Atlantic States Marine Fisheries Commission

River Herring Stock Assessment Update
Volume I: Coastwide Summary

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Vision: Sustainably Managing Atlantic Coastal Fisheries

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Prepared by the
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EXECUTIVE SUMMARY

This document provides an update to the 2012 benchmark assessment of river herring (alewife, *Alosa pseudoharengus*, and blueback herring, *Alosa aestivalis*) stocks of the U.S. Atlantic Coast from Maine through Florida (ASMFC 2012). It was prepared by the River Herring Stock Assessment Subcommittee (SAS) of the Atlantic States Marine Fisheries Commission (ASMFC) Shad and River Herring Technical Committee (TC). The analyses and descriptions stem from data and summary reports provided by U.S. federal and state freshwater and marine resource management agencies, power generating companies, and universities to the ASMFC. The assessment update was a recommendation of the SAS following the benchmark stock assessment.

"We recommend an update of trend analyses in 5 years and the next benchmark assessment for river herring be conducted in 10 years (finalized in 2022). Due to the high variability of fisheries independent surveys, a benchmark assessment at a shorter timeframe (e.g. 5 years) will likely not show any significant changes in indices of abundance. Any population changes resulting from closures of fisheries in 2012; improved access to historic spawning grounds; and additional beneficial management measures, such as sustainable fishing plans and action by the federal councils, cannot be expected to result in any population change until at least one cohort of river herring has grown to maturity (assuming age at maturity is 3 – 6 years). A 10 year timeframe for the next benchmark assessment will also allow a longer time series of estimated total incidental catch in non-targeted ocean fisheries to be evaluated."

The recommendation for an update was supported by the TC in 2016 in preparation for this stock assessment. An update of a stock assessment includes updating the peer-reviewed, and Management Board-accepted benchmark assessment approaches with recent data since the benchmark data terminal year (2010). The data terminal year of this update is 2015.

The benchmark assessment included assessment of Atlantic coastal river herring stocks on an individual river basis for a few systems and also on a limited coastwide basis. As an anadromous species, ideally river herring should be assessed and managed by individual river systems. However, the majority of the life history of river herring is spent in the marine environment where factors influencing survival likely have impacts upon multiple river stocks when they mix during marine migrations. The complex life history of anadromous species complicates assessments on a coastwide scale as it is difficult to partition in-river factors from marine factors governing population dynamics. Also complicating the assessment of river herring is the variability in data quality among rivers along the coast.

Severe declines in landings began coastwide in the early 1970s and domestic landings are now a fraction of what they were at their peak having remained at persistently low levels since the mid-1990s. Moratoria were enacted in Massachusetts (commercial and recreational in 2005), Rhode Island (commercial and recreational in 2006), Connecticut (commercial and recreational in 2002), Virginia (for waters flowing into North Carolina in 2007), and North Carolina (commercial and recreational in 2007, with the exception of a four day open season in the Chowan River during the week of Easter). As of January 1, 2012 states or jurisdictions without an approved sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP, were closed. As a result, prohibitions on harvest (commercial or recreational) were extended to the following states: New Jersey, Delaware, Pennsylvania, Maryland, D.C., Virginia (for all waters), Georgia and Florida.

Commercial CPUE

No CPUE data sets reflected declining trends over the last ten years of the update, with one of ten data sets showing an increasing trend and three showing no trend (Table 1). Six were not updated due to discontinuation or changes in methodology.

Run Counts

No run counts reflected declining trends over the last ten years of the updated data time series with eleven of twenty nine showing increasing trends, fourteen showing no trend, and four not being updated (two due to discontinuation and two due to agency recommendation; Table 1).

An updated cluster analysis using the most recent eight years (2008-2015) did not result in groupings of runs similar to the corresponding final eight year period (2003-2010) used in the benchmark analysis. It is difficult to discern any consistent trends as to why the two periods differ, but suggests that rivers along the Atlantic Coast that were previously grouped together for similar trends have not been experiencing similar population trends in the years since the benchmark.

Young-Of-The-Year Seine Surveys

Inclusion of datasets for the period after the benchmark up to 2015 did not show any changes in trends outlined in the benchmark assessment. One of sixteen YOY seine surveys indicated a declining trend over the last ten years, two indicated increasing trends, and thirteen indicated no trend (Table 1). Indices of alewife from young of year (YOY) seine surveys remained at relatively low levels similar to those seen for the period prior to 2011. Blueback herring also remained similar to levels observed in the terminal years of the benchmark assessment, although some surveys (Virginia, Maryland, and District of Columbia) have seen increases in 2014-2015.

Juvenile-Adult Fisheries-Independent Seine, Gillnet and Electrofishing Surveys

Seine CPUE for combined species in Narragansett Bay fluctuated without trend from 1988-1997, increased through 2000, declined and then remained stable from 2001-2004, increased again in 2005, and declined in 2009. The pond survey CPUE increased during 1993-1996, declined through 1998, increased in 1999, declined through 2002, peaked in 2012, and then declined and fluctuated without trend thereafter. Addition of data from 2011 to 2015 does not show a significant correlation ($p=0.413$) with the addition of more years of data, suggesting that the pond survey may not fully capture year-class strength.

The electrofishing CPUE indices for alewives and blueback herring in the Rappahannock River and James River were highly variable for the time series. The electrofishing CPUE indices for blueback herring in the St. John's River declined precipitously from 2001 to 2002 and has fluctuated without trends since 2003. The common trend among the Virginia and Florida electrofishing survey occurred in 2004 and 2015 when the Rappahannock River alewife index, James River blueback herring index, and St. John's River blueback herring index increased.

Juvenile and Adult Trawl Surveys

Trends in trawl survey indices varied greatly with one of twelve indicating a declining trend over the last ten years, four indicating increasing trends, and seven indicating no trend (Table 1). The probability of the final year of the survey being less than the 25th percentile reference point [$P(<0.25)$], as estimated with ARIMA, ranged from 0 to 0.464 for alewives and 0 to 0.540 for blueback herring.

Mean Length

Updated trend analysis shows a continuation of the declining mean size of both species mentioned in the benchmark assessment. A significant decline in mean length of alewives was in 4 of the 9 river systems examined (Table 1). Similarly, blueback herring mean length is significantly declining in 6 of the 9 river systems examined (Table 1). Trends in mean lengths from the NEFSC bottom trawl survey were similar to those of the benchmark.

Maximum Age

Data provided in the update added little information to this visual analysis. In terms of maximum age no trends appear reversed and most runs had stable ages. Lamprey River (NH) alewife maximum age appears to be trending upward, while Nanticoke River (MD) alewife and blueback herring, and Chowan River (NC) blueback herring maximum ages appear to have dropped (Table 1).

Mean Length-at-Age

Of the 112 Rivers-Species-Age combinations updated (111 with data, as there was no data available for Gilbert-Stuart Alewife Male age 6), 26 have reversed in terms of their significance when compared to the analysis preformed in the benchmark assessment. Declines in mean length of at least one age were observed in most rivers examined. There is little indication of a general pattern of size changes along the Atlantic coast.

Repeat Spawner Frequency

There have been no increasing trends in the percent repeat spawners over the full data time series, with declining trends in three rivers assessed and no significant trends for all other data sets (Table 1).

Total Mortality (Z) Estimates

There have been no increasing trends in empirical total mortality estimates over the last ten years of the updated data time series. Three trends have declined and ten have shown no trend (Table 1). 2013-2015 average total mortality estimates for twelve rivers exceeded $Z_{40\%,M=0.7}$ benchmarks, while averages for two rivers were below these benchmarks (Table 2). All 2008-2010 average estimates from the benchmark assessment exceeded $Z_{40\%,M=0.7}$ benchmarks.

Exploitation Rates

In-river exploitation of river herring since the benchmark assessment appears to have declined or remained stable for the two Maine rivers where still observed. Coastwide relative exploitation since the benchmark stock assessment is the lowest of the time series, averaging 0.05.

Stock Status

Of the 54 in-river stocks of river herring for which data were available, 16 experienced increasing trends over the ten most recent years of the update assessment data time series, 2 experienced decreasing trends, 8 were stable, 10 experienced no discernible trend/high variability, and 18 did not have enough data to assess recent trends, including 1 that had no returning fish. The coastwide meta-complex of river herring stocks on the US Atlantic coast remains depleted to near historic lows. A depleted status indicates that there was evidence for declines in abundance due to a number of factors, but the relative importance of these factors in reducing river herring stocks could not be determined.

Table 1. Summary of river herring trends from select rivers along the Atlantic Coast.

State	River**	Commercial CPUE		Run Counts		YOY survey		Z		Trawl Survey†		Mean Length	Max Age	Percent Repeat Spawners	Updated Recent Trends*
		2006-2015	Full Time-series	2006-2015	Full Time-series	2006-2015	Full Time-series	2006-2015	Full Time-series	2006-2015	Full Time-series	Full Time-series	Full Time-series	Full Time-series	2006-2015
NE U.S. Continental Shelf (NMFS Bottom Trawl)^										↑[A,B]	↘↗[A], →↗[B]	↓[A], n.s.[B]			Increasing[A,B]
ME	Androscoggin			↑[A]	↑[A]			↔[A]	↔[A]			n.s.[A]	↔[A]	↓[A]	Increasing[A]
	Kennebeck			↑[RH]	↑[RH]										Increasing[RH]
	Sebasticook			↑[RH]	↑[RH]	↔[A,B]	↔[A], ↑[B]	↔[A]	↔[A]						Increasing[RH]
	Damariscotta			↑[A]	↘↗[A]										Increasing[A]
	Union			↔[A]	↔[A]										No Trend[A]
NH	Cocheco			↑[RH]	↑[RH]			↓[A]	↓[A,BF], ↔[BM]	↑[A], ↔[B]	↑[A], ↓[B]	n.s.[A,BF], ↓[BM]	↔[A,B]	n.s.[A,B]	Increasing[A,B]
	Exeter			↔[RH]	↔[RH]							↓[AM], n.s.[AF]	↔[A]	n.s.[A]	Stable[RH]
	Lamprey			↑[RH]	↑[RH]			↓[AM], ↔[AF]	↓[AM], ↔[AF]			n.s.[A]	↑[A]	n.s.[A]	Increasing[RH]
	Oyster			↔[RH]	↗↘[RH]			↔[B]	↔[B]			↓[B]	↔[B]	n.s.[B]	Decreasing[RH]
	Taylor			D (2015)	↓[RH]									D (2010)	No Returns[RH]
	Winnicut			D (2011)	↔[RH]			D (2011)	↔[A,B]			n.s.[A,B]	D (2011)	D (2010)	Unknown[A,B]
MA	Mattapoisett			↑[A]	↔[A]										Increasing[A]
	Monument			↑[A,B]	↗↘[A], ↓[B]			↔[A]	[AM,BF], ↔[AF,BM]			↓[A,B]	↔[A,B]	↓[A,B]	Increasing[A,B]
	Nemasket			↑[A]	↔[A]			↔[A]	↔[A]					n.s.[A]	Increasing[A]
	Parker			↔[A]	↓[A]				↔[A]						Stable[A]
	Stony Brook														Unknown[A]
RI	Buckeye			↔[A]	↔[A]										Increasing[A]
	Gilbert			↔[A]	↗↘[A]	↔[RH]	↔[RH]	↔[A]	↑[A]	↔[A], ↓[B]	↑[A], ↔[B]		↔[A]	↓[A]	Stable[A]
	Nonquit			↔[A]	↓[A]			↓[A]	↓[A]					n.s.[A]	Decrease[A]
CT	Bride Brook			↑[A]	↑[A]										Increasing[A]
	Connecticut			↔[B]	↗↘[B]	↔[B]	↓[B]								Stable[B]
	Farmington			X	X										Unknown[A,B]
	Mianus			↔[A,B]	↔[A,B]					↔[A,B]	↑[A], ↓[B]				No Trend[A],Increasing[B]
	Mill Brook			↔[A]	↔[A]										No Trend[A]
	Naugatuck			X	X										Unknown[A,B]
	Shetucket			↔[A,B]	↔[A,B]										No Trend[A], Stable[B]
State	River**	Commercial CPUE		Run Counts		YOY survey		Z		Trawl Survey†		Mean Length	Max Age	Percent Repeat Spawners	Updated Recent Trends*
		2006-2015	Full Time-series	2006-2015	Full Time-series	2006-2015	Full Time-series	2006-2015	Full Time-series	2006-2015	Full Time-series	Full Time-series	Full Time-series	Full Time-series	2006-2015
NY	Hudson	↑[RH]	↘↗[RH]			↓[A], ↔[B]	↔[A,B]					↔[A,B]			Increasing[RH]
NJ, DE,PA	Delaware	D (2012)	↓[RH]			↔[A,B]	↔[A], ↓[B]			↑[A], ↔[B]	↔[A], ↑[B]				No Trend[A,B]
MD, DE	Nanticoke	D (2012)	↓[RH]			↔[A,B]	↔[A,B]	↔[A,B]	↔[A,B]			↓[A,B]	↓[A,B]	↓[AM,B], n.s.[AF]	Stable[A],No Trend[B]
VA, MD, DC	Potomac	D (2012)	↓[RH]			↔[A], ↑[B]	↓[A], ↑[B]								Stable[A],Unknown[B]
VA	James	D (2013)	↔[A]												Unknown[A,B]
	Rappahannock	D (2013)	↗↘[A]			↔[A], ↑[B]	↔[A,B]								No Trend[A],Increasing[B]
	York	D (2013)	→↗[A]												Unknown[A,B]
NC	Alligator								↔[A,B]						Unknown[A,B]
	Chowan	↔[A,B]	↓[A,B]	↔[B]	↓[A,B]	↔[A,B]	↔[A], ↓[B]	↔[B]	↔[A,B]	↔[A,B]	↘↗↘[A], ↓[B]	↓[A,B]	↓[A,B]	n.s.[A,B]	No Trend[A],Stable[B]
	Scuppernog								↔[A,B]						Unknown[A,B]
SC	Santee-Cooper	↔[B]	↘↗[B]		↑[B]				↓[B]			n.s.[B]			No Trend[B]
FL	St. Johns River											↓[BF], n.s.[BM]			Unknown[B]

†: Adult or all age fish only; trawl surveys take place in bay or inshore state ocean waters
n.s. Trend was not statistically significant
Supers Data Available for
- A Alewife only
- B Blueback herring only
- A,B Alewife and blueback herring by species
- RH Alewife and blueback herring combined (river herring)
- F Female. If sex is not noted, trends were either the same between sexes or the trend was evaluated for sexes combined.
- M Male. If sex is not noted, trends were either the same between sexes or the trend was evaluated for sexes combined.
- ↔ No trend (flat or high inter-annual variability)
- XXX Consensus not reached
- No data. If data sets ended before the benchmark terminal year of 2010, the cell for recent trends is left blank.

*Updated recent trends reflects the most recent ten years (2006-2015). No trend indicates high inter-annual variability and stable indicates flat.
**Table reflects rivers that had data in addition to landings. Refer to the state chapter and/or coastwide summary for a complete list of assessed rivers and trends.
- D Data collection discontinued since the terminal year of the benchmark assessment. Year data collection discontinued in parenthesis.
- X Data collection continuous, but recommended against use in assessment update (see state chapter for details).

^NE shelf trends are from the spring, coastwide survey data which encounters river herring more frequently than the fall survey

Table 2. 2013-2015 average Z estimates by river with associated $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

Z (red)	3 year average of Z is above both the Z-20% and Z-40% benchmarks
XXXXXXX (red)	No estimates of Z due to lack of returning fish
Z (yellow)	3 year average of Z is between the Z-20% and Z-40% benchmarks
Z (green)	3 year average of Z is below both the Z-20% and Z-40% benchmarks
(blank)	No current estimates of Z are available

State	River	Species	$Z_{40\% (M=0.7)}$	$Z_{20\% (M=0.7)}$	Benchmark $Z_{3yr\text{-}Avg}$	Update $Z_{3yr\text{-}Avg}$
ME	Androscoggin	Alewife	0.93	1.12	1.40*(1.35)	2.13
	Kennebeck	River herring				
	Sebasticook	Alewife	0.93	1.12	1.30*(1.67)	1.21
	Damariscotta	Alewife				
	Union	Alewife				
NH	Cocheco	Alewife	0.92	1.11	1.03	0.37
	Cocheco	Blueback	0.95	1.15	1.14	XXXXXXX
	Exeter	Alewife				
	Lamprey	Alewife	0.92	1.11	1.18	0.63
	Oyster	Blueback	0.95	1.15	1.02	1.60
	Taylor	Blueback				
	Winnicut	Alewife	0.92	1.11	1.12	XXXXXXX
	Winnicut	Blueback	0.95	1.15	1.80*(1.53)	XXXXXXX
MA	Mattapoisett	Alewife				
	Monument	Alewife	0.92	1.11	1.19	2.48
	Monument	Blueback				
	Mystic	Alewife	0.92	1.11	1.14	1.01
	Nemasket	Alewife	0.92	1.11	1.23	1.69
	Parker	Alewife				
	Stony Brook	Alewife				
	Town	Alewife	0.92	1.11	1.06	1.27
RI	Buckeye	Alewife				
	Gilbert	Alewife	0.94	1.14	1.80	1.66
	Nonquit	Alewife	0.94	1.14	1.81	1.68
CT	Bride Brook	Alewife				
	Connecticut	Blueback				
	Farmington	Alewife				
	Farmington	Blueback				
	Mianus	Alewife				
	Mianus	Blueback				
	Mill Brook	Alewife				
	Naugatuck	Alewife				
	Naugatuck	Blueback				
	Shetucket	Alewife				
	Shetucket	Blueback				
NY	Hudson	Alewife				
	Hudson	Blueback				
NJ, DE, PA	Delaware	Alewife				
	Delaware	Blueback				
MD	Nanticoke	Alewife	0.93	1.13	1.08	1.35
	Nanticoke	Blueback	0.92	1.11	1.34	1.05
VA-MD-DC	Potomac	Alewife				
	Potomac	Blueback				
VA	James	Alewife				
	James	Blueback				
	Rappahannock	Alewife				
	Rappahannock	Blueback				
	York	Alewife				
	York	Blueback				
NC	Alligator	Alewife				
	Alligator	Blueback				
	Chowan	Alewife	0.93	1.12	1.60	
	Chowan	Blueback	0.92	1.11	1.07	1.15
	Scuppernog	Alewife				
	Scuppernog	Blueback				
SC	Santee-Cooper	Blueback				

*Estimate changed due to new data discovered following the benchmark stock assessment. The original estimate from the benchmark stock assessment is in parentheses.

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TERMS

Stock Assessment: An evaluation of a stock, including age and size composition, reproductive capacity, mortality rates, stock size, and recruitment.

Benchmarks: A particular value of stock size, catch, fishing effort, and fishing mortality that may be used as a measurement of stock status or management plan effectiveness. Sometimes these may be referred to as biological reference points.

Bycatch: The total catch of river herring, regardless of final disposition, that is taken in fishery operations that target other species.

Catch Curve: An age-based analysis of the catch in a fishery that is used to estimate total mortality of a fish stock. Total mortality is calculated by taking the negative slope of the logarithm of the number of fish caught at successive ages (or with 0, 1, 2... annual spawning marks).

Catch-Per-Unit-Effort (CPUE): The number or weight of fish caught with a given amount of fishing effort.

Cohort: See "Year Class."

Discard: A portion of what is caught and returned to the sea unused. Discards may be either alive or dead.

Exploitation: The annual percentage of the stock removed by fishing either recreationally or commercially.

Fish Passage: The movement of fish above or below an river obstruction, usually by fish-lifts or fishways.

Fish Passage Efficiency: The percent of the fish stock captured or passed through the anthropogenic obstruction.

Fishing Mortality (F): The instantaneous rate at which fish in a stock die because of fishing.

Habitat: All of the living and non-living components in a localized area necessary for the survival and reproduction of a particular organism.

Historic Potential: Historic population size prior to habitat losses due to dam construction and reductions in habitat quality

Iteroparous: Life history strategy characterized by the ability to spawn in multiple seasons.

Incidental catch: See bycatch

Mortality: The rate at which fish die. It can be expressed as annual percentages or instantaneous rates (the fraction of the stock that dies within each small amount of time).

Natural Mortality (M): The instantaneous rate at which fish die from all causes other than harvest or other anthropogenic cause (i.e., turbine mortality). Some sources of natural mortality include predation, spawning mortality, and senescence.

Oxytetracycline (OTC): An antibiotic used to internally mark otoliths of hatchery produced fish.

Recovery: Describes the condition of when a once depleted fish stock reaches a self-sustaining or other stated target level of abundances.

Recruitment: A measure of the weight or number of fish that enter a defined portion of the stock, such as the fishable stock or spawning stock.

Relative Exploitation: An approach used when catch is known or estimated, but no estimates of abundance are available. For example, it may be calculated as the catch divided by a relative index of abundance. Long-term trends in relative exploitation are can be useful in evaluating the impact of fishing versus other sources of mortality.

Restoration: In this assessment, this describes the stocking of hatchery produced young-of-year to augment wild cohorts and the transfer of adults to rivers with depleted spawning stocks. Restoration also includes efforts to improve fish passage or remove barriers to migration.

River herring: Refers to both alewife and blueback herring.

Run Size: The magnitude of the upriver spawning migration of anadromous fish.

Semelparous: Life history strategy in which an organism only spawns once before dying.

Senescence: The process of ageing.

Spawning Stock Biomass: The total weight of mature fish (often females) in a stock.

Stock: A part of a fish population usually with a particular migration pattern, specific spawning grounds, and subject to a distinct fishery.

Stock Status: The agreed perspective of the SASC of the relative level of fish abundance

Sub-adult: Juvenile river herring which are part of the ocean migratory mixed-stock fish.

Total Mortality (Z): The instantaneous rate of removal of fish from a population from both fishing and natural causes.

Year Class: Fish of a particular species born during the same year.

Yield-per-Recruit: The expected lifetime yield per fish of a specific cohort.

1.0 INTRODUCTION

This document provides an update to the 2012 benchmark assessment of river herring (alewife, *Alosa pseudoharengus*, and blueback herring, *Alosa aestivalis*) stocks of the U.S. Atlantic Coast from Maine through Florida (ASMFC 2012). It was prepared by the River Herring Stock Assessment Subcommittee (SAS) of the Atlantic States Marine Fisheries Commission (ASMFC) Shad and River Herring Technical Committee (TC). The analyses and descriptions stem from data and summary reports provided by U.S. federal and state freshwater and marine resource management agencies, power generating companies, and universities to the ASMFC. The assessment update was a recommendation of the SAS following the benchmark stock assessment. For additional details on the results of the benchmark stock assessment, as well as other aspects of river herring such as biology, habitat, and historical fisheries, refer to the benchmark stock assessment report.

1.1 STATE REGULATIONS

Updated by: Ashton Harp, Atlantic States Marine Fisheries Commission; Benchmark Assessment Section by: Dr. Gary Nelson, Massachusetts Division of Marine Fisheries and Kate Taylor, Atlantic States Marine Fisheries Commission

States can harvest river herring if the specific regulations have been approved through a sustainable fisheries management plan (SFMP), as required under ASMFC Amendment 2 to the Shad and River Herring FMP. The SFMP must demonstrate a stock can support a commercial or recreational harvest that will not diminish potential future stock reproduction and recruitment. Data to substantiate these claims can include repeat spawning ratio, SSB, juvenile abundance levels, fish passage counts, bycatch rates, etc. Descriptions of state-specific regulations follow and are also summarized in Appendix 2.

Maine

In 2010, the Board approved the first SFMP to harvest river herring in Maine waters. In 2017, the Board approved an updated SFMP which included a request to open the Card Mill Stream in the town of Franklin for commercial harvest.

Maine has thirty-eight municipalities with the exclusive right to commercially harvest river herring. Currently, twenty-two municipalities actively harvest river herring. Directed commercial harvest of alewife or blueback herring does not occur in the main stem of nine of Maine's largest rivers (Penobscot, Kennebec, Androscoggin, Saco, St. Croix, Presumpscot, Machias, Salmon Falls, and East Machias). Commercial fisheries do exist on the tributaries of larger rivers.

Recreational fishermen are allowed to harvest four-days per week throughout the year. 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 fishing for river herring in Maine is limited and landings are low.

The primary sustainability threshold is an escapement number equal to 35-fish per surface acre of spawning habitat. Escape numbers are measured through passage counts above commercial fisheries and managed by closed fishing days, season length, gear restrictions or continuous escapement. If the escapement threshold is not met than the commercial fishery will close for conservation.

New Hampshire

In 2011, the Board approved the first SFMP to harvest river herring in New Hampshire waters. In 2012, the Oyster River was closed to the taking of river herring by any methods from the head-of-tide dam at Mill Pond to the mouth of the river at Little Bay. In 2015, the Board approved an updated SFMP.

River herring in New Hampshire are currently managed as a statewide management unit with two sustainability targets (one fishery-dependent and one fishery-independent) were established in the SFMP using exploitation rates and numbers of returning river herring per surface acre of available spawning habitat in the Great Bay Estuary. This method was chosen because at least 95% of the river herring harvest in New Hampshire occurs in this estuary and there are currently fish ladders on four of the seven rivers in the Great Bay Estuary, each of which are monitored by the Department annually. Historical monitoring of river herring runs within New Hampshire have shown that the numbers of returning river herring to these four rivers have accounted for greater than 80% of the returning fish enumerated annually at fish passage structures on New Hampshire coastal rivers

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. The fishery-independent sustainability threshold is an escapement number equal to 350-fish per surface acre of spawning habitat (72,450 fish). This target level is slightly above 50% of the mean annual river herring return to the Great Bay Estuary since 1990.

Massachusetts

In 2005, the Massachusetts Marine Fisheries Advisory Commission approved a three year moratorium regulation on the harvest, possession and sale of river herring in the Commonwealth in response to declines of many river herring spawning runs. The moratorium was extended through 2015.

In 2016, Massachusetts prepared a SFMP for the Nemasket River in response to a 2013 request to open the fishery from the Middleborough-Lakeville Herring Fishery Commission. The Board approved the SFMP in October 2016. The primary sustainability measure to monitor run status is the ongoing run count. Harvest will be capped at 10% of the time series mean (TSM), to be calculated each year. The plan also details a threshold that will trigger management action (exceeding cap or below the 25th percentile) and the resulting management action (harvest reduced from 10% to 5% of the TSM or three-year closure).

Connecticut

Since 2002, there has been a prohibition on the commercial or recreational taking of migratory alewives and blueback herring from all marine waters and most inland waters. This action was initially taken in 2002, and was still in place at publication (2017).

River herring were harvested primarily by haul seine, dip net, gill net and otter trawl. The gill net and haul seine fisheries were primarily directed toward collecting fish for bait. The fishermen involved were commercial as well as personal use lobstermen and recreational anglers. The drift gill net fishery operated in Long Island Sound and the Connecticut and the lower Thames River. Trawling is prohibited in Connecticut estuaries and is not allowed inland of a statutory line that is generally not more than ¼ mile from shore.

New York

In 2011, the Board approved New York's first SFMP to harvest river herring in the Hudson River and some of its tributaries. In 2013, the state implemented more restrictive management measures which include a closure of tributaries to nets, net size restrictions for scap nets (also known as lift and/or dip nets), mandatory monthly commercial reporting, and a recreational creel limit. In 2016, New York submitted an updated SFMP that includes recent data and the 2013 regulations. The sustainability benchmark was unchanged. The primary sustainability benchmark is based on young-of year-indices (YOY). Management action is triggered if the YOY indices indicate three consecutive years below the 25th percentile of the time series (1983-2015). Additional sustainability measures are collected annually to evaluate stock status and include: mean length at age, total mortality, frequency of repeat spawning and catch per unit effort (CPUE) of commercial harvest.

New Jersey/Delaware

As of January 1, 2012 commercial and recreational harvest of river herring was prohibited in New Jersey and Delaware, as required by ASMFC Amendment 2 to the Shad and River Herring FMP.

Maryland

As of January 1, 2012 commercial and recreational harvest of river herring was prohibited in Maryland, as required by ASMFC Amendment 2 to the Shad and River Herring FMP.

Potomac River Fisheries Commission / District of Columbia

The PRFC regulates only the mainstem of the river, while the tributaries on either side are under Maryland and Virginia jurisdiction. The District Department of the Environment (DDOE) has authority for the Potomac River to the Virginia shore and other waters within D.C. As of January 1, 2010 harvest of river herring was prohibited in the Potomac River, with a minimal bycatch provision of 50 pounds per licensee per day for pound nets.

Virginia

Virginia's Department of Game and Inland Fisheries (VDGIF) is responsible for the management of fishery resources in the state's inland waters. In 2008, possession of alewives and blueback herring was prohibited on rivers draining into North Carolina. As of January 1, 2012 commercial and recreational harvest of river herring was prohibited in all waters of Virginia, as required by ASMFC Amendment 2 to the Shad and River Herring FMP.

North Carolina

A no harvest provision for river herring, commercial and recreational, within North Carolina was approved in 2007, with one exception. A limited research set aside of 7,500 pounds was established to collect data necessary for stock analysis, and to provide availability of local product for local festivals.

In 2015, the limited research set aside was eliminated. The commercial and recreational harvest of river herring is now prohibited in all waters of North Carolina.

South Carolina

The South Carolina Department of Natural Resources (SCDNR) manages commercial herring fisheries using a combination of seasons, gear restrictions, and catch limits. In 2010, the Board approved a SFMP for the commercial and recreational harvest of blueback herring with the following restrictions. The commercial fishery for blueback herring has a 10 bushel daily limit (500 pounds) per boat in the Cooper and Santee Rivers and the Santee-Cooper Rediversion Canal and a 250 pounds 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. 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. In 2017, South Carolina submitted an updated SFMP with recent data and a request to maintain existing management measures. The Board will consider approval of the SFMP in August 2017.

Georgia

The take of blueback herring is illegal in freshwater. Historically, blueback herring could be taken for bait by using dip nets and cast nets. Harvest of blueback herring for any other purpose other than as bait was prohibited. As of January 1, 2012, harvest of river herring was prohibited in Georgia, as required by ASMFC Amendment 2 to the Shad and River Herring FMP.

Florida

The St. Johns River, Florida harbors the southernmost spawning run of blueback herring. Historically, regulations concerning river herring and shad prohibited the harvest or attempted harvest of any shad or river herring, by or with the use of any gear other than hook and line gear. As of January 1, 2012, harvest of river herring was prohibited, as required by ASMFC Amendment 2 to the Shad and River Herring FMP.

1.2 ASSESSMENT OVERVIEW

As an anadromous species, ideally river herring should be assessed and managed by individual river systems. However, the majority of the life history of river herring is spent in the marine environment where factors influencing survival likely have impacts upon multiple river stocks when they mix during marine migrations. The complex life history of anadromous species complicates assessments on a coastwide scale as it is difficult to partition in-river factors from marine factors governing population dynamics. Also complicating the assessment of river herring is the variability in data quality among rivers along the coast.

The SAS updated assessment approaches used in the benchmark stock assessment to assess Atlantic coastal river herring stocks on an individual river basis, where the data were available, and also on a limited coastwide basis. The following sections include (1) summary of available data and usefulness; (2) a trend analysis overview that provides summaries of the most meaningful data from state and major river systems; (3) a coastwide mixed stock population perspective exploring trend analyses and relative exploitation of mixed stock assemblage in ocean waters. During the benchmark assessment, the SAS also used depletion based stock reduction analysis to assess the coastwide mixed stock population. However, the peer review panel recommended against using this approach for assessment of river herring. Therefore, this assessment approach was not updated.

Coastwide approaches were used in the benchmark in addition to river specific approaches for several reasons. First- river herring stocks have been exploited in oceanic and estuarine mixed-stock fisheries as well as river-specific fisheries. Few of the mixed-stock fisheries are adequately monitored. There is no information about how to allocate the mixed-stock harvest among stocks. In-river data vary widely. Harvest is monitored for most in-river commercial fisheries but recreational harvest is monitored less often or non-existent. Little information is available on bycatch (discard and/or incidental catch) and so an updated analysis is provided.

The data gaps for river herring can be attributed mostly to the low priority the species receives in some agency monitoring efforts. This understandable prioritization results in there being few long-term fishery-independent indices, except on rivers with fish passage. Fishery-dependent indices provide some long time series but most data contain gaps and several have been discontinued since the benchmark stock assessment due to moratoria. Other concerns are on changes in effectiveness (catchability) of gear over time. Some efforts since the benchmark stock assessment have focused on identifying useful data collection for assessment purposes and the standardization of data collection along the coast (ASMFC 2016).

1.2.1 Summary of Available State / Jurisdiction Data

River specific data available for the benchmark assessment and updated for this assessment are summarized in Appendix 1. The quality and quantity of available data varied greatly among river systems. The data used represents a mix of fisheries dependent and independent data sources. Time series ranged in lengths up to as many as 72 years, but most time series were of shorter duration and often were not continuous. Some rivers had a full suite of data (e.g. harvest, age, length, weight, repeat spawner, and fisheries independent surveys) while others were limited in the types of data available or had data that was not reliable for assessment purposes. In addition to river specific data, several coastal trawl surveys were updated for this assessment. Again, the length of time series of these data varied from 8 to 41 years of data.

Throughout the update of the assessment, discrepancies between data provided during the benchmark assessment and data provided during the update for overlapping years (2010 and earlier) were observed. The SAS worked with TC members to identify the cause of these discrepancies and identify the correct data to use in the update, but often the discrepancies could not be explained and the updated data were used in the analyses. It is likely that QA/QC procedures and turnover of TC members since the benchmark assessment contributed to these discrepancies. All discrepancies are noted throughout the individual analysis sections.

The SAS noted during the benchmark assessment that some recent monitoring was not useful due to shortness of time series, but that “some of the current fishery-independent surveys should be of sufficient length to be useful in assessments five to 10 years from now if monitoring continues”. Therefore, the SAS identified all data sets explicitly noted in the benchmark as not being used due to shortness of time series and agree to include these data sets in the benchmark if they had reached ten years in length and could be analyzed with the same approaches used in the benchmark. The only new data set included in the updated trend analyses was the mean length data from the St. Johns River in Florida.

1.2.2 Assessment Approaches

Given the data gaps and issues described above, analyses requiring catch-at-age data were not used to assess most stocks in the benchmark stock assessment. The benchmark assessment was largely confined to analyses of trends, comparisons of trends among rivers or survey gears, and methods designed for data poor stocks, with the exception of the Monument River in Massachusetts, the Chowan River in North Carolina, and the Nanticoke River in Maryland, which had sufficient data to support statistical catch-at-age models. All analyses were updated with recent data (through 2015) except the depletion based stock reduction analysis and the statistical catch-at-age models for the Nanticoke River due to data limitations since the benchmark assessment (i.e., no harvest).

1.2.3 Trends in available state data

Data examined includes some fishery dependent (catch per unit effort) data, but primarily focuses on fishery-independent survey data (e.g. estimated run sizes, relative abundance indices, mean length or mean length at age, estimates of total instantaneous mortality, and in-river exploitation rates). Trends were updated with recent data to provide some perspective of current trends and to examine if patterns in trends were consistent across systems and regions. Analyses of trends included simple non-parametric Mann-Kendall tests for monotonic trends and correlation analyses to compare trends among rivers.

1.2.4 Trends in coastal composite data

Some data were only available as composite coastal populations stocks. There are currently no methods to allow for discrimination of individual stocks from coastal fisheries surveys. This includes several state trawl surveys conducted in near shore ocean waters (ME-NH survey, the Long Island trawl survey conducted by CT, the NJ coastal survey) and coastwide bottom trawl survey conducted by the Northeast Fishery Science Center (NEFSC). Autoregressive integrated moving average (ARIMA) models were used to evaluate trends in trawl surveys.

1.2.5 Total mortality estimates and benchmarks

Although there are issues identified with ageing techniques, total mortality benchmarks developed in the benchmark stock assessment and total mortality estimates were used to provide a perspective of the sustainability of and trends evident in current available mortality estimates. Mortality was also estimated from repeat spawner marks on scales, but the Peer Review Panel that reviewed the benchmark assessment preferred age-based mortality estimate (ASMFC 2012). Therefore, repeat spawner-based mortality estimates were updated, but age-based estimates were the focus of conclusions on mortality.

1.2.6 Relative exploitation

An index of relative exploitation was calculated from minimum swept area estimates of total biomass from the NEFSC bottom trawl survey and estimates of total catch (reported U.S. landings plus incidental catch). Although this approach did not yield absolute estimates of exploitation rates that could be compared to benchmarks, it did provide a means to observe relative trends in exploitation through time.

1.3 DATA UNCERTAINTIES

1.3.1 Age and mortality uncertainty

River herring have been aged historically using scales, using protocols first developed by Cating (1953) for American shad and Marcy (1969) for river herring. Although used extensively, these protocols have not been validated with known-age fish, and there had not been many efforts to standardize river herring ageing across states prior to the benchmark assessment. In recent years, several studies focused on American shad have concluded that Cating's (1953) method for ageing shad scales should no longer be used (Duffy et al. 2012, Elzey et al. 2015). Additionally, some labs have switched to ageing river herring with otoliths since the benchmark assessment. Otolith protocols have not been validated with known-age fish either. As with any ageing method, there is the potential for bias both between labs and within labs over time as personnel change and methods are not consistently standardized. An age sample exchange and subsequent workshop were conducted stemming from recommendations in the benchmark assessment. A report details the varying degree of ageing error identified during this process between age structures and among labs providing age data for assessments (ASMFC 2014). Recommendations were made in efforts to standardize ageing practices across labs, but efforts should continue to assess ageing error and best practices.

Total mortality rates reflect the combined impact of intensive fisheries, spawning mortality, predation, and mortality associated with downstream passage at hydroelectric dams in some systems. Almost no stocks have sufficient information to separate mortality into these sources. Uncertainty about natural mortality is perhaps the biggest limiting factor in drawing strong conclusions about the status of river herring. There are no empirical estimates of natural mortality associated with spawning. Inferences about its magnitude are based almost entirely on total mortality rates and spawning marks on scales. Although interpretation of spawning marks on scales needs a validation study, spawning marks may help in establishing the magnitude of spawning mortality. Unfortunately, a lack of spawning marks may simply be a reflection of intensive fishing; for example, if a high percentage of migrants are harvested fewer will return to spawn. Considerable uncertainty also exists about the magnitude of predation. A brief description appears in the benchmark assessment. This predation could occur in rivers, estuaries, and in the ocean, and may be an important source of mortality for juvenile or adults. Recent concern has focused on predation by striped bass, whose population has increased coastwide. There is much diet information available for striped bass, but the magnitude of predation mortality is difficult to assess because of uncertainty about the proportion of the striped bass population within different bodies of water.

1.3.2 Total harvest uncertainty

Reporting requirements for anadromous fish have been strengthened across all states, and the reported landings from the directed in river commercial fisheries are considered fairly reliable in recent years. However, there are other directed and incidental fisheries that harvest river herring that are not well monitored.

River herring are caught by recreational anglers in-river, either as a target species or as bait for other gamefish. We explored, but did not use data from the National Marine Fisheries Service (NMFS) Marine Recreational Fisheries Statistics Survey (MRFSS) for several reasons. Recreational fishermen rarely catch river herring in marine waters, and MRFSS does not adequately sample the freshwater recreational fishery. As a result, MRFSS estimates of recreational catch, where they exist, have extremely high proportional standard errors (PSEs).

There is also considerable concern about potential species misidentification. Anecdotal evidence from state biologists indicates that hickory shad, which are growing in abundance, have been misidentified as river herring or young American shad, especially by anglers. Data are presented in the Fishery Dependent section, but not used due to the identified issues.

River herring are also caught incidentally at sea in fisheries targeting other species such as Atlantic herring, squid, and mackerel. The magnitude of this ocean catch is highly uncertain because of the short time series of bycatch data due to underreporting and a lack of observer coverage. In addition, there are no data on the stock composition of the incidentally caught fish and thus no way to partition estimates of bycatch among river systems. With no estimates of coastwide stock size, it is also difficult to assess the significance of these removals on the total population.

2.0 COASTWIDE TRENDS

2.1 FISHERY DESCRIPTIONS

2.1.1 Coastwide Commercial Landings

Updated by: Jeff Kipp, Atlantic States Marine Fisheries Commission; Benchmark Assessment Section by: Christine Jensen, North Carolina Division of Marine Fisheries and Katie Drew, Atlantic States Marine Fisheries Commission

Coastwide domestic commercial landings of river herring were presented from 1887 to 2015, where available, in Table 2.1 and Figure 2.1. Landings of alewife and blueback herring were collectively classified as "river herring" by most states. Only a few states had species-specific information recorded for a limited range of years. Commercial landings records were available for each state since 1887 except for Florida, which began in 1929, and the Potomac River Fisheries Commission (PRFC), which began in 1960. It is important to note that historic landings presented here do not include all landings for all states over the entire time period and are likely underestimated, particularly for the first third of the time series, since not all river landings were reported.

Total domestic coastwide landings averaged 18.5 million pounds from 1887 to 1928; however, landings information was sparse and only available intermittently during that time and ranged from a low of 22,000 pounds to a high of 85.5 million pounds. Coastwide landings increased sharply from lows in the early 1940s during World War II to more than 50 million pounds by 1951 and peaked at 74.9 million pounds in 1958. Severe declines in landings began coastwide in the early 1970s and domestic landings are now a fraction of what they were at their peak having remained at persistently low levels since the mid-1990s (Figure 2.1). Since the benchmark stock assessment, landings averaged just over 1.4 million pounds, which was almost identical to the average landings over the last five years of the benchmark stock assessment. Moratoria were enacted in Massachusetts (commercial and recreational in 2005), Rhode Island (commercial and recreational in 2006), Connecticut (commercial and recreational in 2002), Virginia (for waters flowing into North Carolina in 2007), and North Carolina (commercial and recreational in 2007, with the exception of a four day open season in the Chowan River during the week of Easter). As of January 1, 2012 river herring fisheries in states or jurisdictions without an approved sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River

Herring FMP, were closed. As a result, prohibitions on harvest (commercial or recreational) were extended to the following states: New Jersey, Delaware, Pennsylvania, Maryland, D.C., Virginia (for all waters), Georgia and Florida.

Foreign fleet landings of river herring (reported as alewife and blueback shad) are available through the Northwest Atlantic Fisheries Organization (NAFO) and are summarized in Table 2.2. Offshore exploitation of river herring and shad (generally $\leq$190 mm in length) by foreign fleets (NAFO areas 5 and 6; Figure 2.2) began in the late 1960s and landings peaked at about 80 million pounds in 1969. There have been no reported landings by foreign fleets since 1990.

2.1.2 Coastwide Commercial CPUE

Updated by: Dr. Mike Bailey, U.S. Fish and Wildlife Service; Benchmark Assessment Section by: Gary A. Nelson, Massachusetts Division of Marine Fisheries

All indices were normalized and graphed for comparative purposes. Linear and loess smoothers (Maindonald and Braun, 2003) were applied to all time series for a given state and species to elucidate trends in the annual estimates. Although offered as indices of relative abundance, the catch-per-unit-effort indices discussed below need to be validated in the future.

New York

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 lower Hudson River Estuary. All commercial fishers annually fill out mandatory reports. Data reported include catch, discards, gear, effort, and fishing location for each trip. Data within week is summarized as total catch divided by total effort, separately by gear type (fixed gill nets, drift gill nets, and scap nets). CPUE is calculated as the number of river herring caught per unit effort (square yards of net x hours fished). CPUE of the fixed gear fishery is used as an estimate of relative abundance as the fishery is located downriver of the spawning reach and it captures river herring moving through the reach to upriver spawning locations. Only data since 2000 was used as this is when mandatory reporting was enforced. CPUE for this gear declined slightly from 2000 to about 2006 then has slowly increased since (Figure 2.3). Since 2010, the CPUE for the Hudson is increasing.

New Jersey

New Jersey landing estimates for river herring were obtained from the NMFS for 1950 to 1999. These estimates are for the entire state and not solely from the Delaware Bay. River herring estimates for 2000 to 2010 were obtained from mandatory logbooks of the small mesh gill net fishery in Delaware Bay. The average reported landings for the time period is estimated at 8,263 pounds. There are no estimates of underreporting, however it is assumed that the current data for river herring are grossly underreported since the majority of landings are categorized as bait. New Jersey has voluntary effort data from reliable commercial fishermen in Delaware Bay. The fishery is directed towards white perch with river herring being a harvestable bycatch. The gear is not standardized and therefore the data should only be used for potential trends and not absolute numbers. CPUE has declined since 1997 (Figure 2.3). No additional data was entered for the update due to ongoing moratorium.

Maryland

River herring commercial landings and effort data from pound nets are available from the Nanticoke River. In general, CPUE has declined over time (Figure 2.3). No additional data was entered for the update due to ongoing moratorium.

Potomac River Fisheries Commission

River herring harvest in the Potomac River is almost exclusively taken by pound nets. In 1964, licenses were required to commercially harvest fish. After Maryland and Virginia established limited entry fisheries in the 1990's, the PRFC responded to industry's request and, in 1995, capped the Potomac River pound net fishery at 100 licenses. Catch-per-unit effort indices (kilograms of herring per pound net days- fished) are available from 1976-1980 and 1988-2010. CPUE indices from 1998-2008 for alewives are much lower than CPUE indices from 1976-1980 and values have declined since 1988 (Figure 2.3). No additional data was entered for the update due to ongoing moratorium.

Virginia

Annual commercial fishery harvest rates for alewives are available from 1994 to 2010 for selected Virginia waters. The harvest rates are computed as a ratio by dividing commercial harvest (kilograms) by the number of fishing trips for each area and gear. Only fishing trips with positive harvest of alewife were included in the calculations because only positive harvest is reported. Gill net harvest rates for alewife have been variable among Virginia water bodies from 1994 to 2007 (Figure 2.4). Harvest rates in the James River have been variable, but the data suggest a general decline through 2009 and an increase in 2010.

In the Rappahannock River, there was no obvious trend in harvest rates over time, though a small peak is evident in 2000. A three-year period of relatively higher rates occurred from 2002 to 2004 and an increase in 2010. Gill net harvest rates in the York River were highest after 2002 and showed an increasing trend through 2010. No additional data was entered for the update due to ongoing moratorium.

North Carolina

Harvest and effort data from the pound net fishery are available for alewife and blueback herring form the Chowan River from 1977 – 2015. CPUE (harvest divided by pound net weeks fished) for alewife declined from 1977 through the late 1990s, while CPUE for blueback herring declined from 1977 through the late 1980s (Figure 2.4). A slight increase in CPUE for alewife was observed through 2006. Blueback CPUE increased through the late 1990s but declined thereafter. The CPUE for blueback herring has continued to decline post 2010 assessment, while alewife numbers have been variable.

South Carolina

Annual estimates of CPUE (kg catch/man day) are available since 1969 from surveys of the Santee River and Cooper River blueback herring fisheries. Estimates of CPUE fluctuated widely over the time series. Estimates of CPUE were highest early in the time series in the Cooper River and declined dramatically soon after to a low that lasted through the late 1970s (Figure 2.4). Estimates increased 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. CPUE increased in the Rediversion Canal and the Santee River but then began to decline in the late 1990s through 2006 and have since increased. Since 2010 the CPUE has been highly variable with no discernible trend.

Comparison of Trends in CPUE

Cluster analysis were not updated as there are now few systems that retain appropriate datasets for analysis.

2.1.3 Recreational Landings and Releases

Historically, there have been few reports of river herring being taken by recreational anglers for food. Most often, river herring were taken for bait. The Marine Recreational Statistics Survey (MRFSS) provides estimate of numbers of fish harvested and released by recreational fisheries along the Atlantic coast. MRFSS concentrates their sampling strata in coastal water areas and do not capture any data on recreational fisheries that occur in inland waters. Few states conduct creel surveys or other consistent survey instruments (diary or log books) in their inland waters to collect data on recreational catch of river herring. Some data are reported in the state chapters; but data are too sparse to conduct any systematic comparison of trends. These data were deemed not useful for management purposes during the benchmark assessment and were not updated.

2.1.4 Ocean Bycatch of River Herring

The Magnuson-Stevens Act defines bycatch as “fish which are harvested in a fishery but are not sold or kept for personal use […]” – i.e., discards. However, the term “bycatch” is often used to refer to both discarded fish and fish which are not targeted by a fishery but caught incidentally and landed. In this assessment, we do not use the stricter Magnuson-Stevens definition and instead use the terms “bycatch” and “incidental catch” interchangeably to refer to the total catch of river herring, regardless of final disposition, that is taken in fishery operations that target other species. We use the term “discards” to refer to the portion of the incidental catch that is discarded at sea.

2.1.4.1 River herring incidental catch estimates

Update and Benchmark Assessment Section by: Dr. Kiersten Curti, National Marine Fisheries Service

Methods

The total incidental catch of river herring was updated through 2015 following the methods described in the benchmark assessment, which were developed during Amendment 14 to the Atlantic Mackerel, Squid and Butterfish (MSB) Fishery Management Plan.

The total (retained + discarded) incidental catch of river herring (alewife and blueback herring) was quantified by fleet. Fleets included in the analyses were those sampled by the Northeast Fisheries Observer Program (NEFOP) and were stratified by region fished (Mid-Atlantic versus New England), time (year and quarter), gear group, and mesh size. Region fished was defined using statistical areas for reporting commercial fishery data; the Mid-Atlantic region included statistical areas greater than 600, and New England included statistical areas 464 through 599. Gear groups included in the analyses were: bottom trawls, paired midwater trawls, single midwater trawls, gillnets, dredges, handlines, haul seines, longlines, pots/traps, purse seines, scallop trawl/dredge, seines and shrimp trawls. Bottom trawls and gillnets were further stratified into three mesh-size categories:

Mesh category	Bottom Trawl	Gillnet
small	mesh ≤ 3.5	mesh < 5.5
medium	3.5 < mesh < 5.5	---
large	mesh ≥ 5.5	5.5 ≤ mesh < 8
x-large	---	mesh ≥ 8

In the benchmark assessment, trips with missing mesh information were dropped from the analysis. However, in analyses conducted since the benchmark, mesh was assumed based on gear or species caught. In this update assessment, mesh category for bottom trawl fleets was determined for trips with missing mesh information based on the primary species caught. For gillnets, trips with missing mesh information were assumed to come from the large mesh category.

The combined ratio method (Wigley et al. 2007) is the standard discard estimation method implemented in NEFSC stock assessments. We used this method to quantify and estimate the precision (CV) of river herring total incidental catch for 1989 – 2015 across all fleets. Incidental catch estimates for the midwater trawl (MWT) fleets are only provided for 2005-2015 because marked improvements to NEFOP sampling methodologies occurred in the high-volume MWT fisheries beginning in 2005, limiting the interpretability of estimates from these fleets in prior years.

For each trip, NEFOP data were used to calculate a total catch to kept (t/k) ratio, where t represents the total (retained + discarded) catch of an individual species (e.g., alewife) and k is the kept weight of all species. Annual estimates of total incidental catch were derived by quarter. Imputations were used for quarters with one or zero observed trips.

The t/k ratios were expanded using a raising factor to quantify total incidental catch. With the exception of the midwater trawl fleets, total landed weight of all species (from the dealer database) was used as the raising factor. Total landings from the dealer database are considered to be more accurate than those of the VTR database because VTR landings represent a captain's hail estimate. However, for the MWT fleets, we were unable to use the dealer data to estimate the kept weight of all species when stratifying by fishing area. When the area allocation (AA) tables were developed, MWT was not included in effort calculations because of difficulties determining effort for paired MWTs. Only those gears with effort information could be assigned to a statistical area. Consequently, VTR data were used as the expansion factor for the MWT fleets.

Results

Total incidental catch estimates by species are presented in Table 2.4.

From 2005-2015, the total annual incidental catch of alewife ranged from 36.5-531.7 metric tons (mt) in New England and 10.9-295.0 mt in the Mid-Atlantic. The dominant gear varied across years between paired midwater trawls and bottom trawls (Figure 2.5). Corresponding estimates of precision exhibited substantial interannual variation and ranged from 0-10.6 across gears and regions.

Total annual blueback herring incidental catch from 2005-2015 ranged from 8.2–186.6 mt in New England and 1.4-388.3 mt in the Mid-Atlantic. Across years paired and single midwater trawls exhibited the greatest blueback herring catches (Figure 2.6). Corresponding precision estimates ranged from 0-3.6.

The temporal distribution of incidental catches was summarized by quarter and fishing region for the most recent ten-year period (2005-2015) (Table 2.3). River herring catches occurred primarily in midwater trawls (62%, of which 48% were from paired midwater trawls and the rest from single midwater trawls), followed by small mesh bottom trawls (37%). Catches of river herring in gillnets were negligible. Across gear types, catches of river herring were greater in New England (59%) than in the Mid-Atlantic (41%). The percentages of midwater trawl catches of river herring were similar between New England (31.3%) and the Mid-Atlantic (30.5%). However, catches in New England small mesh bottom trawls were almost three times higher (27%) than those from the Mid-Atlantic (10%). Overall, the highest quarterly catches of river herring occurred in midwater trawls during Q1 in the Mid-Atlantic (28%), followed by catches in New England during Q4 (12%). Quarterly catches in small mesh bottom trawls were highest in New England during Q1 (9%) and totaled 5-7% during each of the other three quarters.

2.2 TRENDS IN FISHERIES-INDEPENDENT SURVEYS

Fisheries-independent data on alewives and blueback herring come from mostly historical reports and/or current work conducted by state, federal, and academic agencies as well as local citizen groups interested in protecting river herring resources. The data used in the summaries below were selected by state biologists during the benchmark assessment as reflecting trends in each state's alewife and blueback herring populations. Some data were not used because lack of statistical design, non-reflectance of natural abundance trends, and shortness of time series (see state reports for details).

2.2.1 Run Size Estimates

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Run sizes (total or escapement counts), proxies (number of fish lifted), or population sizes estimates of alewives and blueback herring (or both species combined) were available from six states, primarily from New England. Run sizes for Maine, New Hampshire, Massachusetts and Rhode Island were estimated using electronic counters or visual methods. Connecticut used the number of fish lifted at the Holyoke Dam and run counts made in 11 fishways using a variety of counting methods. North Carolina provided estimates of population sizes of blueback herring alewife in the Chowan River from stock assessments conducted in 2017 and 2005, respectively. South Carolina provided population abundance estimates from mark-recapture experiments for blueback herring in the Santee River. See state reports for full details. All time series were normalized (*Z* transformed) prior to analysis to eliminate scale and to make comparison of trends easier.

Maine

Run size estimates are available for the Androscoggin River (alewife) 1983-2015, Damariscotta River (alewife) 1977-2015, Kennebec River (combined species) 2006-2015, Sebasticook River (combined species) 2000-2015, and Union River (alewife) from 1982-2015 (Figure 2.7).

<u>Androscoggin River</u> - 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. The highest number of fish passed above the Brunswick fishway was 170,191 in 2012.

<u>Damariscotta River</u> - The Damariscotta fishery is one of the most studied fisheries in Maine. A 150-meter stone pool and chute fishway passes river herring into spawning habitat. The elevation of the 1,781-hectare lake is 16 meters above mean high tide. The efficiency of this fishway varies 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. Unobstructed upstream passage is available to migrating fish throughout the run. Harvesters trap fish in a side channel that provides supplemental attraction water at the base of the fishway. The commercial fishery operates four days a week throughout the run. The number of fish entering the lake are counted during a ten minute period each hour and expanded to the hours of operation. The highest number of fish observed was 1,305,380 in 1977. The fishway was rebuilt after the last river herring assessment. Passage appears to have improved significantly as a result of the fishway modifications.

<u>Kennebec and Sebasticook Rivers</u> - The DMR implemented a restoration plan for alewives in the Kennebec River watershed above Augusta in 1986 as the result of an agreement with the majority of hydroelectric dam owners in the watershed. The plan called for the stocking of alewives in the program's initial years to rebuild the population, with fish passage provided later by the hydropower companies. This agreement was modified in 1998 and incorporated into the Kennebec River Settlement Accord, which resulted in the removal of the Edwards Dam in 1999, continued funding for the anadromous fish restoration program, and established new dates for fish passage. The alewife restoration program in the Kennebec River focuses on stocking lakes and ponds in the Sebasticook River watershed and Seven Mile Stream drainage. DMR has mainly stocked warm water lakes due to concerns of Maine Department of Inland Fisheries and Wildlife (IF&W) biologists that the restoration of alewives to cold water lakes might result in competition with smelt, an important forage species for landlocked salmon and brown trout. Results of a ten-year cooperative study in Lake George from 1987 through 1996, involving IF&W, DMR, and the Department of Environmental Protection (DEP),showed that the stocking of six alewives per surface acre of lake habitat had no negative impact on inland fisheries or water quality (Kircheis et al, 2002). Based on these findings, DMR and IF&W staff recommended the initiation of the restoration of alewives in additional lakes in the Sebasticook drainage. The highest numbers of stocked fish was 2,211,658 in 2009 in the Sebasticook River and 93,775 in 2008 in the Kennebec River.

<u>Union River</u> - 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 this hydropower station. The FERC license requires transporting river herring around the dam by Brookfield White Pine, the dam owners. Two lakes support this commercial fishery. 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 highest number of stocked fish was 1,238,790 in 1986.

Common trends in run sizes were observed among rivers. Run sizes peaked during the 1980s in the Androscoggin River, Damariscotta River, and Union River. Run size declined in most rivers during the early 1990s, but it increased gradually and peaked again around 2004. In 2005, run counts dropped dramatically as a result of near-record high spring precipitation impeding upriver passage. Since 2005, increases and small declines in run size have been evident in all rivers (Figure 2.7). Fluctuations in run size for the Androscoggin, Kennebec, Sebasticook and Union rivers are likely influenced by DMR lifting and stocking activities.

New Hampshire

Run size estimates are available for the Cocheco River, Exeter River, Lamprey River, Oyster River, Taylor River and Winnicut River from 1972-2015 (Figure 2.8). Counts represent combined species totals or escapement numbers.

<u>Cocheco River</u> – 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 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 6.1. 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 10.6. The City of Dover currently owns the dam and leases the attached hydroelectric facility to Southern New Hampshire Hydroelectric Development Corporation (SNHHDC). The 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 PVC tube emptying in a plunge pool below the dam. This system successfully 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. The highest number of river herring (combined species) passed upstream was 79,835 in 1995.

<u>Exeter River</u> - 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) 13.5 and the Pickpocket Dam at rkm 26.9 (each 4.6 km high). The next barrier above Pickpocket Dam is a set of natural falls at rkm 38.1. NHFGD constructed upstream fish passage facilities (Denil fishways) on both dams from 1969 to 1971 for anadromous fish, funded in part by the 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. Despite regulations introduced in 2005 to reduce harvest in the Exeter/Squamscott River it continues to account for between 53-88% of the total river herring harvested in New Hampshire between 2011 and 2015. Exeter/Squamscott River harvest in 2015 accounted for approximately 85% of all the river herring harvested in NH. However, the regulations introduced in 2005 implemented a daily limit of 1 tote per person and limited the fishery to only Saturdays and Mondays allowing for five days of escapement for migrating river herring. The highest number of river herring observed was 15,626 in 1981. The Great Dam and fish ladder were removed in the summer of 2016.

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 Macallen Dam, located at rkm 3.0 in Newmarket, is the lowermost head-of-tide dam (8.2 m high) on the Lamprey River. Fish passage on this river is a Denil fish ladder constructed from 1969 to 1970 for anadromous fish by NHFGD, funded in part by the USFWS. The Wiswall Dam is located 4.8 km above the Macallen Dam and passage Denil fish ladder was constructed in 2012. It has a 3.4 m spillway and is an effective barrier to upstream movement of river herring and other diadromous species. 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 highest number of river herring observed was 86,862 in 2012.

Oyster River - The Oyster River drains a watershed of 27.5 km through southeast New Hampshire. 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 approximately rkm 5. 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 7.6. As with the other rivers, high flows in 2005, 2006, and 2007 might have contributed to lower juvenile production resulting in low returns for this and future years. Unpublished data acquired by the University of New Hampshire in the fall of 2005 showed hypoxic conditions in the impounded reaches of the Oyster River (Brian Smith, personal communication). The highest number of fish observed was 157,024 in 1992.

Taylor River - The Taylor River is located in southeastern New Hampshire and is about 17.1 km long. 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 3.2. There is a Denil fish ladder at this head-of-tide dam that was constructed in the late 1960s. The next dam is a barrier to further fish passage and is located at rkm 5.1. Since 2009 the fish ladder was operated only as a swim through due to staff constraints and low return numbers. Due to the lack of a trap for fish collection, no biological sampling has been conducted since 2010. The Taylor River has had very low return numbers for the past ten years. Eutrophication of the Taylor River impoundment compounded by high flow years in 2005, 2006, and 2007 are believed to be the main reasons for the decline. The highest number of river herring observed was 450,000 in 1976. Annual monitoring of the Taylor River for estimates of river herring returning was removed from the state management plan in 2015.

Winnicut River - The Winnicut River drains a watershed of 36.8 square km in southeast New Hampshire. It originates in the town of North Hampton and flows north through Greenland where it empties into Great Bay. The only barrier to fish passage was a dam at the head-of-tide at approximately 1.6 rkm. The dam was built in 1957 by NHFGD to create waterfowl habitat and is located in the Town of Greenland. It had a height of 4 m and a spillway length of 23.2 m and incorporated a Canadian Step Weir fishway. This type of fishway is not efficient for the passage of river herring; however with modifications, limited numbers of river herring do utilize this fishway. The Winnicut River head-of-tide dam and associated fish ladder were removed during the summer of 2009. A pool-and-weir fishway was constructed approximately 100 meters upstream from the former dam site in a river constriction under the NH Route 33 bridge because under certain flow conditions this constriction could be a possible velocity barrier to upstream migrating adult river herring. Improper design and construction of the fishway has prevented all river herring from passing the site since 2011. The highest number of river herring observed was 8,359 in 2008.

Common trends in run sizes were observed among rivers. Run sizes peaked either during the late 1970s-early 1980s (Lamprey River, Taylor River, and Exeter River) or the early 1990s (Cocheco River and Oyster River) (Figure 2.8). Declines in run size from peak abundance were observed through the mid-1990s in the Lamprey River and Taylor River, or briefly during the mid-1990s in the Cocheco River and Oyster River. Run sizes increased gradually and peaked around 2003-2004 in the Cocheco River, Exeter River, Lamprey River and Winnicut River but they continued to decline in the Oyster River and Taylor River. In 2005, run counts may have dropped as a result of near-record high spring precipitation impeding upriver passage. Run counts dropped dramatically in 2005-2006 in most rivers, but appear to have rebounded or increased during 2007 in the Cocheco River, Lamprey River, and Winnicut River. Run sizes in the Cocheco River and Lamprey River have reached time series highs, while those in the Exeter River, Oyster River and Taylor River remain low. In 2009 and 2010, run size in the Winnicut River declined before passage was halted by an improperly designed fishway.

Massachusetts

Run size estimates are available for the Mattapoisett River, Monument River, Nemasket River and Parker River from 1972-2015 (Figure 2.9).

<u>Mattapoisett River</u> – Since 1988, a local watershed group, Alewives Anonymous, has provided total and escapement abundance estimates of alewives by using an electronic fish counter at the fish ladder located at the outlet of Snipatuit Pond in Rochester (River mile: 11.1). This counter is used to estimate the number of alewives reaching the final and primary spawning impoundment (710 acres). The highest number of alewife observed was 132,500 in 2000.

<u>Monument River</u> - DMF has been scientifically monitoring the abundance, sex composition, length structure, age composition and removals of alewives and blueback herring populations in the Monument River, Bournedale, Massachusetts since the early 1980s. Prior to 1985, abundance was estimated by using visual counts following the statistical design of Rideout et al. (1979). Since 1985, run size has been estimated by using a Smith-Root electronic fish counter that is calibrated daily. The counter is situated just upstream of the river mouth at the top weir of the fish ladder at Benoit's Pond Dam in Bourne (River Mile: 0.2). The highest numbers of alewives and blueback herring observed were 597,937 in 2000 and 104,645 in1984, respectively.

<u>Nemasket River</u> - Since 1996, members of the Middleborough/Lakeville Herring Fishery Commission has provided abundance estimates of alewife escapement using visual counts and the Rideout et al. (1979) design. Counting takes place at the upstream exit of the Wareham Street Dam and fishway (River mile: 7.5). The highest number of alewives observed was 1,919,000 in 2002.

