SEDAR 11

Stock Assessment Report

Large Coastal Shark Complex, Blacktip and Sandbar Shark

2006

NOAA/NMFS
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Stock Assessment Report

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Section I: Introduction

1. SEDAR Overview

SEDAR (Southeast Data, Assessment and Review) was initially developed by the Southeast Fisheries Science Center of the National Marine Fisheries Service (NMFS) and the South Atlantic Fishery Management Council to improve the quality and reliability of stock assessments and to ensure a robust and independent peer review of stock assessment products. SEDAR was expanded in 2003 to address the assessment needs of all three Fishery Management Councils in the Southeast Region (South Atlantic, Gulf of Mexico, and Caribbean) and to provide a platform for reviewing assessments developed through the Atlantic and Gulf States Marine Fisheries Commissions and state agencies within the southeast. In 2005, the SEDAR process was adapted by the NOAA/NMFS Highly Migratory Species Management Division as a means to conduct stock assessments for the large coastal shark and small coastal shark complexes under their jurisdiction.

SEDAR strives to improve the quality of assessment advice provided for managing fisheries resources in the Southeast US by increasing and expanding participation in the assessment process, ensuring the assessment process is transparent and open, and providing a robust and independent review of assessment products.

SEDAR is organized around three workshops. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment workshop, 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. All workshops are open to the public.

SEDAR workshops are organized by SEDAR staff and the appropriate management agency. Data and Assessment Workshops are chaired by the SEDAR coordinator. 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 and 2 reviewers appointed by the Center for Independent Experts (CIE), an independent organization that provides independent, expert reviews of stock assessments and related work. The Review Workshop Chair is appointed by the CIE. Two additional reviewers selected by the Shark SEDAR Coordinator for their expertise in shark stock assessment were also included on the Large Coastal Shark Complex Review Panel.

SEDAR 11 was charged with assessing the large coastal shark complex, blacktip shark, and sandbar shark under the jurisdiction of the Highly Migratory Species Management Division.

2. Management History

2.1 The 1993 Fishery Management Plan

In 1989, the five Atlantic Fishery Management Councils asked the Secretary of Commerce 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.

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 (LCS, small coastal sharks, and pelagic sharks);
- Establishing calendar year commercial quotas for the LCS and pelagic sharks and dividing 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;
- 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 small coastal shark species group;
- Requiring that all sharks not taken as part of a commercial or recreational fishery be released uninjured;
- 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, and permitting and reporting requirements;
- Prohibiting finning by requiring that the ratio between wet fins/dressed carcass weight not exceed 5 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 (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 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.

At that time, NMFS identified LCS as overfished and established the quota at 2,436 metric tons (mt) dressed weight (dw). Under the rebuilding plan established in the 1993 FMP, the LCS quota was expected to increase in 1994 and 1995 up to the maximum sustainable yield (MSY) estimated in the 1992 stock assessment (3,800 mt dw).

2.2 After the 1993 FMP

A number of difficulties arose in the initial year of implementation of the Shark FMP. First, the January to June semi-annual LCS quota was exceeded shortly after implementation of the FMP, and that portion of the commercial fishery was closed on May 10, 1993. The LCS fishery re-opened on July 1, 1993, with an adjusted quota of 875 mt dw. Derby-style fishing, coupled with what some participants observed to be an unusual abundance of sharks, led to an intense and short fishing season for LCS, with the fishery closing within one month. Although fin prices remained strong throughout the brief season, the oversupply of shark carcasses led to reports of record low prices. The closure was significantly earlier than expected, and a number of commercial fishermen and dealers indicated that they were adversely affected. The intense season also complicated the task of monitoring the LCS quota and closing the season with the required advance notice.

To address these problems, a commercial trip limit of 4,000 lb. for permitted vessels for LCS was implemented on December 28, 1993 (58 FR 68556), and a control date for the Atlantic shark fishery was established on February 22, 1994 (59 FR 8457). A final rule to implement additional measures authorized by the FMP was published on October 18, 1994 (59 FR 52453). This rule:

- Clarified operation of vessels with a Federal commercial permit;
- Established the fishing year;
- Consolidated the regulations for drift gillnets;
- Required dealers to obtain a permit to purchase sharks;
- Required dealer reports;
- Established recreational bag limits;
- Established quotas for commercial landings; and
- Provided for commercial fishery closures when quotas were reached.

In 1994, under the rebuilding plan implemented in the 1993 FMP, the LCS quota was increased to 2,570 mt dw. Additionally, a new stock assessment was completed in March 1994. This stock assessment focused on LCS, suggested that recovery to the levels of the 1970s could take as long as 30 years, and concluded that "increases in the [Total Allowable Catch (TAC)] for sharks [are] considered risk-prone with respect to promoting stock recovery." A final rule that capped quotas for LCS at the 1994 levels was published on May 2, 1995 (60 FR 21468).

2.3 The 1996 LCS Stock Assessment and its Results

In June 1996, NMFS convened another stock assessment to examine the status of LCS stocks. The 1996 stock assessment found no clear evidence that LCS stocks were rebuilding and concluded that "[a]nalyses indicate that recovery is more likely to occur with reductions in effective fishing mortality rate of 50 [percent] or more." In response to these results, in 1997, NMFS reduced the LCS commercial quota by 50 percent to 1,285 mt dw and the recreational retention limit to two LCS, small coastal sharks, 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 also prohibited possession of five LCS species: sand tiger, bigeye sand tiger, whale, basking, and white. 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.

On February 26, 1998, Judge Steven D. Merryday of the U.S. District Court for the Middle District of Florida issued an order in the SOFA case finding that the Secretary "failed to conduct a proper analysis to determine the [April 1997 LCS] quotas economic effect on small businesses." As a result of this finding, Judge Merryday directed NMFS "to undertake a rational consideration of the economic effects and potential alternatives to the 1997 [LCS] quotas" on small businesses engaged in the Atlantic shark commercial fishery. Judge Merryday allowed NMFS to maintain the 1997 quotas pending further order of the court.

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 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.

2.4 The 1999 Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks

In 1996, amendments to the Magnuson-Stevens Act modified the definition of overfishing and established new provisions to halt overfishing and rebuild overfished stocks, minimize bycatch and bycatch mortality to the extent practicable, and identify and protect essential fish habitat. Accordingly, in 1997, NMFS began the process of creating a rebuilding plan for overfished highly migratory species (HMS), including LCS, consistent with the new provisions.

In June 1998, NMFS held another LCS stock assessment. The 1998 stock assessment found that LCS were overfished and would not rebuild under 1997 harvest levels. Based in part on the results of the 1998 stock assessment, in April 1999, NMFS published the final Fishery Management Plan for Atlantic Tunas, Swordfish and Sharks (1999 FMP), which included numerous measures to rebuild or prevent overfishing of Atlantic sharks in commercial and recreational fisheries. The 1999 FMP replaced the 1993 FMP. Management measures related to sharks that changed in the 1999 FMP included:

- Reducing commercial LCS and small coastal shark quotas;
- Establishing ridgeback and non-ridgeback categories of LCS;
- Implementing a commercial minimum size for ridgeback LCS;
- Establishing blue shark, porbeagle shark, and other pelagic shark subgroups of the pelagic sharks and establishing a commercial quota for each subgroup;
- Reducing recreational retention limits for all sharks;
- Establishing a recreational minimum size for all sharks except Atlantic sharpnose;
- Expanding the list of prohibited shark species;
- Implementing limited access in commercial fisheries;
- 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). On June 25, 1999, SOFA *et al*. sued NMFS again, this time challenging the Atlantic shark commercial measures implemented in the 1999 FMP. NMFS was also sued by Bluewater Fisherman's Association regarding the pelagic shark management measures adopted in the 1999 FMP and by the Recreational Fishing Alliance regarding the recreational shark regulations adopted in the 1999 FMP.

On June 30, 1999, NMFS received a court order from Judge Merryday relative to the May 1997 lawsuit. Specifically, the order enjoined NMFS from enforcing the 1999 regulations with respect to Atlantic shark commercial catch quotas and fish-counting methods (including the counting of dead discards and state commercial landings after Federal closures), which were different from the quotas and fish counting methods prescribed by the 1997 Atlantic shark regulations. A year later, on June 12, 2000, the court issued an order clarifying that NMFS could proceed with implementation and enforcement of the 1999 prohibited species provisions (64 FR 29090, May 28, 1999).

On September 25, 2000, Judge Roberts of the United States District Court for the District of Columbia rule against the Bluewater Fisherman's Association and stated that the regulations were consistent with the Magnuson-Stevens Act and the Regulatory Flexibility Act. On September 20, 2001, Judge Roberts ruled against the Recreational Fishing Alliance and stated that the recreational retention limits were consistent with the Magnuson-Stevens Act.

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, Judge Merryday 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 the LCS and small coastal shark commercial quotas at 1997 levels.

2.5 The Peer Review of the 1998 LCS Stock Assessment

As noted above, the settlement agreement required, among other things, an independent peer review of the 1998 LCS stock assessment. The original settlement agreement determined that the Center for Independent Experts (CIE) would conduct the peer review. In May 2001, the CIE transmitted three peer reviews of the 1998 LCS stock assessment to NMFS.

In July 2001, NMFS and the plaintiffs revised certain sections of the settlement agreement and included a provision that stated that Natural Resources Consultants, Inc. (NRC) would conduct a second peer review. NMFS received the results of the complete NRC peer reviews in October 2001. Three of the four NRC reviewers found that the scientific conclusions and scientific management recommendations contained in the 1998 Stock assessment report *were not* based on scientifically reasonable uses of appropriate fisheries stock assessment techniques and the best available biological fishery information relating to LCS. The settlement agreement stated that in this case, NMFS would take the appropriate action to maintain the 1997 LCS quota and catch accounting/monitoring procedures, pending a new LCS stock assessment.

Taking into consideration the settlement agreement, the results of all the peer reviews, 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 small coastal shark 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, NMFS maintained the 1997 LCS commercial quota (1,285 mt dw), maintained the 1997 small coastal shark commercial quota (1,760 mt dw), suspended the commercial ridgeback LCS minimum size, suspended counting dead discards and state landings after a Federal closure against the quota, and replaced season-specific quota accounting methods with subsequent-season quota accounting methods. That emergency rule expired on December 30, 2002.

2.6 The 2002 LCS Stock Assessment

On May 28, 2002 (67 FR 36858), NMFS announced the availability of a modeling document that explored the suggestions of the CIE and NRC peer reviews on LCS. Then NMFS held a 2002 LCS stock assessment workshop in June 2002. On October 17, 2002, NMFS announced the availability of the 2002 LCS stock assessment and the workshop meeting report (67 FR 64098). The results of this stock assessment indicated that the LCS complex was still overfished and overfishing was occurring. Additionally, the 2002 LCS stock assessment found that sandbar sharks were no longer overfished but that overfishing was still occurring and that blacktip sharks were rebuilt and overfishing was not occurring.

Based on the results of both the 2002 small coastal shark 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, set the LCS quotas based on the results of stock assessments, 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. Additionally, NMFS announced its intent to conduct an environmental impact statement and amend the 1999 FMP (67 FR 69180, November 15, 2002).

The emergency rule was an interim measure to maintain the status of LCS pending the re-evaluation of management measures in the context of the rebuilding plan through this FMP amendment. The emergency rule for the 2003 fishing year implemented for the first and only time the classification system (ridgeback/non-ridgeback LCS) finalized in the 1999 FMP. NMFS also implemented for the first time a provision to count state landings after a Federal closure and to count dead discards against the quota. To calculate the commercial quotas for these groups, NMFS took the average landings for individual species from 1999 through 2001 and either increased them or decreased them by certain percentages, as suggested by scenarios presented in the stock assessment. Because the stock assessment scenarios suggested that an increase in catch for blacktip sharks would not cause overfishing and that maintaining the sandbar sharks would not increase overfishing (the two primary species in the LCS fishery), this method resulted in an increase in the overall quota for the length of the emergency rule. During the comment period on the emergency rule and scoping for this amendment, NMFS received comments regarding, among other things, the quota levels under the rule, concern over secondary species and discards, the ability of fishermen to target certain species, and impacts of the different season length for ridgeback and non-ridgeback LCS. NMFS responded to these comments when extending the emergency rule and further considered these comments when examining the alternatives presented in the Amendment to the 1999 FMP.

NMFS received the results of the peer review of the 2002 LCS stock assessment in December 2002. These reviews were generally positive.

2.7 Amendment 1 to the 1999 FMP and 2004 Rules

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. The final management measures (December 24, 2003, 68 FR 74746) selected in Amendment 1 included, among other things: aggregating the large coastal shark complex, using maximum sustainable yield as a basis for setting commercial quotas, eliminating the commercial minimum size, establishing regional commercial quotas and trimester commercial fishing seasons, adjusting the recreational bag and size limits, establishing gear restrictions to reduce bycatch or reduce bycatch mortality, establishing a time/area closure off the coast of North Carolina, removing the deepwater/other sharks from the management unit, establishing a mechanism for changing the species on the prohibited species list, updating essential fish habitat identifications for five species of sharks, and changing the administration for issuing permits for display purposes.

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).

2.8 Proposed Consolidated HMS FMP

In April through July 2004, NMFS released an Issues and Options Paper and held many scoping meetings regarding additional changes that may be needed in all aspects of HMS fisheries. Based on the comments received at these scoping meetings and on a Predraft of the Consolidated HMS FMP, NMFS released a proposed rule and Draft HMS FMP on August 19, 2005 (70 FR 48804). The Draft HMS FMP would combine and augment the 1999 FMP and Amendment 1 with the 1988 Billfish FMP and its Amendment. The Draft HMS FMP would not replace any existing management measures unless they were specifically analyzed in the Draft Environmental Impact Statement (DEIS). Most of the proposed management measures analyzed in the DEIS do not affect the LCS fishery. Those that could affect the LCS fishery include a requirement for mandatory workshops for bottom longline and gillnet vessels owners and crew regarding the handling and release of protected species, mandatory workshops for shark dealers regarding shark identification, criteria to consider when implementing new or modifying existing time/area closures, changes to the definition of pelagic and bottom longline gear, a requirement to maintain the second dorsal and anal fin on the shark through landing, and a permit condition for all recreational vessels that Federal regulations must be followed regardless of location of fishing unless a state has more restrictive measures. Additionally, some of the objectives of the 1999 FMP may change to include billfish. These changes are contained in the Draft HMS FMP.

2.9 Exempted Fishing Permits

Under 50 CFR 635.32, and consistent with 50 CFR 600.745, NMFS may authorize for limited testing, public display, and scientific data collection purposes, the target or incidental harvest of species managed under an FMP or fishery regulations that would otherwise be prohibited. Exempted fishing may not be conducted unless authorized by an Exempted Fishing Permit (EFP) or a Scientific Research Permit (SRP) issued by NMFS in accordance with criteria and procedures specified in those sections. As necessary, an EFP or SRP would exempt the named party(ies) from otherwise applicable regulations under 50 CFR part 635. Such exemptions could address fishery closures, possession of prohibited species, commercial permitting requirements, and retention and minimum size limits.

In the 1999 FMP, NMFS established a 60 mt ww shark public display quota for the purpose of collecting sharks for aquariums and other instances of public display. In order to collect sharks under this quota, fishermen must apply for an EFP. This allows them to collect sharks during closed seasons and also allows them to collect sharks that may be prohibited, such as sand tiger sharks. NMFS also issues EFPs for the collection of other HMS for public display.

2.10 Essential Fish Habitat

Under the Magnuson-Stevens Act, each FMP must describe and identify essential fish habitat (EFH) for the fishery, minimize to the extent practicable adverse effects on that EFH caused by fishing, and identify other actions to encourage the conservation and enhancement of EFH. In 1999, NMFS identified EFH for all actively managed species of sharks as well as two habitat areas of particular concern (HAPC). Based on the 2002 LCS and small coastal shark stock assessments and other new information, NMFS considered possible updates to EFH, particularly for species whose status had changed. In Amendment 1, NMFS updated EFH for five species: dusky, sandbar, nurse, finetooth, and blacktip sharks. In the Draft HMS FMP, NMFS is examining additional data to update EFH for all species of sharks. Any changes to EFH would occur in a separate document.

Summary of current shark regulations

PROHIBITED SPECIES

The following sharks cannot be kept commercially or recreationally: Whale, basking, sand tiger, bigeye sand tiger, white, dusky, night, bignose, Galapagos, Caribbean reef, narrowtooth, longfin mako, bigeye thresher, sevengill, sixgill, bigeye sixgill, Caribbean sharpnose, smalltail, and Atlantic angel sharks. There is a mechanism in place to add or remove species, as needed, via rulemaking.

COMMERCIAL REGULATIONS

Management Unit	**Species that can be retained**	**Quota (mt dw)**	**Regional Quotas**	**Authorized Gears**
Large Coastal Sharks - directed commercial retention limit of 4,000 lb dw per trip - incidental retention limit	Sandbar, silky, tiger, blacktip, bull, spinner, lemon, nurse, smooth hammerhead, scalloped hammerhead, great hammerhead	1,017	NA = 7% SA = 41% GM = 52%	Pelagic or Bottom Longline; Gillnet; Rod and Reel; Handline; Bandit Gear
Pelagic Sharks - no directed retention limit - incidental retention limit	Shortfin mako, thresher, oceanic whitetip	488	None	
	Porbeagle	92		
	Blue	273		
Small Coastal Sharks - no directed retention limit - incidental retention limit	Atlantic sharpnose, blacknose, finetooth, bonnethead	454	NA = 3% SA = 87% GM = 10%	

<u>Additional remarks</u>:

- All sharks not retained must be released in a manner that ensures the maximum probability of survival
- Finning is prohibited for all sharks no matter what species
- Fishing seasons: January 1 to April 30; May 1 to August 30; September 1 to December 31
- Fishing regions: NA = Maine through Virginia; SA = N. Carolina through East Florida and Caribbean; GM = Gulf of Mexico
- Quota over- and underharvest adjustments will be made for the same season the following year; no reopening that season
- Count state landings after Federal closure against Federal quota
- Time/area closure for vessels with bottom longline gear on board: January through July between 35" 41'N to 33" 51'N and west of 74" 46'W, roughly following the 60 fathom contour line, diagonally south to 76" 24'W and north to 74" 51'W .
- Vessel Monitoring Systems required for all gillnet vessels during right whale calving season and from January through July for all vessels with bottom longline gear on board between 33" 00' N and 36" 30'N
- Limited access; Exempted Fishing Permit (EFP) requirements; Display permits for collection for public display
- Observer and reporting requirements
- For incidental limited access permit holders: 5 large coastal sharks per trip; a total of 16 pelagic or small coastal sharks (all species combined) per vessel per trip
- Vessel with bottom longline gear on board must: (1) have non-stainless steel corrodible hooks; (2) have a dehooking device (when approved), linecutters, and a dipnet on board; (3) move 1 nmi after an interaction with a protected species; and (4) post sea turtle handling and release guidelines in the wheelhouse

RECREATIONAL REGULATIONS

Management Unit	**Species that can be kept**	**Retention Limit**	Authorized Gear
Large Coastal, Pelagic, and Small Coastal Sharks	LCS: Sandbar, silky, tiger, blacktip, bull, spinner, lemon, nurse, smooth hammerhead, scalloped hammerhead, great hammerhead Pelagic: shortfin mako, thresher, oceanic whitetip, porbeagle, blue SCS: Atlantic sharpnose, blacknose, finetooth, bonnethead	1 shark per vessel per trip (all species) with a 4.5 feet fork length minimum size; allowance for 1 Atlantic sharpnose and 1 bonnethead per person per trip (no minimum size)	Rod and Reel; Handline

<u>Additional remarks</u>:
Harvested sharks must have fins, head, and tail attached (can be bled and gutted if tail is still attached).

3. Assessment History

In 1992, a Shark Fishery Management Plan Regulatory Review Meeting was held in Miami, Florida to reach conclusions regarding the resource assessment of the Atlantic coastal shark resource. This meeting, attended by scientists from NMFS, Harbor Branch Oceanographic Institution, and the International Pacific Halibut Commission, determined that while available data was meager and uncertain, analysis of those data allowed for the initialization of fishery regulations.

After the implementation of the FMP, NMFS convened several Shark Evaluation Workshops (SEW 1994, 1996, 1998, and 2002) as a mechanism to examine the available shark data and provide scientific advice to facilitate the evaluation of Atlantic shark resources. These SEWs lasted several days, after which analysts from the SEFSC conducted a stock assessment and produced a stock assessment report over the next several months.

SEDAR 11

Stock Assessment Report

Large Coastal Shark Complex, Blacktip and Sandbar Shark

Section II: Data Workshop Report

LCS05/06: LARGE COASTAL SHARK COMPLEX, BLACKTIP AND SANDBAR SHARKS

LARGE COASTAL SHARK COMPLEX DATA WORKSHOP REPORT

12 JANUARY 2006

Introduction:
The current assessment for the Large Coastal Shark (LCS) Complex was to be run following, as close as possible, the procedures of the Southeast Data, Assessment, and Review (SEDAR) process. The process involves three meeting Workshops: Data, Assessment, and Review. The Data Workshop for the LCS complex was held in Panama City, FL October 31st through November 4th, 2005. Participants are listed in Appendix 1. Initial data compilations and exploratory analyses for SEDAR assessments were requested from participants in the form of "working documents" to be submitted in advance and evaluated over the course of the workshop. A full list of papers submitted is presented in Appendix 2. Minority opinions can be found in Appendix 3.

Three working groups were established to address the quality and suitability of available data for stock assessment. The working groups were: 1) life history, 2) catch statistics, and 3) indices of relative abundance. Participants were initially assigned to one of the groups based on their expertise and the type of documents they were submitting however participants were allowed to participate in any working group they wished. Group rapporteurs reported issues and progress to Data Workshop plenary sessions several times during the week. Written reports from the life history and catch statistics working groups were substantially complete by week's end, whereas the indices group report was only in the preliminary stages. There was some subsequent editing, and some further analyses sketched out during the Data Workshop has been completed. Some additional analyses recommended at the Data Workshop were too extensive to allow completion prior to circulation of the Data Workshop report. These analyses will be reported and evaluated at the Assessment Workshop scheduled for February, 2006.

This report is divided into three sections, paralleling the choice to establish three working groups. Structure within each section was determined by each working group, following some general guidelines derived from SEDARs for other species and the content previously reported from Shark Evaluation Workshops (SEWs). The LCS complex has a history of previous assessments via the SEWs, so this report has expanded discussion on issues that had been difficult or controversial in past work, but is fairly brief on issues that are reasonably well settled. Figures and tables remain within the individual sections, and are numbered in "Section number.figure number" sequence. Lists of references to the general literature (i.e. papers other than the working documents submitted to this Workshop) also remain with the individual sections. Citations to papers submitted to this workshop as "working documents" are made in the text using the identifying numbers assigned by the Shark SEDAR Coordinator (in the form LCS05/06-DW-xx), and refer to the list in Appendix 2.

As is customary for Data Workshop reports, several of the sections contain recommendations for future research efforts. Many of these recommendations are intended to be considered over the next several years, and are not recommendations for work to be completed prior to the Stock Assessment Workshop portion of the LCS SEDAR in February 2006.

This report is a complete and final documentation of the activities, decisions, and recommendations of the Data Workshop. It will also serve as one of 4 components of the final SEDAR Assessment Report. The final SEDAR Assessment Report will be completed following the last workshop in the cycle, the Review Workshop, and will consist of the following sections: I) Introduction; II) Data Workshop Report; III) Assessment Workshop Report; and IV) Review Workshop Report.

LCS 05/06 SEDAR. Data Workshop Terms of Reference

1. Characterize stock structure and develop a unit stock definition.

2. Tabulate available life history information (e.g., age, growth, natural mortality, reproductive characteristics). Provide models to describe growth, maturation, and fecundity by age, sex, or length as appropriate; recommend life history parameters (or ranges of parameters) for use in population modeling; evaluate the adequacy of life-history information for conducting stock assessments.

3. Provide indices of population abundance. Consider fishery dependent and independent data sources; develop index values for appropriate strata (e.g., age, size, area, and fishery); provide measures of precision; conduct analyses evaluating the degree to which available indices adequately represent fishery and population conditions. Document all programs used to develop indices, addressing program objectives, methods, coverage, sampling intensity, and other relevant characteristics.

4. Characterize commercial and recreational catches, including both landings and discard removals, in weight and numbers. Evaluate the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector. Provide length and age distributions if feasible.

5. Evaluate the adequacy of available data for estimating the impacts of current management actions.

6. Recommend assessment methods and models that are appropriate given the quality and scope of the data sets reviewed and management requirements.

7. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on sampling intensity and coverage where possible.

8. Prepare complete documentation of workshop actions and decisions (Section II. of the SEDAR assessment report).

Contents:

<u>Life History Working Group Report</u>

John Carlson, (Chair) NOAA Fisheries Service
Jose Castro, NOAA Fisheries Service and Mote Marine Laboratory
Robert Hueter, Mote Marine Laboratory
Nancy Kohler, NOAA Fisheries Service
Jack Musick, Virginia Institute of Marine Science
Jason Romine, Virginia Institute of Marine Science

1.1 Summary of Life History Documents

LCS05/06-DW-10:
Life history parameters for blacktip sharks, *Carcharhinus limbatus*, from the United States South Atlantic Bight and Eastern Gulf of Mexico

Summary: Life history traits (e.g., mean size-at-age, growth rate, age-at-maturity) for blacktip sharks were examined for sharks collected from two separate geographical areas (eastern Gulf of Mexico and South Atlantic Bight) to address the potential for separate stocks in southeastern US waters. Samples were obtained from fishery-dependent and independent sources. Growth and logistic models were fitted to observed size-at-age and reproductive ogive data, respectively. Von Bertalanffy growth parameters derived for blacktip shark from the Gulf of Mexico show that they attain a statistically smaller theoretical maximum size (L_∞=141.6 cm vs. L_∞=158.5 cm for female and L_∞=126 cm FL and L_∞=158.5 cm FL for male) and have a faster growth rate (k=0.24 yr^{-1} vs. k=0.16 yr^{-1} for female and k=0.27 yr^{-1} vs. k=0.21 yr^{-1} for male) than conspecifics in the South Atlantic Bight. Mean size-at-age was not significantly different for most ages, and growth rates between ages were similar. Median size- and age-at-maturity were significantly different between sex and area. Size at which 50% of the population is mature was 117.3 cm FL for females and 103.4 cm FL for males in the Gulf of Mexico and 126.6 cm FL for females and 116.7 cm FL for males in the South Atlantic Bight. Median age-at-maturity was 5.7 years and 4.5 years for females and males in the Gulf of Mexico, respectively, while age-at-maturity was 6.7 years for females and 5.0 years for males for sharks from the South Atlantic Bight. Due to varying statistical results, temporal problems of sampling, and potential for gear bias, we could not definitively conclude that differences in life history exist.

LCS05/06-DW-15:
Estimates of natural mortality for sandbar and blacktip shark for use in assessments

Summary: This document reviews ten methods of estimating natural mortality (M) based on life history correlates. Separate estimates for blacktip in the Gulf of Mexico and the Atlantic Ocean were produced, while a single estimate for sandbar was produced. Five of the methods yield a single estimate of M and five yield age-specific estimates. An eleventh estimate of M at age was produced by fitting a negative exponential to the average M over all ten methods. In general, estimates from the Peterson and Wroblewski method, which is based on dry weight, consistently produced lower estimates of M. Also, for blacktip, estimates based on von Bertalanffy growth parameters tended to produce lower estimates than the other methods.

LCS05/06-DW-28:

Genetic heterogeneity among blacktip shark, *Carcharhinus limbatus,* continental nurseries along the U.S. Atlantic and Gulf of Mexico

Summary: Genetic population structure of the blacktip shark, Carcharhinus limbatus, a commercially and recreationally important species in the southeast U.S. shark fishery, was investigated using mitochondrial DNA control region sequences. Neonate blacktip sharks were sampled from three nurseries, Pine Island Sound,Terra Ceia Bay, and Yankeetown, along the Gulf of Mexico coast of Florida (Gulf) and one nursery, Bulls Bay, on the Atlantic Ocean coast of South Carolina (Atlantic). Sequencing of the complete mitochondrial control region of 169 neonates revealed 10 polymorphic sites and 13 haplotypes. Overall haplotype diversity and percent nucleotide diversity were 0.710 and 0.106%, respectively. Haplotype frequencies were compared among nurseries to determine if the high mobility and seasonal migrations of adult blacktip sharks have maintained genetic homogeneity among nurseries in the Atlantic and Gulf. Chi-square analysis and AMOVA did not detect significant structuring of haplotypes among the three Gulf nurseries, P(v2)=0.294, FST=)0.005 to)0.002. All pairwise AMOVA between Gulf nurseries and the Atlantic nursery detected significant partitioning of haplotypes between the Gulf and Atlantic (FST=0.087–0.129, P<0.008), as did comparison between grouped Florida Gulf nurseries and the Atlantic, FCT=0.090, P<0.001. Based upon the dispersal abilities and seasonal migrations of blacktip sharks, these results support the presence of philopatry for nursery areas among female blacktip sharks. Our data also support the treatment of Atlantic and Gulf blacktip shark nursery areas as separate management units.

LCS05/06-DW-29:
Preliminary Tag and Recapture Data for the Sandbar Shark, *Carcharhinus plumbeus*, and the Blacktip Shark, *Carcharhinus limbatus*, in the Western North Atlantic

Summary: Tagging and recapture (T/R) information from the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program (CSTP) covering the period from 1963 through 2004 are summarized for the sandbar shark (*Carcharhinus plumbeus*) and the blacktip shark (*Carcharhinus limbatus*) in the western North Atlantic. The extent of the tagging effort, areas of release and recapture, sources of tags and recaptures, capture methods, and movements of tagged sharks are reported. In order to examine regional trends in size and maturation categories, the study area is divided into geographical areas based on tagging distributions which largely reflects the fishing effort patterns of cooperative taggers aboard private, commercial, and research vessels. These tagging regions are defined as East Coast (US), Gulf of Mexico (US), Gulf of Mexico (Mexico), and Other. Only data with information on size, sex, and mark/recapture location were included in the regional analyses. In the sandbar regional database, sharks that were recaptured (N=1,010) were tagged within all areas except the Gulf of Mexico (Mexico) with the great majority (98%) tagged in the East Coast (US). Of the fish tagged off the US East Coast, 19% moved to the US Gulf of Mexico and 3% moved to Mexican Gulf waters. Of the fish tagged in the US Gulf of Mexico, 27% moved to the US East Coast and 7% moved to Mexican Gulf waters. Overall, none of the neonate-sized fish moved between areas and a larger percentage of the mature fish of both sexes moved out of their original tagging area. In the blacktip regional database, sharks that were recaptured (N=143) were tagged within all areas except the Gulf of Mexico (Mexico). Overall movement between tagging areas was rare and occurred primarily between the Gulf of Mexico (US) and Gulf of Mexico (Mexico) regions. A total of 30 *C. limbatus*, tagged off Texas, were recaptured off Mexico, which represents 21% of the recaptures and

1% of the number of tagged fish in the US Gulf of Mexico region. The true extent of this movement is unclear due to the possibility of under-reporting of recaptures.

LCS05/06-DW-39:
Life history parameters of the sandbar shark, *Carcharhinus plumbeus*, in the Northwest Atlantic

Summary: Published data were examined for estimates of life history parameters for the sandbar shark, *Carcharhinus plumbeus*, in the Northwest Atlantic. Studies estimated von Bertalanffy growth parameters through analyses of vertebral centra and tag-recapture methods. Casey et al. (1985) provided estimates of growth following examination of vertebral centra from 475 sandbar sharks. Von Bertalanffy growth parameter estimates from this study were K=0.0501, t_0 = -4.5, and L_∞=233 cm pre-caudal length (PCL) for males and K=0.04, t_0 = -4.9, and L_∞=270 cm PCL for females. Asymptotic size estimates from this study did not agree with empirical maximum size data for the sandbar shark in the Northwest Atlantic. Casey and Natanson (1992) provided revised estimates of growth parameters from long term tag recapture data. Growth parameters estimated from this study were K=0.046, t_0 = -6.45, and L_∞=168 cm PCL for both sexes combined. Sminkey and Musick (1995) reexamined the age and growth parameters of the sandbar shark following population depletion. This study estimated growth parameters from vertebral centra obtained over two time periods, 1980-1981 and 1990-1991. Growth parameter estimates for the 1980-1981 time period were K=0.059, t_0 = -5.4, and L_∞=184 cm PCL for males and K=0.059, t_0 = -4.8, and L_∞=197 cm PCL for females (n = 188). Growth parameter estimates for the 1990-1991 time period were K=0.087, t_0 = -3.8, and L_∞=166 cm PCL for males and K=0.086, t_0 = -3.9, and L_∞=165 cm PCL for females (n = 412). Tag recapture data reported in Grubbs et al. (in press) corroborate growth parameter estimates from the 1990-1991 period presented by Sminkey and Musick (1995). Fecundity estimates for the Northwest Atlantic ranged from 4-12 pups and averaged 8.4 pups litter $^{-1}$ (Clark and von Schmidt 1965; Sminkey and Musick 1995; Cortés 2000). Merson (1998) estimated size at 50% maturity as 133 cm PCL for males and 141 cm PCL for females. These lengths correspond to 15 and 19 years of age for males and females respectively.

LCS05/06-DW-40:
Long-Term Movements, Migration, and Temporal Delineation of a Summer Nursery for Juvenile Sandbar Sharks in the Chesapeake Bay Region

Summary: Delineation of essential fish habitat for exploited populations is critical to proper management. Spatial delineation of summer nurseries for elasmobranchs has received increased attention in recent years; however, temporal patterns of nursery use and the delineation of wintering areas are as critical. The lower Chesapeake Bay is the largest summer nursery for sandbar sharks *Carcharhinus plumbeus* in the western Atlantic. The goals of this study were to delineate temporally the use of the nursery and the migratory movements of juvenile sandbar sharks in this estuary, to determine the location of wintering areas, and to determine if philopatry or homing to natal summer nurseries occurs in subsequent years. Longline sampling conducted between 1990 and 1999 indicated that immigration to the bay occurred from late May to early July and was highly correlated with increasing water temperature. Emigration from the estuary occurred in late September and early October and was highly correlated with decreasing day length. We hypothesize that photoperiod is the environmental trigger to begin fall and spring migrations, whereas temperature may elicit the response

to move into the estuaries that serve as summer nurseries. Between 1995 and 2003, we tagged 2,288 juvenile sandbar sharks. Seventy-three sharks were recaptured following 4–3,124 d at liberty and the distance from tagging locations ranged from 0 to 2,800 km. Recapture data suggest that most sandbar sharks return to their natal estuaries during summer for at least the first 3 years and return to adjacent coastal waters for up to 9 years. These data also indicate that wintering areas are concentrated off the coast of North Carolina between 33°30'N and 34°30'N latitude, primarily in nearshore waters less than 20 m deep, though sharks older than 7 years were recaptured as far as 60 km from shore. Temporal use of this area by juvenile sandbar sharks occurs from late October until late May for at least the first 7 years and up to 10 years.

LCS05/06-DW-44:
Results of Mote Marine Laboratory Shark Tagging Program for blacktip (*Carcharhinus limbatus*) and sandbar (*C. plumbeus*) sharks

Summary: Mote Marine Laboratory's Center for Shark Research (MML) has been conducting tag-recapture studies of sharks since 1991 along Florida's coast and throughout the Gulf of Mexico. The MML tagging database currently includes 14,365 individuals from 16 species including 4,360 blacktip and 51 sandbar sharks, with 204 and 5 recaptured, respectively. Long-term recaps from Florida-tagged blacktips generally demonstrated a north-south movement and there was no evidence of sharks moving into either the western Gulf or the Atlantic. In the western Gulf, there was evidence of movement from Texas into Mexican waters. Young blacktip sharks tagged in the Yucatan Peninsula primarily moved westward and none entered U.S. or Caribbean waters. Tagged sandbar sharks in the eastern Gulf of Mexico demonstrated long-distance movements to South Carolina. Tag-recapture data for 85 blacktip sharks that had accurate size data at both release and recapture were used to examine age and growth parameters using the GROTAG model. These results indicate that growth at small sizes is rapid, but mature size blacktips grow at around 4 cm per year. Growth variability was low, but measurement error was high. Conversion of the results to von Bertalanffy parameters resulted in values similar to published values from vertebral ageing (L_∞ =179 cm STL; K=0.18 yr^{-1}). Growth rates from tag-recapture data were similar to those from vertebral analysis that have previously reported from the Gulf of Mexico.

LCS05/06-DW-46:
Investigations into the winter habitat of juvenile sandbar sharks, C*archarhinus plumbeus*, using pop-up archival satellite transmitters (PSATs)

Summary: Defining areas of aggregation of Atlantic shark species is important for current and future management efforts. Recent studies have found that the principal summer nursery areas for the North Atlantic population of sandbar sharks occur in shallow coastal bays from New Jersey to South Carolina. The principal overwintering areas for this population are likely found off the North and South Carolina coasts. The primary objective of this project was to use a fishery independent method to examine the overwintering location and habitat preferences of large juvenile sandbar sharks. During the summer of 2003, 21 sandbar sharks captured in the Eastern Shore of Virginia bays and lagoons were outfitted with satellite transmitters that were programmed to detach during the winter of 2003/2004. Of the 21 transmitters: four transmitters did not report, 12 released prematurely, and five reported on time. Nine of the transmitters reported during the targeted overwintering period (November 2004 through February 2005). The data from these nine transmitters, was used to examine

winter habitat preferences and the overwintering localities of large juvenile sandbar sharks. Satellite pop-off locations during the overwintering period were concentrated in central North Carolina coastal waters. The sharks predominantly remained in waters ranging from 18 to 22° C and in depths ranging from 0 to 50 m and there was a shift into deeper and slightly colder waters during this period.

LCS05/06-DW-47:
Nursery grounds and maturation of the sandbar shark in the western North Atlantic

Summary: Sandbar sharks from the western North Atlantic and Gulf of Mexico were sampled between 1995 and 1997 to describe development of the reproductive tract, determine range in the length-at-maturity, reassess litter size and outline seasonal gonadal cycle to assess frequency of pregnancy. In males and females marked increases in reproductive tract anatomy occurs at about 140 cm fork length (FL), indicating the transition between juvenile and subadult stages. The smallest mature female was 148 cm FL and largest immature was175 cm FL. The smallest mature male was 139 cm FL and the largest immature was 153 cm FL. Probit analysis was used to produce maturity schedules for males and females. There was no difference in maturity schedules of either sex produced by data collected during this study and data from the National Marine Fisheries Service reproduction database (1971-1996). Length-at-maturity in both female and male sandbar sharks are consistent with reports in the literature, but the maturity schedules produced here describe the range in length-at-maturity. Females produce a mean litter size of eight pups possibly less frequently as every other year.

LIFE HISTORY INFORMATION SUMMARY AND CONSENSUS

1.2 Sandbar shark

1.2.1 Stock definition

After considering the available data, the working group decided that the stock definition should be the Western North Atlantic from southern New England to Gulf of Mexico. Tagging studies suggest that one unit stock exists from Cape Cod south down the U.S. Atlantic coast and into the Gulf of Mexico, extending around the U.S. and Mexican portions of the Gulf of Mexico to the northern Yucatan peninsula (LCS05/06-DW29; LCS05/06-DW40). Genetic studies conducted on specimens from Virginia waters and the Gulf of Mexico further support the existence of a single stock that utilizes the area of Cape Cod to the northern Yucatan Peninsula (Heist et al. 1995, Heist and Gold 1999).

1.2.2 Age and growth

Age and growth of the sandbar shark has been studied extensively in the Northwest Atlantic. Multiple studies have utilized vertebral centra for determining age at size for the sandbar shark in the Northwest Atlantic. Casey et al. (1985) and Sminkey and Musick (1995) estimated age and growth parameters for sandbar sharks from vertebral centra analyses. Casey and Natanson (1992) utilized tag/recapture methods as another means of estimating life history parameters. Sminkey and Musick (1995) reexamined age and growth of the sandbar shark from samples obtained a decade apart, 1980-1981 and 1991-1992. The sample set from 1991-1992 was the most robust sample size and had the greatest size range of any study conducted on sandbar sharks to date. Sminkey and Musick (1995) produced theoretical estimates for maximum size that were in close agreement with empirical values. Minimum and maximum ages assigned to sharks in this study were 1 and 25 years, respectively.

Estimated values from this work were corroborated by LCS05/06-DW-40. The Sminkey and Musick (1995) estimates were determined to be most robust.

Age-length relationships were taken as determined by Sminkey and Musick (1995). Von Bertalanffy parameters used in length at age determination were estimated from analyses of sandbar shark vertebral centra obtained in 1990-1991 time period. All lengths are in cm: PCL=Pre-caudal length, FL=Fork length, TL=Total length.

	Males			Females		
Age	**PCL**	**FL**	**TL**	**PCL**	**FL**	**TL**
0	47	52	63	48	54	65
1	57	63	76	58	65	78
2	66	73	88	67	75	90
3	74	83	99	76	84	101
4	82	91	110	83	93	112
5	89	99	119	90	100	121
6	95	106	128	97	107	129
7	101	112	135	102	114	137
8	107	118	143	108	120	144
9	111	124	149	113	125	151
10	116	129	155	117	130	157
11	120	133	161	121	134	162
12	124	137	166	125	138	167
13	128	141	171	128	142	172
14	131	145	175	131	146	176
15	134	148	179	134	149	180
16	136	151	183	137	152	183
17	139	154	186	139	154	187
18	141	156	189	142	157	190
19	143	158	192	144	159	192
20	145	161	194	145	161	195
21	147	162	197	147	163	197
22	148	164	199	149	164	199
23	150	166	201	150	166	201
24	151	167	203	151	167	203
25	152	169	204	152	169	204

1.2.3 Size at maturity

Sminkey and Musick (1995) reported sizes at maturity of 135 and 136 cm PCL for males and females, respectively, but did not construct a fertility schedule. As age-structured models require percent maturity by age as an input, further information was needed. Merson (1998; LCS05/06-DW-47) constructed age-specific maturity ogive schedules for her maturity-at-length data using the age and growth model developed by Sminkey and Musick (1995). There was some discussion as to the appropriateness of using the Merson maturity schedules rather than the size-at-maturity estimates provided by Sminkey and Musick (1995). Questions were also raised regarding the data included in Merson's analyses. As age-structured models require percent maturity by age as an input and the Working Group believed the Merson (1998; LCS05/06-DW-47) analysis complemented the Sminkey and Musick (1995) paper, the consensus was to use the maturity schedules produced by Merson (1998) as reported in LCS05/06-DW-47.

1.2.4 Mortality

After reviewing the estimates of mortality presented in LCS05/06-DW-15, the Working Group recommended the following:

- All point estimates based on VBGF parameters should be excluded, as constant mortality of all age classes was believed to be biologically unrealistic.
- Survivorship of age 1 to maximum age should be based on the average of Chen and Watanabe (1989) and Lorenzen (1996) weight-based methods. Criticism of Peterson and Wroblewski (1984) by others prevented inclusion of this data method because the original method was based on larval fish. However, it was noted that values were similar to other weight-based methods.
- Age 0s survivorship should be based on empirical data published by Heupel and Simpfendorfer (2002) and Manire and Gruber (1993), which were used in 2002 assessment. Gruber et al. (2001) determined a survival rate of juvenile lemon sharks by marking a cohort analysis on a marked population. Annual survival rate estimates varied between 38% and 65%.

1.2.5 Summary of Recommended Life History Parameters

Sandbar shark

Biology	Parameter or model	Reference
Pup Survivorship	S=0.6	See mortality section//SEW 2002 assessment
Adult Mortality	use Chen & Watanabe and Lorenzen weight; use average M at age of those methods	LCS05/06-DW15
S-R function	Beverton-Holt	SEW 2002 assessment
S-R parameters, priors		

steepness or alpha	0.2-0.4	Determined by group[1]
R^0	--	
Prior for r (SP model)	--	
Prior for K (SP model)	--	
Spawning Month	June	
Growth parameters		
Linf (cm PCL)	164 PCL	LCS05/06-DW39
K	0.089	LCS05/06-DW39
t_0	-3.8	LCS05/06-DW39
Length-Weight parameters (FL)	Weight (kg)=(1.09E-05)*Fork length (cm) ^ 3.012	Kohler et al. (1995)
a	FL=1.1*PCL +1	LCS05/06-DW39
b	TL=(FL/0.8175)-0.9933	Kohler et al. (1995)
Reproductive cycle	2 years	LCS05/06-DW39
Fecundity	mean litter size: 8.4 +/ 2.3 (SD)	LCS05/06-DW39
Sex-ratio	1:1	LCS05/06-DW39
stock structure	single stock	See stock section

[1]The value chosen as the steepness of the stock-recruitment curve was based on discussion of several studies that have used a stock-recruit function in stock assessment for sharks. Simpfendorfer et al. (2000) used a steepness of about 0.205 in an age-structured model for whiskery shark, *Furgaleus macki*, off southwestern Australia. Harley (2002) estimated steepness values ranging from 0.25 to 0.67 for porbeagle through a relationship between steepness and maximum reproductive rate proposed by Myers et al. (1999). In the previous stock assessment on small and large coastal sharks, Cortés (2002b) and Cortés et al. (2002) assigned uninformative, uniform prior distributions for steepness ranging from 0.2 to 0.9, in Bayesian surplus production and lagged recruitment, survival, and growth models, respectively.

Maturity Ogive (from LCS05/06-DW-47)

Age	Female Prop. Mature	Age	Male Prop. Mature
13.0	0.01	12.0	0.01
14.0	0.05	13.0	0.05
15.0	0.10	13.0	0.10
15.0	0.15	13.0	0.15
16.0	0.20	14.0	0.20
17.0	0.25	14.0	0.25
17.0	0.30	14.0	0.30
17.0	0.35	14.0	0.35
18.0	0.40	15.0	0.40
18.0	0.45	15.0	0.45
19.0	0.50	15.0	0.50
19.0	0.55	15.0	0.55
19.0	0.60	15.0	0.65
20.0	0.65	16.0	0.70
20.0	0.70	16.0	0.75
21.0	0.75	16.0	0.80
21.0	0.80	17.0	0.85
22.0	0.85	18.0	0.90
23.0	0.90	18.0	0.95
25.0	0.95	19.0	0.99
30.0	0.99		

1.3 Blacktip shark

1.3.1 Stock definition

Although LCS05/06-DW-10 could not definitely conclude that differences exist (from a life history perspective) between the Gulf of Mexico and the Atlantic Ocean, conventional tagging evidence suggests little exchange between the U.S. Atlantic Ocean and Gulf of Mexico (LCS05/06-DW-29; LCS05/06-DW-44). Genetic heterogeneity and female philopatry also demonstrates multiple genetic reproductive stocks among blacktip sharks in the Gulf of Mexico and South Atlantic Bight (LCS05/06-DW-28). Moreover, the group discussed that fishing mortalities are likely different between Gulf of Mexico and Atlantic Ocean, which would necessitate separate stock management. Therefore, blacktip sharks were divided into two stocks: an Atlantic stock defined as from Delaware to the Straits of Florida, and a Gulf of Mexico stock designated as from the Florida Keys throughout the Gulf of Mexico. The group also suggested that the Gulf of Mexico could be further divided into eastern and western stocks based on genetic studies which indicate significant differences in haplotype frequencies in neonates and young-of-the-year individuals between the west coast of Florida and Texas, and on tag/recapture data (LCS05/06-DW29; LCS05/06-DW28; Keeney et al. 2005). However, the limited data on catch rates and lack of life history information from the western Gulf of Mexico precludes separate assessments on these hypothetical two stocks.

1.3.2 Age and growth and maturity

Although there were some caveats associated with the life history study of blacktip sharks (LCS05/06-DW-10), the group chose to adopt the separate life history estimates provided in this document.

1.3.3 Mortality

After reviewing the estimates of mortality presented in LCS05/06-DW-15, the Working Group recommended the following:

- All point estimates based on VBGF should be excluded, as constant mortality of all age classes was believed to be biologically unrealistic.
- Survivorship of Age-1 to maximum age should be based on the average of Chen and Watanabe (1989) and Lorenzen (1996) weight based methods. Criticism of Peterson and Wroblewski (1984) by others prevented inclusion of this data method because the original method was based on larval fish. However, it was noted that values were similar to other weight-based methods.
- Age-0's survivorship should be based on empirical data published by Heupel and Simpfendorfer (2002) and Manire and Gruber (1993), which were used in 2002 assessment. Gruber et al. (2001) determined a survival rate of juvenile lemon sharks by marking a cohort analysis on a marked population. Annual survival rate estimates varied between 38% and 65%.

1.3.4 Summary of Recommended Life History Parameters

1.3.4.1 Atlantic Ocean blacktip shark

Biology	Parameter or model	Reference
Pup Survivorship	0.52	Heupel and Simpfendorfer (2002)
Adult Mortality	use Chen and Watanabe and Lorenzen weight; use average M at age of those methods	LCS05/06-DW15
S-R function	Beverton Holt	SEW 2002 assessment
S-R parameters, priors		
steepness or alpha	0.2 - 0.5	Determined by group[1]
R^0	--	
Prior for r (SP model)	--	
Prior for K (SP model)	--	

Spawning Month	June	
Growth parameters	Male | Female | Combined sexes	LCS05/06-DW10
Linf (cm FL)	147.4 | 158.5 | 150.9	
K	0.209 | 0.16 | 0.1896	
t_0	-2.586 | -3.432 | -2.8899	
Length-Weight parameters	Weight (kg)=(1.0 * 10-5) FL (cm) ^3.0549	Kohler et al. (1995)
a	FL (cm)=(1.1009)PC-0.53	LCS05/06-DW10
b	TL (cm)=(1.1955)FL+1.13	LCS05/06-DW10
	STL=1.0185 (TL)+1.3565	LCS05/06-DW10
Reproductive cycle	2 years	LCS05/06-DW10
Fecundity	Mean: 3.2 +/- 1.1 SD	Castro (1996)
Sex-ratio	1:1	LCS05/06-DW10
Stock structure	2 stocks	See Stock section

Atlantic Maturity Ogive (from LCS05/06-DW10)

Age	Male	Female
0.0	0.0	0.0
1.0	0.2	0.0
2.0	1.2	0.1
3.0	6.3	0.4
4.0	26.6	2.0
5.0	66.2	9.5
6.0	91.1	35.4
7.0	97.9	74.1
8.0	99.2	93.7
9.0	100.0	98.7
10.0	100.0	99.8
11.0	100.0	100.0
12.0	100.0	100.0
13.0	100.0	100.0
14.0	100.0	100.0
15.0	100.0	100.0

1.3.4.2 Gulf of Mexico blacktip shark

Biology	Parameter or model	Reference
Pup Survivorship	0.52	Heupel & Simpfendorfer (2002)
Adult Mortality	use Chen and Watanabe and Lorenzen weight; use average M at age of those methods	LCS05/06-DW15
S-R function	Beverton Holt	SEW 2002 assessment
S-R parameters, priors		
steepness or alpha	0.2 - 0.5	Determined by group[1]
R^0	--	
Prior for r (SP model)	--	
Prior for K (SP model)	--	
Spawning Month	June	
Growth parameters	Male | Female | Combined	LCS05/06-DW10
Linf (cm FL)	126.0 | 141.6 | 139.4	
K	0.277 | 0.241 | 0.2316	
t0	-2.21 | -2.182 | -2.3286	
Length-Weight parameters	Weight (kg)=(1.0 * 10-5) FL length (cm) ^3.0549	Kohler et al. (1995)
a	FL (cm)=(1.1009)PC-0.53	LCS05/06-DW10
b	TL (cm)=(1.1955)FL+1.13	LCS05/06-DW10
	STL=1.0185 (TL)+1.3565	LCS05/06-DW10
Reproductive cycle	2 years	
Fecundity	Mean: 4.4	Castro (1996), Castro (unpublished data)
Sex-ratio	1:1	LCS05/06-DW10
Stock structure	2 stocks	Determined by group

Gulf of Mexico Maturity Ogive (from LCS05/06-DW10)

Age	Male	Female
0	0.0	0.1
1	0.0	0.2
2	0.0	0.6
3	0.3	1.9
4	5.3	5.9
5	53.4	16.6
6	95.9	38.7
7	99.8	66.7
8	100.0	86.5
9	100.0	95.3
10	100.0	98.5
11	100.0	99.6
12	100.0	99.9
13	100.0	100.0
14	100.0	100.0
15	100.0	100.0

1.4 INTRINSIC RATES OF INCREASE FOR LARGE COASTAL SHARKS

The group was also tasked with developing intrinsic rates of increase for 3 scenarios: large coastal aggregate (all 22 species), the large coastal aggregate minus prohibited species (11 species), and the large coastal aggregate minus prohibited species, blacktip, and sandbar sharks (9 species). The group used published demographic analysis by Smith et al. (1998) and Cortés (2002a). The estimates for sand tiger shark were based on a new analysis by Goldman (2004). Details on the methods can be found within those papers. The average intrinsic rate for each grouping was calculated as the average of all species found within the complex for each particular scenario, weighed by the average percentage each species made up within the large coastal group. The average percentage was taken from observer data in the bottom longline fishery from the period 1994-2005.

Species	Percentage of large coastal group	Cortés (2002) (λ)	Smith et al. (1998) (r_{2M})
C. plumbeus	0.51	1.022	0.039
C. limbatus	0.14	0.974	0.078
G. cuvier	0.16	1.246	0.060
G. cirratum	0.04	-	-
S. lewini	0.02	1.086	0.039
C. leucas	0.02	0.998	0.039
C. brevipinna	0.02	1.037	
C. falciformis	0.01	1.108	0.061
S. mokarran	0.01	-	-
N. brevirostris	0.01	1.064	0.048

S. zygaena	0.00	-	-
C. obscurus *	0.04	1.030	0.029
*C. taurus**	0.01	0.989	0.009
C. signatus *	0.00	-	-
C. altimus *	0.00	-	-
C. perezi *	0.00	-	-
C. carcharias **	0.00	1.098	0.056
C. galapagensis	0.00	-	-
LCS (11 of 22 species)		1.001	0.045
LCS (minus prohibited)		1.004	0.046
LCS (minus prohibited - sandbar - blacktip)		0.986	0.043

*indicates prohibited species as of 1999 FMP, implemented commercially in 2000
** indicates prohibited species as of 1997 Final Rule

1.5 RESEARCH RECOMMENDATIONS

- Whereas previous assessments have defined maximum sustainable yield (MSY) as 0.5 of carrying capacity, recent life history analysis and peer-reviewed literature has suggested this level is risk-prone, particularly for K-selected species (Musick et al. 2000). The life history group recommends a more conservative definition of MSY be adopted (i.e. 60-70% MSY or 40% of spawning stock biomass) for this assessment.
- Develop more empirical estimates of natural mortality for large coastal species.
- Research into further refining the separation of Gulf of Mexico stock of blacktip sharks using a combination of genetics, demography/life history and conventional and advance tagging technology (i.e. satellite archival tags).
- Updates on demographics using revised life history information.
- Continue research on life history characteristics of prohibited species.
- Research on stock-recruitment function for sharks.
- Accrue data necessary for ecosystem-based management: trophic relationships, bioenergetics, and diet.

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2. Catch Statistics

Catch Statistics Working Group Summary Report

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2.1 SUMMARY OF CATCH DOCUMENTS

LCS05/06-DW-02
Description of estimates of unreported catches
Anonymous

These data are from a single source, which owned a fleet of vessels that fished in the Gulf of Mexico and off the coast of North Carolina. The estimate for 1988 was determined from company landing records. The estimates for other years were prorated based on the 1988 landings record and financial statements indexing income from shark fishing. The 1996 Working Group did not have any way of determining the amount, if any, of these catches that were included. Therefore, the current Working Group followed the logic of the 1996 Working Group and made the assumption that none of the catches were included and kept these data separate, listing them as unreported.

LCS05/06-DW-04
Description of the databases that contain landings of shark species from the Atlantic Ocean and Gulf of Mexico
Balchowsky, H.A., and Poffenberger, J.

The responsibility for collecting the quantities and value of marine resources (also referred to as 'landings statistics') landed at ports along the Atlantic Ocean and Gulf of Mexico is divided between the Southeast Fisheries Science Center (SEFSC) and the Northeast Regional Office (NERO). Consequently, the landings data for the various species of sharks that are unloaded at dealers located in the Gulf of Mexico or in states along the coast of the Southeastern Atlantic Ocean, or the Southeast Region (i.e., the Atlantic coast south of Virginia), are collected and managed by the SEFSC, Miami, Florida, while the landings of sharks at dealers located in the Northeast Region (north of North Carolina) are reported to and managed by the NERO in Gloucester, Massachusetts. The purpose of this report is to describe (1) the procedures that are used by both the SEFSC and the NERO to collect the data and (2) the databases that house the landings statistics for sharks. The report presents details of the two programs that have been implemented by the SEFSC. The first system is the Pelagic Dealer Compliance program (PDC) and is formerly known as the Quota Monitoring System (QMS; from 1997 to 2002) (please note that 'QMS' now refers to a separate system used by the SEFSC to monitor quotas of groupers and tilefish) and the Swordfish Dealer Compliance (SDC) program (from 1993 to 2000). The second system is the general canvass landings data that are housed in the Accumulated Landings System (ALS). The report also contains a description of the SAFIS (Standard Atlantic Fisheries Information System) that is used by dealers in the Northeast region to report landings data to the NERO.

It should be noted that the data from the PDC and SAFIS are summarized by the SEFSC into monthly reports and sent to the Highly Migratory Species Management Division, National Marine Fisheries Service. This summary is used to monitor the respective fishery quotas for sharks.

LCS05/06-DW-05
SEFSC Pelagic Observer Program data summary for 1992 -2000
Beerkirker et al

This document provides a summary of the Pelagic Observer Program operated by the SEFSC. It was provided as reference material should questions arise as to how the data are collected.

LCS05/06-DW-06
Estimation of catches of sandbar (*Carcharhinus plumbeus*) and blacktip (*C. limbatus*) sharks in the Mexican fisheries of the Gulf of Mexico
Bonfil, R. and Babcock, E.

This document presented detailed estimates of Mexican catches of blacktip and sandbar sharks for the period 1962-2000. Species composition in weight for the different shark fisheries taking place along Mexican waters was estimated from the data given in several Mexican studies. These were then used to estimate the total weight and numbers caught of each species in each state. The estimated total level of blacktip catches ranged from 118,000 to 280,000 sharks per year from 1990-2000. In comparison, the corresponding catch of sandbar sharks was estimated at around 7,000-11,000 sharks per year. Because of constraints in the degree of detail contained in the information used to estimate the species composition in weight, these estimates should be taken as a first approximation, especially for blacktip sharks. It is likely that the numbers of small blacktip sharks taken in Mexican fisheries were overestimated.

It was further explained that catches had to be split between small ("cazon") and large ("tiburon") sharks according to the classification used in the official Mexican fishery statistics and several other studies that were reviewed to prepare the document. The studies used typically included the total number of individuals by species, but no weight was included. When available, length-frequency information was transformed into weight-frequency by using length-weight relationships to calculate the total contribution of each species to the catches by weight. It was noted that blacktip sharks were estimated to make up a larger portion by weight of the total small shark component (60%) than they likely contribute in reality. It was noted that this occurs because length-frequency distributions were not available, only an average size of 110 cm, which was transformed into weight. This average size is based not only on small blacktip sharks, but also on larger individuals, and it is thus likely to be overestimated. Tables 9-14 summarize the estimated catches of sandbar and blacktip shark by state in weight and numbers.

LCS05/06-DW-07
Illegal shark fishing off the coast of Texas by Mexican lanchas
Brewster-Geisz, K. and Eytcheson, M.

Since the mid-1990s, the United States Coast Guard (USCG) has been aware of Mexican fishing vessels fishing for sharks and other species in the U.S. Exclusive Economic Zone (EEZ) off the coast of Texas. The vessels originate from Matamoros, Mexico, and fish in the area surrounding South Padre Island, Texas, anywhere from zero to twenty miles offshore. The USCG has observed an increased amount of activity by these vessels, and numbers of observed incursions into U.S. waters has been documented since 2000. It is believed that these vessels, or lanchas, participate in illegal fishing of shark and red snapper with gillnet and longline gear during the day, and drug and migrant smuggling during the night. The previous large coastal shark (LCS) stock assessments have included Mexican catches and have considered open population models. However, the Mexican catches included in the stock assessment have not included this illegal catch and do not represent the full number of sharks that are taken by Mexican fishermen. The potential harvest of these illegal Mexican lanchas could have an impact on the amount of commercial quota allocated the U.S. fishermen and may have an impact on the shark rebuilding plan. The Highly Migratory Species Management Division is providing this catch information for possible inclusion in the stock assessment and/or the sensitivity analyses of the models to changes in this catch.

LCS05/06-DW-16
Updated catches of Atlantic sharks
Cortés, E. and Neer, J.

This document presents updated commercial and recreational landings and discard estimates of Atlantic sharks up to 2004, with special emphasis on sharks of the Large Coastal Shark complex. Species-specific information on the geographical distribution of both commercial and recreational catches is presented along with the different gear types used in the commercial fisheries. Length-frequency information and average weights of the catches in three separate recreational surveys and in the directed shark bottom-longline observer program are also included.

LCS05/06-DW-18
Estimation of large coastal sharks dead discards for the US pelagic longline fishing fleet
Diaz, G. A.

This document describes the methodology used to calculate shark discards for the commercial pelagic longline fishery. This methodology was not developed for use with sharks but for use at ICCAT meetings and for calculating discards for swordfish and tuna. In order to maintain consistency, these methods are also used for shark discards. The data comes from both the Pelagic Longline Logbook and Pelagic Observer Programs. Three approaches were used to calculate shark discards: 1) using actual discard rates from the Pelagic Observer Program for areas and quarter with more than 10 sets observed 2) using discard rates estimated directly from the pelagic logbook program for areas and quarters where not sets were observed and 3) using GLM methods to estimate discard rates for areas and quarters with only 1-9 fishing sets observed. For data sets where the proportion of sets with positive catches is low, better estimates can be obtained using a delta log-normal approach. The use of this technique to estimate LCS discards for the pelagic longline fleet will be explored in the near future.

LCS05/06-DW-32
The Commercial Shark Fishery Observer Program: History, collection methodology and summary statistics 1994-2005(I)
Morgan, A. and Burgess, G.H.

The Commercial Shark Fishery Observer Program (CSFOP) was housed at the Florida Museum of Natural History from 1994-2005 and was responsible for hiring, training, and deploying fisheries observers aboard commercial bottom longline vessels targeting large coastal sharks. A total of 34 individual observers observed the capture of 57,265 sharks, representing 34 species during this time period. The history, methods used for training and data collection, and summary statistics are included in the document.

LCS05/06-DW-34
Estimation of large coastal shark complex, blacktip, and sandbar shark bycatch in the Gulf of Mexico menhaden fishery
Neer, J. and Cortés, E.

Bycatch numbers from the Gulf of Mexico menhaden fishery were estimated for the large coastal shark complex (LCS) as well as for blacktip and sandbar shark individually. Estimates were based on observer data collected in 1994-1995 by de Silva et al. (2001). Two discard rate series are provided for each complex/species, one based on average of observed bycatch (used in the 2002 LCS assessment) and one adjusted for the number of boats in the fishery each year. This document describes how those estimates were obtained, and extends the series through 2004.

LCS05/06-DW-37
Recreational Marine Fishing Surveys in the Gulf of Mexico and Atlantic States, 1981-2004
Phares, P.

Estimates of recreational catch for marine fish species in the Gulf of Mexico and South Atlantic States beginning in 1981 are obtained by a combination of results from three surveys:
• the Marine Recreational Fishery Statistics Survey (MRFSS) conducted by the NOAA Fisheries (also called the National Marine Fisheries Service or NMFS).
• the Texas Marine Sport-Harvest Monitoring Program by the Texas Parks and Wildlife Department (TPWD).
• the Headboat Survey (HBS) conducted by NMFS, Southeast Fisheries Science Center, Beaufort, NC.

These three surveys together provide estimates of catch in numbers (and sometimes weight), estimates of effort, length and weight samples, and catch-effort observations for shore-based and boat fishing. The combined coverage is continuous beginning in 1981 with only minor gaps. In addition, Puerto Rico has been covered since 2000.

The MRFSS and the TPWD survey are both sampling-based, while the Headboat Survey strives to be a census of headboats using logbooks. Differences in survey methodology, strata, data gathered and other quantities estimated must be understood when using the data from the three surveys together. For instance, effort estimates from the three surveys use different measures (angler-trips, man-hours or angler-days) which are not easily standardized. Strata for estimates of catch from the three surveys can be made comparable by summing (e.g., summing Headboat Survey estimates into bi-monthly "waves" to match MRFSS and TPWD), but the lack of estimates for released fish in the TPWD and Headboat Surveys limit some analyses.

LCS05/06-DW-38

Description of the Southeast Fisheries Science Center's logbook program for coastal fisheries
Poffenberger, J.

The Southeast Fisheries Science Center (SEFSC) currently manages two vessel logbook programs. One program principally covers vessels that use pelagic longline gear, and also includes vessels that use other types of gear (harpoon and handline) that target pelagic highly migratory species. This logbook program was initiated in 1986 and has continued uninterrupted since then. The second logbook program was initiated in 1990 by the SEFSC for vessels that held a federal vessel permit to fish in the Gulf reef fish fishery. A similar program was initiated for vessels with federal permits in the snapper-grouper fishery in the South Atlantic region. These two programs (the Gulf reef fishery vessel logbook program and the South Atlantic snapper-grouper vessel logbook program) were combined to form the basis of the coastal fisheries logbook program. In 1993, this program was expanded to include vessels with federal permits in the shark fishery, and in 1999, it was expanded to include vessels with commercial vessel permits in the king and Spanish mackerel fisheries. This coastal fisheries logbook program requires reporting catch and effort data for the entire trip and does not require reporting for individual gear deployments. This report contains a chronology of the coastal fisheries logbook program, how the logbook forms were modified over time, and a description of the record layout and data elements for the coastal fisheries logbook data, as well as a brief explanation of the differences compared to the pelagic longline logbook program.

LCS05/06-DW-42
Review of the Headboat Survey – Questions and Answers
SEFSC

The headboat fishery appears to be a readily identifiable segment of the recreational fishery, and is responsible for high percentages of the recreational catch for some species. Membership in the headboat fleet seems to be known quite accurately, and the boats have been largely accessible to the Headboat Program. The Headboat Program has been used to produce landings, landings per unit effort, and effort estimates for the headboat fishery, and has also been a vehicle for collecting biological samples from the landed catch. These data items are clearly at the core of those needed for stock assessment. This paper constitutes a review of this Headboat Program and its data by the SEFSC. This review is conducted in a question and answer format, evaluates both the scientific and "business" aspects of the Program, and makes recommendations.

2.2. Large Coastal Shark Complex landings and discard estimates

The Catch Statistics working group pointed out that the Large Coastal Shark (LCS) complex landing estimates presented in Table 1 of document LCS-DW-16 included all the 22 species originally part of the complex. A list of species included in the LCS complex, including those that are prohibited, is given in Table 2.1. Given that the 2002 assessment was performed on the LCS complex that included all 22 species, it was decided to use this scenario as a baseline case (BASE scenario). The group discussed other scenarios for which full analyses will be conducted: (1) a catch series that excluded all prohibited species from the entire series (BASE-PROH scenario), and (2) a catch series that excluded all prohibited species as well as sandbar and blacktip sharks from the entire series (BASE-PROH-SB-BT scenario). The BASE scenario catch estimates are provided in Table 2.2

The working group discussed the BASE-PROH scenario (LCS without prohibited species; Table 2.3) because the catch rate working group had already created the catch rate indices without the prohibited species. To the extent that this series removes the species that cannot be landed, this scenario could give an indication of the status of the LCS complex as it is currently defined by management. The working group also noted that while these species are not landed, they are caught, and that because the fishery has not targeted the prohibited species (with the possible exception of dusky sharks), the catches themselves would not change substantially by removing these species. The working group agreed to recommend this scenario and to provide the catch series needed.

The working group discussed the BASE-PROH-SB-BT scenario (LCS without prohibited species, sandbar sharks, or blacktip sharks; Table 2.4) as a result of a request of NMFS' Highly Migratory Species Management Division. By removing the species that are prohibited or that have species-specific assessments, this scenario could indicate the status of the LCS complex without the confounding effects of the main targeted species and help NMFS determine, or at least narrow down, the species that are driving the status of the complex. The working group agreed to recommend this as a scenario and to provide the catch series needed.

2.2.1. Commercial landings

BASE scenario:
U.S. commercial landings of Atlantic sharks for 1995-2004 were compiled based on Northeast Regional and Southeast Regional general canvass landings data, and the SEFSC quota monitoring data based on southeastern region permitted shark dealer reports. Landings reported in the general canvass and quota monitoring data files from southeastern states were combined to define the species composition and volume of landings. The quota monitoring data generally provide a more diverse species listing than the general canvass data SE, whereas the general canvass data SE apportion a higher volume of shark landings as unclassified. The larger reported landing of a given species in the two data sets was taken as the actual landed volume for that species. The positive difference between the quota monitoring data and the general canvass data was then subtracted from the unclassified shark category of the general canvass data to maintain the total landings volume equal to that reported in the general canvass data files. For the state of North Carolina (NC), it was assumed that some "dogfish" might also have been assigned to the unclassified shark category. To adjust for this possibility, the NC unclassified sharks were apportioned between the large coastal, small coastal, pelagic, prohibited, and dogfish categories based on the reported distribution of landings by species and gear for that state. For states other than NC, the remainder of unclassified shark landings was assigned to the large coastal group unless the harvesting gear was pelagic longline, in which case the landings were assigned to the pelagic group. Finally, the values reported from the NE general canvass landings data were added to produce the final values. Landings prior to 1995 only included data from the general canvass data for both regions as the quota monitoring system was not yet established. Landings estimates for 1981-1985 were determined during the 1996 Shark Evaluation Workshop. Because the present Working Group did not have all the details regarding to how the participants of the 1996 Shark Evaluation Workshop estimated those landings, and therefore could not suggest modifications, the continued the

use of those values was recommended. Continued use of those landings was deemed important for the stock assessment as they represent the early years of the fishery.

The data are collected in landed or dressed weight. Various weight-per-fish estimates were used to convert pounds to numbers of fish. For the period 1981 through 1985, a generic factor of 45 pounds dressed weight per fish was used. For 1986 through 1991, an average weight for all species was used. These averages are those used in the 1992 assessment. For 1992 and 1993, a weight of 40 pounds per fish was used. For 1994 and 1995, predicted weights from lengths based on the shark bottom longline fishery observer program (Branstetter and Burgess 1997) and data from the pelagic longline database were used. Average weights used for 1996-2004 came from shark bottom longline fishery observer program data.

BASE-PROH scenario:
For the period 1995-2004, for which species-specific landings are available, prohibited species were removed from the total LCS landings in the BASE scenario. For the period 1981-1994, during which species-specific landings were not always available, the average contribution of prohibited species to the landings was estimated from the bottom longline shark fishery observer program data for the period 1994-1995 data. The Working Group believed that the bottom longline observer program provided accurate species identification and that the earliest years of program would best represent the species composition during the earliest years of the fishery. This consensus was reached after discussion regarding using the observer-obtained species compositions rather than those from the landings data, due to the limited coverage of the observer program and concerns about how representative it is of the fishery at large.

BASE-PROH-SB-BT scenario:
For the period 1995-2004, for which species-specific landings are available, prohibited species and blacktip and sandbar sharks were removed from the total LCS landings in the BASE scenario. For the period 1981-1994, during which species-specific landings were not always available, the average contribution of prohibited species, blacktip, and sandbar sharks to the landings was estimated from the bottom longline shark fishery observer program data for the period 1994-1995. The Working Group believed that the bottom longline observer program provided accurate species identification and that the earliest years of program would best represent the species composition during the earliest years of the fishery. This consensus was reached after discussion regarding using the observer-obtained species compositions rather than those from the landings data, due to the limited coverage of the observer program and concerns about how representative it is of the fishery at large.

2.2.2 Pelagic longline discard estimates

BASE scenario:
Pelagic longline dead discard estimates for the baseline case are presented in Table 2.2 and were estimated following the methods described in LCS05/06-DW-18.

BASE-PROH scenario:
Estimation of discards for the LCS complex excluding the prohibited species requires estimating the species composition of the discards. For the period 1992-2004, the species composition was extracted

from pelagic longline observer program (PLLOP) data. Initially, for the period 1986 to 1991, the Working Group discussed estimating species composition using the reported discards in the pelagic logbook program to maintain consistency with the method used to estimate total discards for that period (LCS05/06-DW-16), which used logbook-reported data. However, examination of pelagic logbook program data for 1986-1991 revealed that only hammerhead and tiger sharks were recorded. For this reason, it was decided that the species composition from the PLLOP would be used rather than the logbook data to estimate the species composition for the period 1981-1991.

BASE-PROH-SB-BT scenario:
The same logic and procedure as described in the BASE-PROH scenario was applied to exclude blacktip and sandbar sharks, in addition to prohibited species, from the BASE scenario.

2.2.3 Recreational landings

BASE scenario:
Recreational landings presented in Table 2.2 correspond to landings estimated from the Marine Recreational Fishery Statistics Survey (MRFSS), the NMFS Headboat Survey, and the Texas Parks and Wildlife (TXPW) data sets. During 1998-1999, the MRFSS tested a new methodology for the estimation of charterboat effort. This new methodology, called the For Hire Survey (FHS), was deemed to provide better estimates of charterboat fishing effort and was officially adopted in 2000. Thus, landing estimates by the charterboat fleet between the 1981-1997 and 1998-2004 periods cannot be directly compared. The Working Group agreed to use conversion factors that the NMFS Southeast Fisheries Science Center personnel estimated, to adjust charterboat landings for 1981-1997 (Diaz and Phares, document SEDAR7-AW-03). These conversion factors were already used in the last stock assessments of red snapper, greater amberjack, vermillion snapper and gray triggerfish in the Gulf of Mexico. MRFSS landings for the period 1981-1997 were thus re-estimated using these conversion factors and the MRFSS landings used for the period 1998-2004 were also those incorporating this new methodology. Total annual recreational landing estimates are the sum of the MRFSS, Headboat, and TXPW survey estimates.

BASE – PROH scenario:
Catch estimates by species are already provided by the three recreational surveys. Prohibited species were thus excluded from the total LCS catches in the BASE scenario.

BASE-PROH-SB-BT scenario:
Catch estimates by species are already provided by the three recreational surveys. Sandbar, blacktip, and prohibited species were thus excluded from the total LCS catches from the BASE scenario.

2.2.4 Unreported catches

BASE scenario
Unreported large coastal shark (LCS) landings were provided by Mr. Chris Brannon to the National Marine Fisheries Service (NMFS) during the 1996 Shark Evaluation Workshop (SEW). These landings have been part of the LCS database since then.

The entirety of these landings correspond to the Gulf of Mexico during 1986, 1987, 1990 and 1991, while half of the landings correspond to the Gulf of Mexico and the other half to the mid Atlantic during 1988 and 1989. Brannon reported that the Gulf of Mexico landings were approximately 2/3 blacktip sharks, with the remaining third being a combination of sandbar sharks and other LCS species. The Working Group did not have any way of determining the amount, if any, of these catches that was included in landing reports presented in commercial catches. Given the general belief that landings before the current reporting systems were underreported, the Working Group made the assumption that none of the catches were included in commercial catches. As such, the Working Group agreed to keep these data as a separate source of landings in the catch series, listing them as unreported.

BASE – PROH scenario
Average species composition analysis for this data set was performed using species composition from 1994 and 1995 from the bottom longline observer program data was used to apportion the unreported catch to individual species. This decision was based on the understanding that the earliest years of the observer program would best represent the species composition during the earliest years of the fishery. Prohibited species were then removed from the BASE scenario.

BASE – PROH-SB-BT scenario:
The same logic and procedures as described in the BASE-PROH scenario were used to exclude blacktip sharks, sandbar sharks, and prohibited species from the BASE scenario using the information from Brannon where the total annual proportion of blacktip and sandbar sharks is approximately 77%.

2.2.5 Bottom longline discards

*BASE scenario:*Discard estimates for the years 1994-2004 are taken from the bottom longline observer program data. The catch statistics Working Group discussed the best way to estimate catches for the period 1981-1993, when no commercial data regarding coastal discards are available. In the previous stock assessment (2002), the average discard ratio for the period 1994-2001 was used to estimate discards for 1993 and no attempt was made to complete the series for the period 1981-1992.

The Working Group determined that leaving the discard series incomplete was not the optimal choice, since there are data available to back-calculate coastal discards for the earlier years (1981-1992). The Working Group decided against using the average for 1994-2001 because the discard rate was believed to be much higher in 1991 and 1992 than during the period before 1991 and because discard rates may have changed once a number of species, particularly dusky sharks, were prohibited in 2000. The variability in discard rates in the early 1990s was related to shifts within the fin market (shark meat could not be sold in the early 1990s due to mercury issues but shark fins could be sold). To compensate for these variable discard rates, the Working Group decided to use the average discard ratio of the first four years of the bottom longline shark fishery observer program data (1994-1998) as an estimate for the years 1981-1993.

BASE – PROH scenario: Discards were estimated using the species composition obtained from the bottom longline shark fishery observer program data. For the period 1981-1993 (prior to the implementation of the observer program), species composition was estimated using the average proportions in the bottom longline observer program data for the period 1994-1998. This decision was based on the understanding that the earlier years of the observer program would best represent the species composition during the earliest years of the fishery and will remain consistent with the methods used to estimate coastal discard rates for the same time period. Annual discards were thus calculated as the product of the corresponding commercial landings and the discard rate for that year (accounting for the exclusion of prohibited species in the discard rate).

BASE – PROH-SB-BT scenario:
The same logic and procedures as described in the BASE-PROH scenario were used to exclude sandbar, blacktip, and prohibited species from the BASE scenario.

2.2.6 Mexican catches

BASE scenario:
The working group recommended retention of this series for use in the current assessment. The estimates were derived as follows: Mexican catches of blacktip shark corresponded to 50% of the sum of small fish caught in the states of Tamaulipas and Veracruz as presented in document LCS05/06-DW-06. This percentage was used to take account of the potential mixing of U.S. and Mexican stocks in the Mexican fishing grounds. These two states were selected, as in previous assessments, because they are thought to include catches of blacktip sharks that cross into U.S. waters. For sandbar sharks, the total sum of catches was used because there is no scientific evidence of nursery areas in Mexican waters. The group decided to use the sum of the Mexican catches corresponding to sandbar and blacktip sharks to represent the catch of the LCS complex.

BASE – PROH scenario:
The working group did not recommend any changes to the estimates proposed in the BASE scenario as there is no information to determine what percentage of the landings, if any, belong to prohibited species.

BASE – PROH-SB-BT scenario:
Since the estimated catches for the LCS complex are derived from the sum of the estimates of sandbar and blacktip sharks, estimates will equal zero for this scenario.

2.2.7 Gulf menhaden fishery discards

BASE scenario:
De Silva et al. (2001) reported on bycatch of sharks in the Gulf of Mexico menhaden fishery for the years 1994 and 1995. Based on observer data, the authors indicated that 75% of the sharks encountered in the fishery died: 97% were large coastal and 3% were small coastal sharks. The total number of sharks caught by this fishery was estimated to be about 36,000 in 1994 and 33,000 in 1995, or about 26,200 (36,000*0.75*0.97) and 24,000 large coastal sharks discarded dead in 1994 and 1995, respectively. Rather than using the same bycatch numbers for the entire timeframe, the Working Group recommended adjusting the bycatch estimates based on effort (i.e., number of vessels) in an attempt to reflect changes in fishing effort of the fleet over time, and the associated changes in bycatch numbers. Estimates were obtained as follows: for each year of the series, the number of vessels

operating in the fishery was divided by the average number of vessels operating for the years in which bycatch estimates were available (55 boats in 1994 and 52 boats in 1995; average = 53.5 vessels). This year-specific multiplier was then multiplied by 25,000, the average number of large coastal sharks discarded dead in 1994 and 1995, as reported above. This provides for year-specific bycatch estimates adjusted for the annual number of vessels in the fleet. The number of vessels operating in the Gulf of Mexico menhaden fleet from 1964 – 1997 was obtained from Vaughan et al. (2000; 1964-1997) and Joseph W. Smith, NMFS (personal communication; 1998 – 2004).

BASE – PROH scenario:
No changes to these estimates were recommended for this scenario as there is no evidence that prohibited species are encountered in this fishery.

BASE – PROH-SB-BT scenario:
Bycatch estimates derived in the BASE scenario were adjusted to reflect the proportion of total LCS that the blacktip and sandbar sharks amounted to in the de Silva et al. (2001) study (45.3% and 1.8%, respectively).

2.2.8 Confiscated Mexican catches in US

BASE scenario:
These data represent a new source that was unknown to previous assessment workshops and therefore has not previously been included in total catch estimates. The Working Group agreed to include these data in the catch series and noted that a number of assumptions would need to be agreed upon. To determine the species being caught, the Working Group discussed where the "lanchas" (boats) are fishing, the depth at which they are fishing, how close they are to the Mexican border, and the gear used. The U.S. Coast Guard provided information indicating that the majority of the fish are caught on gillnet gear close to shore (approximately 80 percent) and the rest are caught on longline gear. The U.S. Coast Guard also provided pictures of the type of fish caught in all the incursions. These pictures included sharks, snappers, eels, and dogfish. Upon examination of these photos, the Working Group determined that the coastal sharks photographed were all caught on gillnet gear (as indicated by the marks left on the sharks). The other species caught (i.e., snappers, eels, dogfish) were all deepwater fish that were likely caught using longline gear in deep water. As such, the Working Group decided to assume that 80 percent of the fishing incursions used gillnet gear and would catch coastal sharks.

The Working Group felt that some of the coastal sharks could be small coastal sharks and should not be included in this assessment. The Working Group agreed to use the proportions of species compositions provided in Castillo et al. (1998), which stated that blacktip sharks made up 33% of the catch in Gulf of Mexico Mexican waters. The Working Group further assumed that 50 percent of the total catch represented large coastal sharks.

Regarding the timeframe, the Working Group discussed whether or not to expand the incursion data back into the 1990s. The U.S. Coast Guard did not begin noticing the fishing incursions until 2000. Anecdotal information indicated that the fishing incursions did not occur until after the early 1990s. The Working Group considered starting the time series in 1995 but did not feel there was enough information on which to base assumptions about effort and catches in those years. As such, the

Working Group decided to begin the time series in 2000, which is the year the U.S. Coast Guard started collecting information on fishing incursions.

Most of the discussions focused on how to include these data given the other Mexican catches that have been included in the past. Everyone in the Working Group agreed that any fish confiscated by the U.S. Coast Guard would not be included in the legal Mexican catches and thus, should be included in the assessment. However, the U.S. Coast Guard estimates that 1900 incursions occur in U.S. waters annually. In any given year, only 100 to 212 of those are successfully intercepted, fishery-related incursions. If the numbers are expanded, based on the percentages listed above, approximately 9,500 large coastal sharks may not be included in the legal Mexican catches. However, the Working Group believed, based on the knowledge of the Mexican markets (i.e., everything is sold, there is no quota, etc.), that there would be no reason why the sharks caught on the "lanchas" that return to Mexico would not be included in the legal Mexican landings. As such, the Working Group decided to include only those sharks that could positively be expanded out from the successful incursions (1,000 to 2,120 large coastal sharks).

Final recommendations for the determination of estimates included:
- Use an average of 25 sharks per "lancha" (10 lb dressed weight average)
- To assume that 50 percent of the estimated 1900 incursions are fishery-related incursions
- To assume that 80 percent of the fishery-related incursions use gillnets and would catch coastal sharks
- To include only those sharks confiscated by U.S. Coast Guard, but not expand the series to earlier years since these sharks may have been already reported in the Mexican landings.

Annual estimates from 2000 to 2004 were thus obtained by multiplying 25 sharks per boat by the number of interdicted boats in each year by 50% of LCS by 80% of sharks being caught on gillnets.

BASE – PROH scenario:
The Working Group did not recommend any changes to the estimates proposed in the BASE scenario as there is no information to determine what percentage of the landings, if any, belong to prohibited species.

BASE – PROH–SB-BT scenario:
The proportion of blacktip sharks in the total shark catches in the state of Tamaulipas (33%) as found by Castillo et al. (1998) was used to reduce the estimates from the BASE scenario.

2.3 SUGGESTED SENSITIVITY ANALYSES

The Working Group recommended three modifications to the BASE scenario for use as sensitivity analyses during the Assessment Workshop.

1) Adjust the recreational catch estimate for 1983. This value was deemed to be unrealistically high. Following the logic used in the 1998 and 2002 assessments, the geometric mean value of the 1982 and

1984 estimates (380.8 thousand fish) should replace the 791.1 thousand fish estimate of the BASE scenario for 1983.

2) Remove the unreported catches. This sensitivity analysis was suggested to examine how those values affect the analysis.

3) An 'alternative' catch series (Table 2.5): This sensitivity analysis was suggested to compensate for under-reporting of landings during the earliest years of the time series (1981-1994). The modifications were as follows (following the logic of the 1998 and 2002 assessments):

Commercial landings: For 1981-1985, commercial catches were assumed underreported by 50% and thus the values in the BASE scenario catch table were multiplied by 1.5. For the period 1986-1992, underreporting was assumed by 100% and thus the values in the BASE scenario catch table were multiplied by 2. For 1993, the catches made prior to the mid-year implementation of the FMP were assumed underreported by 100% and thus the values in the BASE scenario catch table were multiplied by 1.5.

Pelagic longline discards: For the period 1981-1986, longline discards were assumed to be equal to 10,000 fish per year. This value is based on anecdotal information regarding the magnitude of the catch of large coastal sharks during that timeframe.

Recreational catch estimates: the geometric mean value of the 1982 and 1984 estimates (380.8 thousand fish) should replace the 791.1 thousand fish estimate of the BASE scenario for 1983.

2.4. SPECIES-SPECIFIC CATCH HISTORIES

The Working Group also prepared species-species catch histories for blacktip (Tables 2.6 and 2.7) and sandbar (Table 2.8) sharks. Based on the recommendation of the life history group that blacktip sharks should be assessed as two separate stocks, Gulf of Mexico and Atlantic Ocean, two catch histories were developed for that species.

2.4.1 Blacktip Gulf of Mexico:

2.4.1.1 Commercial landings:

U.S. total commercial landings of blacktip sharks in 1996-2004 were compiled based on the Southeast and Northeast Regional general canvass landings data, and the SEFSC quota monitoring data. The larger of the two values reported for blacktip sharks in the southeast general canvass and the SEFSC quota monitoring is taken as the value of blacktip landings for the southeast. The landings from the Northeast Regional general canvass data are then added to the southeast landings to produce total U.S. estimates. Commercial landings of blacktip sharks in the Gulf of Mexico for 1996-2004 were obtained by multiplying the total U.S. landings by the proportion of blacktip landings corresponding to the Gulf of Mexico region as obtained from general canvass data. Total U.S. landings from 1987 to 1995 are from the general canvass data only, as the quota monitoring system did not exist and were obtained based on the proportional allocation of commercial landings of unclassified sharks by gear type and region defined in the 1996 assessment. Landings for the Gulf of Mexico for 1987-1995 were also obtained by multiplying the total US landings by the proportion of blacktip landings corresponding to the Gulf of Mexico region as obtained from general canvass data. For 1981-1986, annual landings were estimated by multiplying the total landings (GOM+SA) by the average proportion corresponding to the GOM in 1987 and 1988 reported in the general canvass program.

Unclassified sharks in 1996-2004 attributed to the LCS grouping were proportionally allocated to blacktip sharks by using the proportion of blacktip sharks observed in the LCS and multiplying the unclassified sharks by that value to estimate the weight of blacktip sharks likely listed as unclassified. The value was then added to the value reported from canvass/quota monitoring to determine the total landings for blacktip sharks.

The data are collected in landed or dressed weight. Various conversions are used to convert dressed weight to number of sharks. The Working Group indicated that the average weight used for the period 1986-1993 in the 2002 assessment was unrealistically low. This value (20.5 lb) was the average of the period 1994-1996. It was decided to use an average weight of 24.0 lb to estimate number of sharks caught for the period 1981-1993. This average weight was a compromise based on discussions among the Working Group participants and information provided by Mr. Chris Brannon regarding the average weight of the blacktip sharks he encountered in his fishing operations during that time period. From 1994 onward, the average weight was determined from bottom longline shark fishery observer program data corresponding to the Gulf of Mexico.

2.4.1.2 Recreational landings

Recreational landings for blacktip sharks in the Gulf of Mexico correspond to landings estimated from the MRFSS, the NMFS Headboat Survey and the TXPW data sets. As explained for the LCS scenarios detailed above, during 1998-1999, the MRFSS tested a new methodology for the estimation of charterboat effort, the For Hire Survey (FHS), which was deemed to provide better estimates of charterboat fishing effort and was officially adopted in 2000. Thus, landing estimates by the charterboat fleet between the 1981-1997 and 1998-2004 periods could not be directly compared. The Working Group agreed to use conversion factors that the NOAA Fisheries Southeast Fisheries Science Center personnel estimated, to adjust charterboat landings for 1981-1997 (Diaz and Phares, document SEDAR7-AW-03). MRFSS landings for the period 1981-1997 were thus re-estimated using these conversion factors and the MRFSS landings used for the period 1998-2004 were also those incorporating this new methodology. Total, annual recreational landing estimates of blacktip sharks in the GOM are the sum of the MRFSS, Headboat, and TXPW survey estimates.

2.4.1.3 Unreported Catches

Unreported large coastal shark (LCS) landings were provided by Mr. Chris Brannon to the National Marine Fisheries Service (NMFS) during the 1996 Shark Evaluation Workshop (SEW). These landings have been part of the LCS database since then.

These landings correspond to the Gulf of Mexico during 1986, 1987, 1990 and 1991, while half of the landings correspond to the Gulf of Mexico and the other half to the mid Atlantic during 1988 and 1989. Brannon reported that the Gulf of Mexico landings were approximately 2/3 blacktip sharks, with the remaining third being a combination of sandbar sharks and other LCS species. The Working Group did not have any way of determining what amount, if any, of these catches were included in landing reports. Therefore, the Working Group made the assumption that none of the catches were included and kept these data separate, listing them as unreported.

Following the information provided by Mr. Brannon, for the years 1986, 1987, 1990, and 1991, the estimate of unreported blacktip sharks in the Gulf of Mexico was calculated by multiplying the total unreported catch estimate by 66%. For the years 1988 and 1989, the estimate was determined by dividing the total annual unreported catch by 50%, to account for the fact that only half the fleet was in the Gulf of Mexico, then that value was multiplied by 66%.

2.4.1.4 Mexican catches

Mexican catches for blacktip shark corresponded to 50% of the sum of small fish caught in the states of Tamaulipas and Veracruz from document LCS05/06-DW-06. This percentage was used to take account of the potential mixing of U.S. and Mexican stocks in the Mexican fishing grounds.

2.4.1.5 Gulf menhaden fishery discards

Effort-adjusted estimates of dead discards for blacktip shark were determined. De Silva et al. (2001) reported that blacktip sharks represented 45.3% of the total observed bycatch in 1994-1995. Considering the reported 75% mortality rate among all sharks, this results in an estimated bycatch of 12,200 (36,000*0.453*0.75) and 11,200 dead blacktip sharks for the two years. The number of vessels operating in the fishery each year was divided by 53.5 vessels, the average number of vessels operating for the years in which bycatch estimates were available (1994 and 1995). The year-specific multipliers were then multiplied by the average number of blacktip (11,700) sharks discarded dead, as determined previously. This provides for year-specific bycatch estimates adjusted for the annual number of vessels in the fleet.

2.4.1.6 Confiscated Mexican catches in the US

The Group recommended inclusion of the confiscated illegal Mexican catches. The estimates of illegal blacktip shark catch were determined using the following guidelines/assumptions:
- Use of an average of 25 sharks per "lancha" (10 lb dressed weight average)
- Fifty percent of the estimated 1900 incursions are fishery-related incursions
- Eighty percent of the fishery-related incursions used gillnets and would catch coastal sharks
- Data series begins in 2000
- Assume 33% of sharks are blacktip sharks following findings in Castillo et al. (1998)
- Include only those sharks confiscated by U.S. Coast Guard, but not expand the series to earlier years since these sharks may have been already reported in the Mexican landings.

2.4.2 Blacktip Atlantic Ocean:

2.4.2.1 Commercial landings:

The same logic and procedures as described above for blacktip shark in the Gulf of Mexico were used to produce commercial landings estimates for blacktip shark in the Atlantic Ocean.

2.4.2.2 Recreational landings

The same logic and procedures as described above for blacktip shark in the Gulf of Mexico were used to produce recreational catch estimates for blacktip shark in the Atlantic Ocean, however the TXPW survey data are not included.

2.4.2.3 Unreported Catches

Half of the unreported large coastal shark landings provided by Mr. Brannon and already described above correspond to the Atlantic during 1988 and 1989. Brannon reported that approximately 7-10% of the Atlantic landings were blacktip sharks, with the remaining mostly sandbar sharks. The Working Group did not have any way of determining what amount, if any, of these catches were included in landing reports. Therefore, the Working Group made the assumption that none of the catches were included and kept these data separate, listing them as unreported.

Following the information provided by Mr. Brannon, for the years 1988 and 1989, the estimate of unreported blacktip sharks in the Atlantic was determined by dividing the total annual unreported catch by 50%, to account for the fact that only half the fleet was in the Atlantic, then that value was multiplied by 7%.

2.4.3. Sandbar shark:

2.4.3.1. Commercial landings:

The same logic and procedures as described above for blacktip shark in the Gulf of Mexico were used to produce commercial landings estimates for sandbar shark.

The data are collected in landed or dressed weight. Various conversions are used to convert weight to number of sharks. From 1981 to 1985, an average weight of 35.9 was used. From 1986 to 1993, an average weight of 34.5 was used. This value was the average of the average weights from 1994 to 1996 from the bottom longline shark fishery observer program. From 1994 onward, the average weight was determined from data provided from the bottom longline shark fishery observer program.

2.4.3.2 Recreational landings

The same logic and procedures as described above for blacktip shark in the Gulf of Mexico were used to produce recreational catch estimates for sandbar shark.

2.4.3.3 Unreported Catches

As stated above, these landings correspond to the Gulf of Mexico during 1986, 1987, 1990 and 1991, while half of the landings correspond to the Gulf of Mexico and the other half to the mid Atlantic during 1988 and 1989. Mr. Brannon reported that the Atlantic landings were approximately 80%

sandbar sharks, with the remaining being a combination of blacktip sharks and other LCS species. The Working Group did not have any way of determining the amount, if any, of these catches that were included in landing reports. Therefore, the Working Group made the assumption that none of the catches were included and kept these data separate, listing them as unreported.

Following the information provided by Mr. Brannon, for the years 1988 and 1989, the estimate was determined by dividing the total annual unreported catch by 50%, to account for the fact that only half the fleet was in the Atlantic, then that value was multiplied by 80%. Since Brannon reported that the Gulf of Mexico landings were approximately 2/3 blacktip sharks, with the remaining third being a combination of sandbar sharks and other LCS species, for 1986, 1987, 1990, and 1991, the estimate was determined by multiplying the total annual unreported catch by 11% (assumed to represent the proportion of sandbar sharks).

2.4.3.4. Mexican catches

The total sum of catches presented for sandbar sharks in LCS05/06-DW-06 was used because there is no scientific evidence of nursery areas in Mexican waters (thus all sandbar sharks would have come from the U.S.).

2.4.3.5. Gulf menhaden fishery bycatch

Effort-adjusted estimates of dead discards were determined. De Silva et al. (2001) reported that sandbar sharks represented 1.8% of the total observed bycatch in 1994-1995. Considering the reported 75% mortality rate among all sharks, this results in an estimated bycatch of 486 (36,000*0.018*0.75) and 445 dead sandbar sharks in 1994 and 1995, respectively. The number of vessels operating in the fishery each year was divided by 53.5 vessels, the average number of vessels operating for the years in which bycatch estimates were available (1994 and 1995). The year-specific multipliers were then multiplied by the average number of sandbar (465) sharks discarded dead, as determined previously. This provides for year-specific bycatch estimates adjusted for the annual number of vessels in the fleet.

2.5 SPECIES-SPECIFIC SELECTIVITY AND AVAILABILITY

2.5.1 Blacktip Gulf of Mexico:

Commercial fishery and unreported landings: selectivity for these fisheries is assumed to follow a logistic curve that covers the entire age range; availability is assumed to be 1 for all ages.

Recreational fishery, Mexican landings and confiscated illegal Mexican catches: selectivity is assumed to be 1 for ages 0-1 with declining selectivity for later ages, but with lower steepness than for sandbar; availability is assumed to be 1 for all ages.

Menhaden fishery: selectivity and availability are assumed to be 1 for all ages.

2.5.2 Blacktip Atlantic Ocean:

Commercial fishery and unreported landings: selectivity for these fisheries is assumed to follow a logistic curve that covers the entire age range; availability is assumed to be 1 for all ages.

Recreational fishery: selectivity is assumed to be 1 for ages 0-1 with declining selectivity for later ages, but with lower steepness than for sandbar; availability is assumed to be 1 for all ages.

2.5.3 Sandbar shark:

Commercial fishery and unreported landings: selectivity for these fisheries is assumed to follow a logistic curve that covers the entire age range; availability is assumed to be 1 for all ages.

Recreational fishery, Mexican landings and confiscated illegal Mexican catches: selectivity is assumed to be 1 for ages 0-1 with declining selectivity for later ages. Because recreational fishing tournaments aim to catch larger sharks, the descending trend should not be too steep. Availability is assumed to be 1 for all ages.

Menhaden fishery: selectivity was assumed to be 1 for all ages. Availability is maximum (1) for ages 0-2 and decreases steeply to age of maturity.

2.6 Additional discussion

There was much discussion after the Workshop about the discrepancy between the species composition determined by the bottom longline observer program (BLLOP) and that determined from the landings data, especially with regards to sandbar and blacktip sharks. The BLLOP indicates that sandbar sharks comprise 51% of the observed sharks, with blacktip sharks accounting for 14%. This is in contrast to the landings data which suggest that sandbar and blacktip sharks represent approximately equal amounts based on landed weight (for 2004: sandbar sharks 1,223,082 lbs vs. blacktip sharks 1,092,600). It is believed this discrepancy arises mostly from the non-representative sampling coverage in the BLLOP.

Prior to 2002, observer coverage was voluntary, meaning that the coverage was restricted to areas and seasons when fishers were willing to take observers on their vessels. After several years of difficulty getting observers on vessels, observer coverage became mandatory in 2002. Vessels were selected for coverage by HMS using the following criteria:

Vessels are selected randomly from a pool of vessels that (1) have a current directed shark permit, (2) reported fishing for sharks with bottom longline gear in the first season of the previous year, (3) reported greater than 25% of landings from sharks during that season, and, beginning in 2004, (4) have not been selected for all of the past three seasons.

As vessels are randomly selected according to the above criteria, one should get a representative sample. However, as there are more vessels operating in the Atlantic than the Gulf of Mexico, there is a greater probability of having observer coverage in the Atlantic rather than the Gulf of Mexico. Since the Atlantic is predominantly a sandbar shark fishery and the Gulf of Mexico predominantly a blacktip shark fishery, this may account for the low percentage of blacktip sharks recorded by the BLLOP in comparison to the percentage of sandbar sharks observed.

Despite concerns as to how representative this data is to the fishery at large, the BLLOP data is still believed to provide the most reliable species specific information due to species identification and recording issues by seafood dealers. It is known that some dealers can correctly identify shark species, while others can not (R. Hudson, pers comm.). It is also difficult to get accurate species-specific landings information due to the way in which sharks are weighed in vats at the docks and there may be several species in a vat that are called “blacktip” or “sandbar” on the landing receipt (R. Hudson, pers comm.). Additionally, the dealers should not be buying and reporting prohibited species, however they are still caught in the fishery. The only data available on the prohibited species is from the BLLOP.

2.7 Research Recommendations

- Biological data should be collected on the illegal Mexican shark catch confiscated in U.S. waters, including species, sex, and length.

- Gear-related information, including effort and gear used for each species should be collected on the interdicted Mexican vessels.

-One central electronic database for biological and gear data should be created to keep information regarding the confiscated sharks and vessels.

- Scientists should help the Coast Guard create the database and teach the agents how to identify the species and collect gear information.

- The Atlantic menhaden fishery data should be examined to determine shark bycatch estimates, if available.

- Historical data should be re-examined to determine if the “unreported catch” from Mr. Brannon is or is not already included in the commercial landings.

- Better landings information on number of species, by weight, from the dealers should be sought

- Dockside sampling information would be helpful to verify landings information such as species composition.

- Determine whether port sampler information for large coastal sharks is available and if so, how to access it.

2.8 REFERENCES

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Table 2.1. List of species that were originally part of the Large Coastal Shark complex, including those that are currently prohibited.

Common name	Species name
Sandbar	*Carcharhinus plumbeus*
Silky	*Carcharhinus falciformis*
Tiger	*Galeocerdo cuvier*
Blacktip	*Carcharhinus limbatus*
Spinner	*Carcharhinus brevipinna*
Bull	*Carcharhinus leucas*
Lemon	*Negaprion brevirostris*
Nurse	*Ginglymostoma cirratum*
Scalloped hammerhead	*Sphyrna lewini*
Great hammerhead	*Sphyrna mokarran*
Smooth hammerhead	*Sphyrna zygaena*
Prohibited Species	
Sand tiger	*Odontaspis taurus*
Bigeye sand tiger	*Odontaspis noronhai*
Whale	*Rhincodon typus*
Basking	*Cetorhinus maximus*
White	*Carcharodon carcharias*
Dusky	*Carcharhinus obscurus*
Bignose	*Carcharhinus altimus*
Galapagos	*Carcharhinus galapagensis*
Night	*Carcharhinus signatus*
Caribbean reef	*Carcharhinus perezi*
Narrowtooth	*Carcharhinus brachyurus*

Table 2.2. BASE scenario - Catch history for the Large Coastal Shark complex (thousands of fish).

BASELINE SCENARIO

CATCHES OF LARGE COASTAL SHARKS: 22 species (in thousands)

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Mexican catches	Gulf Menhaden fishery discards	Confiscated Mexican catches in US	Total
1981	16.2	0.9	285.1		0.5	120.0	37.5		460.2
1982	16.2	0.9	539.3		0.5	81.9	38.5		677.3
1983	17.5	0.9	791.1		0.6	85.4	38.0		933.5
1984	23.9	1.3	268.9		0.8	120.7	38.0		453.5
1985	22.2	1.2	400.8		0.7	87.7	34.2		546.9
1986	54	2.9	432.5	24.9	1.7	81.8	33.8		631.6
1987	104.7	9.7	313.9	70.3	3.3	80.2	35.2		617.3
1988	274.6	11.4	308.7	113.3	8.7	89.3	34.2		840.2
1989	351	10.5	228.1	96.3	11.1	105.6	36.1		838.7
1990	267.5	8	218.2	52.1	8.5	122.2	35.2		711.7
1991	200.2	7.5	299.9	11.3	6.3	95.7	27.2		648.1
1992	215.2	20.9	307.2		6.8	103.4	23.9		677.4
1993	169.4	7.3	255.0		5.4	119.8	24.4		581.3
1994	228	8.8	163.9		3.7	110.7	26.1		541.2
1995	222.4	5.2	187.2		5.2	96.0	24.0		540.0
1996	161.0	5.7	197.5		4.8	106.1	23.9		498.9
1997	130.6	5.6	169.7		6.7	83.1	24.4		420.0
1998	174.9	4.3	160.9		6.6	74.1	23.5		444.3
1999	111.5	9.0	82.1		2.9	57.1	25.8		288.4
2000	111.2	9.4	139.0		4.1	52.1	22.1	1.000	338.9
2001	95.8	5.6	136.7		5.5	52.1	20.6	1.470	317.7
2002	123.7	2.43	80.3		4.8	52.1	20.2	1.390	284.9
2003	122.8	3.5	88.4		6.9	52.1	19.7	1.310	294.7
2004	99.0	5.2	67.0		4.5	52.1	20.2	2.120	250.0

Table 2.3. BASE – PROH scenario - Catch history for the Large Coastal Shark complex minus the prohibited species (thousands of fish).

BASELINE - PROHIBITED SCENARIO

CATCHES OF LARGE COASTAL SHARKS: except Prohibited (in thousands)

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Mexican catches	Gulf Menhaden fishery discards	Confiscated Mexican catches in US	Total
1981	15.1	0.7	223.7		0.5	120.0	37.5		397.5
1982	15.1	0.7	331.9		0.5	81.9	38.5		468.7
1983	16.3	0.7	683.1		0.5	85.4	38		824.1
1984	22.3	1.0	216.5		0.7	120.7	38		399.2
1985	20.7	1.0	355.7		0.7	87.7	34.2		500.0
1986	50.4	2.3	391.1	23.2	1.7	81.8	33.8		584.4
1987	97.7	7.7	274.6	65.6	3.2	80.2	35.2		564.3
1988	256.4	9.1	290.5	105.8	8.4	89.3	34.2		793.6
1989	327.7	8.3	212.9	89.9	10.8	105.6	36.1		791.3
1990	249.7	6.4	206.3	48.6	8.2	122.2	35.2		676.6
1991	186.9	6.0	284.3	10.5	6.1	95.7	27.2		616.7
1992	200.9	19.2	276.1		6.6	103.4	23.9		630.0
1993	158.1	6.3	244.5		5.2	119.8	24.4		558.3
1994	212.9	5.7	153.3		3.0	110.7	26.1		511.7
1995	207.6	4.5	177.3		4.9	96.0	24		514.2
1996	150.1	4.4	181.5		4.7	106.1	23.9		470.7
1997	127.5	5.0	154.0		6.9	83.1	24.4		400.8
1998	168.7	2.2	156.2		6.8	74.1	23.5		431.5
1999	109.0	7.3	76.7		2.8	57.1	25.8		278.7
2000	108.2	4.8	135.8		4.1	52.1	22.1	1.000	328.0
2001	95.7	4.2	129.9		5.0	52.1	20.6	1.470	308.9
2002	123.4	2.4	78.6		4.0	52.1	20.2	1.390	282.0
2003	122.1	3.5	85.7		6.0	52.1	19.7	1.310	290.4
2004	98.9	5.2	66.2		3.2	52.1	20.2	2.120	247.8

Table 2.4. BASE – PROH – SB - BT scenario - Catch history for the Large Coastal Shark complex minus the prohibited species, sandbar, and blacktip sharks (thousands of fish).

BASELINE - PROHIB - SB -BT SCENARIO

CATCHES OF LARGE COASTAL SHARKS: except Prohibited or BT or SB (in thousands)

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Mexican catches	Gulf Menhaden fishery discards	Confiscated Mexican catches in US	Total
1981	3.8	0.7	38.1		0.4		19.8		62.9
1982	3.8	0.7	215.8		0.4		20.4		241.1
1983	4.1	0.7	222.1		0.5		20.1		247.6
1984	5.7	1.0	119.6		0.7		20.1		147.0
1985	5.3	0.9	169.8		0.6		18.1		194.7
1986	12.8	2.3	99.5	5.3	1.5		17.9		139.2
1987	24.8	7.6	111.8	15.1	2.9		18.6		180.8
1988	65.0	8.9	76.2	24.9	7.6		18.1		200.6
1989	83.1	8.2	67.5	21.1	9.7		19.1		208.7
1990	63.3	6.2	52.4	11.2	7.4		18.6		159.2
1991	47.4	5.9	93.3	2.4	5.5		14.4		168.9
1992	51.0	18.8	80.9		6.0		12.6		169.2
1993	40.1	5.6	105.0		4.7		12.9		168.3
1994	54.0	5.1	70.1		2.9		13.8		145.9
1995	63.9	4.3	82.8		5.2		12.7		168.9
1996	42.4	4.4	57.6		4.8		12.6		121.8
1997	17.3	5.0	38.3		2.9		12.9		76.4
1998	9.1	2.2	41.4		1.5		12.4		66.6
1999	8.5	7.3	24.9		0.6		13.6		54.9
2000	13.3	4.8	51.0		1.1		11.7	0.670	82.5
2001	6.0	4.2	44.3		1.4		10.9	0.985	67.8
2002	15.7	2.4	30.6		0.8		10.7	0.932	61.1
2003	14.0	3.5	40.2		1.6		10.4	0.878	70.6
2004	11.6	5.2	31.3		0.8		10.7	1.420	61.0

Table 2.5. Alternative catch scenario for the Large Coastal Shark complex (fish in thousands).

ALTERNATIVE SCENARIO

CATCHES OF LARGE COASTAL SHARKS (in thousands)

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Mexican catches	Gulf Menhaden fishery discards	Confiscated Mexican catches in US	Total
1981	24.3	10	285.1		0.8	120.0	37.5		477.7
1982	24.3	10	539.3		0.8	81.9	38.5		694.8
1983	26.25	10	380.8		0.8	85.4	38		541.3
1984	35.85	10	268.9		1.1	120.7	38		474.6
1985	33.3	10	400.8		1.1	87.7	34.2		567.1
1986	108	10	432.5	24.9	3.4	81.8	33.8		694.4
1987	209.4	9.7	313.9	70.3	6.6	80.2	35.2		725.3
1988	549.2	11.4	308.7	113.3	17.3	89.3	34.2		1123.4
1989	702	10.5	228.1	96.3	22.2	105.6	36.1		1200.8
1990	535	8	218.2	52.1	16.9	122.2	35.2		987.6
1991	400.4	7.5	299.9	11.3	12.6	95.7	27.2		854.6
1992	430.4	20.9	307.2		13.6	103.4	23.9		899.4
1993	254.1	7.3	255.0		8.0	119.8	24.4		668.7
1994	228	8.8	163.9		3.7	110.7	26.1		541.2
1995	222.4	5.2	187.2		5.2	96.0	24		540.0
1996	161.0	5.7	197.5		4.8	106.1	23.9		498.9
1997	130.6	5.6	169.7		6.7	83.1	24.4		420.0
1998	174.9	4.3	160.9		6.6	74.1	23.5		444.3
1999	111.5	9	82.1		2.9	57.1	25.8		288.4
2000	111.2	9.4	139.0		4.1	52.1	22.1	1.000	338.9
2001	95.8	5.6	136.7		5.5	52.1	20.6	1.470	317.7
2002	123.7	2.43	80.3		4.8	52.1	20.2	1.390	284.9
2003	122.8	3.5	88.4		6.9	52.1	19.7	1.310	294.7
2004	99.0	5.2	67.0		4.5	52.1	20.2	2.120	250.0

Table 2.6. Species specific catch history for blacktip sharks in the Gulf of Mexico (thousands of fish).

BASELINE SCENARIO

CATCHES OF BLACKTIP SHARKS (in thousands) : GOM

Year	Commercial Landings	Recreational catches	Unreported catches	Mexican catches	Gulf Menhaden fishery discards	Confiscated Mexican catches in US	Total
1981	7.3	52.0		109.9	17.5		186.7
1982	7.3	54.5		70.1	17.9		149.8
1983	7.8	14.7		74.3	17.7		114.5
1984	10.7	23.0		109.0	17.7		160.4
1985	10.0	52.4		79.8	16.0		158.2
1986	55.0	152.5	16.43	72.5	15.7		312.1
1987	52.4	83.5	46.40	73.2	16.4		271.9
1988	137.5	126.9	37.39	80.1	16.0		397.9
1989	159.2	95.1	31.78	97.2	16.8		400.1
1990	80.6	87.8	34.39	111.5	16.4		330.7
1991	39.0	113.6	7.46	86.6	12.7		259.4
1992	53.2	139.2		93.7	11.2		297.2
1993	57.1	99.9		110.7	11.4		279.1
1994	120.0	52.2		102.0	12.2		286.4
1995	84.9	48.8		86.1	11.2		230.9
1996	58.7	59.4		95.3	11.2		224.5
1997	45.2	57.5		74.7	11.4		188.8
1998	62.5	58.4		66.9	10.9		198.7
1999	52.3	22.9		49.1	12.0		136.3
2000	42.1	67.2		45.0	10.3	0.330	165.0
2001	39.4	34.5		45.0	9.6	0.485	129.1
2002	30.0	34.5		45.0	9.4	0.459	119.4
2003	71.5	10.3		45.0	9.2	0.432	136.5
2004	44.2	27.0		45.0	9.4	0.700	126.3

Table 2.7. Species specific catch history for blacktip sharks in the Atlantic Ocean (thousands of fish).

