephen Dam on the Santee Rediversion Canal. Landings were typically greater in the Cooper River prior to the completion of the canal in 1986 because flow was greater in the Cooper River. The fishery gradually shifted to the Rediversion Canal once the canal was completed. Exceptions occur during low flow or drought years when the hydroelectric facility at St. Stephen dam does not pass water, thus reducing the attraction flow needed for herring. In such years, herring tend to stay in the main channel of the Santee River, bypassing the Rediversion Canal and continuing to the Santee Dam. During those years, the fishery shifts to the Santee River below the Wilson Dam. A small fishery continues below the Pinopolis Dam on the Cooper River.

A haul seine fishery operated below Wilson Dam on the Santee River prior to completion of the Santee-Cooper Rediversion Project in 1985. However, increased water levels and flows have largely prevented the operation of this fishery since rediversion. A recreational bow net fishery also occurred below the Wilson Dam on the Santee River prior to 1985, but only a small percent of the landings occurred in this gear. Fisheries in the Santee-Cooper system target pre-spawning adult blueback herring. Catch from these fisheries is sold for both bait and for human consumption, particularly the roe.

A limited, more traditional gill-net fishery occurs in rivers of the Winyah Bay watershed. Take in these fisheries is presumed to be largely adult blueback herring and most landings are consumed locally by fishers or sold as bait.

Blueback herring are also caught in commercial fisheries of several South Carolina reservoirs. Cast and drop nets are the legal gears for these bait fisheries. Catches within the Santee-Cooper Lakes where passage is provided for adult blueback herring, hickory, and American shad may include a mixture of adults and juveniles of these and other clupeids such as threadfin shad and gizzard shad. The Savannah River impoundments are not equipped with fish passage devices, but blueback herring populations are dam-locked within these reservoirs as a result of forage-fish stockings taken from the Santee-Cooper Lakes. Catches in the Savannah River reservoirs are also likely a mixed bag, but would not include American or hickory shad. "Shad" and "herring" landed in above-dam areas are generally sold (or used personally) as live, or fresh dead, bait for striped bass, hybrid striped bass, or catfishes.

Hook & line and cast nets are the only legal recreational gears for herring in South Carolina. Currently, most of the recreational take occurs as bycatch to the American shad fishery in the Cooper, Santee (including the Rediversion Canal)., There is also some undetermined amount of directed effort for herring by fishermen using sabiki rigs to catch herring to consume or use as bait.

17.9.2. Fishery Data

Reported commercial landings data of river herring in South Carolina are available from the National Marine Fisheries Service and the state. Landings reported to the NMFS prior to 1979 were collected from major wholesale outlets located near the coast and probably did not account for inland landings which were generally not sold at these outlets. NMFS data collected since 1979 usually include inland landings. In 1998, the state of South Carolina instituted mandatory reporting of commercial catch and

effort. However, questions regarding the integrity of the reports, accuracy of effort data, irregular or infrequent fishing by license holders, and year-to-year variability in river-wide records have hindered successful development of total catch and effort statistics by river from these data. The SCDNR is working to improve the scope and reliability of licensee data. The wholesale dealer reporting system utilized by the NMFS may not include herring landings because herring sold as bait to licensed bait dealers may not be reported.

In 1969, the South Carolina Department of Natural Resources instituted a commercial creel survey to estimate catch and effort in the fisheries in the Santee Cooper system. Surveys occurred at landings used to off-load and transport catch. The majority of herring harvested from the Cooper River (1969-1989) were landed at two locations between the hours of six p.m. and ten p.m. daily. Creel clerks stationed at these locations interviewed individual fishermen as the catch was unloaded. The time, date, type of gear used, catch, and number of fishermen aboard were recorded as each boat landed. The survey was expanded to the major landing below the St. Stephen Dam on the Rediversion Canal starting in 1990 as fish abundance declined in the Cooper River and increased in the Santee River and the Rediversion Canal. During low flow years, herring and the fishery move to the Santee River below the Wilson Dam. Surveys have been infrequent at that location. Weight of harvest was estimated from the number of bushels of herring landed and a mean bushel weight of 25.4 kg (Cooke 1998). Numbers of adult blueback herring landed were estimated by dividing kg landed by the mean weight of an adult herring (0.14 kg). Although some landings are occasionally missed during the creel survey, the survey produces the most reliable estimates of catch and effort available for South Carolina waters. Landings were not estimated for reservoir fisheries with landings of mixed species and size composition.

SCDNR has conducted an annual recreational creel survey since 2001 to estimate exploitation and catch-per-effort in the recreational American Shad fishery of the Santee Cooper system. These data consist of access point creel surveys (at end of a party's fishing day) for at least 2 h/d, 4 d/week along with effort estimates made by counting boats below the Pinopolis Dam, the Wilson Dam, or the Rediversion Canal at approximately 1400h each day of survey. Previous data demonstrated that a 1400h boat count measures maximum daily fishing pressure. This does not account for angler turnover, particularly of anglers that fish in the morning only. Also, while the majority of the season is surveyed, some fishing activity occurs prior to and after the study period, so results presented here are underestimated.

SCDNR also conducted sportfishing creel surveys on the Cooper and Santee Rivers in 1981 - 1982 and 1991 - 1993 to evaluate the impact of the Rediversion Canal on these recreational fisheries (Cook and Chapplear 1994). These surveys examined the total recreational fisheries on each river, but did not provide data on catch of blueback herring. Thus, the surveys could only be used to indicate change in the size of the fishery.

Recreational creel surveys were conducted on the Savannah River in the late 1990s by the Georgia Department of Natural Resources in 1997 and SCDNR in 1998 and 1999. Estimates of catch from these surveys varied from year to year largely due to dramatically different flow conditions. Catch estimates from each of these creel surveys were provided in Boltin (1999).

17.9.3. Fishery Dependent Data - Commercial

Reported Landings

Over 1,000,000 kg of river herring were reported from South Carolina commercial fisheries in 1969 (Table 17.2 and Figure 17.3). Landings declined precipitously soon after. They rebounded to a high of approximately 180,000 kg in the early 1980s and have maintained an average of 89,000 kg (1980-2015). The bulk of the reported landings since 1989 have come from the Santee-Cooper system (Table 17.3). Reported landings for the Pee Dee River of the Winyah Bay system are a small fraction of the total South Carolina reported landings, annually averaging 524 kg (range 1 - 3,192 kg) from 1998-2015 (Table 17.4).

Annual variation in reported landings since the early 1970s may have been influenced by changes in allowable catch over the years. Landings in the Santee Cooper system were also affected by changes in discharge from the three dams and concurrent changes in fish migration and gear effectiveness.

Estimated Effort, Harvest, and Catch Rates

Annual estimates of catch in kg, effort in man days, and kg catch/man day (CPUE) are available since 1969 from surveys of the Santee-Cooper fishery (Table 17.5, Figure 17.4). Estimates of all three parameters have fluctuated widely over the time series. Highest estimates of landings and CPUE occurred early in the time series in the Cooper River. Estimates of effort, landings, and CPUE in the Cooper River declined dramatically soon after to a low that lasted through the late 1970s. Estimates climbed again through the early 1980s and then declined as the Rediversion Canal was completed and flows shifted to the Rediversion Canal and the Santee River. Estimates of effort, landings, and CPUE then increased in the Rediversion Canal and the Santee River. Effort and fishing success fluctuated throughout the 2000s due to water availability.

Many factors likely affected effort and landings. To evaluate potential causes of change, we separated data from the Cooper River into two times series (1969 - 1974 and 1975 – 2015) and subset data for the Santee River to those from 1990 – 202015. We then normalized the estimates by dividing annual values by the series mean (Figure 17.5). Sub setting the Cooper River data reduced the influence of the relatively large estimates obtained early in the time series on the rest of the data. Normalizing the time series placed all of the parameters on a comparable scale. Effort and landings were highly correlated in both the Cooper River fisheries (1969-1974, $r^2=0.85$; 1975-2015, $r^2=0.81$) and the Santee River fisheries (1990-2015, $r^2=0.91$) (Figure 17.6). Apparently, effort played an important role in dictating landings. However, CPUE was also related to effort (Figure 17.5). If we assume that CPUE was a measure of relative stock abundance, then we can speculate that changes in stock abundance and related fishing success led to changes in effort and then in landings.

The variation in CPUE among years suggests that several cycles in blueback herring abundance occurred in the Santee Cooper System (Figure 17.4 and Figure 17.5). The dramatic CPUE decline in the first six years of the Cooper River time series may have been caused by overfishing. Following the imposition of harvest restrictions in 1975, CPUE bottomed out and remained at low levels for four years before rebounding through the early 1980s. Cooper River CPUE declined again following completion of the Rediversion Canal in 1985 and it has remained at relatively low levels since 1987. It is likely that reduced flows in the Cooper River led to degradation of spawning and nursery habitat in the river below the Pinopolis Dam and reduced access to flooded rice fields that had been previously used for spawning.

CPUE in the Santee River fishery increased rapidly following increased flows from redirection. CPUE leveled off in the mid to late 1990s, fluctuated significantly from 2001-2008 in relation to below normal stream flow levels, and stabilized at an above average level from 2009-2015. The initial CPUE increase in the Santee River fishery likely resulted from a combination of herring from the Cooper River stock that began to migrate into the Santee River as flow increased and improved production from improved spawning and nursery habitat. Stock increase was enhanced by regulations that prevented harvest from the Redirection Canal from 1985 through 1989. Reduced CPUEs in 2001, 2002, 2004, 2006, and 2008 were related to low fishing success caused by low water levels. It is unknown if stock levels were reduced during the same time frame; however, CPUEs stabilized after the drought and have been trending slightly above average for 2009-2015.

It is interesting to note that the CPUE of the Cooper River fishery during the peak years of 1979 through 1986 (135.2) exceeded estimates obtained for the Santee River fishery during its peak years of 1992 through 2001 (102.9). Highest CPUE on the Cooper River since 1975 was 163.3 in 1983 just before redirection. Highest CPUE on the Santee-Cooper Redirection Canal was 137.2 in 1998 some 13 years after redirection. It is not yet known if habitat in the Santee system will support greater numbers of blueback herring than did the Cooper River prior to redirection. The highest CPUE of the time series (607.5) occurred in the Cooper River in 1969.

CPUE in the Santee-Cooper commercial fisheries may have been affected by changes in harvest regulations. However, affects must have been minor because in many cases the low estimates of catch per man day were well below the minimum daily catch at the time. For example, the fishery went from one with no take limits in the early 1970s to one with a daily maximum take limit of 45.4 kg (100 lbs) per person in 1975. CPUE dropped from a high of 608 kg per fisherman day in 1969 to 55 kg in 1974 and then dropped to and remained at less than 35 kg through 1978. If the daily cap had been the cause of decline, then one would expect the CPUE to drop too and remain at the cap as soon as it was imposed. Since this did not occur, it is more likely that much of the change in CPUE was caused by concomitant changes in herring abundance.

Information on the number of fish harvested in the Santee River Diversion Canal is collected in two ways. Fisherman report their monthly catch via a mandatory reporting system and nightly creel surveys are conducted (March 1-April 30) at the single access point to the fishery where all harvested blueback herring are landed. Information from these two sources was nearly identical from 1998-2015, with the exception of 2005, 2009, and 2010 (Figure 17.7). This discrepancy has not been rectified, however the creel surveys provide more accurate information, and the harvest from 2009 and 2010 is better represented by creel data.

Bycatch

River herring occur as bycatch in fisheries along the Atlantic coast from North Carolina up to the Gulf of Maine. Since blueback herring from South Carolina migrate through this reach of ocean, it is likely that South Carolina fish are included. River herring bycatch in the Atlantic herring and mackerel fishery in the New York Bight and Gulf of Maine is of concern. Results of analysis suggest that bycatch of river herring in the Atlantic herring fishery can be equal to, or exceed the total of all in-river landings (ASMFC 2008, Cieri et al 2008).

Size and Age Distribution

Mean fork length of blueback herring taken in the commercial fishery in the Santee Rediversion Canal fluctuates annually but has remained relatively stable (Table 17.6 and Figure 17.8). From 1995-2001, mean lengths of harvested herring of both sexes were nearly identical; since that time, 2002-2015, harvested females have averaged 15 mm larger than harvested males. Beginning in 2013, blueback herring scales were used to estimate ages of harvested herring in the commercial fishery (Table 17.7). Fish from ages 4-7 were collected and ~30% were repeat spawners (Table 17.8).

17.9.4. Fishery Dependent Data - Recreational

Catch per unit effort of blueback herring in the recreational fishery varied without trend from 2003 through 2007 (Table 17.9). Blueback herring are not targeted in the recreational fishery and are most often not harvested. Therefore CPUE is based on the number of blueback herring the angler remembered catching and releasing and this number was often guessed by the angler. The data was not a reliable source of information and is no longer reported.

17.10. FISHERY INDEPENDENT SURVEYS

A variety of sampling efforts have been conducted to assess the condition of blueback herring stocks in South Carolina. Annual passage counts at St. Stephen Dam on the Santee-Cooper Rediversion Canal and the Pinopolis Dam on the Cooper River provide the longest times series of data. Periodic electrofishing and gill net sampling occurred in the Santee River below the Wilson Dam and population estimates were obtained for several years at that location. In addition, annual electrofishing for juvenile herring has been conducted in Winyah Bay and the Santee, Cooper, Edisto, and Combahee Rivers. Ichthyoplankton surveys were made for several years on the Santee and Cooper Rivers. The following summarizes results of the more useful surveys.

17.11. ASSESSMENT APPROACHES AND RESULTS

17.11.1. Adult Surveys

Santee River Population Estimates

Mark recapture population estimates of blueback herring were conducted in the Santee River from 1977 through 1990. During the first two years, researchers attempted to tag immigrating fish in the lower river and recapture the tagged fish upriver of the tagging sites. Researchers used seines, fyke nets, pound nets, and electrofishing to capture fish, but failed to obtain adequate numbers of fish for valid population estimates (Christie and Cooke 1987). Moreover, fish tagged in the lower reaches of the river often moved downriver and out of the system (Christie and Cooke 1986). Starting in 1979, fish for tagging were collected by electrofishing below Wilson Dam. Additional fish for tagging were obtained from the Cooper River and once the diversion system was in place, from the Rediversion Canal. Number of marked fish was decremented by 10% to account for handling mortality and tag loss for fish caught by electrofishing and by 20% for fish caught in the St. Stephen fish lift. Results were further discounted by estimates of the number of tagged fish that went upstream through the St. Stephen fish lift rather than spawning below the dam and then emigrating downriver. Recaptures were obtained by gill netting downriver of the tagging site in the Santee River. To insure that only the tagged population was included in the recapture effort, only fish moving downriver (from the upriver side of the net) were

counted in recapture collections. Valid recaptures were those captured between three days after tagging began through 10 days after tagging ended.

Estimates were calculated by Chapman's non-stratified modification of the Peterson formula (Ricker 1975):

$$N = ((M+1)*(C+1)/(R+1))-1$$

Where:

- M = number of marked herring tagged and released decremented by the appropriate factor for handling mortality, tag loss, and upriver passage
- C = number of herring captured at the recapture site
- R = number of tagged herring that were recaptured.

Standard error was calculated as:

$$SE = \sqrt{(N-M)*(N-C)/M*C*(N-1)}$$

The coefficient of variation (CV) was calculated as SE/N.

Resulting population estimates varied substantially among years and had wide confidence limits (Table 17.10 and Figure 17.9). Estimates declined from 1980 to 1982, then increased through 1990 with the exception of a one-year decline in 1987 one year after completion of the Rediversion Canal. The increase in Santee River population estimates after completion of the canal occurred concurrently with the decline in CPUE in the commercial fishery on the Cooper River (Figure 17.4 and Figure 17.9). It is interesting to note that estimates began to increase in the Santee River in 1984 which was the second year of a harvest ban in the Santee Fishery, but one year before the rediversion was completed. The population estimates did not correlate with passage numbers at St. Stephen Fish Lift in 1986-1990 ($r^2 = 0.0$).

St. Stephen Fish Lift Counts- Santee-Cooper Rediversion Canal

Fish released upriver of St. Stephen Dam are counted as they pass through the exit channel of the fish lift. Numbers were interpreted from hydro-acoustic sampling in 1986 and 1987, real-time observer counts in 1988-1994, and from time-lapse video recording from 1994 through 2015. Passage counts varied widely among years and did not appear to be affected by changes in counting methodology (Table 17.11 and Figure 17.10). With the exception of 1996 and 2001 annual counts were below 700,000 blueback herring. Passage was less than 100,000 in 1990, 2003, 2004, 2007, 2008, and 2012.

Peaks in passage occurred in 1992, 1996, and 2001 and are of interest. Cooke and Leach (2000) suggested that these peaks reflected the cycling of strong year classes through the population. They developed a predictive model for passage numbers that indicated high passage numbers were expected in 2000 and 2004. Cooke and Leach (2001) explained the lower than expected passage in 2000 and the higher than expected passage in 2001 as a result of differences in spring flows and turbine operation at St Stephen Dam. They hypothesized that four year old fish were not able to enter the fish lift entrance

in 2000 and they returned again in 2001 as five year olds. Unfortunately, no significant increase in mean length of lifted fish occurred in 2001 that would have supported this hypothesis. The hypothesis continues to be unproven as passage numbers continue to vary widely without pattern.

Since efficiency of the lift operation is poorly known and probably varied among years with changes in operational characteristics and river flow, we did not consider passage numbers to be good indices of numbers of blueback herring in the Santee-Cooper system. We normalized annual number lifted at the St. Stephen Dam and CPUE from the Rediversion Canal fishery by dividing each value by the series mean. A comparison of the two time series indicated little, if any relationship among years (Figure 17.11). However, number lifted did constitute a minimum number of fish that survived the canal commercial fishery below the dam. Therefore, we added annual number lifted to annual harvest in numbers for estimates of annual minimum population size in the Rediversion Canal. Annual results were a small fraction of estimated annual population size for the overlapping years of 1986 – 1990 suggesting that a very small fraction of blueback herring in the Santee River are caught or are lifted over the St. Stephen Dam.

Santee River System Abundance Trends

A comparison of population estimates, minimum population size, and CPUE in the Rediversion Canal indicated a very general trend of abundance increase through the 1980s, a peak during the 1990s, a decline in the 2000s, and a return to a more moderate abundance throughout the 2010s (Figure 17.12). Since it is not clear if reduced recruitment or reduced fishing and dam passage efficiency are involved, monitoring of lift numbers and fishery catch rates should continue. It would also be wise to conduct several years of Santee River/Rediversion Canal population estimates to verify trends apparent in other abundance data. Cooke and Leach (2003b) argue convincingly that changes in the flow regimes of the Cooper and Santee Rivers were responsible for the demise of the Cooper River fish and the resurgence of the Santee River stock.

Navigation Lock at the Pinopolis Dam on the Cooper River

We did not consider estimates of fish biomass passed through the lock to be reliable indices of annual run size. Not only was the fish species composition of the estimates poorly known, but double counting of passed fish was a factor in some years of operation. However, estimated biomass of fish has declined since rediversion was completed (Cooke and Leach 2000).

17.11.2. Size and Age Distribution

Mean size (fork length-mm) of blueback herring collected in the St. Stephen Fish Lock on the Rediversion Canal declined between 2003 and 2007, but rebounded to long term averages from 2013-2015 (Table 17.12 and Figure 17.13). Mean lengths of females generally exceeded those of males. The decrease in mean length in the 2000s was concerning, but the increase in recent years may be indicative of a population rebound after many years of drought.

Data on annual age composition of blueback herring were obtained prior to rediversion from fishery independent sampling in the Cooper River in 1975-1982 (Table 17.13) and by fishery independent gill net sampling in the Santee River in 1975-1982 (Table 17.14 and Table 17.15). Mean age of blueback herring in both rivers increased prior to rediversion as the age structure broadened to include older fish (Figure 17.14). This increase was most dramatic in the Cooper River where the increase encompassed a time period prior to and during rapid population increase. Such a change in age structure often

accompanies declining rates of fishing mortality which could also explain the population growth. Mean age of females generally exceeded that of males in the Santee River data (Table 17.14 and Figure 17.14). Current age data from the blueback herring harvested in the commercial fishery in the Santee Rediversion Canal were similar to what was historically occurring in the Cooper River. The age structure of the population continues to be varied containing multiple year classes.

Data on frequency of repeat spawning were obtained for blueback herring in the Santee River prior to redirection. Percent of males and females that spawned more than once varied without trend (Table 17.16 and Table 17.17). Since high variation in frequency of repeat spawning often occurred between years, it likely reflected recruitment variation rather than changes in mortality. Percent of repeat spawn ranged from 0.0% to 31.6 % in males and from 18.4 to 40.0 % in females.

17.11.3. Growth

Mean fork length at age was available for blueback herring of the Cooper River (sexes combined) and the Santee River (by sex). Mean length at age varied without trend among years for herring of both stocks. However interannual variation was greater for Cooper River herring (Table 17.18, Figure 17.15) than for herring of the Santee River (Table 17.19, Figure 17.16 and Figure 17.17). We calculated Von Bertalanffy curves for mean fork length at age for Santee River herring by sex (Figure 17.18). Since growth curves are often influenced by lengths of age one and younger fish, we converted length at date data from young emigrating blueback herring to length at age using an assumed hatch date of March (Table 17.20). Data on length of young blueback herring from the Cooper River came from the forebay of the Pinopolis Dam (Cooke and Coale 1996). Data for blueback herring of the Santee River came from the Wilson Dam tailrace. Von Bertalanffy parameters suggested very similar growth curves for males and females in the Santee system and a slightly larger maximum length for Cooper River herring (Table 17.21).

17.11.4. Mortality Estimates

We calculated total instantaneous mortality (Z) using catch curves of number at age within collection year (Ricker 1975). We confined estimates to ages from the Cooper River because collections were made by a variety of gears. We did not use age date from the Santee River because Santee fish were collected with a single mesh gill net and size/age selectivity was expected. We estimated Z as the negative slope of the linear regression of $\log e^{-Z} \text{ number at age}$ on $\log e^{-Z} \text{ age}$. Results ranged from $Z = 0.23$ in 1977 to $Z = 2.15$ in 1975 (Table 17.22). The extreme interannual fluctuation in Z estimates suggested a strong influence of recruitment variation on analyses. No trend in Z among years was apparent.

We evaluated relative exploitation in the Santee River stock as it appears in Table 17.23. Relative exploitation is calculated as estimated harvest in numbers divided by a minimum population estimate in numbers. The minimum population estimate is calculated as the harvest in numbers plus passage in numbers at the St. Stephen fish lock on the Rediversion Canal. Since only a portion of fish in the Rediversion Canal and the Santee River actually move above the St. Stephen Dam, the minimum population estimate is an underestimate of the actual population. During years when both passage counts and population estimates were made (1986-1990), the minimum population estimates averaged 2.3 percent of the population estimate. Consequently, estimates of relative exploitation are gross over estimates of the true exploitation rate for the Santee stock. To account for this, adjusted exploitation rates were developed using "scalar" values. These were created by dividing minimum population estimates by population estimates for years when population estimates occurred and calculating a mean

for those years (0.023). In an attempt to address variation and the possibility that the relationship between population size and fish passage has changed over time, an additional scaler was created in the same manner using the lower confidence limits for the population estimates (0.440). When compared to other years in this range, the estimate for 1998 appeared to be an outlier. As a result, a final scaler was created using the lower confidence limits, but excluding the estimates for 1998 (0.052). All scalers (0.023, 0.440, and 0.052) were then multiplied by the annual relative exploitation to produce adjusted and more realistic estimates of exploitation rates. The 0.052 scaler was chosen as the most appropriate and realistic to depict exploitation from this fishery.

Adjusted exploitation rates using the 0.052 scaler were very low and no trend was apparent among years. By comparison, U_{msy} (target exploitation rates) for blueback herring of the Chowan River, North Carolina was $U_{msy} = 0.67$, while that for herring of the Connecticut River, Connecticut and St. John River, New Brunswick were $U_{msy} = 0.75$ (Crecco and Gibson 1990). Adjusted estimates of u imposed by the commercial fishery in the Rediversion Canal are well under all of these benchmarks.

Although fishing rates may not be an issue in Santee River blueback herring stock, the picture for fish passage is not as clear. We do not know if fish lift over the St. Stephen Dam emigrate after spawning or if they do, whether they survive emigration through the turbines. It is also not clear if a significant number of juveniles produced above the dams in the Santee Cooper Lake system successfully emigrate to the ocean. If adults lift over the dam do not survive, and if few lake-produced progeny survive emigration to the ocean, then high lift numbers may be harmful to the main river population. Santee River blueback herring were iteroparous prior to construction of dams and it is likely that iteroparourity is necessary for the maintenance of resilient populations. If a high percentage of adults are lifted over the St. Stephens Dam and they do not survive to spawn again, then the population suffers high mortality that erodes age structure and reduces incidence of repeat spawning. Such changes are similar to those caused by excessive fishing mortality. Continued monitoring of population age structure and passage efficiency will be required.

17.11.5. Young-of-the-Year Surveys

Limited juvenile abundance data for blueback herring in South Carolina have been obtained by electrofishing (Table 17.24). Collections were made in Winyah Bay in 2001-2015, the Santee River in 2001-2003, the Cooper River in 2001-2015, the Edisto River in 2001-2015, and the Combahee River 2001-2015. Catches of blueback herring in this sampling program is too low to detect annual trends.

17.12. BENCHMARKS

A benchmark of $u = 0.050$ is in place for the Santee-Cooper herring fishery. Status of the fishery relative to this benchmark will continue to be measured by three year running averages of the scaled annual relative exploitation rates. Since the development of the benchmark, three year running average scaled exploitation rates have not exceeded the sustainability benchmark (Table 17.23).

17.13. CONCLUSIONS AND RECOMMENDATIONS

All available data show that river herring landings have declined from historic levels in South Carolina.

Abundance of blueback herring in the Santee and Cooper Rivers has varied widely between rivers and among years. Changes in abundance appear to have resulted from a combination of habitat alteration from flow regulation and drought, and from fishing.

Abundance of blueback herring in the Cooper River was reduced in the early 1970s from apparent over fishing. It rebounded a bit in the early 1980s after imposition of harvest regulations, but declined again following the rediversion of water from the Cooper back to the Santee River in 1985. Abundance has remained low in the Cooper River since that time.

Blueback herring abundance in the Santee River increased following rediversion and remained at relatively high levels through the 1990s. Abundance declined abruptly in the early 2000s after several years of drought, but has rebounded at in the 2010s. Rates of mortality from commercial harvest of this stock from 1990 through the present have been low and it is unlikely that fishing has affected stock abundance or age structure.

We recommend that age data be obtained from blueback herring of the Santee River, the Santee-Cooper Rediversion Canal, and the Cooper River and that the commercial creel survey of tailrace fisheries in the system be continued. Age and harvest data are important to understanding current stock dynamics and factors affecting recent river herring abundance.

