SEDAR

Southeast Data, Assessment, and Review

SEDAR 39

Stock Assessment Report

HMS Atlantic Smooth Dogfish Shark

March 2015

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

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Southeast Data, Assessment, and Review

SEDAR 39

HMS Gulf of Mexico Smoothhound Sharks

SECTION I: Introduction

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

EXECUTIVE SUMMARY

SEDAR 39 addressed the stock assessments for the Gulf of Mexico smoothhound shark complex and the Atlantic smooth dogfish shark. The assessment process consisted of two in-person workshops, as well as a series of webinars. The Data Workshop was held May 19-23, 2014 in Charleston, SC, Assessment webinars were held between September 2014 and January 2015, and the Review Workshop took place February 10-12, 2015 in Panama City, Florida.

The Stock Assessment Report is organized into 6 sections. Section I – Introduction contains a brief description of the SEDAR Process, Assessment and Management Histories for the species of interest, and the management specifications requested by the Cooperator. The Data Workshop Report can be found in Section II. It documents the discussions and data recommendations from the Data Workshop Panel. Section III is the Assessment Process report. This section details the assessment model, as well as documents any changes to the data recommendations that may have occurred after the data workshop. Consolidated Research Recommendations from all three stages of the process (data, assessment, and review) can be found in Section IV for easy reference. Section V documents the discussions and findings of the Review Workshop (RW). Finally, Section VI – Addenda and Post-Review Workshop Documentation consists of any analyses conducted during or after the RW to address reviewer concerns or requests. It may also contain documentation of the final RW-recommended base model, should it differ from the model put forward in the Assessment Report for review.

The final Stock Assessment Reports (SAR) for the Gulf of Mexico smoothhound shark complex and the Atlantic smooth dogfish shark were disseminated to the public in March 2015.

During the assessment process several data and modeling topics received a lot of discussion. Those topics included: (To be finalized after Review workshop)

- Shrimp trawl fishery bycatch estimation: After much exploration and discussion during the Data Workshop, it was determined that the spatial and temporal overlap of the shrimp fleet and the occurrence of smooth dogfish was minimum and therefore recommended not including shrimp bycatch estimates in the assessment, as the magnitude was very small compared to the directed removals.

- Initial depletion set at 1981: The Data Workshop Panel recommended setting initial depletion to 1981 but the Review Panel found this recommendation questionable since there are documented and undocumented catch prior to that year. They did however determine that the choice was reasonable given the model structure and the uncertainty of the catches prior to 1981.

- Selectivity of NE trawl: The choice of the selectivity (Asymptotic va dome-shaped) to be applied to the main targeted fleet (NE Gillnet Kept) was heavily discussed during the assessment stage of the process. Based on several diagnostics examined, the Assessment Panel recommended the base model use a dome-shaped functional form for this fleet.

- Lack of directly observed ages: The Review Panel noted that Stock Synthesis is fundamentally an age-structured model but direct age composition information was not available for this assessment. It was suggested that the assessment might be improved if such information was available for future assessments.

- Autocorrelation of estimated recruitment deviations: Patterns in recruitment deviations indicate a systematic effect outside of the stock recruitment model or a mis-specification of the model itself. At present, a simple solution does not exist to remedy this issue; therefore the base case remained unchanged.

- Stock status determination: The Review Panel agreed with the methods used and the determination of the stock status but noted that the use of an SPR proxy for MSY may be useful, as a proxy may avoid the problems of uncertainty in the stock-recruitment relationship. The review panel cautioned about inferences drawn about stock status because of the level of uncertainty associated with the stock-recruitment relationship and uncertainty in the catches.

1. SEDAR PROCESS DESCRIPTION

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

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

SEDAR is organized around two workshops and a series of webinars. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. The second stage is the Assessment Process, which is conducted via a series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. Third and final is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products.

The completed assessment, including the reports of all 3 workshops and all supporting documentation, is then forwarded to the Council SSC for certification as 'appropriate for management' and development of specific management recommendations.

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

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

2. MANAGEMENT OVERVIEW

The smoothhound shark complex is composed of three species: smooth dogfish (*Mustelus canis*), Florida smoothhound (*M. norrisi*), and Gulf smoothhound (*M. sinusmexicanus*). While the history below attempts to separate out the history by species, please note that management of these species has been sporadic and, due to identification issues, has generally focused on "smooth dogfish." In most instances, it is unclear if the term "smooth dogfish" refers specifically to the species *M. canis* or if it is being used more generally to mean any species within the genus *Mustelus*.

<u>Smooth Dogfish Management History</u>

Federal

1993: Added to the 1993 FMP for Sharks of the Atlantic Ocean for data collection purposes only.

1999: Smooth dogfish was added to the management unit to provide protection from finning; all landed sharks must have a fin to carcass ratio of not more than five percent.

2003: Removed from the FMU in the 2003 Amendment 1 to the Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks since they were protected from finning under the Shark Finning Prohibition Act (67 FR 6124, February 11, 2002).

2009: NMFS determined that smooth dogfish and Florida smoothhound sharks are oceanic sharks and subject to federal jurisdiction under the Secretary of Commerce, delegated to NMFS, per the Magnuson-Stevens Act. NMFS finalized federal management measures in the fishery including a commercial quota and reporting requirements in Amendment 3 to the 2006 Consolidated HMS FMP. Under Amendment 3, NMFS indicated that, based on preliminary information, it was likely smooth dogfish and Florida smoothhound were the same species.

2011: Effectiveness of Federal management measures for all smoothhound sharks delayed indefinitely.

State

ASMFC

Contact: Marin Hawk, ASMFC, mhawk@asmfc.org

August 2008: Interstate FMP for Coastal Sharks.

Commercial: smooth dogfish possession limit set annually;

Dealer: A federal Commercial Shark Dealer Permit is required to buy and sell any shark caught in state waters;

Recreational: head, tail, fins attached; no minimum size; vessel-based possession limit: Recreational fishing vessels are allowed a maximum harvest of one shark per trip from the federal recreationally permitted species, including smooth dogfish, regardless of the number of people on board the vessel. In addition, each recreational angler fishing from a vessel may harvest one bonnethead, and one Atlantic sharpnose, and one smooth dogfish per trip;

Shore-based possession limit: Each recreational shore-angler is allowed a maximum harvest of one shark from the federal recreationally permitted species, including smooth dogfish, per calendar day. In addition, each recreational shore angler may harvest one additional bonnethead, and one additional Atlantic sharpnose, and one additional smooth dogfish per calendar day.

September 2009: Addendum I to the IFMP for Coastal Sharks.

Commercial: seasonal at-sea processing allowance: from March through June, the tail and all fins may be removed at sea; from July through February, commercial fishermen may completely remove the head, tail, pectoral fins, pelvic (ventral) fins, anal fin, and second dorsal fin, but must keep the dorsal fin attached naturally to the carcass through landing; fin to carcass ratio cannot exceed 5%, year-round;

Recreational: smooth dogfish possession limit removed

May 2013: Addendum II to the IFMP for Coastal Sharks.

Commercial: at-sea processing: commercial fishermen may remove all smoothhound shark fins year round, but fin-to-carcass ratio may not exceed 12 %;

Smoothhound shark state quota shares. Based on the preliminary information in NMFS's Amendment 3, ASMFC indicated that the term "smoothhound shark" referred to smooth dogfish since it was possible that both Florida smoothhound and smooth dogfish were the same species.

State-Share Percentages
ME 0.021%
MA 0.433%
RI 1.363%
CT 0.234%
NY 7.953%

NJ 18.828%
DE 0.339%
MD 6.703%
VA 34.803%
NC 28.583%
SC 0.742%

When the quota in any state is projected to be reached, the commercial landing, harvest and possession of smoothhound sharks will be prohibited in the state waters of that state until the next fishing season begins. Quota transfers are allowed but no rollover of unused quota.

Oct. 2013: Addendum III to the IFMP for Coastal Sharks clarifies that smooth dogfish and Florida smoothhound are part of the smoothhound complex.

<u>State-by-State</u>

Maine (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org

No smooth dogfish-specific regulations; will implement ASMFC state quota share when effective

2009: Federal dealer permit required to purchase sharks; head, fins and tails remain attached to carcass of all species through landing

New Hampshire (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org

No smooth dogfish-specific regulations

Massachusetts (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org

2007: 100 lb commercial trip limit

2009: multi-species recreational possession limit: one federal recreationally permitted species plus one additional smooth dogfish (maximum 2 smooth dogfish); processing smooth dogfish at sea is prohibited

2013: state shares of federal smoothhound quota were established; MA 0.433% of quota (when established)

Rhode Island (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org

2010: COMMERCIAL REGS: Must be properly licensed to land, harvest, possess, and sell sharks in state waters (7.24.1-3a; 7.24.1-7); no commercial trip limits or possession limits (7.24.1-3b); Authorized Commercial Gear (7.24.1-10); Bycatch Reduction Measures (7.24.1-11); and Processing at Sea permitted as follows: Commercial fishermen may completely remove the fins of smooth dogfish from March through June of each year. If fins are removed, the total wet weight of the shark fins may not exceed 5 percent of the total dressed weight of smooth dogfish carcasses landed or found on board a

vessel. From July through February for the smooth dogfish fishery only, commercial fishermen may completely remove the head, tail, pectoral fins, pelvic (ventral) fins, anal fin, and second dorsal fin, but must keep the dorsal fin attached naturally to the carcass through landing. RECREATIONAL REGS: No minimum size (7.24.2-4); No possession limit; landings requirements (must have heads, tails,. and fins attached naturally to the carcass per 7.24.2-3); authorized gear (rod and reel or handline per 7.24.2-5).
2014: COMMERCIAL REGS: changed name from "smooth dogfish" to "smooth hound"; state-shares of federal quota established (7.24.1-6); no possession limit, but RI has ability to set possession limit (7.24.1-3); processing at sea permitted year round (commercial fishermen may remove smoothhound shark fins year-round but wet weight of the fins may not exceed 12% of the dressed weight of carcasses per 7.24.1-12).
RECREATIONAL REGS: changed name from "smooth dogfish" to "smooth hound".

Connecticut (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2010: closed commercial fishing for smooth dogfish
2012: allowed recreational fishing (starting 12/30/2011); allowed federal permit holder commercial fishing 5/1/2012; allowed all commercial fishermen 10/4/2012 with a maximum fin-to-carcass ratio of 5:95
2013: state-shares of federal smoothhound quota were established; MA 0.234% of quota (when established)

New York:
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2008, 2009, and 2013: Adopted regulations for the ASMFC Plan and Addendums

New Jersey (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2010: Adopted ASMFC regulations to match state regulations.
2013: Adopted 12% fin-to-carcass ratio rule for commercial at-sea processing.

Delaware:
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2008, 2009, and 2013: Adopted regulations for the ASMFC Plan and Addendums

Maryland (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2009: multi-species recreational possession limit: one federal recreationally permitted species plus one additional smooth dogfish (maximum 2 smooth dogfish); processing smooth dogfish at sea is prohibited
2013: state-shares of federal smoothhound quota were established; MA 6.703% of quota (when established); must tag smooth dogfish prior to landing (rec only)
2014: may process smooth dogs at sea; maximum ratios are 8% fin to carcass ratio for the combined fin sets of the dorsal and pectoral fins, and 4% for caudal fins (12% if all three fin sets are separated from the smoothhound sharks)

Virginia:
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2008, 2009, and 2013: Adopted regulations for the ASMFC Plan and Addendums

North Carolina (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2008: Unlawful to sell to anyone that is not a federally permitted dealer
2009: From July-February commercial fishermen can remove head, tail, pectoral, pelvic, anal and second dorsal fin of smooth dogfish
2013: Process at sea; 12% Fin:Carcass

South Carolina (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2008, 2009, and 2013: Adopted regulations for the ASMFC Plan and Addendums

Georgia (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2008, 2009, and 2013: Adopted regulations for the ASMFC Plan and Addendums

Florida (provided by state):
Contact: Marin Hawk, ASMFC, mhawk@asmfc.org
2008, 2009, and 2013: Adopted regulations for the ASMFC Plan and Addendums 2010: Recreational: smooth dogfish added as 'shark' species (FL rule 68B-44.002 (7d), (d)" smooth dogfish - any species of genus Mustelus"; also listed as one of the shark species exempt from the 54" FL min. size limit
2012: Commercial: April 2012: added smooth dogfish code (Trip tickets) as option in commercial landings

Alabama:
Contact: Scott Bannon, AL Department of Conservation and Natural Resources, Marine Resources Division, (251) 861-2882
No smooth dogfish-specific regulations

Mississippi:
Contact: Kerwin Cuevas, MS Department of Marine Resources, (228) 374-5000
No smooth dogfish-specific regulations

Louisiana:
Contact: Jason Adriance, LA Department of Wildlife and Fisheries, (504) 284-2032
No smooth dogfish-specific regulations

Texas:
Contact: Mark Lingo, Texas Parks and Wildlife, (956) 350-4490
No smooth dogfish-specific regulations

<u>Florida Smoothhound Management History</u>

Although there have been few management measures specific to the Florida smoothhound, the species is very difficult to distinguish from smooth dogfish. Thus, past smooth dogfish management measures likely impacted Florida smoothhound.

Federal

1993: Added to the 1993 Fishery Management Plan (FMP) for Sharks of the Atlantic Ocean for data collection purposes only.

1999: Florida smoothhound was added to the management unit to provide protection from finning; all landed sharks must have a fin to carcass ratio of not more than five percent.

2003: Removed from the fishery management unit in the 2003 Amendment 1 to the Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks since they were protected from finning under the Shark Finning Prohibition Act (67 FR 6124, February 11, 2002).

2009: NMFS determined that smooth dogfish and Florida smoothhound are oceanic sharks and subject to federal jurisdiction under the Secretary of Commerce, delegated to NMFS, per the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). NMFS finalized federal management measures in the fishery including a commercial quota and reporting requirements in Amendment 3 to the 2006 Consolidated HMS FMP. Under Amendment 3, NMFS indicated that, based on preliminary information, it was likely smooth dogfish and Florida smoothhound were the same species.

2011: Effectiveness of Federal management measures for all smoothhound sharks delayed indefinitely.

State

2010: State of Florida defines "smooth dogfish" as any species in the genus *Mustelus*

<u>Gulf Smoothhound Management History</u>

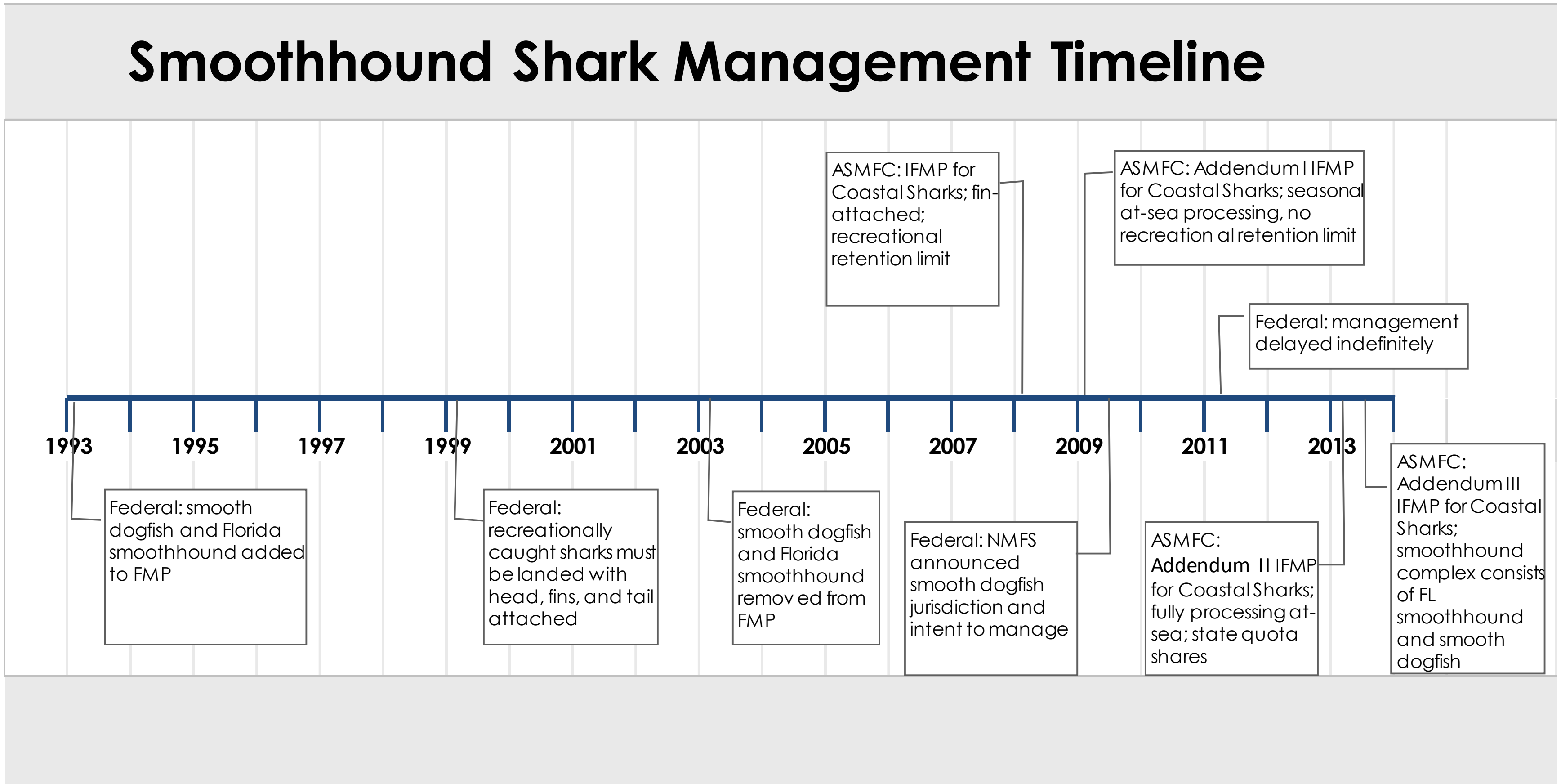
Although there are no management measures specific to the Gulf smoothhound, the species is very difficult to distinguish from smooth dogfish. Thus, past smooth dogfish management measures likely impacted Gulf smoothhound.

Federal

No actions specific to Gulf smoothhound.

State

2010: State of Florida defines "smooth dogfish" as any species in the genus *Mustelus*


Smoothhound Shark Management Timeline
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Federal: smooth dogfish and Florida smoothhound added to FMP
Federal: recreationally caught sharks must be landed with head, fins, and tail attached
Federal: smooth dogfish and Florida smoothhound removed from FMP
ASMFC: IFMP for Coastal Sharks; fin-attached; recreational retention limit
Federal: NMFS announced smooth dogfish jurisdiction and intent to manage
ASMFC: Addendum I IFMP for Coastal Sharks; seasonal at-sea processing, no recreational retention limit
Federal: management delayed indefinitely
ASMFC: Addendum II IFMP for Coastal Sharks; fully processing at-sea; state quota shares
ASMFC: Addendum III IFMP for Coastal Sharks; smoothhound complex consists of FL smoothhound and smooth dogfish

Management Program Specifications

Table 1 General management information for the HMS smoothhound complex

Species	Smooth dogfish (*Mustelus canis*), Florida smoothhound (*M. norrisi*), and Gulf smoothhound (*M. sinusmexicanus*)
Management Unit	Generally Atlantic Ocean, Gulf of Mexico, and Caribbean Sea but would like appropriate definition(s) from assessment
Management Unit Definition	Generally, all federal waters within U.S. EEZ of the western north Atlantic Ocean, including the Gulf of Mexico and the Caribbean Sea, but would like appropriate definition(s) from assessment
Management Entity	NMFS, Highly Migratory Species Management Division
Management Contacts **SERO / Council**	Karyl Brewster-Geisz N/A
Current stock exploitation status	Unknown
Current stock biomass status	Unknown

Table 2 Specific Assessment Summary for HMS Smoothhound Complex

Criteria	Value
MSST	Unknown
MFMT	Unknown
B_{MSY}	Unknown
F_{year}/F_{MSY}	Unknown
SSF_{year}	Unknown
SSF_{year}/SSF_{MSY}	Unknown

Table 3 Stock Projection Information for HMS Smoothhound Complex

Requested Information	Value
First year under current rebuilding program	N/A
End year under current rebuilding program	N/A
First Year of Management based on this assessment	Unknown; possibly 2015 or 2016

Projection Criteria during interim years should be based on (e.g., exploitation or harvest)	Currently there is no specific TAC: suggest F=0; Fixed Exploitation; Modified Exploitation; Fixed Harvest*
Projection criteria values for interim years should be determined from (e.g., terminal year, avg of X years)	Unknown; possibly average landings of previous 2 years

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

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

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

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

Quota Calculations

Table 4 Quota calculation details for HMS Smoothhound Complex.

Current Quota Value	NA
Next Scheduled Quota Change	Post SEDAR 39
Annual or averaged quota ?	Annual quota
If averaged, number of years to average	-
Does the quota include bycatch/discard ?	The overall TAC includes commercial landings, dead discards, and recreational harvest. The commercial quota includes only commercial landings.

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

Quota finalized in Amendment 3 (but not yet effective) used 2 standard deviations above the maximum landings based on the assumption that the reported landings were incomplete (reporting is voluntary at this time).

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

The commercial quota does not include bycatch/discard estimates. The overall TAC will include dead discards and recreational harvest.

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

The commercial quota will be adjusted each year through a season rule. Overharvests will be deducted from the following year. If the species is not overfished and overfishing is not occurring, up to 50 percent of the base quota can be added to the following year's commercial quota in the event of underharvest. The commercial fishery will close when landings reach or are projected to reach 80 percent of the available quota.

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

No.

3. ASSESSMENT HISTORY AND REVIEW

The Atlantic smooth dogfish shark has not be assessed prior to SEDAR 39.

4. SEDAR ABBREVIATIONS

ABC	Allowable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder software program
ALS	Accumulated Landings System; SEFSC fisheries data collection program
AMRD	Alabama Marine Resources Division
ASMFC	Atlantic States Marine Fisheries Commission
B	stock biomass level
BAM	Beaufort Assessment Model

BMSY	value of B capable of producing MSY on a continuing basis
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	catch per unit of effort
EEZ	exclusive economic zone
F	fishing mortality (instantaneous)
FMSY	fishing mortality to produce MSY under equilibrium conditions
FOY	fishing mortality rate to produce Optimum Yield under equilibrium
FXX% SPR	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions
FMAX	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F0	a fishing mortality close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	(State of) Florida Fish and Wildlife Research Institute
GA DNR	Georgia Department of Natural Resources
GLM	general linear model
GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
GULF FIN	GSMFC Fisheries Information Network
HMS	Highly Migratory Species
LDWF	Louisiana Department of Wildlife and Fisheries
LGL	LGL Ecological Research Associates
M	natural mortality (instantaneous)
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources
MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip

MRIP	Marine Recreational Information Program
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished
MSY	maximum sustainable yield
NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OY	optimum yield
SAFMC	South Atlantic Fishery Management Council
SAS	Statistical Analysis Software, SAS Corporation
SC DNR	South Carolina Department of Natural Resources
SEAMAP	Southeast Area Monitoring and Assessment Program
SEDAR	Southeast Data, Assessment and Review
SEFIS	Southeast Fishery-Independent Survey
SEFSC	Fisheries Southeast Fisheries Science Center, National Marine Fisheries Service
SERO	Fisheries Southeast Regional Office, National Marine Fisheries Service
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SS	Stock Synthesis
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
TPWD	Texas Parks and Wildlife Department
Z	total mortality, the sum of M and F

SEDAR

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HMS Atlantic Smooth Dogfish Shark

SECTION II: Data Workshop Report

August 2014

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

Table of Contents

1 INTRODUCTION

1.1 Workshop time and place

The SEDAR 39 Data Workshop was held May 19-123, 2014 in Charleston, SC.

1.2 Terms of Reference

1. Characterize stock structure and develop a unit stock definition. Provide maps of species and stock distribution.
2. Review, discuss, and tabulate available life history information.
   - Evaluate age, growth, natural mortality, and reproductive characteristics
   - Provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length as applicable.
   - Evaluate the adequacy of available life history information for conducting stock assessments and recommend life history information for use in population modeling.

- Evaluate and discuss the sources of uncertainty and error, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].

3. Recommend discard mortality rates.

- Review available research and published literature
- Consider research directed at these species as well as similar species.
- Provide estimates of discard mortality rate by fishery, gear type, depth, and other feasible or appropriate strata.
- Include thorough rationale for recommended discard mortality rates.
- Evaluate, discuss, and characterize the sources of uncertainty, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].

4. Provide measures of relative population abundance that are appropriate for stock assessment.

- Consider and discuss all available and relevant fishery-dependent and -independent data sources.
- Document all programs evaluated; address program objectives, methods, coverage, sampling intensity, and other relevant characteristics.
- Provide maps of fishery and survey coverage.
- Develop fishery and survey CPUE indices by appropriate strata (e.g., age, size, area, and fishery) and include measures of precision and accuracy.
- Discuss the degree to which available indices adequately represent fishery and population conditions. Consider implications of changes in gear, management, fishing effort, etc. in relationship to the different indices
- Recommend which data sources adequately and reliably represent population abundance for use in assessment modeling.
- Evaluate and discuss the sources of uncertainty and error, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].
- Complete the SEDAR index evaluation worksheet for each index considered.
- Rank the available indices with regard to their reliability and suitability for use in assessment modeling.

5. Describe any environmental covariates or episodic events that would be reasonably expected to affect population abundance.
6. Provide commercial catch statistics, including both landings and discards in both pounds and number. Provide average weights used by gear type to convert landings and discards between pounds and numbers.

- Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector or gear. Provide estimates of landings and dead discard proportions by fishery and other strata as appropriate or feasible.
- Evaluate and discuss the sources of uncertainty and error, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].

- Provide length and age distributions for both landings and discards by gear type if feasible.
- Provide maps of fishery effort and harvest by species and fishery sector or gear.

7. Provide recreational catch statistics, including both landings and discards in both pounds and number. Provide average weights used by gear type to convert landings and discards between pounds and numbers.
   - Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector or gear.
   - Evaluate and discuss the sources of uncertainty and error, and data limitations (such as temporal and spatial coverage) for each data source. Provide ranges and/or distributions of uncertainty for data sources used in the stock assessment models[1].
   - Provide length and age distributions for both landings and discards if feasible.
   - Provide maps of fishery effort and harvest by species and fishery sector or gear.
8. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on sampling intensity (number of samples including age and length structures) and appropriate strata and coverage.
9. Prepare the Data Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines (Section II of the SEDAR assessment report).

[1] In providing ranges for uncertain or incomplete information, data workshop groups should consider and distinguish between those ranges and bounds that represent probable values (i.e., likely alternative states) to be included in structured uncertainty analyses, and those that represent extreme values to be considered in evaluating model performance through sensitivity analyses.

1.3 List of participants

Workshop Panel

Enric Cortés. Lead Analyst……………………………………NMFS Panama City
Dean Courtney, Lead Analyst..NMFS Panama City
Xinsheng Zhang, Lead Analyst...NMFS Panama City
Heather Beartlein .... NMMFS Miami
Peter Barile...SE Fisheries Association
Jeanne Boylan .... SC DNR
John Carlson...NMFS Panama City
Chloe Dean.. LDWF
William Driggers ....NMFS Pascagoula
Marin Hawk ....ASMFC
Dewey Hemilright.. Industry Representative
Eric Hoffmayer ....NMFS Pascagoula
Jim Gelsleichter .... University of North Florida
Melissa Giresi ....Texas A&M University
Dean Grubbs ....Florida State University

Robert Latour .... VIMS
Alyssa Mathers .... NMFS Panama City
Cami McChandless .... NMFS Narragansett
Adam Pollack .... NMFS Pascagoula
Katherine Sosebee .... NMFS Woods Hole
Holly White .... NC DMF

Observers
Sonja Fordham .... Shark Advocates International
Christine Seither .... LDWF

Staff
Julie A Neer .... SEDAR
Julie O'Dell .... SAFMC
Karyl Brewster-Geisz .... HMS
Steve Durkee .... HMS
Patrick Gilles .... NMFS/SEFSC Miami

Additional Participants via Webinars/Conference Calls
Shane Cantrell .... Industry
Jennifer Cudney .... HMS
Andrea Del'Apa .... HMS
Alexis Jackson .... HMS
Delisse Ortiz .... HMS
Guy DuBeck .... HMS

1.4 List of Data Workshop papers and reference documents

Document #	Title	Authors	Date Submitted
Documents Prepared for the Data Workshop			
SEDAR39-DW-01	Tag and recapture data for smoothhound sharks, *Mustelus* spp., in the Gulf of Mexico and US South Atlantic: 1998-2012	Dana M. Bethea and William B. Driggers III	14 March 2014
SEDAR39-DW-02	Standardized catch rates of smooth dogfish from the SEAMAP-South Atlantic Shallow Water Trawl Survey	E. Cortés and J. Boylan	9 May 2014
SEDAR39-DW-03	Preliminary catches of smoothhound sharks	E. Cortés and H. Balchowsky	9 May 2014
SEDAR39-DW-04	Relative abundance of *Mustelus spp.* in the Gulf of Mexico based on observer	John Carlson and Elizabeth Scott-	30 April 2014

	data collected in the reeffish bottom longline fishery	Denton	
SEDAR39-DW-05	Shrimp Fishery Bycatch Estimates for Smoothhound Sharks in the Gulf of Mexico, 1972-2012	Xinsheng Zhang, Enric Cortés, Dean Courtney and Elizabeth Scott-Denton	12 May 2014
SEDAR39-DW-06	Smoothhound Abundance Indices from NMFS Bottom Longline Surveys in the Western North Atlantic and Northern Gulf of Mexico	Adam G. Pollack and G. Walter Ingram, Jr.	7 May 2014 Updated 22 May 2014
SEDAR39-DW-07	Smoothhound Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico	Adam G. Pollack and G. Walter Ingram, Jr.	20 May 2014 Updated 22 May 2014
SEDAR39-DW-08	Smoothhound Abundance Indices from NFMS Small Pelagics Surveys in the Northern Gulf of Mexico	Adam G. Pollack and G. Walter Ingram, Jr.	9 May 2014 Updated 16 May 2014
SEDAR39-DW-09	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the Northeast Fisheries Observer Program	C.T. McCandless and J.J. Mello	30 June 2014
SEDAR39-DW-10	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the Rhode Island Department of Environmental Management trawl surveys	C.T. McCandless and S.D. Olszewski	30 June 2014
SEDAR39-DW-11	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the University of Rhode Island trawl survey conducted by the Graduate School of Oceanography.	C.T. McCandless	17 June 2014
SEDAR39-DW-12	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the Long Island Sound Trawl Survey conducted by the Connecticut Department of Energy and Environmental Protection	C.T. McCandless and K. Gottschall	17 June 2014
SEDAR39-DW-13	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the Peconic Bay Small Mesh Trawl Survey conducted by the New York State Department of Environmental Conservation	C.T. McCandless and C. Grahn	17 June 2014

SEDAR39-DW-14	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the New Jersey Division of Fish and Wildlife ocean trawl surveys	C.T. McCandless, J. Pyle, G. Hinks and L. Barry	17 June 2014
SEDAR39-DW-15	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the Delaware Division of Fish and Wildlife 30-foot otter trawl survey	C.T. McCandless and M. Greco	17 June 2014
SEDAR39-DW-16	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) longline surveys in Delaware Bay	C.T. McCandless	30 June 2014
SEDAR39-DW-17	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the Ocean Gillnet Program conducted by the North Carolina Division of Marine Fisheries	C.T. McCandless, C. Stewart, and H. White	30 June 2014
SEDAR39-DW-18	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the University of North Carolina shark longline survey south of Shakleford Banks	C.T. McCandless, F.J. Schwartz, and John J. Hoey	17 June 2014
SEDAR39-DW-19	Standardized indices of abundance for Smooth Dogfish, *Mustelus canis*, from the South Carolina Department of Natural Resources red drum longline survey	C.T. McCandless and B. Frazier	30 June 2014
SEDAR39-DW-20	Mark/Recapture Data for the Smooth Dogfish, *Mustelus Canis*, in the western North Atlantic from the NEFSC Cooperative Shark Tagging Program	N. E. Kohler, P. A. Turner, M. Pezzullo, and C. T. McCandless	19 May 2014 Updated 17 June 2014
SEDAR39-DW-21	A Preliminary Review of Post-release Live-discard Mortality Rate Estimates in Sharks for use in SEDAR 39	Dean Courtney	18 May 2014 Updated: 20 June 2014
SEDAR39-DW-22	Identification, Life History and Distribution of *Mustelus canis*, *M. norrisi* and *M. sinusmexicanus* in the northern Gulf of Mexico	Lisa M. Jones, William B. Driggers III, Kristin M. Hannan, Eric R. Hoffmayer, and Christian M. Jones	16 May 2014 Updated: 22 May 2014
SEDAR39-DW-23	Discards of *Mustelus canis* in the coastal gillnet fishery off the Southeast United States	John Carlson, Alyssa Mathers, and David Gloeckner	9 May 2014 Addendum: 22 May 2014

SEDAR39-DW-24	Biomass. Abundance and distribution of smooth dogfish (Mustelus canis) from the Northeast Fisheries Science Center and Massachusetts Department of Marine Fisheries trawl surveys	Katherine A, Sosebee, Jeremy King, Michele Traver, and Larry Alade	19 May 2014 Updated: 24 June 2014
SEDAR39-DW-25	Estimation of smooth dogfish discards in the Northeast United States fisheries using data collected by the Northeast Fisheries Observer Program	Katherine A, Sosebee	16 May 2014 Updated: 18 June 2014
SEDAR39-DW-26	Discards of *Mustelus spp*. in the Gulf of Mexico reeffish bottom longline fishery	John Carlson, Elizabeth Scott-Denton, and Kevin McCarthy	14 May 2014 Addendum: 21 May 2014
SEDAR39-DW-27	SEDAR 39 Indices Report Cards	S39 Indices WG	18 June 2014
SEDAR39-DW-28	Seasonal Distribution of *Mustelus canis* off the Atlantic coast of the U.S.	Melissa M. Giresi, William B. Driggers, R. Dean Grubbs, Jim Gelsleichter, Eric R. Hoffmayer	21 May 2014
SEDAR39-DW-29	Initial Comparison of Genetic Population Structure of *Mustelus canis* using the mitochondrial gene, NADH-2	Melissa M. Giresi and David S. Portnoy	21 March 2014
SEDAR39-DW-30	Size composition and indices of relative abundance of the smooth dogfish (*Mustelus canis*) in the near shore Atlantic Ocean	Robert J. Latour, Christopher F. Bonzek, and J. Gartland	16 June 2014
SEDAR39-DW-31	Length/weight relationships and life history data for *Mustelus canis* off of the Atlantic coast of the U.S.	Eric R. Hoffmayer, William B. Driggers, R. Dean Grubbs, Melissa M. Giresi, Jim Gelsleichter, Robert Latour	22 May 2014
Reference Documents			
SEDAR39-RD01	Reproductive biology of the smooth dogfish, *Mustelus canis*, in the northwest Atlantic Ocean	Christina L. Conrath & John A. Musick	
SEDAR39-RD02	Age and growth of the smooth dogfish (*Mustelus canis*) in the northwest Atlantic Ocean	Christina L. Conrath, James Gelsleichter, & John A. Musick	
SEDAR39-RD03	A review of the smooth-hound sharks (GENUS *Mustelus,* FAMILY TRIAKIDAE) of the western Atlantic	Phillip C. Heemstra	

	Ocean, with descriptions of two new species and a new subspecies	
SEDAR39-RD04	Smooth Dogfish (*Mustelus canis*) Fin-to-Carcass Ratio Project	Marin Hawk, Russ Babb, and Holly White
SEDAR39-RD05	Occurrence, catch rates, and length frequencies for smooth dogfish (*Mustelus canis*) caught in the VIMS Longline Survey: 1974-2006	R. Dean Grubbs and John A. Musick

2 LIFE HISTORY

2.1 Overview

The Life History working group consisted of Williams Driggers (NMFS Pascagoula), Eric Hoffmayer, (NMFS Pascagoula), Jim Gelsleichter (University of North Florida), Melissa Giresi (Texas A & M University), and Dean Grubbs (Florida State University).

2.2 Summary of Life History Documents

SEDAR39-DW-01: Tag and recapture data for smoothhound sharks, *Mustelus* spp., in the Gulf of Mexico and US South Atlantic: 1998-2012**.**
D.M. Bethea, W.B. Driggers III, M.A. Grace, K.M. Hannan and L.M. Jones

Tag and recapture information for smoothhound sharks, *Mustelus* spp., are summarized from the NOAA Fisheries Southeast Fisheries Science Center Elasmobranch Tagging Management System, 1998-2012. Summary information includes numbers of sharks tagged and recaptured by sex and life stage, as well as time at liberty, distance traveled, and change in length for recaptured individuals.

SEDAR39-DW-20: Mark/recapture data for the smooth dogfish, *Mustelus canis*, in the western North Atlantic from the NMFS Cooperative Shark Tagging Program.
N.E. Kohler, P.A. Turner, M. Pezzullo and C.T. McCandless

Mark/recapture data from the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program (CSTP) were summarized for the smooth dogfish (*Mustelus canis*) along the Atlantic and Gulf coast of the US from 1963 through 2013. Data on fork length, life stage, time at large, and movement are provided. Overall, 1134 sharks were tagged, and 37 of these tagged sharks were recaptured, yielding a total of 1171 smooth dogfish capture locations between 1963 and 2013. All capture locations for smooth dogfish in this study fall within the documented geographic and depth range of *Mustelus canis*. Smooth dogfish were tagged from the Gulf of Maine to the Gulf of Mexico. All smooth dogfish were caught within 200 m depth throughout their range. Adult fish were the most commonly caught life stage with more than twice the number of juveniles for both males and females. Females were caught more often than males, resulting in a male to female sex ratio of 1:3.2. The largest smooth dogfish was estimated as a 130 cm FL female. Capture locations for mature females and YOY overlap off Long Island NY, in Delaware and Chesapeake Bay, and along coastal North Carolina. Maximum displacement distance was 460 nm with distance traveled increasing with increasing FL for the 12 fish at liberty less than 1 year. Seasonal changes in tagging locations were evident. This north-south seasonal migration pattern is further revealed by recaptures at liberty for less than one year with movements between Cape Cod, MA and North Carolina. The three remaining were at liberty for less than 30 days and traveled less than 60 miles from their tagging location during the winter months. Overall, none of the smooth dogfish moved between the Atlantic and Gulf of Mexico.

SEDAR39-DW-28 Seasonal distribution of *Mustelus canis* off the Atlantic coast of the U.S.
M.M. Giresi, W.B. Driggers, R.D. Grubbs, J. Gelsleichter, and E.R. Hoffmayer

Along the Atlantic coast of the United States (U.S.), the dusky smoothhound shark, *Mustelus canis,* is seasonally distributed from Cape Cod, Massachusetts through Florida (Bigelow and Schroeder, 1948; Skomal, 2007; Kohler et al. 2014). We analyzed catch data from fisheries independent and dependent sources as well as completed a literature review to elucidate the seasonal distributions of this species. During the spring and fall months, this species is found throughout the range in the U.S. Atlantic, but over-winters in the Carolinas. It is primarily found in the northern latitudes during the summer months. These seasonal movements may be caused, in part, by temperature preference/tolerance.

SEDAR39-DW-29: Initial comparison of genetic population structure of *Mustelus canis* using the mitochondrial gene, NADH-2.
M.M. Giresi, D.S. Portnoy and J.R. Gold

The population structure of the dusky smoothhound shark, *Mustelus canis,* was examined by direct sequencing of the 1047bp mitochondrially-encoded NADH-2 gene. Fin clips were collected from specimens in the Atlantic; Massachusetts, Delaware Bay, Virginia, North Carolina, South Carolina, Georgia and from the Gulf of Mexico. One hundred and seventy one samples were successfully sequenced (1047 bp); there were 19 total haplotypes. One hundred seventeen individuals shared the central haplotype and there were 18 satellite haplotypes, most of which differed from the central haplotype by a single base-pair, two of which differed from the central haplotype by two-base-pairs. Of the satellite haplotypes, five were found solely in the Gulf of Mexico and 12 were found solely along the Atlantic coast. This preliminary analysis of genetic variance among sample localities indicates that individuals of *Mustelus canis* in the Atlantic may be isolated from those that are found in the Gulf of Mexico.

SEDAR39-DW-31 Length/weight relationships and life history data for *Mustelus canis* off of the Atlantic coast of the U.S.

E.R. Hoffmayer, W.B. Driggers, R.D. Grubbs, M.M. Giresi, J. Gelsleichter, and R. Latour

This document summarizes updated information on length/weight and length/length relationships, size and age at maturity, brood size, reproductive cycle, and age and growth information for the Atlantic population of the smooth dogfish, *Mustelus canis*, based on historical data (Conrath et al., 2002, Conrath and Musick, 2002) and more recent data (2006-2013) collected along the east coast of the United States (U.S.) from New England to Florida.

2.3 Stock Definition and Description

Two working documents provided tag-recapture data for *M. canis* and no movement was reported between the Gulf of Mexico and Atlantic Ocean (SEDAR39-DW-01, SEDAR39-DW-20). A preliminary analysis of genetic stock structure of *M. canis*, based on mitochondrial-encoded NADH-2, was presented by Giresi *et al.* (SEDAR39-DW-29) and showed significant differences in haplotype frequencies between the Gulf of Mexico and the Atlantic coast of the U.S. Both lines of evidence support the hypothesis that *M. canis* in the Gulf of Mexico and the Atlantic Ocean represent two distinct stocks. Based on a number of sources, cited within SEDAR39-DW-28, in the Atlantic Ocean, *M. canis* occurs in northern latitudes during the summer and southern latitudes in the winter (**Figure 2.12.1**). The species can be found from Florida through southern New England during spring and fall: times that coincide with seasonal migrations.

Decision 1: The data support the existence of distinct Atlantic and Gulf of Mexico stocks of *M. canis* separated by peninsular Florida; therefore, we strongly recommend treating these stocks separately. Since *M. canis* is the only species of *Mustelus* occurring in the Atlantic, we recommend conducting a stock assessment for this species in the Atlantic.

2.4 Natural mortality

Natural mortality estimates will be discussed during the assessment process.

2.5 Age & growth

Conrath *et al.* (2002, SEDAR39-RD02) provided age and growth estimates for *M. canis* based on a sample size of 894 individuals (531 females, 363 males) in the U.S. Atlantic (**Table 2.11.1**). Size at birth was between 30 and 40 cm STL and individuals grew to a mean size of approximately 77 cm STL by age one. The maximum observed ages for males and females were 10 and 16 years respectively. The growth constant, *k,* was estimated at 0.44, 0.29 and 0.25 for males, females and combined sexes, respectively (**Figure 2.12.2**).

Decision 2: Use age and growth models from Conrath *et al.* (2002, SEDAR39-RD02) for *M. canis* in the Atlantic Ocean.

2.6 Maturity and Reproduction

Reproductive data were available in Conrath and Musick (2002, SEDAR39-RD01) (**Table 2.11.1**). *Mustelus canis* reproduces annually and has an approximately 11-month gestation period. Females give birth to a mean brood size of 9.53 pups with the sex ratio of female to male embryos not differing from an expected ratio of 1:1. There was a significant relationship between maternal length and brood size. This relationship was best described by the following equation: brood size = 0.239(maternal STL)-18.03. Similarly, there was also a significant relationship between maternal age and brood size: brood size = $42.47(1 - e^{-0.496(age)}) - 31.31$. Pupping occurs during May through June from Virginia through southern New England (**Figure 2.12.1**).

Maturity data were obtained for the Atlantic Ocean from the NEAMAP survey and used to construct size at maturity ogives, but not age at maturity ogives as age estimates were not available (SEDAR 39 WP-31). Results were considerably different from those reported in SEDAR 39-RD01 and due to concerns of inconsistency in maturity assignment methodology during the NEAMAP surveys, ogives from Conrath and Musick (2002, SEDAR39-RD01) were considered more robust. Based on the findings of Conrath and Musick (2002, SEDAR39-RD01), size at 50% maturity was 85.4 cm STL and 102.3 cm STL for males and females, respectively (**Table 2.11.2** and **Figure 2.12.3**). Ages at 50% maturity were estimated to be 2.5 and 4.4 years for males and females, respectively (**Table 2.11.2** and **Figure 2.12.3**). Maturity schedules are presented in **Tables 2.11.3** and **2.11.4**.

Decision 3: Use reproductive data from Conrath and Musick (2002, SEDAR 39-RD01) as this peer-reviewed study was published in the primary literature and used multiple approaches to reliably assess maturity.

2.7 Meristics & conversion factors

Meristic relationships for lengths and body weight were calculated for *M. canis* captured in the Atlantic Ocean (**Table 2.11.1**) and based on data collected from a number of sources listed in SEDAR39-DW-31. There were in excess of 250 specimens directly measured for conversions between fork length (FL) and precaudal length (n = 253) as well as FL to STL (n = 269). There were fewer individuals upon which to base the conversion between FL to total length; however, the r^2 value of 0.79 indicated the resulting conversion adequately described variability within the length data. Sex-specific length weight relationships were based on a combined sample size of over 5,800 specimens (**Table 2.11.1**).

2.8 Comments on the Adequacy of data for assessment analyses

All life history parameters recommended for use in the stock assessment are from peer-reviewed sources (Conrath and Musick 2002; Conratth et al. 2002) and based on robust sample sizes collected over a relatively broad spatial range. Similarly, with the exception of the FL to TL conversion, all length-length and length-weight conversions were based on large sample sizes and resulted in high r^2 values. Additionally, tagging and genetic data clearly support the existence of a single stock of *M. canis* off the east coast of the United States. The consensus of the Life History Group was that all life history data presented in the various documents and references were well suited for assessment analyses.

2.9 Research Recommendations

- Increase tagging effort to examine if there is fine scale structure within *M. canis* off the east coast of the United States to determine if the stock is homogeneous or if it would be more accurately described by northern and southern groupings.
- Conduct genetic analyses in support of Research Recommendation 1.
- Better define seasonal distribution, including regional sex ratios, and identify nursery areas.
- Continue to monitor life history characteristics of *M. canis* off the east coast of the United States to detect potential temporal changes, density-dependent effects or clinal variability among individuals throughout the range.

2.10 Literature Cited

Conrath, C.L. and J.A. Musick. 2002. Reproductive biology of the smooth dogfish, *Mustelus canis*, in the northwest Atlantic Ocean. Environmental Biology of Fishes 64: 367-377.

Conrath, C.L., J.Gelsleichter, J.A. Musick. 2002. Age and growth of the smooth dogfish (*Mustelus canis*) in the northwest Atlantic Ocean. Fishery Bulletin 100: 674-682.

2.11 Tables

Table 2.11.1. Summary of Recommended Life History Parameters for *Mustelus canis:* Atlantic Ocean

Summary of *Mustelus canis* -- Biological Inputs for 2014 Assessment

Pupping month	May	SEDAR39-RD01, SEDAR39-DW31
Growth parameters	Male | Female | Combined	
L_∞ (cm STL)	105.17 | 123.57 | 123.54	SEDAR39-RD02
k	0.440 | 0.292 | 0.254	SEDAR39-RD02
t_o	-1.52 | -1.94 | -2.25	SEDAR39-RD02
Maximum observed age (years)	16 female, 10 male	SEDAR39-RD02, SEDAR39-DW31
Sample size	894 (531 female, 363 male)	SEDAR39-RD02, SEDAR39-DW31
Length-weight relationships	Combined: FL=1.063(PCL) + 1.229 r^2=1.0 (n=253)	SEDAR39-DW31
FL in cm	Combined: FL=0.884(STL) + 1.5579 r^2=1.0 (n=269)	SEDAR39-DW31
	Combined: FL = 0.8827(TL) -0.2438 r^2=0.79 (n=23)	SEDAR39-DW31
WT (kg)	Female: WT = (6.0*10^-6)*FL$^{3.0084}$ Male: WT = (1.0*10^-5)*FL$^{2.8076}$	SEDAR39-DW31
Size at Maturity	Males 85.4 cm STL, females 102.3 cm STL	SEDAR39-RD01, SEDAR39-DW31
Age at maturity (years)	males 2.5, females 4.4	SEDAR39-RD01, SEDAR39-DW31
Reproductive cycle	Annual (pupping in May)	SEDAR39-RD01, SEDAR39-DW31
Fecundity	Brood size = 0.239(STL)-18.03 mean = 9.53 (range = 3-18); mean = 8.28 (range = 1-20) Brood size = $42.47(1 - e^{-0.496(age)}) - 31.31$	SEDAR39-RD01, SEDAR39-DW31
Gestation	11 months	SEDAR39-RD01, SEDAR39-DW31
Sex-ratio	1:1	SEDAR39-RD01, SEDAR39-DW31
Stock structure	Single stock	SEDAR39-DW20

Table 2.11.2. Recommended age and size at maturity for *Mustelus canis* from the Atlantic coast of the United States as reported in Conrath and Musick (2002). Sizes reported for Conrath and Musick (2002) and NEAMAP are stretch total length and fork length, respectively.

Source	Sex	Age (years) at 50% maturity (a, b, n)	Size (cm) at 50% maturity (a, b, n)
Conrath et al. (2002)	Female	4.41 (7.486, -1.697, 409)	102.3 (-40.61, 0.397, 277)
Conrath et al. (2002)	Male	2.46 (8.736, -3.546, 260)	85.4 (-37.13, 0.435, 166)
NEAMAP	Female	NA	78.2 (-17.50, 0.22, 1,259)
NEAMAP	Male	NA	68.0 (-16.17, 0.24, 2,692)

Table 2.11.3. Recommended sex-specific size at maturity schedules for the *Mustelus canis* in the Atlantic Ocean.

Stretch total length (cm)	Female	Male
30	0.00	0.00
35	0.00	0.00
40	0.00	0.00
45	0.00	0.00
50	0.00	0.00
55	0.00	0.00
60	0.00	0.00
65	0.00	0.00
70	0.00	0.00
75	0.00	0.01
80	0.00	0.09
85	0.00	0.45
90	0.01	0.88
95	0.05	0.98
100	0.29	1.00
105	0.75	1.00
110	0.96	1.00
115	0.99	1.00
120	1.00	1.00
125	1.00	1.00

Table 2.11.4. Recommended sex-specific age at maturity schedules for the *Mustelus canis* in the Atlantic Ocean.

Age (years)	Female	Male
0.0	0.00	0.00
0.5	0.00	0.00
1.0	0.00	0.01
1.5	0.01	0.03
2.0	0.02	0.16
2.5	0.04	0.53
3.0	0.08	0.87
3.5	0.18	0.98
4.0	0.33	1.00
4.5	0.54	1.00
5.0	0.73	1.00
5.5	0.86	1.00
6.0	0.94	1.00
6.5	0.97	1.00
7.0	0.99	1.00
7.5	0.99	1.00
8.0	1.00	1.00
8.5	1.00	1.00
9.0	1.00	1.00
9.5	1.00	1.00
10.0	1.00	1.00
10.5	1.00	
11.0	1.00	
11.5	1.00	
12.0	1.00	
12.5	1.00	
13.0	1.00	
13.5	1.00	
14.0	1.00	
14.5	1.00	
15.0	1.00	
15.5	1.00	
16.0	1.00	

2.12 Figures

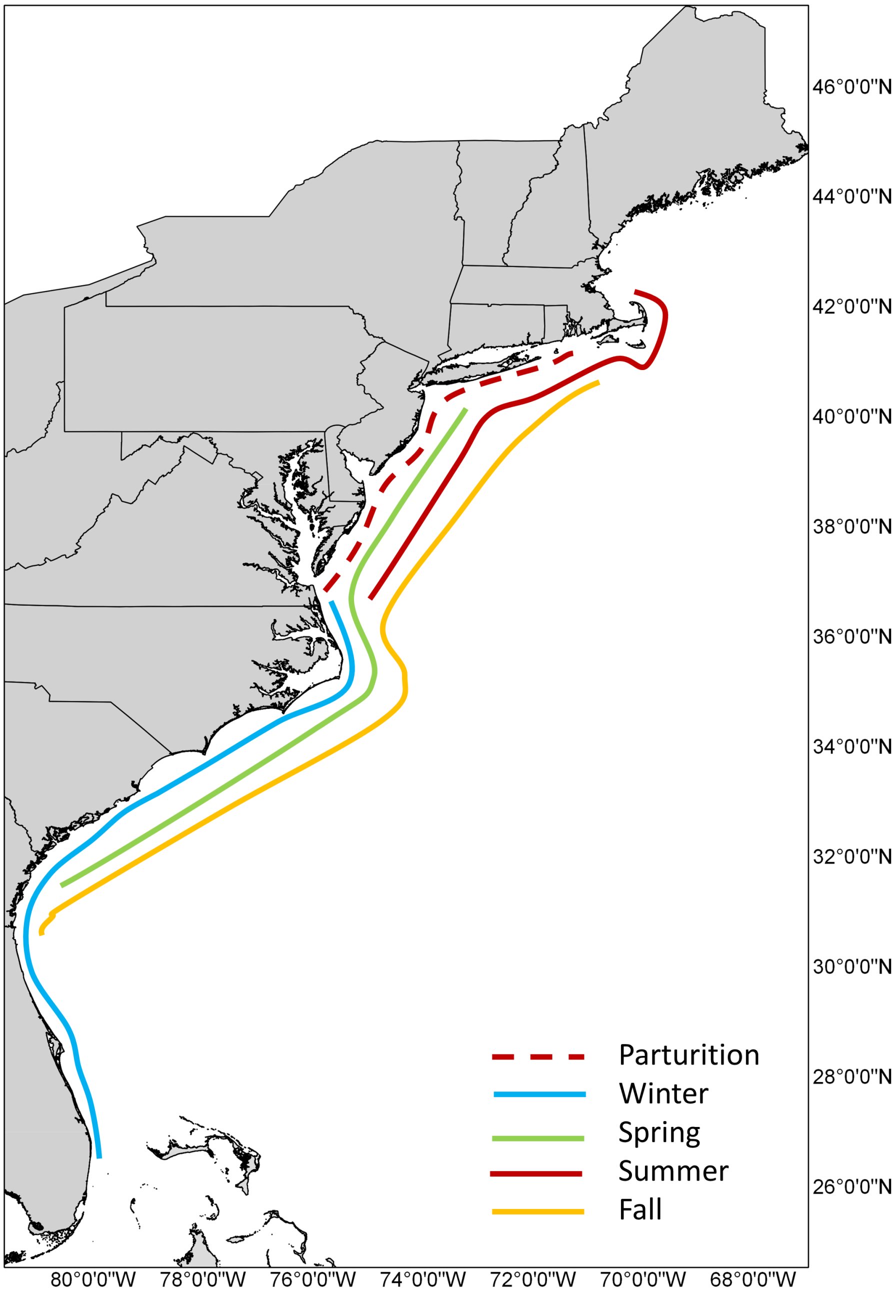

Figure 2.12.1. Seasonal distribution pattern of *Mustelus canis* along the east coast of the United States. Winter (Blue) is the distribution from December to February. Spring (Green) is the distribution from March through May. Summer (Red) is the distribution from June through August. Fall (Orange) is the distribution from September through November (SEDAR39-DW28). X and y axes represent degrees west longitude and degrees north latitude, respectively.