<u>Parker River</u> - The Parker River is a small stream arising in the town of Boxford and flowing 25.8 km north and east into Plum Island Sound. The freshwater portion drops 20 m during its 12.5 km length and flow is impeded by six low head dams. A pool-and-weir fish ladder was built at each dam. In 1974, the pool-and-weir fishway at dam 6 was replaced by a Denil type ladder. Since 1997, the Parker River Clean Water Association has been estimating run size at the first dam using visual counts and the statistical design of Rideout et al. (1979). Due to heavy rains in 2005, the weir at dam 1 was damaged and continues to run at lower efficiency. The highest number of alewives observed was 38,102 in 1973.

Total run sizes of alewives in the Mattapoisett River and Monument River increased from lows in the later 1980s and peaked in 2000 (Figure 2.9). After 2000, alewife run sizes declined precipitously in the Mattapoisett River, Monument River and Parker River. Run size in the Nemasket River peaked in 2002 and declined thereafter. For blueback herring, total run size was highest in the Monument River during 1980-1991, but it dropped to lower levels during 1992-2002. In 2005, run counts may have dropped dramatically as a result of near-record high spring precipitation impeding upriver passage. Since the run lows, river herring abundance has been increasing slowly.

Rhode Island

Run size estimates of alewives are available for Buckeye Brook, Gilbert-Stuart River and Nonquit River from 1980-2015 (Figure 2.10).

<u>Buckeye Brook</u> - The Buckeye Brook Coalition and RI DFW partnered in 2003 to initiate a direct count program utilizing volunteers. The highest number of fish observed was 90,625 in 2012.

<u>Gilbert-Stuart River</u> - 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. RI DFW has estimated spawning stock size since 1981 by electronic fish counter or direct count methods. The highest number of alewife observed was 290,814 in 2000.

<u>Nonquit River</u> - 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. The Division has estimated spawning stock size at Nonquit since 1999 by a solar powered electronic fish counter. The only known data prior to 1999 included run size estimates (80,000) from 1976. The highest number of alewife observed was 230,853 in 1999.

Total run size of alewife in the Gilbert-Stuart River increased from the early 1990s through 2000 (Figure 2.10). Dramatic drops in run size were observed after 1999-2000 in the Gilbert-Stuart River and Nonquit River, and after 2003 in Buckeye Brook. Run sizes in all rivers increased through 2010, but have declined since.

Connecticut

A proxy of blueback herring run size (number of fish lifted) was available for the Connecticut River from 1966 to 2015. Shorter time series (2002-2015) were available for alewives and blueback herring in Bride Brook, Mianus River, Mill Brook, Naugatuck River, Shetucket River, and Farmington River.

<u>Bride Brook</u> – The number of alewives passing has varied considerably over the short time series (Figure 2.11). The highest number observed in the time series (354,862) occurred in 2013.

<u>Connecticut River</u> – The number of blueback herring lifted at the Holyoke Dam increased dramatically from the late 1970s and peaked around 1985 (Figure 2.11). After 1985, the number of fish lifted began to decline and it dropped precipitously after 1991. The number of fish lifted has remained close to pre-1977 levels since 2002. The highest number of fish observed was 630,000 in 1985

<u>Farmington River</u> – Removed from analysis for the update upon request of the state (see CT section of state-specific report for details).

Mianus River - Trends in alewife and blueback counts were nearly identical (Figure 2.11). Counts of both species increased beginning in 2006, peaked in 2007-2008, and declined in 2009, increased again for a few years through 2012-2014 and then declined again. The highest numbers of alewives and blueback herring observed were 121,401 in 2012 and 29,424 in 2014, respectively.

Mill Brook - The number of alewives passing has varied considerably over the short time series (Figure 2.11). Numbers declined in 2008, increased from 2010 to 2012 and have declined. The highest number of fish observed was 15,361 in 2012.

Naugatuck River - Removed from analysis for the update upon request of the state (see CT section of state-specific report for details).

Shetucket River - The numbers of alewives and blueback herring passing have varied considerably without trend over the short time series (Figure 2.11). The highest numbers of alewife and blueback herring observed were 2,422 in 2007 and 394 in 2001, respectively.

North Carolina

Population size estimates of alewives and blueback herring from age-structured assessment models are available for the Chowan River from 1972-2003 and 1972-2015, respectively.

Chowan River - Alewife abundance in the Chowan River fluctuated widely without trend prior to 1985, declined dramatically through 1989, increased slightly in 1990, but it continued to decline through 2003 (Figure 2.12). Blueback herring abundance declined in the late 1970s, increased during the early 1980s and peaked in 1983, and has steadily declined since 1992. The highest numbers of alewife and blueback herring estimated in the model were 19,348,550 fish in 1984 and 133,738,077 fish in 1976, respectively.

South Carolina

Population abundance estimates of blueback herring are available for the Santee River from 1980-1990.

Santee River - Abundance increased from a low of 664,000 fish in 1982 to a high of 9,000,000 fish in 1986 (Figure 2.12). Blueback population size declined briefly in 1987 but then increased to the highest estimated level of 9,353,000 in 1990.

Comparison of Trends

Historical river counts were compared to identify common trends among rivers. It should be noted that trends may not reflect natural variation in some rivers due to events like anthropogenic changes to river access (see state reports for more detail). All data were normalized prior to analysis. Common trends were identified via hierarchical, agglomerative cluster analysis with the group average linking method using linear (Pearson) correlations among all rivers as the measures of similarity. Normalized river counts were then plotted together based on major grouping identified in the cluster dendrogram. Trends among rivers were examined for four time periods: 1984-2010, 1999-2010, 2003-2010, and 2008-2015. The first period was selected to include as many rivers as possible with long time series, and the latter periods were selected to examine recent changes in river counts from as many rivers as possible. Rivers in the analysis of years 1984-2010 included the Union River, Androscoggin River, and Damariscotta River in Maine, the Lamprey River, Taylor River, Cocheco River and Oyster River in New Hampshire, the Monument River in Massachusetts, the Gilbert-Stuart River in Rhode Island, and the

Connecticut River in Connecticut. The 1999-2010 period included the aforementioned rivers plus the Winnicut River and Exeter River in New Hampshire, the Nonquit River in Rhode Island, and the Mattapoisett River, Nemasket River, and Parker River in Massachusetts. The 2003-2010 period included the aforementioned rivers plus the Sebasticook River in Maine, the Buckeye River in Rhode Island, and the Farmington River and Bride Brook in Connecticut.

1984-2010 - Cluster analysis grouped the similarities of trends in river counts into four main groups (Figure 2.13). Group 1 represents rivers (Monument River alewife, Gilbert-Stuart alewife, Oyster River Both, and Cocheco River Both) in which run sizes increased from 1984, peaked around 2000-2005 and remained low thereafter (Oyster River Both and Monument River alewife) or increased (Gilbert-Stuart alewife and Cocheco River Both; Figure 2.13). Group 2 represents rivers (Androscoggin River alewife, Damariscotta River alewife, and Lamprey River Both) in which run sizes increased from 1984, peaked before 1990, declined to lows in the mid 1990s. Group 3 represents rivers (Connecticut River blueback, Monument River blueback, Union River alewife, Chowan River blueback, and Taylor River Both) in which run sizes peaked in the mid 1980s, declined through 1990, before peaking again in the early 1990s. Runs declined after the early 1990s and remain at very low (Chowan, Taylor, and Connecticut) or relatively low (Monument blueback and Union River alewife) levels. River locations for each cluster group are shown in Figure 2.14 and show that the rivers in Group 1 are located in southeastern New England, those in Group 2 are located in New Hampshire, those in Group 3 are located from New Hampshire through northern New England, and those in Group 4 are scattered throughout New England.

1999-2010 - Cluster analysis grouped the similarities of trends in river counts into three main groups (Figure 2.15). Group 1 represents rivers (Gilbert-Stuart River, Mattapoisett River, Parker River, Taylor River, Oyster River, Connecticut River, Monument River, Nonquit River, Chowan River, and Exeter River) in which run sizes declined starting in the early 2000s (Figure 2.16). Since the decline, run sizes have remained low (Oyster River, Connecticut River, Exeter River, Chowan River, and Taylor River) or have increased over time (Gilbert-Stuart River, Monument River alewife, Mattapoisett River, Parker River, and Nonquit River) , albeit slowly in some cases. Group 2 represents rivers (Union River and Nemasket River) in which run sizes increased through 2002, declined through 2004 or 2005, and then increased. Group 3 represents rivers (Androscoggin River, Winnicut River, Lamprey River, Cocheco River, and Damariscotta River) in which run sizes increased from 1999, peaked in 2003-2004, dropped precipitously in 2004-2005, increased through 2007-2009. River locations for each cluster group are shown in Figure 2.17 and show that the rivers in Groups 1 and 3 are located from New Hampshire through north New England and from New Hampshire through southern New England, respectively.

2003-2010 - Cluster analysis grouped the similarities of trends in river counts into three main groups (Figure 2.18). Group 1 represents rivers (Exeter River, Bride Brook, Sebasticook River, Gilbert-Stuart River, Nemasket River, and Union River) in which run sizes increased from 2008 lows to time series or near time series highs between 2009 and 2010. Group 2 represents rivers (Chowan River, Parker River, Monument River, Connecticut River, Mattapoisett River, Lamprey River, Oyster River, Cocheco River, Taylor River, and Damariscotta River) in which run sizes declined from 2000-2004 levels to lows between 2006 and 2007, and either increased or stabilized through 2010. Group 3 represents rivers (Androscoggin River, Winnciut River, Buckeye River and Nonquit River) in which run sizes either increased from 2005-2006 levels to peaks in 2008 and then steep declines after through 2010 (Figure 2.19). River locations for each cluster group are shown in Figure 2.20 and show that the rivers in Group 1 and 2 are scattered throughout New England, while those from Group 3 are primarily located from New Hampshire through southern New England.

2008-2015 - Cluster analysis grouped the similarities of trends in river counts into four main groups (Figure 2.21). Group 1 represents rivers (Nonquit River, Oyster River, and Taylor River) in which run sizes decreased through 2011-2012 and remained low thereafter (Figure 2.22). Group 2 represents rivers (Cocheco River and Exeter River) in which run sizes were relatively stable between 2008 and 2014 and then increased sharply in 2015. Group 3 represents rivers (Androscoggin River, Buckeye River, Gilbert-Stuart River, and Union River) in which run sizes peaked in 2012 and declined thereafter to near time series lows in 2015. Group 4 represents rivers (Chowan River, Mattapoisett River, Damariscotta River, Monument River, Nemasket River, Connecticut River, Bride Brook, Lamprey River, Parker River, and Sebasticook River) in which runs were relatively low early in the time series, increased to peaks between 2011 and 2014 and declined after. River locations for each cluster group are shown in Figure 2.23 and show that the rivers in Group 1 and 2 are scattered throughout New England, while those from Group 3 are primarily located from New Hampshire through southern New England.

Major declines in run sizes occurred in many rivers during 2001 to 2005. These declines were followed by increasing trends (2006 to 2010) in the Androscoggin River (ME), Damaraiscotta River (ME), Nemasket River (MA), Gilbert-Stuart River (RI), and Nonquit River (RI) for alewife and in the Sebasticook River (ME), Cocheco River (NH), Lamprey River (NH), and Winnicut River (NH) for both species combined. No trends in run sizes were evident following the recent major declines in the Union River (ME), Mattapoisett River (MA), and Monument River (MA) for alewife and in the Exeter River (NH) for both species combined. Run sizes have declined or are still declining following recent and historical major declines in the Oyster River (NH) and Taylor River (NH) for both species, in the Parker River (MA) for alewife, and in the Monument River (MA) and Connecticut River for blueback herring.

Cluster analysis was done for the assessment update using the same three periods used in the benchmark (1984-2010, 1999-2010, 2003-2010) with the addition of a fourth period to include the most recent years in the dataset (2008-2015). The grouping for 1984-2010 did not change with the exception of the fact that groups 1 and 2 from the benchmark were combined into a single grouping as there were no apparent differences in the trends of each group used in the benchmark assessment. Similarly, the groupings of the benchmark assessment cluster analysis for the period of 1999-2010 did not change. However, the Chowan River blueback herring dataset was included in the assessment update and was added to this group. For the final period examined in the benchmark assessment (2003-2010) there was a change in groupings as a result of changes in datasets from those previously submitted and the exclusion of the Farmington River. Most notable was the shift of groupings in the update compared to the benchmark assessment caused by the movement of the Exeter River, Damariscotta River, and Monument River alewife, Parker River, and Bride Brook. The new time period to look at trends in the most recent eight years (2008-2015) did not result in groupings similar to the corresponding final eight year period (2003-2010) used in the benchmark analysis. It is difficult to discern any consistent trends as to why the two periods differ, but suggests that rivers along the Atlantic Coast that were previously grouped together for similar trends have not been experiencing similar population trends in the years since the benchmark.

2.2.2 Young-of-the-Year Seine Surveys

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States of Maine, Rhode Island, Connecticut, New York, New Jersey, Maryland, District of Columbia, Virginia, and North Carolina conduct fixed seine surveys that capture young-of-the-year alewives and blueback herring generally during summer and early fall. Detailed descriptions for each survey are found in state reports; a brief description and comparisons of trends are given below.

Maine – The State of Maine conducts an annual YOY alosine survey for six Maine rivers including Merrymeeting Bay. The survey began in 1979 and expanded to include 17 fixed stations and includes data from a separate juvenile striped bass survey designed to assess the numbers of juvenile striped bass in the lower Kennebec River. Geometric mean indices for blueback herring and alewives are used as relative indices of abundance. Indices for alewives fluctuated without trend over the time series, although large peaks in relative abundance occurred in 1979, 1983, 1995, 2000, and 2015 (Figure 2.24). For blueback herring, relative abundance was near zero from 1979 through 1991 but it increased gradually through 2004 before declining in recent years (Figure 2.25).

Rhode Island –The YOY survey is conducted weekly each fall at five stations in the Pawcatuck River estuary. It began in 1988 and the geometric mean index represents relative abundance for combined species. Relative abundance in the Pawcatuck River estuary fluctuated widely but generally increased through 2002 and it declined thereafter (Figure 2.24).

Connecticut – The YOY survey is conducted weekly during the months of July through October at stations located between Essex, CT (river km 10) and Holyoke, MA (river km 140). It began in 1978 and the geometric mean catch per seine haul is used as the relative index of blueback herring abundance. Relative abundance of YOY blueback herring fluctuated widely prior to 1989, but it declined gradually over time with a large increase in 2010 (Figure 2.25).

New York – The YOY survey was designed to index alosines and occurs in the upper half of the estuary (RM 60-140) which is generally fresh water and is the nursery reach for alosines. It began in 1980 and the geometric mean number of fish per haul is used as the relative abundance indices for alewives and blueback herring. Relative abundance of YOY alewives was low prior to 1999, but has increased since then, with large year-to-year fluctuations (Figure 2.24). For blueback herring, indices fluctuated widely throughout the time series, but appeared to decline during the late 1990s and then remained stable but variable through the present (Figure 2.25).

New Jersey – The YOY survey is conducted biweekly from August to October at fixed stations in the Delaware River. The survey began in 1980 and the geometric mean catch per haul is used as a relative index of abundance for alewives and blueback herring. The YOY index for alewives fluctuated without trend over the time series, although peaks in relative abundance occurred in 1988 and 1996 (Figure 2.24). Relative abundance of blueback herring fluctuated widely to high peaks through 2000, and then dropped to lower levels with less variability during 2001-2015 (Figure 2.25).

Maryland – The YOY survey is conducted monthly at fixed stations in the Maryland portion of Chesapeake Bay from summer through late fall. The survey began in 1959 and the geometric mean per haul is used as relative abundance indices for alewives and blueback herring. Relative abundance of alewives fluctuated widely without trend between 1959 and 1977 (peak abundance occurred in 1970) and it declined to lower levels and was less variable during the mid-1980s and early-1990s (Figure 2.24). A slight increase in average relative abundance occurred following 1992. Relative abundance indices for blueback herring also fluctuated without trend prior to 1970, it declined to low levels (except for increase in 1978) and was less variable during the mid-1980s and early-1990s (Figure 2.25). After 1992, the average magnitude and variation in relative abundance increased.

District of Columbia – The YOY survey is conducted annually in the Potomac River and Anacostia River. Sampling occurs monthly from May through August. The survey began in 1990 and the log of the mean number of fish per haul+1 is used as relative abundance indices for blueback herring and alewives. Relative abundance of alewives has declined since the series started in 1990 through 2003, and has remained low since then (Figure 2.24). Relative abundance of blueback herring increased from near zero levels during 1990-1994, and has shown large year-to-year variability and increasing trend since then (Figure 2.25).

Virginia – Indices of YOY relative abundance for alewife and blueback herring come from the VIMS Juvenile Striped Bass Seine Survey which tracks trends in the annual year-class strength of striped bass in the spawning and nursery areas of the lower Chesapeake Bay. The survey began in 1967 with a gap from 1974-1979, and the geometric average number of fish per seine set for all rivers combined (James, York, and Rappahannock rivers) was used as the relative abundance index in the benchmark assessment. VIMS provided data from 1990 onward, when the current sampling stratification was implemented. For the assessment update, only the Rappahannock River survey was included as geometric means of all rivers combined was not provided. Relative abundance of alewives and blueback herring fluctuated at low levels without trend, although increases occurred in 2010 for alewife and 2015 for blueback herring (Figure 2.24 and Figure 2.25).

North Carolina – The seine survey began nursery area sampling for YOY blueback herring and alewives in the Albemarle Sound area in 1972. Sampling occurs at 11 fixed stations during June-October and an additional 13 fixed stations are sampled in September of each year. The geometric mean number of fish per haul is used as the measure of the relative abundance. Relative abundance of alewives peaked during 1977-1980, it dropped to low levels during 1981-1994, and it increased slightly through 2004, but has dropped again in recent years (Figure 2.24). For blueback herring, relative abundance peaked in 1973 and declined through 2010 (Figure 2.25).

Comparison of Trends in YOY Seine Surveys - Indices of relative abundance were compared to identify common trends among river systems. Common trends were identified via hierarchical agglomerative cluster analysis with group average linking (Clarke, 1993) using linear (Pearson) correlations among all rivers as the measures of similarity. All data were normalized ((obs-mean)/sd) prior to analysis. Cluster groupings were identified based primarily on the largest distances shown in the cluster dendrogram; however, secondary groups were identified to aid in comparison of trends. Normalized indices were plotted together based on major grouping identified in the cluster dendrogram. Trends among systems were examined for two time periods: 1980-2015 and 1993-2015. The former period was selected to include as many surveys as possible with long time series, and the latter period was selected to examine recent changes in indices from as many systems as possible. The 1980-2007 period included surveys from Maine, Connecticut, New York, New Jersey, Maryland, and North Carolina. The 1993-2007 period included surveys from Maine, Rhode Island, Connecticut, New York, New Jersey, Maryland, District of Columbia, Virginia, and North Carolina.

1980-2007 - Cluster analysis grouped the similarities of trends in YOY indices into three main groups (Figure 2.26). Group 1 represents YOY indices for blueback herring from New Jersey and Connecticut and both species from North Carolina which shows peak levels in the early 1980s followed by declines, remaining at relatively low levels of abundance. Group 2 represents river systems in which YOY indices were highly variable with no apparent trends present (New Jersey alewife and both species in New York). Group 3 represents YOY indices of both species from Maryland and Maine, which showed similar fluctuations in relative abundance with peaks occurring around 1995 and 2005. With the exception of blueback herring in Maine, they have increased since 2013.

1993-2007 - Cluster analysis grouped the YOY indices into five main groups (Figure 2.27). Group 1 represents YOY indices from Connecticut River blueback herring and the District of Columbia alewife, which showed peaks in the early 1990s then declines to low levels, although the District of Columbian saw a single peak in 2002 and Connecticut River blueback herring had a peak in 2010 and variable thereafter. Group 2 represents YOY indices from Rhode Island and Maine that showed similar peaks in relative abundance in 1995, 2000, and 2004. Group 3 represents New York's Hudson River which showed similar peaks in relative abundance in 1999, 2001, 2004, and 2007. Alewives in the Hudson River remain relatively low and blueback herring show more variability but included a time series peak in 2014. Group 4 represents YOY indices for blueback herring in the District of Columbia and both species in Maryland and Virginia, which showed similar peaks in relative abundance in 1996-1997 and 2011, with abundance at low levels between 2001 and 2005 (except Maryland Alewife) with all increasing in the most recent years. Group 5 represents YOY indices for alewives and blueback herring from New Jersey and North Carolina that showed similar peaks in relative abundance in 1996, 2000-2001, and 2003, but have remained low (New Jersey) or shown greater variability (North Carolina) since.

The young-of-the-year (YOY) seine surveys were quite variable and showed differing patterns of trends among rivers. Maine rivers showed similar trends in alewife and blueback herring YOY indices after 1991 with peaks occurring in 1995 and 2004. YOY indices from North Carolina, and Connecticut showed declines form the 1980s. New York's Hudson River showed peaks in YOY indices in 1999, 2001, 2005, 2007, and 2014. New Jersey and Maryland YOY indices showed peaks in 1994, 1996, and 2001. Virginia YOY surveys showed peaks in 1993, 1996, 2001, and 2003.

Inclusion of datasets for the period after the benchmark up to 2015 did not show any changes in trends outlined in the benchmark assessment. Indices of alewife from YOY seine surveys remained at relatively low levels similar to those seen for the period prior to 2011. Blueback herring also remained similar to levels observed in the terminal years of the benchmark assessment, although some surveys (Virginia, Maryland, and District of Columbia) have seen increases in 2014-2015. The clustering for 1980-2015, was similar to that of the benchmark assessment, although clustering changed as a result of New Jersey seine surveys previously grouped with Maryland is now grouped with New York for alewife and with Connecticut and North Carolina for blueback herring. The five groups from the benchmark assessment cluster analysis for this period have been reduced to three. Two clusters (Maine and Maryland) were combined to a single cluster in this update and the group containing only the Virginia seine survey in the benchmark is absent as no data was submitted for the period of 1980 to 1988. For the cluster analysis of the second time period (1993-2015) five groupings were again selected as was done in the benchmark assessment. Three of the groupings remained the same (Groups 1, 2, and 3 of this update), but two groups changed with the addition of data after 2010. It is difficult to discern a pattern of movement between groupings, but in the benchmark assessment North Carolina alewife and blueback herring were split between two groups and are now in a single group with both species for New Jersey. New Jersey was previously grouped with both species from Virginia and Maryland, which are still grouped together and now also include District of Columbia blueback herring.

2.2.3 Juvenile-Adult Seine, Gillnet and Electrofishing Surveys

Updated by: Dr. Mike Bailey, U.S. Fish and Wildlife Service; Assessment Benchmark Section by: Gary A. Nelson, Massachusetts Division of Marine Fisheries

Rhode Island has conducted large seine fixed station surveys for juvenile and adult river herring in coastal ponds and Narragansett Bay since 1988. Virginia has conducted a multi-panel gillnet surveys for adult river herring in the Rappahannock River since 1991. In addition, Virginia has conducted an electroshocking survey in the Rappahannock and James Rivers since 2000; however the data collection has ended. Similarly, Florida has conducted an electroshocking survey in the St. John's River since 2001 (see state reports for details). Fish biologists from respective states believe that the estimates of catch-per-unit-effort from each watershed reflect changes in river herring abundance.

Rhode Island

Seine CPUE for combined species in Narragansett Bay fluctuated without trend from 1988-1997, increased through 2000, declined and then remained stable from 2001-2004, increased again in 2005, and declined in 2009 (Figure 2.28). The pond survey CPUE increased during 1993-1996, declined through 1998, increased in 1999, declined through 2002, peaked in 2012, and then declined and fluctuated without trend thereafter. A significant correlation (rho=0.71, $p \leq 0.01$) between CPUEs from the pond survey (lagged forward two years) and the Narragansett Bay survey was found in the benchmark analysis. However, addition of data from 2011 to 2015 does not show a significant correlation (p=0.413) with the addition of more years of data, suggesting that the pond survey may not fully capture year-class strength.

Virginia

Gillnet CPUE for both species in the Rappahannock River ended in 2010 and, therefore, was not included in the update. The electrofishing CPUE indices for alewives and blueback herring in the Rappahannock River and James River were highly variable for the time series (Figure 2.29).

Florida

The electrofishing CPUE indices for blueback herring in the St. John's River declined precipitously from 2001 to 2002 and has fluctuated without trends since 2003 (Figure 2.29).

Comparison of Electrofishing CPUE Trends

Simple correlation analysis was used to compare trends in electrofishing CPUE from 2001-2015. The correlation coefficient between Rappahannock alewife and blueback herring indices indicated a significant ($p \leq 0.05$), negative correlation between species in the original analysis; however the addition of 5 more years of data has not shown a continued relationship (p=0.561). The Rappahannock blueback herring indices were not significant for the entire time series for either the James River survey (p=0.01) or the Florida electrofishing survey (p=0.07). For the James River blueback and Florida blueback comparison, a significant ($p \leq 0.01$), positive correlation between the two time series was evident in the original analysis but not significant for the expanded data set (p = 0.233). The common trend among the

Virginia and Florida electrofishing survey occurred in 2004 and 2015 when the Rappahannock River alewife index, James River blueback herring index, and St. John's River blueback herring index increased (Figure 2.29).

2.2.4 Juvenile and Adult Trawl Surveys

Updated by: Dr. Edward A. Hale, DNREC, DFW; Benchmark Assessment Section by: Dr. John A. Sweka, US Fish and Wildlife Service, Northeast Fishery Center

The purpose of this analysis was to update the summarization of trends in river herring relative abundance data from fisheries independent trawl surveys through 2015. The trawl surveys used in this analysis are shown in Table 2.5 . Details of each survey are provided in individual state summaries. The majority of surveys grouped juvenile and adult fish together (Table 2.5) and no effort was made to develop separate juvenile and adult indices from combined data.

Trawl surveys for river herring can be quite variable, making inferences about population trends uncertain. Observed time series of relative abundance indices represent true changes in abundance, within survey sampling error, and varying catchability over time. One approach to minimize measurement error in the survey estimates is by using autoregressive integrated moving average models (ARIMA, Box and Jenkins 1976).

The ARIMA approach derives fitted estimates of abundance over the entire time series whose variance is less than the variance of the observed series (Pennington 1986). Helser and Hayes (1995) extended Pennington's (1986) application of ARIMA models to fisheries survey data to infer population status relative to an index-based reference point. This methodology yields a probability of the fitted index value of a particular year being less than the reference point [P(indext<reference)]. Helser et al. (2002) suggested using a two-tiered approach when evaluating reference points whereby not only is the probability of being below (or above) the reference point is estimated, the statistical level of confidence is also specified. The confidence level can be thought of as a one-tailed *α*-probability from typical statistical hypothesis testing. For example, if the P(indext<reference) = 0.90 at an 80% confidence level, there is strong evidence that the index of the year in question is less than the reference point. This methodology characterizes both the uncertainty in the index of abundance and in the chosen reference point. Helser and Hayes (1995) suggested the lower quartile (25^{th} percentile) of the fitted abundance index as the reference point in an analysis of Atlantic wolffish (*Anarhichas lupus*) data. The use of the lower quartile as a reference point is arbitrary, but does provide a reasonable reference point for comparison for data with relatively high and low abundance over a range of years.

Autoregressive integrated moving average models (ARIMA, Box and Jenkins 1976) were fit to log transformed trawl survey indices. In cases where a survey contained "0" values for one or more years, a small number (0.01) was added to the index prior to log transformation. In this analysis, the final year of a given trawl survey was compared to the 25^{th} percentile of the fitted index values and a confidence level of 80% was used to assess the probability of the final year of the survey being less than the bootstrapped mean (n = 1000) of the 25^{th} percentile reference point [P(<0.25)]. ARIMA models were fit in R version 3.3.2 and functions in the R package 'Fish Methods' (Nelson 2017) were used for the ARIMA model fit and comparison to reference points. Values of P(<0.25) were summarized by location of the trawl surveys – northern vs. southern surveys with a general separation occurring at Long Island. Trawl surveys with 10 or more years of data were included in 2010. Small differences in the survey indices were present in both alewife and blueback herring data sets for the DE adult trawl survey as well as the

Maine-New Hampshire Inshore trawl survey in the updated data. To determine if those differences were significant, the updated data were analyzed through 2010, with similar results being found in terms of the probability of the index value in 2010 being greater than the bootstrapped mean reference point for the time series. Similarly, small difference in the annual indices of the NEFSC bottom trawl at the coast wide and northern regional level were present in the updated data. However, because of changes to the survey design, alewife were no longer present in the southern region in the fall survey. Other than the lack of an alewife index in the southern region during the fall, no substantial differences were present in the updated data when compared to previous analyses. Therefore, all surveys analyzed in 2010, were updated with data through 2015 and reanalyzed.

Trends in trawl survey indices varied greatly with some surveys showing an increase in recent years, some showing a decrease, and some remaining stable. Trawl surveys in northern areas tended to show either an increasing or stable trend in alewife indices (Figure 2.30 and Figure 2.32) whereas trawl surveys in southern areas tended to show stable or decreasing trends in alewife indices (Figure 2.31 and Figure 2.32). The NEFSC surveys showed a consistent increasing trend coastwide and in the northern regions for alewife. The probability of the final year of the survey being less than the 25th percentile reference point [P(<0.25)] ranged from 0 to 0.464 for alewives (Table 2.6) and 0 to 0.540 for blueback herring (Table 2.7). These probabilities tended to be less in northern regions compared to southern areas for alewife (Table 2.8). However, the differences in mean P(<0.25) were not as pronounced between northern and southern regions for blueback herring (Table 2.8). Overall, patterns in trends across surveys were less evident for blueback herring (Figure 2.33, Figure 2.34 and Figure 2.35).

Overall, the results of the 2015 ARIMA assessment update suggest similar spatial trends as were observed in 2010 for river herring. There appeared to be a greater likelihood of trawl surveys showing a decrease for those surveys in the southern areas, particularly for alewife. However, general spatial trends in blueback were less apparent compared to alewife by region, as well as when compared to values observed in 2010 despite the updated analyses showing a greater mean likelihood of surveys below the reference point than the northern region. Again when taken into context with the 2010 assessment, these observations are consistent with hypotheses concerning the effects of climate change on fish species distributions. Nye et al. (2009) showed the center of biomass for many stocks surveyed with the NEFSC bottom trawl survey has moved northward through time and changes in distribution were correlated with large-scale warming and climactic conditions such as the Atlantic Multidecadal Oscillation. In addition to the NMFS data used in this analysis, data from other sources also show similar patterns.

2.3 TRENDS IN MEAN LENGTH

Updated by: Kevin Sullivan, New Hampshire Fish and Game; Benchmark Assessment Section by: Dr. Gary A. Nelson, Massachusetts Division of Marine Fisheries

Length data come from Maine, New Hampshire, Massachusetts, New York, Maryland, North Carolina, South Carolina, and Florida. Fork length data were converted to total length when applicable. Mean length was calculated for each year by species and sex and the time series were examined to determine if changes have occurred over time. The Mann-Kendall test for trends in data was used to test if negative or positive trends occurred in the mean length data. A significance level of 0.05 ($p = 0.05$) was used to determine whether a statistically significant trend was present.

Maine

Plot of the mean total length for female and male alewife from the Androscoggin River versus year indicated that average sizes were slightly larger in the late 1980s than average sizes in the remaining years (Figure 2.36). However, the Mann-Kendall test did not detect a significant trend (Table 2.9).

New Hampshire

Plots of mean total lengths from fisheries-independent monitoring versus year for the Cocheco River, Exeter River, Lamprey River, Winnicut River, and Oyster River showed variable trends depending on river and species. For alewives, mean total lengths varied without trend in the Cocheco River, Lamprey River, and Winnicut River. The only significant trend for alewives detected by the Mann-Kendall test was a decline observed for males in the Exeter River (Figure 2.36; Table 2.9). For blueback herring, mean total lengths of female and males varied without trend in the Winnicut River, but notable declines were observed for males in the Cocheco River and for both sexes in the Oyster River (Figure 2.37). Significant trends in decreasing average size were detected for the Oyster River and Cocheco River blueback herring (Table 2. 9).

Massachusetts

Plots of the mean total length from fisheries-independent monitoring versus year for the Monument River show an apparent decline in the average sizes of male and female alewives (Figure 2.36) and blueback herring (Figure 2.37) from 1979 through the mid-1990s. Trend analyses of mean lengths indicated significant decreases in mean length for males and females of both species in the Monument River (Table 2.9).

New York

Mean lengths represent spawning stock lengths from the Hudson River Estuary. NY used only the least size-biased gears from the NYSDEC surveys: electro-fishing gear, the beach seine (61m) and the herring haul seine (91m). As sample size varied among years, all data were combined to characterize size. Mean total length are shown for adult alewives and blueback by sex ($\geq$170mm TL) in Figure 2.36 and Figure 2.37. Following the benchmark assessment, NYSDEC Staff implemented a new methodology for determining appropriate sample sizes for trend analysis. This new methodology changes the historical data used in the benchmark assessment to a subset of the data presented in Figure 2.36 and Figure 2.37 (see state report), including time series for females of both species that are shorter than 10 years. Trend analyses of mean lengths indicated no significant trend for males of both species (see state report for results).

Maryland

Alewives and blueback herring in the Nanticoke River were collected from commercial pound nets and fyke nets and a minimum of ten alewives and ten blueback herring were selected at random from unculled commercial catches. Samples were counted, sexed, length measured and scales removed for age analysis. Mean lengths of male and female alewives appeared to decline over the time series available (Figure 2.36). Blueback herring of both sexes showed a decline over the time series and are near their lowest values in the time series. Trend analyses of mean lengths indicated significant decreases in mean length for males and females of both species (Table 2.9).

North Carolina

The State of North Carolina conducts biological sampling of alewife and blueback herring from fishery-dependent pound net collections in the Chowan River. Length are available from 1972-2015. Declines in mean sizes of male and female alewife (Figure 2.36) and blueback herring (Figure 2.37) were apparent. Trend analyses of mean lengths indicated significant decreases in mean length for males and females of both species (Table 2.9).

South Carolina

Mean length of blueback herring taken in the commercial fisheries in the Santee Rediversion Canal varied widely among years (Figure 2.37). Mean length of males showed a slight declining trend over the time series through 2010 after which it began increasing. Mean length of females showed a slight increasing trend. Mean length of females has exceeded that of males since 2001. Blueback herring in the commercial catch tended to be smaller than those that survived the fishery and were lifted over the St. Stephen Dam (Figure 2.37). Trend analysis of mean lengths indicated no decline in mean lengths over time (Table 2.9).

Florida

An anadromous fish study in 1972 and 1973 used a commercial herring seine to capture blueback herring and other Alosines in the St. John's River. The seine was 306 m long, 131 meshes deep, 6.03 - 6.35 cm stretched mesh, bag with 5.08 cm stretched mesh. Modern length samples are collected by electrofishing. Mean lengths are lower in the 2001-2007sampling period than they were in the 1972 and 1973 samples (Figure 2.37). Trend analysis of mean lengths indicated a significant decline in mean length of female blueback herring over time (Table 2.9).

The general results of these analyses were that mean sizes for male and female alewife declined in 4 of 9 rivers, and mean sizes for female and male blueback herring declined in 6 of 9 rivers. The common trait among most rivers in which significant declines were detected is that length data were available prior to 1990. Mean lengths started to decline in the mid to late 1980s; therefore, it is likely that declines in other rivers were not detected because of the shortness of the time series.

National Marine Fisheries Service Trawl Survey

NEFSC bottom trawl survey data was analyzed by geographical region and season. Because of the large number of strata (376) and high variability in catches of river herring per tow, strata were aggregated into three regions for spring surveys (March – June): coastwide, north of Long Island and south of Long Island. Fall surveys (September – December) were only aggregated coastwide because of low catches in southern survey strata.

Mean lengths for combined sexes in trawl surveys were quite variable through time for both alewives and blueback herring (Figure 2.38). Despite this variability, alewife mean length tended to be lower in more recent surveys (Figure 2.38). This pattern was less apparent for blueback herring. Trend analysis of mean lengths indicated significant declines in mean lengths over time for alewives coastwide and in both regions in the spring, and for blueback coastwide and in the northern region in the fall (Table 2.10).

In this assessment update, one river systems previously included in the benchmark assessment was excluded due to a time series shorter than ten years (Stony Brook) and one new river system (St. John's

River) was included. Updated trend analysis shows a continuation of the declining mean size of both species mentioned in the benchmark assessment. A significant decline in mean length of alewives was found in 5 of the 9 river systems examined. There were no reversals in significant trends of alewife mean length since the benchmark assessment, but two systems (Exeter River and Nanticoke River) previously exhibiting no significant trend now have significant declines in mean length of alewives. Similarly, blueback herring mean length is significantly declining in 7 of the 9 river systems examined. There was one reversal in trend since the benchmark, with the significant decline in mean length of female blueback herring in the Santee-Cooper fishlift no longer apparent. However, the Cocheco River and St. John's River (not included in benchmark) are two additional significant trends in decreasing mean length of blueback herring.

Trends in mean lengths from the NEFSC bottom trawl survey were similar to those of the benchmark, but previously significant declines for alewives in the fall are no longer significant, and the south region of the spring survey that was not significant in the benchmark is now significant in this update. Blueback herring trends in mean length are the same as they were in the benchmark, with the exception of the lack of the significant decline in blueback mean length during the spring survey in the south region that was observed in the benchmark assessment.

2.4 TRENDS IN AGE DATA

Updated by: Ben Gahagan, Massachusetts Division of Marine Fisheries; Benchmark Assessment Section by: Dr. Gary A. Nelson, Massachusetts Division of Marine Fisheries

Age data comes from commercial and fisheries-independent sampling programs, although lengths of the time series differ greatly (see state reports for more details). In general, female alewife and blueback herring are larger and heavier, and grow slightly faster than males of the same species and age, although blueback herring are smaller than alewife.

2.4.1 Trends in Maximum Age

Age data of fish from rivers in Maine, New Hampshire, Massachusetts, Rhode Island, Maryland, and North Carolina were included in the analysis.

Maine

The maximum age of both male and female alewife from the Androscoggin River was generally ≥age 6 during the 1990s, but it decreased by about one age during the late 1990s and early 2000s (Figure 2.39). Maximum age has since increased to early 1990s levels for female alewife, but male maximum age has fluctuated between 4 and 7 during the 2010's. Scale samples were not collected form Androscoggin River alewife in 2015. The maximum age of both sexes of alewife in the Sebasticook River has been stable in the range of 5 to 6 years, with an occasional max age of 7, throughout the time series.

New Hampshire

In 2010, New Hampshire Fish and Game switched from random sampling to bin sampling, which may have altered biases in the data over the time series. For alewife, the general trend in maximum age of females and males was river dependent. River restoration work on the Winnicut River has caused the time series for both species to be discontinued after 2010. In the Cocheco River and Lamprey maximum age increased from age 6 to ages 7 – 8 in the early 2000s and have remained in that range through 2015.

(Figure 2.39). In the Exeter River, maximum age increased in the early 1990s, but it has been relatively stable at age 6 since that time except for a slight decline in 2010 (Figure 2.39). For blueback herring, the general trend in maximum age of females and males was river dependent. In the Cocheco River, maximum age has fluctuated widely, and a lack of blueback herring in recent years has led to insufficient sample sizes for analysis (Figure 2.40). In the Oyster River, maximum age increased by one age beginning in 2001 and has remained at this level for females. The maximum age for males has shifted between 5 and 6 since 2010.

Massachusetts

In 2013, Massachusetts Division of Marine Fisheries switched ageing structures form scales to otoliths. Analyses suggest that otoliths increased the precision of age estimates but did not alter accuracy biases. Maximum age of male and female alewife (Figure 2.39) and male and female blueback herring (Figure 2.40) in the Monument River declined from ages 7 – 8 in the mid-1980s to ages 5 – 6 during the early 1990s and has remained relatively stable since that time.

Rhode Island

Maximum age of male and female alewife (Figure 2.39) in the Gilbert-Stuart River declined from ages 6 – 7 in the mid-1980s to ages 5 – 6 during the 2000s and has remained stable since.

Maryland

Since the benchmark assessment, Maryland officially adopted the MA DMF ageing protocol (see state report). Maryland also introduced new agers in 2011 and 2014, which may have introduced error or bias into recent age estimates. Maximum age of male and female alewife from the Nanticoke River has decreased slightly over the past 25 years. Male alewife were predominately 7-8 until 2000 with a range of 6-7 since. Female alewife shifted from a range of 8-9 to a range of 7-8 in the late 2000's (Figure 2.39). Maximum age of male and female blueback herring from the Nanticoke River declined from ages >9 during the early 1990s to ages5 – 6 and 6 – 7, respectively, during 2005 – 2014 (Figure 2.40).

North Carolina

The maximum age observed for male and female alewife ranged from ages 5 to 9 (Figure 2.39). Due to ageing error identified during the assessment (see state report), updated alewife data were not included in the analysis and the trend determination from the benchmark assessment (declining) was not updated. Maximum age of male and female blueback herring from the Chowan River was generally ≥age 7 prior to 1984 but it declined thereafter to ages 6 – 7 through 2003 (Figure 2.40). After 2003, maximum age declined to ages 5 – 6 and the lowest maximum age was reported in 2014.

Data provided in the update added little information to this visual analysis. In terms of maximum age no trends appear reversed and most runs had stable ages. Lamprey River (NH) alewife maximum age appears to be trending upward, while Nanticoke River (MD) alewife and blueback herring, and Chowan River (NC) blueback herring maximum ages appear to have dropped. In future assessments, the value of examining the number of age classes present in a population should be examined as an alternate metric to maximum age.

2.5 TRENDS IN MEAN LENGTH-AT-AGE

Updated by: Kevin Sullivan, New Hampshire Fish and Game Department and Dr. Edward A. Hale, DNREC, DFW; Benchmark Assessment Section by: Dr. Gary A. Nelson, Massachusetts Division of Marine Fisheries

Mean lengths-at-age of alewife and blueback herring from state data were examined to determine if changes have occurred over time. The Mann-Kendall test for trends in data was used to test if negative or positive trends occurred in the mean length data for each age. A significance level of 0.05 ($p = 0.05$) was used to determine whether a statistically significant trend was present. Due to low sample sizes, only time series of ages 3-6 mean lengths were tested for trends. In order to determine if mean length-at-age for both alewife and blueback herring has changed since 2010, data were updated to 2015 and re-analyzed. Of the 112 Rivers-Species-Age combinations updated (111 with data, as there was no data available for Gilbert-Stuart Alewife Male age 6), 26 have reversed in terms of their significance when compared to the analysis preformed in 2010. Of those reversals, 11 have become non-significant, when they were categorized as significant in 2010 and 16 changed from non-significant to significant (Table 2.11). Updated data were verified by state specific TC representatives before being analyzed and included in the update to account for disagreements in all cases. In addition to analyzing the total time series for each time series, we separately analyzed a reference period from 2006-2015.

Maine

Maine DNR conducts biological sampling of alewives at fish ladders in the Androscoggin River. Length and age data are available from 1993-2010. For alewives, ages observed on the run ranged from 3 to 7 but most fish were ages 4-6. No updated data was submitted for the update so trend analysis was not possible.

New Hampshire

Length and age data for alewives and blueback herring from the Cocheco River, Exeter River, Lamprey River, Oyster River and Winnicut River have been collected by New Hampshire since 1990. For alewife, ages 3-9 fish were collected on the runs. Plots of mean lengths-at-age showed sizes varied among age, river and sex, but in some rivers, mean lengths-at-age showed some decrease in recent years (Figure 2.41). Trends analyses indicated significant declines in mean lengths-at-age for ages 4-5 female and 3-5 male alewife from the Cocheco River, for age 4 females and ages 3-4 males from the Exeter River, for ages 3-5 females and ages 3 and 4 males from the Lamprey River, and for age 4 females and age 3 males from the Winnicut River (Table 2.11). For blueback herring, ages 3-8 fish were collected on the runs. Plots of mean lengths-at-age showed sizes among age, river and sex, but in some rivers, mean lengths-at-age showed some declines over times (Figure 2.42). Trends analyses indicated significant declines in mean lengths-at-age for ages4-6 females and ages 3-6 male blueback herring from the Cocheco River, for ages 3-5 males and females from the Oyster River, and for age 4 females and age 3 males from the Winnicut River (Table 2.15). Trend analyses of the most recent ten years (2006-2015) detected significant increases in length-at-age for age-6 alewife of both sexes in the Cocheco River age-5 females and ages 5-6 males in the Exeter River (Table 2.11). Trend analyses of blueback herring for the same period detected significant increases in age-4 and age-6 females and age-4 and age-5 males in the Oyster River (Table 2.11).

Massachusetts

Length and age data for alewives and blueback herring from the Monument River have been collected since 1984, although age data were only intermittently collected prior to 1993. Mean lengths-at-age were plotted by sex and year to determine if changes in growth have occurred over time. Unfortunately, data from 1984-1987 were not available for historical comparison. For alewives, ages 3-8 fish were collected on the run. Although variable, mean length-at-age of alewives for ages 3-5 of both sexes appeared to decline in the mid-1990s and increased near the latter part of time series (Figure 2.43). There were no significant changes in size-at-age detected in the trend analyses (Table 2.11). For blueback herring, ages 3-7 fish were collected on the run. Mean lengths-at-age of both sexes varied without trend (Figure 2.42). There was only a significant decline of age 5 males detected in the trend analysis of the time series (Table 2.15). Trends analysis of the most recent ten years (2006-2015) detected a significant increase of age-3 female alewife and age-4 blueback herring of both sexes (Table 2.11).

Rhode Island

The State of Rhode Island conducts biological sampling of alewife at fish ladders in the Nonquit River and Gilbert Stuart River. Length and age data are available from 2000-2015 in the Nonquit River and from 1984-2015 in the Gilbert Stuart River; however no samples were collected during the mid-late 1990s (Figure 2.43). Ages 2-8 alewives were found in both rivers, although the runs were comprised mostly of ages 3-6. No significant changes in mean lengths-at-age for alewife in the Nonquit River were detected by trend analysis with data through 2010 and again with data through 2015. From 2006-2015, significant increases were detected for ages 5 and 6 female, as well as ages 4 and 5 male alewives. Significant decreases in mean length at-age were originally detected for age 4 females and males of the Gilbert Stuart. However, with the updated data, significant decreases in mean length at age were only detected in age 4 males through 2010, and no significant trends were detected using data through 2015 for either sex. From 2006-2015, significant increases in alewives were present in age 3 and age 4 males in the Gilbert-Stuart. No other significant trends were detected (Table 2.11).

Maryland

Maryland DNR collects biological samples of alewife and blueback herring from fishery-dependent pound nets in the Nanticoke River. Length and age data are available from 1989-2015. For blueback herring, individuals of ages 3-9 have occurred on the run, but most fish are ages 3-6 (Figure 2.42). Few fish of ages 7-8 have been observed in catches since the late 1990s. Mean lengths for most ages have shown little trend over time except for slight declines in the latter part of time series. A significant decline in mean length was detected only for age-5 male blueback herring when originally analyzed in 2010. However, updated data demonstrated that significant declines in mean length at age were detected for age-3, age-6 male blueback herring in addition to age-5 through 2010. When analyzed through 2015, significant declines in mean length at age were detected for age-3, age-4, age-5, and age-6 male blueback herring (Table 2.11). For alewife, individuals of ages 3-9 have occurred on the run, but most fish are ages 3-6 (Figure 2.43). Fish of age 9 have been rare in catches since the early 1990s. Mean lengths for most ages have shown little trend over time. Significant declines in mean length were detected only for age-5 female and male alewife when originally evaluated in 2010. However, updates to the data indicate that significant declines have occurred in mean length of age-6 female and age-3, age-4, age-5 male alewife through 2010. Similarly, the results of the updated analyses suggest mean length of age-6 female and age-3, age-4, and age-5 male alewife have declined through 2015. However, no significant trends were detected in mean length at age for either species from 2006-2015 (Table 2.11).

North Carolina

The North Carolina DMF collects biological samples of alewife and blueback herring from fishery-dependent pound nets in the Chowan River. Fork length and age data are available from 1972-2009 for alewife and 1972-2015 for blueback herring. Due to ageing error identified during the assessment (see state report), updated alewife data were not included in the analysis. For alewife, fish of age 2 (rare) through age 8 occur on the run but most fish are ages 3-6 (Figure 2.44). Plots of mean lengths-at-age for female and male alewife show that the sizes of most ages have declined over time (Figure 2.44). Trends analyses detected significant declines in sizes for all ages and sexes tested in 2010, again with updated data through 2010 and data through 2015 (Table 2.11). For blueback herring, fish of age 2 (rare) through age 9 occur on the run but most fish are ages 3-7 (Figure 2.44). Plots of mean lengths-at-age for female and male blueback herring show that the sizes of most ages have declined over time (Figure 2.44). Trends analyses detected significant declines in size for all ages and sexes tested in 2010, again with updated data through 2010 and data through 2015 (Table 2.11). However, significant increases were detected from 2006-2015 in male, age-5 blueback (Table 2.11).

Comparison of Trends

Declines in mean length of at least one age were observed in most rivers examined. The lack of significance in some systems is likely due to the absence of data prior to 1990 when the decline in sizes began, similar to the pattern observed in mean length (see Section 2.3). Declines in mean lengths-at-age for most ages were observed in the north (New Hampshire) and the south (North Carolina). There is little indication of a general pattern of size changes along the Atlantic coast.

2.6 TRENDS IN REPEAT SPAWNING FREQUENCY DATA

2.6.1 Trends in Coastwide Repeat Spawner Rates

Updated by: Ben Gahagan, Massachusetts Division of Marine Fisheries; Benchmark Assessment Section by: Laura M. Lee, North Carolina Division of Marine Fisheries and Katie Drew, Atlantic States Marine Fisheries Commission

Rates characterizing the percentage of repeat spawners were calculated and evaluated for alewife and blueback herring populations along the U.S. East Coast where data were available. Repeat spawner data for these species have been collected from various fisheries-independent (Table 2.12) and fisheries-dependent (Table 2.13) monitoring programs. Detailed information on the individual surveys of state water bodies can be found in the individual state summary reports. 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 sex, year, water body, gear, and species (when possible) for each state.

Comparisons among the repeat spawner rates from different states were not made due to the large variability in sampling gears and time series available. For data series that had at least five continuous years of data and ten years of data overall, the Mann-Kendall test for trend in data collected over time. A significance level of 0.05 ($\alpha = 0.05$) was used to determine whether a statistically significant trend was present.

2.6.1.1 Fisheries Independent Repeat Spawner Rates

A summary of the available repeat spawner data for river herring collected by fisheries-independent surveys is presented in Table 2.12Table 2.12 Summary of fisheries-independent data sources that have collected repeat spawner data from river herring. Species indicates whether data were available for alewives (A), blueback herring (B), or both species combined (river herring, R). Annual estimates of repeat spawner rates based on data from these surveys are presented in Tables 2.14 – 2.23.

Maine

Androscoggin River: Repeat spawner data collected from the Brunswick Fishway on the Androscoggin River were available from 2005 through 2014. Scale samples were not collected in 2015. Species-specific data on repeat spawners were not available and so rates represent alewives and blueback herring combined, although very few bluebacks are sampled in the Androscoggin River. Also, detailed information on the number of spawning marks at age was not available. For the assessment update, Maine provided the entire time series as combined sexes rather than split. Repeat spawner rates ranged between 13.5% and 57.9% over the 10 year time series. The four most recent years were below the 10 year mean (Table 2.14).

New Hampshire

New Hampshire has been collecting repeat spawning data from river herring sampled from fishways on the Cocheco, Exeter, Lamprey, Oyster, and Winnicut Rivers. Because of low sample size by species, the data were not analyzed by sex Table 2.15 and Table 2.16; Figure 2.45). Cocheco River: Alewife in the Cocheco River had up to four spawning marks; repeat spawners ranged from age 3 – 9. The proportion of repeat spawners ranged from 30.4 – 69.6% and showed no statistically significant trends (Table 2.15). Blueback herring in the Cocheco River had up to four spawning marks; repeat spawners ranged from age 3 – 8 (Table 2.16). Sample sizes were inadequate in 2009-2012 and 2014-2015, and low in several years. The proportion of repeat spawners ranged from 12.5 – 44% and showed no statistically significant trends.

Exeter River: Alewife in the Exeter River had up to three spawning marks; repeat spawners ranged from age 4 – 8 (Table 2.15). The proportion of repeat spawners ranged from 9.0 – 48.6% and showed no statistically significant trends. Blueback herring sample sizes from the Exeter River were too small (0-12 fish in most years) to be analyzed.

Lamprey River: Alewife in the Lamprey River had up to four spawning marks; repeat spawners ranged from age 3 – 9 (Table 2.15). The proportion of repeat spawners ranged from 33 – 63% and showed no statistically significant trends. Blueback herring sample sizes from the Lamprey River were too small (0-12 fish in most years) to be analyzed.

Oyster River: Alewife sample sizes from the Oyster River were too small (0-16 fish in most years) to be analyzed. Blueback herring in the Cocheco River had up to four spawning marks; repeat spawners ranged from age 3 – 8 (Table 2.16). The proportion of repeat spawners ranged from 20.0 – 68.8% and showed no statistically significant trends.

Winnicut River: Restoration work in 2010 prevented adequate collection of biological samples from 2011-2015. Alewife in the Winnicut River had up to four spawning marks; repeat spawners ranged from age 4 – 9 (Table 2.15). The proportion of repeat spawners ranged from 32.9 – 63.3% and showed no statistically significant trends. Blueback herring sample sizes from the Oyster River were too small (0-12 fish in most years) to be analyzed.

Massachusetts

Information on repeat spawner percentage of river herring species in Massachusetts was available from fisheries-independent dip net surveys of several rivers. Repeat spawner data from the Mattapoisett River, the Quashnet River, and Stoney Brook were limited and so not summarized here, but calculated repeat spawner rates can be found in Tables 2.17 and 2.18. In 2013, Massachusetts Division of Marine Fisheries discontinued processing scale samples from all site-species combinations with the exception of alewife in the Monument River.

Monument River: Repeat spawner data for alewives sampled during fisheries-independent surveys of the Monument River were available from 1986 through 1987, 1993, and from 1995 through 2015. Age-specific data were not available for 1986 and 1987. Of alewife that had spawned previously in recent years, most had only one spawning mark. Repeat spawner rates for male and female alewives were much higher in 1986 and 1987 (41–45%) compared to the most recent years available (1–15%; Table 2.17 and Table 2.18). The Mann-Kendall test indicated both sexes had experienced a statistically significant decline in percentage of repeat spawners.

Repeat spawner data for blueback herring collected by dip net during fisheries-independent surveys of the Monument River were available from 1986 through, 1993, and from 1995 through 2013. As with alewives, age-specific data were not available for 1986 and 1987. None of the blueback herring sampled from 2004 to 2010 had more than one spawning mark. Repeat spawner rates for both male and female blueback herring were higher in 1986 and 1987 (20–38%) than in recent years (4–14%; Table 2.19 and Table 2.20), similar to what was observed for alewives. As with alewives, the Mann-Kendall test indicated both sexes had experienced a statistically significant downward trend in percentage of repeat spawners.

Mystic River: Repeat spawner data for alewives were collected from 2004 to 2013 and for blueback herring from 2005 to 2013 as part of fishery independent surveys of the river. Alewife had up to four spawning marks on their scales and blueback had up to three. For alewives, the percentage of repeat spawners ranged from 0-33.9% for males and from 0-46.1% for females (Table 2.17 and Table 2.18). For blueback herring, the percentage of repeat spawners ranged from 5.7-48.9% for males and from 2.7 – 51.8% for females (Table 2.19 and Table 2.20). Nemasket River: Repeat spawner data for alewives collected from the Nemasket River were available from 2004 through 2013. Male alewife repeat spawners were between 3 and 7 years old, while females ranged in age from 3 to 7 years. Both male and female alewife repeat spawners had from one to three spawning marks. Repeat spawner rates for males and females were similarly variable from 2004 through 2013, ranging between 9% and 44% (Table 2.17 and Table 2.18). There was no statistically significant trend for either sex over this time-period. No repeat spawner data were available for blueback herring from the Nemasket River.

Town Brook: Repeat spawner data for alewives collected by the fisheries-independent survey of Town Brook were available from 2004 through 2013. Male alewives that previously spawned ranged from 3 to 7 years in age, while females ranged in age from 3 to 7 years. Of alewives that had spawned previously, most had only one spawning mark. The percentage of male alewives that previously spawned ranged from 4.41% to 32.3% (Table 2.17). Repeat spawner rates for female alewives ranged from 7.9% to 36.7% (Table 2.18). There was no statistically significant trend for male alewife over this time-period but female alewife experienced a statistically significant upward trend in percentage of repeat spawners. Blueback herring repeat spawner data were only available for 2005 for Town Brook (Table 2.19 and Table 2.20). All of the blueback herring sampled were virgin spawners, although the sample size was very low.

Rhode Island

Rhode Island has been collecting repeat spawning data from river herring sampled from fishways in Gilbert Stuart Stream and Nonquit Pond. The data were not available by species, so calculated repeat spawner rates represent alewives and blueback herring combined.

Gilbert Stuart Stream: Repeat spawner data collected during sampling of the fishway at Gilbert Stuart Stream were available for intermittent years from 1984 through 1989 and were available for all years from 1991 – 2014. In 2015, returns to the Gilbert Stuart were too low to provide enough biological samples for a repeat spawning percentage calculation. Male repeat spawners ranged from 3 to 7 years in age while female repeat spawners ranged in age from 3 to 8 years. Male and female repeat spawners had from one to three spawning marks, and most had only one spawning mark. Repeat spawner rates have been variable for both male and female river herring through the time series (Table 2.21 and Table 2.22; Figure 2.46). The percentage of males that had previously spawned ranged from a low of 4.44% in 2005 to a high of 81.4% in 1986. Rates of repeat spawner for females ranged from a low of 3.3% in 2009 to a high of 59.3% in 1992. The Mann-Kendall test indicated a statistically significant downward trend over time for both male and female repeat spawner rates.

Nonquit Pond: Repeat spawner data has been collected from river herring sampled at the Nonquit Pond fishway since 2000 and were available through 2015, with the exception of 2010. Male repeat spawners ranged in age from 3 to 7 years and most had only one spawning mark. Estimated repeat spawner rates for male river herring were variable, ranging from 0% to 25.7% over the time series. Female repeat spawners were between 3 and 7 years in age and, like the male repeat spawners, most had one spawning mark. Repeat spawner rates for females ranged from 0 to 34.1% and showed a general decrease from 2000 through 2007. The Mann-Kendall test indicated there was no statistically significant trend in repeat spawner rates for the Nonquit.

New York

River herring repeat spawner data collected from fisheries-independent surveys of the Hudson River Watershed in New York were combined over all gears and areas sampled.

Hudson River: Repeat spawner data for alewives sampled from the Hudson River were available from 1999 through 2001 and 2009 through 2015 (Table 2.23). However, since the benchmark assessment, data from the earlier period have been determined to be unreliable and NYSDEC Staff recommended against their use (see state report). Therefore, the reliable data time series is less than 10 years and no trend analysis results are reported.

Repeat spawner data on blueback herring collected from the Hudson River were available from 1989 through 1990, 1999 through 2001, and 2009 through 2015 (Table 2.19 and Table 2.20). However, since the benchmark assessment, data from 1999-2001 have been determined to be unreliable and NYSDEC Staff recommended against their use (see state report). Therefore, the reliable data time series is less than 10 years and no trend analysis results are reported here.

South Carolina

Santee River: Repeat spawner data for blueback herring sampled from the Santee River were available from 1978 through 1983 and 2014 through 2015. Repeat spawner data for alewives were not available from the Santee River. However, the gear used to collect the fish varied among those years. In 1978, a pound net was used. A haul seine was used in 1979. From 1980 through 1983, samples were collected with a gill net. In 2014 and 2015 samples were collected from a commercial cast net fishery in the lower Santee River. Repeat spawner rates based on data collected by the different gear types are not comparable due to differences in selectivity. As such, only data collected by gill net are summarized here since only one year of data was available from each of the other gears, though repeat spawner rates estimated for all gears are reported in the tables at the end of this report.

Male and female blueback herring that previously spawned ranged in age from 4 to 7 years and had marks indicating from one to three previous spawning events. Repeat spawner rates were variable between 1980 and 1983, ranging from 9.2% to 30.7% for males and from 17.1% to 33.7% for females. Current repeat spawner rates appear to be between 25 and 30%

2.6.1.2 Fisheries Dependent Repeat Spawner Rates

A summary of the available repeat spawner data for river herring collected by fisheries-dependent surveys is presented in Table 2.13. Annual estimates of repeat spawner rates based on data from these surveys are presented in Tables 2.24 through 2.27.

Maryland

Nanticoke River (Pound & Fyke Net): Repeat spawner data for river herring collected during sampling of the pound net and fyke net fisheries on the Nanticoke River were available for most years from 1989 through 2014. During the period from 1989 to 2010, male alewives that previously spawned were between 4 and 8 years old and had from one to four spawning marks. Female alewife repeat spawners ranged from 4 to 9 years in age and had from one to five spawning marks. Repeat spawner rates for male and female alewives were variable over the time series, ranging from 25.0% to 72.0% for males and from 41.8% to 84.9% for females (Table 2.24 and Table 2.24 Continued; Figure 2.47). Rates for female alewife repeat spawners were consistently higher than rates for males, and showed less of a decline over the time series. Both sexes showed a reduction in the abundance of fish that had more than one spawning mark. Application of the Mann-Kendall test indicated no statistically significant trend over time for female alewife repeat spawner rates but did indicate a statistically significant negative trend for male alewife rates.

During the period from 1989 to 2010, male blueback herring repeat spawners sampled from pound nets in the Nanticoke River ranged in age from 4 to 11 years. In 2001, an 11 year-old male blueback herring was observed with eight spawn marks. Female blueback herring that previously spawned ranged from 4 to 10 years in age and had from one to six spawn marks. The percentage of male blueback herring that previously spawned ranged from a low of 13.2% in 2007 to a high of 85.8% in 1997 (Table 2.25, Table 2.26; Figure 2.48). Female blueback herring repeat spawner rates ranged from a low of 20.0% in 2005 to a high of 83.4% in 1990. Repeat spawner rates for male and female blueback herring showed similar variations over the time series. The Mann-Kendall test indicated both sexes had experienced a statistically significant decline in percentage of repeat spawners.

North Carolina

Alligator River (Pound Net): Repeat spawner data for alewives collected by pound nets from the Alligator River were available for all years from 1972 to 1993, except 1974. Male alewife repeat spawners were 3 to 8 years old and had one to four spawning marks. Female alewives that previously spawned ranged from 3 to 10 years in age and had one to five spawning marks. Repeat spawner rates for male and female alewives were similar in magnitude (0–79%) and exhibited similar fluctuations over time (Table 2.24; Figure 2.49). Data collection was discontinued in 1994. Application of the Mann-Kendall test for trend found no statistically significant trend over time in either the male or female alewife repeat spawner rates.

Repeat spawner data for blueback herring sampled from pound nets during fisheries-dependent sampling of the Alligator River were available for intermittent years from 1972 to 1991. Both male and female blueback herring that previously spawned ranged in age from 4 to 8 years and had from one to three spawning marks (Table 2.25 and Table 2.26).

Chowan River (Pound Net): Fisheries-dependent repeat spawner data for alewives collected by pound nets from the Chowan River were available for 1972 through 1989, 1991 through 1994, and 1999 through 2009. Due to ageing error identified during the assessment (see state report), updated alewife data were not included in the analysis and the Mann-Kendall test from the benchmark assessment (no significant trend) was not updated. Male alewife that previously spawned ranged in age from 3 to 8 years and had from one to three spawning marks. Repeat spawner rates for male alewives were highly variable over the time series, ranging from 0% to 66.7% (Table 2.24; Figure 2.49). Female alewife repeat spawners ranged from 3 to 8 years in age and had from one to five spawning marks. The female alewife repeat spawner rates were also variable and as high as 86.7% in 1991, although sample size was very low that year. Repeat spawner data for blueback herring collected during fisheries-dependent pound net sampling of the Chowan River were available for all years from 1972 through 2015. Male blueback herring repeat spawners were 3 to 8 years in age and had from one to four spawning marks. Repeat spawner rates for male blueback herring ranged from a low of 5.5% in 2008 to a high of 64.0% in 1979 (Table 2.25; Figure 2.50). Female blueback herring that previously spawned ranged from 4 to 9 years in age and had from one to four spawning marks. Female blueback herring repeat spawner rates were similar in magnitude to the male rates, ranging from a low of 1.69% in 1987 to a high of 77.8% in 1979. No statistically significant trends over time were detected in the male or female repeat spawner rates when the Mann-Kendall test was applied.

