

SEDAR

Southeast Data, Assessment, and Review

SEDAR 34

Stock Assessment Report

HMS Atlantic Sharpnose Shark

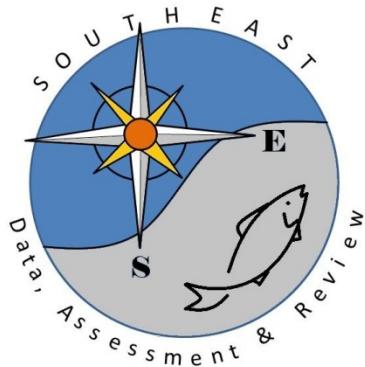
September 2013

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

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SECTION I: Introduction

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1. SEDAR PROCESS DESCRIPTION

SouthEast Data, Assessment, and Review (**SEDAR**) is a cooperative Fishery Management Council process initiated in 2002 to improve the quality and reliability of fishery stock assessments in the South Atlantic, Gulf of Mexico, and US Caribbean. SEDAR seeks improvements in the scientific quality of stock assessments and the relevance of information available to address fishery management issues. SEDAR emphasizes constituent and stakeholder participation in assessment development, transparency in the assessment process, and a rigorous and independent scientific review of completed stock assessments.

SEDAR is managed by the Caribbean, Gulf of Mexico, and South Atlantic Regional Fishery Management Councils in coordination with NOAA Fisheries and the Atlantic and Gulf States Marine Fisheries Commissions. Oversight is provided by a Steering Committee composed of NOAA Fisheries representatives: Southeast Fisheries Science Center Director and the Southeast Regional Administrator; Regional Council representatives: Executive Directors and Chairs of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; and Interstate Commission representatives: Executive Directors of the Atlantic States and Gulf States Marine Fisheries Commissions.

SEDAR is organized around two workshops and a series of webinars. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. The second stage is the Assessment Process, which is conducted via a series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. Third and final is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 3 workshops and all supporting documentation, is then forwarded to the Council SSC for certification as ‘appropriate for management’ and development of specific management recommendations.

SEDAR workshops are public meetings organized by SEDAR staff and the lead Cooperator. Workshop participants are drawn from state and federal agencies, non-government organizations, Council members, Council advisors, and the fishing industry with a goal of including a broad range of disciplines and perspectives. All participants are expected to contribute to the process by preparing working papers, contributing, providing assessment analyses, and completing the workshop report.

SEDAR Review Workshop Panels consist of a chair, 3 reviewers appointed by the Center for Independent Experts (CIE), and three reviewers appointed from the SSC of the Council having jurisdiction over the stocks being assessed. The Review Workshop Chair is appointed by the Council from their SSC. Participating councils may appoint additional representatives of their SSC, Advisory, and other panels as observers.

2. MANAGEMENT OVERVIEW

**Presented to the 2013 Data Workshop of the Atlantic Sharpnose and Bonnethead Shark
Stock Assessments (SEDAR 34)**

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1.0 Fishery Management Plans and Amendments

Given the interrelated nature of the shark fisheries, the following section provides an overview of shark management primarily since 1993 through 2012 for small coastal sharks, particularly Atlantic sharpnose and bonnethead sharks. The summary focuses only on those management actions that likely affect these two species. The latter part of the document is organized according to individual species. The management measures implemented under fishery management plans and amendments are also summarized in Table 1.

The U.S. Atlantic shark fisheries developed rapidly in the late 1970s due to increased demand for their meat, fins, and cartilage worldwide. At the time, sharks were perceived to be underutilized as a fishery resource. The high commercial value of shark fins led to the controversial practice of “finning,” or removing the valuable fins from sharks and discarding the carcasses. Growing demand for shark products encouraged expansion of the commercial fishery throughout the late 1970s and the 1980s. Tuna and swordfish vessels began to retain a greater proportion of their shark incidental catch and some directed fishery effort expanded as well.

Preliminary Fishery Management Plan (PMP) for Atlantic Billfish and Sharks

In January 1978, NMFS published the Preliminary Fishery Management Plan (PMP) for Atlantic Billfish and Sharks (43 FR 3818), which was supported by an Environmental Impact Statement (EIS) (42 FR 57716). This PMP was a Secretarial effort. The management measures contained in the plan were designed to:

1. Minimize conflict between domestic and foreign users of billfish and shark resources;
2. Encourage development of an international management regime; and
3. Maintain availability of billfishes and sharks to the expanding U.S. fisheries.

Primary shark management measures in the Atlantic Billfish and Shark PMP included:

- Mandatory data reporting requirements for foreign vessels;
- A hard cap on the catch of sharks by foreign vessels, which when achieved would prohibit further landings of sharks by foreign vessels;
- Permit requirements for foreign vessels to fish in the Fishery Conservation Zone (FCZ) of the United States;
- Radio checks by foreign vessels upon entering and leaving the FCZ;
- Boarding and inspection privileges for U.S. observers; and
- Prohibition on intentional discarding of fishing gears by foreign fishing vessels within the FCZ that may pose environmental or navigational hazards.

In the 1980s, the Regional Fishery Management Councils were responsible for the management of Atlantic highly migratory species (HMS). Thus, in 1985 and 1988, the five Councils finalized joint FMPs for swordfish and billfish, respectively. As catches accelerated through the 1980s, shark stocks started to show signs of decline. Peak commercial landings of large coastal and pelagic sharks were reported in 1989. In 1989, the five Atlantic Fishery Management Councils asked the Secretary of Commerce (Secretary) to develop a Shark Fishery Management Plan (FMP). The Councils were concerned about the late maturity and low

fecundity of sharks, the increase in fishing mortality, and the possibility of the resource being overfished. The Councils requested that the FMP cap commercial fishing effort, establish a recreational bag limit, prohibit finning, and begin a data collection system.

On November 28, 1990, the President of the United States signed into law the Fishery Conservation Amendments of 1990 (Pub. L. 101-627). This law amended the Magnuson Fishery Conservation and Management Act (later renamed the Magnuson-Stevens Fishery Conservation and Management Act or Magnuson-Stevens Act) and gave the Secretary the authority (effective January 1, 1992) to manage HMS in the exclusive economic zone (EEZ) of the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea under authority of the Magnuson-Stevens Act (16 U.S.C. §1811). This law also transferred from the Fishery Management Councils to the Secretary, effective November 28, 1990, the management authority for HMS in the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea (16 U.S.C. §1854(f)(3)). At this time, the Secretary delegated authority to manage Atlantic HMS to NMFS.

1993 Fishery Management Plan for Sharks of the Atlantic Ocean (1993 FMP)

In 1993, the Secretary of Commerce, through NMFS, implemented the FMP for Sharks of the Atlantic Ocean. The management measures in the 1993 FMP included:

- Establishing a fishery management unit (FMU) consisting of 39 frequently caught species of Atlantic sharks, separated into three groups for assessment and regulatory purposes (Large Coastal Sharks (LCS) (22 species), Small Coastal Sharks (SCS) (7 species), and pelagic sharks (10 species))¹;
- Annual quotas of 2,436 mt (dressed weight) for large coastal species group, 580 mt (dressed weight) for the pelagic species group, and no quota for small coastal sharks;
- Establishing a recreational trip limit of four sharks per vessel for LCS or pelagic shark species groups and a daily bag limit of five sharks per person for sharks in the SCS species group;
- Requiring that all sharks not taken as part of a commercial or recreational fishery be released uninjured;
- Prohibiting finning of large coastal sharks, small coastal sharks, and pelagic sharks by requiring that the ratio between wet fins/dressed carcass weight not exceed five percent;
- Prohibiting the sale by recreational fishermen of sharks or shark products caught in the Economic Exclusive Zone (EEZ);
- Requiring annual commercial permits for fishermen who harvest and sell shark products (meat products and fins);
- Establishing a permit eligibility requirement that the owner or operator (including charter vessel and headboat owners/operators who intend to sell their catch) must show proof

¹ Since this time, Atlantic sharpnose and bonnethead sharks have been managed within the small coastal shark complex.

that at least 50 percent of earned income has been derived from the sale of the fish or fish products or charter vessel and headboat operations or at least \$20,000 from the sale of fish during one of three years preceding the permit request;

- Requiring trip reports by permitted fishermen and persons conducting shark tournaments and requiring fishermen to provide information to NMFS under the Trip Interview Program; and,
- Requiring NMFS observers on selected shark fishing vessels to document mortality of marine mammals and endangered species.

1999 Fishery Management Plan for Atlantic Tunas, Swordfish and Sharks (1999 FMP)

In 1997, a new quota of 1,760 mt dw/year was established for SCS and new recreational bag limits were set (see Section 2.0 below). In 1999, NMFS published the 1999 FMP, which amended and replaced the 1993 FMP. Management measures related to sharks that changed in the 1999 FMP included:

- Maintaining an SCS quota of 1,760 mt dw/year;
- Reducing recreational retention limits for all sharks to 1 shark of any species at least 54" FL and 1 Atlantic sharpnose per person per trip (no minimum size);
- Expanding the list of prohibited shark species to 19 species²;
- Established essential fish habitat (EFH) for 39 species of sharks including Atlantic sharpnose and bonnethead sharks;
- Implementing limited access in commercial shark fisheries, including the small coastal shark fishery;
- Establishing a shark public display quota;
- Establishing new procedures for counting dead discards and state landings of sharks after Federal fishing season closures against Federal quotas; and
- Establishing season-specific over- and underharvest adjustment procedures.

The implementing regulations were published on May 28, 1999 (64 FR 29090). However, in 1999, a court enjoined implementation of the 1999 regulations, as they related to the ongoing litigation on the 1997 quotas. As such, many of the regulations in the 1999 FMP had a delayed implementation. These changes are explained below under Section 2.0.

² In addition to white, basking, sand tiger, bigeye sand tiger, whale sharks, which were already prohibited, NMFS prohibited Atlantic angel, bigeye sixgill, bigeye thresher, bignose, Caribbean reef, Caribbean sharpnose, dusky, Galapagos, longfin mako, narrowtooth, night, sevengill, sixgill, and smalltail sharks.

2003 Amendment 1 to the 1999 FMP for Atlantic Tunas, Swordfish, and Sharks (Amendment 1)

In 2002, additional LCS and SCS stock assessments were conducted. Based on these assessments, in Amendment 1 to the 1999 FMP, NMFS re-examined many of the shark management measures in the 1999 FMP for Atlantic Tunas, Swordfish, and Sharks. The changes in Amendment 1 affected all aspects of shark management. The final management measures affecting small coastal sharks (December 24, 2003, 68 FR 74746) selected in Amendment 1 included, among other things:

- Using maximum sustainable yield as a basis for setting commercial quotas;
- Establishing regional commercial quotas and trimester commercial fishing seasons;
- Removing the minimum size of 54" FL for bonnethead sharks and allowing recreational anglers 1 to possess bonnethead shark per person per trip;
- Establishing a mechanism for changing the species on the prohibited species list; and
- Updating essential fish habitat identifications for five species of sharks.

2006 Consolidated HMS FMP

NMFS issued two separate FMPs in April 1999 for the Atlantic HMS fisheries. The 1999 Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks combined, amended, and replaced previous management plans for swordfish and sharks, and was the first FMP for tunas. Amendment 1 to the Billfish Management Plan updated and amended the 1988 Billfish FMP. The 2006 Consolidated HMS FMP consolidated the management of all Atlantic HMS into one comprehensive FMP, adjusted the regulatory framework measures, continued the process for updating HMS EFH, and combined and simplified the objectives of the previous FMPs.

In 2005, NMFS released the draft Consolidated HMS FMP. In July 2006, the final Consolidated HMS FMP was completed and the implementing regulations were published on October 2, 2006 (71 FR 58058). Measures that were specific to the small coastal shark fisheries included:

- Mandatory workshops and certifications for all vessel owners and operators that have pelagic longline (PLL), bottom longline (BLL) gear, or gillnet gear on their vessels and that had been issued or were required to be issued any of the HMS limited access permits (LAPs) to participate in HMS longline and gillnet fisheries. These workshops provide information and ensure proficiency with using required

equipment to handle release and disentangle sea turtles, smalltooth sawfish, and other non-target species;

- Mandatory Atlantic shark identification workshops for all federally permitted shark dealers to train shark dealers to properly identify shark carcasses; and,
- The requirement that the 2nd dorsal fin and the anal fin remain on all sharks through landing.

The 2006 Consolidated HMS FMP also included a plan for preventing overfishing of finetooth sharks by expanding observer coverage, collecting more information on where finetooth sharks are being landed, and coordinating with other fisheries management entities that are contributing to finetooth shark fishing mortality.

2008 Amendment 2 to the 2006 Consolidated HMS FMP

In 2005/2006, new stock assessments were conducted on the LCS complex, sandbar, blacktip, porbeagle, and dusky sharks. Based on the results of those assessments, NMFS amended the 2006 Consolidated HMS FMP. On April 10, 2008, NMFS released the Final EIS for Amendment 2 to the Consolidated HMS FMP. The final measures in Amendment 2 focused on large coastal sharks. Some of the measures that may have impacted small coastal sharks include:

- Measures to reduce fishing mortality of overfished/overfishing stocks; and,
- Requiring that all Atlantic sharks be offloaded with fins naturally attached.

2010 Amendment 3 to the 2006 Consolidated HMS FMP (Amendment 3)

An SCS stock assessment was finalized during the summer of 2007, which assessed finetooth, Atlantic sharpnose, blacknose, and bonnethead sharks separately. Based on these assessments, NMFS determined that blacknose sharks were overfished with overfishing occurring; however, Atlantic sharpnose, bonnethead, and finetooth sharks were not overfished and overfishing was not occurring, and NMFS issued a Notice of Intent (NOI) announcing its intent to amend the 2006 Consolidated HMS FMP in order to rebuild blacknose sharks, among other things (May 7, 2008, 73 FR 25665).

On July 24, 2009 (74 FR 36706 and 74 FR 36892), the draft EIS and proposed rule were released, which considered a range of alternative management measures from several different topics including small coastal sharks (SCS) commercial quotas, commercial gear restrictions, pelagic shark effort controls, recreational measures for SCS and pelagic sharks, and smooth dogfish management measures. In order to rebuild blacknose sharks, NMFS proposed to establish a new blacknose shark specific quota of 14.9 mt dw and establish a new non-blacknose SCS quota of 56.9 mt dw. In addition, NMFS proposed to prohibit the landings of all sharks from South Carolina south using gillnet gear, and prohibit the landing of blacknose sharks in the recreational shark fishery. However, based on additional data and analyzes and public comment, in the final EIS (75 FR 13276, March 19, 2010) and final rule (75 FR 30484, June 1, 2010), NMFS finalized measures that:

- established a blacknose shark specific quota of 19.9 mt dw;
- established a new non-blacknose SCS quota of 221.6 mt dw (which includes landings of Atlantic sharpnose and bonnethead sharks);
- linked the blacknose and non-blacknose SCS quotas so that when one quota was reached, both fisheries would close together;
- allowed sharks to be landed with gillnet gear and recreational anglers to be able to retain blacknose sharks, as long as they meet the minimum recreational size limit.

Changes in fishing practices, particularly in the gillnet fishery, have occurred as a result of these regulations due to establishment of a blacknose shark quota which closes the other small coastal shark fishery when 80 percent of the quota is achieved. This may provide additional incentive to either avoid fishing in areas where blacknose sharks are present or discard these sharks at sea.

Amendment 5 to the 2006 Consolidated HMS FMP (Amendment 5)

Based on stock assessments completed between 2009 and 2012 for sandbar, dusky, blacknose, scalloped hammerhead, and Gulf of Mexico blacktip sharks, Amendment 5 proposed management measures that would reduce fishing mortality and allow rebuilding of some of these species. The proposed rule and DEIS were released on November 26, 2012 (77 FR 70552).

Amendment 6 to the 2006 Consolidated HMS FMP

In September 2010, NMFS published an Advanced Notice of Proposed Rulemaking (ANPR) (75 FR 57235) to seek public comment on alternative management strategies (quota structure, permit structure, and catch shares) that might better address these issues in the Atlantic shark fisheries. NMFS received comments on a variety of modifications to the existing management structure for the Atlantic shark fisheries, including programs such as catch shares, limited access privilege programs (LAPPs), individual fishing quotas (IFQs), and/or sectors. On September 16, 2011, (76 FR 57709) NMFS published a Notice of Intent (NOI) to prepare an EIS and FMP Amendment that would consider catch shares for the Atlantic shark fisheries. The purpose of the NOI was to establish a control date for eligibility to participate in an Atlantic shark catch share program, announce the availability of a white paper describing design elements of catch share programs in general and issues specific to the Atlantic shark fisheries, announce a catch share workshop at the upcoming HMS Advisory Panel meeting, and request public comment on the implementation of catch shares in the Atlantic shark fisheries.

Table 1 FMP Amendments and regulations affecting Atlantic sharpnose and bonnethead sharks.

| Effective Date | FMP/Amendment | Description of Action |
|----------------|---|---|
| January 1978 | Preliminary Fishery Management Plan (PMP) for Atlantic Billfish and | <ul style="list-style-type: none"> • Mandatory data reporting requirements for foreign vessels; and, • Established a hard cap on the catch of sharks by foreign vessels, which when achieved would prohibit further landings of sharks by foreign vessels |

| Effective Date | FMP/Amendment | Description of Action |
|--|---|---|
| | Sharks | |
| Most parts effective April 26, 1993, such as quotas, complexes, etc. Finning prohibition effective May 26, 1993. Need to have permit, report landings, and carry observers effective July 1, 1993. | FMP for Sharks of the Atlantic Ocean | <ul style="list-style-type: none"> Established a fishery management unit (FMU) consisting of 39 frequently caught species of Atlantic sharks, separated into three groups for assessment and regulatory purposes (LCS, SCS, and pelagic sharks); Established calendar year commercial quotas for the LCS (2,436 mt dw) and pelagic sharks (580 mt dw) and divided the annual quota into two equal half-year quotas that apply to the following two fishing periods – January 1 through June 30 and July 1 through December 31 (no quota established for SCS); Establishing a recreational trip limit of 4 LCS & pelagic sharks/vessel and a daily bag limit of 5 SCS/person; Prohibited finning by requiring that the ratio between wet fins/dressed carcass weight not exceed five percent; Prohibited the sale by recreational fishermen of sharks or shark products caught in the Economic Exclusive Zone (EEZ); Required annual commercial permits for fishermen who harvest and sell shark (meat products and fins); and, Requiring trip reports by permitted fishermen and persons conducting shark tournaments and requiring fishermen to provide information to NMFS under the Trip Interview Program. <p>Other management measures included: establishing a framework procedure for adjusting commercial quotas, recreational bag limits, species size limits, management unit, fishing year, species groups, estimates of maximum sustainable yield (MSY), and permitting and reporting requirements; establishing a permit eligibility requirement that the owner or operator (including charter vessel and headboat owners/operators who intend to sell their catch); and requiring NMFS observers on selected shark fishing vessels to document mortality of marine mammals and endangered species.</p> |
| July 1, 1999 -Limited access permits issued immediately; application and appeals processed over the next year (measures in italics were delayed) | FMP for Atlantic Tunas, Swordfish and Sharks | <ul style="list-style-type: none"> Implemented limited access in commercial fisheries; Reduced commercial SCS quota to 1,760 mt dw, respectively; Reduced recreational retention limits for all sharks to 1 shark/vessel/trip except for Atlantic sharpnose (1 Atlantic sharpnose/person/trip); Established a recreational minimum size for all sharks except Atlantic sharpnose (4.5 feet or 54" FL); Established a shark public display quota (60 mt ww); Expanded the list of prohibited shark species (in addition to sand tiger, bigeye sand tiger, basking, whale, and white sharks, prohibited Atlantic angel, bigeye sixgill, bigeye thresher, bignose, Caribbean reef, Caribbean sharpnose, dusky, galapagos, longfin mako, narrowtooth, night, sevengill, sixgill, smalltail sharks) (<i>effective July 1, 2000</i>); Established new procedures for counting dead discards and state landings of sharks after Federal fishing season closures against Federal quotas; and established season-specific over- and underharvest adjustment procedures (<i>effective January 1, 2003</i>); |
| February 1, 2004, except LCS and SCS quotas, and recreational | Amendment 1 to the FMP for Atlantic Tunas, Swordfish and Sharks | <ul style="list-style-type: none"> Established gear restrictions to reduce bycatch or reduce bycatch mortality (allowed only handline and rod and reel in recreational shark fishery); Used maximum sustainable yield as a basis for setting commercial quotas (SCS quota = 454 mt dw) (<i>effective December 30, 2003</i>); Adjusted the recreational bag and size limits (allowed 1 bonnethead/person/trip in addition to 1 Atlantic sharpnose/person/trip |

| Effective Date | FMP/Amendment | Description of Action |
|---|--|--|
| retention and size limits, which were delayed | | <p>with no size limit for bonnethead or Atlantic sharpnose) (<i>effective December 30, 2003</i>);</p> <ul style="list-style-type: none"> • Established regional commercial quotas and trimester commercial fishing seasons (<i>trimesters not implemented until January 1, 2005; 69 FR 6964</i>); and, <p>Other management measures included: requiring the use of non-stainless steel corrodible hooks and the possession of line cutters, dipnets, and approved dehooking device on BLL vessels; requiring vessel monitoring systems (VMS) for fishermen operating on gillnet vessels operating during the right whale calving season.</p> |
| November 1, 2006, except for workshops | Consolidated HMS FMP | <ul style="list-style-type: none"> • The requirement that the 2nd dorsal fin and the anal fin remain on all sharks through landing; • Mandatory workshops and certifications for all vessel owners and operators that have PLL, BLL, or gillnet gear on their vessels for fishermen with HMS LAPs (<i>effective January 1, 2007</i>); and • Mandatory Atlantic shark identification workshops for all Federally permitted shark dealers (<i>effective January 1, 2007</i>). |
| July 24, 2008 | Amendment 2 to the 2006 Consolidated HMS FMP | <ul style="list-style-type: none"> • Established a shark research fishery which collects shark life history information; • Implemented commercial quotas and retention limits consistent with stock assessment recommendations to prevent overfishing and rebuild overfished stocks; • Modified recreational measures to reduce fishing mortality of overfished/overfishing stocks (prohibiting the retention of silky and sandbar sharks for recreational anglers); • Required that all Atlantic sharks be offloaded with fins naturally attached; and, • Implemented BLL time/area closures recommended by the South Atlantic Fishery Management Council. |
| June 1, 2010 | Amendment 3 to the 2006 Consolidated HMS FMP | <ul style="list-style-type: none"> • Established a non-blacknose SCS quota of 221.6 mt and a blacknose-specific quota of 19.9 mt. |
| Proposed rule published Nov. 26, 2012 | Amendment 5 to the 2006 Consolidated HMS FMP | <ul style="list-style-type: none"> • Proposed management measures consistent with recent stock assessments for sandbar, dusky, scalloped hammerhead, Gulf of Mexico blacktip, and Atlantic and Gulf of Mexico blacknose sharks |
| NOI published Sept. 16, 2011 | Amendment 6 to the 2006 Consolidated HMS FMP | <ul style="list-style-type: none"> • Consider catch shares for the Atlantic shark fisheries |

2.0 Emergency and Other Major Rules

In response to a 1996 LCS stock assessment, in 1997, NMFS reduced the LCS commercial quota by 50 percent to 1,285 mt dw and the recreational retention limit to two LCS, SCS, and pelagic sharks combined per trip with an additional allowance of two Atlantic sharpnose sharks per person per trip (62 FR 16648, April 2, 1997). In this same rule, NMFS established an annual commercial quota for SCS of 1,760 mt dw and prohibited possession of

five LCS: sand tiger, bigeye sand tiger, whale, basking, and white sharks. On May 2, 1997, the Southern Offshore Fishing Association (SOFA) and other commercial fishermen and dealers sued the Secretary of Commerce (Secretary) on the April 1997 regulations.

In May 1998, NMFS completed its consideration of the economic effects of the 1997 LCS quotas on fishermen and submitted the analysis to the court. NMFS concluded that the 1997 LCS quotas may have had a significant economic impact on a substantial number of small entities and that there were no other available alternatives that would both mitigate those economic impacts and ensure the viability of the LCS stocks. Based on these findings, the court allowed NMFS to maintain those quotas while the case was settled in combination with litigation mentioned below regarding the 1999 FMP.

Rules in Relation to the 1999 FMP

On November 21, 2000, SOFA *et al.* and NMFS reached a settlement agreement for the May 1997 and June 1999 lawsuits. On December 7, 2000, the United States District Court for the Middle District of Florida entered an order approving the settlement agreement and lifting the injunction. The settlement agreement required, among other things, an independent (*i.e.*, non-NMFS) review of the 1998 LCS stock assessment. The settlement agreement did not address any regulations affecting the pelagic shark, prohibited species, or recreational shark fisheries. Once the injunction was lifted, on January 1, 2001, the pelagic shark quotas adopted in the 1999 FMP were implemented (66 FR 55). Additionally, on March 6, 2001, NMFS published an emergency rule implementing the settlement agreement (66 FR 13441). This emergency rule expired on September 4, 2001, and established, among other things, a SCS commercial quota of 1,760 mt dw that was the same as 1997 quota levels.

In late 2001, the Agency received the results of the independent peer review of the 1998 LCS stock assessment. These peer reviews found that the 1998 LCS stock assessment was not the best available science for LCS. Taking into consideration the settlement agreement, the results of the peer reviews of the 1998 LCS stock assessment, current catch rates, and the best available scientific information (not including the 1998 stock assessment projections), NMFS implemented another emergency rule for the 2002 fishing year that suspended certain measures under the 1999 regulations pending completion of new LCS and SCS stock assessments and a peer review of the new LCS stock assessment (66 FR 67118, December 28, 2001; extended 67 FR 37354, May 29, 2002). Specifically, among other things, NMFS maintained the 1997 SCS commercial quota (1,760 mt dw). That emergency rule expired on December 30, 2002.

In addition, on May 8, 2002, NMFS announced the availability of a SCS stock assessment (67 FR 30879). The Mote Marine Laboratory and the University of Florida provided NMFS with another SCS assessment in August 2002. Both of these stock assessments indicated that finetooth sharks were experiencing overfishing while the three other species in the SCS complex (Atlantic sharpnose, bonnethead, and blacknose) were not overfished and overfishing was not occurring.

Based on the results of both the 2002 SCS and LCS stock assessments, NMFS implemented an emergency rule to ensure that the commercial management measures in place for the 2003 fishing year were based on the best available science (67 FR 78990, December 27, 2002; extended 68 FR 31987, May 29, 2003). Specifically, the emergency rule implemented the LCS ridgeback/non-ridgeback split established in the 1999 FMP (the ridgeback quota was set at 783 mt dw and the non-ridgeback quota was set at 931 mt dw), suspended the commercial ridgeback LCS minimum size, and allowed both the season-specific quota adjustments and the counting of all mortality measures to go into place, and reduced the SCS annual commercial quota to 325 mt dw. Additionally, NMFS announced its intent to conduct an EIS and amend the 1999 FMP (67 FR 69180, November 15, 2002).

Rules in Relation to 2003 Amendment 1

Based on the 2002 LCS stock assessment, NMFS re-examined many of the shark management measures in the 1999 FMP for Atlantic Tunas, Swordfish, and Sharks. The changes in Amendment 1 affected all aspects of shark management. Shortly after the final rule for Amendment 1 was published, NMFS conducted a rulemaking that adjusted the percent quota for each region, changed the seasonal split for the North Atlantic based on historical landing patterns, finalized a method of changing the split between regions and/or seasons as necessary to account for changes in the fishery over time, and established a method to adjust from semi-annual to trimester seasons (November 30, 2004, 69 FR 6954).

Shark Rules After 2006 Consolidated HMS FMP

On February 16, 2006, NMFS published a temporary rule (71 FR 8223) to prohibit, through March 31, 2006, any vessel from fishing with any gillnet gear in the Atlantic Ocean waters between 32°00' N. Lat. (near Savannah, GA) and 27°51' N. Lat. (near Sebastian Inlet, FL) and extending from the shore eastward out to 80°00' W. long under the authority of the Atlantic Large Whale Take Reduction Plan (ALWTRP) (50 CFR 229.32 (g)) and ESA. NMFS took this action based on its determination that a right whale mortality was the result of an entanglement by gillnet gear within the Southeast U.S. Restricted Area in January of 2006.

NMFS implemented the final rule on June 25, 2007 (72 FR 34632), that prohibits gillnet fishing, including shark gillnet fishing, from November 15 to April 15, between the NC/SC border and 29° 00' N. The action was taken to prevent the significant risk to the wellbeing of endangered right whales from entanglement in gillnet gear in the core right whale calving area during calving season. Limited exemptions to the fishing prohibitions are provided for gillnet fishing for sharks and for Spanish mackerel south of 29°00' N. lat. Shark gillnet vessels fishing between 29° 00' N and 26° 46.5' N have certain requirements as outlined 50 CFR § 229.32 from December 1 through March 31 of each year. These include vessel operators contacting the Southeast Fisheries Science Center (SEFSC) Panama City Laboratory at least 48 hours prior to departure of a fishing trip in order to arrange for an observer.

In addition, a 2007 rule (October 5, 2007, 72 FR 57104) amended restrictions in the Southeast U.S. Monitoring Area from December 1 through March 31. In that area, no person may fish with or possess gillnet gear for sharks with webbing of 5" or greater stretched mesh unless the operator of the vessel is in compliance with the VMS requirements found in 50 CFR 635.69. The Southeast U.S. Monitoring Area is from 27°51' N. (near Sebastian Inlet, FL) south to 26°46.5' N. (near West Palm Beach, FL), extending from the shoreline or exemption line eastward to 80°00' W. In addition, NMFS may select any shark gillnet vessel regulated under the ALWTRP to carry an observer. When selected, the vessels are required to take observers on a mandatory basis in compliance with the requirements for at-sea observer coverage found in 50 CFR 229.7. Any vessel that fails to carry an observer once selected is prohibited from fishing pursuant to 50 CFR § 635. There are additional gear marking requirements that can be found at 50 CFR § 229.32.

In 2007, NMFS expanded the equipment required for the safe handling, release, and disentanglement of sea turtles caught in the Atlantic shark BLL fishery (72 FR 5633, February 7, 2007). As a result, equipment required for BLL vessels is now consistent with the requirements for the PLL fishery. Furthermore, this action implemented several year-round BLL closures to protect EFH to maintain consistency with the Caribbean Fishery Management Council.

Table 2 Chronological list of most of the Federal Register publications relating to Atlantic sharks.

| Federal Register Cite | Date | Rule or Notice |
|------------------------------|-------------|--|
| <i>Pre 1993</i> | | |
| 48 FR 3371 | 1/25/1983 | Preliminary management plan with optimum yield and total allowable level of foreign fishing for sharks |
| 56 FR 20410 | 5/3/1991 | NOA of draft FMP; 8 hearings |
| 57 FR 1250 | 1/13/1992 | NOA of Secretarial FMP |
| 57 FR 24222 | 6/8/1992 | Proposed rule to implement FMP |
| 57 FR 29859 | 7/7/1992 | Correction to 57 FR 24222 |
| <i>1993</i> | | |
| 58 FR 21931 | 4/26/1993 | Final rule and interim final rule implementing FMP |
| 58 FR 27336 | 5/7/1993 | Correction to 58 FR 21931 |
| 58 FR 27482 | 5/10/1993 | LCS commercial fishery closure announcement |
| 58 FR 40075 | 7/27/1993 | Adjusts 1993 second semi-annual quotas |
| 58 FR 40076 | 7/27/1993 | LCS commercial fishery closure announcement |
| 58 FR 46153 | 9/1/1993 | Notice of 13 public scoping meetings |
| 58 FR 59008 | 11/5/1993 | Extension of comment period for 58 FR 46153 |
| 58 FR 68556 | 12/28/1993 | Interim final rule implementing trip limits |
| <i>1994</i> | | |
| 59 FR 3321 | 1/21/1994 | Extension of comment period for 58 FR 68556 |
| 59 FR 8457 | 2/22/1994 | Notice of control date for entry |
| 59 FR 25350 | 5/16/1994 | LCS commercial fishery closure announcement |
| 59 FR 33450 | 6/29/1994 | Adjusts second semi-annual 1994 quota |
| 59 FR 38943 | 8/1/1994 | LCS commercial fishery closure announcement |
| 59 FR 44644 | 8/30/1994 | Reopens LCS fishery with new closure date |
| 59 FR 48847 | 9/23/1994 | Notice of public scoping meetings |
| 59 FR 51388 | 10/11/1994 | Rescission of LCS closure |
| 59 FR 52277 | 10/17/1994 | Notice of additional scoping meetings |
| 59 FR 52453 | 10/18/1994 | Final rule implementing interim final rule in 1993 FMP |
| 59 FR 55066 | 11/3/1994 | LCS commercial fishery closure announcement |
| <i>1995</i> | | |
| 60 FR 2071 | 1/6/1995 | Proposed rule to adjust quotas |
| 60 FR 21468 | 5/2/1995 | Final rule indefinitely establishes LCS quota at 1994 level |
| 60 FR 27042 | 5/22/1995 | LCS commercial fishery closure announcement |
| 60 FR 30068 | 6/7/1995 | Announcement of Shark Operations Team meeting |
| 60 FR 37023 | 7/19/1995 | Adjusts second semi-annual 1995 quota |
| 60 FR 38785 | 7/28/1995 | ANPR - Options for Permit Moratoria |
| 60 FR 44824 | 8/29/1995 | Extension of ANPR comment period |
| 60 FR 49235 | 9/22/1995 | LCS commercial fishery closure announcement |
| 60 FR 61243 | 11/29/1995 | Announces Limited Access Workshop |
| <i>1996</i> | | |
| 61 FR 21978 | 5/13/1996 | LCS commercial fishery closure announcement |
| 61 FR 37721 | 7/19/1996 | Announcement of Shark Operations Team meeting. |
| 61 FR 39099 | 7/26/1996 | Adjusts second semi-annual 1996 quota |
| 61 FR 43185 | 8/21/1996 | LCS commercial fishery closure announcement |

| Federal Register Cite | Date | Rule or Notice |
|------------------------------|-------------|--|
| 61 FR 67295 | 12/20/1996 | Proposed rule to reduce Quotas/Bag Limits |
| 61 FR 68202 | 12/27/1996 | Proposed rule to establish limited entry (Draft Amendment 1 to 1993 FMP) |
| 1997 | | |
| 62 FR 724 | 1/6/1997 | NOA of Draft Amendment 1 to 1993 FMP |
| 62 FR 1705 | 1/13/1997 | Notice of 11 public hearings for Amendment 1 |
| 62 FR 1872 | 1/14/1997 | Extension of comment period and notice of public hearings for proposed rule on quotas |
| 62 FR 4239 | 1/29/1997 | Extension of comment period for proposed rule on quotas |
| 62 FR 8679 | 2/26/1997 | Extension of comment period for Amendment 1 to 1993 FMP |
| 62 FR 16647 | 4/7/1997 | Final rule reducing quotas/bag limits |
| 62 FR 16656 | 4/7/1997 | LCS commercial fishery closure announcement |
| 62 FR 26475 | 5/14/1997 | Announcement of Shark Operations Team meeting |
| 62 FR 26428 | 5/14/1997 | Adjusts second semi-annual 1997 LCS quota |
| 62 FR 27586 | 5/20/1997 | Notice of Intent to prepare an supplemental environmental impact statement |
| 62 FR 27703 | 5/21/1997 | Technical Amendment regarding bag limits |
| 62 FR 38942 | 7/21/1997 | LCS commercial fishery closure announcement |
| 1998 | | |
| 63 FR 14837 | 3/27/1998 | LCS commercial fishery closure announcement |
| 63 FR 19239 | 4/17/1998 | NOA of draft consideration of economic effects of 1997 quotas |
| 63 FR 27708 | 5/20/1998 | NOA of final consideration of economic effects of 1997 quotas |
| 63 FR 29355 | 5/29/1998 | Adjusts second semi-annual 1998 LCS quota |
| 63 FR 41736 | 8/5/1998 | LCS commercial fishery closure announcement |
| 63 FR 57093 | 10/26/1998 | NOA of draft 1999 FMP |
| 1999 | | |
| 64 FR 3154 | 1/20/1999 | Proposed rule for draft 1999 FMP |
| 64 FR 14154 | 3/24/1999 | LCS commercial fishery closure announcement |
| 64 FR 29090 | 5/28/1999 | Final rule for 1999 FMP |
| 64 FR 30248 | 6/7/1999 | Fishing season notification |
| 64 FR 37700 | 7/13/1999 | Technical amendment to 1999 FMP final rule |
| 64 FR 37883 | 7/14/1999 | Fishing season change notification |
| 64 FR 47713 | 9/1/1999 | LCS fishery reopening |
| 64 FR 52772 | 9/30/1999 | Notice of Availability of outline for National Plan of Action for sharks |
| 64 FR 53949 | 10/5/1999 | LCS closure postponement |
| 64 FR 66114 | 11/24/1999 | Fishing season notification |
| 2000 | | |
| 65 FR 16186 | 3/27/2000 | Revised timeline for National Plan of Action for sharks |
| 65 FR 35855 | 6/6/2000 | Fishing season notification and 2nd semi-annual LCS quota adjustment |
| 65 FR 47214 | 8/1/2000 | Final rule closing Desoto Canyon, Florida East Coast, and Charleston Bump and requiring live bait for PLL gear in Gulf of Mexico |
| 65 FR 47986 | 8/4/2000 | Notice of Availability of National Plan of Action for sharks |
| 65 FR 38440 | 6/21/2000 | Implementation of prohibited species provisions and closure change |
| 65 FR 60889 | 10/13/2000 | Final rule closed NED and required dipnets and line clippers for PLL |

| Federal Register Cite | Date | Rule or Notice |
|------------------------------|-------------|--|
| | | vessels |
| 65 FR 75867 | 12/5/2000 | Fishing season notification |
| 2001 | | |
| 66 FR 55 | 1/2/2001 | Implementation of 1999 FMP pelagic shark quotas |
| 66 FR 10484 | 2/15/2001 | NOA of Final National Plan of Action for the Conservation and Management of Sharks |
| 66 FR 13441 | 3/6/2001 | Emergency rule to implement settlement agreement |
| 66 FR 33918 | 6/26/2001 | Fishing season notification and 2nd semi-annual LCS quota adjustment |
| 66 FR 34401 | 6/28/2001 | Proposed rule to implement national finning ban |
| 66 FR 36711 | 7/13/2001 | Emergency rule implementing 2001 BiOp requirements |
| 66 FR 46401 | 9/5/2001 | LCS fishing season extension |
| 66 FR 48812 | 9/24/2001 | Amendment to emergency rule (66 FR 13441) to incorporate change in requirement for handling and release guidelines |
| 66 FR 67118 | 12/28/2001 | Emergency rule to implement measures based on results of peer review and fishing season notification |
| 2002 | | |
| 67 FR 6194 | 2/11/2002 | Final rule implementing national shark finning ban |
| 67 FR 8211 | 2/22/2002 | Correction to fishing season notification 66 FR 67118 |
| 67 FR 30879 | 5/8/2002 | Notice of availability of SCS stock assessment |
| 67 FR 36858 | 5/28/2002 | Notice of availability of LCS sensitivity document and announcement of stock evaluation workshop in June |
| 67 FR 37354 | 5/29/2002 | Extension of emergency rule and fishing season announcement |
| 67 FR 45393 | 7/9/2002 | Final rule to implement measures under 2001 BiOp (gangion placement measure not implemented), including HMS shark gillnet measures |
| 67 FR 64098 | 10/17/2002 | Notice of availability of LCS stock assessment and final meeting report |
| 67 FR 69180 | 11/15/2002 | Notice of intent to conduct an environmental impact assessment and amend the 1999 FMP |
| 67 FR 72629 | 12/6/2002 | Proposed rule regarding EFPs |
| 67 FR 78990 | 12/27/2002 | Emergency rule to implement measures based on stock assessments and fishing season notification |
| 2003 | | |
| 68 FR 1024 | 1/8/2003 | Announcement of 4 public hearings on emergency rule |
| 68 FR 1430 | 1/10/2003 | Extension of comment period for proposed rule on EFPs |
| 68 FR 3853 | 1/27/2003 | Announcement of 7 scoping meetings and notice of availability of Issues and Options paper |
| 68 FR 31983 | 5/29/2003 | Emergency rule extension and fishing season notification |
| 68 FR 45196 | 8/1/2003 | Proposed rule and NOA for draft Amendment 1 to 1999 FMP |
| 68 FR 47904 | 8/12/2003 | Public hearing announcement for draft Amendment 1 to 1999 FMP |
| 68 FR 51560 | 8/27/2003 | Announcement of HMS AP meeting on draft Amendment 1 to 1999 FMP |
| 68 FR 54885 | 9/19/2003 | Rescheduling of public hearings and extending comment period for draft Amendment 1 to 1999 FMP |
| 68 FR 64621 | 11/14/2003 | NOA of availability of Amendment 1 |
| 68 FR 66783 | 11/28/2003 | NOI for SEIS |

| Federal Register Cite | Date | Rule or Notice |
|------------------------------|-------------|---|
| 68 FR 74746 | 12/24/2003 | Final Rule for Amendment 1 |
| 2004 | | |
| 69 FR 6621 | 02/11/04 | Proposed rule for PLL fishery |
| 69 FR 10936 | 3/9/2004 | SCS fishery closure |
| 69 FR 19979 | 4/15/2004 | VMS type approval notice |
| 69 FR 26540 | 5/13/2004 | N. Atlantic Quota Split Proposed Rule |
| 69 FR 28106 | 5/18/2004 | VMS effective date proposed rule |
| 69 FR 30837 | 6/1/2004 | Fishing season notice |
| 69 FR 33321 | 6/15/2004 | N. Atlantic Quota Split Final Rule |
| 69 FR 40734 | 07/06/04 | Final rule for PLL fishery |
| 69 FR 44513 | 07/26/04 | Notice of sea turtle release/protocol workshops |
| 69 FR 47797 | 8/6/2004 | Technical amendment correcting changes to BLL gear requirements |
| 69 FR 49858 | 08/12/04 | Advanced notice of proposed rulemaking; reducing sea turtle interactions with fishing gear |
| 69 FR 51010 | 8/17/2004 | VMS effective date final rule |
| 69 FR 56024 | 9/17/2004 | Regional quota split proposed rule |
| 69 FR 6954 | 11/30/2004 | Regional quota split final rule and season announcement |
| 69 FR 71735 | 12/10/2004 | Correction notice for 69 FR 6954 |
| 2005 | | |
| 70 FR 11922 | 3/10/2005 | 2nd and 3rd season proposed rule |
| 70 FR 21673 | 4/27/2005 | 2nd and 3rd season final rule |
| 70 FR 24494 | 5/10/2005 | North Carolina Petition for Rulemaking |
| 70 FR 29285 | 5/20/2005 | Notice of handling and release workshops for BLL fishermen |
| 70 FR 48804 | 8/19/2005 | Proposed rule Draft Consolidated HMS FMP |
| 70 FR 48704 | 8/19/2005 | NOA of Draft EIS for Draft Consolidated HMS FMP |
| 70 FR 52380 | 9/2/2005 | Correction to 70 FR 48704 |
| 70 FR 53146 | 9/7/2005 | Cancellation of hearings due to Hurricane Katrina |
| 70 FR 54537 | 9/15/2005 | Notice of LCS data workshop |
| 70 FR 55814 | 9/23/2005 | Cancellation of Key West due to Hurricane Rita |
| 70 FR 58190 | 10/5/2005 | Correction to 70 FR 54537 |
| 70 FR 58177 | 10/5/2005 | Extension of comment period for Draft Consolidated HMS FMP |
| 70 FR 58366 | 10/6/2005 | 1st season proposed rule |
| 70 FR 72080 | 12/1/2005 | 1 st season final rule, fishing season notification |
| 70 FR 73980 | 12/14/2005 | Final Agency decision on petition for rulemaking to amend mid-Atlantic closed area |
| 70 FR 76031 | 12/22/2005 | Notice for Large Coastal Shark 2005/2006 Stock Assessment Workshop |
| 70 FR 76441 | 12/27/2005 | Rescheduling and addition of public hearings for Consolidated HMS FMP |
| 2006 | | |
| 71 FR 8223 | 2/16/2006 | Temporary rule prohibiting gillnet gear in areas around the Southeast U.S. Restricted Area |
| 71 FR 8557 | 2/17/2006 | Proposed Rule for third and second trimester seasons |
| 71 FR 12185 | 3/9/2006 | Notice for Large Costal Shark Review Workshop |
| 71 FR 15680 | 3/29/2006 | Proposed rule for gear operation and deployment for BLL and gillnet fishery and complementary closure |
| 71 FR 16243 | 3/31/2006 | Final rule for second and third trimester seasons |

| Federal Register Cite | Date | Rule or Notice |
|------------------------------|-------------|---|
| 71 FR 26351 | 5/4/2006 | Scientific research permit for pelagic shark research |
| 71 FR 30123 | 5/25/2006 | Notice of availability of stock assessment of dusky sharks |
| 71 FR 41774 | 7/24/2006 | Notice of availability of final stock assessment for Large Coastal Sharks |
| 71 FR 58058 | 10/2/2006 | Final Rule for the HMS Consolidated Fishery Management Plan |
| 71 FR 58058 | 10/2/2006 | 1st season proposed rule |
| 71 FR 62095 | 10/23/2006 | Notice of shark dealer identification workshops and protected species safe handling and release workshops |
| 71FR 64213 | 11/1/2006 | Extension of comment period regarding the 2007 first trimester season proposed rule |
| 71 FR 65086 | 11/7/2006 | Notice of Intent to prepare Amendment 2 to the 2006 Consolidated HMS FMP and status determination for sandbar, blacktip, dusky, the LCS complex, and porbeagle sharks based on the latest stock assessments |
| 71 FR 65087 | 11/7/2006 | Notice of Intent to prepare Amendment 1 to the 2006 Consolidated HMS FMP for Essential Fish Habitat for Some Atlantic Highly Migratory Species |
| 71 FR 66154 | 11/13/2006 | Extension of comment period regarding the 2007 first trimester season proposed rule |
| 71 FR 68561 | 11/27/2006 | Notice of shark dealer identification workshops and protected species safe handling and release workshops |
| 71 FR 75122 | 12/14/2006 | Final Rule and Temporary Rule for the 2007 first trimester season and south Atlantic quota modification |
| 71 FR 75714 | 12/18/2006 | Notice of shark dealer identification workshops and protected species safe handling and release workshops |
| 2007 | | |
| 72 FR 123 | 1/3/2007 | Notice of public hearings for scoping for Amendment 2 to the 2006 Consolidated HMS FMP |
| 72 FR 5633 | 2/7/2007 | Final rule for gear operation and deployment for BLL and gillnet fishery and complementary closures |
| 72 FR 6966 | 2/14/2007 | Notice of closure of the Small Coastal Shark fishery for the Gulf of Mexico |
| 72 FR 7417 | 2/15/2007 | Revised list of equipment models for careful release of sea turtles in the PLL and BLL fisheries |
| 72 FR 8695 | 2/27/2007 | Notice of new VMS type approval for HMS fisheries and other programs |
| 72 FR 10480 | 3/8/2007 | Proposed rule for second and third trimester seasons |
| 72 FR 11335 | 3/13/2007 | Schedule of public protected resources dehooking workshops and Atlantic shark identification workshops |
| 72 FR 19701 | 4/19/2007 | Notice of Small Costal Shark stock assessment workshop |
| 72 FR 20765 | 4/26/2007 | Final rule for second and third trimester season |
| 72 FR 32836 | 6/14/2007 | Schedule of public protected resources dehooking workshops and Atlantic shark identification workshops |
| 72 FR 34632 | 6/25/2007 | Final rule prohibiting gillnet gear from November 15-April 15 between NC/SC border and 29°00'N. |
| 72 FR 39606 | 7/18/2007 | Notice of Small Costal Shark 2007 peer review workshop |
| 72 FR 41392 | 7/27/2007 | Proposed rule for Amendment 2 to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan |
| 72 FR 52552 | 9/14/2007 | Schedules for Atlantic shark identification workshops and protected species |

| Federal Register Cite | Date | Rule or Notice |
|------------------------------|-------------|---|
| | | safe handling, release, and identification workshops |
| 72 FR 55729 | 10/1/2007 | Proposed rule for 2008 first trimester quotas |
| 72 FR 56330 | 10/3/2007 | Amendment 2 to the Consolidated FMP – extension of comment period |
| 72 FR 57104 | 10/5/2007 | Final rule amending restriction in the Southeast U.S. Monitoring Area |
| 72 FR 63888 | 11/13/2007 | Notice of Small Coastal Shark Stock Assessment - notice of availability |
| 72 FR 67580 | 11/29/2007 | Final rule for 2008 first trimester quotas |
| 2008 | | |
| 73 FR 11621 | 3/4/2008 | Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops |
| 73 FR 19795 | 4/11/2008 | Proposed rule for renewal of Atlantic tunas longline limited access permits; and, Atlantic shark dealer workshop attendance requirements |
| 73 FR 24922 | 5/6/2008 | Proposed rule for Atlantic tuna fisheries; gear authorization and turtle control devices |
| 73 FR 25665 | 5/7/2008 | Stock Status Determinations; Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS) for Amendment 3 to the 2006 Consolidated HMS FMP |
| 73 FR 32309 | 6/6/2008 | Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops |
| 73 FR 35778 | 6/24/2008 | Final rule for Amendment 2 to the 2006 Consolidated HMS FMP and fishing season notification |
| 73 FR 35834 | 6/24/2008 | Shark research fishery; Notice of intent; request for applications |
| 73 FR 37932 | 7/2/2008 | Notice of availability; notice of public scoping meetings; Extension of comment period for Amendment 3 to the 2006 Consolidated HMS FMP |
| 73 FR 38144 | 7/3/2008 | Final rule for renewal of Atlantic tunas longline limited access permits; and, Atlantic shark dealer workshop attendance requirements |
| 73 FR 40658 | 7/15/2008 | Final rule for Amendment 2 to the 2006 Consolidated HMS FMP and fishing season notification; correction/republication |
| 73 FR 47851 | 8/15/2008 | Effectiveness of collection-of-information requirements to implement fins-on check box on Southeast dealer form |
| 73 FR 51448 | 9/3/2008 | Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops |
| 73 FR 53408 | 9/16/2008 | Notice of public meeting, public hearing, and scoping meetings regarding the AP meeting and various other hearings/meetings |
| 73 FR 53851 | 9/17/2008 | Atlantic Shark Management Measures; Changing the time and location of a scoping meeting |
| 73 FR 54721 | 9/23/2008 | Final rule for Atlantic tuna fisheries; gear authorization and turtle control devices |
| 73 FR 63668 | 10/27/2008 | Proposed rule for 2009 shark fishing season |
| 73 FR 64307 | 10/29/2008 | Extension of scoping comment period for Amendment 3 to the 2006 Consolidated HMS FMP |
| 2009 | | |
| 74 FR 8913 | 2/27/2009 | Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops |
| 74 FR 26803 | 6/4/2009 | Inseason action to close the commercial Gulf of Mexico non-sandbar large coastal shark fishery |

| Federal Register Cite | Date | Rule or Notice |
|------------------------------|-------------|---|
| 74 FR 27506 | 6/10/2009 | Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops |
| 74 FR 30479 | 6/26/2009 | Inseason action to close the commercial non-sandbar large coastal shark fisheries in the shark research fishery and Atlantic region |
| 74 FR 36892 | 7/24/2009 | Proposed rule for Amendment 3 to the 2006 Consolidated HMS FMP |
| 74 FR 39914 | 8/10/2009 | Extension of Comment Period for Amendment 3 to the 2006 Consolidated HMS FMP |
| 74 FR 46572 | 9/10/2009 | Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops |
| 74 FR 51241 | 10/6/2009 | Inseason action to close the commercial sandbar shark research fishery |
| 74 FR 55526 | 10/28/2009 | Proposed rule for 2010 shark fishing season |
| 74 FR 56177 | 10/30/2009 | Notice of intent for 2010 shark research fishery; request for applications |
| 2010 | | |
| 75 FR 250 | 1/5/2010 | Final rule for the 2010 Commercial Quotas and Opening Dates for the Atlantic Shark Fisheries |
| 75 FR 12700 | 3/12/2010 | Closure of the Gulf of Mexico Large Coastal Shark Fishery |
| 75 FR 22103 | 4/27/2010 | Atlantic Coastal Fisheries Cooperative Management Act Provisions; Atlantic Coastal Shark Fishery |
| 75 FR 44938 | 7/30/2010 | Atlantic Coastal Fisheries Cooperative Management Act Provisions; Atlantic Coastal Shark Fishery |
| 75 FR 30484 | 6/1/2010 | Final Rule for Amendment 3 to the Consolidated HMS FMP |
| 75 FR 53871 | 8/31/2010 | Closure of the Commercial Porbeagle Shark Fishery |
| 75 FR 57235 | 9/20/2010 | Notice of Availability of the Advanced Notice of Proposed Rulemaking for the Future of the Atlantic Shark Fishery |
| 75 FR 57240 | 9/20/2010 | Proposed Rule for the Atlantic Shark Fishery |
| 75 FR 57259 | 9/20/2010 | Request for Applications for Participation in the Atlantic Highly Migratory Species 2011 Shark Research Fishery |
| 75 FR 62690 | 10/8/2010 | Closure of the Commercial Non-Sandbar Large Coastal Shark Research Fishery |
| 75 FR 62506 | 10/12/2010 | Notice of Southeast Data Assessment and Review (SEDAR) 21 Assessment Webinar |
| 75 FR 67251 | 10/29/2010 | Closure of the Commercial Blacknose and Non-Blacknose Small Coastal Shark Fisheries |
| 75 FR 70216 | 11/17/2010 | Notice of Southeast Data Assessment and Review (SEDAR) 21 Assessment Webinar |
| 75 FR 74004 | 11/30/2010 | Request for Nominations for the Atlantic HMS SEDAR Pool |
| 75 FR 75416 | 12/2/2010 | Closure of the Commercial Non-Sandbar Large Coastal Shark Fishery in the Atlantic Region |
| 75 FR 76302 | 12/8/2010 | Final rule for the 2011 Commercial Quotas and Opening Dates for the Atlantic Shark Fisheries |
| 2011 | | |
| 76 FR 13985 | 3/15/2011 | Notice of Fisheries of the Gulf of Mexico and South Atlantic; Southeast Data, Assessment, and Review (SEDAR); Public Meetings |

| Federal Register Cite | Date | Rule or Notice |
|------------------------------|-------------|--|
| 76 FR 14884 | 3/18/2011 | Proposed rule for Atlantic Highly Migratory Species; Modification of the Retention of Incidentally-Caught Highly Migratory Species in Atlantic Trawl Fisheries |
| 76 FR 23794 | 4/28/2011 | Notice of Stock Status Determination for Atlantic highly Migratory scalloped Hammerhead Shark |
| 76 FR 23935 | 4/29/2011 | Proposed Rule to Implement the 2010 International Commission for the Conservation of Atlantic Tunas (ICCAT) Recommendations on Sharks |
| 76 FR 41723 | 7/15/2011 | Inseason Action to Close the Commercial Gulf of Mexico Non-Sandbar Large Coastal Shark Fishery |
| 76 FR 44501 | 7/26/2011 | Inseason Action to Close the Commercial Non-Sandbar Large Coastal Shark Research Fishery |
| 76 FR 49368 | 8/10/2011 | Final rule for Atlantic Highly Migratory Species; Modification of the Retention of Incidentally-Caught Highly Migratory Species in Atlantic Trawl Fisheries |
| 76 FR 53343 | 8/26/2011 | Inseason Action to Close the Commercial Porbeagle Shark Fishery |
| 76 FR 53652 | 8/29/2011 | Final Rule to Implement the 2010 International Commission for the Conservation of Atlantic Tunas (ICCAT) Recommendations on Sharks |
| 76 FR 61092 | 10/3/2011 | Notice of Availability of the Stock Assessments for Sandbar, Dusky, and Blacknose Sharks |
| 76 FR 62331 | 10/7/2011 | Notice NMFS Makes Stock Determinations and Requests Comments on Future Options to Manage Atlantic Shark Fisheries |
| 76 FR 67121 | 10/31/2011 | Proposed Rule to Establish the Quotas and opening Dates for the 2012 Atlantic Shark Commercial Fishing Season |
| 76 FR 67149 | 10/31/2011 | Request for Applications for Participation in the Atlantic Highly Migratory Species 2012 Shark Research Fishery |
| 76 FR 69139 | 11/8/2011 | Inseason Action to Close the Commercial Atlantic Non-Sandbar Large Coastal Shark Fishery |
| 76 FR 70064 | 11/10/2011 | Notice of Delay in the Effective Date of Federal Atlantic Smoothhound Shark Management Measures |
| 76 FR 72382 | 11/23/2011 | Notice on Workshops for the Electronic Dealer Reporting System |
| 76 FR 72383 | 11/23/2011 | Extension of Comment Period and Workshops Schedule for Shark Catch Shares Amendment |
| 76 FR 72891 | 11/30/2011 | 90-Day Finding on a Petition To List the Scalloped Hammerhead Shark as Threatened or Endangered Under the Endangered Species Act |
| 77 FR 3393 | 1/24/2012 | Final Rule to Establish the Quotas and Opening Dates for the 2012 Atlantic Shark Commercial Fishing Season |
| 2012 | | |
| 77 FR 8218 | 2/14/2012 | NMFS Announces a Public Meeting for Selected Participants of the 2012 Shark Research Fishery |
| 77 FR 32036 | 5/25/2012 | Inseason Action to Close the Commercial Porbeagle Shark Fishery |
| 77 FR 31562 | 5/29/2012 | NMFS Considers Adding Gulf of Mexico Sharks to Amendment 5 to the 2006 Consolidated HMS FMP |
| 77 FR 32036 | 5/31/2012 | Inseason Action to Close the Commercial Porbeagle Shark Fishery |

| Federal Register Cite | Date | Rule or Notice |
|-----------------------|------------|--|
| 77 FR 35357 | 6/13/2012 | NMFS Announces the Opening Date of the Commercial Atlantic Region Non-Sandbar Large Coastal Fishery |
| 77 FR 37647 | 6/21/2012 | Proposed Rule to Prohibit Retention of Silky Sharks Caught in ICCAT Fisheries |
| 77 FR 39648 | 7/5/2012 | Inseason Action to Close the Commercial Non-Sandbar Large Coastal Shark Fishery in the Gulf of Mexico Region |
| 77 FR 60632 | 10/4/2012 | Final Rule to Prohibit Retention of Silky Sharks Caught in ICCAT Fisheries |
| 77 FR 61562 | 10/10/2012 | Proposed Rule to Establish the Quotas and Opening Dates for the 2013 Atlantic Shark Commercial Fishing Season |
| 77 FR 67631 | 11/13/2012 | Notice of Intent for Applications to the 2013 Shark Research Fishery |
| 77 FR 70552 | 11/15/2012 | Proposed Rule for Amendment 5 to the 2006 Consolidated HMS FMP |
| 77 FR 69596 | 11/20/2012 | Notice to Solicit Nominations for the AP for Atlantic HMS Southeast Data, Assessment, and Review (SEDAR Workshops) |
| 77 FR 73608 | 12/11/2012 | Public Hearings for Amendment 5 to the Consolidated HMS FMP |
| 77 FR 75896 | 12/21/2012 | Final Rule for 2013 Commercial Shark Season |

Table 3 List of Small Coastal Shark Seasons, 1993-2012

| Year | Open Dates | Adjusted Quota (mt dw) |
|------|------------------|------------------------|
| 1993 | No season | No Quota |
| 1994 | No season | No Quota |
| 1995 | No season | No Quota |
| 1996 | No season | No Quota |
| 1997 | Jan. 1 – June 30 | 880 |
| | July 1 - Dec 31 | 880 |
| 1998 | Jan. 1 – June 30 | 880 |
| | July 1 - Dec 31 | 880 |
| 1999 | Jan. 1 – June 30 | 880 |
| | July 1 - Dec 31 | 880 |
| 2000 | Jan. 1 – June 30 | 880 |
| | July 1 - Dec 31 | 880 |
| 2001 | Jan. 1 – June 30 | 880 |
| | July 1 - Dec 31 | 880 |
| 2002 | Jan. 1 – June 30 | 880 |
| | July 1 - Dec 31 | 880 |
| 2003 | Jan. 1 – June 30 | 163 |
| | July 1 - Dec 31 | 163 |

| Year | Open Dates | Adjusted Quota (mt dw) |
|-------------|--------------------------------|-------------------------------|
| 2004 | GOM: Jan. 1 – March 18 | 11.2 |
| | S. Atl: Jan 1 - June 30 | 233.2 |
| | N. Atl: Jan 1 - June 30 | 36.5 |
| | GOM: July 1 – Dec. 31 | 10.2 |
| | S. Atl: July 1 – Dec. 31 | 210.2 |
| | N. Atl: July 1 – Dec. 31 | 33.2 |
| 2005 | GOM: Jan 1 – April 30 | 13.9 |
| | S. Atl: Jan. 1 - April 30 | 213.5 |
| | N. Atl: Jan. 1 - April 30 | 18.6 |
| | GOM: May 1 – Aug. 31 | 31 |
| | S. Atl: May 1 – Aug. 31 | 281 |
| | N. Atl: May 1 – Aug. 31 | 23 |
| | GOM: Sept. 1 – Dec. 31 | 32 |
| | S. Atl: Sept. 1 – Dec. 31 | 201.1 |
| | N. Atl: Sept. 1 – Dec. 31 | 16 |
| 2006 | GOM: Jan 1 – April 30 | 14.8 |
| | S. Atl: Jan 1 – April 30 | 284.6 |
| | N. Atl: Jan 1 – April 30 | 18.7 |
| | GOM: May 1 – Aug. 31 | 38.9 |
| | S. Atl: May 1 – Aug. 31 | 333.5 |
| | N. Atl: May 1 – Aug. 31 | 35.9 |
| | GOM: Sept. 1 – Dec. 31 | 30.8 |
| | S. Atl: Sept. 1 – Dec. 31 | 263.7 |
| | N. Atl: Sept. 1 – Dec. 31 | 28.2 |
| 2007 | GOM: Jan. 1 – Feb. 23 | 15.1 |
| | S. Atl: Jan 1 – April 30 | 308.4 |
| | N. Atl: Jan 1 – April 30 | 18.8 |
| | GOM: May 1 – Aug. 31 | 72.6 |
| | S. Atl: May 1 – Aug. 31 | 291.6 |
| | N. Atl: May 1 – Aug. 31 | 36.2 |
| | GOM: September 1 – Dec. 31 | 80.4 |
| | S. Atl: September 1 – Dec. 31 | 297.5 |
| | N. Atl: September 1 – Dec. 31 | 29.4 |
| 2008 | GOM: Jan 1 – April 30, 2008 | 73.2 |
| | S. Atl: Jan 1 – April 30, 2008 | 354.9 |
| | N. Atl: Jan 1 – April 30, 2008 | 19.3 |

| Year | Open Dates | Adjusted Quota (mt dw) |
|------|-------------------------------|---|
| | GOM: May 1 – July 24, 2008 | 72.6 |
| | S. Atl: May 1 – July 24, 2008 | 74.1 |
| | N. Atl: May 1 – July 24, 2008 | 12.0 |
| | July 24 – Dec. 31, 2008 | 454 |
| 2009 | Jan. 23 – Dec. 31, 2009 | 454 |
| 2010 | June 1 – Nov. 2, 2010 | Blacknose Sharks: 19.9 Other Small Coastal Sharks: 221.6 |
| 2011 | Jan. 1 – Dec. 31, 2011 | Blacknose Sharks: 19.9 Other Small Coastal Sharks: 314.4 |
| 2012 | Jan. 24 – Dec. 31, 2012 | Blacknose Sharks: 19.9 Other Small Coastal Sharks: 332.4 |
| 2013 | Jan. 1 - TBD | Blacknose Sharks: 19.9 Other Small Coastal Sharks: 329.2 |

Table 4 List of species that are LCS, SCS and prohibited species

| Common name | Species name | Notes |
|------------------------------|-----------------------------------|--|
| LCS | | |
| <i>Ridgeback Species</i> | | |
| Sandbar | <i>Carcharhinus plumbeus</i> | |
| Silky | <i>Carcharhinus falciformis</i> | Prohibited on vessels using PLL gear or vessels with HMS Angling/CHB permit and swordfish, billfish, or tuna in possession |
| Tiger | <i>Galeocerdo cuvier</i> | |
| <i>Non-Ridgeback Species</i> | | |
| Blacktip | <i>Carcharhinus limbatus</i> | |
| Spinner | <i>Carcharhinus brevipinna</i> | |
| Bull | <i>Carcharhinus leucas</i> | |
| Lemon | <i>Negaprion brevirostris</i> | |
| Nurse | <i>Ginglymostoma cirratum</i> | |
| Scalloped hammerhead | <i>Sphyrna lewini</i> | Prohibited on vessels using PLL gear or vessels with HMS Angling/CHB permit and swordfish, billfish, or tuna in possession |
| Great hammerhead | <i>Sphyrna mokarran</i> | |
| Smooth hammerhead | <i>Sphyrna zygaena</i> | |
| SCS | | |
| Atlantic sharpnose | <i>Rhizoprionodon terraenovae</i> | |
| Blacknose | <i>Carcharhinus acronotus</i> | |
| Bonnethhead | <i>Sphyrna tiburo</i> | |
| Finetooth | <i>Carcharhinus isodon</i> | |
| Pelagic Sharks | | |

| Common name | Species name | Notes |
|---------------------------|----------------------------------|---|
| Blue | <i>Prionace glauca</i> | |
| Oceanic whitetip | <i>Carcharhinus longimanus</i> | <i>Prohibited on vessels using PLL gear or vessels with HMS Angling/CHB permit and swordfish, billfish, or tuna in possession</i> |
| Porbeagle | <i>Lamna nasus</i> | |
| Shortfin mako | <i>Isurus oxyrinchus</i> | |
| Common thresher | <i>Alopias vulpinus</i> | |
| Prohibited Species | | |
| Sand tiger | <i>Odontaspis taurus</i> | Part of LCS complex until 1997 |
| Bigeye sand tiger | <i>Odontaspis noronhai</i> | Part of LCS complex until 1997 |
| Whale | <i>Rhincodon typus</i> | Part of LCS complex until 1997 |
| Basking | <i>Cetorhinus maximus</i> | Part of LCS complex until 1997 |
| White | <i>Carcharodon carcharias</i> | Part of LCS complex until 1997 |
| Dusky | <i>Carcharhinus obscurus</i> | Part of LCS complex until 1999 |
| Bignose | <i>Carcharhinus altimus</i> | Part of LCS complex until 1999 |
| Galapagos | <i>Carcharhinus galapagensis</i> | Part of LCS complex until 1999 |
| Night | <i>Carcharhinus signatus</i> | Part of LCS complex until 1999 |
| Caribbean reef | <i>Carcharhinus perezi</i> | Part of LCS complex until 1999 |
| Narrowtooth | <i>Carcharhinus brachyurus</i> | Part of LCS complex until 1999 |
| Atlantic angel | <i>Squatina dumerili</i> | Part of SCS complex until 1999 |
| Caribbean sharpnose | <i>Rhizoprionodon porosus</i> | Part of SCS complex until 1999 |
| Smalltail | <i>Carcharhinus porosus</i> | Part of SCS complex until 1999 |
| Bigeye sixgill | <i>Hexanchus nakamurai</i> | Part of Pelagics complex until 1999 |
| Bigeye thresher | <i>Alopias superciliosus</i> | Part of Pelagics complex until 1999 |
| Longfin mako | <i>Isurus paucus</i> | Part of Pelagics complex until 1999 |
| Sevengill | <i>Heptranchias perlo</i> | Part of Pelagics complex until 1999 |
| Sixgill | <i>Hexanchus griseus</i> | Part of Pelagics complex until 1999 |

| Requirement for Specific Fishery | Retention Limits | Quotas | Other Requirements |
|--|--|--|--|
| Inside the Commercial Shark Research Fishery | <p>Sandbar: Trip limit is specific to each vessel and owner(s) combination and is listed on the Shark Research Permit.</p> <p>Non-sandbar LCS: Trip limit is specific to each vessel and owner (s) combination and is listed on the Shark Research Permit.</p> <p>SCS & Pelagic Sharks:</p> <ul style="list-style-type: none"> <u>Directed Permits:</u> No trip limit for pelagic sharks & SCS <u>Incidental Permits:</u> 16 pelagic sharks/SCS combined | <p>Sandbar: Base Commercial Quota (2013): 116.6 mt dw</p> <p>Non-sandbar LCS: Base Commercial Quota(2013): 50 mt dw</p> <p>SCS: Base Commercial Non-blacknose SCS Quota: 221.6 mt dw/year Base Commercial Blacknose Quota: 19.9 mt dw</p> <p>Pelagic Sharks: Pelagic sharks (not blue and porbeagle): 273 mt dw/year Blue sharks: 488 mt dw Porbeagle sharks: 1.7 mt dw/year</p> | <ul style="list-style-type: none"> - Need Shark Research Fishery Permit -100 percent observer coverage when participating in research fishery - Adjusted quotas may be further adjusted based on future overharvests, if any. |
| Outside the Commercial Shark Research Fishery | <p>Non-sandbar LCS As of Jan. 1, 2013:</p> <ul style="list-style-type: none"> Directed Permit: 36 non-sandbar LCS/vessel/trip Incidental Permit: 3 non-sandbar LCS/vessel/trip <p>SCS & Pelagic Sharks:</p> <ul style="list-style-type: none"> <u>Directed Permits:</u> No trip limit for pelagic sharks & SCS <u>Incidental Permits:</u> 16 pelagic sharks/SCS combined | <p>Non-sandbar LCS: Base Commercial Quota Gulf of Mexico Region: 439.5 mt dw/year; Base Commercial Quota Atlantic Region: 188.3 mt dw/year</p> <p>SCS: Base Commercial Non-blacknose SCS Quota: 221.6 mt dw/year Base Commercial Blacknose Quota: 19.9 mt dw</p> <p>Pelagic Sharks: Pelagic sharks (not blue and porbeagle): 273 mt dw/year Blue sharks: 488 mt dw Porbeagle sharks: 1.7 mt dw/year</p> | <ul style="list-style-type: none"> -Vessels subject to observer coverage, if selected - Adjusted quotas may be further adjusted based on future overharvests, if any. |
| All Commercial Shark Fisheries | <p>Gears Allowed: Gillnet; Bottom/Pelagic Longline; Rod and Reel; Handline; Bandit Gear</p> <p>Authorized Species: Non-sandbar LCS (silky, blacktip, spinner, bull, lemon, nurse, great hammerhead, scalloped hammerhead, smooth hammerhead, and tiger sharks), pelagic sharks (porbeagle, common thresher, shortfin mako, oceanic whitetip, and blue sharks), and SCS (bonnethead, finetooth, blacknose, and Atlantic sharpnose sharks)</p> <p>Landings condition: All sharks (sandbar, non-sandbar LCS, SCS, and pelagic sharks) must have <i>fins naturally attached</i> through offloading; fins can be cut slightly for storage but must remain attached to the carcass via at least a small amount of uncut skin; shark carcasses must remain in whole or log form through offloading. Sharks can have the heads removed but the tails must remain naturally attached.</p> <p>Permits Required: Commercial Directed or Incidental Shark Permit</p> <p>Reporting Requirements: All commercial fishermen must submit commercial logbooks; all dealers must report bi-weekly</p> | | |
| All Recreational Shark Fisheries | <p>Gears Allowed: Rod and Reel; Handline</p> <p>Authorized Species: Non-ridgeback LCS (blacktip, spinner, bull, lemon, nurse, great hammerhead, scalloped hammerhead, smooth hammerhead); tiger sharks; pelagic sharks (porbeagle, common thresher, shortfin mako, oceanic whitetip, and blue sharks); and SCS (bonnethead, finetooth, blacknose, and Atlantic sharpnose sharks)</p> <p>Landing condition: Sharks must be landed with head, fins, and tail naturally attached</p> <p>Retention limits: 1 shark > 54" FL vessel/trip, plus 1 Atlantic sharpnose and 1 bonnethead per person/trip (no minimum size)</p> <p>Permits Required: HMS Angling; HMS Charter/Headboat; and, General Category Permit Holders (fishing in a shark tournament)</p> <p>Reporting Requirements: Participate in MRIP and LPS if contacted</p> | | |

Table 5 Summary of current shark regulations

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Definitions of Acronyms in Table 1: Fork Length (FL); Highly Migratory Species (HMS); Large Coastal Sharks (LCS); Large Pelagic Survey (LPS); Marine Recreational Information Program (MRIP); Small Coastal Sharks (SCS).

3.0 Control Date Notices

February 22, 1994 (59 FR 8457)

September 16, 2011 (76 FR 57709)

4.0 Management Program Specifications

Table 6 General management information for the Atlantic sharpnose shark

| | |
|--|---|
| Species | Atlantic sharpnose shark (<i>Rhizoprionodon terraenovae</i>) |
| Management Unit | Atlantic Ocean, Gulf of Mexico, and Caribbean Sea |
| Management Unit Definition | All federal waters within U.S. EEZ of the western north Atlantic Ocean, including the Gulf of Mexico and the Caribbean Sea. |
| Management Entity | NMFS, Highly Migratory Species Management Division |
| Management Contacts | Karyl Brewster-Geisz |
| SERO / Council | N/A |
| Current stock exploitation status | Not experiencing overfishing |
| Current stock biomass status | Not overfished |

Table 7 General management information for the Bonnethead shark

| | |
|--|---|
| Species | Bonnethead shark (<i>Sphyrna tiburo</i>) |
| Management Unit | Atlantic Ocean, Gulf of Mexico, and Caribbean Sea |
| Management Unit Definition | All federal waters within U.S. EEZ of the western north Atlantic Ocean, including the Gulf of Mexico and the Caribbean Sea. |
| Management Entity | NMFS, Highly Migratory Species Management Division |
| Management Contacts | Karyl Brewster-Geisz |
| SERO / Council | N/A |
| Current stock exploitation status | Not experiencing overfishing |
| Current stock biomass status | Not Overfished |

Table 8 Specific Assessment Summary for Atlantic sharpnose sharks

| Criteria | Value |
|---------------------------------------|--|
| MSST (Minimum Stock Size Threshold) | 4,090,000 sharks (based on SSF _{MSY}) |
| MFMT | 0.19 |
| B _{MSY} | SSF _{MSY} = 4,590,000 (numbers of sharks) |
| F ₀₅ /F _{MSY} | 0.74 |
| SSF ₂₀₀₅ | 6,012,300 (numbers of sharks) |
| SSF ₀₅ /SSF _{MSY} | 1.47 |

Table 9 Specific Assessment Summary for Bonnethead sharks

| Criteria | Value |
|---------------------------------------|--|
| MSST (Minimum Stock Size Threshold) | 1,400,000 sharks (based on SSF _{MSY}) |
| MFMT | 0.31 |
| MSY | SSF _{MSY} = 1,990,000 (numbers of sharks) |
| F ₀₅ /F _{MSY} | 0.6 |
| SSF ₂₀₀₅ | 2,248,700 (numbers of sharks) |
| SSF ₀₅ /SSF _{MSY} | 1.13 |

Table 10 Stock Projection Information for Atlantic Sharpnose Sharks

| Requested Information | Value |
|--|--|
| First year under current rebuilding program | N/A |
| End year under current rebuilding program | N/A |
| First Year of Management based on this assessment | 2016 |
| Projection Criteria during interim years should be based on (e.g., exploitation or harvest) | F=0; Fixed Exploitation; Modified Exploitation; Fixed Harvest*; No specific TAC for Atlantic Sharpnose Sharks F=221.6 mt ww (current commercial quota for non-blacknose SCS) |
| Projection criteria values for interim years should be determined from (e.g., terminal year, avg of X years) | Average landings of previous 2 years (2010, 2011) |

Table 11 Stock Projection Information for Bonnethead Sharks

| Requested Information | Value |
|--|--|
| First year under current rebuilding program | N/A |
| End year under current rebuilding program | N/A |
| First Year of Management based on this assessment | 2016 |
| Projection Criteria during interim years should be based on (e.g., exploitation or harvest) | F=0; Fixed Exploitation; Modified Exploitation; Fixed Harvest*; No specific TAC for Bonnethead Sharks F=221.6 mt ww (current commercial quota for non-blacknose SCS) |
| Projection criteria values for interim years should be determined from (e.g., terminal year, avg of X years) | Average landings of previous 2 years (2010, 2011) |

*Fixed Exploitation would be $F=F_{MSY}$ (or $F < F_{MSY}$) that would rebuild overfished stock to B_{MSY} in the allowable timeframe. Modified Exploitation would be allow for adjustment in $F \leq F_{MSY}$, which would allow for the largest landings that would rebuild the stock to B_{MSY} in the allowable timeframe. Fixed harvest would be maximum fixed harvest with $F \leq F_{MSY}$ that would allow the stock to rebuild to B_{MSY} in the allowable timeframe.

First year of Management: Earliest year in which management changes resulting from this assessment are expected to become effective

Interim years: Those years between the terminal assessment year and the first year that any management could realistically become effective.

Projection Criteria: The parameter which should be used to determine population removals, typically either an exploitation rate or an average landings value or a pre-specified landings target.

5.0 Quota Calculations

Atlantic sharpnose and bonnethead sharks

Table 12 Quota calculation details for Atlantic Sharpnose and Bonnethead Sharks. .

| | |
|--|--|
| Current Quota Value | Base Commercial Quota for all non-blacknose SCS = 221.6 mt dw. Up to 50 percent of base can be carried forward in the event of underharvest. |
| Next Scheduled Quota Change | Post SEDAR 34 if necessary |
| Annual or averaged quota ? | Annual quota |
| If averaged, number of years to average | - |
| Does the quota include bycatch/discard ? | The quota is based on average landings 2004-2008 and does not include bycatch or discards. |

How is the quota calculated - conditioned upon exploitation or average landings?

Atlantic sharpnose and bonnethead sharks are both included in the non-blacknose SCS quota. The current base commercial quota of 221.6 mt dw/year was established in Amendment 3 to the Consolidated HMS FMP (June 1, 2010) and is equal to average commercial landings for non-blacknose SCS between 2004-2008.

Does the quota include bycatch/discard estimates? If so, what is the source of the bycatch/discard values? What are the bycatch/discard allowances?

The commercial quota does not include bycatch/discard estimates.

Are there additional details of which the analysts should be aware to properly determine quotas for this stock?

The quota is adjusted each year through a season rule. Overharvests are deducted from the following year. Up to 50 percent of the base quota can be added to the following year's commercial non-blacknose SCS quota in the event of underharvest. No overharvests have been experienced for Atlantic sharpnose or bonnethead sharks since implementation of the 1999 FMP. Table 3 shows the history of shark quotas adjusted for under and overharvest.

Are there additional details of which the analysts should be aware to properly determine quotas for this stock?

No.

6.0 Management and Regulatory Timeline

The following tables provide a timeline of Federal management actions by fishery. It should be noted that federally permitted fishermen must follow federal regulations unless state regulations are more restrictive.

Table 13 Annual commercial Atlantic sharpnose and bonnethead shark regulatory summary (managed within the SCS complex).

Note: Regions = Gulf of Mexico, South Atlantic, and North Atlantic.

| Year | Base Quota (SCS complex) | Fishing Year | | | Possession Limit |
|--------|-----------------------------|---|----------------------------------|---|--|
| | | N. Atlantic | S. Atlantic | Gulf | |
| 1993 | No quota | One region; calendar year with two fishing periods | | | No trip limit |
| 1994 | No quota | One region; calendar year with two fishing periods | | | No trip limit |
| 1995 | No quota | One region; calendar year with two fishing periods | | | No trip limit |
| 1996 | No quota | One region; calendar year with two fishing periods | | | No trip limit |
| 1997 | 1,760 mt dw | One region; calendar year with two fishing periods | | | No trip limit |
| 1998 | 1,760 mt dw | One region; calendar year with two fishing periods | | | No trip limit |
| 1999 | 1,760 mt dw | One region; calendar year with two fishing periods | | | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders* |
| 2000 | 1,760 mt dw | One region; calendar year with two fishing periods | | | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2001 | 1,760 mt dw | One region; calendar year with two fishing periods | | | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2002 | 1,760 mt dw | One region; calendar year with two fishing periods | | | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2003 | 326 mt dw | One region; calendar year with two fishing periods but ridgeback and non-ridgeback split-see Table 3) | | | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2004 | 454 mt dw | Regions with two fishing seasons | Regions with two fishing seasons | Regions with two fishing seasons (fishery closed on March 18, 2004 – see Table 4) | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2005 | 454 mt dw | Trimesters/Regions | Trimesters/Regions | Trimesters/Regions | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2006 | 454 mt dw | Trimesters/Regions | Trimesters/Regions | Trimesters/Regions | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2007 | 454 mt dw | Trimesters/Regions | Trimesters/Regions | Trimesters/Regions (fishery closed on Feb. 23, 2007 – see Table 4) | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2008** | 454 mt dw | One region; calendar year | | | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |

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| | | | |
|------|-------------|---------------------------|---|
| 2009 | 454 mt dw | One region; calendar year | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2010 | 212.6 mt dw | One region; calendar year | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2011 | 212.6 mt dw | One region; calendar year | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |
| 2012 | 212.6 mt dw | One region; calendar year | No trip limit for SCS/pelagics for directed permit holders; 16 SCS & pelagic sharks combined/trip for incidental permit holders |

*Limited Access Permits (LAPs) were implemented for the shark and swordfish fisheries under 1999 FMP

**Sharks required to be offloaded with all fins naturally attached under Amendment 2 and in subsequent years.

**Table 14 Annual recreational Atlantic Sharpnose and Bonnethead shark regulatory summary
(managed within the SCS complex).**

| Year | Fishing Year | Size/Bag Limit |
|-------------|---------------------|---|
| 1993 | Calendar Year | 5 SCS sharks/person, no size limit |
| 1994 | Calendar Year | |
| 1995 | Calendar Year | |
| 1996 | Calendar Year | |
| 1997 | Calendar Year | 2 LCS/SCS/pelagic sharks combined/vessel, no size limit |
| 1998 | Calendar Year | |
| 1999 | Calendar Year | 1 shark, any species, per vessel per trip greater than 54" |
| 2000 | Calendar Year | FL and 1 Atlantic sharpnose per person per trip (no minimum size) |
| 2001 | Calendar Year | |
| 2002 | Calendar Year | |
| 2003 | Calendar Year | |
| 2004 | Calendar Year | 1 shark, any species, per vessel per trip greater than 54" FL and 1 |
| 2005 | Calendar Year | Atlantic sharpnose and 1 |
| 2006 | Calendar Year | bonnethead per person per trip (no minimum size) |
| 2007 | Calendar Year | |
| 2008 | Calendar Year | |
| 2009 | Calendar Year | |
| 2010 | Calendar Year | |
| 2011 | Calendar Year | |
| 2012 | Calendar Year | |

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sharpnose and bonnethead assessment 2-20-2013.docx

Drafted by MLC 2-27-2013

Edits per kbg 3-1-2013

Table 7. State Regulatory History

The following tables include the relevant shark management history for Atlantic and Gulf of Mexico states (including the Commonwealth of Puerto Rico). “Confirmed by state” is related to an information request that was sent to individual states in conjunction with the HMS SAFE Report in 2012. States replying “yes” responded to the information request and confirmed information on the current regulations but were unwilling to confirm past regulations. States replying “no” did not reply to confirm current or historical regulations.

| State | Texas |
|-----------------------------|---|
| *Confirmed by State? | Yes |
| pre-1995 | Sept. 1989: Bag limit set at five sharks per day for both rec and commercial anglers; Sept 1992: Bag limit increased to ten sharks per day. Trotlines were added as allowable gear for sharks. |
| 1996 | no new shark regulations |
| 1997 | 1997: Commercial bag limit of 5 sharks; possession limit of 10 sharks; no min or max size. Recreational bag, possession, and lack of size restrictions same as commercial |
| 1998 | 1998: commercial fishing for sharks can only be done with rod and reel; no entanglement nets |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | Sept: Commercial/Recreational retention limit 1 fish/person/day; Commercial/Recreational possession limit is twice the daily bag limit (i.e., 1 fish/person/day); Commercial/Recreational minimum size 24 in TL |
| 2005 | no new shark regulations |
| 2006 | By May 2006: no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | Sept: Min size 24" TL for Atlantic sharpnose, blacktip, and bonnethead sharks and 64" TL for all other lawful sharks. Bag limit is 1 shark/person/day, Possession limit is 2 sharks/person; Prohibited species: same as federal regulations |
| 2010 | no new shark regulations |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

| State | Louisiana |
|----------------------------|--------------------------|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | Ban on entanglement nets |

| | |
|-------------|--|
| 1998 | no new shark regulations |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | By Feb 2004: Minimum size - 54" except sharpnose; Possession limit - 1 fish/vessel/trip; Trip limit 4,000 lbs dw LCS; Reference to federal regulations; State waters closed to rec/commercial April 1 through June 30 |
| 2005 | no new shark regulations |
| 2006 | By May 2006: Recreational: min size – 54" FL, except Atlantic sharpnose and bonnethead; bag limit - 1 sharpnose/person/day; all other sharks – 1 fish/person/day; Commercial: 4,000 lb LCS trip limit, no min size; Com & Rec Harvest Prohibited: 4/1-6/30; Prohibition: same as federal regulations |
| 2007 | no new shark regulations |
| 2008 | By Oct 2008: Commercial: 33 per vessel per trip limit, no min size |
| 2009 | no new shark regulations |
| 2010 | no new shark regulations |
| 2011 | no new shark regulations |
| 2012 | No minimum size for bonnethead/sharpnose; 1 sharpnose or bonnethead/person/day. |

| State | Mississippi |
|----------------------------|---|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | prohibit taking and possession of sand tiger, bigeye sand tiger, whale, basking, and white sharks; Recreational: bag limit of 4 small coastal sharks (Atlantic sharpnose, Caribbean sharpnose, finetooth, blacknose, smalltail, bonnethead and Atlantic angel shark) per person per day; limit of 3 large coastal and pelagic sharks, in aggregate per vessel per day, same prohibited species as commercial fishers; minimum size of 25 inches total length for small coastal sharks and 37 inches total length for large coastal sharks |
| 1998 | no new shark regulations |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | By Feb 2004: no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | By May 2006: no new shark regulations |

| | |
|-------------|--|
| 2007 | no new shark regulations |
| 2008 | By Oct 2008: Recreational bag limit - LCS/Pelagics 1/person up to 3/vessel; SCS 4/person; Commercial & Prohibited Species - Reference to federal regulations |
| 2009 | no new shark regulations |
| 2010 | no new shark regulations |
| 2011 | SCS minimum size is 25" TL; SCS bag limit is 4/person (possession) |
| 2012 | no new shark regulations |

| State | Alabama |
|----------------------------|--|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | First shark regulations implemented: state shark fishery closes with the federal shark fishery |
| 1997 | no new shark regulations |
| 1998 | By 1998: only short lines in state waters; time/area and size restrictions on the recreational use of gillnets |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | By Feb 2004: Recreational daily bag limit - 2 sharpnose/person/day; all other species - 1 fish/person/day; Recreational minimum size all sharks (except sharpnose) - 54" FL |
| 2005 | no new shark regulations |
| 2006 | By May 2006: Recreational & Commercial non-sharpnose min size – 54" FL or 30" dressed; Prohibition: Atlantic angel, bigeye thresher, dusky, longfin mako, sand tiger, basking, whale, white, and nurse sharks |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | Recreational & commercial sharpnose bag limit dropped to 1 sharpnose per person per day; no shark fishing on weekends, Memorial Day, Independence Day, or Labor Day |
| 2010 | no new shark regulations |
| 2011 | Recreational and commercial: 1 sharpnose/person/day and 1 bonnethead person/day (no min size); state waters close when Federal waters close; regardless of open or closed shark season gillnet fishermen targetting other species may retain wharks with a dressed weight not exceeding 10% of total catch |
| 2012 | no new shark regulations |

| State | Florida |
|----------------------------|---|
| Confirmed by State? | |
| pre-1995 | 1992: first shark-specific regulations: must hold federal shark permit; commercial and recreational possession limit of 1 shark per person per day or 2 sharks per vessel per day, whichever is less (virtually no commercial shark fishery in state waters); prohibition on landing fins without corresponding carcass; released sharks should be released in a manner that maximizes survival; recreationally caught sharks cannot be transferred at sea; recreationally caught sharks cannot be sold; prohibition on harvest, landing and sale of basking and whale sharks; state shark fishery closes with federal shark fishery; 1994: prior to landing, fins cannot be removed from a shark harvested in state waters; fishermen returning from federal waters with sharks or shark parts harvested in federal waters, cannot fish in state waters; 1995: ban on the use of entanglement nets larger than 500 square feet |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | By 1998: ban on longlines; 1998: Added sand tiger, bigeye sandtiger, and white sharks to prohibited species list; prohibition on filleting sharks at sea. |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | March: Same prohibited species as federal regulations, except Caribbean sharpnose is not included |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | no new shark regulations |
| 2010 | Jan: Commercial/recreational min size – 54" except no min. size on blacknose, blacktip, bonnethead, smooth dogfish, finetooth, Atlantic sharpnose; Commercial/recreational possession limit: 1 shark/person/day max 2 sharks/vessel with 2 or more persons onboard; Allowable gear – hook and line only; prohibition on the removal of shark heads and tails in state waters; prohibition on harvest of sandbar, silky, and Caribbean sharpnose sharks in state waters; March: prohibition on all harvest of lemon sharks in state waters. |
| 2011 | no new shark regulations |
| 2012 | Prohibition on harvest of tiger sharks and all hammerhead sharks effective January 1, 2012 |

| State | Georgia |
|----------------------------|---|
| Confirmed by State? | |
| pre-1995 | 1950s: ban on gillnets and longlines; All finfish spp. must be landed with head and fins intact |

| | |
|-------------|---|
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | First shark regulation: prohibition on taking sand tiger sharks; Small Shark Composite (Atl. Sharpnose, bonnethead, spiny dogfish) 30"TL min. size; Creel: 2/person/day All other sharks 2/person/day or 2 /boat/day, whichever is less. 54"TL min. size, only one shark over 84" TL |
| 1999 | no new shark regulations |
| 2000 | Sharks may not be landed in Georgia if harvested using gillnets |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | Recreational: 1 shark from the Small Shark Composite (bonnethead, sharpnose, and spiny dogfish, min size 30" FL; All other sharks - 1 shark/person or boat, whichever is less, min size 54" FL, Prohibited Species: sand tiger sharks, sandbar, silky, bigeye sandtiger, whale, basking, white, dusky, bignose, Galapagos, night, reef, narrowtooth, Caribbean sharpnose, smalltail, Atlantic angel, longfin mako, bigeye thresher, sharpnose sevengill, bluntnose sixgill, and bigeye sixgill. |
| 2010 | no new shark regulations |
| 2011 | Commercial/Recreational: 2/person/day for bonnethead and sharpnose; minimum size is 30"FL; No gillnets in GA state waters |
| 2012 | Commercial/Recreational: 1/person/day for bonnethead and sharpnose |

| State | South Carolina |
|----------------------------|--|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | By 1998: federal regs adopted by reference; use of gillnets prohibited in the shark fishery |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | By Feb 2004: retention limit of 2 Atlantic sharpnose per person per day and 1 bonnethead per person per day; no min size for recreationally caught bonnethead sharks; reference to federal commercial regulations and closures |
| 2005 | no new shark regulations |
| 2006 | By May 2006: non-Atlantic sharpnose/bonnethead sharks – 1 shark/boat/trip, min size – 54" FL |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | No new shark regulations |
| 2010 | no new shark regulations |
| 2011 | Defer to Federal regulations; no gillnets in state waters; state permit required for fishing in state waters |
| 2012 | no new shark regulations |

| State | North Carolina |
|----------------------------|---|
| Confirmed by State? | Yes |
| pre-1995 | 1990: prohibition on finning 1990 – 7500 lbs per trip, dogfish exempt; unlawful to land fins without carcass; fins no more than 10%; unlawful to land dried fins; required record keeping; Recreational - bag limit is 2 per day 1992 – Reduced fins to no more than 7% |
| 1996 | no new shark regulations |
| 1997 | No sharks, except Atlantic sharpnose and pelagic sharks, can be taken by commercial gear in state waters; fins must be landed with the carcass; maximum 5% fin-to-carcass ratio; fishers cannot possess or land dried shark fins |
| 1998 | No new shark regulations |
| 1999 | No new shark regulations |
| 2000 | One shark per vessel per day with commercial gear (except Atlantic sharpnose and dogfish) while federal waters are open for species group; 84 inch maximum size limit except for tiger, thresher, bigeye thresher, shortfin mako and hammerhead species; must be landed with head, tail and fins intact; Recreational – bag limit is 1 per person per day with a minimum size of 54" (none on Atlantic sharpnose) and a maximum of 84" (except for tiger, thresher, bigeye thresher, shortfin mako and hammerhead species); Prohibited species – basking, white, sand tiger and whale sharks |
| 2001 | No new shark regulations |
| 2002 | No new shark regulations |
| 2003 | April: Prohibited ridgebacks (sandbar, silky, and tiger sharks) from Large Coastal Group |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | Open seasons and species groups same as federal; 4000 lb trip limit for LCS; retain fins with carcass through point of landing; longline shall only be used to harvest LCS during open season, shall not exceed 500 yds or have more than 50 hooks (state waters reopened to commercial fishing); Recreational: LCS (54" FL min size) - no more than 1 shark/vessel/day or 1 shark/person/day, SCS (no min size) – no more than 1 finetooth or blacknose shark/vessel/day and no more than 1 Atlantic sharpnose and 1 bonnethead/person/day, pelagics (no min size) -1 shark/vessel/day; Same prohibited shark species as federal regulations |
| 2007 | no new shark regulations |
| 2008 | July: Adopted federal regulations of 33 Large Coastal sharks per trip and fins must be naturally attached to carcass |
| 2009 | Fins must be naturally attached to shark carcass |
| 2010 | no new shark regulations |
| 2011 | Director may impose restrictions for size, seasons, area, quantity, etc. via proclamation. ASMFC plan. |
| 2012 | no new shark regulations |

| State | Virginia |
|----------------------------|---|
| Confirmed by State? | No |
| pre-1995 | 1991: no longlines in state waters; recreational bag limit of 1 shark per person per day; established a commercial trip limit of ____; 1993: mandatory reporting of all shark landings |
| 1996 | no new shark regulations |
| 1997 | 7500 lb commercial trip limit; minimum size of 58 inches FL or 31 inches carcass length (but can keep up to 200 lbs dw of sharks per day less than 31 inches carcass length); prohibition on finning; recreational: possession limit of 1 shark per person per day |
| 1998 | By 1998: no longlining in state waters |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | By May 2006: Recreational: bag limit – 1 LCS, SCS, or pelagic shark/vessel/day with a min size of 54" FL or 30" CL; 1 Atlantic sharpnose and bonnethead/person/day with no min size; Commercial: possession limit - 4000 lb dw/day, min size - 58" FL or 31" CL west of the COLREGS line and no min size limit east of the COLREGS line; Prohibitions: fillet at sea, finning, longlining, same prohibited shark species as federal regulations |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | ASMFC Plan |
| 2010 | no new shark regulations |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

| State | Maryland |
|----------------------------|---|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | 4000 lb shark limit per person per day; fins must accompany carcass and not exceed 5% fin-to-carcass ratio, state shark fishery closes with federal shark fishery |
| 1997 | no new shark regulations |
| 1998 | Size limit of 58 inches FL or a carcass less than 31 inches; recreational bag limit of one shark per person per day; by 1998: maximum gillnet mesh size of 6 inches; no longlining in tidal waters. |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | By Feb 2004: minimum FL reduced to 54 inches, carcass length the same (31 inches); recreational catch limit of 1 shark per person per day; reference to federal regs 50 CFR 635. |
| 2005 | no new shark regulations |
| 2006 | By May 2006: no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | By Oct 2008: no new shark regulations |
| 2009 | ASMFC Plan |
| 2010 | no new shark regulations |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

| State | Delaware |
|----------------------------|---|
| Confirmed by State? | Yes |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | Commercial shark fishermen must hold a federal shark permit even when fishing in state waters, therefore, state regulations match federal regulations; sharks must be landed with meat and fins intact, but head can be removed; any shark not kept must be released in a manner that maximizes survival; taking of basking, white, whale, sand tiger, and bigeye sand tiger prohibited; seasonal gillnet restrictions. Recreational regulations: no more than two sharks per vessel except that 2 sharpnose can also be landed; prohibition on finning and filleting or taking of the 5 prohibited species |
| 1999 | no new shark regulations |
| 2000 | Creel limit on regulated sharks of 1 shark per vessel per day; creel limit for sharpnose is 2 sharks per day; minimum size on regulated sharks is 54 inches FL; fins must be naturally attached; 14 prohibited species added (Atlantic angel shark, bigeye sixgill shark, bigeye thresher, bignose shark, Caribbean reef shark, Caribbean sharpnose shark, dusky shark, Galapagos shark, longfin mako, narrowtooth shark, night shark, sevengill shark, sixgill shark, smalltail shark) |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | ASMFC Plan |
| 2010 | no new shark regulations |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

| State | New Jersey |
|----------------------------|--|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | No shark-specific regulations; by 1998: no longline fishing; restrictions on the use of gillnets |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |

| State | New Jersey |
|--------------|---|
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | By Feb 2004: commercial/recreational possession limit of 2 sharks per vessel; prohibition on finning; dorsal fin to pre-caudal pit must be at least 23 inches in length; total length must be 48 inches in length |
| 2005 | no new shark regulations |
| 2006 | By May 2006: no sale during federal closures; Finning prohibited; Prohibited Species: basking, bigeye sand tiger, sand tiger, whale and white sharks |
| 2007 | no new shark regulations |
| 2008 | By Oct 2008: no new shark regulations |
| 2009 | ASMFC Plan |
| 2010 | no new shark regulations |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

| State | New York |
|----------------------------|--|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | By 1998: prohibition on finning sharks; no other shark regulations |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | By Feb 2004: reference to federal regs 50 CFR part 635; prohibited sharks listed |
| 2005 | no new shark regulations |
| 2006 | By May 2006: no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | By Oct 2008: no new shark regulations |
| 2009 | no new shark regulations |
| 2010 | ASMFC plan |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

| State | Connecticut |
|----------------------------|---|
| Confirmed by State? | Yes |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | no new shark regulations |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | July: No possession or landing of large coastal shark species by any commercial fishing gear or for commercial purposes. |
| 2010 | Feb: Commercial possession of prohibited Small Coastal Sharks: Atlantic sharpnose, finetooth, blacknose, bonnethead until a 2010 quota is set by NMFS; Sandbar shark take prohibited in the commercial and recreational fisheries per ASMFC FMP except under Scientific Collection Permit |
| 2011 | Prohibited species same as Federal regulations; No commercial SCS fishing until further notice |
| 2012 | no new shark regulations |

| State | Rhode Island |
|----------------------------|--------------------------|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | no new shark regulations |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |

| | |
|-------------|--------------------------|
| 2006 | no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | no new shark regulations |
| 2010 | ASMFC plan |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

| State | Massachusetts |
|----------------------------|---|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | no new shark regulations |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | By May 2006: Prohibition on harvest, catch, take, possession, transportation, selling or offer to sell any basking, dusky, sand tiger, or white sharks. |
| 2007 | no new shark regulations |
| 2008 | By Oct 2008: no new shark regulations |
| 2009 | no new shark regulations |
| 2010 | no new shark regulations |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

| State | New Hampshire |
|----------------------------|--------------------------|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | no new shark regulations |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |

| State | New Hampshire |
|--------------|---------------------------------|
| 2003 | no new shark regulations |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | No commercial take of porbeagle |
| 2010 | no new shark regulations |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

| State | Maine |
|----------------------------|---|
| Confirmed by State? | No |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | By 1998: large state water closures to gillnets resulting in virtually no gillnet fishery; 1998: no shark regulations |
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | no new shark regulations |
| 2005 | no new shark regulations |
| 2006 | no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | Maximum 5 % fin-to-carcass ratio |
| 2010 | no new shark regulations |
| 2011 | Prohibited species same as Federal regulations; fins attached |
| 2012 | Commercial harvest of sharks prohibited in state waters; Rec anglers must possess HMS Angling permit |

| State | Puerto Rico |
|----------------------------|--------------------------|
| Confirmed by State? | Yes |
| pre-1995 | no new shark regulations |
| 1996 | no new shark regulations |
| 1997 | no new shark regulations |
| 1998 | no new shark regulations |

| | |
|-------------|--|
| 1999 | no new shark regulations |
| 2000 | no new shark regulations |
| 2001 | no new shark regulations |
| 2002 | no new shark regulations |
| 2003 | no new shark regulations |
| 2004 | Year-round closed season on nurse sharks Shark "finning" is prohibited. PR regulations indicate the need for compliance by local fishers with federal shark regulations. |
| 2005 | no new shark regulations |
| 2006 | no new shark regulations |
| 2007 | no new shark regulations |
| 2008 | no new shark regulations |
| 2009 | no new shark regulations |
| 2010 | no new shark regulations |
| 2011 | no new shark regulations |
| 2012 | no new shark regulations |

3. ASSESSMENT HISTORY AND REVIEW

The Atlantic sharpnose shark was first assessed individually in 2002 (Cortés 2002) and later in 2007. Prior to that, it was part of the Small Coastal Shark complex, which was first assessed in 1991 and not again until 2002. In 2002, results of Bayesian surplus production (BSP; McAllister and Babcock 2004) and lagged recruitment, survival and growth (LRSG; Hilborn and Mangel 1997) models determined that the stock was not overfished and overfishing was not occurring.