We recommend updating population estimates of blueback herring in the Santee system. Estimates should be made for three or more contiguous years.

We also recommend that a sample program be developed or existing programs be improved to track annual production of young. Numbers of blueback herring collected in current sample programs for juvenile fish are too low for meaningful evaluations.

Commercial harvest regulations should not be relaxed for the Santee-Cooper system.

Harvest in the Cooper River and Rediversion Canal recreational fisheries appear to be minor since herring are not target species. However, we advise continuing the creel survey to monitor this fishery.

We recommend that bycatch of river herring in near-shore-ocean fisheries should be evaluated, in concert with other states.

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Table 17.1 Maturity at age of blueback herring collected from the Santee River in SC, 1978-1983

| Age | <u>Percent Mature</u> | |
|-----|-----------------------|---------|
| | Males | Females |
| 1 | 0.0 | 0.0 |
| 2 | 2.5 | 0.7 |
| 3 | 21.4 | 12.6 |
| 4 | 72.2 | 53.4 |
| 5 | 95.6 | 89.8 |
| 6 | 99.6 | 99.6 |
| 7 | 100.0 | 100.0 |

Table 17.2 Reported weight (kg) of blueback herring taken in the commercial fishery of SC, 1969-2015.

| Year | Weight (kg) | Year | Weight (kg) | Year | Weight (kg) |
|------|-------------|------|-------------|------|-------------|
| 1969 | 1,111,774 | 1985 | 111,430 | 2001 | 25,471 |
| 1970 | 145,379 | 1986 | 111,430 | 2002 | 730 |
| 1971 | 629,234 | 1987 | 61,350 | 2003 | 48,559 |
| 1972 | 448,973 | 1988 | 48,830 | 2004 | 14,821 |
| 1973 | 164,657 | 1989 | 37,560 | 2005 | 40,547 |
| 1974 | 40,053 | 1990 | 31,300 | 2006 | 7,619 |
| 1975 | 8,318 | 1991 | 33,800 | 2007 | 51,304 |
| 1976 | 11,689 | 1992 | 88,890 | 2008 | 7,273 |
| 1977 | 13,572 | 1993 | 127,710 | 2009 | 140,776 |
| 1978 | 15,255 | 1994 | 100,160 | 2010 | 212,994 |
| 1979 | 65,341 | 1996 | 130,210 | 2011 | 54,417 |
| 1980 | 169,020 | 1996 | 160,260 | 2012 | 22,729 |
| 1981 | 117,690 | 1997 | 112,680 | 2013 | 47,402 |
| 1982 | 175,280 | 1998 | 187,505 | 2014 | 75,372 |
| 1983 | 146,490 | 1999 | 118,425 | 2015 | 85,124 |
| 1984 | 180,290 | 2000 | 122,193 | | |

Table 17.3 Number and weight of blueback herring reported by the commercial cast net fishery in the Cooper and Santee Rivers, SC, 1998-2015.

| Year | <u>Cooper River</u> | | <u>Santee River</u> | |
|------|---------------------|-----------|---------------------|------------------|
| | Kg | Number | Kg | Mean Weight (Kg) |
| 1998 | 6,207 | 906,500 | 181,296 | 0.20 |
| 1999 | | 592,050 | 118,410 | 0.20 |
| 2000 | 152 | 669,450 | 121,718 | 0.18 |
| 2001 | 856 | 152,014 | 24,184 | 0.16 |
| 2002 | 94 | 2,738 | 497 | 0.18 |
| 2003 | 1,552 | 342,926 | 46,763 | 0.14 |
| 2004 | 6,763 | 59,083 | 8,057 | 0.14 |
| 2005 | 5,240 | 257,500 | 35,114 | 0.14 |
| 2006 | 84 | 50,106 | 7,516 | 0.15 |
| 2007 | 232 | 338,709 | 50,806 | 0.15 |
| 2008 | 3,065 | 26,457 | 3,608 | 0.14 |
| 2009 | 13,050 | 913,250 | 124,534 | 0.14 |
| 2010 | 2,973 | 1,532,490 | 208,976 | 0.14 |
| 2011 | 2,973 | 374,740 | 51,101 | 0.14 |
| 2012 | 2,874 | 126,297 | 18,945 | 0.15 |
| 2013 | 13,273 | 246,227 | 33,576 | 0.14 |
| 2014 | 22,656 | 383,017 | 52,230 | 0.14 |
| 2015 | 61,910 | 165,377 | 22,551 | 0.14 |

Table 17.4 Number and weight (kg) of blueback herring reported by the commercial gill net fishery of the Pee Dee River, SC, 1998-2015.

| Year | Number | Kg | Mean Weight (Kg) |
|------|--------|-------|------------------|
| 1998 | 10 | 2 | 0.23 |
| 1999 | 73 | 15 | 0.20 |
| 2000 | 1,777 | 323 | 0.18 |
| 2001 | 2,375 | 431 | 0.18 |
| 2002 | 768 | 139 | 0.18 |
| 2003 | 1,790 | 244 | 0.14 |
| 2004 | 10 | 1 | 0.14 |
| 2005 | 1,416 | 193 | 0.14 |
| 2006 | 140 | 19 | 0.14 |
| 2007 | 1,779 | 266 | 0.15 |
| 2008 | 4,403 | 600 | 0.14 |
| 2009 | 23,407 | 3,192 | 0.14 |
| 2010 | 6,897 | 1,045 | 0.14 |
| 2011 | 2,513 | 343 | 0.14 |
| 2012 | 6,066 | 910 | 0.15 |
| 2013 | 4,063 | 553 | 0.14 |
| 2014 | 3,567 | 486 | 0.14 |
| 2015 | 4,877 | 663 | 0.14 |

Table 17.5 Estimated commercial effort, landings (kg), and CPUE of blueback herring in the Santee-Cooper System, SC. Data obtained via a point access creel survey of the commercial fishery.

| Year | Cooper River | | | Santee River below Wilson Dam | | | Santee River Rediversion Canal | | | Totals | | |
|------|--------------|----------|-------|-------------------------------|----------|------|--------------------------------|----------|------|-----------|----------|-------|
| | Fisherman | | | Fisherman | | | Fisherman | | | Fisherman | | |
| | Days | Landings | CPUE | Days | Landings | CPUE | Days | Landings | CPUE | Days | Landings | CPUE |
| 1969 | 1830 | 1111774 | 607.5 | | | | | | | 1830 | 1111774 | 607.5 |
| 1970 | 737 | 145379 | 197.3 | | | | | | | 737 | 145379 | 197.3 |
| 1971 | 1059 | 629234 | 594.2 | | | | | | | 1059 | 629234 | 594.2 |
| 1972 | 1215 | 448973 | 369.5 | | | | | | | 1215 | 448973 | 369.5 |
| 1973 | 1065 | 164657 | 154.6 | | | | | | | 1065 | 164657 | 154.6 |
| 1974 | 724 | 40053 | 55.3 | | | | | | | 724 | 40053 | 55.3 |
| 1975 | 399 | 8318 | 20.8 | | | | | | | 399 | 8318 | 20.8 |
| 1976 | 391 | 11689 | 29.9 | | | | | | | 391 | 11689 | 29.9 |
| 1977 | 468 | 13572 | 29.0 | | | | | | | 468 | 13572 | 29.0 |
| 1978 | 449 | 15255 | 34.0 | | | | | | | 449 | 15255 | 34.0 |
| 1979 | 566 | 65341 | 115.4 | | | | | | | 566 | 65341 | 115.4 |
| 1980 | 1399 | 177444 | 126.8 | | 31900 | | | | | 1399 | 209344 | 149.6 |
| 1981 | 755 | 71392 | 94.6 | 500 | 101802 | | | | | 1255 | 173194 | 138.0 |
| 1982 | 639 | 93428 | 146.2 | | | a | | | | 639 | 93428 | 146.2 |
| 1983 | 1608 | 262618 | 163.3 | | | a | | | | 1608 | 262618 | 163.3 |
| 1984 | 1727 | 251450 | 145.6 | | | a | | | | 1727 | 251450 | 145.6 |
| 1985 | 1520 | 135926 | 89.4 | 60 | 9600 | | | | | 1580 | 145526 | 92.1 |
| 1986 | 737 | 66029 | 89.6 | 32 | 35200 | | | | | 769 | 101229 | 131.6 |
| 1987 | 1369 | 67988 | 49.7 | | | | | | | 1369 | 67988 | 49.7 |
| 1988 | 515 | 20133 | 39.1 | | | | | | | 515 | 20133 | 39.1 |
| 1989 | 592 | 17791 | 30.1 | | | | | | | 592 | 17791 | 30.1 |
| 1990 | 662 | 17846 | 27.0 | | | 87 | 1154 | 13.3 | 749 | 19000 | 25.4 | |
| 1991 | 324 | 7829 | 24.2 | | | 296 | 8859 | 29.9 | 620 | 16688 | 26.9 | |
| 1992 | 145 | 7723 | 53.3 | | | 1118 | 82673 | 73.9 | 1263 | 90395 | 71.6 | |
| 1993 | 145 | 4170 | 28.8 | | | 1479 | 162977 | 110.2 | 1624 | 167147 | 102.9 | |
| 1994 | 66 | 3047 | 46.2 | | | 1407 | 116125 | 82.5 | 1473 | 119172 | 80.9 | |
| 1995 | 35 | 472 | 13.5 | | | 1743 | 186378 | 106.9 | 1778 | 186850 | 105.1 | |
| 1996 | | | | | | 1854 | 238781 | 128.8 | 1854 | 238781 | 128.8 | |
| 1997 | | | | | | 1414 | 128133 | 90.6 | 1414 | 128133 | 90.6 | |
| 1998 | | | | | | 1319 | 180919 | 137.2 | 1319 | 180919 | 137.2 | |
| 1999 | | | | | | 1052 | 118164 | 112.3 | 1052 | 118164 | 112.3 | |
| 2000 | NS | NS | NS | NS | NS | 1026 | 120114 | 117.1 | 1026 | 120114 | 117.1 | |
| 2001 | 55 | 550 | 10.0 | NS | NS | 244 | 24134 | 98.9 | 299 | 24684 | 82.6 | |
| 2002 | NS | NS | NS | NS | NS | 0 | 0 | | 0 | 0 | | |
| 2003 | 35 | 807 | 23.1 | NS | NS | 595 | 46665 | 78.4 | 630 | 47472 | 75.4 | |
| 2004 | 56 | 3200 | 57.1 | NS | NS | 259 | 8040 | 31.0 | 315 | 11240 | 35.7 | |
| 2005 | NS | NS | NS | NS | NS | 309 | 10412 | 33.7 | 309 | 10412 | 33.7 | |
| 2006 | NS | NS | NS | NS | NS | 229 | 6743 | 29.4 | 229 | 6743 | 29.4 | |
| 2007 | NS | NS | NS | NS | NS | 439 | 50701 | 115.5 | 439 | 50701 | 115.5 | |
| 2008 | 120 | 3000 | 25 | NS | NS | 89 | 3600 | 40.5 | 209 | 6600 | 31.6 | |
| 2009 | NS | NS | NS | NS | NS | 402 | 71600 | 178.7 | 402 | 71600 | 178.7 | |
| 2010 | NS | NS | NS | NS | NS | 470 | 69600 | 148.1 | 470 | 69600 | 148.1 | |
| 2011 | NS | NS | NS | NS | NS | 475 | 37600 | 79.2 | 475 | 37600 | 79.2 | |
| 2012 | NS | NS | NS | NS | NS | 255 | 18900 | 74.1 | 255 | 18900 | 74.1 | |
| 2013 | NS | NS | NS | NS | NS | 333 | 33500 | 100.6 | 333 | 33500 | 100.6 | |
| 2014 | NS | NS | NS | NS | NS | 386 | 52116 | 135.0 | 386 | 52116 | 135.0 | |
| 2015 | NS | NS | NS | NS | NS | 516 | 22521 | 43.6 | 516 | 22521 | 43.6 | |

a- Fishing prohibited

NS- No Surveyed

Table 17.6 Mean fork length (mm) of blueback herring taken in the commercial cast net fishery below the St. Stephen Dam on the Santee - Cooper Rediversion Canal.

| Year | Males | | | Females | | | Total | | |
|-------|--------|--------|------|---------|--------|------|--------|--------|------|
| | Mean | | | Mean | | | Mean | | |
| | | Fork | | | Fork | | Fork | | |
| Year | Number | Length | SD | Number | Length | SD | Number | Length | SD |
| 1995 | 346 | 232 | | 248 | 231 | | | | |
| 1996 | 128 | 232 | | 122 | 235 | | | | |
| 1997 | 154 | 229 | | 73 | 230 | | | | |
| 1998 | 207 | 223 | | 263 | 221 | | | | |
| 1999 | 207 | 221 | | 193 | 221 | | | | |
| 2000 | 166 | 220 | | 215 | 222 | | | | |
| 2001 | 238 | 237 | 10.4 | 97 | 248 | 17.7 | 335 | 240 | 13.9 |
| 2002 | - | - | - | - | - | - | - | - | - |
| 2003 | 183 | 235 | 10.7 | 127 | 246 | 11.5 | 310 | 239 | 12.3 |
| 2004 | 361 | 223 | 13.8 | 280 | 239 | 15.7 | 641 | 230 | 16.7 |
| 2005 | 539 | 228 | 8.0 | 498 | 238 | 9.1 | 1037 | 233 | 10.0 |
| 2006 | 310 | 219 | 26.6 | 224 | 243 | 30.3 | 554 | 230 | 30.5 |
| 2007 | 333 | 216 | 8.7 | 248 | 234 | 11.2 | 581 | 224 | 13.3 |
| *2008 | | | | | | | | | |
| 2009 | 490 | 219 | 10.4 | 518 | 233 | 10.3 | 1008 | 226 | 0.0 |
| 2010 | 295 | 231 | 9.0 | 581 | 240 | 10.6 | 876 | 329 | 11.0 |
| 2011 | 130 | 214 | 7.1 | 245 | 237 | 28.4 | 375 | 228 | 26.2 |
| 2012 | 12 | 230 | 7.1 | 8 | 236 | 10.5 | 20 | 232 | 8.8 |
| 2013 | 230 | 227 | 9.4 | 183 | 234 | 13.8 | 413 | 227 | 12.9 |
| 2014 | 68 | 233 | 6.9 | 63 | 242 | 8.5 | 131 | 238 | 8.9 |
| 2015 | 90 | 234 | 8.3 | 75 | 248 | 12.0 | 165 | 240 | 12.1 |

*Due to low flows, fishery did not occur in this area

Table 17.7 Number at age of blueback herring harvested in the commercial cast net fishery in the Rediversion Canal, 2013-2015.

| Age | Males | | | Females | | | Totals | | |
|-----|-------|------|------|---------|------|------|--------|------|------|
| | 2013 | 2014 | 2015 | 2013 | 2014 | 2015 | 2013 | 2014 | 2015 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 11 | 22 | 0 | 4 | 13 | 0 | 15 | 35 | 0 |
| 5 | 34 | 60 | 56 | 22 | 57 | 40 | 56 | 117 | 96 |
| 6 | 8 | 11 | 26 | 12 | 31 | 22 | 20 | 42 | 48 |
| 7 | 0 | 0 | 0 | 2 | 1 | 2 | 2 | 1 | 2 |

Table 17.8 Percent of repeat spawning blueback herring harvested in the commercial cast net fishery in the Rediversion Canal, 2013-2015.

| | 2013 | 2014 | 2015 |
|---------------------------|------|------|------|
| % with one spawning mark | 28 | 26 | 22 |
| % with two spawning marks | 7 | 3 | 9 |
| % repeat spawners | 36 | 29 | 30 |

Table 17.9 Catch per unit effort of blueback herring caught in the American shad recreational fishery on the Santee and Cooper Rivers, SC, 2003-2007.

| Year | CPUE |
|------|------|
| 2003 | 0.13 |
| 2004 | 1.15 |
| 2005 | 0.93 |
| 2006 | 1.10 |
| 2007 | 0.85 |

Table 17.10 Mark recapture population estimates of blueback herring in the Santee River, SC.

| Year | N | CV | <u>Confidence Interval</u> | |
|------|-----------|------|----------------------------|------------|
| | | | Lower | Upper |
| 1980 | 5,895,796 | 0.25 | 3,012,000 | 8,780,000 |
| 1981 | 4,054,521 | 0.23 | 2,236,000 | 5,873,000 |
| 1982 | 664,151 | 0.17 | 400,000 | 888,000 |
| 1983 | 2,352,005 | 0.45 | 297,000 | 4,407,000 |
| 1984 | 2,625,000 | 0.24 | 1,417,000 | 3,833,000 |
| 1985 | 6,205,353 | 0.71 | 0 | 14,822,650 |
| 1986 | 9,061,064 | 0.41 | 1,817,496 | 16,304,632 |
| 1987 | 3,805,457 | 0.29 | 1,657,618 | 5,953,296 |
| 1988 | 5,507,918 | 0.50 | 116,348 | 10,899,488 |
| 1989 | 5,501,964 | 0.22 | 3,153,678 | 7,850,250 |
| 1990 | 9,353,003 | 0.22 | 5,358,472 | 13,347,534 |

Table 17.11 Annual number of blueback herring passed at St. Stevph Fish Lift, caught in the commercial fishery, and minimum population size in the Santee-Cooper Rediversion Canal, SC.

| Year | Number Passed | Number Caught | Minimum Population |
|-------|---------------|---------------|--------------------|
| 1986 | 187,000 | | 187,000 |
| 1987 | 74,000 | | 74,000 |
| 1988 | 232,000 | | 232,000 |
| 1989 | 147,000 | | 147,000 |
| 1990 | 71,000 | 9,408 | 80,408 |
| 1991 | 400,000 | 72,251 | 472,251 |
| 1992 | 589,000 | 674,510 | 1,263,510 |
| 1993 | 345,000 | 1,329,762 | 1,674,762 |
| 1994 | 298,000 | 947,489 | 1,245,489 |
| 1995 | 561,000 | 1,520,642 | 2,081,642 |
| 1996 | 1,452,285 | 1,948,191 | 3,400,476 |
| 1997 | 176,814 | 1,045,464 | 1,222,278 |
| 1998 | 112,466 | 1,320,134 | 1,432,600 |
| 1999 | 182,798 | 884,793 | 1,067,591 |
| 2000 | 695,586 | 991,001 | 1,686,587 |
| 2001 | 1,862,015 | 178,532 | 2,040,547 |
| 2002 | 421,459 | 0 | 421,459 |
| 2003 | 86,909 | 384,038 | 470,947 |
| 2004 | 35,545 | 66,150 | 101,695 |
| 2005 | 175,184 | 257,544 | 432,728 |
| 2006 | 105,129 | 55,125 | 160,254 |
| 2007* | 49,343 | 372,645 | 421,988 |
| 2008* | 8,503 | 0 | 8,503 |
| 2009 | 438,746 | 526,260 | 965,006 |
| 2010 | 217,750 | 511,560 | 729,310 |
| 2011 | 336,210 | 276,360 | 612,570 |
| 2012 | 37,117 | 138,915 | 176,032 |
| 2013 | 113,860 | 246,225 | 360,085 |
| 2014 | 171,200 | 383,082 | 554,282 |
| 2015 | 244,631 | 165,375 | 410,006 |

Minimum population size = number lifted + number caught in fishery

**Fish lift was not operated normally due to restricted flows (i.e. extreme drought).*

Table 17.12 Mean fork length (mm) of blueback herring from St. Stephen Dam Fish Lift on the Santee River Rediversion Canal, SC.

| Year | Males | | | Females | | | Combined | | |
|-------|--------|------------------|------|---------|------------------|------|----------|------------------|------|
| | | | | | | | | | |
| | Number | Mean Fork Length | SD | Number | Mean Fork Length | SD | Number | Mean Fork Length | SD |
| 1991 | 166 | 241 | | 258 | 255 | | | | |
| 1992 | 345 | 238 | | 303 | 252 | | | | |
| 1993 | 181 | 235 | | 290 | 247 | | | | |
| 1994 | 75 | 235 | | 126 | 251 | | | | |
| 1995 | 180 | 233 | | 175 | 252 | | | | |
| 1996 | 257 | 237 | | 233 | 248 | | | | |
| 1997 | 140 | 238 | | 102 | 253 | | | | |
| 1998 | 251 | 240 | | 359 | 256 | | | | |
| 1999 | 200 | 238 | | 208 | 245 | | | | |
| 2000 | 250 | 232 | | 230 | 245 | | | | |
| 2001 | 227 | 237 | 10.1 | 86 | 252 | 15.2 | 313 | 241 | 13.3 |
| 2002 | 119 | 235 | 8.7 | 67 | 250 | 17.3 | 186 | 240 | 14.4 |
| 2003 | 122 | 239 | 8.7 | 111 | 254 | 10.5 | 233 | 246 | 12.2 |
| 2004 | 8 | 256 | 35.2 | 29 | 250 | 12.2 | 37 | 251 | 19.1 |
| 2005 | 52 | 231 | 6.8 | 60 | 245 | 8.6 | 112 | 238 | 10.5 |
| 2006 | 34 | 216 | 31.2 | 39 | 233 | 16.3 | 73 | 225 | 25.6 |
| 2007 | 42 | 227 | 10.5 | 30 | 218 | 9.4 | 73 | 223 | 10.9 |
| 2008* | | | | | | | | | |
| 2009 | 34 | 216 | 31.2 | 39 | 233 | 16.2 | 73 | 225 | 25.6 |
| 2010 | 13 | 234 | 9.7 | 15 | 248 | 24.8 | 28 | 241 | 20.2 |
| 2011 | 111 | 220 | 11.6 | 69 | 237 | 20.7 | 180 | 227 | 17.8 |
| 2012 | 20 | 257 | 7.8 | 1 | 292 | N/A | 21 | 258 | 10.9 |
| 2013 | 49 | 231 | 8.5 | 56 | 242 | 11.2 | 105 | 237 | 11.4 |
| 2014 | 51 | 236 | 11.0 | 89 | 249 | 16.2 | 140 | 244 | 15.8 |
| 2015 | 139 | 240 | 11.3 | 176 | 251 | 11.8 | 315 | 241 | 12.9 |

*Due to low flows, fish were not collected in this area

Table 17.13 Age composition (no) of blueback herring collected by fishery independent sampling below the Pinopolis Dam on the Cooper River, SC.

| Sexes Combined | | | | | | | |
|-----------------------|------|------|------|------|------|------|------|
| Age | 1975 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
| 2 | 45 | 4 | 3 | 12 | | 12 | |
| 3 | 103 | 52 | 12 | 33 | 21 | 109 | 10 |
| 4 | 154 | 152 | 121 | 195 | 30 | 69 | 49 |
| 5 | 18 | 80 | 25 | 136 | 29 | 227 | 53 |
| 6 | | | | 3 | 19 | 29 | 11 |
| 7 | | | | | | 8 | 2 |
| Mean | 3.45 | 4.07 | 4.04 | 4.22 | 4.46 | 4.39 | 4.57 |

| Males | | | | | | | |
|--------------|------|------|------|------|------|------|------|
| Age | 1975 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
| 2 | | | | 8 | | | |
| 3 | | | | 15 | | | |
| 4 | | | | 102 | | | |
| 5 | | | | 58 | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| Mean | | | | 4.15 | | | |

| Females | | | | | | | |
|----------------|------|------|------|------|------|------|------|
| Age | 1975 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
| 2 | | | | 4 | | | |
| 3 | | | | 18 | | | |
| 4 | | | | 93 | | | |
| 5 | | | | 78 | | | |
| 6 | | | | 3 | | | |
| 7 | | | | | | | |
| Mean | | | | 4.30 | | | |

Table 17.14 Number at age of blueback herring collected in fishery independent sampling by pound and gill net (GN, PN) and seine (SN) in the lower Santee River, SC.

| Sexes Combined | | GN | PN | SN | GN |
|-----------------------|------|------|------|------|-----|
| Age | 1977 | 1978 | 1979 | 1985 | |
| 1 | 0 | | 3 | 0 | 0 |
| 2 | 0 | | 7 | 0 | 0 |
| 3 | 7 | | 18 | 17 | 2 |
| 4 | 110 | | 44 | 17 | 65 |
| 5 | 15 | | 74 | 19 | 245 |
| 6 | 0 | | 6 | 14 | 105 |
| 7 | 0 | | 0 | 5 | 14 |
| Mean Age | 4.1 | | 4.3 | 4.6 | 5.1 |

| Males | | GN | PN | SN | GN |
|--------------|------|------|------|------|-----|
| Age | 1977 | 1978 | 1979 | 1985 | |
| 1 | 0 | | 3 | 0 | 0 |
| 2 | 0 | | 6 | 0 | 0 |
| 3 | 3 | | 9 | 17 | 2 |
| 4 | 54 | | 24 | 11 | 48 |
| 5 | 5 | | 35 | 9 | 186 |
| 6 | 0 | | 1 | 5 | 61 |
| 7 | 0 | | 0 | 0 | 5 |
| Mean Age | 4.0 | | 4.1 | 4.0 | 5.1 |

| Females | | GN | PN | SN | GN |
|----------------|------|------|------|------|-----|
| Age | 1977 | 1978 | 1979 | 1985 | |
| 2 | 0 | | 1 | | 0 |
| 3 | 4 | | 9 | | 0 |
| 4 | 56 | | 20 | 6 | 17 |
| 5 | 10 | | 39 | 10 | 59 |
| 6 | 0 | | 5 | 9 | 44 |
| 7 | 0 | | 0 | 5 | 9 |
| Mean Age | 4.1 | | 4.5 | 5.4 | 5.3 |

Table 17.15 Age composition (%) of blueback herring collected in fishery independent sampling by gillnet (GN), seine (SN), pound net (PN) in the lower Santee River, SC.

| Males | | | | | | | | | |
|--------------|------|------|------|------|------|------|------|------|------|
| Age | GN | PN | SN | GN | GN | GN | GN | GN | GN |
| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
| 1 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.08 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.05 | 0.12 | 0.40 | 0.02 | 0.06 | 0.12 | 0.07 | 0.03 | 0.01 |
| 4 | 0.87 | 0.31 | 0.26 | 0.74 | 0.16 | 0.43 | 0.36 | 0.59 | 0.16 |
| 5 | 0.08 | 0.45 | 0.21 | 0.23 | 0.71 | 0.15 | 0.44 | 0.34 | 0.62 |
| 6 | 0.00 | 0.01 | 0.12 | 0.00 | 0.06 | 0.25 | 0.12 | 0.04 | 0.20 |
| 7 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.05 | 0.01 | 0.00 | 0.02 |
| Mean Age | 4.0 | 4.1 | 4.0 | 4.2 | 4.8 | 4.7 | 4.6 | 4.4 | 5.1 |

| Females | | | | | | | | | |
|----------------|------|------|-------|------|------|------|------|------|------|
| Age | GN | PN | Seine | GN | GN | GN | GN | GN | GN |
| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.06 | 0.12 | 0.00 | 0.01 | 0.02 | 0.05 | 0.02 | 0.00 | 0.00 |
| 4 | 0.80 | 0.27 | 0.20 | 0.64 | 0.14 | 0.37 | 0.22 | 0.37 | 0.13 |
| 5 | 0.14 | 0.53 | 0.33 | 0.31 | 0.75 | 0.15 | 0.47 | 0.51 | 0.46 |
| 6 | 0.00 | 0.07 | 0.30 | 0.03 | 0.09 | 0.43 | 0.29 | 0.11 | 0.34 |
| 7 | 0.00 | 0.00 | 0.17 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.07 |
| Mean Age | 4.1 | 4.5 | 5.4 | 4.4 | 4.9 | 5.0 | 5.0 | 4.8 | 5.3 |