BASELINE SCENARIO
CATCHES OF BLACKTIP SHARKS (in thousands) : ATL

Year	Commercial Landings	Recreational catches	Unreported catches	Total
1981	0.6	4.5		5.0
1982	0.6	28.0		28.6
1983	0.6	29.3		29.9
1984	0.8	16.1		16.9
1985	0.8	53.3		54.0
1986	4.2	13.6	0	17.8
1987	8.6	46.7	0	55.2
1988	0.1	19.7	4.0	23.7
1989	0.5	21.8	3.4	25.7
1990	4.9	7.2	0	12.1
1991	75.3	40.6	0	115.9
1992	97.2	19.6		116.8
1993	71.5	12.8		84.3
1994	81.2	15.9		97.2
1995	66.3	19.4		85.7
1996	41.9	27.9		69.8
1997	36.0	16.3		52.4
1998	32.4	21.5		53.9
1999	6.8	8.8		15.7
2000	9.7	6.8		16.4
2001	9.7	14.9		24.6
2002	20.6	5.3		25.9
2003	18.4	30.1		48.4
2004	13.4	4.3		17.7

Table 2.8. Species specific catch history for sandbar sharks (thousands of fish).

BASELINE SCENARIO

CATCHES OF SANDBAR SHARKS (in thousands)

Year	Commercial Landings	Recreational catches	Unreported catches	Gulf Menhaden fishery discards	Mexican catches	Total
1981	6.6	129.1		0.7	10.1	146.5
1982	6.6	33.6		0.7	11.8	52.8
1983	7.2	417.0		0.7	11.1	436.0
1984	9.8	57.8		0.7	11.7	80.0
1985	9.1	80.2		0.6	7.9	97.8
1986	23.1	125.6	2.7	0.6	9.4	161.4
1987	66.3	32.7	7.7	0.7	7.0	114.3
1988	79.4	67.7	45.3	0.6	9.1	202.2
1989	122.2	28.6	38.5	0.7	8.3	198.3
1990	116.7	58.8	5.7	0.7	10.7	192.7
1991	95.4	36.8	1.2	0.5	9.1	143.0
1992	100.6	36.4		0.4	9.7	147.1
1993	72.0	26.8		0.5	9.1	108.3
1994	126.5	15.0		0.5	8.8	150.7
1995	84.4	26.3		0.4	9.9	121.0
1996	65.5	36.7		0.4	10.7	113.4
1997	41.4	41.9		0.5	8.4	92.1
1998	62.8	35.0		0.4	7.2	105.4
1999	53.2	20.1		0.5	8.0	81.8
2000	37.3	10.9		0.4	7.1	55.6
2001	50.1	36.1		0.4	7.1	93.7
2002	56.3	8.2		0.4	7.1	72.0
2003	45.2	5.2		0.4	7.1	57.8
2004	39.1	3.6		0.4	7.1	50.1

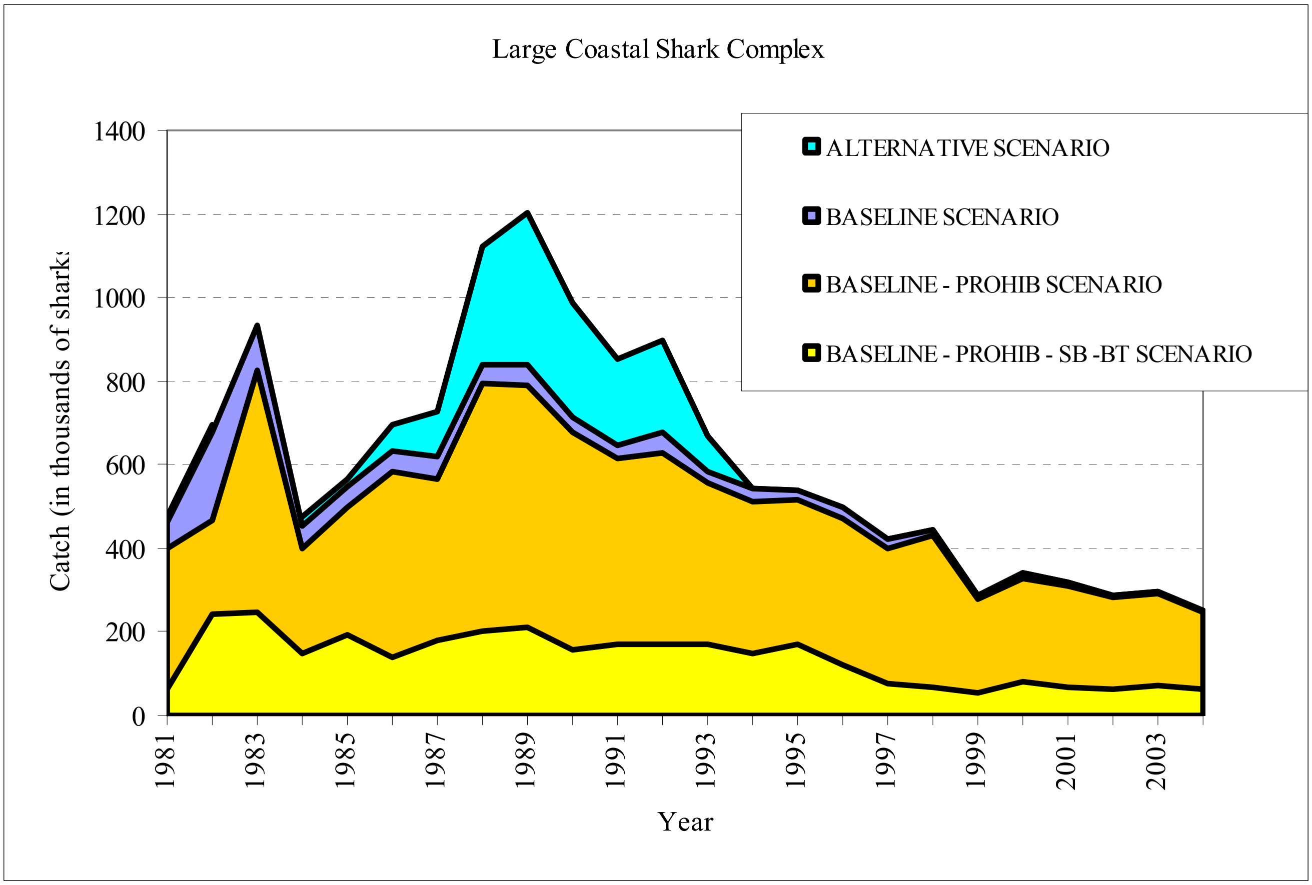

Figure 2.1. Total catches of Large Coastal Sharks (LCS; 22 species), LCS – prohibited species (11 species), and LCS – prohibited species, sandbar and blacktip sharks (9 species). The alternative catch scenario for the LCS complex (22 species) is also shown.

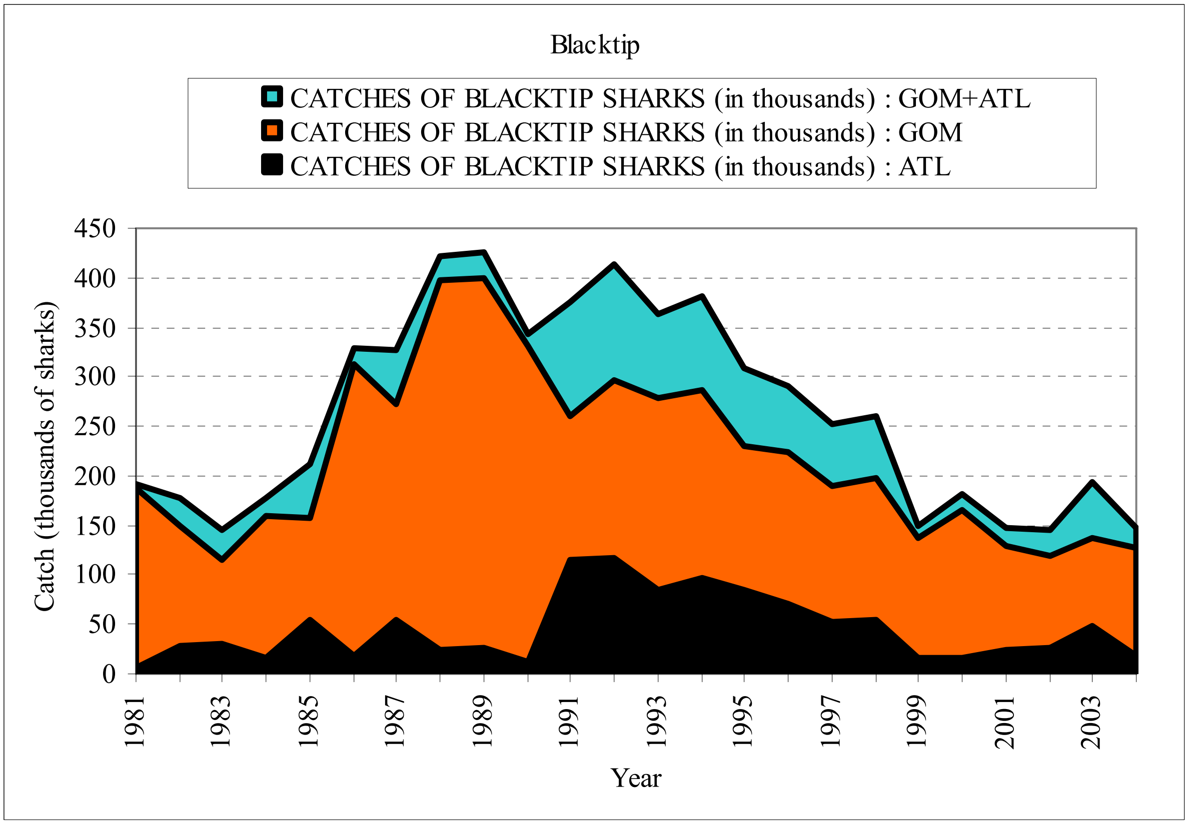

Figure 2.2. Total catches of blacktip sharks in the Gulf of Mexico and Atlantic regions.

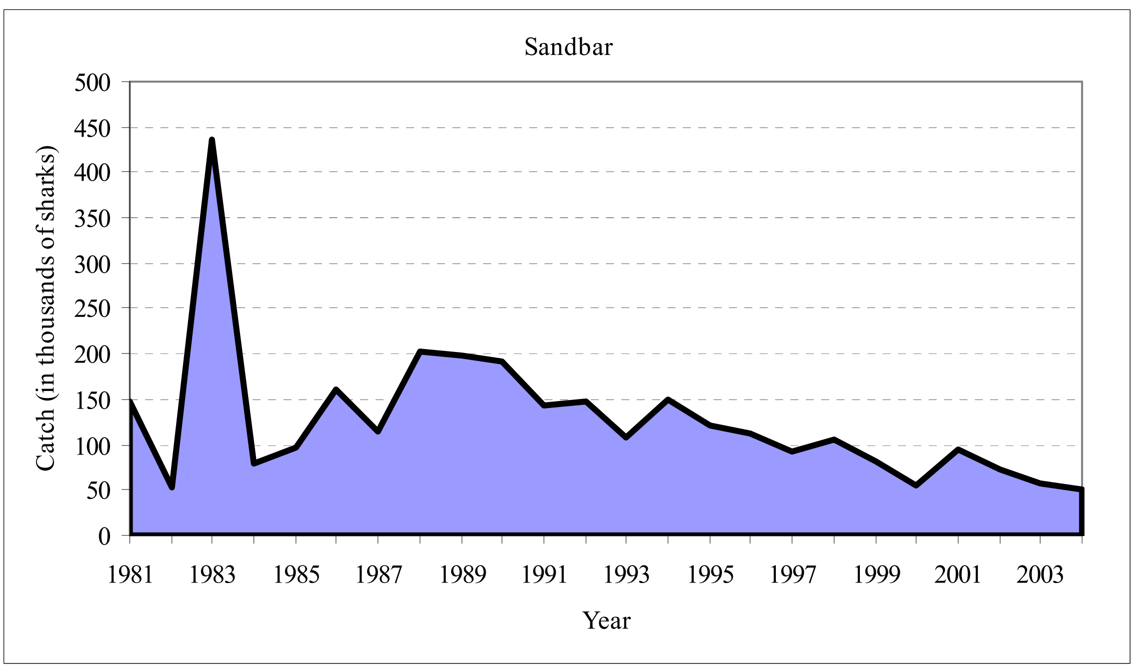

Figure 2.3. Total catches of sandbar sharks.

Abundance Indices Working Group Summary Report

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3.1 SUMMARY OF ABUNDANCE INDEX DOCUMENTS

LCS05/06-DW-01
Documentation for the North Carolina Division of Marine Fisheries catch rate series (NC#)
Anonymous

The paper reports on a fishery dependent survey of directed shark longline trips from 6 vessels from 1988 to 1992. The survey data contained 53 trips and consisted of total weight (kg), number of sharks, total fin weight (kg), days fished, number of sets, number of hooks, miles per set, soak time, location depth, and discard information. A GLM procedure was used and CPUE indices were developed for both numbers and weight.

LCS05/06-DW-09
Standardized catch rates of sandbar (*Carcharhinus plumbeus*) sharks in the Virginia - Massachusetts (U.S.) rod and reel fishery 1986 - 2004
Brown, C.

Abundance indices for sandbar (Carcharhinus plumbeus) sharks off the coast of the United States from Virginia through Massachusetts were developed using data obtained during interviews of rod and reel anglers in 1986-2004. Subsets of the data were analyzed to assess effects of factors such as month, area fished, boat type (private or charter), interview type (dockside or phone) and fishing method on catch per unit effort. Standardized catch rates were estimated through generalized linear models by applying delta-Poisson error distribution assumptions. A stepwise approach was used to quantify the relative importance of the main factors explaining the variance in catch rates.

LCS05/06-DW-11
The Directed Shark Gillnet Fishery: Large Coastal Catch Composition and a Standardized Catch Rate Series
Carlson, J.

A summary of the catch of large coastal sharks and a standardization of catch rate series from the directed shark gillnet fishery was developed based on observer programs from 1993-1995 and 1998-2004. Depending on season and area, large coastal species (primarily blacktip, *Carcharhinus limbatus*) are targeted. Average size of blacktip sharks was similar throughout the observer coverage period. Gillnet selectivity parameters for the blacktip were derived from a fishery independent survey but can be applied to this fishery because of the overlap in mesh sizes. Peak selectivities increased from 550 mm FL for the 8.9 cm and 10.2 cm mesh panel to 850 mm FL for 14.0 cm mesh in 100 mm increments per mesh panel. Selectivity was highest at 1150 mm FL for mesh panel 20.3 cm. Catch rates were standardized for a large coastal aggregate and blacktip shark using a two-part generalized linear model analysis. Depending on species, the final models varied with factors area, season, mesh size, and year. Results from this study indicate that the use of the two-step modeling approach was appropriate for standardizing catch rates for large coastal sharks.

LCS05/06-DW-12
Standardized catch rates of large coastal sharks from a fishery-independent survey in northeast Florida
Carlson, J.K. and D.M. Bethea

Fishery-independent catch rates were standardized using a two-part generalized linear model analysis. One part modeled the proportion of sets that caught any sharks (at least one shark was caught) assuming a binomial distribution with a logit link function while the other part modeled the catch rates of sets with positive catches assuming a Poisson distribution with a log link function. Standardized indices were developed for the large coastal species-aggregate, and blacktip shark, *Carcharhinus limbatus* from a longline survey. From a gillnet survey, catch rates were standardized for the large coastal species-aggregate and blacktip shark. Two additional catch rate series are also developed by age for the blacktip shark; young-of-the year (age 0+) and juvenile (age 1-5). Depending on species, the final models varied with factors area, season, year, and set begin. Although factors such as area and month were significant in most models, results from this study indicate any bias associated with these aspects did not significantly change the trends between nominal and standardized data. Overall, trends were not significant. It is possible additional factors such as sea temperature, dissolved oxygen, and salinity may contribute more to an explanation of the variability within the models. Further analysis using generalized additive models could improve the explanatory ability of the model.

LCS05/06-DW-13
Standardized catch rates of large coastal sharks from the Everglades National Park Creel Survey, 1972-2002
Carlson, J.K., J. Osborne, and T.W. Schmidt

The Everglades National Park was established in 1947 and a fisheries monitoring program by the National Park Service based on sport fisher dock-side interviews began in 1972. Interviewers record landings and releases. Using this data, a standardized index of abundance was created for large coastal sharks. The delta-lognormal index was constructed by combining two general linear models, a binomial model fit to the proportion of positive trips, and a poisson model fit to positive catches. The standardized abundance index is similar to the nominal CPUE series. Sharks catches were relatively similar throughout the 1970's, declined beginning around 1982, stabilized in the early 1990's, and have somewhat increased since 1994. An index was also constructed for blacktip sharks but deemed unusable because of an increase in species-specific reported that coincided with the purported increase in abundance of blacktip sharks.

LCS05/06-DW-14
Documentation of the South Carolina Department of Natural Resources longline survey catch rate series (SC LL Recent)
Cortés, E.

This document examines catch rate series of large coastal sharks, blacktip, and sandbar sharks that became available for the 2002 evaluation. The series is a fishery-independent longline survey conducted by the South Carolina Department of Natural Resources. The series was subjected to a Generalized Linear Model (GLM) standardization methodology to adjust for factors that affect relative abundance. The approach used treats 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, separately from the catch rates of sets with positive catches assuming a Poisson error distribution with a log link function.

LCS05/06-DW-17
Standardized catch rates of large coastal sharks from the Commercial Shark Fishery Observer Program, 1994-2004
Cortés, E. A. Morgan, and G. Burgess

This document examines catch rate series for several groupings/species of sharks from the Commercial Shark Fishery Observer Program (CSFOP) for the period 1994-2004: all species in the originally defined large coastal shark (LCS) complex (22 species), the LCS complex without prohibited species (11 species), and the LCS complex without prohibited species or blacktip or sandbar sharks (9 species). Additionally, separate analyses were conducted for the sandbar shark and for the blacktip shark (Gulf of Mexico, Atlantic, and the two areas combined). All series were subjected to a Generalized Linear Model (GLM) standardization technique that adjusts for factors that affect relative abundance. The approach used to estimate relative abundance indices is a Generalized Linear Mixed Model 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 Poisson error distribution with a log link function. The three standardized LCS series considered showed a positive, statistically significant trend. The standardized series for the sandbar shark was flat and showed high variability around the mean values. The standardized series for the blacktip shark (all areas combined) showed a statistically significant upward tendency, which was also reflected in the standardized series for blacktip in the Gulf of Mexico, whereas the series for blacktip in the Atlantic fluctuated and showed no discernible trend.

LCS05/06-DW-20
A preliminary analysis of Virginia shark longline data 1974 - 2004
Ha, D.S. and J.A. Musick

This document examines catch rates for the large coastal species complex (LCS) and the sandbar shark (*Carcharhinus plumbeus*), from the Virginia Institute of Marine Science's bottom long-line survey. This survey has sampled a set of seven stations since 1973. In this time, the survey has collected over 5200 sandbar sharks and more then 6,000 large coastal species. The nominal data was transformed with the angular transform and analyzed with a generalized additive model, removing effects of covariates where significant. Over the course of the study (1974-2004) both the sandbar shark and the LCS complex showed significant declines, with no signs of recovery.

LCS05/06-DW-21
Documentation for the Brannon catch rate series
Hester, F.J.

This document reports catch and effort data from the Brannon fleet for the years 1986-1991. The landings were not entered into the NMFS LCS landings data base, and were likely mainly blacktip and sandbar. The landings may be useful for compiling the catch tables, but using the effort data is problematic. This is because some of the boats shifted effort and targeting from Alabama to South Carolina in the middle years of the series and probably took sandbar as well as other LCS.

LCS05/06-DW-22
An evaluation of the content and quality of two Commercial Atlantic Shark Fishery logbook data sets for consideration for stock assessment use
Hester, F.J. and R.H. Hudson

Paper 22 examined the possible utility of using the landings data from the CFL series to construct indexes of abundance. The conclusions were that several steps were necessary:
1) the data needed to be verified, in particular the landings reported in the logbooks needed to be compared with the weights and species reported in the weigh out slips, 2) the vessels involved need to be standardized (by length), 3) the gear type should be restricted to bottom long line setting a minimum of 100 hooks, and 4) trips targeting sharks need to be defined.

Even so, the calculated indexes would be limited to some form of landings by species and weight per trip: *e.g.*, average weight landed per set, or average landed per hook because the data are aggregated by weight landed per trip. Actual catches, as opposed to landed, cannot be determined, nor can numbers taken or discarded.

LCS05/06-DW-23
A review of exploratory longline surveys and biological sampling of sharks from the Sandy Hook and Narragansett labs: 1961-1996.
Hoey, J.J., A. Aires-da-Silva, P. Turner, T. Sye, and N. Kohler

The report provides an inventory of sampling cruises using longline gear from 1961 through 1996 from shark research programs run out of the BSFW Sandy Hook and NMFS Narragansett labs. Most of the survey sets deployed pelagic gear similar to shallow rigged "yankee style" swordfish gear. The major change over time related to the annual proportions of sets deployed in shallow coastal areas versus offshore effort along the edge of the continental shelf and in Gulf Stream waters. Early effort (61-65) was primarily in depths shallower than 50 meters depth in the northern Mid-Atlantic bight, whereas after that effort was primarily deployed along the edge of the continental shelf primarily from Cape Hatteras to Georges Bank. After several geographically unique cruises were identified, annual estimates of consistent inshore and offshore pelagic sets were identified as suitable for additional analyses and standardization. Size frequency histograms were provided for several dominant species.

LCS05/06-DW-24
Catch Rates for Blacktip and Other Large Coastal Shark Species from Mississippi Coastal Waters During 1998–2005
Hoffmayer, E.R., G.R. Parsons, and G.W. Ingram

This document examines catches rate series for the large coastal shark complex (LCS) and blacktip sharks calculated from a gillnet survey which was conducted in the Mississippi coastal waters from 1998 to 2005. As a result of 90 net sets and 354 hours of effort, 446 blacktip and 56 other LCS were collected. Because the work was conducted in a known blacktip nursery area, blacktip shark catch was further divided into young-of-the-young (YOY, age-0) and juvenile catch. Standardized catch rates were estimated using a Generalized Linear Mixed modeling approach assuming a delta-lognormal error distribution. Catch rates did not exhibit a clear pattern because of two years of extremely elevated catch rates in 2000 and 2005. The LCS catch rates exhibited similar patterns to total blacktip catch, primarily because blacktips dominated the LCS catch.

LCS05/06-DW-25
Synopsis of a survey of the Florida recreational shark fishery utilizing shark tournament and selected long-line data (Documentation for the Hudson, Jax, Pt. Salerno, and Tampa Bay Recreational Fishing Tournaments catch series, along with the Crooke longline catch series).
Hueter, R.E.

This synopsis of a 1991 report to the state of Florida examines catch data for four recreational shark tournaments in Florida (Hudson, 1985-91; Jacksonville, 1979-90); Port Salerno, 1976-91; and Tampa Bay, 1985-90). Where possible, catch rate was standardized into a CPUE index of sharks per registered angler in the tournament. Declining trends in catch rate are evident. Catch comprised almost entirely species from the LCS complex including sandbar, dusky, tiger, hammerhead, bull, lemon, blacktip, spinner and nurse sharks. The report also contains analysis of a small-scale longline operation conducted off Pensacola, Florida from 1975 to 1989, for which meticulous catch records were kept. Catch comprised primarily LCS species including sandbar, blacktip, bull, tiger, dusky, scalloped and great hammerhead, spinner and nurse sharks. An overall decline in CPUE expressed as sharks per hook is evident; however, the lack of accounting for null sets (sets that caught no sharks) in the operation makes the use of these data problematic.

LCS05/06-DW-26
Relative abundance of juvenile blacktip sharks in three Florida Gulf coastal nursery areas, 1995-2004
Hueter, R., J. Tyminski and C. Simpfendorfer

Monthly, random-stratified, fishery-independent sampling by standardized gill net was conducted in three primary nurseries for the blacktip shark in peninsular Florida Gulf coast waters from 1995-2004. Total catch over the study duration comprised 8,257 sharks including 3,842 blacktip sharks, 90% of which were neonate or young-of-the-year (YOY) animals. Standardized catch rates were calculated using a GLM with month, year, area, grid and block (nested within grid) as factors. The GLM also included an interaction term between year and area to investigate if different nurseries had different patterns of catch rates. To assess overall trends in catch rate, the GLM was applied to data from June through August in the two more productive nurseries of Yankeetown and Charlotte Harbor. There were significant differences in catch rates among all factors tested except month. Regression analysis indicated the slope of the catch time series was not significantly different from zero in either nursery, implying no significant increasing or decreasing trend in recruitment to these blacktip shark nurseries from 1995-2004. Environmental factors such as red tide blooms and pulses of fresh water into estuaries following storm events appear to have affected relative abundance of Year-0 blacktip sharks in these nurseries.

LCS05/06-DW-27
Catch rates, distribution and size composition of large coastal sharks collected during NOAA Fisheries Bottom Longline Surveys from the U.S. Gulf of Mexico and U.S. Atlantic Ocean
Ingram, W., T. Henwood, M. Grace, L. Jones, W. Driggers, and K. Mitchell

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories has conducted standardized bottom longline surveys in the Gulf of Mexico, Caribbean, and Southern North Atlantic since 1995. This document describes the evolution of this survey including changes in hook-type and depth range over time. The effect of hook type was adjusted for using species and area-specific ratios of circle-hook to J-hook catch rates. Initially, blacktip, sandbar and LCS indices were developed for Atlantic (south of 37^{o}), Gulf of Mexico, Eastern Gulf, Central Gulf, and Western Gulf, resulting in 15 indices. After review by the Indices Workgroup I was asked to create six indices using the Lo method: blacktip for Gulf of Mexico with year, area and depth as variables (catch rates increase in later years); blacktip for Atlantic south of 37^o with year and depth as variables (low catches with breaks in the time series); sandbar for Gulf of Mexico and Atlantic combined with year, area and depth as variables (bounces around, stays about the same over time series); large coastal sharks for Gulf of Mexico and Atlantic combined with year, area and depth as variables (bounces around, maybe an increase in later years); large coastal sharks excluding prohibited species for Gulf of Mexico and Atlantic combined with year, area and depth as variables (bounces around, maybe an increase in later years); large coastal sharks excluding prohibited species, blacktip and sandbar for Gulf of Mexico and Atlantic combined with year, area and depth as variables (bounces around, maybe an increase in later years).

LCS05/06-DW-30
Relative abundance trends for juvenile sandbar sharks in Delaware Bay
McCandless, C.T.

Delaware Bay is one of the principal pupping and nursery grounds for sandbar sharks, *Carcharhinus plumbeus*, in the East Coast waters of the United States (Merson and Pratt 2001). To provide information for effective management of this essential sandbar shark habitat, we need to understand and monitor its use by this species. Researchers from the National Marine Fisheries Service (NMFS) and the University of Rhode Island have been conducting gillnet and/or longline surveys for juvenile sandbar sharks in Delaware Bay since 1995. In 2001, a random stratified sampling plan based on depth and geographic location was initiated to assess and monitor the juvenile sandbar shark population. The geographic regions and depth strata ranges were chosen based on differences seen during sampling for juvenile sandbar sharks in Delaware Bay by the National Marine Fisheries Service from 1995 to 2000. Catch per unit effort (CPUE) in number of sharks per 50-hook set per hour was used to examine the relative abundance of juvenile sandbar sharks in Delaware Bay between the summer nursery seasons from 2001 to 2005. The CPUE was standardized using an offset of the natural logarithm of the CPUE in a generalized linear model which took into account the effects of year, month, region, and depth strata. This study also attempts to standardize the CPUE using a modified two-step approach originally proposed by Lo et al (1992). This approach is based on a delta-lognormal model and is a two-step approach that models the zero catch separately from the positive catch. Results from both standardization methods and the nominal CPUE values indicated that the relative abundance of juvenile age 1+ and young of the year sandbar sharks during the summer nursery season in Delaware Bay from 2001 to 2005 has remained fairly constant with only a significant drop in juvenile age 1+ abundance in 2002, which may be attributed to a large storm that passed through the Bay that year.

LCS05/06-DW-31
Standardized catch rates of large coastal sharks from the United States bottom longline fishery during 1996-2004
McCarthy, K. and D. Abercrombie

The available coastal logbook bottom longline catch per unit effort (CPUE) series, from 1996 - 2004, was used to develop six abundance indices for the large coastal shark species complex, blacktip sharks, and sandbar sharks. Prohibited species and unclassified sharks were excluded from the large coastal shark data set. Separate indices of abundance were calculated for each of two groups of vessels (all bottom longline vessels that fished in seven of the nine years examined and the 20% of vessels with the highest CPUE for large coastal sharks). For all indices developed, the factors YEAR, QUARTER, ZONE (Gulf of Mexico, Atlantic, and south Florida), and VESSEL were examined for inclusion in the catch rate models. For the analyses of the large coastal sharks species complex and blacktip sharks the final models were ***PROPORTION SUCCESSFUL TRIPS=YEAR+VESSEL+QUARTER*** and, for the lognormal model of catch rates on successful trips, ***ln(CPUE)=YEAR+VESSEL+QUARTER***. Final models for the analysis of sandbar sharks were ***PROPORTION SUCCESSFUL TRIPS=YEAR+VESSEL+QUARTER*** and ***ln(CPUE)=YEAR+VESSEL+ZONE***. The delta lognormal model approach (Lo et al. 1992) was used to develop the standardized indices of abundance. The standardized abundance indices developed here are similar to those of Brown (2002) for the years 1996-2001. CPUE is essentially flat during the time series for large coastal sharks and for sandbar sharks. Blacktip shark CPUE gradually increased over time before dropping in 2004.

LCS05/06-DW-33
Catch Rate Information Obtained from the NMFS Northeast Longline Survey
Natanson, L.J.

This document details the Northeast Fisheries Science Center (NEFSC) Coastal Shark Survey, conducted by the Apex Predators Investigation, Narragansett Laboratory, Narragansett, RI from 1986-2004. Its primary objective is to conduct a standardized, systematic survey of the shark populations off the US Atlantic coast to provide unbiased indices of the relative abundance for species inhabiting the waters from Florida to the Mid-Atlantic. It also provides an opportunity to tag sharks as part of the NEFSC Cooperative Shark Tagging Program and to collect biological samples and data used in analyses of life history characteristics (age, growth, reproductive biology, trophic ecology, etc.) and other research of sharks in US coastal waters. Two series of data have been identified based on gear characteristics. Information on gear, station locations, depth, hook numbers, catch, and nominal CPUEs from both series are presented.

LCS05/06-DW-35
Standardized catch rates for blacktip shark (Carcharhinus limbatus), sandbar shark (C. plumbeus), and large coastal complex sharks from the U.S. longline fleet 1981-2004
Ortiz, M.

This document presents indices of abundance from the Pelagic Longline Logbook dataset. Indices were calculated for: Large Coastal Shark complex, Sandbar shark (Gulf of Mexico and Atlantic Ocean Combined), Blacktip (Gulf of Mexico and Atlantic Ocean combined, and both areas separately). The same 5 indices were also calculated from the weighout data. Although the data series cover the years 1981-2004, species specific identification for Blacktip (BT) only begins in 1992, and for Sandbar (SB) in 1995. Furthermore, BT dominated LCS landings 1992-1994, and then from 1995-2004 SB dominate the landings. The PLL indices for BT show a decline to about 1995 and then is more or less flat. The PLL index for SB shows an increase from 1994-1996, and then is pretty flat until 2003-2004, where there is an upward trend. The LCS index is more or less flat over the whole time series.

LCS05/06-DW-36
Standardized catch rates for blacktip shark (Carcharhinus limbatus), sandbar shark (C. plumbeus), and large coastal complex sharks from the Marine Recreational Fisheries Statistical Survey (MRFSS)
Ortiz, M.

This document presents indices of abundance from the MRFSS database. Indices were calculated for LCS and SB (Gulf of Mexico and Atlantic Ocean Combined), and for Blacktip (Gulf of Mexico and Atlantic Ocean separately). The data spans the years 1981-2004. Sharks represented about 2% of total number of fish, and of that, LCS comprised about 10% - 20%. Within the LCS catch, SB and BT make up 80%. The data were not subsetted. Factors for area, gear, mode, and guild were tested. The BT Atlantic index is fairly trendless, with a possibly slight increasing trend towards the end of the series; in the Gulf of Mexico, no trend was apparent. For SB, a declining trend for most of the time series was observed. In the LCS index, a downward trend in the late 1980s was observed, with a fairly flat trend from 1992-2004.

LCS05/06-DW-41
Documentation for the Charterboat catch rate series
Scott, G. and Lacey

Data collected under a charterboat survey managed by the SEFSC Panama City laboratory were examined for use in developing standardized catch rate indices for sharks. Effort (directed at sharks) and associated catch of sharks was cross-classified by year, month, fishing area, and method of fishing (troll or not troll). Catch rate (sharks per hr fishing) was standardized for these effects through the General Linear Modeling approach, using the method of Lo et al. (1992). Updated data for 1995 are summarized and results of these calculations are presented in the attached tables and figures.

LCS05/06-DW-43
Large coastal shark surveys in eastern Gulf of Mexico, 2001-2004.
Simpfendorfer, C., J. Tyminski and R. Hueter.

Surveys for LCS species were conducted in the eastern Gulf of Mexico (Tampa Bay to Charlotte Harbor) using longlines and drumlines from 2001 onwards. Data from surveys were used to investigate seasonal and inter-annual changes in the abundance of individual species. Blacktip and bull sharks occurred year-round in surveys, sandbar and spinner sharks occurred in all seasons except summer, and lemon sharks occurred in all seasons except winter. The annual time series showed considerable variation, but were too short to determine any trends in abundance over time. A persistent red tide bloom in coastal waters in 2003 appears to have negatively affected relative abundance of LCS in the area that year.

LCS05/06-DW-45
Documentation for the South Carolina Longline Survey – Early (SCLL Early)
Ulrich, G.

The purpose of this study was to evaluate techniques for conducting fisheries-independent assessments of large coastal sharks and to determine what changes have occurred in their populations in the coastal waters of South Carolina, in response to increased commercial exploitation. The present survey is a continuation of efforts to develop data on the status of these stocks on a regional basis. This report combines data from the 1993-1994 and 1994-1995 projects and compares it to catch composition and CPUE data collected during 1983-1984.

3.2 DISCUSSION OF ABUNDANCE INDICES

Each document was presented to the working group by its author or other representative. The group discussed each index with respect to data quality and completeness, analysis methodology and results, as well as index importance and potential utility. The indices presented to the group are listed in Table 3.1. The group formulated research recommendations for selected index analyses to be implemented, if possible, prior to the assessment being carried out. It was understood that some of the research recommendations might not be completed due to time constraints. The working group also compiled a list of indices recommended for use with each base case, based upon importance of each index and degree of confidence that it is reflective of abundance.

3.2.1 Recommendations

As a result of the decision by the catch statistics working group that separate base case assessments should be conducted for each of the three definitions of a large coastal species group (*BASE, BASE-PROH*, and *BASE-PROH-SB-BT* scenarios), a general recommendation was made that all large coastal species indices be recalculated where necessary and possible for each scenario. Also, the blacktip shark indices should be recalculated, if necessary, separately for the Atlantic and Gulf of Mexico.

After discussing each index, the group proposed specific modifications to some of the analyses in order to improve the applicability of the indices for the assessment. In the case of **LCS05/06-DW-09**, the group expressed concern at the large CVs of the index values. The possibility was raised that this was a result of poor fit of the distribution of proportion positives to the assumed binomial distribution. A recommendation was made to recalculate the index standardization assuming a zero-inflated binomial distribution.

It was determined that the indices in **LCS05/06-DW-11** should be recalculated using a correction formulation for units of effort, as well as restricting the blacktip analysis to Atlantic only, as observations from the Gulf of Mexico were sparse and only covered 3 years.

The lead author of **LCS05/06-DW-13** noted that reporting rates for specific species appeared to vary over time, and recommended against using any of the resulting indices except for the total large coastal complex (*BASE*).

The discussion of **LCS05/06-DW-20** included the possibility of developing an index of young-of-year and juveniles in the Chesapeake Bay nursery ground. It was recommended that the Lo et al. (1990) method be used to standardize the catch rates, for consistency with the other standardized indices.

It was recommended that attempts be made to collate suitable data from among the data sets discussed in **LCS05/06-DW-23 (**and possibly merge with the data from **LCS05/06-DW-33)**, and then standardize the resulting catch rate series. Analysis of species composition was recommended as a possible approach to subset data to trips that would target large coastal sharks. The data could also be restricted to a subset of vessels that consistently reported sharks throughout the time series. There is a need to examine effort allocation as well to see if there was an effect of the management actions to close areas. Results from such analyses should be made available for consideration at the assessment meeting, if possible.

It was noted that the catch rate trends in **LCS05/06-DW-24** showed concurrent peaks for multiple age classes. Because both young-of-the-year and juvenile catch rates were elevated in the same years, without any offset to the patterns as might be expected if the indices reflected abundance trends of different age classes and not reflected in subsequent years, it was suggested that these elevated catch rates resulted from sharks being concentrated within the study area (or being dispersed in other years). It was recommended that other factors should be investigated to help explain these elevated catch rates, such as environmental conditions. The catch rate trends in **LCS05/06-DW-26** also showed some concurrent patterns, primarily in 2001 coinciding with a severe red tide event. It was recommended that the analyses be rerun without including 2001 data. Similarly, catch rates in **LCS05/06-DW-30** during 2002 appear to have been affected by the passage of a hurricane; it is recommended that these indices be rerun without including data from 2002.

It was recommended that that the analyses in **LCS05/06-DW-27** be rerun, following the same geographic breakdown as other studies and incorporating area as a factor in the models, if warranted.

With respect to **LCS05/06-DW-31**, the group made several recommendations. First, that the coastal logbook data should be examined to resolve data quality concerns raised by the group. Next, further data exploration should be conducted to find patterns that might suggest ways to better define coastal shark directed trips and/or vessels which tend to catch coastal sharks. It was recommended that additional factors should be examined for inclusion in the models. The group further recommended that the inclusion of available discard data should be examined. Recent developments in analytical procedures should also be incorporated in the additional analyses.

Finally, the blacktip indices will need to be calculated separately for the Gulf of Mexico and the Atlantic.

The indices shown in **LCS05/06-DW-33**, reported as a nominal trend, should be standardized following the Lo et al. (1990) methodology employed for the other standardized indices.

The group expressed concern that the trends observed for blacktip and sandbar sharks in **LCS05/06-DW-35** may reflect changes in targeting, reporting, and management actions. A recommendation was made that the dataset be reanalyzed (although a blacktip index across all areas is no longer needed), selecting sets/trips based on criteria, such as species composition of the catch or bottom depth, to help determine those that would be targeting large coastal sharks (or at least more likely to encounter them). A further recommendation was made to subset the data to boats that appeared to be consistently reporting sharks throughout the time period. The weighout dataset represents landings and begins immediately following the imposition of regulations to land carcasses with fins. This regulatory change may have introduced a change in proportion of sharks landed, and species composition therein, since some species have proportionately large fins. In addition, other changes such as closed areas, defining protected species, and an incentive for fishermen to establish a landing history in order to qualify for a permit all could have potentially biased the proportion of sharks landed. For all of these reasons, the group felt that the weighout series was not an appropriate index and that it would not be possible to standardize the index to eliminate these potentially misleading signals.

The currently available index values, including those updated following the recommendations described above, are shown in Table 3.2 and Figures 3.1 – 3.12.

3.2.2. Base Case Indices

After discussing all of the available indices, the working group compiled a list of indices recommended for use with each base case. Inclusion as a base case index was determined by the importance of the index (higher if the index covers a long time period and/or there are few or no other indices for some years) and the degree of confidence that it is reflective of abundance (higher if the catch rates are standardized though sampling design or analytically, lower if there are concerns about biases not accounted for). The list of recommended indices by group and species (including area for blacktip sharks) is shown in Table 3.3. It should be noted that it may not be possible to produce each of the listed LCS base case indices for every LCS scenario. The list of indices recommended for sensitivity runs is shown in Table 3.4.

The pelagic longline logbook indices (**Pelagic log**) were originally not included as recommended base case indices. The working group expressed concern that pelagic longline fishing activity may be unlikely to encounter coastal species on a consistent basis, in which case the indices derived from that fishery might not be good indicators of abundance. On this basis, these indices were not recommended for use in the base cases. However, the group also considered that it may be possible to reanalyze the pelagic logbook data, following the research recommendations listed above, thereby focusing on the subset of effort more likely to encounter large coastal sharks. Therefore, the group allowed that it may be possible to include the revised pelagic longline logbook indices among the base case indices if there are convincing indications that the revised indices are reflective of abundance trends. During the calculation of the revised indices, there were indeed such indications. Large coastal sharks appear to be caught in large numbers by the pelagic longline fishery, across a broad geographic range. Such evidence suggests that there is considerable overlap between pelagic longline fishing effort and large coastal shark habitat. Therefore, the **Pelagic log** indices may be considered for use in the base cases.

It may be possible that new indices may be developed from the data bases referenced in **LCS05/06-DW-23** and made available prior to the assessment meeting. In such a case, the indices may be valuable to use during the assessment, but it might not be possible to include them as base case indices.

3.2.3 Recommendations on remaining indices

Many of the remaining indices are recommended for use in sensitivity runs, even though they were not recommended as base case indices. One example is the longline index from **LCS05/06-DW-31** (**Crooke LL**), which represented a long time series of consistently collected data, but for which the presumably valuable information of number of unsuccessful sets is not included. As a result, the **Crooke LL** index might be considered for sensitivity runs, but should not be used for the base cases. Another example of indices that were not considered suitable for use in the base cases, but could be used for sensitivity analyses, is the set of **MRFSS** indices described in **LCS05/06-DW-35**. The main difficulty with the MRFSS indices is the large (and increasing in recent years) proportion of the catch (mainly discarded) which is identified only as “requiem sharks”. This grouping may include various large coastal shark species as well as small coastal shark species, and the proportions therein might be influenced by management measures restricting landings of certain species. This may adversely impact the validity of these indices as relative abundance measures for specific species or species groups. However, the MRFSS indices may be valuable in sensitivity runs, and some approach may be taken to apportion the “requiem shark” catches according to other available information on species composition.

In general, the working group determined that most of the remaining indices could likewise be used for sensitivity runs; these are not specifically discussed. However, the working group recommended against the use of some of the available indices. For instance, the group followed the advice of the lead author of **LCS05/06-DW-13** and recommended against the use of the blacktip index from that paper since reporting rates of blacktip sharks appeared to vary over time.

The index from **LCS05/06-DW-1** was not recommended as it is a short series and there was an apparent discontinuity between the periods 1988-1989 and 1990-1992, with speculation within the group that this might reflect changes in methodology. The index described in **LCS05/06-DW-21** was also not recommended as it is not standardized, is not species-specific, and is derived from observations from both the Gulf of Mexico and the Atlantic with unknown allocation between the two areas. The index from **LCS05/06-DW-22** was not recommended because a longer time series, using more observations, is available from the same data set (**LCS05/06-DW-31**).

The nominal catch rate information from shark tournaments, reported in **LCS05/06-DW-25**, were generally not recommended for use since effort information was crude (number of anglers registered with the tournament) and there was no standardization of (nor even information on) the factors which potentially may have influenced catch rates over time other than changing abundance. However, data from the Port Salerno Tournament were collected over a long term using consistent methodology; this particular series may be considered for sensitivity runs.

The weighout data based indices from **LCS05/06-DW-35** were not recommended for the aforementioned reasons (management measures may have influenced the proportion of sharks being landed over time, etc.). The charter boat survey index reported in **LCS05/06-DW-41** was not recommended for use, as catch rates are reported for total sharks only and the proportions of pelagic and coastal sharks are not known. The various indices in **LCS05/06-DW-43** were not recommended for use until more years of data are available.

3.3 INDEX WEIGHTING RECOMMENDATIONS

The working group recommended inverse weighting based upon CVs as the default weighting scheme whenever indices are not given equal weighting.

Table 3.1. A summary of catch series available for review at the LCS 05/06 Data Workshop.

Species	*Series*	*Author*	*Reference*	*Data Source*	*Area*	*Years*	*Season*	*Biomass/ Number*	*Fishery Type*	*Standardized*	*Selectivity Info*	*Age Range*	*Positive Aspects*	*Negative Aspects*	*Utility for Assessment*
Sharks	NC #	Anon.	LCS05/06-DW-01	6 Directed longline boats	North Carolina	1988-1992	All	Biomass/Number	Commercial	GLM	None	None	Historic	Not species specific, low sample sizes, possible changes in fishing methodology not accounted for	Not recommended
SB	LPS	Brown	LCS05/06-DW-09	Angler interviews	Virginia-Mass.	1986-2004	June-October	Number	Recreational	Lo method	Length frequency	None			Usable, revisit cv calculation
LCS	Gillnet Observer	Carlson	LCS05/06-DW-11	Shark drift gillnet fishery	Florida, Georgia	1993-1995, 1998-2004	All	Number	Commercial	Lo method	Length by mesh size (based on fishery independent study)	None	standardized		Rerun with new effort calculation, need to attempt calcs for all LCS scenarios
BT	Gillnet Observer	Carlson	LCS05/06-DW-11	Shark drift gillnet fishery	Florida, Georgia (Atl)	1993-1995, 1998-2004	All	Number	Commercial	Lo method	Length by mesh size (based on fishery independent study)	None	standardized		Rerun with new effort calculation, restricted to Atlantic only
LCS	PC LL	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Longline Survey	NW Florida	1993-2000	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable, need to attempt calcs for all LCS scenarios
BT-Juvenile	PC LL	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Longline Survey	NW Florida	1993-2000	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable
LCS	PC Gillnet	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable, need to attempt calcs for all LCS scenarios
BT	PC Gillnet	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable
BT-Juvenile	PC Gillnet - juveniles	Carlson and Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	Age 1 to 4 years			Usable
BT-YOY	PC Gillnet – Age 0	Carlson and Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	Age-0			Usable
SB	PC Gillnet	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable, as nominal series
LCS	ENP	Carlson et al.	LCS05/06-DW-13	Angler interviews	Everglades	1972-2002	All (wet and dry seasons)	Number	Recreational	Lo method	None	None			Usable, only possible for total LCS

Species	*Series*	*Author*	*Reference*	*Data Source*	*Area*	*Years*	*Season*	*Biomass/ Number*	*Fishery Type*	*Standardized*	*Selectivity Info*	*Age Range*	*Positive Aspects*	*Negative Aspects*	*Utility for Assessment*
BT	ENP	Carlson et al.	LCS05/06-DW-13	Angler interviews	Everglades	1978-2002	All (wet and dry seasons)	Number	Recreational	Lo method	None	None			Not recommended, changing species id reporting rate
LCS	SC LL Recent	Cortés	LCS05/06-DW-14	Longline surveys	South Carolina	1995-2001	All	Number	Independent	Lo Method	Length frequency	Juveniles			Usable, need to attempt other LCS definition scenarios
BT	SC LL Recent	Cortés	LCS05/06-DW-14	Longline surveys	South Carolina	1995-2001	All	Number	Independent	Lo Method	Length frequency	0-5			Usable
SB	SC LL Recent	Cortés	LCS05/06-DW-14	Longline surveys	South Carolina	1995-2001	All	Number	Independent	Lo Method	Length frequency	1-12			Usable
LCS	BLLOP	Cortés et al.	LCS05/06-DW-17	Directed shark bottom longline fishery	Eastern Gulf, Mid Atlantic Bight, South Atlantic	1994-2004	All	Number	Commercial	Lo method					Usable, need to attempt calcs for all LCS scenarios
BT	BLLOP	Cortés et al.	LCS05/06-DW-17	Directed shark bottom longline fishery	Eastern Gulf, Mid Atlantic Bight, South Atlantic	1994-2004	All	Number	Commercial	Lo method					Usable after rerunning separately for GOM and Atl
SB	BLLOP	Cortés et al.	LCS05/06-DW-17	Directed shark bottom longline fishery	Eastern Gulf, Mid Atlantic Bight, South Atlantic	1994-2004	All	Number	Commercial	Lo method					Usable
LCS (separate indices for 2 of definition scenarios)	VA LL	Ha & Musick	LCS05/06-DW-20	VIMS Bottom Longline Survey	Virginia	1974-2004	Summer	Number	Independent	Transformed data, GAM model	Length frequency	None			Usable, after reanalysis to standardize methods; may be re-analyzed to incorporate additional information
SB	VA LL	Ha and Musick	LCS05/06-DW-20	VIMS Bottom Longline Survey	Virginia	1974-2004	Summer	Number	Independent	Transformed data, GAM model	Length frequency	None			Usable, after reanalysis to standardize methods; may be re-analyzed to incorporate additional information
Sharks	Brannon	Hester	LCS05/06-DW-21	Brannon series	Alabama, North Carolina ?	1986-1991	?	Number	Commercial	Nominal	None	None		Not species specific, not standardized, area unclear	Not recommended
Sharks		Hester and Hudson	LCS05/06-DW-22	Coastal Fishery Logbook	North Atlantic, South Atlantic and Gulf of Mexico	2001-2003	All	Biomass	Commercial	Nominal	None	None	Review of data base/fishing power issues	Short time series	Not recommended; longer time series available from the same data set
Sharks		Hoey et al.	LCS05/06-DW-23	NE Longline Survey	North Atlantic	1961-1993			Independent						Potentially Usable, will be re-analyzed following research recommendations

Species	Series	Author	Reference	Data Source	Area	Years	Season	Biomass/ Number	Fishery Type	Standardized	Selectivity Info	Age Range	Positive Aspects	Negative Aspects	Utility for Assessment
LCS	MS Gillnet	Hoffmayer & Parsons	LCS05/06-DW-24	Gillnet Survey	Mississippi	1998-2005	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None		Concurrent changes across age-specific indices suggest common factor(s) not accounted for in standardization	May be usable if reanalysis following research recommendations accounts for concurrent changes
BT	MS Gillnet	Hoffmayer & Parsons	LCS05/06-DW-24	Gillnet Survey	Mississippi	1998-2005	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None		Concurrent changes across age-specific indices suggest common factor(s) not accounted for in standardization	May be usable if reanalysis following research recommendations accounts for concurrent changes
BT-YOY	MS Gillnet – Age o	Hoffmayer & Parsons	LCS05/06-DW-24	Gillnet Survey	Mississippi	1998-2005	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	Age-0		Concurrent changes across age-specific indices suggest common factor(s) not accounted for in standardization	May be usable if reanalysis following research recommendations accounts for concurrent changes
BT - Juvenile	MS Gillnet - juvenile	Hoffmayer & Parsons	LCS05/06-DW-24	Gillnet Survey	Mississippi	1998-2005	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	Age 1 to 4-5 years		Concurrent changes across age-specific indices suggest common factor(s) not accounted for in standardization	May be usable if reanalysis following research recommendations accounts for concurrent changes
LCS	Jax, Tampa Bay Port Salerno Hudson	Hueter	LCS05/06-DW-25	Multiple Tournaments	Florida	1976-1991	Summer	Number	Recreational	Nominal (sharks per angler)	None	None	Consistent tournament operations, long time series		Some usable as sensitivity
LCS	Crooke LL	Hueter	LCS05/06-DW-25	Crooke data	Florida	1975-1989	?	Number (non-zero catch only)	Commercial	Nominal (sharks per hook)	Length frequency	None	Consistent methods		Usable as sensitivity
BT-YOY	Mote Gillnet-Charlotte Harbor	Hueter et al.	LCS05/06-DW-26	Gillnet Survey	Eastern Gulf (Charlotte Harbor)	1995-2004	May-Sept.	Number	Independent	GLM on log-transformed data	Length frequency	neonate Age-0		Concurrent changes across age-specific indices suggest common factor(s) not accounted for in standardization	May be usable if reanalysis following research recommendations accounts for concurrent changes, should drop 2001 due to red tide
BT-YOY	Mote Gillnet - Yankeetown	Hueter et al.	LCS05/06-DW-26	Gillnet Survey	Eastern Gulf (Yankeetown)	1995-2004	May-Sept.	Number	Independent	GLM on log-transformed data	Length frequency	neonate Age-0		Concurrent changes across age-specific indices suggest common factor(s) not accounted for in standardization	May be usable if reanalysis following research recommendations accounts for concurrent changes
LCS	NMFS LL SE	Ingram et al.	LCS05/06-DW-27	NMFS Bottom Longline Survey	Gulf of Mexico and Atlantic (south of 37^{o} N)	1995-1997, 1999-2004	Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable

Species	Series	Author	Reference	Data Source	Area	Years	Season	Biomass/ Number	Fishery Type	Standardized	Selectivity Info	Age Range	Positive Aspects	Negative Aspects	Utility for Assessment
LCS (without protected species)	NMFS LL SE	Ingram et al.	LCS05/06-DW-27	NMFS Bottom Longline Survey	Gulf of Mexico and Atlantic (south of 37° N)	1995-1997, 1999-2004	Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable
LCS (without protected species, sandbar, blacktip)	NMFS LL SE	Ingram et al.	LCS05/06-DW-27	NMFS Bottom Longline Survey	Gulf of Mexico and Atlantic (south of 37° N)	1995-1997, 1999-2004	Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable
BT	NMFS LL SE	Ingram et al.	LCS05/06-DW-27	NMFS Bottom Longline Survey	Gulf of Mexico	1995-1997, 1999-2004	Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable
BT	NMFS LL SE	Ingram et al.	LCS05/06-DW-27	NMFS Bottom Longline Survey	Atlantic (south of 37° N)	1995-1997, 1999-2000, 2002, 2004, 2005	Summer, Fall	Number	Independent	Zero-inflated, delta lognormal	Length frequency	None			Usable
SB	NMFS LL SE	Ingram et al.	LCS05/06-DW-27	NMFS Bottom Longline Survey	Gulf of Mexico and Atlantic (south of 37° N)	1995-1997, 1999-2004	Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable
SB	DE Bay	McCandless	LCS05/06-DW-30	Bottom Longline Survey	Delaware Bay	2001-2005	Summer	Number	Independent	GLM	Length frequency	All juveniles			May be usable if reanalyzed following research recommendations, drop 2002 due to hurricane
SB-YOY	DE Bay – Age 0	McCandless	LCS05/06-DW-30	Bottom Longline Survey	Delaware Bay	2001-2005	Summer	Number	Independent	GLM	Length frequency	YOY			May be usable if reanalyzed following research recommendations
SB-juvenile	DE Bay - juveniles	McCandless	LCS05/06-DW-30	Bottom Longline Survey	Delaware Bay	2001-2005	Summer	Number	Independent	GLM	Length frequency	1+ juveniles			May be usable if reanalyzed following research recommendations, drop 2002 due to hurricane
LCS	Bottom LL Logs	McCarthy and Abercrombie	LCS05/06-DW-31	Coastal Logbook Program	South Atlantic and Gulf of Mexico	1996-2004	All	Biomass	Commercial	Lo method	None	None			Usable after re-analysis following recommendations
BT	Bottom LL Logs	McCarthy and Abercrombie	LCS05/06-DW-31	Coastal Logbook Program	South Atlantic and Gulf of Mexico	1996-2004	All	Biomass	Commercial	Lo method	None	None			Usable after re-analysis following recommendations, separate GOM and Atl

Species	Series	Author	Reference	Data Source	Area	Years	Season	Biomass/ Number	Fishery Type	Standardized	Selectivity Info	Age Range	Positive Aspects	Negative Aspects	Utility for Assessment
SB	Bottom LL Logs	McCarthy and Abercrombie	LCS05/06-DW-31	Coastal Logbook Program	South Atlantic and Gulf of Mexico	1996-2004	All	Biomass	Commercial	Lo method	None	None			Usable after re-analysis following recommendations
LCS	NMFS LL NE	Natanson	LCS05/06-DW-33	NMFS Northeast Bottom Longline Survey	Atlantic	1996, 1998, 2001, 2004	Spring	Number	Independent	Nominal	Length frequency	Age 0 - adult			May be usable, standardization will be attempted as will combining with comparable NE LL data reported in DW-23
BT	NMFS LL NE	Natanson	LCS05/06-DW-33	NMFS Northeast Bottom Longline Survey	Atlantic	1996, 1998, 2001, 2004	Spring	Number	Independent	Nominal	Length frequency	Age 0 - adult			May be usable, standardization will be attempted as will combining with comparable NE LL data reported in DW-23
SB	NMFS LL NE	Natanson	LCS05/06-DW-33	NMFS Northeast Bottom Longline Survey	Atlantic	1996, 1998, 2001, 2004	Spring	Number	Independent	Nominal	Length frequency	Age 0 - adult			May be usable, standardization will be attempted as will combining with comparable NE LL data reported in DW-23
LCS	Pelagic Log	Ortiz	LCS05/06-DW-35	Pelagic Longline Logbook	Atlantic and Gulf of Mexico	1986-2004	All	Number	Commercial	Lo method	None	None			Usable after re-analysis following recommendations, need to attempt calcs for all LCS scenarios
BT	Pelagic Log	Ortiz	LCS05/06-DW-35	Pelagic Longline Logbook	Atlantic and Gulf of Mexico	1992-2004	All	Number	Commercial	Lo method	None	None			Not used if BT assessed separately for GOM and Atl
BT	Pelagic Log	Ortiz	LCS05/06-DW-35	Pelagic Longline Logbook	Atlantic	1992-2004	All	Number	Commercial	Lo method	None	None			Usable after re-analysis following recommendations
BT	Pelagic Log	Ortiz	LCS05/06-DW-35	Pelagic Longline Logbook	Gulf of Mexico	1992-2004	All	Number	Commercial	Lo method	None	None			Usable after re-analysis following recommendations
SB	Pelagic Log	Ortiz	LCS05/06-DW-35	Pelagic Longline Logbook	Atlantic and Gulf of Mexico	1994-2004	All	Number	Commercial	Lo method	None	None			Usable after re-analysis following recommendations
LCS	Weigh-out	Ortiz	LCS05/06-DW-35	Pelagic longline carcass weigh-out data	Atlantic and Gulf of Mexico	1982-2004	All	Biomass	Commercial	Lo method	None	None			Not recommended as landing rates likely influence by factors other than abundance (fishers response to management, etc.)

Species	Series	Author	Reference	Data Source	Area	Years	Season	Biomass/ Number	Fishery Type	Standardized	Selectivity Info	Age Range	Positive Aspects	Negative Aspects	Utility for Assessment
BT	Weigh-out	Ortiz	LCS05/06-DW-35	Pelagic longline carcass weigh-out data	Atlantic and Gulf of Mexico	1983-2004	All	Biomass	Commercial	Lo method	None	None			Not recommended as landing rates likely influence by factors other than abundance (fishers response to management, etc.)
BT	Weigh-out	Ortiz	LCS05/06-DW-35	Pelagic longline carcass weigh-out data	Atlantic	1983-2004	All	Biomass	Commercial	Lo method	None	None			Not recommended as landing rates likely influence by factors other than abundance (fishers response to management, etc.)
BT	Weigh-out	Ortiz	LCS05/06-DW-35	Pelagic longline carcass weigh-out data	Gulf of Mexico	1985-2004	All	Biomass	Commercial	Lo method	None	None			Not recommended as landing rates likely influence by factors other than abundance (fishers response to management, etc.)
LCS	MRFSS	Ortiz	LCS05/06-DW-36	MRFSS	Louisiana-Maine	1981-2004	All	Number	Recreational	Lo method	Length frequency (available TBD)	None			Usable, need to attempt calcs for all LCS scenarios
BT	MRFSS	Ortiz	LCS05/06-DW-36	MRFSS	Louisiana-Florida (GOM)	1981-2004	All	Number	Recreational	Lo method	Length frequency (available TBD)	None			Usable
BT	MRFSS	Ortiz	LCS05/06-DW-36	MRFSS	Florida-Maine (Atlantic)	1981-2004	All	Number	Recreational	Lo method	Length frequency (available TBD)	None			Usable
SB	MRFSS	Ortiz	LCS05/06-DW-36	MRFSS	Louisiana-Maine	1981-2004	All	Number	Recreational	Lo method	Length frequency (available TBD)	None			Usable
Sharks	Charterboat	Scott & Lacey	LCS05/06-DW-41	Charterboat	Texas-North Carolina	1989-1995	?	Number	Recreational	Lo method	None	None		Not species specific, may include high proportion of pelagics	Not recommended absent further information that it is relevant to LCS
BT	Mote DL	Simpfendorfer et al.	LCS05/06-DW-43	Drumline Survey	Eastern Gulf	2001-2004	All	Number	Independent	Nominal	Length frequency	Older juveniles-adults	Standardized stations/methodology		
BT	Mote LL	Simpfendorfer et al.	LCS05/06-DW-43	Longline Survey	Eastern Gulf	2002-2004	All	Number	Independent	Nominal	Length frequency	Older juveniles-adults	Standardized stations/methodology		
SB	Mote DL	Simpfendorfer et al.	LCS05/06-DW-43	Drumline Survey	Eastern Gulf	2002-2004	All	Number	Independent	Nominal	Length frequency	Older juveniles-adults	Standardized stations/methodology		
SB	Mote LL	Simpfendorfer et al.	LCS05/06-DW-43	Longline Survey	Eastern Gulf	2002-2004	All	Number	Independent	Nominal	Length frequency	Older juveniles-adults	Standardized stations/methodology		
LCS	SC LL Early	Ulrich	LCS05/06-DW-45	Longline survey	South Carolina	1983-1984, 1993-1995	All	Number	Independent	nominal	Length frequency		Historical, consistent methodology		Usable

Table 3.2 Available catch rates series for the large coastal shark complex (3 scenarios) , sandbar, and blacktip shark. The index is the relative (divided by the overall mean) estimated mean CPUE and the CV is the estimated precision of the mean value. Type refers to whether the index is fishery – independent (FI) or fishery-dependent (FD), recreational (R) or commercial (C). Observations with a CV of 1.0 are nominal data for which no measure of the precision of the estimate was available. Recommendation refers to the recommendation by the Indices Working Group to include the particular index as a base index (Base), use it for sensitivity runs (Sensitivity) or not recommended for use in the assessment (NR).

Original LCS Definition (22 species)

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-01	NC #	FD - C	NR	1988	0.758	0.422
				1989	1.242	0.232
LCS05/06-DW-11	Gillnet Observer	FD - C	Base	1993	0.338	1.026
				1994	1.050	0.132
				1995	0.299	0.779
				1998	1.088	0.177
				1999	1.336	0.079
				2000	1.239	0.073
				2001	1.179	0.070
				2002	1.077	0.116
				2003	1.112	0.150
				2004	1.281	0.082
LCS05/06-DW-12	PC Longline	FI	Sensitivity	1993	0.816	0.730
				1994	0.386	0.894
				1995	1.272	0.610
				1996	0.858	0.583
				1997	0.926	0.539
				1998	0.725	0.967
				1999	1.174	0.564
				2000	1.844	0.508
LCS05/06-DW-12	PC Gillnet	FI	Base	1996	0.511	0.241
				1997	1.637	0.132
				1998	0.607	0.310
				1999	0.969	0.297
				2000	0.811	0.326
				2001	1.549	0.211
				2002	0.936	0.201
				2003	1.072	0.186
				2004	0.908	0.220
LCS05/06-DW-13	ENP	FD - R	Base	1972	0.598	0.255
				1973	1.575	0.085

				1974	0.985	0.093
				1975	1.987	0.066
				1976	1.165	0.094
				1977	1.409	0.079
				1978	1.126	0.094
				1979	1.114	0.123
				1980	1.469	0.079
				1981	1.001	0.080
				1982	1.099	0.081
				1983	1.368	0.068
				1984	1.279	0.066
				1985	1.071	0.074
				1986	0.921	0.070
				1987	0.942	0.080
				1988	0.993	0.099
				1989	0.604	0.127
				1990	0.548	0.098
				1991	0.504	0.113
				1992	0.910	0.089
				1993	0.523	0.105
				1994	0.911	0.070
				1995	0.762	0.091
				1996	0.900	0.070
				1997	0.922	0.066
				1998	0.855	0.078
				1999	0.753	0.085
				2000	0.966	0.076
				2001	0.838	0.083
				2002	0.900	0.087
LCS05/06-DW-14	SC LL Recent	FI	Base	1995	0.813	0.359
				1996	0.692	0.257
				1997	1.367	0.183
				1998	0.853	0.194
				1999	1.295	0.148
				2000	1.112	0.169
				2001	0.868	0.216
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.669	0.335
				1995	0.901	0.219
				1996	0.907	0.143
				1997	0.894	0.287
				1998	1.134	0.178
				1999	1.084	0.280
				2000	1.027	0.363
				2001	0.929	0.299
				2002	1.269	0.265
				2003	1.214	0.188
				2004	0.971	0.187

LCS05/06-DW-20	VA LL	FI	Base	1975	2.508	0.307
				1977	1.994	0.344
				1978	0.975	1.006
				1980	2.063	0.246
				1981	1.795	0.237
				1984	0.658	1.611
				1986	0.612	2.715
				1989	0.790	0.526
				1990	0.815	0.437
				1991	0.702	0.524
				1992	1.231	0.560
				1993	0.794	0.619
				1995	0.811	0.448
				1996	0.766	0.406
				1997	0.753	0.276
				1998	0.737	0.318
				1999	0.710	0.437
				2000	0.777	0.365
				2001	0.737	0.356
				2002	0.685	0.509
				2003	0.546	0.373
				2004	0.541	0.514
LCS05/06-DW-21	Bannon	FD - C	NR	1986	0.657	1
				1987	1.348	1
	* nominal index			1988	1.146	1
				1989	0.833	1
				1990	0.994	1
				1991	1.020	1
LCS05/06-DW-24	MS Gillnet	FI	Sensitivity	1998	0.566	0.528
				1999	0.337	0.574
				2000	1.981	0.421
				2001	0.576	0.717
				2003	0.399	0.741
				2004	0.472	0.598
				2005	2.670	0.455
LCS05/06-DW-25	Hudson	FD - R	NR	1985	0.220	1
				1986	0.100	1
	* nominal index			1987	0.120	1
				1988	0.100	1
				1989	0.050	1
				1990	0.020	1
				1991	0.020	1
LCS05/06-DW-25	Jax	FD - R	NR	1979	0.590	1
				1984	0.710	1
	* nominal index			1990	0.160	1

LCS05/06-DW-25	Tampa Bay	FD - R	NR	1985	0.160	1
				1986	0.090	1
	* nominal index			1987	0.030	1
				1988	0.140	1
				1989	0.060	1
				1990	0.050	1
LCS05/06-DW-25	Port Salerno	FD - R	Sensitivity	1976	0.180	1
				1977	0.810	1
	* nominal index			1979	0.890	1
				1980	0.820	1
				1981	0.390	1
				1982	0.500	1
				1983	0.120	1
				1984	0.100	1
				1985	0.150	1
				1986	0.500	1
				1987	0.320	1
				1988	0.200	1
				1989	0.120	1
				1990	0.200	1
LCS05/06-DW-25	Crooke LL	FD - C	Sensitivity	1975	0.882	1
				1976	0.642	1
				1977	1.043	1
				1978	2.005	1
				1979	0.963	1
				1980	1.283	1
				1981	1.043	1
				1982	1.043	1
				1983	1.123	1
				1984	0.963	1
				1985	1.123	1
				1986	0.882	1
				1987	0.642	1
				1988	0.642	1
				1989	0.722	1
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	0.849	0.135
				1996	0.449	0.200
				1997	0.626	0.128
				1999	0.499	0.150
				2000	1.042	0.083
				2001	1.120	0.106
				2002	1.220	0.080
				2003	1.846	0.105
				2004	1.349	0.107
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.615	0.164
				1997	0.945	0.103

				1998	0.848	0.099
				1999	1.210	0.090
				2000	1.204	0.098
				2001	1.146	0.095
				2002	0.958	0.092
				2003	1.231	0.089
				2004	0.844	0.103
LCS05/06-DW-33	NMFS LL NE	FI	Base	1996	0.232	0.263
				1998	1.609	0.124
				2001	1.051	0.141
				2004	1.108	0.147
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	2.007	0.290
				1993	1.487	0.310
				1994	1.330	0.310
				1995	1.048	0.320
				1996	1.351	0.310
				1997	0.741	0.330
				1998	0.537	0.360
				1999	0.634	0.350
				2000	0.805	0.340
				2001	0.681	0.350
				2002	0.790	0.330
				2003	0.745	0.340
				2004	0.846	0.330
LCS05/06-DW-36	MRFSS - excluding requiem	FD - R	Sensitivity	1981	1.505	0.357
				1982	1.298	0.337
				1983	1.948	0.332
				1984	1.597	0.345
				1985	1.608	0.331
				1986	1.722	0.315
				1987	1.102	0.321
				1988	0.952	0.325
				1989	0.747	0.334
				1990	0.762	0.333
				1991	0.81	0.327
				1992	0.887	0.316
				1993	0.672	0.326
				1994	0.707	0.324
				1995	0.848	0.321
				1996	0.803	0.322
				1997	0.726	0.327
				1998	1.003	0.314
				1999	0.663	0.322
				2000	0.805	0.318
				2001	0.794	0.319
				2002	0.782	0.319
				2003	0.813	0.319

				2004	0.448	0.336
LCS05/06-DW-36	MRFSS - including requiem	FD - R	Sensitivity	1981	1.002	0.350
				1982	1.139	0.316
				1983	1.359	0.319
				1984	1.115	0.332
				1985	1.086	0.319
				1986	1.241	0.299
				1987	0.940	0.305
				1988	0.812	0.311
				1989	0.530	0.328
				1990	0.519	0.328
				1991	0.528	0.322
				1992	0.665	0.304
				1993	0.685	0.307
				1994	0.883	0.298
				1995	0.998	0.296
				1996	0.900	0.300
				1997	0.899	0.301
				1998	1.077	0.292
				1999	0.929	0.295
				2000	1.136	0.291
				2001	1.238	0.289
				2002	1.348	0.286
				2003	1.513	0.286
				2004	1.462	0.288
LCS05/06-DW-41	Charterboat	FD - C	NR	1989	1.145	0.469
				1990	1.031	0.125
				1991	1.080	0.121
				1992	0.837	0.118
				1993	0.945	0.125
				1994	0.928	0.156
				1995	1.036	0.152
LCS05/06-DW-45	SC LL Early	FI	Base	1984	1.79251	1
				1994	0.70317	1
				1995	0.50432	1

LCS minus prohibited species (11 species)

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-11	Gillnet Observer	FD - C	Base	1993	0.338	1.026
				1994	1.05	0.132
				1995	0.299	0.779
				1998	1.088	0.177
				1999	1.336	0.079
				2000	1.239	0.073
				2001	1.179	0.07
				2002	1.077	0.116
				2003	1.112	0.15
				2004	1.281	0.082
LCS05/06-DW-12	PC Longline	FI	Sensitivity	1993	0.816	0.730
				1994	0.386	0.894
				1995	1.272	0.610
				1996	0.858	0.583
				1997	0.926	0.539
				1998	0.725	0.967
				1999	1.174	0.564
				2000	1.844	0.508
LCS05/06-DW-12	PC Gillnet	FI	Base	1996	0.511	0.241
				1997	1.637	0.132
				1998	0.607	0.310
				1999	0.969	0.297
				2000	0.811	0.326
				2001	1.549	0.211
				2002	0.936	0.201
				2003	1.072	0.186
				2004	0.908	0.220
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.676	0.238
				1995	0.972	0.172
				1996	0.907	0.153
				1997	0.774	0.295
				1998	1.113	0.172
				1999	1.108	0.253
				2000	1.168	0.333
				2001	0.926	0.242
				2002	1.187	0.160
				2003	1.206	0.131
				2004	0.962	0.150
LCS05/06-DW-24	MS Gillnet	FI	Sensitivity	1998	0.566	0.528
				1999	0.337	0.574

				2000	1.981	0.421
				2001	0.576	0.717
				2003	0.399	0.741
				2004	0.472	0.598
				2005	2.670	0.455
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	0.848	0.135
				1996	0.438	0.203
				1997	0.628	0.128
				1999	0.501	0.150
				2000	1.044	0.083
				2001	1.127	0.106
				2002	1.207	0.080
				2003	1.850	0.105
				2004	1.356	0.107
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.574	0.152
				1997	0.927	0.110
				1998	0.839	0.103
				1999	1.103	0.092
				2000	1.188	0.101
				2001	1.165	0.099
				2002	1.011	0.097
				2003	1.287	0.094
				2004	0.907	0.107
LCS05/06-DW-33	NMFS LL NE	FI	Base	1996	0.258	2.973
				1998	1.750	0.578
				2001	1.037	0.880
				2004	0.955	0.953
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	1.672	0.310
				1993	1.299	0.320
				1994	1.265	0.320
				1995	1.057	0.330
				1996	1.280	0.320
				1997	0.752	0.340
				1998	0.571	0.360
				1999	0.626	0.360
				2000	0.890	0.340
				2001	0.764	0.350
				2002	0.940	0.340
				2003	0.914	0.340
				2004	0.970	0.340
LCS05/06-DW-36	MRFSS - excluding requiem	FD - R	Sensitivity	1981	1.807	0.600
				1982	1.820	0.543
				1983	2.571	0.547
				1984	2.468	0.558
				1985	1.895	0.544

				1986	2.453	0.510
				1987	1.165	0.536
				1988	0.953	0.540
				1989	0.742	0.563
				1990	0.552	0.600
				1991	0.563	0.574
				1992	0.913	0.532
				1993	0.384	0.573
				1994	0.220	0.633
				1995	0.581	0.545
				1996	0.721	0.535
				1997	0.656	0.563
				1998	0.876	0.538
				1999	0.553	0.548
				2000	0.498	0.568
				2001	0.520	0.558
				2002	0.493	0.561
				2003	0.407	0.597
				2004	0.189	0.663
LCS05/06-DW-36	MRFSS - including requiem	FD - R	Sensitivity	1981	0.884	0.37
				1982	1.097	0.325
				1983	1.301	0.328
				1984	1.071	0.341
				1985	1.063	0.327
				1986	1.256	0.305
				1987	0.908	0.312
				1988	0.789	0.318
				1989	0.498	0.34
				1990	0.533	0.336
				1991	0.494	0.334
				1992	0.641	0.312
				1993	0.699	0.312
				1994	0.879	0.304
				1995	1.033	0.301
				1996	0.903	0.305
				1997	0.908	0.307
				1998	1.102	0.297
				1999	0.953	0.3
				2000	1.149	0.296
				2001	1.297	0.293
				2002	1.423	0.291
				2003	1.579	0.29
				2004	1.541	0.292

LCS minus prohibited species, blacktip, and sandbar sharks (9 species)

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-11	Gillnet Observer	FD - C	Base	1993	0.754	0.546
				1994	0.918	0.150
				1995	0.537	0.494
				1998	1.037	0.269
				1999	1.203	0.107
				2000	1.246	0.094
				2001	1.167	0.087
				2002	1.092	0.121
				2003	0.952	0.202
				2004	1.094	0.141
LCS05/06-DW-12	PC Gillnet	FI	Base	1996	0.328	0.532
				1997	1.197	0.272
				1998	0.521	0.494
				1999	0.973	0.463
				2000	1.112	0.411
				2001	1.682	0.309
				2002	1.129	0.280
				2003	1.022	0.276
				2004	1.034	0.314
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.614	0.298
				1995	0.756	0.278
				1996	0.810	0.281
				1997	0.903	0.291
				1998	1.298	0.257
				1999	1.067	0.286
				2000	1.056	0.313
				2001	0.983	0.278
				2002	1.478	0.278
				2003	0.959	0.281
				2004	1.078	0.273
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	0.946	0.152
				1996	0.381	0.236
				1997	0.608	0.145
				1999	0.508	0.186
				2000	1.176	0.092
				2001	1.108	0.125
				2002	1.187	0.095
				2003	1.746	0.132
				2004	1.341	0.120
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.709	0.266

				1997	0.680	0.199
				1998	0.626	0.199
				1999	1.170	0.167
				2000	1.044	0.184
				2001	1.095	0.176
				2002	1.490	0.175
				2003	1.286	0.167
				2004	0.900	0.225
LCS05/06-DW-33	NMFS LL NE	FI	Base	1996	0.212	6.866
				1998	1.127	1.735
				2001	1.282	1.292
				2004	1.379	1.244
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	1.814	0.250
				1993	1.298	0.260
				1994	1.431	0.260
				1995	0.962	0.270
				1996	1.030	0.260
				1997	0.648	0.270
				1998	0.592	0.280
				1999	0.763	0.270
				2000	0.906	0.270
				2001	0.749	0.270
				2002	0.858	0.270
				2003	0.915	0.270
				2004	1.035	0.270

Blacktip - Gulf of Mexico

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-12	PC Longline	FI	Sensitivity	1993	0.768	1.288
				1994	0.133	3.244
				1995	1.018	1.244
				1996	0.758	1.087
				1997	1.299	0.704
				1998	0.974	1.328
				1999	1.136	1.011
				2000	1.914	0.92
LCS05/06-DW-12	PC Gillnet	FI	Base	1996	0.695	0.475
				1997	1.397	0.287
				1998	0.565	0.451
				1999	1.209	0.359
				2000	0.769	0.484
				2001	1.583	0.286
				2002	0.872	0.283
				2003	0.909	0.283
				2004	1.001	0.307
LCS05/06-DW-12	PC Gillnet - juveniles	FI	Base	1996	0.980	0.427
				1997	1.513	0.279
				1998	0.639	0.455
				1999	1.068	0.412
				2000	0.649	0.632
				2001	1.408	0.312
				2002	0.854	0.305
				2003	0.790	0.318
				2004	1.098	0.294
LCS05/06-DW-12	PC Gillnet - Age 0	FI	Base	1996	0.152	1.063
				1997	0.782	0.397
				1998	0.654	0.586
				1999	2.101	0.388
				2000	0.676	0.737
				2001	2.130	0.35
				2002	1.260	0.293
				2003	1.012	0.334
				2004	0.232	0.823
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.430	1.666
				1995	0.817	0.855
				1996	0.724	1.215
				1997	0.588	2.248
				1998	0.796	1.620

				1999	1.055	1.270
				2001	0.162	9.019
				2002	2.062	0.496
				2003	1.542	0.509
				2004	1.824	0.401
LCS05/06-DW-24	MS Gillnet	FI	Sensitivity	1998	0.584	0.572
				1999	0.352	0.590
				2000	2.771	0.404
				2001	0.565	0.717
				2003	0.374	0.751
				2004	0.413	0.624
				2005	1.940	0.491
LCS05/06-DW-24	MS Gillnet - juveniles	FI	Sensitivity	1998	0.835	0.683
				1999	0.412	0.887
				2000	2.655	0.336
				2001	0.409	1.892
				2003	0.092	1.722
				2004	0.198	1.443
				2005	2.398	0.791
LCS05/06-DW-24	MS Gillnet - Age 0	FI	Sensitivity	1998	0.200	0.684
				1999	0.245	1.011
				2000	3.136	0.556
				2001	0.302	1.633
				2003	0.660	0.764
				2004	0.134	1.177
				2005	2.323	0.982
LCS05/06-DW-26	Mote Gillnet - Yankeetown	FI	Sensitivity	1995	0.578	1.287
				1996	1.564	0.910
				1997	1.299	1.186
				1999	0.541	1.368
				2000	0.530	1.836
				2001	0.966	1.521
				2002	0.823	1.463
				2003	1.126	1.256
				2004	1.574	0.994
LCS05/06-DW-26	Mote Gillnet - Charlotte Harbor	FI	Sensitivity	1995	1.143	1.273
				1997	0.444	2.328
				1999	0.901	1.358
				2000	1.851	0.944
				2002	1.502	1.147
				2003	0.564	1.885

				2004	0.595	1.498
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	0.554	0.682
				1996	0.380	0.788
				1997	0.409	0.634
				1999	0.341	0.630
				2000	1.517	0.327
				2001	0.898	0.353
				2002	1.436	0.327
				2003	2.237	0.242
				2004	1.228	0.307
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.249	0.362
				1997	0.931	0.236
				1998	0.334	0.247
				1999	1.506	0.219
				2000	0.883	0.240
				2001	0.985	0.225
				2002	1.078	0.210
				2003	1.967	0.199
				2004	1.068	0.232
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	2.240	0.540
				1993	1.541	0.590
				1994	2.358	0.570
				1995	1.572	0.590
				1996	0.838	0.630
				1997	0.924	0.630
				1998	0.808	0.660
				1999	0.364	0.790
				2000	0.706	0.680
				2001	0.689	0.690
				2002	0.484	0.760
				2003	0.328	0.790
				2004	0.149	1.090
LCS05/06-DW-36	MRFSS	FD - R	Sensitivity	1981	1.358	0.565
				1982	0.325	0.557
				1983	1.130	0.555
				1984	0.673	0.553
				1985	0.816	0.505
				1986	1.452	0.406
				1987	0.636	0.441
				1988	1.319	0.400
				1989	1.186	0.436
				1990	1.318	0.428
				1991	1.477	0.419
				1992	0.877	0.391
				1993	0.772	0.418
				1994	0.726	0.409

1995	1.027	0.409
1996	1.159	0.403
1997	1.090	0.401
1998	1.471	0.372
1999	0.737	0.382
2000	1.259	0.370
2001	0.661	0.390
2002	0.719	0.381
2003	1.064	0.378
2004	0.747	0.387

Blacktip Shark - Atlantic

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-11	Gillnet Observer	FD - C	Base	1993	0.455	0.888
				1994	0.955	0.174
				1995	0.419	0.681
				1998	1.286	0.164
				1999	1.384	0.081
				2000	1.286	0.068
				2001	1.001	0.098
				2002	0.982	0.145
				2003	1.029	0.187
				2004	1.204	0.122
LCS05/06-DW-14	SC LL Recent	FI	Sensitivity	1995	1.750	0.384
				1996	0.808	0.437
				1997	2.094	0.276
				1998	0.487	0.525
				1999	0.482	0.652
				2000	1.147	0.291
				2001	0.232	1.123
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.805	2.423
				1995	2.042	0.854
				1996	1.246	1.640
				1997	0.131	9.878
				1998	0.534	3.352
				1999	0.426	3.775
				2000	0.153	8.354
				2001	0.971	2.814
				2002	4.578	0.012
				2003	0.004	39.339
				2004	0.111	6.517
LCS05/06-DW-27	NMFS LL SE	FI	NR	1995	0	
				1996	0.453	4.403
				1997	0.244	2.725
				1999	0.811	1.706
				2000	0	
				2002	2.748	0.649
				2004	0.745	3.586
				2005	0	
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.678	0.370
				1997	0.474	0.512
				1998	0.689	0.352
				1999	0.423	0.459

				2000	1.005	0.371
				2001	1.620	0.327
				2002	1.948	0.264
				2003	1.081	0.333
				2004	1.083	0.447
LCS05/06-DW-33	NMFS LL NE	FI	Sensitivity	1996	0.202	49.744
				1998	1.578	8.270
				2001	0.797	14.861
				2004	1.423	9.114
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	2.970	0.650
				1993	2.272	0.700
				1994	1.960	0.720
				1995	0.975	0.910
				1996	0.987	0.910
				1997	0.710	1.050
				1998	0.481	1.260
				1999	0.504	1.260
				2000	0.363	1.470
				2001	0.286	1.660
				2002	0.362	1.510
				2003	0.452	1.360
				2004	0.678	1.150
LCS05/06-DW-36	MRFSS	FD - R	Sensitivity	1981	1.046	1.023
				1982	0.531	0.787
				1983	1.186	0.718
				1984	1.145	0.747
				1985	1.285	0.621
				1986	1.427	0.577
				1987	0.755	0.637
				1988	0.578	0.681
				1989	0.567	0.684
				1990	0.421	0.755
				1991	0.748	0.627
				1992	1.243	0.545
				1993	0.523	0.687
				1994	2.264	0.511
				1995	1.039	0.577
				1996	0.986	0.577
				1997	0.515	0.660
				1998	1.183	0.546
				1999	0.536	0.633
				2000	0.877	0.583
				2001	1.730	0.529
				2002	1.196	0.550
				2003	1.249	0.560
				2004	0.969	0.585

Sandbar

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-09	LPS	FD - R	Base	1986	3.557	0.173
				1987	0.859	0.323
				1988	2.326	0.209
				1989	3.204	0.136
				1990	1.008	0.247
				1991	2.327	0.264
				1992	1.382	0.233
				1993	0.739	0.872
				1994	0.378	0.755
				1995	0.302	1.255
				1996	0.369	1.092
				1997	0.530	0.834
				1998	0.124	2.138
				1999	0.202	1.994
				2000	0.213	1.990
				2001	0.986	1.064
				2002	0.236	1.721
				2003	0.181	1.663
				2004	0.076	2.136
LCS05/06-DW-12	PC Gillnet	FI	Sensitivity	1996	1.00*	1.667
				1997	2.250	2.963
	* nominal index			1998	1.220	4.773
				1999	0.530	6.789
				2000	0.690	7.200
				2001	1.250	6.667
				2002	0.610	7.273
				2003	0.970	5.429
				2004	0.470	7.588
LCS05/06-DW-14	SC LL Recent	FI	Sensitivity	1995	0.458	1.049
				1996	0.964	0.446
				1997	0.643	0.576
				1998	0.750	0.377
				1999	2.547	0.207
				2000	0.666	0.396
				2001	0.972	0.344
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.799	1.027
				1995	0.882	0.832
				1996	1.000	0.843
				1997	0.956	1.182
				1998	1.292	1.391
				1999	0.849	1.529

				2000	0.744	2.009
				2001	1.650	1.600
				2002	0.865	1.266
				2003	1.007	0.902
				2004	0.955	0.976
LCS05/06-DW-20	VA LL	FI	Base	1975	1.900	0.23271
				1977	2.077	0.28711
				1978	1.085	0.58275
				1980	1.995	0.20558
				1981	1.925	0.21419
				1984	0.647	1.01363
				1986	0.665	1.08966
				1989	0.911	0.35817
				1990	0.746	0.29514
				1991	0.788	0.30447
				1992	1.331	0.46767
				1993	0.915	0.40248
				1995	0.860	0.26193
				1996	0.770	0.27439
				1997	0.721	0.22527
				1998	0.826	0.20952
				1999	0.528	0.36478
				2000	0.865	0.28108
				2001	0.754	0.23611
				2002	0.626	0.34985
				2003	0.547	0.26489
				2004	0.519	0.37114
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	1.293	0.281
				1996	0.831	0.379
				1997	1.301	0.316
				1999	0.390	0.384
				2000	0.971	0.210
				2001	1.041	0.256
				2002	1.072	0.207
				2003	0.880	0.261
				2004	1.221	0.322
LCS05/06-DW-30	DE Bay	FI	Base	2001	0.950	0.205
				2002	0.386	0.332
				2003	1.409	0.182
				2004	1.070	0.212
				2005	1.185	0.212
LCS05/06-DW-30	DE Bay - Age 0	FI	Base	2001	0.645	0.373
				2002	0.518	0.442
				2003	1.776	0.272
				2004	0.877	0.357
				2005	1.183	0.311

LCS05/06-DW-30	DE Bay - juveniles	FI	Base	2001	1.162	0.184
				2002	0.325	0.377
				2003	1.163	0.194
				2004	1.164	0.207
				2005	1.185	0.199
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.789	0.175
				1997	1.002	0.116
				1998	0.919	0.111
				1999	1.150	0.102
				2000	1.171	0.111
				2001	1.115	0.104
				2002	0.887	0.104
				2003	1.170	0.102
				2004	0.798	0.119
LCS05/06-DW-33	NMFS LL NE	FI	Base	1996	0.321	7.985
				1998	2.045	1.678
				2001	1.004	2.947
				2004	0.629	4.909
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1994	0.083	1.270
				1995	0.854	0.650
				1996	2.050	0.600
				1997	0.770	0.660
				1998	0.883	0.660
				1999	1.024	0.670
				2000	1.167	0.660
				2001	1.032	0.670
				2002	0.707	0.690
				2003	0.872	0.690
				2004	1.557	0.650
LCS05/06-DW-36	MRFSS	FD - R	Sensitivity	1981	2.011	0.645
				1982	2.195	0.592
				1983	2.766	0.592
				1984	2.408	0.610
				1985	2.094	0.591
				1986	2.119	0.560
				1987	1.167	0.594
				1988	0.789	0.621
				1989	0.714	0.639
				1990	0.634	0.674
				1991	0.431	0.679
				1992	0.874	0.600
				1993	0.402	0.679
				1994	0.243	0.776
				1995	0.492	0.643
				1996	0.612	0.617

1997	0.504	0.663
1998	0.917	0.603
1999	0.524	0.639
2000	0.525	0.660
2001	0.503	0.651
2002	0.490	0.656
2003	0.386	0.714
2004	0.201	0.836

Table 3.3. Indices recommended as base case indices.

LCS*	Blacktip - Gulf of Mexico	Blacktip - Atlantic	Sandbar
Gillnet Observer	PC Gillnet	Gillnet Observer	LPS
PC Gillnet	PC Gillnet - Juveniles	BLLOP	BLLOP
ENP	PC Gillnet - Age 0	Bottom LL Logs	VA LL
SC LL Recent	BLLOP	Pelagic Log	NMFS LL SE
BLLOP	NMFS LL SE		DE Bay
VA LL	Bottom LL Logs		DE Bay - Age 0
NMFS LL SE	Pelagic Log		DE Bay - Juveniles
Bottom LL Logs			Bottom LL Logs
NMFS LL NE			NMFS LL NE
Pelagic Log			Pelagic Log
SC LL Early			

*3 scenarios

Table 3.4. Indices recommended for use in sensitivity runs.

LCS*	Blacktip - Gulf of Mexico	Blacktip - Atlantic	Sandbar
PC LL	PC LL	SC LL Recent	PC Gillnet
MS Gillnet	MS Gillnet	NMFS LL NE	SC LL Recent
Port Salerno	MS Gillnet - Juveniles	MRFSS	MRFSS
Crooke LL	MS Gillnet - Age 0		
MRFSS - excluding requiem group	MRFSS		
MRFSS - including requiem group	Mote Gillnet - Yankeetown		
	Mote Gillnet - Charlotte Harbor		

*3 scenarios

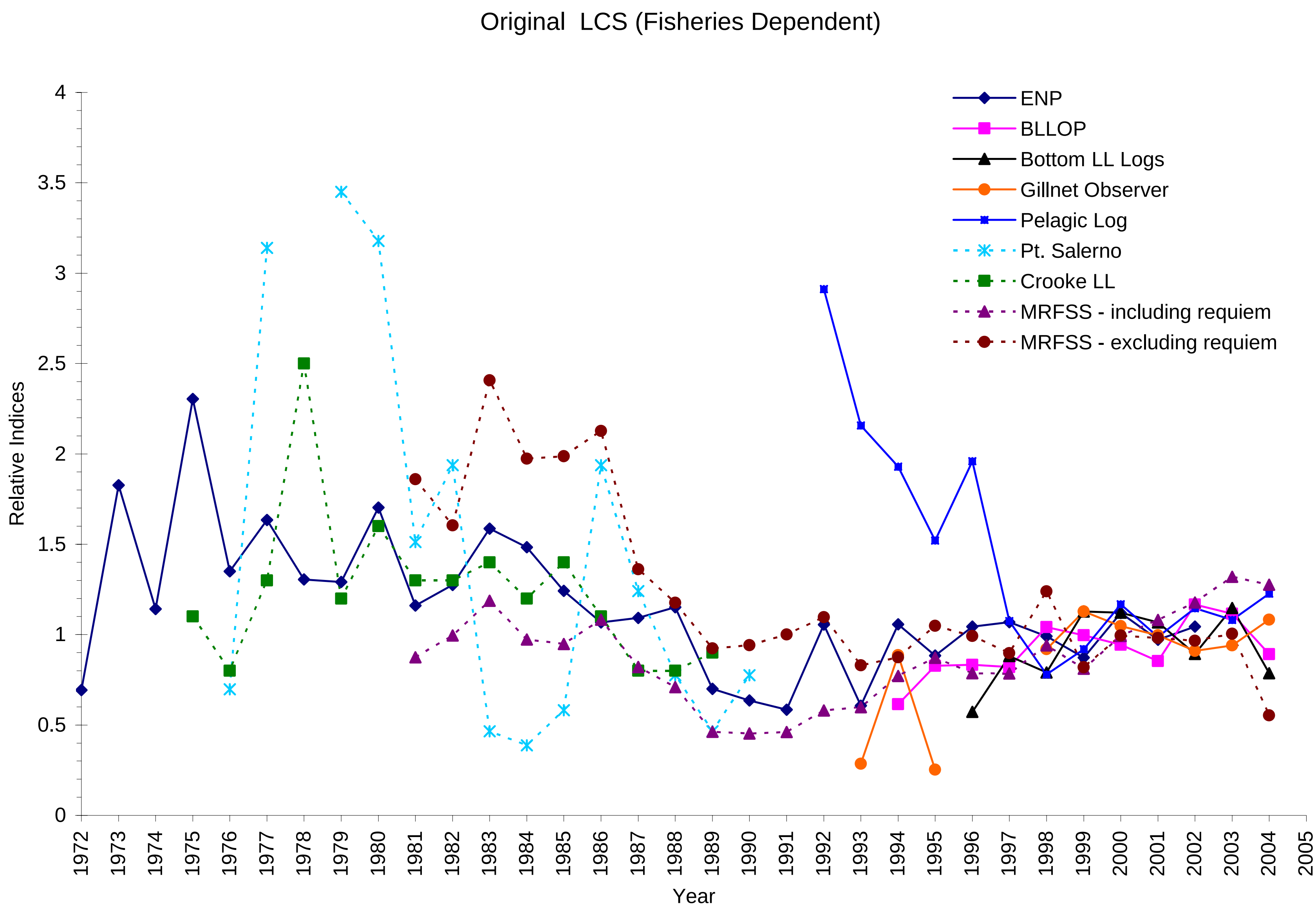

Figure 3.1. Fishery dependent catch rate series for the original large coastal shark complex containing 22 species. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

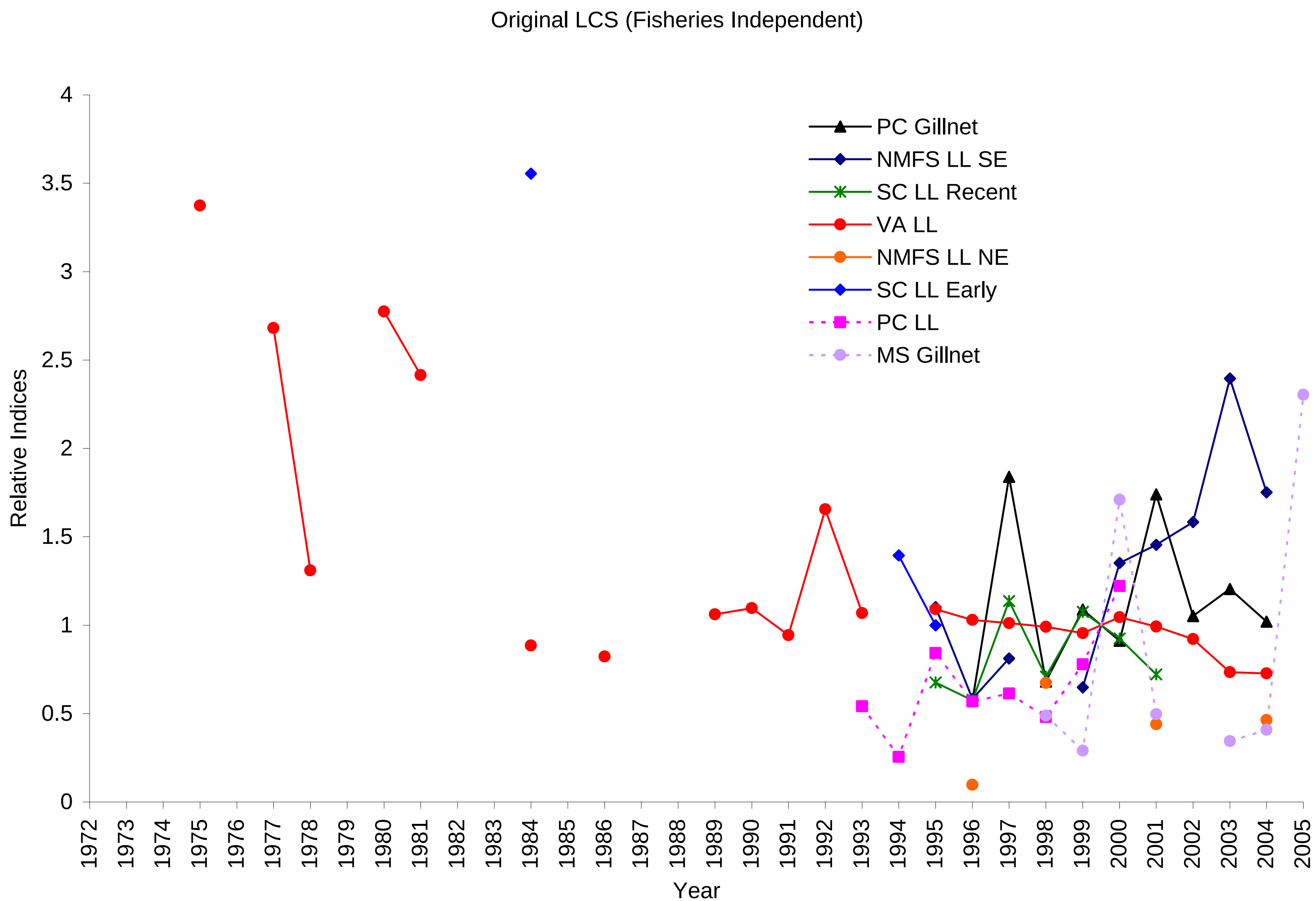

Figure 3.2. Fishery independent catch rate series for the original large coastal shark complex containing 22 species. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

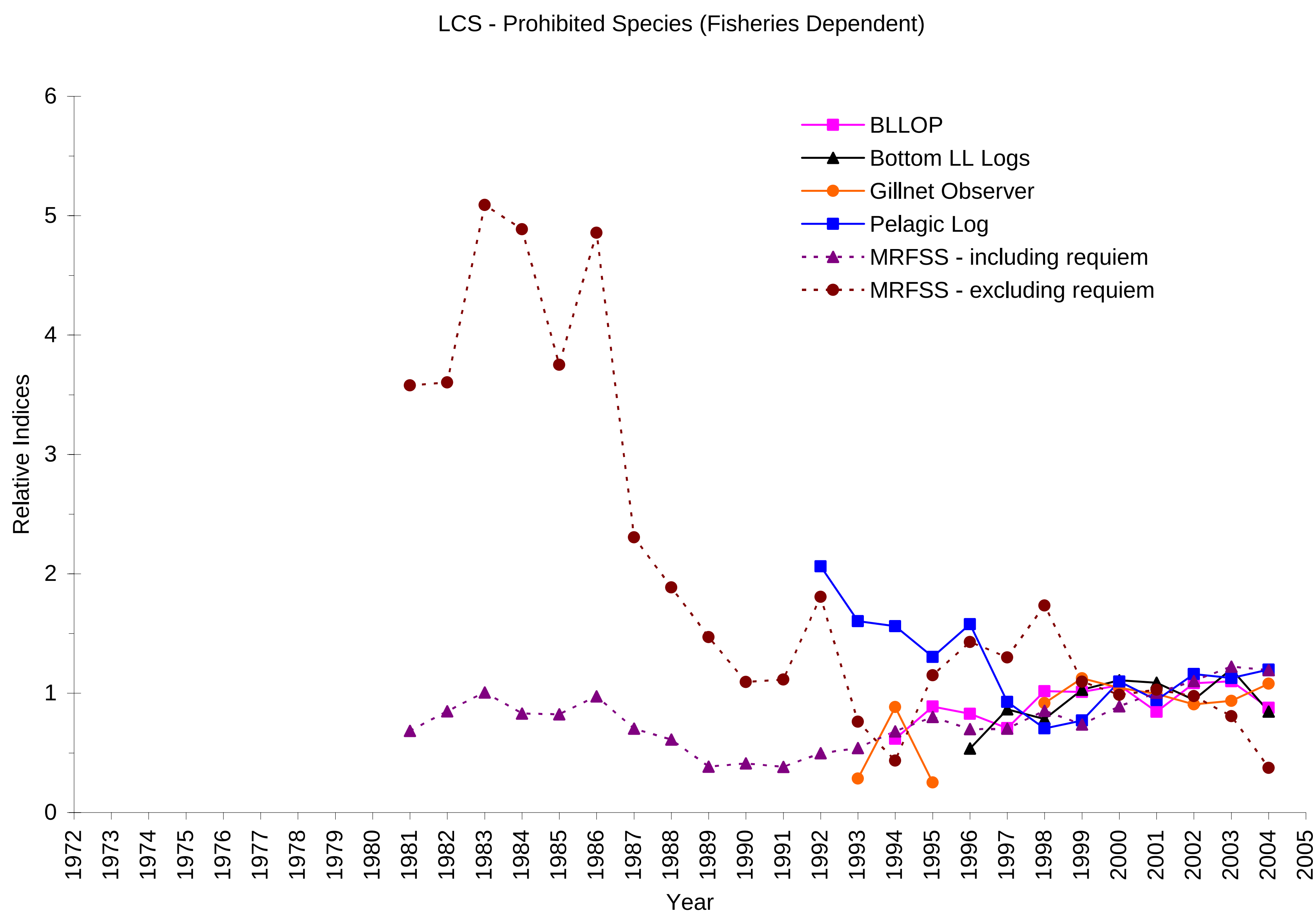

Figure 3.3. Fishery dependent catch rate series for the large coastal shark complex minus prohibited species (11 species). Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

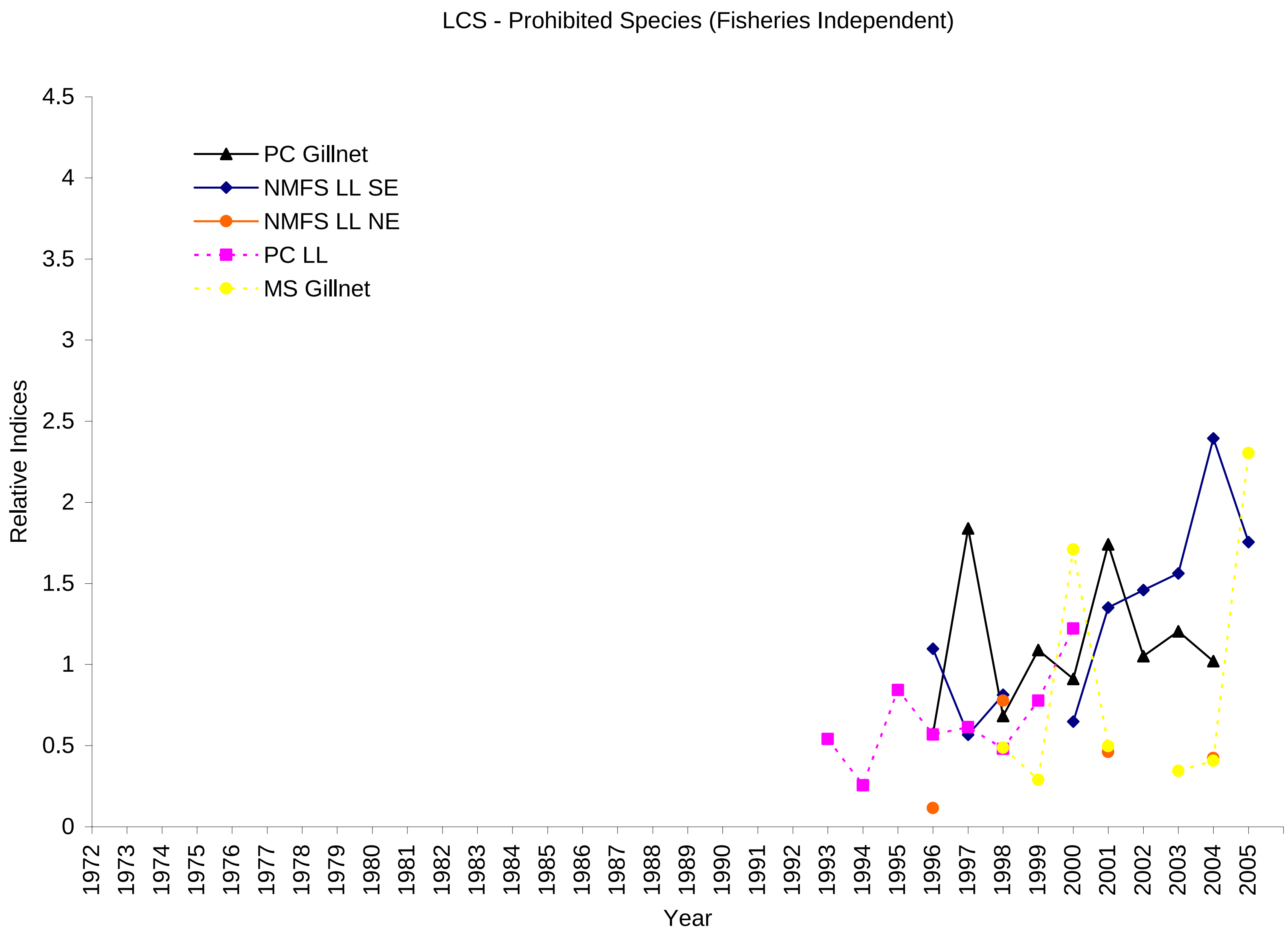

Figure 3.4. Fishery independent catch rate series for the large coastal shark complex minus prohibited species (11 species). Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

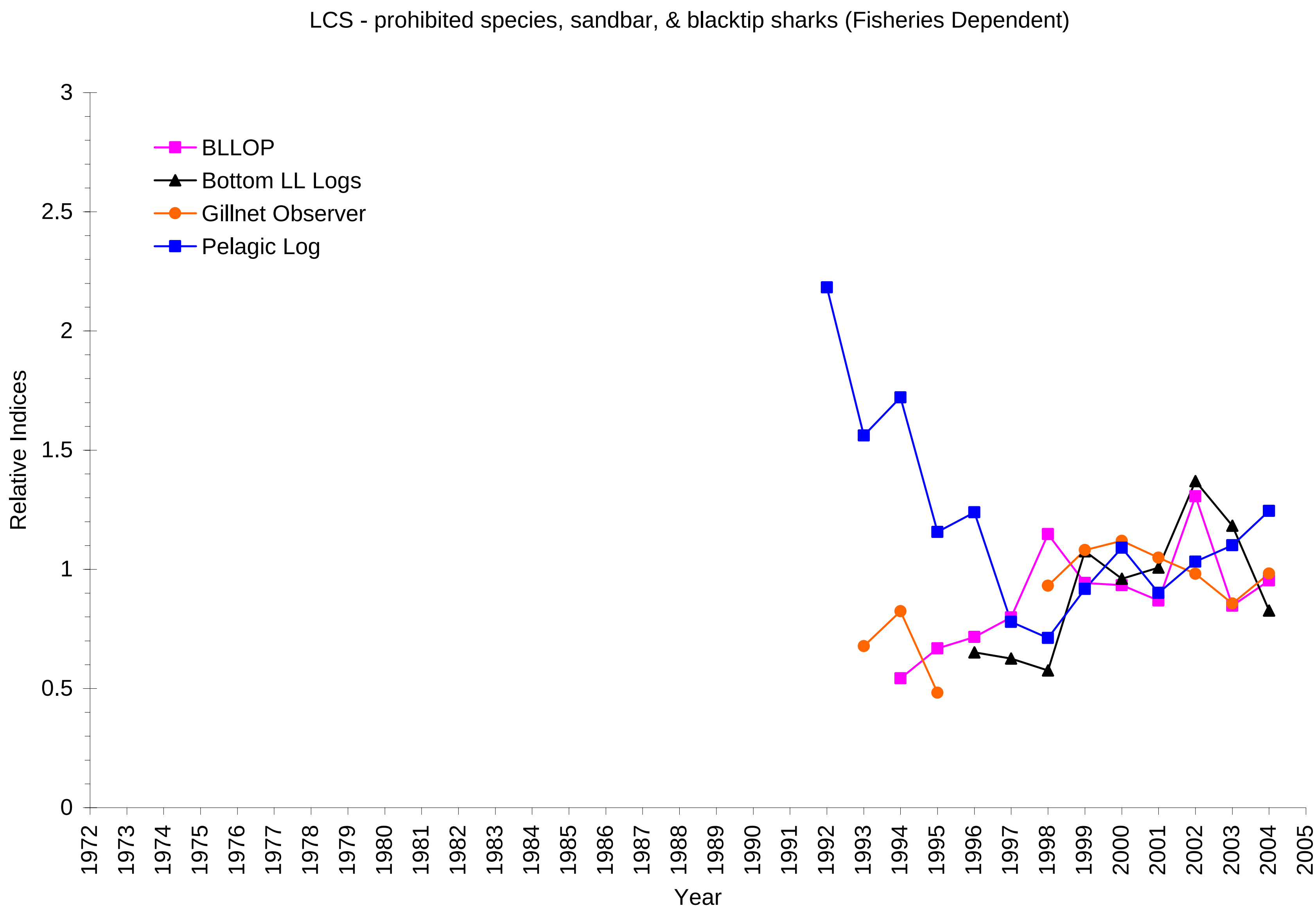

Figure 3.5. Fishery dependent catch rate series for the large coastal shark complex minus prohibited species, blacktip, and sandbar sharks (9 species). Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

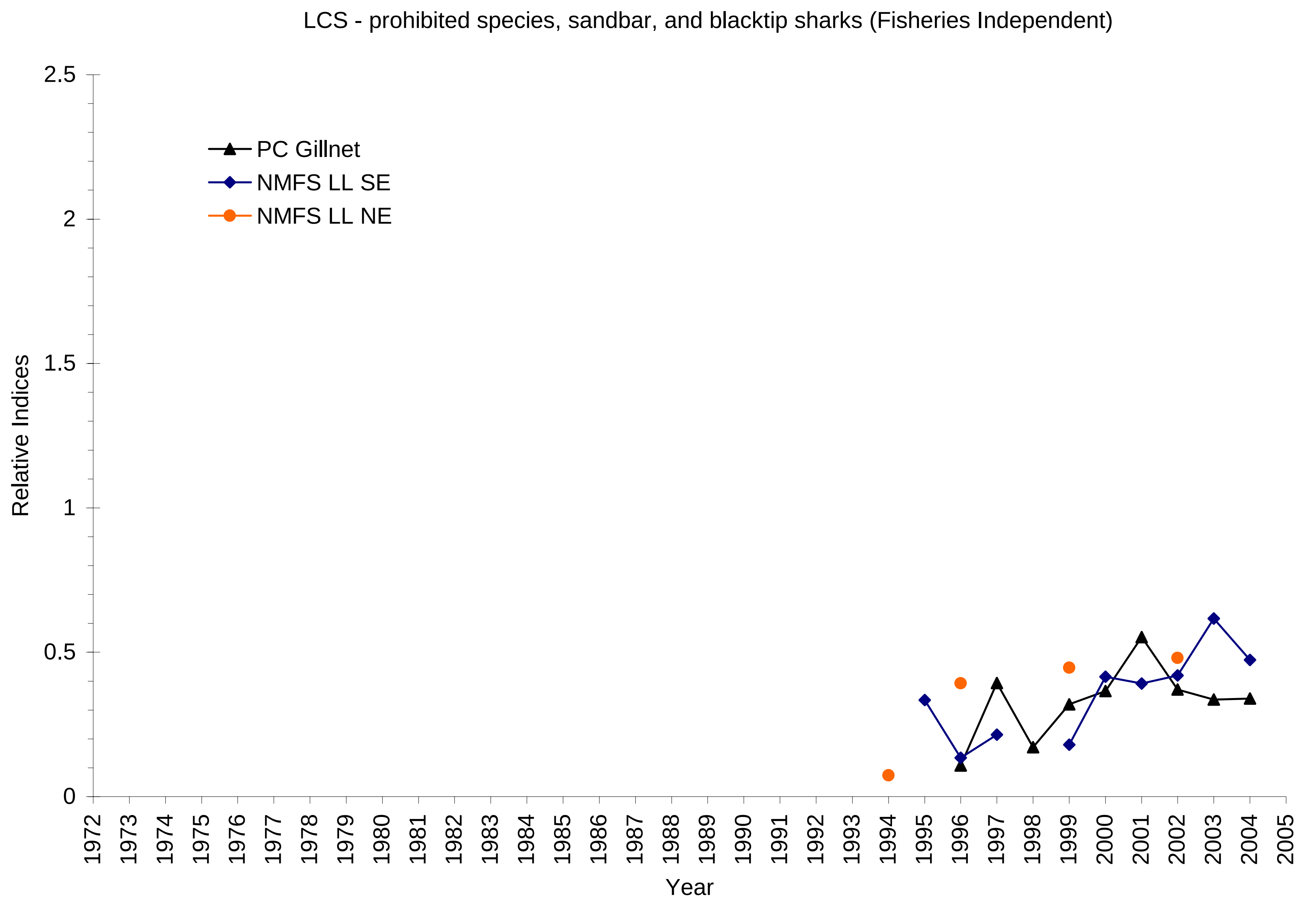

Figure 3.6. Fishery independent catch rate series for the large coastal shark complex minus prohibited species, blacktip, and sandbar sharks (9 species). Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