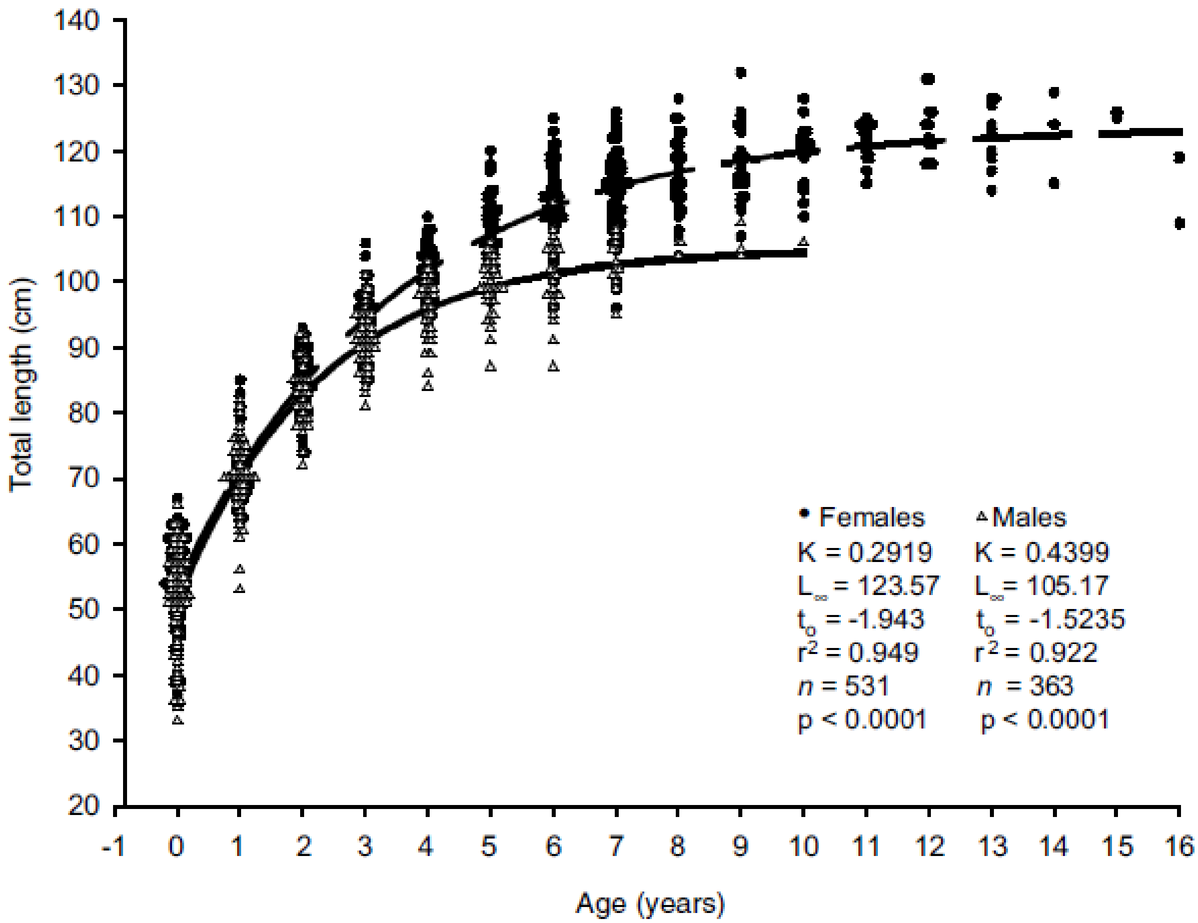

Figure 2.12.2. von Bertalanffy growth models for female and male *Mustelus canis* in the Atlantic Ocean from Conrath et al. (2002, SEDAR39-RD02). Total length = stretch total length.

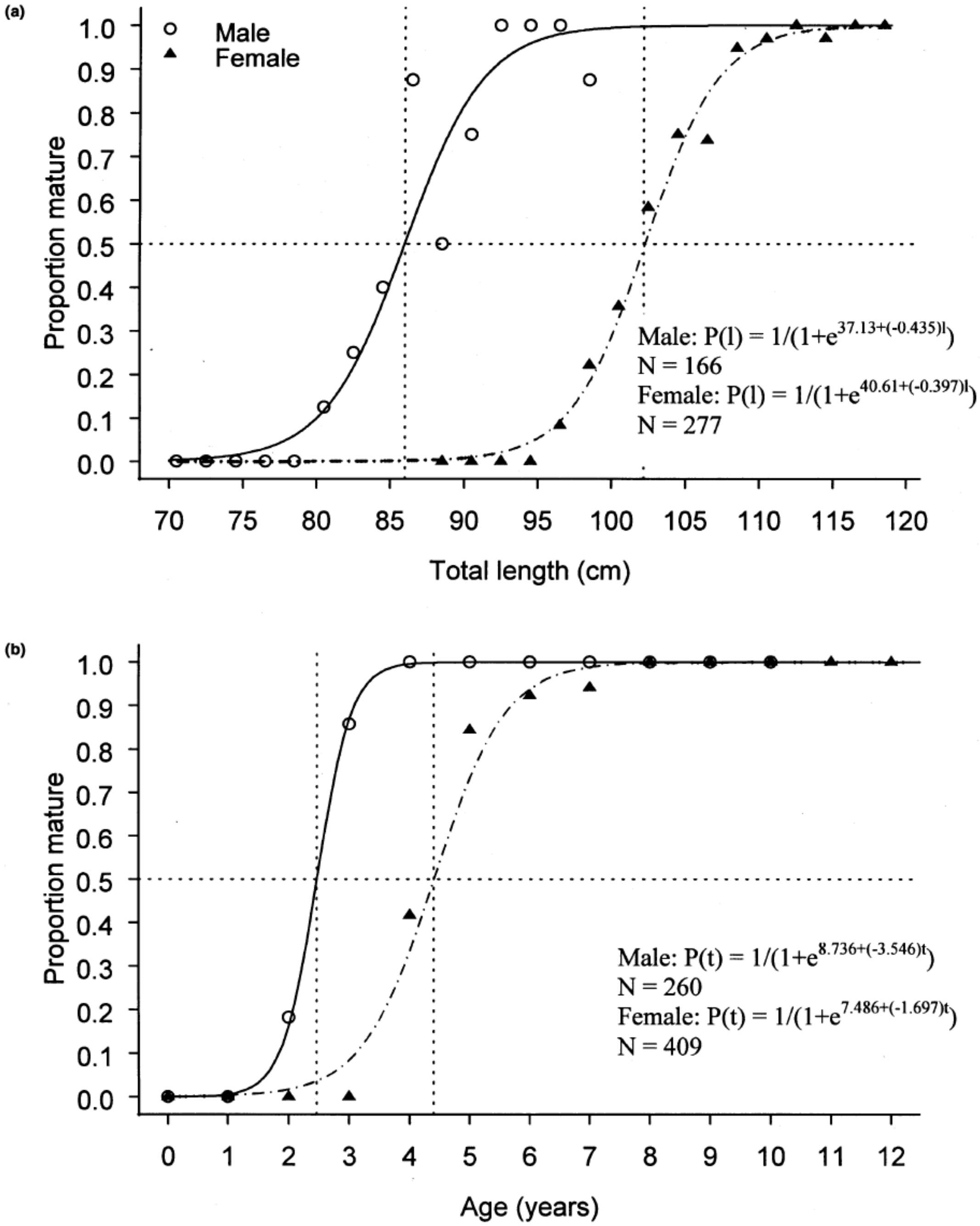

Figure 2.12.3. Size (a) and age (b) at maturity ogives for *Mustelus canis* in the Atlantic Ocean from Conrath and Musick (2002, SEDAR 39-RD01). Total length = stretch total length.

3 COMMERCIAL FISHERY STATISTICS

3.1 Overview

3.1.1 Members

Heather Balchowsky Baertlein (chair, SEFSC), Peter Barile (SE Fisheries Association), Karyl Brewster-Geisz (NOAA/HMS), Enric Cortés (SEFSC), Dean Courtney (SEFSC), Marin Hawk (ASMFC), Dewey Hemilright (Fisherman-North Carolina), Alyssa Mathers (Riverside Technology Inc/SEFSC), Kathy Sosbee (NEFSC), Holly White (NCDNF), Xinsheng Zhang (SEFSC).

3.1.2 Issues

The catch working group (WG) discussed a number of issues concerning the catch data for the smoothhound complex including: 1) creating the commercial landings stream; 2) catch reconstruction; 3) setting the year for virgin biomass; 4) commercial discards in gillnet fishery; 5) post-release live-discard mortality rates; and 6) shrimp trawl fishery bycatch mortality estimation.

3.2 Review of Working Papers

SEDAR 39-DW-03 Preliminary catches of smoothhound sharks.
E. Cortes and H. Balchowsky
This document presents commercial landings, recreational catches, and discard estimates of smoothhound sharks (genus *Mustelus*) for 1981-2012. Information on the geographical distribution of both commercial landings and recreational catches and live discards is presented along with gear-specific information of commercial landings. Data on the disposition of smoothhound sharks in two commercial observer programs and length composition information and trends in average size of the catches from several commercial and recreational sources are also presented.

SEDAR 39-DW-21 A Preliminary Review of Post-release Live-discard Mortality Rate Estimates in Sharks for use in SEDAR 39.
Dean Courtney
This working paper reviewed the primary scientific literature for estimates of delayed discard-mortality rates (MD) in sharks. However, the review was not exhaustive and therefore should be considered preliminary. Delayed discard-mortality rate estimates, MD, obtained from the literature were summarized for smooth dogfish (*Mustelus* spp.) from many geographic regions and for spiny dogfish (*Squalus acanthias*) from the northwest Atlantic. Estimates of immediate (i.e. at-vessel or acute) discard-mortality rates (MA) were also identified for *Mustelus* spp. and *S. acanthias* from the literature and for *Mustelus canis* from northwest Atlantic commercial gillnet observer program data. A range of post-release live-discard mortality (PRLDM) rates (Low, Base, and High) was developed by gear type based on the estimates obtained for MD and MA

following methods analogous to those adopted by previous SEDAR Assessment Process (AP) panels. Alternative PRLDM rates were also developed for gillnet and trawl from the average delayed mortality rates obtained from the literature for *Mustelus spp.* from any region and for *Squalus acanthias* from the northwest Atlantic, and for longline and hook and line using an ad hoc approach described in the working paper.

SEDAR 39-DW-23 Discards of *Mustelus canis* in the coastal gillnet fishery off the Southeast United States.
John Carlson, Alyssa Mathers, and David Gloeckner
Observer reported *Mustelus canis* discard rates from 2007-2012, along with self reported commercial fishing effort data, were used to calculate *Mustelus canis* live and dead discards from the coastal gillnet fishery of the US south Atlantic. Fishing effort data were available from the coastal logbook program for the years 2007-2012. In 2007, the Coastal Fishery Logbook program (CFLP) began using an updated trip report form that provided gillnet fishermen a place to note the type of gillnet used (strike, drift, anchor, or other) as well as space to provide the number of sets. These fields were unavailable on logbook forms prior to 2007. There are some instances where fishermen have submitted a 2007 or later trip on a pre-2007 form. Total discards were calculated as the product of observer reported yearly median discard rates and the yearly total fishing effort (number of sets) reported to the coastal logbook program. An estimate of uncertainty in these estimates was derived from bootstrap re-sampling of the calculated CPUE data set. Total live discards for *Mustelus canis* were higher than those estimated for dead discards.

SEDAR 39-DW-25 Estimation of smooth dogfish discards in the Northeast United States fisheries using data collected by the Northeast Fisheries Observer Program.
Katherine A, Sosebee
Discards were estimated following the NEFSC Standardized Bycatch Reporting Methodology. Total discards range from 1080 mt in 1989 to a low of 41 mt in 2012. On average, otter trawls account for 75 percent of the total with sink gill net around 23 percent. Longline discards represent a very small portion of the total. Overall CV ranged from a low of 15% in 2010 to a high of 82% in 1989.

3.3 Commercial Landings

Smoothhound commercial landings are summarized in SEDAR 39-DW-03. Adjustments were made and final data were summarized at the workshop.

U.S. commercial landings of species in the smoothhound complex in weight were compiled from Atlantic Coastal Cooperative Statistics Program (ACCSP) data for the Atlantic region. Landings data are collected in landed or dressed weight and are maintained in the source databases as live (round) weight using conversions provided by each state. Additional extractions from ACCSP during the workshop using an additional 11 ITIS (Integrated Taxonomic Information System) codes revealed smooth dogfish (*Mustelus canis*) landings from 1981 to present and unclassified dogfish landings under codes for the Family Squalidae (1950-2012) and Order Squaliformes (1990-1993).

Prior to the workshop, it was discovered that the state of NC did not differentiate between smooth dogfish and spiny dogfish (*Squalus acanthias*) until 1995. The state of NC combined all landings into an unclassified dogfish category in 1991-1993 and in 1994, although they appeared identified in the ACCSP database as 8,642,748 lb whole weight (ww) of smooth dogfish and 1,234,931 lb ww of spiny dogfish (total 9,877,658 ww), they were unclassified dogfish (Alan Bianchi, NC Division of Marine Fisheries, pers. comm. to H. Balchowsky). To account for NC unclassified dogfish (smooth and spiny dogfish) that could have been smooth dogfish in 1991-1994, the ratio of smooth to spiny dogfish was calculated by gear for the first four years of data (1995-1998) correctly reported to species level. These gear-specific ratios (Gillnet: 0.10; Trawls: 0.31; Longlines: 0.05; Other Gears: 0.20) were then multiplied by the reported NC unclassified dogfish landings for those specific gears to yield estimates of smooth dogfish landings for 1991, 1992, and 1993. For 1994, the above ratios were multiplied by the sum of reported smooth dogfish and spiny dogfish by gear to yield estimates of smooth dogfish.

The WG discussed the appropriateness of allocating portions of unclassified dogfish towards total smoothhound landings prior to 1981, as well as the time period between 1981 and 1994 as not many states were reporting dogfish to species and some states that were reporting to species may have been doing so inconsistently. The fisherman on the WG reported that market conditions for smooth dogfish did not exist in North Carolina prior to 1987. Market conditions for other areas were essentially unknown. The WG determined that for the time period prior to 1981, it was *not* appropriate to use the unclassified dogfish landings as no species-specific landings were reported during this time and because the market conditions for smooth dogfish were not well understood. For these reasons, the WG decided not to extend commercial landings back to 1972. The WG determined that for the time period between 1981 and 2012 (except for North Carolina, see above), it *was* appropriate to apply calculated proportions to data if species-specific landings were available by gear and year. It was brought to the attention of the WG that Maine did not support a smoothhound market; therefore the WG agreed that all landings of unclassified dogfish and spiny dogfish reported by Maine would be removed throughout the time series (1981-2012) to eliminate any biases. Ratios were created for those years with species-specific gear information and additional landings of smooth dogfish included. For gear and year combinations which did not contain smooth dogfish landings, it was assumed that all reported unclassified dogfish were spiny dogfish. As ratios for unclassified dogfish during 1991-1994 were calculated separately for North Carolina, North Carolina landings were excluded prior to calculating ratios for the remaining Atlantic states.

Landings showed an increasing trend from 1981 to 2012, punctuated by two peaks in 2010 and 1995 (**Figure 3.14.1**). Commercial landings were dominated by gillnets, followed by trawls and a “not coded” gear category, both of which were an order of magnitude lower than gillnets (**Figure 3.14.1**). Averaged over 1982-2012, 83% of smooth dogfish were caught in gillnets, 8% in trawls, 7% in the “not coded” gear category, and 1% in longlines. Geographically, most landings occurred in NC (45%), followed by VA (23%), NJ (18%), MD (6%), and NY (5%), with the contribution from the rest of the Atlantic states being almost negligible (ca. 3%) (**Figures 3.14.2 and 3.14.3**). **Table 3.13.1** shows all catches of smooth dogfish in the Atlantic, including commercial landings in the first four columns. **Figure 3.14.4** shows all annual catches stacked (top) and as a proportion (middle), and catches for the entire time period (1981-2012) as proportions (bottom). Commercial landings accounted for 57% of the total catches, with gillnet landings accounting for almost half of all catches for the whole time period.

Decision 1. Use ratios as described above to account for unclassified dogfish to alter the landings provided in SEDAR39-DW-03.

Decision 2. Treat Gulf of Mexico catches for the smoothhound complex and Atlantic catches for smooth dogfish separately.

3.3.1 Year of Virgin Biomass

Discussions between all WGs (Catches, Life History, Indices of abundance) resulted in setting the year of virgin biomass in the Atlantic to 1981. This choice was based on a combination of available data from indices, commercial landings, recreational catches, and observer data as well as an understanding of the fishery. An alternate year of 1972 was suggested for potential use in sensitivity analysis because at least one index of abundance started in that year.

Decision 3. Set the year of virgin biomass for smooth dogfish in the Atlantic at 1981. An alternate year of virgin biomass was recommended at 1972.

3.4 Commercial Fishery Discards

3.4.1 Southeast Atlantic

Shark-targeted gillnet effort, including smooth dogfish is observed by the Southeast Gillnet Observer Program (GNOP) and covers all anchored (sink and stab), strike, or drift gillnet fishing regardless of target by vessels fishing from Florida to North Carolina and the Gulf of Mexico year-round. A summary of the program and methods are presented in SEDAR 39-DW-23. Panel discussions amongst all WGs prompted recalculation of bycatch rates, total discards and estimates of uncertainty and are included in Addendum to SEDAR 39-DW-23.

Original estimates presented contained data from 2007 to 2012 with extrapolations for total discards conducted using the Coastal Fishery Logbook Program (CFLP) data collected from federally licensed vessels by the Southeast Fisheries Science Center (SEFSC). Following panel discussions, additional data were acquired from the CFLP back to 1998 containing gillnet effort data, although not to gillnet type. A median bycatch rate was calculated from the observer data for the years 2007-2012. Total discards were then calculated using the median discard rate multiplied by the year-specific effort data from the coastal logbook data for 1998-2006. An estimate of uncertainty in these estimates was derived from bootstrap re-sampling of the year-based observer CPUE data set. Calculated live and dead discards for the southeast coastal gillnet fishery are presented in **Tables 3.13.2 and 3.13.3**, respectively. Dead discard estimates were essentially negligible. **Table 3.13.1** also shows commercial discards in the southeast gillnet fishery (eighth column). These were computed as the product of sharks released alive (in numbers), average weight of discards from the Southeast Gillnet Observer Program, and post-release live discard mortality rate for gillnets. **Figure 3.14.4** (bottom) shows that southeast commercial discards accounted for less than 1% of the total catches.

Decision 4. Use the median discard bycatch rate for smooth dogfish in the Atlantic calculated from the Southeast Gillnet Observer Program and gillnet fishery effort for 2007-2012 and apply it to the remainder of the time series (back to 1998 only) to generate discards for 1998-2006.

3.4.2 Northeast Atlantic

Discards of smooth dogfish in the northeast region were initially estimated following the NEFSC Standardized Bycatch Reporting Methodology for the period 1989-2012. After the panel identified the starting year of the model as 1981, discard estimates were hind-casted back to 1981 (1972 for the alternate catch scenario) using the summed discards/sum catch by quarter and gear type for 1989-1991 to get the discard rate (**Table 3.13.4**). This discard rate was then applied to the landings by gear type and quarter. Region was not included because the commercial data did not have any of the Mid-Atlantic states prior to 1978 and not all until 1989. **Table 3.13.1** also shows commercial discards in the northeast gillnet fishery (fifth to seventh columns). These were computed as the product of sharks released (all assumed to be alive) and post-release live discard mortality rate for each gear. **Figure 3.14.4** (bottom) shows that Northeast commercial discards accounted for less than 10% of the total catches.

3.5 Post-release live-discard Mortality

A literature review of post-release mortality studies for smooth and spiny dogfish is summarized in SEDAR 39-DW-21. A range of post-release live-discard mortality (PRLDM) rate values (Low, Base, and High) was developed below for each gear type (gillnet, trawl, hook and line, and longline) from estimates of delayed discard-mortality (MD) and immediate discard-mortality (MA), obtained from a literature search, following the approaches analogous to those adopted by previous SEDAR AP panels. The WG discussed the literature presented in the working document and decided sufficient information existed to use rates directly from the literature. The recommendations for each gear are described below.

Gillnet

A base PRLDM rate for commercial gillnet fisheries was developed as the average of four delayed discard-mortality rates (Base-$MD_{Gillnet}$ = 27%; **Table 3.13.5**) obtained from the scientific literature for *Mustelus* spp.: 31.0 % (Frick et al. 2010a), 6.5 % (Frick et al., 2012), and 36.2 % (Braccini et al., 2012); and for *S. acanthias* from the northwest Atlantic: 33.2 % (Rulifson 2007). Low and high PRLDM rates were developed from the approximate 95% confidence interval of the mean delayed discard-mortality rate obtained from the literature as mean MD ± 1.96*S.E. (13–40%; **Table 3.13.5**).

Trawl

A base PRLDM rate for commercial trawl fisheries was developed as the average of three delayed discard-mortality rates (Base-MD_{Trawl} = 19%; **Table 3.13.5**) obtained from the scientific literature for *Mustelus* spp.: 26.9% (Frick et al. 2010b); and for *S. acanthias* from the northwest Atlantic: 29.0% (Mandelman and Farrington 2007) and 0.0% (Rulifson 2007). Low and high PRLDM rates were developed from the approximate 95% confidence interval of the mean delayed discard-mortality rate obtained from the literature as mean MD ± 1.96*S.E. (0–37%; **Table 3.13.5**).

Hook and Line

A range of PRLDM rates for hook and line (i.e., recreational) fisheries was developed based on the following ad hoc approach. A low PRLDM rate for hook and line fisheries (Low-$PRLDM_{\text{hook and line}}$ = 10 %; **Table 3.13.5**) was developed based on Gurshin and Szedlmayer (2004), who estimated a 10 % delayed discard-mortality rate based on tagged Atlantic sharpnose sharks (n = 10) captured with hook and line (recreational rod and reel) and monitored for six hours. This rate was also used as the base in SEDAR 34 for Atlantic sharpnose and bonnethead (rates shown in Table 4, Panel C of SEDAR 39-DW-21). A high PRLDM rate for hook and line fisheries (High-$PRLDM_{\text{hook and line}}$ = 24 %; **Table 3.13.5**) was developed based on Mandelman and Farrington (2007), who estimated a 24 % delayed mortality in hook and line (hauled by hand) captured spiny dogfish, *S. acanthias*, (n = 55), subsequently held for 72 hrs. A base PRLDM rate for hook and line fisheries was developed as the average of the low and high PRLDM rates for hook and line developed above (Base-$PRLDM_{\text{hook and line}}$ = 17 %; **Table 3.13.5**).

Longline

A range of PRLDM rates for longline fisheries was developed based on the same ad hoc approach described for hook and line above. A low PRLDM rate for longline fisheries was developed based on the delayed discard-mortality rate obtained from the scientific literature for *Mustelus spp.* at 8.0 % (Frick et al 2010a) (Low-$PRLDM_{longline}$ = 8 %; **Table 3.13.5**). A high PRLDM rate for longline fisheries was developed based on Campana et al. (2009), which analyzed pelagic longline fishery mortality of blue sharks and estimated post-release at 19%

mortality (High-PRLDM $_{longline}$ = 19 %; **Table 3.13.5**). A base PRLDM rate for longline fisheries was developed as the average of the low and high PRLDM rates above at 13.5% for longline in a manner similar to hook and line described above (Base-PRLDM $_{longline}$ = 13.5 %; **Table 3.13.5**).

Decision 5: Use a post-release live-discard mortality rate for smoothhound sharks caught on commercial gillnet gear of 27% and, if needed, use low and high values of 13% and 40%.

Decision 6: Use a post-release live-discard mortality rate for smoothhound sharks caught on commercial trawl gear of 19% and, if needed, use low and high values of 0% and 37%.

Decision 7: Use a post-release live-discard mortality rate for smoothhound sharks caught on commercial hook and line gear of 17% and, if needed, use low and high values of 10% and 24%.

Decision 8: Use a post-release live-discard mortality rate for smoothhound sharks caught on commercial bottom longline gear of 13.5% and, if needed, use low and high values of 8% and 19%.

3.6 Shrimp Trawl Fishery Bycatch Estimates

Estimates of smoothhound bycatch in the shrimp trawl fishery in the Gulf of Mexico were provided in document SEDAR 39-DW-05. Four years of appropriate observer data exist (2009-2012) and are applicable for the smoothhound complex range; prior to this time SEAMAP data are available. See the Gulf of Mexico Catch Working Group report for details on bycatch in the Gulf of Mexico.

For the Atlantic, a concern was brought up by a WG member that spatial overlap may not exist between the SEAMAP survey and the shrimp fishery. It was initially discussed that no shrimp bycatch existed in the Atlantic, as the shrimp fishery did not appear to overlap with the stock based on catch data. However, life history data presented to the panel showed some potential overlap between the distribution of the smooth dogfish stock and that of the shrimp trawl fishery during certain months, and prompted additional research during the meeting to investigate the potential for shrimp bycatch of smooth dogfish in the Atlantic. Effort from otter trawls and shrimp trawls was examined for 1978-2013 by month and state for Florida, Georgia, South Carolina and North Carolina. Months were limited to October through March when the range of smoothhounds extended into these areas. This resulted in a potential overlap of 23%. It should be noted, however, that depth information was not included in this analysis, so only horizontal overlap of areas was considered. If the horizontal overlap between the stock and the fishery is multiplied by the proportion of effort in the Atlantic compared to the Gulf of Mexico (14%, the ratio between the South Atlantic and GOM average shrimp fishery trip length derived from the Shrimp Fishery Observer Program for 1992-2012), the resulting magnitude of smooth dogfish bycatch in the Atlantic is only ca. 3% that in the Gulf of Mexico. If instead the ratio between the South Atlantic and GOM total shrimp fishery tow-hours is considered (6.5%), the resulting magnitude of smooth dogfish bycatch in the Atlantic is even lower (1.5% that in the Gulf of Mexico). Nevertheless, the panel decided to further investigate whether bycatch estimates could be derived for the South Atlantic based on observer information. It was subsequently found that only 5 out of 630 tows were non-zero catch for smoothhound sharks based on Observer Program information for 2001-2012. All 5 non-zero-catch tows were from Florida in 2002. Unlike for the GOM, it is thus unrealistic to estimate bycatch CPUE for smoothhound sharks in the South Atlantic based on Observer program data.

Decision 9: Shrimp bycatch mortality for the Atlantic is estimated at 3% (1.5%) of that in the Gulf of Mexico. Ignore this data stream given its low magnitude.

3.7 Commercial effort

Commercial effort was not taken into account because commercial effort directed to sharks is not reported for the various coastal commercial fisheries that catch smoothhound sharks. However, the Indices WG calculated effort estimates and catch-per-unit effort estimates to develop various indices of abundance.

3.8 Biological sampling

Biological samples of smooth dogfish were available from NEAMAP and the NMFS MS Laboratories. For the Atlantic, age and growth, reproductive, and length-weight information was available for *Mustelus canis* from the published scientific literature (SEDAR39-RD01, SEDAR39-RD02) as well as from the available biological samples (see Life History section).

3.9 Commercial Catch-at-Age/Length; directed and discard

No age composition information was available. In contrast, numerous datasets were made available that contained individual lengths (the majority), or alternatively, means representing a subsample of lengths per tow or set. **Table 3.13.6** summarizes the datasets available, including the name, years and area of coverage, whether sex-specific information was available, and sample size. These datasets correspond to indices of abundance that were selected by the Indices Working Group (see Indices section), but there are also some additional length compositions that may be useful to characterize the size composition of catches by gear type.

3.10 Comments on the adequacy of data for assessment analyses

Catch data for smooth dogfish in the Atlantic were considered to be adequate to characterize total removals because *Mustelus canis* is essentially the only species of *Mustelus* that occurs in that area. The commercial landings data are considered adequate because they are provided directly from dealer reports and are therefore nearly a census. Bycatch data are more uncertain because they are estimates; in particular, live discard estimates in the different gears were multiplied by the corresponding post-release live-discard mortality rate to generate total dead discards. An alternate catch scenario starting in 1972 was also considered given that one of the indices of abundance started in 1972 (**Table 3.13.7**).

3.11 Research Recommendations

- Increase temporal/spatial/fleet-specific shrimp fleet Observer Program coverage to improve bycatch estimates of *Mustelus* species in the shrimp trawl fishery.
- Conduct research to explore and test the relationship between CPUEs based on shrimp fleet Observer Program and survey (SEAMAP) to indirectly estimate shrimp bycatch CPUE for *Mustelus* species when Observer program data were very limited.

3.12 Literature Cited

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3.13 Tables

Table 3.13.1. Total catches of smooth dogfish in the Atlantic (all in lb whole weight). The first four columns are commercial landings by gear (GN=gillnets, TR=Trawl, LL=Longline, Other=other gear). The next four columns are discards from the northeast (first three) and the southeast (fourth). Northeast discards represent discards released alive that are assumed to die (discard estimates x post-release live discard mortality rate for each of the gears); Southeast discards are also discards released alive assumed to die (discard estimates in numbers x average weight of discards from the SE Gillnet Observer Program x post-release live discard mortality rate for gillnets). Next are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 in numbers x average weight of A+B1 from MRIP x post-release live discard mortality rate for hook and line).

Year	Com-GN Landings	Com-TR Landings	Com-LL Landings	Com-Other Landings	Com-GN-NE (PRM)	Com-TR-NE (PRM)	Com-LL-NE (PRM)	Com-GN-SE (PRM)	Recreational (A+B1)	Recreational (PRM)
1981	0	2683	0	0	4963	250610	856		483684	87170
1982	0	7619	0	0	3290	317358	616		99148	273632
1983	505	23842	525	11500	3072	300753	537		398513	914075
1984	0	1320	0	0	3624	263474	413		356552	323009
1985	715	7155	0	16644	3483	225716	406		363366	206463
1986	101	5180	0	0	3788	216118	507		696378	314873
1987	9796	60714	19300	0	3722	198031	826		424872	224353
1988	912	813	0	0	3989	185552	763		408454	203522
1989	150253	111703	0	0	4941	448279	600		395156	548304
1990	234113	82536	0	0	4405	122144	412		186795	212962
1991	732671	97683	11010	929	8036	56464	1012		182571	210762
1992	1767170	96567	551	205	200716	223469	1462		179842	173427
1993	1464658	187825	1526	2	145775	26515	1087		294512	256845
1994	1443107	202242	14742	84282	46012	110373	450		118903	292773
1995	2792499	71496	4409	8973	36369	160345	787		154399	392948
1996	1639843	72045	201	4189	68036	161308	1049		110983	290326
1997	944914	60096	1500	13121	28572	62915	1199		161911	509711
1998	748008	194618	391	215739	97263	107399	1462	515	110258	602797
1999	1268515	66604	3675	2096	152501	22494	862	417	53793	355735
2000	1023946	58030	8433	930	43869	195698	974	470	166651	707458
2001	1132671	120994	8933	14400	40119	89388	1986	455	105755	646390
2002	1329510	153683	21309	17403	65834	157999	1424	487	86144	427596
2003	1430755	164128	18385	20246	129168	51019	1949	443	186666	606685
2004	1596868	96115	15887	72389	6726	112426	1312	433	57662	523811
2005	1058452	33787	51029	110366	156489	271388	4123	155	182730	1688246
2006	918780	100142	14426	108628	53572	167047	2324	403	48386	1949045
2007	1313988	98781	16211	229663	43453	249188	1687	13346	322588	821034
2008	1337695	174975	30830	273395	6071	70790	1949	96	168107	951138
2009	1854673	291046	80642	488272	16905	150753	2549	205	78672	733223
2010	3027939	232648	56914	584767	5536	72088	2773	9035	56757	256012
2011	2067545	315187	15465	395322	18095	121515	2998	998	64792	318137
2012	1521436	175789	8862	533254	1905	86414	3336	458	96736	771972

Table 3.13.2. Estimated live discards of *M. canis* from the coastal gillnet fishery in the South Atlantic based on the Southeast Gillnet Observer Program and Costal Fishery Logbook Program data. Discards are reported as number of fish.

Year	Total logbook sets	Total Observer Sets	Per set discard alive	MEAN TOTAL DISCARDS	LCL	UCL
1998	3210		0.0939	301	68	8,053
1999	2597		0.0939	244	55	6,515
2000	2934		0.0939	275	62	7,361
2001	2835		0.0939	266	60	7,112
2002	3036		0.0939	285	64	7,617
2003	2757		0.0939	259	59	6,917
2004	2699		0.0939	253	57	6,771
2005	3010		0.0939	282	64	7,552
2006	3489		0.0939	327	74	8,753
2007	3781	89	2.5955	9,814	0	41,275
2008	3607	135	0.0148	53	0	497
2009	4108	190	0.0158	65	0	
2010	2714	281	2.9075	7,891	0	42,801
2011	3466	398	0.1307	453	0	2,003
2012	3613	298	0.0570	206	0	2,598

Table 3.13.3. Estimated dead discards of *M. canis* from the coastal gillnet fishery in the South Atlantic based on the Southeast Gillnet Observer Program and Costal Fishery Logbook Program data. Discards are reported as number of fish.

Year	Total sets	Total Observer Sets	Per set discard dead	MEAN TOTAL DISCARDS	LCL	UCL
1998	3210		0.0034	11	0	135
1999	2597		0.0034	9	0	109
2000	2934		0.0034	10	0	123
2001	2835		0.0034	10	0	119
2002	3036		0.0034	10	0	128
2003	2757		0.0034	9	0	116
2004	2699		0.0034	9	0	113
2005	3010		0.0034	10	0	126
2006	3489		0.0034	12	0	147
2007	3781	89	0.0000	0	0	0
2008	3607	135	0.0000	0	0	0
2009	4108	190	0.0000	0	0	0
2010	2714	281	0.0605	164	0	214
2011	3466	398	0.0101	35	0	
2012	3613	298	0.0067	24	0	

Table 3.13.4. Estimated discards of *M. canis* from the northeast fisheries using data collected by the Northeast Fisheries Observer Program. Discards are reported in lb whole weight.

Year	Sink gillnet	Otter trawl	Longline	Sink gillnet	Otter trawl	Longline
	Discards			CV		
1972	2252	1145442	6964			
1973	2324	1042410	8184			
1974	3923	963706	8181			
1975	4356	922940	7884			
1976	6682	1045651	4444			
1977	9356	1161780	3475			
1978	12342	1238510	7573			
1979	11658	1329938	9650			
1980	16075	1522638	7226			
1981	18381	1319001	5035			
1982	12184	1670306	3623			
1983	11377	1582910	3160			
1984	13422	1386704	2427			
1985	12901	1187980	2387			
1986	14029	1137466	2983			
1987	13785	1042266	4859			
1988	14775	976589	4487			
1989	18298	2359363	3527	0.83	0.03	0.83
1990	16314	642861	2425	0.59	0.17	0.61
1991	29762	297180	5952	0.51	0.27	0.58
1992	743391	1176154	8598	0.46	0.29	0.74
1993	539907	139551	6393	0.24	0.26	0.66
1994	170416	580912	2646	0.24	0.27	0.30
1995	134701	843921	4630	0.22	0.25	0.25
1996	251986	848991	6173	0.55	0.22	0.72
1997	105821	331131	7055	0.44	0.24	0.58
1998	360232	565259	8598	0.39	0.34	0.61
1999	564819	118387	5071	0.41	0.48	0.70
2000	162479	1029989	5732	0.26	0.35	0.30
2001	148590	470462	11684	0.40	0.59	0.50
2002	243829	831575	8377	0.34	0.39	0.43
2003	478398	268520	11464	0.30	0.41	0.43
2004	24912	591715	7716	0.20	0.33	0.21
2005	579589	1428360	24251	0.37	0.68	0.45
2006	198414	879194	13669	0.32	0.64	0.37
2007	160936	1311517	9921	0.23	0.33	0.26
2008	22487	372577	11464	0.25	0.33	0.27
2009	62611	793436	14991	0.17	0.41	0.18
2010	20503	379412	16314	0.15	0.33	0.16
2011	67020	639554	17637	0.18	0.92	0.18
2012	7055	454809	19621	0.26	0.52	0.27

Table 3.13.5. A range of post-release live-discard mortality (PRLDM) rates (Low, Base, and High) was developed for each gear type (longline, hook and line, gillnet, and trawl) following methods described in SEDAR 39-DW-21; PRLDM rates were developed for gillnet and trawl from the average delayed mortality rates obtained from the literature for *Mustelus spp.* from any region and for *Squalus acanthias* from the northwest Atlantic (mean M_D ± 1.96*S.E.) as described in SEDAR 39-DW-21; PRLDM rates were developed for longline and hook and line using an ad hoc approach as described in SEDAR 39-DW-21.

PRLDM rate	Longline	Hook and line	Gillnet	Trawl
Low	8%	10%	13%	0%
Base	13.5%	17%	27%	19%
High	19%	24%	40%	37%

Table 3.13.6. Length compositions available for smooth dogfish in the Atlantic.

Name	Acronym	Years of coverage	Species	Area	Subarea	State	Sex	N	Index used?
Bottom Longline Observer Program *	BLLOP	1994-2012	*Mustelus* spp.	ATL			Yes	541	no
CT Dep Ener Env Prot Trawl survey	CT DEEP Trawl	1989-2012	*Mustelus canis*	ATL	Long Island Sound	CT-NY	Yes	4112	yes
Delaware Div Fish Wild Trawl survey	DE Trawl	1966-1971; 1974; 1997-2012	*Mustelus canis*	ATL	Delaware Bay	DE	No	16113	yes
Gillnet Fishery Observer Program*	GNOP	2005-2012	*Mustelus canis*	ATL		FL-NC	Yes	645	no
MA Dept of Mar Fish Trawl Fall survey	Fall MA DMF Trawl	1978-2012	*Mustelus canis*	ATL		MA	Yes	1764**	yes
Marine Recreational Information Program*	MRIP	1981-2012	*Mustelus canis*	ATL		FL-ME	Yes	1562	no
Northeast Gillnet Observer Program*	NE GNOP	1992-2012	*Mustelus canis*	ATL		MA-NC	Yes	14174	no
Northeast Trawl Observer Program*	NE TOP	1994-2012	*Mustelus canis*	ATL		MA-NC	Yes	3623	no
NEFSC Fall Trawl survey N of Cape Hatteras	Fall NEFSC N of CH Trawl	1972-2012	*Mustelus canis*	ATL		MA-NC	Yes	3078**	yes
New Jersey DEP Fish and Wildlife Trawl	NJ DFW Trawl	1988-2012	*Mustelus canis*	ATL	Cape May to Sandy Hook	NJ	No	69871	yes
Rhode Island Dept of Env and Mngmt Trawl survey	RI DEM seas Trawl	1980-2012	*Mustelus canis*	ATL	Naragansett Bay et al.	RI	Yes	666	yes
SEAMAP-SA Trawl survey	SEAMAP-SA Trawl	1994-2012	*Mustelus canis*	ATL		FL-NC	Yes	4136	yes
Fall NEAMAP Trawl survey	NEAMAP	2007-2012	*Mustelus canis*	ATL		MA-NC	yes	NA	yes
NEFSC Spring Trawl Survey North*	NEFSC-Spring-North Trawl	1973-2012	*Mustelus canis*	ATL		MA-NC	Yes	2132**	no
NEFSC Spring Trawl Survey South*	NEFSC-Spring-South Trawl	1974-2011	*Mustelus canis*	ATL	Cape Hateras, NC to Cape	NC-FL	Yes	681**	no
MA Dept of Mar Fish Trawl Spring survey*	Spring MA DMF Trawl	1978-2012	*Mustelus canis*	ATL		MA	yes	433**	no
NEFSC Winter Trawl Survey North*	NEFSC-Winter-North Trawl	1992-2007	*Mustelus canis*	ATL		MA-NC	Yes	1484**	no
Total								125015	

* No index of abundance used, but length composition may be useful to characterize the size composition of catches by gear type

** Number of records of mean number measured at length per tow

Table 3.13.7. Total catches of smooth dogfish in the Atlantic (all in lb whole weight) starting in 1972. The first four columns are commercial landings by gear (GN=gillnets, TR=Trawl, LL=Longline, Other=other gear). The next four columns are discards from the northeast (first three) and the southeast (fourth). Northeast discards represent discards released alive that are assumed to die (discard estimates x post-release live discard mortality rate for each of the gears); Southeast discards are also discards released alive assumed to die (discard estimates in numbers x average weight of discards from the SE Gillnet Observer Program x post-release live discard mortality rate for gillnets). Next are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 in numbers x average weight of A+B1 from MRIP x post-release live discard mortality rate for hook and line).

Year	Com-GN Landings	Com-TR Landings	Com-LL Landings	Com-Other Landings	Com-GN-NE (PRM)	Com-TR-NE (PRM)	Com-LL-NE (PRM)	Com-GN-SE (PRM)	Recreational (A+B1)	Recreational (PRM)
1972					608	217634	1184		0	0
1973					628	198058	1391		53743	14194
1974					1059	183104	1391		107485	28387
1975					1176	175359	1340		161228	42581
1976					1804	198674	756		214971	56775
1977					2526	220738	591		268713	70969
1978					3332	235317	1287		322456	85162
1979					3148	252688	1641		376199	99356
1980					4340	289301	1228		429941	113550
1981	0	2683	0	0	4963	250610	856	0	483684	87170
1982	0	7619	0	0	3290	317358	616	0	99148	273632
1983	505	23842	525	11500	3072	300753	537	0	398513	914075
1984	0	1320	0	0	3624	263474	413	0	356552	323009
1985	715	7155	0	16644	3483	225716	406	0	363366	206463
1986	101	5180	0	0	3788	216118	507	0	696378	314873
1987	9796	60714	19300	0	3722	198031	826	0	424872	224353
1988	912	813	0	0	3989	185552	763	0	408454	203522
1989	150253	111703	0	0	4941	448279	600	0	395156	548304
1990	234113	82536	0	0	4405	122144	412	0	186795	212962
1991	732671	97683	11010	929	8036	56464	1012	0	182571	210762
1992	1767170	96567	551	205	200716	223469	1462	0	179842	173427
1993	1464658	187825	1526	2	145775	26515	1087	0	294512	256845
1994	1443107	202242	14742	84282	46012	110373	450	0	118903	292773
1995	2792499	71496	4409	8973	36369	160345	787	0	154399	392948
1996	1639843	72045	201	4189	68036	161308	1049	0	110983	290326
1997	944914	60096	1500	13121	28572	62915	1199	0	161911	509711
1998	748008	194618	391	215739	97263	107399	1462	515	110258	602797
1999	1268515	66604	3675	2096	152501	22494	862	417	53793	355735
2000	1023946	58030	8433	930	43869	195698	974	470	166651	707458
2001	1132671	120994	8933	14400	40119	89388	1986	455	105755	646390
2002	1329510	153683	21309	17403	65834	157999	1424	487	86144	427596
2003	1430755	164128	18385	20246	129168	51019	1949	443	186666	606685
2004	1596868	96115	15887	72389	6726	112426	1312	433	57662	523811
2005	1058452	33787	51029	110366	156489	271388	4123	155	182730	1688246
2006	918780	100142	14426	108628	53572	167047	2324	403	48386	1949045
2007	1313988	98781	16211	229663	43453	249188	1687	13346	322588	821034
2008	1337695	174975	30830	273395	6071	70790	1949	96	168107	951138
2009	1854673	291046	80642	488272	16905	150753	2549	205	78672	733223
2010	3027939	232648	56914	584767	5536	72088	2773	9035	56757	256012
2011	2067545	315187	15465	395322	18095	121515	2998	998	64792	318137
2012	1521436	175789	8862	533254	1905	86414	3336	458	96736	771972

3.14 Figures

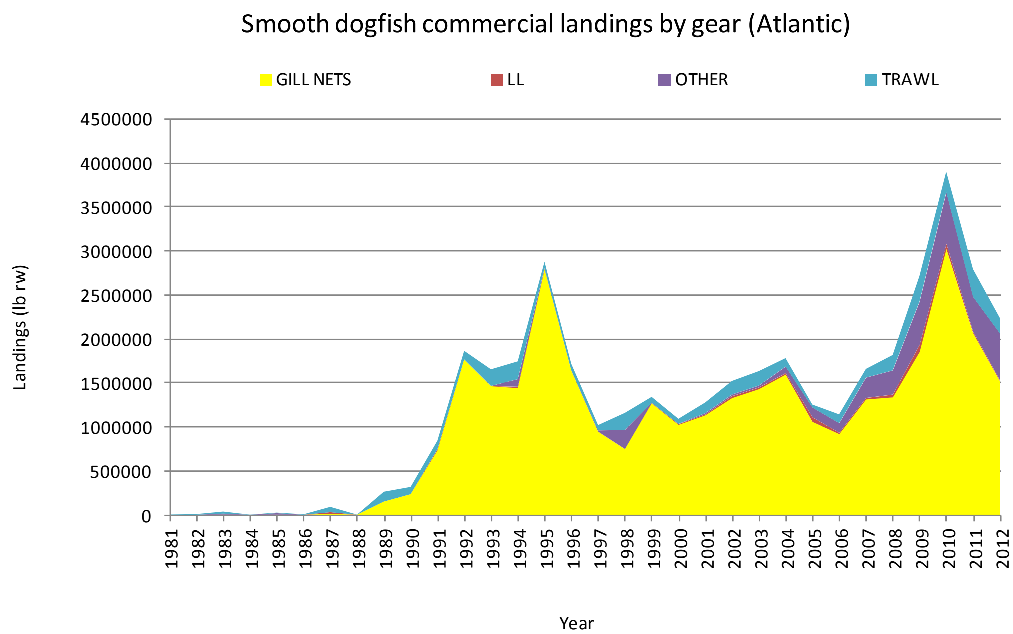


Figure 3.14.1. Commercial landings of smooth dogfish by gear (lb whole weight), 1981-2012, Atlantic.

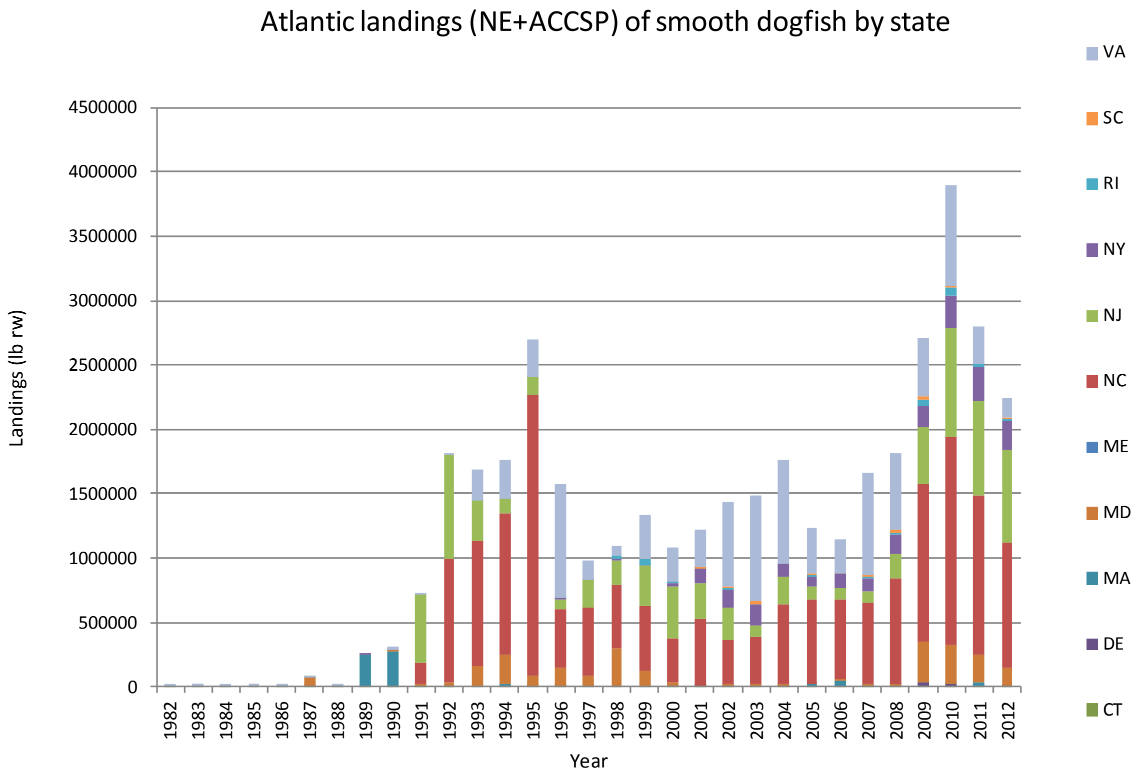


Figure 3.14.2. Commercial landings of smooth dogfish by state (lb whole weight), 1982-2012, Atlantic.

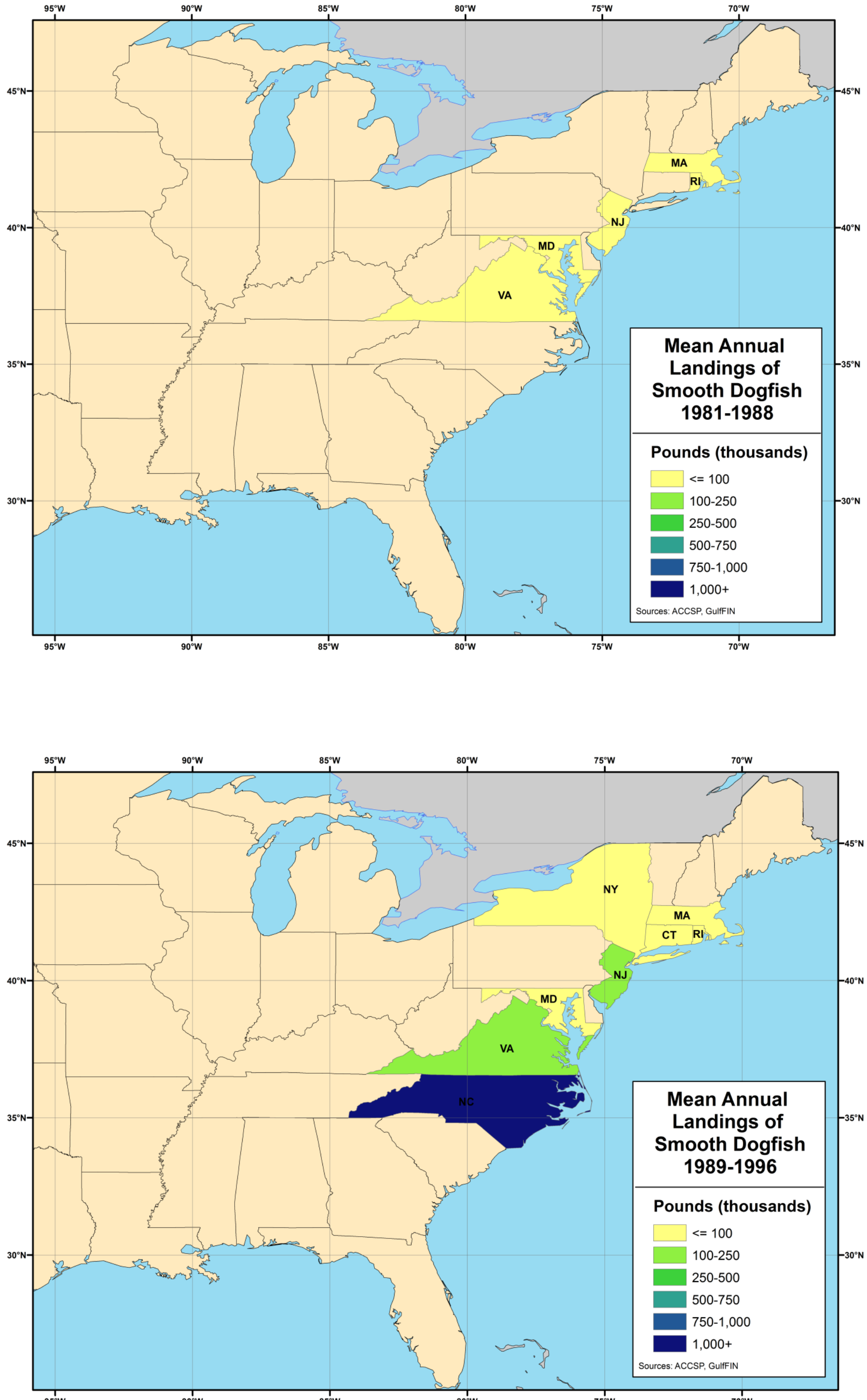
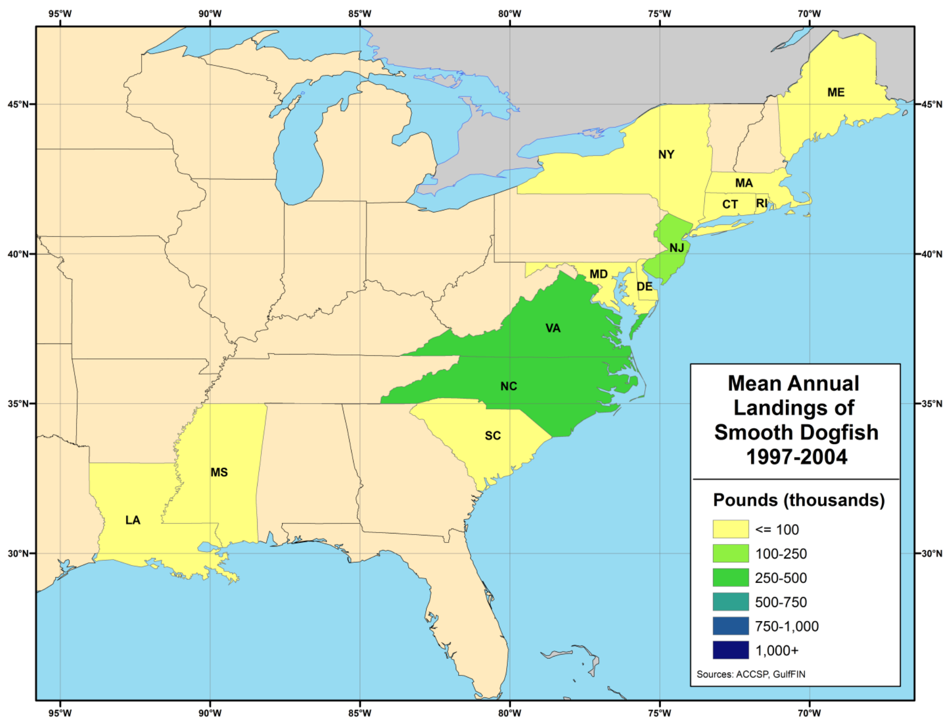


Figure 3.14.3. Commercial landings of smooth dogfish by state (lb whole weight), 1981-1998 (top) and 1989-1996 (bottom), Atlantic.



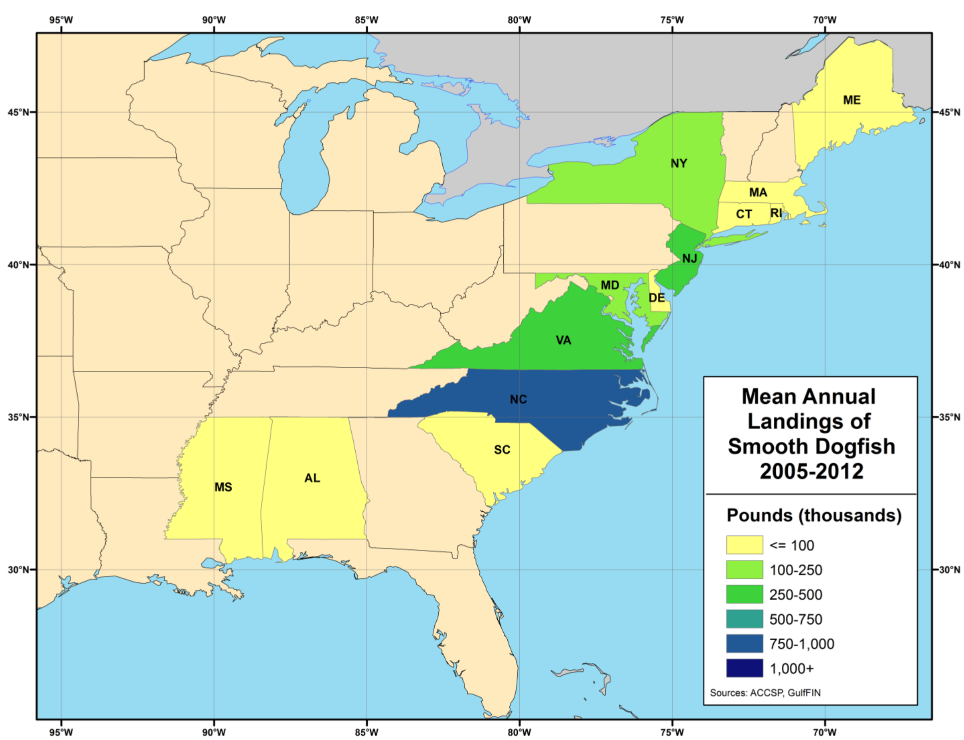


Figure 3.14.3 (continued). Commercial landings of smooth dogfish by state (lb whole weight), 1997-2004 (top) and 2005-2012 (bottom), Atlantic.