Table 17.16 Frequency of repeat spawn of male blueback herring from the Santee River in SC.

| | Spawn Marks | Age | | | | | | Totals | % Virgin | % Repeat |
|------|----------------|-----|----|----|----|----|---|--------|-------------|-------------|
| | | 2 | 3 | 4 | 5 | 6 | 7 | | | |
| 1978 | 0 | 9 | 9 | 23 | 13 | | | 54 | 68.4 | 31.6 |
| | 1 | | | 2 | 19 | | | 21 | | |
| | 2 | | | | 3 | 1 | | 4 | | |
| | Totals | 9 | 9 | 25 | 35 | 1 | | 79 | | |
| | | | | | | | | | | |
| 1979 | 0 | | 17 | 10 | 8 | 2 | | 37 | 100.0 | 0.0 |
| | 1 | | | | | | | 0 | | |
| | 2 | | | | | | | 0 | | |
| | Totals | 0 | 17 | 10 | 8 | 2 | | 37 | | |
| | | | | | | | | | | |
| 1980 | 0 | 1 | 1 | 49 | 12 | | | 63 | 91.3 | 8.7 |
| | 1 | | | | 4 | 2 | 1 | 6 | | |
| | 2 | | | | | | | 0 | | |
| | Totals | 1 | 1 | 49 | 16 | 2 | 1 | 69 | | |
| | | | | | | | | | | |
| 1981 | 0 | 2 | 29 | 14 | 24 | 1 | | 70 | 69.3 | 30.7 |
| | 1 | | | 2 | 25 | 2 | | 29 | | |
| | 2 | | | | 1 | 1 | | 2 | | |
| | Totals | 2 | 29 | 16 | 50 | 4 | 0 | 101 | | |
| | | | | | | | | | | |
| 1982 | 0 | | 15 | 41 | 6 | 3 | | 65 | 76.5 | 23.5 |
| | 1 | | | | 8 | 1 | | 9 | | |
| | 2 | | | | 1 | 10 | 2 | 11 | | |
| | Totals | 0 | 15 | 41 | 15 | 14 | 2 | 85 | | |
| | | | | | | | | | | |
| 1983 | 0 | | 9 | 34 | 34 | 11 | 1 | 88 | 91.7 | 8.3 |
| | 1 | | | 1 | 4 | 1 | | 6 | | |
| | 2 | | | | 2 | | 1 | 2 | | |
| | Totals | 0 | 9 | 35 | 40 | 12 | 2 | 96 | | |
| | | | | | | | | | | |

Table 17.17 Frequency of repeat spawn of female blueback herring from the Santee River in SC.

| | Spawn Marks | Age | | | | | | Totals | % Virgin | % Repeat |
|------|-------------|-----|---|----|----|----|---|--------|----------|----------|
| | | 2 | 3 | 4 | 5 | 6 | 7 | | | |
| 1978 | 0 | 1 | 9 | 19 | 22 | 1 | | 52 | 72.2 | 27.8 |
| | 1 | | | | 15 | 4 | | 19 | | |
| | 2 | | | | 1 | | | 1 | | |
| | Total | 1 | 9 | 19 | 38 | 5 | 0 | 72 | | |
| | | | | | | | | | | |
| 1979 | 0 | | | 6 | 10 | 5 | | 21 | 77.8 | 22.2 |
| | 1 | | | | 4 | 2 | | 6 | | |
| | 2 | | | | | | 3 | 0 | | |
| | Total | 0 | 0 | 6 | 14 | 7 | 3 | 27 | | |
| | | | | | | | | | | |
| 1980 | 0 | | 1 | 39 | 18 | 9 | 1 | 67 | 77.0 | 23.0 |
| | 1 | | | 1 | 3 | 3 | 3 | 7 | | |
| | 2 | | | | 1 | 2 | | 3 | | |
| | 3 | | | | | | 1 | 77 | | |
| | Total | 0 | 0 | 1 | 4 | 5 | 4 | 87 | | |
| 1981 | 0 | | 6 | 15 | 36 | 5 | | 62 | 81.6 | 18.4 |
| | 1 | | | | 12 | 2 | | 14 | | |
| | 2 | | | | | | 1 | 0 | | |
| | Total | 0 | 6 | 15 | 48 | 7 | 1 | 76 | | |
| | | | | | | | | | | |
| 1982 | 0 | | 7 | 36 | 10 | 9 | 1 | 62 | 67.4 | 32.6 |
| | 1 | | | | 2 | 13 | 1 | 15 | | |
| | 2 | | | | 2 | 13 | 1 | 15 | | |
| | Total | 0 | 7 | 36 | 14 | 35 | 3 | 92 | | |
| | | | | | | | | | | |
| 1983 | 0 | | 5 | 24 | 34 | 12 | | 75 | 60.0 | 40.0 |
| | 1 | | | 3 | 6 | 11 | | 20 | | |
| | 2 | | | | 5 | | | 5 | | |
| | 3 | | | | 1 | 2 | | 100 | | |
| | Total | 0 | 0 | 3 | 12 | 13 | 0 | 125 | | |

Table 17.18 Mean fork length at age (mm) of blueback herring, sexes combined, collected by fishery independent sampling below the Pinopolis Dam on the Cooper River, SC.

| Year | Age | | | | | | |
|-----------|-----|-----|-----|-----|-----|-----|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1975 | | 206 | 236 | 261 | 284 | | |
| 1976 | | | | | | | |
| 1977 | | 234 | 243 | 247 | 254 | | |
| 1978 | | 220 | 240 | 261 | 289 | | |
| 1979 | | 198 | 241 | 260 | 277 | 298 | |
| 1980 | | | 234 | 261 | 266 | 277 | |
| 1981 | | 199 | 215 | 222 | 280 | 310 | 319 |
| 1982 | | | 229 | 243 | 254 | 266 | 268 |
| All years | | 242 | 267 | 253 | 309 | 326 | 333 |

Table 17.19 Mean fork length at age (mm) of blueback herring collected by fishery independent gill net sampling below the Wilson Dam on the Santee River, SC.

| Year | Age | | | | | | |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Males | | | | | | | |
| 1980 | 137 | 197 | 227 | 245 | 256 | 270 | 272 |
| 1981 | 133 | 192 | 227 | 247 | 258 | 263 | 282 |
| 1982 | 134 | 191 | 227 | 246 | 259 | 264 | 269 |
| 1983 | 139 | 185 | 220 | 239 | 254 | 263 | 270 |
| 1984 | 125 | 182 | 218 | 237 | 248 | 258 | |
| Mean FL | 134 | 189 | 224 | 243 | 255 | 264 | 273 |
| Females | | | | | | | |
| 1980 | 134 | 200 | 232 | 253 | 266 | 278 | 283 |
| 1981 | 134 | 198 | 233 | 256 | 270 | 279 | 295 |
| 1982 | 136 | 195 | 234 | 255 | 270 | 278 | 284 |
| 1983 | 142 | 186 | 221 | 245 | 262 | 273 | |
| 1984 | 123 | 179 | 216 | 238 | 254 | 268 | 274 |
| Mean FL | 134 | 192 | 227 | 249 | 264 | 275 | 284 |

Table 17.20 Mean fork length (mm) at age (yrs) of young blueback herring from the Cooper and Santee Rivers, SC.

| Cooper River | | Santee River | |
|--------------|--------|--------------|--------|
| Age (yrs) | Length | Age (yrs) | Length |
| 0.67 | 79.0 | 0.42 | 44.6 |
| | | 0.50 | 48.0 |
| | | 0.50 | 47.4 |
| | | 0.75 | 55.3 |

Table 17.21 Von Bertalanffy growth parameters based on fork length (mm) of blueback herring collected by fishery independent sampling below the Pinopolis Dam on the Cooper River and the Wilson Dam on the Santee River, SC.

| Parameter | Cooper River | Santee River | |
|------------|--------------|--------------|----------|
| | | Male | Female |
| L-infinity | 286.5 | 267.6 | 281.0 |
| K | 0.630495073 | 0.6721946 | 0.610289 |
| t0 | 0.164542792 | 0.1417377 | 0.118728 |

Table 17.22 Estimates of total instantaneous mortality (Z) for blueback herring of the Cooper River, SC.

| | Z | SE |
|------|------|------|
| 1975 | 2.15 | |
| 1977 | 0.64 | |
| 1978 | 1.58 | |
| 1979 | 2.09 | 1.14 |
| 1980 | 0.23 | 0.16 |
| 1981 | 1.67 | 0.31 |
| 1982 | 1.64 | 0.05 |

Table 17.23 Estimated number of blueback herring harvested from the Santee-Cooper Rediversion Canal, minimum population size, and maximum exploitation rate (u).

| Year | Estimated Harvest (No.) | Minimum Population Size | Relative Exploitation | Scalar M-R LCI w/o 1988 | 3 Year Running Average |
|------|----------------------------|----------------------------|--------------------------|----------------------------|---------------------------|
| 1990 | 9,408 | 80,408 | 0.12 | 0.006 | |
| 1991 | 72,251 | 472,251 | 0.15 | 0.008 | |
| 1992 | 674,510 | 1,263,510 | 0.53 | 0.028 | 0.014 |
| 1993 | 1,329,762 | 1,674,762 | 0.79 | 0.042 | 0.026 |
| 1994 | 947,489 | 1,245,489 | 0.76 | 0.040 | 0.036 |
| 1995 | 1,520,642 | 2,081,642 | 0.73 | 0.038 | 0.040 |
| 1996 | 1,948,191 | 3,400,476 | 0.57 | 0.030 | 0.036 |
| 1997 | 1,045,464 | 1,222,278 | 0.86 | 0.045 | 0.038 |
| 1998 | 1,320,134 | 1,432,600 | 0.92 | 0.048 | 0.041 |
| 1999 | 884,793 | 1,067,591 | 0.83 | 0.043 | 0.045 |
| 2000 | 991,001 | 1,686,587 | 0.59 | 0.031 | 0.041 |
| 2001 | 178,532 | 2,040,547 | 0.09 | 0.005 | 0.026 |
| 2002 | 0 | 421,459 | 0.00 | 0.000 | 0.012 |
| 2003 | 384,038 | 470,947 | 0.82 | 0.043 | 0.016 |
| 2004 | 66,150 | 101,695 | 0.65 | 0.034 | 0.026 |
| 2005 | 257,544 | 432,728 | 0.60 | 0.031 | 0.036 |
| 2006 | 55,125 | 160,254 | 0.34 | 0.018 | 0.028 |
| 2007 | 372,645 | 421,988 | 0.88 | 0.046 | 0.032 |
| 2008 | 0 | 8,503 | 0.00 | 0.000 | 0.021 |
| 2009 | 526,260 | 965,006 | 0.55 | 0.029 | 0.025 |
| 2010 | 511,560 | 729,310 | 0.70 | 0.037 | 0.022 |
| 2011 | 276,360 | 612,570 | 0.45 | 0.024 | 0.030 |
| 2012 | 138,915 | 176,032 | 0.79 | 0.041 | 0.034 |
| 2013 | 246,225 | 360,085 | 0.68 | 0.036 | 0.034 |
| 2014 | 383,082 | 554,282 | 0.69 | 0.036 | 0.037 |
| 2015 | 165,375 | 410,006 | 0.40 | 0.021 | 0.031 |

Table 17.24 Age zero blueback herring collected by electrofishing from several SC rivers.

| Year | Winyah Bay | Santee River | Cooper River | Edisto River | Combahee River |
|------|------------|--------------|--------------|--------------|----------------|
| 2001 | 0 | 4 | 0 | 0 | 0 |
| 2002 | 0 | 84 | 24 | 0 | 0 |
| 2003 | 0 | 787 | 0 | 2 | 0 |
| 2004 | 11 | NS | 0 | 0 | 0 |
| 2005 | 12 | NS | 0 | 1 | 0 |
| 2006 | 7 | NS | 26 | 0 | 0 |
| 2007 | 3 | NS | 1 | 0 | 1 |
| 2008 | 3 | NS | 1 | 6 | 0 |
| 2009 | 16 | NS | 2 | 1 | 0 |
| 2010 | 2 | NS | 0 | 0 | 0 |
| 2011 | 4 | NS | 0 | 0 | 0 |
| 2012 | 2 | NS | 0 | 0 | 0 |
| 2013 | 11 | NS | 6 | 0 | 2 |
| 2014 | 86 | NS | 13 | 0 | 0 |
| 2015 | 88 | NS | 11 | 1 | 1 |

NS – Not Sampled

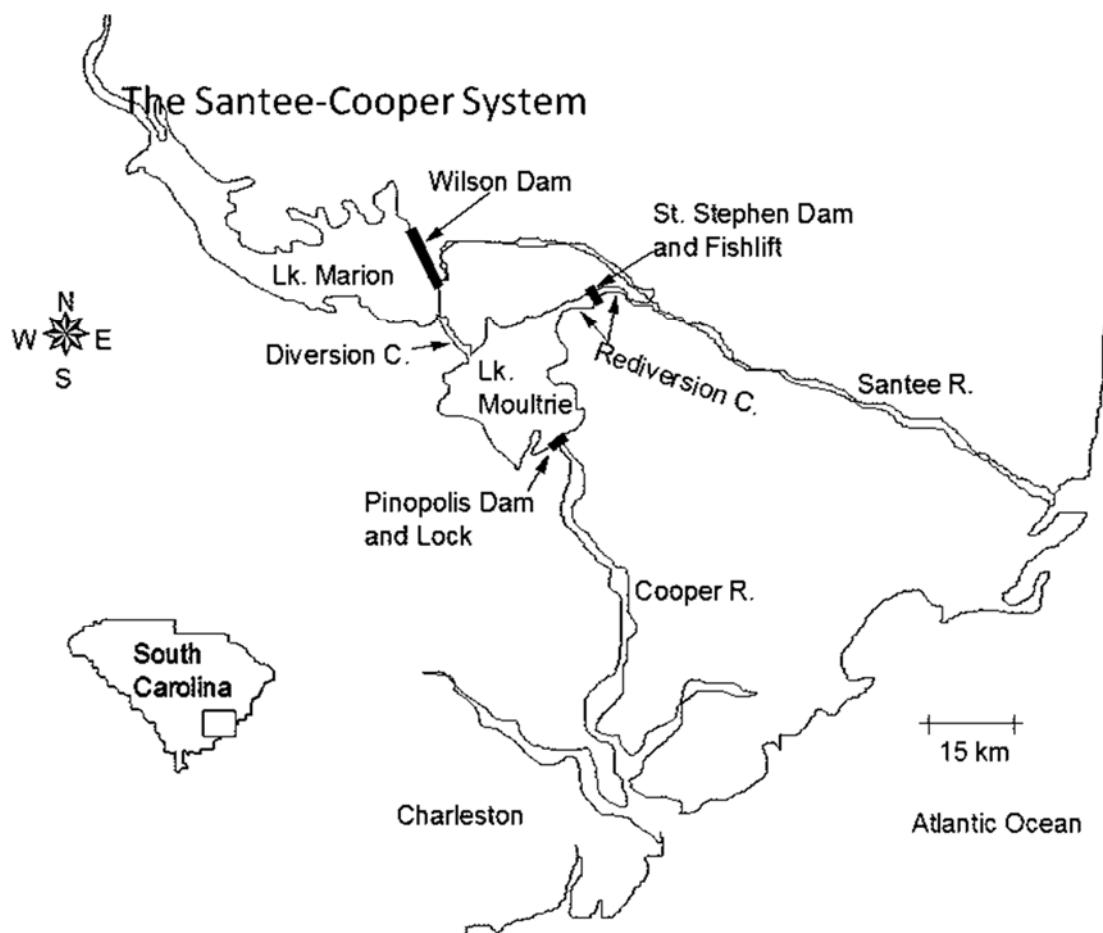


Figure 17.2 Santee-Cooper Rivers complex in South Carolina.



Figure 17.3 Reported landings (kg) of blueback herring taken in the commercial fishery in South Carolina, 1969-2015.

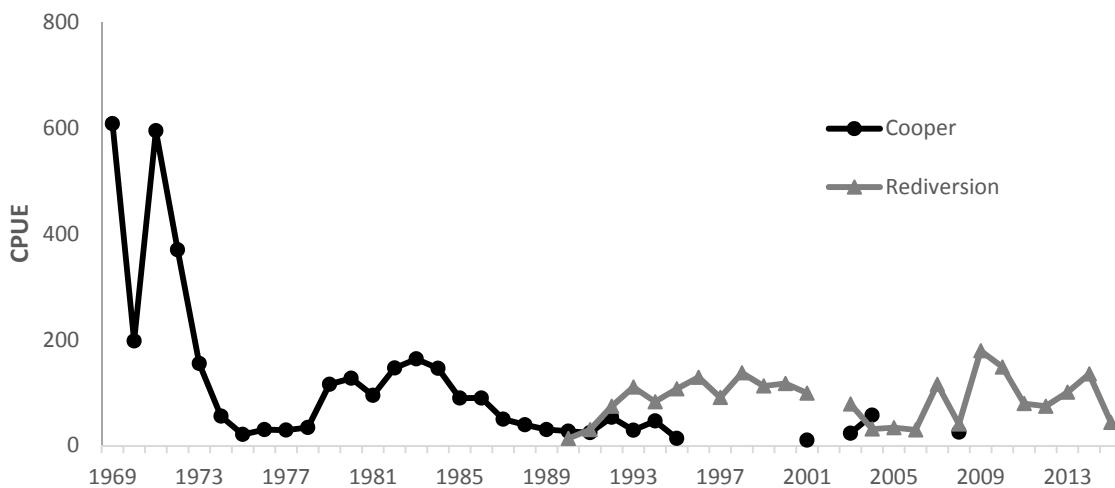
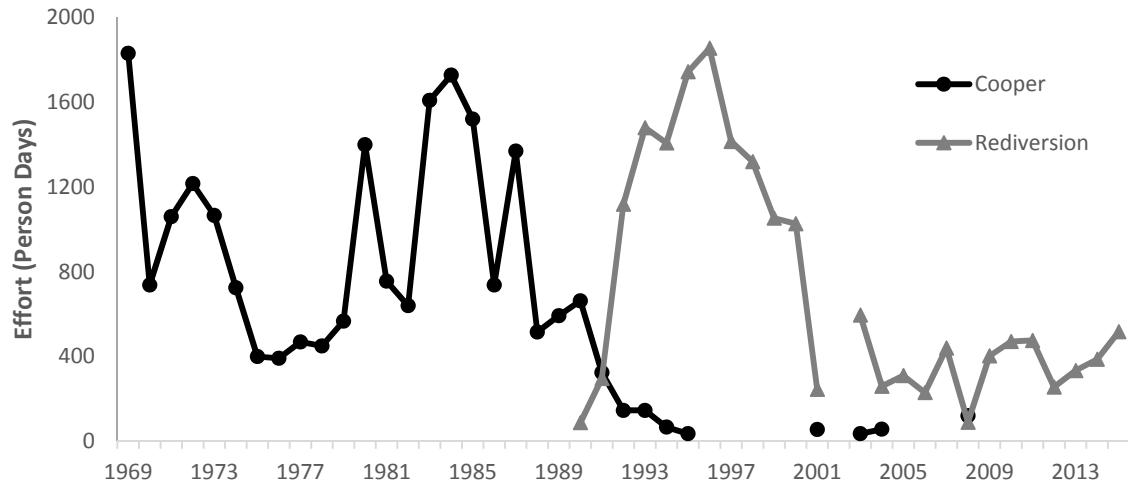


Figure 17.4 Estimated effort (person days, top) and CPUE (bottom) in the commercial fishery for blueback herring in the Cooper River and the Santee-Cooper Rediversion Canal, SC.

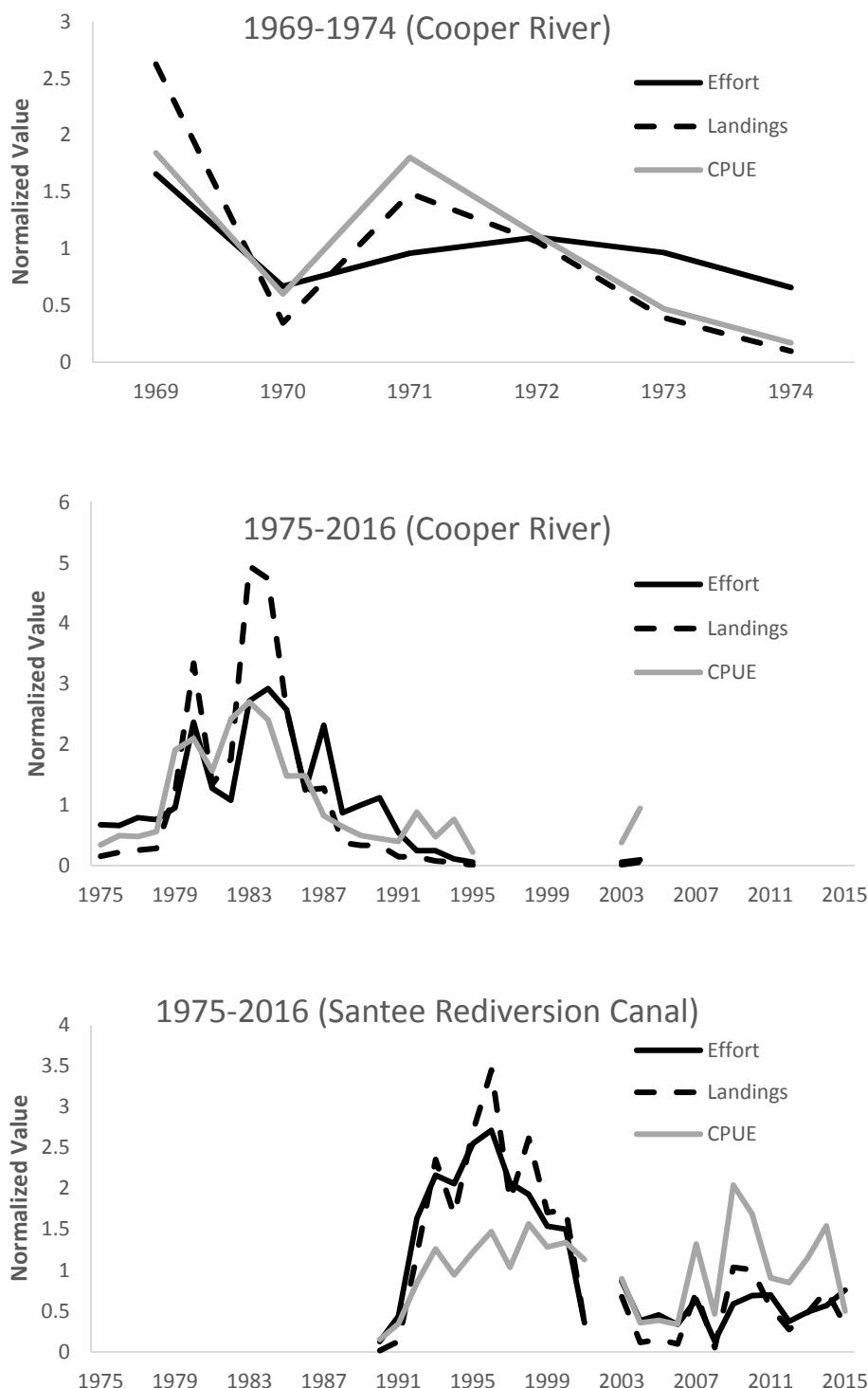


Figure 17.5 Normalized effort (Man days), landings (kg x 1000) and CPUE for the commercial fishery for BBH in the Cooper River (top, 1969 – 1974 and middle, 1975 – 2015) and the Santee-Cooper Rediversion Canal, SC (bottom, 1990 - 2015). River specific data normalized as ratio of annual data divided by long-term mean.

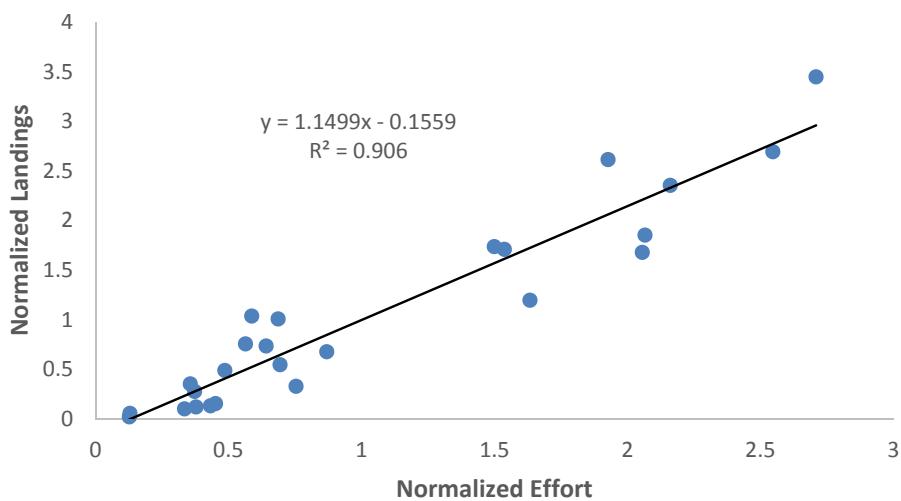
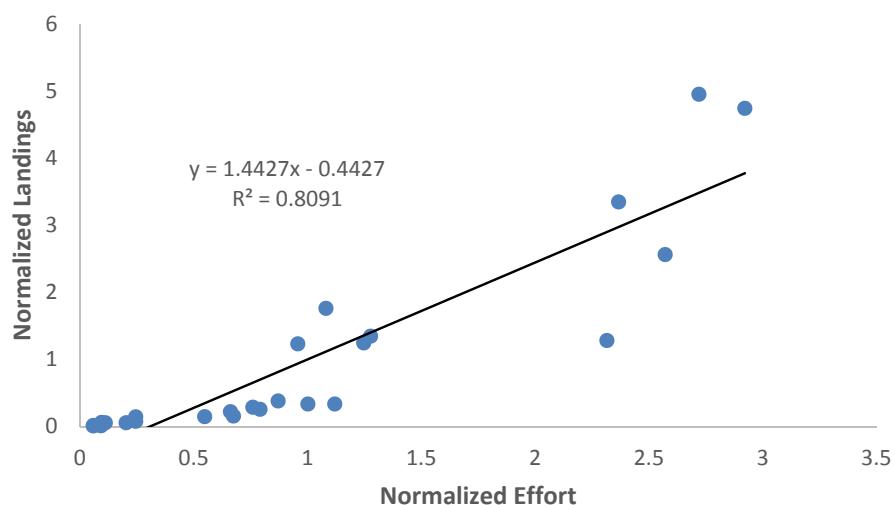
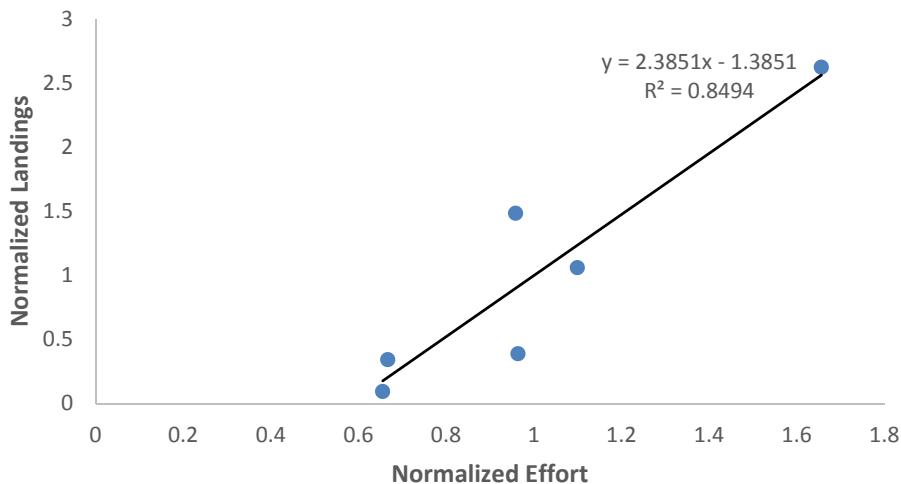


Figure 17.6 Normalized effort vs normalized landings in the commercial fisheries of the Cooper River (top, 1969 – 1974, and middle, 1975 – 2015) and the Santee River (bottom, 1990 – 2015).