The first assessment of Atlantic sharpnose sharks under the SEDAR framework was conducted in 2007 (SEDAR 13, NMFS 2007). Although three models were initially presented, it was decided that an age-structured production model (SSASPM; Porch 2002) would be used as the base model given that catch and age-specific biological and selectivity information had become available. The 2007 assessment concluded that the stock was not overfished ($SSF_{2005}/SSF_{MSY}=1.49-1.92$; range of base and sensitivity model runs) and overfishing was not occurring ($F_{2005}/F_{MSY}=0.35-0.71$; range of base and sensitivity model runs). The main changes between the 2002 and 2007 assessments included differences in the CPUE series used, inclusion of bycatch estimates from the shrimp trawl fishery as well as fleet-specific catch streams, the use of age-specific biological and selectivity information, and the use of different assessment methods.

References

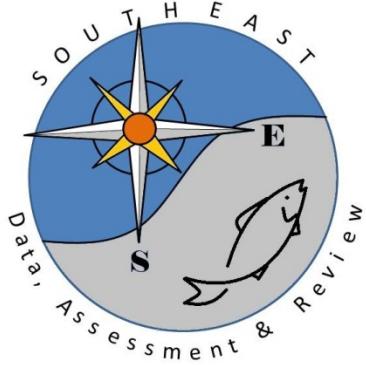
- Cortés, E. 2002. Stock assessment of small coastal sharks in the U.S. Atlantic and Gulf of Mexico. Sustainable Fisheries Division Contribution SFD-01/02-152. 133 pp.
- Hilborn, R. and M. Mangel. 1997. The Ecological Detective. Monographs in Population Biology 28. Princeton University Press, Princeton, New Jersey.
- McAllister, M.K., and E.A. Babcock. 2004. Bayesian surplus production model with the Sampling Importance Resampling algorithm (BSP): a user's guide. May 2004. Available from ICCAT: www.iccat.int.
- NMFS (National Marine Fisheries Service). 2007. Southeast Data, Assessment and Review (SEDAR) 13. Small Coastal Shark complex, Atlantic sharpnose, blacknose, bonnethead, and finetooth shark stock assessment report. NOAA/NMFS Highly Migratory Species Division, Silver Spring, MD.
- Porch, C. E. 2002. A preliminary assessment of Atlantic white marlin (*Tetrapturus albidus*) using a state-space implementation of an age-structured model. SCRS/02/68 23pp.

4. SEDAR ABBREVIATIONS

| | |
|-------|--|
| ABC | Allowable Biological Catch |
| ACCSP | Atlantic Coastal Cooperative Statistics Program |
| ADMB | AD Model Builder software program |
| ALS | Accumulated Landings System; SEFSC fisheries data collection program |
| AMRD | Alabama Marine Resources Division |
| ASMFC | Atlantic States Marine Fisheries Commission |
| B | stock biomass level |
| BAM | Beaufort Assessment Model |
| BMSY | value of B capable of producing MSY on a continuing basis |
| CFMC | Caribbean Fishery Management Council |
| CIE | Center for Independent Experts |
| CPUE | catch per unit of effort |
| EEZ | exclusive economic zone |
| F | fishing mortality (instantaneous) |

| | |
|----------|---|
| FMSY | fishing mortality to produce MSY under equilibrium conditions |
| FOY | fishing mortality rate to produce Optimum Yield under equilibrium |
| FXX% SPR | fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions |
| FMAX | fishing mortality that maximizes the average weight yield per fish recruited to the fishery |
| F0 | a fishing mortality close to, but slightly less than, Fmax |
| FL FWCC | Florida Fish and Wildlife Conservation Commission |
| FWRI | (State of) Florida Fish and Wildlife Research Institute |
| GA DNR | Georgia Department of Natural Resources |
| GLM | general linear model |
| GMFMC | Gulf of Mexico Fishery Management Council |
| GSMFC | Gulf States Marine Fisheries Commission |
| GULF FIN | GSMFC Fisheries Information Network |
| HMS | Highly Migratory Species |
| LDWF | Louisiana Department of Wildlife and Fisheries |
| LGL | LGL Ecological Research Associates |
| M | natural mortality (instantaneous) |
| MARMAP | Marine Resources Monitoring, Assessment, and Prediction |
| MCC | Mary Christman Consulting |
| MDMR | Mississippi Department of Marine Resources |
| MFMT | maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring |
| MRFSS | Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip |
| MRIP | Marine Recreational Information Program |
| MSST | minimum stock size threshold, a value of B below which the stock is deemed to be overfished |
| MSY | maximum sustainable yield |
| NC DMF | North Carolina Division of Marine Fisheries |

| | |
|--------|--|
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanographic and Atmospheric Administration |
| OY | optimum yield |
| SAFMC | South Atlantic Fishery Management Council |
| SAS | Statistical Analysis Software, SAS Corporation |
| SC DNR | South Carolina Department of Natural Resources |
| SEAMAP | Southeast Area Monitoring and Assessment Program |
| SEDAR | Southeast Data, Assessment and Review |
| SEFIS | Southeast Fishery-Independent Survey |
| SEFSC | Fisheries Southeast Fisheries Science Center, National Marine Fisheries Service |
| SERO | Fisheries Southeast Regional Office, National Marine Fisheries Service |
| SPR | spawning potential ratio, stock biomass relative to an unfished state of the stock |
| SSB | Spawning Stock Biomass |
| SS | Stock Synthesis |
| SSC | Science and Statistics Committee |
| TIP | Trip Incident Program; biological data collection program of the SEFSC and Southeast States. |
| TPWD | Texas Parks and Wildlife Department |
| Z | total mortality, the sum of M and F |



SEDAR

Southeast Data, Assessment, and Review

SEDAR 34

HMS Atlantic Sharpnose Shark

Stock Assessment Report

September 2013

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

EXECUTIVE SUMMARY

The Atlantic sharpnose shark is a common, inshore, small coastal carcharhinid species ranging from the Yucatán Peninsula in the Gulf of Mexico to New Jersey in the western North Atlantic. Despite no evidence of movement between the Atlantic Ocean and Gulf of Mexico, a published genetics study concluded that there was no genetic difference between conspecifics in the two areas and the Panel thus decided that Atlantic sharpnose sharks should be treated as a single stock. Maximum age for the combined Atlantic Ocean and Gulf of Mexico stock was increased to 18 yr (compared to 12 yr in the previous assessment) and the maturity ogive and litter size-maternal size relationship were updated based on new information from the Atlantic Ocean and Gulf of Mexico, respectively. Based on this new life history information, natural mortality estimates were also updated using several life history invariant methods.

The state-space, age-structured production model (SSASPM) was used as the assessment modeling approach, as in the previous assessment (SEDAR 13 conducted in 2007). This model considers two periods: a more data-poor “historic period” when only catch and/or effort data are available and a “modern period” when more data (e.g., CPUE indices) become available for model fitting. The base model configuration assumed virgin conditions in 1950 (as in SEDAR 13), a historic period spanning 1950-1971, a modern period spanning 1972-2011, it used a historical reconstructed catch series and updated catch series, updated biological parameters, and 15 CPUE indices, the earliest of which started in 1972. Estimated model parameters were pup (age-0) survival, virgin recruitment (R_0), catchability coefficients associated with the indices, and fleet-specific effort.

Five catch streams were included: three commercial series (bottom longline, gillnets, and lines), recreational catches, and shrimp bycatch. Because of misgivings with model-generated estimates of bycatch in the shrimp trawl fishery, the Panel opted to use stratified nominal estimates instead. Other changes with respect to the previous assessment included using recreational MRIP estimates instead of MRFSS, adding post-release live discard mortality estimates for the recreational and the three commercial series, and adding dead discard estimates in the bottom longline commercial series. A total of fifteen indices of relative abundance, all standardized through Generalized Linear Modeling techniques, were recommended for use by the Panel; only one index was fishery dependent. Age-specific selectivity was estimated

externally to the model after converting lengths from the different surveys and fisheries into ages through the von Bertalanffy growth curve. A total of six selectivity curves, three flat-topped and three dome-shaped, were assigned to the indices and catch series.

In addition to computing asymptotic standard errors for estimated parameters, scientific uncertainty was incorporated through likelihood profiling to examine distributions for several model parameters and provide approximate probabilities of the stock being overfished and overfishing occurring. Uncertainty in data inputs and model configuration was examined through sensitivity scenarios, the majority of which also represented alternative plausible “states of nature” and were further used in stock projections. Sensitivity runs included using indices with increasing or decreasing trends only, considering a lower level of bycatch, using a hierarchical index of relative abundance, using a single index that was well fit in the base run, including no indices, starting the model later (in 1972 vs. 1950), considering a more, or less, productive stock, and doing separate assessments for the Gulf of Mexico and Atlantic. Three weighting schemes of the CPUE series were trialed (equal weighting, inverse CV weighting, and rank weighting), with inverse CV weighting providing the best fit and being used in all sensitivity runs. A historical analysis comparing results of the current assessment to those from assessments conducted in 2002 and 2007 was also included as well as a retrospective analysis to look for systematic bias in key model output quantities over time.

Catches were overwhelmingly dominated by the shrimp trawl discards, which progressively increased up to 2000 and experienced a sharp decline thereafter. The model fit a central tendency through most of the indices and fit some, or at least portions, fairly well while others were hard to fit given large interannual fluctuations in most cases. In general, the fits showed a rather flat tendency prior to the onset of the first index in 1972, followed by a decreasing tendency to about 2000, and then an increasing trend in the last decade. Consequently, predicted abundance and spawning stock fecundity (SSF; defined as numbers x proportion mature x fecundity in numbers) showed slight depletion from 1950 to the beginning of the modern period in 1972, followed by a decreasing trend to about 2000, and a progressive increase in the last decade, which corresponds to decreased effort and catches in the shrimp trawl fishery and a majority of the indices of relative abundance showing increasing tendencies in those years. As expected, fishing mortality was overwhelmingly dominated by the shrimp trawl fleet and exceeded the estimated F_{MSY} of 0.377 in the baseline run several years from 1987 to

2000. The contribution of the remaining fleets to total F was minimal. Fishing mortality was lower in the past decade in accordance with decreased shrimp trawl effort and catches during that period. The model estimated a productive stock, with a steepness of 0.57, and a large current abundance/SSF (on the order of 30 million animals). The median for the posterior of pup survival was higher than the prior (0.89 vs. 0.76 in the base run), whereas the posterior for virgin recruitment of pups ($R_0 \sim 9.4$ million animals in the base run) was informative in contrast to its diffuse uniform prior.

In general, the results of the assessment were robust to structural assumptions of the model. With the exception of the sensitivity run that used decreasing indices only, all other scenarios estimated that the stock was not overfished ($SSF_{2011}/SSF_{MSY}=1.01$ to 2.88) and overfishing was not occurring ($F_{2011}/F_{MSY}=0.03$ to 0.57) in 2011. There was a very high probability that the stock in 2011 was not overfished ($Pr(SSF_{2011}/SSF_{MSST})=0.85-0.99$), with most scenarios having a $Pr>0.90$, with the exception of the “decreasing indices” run. In contrast, because the distribution of F_{2011} was skewed to the right, the probability of overfishing not occurring in 2011 was <0.50 in three cases and ranged between 0.54 and 0.67 in most cases. The retrospective analysis found no systematic pattern of over- or under-estimation of abundance, relative abundance, or fishing mortality. The continuity analysis also found that the stock would not be overfished (with a high probability) and overfishing not occurring (with a low probability) if six years of catch and index data were added to the inputs used in the 2007 assessment. Despite significant differences between the inputs used in the 2002 and 2007 assessments and the current assessment, stock status did not change substantially.

Probabilistic projections at alternative fixed harvest levels were used to provide an approach for reducing the overfishing limit (OFL) to account for scientific uncertainty within individual SSASPM model configurations. Multiple projection scenarios were evaluated with probabilistic projections in an attempt to reflect the full range of plausible states of nature. Among the multiple projection scenarios evaluated, examples of fixed levels of total annual removals due to fishing during the years 2015 – 2041 which resulted in both the $Pr(SSF_t > SSF_{MSY}) \geq 70\%$, and the $Pr(F_t > F_{MSY}) \leq 30\%$ in the year 2041 from 10,000 Monte Carlo bootstrap projections ranged from 250,000 to 2,750,000 sharks. The median buffer (percent decrease) from OFL using this approach was 23%. These values represent a proxy P* approach (based on probabilistic projections at alternative fixed levels of removals) used here to determine the removals associated with a 70% probability of overfishing not occurring ($P^* = 0.3$).

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1. WORKSHOP PROCEEDINGS

1.1. INTRODUCTION

1.1.1. Workshop time and Place

The SEDAR 34 Atlantic Sharpnose and Bonnethead Shark Workshop was held June 25-27, 2013 in Panama City, Florida. In addition to the workshop, several additional webinars were conducted between July and September 2013 to finalize the assessment.

1.1.2. Terms of Reference

1. Update the approved SEDAR 13 Atlantic sharpnose shark model with data through 2011. Provide a model consistent with the previous assessment configuration to incorporate and evaluate any changes allowed for this update.
2. Evaluate and document the following specific changes in input data or deviations from the benchmark model.
 - a. Review updated life history information (reproductive parameters)
 - b. Evaluate fishery-independent abundance indices derived for Mississippi, Alabama, Georgia, and South Carolina, the Gulf of Mexico SEAMAP Nearshore Coastal Longline Program, and the NMFS NE Longline Program,
 - c. Evaluate MRFSS/MRIP conversion factors
 - d. Evaluate commercial and recreational discard information
3. Document any changes or corrections made to model and input datasets and provide updated input data tables. Provide commercial and recreational landings and discards in numbers and weight. Provide available average weights by gear and year used to derive average number of fish calculations.
4. Update model parameter estimates and their variances, model uncertainties, and estimates of stock status and management benchmarks. In addition to the base model, conduct sensitivity analysis to address uncertainty in data inputs and model configuration and consider runs that represent plausible, alternate states of nature.
5. Project future stock conditions regardless of the status of the stock. Develop rebuilding schedules, if warranted. Provide the estimated generation time for each unit stock. Stock projections shall be developed in accordance with the following:
 - A) If the stock is overfished, then utilize projections to determine:
 - Year in which $F=0$ results in a 70% probability of rebuilding (Year $F=0p70$)

- Target rebuilding year (Year F=0p70 + 1 generation time) (Yearrebuild)
- F resulting in 50% and 70% probability of rebuilding by Yearrebuild
- Fixed level or removals (TAC) allowing rebuilding of stock with 50% and 70% probability

B) Otherwise, utilize a P* approach to determine:

- The F needed and corresponding removals associated with a 70% probability of overfishing not occurring ($P^* = 0.3$)

C) If data-limitations preclude classic projections (i.e. A, B above), explore alternate projection models to provide management advice.

6. Develop a stock assessment report to address these TORs and fully document the input data, methods, and results.

1.1.3. List of Participants

Workshop Panel

| | |
|--------------------------------------|-------------------------------|
| Enric Cortés, Lead Analyst | NMFS Panama City |
| Dean Courtney, Co-Lead Analyst..... | NMFS Panama City |
| Xinsheng Zhang, Support Analyst..... | NMFS Panama City |
| Beth Babcock | RSMAS |
| Peter Barile..... | Marine Resources & Consulting |
| Carolyn Belcher | GA DNR |
| Jeanne Boylan | SC DNR |
| Walter Bubley | TXDPW |
| John Carlson..... | NMFS Panama City |
| Trey Driggers | NMFS Pascagoula |
| Marcus Drymon | DISL |
| Bryan Frazier | SC DNR |
| Dean Grubbs | FSU |
| Marin Hawk | ASMFC |
| Eric Hoffmayer | NMFS Pascagoula |
| Bob Hueter | Mote Marine Lab |
| Robert Latour | VIMS |
| Cami McCandless | NMFS Narragansett |
| Adam Pollack..... | NMFS Pascagoula |
| David Stiller | Industry Representative |

Analytic Support

| | |
|-------------------|------------------|
| Dana Bethea | NMFS Panama City |
| Simon Gulak | NMFS Panama City |

Alyssa Mathers.....NMFS Panama City

Attendees

| | |
|-------------------------|------------------|
| Grace Casselberry | NMFS Panama City |
| Drew Delorenzo | NMFS Panama City |
| Shannon Dunnigan..... | NMFS Panama City |
| Rusty Hudson..... | DSF, Inc. |
| Andrea Kroetz..... | DISL |
| Hanna Lang..... | NMFS Panama City |
| Todd Neahr | Texas Tech |
| Ashley Pacicco..... | NMFS Panama City |
| Kelcee Smith..... | NMFS Panama City |

Staff

| | |
|---------------------------|-------|
| Andrea Grabman..... | SEDAR |
| Julie Neer | SEDAR |
| Karyl Brewster-Geisz..... | HMS |

Additional Participants via Webinars

| | |
|--------------------------|----------------|
| Heather Balchowsky | NMFS Miami |
| Peter Cooper..... | HMS |
| Jennifer Cudney | HMS |
| Guy DuBeck..... | HMS |
| Mark Grace | MFS Pascagoula |
| Jill Hendon..... | GCRL/USM |
| Vivian Matter | NMFS Miami |
| Kevin McCarthy..... | NMFS Miami |
| Delisse Ortiz..... | HMS |
| Jackie Wilson | HMS |

1.1.4. List of Working Documents and Reference Papers

| Documents Prepared for the Assessment Process | | |
|--|---|-----------------------------------|
| SEDAR34-WP-01 | Standardized catch rates of Atlantic sharpnose sharks (<i>Rhizoprionodon terraenovae</i>) in the U.S. Gulf of Mexico from the Shark Bottom Longline Observer Program, 1994-2011 | John Carlson and Simon Gulak |
| SEDAR34-WP-02 | Standardized catch rates of bonnetheads from the Everglades National Park Creel Survey | John K. Carlson and Jason Osborne |

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| SEDAR34-WP-03 | Standardized Catch Rates of Bonnethead and Atlantic Sharpnose Shark from the Southeast Shark Drift Gillnet Fishery: 1993-2011 | John Carlson, Alyssa Mathers and Michelle Passerotti |
| SEDAR34-WP-04 | Tag and recapture data for Atlantic sharpnose, <i>Rhizoprionodon terraenovae</i> , and bonnethead shark, <i>Sphyrna tiburo</i> , in the Gulf of Mexico: 1999-2011 | Dana Bethea and Mark Grace |
| SEDAR34-WP-05 | Relative abundance of bonnethead and Atlantic sharpnose sharks based on a fishery-independent gillnet survey off Texas | Walter Bubley and John Carlson |
| SEDAR34-WP-06 | Update to maximum observed age of Atlantic sharpnose sharks (<i>Rhizoprionodon terraenovae</i>) in the western North Atlantic Ocean based on a direct age estimate of a long term recapture | Bryan S. Frazier and Joshua K. Loefer |
| SEDAR34-WP-07 | Validated age and growth of the bonnethead (<i>Sphyrna tiburo</i>) in the western North Atlantic Ocean | Bryan S. Frazier, Douglas H. Adams, William B. Driggers III, Christian M. Jones, Joshua K. Loefer, Linda A. Lombardi |
| SEDAR34-WP-08 | A preliminary review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 34 | Dean Courtney |
| SEDAR34-WP-09 | Standardized catch rates of Atlantic sharpnose (<i>Rhizoprionodon terraenovae</i>) and bonnethead (<i>Sphyrna tiburo</i>) sharks collected during a gillnet survey in Mississippi coastal waters, 1998-2011 | Eric R. Hoffmayer, Glenn R. Parsons, Jill M. Hendon, Adam G. Pollack, and G. Walter Ingram, Jr. |
| SEDAR34-WP-10 | Standardized catch rates of Atlantic sharpnose sharks (<i>Rhizoprionodon terraenovae</i>) collected during a bottom longline survey in Mississippi coastal waters, 2004-2011 | Eric R. Hoffmayer, Jill M. Hendon, and Adam G. Pollack |
| SEDAR34-WP-11 | Standardized catch rates of Atlantic sharpnose sharks (<i>Rhizoprionodon terraenovae</i>) collected during bottom longline surveys in Mississippi, Louisiana, Alabama, and Texas coastal waters, 2004-2011 | Eric Hoffmayer, Adam Pollack, Jill Hendon, Marcus Drymon, and Mark Grace |
| SEDAR34-WP-12 | Atlantic Sharpnose Shark: Standardized index | John Froeschke and J. |

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| | of relative abundance using boosted regression trees and generalized linear models | Marcus Drymon |
| SEDAR34-WP-13 | Atlantic Sharpnose Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico | Adam G. Pollack and G. Walter Ingram, Jr. |
| SEDAR34-WP-14 | Bonnethead Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico | Adam G. Pollack and G. Walter Ingram, Jr. |
| SEDAR34-WP-15 | Atlantic Sharpnose and Bonnethead Abundance Indices from NMFS Bottom Longline Surveys in the Western North Atlantic and Northern Gulf of Mexico | Adam G. Pollack and G. Walter Ingram, Jr. |
| SEDAR34-WP-16 | Continuity Runs for Atlantic Sharpnose and Bonnethead SEAMAP Groundfish Surveys and NMFS Bottom Longline Surveys | Adam G. Pollack and G. Walter Ingram, Jr. |
| SEDAR34-WP-17 | Variability in the Reproductive Biology of the Atlantic Sharpnose Shark in the Gulf of Mexico | Eric R. Hoffmayer, Jill M. Hendon, William B. Driggers III, Lisa M. Jones, and James A. Sulikowski |
| SEDAR34-WP-18 | Shrimp Fishery Bycatch Estimates for Atlantic Sharpnose and Bonnethead Sharks in the Gulf of Mexico, 1972-2011 | Xinsheng Zhang, Brian Linton, Enric Cortés and Dean Courtney |
| SEDAR34-WP-19 | Standardized catch rates of Atlantic sharpnose and bonnethead sharks from the SEAMAP-South Atlantic Shallow Water Trawl Survey | Enric Cortés and J. Boylan |
| SEDAR34-WP-20 | Updated catches of Atlantic sharpnose and bonnethead sharks | Enric Cortés and Ivy Baremore |
| SEDAR34-WP-21 | Dead discards of Atlantic sharpnose sharks in the shark bottom longline fishery | John Carlson, Kevin J. McCarthy and Simon J.B. Gulak |
| SEDAR34-WP-22 | Preliminary data on the reproductive biology of the bonnethead (<i>Sphyrna tiburo</i>) from the southeast U.S. Atlantic coast | Bryan Frazier, Jim Gelsleichter, and Melissa Gonzalez De Acevedo |

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| SEDAR34-WP-23 | Interannual site fidelity of bonnetheads (<i>Sphyrna tiburo</i>) to two coastal ecosystems in the western North Atlantic Ocean | William B. Driggers III, Bryan S. Frazier, Douglas H. Adams, Glenn F. Ulrich and Eric R. Hoffmayer |
| SEDAR34-WP-24 | Size composition and indices of relative abundance of the Atlantic sharpnose shark (<i>Rhizoprionodon terraenovae</i>) in coastal Virginia waters | Robert J. Latour, Christopher F. Bonzek, and J. Gartland |
| SEDAR34-WP-25 | Mark/Recapture Data for the Atlantic Sharpnose Shark (<i>Rhizoprionodon terraenovae</i>), in the Western North Atlantic from the NEFSC Cooperative Shark Tagging Program | Nancy E. Kohler, Danielle Bailey, Patricia A. Turner, and Camilla McCandless |
| SEDAR34-WP-26 | Mark/Recapture Data for the Bonnethead (<i>Sphyrna tiburo</i>), in the Western North Atlantic from the NEFSC Cooperative Shark Tagging Program | Nancy E. Kohler, Elizabeth Sawicki, Patricia A. Turner, and Camilla McCandless |
| SEDAR34-WP-27 | Preliminary mtDNA assessment of genetic stock structure of the bonnethead, <i>Sphyrna tiburo</i> , in the eastern Gulf of Mexico and northwestern Atlantic | Píndaro Díaz-Jaimes' Douglas H. Adams' Nadia S. Laurrabiquio-Alvarado, Elena Escatel-Luna |
| SEDAR34-WP-28 | Standardized Catch Rates of Bonnethead and Atlantic Sharpnose Shark from the Southeast Sink Gillnet Fishery: 2005-2011 | John Carlson, Alyssa Mathers and Michelle Passerotti |
| SEDAR34-WP-29 | Relative abundance of Atlantic sharpnose and bonnethead shark from the northeastern Gulf of Mexico | John K. Carlson, Dana M. Bethea, Eric Hoffmayer, John Tyminski, Robert Hueter, R. Dean Grubbs, Matthew J. Ajemian, and George H. Burgess |
| SEDAR34-WP-30 | Reproductive parameters for Atlantic sharpnose sharks (<i>Rhizoprionodon terraenovae</i>) from the western North Atlantic Ocean | William B. Driggers III, Eric R. Hoffmayer, John K. Carlson and Joshua Loefer |

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| SEDAR34-WP-31 | Tag-recapture results of bonnethead (<i>Sphyrna tiburo</i>) and Atlantic sharpnose (<i>Rhizoprionodon terraenovae</i>) sharks in the Gulf of Mexico and Florida Coastal Waters | John P. Tyminski, Robert E. Hueter, John Morris |
| SEDAR34-WP-32 | Standardized catch rates of bonnethead (<i>Sphyrna tiburo</i>) from the South Carolina Department of Natural Resources trammel net survey | Bryan S. Frazier and Camilla T. McCandless |
| SEDAR34-WP-33 | Tag and recapture data for Atlantic sharpnose, <i>Rhizoprionodon terraenovae</i> , and bonnethead, <i>Sphyrna tiburo</i> , sharks caught in the northern Gulf of Mexico from 1998-2011 | Jill M. Hendon, Eric R. Hoffmayer, and Glenn R. Parsons |
| SEDAR34-WP-34 | Standardized indices of abundance for Atlantic sharpnose sharks from the Georgia Department of Natural Resources red drum longline survey | C.T. McCandless, C.N. Belcher |
| SEDAR34-WP-35 | Standardized indices of abundance for bonnethead and Atlantic sharpnose sharks from the Georgia Department of Natural Resources ecological monitoring trawl surveys | C.T. McCandless, J.Page, C.N. Belcher |
| SEDAR34-WP-36 | Standardized indices of abundance for bonnethead and Atlantic sharpnose sharks caught during the South Carolina Department of Natural Resources red drum longline and Cooperative Atlantic States Shark Pupping and Nursery gillnet surveys | C.T. McCandless, B.S. Frazier |
| SEDAR34-WP-37 | Standardized indices of abundance for bonnethead and Atlantic sharpnose sharks caught during the Cooperative Atlantic States Shark Pupping and Nursery longline surveys from South Carolina to northern Florida | C.T. McCandless, C.N. Belcher, B.S. Frazier, M. McCallister, R. Ford, J. Gelsleichter |
| SEDAR34-WP-38 | Standardized indices of abundance for Atlantic sharpnose sharks from the University of North Carolina bottom longline survey | Frank Schwartz, Camilla McCandless, and John Hoey |
| SEDAR34-WP-39 | A Summary of Evaluation Worksheets of abundance indices for Atlantic sharpnose shark | SEDAR 34 Panel |

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|---------------------------------------|---|--|
| | and bonnethead shark | |
| Final Stock Assessment Reports | | |
| SEDAR34-SAR | Atlantic Sharpnose Sharks | SEDAR 34 Panel |
| SEDAR34-SAR | Bonnethead Sharks | SEDAR 34 Panel |
| Reference Documents | | |
| SEDAR29-RD01 | SEDAR 13 (SCS) Final Stock Assessment Report | SEDAR 13 Panels |
| SEDAR29-RD02 | Abundance Indices Workshop: Developing protocols for submission of abundance indices to the SEDAR process | SEDAR Procedural Workshop I |
| SEDAR29-RD03 | Characterization of the U.S. Gulf of Mexico and South Atlantic Penaeid and Rock Shrimp Fisheries Based on Observer Data | ELIZABETH SCOTT-DENTON, PAT F. CRYER, MATT R. DUFFY, JUDITH P. GOCKE, MIKE R. HARRELSON, DONNA L. KINSELLA, JAMES M. NANCE, JEFF R. PULVER, REBECCA C. SMITH, and JO A. WILLIAMS |
| SEDAR29-RD04 | Effects of Turtle Excluder Devices (TEDs) on the Bycatch of Three Small Coastal Sharks in the Gulf of Mexico Penaeid Shrimp Fishery | Scott W. Raborn, Benny J. Gallaway, John G. Cole, William J. Gazey & Kate I. Andrews |

1.2 STATEMENTS ADDRESSING EACH TERM OF REFERENCE

1.2.1 Term of Reference 1

Update the approved SEDAR 13 Atlantic sharpnose shark model with data through 2011. Provide a model consistent with the previous assessment configuration to incorporate and evaluate any changes allowed for this update.

First, the model used for Atlantic sharpnose shark in SEDAR 13 was updated with six additional years of catch and CPUE data to run a continuity analysis where all other data inputs and

modeling options remained fixed. Continuity data sets are described in more detail in Sections 2.1 and 3.2.7.1. The main changes with respect to the benchmark model used in SEDAR 13 were 1) adding six additional years of catches (2006-2011) to the six catch data streams considered in SEDAR 13, and 2) re-analyzing the 16 indices of relative abundance considered in SEDAR 13 to also include six additional years of data (2006-2011), if appropriate. All other inputs to the model as well as modeling aspects remained the same as used in SEDAR 13. The state-space, age-structured production model (SSASPM) was used in both SEDAR 13 and SEDAR 34. Second, we conducted an extensive set of new analyses incorporating the issues identified in the following TORs as well as additional analyses stemming from discussions held by the Panel.

1.2.2 Term of Reference 2

Evaluate and document the following specific changes in input data or deviations from the benchmark model a) Review updated life history information (reproductive parameters); b) Evaluate fishery-independent abundance indices derived for Mississippi, Alabama, Georgia, and South Carolina, the Gulf of Mexico SEAMAP Nearshore Coastal Longline Program, and the NMFS NE Longline Program; c) Evaluate MRFSS/MRIP conversion factors; and d) Evaluate commercial and recreational discard information.

Multiple changes to biological and fishery inputs used for SEDAR 13 were evaluated in recognition of updated or new information that had become available since that assessment. The main changes considered include:

- a) New maximum age and reproductive information for the stock. Details of new information on maximum age of this species, a study aiming to provide new information on the reproductive characteristics of Atlantic sharpnose sharks in the Gulf of Mexico, as well as an analysis that combined the reproductive information from the Gulf of Mexico and the U.S. South Atlantic for a single stock are presented in Section 2.2.1.
- b) Several fishery-independent relative abundance indices that had not been initiated, consisted of too few years, or were not presented or considered for various reasons when SEDAR 13 was conducted (MS gillnet and longline, AL longline, GA Coastscape longline, FL Coastscape longline, GA red drum longline, GADNR trawl, SEAMAP GOM Coastal longline, and NMFS NE longline), were considered for the current assessment. Section 2.2.3 discusses these as well as other indices that were identified after this TOR was written and the decisions that were made.

- c) Although MRIP (Marine Recreational Information Program) have effectively replaced MRFSS (Marine Recreational Fishery Statistics Survey) estimates, they are only available for 2004-2011. Ratio estimators to convert MRFSS to MRIP estimates were developed for this assessment for the period 1981-2003. Section 2.2.2.2 discusses this in more detail.
- d) SEDAR 13 considered commercial dead discards only from the bottom longline fishery. For the current assessment we also considered post-release live discard mortality from the bottom longline, gillnet, and line commercial fisheries as well as from recreational fisheries. These sources of removals are detailed in Sections 2.2.2.3 and 2.2.2.4. Discussions and decisions related to discards in the shrimp trawl fishery are detailed in Section 2.2.2.5.

1.2.3 Term of Reference 3

Document any changes or corrections made to model and input datasets and provide updated input data tables. Provide commercial and recreational landings and discards in numbers and weight. Provide available average weights by gear and year used to derive average number of fish calculations.

In addition to the changes in input data identified in the TORs, other changes will also be presented throughout this document in the appropriate sections. These include 1) new indices of relative abundance (Sections 2.2.3 and 3.1.2.3); 2) new selectivity functions developed to describe new catch and index series (Section 3.1.2.2); and 3) new biological parameters, including fecundity at age, updated estimates of natural mortality (M) at age, maximum age, proportion mature at age, and pup survival (Section 2.2.2).

Shark assessments are typically conducted in numbers mainly because recreational catch estimates in numbers have traditionally been more reliable owing to the small number of animals measured or weighed in the recreational surveys, and also because discard estimates from various sources are generated in numbers rather than weight. However, catch in weight from the different sectors was also provided. When applicable, we provide the average weights (back-transformed from average lengths) that were used in the conversions (Section 3.1.2.1).

1.2.4 Term of Reference 4

Update model parameter estimates and their variances, model uncertainties, and estimates of stock status and management benchmarks. In addition to the base model, conduct sensitivity analysis to address uncertainty in data inputs and model configuration and consider runs that represent plausible, alternate states of nature.

All modeling methods are described in Section 3.1 and results in Section 3.2. Measures of overall model fit are provided in Section 3.2.1. Estimates of assessment model parameters and associated measures of precision are presented in Section 3.2.2. Also included are: stock abundance and spawning stock fecundity (Section 3.2.3), fishery selectivity (Section 3.2.4), fishing mortality (Section 3.2.5), and stock-recruitment parameters (Section 3.2.6). Further evaluation of uncertainty is presented in Section 3.2.7, which contains historic, continuity, retrospective, and sensitivity analyses, as well as evaluation of model configurations. Benchmarks and reference points are presented in Section 3.2.8. Projections are presented in Section 3.2.9.

1.2.5 Term of Reference 5

Project future stock conditions regardless of the status of the stock. Develop rebuilding schedules, if warranted. Provide the estimated generation time for each unit stock. Stock projections shall be developed in accordance with the following: A) If the stock is overfished, then utilize projections to determine: Year in which $F=0$ results in a 70% probability of rebuilding (Year $F=0p70$); Target rebuilding year (Year $F=0p70 + 1$ generation time) (Yearrebuild); F resulting in 50% and 70% probability of rebuilding by Yearrebuild; and Fixed level or removals (TAC) allowing rebuilding of stock with 50% and 70% probability; B) Otherwise, utilize a P approach to determine: the F needed and corresponding removals associated with a 70% probability of overfishing not occurring ($P^* = 0.3$); and C) If data-limitations preclude classic projections (i.e. A, B above), explore alternate projection models to provide management advice.*

An alternative probabilistic projection approach was developed for HMS shark stocks that are not likely to be under a rebuilding plan (i.e. not in an overfished condition). The projection approach was based on discussions held during a workshop to investigate P* statistical analysis techniques for use in age-structured stock assessments of domestic U.S. shark stocks managed under the 2006 Consolidated Atlantic Highly Migratory Species (HMS) Fisheries Management Plan (FMP) (P* workshop, NOAA/NMFS, Panama City Laboratory, June 11-13, 2013; Report in prep.). During the workshop, several shortcuts to published probabilistic P* approaches currently being implemented (or evaluated) within the framework of the Southeast Data, Assessment, and Review (SEDAR) process were discussed (e.g., Prager and Shertzer 2010, Shertzer et al. 2010).

Preliminary analyses with empirical data from comparative model runs indicated that results from some of the shortcuts were comparable to those obtained from published probabilistic P* approaches. However, when the technical merits of each P* shortcut were discussed within the context of application to an existing HMS shark dataset and age-structured stock assessment model (e.g., NMFS 2012a), it became apparent that the distribution of F_{limit} (F_{MSY} for HMS domestic shark stocks) may be poorly characterized in the existing stock assessment model (SSASPM, e.g., NMFS 2012a). Consequently, within the context of application to the existing HMS age-structured stock assessment model, typical P* approaches may not adequately characterize uncertainty in the distribution of F_{limit} . In contrast, alternative probabilistic projection approaches were also discussed at the workshop, including short-term (~5 to 10 year) projections at fixed harvest levels similar to those used by the International Commission for the Conservation of Atlantic Tunas (ICCAT) Standing Committee on Research and Statistics (SCRS) in their Kobe II tables and plots (e.g., SCRS BFT Stock Assessment Meeting Report 2012; their Tables 16-18, and their figures 36-38). It was noted at the workshop, that probabilistic projections at fixed harvest levels do not require estimates of uncertainty for F_{MSY} and accommodate multiple year lags at fixed harvest levels. It was also noted at the workshop that probabilistic projections at fixed harvest levels could be utilized to provide a buffer based on a pre-specified acceptable probability of overfishing (e.g., $P^* = 0.3; <0.5$). Consequently, within the context of application to the existing HMS domestic shark age structured stock assessment model (SSASPM), probabilistic projections at fixed harvest levels may provide a proxy to a typical P* approach. The methods developed for the alternative probabilistic projection approach are described in section 3.1.7, and the results are presented in section 3.2.9.

1.2.6 Term of Reference 6

Develop a stock assessment report to address these TORs and fully document the input data, methods, and results.

This is the present document.

Recommendations by the Assessment Panel (AP) for future research and data collection are provided in Section 2.4.

2. DATA REVIEW AND UPDATE

2.1. CONTINUITY DATASETS

The continuity analysis consisted of using the same exact model, data inputs and assumptions used in 2007 for SEDAR 13, but adding six additional years of catch data (2006-2011; **Table 2.5.1; Figure 2.6.1**) and the same indices updated to 2011 (**Figure 2.6.2**). The six additional years of catch data were added to all the catch streams, except for shrimp discards, where the 2006-2011 values were assumed to be the mean of the 2003-2005 estimates (see section 2.2.2.5). The same 16 indices used in 2007 were also used in the continuity run. Of those 16 indices, three remained the same as in 2007 because they have been discontinued (PC LL, MML Gillnet Adults and MML Gillnet Juveniles), and an additional one (GNOP) also remained the same because of convergence issues identified by the analyst during re-analysis. The remaining twelve indices were all reanalyzed and had six additional years of data, with the exception of the SCDNR Red Drum Longline which only had one more year of data. The twelve indices were: PC Gillnet Juveniles, PC Gillnet Adults, BLLOP, SEAMAP-SA, Texas Gillnet, VA Longline, NMFS Longline SE, SC Coastspan Gillnet, SCDNR Red Drum Longline, SEAMAP-GOM-ES, SEAMAP-GOM-EF, and UNC Longline. Note also that the same exact methodology used in 2007 to analyze catch rates was not used in the re-analysis of the Texas Gillnet, VA Longline, and SEAMAP-GOM ES indices.

2.2. NEW DATA SOURCES CONSIDERED

2.2.1. Life History

2.2.1.1. Review of Working Papers

SEDAR34-WP-04: Tag and recapture data for Atlantic sharpnose, *Rhizoprionodon terraenovae*, and bonnethead shark, *Sphyrna tiburo*, in the Gulf of Mexico and US South Atlantic: 1998-2011.
D.M. Bethea and M.A. Grace

Tag and recapture information for Atlantic sharpnose, *Rhizoprionodon terraenovae*, and bonnethead shark, *Sphyrna tiburo*, is summarized from the NOAA Fisheries Southeast Fisheries Science Center Elasmobranch Tagging Management System, 1998-2011. Summary information includes numbers of sharks tagged by species, sex, and life stage, numbers of sharks recaptured by species and sex, recapture rates, time at liberty, distance traveled, and change in length for recaptured individuals.

SEDAR34-WP-06: Update to maximum observed age of Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*) in the western North Atlantic Ocean based on a direct age estimate of a long term recapture.

B.S. Frazier and J.K. Loefer

Direct age estimates were obtained from sectioned vertebrae from a recaptured male Atlantic sharpnose shark that had been at liberty for 12.2 years. The specimen was tagged and recaptured by biologists from the South Carolina Department of Natural Resources' (SCDNR) Adult Red Drum longlining program, therefore, accurate length measurements at both initial capture and recapture were recorded. In addition to the direct age estimate, three other long term recaptures provide additional evidence to increase maximum observed age for the Atlantic sharpnose shark population in the South Atlantic Bight (SAB, defined as the coastal waters of the western North Atlantic Ocean off of the southeastern United States).

SEDAR34-WP-17: Variability in the Reproductive Biology of the Atlantic Sharpnose Shark in the Gulf of Mexico.

E.R. Hoffmayer, J.M. Hendon, W.B. Driggers III, L.M. Jones and J.A. Sulikowski

The reproductive biology of the Atlantic sharpnose shark *Rhizoprionodon terraenovae* in the Gulf of Mexico was investigated by examining 1,306 specimens (693 females, 613 males) collected from the Florida Keys to waters off Brownsville, Texas USA. The results of this study confirm the annual reproductive cycle established for this species; however, there was a significant amount of variability present within the cycle. Ovulatory and post-ovulatory females were present from March to October, indicating that mating and ovulation (e.g. May to July) were occurring over a more protracted period than previously described. The occurrence of post-partum females from April to September, the varying sizes of the embryos across several months, and the occurrence of mature spermatozoa in the testes of adults from March to November also corroborates the evidence of reproductive plasticity in this species. This observed variability in the reproductive cycle indicates that the Gulf of Mexico Atlantic sharpnose shark population is not completely synchronous in regards to parturition, mating, and ovulation, as a portion of the population is demonstrating reproductive asynchrony. Although the cause of this asynchrony remains unclear, it may be related to the environmental conditions of the Gulf of Mexico, which could provide water temperatures optimal for reproduction of this species through much of the year (e.g. March to October), resulting in a protracted reproductive cycle. Given the results of the current study, reproductive cycles in other carcharhinid species in this

region should be examined in more detail to determine if asynchrony is also present, as this phenomenon could impact future management strategies.

SEDAR34-WP-25: Mark/Recapture Data for the Atlantic Sharpnose Shark (*Rhizoprionodon terranova*), in the Western North Atlantic from the NEFSC Cooperative Shark Tagging Program.

N.E. Kohler, D. Bailey, P.A. Turner and C. McCandless

Mark/recapture information from the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program (CSTP) covering the period from 1969 through 2012 are summarized for the Atlantic sharpnose shark (*Rhizoprionodon terranova*) in the western North Atlantic. The extent of the tagging effort, areas of release and recapture, and movements and length frequencies of tagged sharks are reported. Two areas were distinguished in order to identify exchange between the Atlantic and Gulf of Mexico. Overall, there was no movement between the Atlantic and Gulf of Mexico and limited exchange (8) between the US and the Mexican-managed portion of the Gulf of Mexico; the true extent of this movement is unclear due to the possibility of under-reporting of recaptures.

SEDAR34-WP-30: Reproductive parameters for Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*) from the western North Atlantic Ocean.

W.B. Driggers III, E.R. Hoffmayer, J.K. Carlson and J. Loefer

Since the update on life history parameters for Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*) at SEDAR 13, additional data have become available pertaining to the reproductive biology of the species in the northern Gulf of Mexico (GOM) (Hoffmayer et al., in press). This document utilizes raw data from Carlson and Loefer (SEDAR13-DW-08-V2) and Hoffmayer et al. (in press) to provide updated estimates of several important reproductive parameters when treating Atlantic sharpnose sharks in U.S. waters of the western North Atlantic Ocean as a single stock.

SEDAR34-WP-31: Tag-recapture results of bonnethead (*Sphyrna tiburo*) and Atlantic sharpnose (*Rhizoprionodon terraenovae*) sharks in the Gulf of Mexico and Florida Coastal Waters.

J.P. Tyminski, R.E. Hueter and J. Morris

Tag-recapture data from Mote Marine Laboratory's Center for Shark Research are summarized for the bonnethead, *Sphyrna tiburo* and Atlantic sharpnose, *Rhizoprionodon terraenovae*, sharks.

Of the 7,781 sharks tagged from these two species, there were 246 reported recaptures (3.2 %). The movement patterns were variable but there is evidence of significant inshore-offshore and north-south movements that is likely related to temperature-mediated seasonal migrations. There was no evidence of either species moving from the Gulf of Mexico into the Atlantic or migrations across the Gulf of Mexico.

SEDAR34-WP-33: Tag and recapture data for Atlantic sharpnose, *Rhizoprionodon terraenovae*, and bonnethead, *Sphyrna tiburo*, sharks caught in the northern Gulf of Mexico from 1998-2011.
J.M. Hendon, E.R. Hoffmayer and G.R. Parsons

Routine, monthly (March to October), fishery-independent shark resource sampling has been conducted in Mississippi, Alabama, and Louisiana coastal waters by The University of Southern Mississippi and the University of Mississippi since 1998. Sampling methods have included gillnet, bottom longline (152 m and 1.8 km), and hook-and-line gear. All sharks in good condition were externally tagged with either a dart (7 or 18 cm) or roto tag and were released. The dart tags were imbedded in the dorsal musculature at the base of the first dorsal fin, and the roto tags were punched through the cartilage of the first dorsal fin. From 1998 to 2011, approximately 6,500 sharks have been tagged on these resource surveys. A total of 3,753 Atlantic sharpnose sharks were tagged and 20 of these were recaptured (0.5%), whereas 160 bonnethead sharks were tagged and two of these were recaptured (1.3%). No Atlantic sharpnose or bonnethead shark traveled from the Gulf of Mexico to the Atlantic Ocean or vice versa.

2.2.1.2. New Dataset Decisions

Stock definition datasets and decisions

Four working papers were presented which examined the movements of Atlantic sharpnose sharks between the Atlantic Ocean and the Gulf of Mexico based on tag-recapture data (SEDAR34-WP-04, SEDAR34-WP-25, SEDAR34-WP-31, SEDAR34-WP-33). There was no evidence of movement between the Atlantic Ocean and the Gulf of Mexico. However, based on restriction fragment length polymorphism analysis of mitochondrial DNA, Heist et al. (1996) concluded that there was no genetic difference between Atlantic sharpnose sharks in the Atlantic Ocean and the Gulf of Mexico.

Decision 1: Based on the results of Heist et al. (1996), the Panel decided that Atlantic sharpnose sharks in the Atlantic Ocean and Gulf of Mexico should be treated as a single stock.

Age and Growth Datasets and Decisions

There were no updated age and growth models for Atlantic sharpnose sharks for the Atlantic Ocean or the Gulf of Mexico since SEDAR13-DW-08V2; however, evidence was presented that increased the maximum age of Atlantic sharpnose sharks to 18+ years in the Atlantic Ocean (Frazier and Loefer, SEDAR34-WP-06).

Decision 2: Based on the new evidence presented, the Panel decided that maximum age of the combined Gulf of Mexico and Atlantic Ocean Atlantic sharpnose shark stock is 18 years.

Reproductive Datasets and Decisions

There were no data presented that updated reproductive information from the Atlantic Ocean since Carlson and Loefer (SEDAR13-DW-08-V2). Hoffmayer et al. (SEDAR34-WP-17) updated information on the reproductive biology of Atlantic sharpnose sharks in the Gulf of Mexico. These data were merged with the Gulf of Mexico-specific data utilized by Carlson and Loefer to generate various reproductive parameters for the region and with Atlantic Ocean data provided by Carlson and Loefer (SEDAR13-DW-08-V2) to generate estimates for the Atlantic Ocean and Gulf of Mexico combined (Driggers et al. SEDAR34-WP-30). All updated parameter estimates are listed in Table 2.5.2. Briefly, in the Gulf of Mexico, female Atlantic sharpnose sharks mature at a slightly larger size (62.3 vs 60.5 cm FL) but younger age (2.0 vs. 1.3 years) than conspecifics in the Atlantic Ocean. Mean litter size is larger in the Gulf of Mexico than in the Atlantic Ocean (4.6 vs 4.1 pups per litter). When comparing regions to the combined areas, parameter values were similar to those estimates for the Gulf of Mexico, likely as a result of sample sizes.

Decision 3: Reproductive parameters presented in SEDAR34-WP-30 are recommended by the Panel because they represent the best information currently available.

Decision 4: The maturity ogive from SEDAR34-WP-30 is recommended by the Panel because it represents the best information currently available.

2.2.2. Catch Statistics

2.2.2.1. Review of working papers

SEDAR 34-WP-08: A preliminary review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 34

Dean Courtney

This working paper reviews post-release live-discard mortality rate estimates for sharks from the primary scientific literature for use in SEDAR 34. However, the review is not exhaustive and therefore should be considered preliminary. Discard mortality rates appear to vary among species and by gear type. As a result, this review identifies estimates of post-release live-discard mortality rate by species and by gear type (longline, hook and line, gillnet, and trawl) where available.

SEDAR 34-WP-18: Shrimp Fishery Bycatch Estimates for Atlantic Sharpnose and Bonnethead Sharks in the Gulf of Mexico, 1972-2011

Xinsheng Zhang, Brian Linton, Enric Cortés and Dean Courtney

WinBUGS shrimp bycatch estimates for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico were generated using the approaches developed by Scott Nichols in the SEDAR 7 Gulf of Mexico red snapper assessment (Nichols 2004a, 2004b) and SEDAR 13 Gulf of Mexico small coastal sharks assessment (Nichols 2007).

SEDAR 34-WP-20: Updated catches of Atlantic sharpnose and bonnethead sharks

Enric Cortés and Ivy Baremore

This document presents updated commercial landings, recreational catches, and discard estimates of Atlantic sharpnose and bonnethead sharks up to 2011. Information on the geographical distribution of both commercial landings and recreational catches is presented along with gear-specific information of commercial landings. Length-frequency information and trends in average size of the catches from several commercial and recreational sources are also presented.

SEDAR 34-WP-21: Dead discards of Atlantic sharpnose sharks in the shark bottom longline fishery**John Carlson, Kevin McCarthy, Simon J.B. Gulak**

Observer reported Atlantic shark dead discard rates from 2006-2011, along with self reported commercial fishing effort data, were used to calculate Atlantic sharpnose shark discards from the shark bottom longline fishery in the Gulf of Mexico. Fishing effort data were available from the coastal logbook program for the years 1993-2011. Beginning in 1993 all commercial vessels with Federal fishing permits (other than those for swordfish, tunas, and shrimp) were required to report landings and effort to the coastal logbook program. Only effort defined as targeting shark (trips with shark landings >2/3 of total landings for the trip) was included in the discard calculations. Total discards were calculated as the product of observer reported yearly mean dead discard rates, number saved for bait (by hooks fished) and the yearly total fishing effort (bottom longline hooks fished) reported to the coastal logbook program. Discard rate by hook fished was not available prior to 2006. To calculate discards for the years 1993-2005 the mean dead discard rate across the years 2006-2011 was used. Yearly total dead discards prior to 2006 were calculated as the product of the weighted mean dead discard rate and the year-specific shark targeted effort.

2.2.2.2. Recreational landings datasets and decisions

The MRIP (Marine Recreational Information Program) has effectively replaced MRFSS (Marine Recreational Fishery Statistics Survey), but new estimates for a suite of fish species, including sharks, are only available for the period 2004-2011. For 1981-2003, MRFSS estimates were adjusted to MRIP using ratio estimators. The new MRIP estimates for this species for the period 1981-2003 were developed specifically for this assessment by SEFSC personnel in charge of recreational statistics (V. Matter, SEFSC, Miami, FL, pers. comm.).

Decision 1: The panel recommended using MRIP catches for the whole time series, including those obtained with ratio estimators for 1981-2003, because this Program has effectively replaced MRFSS.

2.2.2.3. Recreational Discards Datasets and Decisions*Post-release live discard mortality*

Working document SEDAR34-WP-08 provided a summary of the literature regarding post release mortality for shark species. Based on the literature, an equation was developed to calculate the total mortality for several fisheries:

$$\text{Total discard mortality rate} = (\text{Dead-discard rate}) + (\text{Post-release live-discard mortality rate}) * (\text{Live-discard rate})$$

Working document SEDAR34-WP-08 indicated that the best estimate of recreational hook and line post-release discard mortality comes from (Gurshin and Szedlmayer, 2004), who estimated a 10 % rate based on tagged Atlantic sharpnose sharks captured with hook and line. A point was made that this rate was obtained using only ten tagged sharpnose sharks being monitored for six hours and that it might not be appropriate to use. The Panel discussed and decided that if the methodology was externally reviewed and accepted in SEDAR 29 than it should be used here.

Decision 2: Based on the evidence above, the Panel recommended applying a 10% discard mortality rate to the live discards (B2) from MRIP/MRFSS and including a range of 5-15% for the low and high catch sensitivity scenarios (if implemented), for both Atlantic sharpnose and bonnethead shark.

2.2.2.4. Commercial Discards Datasets and Decisions

Commercial dead discards estimated for logbook data

Working document SEDAR34-WP-21 provided estimates of dead discards of Atlantic sharpnose sharks from the logbook bottom longline data using observed discard proportion from the bottom longline observer program (BLLOP) from 1993-2011. Only trips where more than 2/3 of the landed species were sharks were used for the estimates, with the assumption that these were shark-targeted trips.

The methodology used for SEDAR 34 to obtain commercial bottom longline dead discards is the following:

$$\text{Number of sharks kept for bait (BLL data)} + \text{Dead discards (BLL data)} = \text{ (Eq 1)}$$

Total dead discards from the commercial bottom longline fishery.

$$\text{Total dead discards/Total number caught (BLL)} = \text{Dead discard rate} \quad (\text{Eq 2})$$

Dead discard rate * Total commercial landings attributed to longline gear (Eq 3)
from coastal logbooks = Number of dead discards of Atlantic sharpnose shark.

The Panel discussed which years' data to use to calculate the mean rates (discarded dead per hook and used for bait per hook, Eq (1) to generate discard numbers for 1980-1992, for which there are no data. The Panel discussed whether to use the five most recent years of data to remain consistent with the past assessment for Atlantic sharpnose shark or to use different years. The five years after 1992 were proposed because those numbers would better reflect the fishery's activities in 1980-1992.

Decision 3: Based on the above, the Panel recommended using years 1993-1997 to generate mean rates of discarded dead per hook and used for bait per hook to apply to years 1980-1992.

Post-release live discard mortality

Working document SEDAR34-WP-08 provided a summary of the literature regarding post release mortality for shark species. Based on the literature, an equation was developed to calculate the total mortality for several fisheries:

$$\text{Total discard mortality rate} = (\text{Dead-discard rate}) + (\text{Post-release live-discard mortality rate}) * (\text{Live-discard rate})$$

Estimates of post-release live-discard mortality rate were generated by species and by gear type (longline, hook and line, gillnet, and trawl) where available.

Rates from research gillnet studies were used to obtain commercial gillnet post release live discard mortality rates for Atlantic sharpnose sharks. It was noted that commercial rates would most likely be higher than research gillnet rates. As a result, a minimum sensitivity scenario for Atlantic sharpnose shark (35%) was proposed, obtained from research gillnet studies (Hueter and Manire 1994). It was proposed that the commercial bottom longline calculated rates from

working document SEDAR34-WP-08 (82%) could be used as the high sensitivity scenario for commercial gillnet for Atlantic sharpnose shark; the base post release live discard mortality rates could be the midpoint (58.5%) of the respective low (35%) and high (82%) sensitivity ranges.

The Panel discussed the calculated commercial bottom longline rates from SEDAR34-WP-08 and decided that these were sufficient numbers. These calculations followed the SEDAR 29 AP Panel rationale for bottom longline.

There was not sufficient literature to guide the Panel to decide on post release live discard mortality rate estimates for either species caught in commercial trawls.

Decision 4: Based on the evidence above, the Panel recommended applying a post-release live discard mortality rate of 58.5% for commercial gillnet for the base model, with a range of 35-82% for the low and high catch sensitivity scenarios (if implemented) for Atlantic sharpnose shark.

Decision 5: Based on the evidence above, the Panel recommended applying a post-release live discard mortality rate of 35% for commercial bottom longline for the base model, with a range of 19-82% for the low and high catch sensitivity scenarios (if implemented) for Atlantic sharpnose shark.

2.2.2.5. Shrimp Trawl Fishery Discards Datasets and Decisions

Working document SEDAR 34-WP-18 provided WinBUGS shrimp bycatch estimates using approaches developed in SEDAR 7 (GOM Red Snapper) and SEDAR 13 (GOM small coastal sharks).

Because the WinBUGS shrimp bycatch estimation model, priors, and datasets used for the SEDAR 13 Gulf of Mexico Atlantic sharpnose and bonnethead sharks assessment were not well documented, the SEDAR 13 results could not be reproduced. WinBUGS bycatch estimates for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico were presented based on two WinBUGS models with a variety of combinations of prior distribution assumptions, depth-zone strata, and datasets.

The shrimp bycatch rates for the GOM Atlantic sharpnose utilized in SEDAR 13 averaged ~ 400,000 sharks per year, while the initial WinBUGS runs estimated a bycatch of up to 1.6 million

Atlantic sharpnose sharks per year. The estimates presented in these initial WinBUGS runs had extremely high bycatch values for the years 1981, 2009, 2010 and 2011. One possible reason for the anomalies was the change in observer methods in 2009 to begin identification of sharks to the species level, which increased available data. Before this time period, observers grouped all sharks into one category. Another possible reason was the change from voluntary to mandatory observer coverage in 2007, which greatly improved the representation of the commercial shrimp fleet and again increased available data.

The Panel had trouble accepting such high numbers of discards (> 1 million per year) for the above mentioned years and decided to speak with Elizabeth Scott-Denton and James Nance from the Shrimp Fishery Observer Program in Galveston, Texas, to get details about the data. The call presented no new information except the program's confidence in the data for 2009-2011, as those were mandatory observer coverage years and Atlantic sharpnose sharks were identified to species level. The Panel also noted that WinBUGS annual shrimp bycatch estimates have very large variances in most years. The Panel decided to replace the estimates of shrimp bycatch generated with WinBUGS with the stratified nominal estimates recommended. Two approaches were recommended to calculate the 2009-2011 mean of observed season/area/depth specific CPUE. Annual shrimp bycatch estimates were calculated based on the 2009-2011 mean of observed season/area/depth-specific CPUE, year/season/area/depth-specific shrimp effort and year-specific net per vessel (see SEDAR 34-WP-18-addendum for details).

Approach 1:

$$\text{Annual_All_Tow_CPUE_A1}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]} = \text{Average}(\text{All_Tow_CPUE}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]}) \quad (\text{Step1})$$

$$\begin{aligned} \text{2009_2011_Mean_Annual_All_Tow_CPUE_A1}_{[\text{sea}, \text{ar}, \text{dp}]} = \\ \text{Mean}(\text{Annual_All_Tow_CPUE_A1}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]}) \quad (\text{Step2}) \\ \text{where yr} = 2009, 2010 \text{ and } 2011 \end{aligned}$$

$$\begin{aligned} \text{Obs_Bycatch_A1}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]} = \\ \text{2009_2011_Mean_All_Tow_CPUE_A1}_{[\text{sea}, \text{ar}, \text{dp}]} * \text{effort}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]} * \text{npv}_{[\text{yr}]} \quad (\text{Step3}) \\ \text{where yr} = 1972 - 2011 \end{aligned}$$

$$\text{Obs_Bycatch_A1}_{[\text{yr}]} = \text{sum}(\text{Observed_Bycatch_A1}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]}) \quad (\text{Step4})$$

where yr is year (1972-2011), sea is season (3 seasons), ar is area (4 areas), dp is depth (2 depth-zones), Annual_All_Tow_CPUE_A1_[yr, sea, ar, dp] is the observed annual all-tow

year/season/area/depth-specific CPUE estimated with approach 1, All_Tow_CPUE_[yr, sea, ar, dp] is the observed all-tow year/season/area/depth-specific CPUE,
 2009_2011_Mean_Annual_All_Tow_CPUE_A1_[sea, ar, dp] is the 2009-2011 mean of season/area/depth-specific CPUE estimated with approach 1, effort_[yr, sea, ar, dp] is year/season/area/depth-specific effort, npv_[yr] is year-specific nets per vessel,
 Obs_Bycatch_A1_[yr, sea, ar, dp] is the observed year/season/area/depth-specific bycatch estimated with approach 1, Obs_Bycatch_A1_[yr] is the observed annual bycatch estimated with approach 1.

Approach 2:

$$\text{Annual_NZCT_CPUUE_A2}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]} = \exp\{\text{average}[\ln(\text{NZCT_CPUUE}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]})] + 0.5 * \text{var}(\ln(\text{NZCT_CPUUE}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]}))\} \quad (\text{Step1a})$$

$$\begin{aligned} \text{Annual_All_Tow_CPUUE_A2}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]} &= \\ \text{Annual_NZCT_CPUUE_A2}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]} * \text{Percent_of_NZCT}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]} & \end{aligned} \quad (\text{Step1b})$$

$$\begin{aligned} \text{2009_2011_Mean_Annual_All_Tow_CPUUE_A2}_{[\text{sea}, \text{ar}, \text{dp}]} &= \\ \text{Mean}(\text{Annual_All_Tow_CPUUE_A2}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]}) & \end{aligned} \quad (\text{Step2})$$

where yr = 2009, 2010 and 2011

$$\begin{aligned} \text{Obs_Bycatch_A2}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]} &= \\ \text{2009_2011_Mean_All_Tow_CPUUE_A2}_{[\text{sea}, \text{ar}, \text{dp}]} * \text{effort}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]} * \text{npv}_{[\text{yr}]} & \end{aligned} \quad (\text{Step3})$$

where yr = 1972 - 2011

$$\text{Obs_Bycatch_A2}_{[\text{yr}]} = \text{sum}(\text{Observed_Bycatch_A2}_{[\text{yr}, \text{sea}, \text{ar}, \text{dp}]}) \quad (\text{Step4})$$

Annual_NZCT_CPUUE_A2_[yr, sea, ar, dp] is the observed annual non-zero-catch-tow year/season/area/depth-specific CPUE estimated with approach 2, NZCT_CPUUE_[yr, sea, ar, dp] is the observed non-zero-catch-tow year/season/area/depth-specific CPUE,
 Annual_All_Tow_CPUUE_A2_[yr, sea, ar, dp] is the observed annual all-tow year/season/area/depth-specific CPUE estimated with approach 2, Percent_of_NZCT_[yr, sea, ar, dp] is the observed year/season/area/depth-specific percent of non-zero-catch tows,
 2009_2011_Mean_Annual_All_Tow_CPUUE_A2_[sea, ar, dp] is the 2009-2011 mean of season/area/depth-specific CPUE estimated with approach 2, Obs_Bycatch_A2_[yr, sea, ar, dp] is the observed year/season/area/depth-specific bycatch estimated with approach 2,
 Obs_Bycatch_A2_[yr] is the observed annual bycatch estimated with approach 2. Basically, estimates of the observed annual all-tow year/season/area/depth-specific CPUE with approach 2 were calculated based on a simplified delta-lognormal model.

Both approaches were performed and compared, using both observer and research data and only observer data. Both CPUE and bycatch estimates were similar using the two approaches. Both CPUE and bycatch estimates were slightly higher with both observer program and research vessel data than with only observer program data. The majority of the data for the years 2009-

2011 consisted of observer data, which more closely match shrimp fishery effort. The 2009-2011 mean shrimp bycatch estimates and mean observed CPUE for Atlantic sharpnose are 1,213,956 sharks and 0.1564 sharks per net-hour.

Decision 6: The Panel recommended using Approach 2 with observer data only to obtain bycatch estimates because the majority of the data in 2009-2011, which were more reliable, were observer data.

In SEDAR 13, bycatch estimates for the Atlantic had been obtained by scaling the Gulf of Mexico estimates by the ratio of the observed days in the Atlantic (2.2 days on average) to the observed days in the Gulf of Mexico (17.5 days on average) based on observations for 1992-2003. This resulted in a ratio of 12.6%. After the Workshop, this ratio was updated with new information obtained from the Shrimp Fishery Observer Program (L. Scott-Denton, pers. comm.). The average trip length of trips observed in the GOM ($15.85=22,761$ sea days/1,436 trips) was divided by the average trip length of trips observed in the SA ($2.14=2,614$ sea days/1,223 trips) for 1992-2011. The new ratio became 13.5%.

Decision 7: Based on updated information from the Shrimp Fishery Observer Program, the Panel recommended using the new ratio of 13.5% to obtain bycatch estimates in the SA based on the GOM estimates.

2.2.3. Indices of abundance

2.2.3.1 Review of working papers

[SEDAR34-WP-01: Standardized catch rates of Atlantic sharpnose sharks *Rhizoprionodon terraenovae* in the U.S. Gulf of Mexico from the Shark Bottom Longline Observer Program, 1994-2011](#)

J Carlson and S. Gulak

Catch rate series were developed for Atlantic sharpnose shark from the data collected by on-board observers in the shark bottom longline fishery for the period 1994-2011. Data were subjected to a Generalized Linear Model (GLM) standardization technique that treats separately the proportion of sets with positive catches (i.e., where at least one shark was caught) assuming a binomial error distribution with a logit link function, and the catch rates of sets with positive catches assuming a lognormal error distribution with a log link function. Year and bait type were significant as a main effects in the binomial model and year, bait type, area and time of day were

significant in the lognormal model. Outside a peak in 2000, the relative abundance index showed a general flat trend in abundance.

[SEDAR34-WP-03: Standardized Catch Rates of Bonnethead and Atlantic Sharpnose Shark from the Southeast Shark Drift Gillnet Fishery: 1993-2011](#)

J. Carlson, A. Mathers, and M. Passerotti

Catch rate standardization using the Delta lognormal approach for data from the directed shark drift gillnet fishery was developed based on observer programs from 1993-1995 and 1998-2011. For Atlantic sharpnose shark, initial selection of factors indicated the negative of the Hessian was not positive definite for the binomial model when only year was considered as a factor. Given that year is a factor in all model selection no further analysis was performed. For bonnethead shark, year and mesh size were significant as main effects in the binomial model. Year and area were significant in the lognormal model. The relative abundance index was unstable with random peaks throughout the time series likely related to low sample size or missing observations (years with no data) throughout the time series.

[SEDAR34-WP-05: Relative abundance of bonnethead and Atlantic sharpnose sharks based on a fishery-independent gillnet survey off Texas](#)

W. Bubley and J. Carlson

This paper determines a relative abundance index for bonnethead and Atlantic sharpnose sharks utilizing a fishery independent gillnet survey by the Texas Parks and Wildlife Department, Coastal Fisheries Division. The protocol for the survey, as it is constituted today, has been ongoing since 1975 with the purpose of monitoring relative abundance and size of organisms, their spatial and temporal distribution, and species composition of the community and selected environmental parameters known to influence their distribution and abundance (Martinez-Andrade and Fisher 2012). These indices are an extension of those examined during SEDAR-13 to include updated data (Fisher 2007).

[SEDAR34-WP-09: Standardized catch rates of Atlantic sharpnose \(*Rhizoprionodon terraenovae*\) and bonnethead \(*Sphyrna tiburo*\) sharks collected during a gillnet survey in Mississippi coastal waters, 1998-2011](#)

E. Hoffmayer, G. Parsons, J. Hendon, A. Pollack, and G. Ingram

Beginning in 1998, an ongoing monthly standardized gillnet survey has been conducted in Mississippi coastal waters from March to October each year. This fisheries independent dataset was developed to monitor the abundance and distribution of various elasmobranch and teleost species within Mississippi's coastal waters. As a result of 270 net sets and 882 hours of effort,

2,557 Atlantic sharpnose and 217 bonnethead sharks were collected. Standardized catch rates were estimated using a Generalized Linear Mixed modeling approach assuming a delta-lognormal error distribution. Other than slight peaks observed in 2000 and 2007, standardized catch rates remained stable across the time series for Atlantic sharpnose and bonnethead sharks, respectively.

[SEDAR34-WP-10: Standardized catch rates of Atlantic sharpnose sharks \(*Rhizoprionodon terraenovae*\) collected during a bottom longline survey in Mississippi coastal waters, 2004-2011](#)
E. Hoffmayer, J. Hendon and A. Pollack.

In 2004, a standardized monthly (March to October) bottom longline survey, conducted in Mississippi coastal waters, was initiated. This fisheries independent dataset was developed to monitor the abundance and distribution of various elasmobranch and teleost species within Mississippi state waters. As a result of 323 sets and 418 hours of effort, 733 Atlantic sharpnose sharks were caught. Standardized catch rates were estimated using a Generalized Linear Mixed modeling approach assuming a delta-lognormal error distribution. Other than a slight decline observed in the standardized index for 2008 and 2009, Atlantic sharpnose shark catch rates remained stable across the time series.

[SEDAR34-WP-11: Standardized catch rates of Atlantic sharpnose sharks \(*Rhizoprionodon terraenovae*\) collected during bottom longline surveys in Mississippi, Louisiana, Alabama, and Texas coastal waters, 2004-2011](#)

E. Hoffmayer, A. Pollack, J. Hendon, M. Drymon, and M. Grace

In 2004, a monthly bottom longline survey was established in Mississippi's inshore coastal waters. In 2006, Alabama also initiated a bottom longline survey in their coastal waters. Then in 2008 the Southeast Area Monitoring and Assessment Program implemented a standardized bottom longline survey in the state waters of Alabama (incorporated with the 2006 survey), Mississippi/Louisiana and Texas. The four separate bottom longline data sets were combined to describe Atlantic sharpnose shark catch data along the coastal waters of the northern Gulf of Mexico. The data for the combined index included sampling from 2004 to 2011, and resulted in 1114 bottom longline sets, and 3,895 Atlantic sharpnose shark encounters. Standardized catch rates were estimated using a generalized linear mixed modeling approach assuming a delta-lognormal error distribution. Nominal and standardized Atlantic sharpnose shark catch rates remained relatively stable throughout the survey period.

SEDAR34-WP-12: Atlantic Sharpnose Shark: Standardized index of relative abundance using boosted regression trees and generalized linear models

J. Froeschke and M. Drymon

Atlantic sharpnose sharks (ATSN, *Rhizoprionodon terraenovae*) are the most common shark caught on monthly longline surveys conducted off the coast of Alabama. Between May 2006 and December 2011, 1,196 ATSN were captured during 446 bottom longline sets. Length frequency distributions, as well as nominal and modeled catch per unit effort (CPUE, sharks/100 hooks/hour) are presented for ATSN. Length frequency distributions show that ATSN sampled ranged from 480 to 983 mm fork length. Given the preponderance of zero values, a delta-lognormal approach was taken to standardize the nominal index of abundance for ATSN. Two modeling approaches were used to compare the performance of a relatively new technique, boosted regression trees (delta-BRT) with the standard approach using generalized linear models (delta-GLM). Both models were validated by geo-referencing and plotting residuals. Both delta-BRT and delta-GLM models showed less variability than the raw CPUE data. Both delta models showed similar inter annual trends, with relatively stable CPUE across years, with the exception of a notable increase in CPUE in 2010. This suggests both sampling and biological effects may have influenced population levels for ATSN in 2010. The BRT outperformed the GLM for both the binomial and log-normal sub-models, indicating that the increased model flexibility of the BRT approach may be useful in the development of future CPUE indices.

SEDAR34-WP-13: Atlantic Sharpnose Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico

A. Pollack and W. Ingram, Jr.

The Southeast Fisheries Science Center Mississippi Laboratories have conducted groundfish surveys since 1972 in the northern Gulf of Mexico during the summer and fall under several sampling programs. In 1987, both groundfish surveys were brought under the Southeast Area Monitoring and Assessment Program (SEAMAP). These fisheries independent data were used to develop abundance indices for Atlantic sharpnose (*Rhizoprionodon terraenovae*). Separate indices were produced using the summer and fall SEAMAP groundfish survey data. Annual abundance indices were more variable in the early years of the index. Subsequently, in more recent years, they appear to show very little variation. Additionally, age 0 sharks were not able to be separated out due to the lack of lengths from the early years of the survey, but probably comprise a large number of captured individuals.

SEDAR34-WP-15: Atlantic Sharpnose and Bonnethead Abundance Indices from NMFS Bottom Longline Surveys in the Western North Atlantic and Northern Gulf of Mexico

A. Pollack and W. Ingram, Jr.

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories has conducted standardized bottom longline surveys in the Gulf of Mexico (GOM), Caribbean, and Western North Atlantic Ocean (Atlantic) since 1995. Additionally in 2011, the Congressional Supplemental Sampling Program (CSSP) was conducted where high levels of survey effort were maintained from April through October. Data from the SEFSC Bottom Longline Survey and the CSSP Survey were used to produce abundance indices for Atlantic sharpnose. Abundance indices were produced for the Atlantic, GOM and Atlantic and GOM combined. All age 0 sharks were removed from the data at the request of the assessment scientists.

SEDAR34-WP-16: Continuity Runs for Atlantic Sharpnose and Bonnethead SEAMAP Groundfish Surveys and NMFS Bottom Longline Surveys

A. Pollack and W. Ingram, Jr.

Prior to the Data Workshop for SEDAR 34, we were asked to rerun abundance indices for use in continuity runs of the stock assessment models for Atlantic sharpnose, *Rhizoprionodon terraenovae*, and bonnethead, *Sphyrna tiburo*. Six indices were requested from the SEAMAP Groundfish survey and three were requested from the NMFS Bottom Longline survey. All abundance indices were constructed using the delta-lognormal method outlined by Lo et al. 1992. For the SEAMAP Groundfish indices, in the previous working documents a Bayesian approach was used, which was not able to be replicated and was thus replaced with the delta-lognormal approach. In addition, it is not known which version of the data was used; however, the most current set was used for these runs. The same concern and solution about the version of the data also applies to the NMFS Bottom Longline data. For a full review of the data, model variables and model selection refer to the current working document for SEAMAP Groundfish (SEDAR34-DW-14) and NMFS Bottom Longline (SEDAR34-DW-15).

SEDAR34-WP-19: Standardized catch rates of Atlantic sharpnose and bonnethead sharks from the SEAMAP-South Atlantic Shallow Water Trawl Survey

E. Cortés and J. Boylan

This document presents an updated analysis of the relative abundance of Atlantic sharpnose and bonnethead sharks from the SEAMAP-SA Shallow Water Trawl Survey for 1989-2011. Time series data from this survey were standardized with Generalized Linear Mixed Model (GLMM) procedures. Both series showed increasing trends. Examination of lengths of Atlantic sharpnose

and bonnethead sharks over the time period considered revealed no trend. Length-frequency information revealed that mostly immature individuals of these species area caught, but adults are also present.

SEDAR34-WP-24: Size composition and indices of relative abundance of the Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) in coastal Virginia waters

R. Latour, C. Bonzek, and J. Gartland

The Virginia Shark Monitoring and Assessment Program (VASMAP) has been sampling shark populations in the Chesapeake Bay and coastal Virginia waters using standardized fishery-independent longline gear since 1974. Program data for Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) collected from 1975-2011 show that this species is encountered frequently (1585 animals collected over the time-series), Smith Island Shoals (sampling site L) had the highest overall catch, virtually all sampled animals are older than age-0, and that males (88%) dominated longline catches. Additionally, trends in nominal and two differently derived standardized indices of relative abundance (based on delta-lognormal and zero-inflated negative binomial generalized linear models) were all generally similar and showed a decrease from 1995-2003 and a notable increase from 2004-2011 to the highest index values on record. Estimated coefficients of variation for the standardized indices of relative abundance were moderate (0.6-0.8) with higher values in some years. Based on VASMAP data, it appears that the Atlantic sharpnose shark population has been experiencing a notable increase in abundance over the past decade.

SEDAR34-WP-28: Standardized Catch Rates of Bonnethead and Atlantic Sharpnose Shark from the Southeast Sink Gillnet Fishery: 2005-2011

J. Carlson, A. Mathers, and M. Passerotti

A standardized catch rate series was developed for Atlantic sharpnose and bonnethead shark using the Delta lognormal approach based on observer data collected in the southeast sink gillnet fishery. Depending on the species, differing factors were found to be significant as main effects in the final model. For Atlantic sharpnose shark, year, season, area, and meshsize were significant in the binomial model and year, target, season and area in the lognormal model. For the bonnethead sharks, year, area, target and season were significant in the binomial model whereas year and meshsize were significant in the lognormal model. The relative abundance index was relatively stable for both species from 2005-2011.

SEDAR34-WP-29: Relative abundance of Atlantic sharpnose and bonnethead shark from the northeastern Gulf of Mexico

J. Carlson, D. Bethea, E. Hoffmayer, J. Tyminski, R. Hueter, D. Grubbs, M. Ajemian, and G. Burgess

Following recommendations at SEDAR29, fishery independent gillnet data sets from several surveys were combined to form a more spatially expansive inshore eastern Gulf of Mexico gillnet dataset. Since there were differences in the accessory data included with the data sets, several factors including temperature, salinity, year, month, location, depth, set time, and effort were used within a generalized linear model to standardize the series. Additionally, the factor “survey” was added to the dataset. A total of 3313 gillnet sets have been made throughout all areas since 1995. The majority of individuals captured were juveniles and the length distribution did not change significantly over the survey period for Atlantic sharpnose shark or bonnethead shark. The abundance trend was relatively stable for Atlantic sharpnose shark with some evidence for an increasing trend in later years. For bonnethead, outside one dip in the time series in 2005, the time series was relatively flat.

SEDAR34-WP-34: Standardized indices of abundance for Atlantic sharpnose sharks from the Georgia Department of Natural Resources red drum longline survey

C. McCandless and C. Belcher

This document details the shark catches from the Georgia Department of Natural Resources (GADNR) adult red drum longline survey conducted in Georgia and northern Florida’s nearshore and offshore waters from 2007-2011. Catch per unit effort (CPUE) in number of sharks per hook were used to examine Atlantic sharpnose shark relative abundance in Georgia’s coastal waters. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. Nominal and standardized CPUE results from the GADNR red drum survey indicate an initial increase in Atlantic sharpnose shark relative abundance from 2007 to 2008 followed by a gradual decreasing trend in relative abundance during the remaining survey years.

SEDAR34-WP-35: Standardized indices of abundance for bonnethead and Atlantic sharpnose sharks from the Georgia Department of Natural Resources ecological monitoring trawl surveys

C. McCandless, J. Page, and C. Belcher

This document details the shark catches from the Georgia Department of Natural Resources (GADNR) Ecological Monitoring Trawl Survey conducted from 2003-2011. Catch per unit effort (CPUE) in number of sharks per tow hour were used to examine age 1+ bonnethead and Atlantic sharpnose shark relative abundance in Georgia's coastal waters. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The standardized indices of abundance from the GADNR trawl survey show no apparent overall trends in age 1+ bonnethead and Atlantic sharpnose shark relative abundance across survey years.

[SEDAR34-WP-36: Standardized indices of abundance for bonnethead and Atlantic sharpnose sharks caught during the South Carolina Department of Natural Resources red drum longline and Cooperative Atlantic States Shark Pupping and Nursery gillnet surveys](#)
C. McCandless and B. Frazier

This document details shark catches from the South Carolina Department of Natural Resources (SCDNR), Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) gillnet survey and the SCDNR adult red drum longline survey, both conducted in South Carolina's estuarine waters, with additional nearshore stations in the red drum survey. Catch per unit effort (CPUE) in number of sharks per net hour or sharks per hook hour were used to examine bonnethead and/or Atlantic sharpnose shark relative abundance for gillnet and longline surveys, respectively. The SCDNR red drum time series had to be analyzed in two separate time segments (1998-2006 and 2007-2011) due to a change in gear and sampling design. The CPUE for all time series was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. Nominal and standardized CPUE results from the COASTSPAN gillnet survey indicate a decreasing trend in bonnethead relative abundance during the survey years. This survey also shows an overall decreasing trend for total Atlantic sharpnose sharks across survey years; but, once young-of-the year sharks are removed from the gillnet catch, an increasing trend is seen in age 1+ sharks. Atlantic sharpnose shark relative abundance begins an increasing trend during the final years of the 1998-2006 red drum survey. The current red drum survey shows a fairly stable trend in Atlantic sharpnose shark relative abundance.

SEDAR34-WP-37: Standardized indices of abundance for bonnethead and Atlantic sharpnose sharks caught during the Cooperative Atlantic States Shark Pupping and Nursery longline surveys from South Carolina to northern Florida

C. McCandless, C. Belcher, B. Frazier, M. McCallister, R. Ford, and J. Gelsleichter

This document details the shark catches from the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) longline surveys conducted in estuarine and nearshore waters from South Carolina to northern Florida. Catch per unit effort (CPUE) in number of sharks per hook hour were used to examine age 1+ bonnethead and Atlantic sharpnose shark relative abundance from 2000-2011. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The standardized indices of abundance from the COASTSPAN longline surveys show a peak in abundance in 2001 for bonnethead and Atlantic sharpnose sharks. Relative abundance, for both species, then drops closer to previous levels in 2002 and appears to stabilize before starting an increasing trend in recent years.

SEDAR34-WP-38: Standardized indices of abundance for Atlantic sharpnose sharks from the University of North Carolina bottom longline survey

F.J Schwartz, C.T. McCandless, and J. Hoey

This document details the Atlantic sharpnose shark catch from April-November, 1972-2011, at two fixed stations in Onslow Bay south of Shackleford Banks, North Carolina. Catch per unit effort (CPUE) by set in number of sharks per number of set hooks were examined by year. The CPUE was standardized using a two- step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. No Atlantic sharpnose sharks were caught during the three longline sets conducted in 1972. The nominal and standardized relative abundance for Atlantic sharpnose sharks show an increasing trend throughout the majority of the time series that peaks in 2005 and then appears to decrease during the remaining years, ending in 2011.

2.2.3.2. New indices of abundance

Seven new fishery-independent indices (SEDAR34-WP-11, 29, 34, 35, 36, 37), and one new fishery-dependent index (SEDAR34-WP-28) were presented for consideration by the panel (**Table 2.5.4**). Indices were initially reviewed based upon the criteria established at the SEDAR Abundance Indices Workshop held in 2008. The data source, index construction methodology, adherence to statistical assumptions, and model diagnostics were examined for each index. All indices were determined to be appropriately constructed, although in some cases revisions were recommended based on discussion among the participants. Each index was then recommended for either a base run of the assessment model or for use in a potential model sensitivity run. The criteria for recommendation included sample size, proportion of positive trips, length of the time series, spatial extent of the index, and region sampled (e.g. whether the index was restricted to marginal habitat or at the limit of a species range).

Index ranking was completed during SEDAR34 with input from the assessment biologists for the purpose of weighting the indices in the model runs. Indices could, and frequently did, have similar rankings. When determining rankings of the indices (1 = best), the primary consideration was that an index reflect the population trend of the species (or a portion of the population, e.g. juveniles). That judgment was made by considering characteristics of the data used in the construction of each index. In general, the Panel ranked fishery-independent indices higher than fishery-dependent indices. For specific reasoning behind the individual index rankings, see SEDAR34-WP-39.

Following recommendations at SEDAR29, that fishery-independent data from multiple sources be combined in a generalized linear modeling framework, several data sets were combined from SEDAR13 data (SEDAR13-WP-06, 21, 27, 30, 38) with new data sources and analyzed prior to the SEDAR34 workshop (e.g., SEDAR34-WP-11, 29, 37). These documents were presented to the Panel and the Panel accepted these as new time series. Discussion amongst the Panel ensued relative to combining other fishery-independent data sources that were similar in design but not analyzed prior to SEDAR34. Data sources from the SCDNR and GADNR red drum longline surveys (SEDAR34-WP-34 and 36) were combined for Atlantic sharpnose sharks using similar approaches as in SEDAR34-WP-11.

Decision 1: Consistent with the approach used in SEDAR 29, the Panel decided to combine coastal fishery-independent gillnet and longline surveys.

Several series that were used for Atlantic sharpnose shark at SEDAR13 were not used at SEDAR34. A number of factors were outlined as to why the series were not considered. Series with low sample size in some years or no samples taken in many years such as SEDAR13-DW-09 (The Directed Shark Drift Gillnet Fishery) were removed. Series were not considered if there was questionable species identification such as in SEDAR 13-DW-16 (Marine Recreational Fishery Statistics Survey (MRFSS)) and in self reported logbook data from SEDAR13-DW-26 and 41. Logbook data was also not utilized if there was a comparable observer program that collected data from the same fishery (e.g. Shark Bottom Longline Fishery has an observer program that monitors the fishery). Additional series such as SEDAR 13-DW-25 (Northeast Fisheries Observer Program of the coastal gillnet fishery), SEDAR13-DW-28 (NEFSC exploratory longline survey), SEDAR-13-29 (NEFSC Longline Survey) were deemed not useable because most samples were from areas outside the species range, resulting in low sample sizes.

Decision 2: After reviewing the data, the Panel decided to remove some time series that were used for SEDAR13.

There was discussion relative to the inclusion of environmental data in the analysis for the combined fishery-independent longline surveys from Alabama, Mississippi, Louisiana, and Texas state waters (SEDAR34-WP-11). Some panelists felt the Texas data should not be included because it is a much smaller and spatially separate dataset and is different environmentally from other areas in the surveys. The analysis was re-run with and without environmental data with Texas included. The abundance trend was found to be similar regardless of environmental data and the Panel concluded the entire dataset (including Texas) without environmental data should be used.

Decision 3: After considering the effects of environmental data relative to disaggregation of a combined survey, the Panel decided to use the fishery-independent longline survey data provided in SEDAR34-WP-11.

Summaries of the indices of relative abundance considered and decisions made on the rankings are in **Tables 2.5.4** and **2.5.5**. In general, series that were fishery independent, subject to a random-stratified statistical design, stock-wide and were of long temporal scale were ranked

highest. The NMFS Southeast Bottom Longline survey (NMFS LL SE) was ranked highest and the NMFS Panama City Longline Survey (PC LL) was ranked lowest.

Decision 4: Consistent with previous SEDARs, the Panel decided to rank all abundance series.

2.3. LITERATURE CITED

- Gurshin, C. W. D., and S. T. Szedlmayer. 2004. Short-term survival and movements of Atlantic sharpnose sharks captured by hook-and-line in the north-east Gulf of Mexico. *Journal of Fish Biology*, 65:973-986.
- Heist, E.J., J.A. Musick, and J.E. Graves. 1996. Mitochondrial DNA diversity and divergence among sharpnose sharks, *Rhizoprionodon terraenovae*, from the Gulf of Mexico and mid-Atlantic Bight. *Fish. Bull.* 94:664-668.
- Hueter, R. E., and Manire, C. A. 1994. Bycatch and catch-release mortality of small sharks in the Gulf coast nursery grounds of Tampa Bay and Charlotte Harbor. Technical Report No. 368 (Final report to NOAA/NMFS, MARFIN Project NA17FF0378-01), 183 pp.
- Hueter, R. E., Manire, C. A., Tyminski, J. P., Hoenig, J. M., and Hepworth, D. A. 2006. Assessing mortality of released or discarded fish using a logistic model of relative survival derived from tagging data. *Transactions of the American Fisheries Society*, 135:500-508.
- SEDAR 13. 2007. Small coastal shark complex, Atlantic sharpnose, blacknose, bonnethead, and finetooth shark. Stock assessment report. NOAA/NMFS HMS Management Division. 1315 East-West Highway, Silver Spring, MD 20910.

2.4. RESEARCH RECOMMENDATIONS

- More research is necessary on review/improvement/development of shrimp bycatch estimation models for both data-poor and data-rich species
- More research is necessary on integration of various local abundance indices into a global abundance index based on spatio-temporal, physical-biological characteristics and variability.