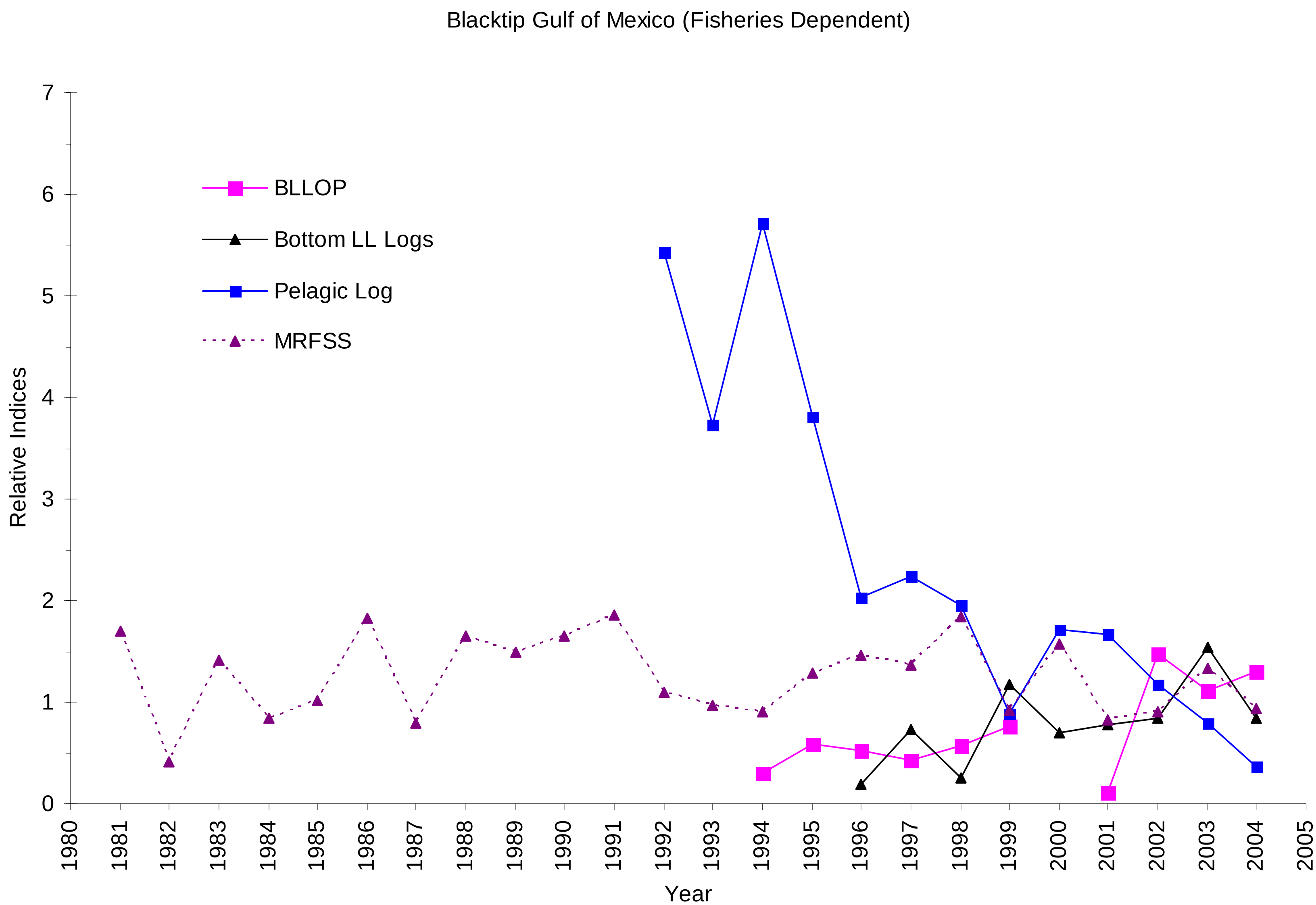

Figure 3.7. Fishery dependent catch rate series for blacktip sharks from the Gulf of Mexico. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

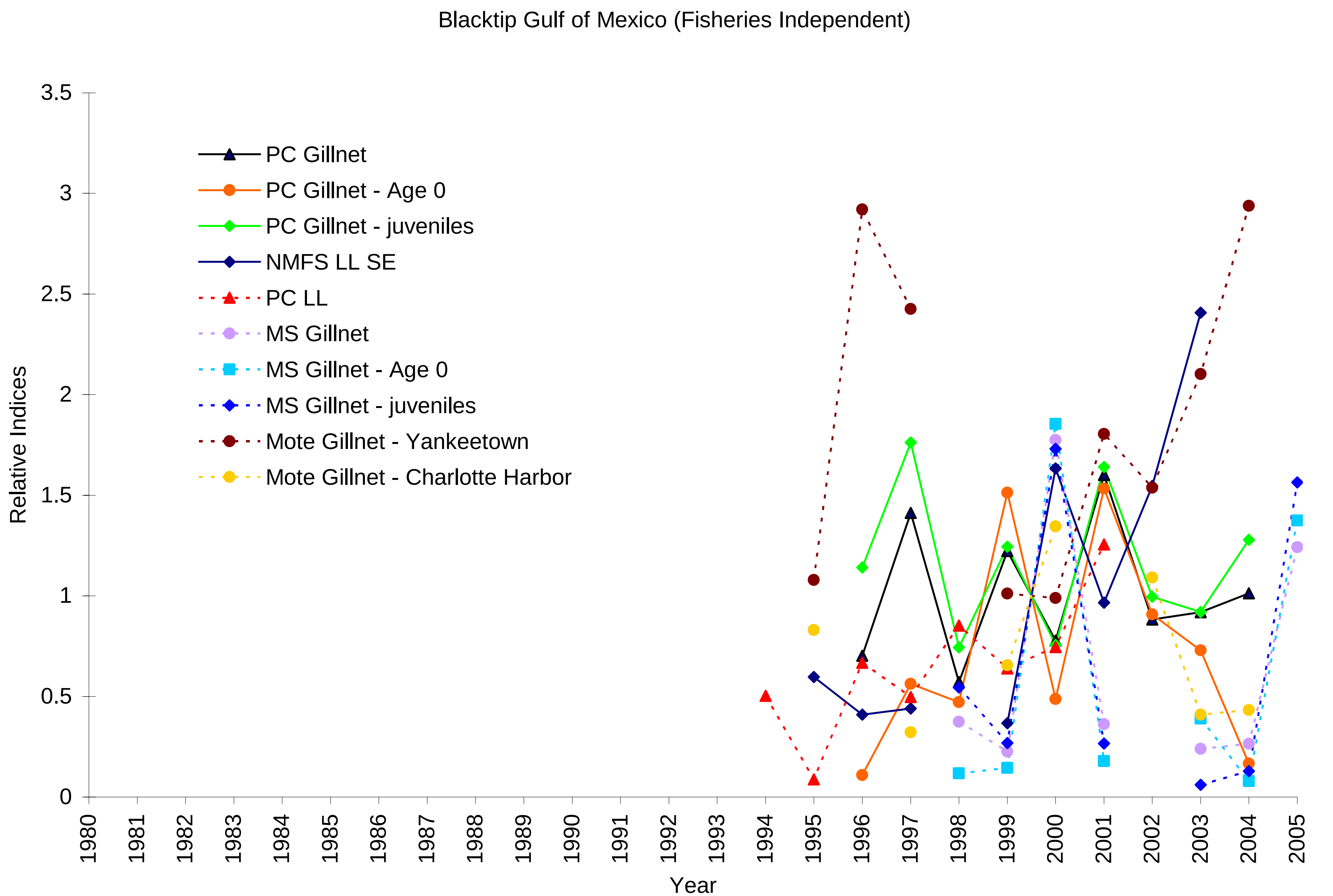

Figure 3.7. Fishery independent catch rate series for blacktip sharks from the Gulf of Mexico. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

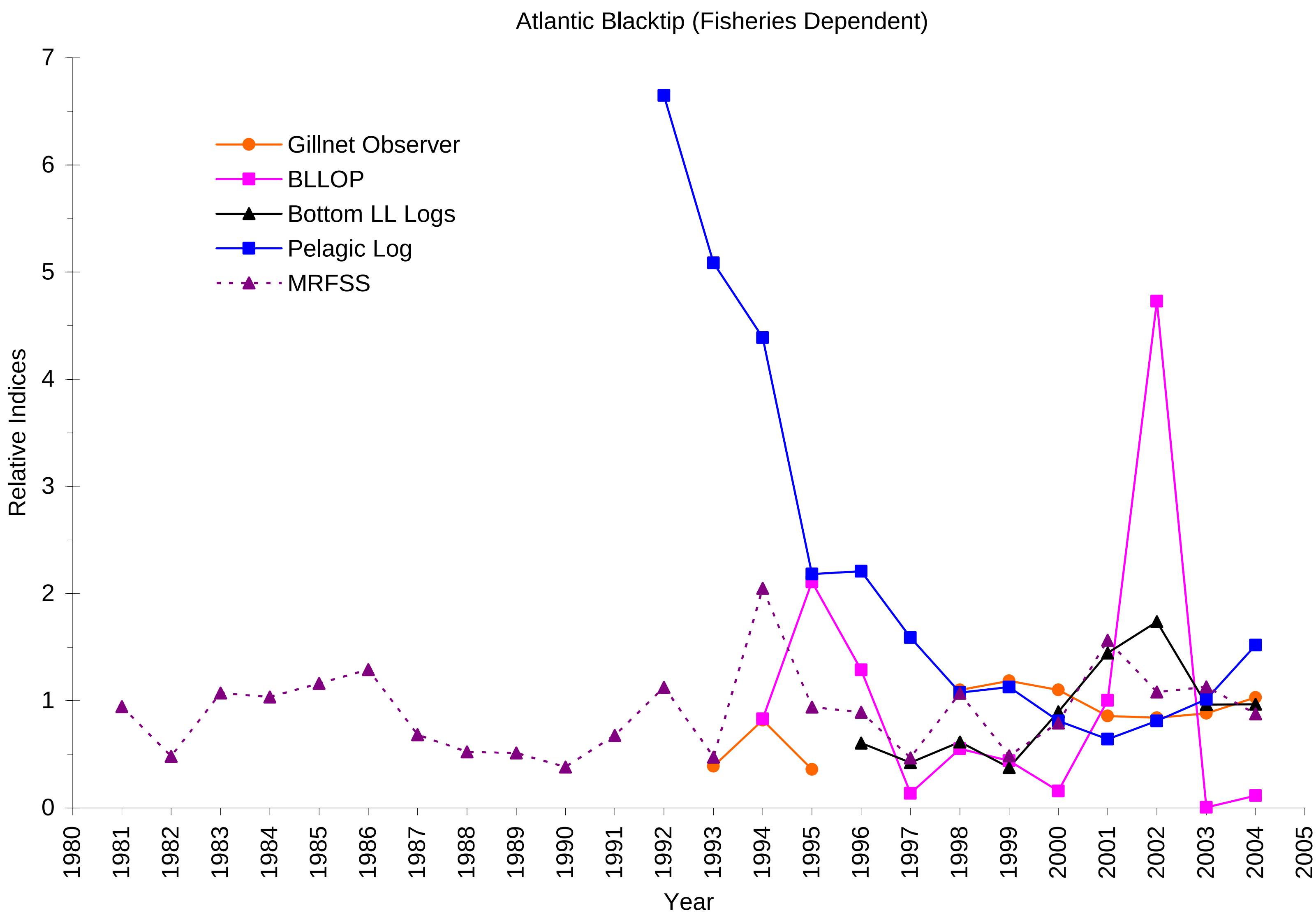

Figure 3.9. Fishery dependent catch rate series for blacktip sharks from the western Atlantic Ocean. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

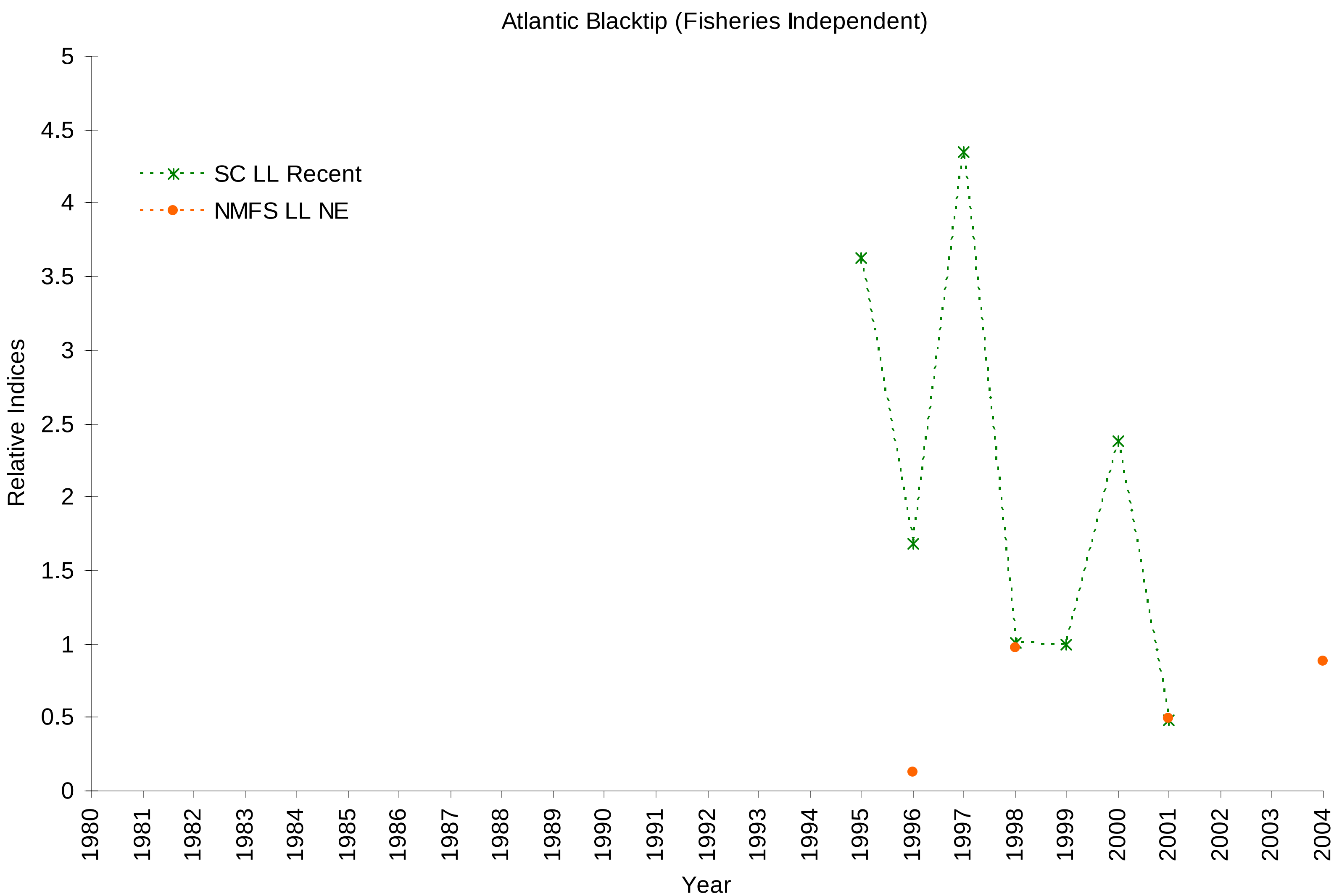

Figure 3.10. Fishery independent catch rate series for blacktip sharks from the western Atlantic Ocean. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

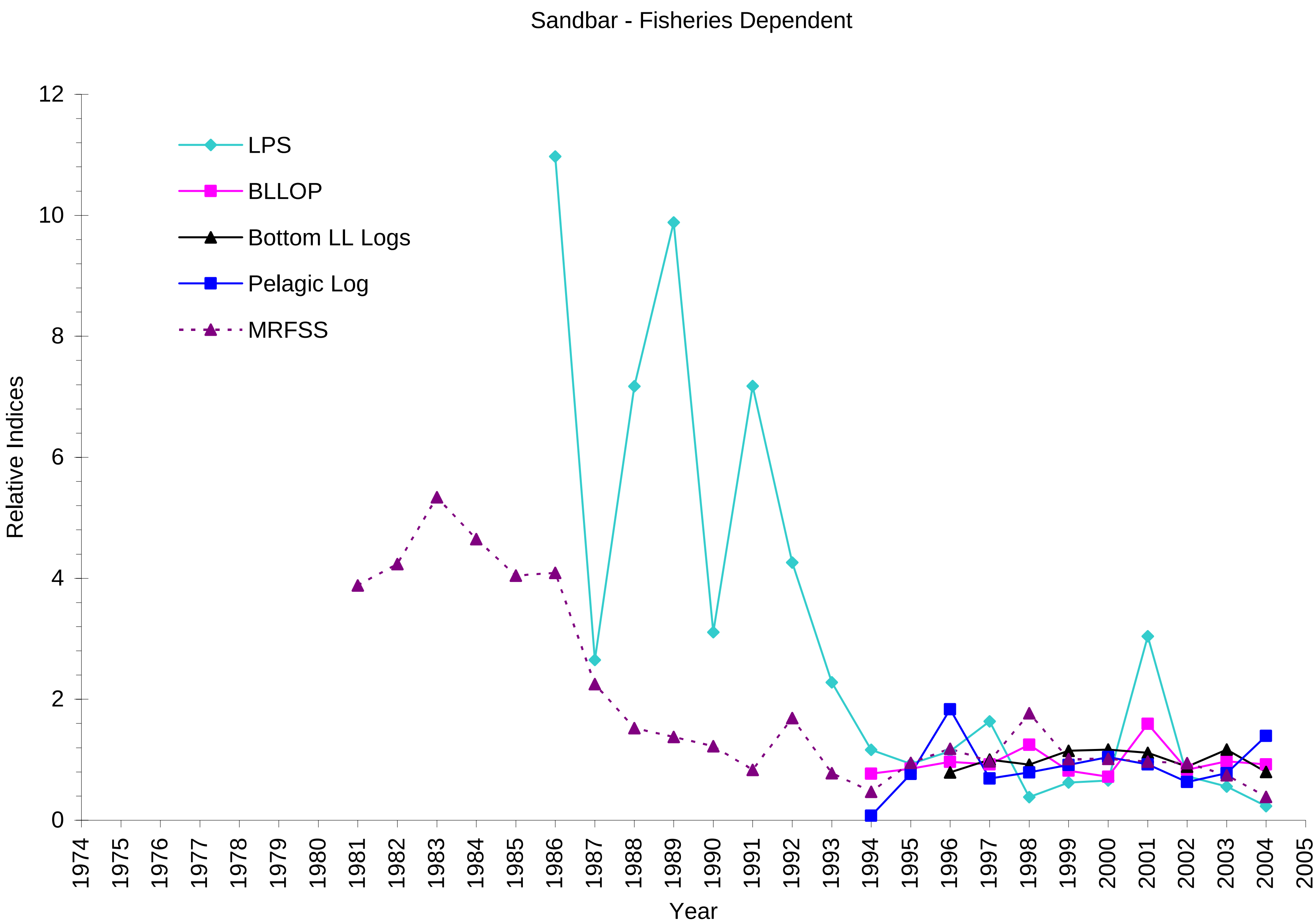

Figure 3.11. Fishery dependent catch rate series for sandbar sharks. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

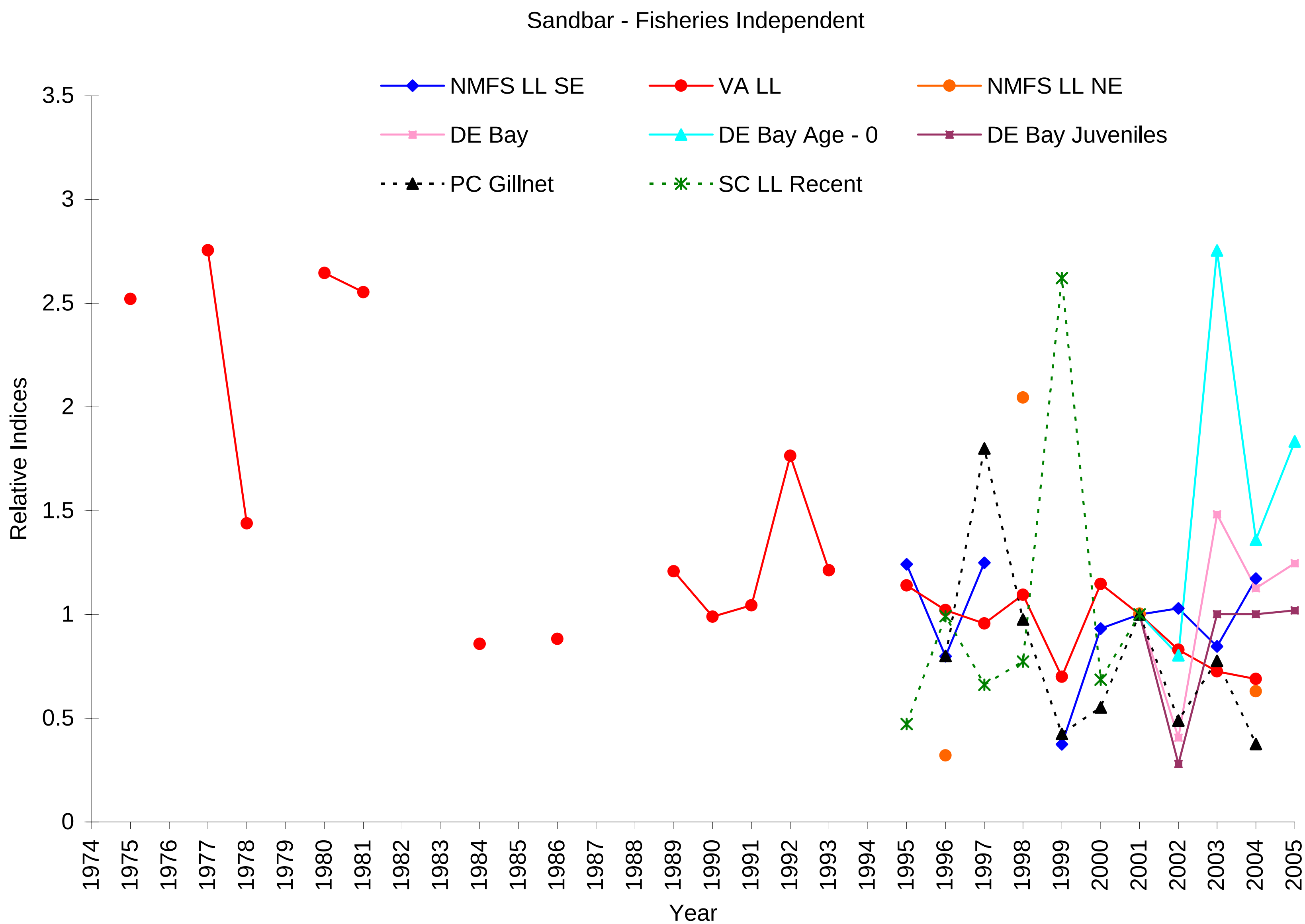

Figure 3.12. Fishery independent catch rate series for sandbar sharks. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

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LCS Data Workshop Working Documents

LCS05/06-DW-01 Anonymous: Documentation for the North Carolina Division of Marine Fisheries catch rate series (NC#)

LCS05/06-DW-02 Anonymous: Description of estimates of unreported catches

LCS05/06-DW-03 Anonymous: Final Meeting Report of the 2002 Shark Evaluation Workshop. NOAA NMFS Panama City Laboratory, Panama City Beach, FL. June 24-28, 2002. Final Meeting Report, 20 August 2002.

LCS05/06-DW-04 Balchowsky & Poffenberger: Description of the Databases that Contain Landings of Shark Species from the Atlantic Ocean and Gulf of Mexico

LCS05/06-DW-05 Beerkircher et al.: SEFSC Pelagic Observer Program data summary for 1992-2000

LCS05/06-DW-06 Bonfil & Babcock: Estimation of catches of sandbar (*Carcharhinus plumbeus*) and blacktip (*C. limbatus*) sharks in the Mexican fisheries of Gulf of Mexico

LCS05/06-DW-07 Brewster-Geisz & Eytcheson: Illegal Fishing off the coast of Texas by Mexican Lanchas

LCS05/06-DW-08 Brewster-Geisz: A summary of the management of Atlantic Large Coastal Sharks

LCS05/06-DW-09 Brown: Standardized catch rates of sandbar (*Carcharhinus plumbeus*) sharks in the Virginia - Massachusetts (U.S.) rod and reel fishery 1986 - 2004

LCS05/06-DW-10 Carlson et al.: Life history parameters for blacktip sharks, *Carcharhinus limbatus*, from the United States South Atlantic Bight and Eastern Gulf of Mexico

LCS05/06-DW-11 Carlson: The Directed Shark Gillnet Fishery: Large Coastal Catch Composition and a Standardized Catch Rate Series.

LCS05/06-DW-12 Carlson & Bethea: Standardized catch rates of large coastal sharks from a fishery-independent survey in northeast Florida

LCS05/06-DW-13 Carlson et al.: Standardized catch rates of large coastal sharks from the Everglades National Park creel survey, 1972 – 2002

LCS05/06-DW-14 Cortés: Documentation of the South Carolina Department of Natural Resources longline survey catch rate series (SC LL Recent)

LCS05/06-DW-15	Cortés & Brooks: Estimates of natural mortality for sandbar and blacktip sharks for use in assessments
LCS05/06-DW-16	Cortés & Neer: Updated catches of Atlantic sharks
LCS05/06-DW-17	Cortés et al.: Standardized catch rates of large coastal sharks from the Commercial Shark Fishery Observer Program, 1994-2004
LCS05/06-DW-18	Diaz: Estimation of large coastal sharks dead discards for the US pelagic longline fishing fleet
LCS05/06-DW-19	Dunnigan: Memo regarding Management Needs for Upcoming Large Coastal Shark (LCS) Stock Assessment
LCS05/06-DW-20	Ha & Musick: A preliminary analysis of Virginia shark longline data 1974 - 2004
LCS05/06-DW-21	Hester: Documentation for the Brannon catch rate series
LCS05/06-DW-22	Hester & Hudson: An evaluation of the content and quality of two Commercial Atlantic Shark Fishery logbook data sets for consideration for stock assessment use
LCS05/06-DW-23	Hoey et al: A review of exploratory longline surveys and biological sampling of sharks from the Sandy Hook and Narragansett labs: 1961-1991
LCS05/06-DW-24	Hoffmayer et al: Catch Rates for Blacktip and Other Large Coastal Shark Species from Mississippi Coastal Waters During 1998–2005
LCS05/06-DW-25	Hueter: Documentation for the Hudson, Jax, Pt. Salerno, and Tampa Bay Recreational Fishing Tournaments catch series, along with the Crooke longline catch rate series
LCS05/06-DW-26	Hueter et al: Relative abundance of juvenile blacktip sharks in three Florida Gulf coast nursery areas, 1995-2004
LCS05/06-DW-27	Ingram et al: Catch rates, distribution and size composition of large coastal sharks collected during NOAA Fisheries Bottom Longline Surveys from the U.S. Gulf of Mexico and U.S. Atlantic Ocean
LCS05/06-DW-28	Keeney et al.: Genetic heterogeneity among blacktip shark, *Carcharhinus limbatus*, continental nurseries along the U.S. Atlantic and Gulf of Mexico

LCS05/06-DW-29 Kohler et al: Preliminary Tag and Recapture Data for the Sandbar Shark, *Carcharhinus plumbeus*, and the Blacktip Shark, *Carcharhinus limbatus*, in the Western North Atlantic

LCS05/06-DW-30 McCandless: Relative abundance trends for juvenile sandbar sharks in Delaware Bay

LCS05/06-DW-31 McCarthy & Abercrombie: Standardized catch rates of large coastal sharks from the United States bottom longline fishery during 1996-2004

LCS05/06-DW-32 Morgan and Burgess: The Commercial Shark Fishery Observer Program: History, collection methodology and summary statistics 1994-2005(1)

LCS05/06-DW-33 Natanson and McCandless: Catch Rate Information Obtained from the NMFS Northeast Longline Survey

LCS05/06-DW-34 Neer and Cortés: Estimation of large coastal shark complex, blacktip, and sandbar shark bycatch in the Gulf of Mexico menhaden fishery

LCS05/06-DW-35 Ortiz: Standardized catch rates for blacktip shark (*Carcharhinus limbatus*), sandbar shark (*C. plumbeus*), and large coastal complex sharks from the U.S. longline fleet 1981-2004

LCS05/06-DW-36 Ortiz: Standardized catch rates for blacktip shark (*Carcharhinus limbatus*), sandbar shark (*C. plumbeus*), and large coastal complex sharks from the Marine Recreational Fisheries Statistical Survey (MRFSS)

LCS05/06-DW-37 Phares: Recreational Marine Fishing Surveys in the Gulf of Mexico and Atlantic States, 1981-2004

LCS05/06-DW-38 Poffenberger: Description of the Southeast Fisheries Science Center's Logbook Program for Coastal Fisheries

LCS05/06-DW-39 Romine & Musick: Life history of the sandbar shark, C. plumbeus, in the Northwestern Atlantic

LCS05/06-DW-40 Grubbs et al.: Long-term movements, migration, and temporal delineation of a summer nursery for juvenile sandbar sharks in the Chesapeake Bay region

LCS05/06-DW-41 Scott & Lacey: Documentation for the Charterboat catch rate series

LCS05/06-DW-42 SEFSC: Review of Headboat Survey – Questions and Answers

LCS05/06-DW-43 Simpfendorfer et al.: Large coastal shark surveys in the eastern Gulf of Mexico 2001-2004

LCS05/06-DW-44	Tyminski et al: Results of Mote Marine Laboratory Shark Tagging Program for blacktip (*Carcharhinus limbatus*) and sandbar (*C. plumbeus*) sharks
LCS05/06-DW-45	Ulrich: Documentation for the South Carolina Longline Survey – Early (SCLL Early)
LCS05/06-DW-46	Conrath & Musick: Investigations into the winter habitat of juvenile sandbar sharks, *Carcharhinus plumbeus*, using pop-up archival satellite transmitters (PSATs).
LCS05/06-DW-47	Merson: Maturation of the sandbar shark in the western North Atlantic

Directed Shark Fisheries, Inc. (DSF)

A Consulting Company

December 26, 2005

Minority statement by Russell Hudson and Frank Hester:

We do not agree that current scientific evidence is sufficient to conclude that blacktip sharks should be divided into two stocks for the assessment. Evidence of female pupping-site fidelity from mtDNA analysis of neonates and a limited number of tag recaptures (LCS05/06-DW29; LCS05/06-DW28; Keeney et al. 20050 does not replace the need identified in LCS05/06-DW-10 for "*A synoptic study sampling* [animals from the commercial catch over] *the entire geographic range of blacktip sharks (i.e., entire Gulf of Mexico and northwest Atlantic Ocean) would be required to fully resolve the question of separate stocks. …"*

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Seafood Coalition (SFC) member

Directed Shark Fisheries, Inc. (DSF)
A Consulting Company

January 12, 2006

Minority statement by Russell Hudson and Frank Hester:

Regarding DW-35 V.2, the Appendix still does not address most of the concerns raised at the meeting. In particular, it does not consider the effects of regulatory changes, nor does it consider the effect of federal and state closures to longlining. The two shark species of greatest importance to the commercial (and recreational) fishery are blacktip and sandbar. It is unlikely that these species are available in offshore areas, and CPUE for these two species will be affected by area closures to a different degree than the LCC as a whole.

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SEDAR 11

Stock Assessment Report

Large Coastal Shark Complex, Blacktip and Sandbar Shark

Section III: Assessment Workshop Report

SEDAR 11

LARGE COASTAL SHARK COMPLEX

ASSESSMENT WORKSHOP REPORT

Prepared by the
SEDAR 11 Stock Assessment Panel
8 May 2006

Contents:

1. Introduction

The current assessment for the Large Coastal Shark (LCS) Complex was to be run following, as close as possible, the procedures of the Southeast Data, Assessment, and Review (SEDAR) process. The process involves three meeting Workshops: Data, Assessment, and Review. The Data Workshop (DW) for the LCS complex was held in Panama City, FL October 31st through November 4th, 2005. The Assessment Workshop (AW) was held in Miami, FL 6 – 10 February 2006. Initial data compilations and exploratory analyses for SEDAR assessments were requested from participants in the form of "working documents" to be submitted in advance and evaluated over the course of the workshop.

This Report represents the discussions, analyses, and stock status determinations for four separate assessments: 1) LCS complex, 2) sandbar shark, 3) Gulf of Mexico blacktip sharks, and 4) northwestern Atlantic Ocean blacktip sharks. These assessments are being reported in one Report as many of the indices, data, and issues overlap among assessments. All discussions were conducted in a plenary format, with analysts conducting requested sensitivities and modifications and reporting back to the panel throughout the week.

This report is divided into four main sections, paralleling the separate assessments conducted. Structure within each section was determined by the lead analyst, following some general guidelines derived from SEDARs for other species and the content previously reported from Shark Evaluation Workshops (SEWs). The LCS complex, sandbar and blacktip sharks have a history of previous assessments via the SEWs, so this report has expanded discussion on issues that had been difficult or controversial in past work, but is fairly brief on issues that are reasonably well settled. Figures and tables remain within the individual sections, and are numbered in "Section number.figure number" sequence. Lists of references to the general literature (i.e. papers other than the working documents submitted to this Workshop) also remain with the individual sections. Citations to papers submitted to this workshop as "working documents" are made in the text using the identifying numbers assigned by the Shark SEDAR Coordinator (in the form SEDAR11-AW-xx). A minority statement provided by the directed shark fishing industry regarding certain components of the sandbar shark assessment can be found in an appendix at the end the report.

This report is a complete and final documentation of the activities, decisions, and recommendations of the Assessment Workshop. It will also serve as one of 4 components of the final SEDAR Assessment Report. The final SEDAR Assessment Report will be completed following the last workshop in the cycle, the Review Workshop, and will consist of the following sections: I) Introduction; II) Data Workshop Report; III) Assessment Workshop Report; and IV) Review Workshop Report.

1.1 SEDAR 11 Assessment Workshop Terms of Reference

1. Select several modeling approaches based on available data sources, parameters and values required to manage the stock, and recommendations of the data workshop.
2. Provide justification for the chosen data sources and for any deviations from data workshop recommendations.
3. Provide estimates of stock parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates and measures of model 'goodness of fit'.
4. Characterize uncertainty in the assessment, considering components such as input data, modeling approach, and model configuration.
5. Provide yield-per-recruit, spawners per recruit, and stock-recruitment analyses when appropriate.
6. Provide complete SFA criteria. This may include evaluating existing SFA benchmarks or estimating alternative SFA benchmarks (SFA benchmarks include MSY, F_{MSY}, B_{MSY}, MSST, and MFMT); recommend proxy values where necessary; provide stock control rules.
7. Provide declarations of stock status relative to SFA benchmarks: MSY, F_{MSY}, B_{MSY}, MSST, MFMT.

   Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; include estimated generation time. Stock projections will be based on constant quotas or various F criteria.
8. Evaluate the results of past management actions and probable impacts of current management actions with emphasis on determining progress toward stated management goals.
9. Provide recommendations for future research and data collection (field and assessment); be as specific as practicable in describing sampling design and sampling intensity.
10. Provide the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report) including tables of estimated values within 5 weeks of workshop conclusion. SEE NOTE.

REPORT COMPLETION NOTE: The final Assessment Workshop report is due no later than Monday, May 1 2006. If final assessment results are not available for review by workshop panelists during the workshop, the panel shall determine deadlines and methods for distribution and review of the final results and completion of the workshop report.

1.2 List of participants

Workshop participants:

Panayiota Apostolaki	CEFAS Lowestoft Lab, UK
Elizabeth Babcock	Pew Institute for Ocean Science
Ramon Bonfil	Wildlife Conservation Society
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1.3 SEDAR 11 Assessment Workshop Documents

SEDAR 11–AW–01 Apostolaki: First estimates of the status of sandbar shark stock off the eastern coast of the US

SEDAR 11–AW–02 Apostolaki: First results on the status of blacktip shark stock in the western Atlantic

SEDAR 11–AW–03 Brooks: A State-Space, Age-Structured Production Model for Sandbar Shark

SEDAR 11–AW–04 Brooks: Preliminary Runs of a State-Space, Age-Structured Production Model for Blacktip Shark

SEDAR 11–AW–05 Cortés and Babcock: Assessment of Large Coastal, Blacktip, and Sandbar Sharks using Surplus Production Methods

SEDAR 11–AW–06 Cortés and Neer: Catch history for blacktip sharks – combined regions

SEDAR 11–AW–07 Freitas: Apex Predator Protection: Assessing Shark Landings and Conservation Measures in Rhode Island

SEDAR 11–AW–08 Hester and Hudson: Some Cautions on the Use of Pelagic Longline Logbook Data to Assess the Abundance of Large Coastal Sharks

SEDAR 11–AW–09 Merson: Length and age at maturity of the sandbar shark, *Carcharhinus plumbeus*

SEDAR 11-AW-10 Brooks and Cortés: Issues related to Biological Inputs to Blacktip and Sandbar assessments

2. SUMMARY OF DATA DOCUMENTS AND ISSUES

Several documents were submitted for review by the Assessment Panel regarding data and indices recommended for use by the Data Workshop. Document summaries and associated Panel discussions, if applicable, follow.

SEDAR11-AW-06
Catch history for blacktip sharks – combined regions
Summary: The Data Workshop Panel recommended that blacktip sharks should be assessed as two separate stocks, Gulf of Mexico and western Atlantic Ocean. Industry representatives disagreed with this decision and produced a Minority Opinion on the matter for inclusion in the Data Workshop Final Report. In response to that concern, the lead analysts agreed to conduct a sensitivity run for blacktip sharks with regions combined. Indices of relative abundance for the combined region analysis were developed, when necessary, for the blacktip series discussed by the Indices Working Group in the DW Final Report and appended to the appropriate DW Working papers. This document provides a description of how the catch history for this sensitivity analysis was developed.

SEDAR 11-AW-08
Some Cautions on the Use of Pelagic Longline Logbook Data to Assess the Abundance of Large Coastal Sharks
Summary Abstract: We challenge four assumptions used in constructing the Pelgaic Log Indices for blacktip sharks (*Carcharhinus limbatus*). These and our accompanying comment are:

1) CPUE reflects only change in abundance. We submit that the initial declines shown by the indices are too steep to be plausible if only change in abundance is involved.
2) Sampling covers the range of the fishery. The areas used in the analysis are too large to detect effects from closures of nearshore fishable grounds where most blacktip occur.
3) CPUE correctly reflects what was caught. There is a great difference in the species composition in catches reported in the Pelagic Log data and the Pelagic Observer Program data. Possible explanations are that other species were misidentified as blacktip shark, or that the Pelagic Log data include many inshore sets in the early years of the series.
4) Availability and catchability are constant over the period. Regulations implemented between 1992 and 1994 rather than a drastic decline in abundance can explain the steep decline in CPUE.

Document SEDAR 11-AW-08 discussed concerns with using the Pelagic Log index as a base case index as recommended by the Data Workshop. It asserted that a series of regulatory changes implemented between 1992 and 1995 affected the fisheries for nearshore large coastal shark species, particularly sandbar and blacktip by closing traditional areas where CPUE was high, and because of the anti-finning and 4000 lb trip limit causing a shift in targeting from blacktip to sandbar in the Atlantic. It was also noted that there was a significant discrepancy between the species composition between observer and commercial data. The point was brought up that observer data was collected in early years for swordfish/tunas etc., so observers were not sent on directed shark boats. This could explain the discrepancy. Misidentification (recording black-tipped sharks [i.e. spinners, etc.] as blacktip shark) was another explanation offered.

The Panel was informed by G. Ortiz (NMFS/ SEFSC Miami, FL) that the Pelagic Log database consists of two types of gear: bottom longline (accounting for approximately 2% of the data) and pelagic longline. It was further noted that bottom longline records accounted for 50% of the catch records for LCS. There was much discussion about this fact and it was recommended that the Pelagic Log index be recalculated using only the pelagic records. This was completed by Tuesday morning and the new index provided to the AW Panel.

The consensus decision was to continue with the re-analyzed index despite the minority opinion presented in the DW Report and the paper presented at the AW (SEDAR 11-AW-08**)** as the panel felt the factors used in the standardization procedure of the revised index addressed the majority of the issues raised. As there was still some concern regarding the appropriateness of the index by one panel member, two sensitivity runs were agreed upon:

1) removing the Pelagic Log index
2) excluding 1992, 1993, and 1994 from the index for Blacktip Atlantic analysis in an to attempt to capture the adjustment by the fleet to the implementation of management polices during the first years after implementation

SEDAR 11-AW-09

Length and age at maturity of the sandbar shark, *Carcharhinus plumbeus*

Summary: The Data Workshop Panel recommended using the maturity ogive for sandbar sharks presented in document LCS05/06-DW-47. The industry members of the Panel questioned the ogive, specifically citing what they believed to be a discrepancy between the ogive developed using the historical NMFS Reproductive Database versus the samples collected directly by Merson during her directed reproductive study. To address this issue, along with the request to see the distribution in time of the samples in the NMFS database and, if possible, conduct an additional analysis by decade, Merson conducted further analyses which are described herein. This additional analysis did not differ from the information recommended by the Life History Working Group during the DW, with both data sets indicating size and age at 50% maturity of 156 cm FL and 18 years or 158 cm and 19 years for the Merson data and the NMFS Reproductive database, respectively. The NMFS Reproduction Database covered samples over three decades however the number of samples was deemed not sufficient to conduct a rigorous temporal comparison of length at maturity.

One AW panelist felt that the updated analysis still failed to address the industries' concerns. Outstanding issues including 1) looking at various time periods, 2) looking at slopes, 3) looking at differences by time, and 4) more statistical examination of the data, specifically the underlying distributions. After additional discussion regarding how the ages estimates used by Merson were obtained (length-age conversion equation rather than direct ageing), the AW Panel consensus was that the new analysis presented addressed the issues raised during and after the Data Workshop and chose to retain the ogive recommended by the DW Panel.

SEDAR 11-AW-10

Issues related to Biological Inputs to Blacktip and Sandbar assessments

Summary: Calculations based on the mean values agreed to by the DW as the best estimates for life-history parameters produce steepness values less than 0.2, the mathematical limit for that parameter. The only life history parameter estimated in the model is pup-survival; if the base case values for maturity, pup-production, and natural mortality at age-1+ are not altered, then in order for steepness to be above 0.2, pup survival must be >0.8 (or in the case of the Blacktip Gulf of Mexico model, pup survival must be >0.9). Considering that survival at age 1 was estimated to be in the range of 0.7-0.77 for these stocks, pup survivals of 0.8-0.9 may be unrealistically high. This document describes various ways to modify the biological input parameters in order for steepness to not hit its lower limit and provides rationale for the various alternatives.

<ins>Other data discussions</ins>

Finally, there was discussion about the Large Pelagic Survey (LCS05/06-DW-9) index. This recreational index was reanalyzed after the DW, following the recommendation of the Data Workshop Panel to use a zero-inflated binomial distribution as an attempt to decrease the large CVs. The reanalysis successfully reduced the CV values by half or more for most years; however one AW panelist continued to express concern with the size of the CV values. It was noted that despite reducing the CV values overall, the CV value in 1993 still increased by a factor of five over the 1992 value. It was suggested this may be related to changes in bag limits imposed that year; however, it was noted by an observer that this data set reports on both catch and landings, so regulatory changes and bag limits should not be of great concern. It was further noted that the frequency of occurrence also decreased after 1993, which will affect the CV values.

The suggestion of not using this index as an equal weighted index was proposed. However, sensitivity runs indicated that the model output was not significantly affected by changing the weighting method. Finally, it was noted that the standard error for the entire time series was similar; reflecting that the variability was relatively constant over time. It was decided to follow the Data Workshop recommendations and include the modified LPS series.

LARGE COASTAL SHARK COMPLEX ASSESSMENT

3. LARGE COASTAL SHARK COMPLEX ASSESSMENT

3.1 Summary of LCS Working Documents

SEDAR11-AW-05
Assessment of Large Coastal, Blacktip, and Sandbar Sharks using Surplus Production Methods
We used two complementary surplus production models (BSP and WinBUGS) to assess the status of three Large Coastal Shark (LCS) groupings, two stocks of blacktip shark, and a single stock of sandbar shark identified as baseline scenarios in the LCS Data Workshop report. Both methodologies use Bayesian inference to estimate stock status, and the BSP further performs Bayesian decision analysis to examine the sustainability of various levels of future catch. Extensive sensitivity analyses were performed with the BSP model to assess the effect of different assumptions on CPUE indices and weighting methods, catches, intrinsic rates of increase, initial depletion, and importance function on results. Baseline scenarios for the three LCS groupings considered predicted that the stock status is not overfished nor overfishing is occurring. Using the inverse variance method to weight the CPUE data changed the predictions on stock status for the LCS grouping, which would then be overfished, with overfishing occurring. The sandbar shark stock was estimated to be significantly depleted (64-71% depletion from virgin level). The Gulf of Mexico blacktip shark stock was healthy (depletion of only 8-23% of virgin level), whereas results for the Atlantic blacktip shark stock from the BSP and WinBUGS models conflicted. The BSP model predicted a considerable level of depletion for this stock regardless of the CPUE weighting method used. In contrast, the assessment of a single blacktip shark stock (GOM+ATL) resulted in very consistent results, with all models predicting a healthy status (depletions of only 10-16% of virgin level). Using the higher values of r from the 2002 SEW or accounting for some depletion from virgin levels in the first year of the model did not affect conclusions. Several assumptions on catches (notably changing the high value of recreational catch in 1983) also had no effect on conclusions. Removing the VIMS CPUE series from the LCS scenario reversed the conclusions on stock status when using inverse variance weighting, highlighting the influence of this series on results; removing the Pelagic Log CPUE series from the ATL blacktip shark analysis also drastically reversed the conclusions on stock status. Fitting one CPUE series at a time had a larger effect on results: the Pelagic Log series greatly influenced conclusions for the three LCS groupings and GOM and ATL blacktip shark, whereas the VIMS series affected conclusions on the two groups for which it is available, LCS and sandbar shark.

3.2 Background

The Large Coastal Shark (LCS) complex has traditionally been assessed through Shark Evaluation Workshops (SEW) using surplus production methods because it consists of a variety of species with widely varying life histories and for some of which both biological and fishery data are very limited, preventing the use of single-species, age-structured models in many cases.

3.3 Available Models

Two surplus production modeling approaches were available for discussion (SEDAR11-AW-05)

1) Bayesian surplus production model (BSP)
2) WinBUGS

The Bayesian Surplus Production (BSP) model program fits a Schaefer model to CPUE and catch data using the SIR algorithm. The BSP software is available, for example, in the ICCAT catalog of methods (McAllister and Babcock 2004) and has been used as the base model in previous assessments of large coastal sharks.

The WinBUGS implementation of the Schaefer surplus production model uses Gibbs sampling, an MCMC method of numerical integration, to sample from the posterior distribution (Spiegelhalter et al. 2000). The model was originally developed by Meyer and Millar (1999a) and modified by Cortés (2002) and Cortés et al. (2002) to apply it to small and large coastal sharks, respectively.

The BSP was selected as the final model because it generally provides a more flexible framework for examining the effects of various modeling issues (e.g., type of importance function used for Bayesian estimation, multiple CPUE weighting methods) and conducts Bayesian decision analysis to project population status into the future and estimate performance indicators under various management policies.

3.4 Model Scenarios

The Assessment Workshop (AW) panel recommended that surplus production models be used to assess the status of the three LCS groupings identified by the Data Workshop (DW) panel and report (the only type of model available for these complexes). Additionally, surplus production models were also used to assess the status of blacktip (Gulf, Atlantic, and areas combined) and sandbar sharks in document SEDAR11-AW-05, but those results are not presented herein (additional results can also be found in the addendum to SEDAR11-AW-05). In the present document we assessed the status of 1) LCS as originally defined (consisting of 22 species), 2) LCS without species presently classified by NMFS as prohibited (11 species), and 3) LCS without prohibited species, sandbar, or blacktip sharks. These three groupings respond to an effort on the part of the DW participants to attempt to examine the effect of prohibited species and the two most important species in the fishery—blacktip and sandbar sharks—on stock assessment results.

3.5 Discussion of weighting methods

The Data Workshop recommended that *equal weighting* for assigning weights to the different CPUE time series available during model fitting should be used for the baseline runs. The panel discussed the advantages and disadvantages of the *equal weighting* vs. the *inverse CV weighting* methods:

Equal weighting ignores the better quality of some data (smaller CVs) but is more stable between assessments because yearly changes on CVs in a given CPUE series do not affect the importance of that time series for the overall fit.

Inverse CV weighting can provide better precision as it tracks individual indices, however, it could be less stable between assessments due to changes on the relative 'noise' of each time series. This method may also not be appropriate in cases in which different standardization techniques have been used for the standardization of the series and therefore, the same value of CV might reflect different levels of error depending on the CPUE it corresponds to.

It was requested by one Panelist to manually weight the indices that cover larger geographic areas to have a stronger influence on the model. The group commented that, while that may be possible in a spatially explicit model, a great deal more data would be required than presently available.

The Assessment Panel decided that equal weighting would be the default weighting method for the current assessment but noted that, as there is at present no objective way to decide which of these two methods is superior other than comparing model convergence diagnostics, future assessments may need to reexamine this issue.

3.6 Methods

3.6.1 Bayesian Surplus Production (BSP) Model description

The Bayesian Surplus Production (BSP) model program fits a Schaefer model to CPUE and catch data using the SIR algorithm. The BSP software is available, for example, in the ICCAT catalog of methods (McAllister and Babcock 2004) and has been used as the base model in previous assessments of large coastal sharks. Herein we used the discrete-time version of the model (although the continuous form is also implemented by the software), so that:

$$B_{t+1} = B_t + rB_t - \frac{r}{K} B_t^2 - C_t$$

where B_t= biomass at the beginning of year t, r is the intrinsic rate of increase, K is carrying capacity and C_t is the catch in year t.

The expected catch rate (CPUE) for each of the available time series j in year t is given by:

$$\hat{I}_{j,t} = q_j B_t e^{\varepsilon_t}$$

where q_j is the catchability coefficient for CPUE series j, and ε_t is the residual error, which is assumed to be normally distributed. The program allows for a variety of methods to weight

CPUE data points. As recommended in the DW report, we used equal weighting (or no weighting) in all baseline scenarios. The model log-likehood is given by:

$$\ln L = -\sum_j \sum_y \frac{\left[\ln(I_{j,y}) - \ln(\hat{q}_j \hat{B}_y)\right]^2}{2\sigma_{j,y}^{\ 2}}$$

were $I_{j,y}$ is the CPUE in year y for series j, $\hat{q}_j$ is the constant of proportionality for series j, $\hat{B}_y$ is the estimated biomass in year y, and $\sigma_{j,y}^{\ 2}$ is the variance (=1/weight; in this case weight=1) applied to series j in year y.

In the inverse variance method, the annual observations are proportional to the annual CV^2 (if available) and the average variance for each series is equal to the MLE estimate. The log likelihood function is expressed as:

$$\ln L = -\sum_{j=1}^{j=s} \sum_{t=1}^{t=y} \left\{ \frac{0.5}{c_j CV_{j,t}^{\ 2} \hat{\sigma}_j^{\ 2}} \left[\ln\left(\frac{I_{j,t}}{q_j N_t} \right) \right]^2 - 0.5 \ln(c_j CV_{j,t}^{\ 2} \hat{\sigma}_j^2) \right\}$$

where s is the number of CPUE series, y is the number of years in each CPUE series, $CV_{j,t}^{\ 2}$ is the coefficient of variation for series j in year t, c_j is a constant of proportionality for each series j chosen such that the average variance for each series equals its estimated average variance, σ_j^2 (the MLE estimate). The catchability coefficient for each time series (q_j) is also estimated as the MLE such that:

$$\hat{q}_j = e^{\left(\frac{\sum_{t=1}^{t=y} \left(\ln(I_{j,t}) - \ln(\hat{B}_t) \right) / c_j CV_{j,t}^{\ 2} \hat{\sigma}_j^{\ 2}}{\sum_{t=1}^{t=y} 1/(c_j CV_{j,t}^{\ 2} \hat{\sigma}_j^{\ 2})} \right)}$$

3.6.2 Data inputs, prior probability distributions, and performance indicators

Baseline scenarios

LCS—Catch data (in numbers of fish) were available from 1981 to 2004 and CPUE data, from 1972 to 2004, as provided in the Data Workshop Report (Table 3.1). Eleven CPUE series identified as "base" in the DW report were used in the baseline scenario. The Pelagic Log series was updated during the AW as discussed previously. All CPUE series used are listed in **Appendix 1**. The fishery was assumed to begin in 1972, the first year for which CPUE data were available. The catches in the years 1972-1980 were assumed to be constant and equal to the model-estimated parameter C_0. The prior for C_0 was lognormal, with a mean equal to the average catch during 1981-2004 (534.9 thousand individuals) and a log-standard deviation (SD) of 1, implying a wide distribution. Other estimated parameters were r, K, and the abundance (in numbers) in 1972 relative to K (N_{72}/K). The constant of proportionality between each abundance index and the biomass trend was calculated using the numerical shortcut of Walters and Ludwig (1994). The prior for K was uniform on log (K), weakly favoring smaller values, and was allowed to vary between 10^5 and 10^9 individuals. Informative, lognormally distributed priors were used for N_{72}/K and r. For N_{72}/K, the mean was set equal to 1, and the log-SD was 0.2. For r, the mean value was taken as recommended in the DW report when considering density dependence (0.045 yr^{-1}). Since no SD was provided in the report, we used a value that would correspond to the same proportion of the mean as used in the 2002 SEW (i.e., the mean r in the 2002 SEW was 0.113, with a log-variance of 0.49 [the BSP uses variance as an input], so the value of log-variance corresponding to a mean of 0.045 is 0.195). Input values can be found in Table 3.2.

LCS without prohibited species—Catch data (in numbers of fish) were available from 1981 to 2004 and CPUE data, from 1992 to 2004, as provided in the DW Report (Table 3.3). Seven CPUE series identified as "base" in the DW report were used in the baseline scenario. The Pelagic Log series was updated during the AW, as discussed previously. All CPUE series used are listed in **Appendix 1**. The fishery was assumed to begin in 1972 (for comparison with the LCS scenario). The catches in the years 1972-1980 were assumed to be constant and equal to the model-estimated parameter C_0. The prior for C_0 was lognormal, with a mean equal to the average catch during 1981-2004 (494.6 thousand individuals) and a log-standard deviation (SD) of 1, implying a wide distribution. The prior for K was uniform on log (K), and ranged between 10^5 and 10^9 individuals. The mean of N_{72}/K was set to 1 and the log-SD to 0.2. The mean value of r as recommended in the DW report when considering density dependence was 0.046 yr^{-1} and the resulting log-variance was 0.199. Input values can be found in Table 3.2.

LCS without prohibited species, blacktip or sandbar—Catch data (in numbers of fish) were available from 1981 to 2004 and CPUE data, from 1992 to 2004, as provided in the DW Report (Table 3.4). Seven CPUE series identified as "base" in the DW report were used in the baseline scenario. The Pelagic Log series was updated during the AW, as discussed previously. All CPUE series used are listed in **Appendix 1**. The fishery was assumed to begin in 1972 (for comparison with the LCS scenario). The catches in the years 1972-1980 were assumed to be constant and equal to the model-estimated parameter C_0. The prior for C_0 was lognormal, with a mean equal to the average catch during 1981-2004 (136.1 thousand individuals) and a log-standard deviation (SD) of 1, implying a wide distribution. The prior for K was uniform on log (K), and ranged between 10^5 and 10^9 individuals. The mean of N_{72}/K was set to 1 and the log-SD to 0.2. The mean value of r as recommended in the DW report when considering density dependence was 0.043 yr^{-1} and the resulting log-variance was 0.186. Input values can be found in Table 3.2.

Performance indicators included the maximum sustainable yield (MSY=rK/4), the stock abundance in the last year of data (N_{2004}), the ratio of stock abundance in the last year of data to carrying capacity and MSY (N_{2004}/K and N_{2004}/MSY), the fishing mortality rate in the last year of data as a proportion of the fishing mortality rate at MSY (F_{2004}/F_{MSY}), the catch in the last year of data as a proportion of the replacement yield (C_{2004}/R_y) and MSY (C_{2004}/MSY), the stock abundance in the first year of the model (N_{init}), and the ratio of stock abundance in the last and first years of the model (N_{2004}/N_{init}). Additionally, the relative abundance (N_i/N_{MSY}) and fishing mortality (F_i/F_{MSY}) trajectories, as well as the predicted abundance trend, were obtained and plotted for the time period considered in each scenario.

3.6.3 Methods of numerical integration, convergence diagnostics, and decision analysis

Numerical integration was carried out using the SIR algorithm (Berger 1985, McAllister and Kirkwood 1998, McAllister et al. 2001) built in the BSP software. The marginal posterior distributions for each of the population parameters of interest were obtained by integrating the joint probability with respect to all the other parameters. Posterior CVs for each population parameter estimate were computed by dividing the posterior SD by the posterior expected value (mean) of the parameter of interest. Two importance functions were used in the SIR algorithm (depending on which function produced better convergence diagnostics): the multivariate Student t distribution and the priors. For the multivariate Student t distribution, the mean is based on the posterior mode of θ (vector of parameter estimates K, r, N_{init}/K, and C_0), and the covariance of θ is based on the Hessian estimate of the covariance at the mode (see McAllister and Kirkwood [1998] and references therein for full details). A variance expansion factor of at least 2 was generally used to make the importance function more diffuse (wider) and ensure that the variance of the parameters was not underestimated when using the multivariate Student t distribution.

Convergence diagnostics included examining the ratio of the CV of the weights to the CV of the product of the likelihood function and the priors, with values <1 indicating convergence and values >10 indicating likely convergence failure, and the maximum weight of any draw as a fraction of the total importance weight, which should be less than 0.5% (SB-02-25; McAllister and Babcock 2004). Predicted model fits to the CPUE series were plotted and examined.

For the BSP model, posterior expected values for several indices of policy performance were calculated using the resampling portion of the SIR algorithm built in the BSP software, which involves randomly drawing 5,000 values of θ with replacement from the discrete approximation to the posterior distribution of θ, with the probability of drawing each value of θ being proportional to the posterior probability calculated during the importance sampling phase. Details of this procedure can be found in McAllister and Kirkwood (1998) and McAllister et al. (2001), and references therein. Once a value of θ was drawn, the model was projected from the initial year of the model to 2007 (although the actual catch series only extended to 2004, catches in 2005, 2006, and 2007 were set equal to the 2004 catch to account for the fact that any management actions would not go into effect until 2008), and then forward in time beginning in 2008 up to 30 years to evaluate the potential consequences of future management actions. Projections were run using constant harvest rates as a fraction of F_{msy}, with F as a fraction of F_{msy} recalculated for each draw from the posterior distribution. The policies explored thus included using: 0.0 * F_{MSY}, 0.75 * F_{MSY}, 1.0 * F_{MSY}, and the median value of F_{2003}/F_{msy} calculated by the model * F_{MSY}. The projections included calculating multiple reference points, among others: the expected value of N_{fin}/K (with fin=2018, 2028, and 2038) and the probabilities that N_{fin} were <

0.2K, $N_{fin} > N_{msy}$, and $N_{fin} > N_{2008}$. Additionally, the probability that the stock in 2030 (present rebuilding target) were > N_{msy} with the F_{2003}/F_{msy} policy option was also calculated.

3.6.4 Sensitivity analyses

To examine the impact of the priors on the results, sensitivity analyses were performed by changing the following items with respect to those in the baseline scenario one at a time. These sensitivity analyses include those identified in the DW report and additional ones identified during the AW. All sensitivities run prior to the AW are referred to as "initial" to distinguish them from the "additional" sensitivities identified and run during or after the AW. All results for the initial sensitivities can be found in document SEDAR11-AW-05 or its addendum. Here, we only report results of the additional sensitivities.

The ***initial*** sensitivities included:

W — Using a complementary surplus production model (**WinBUGS**) that also takes account of process error (vs. observation error only in the BSP) and uses MCMC (vs. the SIR algorithm in the BSP) for numerical integration (all runs identified by a leading "W"). Input values can be found in Table 3.2.

IW — Changing the method for weighting the CPUE series: **inverse CV weighting** (weighting method 3) was used to compare with weighting method 1 in the baseline scenario

IF — Changing the **importance function** from the priors to a multivariate t distribution

As described in section 3.6.3, we only report results obtained with the importance function that yielded the best convergence diagnostics.

OLDR — Using the values of **intrinsic rate of increase** from the 2002 SEW

The values of r used in the baseline scenario were 0.045 yr^{-1} (LCS), 0.046 yr^{-1} (LCS-PRO), and 0.043 yr^{-1} (LCS-PRO-SB-BT). The value of r for LCS used in the 2002 SEW was 0.113 yr^{-1}.

ID — Decreasing the value for the **prior of N_{init}/K** to a mean=0.85

This prior reduces the probability that N_{init}/K (initial depletion) will be much higher than K (18% of the pdf is >1 with this prior vs. 45% if the mean=1).

AC — Considering an **alternative catch series for LCS** (Table 2.5 of the DW) to compensate for under-reporting of landings during the earliest years of the time series (1981-1994)

C83 — Changing the value of **recreational catch for 1983** to the geometric mean value of the 1982 and 1984 estimates

-SERIES NAME — Removing one CPUE series at a time from the full model (with all CPUE series considered in the baseline scenario)

In the initial sensitivities, this was done using the inverse CV weighting method.

+SERIES NAME — Fitting only one CPUE series (of those considered in the baseline scenario) at a time

In the initial sensitivities, this was done using the inverse CV weighting method.

The ***additional*** sensitivities were run during or after the AW and all use the updated Pelagic Log series. They include:

W — Using a complementary surplus production model (**WinBUGS**) that also takes account of process error (vs. observation error only in the BSP) and uses MCMC (vs. the SIR algorithm in the BSP) for numerical integration. This was applied to the LCS (22 species) grouping only.

IW — Changing the method for weighting the CPUE series: **inverse CV weighting** was used to compare with equal weighting in the baseline scenario

IF — Changing the **importance function** from the priors to a multivariate t distribution

As described in section 3.6.3, we only report results obtained with the importance function that yielded the best convergence diagnostics.

C — Considering a **continuity scenario** for the LCS complex with the CPUE series used in the last stock assessment (2002 SEW), extending the series up to 2004 if available, to compare to the predictions from the present baseline analysis. If the CPUE series had been GLM-standardized for the current assessment, the standardized values were used.

R-2001 — Conducting a **retrospective analysis** by stopping the baseline analysis for the LCS complex in 2001 (i.e., using only catch and CPUE data up to 2001 vs. 2004 in the baseline analysis) to compare to the predictions from the stock assessment conducted in 2002 (which included data up to 2001)

ALL — Adding **all the CPUE series** identified as "sensitivity" in the DW report to the baseline series. Two sub-scenarios were run: one that included the "requiem shark" category in the MRFSS series, and another one without that category.

-SERIES NAME — Removing one CPUE series at a time from the full model (with all CPUE series considered in the baseline scenario). This was now done using the equal weighting method.

+SERIES NAME — Fitting only one CPUE series (of those considered in the baseline scenario) at a time. This was now done using the equal weighting method.

FIXED CATCH — Fixing the 1972-1980 annual catch to the 1981 value (first year of catch data)

3.7 Results

3.7.1 Baseline scenarios

LCS—Although the two longest series (ENP and VA LL) showed a declining trend in the early years (1970s and 1980s), all series were rather flat or showed a slightly increasing tendency in the early 2000s (Fig. 3.1). The abundance trajectory at the mode of the posterior distribution showed a similar trend, decreasing from the early 1970s to the mid-1990s, and almost flattening thereafter. The median relative biomass trajectory indicated that the stock did not reach an overfished status in any year (Fig. 3.2A), whereas the median relative fishing mortality trajectory indicated that overfishing had occurred from the early 1980s to the late 1990s, but was no longer occurring from 1999 on (Fig. 3.2B). The model did not fit the early years of the VA LL or Pelagic Log CPUE series well probably because it attempted to track the ENP series (Fig. 3.3). The complete time series of median estimates of stock abundance (N_i), relative stock abundance (N_i/N_{MSY}), fishing mortality rate (F_i), and relative fishing mortality rate (F_i/F_{MSY}) are given in Table 3.5.

Current status of the population was above N_{MSY} and no overfishing was occurring (Table 3.6). The priors were used as an importance function for importance sampling. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV(weights) / CV(likelihood * priors) <1). The posterior distributions of K and r showed that the data supported relatively high values of these two parameters, whereas the posterior for C_0 was very similar to the prior distribution (Fig. 3.4). Population projections showed that there is a 78% probability that the stock will remain above N_{MSY} when applying the F_{msy} policy under any of the three time horizons explored (10, 20, and 30 years; Table 3.7) and that the stock will not become overfished (Fig. 3.5). The probability that the stock will be rebuilt in 2030 ($N_{2030}>N_{msy}$) is 91%.

LCS without prohibited species—The earliest CPUE data point went back to 1992, and with the exception of the Pelagic Log series, all remaining series showed increasing tendencies (Fig. 3.6). The abundance trajectory at the mode of the posterior distribution predicted a slow decrease starting in the early 1980s that progressively decelerated towards the end of the time series. Accordingly, the median relative biomass and fishing mortality trajectories indicated that the stock did not reach an overfished status and that overfishing did not occur for the duration of the time series (Fig. 3.7A and B). Model fits to the CPUE series were all almost flat, probably as a result of the model trying to compensate between the decreasing trend from the Pelagic Log series and the generally increasing tendencies of all remaining CPUE series (Fig. 3.8). The complete time series of median estimates of stock abundance (N_i), relative stock abundance (N_i/N_{MSY}), fishing mortality rate (F_i), and relative fishing mortality rate (F_i/F_{MSY}) are given in Table 3.8.

Current status of the population was above N_{MSY} and no overfishing was occurring (Table 3.6). The priors were used as an importance function for importance sampling. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV(weights) / CV(likelihood * priors) <1). The posterior distribution of K showed that the data supported relatively high values of this parameter (more so than in the LCS scenario), whereas the posteriors of r and C_0 were very similar to those in the LCS scenario (Fig. 3.9). Population projections showed that there is a 92% probability that the stock will remain above N_{MSY} when applying the F_{msy} policy under any of the three time horizons explored (10, 20, and 30 years) and that the stock will not become overfished (Fig. 3.10), and were more optimistic than for the LCS scenario (Table 3.7). The probability that the stock will be rebuilt in 2030 (N_{2030}>N_{msy}) is 99%.

LCS without prohibited species, blacktip or sandbar—The earliest CPUE data point also went back to 1992, and with the exception of the Pelagic Log series, all remaining series also showed increasing tendencies (Fig. 3.11). The abundance trajectory at the mode of the posterior distribution predicted a decrease starting in the early 1980s, followed by a flat trend starting in the mid-1990s. Accordingly, the median relative biomass and fishing mortality trajectories indicated that the stock did not reach an overfished status and that overfishing did not occur for the duration of the time series (Fig. 3.12A and B). Model fits to the CPUE series were all flat since the mid-1990s, probably as a result of the model trying to compensate between the decreasing trend from the Pelagic Log series and the increasing tendencies of all remaining CPUE series (Fig. 3.13). The complete time series of median estimates of stock abundance (N_i), relative stock abundance (N_i/N_{MSY}), fishing mortality rate (F_i), and relative fishing mortality rate (F_i/F_{MSY}) are given in Table 3.9.

Current status of the population was the most optimistic of the three LCS scenarios, being above N_{MSY} and with no overfishing occurring (Table 3.6). The priors were used as an importance function for importance sampling. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV(weights) / CV(likelihood * priors) <1). The posterior distribution of K showed that the data supported relatively high values of this parameter (less so than in the two scenarios considered above), the posterior of r was also very similar to those in the two previous scenarios, and the posterior of C_0 favored smaller values than predicted in the two previous scenarios (Fig. 3.14). Population projections showed that there is a 94% probability that the stock will remain above N_{MSY} when applying the F_{msy} policy under the three time horizons explored (10, 20, and 30 years) and were the most optimistic of the three LCS scenarios (Table 3.7; Fig. 3.15). The probability that the stock will be rebuilt in 2030 (N_{2030}>N_{msy}) is 99%.

3.7.2 Sensitivity analyses

W: Using WinBUGS—Using this structurally different surplus production model resulted in the same predictions of stock status as with the BSP: not overfished (N_{2004}/N_{MSY}=1.26 in both models; F_{2004}/F_{MSY}=0.74 in the BSP vs. 0.53 in WinBUGS).

IW: Changing the CPUE weighting method—We focused on changing the CPUE weighting method from equal weighting (baseline) to inverse variance weighting. We report only those results obtained with the importance function (prior vs. multivariate t) that produced the best convergence diagnostics.

***LCS*—**Current status of the population worsened considerably, dipping below N_{MSY} and overfishing occurred when considering this change (Table 3.10). The multivariate t distribution as an importance function yielded better convergence diagnostics than the priors for the SIR algorithm, but those diagnostics were still not good (maximum weight of any draw was 4.3% and CV (weights) / CV (likelihood * priors) was 3.3). Population projections estimated only a 1% probability of the population reaching N_{MSY} even after 30 years when applying the F_{MSY} policy, but F = 0 would result in an 81% probability of the population reaching N_{MSY} in only 10 years (Table 3.11).

***LCS without prohibited species*—**This change had little impact on results, with current status of the population improving with respect to the baseline scenario (Table 3.10). The priors as an importance function yielded better convergence diagnostics than the multivariate t distribution for the SIR algorithm (maximum weight of any draw <0.5%, but CV (weights) / CV (likelihood * priors) was 1.14). As in the baseline scenario, population projections were very optimistic, with no risk of the population going below N_{MSY} under any of the policies or time horizons considered (Table 3.11).

***LCS without prohibited species, blacktip or sandbar*—**This change had even less impact on results than the previous one, with F_{2004}/F_{MSY} decreasing from 0.29 (baseline scenario) to 0.23 scenario (Table 3.10). The priors as an importance function yielded better convergence diagnostics than the multivariate t distribution for the SIR algorithm (maximum weight of any draw <0.5%, but CV (weights) / CV (likelihood * priors) was 2.09). As in the previous case, population projections were very optimistic, with no risk of the population going below N_{MSY} under any of the policies or time horizons considered (Table 3.11).

C: Considering a continuity scenario for the LCS complex with the CPUE series used in the last stock assessment (2002 SEW)— Although the longest series (VA LL) and the early Port Salerno and Crooke LL series showed declining trends overall, several series showed increasing tendencies in the 1990s and early 2000s resulting in an abundance trajectory at the mode of the posterior distribution that showed a concave shape from the early 1990s to present (Fig. 3.16). The median relative abundance trajectory indicated that the stock was slightly overfished (barely below 1) during 1993-1998, but recovered thereafter (Fig. 3.17A), whereas the median relative fishing mortality trajectory indicated that overfishing had occurred during 1988-1996, but was no longer occurring from 1997 on (Fig. 3.17B). The model fits to several of the CPUE series showed the same concave shape probably as a result of the model trying to compensate between the early declining trends and the upswing in the latter part of the time series (Fig. 3.18).

The continuity scenario results did not vary significantly from those in the baseline scenario: current relative abundance was similar (no overfished status) and relative fishing mortality rate was lower (no overfishing) than in the baseline scenario (Table 3.12). The priors were used as an importance function for importance sampling. The SIR algorithm converged with reasonable diagnostics of convergence (maximum weight of any draw <<0.5%, but CV(weights) / CV(likelihood * priors) = 1.43). The posterior distributions showed that the data supported lower values of K, higher values of r, and lower values of C_0 than in the baseline scenario (Fig. 3.19). Population projections showed that there is an 86% probability that the stock will remain above N_{MSY} when applying the F_{MSY} policy under any of the three time horizons explored (10, 20, and 30 years; Table 3.13), a probability that substantially increases when considering the F_{OY} (F_{MSY} * 0.75)or the other two policies (Fig. 3.20A).

Using inverse CV weighting resulted in an overfished stock status determination (as in the baseline scenario with inverse CV weighting for LCS), but with no overfishing (Table 3.12). The priors were used as an importance function and convergence diagnostics were poorer than when using equal weighting (Table 3.12). In this case, population projections indicated that there is only a 29% probability that the stock will be above N_{MSY} when applying the F_{MSY} policy under any of the three time horizons explored (10, 20, and 30 years; Table 3.13), but a 67% probability of reaching N_{MSY} when applying the)F_{2003}/F_{MSY}) * F_{MSY} policy after only 10 years (Fig. 3.20B).

The lack of reconciliation between these results and the predictions from the 2002 assessment, which indicated an overfished stock with overfishing (N/N_{MSY}=0.70 and F/F_{MSY}=2.04 with equal weighting), suggest that the continuity case we considered may not be a real “continuity” scenario, owing to the fact that the values in several of the CPUE series used in the present analysis have changed. Many of the series used in 2002 were nominal indices that were GLM-standardized for the current assessment. A closer examination of the CPUE series used in the 2002 SEW vs. those used in the continuity scenario reveals that the 2002 SEW and the present continuity analysis only had 53% of points in common up to 2001. Twelve of the 20 CPUE series remained unchanged between the 2002 SEW and the 2006 continuity analysis (Fig. 3.21), whereas eight series changed (Fig. 3.22). The MRFSS series, which in 2002 was split into two nominal indices (REC early and REC late, with the division in 1994), was combined into one single standardized series in the current assessment. Despite these changes due mainly to standardization, overall the trends were maintained (Fig. 3.22).

R-2001: Conducting a retrospective analysis by stopping the baseline analysis for the LCS complex in 2001—For large coastal sharks (all 22 species), we conducted a retrospective analysis by running the baseline assessment (equal weighting, new r prior, baseline CPUE series including the revised Pelagic Log series) using only catch and CPUE data through 2001, consistent with the assessment in 2002. The results were similar to the baseline model results (Figs. 3.23-3.25). Status of the population in 2001 was above N_{MSY} and no overfishing was occurring (Table 3.12). The priors were used as an importance function and convergence diagnostics were good. The retrospective model was also much more optimistic than the 2002 assessment base case model for large coastal sharks.

ALL: Adding the CPUE series identified as “sensitivity” in the DW report to the baseline series—Sensitivity analyses were conducted which included the CPUE series that were identified as sensitivity in the Data Workshop, in addition to the base case series, using equal weighting and the baseline priors. The updated version of the Pelagic Log series was used. For large coastal sharks, the sensitivity series were PC Longline, MS Gillnet, Port Salerno, Crooke LL, and MRFSS. For LCS without prohibited species, they were PC longline, MS Gillnet, and MRFSS. There were no sensitivity series for large coastal sharks without prohibited species, sandbar or blacktip. All model runs converged satisfactorily using the priors as an importance function (Table 3.14). For large coastal sharks (all species), the results were similar to the baseline whether requiem sharks were included in the MRFSS series or not (compare Tables 3.6 and 3.14). For large coastal sharks without prohibited species, the run including MRFSS with requiem sharks was similar to the baseline, whereas the run with MRFSS excluding requiem sharks, unlike the baseline, implied that overfishing was occurring and the stock was barely above N_{MSY} (Table 3.14).

-/+ SERIES: Removing one CPUE series at a time from the full model (with all CPUE series considered in the baseline scenario) and fitting only one CPUE series at a time— For LCS, the priors were used as the importance function for each series removed. The status of the population was not overfished and overfishing was not occurring, as in the full model (Table 3.15). When the series were fitted one at a time, the priors also were the best importance function, and convergence diagnostics were good. As in the full model, six of the individual series fits showed that the population was not overfished and no overfishing. Overfishing occurred if the SC LL Recent, Pelagic Log or VA LL were fit (Table 3.16). The NMFS LL NE and SC LL Early series had too few points to estimate all four model parameters.

For LCS without prohibited species, convergence diagnostics were good drawing from the priors for all runs. The status of the population was not overfished and overfishing was not occurring in all cases regardless of the series being removed (Table 3.17). The runs fitting individual series found the same, except for the runs with the Bottom LL Logs and Pelagic Log series only, which found overfishing (Table 3.18). The BLLOP series failed to converge, and the NMFS LL NE series had too few data points to estimate all four model parameters.

For LCS without prohibited species, blacktip or sandbar, drawing from the priors produced good diagnostics of convergence in all cases. Removing one series did not change the assessment of status, which is not overfished, and overfishing is not occurring (Table 3.19). The runs by individual series were the same and the NMFS LL NE series had too few data points to estimate all four model parameters (Table 3.20).

FIXED CATCH: Fixing the 1972-1980 annual catch to the 1981 value (first year of catch data)—Introducing this change had a negligible effect on results for any of the three LCS groupings. Stock status determination did not change with respect to the corresponding baseline analyses (compare Tables 3.6 and 3.21).

3.8 Discussion

Baseline scenarios for the three LCS groupings considered predicted that the stock status is not overfished nor overfishing is occurring. Removing the species presently designated as prohibited from the LCS complex resulted in more optimistic results as one would expect given that the prohibited species are believed to be less resilient to fishing pressure. Further removing the two main species in the directed shark fisheries (blacktip and sandbar) resulted in even more optimistic results, with a depletion of only 19% of the virgin level, indicating that the sandbar and blacktip had opposing effects on the LCS complex, with the negative tendency of sandbar sharks outperforming the positive influence of blacktip sharks slightly.

The method to weight the CPUE data (equal vs. inverse variance) only had a significant effect on the LCS grouping, changing the predictions on stock status to overfished and overfishing occurring. However, convergence diagnostics for the inverse variance method were not good. Removing one CPUE series at a time from those used in the baseline scenarios did not reverse the conclusions on stock status for LCS, but fitting to the SC LL Recent, Pelagic Log, and VA LL series individually resulted in overfishing. Fitting to the Bottom LL Logs or Pelagic Log series alone also resulted in overfishing for the LCS without prohibited species grouping. Using all the CPUE series (baseline + sensitivities), using fixed catches for 1972-1980, or using the alternative model structure (WinBUGS) did not alter the stock status determination derived from the baseline analysis.

The continuity scenario for the LCS complex was an attempt to explain the large discrepancy between the 2002 SEW results and the present baseline analysis that essentially reversed the sign of stock status from overfished and overfishing to not overfished and no overfishing occurring (Fig. 3.26). The results of the continuity scenario supported the conclusions on stock status derived from the present baseline analysis, but these results must be interpreted cautiously as the two data sets (2002 assessment and continuity) only shared about half of the total number of data points up to 2001, indicating that it was not a continuity analysis per se. Many of the nominal series used in 2002 were GLM-standardized for the current analyses. The present results for LCS and those from the 2002 SEW are thus not directly comparable. Extracting the 2001 stock status criteria (N_{2001}/N_{msy} and F_{2001}/F_{msy}) from the continuity analysis revealed that the stock would also have been classified as not overfished with no overfishing and that the addition of three more years of data would have further improved stock status (Fig. 26). The retrospective analysis for LCS using baseline analysis data but only to 2001, also yielded similar results to those of the present baseline analysis, indicating that the addition of 3 years of data to the present analysis (from 2002 to 2004) did not explain the large change in stock status with respect to the 2002 SEW (Fig. 3.26).

3.9 References

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Table 3.1. Catch history for the Large Coastal Shark complex (22 species) in thousands of fish.

CATCHES OF LARGE COASTAL SHARKS: 22 species (in thousands)

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Mexican catches	Menhaden fishery discards	Confiscated Mexican catches in US	Total
1981	16.2	0.9	285.1		0.5	119.971	37.5		460.2
1982	16.2	0.9	539.3		0.5	81.913	38.5		677.3
1983	17.5	0.9	791.1		0.6	85.437	38.0		933.5
1984	23.9	1.3	268.9		0.8	120.684	38.0		453.5
1985	22.2	1.2	400.8		0.7	87.748	34.2		546.9
1986	54	2.9	432.5	24.9	1.7	81.835	33.8		631.6
1987	104.7	9.7	313.9	70.3	3.3	80.16	35.2		617.3
1988	274.6	11.4	308.7	113.3	8.7	89.29	34.2		840.2
1989	351	10.5	228.1	96.3	11.1	105.562	36.1		838.7
1990	267.5	8	218.2	52.1	8.5	122.22	35.2		711.7
1991	200.2	7.5	299.9	11.3	6.3	95.695	27.2		648.1
1992	215.2	20.9	307.2		6.8	103.366	23.9		677.4
1993	169.4	7.3	255.0		5.4	119.82	24.4		581.3
1994	228	8.8	163.9		3.7	110.734	26.1		541.2
1995	222.4	5.2	187.2		5.2	95.996	24.0		540.0
1996	161.0	5.7	197.5		4.8	106.057	23.9		498.9
1997	130.6	5.6	169.7		6.7	83.051	24.4		420.0
1998	174.9	4.3	160.9		6.6	74.136	23.5		444.3
1999	111.5	9.0	82.1		2.9	57.061	25.8		288.4
2000	111.2	9.4	139.0		4.1	52.057	22.1	1.000	338.9
2001	95.8	5.6	136.7		5.5	52.057	20.6	1.470	317.7
2002	123.7	2.43	80.3		4.8	52.057	20.2	1.390	284.9
2003	122.8	3.5	88.4		6.9	52.057	19.7	1.310	294.7
2004	99.0	5.2	67.0		4.5	52.057	20.2	2.120	250.0

Table 3.2. Prior probability distributions of parameters used in the baseline scenarios (Bayesian Surplus Production Model [BSP] with the SIR algorithm) and the sensitivity analysis with WinBUGS (Bayesian state-space surplus production model with the MCMC algorithm). K is carrying capacity (in numbers), r is the intrinsic rate of population increase, C_0 is the annual catch from 1972 to 1980 (in thousands of individuals), N_{1972}/K is the ratio of abundance in 1972 to carrying capacity, q is the catchability coefficient, σ^2 is the observation error variance in the BSP model (but process error variance in WinBUGS), and τ^2 is observation error variance in WinBUGS.

Grouping/ Model	**K**	**r**	**C_0**	**N_{1972}/K**	**q**	**σ^2**	**τ^2**
BSP (SIR)							
LCS complex	Uniform on log K[1] (10^5-10^9)	Lognormal (0.045,0.44,0.001,2.0)	Lognormal (534.9,1,10,5x10^3)	Lognormal (1,0.2,0.2,1.1`)	Uniform on log[2]	Uniform on log	N/A
LCS - Prohibited	Uniform (10^5-10^9)	Lognormal (0.046,0.45,0.001,2.0)	Lognormal (494.6,1,10,5x10^3)	Lognormal (1,0.2,0.2,1.1)	Uniform on log	Uniform on log	N/A
LCS – Prohibited -sandbar -blacktip	Uniform (10^5-10^9)	Lognormal (0.043,0.43,0.001,2.0)	Lognormal (136.1,1,10,5x10^3)	Lognormal (1,0.2,0.2,1.1)	Uniform on log	Uniform on log	N/A
WinBUGS (MCMC)							
LCS complex	Uniform on log K (10^5-10^9)	Lognormal (0.045,0.44,0.01,1.0)	Normal (534.9,1,10,5x10^3)	Lognormal (1,0.2,0.2,1.1)	MLE[3]	Inverse gamma (0.04-0.08)	Inverse gamma (0.05-0.15)
LCS - Prohibited	Uniform (10^5-10^9)	Lognormal (0.046,0.45,0.01,1.0)	Normal (494.6,1,10,5x10^3)	Lognormal (1,0.2,0.2,1.1)	MLE	Inverse gamma (0.04-0.08)	Inverse gamma (0.05-0.15)
LCS – Prohibited -sandbar -blacktip	Uniform (10^5-10^9)	Lognormal (0.043,0.43,0.01,1.0)	Normal (136.1,1,10,5x10^3)	Lognormal (1,0.2,0.2,1.1)	MLE	Inverse gamma (0.04-0.08)	Inverse gamma (0.05-0.15)

[1] Values in parentheses are lower and upper bounds (uniform distribution), mean, SD, lower bound, and upper bound (lognormal distribution), 10% and 90% quantiles (inverse gamma distribution); [2] Priors for q and σ^2 were given a uniform distribution on a log scale, but were integrated from the joint posterior distribution using the method described by Walters and Ludwig (1994); [3] The maximum likelihood estimate of q for each CPUE series was used instead of a prior for q.

Table 3.3. Catch history for the Large Coastal Shark complex without the prohibited species (11 species) in thousands of fish.

CATCHES OF LARGE COASTAL SHARKS without prohibited species (thousands of fish)

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Mexican catches	Menhaden fishery discards	Confiscated Mexican catches in US	Total
1981	15.1	0.7	223.7		0.5	119.971	37.5		397.5
1982	15.1	0.7	331.9		0.5	81.913	38.5		468.7
1983	16.3	0.7	683.1		0.5	85.437	38		824.1
1984	22.3	1.0	216.5		0.7	120.684	38		399.2
1985	20.7	1.0	355.7		0.7	87.748	34.2		500.0
1986	50.4	2.3	391.1	23.2	1.7	81.835	33.8		584.4
1987	97.7	7.7	274.6	65.6	3.2	80.16	35.2		564.3
1988	256.4	9.1	290.5	105.8	8.4	89.29	34.2		793.6
1989	327.7	8.3	212.9	89.9	10.8	105.562	36.1		791.3
1990	249.7	6.4	206.3	48.6	8.2	122.22	35.2		676.6
1991	186.9	6.0	284.3	10.5	6.1	95.695	27.2		616.7
1992	200.9	19.2	276.1		6.6	103.366	23.9		630.0
1993	158.1	6.3	244.5		5.2	119.82	24.4		558.3
1994	212.9	5.7	153.3		3.0	110.734	26.1		511.7
1995	207.6	4.5	177.3		4.9	95.996	24		514.2
1996	150.1	4.4	181.5		4.7	106.057	23.9		470.7
1997	127.5	5.0	154.0		6.9	83.051	24.4		400.8
1998	168.7	2.2	156.2		6.8	74.136	23.5		431.5
1999	109.0	7.3	76.7		2.8	57.061	25.8		278.7
2000	108.2	4.8	135.8		4.1	52.057	22.1	1.000	328.0
2001	95.7	4.2	129.9		5.0	52.057	20.6	1.470	308.9
2002	123.4	2.4	78.6		4.0	52.057	20.2	1.390	282.0
2003	122.1	3.5	85.7		6.0	52.057	19.7	1.310	290.4
2004	98.9	5.2	66.2		3.2	52.057	20.2	2.120	247.8

Table 3.4. Catch history for the Large Coastal Shark complex without the prohibited species, blacktip or sandbar sharks (9 species) in thousands of fish.

CATCHES OF LARGE COASTAL SHARKS: except Prohibited or BT or SB (in thousands)

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Mexican catches	Menhaden fishery discards	Confiscated Mexican catches in US	Total
1981	3.8	0.7	38.1		0.4		19.8		62.9
1982	3.8	0.7	215.8		0.4		20.4		241.1
1983	4.1	0.7	222.1		0.5		20.1		247.6
1984	5.7	1.0	119.6		0.7		20.1		147.0
1985	5.3	0.9	169.8		0.6		18.1		194.7
1986	12.8	2.3	99.5	5.3	1.5		17.9		139.2
1987	24.8	7.6	111.8	15.1	2.9		18.6		180.8
1988	65.0	8.9	76.2	24.9	7.6		18.1		200.6
1989	83.1	8.2	67.5	21.1	9.7		19.1		208.7
1990	63.3	6.2	52.4	11.2	7.4		18.6		159.2
1991	47.4	5.9	93.3	2.4	5.5		14.4		168.9
1992	51.0	18.8	80.9		6.0		12.6		169.2
1993	40.1	5.6	105.0		4.7		12.9		168.3
1994	54.0	5.1	70.1		2.9		13.8		145.9
1995	63.9	4.3	82.8		5.2		12.7		168.9
1996	42.4	4.4	57.6		4.8		12.6		121.8
1997	17.3	5.0	38.3		2.9		12.9		76.4
1998	9.1	2.2	41.4		1.5		12.4		66.6
1999	8.5	7.3	24.9		0.6		13.6		54.9
2000	13.3	4.8	51.0		1.1		11.7	0.670	82.5
2001	6.0	4.2	44.3		1.4		10.9	0.985	67.8
2002	15.7	2.4	30.6		0.8		10.7	0.932	61.1
2003	14.0	3.5	40.2		1.6		10.4	0.878	70.6
2004	11.6	5.2	31.3		0.8		10.7	1.420	61.0

Table 3.5. Time series of estimates of stock abundance (N_i), relative stock abundance ((N_i/N_{MSY}), fishing mortality rate (F_i), and relative fishing mortality rate (F_i/F_{MSY}) for the BSP model **baseline scenario for the LCS (22 species) complex.** Values listed are medians.

Year	N_i	N_i/N_{MSY}	F_i	F_i/F_{MSY}
1972	27686	1.85	0.0102	0.47
1973	27244	1.83	0.0103	0.47
1974	26879	1.81	0.0104	0.48
1975	26549	1.79	0.0105	0.48
1976	26216	1.78	0.0105	0.48
1977	25910	1.76	0.0106	0.49
1978	25557	1.75	0.0106	0.49
1979	25282	1.74	0.0107	0.49
1980	24946	1.72	0.0108	0.49
1981	24678	1.70	0.0185	0.82
1982	24264	1.67	0.0276	1.22
1983	23626	1.61	0.0389	1.72
1984	23109	1.59	0.0195	0.86
1985	22791	1.57	0.0238	1.05
1986	22500	1.54	0.0279	1.23
1987	22106	1.51	0.0277	1.23
1988	21611	1.46	0.0383	1.70
1989	21039	1.42	0.0394	1.75
1990	20511	1.39	0.0343	1.53
1991	20119	1.36	0.0319	1.43
1992	19706	1.33	0.0340	1.52
1993	19367	1.31	0.0298	1.34
1994	19120	1.29	0.0281	1.27
1995	18862	1.27	0.0284	1.28
1996	18621	1.26	0.0266	1.20
1997	18442	1.25	0.0227	1.02
1998	18322	1.24	0.0242	1.08
1999	18294	1.24	0.0158	0.71
2000	18287	1.24	0.0185	0.83
2001	18263	1.24	0.0174	0.78
2002	18286	1.25	0.0156	0.70
2003	18311	1.25	0.0161	0.72
2004	18339	1.25	0.0137	0.61

Table 3.6. Expected values (EV) of the mean and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for the three LCS groupings (**baseline scenario**) using equal weighting and values of r (intrinsic rate of increase) recommended in the Data Workshop report. Abundances are in thousands of fish.

	LCS		LCS-PROH		LCS-PROH-SB-BT	
	EV	CV	EV	CV	EV	CV
Importance function	priors		priors		priors	
K	35677	0.50	51387	0.45	31534	0.80
r	0.048	0.47	0.050	0.47	0.046	0.46
MSY	395.5	0.59	621.4	0.62	347.7	0.96
N_{2004}	24133	0.71	40500	0.56	27899	0.88
N_{2004}/K	**0.63**	0.25	**0.75**	0.19	**0.81**	0.20
N_{init}	32578	0.52	45485	0.46	27944	0.82
N_{2004}/N_{init}	0.69	0.23	0.85	0.21	0.92	0.21
C_{2004}/MSY	0.80	0.47	0.56	0.61	0.37	0.87
F_{2004}/F_{MSY}	**0.74**	0.70	**0.44**	0.95	**0.29**	1.32
N_{2004}/N_{MSY}	**1.26**	0.25	**1.49**	0.19	**1.61**	0.20
C_{2004}/repy	0.927	0.37	0.792	0.39	0.660	35.39
N_{MSY}	17839	0.50	25693	0.45	15767	0.80
F_{MSY}	0.024		0.025		0.023	
repy	299.2	0.30	351.2	0.33	115.9	0.56
C_0	421.7	1.00	467.0	1.11	137.1	1.24
Diagnostics						
CW (wt)	0.891		0.518		0.389	
CV (L*prior)	1.531		0.961		1.216	
CV (Wt) / CV (L*p)	0.58		0.54		0.32	
%maxpWt	0.006		0.002		0.003	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 3.7. Decision analysis tables for various groupings and species corresponding to the results in Table 3.6.

LCS

Horizon	Policy	$E(N_{fin}/K)$	$E(N_{fin}/N_{msy})$	$P(N_{fin}<0.2K)$	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{cur})$	$P(F_{fin}<F_{cur})$	$P(N_{cur}>N_{ref})$	$P(N_{fin}<0.01K)$
10 -year	HRmsy	0.59	1.18	0	0.78	0.22	0.22	0.22	0
	HRmsy* 0.75	0.62	1.24	0	0.83	0.48	0.37	0.48	0
	HRmsy*(HR/HRmsy)2003	0.62	1.25	0	0.84	0.51	0.39	0.51	0
	HRmsy*0	0.72	1.45	0	0.92	1	1	1	0
20 -year	HRmsy	0.56	1.13	0	0.78	0.22	0.22	0.22	0
	HRmsy* 0.75	0.62	1.23	0	0.88	0.48	0.37	0.48	0
	HRmsy*(HR/HRmsy)2003	0.62	1.25	0	0.89	0.51	0.39	0.51	0
	HRmsy*0	0.8	1.59	0	0.98	1	1	1	0
30 -year	HRmsy	0.55	1.1	0	0.78	0.22	0.22	0.22	0
	HRmsy* 0.75	0.62	1.23	0	0.91	0.48	0.37	0.48	0
	HRmsy*(HR/HRmsy)2003	0.62	1.25	0	0.92	0.51	0.39	0.51	0
	HRmsy*0	0.85	1.7	0	0.99	1	1	1	0

Table 3.7. (continued)

LCS-PROHIBITED

Horizon	Policy	$E(N_{fin}/K)$	$E(N_{fin}/N_{msy})$	$P(N_{fin}<0.2K)$	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{cur})$	$P(F_{fin}<F_{cur})$	$P(N_{cur}>N_{ref})$	$P(N_{fin}<0.01K)$
10 -year	HRmsy	0.66	1.32	0	0.92	0.08	0.08	0.08	0
	HRmsy* 0.75	0.7	1.39	0	0.94	0.2	0.15	0.2	0
	HRmsy*(HR/HRmsy)2003	0.75	1.51	0	0.96	0.59	0.41	0.59	0
	HRmsy*0	0.81	1.63	0	0.97	1	1	1	0
20 -year	HRmsy	0.62	1.23	0	0.92	0.08	0.08	0.08	0
	HRmsy* 0.75	0.67	1.35	0	0.96	0.2	0.15	0.2	0
	HRmsy*(HR/HRmsy)2003	0.76	1.53	0	0.98	0.59	0.41	0.59	0
	HRmsy*0	0.87	1.73	0	0.99	1	1	1	0
30 -year	HRmsy	0.59	1.17	0	0.92	0.08	0.08	0.08	0
	HRmsy* 0.75	0.66	1.32	0	0.97	0.2	0.15	0.2	0
	HRmsy*(HR/HRmsy)2003	0.77	1.55	0	0.99	0.59	0.41	0.59	0
	HRmsy*0	0.9	1.81	0	0.99	1	1	1	0

Table 3.7. (continued)

LCS-PROHIBITED-BLACKTIP-SANDBAR

Horizon	Policy	$E(N_{fin}/K)$	$E(N_{fin}/N_{msy})$	$P(N_{fin}<0.2K)$	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{cur})$	$P(F_{fin}<F_{cur})$	$P(N_{cu}r>N_{ref})$	$P(N_{fin}<0.01K)$
10 -year	HRmsy	0.71	1.41	0	0.94	0.06	0.05	0.06	0
	HRmsy* 0.75	0.74	1.48	0	0.95	0.14	0.1	0.14	0
	HRmsy*(HR/HRmsy)2003	0.83	1.65	0	0.97	0.67	0.45	0.67	0
	HRmsy*0	0.86	1.71	0	0.98	1	1	1	0
20 -year	HRmsy	0.65	1.3	0	0.94	0.06	0.05	0.06	0
	HRmsy* 0.75	0.71	1.41	0	0.97	0.14	0.1	0.14	0
	HRmsy*(HR/HRmsy)2003	0.84	1.69	0	0.99	0.67	0.45	0.67	0
	HRmsy*0	0.89	1.79	0	0.99	1	1	1	0
30 -year	HRmsy	0.61	1.23	0	0.94	0.06	0.05	0.06	0
	HRmsy* 0.75	0.68	1.37	0	0.98	0.14	0.1	0.14	0
	HRmsy*(HR/HRmsy)2003	0.86	1.72	0	0.99	0.67	0.45	0.67	0
	HRmsy*0	0.92	1.85	0	1	1	1	1	0

Table 3.8. Time series of estimates of stock abundance (N_i), relative stock abundance ((N_i/N_{MSY}), fishing mortality rate (F_i), and relative fishing mortality rate (F_i/F_{MSY}) for the BSP model **baseline scenario** for the **LCS without prohibited species (11 species) complex.** Values listed are medians.

Year	N_i	N_i/N_{MSY}	F_i	F_i/F_{MSY}
1972	41477	1.80	0.0074	0.33
1973	41180	1.79	0.0074	0.33
1974	40894	1.78	0.0074	0.33
1975	40651	1.77	0.0074	0.33
1976	40429	1.75	0.0075	0.33
1977	40189	1.75	0.0075	0.34
1978	39987	1.74	0.0075	0.34
1979	39620	1.73	0.0075	0.34
1980	39385	1.73	0.0075	0.34
1981	39202	1.72	0.0101	0.47
1982	39068	1.71	0.0120	0.55
1983	38734	1.68	0.0211	0.98
1984	38335	1.67	0.0104	0.48
1985	38185	1.66	0.0131	0.60
1986	37968	1.65	0.0153	0.71
1987	37681	1.63	0.0149	0.69
1988	37346	1.61	0.0211	0.98
1989	36892	1.59	0.0213	0.99
1990	36487	1.57	0.0185	0.86
1991	36264	1.56	0.0169	0.79
1992	36038	1.54	0.0174	0.81
1993	35860	1.53	0.0155	0.72
1994	35754	1.53	0.0143	0.67
1995	35572	1.52	0.0144	0.67
1996	35503	1.52	0.0132	0.62
1997	35415	1.52	0.0113	0.53
1998	35339	1.51	0.0122	0.57
1999	35338	1.52	0.0079	0.37
2000	35429	1.52	0.0093	0.43
2001	35506	1.52	0.0087	0.41
2002	35559	1.53	0.0079	0.37
2003	35670	1.53	0.0082	0.38
2004	35773	1.54	0.0069	0.32

Table 3.9. Time series of estimates of stock abundance (N_i), relative stock abundance ((N_i/N_{MSY}), fishing mortality rate (F_i), and relative fishing mortality rate (F_i/F_{MSY}) for the BSP model **baseline scenario** for the **LCS without prohibited species, blacktip, and sandbar sharks (9 species) complex.** Values listed are medians.

Year	N_i	N_i/N_{MSY}	F_i	F_i/F_{MSY}
1972	19440	1.79	0.0046	0.22
1973	19347	1.79	0.0046	0.22
1974	19348	1.78	0.0046	0.22
1975	19275	1.77	0.0046	0.22
1976	19265	1.77	0.0046	0.22
1977	19213	1.76	0.0046	0.22
1978	19128	1.76	0.0046	0.22
1979	19109	1.76	0.0046	0.22
1980	19048	1.75	0.0046	0.22
1981	19029	1.76	0.0033	0.16
1982	18997	1.73	0.0126	0.63
1983	18863	1.71	0.0131	0.65
1984	18819	1.71	0.0078	0.39
1985	18737	1.69	0.0104	0.52
1986	18638	1.69	0.0074	0.37
1987	18551	1.68	0.0097	0.48
1988	18475	1.67	0.0108	0.54
1989	18399	1.66	0.0113	0.56
1990	18351	1.66	0.0087	0.43
1991	18309	1.65	0.0092	0.46
1992	18303	1.65	0.0092	0.46
1993	18278	1.64	0.0092	0.46
1994	18237	1.64	0.0080	0.40
1995	18224	1.64	0.0093	0.46
1996	18199	1.64	0.0067	0.33
1997	18254	1.65	0.0042	0.21
1998	18305	1.65	0.0036	0.18
1999	18398	1.66	0.0030	0.15
2000	18436	1.66	0.0045	0.22
2001	18481	1.67	0.0037	0.18
2002	18563	1.67	0.0033	0.16
2003	18625	1.68	0.0038	0.19
2004	18675	1.68	0.0033	0.16

Table 3.10. Expected values (EV) of the mean and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for the three LCS groupings using **inverse CV weighting** and values of r (intrinsic rate of increase) recommended in the Data Workshop report. Results that alter the stock status determination derived from the baseline scenario are boxed and highlighted in red. Poor convergence diagnostics are shaded and highlighted in green. Abundances are in thousands of fish.

	LCS		LCS-PROH		LCS-PROH-SB-BT	
	EV	CV	EV	CV	EV	CV
Importance function	multivariate		priors		priors	
K	12624	0.18	54958	0.41	28497	0.86
r	0.100	0.33	0.058	0.46	0.057	0.51
MSY	298.8	0.19	744.0	0.53	341.8	0.90
N_{2004}	4604	0.14	44108	0.49	24665	0.94
N_{2004}/K	**0.37**	0.17	**0.78**	0.15	**0.79**	0.18
N_{init}	12411	0.18	47027	0.43	24074	0.88
N_{2004}/N_{init}	0.38	0.16	0.92	0.18	0.95	0.21
C_{2004}/MSY	0.88	0.25	0.42	0.51	0.31	0.70
F_{2004}/F_{MSY}	**1.24**	0.41	**0.30**	0.70	**0.23**	0.93
N_{2004}/N_{MSY}	**0.74**	0.17	**1.56**	0.15	**1.59**	0.18
C_{2004}/repy	0.968	0.31	0.659	0.33	0.541	29.45
N_{MSY}	6312	0.18	27479	0.41	14249	0.86
F_{MSY}	0.050		0.029		0.029	
repy	276.3	0.23	412.3	0.31	138.6	0.55
C_0	211	0.79	607	1.13	201.5	1.46
Diagnostics						
CW (wt)	38.622		1.136		2.395	
CV (L*prior)	11.693		0.999		1.147	
CV (Wt) / CV (L*p)	3.30		1.14		2.09	
%maxpWt	4.265		0.013		0.146	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 3.11. Decision analysis tables for various groupings and species corresponding to the results in Table 3.10.

LCS

Horizon	Policy	$E(N_{fin}/K)$	$E(N_{fin}/N_{msy})$	$P(N_{fin}<0.2K)$	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{cur})$	$P(F_{fin}<F_{cur})$	$P(N_{cur}>N_{ref})$	$P(N_{fin}<0.01K)$
10 -year	HRmsy	0.41	0.82	0	0.01	0.99	0.68	0.99	0
	HRmsy* 0.75	0.45	0.9	0	0.28	1	0.94	1	0
	HRmsy*(HR/HRmsy)2003	0.46	0.92	0	0.29	1	0.96	1	0
	HRmsy*0	0.61	1.22	0	0.81	1	1	1	0
20 -year	HRmsy	0.43	0.87	0	0.01	0.99	0.68	0.99	0
	HRmsy* 0.75	0.51	1.02	0	0.64	1	0.94	1	0
	HRmsy*(HR/HRmsy)2003	0.52	1.04	0	0.68	1	0.96	1	0
	HRmsy*0	0.79	1.57	0	0.96	1	1	1	0
30 -year	HRmsy	0.45	0.91	0	0.01	0.99	0.68	0.99	0
	HRmsy* 0.75	0.55	1.1	0	0.83	1	0.94	1	0
	HRmsy*(HR/HRmsy)2003	0.56	1.12	0	0.85	1	0.96	1	0
	HRmsy*0	0.89	1.77	0	0.99	1	1	1	0

Table 3.11. (continued)

LCS-PROHIBITED

Horizon	Policy	$E(N_{fin}/K)$	$E(N_{fin}/N_{msy})$	$P(N_{fin}<0.2K)$	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{cur})$	$P(F_{fin}<F_{cur})$	$P(N_{cur}>N_{ref})$	$P(N_{fin}<0.01K)$
10 -year	HRmsy	0.68	1.35	0	0.97	0.03	0.01	0.03	0
	HRmsy* 0.75	0.72	1.43	0	0.98	0.12	0.04	0.12	0
	HRmsy*(HR/HRmsy)2003	0.78	1.56	0	0.99	0.53	0.24	0.53	0
	HRmsy*0	0.85	1.7	0	0.99	1	1	1	0
20 -year	HRmsy	0.62	1.24	0	0.97	0.03	0.01	0.03	0
	HRmsy* 0.75	0.69	1.37	0	0.99	0.12	0.04	0.12	0
	HRmsy*(HR/HRmsy)2003	0.79	1.57	0	1	0.53	0.24	0.53	0
	HRmsy*0	0.9	1.8	0	1	1	1	1	0
30 -year	HRmsy	0.59	1.18	0	0.97	0.03	0.01	0.03	0
	HRmsy* 0.75	0.67	1.33	0	0.99	0.12	0.04	0.12	0
	HRmsy*(HR/HRmsy)2003	0.79	1.58	0	1	0.53	0.24	0.53	0
	HRmsy*0	0.93	1.87	0	1	1	1	1	0

Table 3.11. (continued)

LCS-PROHIBITED-BLACKTIP-SANDBAR

Horizon	Policy	$E(N_{fin}/K)$	$E(N_{fin}/N_{msy})$	$P(N_{fin}<0.2K)$	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{cur})$	$P(F_{fin}<F_{cur})$	$P(N_{cur}>N_{ref})$	$P(N_{fin}<0.01K)$
10 -year	HRmsy	0.69	1.38	0	0.95	0.05	0.01	0.05	0
	HRmsy* 0.75	0.73	1.46	0	0.97	0.14	0.03	0.14	0
	HRmsy*(HR/HRmsy)2003	0.83	1.66	0	0.99	0.74	0.45	0.74	0
	HRmsy*0	0.86	1.73	0	0.99	1	1	1	0
20 -year	HRmsy	0.63	1.27	0	0.95	0.05	0.01	0.05	0
	HRmsy* 0.75	0.7	1.39	0	0.98	0.14	0.03	0.14	0
	HRmsy*(HR/HRmsy)2003	0.85	1.71	0	1	0.74	0.45	0.74	0
	HRmsy*0	0.91	1.82	0	1	1	1	1	0
30 -year	HRmsy	0.6	1.2	0	0.95	0.05	0.01	0.05	0
	HRmsy* 0.75	0.68	1.35	0	0.99	0.14	0.03	0.14	0
	HRmsy*(HR/HRmsy)2003	0.87	1.74	0	1	0.74	0.45	0.74	0
	HRmsy*0	0.94	1.88	0	1	1	1	1	0

Table 3.12. Expected values (EV) of the mean and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for the LCS complex with equal and inverse CV weighting: **continuity scenario** (using all CPUE series from the 2002 assessment, updated to 2004 when possible) and **retrospective analysis** (limiting the baseline scenario catch and CPUEs through 2001). Results that alter the stock status determination derived from the baseline scenario are boxed and highlighted in red. Poor convergence diagnostics are shaded and highlighted in green. Abundances are in thousands of fish.

	LCS-Continuity, Eq.W		LCS-Continuity, Inv. W		LCS-Retrospective*	
	EV	CV	EV	CV	EV	CV
Importance function	priors		priors		priors	
K	12298	0.65	8109	0.11	35750	0.49
r	0.203	0.55	0.210	0.17	0.047	0.47
MSY	481.3	0.37	417.0	0.07	397.9	0.62
N_{2004}	7492	0.86	3333	0.13	25426	0.70
N_{2004}/K	**0.60**	0.21	**0.41**	0.12	**0.66**	0.25
N_{init}	11292	0.67	8051	0.13	36151	0.52
N_{2004}/N_{init}	0.66	0.22	0.42	0.12	0.66	0.23
C_{2004}/MSY	0.56	0.31	0.60	0.08	0.94	0.52
F_{2004}/F_{MSY}	**0.51**	0.52	**0.74**	0.17	**0.83**	0.75
N_{2004}/N_{MSY}	**1.20**	0.21	**0.83**	0.12	**1.32**	0.25
C_{2004}/repy	0.617	0.27	0.638	0.10	1.711	55.40
N_{MSY}	6149	0.65	4054	0.11	17875	0.49
F_{MSY}	0.101		0.105		0.024	0.47
repy	422.7	0.17	395.6	0.10	279.7	0.38
C_0	291.9	0.94	138.6	0.65	415.3	1.00
Diagnostics						
CW (wt)	5.558		37.011		0.768	
CV (L*prior)	3.901		33.879		1.532	
CV (Wt) / CV (L*p)	1.43		1.09		0.50	
%maxpWt	0.096		2.500		0.015	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield
* Stock status criteria for the retrospective analysis refer to 2001

Table 3.13. Decision analysis tables for various groupings and species corresponding to the results in Table 3.12.

LCS continuity scenario, equal weighting

Horizon	Policy	$E(N_{fin}/K)$	$E(N_{fin}/N_{msy})$	$P(N_{fin}<0.2K)$	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{cur})$	$P(F_{fin}<F_{cur})$	$P(N_{cur}>N_{ref})$	$P(N_{fin}<0.01K)$
10 -year	HRmsy	0.53	1.07	0	0.86	0.14	0.04	0.14	0
	HRmsy* 0.75	0.61	1.23	0	0.95	0.4	0.11	0.4	0
	HRmsy*(HR/HRmsy)2003	0.67	1.34	0	0.97	0.65	0.22	0.65	0
	HRmsy*0	0.89	1.77	0	0.99	1	1	1	0
20 -year	HRmsy	0.51	1.03	0	0.86	0.14	0.04	0.14	0
	HRmsy* 0.75	0.62	1.23	0	0.98	0.4	0.11	0.4	0
	HRmsy*(HR/HRmsy)2003	0.69	1.38	0	0.99	0.65	0.22	0.65	0
	HRmsy*0	0.95	1.9	0	1	1	1	1	0
30 -year	HRmsy	0.51	1.01	0	0.86	0.14	0.04	0.14	0
	HRmsy* 0.75	0.62	1.24	0	0.99	0.4	0.11	0.4	0
	HRmsy*(HR/HRmsy)2003	0.7	1.39	0	0.99	0.65	0.22	0.65	0
	HRmsy*0	0.98	1.95	0	1	1	1	1	0

Table 3.13. (continued)

LCS continuity scenario, inverse CV weighting

Horizon	Policy	$E(N_{fin}/K)$	$E(N_{fin}/N_{msy})$	$P(N_{fin}<0.2K)$	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{cur})$	$P(F_{fin}<F_{cur})$	$P(N_{cur}>N_{ref})$	$P(N_{fin}<0.01K)$
10 -year	HRmsy	0.49	0.97	0	0.29	0.71	0.02	0.71	0
	HRmsy* 0.75	0.57	1.14	0	0.97	0.99	0.25	0.99	0
	HRmsy*(HR/HRmsy)2003	0.51	1.01	0	0.67	0.84	0.04	0.84	0
	HRmsy*0	0.88	1.75	0	1	1	1	1	0
20 -year	HRmsy	0.49	0.99	0	0.29	0.71	0.02	0.71	0
	HRmsy* 0.75	0.61	1.22	0	1	0.99	0.25	0.99	0
	HRmsy*(HR/HRmsy)2003	0.52	1.04	0	0.94	0.84	0.04	0.84	0
	HRmsy*0	0.98	1.96	0	1	1	1	1	0
30 -year	HRmsy	0.5	0.99	0	0.29	0.71	0.02	0.71	0
	HRmsy* 0.75	0.62	1.24	0	1	0.99	0.25	0.99	0
	HRmsy*(HR/HRmsy)2003	0.53	1.05	0	0.99	0.84	0.04	0.84	0
	HRmsy*0	1	1.99	0	1	1	1	1	0

Table 3.14. Expected values (EV) of the mean and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for the LCS and LCS- prohibited species groupings as in the baseline scenario but **including the additional CPUE series identified as "sensitivity"** in the Data Workshop report. The MRFSS series was included both with and without requiem sharks. Results that alter the stock status determination derived from the baseline scenario are boxed and highlighted in red.