Scuppernong River (Pound Net): The fisheries-dependent pound net survey of the Scuppernong River collected repeat spawner data from alewives from 1972 through 1984 and from 1987 through 1993. Male alewife repeat spawners ranged from 3 to 7 years in age, while female repeat spawners were between 3 and 8 years old. Males had from one to three spawning marks and females had one to four spawning marks. Repeat spawner rates for male and female alewives were similar in magnitude (0–69%) and showed similar variability over the time series (Table 2.24; Figure 2.49). Data collection was discontinued in 1994. The Mann-Kendall test found no evidence for a statistically significant upward or downward trend over time for the either the male or female alewife repeat spawner rates.

Blueback herring repeat spawner data collected during the Scuppernong River pound net survey were available for all years from 1972 through 1993. Male blueback herring that previously spawned ranged from 3 to 8 years in age, while females were between 4 and 9 years old. Male blueback herring repeat spawners had from one to three spawning marks and females had from one to four spawning marks.

Repeat spawner rates for male and female blueback herring demonstrated similar fluctuations over the time series, ranging from 0% to 45.8% for males and from 0% to 61.5% for females Tables 2.25, 2.26 and 2.27**;** Figure 2.50). The Mann-Kendall test did not detect a significant trend over time for either the male or female blueback herring repeat spawner rates.

2.7 TRENDS IN TOTAL INSTANTANEOUS (Z) MORTALITY ESTIMATES

Updated by: Michael Brown, Maine Department of Marine Resources; Benchmark Assessment Section by: Dr. Gary A. Nelson, Massachusetts Division of Marine Fisheries

2.7.1 Age-based Total Instantaneous (Z) Estimates

The Chapman-Robson survival estimator (Chapman and Robson, 1960), the least biased estimator of survival compared to catch curve analysis (Murphy, 1997; Dunn et al., 2002), was applied to the annual age-frequency data to generate a single estimate of survival rate for each state, river, species, sex and year. Z was estimated by the natural-log transformation of S. 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. Linear and loess smoothers (Maindonald and Braun, 2003) were applied to all river estimates for a given state, species, and sex to indicate trends in the annual estimates. Estimates of Z are given in state reports and are summarized below.

Maine – Estimates of Z were made for male and female alewife from the Androscoggin and Sebasticook rivers using fisheries-independent data. Z for female alewife in the Androscoggin River declined slightly from around 2.0/yr in the late 1980s to around 0.83 during 1995-1997 and then increased slightly to about 1.3/yr thereafter. During the period 2010-2014 Z values increased to 1.7. The time series average (1986-2015) is 1.4 with no indication of an increasing or decreasing trend (Figure 2.51). Z estimates for males showed little trend over time and averaged 1.6/yr over the time series though Z values averaged 2.0 for the period 2010-2014 (Figure 2.51). The time series of Zs for female and male alewife from the Sebasticook River showed little trend, and averaged 1.5/yr for both sexes for the series 2010-2015.

New Hampshire – Estimates of Z were made for male and female alewife and blueback herring from the Cocheco, Lamprey, Oyster and Winnicut rivers by using fisheries-independent data.

For alewife, declines in Z through 2015 were observed in the Cocheco and Lamprey rivers for both sexes (Figure 2.52). Since 2010, Z has decreased and has averaged 0.7/yr and 0.8/yr for females, and 0.3/yr and 0.8/yr for males in the Cocheco River and Lamprey River, respectively. Significant downward trends in Z for the time series (1992-2015) are noted for male and female alewife in the Cocheco and male alewife in the Lamprey River.

The time series of Zs for female and male alewife from the Winnicut River were short. No data beyond 2009 were provided for this river. Prior to 2010 Z showed little trend, and averaged about 0.9/yr for females and 1.2/yr for males (Figure 2.52). For blueback herring, declines in Z were observed in the Cocheco River for both sexes. A significant downward trend occurred for females for the period 1992-2008. Since 2000, Z has increased slightly for males with no significant trend in either direction (Figure 2.52). There were no data available for blueback herring after 2008 from the Cocheco. Little trend in Z was evident for females and males from the Oyster River; the average Z was 1.1/yr for both sexes prior to 2010. Since 2010 Z for males and female blueback averaged 1.5 and 1.2 respectively. For the time series 1992-2015 Z was 1.2 for males and 1.1 for females (Figure 2.52). The time series of Zs for female and male blueback herring from the Winnicut River were short, showed opposing trends, and averaged about 1.2/yr for females and 1.1/yr for males. No data beyond 2009 are available for this location (Figure 2.52).

Massachusetts – Estimates of Z were made for female and male alewife and blueback herring from the Agawam River, Back River, Charles River, Mattapoisett River, Monument River, Mystic River, Nemasket River, Parker River, Stony Brook, and Town River by using fisheries-independent data. For alewife, Z estimates averaged 1.1/yr and 1.2/yr for female and males, respectively, from the Parker River during the 1970s. There was a slight increase in Z on the Parker River for females and little variation in Z for the period 2010-2015 (Figure 2.53). In the Monument River, estimates of Z for females increased from 0.9/yr in the late 1980s to 1.22/yr in 1999, and then declined to an average of 1.1/yr in the late 2000s. The Z estimate for the years 2010-2015 average 1.8 but did not significantly influence the series trend of 1.3 for the period 1985-2015 (Figure 2.53). Z estimates for males increased from 0.9/yr to an average of 1.4/yr in the late 2000s but for the period 2010-2015 averaged 2.2 indicating a significant upward trend in Z over the time series 1985-2015 (Figure 2.53). In the remaining rivers, the time series of Zs were short and showed little trend except for a significant downward trend in Z estimates for female alewife in the Mystic River for the time series 2004 -2015 and a significant downward trend for females in Town Brook for the series 2004 - 2015 . The Nemasket River Z estimates for males averaged 1.4 for the period 2010-2015 and 1.3 for the time series starting in 2004. The average of Z for females during 2004-2010 was 1.4, similar to the value of 1.5 for the period 2010-2015. For blueback herring, estimates of Z for females and males from the Monument River showed increasing trends over time (Figure 2.54). The series average Z was 1.3/yr and 1.5/yr for females and males, respectively. Blueback herring Z estimates for males averaged 1.5 for the time series 1985-2015 while the Z estimates for female was slightly lower, 1.3 for the series 2005-2015 though it should be noted that several years data in the series are absent. Blueback herring in the Mystic River for both males and females is trending upward since the 2010 assessment. The data series is short for blueback herring in the Mystic, starting in 2007 for males and 2005 for females (Figure 2.54).

New York – Estimates of Z were made for female and male blueback herring from the Hudson River and tributaries collected during 1989 and 1990 (Figure 2.55). Recent Z estimates are available for alewife and blueback herring from 2012-2015 (see state report), but the data time series are less than 10 years and no trend analysis results are reported.

Maryland - Estimates of Z were made for female and male alewife and blueback herring from the Nanticoke River by using fisheries-independent data. Except for the sharp rise in 2003 and 2004, total mortality for female alewife showed little trend over time (Figure 2.56). Estimates of Z for male alewife showed a very slight decrease in mortality for the period 2010-2014 compared to the time series 1991-2014 (Figure 2.56). The average Z was 1.0/yr for females and 1.1/yr for males the period 2010-2014. For blueback herring, Z estimates for females showed little trend (except a slight rise in 1997-1999) over time (average = 1.1/yr), but mortality rose from an average 0.8/yr during the early 1990s to an average of 1.6/yr during 2006-2010 for males but then declined to an average of 1.1 for the period 2010-2014, only slightly higher than the time series trend of 1.0 for years 1989-2014 (Figure 2.56).

North Carolina - Estimates of Z were made for alewife and blueback herring with sexes combined from the Chowan River, Alligator River, Meherrin River, Scuppernong River, and Albemarle Sound by using fisheries-dependent and fisheries-independent data. For alewife, estimates of Z from the Alligator River, Chowan River, Merherrin River and Suppernong River during the 1970s, 1980s, and 1990s averaged 1.3/yr, 1.0/yr, and 0.84/yr, respectively. During the 2000s, estimates of Z from the Chowan River and Albemarle Sound averaged 0.96/yr. For the longest river time series (Chowan), only slight increases in mortality were observed (Figure 2.57). Due to ageing error identified during the assessment (see state report), updated alewife data were not included in the analysis. For blueback herring, estimates of Z from the Chowan River, Merherrin River and Suppernong River during the 1970s, 1980s, and 1990s averaged 0.9/yr in each period. During the 2000s, estimates of Z from the Chowan River and Albemarle Sound averaged 1.1/yr. For the longest river time series (Chowan), slight increases in mortality were observed over the time series and continued to increase over the last 5 year period (Figure 2.57).

South Carolina – Estimates of Z were made for blueback herring with sexes combined from the Cooper River by using fisheries-independent data. A slight decline in Zs was indicated by the loess smooth for blueback herring (Figure 2.58). The average Z over the time series was 1.67/yr. No additional data are available after 2010.

2.7.2 Repeat Spawner Data-based Total Mortality (Z) Estimates

The Chapman-Robson survival estimator (Chapman and Robson, 1960), the least biased estimator of survival compared to catch curve analysis (Murphy, 1997; Dunn et al., 2002), was applied to the repeat-spawner frequency data of most states to generate a single estimate of survival rate (S) for each species, sex and year. The exception was data for New York to which standard catch curve analysis (linear regression) were applied. Z was estimated by the natural-log transformation of S. Only Z estimates made from data with three or more repeat spawner classes (including first fully-recruited class) were deemed valid.

Massachusetts – Estimates of Z were made for female and male alewife and blueback herring from the Back River, Charles River, Monument River, Mystic River, and Town River by using fisheries-independent data. For alewife, average Z estimates for male and female alewife from the Monument River were 0.9/yr and 1.1/yr, respectively, during 1986-1987 and increased to averages of 2.1/yr and 2.4/yr, respectively, during 2007-2010. For the period 2010-2014 Z estimates averaged 1.9 and 2.0 for males and females alewives respectively. There were no long term trends detected or the time series 1986-2015 for either sex (Figure 2.59). For the remaining rivers the time series were short and showed variable trends. The average Zs for females and males alewives from the Mystic River averaged 2.0/yr for males and 1.9 for females though the time series was short (2004-2015) with some year’s data unavailable. The decrease in z estimates for Town Brook observed in the age data were not seen in the repeat spawner data. The series for repeat spawning data includes only eight years and runs from 2004-2013. For blueback herring on the Mystic River there were few Z estimates available for trend analysis (Figure 2.60). The average Zs for the time series for males is 1.8 and 2.0 for females. The time series runs from 2006 to 2015 for females and 2007 to 2014 for males.

Rhode Island – Estimates of Z were made for alewife (combined sexes) from the Gilbert-Stuart River and Nonquit River. For Gilbert-Stuart alewife, Z appeared to decline slightly from 1975 through the early 1990s (average Z=1.3/yr)(Figure 2.61). Starting in 2000, Z estimates increased and averaged 2.2/yr through 2010, suggesting increased mortality. A shorter time series was available for the Nonquit River, but it showed a slight increase in mortality since 2000. The average Z for this system from 2000-2010 was 2.6/yr (Figure 2.61).

New York – Estimates of Z were made for female and male alewife collected during 1999-2001 and blueback herring collected during 1989-1990 and 1999-2001 from the Hudson River and tributaries (Figure 2.62). However, since the benchmark assessment, data from 1999-2001 have been determined to be unreliable and NYSDEC Staff recommended against their use (see state report). Recent Z estimates are available for alewife and blueback herring from 2009-2015 (see state report), but the data time series are less than 10 years and no trend analysis results are reported.

Maryland - Estimates of Z were made for female and male alewife and blueback herring from the Nanticoke River using fisheries-independent data. For alewife, estimates of Z for females and males showed an increase from an average Z of 0.75/yr and 0.84/yr, respectively, in 1990-1993 to an average Z of 1.9yr and 1.7/yr, respectively, in 2000-2002 (Figure 2.63). Since 2003, the Z estimates declined to an average of 1.2/yr for each sex during 2007-2010. During the period 2010-2014 the average Z estimates for female and male alewife are 0.9 and 1.2 respectively. The average Z over each time series, 1991-2014 is 1.2/yr for females and 1.2/yr for males. For blueback herring, estimates of Z for females and males showed a slight decrease increase from an average Z of 0.8/yr and 0.8/yr, respectively in 1989-1993 to average Z of 1.1/yr and 1.5/yr, respectively, in 2000-2002 (Figure 2.63). Since 2003, the Z estimates have declined slightly to an average of 1.0/yr for females and 1.1 for males during 2007-2010 and has remained the same for males and decreased for females to 0.9 for the period 2010-2014. The average Z over the time series was 1.0/yr for females and 1.2/yr for males.

North Carolina - Estimates of Z were made for alewife and blueback herring from the Chowan River, Alligator River, Meherrin River, Scuppernong River, and Albemarle Sound using fisheries-dependent and fisheries-independent data. For alewife, estimates of Z from the Chowan River and Scuppernong River for females and males during the 1970s, 1980s, and 1990s averaged 1.2/yr and 1.6/yr, respectively, 1.4/yr and 1.5/yr, respectively, and 0.8/yr and 1.5/yr, respectively (Figure 2.64). During the 2000s, estimates of Z from the Chowan River and Albemarle Sound averaged 1.13/yr for both sexes. For the longest river time series (Chowan), mortality appeared to increase through 1990 and then decline to current averages of 1.2/yr for females and 1.4/yr for males. Due to ageing error identified during the assessment (see state report), updated alewife data were not included in the analysis. For blueback herring, estimates of Z from the Chowan River, Meherrin River and Scuppernong River during the 1970s, 1980s, and 1990s averaged 1.2/yr for females and 1.3/yr for males, 1.2/yr for female and 1.4/yr for males, 1.2/yr for females and 1.2/yr for males, respectively. During the 2000s, estimates of Z from the Chowan River and Albemarle Sound averaged 1.1/yr for females and 1.5/yr for males. For the longest river time series (Chowan), mortality showed little trend over time but during the last 5-year period estimates of Z have increased slightly above the time series average of 1.12 for females and 1.4 for males(Figure 2.64).

South Carolina – Estimates of Z were made for male and female blueback herring from the Santee River by using fisheries-dependent data. Although the Z estimates for female and male blueback herring showed opposing decreasing and increasing trends (Figure 2.65), the wide variation in the estimates and shortness of the time series suggests general trends may not be accurate. The average Z was 1.58/yr and 1.77/yr for female and male blueback herring, respectively.

2.8 TRENDS IN IN-RIVER EXPLOITATION RATES

Updated by: Jeff Kipp, Atlantic States Marine Fisheries Commission; Benchmark Assessment Section by: Dr. Gary A. Nelson, Massachusetts Division of Marine Fisheries

Trends of in-river exploitation rates of alewife spawning runs were updated for two Maine rivers, the Damariscotta River and the Union River. Trends were not updated for three Massachusetts rivers (Monument River river herring combined, Mattapoisett River alewife, and Nemasket River alewife) due to a moratorium on in-river harvest (i.e., exploitation rate of zero) implemented in 2006, but historical trends are provided in Figure 2.66. In-river exploitation rates were calculated by dividing in-river harvest by total run size (escapement plus harvest) for a given year. Exploitation rates generally varied around declining trends throughout the time series (Figure 2.66), with the exception of very low rates (<0.06) in the Damariscotta River from the mid-1990s to 2000. Damariscotta River estimates for the final three years in the benchmark assessment (2008-2010) increased by about 70% when updated. There are also some slight changes in the updated Union River estimates since 2000 (<$\pm$ 0.1) and there is now an estimate for 2006, while there was no 2006 estimate in the benchmark assessment. This is likely due to updated harvest estimates from hydropower companies (M. Brown, personal communication, March 15, 2017) and the updated estimates are considered more accurate. Since the terminal year of the benchmark assessment, exploitation rates in the Damariscotta River declined from 0.37 in 2011 to 0.14 in 2012 and remained relatively stable since a SFMP was required, averaging 0.11 (Figure 2.67). Rates since a SFMP was required are the lowest during the time series, with the exception of the very low rates from the mid-1990s to 2000. Exploitation rates in the Union River increased following the requirement of SFMPs from 0.63 in 2011 to 0.87 in 2012, were relatively stable from 2013 to 2014, averaging 0.80, and then decreased sharply to the lowest rate during the time series in 2015 (0.42; Figure 2.67).

2.9 INDEX OF RELATIVE RIVER HERRING EXPLOITATION

Updated by: Jeff Kipp, Atlantic States Marine Fisheries Commission; Benchmark Assessment Section by: Dr. John Sweka, US Fish and Wildlife Service

An index of relative exploitation was developed for the coastwide population of river herring. The NEFSC bottom trawl data were used to calculate a minimum swept area estimate of total biomass for spring surveys (1976 – 2015). Minimum swept area estimates are stratified total biomass estimates calculated by expanding the biomass caught within each NEFSC bottom trawl stratum to the area of the stratum and then summing over all strata. Spring surveys were used because river herring are more readily caught during the spring than during the fall surveys (see NEFSC trawl report section in River Herring Benchmark Stock Assessment Volume II). Estimated total catch was calculated from total reported landings (Section 2.1.2), NAFO landings reported from other countries (Section 2.1.1), plus total incidental catch derived via hindcasting methods using the survey-scaling method (NEFSC 2008, Palmer et al. 2008). Estimated total catch was divided by total swept area estimates of biomass to yield an index of relative exploitation. The relative exploitation index was developed for the coastwide population rather than regional populations because estimates of total incidental catch could not be partitioned among regions or discrete river stocks. It should be noted that there is potential for double-counting some of the incidental catch when it is added to the reported landings from the states and NAFO. The method of estimating total incidental catch (retained and discarded) from observer coverage uses total landings from ocean fisheries as the raising factor, and thus any reported river herring landings from federal ocean fisheries would theoretically be included in the incidental catch estimate.

Minimum swept area estimates of total biomass fluctuated greatly between 1976 and 1995 and were lowest between 1988 and 1990. Total biomass estimates remained fairly stable between 2000 and 2008, increased sharply in 2009, and then fluctuated around an increasing trend through 2015 (Figure 2.68 are biomass). Biomass estimates since the benchmark stock assessment are the highest of the time series, with the exception of the 1979 estimate (19,549 MT), and average about 2.2 times greater than the time series average. Total catch estimates showed a consistent decline from 1976 – 2015, decreasing from a high of 8,962 MT in 1976 to a low of 712 MT in 2011 (Figure 2.69). Catch following the benchmark stock assessment was at the lowest level during the time series, with the exception of a slight increase in 2012

(1,162 MT). Relative exploitation fluctuated greatly from 1976 – 1989, but decreased in 1992 and remained relatively stable until 2008. Another decrease occurred in 2009 followed by low and stable relative exploitation through 2015 (Figure 2.70). Relative exploitation since the benchmark stock assessment terminal year is the lowest of the time series, averaging 0.05.

Total catch estimates were often greater than minimum swept area estimates of total biomass in the 1970s and 1980s resulting in relative exploitation rates > 1.0. Catches of river herring from the NEFSC bottom trawl were not corrected by any assumed catchability coefficients, and as the survey stops at Cape Hatteras, NC, estimates do not include the southern range of the stock. Therefore total biomass estimates likely greatly underestimated the true total biomass of river herring. If we assume total biomass estimates are proportional to the true biomass, the calculated relative exploitation values provide an indication of recent trends in river herring exploitation.

2.10 TOTAL MORTALITY (Z) BENCHMARKS

Updated by: Jeff Kipp, Atlantic States Marine Fisheries Commission; Benchmark Assessment Section by: Dr. Gary Nelson, Massachusetts Division of Marine Fisheries and Dr. Katie Drew, Atlantic States Marine Fisheries Commission

River herring are subject to many different sources of mortality, some anthropogenic (e.g., directed and incidental fishing mortality, habitat loss, dam and passage mortality), and some natural (e.g., predation). We can estimate total mortality (Z) for alewives and blueback herring in a number of river systems from age structure and repeat spawner data; however, we often cannot partition this total mortality into its various fishing and non-fishing components.

Total mortality benchmarks were established during the benchmark assessment based on spawning stock biomass per recruit analyses in order to provide reference points for empirical measurements of Z (Table 2, Table 2.28). Reference points were calculated for two age-constant natural mortality estimates (0.3 and 0.7) to evaluate sensitivity of reference points to a range of potential natural mortality. The higher natural mortality results in higher reference points. Therefore, reference points calculated with the lower natural mortality can be considered more precautionary. The SAS and peer review panel favored reference points calculated with the higher natural mortality (ASMFC 2012). Additionally, the peer review panel recommended that a reference point in the range of $Z_{35\%}$-$Z_{40\%}$ is a more appropriate reference point for river herring and, therefore, results are focused on total mortality estimates relative to the $Z_{40\%}$ benchmarks calculated with a natural mortality of 0.7 ($Z_{40\%,M=0.7}$). $Z_{20\%}$ benchmarks and benchmarks calculated with a natural mortality of 0.3 are still included to be consistent with the benchmark and due to the uncertainty in total mortality estimates. In addition, the rates of fishing mortality (*F*), exploitation rate (*u*), and total mortality that cause run-specific river herring populations to collapse due to declining recruitment at low spawning stock biomass ($Z_{collapse}$) used in the benchmark were obtained from previously-derived estimates in Crecco and Gibson (1990), updates of their methods, literature values, or using stock assessment models (Table 2.29 and Table 2.30).

Though benchmark values are derived from assessment data in some cases, the values were not updated. Reference point adjustments should not be considered due to minor interannual variation in data over short time frames, as changing values create “moving targets” that are difficult to achieve through management (McKown et al. 2008). See the benchmark stock assessment for additional details on total mortality benchmarks.

2.10.1 Results

2.10.1.1 Spawning stock biomass per recruit

Empirical estimates of *Z* from several of the stock-sex combinations have been above $Z_{40\%,M=0.7}$ benchmarks since the benchmark assessment (Figure 2.71 - Figure 2.79). These include Sebasticook female alewives, Androscoggin male alewives, Monument female and male alewives, Nemasket female and male alewives, Gilbert-Stuart alewives (both sexes combined), and Nonquit alewives (both sexes combined). Additionally, all estimates for several other stock-sex combinations since the benchmark, with the exception of one year during that period, have been above $Z_{40\%,M=0.7}$ benchmarks. These include Sebasticook male alewives, Androscoggin female alewives, Mystic female and male alewives, Town male alewives, and Nanticoke female and male bluebacks.

Empirical estimates of Z for Cocheco male and female alewives were below $Z_{40\%,M=0.7}$ benchmarks in all years since the benchmark assessment. Additionally, estimates for Lamprey male and female alewives and Nanticoke female alewives were all below $Z_{40\%,M=0.7}$ benchmarks since the benchmark assessment, with the exception of one estimate during that period. Estimates for all other stock-sex combinations fluctuated around $Z_{40\%,M=0.7}$ benchmarks.

Terminal three year average Z estimates for ten of the eighteen stocks were above $Z_{40\%,M=0.7}$ benchmarks, while four were below (Table 2). Of the four stocks above the $Z_{40\%,M=0.7}$ benchmark, two exceeded the $Z_{20\%,M=0.7}$ benchmark. Four stocks did not have updated estimates during these years.

2.10.1.2 Z-collapse

Where applicable, the minimum, maximum and average $Z_{collapse}$ values were plotted for each river (Androscoggin values were used for the Sebasticook River) and compared to age-based *Z* estimates for alewife (Figure 2.80) and blueback herring (Figure 2.81). Total mortality estimates for female and male alewives exceed the maximum $Z_{collapse}$ benchmark in the Androscoggin River in 2013 and 2014, respectively. The male estimate also exceeds the average $Z_{collapse}$ benchmark in 2013. Empirical Z estimates for male and female alewives in the Monument River exceed the average $Z_{collapse}$ benchmark in 2014 and 2015 and all but the female estimate in 2014 exceeded the maximum $Z_{collapse}$ benchmark, while the total mortality estimates from the escapement model remain well below the minimum $Z_{collapse}$ benchmark. The empirical male estimates exceeded the minimum $Z_{collapse}$ every year since the benchmark terminal year except 2012. The total mortality estimate for female alewife in the Nemasket River exceeded the average $Z_{collapse}$ benchmark in 2014 and the male estimate exceeded the minimum $Z_{collapse}$ benchmark in 2015. The 2011 empirical estimate for bluebacks (combined sexes) in the Chowan River exceeded the minimum $Z_{collapse}$ benchmark, but declined to levels below this benchmark since. The SCA estimated total mortality similar to the empirical estimates, below the $Z_{collapse}$ benchmarks, since 2012 while the SCA 2011 estimate disagrees with the 2011 empirical estimate and is also well below the $Z_{collapse}$ benchmarks. Empirical total mortality estimates for all other rivers and years have been below the minimum $Z_{collapse}$ benchmark since the benchmark stock assessment.

2.10.1.3 Discussion

In recent years, the majority of the rivers examined were above the $Z_{40\%,M=0.7}$, with a few of those rivers above the $Z_{collpase}$ benchmarks as well. Conversely, Z estimates for a few rivers have declined to or near time series lows. However, there is uncertainty in our estimates of current *Z*, due to ageing error, the potential for violations in the assumptions of the Chapman-Robson method, such as constant recruitment, and the deterioration of the SCA model for the Chowan River.

The SPR benchmarks were sensitive to assumptions about *M*, which is difficult to estimate empirically for these species. However, results focused on here were from the higher natural mortality scenario. Therefore Z estimates that exceeded reference points calculated with the higher natural mortality would exceed the reference point calculated with the lower natural mortality by an even greater amount.

Additionally, these benchmarks are sensitive to the selectivity pattern assumed for the fishing mortality. A population can sustain a higher *F* if that *F* is applied to older, mature ages rather than juveniles. The *F* in these analyses represents a combination of fishing and other anthropogenic and non-anthropogenic sources of mortality, most of which we cannot quantify at the moment. Improving our understanding of the selectivity patterns of these different sources of mortality would improve our benchmark estimates as well as provide guidance on the best way to reduce excess mortality on these stocks.

3.0 CONCLUSIONS

Assessment of river herring along the U.S. Atlantic coast is difficult. River herring have a complex life history and life history characteristics vary spatially among different river systems (Munroe 2002). Also, factors that influence population dynamics differ among rivers, such as differences among agencies in harvest regulations, the degree of historic habitat alterations, and potential sources of mortality such as predation (Walter et al. 2003). The fate of river-specific stocks during marine migrations is still largely unknown as is the stock composition of river herring in bycatch of ocean fisheries. Among-system differences and uncertainty in the marine life stages of river herring combined with the great variation in the amount, types, and quality of data collected by different agencies limited the types of assessment methods used during the benchmark assessment and, subsequently, updated for this assessment.

Trend analyses and population models for a few rivers were evaluated to update generalizations about the status of the coastwide river herring meta-population. For the benchmark stock assessment, the SAS provided directions of recent abundance and total mortality trends by data set over the last five years of the benchmark assessment data time series (2006-2010) and collective abundance trends by stock over the last ten years. Directions of trends were determined with a consensus-based, expert opinion framework based on both qualitative, visual inspection and quantitative, statistical tests such as the Mann-Kendall test. For this update of the assessment, the SAS provided directions of recent trends with the same framework applied to the last ten years of the update assessment data time series (2006-2015) by abundance and total mortality data set and collectively by stock abundance. The SAS believes a decadal time period is more reflective of true trends in river herring population parameters due to the high inter-annual variability of data and the life span of the species. This period also encompasses the majority of management actions taken specifically for river herring (i.e., pre-benchmark period moratoria, ASMFC requirement of SFMPs in 2012). Recent trend designations include increasing, decreasing, stable, no trend, unknown, and no returns. Stable indicates a relatively flat time series over the time series evaluated. It does not indicate stock condition relative to other time periods. Stocks can be stable at historically low levels. No trend indicates relatively high inter-annual variability, impeding ability to differentiate between increasing, decreasing, or stable. Unknown indicates there was no river-specific abundance data to evaluate the trend specifically for the stock. No returns indicates a stock where fish stopped returning to the monitoring site(s). In addition to the recent trends evaluated during the benchmark assessment and summarized in Table 1 of that assessment, the SAS summarized recent trends of river herring on the northeast U.S. continental shelf based on data from the NEFSC bottom trawl survey and the St. Johns River in Florida during this update. Trends for the northeast U.S. continental shelf represent mixed stocks with unknown proportion contribution from river-specific stocks and should not be interpreted as reflecting the trends of any individual river-specific stock(s).

Several data sets have been discontinued since the benchmark stock assessment, primarily commercial CPUE and total harvest. Though fishery-independent data are typically preferred for assessment purposes, the discontinued CPUE time series are from several rivers that lack fishery-independent sampling. The SCA models for Nanticoke River river herring could not be updated due to moratoria on commercial harvest and the stability of the SCA model for the Chowan River bluebacks has deteriorated, partly due to reduced information coming from reduced harvest data. The SAS notes that, while management measures taken that have impacted data collection since the benchmark stock assessment were necessary, the reduced information has hindered the ability to draw conclusions from an assessment update.

Recent trends in abundance data sets were variable, but generally showed no trend or, to a lesser degree, increasing trends. No CPUE data sets reflected declining trends over the last ten years of the update, with one of ten data sets showing an increasing trend and three showing no trend. Six were not updated due to discontinuation or changes in methodology. No run counts reflected declining trends over the last ten years with eleven of twenty nine showing increasing trends, fourteen showing no trend, and four not being updated (two due to discontinuation and two due to agency recommendation). One of sixteen YOY seine surveys indicated a declining trend over the last ten years, two indicated increasing trends, and thirteen indicated no trend. One of twelve trawl surveys evaluated with ARIMA indicated a declining trend over the last ten years, four indicated increasing trends, and seven indicated no trend. The ranges of the probability of the final year of surveys being less than the 25th percentile reference points decreased relative to the ranges estimated during the benchmark for both species. Similarly to the benchmark, most of the fishery-independent indices indicate interannual variation at low stock sizes and more time is needed to reflect large scale changes in abundance. As noted in the benchmark assessment, the interannual variation observed may also be a factor of the high mortality the stocks have experienced historically. Fishing effort has been shown to increase variation in fish abundance through truncation of the age structure and recruitment becomes primarily governed by environmental variation (Hsieh et al. 2006; Anderson et al. 2008). When fish species are at very low abundances, as is believed for river herring, it is possible that the only population regulatory processes operating are stochastic fluctuations in the environment (Shepherd and Cushing 1990).

Biological indicators from river herring generally suggest total mortality may be stable or increasing. There have been no increasing trends in percent repeat spawners or mean length through the full data time series and declining trends were detected for several rivers. Declines in mean length-at-age were also observed in many rivers. Trends in maximum age have generally been stable. There have been no increasing trends in empirical total mortality estimates over the last ten years, three trends have declined, and ten have shown no trend. Only three trends have increased over the full time series. The lack of trends in age-based Z estimates could be due in part to relatively short time series of data or inconsistencies and uncertainties in aging methods through time. Also, age-based Z estimates were only performed on data sets that had three or more year classes which may have eliminated some data sets from these analyses that have experienced truncation of age distributions due to increasing mortality. These different indicators of mortality are often in conflict within stocks, with stable or decreasing empirical mortality estimates and decreasing mean length and/or percent repeat spawners.

River-specific three-year average total mortality estimates relative to $Z_{20\%}$ and $Z_{40\%}$ benchmarks were variable relative to these comparisons from the benchmark assessment. Average mortality estimates and benchmarks indicated deteriorating conditions (i.e., move from exceeding the $Z_{40\%}$ to exceeding the $Z_{20\%}$ reference points) for four rivers, improved conditions (i.e., fall from above to below $Z_{20\%}$ or fall from above to below $Z_{40\%}$) for four rivers, and no change for six rivers. Age-based total mortality estimates in recent years were not available for four stocks due to the lack of returning fish (Winnicut River alewife and blueback, Cocheco River blueback) or recent ageing error (Chowan River alewife). While all rivers assessed in the benchmark stock assessment were above the $Z_{40\%}$ benchmark, two rivers assessed during the update fell below the $Z_{40\%}$ benchmark. There is no apparent latitudinal pattern as stocks that appeared to deteriorate since the benchmark (Oyster blueback, Town alewife, Nanticoke alewife, Chowan blueback) were spread along the coast and stocks that appeared to improve (Cocheco alewife, Lamprey alewife, Mystic alewife, Nanticoke blueback) were also spread along the coast. Conditions even changed within rivers between species (Nanticoke). While most total mortality estimates were below $Z_{collapse}$ reference points, a few estimates in recent years exceed at least the minimum $Z_{collapse}$ reference point.

Given the conflicting results from mortality indicators and uncertainty of total mortality estimates due to ageing error, uncertain natural mortality estimates, and estimator assumptions, conclusions about mortality remain uncertain. However, the comparison to reference points indicate that total mortality in recent years may be unsustainable in some rivers.

The benchmark assessment concluded that river herring abundance had declined significantly as evidenced by declines in commercial landings to less than 3% of the historical peaks in the late 1960s. Reported coastwide commercial landings have remained relatively stable since the benchmark stock assessment. Utility of these data for inferring about coastwide meta-population size have decreased due to the number of moratoria that have been implemented since the benchmark. However, the level of landings do not suggest any major changes since the benchmark stock assessment. Average incidental catch since the benchmark stock assessment (227 mt) was less than 50% of the 2005-2010 average (496 mt). Estimates starting in 2005 are considered the most certain estimates as this was the period of time when improvements in the NEFOP occurred in the high volume midwater trawl fisheries. Some unknown fraction of the total incidental catch is reported by NMFS and included in the U.S. landings, making direct comparisons uncertain. More specifically, the majority of river herring caught incidentally in the midwater trawl fleets is retained, but an unknown proportion of this retained catch is reported as river herring by the dealers. In a limited number of comparisons, some trips that listed river herring as landed on the VTR reports did not list river herring on the corresponding dealer reports. Therefore, it is unclear what proportion of reported landings is distinct from estimates of total incidental catch, making direct comparisons difficult. The impact of this incidental catch upon stock status remains largely unknown.

In-river exploitation of alewives has continued to decline in the Damariscotta River with the lowest levels occurring in the last five years, with the exception of very low values that occurred in the 1990s (due to lack of harvest). In-river exploitation of alewives has remained relatively stable in the Union River, but did decline to the lowest level of the time series in the terminal year of the update. Exploitation has essentially ceased on other rivers assessed during the benchmark due to moratoria (MA rivers). Coastwide relative exploitation has continued to decline since the benchmark to the lowest levels of the time series, as catches have continued to decline and biomass from the NEFSC bottom trawl survey has increased.

In summary, updated trend analyses generally indicate similar conditions as observed in recent years of the benchmark assessment and a more detectable response to restoration efforts will require more time. The SAS reiterates that multiple factors are likely responsible for river herring decline such as overfishing, inadequate fish passage at dams, predation, pollution, water withdrawals, acidification, changing ocean conditions, and climate change. It is difficult to partition mortality into these possible sources and evaluate importance in the decline of river herring. Thus, the recovery of river herring needs to address multiple factors including anthropogenic habitat alterations, predation by native and non-native predators, and exploitation by fisheries.

3.1 Stock Status

Though some positive signs were apparent through the update (e.g., few declining abundance trends by data set in recent years), the information updated indicates that the status of the coastwide river-herring meta-population being depleted to near historic lows remains unchanged since the benchmark stock assessment. A depleted status indicates that there was evidence for declines in abundance due to a number of factors, but the relative importance of these factors in reducing river herring stocks could not be determined. Combined factors such as intense historic fishing pressure, continued exploitation (both directed and incidental), ineffective fish passage resulting in the loss of riverine habitat, changing ocean conditions due to climate change, and increased abundance of native and non-native predator species are likely responsible for depleted river herring stocks and continue to hinder recovery of the stocks. More work is needed to evaluate the synergistic effects of the many factors that may be responsible for the decline in river herring.

Of the 54 in-river stocks of river herring for which data were available, 16 experienced increasing trends over the ten most recent years of the update assessment data time series, 2 experienced decreasing trends, 8 were stable, 10 experienced no discernible trend/high variability, and 18 did not have enough data to assess recent trends, including 1 that had no returning fish. A majority of the increasing trends occurred in the northeast which is also where there tends to be more data available. A majority of the unknown and no trend designations occurred in the Mid-Atlantic and southeast. The SAS notes that stocks included are due to data availability and don't necessarily reflect stocks that are more important than stocks not included in the assessment.

Overfished and overfishing status could not be determined for the coastwide stock complex, as estimates of total biomass, fishing mortality rates and corresponding reference points could not be developed.

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TABLES

Table 2.1. Annual reported coastwide commercial landings (lb) of river herring, 1887-2015.

Year	Total	Year	Total	Year	Total	Year	Total
1887	21,952,075	1920	101,850	1953	46,535,253	1986	10,378,923
1888	22,641,527	1921	10,852	1954	48,153,600	1987	6,939,347
1889	18,297,800	1922	73,431	1955	41,952,500	1988	6,547,357
1890	16,480,263	1923	6,573,144	1956	48,394,404	1989	3,562,566
1891	0	1924	2,649,620	1957	53,767,400	1990	2,816,214
1892	3,651,000	1925	92,188	1958	70,334,100	1991	3,332,586
1893	0	1926	131,535	1959	45,326,300	1992	4,066,425
1894	0	1927	14,230,024	1960	50,204,218	1993	2,189,389
1895	0	1928	10,055,525	1961	54,610,885	1994	1,432,175
1896	5,356,000	1929	24,870,348	1962	56,521,722	1995	1,638,639
1897	20,420,770	1930	27,136,169	1963	59,713,801	1996	1,750,306
1898	2,900,000	1931	27,630,327	1964	49,652,734	1997	1,511,009
1899	0	1932	21,691,925	1965	69,431,946	1998	1,744,105
1900	0	1933	20,275,417	1966	65,075,187	1999	1,590,890
1901	0	1934	20,939,048	1967	62,510,234	2000	1,554,219
1902	15,550,475	1935	12,207,505	1968	57,966,781	2001	1,692,161
1903	0	1936	20,825,582	1969	58,237,135	2002	1,994,595
1904	501,438	1937	22,195,865	1970	40,166,957	2003	1,673,856
1905	5,138,225	1938	30,103,611	1971	32,655,990	2004	1,469,063
1906	0	1939	23,689,906	1972	32,618,493	2005	791,326
1907	0	1940	21,193,653	1973	23,093,126	2006	1,484,741
1908	15,211,711	1941	12,173,975	1974	26,837,288	2007	1,033,421
1909	111,334	1942	10,392,322	1975	28,748,865	2008	1,435,629
1910	0	1943	1,795,339	1976	15,714,244	2009	1,656,560
1911	0	1944	20,264,444	1977	14,496,457	2010	1,565,591
1912	0	1945	23,752,819	1978	14,321,259	2011	1,293,472
1913	92,175	1946	13,408,602	1979	11,074,915	2012	1,627,364
1914	0	1947	22,912,389	1980	11,656,881	2013	1,361,845
1915	0	1948	20,268,718	1981	6,304,996	2014	1,548,723
1916	21,762	1949	24,118,735	1982	13,432,844	2015	1,344,101
1917	49,935	1950	40,999,400	1983	11,524,000		
1918	14,562,044	1951	50,408,400	1984	10,574,011		
1919	3,064,000	1952	41,494,400	1985	14,321,083		

Table 2.2 Reported landings (pounds) of river herring in ICNAF/NAFO Areas 5 and 6 by country.

Year	Bulgaria	Germany	Poland	USSR	USA	Grand Total
1967	0	0	0	14,356,355	57,220,393	71,576,748
1968	0	0	0	49,184,626	55,141,455	104,326,081
1969	1,333,164	249,120	0	78,322,824	55,974,794	135,879,902
1970	1,481,491	418,874	0	42,083,609	36,047,415	80,031,389
1971	2,290,579	18,538,481	4,905,235	24,887,729	28,227,698	78,849,722
1972	1,128,755	7,674,213	4,162,285	14,755,388	2,707,249	30,427,890
1973	1,787,931	3,593,498	7,167,155	2,347,899	22,729,426	37,625,909
1974	1,704,156	5,862,031	2,398,605	1,042,776	24,490,901	35,498,469
1975	1,219,144	4,675,957	136,685	2,290,579	23,803,066	32,125,431
1976	564,378	2,777,796	30,864	537,922	14,290,217	18,201,177
1977	0	152,117	0	264,552	13,584,745	14,001,414
1978	0	0	0	46,297	12,632,358	12,678,655
1979	0	0	0	26,455	9,607,647	9,634,102
1980	0	0	2,205	0	10,498,305	10,500,510
1981	0	0	22,046	0	7,087,789	7,109,835
1982	0	0	178,573	0	12,784,475	12,963,048
1983	0	0	169,754	0	9,224,046	9,393,800
1984	0	17,637	436,511	0	9,003,586	9,457,734
1985	0	50,706	346,122	0	2,206,805	2,603,633
1986	0	37,478	103,616	0	8,988,154	9,129,248
1987	0	59,524	48,501	0	4,261,492	4,369,517
1988	0	63,933	66,138	0	5,251,357	5,381,428
1989	0	50,706	52,910	0	3,362,015	3,465,631
1990	0	30,864	0	0	2,892,435	2,923,299
1991	0	0	0	0	2,925,504	2,925,504
1992	0	0	0	0	3,209,898	3,209,898
1993	0	0	0	0	551,150	551,150
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	0	0	0	0	0	0
2001	0	0	0	0	0	0
2002	0	0	0	0	284,393	284,393
2003	0	0	0	0	0	0
2004	0	0	0	0	0	0
2005	0	0	0	0	0	0
2006	0	0	0	0	0	0
2007	0	0	0	0	315,258	315,258
2008	0	0	0	0	286,598	286,598
2009	0	0	0	0	509,263	509,263
2010	0	0	0	0	0	0
2011	0	0	0	0	416,673	416,673
2012	0	0	0	0	105,822	105,822
2013	0	0	0	0	30,865	30,865
2014	0	0	0	0	2,205	2,205
2015	0	0	0	0	11,023	11,023

*: Italy, the Netherlands, Romania, and Spain also reported catch, but only in one or two years; they are included in the Grand Total.

Table 2.3 Proportion of 2005-2015 incidental catch of river herring by region, fleet and quarter for the dominant gears.

		BT			Gillnet			Paired MWT	Single MWT	Total MWT	Grand Total
Area fished	Quarter	sm	med	lg	sm	lg	xlg				
MA	1	0.027	0.001	0.001	0.000	0.000	0.000	0.229	0.051	0.280	0.309
MA	2	0.016	0.000	0.001	0.000	0.000	0.000	0.013	0.005	0.018	0.035
MA	3	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.040
MA	4	0.018	0.001	0.001	0.000	0.000	0.000	0.006	0.001	0.007	0.026
MA		**0.099**	**0.002**	**0.003**	**0.000**	**0.000**	**0.000**	**0.248**	**0.057**	**0.305**	**0.409**
NE	1	0.091	0.000	0.002	0.000	0.000	0.000	0.030	0.014	0.044	0.137
NE	2	0.049	0.000	0.002	0.000	0.000	0.000	0.045	0.040	0.085	0.136
NE	3	0.070	0.000	0.002	0.000	0.000	0.000	0.055	0.009	0.064	0.136
NE	4	0.059	0.000	0.002	0.000	0.000	0.000	0.099	0.022	0.120	0.181
NE		**0.268**	**0.000**	**0.009**	**0.000**	**0.000**	**0.000**	**0.229**	**0.085**	**0.313**	**0.591**
Total		**0.367**	**0.003**	**0.011**	**0.000**	**0.000**	**0.000**	**0.477**	**0.142**	**0.619**	**1.000**

Table 2.4 Species-specific total annual incidental catch (mt) and the associated coefficient of variation across all fleets and regions. Midwater trawl estimates were only included beginning in 2005.

	Alewife		American shad		Blueback herring		Herring NK		Hickory shad	
	Catch	CV	Catch	CV	Catch	CV	Catch	CV	Catch	CV
1989	44.16	0.49	229.10	0.98	37.65	0.42	17.53	1.13	0.00	
1990	101.63	0.85	45.20	0.34	170.01	0.45	681.30	0.59	0.00	
1991	148.56	0.44	176.09	0.25	285.07	0.40	265.61	0.51	39.35	0.00
1992	65.74	0.43	168.95	0.28	1190.98	0.42	786.21	0.39	0.00	
1993	381.05	2.42	211.34	1.00	745.60	0.28	135.86	4.83	0.00	
1994	5.56	0.30	109.93	0.64	240.17	0.87	58.34	0.47	0.95	0.82
1995	8.44	0.61	127.43	0.38	348.33	0.44	99.87	1.23	0.53	0.64
1996	704.10	1.14	64.52	0.39	2800.04	2.09	451.39	0.39	222.46	1.04
1997	49.42	1.36	65.95	0.61	1593.60	0.69	90.27	5.09	20.64	1.25
1998	145.64	1.47	161.03	0.23	76.81	1.52	228.12	2.08	479.82	0.72
1999	6.12	1.16	82.03	0.41	359.21	0.60	3457.27	0.74	208.75	0.94
2000	113.33	0.81	264.43	0.77	109.57	0.45	70.86	0.78	2.41	0.76
2001	189.63	0.84	67.82	0.39	309.86	0.32	2.51	0.44	330.44	0.27
2002	4.35	3.35	43.81	0.40	269.14	0.33	124.05	1.88	1.87	0.83
2003	388.04	1.43	60.20	0.54	526.83	0.56	26.21	1.17	18.80	0.85
2004	163.18	0.64	53.06	0.36	231.67	0.46	237.06	0.74	401.75	1.13
2005	404.42	0.40	94.50	0.28	254.68	0.34	29.46	0.58	27.42	0.34
2006	78.73	0.83	78.23	9.73	190.78	0.66	267.81	1.10	25.07	0.78
2007	543.58	0.71	79.08	0.56	187.99	1.42	357.43	0.91	16.72	0.90
2008	159.16	0.42	74.04	0.29	539.32	0.56	1669.08	0.50	5.56	0.80
2009	154.22	0.26	106.70	1.99	195.41	0.30	352.25	0.66	11.70	0.79
2010	134.60	0.19	60.61	0.16	132.42	0.20	106.67	0.32	1.26	0.59
2011	96.53	0.34	103.32	0.12	28.19	0.30	125.99	0.28	0.09	0.77
2012	173.85	0.24	76.53	0.16	249.35	0.31	91.72	0.30	0.51	0.55
2013	238.95	0.33	73.48	0.41	28.92	0.46	75.08	0.69	0.42	0.76
2014	83.61	0.14	63.46	0.19	29.55	0.25	76.68	0.44	0.68	0.39
2015	123.66	0.31	46.40	0.15	82.44	0.48	40.47	0.75	2.46	0.77

Table 2.5 Trawl surveys for river herring. Only those surveys used in the benchmark assessment were included in ARIMA model analysis.

Species	Age	Survey	Season	Duration	n	Index Units
Alewife	Adult	DE Deleware River and Bay Adult finfish survey	All	1966 - 2015	38	Arithmetic Mean Catch per Nautical Mile Towed
	Age1	DE Delaware River and Bay Juvenile finfish survey	All	1991 - 2015	24	Geometric Mean Count Per Tow
		Massachusetts DMF Inshore North Cape Cod	Spring	1978 - 2015	38	Mean Number per Tow
		Massachusetts DMF Inshore South Cape Cod	Spring	1978 - 2015	38	Mean Number per Tow
	All	Ches. Bay Multispecies Monitoring and Assessment Program	Spring	2002 - 2015	14	Number per square nautical mile
		CT DEEP Long Island Sound Trawl Survey	Fall	1984 - 2015	32	Geometric Mean Count Per Tow
		CT DEEP Long Island Sound Trawl Survey	Spring	1984 - 2015	32	Geometric Mean Count Per Tow
		ME-MH Fall Inshore Gulf of Maine	Fall	2000 - 2015	16	Stratified Mean Catch Per Tow
		ME-MH Fall Inshore Gulf of Maine	Spring	2001 - 2015	15	Stratified Mean Catch Per Tow
		New Jersey Ocean Trawl Survey	All	1989 - 20015	27	Geometric Mean CPUE
		NEFSC bottom trawl-Coast	Fall	1975 - 2015	41	Mean number per tow
		NEFSC bottom trawl-Coast	Spring	1976 - 2015	40	Mean number per tow
		NEFSC bottom trawl-North	Spring	1976 - 2015	40	Mean number per tow
		NEFSC bottom trawl-South	Spring	1976 - 2015	40	Mean number per tow
		Northeast Area Monitoring and Assessment Program	Fall	2007 - 2015	9	Number per 25K square miles
		Northeast Area Monitoring and Assessment Program	Spring	2008 - 2015	8	Number per 25K square miles
		Rhode Island Combined Coastal Trawl Survey	All	1979 - 2015	37	Arithmetic Mean Catch Per Tow
	YOY	DE Delaware River and Bay Juvenile finfish survey	All	1990 - 2015	26	Geometric Mean Count Per Tow
		North Carolina DMF Western Sound	Summer-Fall	1982 - 2015	34	Arithmetic Mean CPUE

Table 2.5 Continued.

Species	Age	Survey	Season	Duration	n	Index Units
Blueback	Adult	DE Deleware River and Bay Adult finfish survey	All	1966 - 2015	38	Arithmetic Mean Catch per Nautical Mile Towed
	Age1	DE Delaware River and Bay Juvenile finfish survey	All	1991 - 2015	24	Geometric Mean Count Per Tow
		Massachusetts DMF Inshore North Cape Cod	Spring	1978 - 2015	38	Mean Number per Tow
		Massachusetts DMF Inshore South Cape Cod	Spring	1978 - 2015	38	Mean Number per Tow
	All	Ches. Bay Multispecies Monitoring and Assessment Program	Spring	2002 - 2015	14	Number per square nautical mile
		CT DEEP Long Island Sound Trawl Survey	Fall	1984 - 2015	32	Geometric Mean Count Per Tow
		CT DEEP Long Island Sound Trawl Survey	Spring	1984 - 2015	32	Geometric Mean Count Per Tow
		ME-MH Fall Inshore Gulf of Maine	Fall	2002 - 2015	14	Stratified Mean Catch Per Tow
		ME-MH Fall Inshore Gulf of Maine	Spring	2001 - 2015	15	Stratified Mean Catch Per Tow
		New Jersey Ocean Trawl Survey	All	1989 - 2015	27	Geometric Mean CPUE
		NEFSC bottom trawl-Coast	Fall	1975 - 2015	41	Mean number per tow
		NEFSC bottom trawl-Coast	Spring	1976 - 2015	40	Mean number per tow
		NEFSC bottom trawl-North	Spring	1976 - 2015	40	Mean number per tow
		NEFSC bottom trawl-South	Spring	1976 - 2015	40	Mean number per tow
		Northeast Area Monitoring and Assessment Program	Fall	2007 - 20015	9	Number per 25K square miles
		Northeast Area Monitoring and Assessment Program	Spring	2008 - 2015	8	Number per 25K square miles
		Rhode Island Combined Coastal Trawl Survey	All	1979 - 2015	37	Arithmetic Mean Catch Per Tow
	YOY	DE Delaware River and Bay Juvenile finfish survey	All	1990 - 2015	26	Geometric Mean Count Per Tow
		North Carolina DMF Western Sound	Summer-Fall	1982 - 2015	34	Arithmetic Mean CPUE

Table 2.6 Summary statistics from ARIMA model fits to **alewife** trawl survey data. Q0.25 is the 25th percentile of the fitted values; P(<0.25) is the probability of the final year of the survey being below the bootstrapped mean Q0.25 with 80% confidence; r1 - r3 are the first three autocorrelations; θ is the moving average parameter; SE is the standard error of θ; and σ2c is the variance of the index.

Survey	Season	Age	FinalYear	n	P(<0.25)	Mean $Q_{0.25}$	r1	r2	r3	θ	SE	σ^2_c
CT DEP Long Island Sound Trawl Survey	Fall	All	2015	32	0.057	-1.53847	-0.6	0.13	-0.1	0.8	0.1	1
CT DEP Long Island Sound Trawl Survey	Spring	All	2015	32	0.043	-0.27407	-0.4	-0.2	0.28	0.6	0.1	0.3
DE Delaware River and Bay Adult finfish survey	All	Adult	2015	38	0.007	-0.59043	-0.3	-0.2	0.28	1	0.1	0.9
DE Delaware River and Bay Juvenile finfish survey	All	Age 1	2015	25	0.381	-3.41287	-0.8	0.55	-0.4	0.8	0.1	2.5
DE Delaware River and Bay Juvenile finfish survey	All	Age 0	2015	26	0.017	-1.80505	-0.5	0.02	-0.1	1	0.6	2.2
Massachusetts DMF Inshore North Cape Cod	Spring	Age 1	2015	38	0.009	2.20236	-0.3	-0.3	0.21	0.9	0.1	1.1
Massachusetts DMF Inshore South Cape Cod	Spring	Age 1	2015	38	0.148	-0.39794	-0.5	0.13	-0.1	1	0.1	2
ME-NH Inshore Gulf of Maine	Fall	All	2015	16	0.001	5.59119	-0.2	-0.2	-0.2	0.7	0.2	0.2
ME-NH Inshore Gulf of Maine	Spring	All	2015	15	0	5.05178	-0.5	0.38	-0.4	0.6	0.2	0.2
New Jersey Ocean Trawl Survey	All	All	2015	27	0.404	1.03283	-0.4	-0.1	0.01	0.8	0.2	0.6
NEFSC bottom trawl-Coast	Fall	All	2015	41	0	0.53968	-0.5	0.01	-0.2	0.7	0.1	0.6
NEFSC bottom trawl-Coast	Spring	All	2015	40	0	1.94602	-0.2	-0.2	0.03	0.4	0.2	0.2
NEFSC bottom trawl-North	Fall	All	2015	41	0	0.8866	-0.5	0.01	-0.2	0.6	0.1	0.6
NEFSC bottom trawl-North	Spring	All	2015	40	0	1.83144	-0.4	0.01	-0.2	0.5	0.2	0.3
NEFSC bottom trawl-South	Spring	All	2015	40	0.271	1.35078	-0.3	-0.2	0.04	0.9	0.1	1.2
North Carolina DMF Western Sound	Summer-Fall	Age 0	2015	34	0.056	-2.3188	-0.3	-0.1	-0.1	0.4	0.3	3.4
Rhode Island Coastal Trawl Survey	All	All	2015	37	0	0.14138	-0.5	0.11	-0.3	0.5	0.1	1.5

Table 2.7 Summary statistics from ARIMA model fits to **blueback herring** trawl survey data. Q0.25 is the 25th percentile of the fitted values; P(<0.25) is the probability of the final year of the survey being below the bootstrapped mean Q0.25 with 80% confidence; r1 - r3 are the first three autocorrelations; θ is the moving average parameter; SE is the standard error of θ; and σ2c is the variance of the index.

Survey	Season	Age	FinalYear	n	P(<0.25)	Mean $Q_{0.25}$	r1	r2	r3	θ	SE	σ^2_c
CT DEP Long Island Sound Trawl Survey	Fall	All	2015	32	0.03	-0.28326	-0.4	-0.2	0.28	0.6	0.1	0.3
CT DEP Long Island Sound Trawl Survey	Spring	All	2015	32	0.112	-2.12008	-0	0.03	0.02	0.4	0.2	1
DE Delaware River and Bay Adult finfish survey	All	Adult	2015	38	0	-2.82457	-0.4	0.13	-0.1	1	0.2	1.3
DE Delaware River and Bay Juvenile finfish survey	All	Age 1	2015	25	0.067	-3.44167	-0.5	-0	0.03	0.9	0.2	1.8
DE Delaware River and Bay Juvenile finfish survey	All	Age 0	2015	26	0.436	-3.80433	-0.7	0.48	-0.4	0.7	0.1	1.2
Massachusetts DMF Inshore North Cape Cod	Spring	Age 1	2015	38	0.006	0.45707	-0.4	-0.2	0.03	1	0.1	1.5
Massachusetts DMF Inshore South Cape Cod	Spring	Age1	2015	38	0.264	-2.74304	-0.5	0.01	0.12	0.9	0.1	3.1
ME-NH Inshore Gulf of Maine	Spring	All	2015	15	0.241	2.80829	-0.5	0.03	-0	1	0.3	0.7
New Jersey Ocean Trawl Survey	All	All	2015	27	0.058	1.30298	-0.2	-0.4	0.05	1	0.1	0.2
NEFSC bottom trawl-Coast	Fall	All	2015	41	0	-2.80216	-0.5	0.11	0.07	0.7	0.1	2
NEFSC bottom trawl-Coast	Spring	All	2015	40	0	0.59159	-0.3	-0.3	0.32	0.6	0.2	0.7
NEFSC bottom trawl-North	Fall	All	2015	41	0	-2.54985	-0.5	0.13	0.04	0.7	0.1	2.3
NEFSC bottom trawl-North	Spring	All	2015	40	0	-0.34661	-0.4	-0	-0.2	0.7	0.1	0.9
NEFSC bottom trawl-South	Fall	All	2015	41	0	-4.54659	-0.2	-0.3	0	0.9	0.1	0.1
NEFSC bottom trawl-South	Spring	All	2015	40	0.005	1.0361	-0.4	-0.1	0.18	0.7	0.1	1.6
North Carolina DMF Western Sound	Summer-Fall	Age 0	2015	34	0.393	-0.84596	-0.1	-0.6	0.23	0.8	0.1	8.8
Rhode Island Coastal Trawl Survey	All	All	2015	37	0.342	0.21024	-0.4	-0.1	-0.1	0.8	0.1	2

Table 2.8 Summary of P(<0.25) values from Tables 1 & 2 comparing northern to southern trawl surveys for river herring. Coastwide NMFS surveys were not included in this summary. N is the number of surveys included in each region.

Species	Region	n	Min.	Max.	Median	Average
Alewife	North	7	0.000	0.148	0.009	0.037
	South	5	0.007	0.464	0.056	0.173
Blueback	North	6	0.006	0.342	0.177	0.166
	South	5	0.000	0.540	0.067	0.191

Table 2.9 Results of the Mann-Kendall test for trends in mean length by river (state), species and sex. n = sample size, S is the Mann-Kendall test statistics, and p is the two-tailed probability. Significant results are bolded. The sign of the test statistic indicates the direction of the trend. *Hudson River (NY) results are provided in the updated NY state report due to changes in historical data between the benchmark and update assessments.

River (State)*	Species	Sex	n	S	p
Androscoggin River (ME)	Alewife	Male	25	-53	0.224
		Female	25	-57	0.191
Cocheco River (NH)	Alewife	Male	25	-46	0.293
		Female	25	-32	0.469
	Blueback	**Male**	**21**	**-94**	**0.005**
		Female	22	-63	0.080
Exeter River (NH)	Alewife	**Male**	**24**	**-94**	**0.021**
		Female	24	-66	0.107
Lamprey River (NH)	Alewife	Male	26	-11	0.826
		Female	26	13	0.791
Oyster River (NH)	Blueback	**Male**	**25**	**-150**	**0.001**
		Female	**25**	**-102**	**0.018**
Winnicut River (NH)	Alewife	Male	12	2	0.308
		Female	12	28	1.000
	Blueback	Male	12	-2	0.734
		Female	12	-12	0.734
Monument River (NH)	Alewife	**Male**	**30**	**-215**	**0.000**
		Female	**30**	**-197**	**0.000**
	Blueback	**Male**	**30**	**-211**	**0.000**
		Female	**30**	**-258**	**0.000**
Nanticoke River (MD)	Alewife	**Male**	**26**	**-105**	**0.022**
		Female	**26**	**-95**	**0.038**
	Blueback	**Male**	**26**	**-207**	**0.000**
		Female	**26**	**-225**	**0.000**
Chowan River (NC)	Alewife	**Male**	**39**	**-367**	**0.000**
		Female	**38**	**-329**	**0.000**
	Blueback	**Male**	**44**	**-648**	**0.000**
		Female	**44**	**-616**	**0.000**
Santee-Cooper River (SC)					
Commercial cast net	Blueback	Male	19	-14	0.649
		Female	19	48	0.099
Fishlift	Blueback	Male	24	-46	0.263
		Female	24	-68	0.095
St. John's River (FL)	Blueback	Male	18	-36	0.185
		Female	**18**	**-59**	**0.028**

Table 2.10 Results of the Mann-Kendall test for trends in mean lengths of alewife and blueback herring from the National Marine Fisheries bottom trawl survey by species and region. *n* = sample size, *S* is the Mann-Kendall test statistics, and *p* is the two-tailed probability. Significant results are bolded. The sign of the test statistic indicates the direction of the trend.

Species	Region	n	S	p
Alewife	Coastwide Spring	40	**-386**	0.0000
Alewife	North Spring	40	**-258**	0.0028
Alewife	South Spring	40	**-376**	0.0000
Alewife	Coastwide Fall	41	-162	0.0706
Alewife	North Fall	41	-162	0.0706
Alewife	South Fall			
Blueback	Coastwide Spring	40	-8	0.9350
Blueback	North Spring	40	-26	0.7708
Blueback	South Spring	40	112	0.1959
Blueback	Coastwide Fall	37	**-225**	0.0034
Blueback	North Fall	37	**-225**	0.0034
Blueback	South Fall	2	1	1.0000

Table 2.11 Results of the Mann-Kendall test for trends in mean length by river (state), species, sex and age. n = sample size, S is the Mann-Kendall test statistics, and p is the two-tailed probability. Significant results are bolded. The sign of the test statistic indicates the direction of the trend.

				Time Series			2006-2015		
River (State)	Species	Sex	Age	n	S	p	n	S	p
Cocheco River (NH)	Alewife	Female	3	13	-19	0.271	3	1	1.000
			4	**25**	**-112**	**0.010**	10	-9	0.474
			5	**25**	**-126**	**0.004**	10	3	0.858
			6	24	-42	0.309	**10**	**29**	**0.012**
		Male	**3**	**20**	**-82**	**0.009**	7	1	1.000
			4	**25**	**-122**	**0.005**	10	-7	0.592
			5	**25**	**-158**	**0.000**	10	1	1.000
			6	24	-60	0.143	**10**	**23**	**0.049**
	Blueback	Female	3	11	-3	0.876	0	0	1.000
			4	**19**	**-78**	**0.007**	5	-8	0.086
			5	**15**	**-53**	**0.010**	2	1	1.000
			6	**10**	**-31**	**0.007**	4	-2	0.734
		Male	**3**	**13**	**-38**	**0.024**	2	1	1.000
			4	**20**	**-98**	**0.002**	5	-6	0.221
			5	**15**	**-59**	**0.004**	3	-3	1.000
			6	**8**	**-18**	**0.035**	2	-1	1.000
Exeter River (NH)	Alewife	Female	3	13	-28	0.100	5	-4	0.462
			4	**23**	**-105**	**0.006**	9	6	0.602
			5	24	-58	0.157	**10**	**25**	**0.032**
			6	23	-34	0.383	10	13	0.283
		Male	**3**	**17**	**-82**	**0.001**	6	-5	0.452
			4	**24**	**-118**	**0.004**	10	-5	0.721
			5	24	-56	0.172	**10**	**25**	**0.032**
			6	21	-18	0.608	**9**	**32**	**0.001**
	Blueback	Female	3	6	-5	0.452	1	0	1.000
			4	**12**	**-33**	**0.028**	3	3	1.000
			5	13	-15	0.392	3	-1	1.000
			6	**10**	**-31**	**0.007**	3	-1	1.000
		Male	**3**	**13**	**-36**	**0.033**	4	2	0.734
			4	16	-39	0.087	5	0	1.000
			5	**15**	**-63**	**0.002**	4	0	1.000
			6	**10**	**-24**	**0.037**	3	2	1.000
Lamprey River (NH)	Alewife	Female	**3**	**15**	**-77**	**0.000**	4	-6	0.089
			4	**25**	**-173**	**0.000**	10	-1	1.000
			5	**26**	**-131**	**0.004**	10	5	0.721
			6	25	-14	0.761	10	13	0.283
		Male	**3**	**19**	**-88**	**0.002**	7	4	0.649
			4	**26**	**-185**	**0.000**	10	3	0.858
			5	26	-75	0.103	10	17	0.152
			6	24	-26	0.535	10	17	0.152
	Blueback	Female	3	3	-3	1.000	1	0	1.000
			4	5	0	1.000	2	1	1.000
			5	3	-1	1.000	1	0	1.000
			6	2	-1	1.000	1	0	1.000
		Male	3	5	0	1.000	4	2	0.734
			4	5	-6	0.221	2	-1	1.000
			5	7	-11	0.133	4	-4	0.308
			6	2	-1	1.000	2	-1	1.000
Oyster River (NH)	Alewife	Female	3	7	-6	0.448	5	0	1.000
			4	11	-7	0.640	7	7	0.368
			5	11	7	0.640	**8**	**20**	**0.019**
			6	8	0	1.000	6	9	0.133
		Male	3	9	-12	0.251	6	3	0.707
			4	11	-2	0.938	7	12	0.095
			5	12	0	1.000	8	16	0.063
			6	9	12	0.251	7	11	0.133
	Blueback	Female	**3**	**21**	**-120**	**0.000**	8	4	0.711
			4	**25**	**-95**	**0.028**	**10**	**32**	**0.005**
			5	**25**	**-144**	**0.001**	10	21	0.074
			6	25	-49	0.262	**10**	**31**	**0.007**
		Male	**3**	**24**	**-150**	**0.000**	9	6	0.602
			4	**25**	**-132**	**0.002**	**10**	**23**	**0.049**
			5	**25**	**-92**	**0.034**	**10**	**33**	**0.004**
			6	20	-52	0.098	8	0	1.000
Winnicut River (NH)	Alewife	Female	3	8	-6	0.536	2	-1	1.000
			4	**11**	**-35**	**0.008**	3	-3	1.000
			5	11	-21	0.119	4	2	0.734
			6	11	-6	0.696	4	-2	0.734
		Male	**3**	**12**	**-30**	**0.047**	4	2	0.734
			4	12	-24	0.115	4	4	0.308
			5	11	-23	0.087	4	6	0.089
			6	11	-15	0.276	4	-2	0.734
	Blueback	Female	3	9	-1	1.000	2	1	1.000
			4	**11**	**-27**	**0.043**	3	1	1.000
			5	10	-21	0.074	3	1	1.000
			6	9	-14	0.175	3	-1	1.000
		Male	3	11	-20	0.138	3	3	1.000
			4	12	-18	0.244	4	2	0.734
			5	**12**	**-30**	**0.047**	4	4	0.308
			6	9	-5	0.675	3	3	1.000

Table 2.11 Continued.