2.5. TABLES

Table 2.5.1. Catches of Atlantic sharpnose shark by fleet in numbers used in the continuity analysis. Catches are separated into six fisheries: commercial bottom longline, gillnet, handline, and bottom longline discards, recreational catches, and shrimp trawl bycatch. Catches for 1950-2005 are identical to those used for SEDAR 13. For shrimp discards, 2006-2011 values are the mean of 2003-2005 values.

| Year | Com-BLL | Com-GN | Com-L | Com-BLL disc | Recreational | Shrimp discards |
|------|---------|--------|-------|--------------|--------------|-----------------|
| 1950 | 0 | 0 | 0 | 0 | 12114 | 199157 |
| 1951 | 0 | 0 | 12 | 0 | 13314 | 255841 |
| 1952 | 0 | 0 | 24 | 0 | 14514 | 258937 |
| 1953 | 0 | 0 | 36 | 0 | 15714 | 297766 |
| 1954 | 0 | 0 | 48 | 0 | 16914 | 307492 |
| 1955 | 0 | 0 | 61 | 0 | 18114 | 278697 |
| 1956 | 0 | 0 | 73 | 0 | 19314 | 253339 |
| 1957 | 0 | 0 | 85 | 0 | 20514 | 227780 |
| 1958 | 0 | 0 | 97 | 0 | 21714 | 226216 |
| 1959 | 0 | 0 | 109 | 0 | 22914 | 253769 |
| 1960 | 0 | 0 | 121 | 0 | 24114 | 271849 |
| 1961 | 0 | 0 | 133 | 0 | 24815 | 136426 |
| 1962 | 0 | 0 | 145 | 0 | 25517 | 178861 |
| 1963 | 0 | 0 | 157 | 0 | 26218 | 269133 |
| 1964 | 0 | 0 | 169 | 0 | 26920 | 240757 |
| 1965 | 0 | 0 | 182 | 0 | 27621 | 258877 |
| 1966 | 0 | 0 | 194 | 0 | 28322 | 244276 |
| 1967 | 0 | 0 | 206 | 0 | 29024 | 299894 |
| 1968 | 0 | 0 | 218 | 0 | 29725 | 273578 |
| 1969 | 0 | 0 | 230 | 0 | 30427 | 286401 |
| 1970 | 0 | 0 | 242 | 0 | 31128 | 315416 |
| 1971 | 0 | 0 | 254 | 0 | 34310 | 323214 |
| 1972 | 0 | 0 | 266 | 0 | 34613 | 546849 |
| 1973 | 0 | 0 | 278 | 0 | 34916 | 115836 |
| 1974 | 0 | 0 | 291 | 0 | 35220 | 208340 |
| 1975 | 0 | 0 | 303 | 0 | 35523 | 216843 |
| 1976 | 0 | 0 | 315 | 0 | 35827 | 159043 |
| 1977 | 0 | 0 | 327 | 0 | 36130 | 560188 |
| 1978 | 0 | 0 | 339 | 0 | 36434 | 651041 |
| 1979 | 0 | 0 | 351 | 0 | 36737 | 530051 |
| 1980 | 50 | 0 | 363 | 39 | 41970 | 852586 |
| 1981 | 75 | 0 | 375 | 58 | 43490 | 424066 |
| 1982 | 112 | 0 | 387 | 87 | 40656 | 235138 |
| 1983 | 168 | 0 | 399 | 130 | 50170 | 386130 |
| 1984 | 250 | 0 | 412 | 194 | 37539 | 217712 |
| 1985 | 373 | 0 | 424 | 290 | 37994 | 330027 |
| 1986 | 556 | 0 | 436 | 432 | 45392 | 228189 |
| 1987 | 830 | 726 | 448 | 644 | 46792 | 639555 |
| 1988 | 1238 | 1452 | 460 | 961 | 103375 | 362917 |
| 1989 | 1847 | 2178 | 472 | 1434 | 65058 | 304957 |
| 1990 | 2755 | 2904 | 484 | 2139 | 45233 | 342124 |
| 1991 | 4110 | 3630 | 496 | 3191 | 134905 | 518206 |
| 1992 | 6132 | 4355 | 508 | 4761 | 85972 | 968330 |
| 1993 | 9148 | 5081 | 521 | 7103 | 67719 | 433492 |
| 1994 | 13647 | 5807 | 533 | 10596 | 101774 | 259349 |
| 1995 | 20359 | 6533 | 545 | 15807 | 128478 | 638341 |
| 1996 | 12074 | 35721 | 1318 | 9374 | 73114 | 503193 |
| 1997 | 6925 | 70619 | 854 | 5377 | 67675 | 329038 |
| 1998 | 6580 | 64506 | 1794 | 5109 | 83748 | 512281 |
| 1999 | 5248 | 69727 | 1576 | 4075 | 69153 | 311118 |
| 2000 | 3951 | 35610 | 1145 | 3068 | 130727 | 539085 |
| 2001 | 4787 | 53890 | 1190 | 3717 | 131912 | 318995 |
| 2002 | 11635 | 59098 | 819 | 9034 | 88297 | 639044 |
| 2003 | 19783 | 40159 | 1469 | 15362 | 85299 | 295059 |
| 2004 | 25639 | 47693 | 644 | 20329 | 67870 | 173326 |
| 2005 | 24876 | 80539 | 1159 | 19352 | 80761 | 325764 |
| 2006 | 38728 | 100488 | 2122 | 20069 | 81817 | 264716 |
| 2007 | 12887 | 85769 | 3130 | 6678 | 111967 | 264716 |
| 2008 | 10425 | 76165 | 1319 | 5402 | 78885 | 264716 |
| 2009 | 31861 | 56004 | 1270 | 16510 | 65709 | 264716 |
| 2010 | 16852 | 46710 | 4922 | 8733 | 63695 | 264716 |
| 2011 | 24849 | 54462 | 6377 | 12877 | 49916 | 264716 |

Table 2.5.2. Summary of Recommended Life History Parameters

| | Atlantic Ocean | Gulf of Mexico | Single stock |
|--|---|---|---|
| | Female / Male / Combined | Female / Male / Combined | Female / Male / Combined |
| Growth parameters | | | |
| L_∞ (cm FL) | 81.9 / 81.3 / 81.6 | 80.8 / 77.8 / 79.5 | 80.2 / 79.3 / 79.8 |
| k | 0.48 / 0.50 / 0.49 | 0.63 / 0.86 / 0.73 | 0.61 / 0.66 / 0.64 |
| t_o | -0.99 / -0.94 / -0.97 | -1.01 / -0.72 / -0.86 | -0.84 / -0.76 / -0.80 |
| Max observed age (years) | 18 | 9.5 | 18 |
| | | | |
| Maturity ogive | SEDAR13-DW-08-V2 | SEDAR34-WP-30 | SEDAR34-WP-30 |
| | Female | Female | Female |
| FL (cm) at 50% maturity | 60.5 | 62.3 | 62.5 |
| a and b | Not reported | $a = -24.7204, b = 0.394444$ | $a = -25.2920, b = 0.404938$ |
| Age (years) at 50% maturity | 2 | 1.3 | 1.3 |
| a and b | Not reported | $a = -6.76532, b = 5.15161$ | $a = -5.9641, b = 4.48244$ |
| Reproductive cycle | Annual | Annual | Annual |
| Fecundity | mean = 4.1 | mean = 4.6 | mean = 4.3 |
| Maternal size (cm FL)-litter size relationship | $y = 0.0534e^{0.0544FL}$ | $y = \exp(-3.07042+0.0570151*FL)$ | $y = \exp(-3.03167+0.056090*FL)$ |
| Pupping month | June | June | June |
| Sex ratio | 1:1 | 1:1 | 1:1 |
| L-W relationship | $WT = 5.56 \times 10^{-6} FL^{(3.074)}$ | $WT = 2.0 \times 10^{-6} (FL^{3.3071})$ | $WT = 5.56 \times 10^{-6} FL^{(3.074)}$ |

Table 2.5.3. Recommended female Atlantic sharpnose shark maturity ogive:

| Age | Proportion Mature |
|-------|----------------------|
| 0.00 | 0.00 |
| 1.00 | 0.19 |
| 2.00 | 0.95 |
| 3.00 | 1.00 |
| 4.00 | 1.00 |
| 5.00 | 1.00 |
| 6.00 | 1.00 |
| 7.00 | 1.00 |
| 8.00 | 1.00 |
| 9.00 | 1.00 |
| 10.00 | 1.00 |
| 11.00 | 1.00 |
| 12.00 | 1.00 |
| 13.00 | 1.00 |
| 14.00 | 1.00 |
| 15.00 | 1.00 |
| 16.00 | 1.00 |
| 17.00 | 1.00 |
| 18.00 | 1.00 |

Table 2.5.4. A summary of indices of abundance considered for the Atlantic sharpnose shark assessment at SEDAR34.

| Document Number | Series Name | Type | Years | Season | Spatial | Statistical design | Recommendation | Positive aspects | Negative aspects |
|-----------------|----------------------------|--------------------------------|----------------------|---------|--------------------------|--------------------|-----------------|--------------------------------------|-------------------------|
| SEDAR 13-DW-05 | PC LL | Fishery independent | 1993-2000 | Apr-Oct | Coastal NW Florida | Fixed | Base | Fishery independent | Limited spatial |
| SEDAR 13-DW-09 | GNOP | Fishery Dependent-Commercial | 1993-1995, 2008-2012 | Jan-Dec | South Atl | None | Not recommended | | |
| SEDAR 13-DW-16 | MRFSS | Fishery Dependent-Recreational | 1981-2011 | Jan-Dec | South Atl_Gulf of Mexico | None | Not recommended | | |
| SEDAR 13-DW-25 | NE Coastal Gillnet Fishery | Fishery Dependent-Commercial | 1995-2011 | Jan-Dec | North Atlantic | None | Not recommended | | |
| SEDAR 13-DW-26 | Gillnet Logbook | Fishery Dependent-Commercial | 1998-2011 | Jan-Dec | South Atl_Gulf of Mexico | None | Not recommended | | |
| SEDAR 13-DW-28 | NEFSC early | Fishery independent | 1961-1991 | Jan-Dec | Atlantic Ocean | Fixed | Not recommended | | |
| SEDAR 13-DW-29 | NEFSC late | Fishery independent | 1996-2011 | July | Atlantic Ocean | Fixed | Not recommended | | |
| SEDAR 13-DW-41 | Longline Logbook | Fishery Dependent-Commercial | 1996-2011 | Jan-Dec | South Atl_Gulf of Mexico | None | Not recommended | | |
| SEDAR 34-DW-01 | BLLOP combined | Fishery Dependent-Commercial | 1994-2011 | Jan-Dec | South Atl_Gulf of Mexico | No | Base | High spatial coverage/Long series | Commercial fishing data |
| SEDAR 34-DW-05 | Texas Gillnet | Fishery independent | 1975-2011 | Apr-Nov | Texas | Stratified | Not recommended | Fishery independent Long time series | Spatial limited |

| | | | | | | | | | |
|----------------|--------------------------------------|------------------------------|-----------|---------|--------------------------------|------------------|-------------|---|--------------------------------|
| SEDAR 34-DW-11 | GOM COMBINED LL | Fishery independent | 2004-2011 | Mar-Oct | Miss/Alabama/Texas | Stratified | Base | Fishery independent/High spatial coverage | Shorter time series |
| SEDAR 34-DW-13 | SEAMAP - GoM - Ext Fall | Fishery independent | 1972-2011 | Oct-Nov | Gulf of Mexico | Stratified | Base | Fishery independent Long time series | Limited size classes |
| SEDAR 34-DW-13 | SEAMAP - GoM - Ext Summer | Fishery independent | 1982-2011 | Jun-Jul | Gulf of Mexico | Stratified | Base | Fishery independent Long time series | Limited size classes |
| SEDAR 34-DW-15 | NMFS LL SE | Fishery independent | 1995-2011 | Jul-Sep | South Atl_Gulf of Mexico | Stratified | Base | Fishery independent Long time series | Limited size classes |
| SEDAR 34-DW-19 | SEAMAP - SA | Fishery independent | 1989-2011 | Apr-Nov | South Atl | Stratified | Base | Fishery independent Long time series | Limited size classes |
| SEDAR 34-DW-24 | VA LL | Fishery independent | 1975-2011 | Jun-Sep | Virginia | Fixed | Base | Long time series | Fixed stations Spatial limited |
| SEDAR 34-DW-28 | Sink GNOP | Fishery Dependent-Commercial | 2005-2011 | Jan-Dec | South Atlantic | None | Sensitivity | High spatial coverage | Commercial fishing data |
| SEDAR 34-DW-29 | GOM COMBINED GN | Fishery independent | 1995-2011 | Apr-Oct | East Gulf of Mexico | Stratified/Fixed | Base | Fishery independent | Limited spatial |
| SEDAR 34-DW-34 | SCGA_DNR red drum longline 2007-2011 | Fishery independent | 2007-2011 | Aug-Dec | South Carolina | Stratified | Base | Fishery independent | Limited spatial |
| SEDAR 34-DW-35 | GADNR Trawl | Fishery independent | 2003-2011 | Apr-Oct | Georgia | Stratified | Base | Fishery independent | Limited spatial |
| SEDAR 34-DW-36 | SC Coastspan GN | Fishery independent | 1998-2011 | Apr-Aug | South Carolina | Fixed | Base | Fishery independent | Limited spatial |
| SEDAR 34-DW-36 | SCDNR red drum longline 1998-2006 | Fishery independent | 1998-2006 | Aug-Dec | South Carolina | Fixed | Base | Fishery independent | Limited spatial |
| SEDAR 34-DW-37 | Atl_Coastspan LL | Fishery independent | 2000-2011 | Apr-Sep | South Carolina/Georgia/Florida | Stratified/Fixed | Base | Fishery indep/High spatial coverage | Shorter time series |
| SEDAR 34-DW-38 | UNC | Fishery independent | 1973-2011 | Apr-Nov | North Carolina | Fixed | Base | Long time series | Fixed stations/Spatial limited |

Table 2.5.5. A summary of Atlantic sharpnose shark abundance indices used for base or sensitivity model runs with the associated rank of the time series. All data series were standardized using a lognormal or delta-lognormal generalized linear modeling approach

| Document Number | Series Name | Type | Unit | Recommendation | Ranking | Years | Statistical design |
|-----------------|--------------------------------------|------------------------------|-------------------|----------------|---------|-----------|--------------------|
| SEDAR 13-DW-05 | PC LL | Fishery independent | shark/hk hr | Base | 4 | 1993-2000 | Fixed |
| SEDAR 34-DW-01 | BLLOP combined | Fishery dependent-commercial | shark/10,000 hk | Base | 2 | 1994-2011 | No |
| SEDAR 34-DW-11 | GOM COMBINED LL | Fishery independent | shark/hk hr | Base | 2.5 | 2004-2011 | Stratified |
| SEDAR 34-DW-13 | SEAMAP - GoM - Ext Fall | Fishery independent | shark/tow | Base | 1.5 | 1972-2011 | Stratified |
| SEDAR 34-DW-13 | SEAMAP - GoM - Ext Summer | Fishery independent | shark/tow | Base | 1.5 | 1982-2011 | Stratified |
| SEDAR 34-DW-15 | NMFS LL SE | Fishery independent | shark/100 hk hr | Base | 1 | 1995-2011 | Stratified |
| SEDAR 34-DW-19 | SEAMAP - SA | Fishery independent | shark/tow | Base | 1.5 | 1989-2011 | Stratified |
| SEDAR 34-DW-24 | VA LL | Fishery independent | shark/100 hk hr | Base | 2 | 1975-2011 | Fixed |
| SEDAR 34-DW-28 | Sink GNOP | Fishery dependent-commercial | shark/net area hr | Sensitivity | | 2005-2011 | No |
| SEDAR 34-DW-29 | GOM COMBINED GN | Fishery independent | shark/net hr | Base | 2 | 1995-2011 | Stratified/Fixed |
| SEDAR 34-DW-34 | SCGA_DNR red drum longline 2007-2011 | Fishery independent | shark/hk hr | Base | 3 | 2007-2011 | Stratified |
| SEDAR 34-DW-35 | GADNR Trawl | Fishery independent | shark/tow | Base | 3 | 2003-2011 | Stratified |
| SEDAR 34-DW-36 | SC Coastsapn GN | Fishery independent | shark/net hr | Base | 3 | 1998-2011 | Fixed |
| SEDAR 34-DW-36 | SCDNR red drum longline 1998-2006 | Fishery independent | shark/hk hr | Base | 3 | 1998-2006 | Fixed |
| SEDAR 34-DW-37 | Atl_Coastsapn LL | Fishery independent | shark/hk hr | Base | 2 | 2000-2011 | Stratified/Fixed |
| SEDAR 34-DW-38 | UNC | Fishery independent | shark/hk hr | Base | 3 | 1973-2011 | Fixed |

Table 2.5.6. All indices recommended by SEDAR34 for Atlantic sharpnose shark, including the corresponding SEDAR document number and run type (base or sensitivity). Index values are absolute and CV=coefficient of variation.

| Document Number | Series Name | Type | Recommendation | Year | Index | CV |
|-----------------|-------------|------|----------------|------|---------|-------|
| SEDAR 13-DW-05 | PC LL | FI | Base | 1993 | 0.481 | 0.516 |
| | | | | 1994 | 0.136 | 0.882 |
| | | | | 1995 | 0.301 | 0.52 |
| | | | | 1996 | 0.951 | 0.098 |
| | | | | 1997 | 0.531 | 0.196 |
| | | | | 1998 | 0.38 | 0.413 |
| | | | | 1999 | 1.16 | 0.111 |
| | | | | 2000 | 0.445 | 0.337 |
| SEDAR 34-DW-01 | BLLOP | FD-C | Base | 1994 | 14.450 | 0.567 |
| | | | | 1995 | 92.725 | 0.468 |
| | | | | 1996 | 80.747 | 0.466 |
| | | | | 1997 | 181.956 | 0.473 |
| | | | | 1998 | 245.977 | 0.448 |
| | | | | 1999 | 383.974 | 0.449 |
| | | | | 2000 | 445.425 | 0.467 |
| | | | | 2001 | 215.125 | 0.461 |
| | | | | 2002 | 184.152 | 0.454 |
| | | | | 2003 | 130.171 | 0.451 |
| | | | | 2004 | 126.152 | 0.461 |
| | | | | 2005 | 149.740 | 0.458 |
| | | | | 2006 | 78.149 | 0.460 |
| | | | | 2007 | 184.021 | 0.581 |
| | | | | 2008 | 317.227 | 0.502 |
| | | | | 2009 | 209.265 | 0.476 |
| | | | | 2010 | 224.738 | 0.439 |
| | | | | 2011 | 133.191 | 0.448 |
| SEDAR 34-DW-19 | SEAMAP - SA | FI | Base | 1989 | 3.114 | 0.334 |
| | | | | 1990 | 2.784 | 0.328 |
| | | | | 1991 | 2.968 | 0.306 |
| | | | | 1992 | 2.711 | 0.319 |
| | | | | 1993 | 2.08 | 0.349 |
| | | | | 1994 | 1.468 | 0.389 |
| | | | | 1995 | 2.935 | 0.275 |
| | | | | 1996 | 1.693 | 0.374 |
| | | | | 1997 | 3.695 | 0.286 |
| | | | | 1998 | 2.53 | 0.318 |
| | | | | 1999 | 2.591 | 0.313 |
| | | | | 2000 | 3.66 | 0.291 |
| | | | | 2001 | 3.227 | 0.246 |
| | | | | 2002 | 5.152 | 0.223 |
| | | | | 2003 | 5.296 | 0.252 |

| | | | | | |
|---------------------------|----|------|------|-------|-------|
| | | | 2004 | 3.684 | 0.256 |
| | | | 2005 | 4.587 | 0.289 |
| | | | 2006 | 6.41 | 0.24 |
| | | | 2007 | 6.42 | 0.202 |
| | | | 2008 | 4.451 | 0.226 |
| | | | 2009 | 5.618 | 0.206 |
| | | | 2010 | 4.674 | 0.233 |
| | | | 2011 | 4.11 | 0.226 |
| SEDAR 34-DW-24 VA LL | FI | Base | 1975 | 0.26 | 2.77 |
| | | | 1976 | | |
| | | | 1977 | 0.24 | 2.15 |
| | | | 1978 | | |
| | | | 1979 | | |
| | | | 1980 | 0.39 | 0.83 |
| | | | 1981 | 0.47 | 0.38 |
| | | | 1982 | | |
| | | | 1983 | 0.40 | 1.35 |
| | | | 1984 | | |
| | | | 1985 | | |
| | | | 1986 | | |
| | | | 1987 | | |
| | | | 1988 | | |
| | | | 1989 | | |
| | | | 1990 | 0.35 | 0.76 |
| | | | 1991 | 0.32 | 0.91 |
| | | | 1992 | 0.42 | 0.56 |
| | | | 1993 | 0.27 | 0.73 |
| | | | 1994 | | |
| | | | 1995 | 0.53 | 0.48 |
| | | | 1996 | 0.32 | 0.54 |
| | | | 1997 | 0.22 | 0.71 |
| | | | 1998 | 0.52 | 0.40 |
| | | | 1999 | 0.6 | 0.46 |
| | | | 2000 | 0.15 | 0.70 |
| | | | 2001 | 0.28 | 0.56 |
| | | | 2002 | 0.14 | 0.74 |
| | | | 2003 | 0.11 | 1.17 |
| | | | 2004 | 0.14 | 0.76 |
| | | | 2005 | 0.38 | 0.77 |
| | | | 2006 | 0.37 | 0.37 |
| | | | 2007 | 0.7 | 0.35 |
| | | | 2008 | 0.4 | 0.35 |
| | | | 2009 | 0.82 | 0.44 |
| | | | 2010 | 0.41 | 0.55 |
| | | | 2011 | 0.51 | 0.5 |
| SEDAR 34-DW-15 NMFS LL SE | FI | Base | 1995 | 1.027 | 0.330 |

| | | | | | | |
|----------------|---------------------------------|----|------|--------|-------|-------|
| | | | 1996 | 1.373 | 0.372 | |
| | | | 1997 | 1.231 | 0.274 | |
| | | | 1998 | | | |
| | | | 1999 | 1.071 | 0.292 | |
| | | | 2000 | 2.490 | 0.231 | |
| | | | 2001 | 3.637 | 0.218 | |
| | | | 2002 | 4.626 | 0.145 | |
| | | | 2003 | 5.198 | 0.166 | |
| | | | 2004 | 8.477 | 0.151 | |
| | | | 2005 | 9.053 | 0.247 | |
| | | | 2006 | 9.013 | 0.162 | |
| | | | 2007 | 3.779 | 0.270 | |
| | | | 2008 | 4.891 | 0.200 | |
| | | | 2009 | 11.351 | 0.137 | |
| | | | 2010 | 7.742 | 0.172 | |
| | | | 2011 | 4.877 | 0.128 | |
| SEDAR 34-DW-36 | SC Coastspan GN | FI | Base | 1998 | 2.366 | 0.795 |
| | | | | 1999 | | |
| | | | | 2000 | 0.020 | 1.697 |
| | | | | 2001 | 0.303 | 0.730 |
| | | | | 2002 | 1.285 | 0.492 |
| | | | | 2003 | 3.990 | 0.296 |
| | | | | 2004 | | |
| | | | | 2005 | 0.612 | 0.608 |
| | | | | 2006 | 1.242 | 0.525 |
| | | | | 2007 | 1.193 | 0.438 |
| | | | | 2008 | 2.612 | 0.372 |
| | | | | 2009 | 1.127 | 0.708 |
| | | | | 2010 | 2.602 | 0.462 |
| | | | | 2011 | 1.430 | 0.422 |
| SEDAR 34-DW-36 | SCDNR red drum longline Early | FI | Base | 1998 | 0.079 | 0.210 |
| | | | | 1999 | 0.046 | 0.224 |
| | | | | 2000 | 0.105 | 0.201 |
| | | | | 2001 | 0.141 | 0.177 |
| | | | | 2002 | 0.135 | 0.241 |
| | | | | 2003 | 0.084 | 0.189 |
| | | | | 2004 | 0.030 | 0.369 |
| | | | | 2005 | 0.036 | 0.407 |
| | | | | 2006 | 0.078 | 0.256 |
| SEDAR 34-DW-34 | GA-SCDNR red drum longline Late | FI | Base | 2007 | 0.051 | 0.107 |
| | | | | 2008 | 0.044 | 0.108 |
| | | | | 2009 | 0.055 | 0.117 |
| | | | | 2010 | 0.035 | 0.125 |
| | | | | 2011 | 0.046 | 0.121 |
| SEDAR 34-DW-13 | SEAMAP - GoM - Ext Summer | FI | Base | 1982 | 0.019 | 0.751 |

| | | | | | |
|--|----|------|------|-------|-------|
| | | | 1983 | 0.452 | 0.367 |
| | | | 1984 | 0.030 | 1.030 |
| | | | 1985 | 0.100 | 0.543 |
| | | | 1986 | 0.063 | 0.753 |
| | | | 1987 | 0.293 | 0.311 |
| | | | 1988 | 0.274 | 0.301 |
| | | | 1989 | 0.199 | 0.338 |
| | | | 1990 | 0.067 | 0.392 |
| | | | 1991 | 0.218 | 0.304 |
| | | | 1992 | 0.199 | 0.268 |
| | | | 1993 | 0.242 | 0.324 |
| | | | 1994 | 0.098 | 0.418 |
| | | | 1995 | 0.431 | 0.238 |
| | | | 1996 | 0.366 | 0.243 |
| | | | 1997 | 0.188 | 0.302 |
| | | | 1998 | 0.144 | 0.276 |
| | | | 1999 | 0.201 | 0.291 |
| | | | 2000 | 0.217 | 0.234 |
| | | | 2001 | 0.097 | 0.490 |
| | | | 2002 | 0.253 | 0.238 |
| | | | 2003 | 0.152 | 0.338 |
| | | | 2004 | 0.098 | 0.372 |
| | | | 2005 | 0.124 | 0.372 |
| | | | 2006 | 0.212 | 0.292 |
| | | | 2007 | 0.170 | 0.301 |
| | | | 2008 | 0.295 | 0.243 |
| | | | 2009 | 0.245 | 0.222 |
| | | | 2010 | 0.172 | 0.270 |
| | | | 2011 | 0.110 | 0.308 |
| SEDAR 34-DW-13 SEAMAP - GoM - Ext Fall | FI | Base | 1972 | 0.203 | 0.482 |
| | | | 1973 | 0.232 | 0.289 |
| | | | 1974 | 1.019 | 0.238 |
| | | | 1975 | 0.726 | 0.252 |
| | | | 1976 | 0.677 | 0.215 |
| | | | 1977 | 0.302 | 0.260 |
| | | | 1978 | 0.373 | 0.290 |
| | | | 1979 | 0.383 | 0.274 |
| | | | 1980 | 0.686 | 0.262 |
| | | | 1981 | 0.565 | 0.259 |
| | | | 1982 | 0.479 | 0.271 |
| | | | 1983 | 0.330 | 0.303 |
| | | | 1984 | 0.273 | 0.332 |
| | | | 1985 | 0.284 | 0.331 |
| | | | 1986 | 0.304 | 0.316 |
| | | | 1987 | 0.559 | 0.423 |
| | | | 1988 | 0.174 | 0.324 |
| | | | 1989 | 0.168 | 0.419 |
| | | | 1990 | 0.181 | 0.341 |

| | | | | | |
|--------------------|----|------|------|-------|-------|
| | | | 1991 | 0.122 | 0.356 |
| | | | 1992 | 0.072 | 0.284 |
| | | | 1993 | 0.164 | 0.338 |
| | | | 1994 | 0.233 | 0.344 |
| | | | 1995 | 0.128 | 0.328 |
| | | | 1996 | 0.315 | 0.327 |
| | | | 1997 | 0.154 | 0.384 |
| | | | 1998 | 0.139 | 0.452 |
| | | | 1999 | 0.273 | 0.435 |
| | | | 2000 | 0.209 | 0.319 |
| | | | 2001 | 0.092 | 0.364 |
| | | | 2002 | 0.109 | 0.351 |
| | | | 2003 | 0.149 | 0.305 |
| | | | 2004 | 0.139 | 0.402 |
| | | | 2005 | 0.187 | 0.418 |
| | | | 2006 | 0.149 | 0.389 |
| | | | 2007 | 0.140 | 0.363 |
| | | | 2008 | 0.160 | 0.282 |
| | | | 2009 | 0.219 | 0.305 |
| | | | 2010 | 0.132 | 0.306 |
| | | | 2011 | 0.131 | 0.350 |
| SEDAR 34-DW-38 UNC | FI | Base | 1973 | 0.010 | 0.769 |
| | | | 1974 | 0.004 | 1.166 |
| | | | 1975 | 0.009 | 0.652 |
| | | | 1976 | 0.004 | 0.830 |
| | | | 1977 | 0.007 | 0.669 |
| | | | 1978 | 0.016 | 0.470 |
| | | | 1979 | 0.012 | 0.461 |
| | | | 1980 | 0.010 | 0.427 |
| | | | 1981 | 0.007 | 0.504 |
| | | | 1982 | 0.004 | 0.502 |
| | | | 1983 | 0.016 | 0.357 |
| | | | 1984 | 0.010 | 0.362 |
| | | | 1985 | 0.012 | 0.394 |
| | | | 1986 | 0.014 | 0.600 |
| | | | 1987 | 0.018 | 0.411 |
| | | | 1988 | 0.033 | 0.347 |
| | | | 1989 | 0.012 | 0.501 |
| | | | 1990 | 0.017 | 0.355 |
| | | | 1991 | 0.027 | 0.358 |
| | | | 1992 | 0.054 | 0.319 |
| | | | 1993 | 0.031 | 0.588 |
| | | | 1994 | 0.027 | 0.406 |
| | | | 1995 | 0.049 | 0.389 |
| | | | 1996 | 0.022 | 0.303 |
| | | | 1997 | 0.031 | 0.356 |
| | | | 1998 | 0.037 | 0.261 |
| | | | 1999 | 0.033 | 0.304 |

| | | | | | | |
|----------------|------------------|----|------|-------|---------|-------|
| | | | 2000 | 0.044 | 0.273 | |
| | | | 2001 | | | |
| | | | 2002 | 0.042 | 0.295 | |
| | | | 2003 | 0.087 | 0.283 | |
| | | | 2004 | 0.068 | 0.304 | |
| | | | 2005 | 0.106 | 0.237 | |
| | | | 2006 | 0.059 | 0.197 | |
| | | | 2007 | 0.065 | 0.262 | |
| | | | 2008 | 0.067 | 0.298 | |
| | | | 2009 | 0.040 | 0.350 | |
| | | | 2010 | 0.066 | 0.324 | |
| | | | 2011 | 0.035 | 0.237 | |
| SEDAR 34-DW-11 | GOM COMBINED LL | FI | Base | 2004 | 3.989 | 0.211 |
| | | | | 2005 | 4.000 | 0.203 |
| | | | | 2006 | 3.085 | 0.140 |
| | | | | 2007 | 3.040 | 0.118 |
| | | | | 2008 | 3.574 | 0.131 |
| | | | | 2009 | 3.274 | 0.147 |
| | | | | 2010 | 3.661 | 0.122 |
| | | | | 2011 | 3.091 | 0.146 |
| SEDAR 34-DW-29 | GOM COMBINED GN | FI | Base | 1995 | 0.848 | 0.67 |
| | | | | 1996 | 0.816 | 0.42 |
| | | | | 1997 | 1.399 | 0.35 |
| | | | | 1998 | 0.968 | 0.53 |
| | | | | 1999 | 1.469 | 0.40 |
| | | | | 2000 | 1.962 | 0.35 |
| | | | | 2001 | 1.595 | 0.35 |
| | | | | 2002 | 1.772 | 0.34 |
| | | | | 2003 | 1.529 | 0.36 |
| | | | | 2004 | 1.509 | 0.37 |
| | | | | 2005 | 1.272 | 0.46 |
| | | | | 2006 | 2.007 | 0.38 |
| | | | | 2007 | 1.763 | 0.33 |
| | | | | 2008 | 1.979 | 0.33 |
| | | | | 2009 | 2.483 | 0.31 |
| | | | | 2010 | 2.785 | 0.30 |
| | | | | 2011 | 2.577 | 0.32 |
| SEDAR 34-DW-37 | ATL COASTSPAN LL | FI | Base | 2000 | 30.037 | 0.34 |
| | | | | 2001 | 158.545 | 0.34 |
| | | | | 2002 | 33.902 | 0.57 |
| | | | | 2003 | 46.325 | 0.27 |
| | | | | 2004 | 38.637 | 0.27 |
| | | | | 2005 | 48.276 | 0.27 |
| | | | | 2006 | 63.643 | 0.19 |
| | | | | 2007 | 28.724 | 0.28 |
| | | | | 2008 | 71.656 | 0.19 |

| | | | | | | |
|----------------|-------------|------|-------------|------|---------|-------|
| | | | | 2009 | 82.680 | 0.17 |
| | | | | 2010 | 119.011 | 0.13 |
| | | | | 2011 | 89.741 | 0.14 |
| SEDAR 34-DW-35 | GADNR Trawl | FI | Base | 2003 | 3.169 | 0.16 |
| | | | | 2004 | 2.277 | 0.23 |
| | | | | 2005 | 0.892 | 0.35 |
| | | | | 2006 | 1.554 | 0.14 |
| | | | | 2007 | 1.740 | 0.17 |
| | | | | 2008 | 0.832 | 0.19 |
| | | | | 2009 | 2.692 | 0.13 |
| | | | | 2010 | 1.521 | 0.15 |
| | | | | 2011 | 1.865 | 0.14 |
| SEDAR 34-DW-28 | Sink GNOP | FD | Sensitivity | 2005 | 2320.0 | 0.30 |
| | | | | 2006 | 1408.9 | 0.25 |
| | | | | 2007 | 1615.4 | 0.47 |
| | | | | 2008 | 1189.7 | 0.38 |
| | | | | 2009 | 2280.5 | 0.30 |
| | | | | 2010 | 471.5 | 0.37 |
| | | | | 2011 | 291.2 | 0.29 |
| SEDAR 34-DW-01 | BLLOP-GOM | FD-C | Sensitivity | 1994 | 0.070 | 3.390 |
| | | | | 1995 | 2.860 | 0.790 |
| | | | | 1996 | 10.460 | 0.760 |
| | | | | 1997 | 163.690 | 0.510 |
| | | | | 1998 | 49.790 | 0.520 |
| | | | | 1999 | 95.310 | 0.400 |
| | | | | 2000 | | |
| | | | | 2001 | 48.570 | 0.570 |
| | | | | 2002 | 62.940 | 0.450 |
| | | | | 2003 | 85.460 | 0.360 |
| | | | | 2004 | 110.840 | 0.370 |
| | | | | 2005 | 91.190 | 0.370 |
| | | | | 2006 | 124.190 | 0.350 |
| | | | | 2007 | 191.990 | 0.440 |
| | | | | 2008 | 48.190 | 0.460 |
| | | | | 2009 | 53.820 | 0.380 |
| | | | | 2010 | 313.440 | 0.300 |
| | | | | 2011 | 328.630 | 0.300 |
| SEDAR 34-DW-01 | BLLOP-ATL | FD-C | Sensitivity | 1994 | 55.89 | 0.36 |
| | | | | 1995 | 199.43 | 0.20 |
| | | | | 1996 | 178.08 | 0.21 |
| | | | | 1997 | 215.22 | 0.28 |
| | | | | 1998 | 415.10 | 0.20 |
| | | | | 1999 | 379.49 | 0.24 |
| | | | | 2000 | 600.22 | 0.23 |
| | | | | 2001 | 352.50 | 0.23 |

| | | | | | | |
|----------------|----------------|----|-------------|--------|--------|-------|
| | | | 2002 | 365.00 | 0.23 | |
| | | | 2003 | 218.39 | 0.24 | |
| | | | 2004 | 277.85 | 0.30 | |
| | | | 2005 | 435.15 | 0.23 | |
| | | | 2006 | 105.70 | 0.36 | |
| | | | 2007 | 168.49 | 0.35 | |
| | | | 2008 | 373.63 | 0.34 | |
| | | | 2009 | 475.71 | 0.43 | |
| | | | 2010 | 171.86 | 0.24 | |
| | | | 2011 | 79.34 | 0.27 | |
| SEDAR 34-DW-xx | NMFS LL SE-GOM | FI | Sensitivity | 1995 | 1.042 | 0.367 |
| | | | | 1996 | 1.742 | 0.372 |
| | | | | 1997 | 0.909 | 0.295 |
| | | | | 1998 | | |
| | | | | 1999 | 0.928 | 0.259 |
| | | | | 2000 | 2.430 | 0.258 |
| | | | | 2001 | 2.830 | 0.188 |
| | | | | 2002 | 3.520 | 0.174 |
| | | | | 2003 | 4.164 | 0.147 |
| | | | | 2004 | 6.156 | 0.156 |
| | | | | 2005 | 4.697 | 0.291 |
| | | | | 2006 | 6.225 | 0.184 |
| | | | | 2007 | 2.677 | 0.234 |
| | | | | 2008 | 2.718 | 0.238 |
| | | | | 2009 | 8.889 | 0.136 |
| | | | | 2010 | 6.111 | 0.165 |
| | | | | 2011 | 3.240 | 0.127 |
| SEDAR 34-DW-xx | NMFS LL SE-ATL | FI | Sensitivity | 1995 | 1.548 | 0.530 |
| | | | | 1996 | 0.911 | 0.592 |
| | | | | 1997 | 2.162 | 0.523 |
| | | | | 1998 | | |
| | | | | 1999 | | |
| | | | | 2000 | 3.107 | 0.422 |
| | | | | 2001 | | |
| | | | | 2002 | 11.321 | 0.187 |
| | | | | 2003 | | |
| | | | | 2004 | 13.185 | 0.336 |
| | | | | 2005 | 26.175 | 0.294 |
| | | | | 2006 | 21.932 | 0.205 |
| | | | | 2007 | | |
| | | | | 2008 | 12.927 | 0.181 |
| | | | | 2009 | 20.256 | 0.282 |
| | | | | 2010 | 13.993 | 0.347 |
| | | | | 2011 | 16.034 | 0.187 |

2.6. FIGURES

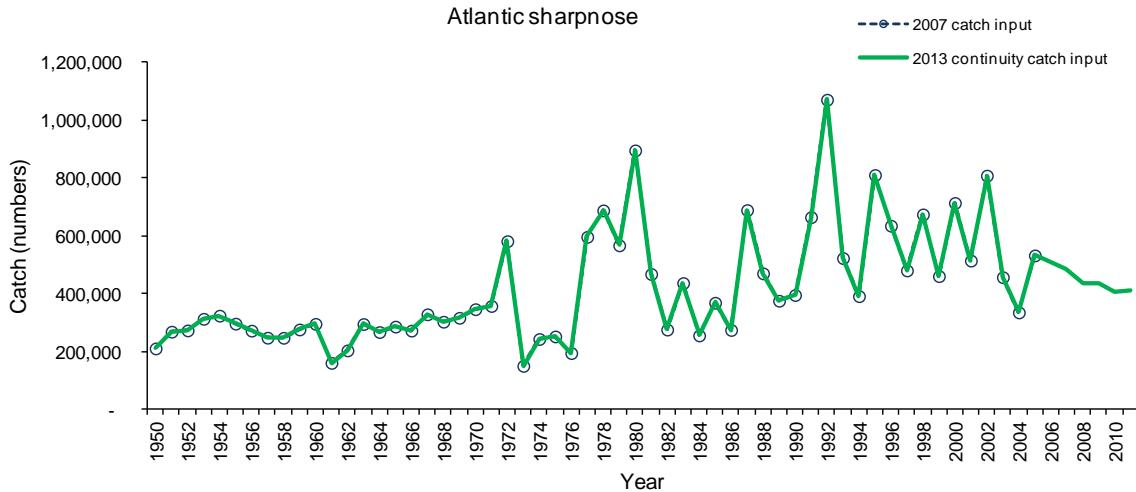


Figure 2.6.1. Catches used in the 2007 assessment (circles) and in the continuity analysis (thick green line), where six years of data (2006-2011) were added.

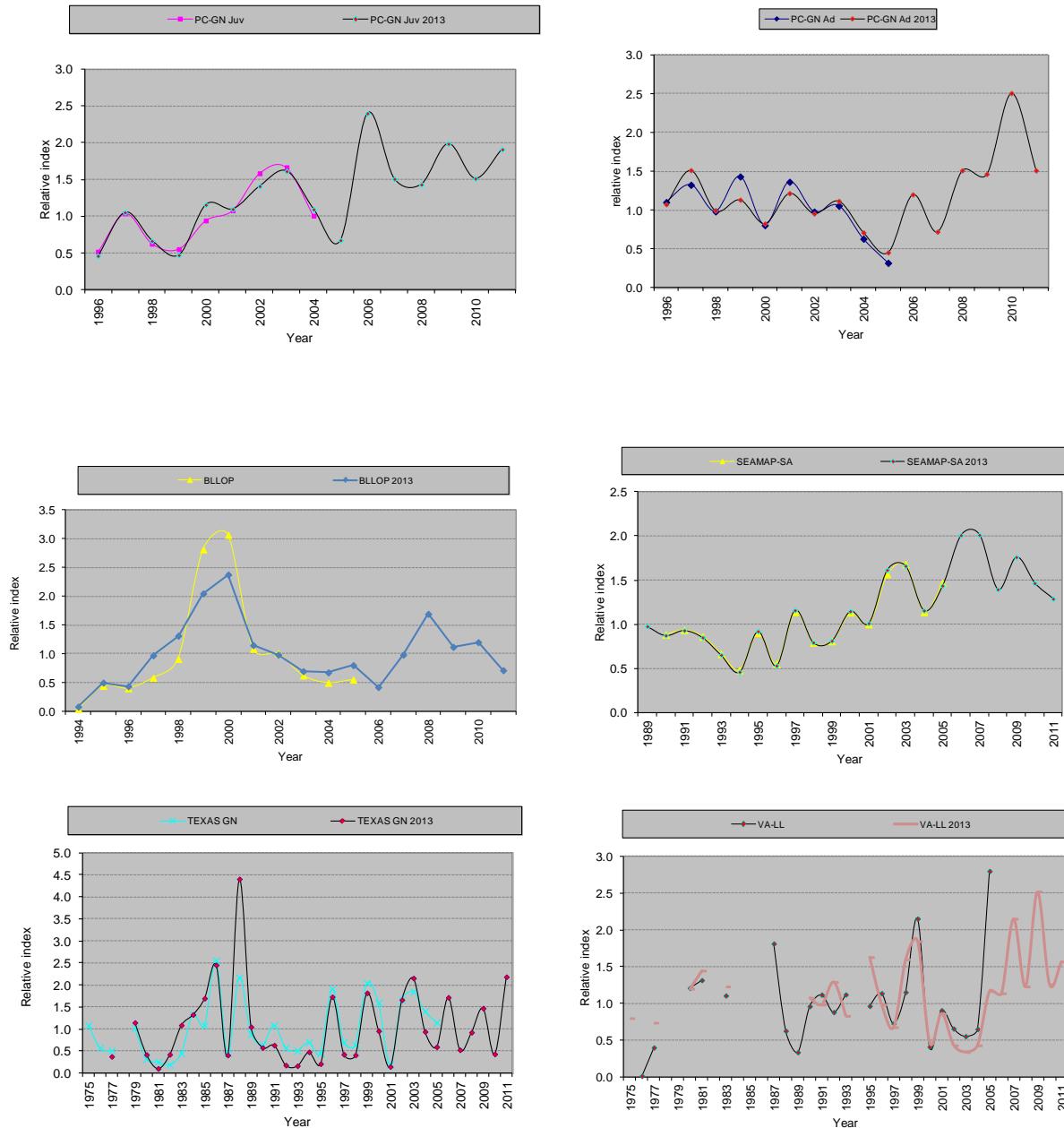


Figure 2.6.2. Indices used in the 2007 assessment vs. current continuity analysis. Only those indices that had additional years and were reanalyzed are shown: PC Gillnet Juveniles, PC Gillnet Adults, BLLOP, SEAMAP-SA, Texas Gillnet, and VA Longline. All indices are scaled (divided by the mean of overlapping years).

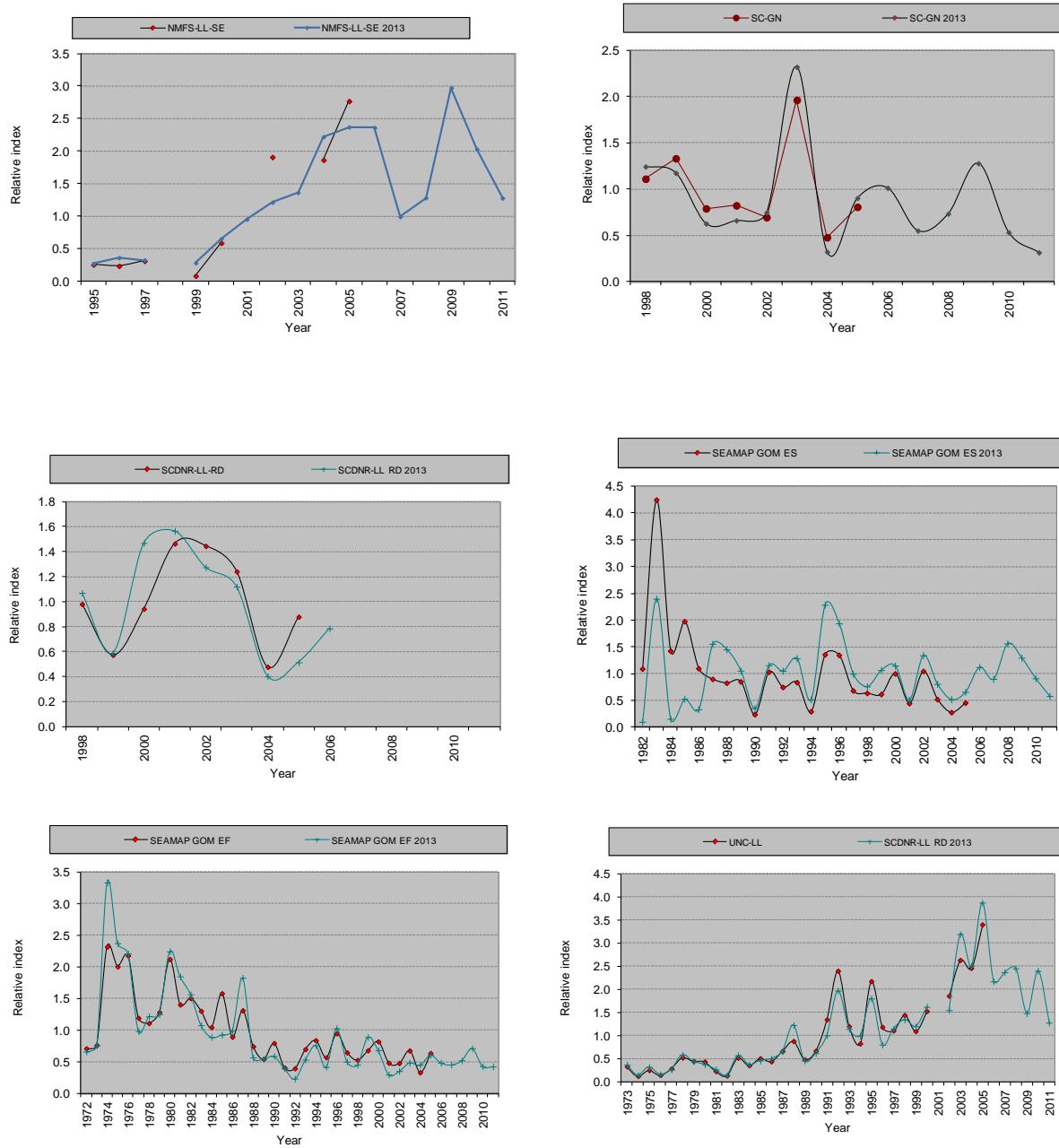


Figure 2.6.2 (continued). Indices used in the 2007 assessment vs. current continuity analysis. Only those indices that had additional years and were reanalyzed are shown: NMFS Longline SE, SC Coastsan Gillnet, SCDNR Red Drum Longline, SEAMAP-GOM-ES, SEAMAP-GOM-EF, and UNC Longline. All indices are scaled (divided by the mean of overlapping years).

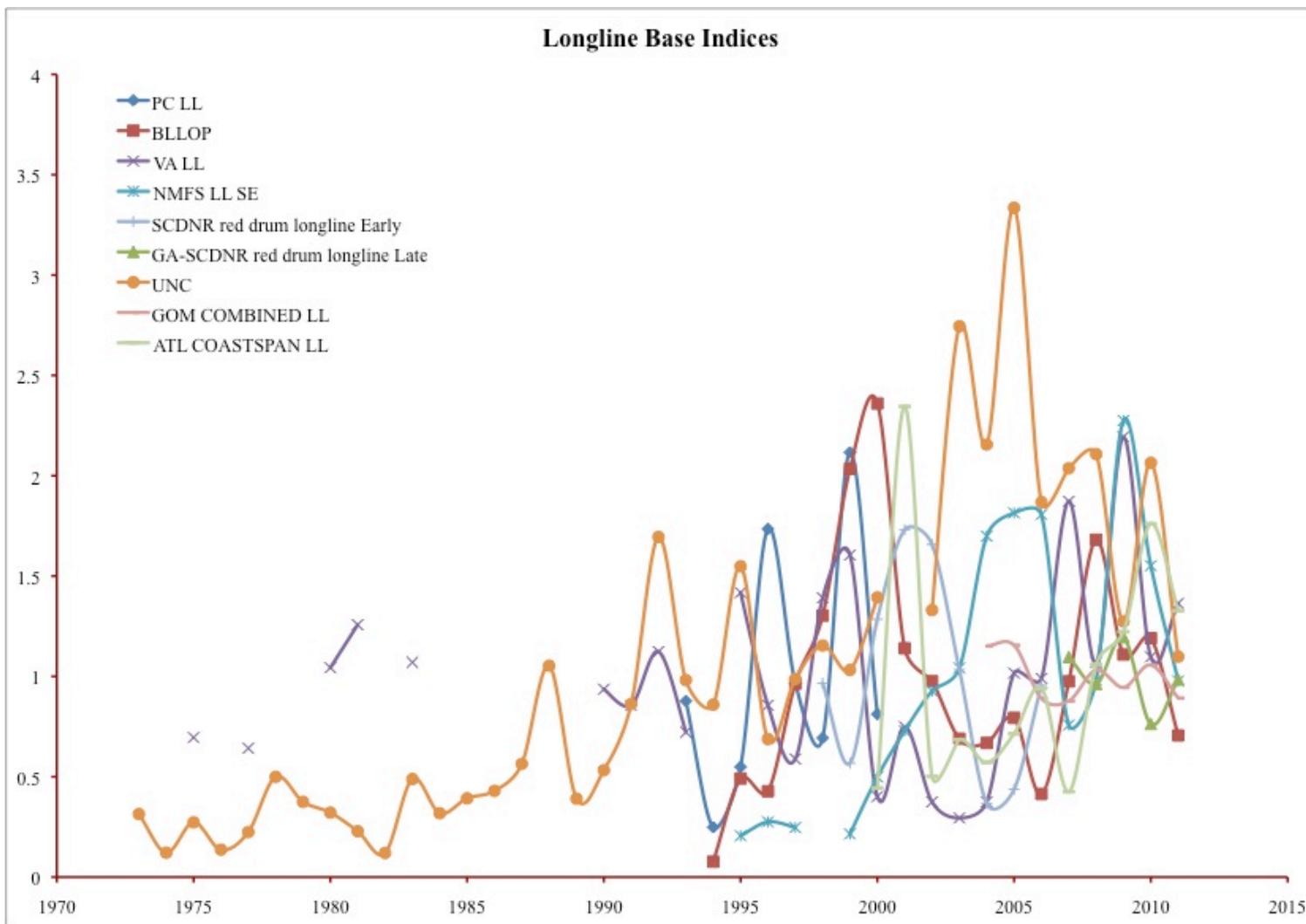


Figure 2.6.3. Relative base longline indices recommended by SEDAR34 for Atlantic sharpnose shark. Each index is divided by the mean of its respective index for graphing purposes.

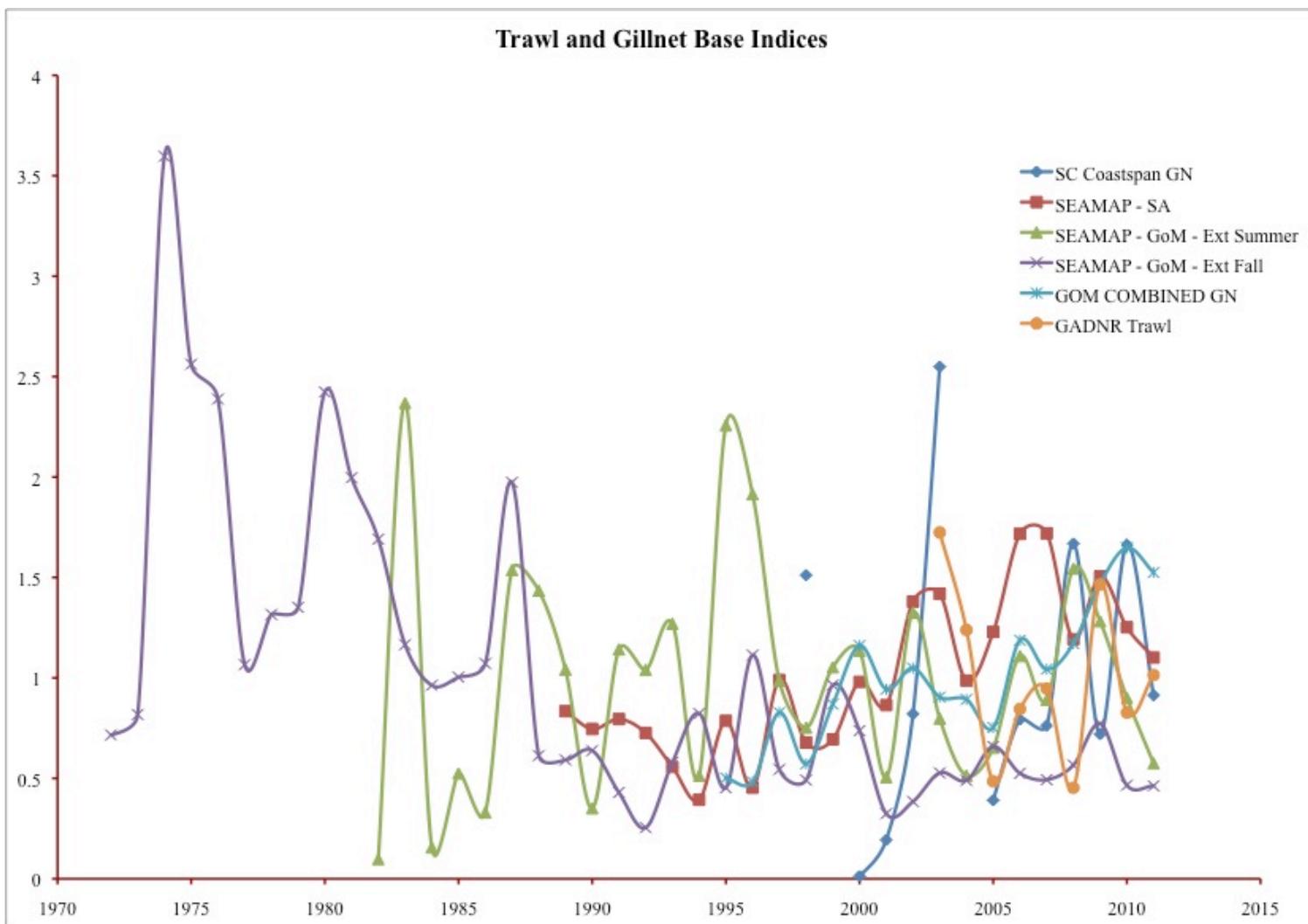


Figure 2.6.4. Relative base gillnet indices recommended by SEDAR34 for Atlantic sharpnose shark. Each index is divided by the mean of its respective index for graphing purposes.

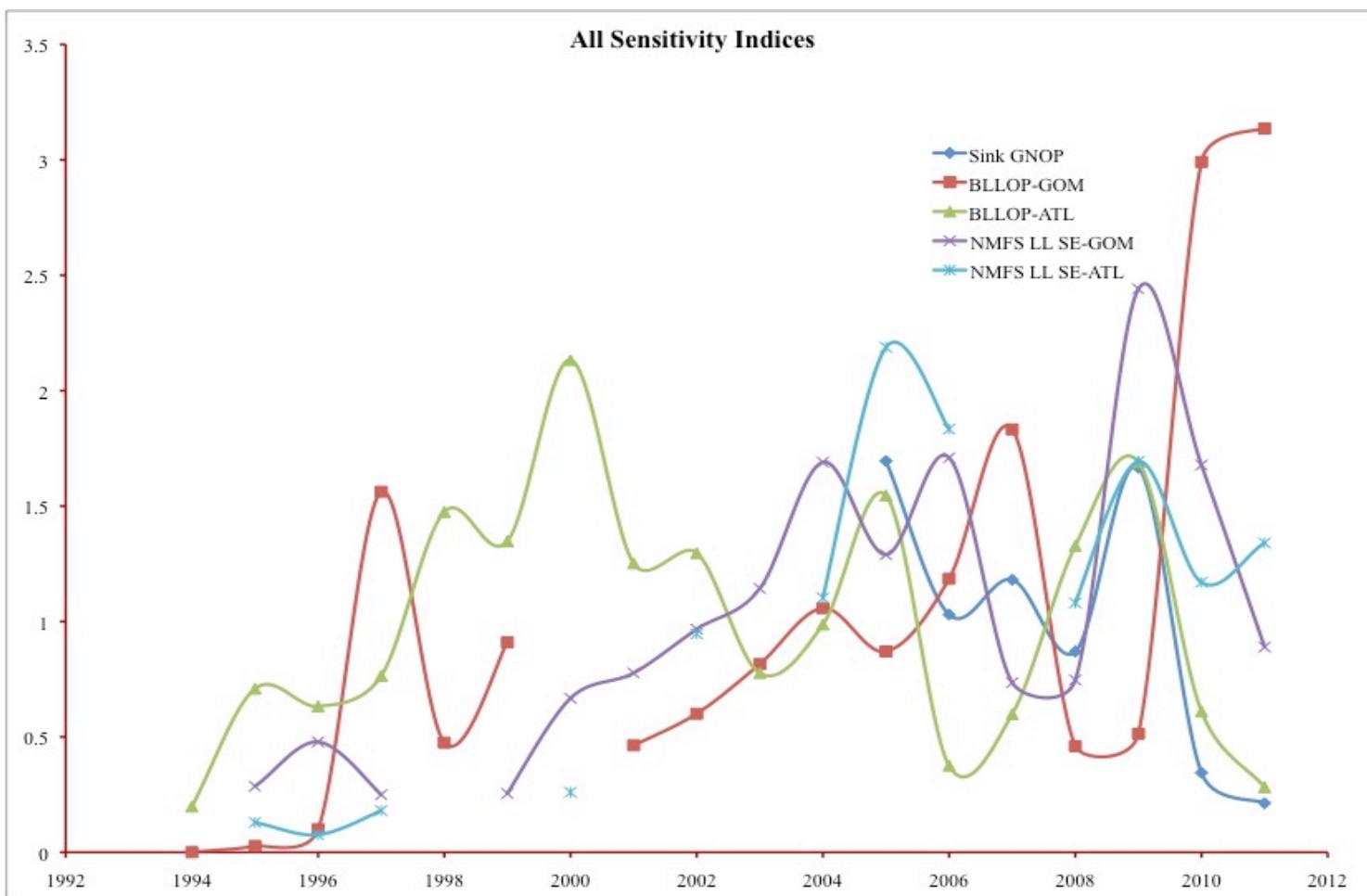


Figure 2.6.5. Relative sensitivity indices recommended by SEDAR34 for Atlantic sharpnose shark. Each index is divided by the mean of its respective index for graphing purposes.

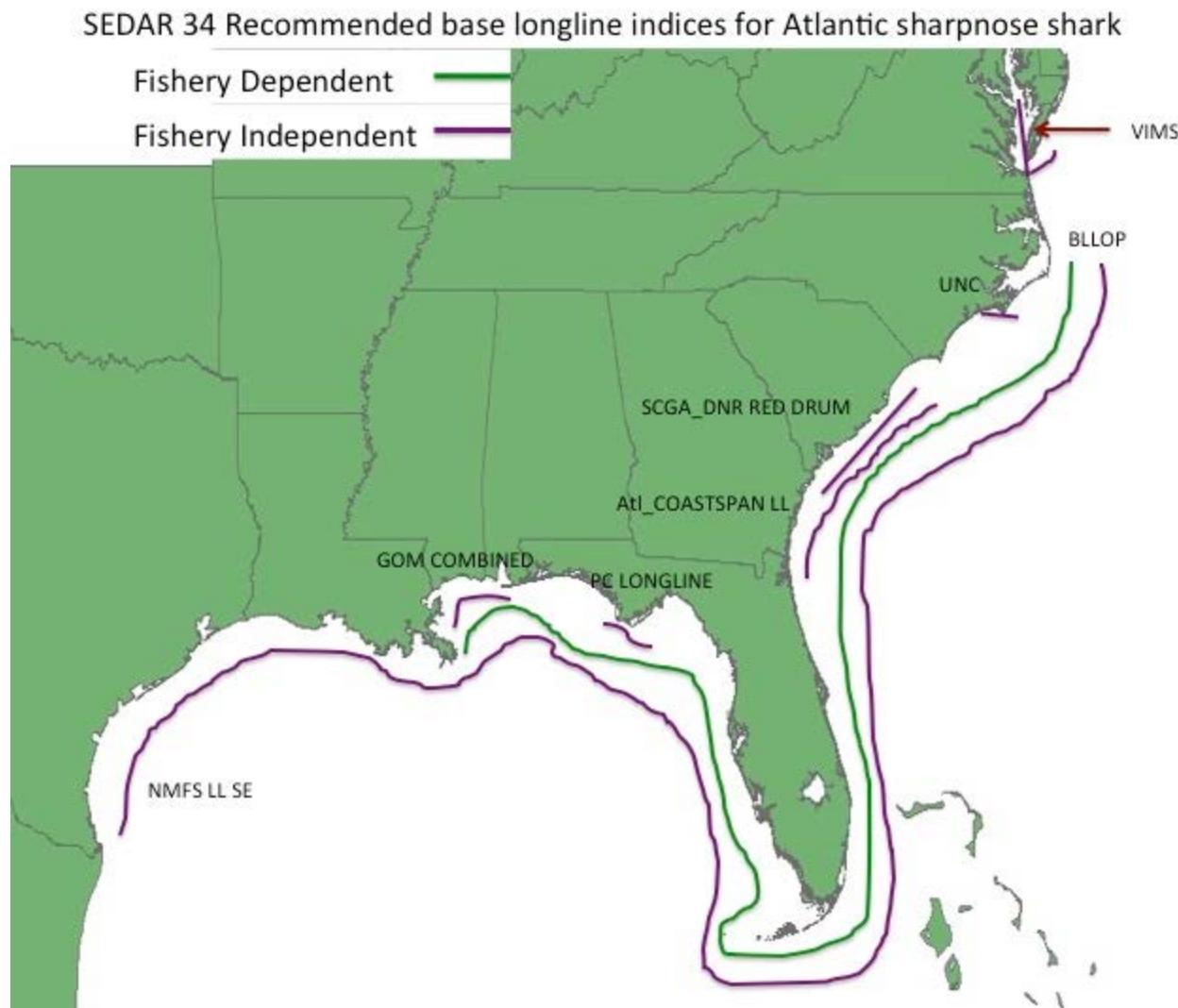


Figure 2.6.6. Distribution of sampling effort for longline indices recommended by SEDAR34 for Atlantic sharpnose shark.

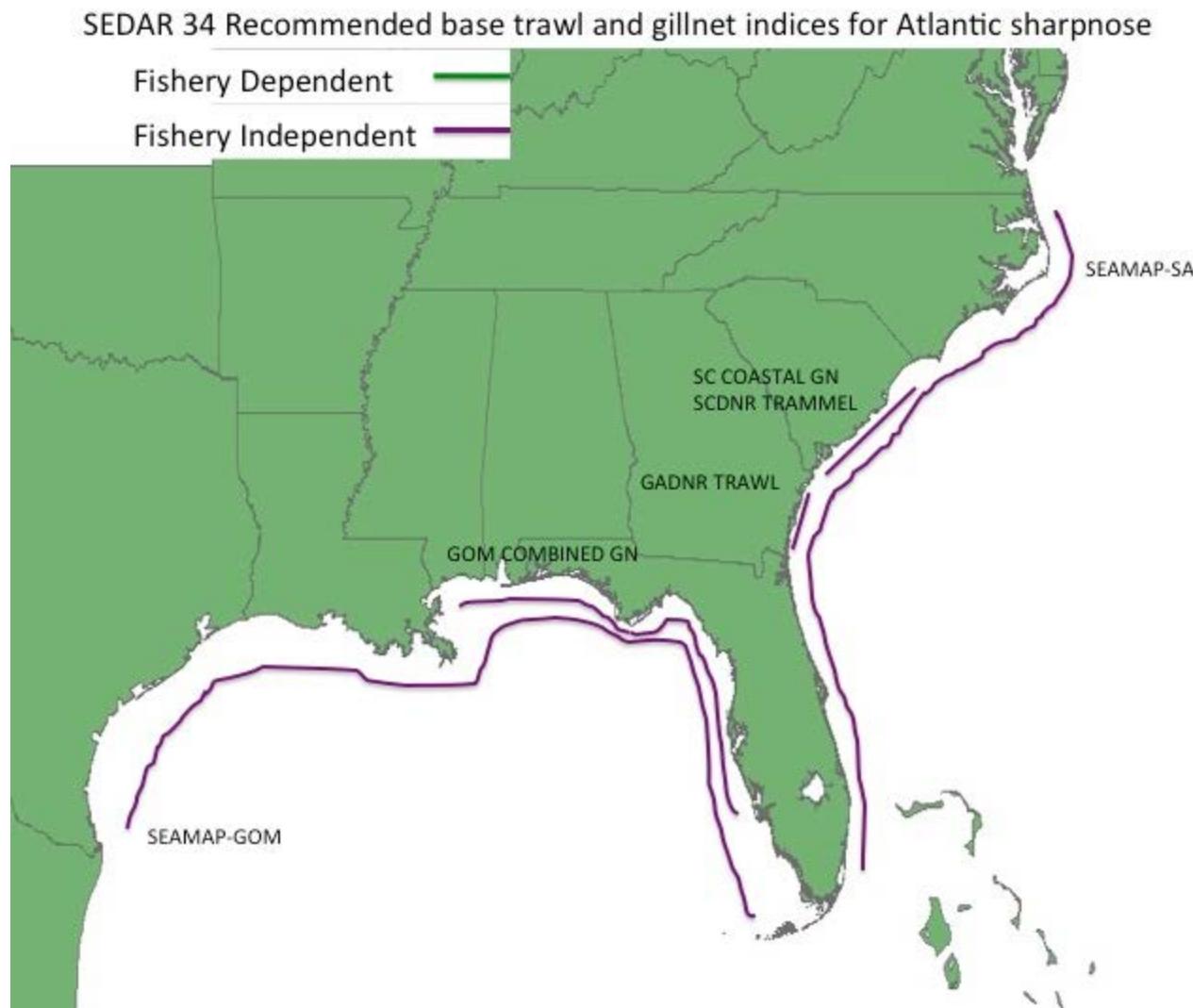


Figure 2.6.7. Distribution of sampling effort for gillnet indices recommended by SEDAR34 for Atlantic sharpnose shark

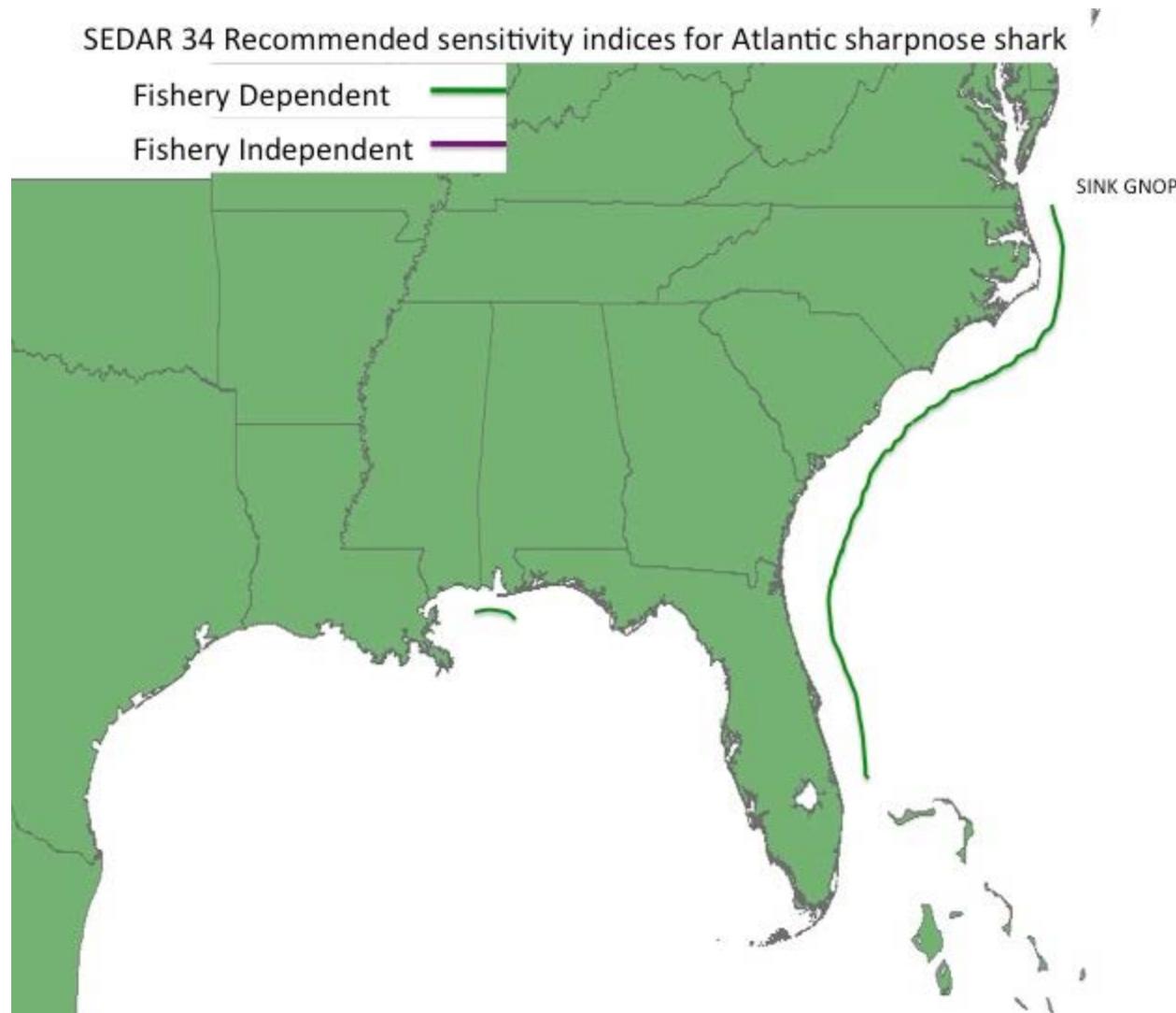


Figure 2.6.8. Distribution of sampling effort for indices recommended for sensitivity by SEDAR34 for Atlantic sharpnose shark

3. STOCK ASSESSMENT MODEL AND RESULTS

3.1. MODEL METHODS: STATE-SPACE AGE-STRUCTURED PRODUCTION MODEL (SSASPM)

3.1.1. Overview

The state-space, age-structured production model (SSASPM) was used as the assessment modeling approach. The SSASPM has been used extensively for assessing shark stocks domestically and under the auspices of ICCAT since 2002 (see e.g. ICCAT 2005, SEDAR 21). The SSASPM allows incorporation of several of the important biological (mortality, growth, reproduction) and fishery (selectivity, effort) processes in conjunction with observed catches and CPUE indices. A first step in applying this method is to identify a year in which the stock can be considered to be at virgin conditions. Assuming that there is some basis for deriving historic removals, one can estimate a population trajectory from virgin conditions through a more data-poor historic period when only catch or effort data are available, until a more recent year (“modern period”) when more data (e.g., CPUE indices) become available for model fitting.

3.1.2. Data Sources

Catches, indices of abundance, length and age compositions to derive selectivities, selectivities, and biological inputs used in the SSASPM are described next.

3.1.2.1. Catches

One of the main changes introduced to the catch streams with respect to SEDAR 13 was replacing the estimates of shrimp bycatch generated with WinBUGS with the stratified nominal estimates recommended by the Panel (see decision 6 in Section 2.2.2.5). Other changes included: 1) using the recreational estimates from MRIP instead of those from MRFSS (see decision 1 in Section 2.2.2.2), 2) addition of post-release live discard mortality estimates for B2 (release alive) sharks from MRFSS/MRIP (see decision 2 in Section 2.2.2.3), 3) addition of dead discard estimates in the bottom longline commercial series starting in 1980 (see decision 3 in Section 2.2.2.4), and 4) addition of post-release live discard mortality estimates in the bottom longline commercial series and the gillnet and line commercial series (see decisions 4 and 5 in Section 2.2.2.4). All other procedures for developing catch series are explained in SEDAR34-WP-20 and section 2.2.2.

Commercial, recreational, and shrimp fishery catches are presented in **Table 3.5.1A** and **Figure 3.6.1A** (in numbers, as used in the assessment). As requested in TOR#4 we also developed catch streams in weight (**Table 3.5.1B**; **Figure 3.6.1B**). The intermediate steps for obtaining catch in weight (lb dw) were as follows. Commercial landings are originally provided in weight. For years where catches were reconstructed (prior to 1995), the grand mean of average weights from the BLLOP for 1993-2011 (3.17 lb dw) was used to multiply numbers and obtain weight for the bottom longline and line fisheries; for the gillnet fishery, the grand mean of average weights from the DGNOP for 2002-2011 (3.74 lb dw) was used to multiply numbers and obtain weight. Dead discards from the bottom longline fishery were estimated in numbers so year-specific average weights from the BLLOP for 1993-2011 were used to convert numbers into weight for the bottom longline fishery. These same average weights were used to convert estimated number of live post-release mortality estimates into weight for the bottom longline fishery and the line fishery; for the gillnet fishery, year-specific average weights from the DGNOP for 1995-2011 were used to convert numbers into weight. **Appendix 1** lists available annual average weights used for commercial gears. For recreational catches, estimates of A+B1 catches for 1981-2011 were also made available in weight, including MRIP estimates for 2004-2011 and MRIP-adjusted estimates for 1981-2003. For 1950-1980, the mean of the year-specific ratios of catches in weight to catches in numbers for the period 1981-2011 (6.71 lb dw) was used as a multiplier for catches in numbers to obtain catches in weight. Since sharks released alive (B2s) are only available in numbers, we also used the ratio of the weight to the number of A+B1 sharks as average weights to multiply live post-release mortality estimates in numbers and obtain catches in weight. All transformations of ww to dw used a factor of 2.0 (i.e., $ww=2dw$). There was very limited size information to help guide conversion of numbers into weight for the shrimp fishery discards. Data from the Shrimp Fishery Observer Program ($n=1,064$ available only for 2010-2011) indicated an average size of 61.9 cm TL for observed Atlantic sharpnose sharks, which corresponds to a weight of 0.92 kg or 1.01 lb dw and was used as average weight to transform numbers into weight for the whole time series. When expressed in weight compared to numbers, it becomes apparent that both the commercial and recreational fisheries catch larger sharks than the shrimp trawl fishery (**Figure 3.6.1A** and **3.6.1B**).

3.1.2.2. Length Compositions, Age Compositions, and Selectivities

Size composition of the catch (by length, but especially by age) is not routinely collected for sharks; only limited length information from observer and other programs and some surveys is available. The SSASPM cannot accommodate lengths, but in theory can accept age compositions. Early attempts at estimating selectivity within the model through the use of the limited available age compositions (obtained from length compositions after back-transforming through the von Bertalanffy growth curve as explained below) were unsuccessful and thus, as in previous implementations of the model, selectivities had to be estimated externally to the model. Available length-frequency information from animals caught in scientific observer programs, recreational fishery surveys, and multiple fishery-independent surveys was used to generate age-frequency distributions by back-transforming through the von Bertalanffy growth curve (**Appendix 2**). The simplest way to obtain an age-frequency distribution from a length-frequency distribution is to back-transform length into age through a growth curve (in the present case the von Bertalanffy function). This approach was adopted bearing in mind that it has several biases, among them that 1) any observed length $> L_{\infty}$ must be eliminated or arbitrarily assigned to older ages and 2) when an observed length approaches L_{∞} , it is mathematically allocated to ages above those attainable by aged fish within the stock, yielding in some cases unreasonably old ages. The next way to obtain an age-frequency distribution from a length-frequency distribution is an age-length key, an approach that also has biases and whose main assumption is that age can be estimated from length using information contained in a previously aged sample from the population. Based in part on recommendations from previous peer reviews, it was decided that age frequencies be estimated by back-transforming from the von Bertalanffy growth function.

The age-frequency distributions thus obtained were then used to estimate selectivity curves externally to the stock assessment model. The derivation of selectivities from age-frequency distributions was done under the following assumptions. With only natural mortality (M) operating, one would expect an age-frequency histogram to decline with age. However, with both M and fishing mortality (F) operating, what is observed instead is an increase in the age frequency that reflects the increase in selectivity with age up to a “fully selected” age. Beyond the “fully selected” age, all subsequent ages are expected to consistently decline because they all experience (approximately) the same F and M. The fully selected age is thus determined by looking at the age-frequency distribution and identifying the “fulcrum” or modal age class,

where younger ages show an increasing frequency and all subsequent ages decrease in frequency. The specific algorithm for deriving selectivities is detailed in **Appendix 3**. Based on the above, the following selectivity curves were fitted statistically or approximated by eye (to accommodate beliefs of the selectivity of a particular gear type) to each catch and CPUE series:

Catches

Commercial bottom longline and lines—Logistic curve, with age at full selectivity of 3.

Commercial gillnets—A dome-shaped selectivity curve (double exponential) with maximum selection at age 4.

Recreational hook and line—Logistic curve, with age at full selectivity of 1.

Shrimp trawl fishery discards—A dome-shaped selectivity curve with only the descending right limb and maximum selection at age 1.

Indices of relative abundance

BLLOP, NMFS-LL-SE, ATL Coastspan LL— Logistic curve, with age at full selectivity of 3 (same selectivity pattern assigned to the commercial bottom longline and line catches).

SCDNR LL RD early, SCDNR LL RD late (also referred to as GA-SCDNR LL RD late), UNC LL, VA LL—Logistic curve, with age at full selectivity of 4.

GOM Combined GN, SEAMAP GOM ES and SEAMAP GOM EF—Double exponential curve with maximum selection at age 1 (same selectivity pattern assigned to the shrimp trawl fishery discards).

SINK GNOP and GNOP—Double exponential with maximum selection at age 4 (same selectivity pattern assigned to the commercial gillnet catches). These two indices were not used in any of the runs.

SEAMAP-SA, SC Coastspan, and GADNR Trawl— Double exponential with maximum selection at age 3.

GOM Combined LL, PCLL— Logistic curve, with age at full selectivity of 1.

Logistic curves fitted to the data were:

$$s = \frac{1}{1 + e^{-(\frac{x-a_{50}}{b})}}$$

where a_{50} is the median selectivity age (inflection point) and b is the slope. Double logistic curves were expressed as:

$$s = \frac{\frac{1}{1 + e^{-(\frac{x-a_{50}}{b})}} \times \left(1 - \frac{1}{1 + e^{-(\frac{x-c_{50}}{d})}}\right)}{\max(\frac{1}{1 + e^{-(\frac{x-a_{50}}{b})}} \times \left(1 - \frac{1}{1 + e^{-(\frac{x-c_{50}}{d})}}\right))}$$

where a_{50} and c_{50} are the ascending and descending inflection points, and b and d are the ascending and descending slopes, respectively.

All selectivities used in the baseline scenario are summarized in **Table 3.5.2** and **Figure 3.6.2**.

3.1.2.3. Indices of Relative Abundance

The standardized indices of relative abundance used in the baseline run of the assessment are presented in **Table 3.5.3** and **Figure 3.6.3**. The Panel recommended the use of 15 indices, only one of which was fishery dependent (BLLOP). The other 14 indices were: PCLL (Panama City longline), ATL Coastspan LL (Atlantic Coastspan (or combined) longline), GOM Comb LL (Gulf of Mexico combined longline), SEAMAP-SA (SEAMAP South Atlantic trawl), GOM Comb GN (Gulf of Mexico combined gillnet), VA LL (Virginia Institute of Marine Science longline), NMFS LL SE (NMFS Pascagoula Laboratories bottom longline), SC Coastspan GN (South Carolina Coastspan gillnet), SCDNR RD LL E (South Carolina Department of Natural Resources longline red drum early), SCDNR RD LL L (Georgia and South Carolina Departments of Natural Resources red drum longline late), SEAMAP GOM ES (SEAMAP Gulf of Mexico Extended Summer), SEAMAP GOM EF (SEAMAP Gulf of Mexico Extended Fall), UNC LL (University of North Carolina longline), and GADNR Trawl (Georgia Department of Natural Resources Trawl).

The AP assigned ranks as one of the modalities for index weighting in the baseline run as follows (rankings indicated in parentheses): PCLL (4), ATL Coastsan LL (2), GOM Comb LL (2.5), BLLOP (2), SEAMAP-SA (1.5), GOM Comb GN (2), VA LL (2), NMFS LL SE (1), SC Coastsan GN (3), SCDNR LL RD E (3), SCDNR LL RD L (3), SEAMAP GOM ES (1.5), SEAMAP GOM EF (1.5), UNC LL (3), and GADNR Trawl (3). Equal weighting (i.e., no weights) and inverse CV weighting were also used. Coefficients of variation (CV) associated with the baseline indices are presented in **Table 3.5.4**.

3.1.2.4. Life History Inputs

The life history inputs used in the assessment are presented in **Table 3.5.5**. These include age and growth, as well as several parameters associated with reproduction, including sex ratio, reproductive frequency, fecundity at age, maturity at age, and month of pupping, and natural mortality. The SSASPM uses most life history characteristics as constants (inputs) and others are estimated parameters, which are given priors and initial values. The estimated parameters are described in the Parameters Estimated section (3.1.4) of the report.

All biological input values in **Table 3.5.5** were decided by the Panel from information reported in papers described in Section 2.2.2 and summarized at the Workshop or in ensuing webinars. Additionally, age-specific values of instantaneous natural mortality (M) were estimated through several life history invariant methods commonly used for sharks, which include Hoenig's (1983), Chen and Watanabe's (1989), Peterson and Wroblewski's (1984), and Lorenzen's (1996) methods. To ensure positive population growth rates and emulate a density-dependent response, the maximum value of survivorship of the four methods was taken (refer to the "ATSH_demographic gamer_2013.xls" spreadsheet implementation of a life table to see how M values were derived).

3.1.3. Model Configuration and Equations

To derive numbers at age for the first model year, one must define a year when the stock could be considered to be at virgin conditions. The year of virgin conditions was set at 1950 in the previous assessment (SEDAR 13) and remained the same for the present assessment.

Population Dynamics

The dynamics of the model are described below, and are extracted (and/or modified) from Porch (2002). The model begins with the population at unexploited conditions, where the age structure is given by

$$(1) \quad N_{a,y=1,m=1} = \begin{cases} R_0 & a = 1 \\ R_0 \exp\left(-\sum_{j=1}^{a-1} M_j\right) & 1 < a < A \\ \frac{R_0 \exp\left(-\sum_{j=1}^{A-1} M_j\right)}{1 - \exp(-M_A)} & a = A \end{cases},$$

where $N_{a,y,1}$ is the number of sharks in each age class in the first model year ($y=1$), in the first month ($m=1$), M_a is natural mortality at age, A is the plus-group age, and recruitment (R) is assumed to occur at age 1. Recruitment is assumed to occur at age 1 because the stock-recruitment relationship includes survival to age 1 (pup survival; see below).

The stock-recruit relationship was assumed to be a Beverton-Holt function, which was parameterized in terms of the maximum lifetime reproductive rate, α :

$$(2) \quad R = \frac{R_0 S \alpha}{1 + (\alpha - 1)S}.$$

In (2), R_0 is virgin number of recruits (age-1 pups) and S is spawners or “spawning stock fecundity” (units are number of mature adult females times pup production at age). The parameter α is calculated as:

$$(3) \quad \alpha = e^{-M_0} \left[\left(\sum_{a=1}^{A-1} p_a m_a \prod_{j=1}^{a-1} e^{-M_a} \right) + \frac{p_A m_A}{1 - e^{-M_A}} e^{-M_A} \right] = e^{-M_0} \varphi_0,$$

where p_a is pup-production at age a , m_a is maturity at age a , and M_a is natural mortality at age a . The first term in (3) is pup survival at low population density (Myers et al. 1999). Thus, α is virgin spawners per recruit (φ_0) scaled by the slope at the origin (pup-survival).

Recruitment follows a first-order lognormal autoregressive process (see eq. 14). The correlation coefficient ρ was set to 0.5, and η is a normally distributed random error with mean=0 and CV=0.25. These choices reflect a high level of autocorrelation in process error and a low level of process error in recruitment, which is compatible with the life history of sharks, where interannual variation in recruitment is expected to be low. Annual deviations in recruitment were not estimated. Through the reparameterization of the Beverton-Holt curve (eqs. 2 and 3), whereby the virgin number of recruits (R_0) and pup survival (S_0) are given prior pdfs and estimated in a Bayesian framework, all relevant biological information available is fully utilized in describing the recruitment process.

The time period from the first model year (y_1) to the last model year (y_T) is divided into a historic and a modern period (mod), where y_i for $i < \text{mod}$ are historic years, and modern years are y_i for which $\text{mod} \leq i \leq T$. The historic period is characterized by having relatively fewer data compared to the modern period. The manner in which effort is estimated depends on the period modeled. In the historic period, effort is estimated as either a constant (4a) or a linear trend (4b)

$$(4a) \quad f_{y,i} = b_0 \quad (\text{constant effort})$$

or

$$(4b) \quad f_{y,i} = b_0 + \frac{(f_{y=\text{mod},i} - b_0)}{(y_{\text{mod}} - 1)} f_{y=\text{mod},i} \quad (\text{linear effort}),$$

where $f_{y,i}$ is annual fleet-specific effort, b_0 is the intercept, and $f_{y=\text{mod},i}$ is a fleet-specific constant. The historic period spanned 1950-1971 and included reconstructed catches, but no indices of relative abundance. The modern period started in 1972 (the first year with an index of relative abundance) and ended in 2011. Following SEDAR 13, historic effort for the bottom longline (BLL) and gillnet (GN) commercial fleets and the shrimp fishery were modeled as a constant with a very small value (eq. 4a) whereas historic effort for the line commercial and the recreational fleet were modeled as a linear trend interpolated from a constant value equal to zero

or close to zero in 1950 to a higher value estimated for the first year of the modern period (eq. 4b). Only historic effort for the recreational fleet and the shrimp fishery was estimated.

In the modern period, fleet-specific effort is estimated as a constant with annual deviations, which are assumed to follow a first-order lognormal autoregressive process (see also eq. 14):

$$(5) \quad \begin{aligned} f_{y=\text{mod},i} &= f_i \exp(\delta_{y,i}) \\ \delta_{y,i} &= \rho_i \delta_{y-1} + \eta_{y,i} \\ \eta_{y,i} &\sim N(0, \sigma_i) \end{aligned}$$

From the virgin age structure defined in (1), abundance at the beginning of subsequent months is calculated as

$$(6) \quad N_{a,y,m+1} = (N_{a,y,m} e^{-M_a \delta/2} - \sum_i C_{a,y,m,i}) e^{-M_a \delta/2},$$

where δ is the fraction of the year ($m/12$) and $C_{a,y,m,i}$ is the catch in numbers of fleet i. The monthly catch by fleet is assumed to occur sequentially as a pulse in the middle of the month, after natural mortality:

$$(7) \quad C_{a,y,m,i} = F_{a,y,i} (N_{a,y,m} e^{-M_a \delta/2}) \frac{\delta}{\tau_i},$$

where τ_i is the duration of the fishing season for fleet i. Catch in weight is computed by multiplying (7) by $w_{a,y}$, where weight at age for the plus-group is updated based on the average age of the plus-group.

The fishing mortality rate, F , is separated into fleet-specific components representing age-specific relative-vulnerability, v , annual effort expended, f , and an annual catchability coefficient, q :

$$(8) \quad F_{a,y,i} = q_{y,i} f_{y,i} v_{a,i}.$$

Catchability is the fraction of the most vulnerable age class taken per unit of effort. The relative vulnerability would incorporate such factors as gear selectivity, and the fraction of the stock exposed to the fishery. Both vulnerability and catchability were assumed to be constant over years.

Predicted catch by fleet is compared to observed catch by fleet in the objective function (as in eq. 16; see below). Predicted catch by fleet is obtained as the sum of the predicted age-specific catch by fleet:

$$(9) \quad \hat{C}_{y,m,i} = \sum_a \hat{C}_{a,y,m,i}$$

Catch per unit effort (CPUE) or fishery abundance surveys are modeled as though the observations were made just before the catch of the fleet with the corresponding index, i:

$$(10) \quad I_{y,m,i} = q_{y,i} \sum_a v_{a,i} \left(N_{a,y,m} e^{-M_a \delta/2} \right) \frac{\delta}{\tau_i} .$$

Equation (10) provides an index in numbers; the corresponding CPUE in weight is computed by multiplying $v_{a,i}$ in (9) by $w_{a,y}$.

MSY calculation

The values of F_{MSY} and MSY are obtained in SSASPM through a grid search algorithm. F_{MSY} is obtained by solving for the value of F that maximizes equilibrium yield (Y), calculated as $Y=YPR(F) \cdot S(F)/\varphi(F)$ where

$$(11) \quad YPR(F) = \sum_{a=1}^{A-1} w_a F s_a \frac{(1 - \exp(-M - F s_a))}{(M + F s_a)} \prod_{j=1}^{a-1} \exp(-M - F s_j) \\ + \frac{w_A F s_A}{(M + F s_A)} \prod_{j=1}^{A-1} \exp(-M - F s_j)$$

$$(12) \quad \varphi(F) = \sum_{a=1}^{A-1} \mu_a E_a \prod_{j=1}^{a-1} \exp(-M - F s_j) + \frac{\mu_A}{(1 - \exp(-M - F s_A))} \prod_{j=1}^A \exp(-M - F s_j)$$

$$(13) \quad \check{S}(F) = \frac{R_0 \hat{\alpha} \varphi(F) - R_0 \varphi_0}{\hat{\alpha} - 1} = \frac{4h R_0 \varphi(F) - R_0 \varphi_0 (1-h)}{5h - 1}$$

In the above equations, A is maximum age, w_a is weight at age, s_a is selectivity at age, μ_a is the proportion mature at age, E_a is fecundity at age, R_0 is virgin recruitment, $\hat{\alpha}$ is the maximum lifetime reproductive rate, ϕ_0 is unexploited spawners per recruit, h is steepness, $\check{S}(F)$ is the equilibrium spawning biomass for a given F and $\phi(F)$ is the lifetime production of spawners per recruit for a given F (Brooks et al. 2010).

State space implementation

In general, process errors in the state variables and observation errors in the data variables can be modeled as a first-order autoregressive model:

$$(14) \quad g_{t+1} = E[g_{t+1}]e^{\varepsilon_{t+1}} \\ \varepsilon_{t+1} = \rho\varepsilon_t + \eta_{t+1}$$

In equation 14, g is a given state or observation variable, η is a normally distributed random error with mean 0 and standard deviation σ_g , and ρ is the correlation coefficient. $E[g]$ is the deterministic expectation. When g refers to data, then g_t is the observed quantity, but when g refers to a state variable, then those g terms are estimated parameters. For example, effort in the modern period is treated in this fashion.

The variances for process and observation errors (σ_g) are parameterized as multiples of an overall model coefficient of variation (CV):

$$(15a) \quad \sigma_g = \ln[(\lambda_g CV)^2 + 1]$$

$$(15b) \quad \sigma_g = \ln[(\omega_{i,y}\lambda_g CV)^2 + 1]$$

The term λ_g is a variable-specific multiplier of the overall model CV. For catch series and indices (eq. 15b), the additional term, $\omega_{i,y}$, is the weight applied to individual points within those series. Thus, for indices, $\omega_{i,y}$ vary according to the weighting scheme used (i.e., $\omega_{i,y} = 1$ for equal weighting, $\omega_{i,y}=1/\text{rank}$ for rank weighting, and $\omega_{i,y} = 1/\text{CV}$ for inverse CV weighting) and the same λ_g was applied to all indices.

Additional model specifications

Individual points within catch and index series can be assigned different weights, based either on estimated precision or expert opinion. All reconstructed catches (1950 to 1994 for the commercial BLL, GN, and HL catches; 1950-1980 for the recreational catches; and 1950-1971 for the shrimp bycatch series) were down-weighted to a weight of 2 to reflect the comparatively lower degree of confidence in those reconstructed catches, as was done in SEDAR 13. All indices were weighted by an assigned rank, inverse CV, or given the same weight (1 or no weight) as described above.

One further model specification was the degree to which the model-predicted values matched catches vs. indices. An overall model CV is estimated (see equations 15a and 15b), and multiples (λ_g) of this overall CV can be specified separately for catches, indices, and effort (see Porch 2002). All catch series were assigned the same CV multiple, all indices were assigned a single CV multiple, and all effort series were also assigned a single CV multiple. In the case of the effort series, by allowing for large process error it was effectively a free parameter (a log-scale variance of 700 was used); the correlation was fixed at 0.3.

As in previous assessments, an initial attempt was made to estimate all these multipliers, but the index multiplier hit a boundary solution (upper limit). Attempts to estimate one or more of the multipliers generally resulted in boundary solutions for the multipliers or other estimated parameters. An explanation for this behavior when trying to estimate the index multiplier is likely that the interannual variability within indices is substantial in some cases, and additionally, some indices with similar selectivity had conflicting trends. In 2007, the CV multiplier of indices had to be given a value 3 times the catch CV multiplier (this implies that indices are less certain than catches) for the Hessian to be estimated, while the effort multiplier was fixed at 1. In the present assessment, fixing the three multipliers at the same value resulted in a slightly poorer fit to the shrimp bycatch series and F_{2011} being estimated more imprecisely, but conclusions on stock status were unaffected (stock not overfished and overfishing not occurring). It was thus decided to proceed by placing relatively more confidence in the catch series compared to the indices. Placing less certainty in the indices relative to the catch is somewhat justified because of the lack of a consistent signal and interannual variability in the indices, which resulted in somewhat poorer fits likely because the model could not always reconcile

those conflicting indices. The CV multipliers were thus fixed at 3 (indices), 1 (catches), and 1 (effort).

3.1.4. Parameter Estimation

Parameters were estimated by minimizing the objective function (the negative log joint posterior density function) using AD Model Builder software (Otter Research, Ltd. 2004). The (log) joint posterior distribution was specified up to a proportionality constant and included log likelihood components for observed data (Λ_1), process error components (Λ_2), and prior distribution components (Λ_3). The total objective function was then given by $\Lambda = \Lambda_1 + \Lambda_2 + \Lambda_3$, with each component as described below.

Observed data log likelihood—The observed data log likelihoods were specified as lognormal, but included a number of variance terms that could be estimated or fixed to allow for a wide range of choices for how to fit the data. The objective function takes the sum of the negative log likelihood contributions from indices, catches, and effort. The indices contribution is provided by

$$(16) \quad \Lambda_1 = 0.5 \sum_i \sum_y \sum_m \frac{(\log(I_{i,y,m}) - \log(\tilde{I}_{i,y,m}))^2}{\sigma_{i,y}^2} + \log(\sigma_{i,y}^2),$$

where $I_{i,m,y}$ and $\tilde{I}_{i,m,y}$ give observed and predicted indices, respectively, and

$$(17) \quad \sigma_{i,y}^2 = \log(1 + \text{CV}_{i,y}^2).$$

The catch and effort contributions have the same form. The term $\text{CV}_{i,y}$ gives the observed CV reported along with index i in year y (for example, as a result of the CPUE standardization process).

Process errors—Process errors for effort deviations made a contribution to the objective function. The contribution for effort deviations is given by

$$(18) \quad \Lambda_2 = 0.5 \sum_{1972 \leq y \leq 2011} \frac{(\varepsilon_{ey} - \rho_e \varepsilon_{ey-1})^2}{\sigma_e + (y-1) \log \sigma_e}$$

Prior distributions—The model started in 1950 and ended in 2011. Estimated model parameters were pup (age-0) survival, virgin recruitment (R_0), catchability coefficients associated with indices, and fleet-specific effort. Virgin recruitment was given a wide uniform prior distribution ranging from 1,000 to 10 billion individuals, whereas pup survival was given an informative lognormal prior with median=0.76 (mean=0.79, mode=0.69), a CV of 0.3, and bounded between 0.50 and 0.99. The mean value for pup survival was obtained using life-history invariant methods (see Section 3.1.2.4).

The total contribution for prior distributions to the objective function was then

$$(19) \quad \Lambda_3 = \log(p(e^{-M_0})) + \log(p(R_0)) + \sum_i \log(p(q_i)) + \sum_i \log(p(e_i))$$

A list of estimated model parameters is presented in **Table 3.5.6** (other parameters were held constant and thus not estimated, see Section 3.1.2). The table includes predicted parameter values and their associated SDs from SSASPM, initial parameter values, minimum and maximum values a parameter could take, and prior densities assigned to parameters.

3.1.5. Uncertainty and Measures of Precision

Numerical integration for this model was done in AD Model Builder (Otter Research Ltd. 2001), which uses the reverse mode of AUTODIF (automatic differentiation). Estimation can be carried out in phases, where convergence for a given phase is determined by comparing the maximum gradient to user-specified convergence criteria. The final phase of estimation used a convergence criterion of 10^{-6} . For models that converge, the variance-covariance matrix is obtained from the inverse Hessian. Uncertainty in parameter estimates was quantified by computing asymptotic standard errors for each parameter (**Table 3.5.6**), which are calculated by ADMB by inverting the Hessian matrix (i.e., the matrix of second derivatives) after the model fitting process. Stability of parameter estimates in the base run was explored through a jitter test, where initial values for some of the estimated parameters were varied individually or simultaneously from within their allowable ranges. Additionally, likelihood profiling was performed to examine posterior distributions for several model parameters. Likelihood profiles are calculated by assuming that the posterior probability distribution is well approximated by a

multivariate normal (Otter Research Ltd. 2001). The relative negative log-likelihood (objective function) and AICc (small sample AIC) values are listed in the tables of model results. However, it must be remembered that these metrics are not always comparable across model runs because different model configurations use different data sets (e.g, more or fewer indices, decreased catches) and thus affect the scale of the likelihood and AIC. For this reason, we decided not to include plots of the relative contribution to the likelihood by model source (catches, indices, effort, recruitment, catchabilities).

We also computed the approximate probability of the stock being overfished and overfishing occurring in the terminal year (2011) by using the likelihood profile of SSF₂₀₁₁ and F₂₀₁₁ and the point estimates of SSF_{MSY} and F_{MSY}, respectively. In one sensitivity run where likelihood profiling failed (see “Model start in 1972” below), we also performed MCMC with two chains of initial length=2,500,000 with a thinning rate of 100 such that very 100th value or 25,000 runs were saved.

Uncertainty in data inputs and model configuration was examined through the use of sensitivity scenarios in an attempt to depict the range of plausible states of nature. Twelve alternative runs are included in this report in addition to the baseline run. We also include continuity (see Section 2.1) and retrospective analyses. In the retrospective analyses of the baseline run, the model was refit while sequentially dropping the last four years of catch and index data to look for systematic bias in key model output quantities over time.

We now specifically describe how each of these sensitivities was implemented.

Baseline run: the base model configuration assumed virgin conditions in 1950, the historic period spanned 1950-1971, the modern period spanned 1972-2011, it used the historical reconstructed catch series and updated catch series, updated biological parameters, and 15 CPUE indices (the earliest of which, SEAMAP-GOM-EF, started in 1972). Catches were assumed to be 3 times more certain than the indices. Three variants were investigated for weighting the indices of relative abundance (equal weights, inverse CVs, and ranks), and inverse CV weighting was adopted as the weighting scheme for all ensuing sensitivity runs (see section 3.2.7).

Increasing and decreasing indices—The motivation for exploring this sensitivity was to inform the model with more consistent indices, rather than using the 15 indices from the base run that showed conflicting trends for given time periods. This would in principle free the model from having to reconcile conflicting trends and more explicitly show the consequences of using different subsets of indices. To that end, we fitted simple linear regressions to the 15 baseline indices and noted those with increasing or decreasing tendencies. Nine indices showed an increasing trend (PC-LL, ATL Coastspan LL, BLLOP, SEAMAP-SA, GOM combined GN, VA-LL, NMFS-LL-SE, SC Coastspan GN, and UNC-LL) (**Figure 3.6.4**), five showed a decreasing trend (GOM combined BLL, SCDNR-RD-LL Early, SCDNR-RD-LL-Late, SEAMAP-GOM-EF, and GADNR Trawl) (**Figure 3.6.5**), whereas one showed no trend (SEAMAP-GOM-ES).

Low catch—The Panel felt that the large magnitude of the shrimp bycatch series already constituted a high catch scenario and thus decided to consider a low catch scenario only. This scenario was an attempt to capture the uncertainty in the magnitude of the estimated catches, specifically shrimp discards. In light of the overwhelming contribution of the shrimp bycatch series to the total catches, only this series was altered: instead of the values used in the baseline run, the mean of the SEDAR 13 values scaled by the effort exerted by the shrimp fleet were used (**Table 3.5.7**).

Hierarchical index—The motivation for this scenario, which uses a single hierarchical index of relative abundance (see Conn 2010 and SEDAR21-AW-01 for a full description of the method), (**Table 3.5.8; Figure 3.6.6**) is that the individual indices in the baseline run are attempting to estimate relative abundance, but are subject to both sampling and process error. While sampling error is assumed to be captured by previous standardization of indices (via CVs), each index is also subject to process variation, which describes the degree to which a given index measures “artifacts” above and beyond relative abundance in the population. The selectivity used for the single index was developed as a weighted average of the age-specific selectivities associated with the individual indices. The inverse variance weights obtained when calculating the hierarchical index were used to weight the individual selectivity curves. A weighted selectivity vector was thus obtained, which has to be approximated by a functional form for input into SSASPM. We attempted to approximate the selectivity vector by using two functional forms: 1) a logistic (flat-topped) curve and 2) a double exponential (dome-shaped) curve (**Figure 3.6.7**).

SEAMAP-SA index—We also wished to investigate how the model would respond if fitted only to one of the indices of relative abundance that were best fit in the baseline run. To that end, we ran the model with only the SEAMAP-SA index

No indices—Along the same lines, we wanted to see the model response when no indices of relative abundance were present at all to contrast with the results of the baseline run.

Model start in 1972—The motivation for this sensitivity was mostly to see the effect that catch reconstruction, with emphasis on the shrimp bycatch series, had on results.

High and low productivity—The aim of this scenario was to incorporate variability in productivity to try to encompass plausible biological limits. To simplify the process we assumed a 10% increase or 10% decrease in the following biological input parameters used in the baseline run: L_{∞} (80.2 cm FL) and k (0.61 yr^{-1}) von Bertalanffy growth function parameters, proportion mature at age (up to a maximum of 100%), pup production at age, and natural mortality (M) at age (**Table 3.5.9**).

Atlantic and Gulf of Mexico stocks—Based on evidence that shows that this species may consist of two separate stocks, one in the Atlantic (ATL) and one in the Gulf of Mexico (GOM), we ran a sensitivity scenario for these two separate stocks. This entailed separating the catches and indices into ATL and GOM components as well as using the area-specific biological inputs.

Tables 3.5.10 and 3.5.11 and **Figure 3.6.8** show the area-specific catches, **Tables 3.5.12 and 3.5.13** and **Figure 3.6.9** show the area-specific indices, and **Table 3.5.14** shows the area-specific biological inputs.

3.1.6. Benchmark/Reference points methods

Benchmarks included estimates of absolute population levels and fishing mortality for 2011 (F_{2011} , SSF_{2011} , B_{2011} , N_{2011} , $N_{\text{mature}2011}$), reference points based on MSY (F_{MSY} , SSF_{MSY} , SPR_{MSY}), current status relative to MSY and MSST ($(1-M)^*MSY$) levels, and depletion estimates (current status relative to virgin levels). In addition, trajectories for $F_{\text{year}}/F_{\text{MSY}}$ and $SSF_{\text{year}}/SSF_{\text{MSY}}$ were plotted and phase plots provided.

3.1.7. Projection methods

The estimate of generation time for the baseline run is 5.3 years, and was calculated as:

$$(20) \quad GenTime = \frac{\sum_i if_i \prod_{j=1}^{i-1} s_j}{\sum_i f_i \prod_{j=1}^{i-1} s_j}$$

where i is age, f_i is the product of (fecundity at age) \times (maturity at age), and s_j is survival at age. Maximum age used in the calculations was 18 years. This generation time corresponds to the mean age of parents of offspring produced by a cohort over its lifetime (v_1 ; Caswell 2001).

Projections were governed with the same set of population dynamics equations as the original assessment model (section 3.1.3), but allowed for uncertainty in initial conditions at the beginning of the time series (2011) as well as in underlying productivity. Projections were run using Monte Carlo bootstrap simulation, where initial numbers (N_{2011}^{boot}) and fishing mortality (F_{2011}^{boot}) were sampled from a bivariate normal distribution. Pup survival at low biomass ($e^{-M_0 2011^{boot}}$) and equilibrium recruitment (R_{02011}^{boot}) were sampled from a second bivariate normal distribution. Expectations were equivalent to posterior modes from SSASPM, and the standard deviations and covariance values were obtained from the Hessian approximation of the variance-covariance matrix at the posterior mode. The bivariate normal approximation was chosen because it reduced the probability of selecting values of the different parameters that were unlikely to have generated the data. A separate bivariate distribution was chosen for $e^{-M_0 2011^{boot}}$ and R_{02011}^{boot} in order to simulate recruitment variability in the projections (e.g., section 3.1.3 equations 2 and 3).

The first projection year was 2012, and projections were run until the year 2041 (30 years). As a result, the projection interval included multiple generations (generation time c.f., 5.3 years). Projections were implemented with current fishing mortality F_{2011}^{boot} during the first three years (2012, 2013, 2014), and then with the fishing mortality rate evaluated for the projection scenario during the remaining years (2015 – 2041). Projections used the same selectivity as used in the ending year (2011) of SSASPM. Thus, the anticipated allocation of effort within the fishery (between fleets) was assumed to remain the same as that in 2011. Total annual removals due to fishing represented catch (in 1000s) from all fleets combined (e.g., commercial longlines, gillnets, and lines, recreational catches, and shrimp trawl fishery discards; **Table 3.5.1A**).

All projections used 10,000 Monte Carlo bootstrap simulations. Each projection was summarized with respect to the projected distribution in mature spawning stock fecundity (SSF) and fishing mortality rate (F) for each projection year (t). Moments of the distribution were summarized each year (2012 – 2041) using quantiles, with the median used for the central tendency, and the 30th and 70th percentiles used as the lower and upper ranges, respectively. In addition, for the last 10 years of projections (2032 – 2041) and a given fixed level of total annual removals (in 1000s), the $\text{Pr}(\text{SSF}_t > \text{SSF}_{\text{MSY}})$ was calculated as $1 - \text{Pr}(\text{SSF}_t \leq \text{SSF}_{\text{MSY}})$, where $\text{Pr}(\text{SSF}_t \leq \text{SSF}_{\text{MSY}})$ was calculated as the cumulative relative frequency of $(\text{SSF}_{t,\text{boot}} \leq \text{SSF}_{\text{MSY}}) = (\text{cumulative frequency}) / (\text{sample size})$. Analogously, for the last 10 years of projections (2032 – 2041) and a given fixed level of total annual removals (in 1000s), the $\text{Pr}(F_t > F_{\text{MSY}})$ was calculated as $1 - \text{Pr}(F_t \leq F_{\text{MSY}})$, where $\text{Pr}(F_t \leq F_{\text{MSY}})$ was calculated as the cumulative relative frequency of $(F_{t,\text{boot}} \leq F_{\text{MSY}}) = (\text{cumulative frequency}) / (\text{sample size})$. All projections were conducted with R statistical software (R Development Core Team; RDCT 2009).

Projection methods followed those developed during SEDAR 21 for an age-structured catch-free model (ASCFM) applied to HMS dusky sharks (NMFS 2011), as modified during SEDAR 29 for a SSASPM model applied to HMS blacktip sharks (NMFS 2012a, 2012b), except as described below. First, during the P* workshop (P* workshop, NOAA/NMFS, Panama City Laboratory, June 11-13, 2013; Report in prep.), it was noted that the projection methodology from SEDAR 29 (NMFS 2012b) may not have adequately characterized recruitment variability. For example, the 30th and 70th percentiles (e.g., NMFS 2012b; their Figures 2.1-2.7) appeared to narrow over time, an implausible result. Consequently, the following changes to the HMS domestic shark projection methodology (e.g., NMFS 2012b) were implemented here, based on recommendations made at the P* workshop to more adequately characterize recruitment variability: 1) Remove pup survival at low biomass (e^{-M_0}) from the multivariate normal distribution with F and N (NMFS 2012b); 2) Model F, and N together in a bivariate normal distribution; 3) Add uncertainty in equilibrium recruitment, R_0 , to the projections; 4) Model uncertainty in R_0 and e^{-M_0} together in a separate bivariate normal distribution.

Second, during preliminary projection runs, it was noted that very high fixed levels of total annual removals due to fishing were required to achieve $\text{Pr}(\text{SSF}_t > \text{SSF}_{\text{MSY}}) = 70\%$, and

$\text{Pr}(F_t > F_{\text{MSY}}) = 30\%$ from 10,000 Monte Carlo bootstrap projections. However, diagnostic output plots indicated that at the same very high fixed levels of total annual removals there was a high probability that projected stock size would decline ($\text{Pr}(\text{SSF}_t > \text{SSF}_{\text{MSY}}) < 30\%$) over longer-term projection periods (e.g., 30 years). In contrast, during preliminary projection runs, it was noted that more moderate fixed levels of total annual removals due to fishing were required to achieve $\text{Pr}(\text{SSF}_t > \text{SSF}_{\text{MSY}}) = 70\%$, and $\text{Pr}(F_t > F_{\text{MSY}}) = 30\%$ from 10,000 Monte Carlo bootstrap projections for longer-term projections (e.g., 30 years). The more moderate fixed levels of total annual removals due to fishing also resulted in relatively more stable population trajectories over time which appeared to approximate equilibrium by about 30 years. Consequently, results are presented here for longer-term (30 years) rather short-term (~5 to 10 years) probabilistic projections.

Third, during preliminary projection runs, it was noted that the retrospective annual catches in weight computed in the R projections differed from those in SSAPSM. In contrast, retrospective annual catches in numbers computed in the R projections were nearly identical (c.f. 1% difference) to those from SSAPSM. Annual catch data are currently entered in numbers in SSAPSM. Weight at age of the catch is then computed internally in SSAPSM by fleet at a monthly time step. In contrast, weight at age of the catch is computed in the R projections for all fleets combined at an annual time step. As a result, projected catch in weight in the R projections may not be directly comparable to catch in weight estimated in SSAPSM. Consequently results are presented here for projections at a given fixed level of total annual removals due to fishing in numbers (1000s) rather than in weight.

3.2. MODEL RESULTS

3.2.1. Measures of Overall Model Fit

Inverse CV weighting of the indices was selected as the weighting scheme that provided the best model fit and was thus used in all sensitivity runs. Catches were fit well with the exception of some points in the shrimp bycatch series (**Figure 3.6.10**). The model fit a central tendency through most of the indices and fit some, or at least portions, fairly well (SEAMAP-SA, GOM Combined GN, VA LL, SEAMAP GOM ES, SEAMAP GOM EF), while others were hard to fit given the large interannual fluctuations in most cases (PCLL, BLLOP, NMFS LL SE, SC

Coastspan GN, SCDNR RD LL Early, and especially UNC LL) (**Figure 3.6.11**). In general, the fits showed a rather flat tendency prior to the onset of the first index in 1972, followed by a decreasing tendency to about 2000, and then an increasing trend in the last decade. Individually, the PCLL, ATL Coastspan LL, BLLOP, SEAMAP-SA, GOM Combined GN, VA LL, NMFS LL SE, SC Coastspan GN, and UNC LL indices showed increasing tendencies, whereas the GOM Combined BLL, SC RD LL Early and Late, SEAMAP GOM EF, and GADNR Trawl indices showed a decreasing trend and the SEAMAP GOM ES index was essentially flat. In the early part of the modern period, starting in 1972, the SEAMAP GOM EF index showed a decreasing trend, whereas the SEAMAP GOM ES and VA LL indices showed no trend and the UNC LL index increased (**Figure 3.6.3**, upper panel). Catches progressively increased from 1972 to 2000 and started declining thereafter (**Figure 3.6.3**, bottom panel).

3.2.2. Parameter estimates and associated measures of uncertainty

A list of model parameters is presented in **Table 3.5.6**. The table includes predicted parameter values with associated SDs, initial parameter values, minimum and maximum allowed values, and prior density functions assigned to parameters. Parameters designated as type “constant” were estimated as such; parameters that were held fixed (not estimated) are not included in this table.

3.2.3. Stock Abundance and Spawning Stock Fecundity

Predicted abundance and spawning stock fecundity (numbers x proportion mature x fecundity in numbers) are presented in **Table 3.5.15** and **Figure 3.6.12**. Both trajectories show slight depletion from 1950 to the beginning of the modern period in 1972, followed by a decreasing trend to about 2000, and a progressive increase in the last decade, which corresponds to decreased effort and catches in the shrimp trawl fishery and a majority of the indices of relative abundance showing increasing tendencies in those years.

3.2.4. Fishery Selectivity

As explained in Section 3.1.2.2 and shown in **Table 3.5.2** and **Figure 3.6.2**, selectivities are estimated externally to the model and a functional form inputted for each fleet and index. In

Figure 3.6.2 one can see that most fleets and indices select for mature animals, but the most important fleet, the shrimp trawl, selects predominantly immature animals, especially age-1s (and age-0s, which are not modeled explicitly but are caught in that fishery).

3.2.5. Fishing Mortality

Predicted total and fleet-specific instantaneous fishing mortality rates are presented in **Table 3.5.16** and **Figure 3.6.13**. Fishing mortality was overwhelmingly dominated by the shrimp trawl fleet and exceeded the estimated F_{MSY} of 0.377 in the baseline run several years from 1987 to 2000. The contribution of the remaining fleets to total F was minimal. Fishing mortality was lower in the past decade in accordance with decreased shrimp trawl effort and catches during that period.