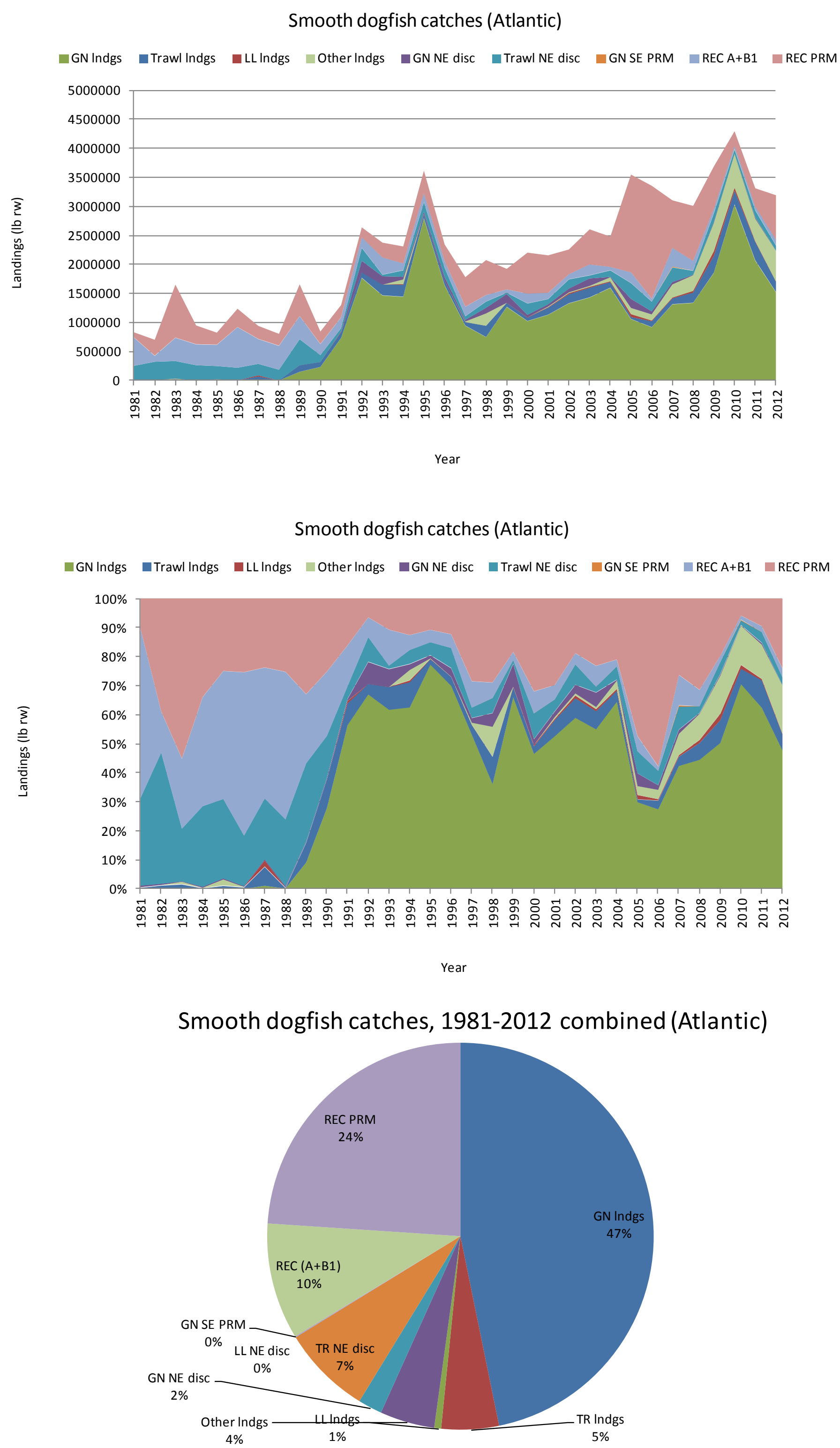


Figure 3.14.4. Catches of smooth dogfish in the Atlantic, 1981-2012: stacked (top), as a proportion (middle), and as a proportion for all years combined (bottom).

4 RECREATIONAL FISHERY STATISTICS

4.1 Overview

4.1.1 Members

Heather Balchowsky Baertlein (chair, SEFSC), Peter Barile (SE Fisheries Association), Karyl Brewster-Geisz (NOAA/HMS), Enric Cortés (SEFSC), Dean Courtney (SEFSC), Marin Hawk (ASMFC), Dewey Hemilright (Fisherman-North Carolina), Alyssa Mathers (Riverside Technology Inc/SEFSC), Kathy Sosebee (NEFSC), Holly White (NCDNF), Xinsheng Zhang (SEFSC).

4.1.2 Issues

Several issues were discussed by the recreational catch working group (WG), including: 1) catch reconstruction; 2) assessing recreational catches 3) setting the year of virgin biomass; 4) post-release discard mortality rates; and 5) number of live releases from the recreational fishery.

4.2 Review of working papers

SEDAR 39-DW-03 Preliminary catches of smoothhound sharks.
E. Cortes and H. Balchowsky
This document presents commercial landings, recreational catches, and discard estimates of smoothhound sharks (genus *Mustelus*) for 1981-2012. Information on the geographical distribution of both commercial landings and recreational catches and live discards is presented along with gear-specific information of commercial landings. Data on the disposition of smoothhound sharks in two commercial observer programs and length composition information and trends in average size of the catches from several commercial and recreational sources are also presented.

SEDAR 39-DW-21 A Preliminary Review of Post-release Live-discard Mortality Rate Estimates in Sharks for use in SEDAR 39.
Dean Courtney
This working paper reviewed the primary scientific literature for estimates of delayed discard-mortality rates (MD) in sharks. However, the review was not exhaustive and therefore should be considered preliminary. Delayed discard-mortality rate estimates, MD, obtained from the literature were summarized for smooth dogfish (*Mustelus* spp.) from many geographic regions and for spiny dogfish (*Squalus acanthias*) from the northwest Atlantic. Estimates of immediate (i.e. at-vessel or acute) discard-mortality rates (MA) were also identified for *Mustelus* spp. and *S. acanthias* from the literature and for *Mustelus canis* from northwest Atlantic commercial gillnet observer program data. A range of post-release live-discard mortality (PRLDM) rates (Low, Base, and High) was developed by gear type based on the estimates obtained for MD and MA following methods analogous to those adopted by previous SEDAR Assessment Process (AP)

panels. Alternative PRLDM rates were also developed for gillnet and trawl from the average delayed mortality rates obtained from the literature for *Mustelus spp.* from any region and for *Squalus acanthias* from the northwest Atlantic, and for longline and hook and line using an ad hoc approach described in the working paper.

4.3 Recreational landings

4.3.1 Recreational Fisheries

Recreational catches of smoothhound sharks in the Atlantic correspond to estimates from two data collection programs: the Marine Recreational Information Program (MRIP) and the NMFS Headboat Survey (HBOAT) operated by the SEFSC Beaufort Laboratory. The MRIP has effectively replaced MRFSS (Marine Recreational Fishery Statistics Survey), but new estimates for a suite of fish species, including sharks, are only available for the period 2004-2012. For 1981-2003, MRFSS estimates were adjusted to MRIP using ratio estimators (see SEDAR32-WP-02). Annual recreational catch estimates of smooth dogfish were computed as the sum of the MRIP (A+B1, where A=fished landed and B1=dead discards) and HBOAT (fish landed) survey estimates as appropriate.

In the Atlantic region, virtually all catches were of smooth dogfish and, overwhelmingly, from the MRIP. It is possible that some unidentified carcharhinid sharks might have been smoothhound sharks, but there is no way to verify it. Catches in numbers showed a decreasing trend from 1982 to 2012, punctuated by a high peak in 1984 (from MRIP). However, the WG considered that this large value was suspicious and decided to use the geometric mean of the three preceding (1981-83) and ensuing years (1985-87) as a more sensible option (**Figure 4.13.1, top panel**). Most of the catches corresponded to NJ, DE, NY, NC, VA, MA, and MD, respectively, with those states accounting for about 88% of the total catches in both the Atlantic and Gulf of Mexico (**Figure 4.13.2, top panel**). **Table 1** shows all catches of smooth dogfish in the Atlantic, including recreational landings and dead discards (A+B1) in the next-to-last column. **Figure 4.13.3** shows all annual catches stacked (top) and as a proportion (middle), and catches for the entire time period (1981-2012) as proportions (bottom). Recreational landings and dead discards accounted for 10% of the total catches.

Confidence intervals for A+B1 and B2 (live releases) catches of smooth dogfish in the Atlantic were calculated based on CVs and are presented in **Figure 4.13.4**.

4.3.2 Assessment of Recreational Catches

The high peak in 1984 in the MRIP data is believed to be part of some erroneous information in the database, as many species in the database show unusually high numbers between 1983 and 1984. Other SEDAR Data workshops have smoothed this high peak by using the geometric mean of surrounding years. The WG discussed options on how to handle this artifact and it was decided that, since high variability existed in surrounding years, the geometric mean would be calculated using the three years preceding and the three years following 1984.

Decision 1. Use the geometric mean of the three years preceding 1984 (1981-83) and the three ensuing years (1985-87) to address the high estimate in MRIP in 1984.

4.4 Recreational discards

Sharks classified as released alive in MRIP (B2s) were computed to calculate how many were likely to die based on the hook-and-line post-release mortality rate for smooth dogfish (see Post-release live discard mortality section). B2 catches (available only in numbers) in the Atlantic followed an almost opposite trend to A+B1 catches (**Figure 4.13.5 top panel**). The states of NJ (54%) and DE (21%) accounted for three quarters of all live releases (**Figure 4.13.5 bottom panel**). **Table 4.12.1** also shows recreational discards released alive (B2) assumed to die (B2 in numbers x average weight of A+B1 from MRIP x post-release live discard mortality rate for hook and line) in the last column. **Figure 4.13.3** (bottom) shows that these recreational discards accounted for almost one fourth of all catches for the entire time period.

4.5 Post-release live-discard Mortality

Hook and Line

A range of PRLDM rates for hook and line (i.e., recreational) fisheries was developed based on the following ad hoc approach. A low PRLDM rate for hook and line fisheries (Low-PRLDM $_{\text{hook and line}}$ = 10 %; **Table 4.12.2**) was developed based on Gurshin and Szedlmayer (2004), who estimated a 10 % delayed discard-mortality rate based on tagged Atlantic sharpnose sharks (n = 10) captured with hook and line (recreational rod and reel) and monitored for six hours. This rate was also used as the base in SEDAR 34 for Atlantic sharpnose and bonnethead (rates shown in Table 4, Panel C of SEDAR 39-DW-21). A high PRLDM rate for hook and line fisheries (High-PRLDM $_{\text{hook and line}}$ = 24 %; **Table 4.12.2**) was developed based on Mandelman and Farrington (2007), who estimated a 24 % delayed mortality in hook and line (hauled by hand) captured spiny dogfish, *S. acanthias*, (n = 55), subsequently held for 72 hrs. A base PRLDM rate for hook and line fisheries was developed as the average of the low and high PRLDM rates for hook and line developed above (Base-PRLDM $_{\text{hook and line}}$ = 17 %; **Table 4.12.2**).

Decision 2: Use a post-release live-discard mortality rate for smoothhound sharks caught on recreational hook and line gear of 17% and, if needed, use low and high values of 10% and 24%.

4.6 Recreational effort

While recreational effort data are available from Marine Recreation Information Program, the Headboat program, and Texas Parks and Wildlife Department, they were not considered because effort will not be used as an input in the stock assessment model.

4.7 Biological sampling

No biological samples for sharks are available from recreational surveys.

4.8 Recreational Catch-at-Age/Length; directed and discard

No age composition information was available. The only recreational information available on individual lengths came from MRIP, but was very limited (Table 3).

4.9 Comments on the adequacy of data for assessment analyses

Catch data for smooth dogfish in the Atlantic were considered to be adequate to characterize total removals because *Mustelus canis* is essentially the only species of *Mustelus* that occurs in that area. Unlike commercial landings, recreational catches and dead discards are estimated and subject to the same criticisms that are sometimes expressed for other species. The total number of sharks discarded alive that are assumed to die is also uncertain because of the compound effect of multiplying the estimate of sharks released alive by the post-release live-discard mortality rate.

An alternate catch scenario starting in 1972 was also considered given that one of the indices of abundance started in 1972 (**Table 4.12.4**). To that end, the WG decided to reconstruct the recreational catch series from 1981 back to 1972 by applying a linear interpolation to both the landings and discards, from a value of 0 in 1972 to the value for 1981.

Decision 3: Use a linear interpolation starting at 0 in 1972 to the value for 1981 to reconstruct the two recreational catch series: landings + dead discards (A+B1) and live discards (B2) assumed to die.

4.10 Research Recommendations

No research recommendations relative to recreational fisheries were formulated.

4.11 Literature Cited

Gurshin, C. W. D., and Szedlmayer, S. T. 2004. Short-term survival and movements of Atlantic sharpnose sharks captured by hook-and-line in the north-east Gulf of Mexico. Journal of Fish Biology, 65:973-986.

Mandelman, J. W., and Farrington, M. A. 2007. The estimated short-term discard mortality of a trawled elasmobranch, the spiny dogfish (*Squalus acanthias*). Fisheries Research, 83:238-245.

4.12 Tables

Table 4.12.1. Total catches of smooth dogfish in the Atlantic (all in lb whole weight). The first four columns are commercial landings by gear (GN=gillnets, TR=Trawl, LL=Longline, Other=other gear). The next four columns are discards from the northeast (first three) and the southeast (fourth). Northeast discards represent discards released alive that are assumed to die (discard estimates x post-release live discard mortality rate for each of the gears); Southeast discards are also discards released alive assumed to die (discard estimates in numbers x average weight of discards from the SE Gillnet Observer Program x post-release live discard mortality rate for gillnets). Next are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 in numbers x average weight of A+B1 from MRIP x post-release live discard mortality rate for hook and line).

Year	Com-GN Landings	Com-TR Landings	Com-LL Landings	Com-Other Landings	Com-GN-NE (PRM)	Com-TR-NE (PRM)	Com-LL-NE (PRM)	Com-GN-SE (PRM)	Recreational (A+B1)	Recreational (PRM)
1981	0	2683	0	0	4963	250610	856		483684	87170
1982	0	7619	0	0	3290	317358	616		99148	273632
1983	505	23842	525	11500	3072	300753	537		398513	914075
1984	0	1320	0	0	3624	263474	413		356552	323009
1985	715	7155	0	16644	3483	225716	406		363366	206463
1986	101	5180	0	0	3788	216118	507		696378	314873
1987	9796	60714	19300	0	3722	198031	826		424872	224353
1988	912	813	0	0	3989	185552	763		408454	203522
1989	150253	111703	0	0	4941	448279	600		395156	548304
1990	234113	82536	0	0	4405	122144	412		186795	212962
1991	732671	97683	11010	929	8036	56464	1012		182571	210762
1992	1767170	96567	551	205	200716	223469	1462		179842	173427
1993	1464658	187825	1526	2	145775	26515	1087		294512	256845
1994	1443107	202242	14742	84282	46012	110373	450		118903	292773
1995	2792499	71496	4409	8973	36369	160345	787		154399	392948
1996	1639843	72045	201	4189	68036	161308	1049		110983	290326
1997	944914	60096	1500	13121	28572	62915	1199		161911	509711
1998	748008	194618	391	215739	97263	107399	1462	515	110258	602797
1999	1268515	66604	3675	2096	152501	22494	862	417	53793	355735
2000	1023946	58030	8433	930	43869	195698	974	470	166651	707458
2001	1132671	120994	8933	14400	40119	89388	1986	455	105755	646390
2002	1329510	153683	21309	17403	65834	157999	1424	487	86144	427596
2003	1430755	164128	18385	20246	129168	51019	1949	443	186666	606685
2004	1596868	96115	15887	72389	6726	112426	1312	433	57662	523811
2005	1058452	33787	51029	110366	156489	271388	4123	155	182730	1688246
2006	918780	100142	14426	108628	53572	167047	2324	403	48386	1949045
2007	1313988	98781	16211	229663	43453	249188	1687	13346	322588	821034
2008	1337695	174975	30830	273395	6071	70790	1949	96	168107	951138
2009	1854673	291046	80642	488272	16905	150753	2549	205	78672	733223
2010	3027939	232648	56914	584767	5536	72088	2773	9035	56757	256012
2011	2067545	315187	15465	395322	18095	121515	2998	998	64792	318137
2012	1521436	175789	8862	533254	1905	86414	3336	458	96736	771972

Table 4.12.2. A range of post-release live-discard mortality (PRLDM) rates (Low, Base, and High) was developed for each gear type (longline, hook and line, gillnet, and trawl) following methods described in SEDAR 39-DW-21; PRLDM rates were developed for gillnet and trawl from the average delayed mortality rates obtained from the literature for *Mustelus spp.* from any region and for *Squalus acanthias* from the northwest Atlantic (mean $M_D \pm 1.96$*S.E.) as described in SEDAR 39-DW-21; PRLDM rates were developed for longline and hook and line using an ad hoc approach as described in SEDAR 39-DW-21.

PRLDM rate	Longline	Hook and line	Gillnet	Trawl
Low	8%	10%	13%	0%
Base	13.5%	17%	27%	19%
High	19%	24%	40%	37%

Table 4.12.3. Length compositions available for smooth dogfish in the Atlantic.

Name	Acronym	Years of coverage	Species	Area	Subarea	State	Sex	N	Index used?
Bottom Longline Observer Program *	BLLOP	1994-2012	*Mustelus* spp.	ATL			Yes	541	no
CT Dep Ener Env Prot Trawl survey	CT DEEP Trawl	1989-2012	*Mustelus canis*	ATL	Long Island Sound	CT-NY	Yes	4112	yes
Delaware Div Fish Wild Trawl survey	DE Trawl	1966-1971; 1974; 1997-2012	*Mustelus canis*	ATL	Delaware Bay	DE	No	16113	yes
Gillnet Fishery Observer Program*	GNOP	2005-2012	*Mustelus canis*	ATL		FL-NC	Yes	645	no
MA Dept of Mar Fish Trawl Fall survey	Fall MA DMF Trawl	1978-2012	*Mustelus canis*	ATL		MA	Yes	1764**	yes
Marine Recreational Information Program*	MRIP	1981-2012	*Mustelus canis*	ATL		FL-ME	Yes	1562	no
Northeast Gillnet Observer Program*	NE GNOP	1992-2012	*Mustelus canis*	ATL		MA-NC	Yes	14174	no
Northeast Trawl Observer Program*	NE TOP	1994-2012	*Mustelus canis*	ATL		MA-NC	Yes	3623	no
NEFSC Fall Trawl survey N of Cape Hatteras	Fall NEFSC N of CH Trawl	1972-2012	*Mustelus canis*	ATL		MA-NC	Yes	3078**	yes
New Jersey DEP Fish and Wildlife Trawl	NJ DFW Trawl	1988-2012	*Mustelus canis*	ATL	Cape May to Sandy Hook	NJ	No	69871	yes
Rhode Island Dept of Env and Mngmt Trawl survey	RI DEM seas Trawl	1980-2012	*Mustelus canis*	ATL	Naragansett Bay et al.	RI	Yes	666	yes
SEAMAP-SA Trawl survey	SEAMAP-SA Trawl	1994-2012	*Mustelus canis*	ATL		FL-NC	Yes	4136	yes
Fall NEAMAP Trawl survey	NEAMAP	2007-2012	*Mustelus canis*	ATL		MA-NC	yes	NA	yes
NEFSC Spring Trawl Survey North*	NEFSC-Spring-North Trawl	1973-2012	*Mustelus canis*	ATL		MA-NC	Yes	2132**	no
NEFSC Spring Trawl Survey South*	NEFSC-Spring-South Trawl	1974-2011	*Mustelus canis*	ATL	Cape Hateras, NC to Cape	NC-FL	Yes	681**	no
MA Dept of Mar Fish Trawl Spring survey*	Spring MA DMF Trawl	1978-2012	*Mustelus canis*	ATL		MA	yes	433**	no
NEFSC Winter Trawl Survey North*	NEFSC-Winter-North Trawl	1992-2007	*Mustelus canis*	ATL		MA-NC	Yes	1484**	no
Total								125015	

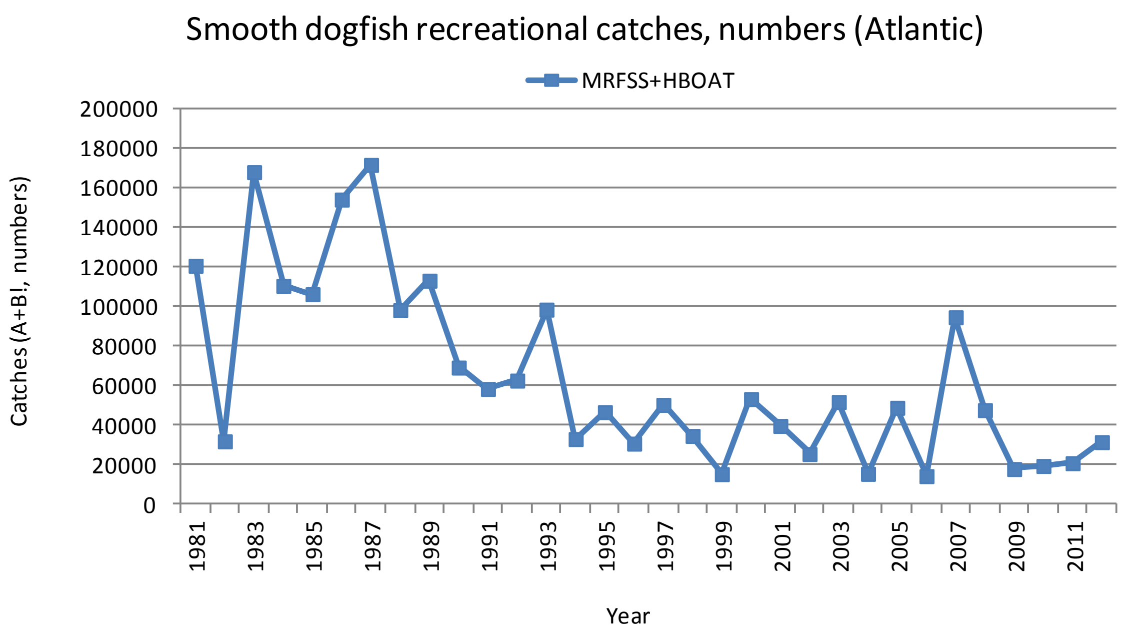
* No index of abundance used, but length composition may be useful to characterize the size composition of catches by gear type

** Number of records of mean number measured at length per tow

Table 4.12.4. Total catches of smooth dogfish in the Atlantic (all in lb whole weight) starting in 1972. The first four columns are commercial landings by gear (GN=gillnets, TR=Trawl, LL=Longline, Other=other gear). The next four columns are discards from the northeast (first three) and the southeast (fourth). Northeast discards represent discards released alive that are assumed to die (discard estimates x post-release live discard mortality rate for each of the gears); Southeast discards are also discards released alive assumed to die (discard estimates in numbers x average weight of discards from the SE Gillnet Observer Program x post-release live discard mortality rate for gillnets). Next are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 in numbers x average weight of A+B1 from MRIP x post-release live discard mortality rate for hook and line).

Year	Com-GN Landings	Com-TR Landings	Com-LL Landings	Com-Other Landings	Com-GN-NE (PRM)	Com-TR-NE (PRM)	Com-LL-NE (PRM)	Com-GN-SE (PRM)	Recreational (A+B1)	Recreational (PRM)
1972					608	217634	1184		0	0
1973					628	198058	1391		53743	14194
1974					1059	183104	1391		107485	28387
1975					1176	175359	1340		161228	42581
1976					1804	198674	756		214971	56775
1977					2526	220738	591		268713	70969
1978					3332	235317	1287		322456	85162
1979					3148	252688	1641		376199	99356
1980					4340	289301	1228		429941	113550
1981	0	2683	0	0	4963	250610	856	0	483684	87170
1982	0	7619	0	0	3290	317358	616	0	99148	273632
1983	505	23842	525	11500	3072	300753	537	0	398513	914075
1984	0	1320	0	0	3624	263474	413	0	356552	323009
1985	715	7155	0	16644	3483	225716	406	0	363366	206463
1986	101	5180	0	0	3788	216118	507	0	696378	314873
1987	9796	60714	19300	0	3722	198031	826	0	424872	224353
1988	912	813	0	0	3989	185552	763	0	408454	203522
1989	150253	111703	0	0	4941	448279	600	0	395156	548304
1990	234113	82536	0	0	4405	122144	412	0	186795	212962
1991	732671	97683	11010	929	8036	56464	1012	0	182571	210762
1992	1767170	96567	551	205	200716	223469	1462	0	179842	173427
1993	1464658	187825	1526	2	145775	26515	1087	0	294512	256845
1994	1443107	202242	14742	84282	46012	110373	450	0	118903	292773
1995	2792499	71496	4409	8973	36369	160345	787	0	154399	392948
1996	1639843	72045	201	4189	68036	161308	1049	0	110983	290326
1997	944914	60096	1500	13121	28572	62915	1199	0	161911	509711
1998	748008	194618	391	215739	97263	107399	1462	515	110258	602797
1999	1268515	66604	3675	2096	152501	22494	862	417	53793	355735
2000	1023946	58030	8433	930	43869	195698	974	470	166651	707458
2001	1132671	120994	8933	14400	40119	89388	1986	455	105755	646390
2002	1329510	153683	21309	17403	65834	157999	1424	487	86144	427596
2003	1430755	164128	18385	20246	129168	51019	1949	443	186666	606685
2004	1596868	96115	15887	72389	6726	112426	1312	433	57662	523811
2005	1058452	33787	51029	110366	156489	271388	4123	155	182730	1688246
2006	918780	100142	14426	108628	53572	167047	2324	403	48386	1949045
2007	1313988	98781	16211	229663	43453	249188	1687	13346	322588	821034
2008	1337695	174975	30830	273395	6071	70790	1949	96	168107	951138
2009	1854673	291046	80642	488272	16905	150753	2549	205	78672	733223
2010	3027939	232648	56914	584767	5536	72088	2773	9035	56757	256012
2011	2067545	315187	15465	395322	18095	121515	2998	998	64792	318137
2012	1521436	175789	8862	533254	1905	86414	3336	458	96736	771972

4.13 Figures



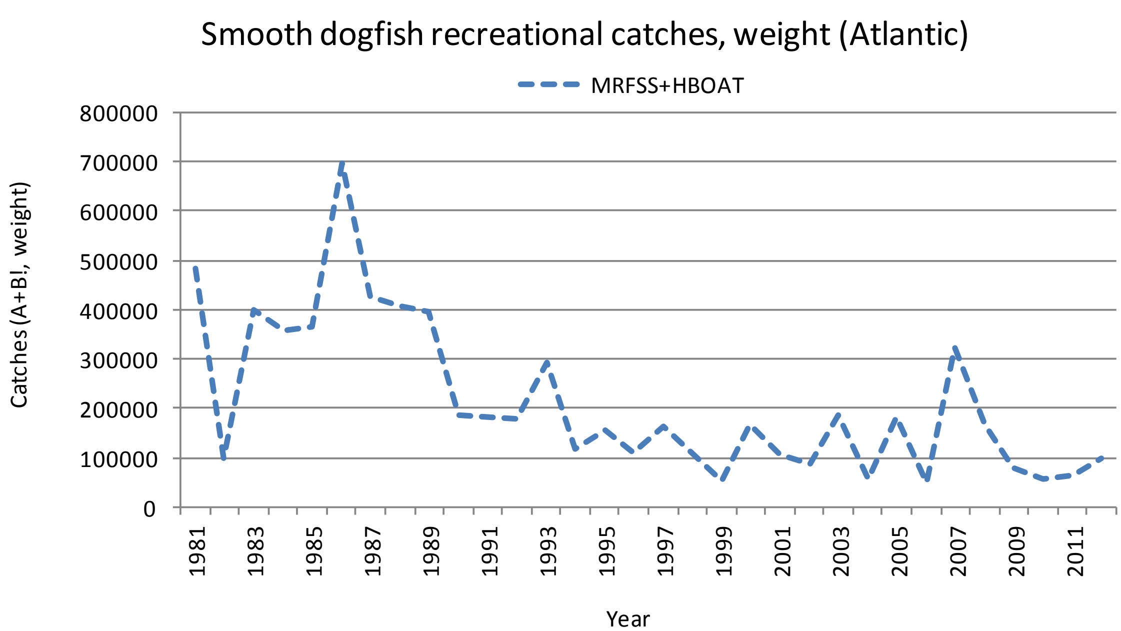
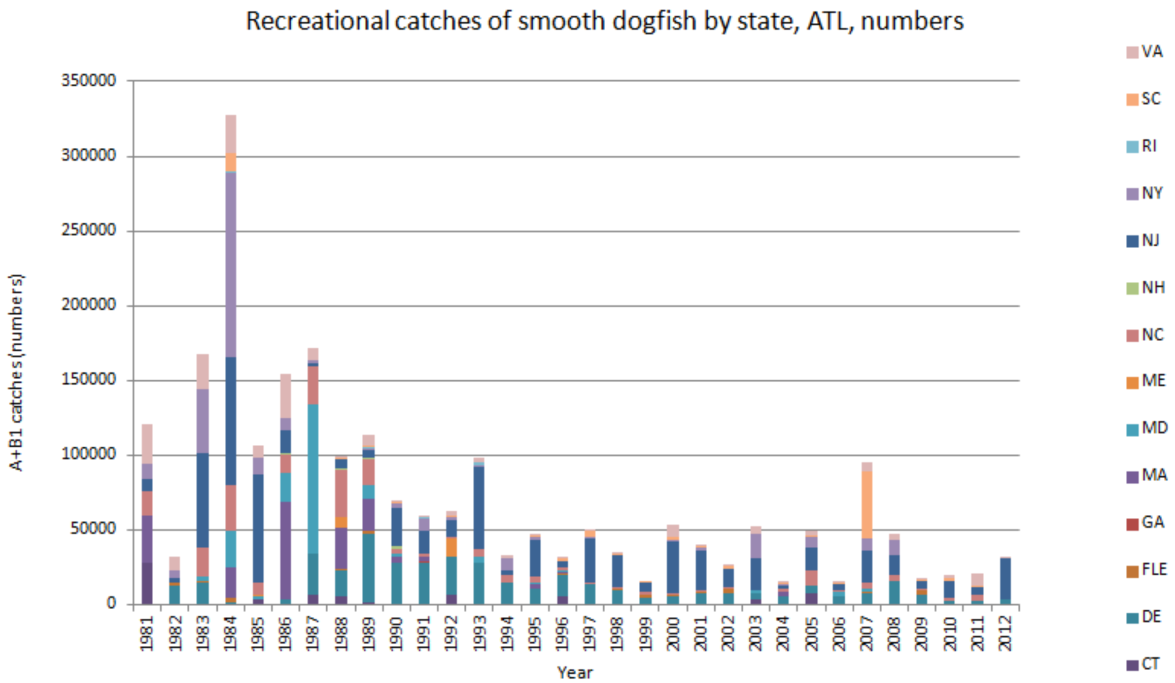


Figure 4.13.1. Recreational catches of smooth dogfish in the Atlantic region in numbers (A+B1, top) and whole weight (lb ww, A+B1, bottom)



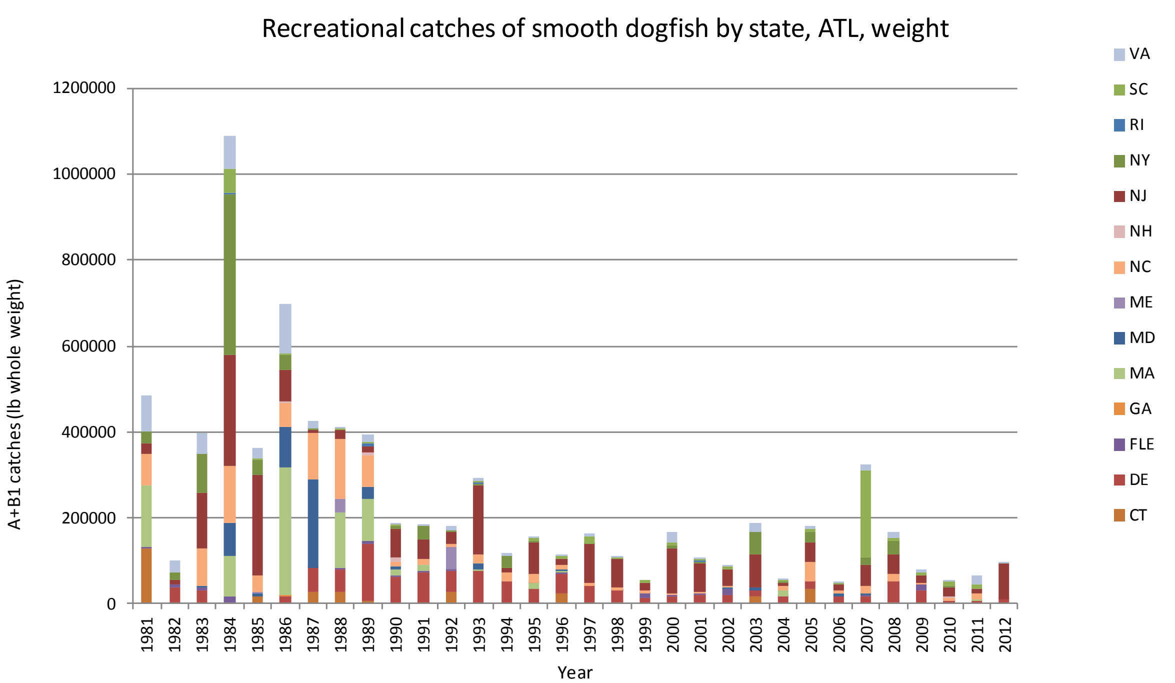


Figure 4.13.2. Recreational catches of smooth dogfish in the Atlantic region by state in numbers (A+B1, top) and whole weight (lb ww, A+B1, bottom).

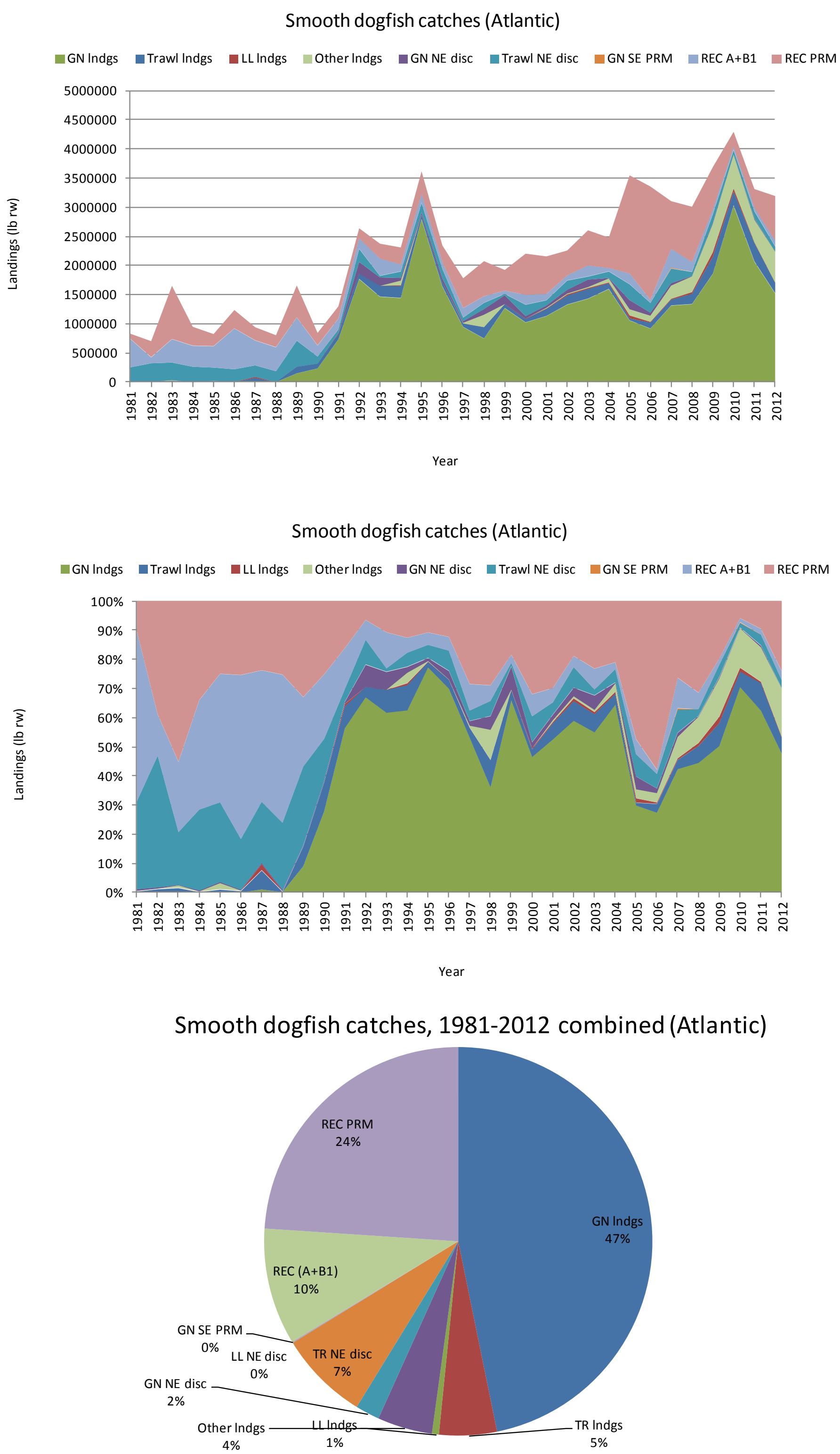
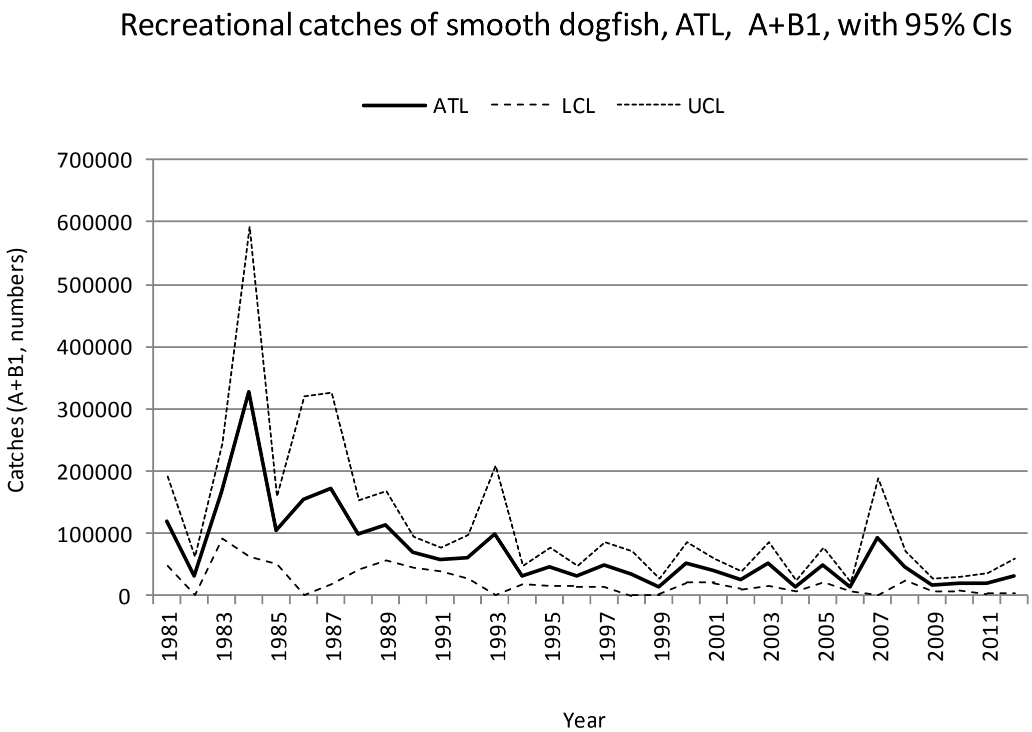


Figure 4.13.3. Catches of smooth dogfish in the Atlantic, 1981-2012: stacked (top), as a proportion (middle), and as a proportion for all years combined (bottom).



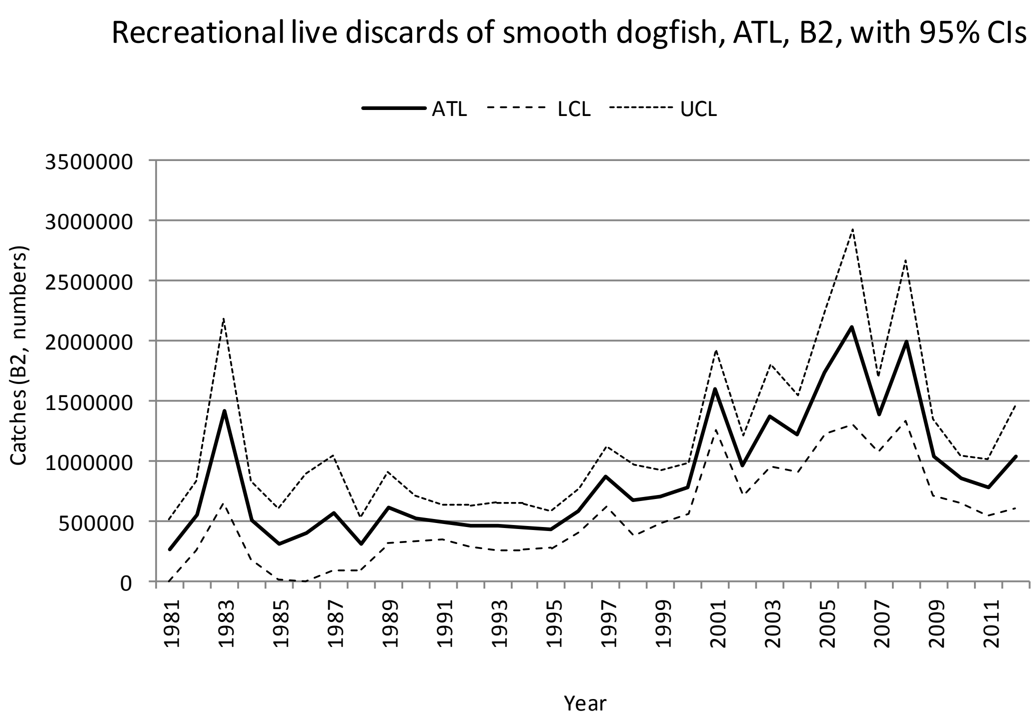
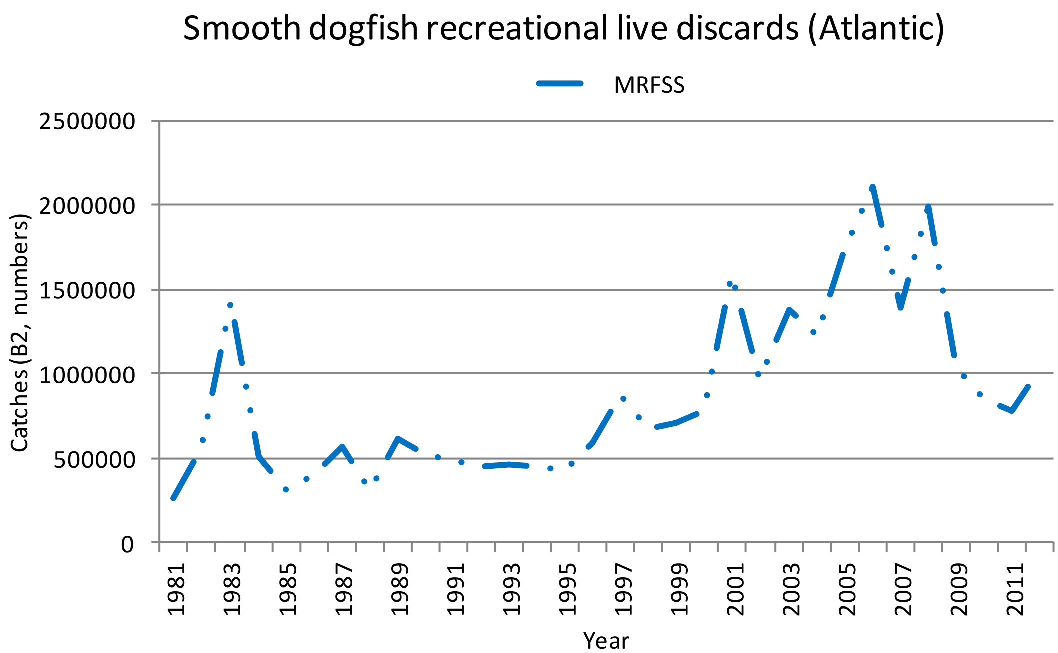


Figure 4.13.4. Variability (as 95% CIs) in estimates of recreational catches of smooth dogfish in the Atlantic (A+B1, numbers, top; B2, numbers, bottom).



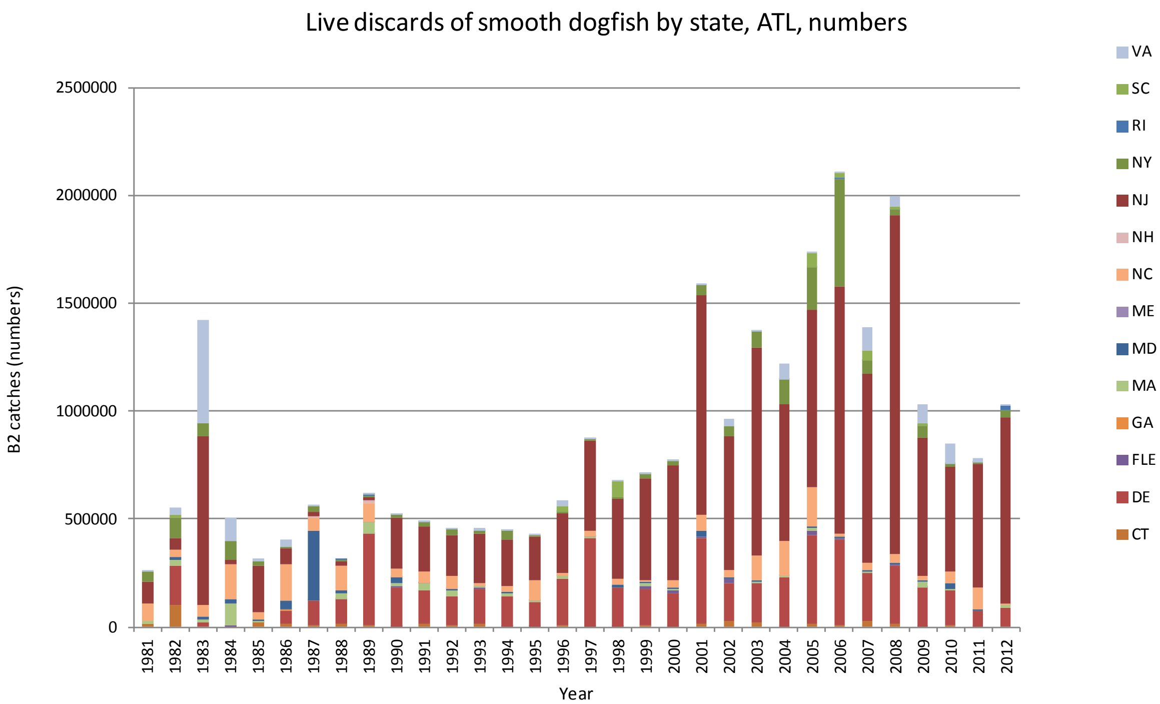


Figure 4.13.5. Recreational live releases (B2) of smooth dogfish in numbers in the Atlantic region (top) and by state (bottom).

5 MEASURES OF POPULATION ABUNDANCE

5.1 Overview

Twenty indices of abundance were considered for use in the assessment models for *Mustelus canis* in the Atlantic Ocean. Indices were constructed using both fishery independent and dependent data. For the stock of *Mustelus canis,* the Indices Working Group recommended the following indices for use in the stock assessment model for the base run: SEAMAP South Atlantic (SA) Shallow Water Trawl Survey (SEAMAP SA Trawl, SEDAR39-DW-02), New Jersey Department of Fish and Wildlife Ocean Trawl Survey (NJ DFW Trawl, SEDAR39-DW-14), Connecticut Department of Energy and Environmental Protection Long Island Sound Trawl Survey (CT DEEP Trawl, SEDAR39-DW-12), Delaware Division of Fish and Wildlife 30-foot Trawl Survey (DE DFW Trawl, SEDAR39-DW-15), Rhode Island Division of Fish and Wildlife Seasonal Trawl Survey (RI DFW Trawl, SEDAR39-DW-10), Fall NMFS NEFSC Bottom Trawl Survey-north of Cape Hatteras, North Carolina (Fall NEFSC Bottom Trawl, SEDAR39-DW-24), Fall Massachusetts Division of Marine Fisheries Trawl Survey (Fall MA DMF Trawl, SEDAR39-DW-24) and the Fall NEAMAP Trawl Survey (Fall NEAMAP Trawl, SEDAR39-DW-30).

Twelve indices were reviewed, but not recommended for use: Northeast Fisheries Observer Program anchored gillnet series (SEDAR39-DW-09), Rhode Island Division of Fish and Wildlife Monthly Trawl Survey (SEDAR39-DW-10), University of Rhode Island (URI) Graduate School of Oceanography Trawl Survey (SEDAR39-DW-11), New York State Department of Environmental Conservation (NYS DEP) Peconic Bay Small Mesh Trawl Survey (SEDAR39-DW-13), Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Longline Survey in Delaware Bay (SEDAR39-DW-16), North Carolina Division of Marine Fisheries (NC DMF) Ocean Gillnet Program (SEDAR39-DW-17), University of North Carolina (UNC) Longline Survey (SEDAR39-DW-18), South Carolina Department of Natural Resources (SC DNR) Red Drum Longline Survey (SEDAR39-DW-19), NMFS NEFSC Bottom Trawl Survey-south of Cape Hatteras, Spring NMFS NEFSC Bottom Trawl Survey-north of Cape Hatteras, Winter NMFS NEFSC Bottom Trawl Survey, and Spring MA DMF Trawl Survey (SEDAR39-DW-24). The majority of these indices were not recommended for use because of high coefficients of variation due to sporadic catches and sampling in spatial and temporal strata when the species did not have a high occurrence.

5.1.1 Group Membership

Membership of this DW Indices Working Group included John Carlson (co-leader), Cami McCandless, (co-leader), Adam Pollack, Robert Latour, Peter Barile, Chloe Dean, Christine Seither, and Dean Courtney.

5.2 Review of working papers

The working group reviewed 14 working papers describing index construction:

SEDAR39-DW-02	SEAMAP SA Trawl Survey
SEDAR39-DW-09	Northeast Fisheries Observer Program
SEDAR39-DW-10	RI DFW Monthly and Seasonal Trawl Surveys
SEDAR39-DW-11	URI Trawl Survey
SEDAR39-DW-12	CT DEEP Trawl Survey
SEDAR39-DW-13	NYS DEP Peconic Bay Small Mesh Trawl Survey
SEDAR39-DW-14	NJ DFW Ocean Trawl Survey
SEDAR39-DW-15	DE DFW Trawl Survey
SEDAR39-DW-16	COASTSPAN Longline Survey
SEDAR39-DW-17	NC DMF Ocean Gillnet Program
SEDAR39-DW-18	UNC Longline Series
SEDAR39-DW-19	SC DNR Red Drum Longline Survey
SEDAR39-DW-24	NEFSC and MA DMF Trawl Surveys
SEDAR39-DW-30	NEAMAP Trawl Survey

5.3 Fishery Independent Indices

5.3.1 Standardized catch rates of smooth dogfish from the SEAMAP-South Atlantic Shallow Water Trawl Survey (SEDAR 39-DW-02).

This document presents an analysis of the relative abundance of smooth dogfish (Mustelus canis) from the SEAMAP-SA Shallow Water Trawl Survey for 1994-2012. Time series data from this survey were standardized with Generalized Linear Mixed Model (GLMM) procedures. The series showed an increasing trend, followed by a decreasing tendency. Examination of lengths of smooth dogfish over the time period considered revealed no trend. Length compositions revealed that mostly immature individuals of this species are caught in this survey, but adults are also present especially in males.

5.3.2 Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the Rhode Island Department of Environmental Management trawl surveys (SEDAR39-DW-10).

This document details the smooth dogfish, *Mustelus canis*, catch from the Rhode Island Department of Environmental Management monthly trawl survey in Narragansett Bay from 1990-2013 and seasonal trawl survey in Block Island Sound, Rhode Island Sound, and Narragansett Bay from 1979-2013. Catch per unit effort (CPUE) in number of sharks per 20 minute tow were examined by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. Both time series show an overall increasing trend in relative abundance. Additional analyses were conducted during the data workshop to look at combining the indices, include bottom temperature data to account for some of the variability, and change the years used in the standardization process to fit with the time span of the assessment model.

5.3.3 *Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the University of Rhode Island trawl survey conducted by the Graduate School of Oceanography (SEDAR39-DW-11).*

This document details the smooth dogfish, *Mustelus canis*, catch from the University of Rhode Island (URI) trawl survey conducted by the Graduate School of Oceanography from 1959-2013. Catch per unit effort (CPUE) in number of sharks per 30 minute tow was examined by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The nominal and standardized relative abundance for smooth dogfish shows an overall decreasing trend in relative abundance through the 1990s followed by a peak in abundance in 2003 and then a gradual increasing trend at the end of time series. The 2003 peak in abundance is also seen in the time series for the monthly and seasonal trawl surveys conducted by the Rhode Island Department of Environmental Management (SEDAR39-DW-10) in the same area as the URI trawl survey. The standardization process was unable to account for any variability seen in the URI time series. The observed CPUE mirrors the proportion of positive catch sets through time and may not be indicative of the true trend in abundance.

5.3.4 *Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the Long Island Sound Trawl Survey conducted by the Connecticut Department of Energy and Environmental Protection (SEDAR39-DW-12).*

This document details the smooth dogfish, *Mustelus canis*, catch from the Long Island Sound Trawl Survey conducted during the spring and fall from 1984 to 2013. There was no fall survey in 2010 when the research vessel was in service. Catch per unit effort (CPUE) in number of sharks per 30 minute tow was examined by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The nominal and standardized relative abundance for smooth dogfish show an overall increasing trend throughout the majority of the time series with a large peak in 2002 and a notable drop in 2010. The peak occurs in a year when a high proportion of sets had smooth dogfish catch, and many of them in large numbers. The 2010 drop in abundance can be partially attributed to a substantial reduction in effort that year. Both a large peak in 2002 and a less substantial drop in 2010 relative abundance were seen in New Jersey coastal waters (SEDAR39-DW-14). An additional analysis was conducted during the data workshop to remove 2013 from the time series to fit with the time span of the assessment model.