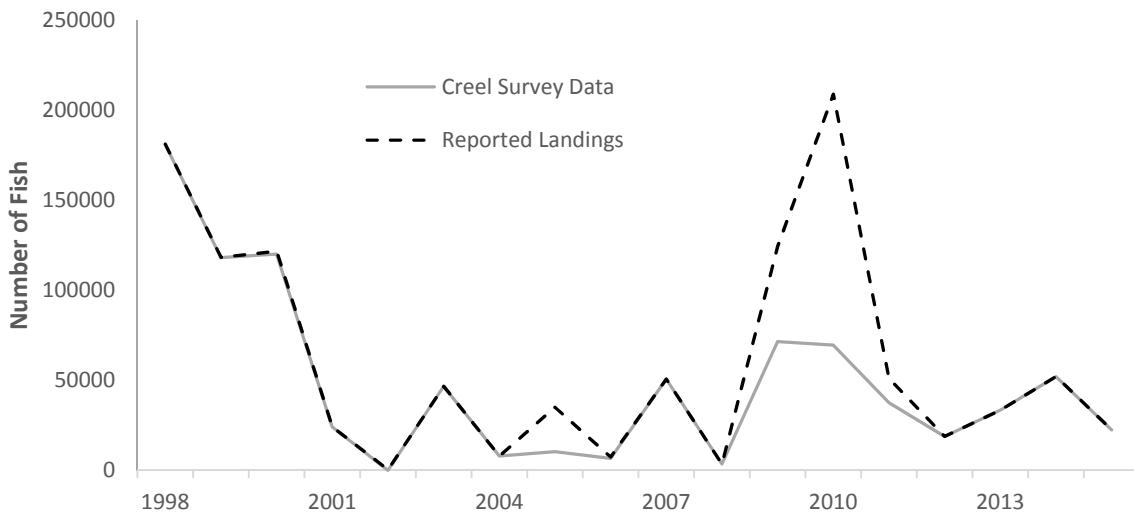


Figure 17.7 Creel survey data and reported landings of blueback herring in the Rediversion Canal of the Santee River, 1998-2015.

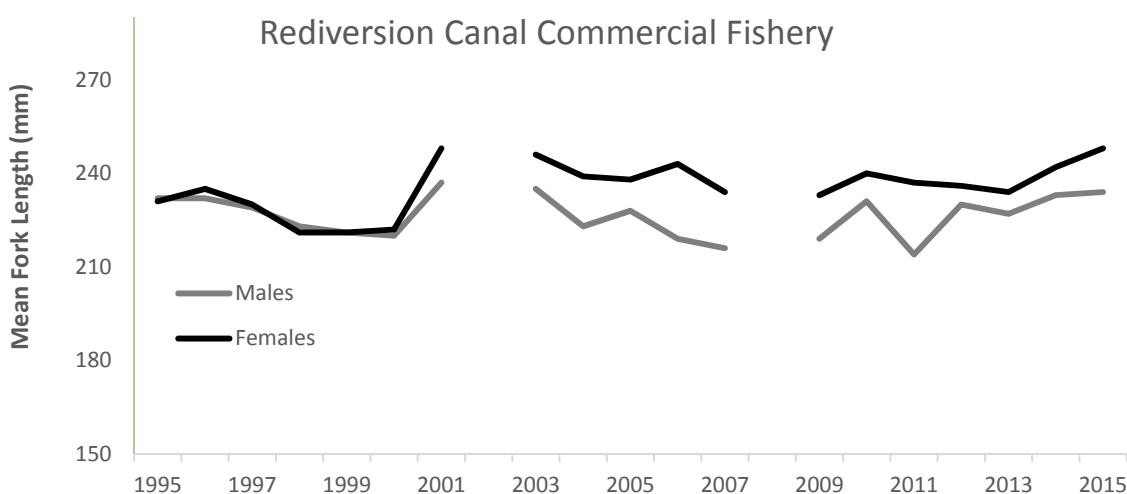


Figure 17.8 Mean fork length (mm) of blueback herring taken in the commercial fishery below the St. Stephen Dam on the Santee-Cooper Rediversion, 1995-2015.

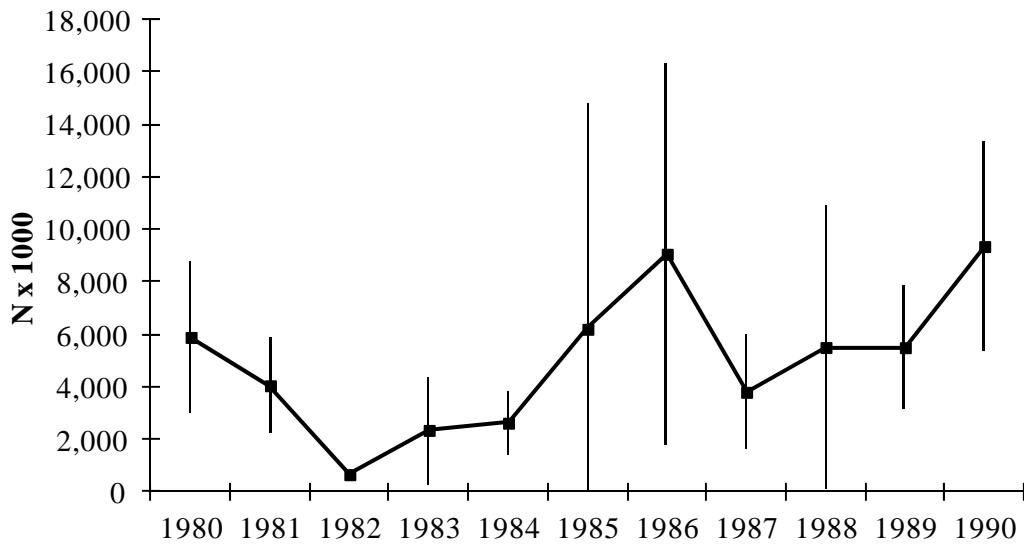


Figure 17.9 Population estimates of blueback herring in the Santee River, SC. Vertical lines denote 95% confidence interval, 1980-1990.

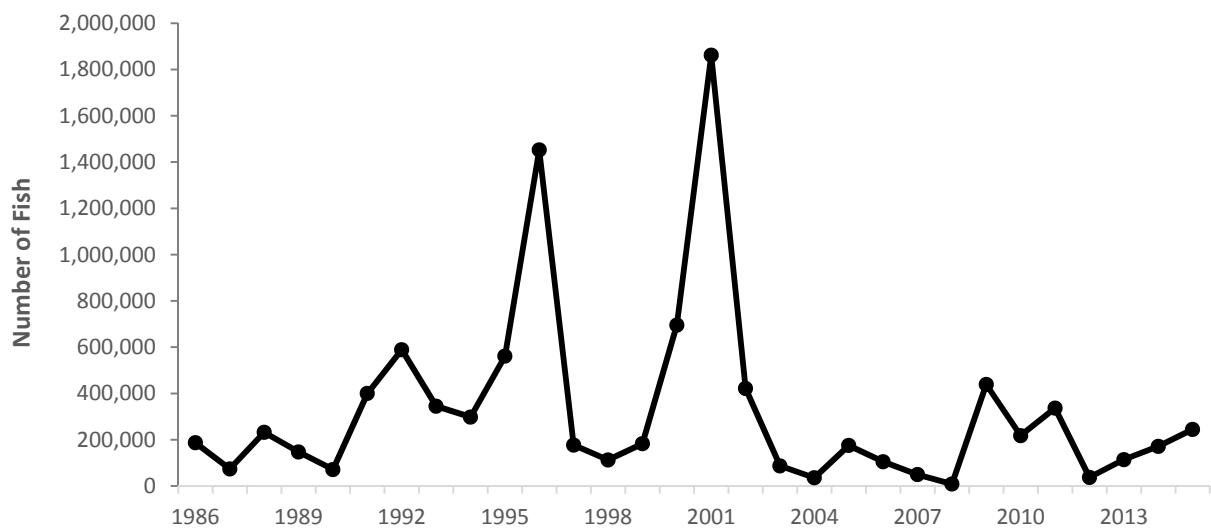


Figure 17.10 Number of blueback herring lifted over the St. Stephen Dam on the Santee-Cooper Rediversion Canal, SC, 1986-2015.

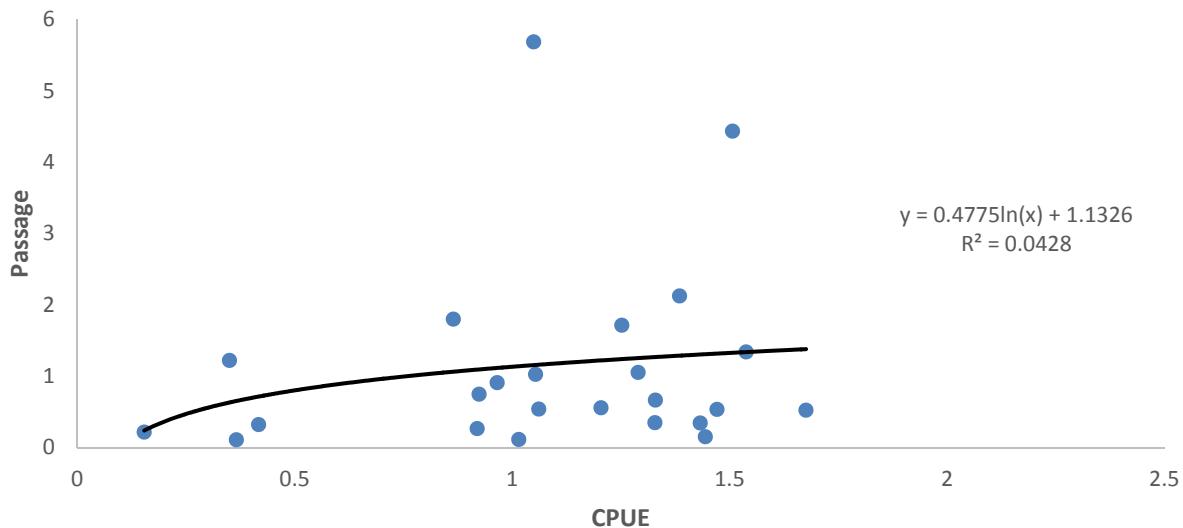


Figure 17.11 Relationship between normalized CPUE of blueback herring in the Santee-Cooper Rediversion Canal commercial fishery and normalized passage numbers in the St. Stephens Dam Fish Lift.

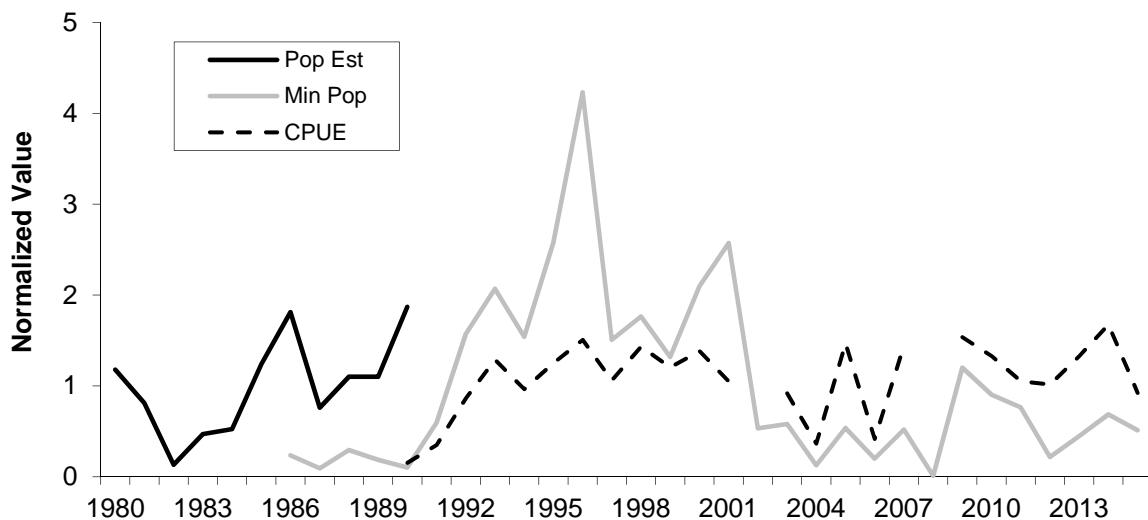


Figure 17.12 Available abundance indices for blueback herring on the Santee River and Santee-Cooper Rediversion Canal, South Carolina. CPUE as kg per man day in the commercial fishery. Passage and population estimates in numbers. All data normalized as annual value / time series mean.

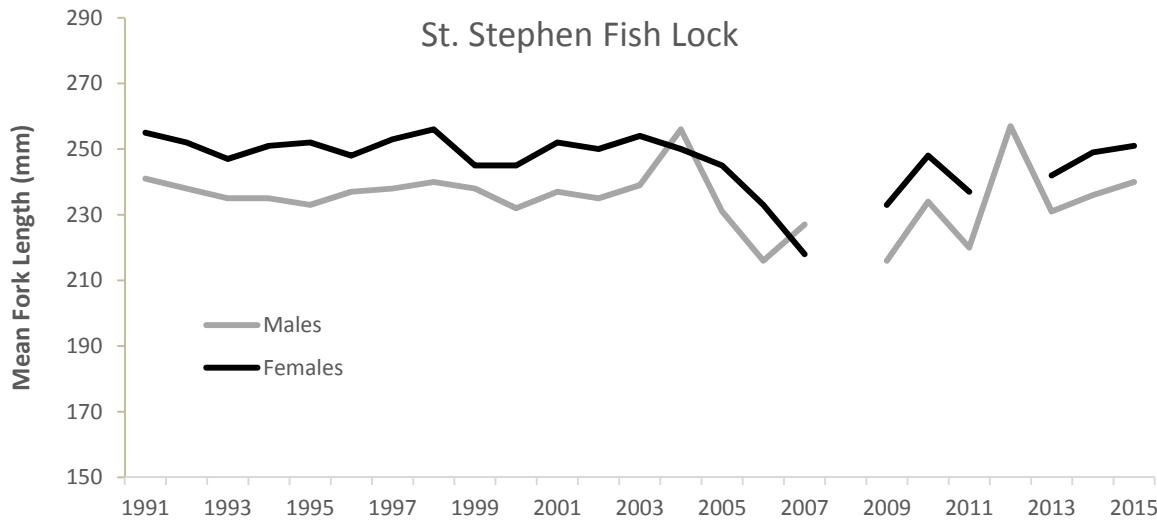


Figure 17.13 Mean fork length (mm) of blueback herring taken in the commercial fishery below the St. Stephen Dam on the Santee-Cooper Rediversion, 1991-2015.

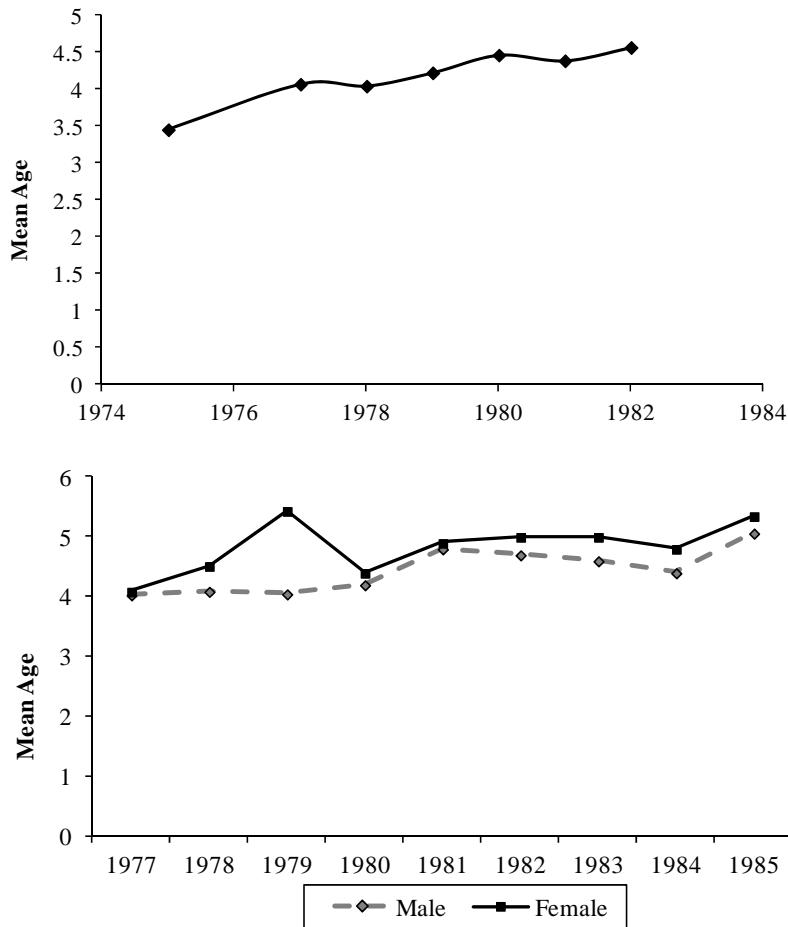


Figure 17.14 Mean age of blueback herring collected from the Santee River (bottom, male and female) and Cooper River (top, sexes combined) prior to rediversion in 1985.

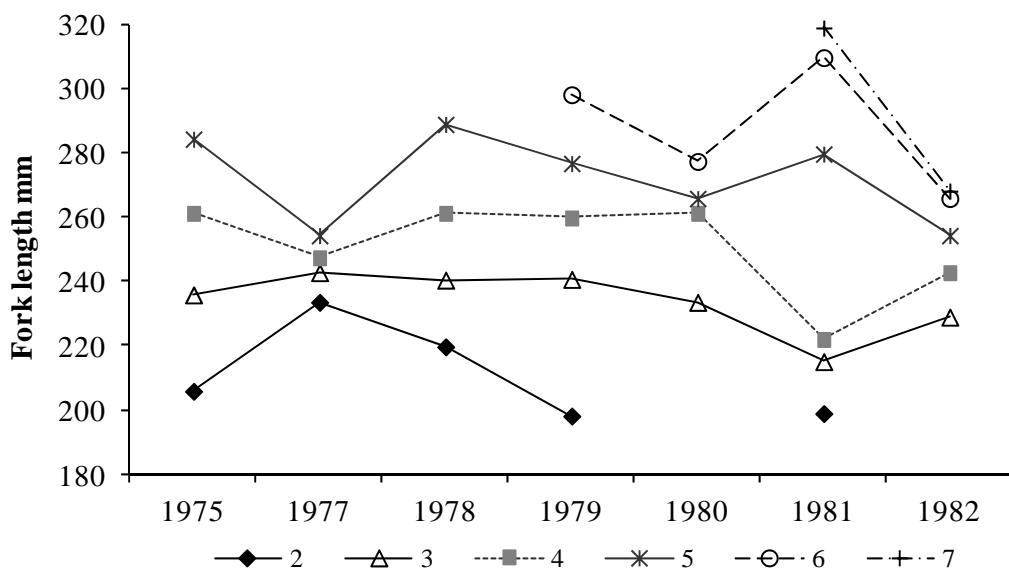
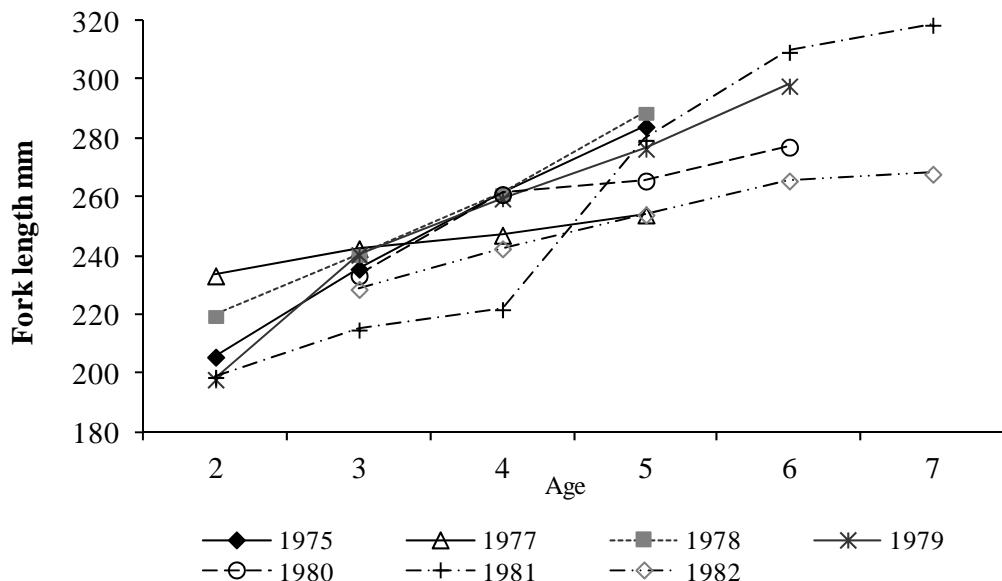


Figure 17.15 Mean fork length (mm) (bottom) and length at age (top) of blueback herring collected from the Cooper River in SC. Lengths for sexes were combined.

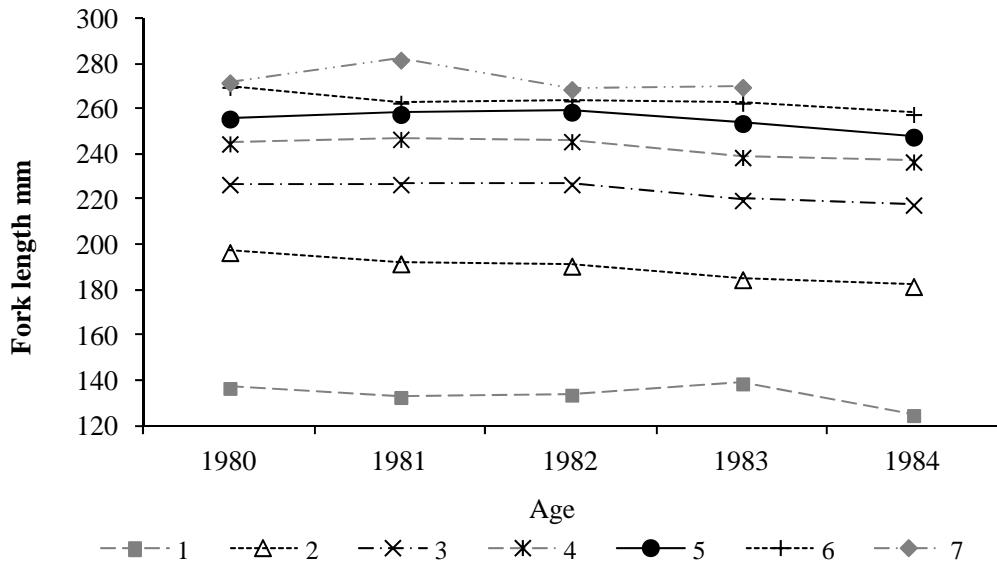


Figure 17.16 Mean fork length (mm) at age of male blueback herring from the Santee River, SC.

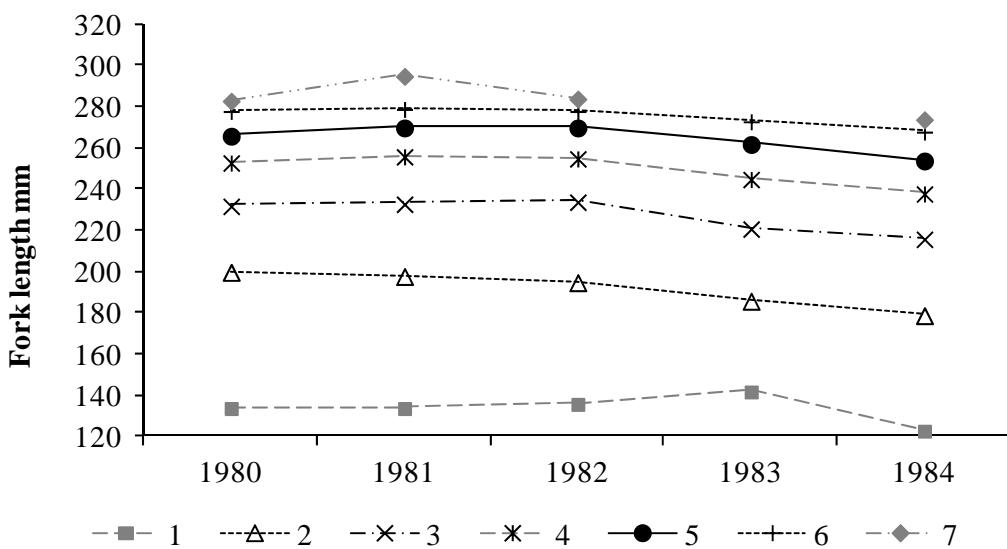


Figure 17.17 Mean fork length (mm) at age of female blueback herring from the Santee River, SC.