River (State)	Species	Sex	Age	Time Series n	Time Series S	Time Series p	2006-2015 n	2006-2015 S	2006-2015 p
Monument River (MA)	Alewife	Female	3	21	39	0.251	**10**	**27**	**0.020**
			4	23	27	0.492	10	17	0.152
			5	23	37	0.342	10	5	0.721
			6	21	24	0.487	9	-2	0.917
		Male	3	23	-9	0.833	10	21	0.074
			4	23	7	0.874	10	11	0.371
			5	23	37	0.342	10	-3	0.858
			6	20	14	0.673	7	-11	0.133
	Blueback	Female	3	18	15	0.596	10	19	0.107
			4	24	-32	0.442	**10**	**29**	**0.012**
			5	**24**	**-84**	**0.040**	10	15	0.210
			6	15	-15	0.488	6	5	0.452
		Male	3	24	24	0.568	10	19	0.107
			4	24	48	0.244	**10**	**23**	**0.049**
			5	24	54	0.189	10	9	0.474
			6	13	-7	0.714	6	-4	0.566
Gilbert-Stuart (RI)	Alewife	Female	3	10	-7	0.592	4	2	0.734
			4	15	-5	0.843	9	16	0.118
			5	15	8	0.729	9	9	0.402
			6	15	7	0.767	9	2	0.917
		Male	3	15	10	0.656	**9**	**21**	**0.036**
			4	15	-32	0.123	**9**	**21**	**0.033**
			5	15	-7	0.767	9	12	0.251
			6	*	*	*	*	*	*
Nonquit (RI)	Alewife	Female	3	11	-16	0.241	5	0	1.000
			4	15	-3	0.921	9	18	0.076
			5	15	20	0.346	**9**	**29**	**0.003**
			6	15	20	0.346	**9**	**23**	**0.021**
		Male	3	14	-13	0.511	8	14	0.108
			4	15	-1	1.000	**9**	**28**	**0.005**
			5	15	1	1.000	**9**	**20**	**0.048**
			6	8	5	0.618	7	12	0.095
Nanticoke (MD)	Alewife	Female	3	23	-5	0.916	8	7	0.454
			4	26	-13	0.791	9	-3	0.834
			5	26	-71	0.123	9	-12	0.251
			6	**26**	**-112**	**0.014**	9	-5	0.675
		Male	**3**	**26**	**-134**	**0.003**	9	-4	0.754
			4	**26**	**-163**	**0.000**	9	-14	0.175
			5	**26**	**-103**	**0.025**	9	0	1.000
			6	26	-80	0.081	9	-6	0.602
	Blueback	Female	3	22	-61	0.090	8	6	0.536
			4	26	-50	0.280	9	6	0.602
			5	26	-70	0.128	9	0	1.000
			6	26	-88	0.055	9	4	0.754
		Male	**3**	**26**	**-135**	**0.003**	9	4	0.754
			4	**25**	**-122**	**0.005**	8	-2	0.902
			5	**26**	**-151**	**0.001**	9	4	0.754
			6	**23**	**-143**	**0.000**	7	-1	1.000
Chowan (NC)*	Alewife	Female	**3**	**12**	**-51**	**0.001**	NA	NA	NA
			4	**29**	**-236**	**0.000**	NA	NA	NA
			5	**30**	**-279**	**0.000**	NA	NA	NA
			6	**29**	**-206**	**0.000**	NA	NA	NA
		Male	**3**	**25**	**-175**	**0.000**	NA	NA	NA
			4	**32**	**-331**	**0.000**	NA	NA	NA
			5	**30**	**-235**	**0.000**	NA	NA	NA
			6	**30**	**-237**	**0.000**	NA	NA	NA
	Blueback	Female	**3**	**29**	**-268**	**0.000**	7	-11	0.133
			4	**44**	**-592**	**0.000**	10	9	0.474
			5	**44**	**-501**	**0.000**	10	19	0.107
			6	**43**	**-484**	**0.000**	9	14	0.175
		Male	**3**	**43**	**-601**	**0.000**	10	5	0.721
			4	**44**	**-660**	**0.000**	10	7	0.592
			5	**44**	**-499**	**0.000**	**10**	**27**	**0.020**
			6	**41**	**-347**	**0.001**	9	16	0.118

*Chowan (NC) alewife results from the 2012 Benchmark Assessment.

Table 2.12 Summary of fisheries-independent data sources that have collected repeat spawner data from river herring. Species indicates whether data were available for alewives (A), blueback herring (B), or both species combined (river herring, R).

State	Water Body	Gear	Species	Years	
				From	To
Maine	Androscoggin River	Fishway	R	2005	20014
New Hampshire	Cocheco River	Fishway	A, B	2000	2015
New Hampshire	Exeter River	Fishway	A, B	2000	2015
New Hampshire	Lamprey River	Fishway	A	2000	2015
New Hampshire	Oyster River	Fishway	B	2000	215
New Hampshire	Taylor River	Fishway	B	2000	2005
New Hampshire	Winnicut River	Fishway	A	2000	2010
Massachusetts	Mattapoisett River	Dip Net	A	2006	2006
Massachusetts	Monument River	Dip Net	A, B	1986	1987
Massachusetts	Monument River	Dip Net	A, B	1993	1993
Massachusetts	Monument River	Dip Net	A, B	1995	2015
Massachusetts	Mystic River	Dip Net	A, B	2004	2010
Massachusetts	Nemasket River	Dip Net	A	2004	2013
Massachusetts	Quashnet River	Dip Net	A, B	2004	2004
Massachusetts	Stoney Brook	Dip Net	A	2004	2004
Massachusetts	Town Brook	Dip Net	A, B	2004	2013
Rhode Island	Gilbert Stuart Stream	Fishway	R	1984	2015
Rhode Island	Nonquit Pond	Fishway	R	2000	2015
New York	Hudson River	Various, Combined	B	1989	1990
New York	Hudson River	Various, Combined	A, B	1999	2001
New York	Hudson River	Various, Combined	A, B	2009	2015
South Carolina	Santee River	Pound Net	B	1978	1978
South Carolina	Santee River	Haul Seine	B	1979	1979
South Carolina	Santee River	Gill Net	B	1980	1983

Table 2.13 Summary of fisheries-dependent data sources that have collected repeat spawner data from river herring. Species indicates whether data were available for alewives (A), blueback herring (B), or both species combined (river herring, R).

State	Water Body	Gear	Species	Years	
				From	**To**
Maryland	Nanticoke River	Pound & Fyke Nets	A, B	1989	2014
North Carolina	Alligator River	Pound Net	A, B	1972	1993
North Carolina	Chowan River	Pound Net	A	1972	2009
North Carolina	Chowan River	Pound Net	B	1972	2015
North Carolina	Scuppernong River	Pound Net	A, B	1972	1993

Table 2.14 Estimated rates of repeat spawning for river herring (alewives and blueback herring combined) observed in Maine's fisheries-independent fishway survey of the Androscoggin River by year.

Year	Maine
	Fishway
	Androscoggin River
2005	47.3
2006	57.9
2007	56.5
2008	24.0
2009	41.5
2010	18.0
2011	20.0
2012	13.5
2013	27.2
2014	22.0

Table 2.15 Estimated rates of repeat spawning for male and female alewives observed in New Hampshire's fisheries-independent fishway survey of the Cocheco, Exeter, Lamprey and Winnicut Rivers by year.

	New Hampshire			
	Fishway			
Year	Cocheco River	Exeter River	Lamprey River	Winnicut River
2000	32.1	10.6	46.2	46.2
2001	43.6	37.5	58.6	58.6
2002	46.2	19.2	63.3	63.3
2003	30.6	38.9	51.4	51.4
2004	69.6	36.4	54.9	54.9
2005	54.2	21.9	51.6	51.6
2006	50.6	37.5	59.8	59.8
2007	31.2	17.5	57.1	57.1
2008	29.6	9.0	32.9	32.9
2009	30.4	11.7	50.8	50.8
2010	65.3	18.8	63.0	63.0
2011	42.7	11.1	47.6	
2012	58.7	33.9	45.6	
2013	48.8	28.6	53.7	
2014	56.6	48.6	57.4	
2015	37.5	27.0	57.8	

Table 2.16 Estimated rates of repeat spawning for blueback herring (both sexes combined) observed in New Hampshire's fisheries-independent fishway surveys of the Cocheco and Oyster Rivers by year. [-- indicates inadequate sample size.]

	New Hampshire	
	Fishway	
Year	Cocheco River	Oyster River
2000	44.00	34.97
2001	40.00	64.58
2002	20.75	36.17
2003	24.00	51.01
2004	41.18	69.53
2005	20.00	50.00
2006	12.50	42.55
2007	31.34	37.99
2008	37.50	27.59
2009	--	38.66
2010	--	52.56
2011		46.8
2012		56.5
2013	0.0	20.0

Table 2.17 Estimated rates of repeat spawning for male alewife observed in Massachusetts' fisheries-independent dipnet surveys in select rivers by year. Scale processing was discontinued at all sites other than the Monument River after 2013.

	Massachusetts						
	Dip Net						
Year	Mattapoisett River	Monument River	Mystic River	Nemasket River	Quashnet River	Stoney Brook	Town Brook
1986		38.6					
1987		41.1					
1988							
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
1993		22.7					
1995		5.2					
1996		23.9					
1997		22.0					
1998		28.7					
1999		12.2					
2000		9.8					
2001		17.8					
2002		31.2					
2003		18.8					
2004		6.5	32.4	43.9	4.6	12.1	16.9
2005		3.7	30.0	33.8			9.7
2006	2.86	4.9	0.0	9.7			4.4
2007		6.2	6.7	11.9			22.8
2008		12.6	15.7	20.1			32.3
2009		10.2	20.7	17.5			32.0
2010		6.7	14.3	15.9			16.7
2011		9.0	22.4	26.4			24.6
2012		5.9	33.9	15.4			27.4
2013		4.1	16.0	20.9			30.9
2014		10.9					
2015		4.7					

Table 2.18 Estimated rates of repeat spawning for female alewife observed in Massachusetts' fisheries-independent dipnet surveys in select rivers by year. Alewife scale processing was discontinued at all sites other than the Monument River after 2013.

Year	Massachusetts						
	Dip Net						
	Mattapoisett River	Monument River	Mystic River	Nemasket River	Quashnet River	Stoney Brook	Town Brook
1986		45.3					
1987		43.6					
1988							
1993		19.6					
1995		7.9					
1996		18.2					
1997		28.6					
1998		41.3					
1999		10.8					
2000		7.6					
2001		13.8					
2002		28.7					
2003		12.1					
2004		1.4	35.7	43.1	7.06	20.6	13.8
2005		7.6	8.33	18.8			18.4
2006	4.17	15.8	0.0	9.7			7.9
2007		8.4	12.7	13.5			16.9
2008		14.9	24.5	21.6			29.5
2009		13.5	28.6	30.4			31.1
2010		13.3	15.4	22.8			20.7
2011		16.0	35.3	26.4			22.9
2012		11.8	46.1	19.5			36.7
2013		11.9	22.1	17.0			29.1
2014		12.8					
2015		6.2					

Table 2.19 Estimated rates of repeat spawning for male blueback herring observed in Massachusetts, New York and South Carolina fisheries-independent surveys in select rivers by year and gear type.

Year	Massachusetts				New York	South Carolina			
	Dip Net				Various, Combined	Pound Net	Haul Seine	Gill Net	Cast Net
	Monument River	Mystic River	Quashnet River	Town Brook	Hudson River	Santee River	Santee River	Santee River	Santee River
1978						31.6			
1979							0		
1980								10.0	
1981								30.7	
1982								25.3	
1983								9.18	
1984									
1985									
1986	21.6								
1987	20.0								
1988									
1989					35.1				
1990					21.4				
1991									
1992									
1993									
1994									
1995									
1996									
1997									
1998									
1999					21.4				
2000					6.33				
2001					11.7				
2002									
2003									
2004	6.25		100						
2005	8.00	5.71		0					
2006	13.80	20.91							
2007	6.17	17.72							
2008	5.56	27.39							
2009	3.53	12.96			40.6				
2010	1.25	12.85			20.3				
2011	7.0	19.7			16.5				
2012	15.1	48.9			10.6				
2013	4.0	10.0			7.8				
2014					19.7				26.9
2015					25.0				29.6

Table 2.20 Estimated rates of repeat spawning for female blueback herring observed in Massachusetts, New York and South Carolina fisheries-independent surveys in select rivers by year and gear type.

Year	Massachusetts				New York	South Carolina			
	Dip Net				Various, Combined	Pound Net	Haul Seine	Gill Net	Cast Net
	Monument River	Mystic River	Quashnet River	Town Brook	Hudson River	Santee River	Santee River	Santee River	Santee River
1978						27.8			
1979							30.0		
1980								17.1	
1981								19.5	
1982								33.7	
1983								27.2	
1984									
1985									
1986	38.5								
1987	38.7								
1988									
1989					24.6				
1990					21.3				
1991									
1992									
1993									
1994									
1995									
1996									
1997									
1998									
1999					22.9				
2000					13.6				
2001					12.9				
2002									
2003									
2004	4.17		100						
2005	5.00	2.70		0					
2006	14.29	16.13							
2007	1.47	15.49							
2008	5.97	35.71							
2009	5.41	11.76			25.4				
2010	1.49	15.25			30.3				
2011	6.1	21.2			28.6				
2012	11.5	51.8			21.3				
2013	6.5	17.8			21.9				
2014					35.1				30.4
2015					48.1				30.3

Table 2.21 Estimated rates of repeat spawning for male river herring observed in Rhode Island's fisheries-independent fishway surveys in select rivers by year.

	Rhode Island	
	Fishway	
Year	Gilbert Stuart Stream	Nonquit Pond
1984	24.7	
1985	26.8	
1986	81.4	
1987		
1988	16.4	
1989	27.3	
1990		
1991	17.0	
1992	16.5	
2000	20.9	11.5
2001	18.8	5.26
2002	13.0	6.76
2003	6.58	15.6
2004	5.41	3.77
2005	4.44	0
2006	10.0	3.09
2007	7.06	8.18
2008	17.02	14.12
2009	13.43	20.27
2010	6.25	
2011	12.3	13.3
2012	17.9	6.7
2013	17.2	10.2
2014	16.7	15.6
2015		25.7

Table 2.22 Estimated rates of repeat spawning for female river herring observed in Rhode Island's fisheries-independent fishway surveys in select rivers by year.

	Rhode Island	
	Fishway	
Year	Gilbert Stuart Stream	Nonquit Pond
1984	20.5	
1985	31.4	
1986	58.1	
1987		
1988	56.8	
1989	29.3	
1990		
1991	36.6	
1992	59.3	
2000	19.0	16.7
2001	23.4	15.2
2002	26.2	11.3
2003	10.3	15.2
2004	11.1	6.06
2005	5.71	12.0
2006	34.4	0
2007	3.6	5.13
2008	25.6	25.0
2009	3.3	13.1
2010	9.09	
2011	27.4	22.6
2012	11.8	10.5
2013	33.3	52
2014	11.5	13.4
2015		34.1

Table 2.23 Estimated rates of repeat spawning for male and female alewife observed in New York's fisheries-independent surveys in the Hudson River by year.

	New York	
	Various Gear, Combined	
	Hudson River	
Year	Male	Female
1999	39.0	75.0
2000	4.08	15.4
2001	11.9	34.9
2009	25.2	42.2
2010	19.9	49.5
2011	17.9	31.7
2012	28.5	33.0
2013	20.2	40.8
2014	38.1	48.2
2015	49.1	64.0

Table 2.24 Estimated rates of repeat spawning for male alewife observed in Maryland and North Carolina's fisheries-dependent surveys by river and year. [-- indicates inadequate sample size and X indicates data excluded due to ageing error (see state report)]

Year	**Maryland**	**North Carolina**		
	Pound & Fyke Net	Pound Net		
	Nanticoke River	Alligator River	Chowan River	Scuppernong River
1972		77.8	36.5	47.0
1973		40.5	27.0	34.1
1974			13.5	4.55
1975		20.3	41.7	10.1
1976		20.2	40.4	14.9
1977		28.2	13.8	22.7
1978		37.9	13.8	0
1979		65.1	28.2	20.0
1980		38.6	42.4	36.7
1981		20.5	21.1	15.4
1982		28.7	28.4	51.0
1983		36.6	26.7	30.0
1984		18.8	32.5	21.7
1985		61.1	15.0	
1986		30.2	37.9	
1987		0	0	0
1988		38.5	27.5	35.7
1989	57.8	32.5	16.7	26.5
1990	67.1	36.7	--	68.4
1991	44.6	28.5	66.7	25.0
1992	52.7	14.9	26.3	10.3
1993	62.4	17.4	--	10.1
1994	50.8		--	
1995	45.5			
1996	35.1			
1997	52.3			
1998	51.5			
1999	63.6		40.0	
2000	31.4		20.3	

Table 2.24 Continued.

Year	Maryland	North Carolina		
	Pound & Fyke Net	Pound Net		
	Nanticoke River	Alligator River	Chowan River	Scuppernong River
2001	50.0		48.1	
2002	70.4		57.4	
2003	64.6		20.0	
2004	41.2		39.7	
2005	34.3		59.5	
2006	72.0		13.0	
2007	25.0		29.6	
2008	59.1		20.3	
2009	31.0		35.7	
2010	32.0		X	
2011	57.1		X	
2012	26.2		X	
2013	27.9		X	
2014	23.9		X	
2015			X	

Table 2.25 Estimated rates of repeat spawning for female alewife observed in Maryland and North Carolina's fisheries-dependent surveys by river and year. [-- indicates inadequate sample size and X indicates data excluded due to ageing error (see state report)]

Year	**Maryland**	**North Carolina**		
	Pound & Fyke Net	Pound Net		
	Nanticoke River	Alligator River	Chowan River	Scuppernong River
1972		46.7	51.3	58.3
1973		43.4	37.3	56.8
1974			12.1	0
1975		30.4	41.7	11.3
1976		22.6	68.2	14.3
1977		26.5	20.5	25.2
1978		45.3	39.2	0
1979		65.6	39.5	33.3
1980		78.8	57.3	52.0
1981		41.3	35.5	45.5
1982		19.7	31.3	37.8
1983		28.3	31.7	21.9
1984		27.0	32.0	12.5
1985		43.3	19.5	
1986		27.6	45.8	
1987		0	--	0
1988		53.7	20.8	28.6
1989	63.0	42.9	9.09	29.6
1990	73.9	50.9	--	63.2
1991	55.5	48.5	86.7	45.2
1992	57.7	39.6	51.7	58.7
1993	75.5	40.0	--	11.8
1994	66.7		--	
1995	55.4			
1996	58.7			
1997	61.2			
1998	57.6			
1999	74.2		--	
2000	41.8		25.5	
2001	67.7		34.5	
2002	84.9		42.3	
2003	83.5		36.7	
2004	66.1		52.3	
2005	58.6		57.1	
2006	84.8			

Table 2.25 Continued.

	Maryland	North Carolina		
	Pound & Fyke Net	Pound Net		
Year	Nanticoke River	Alligator River	Chowan River	Scuppernong River
2007	55.0		57.9	
2008	71.8		30.0	
2009	58.2		39.5	
2010	65.9		X	
2011	60.2		X	
2012	58.4		X	
2013	56.5		X	
2014	27.6		X	
2015			X	

Table 2.26 Estimated rates of repeat spawning for male blueback herring observed in Maryland and North Carolina's fisheries-dependent surveys by river and year.

	Maryland	**North Carolina**		
	Pound Net	Pound Net		
Year	Nanticoke River	Alligator River	Chowan River	Scuppernong River
1972		55.2	43.1	35.9
1973		41.2	43.7	13.8
1974			41.3	21.2
1975			15.2	6.99
1976		21.6	33.8	10.3
1977		41.8	18.4	21.4
1978			23.9	15.3
1979			64.0	20.6
1980		0	50.5	34.3
1981			37.4	14.3
1982			29.3	30.8
1983		66.7	33.9	21.8
1984		7.41	20.8	18.8
1985		28.6	42.7	45.6
1986			53.3	31.0
1987			11.0	0
1988		0	19.8	6.25
1989	66.5		22.6	18.4
1990	81.6		24.3	41.4
1991	66.0	9.09	18.6	45.8

Table 2.26 Continued.

1992	75.2		35.0	42.9
1993	82.7		63.3	23.1
1994	51.3		34.1	
1995	55.0		41.7	
1996	56.1		32.6	
1997	85.8		22.2	
1998	70.8		38.2	
1999	69.0		53.3	
2000	40.7		42.7	
2001	52.9		38.6	
2002	67.2		45.1	
2003	63.8		41.1	
2004	30.4		36.6	
2005	25.0		23.2	
2006	73.1		13.7	
2007	13.2		53.2	
2008	36.1		5.5	
2009	29.0		21.7	
2010	27.3		14.1	
2011	39.3		47.3	
2012	22.4		47.4	
2013	38.9		46.4	
2014	30.7		27.0	
2015			52.8	

Table 2.27 Estimated rates of repeat spawning for female blueback herring observed in Maryland and North Carolina's fisheries-dependent surveys by river and year.

	Maryland	**North Carolina**		
	Pound & Fyke Net	Pound Net		
Year	Nanticoke River	Alligator River	Chowan River	Scuppernong River
1972		61.9	44.0	32.1
1973		38.2	46.9	23.3
1974			48.1	20.6
1975			28.6	9.64
1976		39.7	42.4	23.3
1977		38.4	21.4	35.7
1978			19.3	17.5
1979			77.8	37.5
1980		20.0	57.9	34.1
1981			47.6	20.0
1982			36.2	25.0
1983		21.4	37.1	44.1
1984		13.0	37.5	19.4
1985		0	48.1	46.3
1986			52.6	42.6
1987			1.69	0
1988		25.0	36.0	36.8
1989	67.3		33.3	27.3
1990	83.4		27.0	44.4
1991	73.9	50.0	31.6	61.5
1992	74.7		31.3	14.3

Table 2.27 Continued.

1993	80.7		64.5	35.3
1994	56.2		23.3	
1995	40.0		41.9	
1996	61.0		46.2	
1997	77.8		47.9	
1998	67.1		43.3	
1999	81.5		59.7	
2000	41.2		66.4	
2001	41.8		37.4	
2002	65.9		27.4	
2003	48.6		36.8	
2004	44.4		35.6	
2005	20.0		25.8	
2006	54.8		22.9	
2007	35.0		65.7	
2008	43.8		26.8	
2009	28.6		37.6	
2010	40.0		31.0	
2011	50		51.3	
2012	38.2		54.7	
2013	33.3		51.0	
2014	39.7		23.6	
2015			48.4	

Table 2.28 Spawner-per-recruit Z benchmarks and terminal year estimates of Z by river system.

Year	State	River	Species	Sex	Z	Benchmark Z40% (M=0.3)	Z20% (M=0.3)	Z40% (M=0.7)	Z20% (M=0.7)
2014	ME	Androscoggin	Alewife	Male	2.56	0.47	0.62	0.93	1.12
2014	ME	Androscoggin	Alewife	Female	0.92	0.47	0.62	0.93	1.12
2015	ME	Sebasticook	Alewife	Male	1.73	0.47	0.62	0.93	1.12
2015	NH	Cocheco	Alewife	Male	0.185	0.46	0.6	0.92	1.11
2015	NH	Cocheco	Alewife	Female	0.54	0.46	0.6	0.92	1.11
2015	NH	Lamprey	Alewife	Male	0.71	0.46	0.6	0.92	1.11
2015	NH	Oyster	Blueback	Male	2.83	0.48	0.64	0.95	1.15
2015	NH	Oyster	Blueback	Female	0.8	0.48	0.64	0.95	1.15
NA	NH	Winnicut	Alewife	Male	NA	0.46	0.6	0.92	1.11
NA	NH	Winnicut	Alewife	Female	NA	0.46	0.6	0.92	1.11
NA	NH	Winnicut	Blueback	Female	NA	0.48	0.64	0.95	1.15
2015	MA	Monument	Alewife	Male	3.52	0.46	0.61	0.92	1.11
2015	MA	Mystic	Alewife	Male	1.14	0.46	0.61	0.92	1.11
2015	MA	Nemasket	Alewife	Male	2.13	0.46	0.61	0.92	1.11
2015	MA	Town	Alewife	Male	1.93	0.46	0.61	0.92	1.11
2015	MA	Monument	Alewife	Female	2.87	0.46	0.61	0.92	1.11
2015	MA	Mystic	Alewife	Female	0.93	0.46	0.61	0.92	1.11
2015	MA	Nemasket	Alewife	Female	1.97	0.46	0.61	0.92	1.11
2015	MA	Town	Alewife	Female	0.89	0.46	0.61	0.92	1.11
2014	RI	Gilbert-Stuart	Alewife	Both	1.78	0.48	0.64	0.94	1.14
2015	RI	Nonquit	Alewife	Both	1.88	0.48	0.64	0.94	1.14
2014	MD	Nanticoke	Alewife	Male	1.74	0.46	0.61	0.93	1.13
2014	MD	Nanticoke	Alewife	Female	1.55	0.46	0.61	0.93	1.13
2014	MD	Nanticoke	Blueback	Male	1.2	0.47	0.61	0.92	1.11
2014	MD	Nanticoke	Blueback	Female	1.61	0.47	0.61	0.92	1.11
NA	NC	Chowan	Alewife	Both	NA	0.48	0.62	0.93	1.12
NA	NC	Albemarle FI	Alewife	Both	NA	0.48	0.62	0.93	1.12
2015	NC	Chowan	Blueback	Both	1.28	0.47	0.62	0.92	1.11
NA	NC	Albemarle FI	Blueback	Both	NA	0.47	0.62	0.92	1.11

Table 2.29 Estimates of Fcollapse, Ucollapse, and Zcollapse for alewife by river and method.

River	Method	Years	r_m	α (lbs)	F_{coll}	U_{coll}	Z_{coll}
Androscoggin	C & G M1		0.38	10.2	1.33	0.74	2.33
ME	M3			15.5	1.46	0.77	2.46
Damariscotta[1]	C& G S-R	1949-1989		19.7	2.00	0.86	3.00
ME	M1	1997-2004	0.23	5.6	1.06	0.65	2.06
	M3			15.5	1.46	0.77	2.46
	M4	1977-2010		10.8	0.94	0.61	1.64
Union	C & G M1		0.47	14.3	1.59	0.80	2.59
ME	M1	1993-2001	0.16	4.2	0.98	0.62	1.98
	M3			15.5	1.46	0.77	2.46
Cocheco	M1	1999-2003	0.36	9.4	1.29	0.72	2.29
NH	M3			15.5	1.46	0.77	2.46
	M5	1976-2004		29.8	1.83	0.84	2.53
Lamprey	C & G S-R			19.7	1.90	0.85	2.90
NH	C & G M1		0.48	15.2	1.63	0.80	2.63
	M1	1996-2004	0.25	6.0	1.09	0.66	2.09
	M3			15.5	1.46	0.77	2.46
	M5	1972-2004		60.9	2.48	0.92	3.18
Monument	C & G M2				1.61	0.80	2.61
MA	M1	1980-1996	0.10	3.2	0.93	0.60	1.93
	M1	2006-2010	0.20	4.9	1.02	0.64	1.79
	M3			15.5	1.46	0.77	2.46
	M4	1983-2006		16.5	1.29	0.72	1.99
Nemasket	M1	2005-2010	0.25	6.0	1.09	0.61	2.09
MA	M3			15.5	1.46	0.77	2.46
Wankinco	M1	2007-2010	0.38	10.2	1.33	0.74	2.33
MA	M3			15.5	1.46	0.77	2.46
Annaquatuc-	C & G S-R			8.8	1.10	0.67	2.10
ket RI	C & G M1		0.47	14.7	1.59	0.80	2.59
	M3			15.5	1.46	0.77	2.46
Gilbert-Stuart	M1	1985-1989	0.38	10.2	1.33	0.74	2.33
RI	M1	1993-2000	0.36	9.4	1.28	0.72	2.28
	M3			15.5	1.46	0.77	2.46

[1]Age and repeat spawner data from the Androscoggin River were used for the Damariscotta River to generate the recruitment and female spawning stock biomass data for 1977-2010 used in the M5 method.

Table 2.30 Estimates of Fcollapse, Ucollapse, and Zcollapse and required parameters for blueback herring by river and method.

River	Method	Years	r_m	α (lbs)	F_{coll}	U_{coll}	Z_{coll}
Connecticut	C & G S-R			28.2	2.20	0.89	3.20
CT	C & G M1		0.55	20.1	1.91	0.85	2.91
Chowan	C & G S-R			16.7	1.80	0.83	2.80
NC	M4			10.2	0.91	0.60	1.61

FIGURES

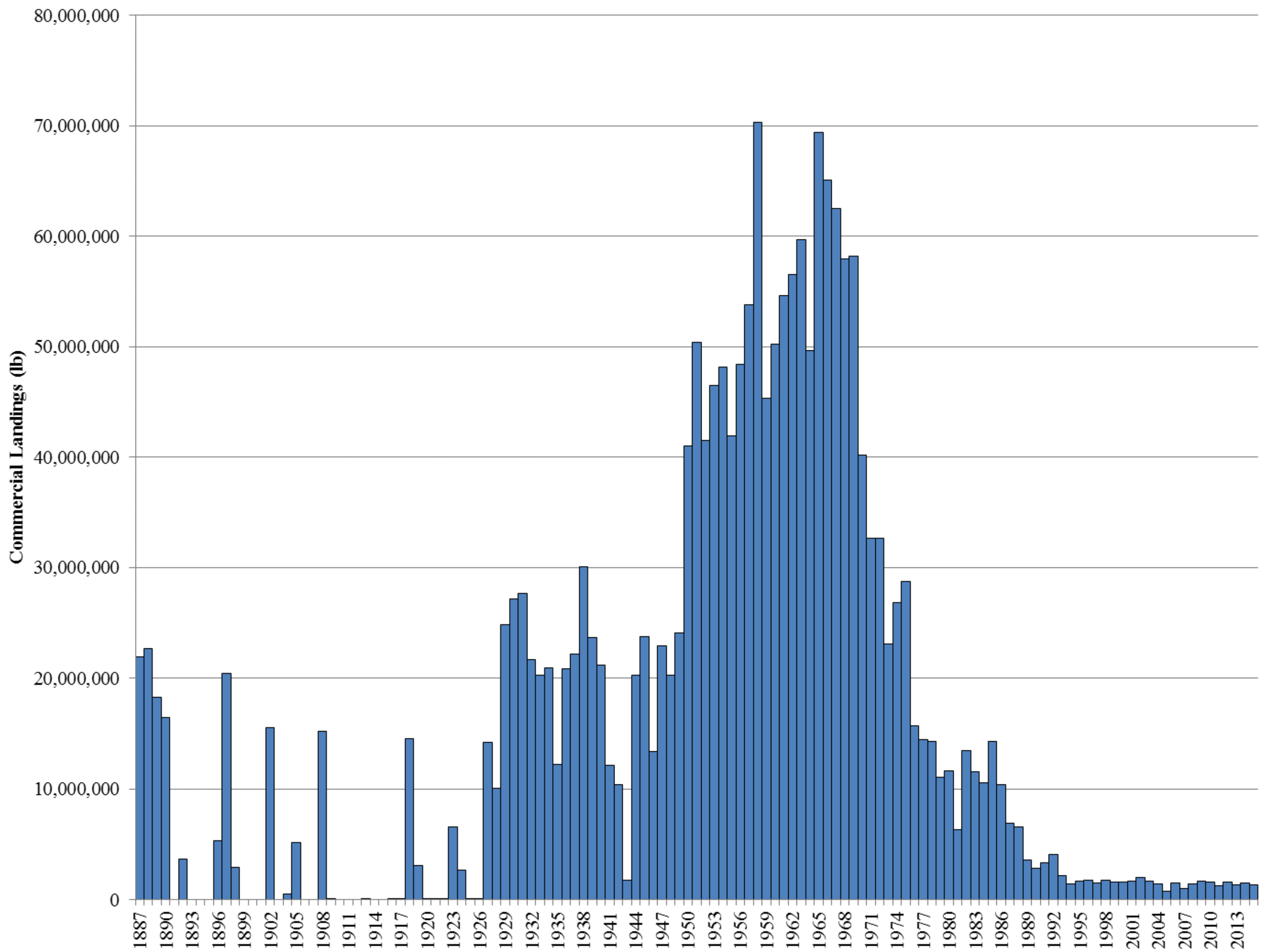


Figure 2.1 Domestic commercial landings of river herring from 1887 to 2015.

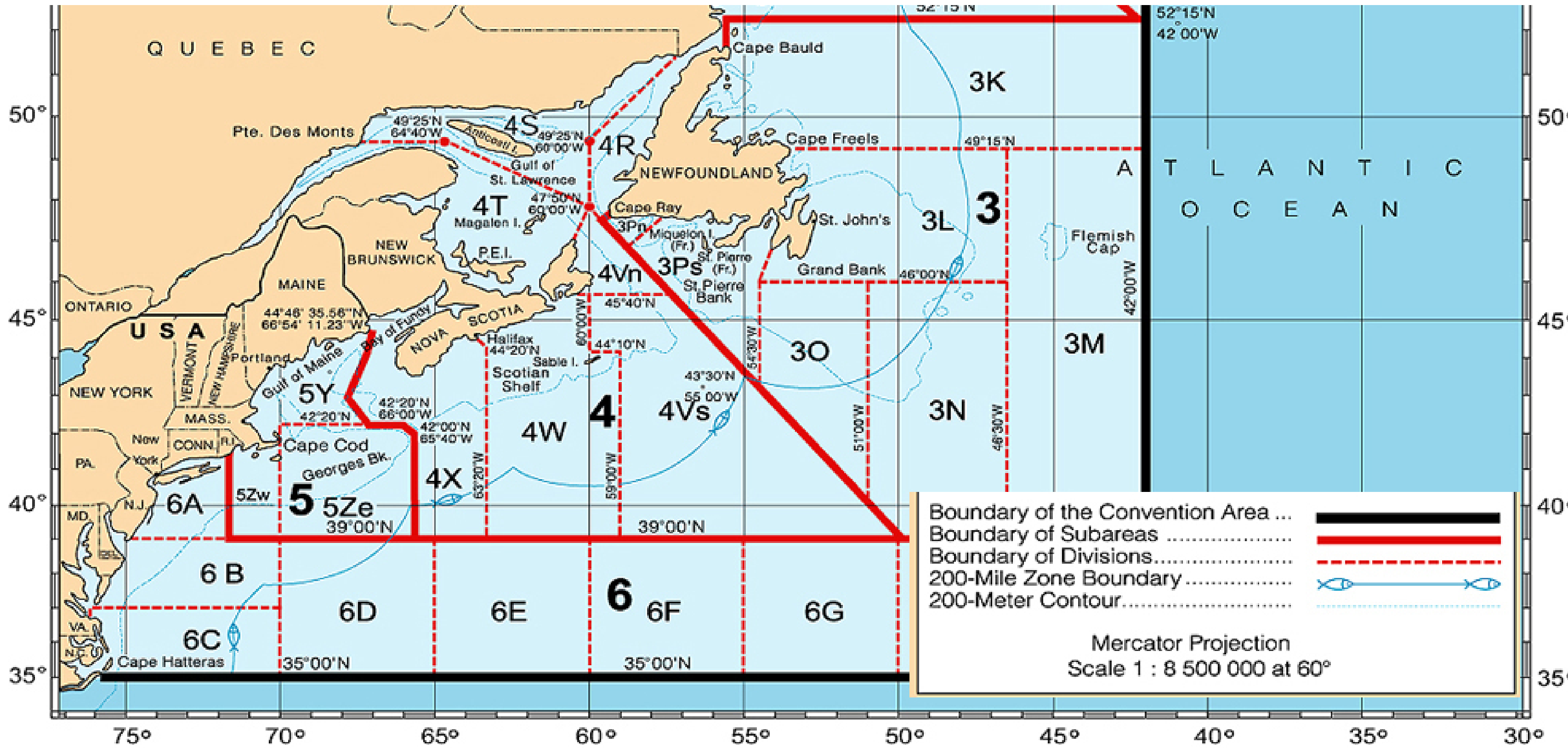


Figure 2.2 NAFO Convention areas off the coast of the US and Canada. The full convention area extends to the northern coast of Greenland.

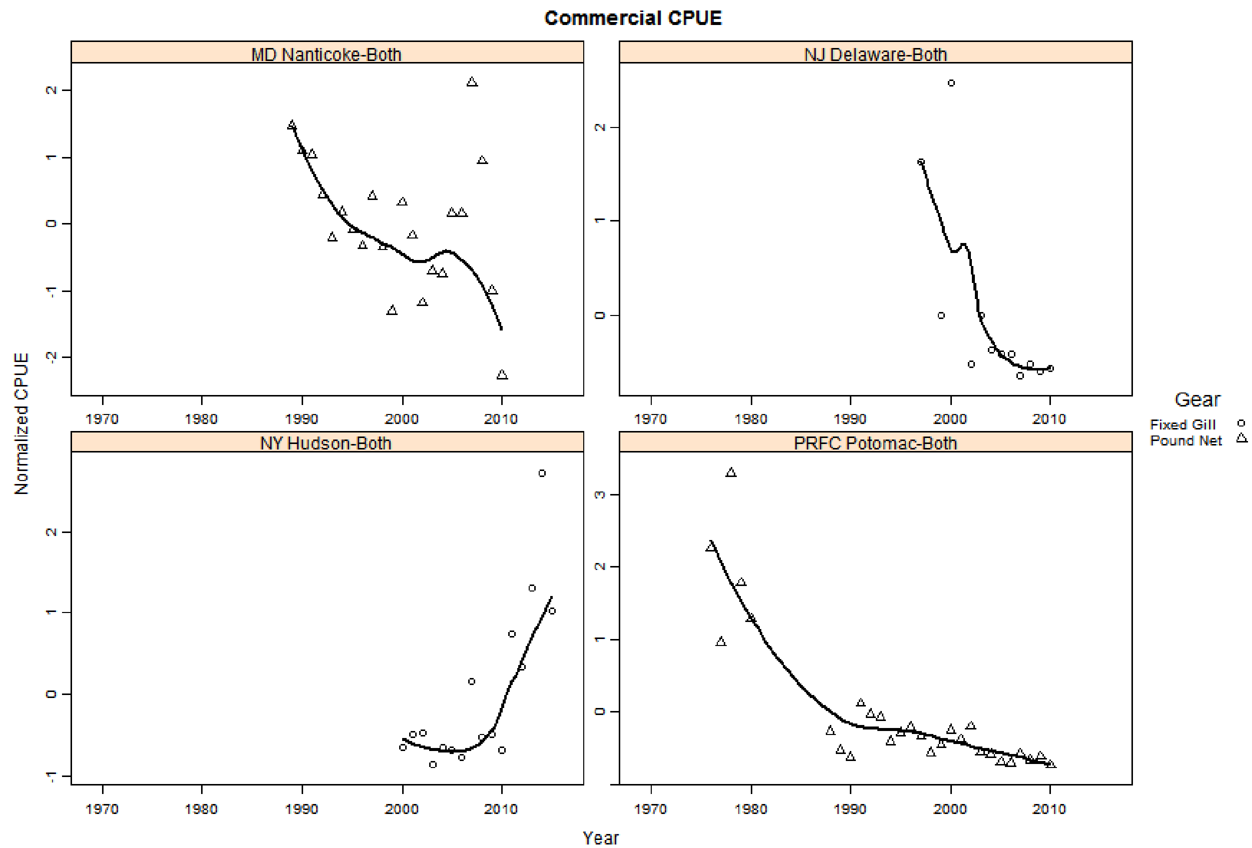


Figure 2.3 Normalized CPUE (catch-per-unit-effort) data for river herring in the Hudson River (NY), Delaware Bay (NJ), Nanticoke River (MD) and the Potomac River (PRFC) by year and gear type. Loess smooths are shown as indications of general trends.

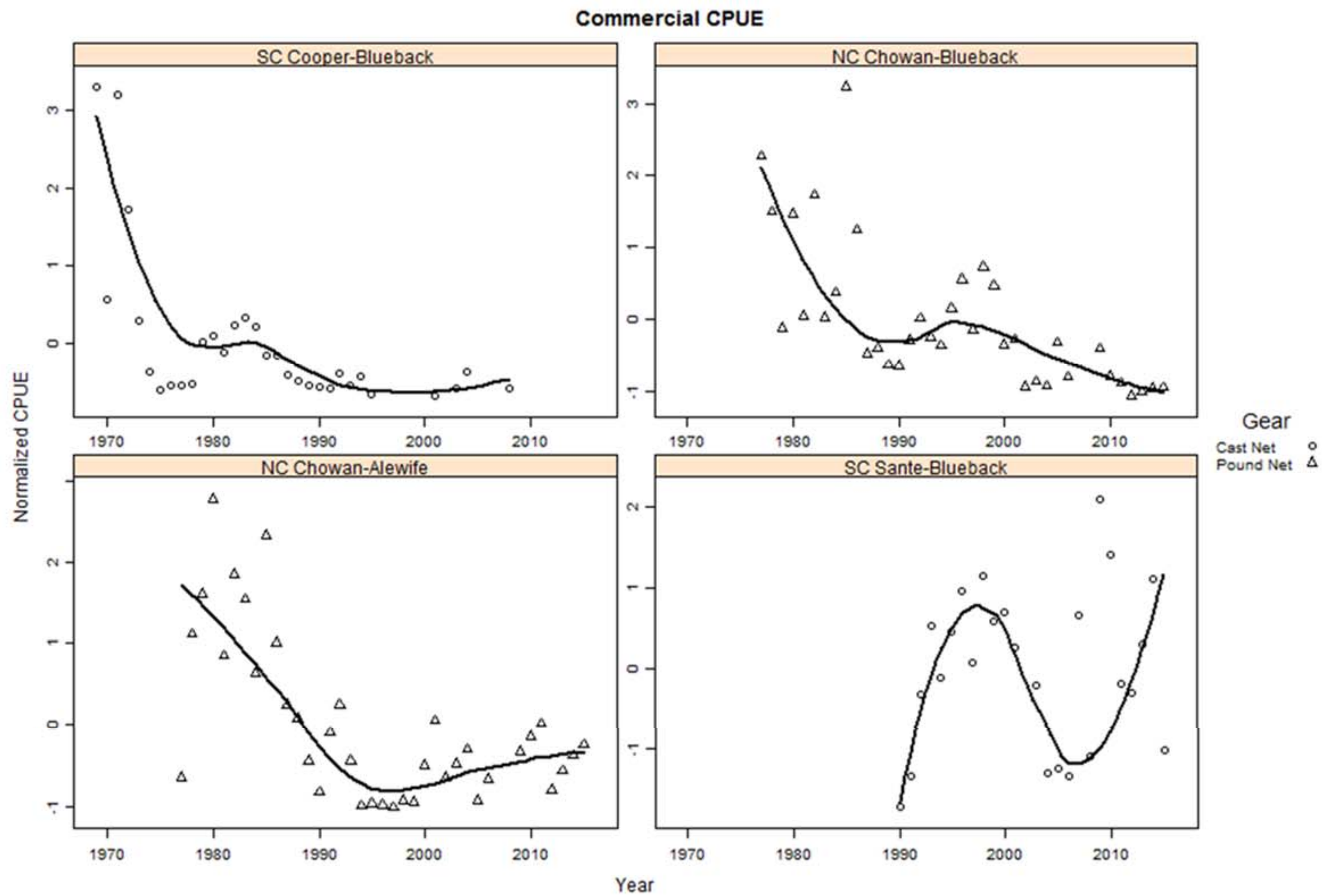


Figure 2.4 Normalized CPUE (catch-per-unit-effort) data for river herring in the Chowan River (NC), Cooper River (SC) and Santee River Diversion Canal (SC) by year and gear type. Loess smooths are shown as indications of general trends.

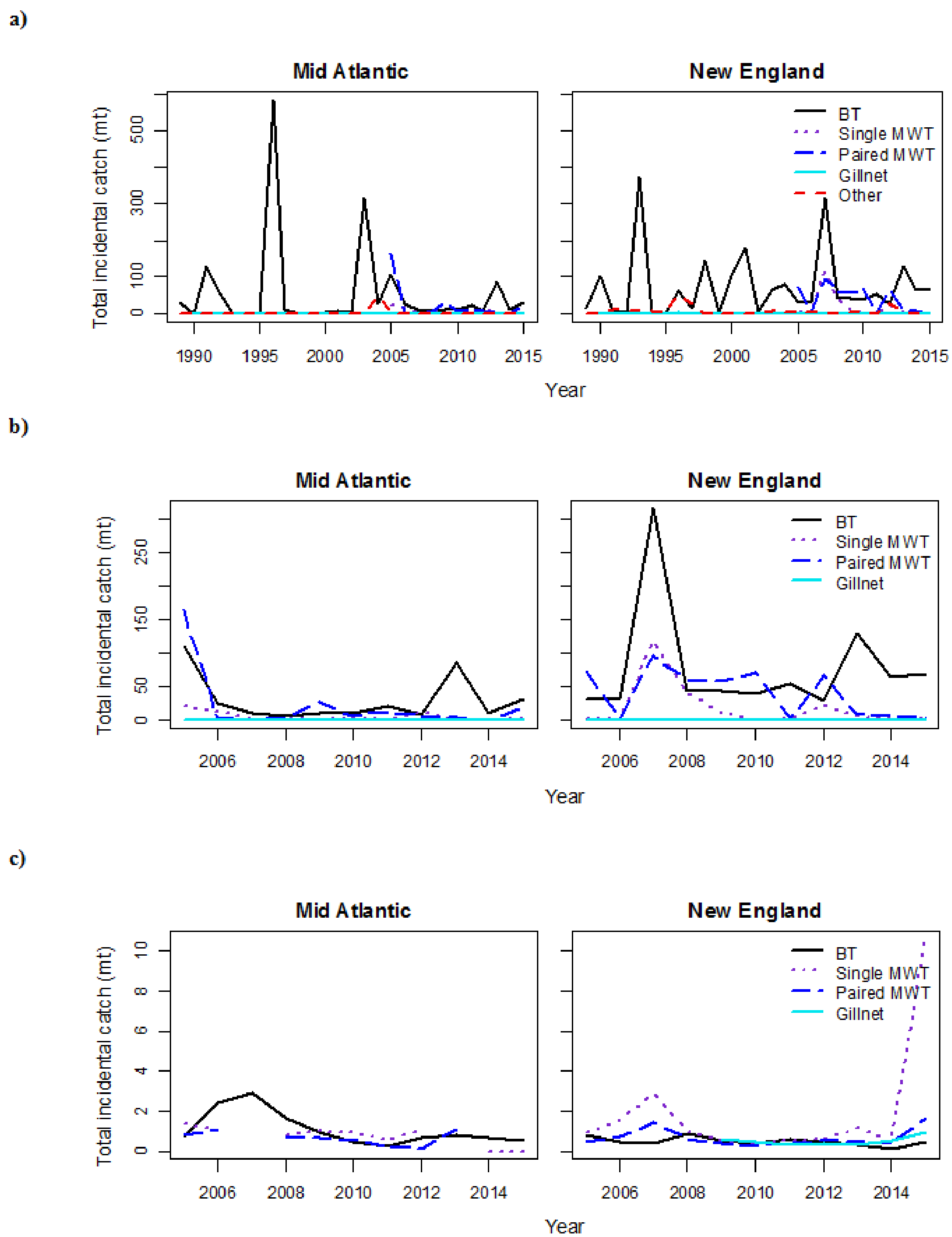


Figure 2.5 Alewife total annual incidental catch (mt) by region for the four gears with the largest catches from a) 1989 – 2015 and b) 2005 – 2015, and c) the corresponding estimates of precision. Midwater trawl estimates are only included beginning in 2005.

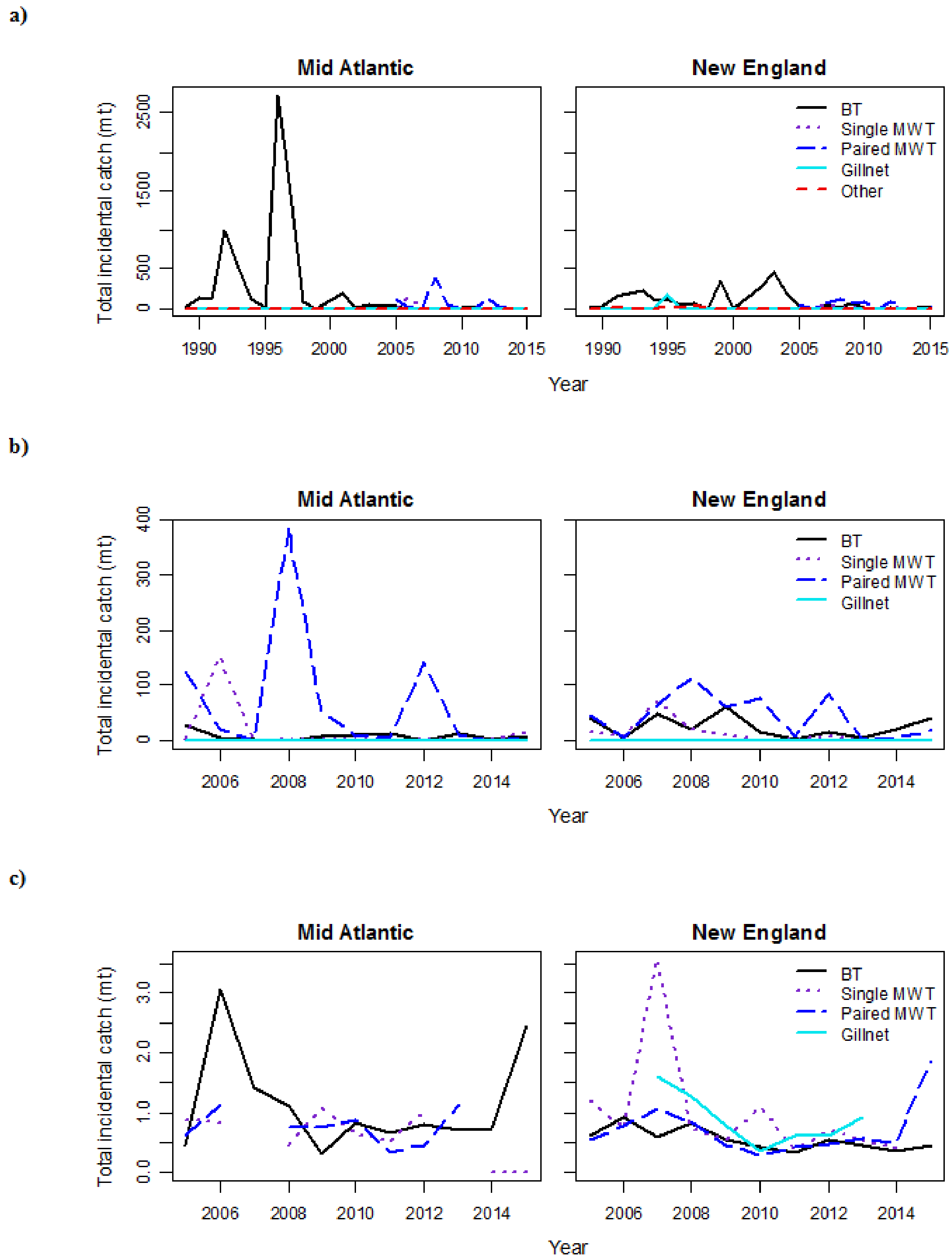


Figure 2.6 Blueback herring total annual incidental catch (mt) by region for the four gears with the largest catches from a) 1989 – 2015 and b) 2005 – 2015, and c) the corresponding estimates of precision. Midwater trawl estimates are only included beginning in 2005.

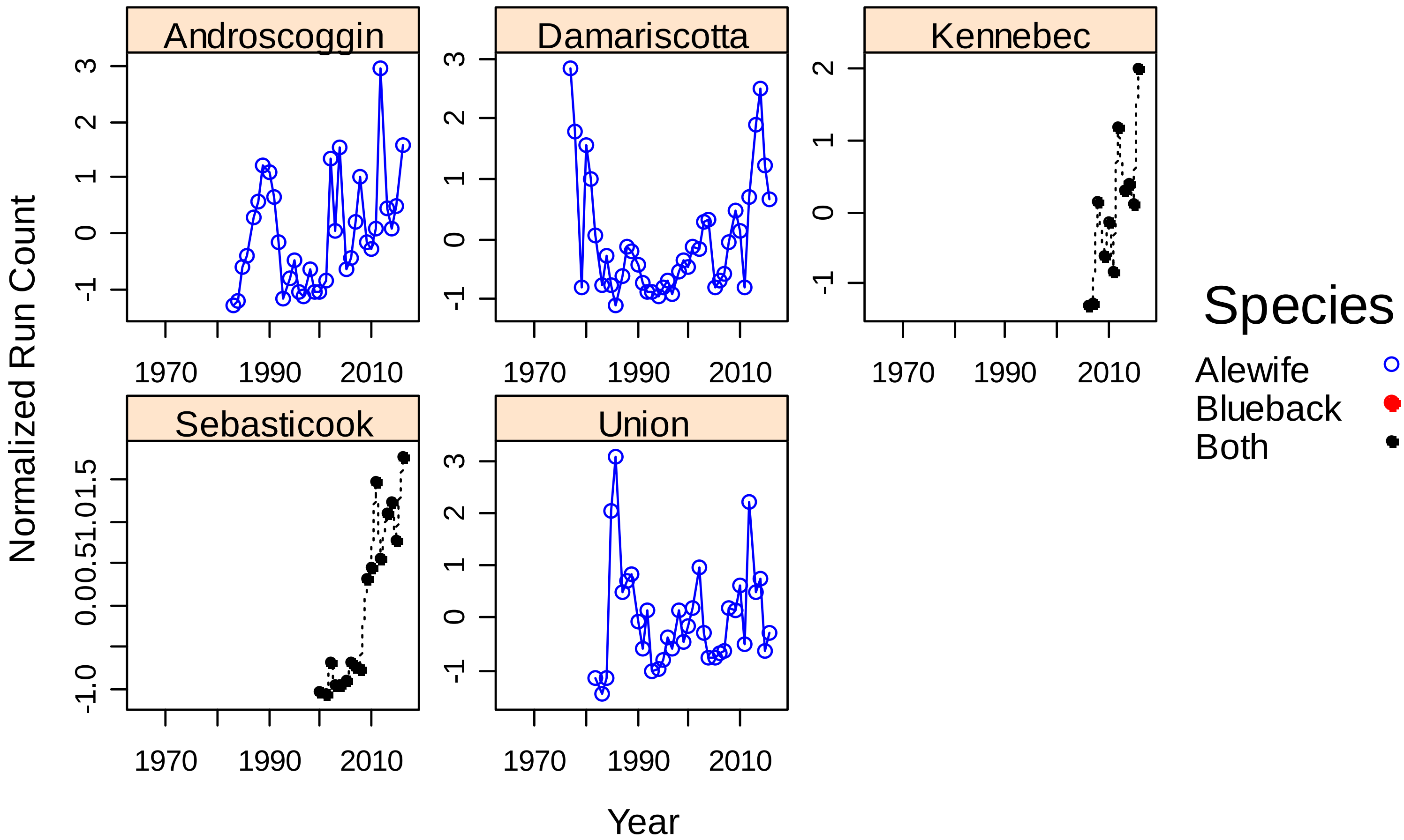


Figure 2.7 Plots of normalized run counts of alewife, blueback and combined species from Maine by river and year.

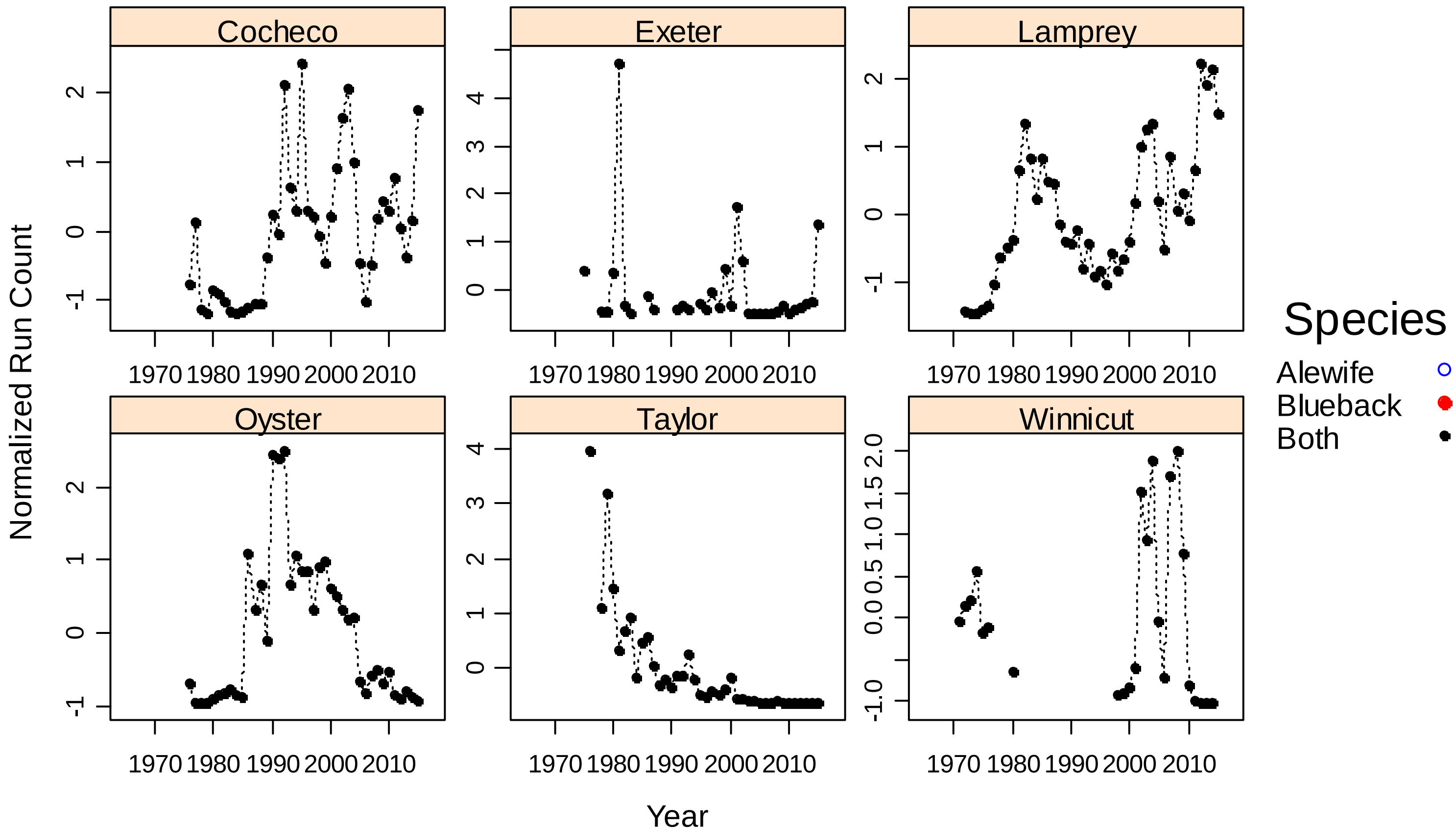


Figure 2.8 Plots of normalized run counts of alewife, blueback and combined species from New Hampshire by river and year.

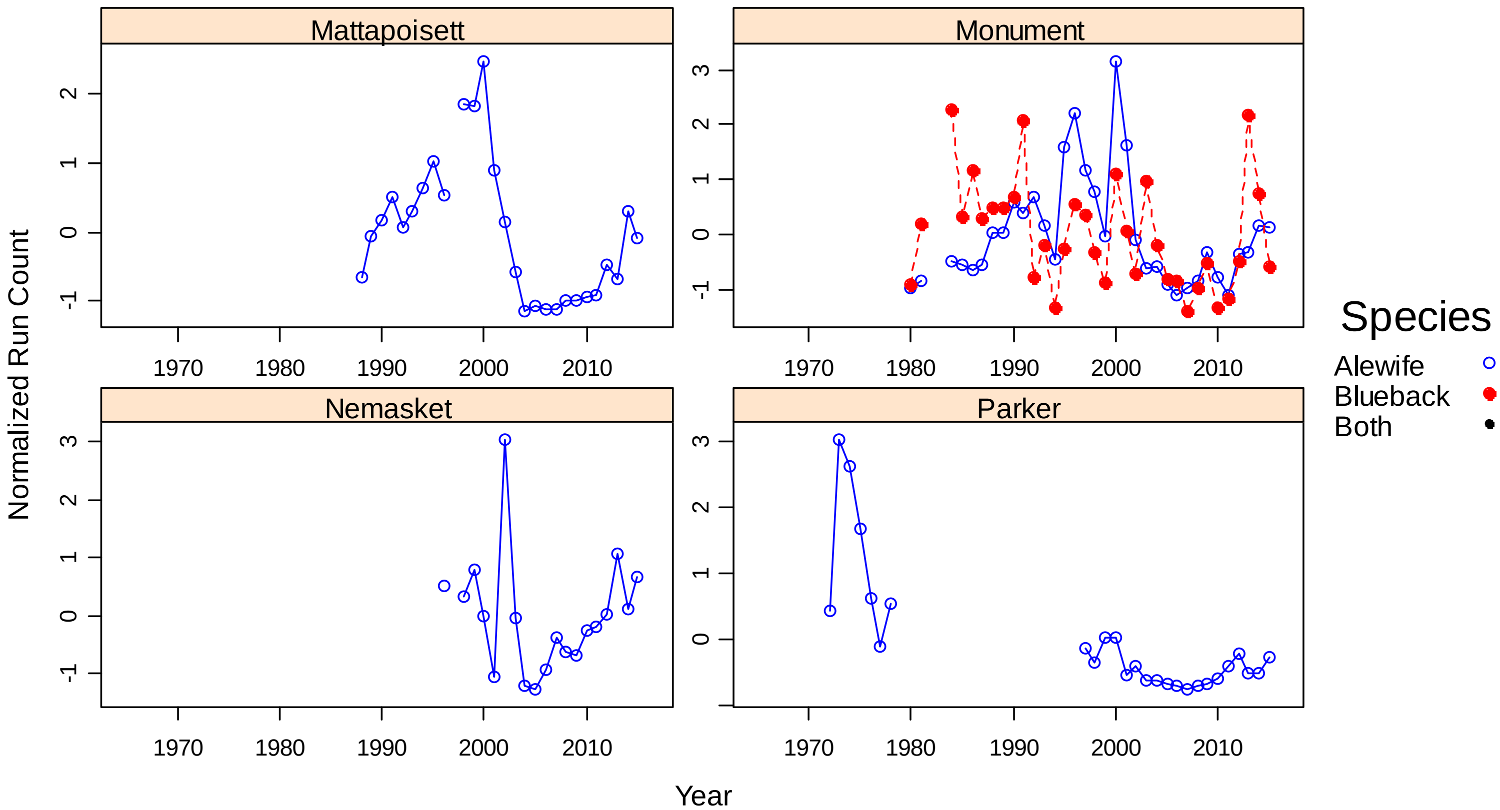


Figure 2.9 Plots of normalized run counts of alewife and blueback herring from Massachusetts by river and year.