5.3.5 *Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the Peconic Bay Small Mesh Trawl Survey conducted by the New York State Department of Environmental Conservation (SEDAR39-DW-13).*

This document details the smooth dogfish, *Mustelus canis*, catch from the Peconic Bay Small Mesh Trawl Survey conducted May through October from 1987 to 2013. Catch per unit effort (CPUE) in number of sharks per 10 minute tow were examined by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The standardized relative abundance for smooth dogfish shows a barely discernible increasing trend across the time series with lots of variability and a large peak in abundance during the last three years of the survey. Many of the smooth dogfish caught during this survey are young-of-the-year fish. The trend produced from this survey may not represent the overall population of smooth dogfish in the northwest Atlantic, but would likely provide a good index of recruitment for the species.

5.3.6 Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the New Jersey Division of Fish and Wildlife trawl surveys (SEDAR39-DW-14).

This document details the smooth dogfish, *Mustelus canis*, catch from the New Jersey Ocean Trawl Survey between 1988 and 2013. Catch per unit effort (CPUE) in number of sharks per 20 minute tow were examined by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The nominal and standardized relative abundance for smooth dogfish show an overall increasing trend throughout the majority of the time series with a large peak in 2002. The peak occurs in a year when a high proportion of sets had smooth dogfish catch, and many of them in large numbers. A large peak in 2002 relative abundance was also seen in Long Island Sound (SEDAR39-DW-12). An additional analysis was conducted during the data workshop to remove the year 2013 from the time series to fit within the time span of the assessment model.

5.3.7 Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the Delaware Division of Fish and Wildlife trawl surveys (SEDAR39-DW-15).

This document details the smooth dogfish, *Mustelus canis*, catch from the Delaware Bay 30-foot otter trawl survey from 1966-1971, 1979-1984, and from 1990-2013. Catch per unit effort (CPUE) in number of sharks per nautical mile towed were examined by year. The CPUE was standardized using a two-step delta-lognormal approach originally proposed by Lo et al (1992) that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The standardized relative abundance for smooth dogfish shows an initial decrease in relative abundance during the 1970s with continued low levels in the early 1980s, followed by an overall increasing trend from the 1990s through 2013. During the end of the time series a large drop in abundance is seen in 2004 and 2005. These years were particularly busy with strong summer storms in the area bringing high rainfall and rough seas to Delaware Bay. Additional analyses were conducted during the data workshop to fit with the time span of the assessment models; one with a time span of 1974-2012 and the other from 1981-2013.

5.3.8 Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) longline survey in Delaware Bay (SEDAR39-DW-16).

This document details the smooth dogfish, *Mustelus canis*, catch from the Northeast Fisheries Science Center, Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) survey conducted in Delaware Bay from 2001 to 2013 in July and August. Catch per unit effort (CPUE) in number of sharks per 50-hook hours was used to examine smooth dogfish relative abundance by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The nominal and standardized relative abundance for smooth dogfish shows an overall decreasing trend in relative abundance across the time series. The timing of this survey does not coincide with the peak use of Delaware Bay by smooth dogfish in the spring; therefore, this survey may not provide annual estimates of relative abundance that represent the true trend in abundance over time.

5.3.9 Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the Ocean Gillnet Program conducted by the North Carolina Division of Marine Fisheries (SEDAR39-DW-17).

This document details the smooth dogfish, *Mustelus canis*, catch from the Ocean Gillnet Program conducted by the North Carolina Division of Marine Fisheries from 2009-2013. Catch per unit effort (CPUE) in number of sharks per gillnet array (270 net yards) were examined by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The diagnostics (residual plots) for the model indicated that the standardization process did not perform well. In addition, the CPUE mirrors the proportion of positive catch sets through time and may not be indicative of the true trend in abundance.

5.3.10 Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the University of North Carolina shark longline survey south of Shakleford Banks (SEDAR39-DW-18).

This document details the smooth dogfish, *Mustelus canis*, catch from April-November, 1972-2013, at two fixed stations in Onslow Bay south of Shackleford Banks, North Carolina. Catch per unit effort (CPUE) by set in number of sharks per number of set hooks were examined by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. There were no smooth dogfish catches during the last two years of the time series. The majority of catches occurred during April and early May (82%), which were not consistently sampled across years due to weather and logistical constraints. The standardized relative abundance for smooth dogfish shows an overall slight decreasing trend throughout the time series with peaks in abundance in 2005 and 2010.

5.3.11 Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the South Carolina Department of Natural Resources red drum longline survey (SEDAR39-DW-19).

This document details smooth dogfish, *Mustelus canis*, catches from the South Carolina Department of Natural Resources (SCDNR) adult red drum longline survey conducted in South Carolina's estuarine and nearshore waters from 1984-2006. Catch per unit effort (CPUE) in number of sharks per hook hour were used to examine smooth dogfish relative abundance by year. The SCDNR red drum time series used for these analyses ends in 2006 due to a change in gear and sampling design. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The majority of catches occurred during late November, December, and January (88%), which were not consistently sampled across years. Only 9% of the total sets had smooth dogfish catch. The standardized relative abundance for smooth dogfish shows an overall slight increasing trend throughout the time series with peaks in abundance in 1998 and 2001.

5.3.12 Biomass. Abundance and distribution of smooth dogfish (Mustelus canis) from the Northeast Fisheries Science Center and Massachusetts Department of Marine Fisheries trawl surveys (SEDAR39-DW-24).

Temporal and spatial patterns in biomass and abundance of smooth dogfish during 1967-2013 were determined using data from annual spring, autumn and winter research vessel bottom trawl surveys conducted by the Northeast Fisheries Science Center (NEFSC) and the Massachusetts Department of Marine Fisheries (MADMF). Indices of abundance and biomass (stratified mean number and weight/tow) were calculated for the NEFSC spring and fall surveys from both north and south of Cape Hatteras. Time series of relative abundance and biomass were calculated for the NEFSC winter survey as well as the MADMF spring and fall surveys. Maps of the spring and fall surveys were created depicting abundance distributions, within five-year periods, for all dogfish and for the entire time series by sex for the winter survey and the MADMF surveys.

5.3.13 Size composition and indices of relative abundance of the smooth dogfish (Mustelus canis) from the NEAMAP trawl survey in the near shore Atlantic Ocean (SEDAR39-DW-30).

The Northeast Area Monitoring and Assessment Program (NEAMAP) has been sampling fish populations within the near coastal Atlantic waters since fall 2007. NEAMAP data for smooth dogfish (*Mustelus canis*) collected during fall cruises from 2007-2012 showed that this species was encountered frequently (5317 animals collected over the time-series), year-specific overall catches were highest in 2007, 2009, 2012, respectively, state-specific overall catches were highest in Delaware, New Jersey, and New York, respectively, and the sex ratio of captured animals was approximately equal (49.7% female, 50.3% male). Trends in nominal and stratified sampling indices of relative abundance were virtually identical showing the highest values in 2007 followed by a slightly decreased and variable pattern thereafter. The generalized linear model (GLM) based index of relative abundance was more variable and showed a dome-shaped pattern across years. Estimated coefficients of variation (CVs) for all indices were fairly low and generally less than 0.4 for all years.

5.4 Fishery Dependent Indices

5.4.1 Standardized indices of abundance for Smooth Dogfish, Mustelus canis, from the Northeast Fisheries Observer Program (SEDAR39-DW-09).

This document details the smooth dogfish, *Mustelus canis*, catch from the anchored sink gillnet fishery observed by the Northeast Fisheries Observer Program from 1995 to 2013 and fish lengths measured during observed trips in this fishery, as well as the drift sink gillnet and otter trawl fisheries. Catch per unit effort (CPUE) in pounds whole weight per (number of nets * net length * soak duration)/1000 were examined by year. The CPUE was standardized using a generalized linear model of the positive catch assuming a lognormal error distribution. Only a subset of the observer data was used to model the trend in abundance. The need to standardize effort across the observed sets required the use of several variables, some of which contained missing data and were therefore not used. The standardized relative abundance for smooth dogfish caught during the observed anchored sink gillnet trips shows an overall decreasing trend across the time series. The individual fish length data provided from the observer program may provide valuable information to help characterize the length distribution sampled by the different fisheries.

5.5 Consensus Recommendations and Survey Evaluations

Indices were initially reviewed based upon the criteria established at the SEDAR Abundance Indices Workshop held in 2008. The data source, index construction methodology, adherence to statistical assumptions, and model diagnostics were examined for each index. All indices reviewed were judged to be appropriately constructed, although in some cases revisions were recommended. Each index was then either recommended for a base run of the assessment model, for use in a model sensitivity run, or not recommended for use. None of the indices were considered for sensitivity runs. The criteria for recommendation included sample size, proportion of positive trips, length of the time series, spatial and temporal extent of the index, and region sampled (e.g. was the index restricted to marginal habitat or at the limit of a species range). Initial discussion suggested environmental factors such as temperature and potentially the North Atlantic Oscillation may influence the indices of abundances and where applicable might be considered in the models. Series that overlapped in spatial coverage (e.g. Narragansett Bay has three surveys) were examined on the utility of combining these surveys into one time series (see also SEDAR29 and SEDAR34). However, the Working Group decided not to recommend combination of all three series due to differences in survey methodology for one of the surveys.

Combination of the remaining two indices resulted in higher annual coefficients of variation. Only the seasonal RI DFW Trawl series was recommended for use, because of the greater spatial coverage and long time span. The Working Group did not consider time series that surveyed in areas or time periods when *Mustelus canis* were not considered to be abundant. Indices that were deemed problematic due to difficulties in standardizing effort across sets, such as from the Northeast Fisheries Observer and the NC DMF Ocean Gillnet Programs, were also considered not to be useful at the current time. See the evaluation worksheets compiled in SEDAR39-DW-27 for detailed information by time series.

The Working Group, for the purpose of weighting the indices in the model runs, completed Index ranking. Indices could have the same ranking. When determining rankings of the indices (1 = best), the primary consideration was that an index reflects the population trend of the species (or a portion of the population, e.g. juveniles). That judgment was made by considering characteristics of the data used in the construction of each index. The extent of temporal and spatial coverage encompassed by an index was also very important for the ranking process. Short time series or limited spatial coverage frequently reduced the ranking of an index.

The Working Group felt that the Fall NEFSC Bottom Trawl survey, north of Cape Hatteras, due to its spatial and temporal coverage should be given the highest ranking. The Fall NEAMAP trawl survey, also due to its spatial coverage, which complemented the Fall NEFSC Bottom Trawl survey, north of Cape Hatteras, was considered the next best series. All of the smaller scale surveys were ranked equally and the SEAMAP SA Trawl series was ranked lowest due to sampling in areas outside the primary range of *Mustelus canis*.

5.6 Literature Cited

Lo, N.C.H., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. *Canadian Journal of Fisheries and Aquatic Science* 49:2515-2526.

5.7 Research Recommendations

- Monitor/record bottom temperature, salinity, DO on all fishery independent surveys

5.8 Tables

Table 5.8.1. Indices recommended by the Indices Working Group for a model base run for the Atlantic stock of *Mustelus canis,* including the corresponding SEDAR document number, index type (fishery independent or dependent) and ranking. Rankings are the Indices Working Group's recommendation for index weighting.

SEDAR Document Number	Index Name	Index Type	Rank
SEDAR39-DW-02	SEAMAP SA Trawl	Independent	4
SEDAR39-DW-10	RI DFW Trawl	Independent	3
SEDAR39-DW-12	CT DEEP Trawl	Independent	3
SEDAR39-DW-15	DE DFW Trawl	Independent	3
SEDAR39-DW-17	NJ DFW Trawl	Independent	3
SEDAR39-DW-24	Fall NEFSC Bottom Trawl	Independent	1
SEDAR39-DW-24	Fall MA DMF Trawl	Independent	3
SEDAR39-DW-30	Fall NEAMAP Trawl	Independent	2

Table 5.8.2. Recommended indices of abundance for a model base run for the Atlantic stock of *Mustelus canis*, including index name and SEDAR document number. CV is the coefficient of variation for the annual index value. The two longer time series standardized using GLM methods are provided for two different time periods to fit both the base (1981-2012) and alternate (1972-2012) assessment models.

	SEDAR39 DW-02		SEDAR39 DW-30		SEDAR39 DW-12		SEDAR39 DW-24		SEDAR39 DW-24		SEDAR39 DW-10		SEDAR39 DW-10		SEDAR39 DW-14		SEDAR39 DW-15		SEDAR39 DW-15	
YEAR	SEAMAP SA Trawl	CV	Fall NEAMAP Trawl	CV	CT DEEP Trawl	CV	Fall NEFSC Bottom Trawl	CV	Fall MA DMF Trawl	CV	RI DFW Trawl 1981-2012	CV	RI DFW Trawl 1980-2012	CV	NJ DFW Trawl	CV	DE DFW Trawl 1981-2012	CV	DE DFW Trawl 1974-2012	CV
1972							0.467	0.277												
1973							1.216	0.179												
1974							0.773	0.211											0.224	0.948
1975							1.939	0.233												
1976							2.004	0.324												
1977							1.709	0.245												
1978							0.798	0.314	4.784	0.292										
1979							1.385	0.359	6.680	0.353									0.058	0.575
1980							0.561	0.155	5.814	0.294			1.573	0.470					0.100	0.557
1981							0.441	0.320	2.383	0.189	1.681	0.487	1.769	0.475			4.864	0.441	0.381	0.420
1982							0.629	0.447	3.035	0.317	1.256	0.463	1.264	0.577			12.036	0.455	0.868	0.432
1983							0.317	0.401	6.194	0.461	0.430	0.748	0.280	1.100			1.033	0.841	0.090	0.804
1984					7.527	0.333	0.939	0.261	8.234	0.372	1.449	0.391	1.759	0.380			3.175	0.570	0.237	0.541
1985					12.540	0.239	1.026	0.138	11.320	0.224	1.155	0.537	1.272	0.549						
1986					7.725	0.216	0.406	0.367	9.422	0.399	0.625	0.608	0.472	0.642						
1987					3.089	0.349	0.544	0.487	4.124	0.482	0.078	1.089	0.070	1.132						
1988					5.127	0.260	0.466	0.396	0.967	0.416					4.708	0.614				
1989					4.018	0.259	0.438	0.240	0.535	0.210	0.035	1.061	0.040	1.100	12.536	0.400				
1990					2.950	0.287	0.734	0.268	2.691	0.247	1.287	1.044	1.319	1.100	39.623	0.329	6.727	0.492	0.476	0.472
1991					3.699	0.278	0.219	0.309	3.369	0.258	0.159	0.756	0.121	0.796	18.823	0.340	4.620	0.433	0.322	0.410
1992					3.997	0.328	0.42	0.262	0.773	0.352	0.069	0.841	0.051	0.882	5.796	0.451	3.750	0.448	0.256	0.429
1993					4.312	0.308	0.329	0.176	0.769	0.206	0.545	0.564	0.508	0.651	7.001	0.428	10.679	0.341	0.665	0.324
1994	0.770	0.860			5.616	0.233	0.416	0.226	0.776	0.271	0.141	0.749	0.100	0.795	5.169	0.494	3.960	0.580	0.250	0.565
1995	1.224	0.790			3.310	0.278	0.572	0.257	1.943	0.479	0.213	1.043	0.220	1.100	39.900	0.319	3.406	0.424	0.209	0.405
1996	2.476	0.800			4.859	0.241	0.706	0.285	2.180	0.234	1.102	0.453	0.889	0.471	26.184	0.360	9.467	0.369	0.538	0.349
1997	0.467	0.940			2.123	0.349	0.498	0.268	2.012	0.206	0.332	1.047	0.325	1.101	15.680	0.360	19.620	0.303	1.045	0.288
1998	4.809	0.550			4.093	0.278	1.12	0.212	0.752	0.243	0.058	1.040	0.060	1.100	21.397	0.340	14.589	0.387	0.817	0.366
1999	12.449	0.500			7.365	0.209	2.052	0.228	0.876	0.239	0.333	0.528	0.347	0.545	38.408	0.398	18.939	0.311	1.005	0.296
2000	0.216	1.280			9.438	0.241	0.528	0.216	0.927	0.196	0.426	0.754	0.325	0.801	34.102	0.299	32.716	0.249	1.687	0.240
2001	5.460	0.670			9.414	0.259	1.808	0.403	0.622	0.252	0.764	0.618	0.862	0.643	36.709	0.340	28.021	0.261	1.542	0.250
2002	5.696	0.650			21.957	0.181	0.951	0.161	2.225	0.245	1.682	0.495	1.268	0.542	110.922	0.201	12.907	0.269	0.743	0.257
2003	13.356	0.530			10.770	0.325	2.085	0.242	1.524	0.215	1.526	0.369	1.800	0.413	54.808	0.360	25.172	0.305	1.402	0.292
2004	10.390	0.520			7.280	0.241	1.713	0.173	1.323	0.270	1.067	0.544	1.463	0.487	37.220	0.380	3.600	0.397	0.227	0.378
2005	17.263	0.510			5.883	0.307	1.125	0.202	4.170	0.234	0.727	0.645	0.903	0.794	52.956	0.360	2.129	0.437	0.126	0.417
2006	17.306	0.550			6.215	0.277	1.582	0.199	0.529	0.249	0.713	0.417	0.893	0.472	75.088	0.220	38.530	0.211	1.798	0.206
2007	2.431	0.690	12.140	0.612	9.590	0.242	1.266	0.260	1.377	0.216	0.875	0.519	1.352	0.540	61.482	0.299	37.001	0.207	1.982	0.202
2008	1.713	0.750	2.810	0.363	9.561	0.261	0.897	0.205	3.567	0.401	0.457	0.581	0.674	0.641	37.388	0.251	8.414	0.327	0.597	0.311
2009	1.395	0.740	7.100	0.217	11.347	0.225	1.262	0.233	1.768	0.370	0.756	0.608	1.653	0.542	32.989	0.380	10.505	0.284	0.664	0.270
2010	3.422	0.660	5.510	0.591	3.461	0.581	0.64	0.246	2.018	0.317	0.983	0.555	1.286	0.540	29.152	0.281	18.906	0.187	1.021	0.184
2011	1.901	0.680	4.170	0.330	11.663	0.233	0.794	0.179	0.797	0.243	0.703	0.488	0.859	0.470	63.803	0.238	17.652	0.262	0.999	0.251
2012	0.217	1.160	5.350	0.374	14.029	0.172	0.78	0.337	2.668	0.250	2.513	0.469	3.668	0.468	42.070	0.251	18.224	0.197	1.000	0.193

5.9 Figures

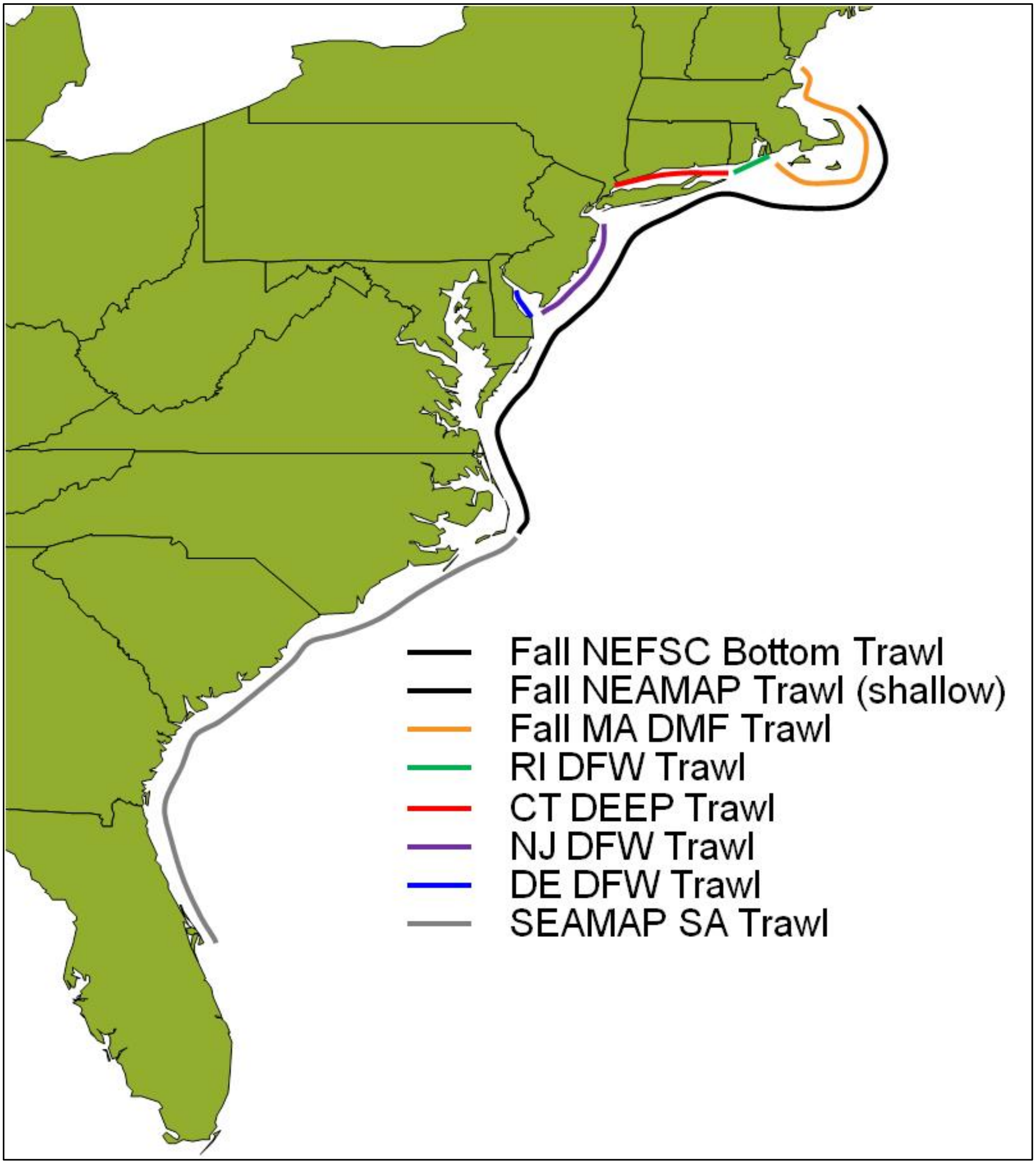


Figure 5.9.1. Approximate linear coverage of specific abundance indices for *Mustelus canis* in the Atlantic Ocean. The Fall NEAMAP Trawl survey mirrors the spatial range of the Fall NEFSC Bottom Trawl survey, but in shallower waters.

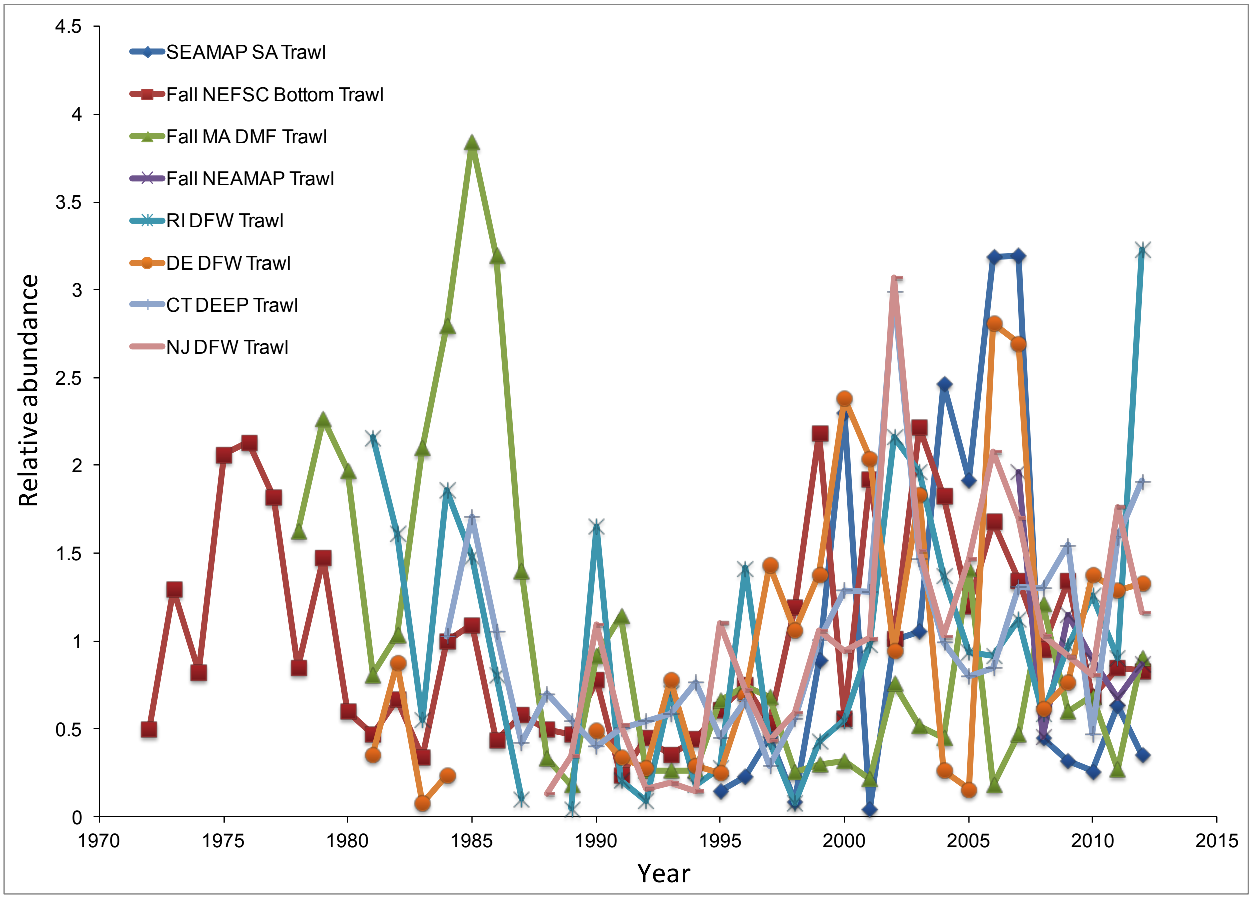


Figure 5.9.2. Plot of mean annual indices of relative abundance for each time series recommended for the Atlantic Ocean stock of *Mustelus canis* by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that time series. For the RI DFW and DE DFW trawl surveys only the 1981-2012 time series were plotted.

6 ANALYTIC APPROACH

6.1 Suggested analytic approach given the data

Two analytical approaches will be explored for assessment of the Atlantic stock of *Mustelus canis*. The first approach will use a length-based age-structured statistical model (Stock Synthesis; Methot and Wetzel 2013; e.g., Wetzel and Punt 2011a, 2011b). Stock Synthesis will be utilized as an integrated modeling approach (Maunder and Punt 2013) to take advantage of the many data sources available for the Atlantic stock of *Mustelus canis*. An advantage of the integrated modeling approach is that the development of statistical methods that combine several sources of information into a single analysis allows for consistency in assumptions and permits the uncertainty associated with both data sources to be propagated to final model outputs (Maunder and Punt 2013). A disadvantage of the integrated modeling approach is the increased model complexity.

A second, less complex, analytical approach will also be explored for the Atlantic stock of *Mustelus canis.* The second approach will utilize a Bayesian surplus production model (McAllister and Babcock 2006). An advantage of using a less complex modeling approach is that it leads to consistency if results are similar to those obtained with the more complex model; if results differ it can still be informative about the influence of different types of data and sensitivity to different parameters (Haddon 2001).

Haddon, M. 2001. Modelling and quantitative methods in fisheries. Chapman and Hall/CRC Press, Boca Raton, FL, USA.

Maunder, M. N. and A. E. Punt. 2013. A review of integrated analysis in fisheries stock assessment. Fisheries Research 142: 61-74.

McAllister, M. K. E. A. Babcock. 2006. Bayesian surplus production model with the Sampling Importance Resampling algorithm (BSP): a user's guide. May 2006. Web link: http://www.iccat.int/en/AssessCatalog.htm

Methot Jr., R. D., and C. R. Wetzel. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment. Fisheries Research 142:86-99.

Wetzel, C. R., and A. E. Punt. 2011a. Model performance for the determination of appropriate harvest levels in the case of data-poor stocks. Fisheries Research 110:342-355.

Wetzel, C. R., and A. E. Punt. 2011b. Performance of a fisheries catch-at-age model (Stock Synthesis) in data-limited situations. Marine and Freshwater Research 62: 927-936.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 39

HMS Atlantic Smooth dogfish

SECTION III: Assessment Process Report

January 2015

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

Table of Contents

1. WORKSHOP PROCEEDINGS

1.1. INTRODUCTION

1.1.1. Workshop Time and Place

The SEDAR 39 Assessment Process was held via a series of webinars between June 2014 and January 2015.

1.1.2. Terms of Reference

1. Review any changes in data following the Data Workshop and any analyses suggested by the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
2. Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations for each model considered.
3. Provide estimates of stock population parameters, including:
   - Fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, and other parameters as necessary to describe the population.
   - Appropriate measures of precision for parameter estimates.
4. Characterize uncertainty in the assessment and estimated values.
   - Consider uncertainty in input data, modeling approach, and model configuration.
   - Consider and include other sources as appropriate for this assessment.
   - Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
   - Provide measures of uncertainty for estimated parameters.
5. Provide estimates of yield and productivity.
   - Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models if the modeling platform allows.
6. Provide estimates of population benchmarks or management criteria consistent with available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards.

- Evaluate existing or proposed management criteria as specified in the management summary.
- Recommend proxy values when necessary.

7. Provide declarations of stock status relative to management benchmarks or alternative data poor approaches if necessary.
8. Provide uncertainty distributions of proposed reference points and stock status metrics that provide the values indicated in the management specifications. Include probability density functions for biological reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.
9. Project future stock conditions (biomass, abundance, and exploitation; including probability density functions) and develop rebuilding schedules if warranted; include estimated generation time. Develop stock projections for the following circumstances, in accordance with the guidance on management needs provided in the management history:

   A) If the stock is overfished, then utilize projections to determine:
   - Year in which F=0 results in a 70% probability of rebuilding (Year F=0p70)
   - Target rebuilding year (Year F=0p70 + 1 generation time if Year F=0p70>10) ($Year_{rebuild}$).
   - F resulting in 50% and 70% probability of rebuilding by $Year_{rebuild}$.
   - Fixed level or removals (TAC) allowing rebuilding of stock with 50% and 70% probability.

   B) Otherwise, utilize a P* approach to determine:
   - The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (P* = 0.3).

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

10. Provide recommendations for future research and data collection.
    - Be as specific as practicable in describing sampling design and sampling intensity.
    - Emphasize items which will improve future assessment capabilities and reliability.

- Consider data, monitoring, and assessment needs. Suggest the interval needed for future assessments taking into consideration the scientific needs of the stock including life history and stock status.

11. Complete the Assessment Workshop Report in accordance with project schedule deadlines (Section III of the SEDAR Stock Assessment Report).

1.1.3. List of Participants

Assessment Panel

Enric Cortés, Lead Analyst .... NMFS Panama City
Dean Courtney, Lead Analyst .... NMFS Panama City
Xinsheng Zhang, Lead Analyst .... NMFS Panama City
Peter Barile .... SFA
Yan Jiao .... Virginia Tech
Robert Latour .... VIMS
Katherine Sosebee .... NMFS Woods Hole

Observers

Jennifer Cudney .... HMS
Andrea Del'Apa .... NMFS HQ
Guy DuBeck .... HMS
Steve Durkee .... HMS
Dewey Hemilright .... Industry Representative
Rusty Hudson .... DSF
Alexis Jackson .... HMS
Kathryn Kulberg .... HSUS
Cami McCandless .... NMFS Narragansett
Holly White .... NC DMF
Jackie Wilson .... HMS

Staff

Julie A Neer .... SEDAR
Karyl Brewster-Geisz .... HMS

1.1.4. List of Assessment Process Working and Reference Papers

Documents Prepared for the Assessment Process			
SEDAR39-AW-01	Review of Available Length Composition Data Submitted for use in the SEDAR 39 *Mustelus canis* Atlantic Stock Assessment	Dean Courtney	10 Sept 2014
SEDAR39-AW-02	Hierarchical analysis of U.S Atlantic Smooth dogfish and Gulf of Mexico smoothhound species indices of abundance	Cami McCandless	15 Oct 2014

Reference Documents		
SEDAR39-RD06	A review of integrated analysis in fisheries stock assessment	Mark N. Maunder and Andre A. Punt
SEDAR39-RD07	Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management	Richard D. Methot Jr., and Chantell R. Wetzel
SEDAR39-RD08	Appendix A: Technical Description of the Stock Synthesis assessment program	Richard D. Methot Jr., and Chantell R. Wetzel
SEDAR39-RD09	Model selection for selectivity in fisheries stock assessments	Andre E. Punt, F. Hurtado-Ferro, F. and A.R. Whitten
SEDAR39-RD10	Bayesian surplus production model with the Sampling Importance Resampling algorithm (BSP): a User's Guide	Murdoch K. McAllister and Elizabeth A. Babcock
SEDAR39-RD11	Adjusting for bias due to variability of estimated recruitments in fishery assessment models	Richard D. Methot, Jr. and Ian G. Taylor
SEDAR39-RD12	Package 'r4ss': r code for Stock Synthesis	Ian Taylor, Ian Stewart, Allan Hicks, Tommy Garrison, Andre Punt, John Wallace, Chantell Wetzel, James Thorson, Yukio Takeuchi, Cole Monahan, and other contributors
SEDAR39-RD13	User Manual for Stock Synthesis -	Richard D. Methot Jr.

	Model Version 3.24s	
SEDAR39-RD14	Final Report for the Assessment Methods Working Group Summarizing the Domestic Shark *P** Standardization Workshop	Dean L. Courtney, Enric Cortés, and Xinsheng Zhang

1.2. PANEL RECOMMENDATIONS AND COMMENTS

1.2.1. Term of Reference 1

Review any changes in data following the Data Workshop and any analyses suggested by the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.

The following changes were made to input data following the Data Workshop:

1. One change was introduced here to the catches obtained from the SEDAR 39 Data Workshop report. The Com-LL-NE (PRM) data obtained from the SEDAR 39 Data Workshop report were corrected based on the post-release live-discard mortality rate of 13.5% recommended for smoothhound sharks caught on commercial bottom longline gear at the SEDAR 39 DW (**Table 2.1**).
2. The catch time series obtained from the SEDAR 39 Data Workshop report, including the updated catches for Com-LL-NE (PRM), were aggregated into six fleets (F1 – F6) for use in the stock assessment model (**Table 2.2**). Catch aggregation was based on a review of the available length composition data described below in Section 2. At the request of HMS management, we also provide annual average weights obtained from commercial observer programs and the recreational fishery to enable conversion of weights into numbers for the different fleets considered in the HMS Atlantic smooth dogfish stock assessment (**Table 2.2.b)**.
3. One change was introduced here to the accepted indices obtained from the SEDAR 39 Data Workshop report. The DE DFW Trawl GLM standardized CPUE estimates (1974-2012) provided in the SEDAR 39 Data Workshop report were corrected here based on the values provided in the addendum to the SEDAR39-DW-15 (**Table 2.6**).
4. Options for use of the length composition data obtained for *Mustelus canis* in the northwest Atlantic within the stock assessment base model were identified and reviewed during the SEDAR 39 Assessment Webinars, summarized in Courtney (2014), and are listed below in

Section 2. Length composition data recommended for use in the stock assessment model (**Tables 2.3 and 2.4)** were then associated with each aggregated catch time series (fleets F1 – F6) and each index of abundance (surveys S1 – S8) as described in **Table 2.5**).

5. The index rankings determined by the Index Working Group of the Data Workshop for each accepted index were not used in the base model configuration. Sensitivity analyses, described below, indicated that the base model results were sensitive to differences in modeling approaches used to implement the recommended index rankings. Consequently, inverse CV weighting was used in the proposed base model, and index ranking was included in sensitivity analyses to compare the results of modeling approaches between index ranking and inverse CV weighting (Section 2).

6. The von Bertalanffy growth (VBG) parameters recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean were converted here to cm fork length (cm FL) separately for females and males for input in the proposed base model (Section 2).

7. The life history data recommended in the SEDAR 39 Data Workshop Report for female *Mustelus canis* in the Atlantic Ocean (**Appendix 2.B.**) were used to compute the average annual number of pups (male and female) produced by each female at age for input in the proposed base model (Section 2).

8. The life history data recommended in the SEDAR 39 Data Workshop Report for *Mustelus canis* in the Atlantic Ocean (**Appendix 2.B.**) were also used to develop a prior for steepness. Details of the procedure can be found in Section 2.

9. Additional analyses not developed at the DW included development of 1) a hierarchical index of abundance (SEDAR39-AW-02), 2) low and high productivity scenarios, and 3) low and high catch scenarios (Section 2).

10. Based on the Data Workshop recommendations, the start year of the base model configurations was set equal to 1981, and the base model configurations assumed virgin biomass in 1981. Based on the Data Workshop recommendations, sensitivity analyses were also conducted for an alternative start year of 1972 utilizing reconstructed catches from 1972 – 1980, and several extended time series of relative abundance developed during the Data Workshop. The Data Workshop recommended sensitivity analyses assuming virgin biomass in 1972. However, the sensitivity analysis with a model start year in 1972 was implemented here with

initial fishing mortalities estimated for some fleets because extrapolated catches were not zero for all fleets in 1972.

1.2.2. Term of Reference 2

Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations for each model considered.

Only one analytical approach was implemented in this assessment of the Atlantic stock of *Mustelus canis*. The approach used a length-based age-structured statistical model (Stock Synthesis; Methot and Wetzel 2013; e.g., Wetzel and Punt 2011a, 2011b). Stock Synthesis was utilized as an integrated modeling approach (Maunder and Punt 2013) to take advantage of the many data sources available for the Atlantic stock of *Mustelus canis*. An advantage of the integrated modeling approach is that the development of statistical methods that combine several sources of information into a single analysis allows for consistency in assumptions and permits the uncertainty associated with both data sources to be propagated to final model outputs (Maunder and Punt 2013). A disadvantage of the integrated modeling approach is the increased model complexity. All analyses and their configurations with Stock Synthesis are fully described in Section 3.

A second, less complex, analytical approach was also explored for the Atlantic stock of *Mustelus canis*. This approach was based on a state-space Bayesian surplus production model (SSSPM; Meyer and Millar 1999); see also HMS Gulf of Mexico Smoothhound complex report). However, due to time constraints, the SSSPM model was not implemented in the final assessment.

Two alternative base model configurations were proposed in the current Stock Synthesis assessment based on the alternative functional forms of selectivity (Sel-1 and Sel-2) evaluated for the main targeted fishery (fleet F1 – NE Gillnet Kept) as described below:

1. Preliminary parameter values and the approximate shape for selectivity at age were obtained from length composition data obtained for *Mustelus canis* in the northwest Atlantic externally of the stock assessment model based on methods used in previous HMS shark assessments conducted with age-structured models (**Appendix 2A**). Final parameter values for selectivity were obtained with the algorithm described in **Appendix 4A**.

2. Using the algorithm described in **Appendix 4.A**, asymptotic selectivity (Sel-1; modeled with a simple logistic function at length) was obtained for the main targeted fishery (fleet F1 – NE Gillnet Kept). However, based on Assessment Panel recommendations, a dome-shaped functional form (Sel-2; modeled with a double logistic function at length) was also evaluated in this assessment as an alternative functional form of selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept). This resulted in two alternative base model configurations in the current assessment based on the alternative functional forms of selectivity (Sel-1 and Sel-2) evaluated for the main targeted fishery (fleet F1 – NE Gillnet Kept).
3. Based on Assessment Panel recommendations, several model diagnostics were also evaluated to compare model fits to data between the two alternative base model configurations (Sel-1 and Sel-2) as follows: 1) Akaike's information criterion (AIC); 2) the root mean squared error (RMSE); and 3) a Kolmogorov-Smirnov (K-S) test. Methods used to implement the diagnostics are described in Section 3 and results of the diagnostics are presented in Section 4.

The Assessment Panel recommended the alternative model configuration with a dome-shaped functional form (Sel-2; modeled with a double logistic function at length) for the main targeted fishery (fleet F1 – NE Gillnet Kept) as the base model for the assessment based on the following criteria:

1. The proposed base model under the Sel-2 configuration (dome-shaped selectivity for fleet F1) had a substantially better fit to the data based on the minimum AIC value (5633.5) than the proposed base model under the Sel-1 configuration (asymptotic-shaped selectivity for fleet F1 (Sel-1) (Δ_i = 100.1) (See Section 4.1.1 and **Table 4.6**).
2. The Sel-2 configuration had a better fit (smaller RMSE) to the length composition data for fleet F1 (NE Gillnet Kept) than the Sel-1 configuration (See Section 4.1.2; **Table 4.7**), and fits to female length composition data for the largest size bins were improved under the Sel-2 configuration (**Figures 4.7 and 4.9**).

1.2.3. Term of Reference 3

Provide estimates of stock population parameters, including (a) fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, and other parameters as necessary to describe the population and (b) appropriate measures of precision for parameter estimates.

Estimates of assessment model parameters and their associated CVs are reported in Section 4.3. Estimates of total biomass (*B*), spawning stock fecundity (SSF), recruits (*R*), and annual fishing mortality (*F*) are reported in Section 4.6. Selectivity parameters are reported in Section 4.4. Recruitment parameters and the predicted stock-recruitment relationship, predicted log recruitment deviations, and predicted age-0 recruits are reported in Section 4.5.

1.2.4. Term of Reference 4

Characterize uncertainty in the assessment and estimated values (a) considering uncertainty in input data, modeling approach, and model configuration, (b) considering and including other sources as appropriate for this assessment. Provide appropriate measures of model performance, reliability, and 'goodness of fit' and measures of uncertainty for estimated parameters.

Uncertainty in the assessment and estimated values is characterized Sections 4.3 and 4.8. Model convergence and diagnostics are addressed in Section 4.1. Model fits to the abundance indices and length composition data are provided in Section 4.2.

1.2.5. Term of Reference 5

Provide estimates of yield and productivity, including yield-per-recruit, spawner-per-recruit, and stock-recruitment models if the modeling platform allows.

As stated for TOR 3 above, we provide estimates of recruitment parameters, the predicted stock-recruitment relationship, predicted log recruitment deviations, and predicted age-0 recruits in Section 4.5. Productivity is imputed as an informative prior to take advantage of the biological information available (Section 3.1.4).

1.2.6. Term of Reference 6

Provide estimates of population benchmarks or management criteria consistent with available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards. Evaluate existing or proposed management criteria as specified in the management summary. Recommend proxy values when necessary.

Estimates of benchmark and biological reference points (MSY, MSST, F_{MSY}, SSF_{MSY}, SSF/SSF_{MSY}, F/F_{MSY}) are provided in Section 4.9.

1.2.7. Term of Reference 7

Provide declarations of stock status relative to management benchmarks or alternative data poor approaches if necessary.

Stock status based on the status determination criteria is also reported in Section 4.9.

1.2.8. Term of Reference 8

Provide uncertainty distributions of proposed reference points and stock status metrics that provide the values indicated in the management specifications. Include probability density functions for biological reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.

Probability distributions for the reference points are not provided per se but the time series trajectories of the two stock status metrics (SSF/SSF_{MSY}, F/F_{MSY}) with approximate 95% asymptotic confidence intervals are reported in Section 4.6 and associated figures.

1.2.9. Term of Reference 9

Project future stock conditions (biomass, abundance, and exploitation; including probability density functions) and develop rebuilding schedules if warranted; include estimated generation time. Develop stock projections for the following circumstances, in accordance with the guidance on management needs provided in the management history

This section is still in progress. Stochastic projections of future stock conditions under different catch levels will be provided separately.

1.2.10. Term of Reference 10

Provide recommendations for future research and data collection. Be as specific as practicable in describing sampling design and sampling intensity. Emphasize items which will improve future assessment capabilities and reliability. Consider data, monitoring, and assessment needs. Suggest the interval needed for future assessments taking into consideration the scientific needs of the stock including life history and stock status.

Recommendations for future research and data collection are provided in Section 4.12.

1.2.11. Term of Reference 11

Complete the Assessment Workshop Report in accordance with project schedule deadlines (Section III of the SEDAR Stock Assessment Report).

This document is Section III of the SEDAR Stock Assessment Report.

2. DATA REVIEW AND UPDATE

2.1. CATCHES

One change was introduced in the assessment report to the catches obtained from the SEDAR 39 Data Workshop report. The Com-LL-NE (PRM) data obtained from the SEDAR 39 Data Workshop report were corrected based on the post-release live-discard mortality rate of 13.5% recommended for smoothhound sharks caught on commercial bottom longline gear at the SEDAR 39 DW (**Table 2.1**). Otherwise, catches used in the assessment model were unchanged from those in the SEDAR 39 Data Workshop report. Commercial gillnet landings (47%) and animals released alive but assumed to die in the recreational fishery (24%) and those kept or dead in the recreational fishery (10%) made up the majority of the catches during 1981 – 2012 (**Table 2.1**; **Figure 2.1**). We also attempted to quantify uncertainty in those catches that were estimated by developing two sensitivity scenarios: a low catch scenario and a high catch scenario, both of which are described in Section 3.

The catch time series obtained from the SEDAR 39 Data Workshop report, including the updated catches for Com-LL-NE (PRM), were aggregated into six fleets (F1 – F6) for use in the stock assessment model (**Table 2.2**). Catch aggregation was based on a review of the available length composition data described below. Aggregated catch time series were input in the stock assessment model in units of metric tons (mt), based on the conversion factors 1 mt = 1,000 kg, and 1 kg = 2.20462 lb. Aggregated catch time series were obtained as follows:

F1 (Com-GN Kept) = Com-GN Landings.
F2 (Com-GN Discard) = Com-GN-NE (PRM) + Com-GN-SE (PRM).
F3 (Com-TR) = Com-TR Landings + Com-TR-NE (PRM).
F4 (Com-LL) = Com-LL Landings + updated Com-LL-NE (PRM).
F5 (Com-Other) = Com-Other Landings.
F6 (Recreational) = Recreational (A+B1) + Recreational (PRM).

At the request of HMS management, we also provide annual average weights obtained from commercial observer programs and the recreational fishery to enable conversion of weights into numbers for the different fleets considered in the HMS Atlantic smooth dogfish stock assessment (**Table 2.2.b**). Average weights from the Southeast Reef Fish and Shark Bottom

Longline Observer Program, the Southeast Gillnet Observer Program, and the MRFSS/MRIP recreational programs were depicted in SEDAR39-DW-03 and are now included in tabular form. We also obtained average weights from the Northeast Gillnet Observer Program (combined mesh, kept, and combined mesh, discards) and the Northeast Trawl Observer Program (combined mesh, combined disposition). All weights were obtained by converting lengths to weights with the sex-specific length-weight relationships recommended by the DW (their Table 2.11.1). Note that for the Northeast observer programs, lengths represent the mean number of lengths measured per observation.

2.2. LENGTH COMPOSITIONS, AGE COMPOSITIONS, AND SELECTIVITIES

2.2.1. Length Compositions

Length composition data used in the stock assessment model were obtained from observed catches and accepted CPUE indices submitted for *Mustelus canis* in the northwest Atlantic during the SEDAR 39 Data Workshop, reviewed during the SEDAR 39 Assessment Webinars, and summarized in Courtney (2014) (**Tables 2.3 and 2.4; Figures 2.2 and 2.3**). Options for use of the length composition data in the stock assessment model were identified and reviewed during the SEDAR 39 Assessment Webinars, summarized in Courtney (2014), and listed below.

The following options were identified for the use of length composition data obtained from observed catches for *Mustelus canis* in the northwest Atlantic (see Courtney 2014):

1. Use Northeast Observer Program sink gillnet (NE-GNOP) length compositions to represent the selectivity of the commercial gillnet catch.

    1.a. Split the NE-GNOP length compositions (and the commercial gillnet catch) into kept and discarded catch.

2. Use the Northeast Observer Program otter trawl (NE-TOP) length compositions to represent the selectivity of the commercial trawl catch (kept, discarded, and unknown disposition combined).

3. Exclude Southeast Observer Program gillnet (SE GNOP) length compositions as they may not be representative of commercial catch from the northeast.

3.a. Include SE GNOP length compositions in exploratory analysis if time permits.

4. Include Southeast Observer Program bottom longline (SE BLLOP) length compositions to represent the length composition of longline catch because most longline catch appears to be from North and South Carolina where the SE BLLOP operates.

5. Use Marine Recreational Information Program (MRIP/MRFSS) length compositions to represent the selectivity of the recreational catch.

6. Use sex specific, sex combined, or unknown sex length compositions, where available.

The following options were identified for use of length composition data obtained from accepted CPUE indices for *Mustelus canis* in the northwest Atlantic (see Courtney 2014):

1. Use the length compositions from each accepted CPUE index to represent the selectivity of the index.

2. Use sex specific, sex combined, or unknown sex length compositions, where available.

The following options were identified for use of length composition data obtained from rejected CPUE series for *Mustelus canis* in the northwest Atlantic (see Courtney 2014):

1 Exclude length compositions from rejected indices because the CPUE series have all been rejected and because other length compositions are available from the accepted CPUE indices, which may more accurately reflect the length composition of sharks captured in those data series.

1.a. Include length compositions from rejected indices in exploratory analysis if time permits.

Based on the options identified above, the catch data were aggregated into six fleets (see Section 2.1). The available length composition data were then associated with each aggregated time series of catch (fleets F1 – F6) and each accepted index of abundance (surveys S1 – S8) based on the options described above (**Table 2.5)**. The length composition data were limited to the years 1981 – 2012 for the base model (assuming virgin biomass in 1981) and to the years 1972 – 2012 for the sensitivity analysis assuming virgin biomass in 1972. All length compositions were input in the stock assessment model in units of cm fork length (cm FL) based on the conversion factors provided in the SEDAR 39 DW report.

2.2.2. Preliminary Selectivity Values

Preliminary parameter values and the approximate shape for selectivity at age were obtained externally of the stock assessment model from length composition data obtained for *Mustelus canis* in the northwest Atlantic and associated with each fleet and survey (see Section 2.2.1; **Table 2.5**; **Appendix 2.A**). Previous HMS shark assessments conducted with age-structured models derived selectivity at age externally of the stock assessment model (NMFS 2012, 2013a, 2013b). Consequently, the same methods were used in this assessment. The available length composition data associated with each fleet and survey were obtained as described above (see Section 2.2.1; **Table 2.5)**. Age-frequency data were obtained from the available length composition data associated with each fleet and survey by back-transforming the length composition data through the sex-specific von Bertalanffy growth equations obtained for *Mustelus canis* in the northwest Atlantic from the SEDAR 39 Data Workshop report (**Appendix 2.A**). Externally derived selectivity at age was modeled with a double normal selectivity function fit by eye to the normalized ratio of the observed to the expected proportion captured at each age (Obs[prop.CAA]/E[prop.CAA]) (**Appendix 2.A**). Preliminary parameter values for externally derived selectivity at age (**Table 2.A.1**) and the approximate shape of the selectivity curve (**Figure 2.A.1**) were obtained for each fleet and survey in the proposed stock assessment base model configuration using the MS Excel file SELEX-24.xls (Methot 2013).

2.3. INDICES OF ABUNDANCE

One change was introduced here to the accepted indices obtained from the SEDAR 39 Data Workshop report. The DE DFW Trawl GLM standardized CPUE estimates (1974-2012) provided in the SEDAR 39 Data Workshop report were corrected here based on the values provided in the addendum to the SEDAR39-DW-15 (**Table 2.6**). Otherwise, indices of abundance used in the assessment model were unchanged from those in the SEDAR 39 Data

Workshop report. The Index Working Group of the SEDAR 39 Data Workshop recommended the following eight fishery-independent indices of relative abundance for the Atlantic stock of *Mustelus canis* base model (**Table 2.6**): Southeast Area Monitoring and Assessment Program (SEAMAP) South Atlantic Shallow Water Trawl Survey (SEAMAP-SA Trawl, SEDAR39-DW-02), New Jersey Department of Fish and Wildlife Ocean Trawl Survey (NJ DFW Trawl, SEDAR39-DW-14), Connecticut Department of Energy and Environmental Protection Long Island Sound Trawl Survey (CT DEEP Trawl, SEDAR39-DW-12), Delaware Division of Fish and Wildlife 30-foot Trawl Survey (DE DFW Trawl, SEDAR39-DW-15), Rhode Island Department of Environmental Management Seasonal Trawl Survey (RI DEM Seas. Trawl, SEDAR39-DW-10), NMFS NEFSC Fall Bottom Trawl Survey-north of Cape Hatteras, North Carolina (NEFSC Fall Trawl-N, SEDAR39-DW-24), Massachusetts Division of Marine Fisheries Fall Trawl Survey (MA DMF Fall Trawl, SEDAR39-DW-24), and the Northeast Area Monitoring and Assessment Program (NEAMAP) Fall Trawl Survey (NEAMAP Fall Trawl, SEDAR39-DW-30). All indices were standardized by the respective authors either through a standardized survey sampling design (NEFSC Fall Trawl-N, and MA DMF Fall Trawl) or through GLM techniques (all others) (see SEDAR 39 DW Report).

The Index Working Group of the SEDAR 39 Data Workshop also completed index ranking for the purpose of weighting the indices in the base model (**Table 2.7**). Indices could have the same ranking (1 = best). When determining rankings of the indices, the primary consideration was that an index reflects the population trend of the species (or a portion of the population, e.g. juveniles). That judgment was made by considering characteristics of the data used in the construction of each index. The extent of temporal and spatial coverage encompassed by an index (**Figure 2.4**) relative to the seasonal distribution pattern of *Mustelus canis* along the east coast of the United States (**Figure 2.5**) was also very important for the ranking process. Short time series or limited spatial coverage frequently also reduced the ranking of an index.

The Index Working Group of the SEDAR 39 Data Workshop determined that the NEFSC Fall Bottom Trawl survey, north of Cape Hatteras, due to its spatial and temporal coverage should be given the highest ranking. The NEAMAP Fall trawl survey, also due to its spatial coverage, which complemented the NEFSC Fall Bottom Trawl survey, north of Cape Hatteras, was considered the next best series. All of the smaller scale surveys were ranked equally and the SEAMAP-SA Trawl series was ranked lowest due to sampling in areas outside the primary range of *Mustelus canis*.

However, sensitivity analyses described in Section 3, indicated that the stock assessment model results were sensitive to different choices for how to implement the recommended index rankings as weighting terms within the stock assessment model. Consequently, inverse CV weighting was used for the proposed base model. The index rankings were included in sensitivity analyses to compare the results of modeling approaches between index ranking and inverse CV weighting.

2.4. LIFE HISTORY INPUTS

2.4.1. von Bertalanffy Growth (VBG) Parameters

The von Bertalanffy growth (VBG) parameters recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean were converted here to cm fork length (cm FL) separately for females and males for input in the stock assessment model as follows (**Table 2.8**):

1. Length at each age (0 – 18 yr) was predicted in cm STL from the VBG parameters recommended in the SEDAR 39 Data Workshop report separately for females and males.
2. Length at each age (0 – 18 yr) was obtained in cm FL from length in cm STL with the conversion factors (cm STL to cm FL) in the SEDAR 39 Data Workshop report separately for females and males.
3. Length at each age (0 – 18 yr) in cm FL was then predicted from a VBG model with the parameter values obtained by minimizing the sum of the squared differences in predicted versus observed length at age in cm FL separately for females and males.
4. Length at age-0 (L_{Amin} cm FL) and length at age-18 (L_{Amax} cm FL) along with the VBG growth coefficient (*k*) were then input in the proposed base model separately for females and males.

We note that the VBG growth coefficient (*k*) obtained as described above remained unchanged from the parameters recommended in the SEDAR 39 DW report. We also note that the VBG models recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean resulted in a relatively large length at age-0 (L_{Amin}) for males and females (46.94 and 48.84 cm FL, respectively), relative to the approximate size at birth (c. 32.5 cm FL) obtained from the scientific literature (see SEDAR39-RD01).