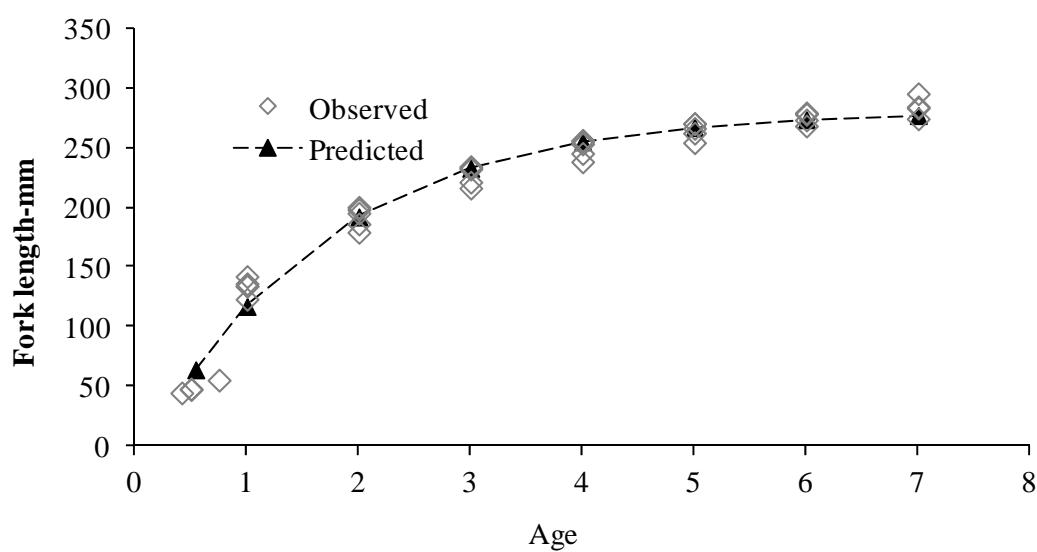
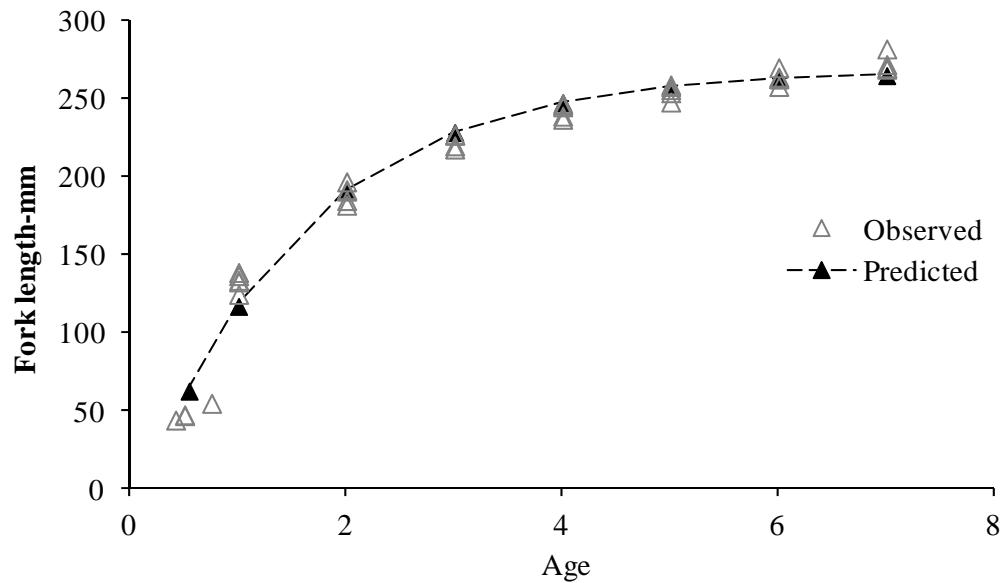


Figure 17.18 Growth curves for male (top) and female (bottom) blueback herring from the Santee River.

Appendix. Summary of current regulations on take of blueback herring in South Carolina.

General

There is no commercial fishing activity for herring in the Ashley, Edisto, Combahee, Coosawhatchie, and Savannah Rivers or in State territorial Atlantic Ocean waters.

Season

The open season is 15 February - 15 April in the rivers draining into Winyah Bay, the Ashley River, and Charleston Harbor. The open season in the Santee River is 15 February - 1 May. The open commercial season for the Rediversion Canal of Santee River and the Tailrace Canal of Cooper River is 1 March - 1 May of each year. There is no closed season for the commercial take of herring in the Santee-Cooper Lakes with legal gears in open areas.

Harvest Limits

The allowable daily take of herring (including the allowable by-catch) for net fisheries is 10 US bushels per boat in the Tailrace Canal of the Cooper River, 250 lbs per boat in the Santee-Cooper Lakes, and 10 US bushels per boat in the Rediversion Canal. There are no other caps or quotas in effect for commercial herring fisheries in South Carolina.

Gears

Approved commercial gears are anchored (set or stationary) and drift gill-nets in all open riverine waters seaward of dams, with the exceptions of open portions of the Santee and Cooper River where other gears are allowed. Circular drop-nets up to six feet in diameter, lift-nets and cast-nets are the only gears allowed in the upper Tailrace Canal of the Cooper River and in the open portions of the Rediversion Canal of the Santee River. Lift-nets, cast-nets, and hook & line may be used within the Santee-Cooper Lakes and cast-nets and/or hook & line are legal gear in other inland reservoirs. Legal minimum mesh size for gill-nets is 2 1/2" stretched mesh in all State waters open to such gear. The length of any gill-net may not exceed one half of the width of the waterway where it is fished. Gill-nets may not be fished within 200 yards of any previously deployed net. Regulatory changes implemented in 2001 restricted net lengths to a maximum of 200 yards in freshwaters and 300 yards in inland marine waters.

Lift Periods

There is a weekly 84-hour lift period in effect for all waters of the Winyah Bay system during the open gill-netting season. The Ashley River and Charleston Harbor have no weekly lift period during open gill-netting season. The use of nets in the Cooper River Tailrace Canal is allowed only from sunrise until 10:00. Fishing with nets in the Rediversion Canal is allowed from 7:00 PM - 12:00 midnight EST or 8:00 PM – 12:00 midnight EDT, with no lift period. Portions of several rivers are closed to commercial gear.

Actual regulations can be found at: <http://www.scstatehouse.gov/code/t50c005.htm>, under Title 15.

18 Status of River Herring in Georgia and Florida

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Executive Summary

The St. Johns River, Florida harbors the southernmost spawning run of Blueback herring *Alosa aestivalis* on the Atlantic coast of the United States. The run is currently not harvested by either commercial or recreational anglers and no harvest has been recorded since the 1960s. Limited landings data and anecdotes suggest that the Blueback herring run in the St. Johns River was large in the past. There are no long time series of either fishery dependent or fishery independent data for this stock. Modern abundance indices are not directly comparable to the limited historical data because gears used and sampling methods differ. Available data, though limited in scope, suggest that modern Blueback herring abundance is low in the St. Johns River, Florida. Spawning adults are smaller than those collected by researchers in 1972 and 1973. Blueback herring were much more abundant than American shad *Alosa sapidissima* in fishery independent samples in 1972 and 1973 and are now the less abundant in contemporary sampling within the St. Johns River even with shad abundance also historically low.

Due to the limited amount of data on river herring in Georgia, information collected from the state of Georgia has been included with the state of Florida. Inclusion of this data in no way implies that these stocks are genetically similar or should be treated as one management unit. The St. Mary's River on the Georgia/Florida border is known to have historically contained a blueback herring run but no data are available for an assessment of the St. Mary's. Additional populations of blueback herring have been reported in Georgia include the Altamaha and Ogeechee Rivers, as well as the Savannah River on the Georgia/South Carolina Border. For information on river herring in the Savannah River refer to Section 17 (South Carolina).

18.1 INTRODUCTION

Blueback herring were likely an important fishery in Florida in the 19th and early 20th centuries but the available catch data are unreliable. Landings of 'alewife' are reported up to a peak around 1 million pounds in the early 20th Century. However, 'alewife' were often the combined landings of Blueback herring, hickory shad (*Alosa mediocris*), and menhaden (*Brevoortia* spp.). It is unclear what proportion

of these was herring though herring were harvested and salted for market at the time. By the mid-20th Century, herring harvest was limited to bycatch in other fisheries that was sold as crab and catfish bait (Williams et al., 1975). In Georgia, historically the Blueback herring fishery was minimal to non-existent, especially when compared to the American and hickory shad fisheries.

In Georgia there is currently no known commercial or recreational fishing for Blueback herring while in Florida various gear restrictions have effectively eliminated all commercial harvest of blueback herring and there is no known recreational fishing for them. River herring were largely ignored until the approval of Amendment 1 of the Shad and River Herring Fishery Management Plan in 1999 which required monitoring of American shad stocks. Since the spawning and nursery habitats of the American shad and blueback herring overlap (Williams and Bruger 1972) this allows the collection of data on the relative abundance, size structure, and sex ratio of blueback herring in addition to the targeted sampling for American shad. In Florida, current data are collected using electrofishing for adults and pushed trawls pushed trawls for juveniles and so are not quantitatively comparable to the two years of data provided by Williams et al. 1975 from seine and surface trawl collections. The only inference on historic and modern abundance of Blueback herring is derived from the abundance of Blueback herring relative to American shad in fishery independent samples. Sampling that targets adult American shad in Georgia has not yielded any data on Blueback herring.

18.2 MANAGEMENT UNIT DEFINITION

There is no active management of Blueback herring in Georgia or Florida. Blueback herring are known to occur in Florida in the St. Johns and St. Mary's rivers, which would presumptively be two independent management units.

18.3 REGULATORY HISTORY

18.3.1 Georgia

There are no laws regarding the recreational take of river herring in Georgia's rivers. Castnets can be utilized to capture landlocked blueback herring for bait within Georgia reservoirs.

18.3.2 Florida

Blueback herring have not been specifically regulated in the St. Johns River, Florida. Gear restrictions in other fisheries have affected Blueback herring catch. New pound net licenses were no longer issued for the St. Johns River after 1982. Existing pound net licenses were non-transferable (FAC 68A-23.003) and no pound nets are operating on the St. Johns River, Florida. The Florida Constitution was amended by voter referendum to prohibit entanglement nets larger than 500ft² in state waters. This net ban became effective on July 1, 1995 (Art. X, Sec. 16).

As of January 1, 1997 hook and line is the only permissible gear for all *Alosa* in Florida (FAC 68B-52.001). Recreational anglers must possess a valid saltwater fishing license in order to retain anadromous species in fresh water.

18.4 ASSESSMENT HISTORY

McBride et al. (2010) described the 2002 – 2005 spawning runs of Blueback herring in the St. Johns River including feeding, reproduction, sex ratio, and size distribution. Overall, McBride et al. (2010) concluded that the stock is persistent, but its status is unknown and the smaller individual sizes evident today suggest that this population could be experiencing higher mortality now than a few decades ago. The Benchmark Stock Assessment for River Herring in 2012 extended the electrofishing dataset from McBride et al. (2010) from 2005 through 2010 and introduced a juvenile pushnet survey dataset for the St. Johns River. Recent data suggest that the St. Johns River population of Blueback herring is of high priority for conservation due to unique genetics and apparent demographic changes (Palkovacs et al. 2013).

18.5 STOCK-SPECIFIC LIFE HISTORY

Blueback herring in Florida are iteroparous and spawn in the St. Johns River from January to late March and occasionally early April (Williams et al. 1975, McBride et al. 2010). They spawn in the St. Johns River mature as early as age three for males and age four for females. Males mature slightly earlier with a greater proportion of males than females being age four. The majority of males mature by age five and females by age six. Mature male blueback herring collected from the 1972 and 1973 runs were age three to eight with ages five and six being 83.4% to 77.7% of the population in 1972 and 1973 respectively. Mature female blueback herring collected from the 1972 and 1973 runs were age four to eight and age six was most common (Williams et al. 1975)

18.5.1 Fecundity

Fecundity estimates of blueback herring in the Altamaha River Georgia were 120,000 – 400,000 eggs per female with a mean of 244,000 eggs per female (Street 1970).

Fecundity for blueback herring in the St. John's River was reported in Williams et al., 1975. It was estimated that blueback herring contained 151,000 to 349,000 eggs with a mean of 262,024 (N = 24) based off of:

$$F = (110.4198 + 0.7183 * Wt) * 1000$$

F = Fecundity, Wt = total weight

18.6 HABITAT DESCRIPTION

18.6.1 Georgia

The Altamaha is one of the largest rivers within Georgia. The Altamaha River forms at the confluence of the Oconee and Ocmulgee Rivers and flows unobstructed for 137 miles to the Atlantic Ocean (Godwin and Adams, 1969). There is no information available on the use of this habitat by river herring at any life stage.

18.6.2 Florida

Spawning occurs in the St. Johns River between river kilometer (rkm) 200 and 375 as well as in some tributaries such as the Wekiva River, Dunn's Creek, and Black Creek, although most spawning appears to occur along the main river (Williams et al., 1975, McBride et al., 2010). The St. Johns River is entirely coastal and drops a total of 9.1 m over its entire 499km length. Most of that drop occurs upstream of river kilometer 314 (McLane 1955). The head of the tide is generally at Lake George (rkm 199). Weak tides can reach as far as the Lake Monroe outlet at river kilometer 266 during low flow. The St. Johns River has a “southern river flow pattern” (Kelly and Gore 2008) in which low flow typically occurs from late winter into early summer and high flows occur in the late summer and early fall corresponding to a summer wet season. The floodplain is rarely inundated during the spawning season. Available habitats along the 175 km of river where spawning has been documented are diverse and include several broad lakes.

The St. Johns River is a large meandering channel averaging three to six meters deep and about 80 meters wide from rkm 200 to 266, between lakes George and Monroe. It is bounded almost entirely by bottomland hardwood floodplain forest and has numerous oxbows and sloughs known as “dead rivers”. There are three shallow lakes connected to this stretch; Lake Dexter (1902 acres), Lake Woodruff (2200 acres), Lake Beresford (800 acres). This stretch is at sea level during low flow and is weakly (< 4 cm) affected by lunar tides when flow is below 4000 cubic feet per second. Flow rarely reverses on flood tides but instead slows while the river backs up. Wind events can cause the flow to stop or reverse for a period of days at low flows (Kroening 2004). Substrates are a mix of sand and detritus muck with sand prominent along bluffs and scoured bends and deep muck in backwaters. The littoral zone is generally vegetated and fringed by trees, emergent vegetation such as *Nuphar lutea*, or submerged vegetation such as eelgrass *Vallisneria Americana*. This stretch was altered between 1884 and 1945 for navigation improvement. Numerous bends were cut off by dug channels thus straightening the channel and creating artificial oxbows. Sandbars were removed to establish a minimum depth of 12 feet between Palatka and Sanford (USACE 2011).

The St. Johns River passes through Lake Monroe (9400 acres) between rkm 266 and 276. Lake Monroe is a round shallow basin averaging two meters in depth. The river braids through seasonally flooded marsh and wet prairie upstream of Lake Monroe between river kilometers 276 and 306. Sand is the dominant substrate in the main river channels with organic detritus dominant in backwater sections. Emergent *Nuphar lutea* fringes much of this stretch of river. The river passes through Lake Harney (6200 acres) between rkm 306 and 314. Lake Harney, like Lake Monroe, is a round shallow basin. Both lakes have sandy bottoms and are usually fringed with submerged vegetation dominated by eelgrass and sometimes hydrilla.

There the river is braided through extensive wet prairie upstream of Lake Harney where the majority of the fall in elevation occurs. Substrate in the channel varies from fine sand to peat. There is a weir at rkm 415 but this is upstream of any documented spawning location for blueback herring and the highest density of eggs and larvae and spawning adults collected in previous studies were well downstream of this location in the 30 km reach between Lake Monroe and Lake Harney (Williams et al. 1975, McBride et al. 2010).

Blueback herring have been documented to spawn in both lentic and lotic habitats (Walsh et al. 2005), both which are extensive in the St. Johns River. Spawning may occur in some of the lakes through which the St. Johns River passes but specific habitat selection has not been delineated for this system.

Juveniles reside in the river until late fall or early winter, generally between rkm 125 and 305, with the range gradually shifting downstream to below rkm 125 from late summer to winter. Some Blueback herring may over winter far upstream near the spawning grounds in low flow and/or warm years (Williams et al. 1975). The habitat upstream of rkm 200 is described above. Downstream of rkm 200, the St. Johns River is a tidal freshwater estuary that includes 40,000 acre Lake George at the upstream end between rkm 182 and 200. Lake George is approximately 18 km long by 10.5 km wide and averages 3 m deep. Below Lake George the tidal freshwater reach varies in width from 0.18 km to 2 km and has an average tide range of 0.33 m.

It is not known what habitat(s) in the St. Johns are most beneficial to Blueback herring spawning. New physical habitat alteration is not an imminent threat and most activities on the flood plain center around restoration and protection. As much as 62 percent of the floodplain upstream of Lake Harney was drained for agriculture by the 1970s and much water was diverted out of the basin. Habitats in the primary spawning area, though, remain largely intact. Efforts to restore the upper river floodplain and a natural hydro-period are underway (St. Johns River Water Management District 2007).

18.7 RESTORATION PROGRAMS

There are no restoration programs in Georgia or Florida.

18.8 AGE

No age data are currently available.

18.9 FISHERIES DESCRIPTIONS

There is no directed fishery (commercial or recreational) in Florida. Gear restrictions preclude there being any fisheries operating where bycatch is likely.

There is no evidence that a directed fishery (commercial or recreational) has ever existed for river herring Georgia's rivers or coastal waters. A 1999 creel survey conducted by the South Carolina Department of Natural Resources at the New Savannah Bluff Lock and Dam documented the only known recreational harvest of blueback herring in Georgia's rivers. This survey was conducted from February 1, 1999 through June 30, 1999 and anglers harvested an estimated total of 95 blueback herring. During this same time period anglers harvested an estimated 3,828 American shad. The extremely low blueback herring harvest numbers seem to indicate that anglers targeting American shad incidentally harvested these fish. The Army Corps of Engineers closed public access to the lock and dam in 2014, thus essentially eliminating the recreational shad fishery on Georgia's side of the river.

18.10 FISHERIES INDEPENDENT MONITORING

18.10.1 Spawning stock surveys

18.10.1.1 Seine Survey

In-migrating adult *Alosa* species were collected in the St. Johns River, FL by seine in 1972 and 1973. The seine was a 306m commercial herring seine (6 cm stretched mesh) fished two to three nights per month from January to March at rkm 152. Blueback herring were enumerated and subsampled for biological data, age and fecundity. Juveniles were collected by seine and towed surface trawl throughout the year in 1972 and 1973 (Williams et al. 1975).

18.10.1.2 Electrofishing Survey

Adult *Alosa* species were collected on the spawning grounds in the St. Johns River by electrofishing beginning in 2001. In 2001 and 2002 sampling was haphazard 10 minute transects. The sampling protocol was standardized beginning in 2003. Standard sampling occurred from January to April in each year. Ten random transects were sampled in two representative river sections lying between rkm 278 and 357. One section is referred to as the “Creel Area”. The other section is referred to as “Upstream” and combines two sub-areas. The Creel Area lies between river kilometers 274 and 297 as measured from the river mouth and falls between Lake Monroe and Lake Harney. “Upstream” includes four transects in a six kilometer reach between Lake Harney and Puzzle Lake (rmk 314-320) and six transects in 12 km of river bracketing State Road (SR) 50 near Christmas, Florida (rmk 345-357) (Figure 1). In 2009 and 2010, peak-season trips were made to various tributaries in search for spawning locations of *Alosa* species outside the mainstem of the St. Johns River (Figure 2). These locations included spring fed streams, blackwater creeks, and back channels in the braided section of the St. Johns River.

Sampling was conducted using an 18-foot aluminum boat outfitted with a Smith-Root GPP 9.0 electrofisher using two four-dropper Wisconsin rings. Pulsed direct current (60 Hz) was used at 340 or 680 volts depending on water conductivity. Amperage was standardized for effective power transfer and the electricity was cycled 25 seconds on by 5 seconds off. Sampling lasted for 10 minutes of “on pedal” in each transect and targeted open water. The boat path meandered between the center of the channel and the two-foot depth contour or outer edge of vegetation where channel width exceeded 50 meters. The entire navigable channel was covered where channel width was less than 50 m. Electrofishing direction was downstream with boat speed about 1-2 mph faster than ambient current. Two netters were used for all samples in the St. Johns River for catch per unit effort (CPUE) samples.

Fish collected were held live, processed between transects, and then released except when retained for biological sampling. Sex, total length (TL) (mm), and weight (g) were recorded for all *Alosa spp.* collected. From 2003 to 2005 scales and otoliths were retained but aging has not been attempted. River herring are present primarily in February and March so CPUE for the adult index is calculated from sampling conducted in these months.

18.10.2 Juvenile Surveys

18.10.2.1 Pushnet Survey

A bow mounted pushnet was constructed in 2006 to begin developing a juvenile abundance index for Alosa species in the St. Johns River, Florida. The sample gear consisted of a 5.3 m aluminum boat used to push a modified four panel Cobb trawl mounted on a rigid frame. The net opening was 1.2 m high X 1.5 m wide. The body was 3 m deep and constructed of 19 mm stretched mesh knotless nylon. The cod end was 2 m deep and constructed of 12.7 mm stretched mesh knotless nylon

Pushnet sampling was haphazard in 2006 while the gear was being tested for efficacy in the river. Sampling was expanded to cover the entire nursery zone during the spring, summer, and early fall of 2007 through 2009. The nursery zone was sampled monthly from March to September. Sampling consisted of 48 five-minute tows at randomly selected stations between Warner Point and Lake Harney which corresponds to river kilometers 125 and 305, respectively. The river was stratified into 10 km blocks with 3 samples selected in each block to ensure sample coverage throughout the nursery zone in a sampling month. Sampling occurred on four consecutive nights starting 45 minutes after sunset with 12 stations visited each night along a 40 km river reach. Juveniles appear to be most vulnerable to the gear for the longest period of time between Lake George and Lake Monroe. Therefore, a 40 km reach was selected from rkm 210 to 250 for annual monitoring (Figure 3). In 2010 this stretch was sampled biweekly from the end of March until September. Twelve stations were visited each night with three randomly selected in each 10 km block. The index is calculated as the geometric mean of April through July catches. A second sampling reach in tidal freshwater between rkm 125 and 165 was added in 2011 (Figure 3) and bi-weekly sampling has occurred in this reach from April through July in each year since.

Distance pushed through the water was measured using a General Oceanics 2030R mechanical flowmeter mounted between the inner and outer vertical bars of the frame. Tow speed was standardized with the motor at 2000 rpm corresponding to a speed of approximately 2.6 statute miles per hour in still water.

Catch per tow was standardized to the average volume of a five-minute tow in the survey to date using the formula:

$$SC_i = C_i * (686m^3/V_i)$$

where SC_i = standardized catch in the ith tow. C_i = catch of the ith tow. V_i = volume of the ith tow and volume = net aperture area * distance towed.

18.10.2.2 Seine Survey

In 2010, Georgia Department of Natural Resources initiated juvenile Alosine sampling on the Altamaha, Ogeechee, and Savannah rivers to prepare for the implementation of ASMFC Amendment 3. Juvenile Alosines were sampled utilizing a 50' seine pulled along the edges of sandbars in each of the three rivers.

Low numbers of blueback herring are captured from the Altamaha and Savannah rivers each year during the seine survey. The highest geometric means recorded since 2010 were 1.8 herring/haul for the Altamaha River and 2.0 herring/haul for the Savannah River. No blueback herring have ever been collected from the Ogeechee River in the seine survey.

18.11 ASSESSMENT APPROACHES AND RESULTS

18.11.1 Relative Abundance

Adult herring were far more abundant in the St. Johns River, FL, 9.7 and 7.4 times, than American Shad in seine samples in 1972 and 1973 but shad were more numerous in modern electrofishing samples, often by greater than a factor of 10 (Figure 4) even though the American Shad population is at low abundance (McBride and Holder 2008). There is no trend in the CPUE of Blueback herring in the electrofishing survey. The CPUE is low with a high standard error (Table 3). We do not know whether or not electrofishing is selective for American Shad relative to Blueback herring or whether by focusing on the primary river channels sampling is missing areas where herring aggregate in this system. Winter-spring time electrofishing in small tributaries and along the littoral zones of larger lakes for other monitoring has not detected blueback herring. To date they are primarily encountered in the main stem of the river when electrofishing for American shad. Electrofishing CPUE has been low and without trend since 2003 (Table 3, Figure 4).

American shad were more abundant than Blueback herring in all years of standard sampling (Figure 4). Tributary sampling to date has located mature blueback herring only in the Wekiva River and in Haw Creek at very low densities.

18.11.2 Trends in Juvenile Abundance

Previously, in the St. Johns River, FL, Williams et al. 1975 reported 355.3 and 268.3 Blueback herring per seine haul during January – March in 1972 and 1973 respectively. Subsequent juvenile sampling in those years yielded 1,983 blueback herring in 1972 and 4,050 blueback herring in 1973.

The CPUE of juvenile Blueback herring was greatest in 2006 during testing of the new gear in the rkm 210-250 river reach (Table 5). Since then, catches have been lower under the standard protocol with catches of juvenile American shad being similar to or exceeding the catch of blueback herring (Figure 5). The CPUE of YOY Blueback herring has been erratic in the rkm 210-20 reach from 2006 through 2016 (Figure 5). There has been an increase in the CPUE of YOY in the tidal freshwater rkm 125-165 river reach during the 2007 to 2016 time (Figure 5).

While catch rates are not comparable between the different gears it is apparent that the proportion of each species present has changed. Juvenile herring were six to seven times more abundant than American Shad in 1972 and 1973 samples. Juvenile American Shad were as or more abundant than juvenile blueback herring in most years sampling with a pushed trawl. The geographic and temporal coverage was similar between the 1972-73 sampling and modern sampling. There is no reason to believe that the pushed trawl is more selective for American shad relative to herring than the surface trawls and seines used in 1972 and 1973.

18.11.3 Trends in Size

Blueback herring collected from the St. Johns River, FL in 1972 and 1973 were larger than those collected in modern sampling (Table 4, McBride et al. 2010). Although the gears are different and were fishing different sections of the river there isn't reason to believe that either gear was size selective. Electrofishing tends to bias towards larger individuals when there is a measurable selectivity difference between sizes. The reduced mean length of adult blueback herring during 2001-2017 as compared to the runs in 1972 and 1973 could point to a demographic shift. Demographic change has recently been

documented for an alewife *Alosa pseudoharengus* run. A comparison of Alewife from 1966-1967 to alewife from 2003-2006 in Bride Brook, Connecticut showed a reduction of mean length, mean age, age of recruitment, and the proportion of repeat spawners in the modern runs (Davis and Schultz 2009). Mean age of the run in Bride Brook declined from 5-7 year to 3-4 years. The mean size of blueback herring spawning in the St. Johns River in 2001-2016 corresponds to age 3-4 fish in the 1972 and 1973 runs during which 2.9% and 17% of males and 0.6% and 9.6% of females were age 4 in those years. The majority of spawning herring in 1972 and 1973 were older than age 4. Such a shift in demographics can be the result of increased mortality. We have no modern age data so we cannot confirm that the change in size is reflective of reduced growth or age truncation in the St. Johns River population.