	LCS				LCS-prohibited			
	MRFSS with requiem		MRFSS without requiem		MRFSS with requiem		MRFSS without requiem	
	EV	CV	EV	CV	EV	CV	EV	CV
Importance function	priors		priors		priors		priors	
K	35484	0.47	26781	0.44	55699	0.40	25945	0.57
r	0.05	0.49	0.05	0.48	0.05	0.47	0.05	0.48
MSY	430	0.53	313	0.49	704.57	0.56	289.37	0.65
N_{2004}	25804	0.64	16803	0.70	44461	0.48	14866	0.97
N_{2004}/K	**0.69**	0.21	**0.59**	0.25	**0.77**	0.15	**0.50**	0.35
N_{init}	36247	0.50	27462	0.49	48720	0.42	23466	0.59
N_{2004}/N_{init}	0.68	0.19	0.58	0.22	0.89	0.17	0.56	0.33
C_{2004}/MSY	0.72	0.46	0.95	0.42	0.46	0.55	1.09	0.46
F_{2004}/F_{MSY}	**0.58**	0.62	**0.90**	0.59	**0.33**	0.74	**1.32**	0.70
N_{2004}/N_{MSY}	**1.37**	0.21	**1.18**	0.25	**1.54**	0.15	**1.01**	0.35
C_{2004}/repy	0.94	3.82	1.09	3.10	0.70	0.37	1.23	0.44
N_{MSY}	17742	0.47	13390	0.44	27850	0.40	12972	0.57
F_{MSY}	0.03	0.49	0.03	0.48	0.03	0.47	0.02	0.48
repy	303	0.32	260	0.32	398	0.33	236	0.38
C_0	426	0.99	352	0.93	514	1.12	347	1.05
Diagnostics								
CW (wt)	1.13		1.47		0.81		1.33	
CV (L*prior)	1.56		2.04		1.04		2.02	
CV (Wt) / CV (L*p)	0.73		0.72		0.78		0.66	
%maxpWt	0.036		0.051		0.025		0.071	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 3.15. Expected values (EV) of the mean of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for LCS using equal weighting (baseline) and **removing one CPUE series at a time**. Abundances are in thousands of fish.

Series removed	Gillnet Observer	PC Gillnet	ENP	SC LL Recent	BLLOP	NMFS LL SE	Bottom LL Logs	NMFS LL NE	Pelagic Log	SC LL Early	VA LL
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors	priors	priors	priors	priors	priors	priors
K	33401	35128	36517	35184	34807	34626	35113	34851	37259	37233	44171
r	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MSY	367	396	415	397	390	382	395	390	433	422	514
N_{2004}	23054	24907	25825	24960	24556	24332	24889	24604	27133	27027	33867
N_{2004}/K	**0.64**	**0.66**	**0.65**	**0.66**	**0.65**	**0.65**	**0.66**	**0.66**	**0.68**	**0.68**	**0.72**
N_{init}	33903	35599	36520	35622	35274	35163	35576	35345	37555	37627	43283
N_{2004}/N_{init}	0.63	0.66	0.65	0.66	0.65	0.65	0.66	0.65	0.68	0.68	0.74
C_{2004}/MSY	0.87	0.81	0.80	0.81	0.82	0.84	0.81	0.82	0.74	0.76	0.65
F_{2004}/F_{MSY}	**0.80**	**0.71**	**0.74**	**0.70**	**0.72**	**0.75**	**0.71**	**0.72**	**0.62**	**0.64**	**0.51**
N_{2004}/N_{MSY}	**1.27**	**1.32**	**1.29**	**1.32**	**1.31**	**1.30**	**1.32**	**1.31**	**1.36**	**1.35**	**1.45**
C_{2004}/repy	1.08	1.04	1.03	1.04	1.05	1.07	1.04	1.05	0.98	1.01	0.92
N_{MSY}	16700	17564	18258	17592	17403	17313	17557	17425	18629	18616	22085
F_{MSY}	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02
repy	269	281	287	283	279	274	282	278	298	290	319
C_0	401	417	476	418	414	408	417	413	440	432	432
Diagnostics											
CW (wt)	0.88	0.85	0.72	0.85	0.85	0.84	0.85	0.85	0.84	0.78	0.57
CV (L*prior)	1.66	1.57	1.41	1.56	1.58	1.60	1.57	1.58	1.46	1.48	1.24
CV (Wt) / CV (L*p)	0.53	0.54	0.51	0.55	0.54	0.52	0.54	0.54	0.57	0.53	0.45
%maxpWt	0.014	0.017	0.019	0.017	0.016	0.012	0.017	0.015	0.032	0.016	0.009

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 3.16. Expected values (EV) of the mean of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for LCS using equal weighting (baseline) and **fitting one CPUE series at a time**. Results that alter the stock status determination derived from the full model (all baseline CPUE series included) are boxed and highlighted in red. The NMFS LL NE and SC LL Early had too few data points to estimate all four model parameters. Abundances are in thousands of fish.

Series fit	Gillnet Observer	PC Gillnet	ENP	SC LL Recent	BLLOP	NMFS LL SE	Bottom LL Logs	NMFS LL NE	Pelagic Log	SC LL Early	VA LL
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors	priors	priors		priors		priors
K	48638	44478	43111	43657	45699	46496	44535		36248		32714
r	0.05	0.05	0.05	0.05	0.05	0.05	0.05		0.04		0.04
MSY	574	509	477	498	526	542	509		396		347
N_{2004}	37801	33483	32636	32596	34778	35608	33549		24789		21468
N_{2004}/K	**0.73**	**0.68**	**0.70**	**0.66**	**0.69**	**0.70**	**0.68**		**0.56**		**0.57**
N_{init}	46467	42873	42572	42090	44014	44591	42942		35267		32798
N_{2004}/N_{init}	0.76	0.71	0.72	0.69	0.72	0.74	0.71		0.58		0.57
C_{2004}/MSY	0.63	0.76	0.74	0.79	0.72	0.69	0.76		1.03		1.01
F_{2004}/F_{MSY}	**0.56**	**0.90**	**0.63**	**1.22**	**0.75**	**0.66**	**0.90**		**1.99**		**1.22**
N_{2004}/N_{MSY}	**1.45**	**1.35**	**1.41**	**1.32**	**1.39**	**1.41**	**1.35**		**1.12**		**1.15**
C_{2004}/repy	0.94	1.10	1.03	1.22	1.04	0.99	1.10		1.58		1.28
N_{MSY}	24319	22239	21555	21828	22849	23248	22268		18124		16357
F_{MSY}	0.02	0.02	0.02	0.02	0.02	0.02	0.02		0.02		0.02
repy	334	303	296	296	311	321	303		245		245
C_0	475	451	411	448	456	464	451		421		449
Diagnostics											
CW (wt)	0.40	0.19	0.46	0.11	0.26	0.32	0.19		0.45		0.70
CV (L*prior)	1.00	1.07	1.26	1.08	1.04	1.02	1.06		1.63		1.59
CV (Wt) / CV (L*p)	0.40	0.18	0.37	0.11	0.25	0.31	0.18		0.28		0.44
%maxpWt	0.007	0.002	0.004	0.002	0.001	0.005	0.001		0.006		0.007

N_{init} is initial abundance (for the first year of the model), repy is replacement yield.

Table 3.17. Expected values (EV) of the mean of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for LCS without prohibited species using equal weighting (baseline) and **removing one CPUE series at a time**.

Series removed	Gillnet Observer	PC Gillnet	BLLOP	NMFS LL SE	Bottom LL Logs	NMFS LL NE	Pelagic Log
	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors	priors	priors
K	48796	51093	50693	50383	50925	50770	52207
r	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MSY	575	615	609	599	612	610	650
N_{2004}	37572	39888	39488	39168	39725	39572	40955
N_{2004}/K	**0.72**	**0.74**	**0.73**	**0.73**	**0.74**	**0.74**	**0.75**
N_{init}	43426	45271	44921	44764	45122	45003	45809
N_{2004}/N_{init}	0.81	0.84	0.83	0.83	0.84	0.84	0.86
C_{2004}/MSY	0.62	0.56	0.57	0.59	0.57	0.57	0.52
F_{2004}/F_{MSY}	**0.53**	**0.45**	**0.46**	**0.49**	**0.46**	**0.46**	**0.40**
N_{2004}/N_{MSY}	**1.44**	**1.48**	**1.47**	**1.46**	**1.47**	**1.47**	**1.49**
C_{2004}/repy	0.84	0.79	0.79	0.81	0.79	0.79	0.74
N_{MSY}	24398	25547	25346	25192	25463	25385	26104
F_{MSY}	0.02	0.03	0.03	0.02	0.03	0.03	0.03
repy	343	360	358	351	359	358	378
C_0	439	460	457	447	458	457	496
Diagnostics							
CW (wt)	0.41	0.52	0.50	0.47	0.51	0.51	2.83
CV (L*prior)	1.00	0.97	0.98	0.98	0.98	0.98	2.83
CV (Wt) / CV (L*p)	0.41	0.53	0.51	0.47	0.52	0.52	1.00
%maxpWt	0.006	0.004	0.009	0.006	0.008	0.008	0.062

N_{init} is initial abundance (for the first year of the model), repy is replacement yield.

Table 3.18. Expected values (EV) of the mean of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for LCS without prohibited species using equal weighting (baseline) and **fitting one CPUE series at a time**. Results that alter the stock status determination derived from the full model (all baseline CPUE series included) are boxed and highlighted in red. The NMFS LL NE had too few data points to estimate all four model parameters. The model did not converge with the BLLOP series. Abundances are in thousands of fish.

Series fit	Gillnet Observer	PC Gillnet	BLLOP	NMFS LL SE	Bottom LL Logs	NMFS LL NE	Pelagic Log
	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors		priors	priors		priors
K	49502	45234		47445	44399		40558
r	0.05	0.05		0.05	0.05		0.05
MSY	582	517		552	506		451
N_{2004}	38229	33826		36139	32951		28988
N_{2004}/K	**0.72**	**0.67**		**0.70**	**0.66**		**0.61**
N_{init}	44055	40423		42290	39687		36357
N_{2004}/N_{init}	0.81	0.75		0.79	0.74		0.68
C_{2004}/MSY	0.63	0.75		0.68	0.78		0.89
F_{2004}/F_{MSY}	**0.56**	**0.91**		**0.66**	**1.06**		**1.33**
N_{2004}/N_{MSY}	**1.44**	**1.34**		**1.40**	**1.31**		**1.22**
C_{2004}/repy	0.86	1.03		0.91	1.09		1.23
N_{MSY}	24751	22617		23723	22200		20279
F_{MSY}	0.02	0.02		0.02	0.02		0.02
repy	342	312		331	306		280
C_0	441	419		432	415		400
Diagnostics							
CW (wt)	0.40	0.19		0.32	0.15		0.23
CV (L*prior)	0.95	1.03		0.98	1.06		1.29
CV (Wt) / CV (L*p)	0.42	0.19		0.32	0.14		0.18
%maxpWt	0.007	0.003		0.005	0.002		0.003

N_{init} is initial abundance (for the first year of the model), repy is replacement yield.

Table 3.19. Expected values (EV) of the mean of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for LCS without prohibited species, blacktip, and sandbar sharks using equal weighting (baseline) and **removing one CPUE series at a time**. Abundances are in thousands of fish.

Series removed	Gillnet Observer	PC Gillnet	BLLOP	NMFS LL SE	Bottom LL Logs	NMFS LL NE	Pelagic Log
	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors	priors	priors
K	30695	31190	30874	31255	31381	31270	32600
r	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MSY	353	357	355	360	361	359	378
N_{2004}	27070	27548	27243	27611	27734	27636	28894
N_{2004}/K	**0.79**	**0.80**	**0.79**	**0.80**	**0.80**	**0.80**	**0.81**
N_{init}	27346	27804	27509	27819	27946	27887	28901
N_{2004}/N_{init}	0.90	0.90	0.90	0.91	0.91	0.90	0.93
C_{2004}/MSY	0.39	0.38	0.39	0.37	0.37	0.38	0.34
F_{2004}/F_{MSY}	**0.33**	**0.31**	**0.32**	**0.31**	**0.31**	**0.32**	**0.26**
N_{2004}/N_{MSY}	**1.59**	**1.60**	**1.59**	**1.60**	**1.60**	**1.60**	**1.63**
C_{2004}/repy	0.72	0.68	0.72	0.71	0.71	0.71	0.61
N_{MSY}	15347	15595	15437	15627	15690	15635	16300
F_{MSY}	0.02	0.02	0.02	0.02	0.02	0.02	0.02
repy	119	119	119	120	120	119	126
C_0	132	132	132	133	132	131	142
Diagnostics							
CW (wt)	0.31	0.31	0.31	0.33	0.32	0.30	3.00
CV (L*prior)	1.28	1.26	1.27	1.25	1.25	1.26	3.82
CV (Wt) / CV (L*p)	0.24	0.25	0.25	0.26	0.26	0.24	0.78
%maxpWt	0.008	0.002	0.008	0.008	0.008	0.006	0.074

N_{init} is initial abundance (for the first year of the model), repy is replacement yield.

Table 3.20. Expected values (EV) of the mean of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for LCS without prohibited species, blacktip, and sandbar sharks using equal weighting (baseline) and **fitting one CPUE series at a time**. The NMFS LL NE had too few data points to estimate all four model parameters. Abundances are in thousands of fish.

Series fit	Gillnet Observer	PC Gillnet	BLLOP	NMFS LL SE	Bottom LL Logs	NMFS LL NE	Pelagic Log
	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors		priors
K	31490	30716	31153	30413	30168		27339
r	0.05	0.05	0.05	0.05	0.05		0.04
MSY	359	350	353	345	342		306
N_{2004}	27865	27099	27527	26804	26564		23791
N_{2004}/K	**0.79**	**0.78**	**0.79**	**0.77**	**0.77**		**0.72**
N_{init}	28220	27509	27918	27277	27064		24651
N_{2004}/N_{init}	0.89	0.88	0.89	0.87	0.87		0.81
C_{2004}/MSY	0.41	0.43	0.42	0.44	0.46		0.56
F_{2004}/F_{MSY}	**0.40**	**0.46**	**0.42**	**0.50**	**0.55**		**0.81**
N_{2004}/N_{MSY}	**1.58**	**1.56**	**1.57**	**1.55**	**1.54**		**1.45**
C_{2004}/repy	0.77	0.80	0.76	0.81	0.84		0.95
N_{MSY}	15745	15358	15577	15207	15084		13669
F_{MSY}	0.02	0.02	0.02	0.02	0.02		0.02
repy	116	114	115	112	112		102
C_0	128	127	127	126	126		121
Diagnostics							
CW (wt)	0.21	0.17	0.20	0.15	0.13		0.20
CV (L*prior)	1.27	1.31	1.28	1.34	1.36		1.70
CV (Wt) / CV (L*p)	0.16	0.13	0.15	0.11	0.09		0.12
%maxpWt	0.00	0.00	0.00	0.00	0.00		0.00

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 3.21. Expected values (EV) of the mean and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian SPM using the SIR algorithm. Results for the three LCS groupings using equal weighting and values of r (intrinsic rate of increase) recommended in the Data Workshop report and the **1981 catch as a fixed catch for the years 1972-1980**. Abundances are in thousands of fish.

	LCS		LCS-PROH		LCS-PROH-SB-BT	
	EV	CV	EV	CV	EV	CV
Importance function	priors		priors		priors	
K	35553	0.49	50941	0.45	31162	0.81
r	0.048	0.47	0.050	0.47	0.046	0.46
MSY	393.9	0.58	614.9	0.63	343.1	0.97
N_{2004}	23777	0.72	40134	0.56	27695	0.89
N_{2004}/K	**0.62**	0.24	**0.74**	0.19	**0.81**	0.18
N_{init}	32414	0.52	45173	0.47	27701	0.83
N_{2004}/N_{init}	0.68	0.22	0.85	0.20	0.92	0.20
C_{2004}/MSY	0.79	0.45	0.56	0.60	0.39	0.88
F_{2004}/F_{MSY}	**0.74**	0.67	**0.44**	0.92	**0.30**	1.29
N_{2004}/N_{MSY}	**1.23**	0.24	**1.49**	0.19	**1.62**	0.18
C_{2004}/repy	0.9	0.4	0.8	0.4		
N_{MSY}	17777	0.49	25471	0.45	15581	0.81
F_{MSY}	0.024		0.025		0.023	
repy	305.9	0.30	355.0	0.31	113.6	0.60
C_0	n/a	n/a	n/a	n/a	n/a	n/a
Diagnostics						
CW (wt)	0.902		0.520		0.382	
CV (L*prior)	1.273		0.712		0.940	
CV (Wt) / CV (L*p)	0.71		0.73		0.28	
%maxpWt	0.005		0.002		0.002	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

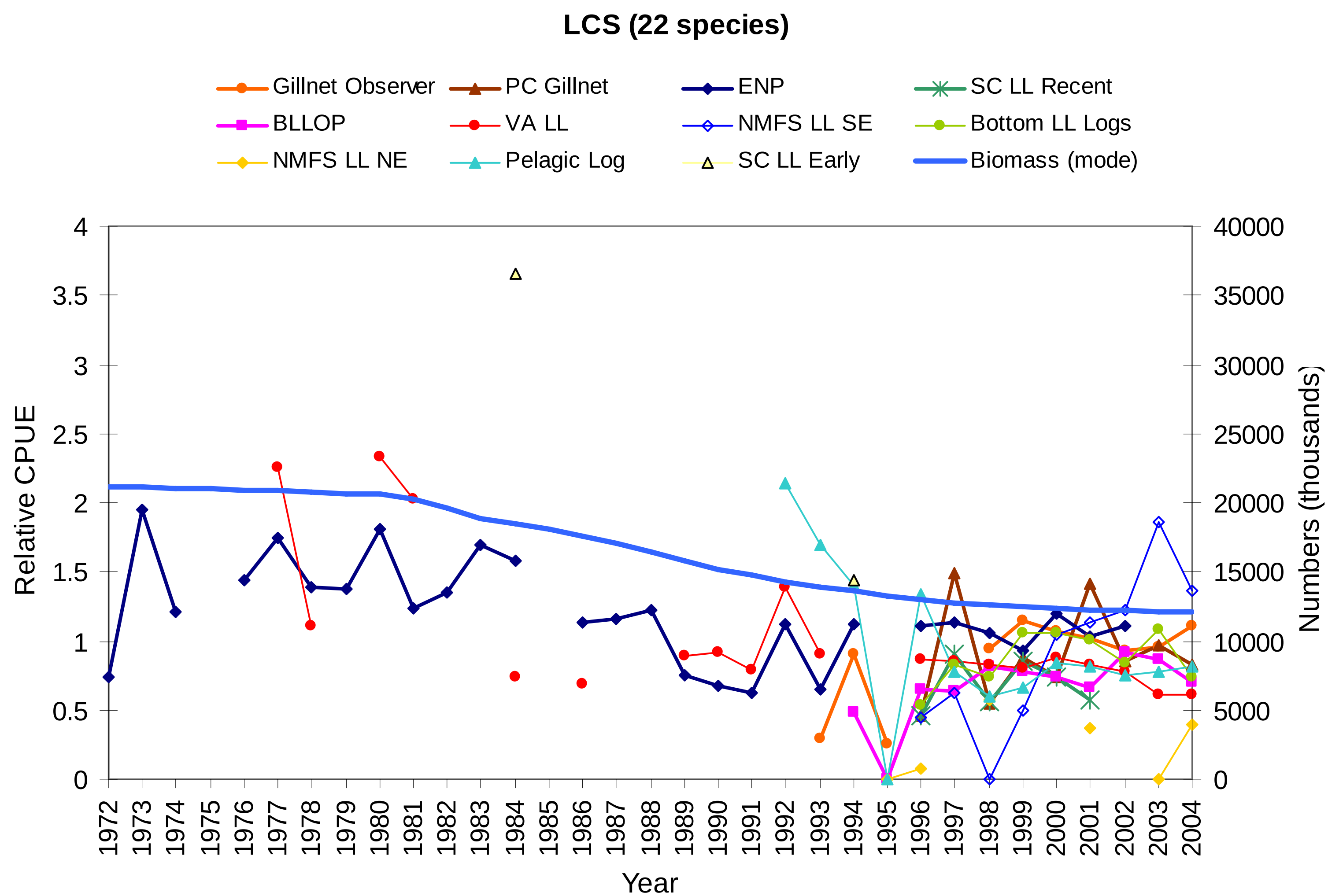
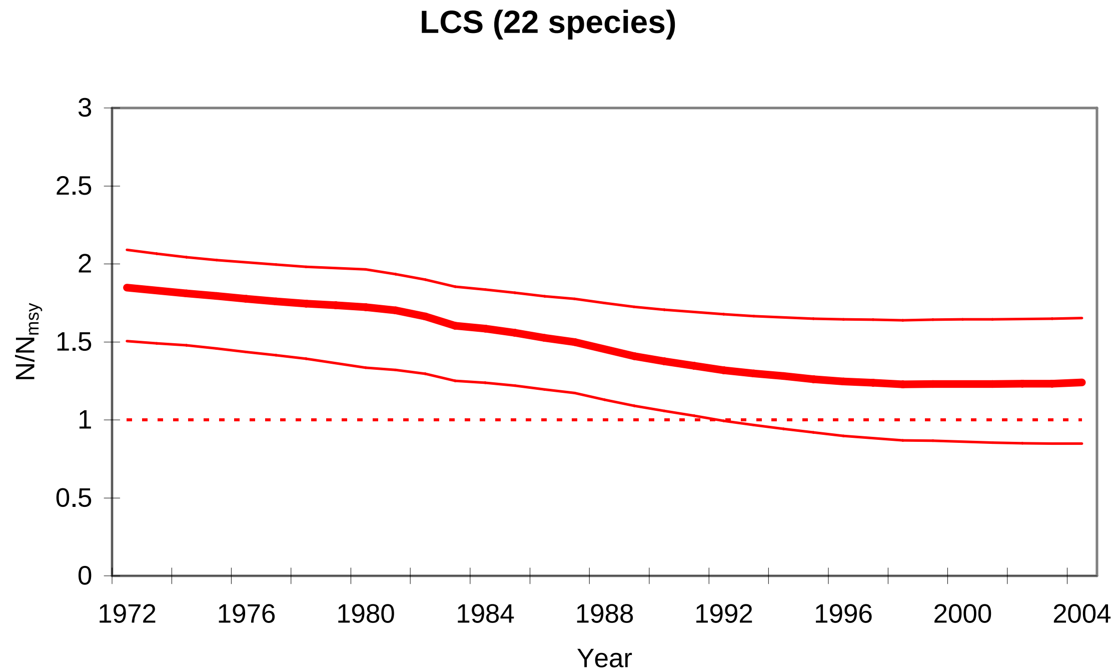


Figure 3.1. Predicted abundance trend of the BSP model fitted to the catch and CPUE data. CPUE series shown are scaled (divided by the mean of the overlapping years among all series, by the catchability coefficient for each series, and by the overall mean for all series).

A.



B.

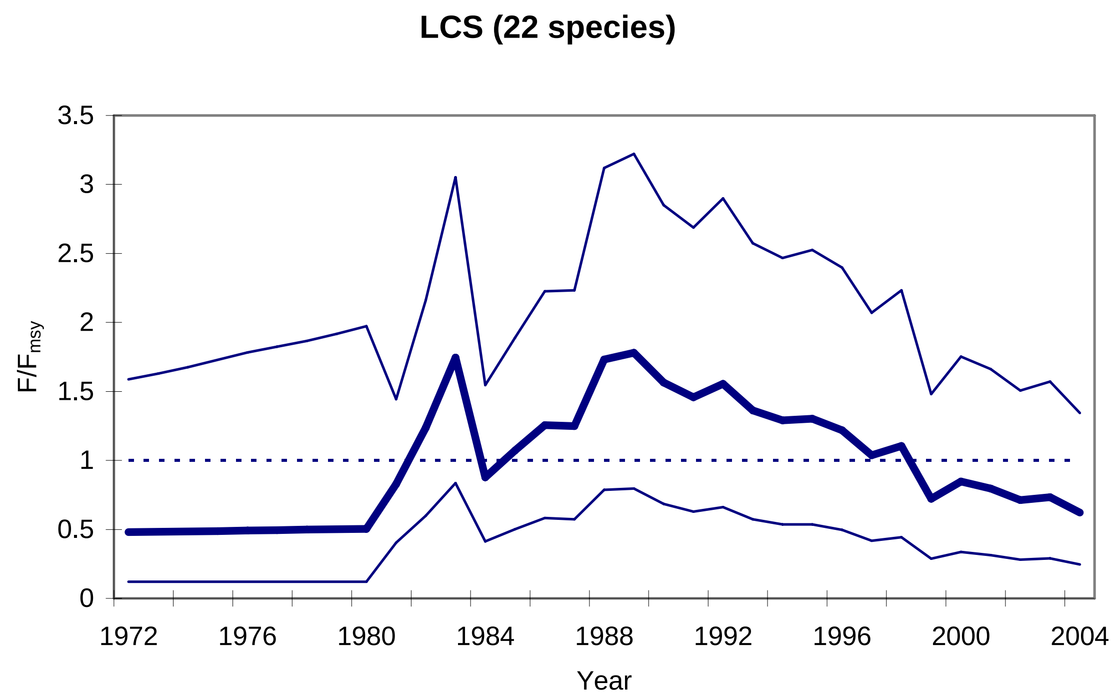


Figure 3.2. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for LCS with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels.

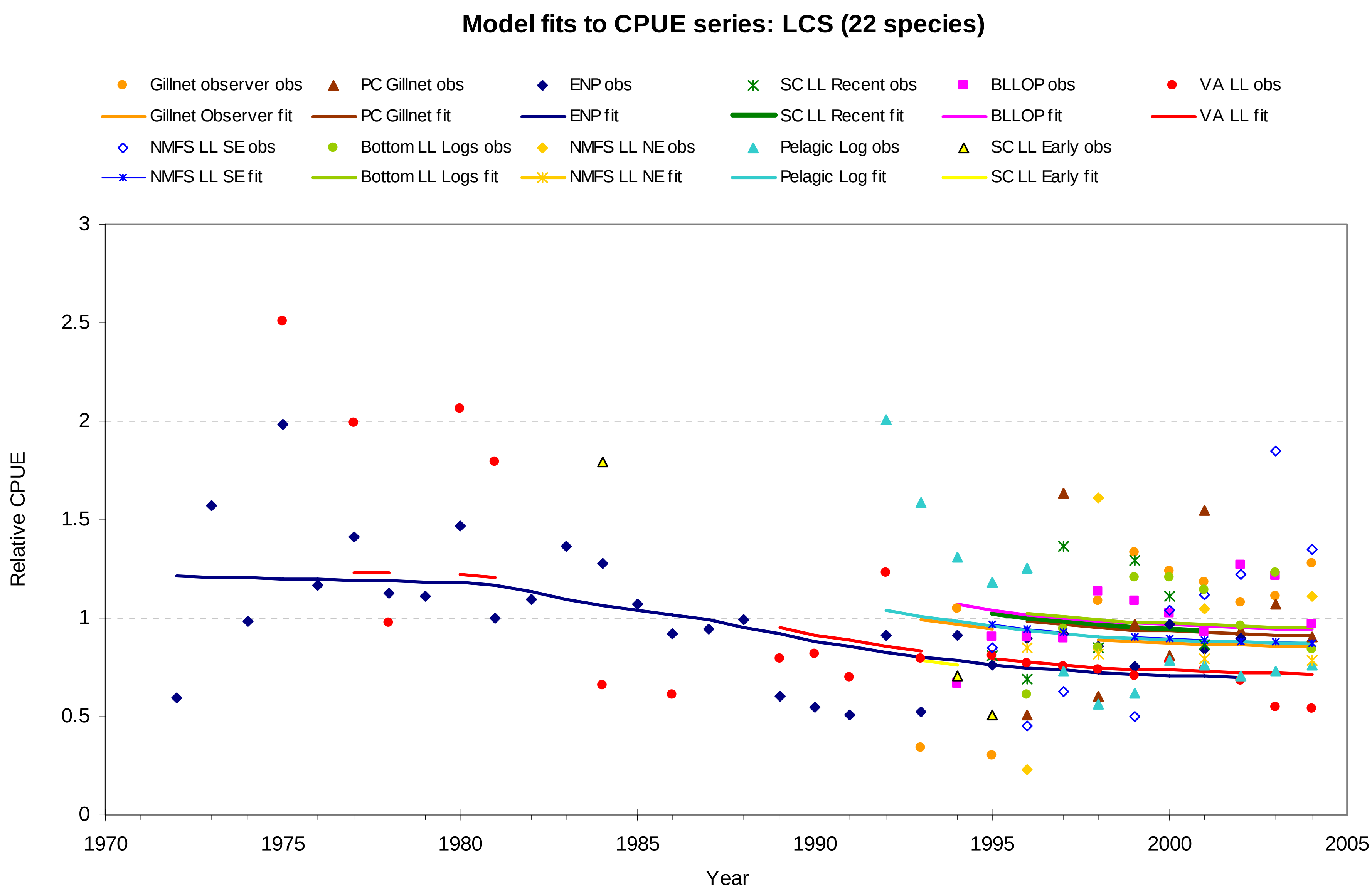


Figure 3.3. BSP model fits to the individual CPUE series for the LCS complex (22 species).

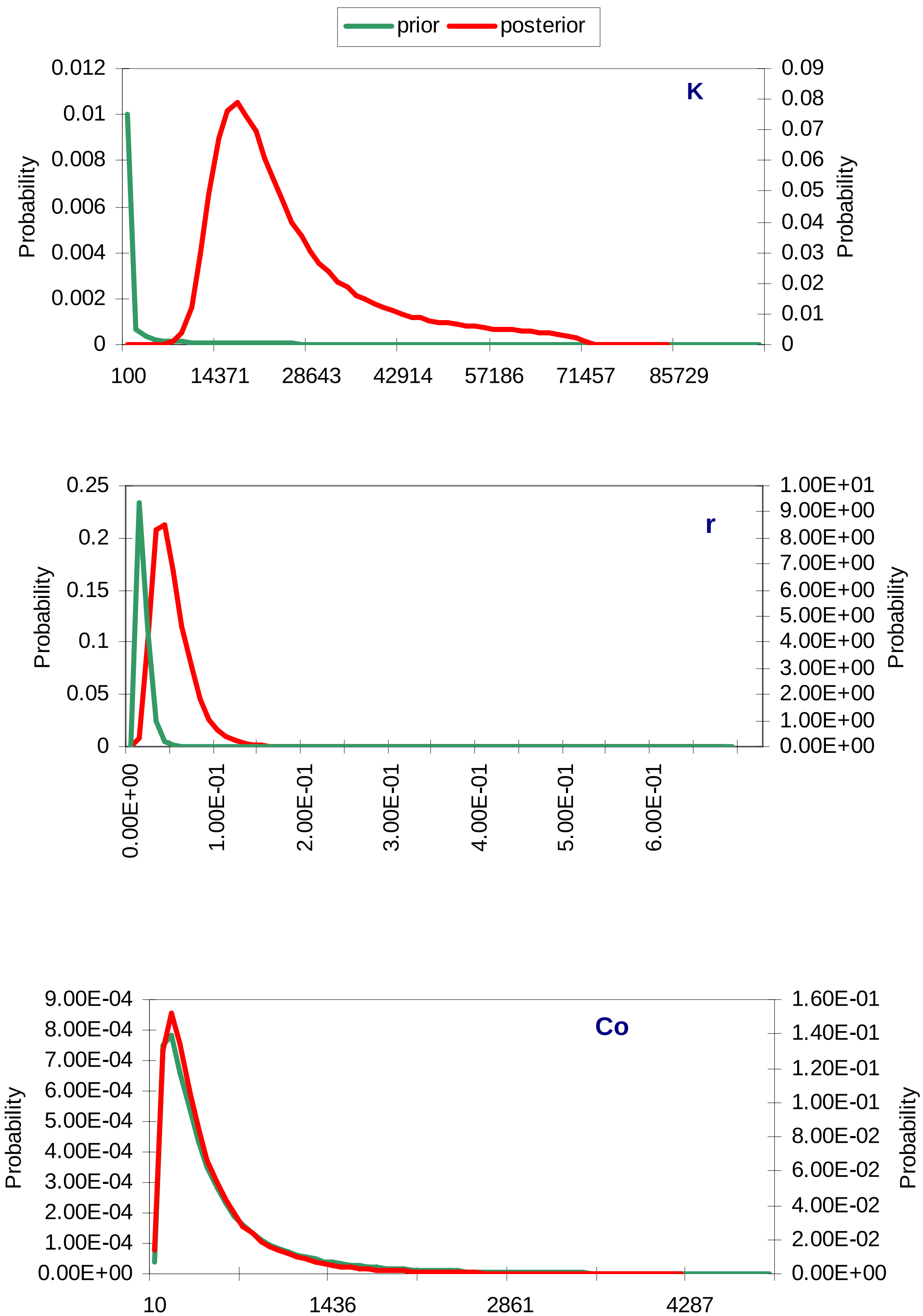


Figure 3.4. Prior (green) and posterior (red) probability distributions for K, r, and C_0 for LCS from the BSP model.

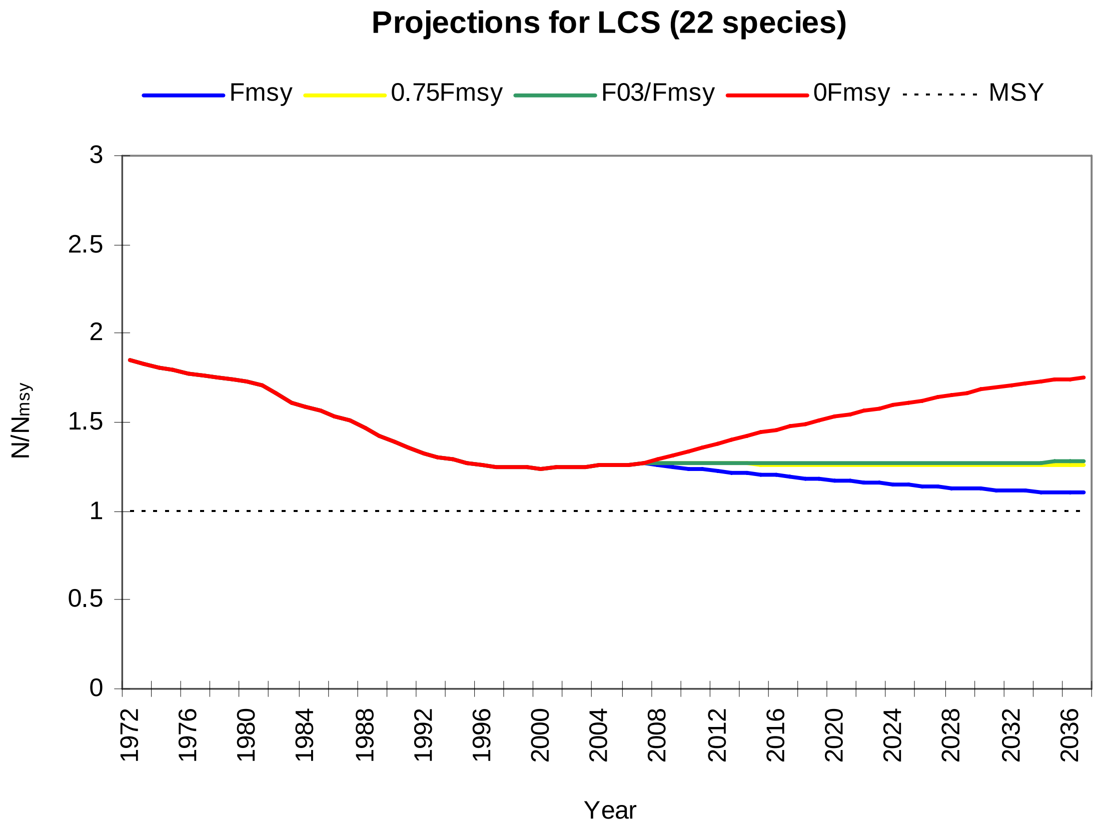


Figure 3.5. Estimated median relative abundance trajectory and projections (from 2008 to 2037) for alternative F_{MSY}-based harvesting policies (0, 0.75, and 1 times F_{MSY} and ((F_{2003}/F_{MSY}) * F_{MSY})) for the LCS complex (22 species) baseline scenario. The dashed horizontal line at 1 denotes the MSY level.

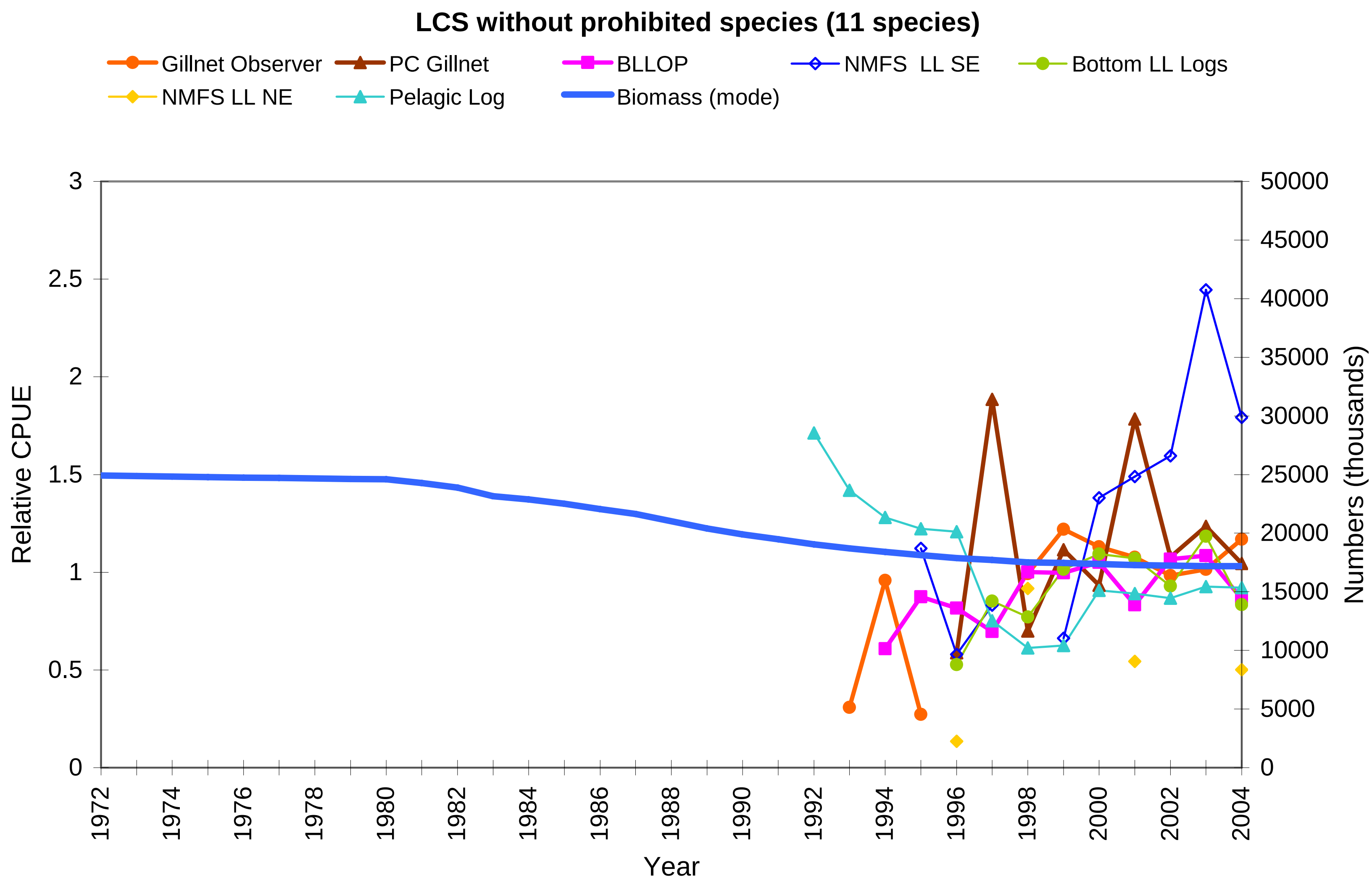
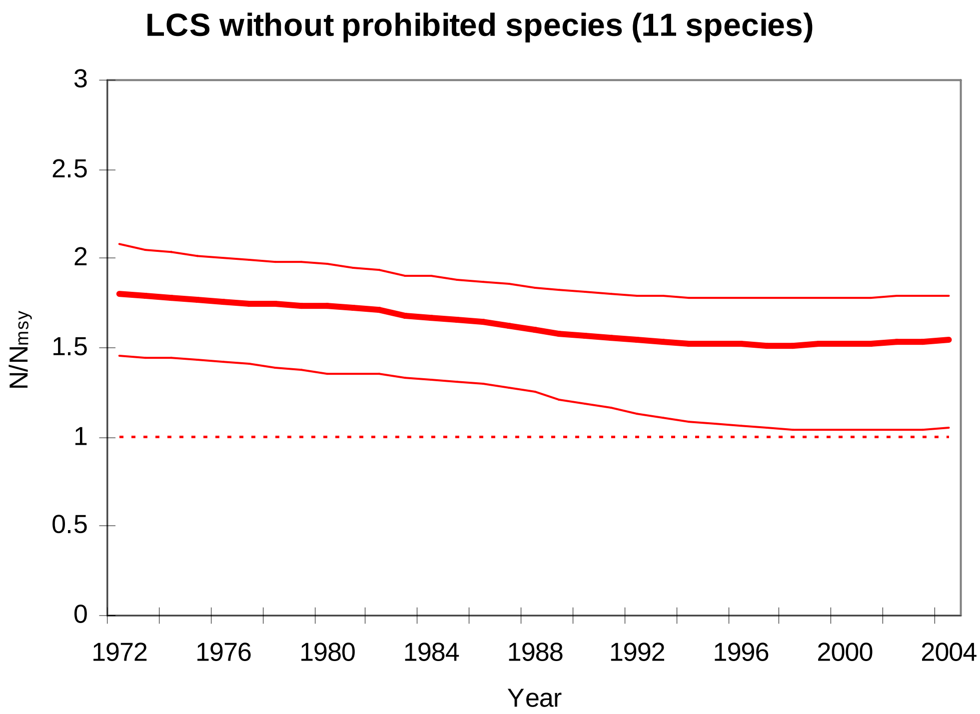


Figure 3.6. Predicted abundance trend of the BSP model fitted to the catch and CPUE data for LCS without prohibited species. CPUE series shown are scaled (divided by the mean of the overlapping years among all series, by the catchability coefficient for each series, and by the overall mean for all series).

A.



B.

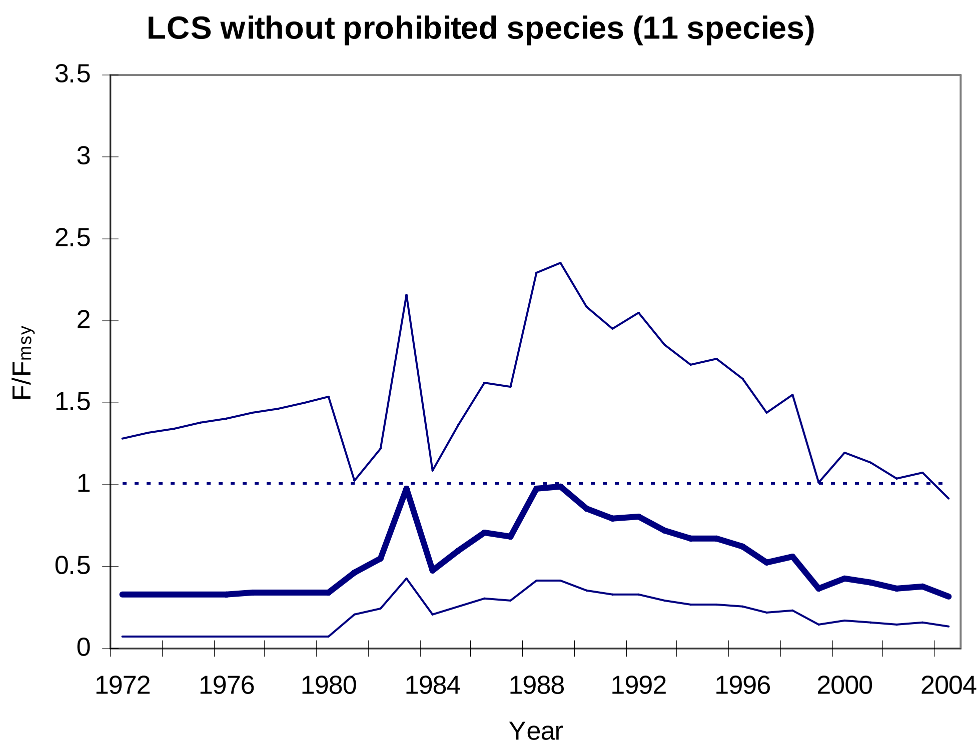
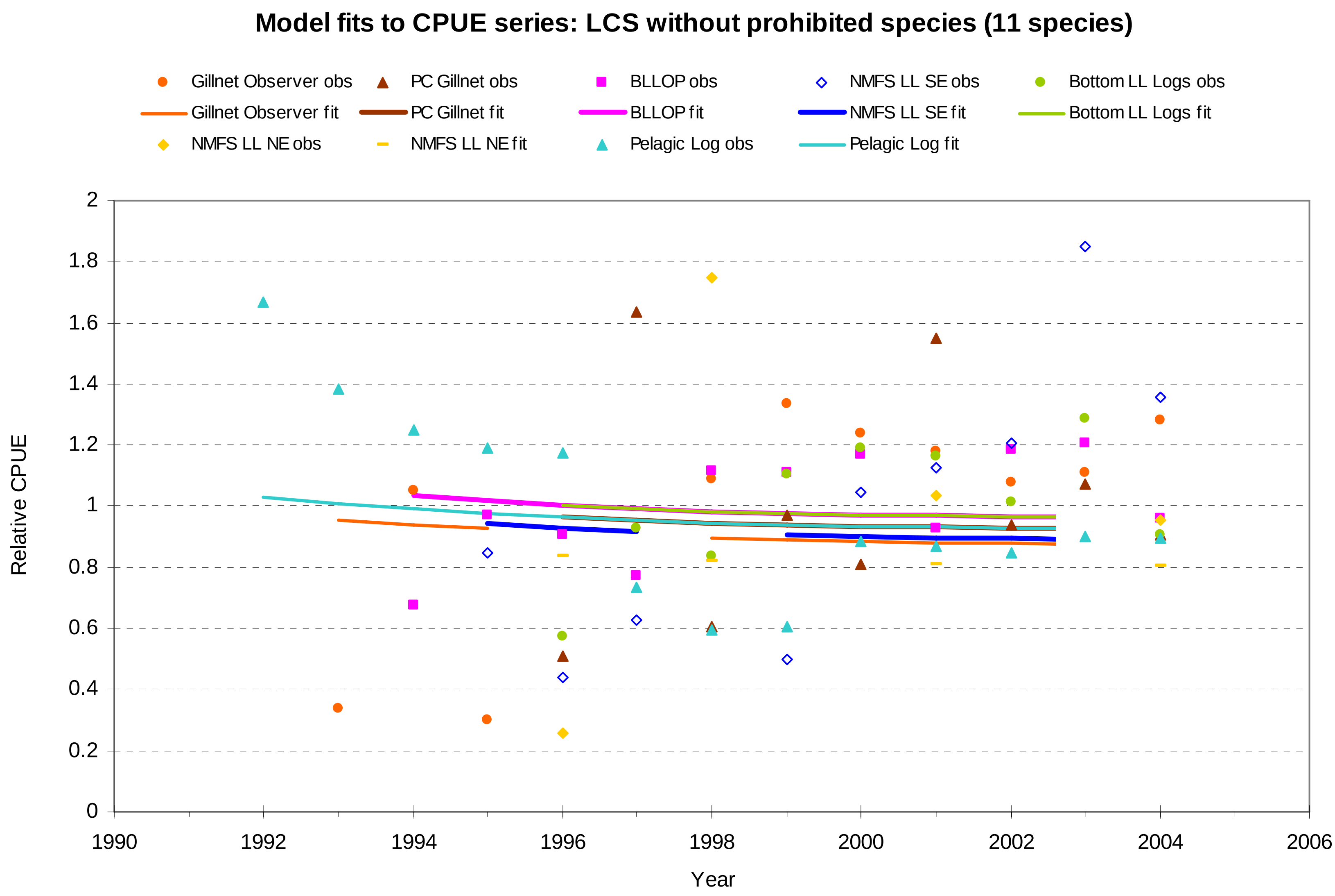


Figure 3.7. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for LCS without prohibited species with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels.



3.8. BSP model fits to the individual CPUE series for the LCS without prohibited species (11 species).

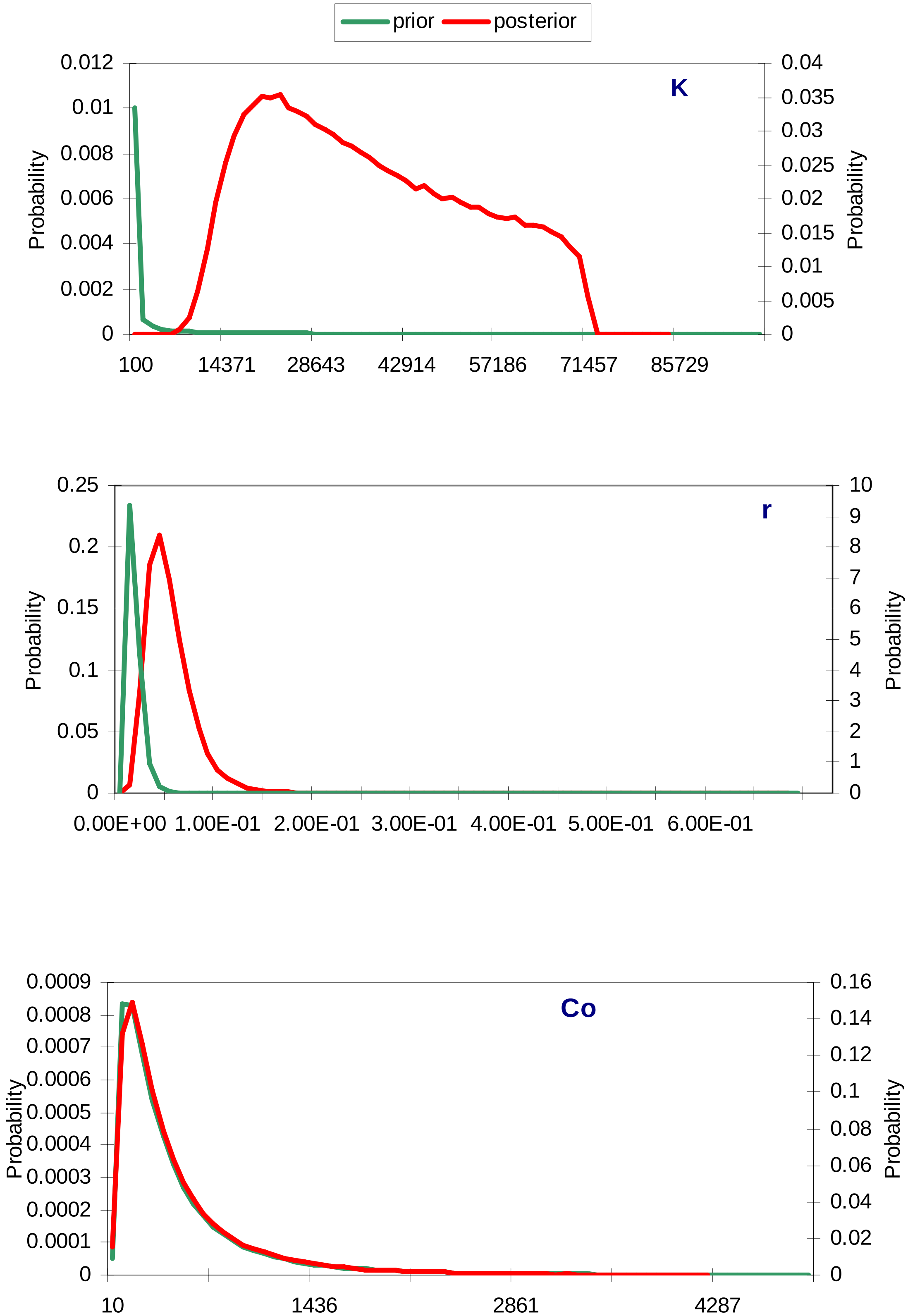


Figure 3.9. Prior (green) and posterior (red) probability distributions for K, r, and C_0 for LCS without prohibited species from the BSP model.

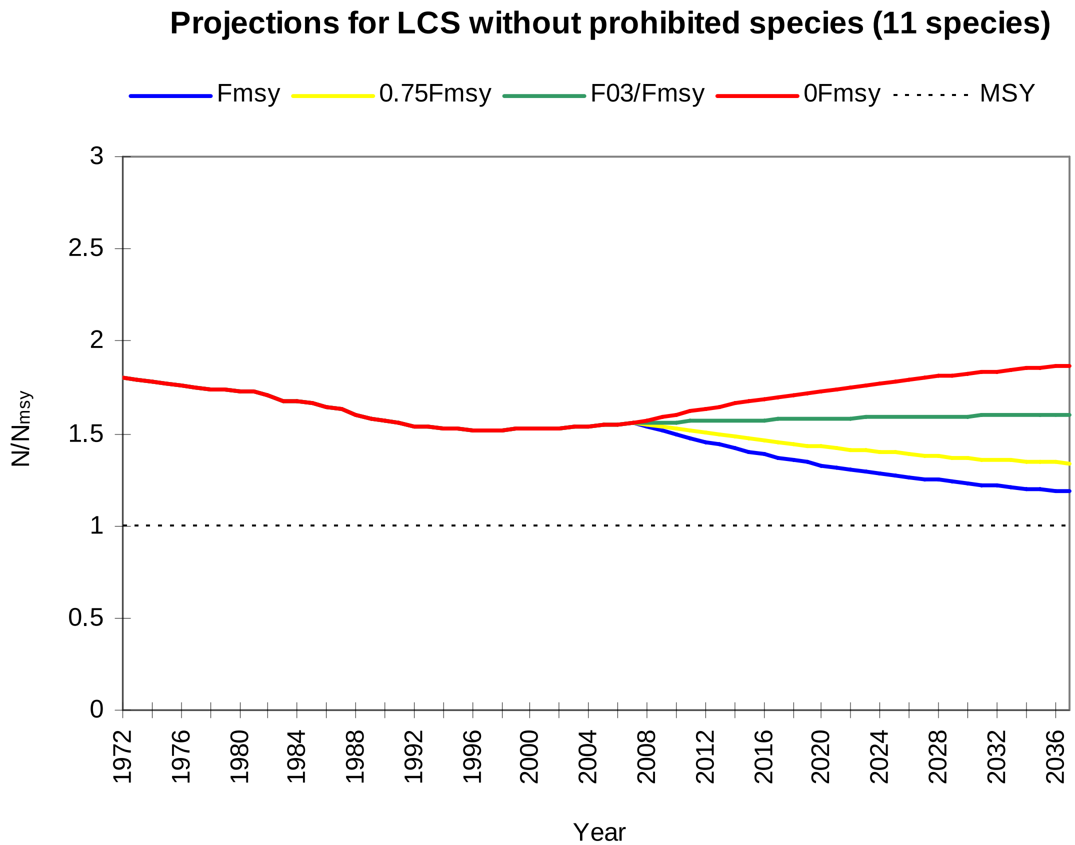


Figure 3.10. Estimated median relative abundance trajectory and projections (from 2008 to 2037) for alternative F_{MSY}-based harvesting policies (0, 0.75, and 1 times F_{MSY} and ((F_{2003}/F_{MSY}) * F_{MSY})) for the LCS without prohibited species (11 species) baseline scenario. The dashed horizontal line at 1 denotes the MSY level.

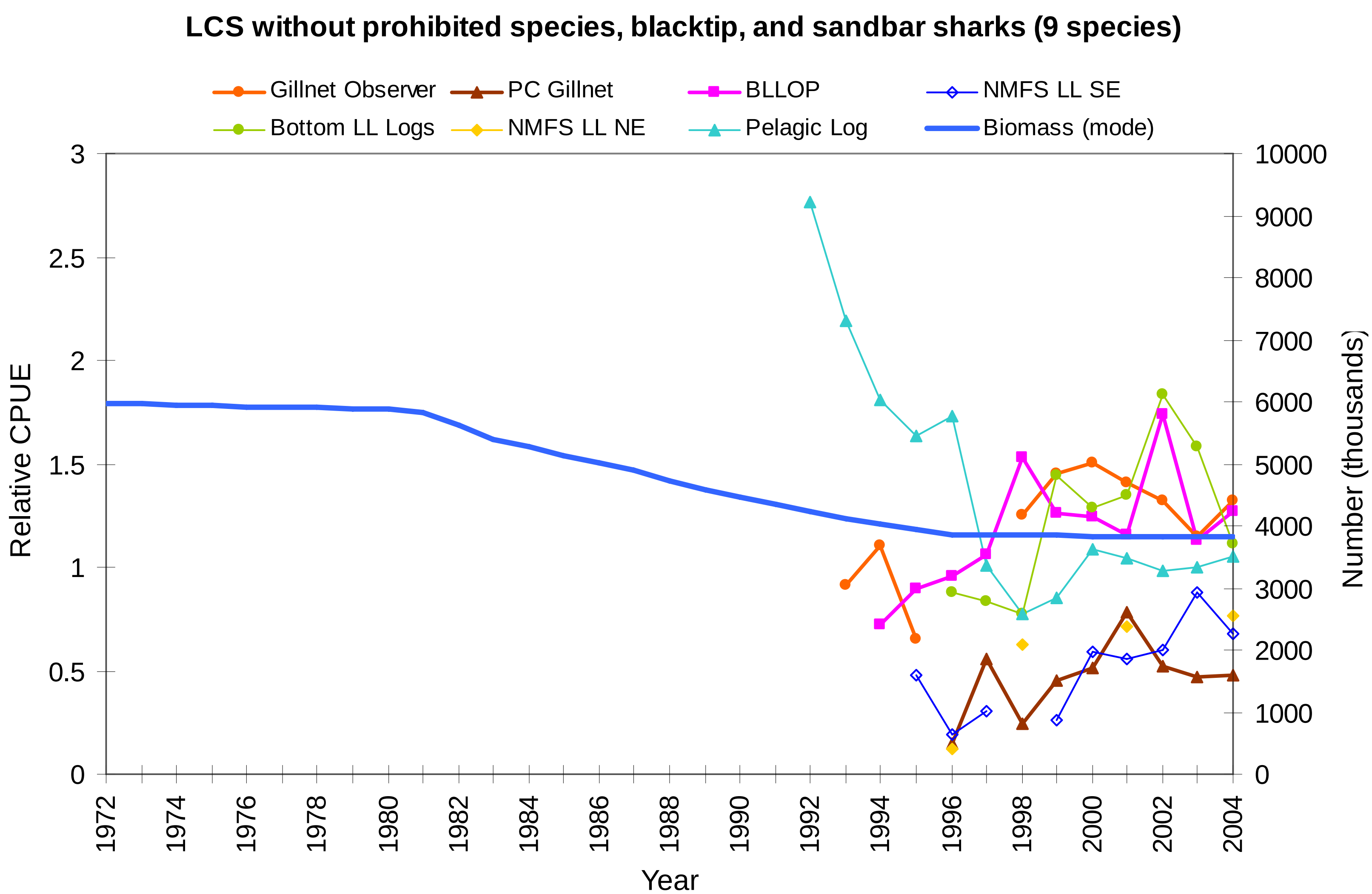
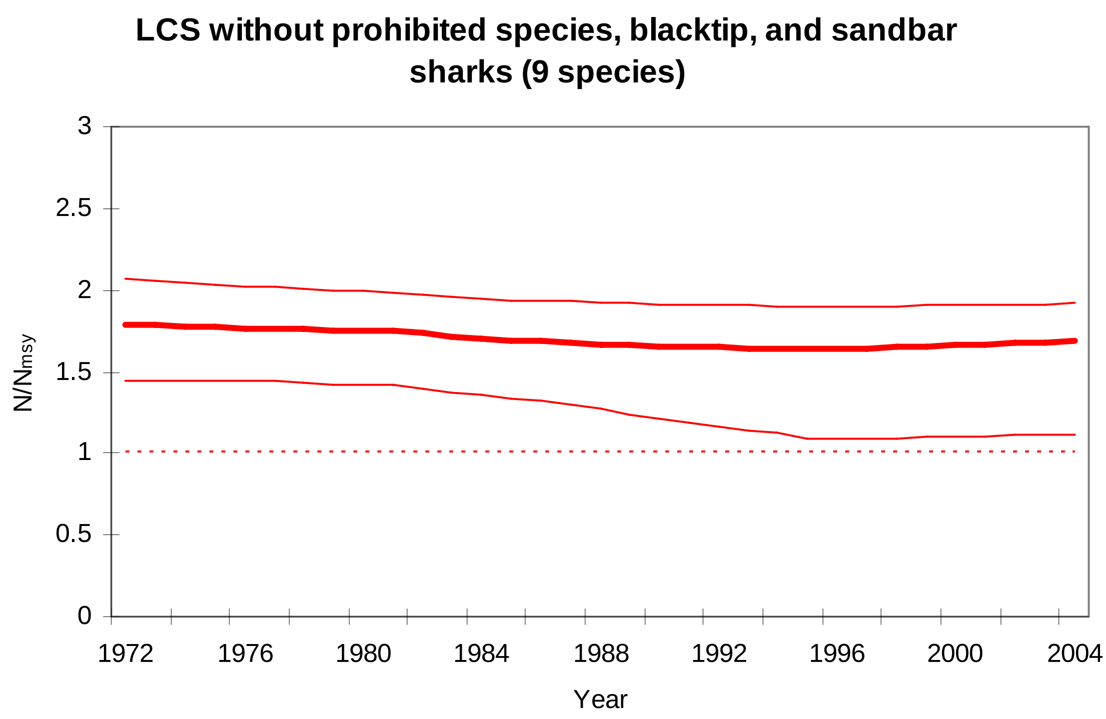


Figure 3.11. Predicted abundance trend of the BSP model fitted to the catch and CPUE data for LCS without prohibited species, blacktip, and sandbar sharks. CPUE series shown are scaled (divided by the mean of the overlapping years among all series, by the catchability coefficient for each series, and by the overall mean for all series).

A.



B.

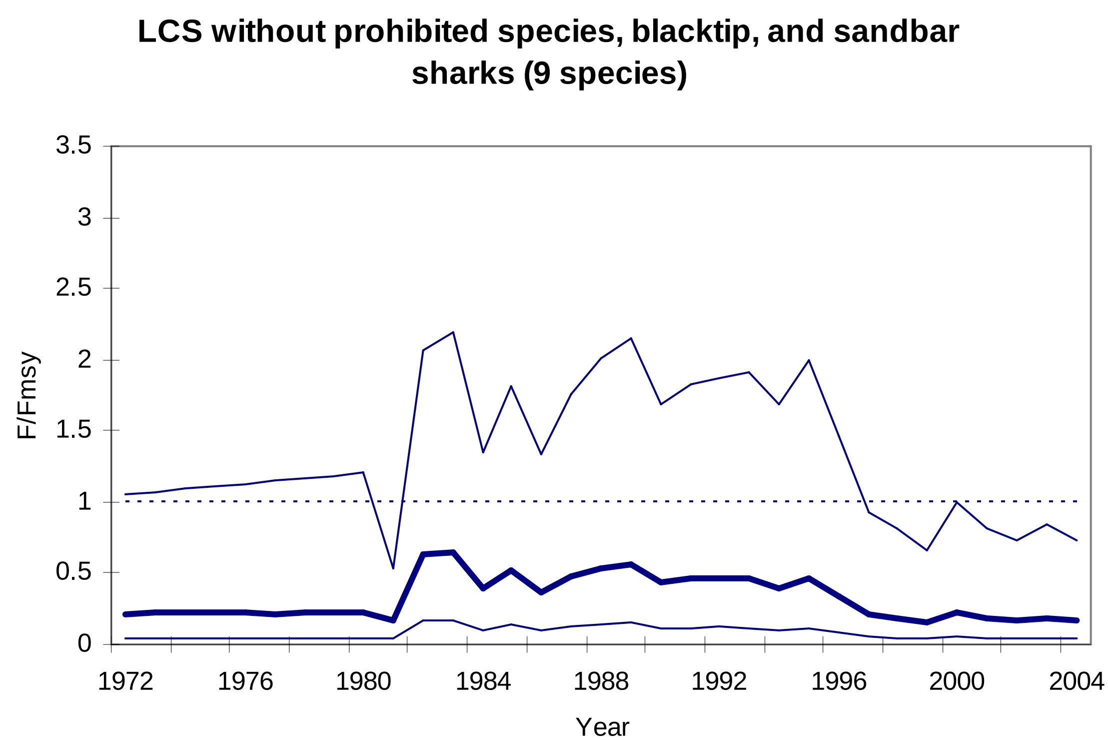
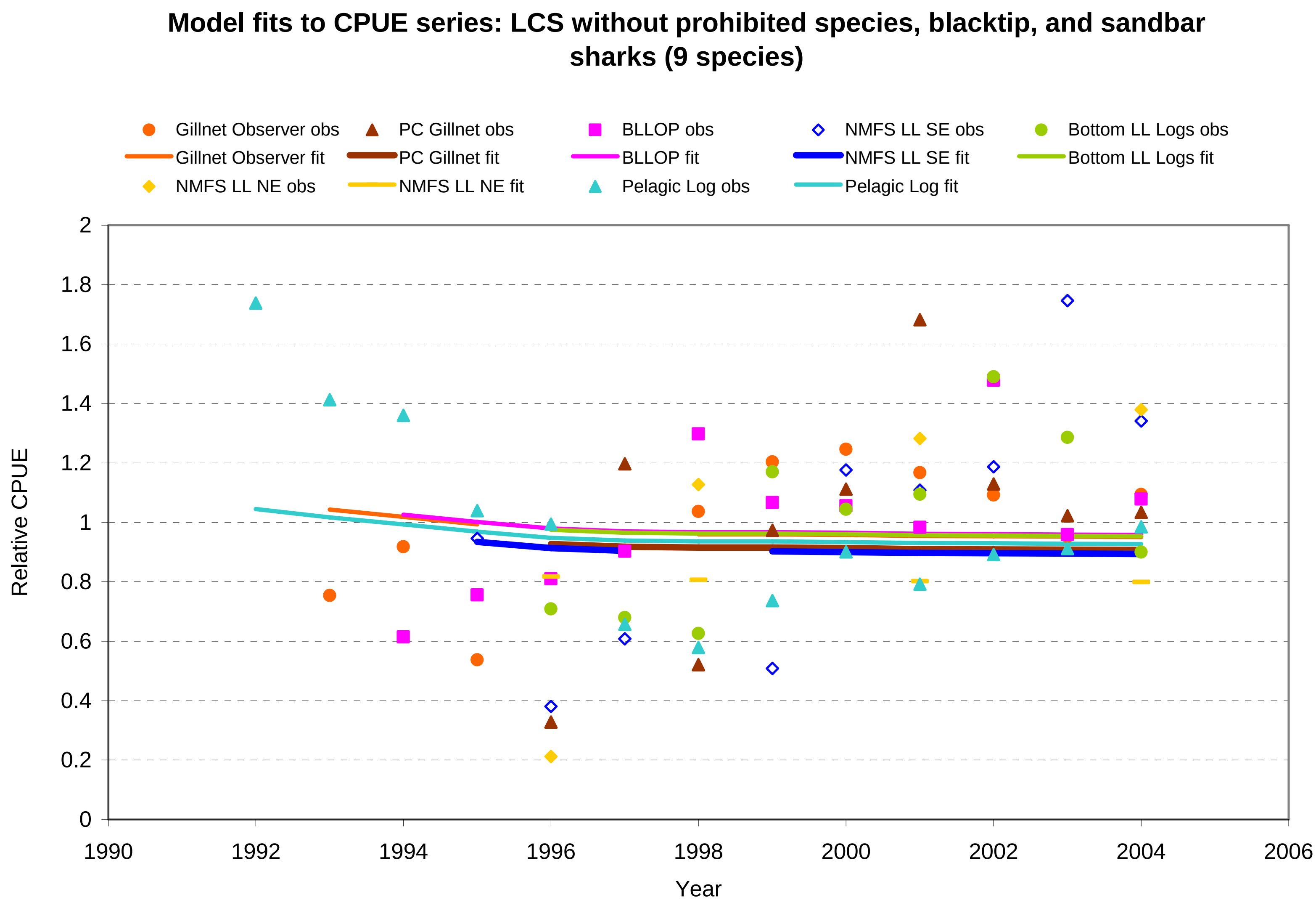


Figure 3.12. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for LCS without prohibited species, blacktip, and sandbar sharks with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels. .



3.13. BSP model fits to the individual CPUE series for the LCS without prohibited species, blacktip, and sandbar sharks (9 species).

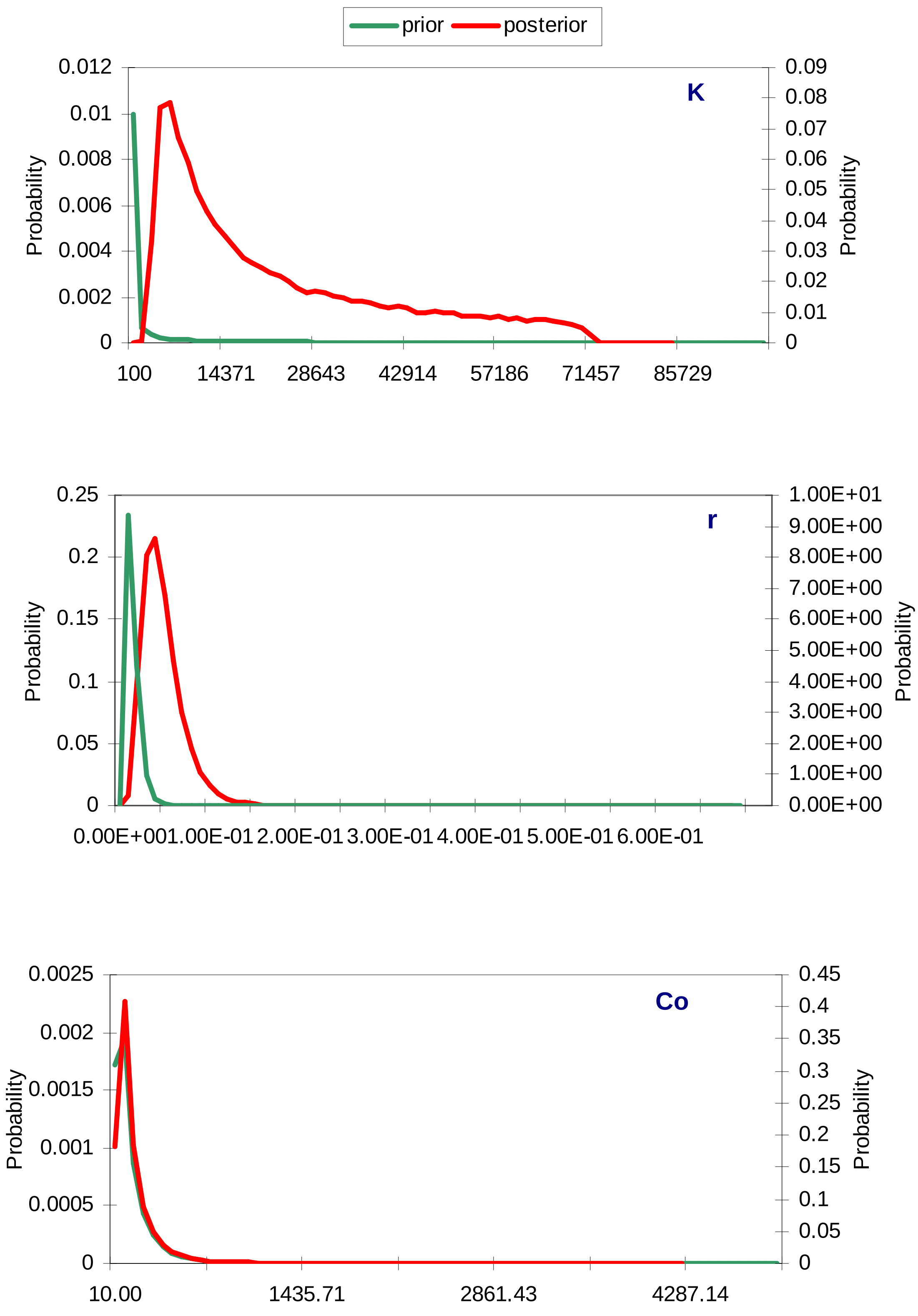


Figure 3.14. Prior (green) and posterior (red) probability distributions for K, r, and C_0 for LCS without prohibited species, blacktip, and sandbar sharks from the BSP model.

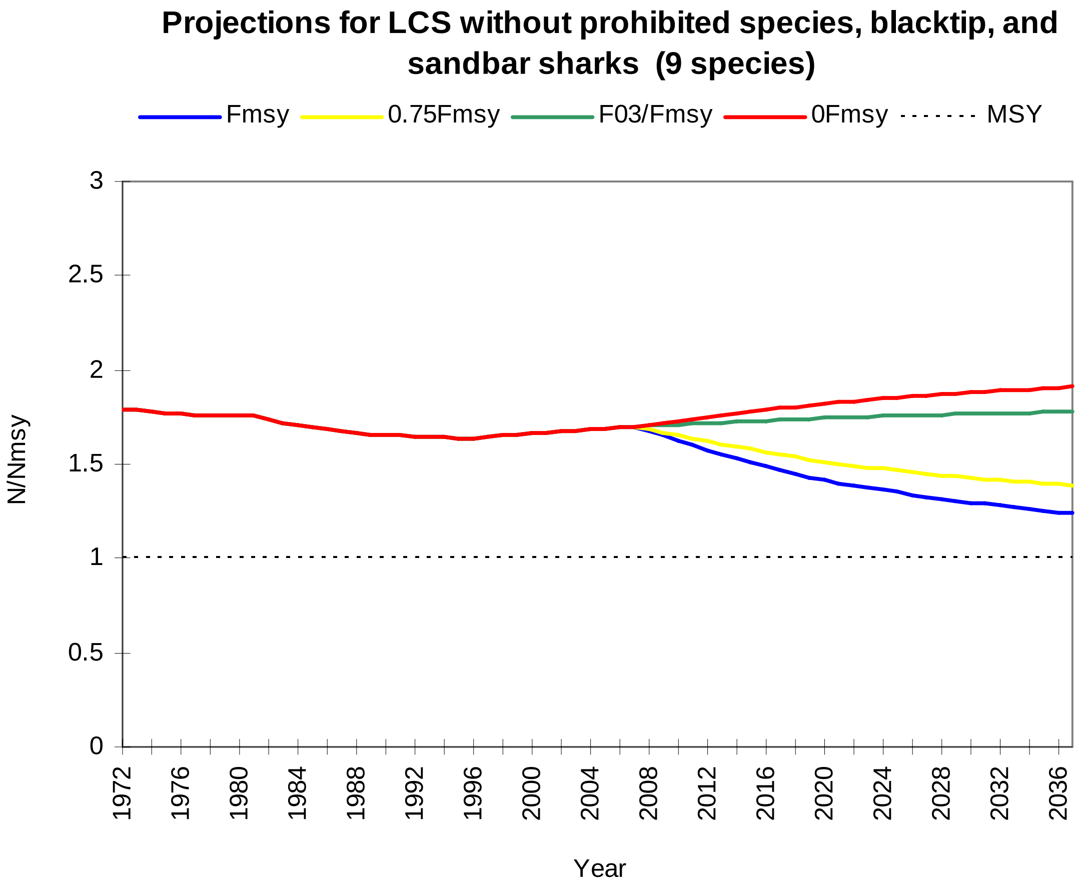


Figure 3.15. Estimated median relative abundance trajectory and projections (from 2008 to 2037) for alternative F_{MSY}-based harvesting policies (0, 0.75, and 1 times F_{MSY} and $((F_{2003}/F_{MSY}) * F_{MSY})$) for the LCS without prohibited species, blacktip, and sandbar sharks (9 species) baseline scenario. The dashed horizontal line at 1 denotes the MSY level.

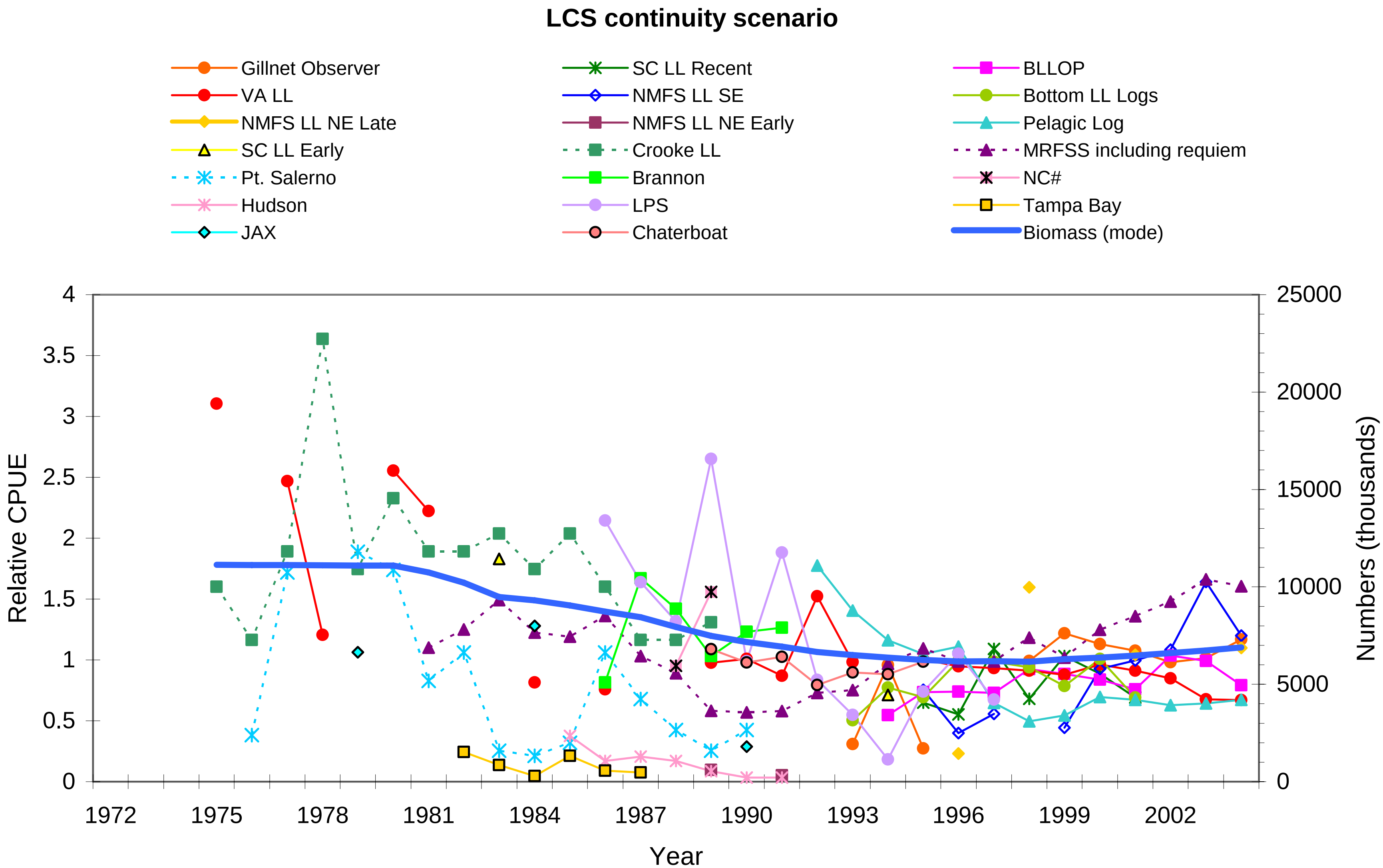
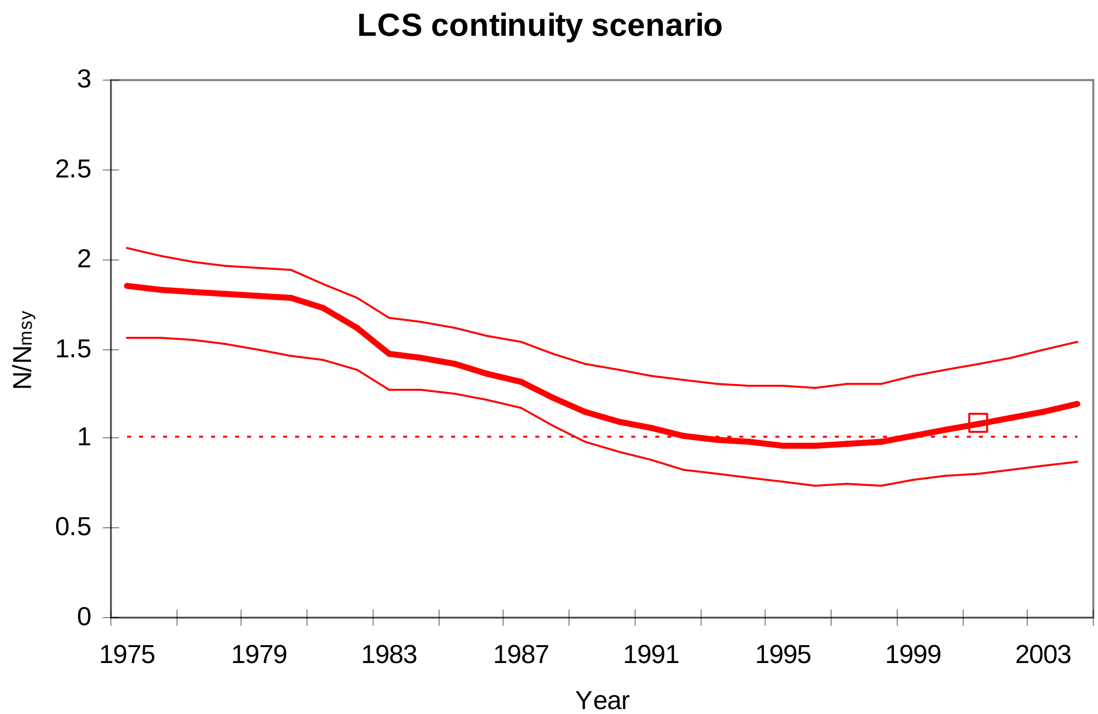


Figure 3.16. Predicted abundance trend of the BSP model fitted to the catch and CPUE data for LCS continuity analysis. CPUE series shown are scaled (divided by the catchability coefficient for each series, and by the overall mean for all series).

A.



B.

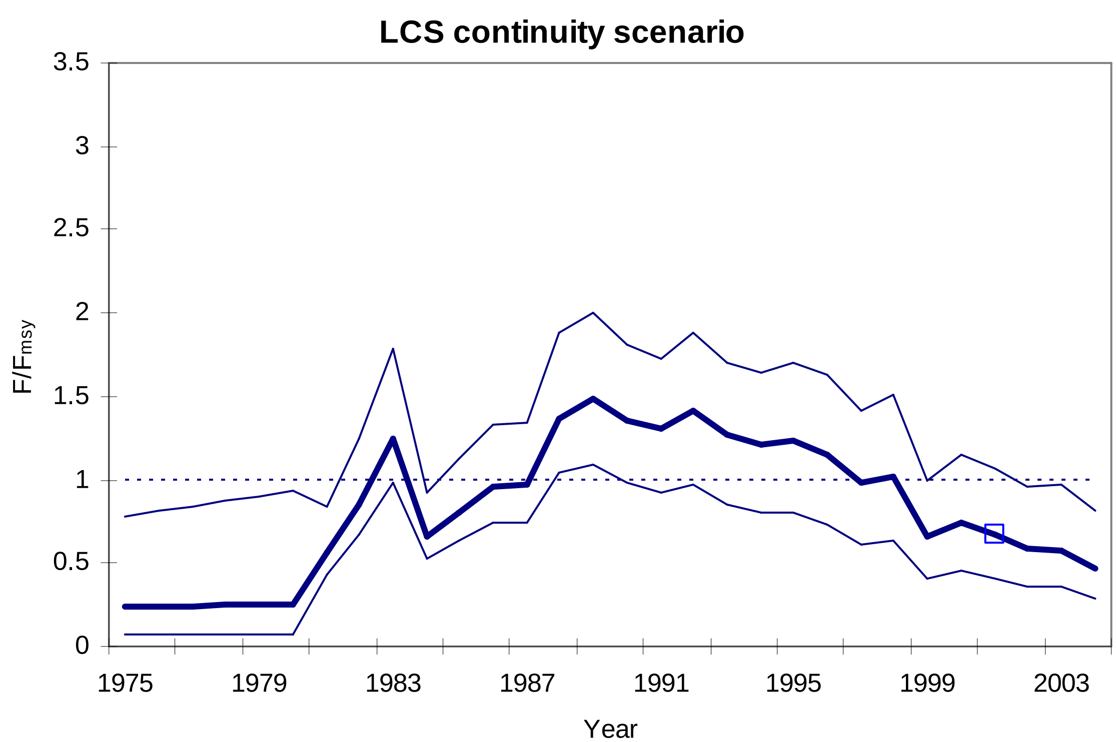
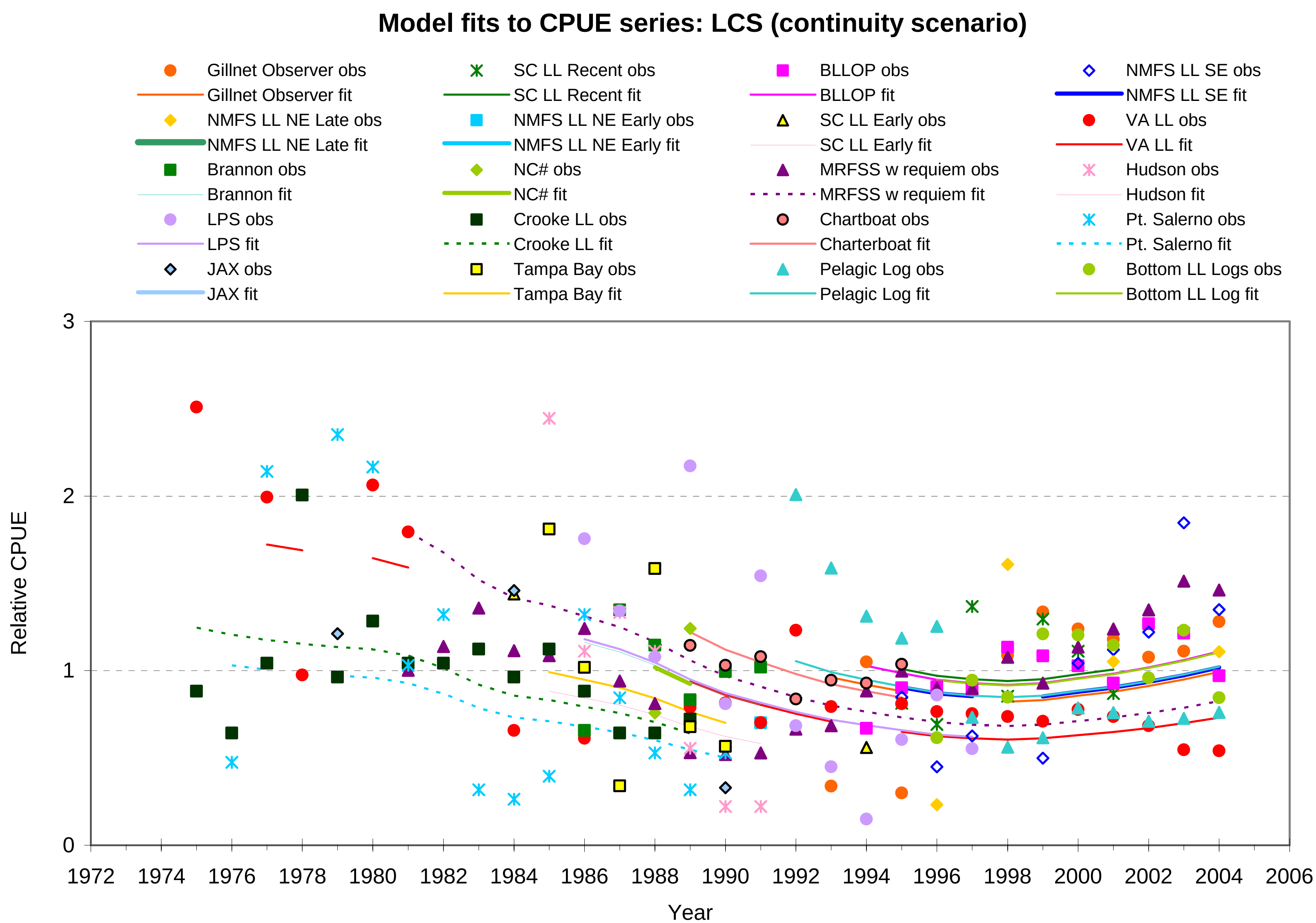


Figure 3.17. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for the LCS continuity scenario with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels. Open squares denote the status in 2001.



3.18. BSP model fits to the individual CPUE series for the LCS continuity scenario.

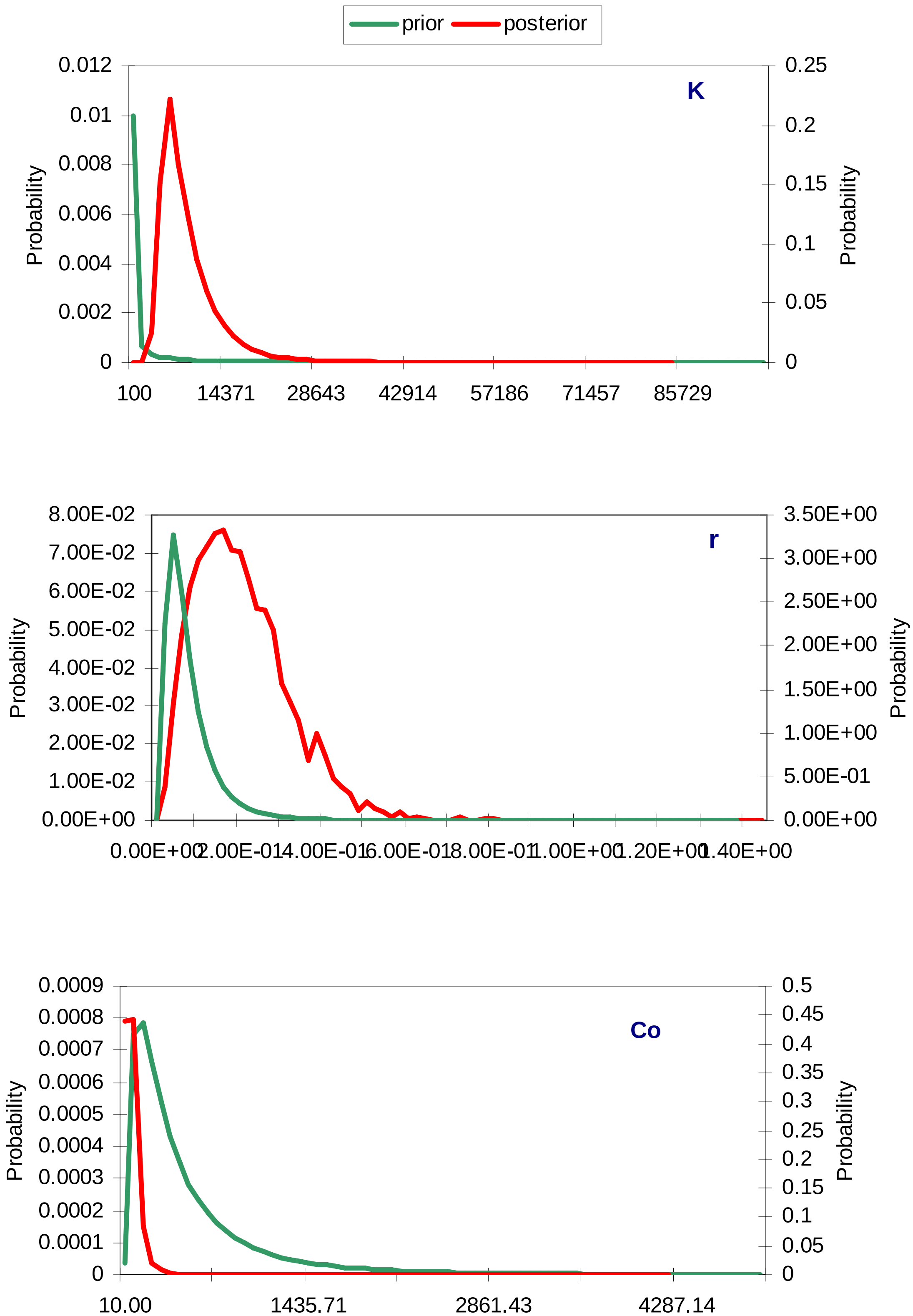
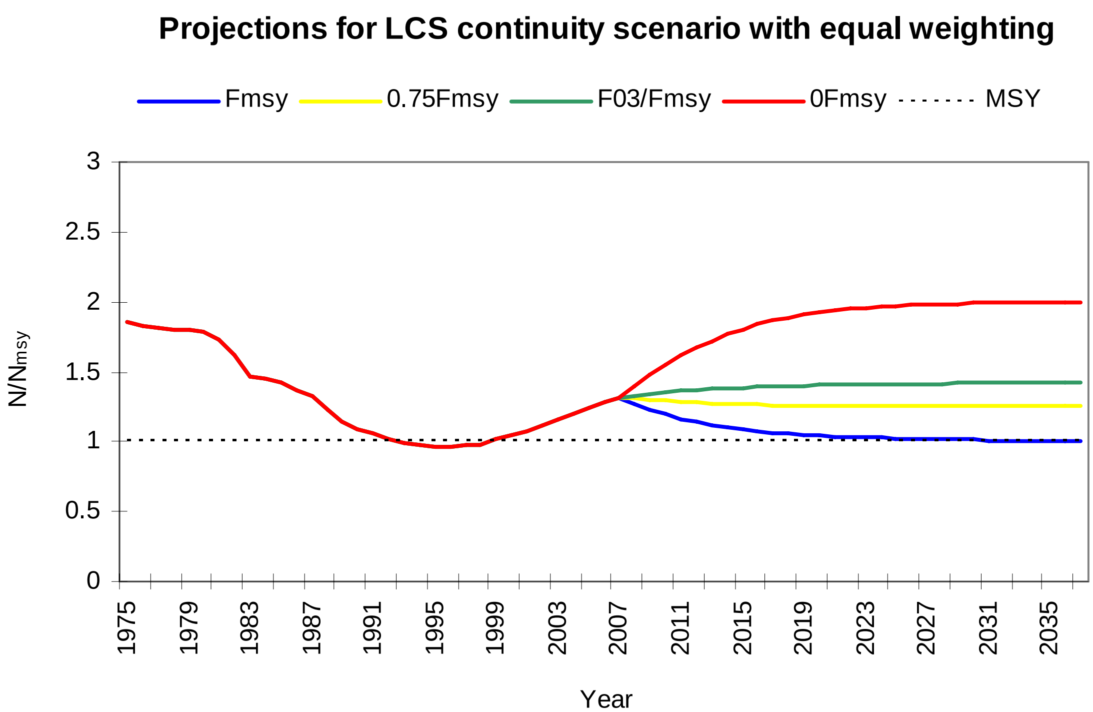


Figure 3.19. Prior (green) and posterior (red) probability distributions for K, r, and C_0 for LCS continuity scenario from the BSP model.

A.



B.

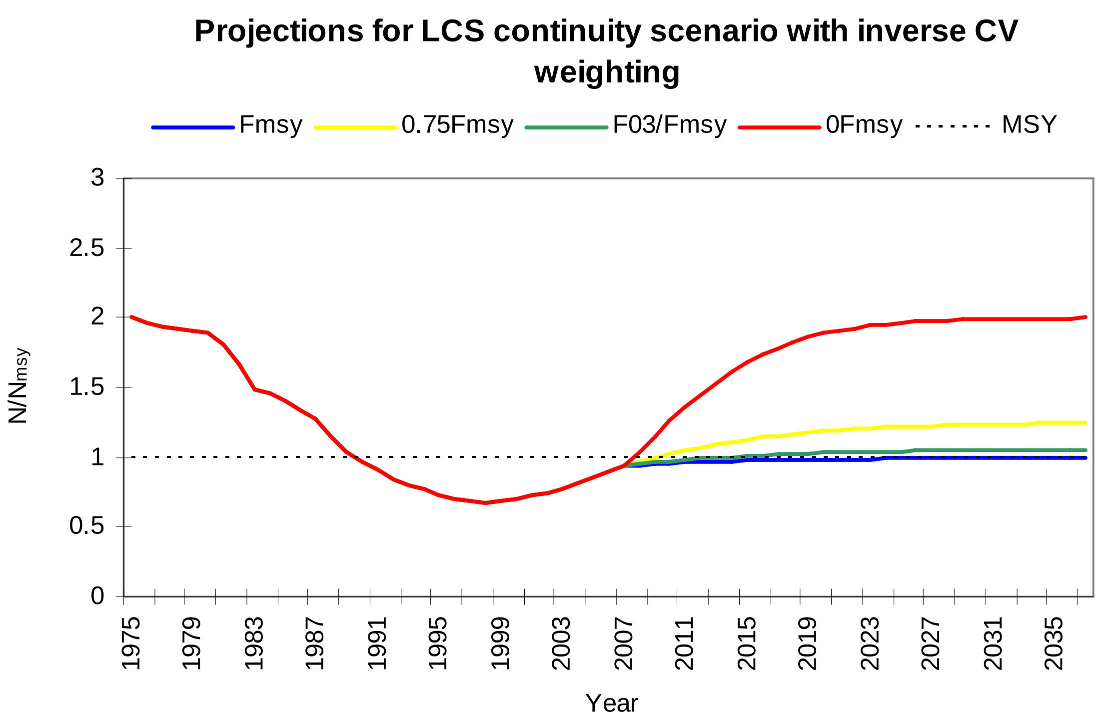


Figure 3.20. Estimated median relative abundance trajectory and projections (from 2008 to 2037) for alternative F_{MSY}-based harvesting policies (0, 0.75, and 1 times F_{MSY} and ((F_{2003}/F_{MSY}) * F_{MSY})) for the LCS continuity scenario with equal (A) and inverse CV weighting (B). The dashed horizontal line at 1 denotes the MSY level.

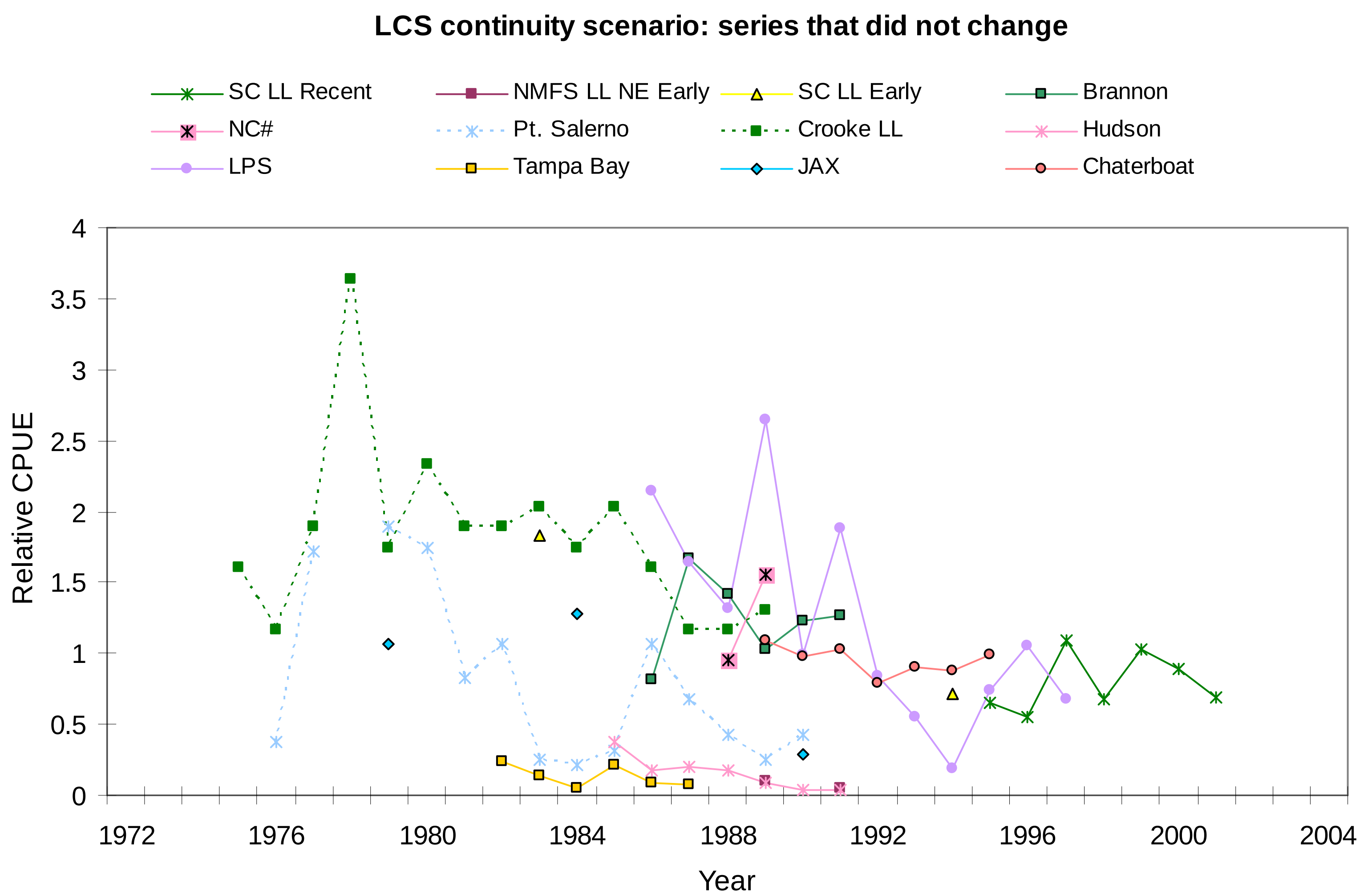


Figure 3.21. CPUE series used in the continuity analysis that did not change between the 2002 and current assessment. Series are scaled (divided by the mean of each series).

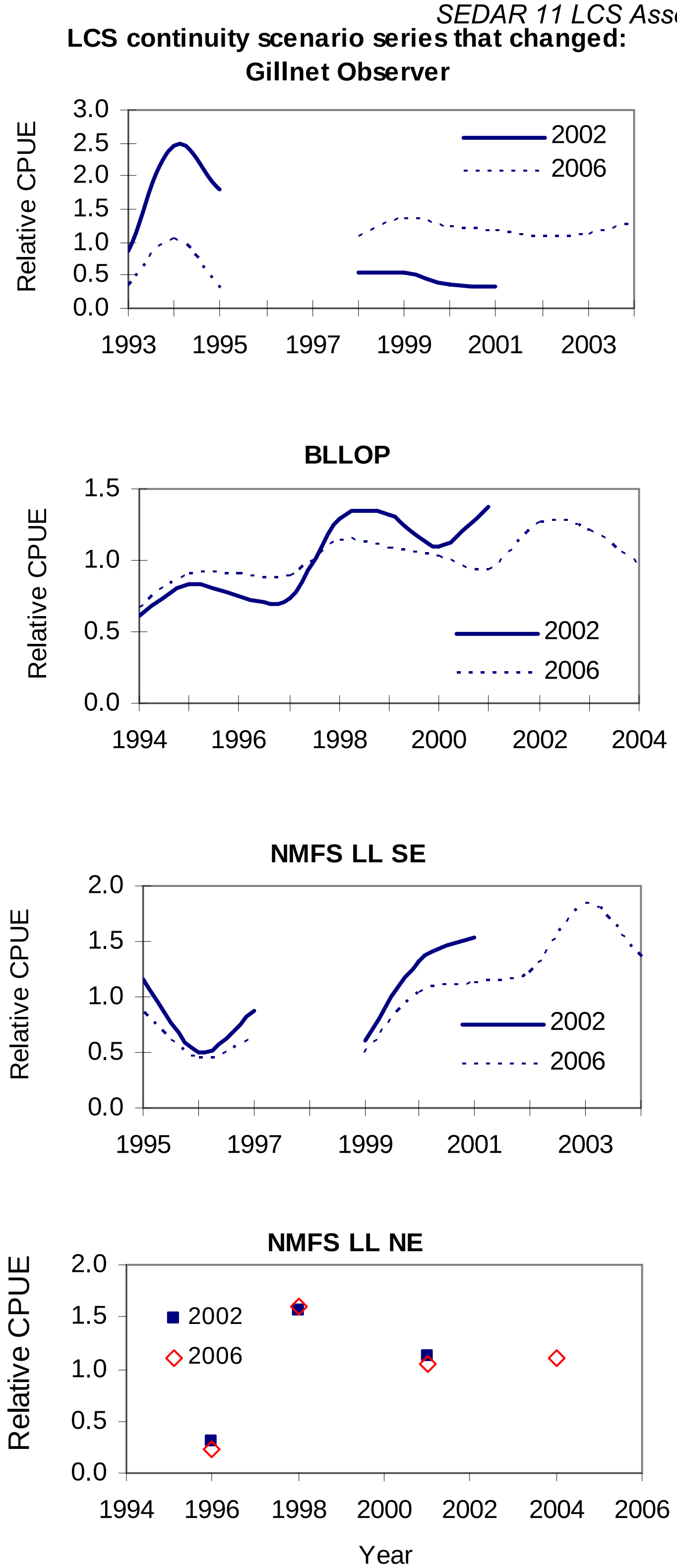


Figure 3.22. Series considered in the continuity analysis that changed between the 2002 and current assessment. Series shown are scaled (each series divided by its mean). The asterisk in the MRFSS graph indicates where the "early" and "recent" series from the 2002 assessment were connected for graphing.