2.4.2. Length-weight Relationship

The sex-combined fixed length-weight relationship recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean was used to convert body length (cm FL) to body weight (kg) (**Table 2.8**).

2.4.3. Average Number of Pups

The life history data recommended in the SEDAR 39 Data Workshop report for female *Mustelus canis* in the Atlantic Ocean (**Appendix 2.B.**) were used to compute the average annual number of pups (male and female) produced by each female at age for input in the proposed base model as follows (**Table 2.9**):

1. Fecundity at each age (0 – 18 yr) was obtained from the SEDAR 39 Data Workshop report (**Appendix 2.B.**) as

   Fecundity (age) = -31.31 + 42.47(1 – exp(-0.496(age)).
2. The proportion of females mature at each age (0 – 18 yr) was obtained from the SEDAR 39 Data Workshop report (**Appendix 2.B.**) as

   Maturity (age) = 1/(1 + exp(7.486+(−1.697)age)).
3. The gestation period was obtained from the SEDAR 39 Data Workshop report (**Appendix 2.B.**) as

   Gestation period = 11 months.
4. The reproductive cycle was obtained from the SEDAR 39 Data Workshop report (**Appendix 2.B.**) as

   Reproductive cycle = annual.
5. The proportion of females in a maternal condition at each age (0 – 18 yr) was then calculated here as the proportion mature at age minus the approximate gestation period (approximately one year) as

   Maternity (age) = Female proportion mature (age – 1).

6. The average annual number of pups (male and female) produced by each female at age was then calculated here as

   Pups (age) = ([Fecundity (age)] * [Maternity (age)])/(1.0),

   where 1.0 represents an annual reproductive cycle.

We note that pups were not reported at ages < 4 yr for *Mustelus canis* in the Atlantic Ocean (see SEDAR39-RD01). Consequently, fecundity was set equal to zero for Mustelus canis in the Atlantic Ocean at ages < 3 yr.

*2.4.4. Prior for Steepness (*h*)*

The life history inputs used to develop an informative prior distribution for steepness (h) are presented in **Table 2.10**. An analytically derived value of steepness can be generated through the equation (Brooks et al. 2010; see Section 3):

$$\Phi_0 = \frac{S_0}{R_0} = \sum_{a=r}^{\omega} \mu_a E_a \prod_{j=r}^{a-1} e^{-M_j}$$

where Φ_0 is virgin spawners per recruit, r is recruitment age, ω is maximum age, μ_a is proportion mature at age, E_a is age-specific fecundity (the number of female offspring produced per breeding female of age a on an annual basis), and M_j is age-specific natural mortality. Note that virgin spawners per recruit (Φ_0) is equivalent to the net reproductive rate (R_0) in life table/Leslie matrix approaches.

The term bΦ_0 is also the maximum lifetime reproductive rate at low population density ($\hat{\alpha}$) defined by Myers et al. (1999):

$$\hat{\alpha} = b\Phi_0$$

where b is the slope at the origin of the Beverton-Holt stock-recruitment curve, which in sharks is effectively pup survival (e^{-M_0}). Finally, steepness (h) can be derived from:

$$h = \frac{\hat{\alpha}}{\hat{\alpha} + 4}$$

Biological input values in **Table 2.10** are as reported in the SEDAR 39 Data Workshop report, with the exception of natural mortality (*M*) at age, which was not reported therein. The values of *M* at age were estimated from four life history invariant methods (Hoenig 1983, Chen and Watanabe 1989, Peterson and Wroblewski 1984, and Lorenzen 1996). The maximum value at age of the four methods was then used to approximate a maximum compensatory response. The value of steepness obtained for *M. canis* using these life history inputs was 0.54.

To examine other plausible states of nature (see Section 3), we also developed two additional scenarios: high and low productivity. The high productivity run used the upper 95% confidence limits of the von Bertalanffy growth function parameters used in the base run, a constant fecundity of 9.53 pups per litter (in contrast to a relationship between age of the mother and fecundity used in the base run), and a constant value of *M*, which was the lowest age-specific value (0.202 corresponding to *M* at maximum age) (**Table 2.11**). The low productivity run used the lower 95% confidence limits of the von Bertalanffy growth function parameters used in the base run and a constant value of *M*, which was the highest age-specific value (0.260 corresponding to *M* at age 0) (**Table 2.12**). These life history inputs yielded steepness values of 0.62 and 0.49, for the high and low productivity scenarios, respectively (see Section 3).

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2.6. TABLES

Table 2.1. Total catches of *Mustelus canis* in the Atlantic Ocean (all in lb whole weight) obtained from the SEDAR 39 Data Workshop report for the base model (assuming virgin biomass in 1981) and for sensitivity analyses (assuming virgin biomass in 1972); The first four columns are commercial landings by gear (GN=gillnets, TR=Trawl, LL=Longline, Other=other gear). The next four columns are discards from the northeast (first three) and the southeast (fourth). Northeast discards represent discards released alive that are assumed to die (discard estimates x post-release live discard mortality rate for each of the gears); Southeast discards are also discards released alive assumed to die (discard estimates in numbers x average weight of discards from the SE Gillnet Observer Program x post-release live discard mortality rate for gillnets). Next are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 in numbers x average weight of A+B1 from MRIP x post-release live discard mortality rate for hook and line).

Year	Com-GN Landings	Com-TR Landings	Com-LL Landings	Com-Other Landings	Com-GN-NE (PRM)	Com-TR-NE (PRM)	Com-LL-NE (PRM)[1]	Com-GN-SE (PRM)	Recreational (A+B1)	Recreational (PRM)
Catch data for sensitivity analyses (assuming virgin biomass in 1972)										
1972	0	0	0	0	608	217634	940	0	0	0
1973	0	0	0	0	628	198058	1105	0	53743	14194
1974	0	0	0	0	1059	183104	1105	0	107485	28387
1975	0	0	0	0	1176	175359	1064	0	161228	42581
1976	0	0	0	0	1804	198674	600	0	214971	56775
1977	0	0	0	0	2526	220738	469	0	268713	70969
1978	0	0	0	0	3332	235317	1022	0	322456	85162
1979	0	0	0	0	3148	252688	1303	0	376199	99356
1980	0	0	0	0	4340	289301	976	0	429941	113550

[1] The Com-LL-NE (PRM) data provided in the SEDAR 39 DW Report were corrected here based on the recommended post-release live-discard mortality rate for smoothhound sharks caught on commercial bottom longline gear (13.5%) from the Data Workshop.

Table 2.1. Continued.

Year	Com-GN Landings	Com-TR Landings	Com-LL Landings	Com-Other Landings	Com-GN-NE (PRM)	Com-TR-NE (PRM)	Com-LL-NE (PRM)[1]	Com-GN-SE (PRM)	Recreational (A+B1)	Recreational (PRM)
Catch data for base model (assuming virgin biomass in 1981)										
1981	0	2683	0	0	4963	250610	680	0	483684	87170
1982	0	7619	0	0	3290	317358	489	0	99148	273632
1983	505	23842	525	11500	3072	300753	427	0	398513	914075
1984	0	1320	0	0	3624	263474	328	0	356552	323009
1985	715	7155	0	16644	3483	225716	322	0	363366	206463
1986	101	5180	0	0	3788	216118	403	0	696378	314873
1987	9796	60714	19300	0	3722	198031	656	0	424872	224353
1988	912	813	0	0	3989	185552	606	0	408454	203522
1989	150253	111703	0	0	4941	448279	476	0	395156	548304
1990	234113	82536	0	0	4405	122144	327	0	186795	212962
1991	732671	97683	11010	929	8036	56464	804	0	182571	210762
1992	1767170	96567	551	205	200716	223469	1161	0	179842	173427
1993	1464658	187825	1526	2	145775	26515	863	0	294512	256845
1994	1443107	202242	14742	84282	46012	110373	357	0	118903	292773
1995	2792499	71496	4409	8973	36369	160345	625	0	154399	392948
1996	1639843	72045	201	4189	68036	161308	833	0	110983	290326
1997	944914	60096	1500	13121	28572	62915	952	0	161911	509711
1998	748008	194618	391	215739	97263	107399	1161	515	110258	602797
1999	1268515	66604	3675	2096	152501	22494	685	417	53793	355735
2000	1023946	58030	8433	930	43869	195698	774	470	166651	707458
2001	1132671	120994	8933	14400	40119	89388	1577	455	105755	646390
2002	1329510	153683	21309	17403	65834	157999	1131	487	86144	427596
2003	1430755	164128	18385	20246	129168	51019	1548	443	186666	606685
2004	1596868	96115	15887	72389	6726	112426	1042	433	57662	523811
2005	1058452	33787	51029	110366	156489	271388	3274	155	182730	1688246
2006	918780	100142	14426	108628	53572	167047	1845	403	48386	1949045
2007	1313988	98781	16211	229663	43453	249188	1339	13346	322588	821034
2008	1337695	174975	30830	273395	6071	70790	1548	96	168107	951138
2009	1854673	291046	80642	488272	16905	150753	2024	205	78672	733223
2010	3027939	232648	56914	584767	5536	72088	2202	9035	56757	256012
2011	2067545	315187	15465	395322	18095	121515	2381	998	64792	318137
2012	1521436	175789	8862	533254	1905	86414	2649	458	96736	771972

[1] The Com-LL-NE (PRM) data provided in the SEDAR 39 DW Report were corrected here based on the recommended post-release live-discard mortality rate for smoothhound sharks caught on commercial bottom longline gear (13.5%) from the Data Workshop.

Table 2.2. Aggregated total catch of *Mustelus canis* in the Atlantic Ocean (in mt whole weight) used in the assessment model (assuming virgin biomass in 1981) and for sensitivity analyses (assuming virgin biomass in 1972). Catches obtained from the SEDAR 39 Data Workshop report, along with the updated catches for Com-LL-NE (PRM), were aggregated here into six fleets (F1 – F6) for use in the assessment model as follows: F1 (Com-GN Kept) = Com-GN Landings; F2 (Com-GN Discard) = Com-GN-NE (PRM) + Com-GN-SE (PRM); F3 (Com-TR) = Com-TR Landings + Com-TR-NE (PRM); F4 (Com-LL) = Com-LL Landings + updated Com-LL-NE (PRM); F5 (Com-Other) = Com-Other Landings; and F6 (Recreational) = Recreational (A+B1) + Recreational (PRM). Catch aggregation was based on a review of the available length composition data as described above. Units of metric tons (mt) were obtained from the conversion factors 1 mt = 1,000 kg, and 1 kg = 2.20462 lb.

Year	Com-GN Kept	Com-GN Discard	Com-TR	Com-LL	Com-Other	Recreational
	Aggregated catch data for sensitivity analyses (assuming virgin biomass in 1972)					
1972	0.0	0.3	98.7	0.4	0.0	0.0
1973	0.0	0.3	89.8	0.5	0.0	30.8
1974	0.0	0.5	83.1	0.5	0.0	61.6
1975	0.0	0.5	79.5	0.5	0.0	92.4
1976	0.0	0.8	90.1	0.3	0.0	123.3
1977	0.0	1.1	100.1	0.2	0.0	154.1
1978	0.0	1.5	106.7	0.5	0.0	184.9
1979	0.0	1.4	114.6	0.6	0.0	215.7
1980	0.0	2.0	131.2	0.4	0.0	246.5

Table 2.2. Continued.

Year	Com-GN Kept	Com-GN Discard	Com-TR	Com-LL	Com-Other	Recreational
	Aggregated catch data for base model (assuming virgin biomass in 1981)					
1981	0.0	2.3	114.9	0.3	0.0	258.9
1982	0.0	1.5	147.4	0.2	0.0	169.1
1983	0.2	1.4	147.2	0.4	5.2	595.4
1984	0.0	1.6	120.1	0.1	0.0	308.2
1985	0.3	1.6	105.6	0.1	7.5	258.5
1986	0.0	1.7	100.4	0.2	0.0	458.7
1987	4.4	1.7	117.4	9.1	0.0	294.5
1988	0.4	1.8	84.5	0.3	0.0	277.6
1989	68.2	2.2	254.0	0.2	0.0	427.9
1990	106.2	2.0	92.8	0.1	0.0	181.3
1991	332.3	3.6	69.9	5.4	0.4	178.4
1992	801.6	91.0	145.2	0.8	0.1	160.2
1993	664.4	66.1	97.2	1.1	0.0	250.1
1994	654.6	20.9	141.8	6.8	38.2	186.7
1995	1266.7	16.5	105.2	2.3	4.1	248.3
1996	743.8	30.9	105.8	0.5	1.9	182.0
1997	428.6	13.0	55.8	1.1	6.0	304.6
1998	339.3	44.4	137.0	0.7	97.9	323.4
1999	575.4	69.4	40.4	2.0	1.0	185.8
2000	464.5	20.1	115.1	4.2	0.4	396.5
2001	513.8	18.4	95.4	4.8	6.5	341.2
2002	603.1	30.1	141.4	10.2	7.9	233.0
2003	649.0	58.8	97.6	9.0	9.2	359.9
2004	724.3	3.2	94.6	7.7	32.8	263.8
2005	480.1	71.1	138.4	24.6	50.1	848.7
2006	416.8	24.5	121.2	7.4	49.3	906.0
2007	596.0	25.8	157.8	8.0	104.2	518.7
2008	606.8	2.8	111.5	14.7	124.0	507.7
2009	841.3	7.8	200.4	37.5	221.5	368.3
2010	1373.5	6.6	138.2	26.8	265.2	141.9
2011	937.8	8.7	198.1	8.1	179.3	173.7
2012	690.1	1.1	118.9	5.2	241.9	394.0

Table 2.2.b. Mean weights of Atlantic smooth dogfish from commercial observer programs and the recreational fishery obtained by converting lengths into weights using the sex-specific length-weight equations recommended by the DW. All weights are in lb (whole weight).

Year	NE Gillnet OP (kept)	NE Gillnet OP (discard)	NE Trawl OP (combined)	SE Bottom longline OP	SE Gillnet OP	Recreational (MRFSS/MRIP)
1981						1.974
1982						2.921
1983						3.784
1984						3.744
1985						3.862
1986						4.549
1987						2.329
1988						3.827
1989						5.263
1990						2.387
1991						2.529
1992						2.240
1993						3.286
1994	8.525	8.370	3.416	11.472		3.790
1995	7.563	3.017		9.977		5.386
1996	6.636	1.946	5.007	8.110		2.908
1997	10.394	1.805	3.907	10.213		3.431
1998	7.375	5.415	2.499	9.821		5.241
1999	7.274	1.987	7.168	11.798		2.947
2000	8.964	2.622	3.111			5.355
2001	8.137	2.438	1.659			2.388
2002	9.040	5.561	1.555			2.614
2003	8.322	4.189	3.060	12.410		2.597
2004	6.517	5.099	5.013	9.603		2.517
2005	6.559	4.371	5.921	17.486	2.040	5.712
2006	5.365	2.564	6.247	16.596	4.570	5.430
2007	8.337	4.710	6.100	13.162	5.037	3.477
2008	7.377	6.337	6.551	9.876	6.685	2.804
2009	5.757	7.180	6.858	12.695	11.693	4.170
2010	7.204	5.598	6.157	12.462	4.241	1.766
2011	9.059	9.198	4.561	11.394	8.156	2.398
2012	10.870	9.754	3.905	13.998	8.234	4.399

Table 2.3. Fishery-independent length composition data submitted for the Atlantic stock of *Mustelus canis* during the SEDAR 39 Data Workshop, reviewed for use in the stock assessment model during the SEDAR 39 Assessment Webinars, and summarized in Courtney (2014).

Name (and acronym used in this report)	Years of coverage	State	Sex specific data (Yes or No)	N (n)	Index rank [3]	SEDAR 39 Data Workshop document number	Provider	Length data source number
Northeast Fisheries Science Center Fall Trawl Survey North of Cape Hatteras (NEFSC Fall Trawl-N)	1972-2012	MA-NC	Yes	3,078 [1]	Rank 1	SEDAR 39-DW-24	NEFSC (Woods Hole)	1.1
NEAMAP Shallow Water Fall Trawl Survey (NEAMAP Fall Trawl)	2007-2012	MA-NC	Yes	4,317 [1]	Rank 2	SEDAR 39-DW-30	VIMS	1.2
Massachusetts Department of Marine Fisheries Fall Trawl Survey (MA DMF Fall Trawl)	1978-2012	MA	Yes	1,764 [1]	Rank 3	SEDAR 39-DW-24	NEFSC (Woods Hole)	1.3
Rhode Island Department of Environmental Management trawl surveys (RI DEM Seas Trawl)	1980-2012	RI	Yes	(n = 666 [2])	Rank 3	SEDAR 39-DW-10	NEFSC (Narragansett)	1.4
Connecticut Department of Energy and Environmental Protection Long Island Sound trawl surveys (CT DEEP Trawl)	1989-2012	CT/NY	Yes	(n = 4,112 [2])	Rank 3	SEDAR 39-DW-12	NEFSC (Narragansett)	1.5
Delaware Division of Fish and Wildlife trawl surveys (DE DFW Trawl)	1966-1971; 1974; 1997-2012	DE	No	(n = 16,113 [2])	Rank 3	SEDAR 39-DW-15	NEFSC (Narragansett)	1.6
New Jersey Division of Fish and Wildlife trawl surveys (NJ DFW Trawl)	1988-2012	NJ	No	(n = 69,871 [2])	Rank 3	SEDAR 39-DW-14	NEFSC (Narragansett)	1.7
SEAMAP South Atlantic Shallow Water Trawl Survey (SEAMAP-SA Trawl)	1994-2012	FL-NC	Yes	(n = 4,136 [2])	Rank 4	SEDAR 39-DW-02	SEFSC (Panama City)	1.8

[1] Sample size (N) indicates the number of records obtained from the mean number measured at length per tow (NEFSC survey data) or from sharks sub-sampled for length measurements NEAMAP).

[2] Sample size (n) indicates the number of lengths measured for length.

[3] The relative ranking assigned to each index at the SEDAR 39 Data Workshop.

Table 2.4. Fishery-dependent length composition data submitted for the Atlantic stock of *Mustelus canis* during the SEDAR 39 Data Workshop, reviewed for use in the stock assessment model during the SEDAR 39 Assessment Webinars, and summarized in Courtney (2014).

Name (and acronym used in this report)	Years of coverage	State	Sex specific data (Yes or No)	N (n)	Index rank	SEDAR 39 Data Workshop document number	Provider	Length data source number
Northeast Observer Program Sink Gillnet (NE GNOP; Combined Mesh, Kept)	1992-2012	MA-NC	Yes	8,016 [1] (n = 11,751 [2])	NA	SEDAR 39-DW-25	NEFSC (Woods Hole)	**2.1**
Northeast Observer Program Sink Gillnet (NE GNOP; Combined Mesh, Discard)	1992-2012	MA-NC	Yes	8,016 [1] (n = 2,337 [2])	NA	SEDAR 39-DW-25	NEFSC (Woods Hole)	**2.2**
Northeast Observer Program (Otter Trawl) (NE TOP; Combined Mesh and Disposition)	1994-2012	MA-NC	Yes	2,606 [1] (n = 3,623 [2])	NA	SEDAR 39-DW-25	NEFSC (Woods Hole)	**2.3**
Southeast Gillnet Fishery Observer Program (SE GNOP)	2005-2012	FL-NC	Yes	(n = 645 [2])	NA	SEDAR 39-DW-03	SEFSC- (Panama City)	**2.4**
Southeast Bottom Longline Observer Program (SE BLLOP)	1994-2012	-	Yes	(n = 507 [2])	NA	SEDAR 39-DW-03	SEFSC- (Panama City)	**2.5**
Marine Recreational Information Program (MRIP; MRFSS)	1981-2012	FL-ME	No	(n = 1,562 [2])	NA	SEDAR 39-DW-03	SEFSC- (Panama City)	**2.6**

[1] Sample size (N) indicates the number of records obtained from each subsample (NEFSC Observer Program data)

[2] Sample size (n) indicates the number of lengths measured.

Table 2.5. Length composition data recommended for use in the stock assessment model (**Tables 2.3 and 2.4)** were associated with each aggregated catch time series (fleets F1 – F6) and each index of abundance (surveys S1 – S8). Catch aggregation and the association of length composition data with catch and survey data were based on a review of the available length composition data during the SEDAR 39 Assessment Webinars as described above (also see Courtney 2014).

Time series	Series type	Series name	Associated length composition data source
F1	Catch	Com-GN Kept	2.1 NE GNOP (Combined Mesh, Kept)
F2	Catch	Com-GN Discard	2.2 NE GNOP (Combined Mesh, Discard)
F3	Catch	Com-TR	2.3 NE TOP (Combined Mesh and Disposition)
NA[1]			2.4 SE GNOP
F4	Catch	Com-LL	2.5 SE BLLOP
F5 [2]	Catch	Com-Other	NA
F6	Catch	Recreational	2.6 MRIP
S1	Survey	NEFSC Fall Trawl-N	1.1 NEFSC Fall Trawl-N
S2	Survey	NEAMAP Fall Trawl	1.2 NEAMAP Fall Trawl
S3	Survey	MA DMF Fall Trawl	1.3 MA DMF Fall Trawl
S4	Survey	RI DEM Seas. Trawl	1.4 RI DEM Seas. Trawl
S5	Survey	CT DEEP Trawl	1.5 CT DEEP Trawl
S6	Survey	DE DFW Trawl	1.6 DE DFW Trawl
S7	Survey	NJ DFW Trawl	1.7 NJ DFW Trawl
S8	Survey	SEAMAP-SA Trawl	1.8 SEAMAP-SA Trawl

[1] Associated length data were not representative of any catch time series used in the assessment.
[2] Associated length data were not available for fleet 5 (F5).

Table 2.6. Indices of relative abundance recommended by the Index Working Group of the SEDAR 39 Data Workshop for the Atlantic stock of *Mustelus canis* (see SEDAR 39 Data Workshop report). The associated SEDAR document number is also provided. The CV is the coefficient of variation for the annual index value (see SEDAR 39 Data Workshop report). The two longer time series standardized using GLM methods (RI DEM Seas. Trawl and DE DFW Trawl) are provided for two different time periods, 1981 – 2012 (based model) and 1972 – 2012 (sensitivity analyses).

	SEDAR39 DW-02		SEDAR39 DW-30		SEDAR39 DW-12		SEDAR39 DW-24		SEDAR39 DW-24		SEDAR39 DW-10		SEDAR39 DW-10		SEDAR39 DW-14		SEDAR39 DW-15		SEDAR39 DW-15	
Year	SEAMAP-SA Trawl	CV	NEAMAP Fall Trawl	CV	CT DEEP Trawl	CV	NEFSC Fall Trawl-N	CV	MA DMF Fall Trawl	CV	RI DEM Seas. Trawl 1981-2012	CV	RI DEM Seas. Trawl 1980-2012	CV	NJ DFW Trawl	CV	DE DFW Trawl 1981-2012	CV	DE DFW Trawl 1974-2012[1]	CV
1972							0.467	0.277												
1973							1.216	0.179												
1974							0.773	0.211											3.049	0.948
1975							1.939	0.233												
1976							2.004	0.324												
1977							1.709	0.245												
1978							0.798	0.314	4.784	0.292										
1979							1.385	0.359	6.680	0.353									0.806	0.575
1980							0.561	0.155	5.814	0.294			1.573	0.470					1.442	0.557
1981							0.441	0.320	2.383	0.189	1.681	0.487	1.769	0.475			4.864	0.441	5.691	0.420
1982							0.629	0.447	3.035	0.317	1.256	0.463	1.264	0.577			12.036	0.455	13.263	0.432
1983							0.317	0.401	6.194	0.461	0.430	0.748	0.280	1.100			1.033	0.841	1.385	0.804
1984					7.527	0.333	0.939	0.261	8.234	0.372	1.449	0.391	1.759	0.380			3.175	0.570	3.780	0.541
1985					12.540	0.239	1.026	0.138	11.320	0.224	1.155	0.537	1.272	0.549						
1986					7.725	0.216	0.406	0.367	9.422	0.399	0.625	0.608	0.472	0.642						
1987					3.089	0.349	0.544	0.487	4.124	0.482	0.078	1.089	0.070	1.132						
1988					5.127	0.260	0.466	0.396	0.967	0.416					4.708	0.614				
1989					4.018	0.259	0.438	0.240	0.535	0.210	0.035	1.061	0.040	1.100	12.536	0.400				
1990					2.950	0.287	0.734	0.268	2.691	0.247	1.287	1.044	1.319	1.100	39.623	0.329	6.727	0.492	7.841	0.472
1991					3.699	0.278	0.219	0.309	3.369	0.258	0.159	0.756	0.121	0.796	18.823	0.340	4.620	0.433	5.430	0.410
1992					3.997	0.328	0.420	0.262	0.773	0.352	0.069	0.841	0.051	0.882	5.796	0.451	3.750	0.448	4.464	0.429
1993					4.312	0.308	0.329	0.176	0.769	0.206	0.545	0.564	0.508	0.651	7.001	0.428	10.679	0.341	12.018	0.324
1994	0.770	0.860			5.616	0.233	0.416	0.226	0.776	0.271	0.141	0.749	0.100	0.795	5.169	0.494	3.960	0.580	4.601	0.565
1995	1.224	0.790			3.310	0.278	0.572	0.257	1.943	0.479	0.213	1.043	0.220	1.100	39.900	0.319	3.406	0.424	4.008	0.405
1996	2.476	0.800			4.859	0.241	0.706	0.285	2.180	0.234	1.102	0.453	0.889	0.471	26.184	0.360	9.467	0.369	10.786	0.349
1997	0.467	0.940			2.123	0.349	0.498	0.268	2.012	0.206	0.332	1.047	0.325	1.101	15.680	0.360	19.620	0.303	21.553	0.288
1998	4.809	0.550			4.093	0.278	1.120	0.212	0.752	0.243	0.058	1.040	0.060	1.100	21.397	0.340	14.589	0.387	16.790	0.366
1999	12.449	0.500			7.365	0.209	2.052	0.228	0.876	0.239	0.333	0.528	0.347	0.545	38.408	0.398	18.939	0.311	20.938	0.296
2000	0.216	1.280			9.438	0.241	0.528	0.216	0.927	0.196	0.426	0.754	0.325	0.801	34.102	0.299	32.716	0.249	35.126	0.240
2001	5.460	0.670			9.414	0.259	1.808	0.403	0.622	0.252	0.764	0.618	0.862	0.643	36.709	0.340	28.021	0.261	30.259	0.250
2002	5.696	0.650			21.957	0.181	0.951	0.161	2.225	0.245	1.682	0.495	1.268	0.542	110.922	0.201	12.907	0.269	13.868	0.257
2003	13.356	0.530			10.770	0.325	2.085	0.242	1.524	0.215	1.526	0.369	1.800	0.413	54.808	0.360	25.172	0.305	26.840	0.292
2004	10.390	0.520			7.280	0.241	1.713	0.173	1.323	0.270	1.067	0.544	1.463	0.487	37.220	0.380	3.600	0.397	4.147	0.378
2005	17.263	0.510			5.883	0.307	1.125	0.202	4.170	0.234	0.727	0.645	0.903	0.794	52.956	0.360	2.129	0.437	2.527	0.417
2006	17.306	0.550			6.215	0.277	1.582	0.199	0.529	0.249	0.713	0.417	0.893	0.472	75.088	0.220	38.530	0.211	40.541	0.206
2007	2.431	0.690	12.140	0.612	9.590	0.242	1.266	0.260	1.377	0.216	0.875	0.519	1.352	0.540	61.482	0.299	37.001	0.207	38.754	0.202
2008	1.713	0.750	2.810	0.363	9.561	0.261	0.897	0.205	3.567	0.401	0.457	0.581	0.674	0.641	37.388	0.251	8.414	0.327	9.378	0.311
2009	1.395	0.740	7.100	0.217	11.347	0.225	1.262	0.233	1.768	0.370	0.756	0.608	1.653	0.542	32.989	0.380	10.505	0.284	11.492	0.270
2010	3.422	0.660	5.510	0.591	3.461	0.581	0.640	0.246	2.018	0.317	0.983	0.555	1.286	0.540	29.152	0.281	18.906	0.187	19.643	0.184
2011	1.901	0.680	4.170	0.330	11.663	0.233	0.794	0.179	0.797	0.243	0.703	0.488	0.859	0.470	63.803	0.238	17.652	0.262	18.999	0.251
2012	0.217	1.160	5.350	0.374	14.029	0.172	0.780	0.337	2.668	0.250	2.513	0.469	3.668	0.468	42.070	0.251	18.224	0.197	19.054	0.193

[1] The DE DFW Trawl CPUE data for the years 1974-2012 provided in the SEDAR 39 Data Workshop report were corrected here based on the values provided in the addendum to the SEDAR39-DW-15 (their Table A1).

Table 2.7. Index ranks recommended by the Index Working Group of the SEDAR 39 Data Workshop (see SEDAR 39 Data Workshop report). The corresponding SEDAR document number and index type (fishery independent or dependent) are also provided.

SEDAR Document Number	Index Name	Index Type	Rank
SEDAR39-DW-02	SEAMAP-SA Trawl	Independent	4
SEDAR39-DW-10	RI DEM Seas. Trawl	Independent	3
SEDAR39-DW-12	CT DEEP Trawl	Independent	3
SEDAR39-DW-15	DE DFW Trawl	Independent	3
SEDAR39-DW-14	NJ DFW Trawl	Independent	3
SEDAR39-DW-24	NEFSC Fall Trawl-N	Independent	1
SEDAR39-DW-24	MA DMF Fall Trawl	Independent	3
SEDAR39-DW-30	NEAMAP Fall Trawl	Independent	2

Table 2.8. The von Bertalanffy growth (VBG) parameters recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean were converted here to cm fork length (cm FL) separately for females and males for input into the stock assessment model (see Section 2.4.1). The minimum and maximum ages in the stock assessment model were set to age-0 and age-18, respectively. Length at age-0 (L_{Amin} cm FL) and length at age-18 (L_{Amax} cm FL) along with the VBG growth coefficient (k) were input separately for females and males in the stock assessment model. The sex-specific fixed length-weight relationships recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean was used in the stock assessment model to convert body length (cm FL) to body weight (kg). The approximate size at birth (c. 32.5 cm FL) is also provided from the scientific literature (see SEDAR39-RD01).

Growth parameters	Male | Female	Notes
VBG parameters converted from cm STL to cm FL		
L_∞ (cm FL)	94.53 | 110.78	Based on conversion factors (from cm STL to cm FL) obtained from the SEDAR 39 Data Workshop report
k	0.44 | 0.29	
t_0	-1.56 | -1.99	
VBG parameters (in cm FL) for input in the proposed base model		
L_{Amin} (cm FL)	46.96 | 48.84	Amin = age-0
L_{Amax} (cm FL)	94.51 | 110.46	Amax = age-18
k	0.44 | 0.29	
Approximate size at birth obtained from the scientific literature		
Size at birth (cm STL)	c. 30 to 40 (mean c. 35) cm STL	(see SEDAR39-RD01)
Size at birth (cm FL)	c. 28.1 – 36.9 (mean c. 32.5) cm FL	Based on conversion factors (from cm STL to cm FL) obtained from the SEDAR 39 Data Workshop report
Sex-specific fixed length-weight relationships		
Female weight (kg) = $(6.0*10^{-6})*(\text{cm FL})^{3.0084}$		SEDAR 39 Data Workshop report
Male weight (kg) = $(1.0*10^{-5})*(\text{cm FL})^{2.8076}$		

Table 2.9. The life history data recommended in the SEDAR 39 Data Workshop report for female *Mustelus canis* in the Atlantic Ocean were used here to compute the average annual number of pups (male and female) produced by each female at age for input in the stock assessment model (see Section 2.4.3).

Age (yr)	Fecundity	Proportion mature	Proportion maternal	Average annual number of pups (male and female) produced per female
0	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00
2	0.00	0.02	0.00	0.00
3	1.57	0.08	0.02	0.03
4	5.32	0.33	0.08	0.44
5	7.60	0.73	0.33	2.53
6	8.99	0.94	0.73	6.57
7	9.84	0.99	0.94	9.22
8	10.36	1.00	0.99	10.23
9	10.67	1.00	1.00	10.65
10	10.86	1.00	1.00	10.86
11	10.98	1.00	1.00	10.98
12	11.05	1.00	1.00	11.05
13	11.09	1.00	1.00	11.09
14	11.12	1.00	1.00	11.12
15	11.14	1.00	1.00	11.14
16	11.14	1.00	1.00	11.14
17	11.15	1.00	1.00	11.15
18	11.15	1.00	1.00	11.15

Table 2.10. Life history inputs used to calculate steepness for developing a prior distribution for *Mustelus canis* for the base run.

Mustelus canis				
	Proportion		Fecundity	
Age	mature	M	(female pups)	
0	0.001	0.262		
1	0.003	0.262		
2	0.016	0.262		
3	0.084	0.248		
4	0.332	0.235		
5	0.731	0.226	3.802	
6	0.937	0.219	4.497	
7	0.988	0.215	4.921	
8	0.998	0.212	5.178	
9	1.000	0.209	5.335	
10	1.000	0.208	5.431	
11	1.000	0.206	5.489	
12	1.000	0.205	5.525	
13	1.000	0.205	5.546	
14	1.000	0.204	5.560	
15	1.000	0.204	5.568	
16	1.000	0.204	5.572	
Maturity ogive:		1/(1+EXP(7.486-1.697*age))		
Sex ratio:		1:1		
Reproductive frequency:		1 yr		
Fecundity:		-31.31+42.47*(1-EXP(-0.496*age))		
L_{inf}		123.57	(cm TL)	
k		0.292		
t_0		-1.943		
Weight vs length relation:		$W=0.000006L^{3.0084}$		
(W is in kg; L is cm FL)				

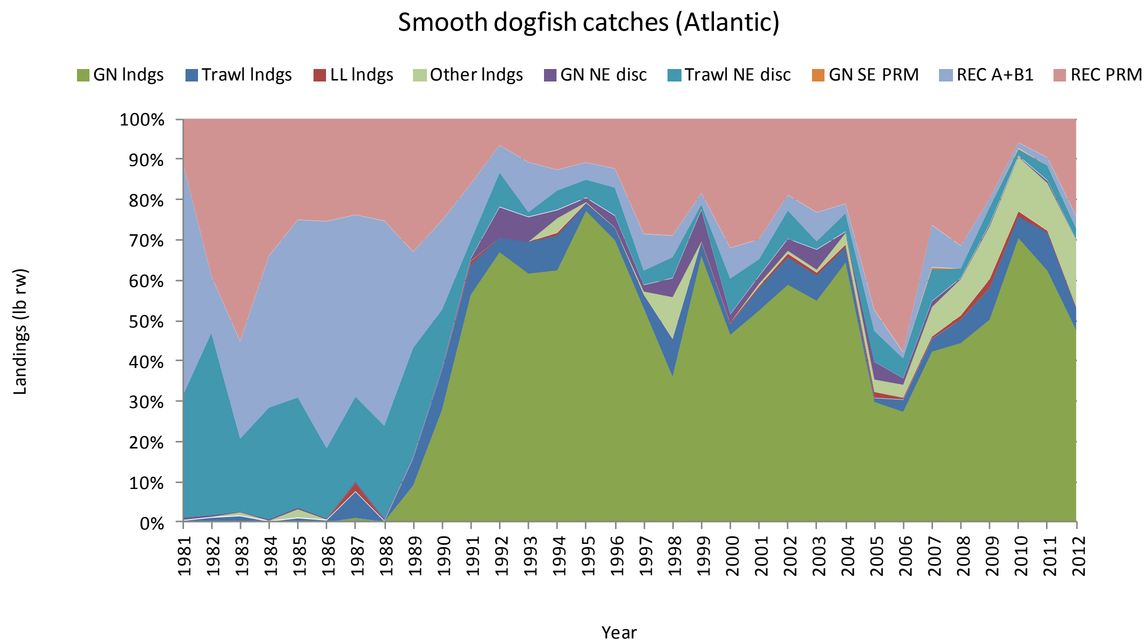
Table 2.11. Life history inputs used to calculate steepness for developing a prior distribution for *Mustelus canis* for the high productivity run.

Mustelus canis				
	Proportion		Fecundity	
Age	mature	M	(female pups)	
0	0.001	0.202		
1	0.003	0.202		
2	0.016	0.202		
3	0.084	0.202		
4	0.332	0.202		
5	0.731	0.202	4.765	
6	0.937	0.202	4.765	
7	0.988	0.202	4.765	
8	0.998	0.202	4.765	
9	1.000	0.202	4.765	
10	1.000	0.202	4.765	
11	1.000	0.202	4.765	
12	1.000	0.202	4.765	
13	1.000	0.202	4.765	
14	1.000	0.202	4.765	
15	1.000	0.202	4.765	
16	1.000	0.202	4.765	
Maturity ogive:		1/(1+EXP(7.486-1.697*age))		
Sex ratio:		1:1		
Reproductive frequency:		1 yr		
Fecundity:		9.53 (constant)		
L_{inf}		125.0112	(cm TL)	
k		0.309		
t_0		-1.81736		
Weight vs length relation:		$W=0.000006L^{3.0084}$		
(W is in kg; L is cm FL)				

Table 2.12. Life history inputs used to calculate steepness for developing a prior distribution for *Mustelus canis* for the low productivity run.

Mustelus canis				
	Proportion		Fecundity	
Age	mature	M	(female pups)	
0	0.001	0.262		
1	0.003	0.262		
2	0.016	0.262		
3	0.084	0.262		
4	0.332	0.262		
5	0.731	0.262	3.802	
6	0.937	0.262	4.497	
7	0.988	0.262	4.921	
8	0.998	0.262	5.178	
9	1.000	0.262	5.335	
10	1.000	0.262	5.431	
11	1.000	0.262	5.489	
12	1.000	0.262	5.525	
13	1.000	0.262	5.546	
14	1.000	0.262	5.560	
15	1.000	0.262	5.568	
16	1.000	0.262	5.572	
Maturity ogive:		1/(1+EXP(7.486-1.697*age))		
Sex ratio:		1:1		
Reproductive frequency:		1 yr		
Fecundity:		-31.31+42.47*(1-EXP(-0.496*age))		
L_{inf}		122.1288	(cm TL)	
k		0.275		
t_0		-2.06864		
Weight vs length relation:		$W=0.000006L^{3.0084}$		
(W is in kg; L is cm FL)				

2.7. FIGURES



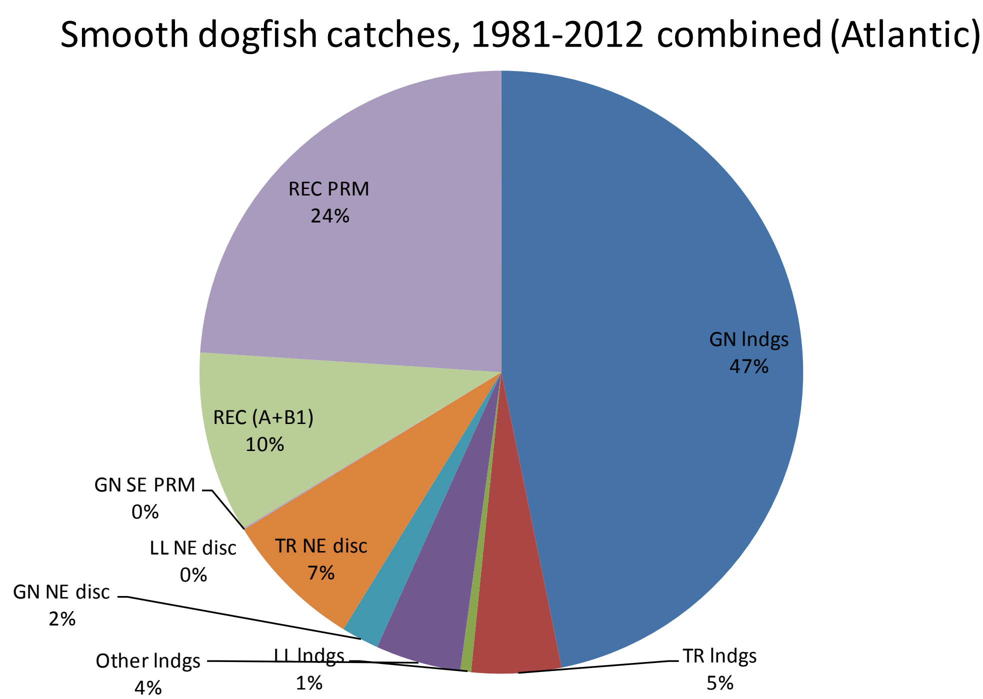


Figure 2.1. Catches of smooth dogfish in the Atlantic, 1981 – 2012 (top) and as a proportion for all years combined (bottom) as described in the SEDAR 39 DW Report.

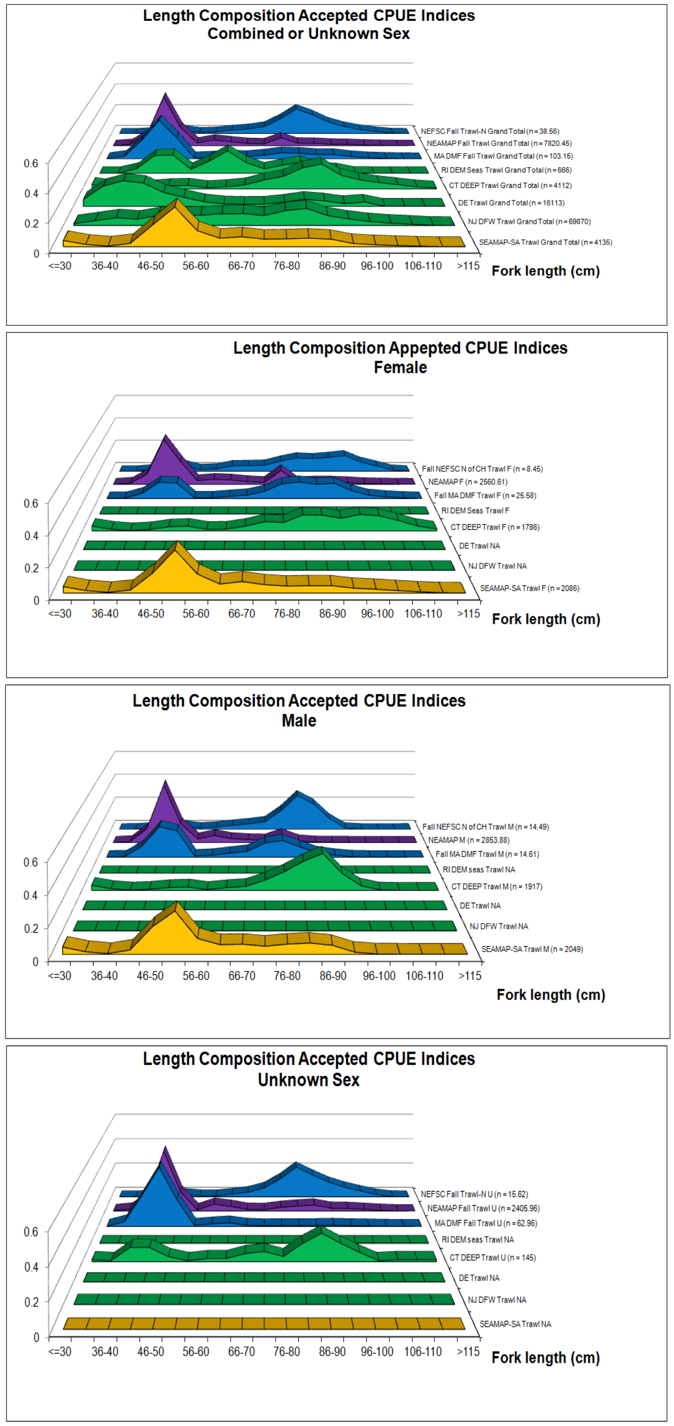


Figure 2.2. Fishery-independent length composition data submitted for the Atlantic stock of *Mustelus canis* during the SEDAR 39 Data Workshop, reviewed for use in the stock assessment model during the SEDAR 39 Assessment Webinars, and summarized in Courtney (2014); Combined data (top panel), sex-specific data (two middle panels) and unknown sex (lower panel); Sample sizes (n) reflect either the number of records or the number of lengths measured (Courtney 2014).

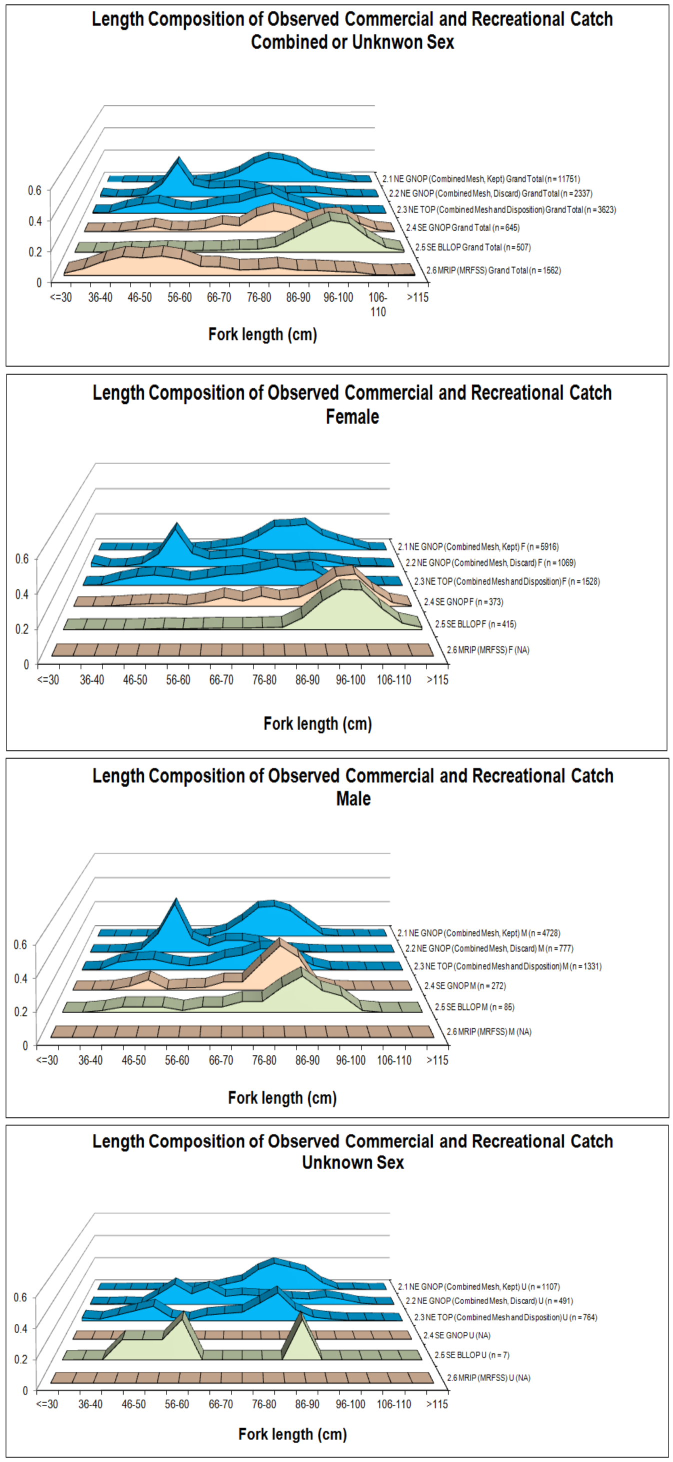


Figure 2.3. Fishery-dependent length composition data submitted for the Atlantic stock of *Mustelus canis* during the SEDAR 39 Data Workshop, reviewed for use in the stock assessment model during the SEDAR 39 Assessment Webinars, and summarized in Courtney (2014); Combined data (top panel), sex-specific data (two middle panels) and unknown sex (lower panel); Sample sizes (n) reflect either the number of records or the number of lengths measured (Courtney 2014).

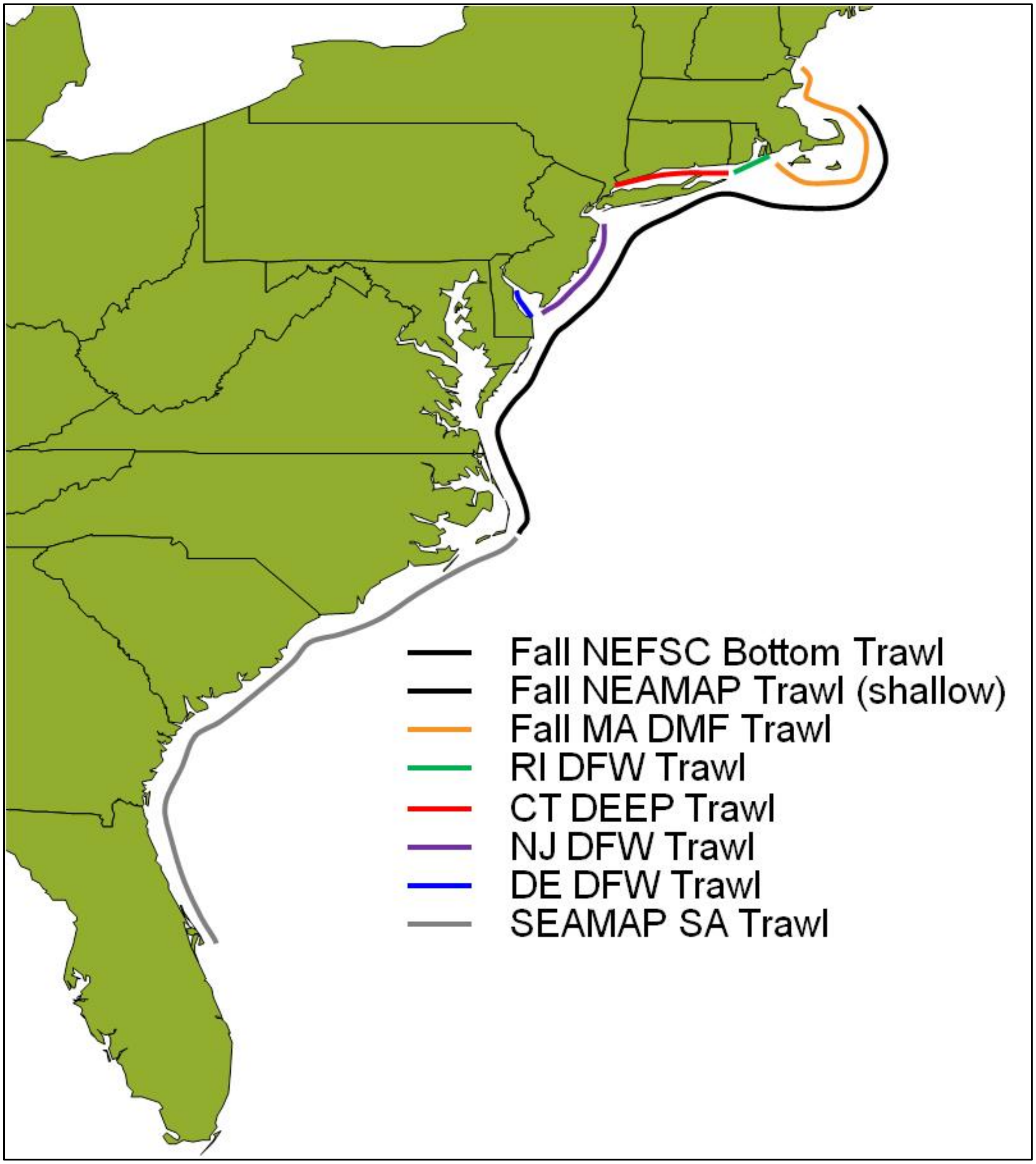


Figure 2.4. Approximate linear coverage of abundance indices recommended for the Atlantic stock of *Mustelus canis* by the Index Working Group of the SEDAR 39 Data Workshop (see SEDAR 39 Data Workshop report). The Fall NEAMAP Trawl survey mirrors the spatial range of the Fall NEFSC Bottom Trawl survey, but in shallower waters.

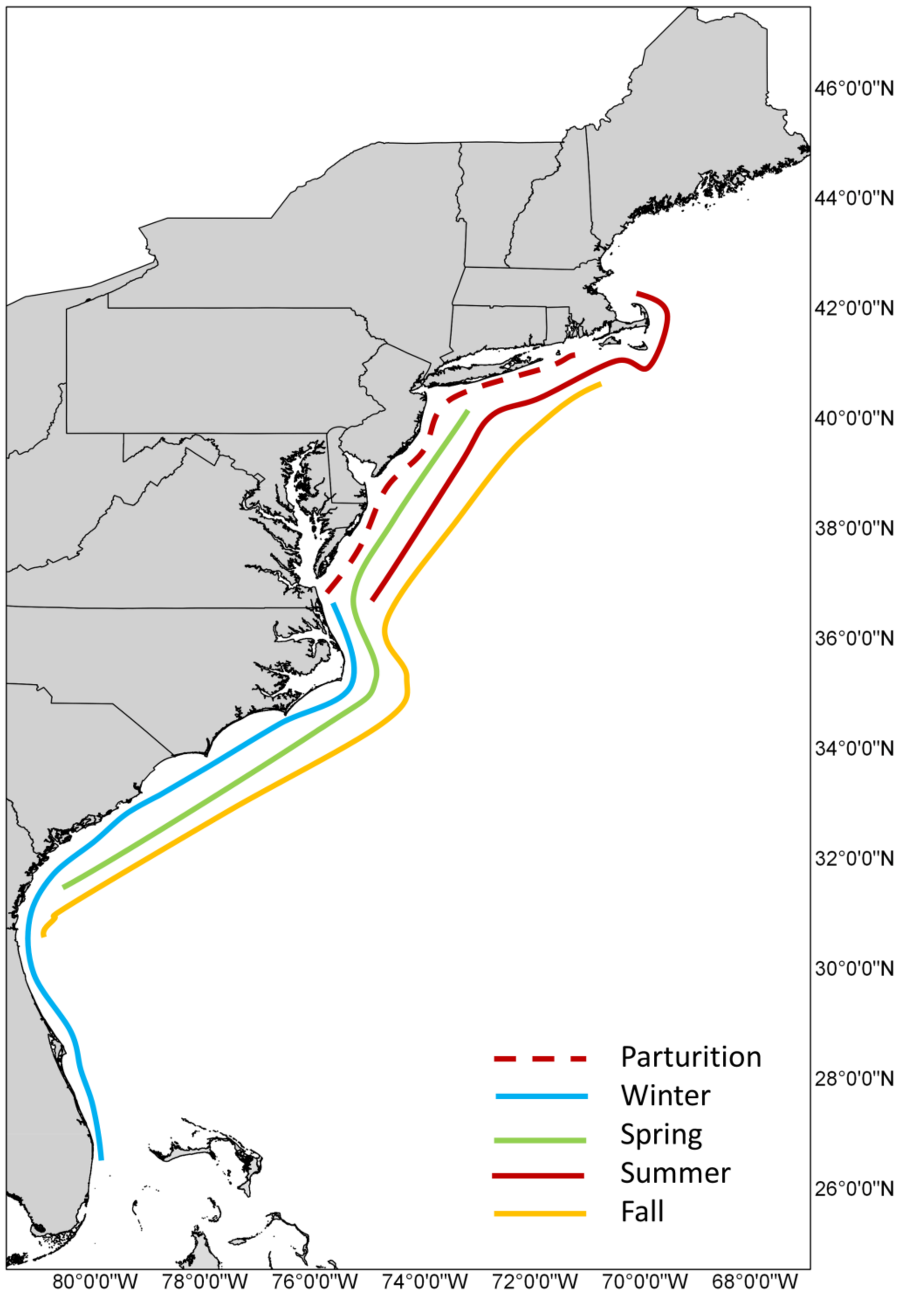


Figure 2.5. Approximate seasonal distribution pattern of *Mustelus canis* along the east coast of the United States obtained from the SEDAR 39 Data Workshop report (see SEDAR39-DW28). Winter (Blue) is the distribution from December to February. Spring (Green) is the distribution from March through May. Summer (Red) is the distribution from June through August. Fall (Orange) is the distribution from September through November. X and y axes represent degrees west longitude and degrees north latitude, respectively.