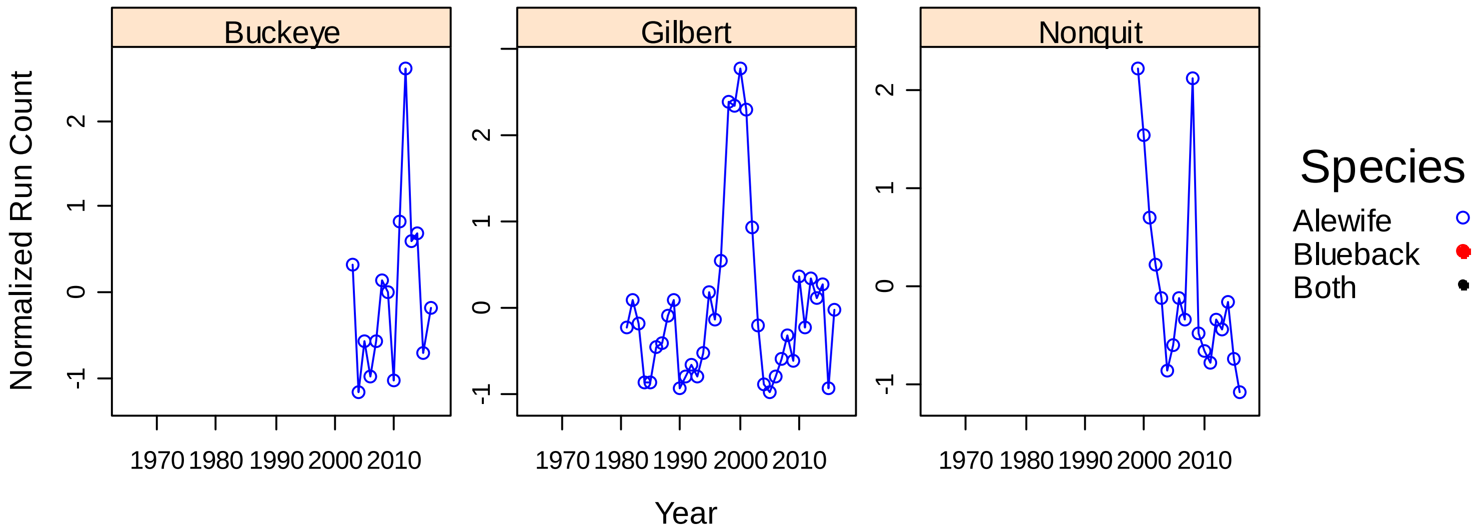


Figure 2.10 Plots of normalized run counts of alewife and blueback herring from Rhode Island by river and year.

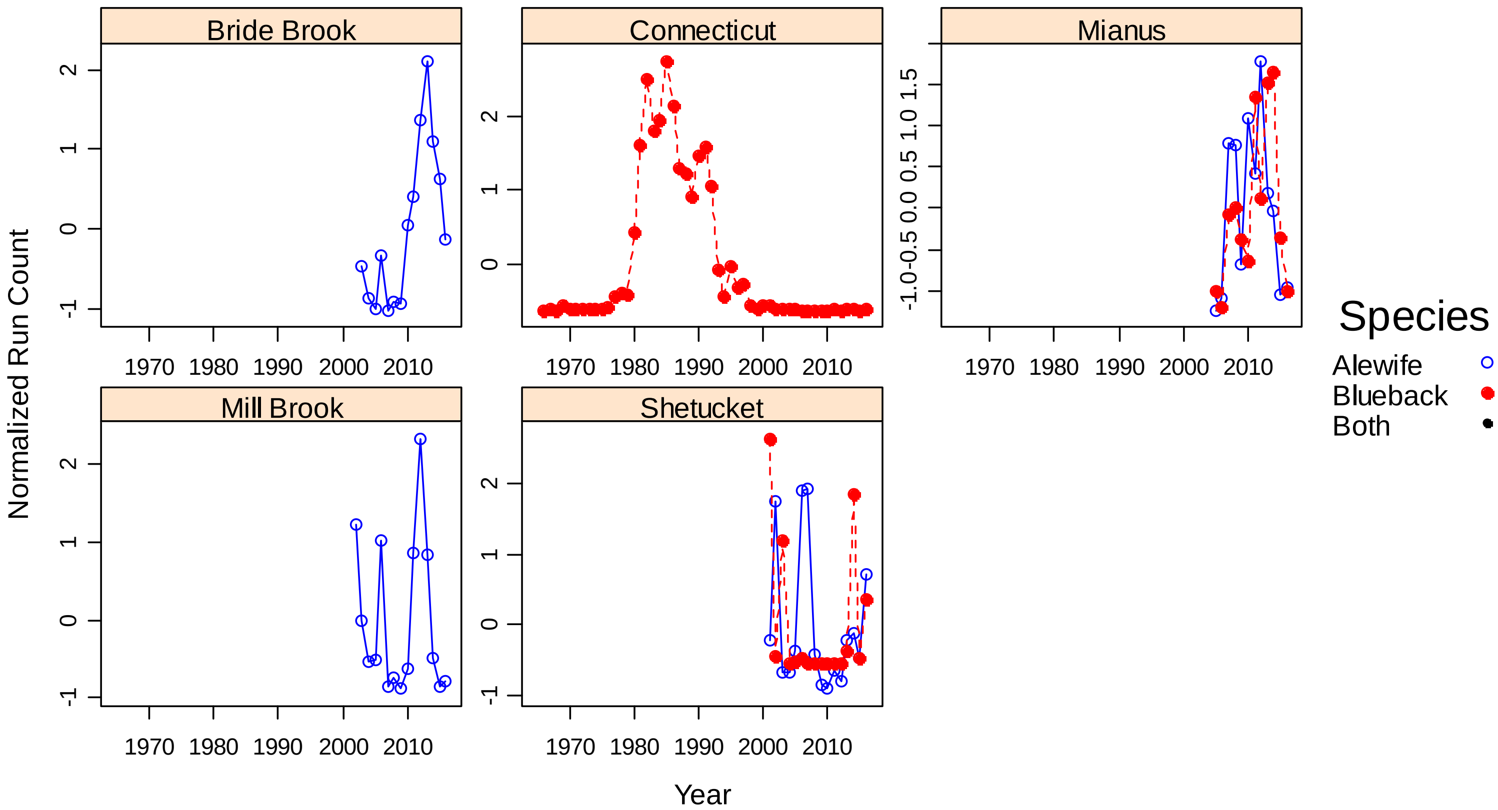


Figure 2.11 Plots of normalized run counts of alewife and blueback herring from Connecticut by river and year.

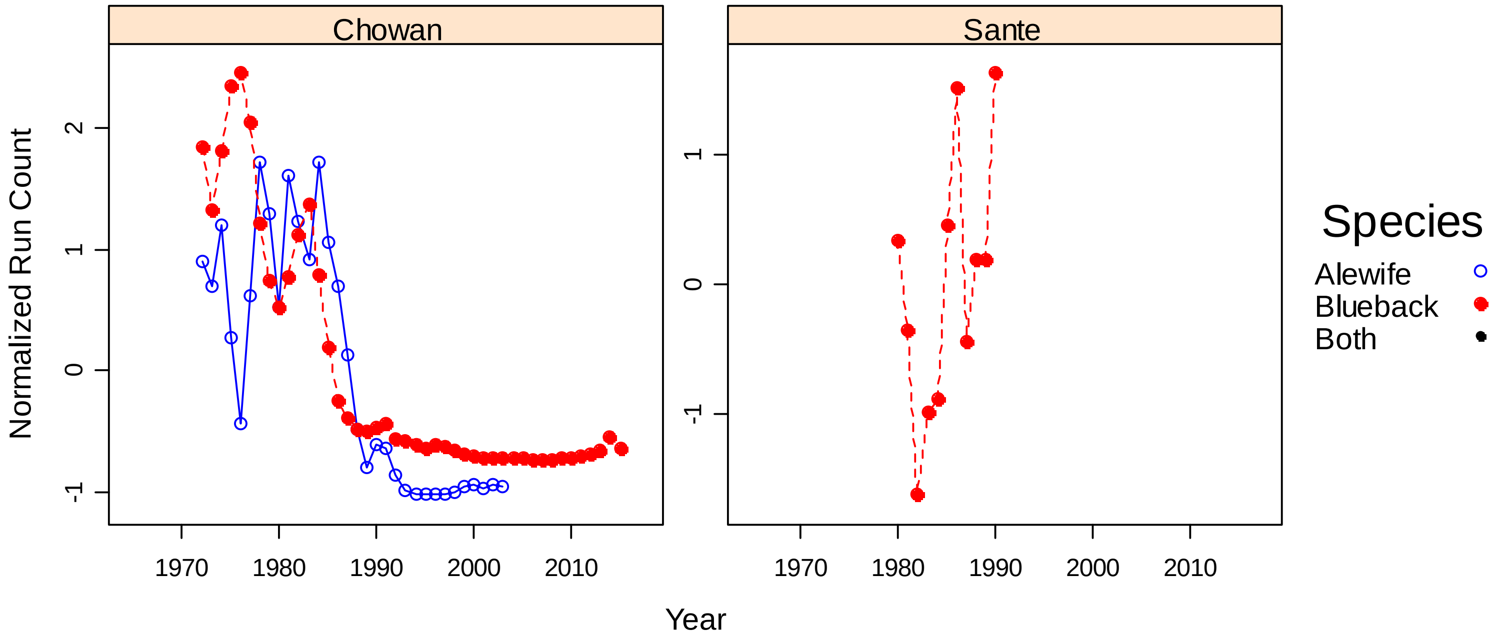


Figure 2.12 Plots of normalized run counts of alewife and blueback herring from North Carolina and South Carolina by river and year

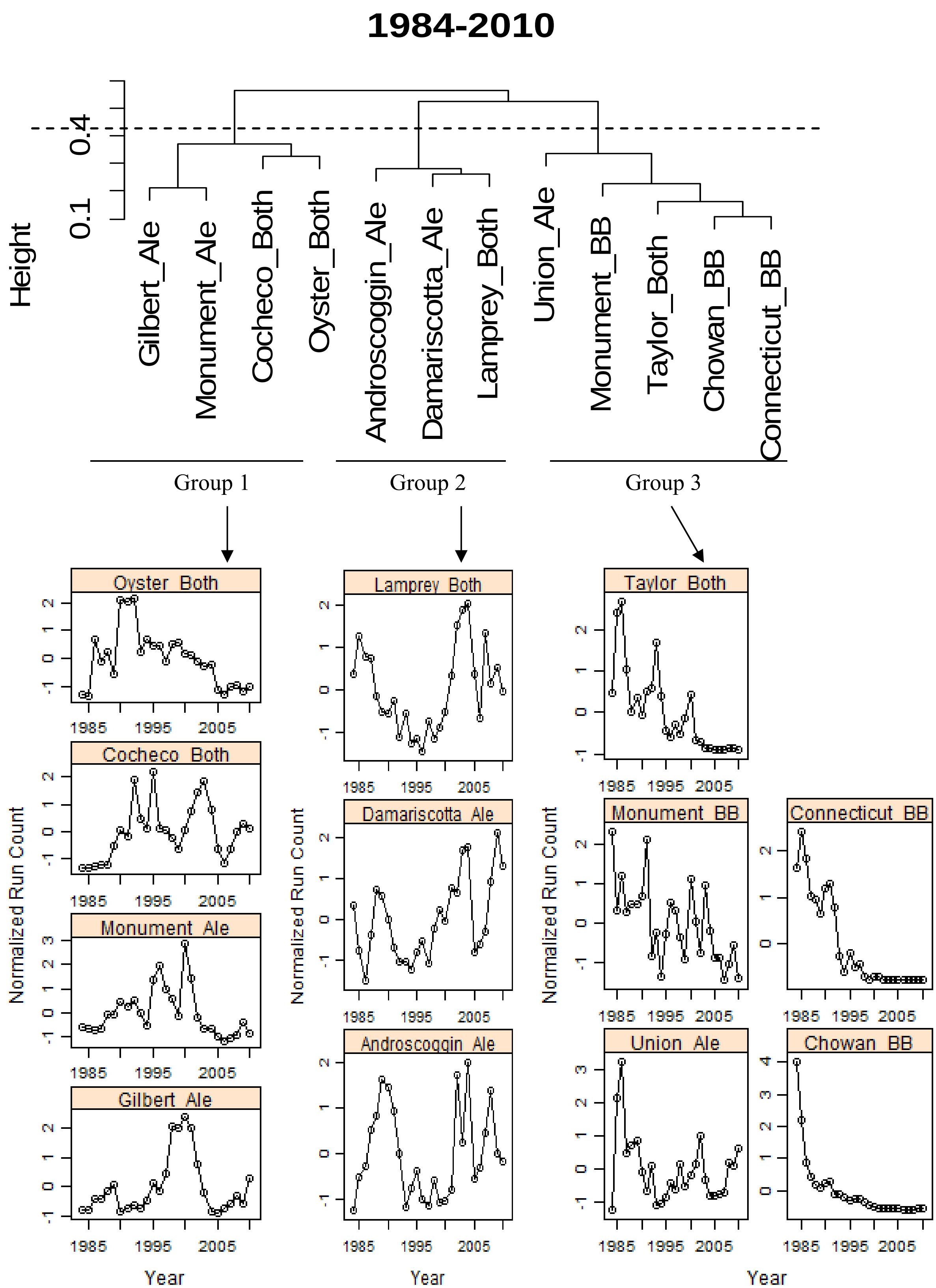


Figure 2.13 The resulting cluster dendrogram of river trends for 1984-2010 and plots of river counts for each grouping. The dotted line indicates the level of similarity selected to define groups.

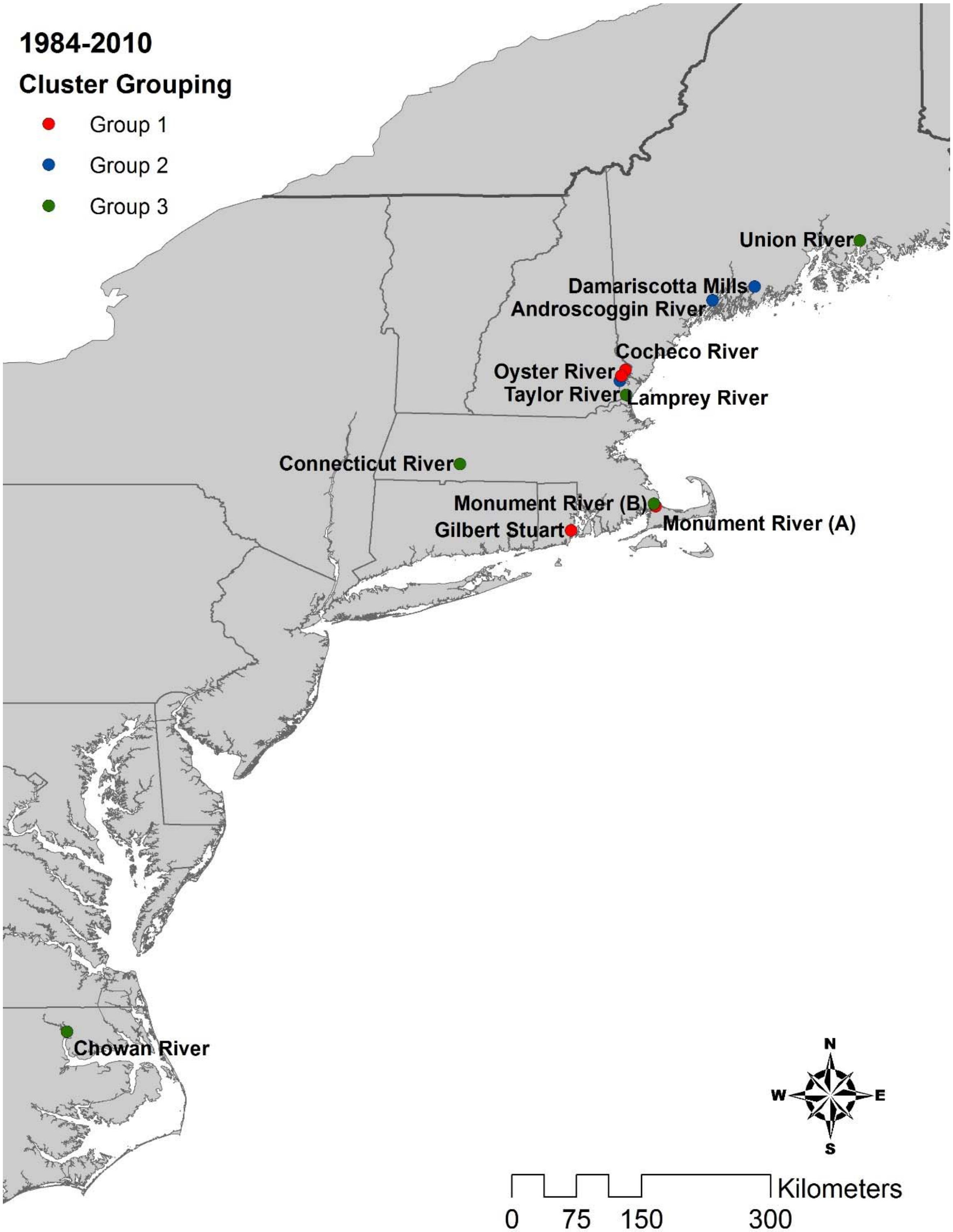


Figure 2.14 Locations of rivers used in the 1984-2010 cluster analysis. Both in the legend refers to sites where both species were counted separately and combined refers to sites where both species were counted together.

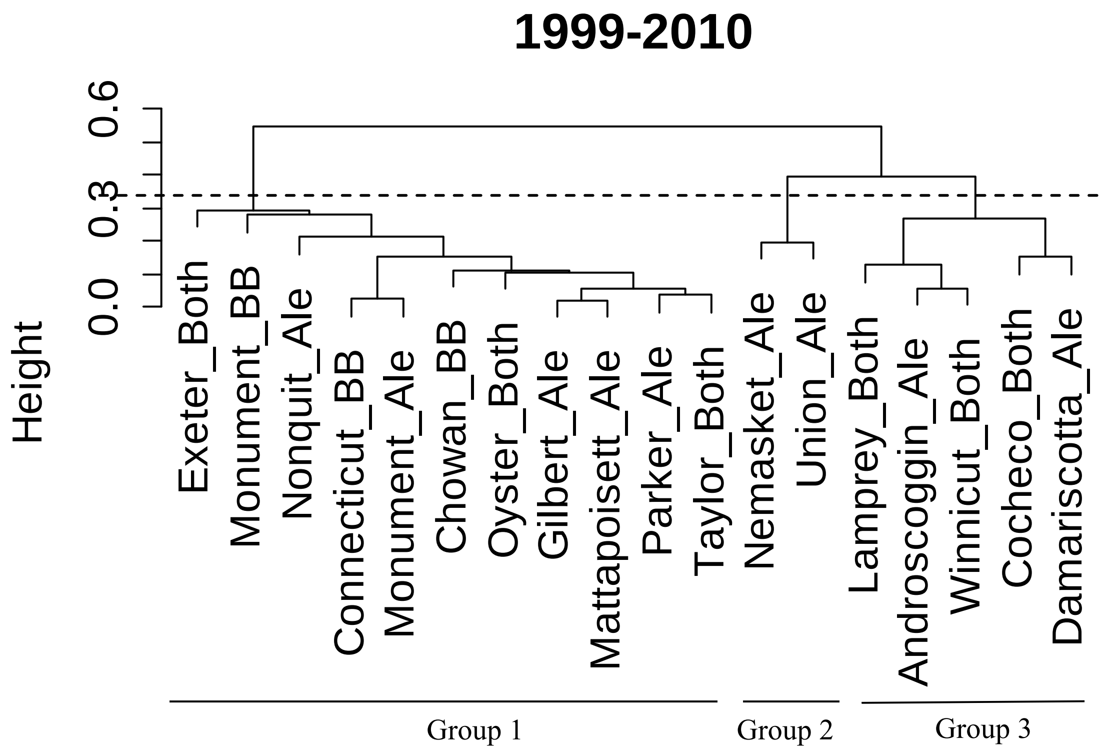


Figure 2.15 The resulting cluster dendrogram of river trends for 1999-2010. The dotted line indicates the level of similarity selected to define groups.

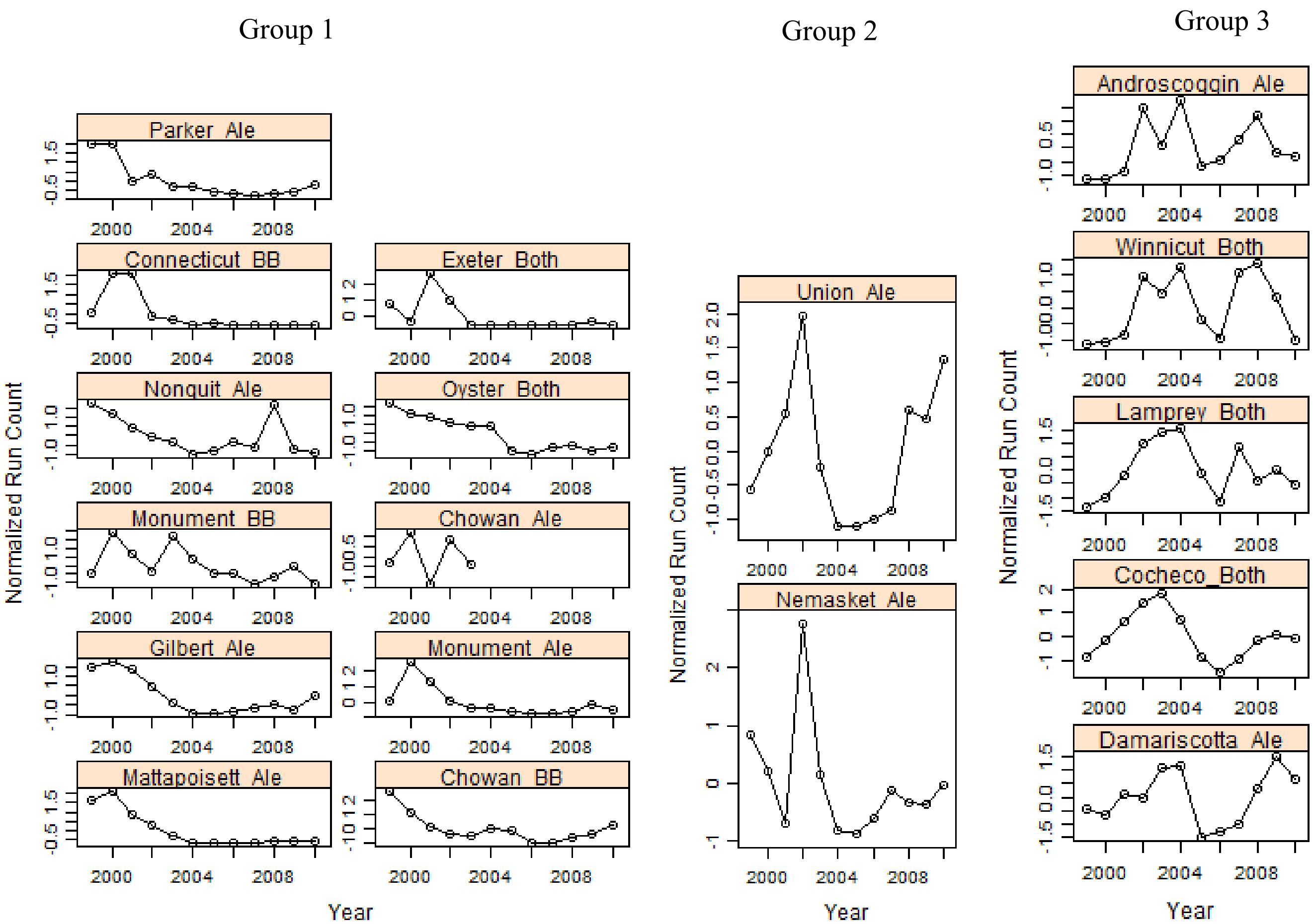


Figure 2.16 Plots of river counts for each grouping associated with the cluster analysis of data from 1999-2010.

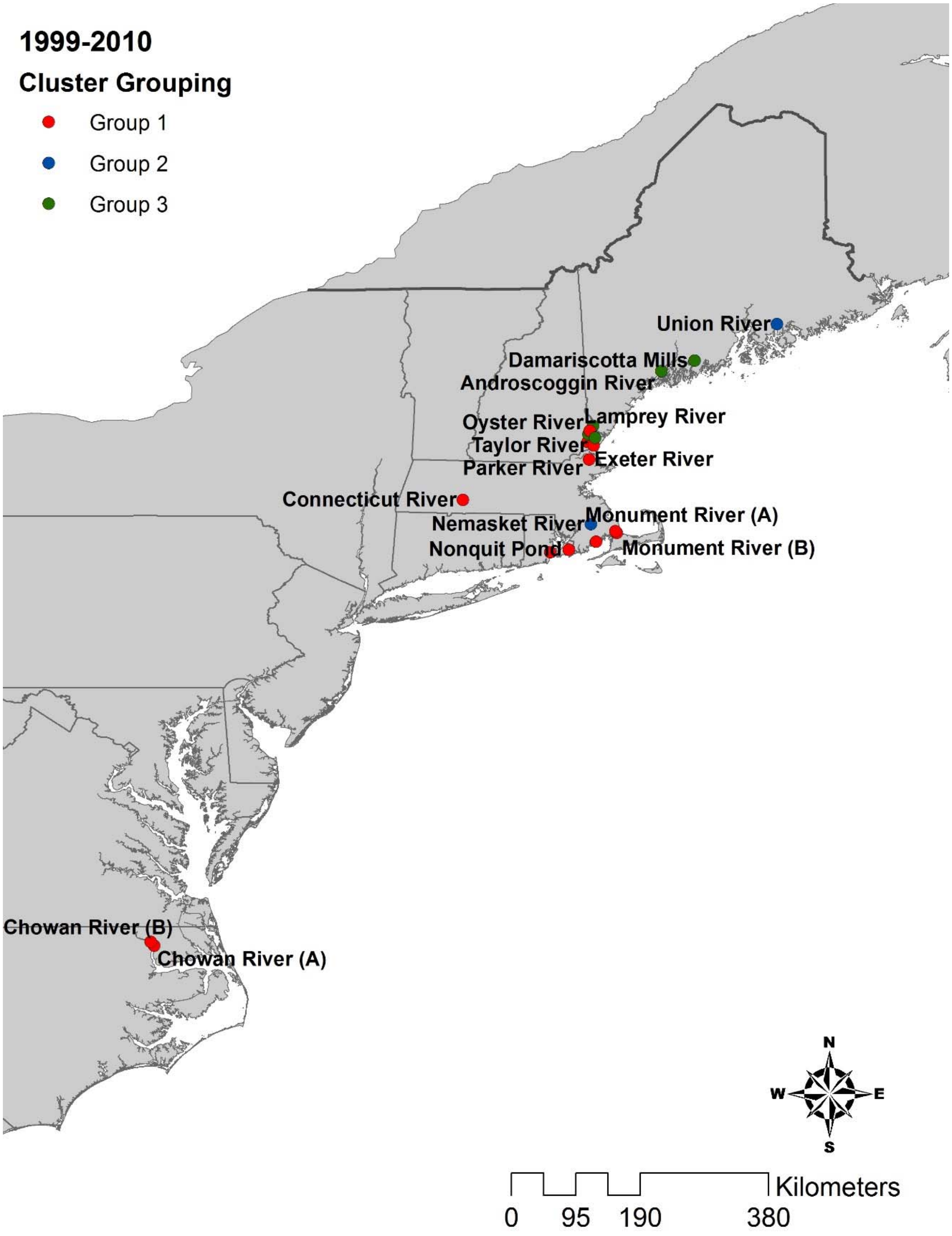


Figure 2.17 Locations of rivers used in the 1999-2010 cluster analysis. Both in the legend refers to sites where both species were counted separately and combined refers to sites where both species were counted together.

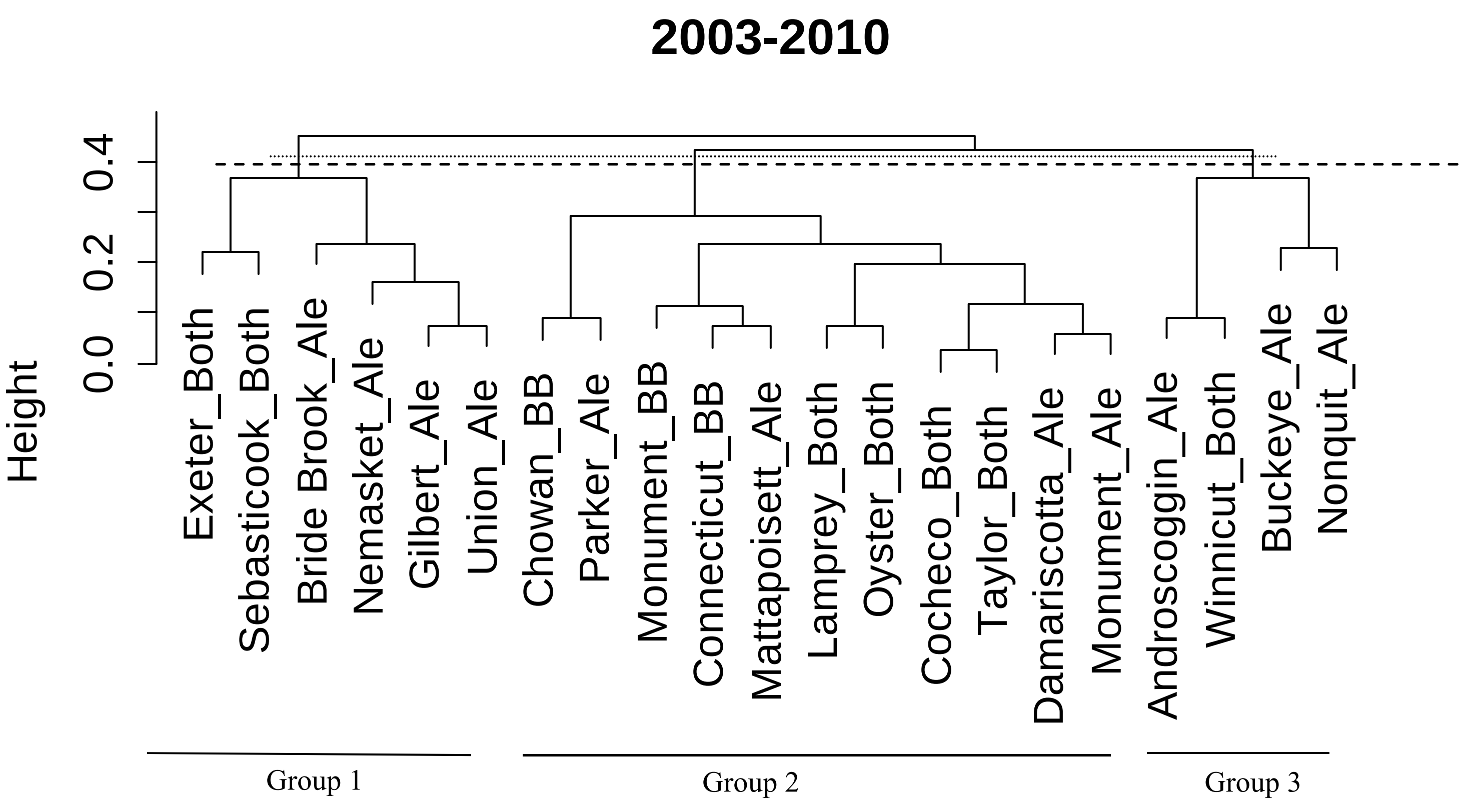


Figure 2.18 The resulting cluster dendrogram of river trends for 2003-2010. The dotted line indicates the level of similarity selected to define groups.

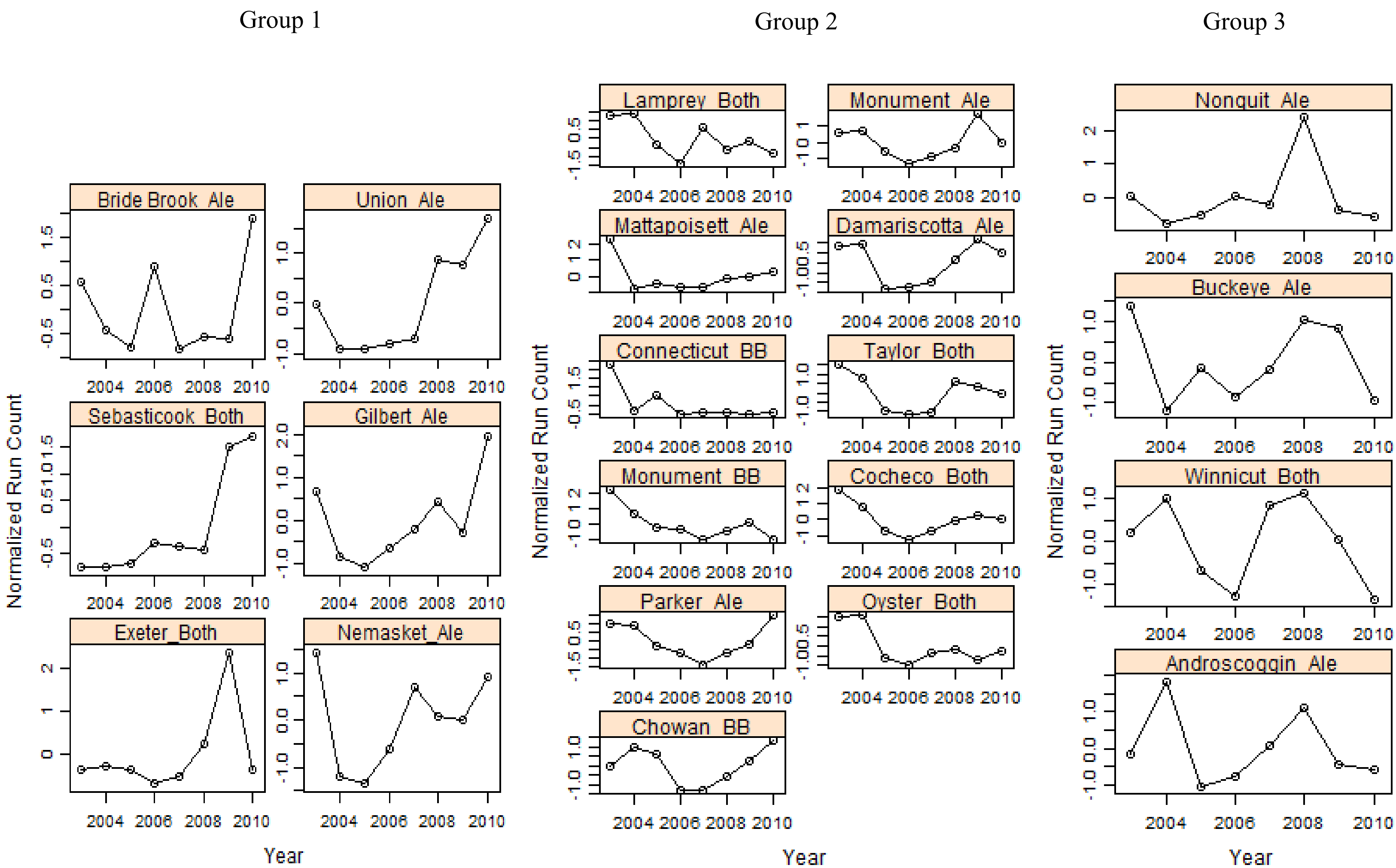


Figure 2.19 Plots of river counts for each grouping associated with the cluster analysis of data from 2003-2010.

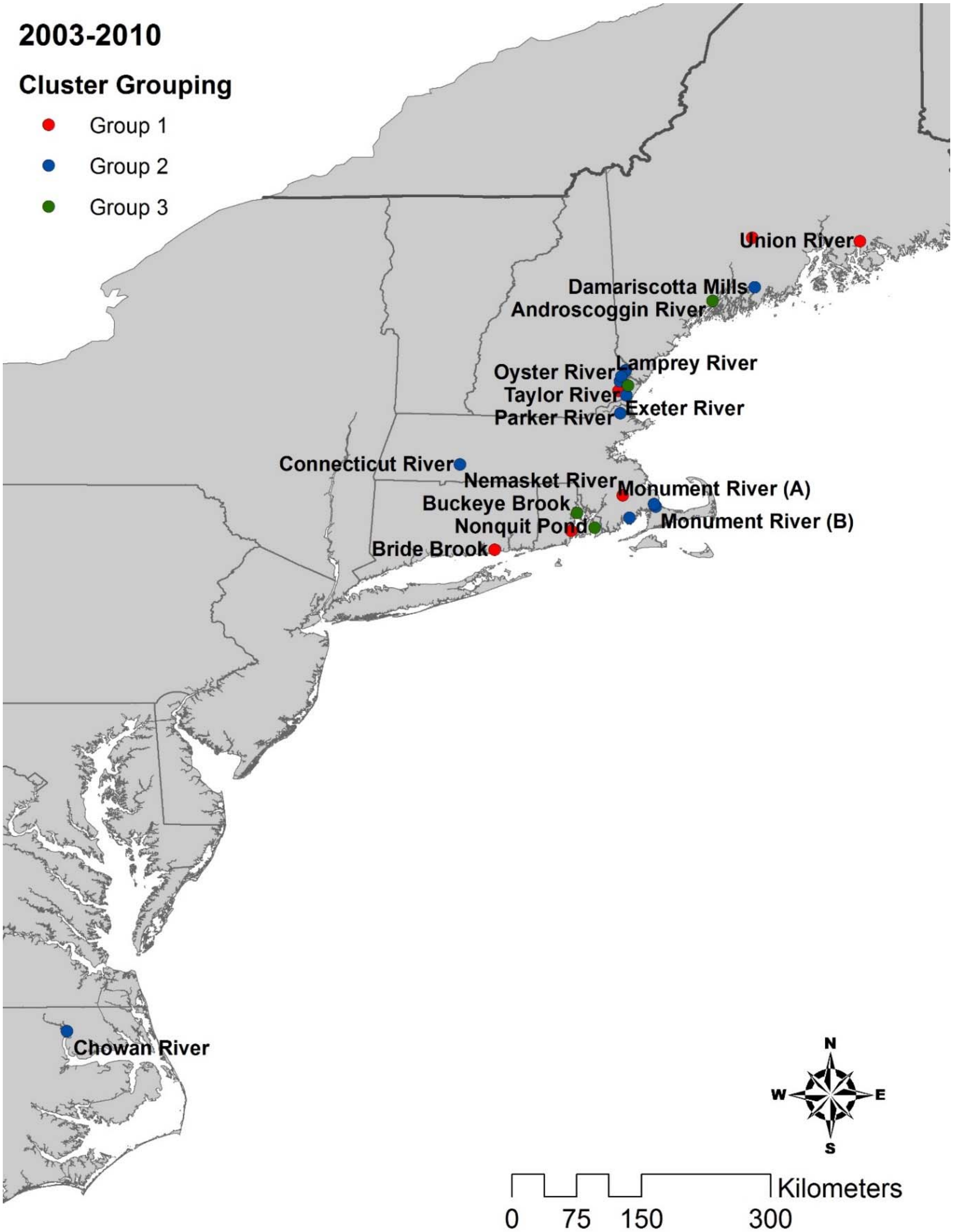


Figure 2.20 Locations of rivers used in the 2003-2010 cluster analysis. Both in the legend refers to sites where both species were counted separately and combined refers to sites where both species were counted together.

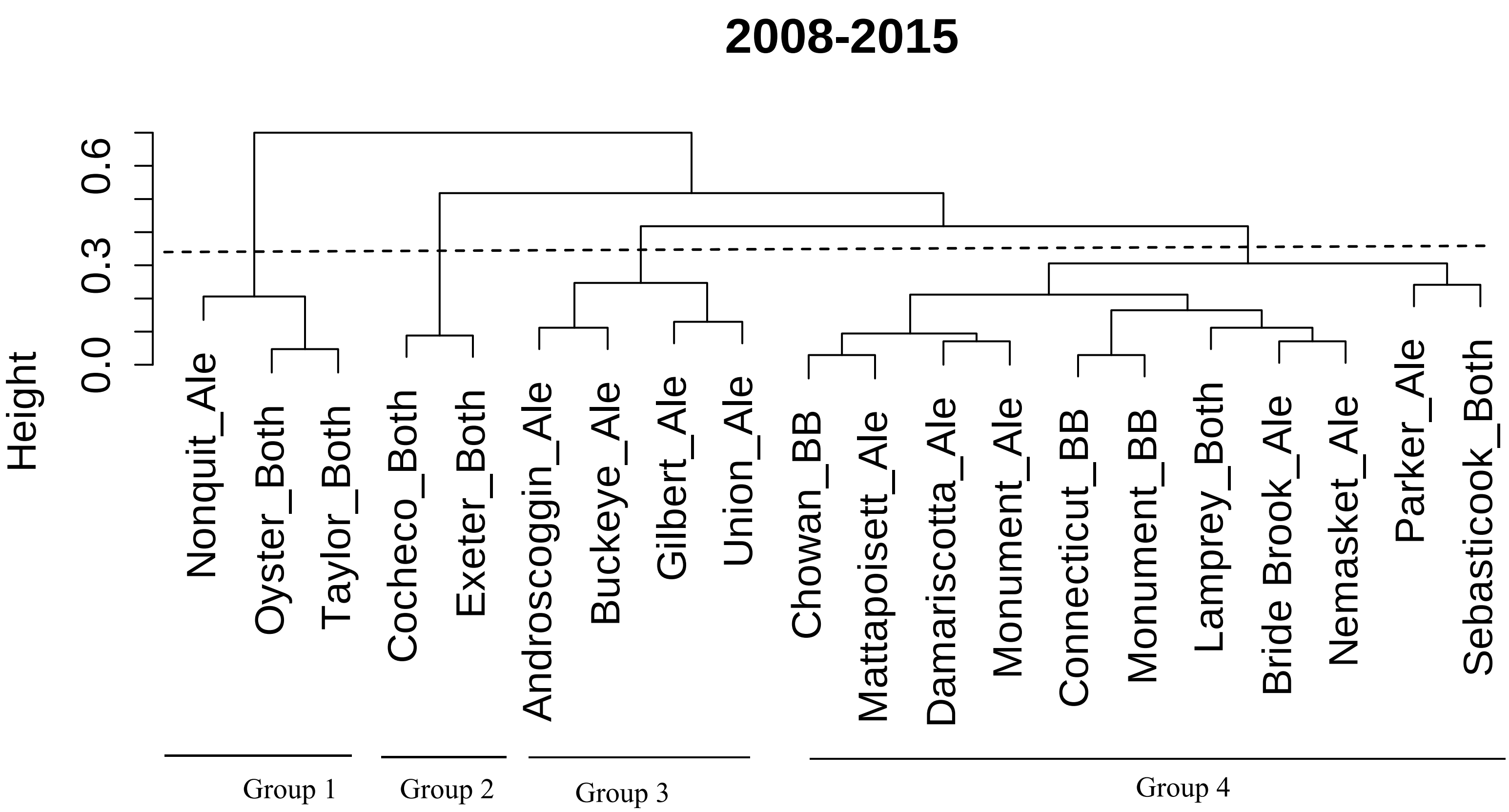


Figure 2.21 The resulting cluster dendrogram of river trends for 2008-2015. The dotted line indicates the level of similarity selected to define groups.

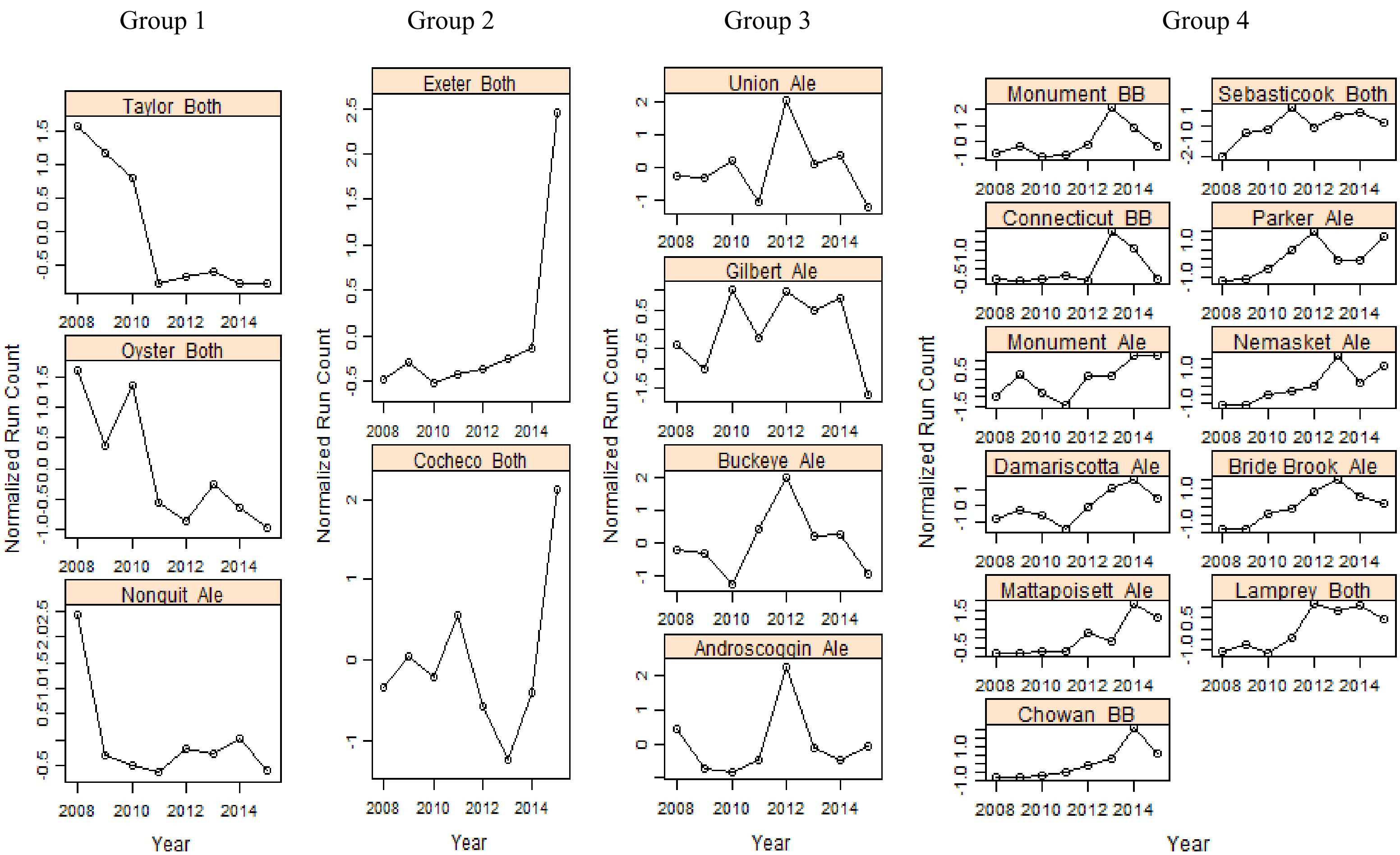


Figure 2.22 Plots of river counts for each grouping associated with the cluster analysis of data from 2008-2015.

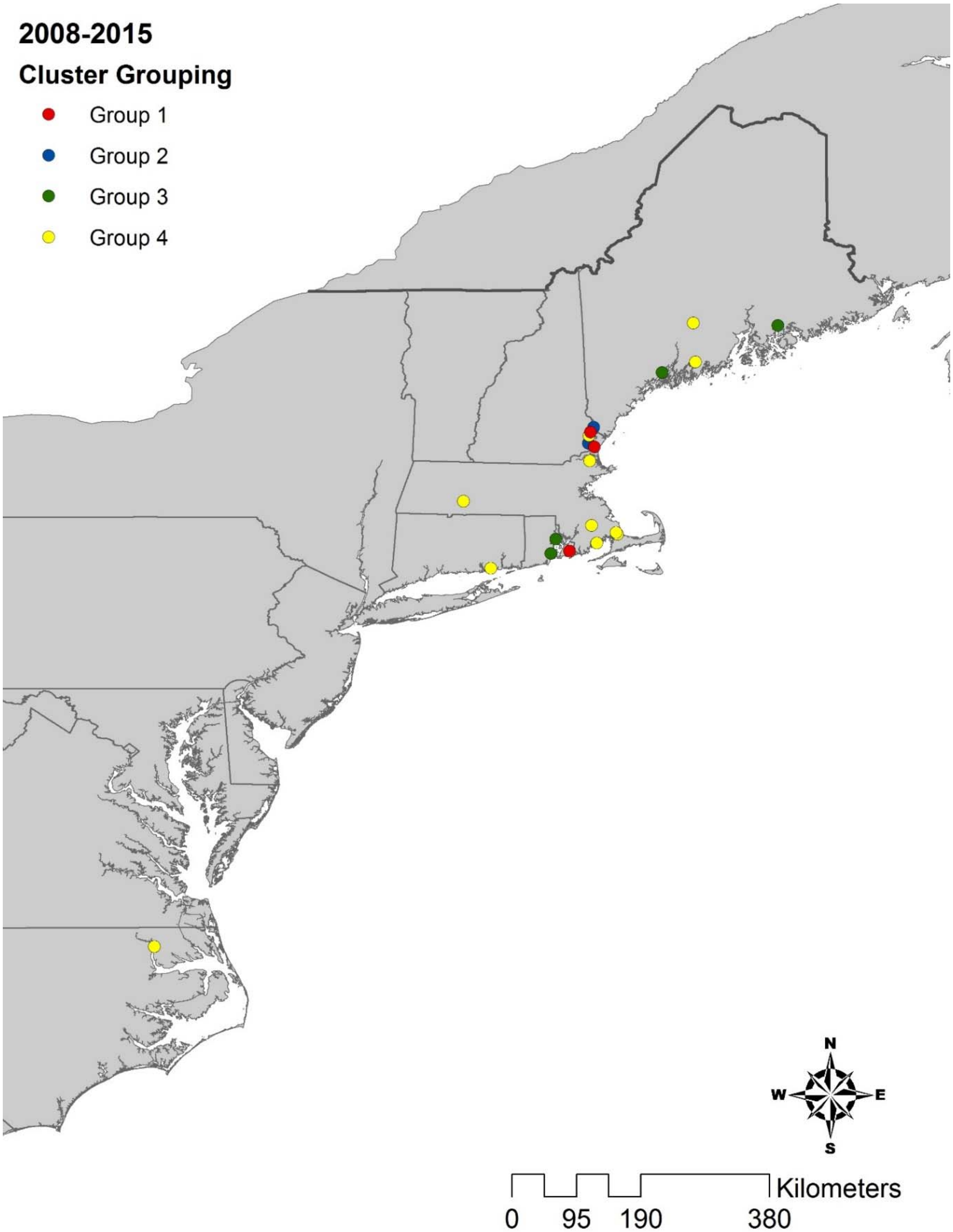


Figure 2.23 Locations of rivers used in the 2008-2015 cluster analysis. Both in the legend refers to sites where both species were counted separately and combined refers to sites where both species were counted together.

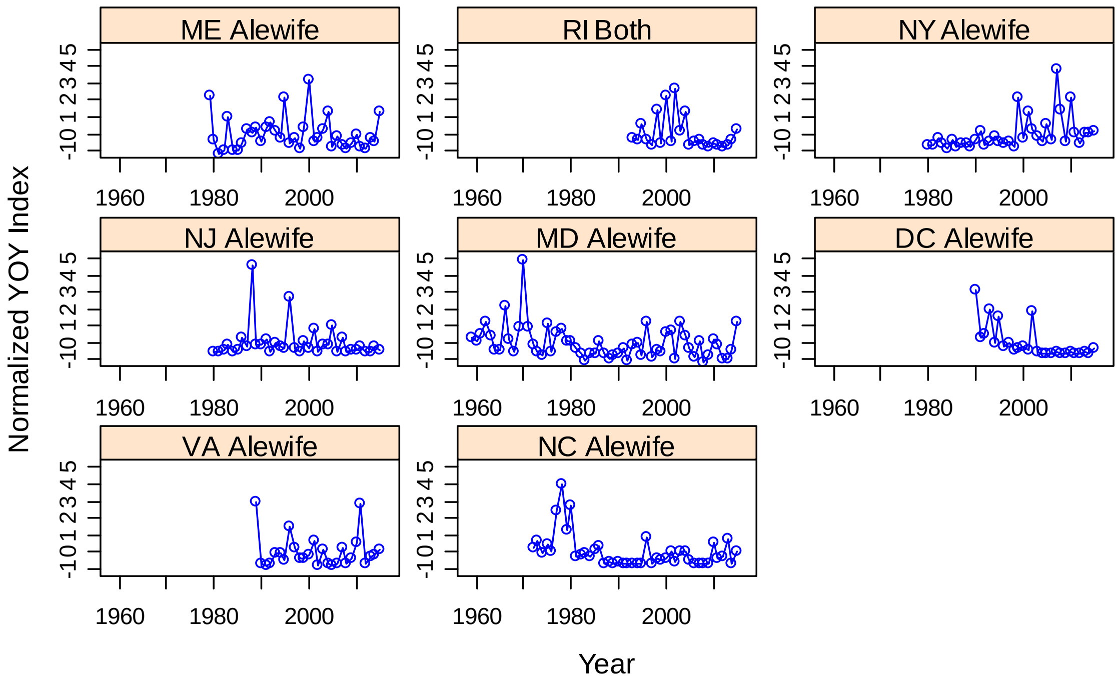


Figure 2.24 Normalized YOY indices of relative abundance for alewife from seine surveys.

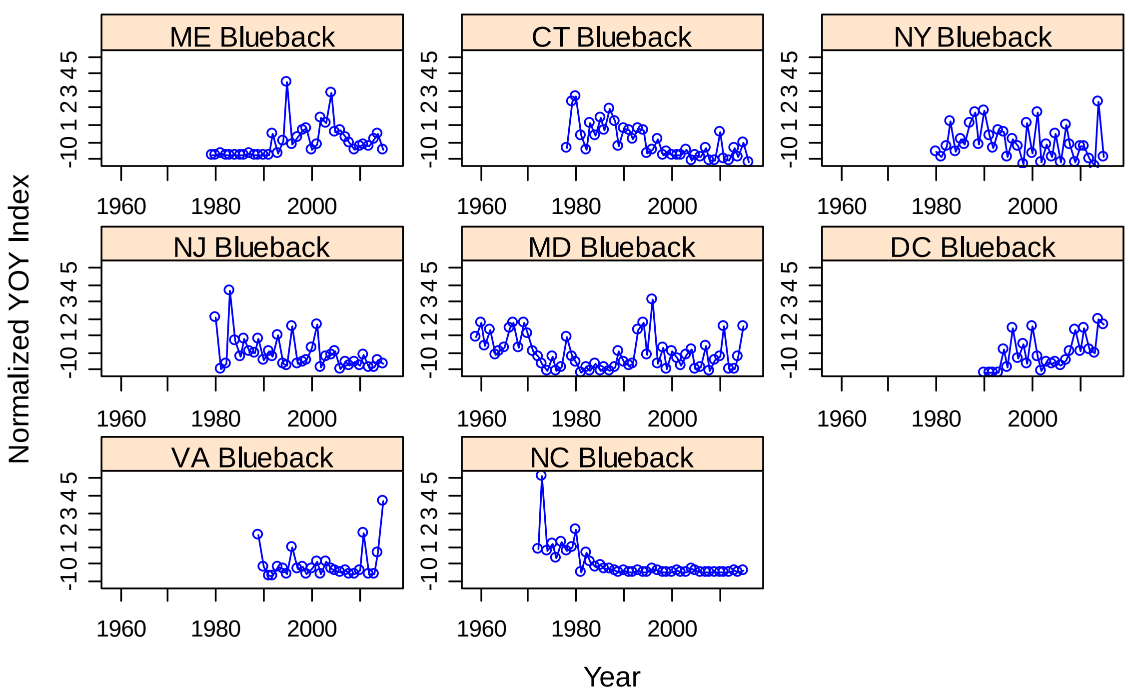
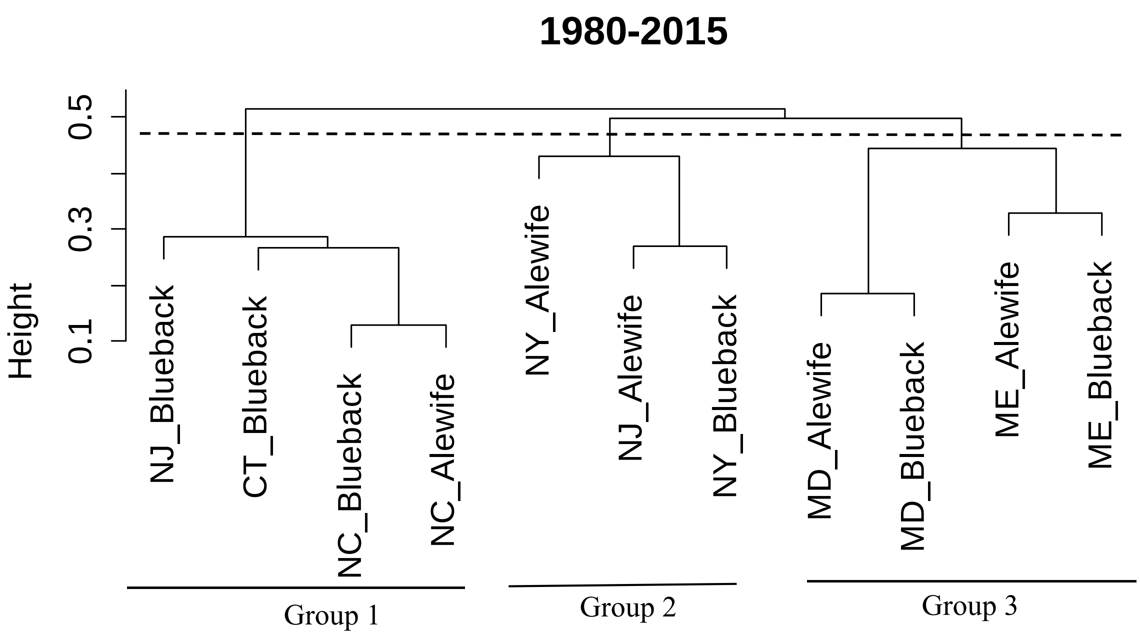


Figure 2.25 Normalized YOY indices of relative abundance for blueback herring from seine surveys.



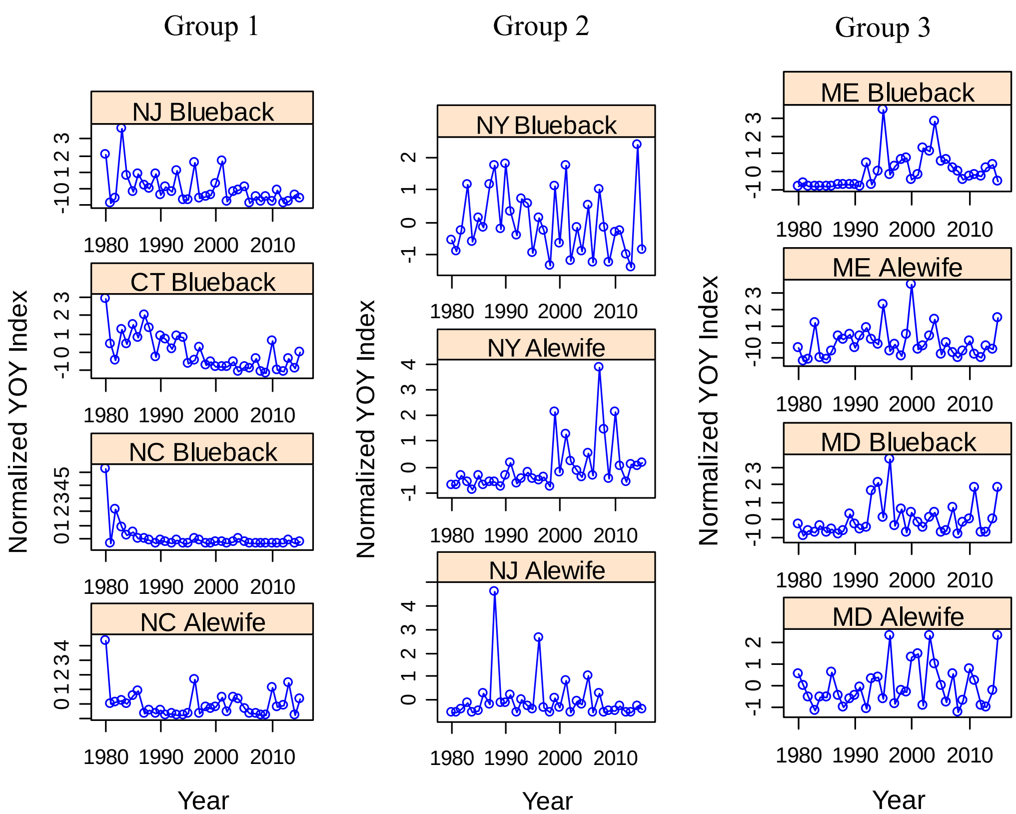


Figure 2.26 Results of cluster analysis of YOY seine indices of relative abundance, 1980-2015.