3.2.6. Stock-Recruitment Parameters

The predicted virgin recruitment (R_0 ; number of age 1 pups) was on the order of 9,300,000 animals regardless of the variant used to weight the indices in the baseline run (**Figure 3.6.14**).

The predicted steepness was 0.56-0.57 and the maximum lifetime reproductive rate was 5.1-5.3.

The estimated pup (age-0) survival at low density was high, ranging from 0.86 to 0.89 (see next section for further discussion on pup survival). In all, the model estimated the stock to be highly productive, which seems in line with the life history of this species (Brooks et al. 2010).

3.2.7. Evaluation of Uncertainty

Estimates of asymptotic standard errors for all model parameters are presented in **Table 3.5.6**. The jitter test confirmed that varying the initial values of some of the estimated parameters individually or simultaneously from within their allowable ranges, did not generally affect results. Posterior distributions for several model parameters of interest were obtained through likelihood profiling and, in some cases, MCMC. Prior and posterior distributions for pup survival and virgin recruitment are shown in **Figure 3.6.14**. There appeared to be information in the data since the posteriors for these two parameters were different from the priors. The median for the posterior of pup survival was estimated at a higher value than the prior (0.89 vs. 0.76),

whereas the posterior for virgin recruitment of pups was informative in contrast to its diffuse uniform prior (**Figure 3.6.14**).

Posterior distributions were also obtained for several benchmarks. The distribution for spawning stock fecundity in 2011 shows overlap with the distribution for virgin conditions and most of its density is above the MSST reference point, which translates to a probability of the stock not being overfished ($P(\text{SSF}_{2011} > \text{SSF}_{\text{MSST}})$) of 98% (**Figure 3.6.15**). The distributions for total biomass depletion and spawning stock fecundity depletion are wide, with most of the density concentrated between ca. 0.1 and 0.8 (**Figure 3.6.15**). The pdf of F_{2011} shows the highest density towards the lower values, but there is a tail with substantial density for considerably higher values, which translates to a probability of overfishing not occurring ($P(F_{2011} < F_{\text{MSY}})$) of 54%. In fact, we had to run MCMC to obtain a more reasonable posterior pdf for this parameter, probably because it was very imprecisely estimated (CVs of 1.94 to 2.02). The overlap between mature number of fish in 2011 and in virgin conditions was very similar to that for biomass or spawning stock fecundity (**Figure 3.6.16**).

Results of the baseline scenario with the three index weighting schemes (ranks, inverse CV, equal weights) are summarized in **Table 3.5.17**. The three variants estimated that the stock is not overfished and overfishing is not occurring. Inverse CV weighting of the base run estimated less depletion than not weighting or weighting the indices with ranks and thus a relatively more optimistic status compared to the other two weighting options. These three models had the same number of observations and estimated parameters and are thus directly comparable. Since the AICc and objective function were lowest for inverse CV weighting, indicating a better fit of that model, it was selected as the method for index weighting for all subsequent sensitivities.

Results of all the sensitivity analyses are summarized in **Table 3.5.18**. Using only the indices of relative abundance that showed an increasing tendency (“increasing indices” sensitivity) resulted in a more optimistic outcome and a slightly better fit to the catches (**Figure 3.6.17**), but the fit to the indices was similar to the corresponding ones in the base run (**Figure 3.6.18**). In contrast, using only the indices of relative abundance that showed a decreasing tendency (“decreasing indices” sensitivity) resulted in a more pessimistic outcome, as expected. In this scenario, the stock would be overfished with overfishing occurring. The fit to the catches

was also slightly better than in the base run (**Figure 3.6.19**), but the indices were fit much better compared to the corresponding ones in the base run (**Figure 3.6.20**).

Considering catches lower than those in the base run (“low catch” sensitivity) predicted a more optimistic stock status. With lower catches the model estimated a lower virgin stock size and recruitment, but concurrently less depletion and a correspondingly more optimistic status when compared to the base run (**Table 3.5.18**). In this scenario neither catches nor indices were fit as well as in the base run (**Figures 3.6.21** and **3.6.22**), with the estimated relative abundance showing a much flatter trend, without the more marked decrease from the early 1970s to the 2000s and the marked increase from the early 2000s to 2011 predicted in the base run (**Figure 3.6.22**).

Using the hierarchical index of relative abundance with a flat-topped selectivity (“hierarchical index log sel” sensitivity run) resulted in a substantially more optimistic stock status than in the base run (**Table 3.5.18**). The model estimated a virgin stock size and recruitment approximately double that of the base run. In contrast, using the hierarchical index of relative abundance with a dome-shaped selectivity (“hierarchical index dexp sel” sensitivity run) resulted in a more optimistic stock status than in the base run, but with all the benchmarks and estimated metrics of similar magnitude to those in the base run (**Table 3.5.18**). Fits to the catches with the logistic selectivity sensitivity run were very good (**Figure 3.6.23**) whereas those with the double exponential selectivity sensitivity run were a little better than with the base run (**Figure 3.6.24**). The fit to the hierarchical index, however, was not good in either of the two runs, with the logistic selectivity run predicting a much shallower trend than the double exponential selectivity run (**Figure 3.6.25**).

Using the SEAMAP-SA index only (“SEAMAP-SA” sensitivity) resulted in a more optimistic status than in the base run (**Table 3.5.18**). The fit to the catches was a little better than in the base run (**Figure 3.6.26**) and the fit to the SEAMAP-SA index did not differ appreciably from that in the base run (**Figure 3.6.27**). The “No indices” sensitivity run predicted almost no depletion and a huge virgin stock and current abundance (on the order of 500 million animals). With no signal from any indices, this scenario fit the catches almost perfectly (**Figure 3.6.28**).

Starting the model in 1972 compared to 1950 had no notable effect on results, probably because catches in the historic period (1950-1971) were much lower than in the modern period (1972-2011), and stock status was only slightly less optimistic than in the base run (**Table**

3.5.18). Pup survival had to be fixed (not estimated) in this run because it otherwise hit the upper bound. While the fit to the three commercial catch series was slightly better than for the base, the fit to the recreational catches, and especially the shrimp bycatch series, was substantially worse than in the base run (**Figure 3.6.29**). The predicted relative abundance showed a flatter trend than in the base run and the fits to the indices were comparable (**Figure 3.6.30**).

Assuming higher and lower stock productivity, resulted in a more, and less, optimistic status, respectively (**Table 3.5.18**). As expected, the “high productivity” sensitivity run estimated a higher maximum lifetime reproductive rate and steepness than the base run and the “low productivity” sensitivity run, lower values for these two parameters. The fit to the catches (**Figure 3.6.31** for “high productivity” and **Figure 3.6.33** for “low productivity”) and indices (**Figure 3.6.32** for “high productivity” and **Figure 3.6.34** for “low productivity”) for both scenarios were very similar and also similar to those in the base run.

Assuming separate stocks for the Atlantic and Gulf of Mexico yielded contrasting results. The “Atlantic stock” sensitivity run resulted in a more optimistic status than the base run, whereas the “Gulf of Mexico stock” sensitivity run predicted a considerably more pessimistic status, with this scenario estimating much more depletion with respect to virgin levels than the base run; however, the stock was not overfished and overfishing was not occurring according to the deterministic results (**Table 3.5.18**). Fits to the Atlantic catch data were generally good (**Figure 3.6.35**); however, the estimated relative abundance trajectory was much flatter than in the base run with the model attempting to find a central tendency to fit the observed indices (**Figure 3.6.36**). The fit to the Gulf of Mexico catch data was very good, except for several data points in the modern period of the shrimp bycatch series (**Figure 3.6.37**). The estimated relative abundance trajectory showed a steeper decline than in the base run, but the fits to some of the indices improved with respect to those in the base run (**Figure 3.6.38**).

3.2.7.1. Continuity analysis

Table 3.5.19 shows the summarized results of the continuity analysis and of the 2007 base run. The base run in 2007 indicated that the stock was not overfished and overfishing was not occurring, a status supported by the continuity run (but see probabilistic results in section 3.2.8), which, however, estimated more depletion had occurred with the addition of six more years of

data as well as a substantially higher pup survival. The magnitude of some of the estimated parameters was substantially lower in the continuity and 2007 base run compared to the current base run. Catches showed a slow decline with the additional years of data (**Figure 2.6.1**). The same 16 indices as in the 2007 base run were used for the continuity analysis. Four of those indices did not have additional years of data and thus remained unchanged (PCLL, MML-GN-adults, and MML-GN-juveniles; the GNOP because of convergence issues). Of the remaining 12 indices, four increased since 2007 (PC-GN-Juveniles, PC-GN-Adults, BLLOP, and Texas GN), six decreased (SEAMAP-SA, VA LL, NMFS LL SE, SC Coasts span GN, SEAMAP-GOM-EF, and UNC LL), and two showed no clear trend (SEAMAP-GOM-ES and SCDNR RD LL [this series with only one more year of data]) (**Figure 2.6.2**). The six catch series were unevenly fit, with the commercial BLL, commercial handline, and commercial BLL discard series fit well, but several years of the commercial gillnet, recreational catches, and especially the shrimp bycatch series not fit well (**Figure 3.6.39**). As in 2007, the model still interpreted the fluctuations in relative abundance shown by the different indices by fitting a fairly flat relative abundance trajectory, with varying levels of depletion (**Figure 3.6.40**).

3.2.7.2. Retrospective analysis

Results of the retrospective analysis of the base run are presented in **Table 3.5.20** and **Figure 3.6.41**. Three model output quantities were examined in the analysis: 1) spawning stock fecundity, 2) relative spawning stock fecundity, and 3) relative fishing mortality. There were no apparent retrospective patterns in the SSF or relative spawning fecundity (SSF/SSF_{MSY}) trajectories, which appeared to converge quickly. The relative fishing mortality (F/F_{MSY}) trajectories for the 2008 and 2007 retrospective runs showed a little pattern (did not overlap with the other series) until about 2005, but appeared to merge prior to that, except for another divergence for the 2007 retrospective run in 2003. We conclude that no systematic pattern of over- or under-estimation of abundance, relative abundance, or fishing mortality was evident.

3.2.8. Benchmarks/Reference Points

Benchmarks for the MSY reference points for the base run are summarized in **Table 3.5.17**, those for all sensitivity scenarios in **Table 3.5.18**, those for the continuity analysis in **Table 3.5.19**, and those for the retrospective analyses, in **Table 3.5.20**. The base model estimated that

the stock was not overfished and overfishing was not occurring (**Table 3.5.17**) and that the stock had never been overfished, but it had fluctuated well above the overfishing threshold and a little below it several times between 1987 and 2000 (**Figures 3.6.42** and **3.6.43**).

As a form of *historical analysis*, **Figure 3.6.44** is a phase plot showing the outcomes of the base model (with the three weighting options), the continuity analysis, the results of the base models from the 2007 and 2002 assessments (also using SSASPM), as well as the results obtained with the Bayesian Surplus Production (BSP; McAllister and Babcock 2004) base model and WinBUGS base model in 2007. Stock status in the base runs did not deviate far from the 2002 base model prediction or that of the 2007 WinBUGS model. Results of the 2007 base model and the continuity run predicted a progressively less optimistic status, but still within the not overfished/no overfishing quadrant.

Figure 3.6.45 shows the outcomes of all historical and current base and sensitivity results. With the exception of the “decreasing indices” sensitivity run, all other scenarios estimated that the stock was not overfished and overfishing was not occurring. The “GOM stock” scenario predicted the stock biomass would be very close to MSY conditions, but still well above the MSST criterion, which is used to determine the overfished status. The results of the retrospective analyses support the conclusions from the base run (**Figure 3.6.46**).

In order not to rely solely on the terminal year to determine stock condition, we also computed stock status as the geometric mean of the last three years of the assessment (2009-2011) and associated a probability with the statement of whether the stock was overfished or overfishing was occurring in the terminal year (2011). **Table 3.5.21** shows that, with the exception of the “decreasing indices” sensitivity, there was a very high probability that the stock in 2011 was not overfished ($P=0.85-0.99$, with most scenarios having a $P>0.90$). In contrast, when expressed probabilistically and because the distribution of F_{2011} is skewed to the right, the probability of overfishing not occurring in 2011 was <0.50 in three cases and ranged between 0.54 and 0.67 in the majority of the cases.

3.2.9. Projections

Projections were conducted over a range (21) of fixed levels of total annual removals (**Table 3.5.22**). Projections were completed for the baseline SSASPM model (inverse CV weighting) and additional sensitivity configurations evaluated in the stock assessment (**Table 3.5.23**):

Projection scenario-1 (Baseline, Inverse CV Weighting), Projection scenario-2 (Sensitivity, Increasing Indices), Projection scenario-3 (Sensitivity, Decreasing Indices), Projection scenario-4 (Sensitivity, Low Catch), Projection scenario-5.1 (Sensitivity, Hierarchical Index log), Projection scenario-5.2 (Sensitivity, Hierarchical Index db exp), Projection scenario-6 (Sensitivity, Model Start in 1972), Projection scenario-7 (Sensitivity, High Productivity), Projection scenario-8 (Sensitivity, Low Productivity), Projection scenario-9 (Sensitivity, SEAMAP-SA), Projection scenario-10 (Sensitivity, Gulf of Mexico Stock), and Projection scenario-11 (Sensitivity, Atlantic Stock). The SSASPM model configurations chosen for projections were intended to be representative of the range of uncertainty in data inputs and model configuration examined in the stock assessment. Examples from each projection scenario are provided for a given fixed level of total annual removals due to fishing (1,000s) during the years (2012 – 2041) which resulted in both the $\Pr(\text{SSF}_t > \text{SSF}_{\text{MSY}}) \geq 70\%$, and the $\Pr(F_t > F_{\text{MSY}}) \leq 30\%$ in the year 2041 from 10,000 Monte Carlo bootstrap projections (**Table 3.5.23**). These values represent a proxy P* approach (based on probabilistic projections at alternative fixed levels of removals) used here to determine the removals (in 1000s) associated with a 70% probability of overfishing not occurring ($P^* = 0.3$), in response to Term of Reference 5 (section 1.2.5).

The 30th percentile of $\text{SSF}_{t,\text{boot}} / \text{SSF}_{\text{MSY}}$ was summarized for each projection year (2012 – 2041) and each fixed level of total annual removals due to fishing (**Figure 3.6.47**). The 30th percentile of $\text{SSF}_{t,\text{boot}} / \text{SSF}_{\text{MSY}}$ represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2012 – 2041) (**Figure 3.6.47**). The $\Pr(\text{SSF}_t > \text{SSF}_{\text{MSY}})$ was summarized for the last 10 years of projections (2032 – 2041) and a given fixed level of total annual removals (in 1000s) (**Table 3.5.24**). Fixed removals that resulted in $\Pr(\text{SSF}_t > \text{SSF}_{\text{MSY}}) \geq 70\%$ represented at most a 30% probability of exceeding SSF_{MSY} and were highlighted in green. Fixed removals that resulted in $70\% > \Pr(\text{SSF}_t > \text{SSF}_{\text{MSY}}) \geq 50\%$ represented more than a 30% probability of exceeding SSF_{MSY} but less than or equal to a 50% probability of exceeding SSF_{MSY} and were highlighted in yellow. Fixed removals that resulted in $\Pr(\text{SSF}_t > \text{SSF}_{\text{MSY}}) < 50\%$ represented more than a 50% probability of exceeding SSF_{MSY} and were highlighted in red.

The 70th percentile of $F_{t,\text{boot}}/F_{\text{MSY}}$ was summarized for each projection year (2012 – 2041) and each fixed level of total annual removals due to fishing (**Figure 3.6.48**). The 70th percentile of $F_{t,\text{boot}}/F_{\text{MSY}}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2012 – 2041) (**Figure 3.6.48**). The $\Pr(F_t > F_{\text{MSY}})$ was summarized for the last 10 years of projections (2032 – 2041) and each fixed level of total annual removals due to fishing (**Table 3.5.25**). Fixed landings that resulted in $\Pr(F_t > F_{\text{MSY}}) \leq 30\%$ represented at most a 30% probability of exceeding F_{MSY} and were highlighted in green. Fixed landings that resulted in $30\% > \Pr(F_t > F_{\text{MSY}}) \leq 50\%$ represented more than a 30% probability of exceeding F_{MSY} but less than or equal to a 50% probability of exceeding F_{MSY} and were highlighted in yellow. Fixed landings that resulted in $\Pr(F_t > F_{\text{MSY}}) > 50\%$ represented more than a 50% probability of exceeding F_{MSY} and were highlighted in red.

3.3. DISCUSSION

Although there has been and still is some directed commercial fishing for Atlantic sharpnose sharks and they are also frequently caught in recreational fisheries, catches of this species are dominated by bycatch in the Gulf of Mexico shrimp trawl fishery. Given the Panel's lack of confidence in the (WinBUGS) model-generated estimates, stratified nominal estimates were used instead, which were several times larger than the values used in SEDAR 13. Estimates of removals in the historical period (1950–1971) were kept the same as in SEDAR 13, where they were reconstructed based on expert opinion. The assumption of the stock being in virgin conditions in 1950 thus seems reasonable.

It is notable that of the 15 indices of relative abundance recommended for use in the base run, only one was fishery dependent. Furthermore, several individual indices were combined into single Atlantic coastal longline, Gulf of Mexico longline, and Gulf of Mexico coastal gillnet indices. Since indices theoretically track relative abundance, inconsistent signals likely lead to tensions among the different indices when fitting the model, which may propose an abundance trend that represents a compromise solution attempting to accommodate the sometimes different trends displayed by the indices. Another issue that has been pointed out in previous shark stock assessments is that many indices show interannual variability that does not seem to be compatible with the life history of the species, which would suggest that the standardization

methods were not fully successful in tracking relative abundance. This is not as much of an issue in the current assessment given the higher productivity and life history traits of this species compared to other larger species of sharks. Nevertheless, it is unclear why the model was able to fit some of the indices relatively well, while others were poorly fit.

Since the model cannot ultimately distinguish which of the trends in abundance is most likely to represent reality, we explored the use of different combinations of indices through sensitivity analyses. While considering only indices that showed increasing trends resulted in a moderate improvement in stock status, the fit to the indices did not vary appreciably. In contrast, considering only indices that showed decreasing tendencies resulted in improved fits to the indices and a reversal of stock status, which became overfished with overfishing. We also attempted to remove some of the process variation in the indices by computing a hierarchical index of relative abundance with two different assumptions about the shape of the selectivity curve, but the index was not fit well either. Fitting to a single index that had been relatively well fit in the base run (SEAMAP-SA) resulted in a similar fit to that index and improved fit to catches. We also explored using no indices at all, which the model interpreted as the stock being very large and almost no depletion having occurred.

We explored three variants of the base model that used equal weights, inverse CV, and ranks to weight the indices. Since the fit with inverse CV weighting was better, we used this variant of the model for all subsequent sensitivity runs. Exploring the uncertainty associated with catches by considering a much lower level of bycatch in the GOM shrimp trawl fishery revealed that the model responded to lowered catch in a predictable way, improving stock status. Addressing the possible effect of reconstructing the catch series back to 1950 by starting the model in the modern period (1972) had very little effect on results, probably because of the relatively low magnitude of the historic catches compared to those in the modern period. Consideration of uncertainty in biological parameters, explored through sensitivity runs that tried to encompass plausible variability in those parameters, also had a predictable effect on model results, improving stock status when the stock was assumed to be more productive and vice versa, but did not affect results substantially. Finally, consideration of two separate stocks, one in the Atlantic and one in the Gulf of Mexico, led to the conclusion that the Gulf of Mexico stock is considerably more depleted than its Atlantic counterpart likely as a result of increased exploitation and lower productivity.

Considering the multiple sources of uncertainty that were examined through sensitivity analyses, it can be concluded that the assessment provided a consistent picture of stock status, especially in terms of the stock not being overfished. With one exception, all the sensitivity runs we explored in an effort to encapsulate plausible alternate states of nature predicted that the stock of Atlantic sharpnose sharks was not overfished and overfishing was not occurring, although when we express results probabilistically, the overfishing status ($P=0.30\text{--}0.97$) is much more uncertain than the overfished status ($P=0.85\text{--}0.99$) (**Table 3.5.21**).

Despite the significant differences between the inputs used in the 2007 and 2002 assessments and the current assessment, stock status did not change substantially, although the magnitude of some of the estimated parameters varied significantly (**Table 3.5.19**). The current base model estimated substantially higher virgin and current SSF and virgin recruitment as well as a more productive stock than the 2007 assessment. The main differences between the 2007 and current assessment include: the magnitude of the shrimp bycatch series increased ca. six-fold; an additional selectivity function and slight changes to some of those previously used were introduced; there are now 15 indices of relative abundance in the base run (vs. 16 in 2007), but five of them were not used in 2007 and all (except PC LL) were re-analyzed and include six more years of data; there are new biological parameters, including a new maximum age of 18 yr (vs. 12), a maternal length vs. litter size relationship is used (vs. a fixed fecundity of 4.1), and there are new estimates of natural mortality at age (0.23 vs. 0.36 to 0.24), changes which have the combined effect of increasing the productivity of the stock.

As noted in previous assessments that also used SSASPM, the estimation of selectivities externally to the model may not be ideal and not have captured the uncertainty associated with the transformation of lengths into ages to produce age-frequency distributions to which selectivity curves were fitted or assigned. Unfortunately, SSASPM cannot accommodate length composition data but can in theory accept age composition data as input. However, early attempts at estimating selectivity within the model through the use of available age compositions (obtained from length compositions through the von Bertalanffy growth function) were unsuccessful and thus, as in previous implementations of the model, selectivities had to be estimated externally to the model. In the future, when benchmark assessments for this species are conducted, we hope to use a length-based, age-structured model.

Based on the similar results obtained in the present and 2007 and 2002 assessments, it appears that despite very large catches in the 1980s and 1990s, the updated productivity of the stock combined with the decline in catches in the past decade and generally stable or increasing indices of relative abundance, makes the stock of Atlantic sharpnose sharks resilient enough to be in a not overfished condition with overfishing likely not occurring.

Probabilistic projections at alternative fixed harvest levels were used to provide an approach for reducing the overfishing limit (OFL) to account for scientific uncertainty within individual SSASPM model configurations. Multiple projection scenarios were evaluated with probabilistic projections in an attempt to reflect the full range of plausible states of nature evaluated among SSASPM model configurations. Among all projection scenarios evaluated, except Projection scenario-6, examples of fixed levels of total annual removals due to fishing during the years 2015 – 2041 which resulted in both the $\Pr(\text{SSF}_t > \text{SSF}_{\text{MSY}}) \geq 70\%$, and the $\Pr(F_t > F_{\text{MSY}}) \leq 30\%$ in the year 2041 from 10,000 Monte Carlo bootstrap projections ranged from 250,000 to 2,750,000 sharks (**Table 3.5.23**). Pup survival was fixed in the SSASPM sensitivity configuration Model Start in 1972, which resulted in an unreasonably small buffer (percent decrease from MSY) for Projection scenario-6. The median buffer from OFL from multiple projection scenarios, excluding Projection scenario-6, was 23% (**Table 3.5.23**). These values represent a proxy P^* approach (based on probabilistic projections at alternative fixed levels of removals) used here to determine the removals associated with a 70% probability of overfishing not occurring ($P^* = 0.3$).

3.4. LITERATURE CITED

- Brooks, E.N., J.E. Powers, and E. Cortés. 2010. Analytic reference points for age-structured models: application to data-poor fisheries. *ICES J. Mar. Sci.* 67:165-175.
- Caswell, H. 2001. Matrix population models. 2nd ed. Sinauer, Sunderland, MA.
- Chen, S.B. and Watanabe, S. 1989. Age dependence of natural mortality coefficient in fish population dynamics. *Nippon Suisan Gak*. 55:205-208.
- Conn, P.B. 2010. Hierarchical analysis of multiple noisy abundance indices. *Can. J. Fish. Aquat. Sci.* 67:108-120.
- Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. *Fish. Bull.* 81:898–903.

- ICCAT (International Commission for the Conservation of Atlantic Tunas). 2005. Report of the 2004 Inter-sessional meeting of the ICCAT Subcommittee on by-catches: shark stock assessment. Col. Vol. Sci. Pap. ICCAT 58:799-890.
- Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. J. Fish Biol. 49:627-647.
- McAllister, M.K. and E.A. Babcock. 2004. Bayesian surplus production model with the Sampling Importance Resampling algorithm (BSP): a user's guide. May 2004. Available from ICCAT: www.iccat.es.
- Myers, R.A., K.G. Bowen, and N.J. Barrowman. 1999. Maximum reproductive rate of fish at low population sizes. Can. J. Fish. Aquat. Sci. 56:2404-2419.
- NMFS. 2011. SEDAR 21 Stock Assessment Report; HMS Dusky Shark. DOC/NOAA/NMFS SEDAR, 4055 Faber Place Drive, Suite 201, North Charleston, SC 29405. Available: http://www.sefsc.noaa.gov/sedar/download/Dusky_SAR.pdf?id=DOCUMENT (last accessed October 2011).
- NMFS. 2012a. SEDAR 29 Stock Assessment Report: HMS Gulf of Mexico Blacktip Shark. DOC/NOAA/NMFS SEDAR, 4055 Faber Place Drive, Suite 201, North Charleston, SC 29405. Available: http://www.sefsc.noaa.gov/sedar/download/S29_GOM%20blacktip%20report_SAR_final.pdf?id=DOCUMENT (last accessed September 2012).
- NMFS. 2012b. SEDAR 29 HMS GOM Blacktip Shark Post-Review Updates and Projections, SEDAR, 4055 Faber Place Drive, Suite 201, North Charleston, SC 29405. Available: http://www.sefsc.noaa.gov/sedar/download/S29_Post%20review%20updates%20and%20projections%20GOM%20blacktip.pdf?id=DOCUMENT
- Otter Research Ltd. 2001. An introduction to AD MODEL BUILDER Version 6.0.2. Box 2040, Sidney, B. C. V8L 3S3, Canada.
- Peterson, I. and Wroblewski, J.S. 1984. Mortality rates of fishes in the pelagic ecosystem. Can. J. Fish. Aquat. Sci. 41:1117-1120.
- Porch, C. E. 2002. A preliminary assessment of Atlantic white marlin (*Tetrapturus albidus*) using a state-space implementation of an age-structured model. SCRS/02/68 23pp.
- Prager, M. H., Porch, C. E., Shertzer, K. W., and J. F. Caddy. 2003. Targets and limits for management of fisheries: A simple probability-based approach. North American Journal of Fisheries Management 23:349-361.
- Prager, M. H., and K. W. Shertzer. 2010. Deriving acceptable biological catch from the overfishing limit: Implications for assessment models. North American Journal of Fisheries Management 30:289-294.
- R Development Core Team. 2009. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available: R-project.org (September 2010).

SEDAR 13. 2007. Small coastal shark complex, Atlantic sharpnose, blacknose, bonnethead, and finetooth shark. Stock assessment report. NOAA/NMFS HMS Management Division. 1315 East-West Highway, Silver Spring, MD 20910.

SEDAR 21-AW-01. Hierarchical analysis of blacknose, sandbar, and dusky shark CPUE indices.

SEDAR 29-WP-20. Updated catches of Atlantic sharpnose and bonnethead sharks.

Standing Committee on Research and Statistics (SCRS) BFT Stock Assess. Meeting Report. 2012. Report of the 2012 Atlantic bluefin tuna stock assessment session. Madrid, Spain – September 4 to 11, 2012, The International Commission for the Conservation of Atlantic Tunas (ICCAT) Doc. No. SCI-033 / 2012. Available: http://www.iccat.int/Documents/Meetings/Docs/2012_BFT_ASSESS.pdf (July 2013).

3.5. TABLES

Table 3.5.1A. Catches of Atlantic sharpnose shark by fleet in numbers. Catches are separated into five fisheries: commercial longlines, gillnets, and lines, recreational catches, and shrimp trawl fishery discards.

| Year | Com-BLL | Com-GN | Com-L | Recreational | Shrimp discards |
|------|---------|--------|-------|--------------|-----------------|
| 1950 | 0 | 0 | 0 | 12114 | 199157 |
| 1951 | 0 | 0 | 0 | 13314 | 255841 |
| 1952 | 0 | 0 | 1 | 14514 | 258937 |
| 1953 | 0 | 0 | 1 | 15714 | 297766 |
| 1954 | 0 | 0 | 2 | 16914 | 307492 |
| 1955 | 0 | 0 | 2 | 18114 | 278697 |
| 1956 | 0 | 0 | 2 | 19314 | 253339 |
| 1957 | 0 | 0 | 3 | 20514 | 227780 |
| 1958 | 0 | 0 | 3 | 21714 | 226216 |
| 1959 | 0 | 0 | 4 | 22914 | 253769 |
| 1960 | 0 | 0 | 4 | 24114 | 271849 |
| 1961 | 0 | 0 | 4 | 24815 | 136426 |
| 1962 | 0 | 0 | 5 | 25517 | 178861 |
| 1963 | 0 | 0 | 5 | 26218 | 269133 |
| 1964 | 0 | 0 | 6 | 26920 | 240757 |
| 1965 | 0 | 0 | 6 | 27621 | 258877 |
| 1966 | 0 | 0 | 6 | 28322 | 244276 |
| 1967 | 0 | 0 | 7 | 29024 | 299894 |
| 1968 | 0 | 0 | 7 | 29725 | 273578 |
| 1969 | 0 | 0 | 8 | 30427 | 286401 |
| 1970 | 0 | 0 | 8 | 31128 | 315416 |
| 1971 | 0 | 0 | 8 | 34310 | 323214 |
| 1972 | 0 | 0 | 9 | 34613 | 1403939 |
| 1973 | 0 | 0 | 9 | 34916 | 1224615 |
| 1974 | 0 | 0 | 9 | 35220 | 1488981 |
| 1975 | 0 | 0 | 10 | 35523 | 1007433 |
| 1976 | 0 | 0 | 10 | 35827 | 1928857 |
| 1977 | 0 | 0 | 11 | 36130 | 2104965 |
| 1978 | 0 | 0 | 11 | 36434 | 2746465 |
| 1979 | 0 | 0 | 11 | 36737 | 3896932 |
| 1980 | 20140 | 0 | 12 | 41970 | 2261144 |
| 1981 | 20165 | 0 | 12 | 44075 | 2754240 |
| 1982 | 20202 | 0 | 13 | 34837 | 2591957 |
| 1983 | 20258 | 0 | 13 | 39881 | 2557525 |
| 1984 | 20340 | 0 | 13 | 36695 | 2530402 |
| 1985 | 20463 | 0 | 14 | 22568 | 2905822 |
| 1986 | 20646 | 0 | 14 | 35633 | 3402573 |
| 1987 | 20920 | 663 | 15 | 36221 | 4632197 |
| 1988 | 21328 | 1326 | 15 | 82228 | 3206838 |
| 1989 | 21937 | 1989 | 15 | 55866 | 4076237 |
| 1990 | 22845 | 2652 | 16 | 52842 | 3920057 |
| 1991 | 24200 | 3315 | 16 | 122400 | 4275462 |
| 1992 | 26222 | 3978 | 17 | 85537 | 3217356 |
| 1993 | 17791 | 4641 | 17 | 82573 | 2995442 |
| 1994 | 28788 | 5305 | 17 | 111969 | 3613709 |
| 1995 | 53212 | 6310 | 19 | 158522 | 3245293 |
| 1996 | 93206 | 3090 | 15 | 88897 | 3345772 |
| 1997 | 27196 | 65059 | 956 | 76944 | 3404777 |
| 1998 | 22017 | 57737 | 2128 | 79455 | 3976312 |
| 1999 | 21338 | 60540 | 4342 | 80092 | 4158720 |
| 2000 | 18316 | 35222 | 1220 | 148343 | 3809182 |
| 2001 | 18376 | 49853 | 1301 | 170093 | 3197969 |
| 2002 | 25728 | 45161 | 953 | 109597 | 2969866 |
| 2003 | 48485 | 21016 | 2791 | 113442 | 2873080 |
| 2004 | 40079 | 36114 | 731 | 100899 | 2329118 |
| 2005 | 42424 | 70151 | 1225 | 110328 | 1525548 |
| 2006 | 49001 | 93272 | 2243 | 139702 | 1764730 |
| 2007 | 20638 | 122039 | 3309 | 143935 | 1570637 |
| 2008 | 15514 | 58008 | 1395 | 102155 | 1287044 |
| 2009 | 36266 | 59639 | 1342 | 96923 | 1715665 |
| 2010 | 22426 | 39657 | 5205 | 156814 | 1220501 |
| 2011 | 28198 | 54744 | 6742 | 60314 | 1197353 |

Table 3.5.1B. Catches of Atlantic sharpnose shark by fleet in weight (lb dw). Catches are separated into five fisheries: commercial longlines, gillnets, and lines, recreational catches, and shrimp trawl fishery discards.

| Year | Com-BLL | Com-GN | Com-L | Recreational | Shrimp discards |
|------|---------|--------|-------|--------------|-----------------|
| 1950 | 0 | 0 | 0 | 40617 | 201149 |
| 1951 | 0 | 0 | 1 | 44641 | 258400 |
| 1952 | 0 | 0 | 3 | 48665 | 261526 |
| 1953 | 0 | 0 | 4 | 52688 | 300744 |
| 1954 | 0 | 0 | 5 | 56712 | 310567 |
| 1955 | 0 | 0 | 6 | 60736 | 281484 |
| 1956 | 0 | 0 | 8 | 64760 | 255873 |
| 1957 | 0 | 0 | 9 | 68783 | 230058 |
| 1958 | 0 | 0 | 10 | 72807 | 228478 |
| 1959 | 0 | 0 | 11 | 76831 | 256307 |
| 1960 | 0 | 0 | 13 | 80854 | 274568 |
| 1961 | 0 | 0 | 14 | 83206 | 137791 |
| 1962 | 0 | 0 | 15 | 85558 | 180649 |
| 1963 | 0 | 0 | 16 | 87910 | 271824 |
| 1964 | 0 | 0 | 18 | 90261 | 243164 |
| 1965 | 0 | 0 | 19 | 92613 | 261465 |
| 1966 | 0 | 0 | 20 | 94965 | 246719 |
| 1967 | 0 | 0 | 21 | 97316 | 302893 |
| 1968 | 0 | 0 | 23 | 99668 | 276313 |
| 1969 | 0 | 0 | 24 | 102020 | 289265 |
| 1970 | 0 | 0 | 25 | 104372 | 318570 |
| 1971 | 0 | 0 | 26 | 115039 | 326446 |
| 1972 | 0 | 0 | 28 | 116057 | 1417978 |
| 1973 | 0 | 0 | 29 | 117075 | 1236861 |
| 1974 | 0 | 0 | 30 | 118092 | 1503871 |
| 1975 | 0 | 0 | 31 | 119110 | 1017508 |
| 1976 | 0 | 0 | 33 | 120127 | 1948146 |
| 1977 | 0 | 0 | 34 | 121145 | 2126015 |
| 1978 | 0 | 0 | 35 | 122162 | 2773930 |
| 1979 | 0 | 0 | 36 | 123180 | 3935901 |
| 1980 | 63845 | 0 | 38 | 140724 | 2283756 |
| 1981 | 63924 | 0 | 39 | 133471 | 2781782 |
| 1982 | 64042 | 0 | 40 | 115866 | 2617877 |
| 1983 | 64219 | 0 | 41 | 123987 | 2583100 |
| 1984 | 64479 | 0 | 43 | 122372 | 2555706 |
| 1985 | 64869 | 0 | 44 | 72432 | 2934881 |
| 1986 | 65449 | 0 | 45 | 117462 | 3436599 |
| 1987 | 66318 | 2478 | 46 | 144539 | 4678519 |
| 1988 | 67611 | 4957 | 48 | 307072 | 3238906 |
| 1989 | 69542 | 7435 | 49 | 203390 | 4117000 |
| 1990 | 72420 | 9913 | 50 | 189459 | 3959258 |
| 1991 | 76716 | 12391 | 51 | 418395 | 4318216 |
| 1992 | 83126 | 14870 | 53 | 273478 | 3249530 |
| 1993 | 58690 | 17348 | 54 | 245894 | 3025397 |
| 1994 | 95671 | 19826 | 55 | 445513 | 3649846 |
| 1995 | 168521 | 23583 | 60 | 607044 | 3277746 |
| 1996 | 241730 | 11550 | 39 | 308826 | 3379230 |
| 1997 | 83600 | 243165 | 2939 | 240079 | 3438825 |
| 1998 | 69397 | 215798 | 6707 | 273983 | 4016075 |
| 1999 | 67462 | 226276 | 13726 | 273337 | 4200307 |
| 2000 | 64034 | 131645 | 4265 | 500111 | 3847274 |
| 2001 | 60179 | 186330 | 4259 | 520815 | 3229949 |
| 2002 | 84254 | 188149 | 3121 | 329336 | 2999564 |
| 2003 | 148735 | 91707 | 8561 | 383537 | 2901811 |
| 2004 | 122894 | 162413 | 2240 | 338806 | 2352409 |
| 2005 | 146555 | 284187 | 4232 | 372847 | 1540804 |
| 2006 | 159132 | 345042 | 7285 | 542175 | 1782377 |
| 2007 | 62832 | 276092 | 10074 | 406913 | 1586344 |
| 2008 | 46519 | 241472 | 4182 | 347119 | 1299915 |
| 2009 | 112081 | 183003 | 4149 | 299831 | 1732821 |
| 2010 | 71047 | 156458 | 16488 | 453647 | 1232706 |
| 2011 | 84707 | 172984 | 20254 | 191942 | 1209326 |

Table 3.5.2. Selectivity curves for catches and indices of relative abundance. Parameters are ascending inflection point (a_{50}), ascending slope (b), descending inflection point (c_{50}), descending slope (d), and maximum selectivity (max(sel)).

| Series | Name | Selectivity | a_{50} | b | c_{50} | d | max(sel) |
|-----------------------------|----------------|--------------------|----------|------|----------|-----|----------|
| CATCHES | | | | | | | |
| Commercial bottom longline | Longline age 3 | Logistic | 0.60 | 1.32 | | | |
| Commercial gillnet | Gillnet age 4 | Double exponential | 3 | 0.5 | 6 | 0.8 | 0.81 |
| Commercial line | Longline age 3 | Logistic | 0.60 | 1.32 | | | |
| Recreational | Longline age 1 | Logistic | 0.25 | 0.5 | | | |
| Shrimp trawl | Gillnet age 1 | Double exponential | 1 | 12 | 1.5 | 1 | 0.31 |
| | | | | | | | |
| INDICES OF ABUNDANCE | | | | | | | |
| PC LL | Longline age 1 | Logistic | 0.25 | 0.5 | | | |
| ATL Coastspan LL | Longline age 3 | Logistic | 0.60 | 1.32 | | | |
| GOM Comb LL | Longline age 1 | Logistic | 0.25 | 0.5 | | | |
| BLLOP | Longline age 3 | Logistic | 0.60 | 1.32 | | | |
| SEAMAP-SA | Gillnet age 3 | Double exponential | 2 | 0.1 | 5 | 0.5 | 0.98 |
| GOM Comb GN | Gillnet age 1 | Double exponential | 1 | 12 | 1.5 | 1 | 0.31 |
| VA LL | Longline age 4 | Logistic | 0.32 | 2.95 | | | |
| NMFS LL SE | Longline age 3 | Logistic | 0.60 | 1.32 | | | |
| SC Coastspan GN | Gillnet age 3 | Double exponential | 2 | 0.1 | 5 | 0.5 | 0.98 |
| SCDNR RD LL Early | Longline age 4 | Logistic | 0.32 | 2.95 | | | |
| GA-SCDNR RD LL Late | Longline age 4 | Logistic | 0.32 | 2.95 | | | |
| SEAMAP GOM ES | Gillnet age 1 | Double exponential | 1 | 12 | 1.5 | 1 | 0.31 |
| SEAMAP GOM EF | Gillnet age 1 | Double exponential | 1 | 12 | 1.5 | 1 | 0.31 |
| UNC LL | Longline age 4 | Logistic | 0.32 | 2.95 | | | |
| GADNR Trawl | Gillnet age 3 | Double exponential | 2 | 0.1 | 5 | 0.5 | 0.98 |
| Hierarchical index | | Logistic | 0.65 | 0.65 | | | |
| Hierarchical index | | Double exponential | 1.3 | 1 | -10 | 6 | 0.09 |

Table 3.5.3. Standardized indices of relative abundance used in the baseline scenario.

| YEAR | PC-LL | ATL Coastspan LL | GOM Comb BLL | BLLOP | SEAMAP-SA | GOM Comb GN | VA-LL | NMFS-LL-SE | SC-GN | SCDNR-LL-RD Early | GA-SCDNR-LL-RD Late | SEAMAP GOM ES | SEAMAP GOM EF | UNC-LL | GADNR Trawl |
|------|-------|------------------|--------------|---------|-----------|-------------|-------|------------|-------|-------------------|---------------------|---------------|---------------|--------|-------------|
| 1972 | | | | | | | | | | | | | | 0.203 | |
| 1973 | | | | | | | | | | | | | | 0.232 | 0.010 |
| 1974 | | | | | | | | | | | | | | 1.019 | 0.004 |
| 1975 | | | | | | | 0.26 | | | | | | | 0.726 | 0.009 |
| 1976 | | | | | | | 0.24 | | | | | | | 0.677 | 0.004 |
| 1977 | | | | | | | | | | | | | | 0.302 | 0.007 |
| 1978 | | | | | | | | | | | | | | 0.373 | 0.016 |
| 1979 | | | | | | | | | | | | | | 0.383 | 0.012 |
| 1980 | | | | | | | 0.39 | | | | | | | 0.686 | 0.010 |
| 1981 | | | | | | | 0.47 | | | | | | | 0.565 | 0.007 |
| 1982 | | | | | | | | | | | | 0.019 | 0.479 | 0.004 | |
| 1983 | | | | | | | 0.40 | | | | | 0.452 | 0.330 | 0.016 | |
| 1984 | | | | | | | | | | | | 0.030 | 0.273 | 0.010 | |
| 1985 | | | | | | | | | | | | 0.100 | 0.284 | 0.012 | |
| 1986 | | | | | | | | | | | | 0.063 | 0.304 | 0.014 | |
| 1987 | | | | | | | | | | | | 0.293 | 0.559 | 0.018 | |
| 1988 | | | | | | | | | | | | 0.274 | 0.174 | 0.033 | |
| 1989 | | | | | 3.114 | | | | | | | 0.199 | 0.168 | 0.012 | |
| 1990 | | | | | 2.784 | | 0.35 | | | | | 0.067 | 0.181 | 0.017 | |
| 1991 | | | | | 2.968 | | 0.32 | | | | | 0.218 | 0.122 | 0.027 | |
| 1992 | | | | | 2.711 | | 0.42 | | | | | 0.199 | 0.072 | 0.054 | |
| 1993 | 0.481 | | | | 2.080 | | 0.27 | | | | | 0.242 | 0.164 | 0.031 | |
| 1994 | 0.136 | | | 14.450 | 1.468 | | | | | | | 0.098 | 0.233 | 0.027 | |
| 1995 | 0.301 | | | 92.725 | 2.935 | 0.848 | 0.53 | 1.027 | | | | 0.431 | 0.128 | 0.049 | |
| 1996 | 0.951 | | | 80.747 | 1.693 | 0.816 | 0.32 | 1.373 | | | | 0.366 | 0.315 | 0.022 | |
| 1997 | 0.531 | | | 181.956 | 3.695 | 1.399 | 0.22 | 1.231 | | | | 0.188 | 0.154 | 0.031 | |
| 1998 | 0.380 | | | 245.977 | 2.530 | 0.968 | 0.52 | | 2.366 | 0.079 | | 0.144 | 0.139 | 0.037 | |
| 1999 | 1.160 | | | 383.974 | 2.591 | 1.469 | 0.60 | 1.071 | | 0.046 | | 0.201 | 0.273 | 0.033 | |
| 2000 | 0.445 | 30.037 | | 445.425 | 3.660 | 1.962 | 0.15 | 2.490 | 0.020 | 0.105 | | 0.217 | 0.209 | 0.044 | |
| 2001 | | 158.545 | | 215.125 | 3.227 | 1.595 | 0.28 | 3.637 | 0.303 | 0.141 | | 0.097 | 0.092 | | |
| 2002 | | 33.902 | | 184.152 | 5.152 | 1.772 | 0.14 | 4.626 | 1.285 | 0.135 | | 0.253 | 0.109 | 0.042 | |
| 2003 | | 46.325 | | 130.171 | 5.296 | 1.529 | 0.11 | 5.198 | 3.990 | 0.084 | | 0.152 | 0.149 | 0.087 | 3.169 |
| 2004 | | 38.637 | 3.989 | 126.152 | 3.684 | 1.509 | 0.14 | 8.477 | | 0.030 | | 0.098 | 0.139 | 0.068 | 2.277 |
| 2005 | | 48.276 | 4.000 | 149.740 | 4.587 | 1.272 | 0.38 | 9.053 | 0.612 | 0.036 | | 0.124 | 0.187 | 0.106 | 0.892 |
| 2006 | | 63.643 | 3.085 | 78.149 | 6.410 | 2.007 | 0.37 | 9.013 | 1.242 | 0.078 | | 0.212 | 0.149 | 0.059 | 1.554 |
| 2007 | | 28.724 | 3.040 | 184.021 | 6.420 | 1.763 | 0.70 | 3.779 | 1.193 | | 0.051 | 0.170 | 0.140 | 0.065 | 1.740 |
| 2008 | | 71.656 | 3.574 | 317.227 | 4.451 | 1.979 | 0.40 | 4.891 | 2.612 | | 0.044 | 0.295 | 0.160 | 0.067 | 0.832 |
| 2009 | | 82.680 | 3.274 | 209.265 | 5.618 | 2.483 | 0.82 | 11.351 | 1.127 | | 0.055 | 0.245 | 0.219 | 0.040 | 2.692 |
| 2010 | | 119.011 | 3.661 | 224.738 | 4.674 | 2.785 | 0.41 | 7.742 | 2.602 | | 0.035 | 0.172 | 0.132 | 0.066 | 1.521 |
| 2011 | | 89.741 | 3.091 | 133.191 | 4.110 | 2.577 | 0.51 | 4.877 | 1.430 | | 0.046 | 0.110 | 0.131 | 0.035 | 1.865 |

Table 3.5.4. Coefficients of variation (CVs) of the relative abundance indices used in inverse weighting scenarios.

| YEAR | PC-LL | ATL Coasts pan LL | GOM Comb BLL | BLLOP | SEAMAP-SA | GOM Comb GN | VA-LL | NMFS-LL-SE | SC-GN | SCDNR-LL-RD Early | GA-SCDNR-LL-RD Late | SEAMAP GOM ES | SEAMAP GOM EF | UNC-LL | GADNR Trawl |
|------|-------|--------------------------------|--------------|-------|-----------|-------------|-------|------------|-------|-------------------|---------------------|---------------|---------------|--------|-------------|
| 1972 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.482 | 1 | 1 |
| 1973 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.289 | 0.769 | 1 |
| 1974 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.238 | 1.166 | 1 |
| 1975 | 1 | 1 | 1 | 1 | 1 | 1 | 2.77 | 1 | 1 | 1 | 1 | 1 | 0.252 | 0.652 | 1 |
| 1976 | 1 | 1 | 1 | 1 | 1 | 1 | 1.00 | 1 | 1 | 1 | 1 | 1 | 0.215 | 0.830 | 1 |
| 1977 | 1 | 1 | 1 | 1 | 1 | 1 | 2.15 | 1 | 1 | 1 | 1 | 1 | 0.260 | 0.669 | 1 |
| 1978 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.290 | 0.470 | 1 |
| 1979 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.274 | 0.461 | 1 |
| 1980 | 1 | 1 | 1 | 1 | 1 | 1 | 0.83 | 1 | 1 | 1 | 1 | 1 | 0.262 | 0.427 | 1 |
| 1981 | 1 | 1 | 1 | 1 | 1 | 1 | 0.38 | 1 | 1 | 1 | 1 | 1 | 0.259 | 0.504 | 1 |
| 1982 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.751 | 0.271 | 0.502 |
| 1983 | 1 | 1 | 1 | 1 | 1 | 1 | 1.35 | 1 | 1 | 1 | 1 | 1 | 0.367 | 0.303 | 0.357 |
| 1984 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.030 | 0.332 | 0.362 |
| 1985 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.543 | 0.331 | 0.394 |
| 1986 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.753 | 0.316 | 0.600 |
| 1987 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.311 | 0.423 | 0.411 |
| 1988 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.301 | 0.324 | 0.347 |
| 1989 | 1 | 1 | 1 | 1 | 0.334 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.338 | 0.419 | 0.501 |
| 1990 | 1 | 1 | 1 | 1 | 0.328 | 1 | 0.76 | 1 | 1 | 1 | 1 | 1 | 0.392 | 0.341 | 0.355 |
| 1991 | 1 | 1 | 1 | 1 | 0.306 | 1 | 0.91 | 1 | 1 | 1 | 1 | 1 | 0.304 | 0.356 | 0.358 |
| 1992 | 1 | 1 | 1 | 1 | 0.319 | 1 | 0.56 | 1 | 1 | 1 | 1 | 1 | 0.268 | 0.284 | 0.319 |
| 1993 | 0.516 | 1 | 1 | 1 | 0.349 | 1 | 0.73 | 1 | 1 | 1 | 1 | 1 | 0.324 | 0.338 | 0.588 |
| 1994 | 0.882 | 1 | 1 | 0.567 | 0.389 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.418 | 0.344 | 0.406 |
| 1995 | 0.520 | 1 | 1 | 0.468 | 0.275 | 0.670 | 0.48 | 0.330 | 1 | 1 | 1 | 1 | 0.238 | 0.328 | 0.389 |
| 1996 | 0.098 | 1 | 1 | 0.466 | 0.374 | 0.420 | 0.54 | 0.372 | 1 | 1 | 1 | 1 | 0.243 | 0.327 | 0.303 |
| 1997 | 0.196 | 1 | 1 | 0.473 | 0.286 | 0.350 | 0.71 | 0.274 | 1 | 1 | 1 | 1 | 0.302 | 0.384 | 0.356 |
| 1998 | 0.413 | 1 | 1 | 0.448 | 0.318 | 0.530 | 0.40 | 1.000 | 0.795 | 0.210 | 1 | 0.276 | 0.452 | 0.261 | 1 |
| 1999 | 0.111 | 1 | 1 | 0.449 | 0.313 | 0.400 | 0.46 | 0.292 | 1 | 0.224 | 1 | 0.291 | 0.435 | 0.304 | 1 |
| 2000 | 0.337 | 0.340 | 1 | 0.467 | 0.291 | 0.350 | 0.70 | 0.231 | 1.697 | 0.201 | 1 | 0.234 | 0.319 | 0.273 | 1 |
| 2001 | 1 | 0.335 | 1 | 0.461 | 0.246 | 0.350 | 0.56 | 0.218 | 0.730 | 0.177 | 1 | 0.490 | 0.364 | 1.000 | 1 |
| 2002 | 1 | 0.571 | 1 | 0.454 | 0.223 | 0.340 | 0.74 | 0.145 | 0.492 | 0.241 | 1 | 0.238 | 0.351 | 0.295 | 1 |
| 2003 | 1 | 0.269 | 1 | 0.451 | 0.252 | 0.360 | 1.17 | 0.166 | 0.296 | 0.189 | 1 | 0.338 | 0.305 | 0.283 | 0.162 |
| 2004 | 1 | 0.266 | 0.211 | 0.461 | 0.256 | 0.370 | 0.76 | 0.151 | 1 | 0.369 | 1 | 0.372 | 0.402 | 0.304 | 0.233 |
| 2005 | 1 | 0.274 | 0.203 | 0.458 | 0.289 | 0.460 | 0.77 | 0.247 | 0.608 | 0.407 | 1 | 0.372 | 0.418 | 0.237 | 0.350 |
| 2006 | 1 | 0.191 | 0.140 | 0.460 | 0.240 | 0.380 | 0.37 | 0.162 | 0.525 | 0.256 | 1 | 0.292 | 0.389 | 0.197 | 0.144 |
| 2007 | 1 | 0.278 | 0.118 | 0.581 | 0.202 | 0.330 | 0.35 | 0.270 | 0.438 | 1 | 0.107 | 1 | 0.301 | 0.363 | 0.262 |
| 2008 | 1 | 0.190 | 0.131 | 0.502 | 0.226 | 0.330 | 0.35 | 0.200 | 0.372 | 1 | 0.108 | 0.243 | 0.282 | 0.298 | 0.195 |
| 2009 | 1 | 0.175 | 0.147 | 0.476 | 0.206 | 0.310 | 0.44 | 0.137 | 0.708 | 1 | 0.117 | 0.222 | 0.305 | 0.350 | 0.134 |
| 2010 | 1 | 0.133 | 0.122 | 0.439 | 0.233 | 0.300 | 0.55 | 0.172 | 0.462 | 1 | 0.125 | 0.270 | 0.306 | 0.324 | 0.151 |
| 2011 | 1 | 0.143 | 0.146 | 0.448 | 0.226 | 0.320 | 0.50 | 0.128 | 0.422 | 1 | 0.121 | 0.308 | 0.350 | 0.237 | 0.137 |

Table 3.5.5. Life history inputs used in the assessment. All these quantities are treated as constants in the model. Von Bertalanffy growth function parameters are for females.

| Age | Proportion | | Fecundity (female pups) |
|-----|------------|-------|-------------------------------|
| | mature | M | |
| 1 | 0.185 | 0.232 | 0.501 |
| 2 | 0.953 | 0.232 | 0.978 |
| 3 | 0.999 | 0.232 | 1.407 |
| 4 | 1.000 | 0.232 | 1.714 |
| 5 | 1.000 | 0.232 | 1.908 |
| 6 | 1.000 | 0.232 | 2.022 |
| 7 | 1.000 | 0.232 | 2.087 |
| 8 | 1.000 | 0.232 | 2.124 |
| 9 | 1.000 | 0.232 | 2.144 |
| 10 | 1.000 | 0.232 | 2.154 |
| 11 | 1.000 | 0.232 | 2.160 |
| 12 | 1.000 | 0.232 | 2.164 |
| 13 | 1.000 | 0.232 | 2.165 |
| 14 | 1.000 | 0.232 | 2.166 |
| 15 | 1.000 | 0.232 | 2.167 |
| 16 | 1.000 | 0.232 | 2.167 |
| 17 | 1.000 | 0.232 | 2.167 |
| 18 | 1.000 | 0.232 | 2.167 |

| | |
|------------------------------|--------------------------------|
| Sex ratio: | 1:1 |
| Reproductive frequency: | 1 yr |
| Pupping month: | June |
| Age vs litter size relation: | pups =exp(-3.03167+0.05609*FL) |
| L _{inf} | 80.2 (cm FL) |
| k | 0.610 |
| t ₀ | -0.84 |
| Weight vs length relation: | W=0.00000556L ^{3.074} |

Table 3.5.6. List of parameters estimated in SSASPM for Atlantic sharpnose shark (baseline run). The list includes predicted parameter values with associated SDs, initial parameter values, minimum and maximum allowed values, and prior density functions assigned to parameters. Parameters that were held fixed (not estimated) are not included in this table.

| Parameter/Input name | Predicted | | | | | Prior pdf | | | |
|---|-----------|----------|-----------------------|-----------|-----------|-----------|-------|---------|-----------|
| | Value | SD | Initial | Min | Max | Type | Value | SD (CV) | Status |
| Virgin recruitment | 9.37E+06 | 1.49E+06 | 6.15E+07 | 1.00E+03 | 1.00E+10 | uniform | - | - | estimated |
| Pup (age-0) survival | 8.91E-01 | 2.38E-01 | 7.60E-01 | 2.00E-01 | 9.90E-01 | lognormal | 0.76 | (0.3) | estimated |
| Catchability coefficient PC LL index | 3.72E-08 | 2.28E-08 | 5.70E-06 | 1.10E-08 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient ATL Coastspan LL index | 3.99E-06 | 2.10E-06 | 3.44E-07 | 1.10E-08 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient GOM Comb LL index | 1.63E-07 | 8.80E-08 | 5.70E-07 | 1.10E-08 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient BLLOP index | 1.10E-05 | 3.15E-07 | 3.44E-02 | 1.10E-05 | 1.00E-02 | constant | - | - | estimated |
| Catchability coefficient SEAMAP-SA index | 5.54E-07 | 2.52E-07 | 5.70E-05 | 1.10E-08 | 1.00E-04 | constant | - | - | estimated |
| Catchability coefficient GOM Comb GN index | 1.88E-07 | 9.60E-08 | 3.44E-06 | 1.10E-08 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient VA LL index | 4.07E-08 | 2.02E-08 | 5.70E-07 | 1.10E-09 | 1.00E-06 | constant | - | - | estimated |
| Catchability coefficient NMFSLLSE index | 3.05E-07 | 1.44E-07 | 3.44E-06 | 1.10E-08 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient SC Coastscape GN index | 1.61E-07 | 1.05E-07 | 5.70E-05 | 1.10E-08 | 1.00E-04 | constant | - | - | estimated |
| Catchability coefficient SCDNR LL RD E index | 1.24E-08 | 4.04E-09 | 3.44E-06 | 1.10E-08 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient SCDNR LL RD L index | 4.64E-09 | 2.84E-09 | 5.70E-08 | 1.10E-10 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient SEAMAP GOM ES index | 1.97E-08 | 7.74E-09 | 3.44E-06 | 1.10E-08 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient SEAMAP GOM EF index | 2.81E-08 | 1.01E-08 | 5.70E-06 | 1.10E-08 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient UNC LL index | 2.27E-09 | 9.13E-10 | 3.44E-05 | 1.10E-11 | 1.00E-05 | constant | - | - | estimated |
| Catchability coefficient GADNR Trawl index | 2.32E-07 | 1.28E-07 | 5.70E-07 | 1.10E-08 | 1.00E-05 | constant | - | - | estimated |
| Historic effort Recreational fleet | 0.0003 | 3.41E-04 | 6.00E-03 | 0.00E+00 | 2.00E-01 | constant | - | - | estimated |
| Historic effort Shrimp trawl fleet | 0.0182 | 7.81E-03 | 6.00E-02 | 0.00E+00 | 1.00E-01 | constant | - | - | estimated |
| Modern effort Commercial BLL fleet | 0.000011 | 1.02E-05 | 5.00E-02 | 0.00E+00 | 4.00E-01 | constant | - | - | estimated |
| Modern effort Commercial GN fleet | 0.000022 | 1.31E-04 | 1.20E-01 | 0.00E+00 | 4.00E-01 | constant | - | - | estimated |
| Modern effort Commercial L fleet | 0.000004 | 2.56E-05 | 8.00E-02 | 0.00E+00 | 4.00E-01 | constant | - | - | estimated |
| Modern effort Recreational fleet | 0.002688 | 1.59E-02 | 1.00E-02 | 0.00E+00 | 4.00E-01 | constant | - | - | estimated |
| Modern effort Shrimp trawl fleet | 0.219680 | 1.30E+00 | 8.50E-02 -5.00E-01 | 0.00E+00 | 4.00E-01 | constant | - | - | estimated |
| Overall variance | -5.0000 | 7.99E-05 | 01 | -5.00E+00 | -4.00E-02 | constant | - | - | estimated |
| Effort deviation for Com BLL fleet in 1972 | -8.000 | 1.29E-02 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1973 | -8.000 | 1.48E-02 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1974 | -8.000 | 1.94E-02 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1975 | -8.000 | 2.81E-02 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1976 | -8.0000 | 4.78E-02 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1977 | -7.9931 | 2.33E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1978 | -7.9547 | 2.34E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1979 | -7.8727 | 2.34E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1980 | 4.35E+00 | 1.17E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1981 | 4.38E+00 | 1.17E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1982 | 4.41E+00 | 1.17E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1983 | 4.43E+00 | 1.17E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1984 | 4.46E+00 | 1.17E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1985 | 4.48E+00 | 1.17E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1986 | 4.52E+00 | 1.17E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1987 | 4.58E+00 | 1.17E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Com BLL fleet in 1988 | 4.66E+00 | 1.17E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |

| | | | | | | | | | |
|---|-----------|----------|----------|-----------|----------|-----------|---|---|-----------|
| Effort deviation for Shrimp trawl fleet in 1979 | 4.58E-01 | 5.95E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1980 | -1.21E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1981 | 8.57E-02 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1982 | 4.39E-02 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1983 | 8.70E-03 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1984 | 2.21E-02 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1985 | 1.49E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1986 | 3.13E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1987 | 6.32E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1988 | 3.51E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1989 | 6.26E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1990 | 6.35E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1991 | 7.53E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1992 | 4.96E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1993 | 3.61E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1994 | 5.14E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1995 | 3.54E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1996 | 3.32E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1997 | 3.80E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1998 | 5.31E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 1999 | 5.43E-01 | 5.93E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2000 | 4.38E-01 | 5.93E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2001 | 2.71E-01 | 5.93E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2002 | 1.88E-01 | 5.93E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2003 | 2.11E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2004 | 3.76E-02 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2005 | -4.07E-01 | 5.94E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2006 | -4.72E-01 | 6.11E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2007 | -5.08E-01 | 6.13E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2008 | -7.39E-01 | 6.14E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2009 | -4.11E-01 | 6.14E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2010 | -5.50E-01 | 6.21E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |
| Effort deviation for Shrimp trawl fleet in 2011 | -6.14E-01 | 6.21E+00 | 0.00E+00 | -8.00E+00 | 8.00E+00 | lognormal | 0 | 1 | estimated |

Table 3.5.7. Low catch scenario of Atlantic sharpnose shark. Catches are by fleet in numbers. The lower catch (with respect to the base run) of the shrimp trawl fleet is italicized.

| Year | Com-BLL | Com-GN | Com-L | Recreational | Shrimp discards |
|------|---------|--------|-------|--------------|-----------------|
| 1950 | 0 | 0 | 0 | 12114 | 199157 |
| 1951 | 0 | 0 | 0 | 13314 | 255841 |
| 1952 | 0 | 0 | 1 | 14514 | 258937 |
| 1953 | 0 | 0 | 1 | 15714 | 297766 |
| 1954 | 0 | 0 | 2 | 16914 | 307492 |
| 1955 | 0 | 0 | 2 | 18114 | 278697 |
| 1956 | 0 | 0 | 2 | 19314 | 253339 |
| 1957 | 0 | 0 | 3 | 20514 | 227780 |
| 1958 | 0 | 0 | 3 | 21714 | 226216 |
| 1959 | 0 | 0 | 4 | 22914 | 253769 |
| 1960 | 0 | 0 | 4 | 24114 | 271849 |
| 1961 | 0 | 0 | 4 | 24815 | 136426 |
| 1962 | 0 | 0 | 5 | 25517 | 178861 |
| 1963 | 0 | 0 | 5 | 26218 | 269133 |
| 1964 | 0 | 0 | 6 | 26920 | 240757 |
| 1965 | 0 | 0 | 6 | 27621 | 258877 |
| 1966 | 0 | 0 | 6 | 28322 | 244276 |
| 1967 | 0 | 0 | 7 | 29024 | 299894 |
| 1968 | 0 | 0 | 7 | 29725 | 273578 |
| 1969 | 0 | 0 | 8 | 30427 | 286401 |
| 1970 | 0 | 0 | 8 | 31128 | 315416 |
| 1971 | 0 | 0 | 8 | 34310 | 323214 |
| 1972 | 0 | 0 | 9 | 34613 | 248412 |
| 1973 | 0 | 0 | 9 | 34916 | 232375 |
| 1974 | 0 | 0 | 9 | 35220 | 231780 |
| 1975 | 0 | 0 | 10 | 35523 | 204673 |
| 1976 | 0 | 0 | 10 | 35827 | 255212 |
| 1977 | 0 | 0 | 11 | 36130 | 300940 |
| 1978 | 0 | 0 | 11 | 36434 | 386403 |
| 1979 | 0 | 0 | 11 | 36737 | 424138 |
| 1980 | 20140 | 0 | 12 | 41970 | 296944 |
| 1981 | 20165 | 0 | 12 | 44075 | 369123 |
| 1982 | 20202 | 0 | 13 | 34837 | 365814 |
| 1983 | 20258 | 0 | 13 | 39881 | 356218 |
| 1984 | 20340 | 0 | 13 | 36695 | 393015 |
| 1985 | 20463 | 0 | 14 | 22568 | 402630 |
| 1986 | 20646 | 0 | 14 | 35633 | 463017 |
| 1987 | 20920 | 663 | 15 | 36221 | 512510 |
| 1988 | 21328 | 1326 | 15 | 82228 | 438481 |
| 1989 | 21937 | 1989 | 15 | 55866 | 476379 |
| 1990 | 22845 | 2652 | 16 | 52842 | 467572 |
| 1991 | 24200 | 3315 | 16 | 122400 | 522328 |
| 1992 | 26222 | 3978 | 17 | 85537 | 488990 |
| 1993 | 17791 | 4641 | 17 | 82573 | 461011 |
| 1994 | 28788 | 5305 | 17 | 111969 | 441389 |
| 1995 | 53212 | 6310 | 19 | 158522 | 424952 |
| 1996 | 93206 | 3090 | 15 | 88897 | 474544 |
| 1997 | 27196 | 65059 | 956 | 76944 | 519166 |
| 1998 | 22017 | 57737 | 2128 | 79455 | 520531 |
| 1999 | 21338 | 60540 | 4342 | 80092 | 503726 |
| 2000 | 18316 | 35222 | 1220 | 148343 | 485999 |
| 2001 | 18376 | 49853 | 1301 | 170093 | 499579 |
| 2002 | 25728 | 45161 | 953 | 109597 | 527645 |
| 2003 | 48485 | 21016 | 2791 | 113442 | 430302 |
| 2004 | 40079 | 36114 | 731 | 100899 | 366313 |
| 2005 | 42424 | 70151 | 1225 | 110328 | 243689 |
| 2006 | 49001 | 93272 | 2243 | 139702 | 230965 |
| 2007 | 20638 | 122039 | 3309 | 143935 | 194585 |
| 2008 | 15514 | 58008 | 1395 | 102155 | 151113 |
| 2009 | 36266 | 59639 | 1342 | 96923 | 204914 |
| 2010 | 22426 | 39657 | 5205 | 156814 | 148771 |
| 2011 | 28198 | 54744 | 6742 | 60314 | 167625 |

Table 3.5.8. Standardized hierarchical index of relative abundance used in “hierarchical index” sensitivities, with associated CVs.

| YEAR | Hierarchical index | CV |
|------|-----------------------|------|
| 1972 | 1.05 | 0.84 |
| 1973 | 0.69 | 0.60 |
| 1974 | 1.05 | 0.67 |
| 1975 | 0.87 | 0.56 |
| 1976 | 0.76 | 0.64 |
| 1977 | 0.63 | 0.54 |
| 1978 | 0.86 | 0.55 |
| 1979 | 0.75 | 0.55 |
| 1980 | 0.86 | 0.47 |
| 1981 | 0.97 | 0.37 |
| 1982 | 0.32 | 0.51 |
| 1983 | 1.20 | 0.39 |
| 1984 | 0.47 | 0.47 |
| 1985 | 0.63 | 0.43 |
| 1986 | 0.63 | 0.47 |
| 1987 | 1.19 | 0.41 |
| 1988 | 1.20 | 0.38 |
| 1989 | 0.86 | 0.29 |
| 1990 | 0.71 | 0.27 |
| 1991 | 0.92 | 0.27 |
| 1992 | 0.98 | 0.27 |
| 1993 | 0.81 | 0.27 |
| 1994 | 0.48 | 0.29 |
| 1995 | 0.98 | 0.23 |
| 1996 | 0.82 | 0.23 |
| 1997 | 0.96 | 0.22 |
| 1998 | 0.97 | 0.22 |
| 1999 | 1.07 | 0.22 |
| 2000 | 1.09 | 0.21 |
| 2001 | 1.08 | 0.23 |
| 2002 | 1.32 | 0.20 |
| 2003 | 1.48 | 0.22 |
| 2004 | 1.23 | 0.21 |
| 2005 | 1.33 | 0.21 |
| 2006 | 1.40 | 0.19 |
| 2007 | 1.44 | 0.18 |
| 2008 | 1.42 | 0.19 |
| 2009 | 1.65 | 0.18 |
| 2010 | 1.55 | 0.19 |
| 2011 | 1.33 | 0.18 |

Table 3.5.9. Values of age-specific natural mortality (M) used in the high (low M) and low (high M) productivity scenarios.

| Age | Low | High |
|-----|-------|-------|
| | M | M |
| 1 | 0.209 | 0.256 |
| 2 | 0.209 | 0.256 |
| 3 | 0.209 | 0.256 |
| 4 | 0.209 | 0.256 |
| 5 | 0.209 | 0.256 |
| 6 | 0.209 | 0.256 |
| 7 | 0.209 | 0.256 |
| 8 | 0.209 | 0.256 |
| 9 | 0.209 | 0.256 |
| 10 | 0.209 | 0.256 |
| 11 | 0.209 | 0.256 |
| 12 | 0.209 | 0.256 |
| 13 | 0.209 | 0.256 |
| 14 | 0.209 | 0.256 |
| 15 | 0.209 | 0.256 |
| 16 | 0.209 | 0.256 |
| 17 | 0.209 | 0.256 |
| 18 | 0.209 | 0.256 |

Table 3.5.10. Catches for the “Atlantic stock” sensitivity run. Catches are by fleet in numbers.

| Year | Com-BLL | Com-GN | Com-L | Recreational | Shrimp discards |
|------|---------|--------|-------|--------------|-----------------|
| 1950 | 0 | 0 | 0 | 3257 | 23435 |
| 1951 | 0 | 0 | 0 | 3990 | 31603 |
| 1952 | 0 | 0 | 1 | 4723 | 29353 |
| 1953 | 0 | 0 | 1 | 5456 | 37803 |
| 1954 | 0 | 0 | 1 | 6189 | 32881 |
| 1955 | 0 | 0 | 2 | 6922 | 32746 |
| 1956 | 0 | 0 | 2 | 7656 | 29140 |
| 1957 | 0 | 0 | 2 | 8389 | 32719 |
| 1958 | 0 | 0 | 3 | 9122 | 25481 |
| 1959 | 0 | 0 | 3 | 9855 | 29703 |
| 1960 | 0 | 0 | 3 | 10588 | 35544 |
| 1961 | 0 | 0 | 4 | 10960 | 22669 |
| 1962 | 0 | 0 | 4 | 11331 | 29933 |
| 1963 | 0 | 0 | 4 | 11702 | 23155 |
| 1964 | 0 | 0 | 5 | 12073 | 25337 |
| 1965 | 0 | 0 | 5 | 12445 | 37102 |
| 1966 | 0 | 0 | 5 | 12816 | 30904 |
| 1967 | 0 | 0 | 6 | 13187 | 29785 |
| 1968 | 0 | 0 | 6 | 13559 | 34251 |
| 1969 | 0 | 0 | 7 | 13930 | 38364 |
| 1970 | 0 | 0 | 7 | 14301 | 29517 |
| 1971 | 0 | 0 | 7 | 14817 | 42122 |
| 1972 | 0 | 0 | 8 | 15332 | 166988 |
| 1973 | 0 | 0 | 8 | 15847 | 145659 |
| 1974 | 0 | 0 | 8 | 16362 | 177103 |
| 1975 | 0 | 0 | 9 | 16878 | 119827 |
| 1976 | 0 | 0 | 9 | 17393 | 229424 |
| 1977 | 0 | 0 | 9 | 17908 | 250370 |
| 1978 | 0 | 0 | 10 | 18423 | 326672 |
| 1979 | 0 | 0 | 10 | 18939 | 463512 |
| 1980 | 0 | 0 | 10 | 19454 | 268947 |
| 1981 | 0 | 0 | 11 | 0 | 327597 |
| 1982 | 0 | 0 | 11 | 30905 | 308295 |
| 1983 | 0 | 0 | 11 | 9522 | 304199 |
| 1984 | 0 | 0 | 12 | 33514 | 300973 |
| 1985 | 0 | 0 | 12 | 12416 | 345626 |
| 1986 | 0 | 0 | 12 | 821 | 404711 |
| 1987 | 0 | 2835 | 13 | 15880 | 550966 |
| 1988 | 0 | 5669 | 13 | 27038 | 381430 |
| 1989 | 0 | 8504 | 13 | 34791 | 484839 |
| 1990 | 0 | 11338 | 14 | 32503 | 466262 |
| 1991 | 0 | 14173 | 14 | 110204 | 508535 |
| 1992 | 0 | 17008 | 14 | 61558 | 382681 |
| 1993 | 3795 | 19842 | 15 | 29607 | 356286 |
| 1994 | 8113 | 22677 | 15 | 70242 | 429824 |
| 1995 | 3101 | 25512 | 15 | 66174 | 386004 |
| 1996 | 9018 | 46781 | 10 | 48729 | 397955 |
| 1997 | 11276 | 65062 | 762 | 43579 | 404973 |
| 1998 | 11319 | 57551 | 1720 | 35371 | 472953 |
| 1999 | 9381 | 60550 | 3546 | 57936 | 494649 |
| 2000 | 7593 | 35221 | 1104 | 73388 | 453075 |
| 2001 | 10042 | 49853 | 1104 | 86796 | 380375 |
| 2002 | 10867 | 44538 | 705 | 54163 | 353244 |
| 2003 | 17505 | 11145 | 776 | 59340 | 341732 |
| 2004 | 14414 | 34480 | 358 | 55072 | 277032 |
| 2005 | 19274 | 59410 | 999 | 86467 | 181453 |
| 2006 | 11562 | 65120 | 1805 | 112163 | 209902 |
| 2007 | 12304 | 112018 | 3784 | 101039 | 186816 |
| 2008 | 9063 | 50283 | 821 | 69755 | 153085 |
| 2009 | 34847 | 55036 | 1273 | 72792 | 204066 |
| 2010 | 19562 | 37315 | 4031 | 132742 | 145170 |
| 2011 | 26113 | 42105 | 6081 | 52172 | 142416 |

Table 3.5.11. Catches for the “Gulf of Mexico stock” sensitivity run. Catches are by fleet in numbers.

| Year | Com-BLL | Com-GN | Com-L | Recreational | Shrimp discards |
|------|---------|--------|-------|--------------|-----------------|
| 1950 | 0 | 0 | 0 | 8857 | 175722 |
| 1951 | 0 | 0 | 0 | 9324 | 224238 |
| 1952 | 0 | 0 | 0 | 9791 | 229584 |
| 1953 | 0 | 0 | 0 | 10258 | 259963 |
| 1954 | 0 | 0 | 0 | 10725 | 274611 |
| 1955 | 0 | 0 | 0 | 11191 | 245951 |
| 1956 | 0 | 0 | 0 | 11658 | 224199 |
| 1957 | 0 | 0 | 0 | 12125 | 195061 |
| 1958 | 0 | 0 | 0 | 12592 | 200735 |
| 1959 | 0 | 0 | 0 | 13059 | 224067 |
| 1960 | 0 | 0 | 0 | 13526 | 236305 |
| 1961 | 0 | 0 | 0 | 13856 | 113758 |
| 1962 | 0 | 0 | 0 | 14186 | 148927 |
| 1963 | 0 | 0 | 0 | 14516 | 245978 |
| 1964 | 0 | 0 | 0 | 14846 | 215420 |
| 1965 | 0 | 0 | 0 | 15176 | 221774 |
| 1966 | 0 | 0 | 0 | 15506 | 213372 |
| 1967 | 0 | 0 | 0 | 15836 | 270109 |
| 1968 | 0 | 0 | 0 | 16166 | 239327 |
| 1969 | 0 | 0 | 0 | 16496 | 248037 |
| 1970 | 0 | 0 | 0 | 16827 | 285899 |
| 1971 | 0 | 0 | 0 | 19493 | 281092 |
| 1972 | 0 | 0 | 0 | 19281 | 1236950 |
| 1973 | 0 | 0 | 0 | 19069 | 1078956 |
| 1974 | 0 | 0 | 0 | 18858 | 1311877 |
| 1975 | 0 | 0 | 0 | 18646 | 887606 |
| 1976 | 0 | 0 | 0 | 18434 | 1699434 |
| 1977 | 0 | 0 | 0 | 18222 | 1854595 |
| 1978 | 0 | 0 | 0 | 18010 | 2419793 |
| 1979 | 0 | 0 | 0 | 17799 | 3433420 |
| 1980 | 2 | 0 | 0 | 22516 | 1992198 |
| 1981 | 2 | 0 | 0 | 44075 | 2426643 |
| 1982 | 2 | 0 | 0 | 3932 | 2283663 |
| 1983 | 2 | 0 | 0 | 31257 | 2253326 |
| 1984 | 2 | 0 | 0 | 4544 | 2229429 |
| 1985 | 2 | 0 | 0 | 15035 | 2560196 |
| 1986 | 2 | 0 | 0 | 43443 | 2997862 |
| 1987 | 2 | 0 | 0 | 39643 | 4081231 |
| 1988 | 2 | 0 | 0 | 80964 | 2825408 |
| 1989 | 2 | 0 | 0 | 38273 | 3591398 |
| 1990 | 2 | 0 | 0 | 33483 | 3453795 |
| 1991 | 2 | 0 | 0 | 24171 | 3766927 |
| 1992 | 9 | 0 | 0 | 57558 | 2834675 |
| 1993 | 7525 | 0 | 0 | 69794 | 2639156 |
| 1994 | 13080 | 0 | 0 | 57115 | 3183885 |
| 1995 | 22928 | 0 | 0 | 112983 | 2859289 |
| 1996 | 26323 | 0 | 0 | 58208 | 2947817 |
| 1997 | 11201 | 0 | 0 | 52582 | 2999804 |
| 1998 | 11857 | 189 | 18 | 74748 | 3503358 |
| 1999 | 12041 | 0 | 12 | 48422 | 3664070 |
| 2000 | 11057 | 0 | 1 | 103171 | 3356108 |
| 2001 | 9542 | 0 | 0 | 95498 | 2817594 |
| 2002 | 18178 | 26 | 13 | 71985 | 2616622 |
| 2003 | 41975 | 2290 | 1188 | 62930 | 2531348 |
| 2004 | 25618 | 450 | 126 | 66686 | 2052087 |
| 2005 | 23019 | 10675 | 10 | 51034 | 1344095 |
| 2006 | 37015 | 28152 | 102 | 52551 | 1554828 |
| 2007 | 8249 | 10021 | 529 | 65222 | 1383821 |
| 2008 | 6438 | 7725 | 152 | 53780 | 1133960 |
| 2009 | 1624 | 4603 | 37 | 47625 | 1511599 |
| 2010 | 359 | 2342 | 17 | 44505 | 1075332 |
| 2011 | 1758 | 12639 | 128 | 28253 | 1054936 |

Table 3.5.12. Standardized indices of relative abundance for the “Atlantic stock” sensitivity run.

| YEAR | ATL Coastspan LL | BLLOP | SEAMAP-SA | VA-LL | NMFS-LL-SE | SC-GN | SCDNR-LL-RD Early | GA-SCDNR-LL-RD Late | UNC-LL | GADNR Trawl |
|------|------------------|--------|-----------|-------|------------|-------|-------------------|---------------------|--------|-------------|
| 1972 | | | | | | | | | | |
| 1973 | | | | | | | | | 0.010 | |
| 1974 | | | | | | | | | 0.004 | |
| 1975 | | | | 0.26 | | | | | 0.009 | |
| 1976 | | | | | | | | | 0.004 | |
| 1977 | | | | 0.24 | | | | | 0.007 | |
| 1978 | | | | | | | | | 0.016 | |
| 1979 | | | | | | | | | 0.012 | |
| 1980 | | | | 0.39 | | | | | 0.010 | |
| 1981 | | | | | 0.47 | | | | 0.007 | |
| 1982 | | | | | | | | | 0.004 | |
| 1983 | | | | 0.40 | | | | | 0.016 | |
| 1984 | | | | | | | | | 0.010 | |
| 1985 | | | | | | | | | 0.012 | |
| 1986 | | | | | | | | | 0.014 | |
| 1987 | | | | | | | | | 0.018 | |
| 1988 | | | | | | | | | 0.033 | |
| 1989 | | | 3.114 | | | | | | 0.012 | |
| 1990 | | | 2.784 | 0.35 | | | | | 0.017 | |
| 1991 | | | 2.968 | 0.32 | | | | | 0.027 | |
| 1992 | | | 2.711 | 0.42 | | | | | 0.054 | |
| 1993 | | | 2.080 | 0.27 | 2.162 | | | | 0.031 | |
| 1994 | | 55.89 | 1.468 | | | | | | 0.027 | |
| 1995 | | 199.43 | 2.935 | 0.53 | 1.548 | | | | 0.049 | |
| 1996 | | 178.08 | 1.693 | 0.32 | 0.911 | | | | 0.022 | |
| 1997 | | 215.22 | 3.695 | 0.22 | | | | | 0.031 | |
| 1998 | | 415.10 | 2.530 | 0.52 | | 2.366 | 0.079 | | 0.037 | |
| 1999 | | 379.49 | 2.591 | 0.60 | | | 0.046 | | 0.033 | |
| 2000 | 30.037 | 600.22 | 3.660 | 0.15 | 3.107 | 0.020 | 0.105 | | 0.044 | |
| 2001 | 158.545 | 352.50 | 3.227 | 0.28 | | 0.303 | 0.141 | | | |
| 2002 | 33.902 | 365.00 | 5.152 | 0.14 | 11.321 | 1.285 | 0.135 | | 0.042 | |
| 2003 | 46.325 | 218.39 | 5.296 | 0.11 | | 3.990 | 0.084 | | 0.087 | 3.169 |
| 2004 | 38.637 | 277.85 | 3.684 | 0.14 | 13.185 | | 0.030 | | 0.068 | 2.277 |
| 2005 | 48.276 | 435.15 | 4.587 | 0.38 | 26.175 | 0.612 | 0.036 | | 0.106 | 0.892 |
| 2006 | 63.643 | 105.70 | 6.410 | 0.37 | 21.932 | 1.242 | 0.078 | | 0.059 | 1.554 |
| 2007 | 28.724 | 168.49 | 6.420 | 0.70 | | 1.193 | | 0.051 | 0.065 | 1.740 |
| 2008 | 71.656 | 373.63 | 4.451 | 0.40 | 12.927 | 2.612 | | 0.044 | 0.067 | 0.832 |
| 2009 | 82.680 | 475.71 | 5.618 | 0.82 | 20.256 | 1.127 | | 0.055 | 0.040 | 2.692 |
| 2010 | 119.011 | 171.86 | 4.674 | 0.41 | 13.993 | 2.602 | | 0.035 | 0.066 | 1.521 |
| 2011 | 89.741 | 79.34 | 4.110 | 0.51 | 16.034 | 1.430 | | 0.046 | 0.035 | 1.865 |

Table 3.5.13. Standardized indices of relative abundance for the “Gulf of Mexico stock” sensitivity run.

| YEAR | PC-LL | GOM Comb BLL | BLLOP | GOM Comb GN | NMFS-LL-SE | SEAMAP GOM ES | SEAMAP GOM EF |
|------|-------|--------------|--------|-------------|------------|---------------|---------------|
| 1972 | | | | | | | 0.203 |
| 1973 | | | | | | | 0.232 |
| 1974 | | | | | | | 1.019 |
| 1975 | | | | | | | 0.726 |
| 1976 | | | | | | | 0.677 |
| 1977 | | | | | | | 0.302 |
| 1978 | | | | | | | 0.373 |
| 1979 | | | | | | | 0.383 |
| 1980 | | | | | | | 0.686 |
| 1981 | | | | | | | 0.565 |
| 1982 | | | | | | 0.019 | 0.479 |
| 1983 | | | | | | 0.452 | 0.330 |
| 1984 | | | | | | 0.030 | 0.273 |
| 1985 | | | | | | 0.100 | 0.284 |
| 1986 | | | | | | 0.063 | 0.304 |
| 1987 | | | | | | 0.293 | 0.559 |
| 1988 | | | | | | 0.274 | 0.174 |
| 1989 | | | | | | 0.199 | 0.168 |
| 1990 | | | | | | 0.067 | 0.181 |
| 1991 | | | | | | 0.218 | 0.122 |
| 1992 | | | | | | 0.199 | 0.072 |
| 1993 | 0.481 | | | | | 0.242 | 0.164 |
| 1994 | 0.136 | | 0.07 | | | 0.098 | 0.233 |
| 1995 | 0.301 | | 2.86 | 0.848 | 1.042 | 0.431 | 0.128 |
| 1996 | 0.951 | | 10.46 | 0.816 | 1.742 | 0.366 | 0.315 |
| 1997 | 0.531 | | 163.69 | 1.399 | 0.909 | 0.188 | 0.154 |
| 1998 | 0.380 | | 49.79 | 0.968 | | 0.144 | 0.139 |
| 1999 | 1.160 | | 95.31 | 1.469 | 0.928 | 0.201 | 0.273 |
| 2000 | 0.445 | | | 1.962 | 2.430 | 0.217 | 0.209 |
| 2001 | | | 48.57 | 1.595 | 2.830 | 0.097 | 0.092 |
| 2002 | | | 62.94 | 1.772 | 3.520 | 0.253 | 0.109 |
| 2003 | | | 85.46 | 1.529 | 4.164 | 0.152 | 0.149 |
| 2004 | | 3.989 | 110.84 | 1.509 | 6.156 | 0.098 | 0.139 |
| 2005 | | 4.000 | 91.19 | 1.272 | 4.697 | 0.124 | 0.187 |
| 2006 | | 3.085 | 124.19 | 2.007 | 6.225 | 0.212 | 0.149 |
| 2007 | | 3.040 | 191.99 | 1.763 | 2.677 | 0.170 | 0.140 |
| 2008 | | 3.574 | 48.19 | 1.979 | 2.718 | 0.295 | 0.160 |
| 2009 | | 3.274 | 53.82 | 2.483 | 8.889 | 0.245 | 0.219 |
| 2010 | | 3.661 | 313.44 | 2.785 | 6.111 | 0.172 | 0.132 |
| 2011 | | 3.091 | 328.63 | 2.577 | 3.240 | 0.110 | 0.131 |

Table 3.5.14. Life history inputs used in the “Atlantic stock” and “Gulf of Mexico stock” sensitivity runs. All these quantities are treated as constants in the model. Von Bertalanffy growth function parameters are for females.

| | | ATL | | GOM | | |
|----------------------------|---|-------|----------------------------|--|-------|----------------------------|
| | Proportion mature | M | Fecundity (female pups) | Proportion mature | M | Fecundity (female pups) |
| Age | | | | | | |
| 1 | 0.185 | 0.232 | 0.401 | 0.166 | 0.316 | 0.634 |
| 2 | 0.953 | 0.232 | 0.762 | 0.972 | 0.275 | 1.164 |
| 3 | 0.999 | 0.232 | 1.133 | 1.000 | 0.258 | 1.608 |
| 4 | 1.000 | 0.232 | 1.448 | 1.000 | 0.249 | 1.910 |
| 5 | 1.000 | 0.232 | 1.686 | 1.000 | 0.245 | 2.093 |
| 6 | 1.000 | 0.232 | 1.852 | 1.000 | 0.243 | 2.198 |
| 7 | 1.000 | 0.232 | 1.963 | 1.000 | 0.242 | 2.256 |
| 8 | 1.000 | 0.232 | 2.035 | 1.000 | 0.241 | 2.288 |
| 9 | 1.000 | 0.232 | 2.081 | 1.000 | 0.241 | 2.304 |
| 10 | 1.000 | 0.232 | 2.110 | 1.000 | 0.241 | 2.314 |
| 11 | 1.000 | 0.232 | 2.128 | | | |
| 12 | 1.000 | 0.232 | 2.139 | | | |
| 13 | 1.000 | 0.232 | 2.146 | | | |
| 14 | 1.000 | 0.232 | 2.150 | | | |
| 15 | 1.000 | 0.232 | 2.153 | | | |
| 16 | 1.000 | 0.232 | 2.155 | | | |
| 17 | 1.000 | 0.232 | 2.156 | | | |
| 18 | 1.000 | 0.232 | 2.156 | | | |
| | | | | | | |
| Sex ratio: | | 1:1 | | | 1:1 | |
| Reproductive frequency: | | 1 yr | | | 1 yr | |
| Pupping month: | | June | | | June | |
| Length vs litter size rel: | $\text{pups} = 0.0544 \exp(0.0534 * \text{FL})$ | | | $\text{pups} = \exp(-3.0704 + 0.0570 * \text{FL})$ | | |
| L_{inf} | | 81.9 | (cm FL) | | 80.8 | (cm FL) |
| k | | 0.480 | | | 0.630 | |
| t_0 | | -0.99 | | | -1.01 | |
| Weight vs length relation: | $W = 0.00000556 L^{3.074}$ | | | $W = 0.000002 L^{3.3071}$ | | |
| | | | | | | |

Table 3.5.15. Predicted abundance (numbers) and spawning stock fecundity (numbers) of Atlantic sharpnose sharks for the base run.

| Year | N | SSF |
|------|------------|------------|
| 1950 | 45,257,730 | 55,512,000 |
| 1951 | 45,003,710 | 55,131,000 |
| 1952 | 44,790,950 | 54,839,000 |
| 1953 | 44,612,550 | 54,565,000 |
| 1954 | 44,461,990 | 54,320,000 |
| 1955 | 44,333,690 | 54,107,000 |
| 1956 | 44,224,260 | 53,923,000 |
| 1957 | 44,130,820 | 53,765,000 |
| 1958 | 44,050,740 | 53,630,000 |
| 1959 | 43,981,870 | 53,513,000 |
| 1960 | 43,922,310 | 53,413,000 |
| 1961 | 43,871,080 | 53,326,000 |
| 1962 | 43,826,880 | 53,251,000 |
| 1963 | 43,788,200 | 53,185,000 |
| 1964 | 43,754,780 | 53,128,000 |
| 1965 | 43,725,360 | 53,078,000 |
| 1966 | 43,699,480 | 53,034,000 |
| 1967 | 43,676,550 | 52,995,000 |
| 1968 | 43,656,300 | 52,961,000 |
| 1969 | 43,638,100 | 52,930,000 |
| 1970 | 43,621,890 | 52,902,000 |
| 1971 | 43,607,280 | 52,877,000 |
| 1972 | 43,593,660 | 52,476,000 |
| 1973 | 42,533,930 | 51,395,000 |
| 1974 | 41,830,930 | 50,314,000 |
| 1975 | 41,012,460 | 49,308,000 |
| 1976 | 40,755,030 | 48,405,000 |
| 1977 | 39,671,890 | 46,975,000 |
| 1978 | 38,567,260 | 45,251,000 |
| 1979 | 37,029,090 | 42,837,000 |
| 1980 | 34,635,660 | 40,349,000 |
| 1981 | 34,170,920 | 38,911,000 |
| 1982 | 33,255,970 | 37,533,000 |
| 1983 | 32,582,980 | 36,447,000 |
| 1984 | 32,071,480 | 35,576,000 |
| 1985 | 31,597,950 | 34,745,000 |
| 1986 | 30,920,840 | 33,702,000 |
| 1987 | 29,947,820 | 32,173,000 |
| 1988 | 28,241,490 | 30,440,000 |
| 1989 | 27,669,020 | 29,123,000 |
| 1990 | 26,375,880 | 27,531,000 |
| 1991 | 25,316,950 | 25,938,000 |
| 1992 | 24,012,360 | 24,542,000 |
| 1993 | 23,686,300 | 23,905,000 |
| 1994 | 23,664,590 | 23,471,000 |
| 1995 | 23,173,210 | 22,947,000 |
| 1996 | 23,093,170 | 22,731,000 |
| 1997 | 23,069,210 | 22,592,000 |
| 1998 | 22,931,310 | 22,307,000 |
| 1999 | 22,448,380 | 21,805,000 |
| 2000 | 22,030,610 | 21,379,000 |
| 2001 | 21,907,168 | 21,227,000 |
| 2002 | 22,114,440 | 21,421,000 |
| 2003 | 22,479,293 | 21,765,000 |
| 2004 | 22,731,634 | 22,185,000 |
| 2005 | 23,294,252 | 22,979,000 |
| 2006 | 24,405,579 | 24,173,000 |
| 2007 | 25,403,334 | 25,399,000 |
| 2008 | 26,325,101 | 26,770,000 |
| 2009 | 27,501,675 | 28,149,000 |
| 2010 | 28,132,584 | 29,199,000 |
| 2011 | 28,863,603 | 30,294,000 |

Table 3.5.16. Estimated total and fleet-specific instantaneous fishing mortality rates by year.

| Year | Total F | Fleet-specific F | | | | Shrimp trawl |
|------|---------|------------------|--------|--------|--------------|-----------------|
| | | Com-BLL | Com-GN | Com-L | Recreational | |
| 1950 | 0.0191 | 0.0000 | 0.0000 | 0.0000 | 0.0003 | 0.0182 |
| 1951 | 0.0192 | 0.0000 | 0.0000 | 0.0000 | 0.0003 | 0.0182 |
| 1952 | 0.0192 | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0182 |
| 1953 | 0.0192 | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0182 |
| 1954 | 0.0192 | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0182 |
| 1955 | 0.0193 | 0.0000 | 0.0000 | 0.0000 | 0.0005 | 0.0182 |
| 1956 | 0.0193 | 0.0000 | 0.0000 | 0.0000 | 0.0005 | 0.0182 |
| 1957 | 0.0193 | 0.0000 | 0.0000 | 0.0000 | 0.0005 | 0.0182 |
| 1958 | 0.0193 | 0.0000 | 0.0000 | 0.0000 | 0.0005 | 0.0182 |
| 1959 | 0.0193 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0182 |
| 1960 | 0.0194 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0182 |
| 1961 | 0.0194 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0182 |
| 1962 | 0.0194 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0182 |
| 1963 | 0.0194 | 0.0000 | 0.0000 | 0.0000 | 0.0007 | 0.0182 |
| 1964 | 0.0195 | 0.0000 | 0.0000 | 0.0000 | 0.0007 | 0.0182 |
| 1965 | 0.0195 | 0.0000 | 0.0000 | 0.0000 | 0.0007 | 0.0182 |
| 1966 | 0.0195 | 0.0000 | 0.0000 | 0.0000 | 0.0007 | 0.0182 |
| 1967 | 0.0195 | 0.0000 | 0.0000 | 0.0000 | 0.0008 | 0.0182 |
| 1968 | 0.0196 | 0.0000 | 0.0000 | 0.0000 | 0.0008 | 0.0182 |
| 1969 | 0.0196 | 0.0000 | 0.0000 | 0.0000 | 0.0008 | 0.0182 |
| 1970 | 0.0196 | 0.0000 | 0.0000 | 0.0000 | 0.0009 | 0.0182 |
| 1971 | 0.0196 | 0.0000 | 0.0000 | 0.0000 | 0.0009 | 0.0182 |
| 1972 | 0.1059 | 0.0000 | 0.0000 | 0.0000 | 0.0009 | 0.1001 |
| 1973 | 0.0936 | 0.0000 | 0.0000 | 0.0000 | 0.0009 | 0.0886 |
| 1974 | 0.1145 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.1082 |
| 1975 | 0.0771 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.0729 |
| 1976 | 0.1542 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.1451 |
| 1977 | 0.1771 | 0.0000 | 0.0000 | 0.0000 | 0.0010 | 0.1662 |
| 1978 | 0.2432 | 0.0000 | 0.0000 | 0.0000 | 0.0011 | 0.2264 |
| 1979 | 0.3797 | 0.0000 | 0.0000 | 0.0000 | 0.0012 | 0.3474 |
| 1980 | 0.2088 | 0.0008 | 0.0000 | 0.0000 | 0.0014 | 0.1946 |
| 1981 | 0.2583 | 0.0008 | 0.0000 | 0.0000 | 0.0015 | 0.2393 |
| 1982 | 0.2472 | 0.0009 | 0.0000 | 0.0000 | 0.0012 | 0.2296 |
| 1983 | 0.2386 | 0.0009 | 0.0000 | 0.0000 | 0.0014 | 0.2216 |
| 1984 | 0.2418 | 0.0009 | 0.0000 | 0.0000 | 0.0013 | 0.2246 |
| 1985 | 0.2750 | 0.0009 | 0.0000 | 0.0000 | 0.0008 | 0.2549 |
| 1986 | 0.3268 | 0.0010 | 0.0000 | 0.0000 | 0.0014 | 0.3005 |
| 1987 | 0.4565 | 0.0010 | 0.0001 | 0.0000 | 0.0015 | 0.4131 |
| 1988 | 0.3420 | 0.0011 | 0.0002 | 0.0000 | 0.0035 | 0.3121 |
| 1989 | 0.4548 | 0.0012 | 0.0003 | 0.0000 | 0.0025 | 0.4108 |
| 1990 | 0.4594 | 0.0013 | 0.0004 | 0.0000 | 0.0024 | 0.4147 |
| 1991 | 0.5239 | 0.0015 | 0.0006 | 0.0000 | 0.0060 | 0.4665 |
| 1992 | 0.3988 | 0.0017 | 0.0007 | 0.0000 | 0.0043 | 0.3608 |
| 1993 | 0.3463 | 0.0011 | 0.0008 | 0.0000 | 0.0042 | 0.3152 |
| 1994 | 0.4078 | 0.0019 | 0.0010 | 0.0000 | 0.0058 | 0.3673 |
| 1995 | 0.3487 | 0.0035 | 0.0011 | 0.0000 | 0.0082 | 0.3131 |
| 1996 | 0.3383 | 0.0061 | 0.0005 | 0.0000 | 0.0046 | 0.3060 |
| 1997 | 0.3536 | 0.0018 | 0.0110 | 0.0001 | 0.0040 | 0.3213 |
| 1998 | 0.4138 | 0.0015 | 0.0098 | 0.0001 | 0.0042 | 0.3737 |
| 1999 | 0.4193 | 0.0015 | 0.0104 | 0.0003 | 0.0043 | 0.3783 |
| 2000 | 0.3792 | 0.0013 | 0.0063 | 0.0001 | 0.0081 | 0.3405 |
| 2001 | 0.3207 | 0.0013 | 0.0090 | 0.0001 | 0.0092 | 0.2881 |
| 2002 | 0.2918 | 0.0018 | 0.0080 | 0.0001 | 0.0059 | 0.2651 |
| 2003 | 0.2994 | 0.0033 | 0.0036 | 0.0002 | 0.0060 | 0.2713 |
| 2004 | 0.2503 | 0.0027 | 0.0059 | 0.0000 | 0.0053 | 0.2281 |
| 2005 | 0.1610 | 0.0027 | 0.0110 | 0.0001 | 0.0055 | 0.1463 |
| 2006 | 0.1521 | 0.0029 | 0.0130 | 0.0001 | 0.0064 | 0.1371 |
| 2007 | 0.1462 | 0.0012 | 0.0159 | 0.0002 | 0.0064 | 0.1322 |
| 2008 | 0.1147 | 0.0009 | 0.0072 | 0.0001 | 0.0044 | 0.1049 |
| 2009 | 0.1586 | 0.0019 | 0.0070 | 0.0001 | 0.0041 | 0.1457 |
| 2010 | 0.1402 | 0.0011 | 0.0045 | 0.0003 | 0.0065 | 0.1268 |
| 2011 | 0.1281 | 0.0014 | 0.0061 | 0.0003 | 0.0024 | 0.1188 |

Table 3.5.17. Summary of results for base runs with several weighting schemes for Atlantic sharpnose shark. R_0 is the number of age-1 pups at virgin conditions. SSF is spawning stock fecundity (sum of number at age times pup production at age). MSY is expressed in numbers. AICc is the Akaike Information Criterion for small sample sizes, which converges to the AIC statistic as the number of data points gets large. The weighting schemes were: inverse of ranks (ranks), inverse CV weighting (inv CV), and equal weighting (eq weights). See text for further details.