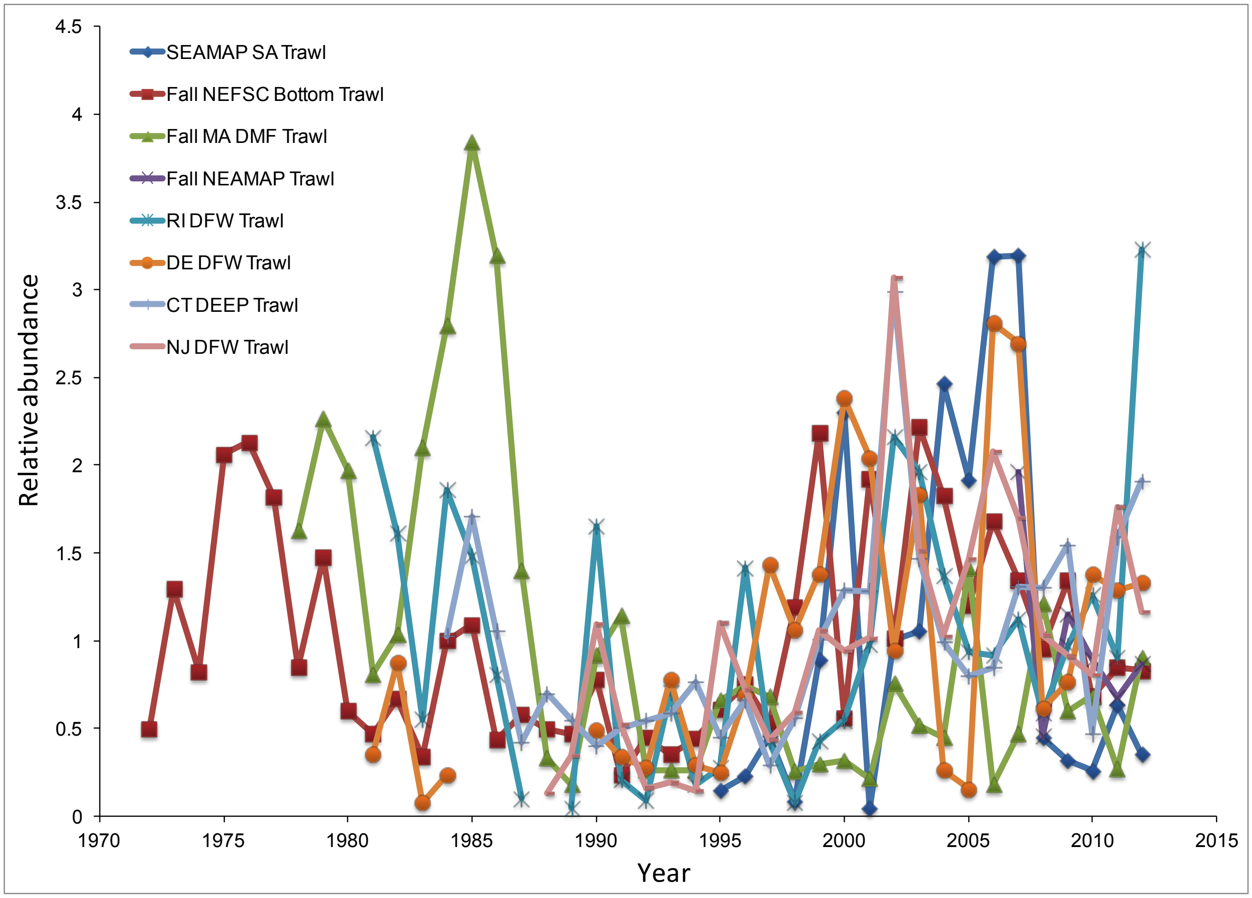


Figure 2.6. Plot of mean annual indices of relative abundance for each time series recommended for the Atlantic stock of *Mustelus canis* by the Index Working Group of the Data Workshop (see SEDAR 39 Data Workshop report). For each index, values were converted to a common scale for plotting purposes by dividing the mean annual values for a time series by the average of all annual values for that time series. For the RI [DEM] DFW and DE DFW trawl surveys only the 1981-2012 time series were plotted.

Appendix 2.A. *Preliminary parameter values and the approximate shape of the selectivity at age curve obtained externally of the stock assessment model*

Preliminary parameter values and the approximate shape for selectivity at age were obtained externally of the stock assessment model as in previous HMS shark stock assessments (NMFS 2012, NMFS 2013a, 2013b). Available length-frequency information from animals caught in scientific observer programs, recreational fishery surveys, and multiple fishery-independent surveys was used to generate age-frequency distributions. The simplest way to obtain an age-frequency distribution from a length-frequency distribution is to back-transform length into age through a growth curve (in the present case the von Bertalanffy function) (e.g., NMFS 2013a, 2013b). This approach was adopted here bearing in mind that it has several biases, among them that 1) any observed length > L_∞ must be eliminated or arbitrarily assigned to older ages and 2) when an observed length approaches L_∞, it is mathematically allocated to ages above those attainable by aged fish within the stock, yielding in some cases unreasonably old ages. The next way to obtain an age-frequency distribution from a length-frequency distribution is an age-length key (e.g., NMFS 2012), an approach that also has biases and whose main assumption is that age can be estimated from length using information contained in a previously aged sample from the population. Based in part on recommendations from previous peer reviews, it was decided that age frequencies be estimated by back-transforming from the von Bertalanffy growth function.

The age-frequency distributions thus obtained were then used to estimate selectivity curves externally to the stock assessment model as in previous HMS shark stock assessments (NMFS 2012, NMFS 2013a, 2013b). The derivation of selectivities from age-frequency distributions was done under the following assumptions. With only natural mortality (M) operating, one would expect an age-frequency histogram to decline with age. However, with both M and fishing mortality (F) operating, what is observed instead is an increase in the age frequency that reflects the increase in selectivity with age up to a “fully selected” age. Beyond the “fully selected” age, all subsequent ages are expected to consistently decline because they all experience (approximately) the same F and M. The fully selected age is thus determined by looking at the age-frequency distribution and identifying the “fulcrum” or modal age class, where younger ages show an increasing frequency and all subsequent ages decrease in frequency. The specific algorithm for deriving selectivities is detailed below. Based on the above, selectivity curves were approximated by eye externally to the stock assessment model for each fleet and survey in the proposed stock assessment base model configuration using a double normal equation. Parameter values for the double normal selectivity function were obtained using the MS Excel file SELEX-24.xls (Methot 2013; e.g. see text excerpted below).

Algorithm used to obtain preliminary selectivity at age externally of the stock assessment model

1. Obtain age frequencies.
2. Calculate the normalized ratio of the observed proportion captured at each age to the expected proportion captured at each age.
2.1. Identify age of full selectivity—You should expect to see the age frequency bar chart increase with age to a modal age (*age_full*), after which it begins to decline again. One can assume that *age_full* is the age which is fully selected—.
2.2. Calculate the observed proportion at age as Obs[prop.CAA] = freq(age)/Total_samples.
2.3. Take the natural log of observed proportion at age, plot age against it, and fit a trend line through the fully selected ages.
2.4. Use the fitted trend line to predict expected proportion at age, where E[prop.CAA]=exp(trend line).
2.5. Use the ratio of Obs[prop.CAA]/E[prop.CAA] to estimate the non-fully selected ages (i.e. selectivity of ages < *age_full*).
2.6. Normalize the column of Obs/Exp by dividing by the ratio value for *age_full* (this will scale ages so that the maximum selectivity will be 1 for *age_full*).
2.7. The age frequency for ages > *age_full* should decline as a result of natural mortality alone. 2.8. If natural mortality is relatively constant for those ages, this should be a linear decline when you look at the log(Obs[prop.CAA]).
2.9. If that decline departs severely from a linear trend, it may be that true selectivity is dome-shaped; Also, you may know because of gear characteristics that selectivity is lower for older animals—In this instance, a functional form for selectivity (e.g. double exponential) could be estimated to capture the decline in selectivity for the older animals—.
3. Fit a selectivity curve by minimizing the sum of squared residuals of the expected value and the normalized Obs/Exp value or fit the curve by eye by manipulating parameter values to ensure coverage of all ages represented in the sample.

Implementation of the double normal selectivity function in Stock Synthesis

The double normal selectivity function parameters are described below (excerpted from the user manual for Stock Synthesis; Methot 2013):

"…

9.3.19 Selectivity Details

…

Pattern 24 (recommended double normal).
See spreadsheet SELEX-24.xls

p1 – PEAK: beginning size for the plateau (in cm)
p2 – TOP: width of plateau, as logistic between PEAK and MAXLEN
p3 – ASC-WIDTH: parameter value is ln(width)
p4 – DESC-WIDTH: parameter value is ln(width)
p5 – INIT: selectivity at first bin, as logistic between 0 and 1.
p6 – FINAL: selectivity at last bin, as logistic between 0 and 1. (for pattern #24)

…

With SS_v3's separation of the population bin structure from the data bin structure, the interpretation of parameter p5 needed to change. Now, p5 refers to selex at the first DATA size bin and selex declines below that size according to (L/Lref)^2. Other recent changes include:

For the initial selectivity parameter (#5)

-999 or –1000: ignore the initial selectivity algorithm and simply decay the small fish selectivity according to P3,

< -1000: ignore the initial selectivity algorithm as above and then set selectivity equal to 1.0e-06 for size bins 1 through bin = -1001 –value. So a value of –1003 would set selectivity to a nil level for bins 1 through 2 and begin using the modeled selectivity in bin 3.

For the final selectivity parameter (#6),

-999 or –1000: ignore the final selectivity algorithm and simply decay the large fish selectivity according to parameter #4,

<-1000: set selectivity constant for bins greater than bin number = -1000 – value.

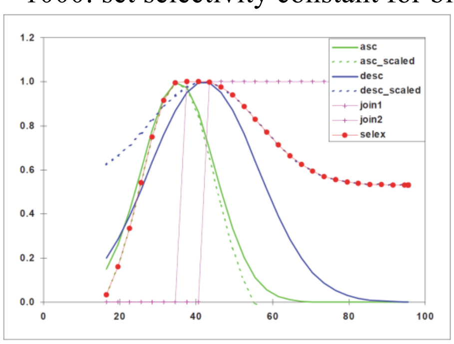


Figure 1 Selectivity pattern 24, double normal, showing sub-functions and steep logistic joiners

…

2.3 Auxiliary Files

…

2. *SELEX24_dbl_normal.XLS*:
    a. This excel file is used to show the shape of a double normal selectivity (option number 20 for age-based and 24 for length-based selectivity) given user-selected parameter values.
    b. Instructions are noted in the XLS file but, to summarize
        i. Users should only change entries in a yellow box.

ii. Parameter values are changed manually or using sliders, depending on the value of cell I5.

c. It is recommend that users select plausible starting values for double-normal selectivity options, especially when estimating all 6 parameters

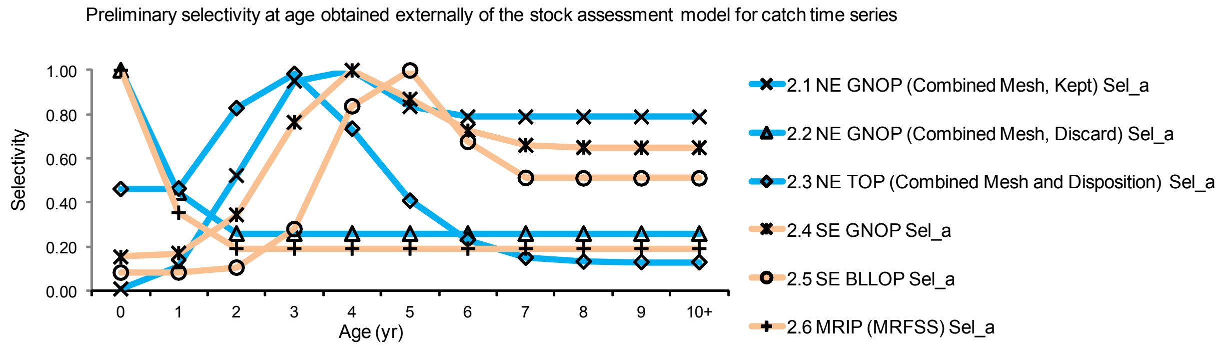
d. Please note that the XLS does NOT show the impact of setting parameters 5 or 6 to "-999". In SS3, this allows the value of selectivity at the initial and final age or length to be determined by the shape of the double-normal arising from parameters 1-4, rather than forcing the selectivity at the initial and final age or length to be estimated separately using the value of parameters 5 and 6.

…"

Table 2.A.1. Preliminary parameter values for selectivity at age obtained externally of the stock assessment model from the available length composition data associated with each time series of catch (fleets F1 – F6) and each index of abundance (surveys S1 – S8) included in the proposed base model configuration.

Series	Associated length data source	PEAK	TOP	ASC-WIDTH	DSC-WIDTH	INIT	FINAL
F1	2.1 NE GNOP (Combined Mesh, Kept)	3.35	-2.76	0.88	-1.00	-4.82	1.31
F2	2.2 NE GNOP (Combined Mesh, Discard)	0.09	-6.00	7.91	-0.85	9.00	-1.05
F3	2.3 NE TOP (Combined Mesh, Combined Disposition)	2.48	-5.51	-1.00	1.63	-0.16	-1.91
NA[1]	2.4 SE GNOP	3.80	-6.00	0.66	0.99	-1.71	0.61
F4	2.5 SE BLLOP	4.63	-3.46	0.55	-0.48	-2.41	0.04
F5 [2]	NA						
F6	2.6 MRIP	0.09	-6.00	-1.00	-1.00	9.00	-1.44
S1	1.1 NEFSC Fall Trawl-N	3.15	-4.51	0.13	2.85	-2.14	1.05
S2	1.2 NEAMAP Fall Trawl	0.09	-6.00	5.37	-1.00	9.00	-1.36
S3	1.3 MA DMF Fall Trawl	0.09	-6.00	5.37	-1.00	9.00	-0.55
S4	1.4 RI DEM Seas Trawl	2.85	-6.00	-0.20	1.74	-0.55	-4.93
S5	1.5 CT DEEP Trawl	3.64	-5.42	0.68	0.41	-1.64	0.89
S6	1.6 DE Trawl	0.09	-6.00	4.09	2.07	9.00	-4.34
S7	1.7 NJ DFW Trawl	0.09	-6.00	5.37	2.42	9.00	-0.73
S8	1.8 SEAMAP-SA Trawl	0.09	-6.00	0.21	-1.00	9.00	-1.36

[1] Associated length data were not representative of any catch time series used in the proposed base model structure.
[2] Associated length data were not available for fleet 5 (F5).



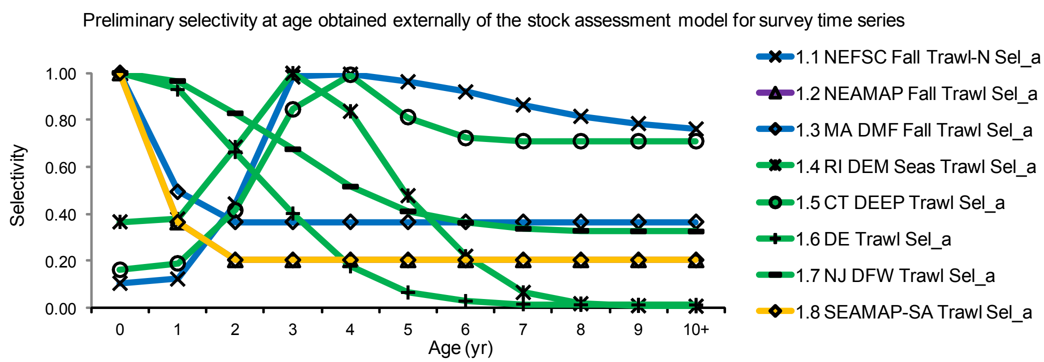


Figure 2.A.1. Preliminary selectivity at age obtained externally of the stock assessment model for each aggregated catch time series (fleets F1 – F6; top panel) and each index of abundance (surveys S1 – S8; lower panel) proposed for use in the Atlantic stock of *Mustelus canis* base model.

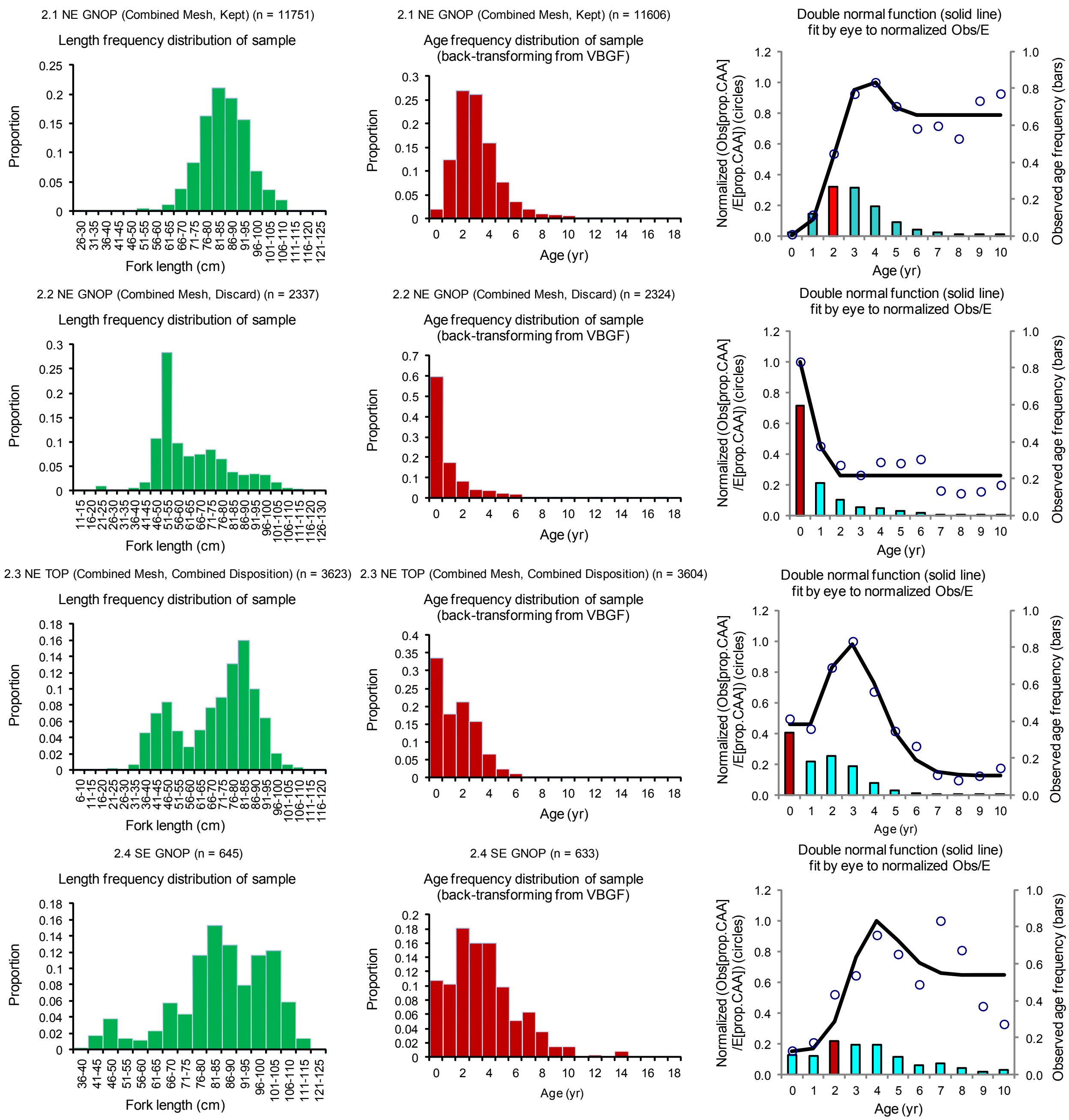


Figure 2.A.2. Preliminary selectivity curves obtained externally to stock assessment model. Length composition data reviewed for use in the Atlantic stock of *Mustelus canis* base model (**Tables 2.3 and 2.4)** were associated with each aggregated catch time series (fleets F1 – F6) and each index of abundance (surveys S1 – S8) proposed for use in the Atlantic stock of *Mustelus canis* base model (**Table 2.5**); Age-frequency data (middle panel) were obtained by back-transforming the available length frequency data (left panel) through the sex-specific von Bertalanffy growth equation obtained during the SEDAR 39 Data Workshop. Length frequency data were limited to years used in the proposed base model configuration (1981 – 2012). Selectivity at age (solid line in right panel) was modeled with a double normal selectivity function fit by eye to the normalized ratio of the observed to expected proportion captured at each age (Obs[prop.CAA]/E[prop.CAA]) (open circles in right panel). The assumed age of full selectivity is identified with a red bar in right panel.

Figure 2.A.2. Continued.

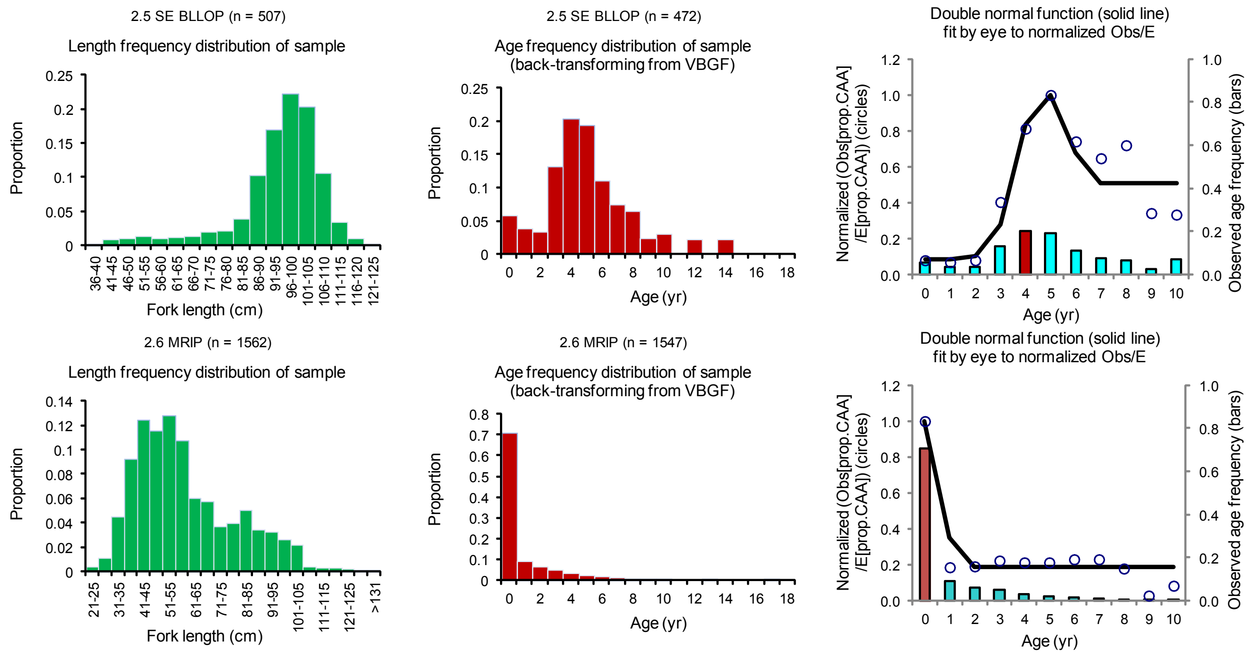


Figure 2.A.2. Continued.

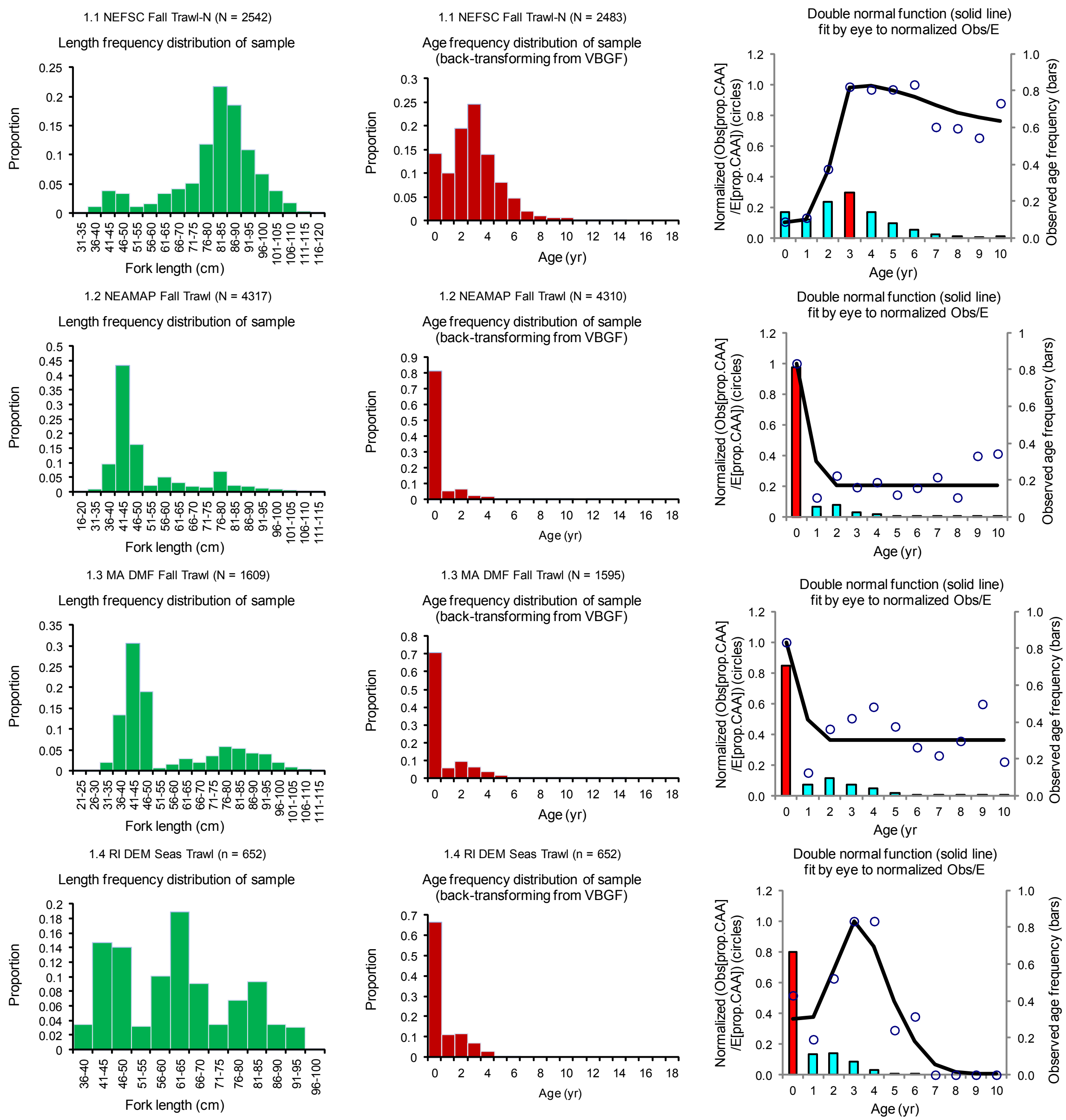
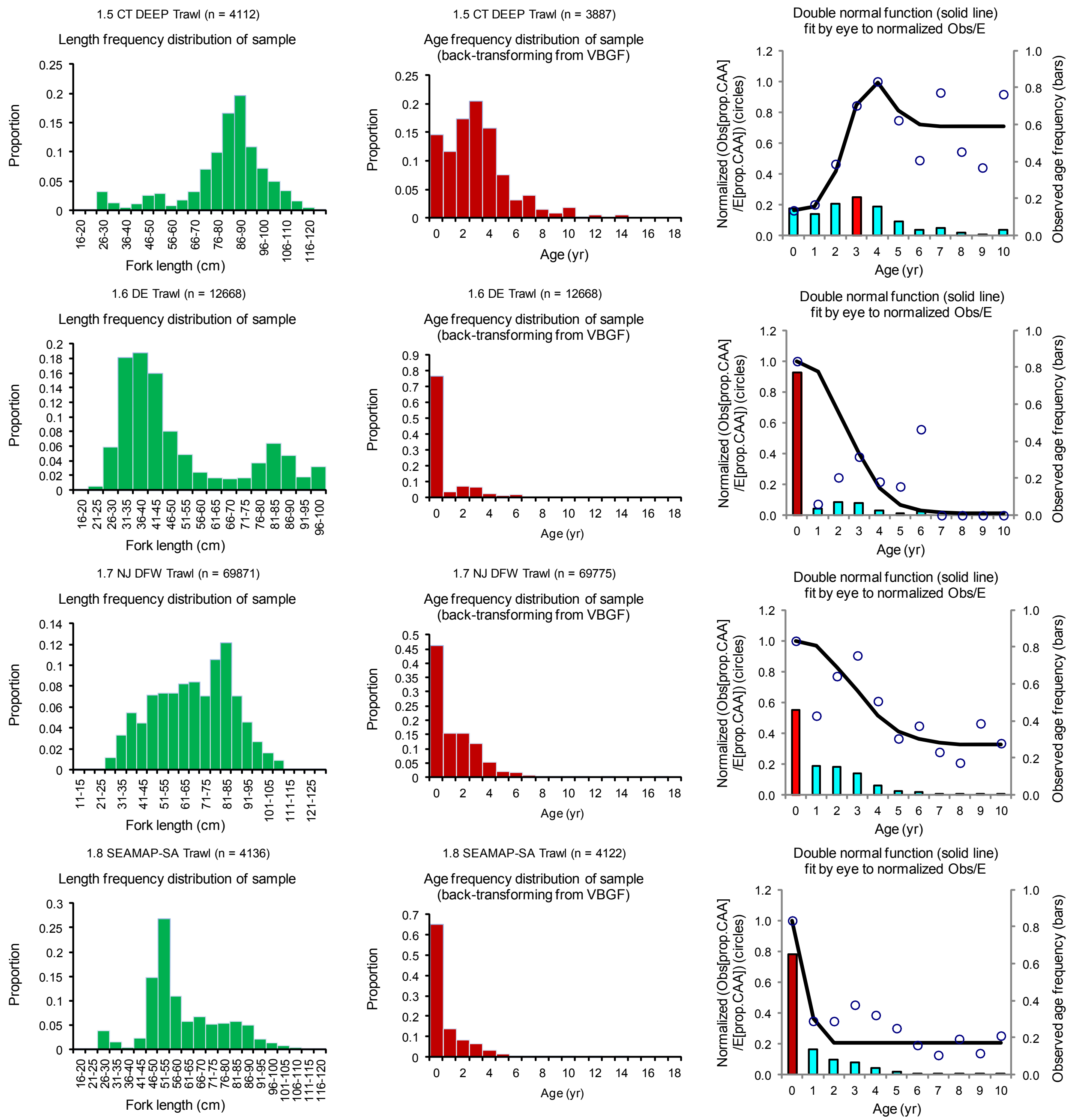


Figure 2.A.2. Continued.



***Appendix 2.B**. Summary of recommended life history parameters for Mustelus canis in the Atlantic Ocean obtained from the SEDAR 39 Data Workshop report.*

Summary of *Mustelus canis* -- Biological Inputs for 2014 Assessment

Pupping month	May	SEDAR39-RD01, SEDAR39-DW31
Growth parameters	Male | Female | Combined	
L_∞ (cm STL)	105.17 | 123.57 | 123.54	SEDAR39-RD02
k	0.440 | 0.292 | 0.254	SEDAR39-RD02
t_o	-1.52 | -1.94 | -2.25	SEDAR39-RD02
Maximum observed age (years)	16 female, 10 male	SEDAR39-RD02, SEDAR39-DW31
Sample size	894 (531 female, 363 male)	SEDAR39-RD02, SEDAR39-DW31
Length-weight relationships	Combined: FL=1.063(PCL) + 1.229 r^2=1.0 (n=253)	SEDAR39-DW31
FL in cm	Combined: FL=0.884(STL) + 1.5579 r^2=1.0 (n=269)	SEDAR39-DW31
	Combined: FL = 0.8827(TL) -0.2438 r^2=0.79 (n=23)	SEDAR39-DW31
WT (kg)	Female: WT = (6.0*10^-6)*$FL^{3.0084}$ Male: WT = (1.0*10^-5)*$FL^{2.8076}$	SEDAR39-DW31
Size at Maturity	Males 85.4 cm STL, females 102.3 cm STL	SEDAR39-RD01, SEDAR39-DW31
Age at maturity (years)	males 2.5, females 4.4	SEDAR39-RD01, SEDAR39-DW31
Reproductive cycle	Annual (pupping in May)	SEDAR39-RD01, SEDAR39-DW31
Fecundity	Brood size = 0.239(STL)-18.03 mean = 9.53 (range = 3-18); mean = 8.28 (range = 1-20) Brood size = $42.47(1 - e^{-0.496(age)}) - 31.31$	SEDAR39-RD01, SEDAR39-DW31
Gestation	11 months	SEDAR39-RD01, SEDAR39-DW31
Sex-ratio	1:1	SEDAR39-RD01, SEDAR39-DW31
Stock structure	Single stock	SEDAR39-DW20

3. STOCK ASSESSMENT MODEL – STOCK SYNTHESIS

Only one analytical approach was implemented in this assessment of the Atlantic stock of *Mustelus canis*. The approach used a length-based age-structured statistical model (Stock Synthesis; Methot and Wetzel 2013; e.g., Wetzel and Punt 2011a, 2011b). A second approach was evaluated using a less complex analytical approach based on a state-space Bayesian surplus production model (SSSPM; Meyer and Millar (1999); see also HMS Gulf of Mexico Smoothhound complex report). However, due to time constraints, the SSSPM model was not implemented in the final assessment. Also, because this assessment was conducted with Stock Synthesis, the stock assessment methods and results were formatted following those in a recent SEDAR assessment implemented with Stock Synthesis (SEDAR 38 Stock Assessment Report for South Atlantic King Mackerel).

3.1. OVERVIEW

The assessment model was implemented in Stock Synthesis version 3.21d (SS3) (Methot 2011). A more recent version of Stock Synthesis (3.24s) is currently available (Methot 2013). However, the reference materials for the two versions appeared to be very similar for the features implemented in this assessment. Consequently, due to both time constraints and the apparent similarity of the model versions for the features implemented in this assessment, the SS3 model was not updated to version 3.24s for this assessment.

SS3 (v. 3.21d) was implemented here as a length-based age-structured stock assessment model (Methot and Wetzel 2013; e.g., Wetzel and Punt 2011a, 2011b). SS3 utilizes an integrated modeling approach (Maunder and Punt 2013) to take advantage of the many data sources available for the Atlantic stock of *Mustelus canis*. An advantage of the integrated modeling approach is that the development of statistical methods that combine several sources of information into a single analysis allows for consistency in assumptions and permits the uncertainty associated with each data source to be propagated to final model outputs (Maunder and Punt 2013).

This is the first HMS shark assessment conducted within the SEDAR process to utilize the Stock Synthesis modeling framework. Previous HMS shark assessments conducted within the SEDAR process used a State Space Age Structured Production Model (SSASPM). It is important when transitioning between modeling platforms to identify the potential impacts of differences in modeling approaches on assessment outcomes. Consequently, an attempt was made in this assessment to implement many of the features previously implemented in HMS shark assessments conducted with SSASPM in order to identify and evaluate the potential impacts of differences in modeling approaches on assessment outcomes. Consequently, spawning stock fecundity (SSF), natural mortality (*M*), and the steepness (*h*) of the Beverton-Holt stock-recruitment relationship were implemented in this assessment using the same methods as in previous HMS shark assessments conducted with SSASPM (NMFS 2012, 2013a, 2013b).

Previous HMS shark assessments conducted with SSASPM also derived selectivity at age externally of the stock assessment model (NMFS 2012, 2013a, 2013b). Consequently, the same methods were implemented in this assessment to obtain preliminary parameter values and the approximate shape of the selectivity curve as described in Section 2 and **Appendix 2.A**. The previous approach for modeling selectivities was then extended in this assessment by estimating some selectivity parameters within SS3 while maintaining the general shape of the selectivity curve obtained from the externally derived selectivity as described below in Section 3 and **Appendix 4.A**.

Final selectivity patterns used in this assessment model were obtained using the algorithm described in **Appendix 4.A.** Using the algorithm described in **Appendix 4.A**, asymptotic selectivity (Sel-1; modeled with a simple logistic function at length) was obtained for the main targeted fishery (fleet F1 – NE Gillnet Kept). However, based on Assessment Panel recommendations, a dome-shaped functional form (Sel-2; modeled with a double logistic function at length) was also evaluated in this assessment as an alternative functional form of selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept). This resulted in two alternative base model configurations in the current assessment based on the alternative functional forms of selectivity (Sel-1 and Sel-2) evaluated for the main targeted fishery (fleet F1 – NE Gillnet Kept).

Based on SEDAR 39 Assessment Panel recommendations, several model diagnostics were also evaluated to compare model fits to data between the two alternative base model configurations (Sel-1 and Sel-2) as follows: 1) Akaike's information criterion (AIC); 2) the root mean squared error (RMSE); and 3) a Kolmogorov-Smirnov (K-S) test. Methods used to implement the diagnostics are described in Section 3 and results of the diagnostics are presented in Section 4.

3.2. DATA SOURCES

The catch streams, indices of abundance, and life history used in this assessment were obtained from the SEDAR 39 Data Workshop report as described in Section 2. Total catches of *Mustelus canis* in the Atlantic Ocean (in lb whole weight) were obtained from the Data Workshop (**Figure 2.1**), updated as described in Section 2 (**Table 2.1**) and aggregated into six fleets (in mt whole weight) as described in Section 2 (**Table 2.2**). Aggregated catch data (mt whole weight) obtained during the years 1981 – 2012 (**Table 2.2**) were input in the base model configurations. Aggregated catch data (mt whole weight) obtained during the years 1972 – 1980 (**Table 2.2**) were used in sensitivity analyses described below. Indices of relative abundance and the associated annual coefficients of variation (CVs) for each index were obtained from the Data Workshop (**Figures 2.4 and 2.6**) and updated as described in Section 2 (**Table 2.6**). Indices of relative abundance and the associated CVs obtained during the years 1981 – 2012 (**Table 2.6**) were input in the base model configurations. Indices of relative abundance and the associated CVs obtained during the years 1972 – 1980, and some modified time series for the years 1972 – 2012, (**Table 2.6**) were used in sensitivity analyses described below. Life history data were obtained from the SEDAR 39 Data Workshop report for input into both the base model configurations (**Tables 2.8 – 2.10**) and sensitivity analyses (**Tables 2.11 and 2.12**) as described in Section 2.

Length composition data used in this assessment were obtained for *Mustelus canis* in the northwest Atlantic from observed catches and accepted CPUE indices submitted during the SEDAR 39 Data Workshop, reviewed during the SEDAR 39 Assessment Webinars, and summarized in Courtney (2014) (**Tables 2.3 and 2.4; Figures 2.2 and 2.3**). Length composition data were associated with each aggregated time series of catch (fleets F1 – F6) and each index of relative abundance (surveys S1 – S8) based on a review of the available length composition data (Courtney 2014) as summarized in Section 2 (**Table 2.5**).

3.3. BASE MODEL CONFIGURATION AND EQUATIONS

The proposed base model configuration for the Atlantic population of *Mustelus canis* is a single stock that encompasses all U.S. waters of the northwest Atlantic (**Figures 2.4 and 2.5**). Based on the Data Workshop recommendations, the end year of the assessment data included in the model was 2012, and the start year of the base model configurations was 1981, based on the availability of catch data. Based on the Data Workshop recommendations, sensitivity analyses were conducted with extrapolated catches from 1972 to 1980.

3.3.1. Life History

A two sex model was implemented to account for sexually dimorphic growth. Maximum age in the assessment model was set at 18 years for both sexes in order to accommodate the uncertainty in the range in maximum age identified in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean (16 years female, 10 years male). Recruitment was assumed to occur at age-0 in order to accommodate the high proportions of sharks captured at small sizes in many of the length composition data sources (Courtney 2014) (**Tables 2.3 and 2.4; Figures 2.2 and 2.3**).

3.3.2. Length at Age and Weight at Length

Growth in length at age was assumed to follow a von Bertalanffy growth (VBG) relationship. VBG parameters recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean were converted here to cm fork length (cm FL) separately for females and males as described above (see Section 2; **Table 2.8**). Length at age-0 (L_{Amin} cm FL) and length at age-18 (L_{Amax} cm FL) along with the VBG growth coefficient (k) were then input in the assessment base model configurations separately for males and females. The distribution of mean length at each age was modeled as a normal distribution and the CV in mean length at age was modeled as a linear function of length. In the base model configurations, the CVs were fixed at L_{Amin} (0.15) and at L_{Amax} (0.12). Sex-specific fixed length-weight relationships recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean (see Section 2; **Table 2.8**) were input in the base model configurations separately for males and females to convert body length (cm FL) to body weight (kg).

In SS3, fish recruit at the real age of 0.0 at the beginning of their birth season, with a body size equal to the lower edge of the first population size bin (fixed here at 30 cm FL). Fish then grow linearly until they reach the real age associated with L_{Amin} (fixed here at age-0) and have a size equal to the parameter value for L_{Amin} (fixed here at 46.96 and 48.84 cm FL for males and females, respectively; **Table 2.8)**. As fish continue to age, they grow according to the VBG equation (implemented here separately for males and females, as described above). The growth curve is calibrated to go through the size equal to the parameter value for L_{Amax} (fixed here at 94.51 and 110.46 cm FL for males and females, respectively) when they reach the age associated with L_{Amax} (fixed here at age-18) (**Table 2.8)**.

We noted that, in this assessment, the VBG models recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean, and implemented as described above, resulted in a relatively large length at age-0 (L_{Amin}) for males and females (46.94 and 48.84 cm FL, respectively), when compared to the approximate size at birth (c. 32.5 cm FL) obtained from the scientific literature (see SEDAR39-RD01). Consequently, an attempt was made to account for the approximate size at birth (c. 32.5 cm FL) obtained from the scientific literature (see SEDAR39-RD01) by fixing the lower edge of the first population size bin equal to 30 cm FL in the assessment model

3.3.3. Spawning Stock Fecundity (SSF)

Previous HMS shark assessments conducted with SSASPM utilized spawning stock fecundity (SSF), calculated as the sum of numbers at age times pup production at age, as the measure of spawning output in the stock-recruitment relationship (NMFS 2012, 2013a, 2013b). Consequently, the same approach was implemented in this assessment. The life history data recommended in the SEDAR 39 Data Workshop report for female *Mustelus canis* in the Atlantic Ocean (**Appendix 2.B**) were used as described above (see Section 2; **Table 2.9**) to compute the average annual number of pups (male and female) produced by each female at age. The resulting age specific vector of fecundity was input in the assessment base model configurations along with the assumed fraction female (fixed at 0.5). The resulting measure of spawning output in the stock-recruitment relationship was spawning stock fecundity, SSF, calculated here as the sum of female numbers at age multiplied by pup production (males and females) at age. SSF was obtained in the base model configuration at the beginning of each calendar year and used as the basis for total annual recruitment obtained from the stock-recruitment relationship.

*3.3.4. Natural Mortality (*M*)*

Previous HMS shark assessments conducted with SSASPM calculated natural mortality, M, externally of the stock assessment model (NMFS 2012, 2013a, 2013b). Consequently, the same approach was implemented in this assessment. For the base model configurations, values of M at age were estimated from four life history invariant methods (Hoenig 1983; Chen and Watanabe 1989; Peterson and Wroblewski 1984; and Lorenzen 1996) as described above in Section 2. The maximum value at age of the four methods was then used to approximate a maximum compensatory response (see Section 2; **Table 2.10**). The resulting age specific vector of natural mortality was then input in the assessment base model configurations for both males and females. Similar methods were used to calculate M for the high and low productivity scenarios (see Section 2; **Tables 2.11 and 2.12**).

*3.3.5. Stock-recruitment Model and Steepness (*h*)*

Previous HMS shark assessments conducted with SSASPM utilized a Beverton-Holt stock-recruitment relationship parameterized in terms of the steepness of the stock-recruitment relationship (NMFS 2012, 2013a, 2013b). Consequently, the same approach was used in this assessment, and a Beverton-Holt stock-recruitment model was implemented and parameterized as described below. In SS3, the Beverton-Holt stock-recruitment model is parameterized with three parameters, the log of unexploited equilibrium recruitment (R_0), the steepness (h) parameter that describes the fraction of the unexploited recruits produced at 20% of the equilibrium spawning biomass level, and a parameter representing the standard deviation in recruitment (σ_R) (Methot and Wetzel 2013; e.g., Wetzel and Punt 2011a, 2011b). Only one stock-recruitment parameter, $\ln(R_0)$, was estimated in this assessment. The remaining parameters of the Beverton-Holt stock-recruitment model were obtained externally of the stock assessment model as described below.

Previous HMS shark assessments conducted with SSASPM derived a prior for the steepness, h, of the Beverton-Holt stock-recruitment relationship externally of the stock assessment model (NMFS 2012, 2013a, 2013b). Consequently, the same approach was implemented in this assessment, as described in Section 2 (**Table 2.10**). The prior for steepness obtained using this approach for the base model configurations (h = 0.54) was implemented in this assessment as a fixed value. Similarly, priors for steepness were obtained using this approach for the low (h = 0.49) and high (h = 0.62) productivity scenarios (see Section 2; **Tables 2.11 and 2.12**) and implemented in sensitivity analyses described below as fixed values.

The initial value of the parameter representing the standard deviation in recruitment, σ_R, was input as a fixed value (0.4), and the final value was obtained by iteratively re-weighting σ_R based on the RMSE of recruitment residuals obtained from SS3 output for each model configuration. This approach was implemented separately for the two alternatives proposed for the base assessment model (Sel-1 and Sel-2) and resulted in two values of σ_R (0.73 and 0.62, respectively).

Annual deviations from the stock-recruit function were estimated for the time period 1981 – 2009 based on the availability of length composition data used in the stock assessment base model configurations. Over this time period, recruitment deviations were assumed to sum to zero on the log scale. Because recruitment deviations are estimated on the log scale in Stock Synthesis, the expected recruitments require a bias adjustment so that the resulting recruitment level on the standard scale is mean unbiased. For the base model configurations, recruitment deviations were implemented with full bias adjustment applied during the years 1985 – 2009. The years chosen for full bias adjustment, and the maximum bias adjustment parameter values were obtained from SS3 output separately for each base model configuration with the program r4ss (Taylor et al 2014) as follows:

1. Lognormal annual recruitment deviations are estimated internally in SS3 from the Beverton-Holt stock-recruitment relationship (Methot 2013; Methot and Wetzel 2013; e.g., Methot and Taylor 2011) as $R_y^* = R_y e^{\hat{r}_y - b_y \sigma_R^2/2}$. The parameter R_y is the mean value of recruitment, calculated as a Beverton-Holt function of spawning stock fecundity. The parameter $\hat{r}_y$ is the estimated recruitment deviation in year y, which is assumed to have a normal distribution, so that $\exp(r_y)$ is log normally distributed. The parameter σ_R is the standard deviation for recruitment in log space. The term $b_y \sigma_R^2/2$ is the bias adjustment (Methot and Taylor 2011), which is subtracted from the estimated recruitment deviation in year y.

2. The annual bias adjustment factor, b_y, and the years recommended for full bias adjustment were obtained from SS3 output for each model configuration with the program r4ss (Taylor et al 2014; e.g., see Methot 2013 citing Gertseva and Thorson 2013).
3. An examination of SS3 output in this assessment with the program r4ss under both of the alternatives proposed for the base assessment model configuration (Sel-1 and Sel-2) resulted in recommended full bias adjustment for the years 1985 – 2009.
4. Maximum bias adjustment recommendations range from 0 – 1. Values near 0 indicate that there is very little information in the data to estimate recruitment deviations. An examination SS3 output in this assessment with the program r4ss under both of the alternatives proposed for the base assessment model configuration (Sel-1 and Sel-2) indicated that there was little information in the data to estimate recruitment deviations prior to 1981 and after 2009. Consequently, early recruitment deviations (prior to 1981) were not estimated, and recruitment was set equal to the mean, R_y, for the years 2010 – 2012 for both of the alternatives proposed for the base assessment model configuration (Sel-1 and Sel-2).

3.3.6. Starting Conditions

Based on the Data Workshop recommendations, the start year of the base model configurations was set equal to 1981, and the base model configurations assumed virgin biomass in 1981. Based on the Data Workshop recommendations sensitivity analyses were also conducted for an alternative start year of 1972 utilizing reconstructed catches from 1972 – 1980, and the extended time series of relative abundance developed during the Data Workshop. The Data Workshop recommended sensitivity analyses assuming virgin biomass in 1972. However, the sensitivity analysis with a model start year in 1972 was implemented here with initial fishing mortalities estimated for some fleets because extrapolated catches were not zero for all fleets in 1972.

3.3.7. Definitions of Fleets and Indices of Abundance

Catch aggregation into fleets is described above (see Section 2; **Table 2.2**), and was based on a review of the available length composition data during the SEDAR 39 Assessment Webinars and summarized in Courtney (2014).

Eight indices of relative abundance recommended by the Index Working Group of the Data Workshop for the base model (**Table 2. 6**) were input in the base model configurations with inverse CV weighting. Indices were treated as relative abundance in SS3 and assumed to have log-normally distributed error. Inverse CV weighting was calculated from the annual CVs obtained for each index (**Table 2. 6**) as sqrt(ln(1+CV^2)), which are approximated by the CV. Indices of relative abundance were assumed to be proportional to available biomass at the middle of the calendar year, with constant catchability (*q*) (Methot and Wetzel 2013). The median unbiased analytical solution for *q* was accepted from SS3 for each index by setting *q* equal to a constant scaling factor (Methot 2011).

3.3.8. Length Composition Input

Length composition data reviewed for use in the Atlantic stock of *Mustelus canis* base model (**Tables 2.3 and 2.4)** were associated with each aggregated catch time series (fleets F1 – F6) and with each index of relative abundance (surveys S1 – S8) as described in Section 2 (**Table 2.5**). The association of length composition data with catch and survey data were based on a review of the available length composition data during the SEDAR 39 Assessment Webinars as described above (also see Courtney 2014).

The smallest data length bin in the assessment model was fixed at 30–40 cm FL. The remaining data length bins ranged from 40 cm FL to 110 cm FL in 5 cm bins. The largest length bin was a plus group. Population length bins in the assessment model were the same as the data length bins except that the largest population length bin was fixed at 110–120 cm FL.

The sample sizes for length composition data were iteratively re-weighted within SS3 based on the effective sample size estimated in SS3 (e.g., see Punt et al. 2014 citing the approach of McAllister and Ianelli 1997). Initial annual sample sizes input in the assessment model for length composition data associated with surveys S1and S3 were the annual numbers of positive tows for each survey obtained from the working document submitted with the respective indices (SEDAR 39-DW-24 Table 2 and SEDAR 39-DW-24 Table 6, respectively). The annual sample sizes input in the assessment model for the remainder of the length composition data sources were the numbers of sharks measured for length in each sample. The numbers of sharks measured for length for survey S2 were calculated based on sub-sampling expansion factors obtained from the working document submitted with the index for the same data source (SEDAR 39-WP-30). Annual length compositions were not included in the assessment from a data source if there were less than 30 sharks measured for length (either separately by sex, or for combined sex, depending upon which data were used in the assessment).

Time series	Input sample sizes	Notes
F1	Number of measured lengths	
F2	Number of measured lengths	
F3	Number of measured lengths	
F4	Number of measured lengths	
F5	NA	No length data
F6	Number of measured lengths	
S1	Number of positive tows	(SEDAR 39-DW-24 Table 2)
S2	Number of measured lengths – based on expansion factors from sub-sampling	(SEDAR 39-WP-30)
S3	Number of positive tows	(SEDAR 39-DW-24 Table 6)
S4	Number of measured lengths	
S5	Number of measured lengths	
S6	Number of measured lengths	
S7	Number of measured lengths	
S8	Number of measured lengths	

3.3.9. Selectivity Functions

The final selectivity patterns used in this assessment to model selectivity were obtained using the algorithm described in **Appendix 4.A (Table 4.1).** The preliminary shape of the selectivity curve for each length composition data source was identified externally of the stock assessment model (**Appendix 2.A**). Two alternative functional forms of selectivity (asymptotic-shaped and dome-shaped) were evaluated for length based selectivity of the main targeted fishery (fleet F1 – NE Gillnet Kept). This resulted in two alternative base model configurations in the current assessment based on the alternative functional forms of selectivity (Sel-1 and Sel-2) evaluated for the main targeted fishery (fleet F1 – NE Gillnet Kept) (**Table 4.1**).

The following diagnostics were evaluated to compare model fits to data between the two alternative base model configurations (Sel-1 and Sel-2): 1) Akaike's information criterion, AIC;

2) the root mean squared error, RMSE; and 3) a Kolmogorov-Smirnov, K-S, test. Methods used for each diagnostic are described below and results of the diagnostics are presented in Section 4.

3.3.9.1.AIC

Akaike's information criterion, AIC, was used to compare model fits to data given the number of estimated parameters (Akaike 1973; Burnham and Anderson 2002; e.g., Hilborn and Mangel 1997). AIC was used to compare model fits for the two alternative base assessment model configurations (Sel-1 and Sel-2). AIC was calculated here as: AIC = 2LL+2p (LL= negative natural log of the likelihood function at the maximum likelihood estimates and *p* is the number of estimated parameters. In this assessment, annual fishing mortality for each fleet was obtained in SS3 for all model configurations with a hybrid method that does a Pope's approximation to provide initial values for iterative adjustment of the continuous *F* values to closely approximate the observed catch (Methot 2013). Consequently, the annual fishing mortality coefficients calculated for each fleet are not true estimated parameters in this assessment and were not counted as part of *p* (e.g., Helu et al. 2000).

The AIC difference ($\Delta_i = \mathrm{AIC}_i - \mathrm{AIC}_{\min}$) was then used to evaluate relative differences in model fits to data (Burnham and Anderson 2002). Models with AIC differences greater than 10 have a substantially worse fit to the data than the model with $\mathrm{AIC}_{\min}$, given the number of parameters estimated in each model (Burnham and Anderson 2002).

3.3.9.2.RMSE

The root mean squared error, RMSE, of model residuals was used to compare model fit to the length composition data associated with each fleet (F1 – F6) and survey (S1 – S8) as defined in Section 2 (**Table 2.5**) under both alternative base model configurations (Sel-1 and Sel-2). The RMSE of model fits for length composition time series was obtained as

$\mathrm{RMSE}_{P_l} = \sqrt{\sum \left(P_{i,t,l} - \hat{P}_{i,t,l} \right)^2 / n}$. The parameter $P_{i,t,l}$ is the observed proportion for dataset *i* in year *t* at length bin *l*, $\hat{P}_{i,t,l}$ is the predicted proportion for dataset *i* in year *t* at length bin *l*, and *n* is the total sample size.

Similarly, the RMSE of model residuals was also used to compare each standardized abundance index (surveys S1 – S8) and was obtained as $\text{RMSE}_I = \sqrt{\frac{\sum_t \left[\ln\left(I_t / \hat{I}_t\right)\right]^2}{t}}$ (Methot 2000 their eq. 34; Methot and Wetzel 2013). The parameter I_t is the standardized abundance index in year *t*, and $\hat{I}_t$ is the expected abundance index in year *t* based on model fit to data. In each case, a lower RMSE indicates a better fit to the data (e.g., Brodziak and Ishimura 2011).