Females were larger than males and both males and females were smaller than males and females collected in 1972 and 1973 (Table 4, McBride et al. 2010).

18.11.4 Trends in Lengths at Age

Length at age is reported in Williams et al. 1975 (Table 1).

18.11.5 Potential Sources of Increased Mortality and other Threats

No fisheries target blueback herring in Florida and Georgia. No fisheries are operating in the rivers that are likely to encounter blueback herring as bycatch. Any additional source of fishing mortality of sub-adults or adults is probably remote to the St. Johns River such as those in the Atlantic mackerel and Atlantic herring fisheries in the northeast (Harrington et al. 2005). The shrimp trawl fishery is the most likely fishery in Georgia waters that may inadvertently capture river herring. However, no bycatch of herring has ever been reported from this fishery.

New surface water withdrawals of up to 262 million gallons per day (mgd) for consumption are being sought from the St. Johns River basin to accommodate a projected population growth in the region from 4.4 million people to 7.3 million people by 2030. The withdrawal may reduce average daily discharge by 7.8 percent with 155 mgd projected to come from three locations along the spawning grounds of Blueback herring and other Alosines. The effects of this withdrawal on water quality and ecology as well as possible impingement/entrainment of early life stages have been reviewed with recommendations made to avoid adverse impacts on Alosines (Miller et al. 2012a, 2012b).

Some of the water in the spawning and nursery habitats are currently considered impaired due to non-attainment of standards for several water quality parameters including nutrient loads and dissolved oxygen. Various actions are underway to attempt to mitigate these issues (Florida Department of Environmental Protection FDEP 2005). The trend in water quality during the last two decades has generally been a slow decline with chlorophyll a, total nitrogen, total phosphorous, and total suspended solids increasing in the middle St. Johns River (Keller et al. 2004). High water is commonly associated with dissolved oxygen levels well below 5 mg/l but high water typically occurs during September-November upstream of the nursery zone. The tidal freshwater portion from Lake George to the river mouth are also subject to summer and fall algae blooms and hypoxia events common in systems with high nutrient loading (Magley and Joyner 2008). It is not known if the downstream water quality is affecting the ability of juveniles to emigrate successfully in years when algae blooms are intense and persistent. Basin management action plans for implementation of TMDLs for relevant criteria have been established for the middle and lower St. Johns River (FDEP 2008, FDEP 2012). The BMAP for the lower river has resulted in some progress toward meeting nutrient TMDLs (FDEP 2013).

18.12 BENCHMARKS

Data are insufficient to establish a benchmark for Georgia or Florida.

18.13 CONCLUSIONS AND RECOMMENDATIONS

The reduced size of adults might indicate increased mortality remote to the St. Johns River. The age structure of the returning adults needs to be determined in order to establish whether the reduced size is a result of a change in growth or age structure of returning adults. Knowing the age structure of the spawning stock would also be helpful in determining if the JAI is reflective of year class strength.

Water quantity and quality are potential threats to both spawning success and juvenile growth and survival to out-migration in the St. Johns River. As noted in the habitat section, alosines spawn during the dry season in the St. Johns River when water levels are typically low. This may make them particularly sensitive to withdrawals. Data are needed on habitat selection by adults for spawning in order to assess how habitat might be affected by proposed water withdrawals and changes in average stage.

Juvenile monitoring should continue to assess whether any changes in water quality or habitat impact annual juvenile abundance.

There is no Blueback herring fishery in Florida therefore there are no possible fishery interventions that would improve the population of Blueback herring in the St. Johns River, Florida. The source of at-sea mortality needs to be determined and reduced and water quality problems within the St. Johns River should be addressed if blueback herring population of the St. Johns River is to increase.

Neither measure of adult or juvenile abundance is conclusive and it may be a stretch to base the assessment of Blueback herring abundance on the relative abundance of Blueback herring as compared to the relative abundance of American Shad in common samples. However, the low adult relative abundance of blueback herring in electrofishing samples corresponds to what appears to be low relative abundance of juveniles in trawl gear. Blueback herring were the most abundant alosine in the St. Johns River, Florida in past decades (Hale et al. 1985, Moody 1961, Williams et al. 1975). Taken in aggregate these indices do point to low blueback herring abundance relative to historic levels in the St. Johns River.

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Table 1. Mean total length (TL) at age as reported in Williams et al. 1975. Lengths here converted from fork lengths (FL) using the equation: $TL = 1.1458 * FL - 1.2495$

| <u>Age</u> | <u>Female</u> | | <u>Male</u> | |
|------------|---------------|----------------|-------------|----------------|
| | <u>N</u> | <u>Mean TL</u> | <u>N</u> | <u>Mean TL</u> |
| 3 | | | 1 | 237 |
| 4 | 2 | 262 | 6 | 268 |
| 5 | 45 | 276 | 69 | 269 |
| 6 | 65 | 289 | 66 | 279 |
| 7 | 39 | 295 | 12 | 284 |
| 8 | 3 | 302 | | |

Table 2. Mean catch per seine haul of blueback herring and American shad in 1972 and 1973. N is the number of nights. One to four seine hauls were made during a sampling night but Williams et al. 1975 only reports a mean catch rate for a given night and not the catch in each haul.

| <u>Year</u> | <u>N</u> | <u>blueback herring</u> | | <u>American shad</u> | |
|-------------|----------|-------------------------|-----------|----------------------|-----------------------|
| | | <u>Mean fish/haul</u> | <u>SE</u> | <u>N</u> | <u>Mean fish/haul</u> |
| 1972 | 6 | 355.3 | 85.0 | 6 | 36.8 |
| 1973 | 6 | 268.3 | 36.5 | 6 | 71.3 |

Table 3. Electrofishing CPUE (geometric mean) of Blueback Herring on the spawning ground in the St. Johns River Florida during February and March. Few stations were visited over a short period of the spawning season in 2001 and 2002.

| <u>Year</u> | <u>Mean Catch per Sample</u> | <u>SE</u> | <u>Number of Stations</u> |
|-------------|------------------------------|-----------|---------------------------|
| 2001 | 4.63 | 0.32 | 16 |
| 2002 | 0.19 | 0.12 | 18 |
| 2003 | 0.20 | 0.06 | 60 |
| 2004 | 0.58 | 0.12 | 105 |
| 2005 | 0.11 | 0.03 | 124 |
| 2006 | 0.19 | 0.05 | 80 |
| 2007 | 0.11 | 0.04 | 81 |
| 2008 | 0.20 | 0.05 | 70 |
| 2009 | 0.32 | 0.07 | 90 |
| 2010 | 0.53 | 0.15 | 51 |
| 2011 | 0.16 | 0.07 | 54 |
| 2012 | 0.09 | 0.03 | 60 |
| 2013 | 0.44 | 0.08 | 70 |
| 2014 | 1.54 | 0.14 | 70 |
| 2015 | 0.86 | 0.12 | 80 |
| 2016 | 0.46 | 0.46 | 80 |

Table 4. Mean total length (mm) and mean weight (g) of male and female Blueback Herring collected from the St. Johns River. Mean weight for 1973 and 1972 is estimated by applying the weight/length relationships reported in Williams et al. 1975 to the lengths reported therein. FWC discontinued collection of weights in the field during routine monitoring of *Alosa* on the spawning grounds in 2011.

| YEAR | Male | | | | | Female | | | | |
|------|------|--------|-------|--------|-------|--------|--------|-------|--------|-------|
| | N | LENGTH | SD | WEIGHT | SD | N | LENGTH | SD | WEIGHT | SD |
| 1972 | 743 | 273 | | 161.91 | | 1322 | 286 | | 218.31 | |
| 1973 | 939 | 266 | | 150.93 | | 1044 | 280 | | 204.25 | |
| 2001 | 45 | 253 | 10.13 | 132.02 | 24.96 | 20 | 264 | 9.99 | 156.27 | 26.90 |
| 2002 | 2 | 255 | 21.21 | 135.65 | 31.18 | 4 | 267 | 9.81 | 157.30 | 19.62 |
| 2003 | 5 | 236 | 7.64 | 106.42 | 19.60 | 11 | 266 | 13.18 | 154.25 | 39.35 |
| 2004 | 92 | 250 | 7.43 | 126.12 | 19.54 | 103 | 260 | 7.55 | 141.98 | 19.08 |
| 2005 | 7 | 245 | 16.41 | 119.64 | 25.20 | 12 | 266 | 6.12 | 137.24 | 16.98 |
| 2006 | 23 | 242 | 10.98 | 106.71 | 18.36 | 14 | 257 | 6.98 | 135.79 | 20.58 |
| 2007 | 15 | 257 | 32.93 | 144.27 | 85.40 | 12 | 263 | 11.41 | 151.17 | 41.73 |
| 2008 | 21 | 250 | 8.28 | 130.86 | 15.69 | 14 | 257 | 8.73 | 151.29 | 19.11 |
| 2009 | 42 | 244 | 7.16 | 117.14 | 16.45 | 24 | 258 | 9.31 | 133.67 | 17.59 |
| 2010 | 61 | 250 | 7.05 | 123.34 | 18.44 | 25 | 263 | 8.18 | 159.56 | 28.48 |
| 2011 | 11 | 249 | 11.00 | | | 10 | 255 | 13.60 | | |
| 2012 | 3 | 246 | 4.04 | | | 8 | 266 | 6.93 | | |
| 2013 | 21 | 242 | 8.87 | | | 30 | 252 | 9.87 | | |
| 2014 | 123 | 253 | 6.87 | | | 55 | 263 | 6.87 | | |
| 2015 | 41 | 256 | 9.07 | | | 80 | 270 | 9.96 | | |
| 2016 | 57 | 248 | 9.70 | | | 27 | 261 | 9.80 | | |

Table 5. The geometric mean catch per tow of juvenile Blueback Herring collected by nocturnal pushnet during April to July from 2006 through 2016 in the St. Johns River, Florida between river kilometer 210 and 250.

| <u>Year</u> | <u>Number of hauls</u> | <u>Number of fish</u> | <u>Geometric Mean</u> | <u>SD</u> | <u>SE</u> | <u>Zero hauls</u> |
|-------------|----------------------------|---------------------------|---------------------------|-----------|-----------|-----------------------|
| 2006 | 22 | 349 | 10.04 | 1.83 | 0.39 | 1 |
| 2007 | 46 | 846 | 2.95 | 3.73 | 0.55 | 20 |
| 2008 | 48 | 209 | 1.41 | 2.15 | 0.31 | 32 |
| 2009 | 48 | 201 | 1.13 | 2.18 | 0.31 | 43 |
| 2010 | 96 | 522 | 1.23 | 2.36 | 0.24 | 59 |
| 2011 | 96 | 722 | 3.01 | 2.25 | 0.23 | 27 |
| 2012 | 60 | 96 | 1.07 | 0.92 | 0.12 | 20 |
| 2013 | 72 | 371 | 1.43 | 2.28 | 0.27 | 37 |
| 2014 | 60 | 1944 | 8.84 | 3.91 | 0.46 | 5 |
| 2015 | 72 | 133 | 0.67 | 1.19 | 0.14 | 42 |
| 2016 | 72 | 181 | 1.11 | 1.5 | 0.18 | 36 |

Table 6. The geometric mean catch per tow of juvenile Blueback Herring collected by nocturnal pushnet during April to July from 2007 through 2016 in the St. Johns River, Florida between river kilometer 125 and 165.

| <u>Year</u> | <u>Number of hauls</u> | <u>Number of fish</u> | <u>Geometric Mean</u> | <u>SD</u> | <u>SE</u> | <u>Zero hauls</u> |
|-------------|----------------------------|---------------------------|---------------------------|-----------|-----------|-----------------------|
| 2007 | 33 | 83 | 1.45 | 1.27 | 0.22 | 11 |
| 2008 | 48 | 118 | 1.21 | 1.23 | 0.18 | 16 |
| 2009 | 46 | 21 | 0.25 | 0.61 | 0.09 | 36 |
| 2010 | 12 | 43 | 1.55 | 2.02 | 0.58 | 6 |
| 2011 | 24 | 30 | 0.68 | 1.04 | 0.21 | 14 |
| 2012 | 60 | 176 | 0.91 | 1.55 | 0.20 | 32 |
| 2013 | 72 | 272 | 2.16 | 1.45 | 0.17 | 18 |
| 2014 | 96 | 953 | 3.35 | 2.80 | 0.29 | 29 |
| 2015 | 84 | 532 | 3.08 | 1.94 | 0.21 | 18 |
| 2016 | 72 | 1730 | 5.06 | 3.87 | 0.46 | 20 |

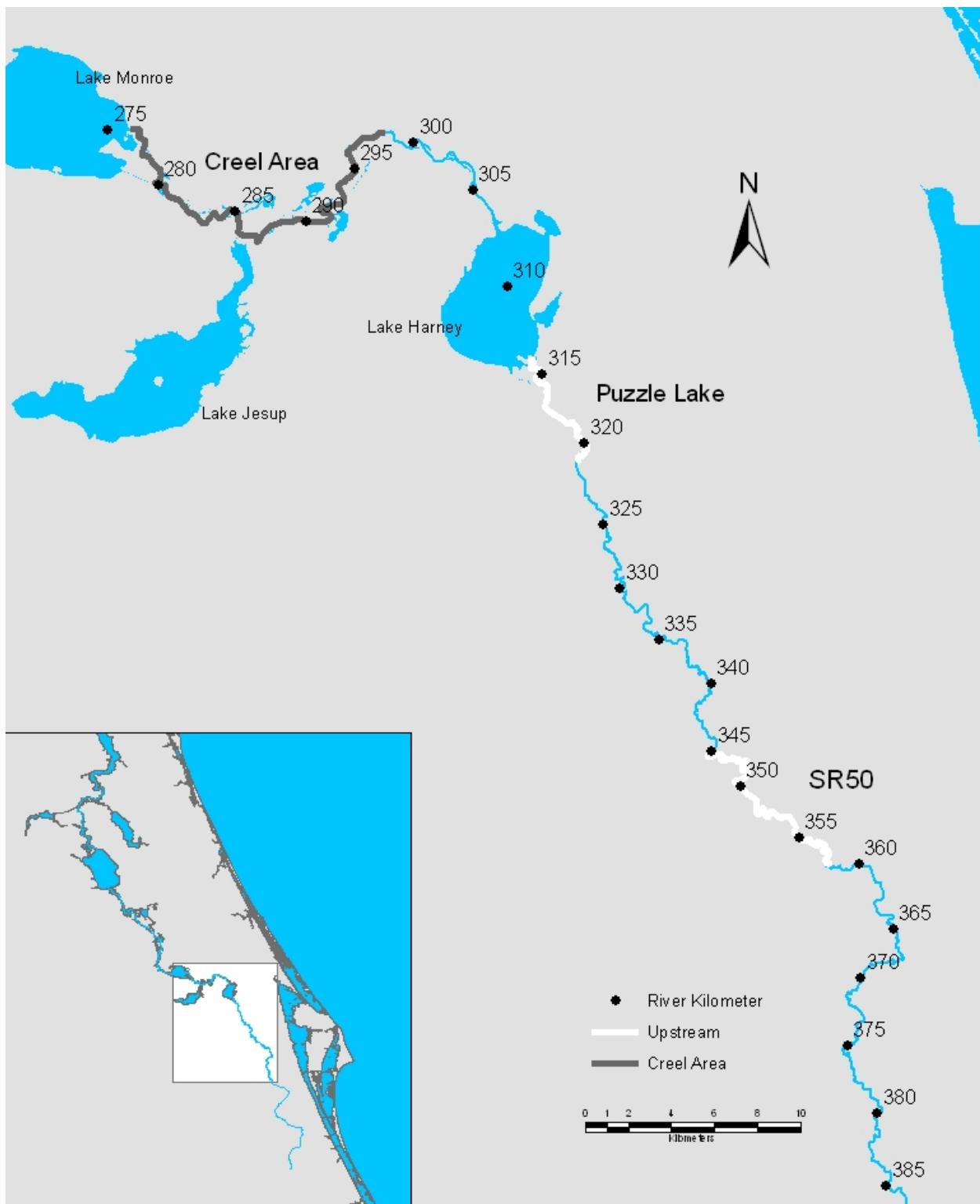


Figure 1. Map of areas sampled in the St. Johns River for monitoring of the spawning runs of adult American shad and other *Alosa* species. Numbers refer to kilometers upstream from the river mouth.

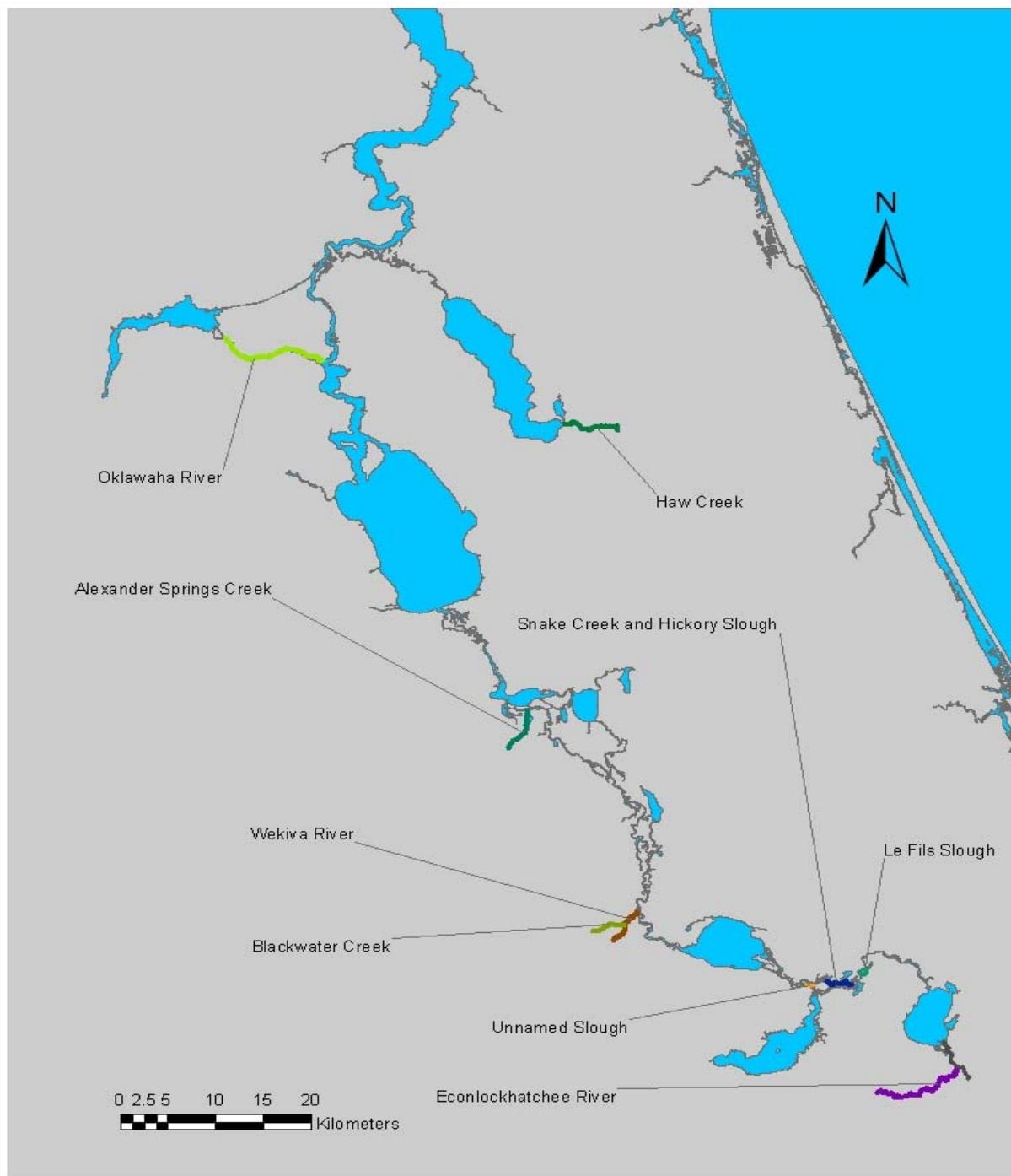


Figure 2. Map of targeted tributaries of the St. Johns River for monitoring of the spawning run of adult American shad and other *Alosa* species.

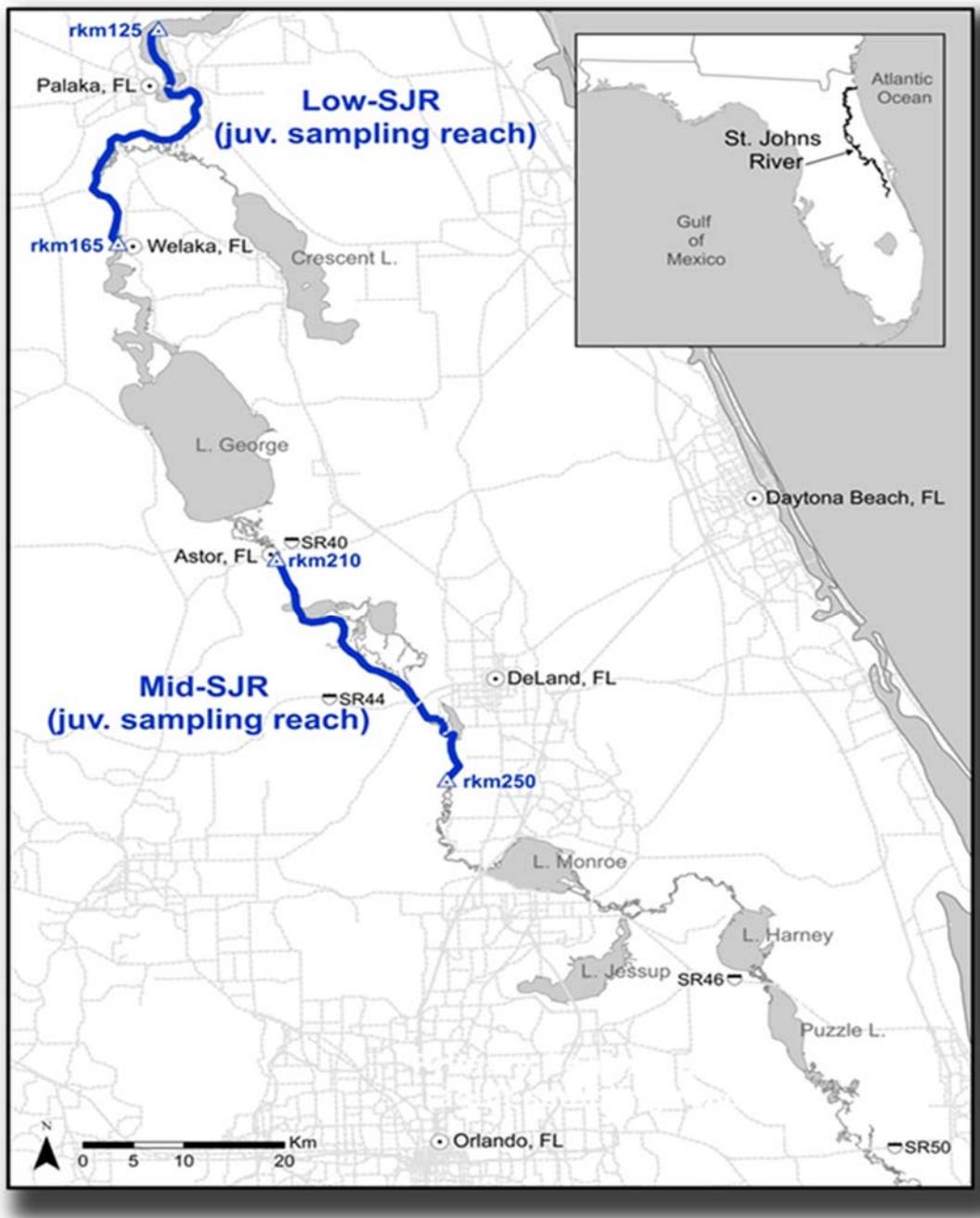


Figure 3. Middle and lower St. Johns River juvenile sample zones. Tidal freshwater extends from river kilometer 30 to Lake George. The “Low-SJR” sample reach is entirely in tidal freshwater. The river bottom of the reach between Lake George and Lake Monroe is below sea level but flow is dictated by river discharge with flow reversal only by wind driven sloshing in Lake George during period of very low discharge. The “Mid-SJR” sampling reach is a dark water river flowing between bottomland hardwood swamps.