| | Base (eq weights) | | Base (ranks) | | Base (inv CV) | |
|------------------------|-------------------|------|--------------|---------|---------------|------|
| | Est | CV | Est | CV | Est | CV |
| | | | | | | |
| AICc | 3837.72 | | 3892.15 | | 3702.31 | |
| Objective function | 1550.62 | | 1577.84 | | 1482.91 | |
| SSF_{2011}/SSF_{MSY} | 1.66 | 0.43 | 1.57 | 0.48 | 1.73 | 0.41 |
| F_{2011}/F_{MSY} | 0.33 | 1.94 | 0.34 | 1.95 | 0.34 | 2.02 |
| N_{2011}/N_{MSY} | 1.47 | --- | 1.41 | --- | 1.52 | --- |
| MSY | 3.01.E+06 | --- | 2.94.E+06 | --- | 3.06.E+06 | --- |
| SPR_{MSY} | 0.45 | 0.19 | 0.45 | 0.19 | 0.45 | 0.19 |
| F_{MSY} | 0.368 | --- | 0.364 | --- | 0.377 | --- |
| SSF_{MSY} | 1.76.E+07 | --- | 1.75.E+07 | --- | 1.75.E+07 | --- |
| N_{MSY} | 1.90.E+07 | --- | 1.88.E+07 | --- | 1.90.E+07 | --- |
| F_{2011} | 0.120 | 1.94 | 0.125 | 1.95 | 0.128 | 2.02 |
| SSF_{2011} | 2.92.E+07 | 0.35 | 2.74.E+07 | 0.454 | 3.03.E+07 | 0.31 |
| N_{2011} | 2.81.E+07 | --- | 2.66.E+07 | --- | 2.89.E+07 | --- |
| SSF_{2011}/SSF_0 | 0.53 | 0.25 | 0.50 | 0.317 | 0.55 | 0.22 |
| B_{2011}/B_0 | 0.51 | 0.24 | 0.49 | 0.300 | 0.53 | 0.22 |
| R_0 | 9.36.E+06 | 0.17 | 9.23.E+06 | 2.E-01 | 9.37.E+06 | 0.16 |
| Pup-survival | 0.87 | 0.27 | 0.86 | 0.28 | 0.89 | 0.27 |
| alpha | 5.14 | --- | 5.08 | --- | 5.28 | --- |
| steepness | 0.56 | --- | 0.56 | --- | 0.57 | --- |
| SSF_0 | 5.54.E+07 | 0.17 | 5.47.E+07 | 0.20343 | 5.55.E+07 | 0.16 |
| SSF_{MSY}/SSF_0 | 0.32 | --- | 0.32 | --- | 0.32 | --- |
| $N_{mat_{MSY}}$ | 8.82.E+06 | --- | 8.76.E+06 | --- | 8.77.E+06 | --- |

Table 3.5.18. Summary of results for base and sensitivity runs for Atlantic sharpnose shark. All runs used inverse CV weighting. R_0 is the number of age-1 pups at virgin conditions. SSF is spawning stock fecundity (sum of number at age times pup production at age). MSY is expressed in numbers. AICc is the Akaike Information Criterion for small sample sizes, which converges to the AIC statistic as the number of data points gets large. Sensitivity runs are: increasing and decreasing indices, low catch, and hierarchical index (with logistic and double exponential selectivity).

| | Base (inv CV) | | Increasing indices | | Decreasing indices | | Low catch | | Hierarchical (log) | | Hierarchical (d exp) | |
|---|---------------|------|--------------------|------|--------------------|------|-------------|------|--------------------|------|----------------------|------|
| | Est | CV | Est | CV | Est | CV | Est | CV | Est | CV | Est | CV |
| AICc | 3702.31 | | 3686.02 | | 3685.85 | | 3698.95 | | 3732.95 | | 3736.42 | |
| Objective function | 1482.91 | | 1438.70 | | 1346.47 | | 1481.24 | | 1331.33 | | 1333.06 | |
| SSF ₂₀₁₁ /SSF _{MSY} | 1.73 | 0.41 | 1.83 | 0.41 | 0.40 | 1.18 | 2.04 | 0.93 | 2.41 | 0.40 | 1.40 | 0.48 |
| F ₂₀₁₁ /F _{MSY} | 0.34 | 2.02 | 0.27 | 1.85 | 1.06 | 2.22 | 0.25 | 1.63 | 0.13 | 2.00 | 0.36 | 1.88 |
| N ₂₀₁₁ /N _{MSY} | 1.52 | --- | 1.59 | --- | 0.48 | --- | 1.69 | --- | 1.97 | --- | 1.30 | --- |
| MSY | 3.06.E+06 | --- | 3.23.E+06 | --- | 2.54.E+06 | --- | 7.70.E+05 | --- | 5.89.E+06 | --- | 2.79.E+06 | --- |
| SPR _{MSY} | 0.45 | 0.19 | 0.45 | 0.19 | 0.47 | 0.25 | 0.47 | 0.50 | 0.48 | 0.16 | 0.45 | 0.21 |
| F _{MSY} | 0.377 | --- | 0.363 | --- | 0.331 | --- | 0.227 | --- | 0.343 | --- | 0.364 | --- |
| SSF _{MSY} | 1.75.E+07 | --- | 1.91.E+07 | --- | 1.65.E+07 | --- | 5.18.E+06 | --- | 3.83.E+07 | --- | 1.63.E+07 | --- |
| N _{MSY} | 1.90.E+07 | --- | 2.07.E+07 | --- | 1.75.E+07 | --- | 5.68.E+06 | --- | 4.05.E+07 | --- | 1.77.E+07 | --- |
| F ₂₀₁₁ | 0.128 | 2.02 | 0.098 | 1.85 | 0.352 | 2.22 | 0.057 | 1.63 | 0.043 | 2.00 | 0.132 | 1.88 |
| SSF ₂₀₁₁ | 3.03.E+07 | 0.31 | 3.50.E+07 | 0.36 | 6.66.E+06 | 1.14 | 1.06.E+07 | 0.43 | 9.25.E+07 | 1.02 | 2.29.E+07 | 0.37 |
| N ₂₀₁₁ | 2.89.E+07 | --- | 3.28.E+07 | --- | 8.38.E+06 | --- | 9.60.E+06 | --- | 7.97.E+07 | --- | 2.29.E+07 | --- |
| SSF ₂₀₁₁ /SSF ₀ | 0.55 | 0.22 | 0.58 | 0.22 | 0.13 | 1.08 | 0.67 | 0.17 | 0.79 | 0.23 | 0.45 | 0.33 |
| B ₂₀₁₁ /B ₀ | 0.53 | 0.22 | 0.56 | 0.20 | 0.14 | 1.15 | 0.64 | 0.15 | 0.73 | 0.21 | 0.44 | 0.31 |
| R ₀ | 9.37.E+06 | 0.16 | 1.01.E+07 | 0.20 | 8.48.E+06 | 0.17 | 2.65.E+06 | 0.29 | 1.96.E+07 | 0.79 | 8.66.E+06 | 0.14 |
| Pup-survival | 0.89 | 0.27 | 0.86 | 0.28 | 0.78 | 0.29 | 0.80 | 0.28 | 0.77 | 0.29 | 0.88 | 0.27 |
| alpha | 5.28 | --- | 5.08 | --- | 4.62 | --- | 4.76 | --- | 4.57 | --- | 5.19 | --- |
| steepness | 0.57 | --- | 0.56 | --- | 0.54 | --- | 0.54 | --- | 0.53 | --- | 0.56 | --- |
| SSF ₀ | 5.55.E+07 | 0.16 | 6.00.E+07 | 0.20 | 5.02.E+07 | 0.17 | 1.57.E+07 | 0.29 | 1.16.E+08 | 0.79 | 5.13.E+07 | 0.14 |
| SSF _{MSY} /SSF ₀ | 0.32 | --- | 0.32 | --- | 0.33 | --- | 0.33 | --- | 0.33 | --- | 0.32 | --- |
| Nmat _{MSY} | 8.77.E+06 | --- | 9.61.E+06 | --- | 8.32.E+06 | --- | 2.65.E+06 | --- | 1.93.E+07 | --- | 8.17.E+06 | --- |

Table 3.5.18 (continued). Summary of results for base and sensitivity runs for Atlantic sharpnose shark. All runs used inverse CV weighting. R_0 is the number of age-1 pups at virgin conditions. SSF is spawning stock fecundity (sum of number at age times pup production at age). MSY is expressed in numbers. AICc is the Akaike Information Criterion for small sample sizes, which converges to the AIC statistic as the number of data points gets large. Sensitivity runs are: SEAMAP-SA index, No indices, Model start 1972, and high and low productivity.

| | Base (inv CV) | | SEAMAP-SA | | No indices | | Model start 1972 | | High productivity | | Low productivity | |
|------------------------|---------------|------|-------------|------|-------------|------|------------------|------|-------------------|------|------------------|------|
| | Est | CV | Est | CV | Est | CV | Est | CV | Est | CV | Est | CV |
| AICc | 3702.31 | | 3781.15 | | 4276.60 | | 1880.85 | | 3702.37 | | 3702.88 | |
| Objective function | 1482.91 | | 1309.89 | | 1307.94 | | 518.80 | | 1482.94 | | 1483.20 | |
| SSF_{2011}/SSF_{MSY} | 1.73 | 0.41 | 2.05 | 0.61 | 2.88 | 0.41 | 1.68 | 0.07 | 1.85 | 0.43 | 1.55 | 0.40 |
| F_{2011}/F_{MSY} | 0.34 | 2.02 | 0.21 | 2.09 | 0.03 | 5.80 | 0.33 | 0.32 | 0.33 | 2.05 | 0.37 | 1.98 |
| N_{2011}/N_{MSY} | 1.52 | --- | 1.73 | --- | 2.26 | --- | 1.50 | --- | 1.59 | --- | 1.41 | --- |
| MSY | 3.06.E+06 | --- | 3.95.E+06 | --- | 2.50.E+07 | --- | 2.97.E+06 | --- | 3.14.E+06 | --- | 2.89.E+06 | --- |
| SPR _{MSY} | 0.45 | 0.19 | 0.47 | 0.17 | 0.48 | 0.15 | 0.48 | 0.03 | 0.40 | 0.21 | 0.52 | 0.15 |
| F_{MSY} | 0.377 | --- | 0.345 | --- | 0.341 | --- | 0.338 | --- | 0.429 | --- | 0.310 | --- |
| SSF_{MSY} | 1.75.E+07 | --- | 2.54.E+07 | --- | 1.65.E+08 | --- | 1.97.E+07 | --- | 1.84.E+07 | --- | 1.58.E+07 | --- |
| N_{MSY} | 1.90.E+07 | --- | 2.69.E+07 | --- | 1.74.E+08 | --- | 2.07.E+07 | --- | 1.76.E+07 | --- | 2.14.E+07 | --- |
| F_{2011} | 0.128 | 2.02 | 0.072 | 2.09 | 0.009 | 5.80 | 0.112 | 0.32 | 0.140 | 2.05 | 0.116 | 1.98 |
| SSF_{2011} | 3.03.E+07 | 0.31 | 5.19.E+07 | 1.25 | 4.75.E+08 | 5.65 | 3.31.E+07 | 0.08 | 3.41.E+07 | 0.31 | 2.45.E+07 | 0.30 |
| N_{2011} | 2.89.E+07 | --- | 4.67.E+07 | --- | 3.92.E+08 | --- | 3.11.E+07 | --- | 2.80.E+07 | --- | 3.02.E+07 | --- |
| SSF_{2011}/SSF_0 | 0.55 | 0.22 | 0.67 | 0.49 | 0.95 | 0.26 | 0.56 | 0.05 | 0.54 | 0.22 | 0.54 | 0.22 |
| B_{2011}/B_0 | 0.53 | 0.22 | 0.63 | 0.44 | 0.86 | 0.23 | 0.53 | 0.05 | 0.52 | 0.23 | 0.52 | 0.22 |
| R_0 | 9.37.E+06 | 0.16 | 1.31.E+07 | 0.77 | 8.40.E+07 | 5.39 | 1.00.E+07 | 0.05 | 8.36.E+06 | 0.15 | 1.09.E+07 | 0.17 |
| Pup-survival | 0.89 | 0.27 | 0.78 | 0.29 | 0.76 | 0.29 | 0.76 | --- | 0.88 | 0.27 | 0.93 | 0.26 |
| alpha | 5.28 | --- | 4.64 | --- | 4.50 | --- | 4.50 | --- | 6.70 | --- | 3.87 | --- |
| steepness | 0.57 | --- | 0.54 | --- | 0.53 | --- | 0.53 | --- | 0.63 | --- | 0.49 | --- |
| SSF_0 | 5.55.E+07 | 0.16 | 7.74.E+07 | 0.77 | 4.98.E+08 | 5.39 | 5.94.E+07 | 0.05 | 6.34.E+07 | 0.15 | 4.55.E+07 | 0.17 |
| SSF_{MSY}/SSF_0 | 0.32 | --- | 0.33 | --- | 0.33 | --- | 0.33 | --- | 0.29 | --- | 0.35 | --- |
| $N_{mat_{MSY}}$ | 8.77.E+06 | --- | 1.27.E+07 | --- | 8.29.E+07 | --- | 9.90.E+06 | --- | 8.25.E+06 | --- | 9.86.E+06 | --- |

Table 3.5.18 (continued). Summary of results for base and sensitivity runs for Atlantic sharpnose shark. All runs used inverse CV weighting. R_0 is the number of age-1 pups at virgin conditions. SSF is spawning stock fecundity (sum of number at age times pup production at age). MSY is expressed in numbers. AICc is the Akaike Information Criterion for small sample sizes, which converges to the AIC statistic as the number of data points gets large. Sensitivity runs are: Atlantic stock and Gulf of Mexico stock.

| | Base (inv CV) | | ATL stock | | GOM stock | |
|------------------------|---------------|------|-------------|------|-------------|------|
| | Est | CV | Est | CV | Est | CV |
| <hr/> | | | | | | |
| AICc | 3702.31 | | 3655.52 | | 3643.45 | |
| Objective function | 1482.91 | | 1415.59 | | 1397.24 | |
| SSF_{2011}/SSF_{MSY} | 1.73 | 0.41 | 2.07 | 0.97 | 1.01 | 0.55 |
| F_{2011}/F_{MSY} | 0.34 | 2.02 | 0.23 | 1.63 | 0.57 | 2.10 |
| N_{2011}/N_{MSY} | 1.52 | --- | 1.70 | --- | 1.01 | --- |
| MSY | 3.06.E+06 | --- | 6.89.E+05 | --- | 2.61.E+06 | --- |
| SPR _{MSY} | 0.45 | 0.19 | 0.51 | 0.48 | 0.49 | 0.18 |
| F_{MSY} | 0.377 | --- | 0.184 | --- | 0.331 | --- |
| SSF_{MSY} | 1.75.E+07 | --- | 4.86.E+06 | --- | 1.79.E+07 | --- |
| N_{MSY} | 1.90.E+07 | --- | 6.39.E+06 | --- | 1.81.E+07 | --- |
| F_{2011} | 0.128 | 2.02 | 0.043 | 1.63 | 0.190 | 2.10 |
| SSF_{2011} | 3.03.E+07 | 0.31 | 1.01.E+07 | 0.54 | 1.82.E+07 | 0.44 |
| N_{2011} | 2.89.E+07 | --- | 1.09.E+07 | --- | 1.83.E+07 | --- |
| SSF_{2011}/SSF_0 | 0.55 | 0.22 | 0.72 | 0.17 | 0.34 | 0.40 |
| B_{2011}/B_0 | 0.53 | 0.22 | 0.69 | 0.15 | 0.31 | 0.41 |
| R_0 | 9.37.E+06 | 0.16 | 2.84.E+06 | 0.39 | 9.73.E+06 | 0.16 |
| Pup-survival | 0.89 | 0.27 | 0.81 | 0.28 | 0.76 | 0.26 |
| alpha | 5.28 | --- | 3.97 | --- | 4.19 | --- |
| steepness | 0.57 | --- | 0.50 | --- | 0.51 | --- |
| SSF_0 | 5.55.E+07 | 0.16 | 1.39.E+07 | 0.39 | 5.35.E+07 | 0.16 |
| SSF_{MSY}/SSF_0 | 0.32 | --- | 0.35 | --- | 0.33 | --- |
| $N_{mat,MSY}$ | 8.77.E+06 | --- | 3.18.E+06 | --- | 8.01.E+06 | --- |

Table 3.5.19. Summary of results for continuity run, 2007 base run, and 2013 (current) base run (inverse CV weighting) for Atlantic sharpnose shark. R_0 is the number of age-1 pups at virgin conditions. SSF is spawning stock fecundity (sum of number at age times pup production at age). MSY is expressed in numbers. AICc is the Akaike Information Criterion for small sample sizes, which converges to the AIC statistic as the number of data points gets large.

| | Base (inv CV) | | Continuity | | 2007 Base | |
|---|---------------|------|-------------|------|-------------|------|
| | Est | CV | Est | CV | Est | CV |
| | | | | | | |
| AICc | 3702.31 | | 4770.90 | | | |
| Objective function | 1482.91 | | 1948.08 | | | |
| SSF_{cur}/SSF_{MSY} | 1.73 | 0.41 | 1.17 | 0.80 | 1.49 | 0.45 |
| F_{cur}/F_{MSY} | 0.34 | 2.02 | 0.86 | 1.68 | 0.70 | 0.78 |
| N_{cur}/N_{MSY} | 1.52 | --- | 1.12 | --- | 1.35 | --- |
| MSY | 3.06.E+06 | --- | 4.35.E+05 | --- | 1.27.E+06 | --- |
| SPR_{MSY} | 0.45 | 0.19 | 0.55 | 0.34 | 0.59 | 0.11 |
| F_{MSY} | 0.377 | --- | 0.217 | --- | 0.190 | --- |
| SSF_{MSY} | 1.75.E+07 | --- | 2.94.E+06 | --- | 4.59.E+06 | --- |
| N_{MSY} | 1.90.E+07 | --- | 3.76.E+06 | --- | 4.62.E+06 | --- |
| F_{cur} | 0.128 | 2.02 | 0.186 | 1.68 | 0.130 | 0.78 |
| SSF_{cur} | 3.03.E+07 | 0.31 | 3.45.E+06 | 0.39 | 6.81.E+06 | 0.65 |
| N_{cur} | 2.89.E+07 | --- | 4.22.E+06 | --- | 6.22.E+06 | --- |
| SSF_{cur}/SSF_0 | 0.55 | 0.22 | 0.42 | 0.31 | 0.56 | 0.32 |
| B_{cur}/B_0 | 0.53 | 0.22 | 0.38 | 0.32 | 0.49 | 0.31 |
| R_0 | 9.37.E+06 | 0.16 | 2.18.E+06 | 0.17 | 3.24.E+06 | 0.35 |
| Pup-survival | 0.89 | 0.27 | 0.90 | 0.25 | 0.76 | 0.28 |
| alpha | 5.28 | --- | 3.37 | --- | 2.85 | --- |
| steepness | 0.57 | --- | 0.46 | --- | 0.42 | --- |
| SSF_0 | 5.55.E+07 | 0.16 | 8.20.E+06 | 0.17 | --- | --- |
| SSF_{MSY}/SSF_0 | 0.32 | --- | 0.36 | --- | --- | --- |
| $N_{mat_{MSY}}$ | 8.77.E+06 | --- | 1.53.E+06 | --- | --- | --- |
| cur = 2011 for base and continuity, 2005 for Base 2007 assessment | | | | | | |

Table 3.5.20. Summary of results of retrospective analyses of the baseline run. All runs used inverse CV weighting. R_0 is the number of age-1 pups at virgin conditions. SSF is spawning stock fecundity (sum of number at age times pup production at age). MSY is expressed in numbers. AICc is the Akaike Information Criterion for small sample sizes, which converges to the AIC statistic as the number of data points gets large.

| | Base (inv CV) | | Retrospective 2010 | | Retrospective 2009 | | Retrospective 2008 | | Retrospective 2007 | |
|-----------------------|---------------|------|--------------------|------|--------------------|------|--------------------|------|--------------------|------|
| | Est | CV | Est | CV | Est | CV | Est | CV | Est | CV |
| AICc | 3702.31 | | 3639.05 | | 3575.19 | | 3511.62 | | 3447.79 | |
| Objective function | 1482.91 | | 1457.36 | | 1431.44 | | 1405.59 | | 1379.52 | |
| SSF_{cur}/SSF_{MSY} | 1.73 | 0.41 | 1.68 | 0.47 | 1.60 | 0.40 | 1.49 | 0.46 | 1.39 | 0.56 |
| F_{cur}/F_{MSY} | 0.34 | 2.02 | 0.34 | 1.84 | 0.40 | 1.75 | 0.36 | 1.85 | 0.53 | 1.98 |
| N_{cur}/N_{MSY} | 1.52 | --- | 1.48 | | 1.44 | | 1.35 | | 1.29 | |
| MSY | 3.06.E+06 | --- | 3.05.E+06 | | 3.06.E+06 | | 3.04.E+06 | | 3.00.E+06 | |
| SPR_{MSY} | 0.45 | 0.19 | 0.45 | 0.23 | 0.45 | 0.19 | 0.45 | 0.21 | 0.45 | 0.27 |
| F_{MSY} | 0.377 | --- | 0.361 | | 0.372 | | 0.366 | | 0.353 | |
| SSF_{MSY} | 1.75.E+07 | --- | 1.76.E+07 | | 1.75.E+07 | | 1.76.E+07 | | 1.75.E+07 | |
| N_{MSY} | 1.90.E+07 | --- | 1.92.E+07 | | 1.91.E+07 | | 1.91.E+07 | | 1.91.E+07 | |
| F_{cur} | 0.128 | 2.02 | 0.122 | 1.84 | 0.148 | 1.75 | 0.131 | 1.85 | 0.188 | 1.98 |
| SSF_{cur} | 3.03.E+07 | 0.31 | 2.95.E+07 | 0.30 | 2.81.E+07 | 0.31 | 2.63.E+07 | 0.34 | 2.44.E+07 | 0.35 |
| N_{cur} | 2.89.E+07 | --- | 2.84.E+07 | | 2.74.E+07 | | 2.59.E+07 | | 2.46.E+07 | |
| SSF_{cur}/SSF_0 | 0.55 | 0.22 | 0.53 | 0.21 | 0.51 | 0.22 | 0.47 | 0.24 | 0.44 | 0.25 |
| B_{cur}/B_0 | 0.53 | 0.22 | 0.51 | 0.21 | 0.49 | 0.22 | 0.46 | 0.24 | 0.43 | 0.27 |
| R_0 | 9.37.E+06 | 0.16 | 9.40.E+06 | 0.16 | 9.39.E+06 | 0.16 | 9.40.E+06 | 0.16 | 9.34.E+06 | 0.16 |
| Pup-survival | 0.89 | 0.27 | 0.89 | 0.27 | 0.89 | 0.27 | 0.88 | 0.27 | 0.88 | 0.27 |
| alpha | 5.28 | --- | 5.29 | | 5.28 | | 5.23 | | 5.21 | |
| steepness | 0.57 | --- | 0.57 | | 0.57 | | 0.57 | | 0.57 | |
| SSF_0 | 5.55.E+07 | 0.16 | 5.57.E+07 | 0.16 | 5.56.E+07 | 0.16 | 5.57.E+07 | 0.16 | 5.53.E+07 | 0.16 |
| SSF_{MSY}/SSF_0 | 0.32 | --- | 0.32 | | 0.32 | | 0.32 | | 0.32 | |
| $N_{mat_{MSY}}$ | 8.77.E+06 | --- | 8.82.E+06 | | 8.79.E+06 | | 8.83.E+06 | | 8.81.E+06 | |

Table 3.5.21. Summary of stock status results (relative to SSF_{MSY} and F_{MSY}) for all runs conducted in the assessment. For SSF, stock status with respect to MSY in 2011 (2005 for continuity run and respective year for retrospective runs) and as the geometric mean of 2009-2011 values (2003-2005 for continuity run and 2008-2010 for retrospective 2010 run, etc.) are shown, along with the MSST and the approximate probability of the stock being overfished in the terminal year. For F, stock status with respect to MSY in 2011 (2005 for continuity run and respective year for retrospective runs) and as the geometric mean of 2009-2011 values (2003-2005 for continuity run and 2008-2010 for retrospective 2010 run, etc.) are shown, along with the approximate probability of overfishing occurring in the terminal year.

| Run | SSF | | | | F | | | |
|---|--|------|-----------------------------------|--|------------------------------------|------------------------------------|----------|--|
| | SSF _{CUR} /SSF _{MSY} | MSST | P _{CUR} (Not overfished) | Geo mean | F _{CUR} /F _{MSY} | P _{CUR} (Not overfishing) | Geo mean | F _{(CUR-2) - CUR} /F _{MSY} |
| | | | | SSF _{(CUR-2) - CUR} /SSF _{MSY} | | | | |
| Base (eq wt) | 1.66 | 0.77 | 0.96 | 1.59 | 0.33 | 0.54 | 0.37 | |
| Base (inv CV) | 1.73 | 0.77 | 0.98 | 1.67 | 0.34 | 0.54 | 0.38 | |
| Base (ranks) | 1.57 | 0.77 | 0.94 | 1.50 | 0.34 | 0.55 | 0.39 | |
| Increasing indices | 1.83 | 0.77 | 0.98 | 1.76 | 0.27 | 0.67 | 0.30 | |
| Decreasing indices | 0.40 | 0.77 | 0.32 | 0.39 | 1.06 | 0.26 | 1.31 | |
| Low catch | 2.04 | 0.77 | 0.99 | 2.00 | 0.25 | 0.65 | 0.27 | |
| Hierarchical log sel | 2.41 | 0.77 | 0.87 | 2.38 | 0.13 | 0.79 | 0.14 | |
| Hierarchical dex sel | 1.40 | 0.77 | 0.91 | 1.32 | 0.36 | 0.53 | 0.43 | |
| SEAMAP-SA | 2.05 | 0.77 | 0.96 | 1.99 | 0.21 | 0.77 | 0.24 | |
| No indices | 2.88 | 0.77 | 0.99 | 2.87 | 0.03 | 0.97 | 0.03 | |
| Start 1972 | 1.68 | 0.77 | 0.99 | 1.63 | 0.33 | 0.93 | 0.39 | |
| High prod | 1.83 | 0.79 | 0.98 | 1.79 | 0.33 | 0.56 | 0.36 | |
| Low prod | 1.55 | 0.74 | 0.97 | 1.49 | 0.37 | 0.54 | 0.41 | |
| GOM stock | 1.01 | 0.74 | 0.85 | 0.95 | 0.57 | 0.41 | 0.61 | |
| ATL stock | 2.07 | 0.77 | 0.98 | 2.05 | 0.23 | 0.67 | 0.27 | |
| Continuity | 1.17 | 0.70 | 0.91 | 1.16 | 0.85 | 0.30 | 0.82 | |
| Retrospective 2010 | 1.68 | 0.77 | 0.98 | 1.61 | 0.34 | 0.58 | 0.35 | |
| Retrospective 2009 | 1.60 | 0.77 | 0.97 | 1.52 | 0.40 | 0.58 | 0.37 | |
| Retrospective 2008 | 1.49 | 0.77 | 0.95 | 1.43 | 0.36 | 0.57 | 0.44 | |
| Retrospective 2007 | 1.39 | 0.77 | 0.94 | 1.34 | 0.53 | 0.44 | 0.58 | |
| <hr/> | | | | | | | | |
| * Start 1972 run with MCMC | | | | | | | | |
| * CUR = 2011 in all cases, except for continuity (2005) and retrospective (2010, 2009, 2008 or 2007) runs | | | | | | | | |

Table 3.5.22. Stock projection information.

| Projection information | Value |
|---|---|
| First projection year | 2012 |
| End projection year | 2041 (30 years) (One generation is cf., 5.3 years) |
| Interim projection years at current fishing mortality rate | 2012, 2013, 2014 (3 years) |
| Projection criteria (Iteratively solve for annual fishing mortality at a fixed level of total removals due to fishing) | Fixed removals (2015-2041) |
| Alternative levels | Fixed removals (1000s) |
| 1 | 0 |
| 2 | 250 |
| 3 | 500 |
| 4 | 750 |
| 5 | 1000 |
| 6 | 1250 |
| 7 | 1500 |
| 8 | 1750 |
| 9 | 2000 |
| 10 | 2250 |
| 11 | 2500 |
| 12 | 2750 |
| 13 | 3000 |
| 14 | 3250 |
| 15 | 3500 |
| 16 | 3750 |
| 17 | 4000 |
| 18 | 4250 |
| 19 | 4500 |
| 20 | 4750 |
| 21 | 5000 |

Table 3.5.23. Examples from each projection scenario are provided for a given fixed level of total annual removals due to fishing (1,000s of sharks) during the years (2015 – 2041) which resulted in both the $\text{Pr}(\text{SSF}_t > \text{SSF}_{\text{MSY}}) \geq 70\%$, and the $\text{Pr}(F_t > F_{\text{MSY}}) \leq 30\%$ in the year 2041 from 10,000 Monte Carlo bootstrap projections.

| Projection scenario | SSASPM configuration | MSY (1000s) | Example of fixed removals (1,000s) | Buffer from MSY (% Decrease) |
|------------------------|--|-------------|------------------------------------|------------------------------|
| 1 | Baseline, Inverse CV Weighting | 3060 | 2750 | 10% |
| 2 | Sensitivity, Increasing Indices | 3230 | 2750 | 15% |
| 3 | Sensitivity, Decreasing Indices | 2540 | 1000 | 61% |
| 4 | Sensitivity, Low Catch | 770 | 500 | 35% |
| 5.1 | Sensitivity, Hierarchical Index (log) | 5890 | 2500 | 58% |
| 5.2 | Sensitivity, Hierarchical Index (db exp) | 2790 | 2250 | 19% |
| 6* | Sensitivity, Model Start in 1972 | 2970 | 3000 | -1% |
| 7 | Sensitivity, High Productivity | 3140 | 2750 | 12% |
| 8 | Sensitivity, Low Productivity | 2890 | 2500 | 13% |
| 9 | Sensitivity, SEAMAP-SA | 3950 | 1750 | 56% |
| 10 | Sensitivity, Gulf of Mexico Stock | 2610 | 2000 | 23% |
| 11 | Sensitivity, Atlantic Stock | 689 | 250 | 64% |
| Median buffer from MSY | | | | 23% |
| Mean buffer from MSY | | | | 33% |

*Some model parameters were fixed within the SASSPM sensitivity configuration, Model Start in 1972, which resulted in an unreasonably small buffer for Projection scenario-6.

Table 3.5.24. Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel A. Projection Scenario-1 (Baseline, Inverse CV Weighting)

| Alternative levels | Fixed removals (1,000s) | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
|--------------------|-------------------------|------|------|------|------|------|------|------|------|------|------|
| 1 | 0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2 | 250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 3 | 500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 4 | 750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 5 | 1000 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 6 | 1250 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 | 0.98 | 0.98 |
| 7 | 1500 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.97 | 0.97 | 0.97 | 0.97 |
| 8 | 1750 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| 9 | 2000 | 0.94 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.92 | 0.92 | 0.92 | 0.92 |
| 10 | 2250 | 0.89 | 0.89 | 0.88 | 0.88 | 0.88 | 0.87 | 0.87 | 0.86 | 0.86 | 0.86 |
| 11 | 2500 | 0.84 | 0.83 | 0.82 | 0.82 | 0.81 | 0.80 | 0.80 | 0.79 | 0.79 | 0.78 |
| 12 | 2750 | 0.77 | 0.76 | 0.75 | 0.74 | 0.73 | 0.73 | 0.72 | 0.71 | 0.70 | 0.70 |
| 13 | 3000 | 0.67 | 0.66 | 0.65 | 0.64 | 0.63 | 0.62 | 0.61 | 0.60 | 0.60 | 0.59 |
| 14 | 3250 | 0.58 | 0.56 | 0.55 | 0.54 | 0.52 | 0.51 | 0.50 | 0.49 | 0.48 | 0.47 |
| 15 | 3500 | 0.47 | 0.45 | 0.44 | 0.43 | 0.41 | 0.40 | 0.39 | 0.38 | 0.37 | 0.36 |
| 16 | 3750 | 0.38 | 0.36 | 0.34 | 0.33 | 0.32 | 0.31 | 0.30 | 0.29 | 0.28 | 0.28 |
| 17 | 4000 | 0.28 | 0.26 | 0.25 | 0.24 | 0.22 | 0.21 | 0.21 | 0.20 | 0.19 | 0.18 |
| 18 | 4250 | 0.20 | 0.19 | 0.17 | 0.16 | 0.16 | 0.15 | 0.14 | 0.13 | 0.13 | 0.12 |
| 19 | 4500 | 0.14 | 0.13 | 0.12 | 0.11 | 0.10 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 |
| 20 | 4750 | 0.10 | 0.09 | 0.09 | 0.08 | 0.07 | 0.07 | 0.06 | 0.06 | 0.06 | 0.05 |
| 21 | 5000 | 0.06 | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel B. Projection Scenario-2 (Sensitivity, Increasing Indices)

| Alternative levels | Fixed removals (1,000s) | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
|--------------------|-------------------------|------|------|------|------|------|------|------|------|------|------|
| 1 | 0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2 | 250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 3 | 500 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 4 | 750 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 5 | 1000 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| 6 | 1250 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| 7 | 1500 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.94 | 0.94 |
| 8 | 1750 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| 9 | 2000 | 0.90 | 0.89 | 0.89 | 0.89 | 0.88 | 0.88 | 0.88 | 0.88 | 0.87 | 0.87 |
| 10 | 2250 | 0.86 | 0.86 | 0.85 | 0.85 | 0.85 | 0.84 | 0.84 | 0.84 | 0.83 | 0.83 |
| 11 | 2500 | 0.82 | 0.81 | 0.80 | 0.80 | 0.79 | 0.79 | 0.78 | 0.78 | 0.77 | 0.77 |
| 12 | 2750 | 0.76 | 0.75 | 0.75 | 0.74 | 0.73 | 0.73 | 0.72 | 0.72 | 0.71 | 0.71 |
| 13 | 3000 | 0.70 | 0.69 | 0.68 | 0.67 | 0.66 | 0.65 | 0.65 | 0.64 | 0.63 | 0.63 |
| 14 | 3250 | 0.63 | 0.62 | 0.61 | 0.60 | 0.59 | 0.58 | 0.57 | 0.57 | 0.56 | 0.55 |
| 15 | 3500 | 0.56 | 0.54 | 0.53 | 0.52 | 0.51 | 0.50 | 0.49 | 0.48 | 0.48 | 0.47 |
| 16 | 3750 | 0.48 | 0.47 | 0.46 | 0.44 | 0.43 | 0.42 | 0.42 | 0.41 | 0.40 | 0.39 |
| 17 | 4000 | 0.41 | 0.40 | 0.39 | 0.37 | 0.37 | 0.35 | 0.35 | 0.34 | 0.33 | 0.33 |
| 18 | 4250 | 0.34 | 0.33 | 0.32 | 0.30 | 0.29 | 0.28 | 0.28 | 0.27 | 0.26 | 0.26 |
| 19 | 4500 | 0.27 | 0.26 | 0.25 | 0.23 | 0.22 | 0.21 | 0.21 | 0.20 | 0.20 | 0.19 |
| 20 | 4750 | 0.23 | 0.22 | 0.20 | 0.19 | 0.18 | 0.18 | 0.17 | 0.16 | 0.16 | 0.15 |
| 21 | 5000 | 0.18 | 0.16 | 0.15 | 0.14 | 0.14 | 0.13 | 0.12 | 0.12 | 0.11 | 0.11 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel C. Projection Scenario-3 (Sensitivity, Decreasing Indices)

| Alternative levels | Fixed removals (1,000s) | Fixed | | | | | | | | | |
|--------------------|-------------------------|-------|------|------|------|------|------|------|------|------|------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | 0.95 | 0.96 | 0.97 | 0.97 | 0.98 | 0.98 | 0.98 | 0.98 | 0.99 | 0.99 |
| 2 | 250 | 0.87 | 0.88 | 0.89 | 0.89 | 0.89 | 0.90 | 0.90 | 0.91 | 0.91 | 0.91 |
| 3 | 500 | 0.80 | 0.81 | 0.81 | 0.82 | 0.82 | 0.83 | 0.83 | 0.83 | 0.84 | 0.84 |
| 4 | 750 | 0.76 | 0.76 | 0.76 | 0.77 | 0.77 | 0.77 | 0.78 | 0.78 | 0.78 | 0.78 |
| 5 | 1000 | 0.70 | 0.71 | 0.72 | 0.72 | 0.72 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 |
| 6 | 1250 | 0.64 | 0.65 | 0.65 | 0.66 | 0.66 | 0.67 | 0.67 | 0.67 | 0.68 | 0.68 |
| 7 | 1500 | 0.56 | 0.57 | 0.58 | 0.58 | 0.59 | 0.59 | 0.59 | 0.60 | 0.60 | 0.60 |
| 8 | 1750 | 0.48 | 0.49 | 0.49 | 0.50 | 0.50 | 0.50 | 0.51 | 0.51 | 0.51 | 0.51 |
| 9 | 2000 | 0.40 | 0.40 | 0.41 | 0.41 | 0.41 | 0.42 | 0.42 | 0.42 | 0.42 | 0.43 |
| 10 | 2250 | 0.31 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.33 |
| 11 | 2500 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| 12 | 2750 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 |
| 13 | 3000 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| 14 | 3250 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 |
| 15 | 3500 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 16 | 3750 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 17 | 4000 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 18 | 4250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 19 | 4500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 | 4750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 | 5000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel D. Projection Scenario-4 (Sensitivity, Low Catch)

| Alternative levels | Fixed removals (1,000s) | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
|--------------------|-------------------------|------|------|------|------|------|------|------|------|------|------|
| 1 | 0 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| 2 | 250 | 0.90 | 0.89 | 0.89 | 0.89 | 0.89 | 0.89 | 0.89 | 0.89 | 0.88 | 0.88 |
| 3 | 500 | 0.77 | 0.77 | 0.76 | 0.75 | 0.75 | 0.75 | 0.74 | 0.74 | 0.74 | 0.73 |
| 4 | 750 | 0.59 | 0.58 | 0.58 | 0.57 | 0.56 | 0.56 | 0.55 | 0.55 | 0.54 | 0.54 |
| 5 | 1000 | 0.39 | 0.38 | 0.37 | 0.36 | 0.36 | 0.35 | 0.34 | 0.34 | 0.33 | 0.33 |
| 6 | 1250 | 0.23 | 0.22 | 0.22 | 0.21 | 0.20 | 0.20 | 0.19 | 0.19 | 0.18 | 0.18 |
| 7 | 1500 | 0.11 | 0.10 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 |
| 8 | 1750 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 9 | 2000 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 10 | 2250 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | 2500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 12 | 2750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13 | 3000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 14 | 3250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 3500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 16 | 3750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 17 | 4000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 18 | 4250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 19 | 4500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 | 4750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 | 5000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel E. Projection Scenario-5.1 (Sensitivity, Hierarchical Index log)

| Alternative levels | Fixed removals (1,000s) | Fixed | | | | | | | | | |
|--------------------|-------------------------|-------|------|------|------|------|------|------|------|------|------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | 0.83 | 0.83 | 0.83 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 |
| 2 | 250 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 |
| 3 | 500 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.80 |
| 4 | 750 | 0.80 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.78 | 0.78 |
| 5 | 1000 | 0.78 | 0.78 | 0.78 | 0.78 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 |
| 6 | 1250 | 0.78 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.76 | 0.76 | 0.76 |
| 7 | 1500 | 0.77 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.75 | 0.75 | 0.75 | 0.75 |
| 8 | 1750 | 0.76 | 0.76 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.74 | 0.74 |
| 9 | 2000 | 0.74 | 0.74 | 0.74 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 |
| 10 | 2250 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 |
| 11 | 2500 | 0.73 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.71 | 0.71 | 0.71 | 0.71 |
| 12 | 2750 | 0.71 | 0.71 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.69 | 0.69 | 0.69 |
| 13 | 3000 | 0.70 | 0.70 | 0.70 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 |
| 14 | 3250 | 0.68 | 0.68 | 0.68 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.66 |
| 15 | 3500 | 0.67 | 0.67 | 0.67 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.65 | 0.65 |
| 16 | 3750 | 0.67 | 0.67 | 0.66 | 0.66 | 0.66 | 0.66 | 0.65 | 0.65 | 0.65 | 0.65 |
| 17 | 4000 | 0.66 | 0.65 | 0.65 | 0.65 | 0.65 | 0.64 | 0.64 | 0.64 | 0.64 | 0.64 |
| 18 | 4250 | 0.65 | 0.64 | 0.64 | 0.64 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 |
| 19 | 4500 | 0.64 | 0.64 | 0.64 | 0.63 | 0.63 | 0.63 | 0.63 | 0.62 | 0.62 | 0.62 |
| 20 | 4750 | 0.63 | 0.63 | 0.62 | 0.62 | 0.62 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 |
| 21 | 5000 | 0.61 | 0.61 | 0.61 | 0.60 | 0.60 | 0.60 | 0.60 | 0.59 | 0.59 | 0.59 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), $\Pr(SSF_t > SSF_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \geq 70\%$, Yellow $70\% > \Pr \geq 50\%$, Red $\Pr < 50\%$.

Panel F. Projection Scenario-5.2 (Sensitivity, Hierarchical Index db exp)

| Alternative levels | Fixed removals 1,000s | Projected Probabilities ($\Pr(SSF_t > SSF_{MSY})$) by Year | | | | | | | | | |
|--------------------|--------------------------|--|------|------|------|------|------|------|------|------|------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2 | 250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 3 | 500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 4 | 750 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 5 | 1000 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 6 | 1250 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| 7 | 1500 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.96 | 0.96 | 0.96 | 0.96 |
| 8 | 1750 | 0.94 | 0.94 | 0.94 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| 9 | 2000 | 0.89 | 0.89 | 0.89 | 0.89 | 0.88 | 0.88 | 0.88 | 0.87 | 0.87 | 0.87 |
| 10 | 2250 | 0.83 | 0.82 | 0.82 | 0.81 | 0.81 | 0.81 | 0.80 | 0.80 | 0.80 | 0.79 |
| 11 | 2500 | 0.73 | 0.73 | 0.72 | 0.71 | 0.70 | 0.70 | 0.69 | 0.69 | 0.68 | 0.67 |
| 12 | 2750 | 0.62 | 0.61 | 0.60 | 0.59 | 0.58 | 0.57 | 0.57 | 0.56 | 0.55 | 0.54 |
| 13 | 3000 | 0.50 | 0.48 | 0.47 | 0.46 | 0.45 | 0.44 | 0.43 | 0.42 | 0.41 | 0.41 |
| 14 | 3250 | 0.38 | 0.37 | 0.35 | 0.34 | 0.32 | 0.32 | 0.31 | 0.30 | 0.29 | 0.28 |
| 15 | 3500 | 0.27 | 0.26 | 0.25 | 0.23 | 0.22 | 0.21 | 0.20 | 0.20 | 0.19 | 0.18 |
| 16 | 3750 | 0.17 | 0.16 | 0.15 | 0.14 | 0.14 | 0.13 | 0.12 | 0.12 | 0.11 | 0.11 |
| 17 | 4000 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.06 | 0.06 |
| 18 | 4250 | 0.06 | 0.06 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| 19 | 4500 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| 20 | 4750 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 21 | 5000 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel G. Projection Scenario-6 (Sensitivity, Model Start in 1972)

| Alternative levels | Fixed removals (1,000s) | Fixed removals (1,000s) | | | | | | | | | |
|--------------------|-------------------------|-------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 |
| 2 | 250 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 |
| 3 | 500 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 |
| 4 | 750 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 |
| 5 | 1000 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 |
| 6 | 1250 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 |
| 7 | 1500 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 |
| 8 | 1750 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 |
| 9 | 2000 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 | >=0.99 |
| 10 | 2250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 11 | 2500 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 12 | 2750 | 0.98 | 0.98 | 0.97 | 0.96 | 0.96 | 0.95 | 0.94 | 0.94 | 0.93 | 0.92 |
| 13 | 3000 | 0.91 | 0.90 | 0.88 | 0.86 | 0.84 | 0.82 | 0.80 | 0.78 | 0.76 | 0.74 |
| 14 | 3250 | 0.74 | 0.70 | 0.67 | 0.63 | 0.59 | 0.56 | 0.53 | 0.50 | 0.48 | 0.45 |
| 15 | 3500 | 0.47 | 0.42 | 0.38 | 0.34 | 0.31 | 0.28 | 0.25 | 0.23 | 0.21 | 0.19 |
| 16 | 3750 | 0.22 | 0.18 | 0.15 | 0.13 | 0.11 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 |
| 17 | 4000 | 0.07 | 0.05 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| 18 | 4250 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 19 | 4500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 | 4750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 | 5000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel H. Projection Scenario-7 (Sensitivity, High Productivity)

| Alternative levels | Fixed removals (1,000s) | Fixed | | | | | | | | | |
|--------------------|-------------------------|-------|------|------|------|------|------|------|------|------|------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2 | 250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 3 | 500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 4 | 750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 5 | 1000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 6 | 1250 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 7 | 1500 | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| 8 | 1750 | 0.98 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| 9 | 2000 | 0.95 | 0.95 | 0.95 | 0.95 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 |
| 10 | 2250 | 0.92 | 0.92 | 0.92 | 0.91 | 0.91 | 0.91 | 0.90 | 0.90 | 0.90 | 0.89 |
| 11 | 2500 | 0.88 | 0.87 | 0.87 | 0.86 | 0.85 | 0.85 | 0.84 | 0.84 | 0.84 | 0.83 |
| 12 | 2750 | 0.80 | 0.79 | 0.78 | 0.77 | 0.77 | 0.76 | 0.75 | 0.74 | 0.74 | 0.73 |
| 13 | 3000 | 0.72 | 0.71 | 0.69 | 0.68 | 0.67 | 0.66 | 0.65 | 0.64 | 0.63 | 0.63 |
| 14 | 3250 | 0.62 | 0.61 | 0.59 | 0.58 | 0.57 | 0.55 | 0.54 | 0.54 | 0.53 | 0.52 |
| 15 | 3500 | 0.51 | 0.49 | 0.48 | 0.47 | 0.45 | 0.44 | 0.43 | 0.42 | 0.41 | 0.40 |
| 16 | 3750 | 0.41 | 0.39 | 0.37 | 0.36 | 0.34 | 0.33 | 0.32 | 0.31 | 0.30 | 0.29 |
| 17 | 4000 | 0.30 | 0.29 | 0.27 | 0.26 | 0.24 | 0.24 | 0.22 | 0.22 | 0.21 | 0.20 |
| 18 | 4250 | 0.22 | 0.20 | 0.19 | 0.17 | 0.16 | 0.15 | 0.14 | 0.13 | 0.13 | 0.12 |
| 19 | 4500 | 0.14 | 0.13 | 0.12 | 0.11 | 0.10 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 |
| 20 | 4750 | 0.10 | 0.09 | 0.08 | 0.07 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 | 0.04 |
| 21 | 5000 | 0.06 | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel I. Projection Scenario-8 (Sensitivity, Low Productivity)

| Alternative levels | Fixed removals (1,000s) | Fixed removals (1,000s) | | | | | | | | | |
|--------------------|-------------------------|-------------------------|------|------|------|------|------|------|------|------|------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2 | 250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 3 | 500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 4 | 750 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 5 | 1000 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 6 | 1250 | 0.98 | 0.98 | 0.98 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| 7 | 1500 | 0.96 | 0.96 | 0.96 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| 8 | 1750 | 0.93 | 0.93 | 0.93 | 0.93 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| 9 | 2000 | 0.89 | 0.89 | 0.89 | 0.88 | 0.88 | 0.87 | 0.87 | 0.87 | 0.87 | 0.87 |
| 10 | 2250 | 0.85 | 0.84 | 0.84 | 0.83 | 0.83 | 0.82 | 0.82 | 0.81 | 0.81 | 0.81 |
| 11 | 2500 | 0.77 | 0.76 | 0.75 | 0.75 | 0.74 | 0.73 | 0.73 | 0.73 | 0.72 | 0.72 |
| 12 | 2750 | 0.69 | 0.68 | 0.67 | 0.66 | 0.65 | 0.65 | 0.64 | 0.63 | 0.63 | 0.62 |
| 13 | 3000 | 0.61 | 0.60 | 0.59 | 0.58 | 0.57 | 0.56 | 0.55 | 0.54 | 0.54 | 0.53 |
| 14 | 3250 | 0.51 | 0.49 | 0.48 | 0.47 | 0.45 | 0.45 | 0.44 | 0.43 | 0.42 | 0.41 |
| 15 | 3500 | 0.41 | 0.40 | 0.38 | 0.37 | 0.36 | 0.35 | 0.34 | 0.33 | 0.33 | 0.32 |
| 16 | 3750 | 0.33 | 0.31 | 0.30 | 0.29 | 0.27 | 0.27 | 0.26 | 0.25 | 0.24 | 0.23 |
| 17 | 4000 | 0.25 | 0.24 | 0.22 | 0.21 | 0.20 | 0.19 | 0.19 | 0.18 | 0.17 | 0.16 |
| 18 | 4250 | 0.18 | 0.17 | 0.16 | 0.15 | 0.14 | 0.14 | 0.13 | 0.12 | 0.11 | 0.11 |
| 19 | 4500 | 0.12 | 0.11 | 0.10 | 0.10 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 |
| 20 | 4750 | 0.09 | 0.08 | 0.07 | 0.06 | 0.06 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 |
| 21 | 5000 | 0.06 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel J. Projection Scenario-9 (Sensitivity, SEAMAP-SA)

| Alternative levels | Fixed removals (1,000s) | Fixed removals (1,000s) | | | | | | | | | |
|--------------------|-------------------------|-------------------------|------|------|------|------|------|------|------|------|------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | 0.84 | 0.84 | 0.84 | 0.84 | 0.84 | 0.84 | 0.84 | 0.84 | 0.84 | 0.84 |
| 2 | 250 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 |
| 3 | 500 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| 4 | 750 | 0.79 | 0.79 | 0.78 | 0.78 | 0.78 | 0.78 | 0.78 | 0.78 | 0.78 | 0.78 |
| 5 | 1000 | 0.77 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| 6 | 1250 | 0.75 | 0.75 | 0.75 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 |
| 7 | 1500 | 0.73 | 0.73 | 0.73 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 |
| 8 | 1750 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.70 | 0.70 | 0.70 |
| 9 | 2000 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 |
| 10 | 2250 | 0.69 | 0.69 | 0.69 | 0.69 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 |
| 11 | 2500 | 0.67 | 0.67 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.65 | 0.65 |
| 12 | 2750 | 0.65 | 0.65 | 0.65 | 0.64 | 0.64 | 0.64 | 0.64 | 0.64 | 0.64 | 0.63 |
| 13 | 3000 | 0.64 | 0.64 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.62 | 0.62 | 0.62 |
| 14 | 3250 | 0.63 | 0.62 | 0.62 | 0.62 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.60 |
| 15 | 3500 | 0.61 | 0.60 | 0.60 | 0.60 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.58 |
| 16 | 3750 | 0.59 | 0.59 | 0.58 | 0.58 | 0.58 | 0.58 | 0.57 | 0.57 | 0.57 | 0.57 |
| 17 | 4000 | 0.57 | 0.57 | 0.57 | 0.56 | 0.56 | 0.56 | 0.56 | 0.55 | 0.55 | 0.55 |
| 18 | 4250 | 0.57 | 0.56 | 0.56 | 0.56 | 0.55 | 0.55 | 0.55 | 0.55 | 0.54 | 0.54 |
| 19 | 4500 | 0.54 | 0.54 | 0.53 | 0.53 | 0.53 | 0.53 | 0.52 | 0.52 | 0.52 | 0.52 |
| 20 | 4750 | 0.52 | 0.51 | 0.51 | 0.51 | 0.50 | 0.50 | 0.50 | 0.49 | 0.49 | 0.49 |
| 21 | 5000 | 0.51 | 0.50 | 0.50 | 0.50 | 0.49 | 0.49 | 0.49 | 0.49 | 0.48 | 0.48 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), Pr(SSF_t > SSF_{MSY}), for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel K. Projection Scenario-10 (Sensitivity, Gulf of Mexico Stock)

| Alternative levels | Fixed removals (1,000s) | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
|--------------------|-------------------------|------|------|------|------|------|------|------|------|------|------|
| 1 | 0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2 | 250 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 3 | 500 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| 4 | 750 | 0.96 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| 5 | 1000 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| 6 | 1250 | 0.92 | 0.92 | 0.92 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| 7 | 1500 | 0.87 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 |
| 8 | 1750 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.82 | 0.82 | 0.82 |
| 9 | 2000 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 |
| 10 | 2250 | 0.62 | 0.62 | 0.62 | 0.62 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 |
| 11 | 2500 | 0.50 | 0.50 | 0.49 | 0.49 | 0.49 | 0.48 | 0.48 | 0.48 | 0.48 | 0.47 |
| 12 | 2750 | 0.39 | 0.38 | 0.38 | 0.37 | 0.37 | 0.37 | 0.36 | 0.36 | 0.36 | 0.35 |
| 13 | 3000 | 0.28 | 0.28 | 0.27 | 0.27 | 0.26 | 0.26 | 0.25 | 0.25 | 0.25 | 0.24 |
| 14 | 3250 | 0.20 | 0.19 | 0.19 | 0.18 | 0.18 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 |
| 15 | 3500 | 0.12 | 0.12 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | 0.09 | 0.09 | 0.09 |
| 16 | 3750 | 0.08 | 0.07 | 0.07 | 0.07 | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 |
| 17 | 4000 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 |
| 18 | 4250 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| 19 | 4500 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| 20 | 4750 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 | 5000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 3.5.24 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce MSY (SSF_{MSY}), $\Pr(SSF_t > SSF_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \geq 70\%$, Yellow $70\% > \Pr \geq 50\%$, Red $\Pr < 50\%$.

Panel L. Projection Scenario-11 (Sensitivity, Atlantic Stock)

| Alternative levels | Fixed removals (1,000s) | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
|--------------------|-------------------------|------|------|------|------|------|------|------|------|------|------|
| 1 | 0 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| 2 | 250 | 0.81 | 0.80 | 0.80 | 0.80 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| 3 | 500 | 0.67 | 0.67 | 0.67 | 0.66 | 0.66 | 0.65 | 0.65 | 0.65 | 0.65 | 0.64 |
| 4 | 750 | 0.53 | 0.52 | 0.51 | 0.51 | 0.50 | 0.50 | 0.49 | 0.48 | 0.48 | 0.48 |
| 5 | 1000 | 0.38 | 0.38 | 0.37 | 0.36 | 0.36 | 0.35 | 0.34 | 0.34 | 0.34 | 0.33 |
| 6 | 1250 | 0.27 | 0.26 | 0.25 | 0.24 | 0.24 | 0.23 | 0.23 | 0.22 | 0.22 | 0.22 |
| 7 | 1500 | 0.17 | 0.17 | 0.16 | 0.15 | 0.15 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 |
| 8 | 1750 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 | 0.07 |
| 9 | 2000 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| 10 | 2250 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 11 | 2500 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 12 | 2750 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13 | 3000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 14 | 3250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 3500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 16 | 3750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 17 | 4000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 18 | 4250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 19 | 4500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 | 4750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 | 5000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 3.5.25. Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel A. Projection Scenario-1 (Baseline, Inverse CV Weighting)

| Alternative levels | Fixed removals (1,000s) | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
|--------------------|-------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1 | 0 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 2 | 250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 1000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 1250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 7 | 1500 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 8 | 1750 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 9 | 2000 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 |
| 10 | 2250 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.10 | 0.10 | 0.10 |
| 11 | 2500 | 0.14 | 0.14 | 0.15 | 0.15 | 0.16 | 0.16 | 0.17 | 0.17 | 0.18 | 0.18 |
| 12 | 2750 | 0.23 | 0.23 | 0.24 | 0.25 | 0.26 | 0.26 | 0.27 | 0.27 | 0.28 | 0.28 |
| 13 | 3000 | 0.36 | 0.37 | 0.37 | 0.38 | 0.39 | 0.40 | 0.40 | 0.41 | 0.42 | 0.42 |
| 14 | 3250 | 0.50 | 0.51 | 0.52 | 0.52 | 0.53 | 0.54 | 0.55 | 0.55 | 0.56 | 0.56 |
| 15 | 3500 | 0.64 | 0.65 | 0.66 | 0.67 | 0.67 | 0.68 | 0.69 | 0.69 | 0.70 | 0.70 |
| 16 | 3750 | 0.75 | 0.76 | 0.77 | 0.77 | 0.78 | 0.78 | 0.79 | 0.79 | 0.80 | 0.80 |
| 17 | 4000 | 0.86 | 0.86 | 0.87 | 0.87 | 0.87 | 0.88 | 0.88 | 0.88 | 0.88 | 0.89 |
| 18 | 4250 | 0.92 | 0.92 | 0.92 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.94 | 0.94 |
| 19 | 4500 | 0.96 | 0.96 | 0.96 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| 20 | 4750 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| 21 | 5000 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel B. Projection Scenario-2 (Sensitivity, Increasing Indices)

| Alternative levels | Fixed removals (1,000s) | Projected Probability of Exceeding MSY (F_{MSY}) | | | | | | | | | |
|--------------------|-------------------------|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 2 | 250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 1000 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 6 | 1250 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 7 | 1500 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 8 | 1750 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 9 | 2000 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 |
| 10 | 2250 | 0.10 | 0.10 | 0.10 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.13 |
| 11 | 2500 | 0.15 | 0.16 | 0.16 | 0.17 | 0.17 | 0.17 | 0.18 | 0.18 | 0.19 | 0.19 |
| 12 | 2750 | 0.22 | 0.23 | 0.23 | 0.24 | 0.25 | 0.25 | 0.26 | 0.26 | 0.26 | 0.27 |
| 13 | 3000 | 0.31 | 0.32 | 0.32 | 0.33 | 0.34 | 0.34 | 0.35 | 0.36 | 0.36 | 0.37 |
| 14 | 3250 | 0.41 | 0.42 | 0.42 | 0.43 | 0.43 | 0.44 | 0.45 | 0.45 | 0.46 | 0.46 |
| 15 | 3500 | 0.51 | 0.52 | 0.53 | 0.54 | 0.54 | 0.55 | 0.56 | 0.56 | 0.57 | 0.57 |
| 16 | 3750 | 0.61 | 0.62 | 0.63 | 0.64 | 0.64 | 0.65 | 0.65 | 0.65 | 0.66 | 0.66 |
| 17 | 4000 | 0.70 | 0.71 | 0.71 | 0.72 | 0.72 | 0.73 | 0.73 | 0.74 | 0.74 | 0.74 |
| 18 | 4250 | 0.79 | 0.79 | 0.80 | 0.80 | 0.81 | 0.81 | 0.81 | 0.82 | 0.82 | 0.82 |
| 19 | 4500 | 0.86 | 0.86 | 0.87 | 0.87 | 0.87 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 |
| 20 | 4750 | 0.90 | 0.90 | 0.90 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.92 | 0.92 |
| 21 | 5000 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.95 | 0.95 | 0.95 | 0.95 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel C. Projection Scenario-3 (Sensitivity, Decreasing Indices)

| Alternative levels | Fixed removals (1,000s) | Projected Probability ($\Pr(F_t > F_{MSY})$) | | | | | | | | | |
|--------------------|-------------------------|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 2 | 250 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| 3 | 500 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| 4 | 750 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| 5 | 1000 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| 6 | 1250 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| 7 | 1500 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| 8 | 1750 | 0.45 | 0.45 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| 9 | 2000 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 |
| 10 | 2250 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 |
| 11 | 2500 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| 12 | 2750 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.85 |
| 13 | 3000 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| 14 | 3250 | 0.97 | 0.97 | 0.97 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| 15 | 3500 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 16 | 3750 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 17 | 4000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 18 | 4250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 19 | 4500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 20 | 4750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 21 | 5000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel D. Projection Scenario-4 (Sensitivity, Low Catch)

| Alternative levels | Fixed removals (1,000s) | Projected Probabilities ($\Pr(F_t > F_{MSY})$) by Year | | | | | | | | | |
|--------------------|-------------------------|--|--------|--------|--------|--------|--------|--------|--------|--------|------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | 0.00 |
| 2 | 250 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 3 | 500 | 0.17 | 0.18 | 0.18 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.21 | 0.21 |
| 4 | 750 | 0.42 | 0.42 | 0.43 | 0.43 | 0.44 | 0.44 | 0.45 | 0.45 | 0.46 | 0.46 |
| 5 | 1000 | 0.70 | 0.70 | 0.71 | 0.71 | 0.71 | 0.71 | 0.72 | 0.72 | 0.72 | 0.73 |
| 6 | 1250 | 0.88 | 0.88 | 0.89 | 0.89 | 0.89 | 0.89 | 0.89 | 0.89 | 0.90 | 0.90 |
| 7 | 1500 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.98 | 0.98 | 0.98 |
| 8 | 1750 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 9 | 2000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 10 | 2250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 11 | 2500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 12 | 2750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 13 | 3000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 14 | 3250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 15 | 3500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 16 | 3750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 17 | 4000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 18 | 4250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 19 | 4500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 20 | 4750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 21 | 5000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel E. Projection Scenario-5.1 (Sensitivity, Hierarchical Index log)

| Alternative levels | Fixed removals (1,000s) | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
|--------------------|-------------------------|------|--------|--------|--------|--------|--------|--------|------|--------|------|
| 1 | 0 | 0.00 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | 0.00 | <=0.01 | 0.00 |
| 2 | 250 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 |
| 3 | 500 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 |
| 4 | 750 | 0.10 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 |
| 5 | 1000 | 0.13 | 0.13 | 0.14 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 |
| 6 | 1250 | 0.14 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 |
| 7 | 1500 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 | 0.17 | 0.17 | 0.18 | 0.18 |
| 8 | 1750 | 0.17 | 0.17 | 0.18 | 0.18 | 0.18 | 0.18 | 0.19 | 0.19 | 0.19 | 0.19 |
| 9 | 2000 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| 10 | 2250 | 0.21 | 0.21 | 0.21 | 0.22 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 |
| 11 | 2500 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.24 | 0.24 | 0.24 | 0.24 |
| 12 | 2750 | 0.24 | 0.25 | 0.25 | 0.25 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.27 |
| 13 | 3000 | 0.25 | 0.25 | 0.26 | 0.26 | 0.26 | 0.26 | 0.27 | 0.27 | 0.27 | 0.27 |
| 14 | 3250 | 0.28 | 0.28 | 0.28 | 0.29 | 0.29 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 |
| 15 | 3500 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.32 |
| 16 | 3750 | 0.30 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.33 |
| 17 | 4000 | 0.32 | 0.33 | 0.33 | 0.33 | 0.33 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |
| 18 | 4250 | 0.33 | 0.34 | 0.34 | 0.34 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.36 |
| 19 | 4500 | 0.35 | 0.35 | 0.35 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 |
| 20 | 4750 | 0.36 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.38 | 0.38 | 0.38 | 0.38 |
| 21 | 5000 | 0.38 | 0.39 | 0.39 | 0.39 | 0.39 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel F. Projection Scenario-5.2 (Sensitivity, Hierarchical Index db exp)

| Alternative Levels | Fixed removals (1,000s) | Projected Probabilities ($\Pr(F_t > F_{MSY})$) by Year | | | | | | | | | |
|-----------------------|-------------------------------|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 2 | 250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 1000 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 6 | 1250 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 7 | 1500 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 8 | 1750 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 9 | 2000 | 0.07 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 |
| 10 | 2250 | 0.13 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.17 |
| 11 | 2500 | 0.25 | 0.25 | 0.26 | 0.27 | 0.27 | 0.28 | 0.29 | 0.29 | 0.30 | 0.30 |
| 12 | 2750 | 0.40 | 0.41 | 0.42 | 0.43 | 0.43 | 0.44 | 0.45 | 0.45 | 0.46 | 0.46 |
| 13 | 3000 | 0.58 | 0.58 | 0.59 | 0.60 | 0.61 | 0.61 | 0.62 | 0.63 | 0.63 | 0.63 |
| 14 | 3250 | 0.73 | 0.74 | 0.75 | 0.75 | 0.76 | 0.76 | 0.77 | 0.77 | 0.78 | 0.78 |
| 15 | 3500 | 0.85 | 0.86 | 0.86 | 0.87 | 0.87 | 0.87 | 0.88 | 0.88 | 0.88 | 0.88 |
| 16 | 3750 | 0.93 | 0.93 | 0.93 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.95 | 0.95 |
| 17 | 4000 | 0.97 | 0.97 | 0.97 | 0.97 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| 18 | 4250 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 19 | 4500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 20 | 4750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 21 | 5000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel G. Projection Scenario-6 (Sensitivity, Model Start in 1972)

| Alternative levels | Fixed removals (1,000s) | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
|--------------------|-------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1 | 0 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 2 | 250 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 3 | 500 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 4 | 750 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 5 | 1000 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 6 | 1250 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 7 | 1500 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 8 | 1750 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 9 | 2000 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 10 | 2250 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | 2500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 12 | 2750 | 0.02 | 0.02 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.06 | 0.06 |
| 13 | 3000 | 0.16 | 0.17 | 0.19 | 0.21 | 0.23 | 0.25 | 0.26 | 0.28 | 0.29 | 0.30 |
| 14 | 3250 | 0.52 | 0.55 | 0.57 | 0.60 | 0.62 | 0.64 | 0.65 | 0.67 | 0.68 | 0.70 |
| 15 | 3500 | 0.86 | 0.88 | 0.89 | 0.90 | 0.91 | 0.91 | 0.92 | 0.93 | 0.93 | 0.94 |
| 16 | 3750 | 0.98 | 0.98 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 17 | 4000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 18 | 4250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 19 | 4500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 20 | 4750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 21 | 5000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel H. Projection Scenario-7 (Sensitivity, High Productivity)

| Alternative levels | Fixed removals (1,000s) | Projected Probability of Exceeding MSY (F_{MSY}) | | | | | | | | | |
|--------------------|-------------------------|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 2 | 250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 1000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 1250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | 1500 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 8 | 1750 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| 9 | 2000 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 |
| 10 | 2250 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 |
| 11 | 2500 | 0.10 | 0.10 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.13 | 0.14 | 0.14 |
| 12 | 2750 | 0.19 | 0.20 | 0.21 | 0.21 | 0.22 | 0.23 | 0.23 | 0.24 | 0.25 | 0.25 |
| 13 | 3000 | 0.31 | 0.32 | 0.33 | 0.34 | 0.35 | 0.35 | 0.36 | 0.37 | 0.37 | 0.38 |
| 14 | 3250 | 0.45 | 0.46 | 0.47 | 0.48 | 0.48 | 0.49 | 0.50 | 0.51 | 0.51 | 0.52 |
| 15 | 3500 | 0.59 | 0.60 | 0.61 | 0.62 | 0.63 | 0.64 | 0.64 | 0.65 | 0.65 | 0.66 |
| 16 | 3750 | 0.73 | 0.73 | 0.74 | 0.75 | 0.75 | 0.76 | 0.77 | 0.77 | 0.77 | 0.78 |
| 17 | 4000 | 0.84 | 0.84 | 0.85 | 0.85 | 0.86 | 0.86 | 0.87 | 0.87 | 0.87 | 0.88 |
| 18 | 4250 | 0.92 | 0.92 | 0.92 | 0.93 | 0.93 | 0.93 | 0.93 | 0.94 | 0.94 | 0.94 |
| 19 | 4500 | 0.95 | 0.95 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| 20 | 4750 | 0.98 | 0.98 | 0.98 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 21 | 5000 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel I. Projection Scenario-8 (Sensitivity, Low Productivity)

| Alternative levels | Fixed removals (1,000s) | Probability of exceeding MSY (F_{MSY}) | | | | | | | | | |
|--------------------|-------------------------|--|--------|--------|--------|--------|--------|--------|--------|------|--------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | 0.00 | <=0.01 |
| 2 | 250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 1000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 1250 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 7 | 1500 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 8 | 1750 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 9 | 2000 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 |
| 10 | 2250 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.13 | 0.13 | 0.14 | 0.14 | 0.15 |
| 11 | 2500 | 0.20 | 0.21 | 0.22 | 0.23 | 0.23 | 0.24 | 0.24 | 0.25 | 0.25 | 0.26 |
| 12 | 2750 | 0.31 | 0.32 | 0.33 | 0.34 | 0.35 | 0.35 | 0.36 | 0.36 | 0.37 | 0.38 |
| 13 | 3000 | 0.44 | 0.44 | 0.45 | 0.46 | 0.47 | 0.47 | 0.48 | 0.49 | 0.49 | 0.50 |
| 14 | 3250 | 0.58 | 0.59 | 0.60 | 0.61 | 0.62 | 0.62 | 0.63 | 0.63 | 0.64 | 0.64 |
| 15 | 3500 | 0.71 | 0.72 | 0.73 | 0.73 | 0.74 | 0.74 | 0.75 | 0.75 | 0.76 | 0.76 |
| 16 | 3750 | 0.81 | 0.82 | 0.82 | 0.83 | 0.83 | 0.83 | 0.84 | 0.84 | 0.84 | 0.84 |
| 17 | 4000 | 0.89 | 0.89 | 0.89 | 0.90 | 0.90 | 0.90 | 0.90 | 0.91 | 0.91 | 0.91 |
| 18 | 4250 | 0.94 | 0.94 | 0.94 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| 19 | 4500 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.98 | 0.98 | 0.98 |
| 20 | 4750 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 21 | 5000 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel J. Projection Scenario-9 (Sensitivity, SEAMAP-SA)

| Alternative levels | Fixed removals (1,000s) | Probability of exceeding MSY (F_{MSY}) | | | | | | | | | |
|--------------------|-------------------------|--|--------|------|--------|--------|--------|------|------|--------|--------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | <=0.01 | <=0.01 | 0.00 | <=0.01 | <=0.01 | <=0.01 | 0.00 | 0.00 | <=0.01 | <=0.01 |
| 2 | 250 | 0.07 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| 3 | 500 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| 4 | 750 | 0.13 | 0.13 | 0.13 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 |
| 5 | 1000 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| 6 | 1250 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| 7 | 1500 | 0.21 | 0.21 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| 8 | 1750 | 0.23 | 0.23 | 0.23 | 0.24 | 0.24 | 0.24 | 0.25 | 0.25 | 0.25 | 0.25 |
| 9 | 2000 | 0.26 | 0.26 | 0.27 | 0.27 | 0.27 | 0.27 | 0.28 | 0.28 | 0.28 | 0.28 |
| 10 | 2250 | 0.27 | 0.28 | 0.28 | 0.28 | 0.28 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| 11 | 2500 | 0.30 | 0.31 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 |
| 12 | 2750 | 0.33 | 0.33 | 0.33 | 0.33 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |
| 13 | 3000 | 0.35 | 0.35 | 0.35 | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| 14 | 3250 | 0.37 | 0.37 | 0.37 | 0.37 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| 15 | 3500 | 0.39 | 0.40 | 0.40 | 0.40 | 0.40 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 |
| 16 | 3750 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| 17 | 4000 | 0.44 | 0.44 | 0.44 | 0.44 | 0.45 | 0.45 | 0.45 | 0.45 | 0.46 | 0.46 |
| 18 | 4250 | 0.45 | 0.45 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.47 | 0.47 |
| 19 | 4500 | 0.48 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.50 |
| 20 | 4750 | 0.51 | 0.52 | 0.52 | 0.52 | 0.52 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 |
| 21 | 5000 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel K. Projection Scenario-10 (Sensitivity, Gulf of Mexico Stock)

| Alternative levels | Fixed removals (1,000s) | Probability of exceeding MSY by year | | | | | | | | | |
|--------------------|-------------------------|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
| 1 | 0 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | <=0.01 |
| 2 | 250 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 500 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 4 | 750 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 5 | 1000 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 6 | 1250 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 7 | 1500 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| 8 | 1750 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| 9 | 2000 | 0.20 | 0.20 | 0.20 | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.22 |
| 10 | 2250 | 0.32 | 0.33 | 0.33 | 0.33 | 0.33 | 0.34 | 0.34 | 0.34 | 0.34 | 0.35 |
| 11 | 2500 | 0.49 | 0.49 | 0.49 | 0.49 | 0.50 | 0.50 | 0.50 | 0.51 | 0.51 | 0.51 |
| 12 | 2750 | 0.64 | 0.64 | 0.65 | 0.65 | 0.65 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 |
| 13 | 3000 | 0.78 | 0.78 | 0.78 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.80 |
| 14 | 3250 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.89 | 0.89 | 0.89 |
| 15 | 3500 | 0.94 | 0.94 | 0.94 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| 16 | 3750 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| 17 | 4000 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 18 | 4250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 19 | 4500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 20 | 4750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 21 | 5000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Table 3.5.25 (continued). Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce MSY (F_{MSY}), $\Pr(F_t > F_{MSY})$, for a given year (2032 – 2041) and a given fixed removals level (1,000s); Green $\Pr \leq 30\%$, Yellow $30\% > \Pr \leq 50\%$, Red $\Pr > 50\%$.

Panel L. Projection Scenario-11 (Sensitivity, Atlantic Stock)

| Alternative Levels | Fixed removals (1,000s) | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 |
|-----------------------|-------------------------------|--------|------|--------|--------|------|--------|--------|--------|--------|------|
| 1 | 0 | <=0.01 | 0.00 | <=0.01 | <=0.01 | 0.00 | <=0.01 | <=0.01 | <=0.01 | <=0.01 | 0.00 |
| 2 | 250 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.13 | 0.13 | 0.13 |
| 3 | 500 | 0.29 | 0.29 | 0.30 | 0.30 | 0.30 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 |
| 4 | 750 | 0.51 | 0.52 | 0.52 | 0.52 | 0.53 | 0.53 | 0.53 | 0.54 | 0.54 | 0.54 |
| 5 | 1000 | 0.71 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.73 | 0.73 | 0.73 | 0.73 |
| 6 | 1250 | 0.85 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 |
| 7 | 1500 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 |
| 8 | 1750 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| 9 | 2000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 10 | 2250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 11 | 2500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 12 | 2750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 13 | 3000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 14 | 3250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 15 | 3500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 16 | 3750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 17 | 4000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 18 | 4250 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 19 | 4500 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 20 | 4750 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 21 | 5000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

3.6. FIGURES

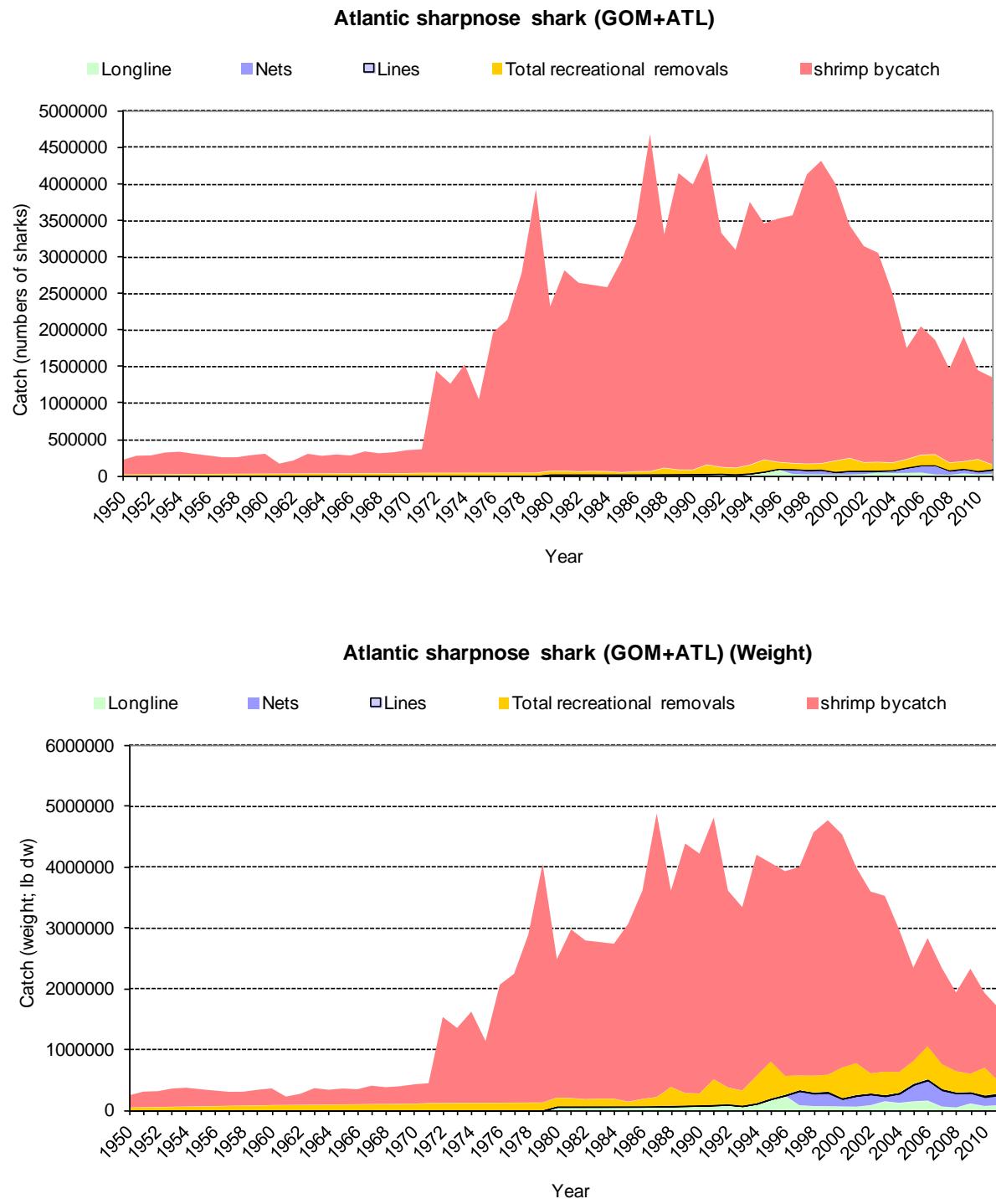


Figure 3.6.1. Catches of Atlantic sharpnose shark by fleet in numbers (top) and weight (lb dw; bottom). Catches are separated into five fleets: commercial bottom longline, gillnet, and line, recreational, and shrimp trawl discards.

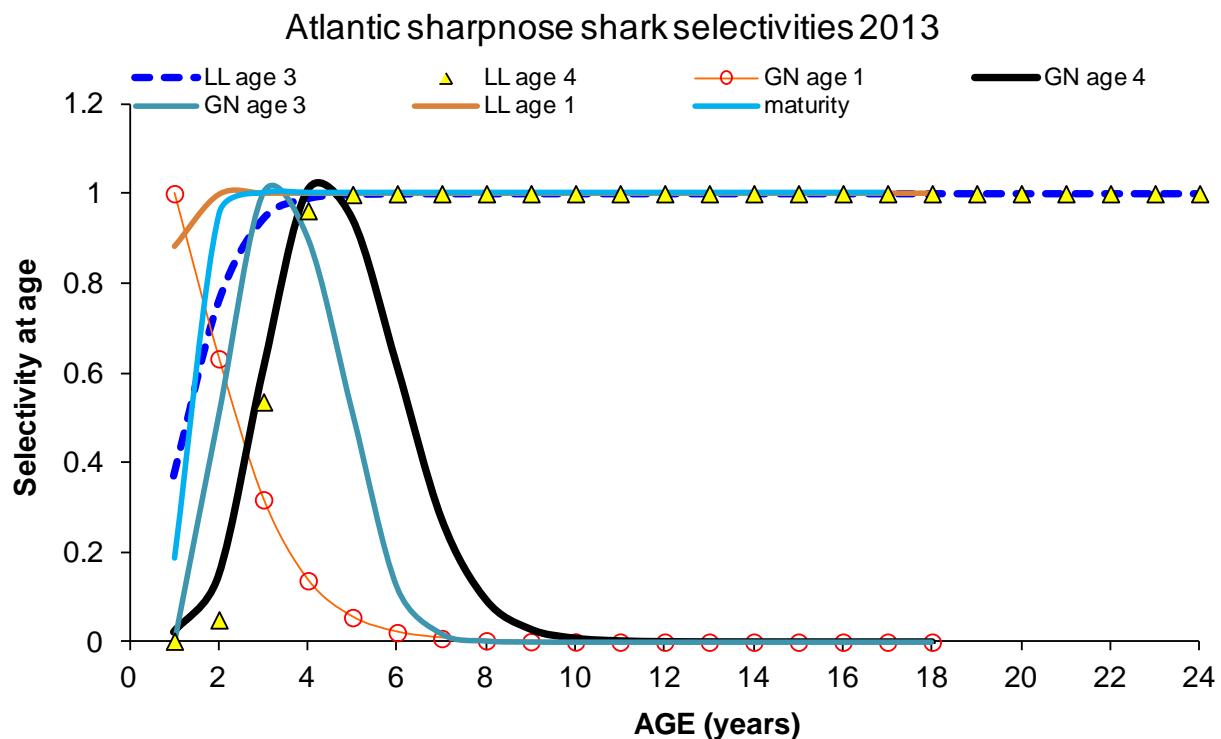


Figure 3.6.2. Selectivity curves for catches and indices of relative abundance used in the baseline run. The maturity ogive has been added for reference. Refer to Table 3.5.2 to see what catch or index of relative abundance series each selectivity curve corresponds to.

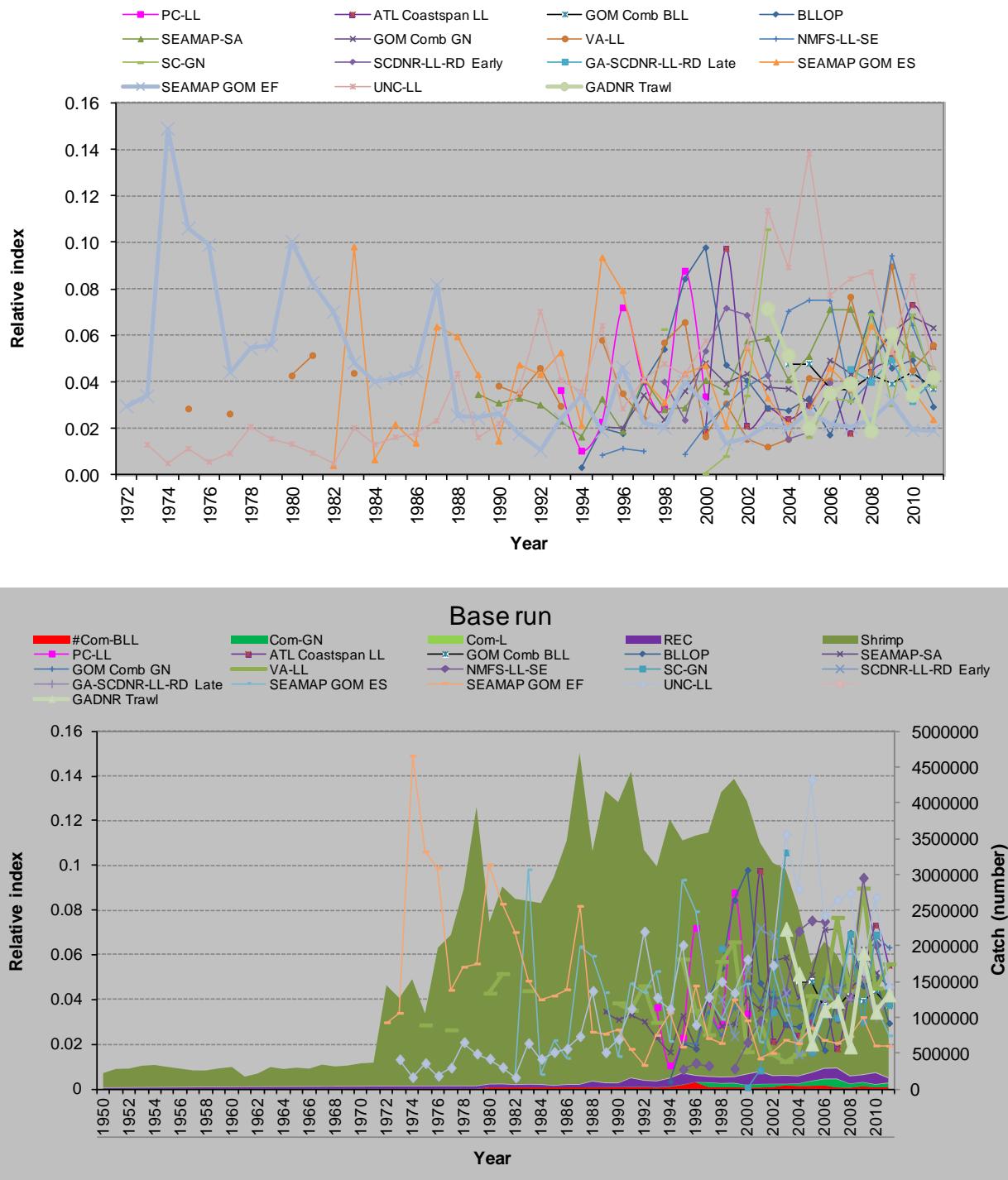


Figure 3.6.3. Indices of relative abundance used for the baseline scenario (top panel). All indices are statistically standardized and scaled (divided by their respective mean and a global mean for overlapping years for plotting purposes). Same indices superimposed on catches (bottom panel).

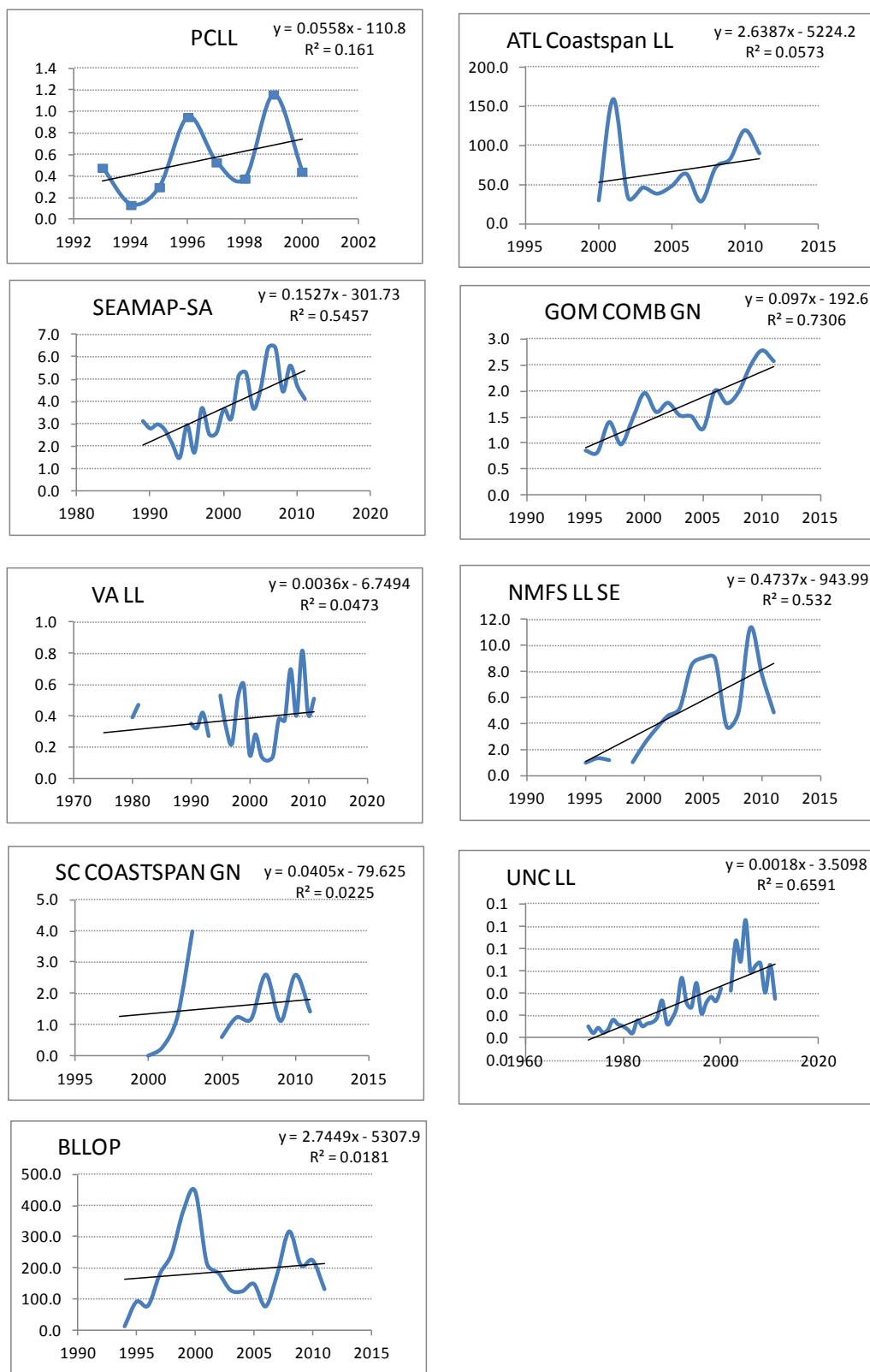


Figure 3.6.4. Indices of relative abundance used for the “increasing indices” scenario. These nine indices showed an increasing trend.

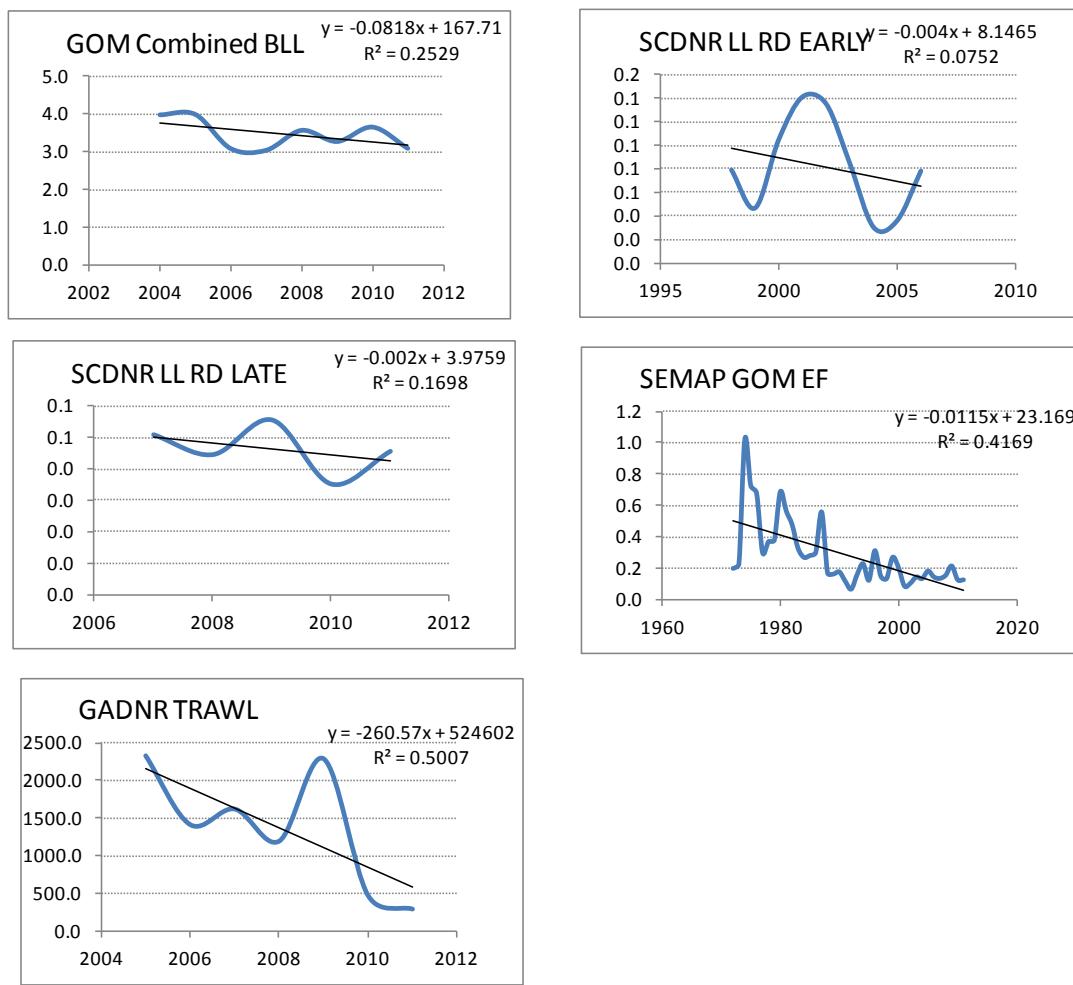


Figure 3.6.5. Indices of relative abundance used for the “decreasing indices” scenario. These five indices showed a decreasing trend.

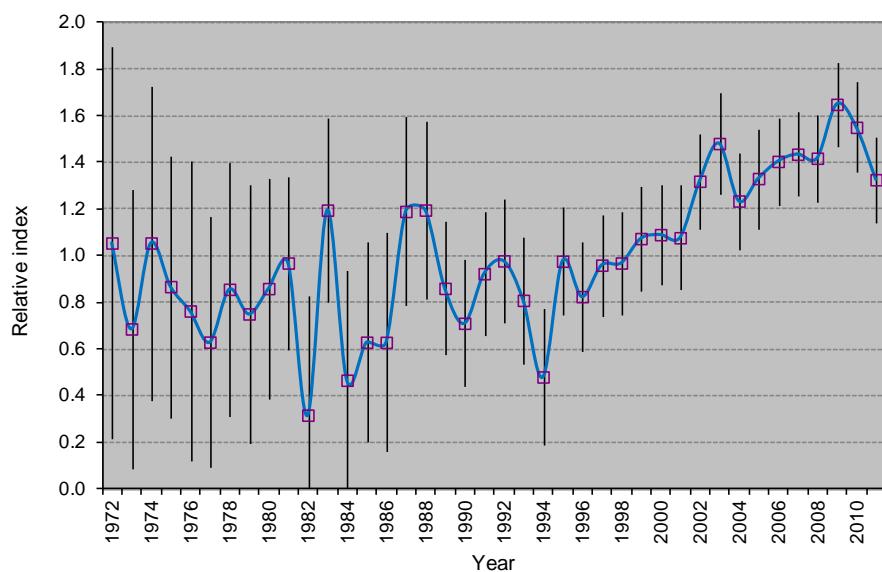


Figure 3.6.6. Hierarchical index of relative abundance used in sensitivity analyses. The index is scaled (divided by its mean). Vertical bars are ± 1 CV.

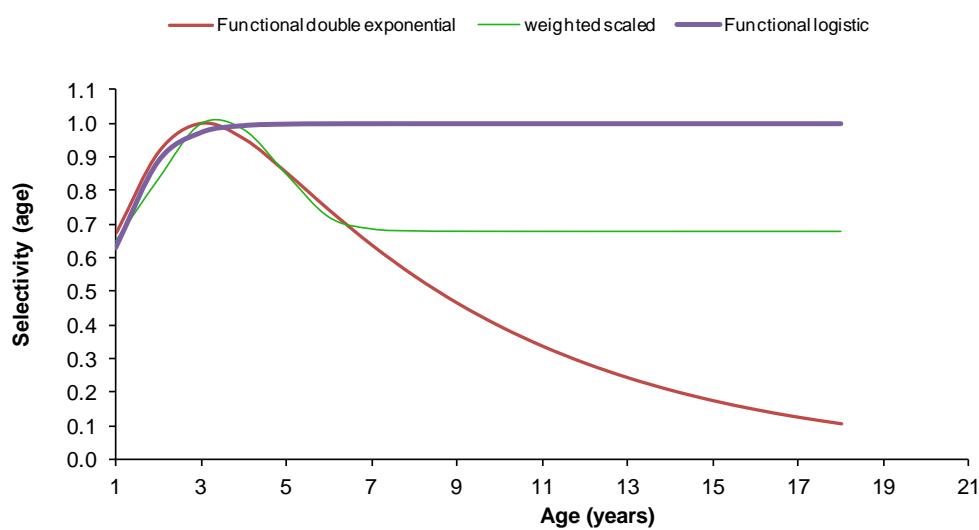


Figure 3.6.7. Selectivities for the hierarchical index. “Weighted scaled” is the selectivity obtained by weighting the base run selectivities by the inverse variance weights and scaled to the maximum value; “functional logistic” and “functional double exponential” are approximations of the weighted selectivity for input into the “hierarchical index” sensitivity runs.

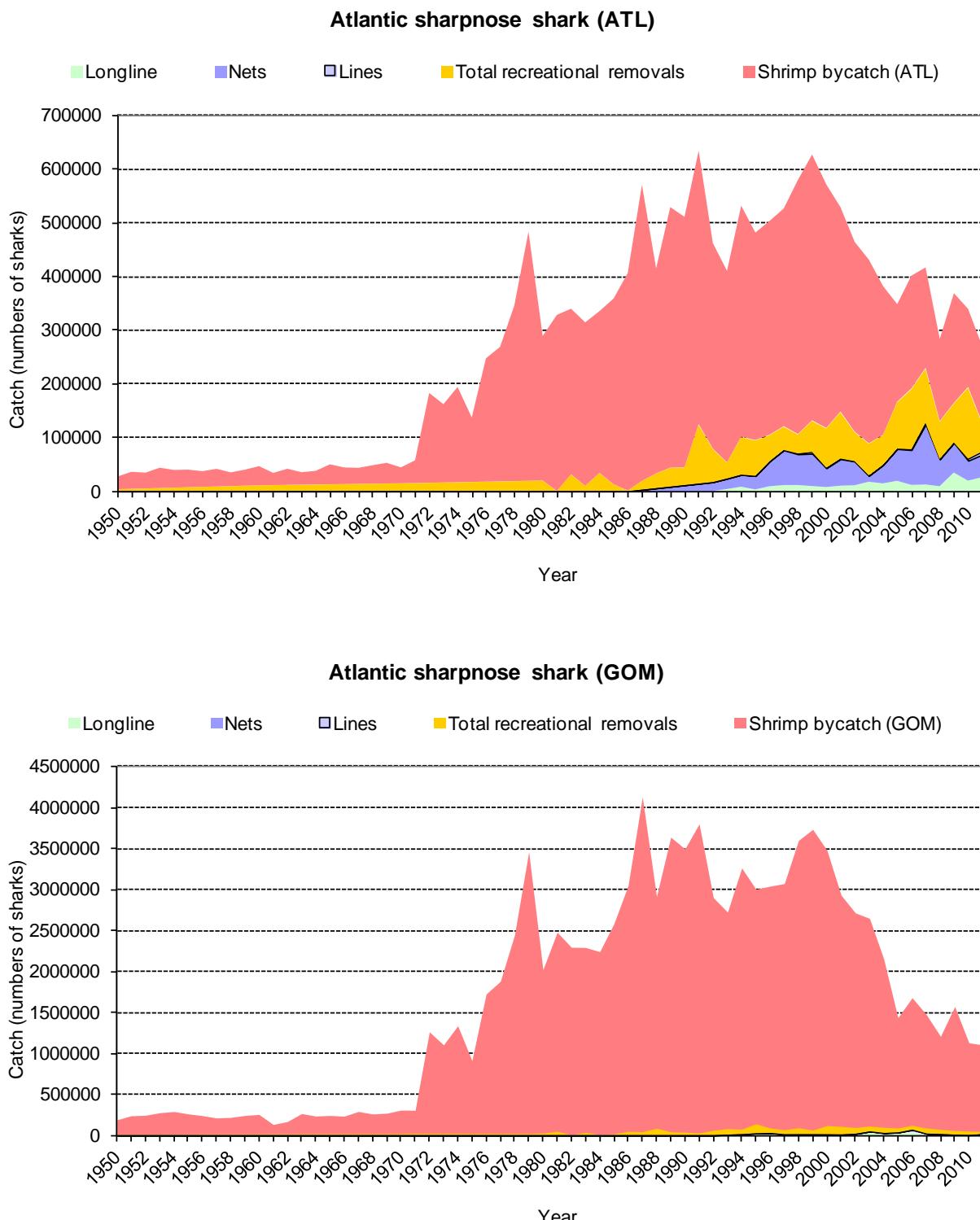


Figure 3.6.8. Catches of Atlantic sharpnose shark by fleet in the Atlantic (top) and Gulf of Mexico (bottom). Catches are in numbers and separated into five fleets: commercial bottom longline, gillnet, and line, recreational, and shrimp trawl discards.

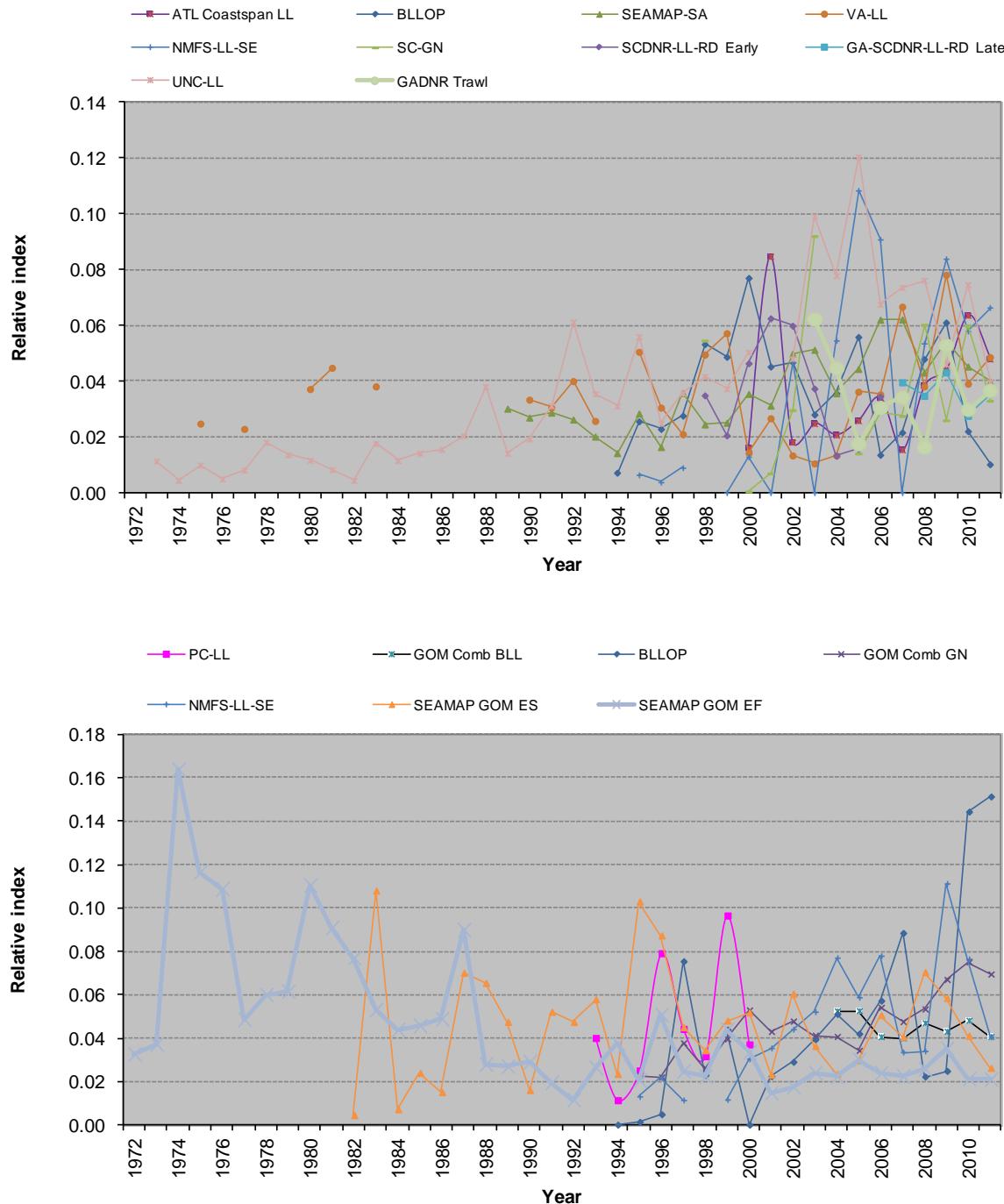


Figure 3.6.9. Indices of relative abundance used for the “Atlantic stock” (top panel) and “Gulf of Mexico” (bottom panel) sensitivity runs. All indices are statistically standardized and scaled (divided by their respective mean and a global mean for overlapping years for plotting purposes).