3.3.9.3. K-S Tests

In response to Assessment Panel recommendations, we examined the shape of the length frequency distribution associated with fleet F1 (**Table 2.5**, data source 2.1 NE GNOP Combined Mesh, Kept) relative to the shape of the length frequency distributions associated with other fleets and surveys used in this assessment (**Table 2.5**) in order to determine if relatively large sharks occurred in significantly higher proportions in any of the other data sources used in this assessment. The shape of the aggregate length frequency distribution associated with fleet F1 was compared to the shape of the aggregate length frequency distribution associated with each other fleet and survey used in the assessment with a Kolmogorov-Smirnov, K-S, two sample test statistic (e.g., Fryer 1998). For the K-S test, the aggregated length frequency data were obtained from each data source in **Table 2.5** either by sex or as combined sex, depending on how the length data were implemented in the assessment, and then converted to aggregate proportions at length for each data source. The K-S two-sample test statistic (*D*) was then calculated as the maximum absolute difference in the cumulative aggregate proportions at length between two data sources (Sokal and Rohlf 1995 their Box 13.9 p. 435; e.g., Fryer 1998). The critical value for the K-S test statistic (D_α) was obtained for alpha = 0.05 as

$D_\alpha = K_\alpha \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$, where $K_\alpha = \sqrt{\frac{1}{2}\left[-\ln\left(\frac{\alpha}{2}\right)\right]}$ (Sokal and Rohlf 1995 their Box 13.9 p. 435).

The sample size for each aggregated length composition was calculated here as the number of years of data multiplied by the number of length bins used in the Stock Synthesis model (16). If the test statistic, *D*, was greater than the critical value, D_α, then the shape of the two distributions differed at the alpha significance level. All calculations were performed in MS Excel.

3.4. ESTIMATED PARAMETERS

Estimated parameters along with their associated asymptotic standard errors, initial parameter values, minimum and maximum bounds, priors if any, and phase of estimation are provided in **Tables 4.2.a and 4.2.b**. A total of 50 parameters were estimated in the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the asymptotic-shaped functional form of length based selectivity (Sel-1) for the main targeted fishery (fleet F1 – NE Gillnet Kept) (**Table 4.2.a**). Estimated parameters included 29 recruitment deviations, 20 selectivity parameters, and 1 stock-recruitment parameter.

Similarly, a total of 52 parameters were estimated in the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the dome-shaped functional form of length based selectivity (Sel-2) for the main targeted fishery (fleet F1 – NE Gillnet Kept) (**Table 4.2.b**). Estimated parameters included 29 recruitment deviations, 22 selectivity parameters, and 1 stock-recruitment parameter. All parameters were estimated as described above.

Parameter estimation for ln(R_0) and selectivity utilized a normal prior with a large standard deviation and independent minimum and maximum boundary conditions for each parameter (**Tables 4.2.a and 4.2.b**). Parameters with a negative phase were fixed at their initial value. The soft bounds option in SS3 was utilized in all model configurations, which creates a weak symmetric beta penalty to keep parameters within bounds (Methot 2011).

Annual recruitment deviations from the stock-recruit function were estimated for the time period 1981 – 2009 based on the availability of length composition data used in the stock assessment base model configurations, as described above (see Section 3.3.2). Over this time period, recruitment deviations were assumed to sum to zero on the log scale. Because recruitment deviations are estimated on the log scale in Stock Synthesis, the expected recruitments require a bias adjustment so that the resulting recruitment level on the standard scale is mean unbiased. For the base model configurations, recruitment deviations were implemented with full bias adjustment applied during the years 1985 – 2009. The years chosen for full bias adjustment, and the maximum bias adjustment parameter values were obtained from

SS3 output separately for each base model configuration with the program r4ss (Taylor et al 2014), as described above (see Section 3.3.2).

As described above, annual fishing mortality coefficients (continuous *F*) for each fleet were obtained in this assessment with a hybrid method that does a Pope's approximation to provide initial values for iterative adjustment of the continuous *F* values to closely approximate the observed catch (Methot 2011). With the hybrid method, the final values are in terms of continuous *F*, and are specified as full parameters (Methot 2011). However, the annual fishing mortality coefficients are not considered to be estimated parameters for the purposed of AIC calculations.

3.5. MODEL CONVERGENCE AND DIAGNOSTICS

Model convergence was based on whether or not the Hessian, (i.e., the matrix of second derivatives of the likelihood with respect to the parameters) inverted. The model was assumed to have converged if the standard error of the parameter estimates could be derived from the inverted Hessian matrix. Other convergence diagnostics were also evaluated. Excessive CVs (StDev/Parm >> 50%) on estimated quantities were indicative of uncertainty in parameter estimates or assumed model structure. The correlation matrix was examined for highly correlated (> 0.95) and non-informative (< 0.01) parameters. Parameters estimated at a bound were a diagnostic for possible problems with data or the assumed model structure. Individual likelihood component fits were evaluated for CPUE, and length frequency. Fits to CPUE and patterns in Pearson's residuals of fits to length composition data were examined as diagnostics for problems with data or the assumed model structure. A suite of model diagnostics (AIC, RMSE, and K-S test) was also used to compare model fits between the two alternative base assessment model configurations as described above.

3.6. UNCERTAINTY AND MEASURES OF PRECISION

Uncertainty in parameter estimation was quantified by computing asymptotic standard errors for each estimated parameter (**Tables 4.2.a and 4.2.b**). Asymptotic standard errors are based upon the maximum likelihood estimates of parameter variances at the converged solution. Uncertainty in derived parameters was also quantified with their asymptotic standard errors. In SS3 asymptotic standard errors are obtained for derived quantities by including the derived parameters in the inverted Hessian matrix calculation.

Uncertainty in data inputs and model configuration was examined through the use of sensitivity analysis. Model sensitivity scenarios 1 – 4 were designed to evaluate model sensitivity to a plausible range of uncertainty in possible data inputs and model configurations. Model sensitivity scenarios 5 – 7 were designed to correspond to plausible states of nature, alternative to the base run.

Results of sensitivity analyses 1 – 7 are summarized with plots of the total likelihood component fits for CPUE and length composition (in likelihood units) along with plots of the fishing mortality and spawning stock fecundity relative to their values at MSY.

3.7. MODEL SENSITIVITIES

Methods used to implement each sensitivity scenario are described below.

3.7.1. Sensitivity Run 1: Selectivity

Model sensitivity to selectivity was evaluated with four model runs implemented as follows:

Model 1. Proposed Base (Sel-1): Asymptotic F1– simple logistic (2 parameters).
Model 2. Proposed Base (Sel-2): Dome-shaped F1 – double logistic (4 parameters).
Model 3. Externally derived selectivity for fleet F1 obtained as described in **Appendix 2.A** and selectivities for the remaining fleets and surveys obtained as described in **Appendix 4.A**.
Model 4. Externally derived selectivity for all fleets and surveys, analogous to methods used in previous HMS shark assessments conducted with SSASPM and obtained as described in **Appendix 2.A.**

Results are provided below for Model 1—Proposed Base (Sel-1)—, Model 2—Proposed Base (Sel-2) —, and Model 4—External Selectivity. Results from Model 3 were similar to those obtained for Model 1 and are not provided below.

3.7.2. Sensitivity Run 2: Model Start Year

Model sensitivity to the assumed start year of 1972 was evaluated separately for each proposed base model configuration (Sel-1 and Sel-2) with two model runs as follows:

Model 1. Proposed Base; Model start year 1981; Assume no catch prior to 1981; Assume equilibrium (unfished) conditions prior to 1981.
Model 2. Start Year 1972; Change model start year 1972; Include extrapolated catch from Data Workshop (1972 – 1980); Include longer term relative abundance indices from Data Workshop (1972 – 1980, and 1972 – 2012 as available); Include longer term time series of available length composition; Estimate equilibrium fishing mortality prior to 1972 for fleet F3 (**Table 2.2**) based on average annual extrapolated catch for fleet F3 from 1972 – 1980 (99.3 mt).

Results are provided below for Model 1—Proposed Base (under both Sel-1 and Sel-2)—, and Model 2—Start Year 1972 (under both Sel-1 and Sel-2).

3.7.3. Sensitivity Run 3: CPUE Ranks

Model sensitivity to CPUE ranks assigned at the Data Workshop was evaluated with four model runs as follows:

Model 1. Proposed Base:
CPUE weighting = inverse CV weighting;
Model 2. Ranked CPUE Alt-1:
CPUE weighting = (inverse CV weighting)*1/(survey rank);
Model 3. Ranked CPUE Alt-2:
CPUE weighting = (inverse CV weighting)*1/(survey rank), with 1/(survey rank) standardized to a sum of 1.0; and
Model 4. Ranked CPUE Alt-3:
CPUE weighting = (inverse CV weighting)*1/(survey rank), with 1/(survey rank) standardized to an average of 1.0.

Alternative CPUE weightings (Models 2 – 4) were implemented in SS3 as multiples of the inverse CV weighting used in the base model (Model 1). Three alternative weighting schemes (Models 2 – 4) were developed here to evaluate alternative methods for implementing the CPUE ranks assigned at the Data Workshop (see Section 2; **Table 2.7**) as follows:

Data source (SS3)	Survey name (SS3)	Fleet name (SS3)	Report (Data Workshop)	Recommended survey ranking (Data Workshop)	Ranks Alt-1; weight = 1/(survey ranking)	Ranks Alt-2; weights sum to 1.0)	Ranks Alt-3; average weight = 1.0)
7	NEFSC Fall Trawl-N	S1	SEDAR39-DW-24	1	1	1*(12/41)	1*(12/41)*8
8	NEAMAP Fall Trawl	S2	SEDAR39-DW-30	2	1/2	1/2*(12/41)	1/2*(12/41)*8
9	MA DMF Fall Trawl	S3	SEDAR39-DW-24	3	1/3	1/3*(12/41)	1/3*(12/41)*8
10	RI DEM Seas Trawl	S4	SEDAR39-DW-10	3	1/3	1/3*(12/41)	1/3*(12/41)*8
11	CT DEEP Trawl	S5	SEDAR39-DW-12	3	1/3	1/3*(12/41)	1/3*(12/41)*8
12	DE Trawl	S6	SEDAR39-DW-15	3	1/3	1/3*(12/41)	1/3*(12/41)*8
13	NJ DFW Trawl	S7	SEDAR39-DW-17	3	1/3	1/3*(12/41)	1/3*(12/41)*8
14	SEAMAP-SA Trawl	S8	SEDAR39-DW-02	4	1/4	1/4*(12/41)	1/4*(12/41)*8
				Sum	41/12	1	8
				Average	0.427	0.125	1

Results are provided below for Model 1—Proposed Base (under both Sel-1 and Sel-2)—and for Model 4—Ranked CPUE Alt-3 (under both Sel-1 and Sel-2). Model results were sensitive to the alternative methods developed above for implementing the CPUE ranks assigned at the Data Workshop (Models 2 – 4). Model 4 was chosen in an attempt to represent the effect of ranking CPUE while not down-weighting the overall fit to CPUE (i.e. average weight = 1.0) relative to the other data components in the model likelihood.

3.7.4. Sensitivity Run 4: Fit one Abundance Index (CPUE) at a Time

This section is still in progress and will be reported separately.

3.7.5. Sensitivity Run 5: Low and High Catch

The low and high catch series were constructed in an attempt to incorporate uncertainty in the magnitude of the catches as recommended by previous CIE reviewers for other stocks. Since commercial landings are almost census-like, no variability was introduced in this portion of the catches. Variability was introduced in commercial discards from the Northeast (gillnet, trawl, and longline) by calculating 95% CLs based on CVs available from 1989 on and in commercial discards form the Southeast gillnet by using the 95% CLs available from 1998 on. For recreational catches (landings + dead discards [A+B1] and released alive believed to die [B2]), variability was introduced by calculating 95% CLs based on CVs available since the onset of the MRFSS/MRIP program (**Tables 4.3 and 4.4**). The low and high catch scenarios compared to the base run catches are depicted in **Figure 4.2**.

Model sensitivity to the low and high catch scenarios was then evaluated with three model runs for each proposed base model configuration (Sel-1and Sel-2) as follows:

Model 1. Proposed Base (under both Sel-1and Sel-2).
Model 2. Low Catch (under both Sel-1and Sel-2).
Model 3. High Catch (under both Sel-1and Sel-2).

3.7.6. Sensitivity Run 6: Low and High Productivity

Previous HMS shark assessments conducted with SSASPM derived a prior for the steepness parameter, *h*, of the Beverton-Holt stock-recruitment relationship externally of the stock assessment model (NMFS 2012, 2013a, 2013b). The same approach was implemented in this assessment. The priors for steepness obtained for the low and high productivity scenarios were obtained externally of the stock assessment model as $h = 0.49$ and $h = 0.62$, respectively (see Section 2; **Tables 2.11 and 2.12**) and implemented in sensitivity analyses as fixed values.

Similarly, previous HMS shark assessments conducted with SSASPM calculated natural mortality, *M*, externally of the stock assessment model (NMFS 2012, 2013a, 2013b). The same approach was implemented in this assessment. The natural mortality, *M*, for the low and high productivity scenarios were obtained externally of the stock assessment model as described in Section 2 (**Tables 2.11 and 2.12**) and implemented in sensitivity analyses as fixed values.

Model sensitivity to the low and high productivity scenarios was then evaluated with three model runs for each proposed base model configuration (Sel-1and Sel-2) as follows:

Model 1. Proposed Base (under both Sel-1and Sel-2).
Model 2. Low Productivity (under both Sel-1and Sel-2).
Model 3. High Productivity (under both Sel-1and Sel-2).

3.7.7. Sensitivity Run 7: Fit the Hierarchical Index of Abundance

The motivation for this scenario, which uses the same inputs as the base run, but only a single hierarchical index of abundance weighted by the inverse of the CV (see document SEDAR39-AW-02 and Conn (2010) for a full description of the method; **Table 4.5, Figure 4.3**) is that the individual indices of abundance attempting to estimate relative abundance in the base run are subject to both sampling and process error. While sampling error is assumed to be captured by the previous statistical standardization of the indices, each index is also subject to process variation, which describes the degree to which a given index measures "artifacts" above and beyond stock abundance.

The selectivity used for the single index was a weighted average of the selectivities associated with the individual indices (**Figure 4.4**). The inverse variance selectivity weights reported in SEDAR39-AW-02 (NEFSC Fall Trawl-N: 0.0276; NEAMAP Fall Trawl: 0.1434; MA DMF Fall Trawl: 0.2488; RI DEM Seas Trawl: 0.2126; CT DEEP Trawl: 0.0441; DE Trawl: 0.0750; NJ DFW Trawl: 0.1931; SEAMAP-SA Trawl: 0.0554) were used to weight the individual selectivity curves.

Model sensitivity to the hierarchical index of abundance was then evaluated with two model runs for each proposed base model configuration (Sel-1and Sel-2) as follows:

Model 1. Proposed Base (under both Sel-1and Sel-2).

Model 2. Hierarchical (under both Sel-1and Sel-2).

3.8. BENCHMARK AND REFERENCE POINT METHODS

Benchmarks for stock status were based upon F_{MSY} and SSB_{MSY} using female fecundity as the metric for SSB, and direct MSY calculation.

3.9. PROJECTION METHODS

Projections were not completed in time to be included in this assessment report. Consequently, projection results will be provided separately. Projections will be implemented following the same methods as used in recent HMS shark assessments conducted within the SEDAR process and described separately in Courtney et al. (2014) in order to provide examples for reducing the OFL to account for scientific uncertainty in the assessment.

4. STOCK ASSESSMENT MODEL RESULTS

4.1. MODEL CONVERGENCE AND DIAGNOSTICS

Asymptotic standard errors were obtained for estimated parameters from the inverted Hessian matrix for both of the proposed base model configurations (Sel-1 and Sel-2) (**Tables 4.2.a and 4.2.b**). The final gradients for both of the proposed base model configurations (Sel-1 and Sel-2) appeared to be reasonably small (7.41E-05, and 2.19E-06, respectively) (**Tables 4.2.a and 4.2.b**).

4.1.1. AIC

The model with dome-shaped selectivity for fleet F1 (Sel-2) had the best fit to the data based on the minimum AIC value (5633.5), and there was a substantial difference in Δ_i between the model with dome-shaped selectivity for fleet F1, and the model with asymptotic-shaped selectivity for fleet F1 (Sel-1) (Δ_i = 100.1) (**Table 4.6**).

4.1.2. RMSE

The model evaluated with dome-shaped selectivity for fleet F1 (Sel-2) had a better fit to the observed length composition data for fleet F1 than the model evaluated with asymptotic-shaped selectivity for fleet F1 (Sel-1) based on a smaller RMSE (**Table 4.7**). There was not much difference between the two models in the model fits to the other length composition data or to the abundance index data based on RMSE (**Tables 4.7 and 4.8**).

4.1.3. K-S Tests

There was a significant difference (K-S test, alpha = 0.05) between the shape of the female length frequency distribution associated with fleet F1 and that associated with the main survey (S1, 1.1 NEFSC Fall Trawl-N) (**Table 4.9**). However, the length bin with the maximum difference was relatively small (75 cm FL) (**Table 4.9; Appendix 4.B**). There were also many other significant differences in the shapes of the sex specific and sex combined length frequency distributions obtained from other fleets relative to those obtained for fleet F1 (**Table 4.9; Appendix 4.B).** However, in most cases, the maximum difference in the length frequency occurred at relatively smaller sizes (length bins ≤ 75 cm FL) (**Table 4.9; Appendix 4.B**).

There was one significant difference between the shape of the female length frequency distribution associated with fleet F1 and that of another fleet or survey (F4) in which the length bin with the maximum difference occurred at a relatively large size (90 cm FL) (**Table 4.9; Appendix 4.B**). This result indicates that large sharks occur in a relatively higher proportion in fleet F4 (2.5 SE BLLOP) than F1 (2.1 NE GNOP Combined Mesh, Kept). However, it was not clear which of the length frequency data sources examined, if any, accurately reflects the true length frequency distribution of the underlying population.

4.2. MEASURES OF MODEL FIT

4.2.1. Landings

As described above, annual fishing mortality coefficients were obtained for each fleet in this assessment with a hybrid method that does a Pope's approximation to provide initial values for iterative adjustment of the continuous *F* values to closely approximate the observed catch (Methot 2011). Consequently, total catch (mt) is fit exactly as input (see Section 2, **Table 2.2**) (**Figure 4.5**).

4.2.2. Indices of Abundance

Model fits to standardized indices of relative abundance are provided for both proposed base model configurations (**Figure 4.6).** See Section 3.2 (and **Tables 2.5** and **2.6)** for a description of the data sources for each index of relative abundance (surveys S1 – S8). The 95% confidence intervals are provided for each index assuming lognormal errors in the CVs provided for each index (**Table 2.6**). Both selectivity scenarios resulted in similar fits to standardized indices of relative abundance (**Figure 4.6**). The fits to survey S1 were reasonable (model predicted index within the 95% confidence intervals of the observed index) for most survey years. However, there was a poor fit (model predicted index outside the 95% confidence intervals of the observed index) for the peak of the index and a poor fit in the earliest survey years (**Figure 4.6**). The fits to survey S2 were reasonable in most survey years (**Figure 4.6**). The fits to survey S3 were reasonable in most survey years, but there was a poor fit in the earliest survey years (**Figure 4.6**). The fits to survey S4 were reasonable in most survey years, but there was a poor fit in the earliest survey years (**Figure 4.6**). The fits to survey S5 were reasonable in early survey years, but did not follow the trend of the index in recent survey years (**Figure 4.6**). The fits to survey S6 were reasonable in most survey years, but there was a poor fit in the earliest survey years and high inter-annual variability during the middle years of the index (**Figure 4.6**). The fits to survey S7 appeared to track the index very closely and to have the best fit to the indices except for some survey years with high inter-annual variability (**Figure 4.6**). The fits to survey S8 were reasonable in early and recent survey years but did not fit the peak of the index during the middle survey years (**Figure 4.6**).

4.2.3. Length Compositions

4.2.4. Fits to Annual Length Compositions

Observed and model predicted female annual length compositions for the main targeted fishery (fleet F1 – NE Gillnet Kept) are provided for both of the proposed based model configurations (Sel-1 and Sel-2) (**Figure 4.7**). The fits for the base model configuration with a dome-shaped functional form of selectivity for fleet F1 (Sel-2; modeled with a double logistic function at length) were relatively better than those for the proposed base model configuration with asymptotic selectivity (Sel-1; modeled with a simple logistic function at length), especially for the largest size classes which were over predicted in the model with asymptotic selectivity (**Figure 4.7**).

Observed and model predicted male annual length compositions for the main targeted fishery (fleet F1 – NE Gillnet Kept) are provided for both of the proposed based model configurations (Sel-1 and Sel-2) (**Figure 4.8**). The fits for the base model configuration with a dome-shaped functional form of selectivity for fleet F1 (Sel-2; modeled with a double logistic function at length) were also relatively better than those for the proposed base model configuration with asymptotic selectivity (Sel-1; modeled with a simple logistic function at length), especially for the peak size classes which were under predicted in many years in the model with asymptotic selectivity (**Figure 4.8**).

4.2.5. Fits to Aggregated Length Compositions

Model fits to aggregated female length compositions for data sources with sex specific length compositions are provided for both of the proposed based model configurations (Sel-1 and Sel-2) (**Figure 4.9**), see Section 3.2 (**Tables 2.3 - 2.5)** for a description of the length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8). The fits to aggregated female length composition data for fleet F1 were the same as those described above for the disaggregated data (**Figures 4.7 and 4.8**). Both model configurations (Sel-1 and Sel-2) had similar fits to the aggregated female length composition data for the other fleets (F2 – F6) and surveys (S1 – S8) (**Figure 4.9**). Some large sizes (length bins associated with the largest size sharks) were overestimated (predicted proportions higher than observed proportions) in fleets F1 and F4 and in surveys S1 and S5 (**Figure 4.9**). Some small sizes (length bins associated with the smallest size sharks) were underestimated (predicted proportions lower than observed proportions) in surveys S2 and S3 (**Figure 4.9**).

Model fits to aggregated male length compositions for data sources with sex specific length compositions are provided for both of the proposed based model configurations (Sel-1 and Sel-2) (**Figure 4.10**). The fits to aggregated male length composition data for fleet F1 were the same as those described above for the disaggregated data (**Figures 4.7 and 4.8**). Both model configurations (Sel-1 and Sel-2) had similar fits to the aggregated male length composition data for the other fleets (F2 – F6) and surveys (S1 – S8) (**Figure 4.10**). Some small sizes were underestimated in surveys S2, S3, and S8 (**Figure 4.10**).

Model fits to aggregated combined or unknown sex length compositions for data sources without sex specific length compositions are provided for both of the proposed based model configurations (Sel-1 and Sel-2) (**Figure 4.11**). Both model configurations (Sel-1 and Sel-2) had similar fits to the aggregated length composition data (**Figure 4.11**). Some small sizes were underestimated in fleet F6 and surveys S3, S6, and S7 (**Figure 4.11**).

4.3. PARAMETER ESTIMATES AND ASSOCIATED MEASURES OF UNCERTAINTY

A list of model parameters and their associated asymptotic standard errors are provided in Tables 4**.2.a** and **4.2.b**. All estimated parameters were within reasonable correlation thresholds (≥ 0.01, and ≤ 0.95) and no parameters were estimated at boundary conditions, based on diagnostics completed after each run with the program r4ss (not shown). However, some parameters were estimated at values very close to their boundary conditions (e.g., Table 4.2.b SizeSel_3P_2_F3). These estimated parameter values may have been kept off the boundary condition by the use of the soft boundary option in SS3, and may have been poorly estimated (**Tables 4.2.a and 4.2.b**). Three estimated selectivity parameters (SizeSel_3P_1_F3, SizeSel_3P_2_F3, SizeSel_10P_3_S4) had very large SEs (relative to the parameter estimates) under both of the proposed base model configurations (Sel-1 and Sel-2) **(Tables 4.2.a and 4.2.b)**, indicating that these parameters were poorly estimated.

For both of the proposed base model configurations, the influence of parameter priors was investigated by turning off the priors within Stock Synthesis model likelihood. For both of the proposed base model configurations, the estimated parameter values were unchanged, either with or without the parameter priors turned on, indicating that the final estimated parameter values were not dependent on the parameter priors.

4.4. SELECTIVITY

Two alternative base model configurations were proposed in the current assessment based on the alternative functional forms of selectivity (Sel-1 and Sel-2) evaluated for the main targeted fishery (fleet F1 – NE Gillnet Kept) as described below:

1. Preliminary parameter values and the approximate shape for selectivity at age were obtained from length composition data obtained for *Mustelus canis* in the northwest Atlantic externally of the stock assessment model based on methods used in previous HMS shark assessments conducted with age-structured models (**Appendix 2A**). Final parameter values for selectivity were obtained with the algorithm described in **Appendix 4A**.
2. Using the algorithm described in **Appendix 4.A**, asymptotic selectivity (Sel-1; modeled with a simple logistic function at length) was obtained for the main targeted fishery (fleet F1 – NE Gillnet Kept). However, based on Assessment Panel

recommendations, a dome-shaped functional form (Sel-2; modeled with a double logistic function at length) was also evaluated in this assessment as an alternative functional form of selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept). This resulted in two alternative base model configurations in the current assessment based on the alternative functional forms of selectivity (Sel-1 and Sel-2) evaluated for the main targeted fishery (fleet F1 – NE Gillnet Kept).

3. Based on Assessment Panel recommendations, several model diagnostics were also evaluated to compare model fits to data between the two alternative base model configurations (Sel-1 and Sel-2) as follows: 1) Akaike's information criterion (AIC); 2) the root mean squared error (RMSE); and 3) a Kolmogorov-Smirnov (K-S) test. Methods used to implement the diagnostics are described in Section 3 and results of the diagnostics are presented in Section 4.

The Assessment Panel recommended the alternative model configuration with a dome-shaped functional form (Sel-2; modeled with a double logistic function at length) for the main targeted fishery (fleet F1 – NE Gillnet Kept) as the base model for the assessment based on the following criteria:

1. The proposed base model under the Sel-2 configuration (dome-shaped selectivity for fleet F1) had a substantially better fit to the data based on the minimum AIC value (5633.5) than the proposed base model under the Sel-1 configuration (asymptotic-shaped selectivity for fleet F1 (Sel-1) (Δ_i = 100.1) (See Section 4.1.1 and **Table 4.6**).
2. The Sel-2 configuration had a better fit (smaller RMSE) to the length composition data for fleet F1 (NE Gillnet Kept) than the Sel-1 configuration (See Section 4.1.2; **Table 4.7**), and fits to female length composition data for the largest size bins were improved under the Sel-2 configuration (**Figures 4.7 and 4.9**).

Selectivity parameters used in this assessment for the proposed base model configuration Sel-1 are provided in **Table 4.A.1** (**Figures 4.A.1, 4.A.2, and 4.A.5**). Selectivity parameters used in this assessment for the proposed base model configuration Sel-2 are provided in Table **4.A.2** (**Figures 4.A.3, 4.A.4, and 4.A.6**).

4.5. RECRUITMENT

The two parameters defined for the stock-recruitment relationship were steepness, h, and the natural log of virgin recruitment, $\ln(R_0)$. In this assessment, the steepness parameter was fixed at its prior value for all model configurations. Priors for steepness were obtained externally to the stock assessment model, as described in Sections 2 and 3. Virgin recruitment, $\ln(R_0)$, appeared reasonably estimated under both proposed base model configurations (Sel-1 and Sel-2) based on its relatively small asymptotic SEs under both model configurations (**Tables 4.2.a and 4.2.b**). The predicted stock-recruitment relationship (**Figure 4.12**), the predicted log recruitment deviations (**Figure 4.13**), and predicted age-0 recruits (**Figure 4.14**) were similar under both proposed base model configurations (Sel-1 and Sel-2). Similarly, the bias adjustment applied to the stock-recruitment relationship (**Figure 4.15**) was similar under both proposed base model configurations (Sel-1 and Sel-2)

4.6. STOCK BIOMASS AND FISHING MORTALITY

Total biomass, B, spawning stock fecundity, SSF, recruits, R, and aggregate annual fishing mortality, F calculated as overall exploitation rate in numbers, obtained under both proposed base model configurations (Sel-1 and Sel-2) are provided in **Tables 4.10.a and 4.10.b**. Aggregate annual fishing mortality relative to fishing mortality at MSY (F/F_{MSY}) and $\mathrm{SSF/SSF_{MSY}}$ obtained under both proposed base model configurations (Sel-1 and Sel-2) are provided in **Tables 4.11.a and 4.11.b**. The trajectories obtained for total biomass, B, spawning stock fecundity, SSF, recruits, R, and annual fishing mortality, F, are consistent with a period of high exploitation and stock depletion in the 1990s followed by a period of relatively lower exploitation and stock recovery in the recent 2000s **(Figures 4.16 and 4.17)**.

For comparison, continuous F values obtained with iterative adjustment to observed catch for each fleet (F1 – F6) are provided in **Figure 4.18** for both proposed base model configurations (Sel-1 and Sel-2). The same catch streams (see Sections 2 and 3 and **Tables 2.2 and 2.5**) were associated with each fleet (F1 – F6) under both proposed base model configurations (Sel-1 and Sel-2) (**Figure 4.19**).

As described above, the aggregate annual fishing mortality rates, F, were obtained as the aggregate annual exploitation rate in numbers for all fleets combined (**Tables 4.10 – 4.13 and**

Figures 4.16, 4.17 and 4.21 – 4.24). This could cause some difficulty in interpreting annual fishing mortality rate results**.** For example, the aggregate annual fishing mortality rates, *F*, for the years 2010 and 2012 were about the same within respective scenarios (Sel-1 and Sel-2) (**Figures 4.16** and **4.17)** despite lower catch in weight for all fleets combined in 2012 compared to 2010 (**Table 2.2, Figure 4.19**). One reason for this result is that the catch in numbers for all fleets combined was similar for the years 2010 and 2012 despite the lower catch in weight during the same period. Catch in numbers is calculated internally in Stock Synthesis based on both the size composition of each fleet and the relative proportion of the total catch taken by each fleet. For example, the catch for fleet F1 (Com-GN kept) had a higher proportion of large sharks than the catch for fleet F6 (Recreational) (e.g., **Figures 4.A.5 and 4.A.6**), and while the catch in weight went down for all fleets combined from 2010 to 2012, the catch in weight of fleet F1 (Com-GN kept) in 2012 was about half that of 2010, while the catch in weight of fleet F6 (Recreational) in 2012 was about double that of 2010 (**Table 2.2; Figure 4.19**). Consequently, the catch in numbers for all fleets combined was similar for the years 2010 and 2012 despite the lower catch in weight during the same period. Since the aggregate annual fishing mortality rates, *F*, were obtained from catch in numbers, they were also similar for the years 2010 and 2012 despite the lower catch in weight during the same period.

4.7. MODELING GROWTH IN LENGTH AT AGE

Growth in length at age was assumed to follow a von Bertalanffy growth (VBG) relationship under both of the proposed base model configurations (Sel-1 and Sel-2) based on externally derived parameters obtained separately for females and males as described above (see Sections 2 and 3; **Table 2.8**) (**Figure 4.20**).

4.8. EVALUATION OF UNCERTAINTY

Model uncertainty was evaluated in this assessment with a set of sensitivity scenarios for each proposed base model configuration. Summaries of model results for the proposed base configuration under Sel-1and eight model sensitivities conducted either with externally derived selectivity or selectivity under the same model configuration as Sel-1 (asymptotic-shaped functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept)) are provided in **Table 4.12 and Figure 4.21**. Parameters provided in the summary are the

MSY (mt) obtained directly from Stock Synthesis as the equilibrium yield at F_{MSY}, spawning stock fecundity, SSF (1,000s), recruits, R (1,000s), and aggregate annual fishing mortality, F, calculated as overall exploitation rate in numbers. Model sensitivities (MS) are described above and defined here as follows: MS-1 External Selectivity, MS-2 Start Year 1972 (Sel-1), MS-3 Ranked CPUE (Sel-1), MS-4 Low Catch (Sel-1), MS-5 High Catch (Sel-1), MS-6 Low Productivity (Sel-1), MS-7 High Productivity (Sel-1), and MS-8 Hierarchical (Sel-1). Values are also provided for the Akaike information criteria (AIC), total objective function, final gradient, 1 - average natural mortality at age ($1-\bar{M}_a$), minimum stock size threshold (MSST) = ($1-\bar{M}_a$)×SSF_{MSY}, and stock-recruitment steepness (h) for each model. AIC values are not comparable among models with different data inputs.

Summaries of model results for the proposed base configuration under Sel-2 and seven model sensitivities conducted under the same model configuration as Sel-2 (dome-shaped functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept)) are provided in **Table 4.13 and Figure 4.22**. Model sensitivities (MS) are described above and defined here as follows: MS-9 Start Year 1972 (Sel-2), MS-10 Ranked CPUE (Sel-2), MS-11 Low Catch (Sel-2), MS-12 High Catch (Sel-2), MS-13 Low Productivity (Sel-2), MS-14 High Productivity (Sel-2), and MS-15 Hierarchical (Sel-2).

Sensitivity runs under model configurations with both externally derived selectivity and with the same selectivity configuration as Sel-1 resulted in moderate changes to the fits to length and CPUE (as indicated by relatively little change in likelihood units among sensitivity runs) except for the Hierarchical sensitivity (MS-8) which resulted in a large change in likelihood units for both length and CPUE relative to the base model structure (**Figure 4.21** top panel). Similarly, sensitivity runs under model configurations with the same selectivity configuration as Sel-2 resulted in moderate changes to the fits to length and CPUE except for the Hierarchical sensitivity (MS-15) which resulted in a large change in likelihood units for both length and CPUE relative to the base model structure (**Figure 4.22** top panel). The large change in length and CPUE likelihood units for the Hierarchical sensitivity runs (MS-8 and MS-15) was expected because these sensitivity runs have much less data than the other model runs, which reduces the overall number of likelihood units for length and CPUE data, independent of model fit to data.

Sensitivity runs under model configurations with both externally derived selectivity and with the same selectivity configuration as Sel-1 resulted in large changes in F/F_{MSY} relative to the base model structure (Sel-1) and to the benchmark for F/F_{MSY} (i.e., F/F_{MSY} fluctuated above and below the benchmark of 1.0 depending upon the sensitivity run examined) (**Figure 4.21** bottom panel). In contrast, sensitivity runs under model configurations with the same selectivity configuration as Sel-2 resulted in more moderate changes in F/F_{MSY} relative to the base model structure (Sel-2) and to the benchmark for F/F_{MSY} (i.e., F/F_{MSY} remained below the benchmark of 1.0 for all sensitivity runs) (**Figure 4.22** bottom panel). For the sensitivity analyses, F was calculated as the aggregate annual fishing mortality averaged over the most recent 10 years and then divided by F_{MSY}.

Sensitivity runs under model configurations with both externally derived selectivity and with the same selectivity configuration as Sel-1 resulted in moderate changes in $\mathrm{SSF/SSF_{MSY}}$ relative to the base model structure (Sel-1) and to the benchmark for $\mathrm{SSF/SSF_{MSY}}$ (i.e., $\mathrm{SSF/SSF_{MSY}}$ remained above the benchmark of 1.0 for all sensitivity runs) (**Figure 4.21** bottom panel). Similarly, sensitivity runs under model configurations with the same selectivity configuration as Sel-2 resulted in moderate changes in $\mathrm{SSF/SSF_{MSY}}$ relative to the base model structure (Sel-2) and to the benchmark for $\mathrm{SSF/SSF_{MSY}}$ (i.e., $\mathrm{SSF/SSF_{MSY}}$ remained above the benchmark of 1.0 for all sensitivity runs) (**Figure 4.22** bottom panel).

4.9. BENCHMARKS/REFERENCE POINTS

The proposed base model under the Sel-1 configuration estimated that the stock was not overfished ($\mathrm{SSF_{2012}} > \mathrm{SSF_{MSY}}$), but that the stock was close to being in an overfishing condition ($F_{2012} \approx F_{\mathrm{MSY}}$; i.e., either $F_{2012} > F_{\mathrm{MSY}}$ or $F_{2012} = F_{\mathrm{MSY}}$, depending upon how rounding is calculated) (**Table 4.12).** The proposed base model under the Sel-1 configuration had fluctuated above the F_{MSY} threshold and below both the $\mathrm{SSF_{MSY}}$ and the MSST thresholds in some years (**Figures 4.16 and 4.23.a**). The proposed base model under the Sel-2 configuration estimated that the stock was not overfished ($\mathrm{SSF_{2012}} > \mathrm{SSF_{MSY}}$) and that overfishing was not occurring ($F_{2012} < F_{\mathrm{MSY}}$) (**Table 4.13).** The proposed base model under the Sel-2 configuration had also fluctuated above the F_{MSY} threshold and below the $\mathrm{SSF_{MSY}}$ threshold in some years (**Figures 4.17 and 4.23.b**).

All of the sensitivity runs examined in this assessment estimated that the stock was not overfished ($SSF_{2012} > SSF_{MSY}$) (**Tables 4.12** and **4.13; Figures 4.24.a** and **4.24.b).** Benchmarks for the proposed base model under the Sel-1 configuration and for eight model sensitivities conducted either with externally derived selectivity or with selectivity under the same model configuration as Sel-1 are summarized in **Table 4.12**. Benchmarks for the proposed base model under the Sel-2 configuration and for seven model sensitivities conducted under the same model configuration as Sel-2 are summarized in **Table 4.13**.

The model sensitivity conducted with externally derived selectivity (MS-1 External Selectivity) and two model sensitivities conducted under model configuration Sel-1 (MS-2 Start Year 1972, and MS-7 High Productivity) estimated that the stock was in an overfishing condition ($F_{2012} > F_{MSY}$) (**Table 4.12** and **Figure 4.24.a**). One model sensitivity conducted under model configuration Sel-1 (MS-4 Low Catch) estimated that the stock was close to being in an overfishing condition ($F_{2012} \approx F_{MSY}$; i.e., either $F_{2012} > F_{MSY}$ or $F_{2012} = F_{MSY}$ depending upon how rounding is calculated) (**Table 4.12** and **Figure 4.24.a**). The remaining four model sensitivities conducted under model configuration Sel-1 (MS-3 Ranked CPUE, MS-5 High Catch, MS-6 Low Productivity, and MS-8 Hierarchical) estimated that the stock was not in an overfishing condition (**Table 4.12** and **Figure 4.24.a**).

Most sensitivities conducted under model configuration Sel-2 **(**MS-10 Ranked CPUE, MS-11 Low Catch, MS-12 High Catch, MS-13 Low Productivity, MS-14 High Productivity, and MS-15 Hierarchical) estimated that the stock was not in an overfishing condition ($F_{2012} < F_{MSY}$) (**Table 4.13** and **Figure 4.24.b).** One model sensitivity conducted under model configuration Sel-2 (MS-9 Start Year 1972) estimated that the stock was close to F_{MSY} ($F_{2012} \approx F_{MSY}$; i.e., either $F_{2012} < F_{MSY}$ or $F_{2012} = F_{MSY}$ depending upon how rounding is calculated) (**Table 4.13** and **Figure 4.24.b).** The remaining six model sensitivities conducted under model configuration Sel-2 estimated that $F_{2012} < F_{MSY}$ (**Table 4.13** and **Figure 4.24.b**).

4.10. PROJECTIONS

This section is still in progress. Stochastic projections of future stock conditions under different catch levels will be provided separately.

4.11. DISCUSSION

In all, both proposed base model configurations predicted that the stock was not overfished and that there was an almost equal chance of overfishing occurring or not (Sel-1 configuration; **Table 4.12**, **Figures 4.16** and **4.23a**) or an almost negligible chance of overfishing occurring at all (Sel-2 configuration; **Table 4.13**, **Figure 4.17** and **4.23b**). Similarly, all of the sensitivity scenarios examined in this assessment estimated that the stock was not overfished, and all of the sensitivity scenarios conducted under model configuration Sel-2 estimated that the stock was not in an overfishing condition, although one scenario was estimated close to an overfishing condition (either $F_{2012} < F_{\mathrm{MSY}}$ or $F_{2012} = F_{\mathrm{MSY}}$ depending upon how rounding is calculated) (**Tables 4.12** and **4.13; Figures 4.24.a** and **4.24.b).** In contrast, the sensitivity scenario with externally derived selectivity and two sensitivity scenarios conducted under model configuration Sel-1 estimated that the stock was in an overfishing condition, and one sensitivity scenario conducted under model configuration Sel-1 estimated that the stock was close to being in an overfishing condition (either F2012 > FMSY or F2012 = FMSY depending upon how rounding is calculated) (**Table 4.12; Figure 4.24.a**).

The proposed base model under the Sel-2 configuration (dome-shaped selectivity for fleet F1) had a substantially better fit to the data based on the minimum AIC value (5633.5) than the proposed base model under the Sel-1 configuration (asymptotic-shaped selectivity for fleet F1 (Sel-1) (Δ_i = 100.1) (See Section 4.1.1 and **Table 4.6**). The Sel-2 configuration had a better fit (smaller RMSE) to the length composition data for fleet F1 (NE Gillnet Kept) than the Sel-1 configuration (See Section 4.1.2; **Table 4.7**), and fits to female length composition data for the largest size bins were improved under the Sel-2 configuration (**Figures 4.7 and 4.9**). There was one significant difference between the shape of the female length frequency distribution associated with fleet F1 and that of another fleet or survey (F4) in which the length bin with the maximum difference occurred at a relatively large size (90 cm FL) (**Table 4.9; Appendix 4.B**). However, it was not clear which of the length frequency data sources examined, if any, accurately reflects the true length frequency distribution of the underlying population.

Fits to data sources other than the length composition for fleet F1 were similar for the proposed base models under both the Sel-1 and Sel-2 configurations (**Figures 4.6 – 4.11**). The predicted stock recruitment relationship, estimated recruitment deviations, and continuous fishing mortalities were also similar (**Figures 4.12 – 4.15, and Figure 4.18**).

The range of sensitivity analyses explored under both Sel-1 and Sel-2 model configurations resulted in moderate changes to the fits to length and CPUE except for the Hierarchical sensitivity which resulted in a large change in likelihood units for both length and CPUE relative to the base model structure under both Sel-1 and Sel-2 (**Figures 4.21 and 4.22** top panel). However, the change in likelihood units was probably due to the relatively more limited data used in the Hierarchical sensitivity runs than in the other models. The range of sensitivity analyses explored under the Sel-1 model configuration resulted in large changes in F/F_{MSY} relative to the base model structure and to benchmarks (1.0) for F/F_{MSY} (**Figure 4.21** bottom panel). In contrast, the range of sensitivity analyses explored under the Sel-2 model configuration resulted in more moderate changes in F/F_{MSY} relative to the base model structure and to benchmarks (1.0) for $\mathrm{F/F_{MSY}}$ (**Figure 4.22** bottom panel).

<u>Modeling strengths</u>

SS3 utilizes an integrated modeling approach (Maunder and Punt 2013) to take advantage of the many data sources available for the Atlantic stock of *Mustelus canis*. An advantage of the integrated modeling approach is that the development of statistical methods that combine several sources of information into a single analysis allows for consistency in assumptions and permits the uncertainty associated with each data source to be propagated to final model outputs (Maunder and Punt 2013).

<u>Modeling challenges</u>

This is the first HMS shark assessment conducted within the SEDAR process to utilize the Stock Synthesis modeling framework. Previous HMS shark assessments conducted within the SEDAR process used a State Space Age Structured Production Model (SSASPM). It is important when transitioning between modeling platforms to identify the potential impacts of differences in modeling approaches on assessment outcomes. Consequently, an attempt was made in this assessment to implement many of the features previously implemented in HMS shark assessments conducted with SSASPM in order to identify and evaluate the potential impacts of differences in modeling approaches on assessment outcomes.

However, two differences were identified between this assessment and previous assessments for HMS sharks conducted with SSASPM

1. This assessment included length data from age-0 sharks. Previous assessments for HMS sharks conducted with SSASPM excluded age-0 sharks from the assessment.

2. This assessment estimated selectivity internally to the model. Previous assessments for HMS sharks conducted with SSASPM estimated selectivity externally of the stock assessment model.

Fits to the smallest length bins in this assessment were poor for many length composition data sources (**Figures 4.9 – 4.11**). It is possible that the fits the smallest length bins could be improved by removing age-0 sharks from the assessment as in previous assessments conducted with SSASPM. For example, it should be possible in Stock Synthesis to include indices of relative abundance from fleets which capture primarily age-0 sharks as recruitment indices. It may also be possible to improve the fits for the smallest length bins by estimating growth parameters within the stock assessment model. However preliminary attempts to estimate growth parameters within this assessment were not successful.

Fits to the largest length bins in this assessment were also poor for many length composition data sources (**Figures 4.9 – 4.11**). It may also be possible to improve the fits for the largest length bins by estimating growth parameters, for example the CVs of the length at age relationship, within the stock assessment model. However preliminary attempts to estimate the CVs of the length at age relationship within this assessment were not successful.

4.12. RECOMMENDATIONS FOR DATA COLLECTION AND FUTURE RESEARCH

1. Modeling considerations.

Improve the fits to length composition data. For example Stock Synthesis allows for the estimation of sex specific selectivity and includes options to utilize parameter offset approaches in the estimation of selectivity parameters in order to improve parameter estimation. Several methods are also available for selecting among alternative functional forms for selectivity (e.g., Helu et al 2000; Maunder and Harley 2011; Punt et al. 2014). For example, the use of Akaike's information criterion (AIC) (Akaike 1973; Burnham and Anderson 2002; e.g., Hilborn and

Mangel 1997) is appropriate for comparing alternative forms of selectivity, as implemented here for comparing proposed base runs Sel-1 and Sel-2, if models compared use the same data and have the same data structure (Helu et al 2000). Alternative methods would be required for selecting among models with different data or with different data structure. For example, the hold-out cross validation has been used for comparison of models run with different data sets (Maunder and Harley 2011).

2. Data Considerations.

Obtain age composition data from existing surveys in order to not have to rely solely only length composition data in the model.

Update age and growth studies in order to resolve potential differences in observed and predicted size at birth.

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4.14. TABLES

Table 4.1. Final selectivity patterns used in this assessment to model selectivity were obtained using the algorithm described in **Appendix 4.A.** The preliminary shape of the selectivity curve for each length composition data source was identified externally of the stock assessment model (**Appendix 2.A**). Two alternative functional forms of selectivity (asymptotic-shaped and dome-shaped) were evaluated for length based selectivity of the main targeted fishery (fleet F1 – NE Gillnet Kept). This resulted in two alternative base model configurations in the current assessment based on the alternative functional forms of selectivity (Sel-1 and Sel-2) evaluated for the main targeted fishery (fleet F1 – NE Gillnet Kept).

			Final selectivity pattern[1]	
Time series	Associated length data source	Preliminary shape	(size)	(age)
F1 (Sel-1)	2.1 NE GNOP Combined Mesh, Kept	Asymptotic or slightly dome-shaped	1	11
F1 (Sel-2)	2.1 NE GNOP Combined Mesh, Kept	Asymptotic or slightly dome-shaped	9	11
F2	2.2 NE GNOP Combined Mesh, Discard	Asymptotic (descending to an asymptote)	9	11
F3	2.3 NE TOP Combined Mesh, Combined Disposition	Dome-shaped (ascending and then descending)	9	11
NA	2.4 SE GNOP	Asymptotic or slightly dome-shaped	NA	NA
F4	2.5 SE BLLOP	Asymptotic or slightly dome-shaped	1	11
F5	NA		0	15
F6	2.6 MRIP	Asymptotic (descending to an asymptote)	0	19
S1	1.1 NEFSC Fall Trawl-N	Asymptotic (ascending to an asymptote)	0	12
S2	1.2 NEAMAP Fall Trawl	Asymptotic (descending to an asymptote)	0	19
S3	1.3 MA DMF Fall Trawl	Asymptotic (descending to an asymptote)	0	19
S4	1.4 RI DEM Seas Trawl	Dome-shaped (ascending and then descending)	9	11
S5	1.5 CT DEEP Trawl	Asymptotic (ascending to an asymptote)	0	12
S6	1.6 DE Trawl	Asymptotic (descending to an asymptote)	0	20
S7	1.7 NJ DFW Trawl	Asymptotic (descending to an asymptote)	0	20

S8	1.8 SEAMAP-SA Trawl	Asymptotic (descending to an asymptote)	0	19

[1] The following Stock Synthesis selectivity patterns were implemented in the proposed base model configurations: Patterns 1 (size) and 12 (age) --Simple logistic (up to 2 estimated parameters); Patterns 9 (size) and 19 (age) -- Double logistic (up to 4 estimated parameters); Pattern 0 -- Mirror age based selectivity; Pattern 11 -- Mirror length based selectivity; Pattern 15 – Mirror selectivity of another fleet; and Patterns 20 (age) -- Double normal (parameters derived externally).

Table 4.2.a. A total of 50 parameters were estimated in the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the asymptotic-shaped functional form of length based selectivity (Sel-1) for the main targeted fishery (fleet F1 – NE Gillnet Kept). Parameter estimation for ln(R_0) and selectivity utilized a normal prior with a large standard deviation (Prior_SD = 1,000 or 999, respectively) and independent minimum and maximum boundary conditions for each parameter. Recruitment deviations were estimated as described above (see Section 3). Parameters with a negative phase were fixed at their initial value. The final gradient for of the proposed base model configuration Sel-1 was 7.41E-05.

Label	Active number	Phase	Min	Max	Init	PR_type	Prior	Prior_SD	Estimate	SE
L_at_Amin_Fem_GP_1	_	-3	5	100	48.84	NA	NA	NA	48.842	NA
L_at_Amax_Fem_GP_1	_	-4	50	400	110.46	NA	NA	NA	110.461	NA
VonBert_K_Fem_GP_1	_	-5	0.01	0.65	0.29	NA	NA	NA	0.292	NA
CV_young_Fem_GP_1	_	-2	0.01	0.3	0.15	NA	NA	NA	0.150	NA
CV_old_Fem_GP_1	_	-3	0.01	0.3	0.12	NA	NA	NA	0.120	NA
L_at_Amin_Mal_GP_1	_	-3	5	100	46.96	NA	NA	NA	46.964	NA
L_at_Amax_Mal_GP_1	_	-4	50	400	94.51	NA	NA	NA	94.511	NA
VonBert_K_Mal_GP_1	_	-5	0.01	0.65	0.44	NA	NA	NA	0.440	NA
CV_young_Mal_GP_1	_	-2	0.01	0.3	0.15	NA	NA	NA	0.150	NA
CV_old_Mal_GP_1	_	-3	0.01	0.3	0.12	NA	NA	NA	0.120	NA
Wtlen_1_Fem	_	-3	-3	3	6.00E-06	NA	NA	NA	0.000	NA
Wtlen_2_Fem	_	-3	-3	3.4	3.01	NA	NA	NA	3.008	NA
Mat50%_Fem*	_	-3	1	150	91.98	NA	NA	NA	91.984	NA
Mat_slope_Fem*	_	-3	-3	3	-0.45	NA	NA	NA	-0.449	NA
Eggs_scalar_Fem*	_	-3	-3	10	9.53	NA	NA	NA	9.530	NA
Eggs_exp_len_Fem*	_	-3	-3	3	0.00	NA	NA	NA	0.000	NA
Wtlen_1_Mal	_	-3	-3	3	1.00E-05	NA	NA	NA	0.000	NA
Wtlen_2_Mal	_	-3	-3	3.3	2.81	NA	NA	NA	2.808	NA
RecrDist_GP_1	_	-3	-4	4	0.00	NA	NA	NA	0.000	NA
RecrDist_Area_1	_	-3	-4	4	0.00	NA	NA	NA	0.000	NA
RecrDist_Seas_1	_	-3	-4	4	0.00	NA	NA	NA	0.000	NA
CohortGrowDev	_	-3	-4	4	0.00	NA	NA	NA	0.000	NA
SR_LN(R0)	1	1	2.3	13.82	7.04	Normal	7.04	1000	7.701	0.055
SR_BH_steep	_	-2	0.2	1	0.54	NA	NA	NA	0.542	NA
SR_sigmaR	_	-4	0.2	1.9	0.72	NA	NA	NA	0.723	NA
SR_envlink	_	-3	-5	5	0.00	NA	NA	NA	0.000	NA
SR_R1_offset	_	-4	-5	5	0.00	NA	NA	NA	0.000	NA
SR_autocorr	_	-4	-5	5	0.00	NA	NA	NA	0.000	NA

*Maturity and fecundity were implemented in this assessment with an age specific vector of fecundity at age as described above (see Sections 2; **Table 2.9**). The parameter values identified in this table for Mat50%_Fem, Mat_slope_Fem, Eggs_scalar_Fem, and Eggs_exp_len_Fem, are place holders required by SS3 but are not implemented in this assessment. Similarly, the parameters RecrDist_GP_1, RecrDist_Area_1, RecrDist_Seas_1, CohortGrowDev , SR_envlink, SR_R1_offset, and SR_autocorr are place holders in SS3 and are not implemented in this assessment.

Table 4.2.a. Continued.

Label	Active number	Phase	Min	Max	Init	PR_type	Prior	Prior_SD	Estimate	SE
Main_RecrDev_1981	2	_	_	_	_	dev	0.00	0	-0.352	0.242
Main_RecrDev_1982	3	_	_	_	_	dev	0.00	0	-0.779	0.320
Main_RecrDev_1983	4	_	_	_	_	dev	0.00	0	-0.789	0.277
Main_RecrDev_1984	5	_	_	_	_	dev	0.00	0	-0.346	0.230
Main_RecrDev_1985	6	_	_	_	_	dev	0.00	0	-0.369	0.226
Main_RecrDev_1986	7	_	_	_	_	dev	0.00	0	-0.818	0.248
Main_RecrDev_1987	8	_	_	_	_	dev	0.00	0	-0.729	0.233
Main_RecrDev_1988	9	_	_	_	_	dev	0.00	0	-1.527	0.325
Main_RecrDev_1989	10	_	_	_	_	dev	0.00	0	-0.937	0.190
Main_RecrDev_1990	11	_	_	_	_	dev	0.00	0	0.159	0.128
Main_RecrDev_1991	12	_	_	_	_	dev	0.00	0	-0.681	0.237
Main_RecrDev_1992	13	_	_	_	_	dev	0.00	0	-1.219	0.304
Main_RecrDev_1993	14	_	_	_	_	dev	0.00	0	0.152	0.170
Main_RecrDev_1994	15	_	_	_	_	dev	0.00	0	-0.359	0.266
Main_RecrDev_1995	16	_	_	_	_	dev	0.00	0	0.495	0.173
Main_RecrDev_1996	17	_	_	_	_	dev	0.00	0	0.843	0.154
Main_RecrDev_1997	18	_	_	_	_	dev	0.00	0	0.278	0.249
Main_RecrDev_1998	19	_	_	_	_	dev	0.00	0	0.174	0.223
Main_RecrDev_1999	20	_	_	_	_	dev	0.00	0	0.866	0.158
Main_RecrDev_2000	21	_	_	_	_	dev	0.00	0	0.500	0.177
Main_RecrDev_2001	22	_	_	_	_	dev	0.00	0	1.091	0.115
Main_RecrDev_2002	23	_	_	_	_	dev	0.00	0	1.459	0.102
Main_RecrDev_2003	24	_	_	_	_	dev	0.00	0	0.673	0.170
Main_RecrDev_2004	25	_	_	_	_	dev	0.00	0	0.834	0.159
Main_RecrDev_2005	26	_	_	_	_	dev	0.00	0	0.891	0.142
Main_RecrDev_2006	27	_	_	_	_	dev	0.00	0	0.877	0.155
Main_RecrDev_2007	28	_	_	_	_	dev	0.00	0	0.157	0.169
Main_RecrDev_2008	29	_	_	_	_	dev	0.00	0	-0.270	0.182
Main_RecrDev_2009	30	_	_	_	_	dev	0.00	0	-0.273	0.135
InitF_1F1	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_2F2	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_3F3	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_4F4	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_5F5	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_6F6	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
SizeSel_1P_1_F1	31	2	0	100	75.97	Normal	75.97	999	71.369	0.744
SizeSel_1P_2_F1	32	3	0.01	60	4.34	Normal	4.34	999	9.050	1.025
SizeSel_2P_1_F2	33	2	1	90	75.00	Normal	75.00	999	31.885	29.971
SizeSel_2P_2_F2	34	3	-9	9	-0.20	Normal	-0.20	999	-0.058	0.014
SizeSel_2P_3_F2	_	-2	0	140	100.04	NA	NA	NA	100.037	NA
SizeSel_2P_4_F2	_	-3	0	9	0.00	NA	NA	NA	0.000	NA
SizeSel_2P_5_F2	_	-88	1	24	1.00	NA	NA	NA	1.000	NA
SizeSel_2P_6_F2	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
SizeSel_3P_1_F3	35	2	1	90	75.00	Normal	75.00	999	32.022	79.653
SizeSel_3P_2_F3	36	3	0	9	0.20	Normal	0.20	999	4.815	92.688
SizeSel_3P_3_F3	37	2	0	140	115.00	Normal	115.00	999	95.581	1.109
SizeSel_3P_4_F3	38	3	0	9	0.20	Normal	0.20	999	0.330	0.075
SizeSel_3P_5_F3	_	-88	1	24	1.00	NA	NA	NA	1.000	NA
SizeSel_3P_6_F3	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
SizeSel_4P_1_F4	39	2	0	100	75.97	Normal	75.97	999	86.563	3.022
SizeSel_4P_2_F4	40	3	0.01	60	4.34	Normal	4.34	999	14.072	3.403
SizeSel_10P_1_S4	_	-2	1	90	60.84	NA	NA	NA	60.835	NA
SizeSel_10P_2_S4	_	-3	0	9	0.00	NA	NA	NA	0.003	NA
SizeSel_10P_3_S4	41	2	0	140	115.00	Normal	115.00	999	0.214	6.721
SizeSel_10P_4_S4	42	3	0	9	0.20	Normal	0.20	999	0.074	0.012
SizeSel_10P_5_S4	_	-88	1	24	1.00	NA	NA	NA	1.000	NA
SizeSel_10P_6_S4	_	-88	0	1	0.00	NA	NA	NA	0.000	NA

Table 4.2.a. Continued.