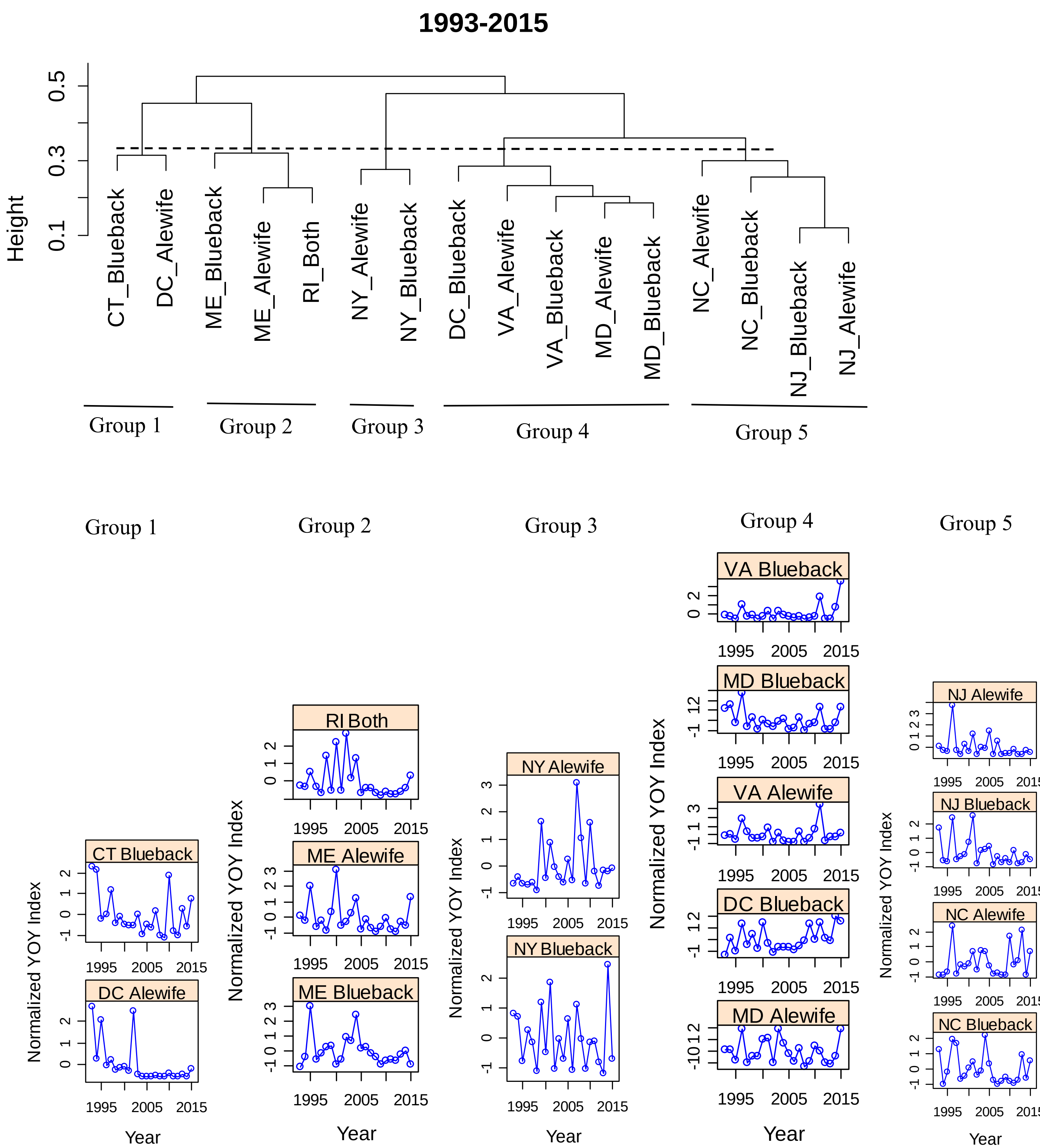


Figure 2.27 Results of cluster analysis of YOY seine survey trends for 1993-2015 showing the cluster dendrogram and plots of YOY indices for each grouping.

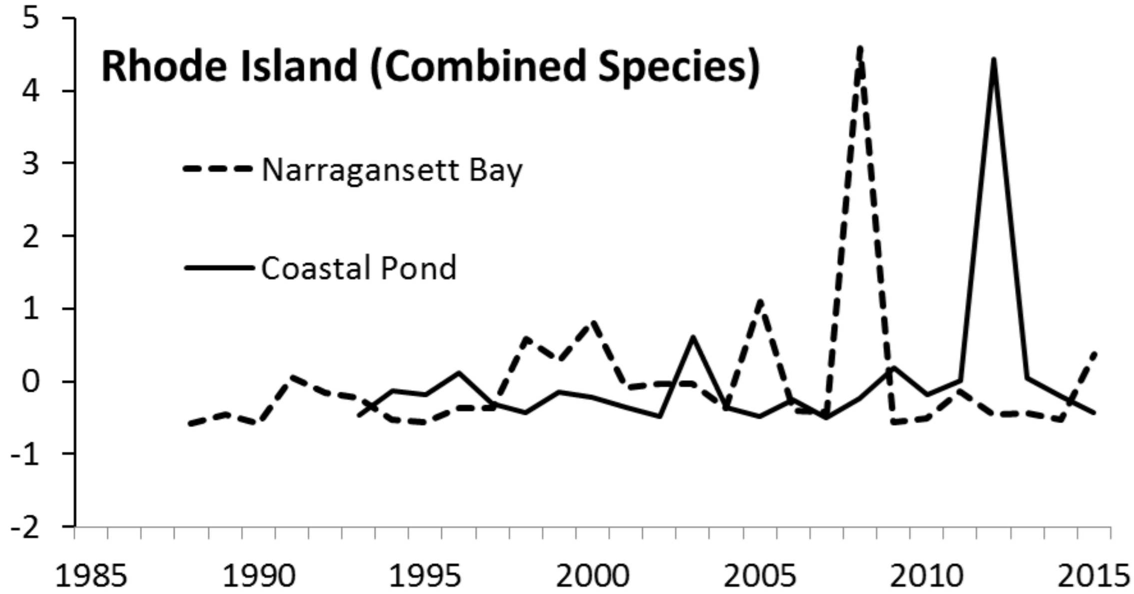


Figure 2.28 Normalized gillnet CPUE from Rhode Island, 1988-2015.

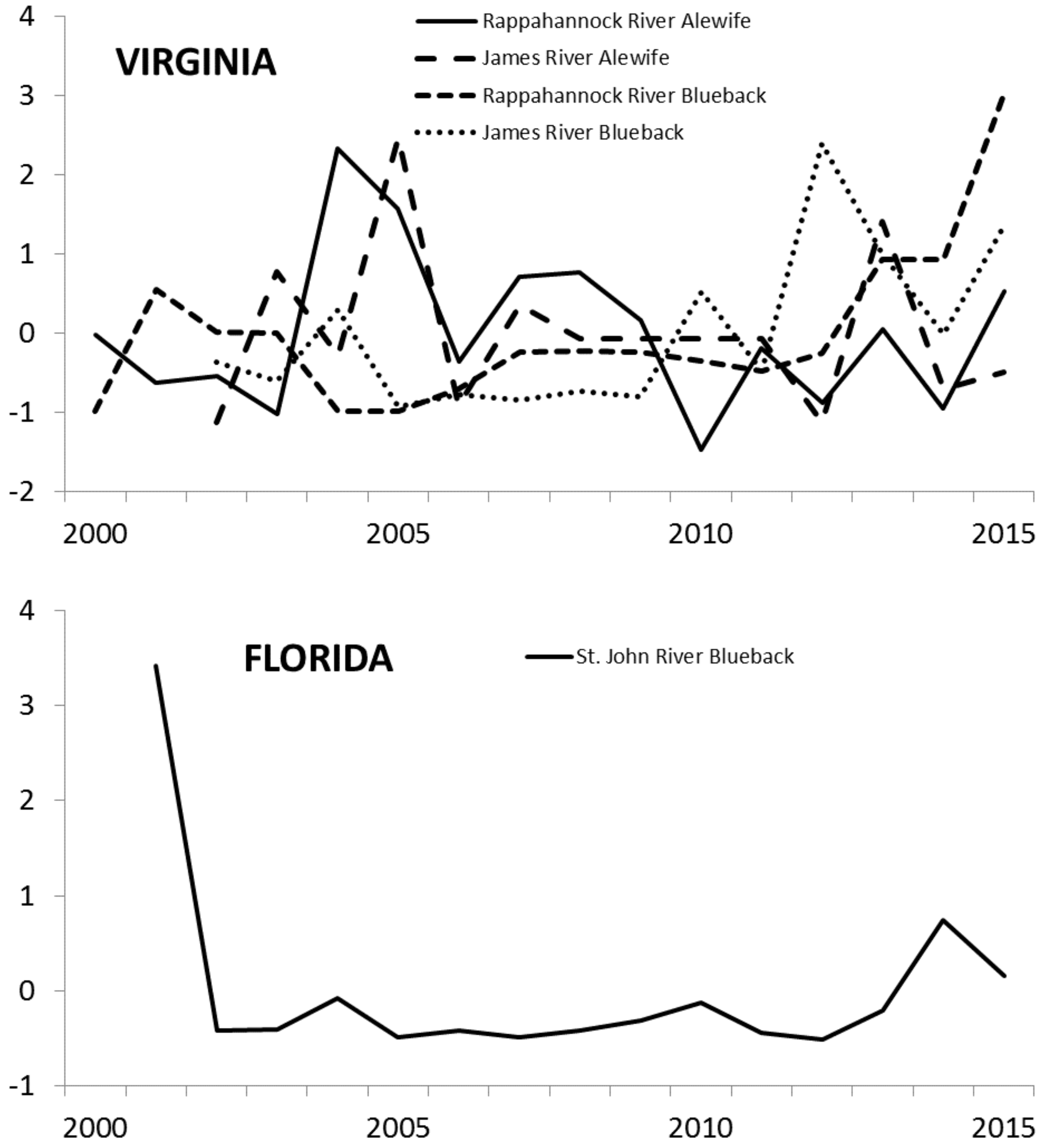


Figure 2.29 Comparison of normalized electrofishing surveys from Virginia and Florida, 2000-2016.

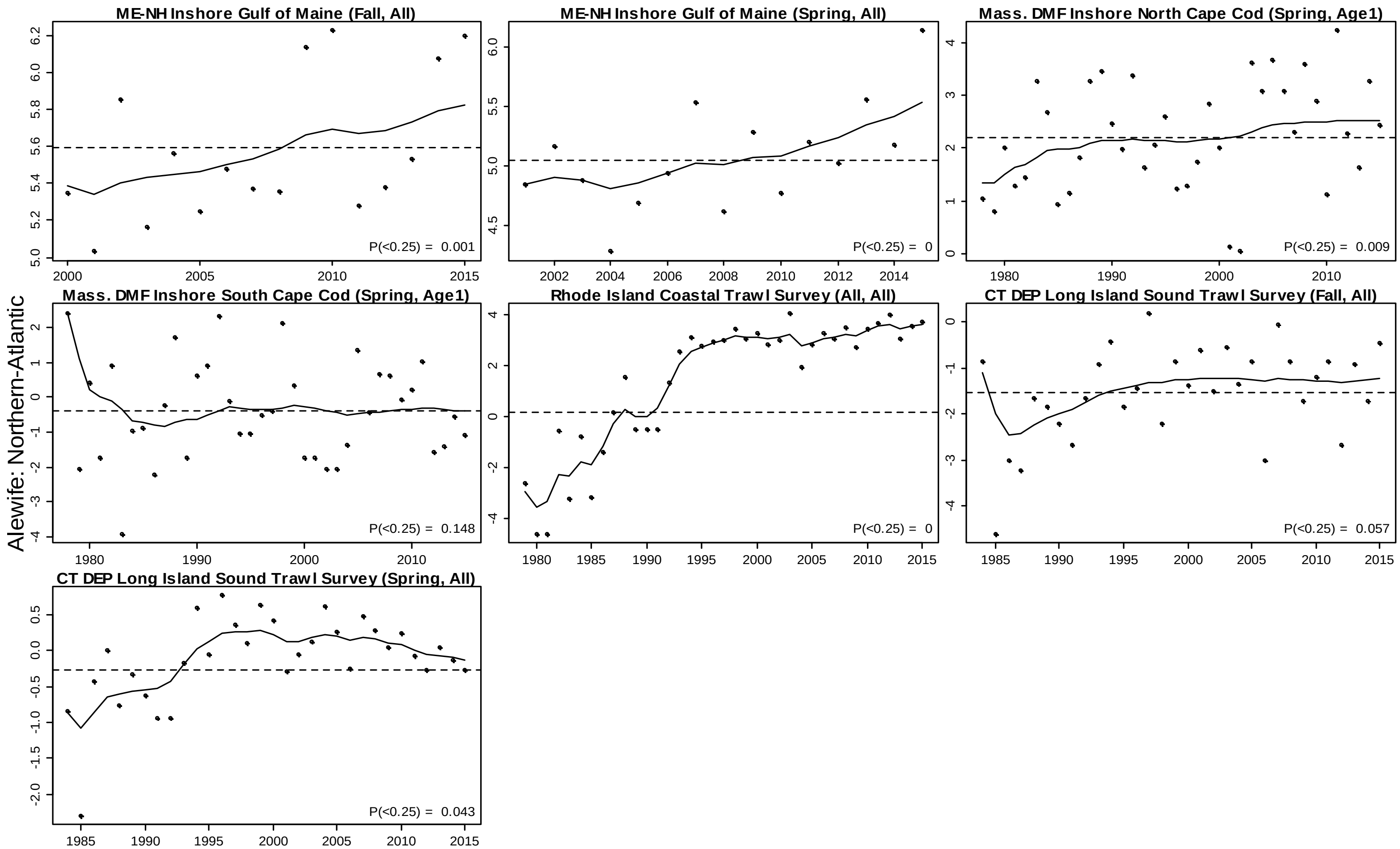


Figure 2.30 Autoregressive integrated moving average (ARIMA) model fits to log transformed **alewife** trawl survey indices from northern regions. The dotted horizontal lines correspond to the bootstrapped mean 25th percentile of the fitted values (Q0.25). Text on the graphs represents the probability of the last year of the survey being less than Q0.25 [P(<0.25)], the season of the trawl survey, and the ages of alewife in the trawl survey.

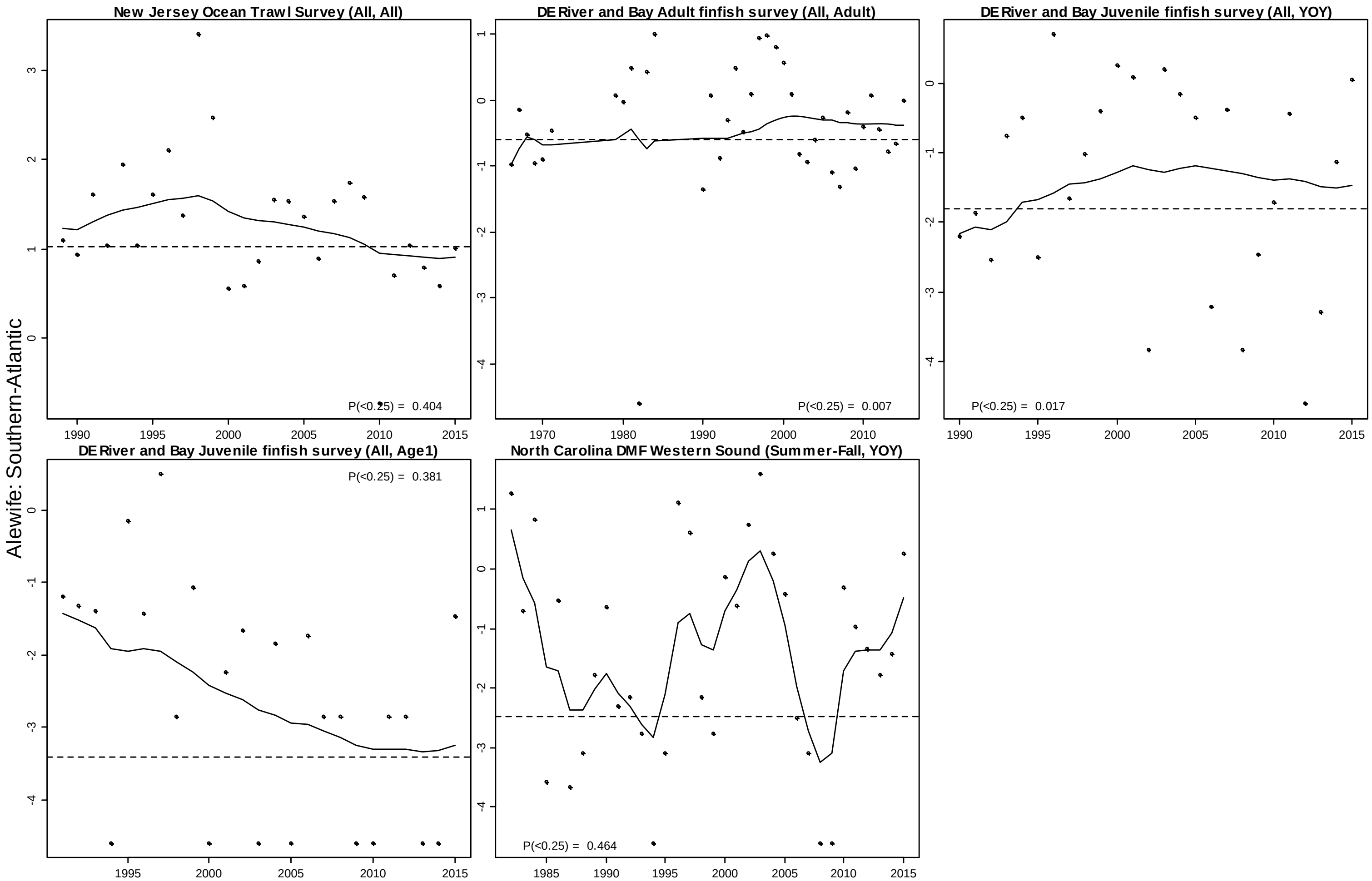


Figure 2.31 Autoregressive integrated moving average (ARIMA) model fits to log transformed **alewife** trawl survey indices from southern regions. The dotted horizontal lines correspond to the bootstrapped mean 25th percentile of the fitted values (Q0.25). Text on the graphs represents the probability of the last year of the survey being less than Q0.25 [P(<0.25)], the season of the trawl survey, and the ages of alewife in the trawl survey.

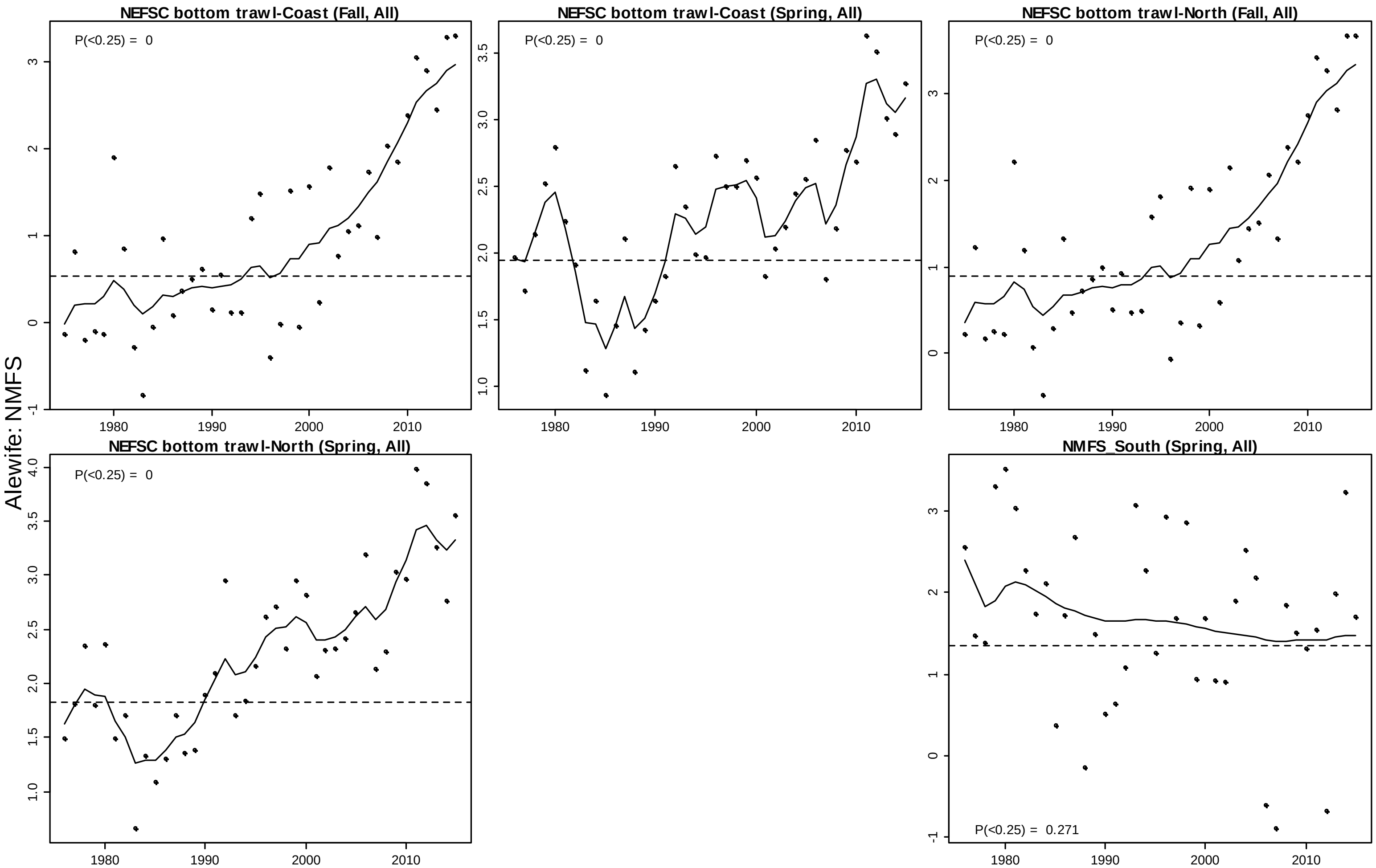


Figure 2.32 Autoregressive integrated moving average (ARIMA) model fits to log transformed **alewife** trawl survey indices from the NEFSC bottom trawl survey. The dotted horizontal lines correspond to the bootstrapped mean 25th percentile of the fitted values (Q0.25). Text on the graphs represents the probability of the last year of the survey being less than Q0.25 [P(<0.25)], the season of the trawl survey, and the ages of alewife in the trawl survey.

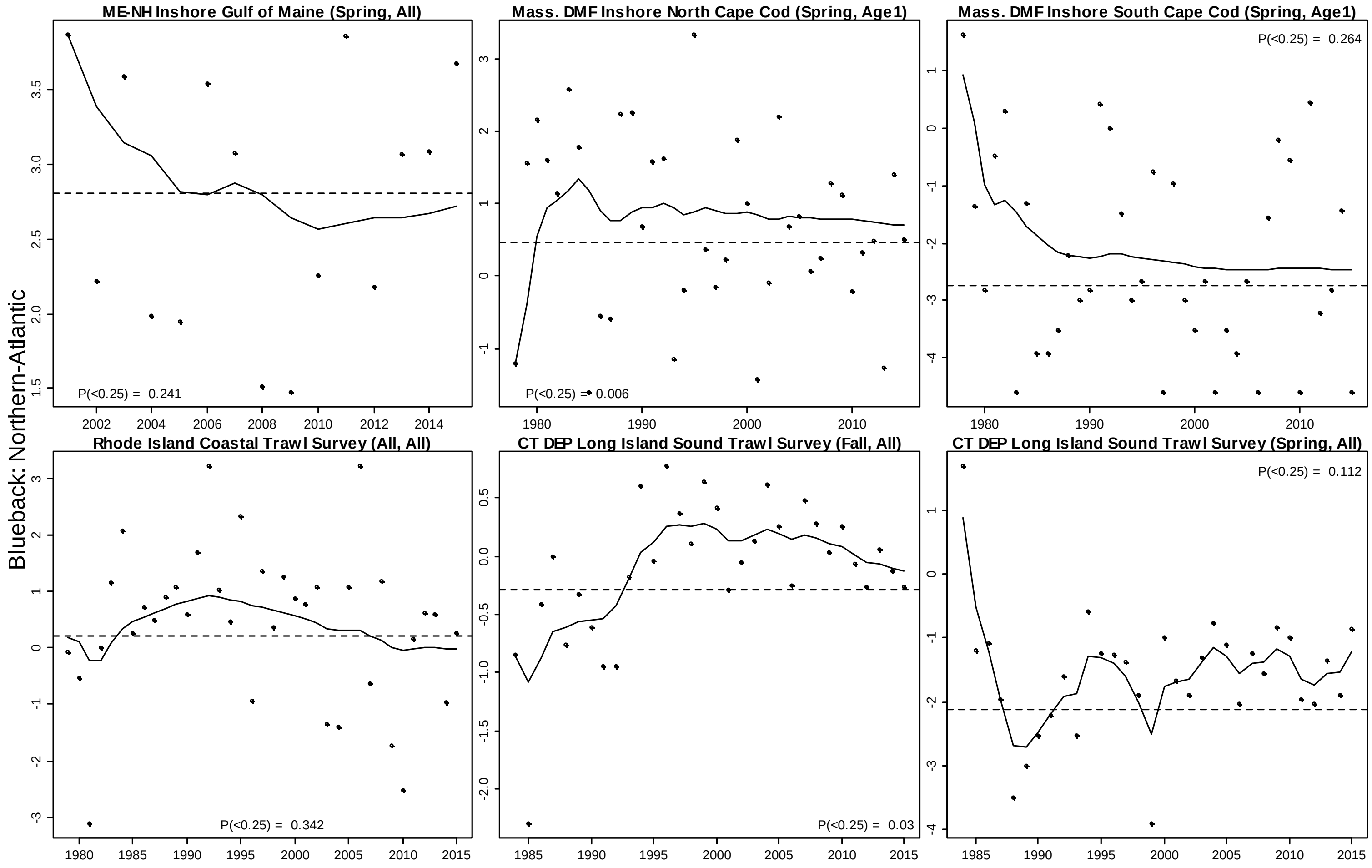


Figure 2.33 Autoregressive integrated moving average (ARIMA) model fits to log transformed **blueback herring** trawl survey indices from northern regions. The dotted horizontal lines correspond to the bootstrapped mean 25th percentile of the fitted values (Q0.25). Text on the graphs represents the probability of the last year of the survey being less than Q0.25 [P(<0.25)], the season of the trawl survey, and the ages of alewife in the trawl survey.

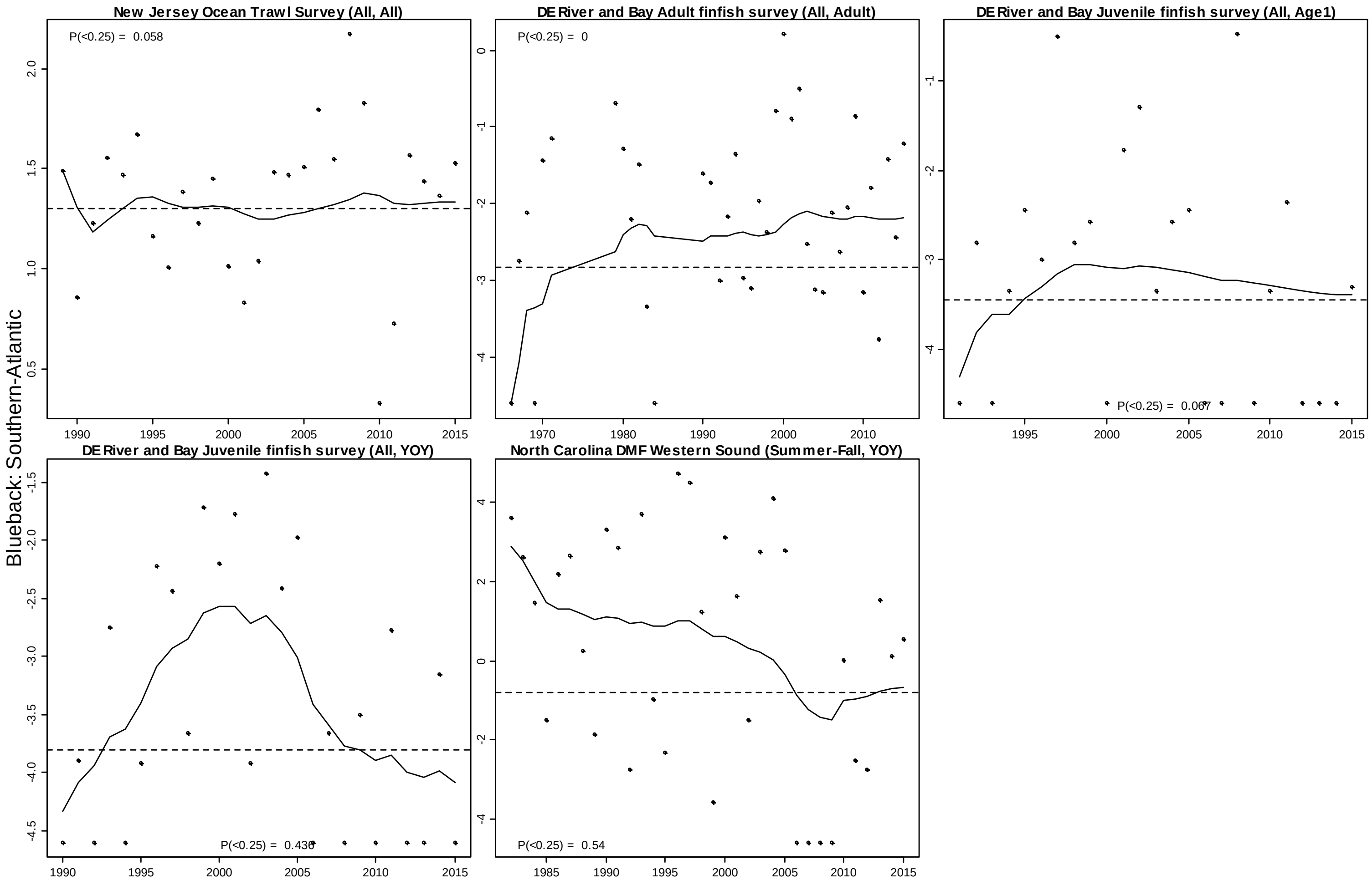


Figure 2.34 Autoregressive integrated moving average (ARIMA) model fits to log transformed **blueback herring** trawl survey indices from southern regions. The dotted horizontal lines correspond to the bootstrapped mean 25th percentile of the fitted values (Q0.25). Text on the graphs represents the probability of the last year of the survey being less than Q0.25 [P(<0.25)], the season of the trawl survey, and the ages of alewife in the trawl survey.

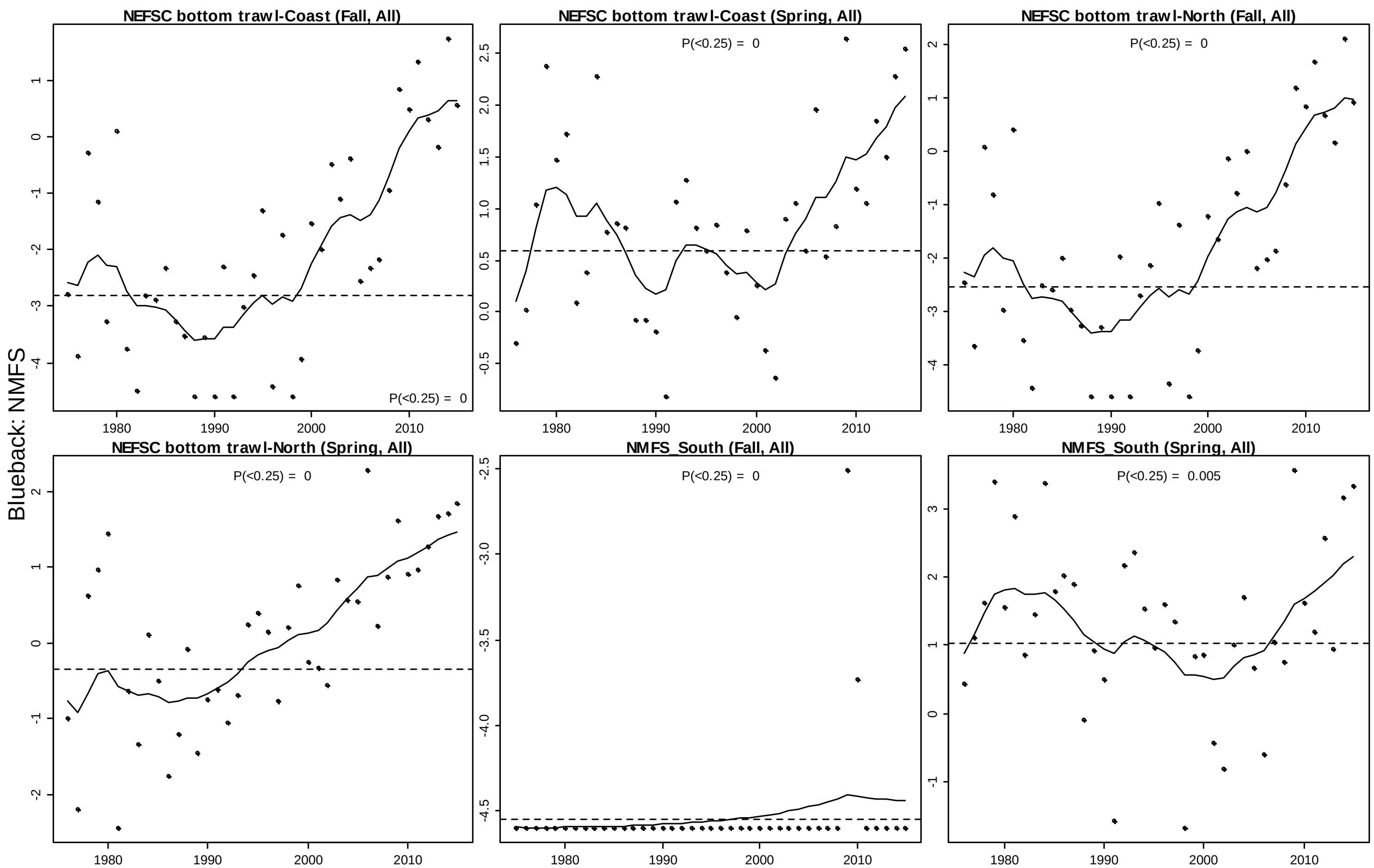


Figure 2.35 Autoregressive integrated moving average (ARIMA) model fits to log transformed **blueback herring** trawl survey indices from the NEFSC bottom trawl survey. The dotted horizontal lines correspond to the bootstrapped mean 25th percentile of the fitted values (Q0.25). Text on the graphs represents the probability of the last year of the survey being less than Q0.25 [P(<0.25)], the season of the trawl survey, and the ages of alewife in the trawl survey.

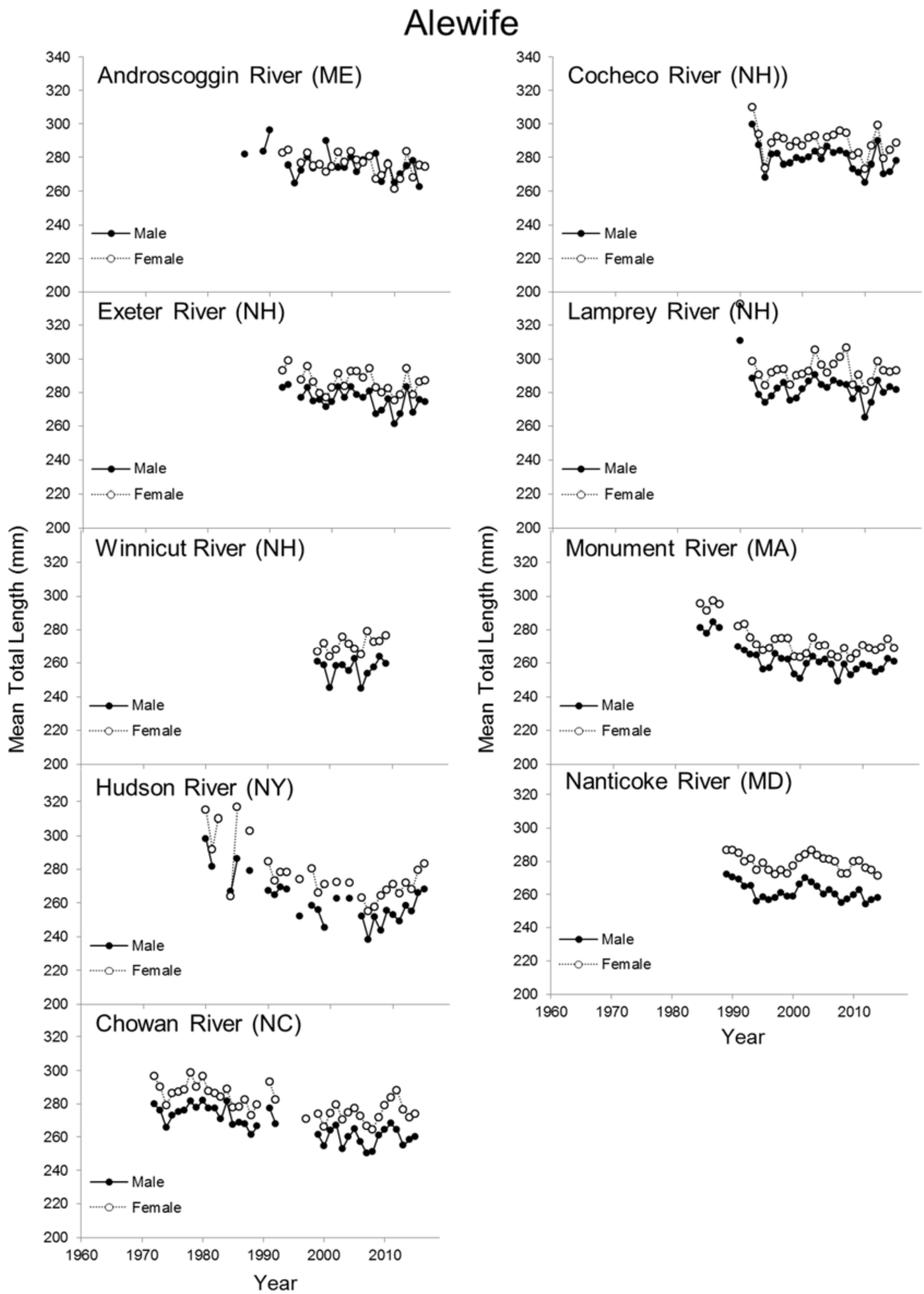


Figure 2.36 Mean lengths of male and female alewife by river and year.

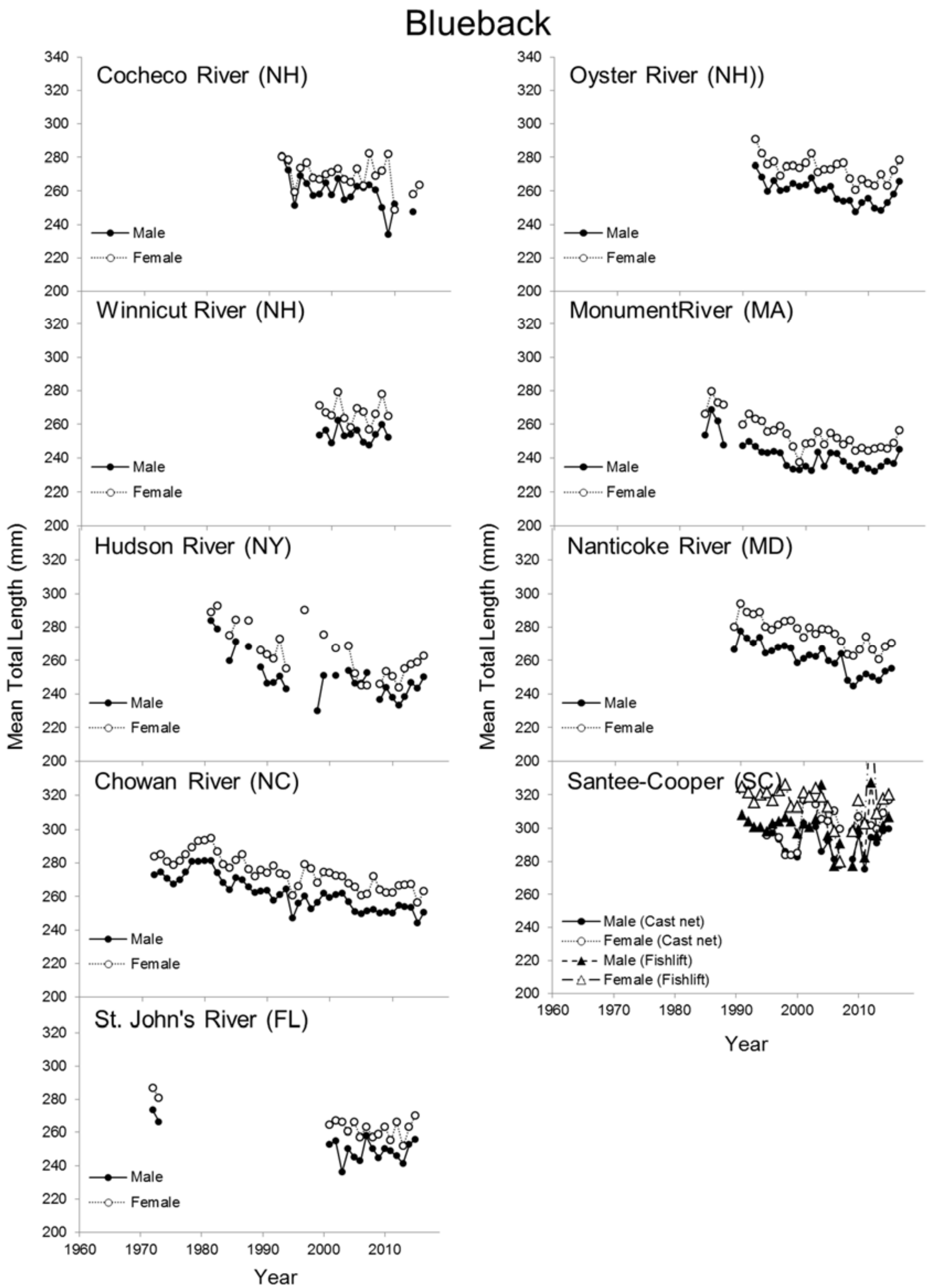


Figure 2.37 Mean lengths of male and female blueback herring by river and year.

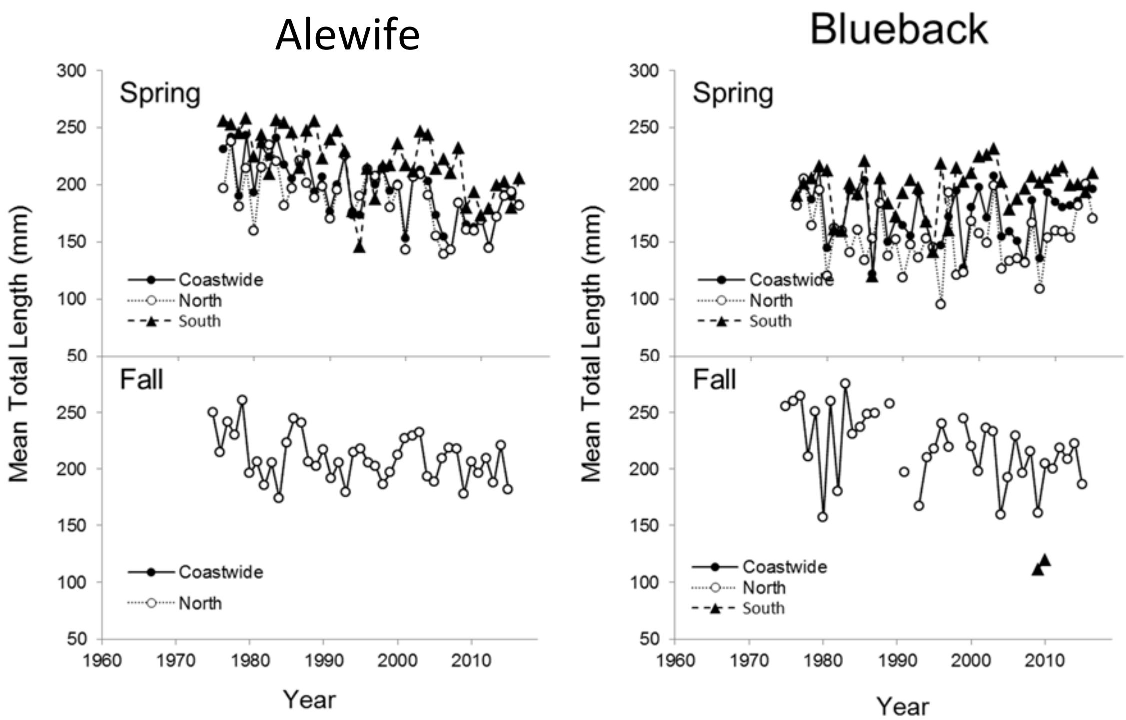


Figure 2.38 Mean lengths of alewife and blueback herring by region and year from the National Marine Fisheries Service bottom trawl survey.

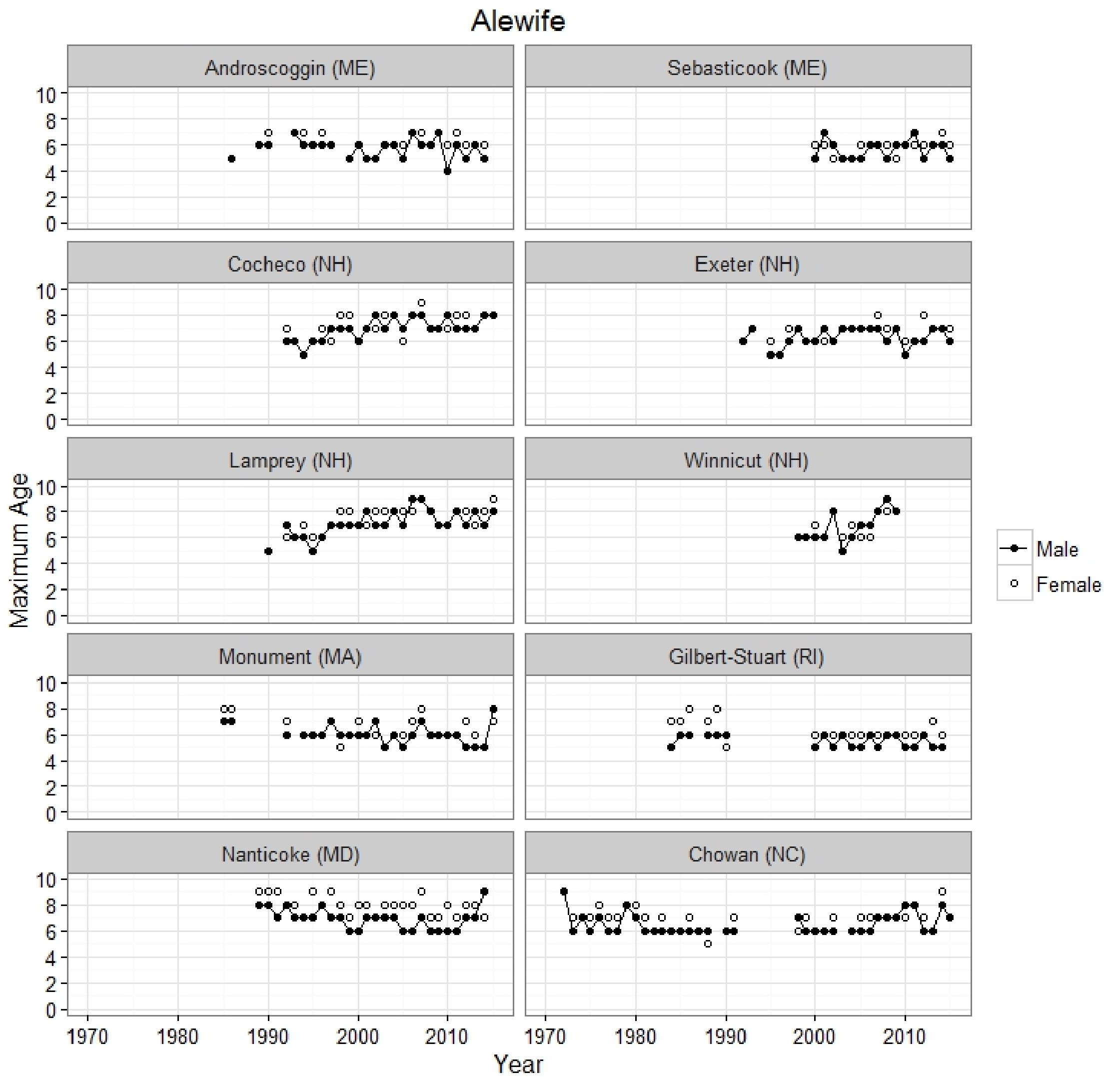


Figure 2.39 Maximum ages for male and female alewife by river. Updated data for the Chowan River (2010-2015) were determined to be unreliable due to ageing error (see state report) and were not used to update the trend in maximum age from the benchmark assessment.

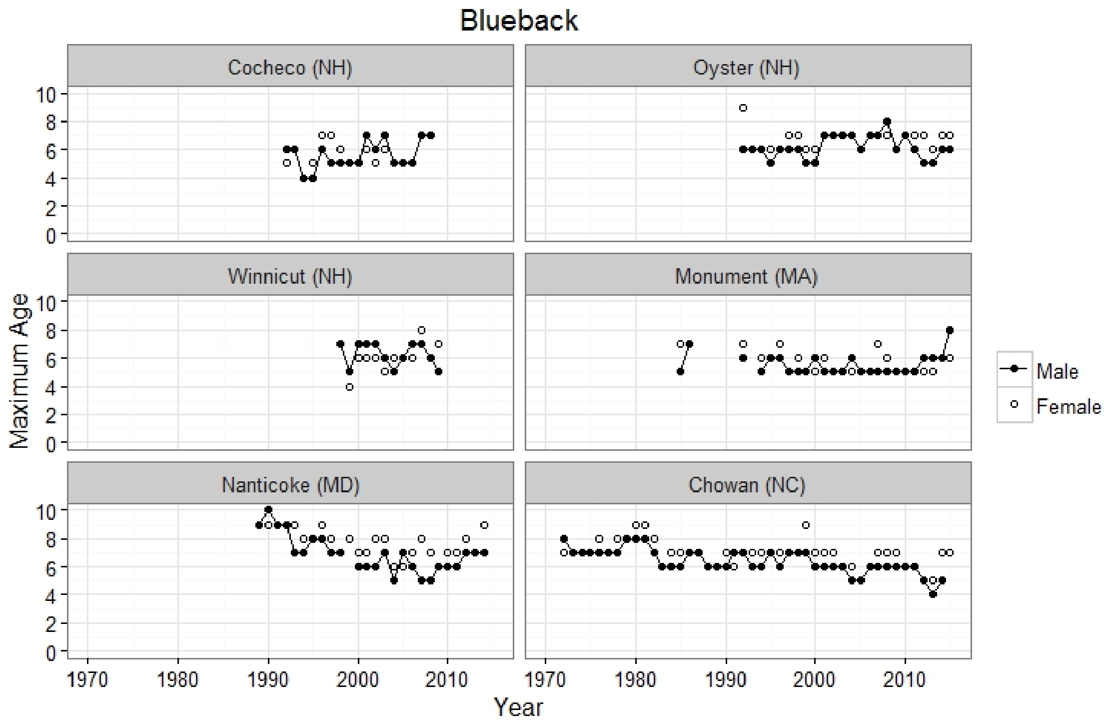


Figure 2.40 Maximum ages for male and female blueback by river.

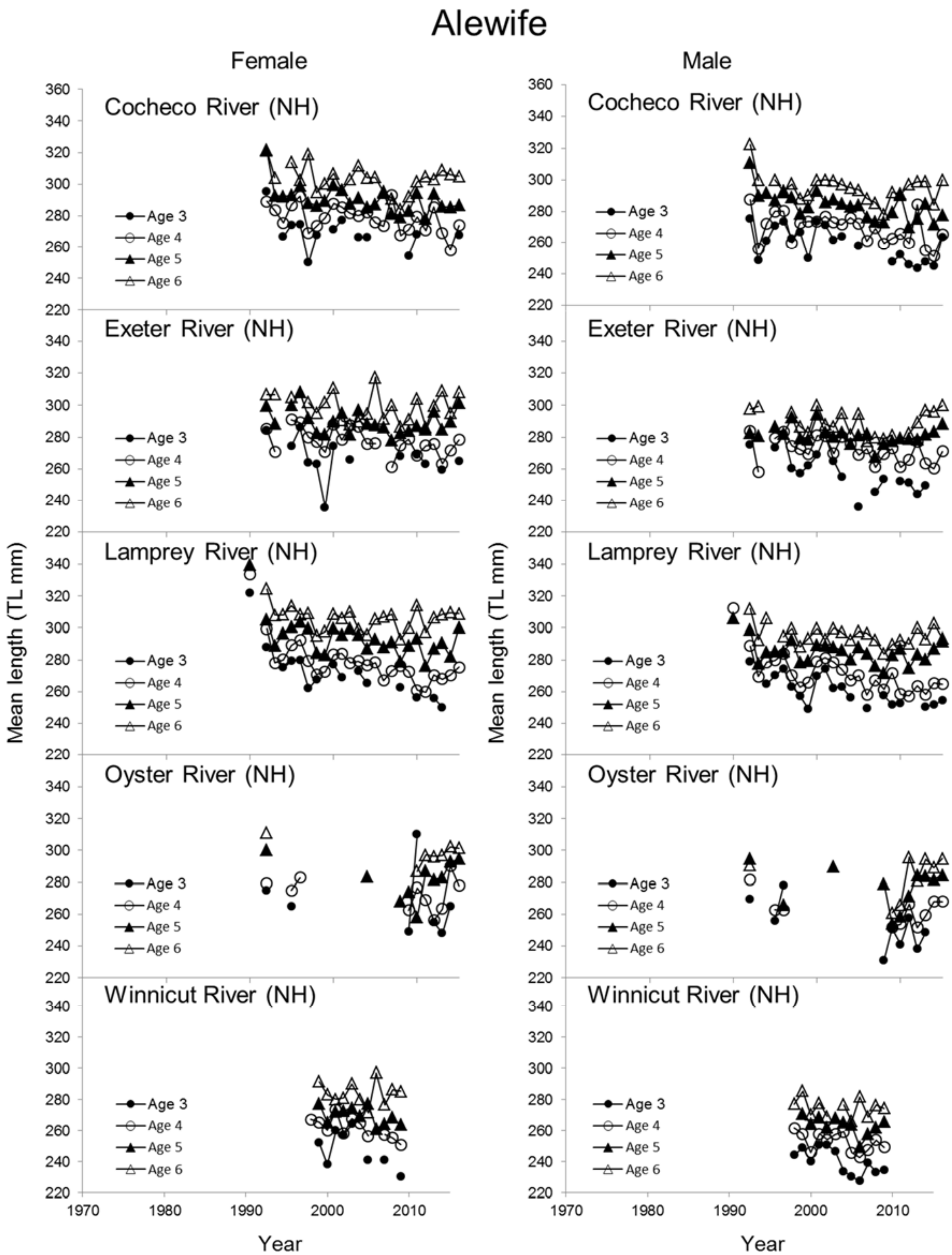


Figure 2.41 Mean lengths-at-age of male and female alewife from New Hampshire and Maine by sex, river, age and year.

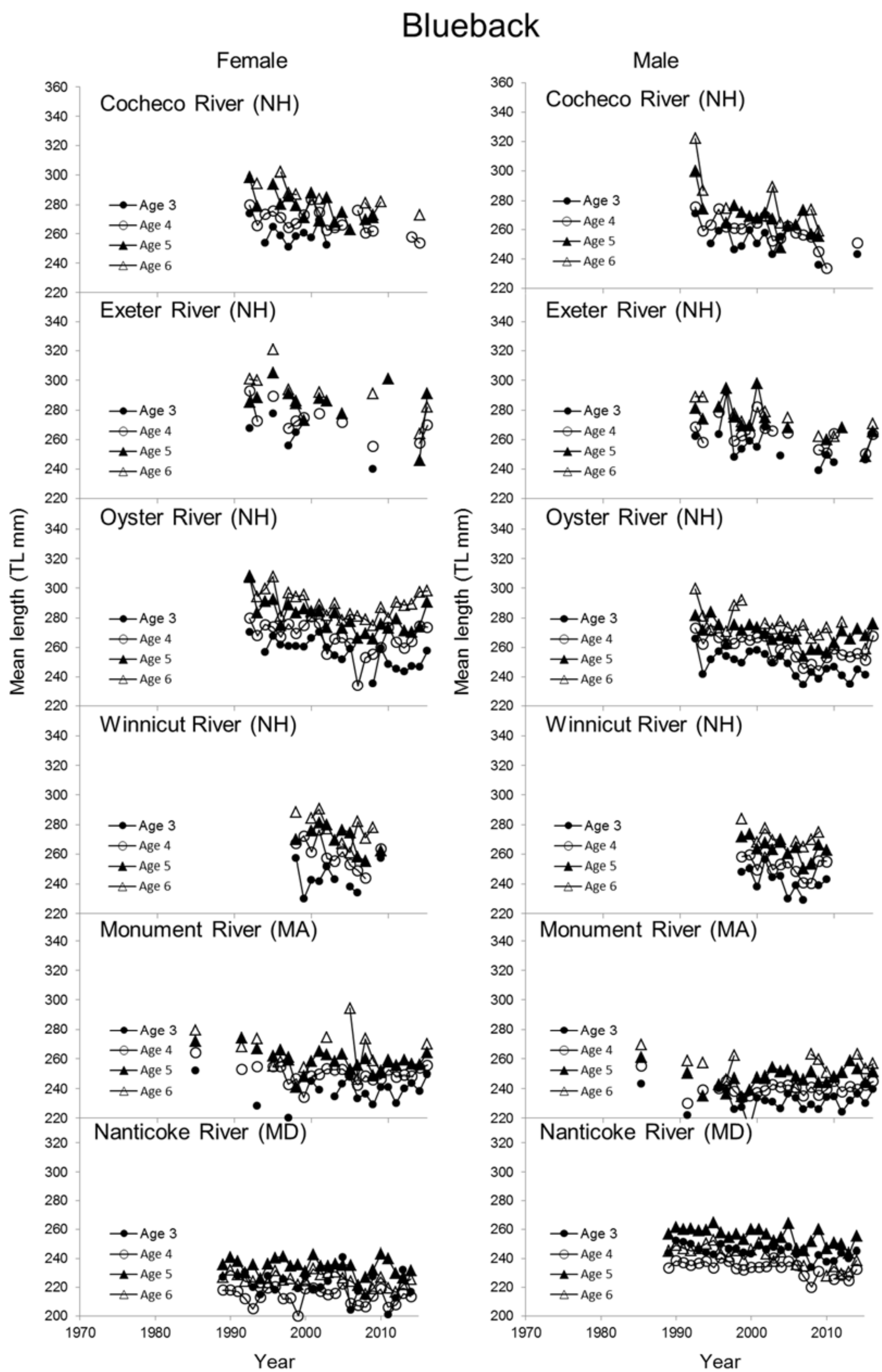


Figure 2.42 Mean lengths-at-age of male and female blueback herring from New Hampshire, Massachusetts, and Maryland by sex, river, age and year.

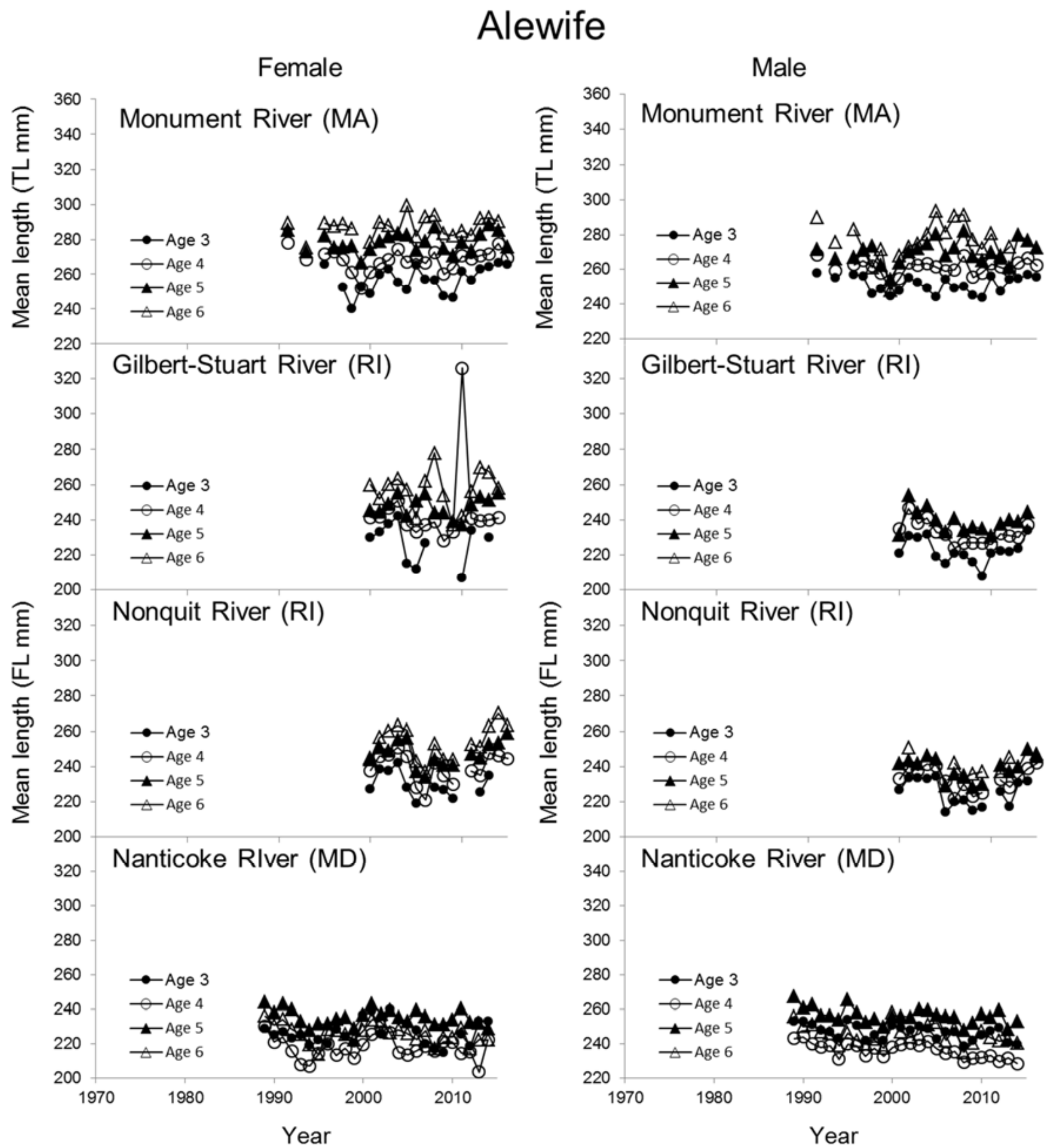


Figure 2.43 Mean lengths-at-age of male and female alewife from Massachusetts, Rhode Island and Maryland by sex, river, age and year.