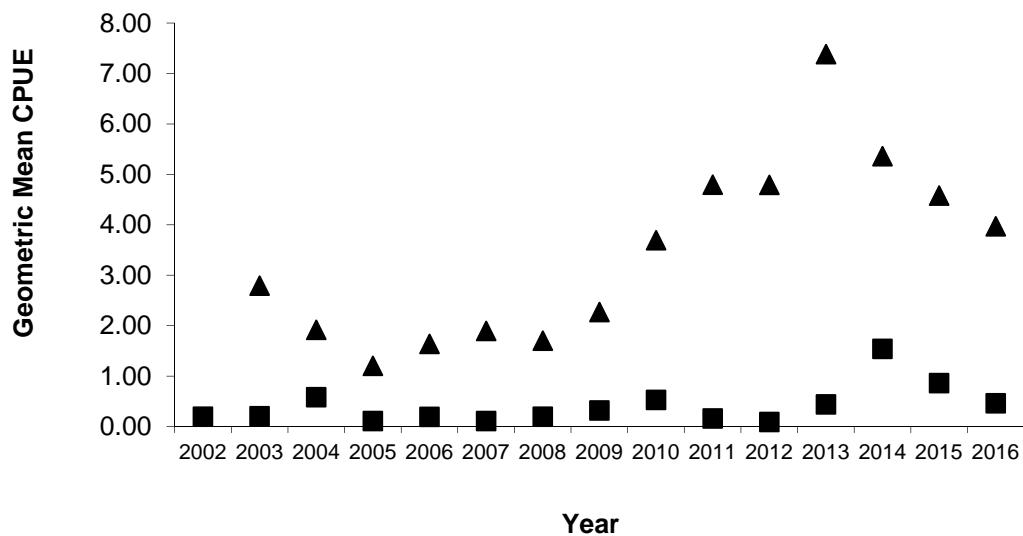


Figure 4. The geometric mean catch per sample of Blueback Herring (squares) and American Shad (diamonds) from standardized 10 minute electrofishing transects on the spawning grounds during January, February, and March in each year

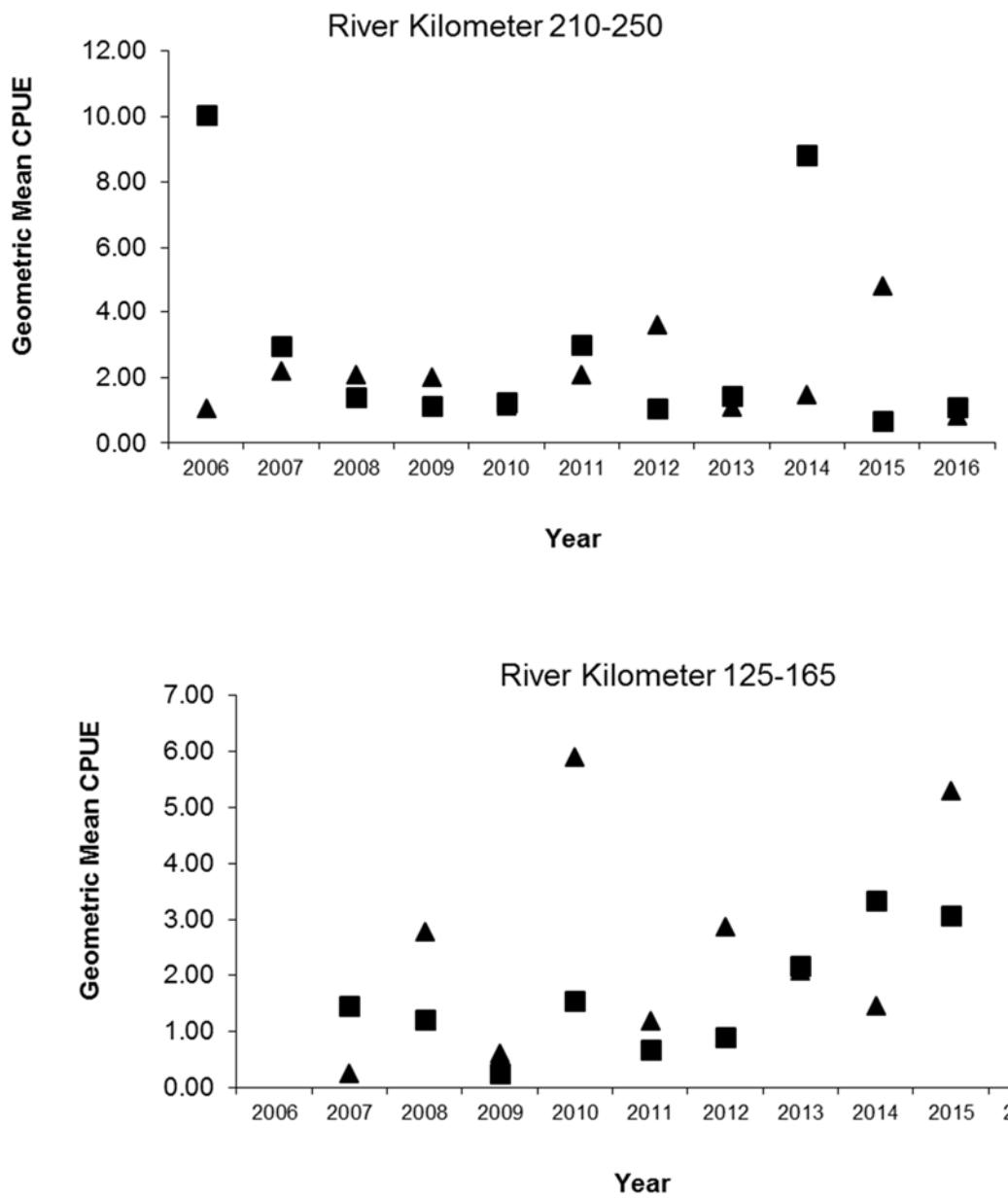


Figure 5. Geometric mean catch per 5-minute pushnet sample of juvenile Blueback Herring (squares) and American Shad (triangles) during April to July from 2006 through 2016 between river kilometer 210 and 250 and from 2007 through 2016 between river kilometer 125 and 165.

19 Trends in Alewife and Blueback Herring from the Northeast Fisheries Science Center Bottom Trawl Surveys

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Objectives

The Northeast Fisheries Science Center (NEFSC) bottom trawl surveys are conducted in both the spring and fall and sample from Maine through North Carolina (Azarovitz et al 1997). These surveys were used to investigate trends in alewife and blueback herring relative abundance and biomass, and mean length.

Methods

Data collected during the NEFSC bottom trawl surveys were used to derive seasonal relative abundance and biomass indices. The surveys follow a stratified random sampling design with strata defined primarily by depth and stations allocated approximately in proportion to stratum area (Azarovitz 1981). Inshore (8-27 m) and offshore strata (27-366 m) have been most consistently sampled by the research vessels *Albatross IV* and *Delaware II* since the fall of 1975 and spring of 1976. Prior to these time periods, either only a portion of the survey area was sampled or a different vessel and gear were used to sample the inshore strata (Azarovitz 1981). Accordingly, seasonal alewife and blueback herring relative abundance indices were derived from these trawl surveys for 1975-2015 in the fall and 1976-2015 in the spring.

Through 2008, standard bottom trawl tows were conducted for 30 minutes at 6.5 km/hour (3.5 knots) with the *Albatross IV* as the primary survey research vessel (Despres-Patanjo et al. 1988). However, vessel, door and net changes did occur during this time, resulting in the need for conversion factors to adjust survey catches for some species. Conversion factors were not available for net and door changes, but a vessel conversion factor for alewife was available to account for years where the RV *Delaware II* was used. A vessel conversion factor of 0.58 was applied to alewife weight-per-tow indices. Alewife number-per-tow indices did not require a conversion factor (Byrne and Forrester 1991).

In 2009, the survey changed primary research vessels from the *Albatross IV* to the *Henry B. Bigelow*. Due to the deeper draft of the *Bigelow*, the two shallowest series of inshore strata (8-18m depths) are no longer sampled. Concurrent with the change in fishing vessel, substantial changes to the characteristics of the sampling protocol and trawl gear were made, including tow speed, net type and tow duration (NEFSC 2007). Calibration experiments, comprising paired standardized tows of the two fishing vessels, were conducted to measure the relative catchability between the two vessel-gear combinations and develop calibration factors to convert *Bigelow* survey catches to *Albatross* equivalents (Miller et al. 2010). Species-specific calibration coefficients were estimated for both catch numbers and weights using the method of Miller et al. (2010) (Table 1). The calibration factors were combined across seasons due to low within-season sample sizes from the 2008 calibration studies (less than 30 tows with positive catches by one or both vessels).

Bottom trawl catches of the subject alosid species tend to be higher during the daytime due to diel migration patterns (Loesch et al. 1982; Stone and Jessop 1992). Accordingly, only daytime tows were used to compute relative abundance and biomass indices. In addition, the calibration factors used to convert *Bigelow* catches to *Albatross* equivalents were estimated using only catches from daytime tows.

Daytime tows, defined as those tows between sunrise and sunset, were determined for each survey station based on sampling date, location, and solar zenith angle using the method of Jacobson et al. (2011). Although there is a clear general relationship between solar zenith and time of day, tows carried out at the same time but at different geographic locations may have substantially different irradiance levels that could influence survey catchability (NEFSC 2011). Preliminary analyses (Lisa Hendrickson, NMFS – *unpublished data*) confirmed that river herring catches were generally greater during daylight hours compared to nighttime hours.

Relative abundance and biomass indices

Relative abundance (stratified mean number-per-tow) and biomass (stratified mean kilogram-per-tow) indices, as well as the proportion of positive tows were calculated for alewife and blueback herring using data from NEFSC spring (1976–2015) and autumn (1975–2015) bottom trawl surveys. Survey indices were developed for each species. For both seasons, survey indices were computed for the entire northwest Atlantic coast. For the spring survey, indices were also calculated separately for a northern set and a southern set of survey strata (Figure 1). The two strata sets were used to examine whether general trends in run count differences between northern and southern rivers along the U.S. Atlantic coast were apparent in NEFSC survey indices for similar regions. The geographic boundary between the northern and southern NEFSC survey regions reflects the monthly timing of the spring surveys with April as the median month of sampling in the north and March as the median month of sampling in the south. Also, the boundary between northern and southern regions roughly corresponds to the Hudson Canyon. In the spring of 2014, stations south of Maryland were not sampled due to delays in the survey. Accordingly, the spring survey index in this year is not based on all of the strata incorporated into other years. Fall surveys were not split into northern and southern regions because of very limited catches of river herring in southern strata.

Autoregressive integrated moving average (ARIMA) models developed in the benchmark assessment to assess trends in relative abundance were updated and are discussed in the coastwide assessment report.

Trends in size structure

Length frequencies were calculated seasonally (spring and fall) for the coastwide population as well as northern and southern regions separately. Trends in mean length (fork length, cm) of alewife and blueback herring were updated using a non-parametric Mann-Kendall test for a monotonic trend and are presented in the coastwide assessment report. Data used in this analysis included lengths from daytime tows only.

Age and Growth

Age data for river herring were only available for a limited time period from 1973 – 1987; therefore, von Bertalanffy growth models were not updated for the NEFSC trawl surveys because new data were not available.

Results

Proportion positive tows

The proportion of tows that encountered river herring was greater during the spring than the fall (Figure 2). During the spring survey, there was little trend in the coastwide proportions for alewife but those for blueback increased slightly over the time series. Furthermore, trends in the proportion of positive tows varied between regions. In the case of alewife, northern and southern regions tracked fairly consistently until the mid-1980s, at which point the northern region began to slightly increase, while the southern region showed a slightly decreasing trend (Figure 2).

In contrast, for blueback herring the southern region generally had a higher proportion of positive tows compared to the northern region until the late-1990s. In the early 2000s, northern and southern regions exhibited similar proportions of positive tows; however, the northern region exhibited a slightly higher proportion of positive tows from the late 2000's onward. Fall surveys showed little fluctuation in the proportion of positive tows compared to the spring surveys but generally increased slightly.

Relative abundance indices

Across all regions, alewife number- and weight-per-tow generally varied without trend until the mid-1990s (Figure 3 and Figure 4). In the 2000's, coastwide indices for both seasons as well as northern indices during the spring exhibited an increasing trend. The southern region did not exhibit a consistent temporal trend during the spring surveys, though the greatest catches occurred near the beginning of the time series. Indices since 2010 have exhibited notable interannual variability. Trends in blueback herring number- and weight-per-tow were similar to those for alewife (Figure 5 and Figure 6). Across both seasons, alewives were typically caught in greater abundances than blueback herring. Differences in relative abundance trends among regions could be a consequence of true regional differences in population trends or a distributional shift of the species.

Trends in size structure

Modes of length distributions varied through time for both species. Modes in alewife length frequencies ranged from 10 cm to 28 cm and tended to be slightly lower during the 2000s during coastwide spring surveys (Table 2) but this temporal pattern was not apparent during coastwide fall surveys (Table 3).

Modes in alewife length frequencies in the northern region during spring surveys were also lower during the 2000s (Table 4) but showed no temporal patterns in the southern region (Table 5). Modes in blueback herring length frequencies ranged from 7 to 25 cm and showed no consistent pattern temporally (Table 6 – Table 9).

Survey timing

The benchmark assessment indicated that the timing of the NEFSC bottom trawl surveys changed during 1975-2011. Linear regressions between median Julian day of sampling and year indicated significant relationships across both seasons and regions. Median Julian day significantly decreased with surveys occurring earlier in the year as the time series progressed. This variability in the timing of the trawl surveys may influence the availability of the species to the survey gear. However, across regions and seasons, there was not a consistent significant relationship between median bottom temperature at the time of sampling and year. In the northern region, the relationship between temperature and year was

not significant, indicating that the median temperature when the northern region was sampled has not significantly changed even though the survey has occurred progressively earlier. In the southern region, median sampling temperature significantly increased over time in the fall but did not exhibit a significant relationship with year the spring.

Changes in the timing of the trawl surveys make interpretation of regional trends in relative abundance for anadromous species such as river herring difficult. Changes in relative abundance in northern or southern regions could be an artifact of the timing of sampling rather than true population changes. However, even though the median Julian day for the surveys has changed, the bottom temperature encountered while sampling has largely remained the same. One exception is the median temperature of the southern region in the fall; however, fall regional indices were not examined in this analysis. If river herring migratory behavior is governed by water temperature as it is for Atlantic herring (Maravelias and Reid 1997), observed trends in relative abundance may represent changes in river herring population abundance.

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Table 1: Coefficients and associated standard errors used to convert RV *Bigelow* catches of alewife and blueback herring to RV *Albatross* I/V equivalents for the 2009-2011 NEFSC bottom trawl surveys.

| Species | Number | | Biomass | |
|------------------|-------------|------|-------------|------|
| | Coefficient | SE | Coefficient | SE |
| Alewife | 1.05 | 0.16 | 0.72 | 0.11 |
| Blueback herring | 0.87 | 0.17 | 1.59 | 0.45 |

Table 2: Length frequency of alewives from the coastwide NEFSC bottom trawl survey during the spring.

Table 3: Length frequency of alewives from the coastwide NEFSC bottom trawl survey during the fall.

| Length | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 | | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 46 | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 91 | | | | |
| 13 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | |
| 14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 55 | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 818 | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 110 | | | | |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 709 | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 534 | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1150 | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 837 | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 452 | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 271 | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 244 | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 148 | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 110 | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 65 | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 34 | | | | |
| 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | |
| 32 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | |
| 33 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | |
| 34 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | |
| 35 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | |
| 36 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | |
| 37 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | |
| 38 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | |

Table 4: Length frequency of alewives from the NEFSC bottom trawl survey in the northern region during the spring.

Table 5: Length frequency of alewives from the NEFSC bottom trawl survey in the southern region during the spring.

| Length | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 5 | 1 | 1 | | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | 4 | 2 | | | | | | 30 | 1 | 1 | 2 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 2 | 1 | | | | | | 35 | 1 | 1 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | 2 | | | | | | | 54 | | | 1 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 1 | 7 | | | | | | 77 | 1 | 1 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | 2 | 1 | | | | | | 24 | 4 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | 3 | 1 | 1 | | | | | 5 | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | 4 | 2 | 1 | 4 | 26 | 3 | 20 | 35 | 4 | 9 | 7 | 6 | 1 | 8 | 2 | 1 | 115 | 11 | 3 | 159 | 3 | 15 | 6 | 1 | 9 | | | | | | | | | | | | | | | |
| 18 | 2 | 1 | 1 | 24 | 59 | 17 | 45 | 39 | 1 | 8 | 43 | 19 | | 25 | | 1 | 3 | 60 | 12 | 4 | 255 | 1 | 50 | 4 | 2 | 2 | | | | | | | | | | | | | | |
| 19 | 7 | 2 | 4 | 32 | 101 | 27 | 60 | 26 | 3 | 7 | 23 | 29 | | 25 | 1 | 1 | 54 | 5 | 12 | 122 | 6 | 77 | 3 | 9 | 1 | 1 | 26 | 23 | | | | | | | | | | | | |
| 20 | 5 | 3 | 6 | 31 | 97 | 53 | 66 | 14 | 1 | 2 | 17 | 41 | | 16 | 4 | 3 | 6 | 93 | 11 | 19 | 104 | 16 | 57 | 2 | 9 | 1 | 20 | 17 | 5 | 1 | 14 | 7 | 27 | 45 | 2 | 289 | 14 | 7 | | |
| 21 | 9 | 2 | 5 | 18 | 107 | 60 | 29 | 10 | 3 | 1 | 11 | 46 | | 5 | 5 | 2 | 10 | 66 | 2 | 9 | 43 | 25 | 39 | 2 | 8 | 6 | 6 | 98 | 27 | 6 | 2 | 14 | 11 | 23 | 12 | 1 | 234 | 61 | 13 | |
| 22 | 24 | 7 | 4 | 44 | 121 | 85 | 33 | 15 | 4 | 2 | 13 | 45 | | 2 | 3 | 5 | 20 | 24 | 2 | 16 | 28 | 19 | 64 | 13 | 21 | 13 | 2 | 4 | 108 | 46 | 4 | 1 | 10 | 13 | 10 | 20 | 105 | 126 | 29 | |
| 23 | 29 | 6 | 21 | 98 | 139 | 106 | 32 | 22 | 11 | 4 | 19 | 34 | 1 | 2 | 9 | 6 | 17 | 15 | 10 | 16 | 31 | 21 | 103 | 21 | 26 | 12 | 8 | 37 | 27 | 33 | 1 | 5 | 23 | 3 | 11 | 80 | 66 | 17 | | |
| 24 | 76 | 28 | 27 | 134 | 135 | 127 | 24 | 34 | 26 | 4 | 13 | 37 | 5 | 4 | 11 | 8 | 19 | 12 | 2 | 13 | 22 | 14 | 79 | 43 | 16 | 20 | 30 | 40 | 22 | 33 | 2 | 5 | 11 | 30 | 5 | 5 | 2 | 16 | 29 | 38 |
| 25 | 99 | 36 | 37 | 227 | 73 | 146 | 26 | 38 | 37 | 3 | 27 | 36 | 7 | 7 | 15 | 10 | 9 | 9 | 9 | 14 | 11 | 7 | 34 | 23 | 9 | 14 | 25 | 41 | 8 | 28 | 2 | 6 | 2 | 27 | 2 | 7 | 14 | 21 | 29 | |
| 26 | 68 | 82 | 46 | 234 | 66 | 101 | 18 | 46 | 48 | 10 | 18 | 53 | 3 | 12 | 4 | 7 | 10 | 3 | 1 | 4 | 3 | 3 | 19 | 12 | 4 | 8 | 16 | 29 | 25 | 19 | 5 | 6 | 11 | 3 | 12 | 3 | 9 | | | |
| 27 | 73 | 57 | 43 | 213 | 86 | 89 | 21 | 52 | 36 | 11 | 14 | 39 | 2 | 19 | 5 | 6 | 5 | 3 | 1 | 2 | 2 | 8 | 3 | 1 | 4 | 7 | 15 | 6 | 12 | 1 | 4 | 3 | 1 | 1 | 2 | 1 | | | | |
| 28 | 71 | 29 | 18 | 177 | 44 | 51 | 15 | 46 | 20 | 6 | 8 | 13 | 1 | 21 | 5 | 6 | 2 | 1 | 1 | 1 | 1 | 4 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | |
| 29 | 30 | 7 | 2 | 84 | 9 | 33 | 11 | 32 | 20 | 6 | 2 | 12 | 5 | 3 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | 9 | 3 | 1 | 28 | 5 | 23 | 5 | 17 | 4 | 3 | 1 | 5 | | 3 | 2 | 1 | 2 | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | 6 | | | 17 | 10 | | 15 | | | | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | | 1 | 6 | | 5 | 3 | 6 | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 33 | | | | 1 | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 6: Length frequency of blueback herring from the coastwide NEFSC bottom trawl survey during the spring.

| Length | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 1 | | 9 | 8 | 82 | 23 | 27 | 10 | 4 | 48 | 41 | | 4 | 1 | 3 | 6 | 8 | 60 | 85 | 67 | 21 | 82 | 19 | 2 | 21 | 18 | 27 | 102 | 29 | 18 | 17 | 8 | 1 | 13 | 5 | | | | | |
| 9 | 4 | 1 | 71 | 26 | 192 | 169 | 44 | 19 | 25 | 103 | 48 | 1 | 31 | 3 | 2 | 3 | 10 | 38 | 42 | 48 | 32 | 42 | 18 | 8 | 3 | 32 | 24 | 28 | 173 | 4 | 63 | 25 | 24 | 7 | 55 | | | | | |
| 10 | 16 | | 70 | 37 | 187 | 60 | 13 | 24 | 23 | 72 | 10 | 33 | 17 | 8 | 59 | 25 | 14 | 33 | 46 | 27 | 9 | 10 | 2 | 15 | 27 | 9 | 295 | 2 | 46 | 32 | 29 | 16 | 16 | 1 | 2 | 31 | | | | |
| 11 | 7 | | 25 | 42 | 153 | 8 | 16 | 32 | 12 | 38 | 3 | 1 | 21 | 18 | 3 | 10 | 52 | 22 | 10 | 23 | 49 | 23 | 2 | 8 | 3 | 1 | 10 | 24 | 7 | 436 | 7 | 29 | 39 | 18 | 52 | 60 | 6 | 21 | 17 | |
| 12 | 10 | | 24 | 39 | 122 | 17 | 24 | 25 | 15 | 23 | 3 | 12 | 15 | 2 | 12 | 31 | 56 | 29 | 31 | 20 | 36 | 16 | 25 | 14 | 10 | 1 | 17 | 24 | 37 | 371 | 7 | 11 | 28 | 23 | 36 | 883 | 10 | 24 | 22 | |
| 13 | 12 | 2 | 28 | 23 | 65 | 5 | 16 | 4 | 17 | 28 | 1 | 11 | 5 | 6 | 14 | 46 | 21 | 8 | 24 | 17 | 10 | 9 | 13 | 8 | 28 | 1 | 51 | 24 | 65 | 316 | 12 | 19 | 30 | 45 | 20 | 1011 | 29 | 32 | 64 | |
| 14 | 2 | 2 | 39 | 36 | 66 | 16 | 3 | 5 | 9 | 37 | 3 | 26 | 3 | 6 | 90 | 32 | 3 | 14 | 22 | 2 | 8 | 17 | 7 | 52 | 1 | 64 | 17 | 58 | 288 | 12 | 11 | 39 | 24 | 138 | 472 | 31 | 23 | 59 | | |
| 15 | 5 | 26 | 50 | 88 | 81 | 8 | 2 | 25 | 12 | 15 | 15 | 19 | 9 | 2 | 2 | 111 | 63 | 11 | 8 | 32 | 2 | 15 | 41 | 6 | 21 | 1 | 99 | 12 | 35 | 415 | 6 | 6 | 72 | 36 | 28 | 28 | 41 | 18 | 41 | |
| 16 | 4 | 26 | 12 | 173 | 42 | 125 | 20 | 5 | 53 | 22 | 12 | 14 | 11 | 13 | 2 | 4 | 132 | 101 | 14 | 13 | 45 | 3 | 10 | 28 | 1 | 27 | 9 | 32 | 24 | 13 | 210 | 7 | 6 | 146 | 80 | 30 | 17 | 69 | 15 | 77 |
| 17 | 5 | 37 | 5 | 424 | 30 | 82 | 15 | 20 | 138 | 69 | 48 | 48 | 9 | 22 | 8 | 12 | 43 | 81 | 7 | 10 | 64 | 11 | 7 | 17 | 6 | 8 | 8 | 14 | 19 | 15 | 69 | 38 | 6 | 160 | 57 | 30 | 54 | 136 | 71 | 62 |
| 18 | 13 | 68 | 7 | 225 | 33 | 51 | 14 | 65 | 248 | 38 | 33 | 55 | 7 | 21 | 40 | 13 | 10 | 54 | 4 | 9 | 37 | 14 | 10 | 16 | 16 | 7 | 8 | 21 | 45 | 22 | 45 | 55 | 6 | 134 | 28 | 18 | 31 | 123 | 119 | 98 |
| 19 | 15 | 59 | 14 | 77 | 21 | 31 | 7 | 52 | 92 | 19 | 18 | 48 | 4 | 5 | 37 | 3 | 1 | 49 | 4 | 12 | 16 | 11 | 8 | 15 | 16 | 6 | 10 | 4 | 35 | 11 | 9 | 12 | 12 | 123 | 67 | 46 | 243 | 185 | 265 | 149 |
| 20 | 19 | 19 | 16 | 76 | 9 | 26 | 4 | 37 | 31 | 10 | 15 | 63 | 4 | 2 | 42 | 5 | 14 | 12 | 7 | 6 | 15 | 1 | 27 | 18 | 7 | 5 | 6 | 22 | 11 | 10 | 7 | 24 | 155 | 64 | 37 | 374 | 80 | 368 | 94 | |
| 21 | 34 | 6 | 28 | 327 | 14 | 66 | 10 | 31 | 27 | 10 | 4 | 29 | 1 | 2 | 12 | 2 | 2 | 3 | 19 | 16 | 6 | 19 | 2 | 19 | 13 | 3 | 11 | 16 | 35 | 2 | 6 | 19 | 18 | 362 | 105 | 44 | 117 | 80 | 288 | 41 |
| 22 | 18 | 11 | 25 | 454 | 21 | 92 | 3 | 13 | 35 | 8 | 4 | 22 | 6 | 4 | 7 | 1 | 4 | 2 | 15 | 14 | 6 | 26 | 1 | 13 | 28 | 7 | 11 | 17 | 23 | 2 | 3 | 20 | 30 | 278 | 82 | 55 | 98 | 93 | 118 | 53 |
| 23 | 19 | 14 | 13 | 410 | 26 | 36 | 7 | 12 | 31 | 14 | 3 | 22 | 2 | 1 | 1 | 19 | 3 | 11 | 16 | 5 | 42 | 1 | 12 | 38 | 7 | 44 | 8 | 20 | 3 | 2 | 24 | 12 | 59 | 52 | 67 | 46 | 110 | 51 | 71 | |
| 24 | 12 | 15 | 17 | 239 | 30 | 14 | 15 | 10 | 40 | 29 | 1 | 20 | 2 | 1 | 1 | 24 | 1 | 11 | 12 | 12 | 21 | 12 | 66 | 13 | 24 | 17 | 4 | 5 | 6 | 2 | 31 | 24 | 33 | 8 | 48 | 24 | 45 | | | |
| 25 | 8 | 15 | 18 | 188 | 46 | 10 | 11 | 13 | 27 | 35 | 1 | 12 | 2 | 4 | 17 | 18 | 8 | 6 | 11 | 11 | 61 | 4 | 11 | 7 | 4 | 5 | 5 | 5 | 13 | 7 | 6 | 8 | 16 | 16 | | | | | | |
| 26 | 1 | 8 | 47 | 163 | 32 | 12 | 5 | 13 | 22 | 19 | 2 | 14 | 1 | 2 | 1 | 19 | 1 | 9 | 9 | 5 | 2 | 9 | 19 | 1 | 3 | 4 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 5 | | | | | |
| 27 | 2 | 3 | 44 | 133 | 12 | 7 | 10 | 8 | 17 | 6 | 2 | 7 | 2 | 2 | 3 | 13 | 1 | 10 | 6 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | | | | | |
| 28 | 1 | 23 | 41 | 17 | 9 | 3 | 5 | 4 | 5 | 5 | 4 | 1 | 1 | 1 | 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | |
| 29 | 1 | 8 | 50 | 6 | 3 | 1 | 5 | 3 | 4 | 1 | 1 | 2 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| 30 | 1 | 2 | 21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 34 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 35 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 36 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 37 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 7: Length frequency of blueback herring from the coastwide NEFSC bottom trawl survey during the fall.

| Length | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1993 | 1994 | 1995 | 1996 | 1997 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 8: Length frequency of blueback herring from the NEFSC bottom trawl survey in the northern region during the spring.