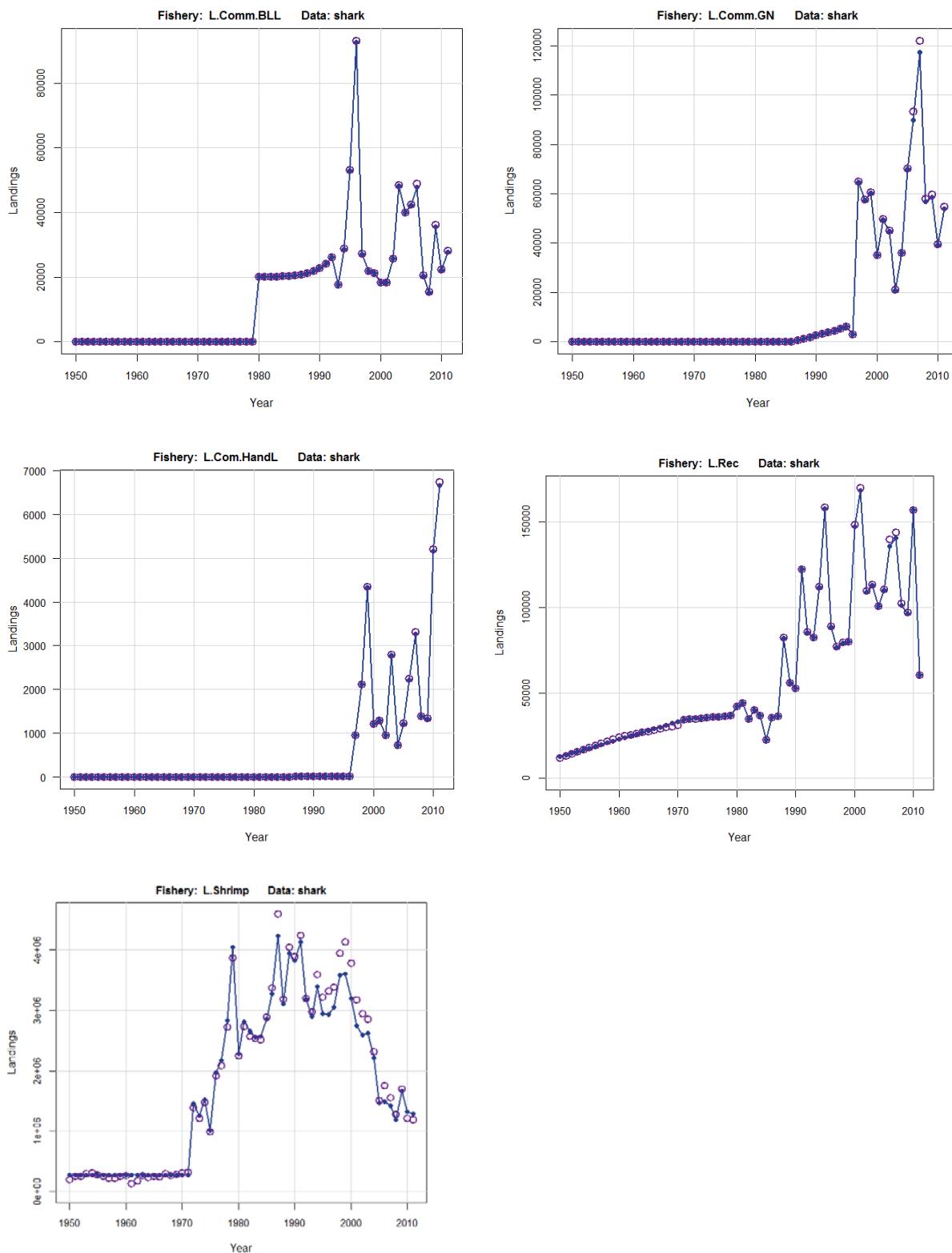


Figure 3.6.10. Predicted fits to the 5 catch data streams for the base run (inverse CV weights).

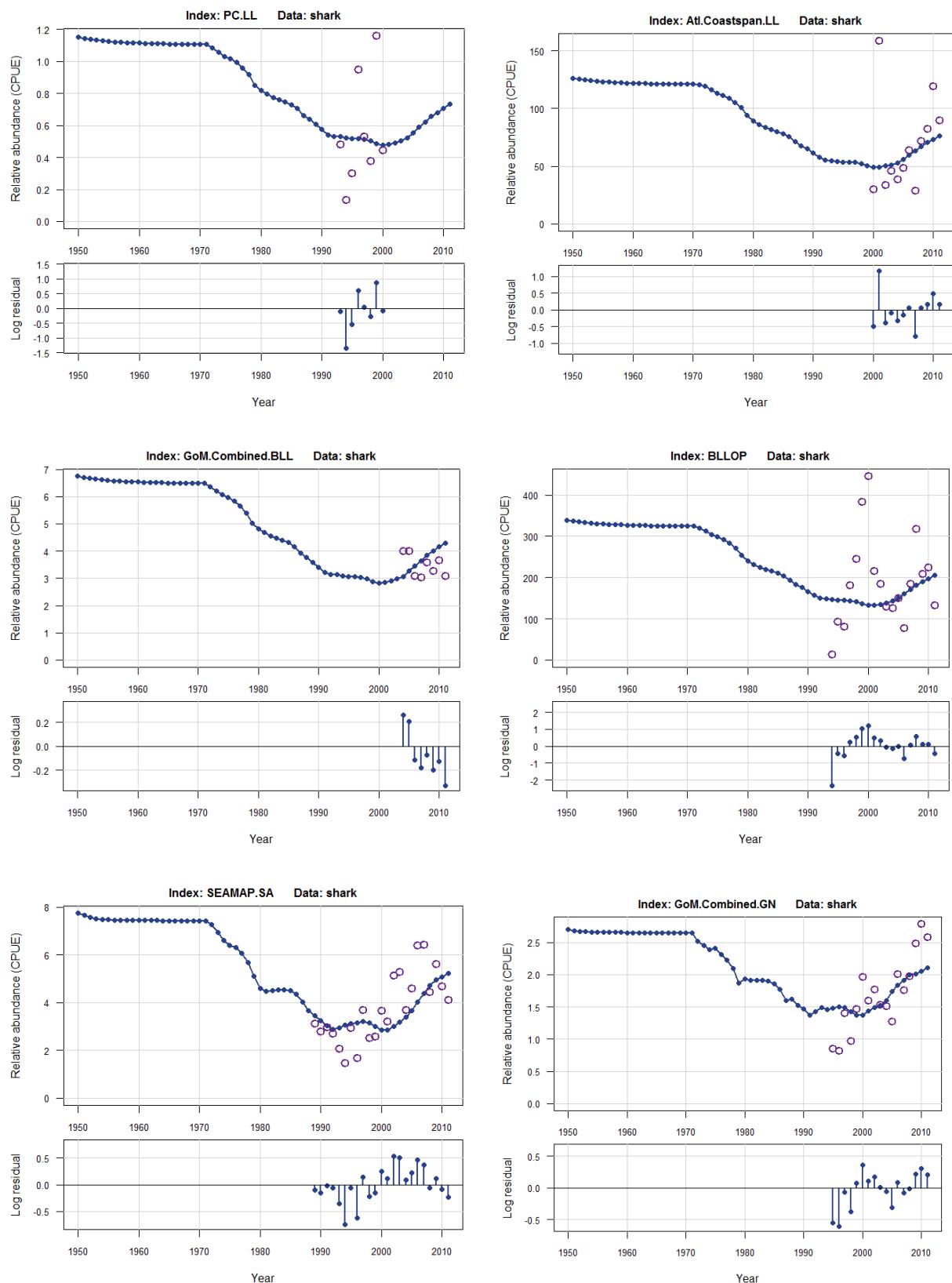


Figure 3.6.11. Predicted fits to indices and residual plots for the base run (inverse CV weights).

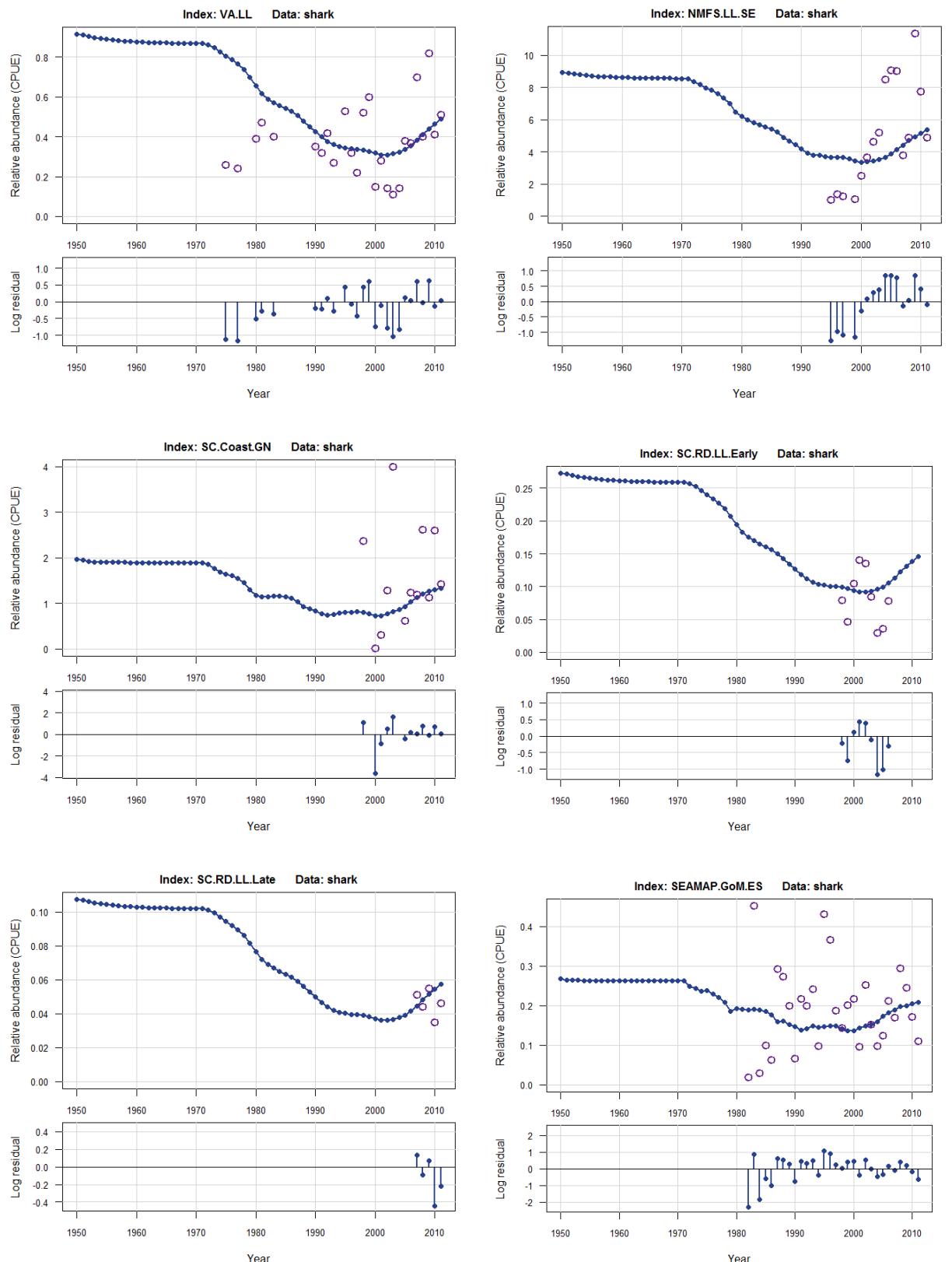


Figure 3.6.11 (continued). Predicted fits to indices and residual plots for the base run (inverse CV weights).

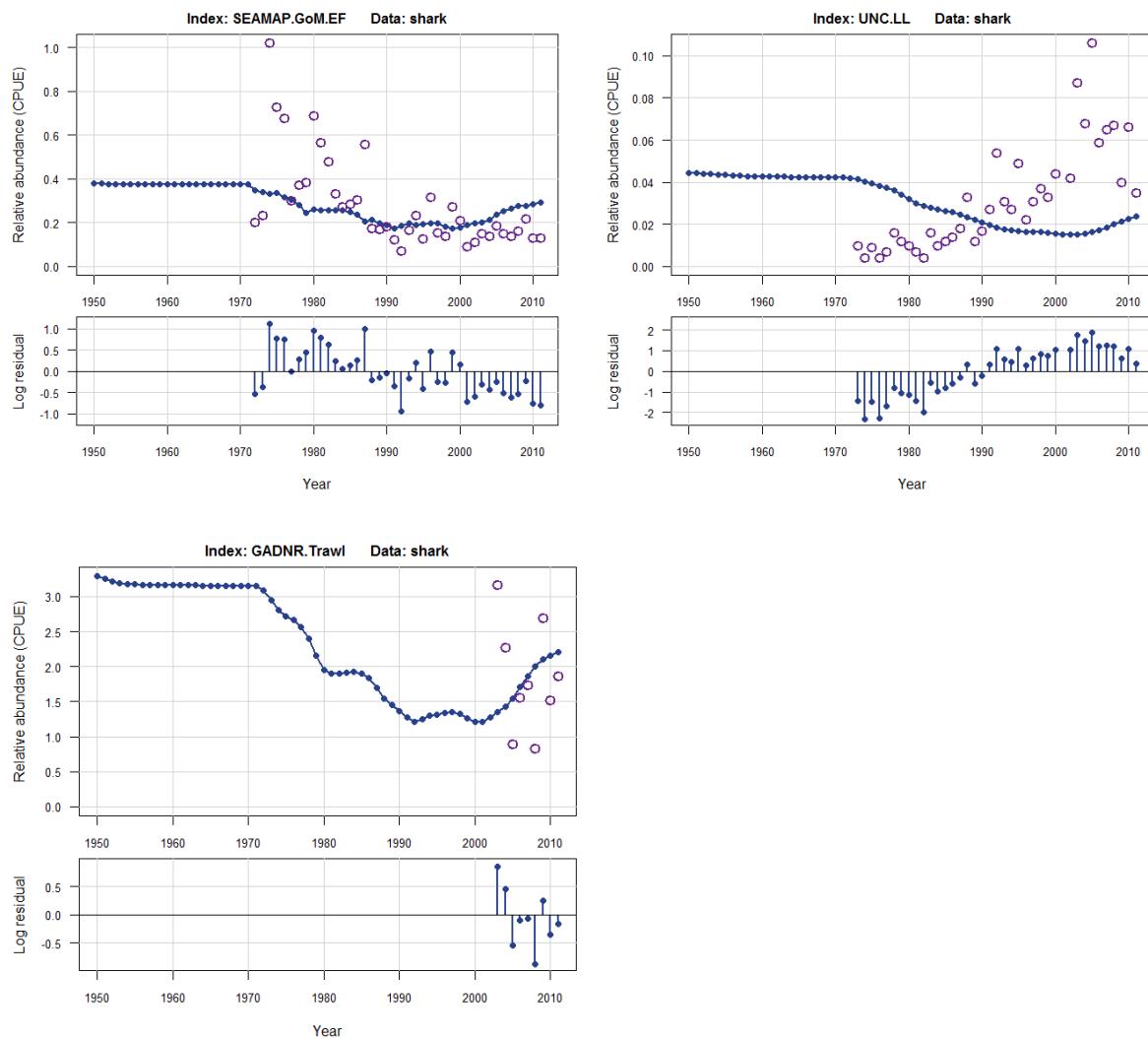


Figure 3.6.11 (continued). Predicted fits to indices and residual plots for the base run (inverse CV weights).

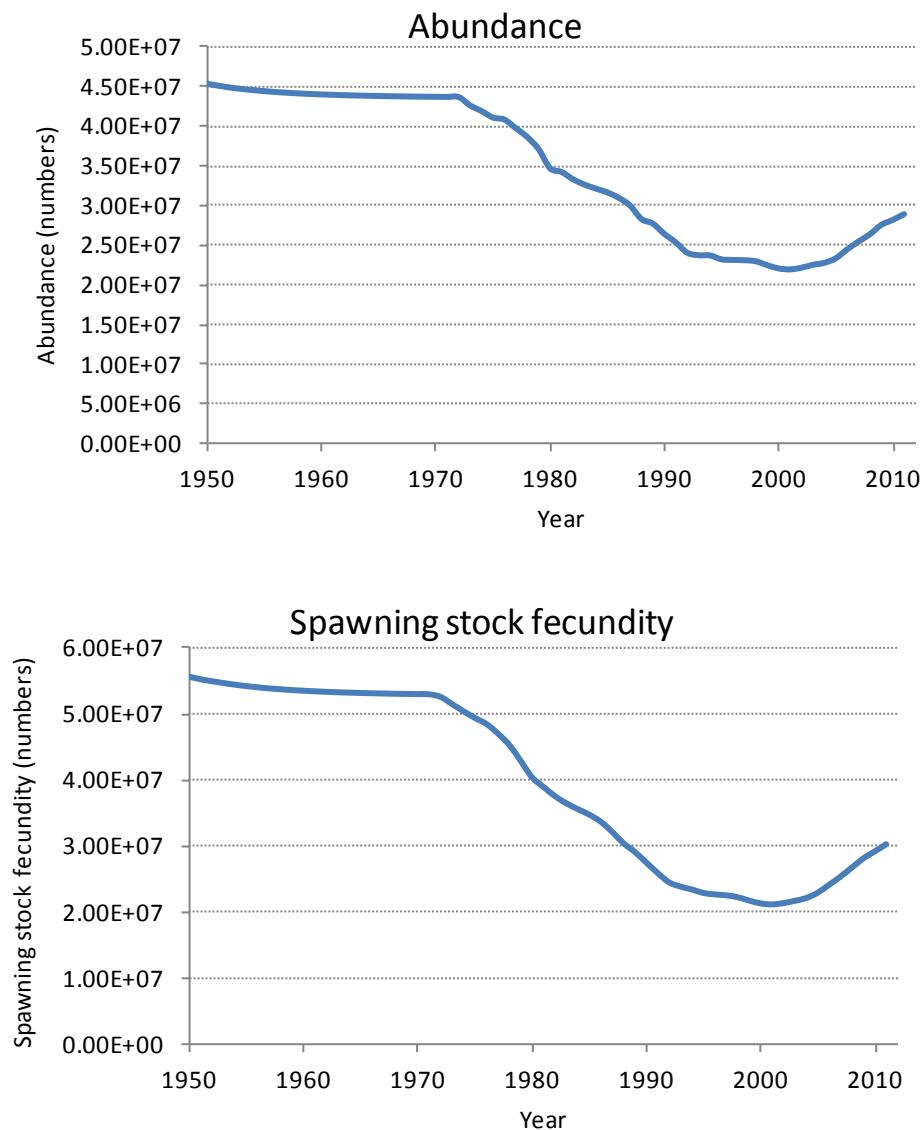


Figure 3.6.12. Predicted abundance and spawning stock fecundity trajectories for Atlantic sharpnose shark.

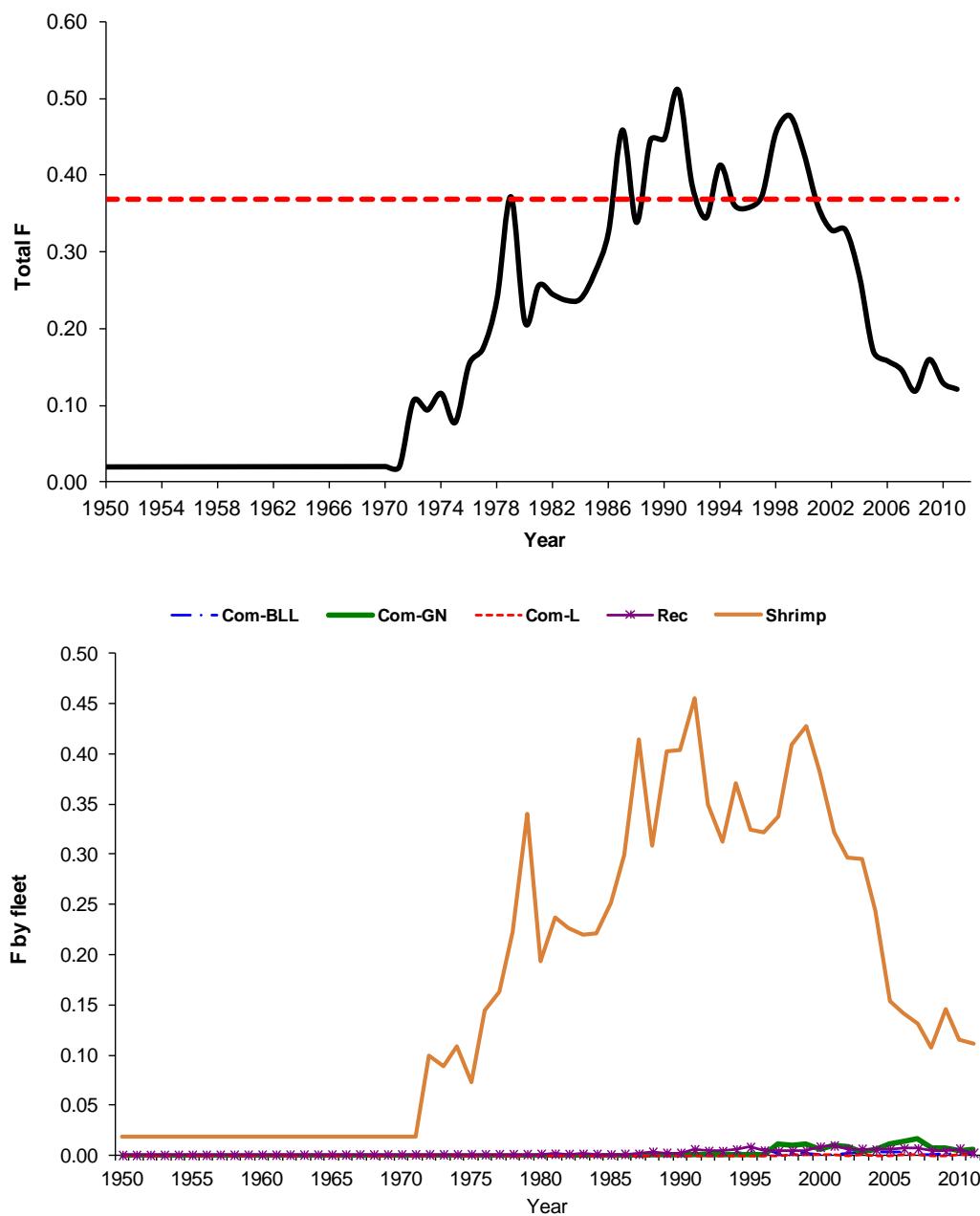


Figure 3.6.13. Estimated total fishing mortality (top) and fleet-specific F (bottom) for Atlantic shark. The dashed line in the top panel indicates F_{MSY} (0.377).

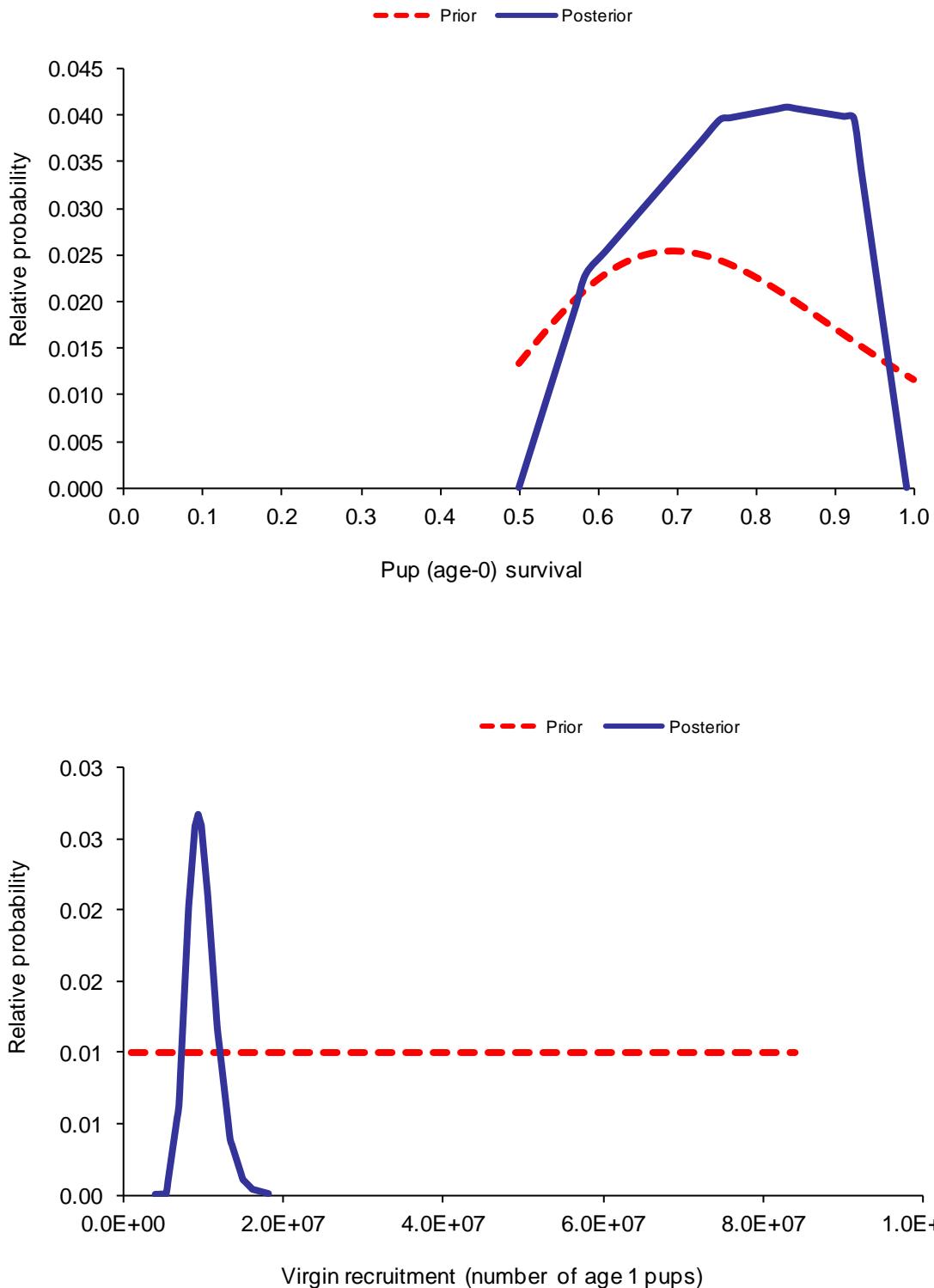


Figure 3.6.14. Prior and posterior distributions for pup survival and virgin recruitment. The prior for R_0 ranged from 10^3 to 10^{10} (not shown here for plotting purposes).

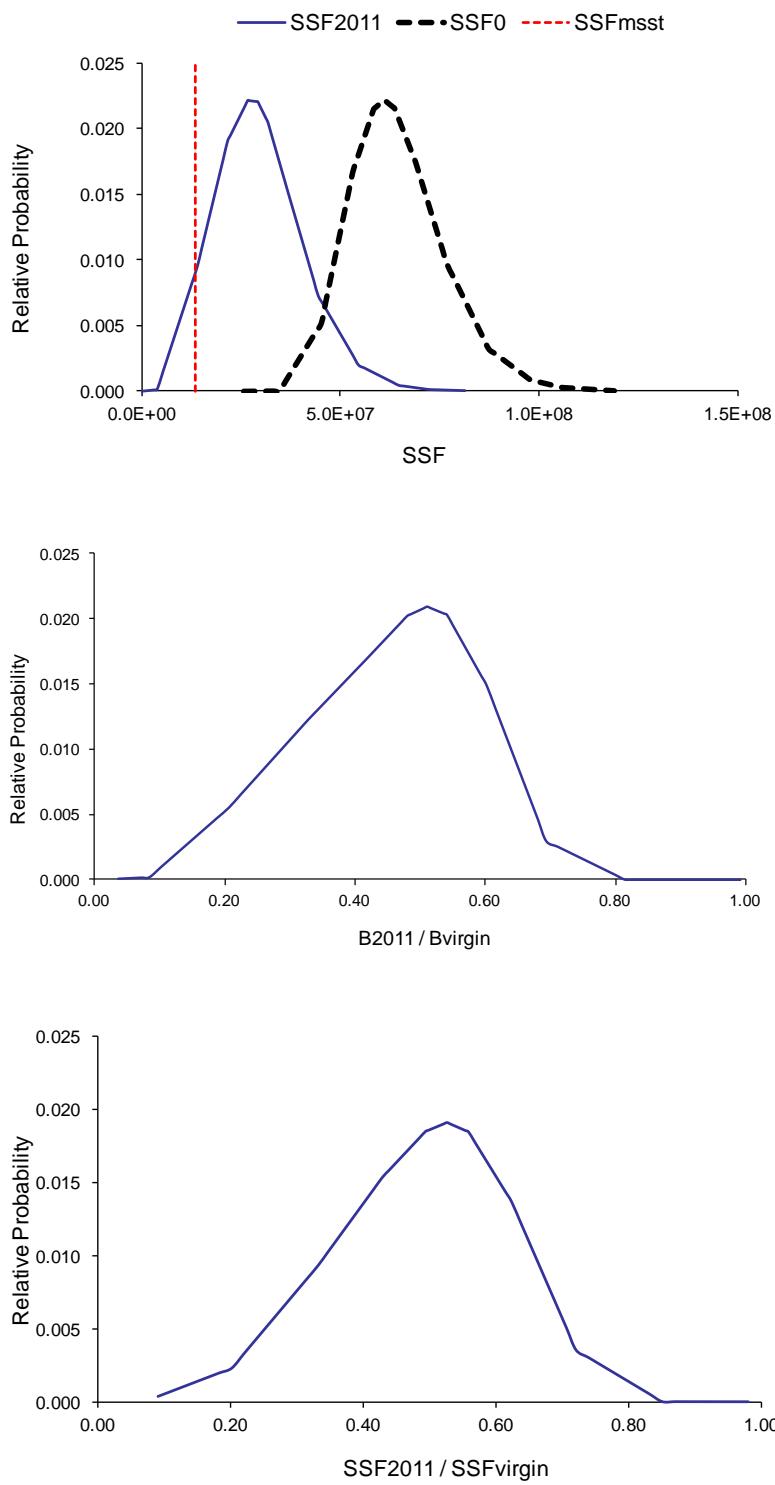


Figure 3.6.15. Profile likelihoods for spawning stock fecundity (SSF) in virgin conditions and in 2011 (top), depletion in biomass (middle), and SSF depletion (bottom). The MSST reference point is indicated in the upper panel.

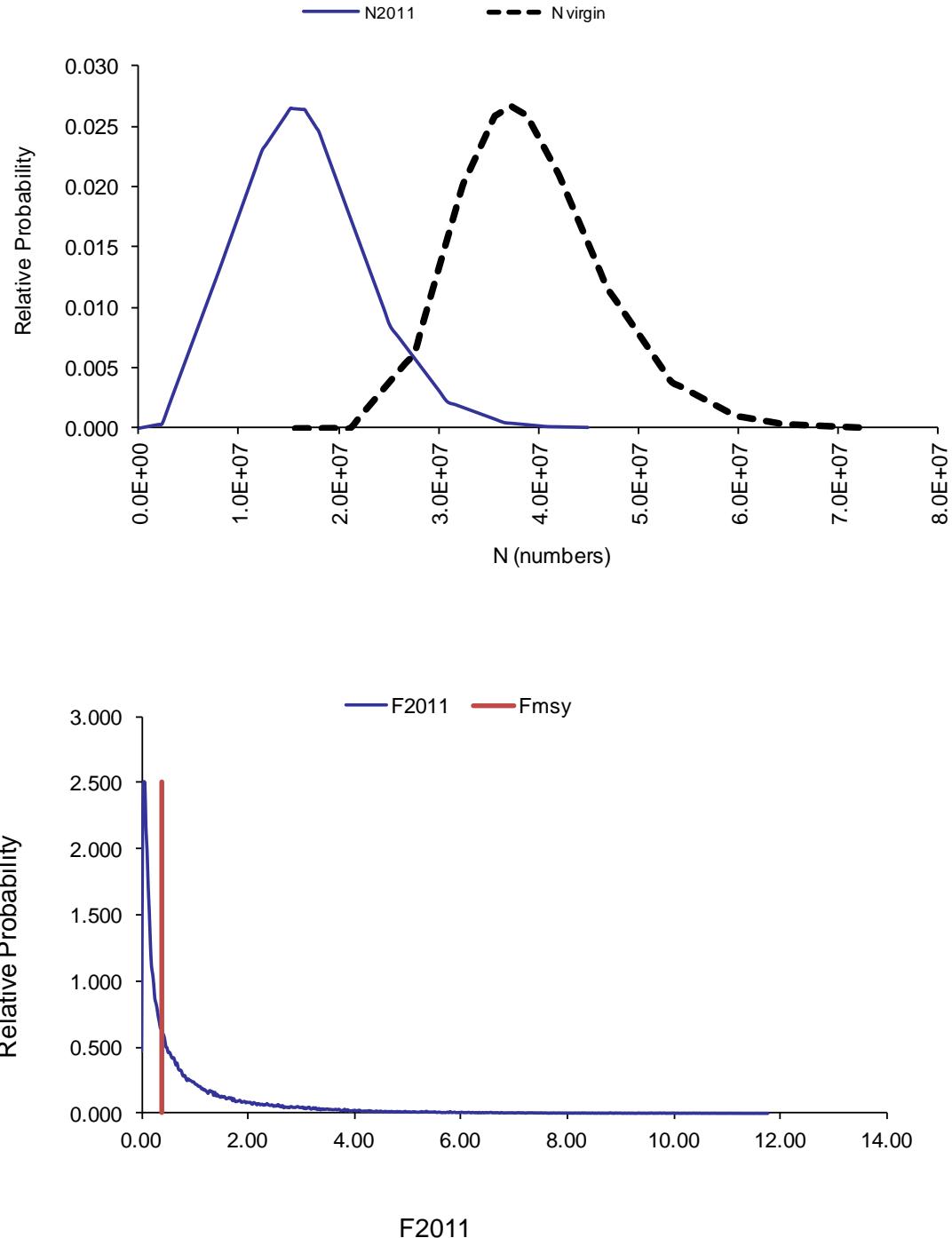


Figure 3.6.16. Profile likelihoods for number of mature individuals in virgin conditions and in 2011 (top) and for fishing mortality in 2011 (bottom). The F_{MSY} reference point is indicated in the bottom panel.

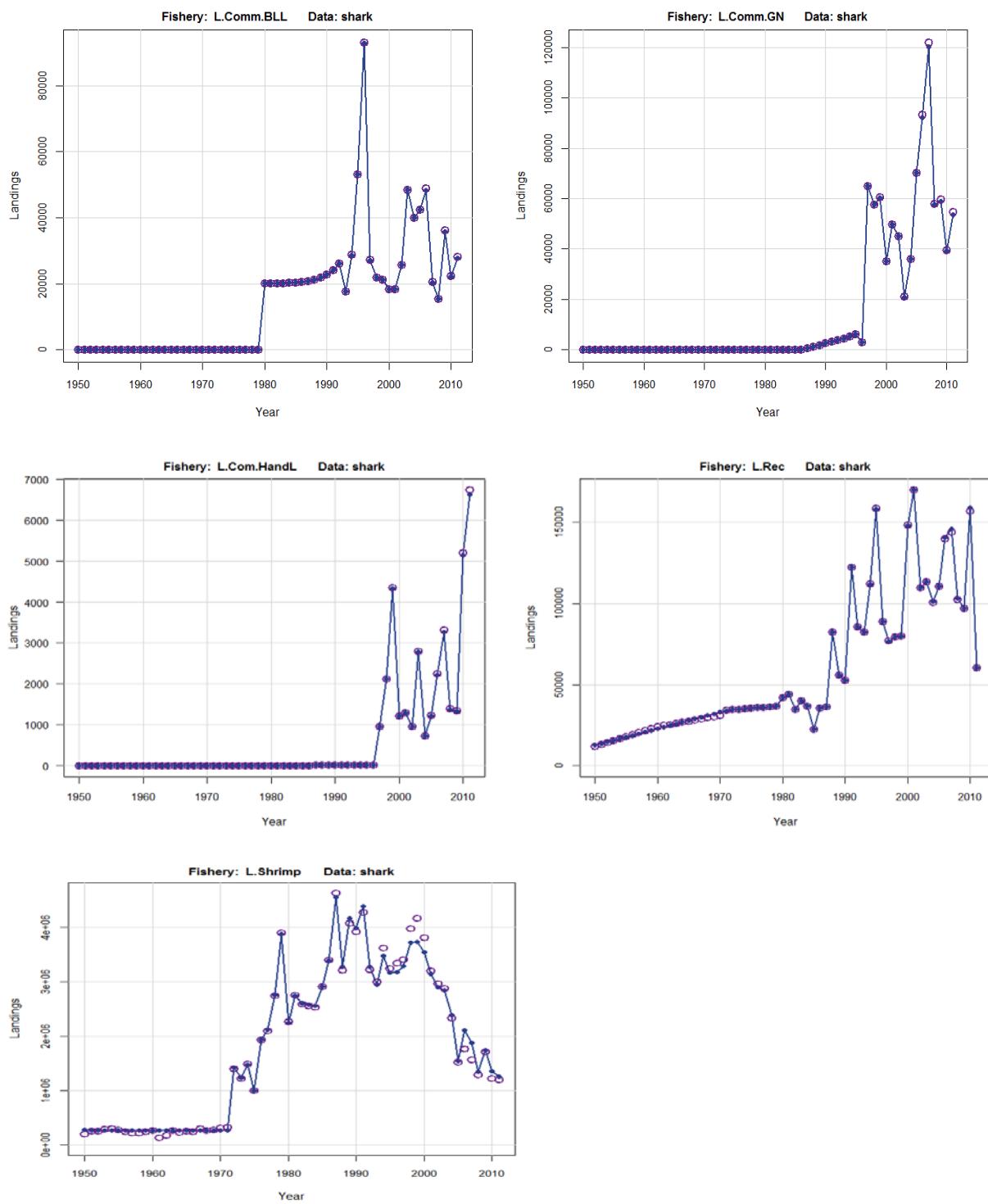


Figure 3.6.17. Predicted fits to the five catch data streams for the “increasing indices” sensitivity run.

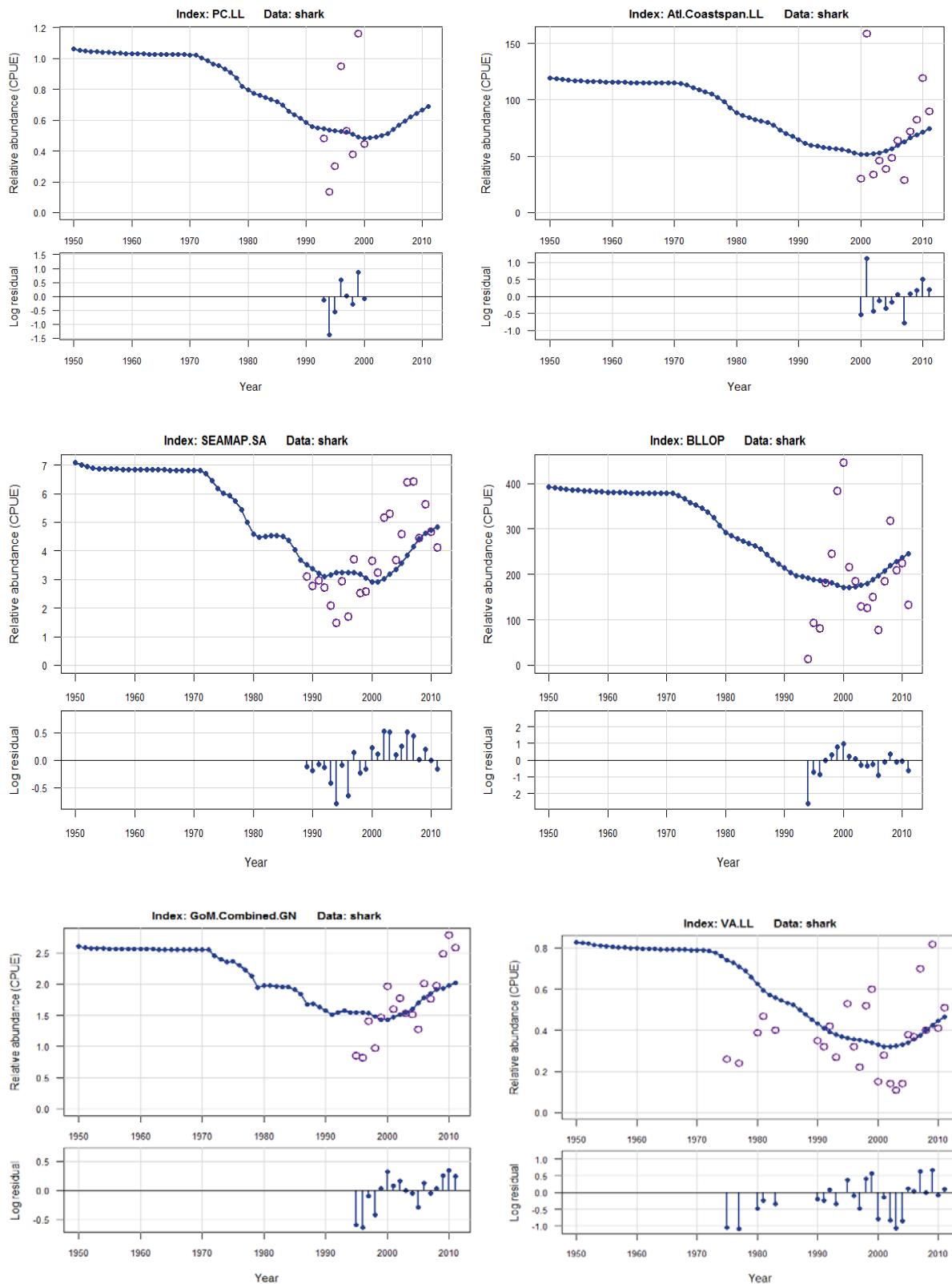


Figure 3.6.18. Predicted fits to indices and residual plots for the “increasing indices” sensitivity run.

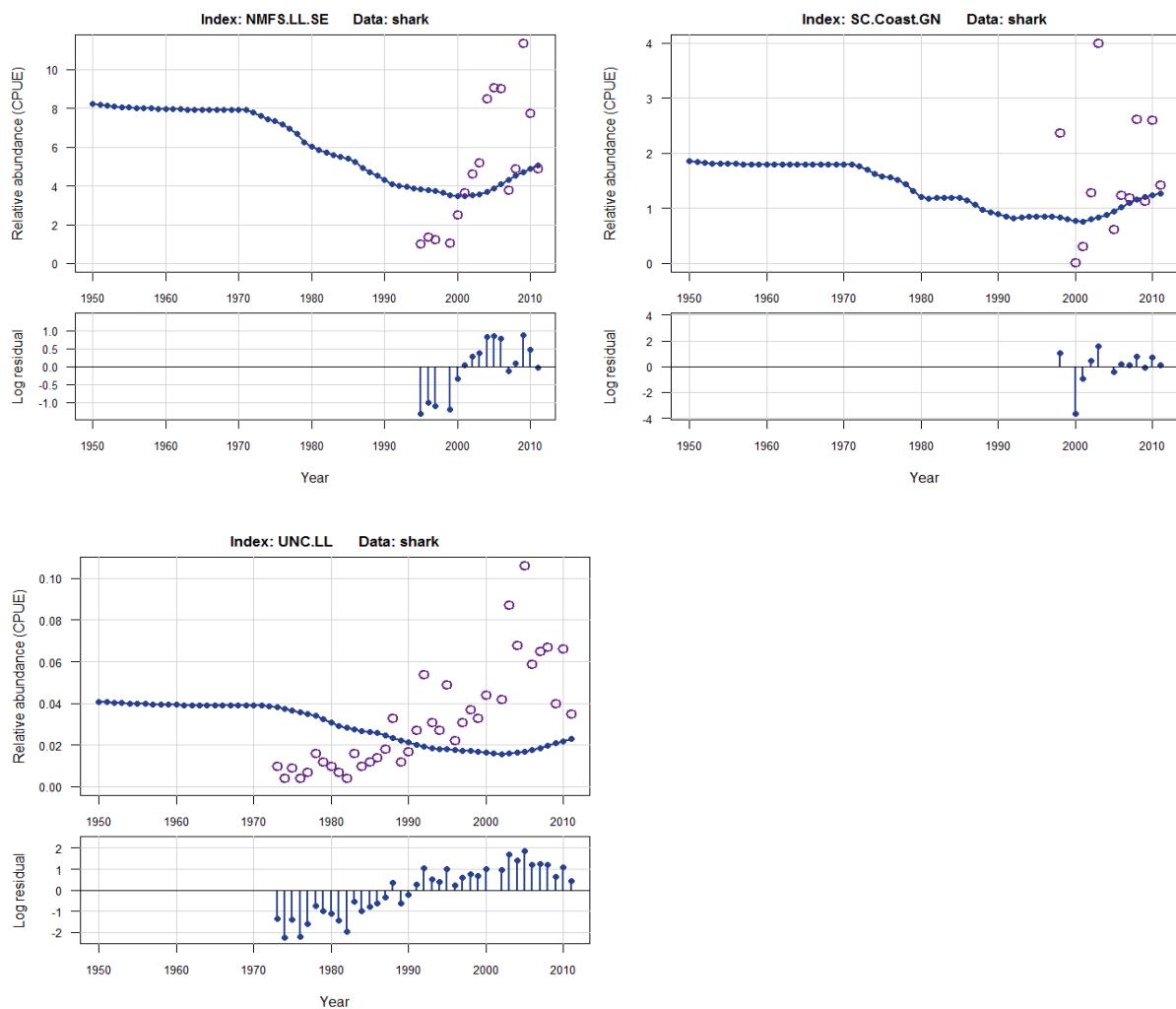


Figure 3.6.18 (continued). Predicted fits to indices and residual plots for the “increasing indices” sensitivity” run.

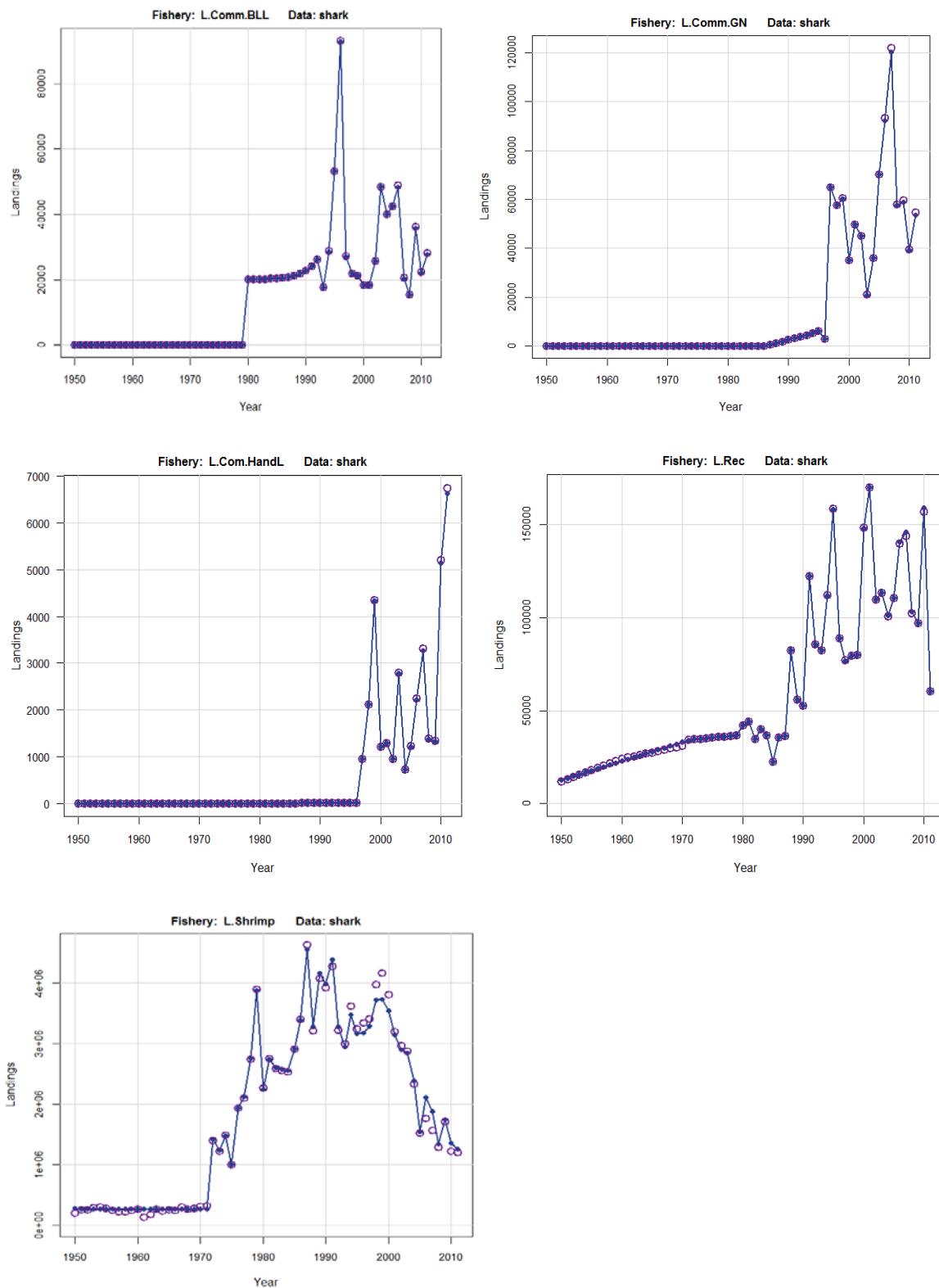


Figure 3.6.19. Predicted fits to the five catch data streams for the “decreasing indices” sensitivity run.

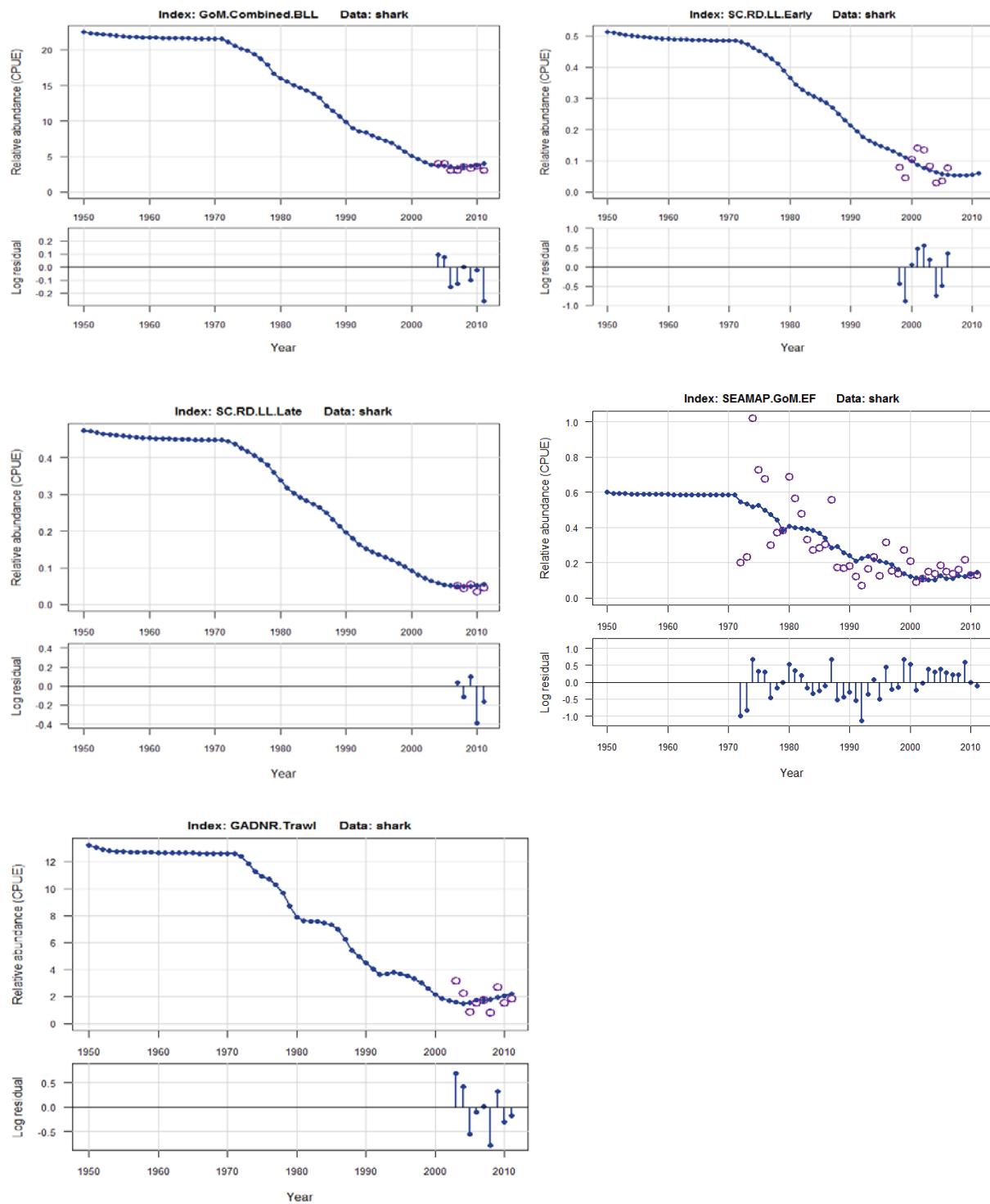


Figure 3.6.20. Predicted fits to indices and residual plots for the “decreasing indices” sensitivity run.

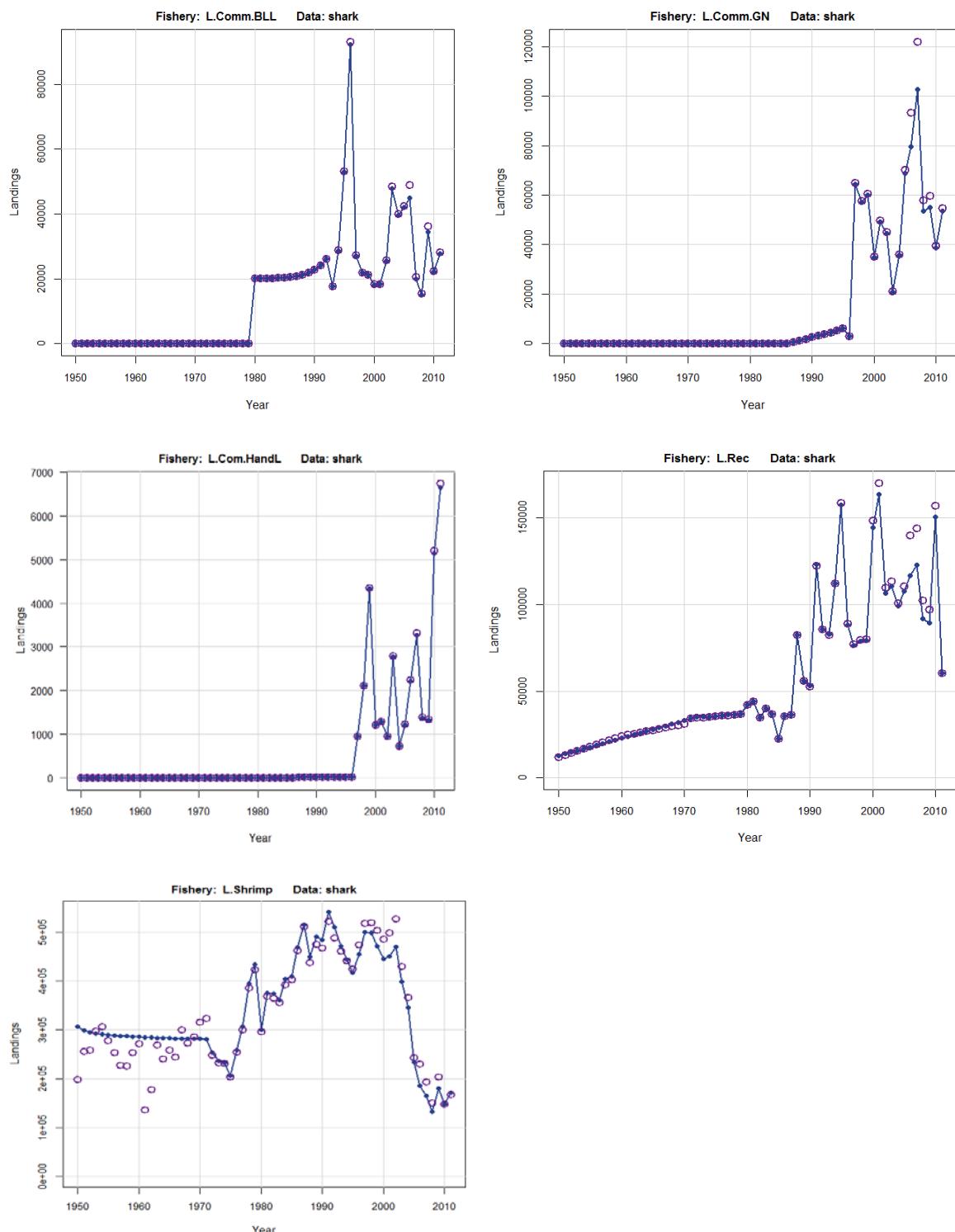


Figure 3.6.21. Predicted fits to the five catch data streams for the “low catch” sensitivity run. Note that the scale on the Y-axis is smaller than in the base run.

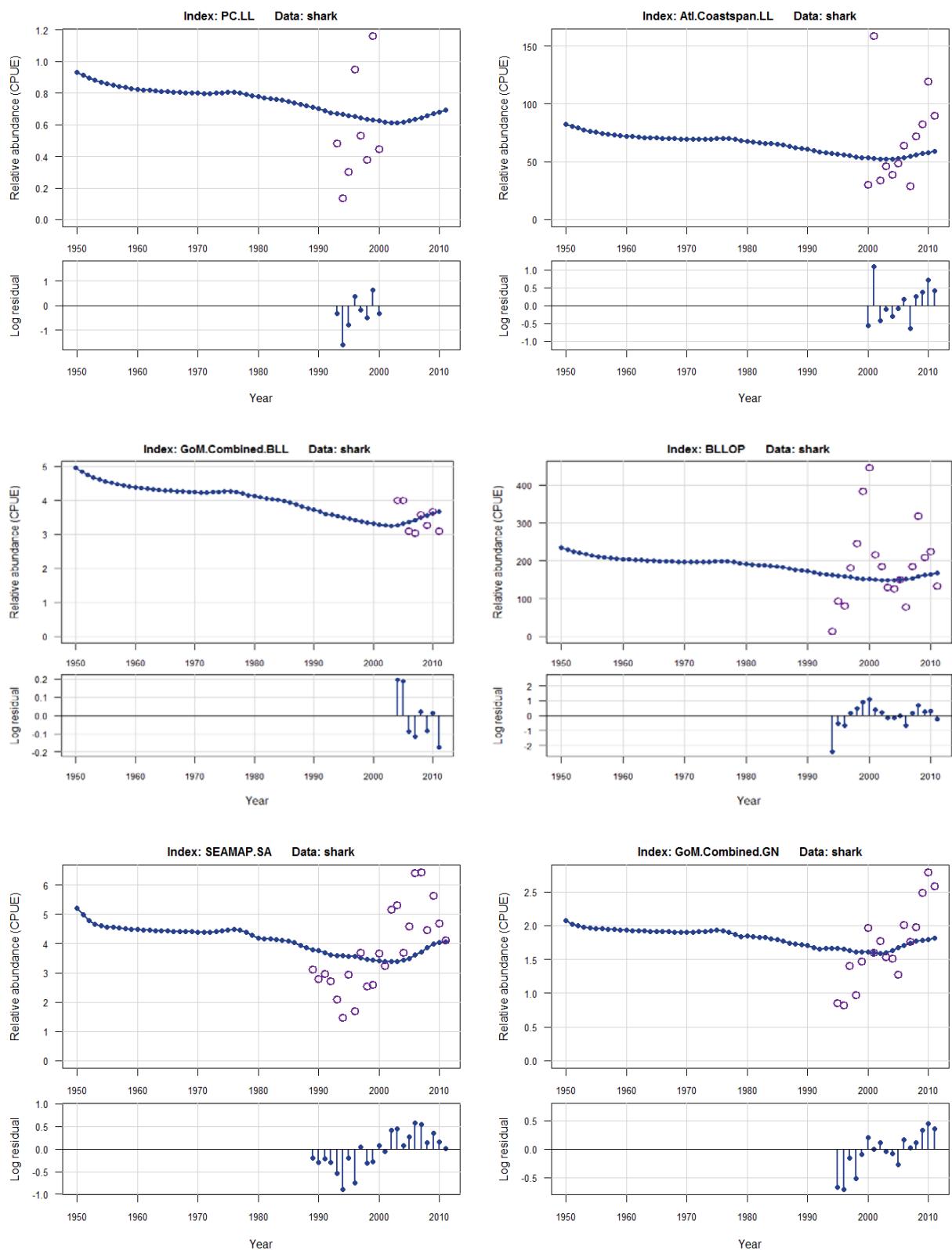


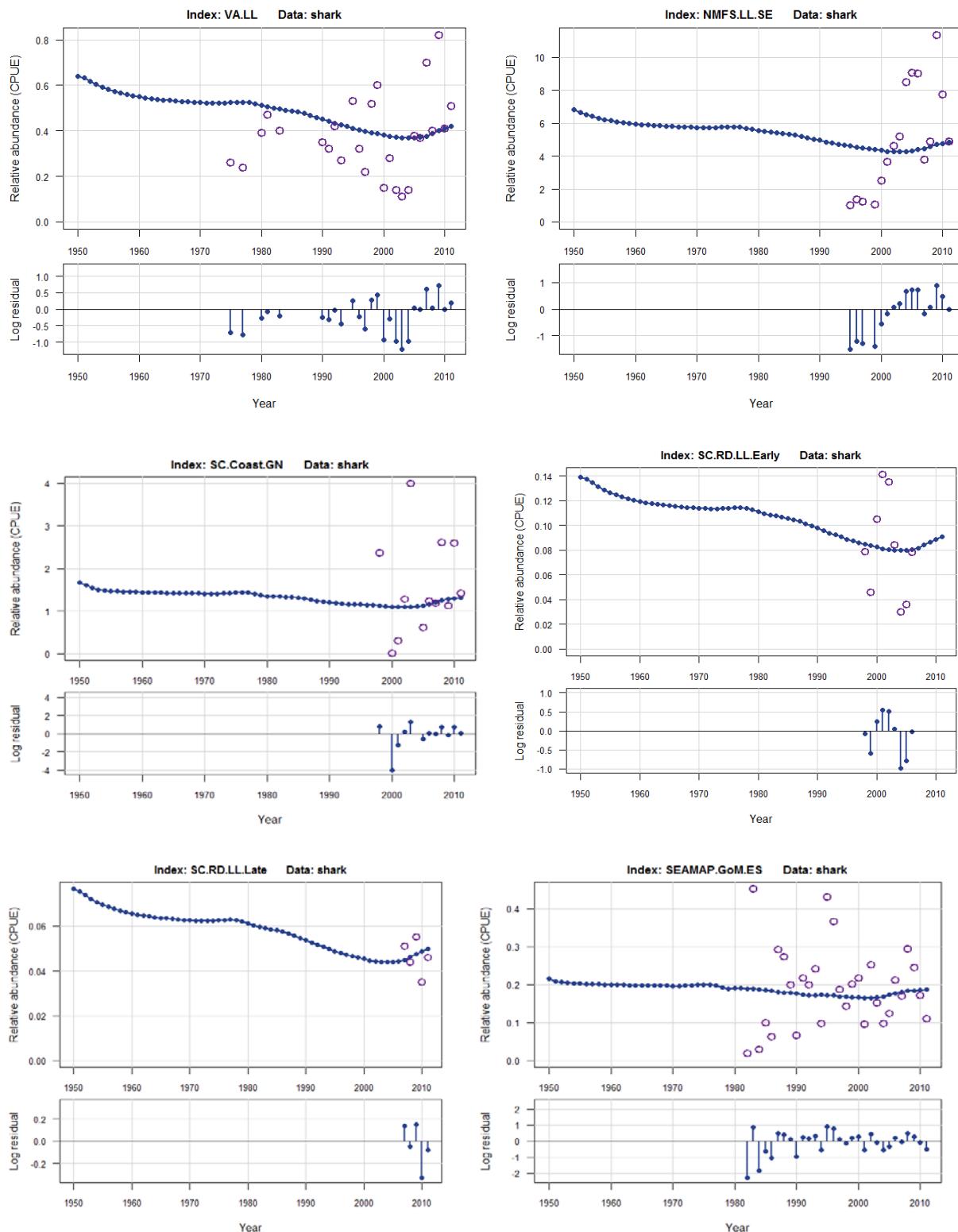
Figure 3.6.22. Predicted fits to indices and residual plots for the “low catch” sensitivity run.

Figure 3.6.22 (continued). Predicted fits to indices and residual plots “low catch” sensitivity run.

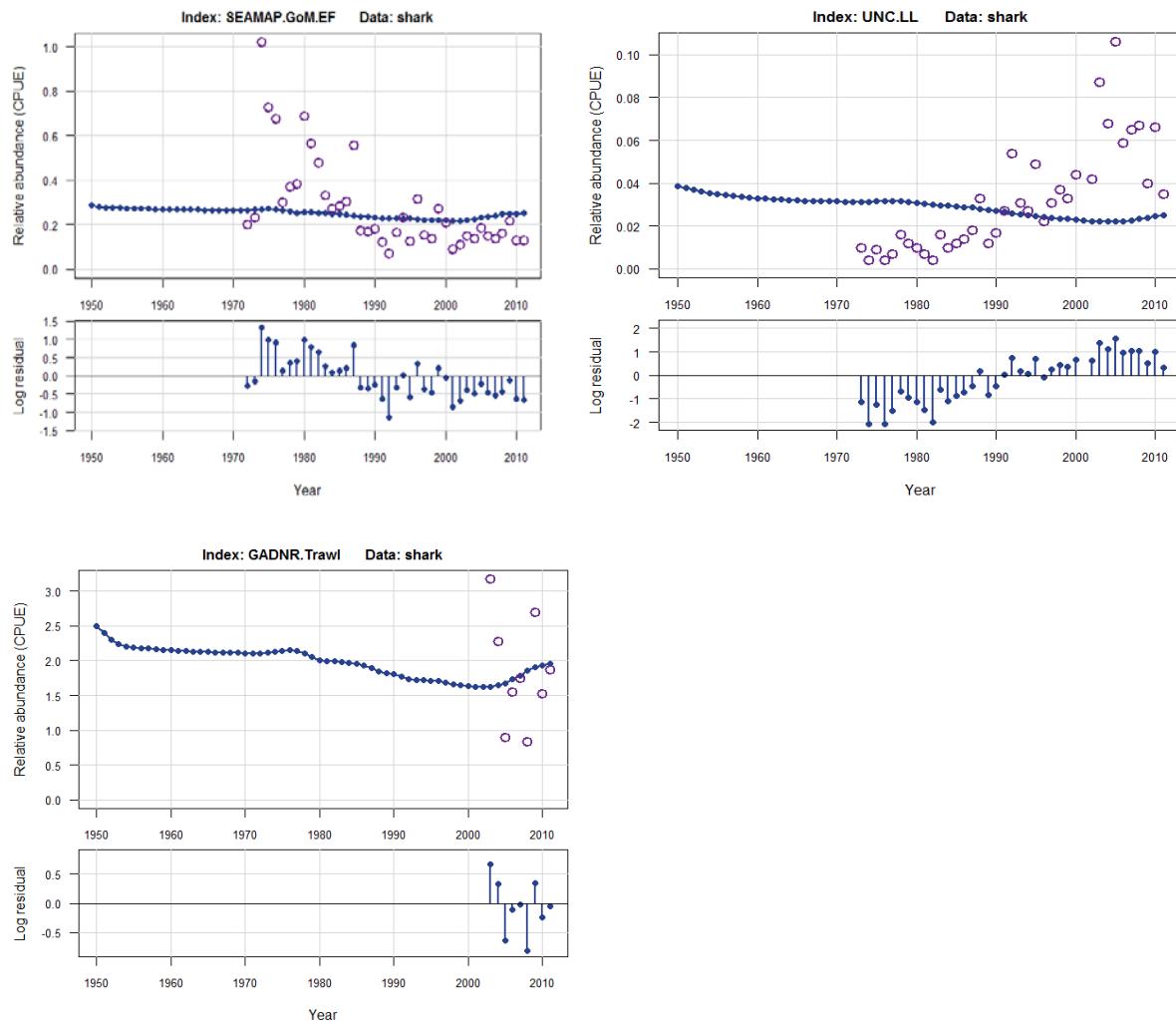


Figure 3.6.22 (continued). Predicted fits to indices and residual plots “low catch” sensitivity run.

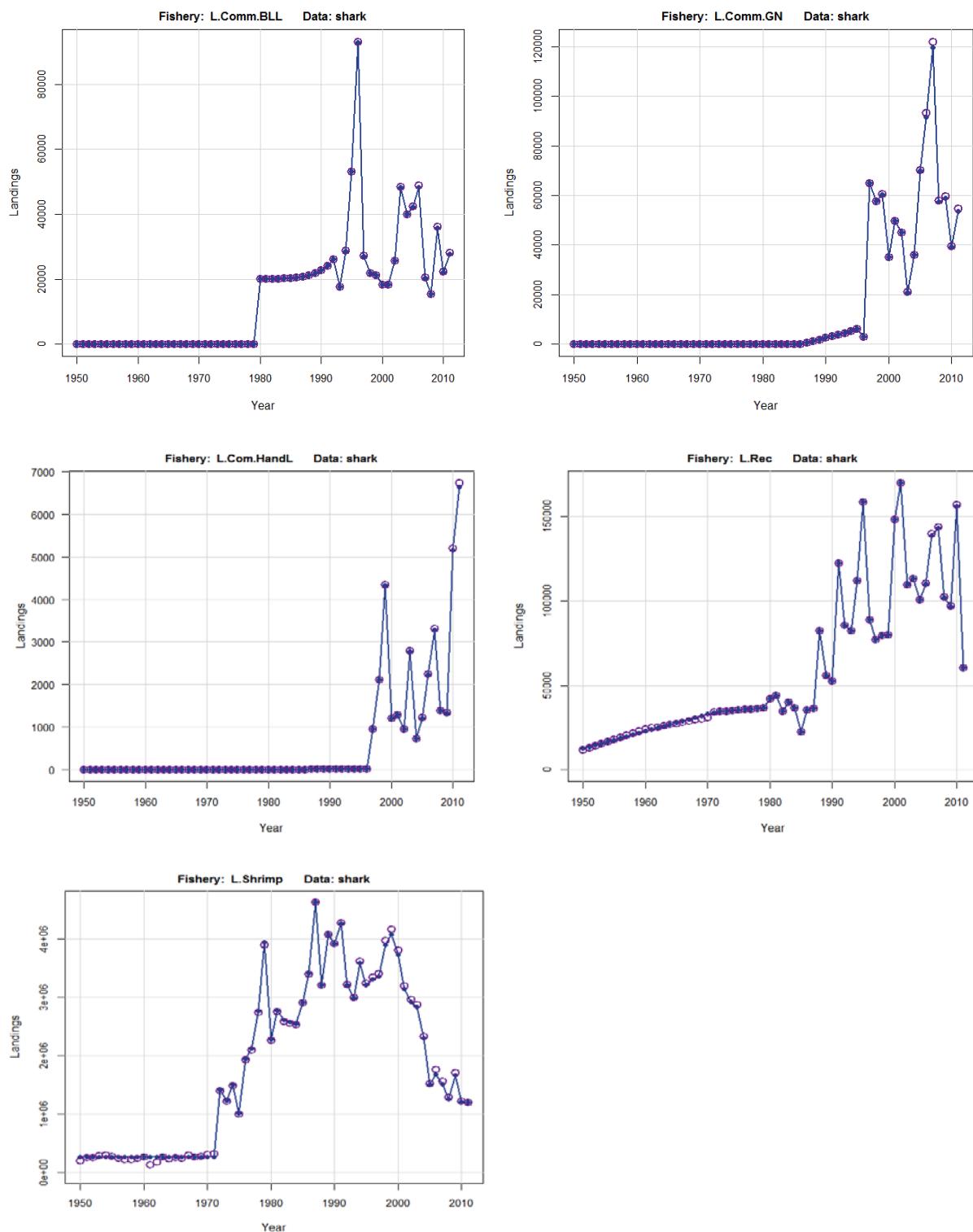


Figure 3.6.23. Predicted fits to the five catch data streams for the “hierarchical index log sel” sensitivity run.

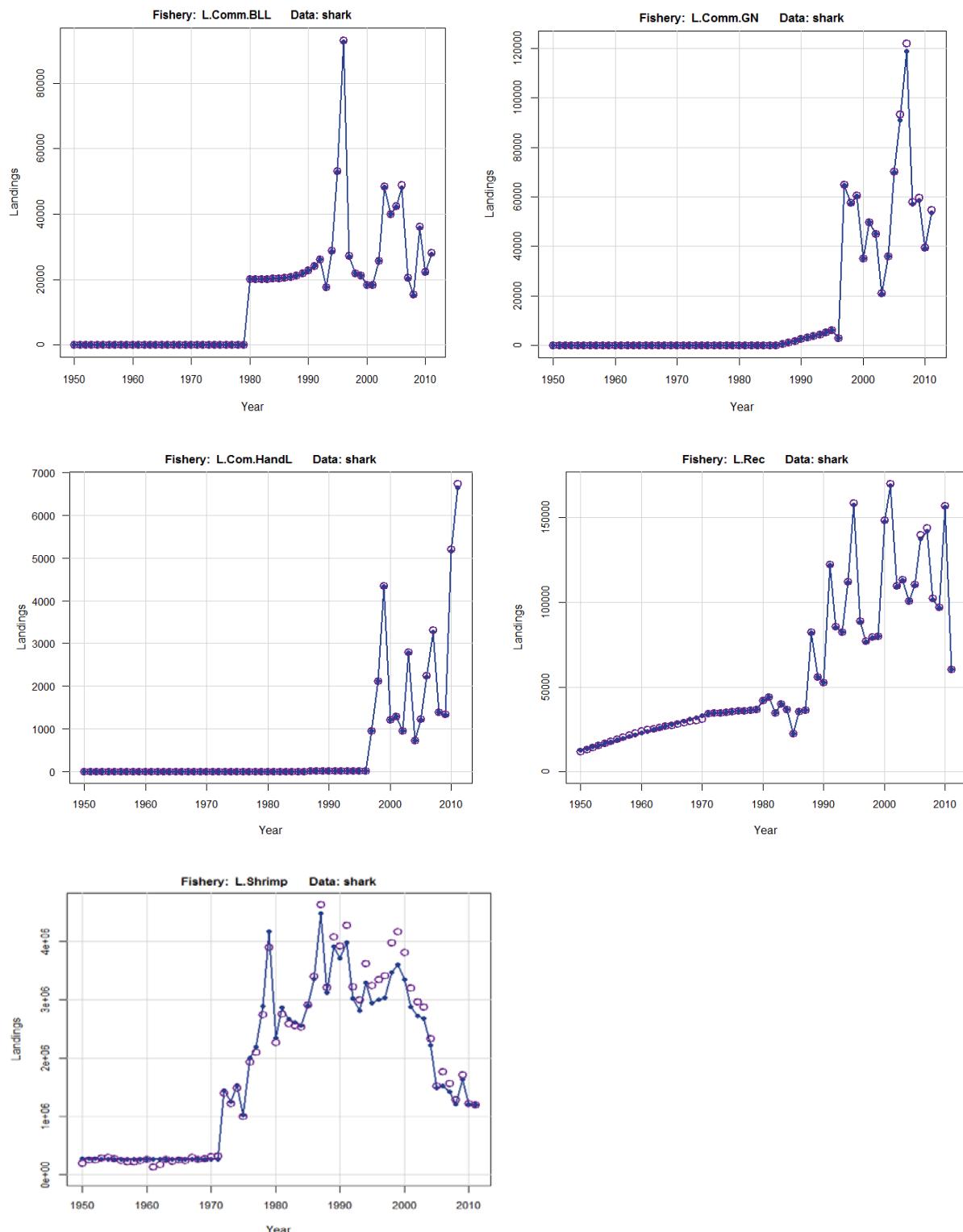


Figure 3.6.24. Predicted fits to the five catch data streams for the “hierarchical index dexp sel” sensitivity run.

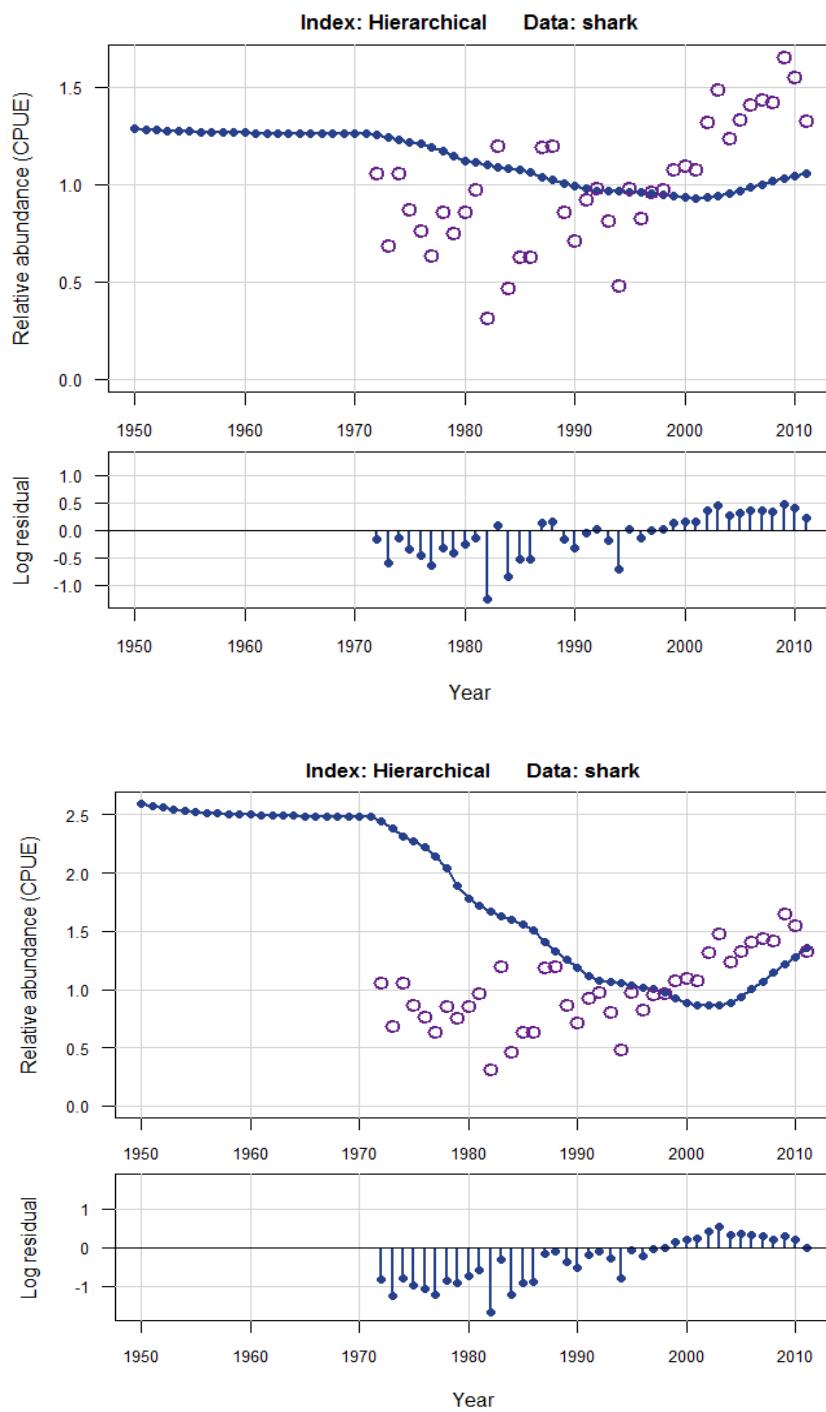


Figure 3.6.25. Predicted fits to the index and residual plots for the “hierarchical index log sel” sensitivity run (top) and the “hierarchical index dexp sel” sensitivity run (bottom).

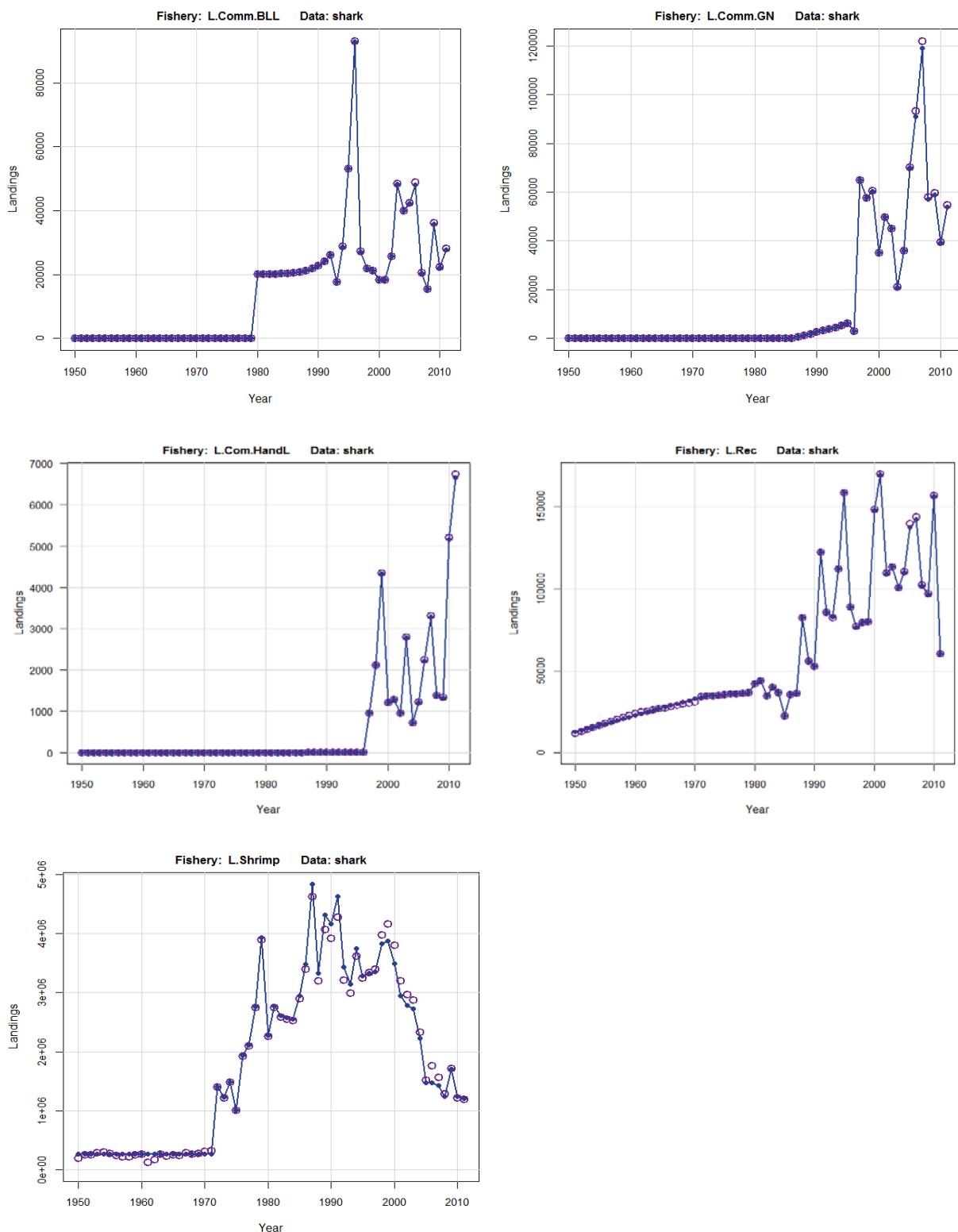


Figure 3.6.26. Predicted fits to the five catch data streams for the “SEAMAP-SA” sensitivity run.

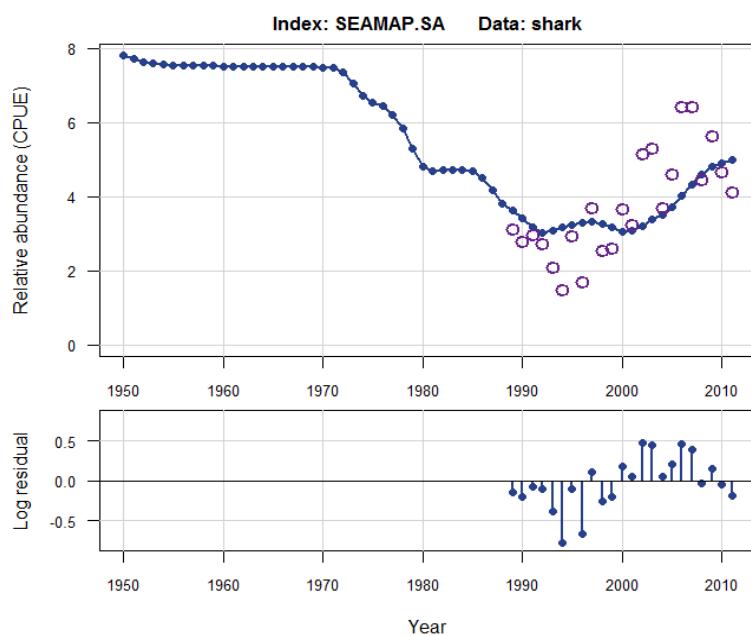
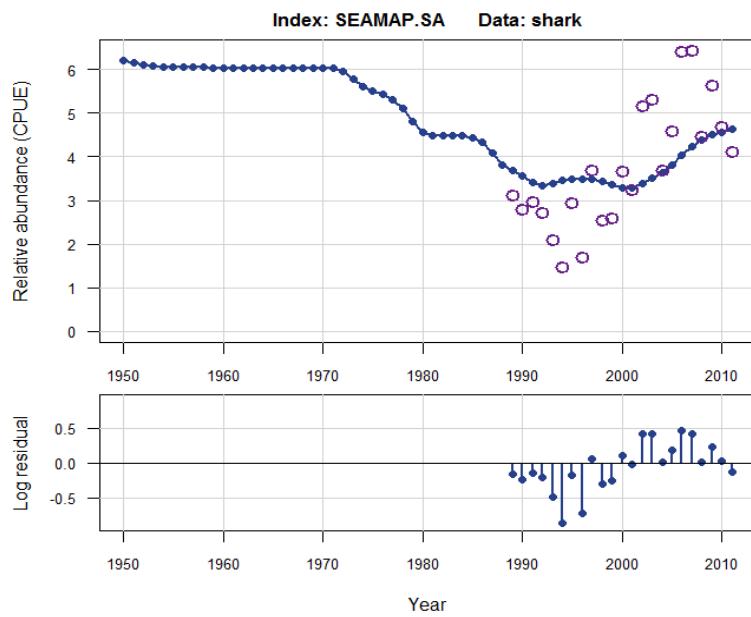


Figure 3.6.27. Predicted fit to the SEAMAP-SA index and residual plot for the “SEAMAP-SA” sensitivity run (top). The bottom panel shows the fit of the index in the base run.

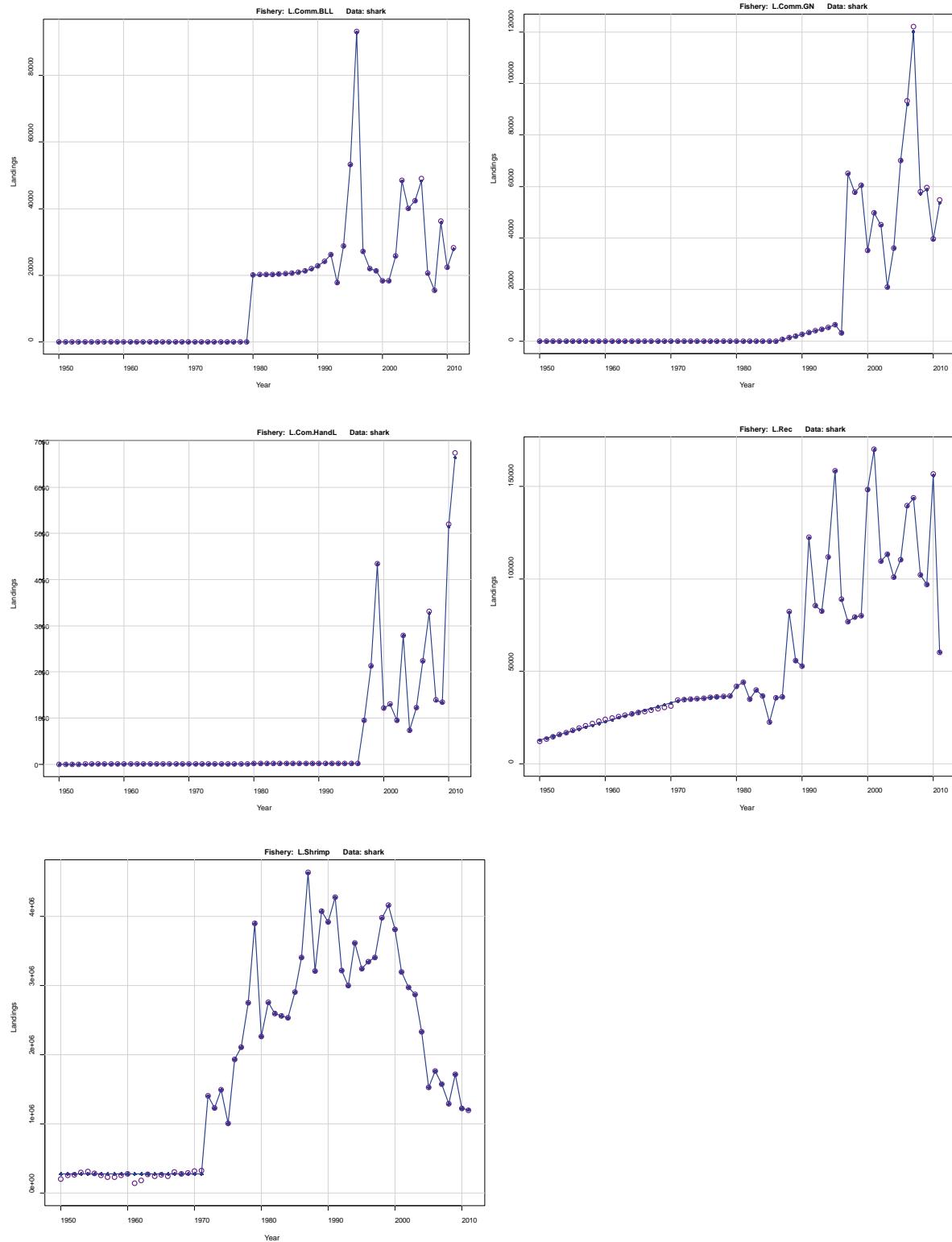


Figure 3.6.28. Predicted fits to the five catch data streams for the “No indices” sensitivity run.

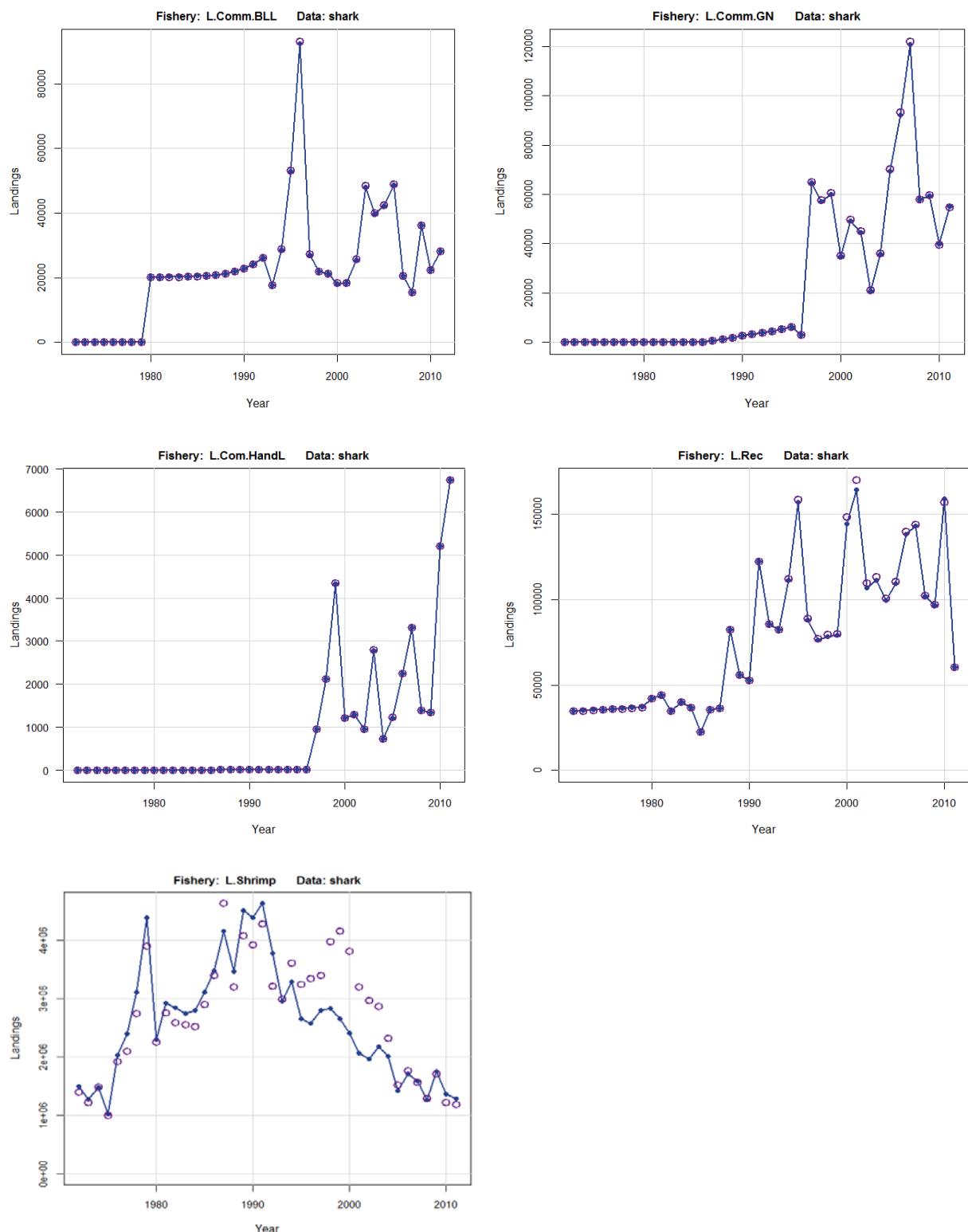


Figure 3.6.29. Predicted fits to the five catch data streams for the “start 1972” sensitivity run.

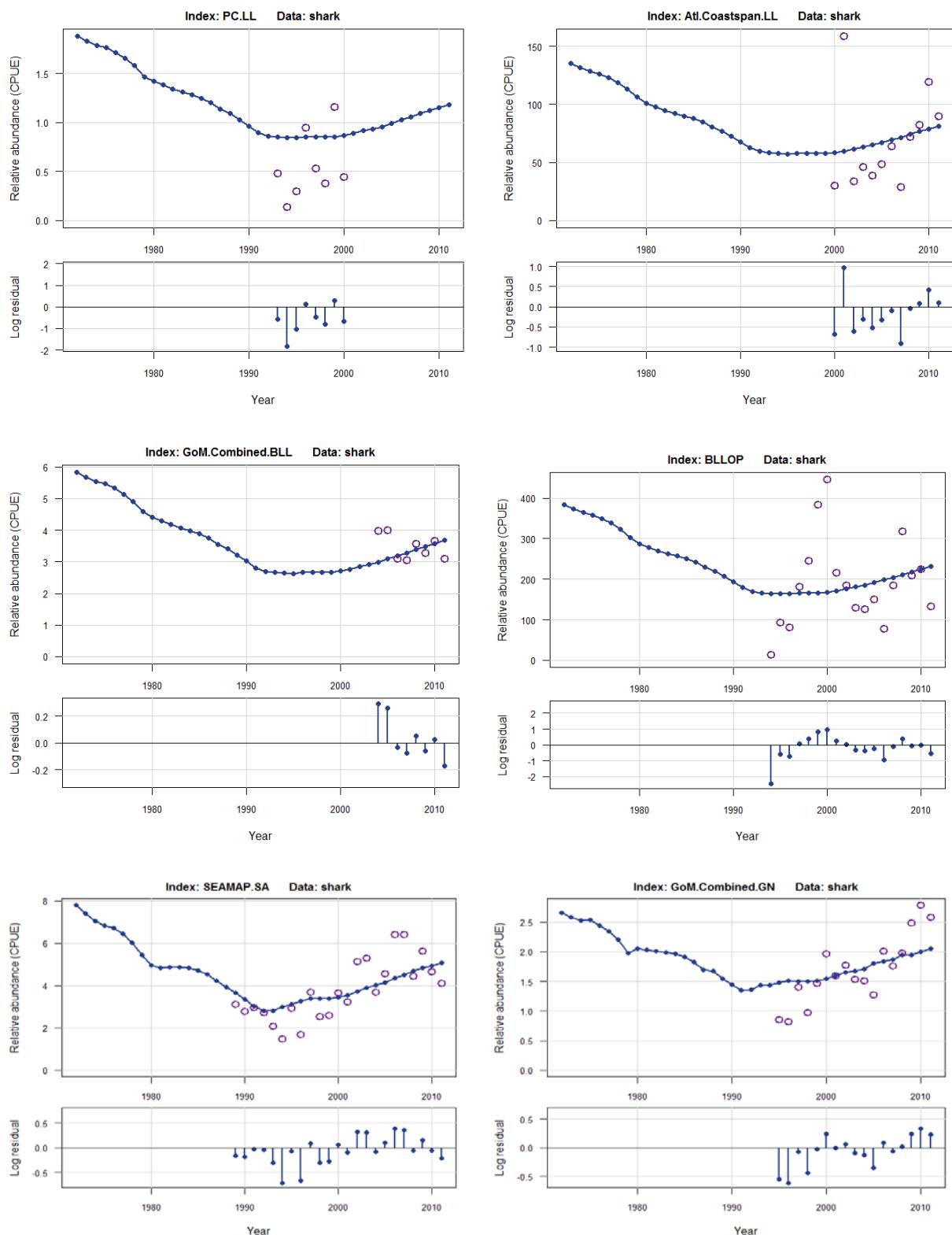


Figure 3.6.30. Predicted fits to indices and residual plots for the "start 1972" sensitivity run.