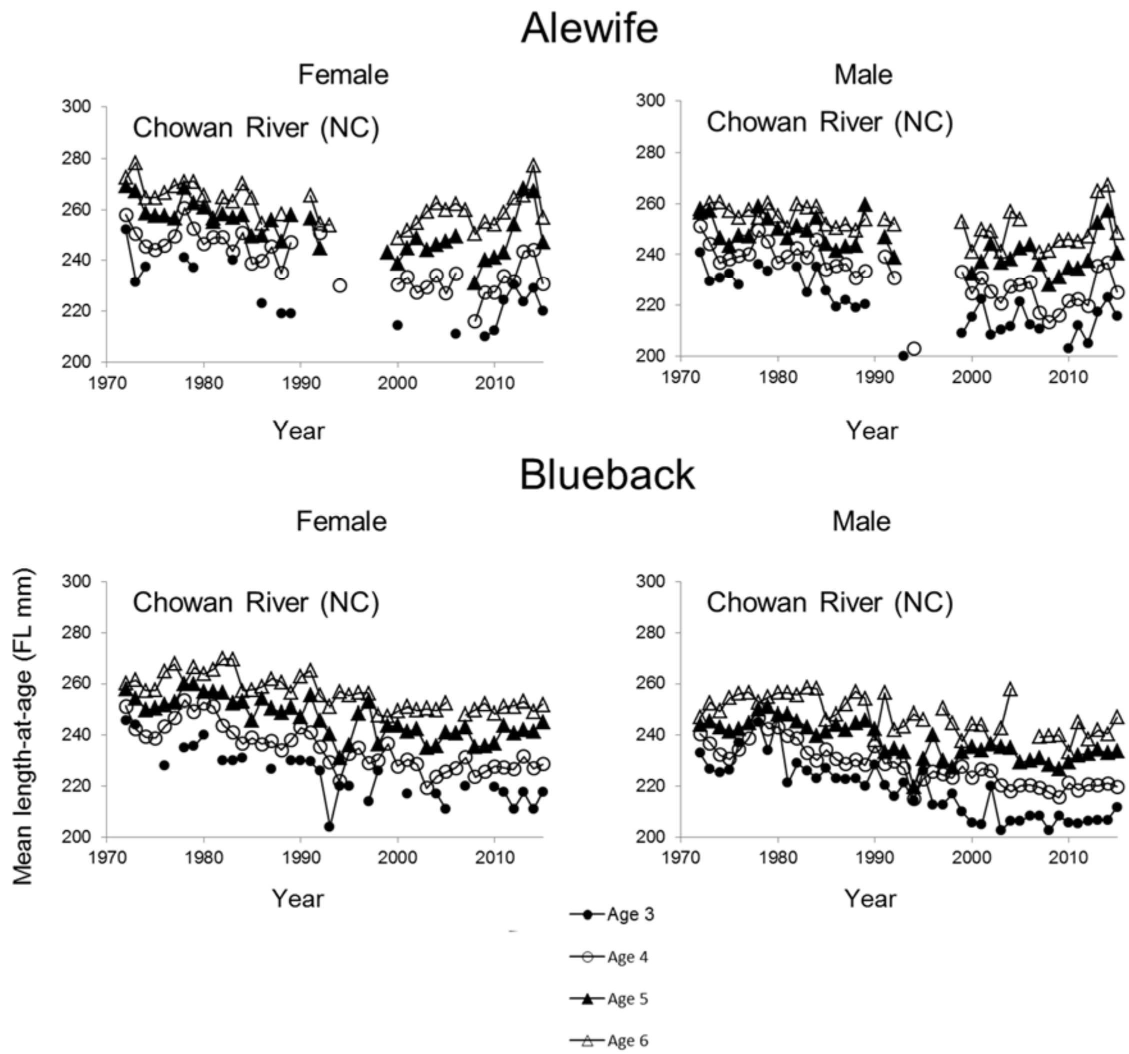
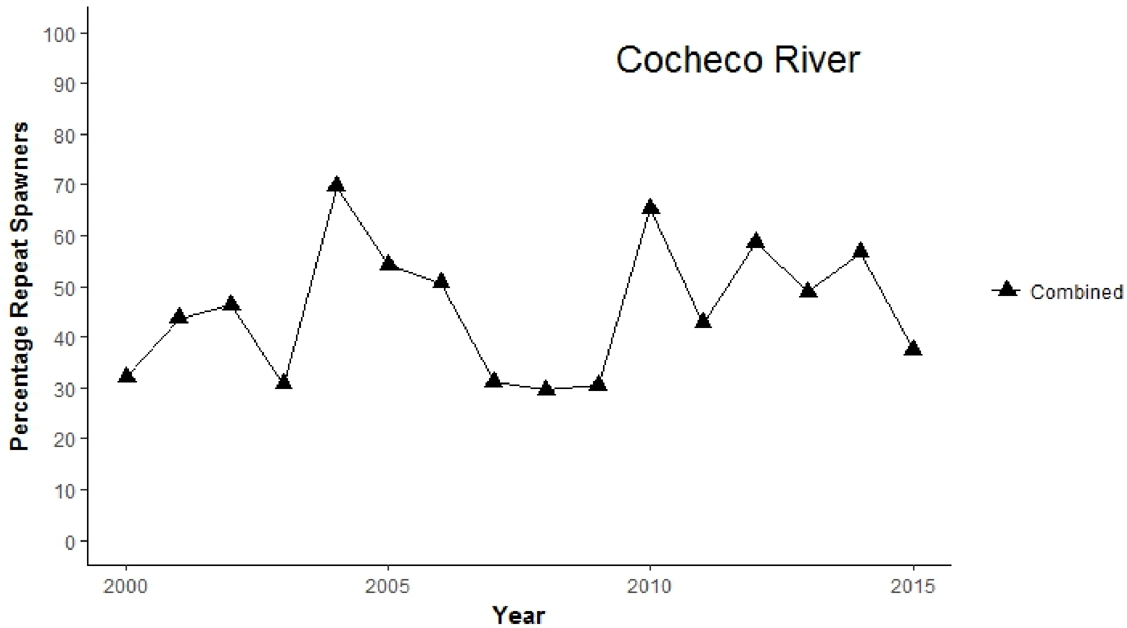


Figure 2.44 Mean lengths-at-age of male and female alewife and blueback herring from North Carolina by species, sex, age and year.



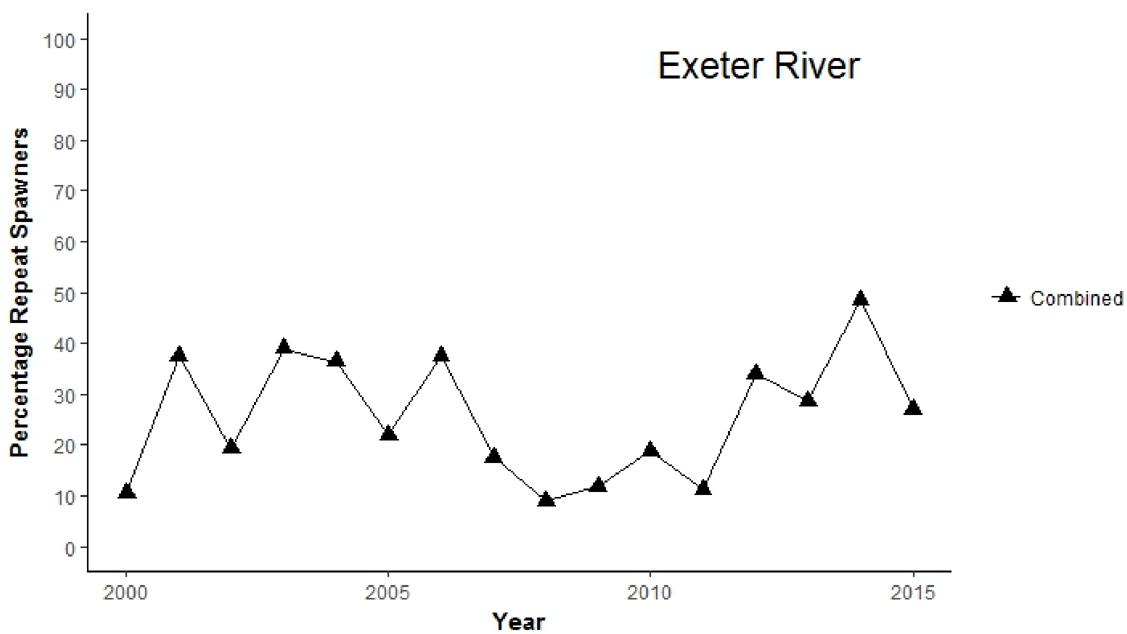


Figure 2.45. Annual repeat spawner rates for alewife observed in fisheries-independent surveys in New Hampshire by water body and year.

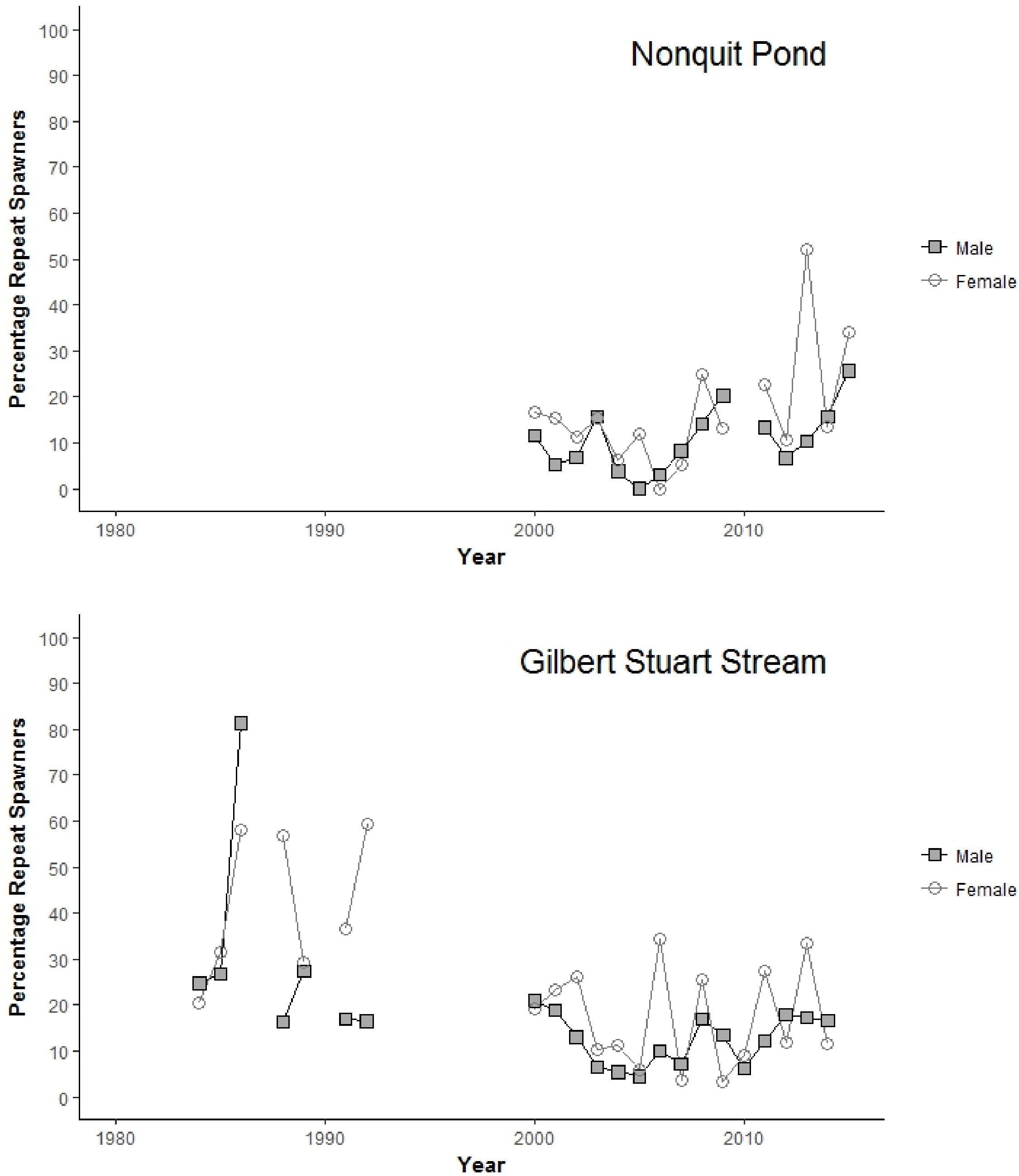


Figure 2.46. Annual repeat spawner rates for alewives observed in fisheries-independent surveys in Rhode Island by water body, sex, and year.

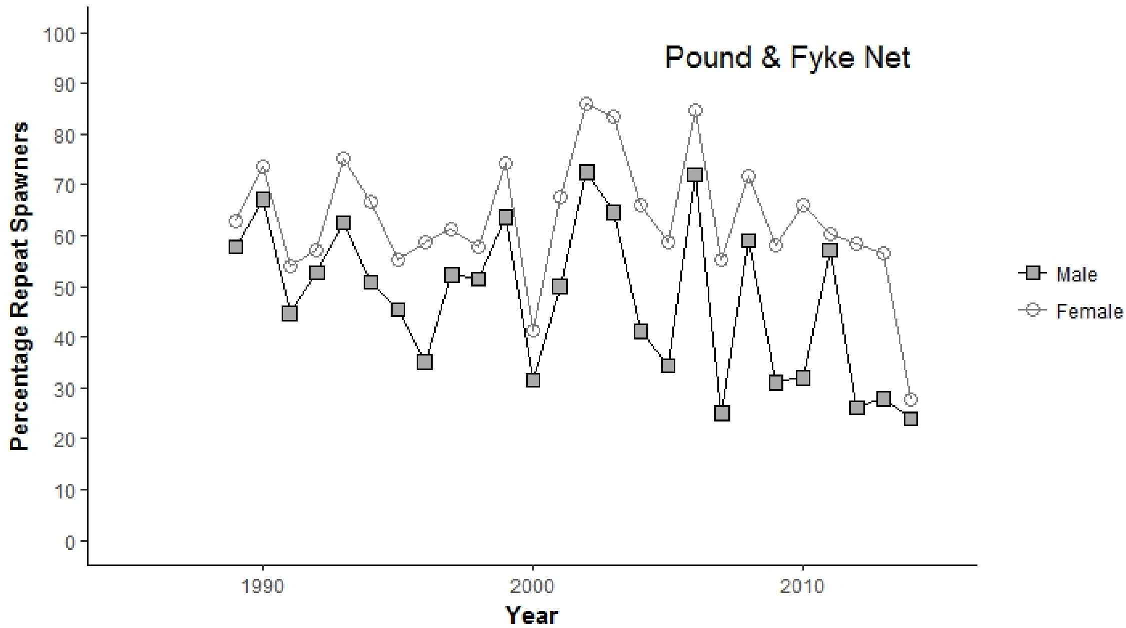


Figure 2.47. Annual repeat spawning rates for alewives observed in fisheries-dependent surveys of the Nanticoke River, MD by sex and year.

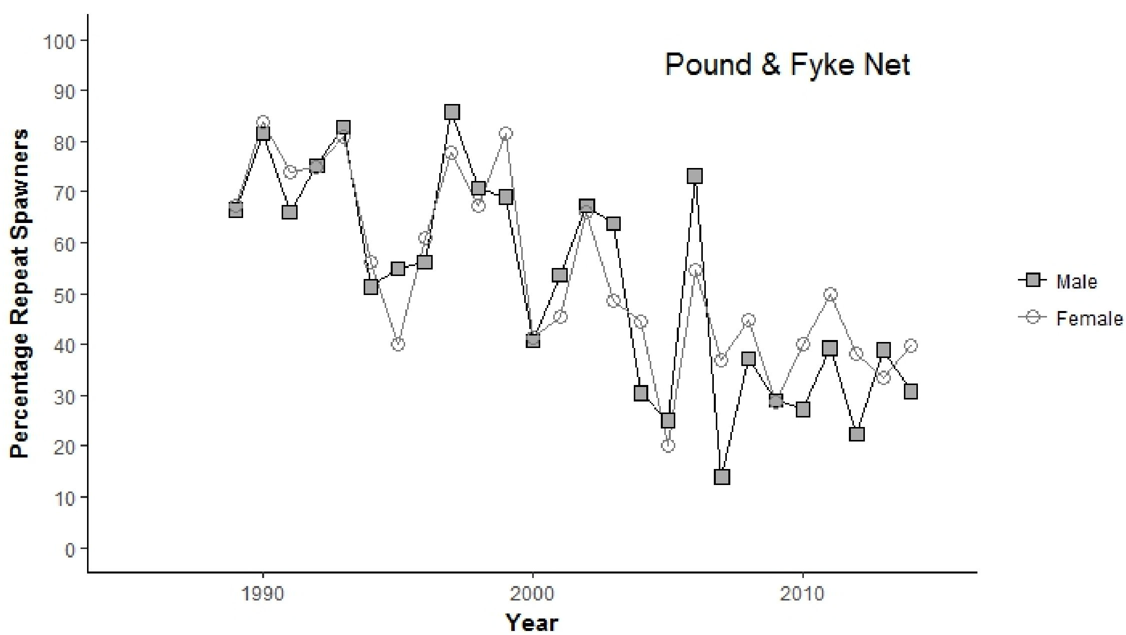


Figure 2.48. Annual repeat spawner rates for blueback herring observed in fisheries-dependent surveys of the Nanticoke River, MD by sex and year.

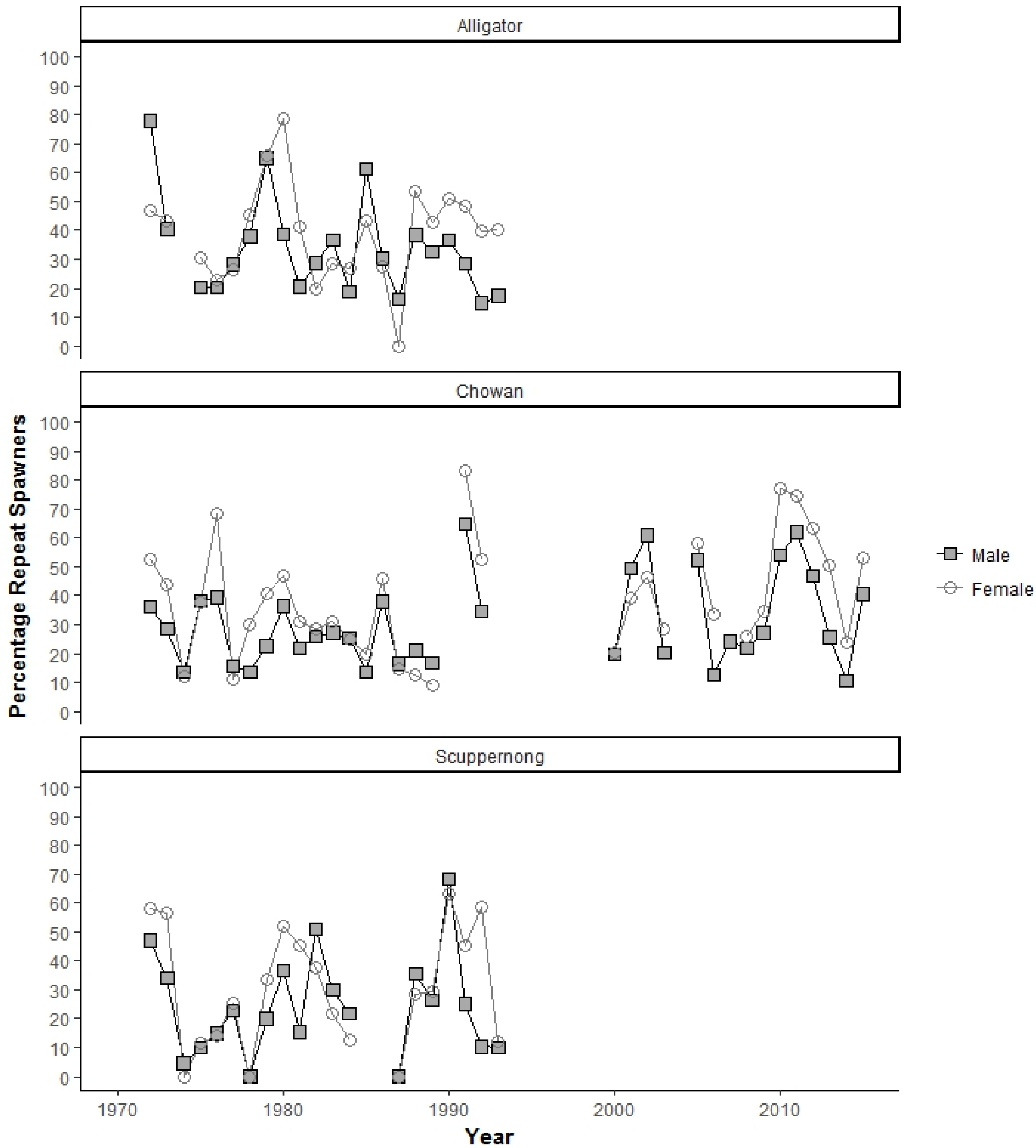


Figure 2.49. Annual repeat spawner rates for alewives observed in fisheries-dependent pound net surveys in North Carolina by water body, sex, and year. Updated data for the Chowan River (2010-2015) were determined to be unreliable due to ageing error (see state report) and were not included in the Mann-Kendall test.

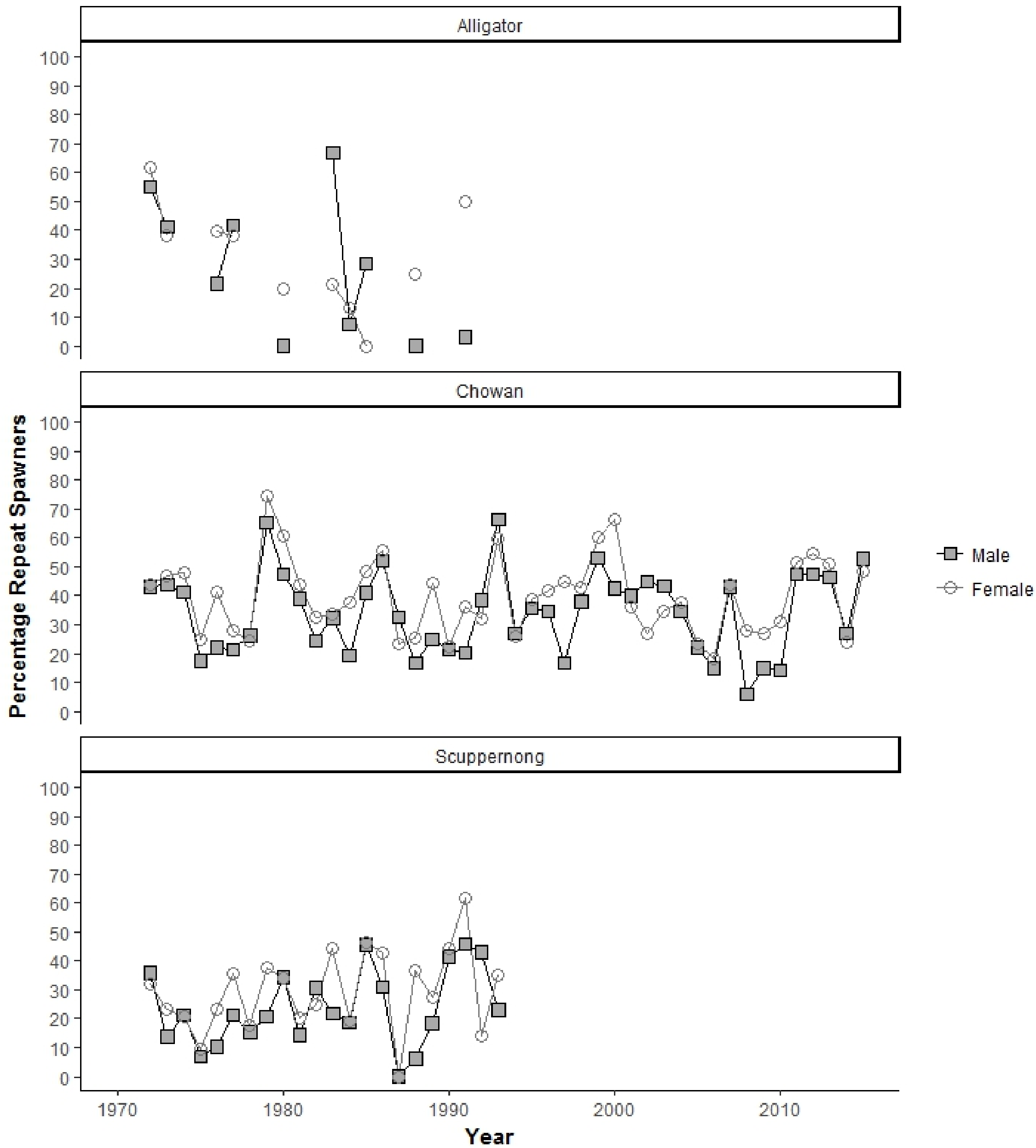


Figure 2.50. Annual repeat spawner rates for blueback herring observed in fisheries-dependent pound net surveys in North Carolina by water body, sex, and year.

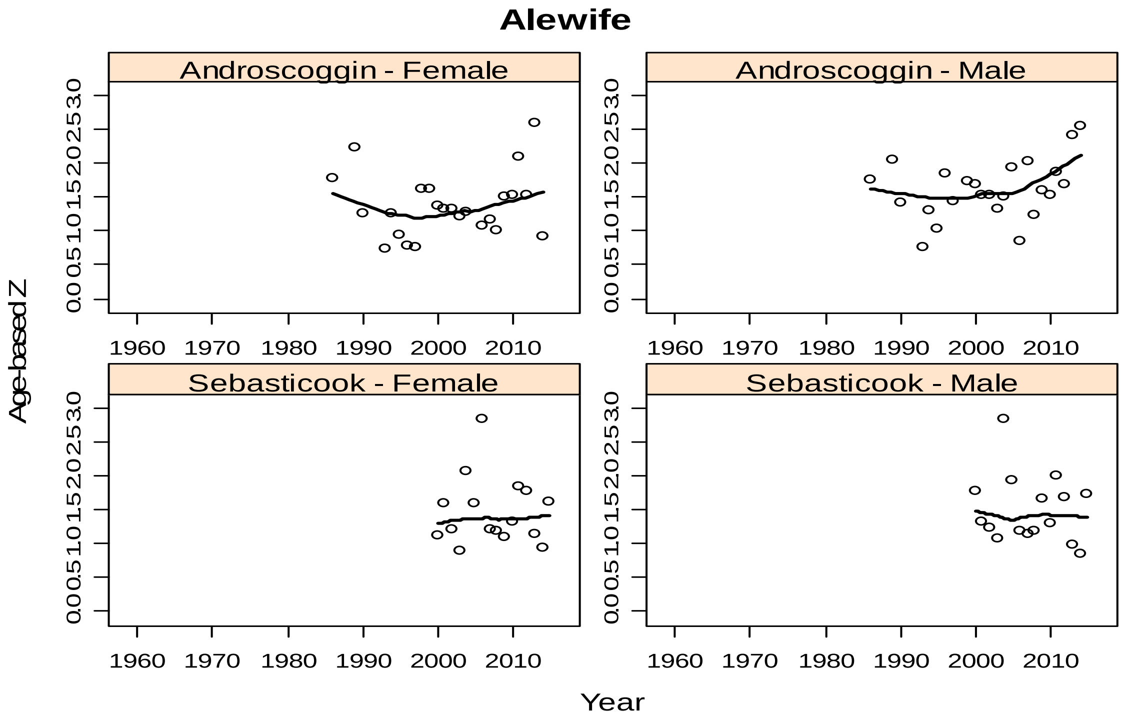


Figure 2.51 Age-based estimates of total instantaneous mortality (Z) for alewife from Maine by river, sex, and year. Linear or loess smooths are drawn to indicate trend.

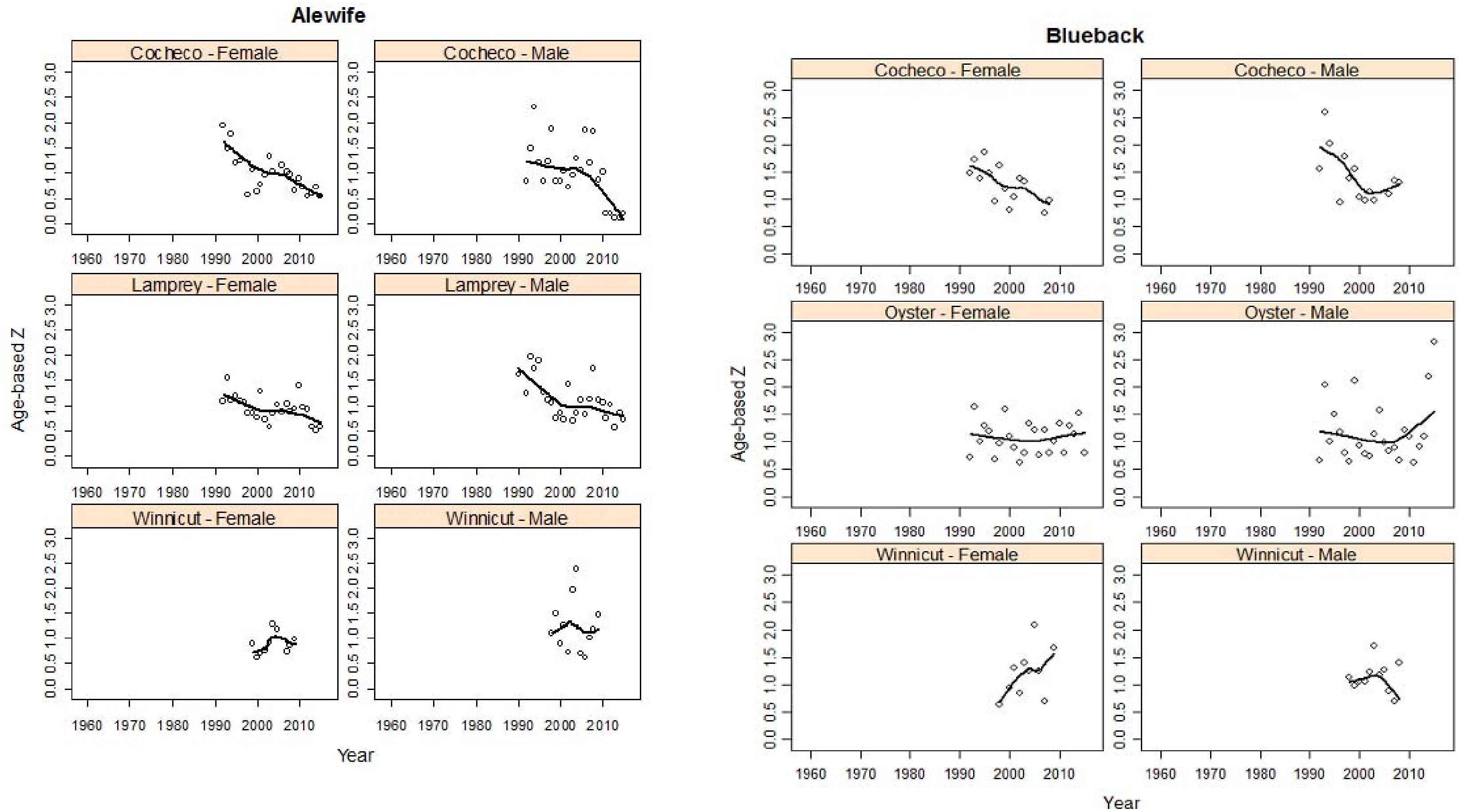
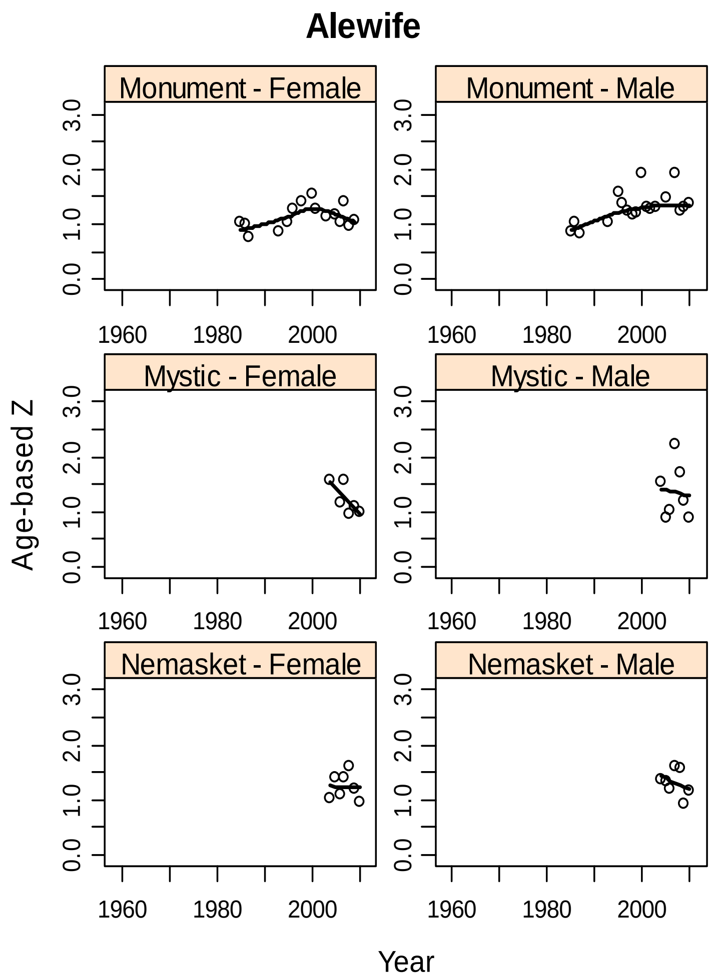


Figure 2.52 Age-based estimates of total instantaneous mortality (Z) for alewife and blueback herring from New Hampshire by river, sex, and year. Linear or loess smooths are drawn to indicate trend.



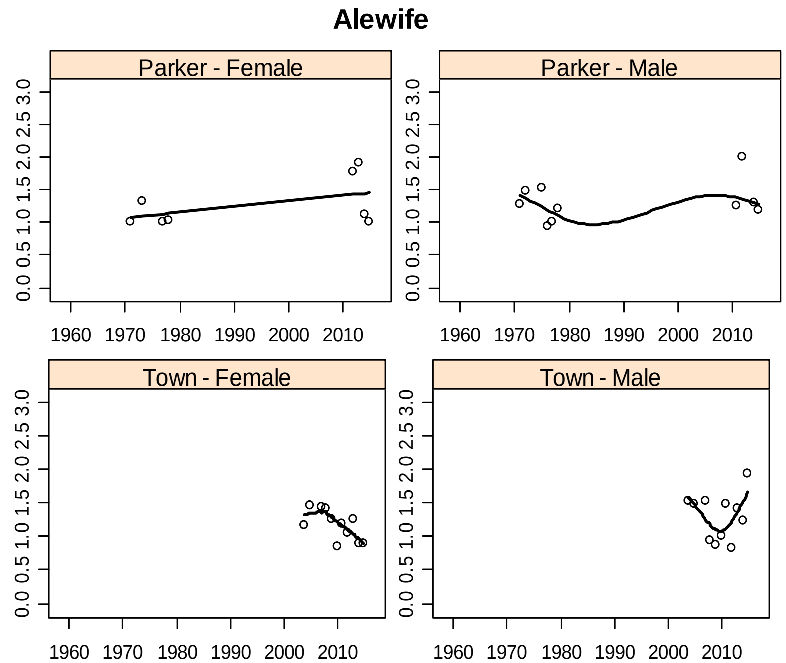


Figure 2.53. Age-based estimates of total instantaneous mortality (Z) for alewife from Massachusetts by river, sex, and year. Linear or loess smooths are drawn to indicate trend.

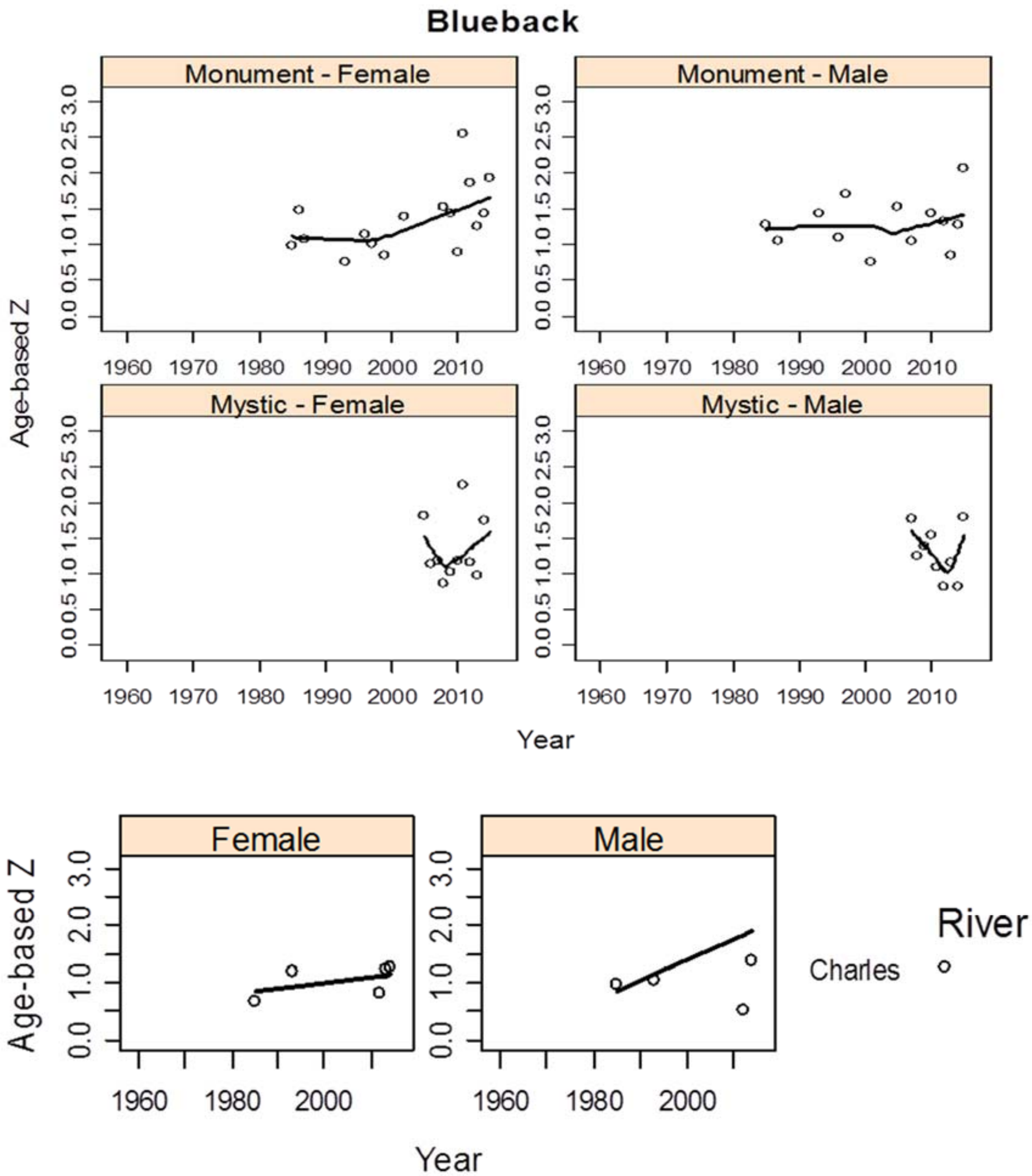


Figure 2.54. Age-based estimates of total instantaneous mortality (Z) for blueback herring from Massachusetts by river, sex, and year. Linear or loess smooths are drawn to indicate trend.

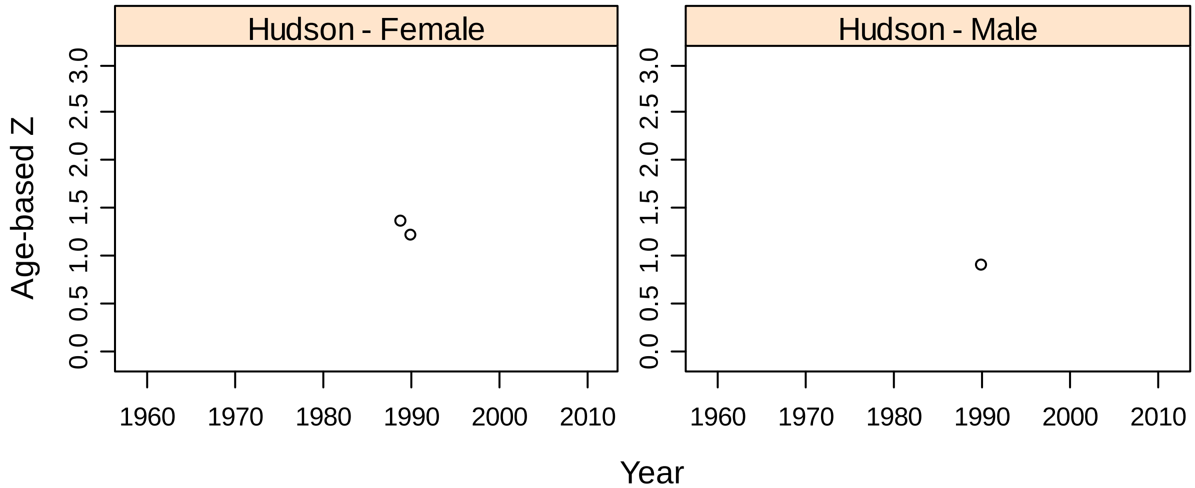
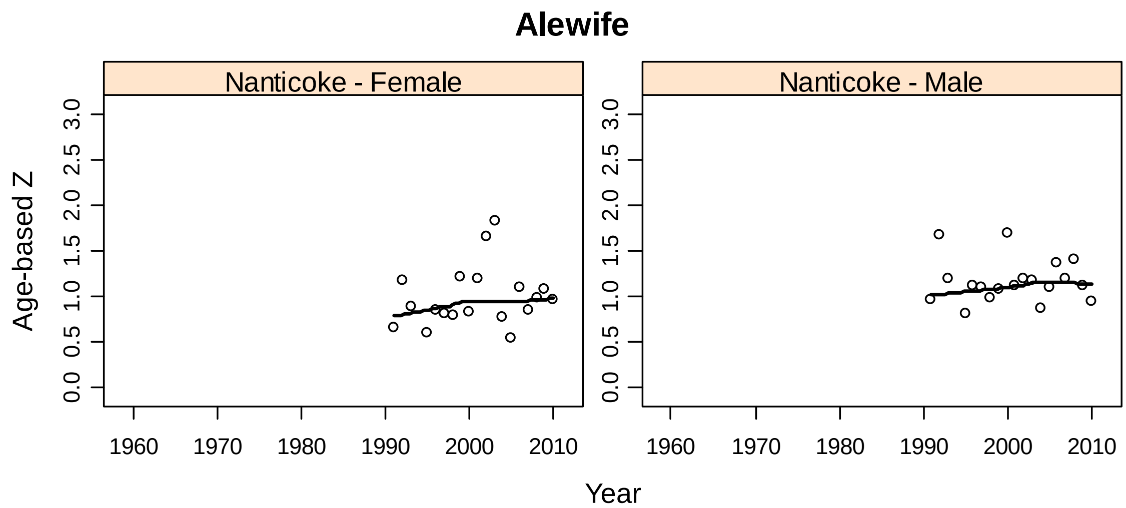


Figure 2.55. Age-based estimates of total instantaneous mortality (Z) for blueback herring from New York by river, sex, and year. Linear or loess smooths are drawn to indicate trend.



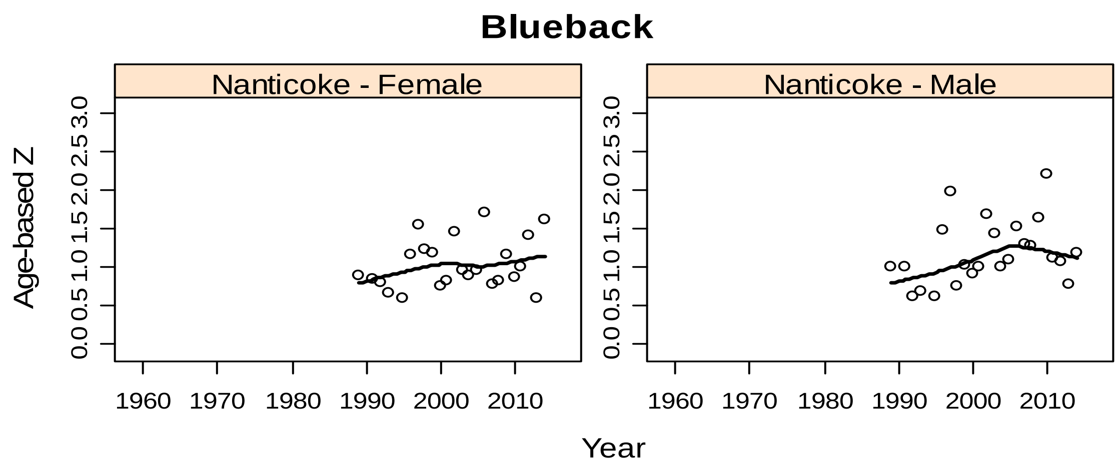


Figure 2.56. Age-based estimates of total instantaneous mortality (Z) for alewife and blueback herring from Maryland by river, sex, and year. Linear or loess smooths are drawn to indicate trend.

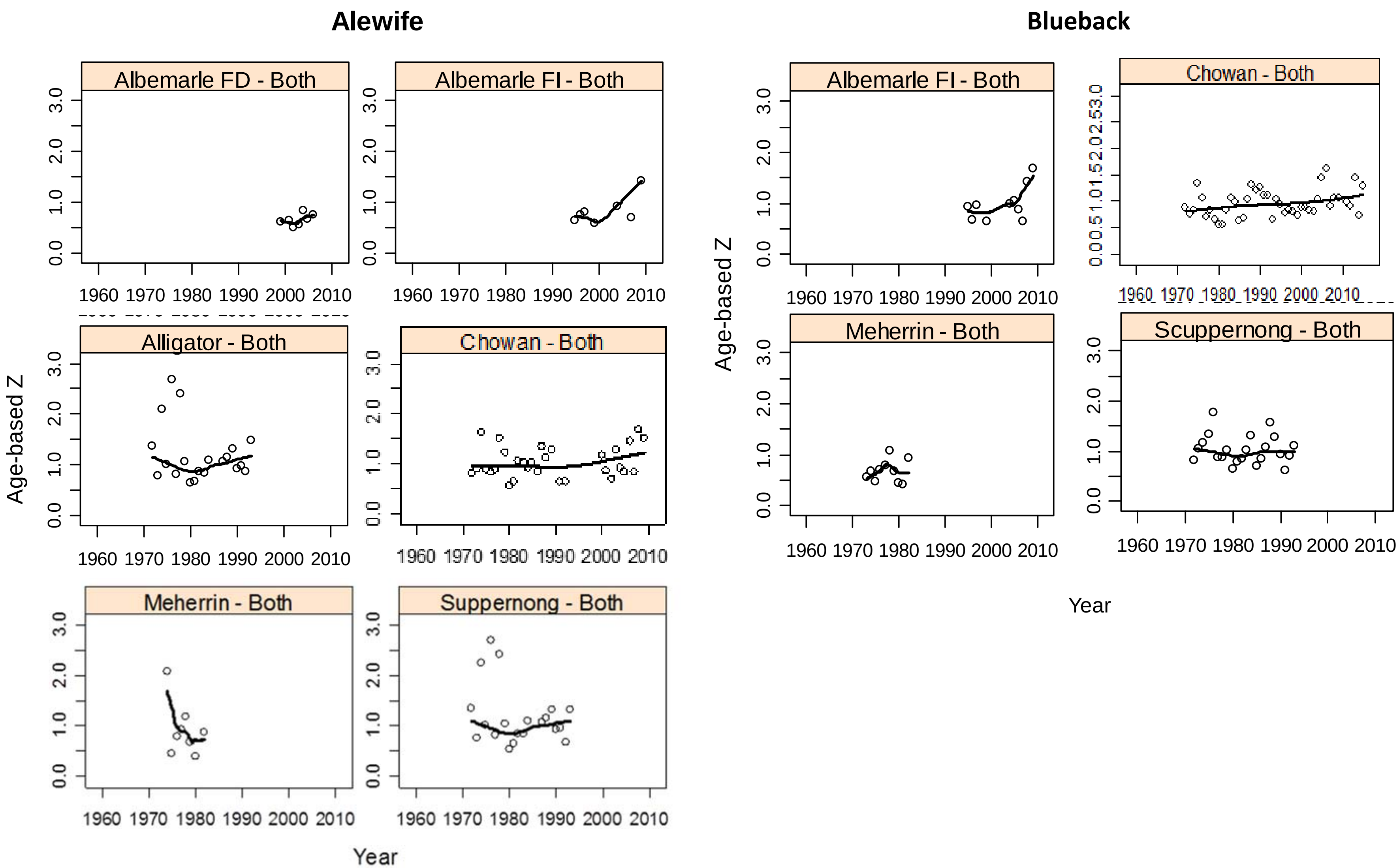


Figure 2.57. Age-based estimates of total instantaneous mortality (Z) for alewife and blueback herring (sexes combined) from North Carolina by river. Linear or loess smooths are drawn to indicate trend.

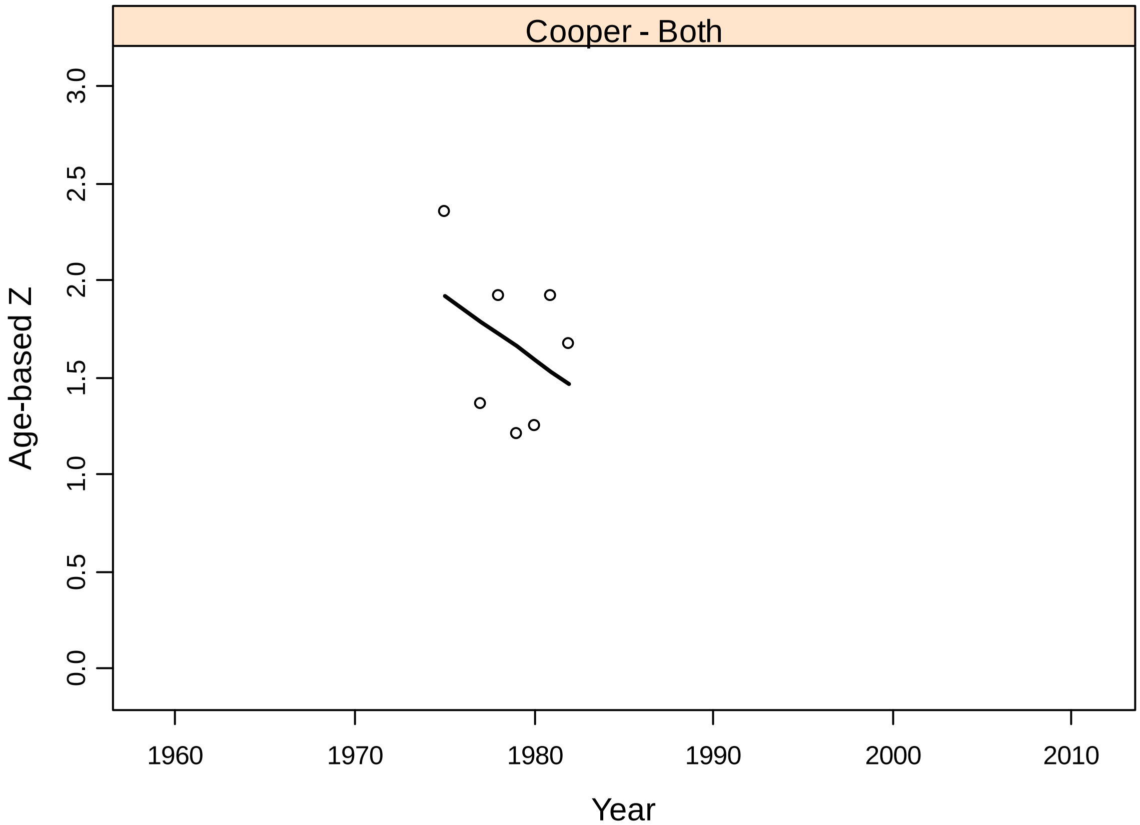


Figure 2.58. Age-based estimates of total instantaneous mortality (Z) for blueback herring (sexes combined) from South Carolina. Linear or loess smooths are drawn to indicate trend.

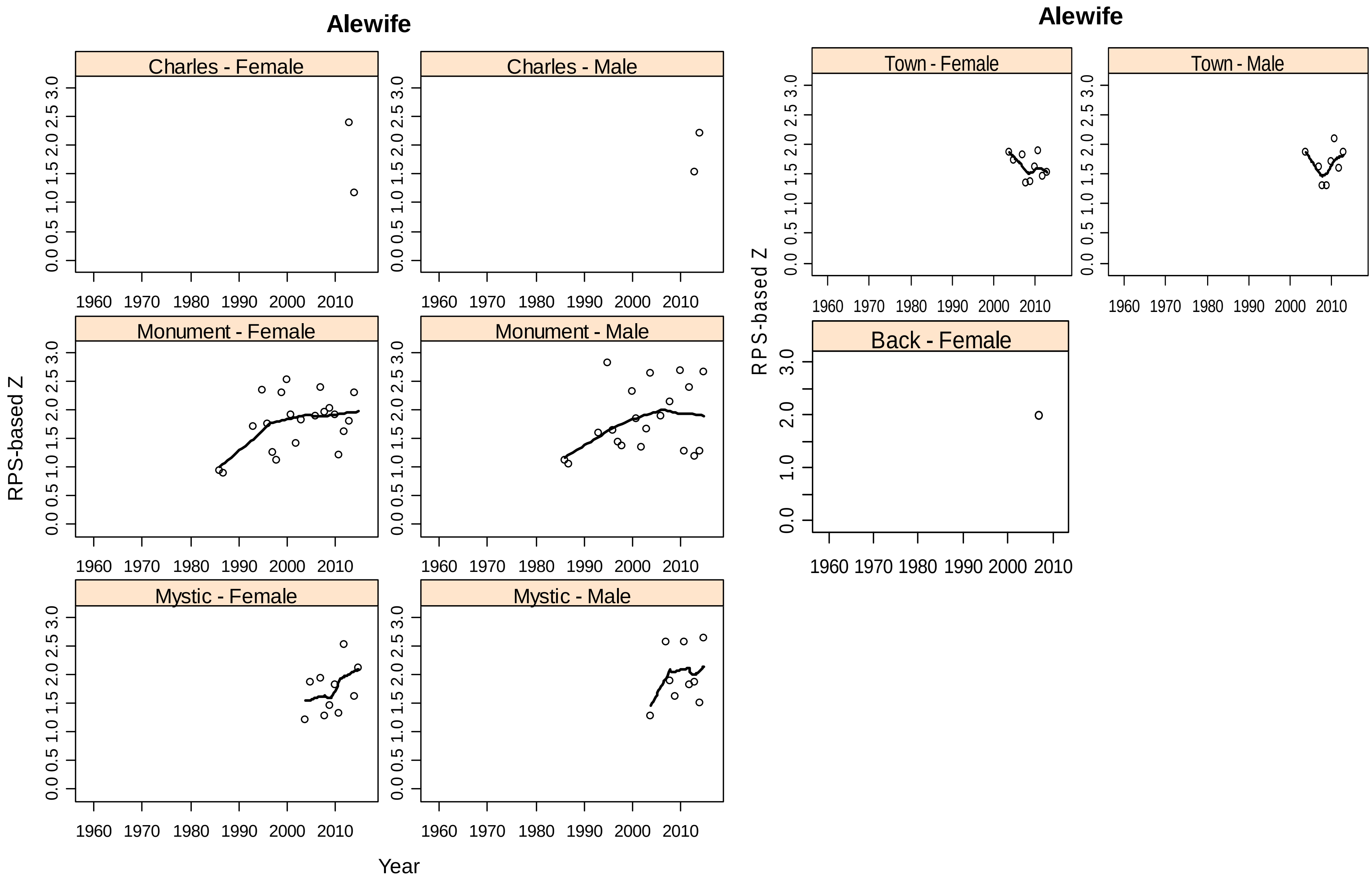


Figure 2.59 Repeat spawner-based estimates of total instantaneous mortality (Z) for alewife from Massachusetts by year, sex and river from Massachusetts. Linear or loess smooths are drawn to indicate trend.

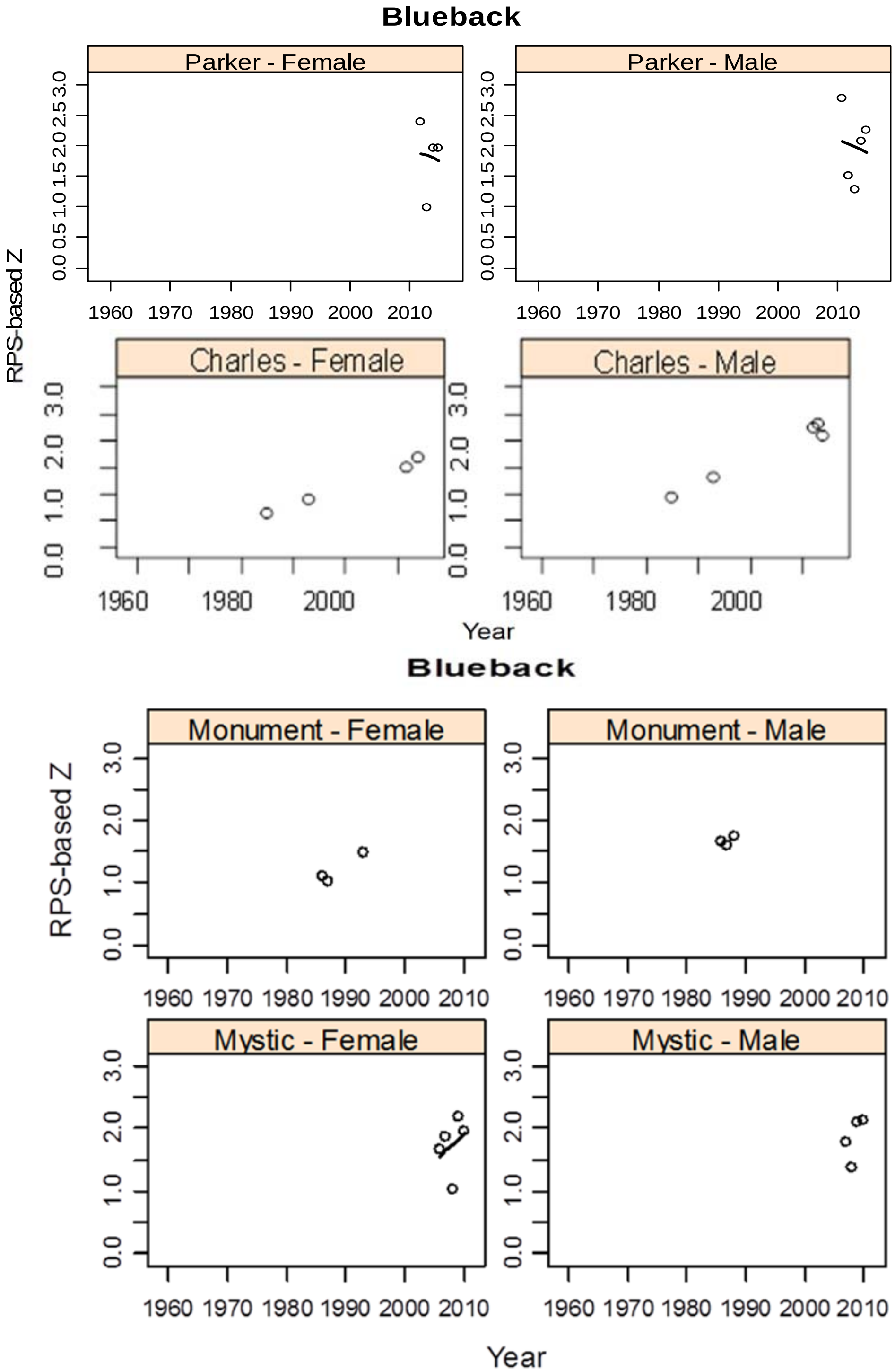


Figure 2.60. Repeat spawner-based estimates of total instantaneous mortality (Z) for blueback herring from Massachusetts by year, sex and river from Massachusetts. Linear or loess smooths are drawn to indicate trend.

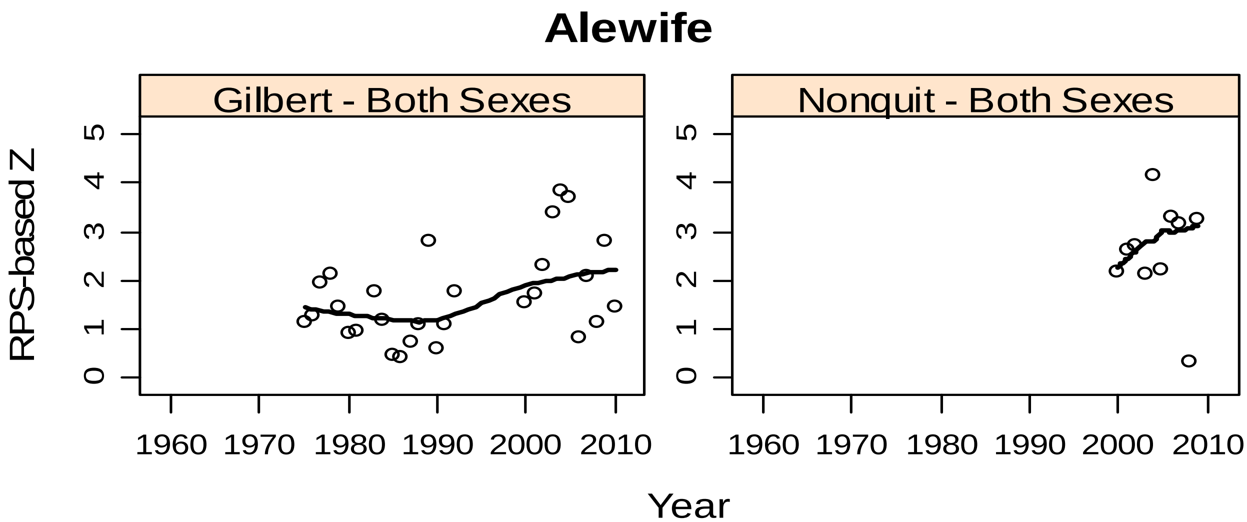


Figure 2.61. Repeat spawner-based estimates of total instantaneous mortality (Z) for alewife (sexes combined) from Rhode Island by river and year. Linear or loess smooths are drawn to indicate trend.

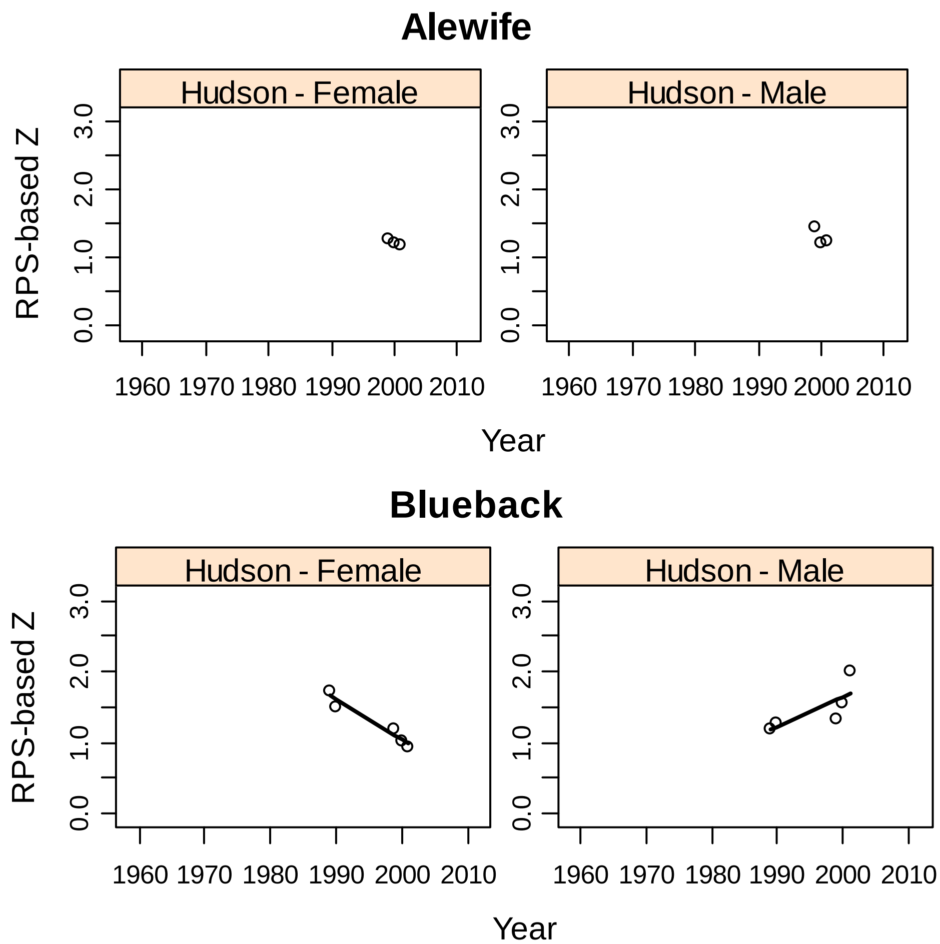


Figure 2.62. Repeat spawner-based estimates of total instantaneous mortality (Z) for male and female alewife and blueback herring by year, sex and river from New York. Linear or loess smooths are drawn to indicate trend.