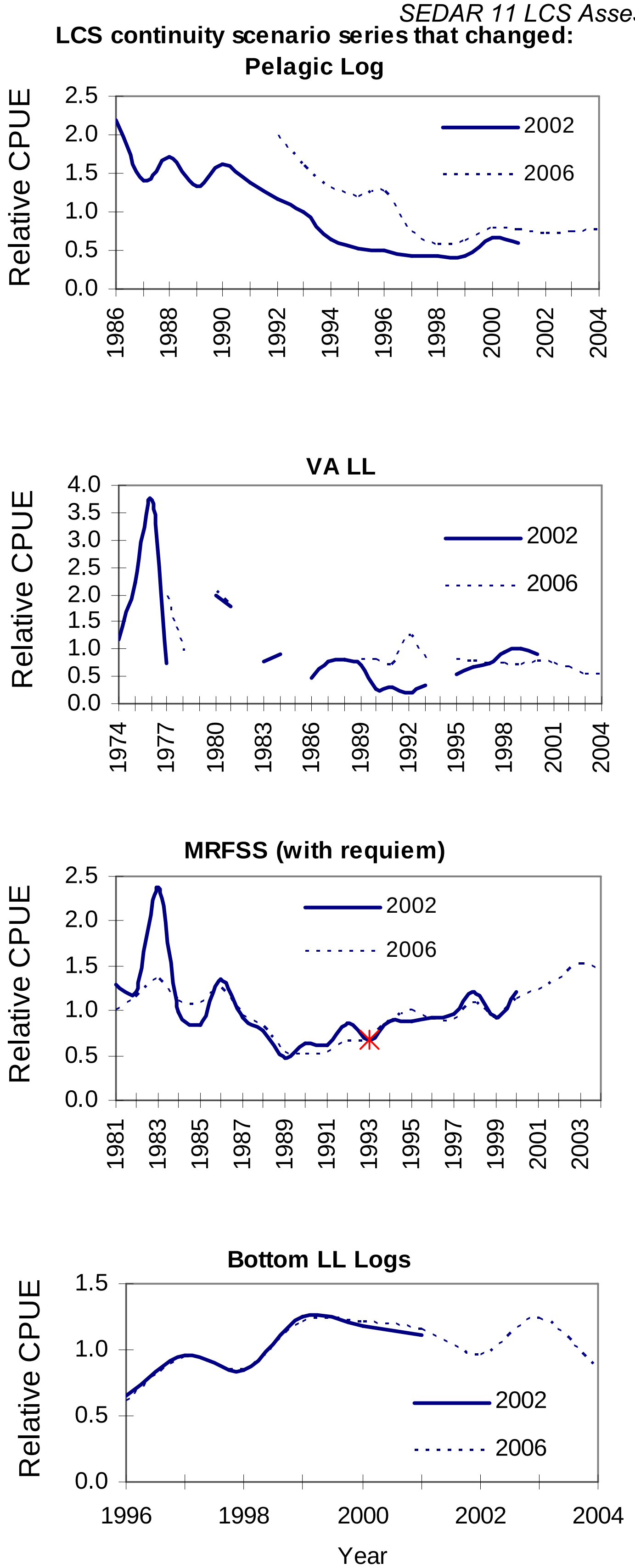


Figure 3.22. (continued)

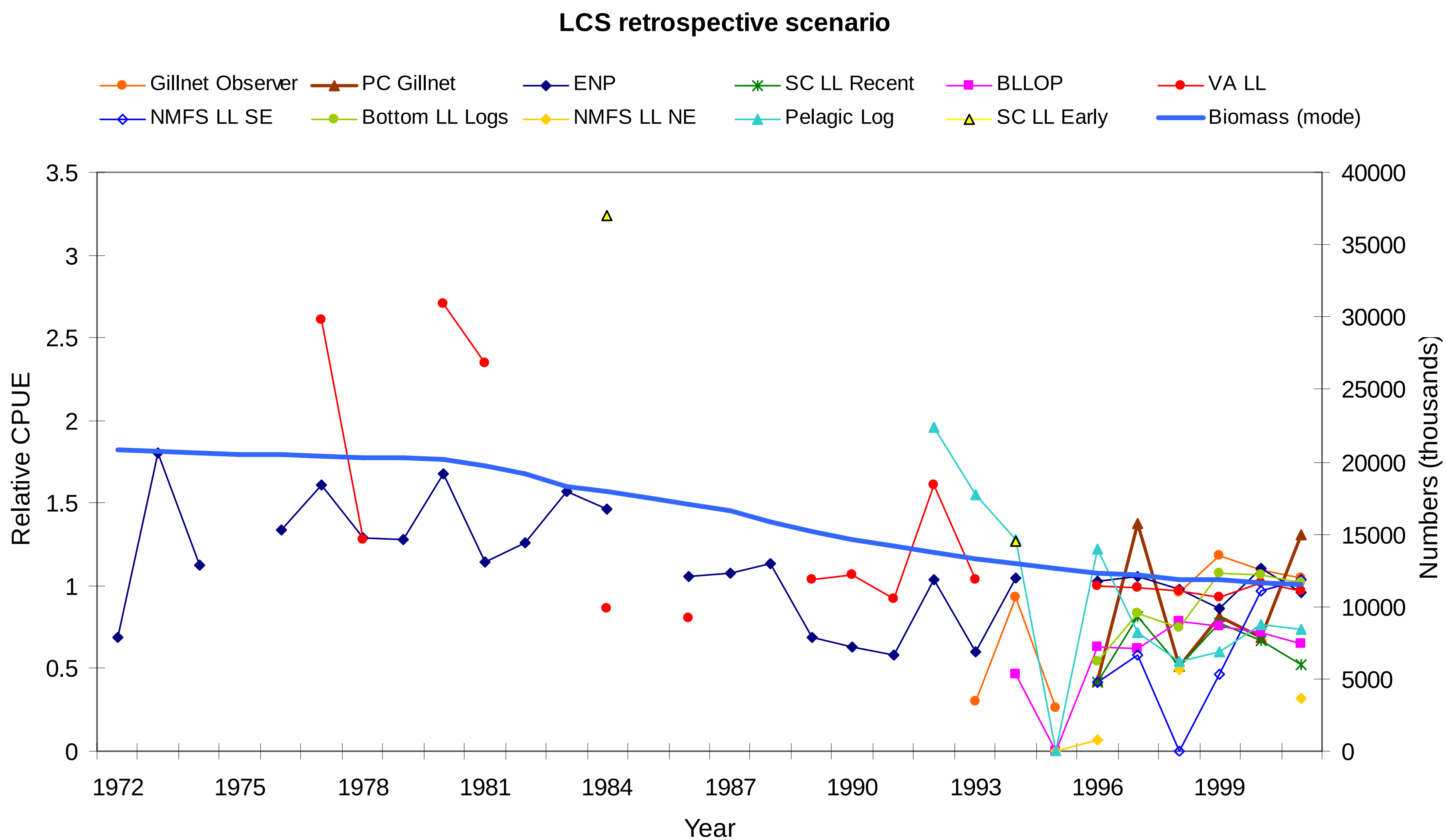
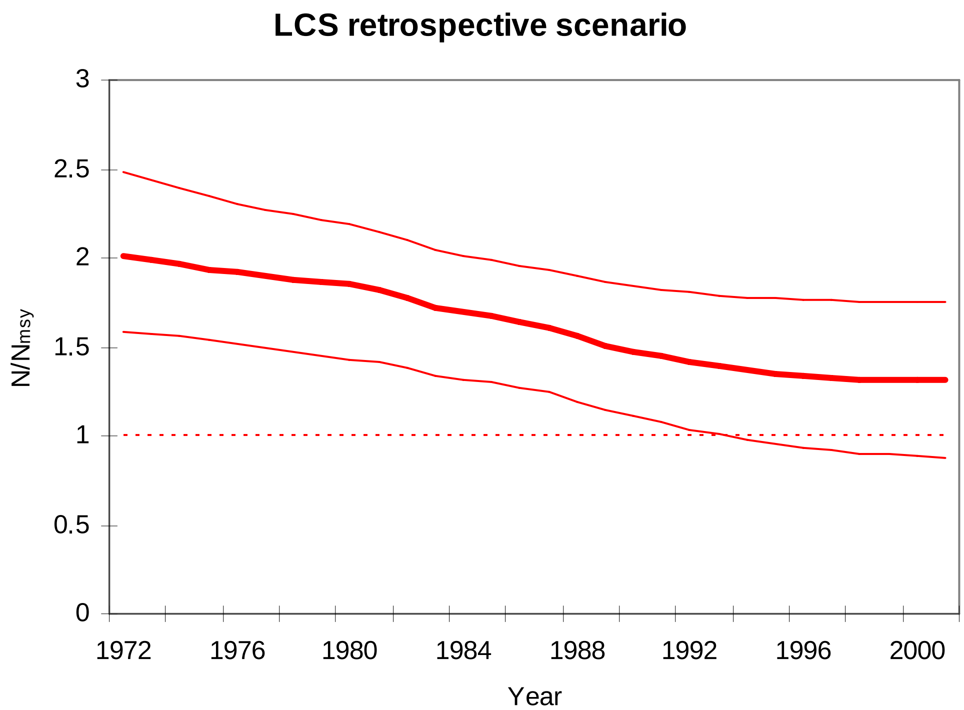


Figure 3.23. Predicted abundance trend of the BSP model fitted to the catch and CPUE data for LCS retrospective analysis. CPUE series shown are scaled (divided by the catchability coefficient for each series, and by the overall mean for all series).

A.



B.

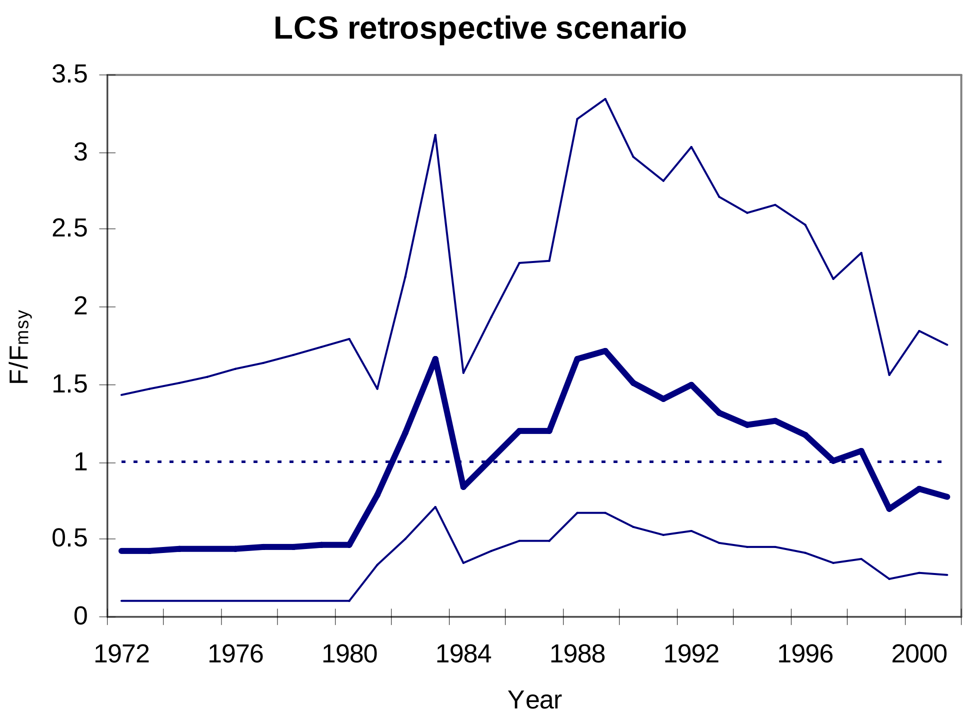


Figure 3.24. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for the LCS retrospective scenario with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels. .

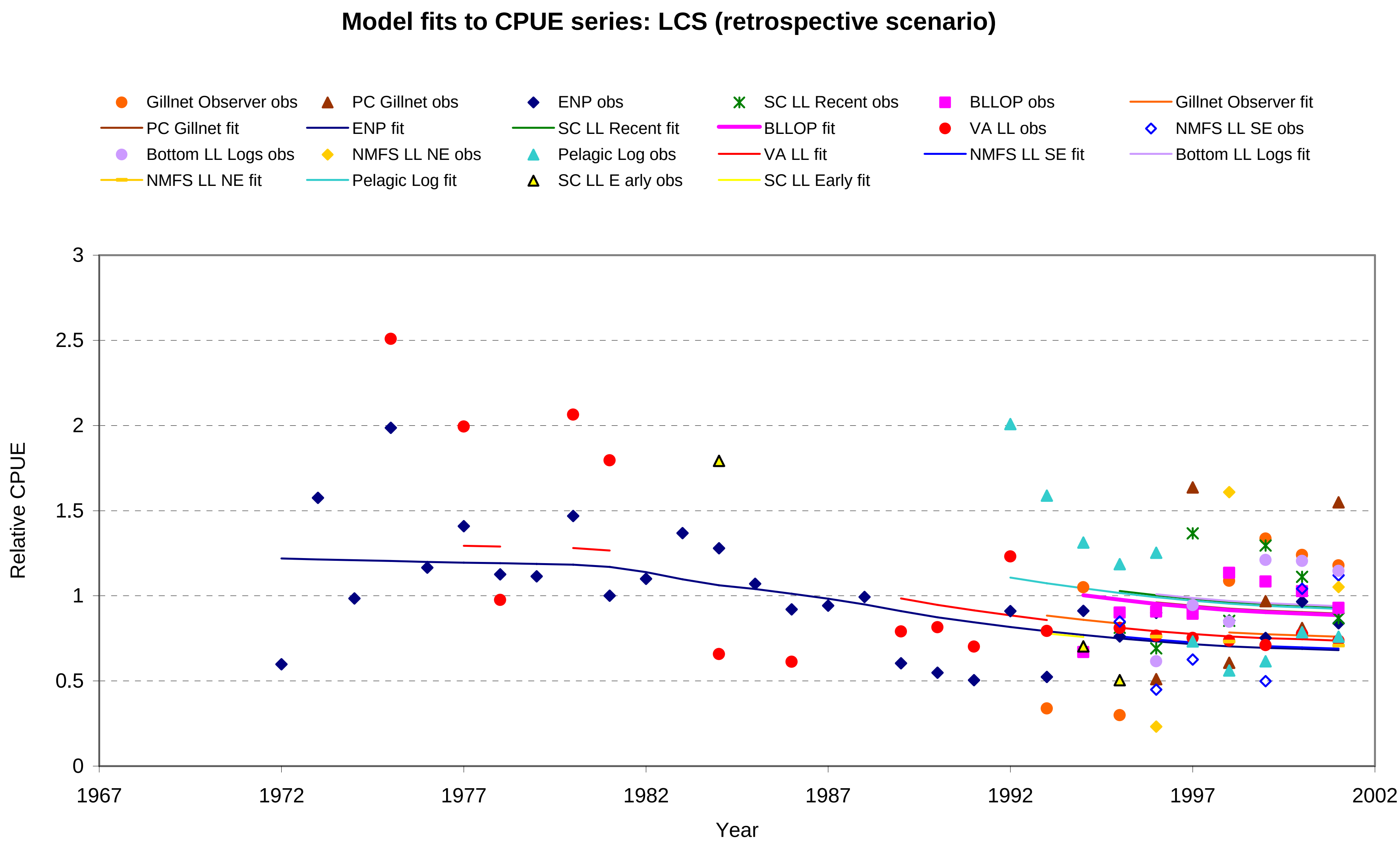


Figure 3.25. BSP model fits to the individual CPUE series for the LCS retrospective scenario.

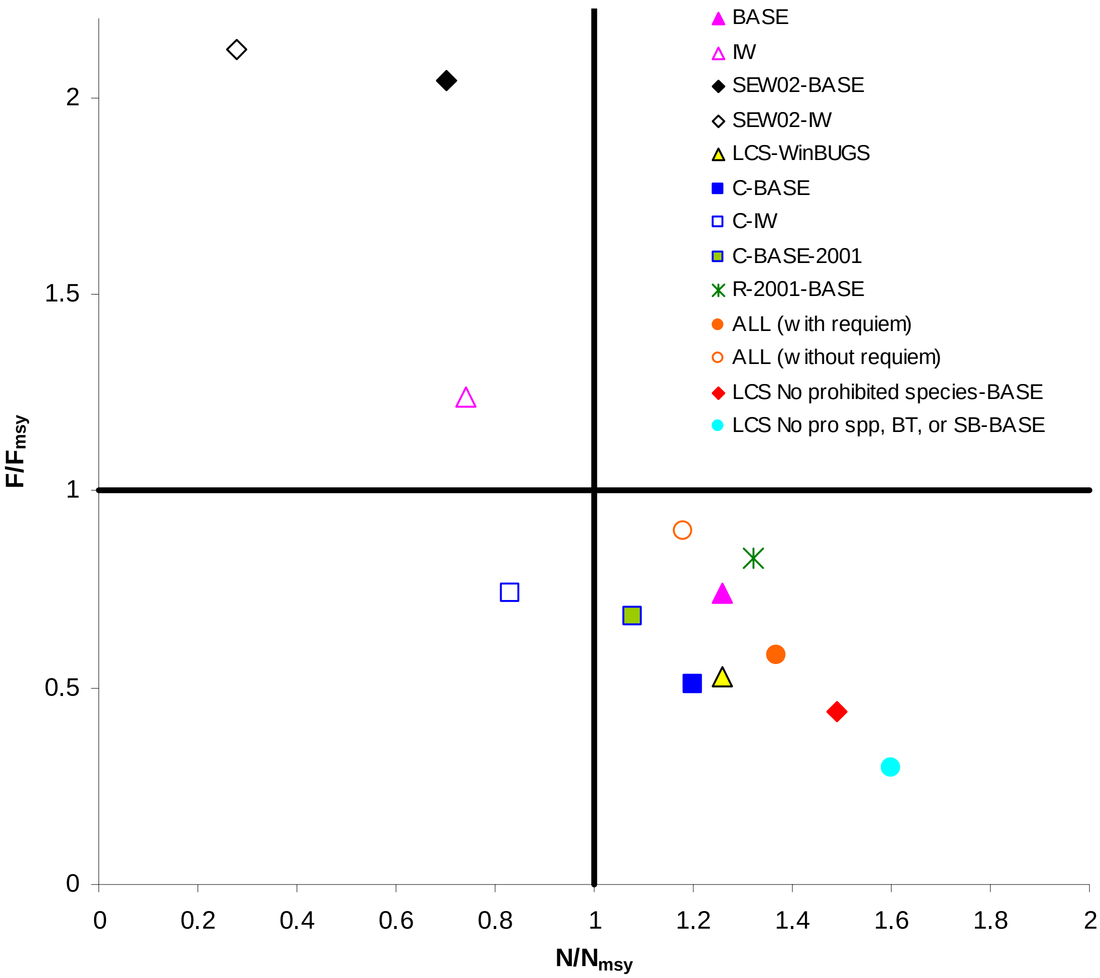


Figure 3.26. Phase plot for the LCS complex showing values of N_{2004}/N_{MSY} and F_{2004}/F_{MSY} obtained in the baseline scenarios using the BSP model. Selected sensitivity analyses and the baseline scenarios for the LCS without prohibited species, and LCS without prohibited species, blacktip or sandbar sharks are also included for comparison. The models include: BASE (LCS baseline), IW (LCS with inverse CV weighting), SEW02-BASE (results of 2002 LCS assessment with equal weighting), SEW02-IW (results of 2002 LCS assessment with inverse CV weighting), LCS-WinBUGS (LCS using WinBUGS surplus production model), C-BASE (continuity scenario for LCS with equal weighting), C-IW (continuity scenario for LCS, with inverse CV weighting), C-BASE-2001 (continuity scenario for LCS with equal weighting up to 2001 only), R-2001-BASE (retrospective scenario for LCS to 2001 only), ALL (with requiem) (LCS with all CPUE series including requiem shark category for MRFSS), ALL (without requiem) (LCS with all CPUE series excluding requiem shark category from MRFSS), LCS No prohibited species-BASE (baseline LCS without prohibited species), LCS No pro spp, BT, or SB – BASE (baseline without prohibited species, sandbar or blacktip shark). See text for full details. Several control rules are illustrated: the solid horizontal line indicates the MFMT (Maximum Fishing Mortality Threshold) and the solid vertical line denotes the target biomass (biomass or number at MSY). Note that the value of N_{2001}/N_{MSY} for SEW02-IW was 12.12 but was decreased to 2.12 here for viewing purposes only.

SANDBAR SHARK ASSESSMENT

4. SANDBAR SHARK ASSESSMENT

4.1 Summary of Sandbar Shark Working Documents

SEDAR 11–AW–01
First estimates of the status of sandbar shark stock off the eastern coast of the US
Summary: Predictions about the current status of sandbar shark stock off the eastern coast of the US are presented in this document. An age-structured population dynamics model has been used as part of a Bayesian statistical framework to analyze CPUE series and catch data. The model was run under a base case scenario but sensitivity runs were also conducted to evaluate model sensitivity to assumptions about the value of parameters such as pup survival. The results show that the size of the stock has been reduced to less than 35% of its virgin size. This prediction remained the same under both the base case and sensitivity runs.

SEDAR 11–AW–03
A State-Space, Age-Structured Production Model for Sandbar Shark
Two forms of an age-structured production model were employed to assess sandbar shark. The first was the continuity model used in the 2002 assessment. The second model (2006 base model) does not use catch, and all calculations are made relative to the unexploited stock. Both the continuity model and the 2006 base model (catch-free) reached the same conclusion that the stock is overfished and undergoing overfishing. Despite the differences in the way fishing mortality is estimated, and the fact that one model used catch and the other did not, both models agreed remarkably well on the estimates of biomass relative to MSY (continuity: 0.21-0.47; catch-free: 0.35-0.51) and on the level of current depletion (continuity: 0.15-0.26; catch-free: 0.19-0.26). One major input difference between the continuity model and the 2006 base model was the maturity ogive. Conclusions about status did not appear sensitive to this model input.

SEDAR11-AW-05
Assessment of Large Coastal, Blacktip, and Sandbar Sharks using Surplus Production Methods
We used two complementary surplus production models (BSP and WinBUGS) to assess the status of three Large Coastal Shark (LCS) groupings, two stocks of blacktip shark, and a single stock of sandbar shark identified as baseline scenarios in the LCS Data Workshop report. Both methodologies use Bayesian inference to estimate stock status, and the BSP further performs Bayesian decision analysis to examine the sustainability of various levels of future catch. Extensive sensitivity analyses were performed with the BSP model to assess the effect of different assumptions on CPUE indices and weighting methods, catches, intrinsic rates of increase, initial depletion, and importance function on results. Baseline scenarios for the three LCS groupings considered predicted that the stock status is not overfished nor overfishing is occurring. Using the inverse variance method to weight the CPUE data changed the predictions on stock status for the LCS grouping, which would then be overfished, with overfishing occurring. The sandbar shark stock was estimated to be significantly depleted (64-71% depletion from virgin level). The Gulf of Mexico blacktip shark stock was healthy (depletion of only 8-23% of virgin level), whereas results for the Atlantic blacktip shark stock from the BSP and WinBUGS models conflicted. The BSP model predicted a considerable level of depletion for this

stock regardless of the CPUE weighting method used. In contrast, the assessment of a single blacktip shark stock (GOM+ATL) resulted in very consistent results, with all models predicting a healthy status (depletions of only 10-16% of virgin level). Using the higher values of r from the 2002 SEW or accounting for some depletion from virgin levels in the first year of the model did not affect conclusions. Several assumptions on catches (notably changing the high value of recreational catch in 1983) also had no effect on conclusions. Removing the VIMS CPUE series from the LCS scenario reversed the conclusions on stock status when using inverse variance weighting, highlighting the influence of this series on results; removing the PELAGIC LOG CPUE series from the ATL blacktip shark analysis also drastically reversed the conclusions on stock status. Fitting one CPUE series at a time had a larger effect on results: the PELAGIC LOG series greatly influenced conclusions for the three LCS groupings and GOM and ATL blacktip shark, whereas the VIMS series affected conclusions on the two groups for which it is available, LCS and sandbar shark.

4.2 Background

Blacktip and sandbar sharks are the two most important species in the fishery, and have been the subjects of species-specific assessments in the past conducted through Shark Evaluation Workshops (SEWs). As such, the Panel was tasked with conducting species-specific assessments for these species. The Data Workshop (DW) determined catch histories, relative abundance indices, and biological input parameters for three assessments: one stock of sandbar sharks and two stocks of blacktip sharks, one for the Gulf of Mexico and one for the northwestern Atlantic Ocean.

4.3 Available Models

Five models were available for discussion for the sandbar shark assessment: two surplus production models, the BSP and WinBUGS models described previously, and three age-structured approaches. These included a catch free model which is an age-structured production model recast in terms relative to pre-exploitation levels (Porch et al. 2006), and two forms of an age-structured production model (Apostolaki et al. in press, Porch 2002).

4.4 Details about surplus production model and age-structured model

A surplus production model simulates the dynamics of a population using total population biomass as the parameter that reflects changes in population size relative to its virgin condition. In comparison to more complicated models, the surplus production model is simpler in its formulation, takes less time to run and requires less input information. However, due to its formulation, the surplus production model does not describe changes that occur in subgroups of the population (adults, juveniles, etc). In addition, the sensitivity of model predictions to key stage-dependent biological parameters cannot be evaluated using a surplus production model. Finally, surplus production models are not able to incorporate a lag time into the results.

An age-structured population dynamics model describes the dynamics of each age class in the population separately and therefore, requires age-specific input information. Due to the higher complexity of these models, they usually take longer to run and require a higher volume of information relative to simpler models. However, they can account for age-dependent differences in biology, dynamics and exploitation of fish and provide an insight into the structure of the population and the processes that are more important at different life stages. They also allow for the incorporation of age-specific selectivity information.

With regard to management benchmarks, the surplus production model generally assumes that the population biomass that corresponds to MSY is equal to half of the virgin population biomass, whereas the relative biomass at MSY calculated with an age-structured model (and other benchmarks associated to it) is species-specific and could be any fraction of virgin biomass.

The Assessment Panel decided to use the state-space, age-structured production model described in document SEDAR11-AW-03 for sandbar sharks. This model was selected as it allowed for the incorporation of age-specific biological and selectivity information, along with the ability to produce required management benchmarks.

4.5 Discussion of weighting methods

The Data Workshop recommended that *equal weighting* for assigning weights to the different CPUE time series available during model fitting should be used for the baseline runs. The panel discussed the advantages and disadvantages of the *equal weighting* vs. the *inverse CV weighting* methods:

Equal weighting ignores the better quality of some data (smaller CVs) but is more stable between assessments because yearly changes on CVs in a given CPUE series do not affect the importance of that time series for the overall fit.

Inverse CV weighting can provide better precision as it tracks individual indices however, it could be less stable between assessments due to changes on the relative 'noise' of each time series. This method may also not be appropriate in cases in which different standardization techniques have been used for the standardization of the series and therefore, the same value of CV might reflect different levels of error depending on the CPUE it corresponds to.

It was requested by one Panelist to manually weight the indices that cover larger geographic areas to have a stronger influence on the model. The group commented that, while that may be possible in a spatially explicit model, a great deal more data would be required than presently available.

The Assessment Panel decided that equal weighting would be the default weighting method for the current assessment but noted that, as there is at present no objective way to decide which of these two methods is superior other than comparing model convergence diagnostics, future assessments may need to reexamine this issue.

4.6 New biological parameters derived during the assessment workshop

As discussed in SEDAR 11-AW-10, the values for life history parameters that the Data Workshop determined to be the best estimates did not produce viable estimates for steepness (steepness was <0.2 for all stocks). The group reviewed the inputs that produce steepness (pup-survival, M at age for ages 1+, maturity at age, and pup-production at age), and determined that pup-production and estimates of maturity should be known with greater certainty than estimates of mortality or pup survival. Therefore, in order to satisfy the lower bound on steepness, and to meet the data workshop recommendation that steepness should be between 0.2-0.4, the mode of the lognormal prior for pup survival was increased to 0.75 with a CV of 0.3. In addition, survival increased by 3% for ages 1+. The data workshop values for M at age as well as the values derived in plenary at the assessment workshop are given in Tables 4.1a and b, and plotted in Figure 4.1. Note that in the 2002 assessment, the same problem was encountered with the lower limit of steepness. In 2002, the base parameter values gave a steepness of about 0.16, so the analysts increased pup production from 8.4 to 12, achieving a steepness of about 0.22.

4.7 Methods

4.7.1 State-space, age-structured production model description

It was decided at the assessment workshop that the age-structured production model would be used as the base model for the 2006 assessment rather than the catchfree model, as catch was available. To derive N at age for the first model year, one must define a year when the stock could be considered to be at virgin conditions. Then, assuming that there is some basis for deriving historic removals, one can estimate a population trajectory from virgin conditions through a “historic period,” until a more recent year when more data are available for model fitting.

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

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

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.

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

$$(2)\qquad R=\frac{R_0 S\alpha}{S_0+(\alpha-1)S}\quad .$$

In (2), R_0 and S_0 are virgin number of recruits (age-1 pups) and spawners (units are number of mature adult females times pup production at age), respectively. The parameter α is calculated as:

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

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).

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<mod are historic years, and modern years are y_i for which mod ≤ i ≤ T. The historic period is characterized by having relatively less 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)

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

or

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

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

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

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

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 at the end of the month, after natural mortality:

(7) $$C_{a,y,m,i} = F_{a,y,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad ,$$

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

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. For this model application to sandbar sharks, both vulnerability and catchability were assumed to be constant over years.

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:

$$(9) \qquad I_{y,m,i} = q_{y,i} \sum_a v_{a,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad .$$

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

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:

$$(10) \qquad \begin{aligned} g_{t+1} &= E[g_{t+1}] e^{\varepsilon_{t+1}} \\ \varepsilon_{t+1} &= \rho \varepsilon_t + \eta_{t+1} \end{aligned} \quad .$$

In (10), g is a given state or observation variable, η is a normal-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):

$$(11a) \quad \sigma_g = \ln\left[(\lambda_g CV)^2 + 1 \right]$$

$$(11b) \quad \sigma_g = \ln\left[(\omega_{i,y} \lambda_g CV)^2 + 1 \right] \quad .$$

The term λ_g is a variable-specific multiplier of the overall model CV. For catch series and indices (eq 11b), the additional term, $\omega_{i,y}$, is the weight applied to individual points within those series. For instance, because the indices are standardized external to the model, the estimated variance of points within each series is available and could be used to weight the model fit. Given the Data Workshop decision to use equal weighting between indices, all $\omega_{i,y}$ were fixed to 1.0 and the same λ_g was applied to all indices. To evaluate the sensitivity case where indices were weighted by the inverse of their CV, each $\omega_{i,y}$ was fixed to the estimated CV for point *y* in series *i*; an attempt was also made to estimate a separate λ_g for each series, however those multipliers were not estimable and so a single λ was applied to all indices.

In the present model, these multipliers on catches and indices were fixed after exploring the effects on model outputs for several different values. A fleet-specific effort constant was estimated, but by allowing for large process error it was effectively a free parameter (a log-scale variance of 5 was used); the correlation was fixed at 0.5.

4.7.2 Data inputs, prior probability distributions, and performance indicators

Baseline scenario (ASPM-BASE)

The base model represented the decisions made by the Data Workshop as well as any additional decisions or modifications made by the assessment workshop. Data inputted to the model included maturity at age, fecundity at age (pups per mature female), spawning season, catches, indices, and selectivity functions (Tables 4.1a and b, 4.2, and 4.3; Figures 4.1 - 4.3). Catches were made by the commercial sector, the recreational sector, and the Mexican fishery. In addition, unreported commercial catches were estimated, as were Gulf of Mexico menhaden fishery discards. Because of similar selectivity functions, the commercial and unreported catches were combined, and recreational catches were combined with Mexican catches, yielding a model with 3 distinct "fleets" (Table 4.2). A total of 13 indices were made available after the data workshop (Table 4.3, Figure 4.2). The "DE Bay age 0" index was not used in this application, as this model began with age class 1.

Selectivities are imputed in the age-structured surplus production model (as a functional form) and linked to each individual catch or CPUE series. Individual selectivity functions to be applied to catch series were identified by the DW catch working group based on information used in previous assessments, length frequency data presented at the DW, and the collective knowledge of shark fisheries of the group members. The selectivity recommendations can be found on pages 38-39 of the DW report. Selectivities linked to individual catch series were a compromise because the series often encompass various components of the fishery (e.g., commercial + unreported selectivity refers to commercial fisheries, most of which are bottom longline fisheries, but also include pelagic longline and drift gillnet fisheries, which are likely to have somewhat different selectivity patterns). The selectivity functions identified were then applied to the individual CPUE series based on the type of index represented (e.g., the BLLOP and VA LL indices were assigned the commercial + unreported logistic selectivity function because both indices use bottom longline gear).

-Commercial landings + unreported catch series: a logistic curve was selected based on the 2002 SEW assessment. The rationale was that younger ages were relatively less selected by the commercial gear as a whole, which as stated above may also include pelagic longline gear that is set in deeper waters where juveniles are less available, and drift gillnet gear that uses large mesh sizes targeting adults (Figure 4.3).

-Recreational and Mexican catch series: this selectivity pattern was largely based on the MRFSS, which includes data from recreational anglers fishing in nearshore waters and targeting mostly juveniles. Based on this, very limited length-frequency information presented in document LCS05/06-DW-16, and information from the 2002 SEW assessment, selectivity for sandbars was given a dome-shaped curve covering mostly juvenile ages (Figure 4.3).

-Menhaden bycatch series: based on data from this fishery, all age groups were assumed to be fully selected and thus given a constant selectivity of 1 (Figure 4.3).

-Juvenile indices: this selectivity pattern was intended for surveys targeting juveniles and thus assumes full selectivity for the first age groups, with a rapid decline as sharks approach maturity (note that the 2002 ages at maturity were used; Figure 4.3).

Catch data begin in 1981, while the earliest data for the indices is 1975 (VA-LL). To make use of the longer time series of this index, and the possible contrast offered therein, catches from 1981 were imputed back to 1975, when a virgin assumption was imposed. The catches for each fleet were imputed as follows: the commercial+unreported was fixed to the 1981 value, the recreational+Mexican was fixed with a linear decrease from the 1981 value, and the menhaden catches were fixed at the series average (Table 4.2).

It was discussed at the assessment workshop that a commercial fishery existed in the mid-1930s for shark livers, but that this fishery disappeared after the development of synthesized vitamin A. A small amount of bycatch in the Pelagic Longline fishery and menhaden fishery probably began in the 1960s, but this is assumed to be negligible compared to the removals in the 1970s. Following the release of the movie JAWS in 1975, a recreational fishery rapidly developed. Thus, the assumption that the initiation of significant exploitation began in 1975 does not seem unreasonable.

Individual points within catch and index series can be assigned different weights, based either on estimated precision or expert opinion. The base case model configuration downweighted the historical catches, giving them ½ of the weight of catches from 1981-2004, on the rationale that they were less well known. In addition, several weighting factors were evaluated for the value of the recreational catch in 1983. Recreational catch in 1983 is roughly ten times the value in 1982 and six times the value in 1984; also, it is about nine times the series average without that point. For these reasons, the value for 1983 catch seems anomalously high. Downweighting it by ½ led to the predicted value matching it within 3%; downweighting it by 1/10 led to a predicted value within 25%. In both cases, the relative benchmarks were nearly identical. It was decided to proceed by downweighting that point by 1/10.

One further model specification was the degree to which the model predicted values matched catches versus indices. An overall model CV is estimated (see equations 11a and 11b), and multiples (λ_g) of this overall CV can be specified separately for catches and indices (see Porch 2002). All catch series were assigned the same CV multiple, and all indices were assigned a single CV multiple (this forces equal weighting of the indices). Initially, an attempt was made to estimate these multipliers. This resulted in boundary solutions for the multipliers. In a second attempt, the multiplier for catch was fixed at 1 and the index multiplier was estimated. Again, this resulted in the index multiplier estimate at the upper bound. An explanation for this behavior is that the interannual variability within indices is substantial in some cases, and additionally, indices with the same selectivity have conflicting trends (Figure 4.4). To deal with this, two values were evaluated for the CV multiplier of indices: a value that was 5 times the catch CV multiplier, and a value equal to the catch CV multiplier. The former case implies that indices are less certain than catches, while the latter case implies the same relative certainty in catches and indices. Both results indicated an overfished stock with overfishing. The estimate of relative biomass (B_{2004}/B_{MSY}) was nearly identical between these two configurations (0.72 vs.

0.73, respectively), while the degree of overfishing (F_{2004}/F_{MSY}) was about 10% less (3.72 vs. 3.29). Given that the estimated stock status did not vary based on the weighting between catch and indices, it was decided to proceed by placing relatively more confidence in the catch series (notwithstanding the weighting of individual points within the catch series, as described in the paragraph above).

Estimated model parameters were pup survival, virgin recruitment (R_0), catchabilities associated with catches and indices, and fleet-specific effort. Natural mortality at ages 1+ was fixed at the updated values (Table 4.1a), and the priors for pup survival and virgin recruitment are listed in Table 4.1b.

In summary, the base model configuration assumed virgin conditions in 1975, used the imputed historical catch series, the updated biological parameters, the updated prior for pup survival, and the base case indices with an updated Pelagic Longline Log index (referred to as Pelagic Log). In addition, historic catches (1975-1980) were downweighted by ½ and the 1983 recreational catch was downweighted by 1/10; lastly, catches were assumed to be 5 times more certain than the indices. All inputs are given in Tables 4.1, 4.2, and 4.3. Base indices are in black font in Table 4.3 (the DE Bay age 0 index was not used because the model started with age 1).

Performance indicators included estimates of absolute population levels and fishing mortality for year 2004 (F_{2004}, SSF_{2004}, B_{2004}, $Nmature_{2004}$), population statistics at MSY (F_{MSY}, SSF_{MSY}, SPR_{MSY}), current status relative to MSY levels, and depletion estimates (current status relative to virgin levels). In addition, trajectories for F_{year}/F_{MSY} and SSF_{year}/SSF_{MSY} were plotted. SSF spawning stock fecundity.

4.7.3 Methods of numerical integration, convergence diagnostics, and decision analysis

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. 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). Model fit was assessed by comparing components of the relative negative log-likelihood (relative rather than exact because the constants in the likelihood were not included). The relative negative log-likelihood (objective function) and AICc (small sample AIC) values are listed in the table of model results.

4.7.4 Sensitivity analyses

Three sensitivity runs to the base model were performed. In the first sensitivity (**ASPM-SB-1**), the base configuration was retained and observations within each index were weighted by the inverse CV of each point. An attempt was made to estimate a separate CV multiplier for each index, but there were boundary solutions again, so the multiplier from the base case was retained for all indices. In the second sensitivity (**ASPM-SB-2**), the base configuration was retained, and all available indices were used. For the third sensitivity (**ASPM-SB-SPR$_{50}$**), the base case weighting and indices were used, but the model was forced to have SPR_{MSY}=0.5. To achieve this SPR level, the base case values for survival at age (the updated values as described in Section 4.6) were increased by 1.5% for ages 1+, and the median for pup survival was fixed at 0.82.

One Panel member noted that many of the sandbar indices are localized, seasonal surveys and requested that a sensitivity be run using the surplus production model including only the BLLOP, Pelagic Log, and Bottom LL Logs indices because they cover the greatest area and time. However, it was noted that the BSP was not the final model selected for sandbar sharks. Additionally, similar sensitivity runs had been completed using the BSP and did not change the stock status. It was also noted that the commercial indices do have gaps in time and space due to closed areas and fishing seasons. Additionally it was pointed out that many of the "seasonal" surveys are conducted in that fashion as the sharks are not present year-round in those areas so sampling when the sharks are not available to the gear would confound the data. Finally, it was noted that removing all the others indices would remove the indices which cover the greatest time span, including those prior to management intervention, which contain most of the contrast over time, leaving only relatively short, non informative indices beginning after management intervention for the model to fit to. It was decided not to conduct this sensitivity.

4.8. Results

4.8.1 Baseline scenario

The base model estimated an overfished stock with overfishing (Tables 4.4 and 4.5; Figure 4.5). The model estimate of F by fleet is dominated by the recreational fleet (includes recreational fishery plus estimated Mexican catches) for the first decade of the time series (1975-1986), and thereafter the commercial and recreational fleets are more or less on par (Figure 4.5). Model fits to catches are shown in Figure 4.6 and show very good agreement; the estimated recreational 1983 value is below the observed value due to the downweighting of that point (see discussion in section 4.7.2). The VA-LL index is the longest time series, beginning in 1975, and its trend was fit well by the model (Figure 4.7). The next longest series is LPS, which begins in 1986. The LPS index showed steep oscillations the first 8 years, which the model could not match (Figure 4.7). The remaining indices span only a few years, and the model adequately predicts an average trend through the observed points (Figure 4.7).

Likelihood profiling was performed in ADModel Builder (Otter Research Ltd. 2000) to obtain posterior distributions for several model parameters (Figures 4.8 and 4.9). The distributions for total biomass depletion or spawning stock fecundity depletion range from about 0.2-0.5 (Figure 4.8). The estimate of F_{2004} ranges from about 0.03-0.08 (Figure 4.9). The mode for the posterior of pup survival was estimated at a lower value than the prior mode (it was closer to the original data workshop specification of 0.6), while the posterior for virgin recruitment of pups became much more concentrated around the prior mode (Figure 4.9).

4.8.2 Sensitivity analyses

The results of the three sensitivity cases also estimated that the stock was overfished with overfishing (Table 4.4). For **ASPM-SB-1**, the results were very similar to the base case. Although the estimate of SSF_{2004}/SSF_{MSY} was similar to the base model, **ASPM-SB-2** estimated a much higher relative F (six to ten times larger than the other models). This is due to the model estimating a very low pup survival (0.37), which led to an F_{MSY} that was ten times lower than the other model. The low resiliency implied by these estimates is also reflected in the estimate of SPR_{MSY} (0.96). It appears that the flatter fit to indices (as compared to the base model) is the reason that SSF_{2004}/SSF_{MSY} is more similar to the base and sensitivity cases. **ASPM-SB-SPR$_{50}$** was the most optimistic scenario, but that is due to the fact that SPR_{MSY} was forced to be 0.5; the other models estimated SPR_{MSY} in the range of 0.7-0.96.

A phase-plot of stock-status shows the outcomes of the base model, the three sensitivity analyses, the continuity and retrospective analyses, and the estimates from BSP and WinBUGS (Figure 4.10). Note that the x values for BSP and WinBUGS are in numbers of fish (N_{2004}/N_{MSY}) rather than SSF_{2004}/SSF_{MSY}. These values from BSP and WinBUGS should be comparable, however, because they are relative statistics, and they only differ from the ASPM by the maturity ogive. No prior was assumed for catchability so its contribution to the likelihood is 0.0 for all models.

4.8.3 Comparison of model fits

The relative likelihood values by model source (catch, indices, effort, catchability, and recruitment) as well as a breakdown of likelihood by individual catch and index series are shown in Figures 11 and 12. The total approximate likelihood is lowest for the base model (see Table 4.4, value for "objective function"). Catches are best fit by the base model, while indices are better fit by the sensitivity using inverse CV to weight the series (ASPM-SB-1). However, the difference between the best versus the worst fit to indices is only 10 points, whereas there is a difference of about 60 points in the fit to catches. None of the model configurations impacted the contribution to the likelihood by effort or recruitment parameters (pup survival and virgin number of pups). The AICc is lowest for ASPM-SB-2, but this model run used 3 additional sensitivity indices (39 additional data points, and only 3 additional parameters estimated compared to the base model). The next lowest AICc used the same data as the base model, but estimated one fewer parameter (pup survival was fixed, ASPM-SB-SPR50). The AICc is about 3.5 points lower for this sensitivity, which may indicate a slightly better fit than the base model.

4.9 Projections of the base model

The base model was projected at F = 0 to determine the year when the stock could be declared recovered ($SSF/SSF_{MSY} > 1$). In making projections, the estimate of F in 2004 was applied for years 2005-2007, as it is unlikely that any management actions could be realized until that year.

Projections were done using Pro-2Box (Porch 2003). Projecting the stock at F = 0 (with F = F_{2004} for years 2005-2007), a deterministic estimate indicates stock recovery by 2038 (SSF2038 = SSF_{MSY}), or 34 years from the current year of data (2004). This projection was bootstrapped 500 times by allowing for process error in the spawner-recruit relationship. Lognormal recruitment deviations with CV = 0.4, with no autocorrelation, were assumed. No other variability was introduced into the projections. Under these assumptions, the year with 70% probability of recovering to SSF_{MSY} is 2041, which is a rebuilding time of 38 years from 2004.

Given that the rebuilding time is greater than 10 years, then management action should be implemented to rebuild the stock within the estimated **rebuild time+1 generation time** (Restrepo et al. 1998). The estimate of generation time is about 34 years, which gives (**38 years) + (34 years) = 72 years** to rebuild, or the **year 2076**. Generation time was calculated as

$$GenTime = \frac{\sum_i i f_i \prod_{j=1}^{i-1} s_j}{\sum_i f_i \prod_{j=1}^{i-1} s_j}$$

where i is age, f_i is the product of (fecundity at age) x (maturity at age), and s_j is survival at age. The calculations were carried out to an age, A, such that the difference between performing the calculation to age A or A+1 was negligible. This calculation is consistent with the assessment model, which treats survival of the plus group as the sum of a geometric series (e.g. see third line in equation 1). The 2006 maturity ogive was used, 8.4 pups per female was the fecundity for all ages, adjusted age-specific survival at age was used (see section 4.6), and the mode of 0.75 for the prior on pup survival was used. As was done in the assessment model, to account for the approximately one year gestation period, maturity at age was shifted by 1 year, and the number of pups was halved to account for the fact that only half of the mature population would reproduce in a given year. Note that because pup-production is constant for all ages, it factors out of both numerator and denominator, and the resulting estimate of generation time is insensitive to that value.

A fixed F strategy and a fixed TAC strategy were estimated that would attain rebuilding by the year 2076. Assumptions for these projections included the above process error in stock-recruitment, the selectivity vector was the geometric mean of the last 3 years (2002-2004), and it was assumed that any modification to F or a TAC would impact each fishery by the same proportion.

A constant F of 0.01 beginning in 2008 leads to rebuilding by the year 2076 with 70% probability, while F = 0.011 rebuilds the stock by 2076 with 50% probability (median of bootstraps; Figure 4.13). The current estimate of F (F_{2004}) is 0.065, implying that a reduction of about 83-85% is needed. The yield (kg) associated with these F values in 2008 is approximately 15-17% of the yield in 2007.

Constant TAC scenarios were explored by implementing a constant yield (in kg) beginning in 2008; in years 2005-2007 the estimated fishing mortality rate from 2004 was applied. A constant TAC of 2.4E+05 kg allows the population to rebuild by 2076 with 70% probability (70% of the bootstraps have $SSF_{2076}/SSF_{MSY}>1.0$; Fig. 4.14). A constant TAC of 2.7E+05 kg allows rebuilding by 2076 with 50% probability (median of the bootstrap runs). A TAC of 2.4E+05 kg or 2.7E+05 kg is 20% or 23% of the yield obtained in 2007.

4.10 Continuity analysis

A continuity base model was run using the 2002 state-space age structured production model. In that model formulation, a level of historic fishing (F_{hist}) is estimated. F_{hist} is then used to calculate the corresponding equilibrium population age structure for the first year that data is available. A historic selectivity vector is specified by the user, which is multiplied by F_{hist} to arrive at the historic age-specific fishing mortality rate. A historic selectivity vector of 1 for all ages was assumed. This methodology is fully documented in section 5.7.1 of the Gulf of Mexico blacktip shark assessment.

Biological inputs to the continuity model were the same as those used in 2002 (Table 4.1a). Catches and indices used were the updated values through 2004. The updated catches were nearly identical (Figure 4.15). All indices in Table 4.3 were used except the "Del Bay age 0," because the model started at age 1. The indices available for 2006 and those used in 2002 are plotted in Figures 4.2 and 4.16 respectively. Several of these indices were directly compared to see more clearly the recent trend (Figure 4.17). It was noted that several of the indices for the 2002 assessment had an upswing in the terminal year for input (2001). Several of those indices, when updated to 2004, showed a consistent decline from the upswing in 2001.

The direct comparisons between indices used in 2002 versus those used in 2006 is confounded somewhat by several issues. First, a number of the indices in 2002 were not available in 2006. In some cases, indices which were not standardized in 2002 were standardized in 2006; in other cases, indices which were not standardized and which were split into two separate nominal indices in 2002 were combined and standardized to one index in 2006 (MRFSS, e.g.). Also, the VIMS data were split into four age-specific indices and one biomass index in 2002, while in 2006 only one VIMS index in numbers for all ages was available. Despite these issues, the overlay of indices from similar data sources shows very similar trends for the years of overlap (Figure 4.17).

Because one index started in 1975, while the catch started in 1981, the model was allowed to estimate catch in the years 1975-1980. Alternative treatments of this 'missing catch' were evaluated in SEDAR11-AW-03.

The result of the continuity model was an overfished stock with overfishing (SSF_{2004}/SSF_{MSY} = 0.38, F_{2004}/F_{MSY} = 65.6). The estimate of F_{hist} was 9.8E-5, but the population was depleted to 72% of virgin conditions at the start of the time series (B_{1975}/B_0= 0.72). The estimate of SPR_{MSY} was 0.95 and F_{MSY} was 0.003, which explains why such a small level of fishing mortality had such a measurable effect on the population. This low resiliency compared to the 2002 result was driven in part by the estimated age-constant of M, which was 0.224 in this application versus 0.137 in 2002. The prior for M was specified the same for 2002 and 2006 (lognormal distribution with median = 0.18 and CV = 0.25).

4.11 Retrospective analyses

It was noted that the conclusion regarding stock status from the continuity and base models (an overfished stock with overfishing) in this 2006 assessment contradicted the base model conclusion from the 2002 assessment.

Given that direct comparisons between indices used in 2002 vs. those used in 2006 is confounded somewhat by the issues discussed in the continuity section above, several retrospective analyses were examined to try to determine what was driving the new results. All retrospective runs used the age structured production model from the 2002 assessment, 2002 values for biological parameters (Tables 4.1a and b), and catch and indices updated through 2004. The retrospective analyses examined were:

R1 – Using updated data through 2004, the updated Pelagic Log index, equal weighting, and using the imputed catches from 1975-1980 (Table 4.2; same as Catch Scenario 2 in SEDAR11-AW-03)
R2 – Using updated data through 2001, the updated Pelagic Log index, equal weighting, and using the imputed catches from 1975-1980 (Table 4.2; same as Catch Scenario 2 in SEDAR11-AW-03)
R3 – Using updated data through 2001, the updated Pelagic Log index, equal weighting, and model started in 1981 (did not use imputed historical catches)
R4 – Using updated data through 2001, the updated Pelagic Log index, equal weighting, and model started in 1981 (did not use imputed historical catches), added the VIMS age 0-1 index from the last assessment
R5 – Using updated data through 2001, the updated Pelagic Log index, equal weighting, and model started in 1981 (did not use imputed historical catches), added the VIMS age 13-max index from the last assessment
R6 – Using updated data through 2001, the updated Pelagic Log index, equal weighting, and model started in 1981 (did not use imputed historical catches), added all of the VIMS indices from the last assessment

Model runs R4 and R5 did not converge. All of the remaining retrospective model runs estimated that the stock was overfished with overfishing occurring (Table 4.6), and it was not possible (with this set of runs) to arrive at the 2002 assessment conclusion. It should be noted that using the data input files from 2002 reproduced exactly the output from 2002, which demonstrates that there were no changes to the model code that affected the estimation procedure.

4.12 Discussion

There was some uncertainty associated with the biological parameters, which led to the AW updating the fixed values for M at age, and the mode of the prior for pup-survival (corresponding to density-independent level). Even fixing pup survival to a relatively high level (median of 0.82) so that SPR_{MSY}=0.5 produced a very low sustainable level of fishing mortality (F_{MSY}=0.03). In the base model, total fishing mortality from 1990-2000 averages 0.12, and for 2001-2004 it averages 0.08. These levels are 3-4 times the estimate of F_{MSY}, assuming the most optimistic survival rates, and 6-8 times the base case estimate of F_{MSY}. A contributing factor to having low resiliency to fishing is the late age at first maturity. The combination of life-history parameters and the vulnerability of sharks to the various gears long before they are mature suggest a population that cannot support much exploitation.

The result from 2002 ASPM with equal weighting was that the stock was not overfished, and no overfishing was occurring, although the value of F_{2001}/F_{MSY} = 0.9 was only slightly below 1.0. Retrospective analyses using the biological inputs from 2002 failed to identify a reason for the change in estimated status for 2006. However, these retrospective analyses did not use the exact same data sets, for the various reasons mentioned in Sections 4.10 and 4.11.

Between the 2002 and 2006 base cases, there are differences beyond the indices. The values and treatment of biological parameters differed. The maturity ogive for 2006 was shifted to older ages; a fixed M at age was used in 2006 while an age-constant M was estimated in 2002. Assumptions relating to virgin conditions and historic exploitation also differed. In 2002, the model began in 1981 and estimated a historical level of fishing (F_{hist}) that was used to calculate the initial equilibrium age structure under that fishing rate. The estimate of F_{hist} was 1E-8, which effectively started the population at virgin conditions in 1981. In 2006, the model began at virgin conditions in 1975, and catches were imputed for the years 1975-1980. The 2006 model result estimated the total biomass in 1981 to be at 93% of virgin levels, and SSF_{1981}/SSF_{virgin} = 0.98. The estimate of virgin recruitment (age-1 pups) and pup-survival were similar between 2002 and 2006, but the estimate of MSY for the 2002 assessment was double that for 2006. This is because in 2002, the estimate of SPR_{MSY} was 0.46 (vs. 0.73 in 2006), a result of the different survival and maturity rates at age.

4.13 References

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Table 4.1a. Biological inputs from 2002 assessment, 2006 base case values from the data workshop, or values updated at the 2006 assessment workshop. In the continuity case, M was estimated, while in the 2006 base case, M at age values were fixed. The * for the age 0 entries in the first three columns is to distinguish those values as survival rates rather than natural mortality rates.

Age	M 2002	M 2006	M 2006 Updated	Female Maturity 2002	Female Maturity 2006	Pups-per-Female 2002	Pups-per-Female 2006
0	0.6*	0.6*	0.75*	0	0	0	0
1	0.18	0.26	0.232	0	0	12	8.4
2	0.18	0.23	0.198	0	0	12	8.4
3	0.18	0.2	0.174	0	0	12	8.4
4	0.18	0.19	0.156	0	0	12	8.4
5	0.18	0.17	0.143	0	0	12	8.4
6	0.18	0.16	0.132	0	0	12	8.4
7	0.18	0.15	0.123	0	0	12	8.4
8	0.18	0.15	0.116	0	0	12	8.4
9	0.18	0.14	0.109	0	0	12	8.4
10	0.18	0.13	0.104	0.01	0	12	8.4
11	0.18	0.13	0.100	0.04	0	12	8.4
12	0.18	0.13	0.096	0.15	0	12	8.4
13	0.18	0.12	0.093	0.43	0.01	12	8.4
14	0.18	0.12	0.090	0.76	0.05	12	8.4
15	0.18	0.12	0.088	0.93	0.125	12	8.4
16	0.18	0.11	0.085	0.98	0.200	12	8.4
17	0.18	0.11	0.083	1	0.300	12	8.4
18	0.18	0.11	0.082	1	0.425	12	8.4
19	0.18	0.11	0.080	1	0.550	12	8.4
20	0.18	0.11	0.079	1	0.675	12	8.4
21	0.18	0.11	0.078	1	0.775	12	8.4
22	0.18	0.11	0.076	1	0.85	12	8.4
23	0.18	0.11	0.075	1	0.90	12	8.4
24	0.18	0.10	0.075	1	0.93	12	8.4
25	0.18	0.10	0.074	1	0.95	12	8.4
26	0.18	0.10	0.073	1	0.96	12	8.4
27	0.18	0.10	0.072	1	0.96	12	8.4
28	0.18	0.10	0.072	1	0.97	12	8.4
29	0.18	0.10	0.071	1	0.98	12	8.4
30	0.18	0.10	0.071	1	0.99	12	8.4
31	0.18	0.10	0.070	1	1	12	8.4

Table 4.1b. Additional parameter specifications where L_∞, K, and t_0 are von Bertalanffy parameters; a is the scalar coefficient of weight on length; and b is the power coefficient of weight on length. Weight units are kg.

Parameter	**Value**	**Prior**
L_∞	164 (cm PCL)	*constant*
K	0.089	*constant*
t_0	-3.8	*constant*
a	1.09E-05	*constant*
b	3.012	*constant*
Pup Survival	0.75 (mode)	~LN with CV=0.30
Virgin Recruitment (R_0)	5.00E+05	~N with CV=0.7, defined on [1.0E+3, 1.0E+10]

Table 4.2. Catches of sandbar shark by fleet. For the missing historic catches (1975-1980), the commercial+unreported was fixed to the 1981 value, the recreational+Mexican was fixed with a linear decrease from the 1981 value, and the menhaden catches were fixed at the series average. The 1983 recreational catch (boxed; red font) was downweighted in the base model.

Year	Commercial +Unreported	Recreational + Mexican	Menhaden
1975	***6640***	***19880***	***531***
1976	***6640***	***39760***	***531***
1977	***6640***	***59640***	***531***
1978	***6640***	***79520***	***531***
1979	***6640***	***99400***	***531***
1980	***6640***	***119280***	***531***
1981	6640	139160	696
1982	6640	45402	713
1983	7173	**428112**	705
1984	9797	69503	705
1985	9100	88083	635
1986	25826	134938	626
1987	73983	39625	653
1988	124680	76875	635
1989	160712	36950	670
1990	122440	69559	653
1991	96680	45857	505
1992	100592	46081	444
1993	71977	35870	452
1994	126454	23738	486
1995	84371	36188	445
1996	65515	47403	444
1997	41415	50264	452
1998	62776	42200	435
1999	53248	28060	479
2000	37330	17909	409
2001	50138	43145	383
2002	56342	15278	374
2003	45190	12202	365
2004	39068	10669	374

Table 4.3. Indices available for use in the current sandbar shark assessment. Sensitivity indices in green (last 3 columns).

YEAR	LPS	BLLOP	VA LL	NMFS LL SE	DE Bay	DE Bay age 0	DE Bay Juveniles	Bottom LL Logs	NMFS LL NE	Pelagic Log	PC gillnet	SC LL recent	MRFSS
1975			1.900										
1976													
1977			2.077										
1978			1.085										
1979													
1980			1.995										
1981			1.925										2.011
1982													2.195
1983													2.766
1984			0.647										2.408
1985													2.094
1986	3.557		0.665										2.119
1987	0.859												1.167
1988	2.326												0.789
1989	3.204		0.911										0.714
1990	1.008		0.746										0.634
1991	2.327		0.788										0.431
1992	1.382		1.331										0.874
1993	0.739		0.915										0.402
1994	0.378	0.799								0.140			0.243
1995	0.302	0.882	0.860	1.293						0.912		0.458	0.492
1996	0.369	1	0.770	0.831				0.789	0.321	2.116		0.964	0.612
1997	0.530	0.956	0.721	1.301				1.002		0.762	2.250	0.643	0.504
1998	0.124	1.292	0.826					0.919	2.045	1.050	1.220	0.750	0.917
1999	0.202	0.849	0.528	0.390				1.150		1.022	0.530	2.547	0.524
2000	0.213	0.744	0.865	0.971				1.171		1.266	0.690	0.666	0.525
2001	0.986	1.650	0.754	1.041	0.950	0.645	1.162	1.115	1.004	1.161	1.250	0.972	0.503
2002	0.236	0.865	0.626	1.072	0.386	0.518	0.325	0.887		0.518	0.610		0.490
2003	0.181	1.007	0.547	0.880	1.409	1.776	1.163	1.170		0.801	0.970		0.386
2004	0.076	0.955	0.519	1.221	1.070	0.877	1.164	0.798	0.629	1.251	0.470		0.201
Ages Vulnerable													
	all	all	all	all	"juveniles"	0	"juveniles"	all	all	all	all	"juveniles"	"2-7"
Selectivity function													
	Comm+Unrep	Comm+Unrep	Comm+Unrep	Comm+Unrep	"juveniles"		"juveniles"	Comm+Unrep	Comm+Unrep	Comm+Unrep	Comm+Unrep	"juveniles"	MRFSS

Table 4.4. Results for the base model runs using the updated biological parameters. Pups-virgin is the number of age 1 pups at virgin conditions. SSF is spawning stock fecundity, which is the sum of number mature at age times pup-production at age (rather than SSB, since biomass does not influence pup production in sharks). For sensitivity case BS-SPR_{50}, pup survival was fixed to force an SPR_{MSY} of 50%. AICc is the small sample Akaike Information Criterion, which converges to the AIC statistic as the number of data points gets large.

Parameter	BASE Est	CV	SB-1 Est	CV	SB-2 Est	CV	SB-SPR_{50} Est	CV
AICc	145.129		247.833		120.087		141.61	
Objective Function	-118.92		-67.57		-109.1		-116.42	
MSY (kg)	4.03E+05	---	4.94E+05	---	7.96E+04	---	8.10E+05	---
Pups-virgin	4.61E+05	0.07	5.06E+05	0.07	6.13E+05	0.08	3.52E+05	0.06
SSF_{2004}	4.28E+05	0.19	5.38E+05	0.14	8.59E+05	0.15	4.95E+05	0.18
$Nmature_{2004}$	9.66E+04	0.19	1.22E+05	0.14	1.95E+05	0.15	1.13E+05	0.18
B_{2004}	3.06E+07	0.16	3.87E+07	0.12	5.42E+07	0.13	3.28E+07	0.16
B_{2004}/B_{virgin}	0.35	0.1	0.4	0.08	0.47	0.07	0.35	0.11
SSF_{2004}/SSF_{virgin}	0.31	0.13	0.35	0.1	0.47	0.07	0.28	0.13
$Nmature_{2004}/Nmature_{virgin}$	0.28	0.13	0.33	0.1	0.43	0.08	0.26	0.13
SSF_{2004}/SSF_{MSY}	0.72	0.46	0.85	0.37	0.83	2.28	0.82	0.14
SPR_{MSY}	0.73	---	0.7	---	0.96	---	0.5	---
F_{2004}	0.06	0.15	0.04	0.16	0.04	0.15	0.05	0.14
F_{MSY}	0.015	---	0.017	---	0.002	---	0.031	---
F_{2004}/F_{MSY}	3.72	0.15	2.62	0.16	18.3	0.15	1.73	0.14
Pup-survival	0.62	0.27	0.67	0.24	0.37	0.28	0.82	(fixed)
alpha	1.88	---	2.02	---	1.1	---	4.09	---
steepness	0.32	---	0.34	---	0.22	---	0.51	---

Table 4.5. Estimates of total number, spawning stock fecundity, and fishing mortality by year for base model for sandbar shark.

Year	N(year)	SSF(year)	F(year)
1975	3,678,734	1,385,200	0.027
1976	3,653,994	1,381,500	0.059
1977	3,610,142	1,377,800	0.092
1978	3,551,582	1,374,100	0.125
1979	3,482,026	1,370,500	0.157
1980	3,404,378	1,366,800	0.190
1981	3,321,045	1,363,100	0.223
1982	3,233,133	1,359,000	0.077
1983	3,233,953	1,354,800	0.576
1984	2,987,888	1,349,400	0.141
1985	2,992,174	1,342,800	0.160
1986	2,974,921	1,331,400	0.243
1987	2,897,082	1,300,000	0.092
1988	2,863,328	1,236,400	0.170
1989	2,736,323	1,144,600	0.121
1990	2,606,223	1,050,400	0.168
1991	2,475,767	975,470	0.121
1992	2,389,954	907,740	0.126
1993	2,293,942	845,410	0.098
1994	2,230,396	779,890	0.103
1995	2,117,106	709,430	0.112
1996	2,026,801	657,180	0.133
1997	1,940,705	616,840	0.134
1998	1,874,080	580,750	0.133
1999	1,792,962	543,750	0.099
2000	1,732,341	515,230	0.066
2001	1,694,431	491,310	0.142
2002	1,618,434	466,150	0.077
2003	1,563,336	444,230	0.063
2004	1,520,555	428,340	0.056

Table 4.6. Results of baseline and retrospective sensitivity model runs. Retrospective runs (R1-R6) were done with the continuity age structured production model from the 2002 assessment. The reference year for B/B_{MSY} and F/F_{MSY} depend on the terminal year for data in the model. In model run R1, the terminal year is 2004; model runs R2-R6 used 2001 as the terminal year.

Model Run	SSF/SSF_{MSY}	F/F_{MSY}
ASPM-SB-1	0.85	2.62
ASPM-SB-2	0.83	18.3
ASPM-SB-SPR_{50}	0.82	1.73
R1	0.15	235
R2	0.15	82.3
R3	0.18	124
R4	--	--
R5	--	--
R6	0.48	3.45

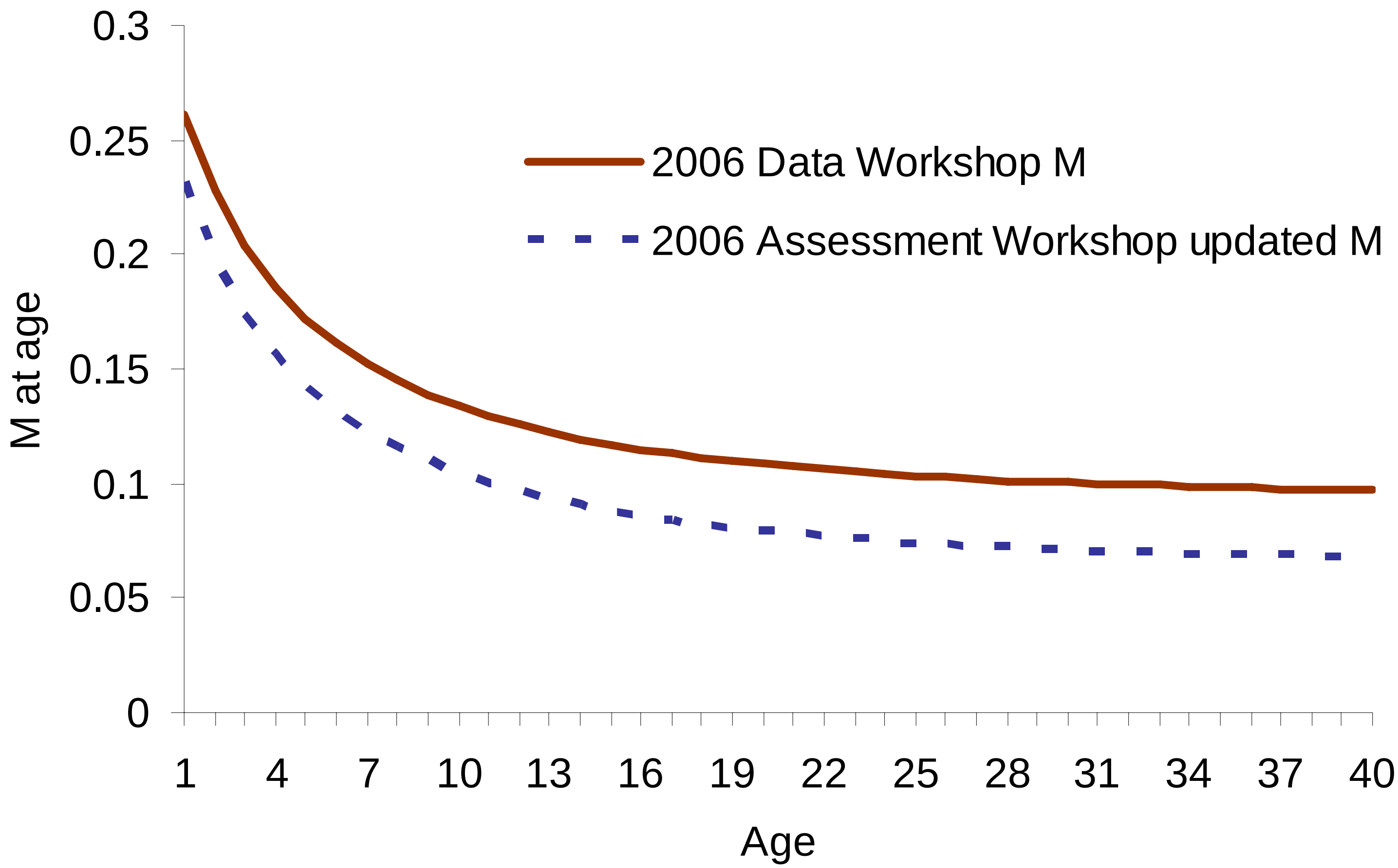


Figure 4.1 Comparison of natural mortality recommended by the data workshop (DW, solid line) and that agreed to in plenary at the assessment workshop (AW, dashed line).

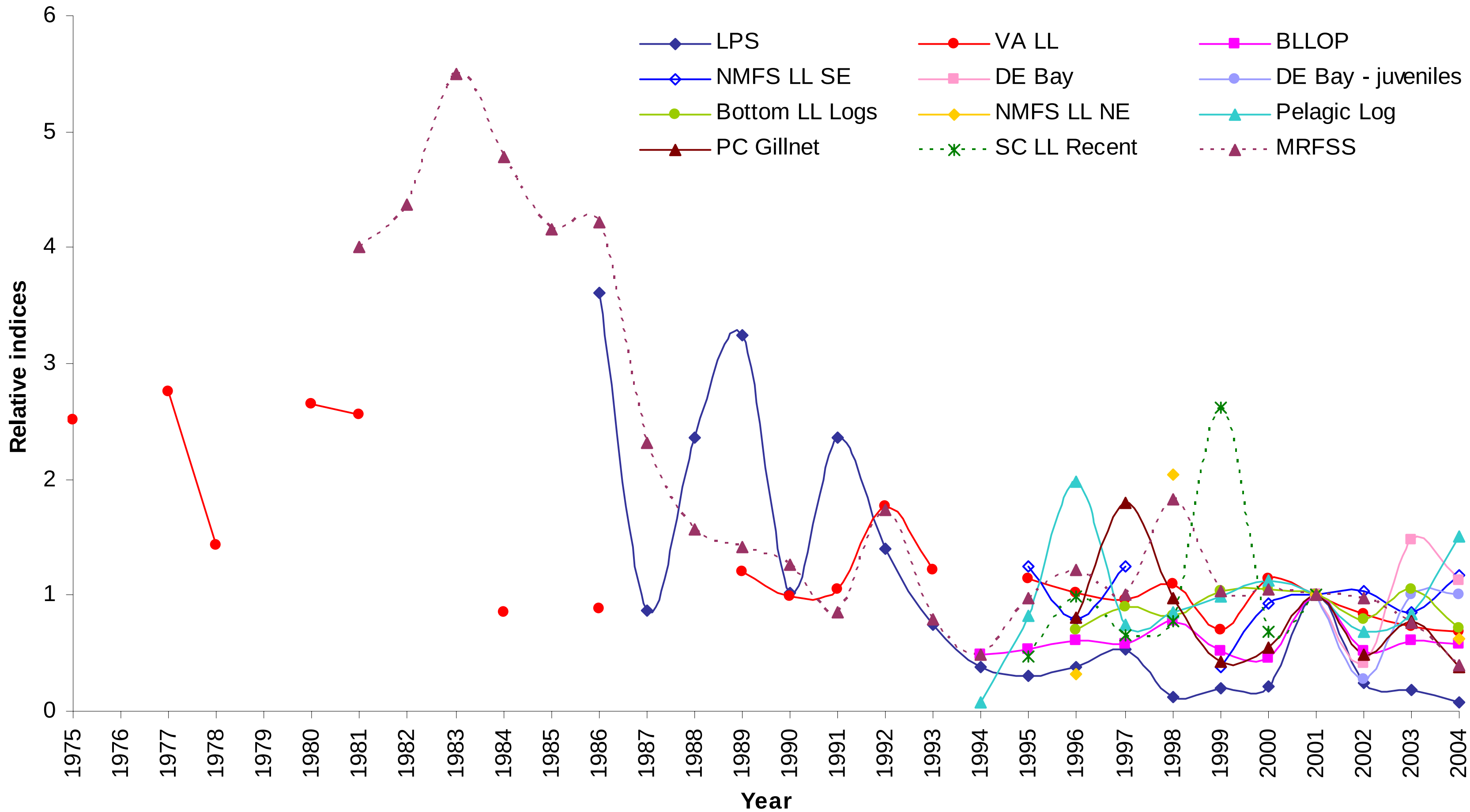


Figure 4.2 Indices available for the current sandbar shark assessment. Indices are scaled by the index-specific mean for overlapping years.

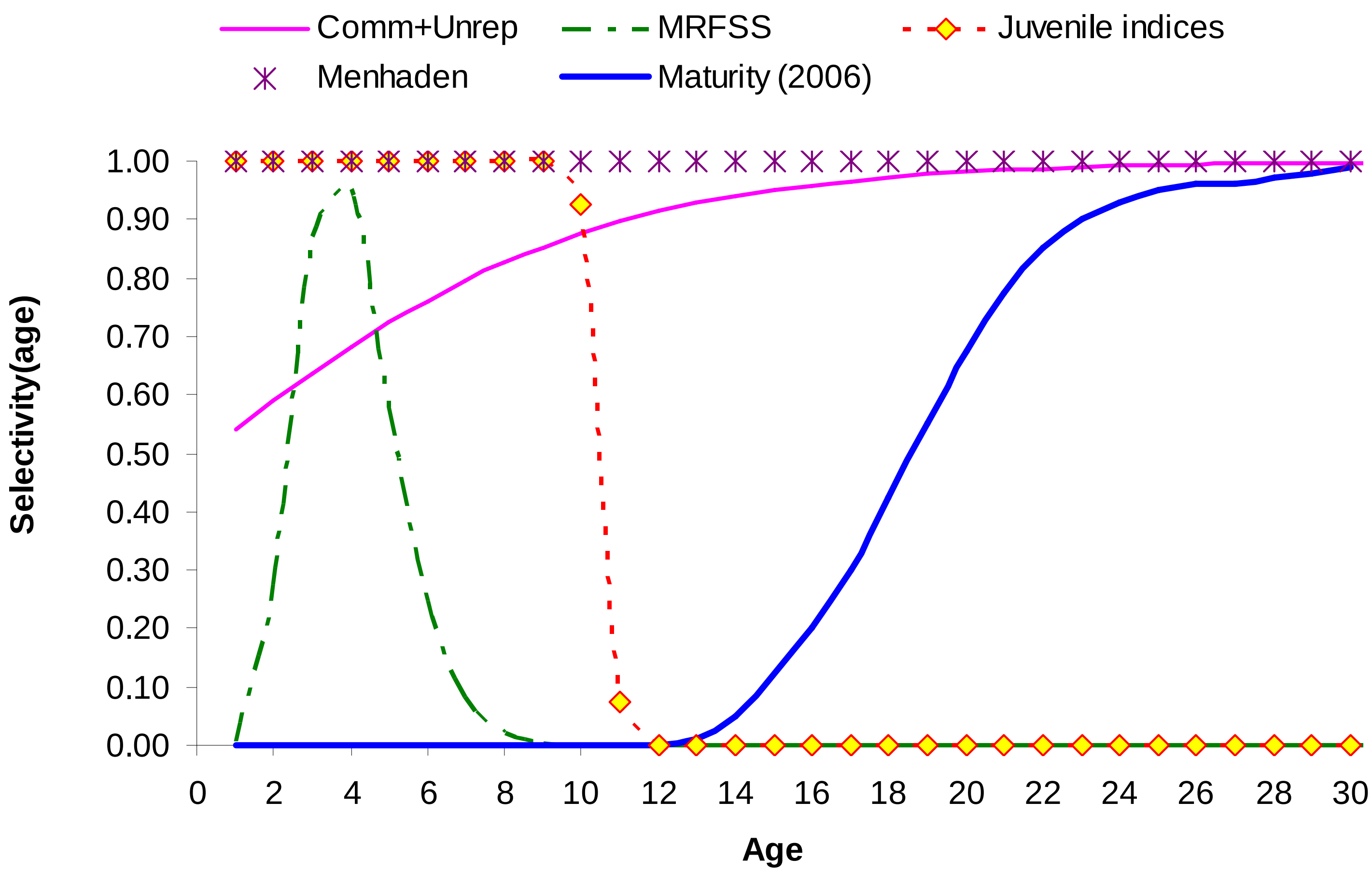
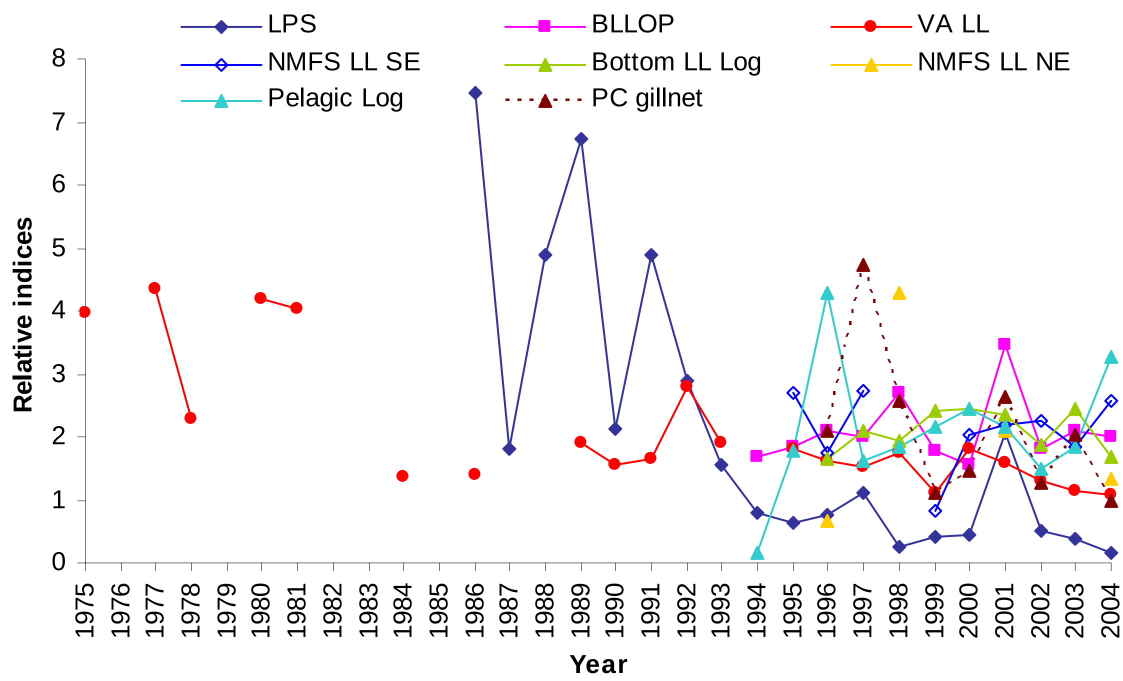


Figure 4.3 Selectivities used in sandbar assessment, with the maturity ogive (solid blue line) as decided at the data workshop. Labels are with the last row in Table 4.3 (all indices available for sandbar).



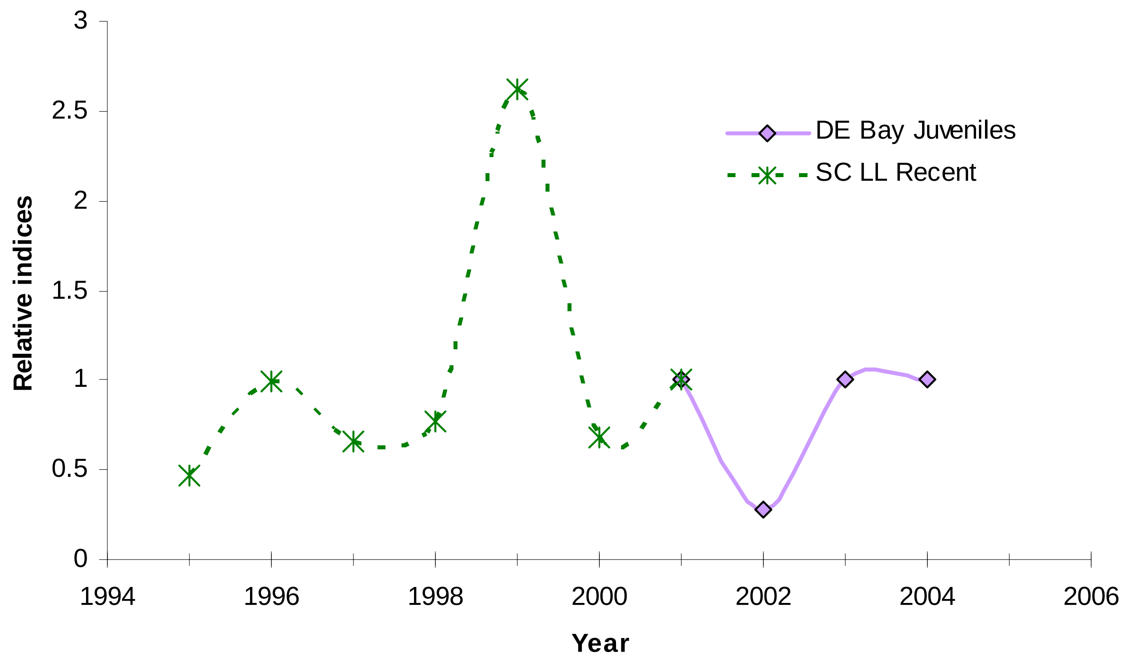


Figure 4.4. Indices with the same selectivity. In the top plot, all indices have the same selectivity as the commercial fishery; the bottom panel includes all indices that select for juveniles. Sensitivity indices, which were not used in the base case are: PC Gillnet and SC LL recent.

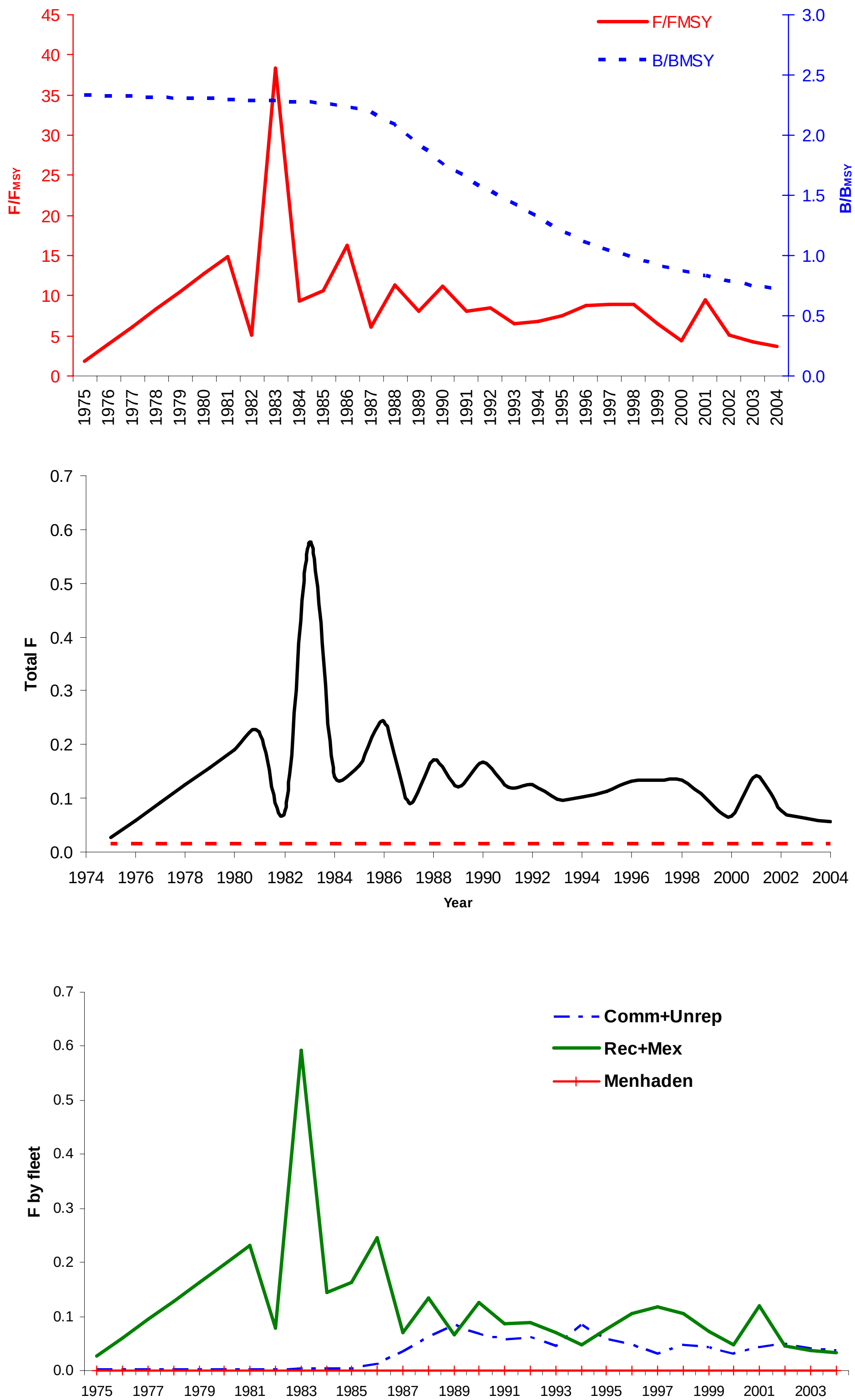


Figure 4.5. Estimated stock status (top), total fishing mortality (middle), and fleet-specific F (bottom). The dashed line in the middle panel indicates F_{MSY} (= 0.015).

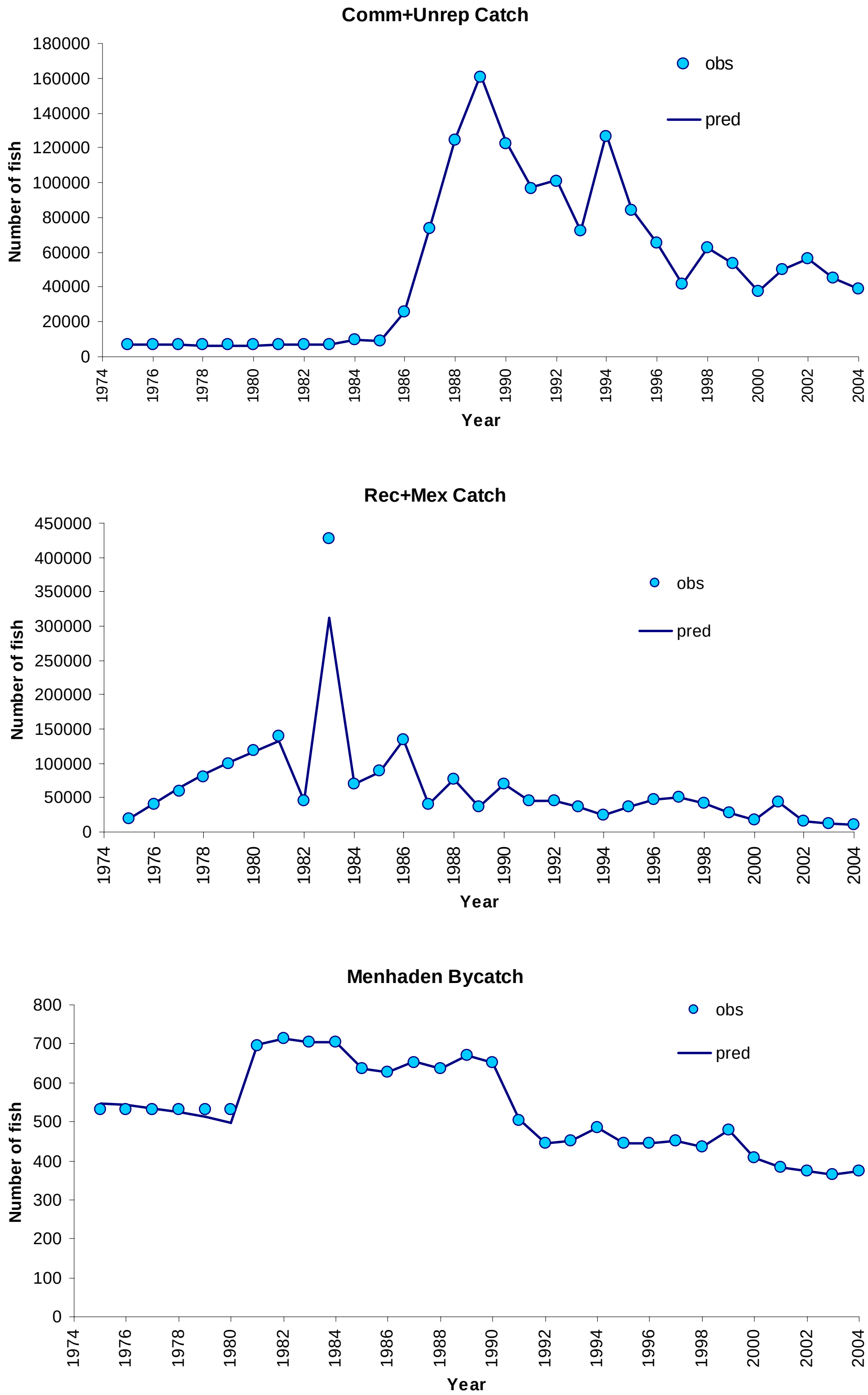


Figure 4.6. Model predicted fit to catch data. Circles represent observed data, solid line is predicted.

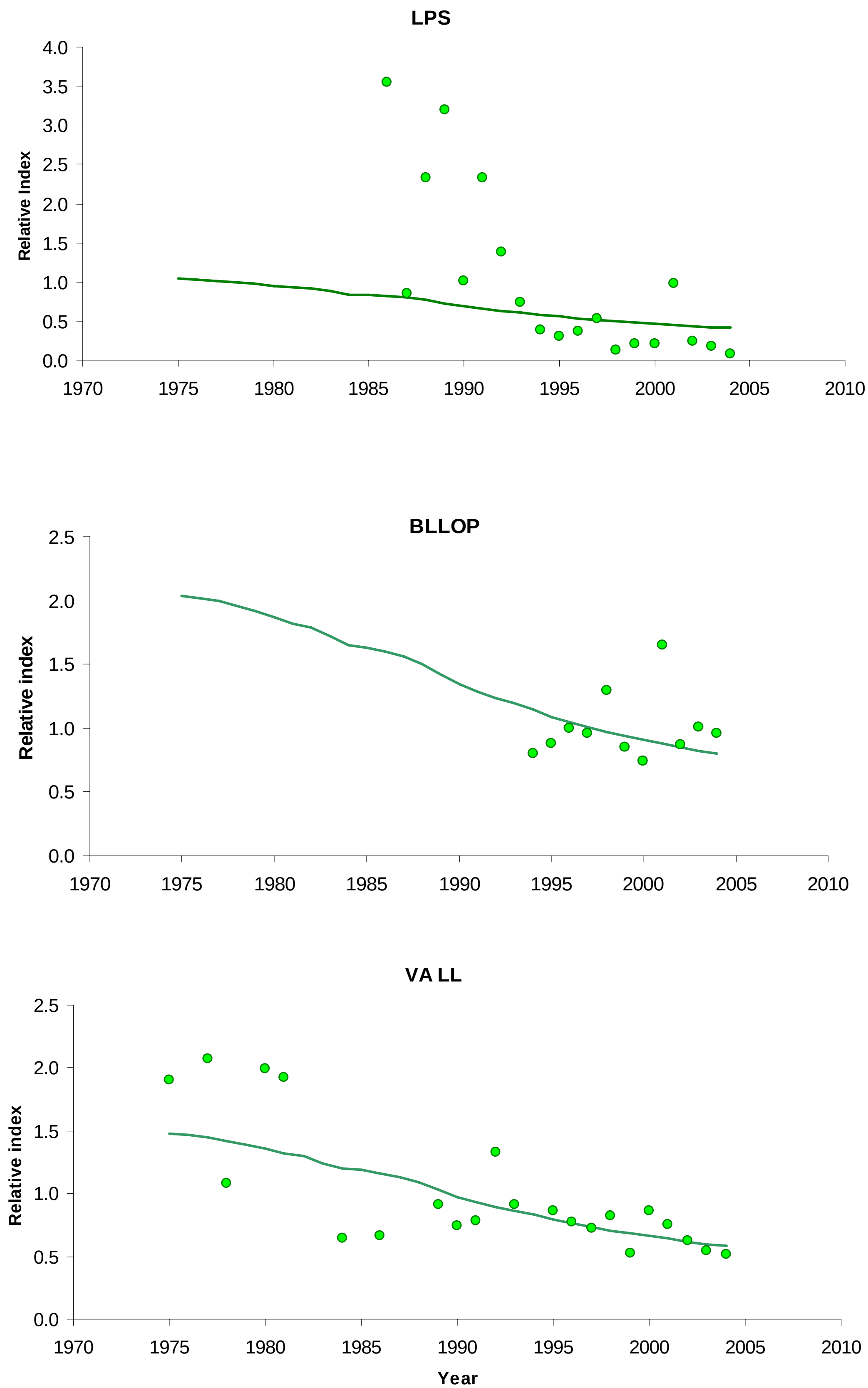


Figure 4.7. Model predicted fit to indices. Circles represent observed data, solid line is predicted.

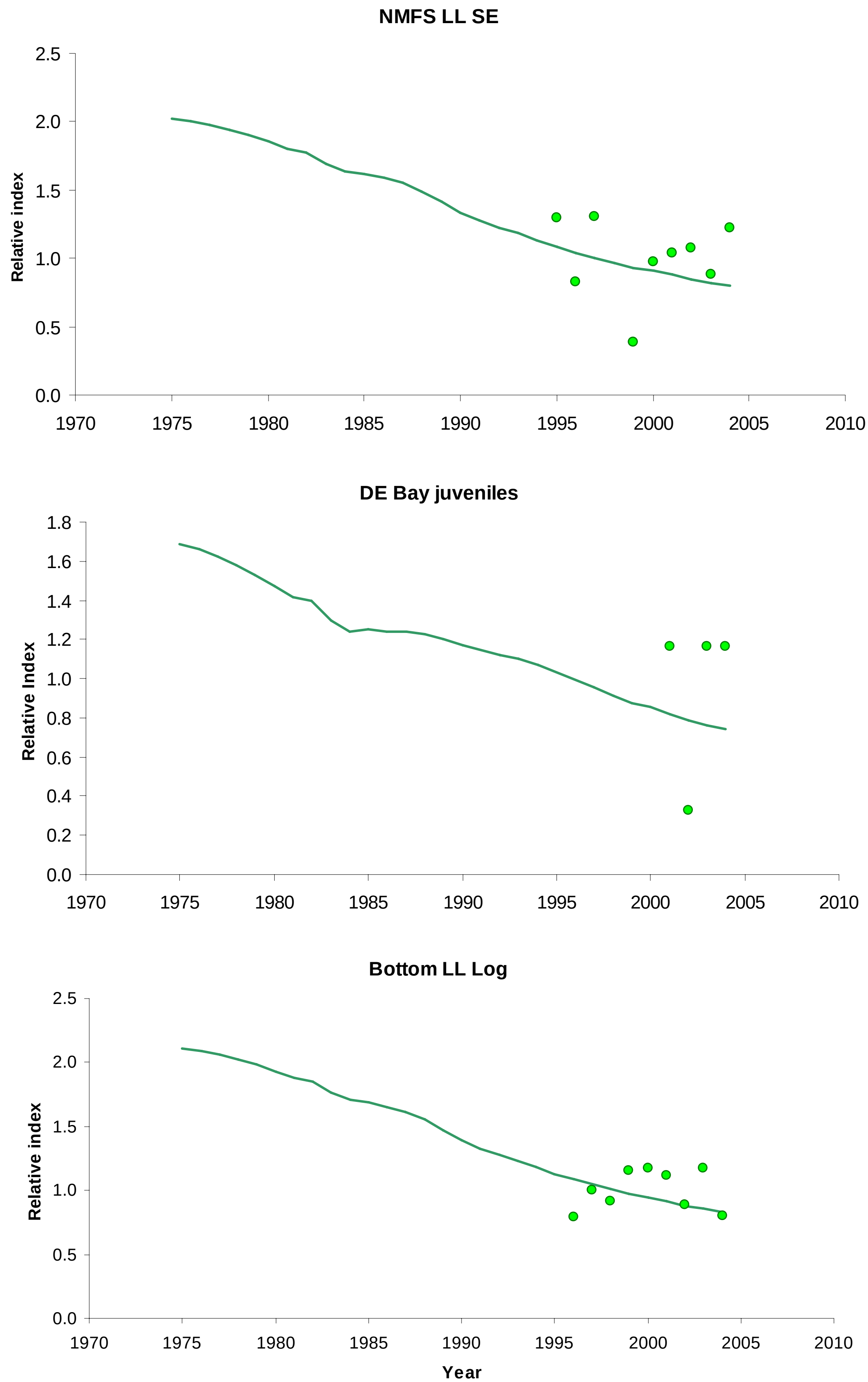
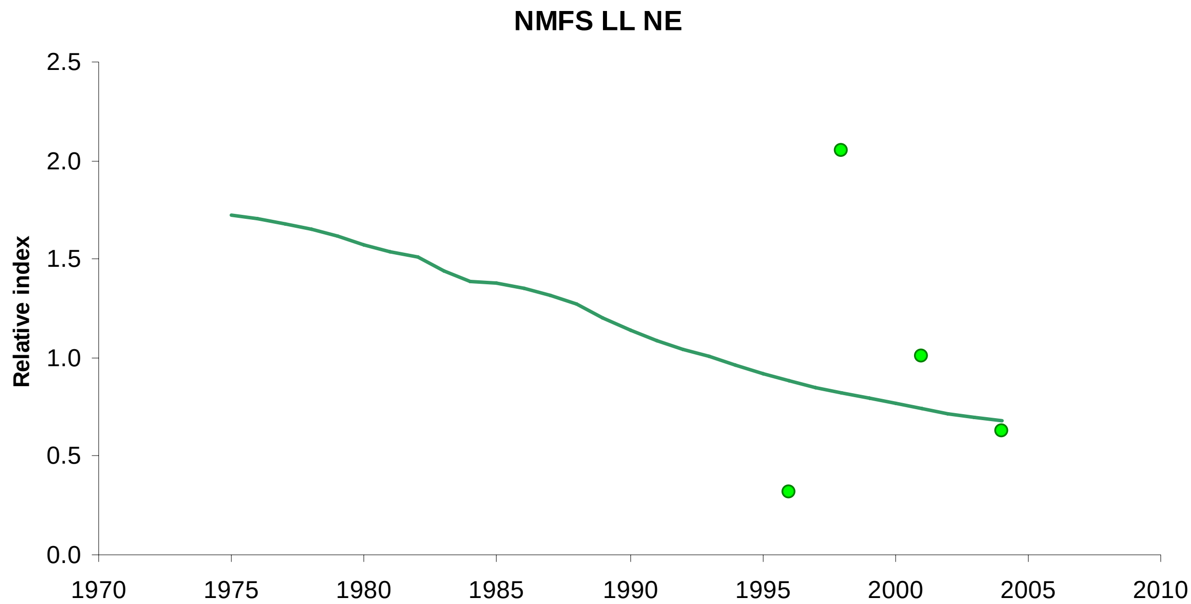


Figure 4.7. (continued)



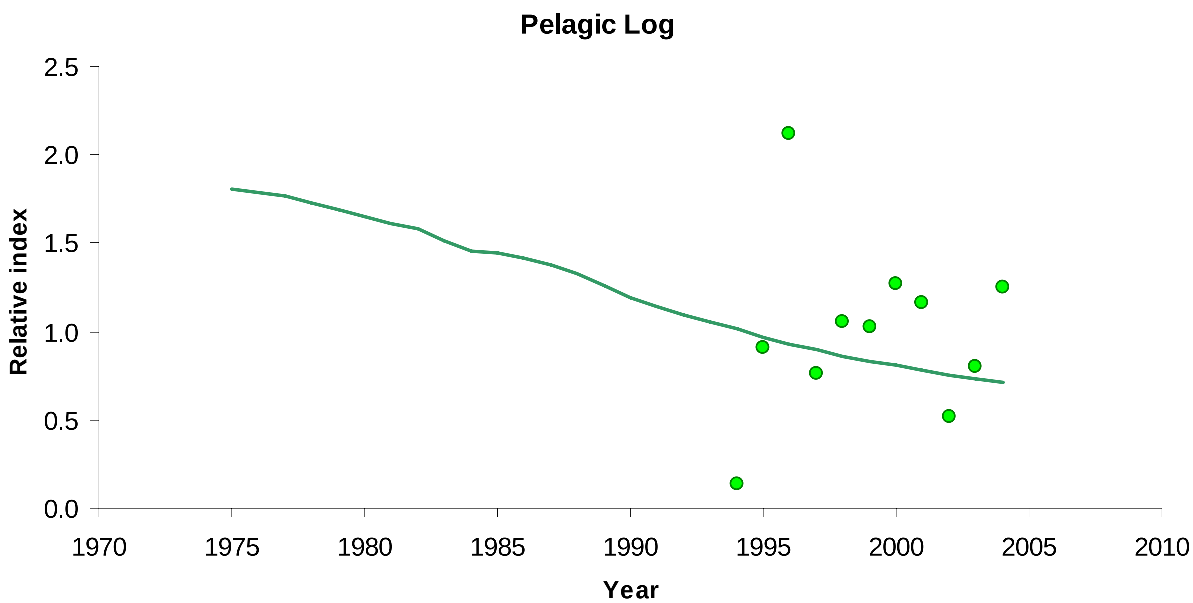


Figure 4.7. (continued)

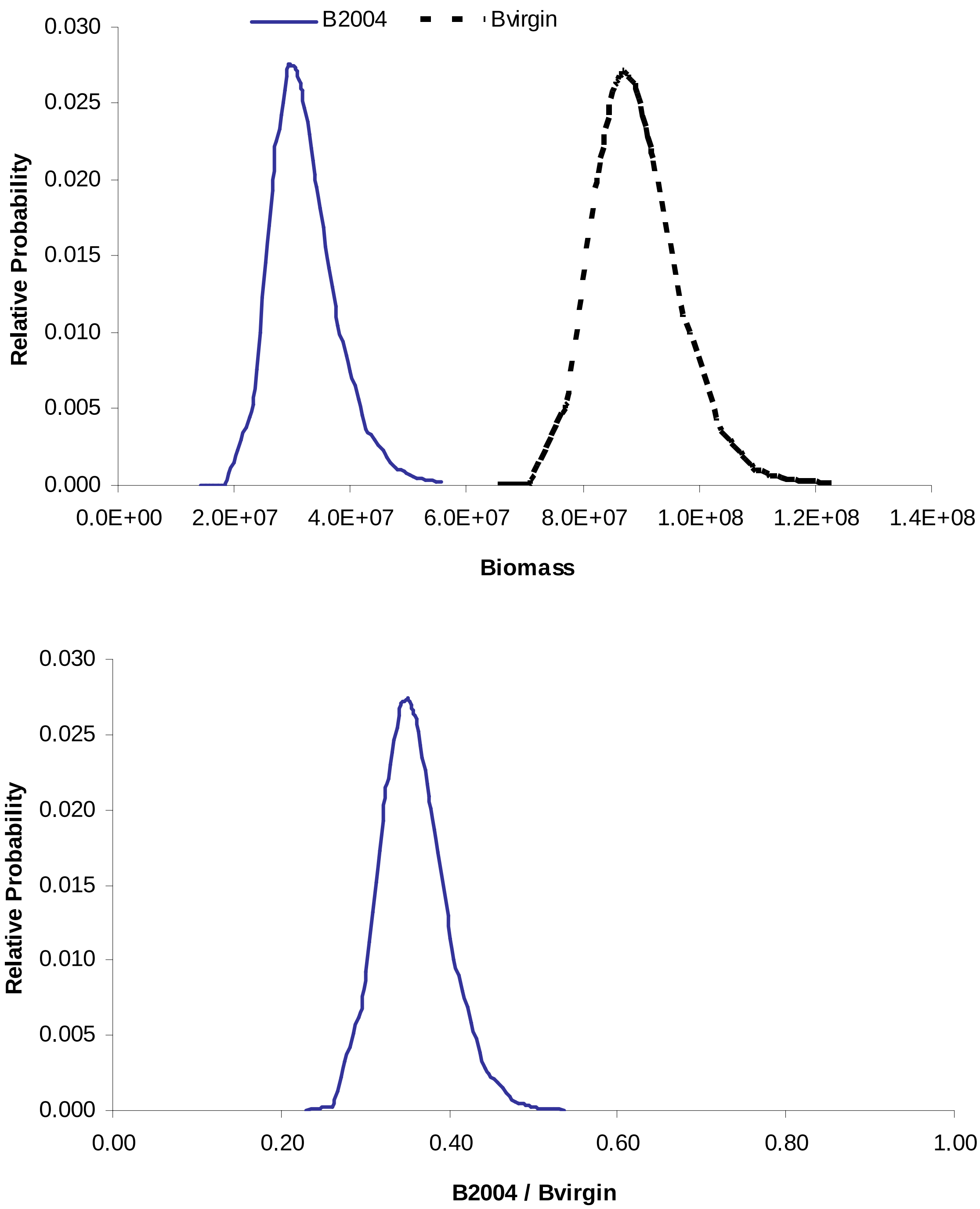
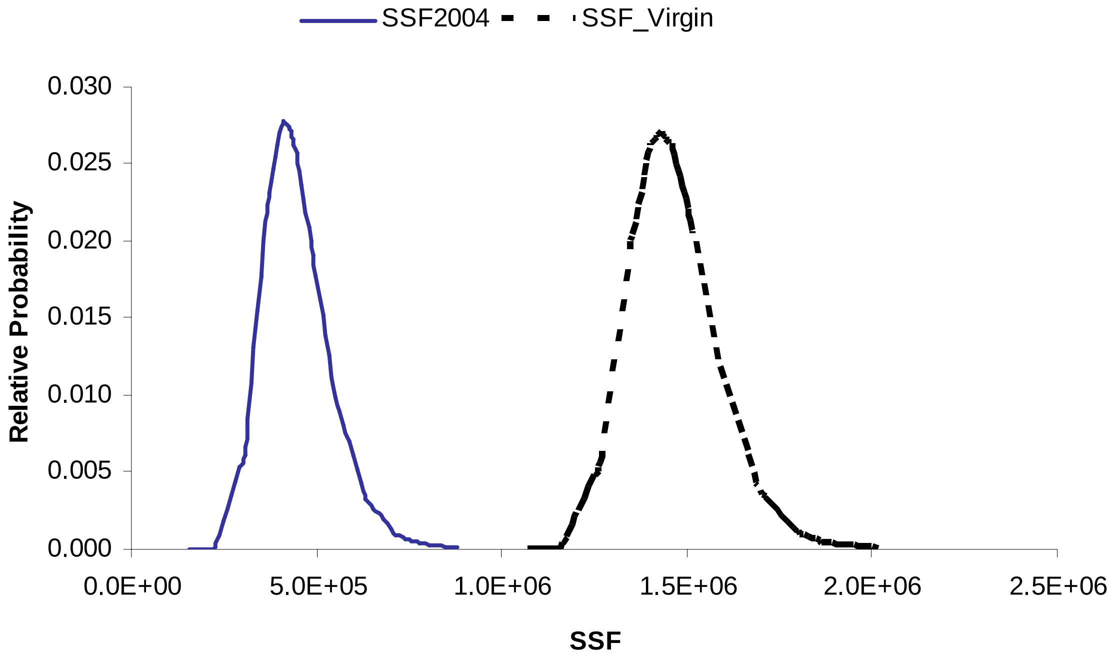


Figure 4.8. Profile likelihoods for biomass and SSF in 2004, as well as depletion estimates of these parameters.



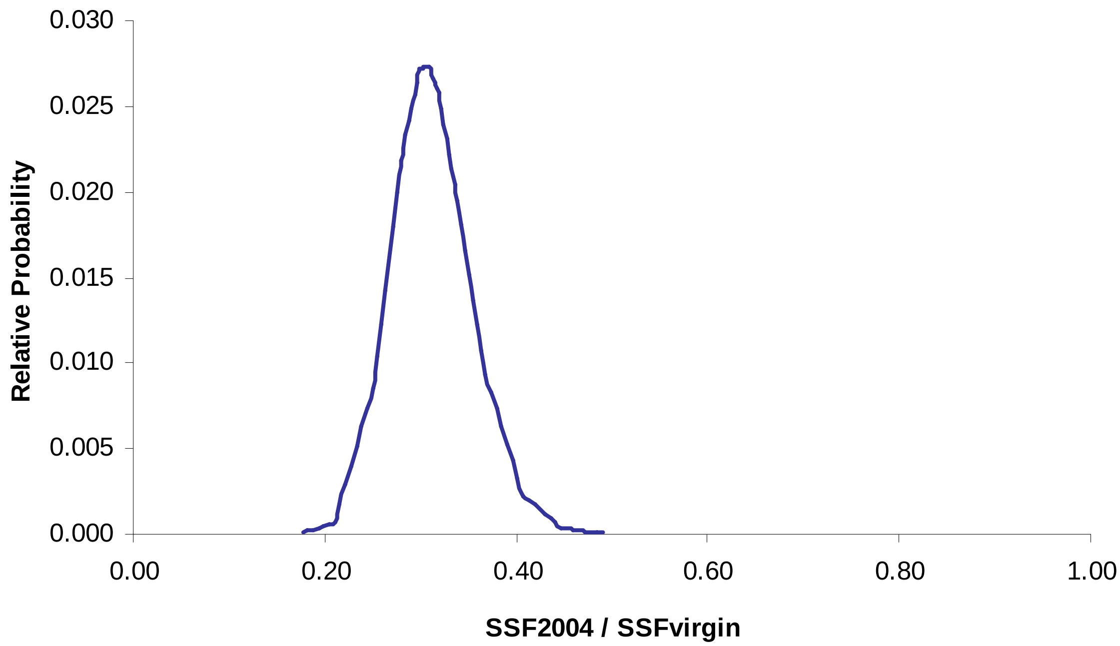
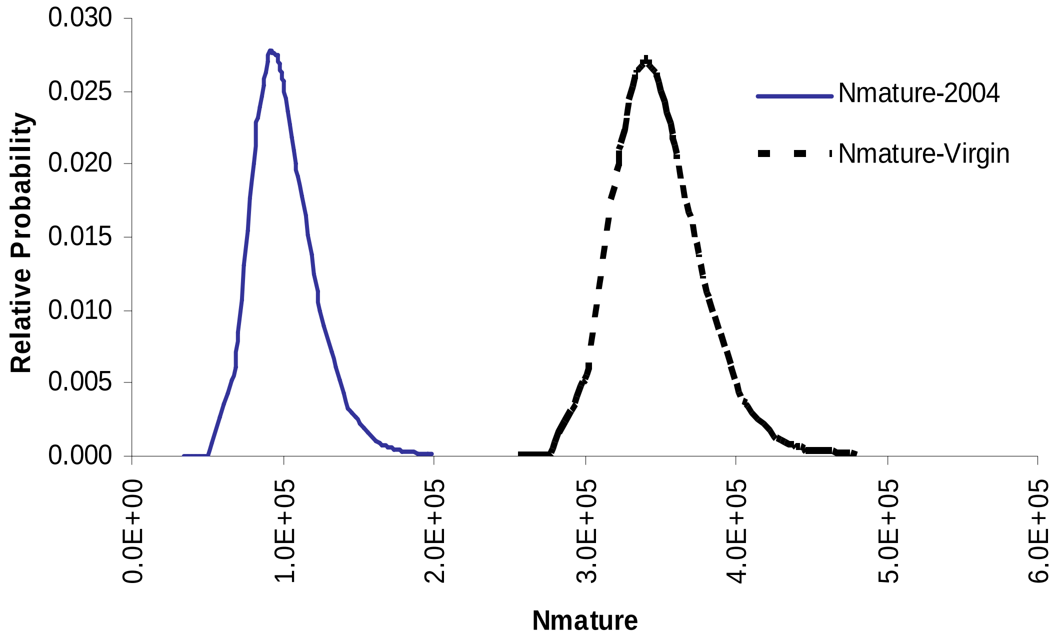


Figure 4.8 (continued)



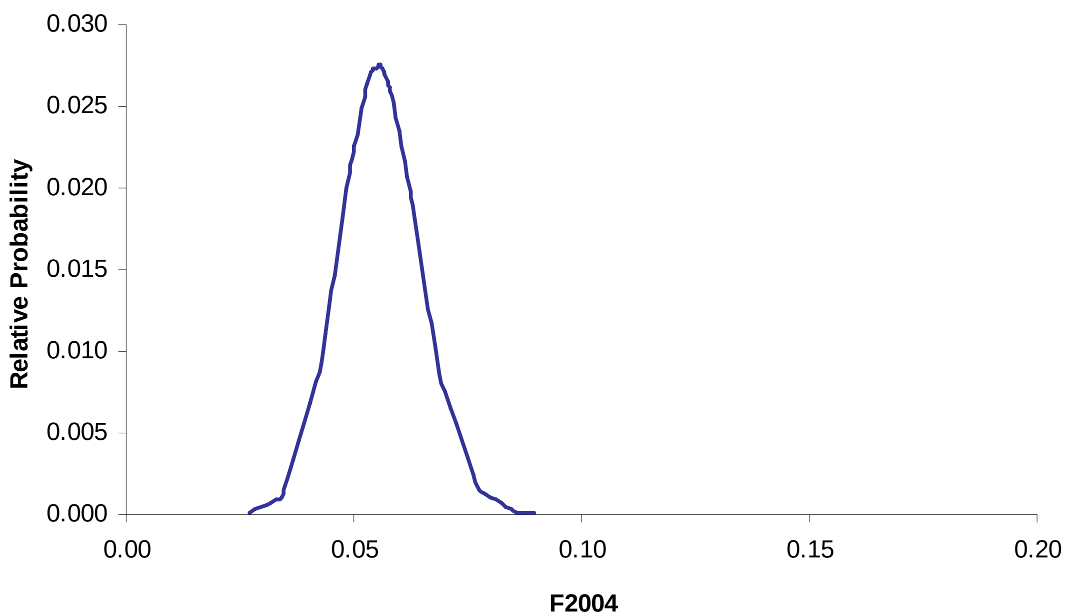


Figure 4.9. Profile likelihoods for number of mature individuals, fishing mortality in 2004; for pup survival and virgin recruitment, the posterior is plotted along with the prior.