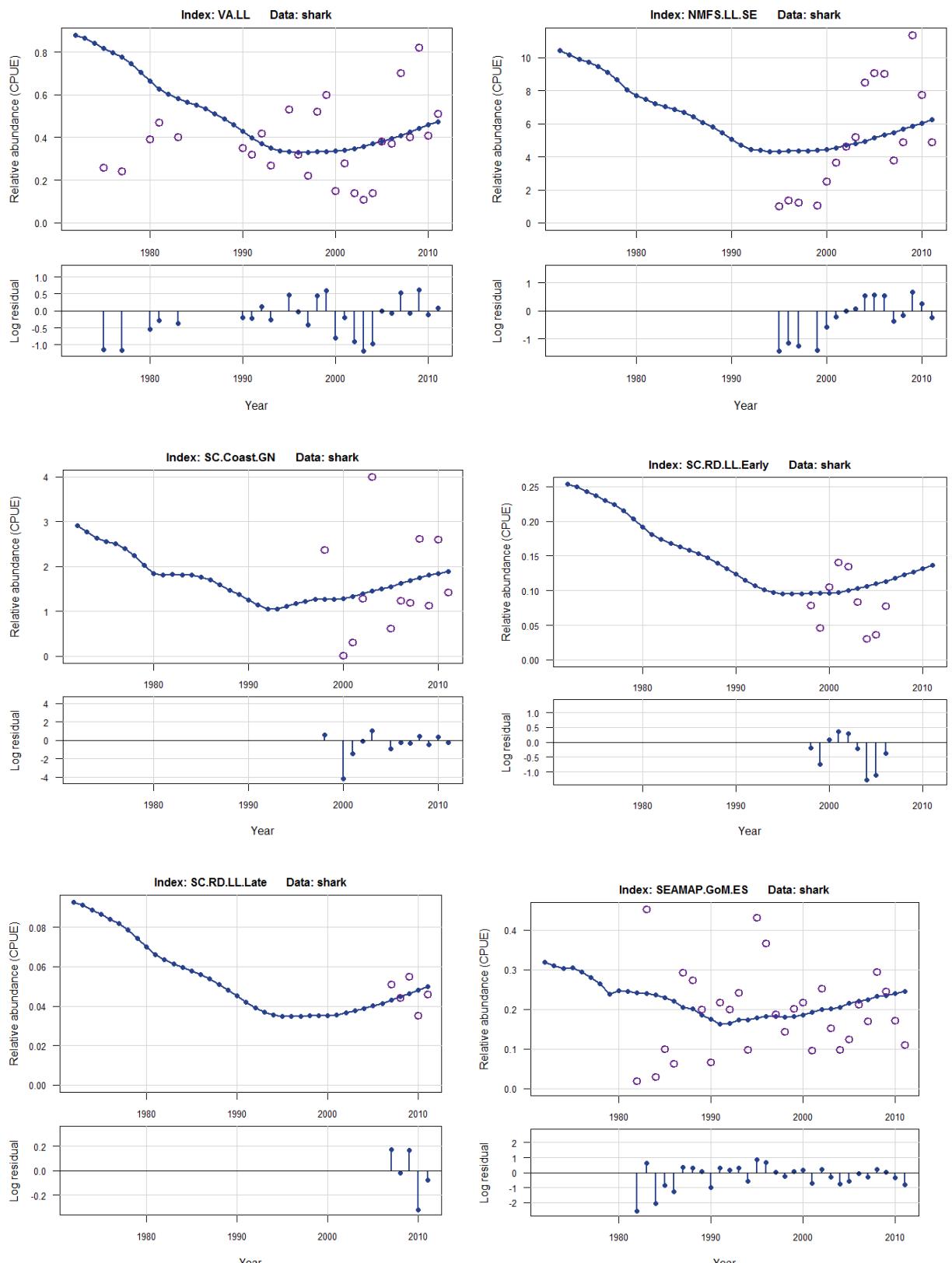


Figure 3.6.30 (continued). Predicted fits to indices and residual plots for the “start 1972” sensitivity run.

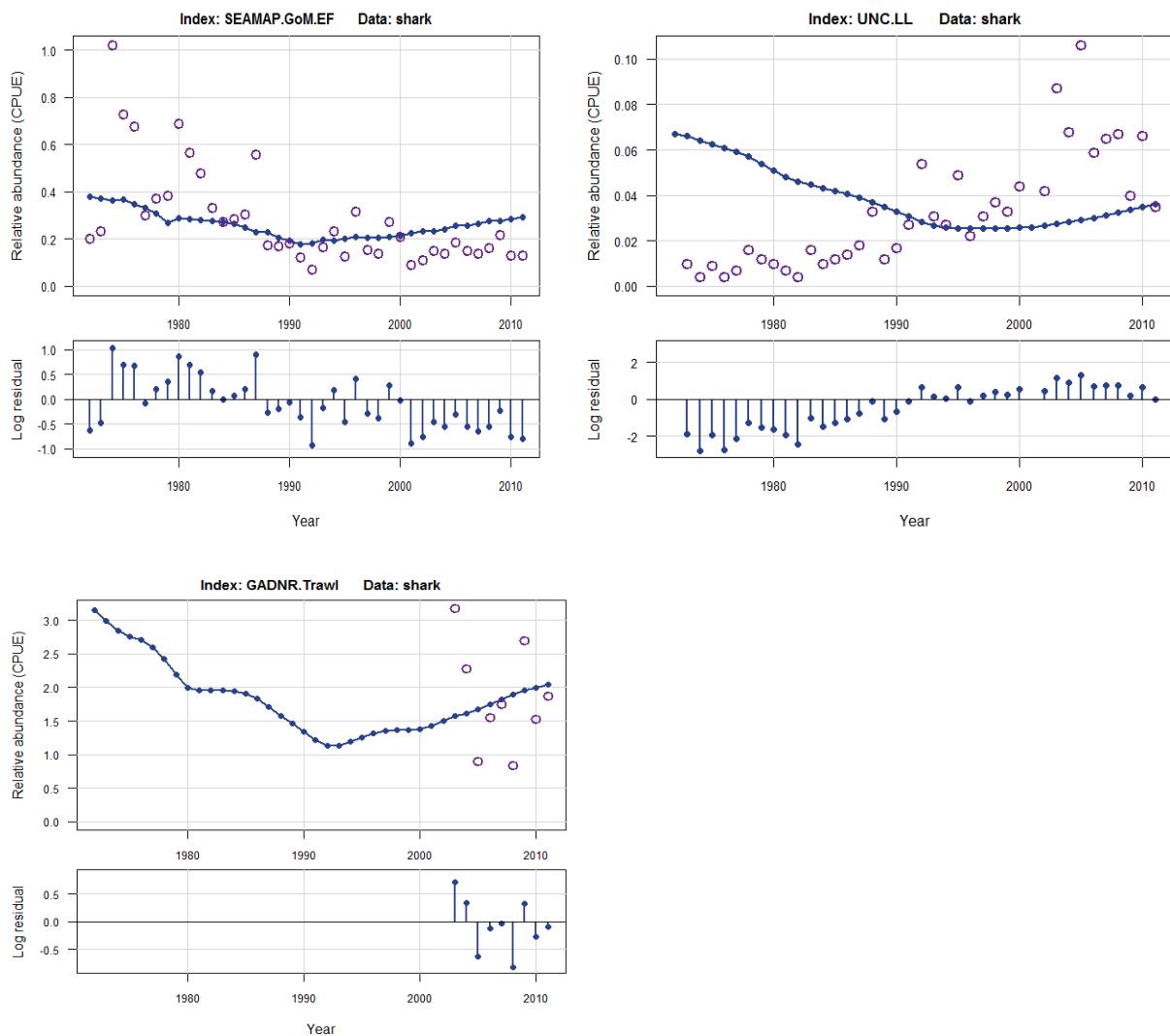


Figure 3.6.30 (continued). Predicted fits to indices and residual plots for the “start 1972” sensitivity run.

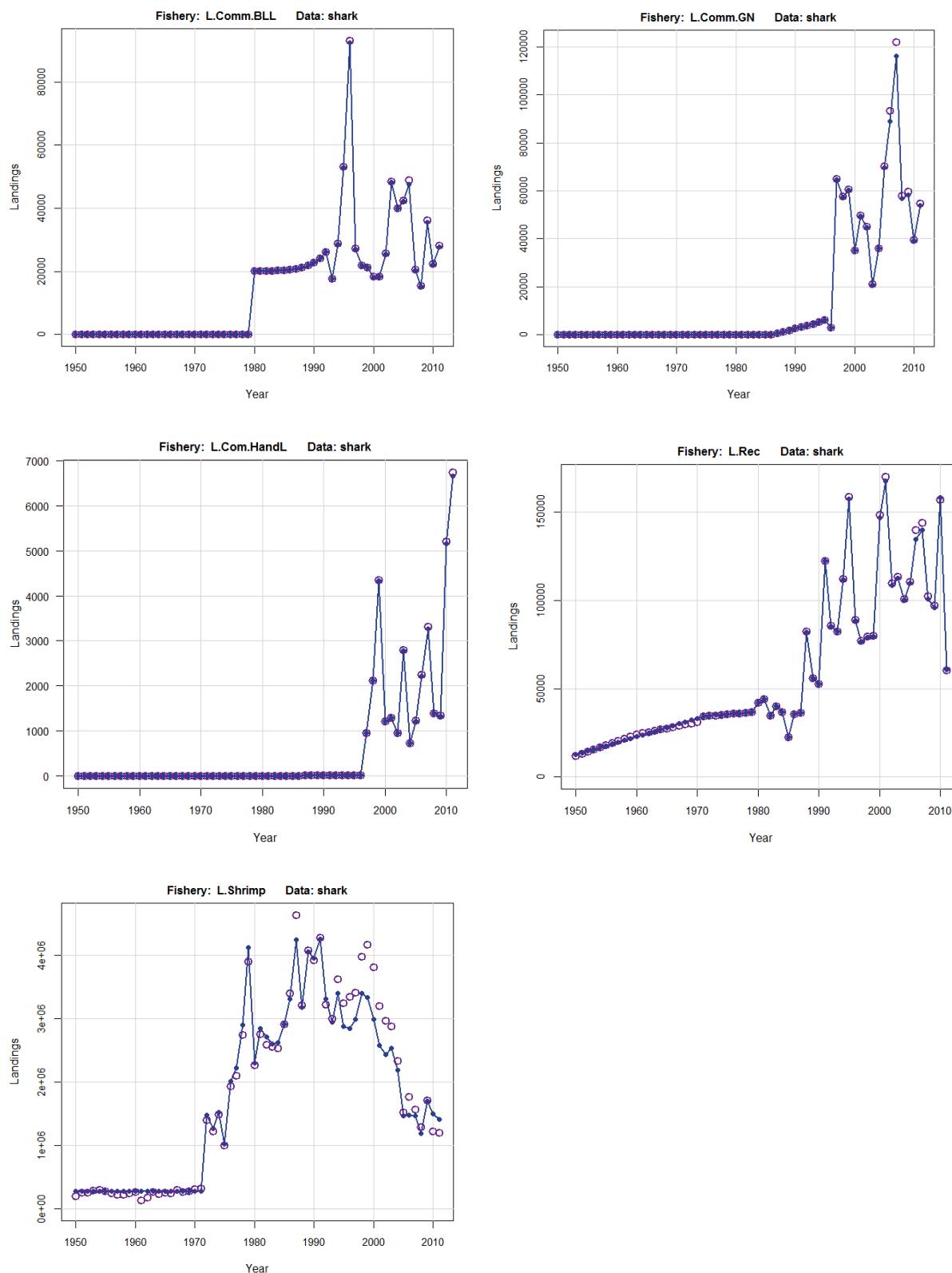


Figure 3.6.31. Predicted fits to the five catch data streams for the “high productivity” sensitivity run.

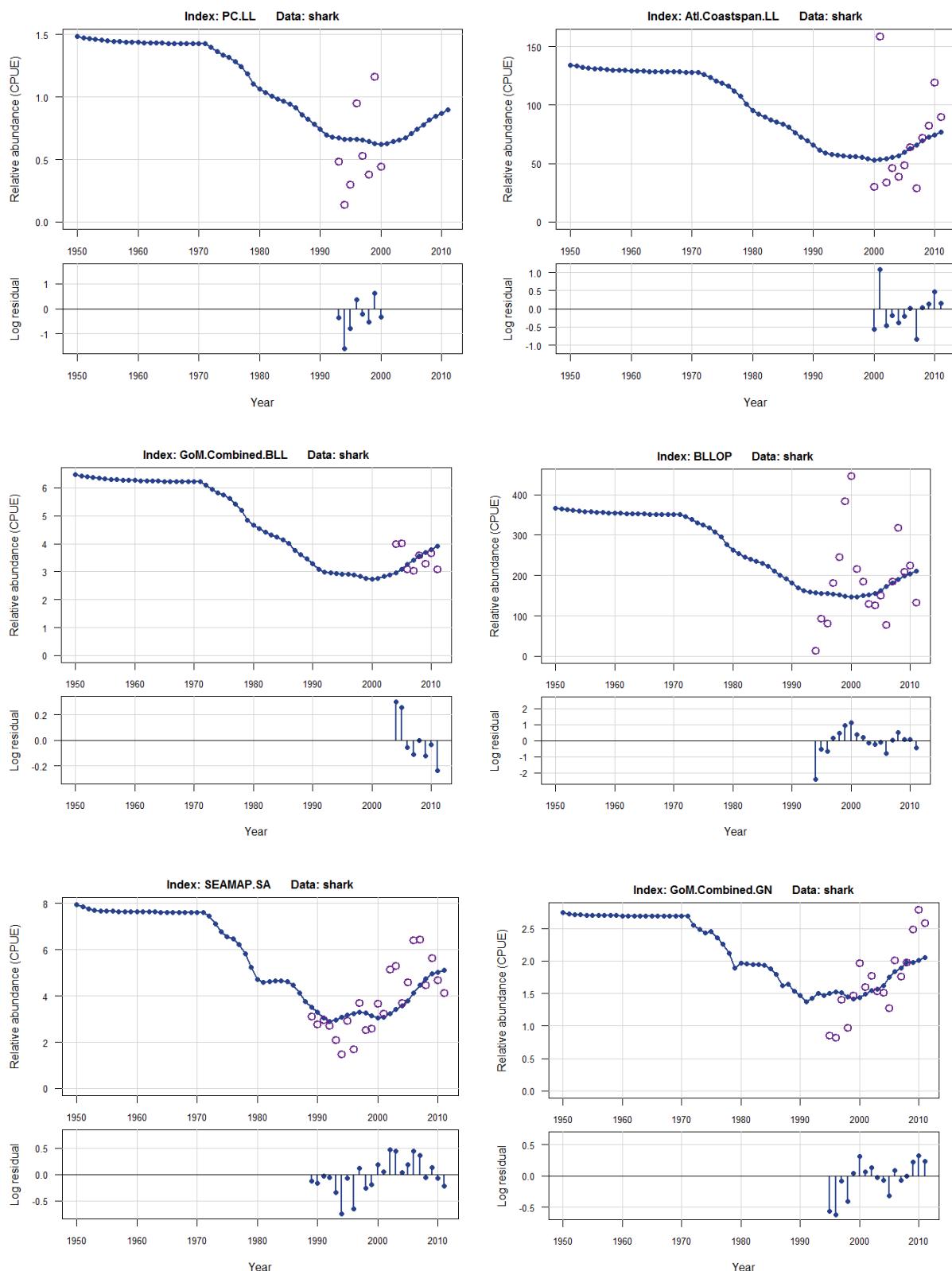


Figure 3.6.32. Predicted fits to indices and residual plots for the “high productivity” sensitivity run.

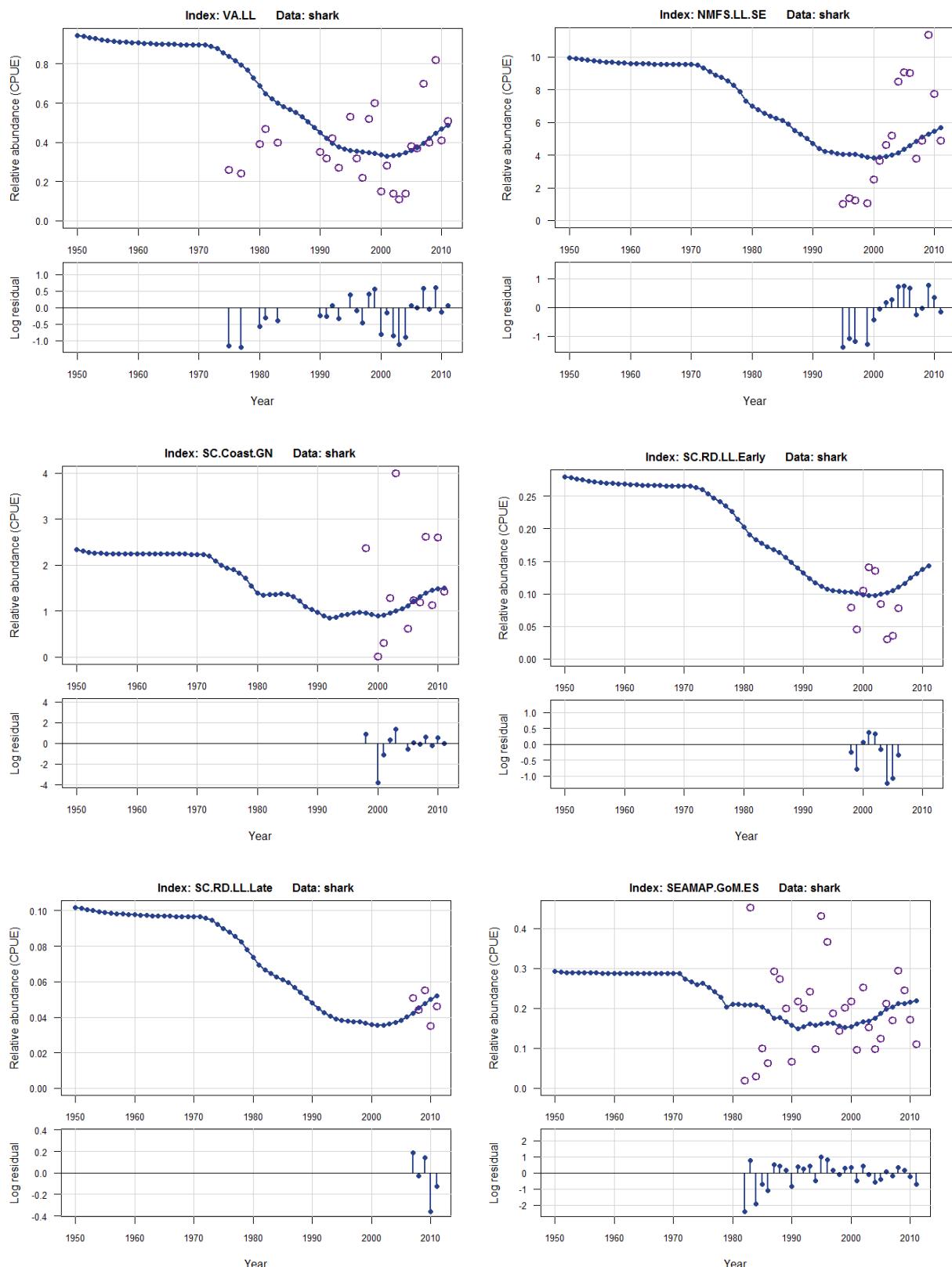


Figure 3.6.32 (continued). Predicted fits to indices and residual plots for the “high productivity” sensitivity run.

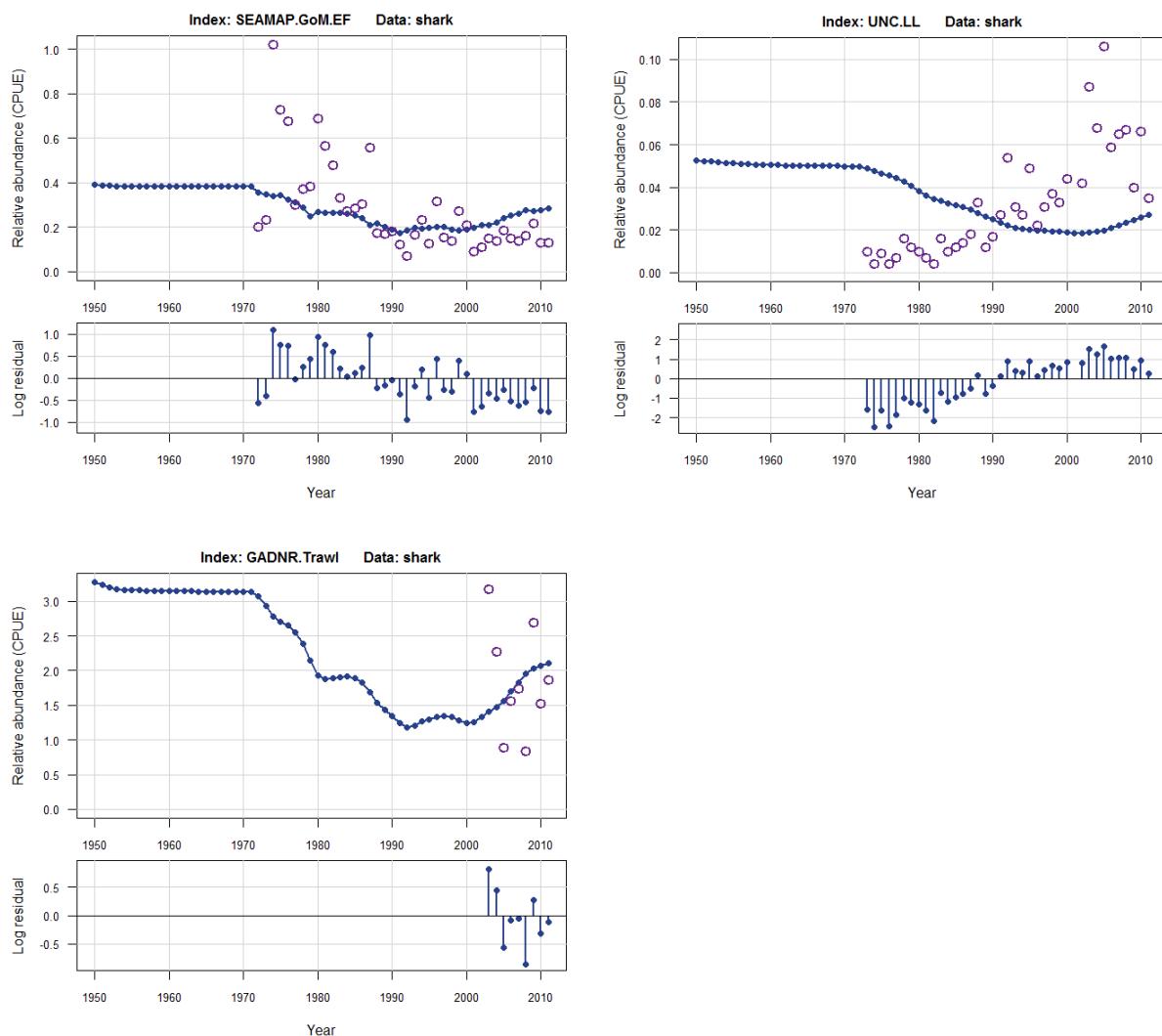


Figure 3.6.32 (continued). Predicted fits to indices and residual plots for the “high productivity” sensitivity run.

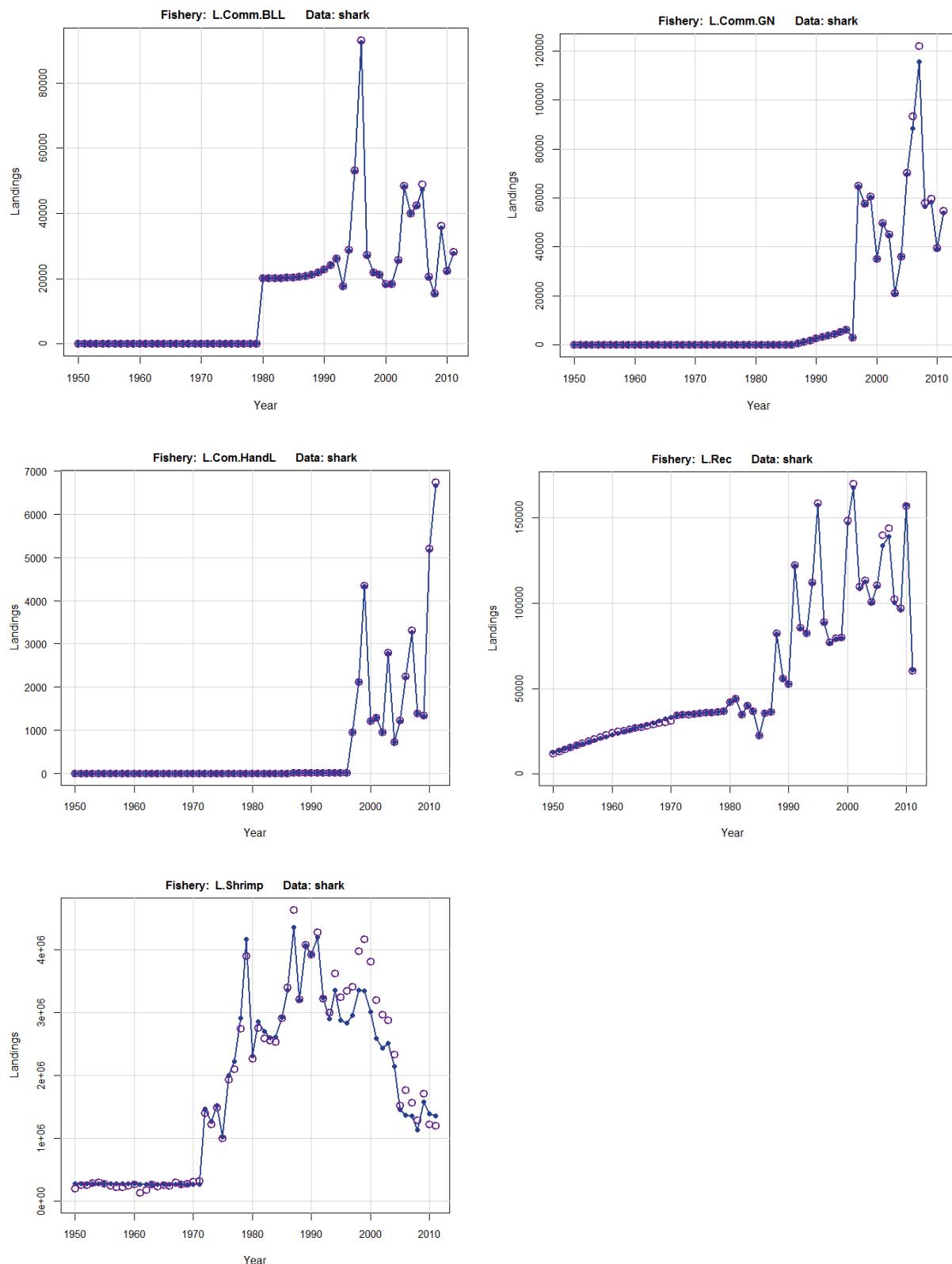


Figure 3.6.33. Predicted fits to the five catch data streams for the “low productivity” sensitivity run.

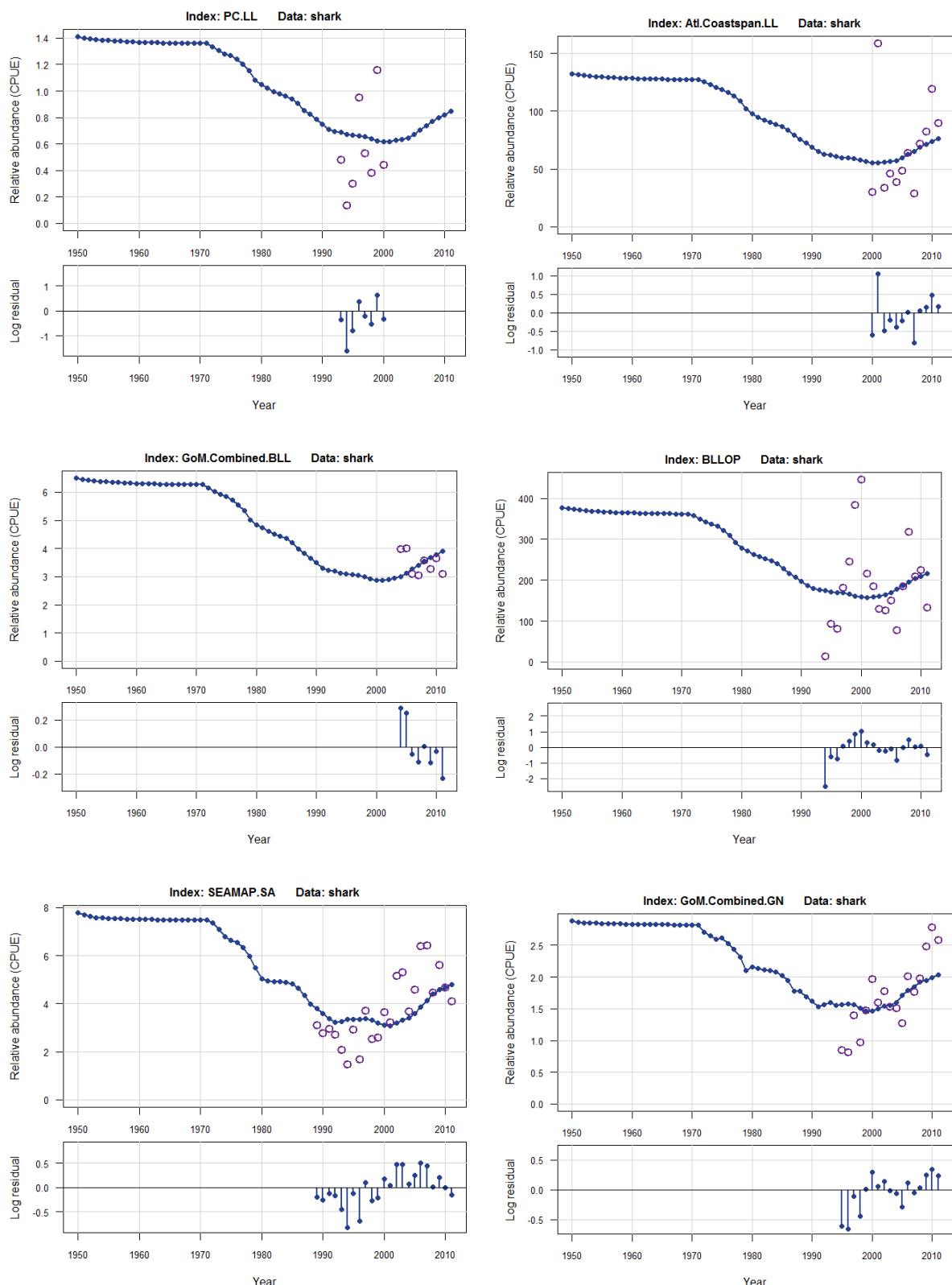


Figure 3.6.34. Predicted fits to indices and residual plots for the “low productivity” sensitivity run.

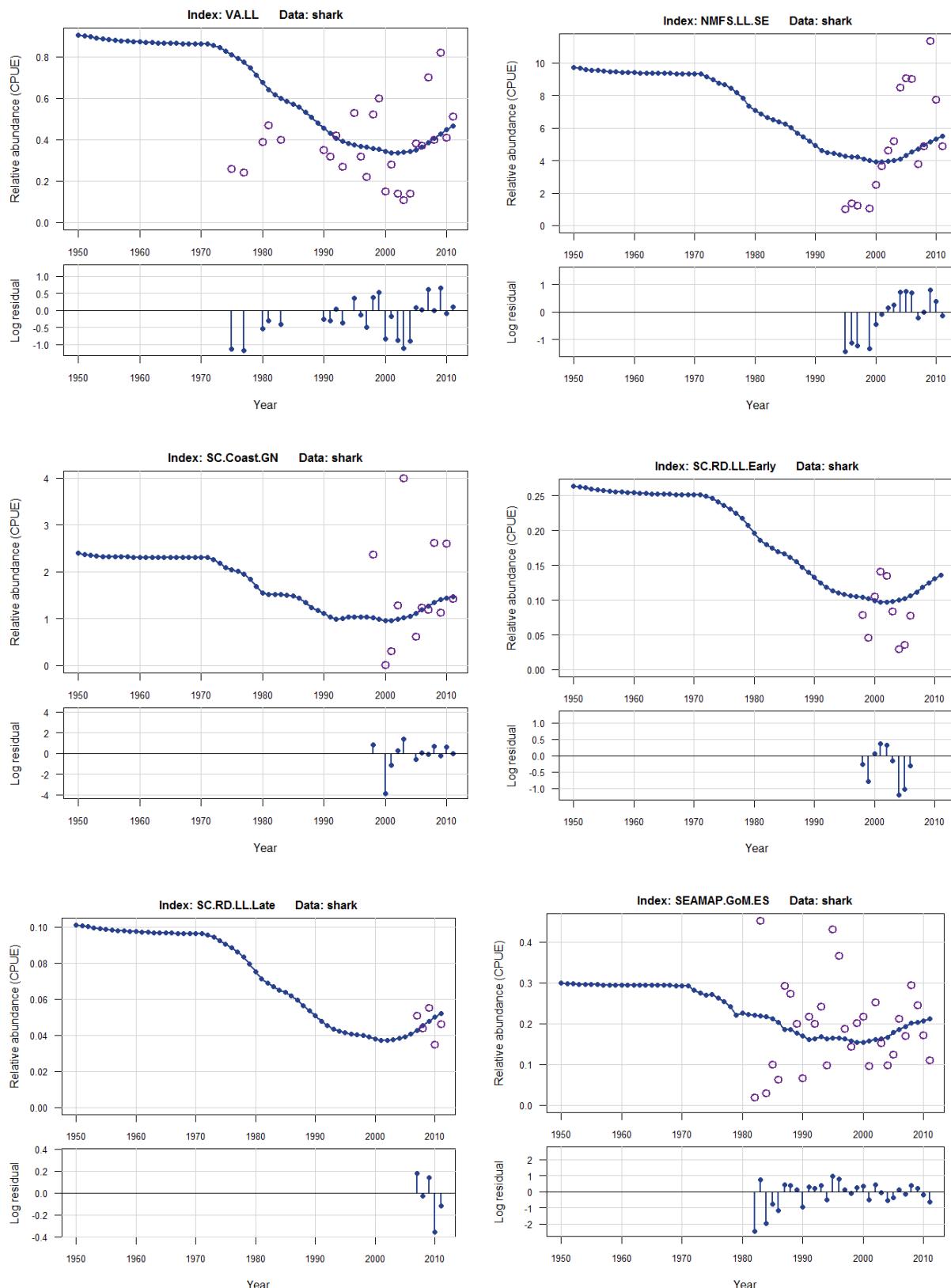


Figure 3.6.34 (continued). Predicted fits to indices and residual plots for the “low productivity” sensitivity run.

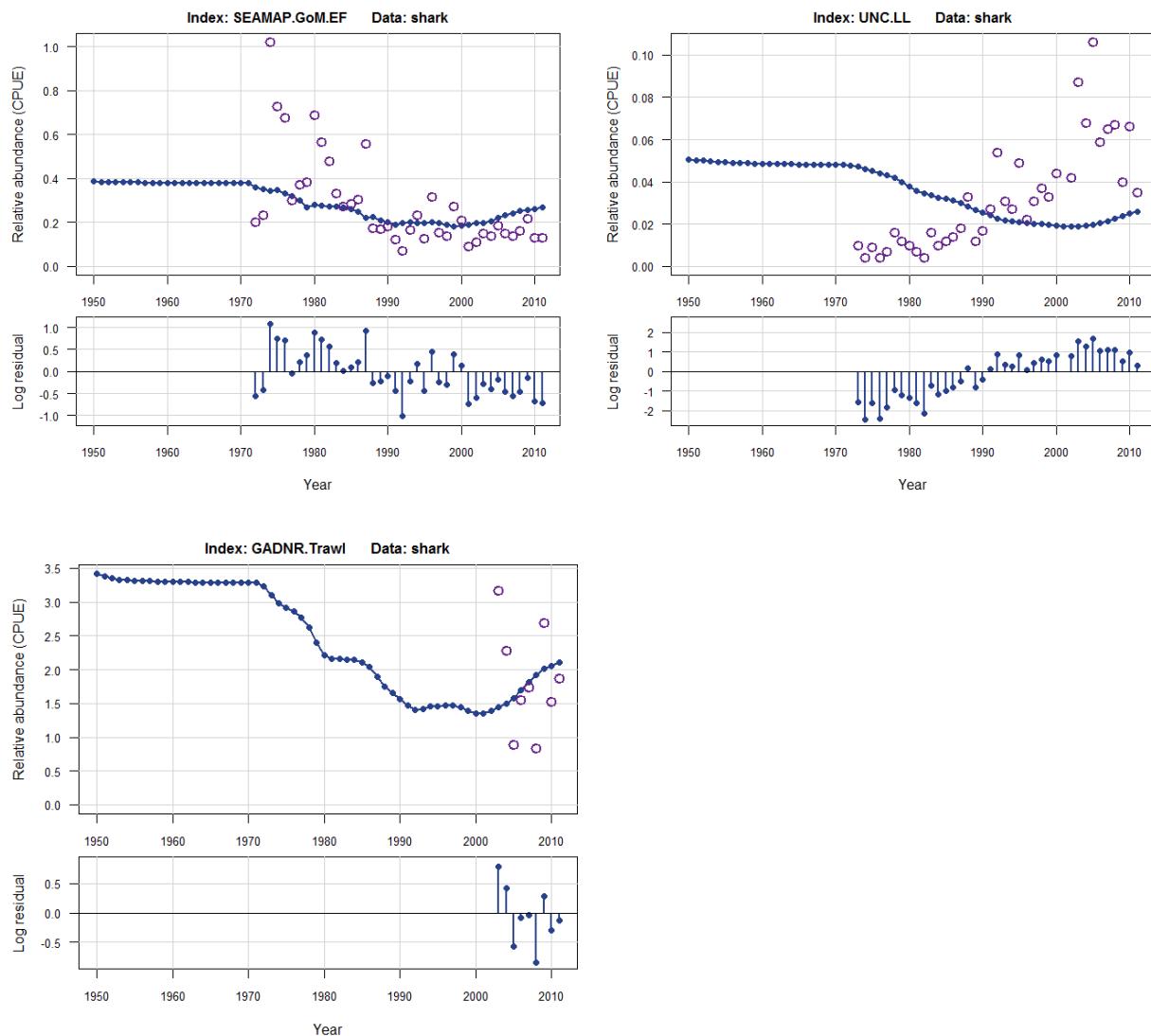


Figure 3.6.34 (continued). Predicted fits to indices and residual plots for the "low productivity" sensitivity run.

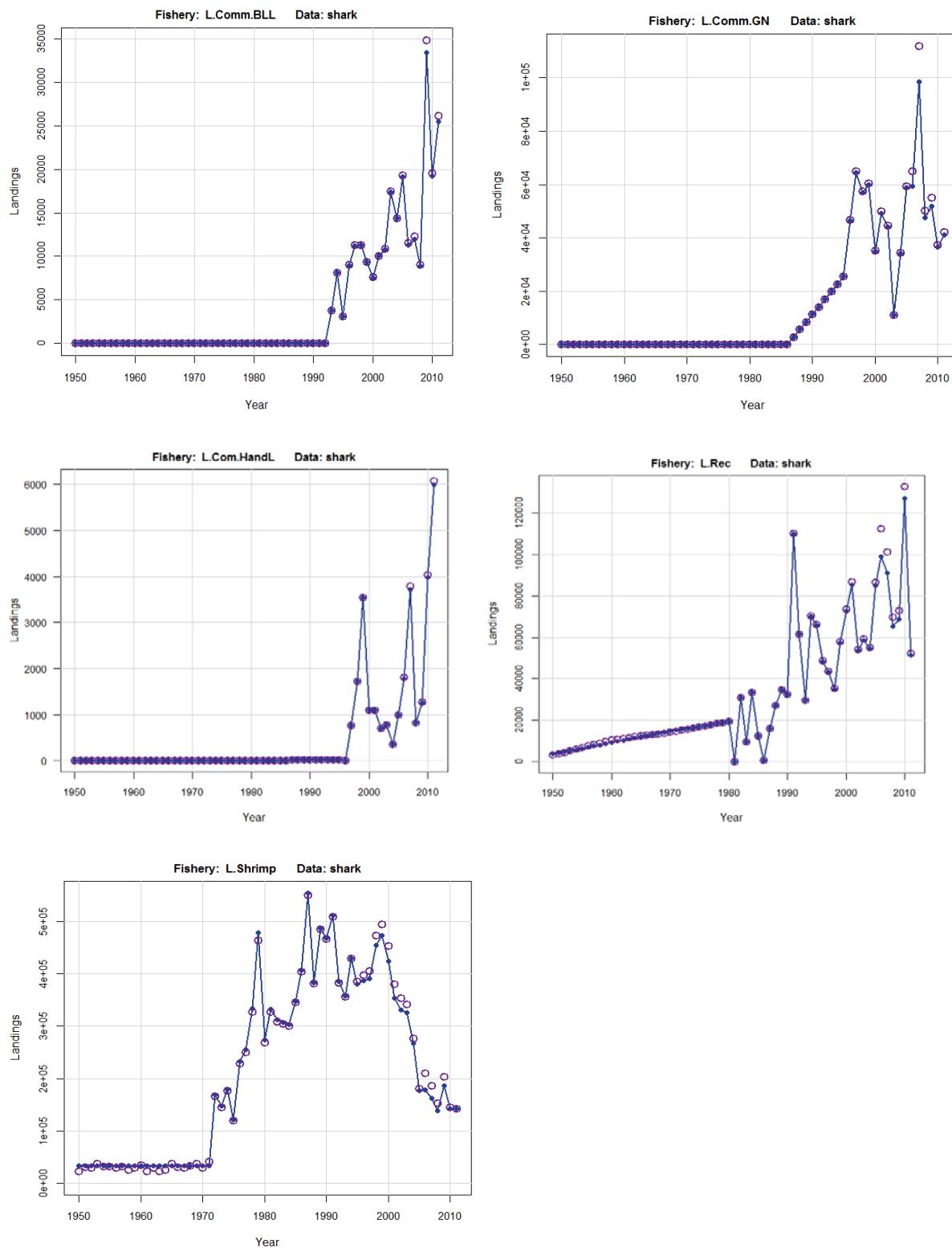


Figure 3.6.35. Predicted fits to the five catch data streams for the “Atlantic stock” sensitivity run.

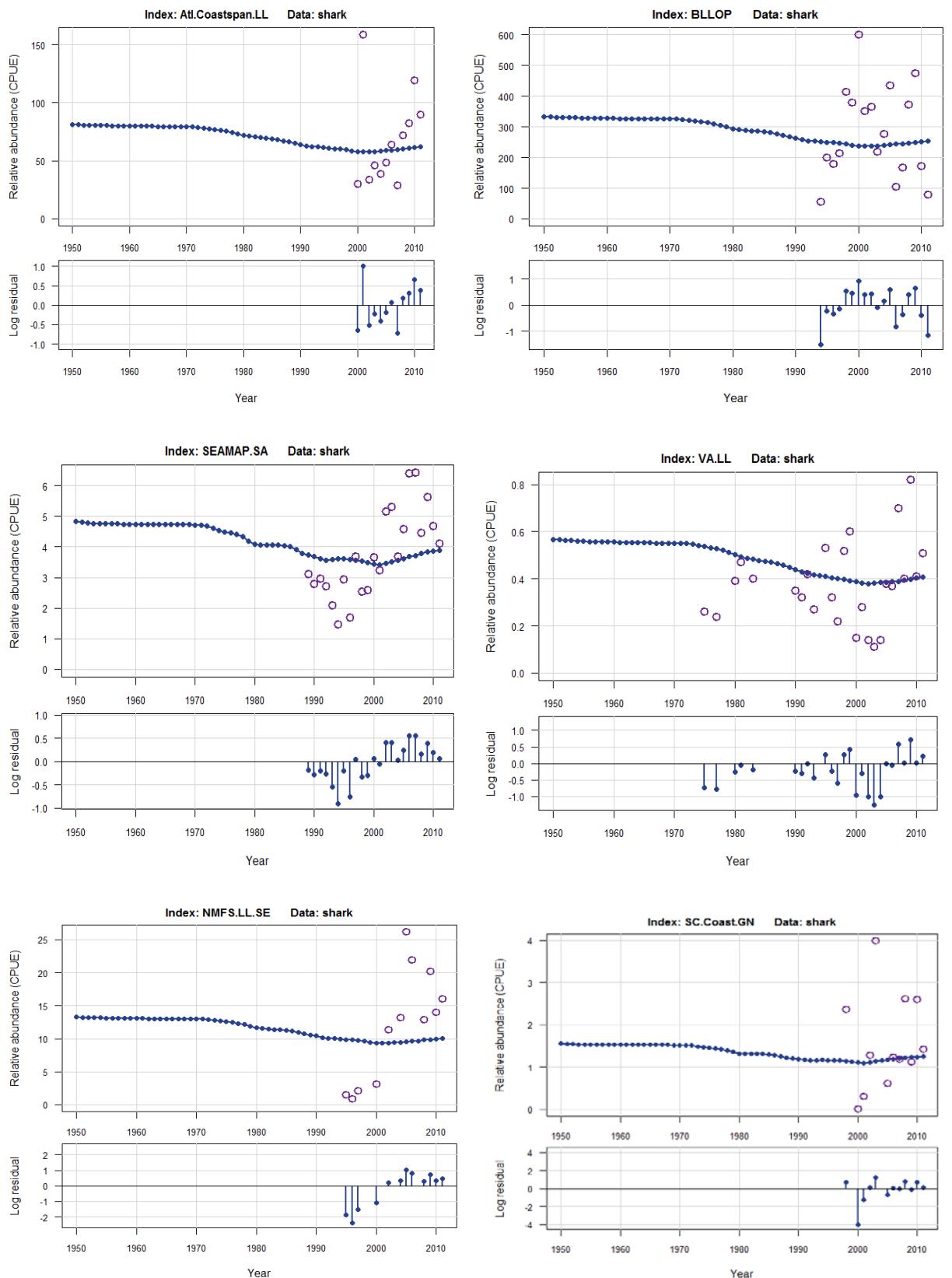


Figure 3.6.36. Predicted fits to indices and residual plots for the “Atlantic stock” sensitivity run.

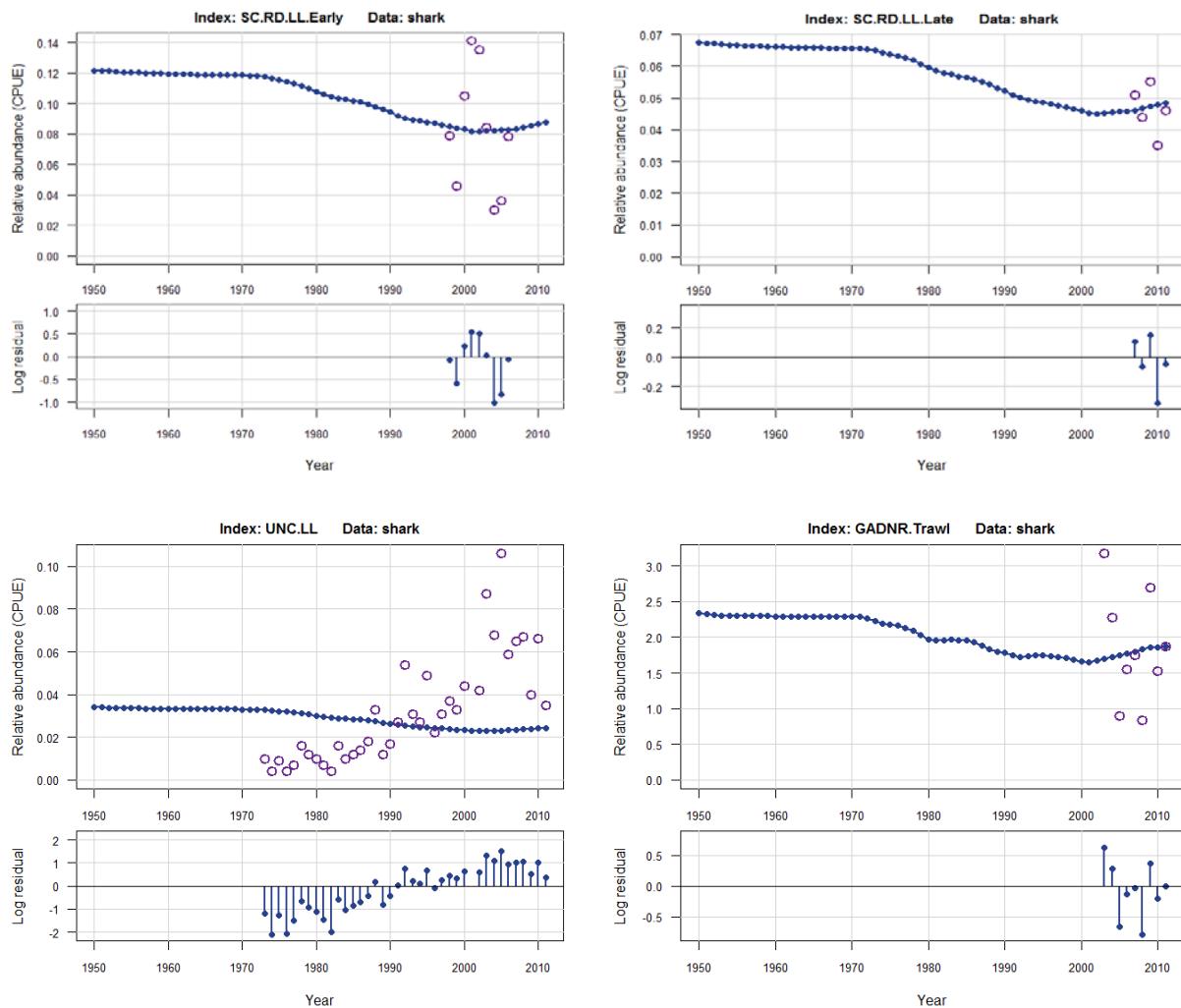


Figure 3.6.36 (continued). Predicted fits to indices and residual plots for the “Atlantic stock” sensitivity run.

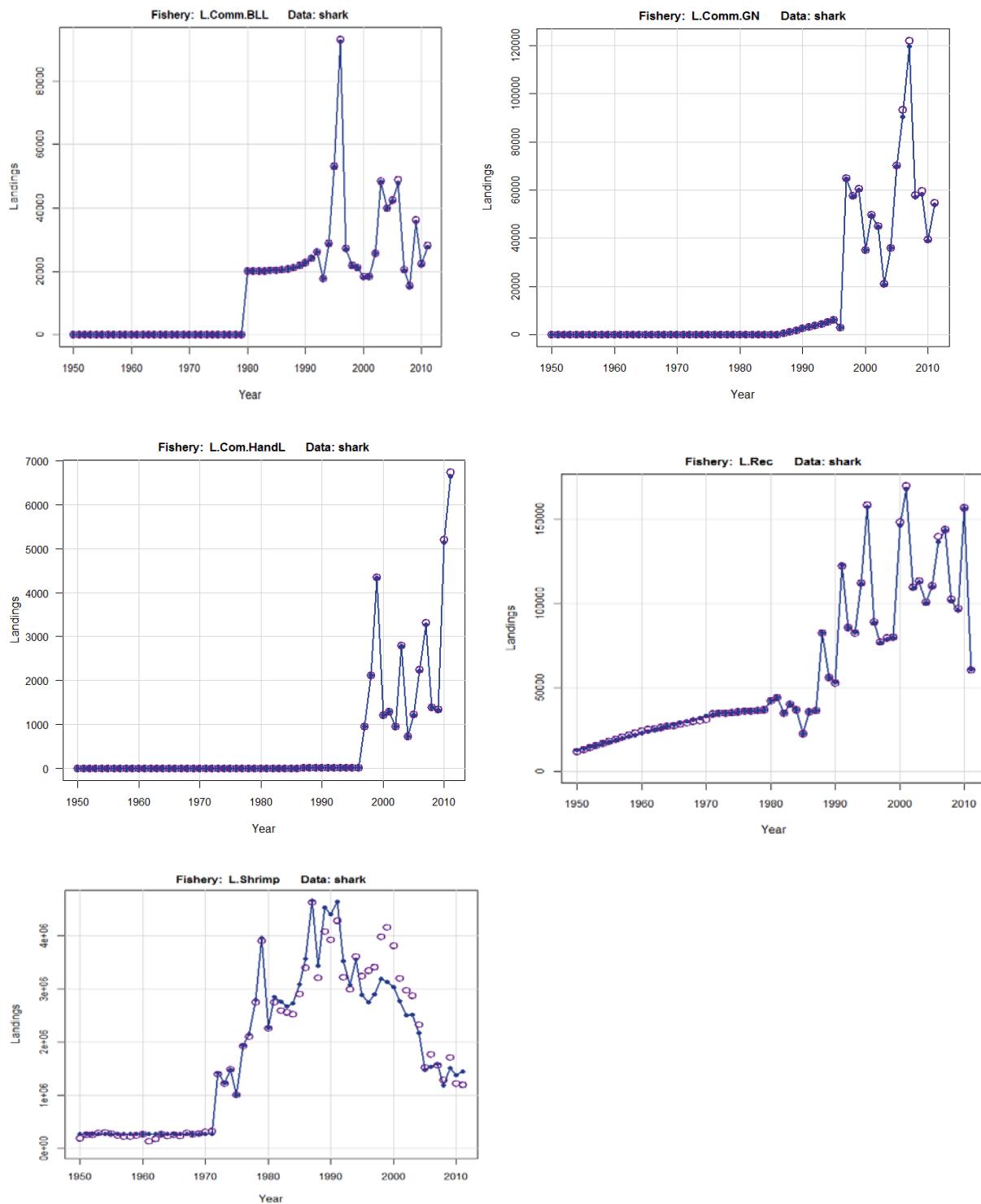


Figure 3.6.37. Predicted fits to the five catch data streams for the “Gulf of Mexico stock” sensitivity run.

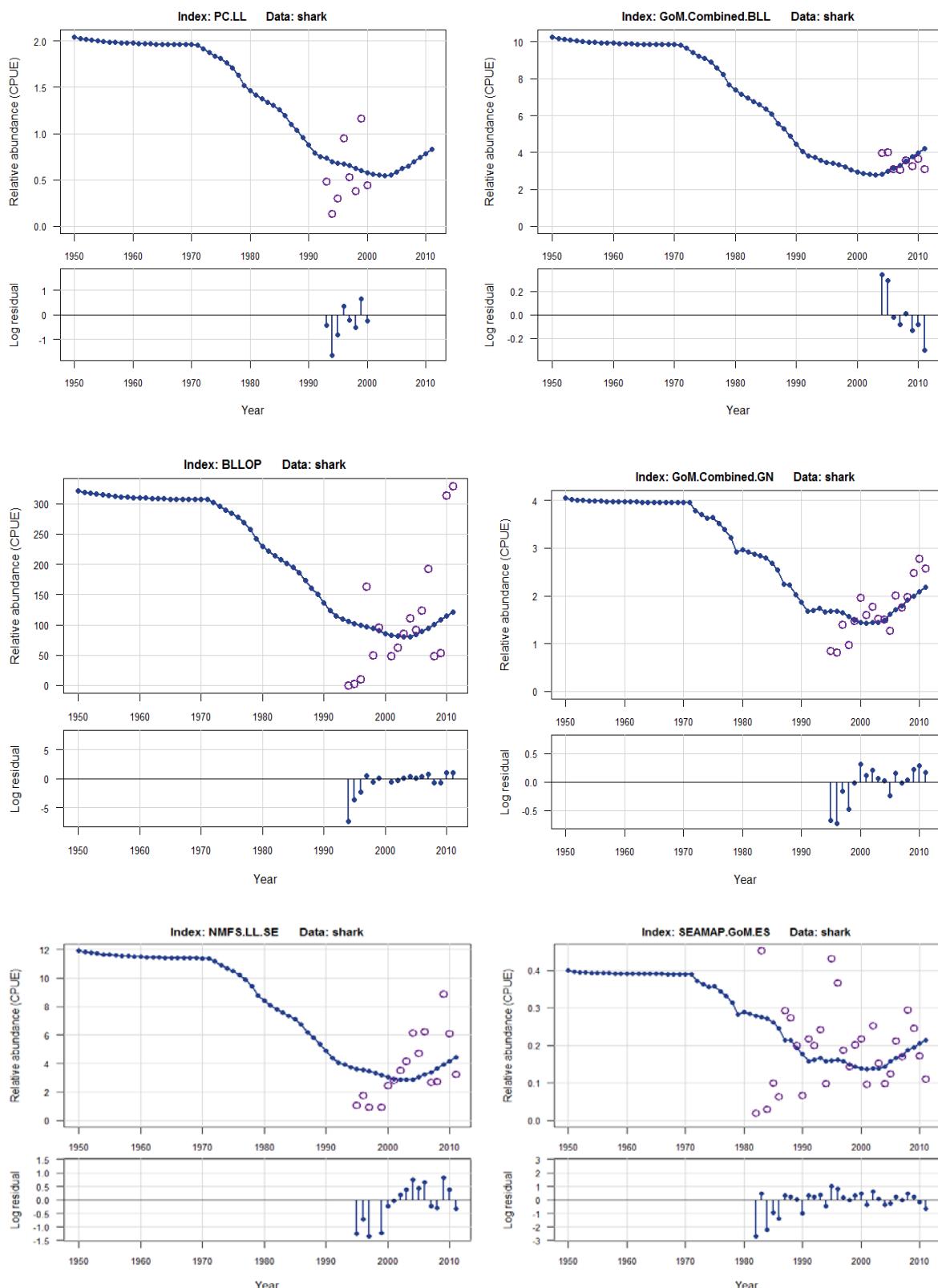


Figure 3.6.38. Predicted fits to indices and residual plots for the “Gulf of Mexico stock” sensitivity run.

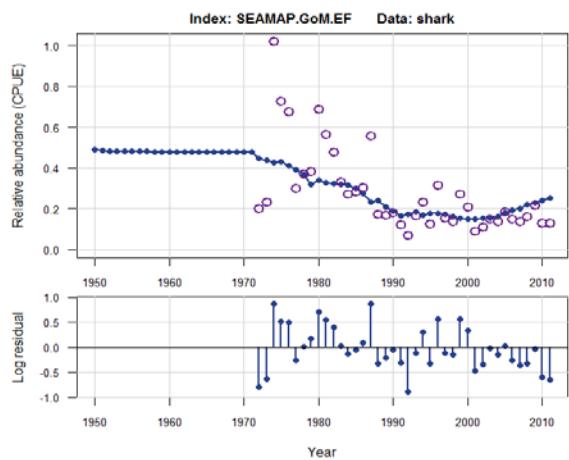


Figure 3.6.38 (continued). Predicted fits to indices and residual plots for the “Gulf of Mexico stock” sensitivity run.

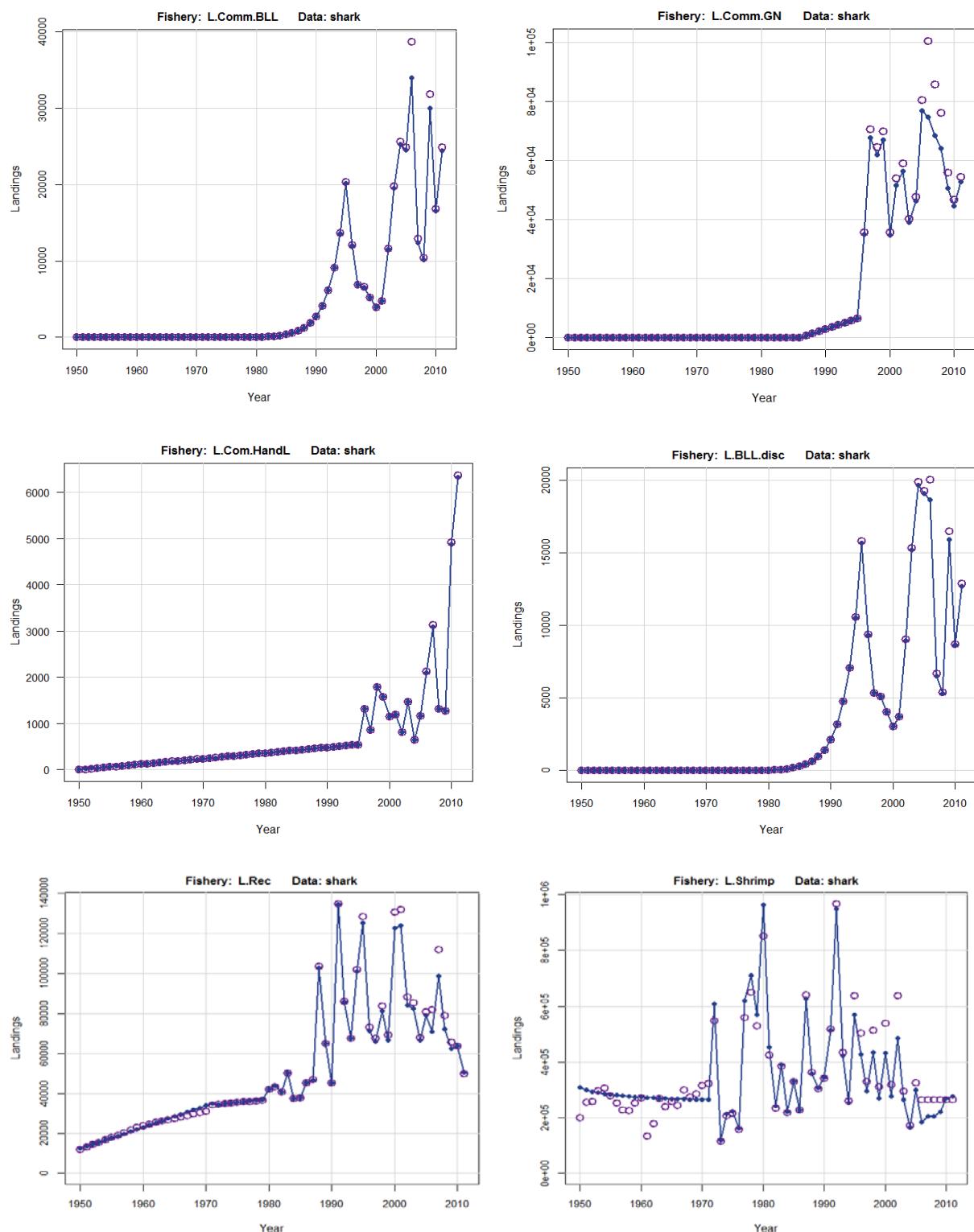


Figure 3.6.39. Predicted fits to the six catch data streams in the continuity run.

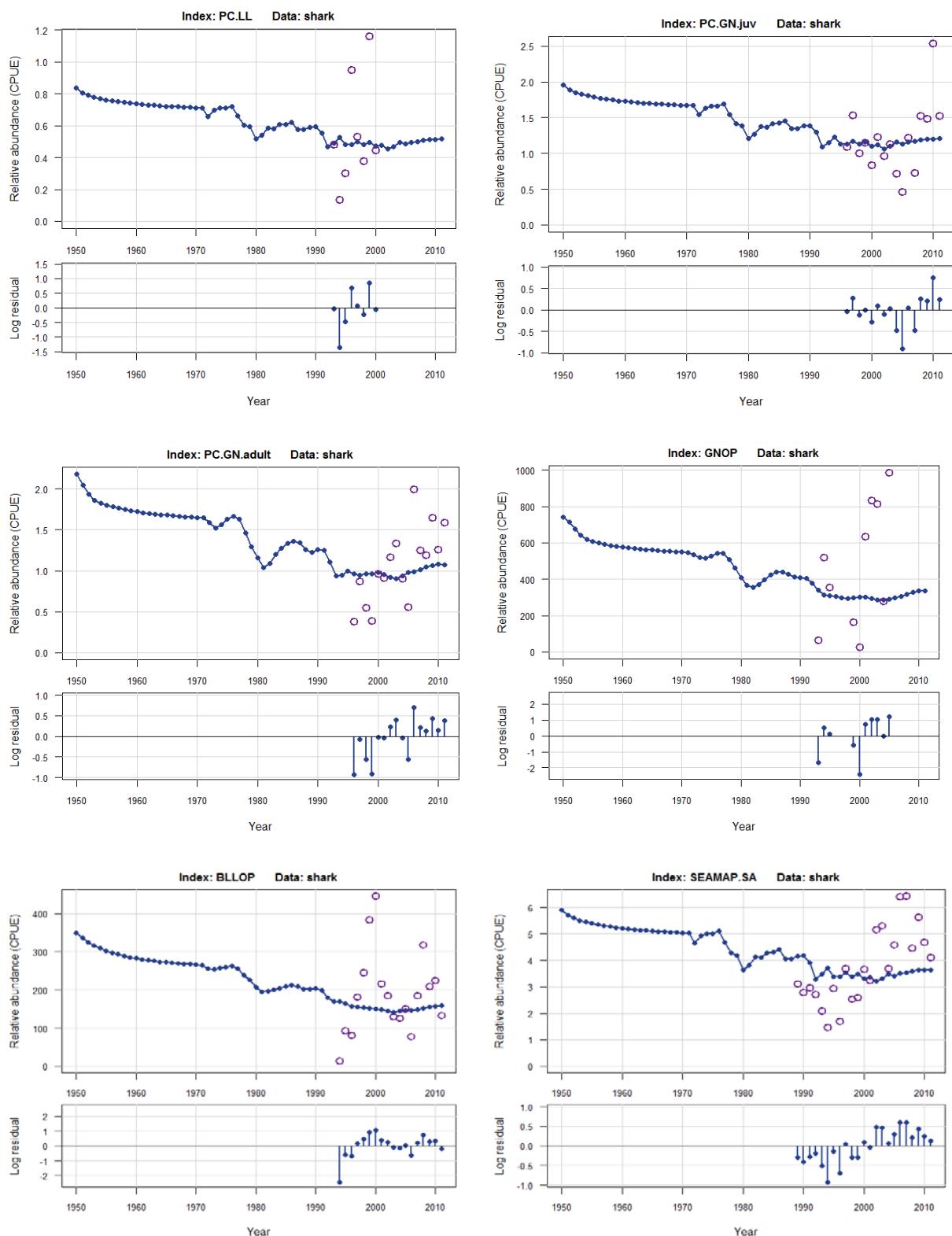


Figure 3.6.40. Predicted fits to indices and residual plots in the continuity run.

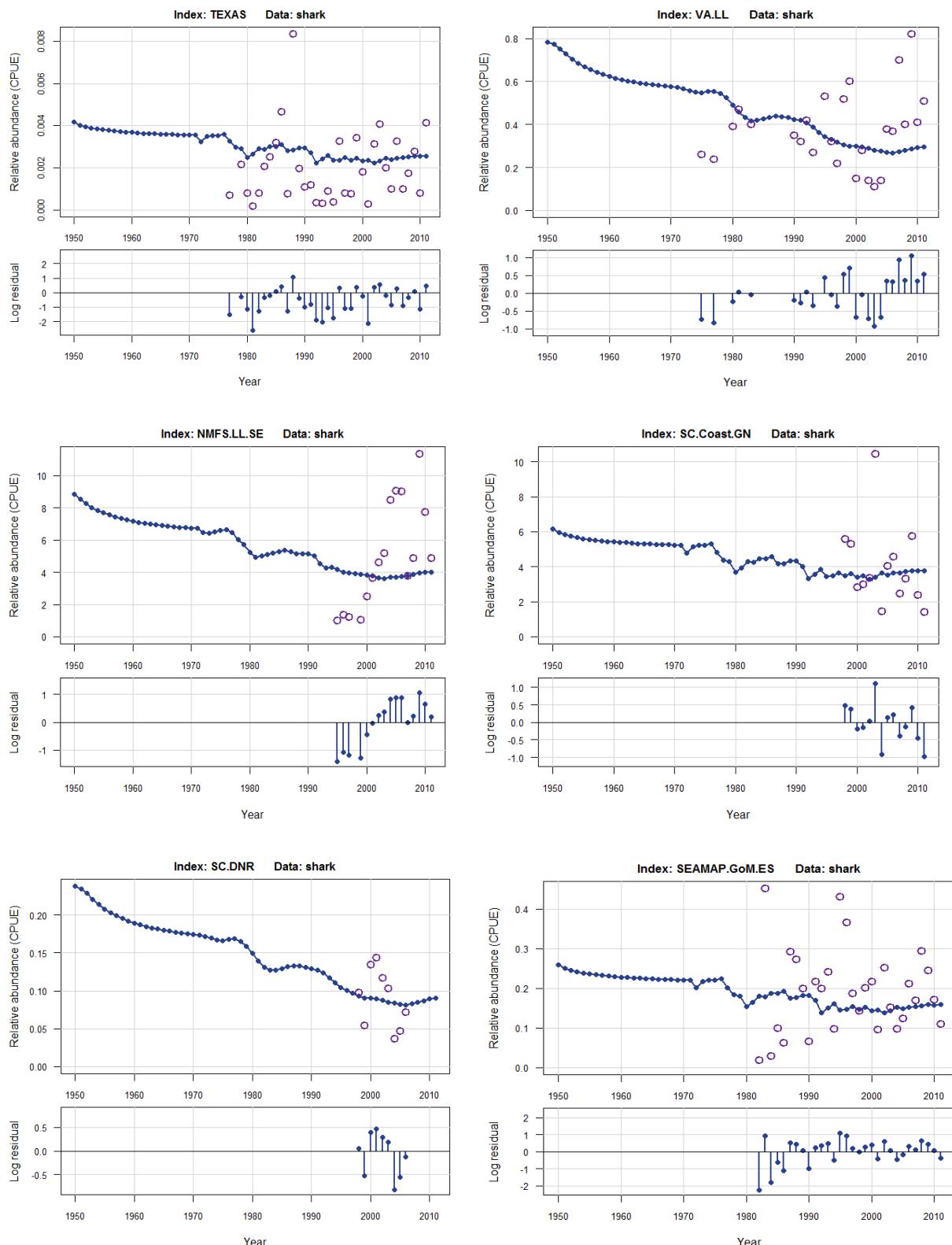


Figure 3.6.40 (continued). Predicted fits to indices and residual plots in the continuity run.

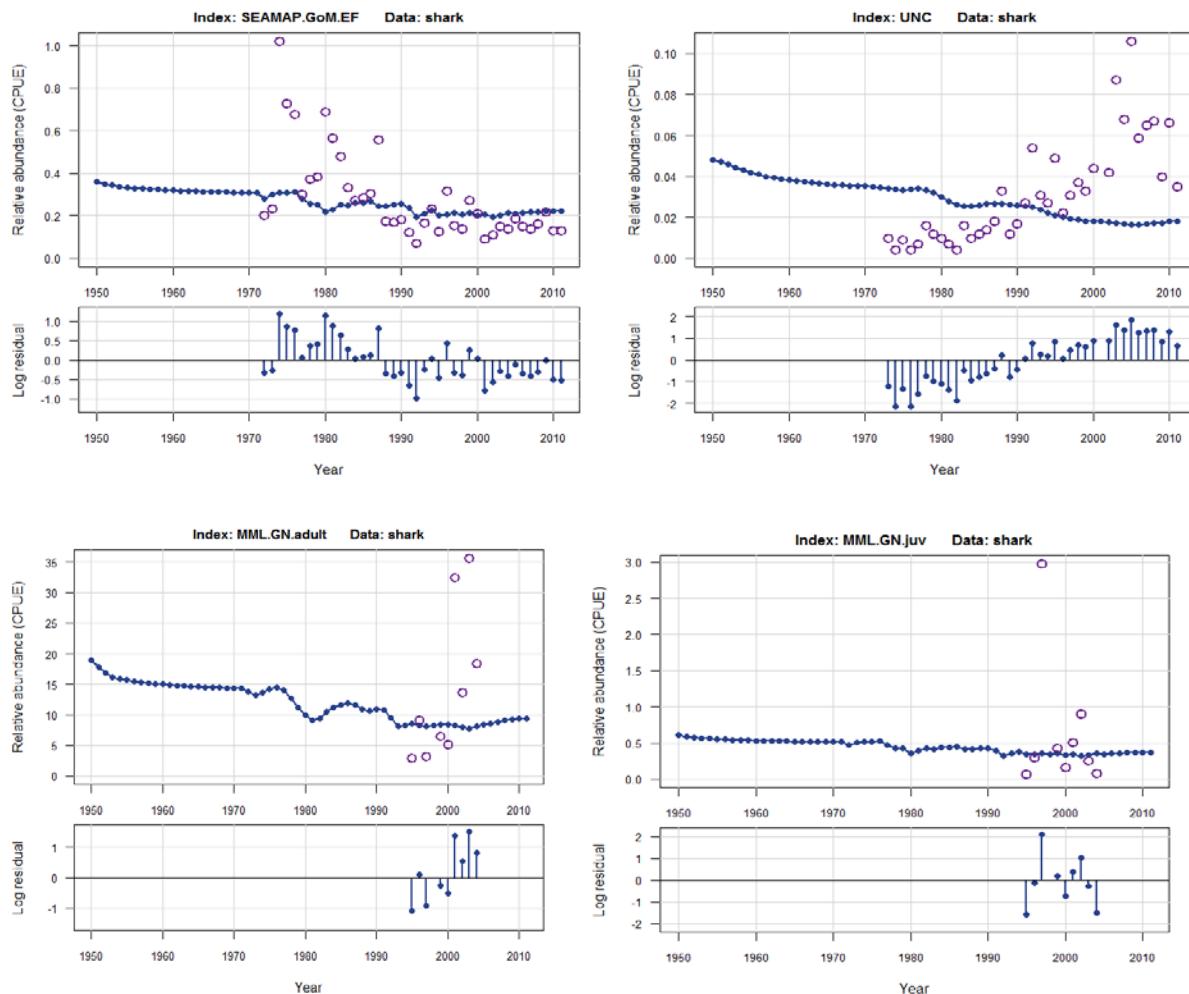


Figure 3.6.40 (continued). Predicted fits to indices and residual plots in the continuity run.

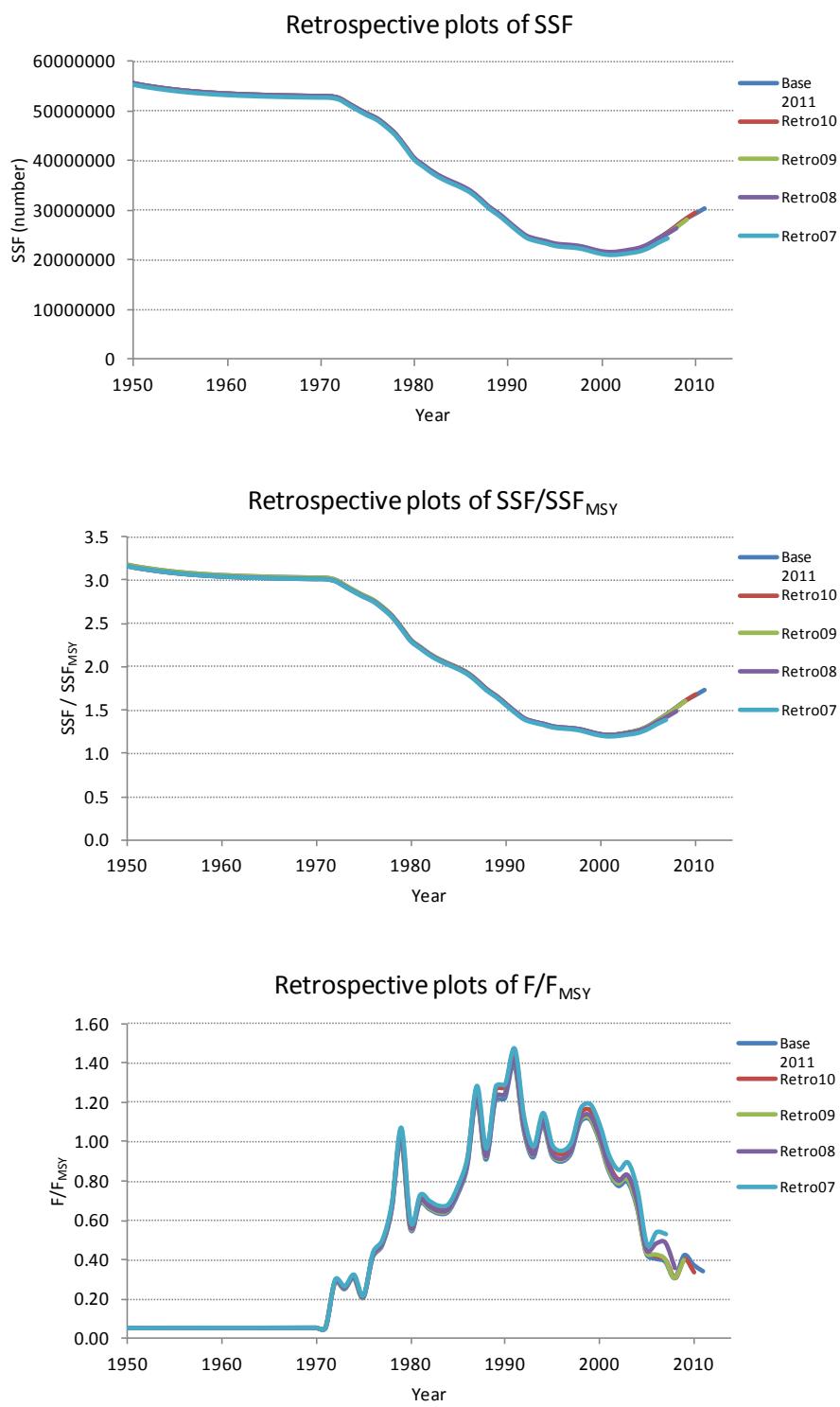


Figure 3.6.41. Retrospective analysis of the baseline run for Atlantic sharpnose shark with last four years of data sequentially removed from the model. Model quantities examined include spawning stock fecundity (top), relative spawning stock fecundity (middle), and relative fishing mortality rate (bottom).

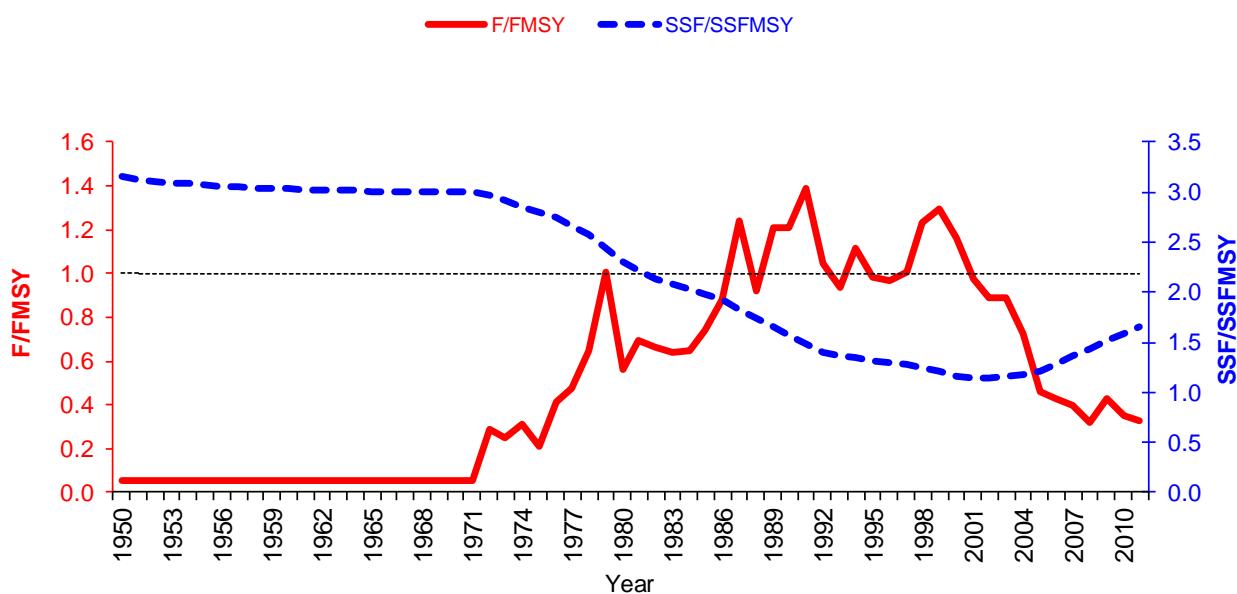


Figure 3.6.42. Estimated relative spawning stock fecundity and fishing mortality rate trajectories for Atlantic sharpnose shark in the base run. The straight dashed line indicates F_{MSY} .

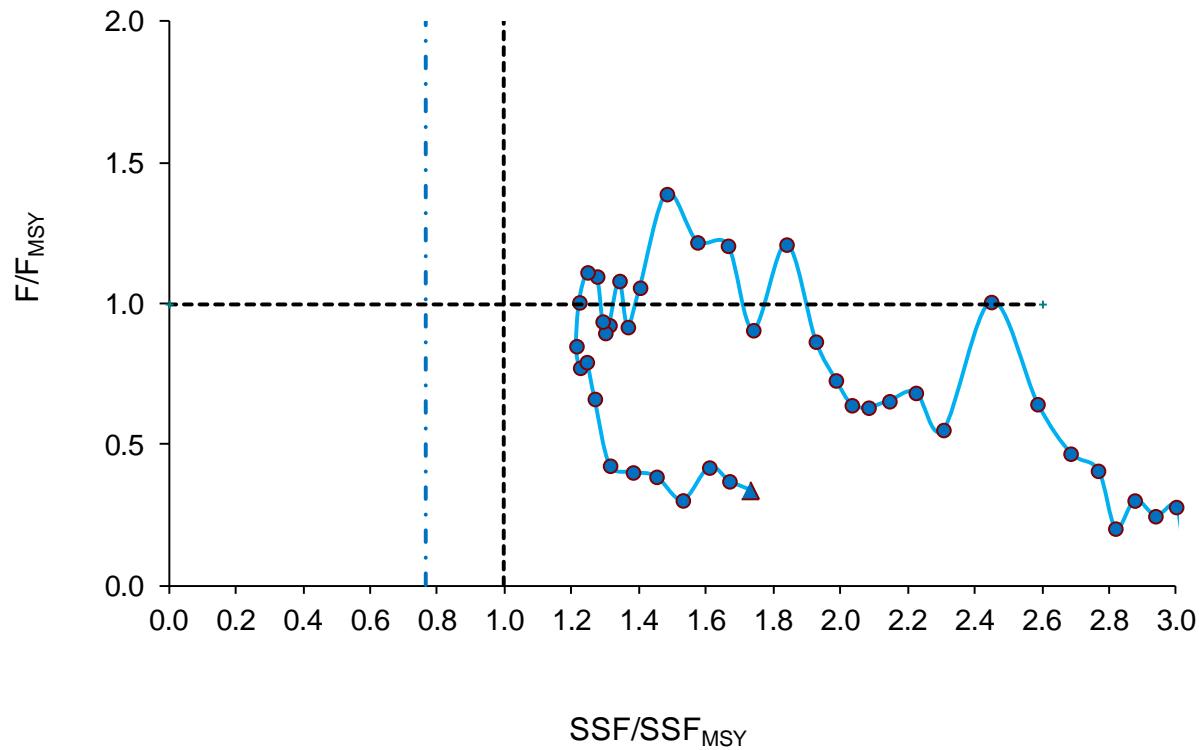


Figure 3.6.43. Phase plot of relative spawning stock fecundity and fishing mortality rate by year for the base run. The triangle (1.73, 0.34) indicates current (for 2011) conditions. The dashed vertical blue line indicates MSST $((1-M)*SSF_{MSY})$.

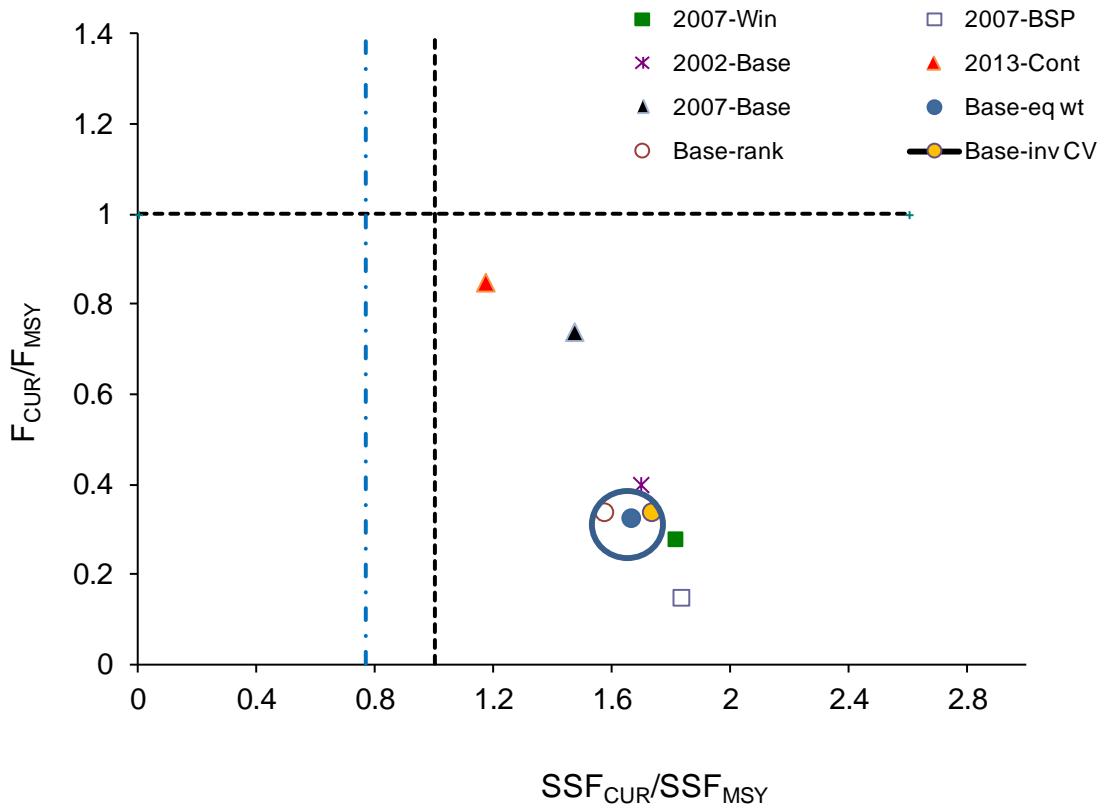


Figure 3.6.44. Phase plot of Atlantic sharpnose shark stock status. Results are shown for the base model (base) with rank weighting (base-rank), inverse CV weighting (base-inv CV), and equal weighting (base-eq wt), continuity analysis (2013-Cont), 2007 and 2002 assessment base models (2007-Base, 2002-Base), and Bayesian Surplus Production (BSP) 2007 base model (2007-BSP) and Bayesian State-Space Surplus Production WinBUGS 2007 base model (2007-Win). The circle indicates the position of the three variants of the base run. The vertical dashed blue line denotes MSST $((1-M)*\text{SSF}_{\text{MSY}})$, where M is the mean of age1+ values. None of the runs estimated an overfished stock (to the left of the MSST line) or that overfishing was occurring (above the horizontal black line). Note that “CUR” refers to different terminal years depending on the assessment: 2011 for this assessment; 2005 for assessments completed in 2007, and 2000 for the 2002 assessment.

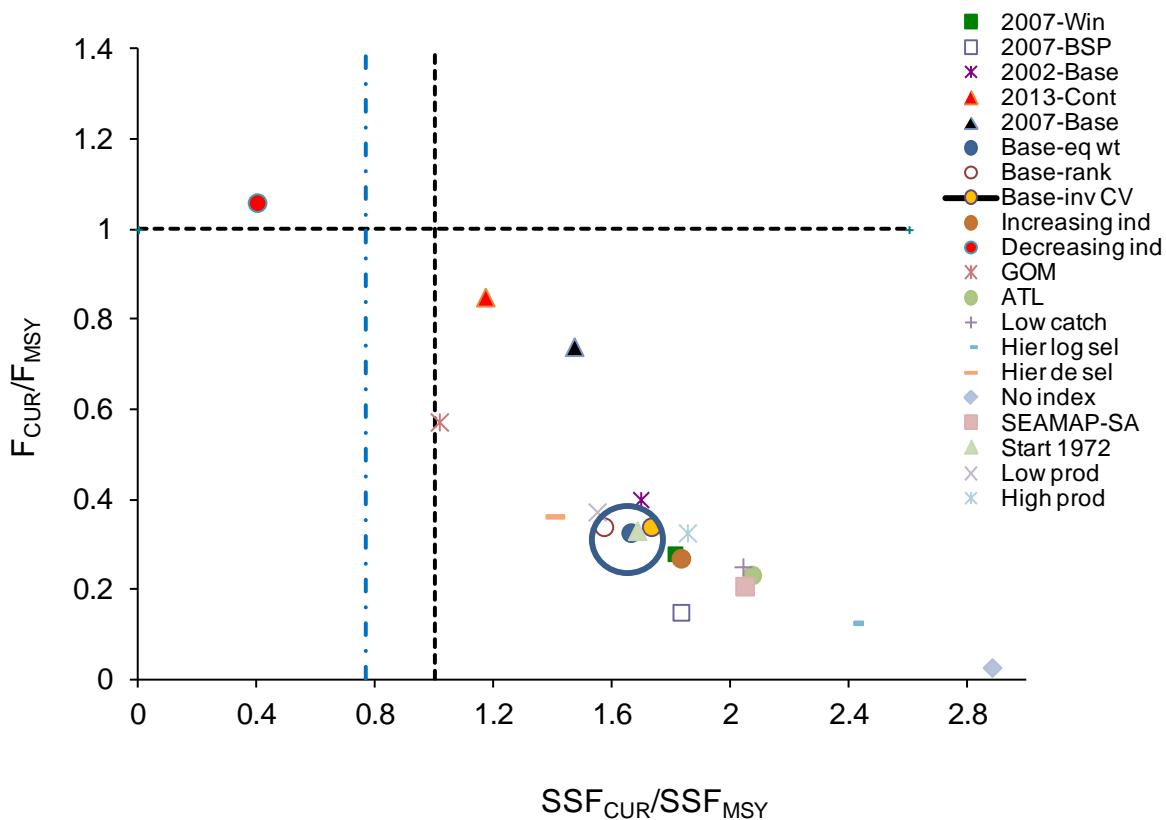


Figure 3.6.45. Phase plot of Atlantic sharpnose shark stock status. In addition to the results shown in the previous figure, those from all the sensitivity scenarios run are depicted: using increasing and decreasing relative abundance indices only (Increasing ind; Decreasing ind); using the hierarchical index with a flat-top selectivity (Hier log sel) or dome-shaped selectivity (Hier de exp), using the SEAMAP-SA index only (SEAMAP-SA), using no indices at all (No index), considering low catches (Low catch), starting the model in 1972 (Start 1972), considering a lower productivity (Low prod) or higher productivity (High prod) than the base run, assessing a Gulf of Mexico stock (GOM) or Atlantic stock (ATL) separately. The vertical dashed blue line denotes MSST $((1-M)*\text{SSF}_{\text{MSY}})$, where M is the mean of age1+ values. Note that “CUR” refers to different terminal years depending on the assessment: 2011 for this assessment; 2005 for assessments completed in 2007, and 2000 for the 2002 assessment. Only the run that used decreasing indices (Decreasing ind) predicted an overfished stock (to the left of the MSST line) and that overfishing was occurring (above the horizontal black line) and the GOM stock run was nearer, but still above, the overfished criterion.

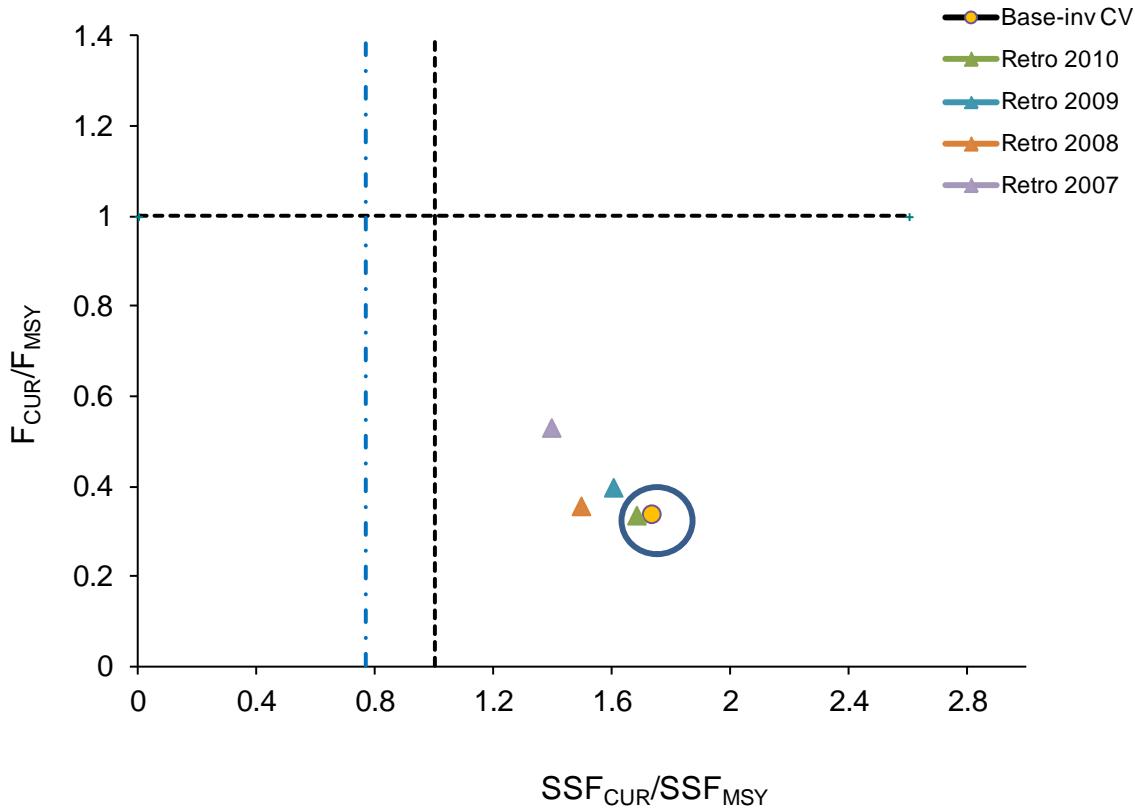


Figure 3.6.46. Phase plot of Atlantic sharpnose shark stock status for the base run with inverse CV weighting and retrospective analysis of that run (sequentially dropping one year from the model: retro10, retro09, retro08, and retro07). The vertical dashed blue line denotes MSST ($(1-M)^*\text{SSF}_{\text{MSY}}$), where M is the mean of age1+ values. None of the runs estimated an overfished stock (to the left of the MSST line) or that overfishing was occurring (above the horizontal black line), but the status progressively became less optimistic with the sequential removal of one year at a time. Note that “CUR” refers to different terminal years depending on the assessment run.