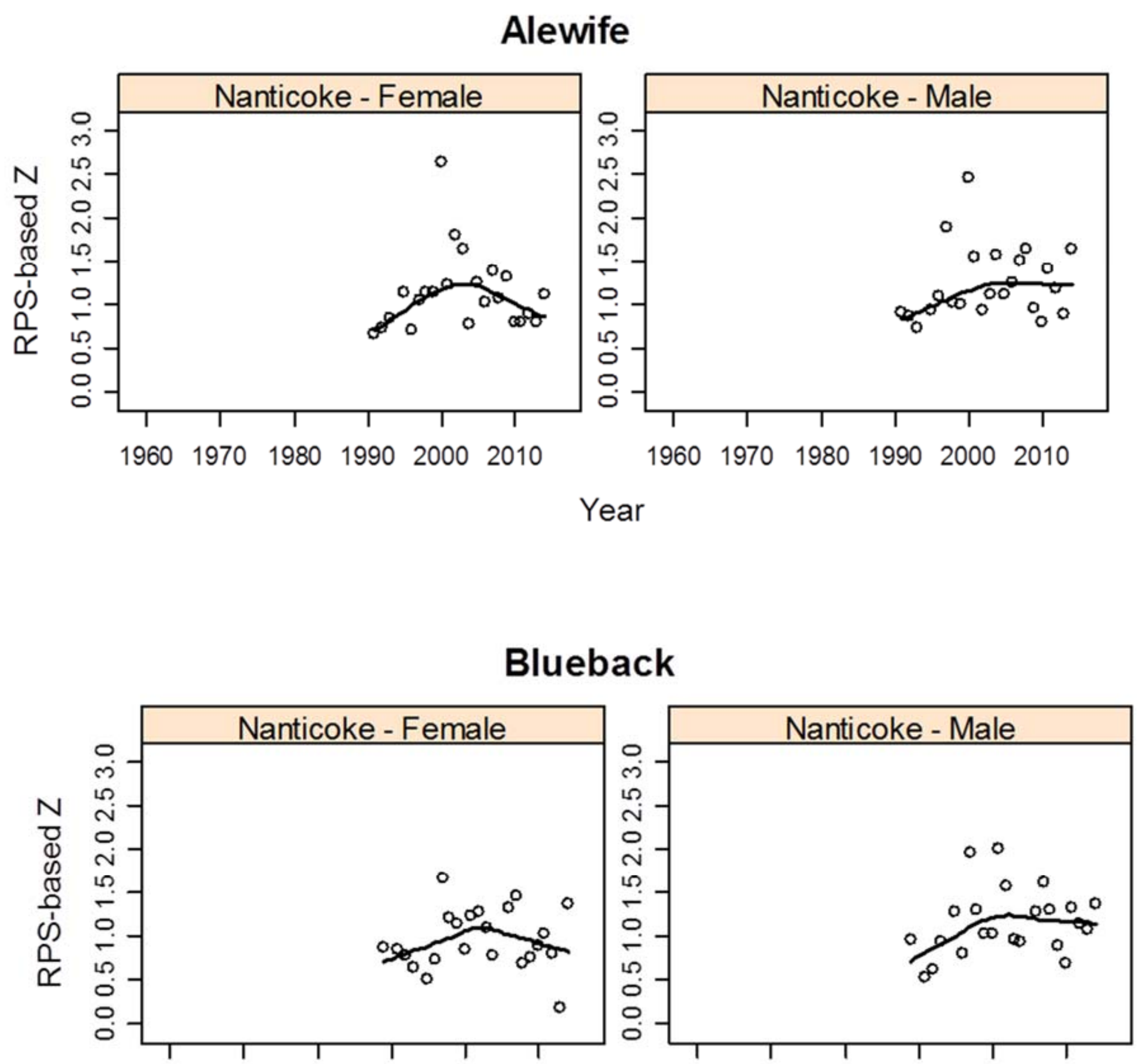


Figure 2.63 Repeat spawner-based estimates of total instantaneous mortality (Z) for alewife and blueback herring from Maryland by river, sex and year. Linear or loess smooths are drawn to indicate trend

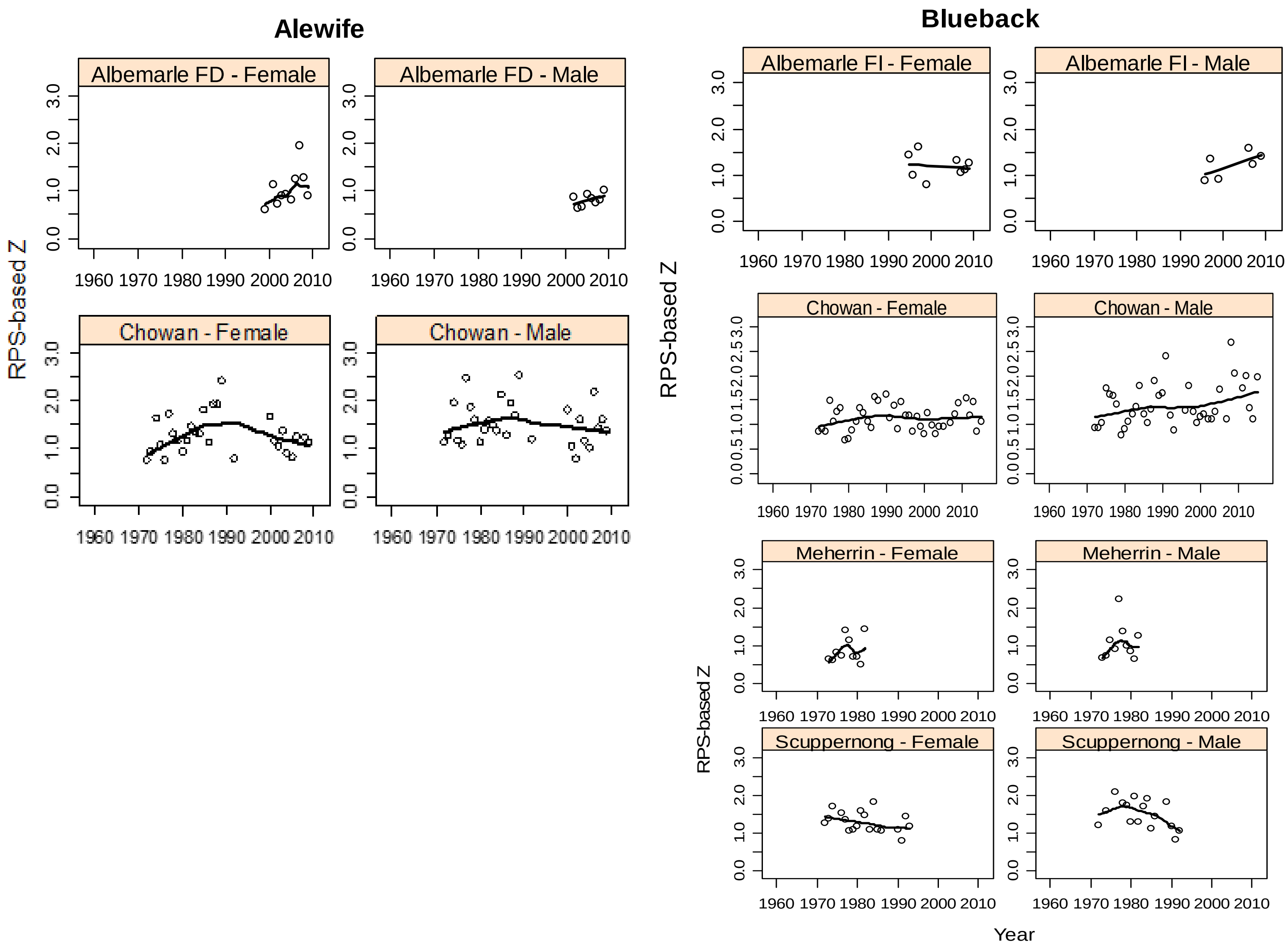


Figure 2.64. Repeat spawner-based estimates of total instantaneous mortality (Z) for alewife and blueback herring from North Carolina by river, sex and year. Linear or loess smooths are drawn to indicate trend.

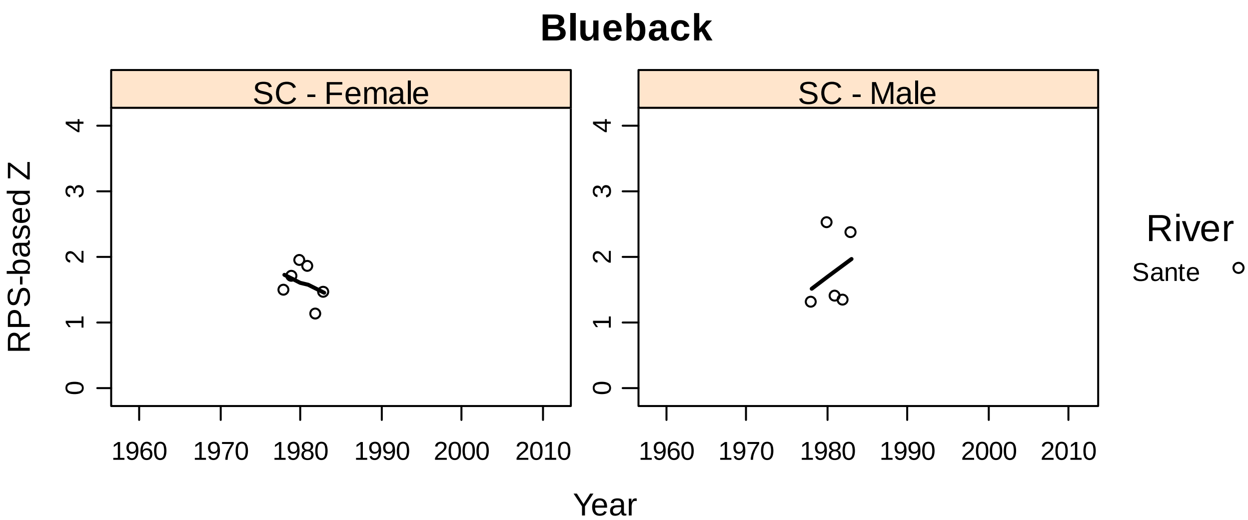


Figure 2.65 Repeat spawner-based estimates of total instantaneous mortality (Z) for blueback herring from South Carolina by river, sex and year. Linear or loess smooths are drawn to indicate trend

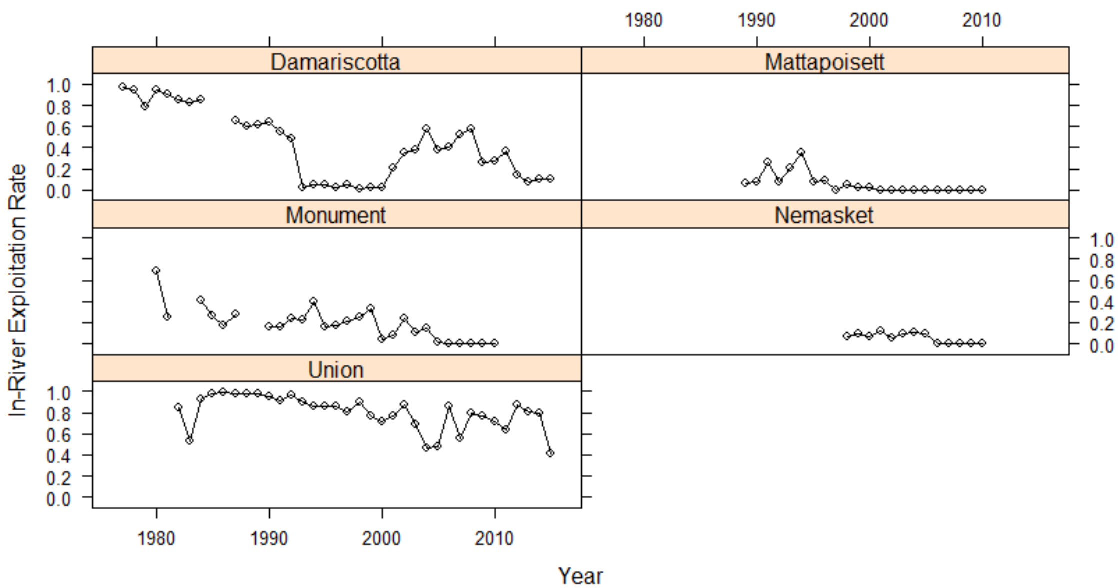


Figure 2.66 In-river exploitation rates for river herring from Massachusetts (Mattapoisett, Monument, and Nemasket) and Maine (Damariscotta and Union) rivers, 1977-2015. In-river exploitation rates are of both river herring species combined in the Monument River and only alewives in all other rivers.

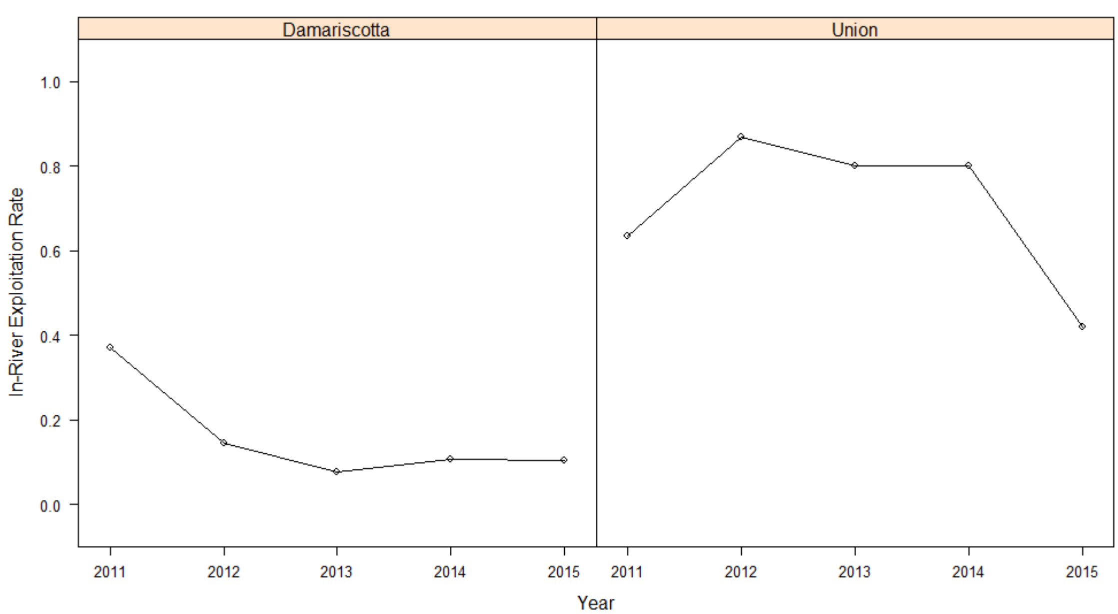


Figure 2.67 In-river exploitation rates for alewives from Maine rivers since the benchmark stock assessment terminal year. SFMPs were required starting in 2012.

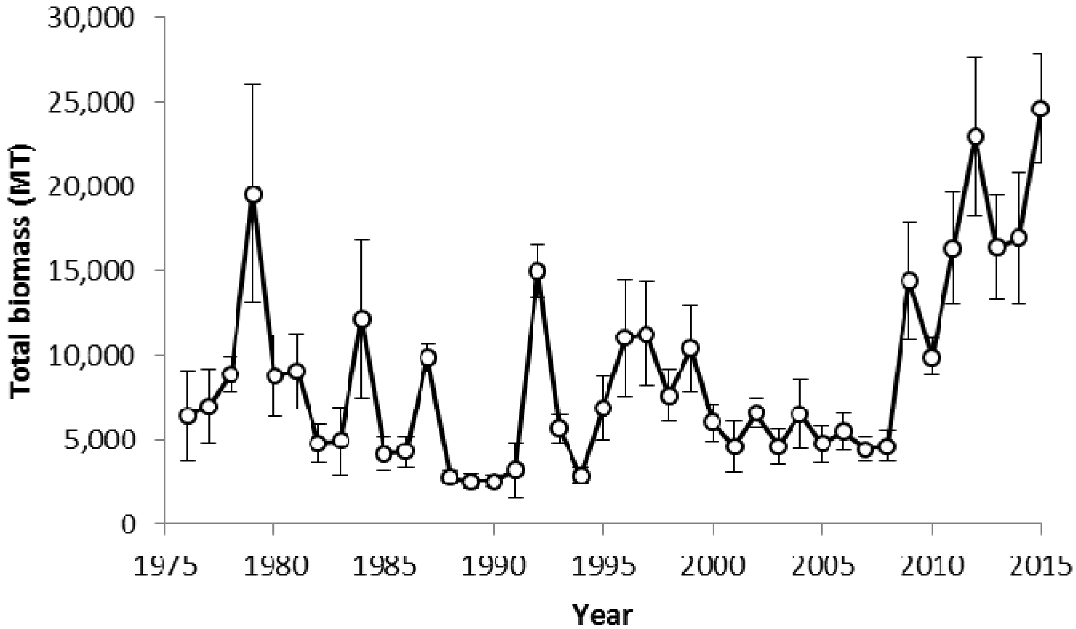


Figure 2.68 Minimum swept area estimates of total river herring biomass from NEFSC spring bottom trawl surveys (1976 – 2015).

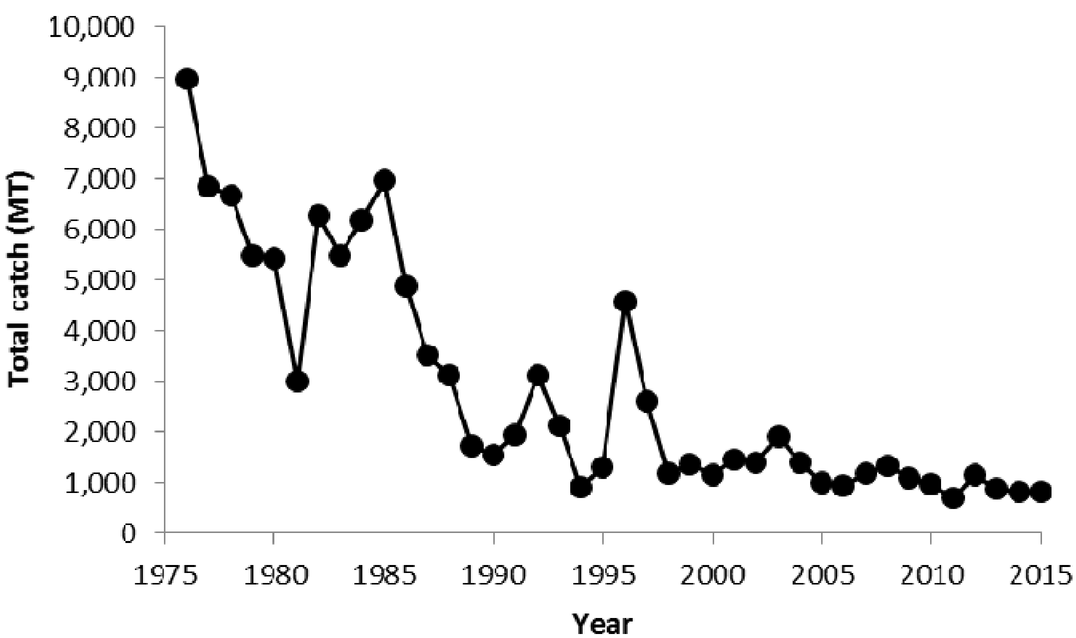


Figure 2.69 Total catch of river herring estimated from total reported landings plus total incidental catch using hindcasting methods.

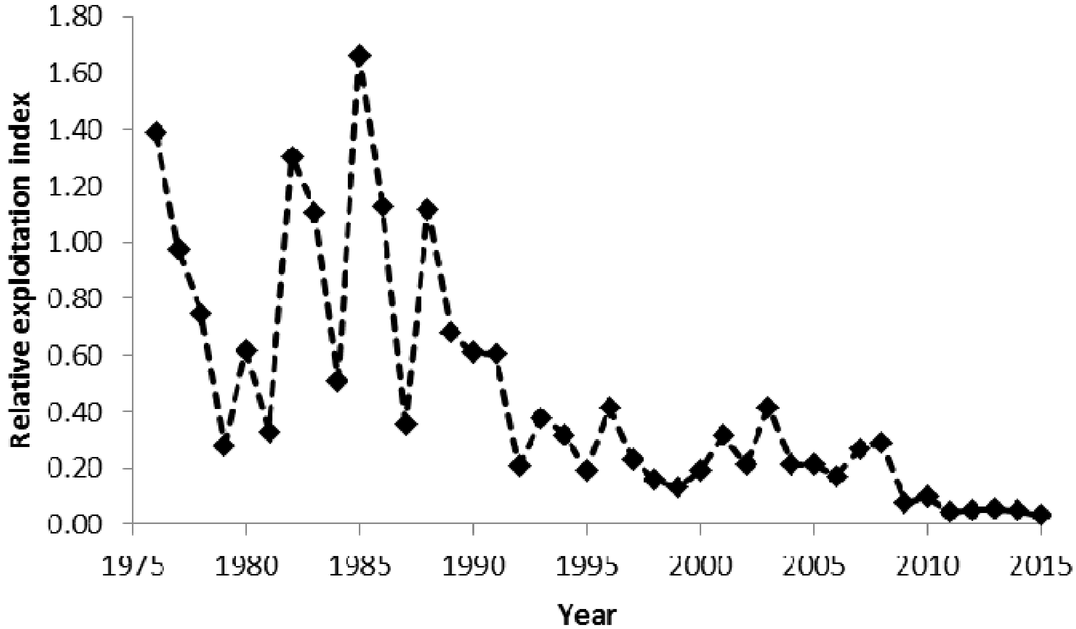


Figure 2.70 Relative exploitation of river herring (1976 – 2015).

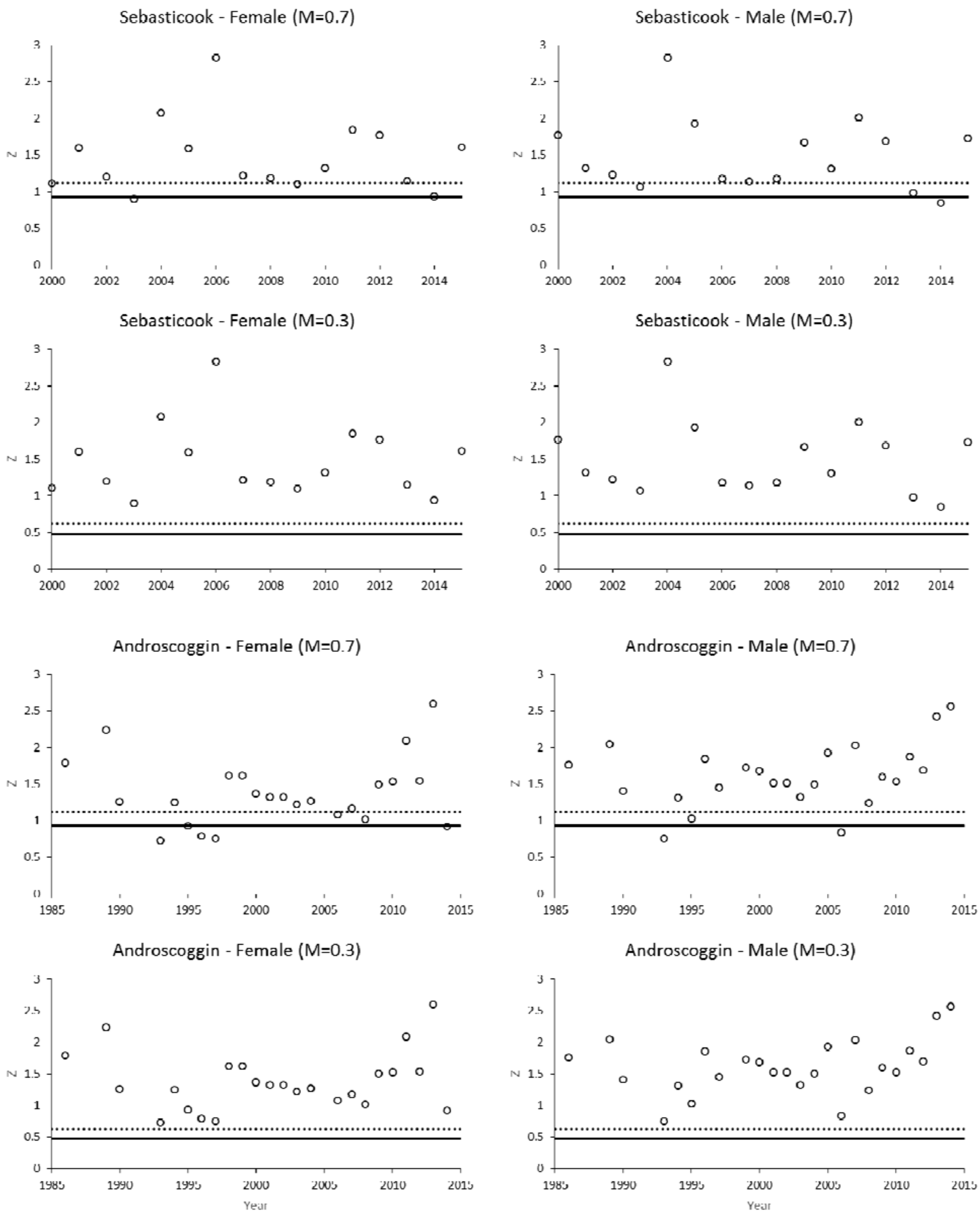


Figure 2.71 Empirical estimates of Z for ME alewife by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

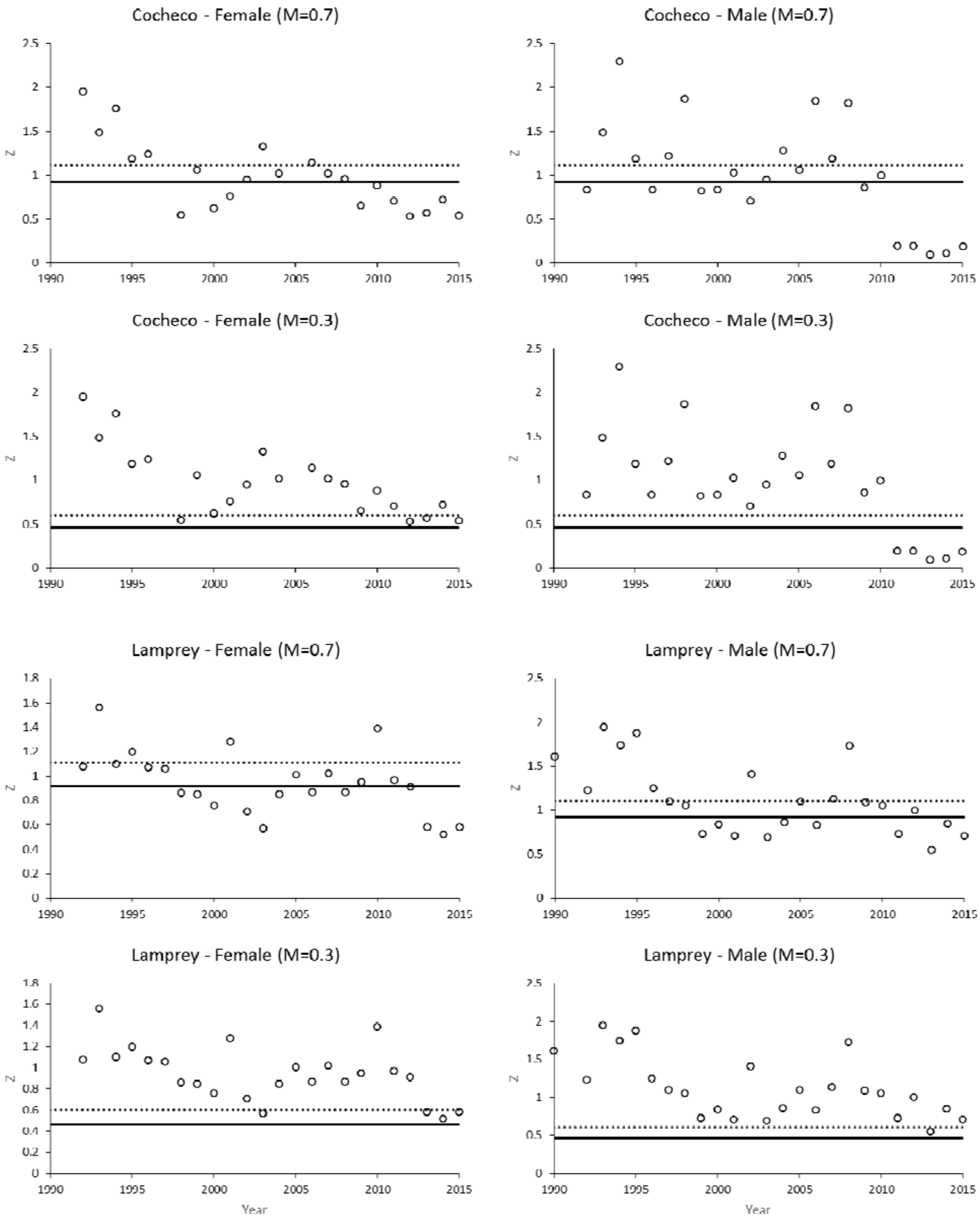


Figure 2.72 Empirical estimates of Z for NH alewife by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

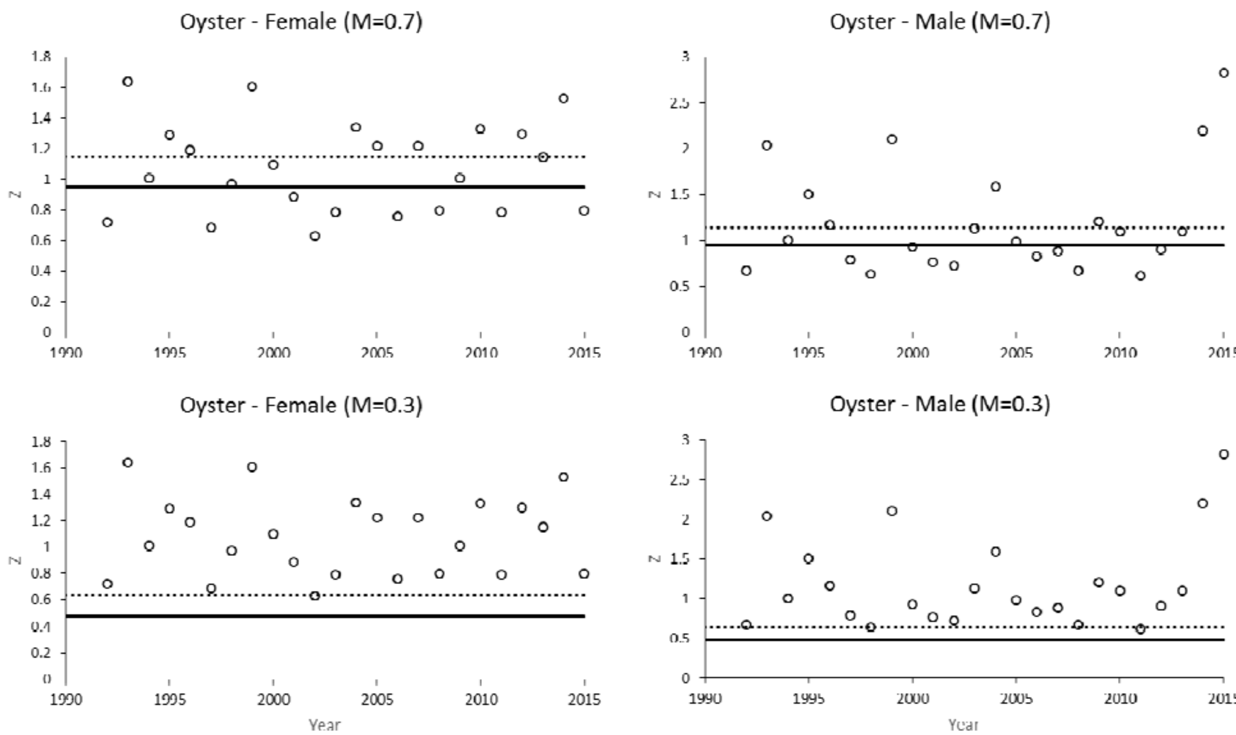


Figure 2.73 Empirical estimates of Z for NH blueback herring by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

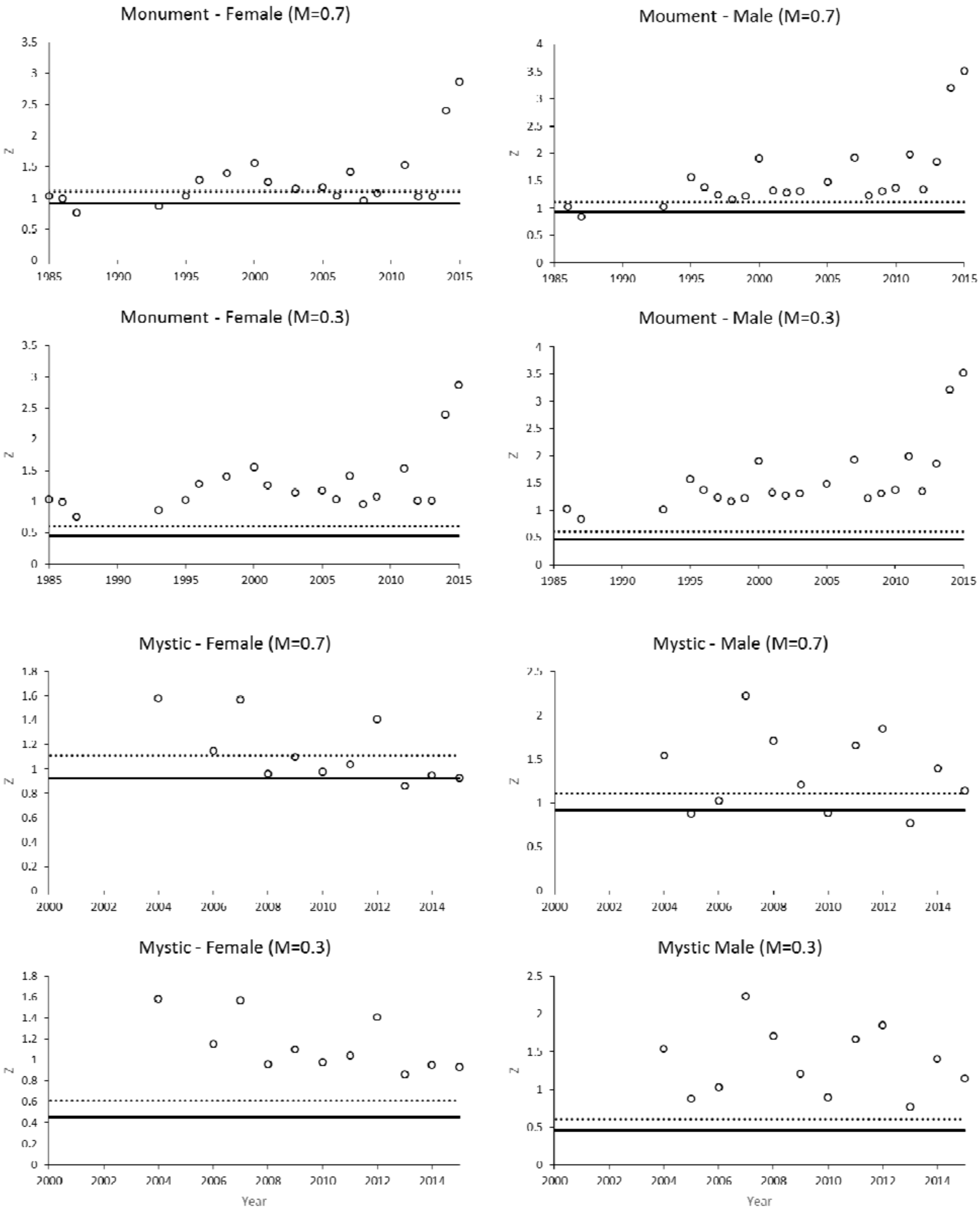


Figure 2.74 Empirical estimates of Z for MA alewife by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

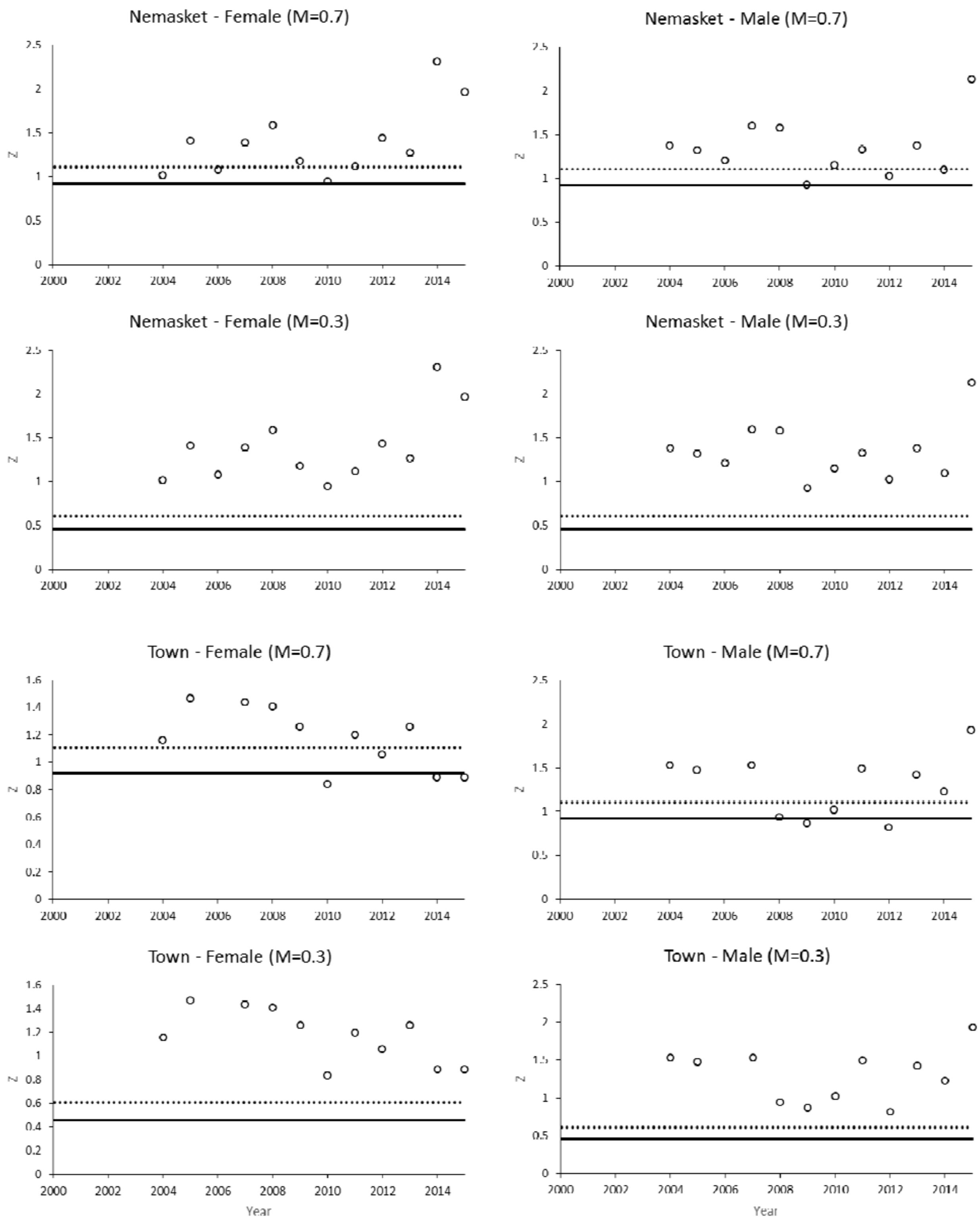


Figure 2.86 Continued.

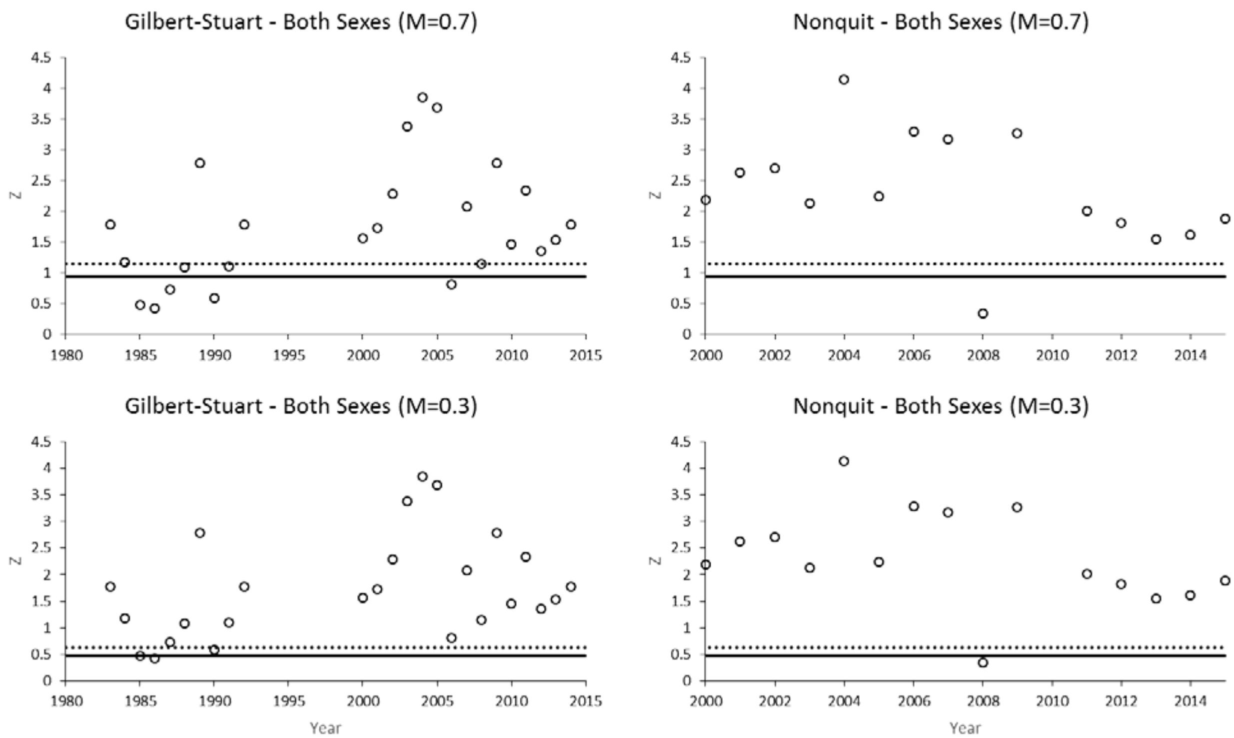


Figure 2.75 Empirical estimates of Z (repeat spawner-based) for RI alewife by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

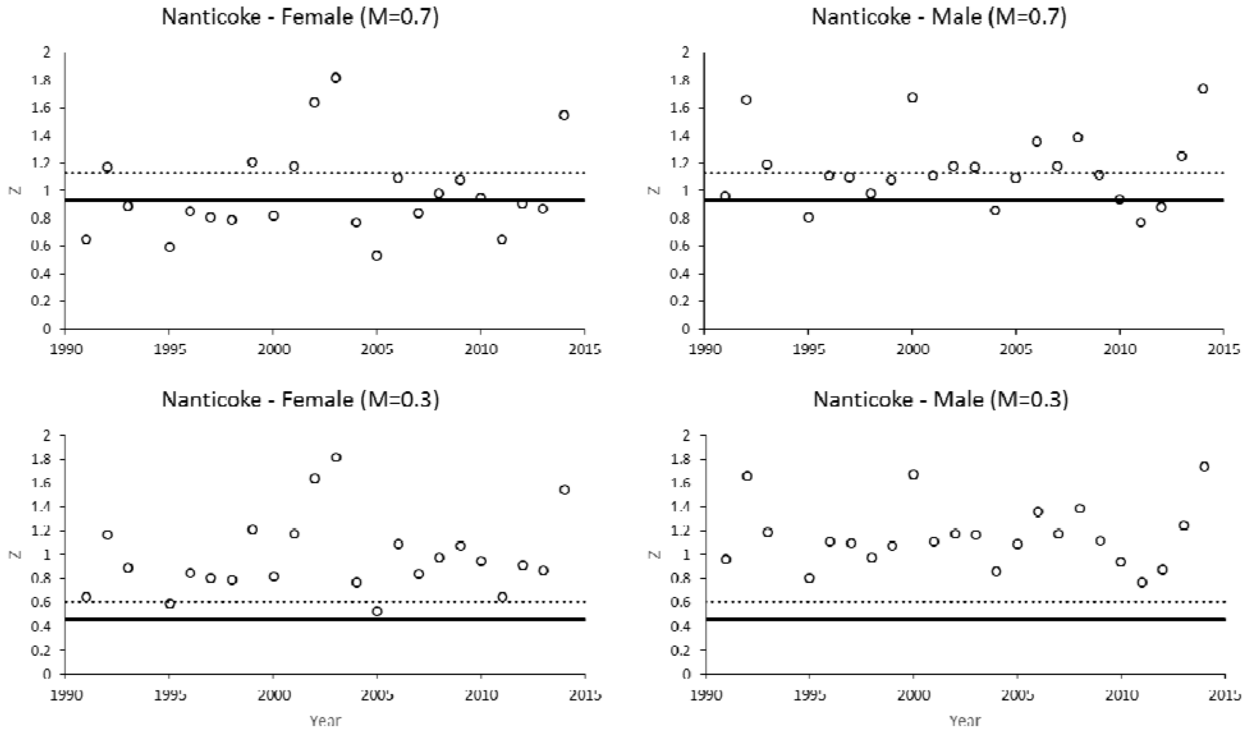


Figure 2.76. Empirical estimates of Z for MD alewife by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

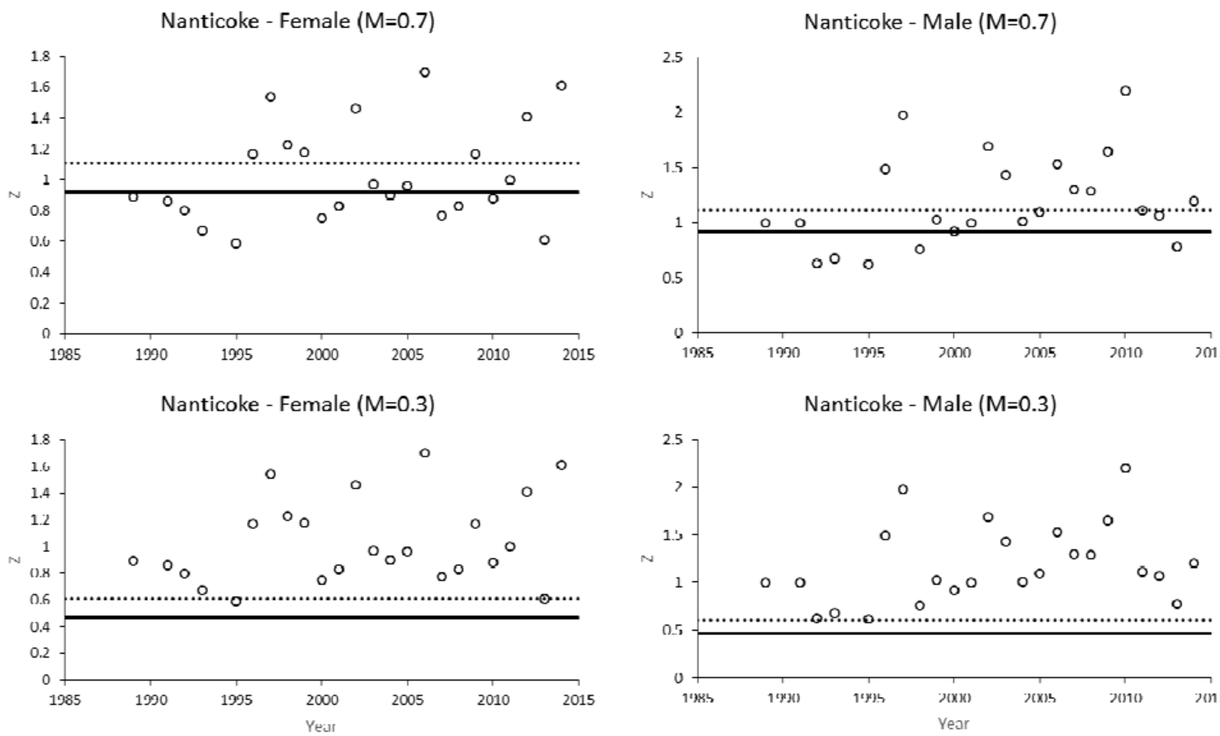


Figure 2.77 Empirical estimates of Z for MD blueback herring by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

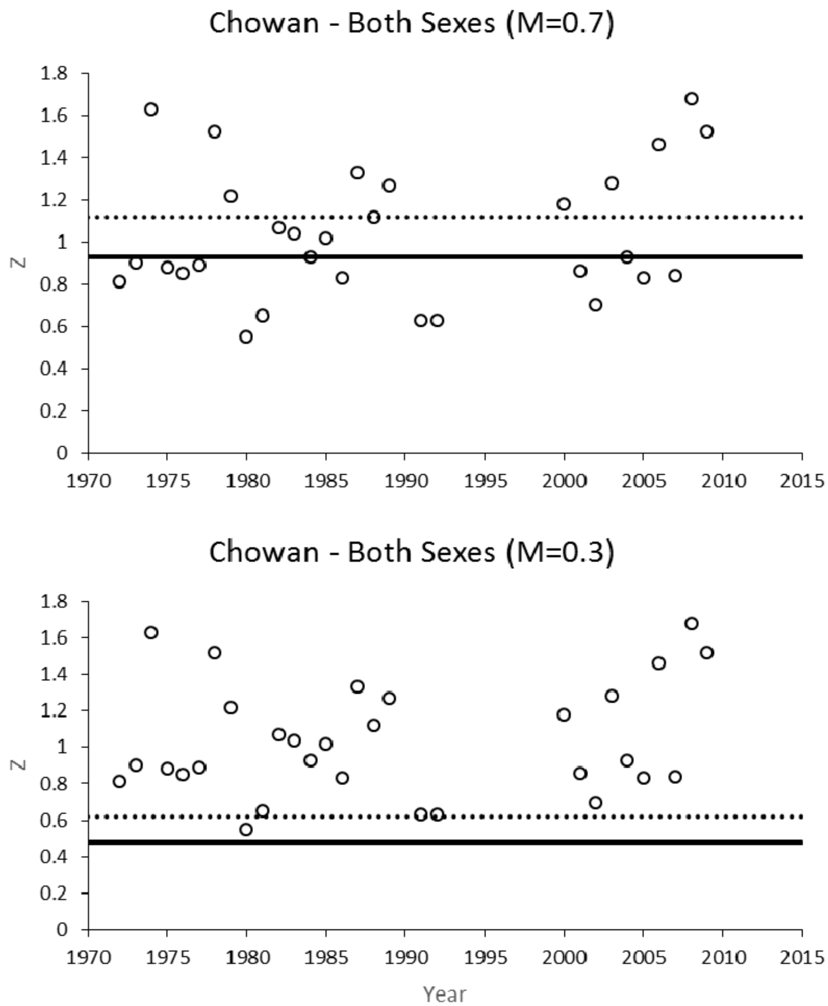


Figure 2.78 Empirical estimates of Z for NC alewife by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

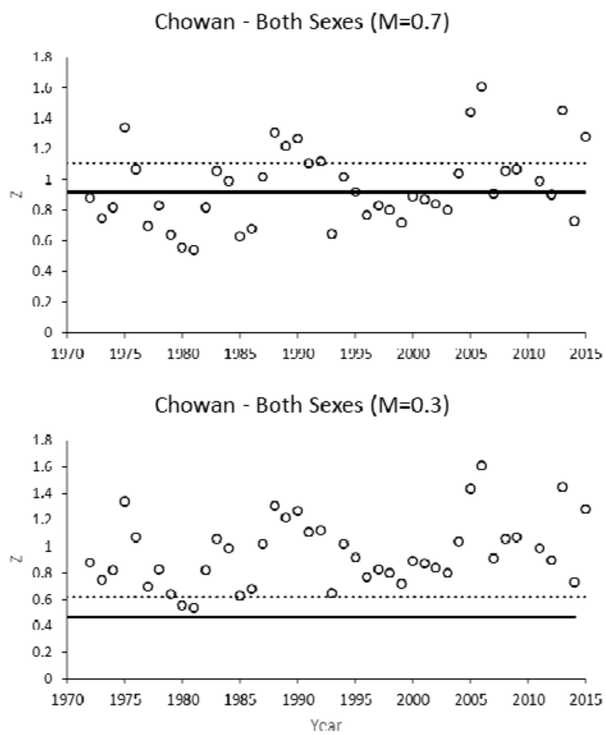


Figure 2.79 Empirical estimates of Z for NC blueback herring by river for different values of M. Dashed lines represent $Z_{20\%SPR}$ and $Z_{40\%SPR}$ benchmarks.

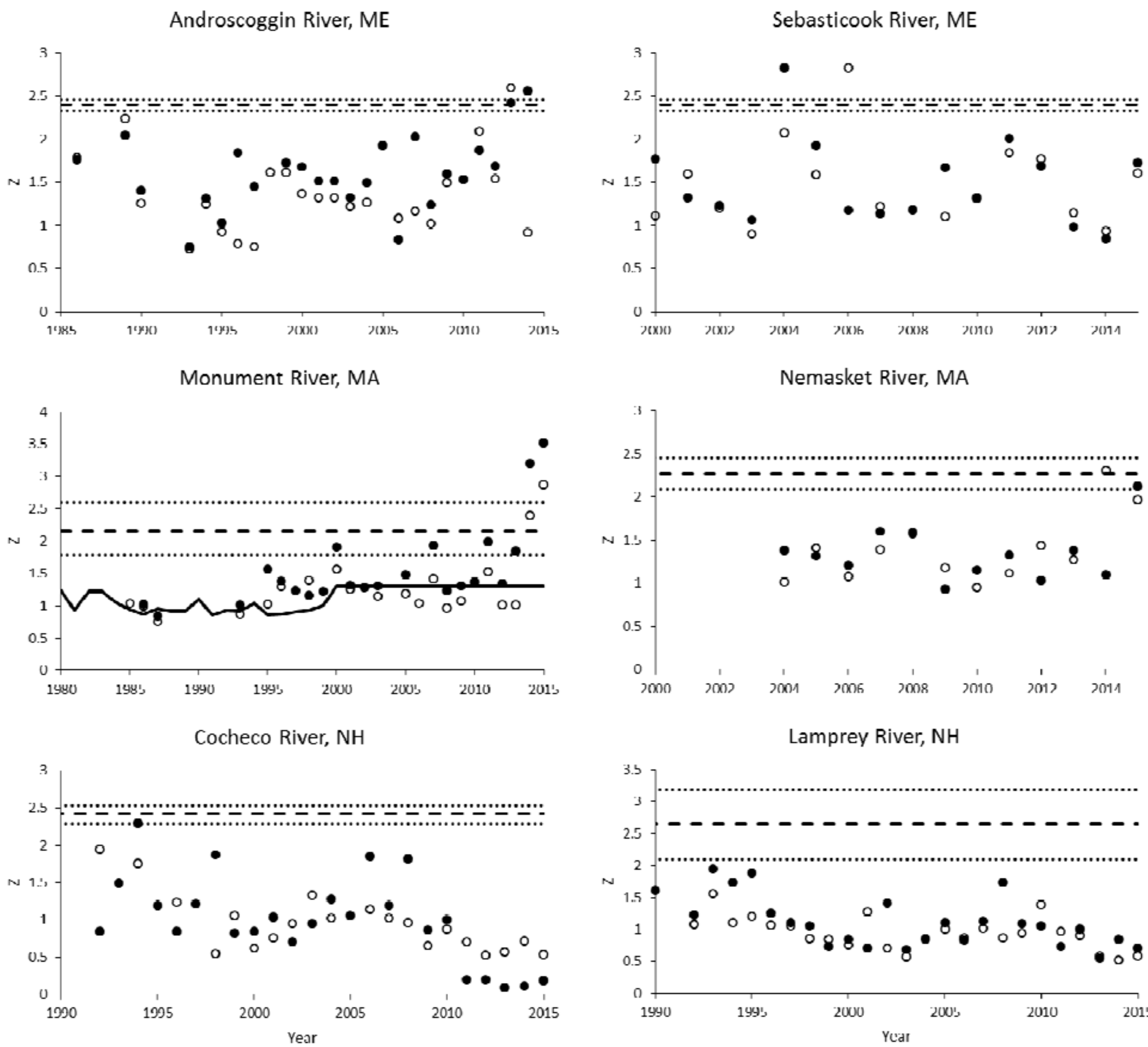


Figure 2.80 Plots of age-based Z estimates for male (closed circles) and female (open circles) alewife derived by using the Chapman-Robson (CR) survival estimator or derived in stock assessment models (solid line; SCAM) compared to the minimum/maximum (dotted lines) and average (dashed line) $Z_{collapse}$ values.

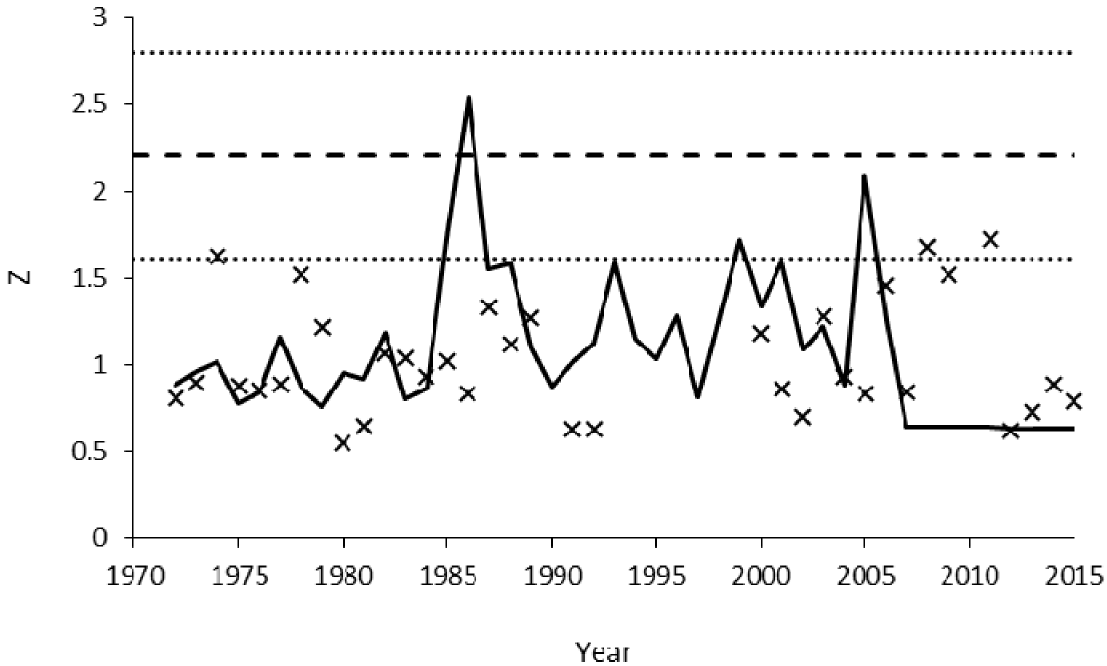


Figure 2.81 Plots of age-based Z estimates from the Chapman-Robson estimator (xs) and SCA model (solid line) for blueback herring in the Cowan River, NC compared to the minimum/maximum (dotted lines) and average (dashed line) $Z_{collapse}$ values.

APPENDIX 1. Summary of available river herring fisheries-independent and fisheries-dependent data.

State	River	Time series	By species	Harvest	Age	Length	Weight	Repeat Spawner	FI Adult	FI JAI	FD CPUE
ME	Damariscotta	1943-2015		●							
	St. George	1943-2015		●							
	Union	1975-2015		●							
	Orland	1943-2015		●							
	Androscoggin	1983-2015	●		●	●					
	Sebasticook	2000-2015	●		●	●					
	Merrymeeting Bay/Tribs	1979-2015	●			●				●	
	Gulf of Maine	2000-2015	●			●			●		
NH	Exeter/Squamscott	1991-2015	●	●	●	●		o	●		
	Lamprey	1991-2015	●	●	●	●		o	●		
	Winnicut	1991-2015	●	●	●	●		o	●		
	Oyster	1991-2015	●	●	●	●		o	●		
	Cocheco	1991-2015	●	●	●	●		o	●		
	Taylor	1991-2015	●	●	●	●		o	●		
	Great Bay Estuary	1997-2015	x			x				x	
MA	Mattapoisett	1988-2015	●	●	o	o	o		●		
	Monument	1980-2015	●	●	o	o		o	●		
	Nemasket	1996-2015	●	●	o	o	o				
	Parker	1971-1978, 2000-2015	●	●	o	o			●		
	Town	2000-2015		●					●		
	Agawam	2006-2015		●	o	o					
	Back	2007-2015	●	●	●	●			●		
	Charles	2008-2015		●	●	●	●	●	●		
	Mystic	2004-2015	●		●	●	●	●			
	Quashnet	2004	●		●	●	●	●			
	Stony Brook	1978-2004	●		o	o	o	o	o		
RI	Gilbert Stuart	1981-2015			●	●	●	●	●	o	
	Nonquit	1999-2015			●	●	●	●	●	o	
	Buckeye Brook	2003-2015							●		
	Pawcatuck	1988-2015			x	x	x	x	o	●	
	Ocean waters	1979-2015				●			●	●	
	Naragansett Bay	1988-2015				●			●	●	
	Coastal ponds	1992-2015				●			●	●	
CT	Bride Brook	1966-1967, 2003-2015	●			o			●		
	Connecticut River	1975-2015	●			o			●	o	
	Farmington River	1976-2015	●						●		
	Thames River	1996-2015	●						●		
NY	Hudson	1975-2015	●	o	o	o	o	o	o	o	o
DE, NJ, PA	Delaware River	1980-2015	o	o	o	o			o	o	o
	Delaware Bay	1966-2015	o	o	o	o			o	o	o
MD	Nanticoke	1959-2015	o		o	o		o		o	o
	Susquehanna	1972-2015	o						x		
	Chesapeake Bay	1959-2015			o						o
MD, VA, DC	Potomac River	1959-2015		●		o			o	o	o
VA	James	1966-2015	o	●	o	o	o	o	o	o	o
	Rappahannock	1966-2015	o	●	o	o	o	o	o	o	o
	York	1966-2015	o	●	o	o	o	o	o	o	o
NC	Albemarle Sound	1972-2015		o				o	o	●	
	Chowan River	1972-2015	●	●	●	●	●	o			●
SC	Wynah Bay									x	
	Santee-Cooper	1969-2015	o	●	o	o	o	o	o	x	●
	Savannah River									x	
	Ashley-Combahee-Edisto Basin									x	
GA	Altamaha River	2010								x	
	Ogeechee River	2010								x	
	Savannah River	2010								x	
FL	St. John's River	2001 -2015	●			●			●	o	

●	Data available for entire time-series
o	Data available for part of the time-series
x	Data available, but not reliable enough for assessment use
	Data not available

APPENDIX 2. Commercial and Recreational River Herring Regulations as of June 1, 2017.

State	River	Moratorium	Commercial Regs	Recreational Regs
ME	Long Pond		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Winnegance Pond		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Sebasticook River		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Narraguagus River		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Pleasant River		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Mill Pond		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Gardiner Lake		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Ellsworth		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Great Pond		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Card Mill Stream		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	West Bay Pond		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Nequasset Lake		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Dyer-Long Pond		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Damariscotta Lake		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Orland River		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Pennimaquan Lake		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Peirce Pond		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Boyden Lake		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Flanders Pond		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Tunk Lake		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	Webber Pond		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
	St. George River		Harvest 4 days/week through 6/5; biological samples	25 fish/day, gear restrictons
NH	Exeter/Squamscott		Harvest 2 days/week, 1 tote/person/day	
	Lamprey		Harvest 6 days/week	
	Winnicut		Harvest 6 days/week	
	Oyster	2012		
	Cocheco		Harvest 6 days/week	
	Taylor		Harvest 6 days/week, closed area	
MA	Mattapoisett	2005		
	Monument	2005		
	Nemasket			Harvest 5 days/week; 20 fish/permit
	Parker	2005		
	Town	2005		
	Agawam	2005		
	Back	2005		
	Charles	2005		
	Mystic	2005		
	Quashnet	2005		
	Stony Brook	2005		

State	River	Moratorium	Commercial Regs	Recreational Regs
RI	Gilbert Stuart	2006		
	Nonquit	2006		
	Buckeye Brook	2006		
	Pawcatuck	2006		
	Ocean waters	2006		
	Naragansett Bay	2006		
	Coastal ponds	2006		
CT	Bride Brook	2002		
	Connecticut River	2002		
	Farmington River	2002		
	Thames River	2002		
NY	Hudson			10 fish/person or 50 fish/boat
DE, NJ, PA	Delaware River	2012		
	Delaware Bay	2012		
MD	Nanticoke	2012		
	Susquehanna	2012		
	Chesapeake Bay	2012		
MD, VA, DC	Potomac River	2010	50 lb bycatch allowance	
VA	James	2012		
	Rappahannock	2012		
	York	2012		
NC	Albemarle Sound	2007		
	Chowan River	2007		
SC	Winyah Bay	2012		
	Waccamaw	2012		
	Little Pee Dee	2012		
	Black	2012		
	Great Pee Dee		Gear Restrictions, lift period; annual harvest up to 1,000 kg	1 bushel/day
	Santee-Cooper		10 bushels/boat/day, gear restrictions	1 bushel/day
	Ashepoo-Combahee-Edisto	2012		
	Savannah	2012		
GA	Altamaha River	2012		
	Ogeechee River	2012		
	Savannah River	2012		
FL	St. Mary's River	2012		