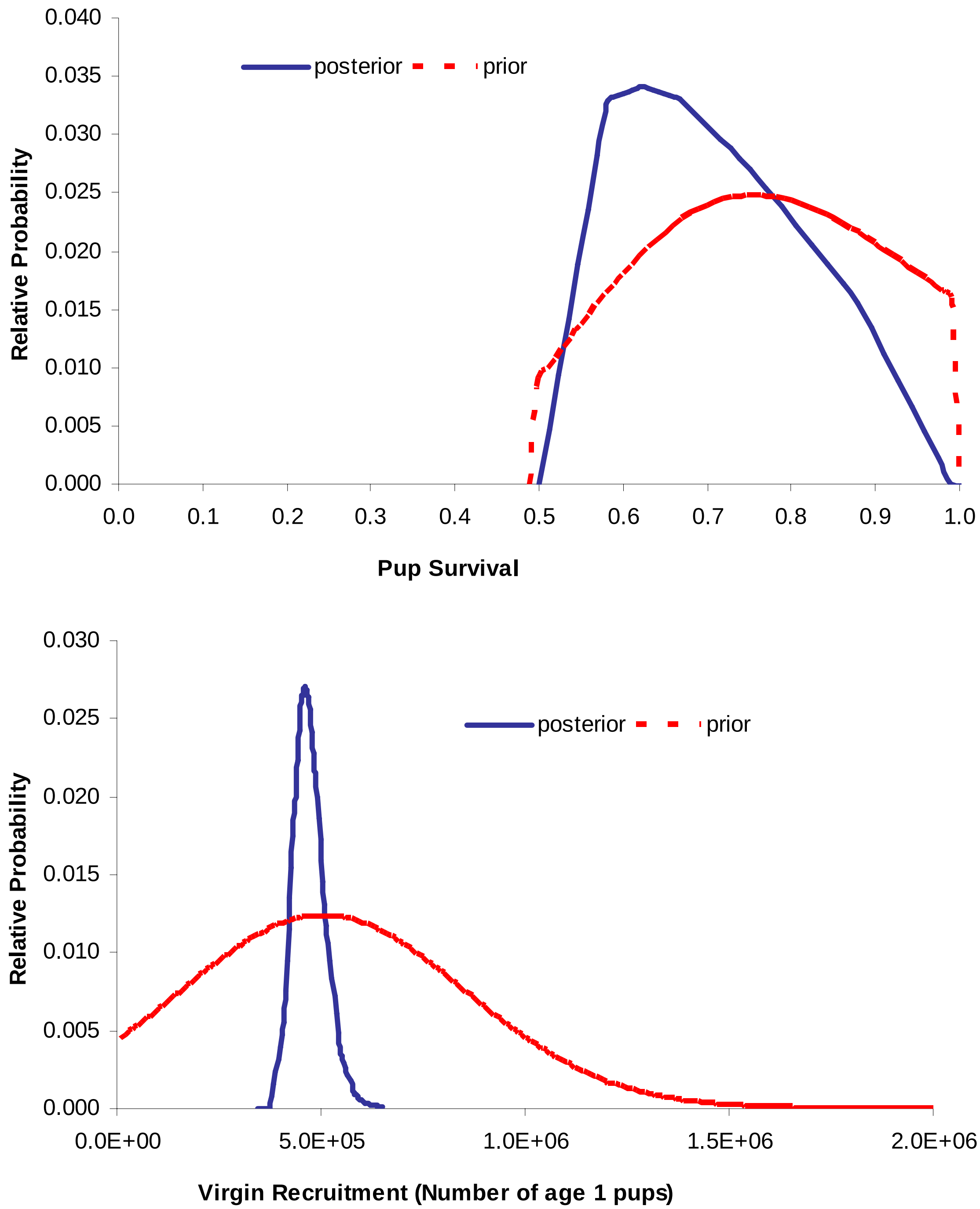


Figure 4.9 (continued)

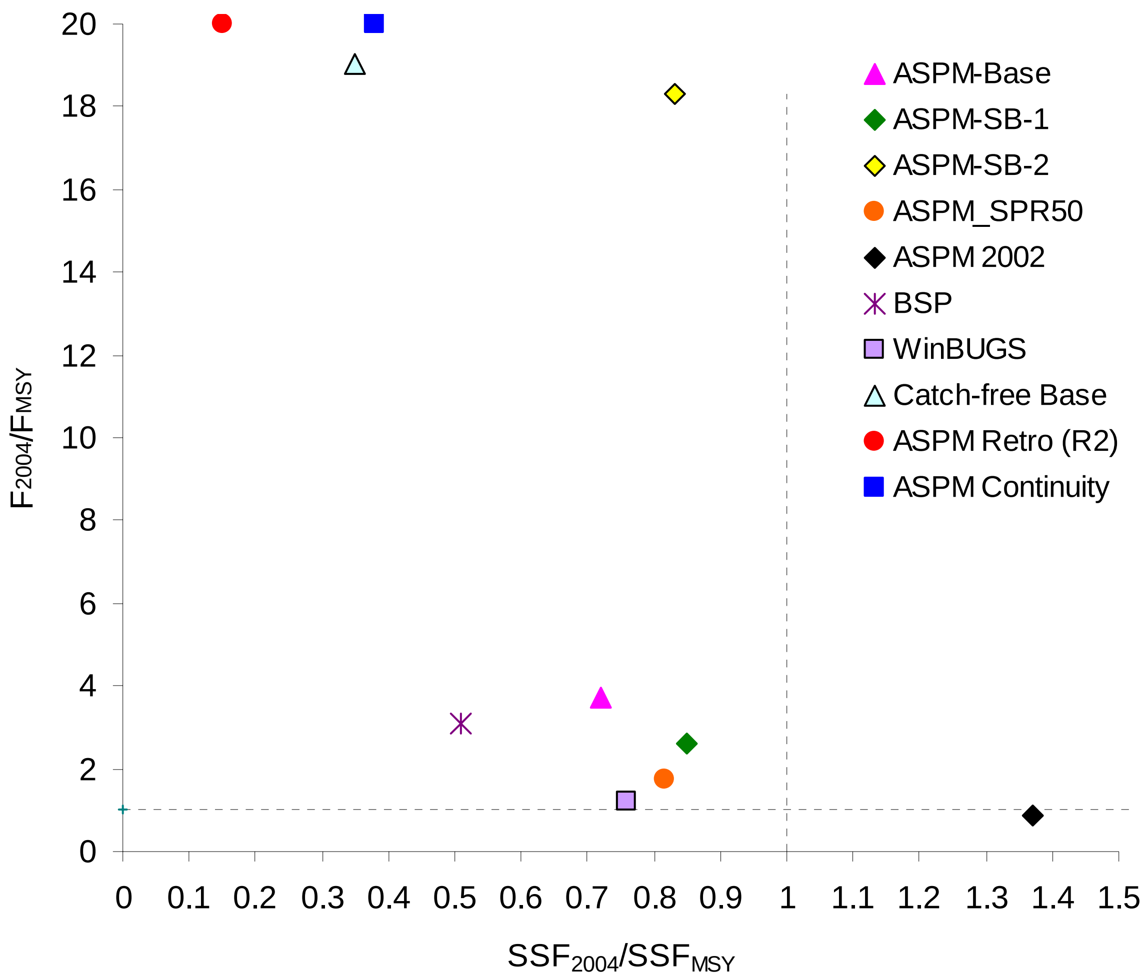
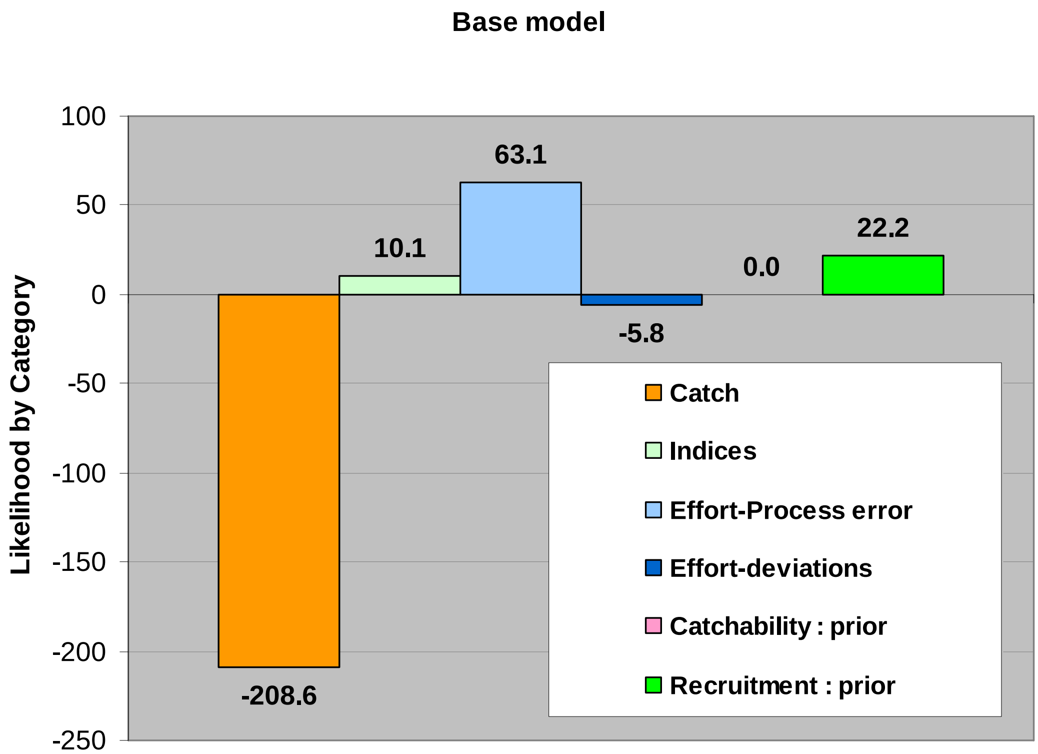


Figure 4.10. Phase-plot of sandbar stock status. Selected sensitivity analyses are also included for comparison. The models include: ASPM-Base, ASPM-SB-1 (base configuration was retained and observations within each index were weighted by the inverse CV of each point), ASPM-SB-2 (the base configuration was retained, and all available indices were used), ASPM_SPR_{50} (base case weighting and indices were used, but the model was forced to have SPR_{MSY}=0.5), ASPM 2002 (results of 2002 sandbar assessment with equal weighting), BSP (sandbar results using the Bayesian surplus production model), WinBUGS (sandbar results using the WinBUGS SPM), Catch-free Base (results from the catch free approach baseline analysis), ASPM Retro (R2) (using updated data through 2001, the updated Pelagic Log index, equal weighting, and using the imputed catches from 1975-1980), and ASPM Continuity. See text for further details. Several control rules are illustrated: the dashed horizontal line indicates the MFMT (Maximum Fishing Mortality Threshold) and the dashed vertical line denotes the target biomass (biomass or number at MSY). Note for the BSP and WinBUGS x values denote N_{2004}/N_{MSY} rather than SSF_{2004}/SSF_{MSY}. SSF is spawning stock fecundity, which is the sum of number mature at age times pup-production at age (rather than SSB, since biomass does not influence pup production in sharks). Also note that the value of F_{2004}/F_{MSY} for ASPM Retro (R2) was 82.3 and for ASPM Continuity was 65.6 but was decreased to 20 here for viewing purposes only.



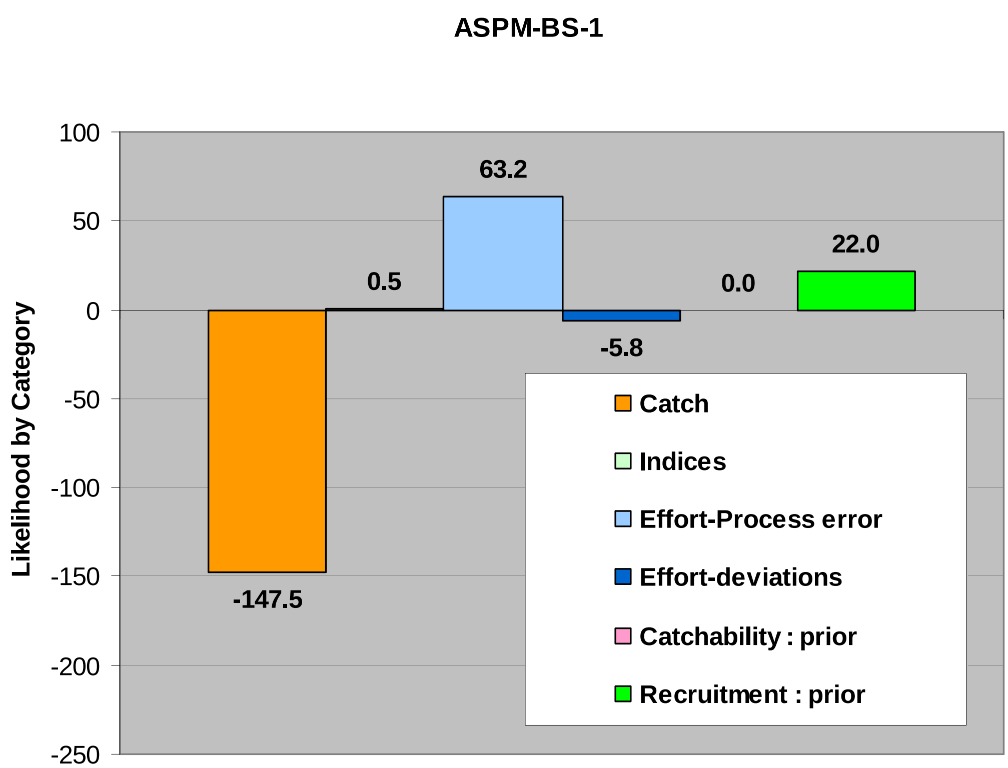
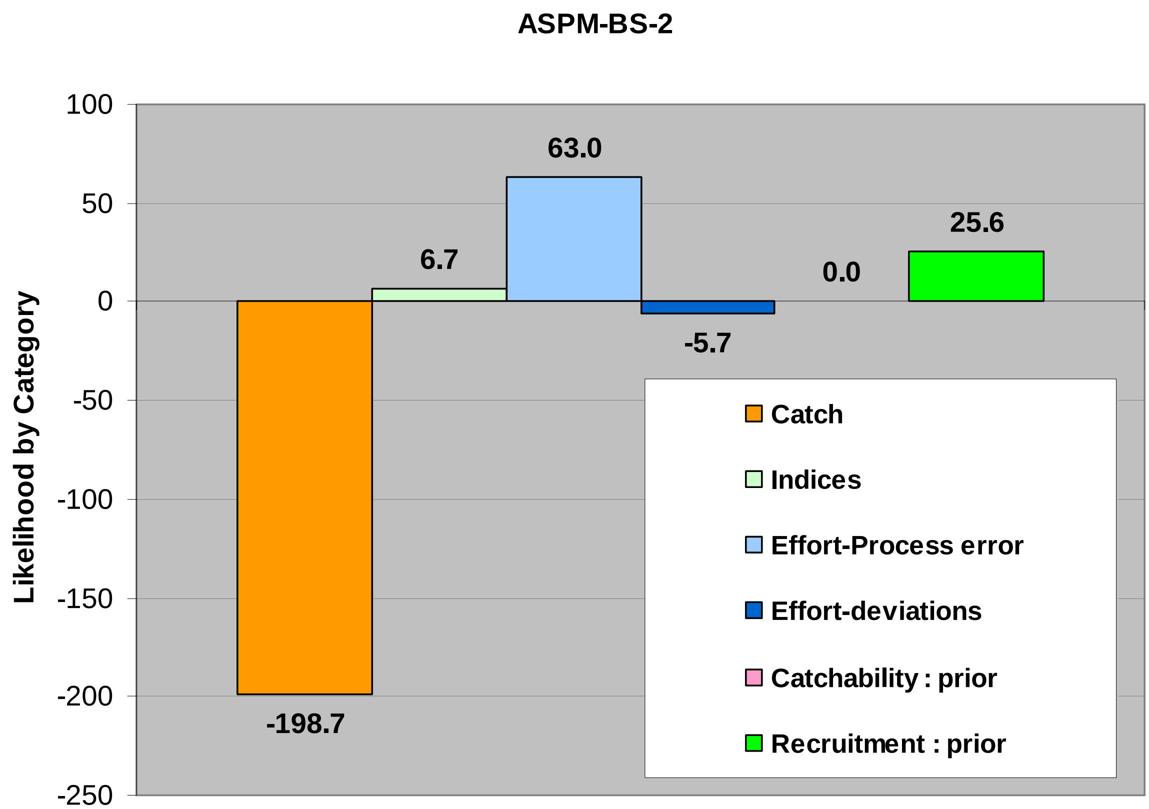


Figure 4.11. Contribution to relative likelihood by category. The recruitment component includes both priors on virgin number of pups and pup survival. Plots refer to the base model, ASPM-BS-1 (inverse CV weighting), ASPM-BS-2 (all indices) and ASPM-BS-3 (SPR50%).



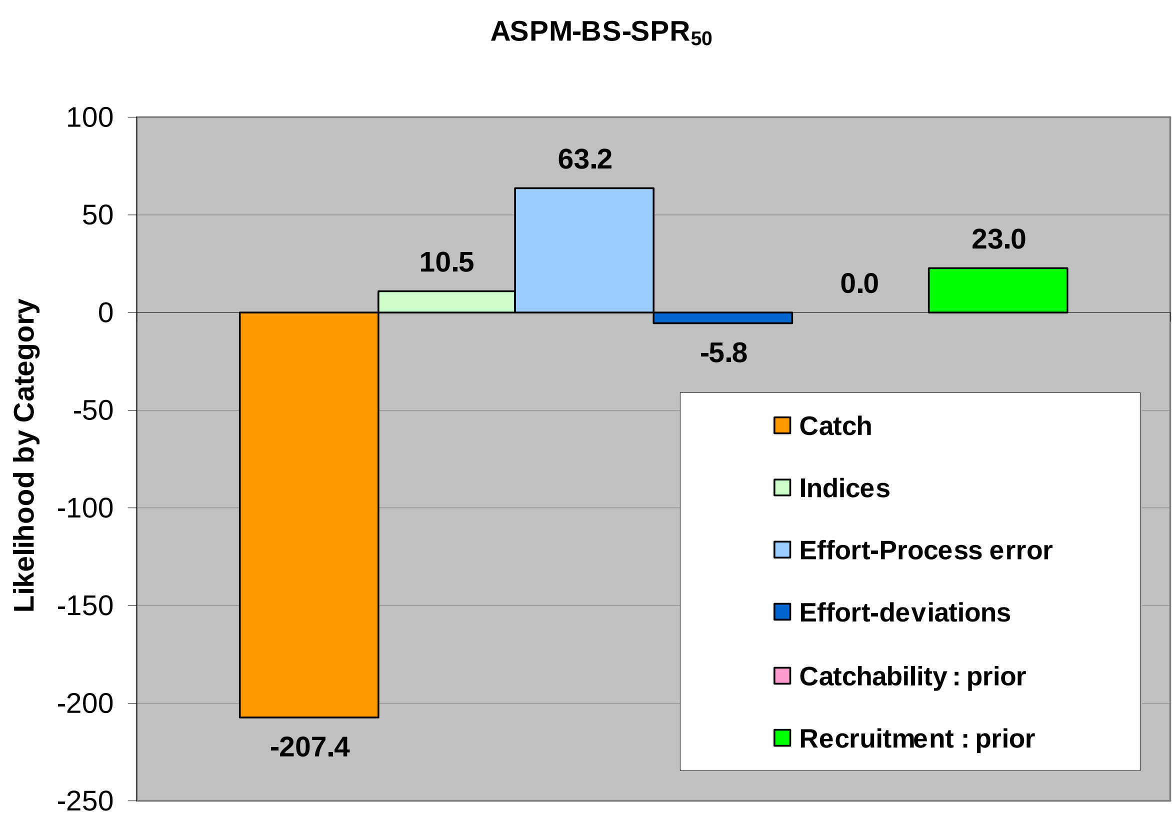
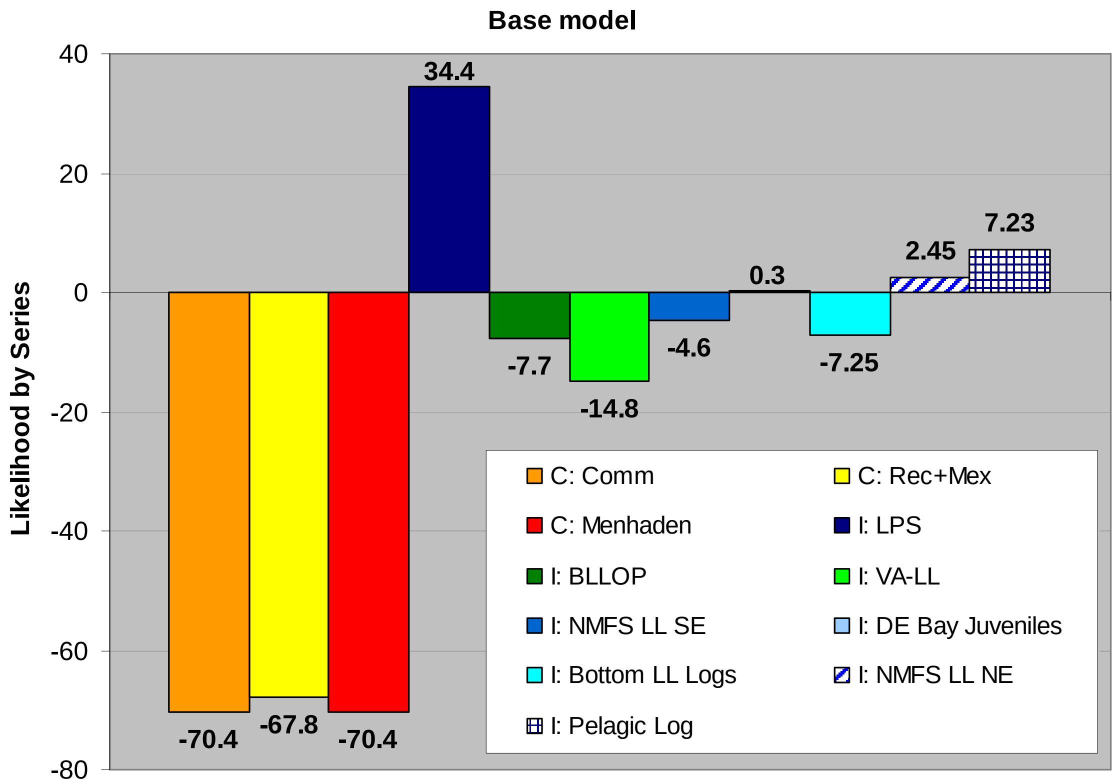


Figure 4.11. (continued)



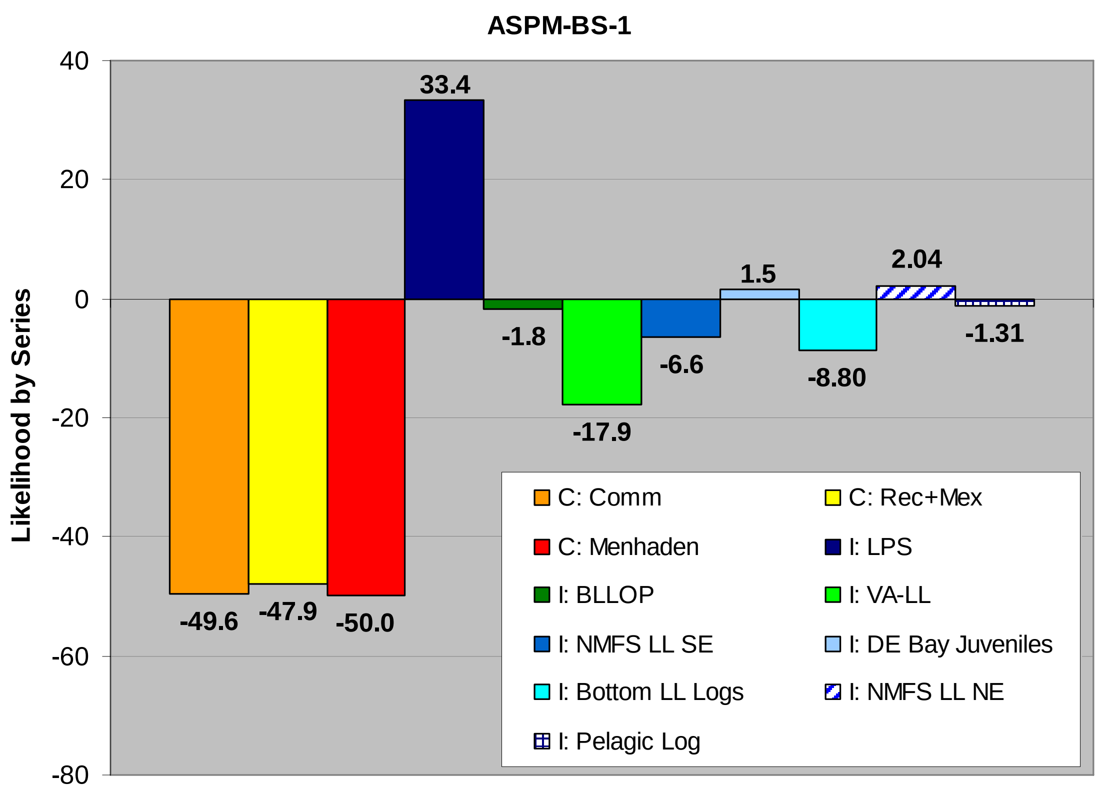
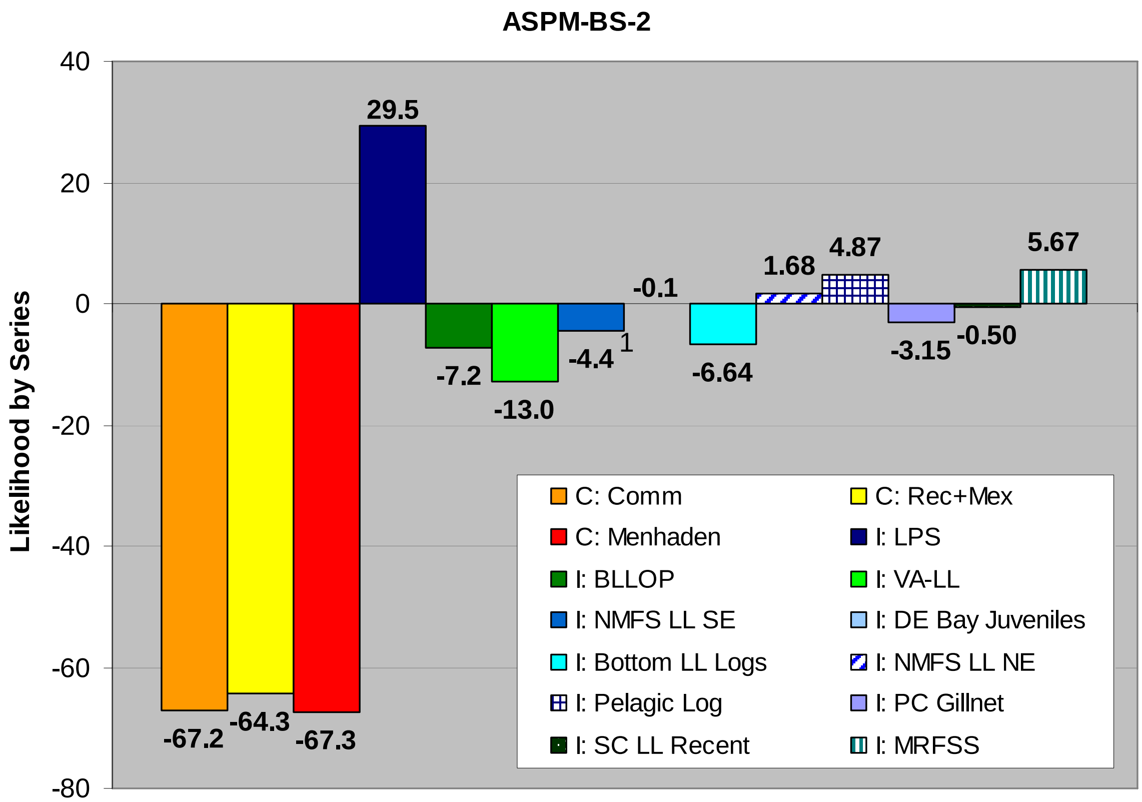


Figure 4.12. Contribution to relative likelihood by catch series and index series for the base model, ASPM-BS-1 (inverse CV weighting), ASPM-BS-2 (all indices) and ASPM-BS-3 (SPR50%). I indicates an index, C indicates a catch.



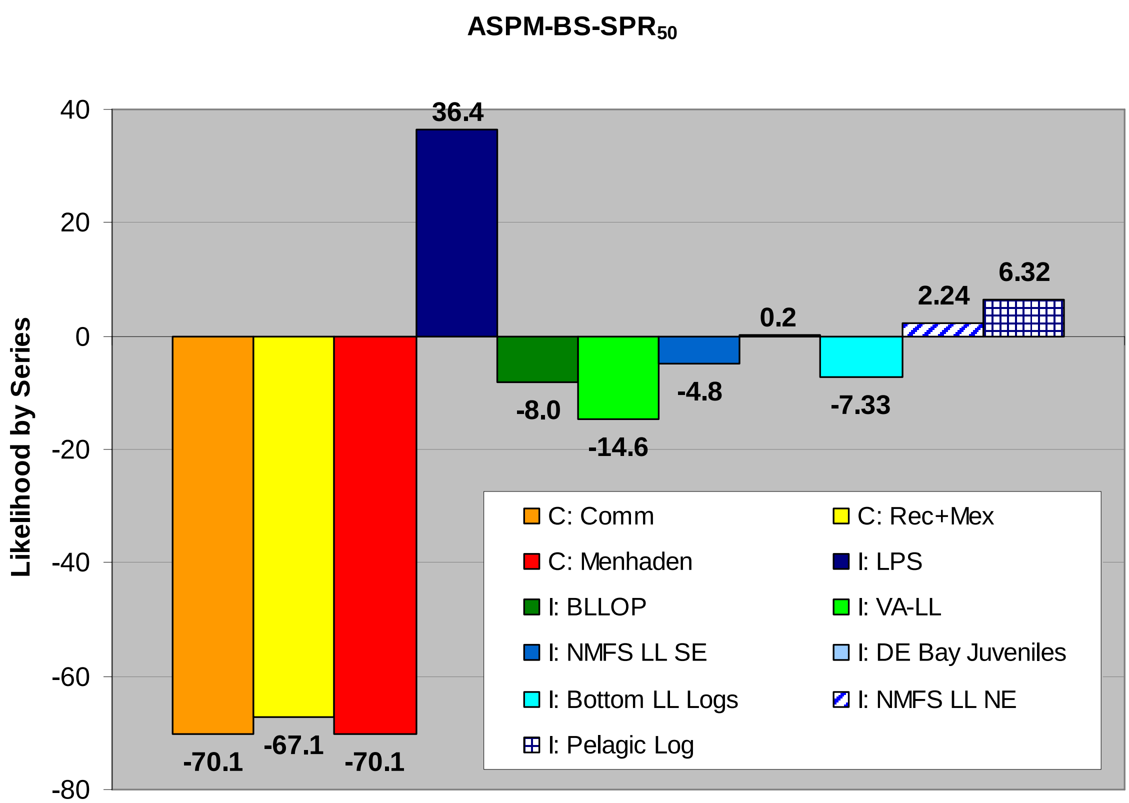


Figure 4.12. (continued)

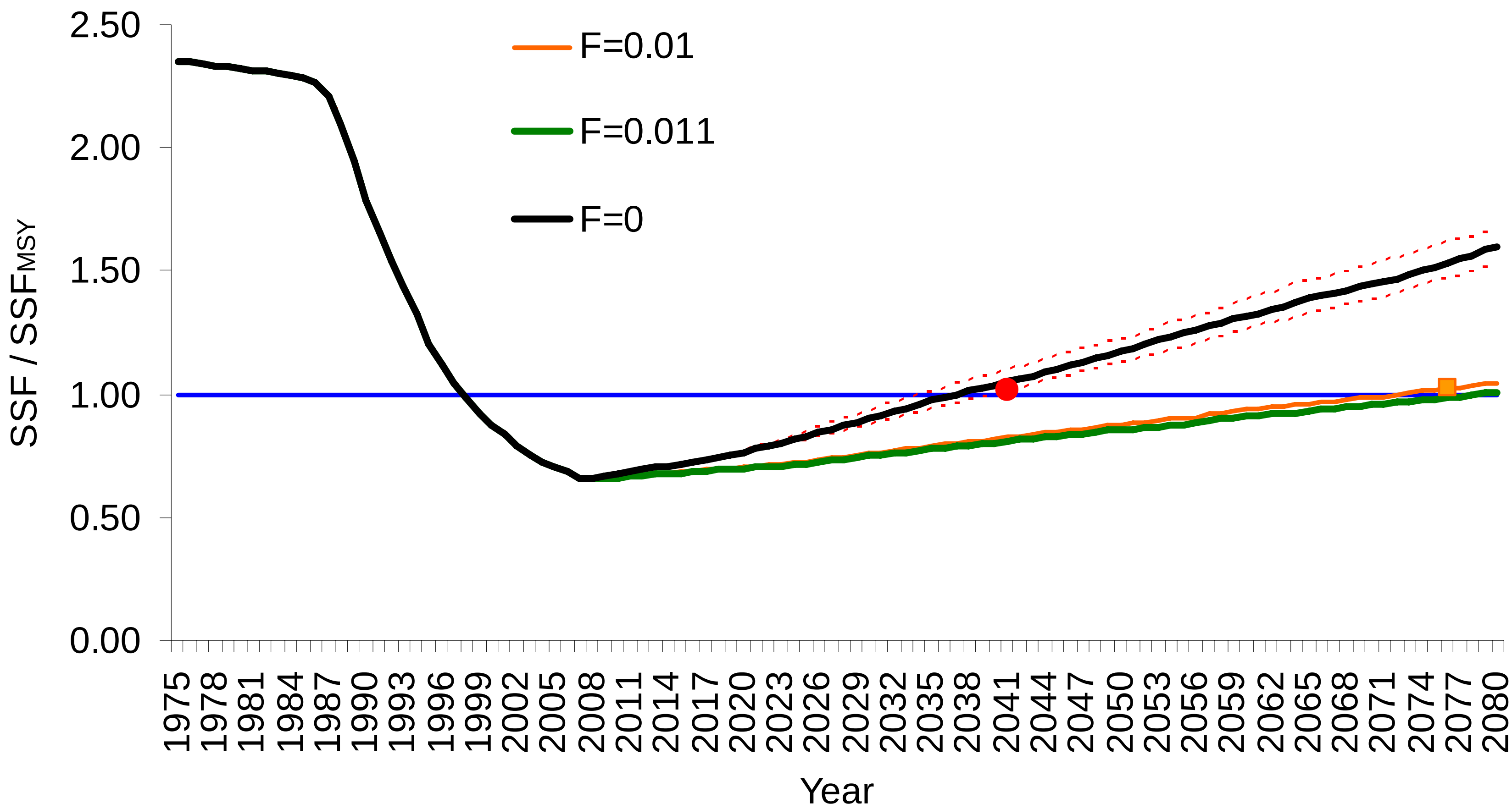


Figure 4.13 Projections with constant F (solid black , orange, and green lines). The dashed red lines represent the 30th percentile (lower) and the 70th percentile (upper). Rebuilding under F = 0 with 70% probability is achieved in year 2041 (solid red circle). F = 0.01 (solid orange) rebuilds by 2076 with 70% probability (indicated by solid orange box); F = 0.011 rebuilds by 2076 with 50% probability (median of the bootstraps).

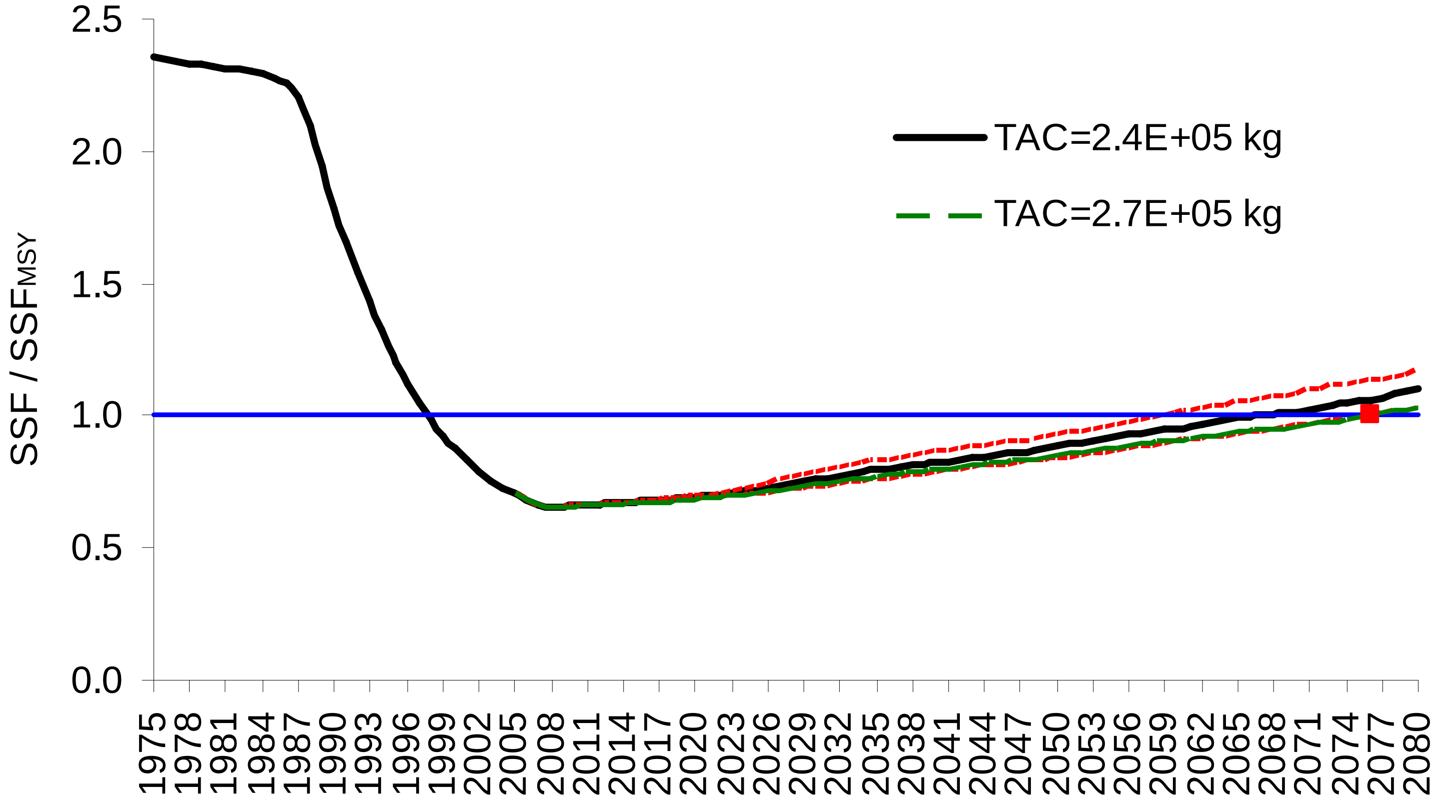


Figure 4.14 Projections with constant TACs (solid black and dashed green lines). The dashed red lines represent the 30th percentile (lower) and the 70th percentile (upper). Rebuilding by year 2076 with 70% probability is the year that the lower percentile crosses the horizontal blue reference line (indicated by a solid red box in year 2076). The dashed green line represents a 50% probability (median of bootstraps) of rebuilding by 2076.

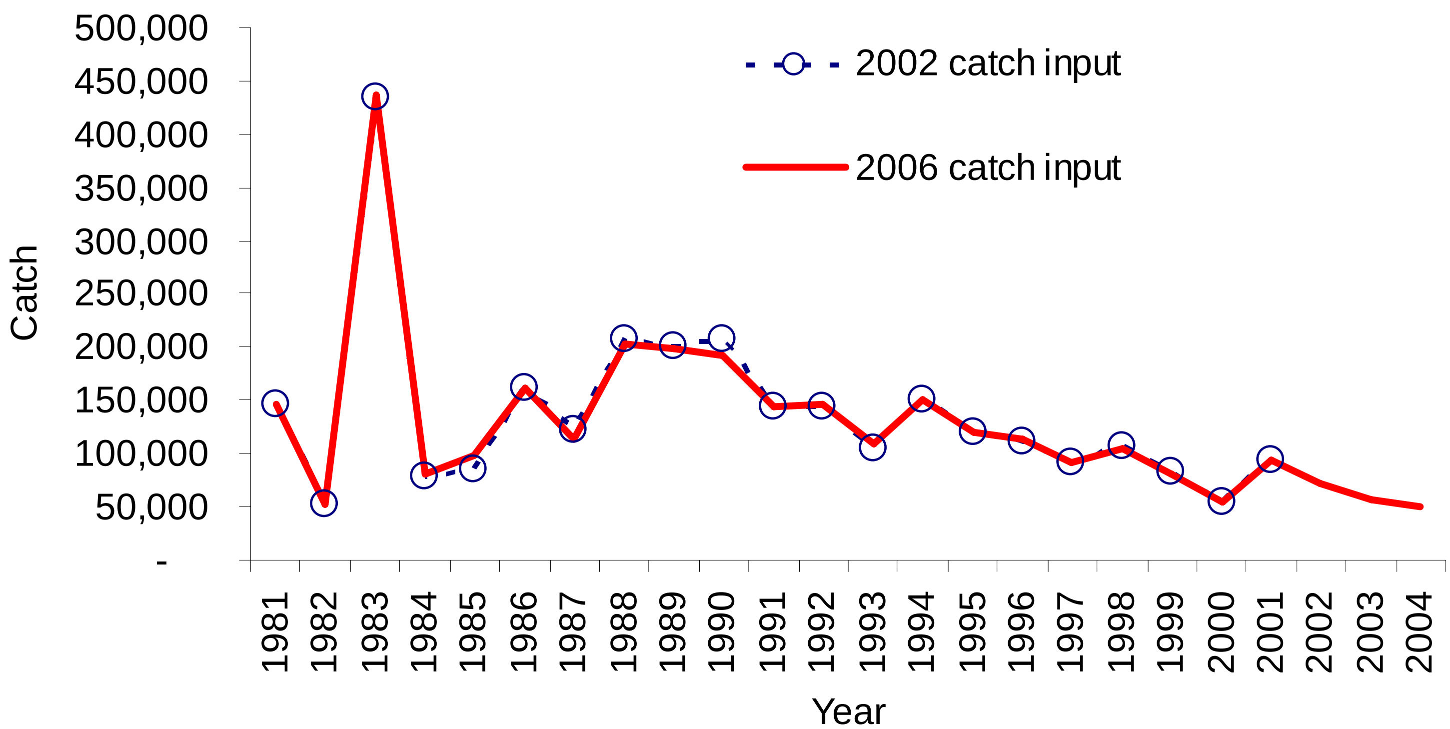


Figure 4.15. Comparison of 2002 and 2006 catch (in numbers of fish).

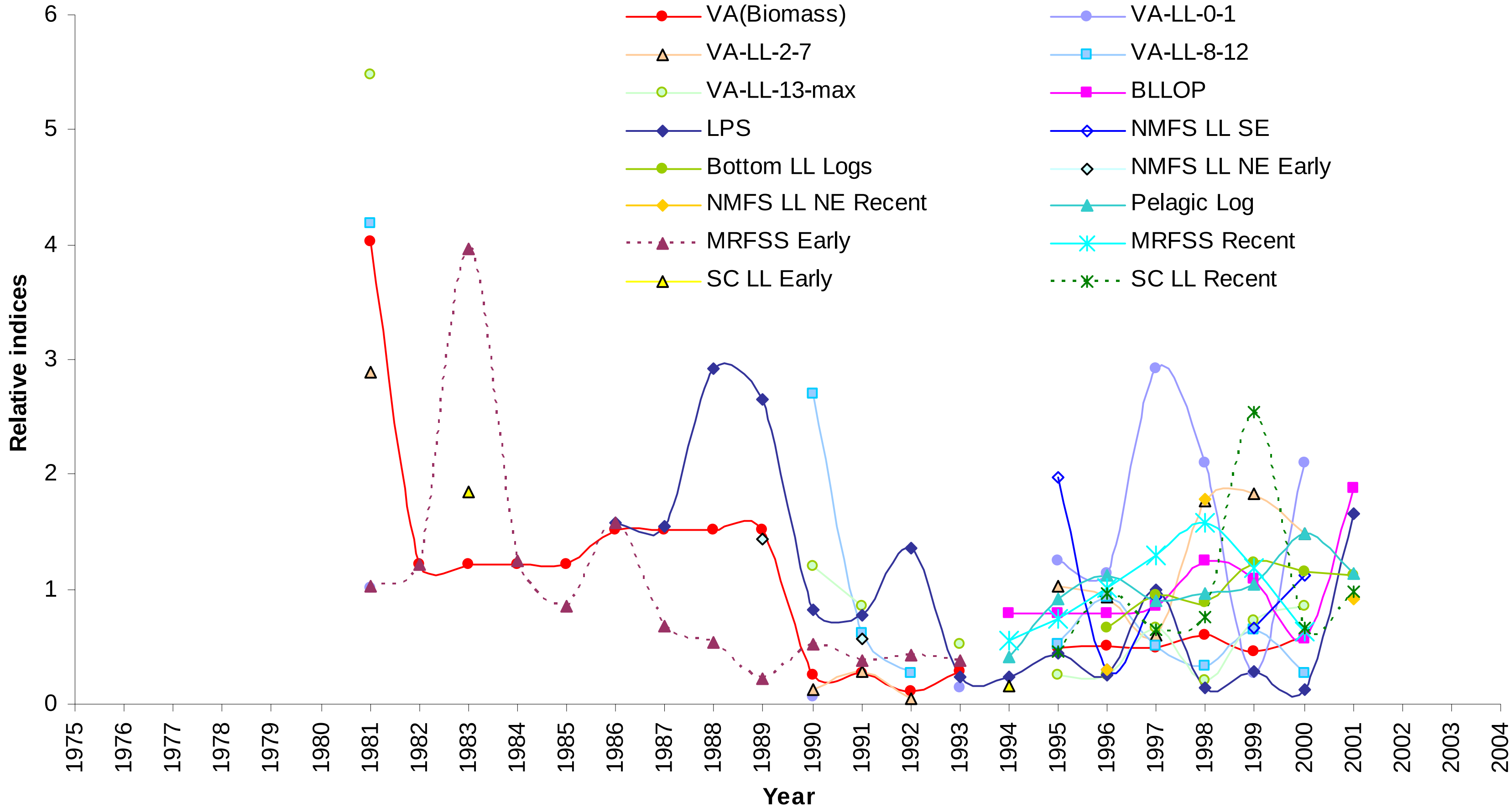
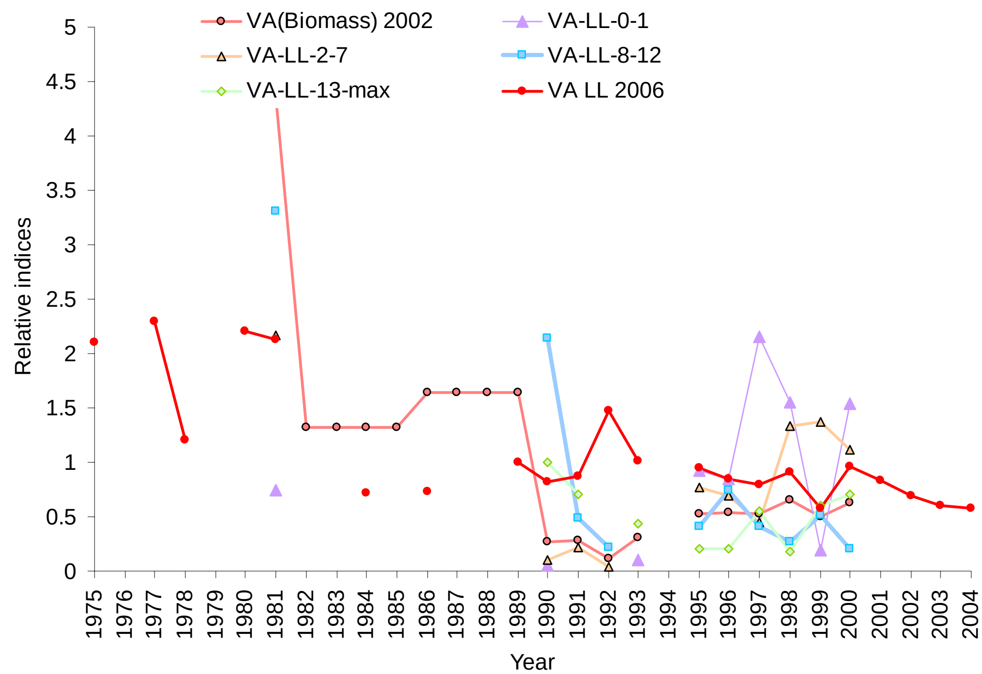


Figure 4.16 Indices available for the 2002 assessment. Note that these indices are scaled (divided by the index-specific mean) but are not relative to each other as there is no year of overlap.



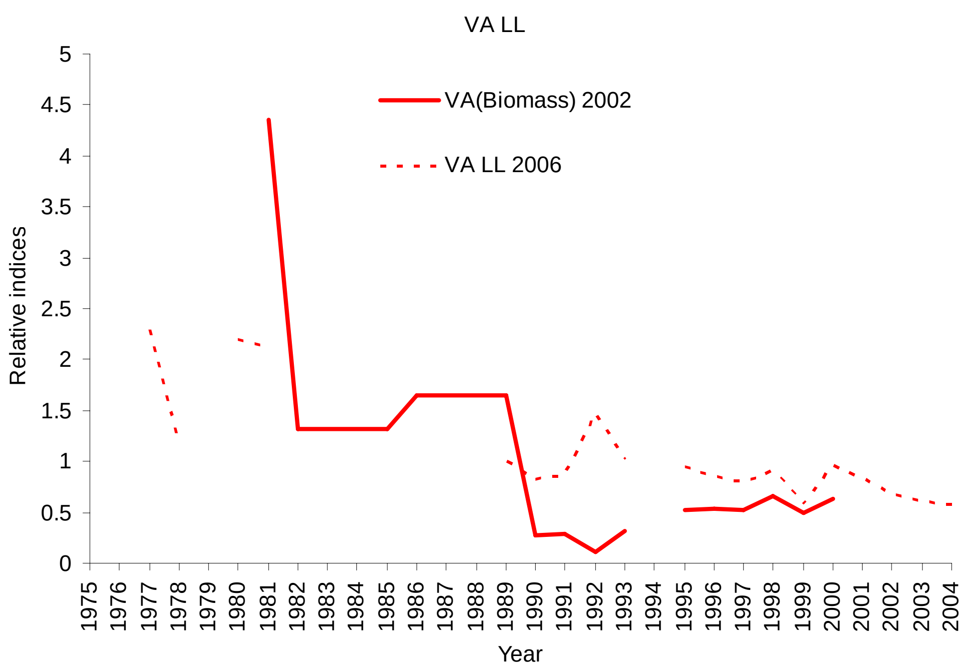
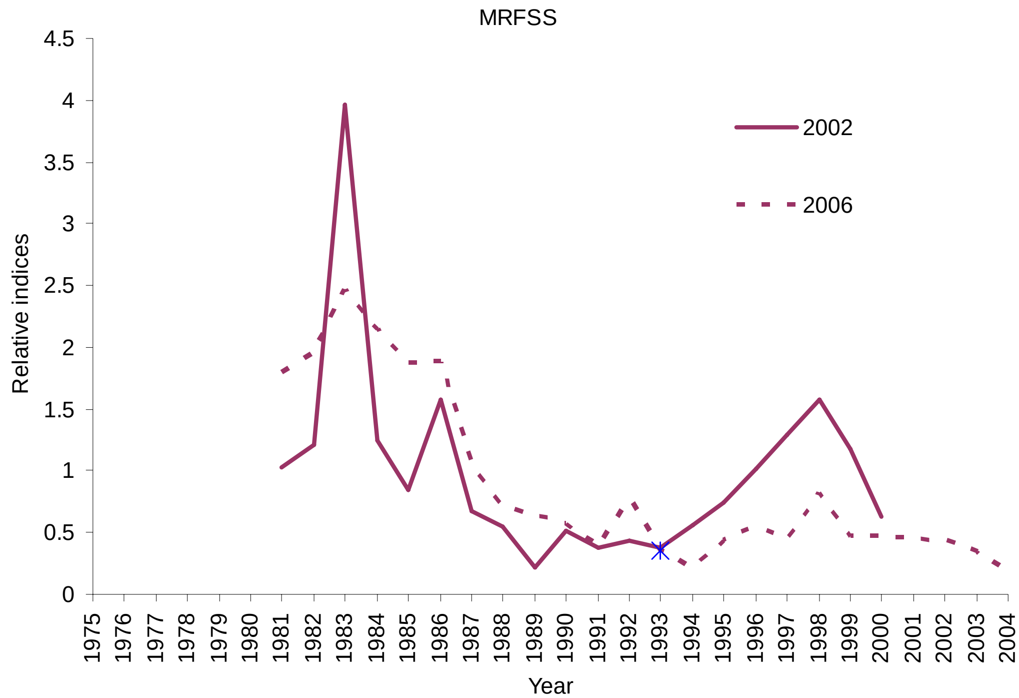


Figure 4.17. Overlaying indices from 2002 (solid lines) versus those indices in 2006 (dashed lines). Note that in 2002, five indices were available from the VA LL data; the 2006 VA LL index is plotted against the VA LL biomass index since it refers to the same age classes, even though the units are not the same. In 2002, the MRFSS index was split into two nominal indices, REC-early and REC-late, with the division in year 1994 (indicated by blue asterisk) whereas in 2006 there was a single MRFSS index that was standardized for the entire time interval.



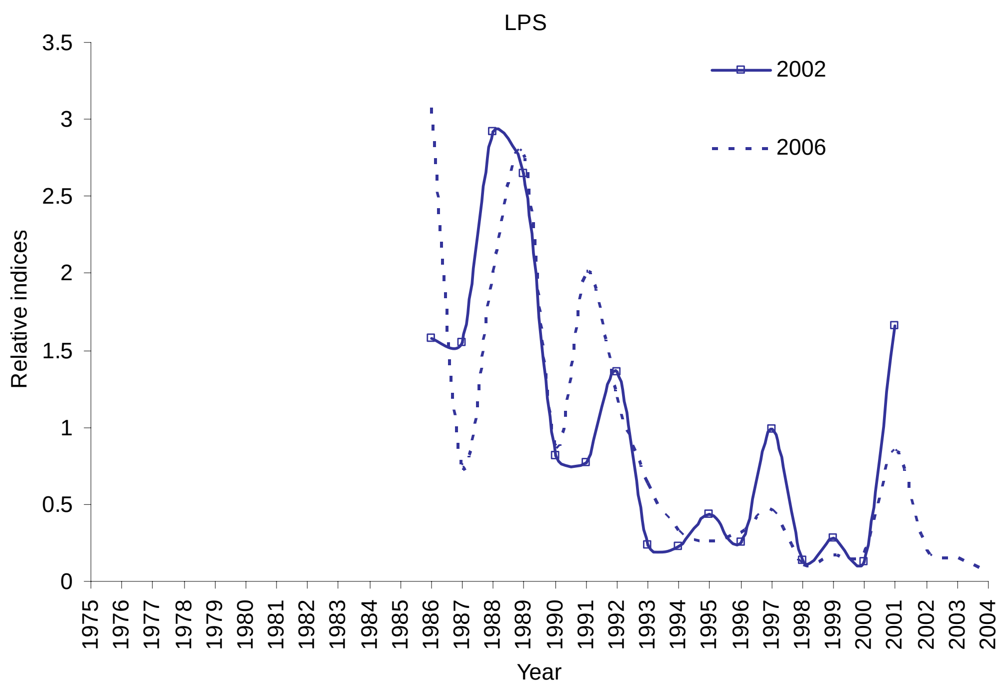
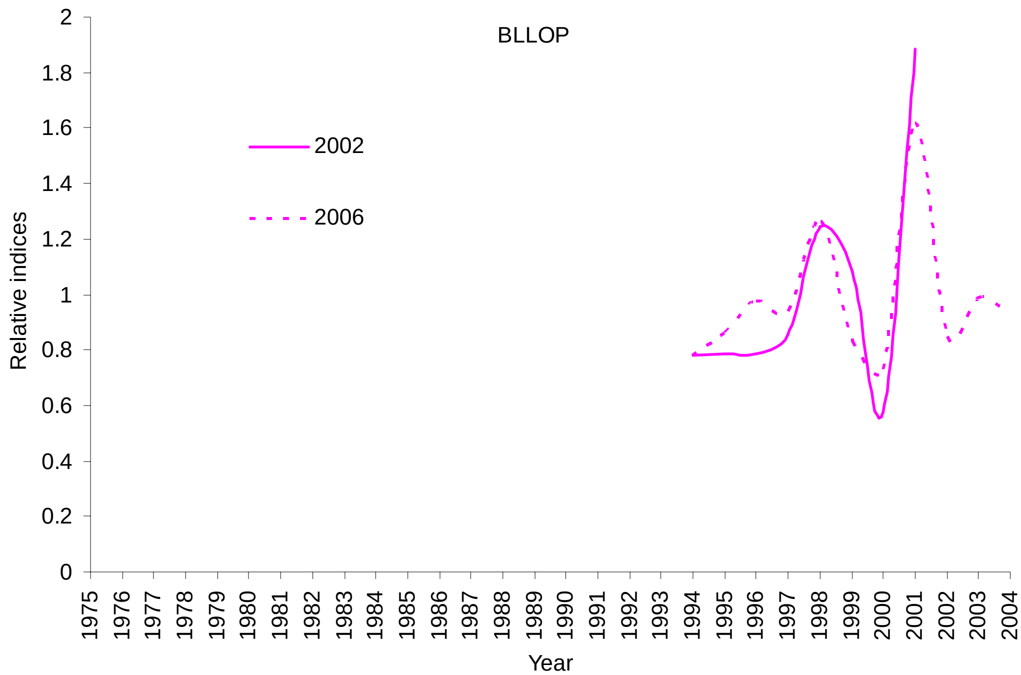


Figure 4.17 (continued)



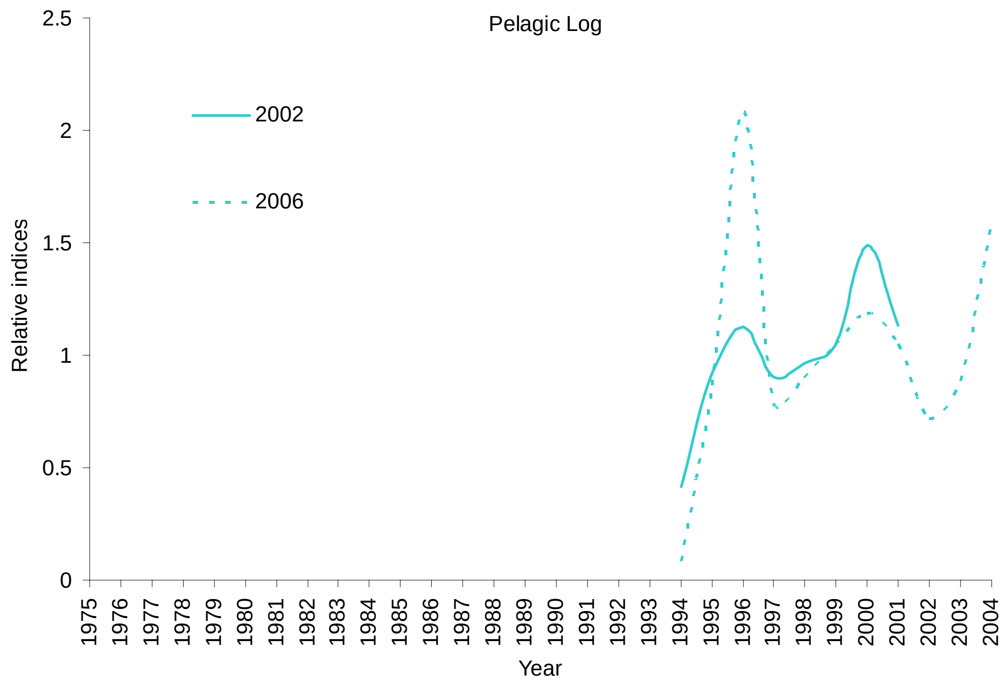


Figure 4.17 (continued)

GULF OF MEXICO BLACKTIP SHARK STOCK ASSESSMENT

5. GULF OF MEXICO BLACKTIP SHARK STOCK ASSESSMENT

5.1 Summary of Blacktip Shark Working Documents

SEDAR 11–AW–04
Preliminary Runs of a State-Space, Age-Structured Production Model for Blacktip Shark
Summary: An age-structured production model was used to assess blacktip shark, the same that was used in the 2002 assessment. A continuity run was made using the 2002 assessment decisions about biology and stock structure. Base models for the 2006 assessment were then run for the Gulf of Mexico and the Atlantic Ocean separately, using decisions made at the data workshop. All runs reached the same conclusion that the stock is not overfished nor, for the most recent years, is overfishing occurring. A number of adjustments to biological inputs were necessary to achieve model convergence, and this point warrants further discussion at the assessment workshop.

SEDAR11-AW-05
Assessment of Large Coastal, Blacktip, and Sandbar Sharks using Surplus Production Methods
We used two complementary surplus production models (BSP and WinBUGS) to assess the status of three Large Coastal Shark (LCS) groupings, two stocks of blacktip shark, and a single stock of sandbar shark identified as baseline scenarios in the LCS Data Workshop report. Both methodologies use Bayesian inference to estimate stock status, and the BSP further performs Bayesian decision analysis to examine the sustainability of various levels of future catch. Extensive sensitivity analyses were performed with the BSP model to assess the effect of different assumptions on CPUE indices and weighting methods, catches, intrinsic rates of increase, initial depletion, and importance function on results. Baseline scenarios for the three LCS groupings considered predicted that the stock status is not overfished nor overfishing is occurring. Using the inverse variance method to weight the CPUE data changed the predictions on stock status for the LCS grouping, which would then be overfished, with overfishing occurring. The sandbar shark stock was estimated to be significantly depleted (64-71% depletion from virgin level). The Gulf of Mexico blacktip shark stock was healthy (depletion of only 8-23% of virgin level), whereas results for the Atlantic blacktip shark stock from the BSP and WinBUGS models conflicted. The BSP model predicted a considerable level of depletion for this stock regardless of the CPUE weighting method used. In contrast, the assessment of a single blacktip shark stock (GOM+ATL) resulted in very consistent results, with all models predicting a healthy status (depletions of only 10-16% of virgin level). Using the higher values of r from the 2002 SEW or accounting for some depletion from virgin levels in the first year of the model did not affect conclusions. Several assumptions on catches (notably changing the high value of recreational catch in 1983) also had no effect on conclusions. Removing the VIMS CPUE series from the LCS scenario reversed the conclusions on stock status when using inverse variance weighting, highlighting the influence of this series on results; removing the PELAGIC LOG CPUE series from the ATL blacktip shark analysis also drastically reversed the conclusions on stock status. Fitting one CPUE series at a time had a larger effect on results: the PELAGIC LOG series greatly influenced conclusions for the three LCS groupings and GOM and ATL

blacktip shark, whereas the VIMS series affected conclusions on the two groups for which it is available, LCS and sandbar shark.

5.2 Background

Blacktip and sandbar sharks are the two most important species in the fishery, and have been the subjects of species specific assessments in the past conducted through Shark Evaluation Workshops (SEWs). As such, the Panel was tasked with conducting species specific assessments for these species. The Data Workshop determined catch histories, relative abundance indices, and biological input parameters for three assessments: one stock of sandbar sharks and two stocks of blacktip sharks, one for the Gulf of Mexico and one for the northwestern Atlantic Ocean.

5.3 Available Models

Four models were available for discussion for the Gulf of Mexico blacktip shark assessment: two surplus production models, the BSP and WinBUGS models described previously, and two age-structured production approaches (Apostolaki et al. in press, Porch 2002).

5.4 Details about surplus production model and age-structured model

A surplus production model simulates the dynamics of a population using total population biomass as the parameter that reflects changes in population size relative to its virgin condition. In comparison to more complicated models, the surplus production model is simpler in its formulation, takes less time to run and requires less input information. However, due to its formulation, the surplus production model does not describe changes that occur in subgroups of the population (adults, juveniles, etc). In addition, the sensitivity of model predictions to key stage-dependent biological parameters cannot be evaluated using a surplus production model. Finally, surplus production models are not able to incorporate a lag time into the results.

An age-structured population dynamics model describes the dynamics of each age class in the population separately and therefore, requires age-specific input information. Due to the higher complexity of these models, they usually take longer to run and require a higher volume of information relative to simpler models. However, they can account for age-dependent differences in biology, dynamics and exploitation of fish and provide an insight into the structure of the population and the processes that are more important at different life stages. They also allow for the incorporation of age-specific selectivity information.

With regard to management benchmarks, the surplus production model assumes that the population biomass that corresponds to MSY is always equal to half of the virgin population biomass, whereas the relative biomass at MSY calculated with an age-structured model (and other benchmarks associated to it) is species-specific and could be any fraction of virgin biomass.

The Assessment Panel decided to use the state-space, age-structured production model described in document SEDAR11-AW-04 for blacktip sharks from the Gulf of Mexico. This model was selected as it allowed for the incorporation of age-specific biological and selectivity information, along with the ability to produce required management benchmarks.

5.5 Discussion of weighting methods

The Data Workshop recommended that *equal weighting* for assigning weights to the different CPUE time series available during model fitting should be used for the baseline runs. The panel discussed the advantages and disadvantages of the *equal weighting* vs. the *inverse CV weighting* methods:

Equal weighting ignores the better quality of some data (smaller CVs) but is more stable between assessments because yearly changes on CVs in a given CPUE series do not affect the importance of that time series for the overall fit.

Inverse CV weighting can provide better precision as it tracks individual indices however, it could be less stable between assessments due to changes on the relative ‘noise’ of each time series. This method may also not be appropriate in cases in which different standardization techniques have been used for the standardization of the series and therefore, the same value of CV might reflect different levels of error depending on the CPUE it corresponds to.

It was requested by one Panelist to manually weight the indices that cover larger geographic areas to have a stronger influence on the model. The group commented that, while that may be possible in a spatially explicit model, a great deal more data would be required than presently available.

The Assessment Panel decided that equal weighting would be the default weighting method for the current assessment but noted that, as there is at present no objective way to decide which of these two methods is superior other than comparing model convergence diagnostics, future assessments may need to reexamine this issue.

5.6 New biological parameters derived during the assessment workshop

As discussed in SEDAR 11-AW-10, the values for life history parameters that the Data Workshop determined to be the best estimates did not produce viable estimates for steepness (steepness was <0.2 for all stocks). The group reviewed the inputs that produce steepness (pup-survival, M at age for ages 1+, maturity at age, and pup-production at age), and determined that pup-production and estimates of maturity should be known with greater certainty than estimates of mortality or pup survival. Therefore, in order to satisfy the lower bound on steepness, and to meet the data workshop recommendation that steepness should be between 0.2-0.4, the mode of the lognormal prior for pup survival was increased to 0.75 with a CV of 0.3. In addition, survival was increased by 10% for ages 1+ for the Gulf of Mexico stock, and by 7% for the Atlantic stock. The data workshop values for M at age as well as the values derived in plenary at the assessment workshop are given in Tables 5.1a and b, and plotted in Figure 5.1. Note that in the 2002 assessment, the same problem was encountered with the lower limit of steepness. In 2002, the base parameter values gave a steepness of about 0.18, so pup production was increased from 3.85 to 10, achieving a steepness of about 0.37. As noted in the 2002 report (p. 24), increasing the fixed level of pup production implies either that there is an unexploited portion of the population that is contributing pups, or that the pups are recruiting from a different population altogether (basically an open population model).

5.7 Methods

5.7.1 State-space, age-structured production model description

It was decided at the assessment workshop that the age-structured production model (SEDAR11-AW-04) would be used as the base model for the 2006 assessment. For Gulf of Mexico blacktip sharks, catches and one index begin in 1981, with the remaining indices beginning in the 1990s. No attempt was made to impute catches prior to the observed values in 1981. The model adopted derives equilibrium N at age for the first model year by estimating a level of historic fishing (F_{hist}). A historic selectivity vector is specified by the user, which is multiplied by F_{hist} to arrive at the historic age-specific fishing mortality rate. A historic selectivity vector of 1 for all ages was assumed.

Population Dynamics

The dynamics of the model are described below, and are extracted (and/or modified) from Porch (2002). This model formulation was the same utilized in the 2002 blacktip shark assessment. A value of historic fishing mortality, F_{hist}, can be estimated or fixed by the user. If F_{hist} is fixed at 0, then this implies that the population begins at virgin conditions. If F_{hist} is estimated or fixed to a value greater than 0, then the population begins in equilibrium at that level of F_{hist}. Given a vector of vulnerability at age for this level of historic fishing, $v_{hist,a}$, then the initial population structure is given by

$$(1) \qquad N_{a,y=1,m=1} = \begin{cases} R_{F_{hist}} & a=1 \\ R_{F_{hist}} \exp(-\sum_{j=1}^{a-1}(M_j + F_{hist} v_{hist,j}) & 1<a<A \\ \dfrac{R_{F_{hist}} \exp(-\sum_{j=1}^{A-1}(M_j + F_{hist} v_{hist,j})}{1-\exp(-M_A - F_{hist} v_{hist,A})} & a=A \end{cases},$$

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.

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

$$(2) \qquad R = \frac{R_0 S \alpha}{S_0 + (\alpha - 1)S} \quad .$$

In (2), R_0 and S_0 are virgin number of recruits (age-1 pups) and spawners (units are number of mature adult females times pup production at age), respectively. The parameter α is calculated as:

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

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).

At equilibrium, spawners per recruit with fishing is simply:

$$(4) \qquad \varphi_F = \left[\left(\sum_{a=1}^{A-1} p_a m_a \prod_{j=1}^{a-1} e^{-M_a - Fv_a}\right) + \frac{p_A m_A}{1 - e^{-M_A - Fv_A}} e^{-M_A - Fv_A}\right] = \frac{S_F}{R_F} \quad ,$$

where R_F and S_F are the equilibrium recruits and spawners, respectively, F is the level of fishing, and v_a is the age-specific vulnerability to fishing. From (4) and (2), we have

$$(5) \qquad R_F = \frac{S_F}{\varphi_F} = \frac{R_0 S_F \alpha}{S_0 + (\alpha - 1)S_F} \quad .$$

Equation (5) can be solved for S_F, and then R_F is simply S_F/φ_F, which allows calculation of the initial number of pups under a non-zero amount of historic fishing:

$$(6) \qquad R_{F_{hist}} = \frac{R_0 \alpha \varphi_F - S_0}{(\alpha - 1)\varphi_F} \quad .$$

Note that if F_{hist} is positive, then in order for $R_{F_{hist}}$ to be positive, we must have the following condition:

$$(7) \qquad \alpha > \frac{S_0}{R_0 \varphi_{F_{hist}}} = \frac{\varphi_0}{\varphi_{F_{hist}}} \quad or \quad \frac{1}{\alpha} < \frac{\varphi_{F_{hist}}}{\varphi_0} \quad .$$

Effectively, condition (7) implies that the level of SPR corresponding to F_{hist} must be greater than 1/ α. For populations where α is near the lower bound of 1, this implies that the level of F_{hist} must be minimal.

Beyond the initial numbers in each age class as defined in (1), abundance at the beginning of subsequent months is calculated by

$$(8) \qquad N_{a,y,m+1} = N_{a,y,m} e^{-M_a \delta} - \sum_i C_{a,y,m,i} \quad ,$$

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 at the end of the month, after natural mortality:

$$(9) \qquad C_{a,y,m,i} = F_{a,y,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad ,$$

where τ_i is the duration of the fishing season for fleet i. Catch in weight is computed by multiplying (9) 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:

$$(10) \qquad F_{a,y,i} = q_{y,i} f_{y,i} v_{a,i} \quad .$$

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. For this model application to blacktip sharks, both vulnerability and catchability were assumed to be constant over years.

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:

$$(11) \qquad I_{y,m,i} = q_{y,i} \sum_a v_{a,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad .$$

Equation (11) provides an index in numbers; the corresponding CPUE in weight is computed by multiplying $v_{a,i}$ in (11) by $w_{a,y}$.

State space implementation

Process errors in the state variables and observation errors in the data variables can be modeled as a first-order autoregressive model:

$$
\text{(12)} \quad \begin{aligned} g_{t+1} &= E[g_{t+1}]e^{\varepsilon_{t+1}} \\ \varepsilon_{t+1} &= \rho\varepsilon_t + \eta_{t+1} \end{aligned} \quad .
$$

In (12), g is a given state or observation variable, η is a normal-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.

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

$$
\text{(13a)} \quad \sigma_g = \ln\left[(\lambda_g CV)^2 + 1\right]
$$

$$
\text{(13b)} \quad \sigma_g = \ln\left[(\omega_{i,y}\lambda_g CV)^2 + 1\right] \quad .
$$

The term λ_g is a variable-specific multiplier of the overall model CV. For catch series and indices (equation 13b), the additional term, $\omega_{i,y}$, is the weight applied to individual points within those series. For instance, because the indices are standardized external to the model, the estimated variance of points within each series is available and could be used to weight the model fit. Given the Data Workshop decision to use equal weighting between indices, all $\omega_{i,y}$ were fixed to 1.0 and the same λ_g was applied to all indices. To evaluate the sensitivity case where indices were weighted by the inverse of their CV, each $\omega_{i,y}$ was fixed to the estimated CV for point *y* in series *i*; an attempt was also made to estimate a separate λ_g for each series, however those multipliers were not estimable and so a single λ was applied to all indices.

In the present model, these multipliers on catches and indices were fixed after exploring the effects on model outputs for several different values. A fleet-specific effort constant was estimated, but by allowing for large process error it was effectively a free parameter (a value of 10 times the overall model CV was used); the correlation was fixed at 0.0.

5.7.2 Data inputs, prior probability distributions, and performance indicators

The base model represented the decisions made by the Data Workshop as well as any additional decisions or modifications made by the assessment workshop. Data inputted to the model included maturity at age, fecundity at age (pups per mature female), spawning season, catches, indices, and selectivity functions (Tables 5.1a and b, 5.2, and 5.3; Figures 5.1-5.3). Catches were made by the commercial sector, the recreational sector, and the Mexican fishery. In addition, estimates of unreported commercial catches and Gulf of Mexico menhaden fishery discards were provided by the DW. Because of similar selectivity functions, the commercial and unreported catches were combined, and recreational catches were combined with Mexican catches, yielding a model with 3 distinct "fleets" (Table 5.2). A total of 13 indices for the Gulf of Mexico were available; eight of these included or were exclusive to age 0. As this model began with age class 1, none of the indices designated as sampling "age 0" were used. This left 5 indices for the base case, and 3 sensitivity indices (Table 5.3 and Fig.5.2).

Selectivities are imputed in the age-structured surplus production model (as a functional form) and linked to each individual catch or CPUE series. Individual selectivity functions to be applied to catch series were identified by the DW catch working group based on information used in previous assessments, length frequency data presented at the DW, and the collective knowledge of shark fisheries of the group members. The selectivity recommendations can be found on pages 38-39 of the DW report. Selectivities linked to individual catch series were a compromise because the series often encompass various components of the fishery (e.g., commercial + unreported selectivity refers to commercial fisheries, most of which are bottom longline fisheries, but also include pelagic longline and drift gillnet fisheries, which are likely to have somewhat different selectivity patterns). The selectivity functions identified were then applied to the individual CPUE series based on the type of index represented (e.g., the BLLOP and VA LL indices were assigned the commercial + unreported logistic selectivity function because both indices use bottom longline gear).

-Commercial landings + unreported catch series: a logistic curve was selected based on the 2002 SEW assessment. The rationale was that younger ages were relatively less selected by the commercial gear as a whole, which as stated above may also include pelagic longline gear that is set in deeper waters where juveniles are less available, and drift gillnet gear that uses large mesh sizes targeting adults (Figure 5.3)

-Recreational and Mexican catch series: this selectivity pattern was largely based on the MRFSS, which includes data from recreational anglers fishing in nearshore waters and targeting mostly juveniles. Based on this, very limited length-frequency information presented in document LCS05/06-DW-16, and information from the 2002 SEW assessment, selectivity for blacktip sharks was fixed at 1 for ages 0 and 1 and rapidly decreased thereafter to reflect the fact that larger and older sharks are progressively less targeted (Figure 5.3).

-Menhaden bycatch series: based on data from this fishery, all age groups were assumed to be fully selected and thus given a constant selectivity of 1 (Figure 5.3).

-Juvenile indices: this selectivity pattern was intended for surveys targeting juveniles and thus assumes full selectivity for the first age groups, with a rapid decline as sharks approach maturity (note that the 2002 ages at maturity were used; Figure 5.3).

Catch data begin in 1981 and the earliest base case index begins in 1992. The base case model in 2002 attempted to estimate a level of historic F, so an attempt was made to estimate F_{hist} for the base model this time. Initial model runs found that F_{hist} was difficult to estimate or it converged to near 0. Therefore, for all runs presented here, F_{hist} was fixed to 0, which implies that the stock was unexploited prior to 1981.

Individual points within catch and index series can be assigned different weights, based either on estimated precision or expert opinion. All points within each catch series were given the same weight; likewise, all points within each index series were given the same weight.

One further model specification was the degree to which the model predicted values matched catches versus indices. An overall model CV is estimated (see equations 13a and 13b), and multiples (λ_g) of this overall CV can be specified separately for catches and indices (see Porch 2002). All catch series were assigned a single CV multiple, and all indices were assigned a single CV multiple (this forces equal weighting of the indices). Initially, an attempt was made to estimate these multipliers. This resulted in boundary solutions for the multipliers. In a second attempt, the multiplier for catch was fixed at 1 and the index multiplier was estimated. Again, this resulted in the index multiplier estimate at the upper bound. Several values were evaluated for the CV multiplier of indices: a value that was 1, 2.5, 4, or 5 times the catch CV multiplier. A value of 1 implies the same relative certainty in catches and indices; the remaining values imply that indices are less certain than catches. In the 2002 assessment, a value of 4 was used. In this assessment, model convergence was not obtained (Hessian could not be estimated) for values of 1, 2.5, or 4, but was obtained for a value of 5. The point estimates for all weighting levels tried (even those that did not converge) concluded that the stock was not overfished and that there was no overfishing. The relative status estimates displayed some spread; however, that depended on the CV multiplier. The estimate of relative biomass (B_{2004}/B_{MSY}) ranged from 1.43 to 2.56, respectively, while the degree of overfishing (F_{2004}/F_{MSY}) ranged from 0.79 to 0.027. Although these reported ranges reflect results from models that did not converge, they are mentioned primarily because the index fits showed a slight downward trend rather than the flat trend for the model that actually converged. Basically, forcing the model to fit the indices as well as catch reduced the relative biomass and increased the relative F benchmark (i.e., closer to overfished and closer to overfishing). Given that there was no convergence for a value less than 5, and that this value is close to the value used in 2002, the weighting scheme selected was to fit catches 5 times better than indices. Placing less certainty in indices relative to catch is further justified when one considers the lack of a consistent signal. The base indices show flat, increasing, or decreasing trends with fairly large annual changes (Figure 5.2 and 5.4). It is likely that one reason the model runs with CV multipliers <5 did not converge is that the model could not reconcile a better fit to those conflicting indices. Of the sensitivity indices, MRFSS is the longest (it begins in 1981), and the average trend is flat over the time period, although there are large interannual fluctuations (Figure 5.2). CV multipliers greater than 5 were not evaluated for the indices, as the model-predicted trend was already poor.

Estimated model parameters were pup survival, virgin recruitment (R_0), catchabilities associated with catches and indices, and fleet-specific effort. Natural mortality at ages 1+ was fixed at the updated values (Table 5.1a), and the priors for pup survival and virgin recruitment are listed in Table 5.1b.

In summary, the base model configuration assumed virgin conditions in 1981, used the data workshop recommended biological parameters, the updated survival at age, the updated prior for pup survival, and the base case indices with an updated Pelagic Longline Log index (referred to as Pelagic Log). Catches were assumed to be 5 times more certain than the indices. All inputs are given in Tables 5.1a and b, 5.2 and 5.3. Base indices are in black font in Table 5.3.

Performance indicators included estimates of absolute population levels and fishing mortality for year 2004 (F_{2004}, SSF_{2004}, B_{2004}, $Nmature_{2004}$), population statistics at MSY (F_{MSY}, SSF_{MSY}, SPR_{MSY}), current status relative to MSY levels, and depletion estimates (current status relative to virgin levels). In addition, trajectories for F_{year}/F_{MSY} and SSF_{year}/SSF_{MSY} were plotted.

5.7.3 Methods of numerical integration, convergence diagnostics, and decision analysis

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. Model fit was assessed by comparing components of the relative negative log-likelihood (relative rather than exact because the constants in the likelihood were not included). The relative negative log-likelihood (objective function) and AICc (small sample AIC) values are listed in the table of model results.

5.7.4 Sensitivity analyses

Three sensitivity runs to the base model were performed. In the first sensitivity (**ASPM-BTG-1**), the Pelagic longline index was excluded. In the second sensitivity (**ASPM-BTG-2**), all indices were used (5 base and 3 sensitivity indices). The third sensitivity (**ASPM-BTG-3**) was the same set up as the base case except that observations within each index were weighted by the inverse CV of each point. An attempt was made to estimate a separate CV multiplier for each index, but there were boundary solutions again, so the multiplier from the base case was retained for all indices.

5.8 Results

5.8.1 Baseline scenario

The base model estimated a stock that was not overfished and there was no overfishing (Tables 5.4 and 5.5; Figure 5.5). The model estimate of F by fleet is dominated by the recreational fleet (includes recreational fishery plus estimated Mexican catches) throughout the time series (1981-2001), which matches the observed pattern in landings (Figure 5.6). Model fits to catches and indices are shown in Figures 5.7 and 5.8. Catches are fit very well. The base indices span at most 13 years, and the model predicts a relatively flat trend through the observed points. The precision is very poor for virgin pup production, and current measures of total biomass, number mature, spawning stock fecundity (SSF), and fishing mortality. No CV is given for steepness or

α as these parameters are calculated directly from pup survival and virgin spawners per recruit rather than estimated. Relative estimates of depletion are very precise, but current abundance estimates are correlated to the estimate of the virgin level. The estimate of pup survival did not move from the prior specification, indicating that there is probably little to no information in the data from which to estimate this parameter. No likelihood profiling was pursued.

5.8.2 Sensitivity analyses

Sensitivity analysis **ASPM-BTG-1**, the base case without the Pelagic longline index, did not converge, although the point estimates indicated that there was no overfishing and the stock was not overfished. The results for **ASPM-BTG-2**, which included all of the indices, and **ASPM-BTG-3**, which weighted the points within indices by their CV, were nearly identical to the base case (Table 5.4). As with the base case, the precision of the model estimates was very poor (CV>1) for the absolute measures of virgin level pups, and current measures of the stock. Given the high CV on virgin pup production, one can infer that the estimate of MSY is not well estimated either. The relative measures of depletion were very precise, however. Again, the estimate of pup survival did not move from the prior specification.

A phase-plot of stock-status shows the outcomes of the base model, the two sensitivity analyses, the continuity analysis (assuming a single stock; see section 5.10), and the estimates from BSP and WinBUGS (Figure 5.9). Note that the x values for BSP and WinBUGS are in numbers of fish (N_{2004}/N_{MSY}) rather than SSF_{2004}/SSF_{MSY}. These values from BSP and WinBUGS should be comparable, however, because they are relative statistics, and they only differ from the ASPM by the maturity ogive.

5.8.3 Comparison of model fits

The relative likelihood values by model source (catch, indices, effort, catchability, and recruitment) as well as a breakdown of likelihood by individual catch and index series are shown in Figures 10 and 11. The total approximate likelihood is lowest for sensitivity 2, where all indices were included, and was worst for sensitivity 3, where the inverse CV weighting scheme was used (see Table 5.4, value for "objective function" or AICc). Catches are best fit (lowest relative likelihood) by the base model. Almost all base indices have slightly smaller likelihoods under sensitivity 2, but the main reason that the objective function is lower is the catchabilities, which were specified with a uniform prior. Considering the fit to catches and indices alone, the base model performed best. None of the model configurations impacted the contribution to the likelihood by effort or recruitment parameters (pup survival and virgin number of pups). Both the base model and ASPM-BTG-3 had the same number of observations, and the same number of estimated parameters, and the AICc ranks the base model as having a better fit than ASPM-BTG-3.

5.9 Projections of the base model

The base model was projected at $F = F_{MSY}$ to the year 2030. Projections were done using Pro-2Box (Porch 2003). This projection was bootstrapped 500 times by allowing for process error in the spawner-recruit relationship. Lognormal recruitment deviations with CV=0.4, with no autocorrelation, were assumed. No other variability was introduced into the projections. The selectivity vector was the geometric mean of the last 3 years (2002-2004).

The estimate of generation time is about 17 years. Generation time was calculated as

$$GenTime = \frac{\sum_i i f_i \prod_{j=1}^{i-1} s_j}{\sum_i f_i \prod_{j=1}^{i-1} s_j}$$

where i is age, f_i is the product of(fecundity at age) x (maturity at age), and s_j is survival at age. The calculations were carried out to an age, A, such that the difference between performing the calculation to age A or A+1 was negligible. This calculation is consistent with the assessment model, which treats survival of the plus group as the sum of a geometric series (e.g., see third line in equation 1). The 2006 maturity ogive was used, 4.4 pups per female was the fecundity for all ages, adjusted age-specific survival at age was used (see section 5.6), and the mode of 0.75 for the prior on pup survival was used. As was done in the assessment model, to account for the approximately one year gestation time, maturity at age was shifted by 1 year, and the number of pups was halved to account for the fact that only half of the mature population would reproduce in a given year. Note that because pup-production is constant for all ages, it factors out of both numerator and denominator, and the resulting estimate of generation time is insensitive to that value.

The estimate of F_{2004} is far below the estimate of F_{MSY}, so projecting the stock at $F = F_{2004}$ does not further deplete the stock, rather it increases slightly (Figure 5.12). Projecting the stock at $F = F_{MSY}$, while allowing that $F_{2005\text{-}2007} = F_{2004}$ due to the time required to implement a new management regime, causes the estimated spawning stock to decrease towards the level that produces MSY (Figure. 5.13). By the year 2086, the stock is 1.27 times the size that would produce MSY.

5.10 Continuity analysis

A continuity base model was run using the 2002 state-space age structured production model (described above under methods). In 2002, blacktip was assessed as a single stock. F_{hist} was fixed at 0, all indices were used and given equal weighting; an age-constant M was estimated; catches for Gulf of Mexico and northwestern Atlantic Ocean combined (Table 5.6); 2002 biological parameters used; 10 pups per mature female was used for fecundity. Available combined blacktip stock indices and values can be found in Appendix 1.

The continuity model estimated a stock status of no overfishing, and not overfished. This model was not truly continuity per se, because the previous assessment had treated blacktip as one stock, and different indices had been available. It also differs from the 2006 base model because the biological parameters were adjusted differently to elevate the steepness parameter above 0.2. Nevertheless, the estimate of stock status in 2002, in this continuity analysis, and in the 2006 base model all concluded that the stock does not appear to be overfished, nor does it appear that there is overfishing. All of these estimates were fairly imprecise, though.

5.11. Discussion

There was some uncertainty associated with the biological parameters, which led to the AW updating the fixed values for M at age, and the mode of the prior for pup-survival (corresponding to density-independent level). All model configurations examined arrived at the same estimate of stock status, namely that the stock is not overfished and there is no overfishing.

Due to lack of information for setting a prior on F_{hist}, and lack of information in the data to estimate this parameter, it was fixed at 0, which forces the model to start at virgin conditions in 1981. Scenarios that start the population at less than virgin levels were not explored. The estimate of current depletion (for year 2004) is that total biomass is about 87% of virgin levels, and spawning stock fecundity (SSF) is about 93% of virgin levels. This suggests relatively little impact over a 24 year time period, and is reflected in the relatively flat fit to all of the indices of abundance. This result may be driven by the relatively short, recent years covered by the indices of abundance, and the lack of consistent trend between those indices. The 2002 assessment estimated that there was 74% of virgin SSF in 2001; the 2006 result would imply an increase of 24% in just three years. Given that landings peaked in the years 1986-1994 (Figure 5.6), a time period for which only 1 sensitivity index is available, and given the large CVs in model estimates of absolute abundance, the results ought to be interpreted cautiously.

Compared to the 2002 assessment of a single blacktip stock, the estimate of virgin pup recruitment is slightly larger for the 2006 Gulf blacktip stock (1.44E7 versus 1.35E7), pup survival in 2006 is nearly double (0.82 versus 0.46). Consequently, estimated steepness in 2006 is larger (0.40 versus 0.27), and the benchmark SPR_{MSY} is lower (0.62 versus 0.83). Because the stock in 2006 is estimated to be more resilient, and the slightly greater estimate of virgin pups, MSY is double that estimated in 2002 (2.42E7 versus 1.14E7). As the higher steepness is a result of the adjusted survival on ages 1+ and the adjusted mode for pup survival (and the estimate did not move from the prior mode), this gives an additional reason to interpret the results cautiously.

5.12. References

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Royal Road, Springfield, VA 22161.

Table 5.1a. Biological inputs from 2002 assessment, 2006 base case values from the data workshop, or values updated at the 2006 assessment workshop for Gulf of Mexico blacktip sharks. In the continuity case, M was estimated, while in the 2006 base case, M at age values were fixed. The * for the age 0 entries in the first three columns is to distinguish those values as survival rates rather than natural mortality rates.

Age	M 2002	M 2006	M 2006 Updated	Female Maturity 2002	Female Maturity 2006	Pups-per-Female 2002	Pups-per-Female 2006
0	0.52*	0.52*	0.75*	0	0.001	0	0
1	0.22	0.358	0.263	0	0.002	10	4.4
2	0.22	0.303	0.208	0	0.006	10	4.4
3	0.22	0.271	0.176	0.02	0.019	10	4.4
4	0.22	0.250	0.155	0.09	0.059	10	4.4
5	0.22	0.235	0.140	0.35	0.166	10	4.4
6	0.22	0.225	0.130	0.74	0.387	10	4.4
7	0.22	0.218	0.123	0.94	0.667	10	4.4
8	0.22	0.212	0.117	0.99	0.865	10	4.4
9	0.22	0.208	0.113	1	0.953	10	4.4
10	0.22	0.205	0.110	1	0.985	10	4.4
11	0.22	0.203	0.107	1	0.996	10	4.4
12	0.22	0.201	0.106	1	0.999	10	4.4
13	0.22	0.200	0.104	1	1	10	4.4
14	0.22	0.198	0.103	1	1	10	4.4
15	0.22	0.198	0.102	1	1	10	4.4

Table 5.1b. Additional parameter specifications for Gulf of Mexico blacktip sharks where L_∞, K, and t_0 are von Bertalanffy parameters; a is the scalar coefficient of weight on length; and b is the power coefficient of weight on length. Weight units are kg.

Parameter	**Value**	**Prior**
L_∞	139 (cm FL)	*constant*
K	0.232	*constant*
t_0	-2.33	*constant*
a	1.00E-05	*constant*
b	3.05	*constant*
F_{hist}	0	*constant*
Historic Selectivity	1 for all ages	*constant*
Pups-per-mature female	4.4	*constant*
Pup Survival	0.75 (mode)	~LN with CV=0.30
Virgin Recruitment (R_0)	1.50E+07	~U on [1.0E+4, 1.0E+9]

Table 5.2. Catches of Gulf of Mexico blacktip shark by fleet. Units are numbers of sharks.

Year	Commercial + Unreported	Recreational + Mexican	Menhaden
1981	7,261	161,954	17,495
1982	7,261	124,603	17,933
1983	7,844	88,980	17,714
1984	10,712	131,959	17,714
1985	9,950	132,272	15,964
1986	71,435	224,930	15,746
1987	98,806	156,674	16,402
1988	174,842	207,083	15,964
1989	190,962	192,279	16,839
1990	115,002	199,323	16,402
1991	46,484	200,210	12,684
1992	53,236	232,849	11,153
1993	57,102	210,606	11,372
1994	120,028	154,194	12,200
1995	84,862	134,884	11,200
1996	58,666	154,722	11,153
1997	45,221	132,184	11,372
1998	62,486	125,280	10,935
1999	52,304	72,013	12,028
2000	42,131	112,581	10,279
2001	39,397	80,034	9,622
2002	30,040	79,944	9,404
2003	71,540	55,778	9,185
2004	44,174	72,734	9,404

Table 5.3. Indices available for use in the current Gulf of Mexico blacktip shark assessment. Sensitivity indices in green (last 3 columns).

Year	PC Gillnet juveniles	BLLOP	NMFS LLSE	Bottom LL Logs	Pelagic Log	PC longline	MS Gillnet juveniles	MRFSS
1981								1.358
1982								0.325
1983								1.130
1984								0.673
1985								0.816
1986								1.452
1987								0.636
1988								1.319
1989								1.186
1990								1.318
1991								1.477
1992					2.240			0.877
1993					1.541	0.768		0.772
1994		0.430			2.358	0.133		0.726
1995		0.817	0.554		1.572	1.018		1.027
1996	0.980	0.724	0.380	0.249	0.838	0.758		1.159
1997	1.513	0.588	0.409	0.931	0.924	1.299		1.090
1998	0.639	0.796		0.334	0.808	0.974	0.835	1.471
1999	1.068	1.055	0.341	1.506	0.364	1.136	0.412	0.737
2000	0.649		1.517	0.883	0.706	1.914	2.655	1.259
2001	1.408	0.162	0.898	0.985	0.689		0.409	0.661
2002	0.854	2.062	1.436	1.078	0.484			0.719
2003	0.790	1.542	2.237	1.967	0.328		0.092	1.064
2004	1.098	1.824	1.228	1.068	0.149		0.198	0.747
Ages Vulnerable								
	1 - 5	all	all	all	all	all	1 - 5	young
Selectivity Vector								
	Juvenile Indices	Comm+Unrep	Comm+Unrep	Comm+Unrep	Comm+Unrep	Comm+Unrep	Juvenile-Indices	MRFSS

Table 5.4. Results for the base model runs and two sensitivity analyses that converged using the updated biological parameters for Gulf of Mexioc blacktip sharks. Pups-virgin is the number of age 1 pups at virgin conditions. SSF is spawning stock fecundity, which is the sum of number mature at age times pup-production at age (rather than SSB, since biomass does not influence pup production in sharks). AICc is the small sample Akaike Information Criterion, which converges to the AIC statistic as the number of data points gets large.

	Base		BTG-2		BTG-3	
Parameter	**Est**	**CV**	**Est**	**CV**	**Est**	**CV**
AICc	282.495		47.6284		421.414	
Objective Function	-158.524		-179.614		-89.0644	
MSY (kg)	2.42E+07	--	2.28E+07	--	1.56E+07	--
$Pups_{virgin}$	1.44E+07	1.79	1.36E+07	1.01	9.99E+06	3.68
SSF_{2004}	4.55E+07	1.83	4.29E+07	1.03	3.12E+07	3.80
$Nmature_{2004}$	1.98E+07	1.83	1.86E+07	1.03	1.36E+07	3.80
B_{2004}	1.93E+09	1.83	1.82E+09	1.03	1.33E+08	3.80
B_{2004}/B_{virgin}	0.87	0.04	0.87	0.02	0.86	0.12
SSF_{2004}/SSF_{virgin}	0.93	0.04	0.92	0.03	0.92	0.13
$Nmature_{2004}/Nmature_{virgin}$	0.89	0.04	0.88	0.03	0.88	0.13
SSF_{2004}/SSF_{MSY}	2.56	0.29	2.54	0.29	2.54	0.33
SPR_{MSY}	0.62	--	0.62	--	0.61	--
F_{2004}	0.01	1.82	0.01	1.03	0.01	3.75
F_{MSY}	0.20	--	0.20	--	0.20	--
F_{2004}/F_{MSY}	0.03	1.82	0.03	1.03	0.04	3.75
Pup-survival	0.82	0.29	0.82	0.29	0.83	0.30
alpha	2.64	--	2.64	--	2.68	--
steepness	0.40	--	0.40	--	0.40	--

Table 5.5. Estimates of total number, spawning stock fecundity, and fishing mortality by year for base model for blacktip shark in the Gulf of Mexico.

Year	N(year)	SSF(year)	F(year)
1981	23,667,920	10,749,000	0.042
1982	23,500,270	10,740,000	0.033
1983	23,393,320	10,729,000	0.024
1984	23,331,750	10,715,000	0.035
1985	23,234,190	10,697,000	0.035
1986	23,150,150	10,669,000	0.066
1987	22,935,150	10,628,000	0.052
1988	22,783,720	10,575,000	0.073
1989	22,531,140	10,513,000	0.072
1990	22,304,540	10,440,000	0.066
1991	22,162,200	10,357,000	0.058
1992	22,090,320	10,265,000	0.067
1993	21,979,560	10,171,000	0.062
1994	21,887,040	10,082,000	0.054
1995	21,786,520	10,001,000	0.045
1996	21,737,270	9,931,500	0.048
1997	21,689,190	9,870,500	0.040
1998	21,670,440	9,816,100	0.040
1999	21,636,060	9,768,300	0.025
2000	21,655,030	9,730,200	0.035
2001	21,638,400	9,702,500	0.026
2002	21,652,720	9,683,200	0.025
2003	21,670,380	9,670,600	0.023
2004	21,667,370	9,663,300	0.024

Table 5.6. Catches of blacktip shark by fleet (regions combined) used in the blacktip shark continuity analysis. Units are numbers of sharks.

Year	Commercial + Unreported	Recreational + Mexican	Menhaden
1981	7812	166452	17495
1982	7812	152653	17933
1983	8439	118279	17714
1984	11525	148058	17714
1985	10705	185539	15964
1986	75607	238556	15746
1987	107379	203334	16402
1988	178868	226745	15964
1989	194834	214072	16839
1990	119898	206497	16402
1991	121804	240823	12684
1992	150426	252476	11153
1993	128624	223430	11372
1994	201273	170135	12200
1995	151157	154315	11200
1996	100567	182589	11153
1997	81244	148520	11372
1998	94904	146779	10935
1999	59111	80863	12028
2000	51797	119334	10279
2001	49051	94979	9622
2002	50674	85221	9404
2003	89896	85840	9185
2004	57571	77012	9404

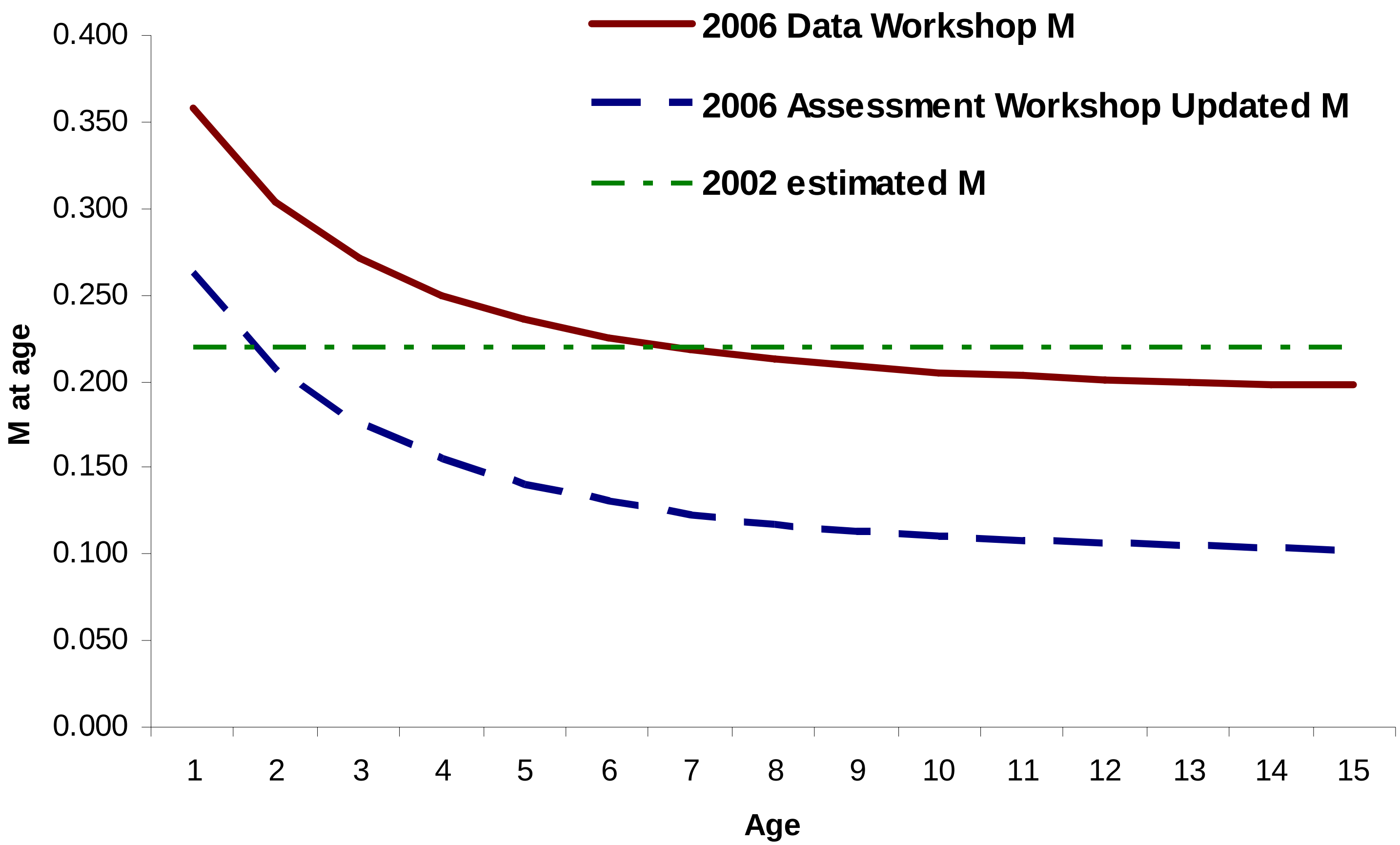


Figure 5.1 Comparison of natural mortality recommended by the data workshop (DW, solid line) and that agreed to in plenary at the assessment workshop (AW, dashed line) for Gulf of Mexico blacktip sharks. In 2002, and age-constant M at age was estimated (dot-dash green line).

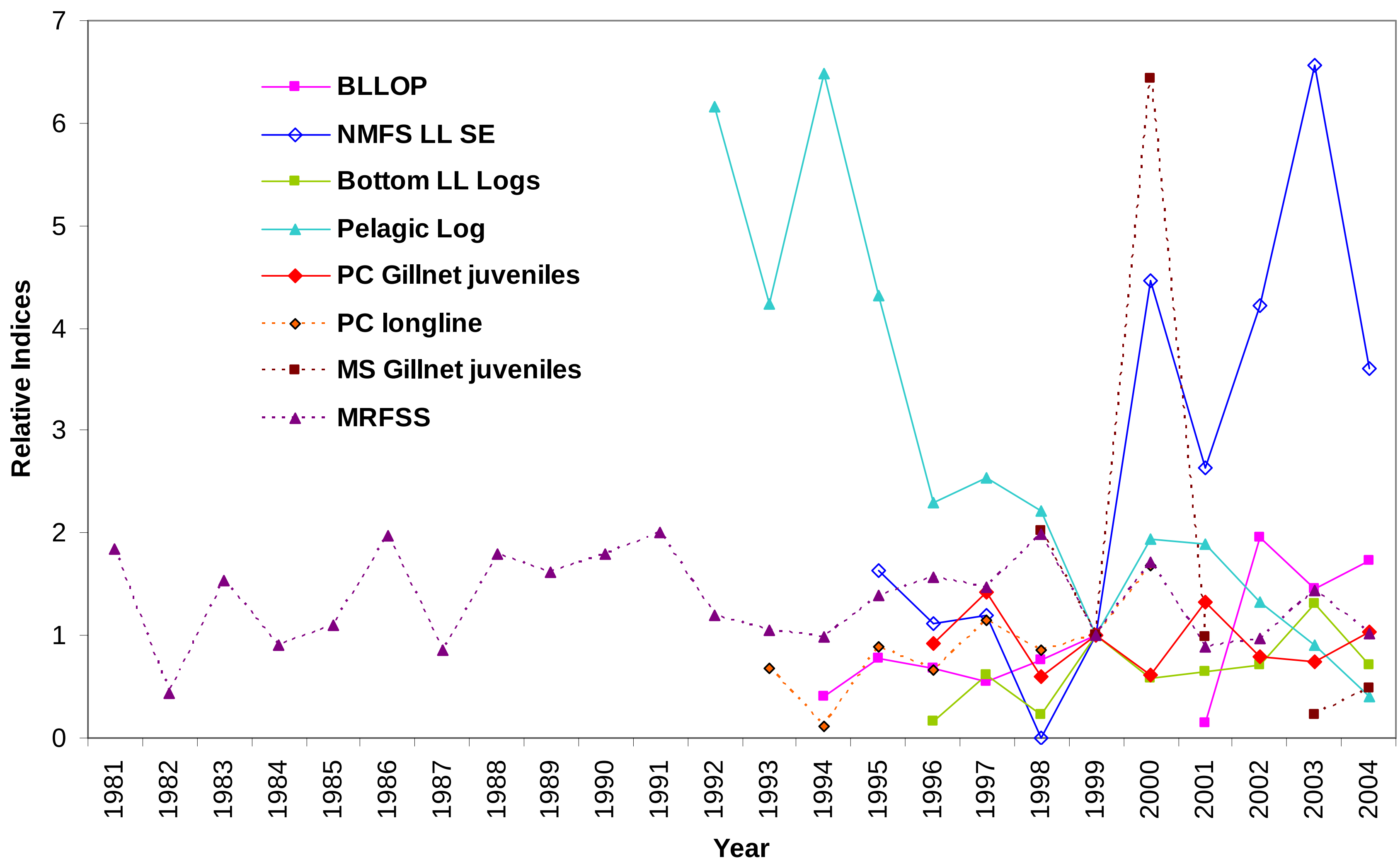


Figure 5.2 Indices available for the current Gulf of Mexico blacktip shark assessment. Indices are scaled by the value for 1998 (the only year of overlap).

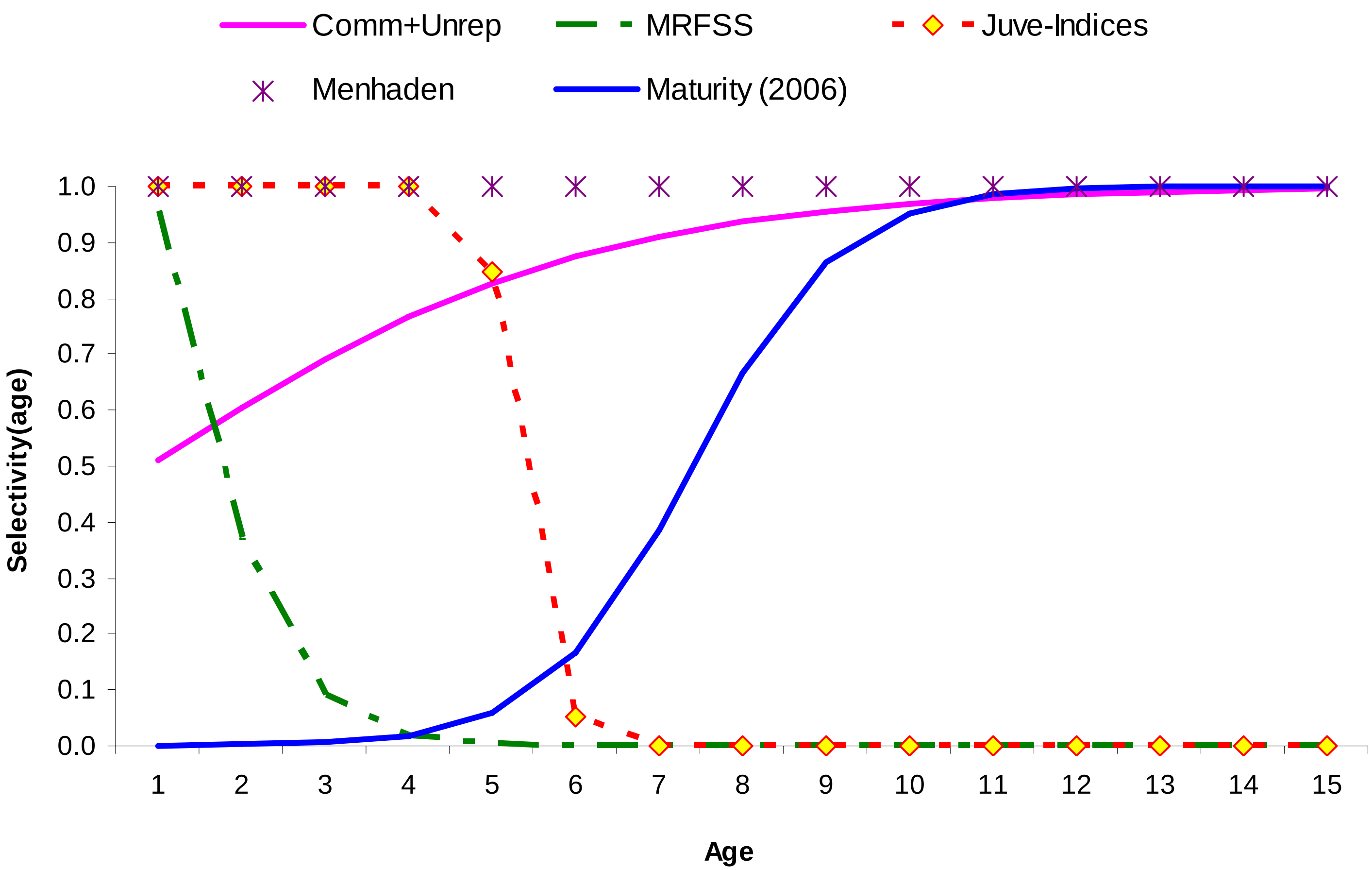


Figure 5.3 Selectivities used in blacktip Gulf of Mexico assessment, with the maturity ogive (solid blue line) as decided at the data workshop. Labels are with the last row in Table 5.3 (all indices available for Gulf of Mexico blacktip).

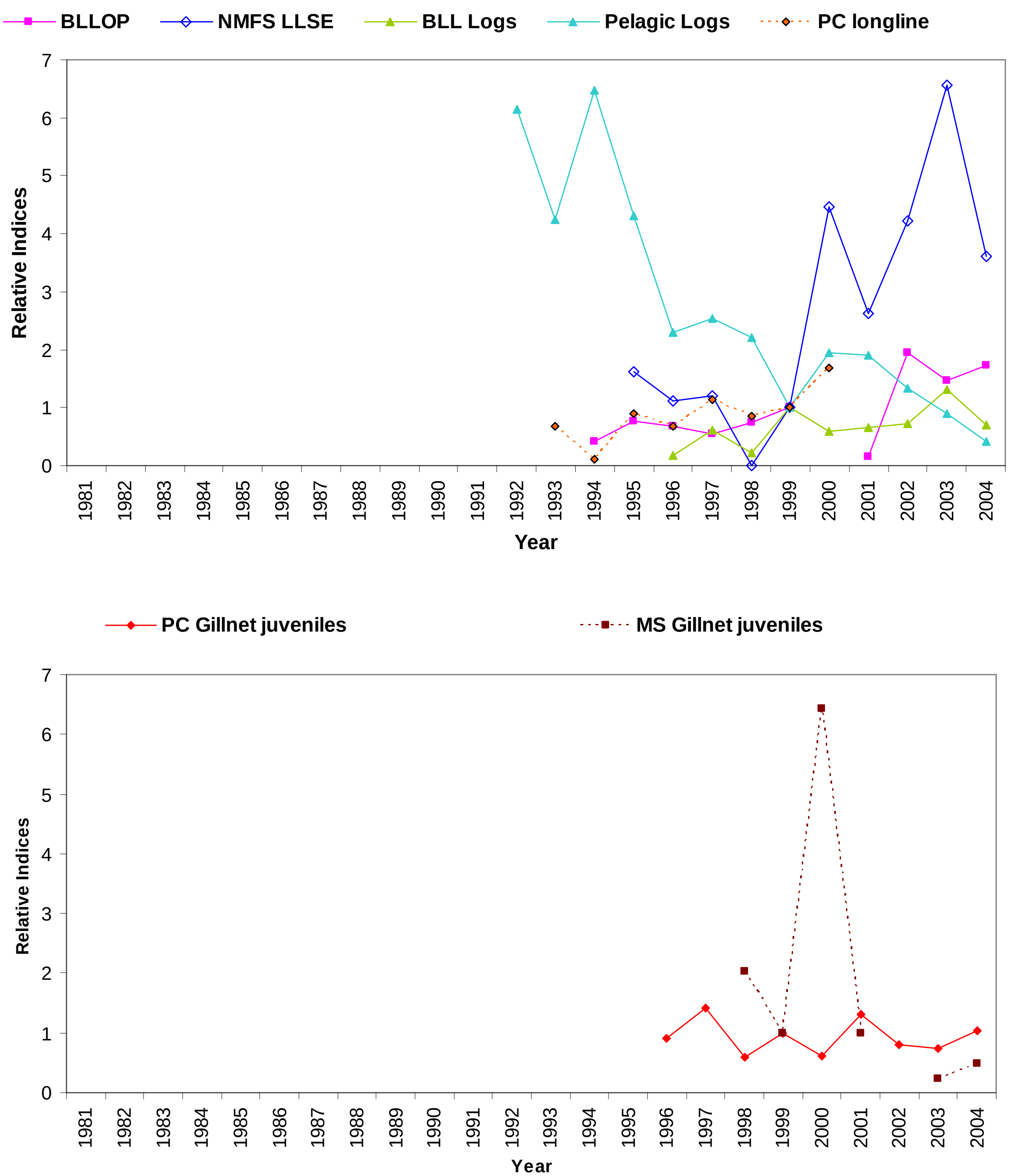


Figure 5.4. Indices with the same selectivity for Gulf of Mexico blacktip shark. In the top, all indices have the same selectivity as the commercial fishery; in the bottom, all indices select for juveniles. Sensitivity indices, which were not used in the base case are: PC Longline and MS Gillnet juveniles.