Panel A. Projection Scenario-1 (Baseline, Inverse CV Weighting)

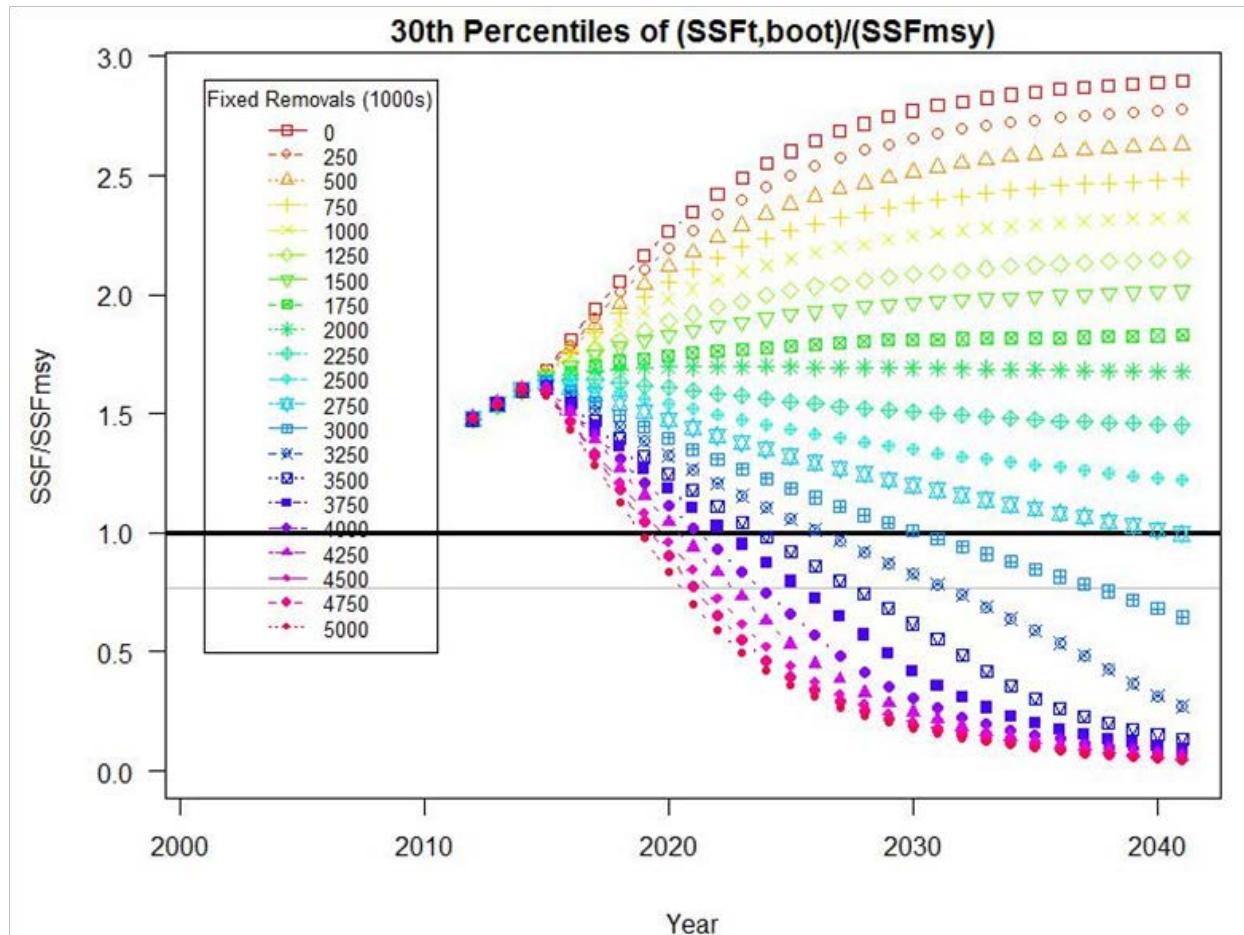


Figure 3.6.47. The 30th percentile of SSF_{t,boot}/ SSF_{MSY} represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel B. Projection Scenario-2 (Sensitivity, Increasing Indices)

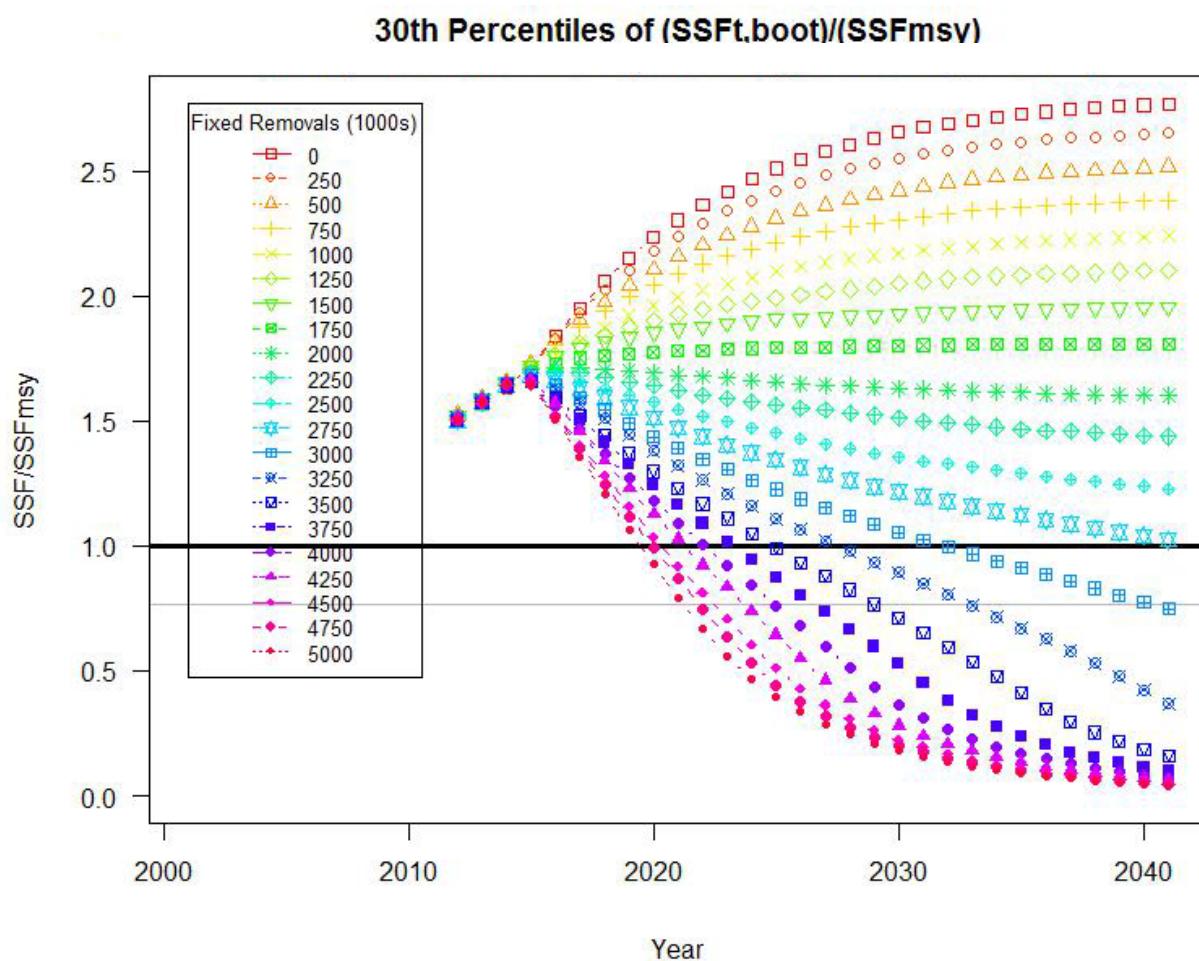


Figure 3.6.47 (continued). The 30th percentile of $SSF_{t,boot}/SSF_{MSY}$ represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel C. Projection Scenario-3 (Sensitivity, Decreasing Indices)

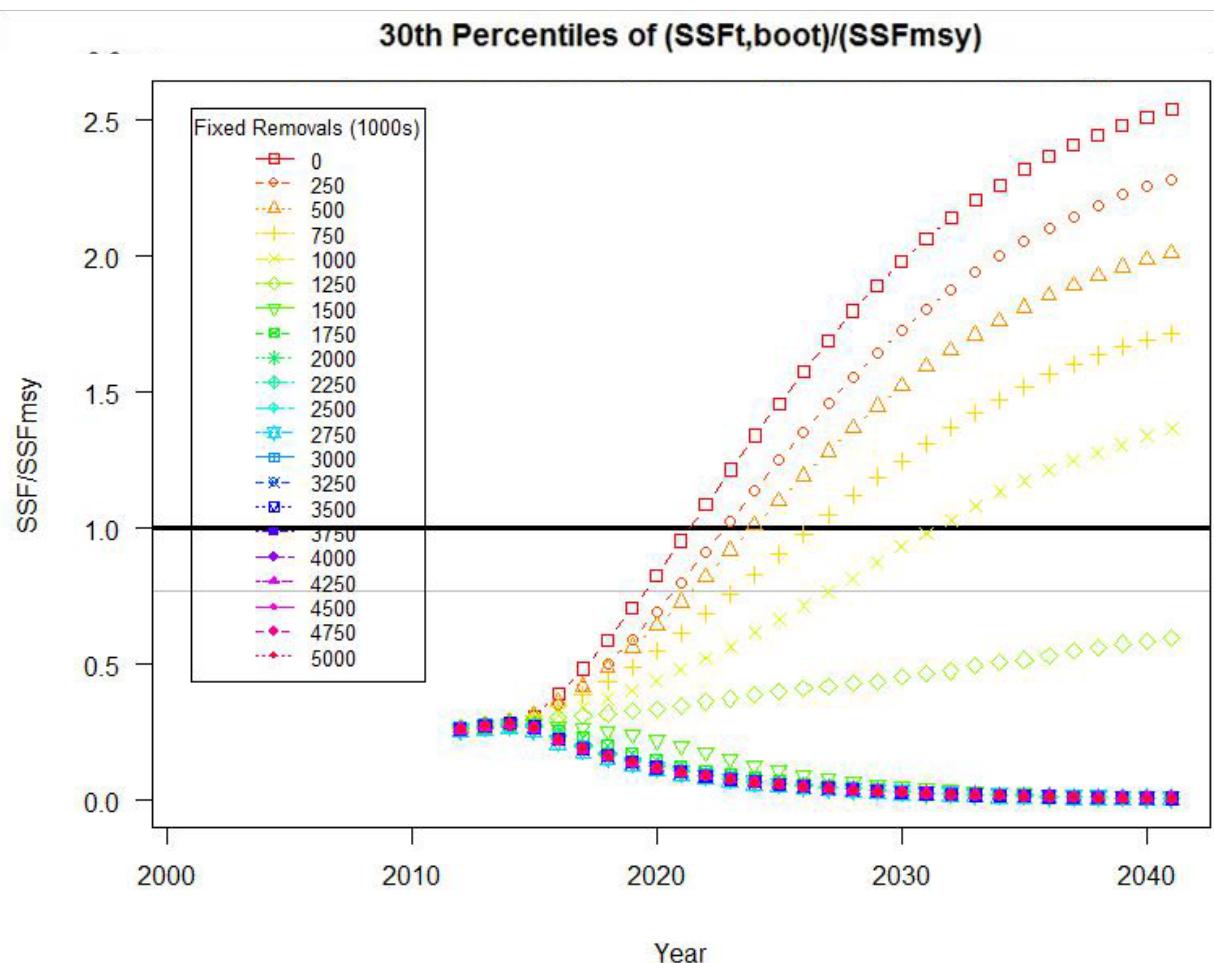


Figure 3.6.47 (continued). The 30th percentile of $\text{SSF}_{t,\text{boot}}/\text{SSF}_{\text{MSY}}$ represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel D. Projection Scenario-4 (Sensitivity, Low Catch)

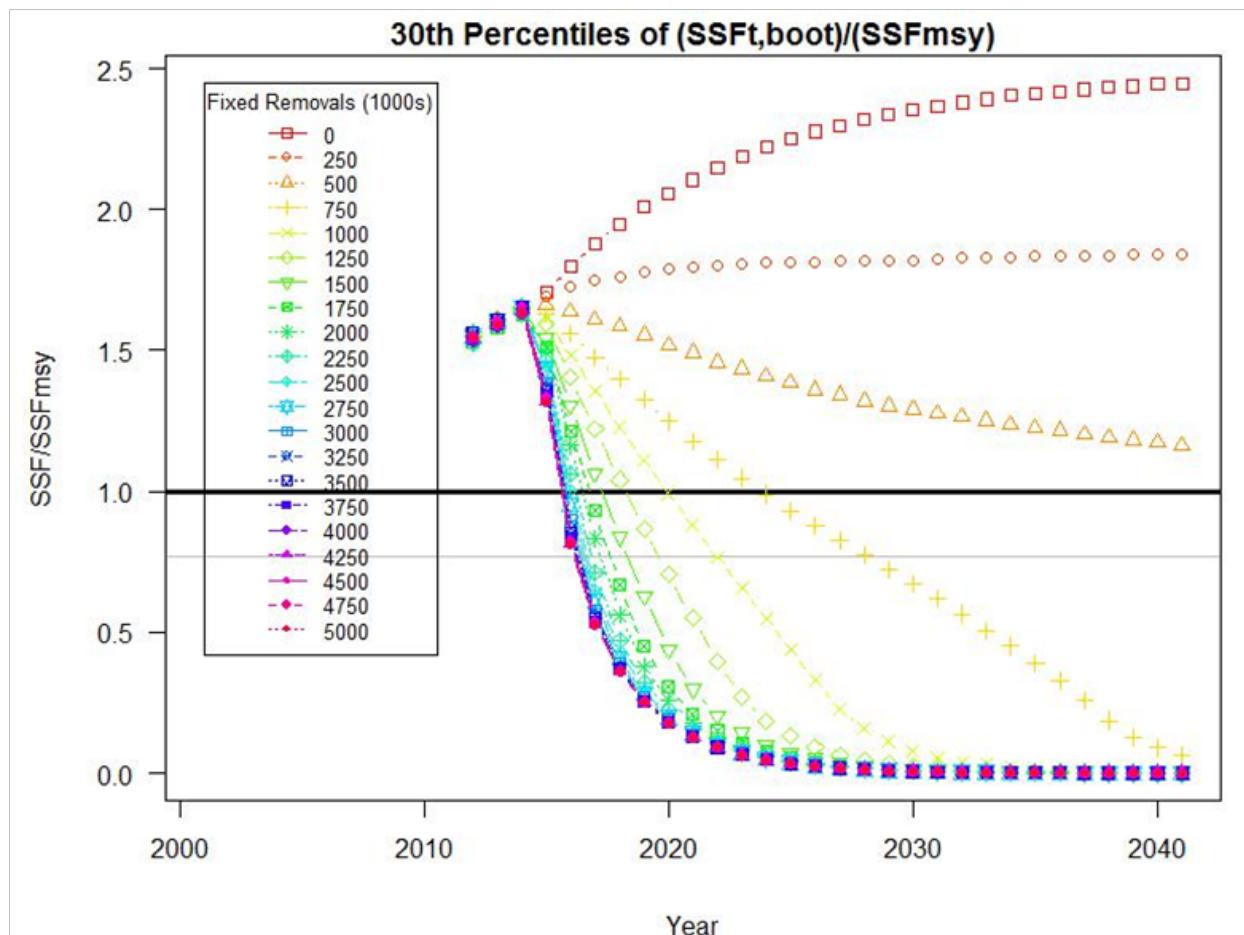


Figure 3.6.47 (continued). The 30th percentile of $SSF_{t,boot}/ SSF_{MSY}$ represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel E. Projection Scenario-5.1 (Sensitivity, Hierarchical Index log)

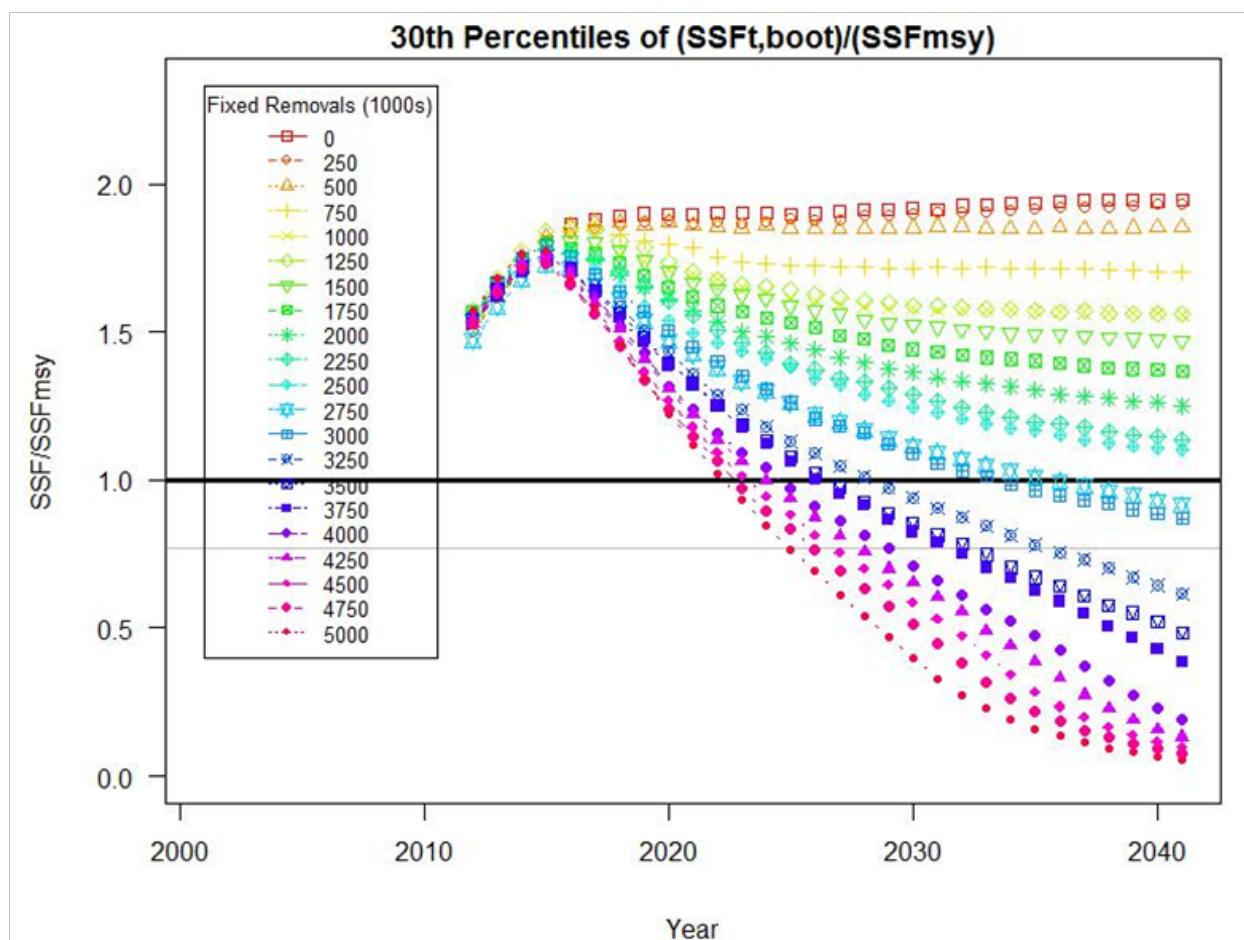


Figure 3.6.47 (continued). The 30th percentile of SSF_{t,boot}/ SSF_{MSY} represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel F. Projection Scenario-5.2 (Sensitivity, Hierarchical Index db exp)

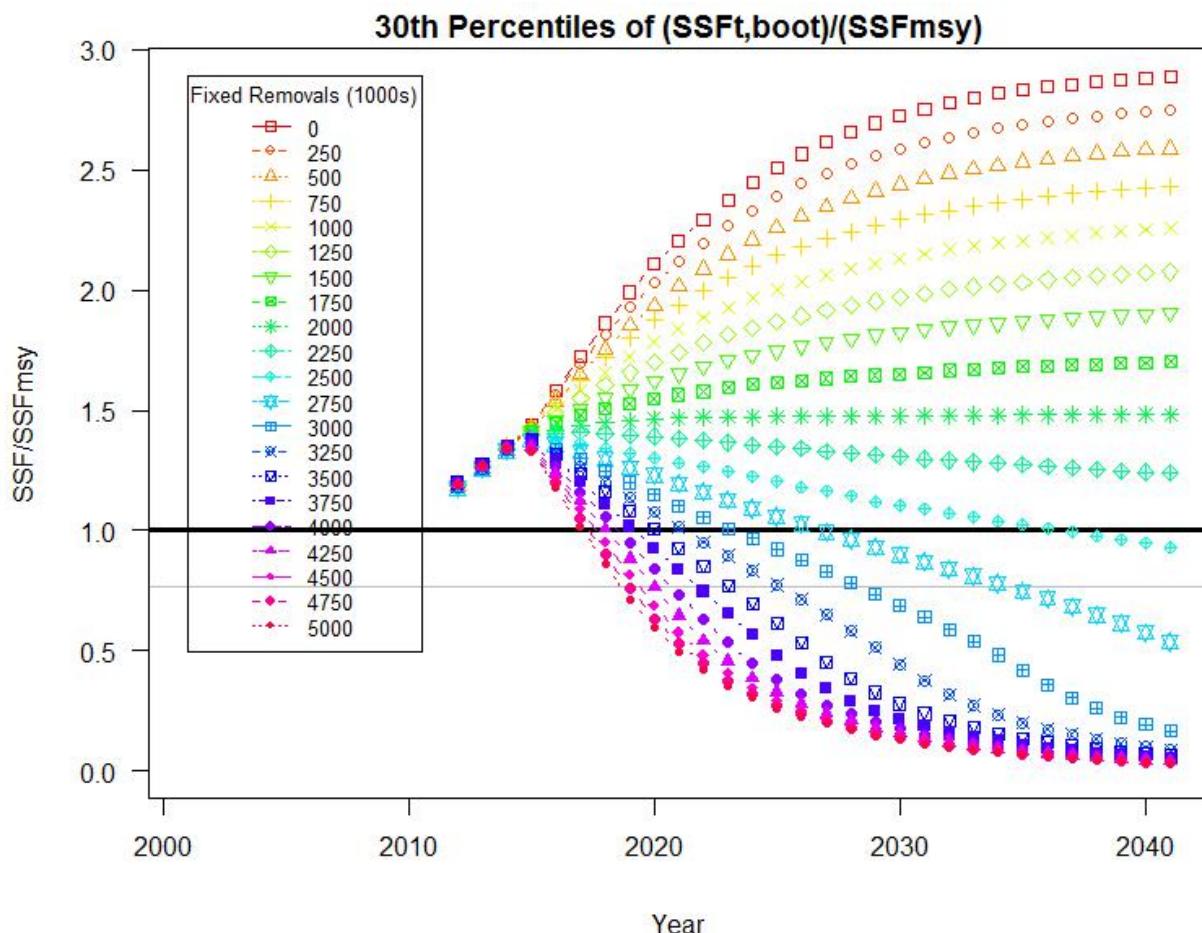


Figure 3.6.47 (continued). The 30th percentile of $SSF_{t,boot}/SSF_{MSY}$ represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel G. Projection Scenario-6 (Sensitivity, Model Start in 1972)

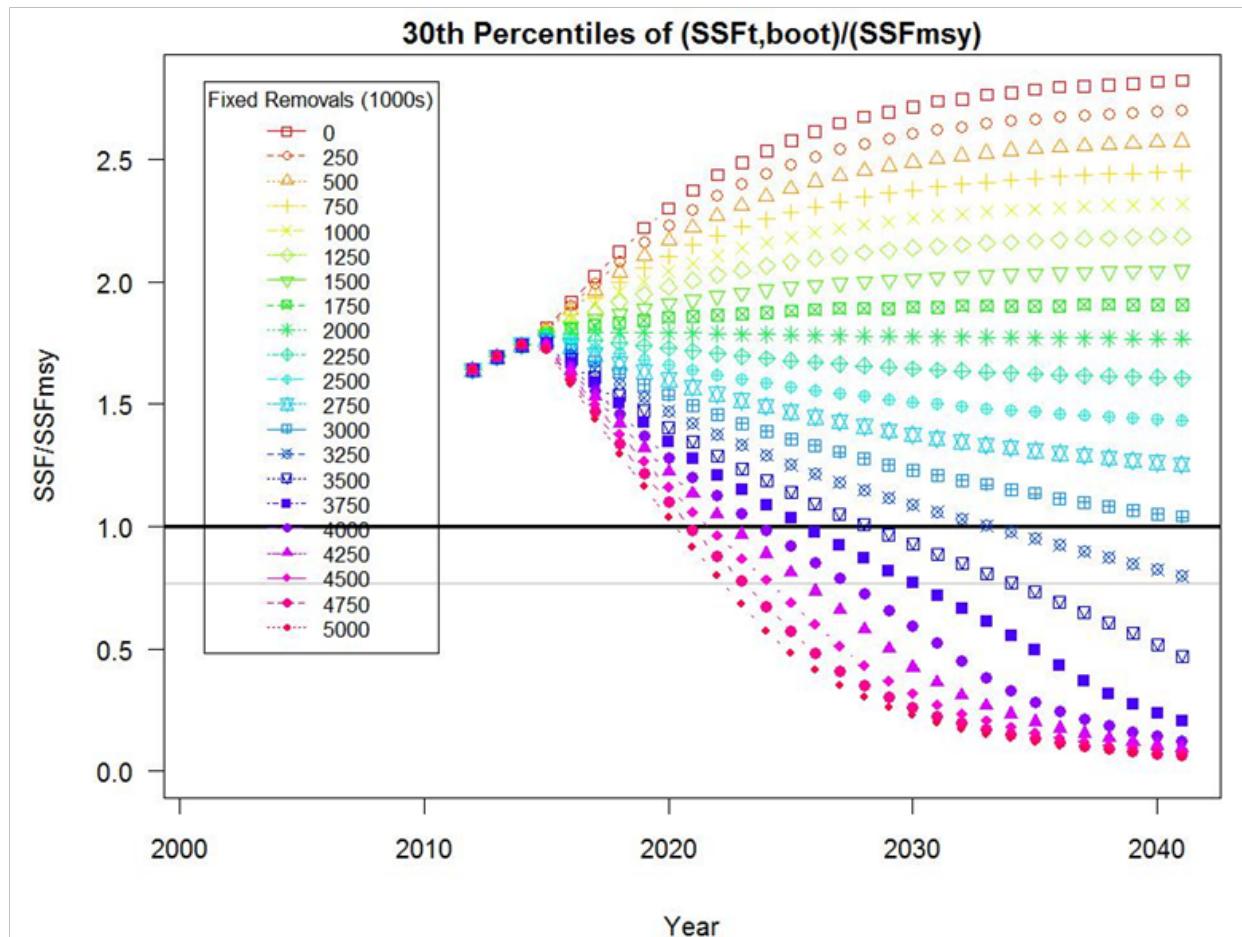


Figure 3.6.47 (continued). The 30th percentile of SSF_{t,boot}/ SSF_{MSY} represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel H. Projection Scenario-7 (Sensitivity, High Productivity)

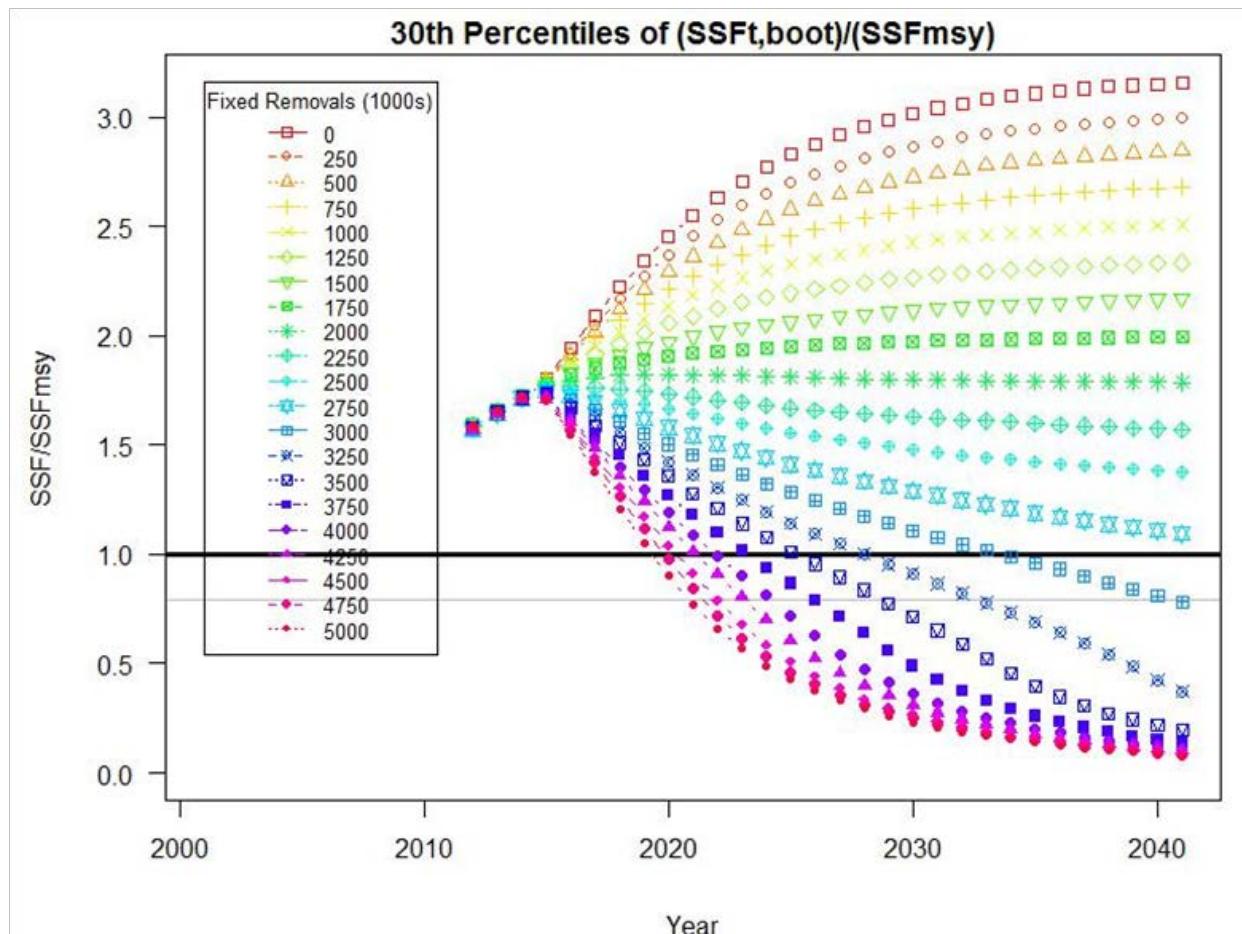


Figure 3.6.47 (continued). The 30th percentile of $SSF_{t,boot}/ SSF_{MSY}$ represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel I. Projection Scenario-8 (Sensitivity, Low Productivity)

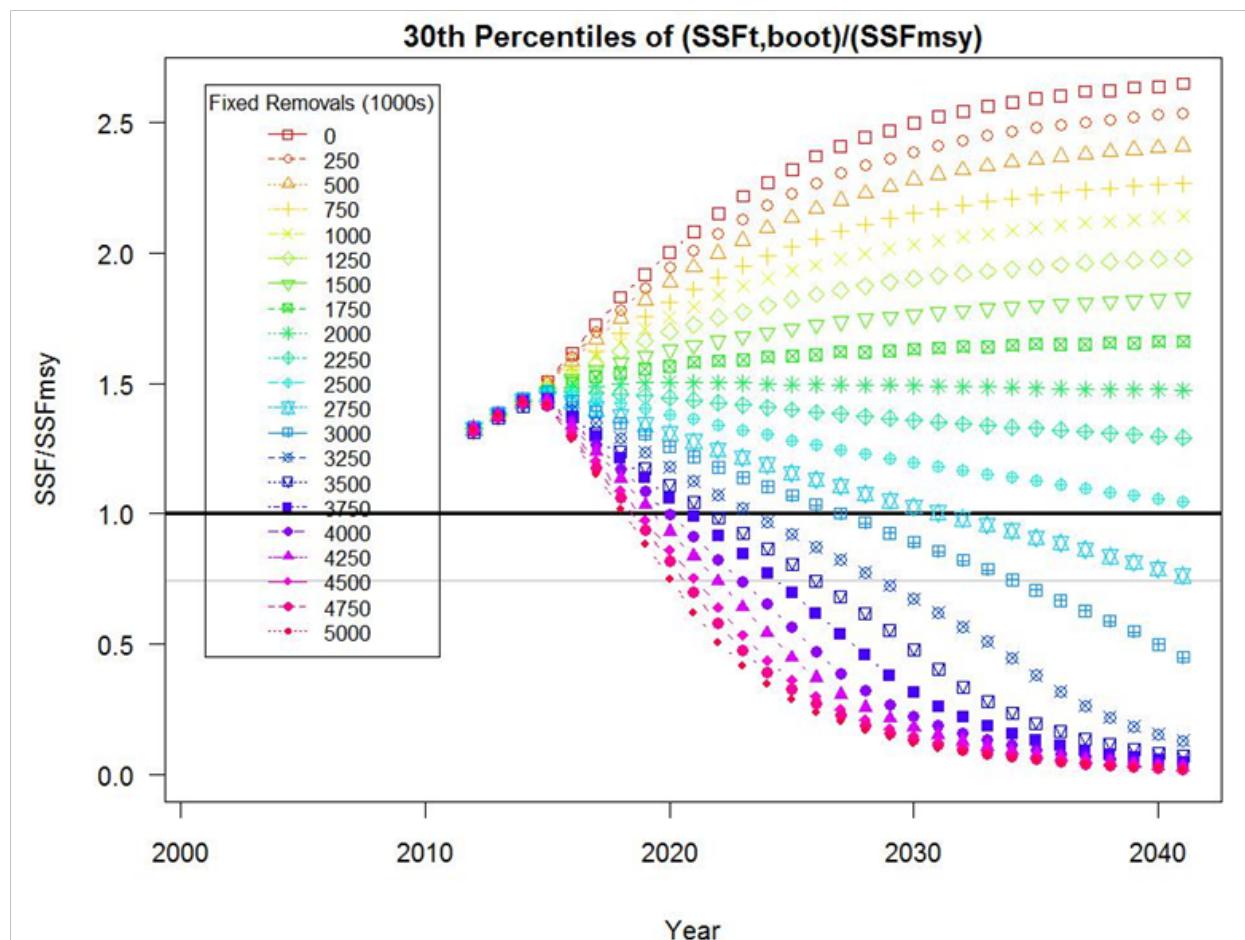


Figure 3.6.47 (continued). The 30th percentile of SSF_{t,boot}/ SSF_{MSY} represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel J. Projection Scenario-9 (Sensitivity, SEAMAP-SA)

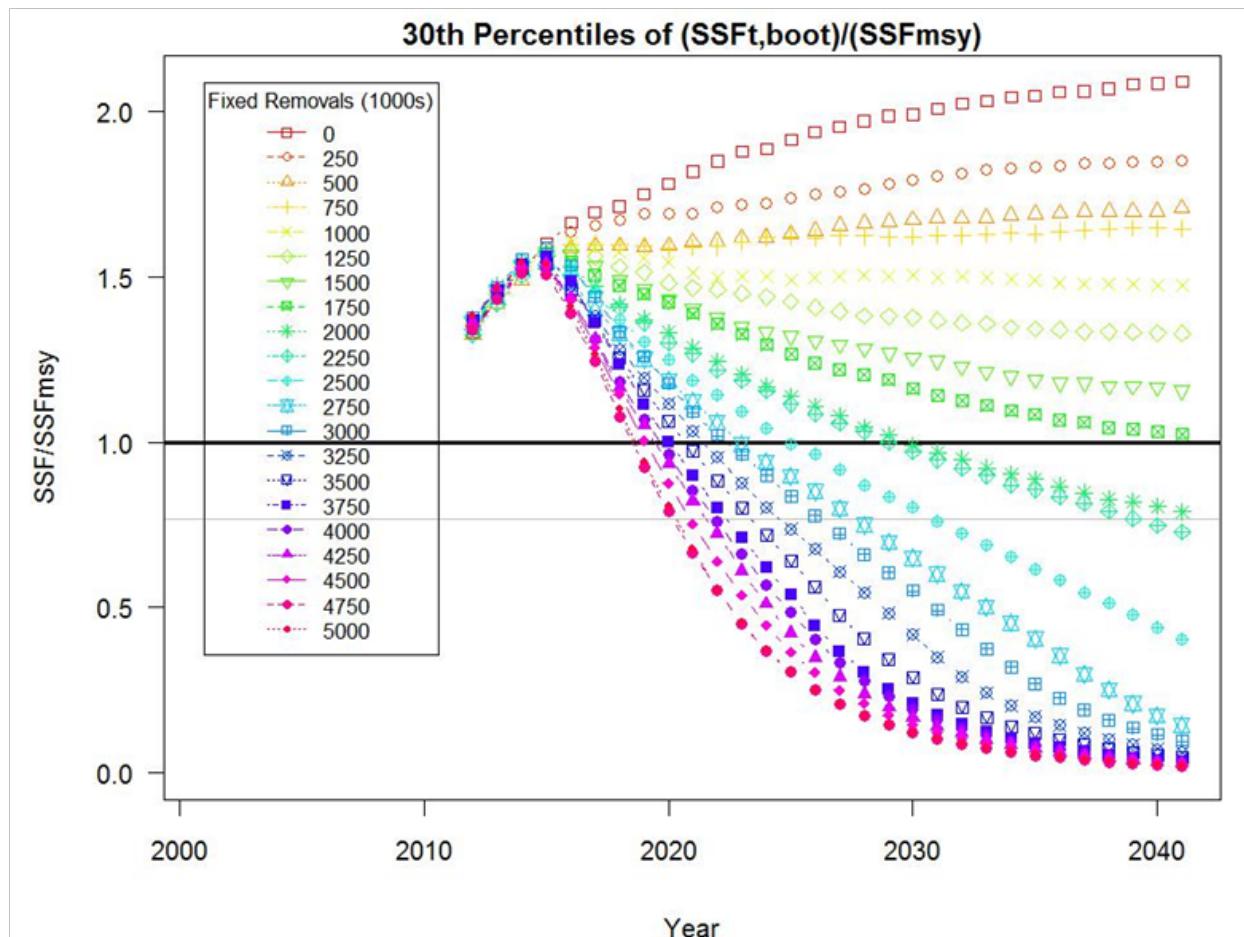


Figure 3.6.47 (continued). The 30th percentile of SSF_{t,boot}/ SSF_{MSY} represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel K. Projection Scenario-10 (Sensitivity, Gulf of Mexico Stock)

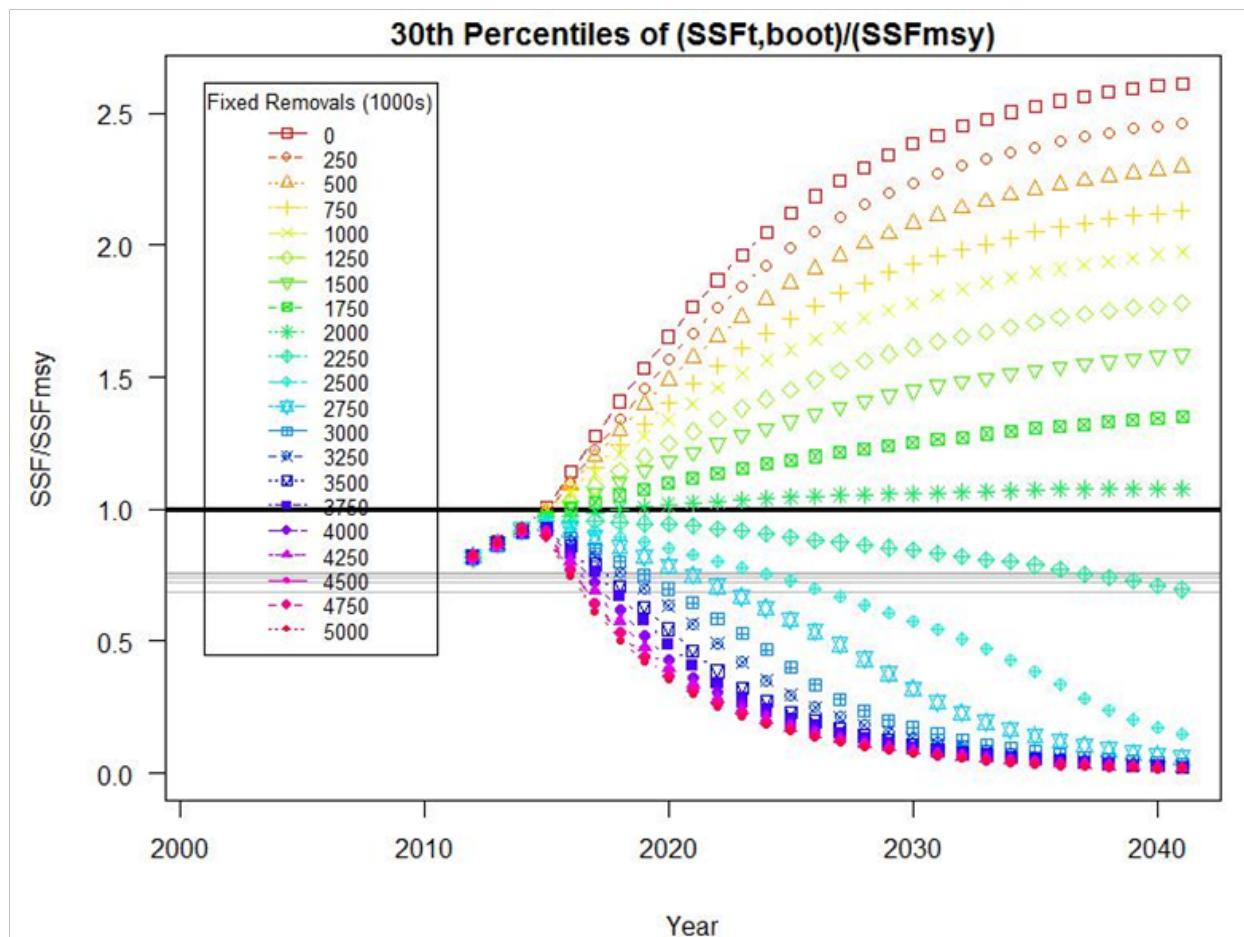


Figure 3.6.47 (continued). The 30th percentile of $SSF_{t,boot}/SSF_{MSY}$ represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel L. Projection Scenario-11 (Sensitivity, Atlantic Stock)

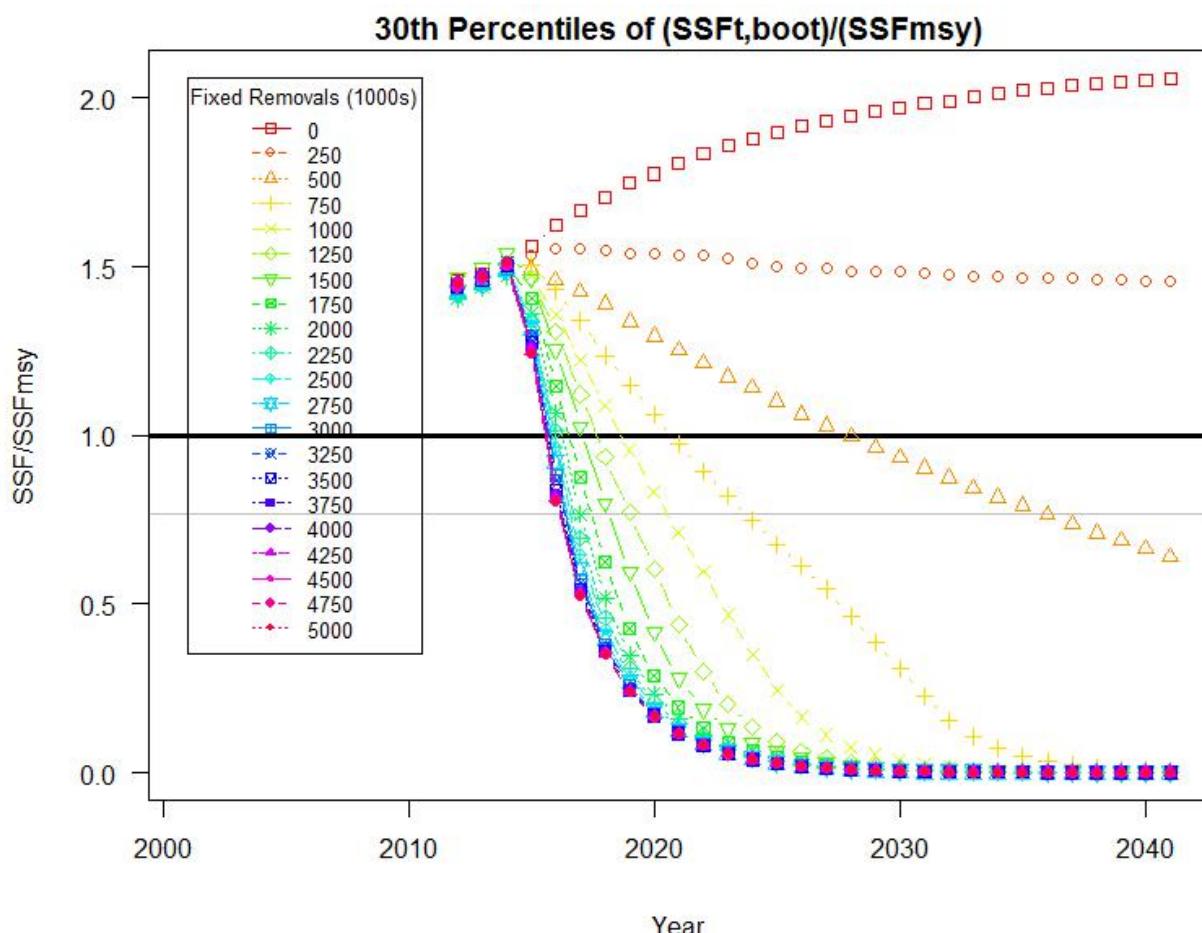


Figure 3.6.47 (continued). The 30th percentile of SSF_{t,boot}/ SSF_{MSY} represents the 70% probability of maintaining SSF_t above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel A. Projection Scenario-1 (Baseline, Inverse CV Weighting)

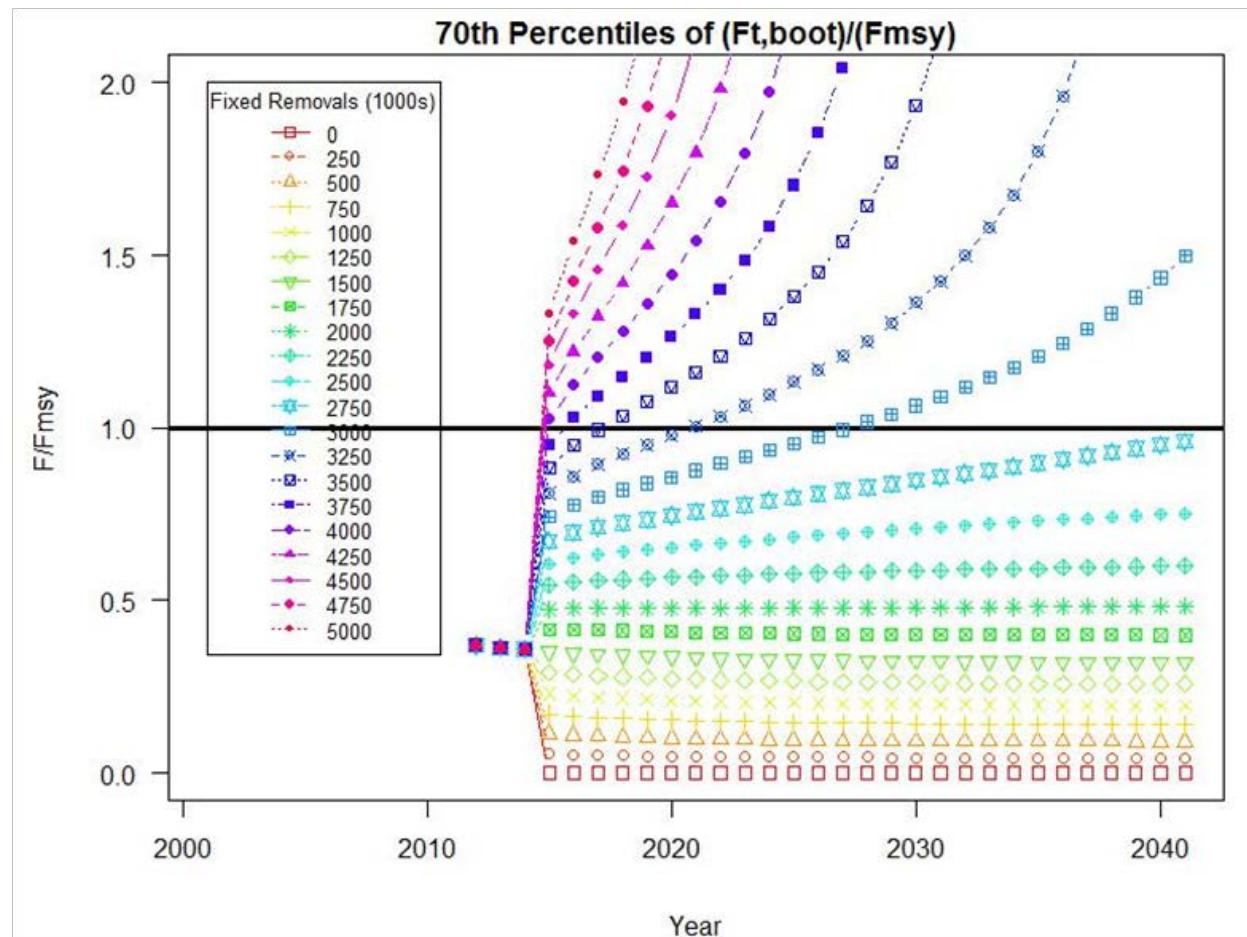


Figure 3.6.48. The 70th percentile of $F_{t,boot}/F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel B. Projection Scenario-2 (Sensitivity, Increasing Indices)

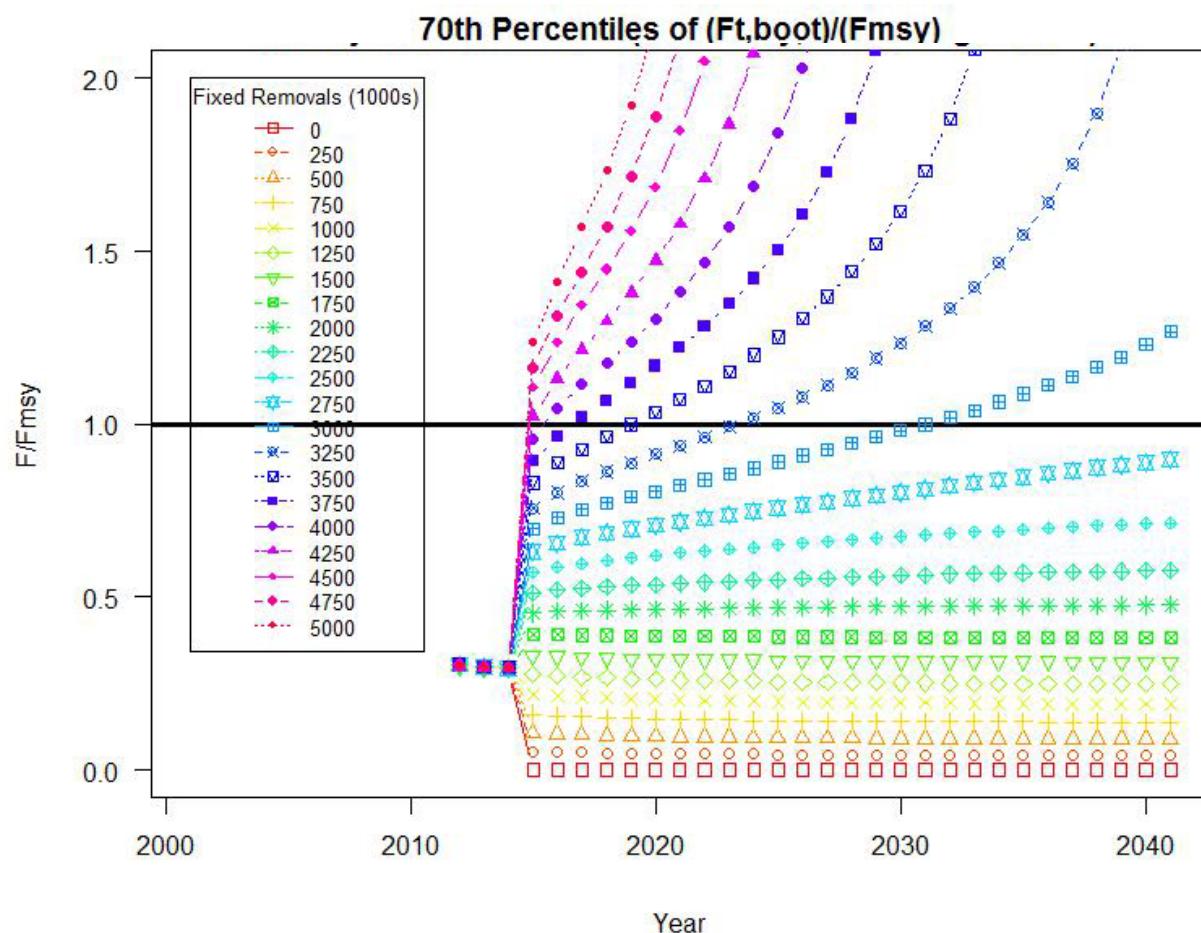


Figure 3.6.48 (continued). The 70th percentile of $F_{t,boot}/F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel C. Projection Scenario-3 (Sensitivity, Decreasing Indices)

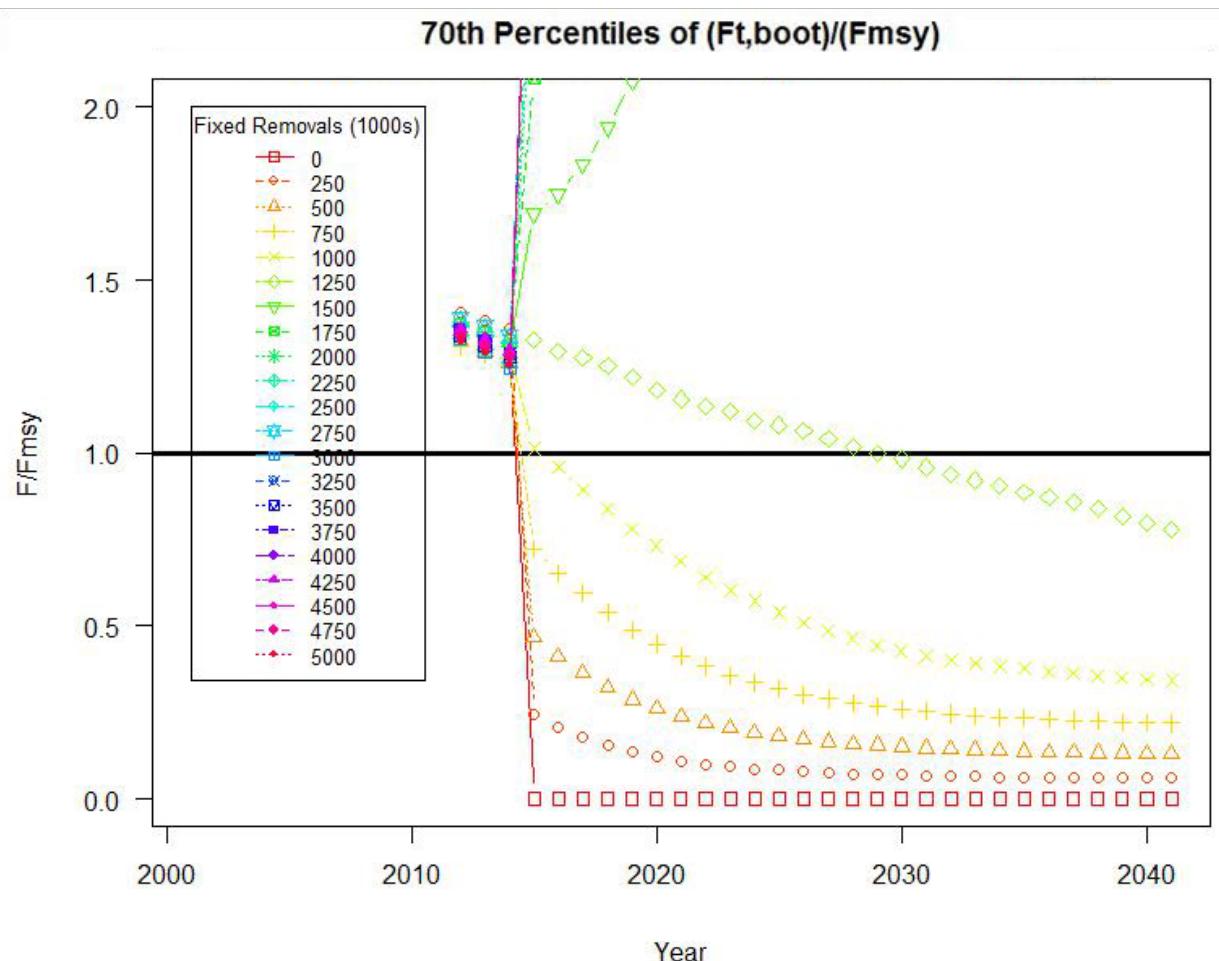


Figure 3.6.48 (continued). The 70th percentile of F_{t,boot}/ F_{MSY} represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel D. Projection Scenario-4 (Sensitivity, Low Catch)

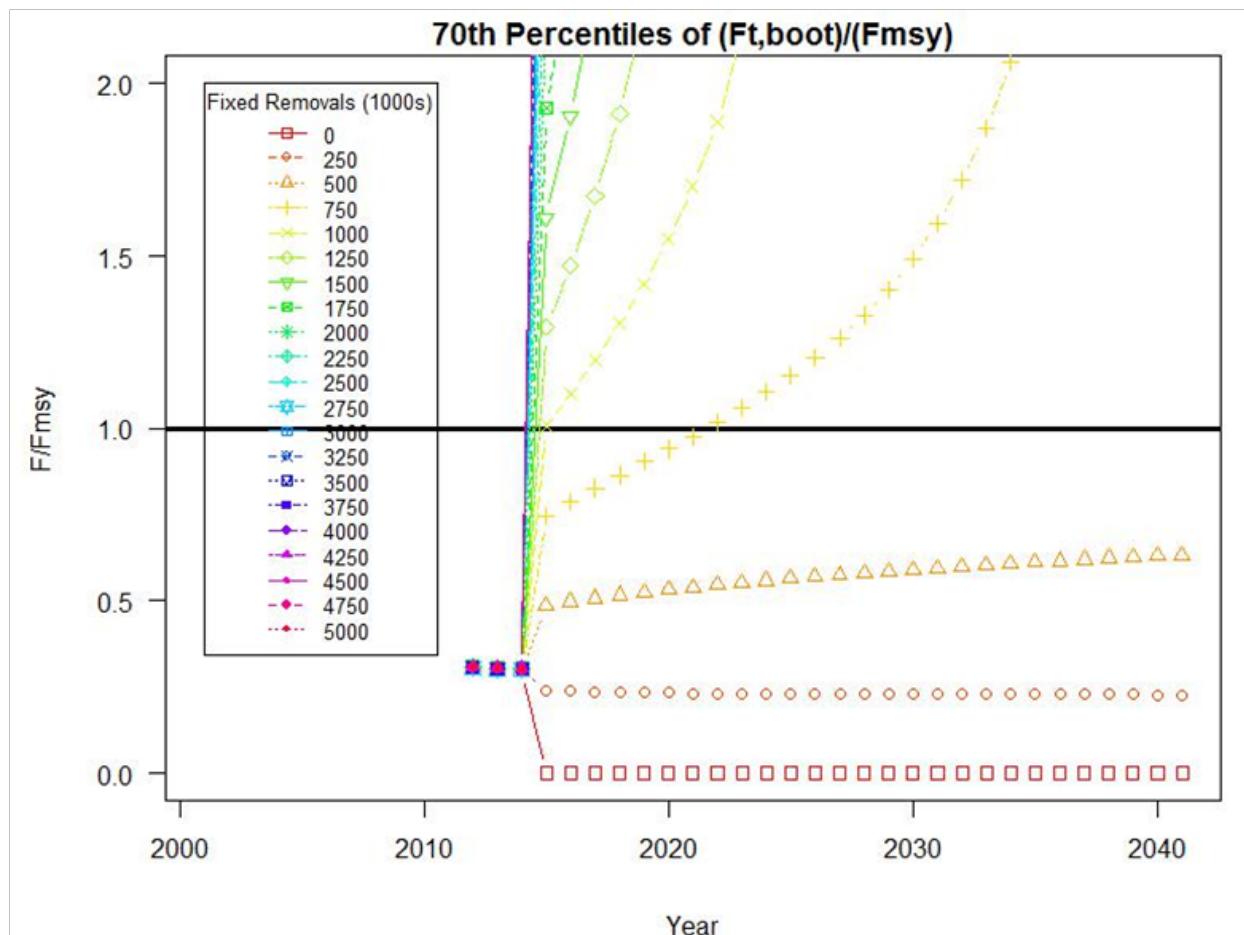


Figure 3.6.48 (continued). The 70th percentile of $F_{t,boot}/F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel E. Projection Scenario-5.1 (Sensitivity, Hierarchical Index log)

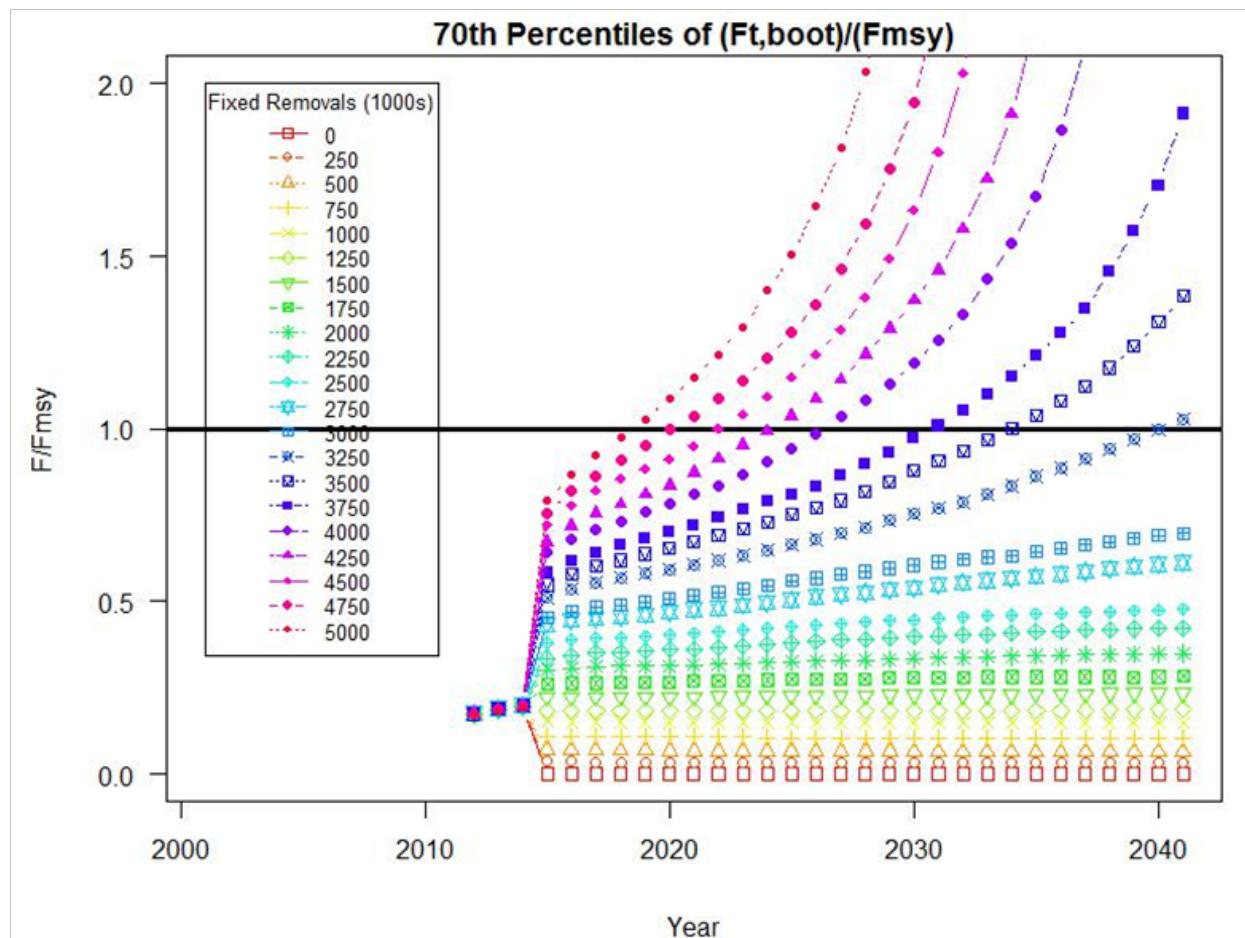


Figure 3.6.48 (continued). The 70th percentile of $F_{t,boot}/F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel F. Projection Scenario-5.2 (Sensitivity, Hierarchical Index db exp)

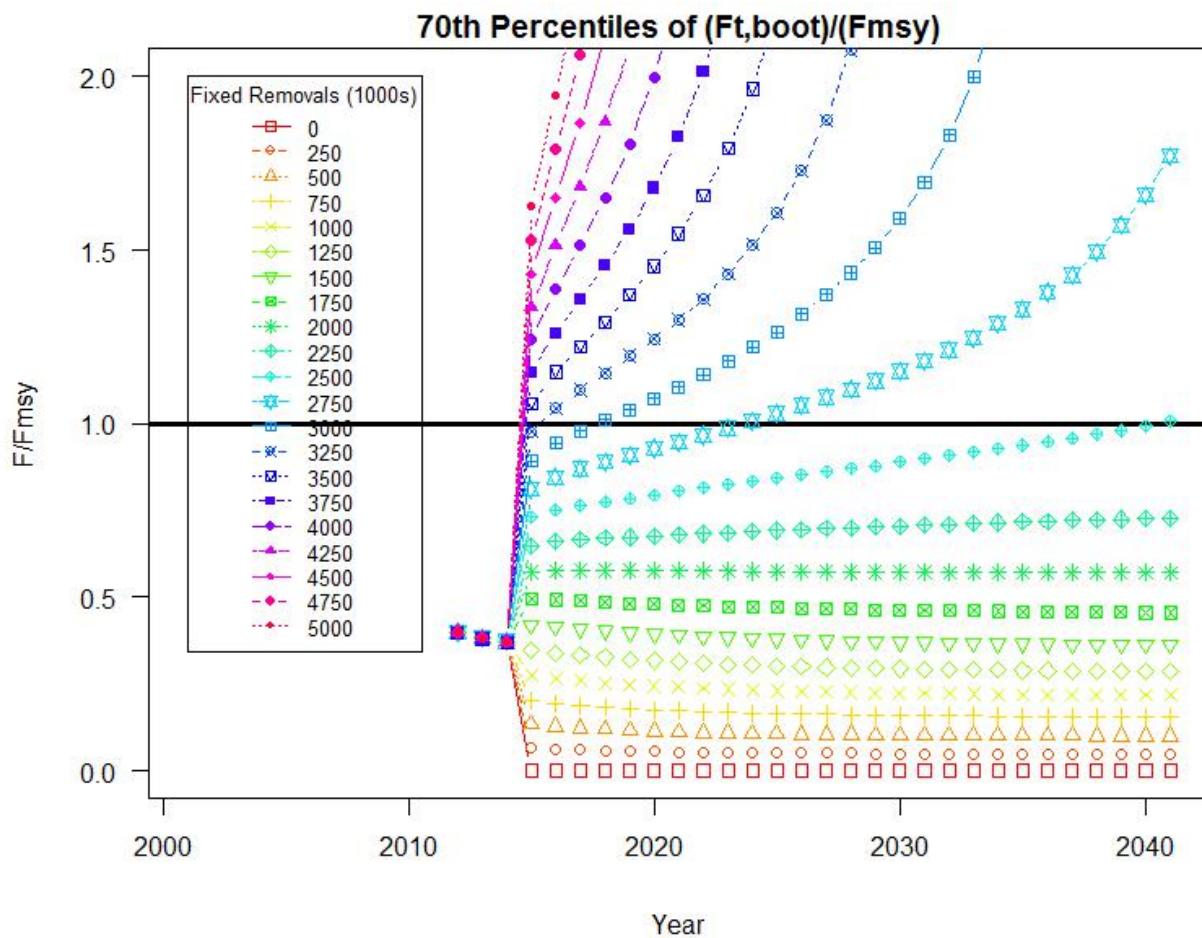


Figure 3.6.48 (continued). The 70th percentile of $F_t, \text{boot}/ F_{\text{MSY}}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel G. Projection Scenario-6 (Sensitivity, Model Start in 1972)

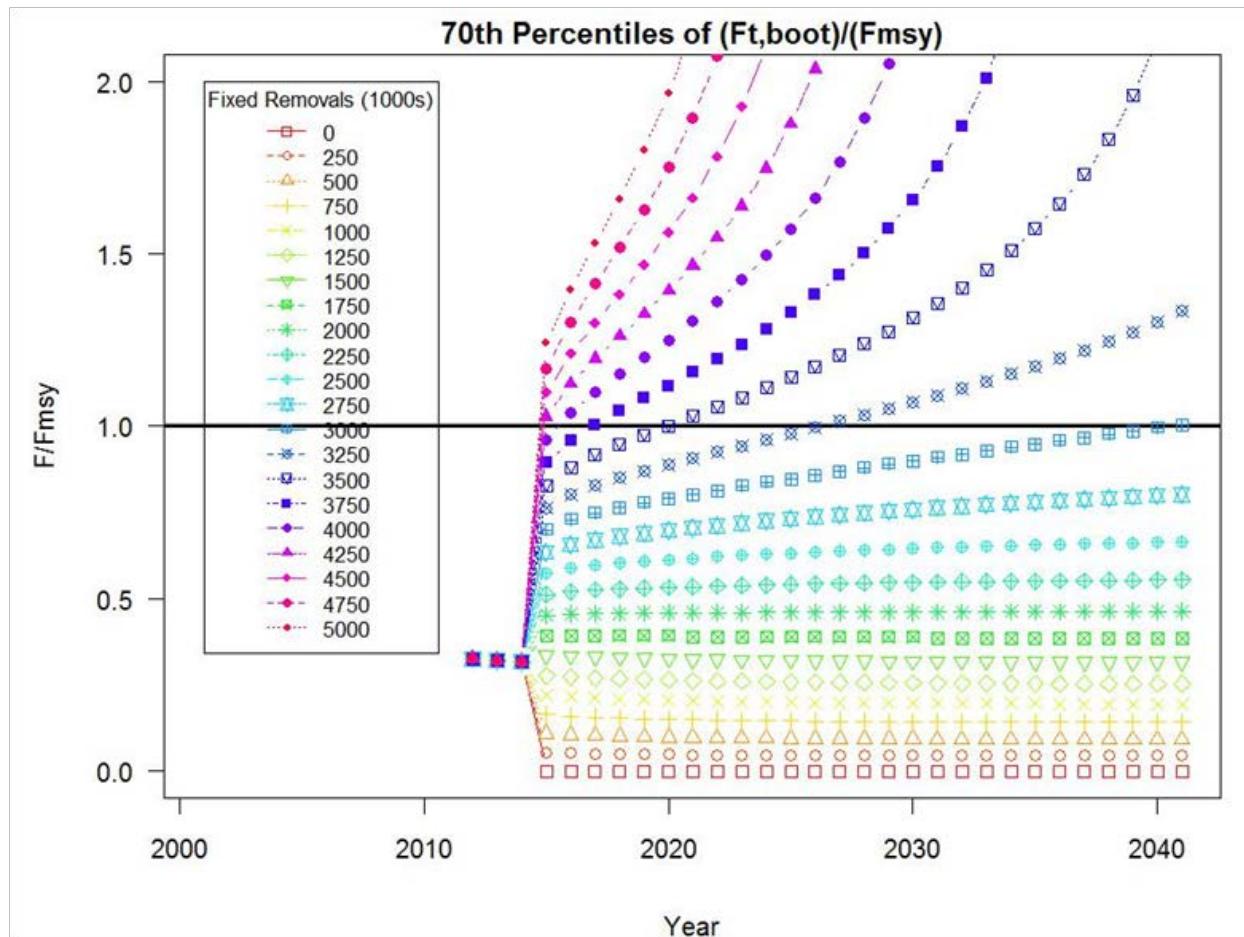


Figure 3.6.48 (continued). The 70th percentile of $F_{t,\text{boot}}/F_{\text{MSY}}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel H. Projection Scenario-7 (Sensitivity, High Productivity)

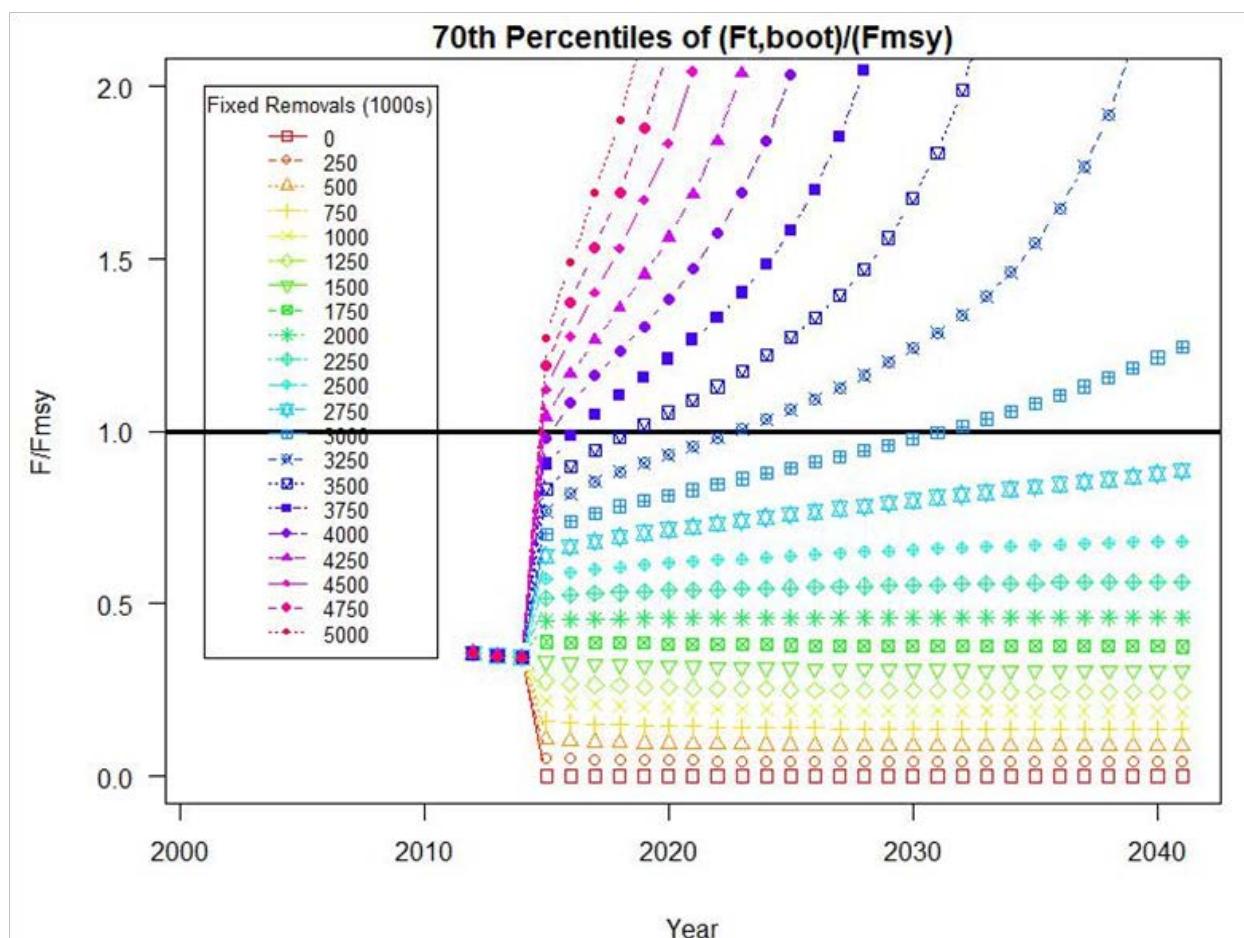


Figure 3.6.48 (continued). The 70th percentile of $F_{t,boot}/F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel I. Projection Scenario-8 (Sensitivity, Low Productivity)

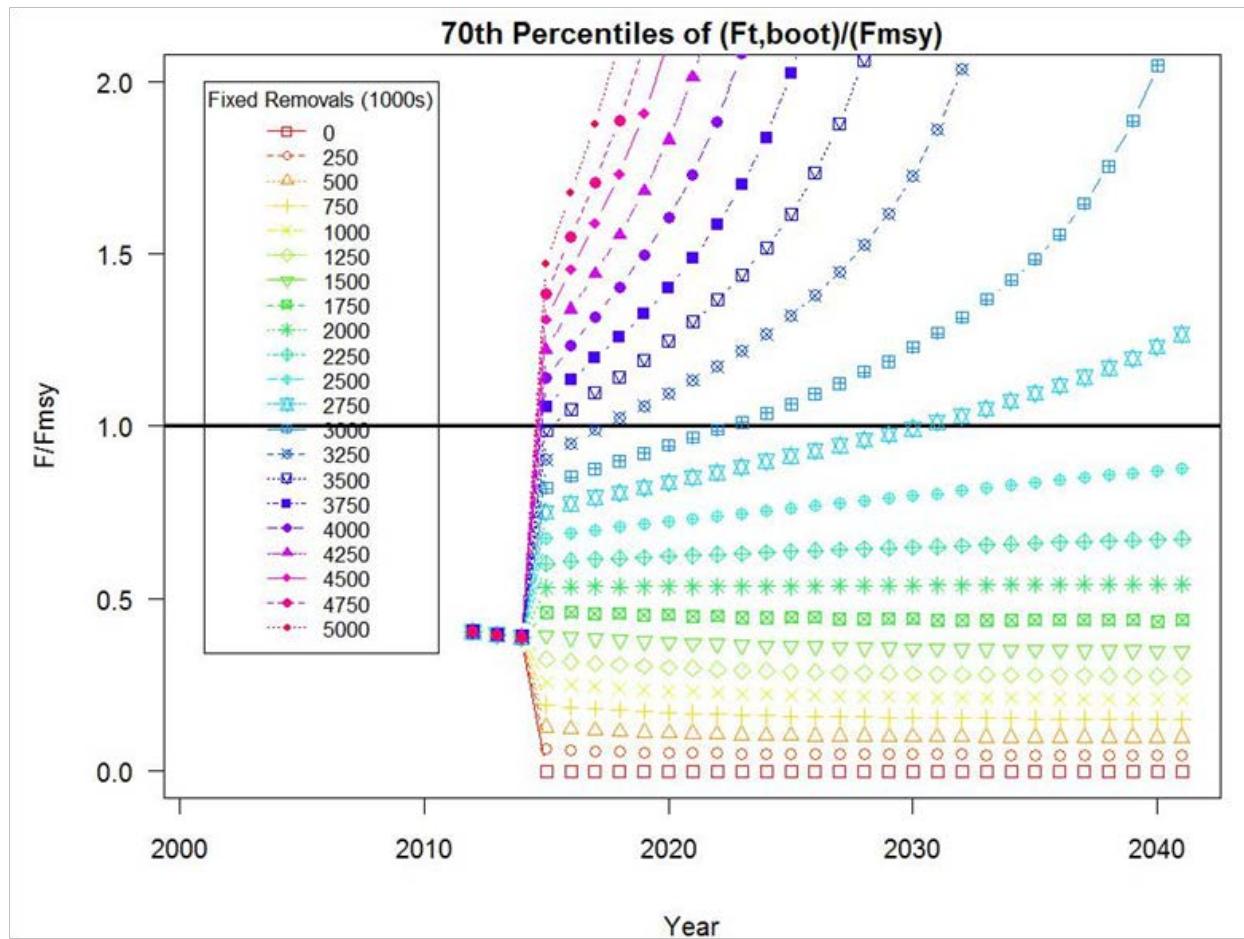


Figure 3.6.48 (continued). The 70th percentile of $F_{t,boot}/F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel J. Projection Scenario-9 (Sensitivity, SEAMAP-SA)

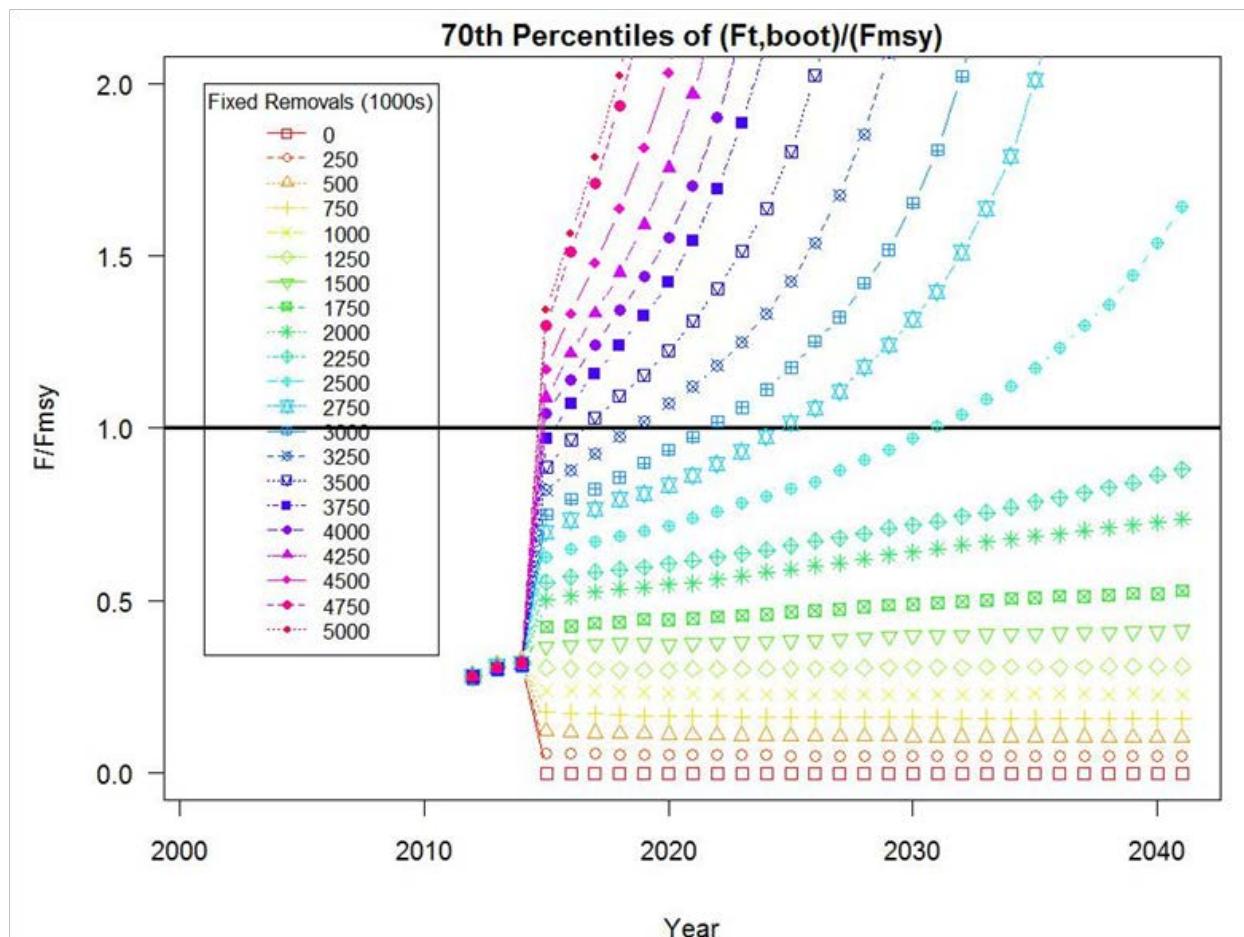


Figure 3.6.48 (continued). The 70th percentile of $F_{t,boot}/F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel K. Projection Scenario-10 (Sensitivity, Gulf of Mexico Stock)

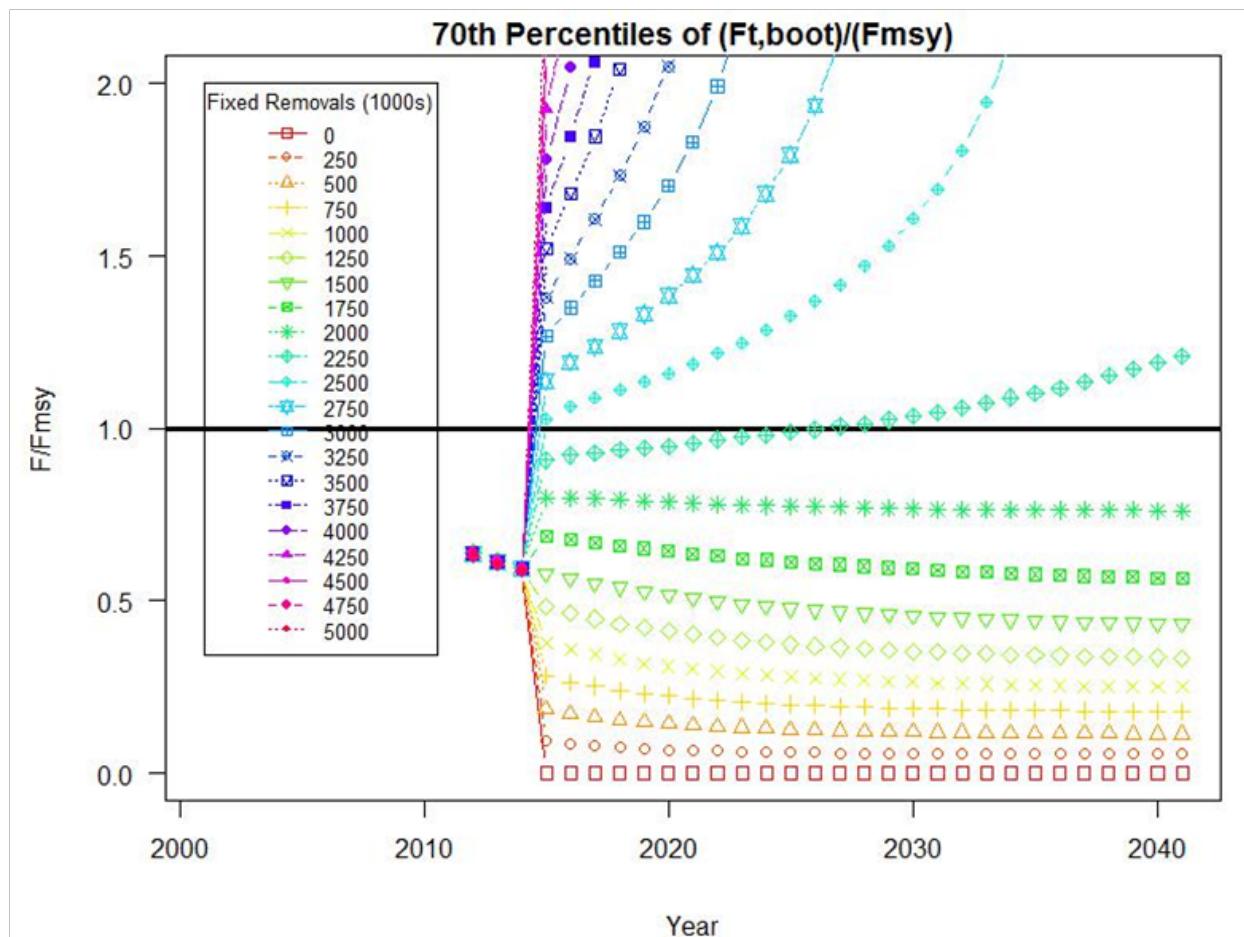


Figure 3.6.48 (continued). The 70th percentile of $F_{t,boot}/F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

Panel L. Projection Scenario-11 (Sensitivity, Atlantic Stock)

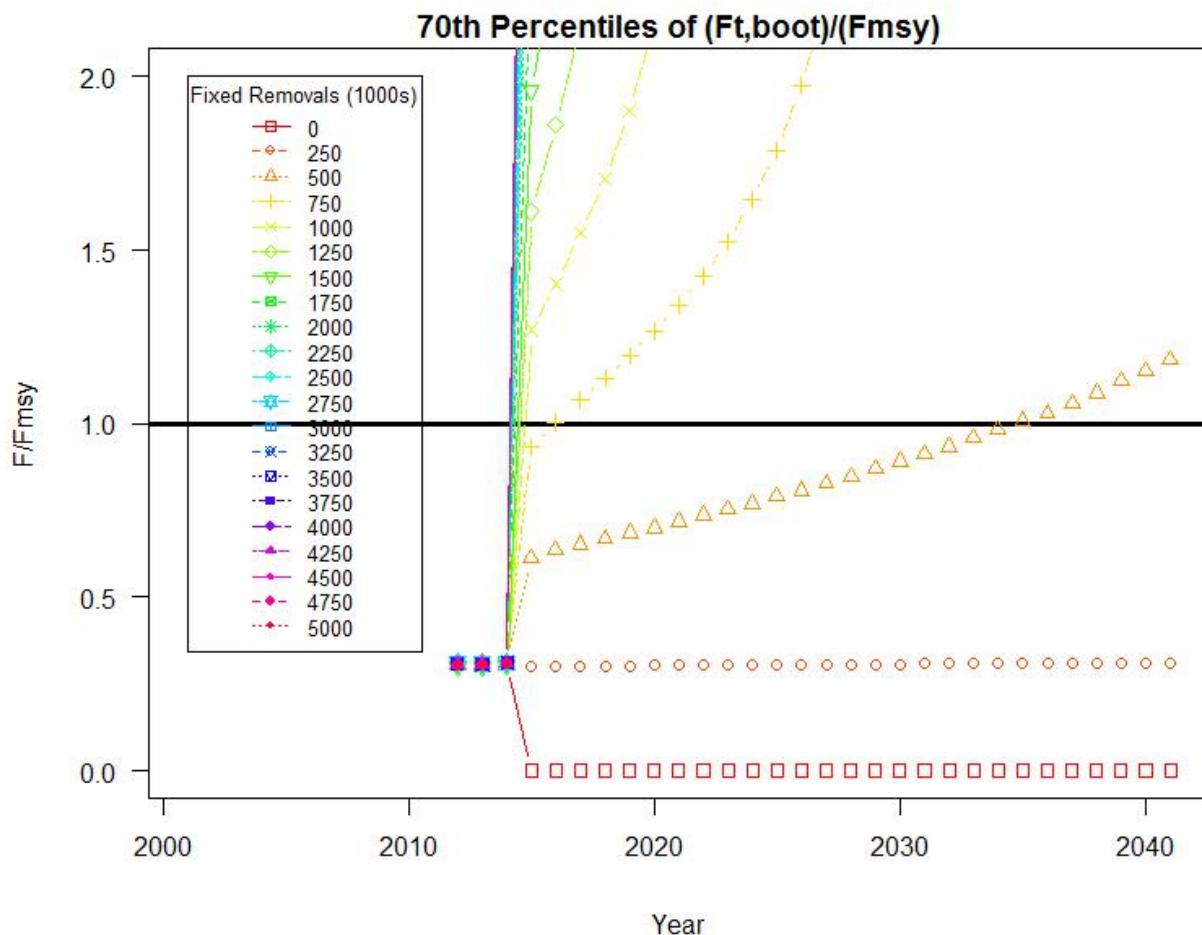


Figure 3.6.48 (continued). The 70th percentile of $F_{t,boot}/F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

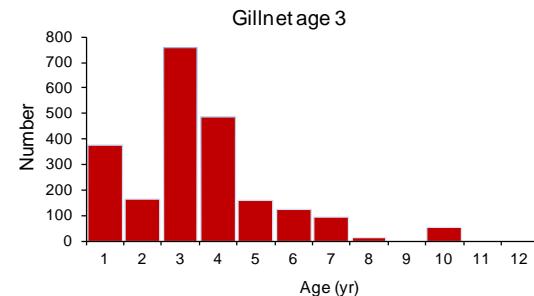
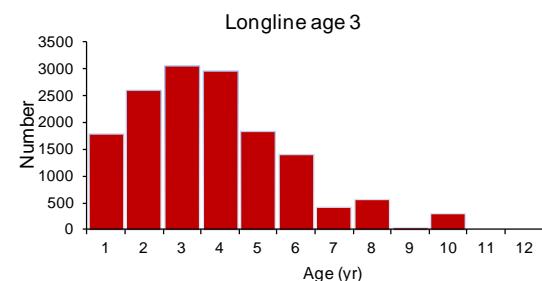
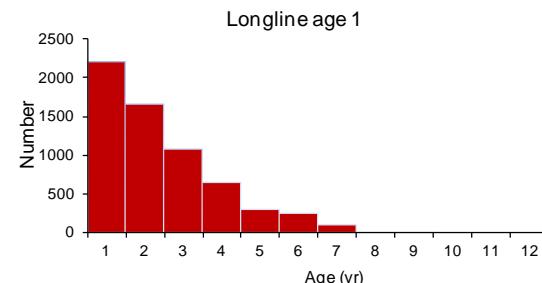
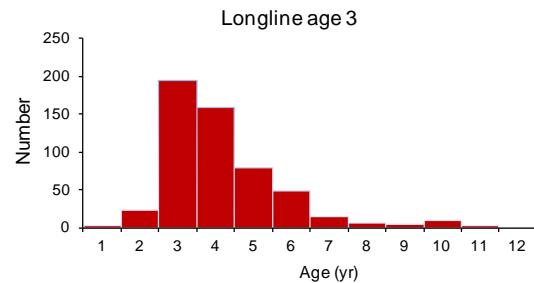
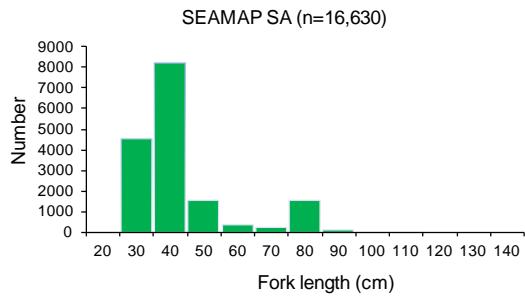
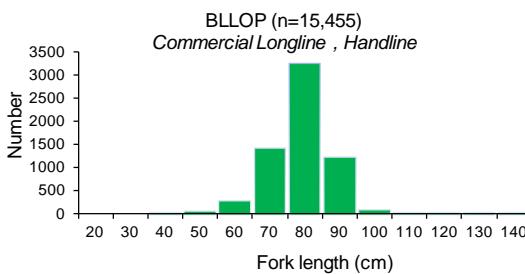
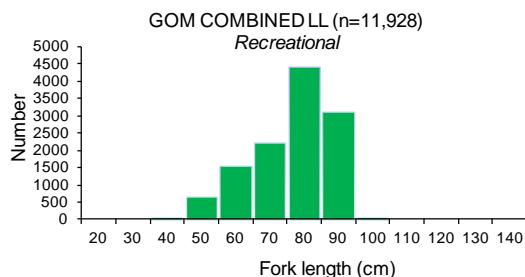
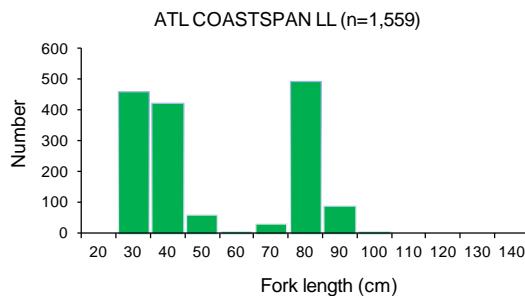
3.7. APPENDICES

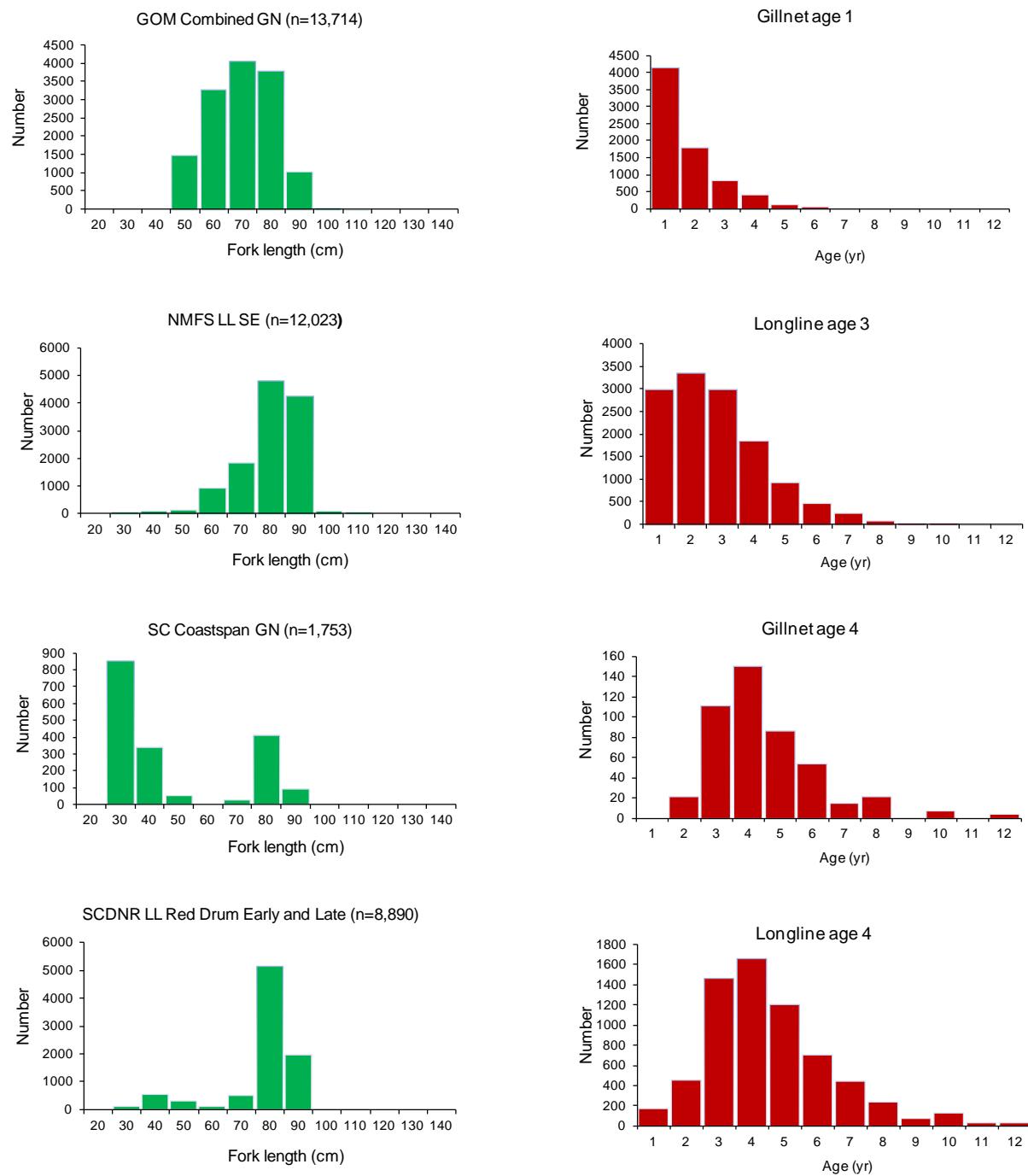
Appendix 1. Average weights (obtained from back-transforming lengths into weights) used for generating catches in weight for some years for commercial gears. BLL is bottom longline; GN is gillnet. See section 3.1.2.1 for details.

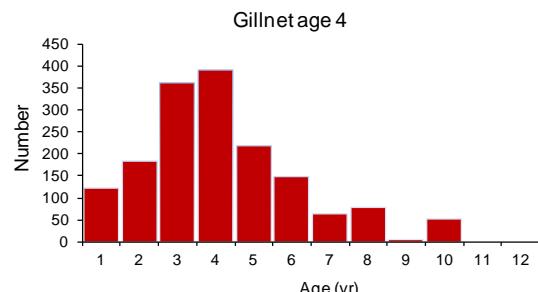
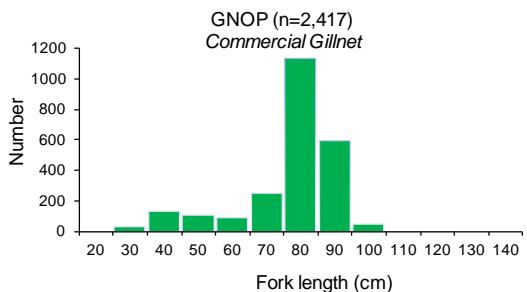
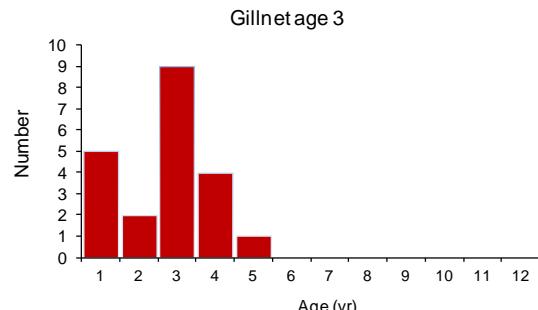
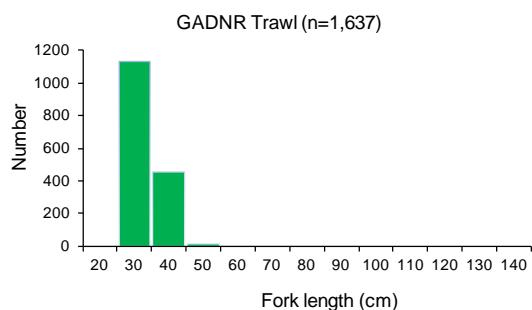
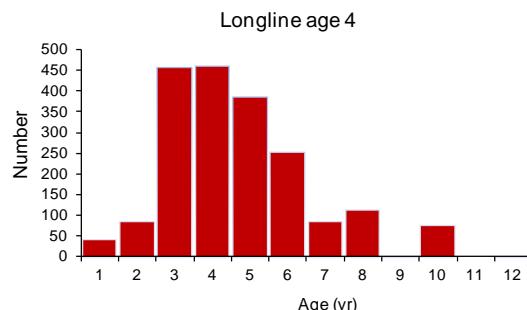
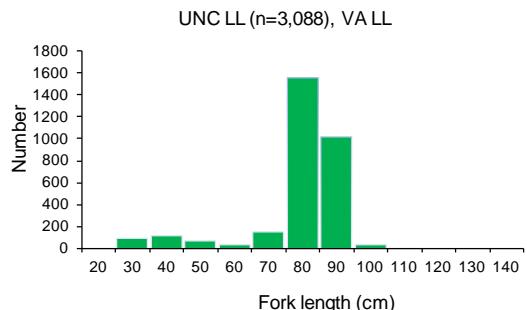
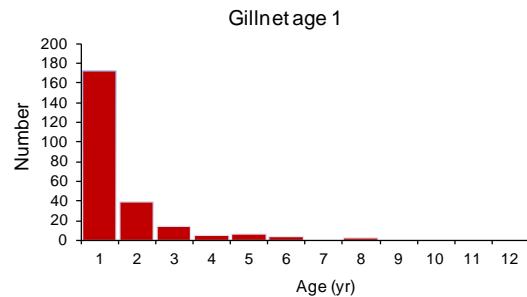
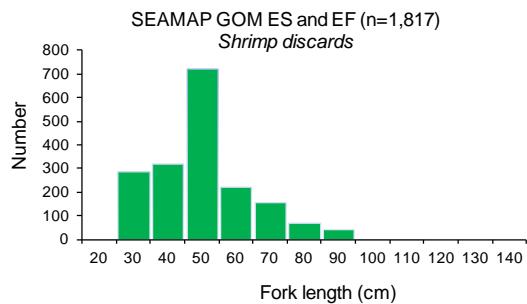
| Year | Weight (lb dw) | | | | | |
|------------|----------------|-------|--|--|--|--|
| | BLL | GN | | | | |
| 1993 | 3.435 | | | | | |
| 1994 | 3.462 | | | | | |
| 1995 | 3.167 | 3.738 | | | | |
| 1996 | 2.594 | 3.738 | | | | |
| 1997 | 3.074 | 3.738 | | | | |
| 1998 | 3.152 | 3.738 | | | | |
| 1999 | 3.162 | 3.738 | | | | |
| 2000 | 3.496 | 3.738 | | | | |
| 2001 | 3.275 | 3.738 | | | | |
| 2002 | 3.275 | 4.166 | | | | |
| 2003 | 3.068 | 4.364 | | | | |
| 2004 | 3.066 | 4.497 | | | | |
| 2005 | 3.455 | 4.051 | | | | |
| 2006 | 3.248 | 3.699 | | | | |
| 2007 | 3.045 | 2.262 | | | | |
| 2008 | 2.999 | 4.163 | | | | |
| 2009 | 3.091 | 3.069 | | | | |
| 2010 | 3.168 | 3.945 | | | | |
| 2011 | 3.004 | 3.160 | | | | |
| Grand mean | 3.170 | 3.738 | | | | |

* Italicized value for BLL in 2001 and 2002 is geometric mean of 2000 and 2003 values
 * Italicized value for GN in 1995-2001 is grand mean of 2002-2011 values

Appendix 2. Age-frequency distributions (right panel) obtained by back-transforming, through the sex-specific von Bertalanffy growth equation, length data (left panel) corresponding to the indices of relative abundance included in the base run. Selectivity functions were later fitted to the age-frequency data (see Table 2.5.2 for details). Figures on the left panel also show the catch series that were assigned the same selectivity as a particular index (in the subtitle in italics); figures in the right panel show the name given to each type of selectivity pattern.







Appendix 3. Algorithm used to estimate selectivities (implemented in MS Excel).

Obtain age-frequencies

Identify age of full selectivity. You should expect to see the age frequency bar chart increase with age to a modal age (*age_full*), after which it begins to decline again. One can assume that *age_full* is the age which is fully selected

Calculate the observed proportion at age: Obs[prop.CAA] = freq(age)/Total_samples

Take the natural log of observed proportion at age, plot age against it, and fit a trend line through the fully selected ages

Use the fitted trend line to predict expected proportion at age, E[prop.CAA]=exp(trend line)

Use the ratio of Obs[prop.CAA]/E[prop.CAA] to estimate the non-fully selected ages (i.e. selectivity of ages < *age_full*)

Normalize the column of Obs/Exp by dividing by the ratio value for *age_full* (this will scale ages so that the maximum selectivity will be 1 for *age_full*)

The age frequency for ages > *age_full* should decline as a result of natural mortality alone. If natural mortality is relatively constant for those ages, this should be a linear decline when you look at the log(Obs[prop.CAA]). If that decline departs severely from a linear trend, it may be that true selectivity is dome-shaped. Also, you may know because of gear characteristics that selectivity is lower for older animals. In this instance, a double exponential could be estimated to capture the decline in selectivity for the older animals

Fit a logistic curve by least squares by minimizing the sum of squared residuals of the expected value and the normalized Obs/Exp value

If fulcrum age=1 (fully selected), fit a double exponential curve by eye by manipulating parameter values to ensure coverage of all ages represented in the sample