| Length | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | 5 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | 1 | 11 | 5 | 41 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | 3 | 3 | 17 | 17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | 7 | 2 | 29 | 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | 7 | 4 | 23 | 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 2 | 2 | 1 | 10 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | 3 | 1 | 2 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | 1 | 1 | 4 | 1 | 1 | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | 3 | 1 | 1 | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | 7 | 9 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | 1 | | 8 | 7 | 1 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | | | 23 | 12 | 3 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | 1 | 20 | 12 | 2 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 13 | 11 | 9 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 5 | 6 | 6 | 6 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 9: Length frequency of blueback herring from the NEFSC bottom trawl survey in the southern region during the spring.

| Length | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 1 | | 8 | | | 1 | | 3 | | 1 | 3 | | | | | | | 1 | 13 | 6 | | 1 | | 1 | | | | | | | | 1 | | | | | | | | |
| 9 | 4 | 1 | 68 | | 5 | 169 | 41 | 17 | 10 | 40 | 48 | | 2 | | 9 | 2 | | 2 | 34 | 3 | 52 | 1 | | 1 | 10 | 2 | 1 | 14 | | 3 | | 3 | | 5 | | | | | | |
| 10 | 15 | 59 | | 2 | 60 | 10 | 23 | 4 | 3 | 10 | | 4 | 10 | | | | | 2 | 26 | 4 | 45 | 1 | | 1 | 12 | 1 | 1 | 10 | | 1 | 10 | | 1 | 7 | | 6 | | | | |
| 11 | 4 | 2 | 1 | 2 | 7 | 7 | 26 | | 2 | 2 | 8 | 11 | | | | | 9 | 45 | 5 | 1 | 15 | | | 1 | 11 | 3 | | 1 | 3 | | 5 | 1 | 1 | 8 | | | | | | |
| 12 | 4 | 4 | 2 | | 14 | 8 | 12 | 4 | 2 | 2 | 4 | 10 | | 1 | | 25 | 47 | 7 | 1 | 17 | | | | 1 | 4 | 1 | | 5 | | 3 | | 3 | 2 | 8 | | | | | | |
| 13 | 7 | | | | 4 | 8 | 2 | 6 | 1 | 4 | 2 | | 41 | 6 | 4 | | 10 | | | | | | 1 | 5 | 7 | 2 | | 2 | | 6 | 2 | 45 | | | | | | | | |
| 14 | 1 | 2 | | | 6 | 16 | | 3 | 12 | | 2 | 7 | 2 | | 89 | 16 | | | 2 | 9 | | | | 3 | 1 | | 1 | | 1 | 5 | | 45 | | | | | | | | |
| 15 | 5 | 1 | 31 | 3 | 81 | 6 | 1 | 15 | 6 | 13 | 13 | 4 | 9 | | 111 | 54 | 6 | 3 | 19 | | | | 2 | 3 | 1 | 1 | 1 | 5 | | | | 15 | | | | | | | | |
| 16 | 4 | 25 | 1 | 168 | 1 | 125 | 19 | 4 | 49 | 15 | 10 | 14 | 2 | 13 | 2 | 3 | 131 | 94 | 11 | 6 | 39 | | 1 | 3 | 13 | 3 | 1 | 4 | 1 | 34 | | 7 | | | | | | | | |
| 17 | 2 | 37 | 2 | 407 | 13 | 82 | 15 | 17 | 137 | 57 | 46 | 45 | 2 | 22 | 8 | 12 | 42 | 77 | 6 | 5 | 63 | 9 | 4 | 1 | 7 | 14 | 10 | 24 | 5 | 61 | 2 | 16 | 44 | 8 | 5 | | | | | |
| 18 | 6 | 68 | 5 | 196 | 22 | 51 | 14 | 62 | 247 | 24 | 32 | 51 | 2 | 19 | 39 | 13 | 7 | 47 | 3 | 9 | 35 | 14 | 2 | 5 | 7 | 18 | 38 | 15 | 39 | 4 | 113 | 14 | 18 | 17 | 78 | 71 | 25 | | | |
| 19 | 8 | 59 | 10 | 54 | 12 | 31 | 6 | 50 | 91 | 6 | 16 | 44 | 1 | 5 | 37 | 2 | 44 | 4 | 12 | 16 | 11 | 1 | 7 | 3 | 4 | 2 | 4 | 30 | 10 | 2 | 6 | 10 | 95 | 32 | 28 | 227 | 146 | 165 | 39 | |
| 20 | 17 | 17 | 15 | 66 | 6 | 26 | 4 | 36 | 25 | 7 | 14 | 60 | 3 | 2 | 42 | | 5 | 12 | 12 | 7 | 5 | 13 | 1 | 18 | 8 | 1 | 1 | 3 | 21 | 11 | 7 | 5 | 22 | 144 | 37 | 28 | 341 | 30 | 70 | 13 |
| 21 | 31 | 5 | 26 | 325 | 14 | 66 | 9 | 31 | 13 | 9 | 4 | 26 | | | | 12 | 2 | 3 | 19 | 14 | 2 | 18 | 1 | 15 | 11 | 3 | 7 | 13 | 35 | 2 | 6 | 15 | 14 | 354 | 83 | 33 | 99 | 11 | 42 | 14 |
| 22 | 17 | 10 | 25 | 450 | 20 | 92 | 2 | 13 | 25 | 8 | 4 | 21 | 6 | 4 | 7 | 1 | 4 | 2 | 14 | 13 | 2 | 25 | | 6 | 27 | 6 | 6 | 16 | 23 | 2 | 3 | 14 | 19 | 271 | 72 | 44 | 78 | 56 | 32 | 46 |
| 23 | 16 | 13 | 12 | 402 | 26 | 36 | 6 | 12 | 31 | 14 | 1 | 22 | 2 | 1 | 1 | 19 | 3 | 11 | 16 | 2 | 42 | 1 | 7 | 37 | 7 | 35 | 7 | 18 | 2 | 2 | 15 | 8 | 55 | 46 | 59 | 38 | 86 | 11 | 68 | |
| 24 | 12 | 15 | 10 | 230 | 27 | 14 | 12 | 10 | 40 | 29 | | 20 | | 2 | 1 | 24 | 1 | 10 | 12 | 4 | 21 | | 4 | 66 | 13 | 21 | 16 | 3 | 3 | 2 | 1 | 28 | 20 | 33 | 3 | 41 | 13 | 42 | | |
| 25 | 7 | 15 | 10 | 181 | 45 | 10 | 9 | 12 | 27 | 35 | 1 | 12 | | 2 | | 1 | 17 | 9 | 8 | 2 | 11 | | 4 | 61 | 4 | 10 | 6 | 7 | | 2 | 2 | 11 | 6 | 6 | 6 | 8 | 6 | 15 | | |
| 26 | 1 | 8 | 24 | 151 | 29 | 12 | 4 | 13 | 22 | 18 | 2 | 12 | 1 | 1 | 1 | 19 | 1 | 3 | 9 | 2 | 1 | | 4 | 19 | 1 | 3 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | | | | | |
| 27 | 2 | 2 | 24 | 121 | 10 | 7 | 7 | 8 | 17 | 6 | 2 | 7 | 2 | | | | 10 | | | | | | | 3 | 1 | | 1 | | | | | | | | | | | | | |
| 28 | 1 | 10 | 30 | 8 | 6 | 3 | 5 | 4 | 5 | 5 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 1 | 3 | 44 | | | 2 | 1 | 5 | 3 | 4 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | 1 | 1 | 21 | | | 1 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |



Figure 1: NEFSC bottom trawl survey strata comprising the northern and southern regions. The division between regions reflects the median months of sampling in the spring survey: April in the north and March in the south.

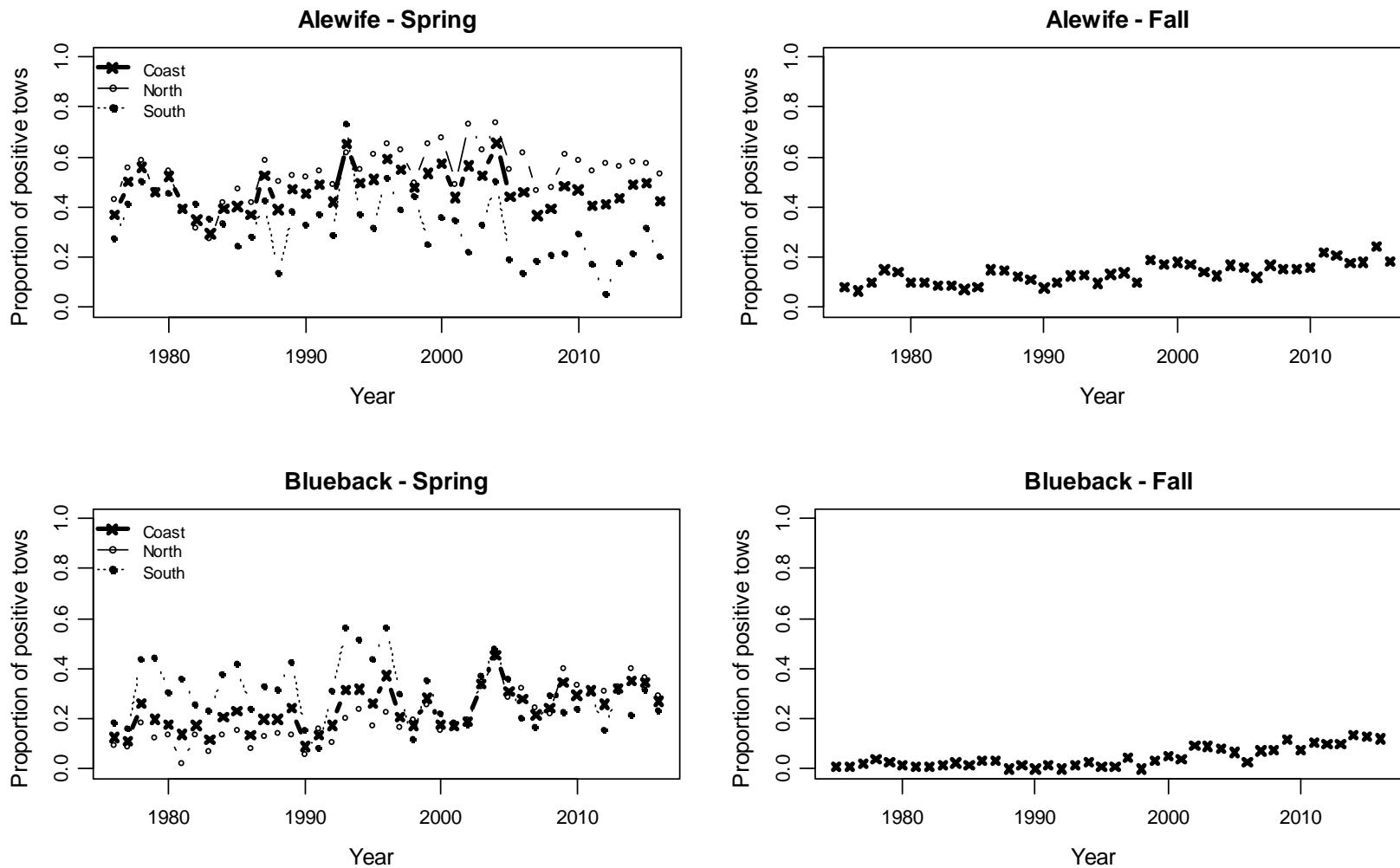


Figure 2: Proportions of positive tows for alewife, blueback herring, and combined species from the NEFSC spring (1976-2011) and fall (1975-2011) bottom trawl surveys. Survey strata were not separated into northern and southern regions for the fall survey.

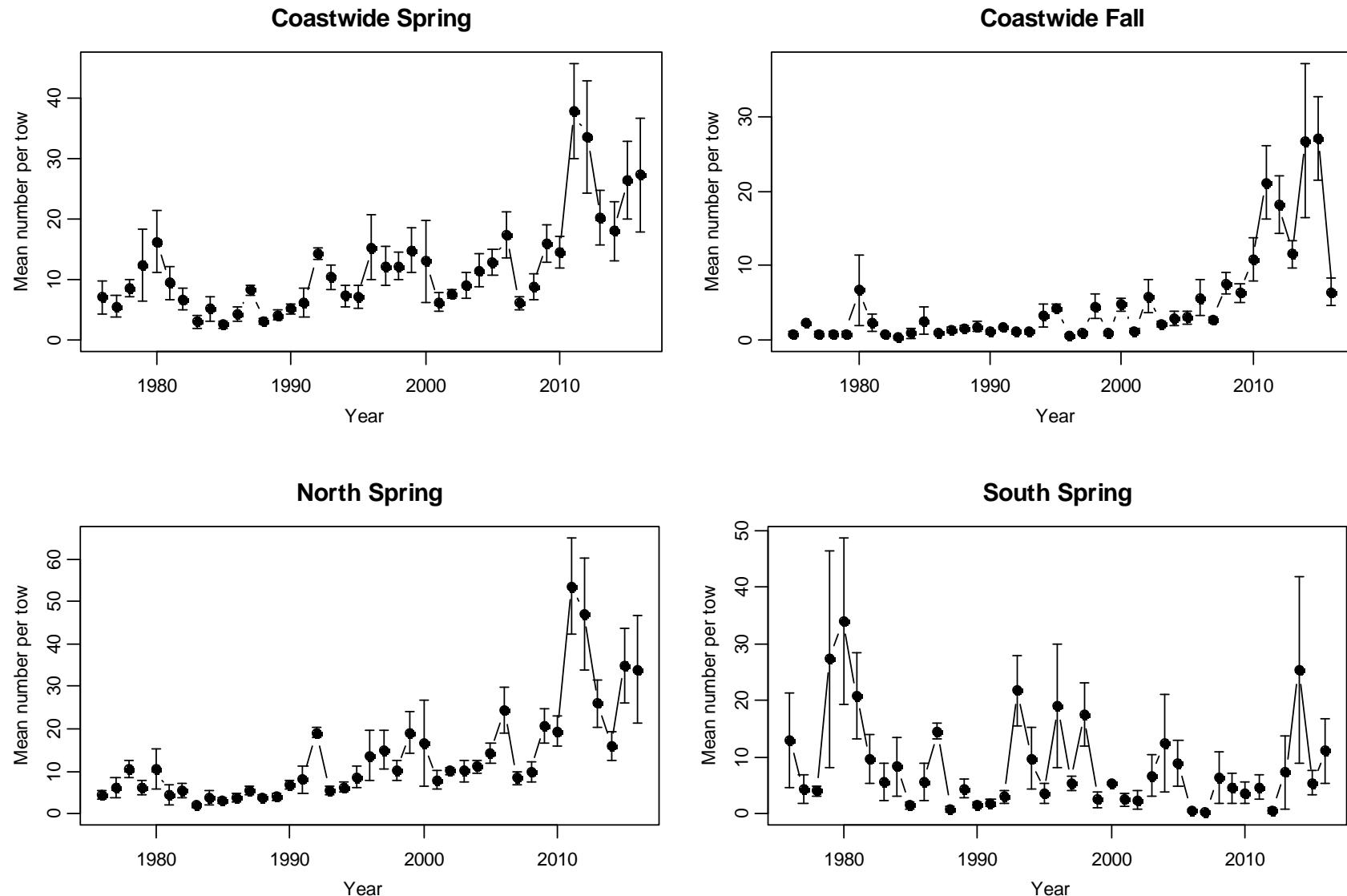


Figure 3: Stratified mean number-per-tow of alewife in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

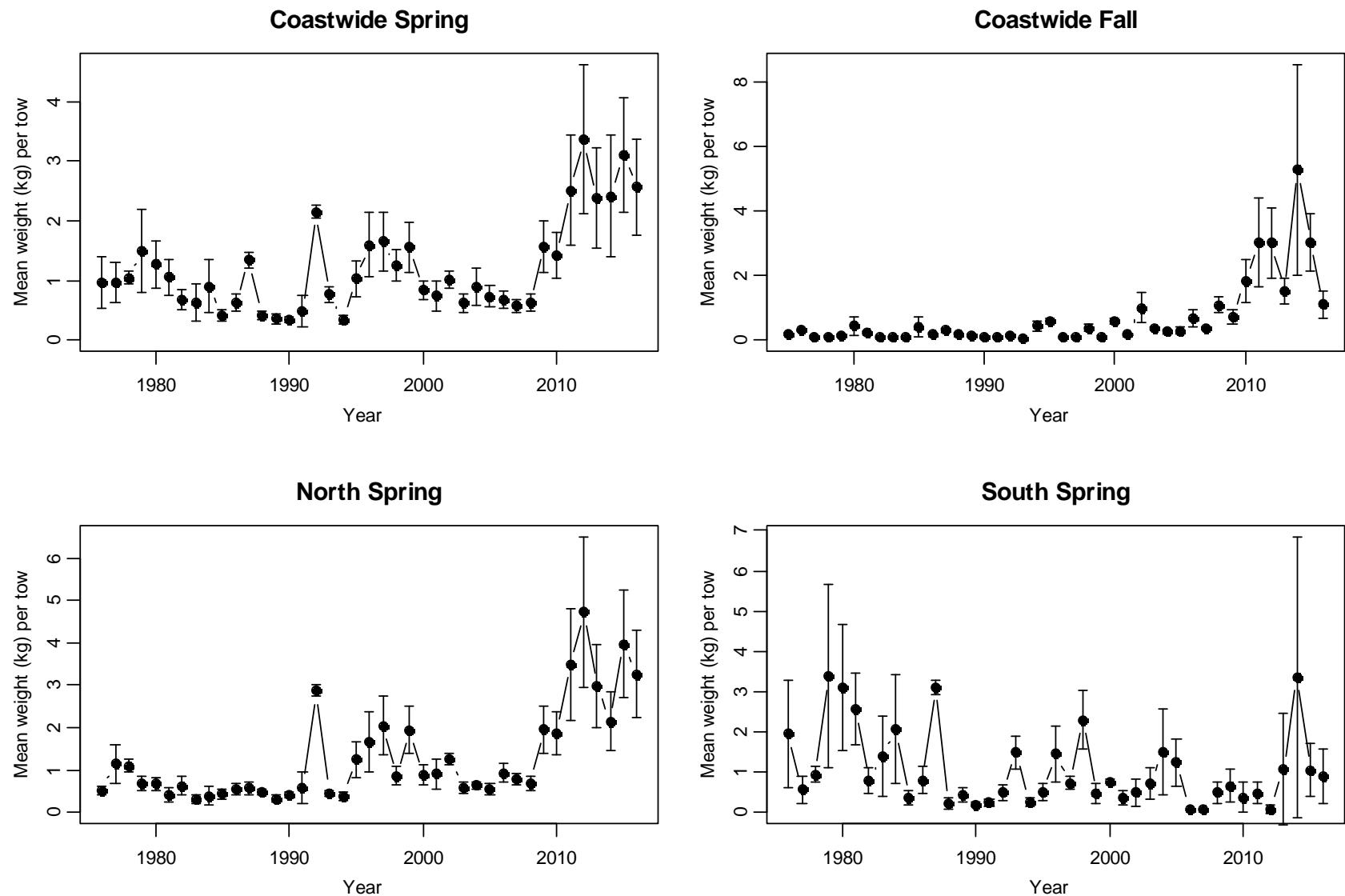


Figure 4: Stratified mean weight (kg)-per-tow of alewife in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

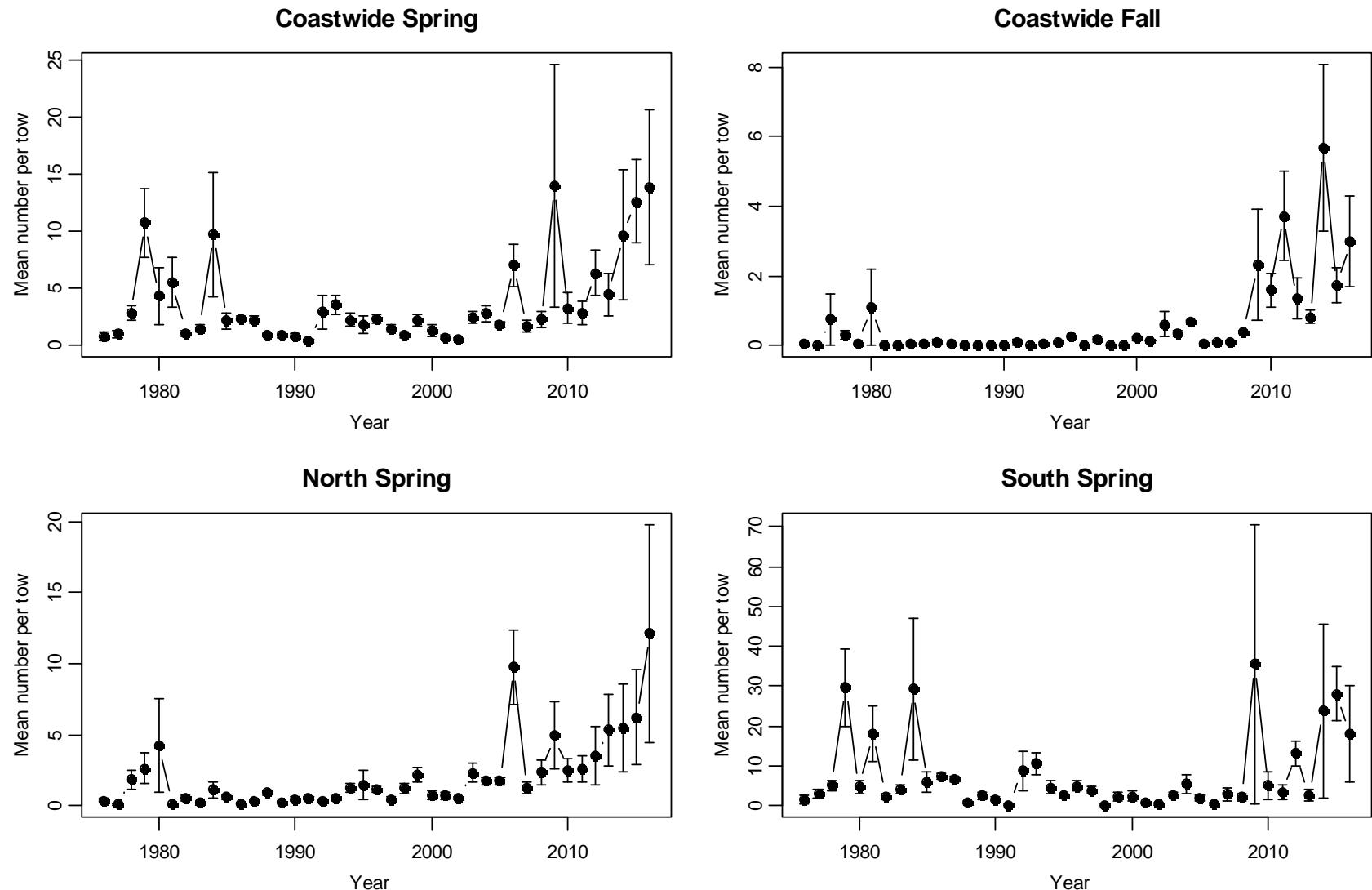


Figure 5: Stratified mean number-per-tow of blueback herring in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

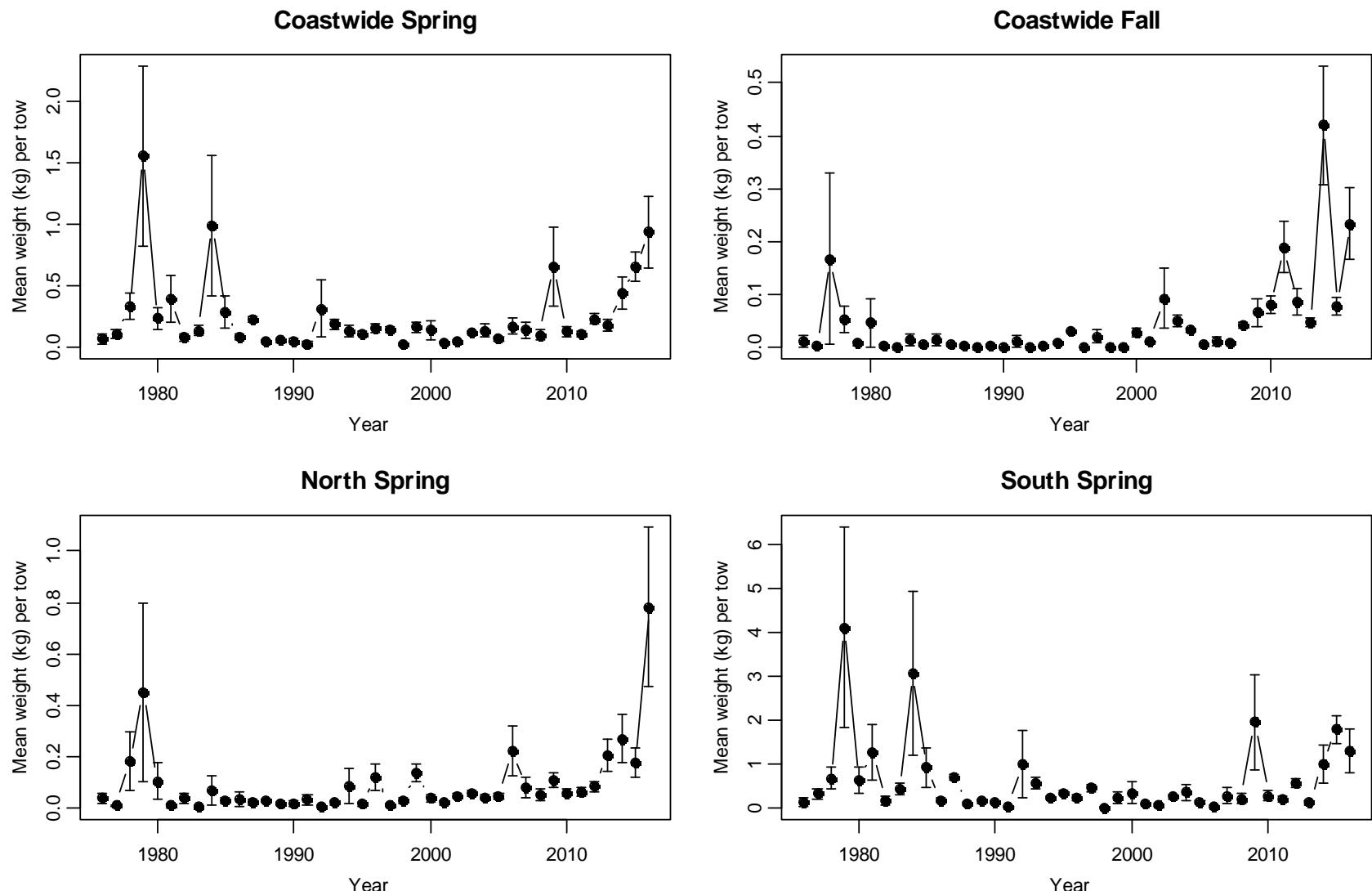


Figure 6: Stratified mean weight (kg)-per-tow of blueback herring in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.