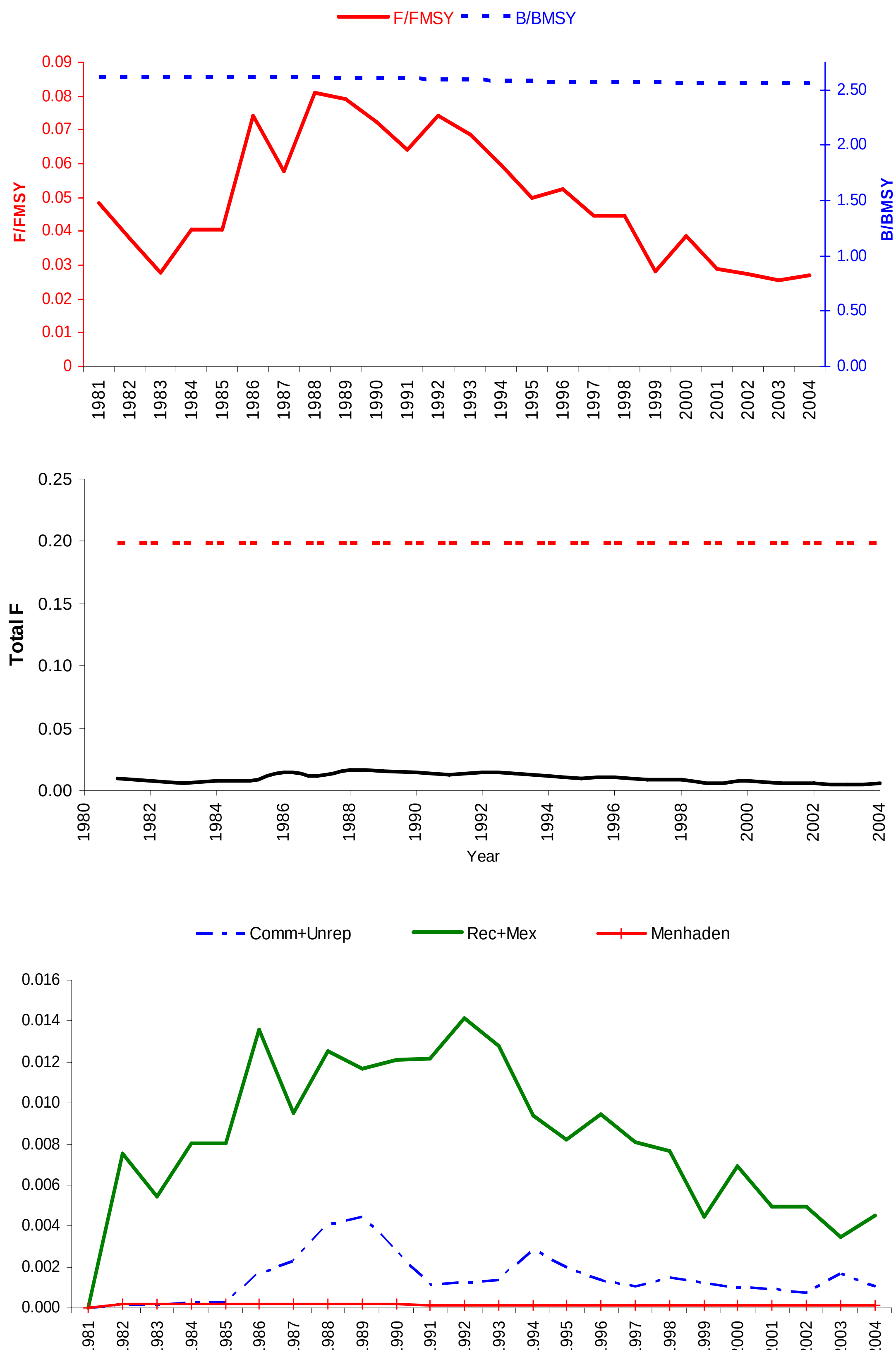
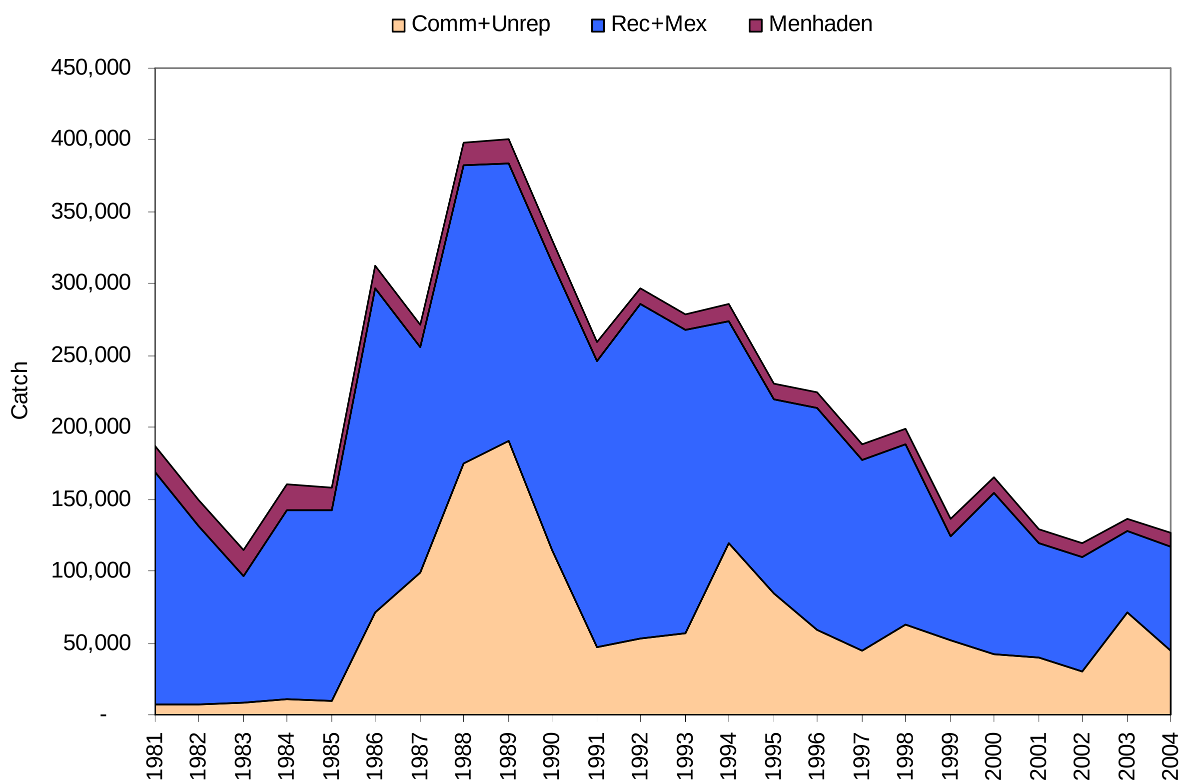


Figure 5.5. Gulf of Mexico blacktip estimated stock status (top), total fishing mortality (middle), and fleet-specific F (bottom). The dashed line in the middle panel indicates F_{MSY} (= 0.015).



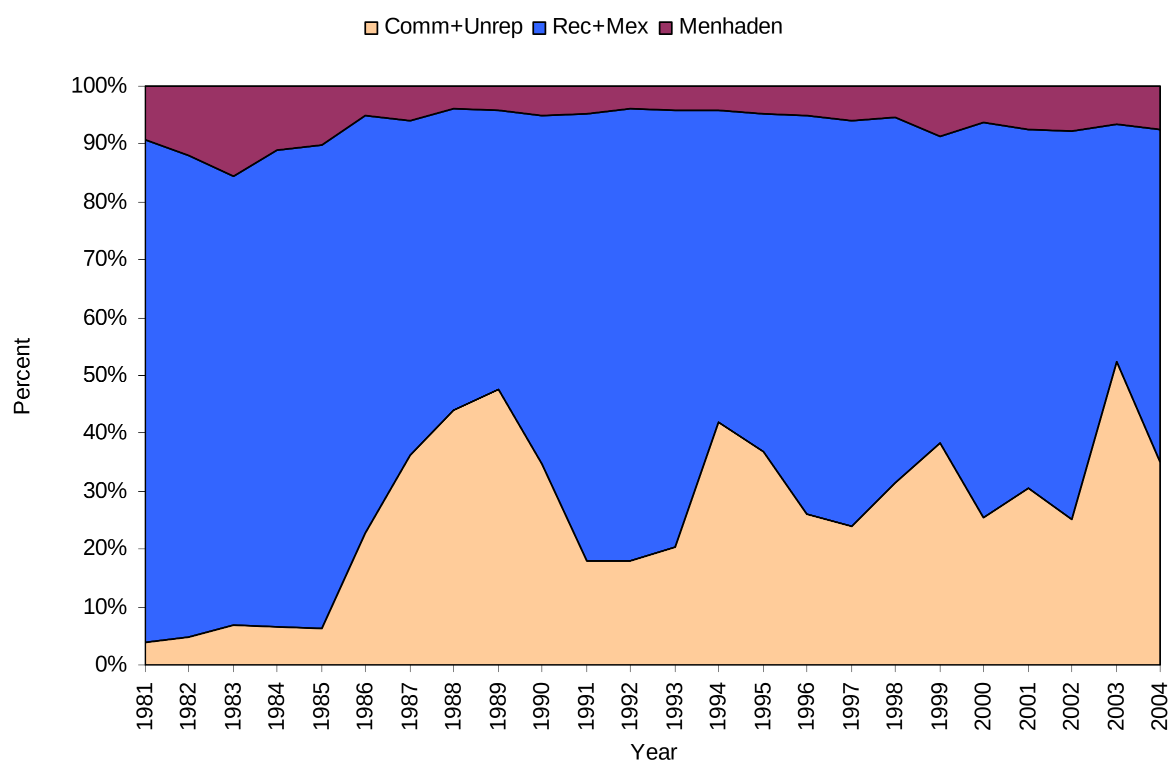


Figure 5.6. Total catch by fleet of blacktip in the Gulf of Mexico (top) and percent of total catch by fleet (bottom).

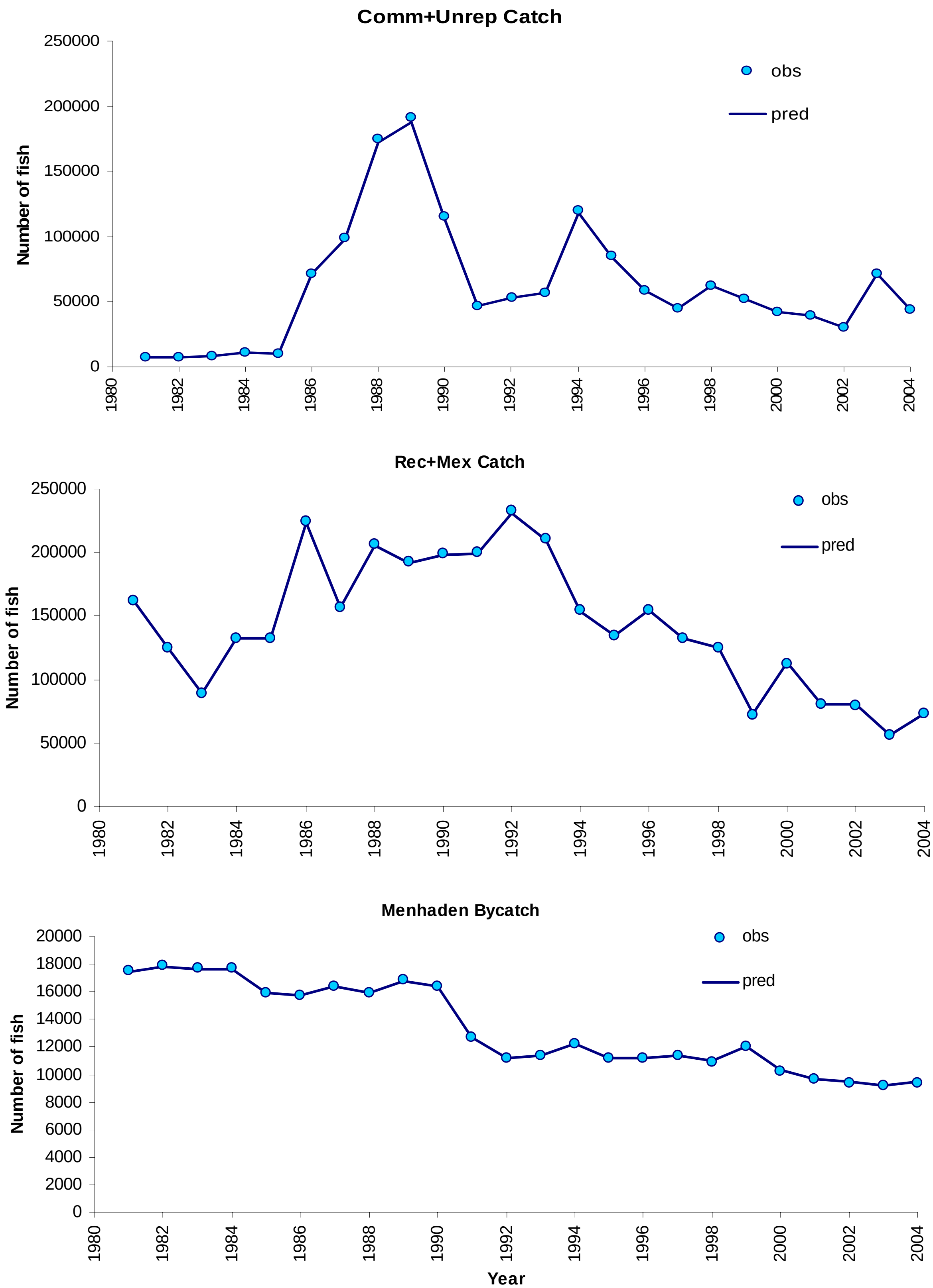


Figure 5.7. Gulf of Mexico blacktip model predicted fit to catch data. Circles represent observed data, solid line is predicted.

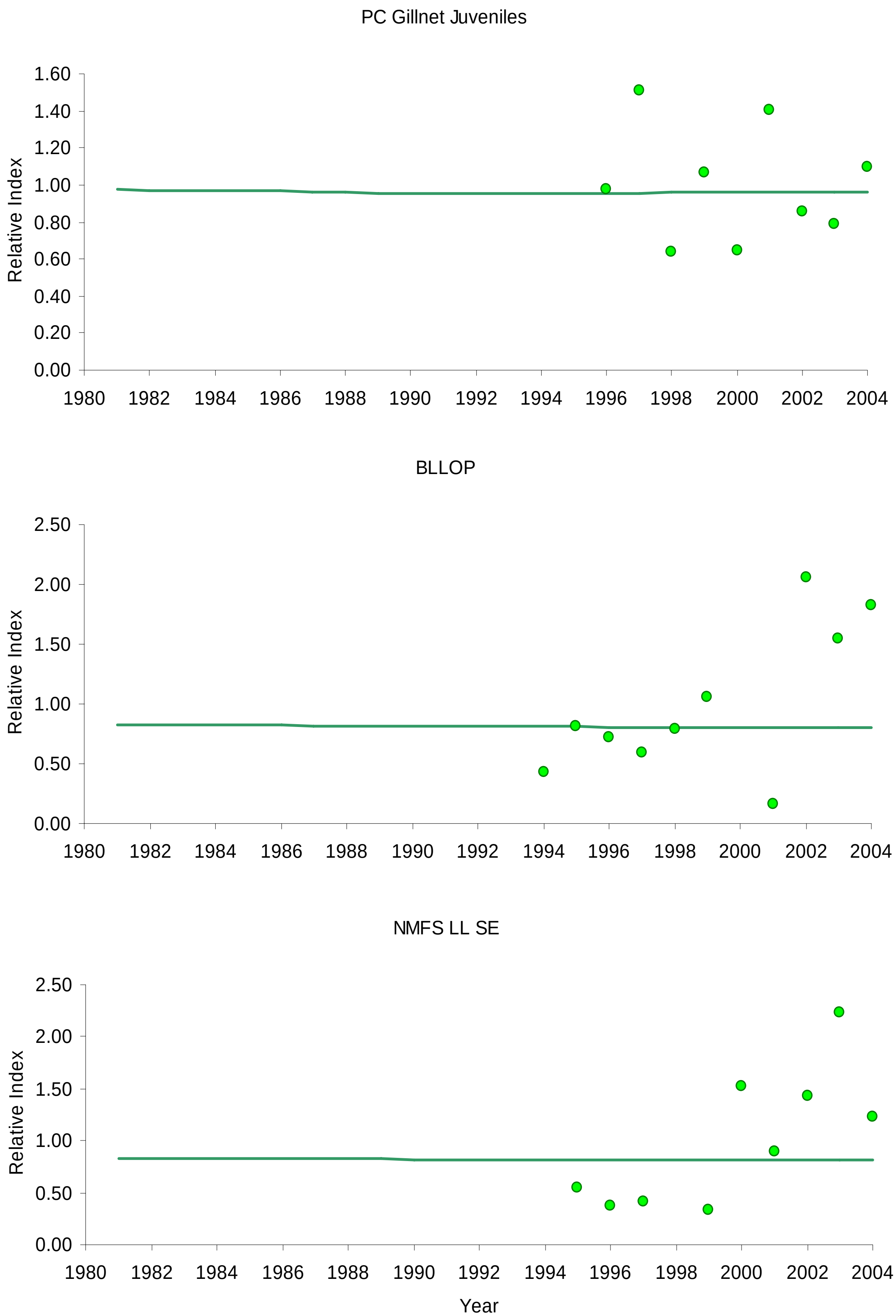
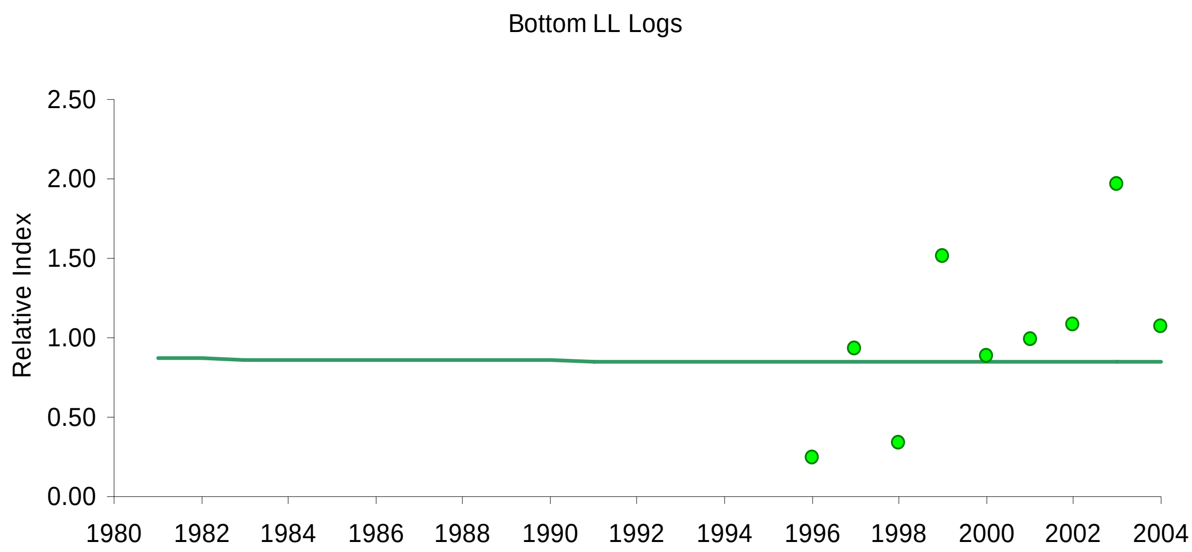


Figure 5.8. Gulf of Mexico blacktip model predicted fit to indices. Circles represent observed data, solid line is predicted.



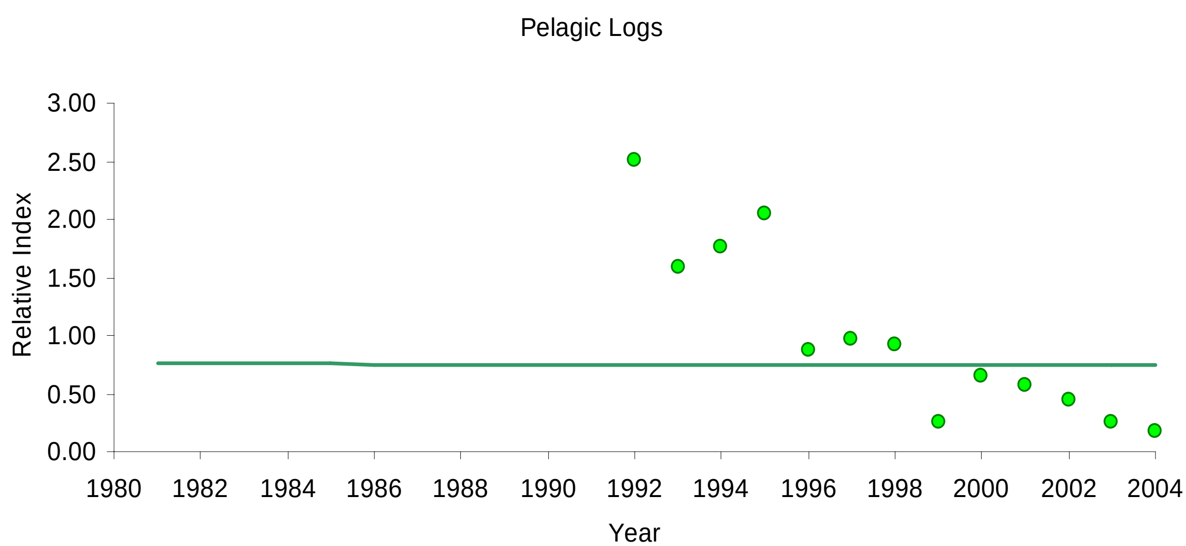


Figure 5.8. (Continued)

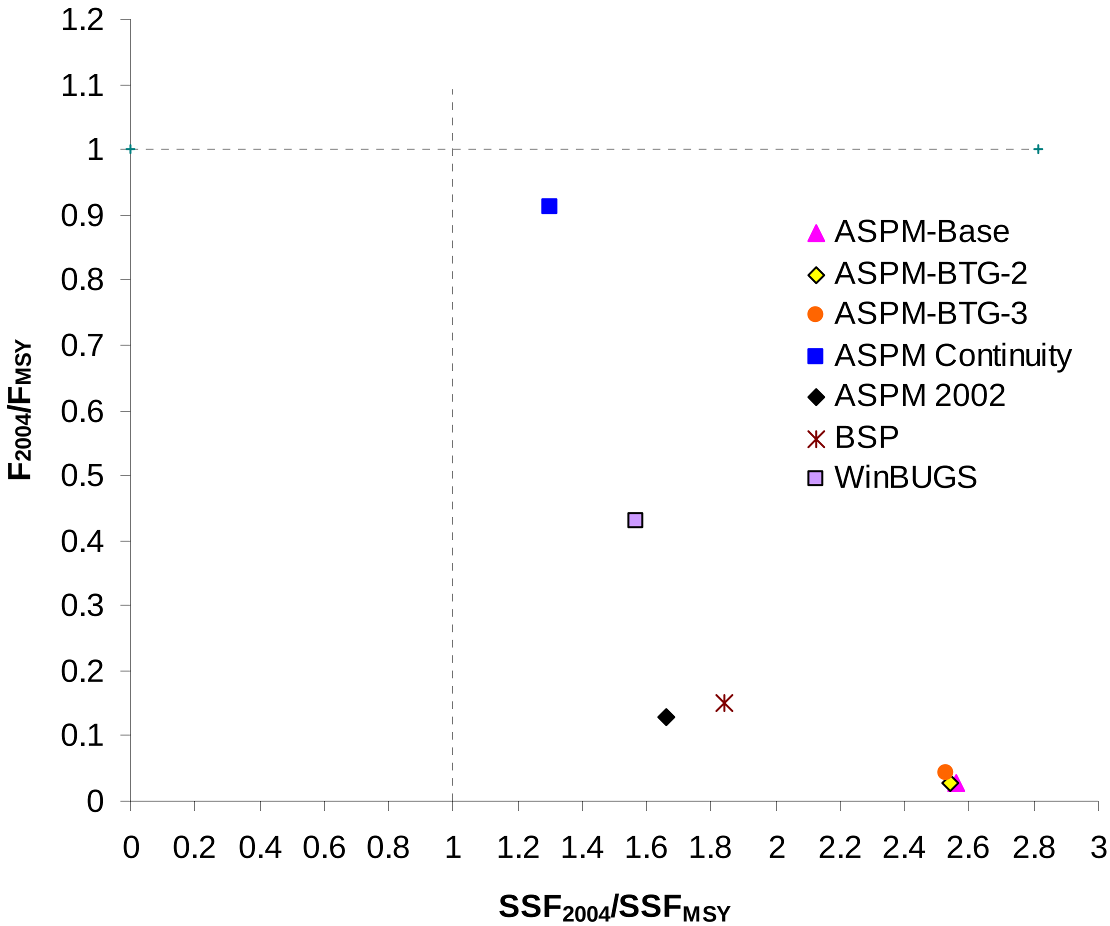
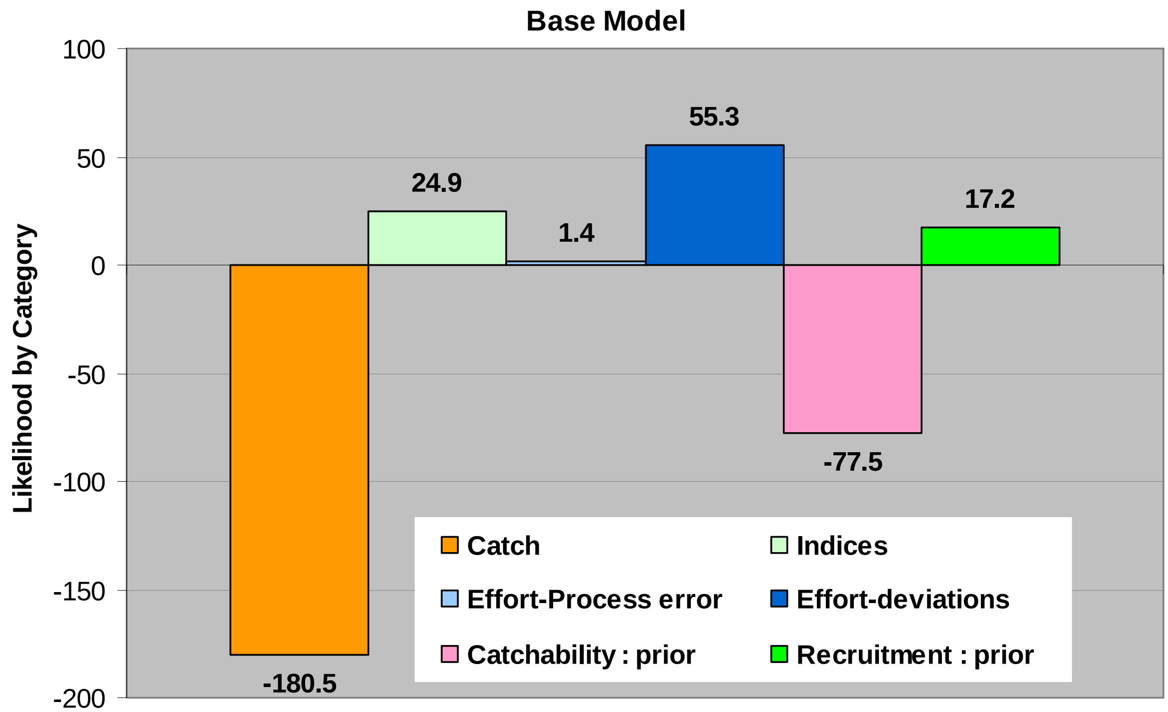


Figure 5.9. Phase-plot of stock status for Gulf of Mexico blacktip. Selected sensitivities are also included for comparison. The models include: ASPM-Base, ASPM-BTG-2 (all indices were used (5 base and 3 sensitivity indices)), ASPM-BTG-3 (same as the base case except that observations within each index were weighted by the inverse CV of each point), ASPM Continuity, ASPM 2002 (results of the 2002 blacktip single stock assessment using equal weighting), BSP (results using the Bayesian surplus production model), and WinBUGS (results using the WinBUGS SPM). See text for further details. Several control rules are illustrated: the dashed horizontal line indicates the MFMT (Maximum Fishing Mortality Threshold) and the dashed vertical line denotes the target biomass (biomass or number at MSY). Note for the BSP and WinBUGS x values denote N_{2004}/N_{MSY} rather than SSF_{2004}/SSF_{MSY}. SSF is spawning stock fecundity, which is the sum of number mature at age times pup-production at age (rather than SSB, since biomass does not influence pup production in sharks).



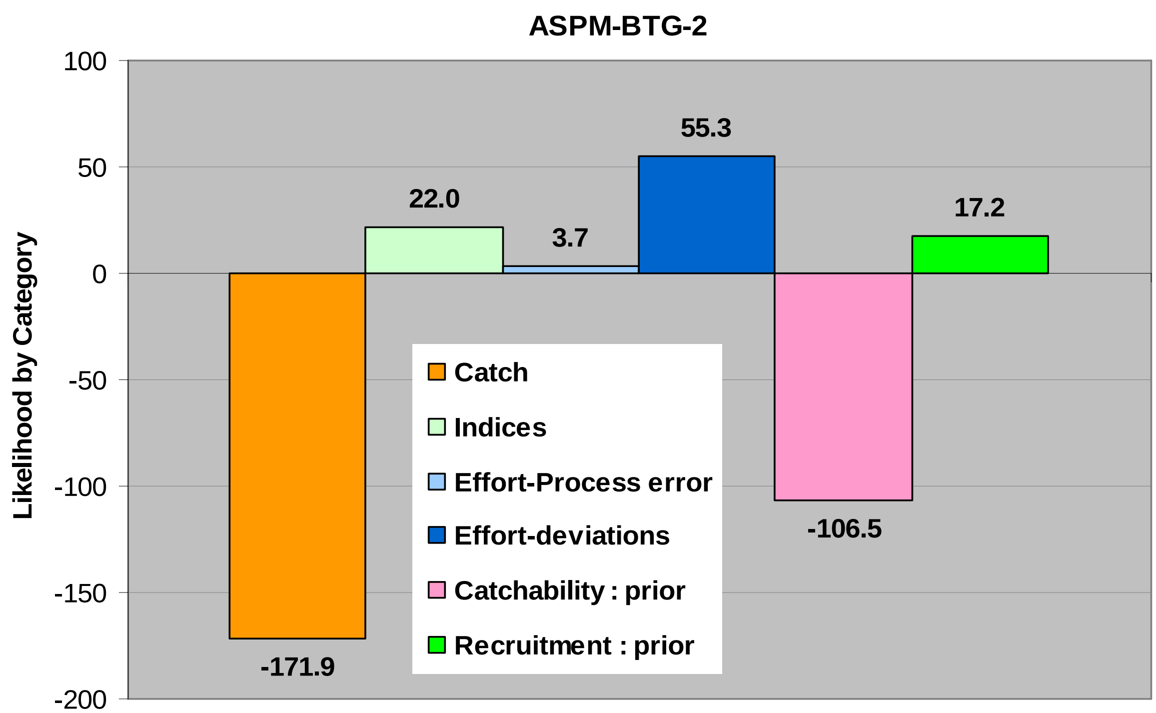


Figure 5.10. Contribution to relative likelihood by category for Gulf of Mexico blacktip sharks. The recruitment component includes both priors on virgin number of pups and pup survival.

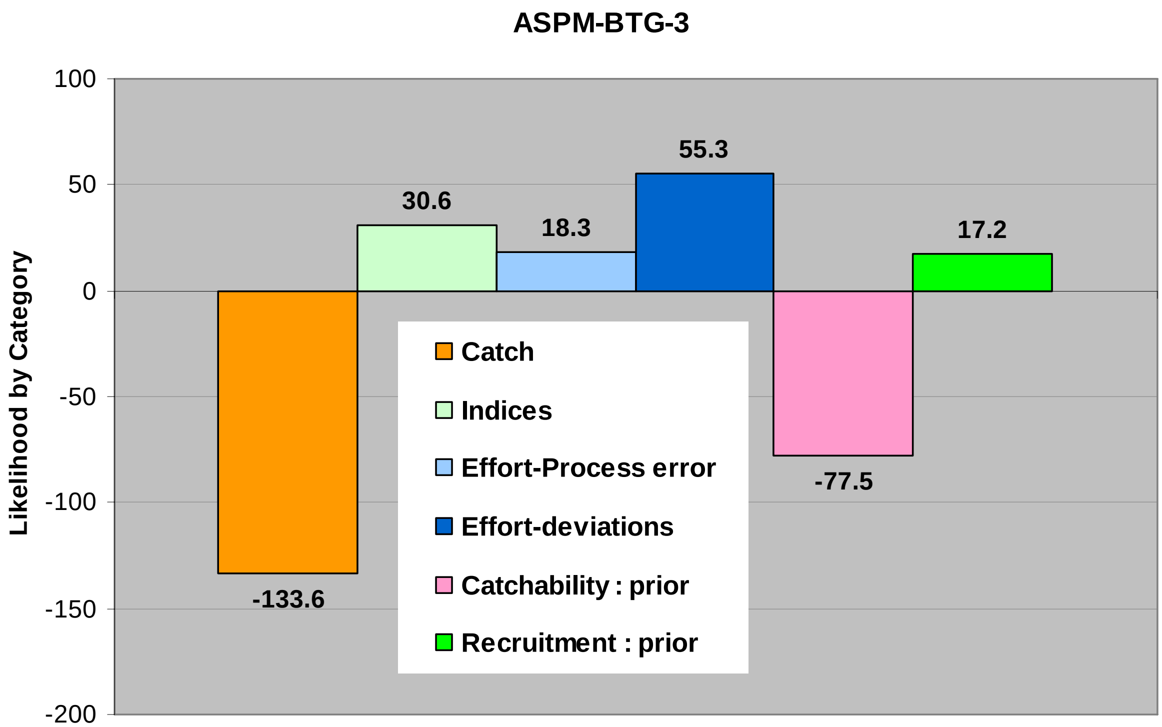
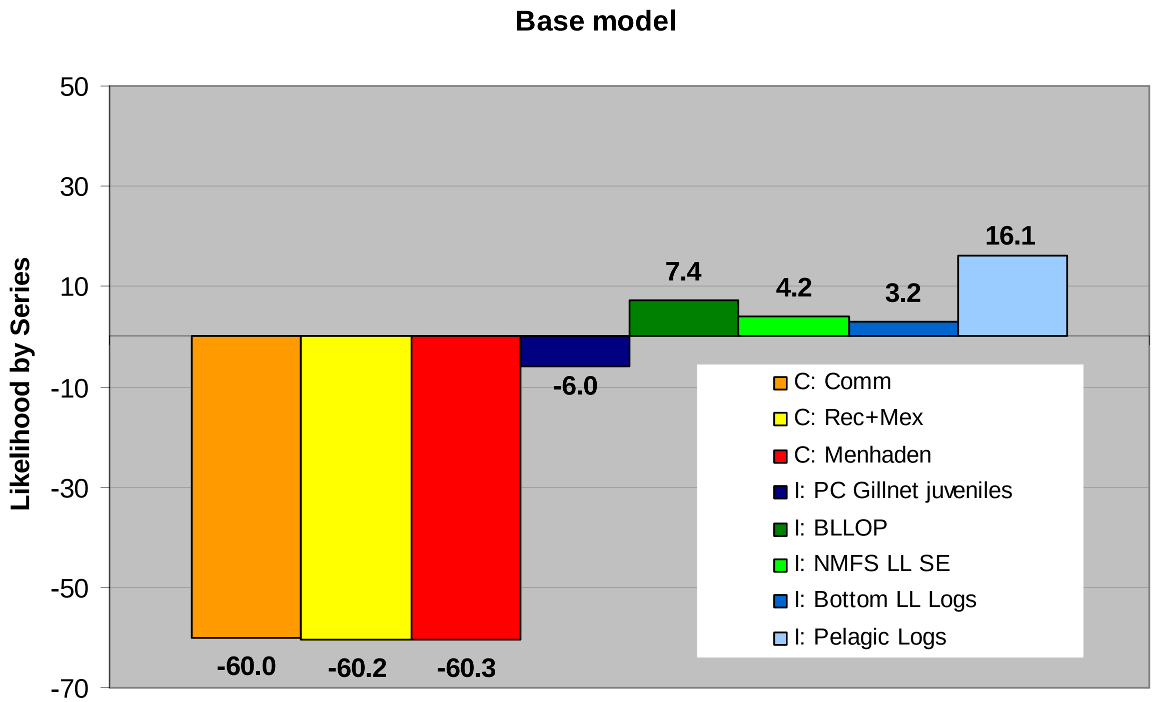


Figure 5.10 (continued)



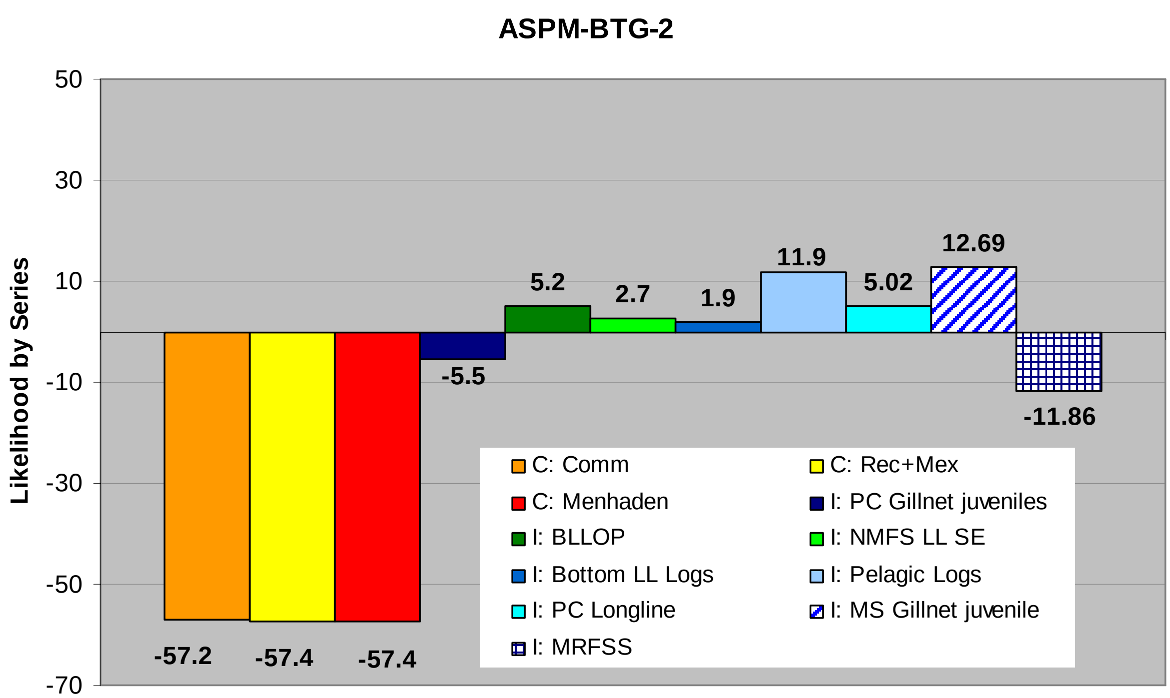


Figure 5.11. Contribution to relative likelihood by catch series and index series for Gulf of Mexico blacktip sharks.

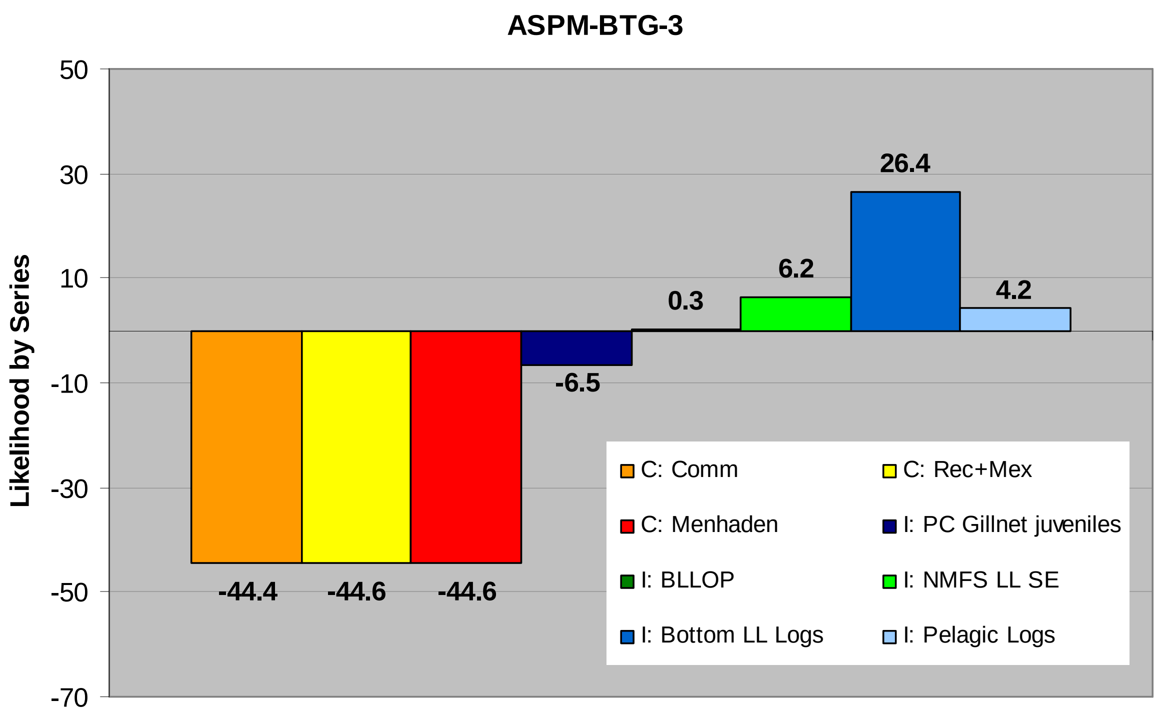


Figure 5.11 (continued)

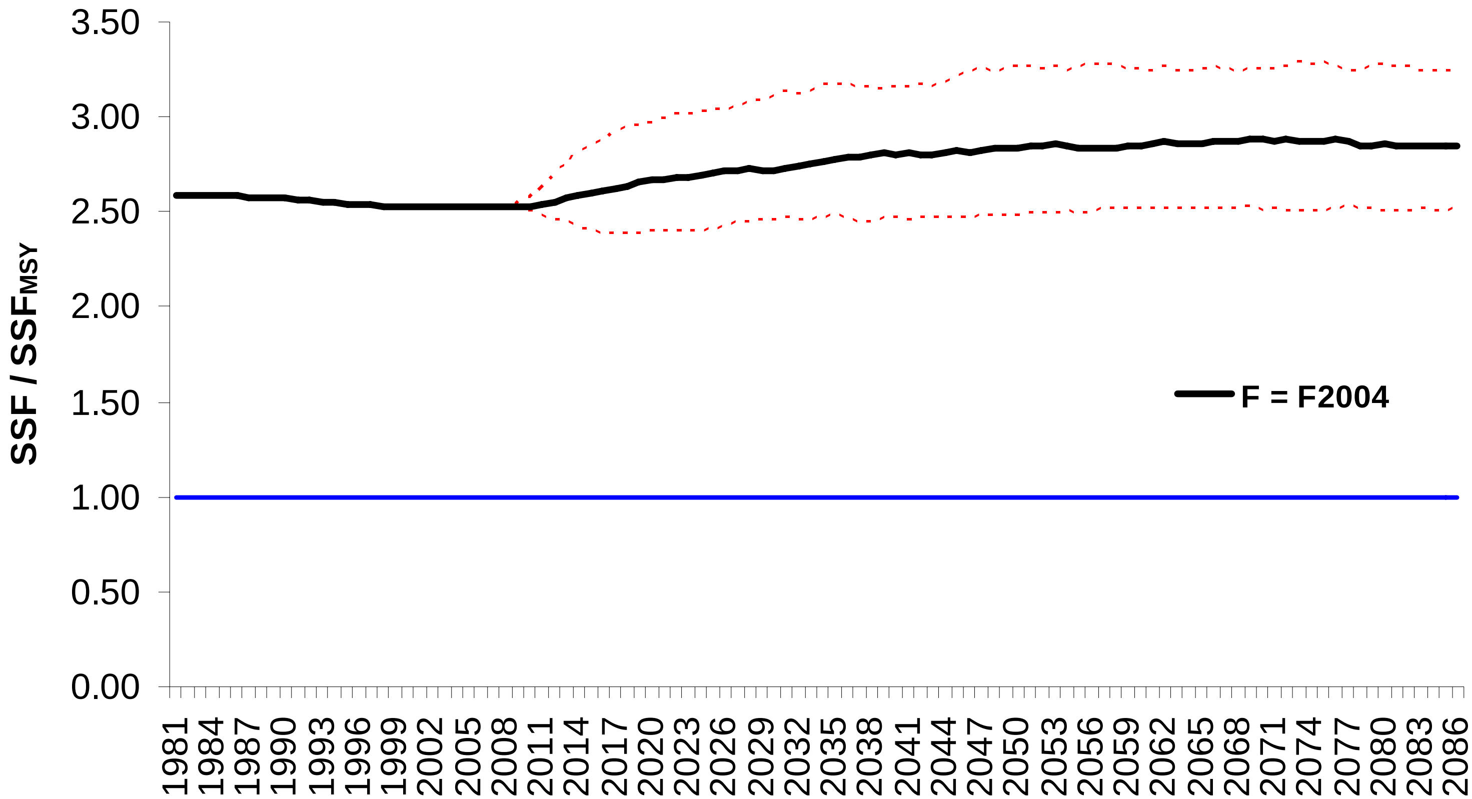


Figure 5.12. Projections at F_{2004} for Gulf of Mexico blacktip sharks. The dashed red lines represent the 10^{th} percentile (lower) and the 90^{th} percentile (upper), while the solid black line is the median of the bootstraps.

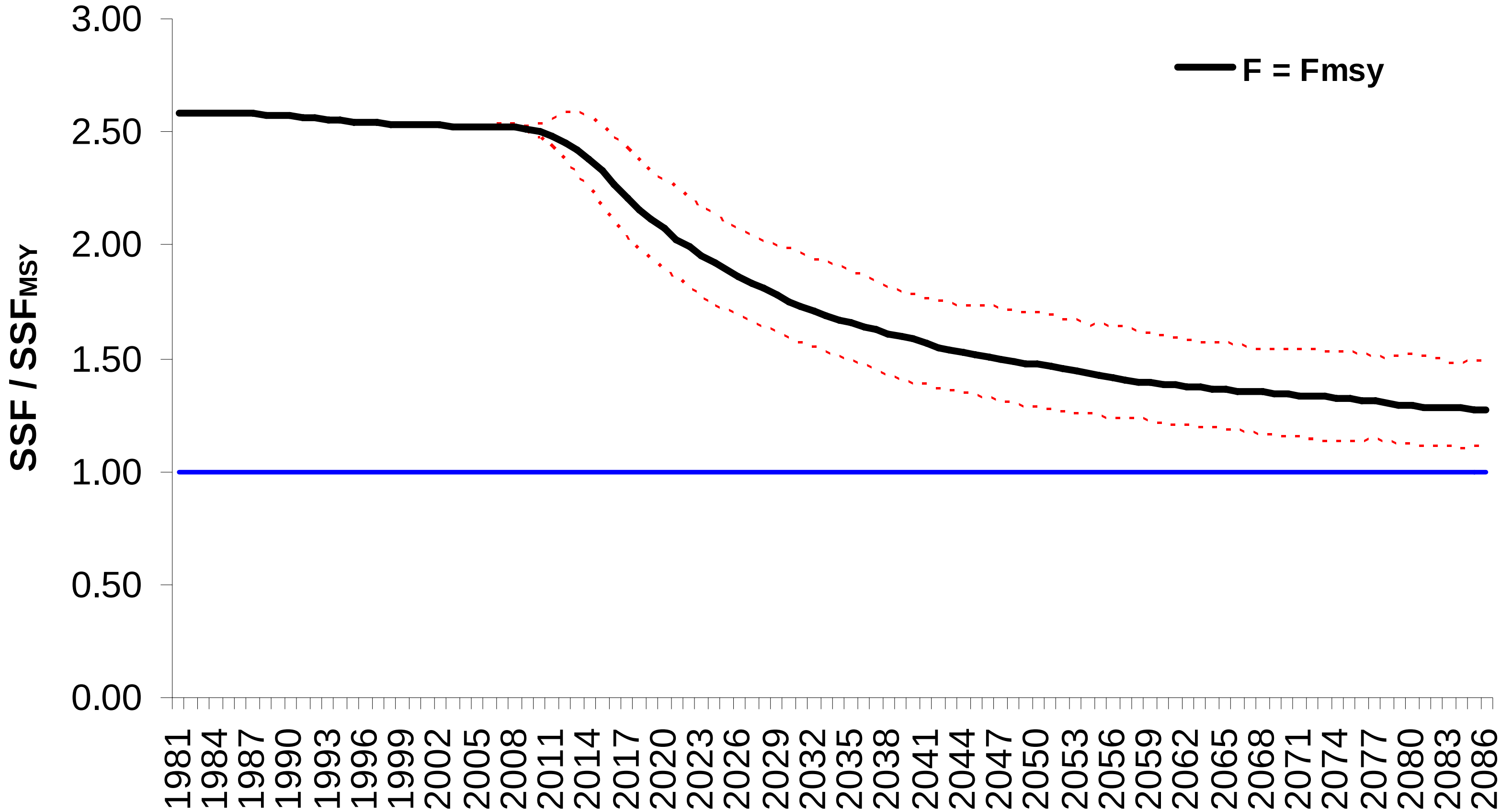


Figure 5.13. Projections at F_{MSY} for Gulf of Mexico blacktip sharks (years 2005-2007 used F_{2004}). The dashed red lines represent the 10^{th} percentile (lower) and the 90^{th} percentile (upper), while the solid black line is the median of the bootstraps.

NORTHWESTERN ATLANTIC OCEAN BLACKTIP SHARK STOCK ASSESSMENT

6. BLACKTIP SHARK NORTHWESTERN ATLANTIC OCEAN

6.1 Summary of Blacktip Shark Working Documents

SEDAR 11–AW–02
First results on the status of blacktip shark stock in the western Atlantic
Summary: The status of the stock of blacktip shark in the western North Atlantic was assessed using an age-structured population dynamics model in a Bayesian statistical framework. The model was run under different assumptions about key biological parameters, such as pup survival at low population densities and combination of CPUE series. There were several problems with the convergence of the model under most of the scenarios considered when the input data adopted in the data preparation workshop were used. For this reason, some changes were made in the input data after discussion during the stock assessment workshop. The results with the updated set of input values are presented here.

SEDAR 11–AW–04
Preliminary Runs of a State-Space, Age-Structured Production Model for Blacktip Shark
Summary: An age-structured production model was used to assess blacktip shark, the same that was used in the 2002 assessment. A continuity run was made using the 2002 assessment decisions about biology and stock structure. Base models for the 2006 assessment were then run for the Gulf of Mexico and the Atlantic Ocean separately, using decisions made at the data workshop. All runs reached the same conclusion that the stock is not overfished nor, for the most recent years, is overfishing occurring. A number of adjustments to biological inputs were necessary to achieve model convergence, and this point warrants further discussion at the assessment workshop.

SEDAR11-AW-05
Assessment of Large Coastal, Blacktip, and Sandbar Sharks using Surplus Production Methods
We used two complementary surplus production models (BSP and WinBUGS) to assess the status of three Large Coastal Shark (LCS) groupings, two stocks of blacktip shark, and a single stock of sandbar shark identified as baseline scenarios in the LCS Data Workshop report. Both methodologies use Bayesian inference to estimate stock status, and the BSP further performs Bayesian decision analysis to examine the sustainability of various levels of future catch. Extensive sensitivity analyses were performed with the BSP model to assess the effect of different assumptions on CPUE indices and weighting methods, catches, intrinsic rates of increase, initial depletion, and importance function on results. Baseline scenarios for the three LCS groupings considered predicted that the stock status is not overfished nor overfishing is occurring. Using the inverse variance method to weight the CPUE data changed the predictions on stock status for the LCS grouping, which would then be overfished, with overfishing occurring. The sandbar shark stock was estimated to be significantly depleted (64-71% depletion from virgin level). The Gulf of Mexico blacktip shark stock was healthy (depletion of only 8-23% of virgin level), whereas results for the Atlantic blacktip shark stock from the BSP and WinBUGS models conflicted. The BSP model predicted a considerable level of depletion for this stock regardless of the CPUE weighting method used. In contrast, the assessment of a single blacktip shark stock (GOM+ATL) resulted in very consistent results, with all models predicting a healthy status (depletions of only 10-16% of virgin level). Using the

higher values of r from the 2002 SEW or accounting for some depletion from virgin levels in the first year of the model did not affect conclusions. Several assumptions on catches (notably changing the high value of recreational catch in 1983) also had no effect on conclusions. Removing the VIMS CPUE series from the LCS scenario reversed the conclusions on stock status when using inverse variance weighting, highlighting the influence of this series on results; removing the PELAGIC LOG CPUE series from the ATL blacktip shark analysis also drastically reversed the conclusions on stock status. Fitting one CPUE series at a time had a larger effect on results: the PELAGIC LOG series greatly influenced conclusions for the three LCS groupings and GOM and ATL blacktip shark, whereas the VIMS series affected conclusions on the two groups for which it is available, LCS and sandbar shark.

6.2 Background

Blacktip and sandbar sharks are the two most important species in the fishery, and have been the subjects of species specific assessments in the past conducted through Shark Evaluation Workshops (SEWs). As such, the Panel was tasked with conducting species specific assessments for these species. The Data Workshop determined catch histories, relative abundance indices, and biological input parameters for three assessments: one stock of sandbar sharks and two stocks of blacktip sharks, one for the Gulf of Mexico and one for the northwestern Atlantic Ocean.

6.3 Available Models

Four models were available for discussion for the northwestern Atlantic Ocean blacktip shark assessment: two surplus production models, the BSP and WinBUGS models described previously, and two age-structured production approaches (Apostolaki et al. in press, Porch 2002).

6.4 Details about surplus production model and age-structured model

A surplus production model simulates the dynamics of a population using total population biomass as the parameter that reflects changes in population size relative to its virgin condition. In comparison to more complicated models, the surplus production model is simpler in its formulation, takes less time to run and requires less input information. However, due to its formulation, the surplus production model does not describe changes that occur in subgroups of the population (adults, juveniles, etc). In addition, the sensitivity of model predictions to key stage-dependent biological parameters cannot be evaluated using a surplus production model. Finally, surplus production models are not able to incorporate a lag time into the results.

An age-structured population dynamics model describes the dynamics of each age class in the population separately and therefore, requires age-specific input information. Due to the higher complexity of these models, they usually take longer to run and require a higher volume of information relative to simpler models. However, they can account for age-dependent differences in biology, dynamics and exploitation of fish and provide an insight into the structure of the population and the processes that are more important at different life stages. They also allow for the incorporation of age-specific selectivity information.

With regard to management benchmarks, the surplus production model assumes that the population biomass that corresponds to MSY is always equal to half of the virgin population biomass, whereas the relative biomass at MSY calculated with an age-structured model (and other benchmarks associated to it) is species-specific and could be any fraction of virgin biomass.

The Assessment Panel decided to use the state-space, age-structured production model described in document SEDAR11-AW-04 for blacktip sharks in the northwestern Atlantic Ocean. This model was selected as it allowed for the incorporation of age-specific biological and selectivity information, along with the ability to produce required management benchmarks.

6.5 Discussion of weighting methods

The Data Workshop recommended that *equal weighting* for assigning weights to the different CPUE time series available during model fitting should be used for the baseline runs. The panel discussed the advantages and disadvantages of the *equal weighting* vs. the *inverse CV weighting* methods:

Equal weighting ignores the better quality of some data (smaller CVs) but is more stable between assessments because yearly changes on CVs in a given CPUE series do not affect the importance of that time series for the overall fit.

Inverse CV weighting can provide better precision as it tracks individual indices however, it could be less stable between assessments due to changes on the relative 'noise' of each time series. This method may also not be appropriate in cases in which different standardization techniques have been used for the standardization of the series and therefore, the same value of CV might reflect different levels of error depending on the CPUE it corresponds to.

It was requested by one Panelist to manually weight the indices that cover larger geographic areas to have a stronger influence on the model. The group commented that, while that may be possible in a spatially explicit model, a great deal more data would be required than presently available.

The Assessment Panel decided that equal weighting would be the default weighting method for the current assessment but noted that, as there is at present no objective way to decide which of these two methods is superior other than comparing model convergence diagnostics, future assessments may need to reexamine this issue.

6.6 New biological parameters derived during the assessment workshop

As discussed in SEDAR 11-AW-10, the values for life-history parameters that the data workshop determined to be the best estimates did not produce viable estimates for steepness (steepness was <0.2 for all stocks). The group reviewed the inputs that produce steepness (pup-survival, M at age for ages 1+, maturity at age, and pup-production at age), and determined that pup-production and estimates of maturity should be known with greater certainty than estimates of mortality or pup survival. Therefore, in order to satisfy the lower bound on steepness, and to meet the data workshop recommendation that steepness should be between 0.2-0.4, the mode of the lognormal prior for pup survival was increased to 0.75 with a CV of 0.3. In addition, survival was increased by 10% for ages 1+ for the Gulf of Mexico stock, and by 7% for the Atlantic stock. The data workshop values for M at age as well as the values derived in plenary at the assessment workshop are given in Tables 6.1a and b, and plotted in Figure 6.1. Note that in the 2002 assessment, the same problem was encountered with the lower limit of steepness. In 2002, the base parameter values gave a steepness of about 0.18, so pup production was increased from 3.85 to 10, achieving a steepness of about 0.37. As noted in the 2002 report (p. 24), increasing the fixed level of pup production implies either that there is an unexploited portion of the population that is contributing pups, or that the pups are recruiting from a different population altogether (basically an open population model).

6.7 Methods

6.7.1 State-space, age-structured production model description

It was decided at the assessment workshop that the age-structured production model (SEDAR11-AW-04) would be used as the base model for the 2006 assessment. For northwestern Atlantic Ocean blacktip sharks, catches and one index begin in 1981, with the remaining indices beginning in the 1990s. No attempt was made to impute catches prior to the observed values in 1981. The model adopted derives equilibrium N at age for the first model year by estimating a level of historic fishing (F_{hist}). A historic selectivity vector is specified by the user, which is multiplied by F_{hist} to arrive at the historic age-specific fishing mortality rate. A historic selectivity vector of 1 for all ages was assumed.

Population Dynamics

The dynamics of the model are described below, and are extracted (and/or modified) from Porch (2002). This model formulation was the same utilized in the 2002 blacktip shark assessment. A value of historic fishing mortality, F_{hist}, can be estimated or fixed by the user. If F_{hist} is fixed at 0, then this implies that the population begins at virgin conditions. If F_{hist} is estimated or fixed to a value greater than 0, then the population begins in equilibrium at that level of F_{hist}. Given a vector of vulnerability at age for this level of historic fishing, $v_{hist,a}$, then the initial population structure is given by

$$(1)\qquad N_{a,y=1,m=1} = \begin{cases} R_{F_{hist}} & a = 1 \\ R_{F_{hist}} \exp(-\sum_{j=1}^{a-1}(M_j + F_{hist} v_{hist,j}) & 1 < a < A \\ \dfrac{R_{F_{hist}} \exp(-\sum_{j=1}^{A-1}(M_j + F_{hist} v_{hist,j})}{1 - \exp(-M_A - F_{hist} v_{hist,A})} & a = A \end{cases},$$

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.

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

$$(2) \qquad R = \frac{R_0 S\alpha}{S_0 + (\alpha - 1)S} \quad .$$

In (2), R_0 and S_0 are virgin number of recruits (age-1 pups) and spawners (units are number of mature adult females times pup production at age), respectively. The parameter α is calculated as:

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

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).

At equilibrium, spawners per recruit with fishing is simply:

$$(4) \qquad \varphi_F = \left[\left(\sum_{a=1}^{A-1} p_a m_a \prod_{j=1}^{a-1} e^{-M_a - Fv_a}\right) + \frac{p_A m_A}{1-e^{-M_A - Fv_A}} e^{-M_A - Fv_A}\right] = \frac{S_F}{R_F} \quad ,$$

where R_F and S_F are the equilibrium recruits and spawners, respectively, F is the level of fishing, and v_a is the age-specific vulnerability to fishing. From (4) and (2), we have

$$(5) \qquad R_F = \frac{S_F}{\varphi_F} = \frac{R_0 S_F \alpha}{S_0 + (\alpha - 1)S_F} \quad .$$

Equation (5) can be solved for S_F, and then R_F is simply S_F/φ_F, which allows calculation of the initial number of pups under a non-zero amount of historic fishing:

$$(6) \qquad R_{F_{hist}} = \frac{R_0 \alpha \varphi_F - S_0}{(\alpha - 1)\varphi_F} \quad .$$

Note that if F_{hist} is positive, then in order for $R_{F_{hist}}$ to be positive, we must have the following condition:

$$(7) \qquad \alpha > \frac{S_0}{R_0 \varphi_{F_{hist}}} = \frac{\varphi_0}{\varphi_{F_{hist}}} \quad or \quad \frac{1}{\alpha} < \frac{\varphi_{F_{hist}}}{\varphi_0} \qquad .$$

Effectively, condition (7) implies that the level of SPR corresponding to F_{hist} must be greater than 1/ α. For populations where α is near the lower bound of 1, this implies that the level of F_{hist} must be minimal.

Beyond the initial numbers in each age class as defined in (1), abundance at the beginning of subsequent months is calculated by

$$(8) \qquad N_{a,y,m+1} = N_{a,y,m} e^{-M_a \delta} - \sum_i C_{a,y,m,i} \qquad ,$$

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 at the end of the month, after natural mortality:

$$(9) \qquad C_{a,y,m,i} = F_{a,y,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad ,$$

where τ_i is the duration of the fishing season for fleet i. Catch in weight is computed by multiplying (9) 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:

$$(10) \qquad F_{a,y,i} = q_{y,i} f_{y,i} v_{a,i} \qquad .$$

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. For this model application to blacktip sharks, both vulnerability and catchability were assumed to be constant over years.

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:

(11) $$I_{y,m,i} = q_{y,i} \sum_a v_{a,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad .$$

Equation (11) provides an index in numbers; the corresponding CPUE in weight is computed by multiplying $v_{a,i}$ in (11) by $w_{a,y}$.

State space implementation

Process errors in the state variables and observation errors in the data variables can be modeled as a first-order autoregressive model:

(12) $$\begin{aligned} g_{t+1} &= E[g_{t+1}] e^{\varepsilon_{t+1}} \\ \varepsilon_{t+1} &= \rho \varepsilon_t + \eta_{t+1} \end{aligned} \quad .$$

In (12), g is a given state or observation variable, η is a normal-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.

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

(13a) $$\sigma_g = \ln\left[(\lambda_g CV)^2 + 1 \right]$$

(13b) $$\sigma_g = \ln\left[(\omega_{i,y} \lambda_g CV)^2 + 1 \right] \quad .$$

The term λ_g is a variable-specific multiplier of the overall model CV. For catch series and indices (equation 13b), the additional term, $\omega_{i,y}$, is the weight applied to individual points within those series. For instance, because the indices are standardized external to the model, the estimated variance of points within each series is available and could be used to weight the model fit. Given the data workshop decision to use equal weighting between indices, all $\omega_{i,y}$ were fixed to 1.0 and the same λ_g was applied to all indices. To evaluate the sensitivity case where indices were weighted by the inverse of their CV, each $\omega_{i,y}$ was fixed to the estimated CV for point *y* in series *i*; an attempt was also made to estimate a separate λ_g for each series, however those multipliers were not estimable and so a single λ was applied to all indices.

In the present model, these multipliers on catches and indices were fixed after exploring the effects on model outputs for several different values. A fleet-specific effort constant was estimated, but by allowing for large process error it was effectively a free parameter (a value of 10 times the overall model CV was used); the correlation was fixed at 0.

6.7.2 Data inputs, prior probability distributions, and performance indicators

Baseline scenario (ASPM-BASE)

The base model represented the decisions made by the data workshop as well as any additional decisions or modifications made by the assessment workshop. Data inputted to the model included maturity at age, fecundity at age (pups per mature female), spawning season, catches, indices, and selectivity functions (Tables 6.1a and b, 6.2, and 6.3; Figures 6.1-6.4). Catches were made by the commercial and the recreational sector. In addition, estimates of unreported commercial catches were provided by the DW. Unlike the sandbar and Atlantic blacktip stocks, there were no menhaden discards, and no Mexican catches. Because of similar selectivity functions, the commercial and unreported catches were combined, yielding a model with 2 distinct "fleets". A total of 7 indices for the Atlantic were available; one of these included age 0. As this model began with age class 1, none of the indices designated as sampling "age 0" were used. This left 4 indices for the base case, and 2 sensitivity indices (Figure 6.2).

Selectivities are imputed in the age-structured surplus production model (as a functional form) and linked to each individual catch or CPUE series. Individual selectivity functions to be applied to catch series were identified by the DW catch working group based on information used in previous assessments, length frequency data presented at the DW, and the collective knowledge of shark fisheries of the group members. The selectivity recommendations can be found on pages 38-39 of the DW report. Selectivities linked to individual catch series were a compromise because the series often encompass various components of the fishery (e.g., commercial + unreported selectivity refers to commercial fisheries, most of which are bottom longline fisheries, but also include pelagic longline and drift gillnet fisheries, which are likely to have somewhat different selectivity patterns). The selectivity functions identified were then applied to the individual CPUE series based on the type of index represented (e.g., the BLLOP and VA LL indices were assigned the commercial + unreported logistic selectivity function because both indices use bottom longline gear).

-Commercial landings + unreported catch series: a logistic curve was selected based on the 2002 SEW assessment. The rationale was that younger ages were relatively less selected by the commercial gear as a whole, which as stated above may also include pelagic longline gear that is set in deeper waters where juveniles are less available, and drift gillnet gear that uses large mesh sizes targeting adults (Figure 6.3)

-Recreational: this selectivity pattern was largely based on the MRFSS, which includes data from recreational anglers fishing in nearshore waters and targeting mostly juveniles. Based on this, very limited length-frequency information presented in document LCS05/06-DW-16, and information from the 2002 SEW assessment, selectivity for blacktip sharks was fixed at 1 for ages 0 and 1 and rapidly decreased thereafter to reflect the fact that larger and older sharks are progressively less targeted (Figure 6.3).

Catch data begin in 1981 and the earliest base case index begins in 1992 (Pelagic Logs). The base case model in 2002 attempted to estimate a level of historic F, so an attempt was made to estimate F_{hist} for the base model this time. Initial model runs found that F_{hist} was difficult to estimate or it converged to near 0. Therefore, for all runs discussed here, F_{hist} was fixed to 0, which implies that the stock was unexploited prior to 1981.

Individual points within catch and index series can be assigned different weights, based either on estimated precision or expert opinion. All points within each catch series were given the same weight; likewise, all points within each index series were given the same weight.

One further model specification was the degree to which the model-predicted values matched catches versus indices. An overall model CV is estimated (see equations 13a and 13b), and multiples (λ_g) of this overall CV can be specified separately for catches and indices (see Porch 2002). All catch series were assigned a single CV multiple, and all indices were assigned a single CV multiple (this forces equal weighting of the indices). Initially, an attempt was made to estimate these multipliers. This resulted in boundary solutions for the multipliers. In a second attempt, the multiplier for catch was fixed at 1 and the index multiplier was estimated. Again, this resulted in the index multiplier estimate at the upper bound. Several values were evaluated for the CV multiplier of indices: a value that was 1, 4, or 5 times the catch CV multiplier. A value of 1 implies the same relative certainty in catches and indices; the remaining values imply that indices are less certain than catches. In the 2002 assessment, a value of 4 was used. In this assessment, model convergence was not obtained (Hessian could not be estimated) for values of 1, or 4, but was obtained for a value of 5. The point estimates for all weighting levels tried (even those that did not converge) concluded that the stock was not overfished and that there was no overfishing. The relative status estimates displayed some spread, however, that depended on the CV multiplier. Although these reported ranges reflect results from models that did not converge, they are mentioned primarily because the index fits showed a slight downward trend rather than the flat trend for the model that actually converged. Basically, forcing the model to fit the indices as well as catch reduced the relative biomass and increased the relative F benchmark (i.e., closer to overfished and closer to overfishing). Given that there was no convergence for a value less than 5, and that this value is close to the value used in 2002, the weighting scheme selected was to fit catches 5 times better than indices. Placing less certainty in indices relative to catch is further justified when one considers the lack of a consistent signal. The base indices show flat, increasing, or decreasing trends with fairly large annual changes (Figures 6.2 and 6.4). It is likely that one reason the model runs with CV multipliers <5 did not converge is that the model could not reconcile a better fit to those conflicting indices. Of the sensitivity indices, MRFSS is the longest index (it begins in 1981), and the average trend is flat over the time period, although there are large interannual fluctuations. CV multipliers greater than 5 were not evaluated for the indices, as the model-predicted trend was already a poor fit.

Estimated model parameters were pup survival, virgin recruitment (R_0), catchabilities associated with catches and indices, and fleet-specific effort. Natural mortality at ages 1+ was fixed at the updated values (Table 6.1a), and the priors for pup survival and virgin recruitment are listed in Table 6.1b.

In summary, the base model configuration assumed virgin conditions in 1981, used the data workshop recommended biological parameters, the updated survival at age, the updated prior for pup survival, and the base case indices with an updated Pelagic Longline Log index (referred to as Pelagic Log). Catches were assumed to be 5 times more certain than the indices. All inputs are given in Tables 6.1a and b, 6.2, and 6.3. Base indices are in black font in Table 6.3.

Performance indicators included estimates of absolute population levels and fishing mortality for year 2004 (F_{2004}, SSF_{2004}, B_{2004}, $Nmature_{2004}$), population statistics at MSY (F_{MSY}, SSF_{MSY},

SPR_{MSY}), current status relative to MSY levels, and depletion estimates (current status relative to virgin levels). In addition, trajectories for F_{year}/F_{MSY} and SSF_{year}/SSF_{MSY} were plotted.

6.7.3 Methods of numerical integration, convergence diagnostics, and decision analysis

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. Model fit was assessed by comparing components of the relative negative log-likelihood (relative rather than exact because constants in the likelihood were not included). The relative negative log-likelihood (objective function) and AICc (small sample AIC) values are listed in the table of model results.

6.7.4 Sensitivity analyses

Given the assessment workshop consensus that the stock status could not be determined, no sensitivity analyses were conducted.

6.8 Results

6.8.1 Baseline scenario

The base model estimated a stock that was not overfished and there was no overfishing occurring (Tables 6.4 and 6.5; Figure 6.5). The model estimate of F by fleet is dominated by the recreational fleet in the 1980s, and to a lesser extend in the 1990s. The landings are also dominated by the recreational fleet in the1980s, by the commercial fleet for most of the 1990s, and the fleets are more or less on par in recent years (Figure 6.6). Model fits to catches and indices are shown in Figures 6.7 and 6.8. Catches are fit very well. The base indices span at most 13 years, and the model predicts a relatively flat trend through the observed points. The flat trend predicted for the indices reflects the estimated flat change in biomass over time, implying that the stock has barely changed since 1981. A CV of about 0.54 was estimated for virgin pup production, and current measures of total biomass, number mature, spawning stock fecundity (SSF), and fishing mortality. No CV is given for steepness or α as these parameters are calculated directly from pup survival and virgin spawners per recruit rather than estimated. Relative estimates of depletion (the ratio of current to virgin level) are very precise, but current abundance estimates are correlated to the estimate of the virgin level. The estimate of pup survival did not move from the prior specification, indicating that there is probably little to no information in the data from which to estimate this parameter. No likelihood profiling was pursued.

A phase-plot of stock-status shows the outcomes of the base model, the continuity analysis (assuming a single stock), the estimates from BSP and WinBUGS, and the alternative age structured production model discussed in SEDAR10-AW-02 (Figure 6.9). Note that the x values for BSP and WinBUGS are in numbers of fish (N_{2004}/N_{MSY}) rather than SSF_{2004}/SSF_{MSY}. These values from BSP and WinBUGS should be comparable, however, because they are relative statistics, and they only differ from the ASPM by the maturity ogive. The alternative age structured production model differs slightly in the relative F benchmark, as it gives the ratio of harvest rate relative to that rate at MSY. The range of outcomes spans the upper left quadrant (overfished with overfishing) and the bottom right (not overfished, with no overfishing).

6.8.2 Sensitivity analyses

No sensitivity analyses were conducted.

6.8.3 Comparison of model fits

The relative likelihood values by model source (catch, indices, effort, catchability, and recruitment) as well as a breakdown of likelihood by individual catch and index series are shown in Figure 6.10. Comparing the likelihood by index, the Bottom Longline Observer Program (BLLOP) index has the poorest fit. It is noted that the BLLOP and Bottom LL Logs have the same trend for the years of overlap (1996-2004), although interannual changes are greater for BLLOP. It is possible that the magnitude between annual changes is more pronounced in the BLLOP index as a result of smaller sample size (coverage is typically 2 -3 % of the fishery). While the likelihood for the indices other than BLLOP indicates a relatively better fit, the predicted values are nearly flat and capture no trend.

6.9 Projections of the base model

Given the uncertainty in assessment results, no projections were done. The estimate of generation time is about 18 years.

Generation time was calculated as

$$GenTime = \frac{\sum_i i f_i \prod_{j=1}^{i-1} s_j}{\sum_i f_i \prod_{j=1}^{i-1} s_j}$$

where i is age, f_i is the product of(fecundity at age) x (maturity at age), and s_j is survival at age. The calculations were carried out to an age, A, such that the difference between performing the calculation to age A or A+1 was negligible. This calculation is consistent with the assessment model, which treats survival of the plus group as the sum of a geometric series (e.g., see third line in equation 1). The 2006 maturity ogive was used, 4.4 pups per female was the fecundity for all ages, adjusted age-specific survival at age was used (see section 6.6), and the mode of 0.75 for the prior on pup survival was used. As was done in the assessment model, to account for the approximately 1 year gestation period, maturity at age was shifted by 1 year, and the number of pups was halved to account for the fact that only half of the mature population would reproduce in a given year. Note that because pup-production is constant for all ages, it factors out of both numerator and denominator, and the resulting estimate of generation time is insensitive to that value.

6.10 Continuity analysis

A continuity base model was run using the 2002 state-space age structured production model (described above under methods). In 2002, blacktip was assessed as a single stock. F_{hist} was fixed at 0, all indices were used and given equal weighting; an age-constant M was estimated; catches for Gulf of Mexico and northwestern Atlantic Ocean combined (Table 5.6); 2002 biological parameters used; 10 pups per mature female was used for fecundity. Available combined blacktip stock indices and values can be found in Appendix 1.

The continuity model estimated a stock status of no overfishing, and not overfished. This model was not truly continuity per se, because the previous assessment had treated blacktip as one stock, and different indices had been available. It also differs from the 2006 base model because the biological parameters were adjusted differently to elevate the steepness parameter above 0.2. Nevertheless, the estimate of stock status in 2002, in this continuity analysis, and in the 2006 base model all concluded that the stock does not appear to be overfished, nor does it appear that there is overfishing. All of these estimates were fairly imprecise, though.

6.11 Discussion

There was some uncertainty associated with the biological parameters, which led to the AW updating the fixed values for M at age, and the mode of the prior for pup-survival (corresponding to density-independent level). The configuration of this model estimated that the stock was not overfished and that there is no overfishing. Other models at the assessment workshop estimated the stock to be overfished with overfishing (Figure 6.9). It was noted that the number of indices and the available time series of those indices were very limited (starting in 1992 at the earliest for base indices), while catch time series are about twice as long (they begin in 1981). An important concern expressed during the assessment workshop is that those limited indices, which cover the same time period and which are assigned the same selectivity vector, have conflicting trends. The model-predicted fits to those indices were essentially flat, and therefore the group expressed limited amount of confidence in the model results. In addition to the conflicting indices, the estimated status differed between assessment models. As a result of the conflicting, limited data, and the conflicting results between models, the group reached consensus that the status of blacktip in the northwestern Atlantic Ocean was uncertain.

6.12 References

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Table 6.1a. Northwestern Atlantic Ocean blacktip biological inputs from 2002 assessment, 2006 base case values from the data workshop, or values updated at the 2006 assessment workshop. In the continuity case, M was estimated, while in the 2006 base cases, M at age values were fixed. The * for the age 0 entries in the first three columns is to distinguish those values as survival rates rather than natural mortality rates.

Age	M 2002	M 2006	M 2006 Updated	Female Maturity 2002	Female Maturity 2006	Pups-per-Female 2002	Pups-per-Female 2006
0	0.52*	0.52*	0.75*	0	0	0	0
1	0.22	0.287	0.219	0	0	10	3.2
2	0.22	0.252	0.185	0	0	10	3.2
3	0.22	0.229	0.161	0.02	0.001	10	3.2
4	0.22	0.212	0.144	0.09	0.004	10	3.2
5	0.22	0.199	0.132	0.35	0.02	10	3.2
6	0.22	0.19	0.122	0.74	0.095	10	3.2
7	0.22	0.182	0.115	0.94	0.354	10	3.2
8	0.22	0.177	0.109	0.99	0.741	10	3.2
9	0.22	0.172	0.104	1	0.937	10	3.2
10	0.22	0.168	0.1	1	0.987	10	3.2
11	0.22	0.165	0.097	1	0.998	10	3.2
12	0.22	0.162	0.095	1	1	10	3.2
13	0.22	0.16	0.093	1	1	10	3.2
14	0.22	0.159	0.091	1	1	10	3.2
15	0.22	0.157	0.089	1	1	10	3.2

Table 6.1b. Additional parameter specifications for northwestern Atlantic Ocean blacktip shark. Weight units are kg.

Parameter	Value	Prior
L_∞	159(cm FL)	*constant*
K	0.16	*constant*
t_0	-3.432	*constant*
a	2.51E-09	*constant*
b	3.13	*constant*
F_{hist}	0	*constant*
Historic Selectivity	1 for all ages	*constant*
Pups-per-mature female	3.2	*constant*
Pup Survival	0.75 (mode)	~LN with CV=0.30
Virgin Recruitment (R_0)	1.50E+06	~U on [1.0E+3, 1.0E+9]

Table 6.2. Catches of blacktip shark by fleet in the northwestern Atlantic Ocean. Units are numbers of sharks.

Year	Commercial + Unreported	Recreational
1981	551	4,498
1982	551	28,050
1983	595	29,299
1984	813	16,099
1985	755	53,267
1986	4,172	13,626
1987	8,573	46,660
1988	4,025	19,662
1989	3,872	21,793
1990	4,896	7,174
1991	75,319	40,613
1992	97,190	19,627
1993	71,522	12,824
1994	81,244	15,941
1995	66,295	19,431
1996	41,901	27,867
1997	36,023	16,336
1998	32,418	21,499
1999	6,807	8,850
2000	9,667	6,753
2001	9,654	14,945
2002	20,634	5,277
2003	18,355	30,063
2004	13,397	4,278

Table 6.3. Indices available for use in the current northwestern Atlantic Ocean blacktip shark assessment. Sensitivity indices in green (last 3 columns).

Year	Gillnet Observer	BLLOP	Bottom LL Logs	Pelagic Log	SC LL Recent	NMFS LL NE	MRFSS
1981							1.046
1982							0.531
1983							1.186
1984							1.145
1985							1.285
1986							1.427
1987							0.755
1988							0.578
1989							0.567
1990							0.421
1991							0.748
1992				3.389			1.243
1993	0.455			2.373			0.523
1994	0.955	0.805		2.019			2.264
1995	0.419	2.042		0.924	1.75		1.039
1996		1.246	0.678	0.785	0.808	0.202	0.986
1997		0.131	0.474	0.603	2.094		0.515
1998	1.286	0.534	0.689	0.36	0.487	1.578	1.183
1999	1.384	0.426	0.423	0.411	0.482		0.536
2000	1.286	0.153	1.005	0.392	1.147		0.877
2001	1.001	0.971	1.62	0.263	0.232	0.797	1.73
2002	0.982	4.578	1.948	0.434			1.196
2003	1.029	0.004	1.081	0.494			1.249
2004	1.204	0.111	1.083	0.55		1.423	0.969
Ages Vulnerable							
	all	all	all	all	0-5	all	young
Selectivity Vector							
	Comm+Unrep	Comm+Unrep	Comm+Unrep	Comm+Unrep	not used	Comm+Unrep	MRFSS

Table 6.4. Results for the base model run for northwestern Atlantic Ocean blacktip using the updated biological parameters. Pups-virgin is the number of age 1 pups at virgin conditions. SSF is spawning stock fecundity, which is the sum of number mature at age times pup-production at age (rather than SSB, since biomass does not influence pup production in sharks). AICc is the small sample Akaike Information Criterion, which converges to the AIC statistic as the number of data points gets large.

	Base	
Parameter	**Est**	**CV**
AICc	-99.96	
Objective Function	-2.51E+02	
MSY (kg)	1.49E+07	--
$Pups_{virgin}$	6.27E+06	0.53
SSF_{2004}	1.82E+07	0.54
$Nmature_{2004}$	1.09E+07	0.54
B_{2004}	1.23E+09	0.54
B_{2004}/B_{virgin}	0.89	0.01
SSF_{2004}/SSF_{virgin}	0.94	0.01
$Nmature_{2004}/Nmature_{virgin}$	0.9	0.01
SSF_{2004}/SSF_{MSY}	2.51	0.32
SPR_{MSY}	0.62	--
F_{2004}	0.001	0.53
F_{MSY}	0.2	--
F_{2004}/F_{MSY}	0.01	0.53
Pup-survival	0.82	0.29
alpha	2.41	--
steepness	0.38	--

Table 6.5. Estimates of total number, spawning stock fecundity, and fishing mortality by year for base model for blacktip shark in the northwestern Atlantic Ocean.

Year	N(year)	SSF(year)	F(year)
1981	50,996,300	18,484,000	0.001
1982	50,992,000	18,484,000	0.004
1983	50,967,100	18,483,000	0.004
1984	50,943,700	18,483,000	0.002
1985	50,936,300	18,482,000	0.007
1986	50,895,800	18,480,000	0.002
1987	50,893,900	18,475,000	0.006
1988	50,855,600	18,467,000	0.003
1989	50,849,800	18,458,000	0.003
1990	50,841,700	18,449,000	0.001
1991	50,844,500	18,422,000	0.005
1992	50,745,900	18,372,000	0.003
1993	50,649,800	18,325,000	0.002
1994	50,587,100	18,284,000	0.002
1995	50,514,100	18,247,000	0.003
1996	50,453,400	18,221,000	0.004
1997	50,411,500	18,205,000	0.002
1998	50,389,100	18,193,000	0.003
1999	50,365,100	18,190,000	0.001
2000	50,380,300	18,194,000	0.001
2001	50,392,900	18,198,000	0.002
2002	50,396,100	18,197,000	0.001
2003	50,398,200	18,194,000	0.004
2004	50,378,500	18,194,000	0.001

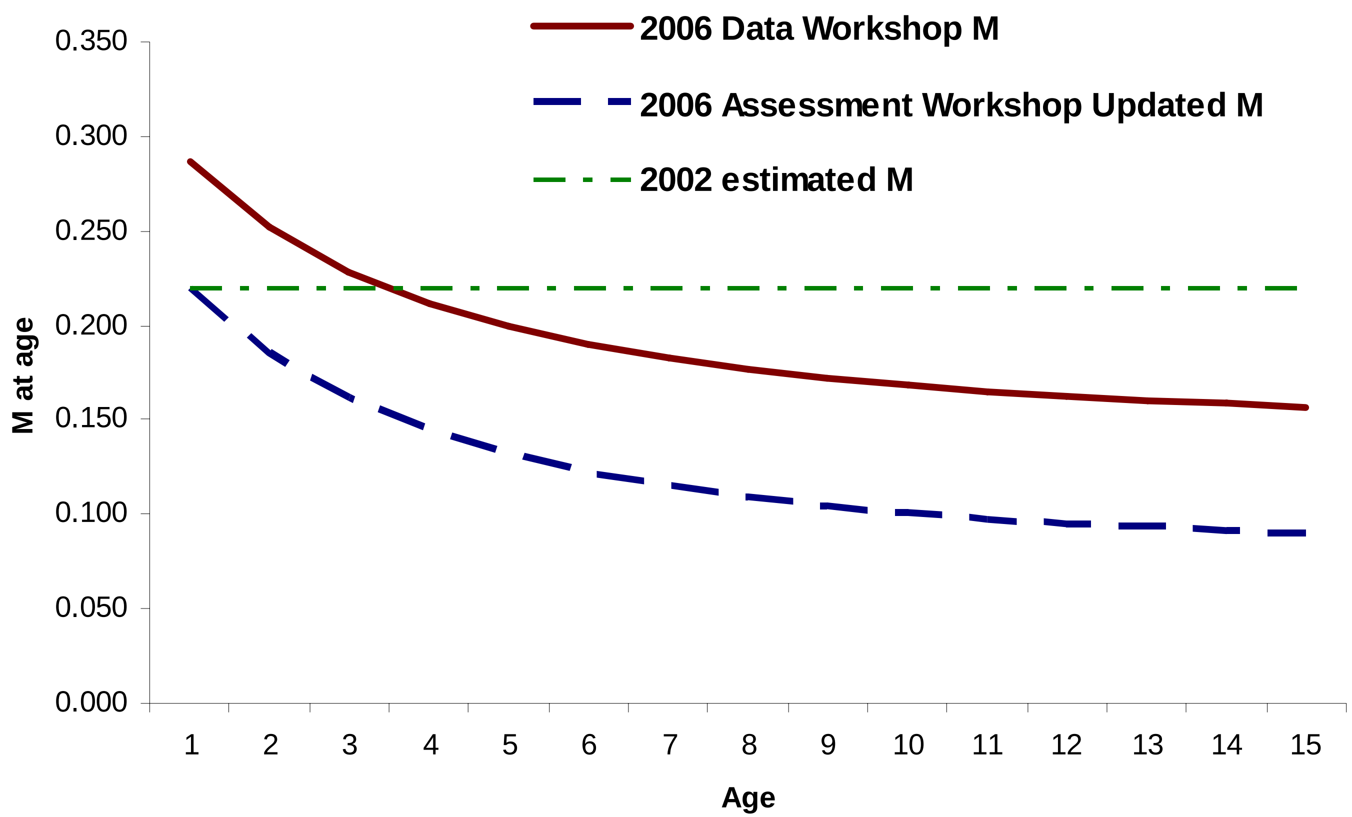


Figure 6.1. Comparison of natural mortality recommended by the data workshop (DW, solid line) and that agreed to in plenary at the assessment workshop (AW, dashed line) for northwestern Atlantic Ocean blacktip sharks.

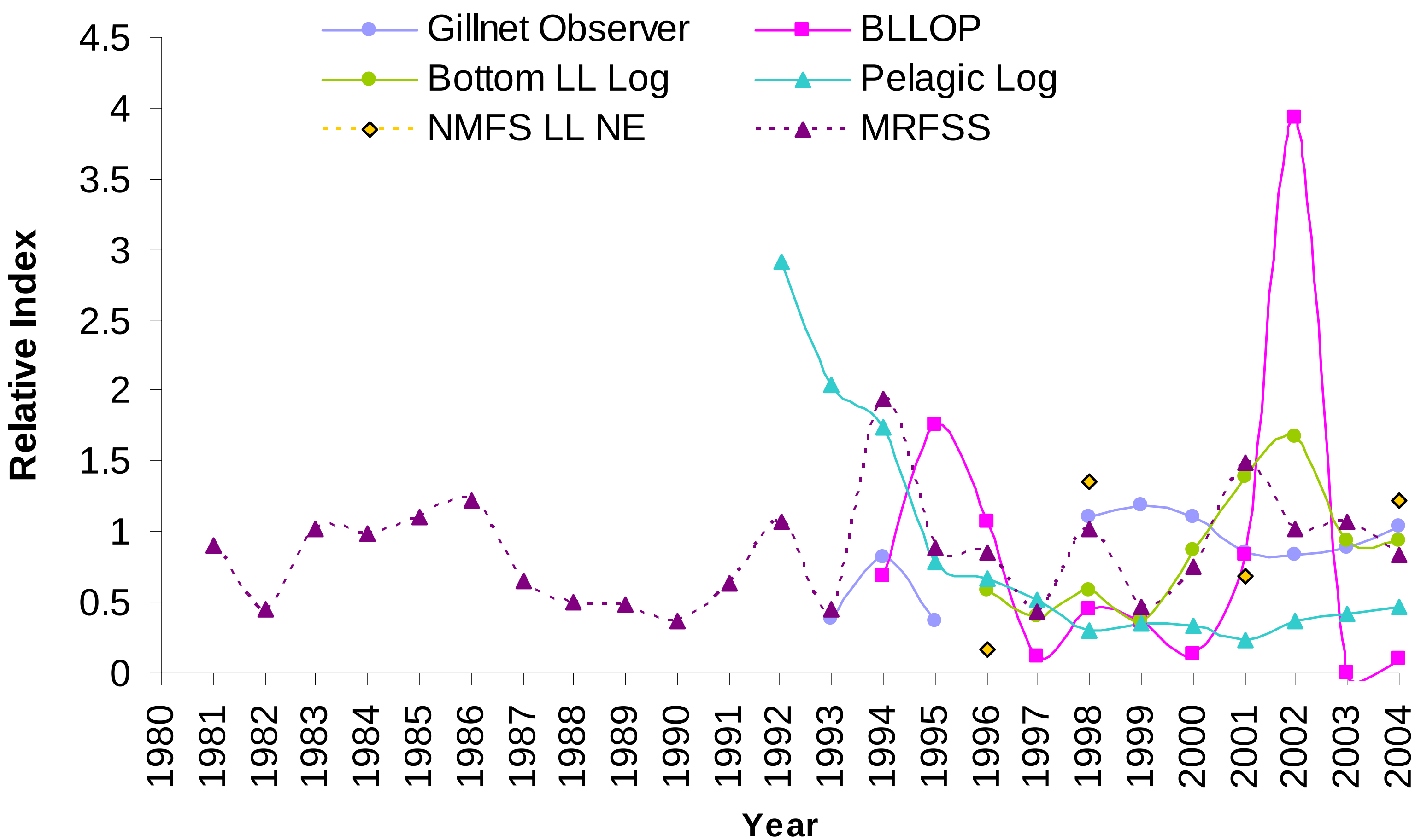


Figure 6.2. Indices available for the current northwestern Atlantic Ocean blacktip shark assessment. Indices are scaled by the value for 1998 (the only year of overlap).

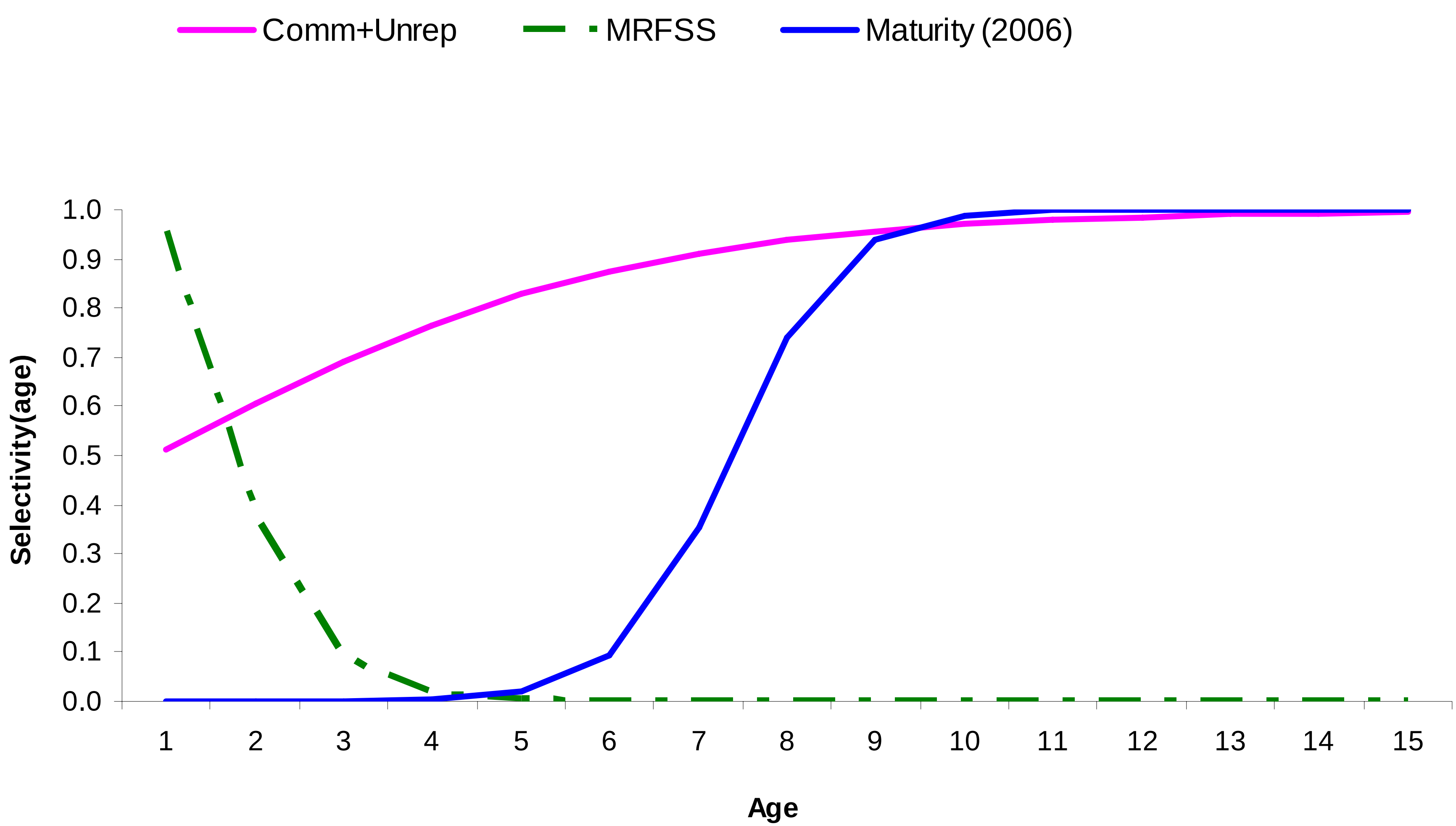


Figure 6.3. Selectivities used in northwestern Atlantic Ocean blacktip assessment, with the maturity ogive (solid blue line) as decided at the data workshop. Labels are consistent with the last row in Table 6.3 (all indices available for blacktip Atlantic)

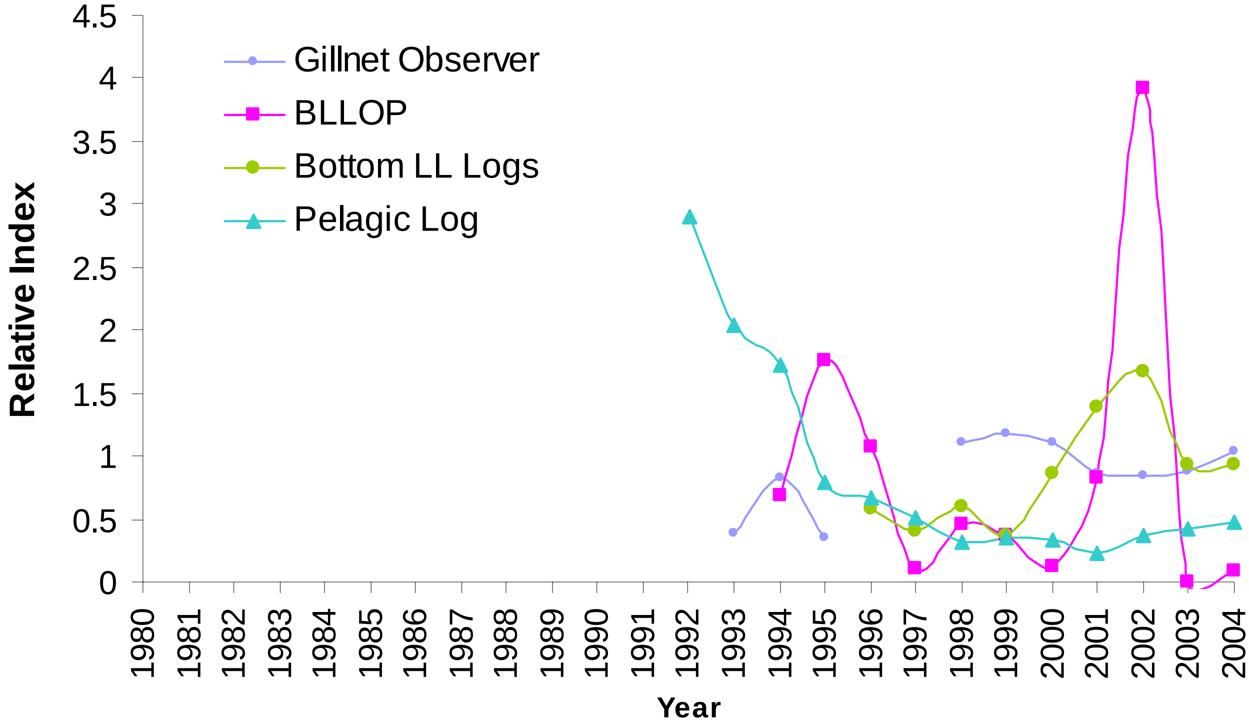


Figure 6.4. Indices with the same selectivity for blacktip sharks in the northwestern Atlantic Ocean.

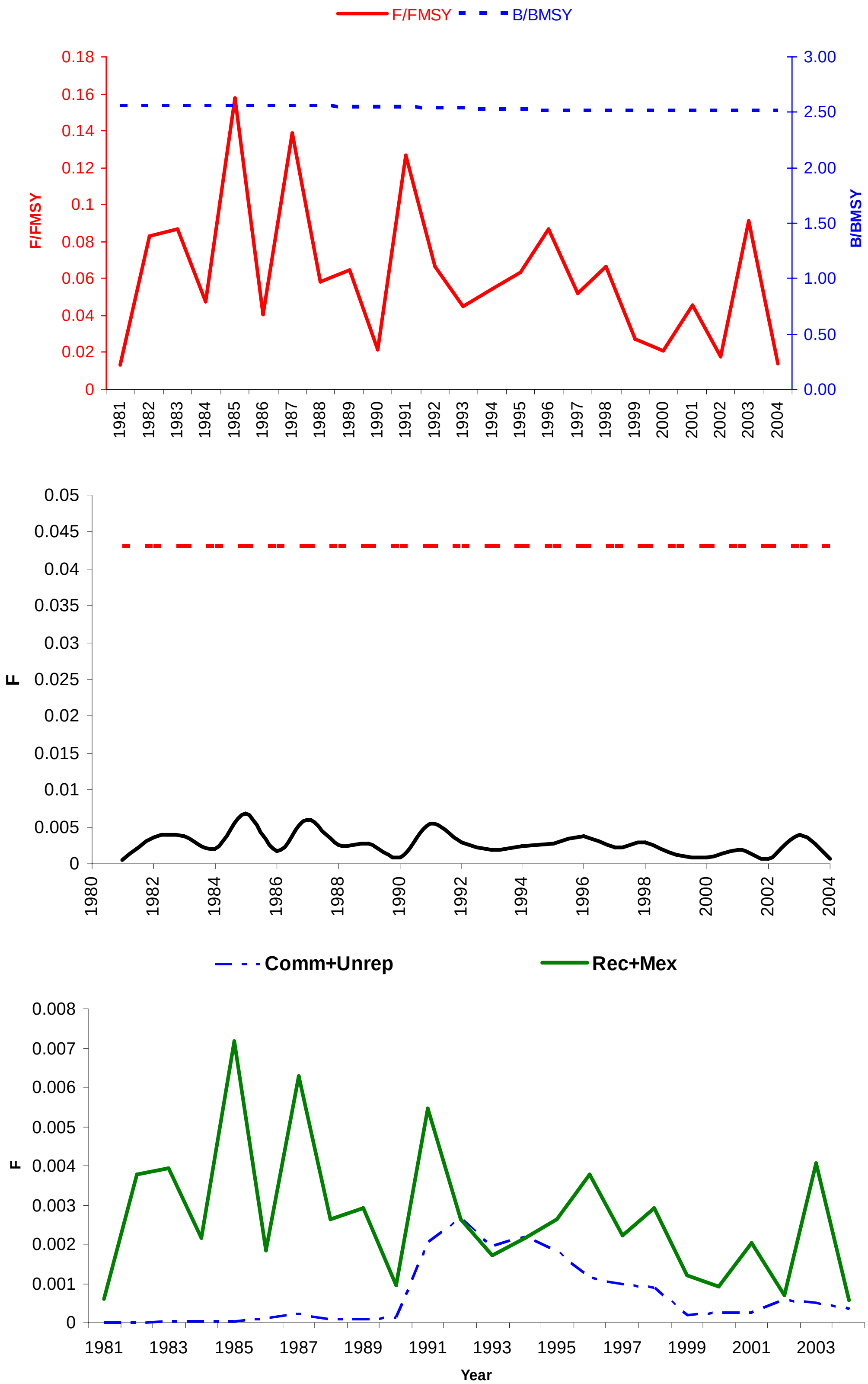


Figure 6.5. Estimated stock status (top), total fishing mortality (middle), and fleet-specific F (bottom) for northwestern Atlantic Ocean blacktip sharks. The dashed line in the middle panel indicates F_{MSY} (= 0.015).

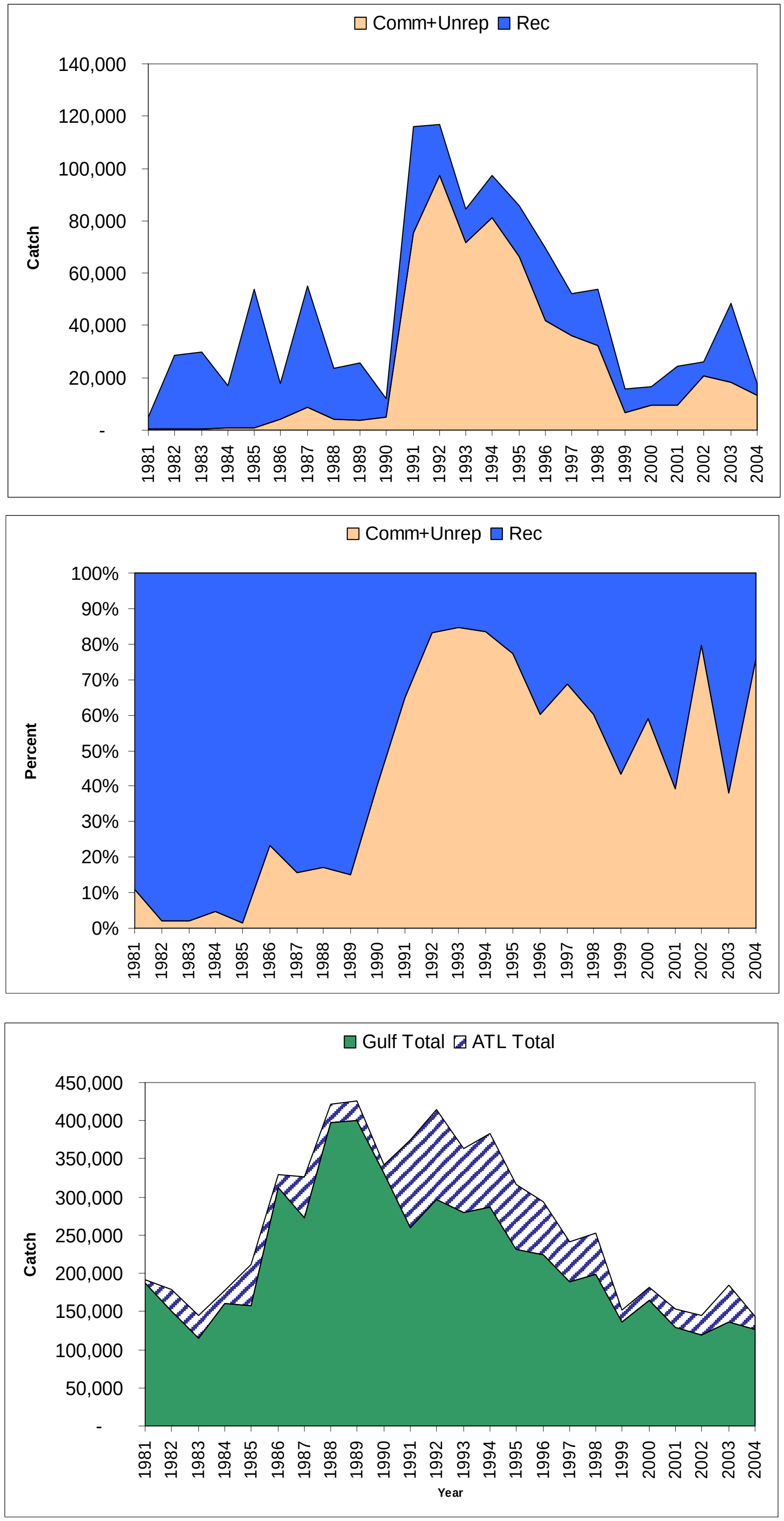
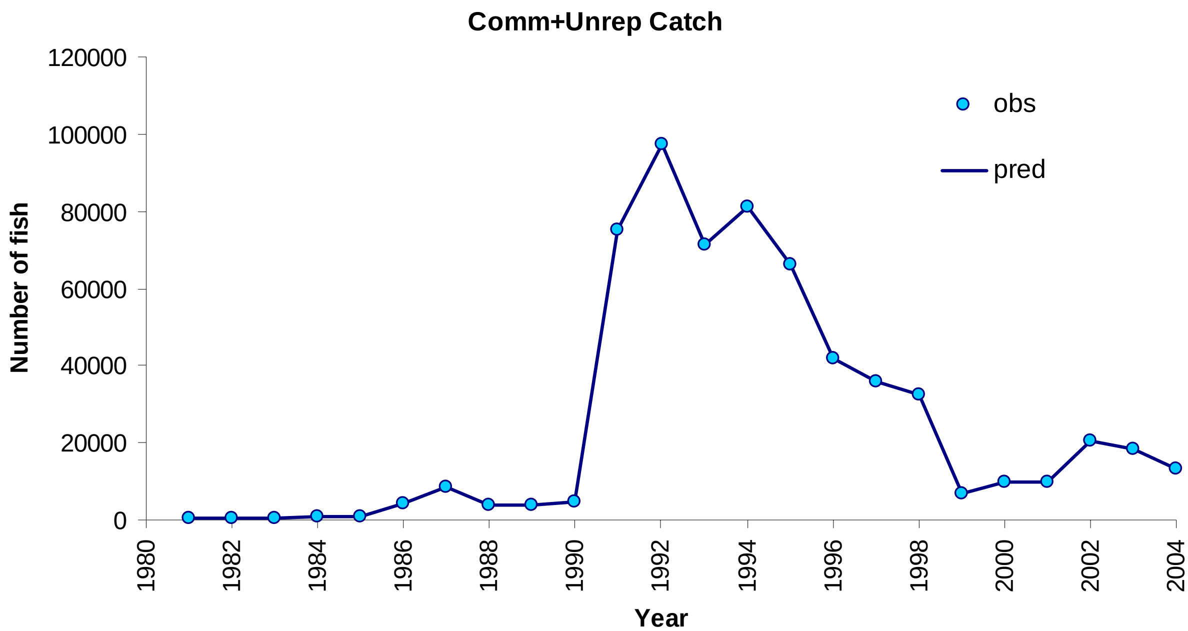


Figure 6.6. Total catch by fleet of blacktip in the northwestern Atlantic Ocean (top), percent of total catch by fleet (middle), and Atlantic versus Gulf of Mexico landings (bottom).



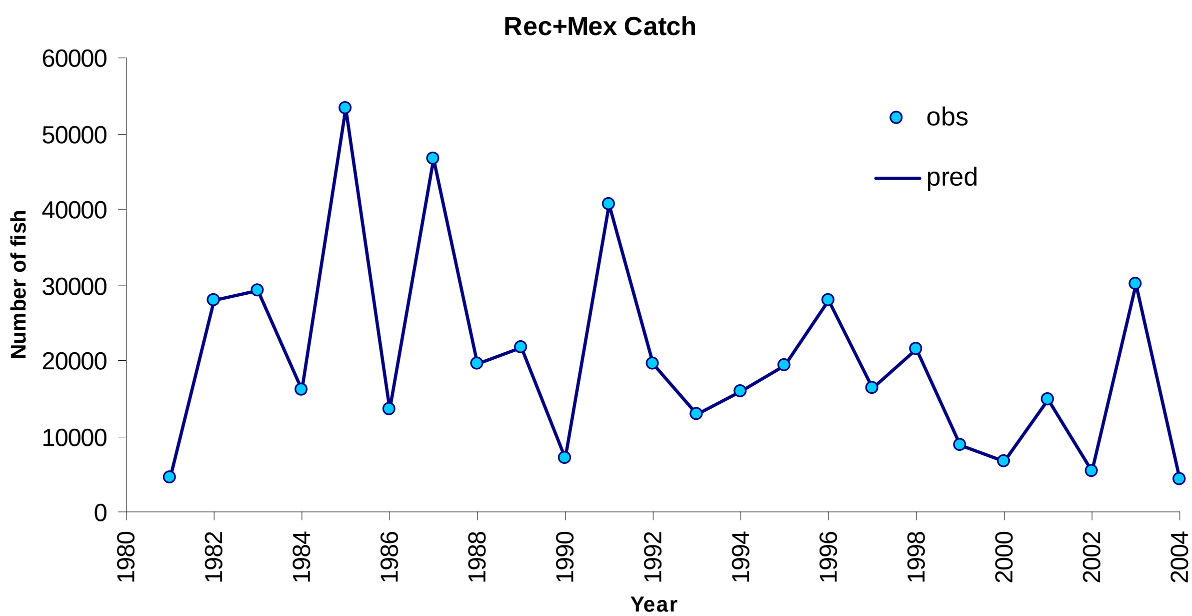
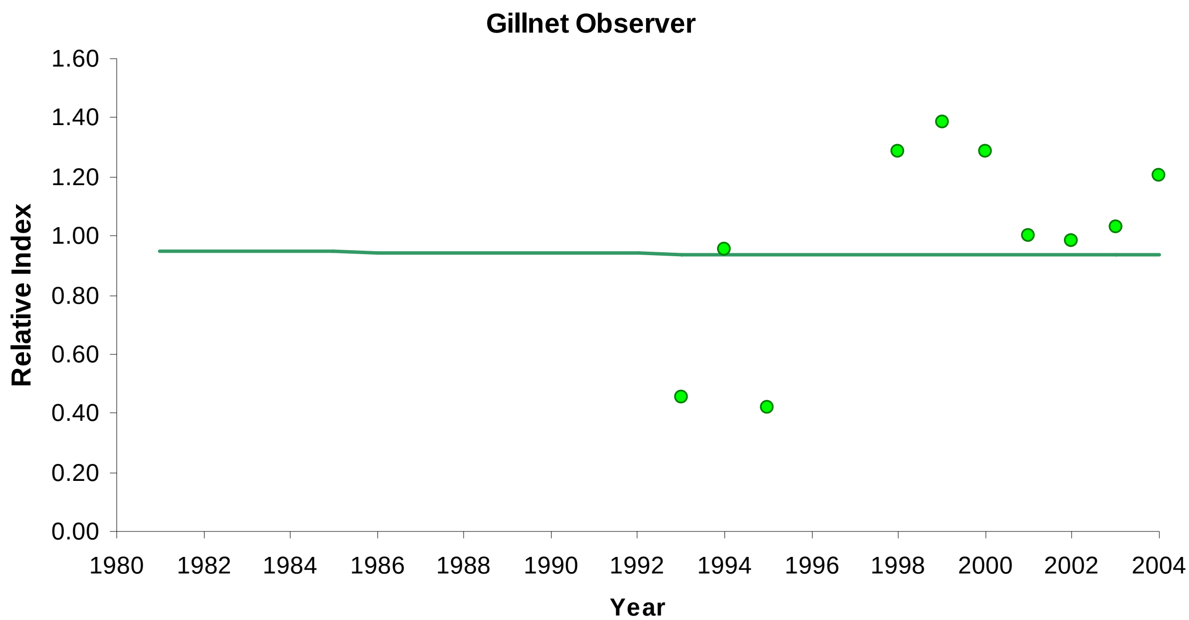


Figure 6.7. Model predicted fit to catch data for northwestern Atlantic Ocean blacktip sharks. Circles represent observed data, solid line is predicted.



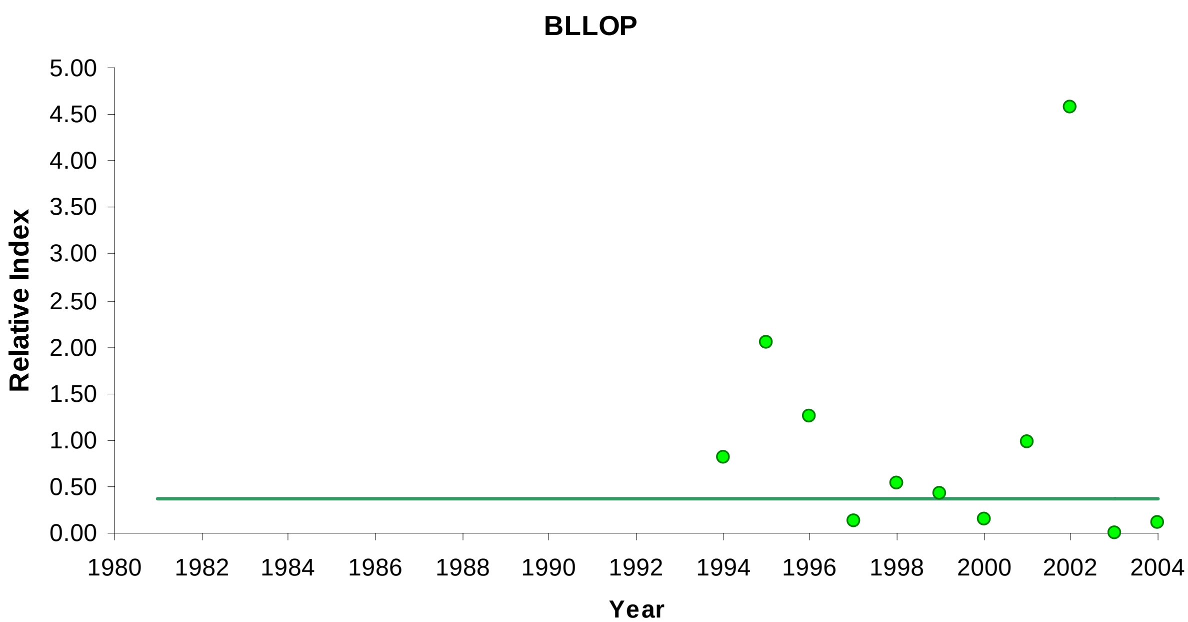
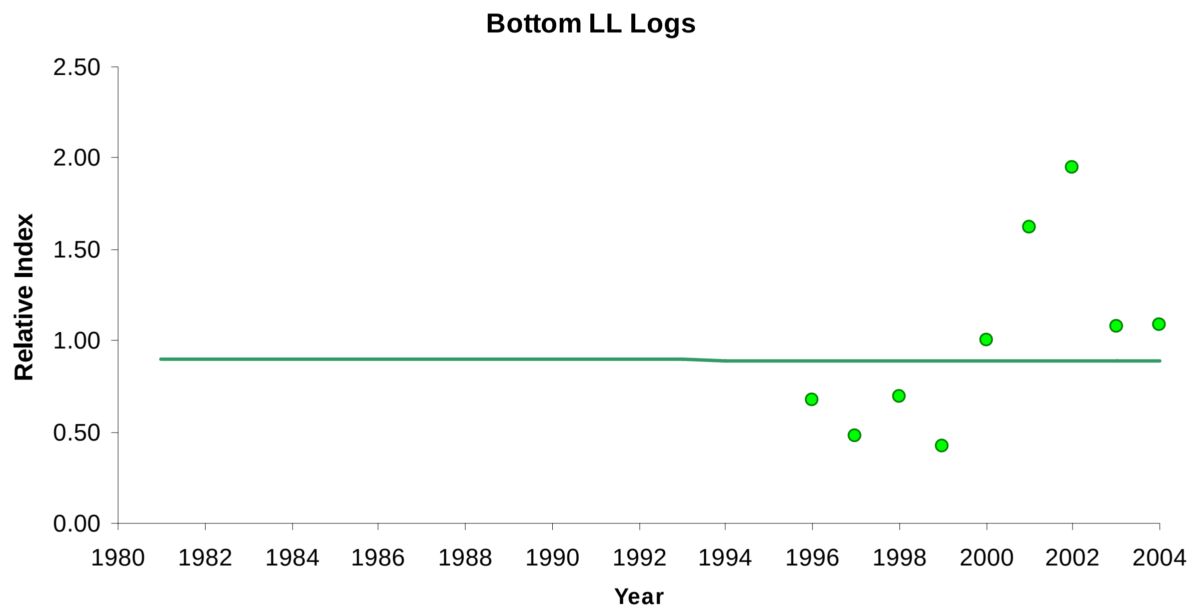


Figure 6.8. Model predicted fit to indices for northwestern Atlantic Ocean blacktip sharks. Circles represent observed data, solid line is predicted.



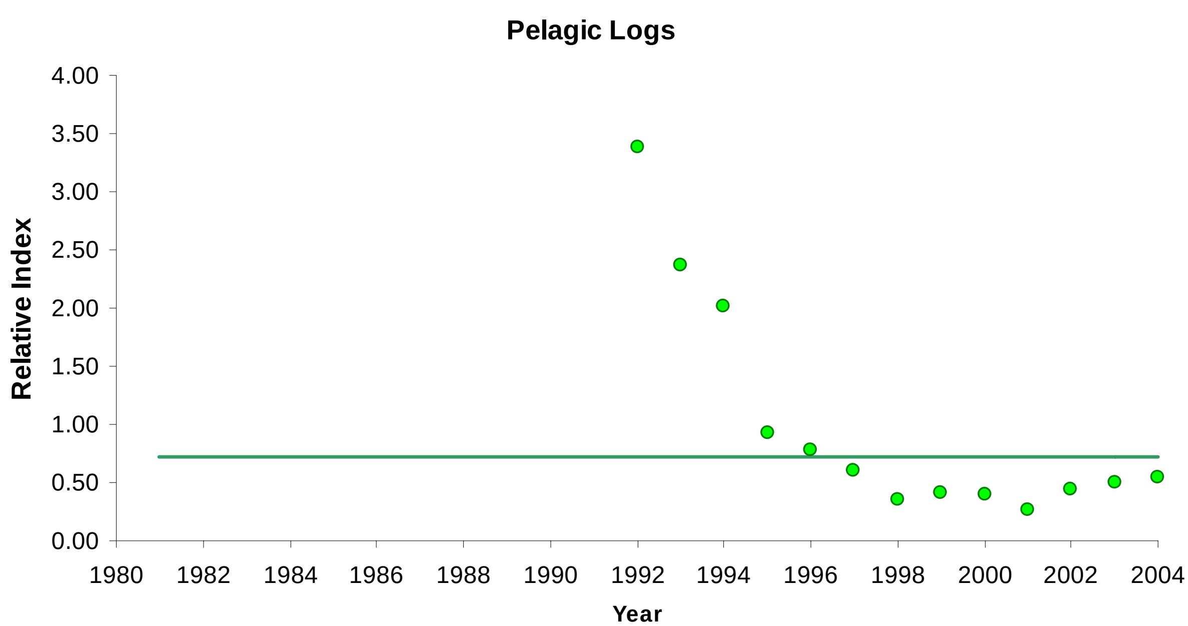


Figure 6.8. (continued)

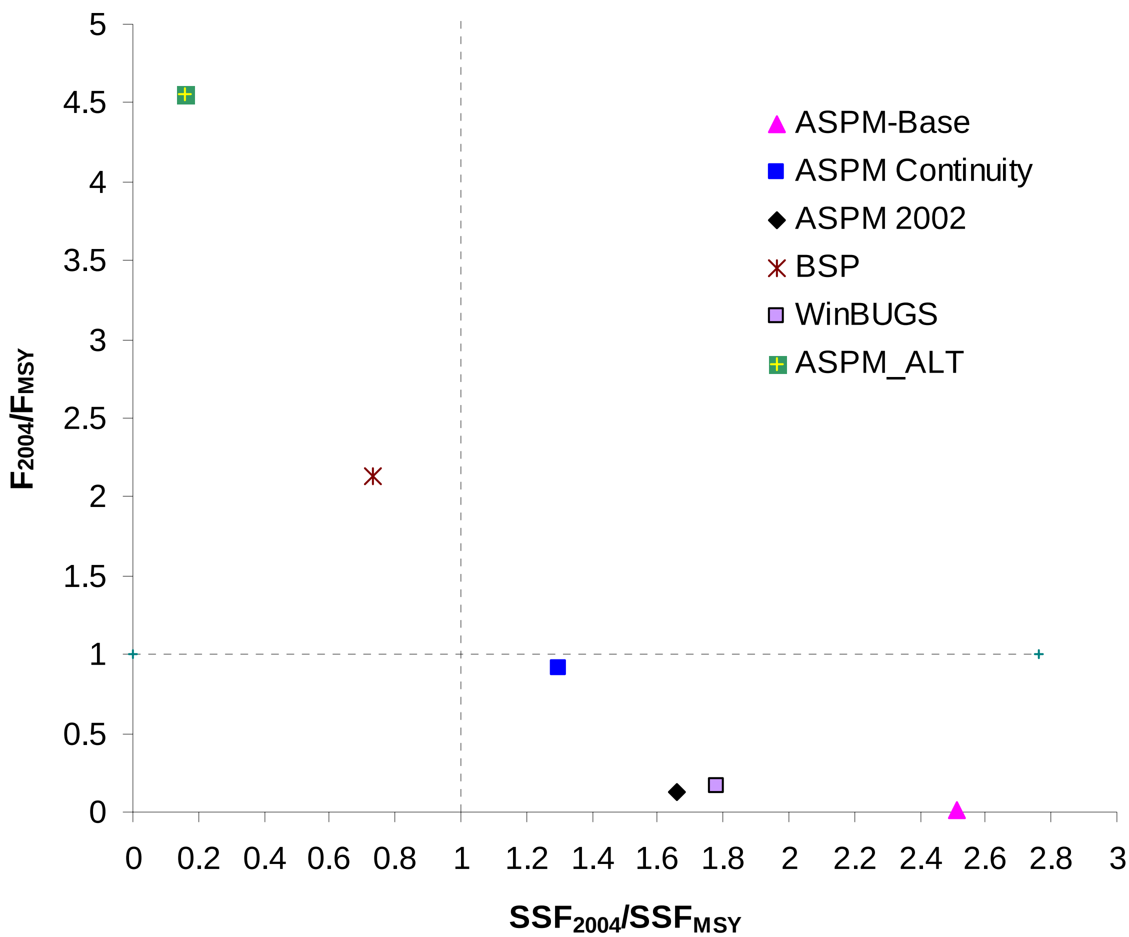


Figure 6.9. Phase-plot of stock status for northwestern Atlantic Ocean blacktip shark stock. Models include: ASPM-Base, ASPM Continuity, ASPM 2002 (results of the 2002 blacktip single stock assessment using equal weighting), BSP (results using the Bayesian surplus production model), and WinBUGS (results using the WinBUGS SPM) and ASPM_ALT. ASPM_ALT is the alternative age structured production model discussed in SEDAR10-AW-02. The F benchmark for ASPM_ALT is in terms of the harvest rate in 2004 relative to that rate at MSY. See text for further details. Several control rules are illustrated: the dashed horizontal line indicates the MFMT (Maximum Fishing Mortality Threshold) and the dashed vertical line denotes the target biomass (biomass or number at MSY). Note for the BSP and WinBUGS x values denote N_{2004}/N_{MSY} rather than SSF_{2004}/SSF_{MSY}. SSF is spawning stock fecundity, which is the sum of number mature at age times pup-production at age (rather than SSB, since biomass does not influence pup production in sharks).

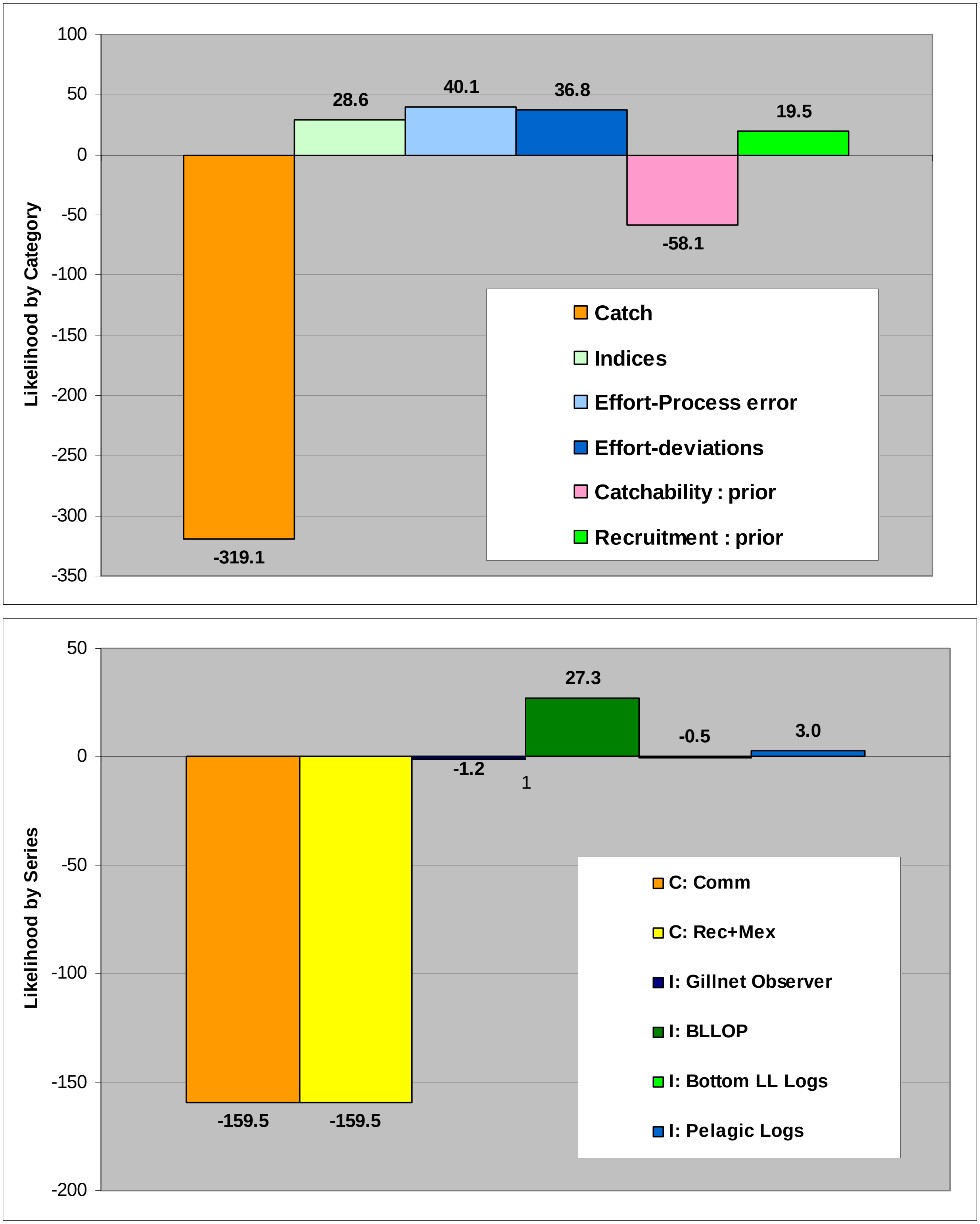


Figure 6.10. Contribution to relative likelihood by category (top) and by catch series and index series (bottom) for the base model for northwestern Atlantic blacktip sharks. The recruitment component includes both priors on virgin number of pups and pup survival.

7. RESEARCH RECOMMENDATIONS

The Assessment Workshop Panel identified the following Research Recommendations which will aid in future assessments.

- Data Workshop participants need to bring raw data to workshop to enable additional analysis to be conducted and reviewed during the workshop when practical
- Length frequency data should be provided when available, with particular reference to the VA LL dataset.
- Examination and analysis of the Pelagic Longline Observer data should be included.
- Identify nursery areas for sandbars in the northern Gulf of Mexico
- Additional life history studies for all complex species to allow for additional species-specific assessments.
- Additional life history research into sandbar sharks to supplement or replace the available data from the mid 1990s
- Incorporation of the University of North Carolina dataset collected by Dr. Frank Schwartz in the next LCS assessment, with recognition that it may also contain valuable information useful for the Small Coastal Shark assessment to be conducted in 2007.
- Examination of methods to incorporate tagging data information into the assessment
- Attempt to recover and quantify information on historic catch, with special emphasis prior to the 1993 FMP.
- Management to force contrast would improve the blacktip assessments.
- Additional length sampling and age composition collection to improve information for developing selectivities
- Initiation or expansion of dock side sampling for sharks
- Ensure that existing independent sampling programs be continued
- Ensure funding for the recently initiated (2002) pelagic survey being conducted by the Pascagoula laboratory- SEFSC

Appendix 1. Available catch rates series for the large coastal shark complex (3 scenarios) , sandbar, and blacktip shark. The index is the relative (divided by the overall mean) estimated mean CPUE and the CV is the estimated precision of the mean value. Type refers to whether the index is fishery – independent (FI) or fishery-dependent (FD), recreational (R) or commercial (C). Observations with a CV of 1.0 are nominal data for which no measure of the precision of the estimate was available. Recommendation refers to the recommendation by the Indices Working Group to include the particular index as a base index (Base), use it for sensitivity runs (Sensitivity) or not recommended for use in the assessment (NR). Indices labeled NR were used in the Continuity analysis.

Original LCS Definition (22 species)

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-01	NC #	FD - C	NR	1988	0.758	0.422
				1989	1.242	0.232
LCS05/06-DW-11	Gillnet Observer	FD - C	Base	1993	0.338	1.026
				1994	1.050	0.132
				1995	0.299	0.779
				1998	1.088	0.177
				1999	1.336	0.079
				2000	1.239	0.073
				2001	1.179	0.070
				2002	1.077	0.116
				2003	1.112	0.150
				2004	1.281	0.082
LCS05/06-DW-12	PC Longline	FI	Sensitivity	1993	0.816	0.730
				1994	0.386	0.894
				1995	1.272	0.610
				1996	0.858	0.583
				1997	0.926	0.539
				1998	0.725	0.967
				1999	1.174	0.564
				2000	1.844	0.508
LCS05/06-DW-12	PC Gillnet	FI	Base	1996	0.511	0.241
				1997	1.637	0.132
				1998	0.607	0.310
				1999	0.969	0.297
				2000	0.811	0.326
				2001	1.549	0.211
				2002	0.936	0.201
				2003	1.072	0.186
				2004	0.908	0.220
LCS05/06-DW-13	ENP	FD - R	Base	1972	0.598	0.255
				1973	1.575	0.085
				1974	0.985	0.093

				1975	1.987	0.066
				1976	1.165	0.094
				1977	1.409	0.079
				1978	1.126	0.094
				1979	1.114	0.123
				1980	1.469	0.079
				1981	1.001	0.080
				1982	1.099	0.081
				1983	1.368	0.068
				1984	1.279	0.066
				1985	1.071	0.074
				1986	0.921	0.070
				1987	0.942	0.080
				1988	0.993	0.099
				1989	0.604	0.127
				1990	0.548	0.098
				1991	0.504	0.113
				1992	0.910	0.089
				1993	0.523	0.105
				1994	0.911	0.070
				1995	0.762	0.091
				1996	0.900	0.070
				1997	0.922	0.066
				1998	0.855	0.078
				1999	0.753	0.085
				2000	0.966	0.076
				2001	0.838	0.083
				2002	0.900	0.087
LCS05/06-DW-14	SC LL Recent	FI	Base	1995	0.813	0.359
				1996	0.692	0.257
				1997	1.367	0.183
				1998	0.853	0.194
				1999	1.295	0.148
				2000	1.112	0.169
				2001	0.868	0.216
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.669	0.335
				1995	0.901	0.219
				1996	0.907	0.143
				1997	0.894	0.287
				1998	1.134	0.178
				1999	1.084	0.280
				2000	1.027	0.363
				2001	0.929	0.299
				2002	1.269	0.265
				2003	1.214	0.188
				2004	0.971	0.187
LCS05/06-DW-20	VA LL	FI	Base	1975	2.508	0.307
				1977	1.994	0.344

				1978	0.975	1.006
				1980	2.063	0.246
				1981	1.795	0.237
				1984	0.658	1.611
				1986	0.612	2.715
				1989	0.790	0.526
				1990	0.815	0.437
				1991	0.702	0.524
				1992	1.231	0.560
				1993	0.794	0.619
				1995	0.811	0.448
				1996	0.766	0.406
				1997	0.753	0.276
				1998	0.737	0.318
				1999	0.710	0.437
				2000	0.777	0.365
				2001	0.737	0.356
				2002	0.685	0.509
				2003	0.546	0.373
				2004	0.541	0.514
LCS05/06-DW-21	Brannon	FD - C	NR	1986	0.657	1
				1987	1.348	1
	* nominal index			1988	1.146	1
				1989	0.833	1
				1990	0.994	1
				1991	1.020	1
LCS05/06-DW-24	MS Gillnet	FI	Sensitivity	1998	0.566	0.528
				1999	0.337	0.574
				2000	1.981	0.421
				2001	0.576	0.717
				2003	0.399	0.741
				2004	0.472	0.598
				2005	2.670	0.455
LCS05/06-DW-25	Hudson	FD - R	NR	1985	0.220	1
				1986	0.100	1
	* nominal index			1987	0.120	1
				1988	0.100	1
				1989	0.050	1
				1990	0.020	1
				1991	0.020	1
LCS05/06-DW-25	Jax	FD - R	NR	1979	0.590	1
				1984	0.710	1
	* nominal index			1990	0.160	1
LCS05/06-DW-25	Tampa Bay	FD - R	NR	1985	0.160	1
				1986	0.090	1
	* nominal index			1987	0.030	1

				1988	0.140	1
				1989	0.060	1
				1990	0.050	1
LCS05/06-DW-25	Port Salerno	FD - R	Sensitivity	1976	0.180	1
				1977	0.810	1
	* nominal index			1979	0.890	1
				1980	0.820	1
				1981	0.390	1
				1982	0.500	1
				1983	0.120	1
				1984	0.100	1
				1985	0.150	1
				1986	0.500	1
				1987	0.320	1
				1988	0.200	1
				1989	0.120	1
				1990	0.200	1
LCS05/06-DW-25	Crooke LL	FD - C	Sensitivity	1975	0.882	1
				1976	0.642	1
				1977	1.043	1
				1978	2.005	1
				1979	0.963	1
				1980	1.283	1
				1981	1.043	1
				1982	1.043	1
				1983	1.123	1
				1984	0.963	1
				1985	1.123	1
				1986	0.882	1
				1987	0.642	1
				1988	0.642	1
				1989	0.722	1
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	0.849	0.135
				1996	0.449	0.200
				1997	0.626	0.128
				1999	0.499	0.150
				2000	1.042	0.083
				2001	1.120	0.106
				2002	1.220	0.080
				2003	1.846	0.105
				2004	1.349	0.107
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.615	0.164
				1997	0.945	0.103
				1998	0.848	0.099
				1999	1.210	0.090
				2000	1.204	0.098
				2001	1.146	0.095

				2002	0.958	0.092
				2003	1.231	0.089
				2004	0.844	0.103
LCS05/06-DW-33	NMFS LL NE	FI	Base	1996	0.232	0.263
				1998	1.609	0.124
				2001	1.051	0.141
				2004	1.108	0.147
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	2.008	0.250
				1993	1.588	0.258
				1994	1.312	0.265
				1995	1.186	0.267
				1996	1.253	0.264
				1997	0.732	0.288
				1998	0.561	0.310
				1999	0.616	0.307
				2000	0.786	0.293
				2001	0.760	0.297
				2002	0.710	0.294
				2003	0.727	0.297
				2004	0.761	0.292
LCS05/06-DW-36	MRFSS - excluding requiem	FD - R	Sensitivity	1981	1.505	0.357
				1982	1.298	0.337
				1983	1.948	0.332
				1984	1.597	0.345
				1985	1.608	0.331
				1986	1.722	0.315
				1987	1.102	0.321
				1988	0.952	0.325
				1989	0.747	0.334
				1990	0.762	0.333
				1991	0.81	0.327
				1992	0.887	0.316
				1993	0.672	0.326
				1994	0.707	0.324
				1995	0.848	0.321
				1996	0.803	0.322
				1997	0.726	0.327
				1998	1.003	0.314
				1999	0.663	0.322
				2000	0.805	0.318
				2001	0.794	0.319
				2002	0.782	0.319
				2003	0.813	0.319
				2004	0.448	0.336
LCS05/06-DW-36	MRFSS - including requiem	FD - R	Sensitivity	1981	1.002	0.350
				1982	1.139	0.316
				1983	1.359	0.319

				1984	1.115	0.332
				1985	1.086	0.319
				1986	1.241	0.299
				1987	0.940	0.305
				1988	0.812	0.311
				1989	0.530	0.328
				1990	0.519	0.328
				1991	0.528	0.322
				1992	0.665	0.304
				1993	0.685	0.307
				1994	0.883	0.298
				1995	0.998	0.296
				1996	0.900	0.300
				1997	0.899	0.301
				1998	1.077	0.292
				1999	0.929	0.295
				2000	1.136	0.291
				2001	1.238	0.289
				2002	1.348	0.286
				2003	1.513	0.286
				2004	1.462	0.288
LCS05/06-DW-41	Charterboat	FD - R	NR	1989	1.145	0.469
				1990	1.031	0.125
				1991	1.080	0.121
				1992	0.837	0.118
				1993	0.945	0.125
				1994	0.928	0.156
				1995	1.036	0.152
LCS05/06-DW-45	SC LL Early	FI	Base	1984	1.79251	1
				1994	0.70317	1
				1995	0.50432	1

LCS minus prohibited species (11 species)

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-11	Gillnet Observer	FD - C	Base	1993	0.338	1.026
				1994	1.05	0.132
				1995	0.299	0.779
				1998	1.088	0.177
				1999	1.336	0.079
				2000	1.239	0.073
				2001	1.179	0.07
				2002	1.077	0.116
				2003	1.112	0.15
				2004	1.281	0.082
LCS05/06-DW-12	PC Longline	FI	Sensitivity	1993	0.816	0.730
				1994	0.386	0.894
				1995	1.272	0.610
				1996	0.858	0.583
				1997	0.926	0.539
				1998	0.725	0.967
				1999	1.174	0.564
				2000	1.844	0.508
LCS05/06-DW-12	PC Gillnet	FI	Base	1996	0.511	0.241
				1997	1.637	0.132
				1998	0.607	0.310
				1999	0.969	0.297
				2000	0.811	0.326
				2001	1.549	0.211
				2002	0.936	0.201
				2003	1.072	0.186
				2004	0.908	0.220
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.676	0.238
				1995	0.972	0.172
				1996	0.907	0.153
				1997	0.774	0.295
				1998	1.113	0.172
				1999	1.108	0.253
				2000	1.168	0.333
				2001	0.926	0.242
				2002	1.187	0.160
				2003	1.206	0.131
				2004	0.962	0.150
LCS05/06-DW-24	MS Gillnet	FI	Sensitivity	1998	0.566	0.528
				1999	0.337	0.574
				2000	1.981	0.421

				2001	0.576	0.717
				2003	0.399	0.741
				2004	0.472	0.598
				2005	2.670	0.455
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	0.848	0.135
				1996	0.438	0.203
				1997	0.628	0.128
				1999	0.501	0.150
				2000	1.044	0.083
				2001	1.127	0.106
				2002	1.207	0.080
				2003	1.850	0.105
				2004	1.356	0.107
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.574	0.152
				1997	0.927	0.110
				1998	0.839	0.103
				1999	1.103	0.092
				2000	1.188	0.101
				2001	1.165	0.099
				2002	1.011	0.097
				2003	1.287	0.094
				2004	0.907	0.107
LCS05/06-DW-33	NMFS LL NE	FI	Base	1996	0.258	2.973
				1998	1.750	0.578
				2001	1.037	0.880
				2004	0.955	0.953
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	1.669	0.268
				1993	1.383	0.275
				1994	1.248	0.279
				1995	1.191	0.279
				1996	1.176	0.278
				1997	0.732	0.297
				1998	0.597	0.314
				1999	0.608	0.314
				2000	0.884	0.297
				2001	0.867	0.298
				2002	0.845	0.295
				2003	0.902	0.296
				2004	0.897	0.293
LCS05/06-DW-36	MRFSS - excluding requiem	FD - R	Sensitivity	1981	1.807	0.600
				1982	1.820	0.543
				1983	2.571	0.547
				1984	2.468	0.558
				1985	1.895	0.544
				1986	2.453	0.510
				1987	1.165	0.536

				1988	0.953	0.540
				1989	0.742	0.563
				1990	0.552	0.600
				1991	0.563	0.574
				1992	0.913	0.532
				1993	0.384	0.573
				1994	0.220	0.633
				1995	0.581	0.545
				1996	0.721	0.535
				1997	0.656	0.563
				1998	0.876	0.538
				1999	0.553	0.548
				2000	0.498	0.568
				2001	0.520	0.558
				2002	0.493	0.561
				2003	0.407	0.597
				2004	0.189	0.663
LCS05/06-DW-36	MRFSS - including requiem	FD - R	Sensitivity	1981	0.884	0.37
				1982	1.097	0.325
				1983	1.301	0.328
				1984	1.071	0.341
				1985	1.063	0.327
				1986	1.256	0.305
				1987	0.908	0.312
				1988	0.789	0.318
				1989	0.498	0.34
				1990	0.533	0.336
				1991	0.494	0.334
				1992	0.641	0.312
				1993	0.699	0.312
				1994	0.879	0.304
				1995	1.033	0.301
				1996	0.903	0.305
				1997	0.908	0.307
				1998	1.102	0.297
				1999	0.953	0.3
				2000	1.149	0.296
				2001	1.297	0.293
				2002	1.423	0.291
				2003	1.579	0.29
				2004	1.541	0.292

LCS minus prohibited species, blacktip, and sandbar sharks (9 species)

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-11	Gillnet Observer	FD - C	Base	1993	0.754	0.546
				1994	0.918	0.150
				1995	0.537	0.494
				1998	1.037	0.269
				1999	1.203	0.107
				2000	1.246	0.094
				2001	1.167	0.087
				2002	1.092	0.121
				2003	0.952	0.202
				2004	1.094	0.141
LCS05/06-DW-12	PC Gillnet	FI	Base	1996	0.328	0.532
				1997	1.197	0.272
				1998	0.521	0.494
				1999	0.973	0.463
				2000	1.112	0.411
				2001	1.682	0.309
				2002	1.129	0.280
				2003	1.022	0.276
				2004	1.034	0.314
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.614	0.298
				1995	0.756	0.278
				1996	0.810	0.281
				1997	0.903	0.291
				1998	1.298	0.257
				1999	1.067	0.286
				2000	1.056	0.313
				2001	0.983	0.278
				2002	1.478	0.278
				2003	0.959	0.281
				2004	1.078	0.273
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	0.946	0.152
				1996	0.381	0.236
				1997	0.608	0.145
				1999	0.508	0.186
				2000	1.176	0.092
				2001	1.108	0.125
				2002	1.187	0.095
				2003	1.746	0.132
				2004	1.341	0.120
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.709	0.266
				1997	0.680	0.199

				1998	0.626	0.199
				1999	1.170	0.167
				2000	1.044	0.184
				2001	1.095	0.176
				2002	1.490	0.175
				2003	1.286	0.167
				2004	0.900	0.225
LCS05/06-DW-33	NMFS LL NE	FI	Base	1996	0.212	6.866
				1998	1.127	1.735
				2001	1.282	1.292
				2004	1.379	1.244
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	1.738	0.242
				1993	1.413	0.250
				1994	1.360	0.250
				1995	1.039	0.257
				1996	0.994	0.255
				1997	0.657	0.272
				1998	0.579	0.287
				1999	0.737	0.274
				2000	0.901	0.266
				2001	0.792	0.271
				2002	0.892	0.264
				2003	0.912	0.266
				2004	0.985	0.263

Blacktip - Gulf of Mexico

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-12	PC Longline	FI	Sensitivity	1993	0.768	1.288
				1994	0.133	3.244
				1995	1.018	1.244
				1996	0.758	1.087
				1997	1.299	0.704
				1998	0.974	1.328
				1999	1.136	1.011
				2000	1.914	0.92
LCS05/06-DW-12	PC Gillnet	FI	Base	1996	0.695	0.475
				1997	1.397	0.287
				1998	0.565	0.451
				1999	1.209	0.359
				2000	0.769	0.484
				2001	1.583	0.286
				2002	0.872	0.283
				2003	0.909	0.283
				2004	1.001	0.307
LCS05/06-DW-12	PC Gillnet - juveniles	FI	Base	1996	0.980	0.427
				1997	1.513	0.279
				1998	0.639	0.455
				1999	1.068	0.412
				2000	0.649	0.632
				2001	1.408	0.312
				2002	0.854	0.305
				2003	0.790	0.318
				2004	1.098	0.294
LCS05/06-DW-12	PC Gillnet - Age 0	FI	Base	1996	0.152	1.063
				1997	0.782	0.397
				1998	0.654	0.586
				1999	2.101	0.388
				2000	0.676	0.737
				2001	2.130	0.35
				2002	1.260	0.293
				2003	1.012	0.334
				2004	0.232	0.823
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.430	1.666
				1995	0.817	0.855
				1996	0.724	1.215
				1997	0.588	2.248
				1998	0.796	1.620
				1999	1.055	1.270

				2001	0.162	9.019
				2002	2.062	0.496
				2003	1.542	0.509
				2004	1.824	0.401
LCS05/06-DW-24	MS Gillnet	FI	Sensitivity	1998	0.584	0.572
				1999	0.352	0.590
				2000	2.771	0.404
				2001	0.565	0.717
				2003	0.374	0.751
				2004	0.413	0.624
				2005	1.940	0.491
LCS05/06-DW-24	MS Gillnet - juveniles	FI	Sensitivity	1998	0.835	0.683
				1999	0.412	0.887
				2000	2.655	0.336
				2001	0.409	1.892
				2003	0.092	1.722
				2004	0.198	1.443
				2005	2.398	0.791
LCS05/06-DW-24	MS Gillnet - Age 0	FI	Sensitivity	1998	0.200	0.684
				1999	0.245	1.011
				2000	3.136	0.556
				2001	0.302	1.633
				2003	0.660	0.764
				2004	0.134	1.177
				2005	2.323	0.982
LCS05/06-DW-26	Mote Gillnet - Yankeetown	FI	Sensitivity	1995	0.578	1.287
				1996	1.564	0.910
				1997	1.299	1.186
				1999	0.541	1.368
				2000	0.530	1.836
				2001	0.966	1.521
				2002	0.823	1.463
				2003	1.126	1.256
				2004	1.574	0.994
LCS05/06-DW-26	Mote Gillnet - Charlotte Harbor	FI	Sensitivity	1995	1.143	1.273
				1997	0.444	2.328
				1999	0.901	1.358
				2000	1.851	0.944
				2002	1.502	1.147
				2003	0.564	1.885
				2004	0.595	1.498
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	0.554	0.682

				1996	0.380	0.788
				1997	0.409	0.634
				1999	0.341	0.630
				2000	1.517	0.327
				2001	0.898	0.353
				2002	1.436	0.327
				2003	2.237	0.242
				2004	1.228	0.307
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.249	0.362
				1997	0.931	0.236
				1998	0.334	0.247
				1999	1.506	0.219
				2000	0.883	0.240
				2001	0.985	0.225
				2002	1.078	0.210
				2003	1.967	0.199
				2004	1.068	0.232
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	2.512	0.525
				1993	1.586	0.614
				1994	1.756	0.608
				1995	2.047	0.581
				1996	0.877	0.685
				1997	0.965	0.685
				1998	0.915	0.716
				1999	0.252	1.202
				2000	0.651	0.822
				2001	0.567	0.859
				2002	0.439	0.960
				2003	0.255	1.140
				2004	0.179	1.430
LCS05/06-DW-36	MRFSS	FD - R	Sensitivity	1981	1.358	0.565
				1982	0.325	0.557
				1983	1.130	0.555
				1984	0.673	0.553
				1985	0.816	0.505
				1986	1.452	0.406
				1987	0.636	0.441
				1988	1.319	0.400
				1989	1.186	0.436
				1990	1.318	0.428
				1991	1.477	0.419
				1992	0.877	0.391
				1993	0.772	0.418
				1994	0.726	0.409
				1995	1.027	0.409
				1996	1.159	0.403
				1997	1.090	0.401
				1998	1.471	0.372

1999	0.737	0.382
2000	1.259	0.370
2001	0.661	0.390
2002	0.719	0.381
2003	1.064	0.378
2004	0.747	0.387

Blacktip Shark - Atlantic

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-11	Gillnet Observer	FD - C	Base	1993	0.455	0.888
				1994	0.955	0.174
				1995	0.419	0.681
				1998	1.286	0.164
				1999	1.384	0.081
				2000	1.286	0.068
				2001	1.001	0.098
				2002	0.982	0.145
				2003	1.029	0.187
				2004	1.204	0.122
LCS05/06-DW-14	SC LL Recent	FI	Sensitivity	1995	1.750	0.384
				1996	0.808	0.437
				1997	2.094	0.276
				1998	0.487	0.525
				1999	0.482	0.652
				2000	1.147	0.291
				2001	0.232	1.123
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.805	2.423
				1995	2.042	0.854
				1996	1.246	1.640
				1997	0.131	9.878
				1998	0.534	3.352
				1999	0.426	3.775
				2000	0.153	8.354
				2001	0.971	2.814
				2002	4.578	0.012
				2003	0.004	39.339
				2004	0.111	6.517
LCS05/06-DW-27	NMFS LL SE	FI	NR	1995	0	
				1996	0.453	4.403
				1997	0.244	2.725
				1999	0.811	1.706
				2000	0	
				2002	2.748	0.649
				2004	0.745	3.586
				2005	0	
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.678	0.370
				1997	0.474	0.512
				1998	0.689	0.352
				1999	0.423	0.459
				2000	1.005	0.371

				2001	1.620	0.327
				2002	1.948	0.264
				2003	1.081	0.333
				2004	1.083	0.447
LCS05/06-DW-33	NMFS LL NE	FI	Sensitivity	1996	0.202	49.744
				1998	1.578	8.270
				2001	0.797	14.861
				2004	1.423	9.114
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1992	3.389	0.618
				1993	2.373	0.675
				1994	2.019	0.700
				1995	0.924	0.907
				1996	0.785	0.978
				1997	0.603	1.109
				1998	0.360	1.409
				1999	0.411	1.380
				2000	0.392	1.402
				2001	0.263	1.687
				2002	0.434	1.365
				2003	0.494	1.282
				2004	0.550	1.241
LCS05/06-DW-36	MRFSS	FD - R	Sensitivity	1981	1.046	1.023
				1982	0.531	0.787
				1983	1.186	0.718
				1984	1.145	0.747
				1985	1.285	0.621
				1986	1.427	0.577
				1987	0.755	0.637
				1988	0.578	0.681
				1989	0.567	0.684
				1990	0.421	0.755
				1991	0.748	0.627
				1992	1.243	0.545
				1993	0.523	0.687
				1994	2.264	0.511
				1995	1.039	0.577
				1996	0.986	0.577
				1997	0.515	0.660
				1998	1.183	0.546
				1999	0.536	0.633
				2000	0.877	0.583
				2001	1.730	0.529
				2002	1.196	0.550
				2003	1.249	0.560
				2004	0.969	0.585

Blacktip Shark - areas combined

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-11	Gillnet Observer	FD - C	Base	1993	0.455	0.888
				1994	0.955	0.174
				1995	0.419	0.681
				1998	1.286	0.164
				1999	1.384	0.081
				2000	1.286	0.068
				2001	1.001	0.098
				2002	0.982	0.145
				2003	1.029	0.187
				2004	1.204	0.122
LCS05/06-DW-12	PC Longline	FI	Sensitivity	1993	0.768	1.288
				1994	0.133	3.244
				1995	1.018	1.244
				1996	0.758	1.087
				1997	1.299	0.704
				1998	0.974	1.328
				1999	1.136	1.011
				2000	1.914	0.920
LCS05/06-DW-12	PC Gillnet	FI	Base	1996	0.695	0.475
				1997	1.397	0.287
				1998	0.565	0.451
				1999	1.209	0.359
				2000	0.769	0.484
				2001	1.583	0.286
				2002	0.872	0.283
				2003	0.909	0.283
				2004	1.001	0.307
LCS05/06-DW-12	PC Gillnet - juveniles	FI	Base	1996	0.980	0.427
				1997	1.513	0.279
				1998	0.639	0.455
				1999	1.068	0.412
				2000	0.649	0.632
				2001	1.408	0.312
				2002	0.854	0.305
				2003	0.790	0.318
				2004	1.098	0.294
LCS05/06-DW-12	PC Gillnet - Age 0	FI	Base	1996	0.152	1.063
				1997	0.782	0.397
				1998	0.654	0.586
				1999	2.101	0.388
				2000	0.676	0.737

				2001	2.130	0.350
				2002	1.260	0.293
				2003	1.012	0.334
				2004	0.232	0.823
LCS05/06-DW-14	SC LL Recent	FI	Sensitivity	1995	1.750	0.384
				1996	0.808	0.437
				1997	2.094	0.276
				1998	0.487	0.525
				1999	0.482	0.652
				2000	1.147	0.291
				2001	0.232	1.123
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.448	0.919
				1995	1.099	0.310
				1996	0.802	0.480
				1997	0.460	1.386
				1998	0.796	0.714
				1999	1.204	0.423
				2000	1.062	0.646
				2001	0.903	0.739
				2002	1.823	0.239
				2003	1.083	0.374
				2004	1.319	0.264
LCS05/06-DW-24	MS Gillnet	FI	Sensitivity	1998	0.584	0.572
				1999	0.352	0.590
				2000	2.771	0.404
				2001	0.565	0.717
				2003	0.374	0.751
				2004	0.413	0.624
				2005	1.940	0.491
LCS05/06-DW-24	MS Gillnet - juveniles	FI	Sensitivity	1998	0.835	0.683
				1999	0.412	0.887
				2000	2.655	0.336
				2001	0.409	1.892
				2003	0.092	1.722
				2004	0.198	1.443
				2005	2.398	0.791
LCS05/06-DW-24	MS Gillnet - Age 0	FI	Sensitivity	1998	0.200	0.684
				1999	0.245	1.011
				2000	3.136	0.556
				2001	0.302	1.633
				2003	0.660	0.764
				2004	0.134	1.177
				2005	2.323	0.982

LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	0.493	0.487
				1996	0.551	0.826
				1997	0.475	0.533
				1999	0.444	0.500
				2000	1.232	0.265
				2001	0.902	0.295
				2002	1.449	0.252
				2003	2.265	0.225
				2004	1.189	0.259
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.328	0.288
				1997	0.760	0.218
				1998	0.699	0.220
				1999	0.861	0.200
				2000	0.970	0.212
				2001	1.242	0.192
				2002	1.463	0.186
				2003	1.735	0.182
				2004	0.943	0.228
LCS05/06-DW-33	NMFS LL NE	FI	Sensitivity	1996	0.202	49.744
				1998	1.578	8.270
				2001	0.797	14.861
				2004	1.423	9.114

Sandbar

Document Number	Series Name	Type	Recommendation	Year	Index	CV
LCS05/06-DW-09	LPS	FD - R	Base	1986	3.557	0.173
				1987	0.859	0.323
				1988	2.326	0.209
				1989	3.204	0.136
				1990	1.008	0.247
				1991	2.327	0.264
				1992	1.382	0.233
				1993	0.739	0.872
				1994	0.378	0.755
				1995	0.302	1.255
				1996	0.369	1.092
				1997	0.530	0.834
				1998	0.124	2.138
				1999	0.202	1.994
				2000	0.213	1.990
				2001	0.986	1.064
				2002	0.236	1.721
				2003	0.181	1.663
				2004	0.076	2.136
LCS05/06-DW-12	PC Gillnet	FI	Sensitivity	1996	1.00*	1.667
				1997	2.250	2.963
	* nominal index			1998	1.220	4.773
				1999	0.530	6.789
				2000	0.690	7.200
				2001	1.250	6.667
				2002	0.610	7.273
				2003	0.970	5.429
				2004	0.470	7.588
LCS05/06-DW-14	SC LL Recent	FI	Sensitivity	1995	0.458	1.049
				1996	0.964	0.446
				1997	0.643	0.576
				1998	0.750	0.377
				1999	2.547	0.207
				2000	0.666	0.396
				2001	0.972	0.344
LCS05/06-DW-17	BLLOP	FD - C	Base	1994	0.799	1.027
				1995	0.882	0.832
				1996	1.000	0.843
				1997	0.956	1.182
				1998	1.292	1.391
				1999	0.849	1.529
				2000	0.744	2.009

				2001	1.650	1.600
				2002	0.865	1.266
				2003	1.007	0.902
				2004	0.955	0.976
LCS05/06-DW-20	VA LL	FI	Base	1975	1.900	0.23271
				1977	2.077	0.28711
				1978	1.085	0.58275
				1980	1.995	0.20558
				1981	1.925	0.21419
				1984	0.647	1.01363
				1986	0.665	1.08966
				1989	0.911	0.35817
				1990	0.746	0.29514
				1991	0.788	0.30447
				1992	1.331	0.46767
				1993	0.915	0.40248
				1995	0.860	0.26193
				1996	0.770	0.27439
				1997	0.721	0.22527
				1998	0.826	0.20952
				1999	0.528	0.36478
				2000	0.865	0.28108
				2001	0.754	0.23611
				2002	0.626	0.34985
				2003	0.547	0.26489
				2004	0.519	0.37114
LCS05/06-DW-27	NMFS LL SE	FI	Base	1995	1.293	0.281
				1996	0.831	0.379
				1997	1.301	0.316
				1999	0.390	0.384
				2000	0.971	0.210
				2001	1.041	0.256
				2002	1.072	0.207
				2003	0.880	0.261
				2004	1.221	0.322
LCS05/06-DW-30	DE Bay	FI	Base	2001	0.950	0.205
				2002	0.386	0.332
				2003	1.409	0.182
				2004	1.070	0.212
				2005	1.185	0.212
LCS05/06-DW-30	DE Bay - Age 0	FI	Base	2001	0.645	0.373
				2002	0.518	0.442
				2003	1.776	0.272
				2004	0.877	0.357
				2005	1.183	0.311
LCS05/06-DW-30	DE Bay - juveniles	FI	Base	2001	1.162	0.184

				2002	0.325	0.377
				2003	1.163	0.194
				2004	1.164	0.207
				2005	1.185	0.199
LCS05/06-DW-31	Bottom LL Logs	FD - C	Base	1996	0.789	0.175
				1997	1.002	0.116
				1998	0.919	0.111
				1999	1.150	0.102
				2000	1.171	0.111
				2001	1.115	0.104
				2002	0.887	0.104
				2003	1.170	0.102
				2004	0.798	0.119
LCS05/06-DW-33	NMFS LL NE	FI	Base	1996	0.321	7.985
				1998	2.045	1.678
				2001	1.004	2.947
				2004	0.629	4.909
LCS05/06-DW-35	Pelagic Log	FD - C	Base	1994	0.140	1.275
				1995	0.912	0.682
				1996	2.116	0.619
				1997	0.762	0.699
				1998	1.050	0.685
				1999	1.022	0.703
				2000	1.266	0.682
				2001	1.161	0.688
				2002	0.518	0.773
				2003	0.801	0.735
				2004	1.251	0.687
LCS05/06-DW-36	MRFSS	FD - R	Sensitivity	1981	2.011	0.645
				1982	2.195	0.592
				1983	2.766	0.592
				1984	2.408	0.610
				1985	2.094	0.591
				1986	2.119	0.560
				1987	1.167	0.594
				1988	0.789	0.621
				1989	0.714	0.639
				1990	0.634	0.674
				1991	0.431	0.679
				1992	0.874	0.600
				1993	0.402	0.679
				1994	0.243	0.776
				1995	0.492	0.643
				1996	0.612	0.617
				1997	0.504	0.663
				1998	0.917	0.603
				1999	0.524	0.639

2000	0.525	0.660
2001	0.503	0.651
2002	0.490	0.656
2003	0.386	0.714
2004	0.201	0.836

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Minority Statement from the Directed Shark Industry

Three technical concerns with the sandbar assessment that we ask the reviewers to consider.

Prepared by Frank Hester and Russell Hudson
Directed Shark Fishery Industry

Sandbar is an import resource and one of the two mainstay species of our industry, and we want to assure the best scientific information has been used in this assessment. Section 4 of the current assessment indicates that sandbar are overfished and that overfishing is occurring. We believe that before accepting the results, some additional sensitivity runs should be made and some additional analyses performed. What these are and the reasons for these requests are addressed in the following three point.

1. Age at (50%) sexual maturity for the 2006 assessment has been increased to 18-19 years. The basis is the new SB maturity ogive (**AW-09: Length and age at maturity of the sandbar shark, *Carcharhinus plumbeus*).** However, we note that none of the specimens examined for maturity state were also aged. Instead, age was estimated from length using a Von Bertalanffy growth curve derived from a different set of animals.

Unfortunately, none of the material that could be used to age each specimen was preserved and there is no way that the study results can be confirmed, or properly aged. Still, we believe the study needs be redone wherein both aged and maturity state is determined for each specimen. This cannot be done immediately, but we asked that a sensitivity run be done using a lesser age to determine how great an effect this new estimate has on the outcome. The assessment group did not agree, and one was not done.

We believe one should be done and included in your report so that one can judge the priority to assign to getting a valid maturity ogive. We suggest using the Base Case and age 13 at 50% mature. This estimate was used for the last assessment. A range of 8-13 seems to be encompass the estimates from other studies of this species.

2. We had a considerable discussion of the LPS Index (**DW-09: Standardized Catch Rates of Sandbar Sharks (*Carcharhinus plumbeus*) in the Virginia - Massachusetts (U.S.) Rod and Reel Fishery during 1986-2004)** in the context of the changes to the sport angling regulations that were imposed in 1993, 1997 and 1999. The regulatory change in 1993 limited the landings to four LCS per trip; reduced to two per trip in 1997 and one in 1999. We question whether even the new analysis (DW-09-V2) deals adequately with the effect of the regulations. The index, if it is to be used at all, needs to

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be reanalyzed to include catches of other LCS species on the trip, as the limit can be (partially) filled by other LCS species.

3. The Virginia Longline Index. As we prepared this paper, the sandbar section of the AW Report lacks tables evaluating the influence of individual indices on the outlook. These should be prepared and included in the final report. The only sensitivity runs done so far provide no information on individual indices, (or the maturity question - our point 1 above).

In lieu of these sensitivity runs, we use the figures of model predicted fit to the indices (Fig 4.7ff) to evaluate how well the model fit the indices. Figure 4.7 shows that the VA – LL index **(LCS05/06-DW-20)** has a disproportioned influence on the outcome. This is not surprising since it the longest index in the base case, and has nice negative "contest."

When a single index essentially determines the results of an assessment, we believe it should be scrutinized carefully. Is it likely to truly reflect change in population size? Because this particular series comprises a few sets per year at a single point in space off Virginia where sandbar are seasonally present, we believe it needs to be regarded with caution. The sandbar population ranges along the Atlantic seaboard, throughout the Gulf of Mexico, and into Mexico, and the VA-LL trend is not reflected by the indices that are derived from catches throughout the range of the species.

A second concern we have with the VA-LL series is that the age composition of the catch changes over time, adults being taken mainly in the early years (age composition data are available, were used in the 2002 Assessment, but were not provided this year). The index this year was given the same selectivity as the commercial catch even though most of the catch after 1975 was juveniles. The biology of sandbar is such the adults are unlikely to be taken in this area early in the season or in shallow water (females may be present, but generally do no feed during pupping). The index needs to be reanalyzed to include age and sex of the catch along with the other factors.

Thank you for your consideration

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SEDAR 11

Stock Assessment Report

Large Coastal Shark Complex, Blacktip and Sandbar Shark

Section IV: Review Workshop Consensus Summary

Consensus Summary Report

A. Large Coastal Shark Complex
B. Sandbar Shark
C. Blacktip Shark – Gulf of Mexico
D. Blacktip Shark – Atlantic

Prepared by the SEDAR 11 (Large Coastal Sharks) Review Panel for:

NOAA/NMFS Highly Migratory Species Management Division

Edited by Andrew I. L. Payne for

SEDAR 11 (Large Coastal Sharks), 5–9 June 2006
Panama City, FL

Executive summary

The SEDAR 11 Review Panel met from 5 to 9 June 2006, in Panama City, FL. A CIE Chair, 2 CIE reviewers, and two independently invited reviewers made up the panel. The two local scientists responsible for the assessments did a good job at summarizing the outputs from the Data and Assessment Workshops that had led to the review.

Overall, the data utilized in the assessment of the **Large Coastal Shark complex** *were the best available to the analysts at the time, and the assessment of the status of the complex was the best possible given the data available. However, the assessment did a poor job at representing the status of the Large Coastal Shark complex (in any of the formulations: i.e. 22, 11, or 9 species) because of the potential for conflicting/ mismatching information from various species components in the catch and abundance index data. Therefore, it was unclear to the Panel what exactly the results of the assessment represented, making it impossible to support use of the results for management of the complex. Further, the Panel stressed that results of previous assessments that used the same approach and similar data (perhaps of lesser quality) would attract the same or even stronger negative criticisms. In summary, continued assessment of the Large Coastal Shark complex with the current approach and data was considered unlikely to produce effective management advice and was not recommended (although for continuity, output from such an approach should be made available when next the complex is subject to review). Instead, research, data analysis and model development to permit species-specific assessments for the main components (except for sandbar and blacktip, which are already assessed separately) of the complex (both permitted and prohibited species) was deemed a priority.*

For **sandbar sharks***, the population model and resulting population estimates were the best possible given the data available. The change in stock status in the 2006 assessment from the more optimistic status in 2002 appears to be mainly attributable to revisions to the life history parameters in the current assessment. The population is assessed to be less productive than was assumed in 2002. In 2006, the SEDAR process was adopted, resulting in more thorough review at all stages, which was not possible with the previous stock assessments. For this reason and those concerning life history parameters, the Panel was confident that the 2006 assessment provided a more reliable estimate of stock status than had been obtained from the 2002 and earlier assessments. Stock status was determined from the results of a range of model fits reflecting the Panel's uncertainty about life history parameters. All results indicated that the stock was overfished and that overfishing is occurring. The target year to rebuild the stock was estimated to be 2070.*

In terms of **blacktip sharks in the Gulf of Mexico***, the Panel accepted that the stock is not overfished and that overfishing is not taking place, but did not accept the absolute estimates of stock status. The three abundance indices believed to be most representative of the stock were consistent with each other, suggesting that stock abundance has been increasing over a period of declining catch during the past 10 years. Based on life history characteristics, blacktip sharks are a relatively productive shark species, and a combination of these characteristics and recent increases in the most representative abundance indices suggests that the blacktip stock is relatively healthy. However, there was no scientific basis for advising an increase in catches at this time.*

For **blacktip sharks in the Atlantic***, the Panel concluded that the data used for the analyses were treated appropriately. However, it was unclear whether catch estimates prior to 1991 adequately represented historical removals. Moreover, it was impossible to judge the extent to which each of the standardized catch-rate series reflected real trends in the abundance of the stock. Therefore, given the widely differing results arising from the different models, the status of the stock of Atlantic blacktip shark was deemed to be uncertain, and no reliable estimates of abundance, biomass or exploitation rate were advanced. Further, in the absence of reliable estimates of abundance, biomass and exploitation rates, no reliable estimates of stock status*

were suggested. In summary, given that current status is unknown, no reliable population projections were possible, so no probable values for future population condition and status were provided. Consequently, the Panel concluded that there was no scientific basis for advising a change in catch levels.

Stakeholders proffered valuable insights during the week's review, and their opinion section is added to the report, although its contents do not wholly reflect Review Panel or expert thinking. In summary, stakeholders support the positive assessments of blacktip, though would be interested in seeing a non-separated (into Gulf and Atlantic components) evaluation, do not subscribe to the negative assessment of sandbar sharks, and support a move towards species-specific assessments rather than assessing a LCS complex, but feel that the current status of the components of the complex is better than the assessment implies.

Recommendations for future research contained in the Data and Assessment Workshop reports were endorsed, and others were added by the Panel. The report closes with a few comments on process, for future consideration.

1. Introduction

1.1 Time and Place

The SEDAR 11 (Large Coastal Sharks) Review Workshop met in Panama City, FL, from 5 to 9 June 2006.

1.2 Terms of Reference for the Review Workshop

1. Evaluate whether data used in the analyses are treated appropriately and are adequate for assessing the stocks; state whether or not the input data are scientifically sound.
2. Evaluate the adequacy, appropriateness, and application of the methods used to assess the populations; state whether or not the methods are scientifically sound.
3. Recommend appropriate or best-estimated values of population parameters such as abundance, biomass, and exploitation (if possible).
4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate stock status criteria (population benchmarks such as MSY, F_{msy}, B_{msy}, MSST, MFMT). State whether or not the methods are scientifically sound.
5. Recommend appropriate values for stock status criteria (if possible).
6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.
7. Recommend probable values for future population condition and status (if possible).
8. Ensure that all desired and necessary assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately

presented in the Stock Assessment Report and that such results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.

9. Evaluate the Data and Assessment Workshops with regard to fulfilling their respective Terms of Reference and state whether or not the Terms of Reference for previous workshops are adequately addressed in the Data Workshop and Stock Assessment Report sections;

10. Develop recommendations for future research for improving data collection and stock assessment.

11. Prepare a Consensus Report summarizing the peer review Panel's evaluation of the reviewed stock assessments and addressing these Terms of Reference. (Drafted during the Review Workshop with a final report due two weeks after the workshop ends.)

1.3 List of Participants

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1.4 Review Workshop working papers

An impressive quantity of documentation was provided before the meeting by the facilitator. Much of this pertained to material provided to either the Data

Workshop or Assessment Workshop for each of the review stocks. No new literature or working papers were provided at the meeting.

2. Terms of Reference

2.1 Background

Generally, the Review Workshop is the third meeting in the SEDAR process, and this situation pertained to all stocks reviewed during SEDAR 11. The Panel records that the Terms of Reference set for Data Workshops and Assessment Workshops for the four "stocks" were fully met, at least to the extent feasible, a notable achievement given that data for assessing such species are traditionally (worldwide) very poor. Overall, short data time-series, recent biological and catch data, and minimal information on basic life history were unlikely to support the development of assessments rigorous to withstand peer-scrutiny for management purposes.

Notwithstanding, the Panel was impressed by the quantity and quality of the work that had gone into the various assessments. The presentations were well structured and clear, and the information provided through the presentations, and in response to questions, gave a sound basis for the Panel's subsequent deliberations and conclusions.

2.2 Review of the Panel's deliberations

The deliberations on each species are presented in the form of responses to the terms of reference questions specifically, generally listing some of the issues and concerns that were raised in discussions, followed by relevant comments on and conclusions from the discussions, and suggestions for future research (the last two non-prioritized). Finally, in the subsequent subsections, endorsement of some of the Data and Assessment Workshop recommendations is provided, and some relevant stakeholder opinion is presented.

A. *Large Coastal Shark Complex*

<u>Terms of reference</u>

1. Evaluate whether data used in the analyses are treated appropriately and are adequate for assessing the stocks; state whether or not the input data are scientifically sound.

The Review Panel considered that the data had in general been appropriately handled. However, the assessment was carried out for a complex of up to 22 species, and this meant that data were combined for all of these species. As such the data do not represent the trends in any one species, or even the status of the group as a whole, because opposing trends in different species could cancel each other out. The Review Panel therefore considered that although the data were well handled, they may not be appropriate for assessing the status of the complex. In addition, the Panel identified a number of issues related to the data used in the assessment:

- Species composition of the catch series used was not specified, nor was the species composition of the catch-rate series (see below; species composition data for the commercial fishery were only available from 1995 onwards). If there were significant differences in the species composition of either of these data sets over time, then the assessment is likely to have produced results that do not reflect the status of the complex as a whole, or even the main components. Similarly, if the catch series had a significantly different composition from those of the abundance indices, then there is a mismatch in the signals to the model, with abundance changes not reflecting the composition of the catch.
- Standardization of catch-rate series was not carried out in a consistent fashion. Different types of standardization were used, although by the time of the Assessment Workshop, most had used the Delta method. This change in standardization for some of the indices was not updated in the documentation, and the Panel recommends that in the future, the details of the index standardization be updated to reflect the finalized information. The application of a variety of standardization techniques may have resulted in indices potentially being biased in the decline/increase that they predict or perhaps in different coefficients of variation (CV). (The Panel recognized that the base model did not use CV to weight the indices, but some sensitivity runs did.)

2. Evaluate the adequacy, appropriateness, and application of the methods used to assess the populations; state whether or not the methods are scientifically sound.

The assessment used a Bayesian surplus production model to assess the population. This method is appropriate for the assessment. Although the method was appropriate, the Review Panel identified a number of concerns related to the assessment:

- The assumption of equal weighting for all the abundance indices means that the large numbers of recent indices that have a flat trend reduce the contribution of the few longer time-series that often showed larger declines in abundance. The longer time-series are the only ones that provide information on abundance from earlier in the assessment period. The Panel also considered the possibility that those series that have lower CVs could be more heavily weighted. However, a sensitivity test was run that examined use of a weighting scheme related to the inverse of the CV of the series. This resulted in a more pessimistic status of the stock for the 22-species complex (overfished and overfishing occurring), but similar results for the 11 and 9 species complexes. The Review Panel therefore considered the approach used at the data workshop, where the series were examined in detail and evaluated for their representation of stock abundance, to be suitable when used in conjunction with equal weighting of indices.

- In a similar way, the abundance indices are based on surveys or data that represent different proportions of the range of the species complex. For example, the Panama City NMFS laboratory gillnet survey (PC gillnet) abundance series was relatively localized, while the NMFS Southeast longline survey (NMFS SE LL) covered significant proportions of the geographic range of the complex. The Review Panel was concerned that indices that represent relatively small portions of the geographic range are likely to be less representative of the overall abundance of the complex, because year-to-year variation in catches is likely to be greater in such series through localized effects. Again, the assumption of equal weighting of all catch-rate series does not represent the spatial extent of the data series, and consideration should be given to weighting the series by geographic extent (e.g. proportion of species range).
- The aggregation of data from 22/11/9 species into the Large Coastal Shark complex forces an assessment on a group of species with diverse life histories. If the species composition of the catch or catch-rate series has changed over the assessment period, then the assumption that the model has a single value of intrinsic rate of population increase (*r*) is incorrect, and *r* can change over time, possibly reflecting changing species composition.
- The assessments are for the Gulf of Mexico and Atlantic combined, and indications are that the abundance indices from these two areas represent different dominant species in the catch. Given that the updated data provided on the species composition of the NMFS longline southeast survey indicated that the two regions were dominated by different species, the Panel considered that aggregation of these areas may lead to misleading results.

3. Recommend appropriate or best-estimated values of population parameters such as abundance, biomass, and exploitation (if possible).

Given the multispecies nature of the assessment, it is unclear which, if any, of the scenarios gave the best estimate of the population parameters.

4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate stock status criteria (population benchmarks such as MSY, F_{msy}, B_{msy}, MSST, MFMT). State whether or not the methods are scientifically sound.

The Review Panel was unable to evaluate whether the methods used to determine the reference points for a stock complex were appropriate. The Review Panel noted that it was assumed that maximum sustainable yield (MSY) occurred at 50% of virgin biomass/numbers (i.e. the inflection point in the production curve). There is evidence to suggest that in some slower growing species, such as some of the shark species, MSY occurs at lower levels of depletion (50–70% of virgin biomass/numbers). If the 50% assumption is incorrect, then the calculations of MSY in the model will be incorrect, and the reference points used in the assessment (e.g. F_{MSY} and B_{MSY}) to determine if the stock is overfished, or if overfishing is occurring, will be inappropriate. In addition, the status of the stocks will also be worse than estimated and have a higher likelihood of being overfished or of overfishing occurring.

5. Recommend appropriate values for stock status criteria (if possible).

Given the concerns regarding reference values for a stock complex, no values for stock status criteria can be recommended.

6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.

Given appropriate model inputs, the methods used in the assessment would be adequate, appropriate, and scientifically sound for a single species. However, the Panel could not evaluate whether projections made for a species complex using this model would be meaningful.

7. Recommend probable values for future population condition and status (if possible).

The uncertainty as to what the results of the assessment represent makes recommendation of appropriate levels of future stock status impossible at the current time.

*8. Ensure that all desired and necessary assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.*

The necessary results fulfilling the SEDAR stock assessment report outline were presented. The Review Panel did not request any additional runs of the models, but they did request clarification of several inputs and outputs from the models:

- Species composition of the catch and main catch-rate series to investigate whether there were substantive changes over time or between the two types of data (see Figures on following pages).

Figure 1. Species composition of the commercial landings of large coastal sharks (LCS – prohibited – sandbar – blacktip) by year. The percentage of this species group of total shark catch is given for each year.

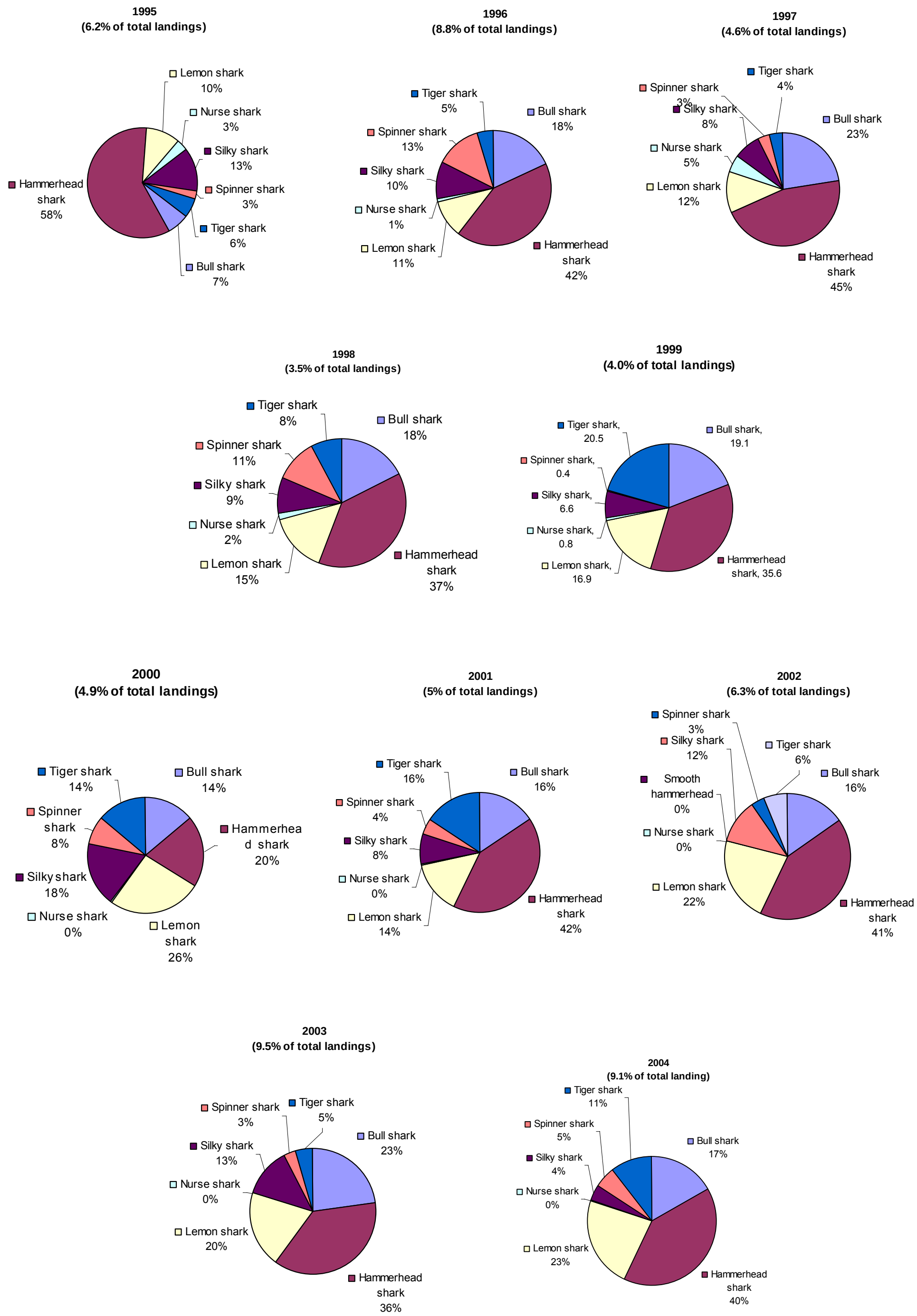
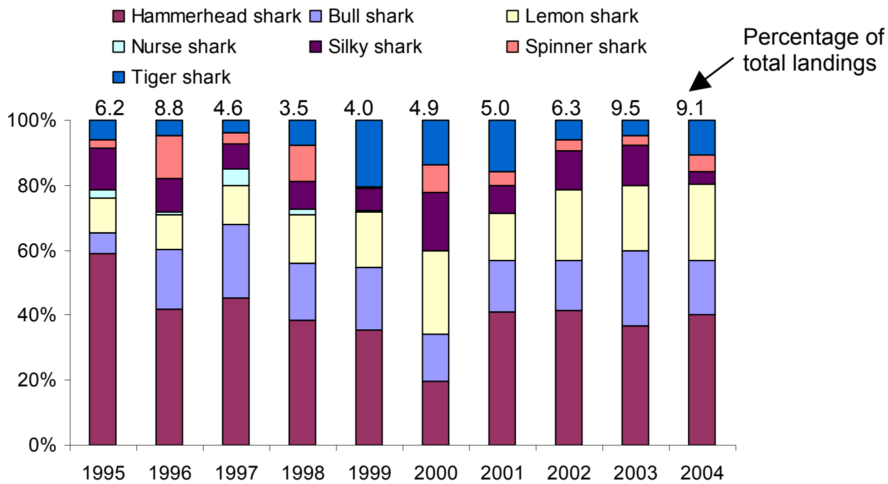
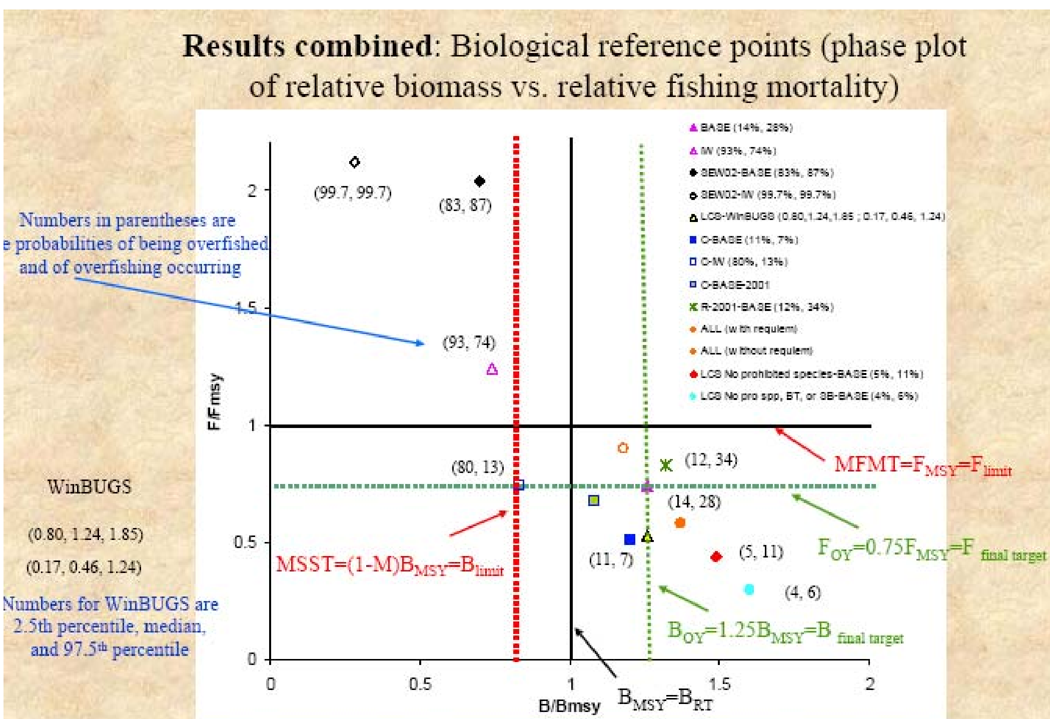


Figure 2. Proportional species composition of commercial shark landings, 1995–2004.



Data on the species composition of the main abundance indices was more difficult to obtain during the meeting, because the information needed to be sourced from originators of the data. However, preliminary investigation of the NMFS longline southeast survey data indicated that in the Gulf of Mexico (GOM), the indices were dominated by spinner and hammerhead sharks, while in the Atlantic (ATL), tiger sharks dominated.

- The probabilities of the outcomes of the base case and sensitivity runs of the model exceeding the two reference thresholds (overfished and overfishing occurring) were produced.



9. Evaluate the Data and Assessment Workshops with regard to fulfilling their respective Terms of Reference and state whether or not the Terms of Reference for previous workshops are adequately addressed in the Data Workshop and Stock Assessment Report sections.

The Data Workshop fulfilled its Terms of Reference. The Assessment Workshop fulfilled its Terms of Reference to the extent possible, given the limitations of the data.

10. Develop recommendations for future research for improving data collection and stock assessment.

Issue: Lack of species-specific data, and the inability to identify carcasses/logs/ fins to species level.

- Improve dockside monitoring of catches
- Increase observer coverage of the commercial fleet
- Use biochemical and/or genetic testing of products (carcasses/logs/fins) to produce reliable species identifications

Issue: Lack of life history data for some species within the large coastal shark species complex, which results in no meaningful estimate of intrinsic rate of increase (*r*) for use in assessments.

- Conduct research on the life history of all species in the complex, including regular sampling and analysis of the main species
- Use life tables (or other similar approaches) to estimate population parameters such as *r*

Issue: Limited numbers of longer term abundance (catch rate) data.

- Utilize all appropriate abundance series available, e.g. the Schwartz data from North Carolina

Issue: Geographic range of abundance surveys is variable, and those with limited geographic coverage are more likely to reflect localized changes than stock-wide changes.

- Evaluate alternative weighting schemes or modelling approaches for abundance data that take account of the geographic range of the surveys

Issue: Lack of species and size composition and effort data for abundance surveys.

- Provide information on species and size composition
- Obtain trends in deployed fishing effort at least for the catch-rate index series in Data Workshops and present them in the Assessment Workshop report, together with corresponding trends in catches and catch rate.

Issue: Information on the type and quality of the standardization used for abundance indices was not always available.

- Document the method of standardization used for all catch-rate indices
- Where possible, use the same standardization methods for all indices

Issue: Assessment of the Large Coastal Shark (LCS) complex does not represent the status of the stocks, or any particular component of the stocks.

- Develop species-specific assessments for the main components of the LCS complex, where possible. Continuing with the current approach will only result in confusion with regards to the status of these resources
- As an interim step, an improvement may be achieved if the complex can be split into smaller groups based on species with similar life history characteristics, or which occur within the same regions (e.g. the Gulf of Mexico or the Atlantic).

Conclusions

- The data utilized in the assessment of the Large Coastal Shark complex were the best available to the analysts at the time.
- The assessment of the status of the Large Coastal Shark complex was the best possible given the data available to the Data and Assessment Workshops.
- The assessment does a poor job at representing the status of the Large Coastal Shark complex (in any of the formulations: i.e. 22, 11, or 9 species) because of the potential for conflicting/mismatching information from various species components in the catch and abundance index data. Therefore, it is unclear what exactly the results of the assessment represent, so the Panel cannot support use of the results for management of the Large Coastal Shark complex. Further, it is stressed that results of previous assessments that used the same approach and similar data (perhaps of lesser quality) would attract the same or even stronger negative criticisms.
- Continued assessment of the Large Coastal Shark complex with the current approach and data is unlikely to produce effective management advice and is not recommended.
- Research, data analysis and model development to permit species-specific assessments for the main components (except for sandbar and blacktip, which are already assessed separately) of the complex (both permitted and prohibited species) should be a priority.

B. *Sandbar Shark*

Terms of reference

1. Evaluate whether data used in the analyses are treated appropriately and are adequate for assessing the stocks; state whether or not the input data are scientifically sound.

Landings data were available from the commercial fishery, the recreational fishery, the Mexican fishery and as bycatch from the Gulf menhaden fishery. There was no shark bycatch information from the larger Atlantic menhaden fishery, and the Review Panel was unable to determine how important that omission was in estimating total removals from the sandbar shark population. Landings prior to 1981 were extrapolated back to 1975 to match the earliest date for the catch-rate series, based upon a number of assumptions related to subsequent catches. There was discussion about the possibility of there being records of landings in the earlier years; if true, then efforts should be made to locate those records.

The population was designated as being in an unfished or virgin state in 1975, while at the same time it was recognized that there had been a smaller scale commercial fishery for sandbar sharks in the years 1935–1951. There was also discussion about the completeness of the landing records for the mid-1980s and whether or not landings from Mexico and perhaps Cuba during this time period had been properly accounted for.

A number of fishery-dependent and -independent catch-rate series were used for the stock assessment. These data series had been evaluated during the Data Workshop, where standardized indices had been developed using generalized linear models, assuming a form of the Delta distribution. All recommended series were used in either the main model run or in sensitivity runs. The Virginia Institute of Marine Science (VIMS) longline series was the only one used in the model runs that had observations prior to 1985. Size and maturity stage information was reported as being collected from the VIMS longline and some of the other series, but those data were not supplied to the stock assessment scientists. Given that the VIMS survey was a designed fishery-independent survey, it would have been helpful to have the size information to see if the component of the population that it was monitoring had been changing over time.

The Panel concluded that the data, even with the shortcomings identified above, were the best currently available for evaluating the stock status of sandbar sharks.

2. Evaluate the adequacy, appropriateness, and application of the methods used to assess the populations; state whether or not the methods are scientifically sound.

An age-structured population model with state-space dynamics for some of the components and prior distributions assigned to some of the parameters was fitted to the data. No age data were used in the model, and the age structure was used mainly to incorporate different natural mortalities- and selectivities-at-age for the different fisheries (i.e. commercial, recreational, bycatch in menhaden fishery). Catch-rate indices were assumed to be proportional to population size, albeit with series-specific catchabilities and selection curves dependent upon whether they were commercial- or recreational-fishery-dependent, or fishery-independent series.

The model adequately incorporated the information from the available catch-rate indices and was the best available for the data provided. However, while catch-rate indices can inform on trends, they do not necessarily help generate understanding of the life history patterns that underpin stock status estimation. Pup survival was the only life history parameter to be estimated in the model, and other parameters such as natural mortality-at-age and the prior mode for pup survival had to be adjusted so that the steepness parameter remained within a reasonable range for the species.

3. Recommend appropriate or best-estimated values of population parameters such as abundance, biomass, and exploitation (if possible).

The base case produced estimates of the number of mature animals, total population biomass, and fishing mortality as 96 600, 30 600 t round weight, and 0.06, respectively. Sensitivity runs resulted in numbers of mature animals ranging from 103 000 to 96 600, total population biomass ranging from 27 600 to 36 600 t, and fishing mortality ranging from 0.05 to 0.13.

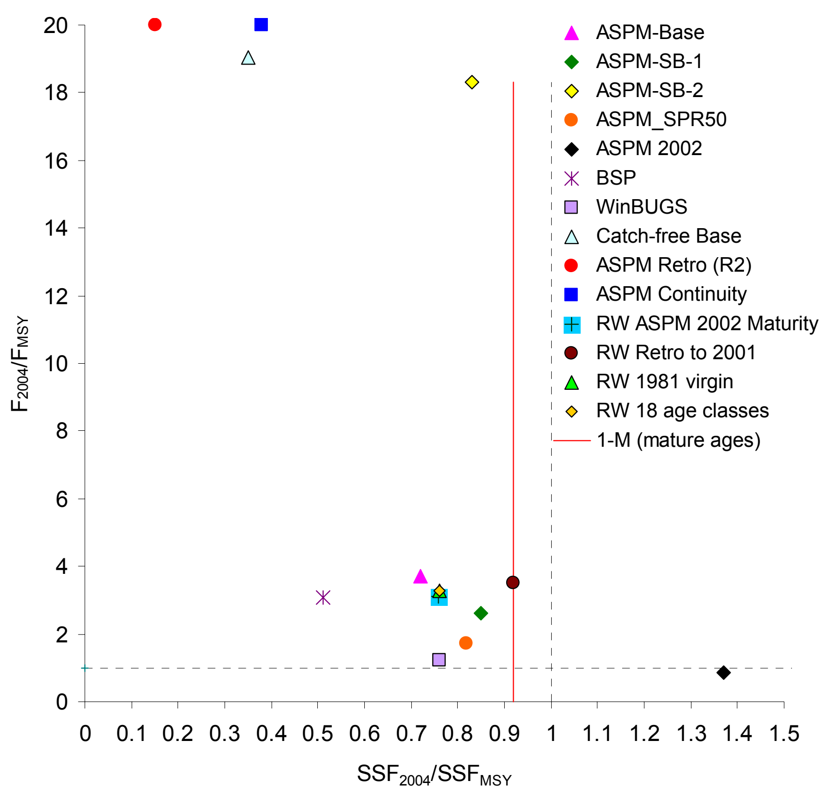
4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate stock status criteria (population benchmarks such as MSY, F_{msy}, B_{msy}, MSST, MFMT). State whether or not the methods are scientifically sound.

The methods used to estimate stock status were appropriate for the population model used in the assessment. They allowed the Panel to test the impact of different assumptions about the data and life history parameters on estimating stock status. In particular, using the maturity-at-age structure from the 2002 assessment, various ways of discounting the high 1983 recreational catch, running the 2002 assessment with 2006 life history parameters, starting the assessment in 1981, and a 10% increase to the 2004 catch in anticipation of post-season revisions, all resulted in not only the same findings of overfished and overfishing occurring, but the estimates were also clustered close together on the phase plot (Figure 3). A model run with the 2002 assumption of constant mortality was unsuccessful. Ultimately, the methods used for estimating stock status were found to have been much more sensitive to assumptions about life history parameters than the catch and catch-rate data used in the model.

5. Recommend appropriate values for stock status criteria (if possible).

All the model runs using the data to 2004 resulted in the finding that the population of sandbar sharks was overfished and that overfishing was occurring. All comparisons led to the conclusion that the change in status in 2006 from that reported in 2002 was attributable mainly to the assumptions about the productivity of the stock (function of steepness, maturity at age, mortality) used in each assessment. In retrospect, the 2002 productivity assumptions were considered by the Panel to have been incorrect, given what is now known about the life history parameters for the population.

Figure 3. Phase plot with results for all the base and sensitivity runs for sandbar shark. Stock status for 2004



6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.

Generation times were calculated for the base model and the sensitivity runs in the cluster around the base model (Figure 3), and these ranged from 27 to 28 years. All generation times were estimated using a cumulative survival of 0.1% as cut-off. Despite the uncertainty associated with the life history parameters, all model projections were quite close. Given that the data and the model are the best currently available, then the same can be said for the projections, assuming that the productivity of the stock continues to be as estimated in the assessment.

7. Recommend probable values for future population condition and status (if possible).

The base-case model estimated the status to be overfished and with overfishing occurring. The rebuilding timeframe under no fishing was calculated. This yielded an estimate of 38 years to rebuild. Adding the estimate of generation time (28 years), the target year for rebuilding the stock was estimated to be 2070. A constant F to achieve rebuilding by that date with 70% probability of $B>B_{MSY}$ is F = 0.009; the median of the bootstrap runs would achieve rebuilding by 2070 with F = 0.011. A similar exercise for constant TAC was performed, and rebuilding is achieved with 70% probability with a TAC of 220 t or with 50% probability with a TAC of 240 t. In all projections, F_{2004} was carried forward for the years 2005–2007, and the constant F or TAC was applied in years 2008 and beyond.

*8. Ensure that all desired and necessary assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.*

All the assessment results were clearly presented in the Assessment Report and by the lead researcher. One omission noted was details on the final models used for standardizing catch-rate indices. Summary tables in the Data Workshop report only showed what was done during the meeting, not what was achieved after the meeting.

9. Evaluate the Data and Assessment Workshops with regard to fulfilling their respective Terms of Reference and state whether or not the Terms of Reference for previous workshops are adequately addressed in the Data Workshop and Stock Assessment Report sections.

Both workshops appeared to have fulfilled their respective terms of reference.

10. Develop recommendations for future research for improving data collection and stock assessment.

Research recommendations are included in the reports from the Data and Assessment Workshops (and in 2.3 below), so what follows is not intended to replace them but rather to emphasize specific needs for sandbar shark.

Issue: There are uncertainties concerning appropriate values for life history parameters in determining stock status.

- While the workshop reports called for more life history research, there needs to be a focus on the type of research needed to provide the necessary information for the population model in terms of density-independent or -dependent conditions, such as estimating mortality at different population levels

Issue: The population model assumed that catch-rate indices were proportionally related to population size.

- Many of the indices are based on longline gear, and the assumption of proportionality needs to be assessed for that type of gear through literature review and directed research

Issue: A number of catch-rate indices were used, and it was not obvious which components of the sandbar population they were monitoring.

- Using information on the size composition of catches from these indices, if available, would be helpful
- Maps of where (and when) the catch-rate series are located, along with the location of the fisheries, would aid in interpreting these series

Issue: The assessment used an age-structured model, but no age information was used.

- The predicted age compositions for the population and the catch in the model may provide useful diagnostics for the performance of the model. Research should be directed into developing these diagnostics, including verification with any available data on age composition. One example of a diagnostic indicator is the mean size/age in the catch and population, and from any catch-rate index that may collect size composition data

Issue: No information on sandbar bycatch from the Atlantic menhaden fishery was provided, and there was no sense of how important such information is for accounting for all removals from the population.

- Determine if these data are available and, if so, include them in the next assessment. If data are not available, then design a study to collect information on shark bycatch either through logbook or onboard observers

<u>Conclusions</u>

- The population model and resulting population estimates were the best possible given the data available.
- The change in stock status in the 2006 assessment from the more optimistic status in 2002 appears to be mainly attributable to revisions to the life history parameters in the current assessment. The population is assessed to be less productive than was assumed in 2002.
- In 2006, the 3-part SEDAR process of data workshop, assessment workshop, and review workshop was adopted for large coastal sharks. This process resulted in a more thorough review at all stages of the process, which was not

possible with the previous stock assessments. For this reason and those concerning the life history parameters given above, the Panel is confident that the 2006 assessment gives a more reliable estimate of stock status than obtained from the 2002 and earlier assessments.

- Stock status was determined from the results of a range of model fits reflecting the Panel's uncertainty about life history parameters. All results indicate that the stock is overfished and that overfishing is occurring. The target year to rebuild the stock is estimated to be 2070.

C. *Blacktip Shark – Gulf of Mexico*

Terms of reference

1. Evaluate whether data used in the analyses are treated appropriately and are adequate for assessing the stocks; state whether or not the input data are scientifically sound.

The data were treated appropriately, and were adequate for the models used to assess the stocks. However, there were deficiencies in the data provided. Historical catches were assumed to be negligible in the assessment model, resulting in the assumption that a virgin population was present in 1981. Yet there was an eightfold increase in commercial catches between 1985 and 1986, suggesting that catches before 1986 were grossly underestimated. Alternative methods for estimating historical catch, such as examination of fish processor records, might prove useful for this purpose.

The various abundance indices were inconsistent among themselves; some showed declining trends, some showed increasing trends, and others were relatively flat. This issue might be addressed if selection of abundance indices was restricted to those most likely to provide reasonable coverage of the population. The three indices believed to be most representative of trends in the stock are bottom longline observer, NMFS longline southeast survey, and Panama City gillnet survey (for juveniles).

Evidence that the abundance indices and commercial catch were sampling the same population component was missing. Maps showing the extent of spatial overlap would help address this.

No information on size or age composition of the indices or catch was presented. An analysis of such data would ensure that the indices are representative of the catch, and can be used as a diagnostic of the adequacy of the age-structured model.

The life history parameters recommended at the Data Workshop appear to be unrealistic, because they had to be changed in order to increase steepness above the minimum level required for a self-sustaining population. The estimates of M at age were set at levels below that recommended by the Data Workshop (M = 0.1 for adults), and first-year survival was set at values higher than those shown in a field study. It was suggested that the inconsistency between expected and assumed life history parameters could have been due to an unknown source contributing pups to the population. Indicators of stock identity such as mtDNA, tagging studies, and phenotypic characters all suggest that blacktip in the Gulf of Mexico and Atlantic are different stocks, so it is unlikely that pups from the Atlantic contributed to the Gulf stock. An alternate explanation is that the expected life history parameters are incorrect and may need to be re-evaluated.

2. Evaluate the adequacy, appropriateness, and application of the methods used to assess the populations; state whether or not the methods are scientifically sound.

The assessment used a state-space age-structured surplus production model to assess the population. This method was both scientifically sound and appropriate for assessing the population, given the data available. Nevertheless more informative models with improved capabilities would be possible if size or age composition data were available (e.g. a forward-projecting age-structured model). Use of these models would require a time-series of age/size structure in both the abundance indices and catch.

The assessment model assumed the presence of a virgin population at the start of the time-series. Simulations to investigate the influence of a depleted population at the start of the current time-series would be helpful.

3. Recommend appropriate or best-estimated values of population parameters such as abundance, biomass, and exploitation (if possible).

The base model produced estimates of total biomass of 193 000 t, mature numbers 19.8 million, and F_{2004} 0.01. The precision around these estimates was very poor, so the Panel had little confidence that they represented the real abundance of the stock.

The three most reliable abundance indices indicated stable or increasing population numbers over the past 10 years during a period of declining catches. The results are consistent with each other, and consistent with the model estimates described above. However, a re-run of the model using only these three indices failed to converge. Similarly, a re-run of the model without the pelagic logbook index failed to converge. Both these findings are a concern.

4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate stock status criteria (population benchmarks such as MSY, F_{msy}, B_{msy}, MSST, MFMT). State whether or not the methods are scientifically sound.

The methods used in the assessment for estimating stock status criteria were adequate, appropriate, and scientifically sound.

5. Recommend appropriate values for stock status criteria (if possible).

The base-case assessment model provided the best estimates for these values, which indicated that the stock was not overfished, and that there was no overfishing. The estimate of F_{msy} was 0.2. All model variations produced comparable results. A proper continuity analysis was not possible, because the previous assessment assumed a single stock and indices that were standardized differently. Nevertheless, the estimate of stock status in 2002 was similar: not overfished with no overfishing occurring, albeit with a lower F_{msy} of 0.06.

Although a number of key reference points were provided (B/B_{msy}, SPR_{msy}, F/F_{msy}), they were not well estimated owing to the shortness of the time-series, conflicting trends from all the abundance indices, and the non-response of the indices to changes in catch. Precision of the estimates was provided, but distributions of the posteriors were not provided. The Panel accepted that the stock is not overfished and that overfishing is not taking place, but did not accept the absolute estimates of stock status. Consequently, there is no scientific basis for advising an increase in catches at this time.

6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.

The methods used for population projections were appropriate and scientifically sound.

7. Recommend probable values for future population condition and status (if possible).

The uncertainty surrounding the estimates of key reference points and current stock status made population projections problematic. On the basis of the three abundance indices believed to be most representative of the Gulf blacktip stock, population numbers have remained stable or increased over the past 10 years during a period of declining catches. These observations are consistent with each other, and suggest that the current population is reasonably healthy. If the stock is indeed at a biomass above that of B_{msy} and being fished at a fishing mortality below F_{msy}, current management guidelines indicate that a rebuilding strategy is not required.

8. Ensure that all desired and necessary assessment results (as listed in the SEDAR Stock Assessment Report Outline) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the

Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.

All desired and necessary assessment results are clearly and accurately presented in the Assessment Report. The results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.

9. Evaluate the Data and Assessment Workshops with regard to fulfilling their respective Terms of Reference and state whether or not the Terms of Reference for previous workshops are adequately addressed in the Data Workshop and Stock Assessment Report sections.

The Data and Assessment workshops fulfilled their Terms of Reference.

10. Develop recommendations for future research for improving data collection and stock assessment.

The Review Panel offers the following comments regarding research needs in terms of data and assessment of blacktip sharks in the Gulf of Mexico.

Issue: Historical catches are assumed to be negligible in the assessment model, resulting in the assumption that a virgin population was present in 1981.

- Explore alternative methods for estimating historical catches, such as examination of fish processor records
- Simulate the existence of a depleted population at the start of the assessment time-series, rather than using the current assumption of a virgin population

Issue: The life history parameters recommended at the Data Workshop appear to be unrealistic, because they had to be changed in order to increase steepness above the minimum level required for a self-sustaining population. The estimates of M at age were set at levels below that recommended by the Data Workshop (M = 0.1 for adults), and first year survival was set at values higher than those shown in a field study. Although there are several possible explanations for this, one is that the life history parameters need to be re-evaluated; another is that an unknown source is contributing pups to the population.

- Re-examine the life history characteristics, particularly reproduction
- Explore possible alternative recruitment sources to the population

Issue: The assessment model provided a poor fit when all the abundance indices were applied, and there was poor consistency among these indices.

- Restrict selection of abundance indices to those that are most likely to provide reasonable coverage of the population. The following indices should be examined to see if they are the most representative: bottom longline observer, NMFS longline southeast survey, and Panama City gillnet survey (for juveniles)

- Evidence that the abundance indices and commercial catch were sampling the same population component was missing. Maps of spatial overlap would help address this
- No information on size or age composition of the indices or catch was presented. An analysis of such data would ensure that the indices are representative of the catch, and could be used as an additional diagnostic of the adequacy of the age-structured model

Issue: Point estimates of stock status do not provide information on the statistical confidence associated with the estimates.

- Presentation of posterior distributions for F/F_{msy} and B/B_{msy} in relation to reference points would aid interpretation of stock status

Issue: Current data sampling protocols do not collect data that can be used to provide improved stock assessments.

- Collect length frequency data from commercial landings and increase data collection from the recreational fishery as additional measures of model fit, among other things
- Examine trends in mean size in the catch as an indication of overexploitation

Conclusions

- The Panel accepted that the stock is not overfished and that overfishing is not taking place, but did not accept the absolute estimates of stock status.
- The three abundance indices believed to be most representative of the stock were consistent with each other, suggesting that stock abundance has been increasing over a period of declining catch during the past 10 years.
- Based on life history characteristics, blacktip sharks are a relatively productive shark species.
- A combination of life history characteristics and recent increases in the most representative abundance indices suggests that the blacktip stock is relatively healthy. However, there is no scientific basis for advising an increase in catches at this time.

D. Blacktip Shark – Atlantic

Terms of reference

1. Evaluate whether data used in the analyses are treated appropriately and are adequate for assessing the stocks; state whether or not the input data are scientifically sound.

The Review Panel considered that the data used for the analysis had been treated appropriately and represented the best estimates of assessment input information currently available to the data and assessment workshops. However, the Panel noted the following:

- There was a large increase in the catches after 1990. Commercial catch estimates for the period prior to 1995 were derived using information from more recent years, to apportion catch between the Gulf of Mexico and the Atlantic. These observations led the Panel to conclude that the commercial catch data may be unreliable prior to 1991 at least.
- The standardized catch-rate indices showed conflicting trends, and the Panel was unable to judge the extent to which each of the series reflected real trends in the abundance of the stock. Additionally, the time-series of catch-rate indices was relatively short compared with the time-series of catch estimates.
- The Panel discussed the appropriateness of applying a single selectivity vector to commercial catch-rate indices and considered that, as the catch-rate series are derived from different fleets operating in different areas and at different times, applying a single selectivity vector may be inappropriate. Moreover, while the separate indices themselves may be good indicators of abundance for the fraction of the population that they sample, the application of an inappropriate selectivity vector may bias the model fit. The Panel proposed that careful examination of size and age composition of the catch-rate index data be undertaken to establish whether appropriate fleet-specific size/age selectivity vectors can be derived.
- The life history parameters recommended at the Data Workshop appear to be unrealistic, because they had to be changed in order to increase steepness above the minimum level required for a self-sustaining population. The estimates of M at age were set at levels well below those recommended by the Data Workshop, and first-year survival was set higher than values derived from a field study. It was suggested that the inconsistency between expected and assumed life history parameters could have been due to an unknown source contributing pups to the population. Indicators of stock identity all suggest that blacktip in the Atlantic and Gulf of Mexico are different stocks, so it is unlikely that pups from the Gulf of Mexico contribute to the Atlantic stock component. An alternative explanation is that the expected life history parameters are incorrect and need to be re-examined.

2. Evaluate the adequacy, appropriateness, and application of the methods used to assess the populations; state whether or not the methods are scientifically sound.

The Review Panel considered that given the information available, the methods used to assess the Atlantic blacktip are scientifically sound and appropriate. However, the Panel agreed that the results largely highlighted the lack of consistency in signals in the catch-rate series.

3. Recommend appropriate or best-estimated values of population parameters such as abundance, biomass, and exploitation (if possible).

The Review Panel noted that depending on the models used, the assessed status of Atlantic blacktip ranged from not overfished with no overfishing occurring, to overfished with overfishing taking place. The Panel agreed that there were no objective criteria to judge which, if any, of the results represents true stock status, so no confidence can be placed in the assessment results. In addition to the conflicting signals arising from the catch-rate series, estimates of population parameters varied widely between different models. Taking each of these issues into account, the status of the stock remains uncertain.

4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate stock status criteria (population benchmarks such as MSY, F_{msy}, B_{msy}, MSST, MFMT). State whether or not the methods are scientifically sound.

The Panel concluded that, given appropriate and reliable input data, the methods available to the assessment workshop to derive estimates of stock status criteria are scientifically sound. However, the assessment model did not provide reliable estimates of abundance, biomass or exploitation rate for Atlantic blacktip. Hence, the results from the methods did not provide reliable estimates of stock status.

5. Recommend appropriate values for stock status criteria (if possible).

For the reasons outlined in (4) above, the Panel concluded that no reliable estimates of stock status for Atlantic blacktip can be recommended at this time.

6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.

Given that the current status of Atlantic blacktip is unknown, no reliable population projections were possible.

7. Recommend probable values for future population condition and status (if possible).

No reliable population projections were possible, so no probable values for future population condition and status of Atlantic blacktip can be given.

8. Ensure that all desired and necessary assessment results (as listed in the SEDAR Stock Assessment Report Outline) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.

All desired and necessary assessment results are clearly and accurately presented in the Assessment Report for the species, but they are currently uninformative on stock status. These results are consistent with the Review

Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.

9. Evaluate the Data and Assessment Workshops with regard to fulfilling their respective Terms of Reference and state whether or not the Terms of Reference for previous workshops are adequately addressed in the Data Workshop and Stock Assessment Report sections.

The Data Workshop fulfilled its Terms of Reference. The Assessment Workshop fulfilled its Terms of Reference to the extent possible, given the limitations of the data and the model outputs.

10. Develop recommendations for future research for improving data collection and stock assessment.

With regard to future assessments of blacktip shark in the Atlantic, the Panel makes the following recommendations:

Issue: Reliability of catch data.

- Any additional sources of information on catches should be sought and examined. The catch data especially for the period prior to 1995 should be re-examined to establish whether all removals have been accounted for and whether they are realistic estimates of actual removals
- Estimates of blacktip bycatch in the fishery for Atlantic menhaden should be derived if possible, and catch information from logbooks and trip weigh-out records from the Florida east coast gillnet fleet for the period 1985–1991 may also be available

Issue: Consistency of catch-rate indices.

- The Panel suggests that careful examination of size and age composition of the catch-rate index data should be undertaken to establish whether appropriate fleet-specific size/age selectivity vectors can be derived

Issue: Trends in fishing effort.

- Trends in deployed fishing effort at least for the catch-rate index series should be developed in future Data Workshops and presented in the Assessment Workshop report, together with corresponding trends in catches and catch rate. It would also be informative to document time-series trends in deployed fishing effort for all fleets that exploit Atlantic blacktip if such data are available

Issue: Information on size and age compositions.

- It would be informative to examine simple metrics such as mean age and mean size in the catches as a whole, and by fleet and geographic area. These may give a crude indication of trends in exploitation rate

Issue: Life history parameters for Atlantic blacktip.

- The life history parameters recommended at the Data Workshop appear to be unrealistic, because they had to be changed in order to increase steepness above the minimum level required for a self-sustaining population. The Panel recommends that data pertaining to life history characteristics be re-examined, and that information that may identify alternative sources of recruitment to the population be explored.

Conclusions

- The Review Panel concluded that the data used for the analyses were treated appropriately. However, it was unclear whether catch estimates prior to 1991 adequately represent historical removals of blacktip shark from the Atlantic stock component. Moreover, the Panel was unable to judge the extent to which each of the standardized catch-rate series reflected real trends in the abundance of the stock.
- The Panel concluded that given the widely differing results arising from the different models, the status of the stock of Atlantic blacktip shark is uncertain, so no reliable estimates of abundance, biomass or exploitation rate can be advanced at the current time.
- Further, in the absence of any reliable estimates of abundance, biomass and exploitation rates, no reliable estimates of stock status for Atlantic blacktip can be suggested.
- Given that the current status of Atlantic blacktip is unknown, no reliable population projections were possible, so no probable values for future population condition and status of Atlantic blacktip can be provided. Furthermore, there is no scientific basis for advising a change in catch levels at this time.

2.3 Additional General Recommendations

In addition to the recommendations and proposals contained in the sections for each stock above, the Panel endorses the following research recommendations proposed by the 11th SEDAR Data and Assessment Workshop reports:

Recommendations from the Data Workshop report

- Biological data should be collected on the illegal Mexican shark catch confiscated in US waters, including species, sex, and length.
- Gear-related information, including effort and gear used for each species, should be collected on the interdicted Mexican vessels.
- One central electronic database for biological and gear data should be created to keep information regarding the confiscated sharks and vessels.
- Scientists should help the Coast Guard create the database and teach the agents how to identify the species and to collect gear information.

- The Atlantic menhaden fishery data should be examined to determine shark bycatch estimates, if available.
- Historical data should be re-examined to determine if the “unreported catch” from Mr Brannon is or is not already included in the commercial landings.
- Better landings information on number of species, by weight, from the dealers should be sought.
- Dockside sampling information would be helpful to verify landings information, such as species composition.
- Determine whether port-sampler information for large coastal sharks is available, and if so, how to access it.

<u>Recommendations from the Assessment Workshop report</u>

- Data Workshop participants need to bring raw data to workshop to enable additional analysis to be conducted and reviewed during the workshop when practical.
- Length frequency data should be provided when available, with particular reference to the Virginia Institute of Marine Science longline data set.
- Examination and analysis of pelagic longline observer data should be included.
- Identify nursery areas for sandbars in the northern Gulf of Mexico.
- Additional life history research into sandbar sharks to supplement or replace the available data from the mid 1990s.
- Additional life history studies for all species of the shark complex should be carried out to allow for additional species-specific assessments.
- Incorporation of the University of North Carolina data set collected by Frank Schwartz in the next LCS assessment, with recognition that it may also contain valuable information useful for the Small Coastal Shark assessment to be conducted in 2007.
- Examination of methods to incorporate tagging data information into the assessment.
- Attempt to recover and quantify information on historical catch, with special emphasis prior to the 1993 Fisheries Management Plan.
- Additional length sampling and age composition collection to improve information for developing selectivities.
- Initiation or expansion of dockside sampling for sharks.
- Ensure that existing independent sampling programmes be continued.
- Ensure that funding for the 2002 pelagic survey being conducted by the Pascagoula laboratory of the SEFSC be continued.

2.4 Stakeholder Opinion

Stakeholder opinion is in many cases encompassed in the text above, because views were willingly offered, often solicited, and enthusiastically given by those stakeholders present throughout the discussions. However, before the meeting was closed, a final opportunity was afforded stakeholders to express concise views on both the process and discussion output, so that they could be used to add value to this report. It is stressed that the views do not necessary mirror those of either the assessment team or the Review Panel.

Large Coastal Shark (LCS) complex

The Directed Shark Fisheries (DSF) stakeholders give a positive response to the 2006 9-species grouping assessment results. The results for the 11 and 22 species assessments appear more optimistic than the highly questionable negative sandbar shark assessment results (concerns detailed below).

Seven of the nine allowable LCS species are commonly caught as part of the annual 5–10% LCS secondary market "landings" component feature, compared with the two target species of commercial LCS landings, sandbars and blacktips, schooling sharks by nature. The common LCS species plus the nurse shark should be individually assessed in the future, in the opinion of DSF.

(1) Bull shark populations mostly stay in nearshore proximity to southern US waters where commercial shark fishing effort has been limited or eliminated for more than a decade, which has helped to maintain a large biomass.
(2) Tiger sharks, particularly juveniles, have been very abundant for nearly two decades, based on tagging data, NMFS observer information and fishing reports. They appear to mature rapidly compared with other sharks, and some adults travel great distances around the Atlantic basin, while mature females have large numbers of pups.
(3) Spinner sharks, mostly adults, have been caught as bycatch by the offshore pelagic longline fleet for decades. They have often been misidentified as blacktip sharks. Both juveniles and adults are commonly caught nearshore.
(4) Scalloped hammerhead, another schooling shark, is caught nearshore and/or offshore by both bottom and pelagic longlines, sometimes in large numbers per set. Incidental catch is common. They reproduce annually.
(5) Great hammerheads are seen routinely, but usually as loners instead of in schools. DSF fishers have encountered several large specimens annually for decades.
(6) Smooth hammerheads have never been a significant component of the shark bycatch. The species is occasionally confused with scalloped hammerheads.
(7) Silky sharks, both juveniles and adults, are a common component of the offshore pelagic longline fleet.
(8) Lemon sharks are common in Florida waters, but have been a minor bycatch for decades.
(9) Nurse sharks are encountered off Florida routinely, but are never marketed and can be successfully released alive most of the time. Currently, they seem to be more common than they used to be.

Sandbar shark

The DSF disagrees with the sudden change in perception from the near-positive 2002 assessment results of being “not overfished” to the current super-negative assessment of severely overfished. DSF also disagrees with the use of extreme demographics such as the 2006 maturity ogive of 19.5 years to 50% maturity compared with the 2002 ogive of 13 years to 50% maturity. VIMS ageing data need to be provided for the VIMS longline series also to be used in age-structured modelling.

The best way to illustrate the problem with the NMFS 2006 sandbar shark assessment results is to show how the 2006 final estimate of 96 600 adult sandbars alive during 2004, or the estimate of 103 000+ adult sandbars alive during 2001, are fundamentally flawed! At a conservative 50-pounds dressed weight per mature sandbar, the number of adults for both years equates to ~5 million pounds dressed weight. If this number (~100 000 adults) is deemed “accurate”, then DSF asks the scientists to consider that the US Atlantic and Gulf of Mexico directed shark fleet has annually landed more than a million pounds of dressed weight adult sandbars every year since 1997, equating to annual total removals of some 20 000 adult sandbars. By simple arithmetic, there should be ~60 000 mature sandbars left by the end of 2006 using the 2004 estimate, and nearly none left at the end of 2006 using the 2001 benchmark. This also does not account for Mexican removals, to which waters many adult sandbars migrate for winter.

The recent abundance indices do not support the rapid decline in stock size that would be expected if the NMFS numbers of adult sandbar sharks are correct. In the opinion of DSF, NMFS should redo the 2006 sandbar shark assessment. The LCS quota is too small for the current fleet of fishing vessels; the DSF fleet could catch more than 5 million pounds annually of adult sandbars if allowed to do so. DSF believes that the current population of adult sandbars probably numbers millions of animals instead of up to 100 000, and rebuilding to ~350 000 in 60+ years. The juvenile population has increased markedly since the early 1990s, further indicating the continued presence of mature sandbars.

Blacktip shark, Gulf of Mexico

DSF endorses the positive results of the assessment, but does feel that geographical catch trends are indicative of some mixing in the Florida Keys region, i.e. a shared population with Atlantic blacktip. It is DSF’s opinion that sensitivity runs for the 2006 one-population blacktip indicate that the total stock is not overfished and that overfishing is not occurring.

The assessment’s impact needs to be better understood in terms of the mixing of the western blacktip shark population of the US and Mexico, especially with regard to total removals and nursery grounds.

Blacktip shark, Atlantic

DSF is troubled by the paucity of Atlantic blacktip landings, especially during the period 1985–1989. These were peak fishing years for the shark gillnetting fleet on the Florida east coast, where millions of pounds dressed weight of blacktip were landed then, alongside some significant longline effort.

Overall Recommendations

NMFS needs to get the LCS database and biological parameters in order to use in the next LCS assessment. It should also maintain *status quo* of the 2002 sandbar results rather than take the controversial results for 2006 into future sandbar management choices. NMFS should re-run the 2006 sandbar modelling exercise with a fresh approach to gain realistic outputs of the number of adults existing.

(1) The VIMS age index for the standardized longline series needs to be provided for the 2006 assessment.
(2) The maturity ogive for sandbars needs to be re-examined for accuracy owing to length-to-age conversion bias. All measurements, vertebrae and reproductive organ samples need to be from the same animals, and taken throughout the species' range.
(3) The Gulf of Mexico blacktip reproductive cycle of annual or biennial needs to be resolved.
(4) The millions of pounds dressed weight of Atlantic blacktip catch landed in Florida from the shark gillnet fleet in the 1980s needs to be found.
(5) Sampling of sandbars and other common species of the large coastal shark complex needs to be enhanced to allow assimilation of better age, biological, conversion and ratio information, as well as genetic sampling from all regions.

2.5 Recommendations for future SEDAR assessments

In terms of the terms of reference provided to the Review Workshop, participants and the Review Panel commented throughout the week on the SEDAR assessment process. What follows is a non-prioritized list of the main points made.

- Enhanced communication between stakeholders, analysts and customers about the management value of the SEDAR process would be useful.
- Acronyms abound in the literature provided. Expert reviewers (generally coming from outside the area) and stakeholders would benefit from these being defined throughout texts, either each time they are used or in terms of a Glossary.
- Continuity of personnel in the workshops is crucial to ensuring both acceptance and enhanced understanding of the dynamics of the resources.

- The information collated and created and the results in terms of management action need to be broadly disseminated, perhaps electronically, but also through making fishers more aware of the process and the output.
- Effort should be made to maximize the time allocated to preparation of data series, carrying out of assessments, and review material. The SEDAR three-part process involving as many participants as possible was considered to be of great value to this specific shark management process, and was suggested as the way to proceed for future initiatives of like nature. There is also clearly a very strong case for incorporating fisher knowledge into the assessment and management process, as done here.
- The Review Panel requires the presence of scientists who have not been involved in the Data and/or Assessment Workshops. While understanding and wholeheartedly endorsing the need for independent peer review, a strong case can be made for Panel meetings to remain open to stakeholders, biologists knowledgeable about the species, and stock assessment scientists who may not have been involved in the immediate assessments. It was felt unlikely that such people would be able to participate in the discussions at the current enthusiastic level unless they were formally invited to participate.
- The independence of the Review Panel chair and a small number of reviewers (currently appointed by the CIE) is deemed paramount and supporting the objective of independence.
- Given the volume of documentation associated with such reviews and the shortage of time often available to assimilate it, a clear executive summary to all substantive documents would be of great value.