Label	Active number	Phase	Min	Max	Init	PR_type	Prior	Prior_SD	Estimate	SE
AgeSel_1P_1_F1	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_1P_2_F1	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_2P_1_F2	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_2P_2_F2	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_3P_1_F3	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_3P_2_F3	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_4P_1_F4	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_4P_2_F4	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_6P_1_F6	_	-2	0	90	0.01	NA	NA	NA	0.010	NA
AgeSel_6P_2_F6	43	3	-9	9	-1.00	Normal	-1.00	999	-0.867	0.090
AgeSel_6P_3_F6	_	-2	0	50	10.00	NA	NA	NA	10.000	NA
AgeSel_6P_4_F6	_	-3	0	9	2.00	NA	NA	NA	2.000	NA
AgeSel_6P_5_F6	_	-88	0	24	0.00	NA	NA	NA	0.000	NA
AgeSel_6P_6_F6	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
AgeSel_7P_1_S1	44	2	0	18	1.90	Normal	1.90	999	0.295	0.159
AgeSel_7P_2_S1	45	3	0	10	0.38	Normal	0.38	999	2.170	0.458
AgeSel_8P_1_S2	_	-2	0	90	0.01	NA	NA	NA	0.010	NA
AgeSel_8P_2_S2	46	3	-9	9	-1.00	Normal	-1.00	999	-2.166	0.517
AgeSel_8P_3_S2	_	-2	0	50	10.00	NA	NA	NA	10.000	NA
AgeSel_8P_4_S2	_	-3	0	9	2.00	NA	NA	NA	2.000	NA
AgeSel_8P_5_S2	_	-88	0	24	0.00	NA	NA	NA	0.000	NA
AgeSel_8P_6_S2	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
AgeSel_9P_1_S3	_	-2	0	90	0.01	NA	NA	NA	0.010	NA
AgeSel_9P_2_S3	47	3	-9	9	-1.00	Normal	-1.00	999	-0.594	0.073
AgeSel_9P_3_S3	_	-2	0	50	10.00	NA	NA	NA	10.000	NA
AgeSel_9P_4_S3	_	-3	0	9	2.00	NA	NA	NA	2.000	NA
AgeSel_9P_5_S3	_	-88	0	24	0.00	NA	NA	NA	0.000	NA
AgeSel_9P_6_S3	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
AgeSel_10P_1_S4	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_10P_2_S4	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_11P_1_S5	48	2	0	18	1.10	Normal	1.10	999	1.202	0.321
AgeSel_11P_2_S5	49	3	-10	10	0.64	Normal	0.64	999	3.106	0.673
AgeSel_12P_1_S6	_	-2	0	17.82	0.09	NA	NA	NA	0.089	NA
AgeSel_12P_2_S6	_	-3	-6	4	-6.00	NA	NA	NA	-6.000	NA
AgeSel_12P_3_S6	_	-3	-1	9	4.09	NA	NA	NA	4.090	NA
AgeSel_12P_4_S6	_	-3	-1	9	2.07	NA	NA	NA	2.070	NA
AgeSel_12P_5_S6	_	-2	-5	9	9.00	NA	NA	NA	9.000	NA
AgeSel_12P_6_S6	_	-2	-5	9	-4.34	NA	NA	NA	-4.342	NA
AgeSel_13P_1_S7	_	-2	0	17.82	0.09	NA	NA	NA	0.089	NA
AgeSel_13P_2_S7	_	-3	-6	4	-6.00	NA	NA	NA	-6.000	NA
AgeSel_13P_3_S7	_	-3	-1	9	5.37	NA	NA	NA	5.370	NA
AgeSel_13P_4_S7	_	-3	-1	9	2.42	NA	NA	NA	2.420	NA
AgeSel_13P_5_S7	_	-2	-5	9	9.00	NA	NA	NA	9.000	NA
AgeSel_13P_6_S7	_	-2	-5	9	-0.73	NA	NA	NA	-0.730	NA
AgeSel_14P_1_S8	_	-2	0	90	0.01	NA	NA	NA	0.010	NA
AgeSel_14P_2_S8	50	3	-9	9	-1.00	Normal	-1.00	999	-0.782	0.100
AgeSel_14P_3_S8	_	-2	0	50	10.00	NA	NA	NA	10.000	NA
AgeSel_14P_4_S8	_	-3	0	9	2.00	NA	NA	NA	2.000	NA
AgeSel_14P_5_S8	_	-88	0	24	0.00	NA	NA	NA	0.000	NA
AgeSel_14P_6_S8	_	-88	0	1	0.00	NA	NA	NA	0.000	NA

Table 4.2.b. A total of 52 parameters were estimated in the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the dome-shaped functional form of length based selectivity (Sel-2) for the main targeted fishery (fleet F1 – NE Gillnet Kept). Parameter estimation for ln(R_0) and selectivity utilized a normal prior with a large standard deviation (Prior_SD = 1,000 or 999, respectively) and independent minimum and maximum boundary conditions for each parameter. Recruitment deviations were estimated as described above (see Section 3). Parameters with a negative phase were fixed at their initial value. The final gradient for the proposed base model configuration Sel-2 was 2.19E-06.

Label	Active number	Phase	Min	Max	Init	PR_type	Prior	Prior_SD	Estimate	SE
L_at_Amin_Fem_GP_1	_	-3	5	100	48.84	NA	NA	NA	48.842	NA
L_at_Amax_Fem_GP_1	_	-4	50	400	110.46	NA	NA	NA	110.461	NA
VonBert_K_Fem_GP_1	_	-5	0.01	0.65	0.29	NA	NA	NA	0.292	NA
CV_young_Fem_GP_1	_	-2	0.01	0.3	0.15	NA	NA	NA	0.150	NA
CV_old_Fem_GP_1	_	-3	0.01	0.3	0.12	NA	NA	NA	0.120	NA
L_at_Amin_Mal_GP_1	_	-3	5	100	46.96	NA	NA	NA	46.964	NA
L_at_Amax_Mal_GP_1	_	-4	50	400	94.51	NA	NA	NA	94.511	NA
VonBert_K_Mal_GP_1	_	-5	0.01	0.65	0.44	NA	NA	NA	0.440	NA
CV_young_Mal_GP_1	_	-2	0.01	0.3	0.15	NA	NA	NA	0.150	NA
CV_old_Mal_GP_1	_	-3	0.01	0.3	0.12	NA	NA	NA	0.120	NA
Wtlen_1_Fem	_	-3	-3	3	6.00E-06	NA	NA	NA	0.000	NA
Wtlen_2_Fem	_	-3	-3	3.4	3.01	NA	NA	NA	3.008	NA
Mat50%_Fem*	_	-3	1	150	91.98	NA	NA	NA	91.984	NA
Mat_slope_Fem*	_	-3	-3	3	-0.45	NA	NA	NA	-0.449	NA
Eggs_scalar_Fem*	_	-3	-3	10	9.53	NA	NA	NA	9.530	NA
Eggs_exp_len_Fem*	_	-3	-3	3	0.00	NA	NA	NA	0.000	NA
Wtlen_1_Mal	_	-3	-3	3	1.00E-05	NA	NA	NA	0.000	NA
Wtlen_2_Mal	_	-3	-3	3.3	2.81	NA	NA	NA	2.808	NA
RecrDist_GP_1	_	-3	-4	4	0.00	NA	NA	NA	0.000	NA
RecrDist_Area_1	_	-3	-4	4	0.00	NA	NA	NA	0.000	NA
RecrDist_Seas_1	_	-3	-4	4	0.00	NA	NA	NA	0.000	NA
CohortGrowDev	_	-3	-4	4	0.00	NA	NA	NA	0.000	NA
SR_LN(R0)	1	1	2.3	13.82	7.04	Normal	7.04	1000	7.777	0.082
SR_BH_steep	_	-2	0.2	1	0.54	NA	NA	NA	0.542	NA
SR_sigmaR	_	-4	0.2	1.9	0.62	NA	NA	NA	0.616	NA
SR_envlink	_	-3	-5	5	0.00	NA	NA	NA	0.000	NA
SR_R1_offset	_	-4	-5	5	0.00	NA	NA	NA	0.000	NA
SR_autocorr	_	-4	-5	5	0.00	NA	NA	NA	0.000	NA

*Maturity and fecundity were implemented in this assessment with an age specific vector of fecundity at age as described above (see Sections 2; **Table 2.9**). The parameter values identified in this table for Mat50%_Fem, Mat_slope_Fem, Eggs_scalar_Fem, and Eggs_exp_len_Fem, are place holders required by SS3 but are not implemented in this assessment. Similarly, the parameters RecrDist_GP_1, RecrDist_Area_1, RecrDist_Seas_1, CohortGrowDev , SR_envlink, SR_R1_offset, and SR_autocorr are place holders in SS3 and are not implemented in this assessment.

Table 4.2.b. Continued.

Label	Active number	Phase	Min	Max	Init	PR_type	Prior	Prior_SD	Estimate	SE
Main_RecrDev_1981	2	_	_	_	_	dev	0.00	0	-0.128	0.216
Main_RecrDev_1982	3	_	_	_	_	dev	0.00	0	-0.475	0.276
Main_RecrDev_1983	4	_	_	_	_	dev	0.00	0	-0.556	0.257
Main_RecrDev_1984	5	_	_	_	_	dev	0.00	0	-0.160	0.218
Main_RecrDev_1985	6	_	_	_	_	dev	0.00	0	-0.218	0.216
Main_RecrDev_1986	7	_	_	_	_	dev	0.00	0	-0.659	0.231
Main_RecrDev_1987	8	_	_	_	_	dev	0.00	0	-0.639	0.220
Main_RecrDev_1988	9	_	_	_	_	dev	0.00	0	-1.333	0.280
Main_RecrDev_1989	10	_	_	_	_	dev	0.00	0	-0.906	0.189
Main_RecrDev_1990	11	_	_	_	_	dev	0.00	0	0.200	0.128
Main_RecrDev_1991	12	_	_	_	_	dev	0.00	0	-0.637	0.222
Main_RecrDev_1992	13	_	_	_	_	dev	0.00	0	-1.155	0.268
Main_RecrDev_1993	14	_	_	_	_	dev	0.00	0	-0.168	0.172
Main_RecrDev_1994	15	_	_	_	_	dev	0.00	0	-0.416	0.224
Main_RecrDev_1995	16	_	_	_	_	dev	0.00	0	0.424	0.159
Main_RecrDev_1996	17	_	_	_	_	dev	0.00	0	0.668	0.146
Main_RecrDev_1997	18	_	_	_	_	dev	0.00	0	0.177	0.222
Main_RecrDev_1998	19	_	_	_	_	dev	0.00	0	0.023	0.210
Main_RecrDev_1999	20	_	_	_	_	dev	0.00	0	0.635	0.154
Main_RecrDev_2000	21	_	_	_	_	dev	0.00	0	0.355	0.167
Main_RecrDev_2001	22	_	_	_	_	dev	0.00	0	0.973	0.112
Main_RecrDev_2002	23	_	_	_	_	dev	0.00	0	1.377	0.100
Main_RecrDev_2003	24	_	_	_	_	dev	0.00	0	0.620	0.165
Main_RecrDev_2004	25	_	_	_	_	dev	0.00	0	0.794	0.155
Main_RecrDev_2005	26	_	_	_	_	dev	0.00	0	0.812	0.140
Main_RecrDev_2006	27	_	_	_	_	dev	0.00	0	0.763	0.156
Main_RecrDev_2007	28	_	_	_	_	dev	0.00	0	0.135	0.164
Main_RecrDev_2008	29	_	_	_	_	dev	0.00	0	-0.260	0.176
Main_RecrDev_2009	30	_	_	_	_	dev	0.00	0	-0.246	0.132
InitF_1F1	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_2F2	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_3F3	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_4F4	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_5F5	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
InitF_6F6	_	-1	0	1.9	0.00	NA	NA	NA	0.000	NA
SizeSel_1P_1_F1	31	2	1	90	75.00	Normal	75.00	999	77.236	2.006
SizeSel_1P_2_F1	32	3	0	9	0.20	Normal	0.20	999	0.234	0.024
SizeSel_1P_3_F1	33	2	0	140	115.00	Normal	115.00	999	93.400	3.685
SizeSel_1P_4_F1	34	3	0	9	0.20	Normal	0.20	999	0.160	0.028
SizeSel_1P_5_F1	_	-88	1	24	1.00	NA	NA	NA	1.000	NA
SizeSel_1P_6_F1	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
SizeSel_2P_1_F2	35	2	1	90	75.00	Normal	75.00	999	34.497	25.880
SizeSel_2P_2_F2	36	3	-9	9	-0.20	Normal	-0.20	999	-0.061	0.014
SizeSel_2P_3_F2	_	-2	0	140	100.04	NA	NA	NA	100.037	NA
SizeSel_2P_4_F2	_	-3	0	9	0.00	NA	NA	NA	0.000	NA
SizeSel_2P_5_F2	_	-88	1	24	1.00	NA	NA	NA	1.000	NA
SizeSel_2P_6_F2	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
SizeSel_3P_1_F3	37	2	1	90	75.00	Normal	75.00	999	45.500	995.047
SizeSel_3P_2_F3	38	3	0	9	0.20	Normal	0.20	999	0.000	0.000
SizeSel_3P_3_F3	39	2	0	140	115.00	Normal	115.00	999	95.273	1.087
SizeSel_3P_4_F3	40	3	0	9	0.20	Normal	0.20	999	0.326	0.071
SizeSel_3P_5_F3	_	-88	1	24	1.00	NA	NA	NA	1.000	NA
SizeSel_3P_6_F3	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
SizeSel_4P_1_F4	41	2	0	100	75.97	Normal	75.97	999	86.058	3.013
SizeSel_4P_2_F4	42	3	0.01	60	4.34	Normal	4.34	999	13.851	3.455
SizeSel_10P_1_S4	_	-2	1	90	60.84	NA	NA	NA	60.835	NA
SizeSel_10P_2_S4	_	-3	0	9	0.00	NA	NA	NA	0.003	NA
SizeSel_10P_3_S4	43	2	0	140	115.00	Normal	115.00	999	0.250	7.834
SizeSel_10P_4_S4	44	3	0	9	0.20	Normal	0.20	999	0.078	0.012
SizeSel_10P_5_S4	_	-88	1	24	1.00	NA	NA	NA	1.000	NA
SizeSel_10P_6_S4	_	-88	0	1	0.00	NA	NA	NA	0.000	NA

Table 4.2.b. Continued.

Label	Active number	Phase	Min	Max	Init	PR_type	Prior	Prior_SD	Estimate	SE
AgeSel_1P_1_F1	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_1P_2_F1	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_2P_1_F2	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_2P_2_F2	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_3P_1_F3	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_3P_2_F3	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_4P_1_F4	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_4P_2_F4	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_6P_1_F6	_	-2	0	90	0.01	NA	NA	NA	0.010	NA
AgeSel_6P_2_F6	45	3	-9	9	-1.00	Normal	-1.00	999	-0.931	0.096
AgeSel_6P_3_F6	_	-2	0	50	10.00	NA	NA	NA	10.000	NA
AgeSel_6P_4_F6	_	-3	0	9	2.00	NA	NA	NA	2.000	NA
AgeSel_6P_5_F6	_	-88	0	24	0.00	NA	NA	NA	0.000	NA
AgeSel_6P_6_F6	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
AgeSel_7P_1_S1	46	2	0	18	1.90	Normal	1.90	999	0.236	0.162
AgeSel_7P_2_S1	47	3	0	10	0.38	Normal	0.38	999	2.144	0.477
AgeSel_8P_1_S2	_	-2	0	90	0.01	NA	NA	NA	0.010	NA
AgeSel_8P_2_S2	48	3	-9	9	-1.00	Normal	-1.00	999	-2.158	0.515
AgeSel_8P_3_S2	_	-2	0	50	10.00	NA	NA	NA	10.000	NA
AgeSel_8P_4_S2	_	-3	0	9	2.00	NA	NA	NA	2.000	NA
AgeSel_8P_5_S2	_	-88	0	24	0.00	NA	NA	NA	0.000	NA
AgeSel_8P_6_S2	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
AgeSel_9P_1_S3	_	-2	0	90	0.01	NA	NA	NA	0.010	NA
AgeSel_9P_2_S3	49	3	-9	9	-1.00	Normal	-1.00	999	-0.613	0.074
AgeSel_9P_3_S3	_	-2	0	50	10.00	NA	NA	NA	10.000	NA
AgeSel_9P_4_S3	_	-3	0	9	2.00	NA	NA	NA	2.000	NA
AgeSel_9P_5_S3	_	-88	0	24	0.00	NA	NA	NA	0.000	NA
AgeSel_9P_6_S3	_	-88	0	1	0.00	NA	NA	NA	0.000	NA
AgeSel_10P_1_S4	_	-99	0	10	0.01	NA	NA	NA	0.010	NA
AgeSel_10P_2_S4	_	-99	10	100	18.00	NA	NA	NA	18.000	NA
AgeSel_11P_1_S5	50	2	0	18	1.10	Normal	1.10	999	1.097	0.328
AgeSel_11P_2_S5	51	3	-10	10	0.64	Normal	0.64	999	3.085	0.716
AgeSel_12P_1_S6	_	-2	0	17.82	0.09	NA	NA	NA	0.089	NA
AgeSel_12P_2_S6	_	-3	-6	4	-6.00	NA	NA	NA	-6.000	NA
AgeSel_12P_3_S6	_	-3	-1	9	4.09	NA	NA	NA	4.090	NA
AgeSel_12P_4_S6	_	-3	-1	9	2.07	NA	NA	NA	2.070	NA
AgeSel_12P_5_S6	_	-2	-5	9	9.00	NA	NA	NA	9.000	NA
AgeSel_12P_6_S6	_	-2	-5	9	-4.34	NA	NA	NA	-4.342	NA
AgeSel_13P_1_S7	_	-2	0	17.82	0.09	NA	NA	NA	0.089	NA
AgeSel_13P_2_S7	_	-3	-6	4	-6.00	NA	NA	NA	-6.000	NA
AgeSel_13P_3_S7	_	-3	-1	9	5.37	NA	NA	NA	5.370	NA
AgeSel_13P_4_S7	_	-3	-1	9	2.42	NA	NA	NA	2.420	NA
AgeSel_13P_5_S7	_	-2	-5	9	9.00	NA	NA	NA	9.000	NA
AgeSel_13P_6_S7	_	-2	-5	9	-0.73	NA	NA	NA	-0.730	NA
AgeSel_14P_1_S8	_	-2	0	90	0.01	NA	NA	NA	0.010	NA
AgeSel_14P_2_S8	52	3	-9	9	-1.00	Normal	-1.00	999	-0.793	0.101
AgeSel_14P_3_S8	_	-2	0	50	10.00	NA	NA	NA	10.000	NA
AgeSel_14P_4_S8	_	-3	0	9	2.00	NA	NA	NA	2.000	NA
AgeSel_14P_5_S8	_	-88	0	24	0.00	NA	NA	NA	0.000	NA
AgeSel_14P_6_S8	_	-88	0	1	0.00	NA	NA	NA	0.000	NA

Table 4.3. Low catch scenario for Atlantic smooth dogfish (in lb whole weight). The first four columns are commercial landings by gear (GN=gillnets, TR=Trawl, LL=Longline, Other=other gear) and were left unchanged with respect to the base run. The next four columns are discards from the northeast (first three) and the southeast (fourth). Northeast discards represent discards released alive that are assumed to die (discard estimates x post-release live discard mortality rate for each of the gears); Southeast discards are also discards released alive assumed to die (discard estimates in numbers x average weight of discards from the SE Gillnet Observer Program x post-release live discard mortality rate for gillnets). For Northeast discards, a low 95% CL was calculated based on CVs, which were available starting in 1989; for Southeast discards a low 95% CL was available starting in 1998. Next are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 in numbers x average weight of A+B1 from MRIP x post-release live discard mortality rate for hook and line). Low 95% CLs were calculated for both A+B1 and B2 based on CVs, which were available from the onset of the MRFSS/MRIP program in 1981.

Year	Com-GN Landings	Com-TR Landings	Com-LL Landings	Com-Other Landings	Com-GN-NE (PRM)	Com-TR-NE (PRM)	Com-LL-NE (PRM)	Com-GN-SE (PRM)	Recreational (A+B1)	Recreational (PRM)
1981	0	2683	0	0	4963	250610	680	0	196265	0
1982	0	7619	0	0	3290	317358	489	0	6376	130559
1983	505	23842	525	11500	3072	300753	427	0	217928	424057
1984	0	1320	0	0	3624	263474	328	0	67867	111889
1985	715	7155	0	16644	3483	225716	322	0	179044	10955
1986	101	5180	0	0	3788	216118	403	0	0	0
1987	9796	60714	19300	0	3722	198031	656	0	44514	35213
1988	912	813	0	0	3989	185552	606	0	176075	63568
1989	150253	111703	0	0	0	425874	0	0	203432	278943
1990	234113	82536	0	0	0	82451	0	0	118110	136942
1991	732671	97683	11010	929	0	26971	0	0	123110	150451
1992	1767170	96567	551	205	18728	98070	0	0	83088	106837
1993	1464658	187825	1526	2	76202	13070	0	0	0	147690
1994	1443107	202242	14742	84282	24630	50904	149	0	68920	167188
1995	2792499	71496	4409	8973	20979	81902	321	0	50050	250506
1996	1639843	72045	201	4189	0	93175	0	0	53560	200105
1997	944914	60096	1500	13121	4010	33221	0	0	43961	364748
1998	748008	194618	391	215739	22381	36481	0	116	0	344166
1999	1268515	66604	3675	2096	28875	1230	0	94	8848	246421
2000	1023946	58030	8433	930	21591	62983	324	106	64341	512901
2001	1132671	120994	8933	14400	8705	0	24	103	54575	510294
2002	1329510	153683	21309	17403	22117	36884	186	109	36515	313734
2003	1430755	164128	18385	20246	52837	9700	250	101	62197	419276
2004	1596868	96115	15887	72389	4054	40172	606	97	23433	387594
2005	1058452	33787	51029	110366	43310	0	406	109	81021	1187785
2006	918780	100142	14426	108628	19741	0	498	127	20273	1204165
2007	1313988	98781	16211	229663	23583	86841	655	0	6432	634725
2008	1337695	174975	30830	273395	3083	24379	719	0	83308	632889
2009	1854673	291046	80642	488272	11418	31056	1314	0	31314	506902
2010	3027939	232648	56914	584767	3932	24854	1507	0	24804	196544
2011	2067545	315187	15465	395322	11726	0	1546	0	12840	223449
2012	1521436	175789	8862	533254	938	0	1226	0	11316	455152

Table 4.4. High catch scenario for Atlantic smooth dogfish (in lb whole weight). The first four columns are commercial landings by gear (GN=gillnets, TR=Trawl, LL=Longline, Other=other gear) and were left unchanged with respect to the base run. The next four columns are discards from the northeast (first three) and the southeast (fourth). Northeast discards represent discards released alive that are assumed to die (discard estimates x post-release live discard mortality rate for each of the gears); Southeast discards are also discards released alive assumed to die (discard estimates in numbers x average weight of discards from the SE Gillnet Observer Program x post-release live discard mortality rate for gillnets). For Northeast discards, a high 95% CL was calculated based on CVs, which were available starting in 1989; for Southeast discards a high 95% CL was available starting in 1998. Next are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 in numbers x average weight of A+B1 from MRIP x post-release live discard mortality rate for hook and line). High 95% CLs were calculated for both A+B1 and B2 based on CVs, which were available from the onset of the MRFSS/MRIP program in 1981.

Year	Com-GN Landings	Com-TR Landings	Com-LL Landings	Com-Other Landings	Com-GN-NE (PRM)	Com-TR-NE (PRM)	Com-LL-NE (PRM)	Com-GN-SE (PRM)	Recreational (A+B1)	Recreational (PRM)
1981	0	2683	0	0	4963	250610	680		771102	175071
1982	0	7619	0	0	3290	317358	489		191920	416705
1983	505	23842	525	11500	3072	300753	427		579099	1404093
1984	0	1320	0	0	3624	263474	328		645236	534129
1985	715	7155	0	16644	3483	225716	322		547687	401970
1986	101	5180	0	0	3788	216118	403		1450465	692229
1987	9796	60714	19300	0	3722	198031	656		805229	413492
1988	912	813	0	0	3989	185552	606		640834	343475
1989	150253	111703	0	0	12932	470684	1254		586879	817665
1990	234113	82536	0	0	9517	161836	718		255481	288982
1991	732671	97683	11010	929	16139	85958	1710		242032	271073
1992	1767170	96567	551	205	382704	348869	2836		276596	240018
1993	1464658	187825	1526	2	215347	39959	1973		627103	366001
1994	1443107	202242	14742	84282	67395	169843	565		168886	418357
1995	2792499	71496	4409	8973	51759	238788	929		258748	535390
1996	1639843	72045	201	4189	141699	229442	2005		168406	380546
1997	944914	60096	1500	13121	53133	92609	2041		279862	654674
1998	748008	194618	391	215739	172144	178318	2554	13767	224924	861428
1999	1268515	66604	3675	2096	276127	43757	1620	11138	98737	465049
2000	1023946	58030	8433	930	66148	328412	1224	12584	268962	902015
2001	1132671	120994	8933	14400	71534	191967	3131	12159	156934	782486
2002	1329510	153683	21309	17403	109551	279115	2076	13022	135773	541458
2003	1430755	164128	18385	20246	205498	92338	2846	11825	311134	794094
2004	1596868	96115	15887	72389	9399	184680	1478	11576	91890	660029
2005	1058452	33787	51029	110366	269668	632191	6142	12911	284438	2188706
2006	918780	100142	14426	108628	87403	377344	3192	14964	76499	2693924
2007	1313988	98781	16211	229663	63322	411535	2023	70563	638744	1007344
2008	1337695	174975	30830	273395	9060	117201	2376	850	252905	1269387
2009	1854673	291046	80642	488272	22392	270450	2733	0	126030	959543
2010	3027939	232648	56914	584767	7139	119322	2898	73172	88711	315480
2011	2067545	315187	15465	395322	24465	340941	3216	3424	116744	412825
2012	1521436	175789	8862	533254	2871	173775	4071	4441	182156	1088791

Table 4.5. Standardized hierarchical index of abundance along with associated CVs used in sensitivity scenarios. The index is scaled (divided by the mean).

Year	Index	CV
1981	0.908	0.372
1982	1.195	0.368
1983	0.549	0.401
1984	1.236	0.291
1985	1.588	0.284
1986	0.949	0.303
1987	0.543	0.350
1988	0.517	0.306
1989	0.439	0.276
1990	0.796	0.279
1991	0.460	0.269
1992	0.377	0.281
1993	0.467	0.269
1994	0.450	0.273
1995	0.649	0.270
1996	0.854	0.257
1997	0.517	0.273
1998	0.744	0.278
1999	1.252	0.274
2000	0.916	0.259
2001	1.308	0.267
2002	2.119	0.260
2003	1.860	0.259
2004	1.254	0.267
2005	1.147	0.264
2006	1.504	0.259
2007	1.537	0.244
2008	0.989	0.236
2009	1.318	0.239
2010	0.920	0.258
2011	1.217	0.237
2012	1.423	0.242

Table 4.6. Akaike's information criterion (AIC) was used to compare model fit to data given the number of estimated parameters obtained for the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configurations (**Tables 4.2.a and 4.2.b**) evaluated with both the asymptotic-shaped (Sel-1) and the dome-shaped (Sel-2) functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept).

Proposed base mode configuration	AIC	Δ_i
Asymptotic-shaped selectivity for fleet F1 (Sel-1)	5733.6	100.1
Dome-shaped selectivity for fleet F1 (Sel-2)	5633.5	0.0

Table 4.7. The root mean squared error, RMSE, of model fit to the length composition data associated with each fleet and survey included in the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configuration (**Tables 4.2.a and 4.2.b**) under both the asymptotic-shaped (Sel-1) and the dome-shaped (Sel-2) functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept).

Fleet or survey	Associated length composition data source	RMSE (Sel-1; Asymptotic-F1)	RMSE (Sel-2; Dome-F1)
F1	2.1 NE GNOP (Combined Mesh, Kept)	0.033	0.028
F2	2.2 NE GNOP (Combined Mesh, Discard)	0.036	0.036
F3	2.3 NE TOP (Combined Mesh and Disposition)	0.037	0.037
F4	2.5 SE BLLOP	0.025	0.026
F5	NA	NA	NA
F6	2.6 MRIP (MRFSS)	0.077	0.077
S1	1.1 NEFSC Fall Trawl-N	0.043	0.043
S2	1.2 NEAMAP Fall Trawl	0.065	0.065
S3	1.3 MA DMF Fall Trawl	0.079	0.079
S4	1.4 RI DEM Seas Trawl	0.108	0.108
S5	1.5 CT DEEP Trawl	0.028	0.029
S6	1.6 DE Trawl	0.128	0.127
S7	1.7 NJ DFW Trawl	0.051	0.051
S8	1.8 SEAMAP-SA Trawl	0.044	0.044

Table 4.8. The root mean squared error, RMSE, of model residuals was used to compare model fit to each standardized abundance index (survey) included in the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configuration (**Tables 4.2.a and 4.2.b**) evaluated with both the asymptotic-shaped (Sel-1) and the dome-shaped (Sel-2) functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept).

Survey	Data source	RMSE (Sel-1; Asymptotic-F1)	RMSE (Sel-2; Dome-F1)
S1	NEFSC Fall Trawl-N	0.52	0.51
S2	NEAMAP Fall Trawl	0.46	0.44
S3	MA DMF Fall Trawl	1.01	0.95
S4	RI DEM Seas Trawl	0.86	0.87
S5	CT DEEP Trawl	0.47	0.48
S6	DE Trawl	0.92	0.95
S7	NJ DFW Trawl	0.56	0.57
S8	SEAMAP-SA Trawl	1.22	1.22

Table 4.9. A Kolmogorov-Smirnov, K-S, two sample test statistic was used to compare the shape of the length frequency distribution (calculated as a proportion) obtained for fleet F1 relative to those obtained for the other fleets and surveys included in both of the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configurations (**Tables 4.2.a and 4.2.b**; **Appendix 4.B)**. The annual length frequency distributions were aggregated either by sex or as combined sex, where available, for each fleet and survey. The K-S two-sample test statistic (*D*), the critical value for the K-S test statistic (D_{α}), the sample sizes (n1 and n2), and the length bin with the maximum absolute difference in the cumulative proportions at length were obtained as described above. Significant differences at the alpha = 0.05 level are indicated with an asterisk.

	D						Length bin with maximum difference		
Fleet or survey	Female	Male	Combined	D_{α}	n1	n2	Female (cm FL)	Male (cm FL)	Combined sex (cm FL)
F1 vs S1	0.16*	0.12	NA	0.12	240	272	75	65	NA
F1 vs S2	0.77*	0.83*	NA	0.19	240	64	60	60	NA
F1 vs S3	0.33*	0.47*	NA	0.12	240	272	75	75	NA
F1 vs S4	NA	NA	0.59*	0.21	240	48	NA	NA	65
F1 vs S5	0.09	0.07	NA	0.15	240	128	90	60	NA
F1 vs S6	NA	NA	0.71*	0.13	240	224	NA	NA	60
F1 vs S7	NA	NA	0.45*	0.12	240	272	NA	NA	70
F1 vs S8	0.63*	0.66*	NA	0.13	240	192	70	65	NA
F1 vs F2	0.71*	0.81*	NA	0.16	240	112	70	65	NA
F1 vs F3	0.42*	0.44*	NA	0.13	240	192	75	70	NA
F1 vs F4	0.47*	0.27	NA	0.35	240	16	90	80	NA
F1 vs F5	NA	NA	NA	NA	NA	NA	NA	NA	NA
F1 vs F6	NA	NA	0.62*	0.13	240	176	NA	NA	65

Table 4.10.a. Total biomass (*B*), spawning stock fecundity (SSF), recruits (*R*), and aggregate fishing mortality (*F*), calculated as overall exploitation rate in numbers, obtained from the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the asymptotic-shaped functional form of length based selectivity (Sel-1) for the main targeted fishery (fleet F1 – NE Gillnet Kept).

Year	*B* (mt)	SSF (1,000s)	R (1,000s)	*F*
Virg		13,762	2,211	
Init		13,762	2,211	
1981	30,262	13,762	1,256	0.024
1982	28,454	13,723	812	0.020
1983	26,206	13,653	798	0.060
1984	23,639	13,505	1,230	0.048
1985	21,665	13,238	1,191	0.045
1986	19,785	12,633	752	0.068
1987	17,796	11,560	805	0.058
1988	15,799	10,270	352	0.051
1989	14,032	9,138	614	0.128
1990	12,808	8,140	1,775	0.087
1991	12,172	7,291	740	0.069
1992	11,179	6,305	410	0.127
1993	10,142	5,082	1,485	0.187
1994	9,346	4,155	814	0.141
1995	9,245	3,573	1,776	0.238
1996	9,462	2,972	2,283	0.152
1997	10,117	2,613	1,205	0.097
1998	10,599	2,473	1,052	0.119
1999	11,239	2,523	2,127	0.114
2000	11,937	2,728	1,544	0.119
2001	13,366	3,220	3,054	0.121
2002	16,515	3,679	4,730	0.093
2003	19,160	3,863	2,208	0.070
2004	21,122	4,079	2,663	0.062
2005	22,847	4,520	2,954	0.115
2006	23,911	5,332	3,128	0.112
2007	23,954	6,744	1,664	0.078
2008	22,961	8,068	1,153	0.078
2009	21,355	8,667	1,175	0.101
2010	19,710	8,698	1,969	0.117
2011	18,297	8,273	1,939	0.103
2012	17,679	7,830	1,906	0.115

Table 4.10.b. Total biomass (*B*), spawning stock fecundity (SSF), recruits (*R*), and aggregate fishing mortality (*F*), calculated as overall exploitation rate in numbers, obtained from the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the dome-shaped functional form of length based selectivity (Sel-2) for the main targeted fishery (fleet F1 – NE Gillnet Kept).

Year	*B* (mt)	SSF (1,000s)	*R* (1,000s)	*F*
Virg		14,849	2,385	
Init		14,849	2,385	
1981	32,937	14,849	1,801	0.024
1982	31,493	14,812	1,264	0.019
1983	29,595	14,750	1,158	0.055
1984	27,392	14,629	1,710	0.041
1985	25,740	14,417	1,603	0.036
1986	24,051	13,946	1,024	0.054
1987	22,108	13,080	1,029	0.045
1988	20,007	11,965	503	0.040
1989	18,038	10,968	754	0.098
1990	16,758	10,112	2,230	0.067
1991	16,051	9,328	943	0.059
1992	14,886	8,347	543	0.113
1993	13,395	7,131	1,380	0.150
1994	12,210	6,110	1,016	0.133
1995	12,005	5,432	2,244	0.227
1996	12,255	4,810	2,715	0.135
1997	13,115	4,321	1,580	0.084
1998	13,772	3,974	1,301	0.099
1999	14,501	3,841	2,358	0.095
2000	15,230	4,040	1,827	0.103
2001	16,879	4,651	3,627	0.105
2002	20,670	5,257	5,736	0.082
2003	23,954	5,529	2,751	0.061
2004	26,533	5,771	3,331	0.054
2005	28,713	6,254	3,502	0.095
2006	30,010	7,195	3,512	0.092
2007	30,087	8,924	2,013	0.068
2008	28,928	10,653	1,427	0.069
2009	27,061	11,525	1,478	0.090
2010	25,073	11,726	2,258	0.108
2011	23,247	11,380	2,241	0.094
2012	22,340	10,847	2,213	0.102

Table 4.11.a. Aggregate annual fishing mortality, calculated as overall exploitation rate in numbers, relative to fishing mortality at MSY (F/F_{MSY}) and SSF/SSF_{MSY} obtained from the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the asymptotic-shaped functional form of length based selectivity (Sel-1) for the main targeted fishery (fleet F1 – NE Gillnet Kept).

Year	F/F_{MSY}	SSF/SSF_{MSY}
1981	0.209	3.138
1982	0.178	3.129
1983	0.533	3.113
1984	0.423	3.079
1985	0.395	3.018
1986	0.596	2.880
1987	0.515	2.636
1988	0.446	2.341
1989	1.133	2.083
1990	0.769	1.856
1991	0.605	1.662
1992	1.123	1.438
1993	1.654	1.159
1994	1.246	0.947
1995	2.103	0.815
1996	1.344	0.678
1997	0.853	0.596
1998	1.054	0.564
1999	1.004	0.575
2000	1.048	0.622
2001	1.067	0.734
2002	0.820	0.839
2003	0.615	0.881
2004	0.544	0.930
2005	1.010	1.030
2006	0.986	1.216
2007	0.690	1.538
2008	0.690	1.840
2009	0.893	1.976
2010	1.034	1.983
2011	0.909	1.886
2012	1.018	1.785

Table 4.11.b. Aggregate annual fishing mortality, calculated as overall exploitation rate in numbers, relative to fishing mortality at MSY (F/F_{MSY}) and SSF/SSF_{MSY} obtained from the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the dome-shaped functional form of length based selectivity (Sel-2) for the main targeted fishery (fleet F1 – NE Gillnet Kept).

Year	F/F_{MSY}	SSF/SSF_{MSY}
1981	0.182	3.129
1982	0.150	3.121
1983	0.430	3.108
1984	0.319	3.082
1985	0.282	3.038
1986	0.418	2.938
1987	0.349	2.756
1988	0.307	2.521
1989	0.759	2.311
1990	0.519	2.131
1991	0.454	1.966
1992	0.876	1.759
1993	1.164	1.502
1994	1.032	1.287
1995	1.760	1.145
1996	1.047	1.014
1997	0.655	0.911
1998	0.765	0.837
1999	0.738	0.809
2000	0.796	0.851
2001	0.814	0.980
2002	0.632	1.108
2003	0.471	1.165
2004	0.419	1.216
2005	0.737	1.318
2006	0.712	1.516
2007	0.527	1.880
2008	0.533	2.245
2009	0.698	2.428
2010	0.834	2.471
2011	0.726	2.398
2012	0.792	2.286

Table 4.12. Summary of model results for the proposed base configuration under Sel-1and eight model sensitivities conducted either with externally derived selectivity or selectivity under the same model configuration as Sel-1 (asymptotic-shaped functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept)). Parameters are the MSY (mt) obtained directly from Stock Synthesis as the equilibrium yield at F_{MSY}, spawning stock fecundity, SSF (1,000s), recruits, R (1,000s), and aggregate annual fishing mortality, F, calculated as overall exploitation rate in numbers. Model sensitivities (MS) are described above and defined here as follows: MS-1 External Selectivity, MS-2 Start Year 1972 (Sel-1), MS-3 Ranked CPUE (Sel-1), MS-4 Low Catch (Sel-1), MS-5 High Catch (Sel-1), MS-6 Low Productivity (Sel-1), MS-7 High Productivity (Sel-1), and MS-8 Hierarchical (Sel-1). Values are also provided for the Akaike information criteria (AIC), total objective function, final gradient, 1- the average natural mortality at age $(1-\bar{M}_a)$, MSST = $(1-\bar{M}_a)\times SSF_{MSY}$, and stock-recruitment steepness for each model configuration. AIC values are not comparable among models with different data inputs.

	Proposed Base (Sel-1)		MS-1		MS-2		MS-3		MS-4		MS-5		MS-6		MS-7		MS-8	
AIC	5733.6		6271.1		5997.8		5660.2		5741.5		5704.1		5703.4		5732.3		1658.4	
Parameters	50		30		60		50		50		50		50		50		41	
Objective function	2816.8		3105.5		2938.9		2780.1		2820.8		2802.0		2801.7		2816.2		788.2	
Gradient	7.41E-05		8.98E-05		8.57E-04		3.00E-05		5.16E-06		1.45E-05		1.68E-04		3.81E-06		2.47E-06	
$(1-\bar{M}_a)$	0.78		0.78		0.78		0.78		0.78		0.78		0.74		0.80		0.78	
Steepness	0.54		0.54		0.54		0.54		0.54		0.54		0.49		0.62		0.54	
MSST	3,421		2,402		3,094		3,508		2,789		4,316		3,657		2,913		2,957	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
SSF_{2012}	7,830	15%	3,387	11%	5,647	14%	8,759	16%	6,394	16%	10,036	16%	10,009	18%	5,519	13%	5,496	25%
F_{2012}	0.115	---	0.186	---	0.131	---	0.107	---	0.106	---	0.114	---	0.086	---	0.155	---	0.162	---
R_{2012}	1,906	8%	1,119	6%	1,595	7%	2,007	9%	1,560	9%	2,411	9%	2,701	11%	1,250	6%	1,534	12%
SSF_0	13,762	5%	9,722	5%	11,968	5%	14,107	6%	11,277	6%	17,305	6%	14,504	8%	12,267	4%	11,906	6%
R_0	2,211	5%	1,562	5%	2,002	5%	2,266	6%	1,811	6%	2,780	6%	3,017	8%	1,484	4%	1,912	6%
MSY	1,059	5%	759	5%	965	5%	1,083	6%	886	6%	1,310	5%	1,212	8%	1,056	3%	920	6%
SSF_{MSY}	4,386	6%	3,080	5%	3,967	5%	4,498	6%	3,576	6%	5,534	6%	4,942	8%	3,641	4%	3,792	6%
F_{MSY}	0.113	2%	0.091	0%	0.110	2%	0.115	2%	0.104	2%	0.121	2%	0.106	2%	0.135	2%	0.112	3%
SSF_{2012}/SSF_{MSY}	1.785	---	1.100	---	1.423	---	1.947	---	1.788	---	1.813	---	2.025	---	1.516	---	1.449	---
F_{2012}/F_{MSY}	1.020	13%	2.050	9%	1.331	11%	0.930	13%	1.023	14%	0.937	13%	0.808	16%	1.145	11%	0.581	23%
Stock status	$SSF_{2012} > SSF_{MSY}$		$SSF_{2012} > SSF_{MSY}$		$SSF_{2012} > SSF_{MSY}$		$SSF_{2012} > SSF_{MSY}$		$SSF_{2012} > SSF_{MSY}$		$SSF_{2012} > SSF_{MSY}$		$SSF_{2012} > SSF_{MSY}$		$SSF_{2012} > SSF_{MSY}$		$SSF_{2012} > SSF_{MSY}$	
Fishery status	$F_{2012} \approx F_{MSY}$*		$F_{2012} > F_{MSY}$		$F_{2012} > F_{MSY}$		$F_{2012} < F_{MSY}$		$F_{2012} \approx F_{MSY}$*		$F_{2012} < F_{MSY}$		$F_{2012} < F_{MSY}$		$F_{2012} > F_{MSY}$		$F_{2012} < F_{MSY}$	

*Either $F_{2012} > F_{MSY}$ or $F_{2012} = F_{MSY}$, depending upon how rounding is calculated.

Table 4.13. Summary of model results for the proposed base configuration under Sel-2 and seven model sensitivities conducted under the same model configuration as Sel-2 (dome-shaped functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept)). Parameters are the MSY (mt) obtained directly from Stock Synthesis as the equilibrium yield at F_{MSY}, spawning stock fecundity, SSF (1,000s), recruits, R (1,000s), and aggregate annual fishing mortality, F, calculated as overall exploitation rate in numbers. Model sensitivities (MS) are described above and defined here as follows: MS-9 Start Year 1972 (Sel-2), MS-10 Ranked CPUE (Sel-2), MS-11 Low Catch (Sel-2), MS-12 High Catch (Sel-2), MS-13 Low Productivity (Sel-2), MS-14 High Productivity (Sel-2), and MS-15 Hierarchical (Sel-2). Values are also provided for the Akaike information criteria (AIC), total objective function, final gradient, 1 - average natural mortality at age $(1-\bar{M}_a)$, MSST = $(1-\bar{M}_a)\times\mathrm{SSF_{MSY}}$, and stock-recruitment steepness for each model. AIC values are not comparable among models with different data inputs.

	Proposed Base (Sel-2)		MS-9		MS-10		MS-11		MS-12		MS-13		MS-14		MS-15	
AIC	5633.5		5918.4		5559.5		5654.1		5634.5		5651.6		5632.7		1654.5	
Parameters	52		62		52		52		52		52		52		43	
Objective function	2764.7		2897.2		2727.7		2775.1		2765.3		2773.8		2764.3		784.2	
Gradient	2.19E-06		3.68E-05		4.06E-05		4.07E-05		4.34E-05		1.46E-05		2.59E-04		8.06E-06	
$(1-\bar{M}_a)$	0.78		0.78		0.78		0.78		0.78		0.74		0.80		0.78	
Steepness	0.54		0.54		0.54		0.54		0.54		0.54		0.49		0.62	
MSST	3,701		3,311		3,866		3,103		4,595		4,169		3,062		3,557	
	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV
SSF_{2012}	10,847	18%	8,329	16%	12,283	18%	9,380	19%	13,081	17%	14,115	23%	7,490	14%	12,809	37%
F_{2012}	0.102	---	0.126	---	0.093	---	0.092	---	0.104	---	0.071	---	0.145	---	0.101	---
R_{2012}	2,213	11%	1,896	9%	2,360	11%	1,876	12%	2,720	10%	3,293	16%	1,405	7%	2,235	22%
SSF_0	14,849	8%	12,793	7%	15,506	9%	12,503	9%	18,383	8%	16,538	13%	12,893	5%	14,245	17%
R_0	2,385	8%	2,135	7%	2,491	9%	2,008	9%	2,953	8%	3,440	13%	1,560	5%	2,288	18%
MSY	1,125	8%	1,011	6%	1,173	9%	966	9%	1,371	8%	1,363	13%	1,065	4%	1,071	18%
$\mathrm{SSF_{MSY}}$	4,746	8%	4,245	7%	4,958	9%	3,979	9%	5,892	8%	5,634	13%	3,827	5%	4,560	18%
$\mathrm{F_{MSY}}$	0.129	2%	0.127	2%	0.130	2%	0.120	2%	0.136	2%	0.116	2%	0.156	2%	0.133	3%
$\mathrm{SSF_{2012}/SSF_{MSY}}$	2.286	---	1.962	---	2.478	---	2.358	---	2.220	---	2.505	---	1.957	---	2.809	---
$\mathrm{F_{2012}/F_{MSY}}$	0.792	16%	0.992	14%	0.716	17%	0.765	17%	0.762	16%	0.614	21%	0.930	12%	0.760	34%
Stock status	$\mathrm{SSF_{2012} > SSF_{MSY}}$		$\mathrm{SSF_{2012} > SSF_{MSY}}$		$\mathrm{SSF_{2012} > SSF_{MSY}}$		$\mathrm{SSF_{2012} > SSF_{MSY}}$		$\mathrm{SSF_{2012} > SSF_{MSY}}$		$\mathrm{SSF_{2012} > SSF_{MSY}}$		$\mathrm{SSF_{2012} > SSF_{MSY}}$		$\mathrm{SSF_{2012} > SSF_{MSY}}$	
Fishery status	$\mathrm{F_{2012} < F_{MSY}}$		$\mathrm{F_{2012} \approx F_{MSY}}$*		$\mathrm{F_{2012} < F_{MSY}}$		$\mathrm{F_{2012} < F_{MSY}}$		$\mathrm{F_{2012} < F_{MSY}}$		$\mathrm{F_{2012} < F_{MSY}}$		$\mathrm{F_{2012} < F_{MSY}}$		$\mathrm{F_{2012} < F_{MSY}}$	

*Either $F_{2012} < F_{\mathrm{MSY}}$ or $F_{2012} = F_{\mathrm{MSY}}$, depending upon how rounding is calculated.

4.15. FIGURES

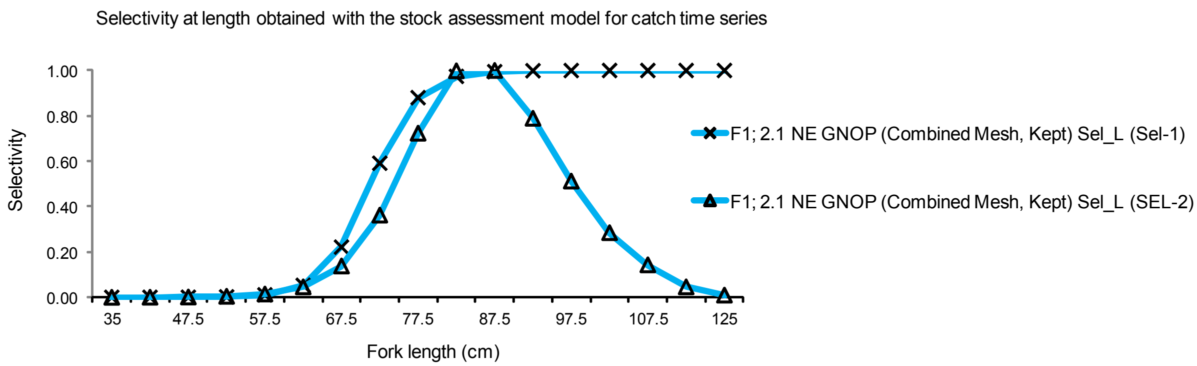
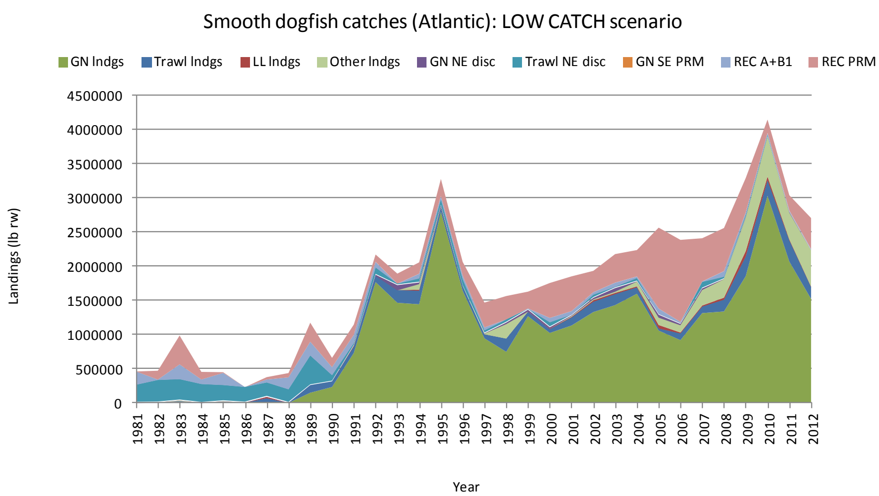
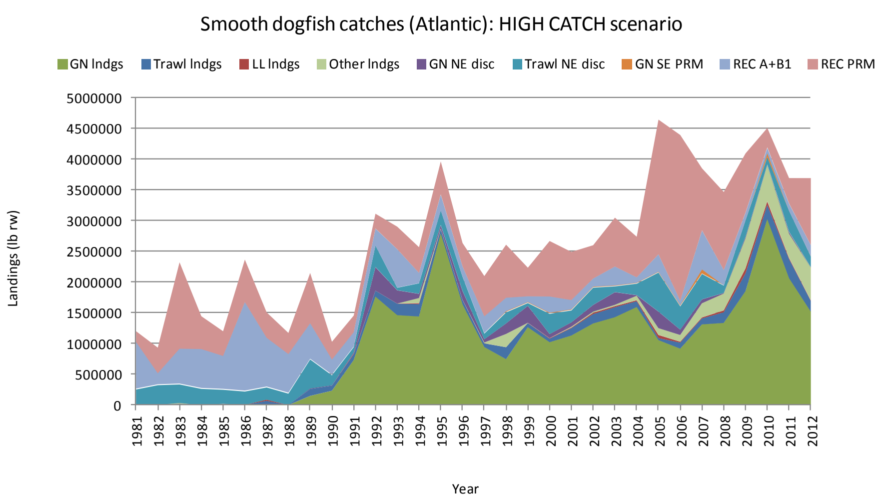


Figure 4.1. Comparison of the final asymptotic-shaped (Sel-1) and the dome-shaped (Sel-2) functional forms of length based selectivity obtained for the main targeted fishery (fleet F1 – NE Gillnet Kept) in the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configurations using two alternative functional forms of selectivity (asymptotic-shaped and dome-shaped) evaluated for length based selectivity of the main targeted fishery (fleet F1 – NE Gillnet Kept).





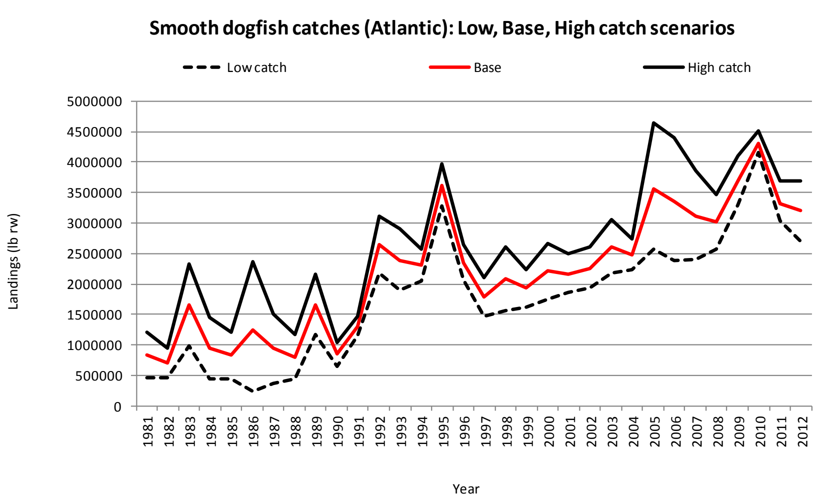


Figure 4.2. Low (top) and high (middle) catches used in the low and high catch sensitivity runs. The base run catches are shown for reference (bottom).

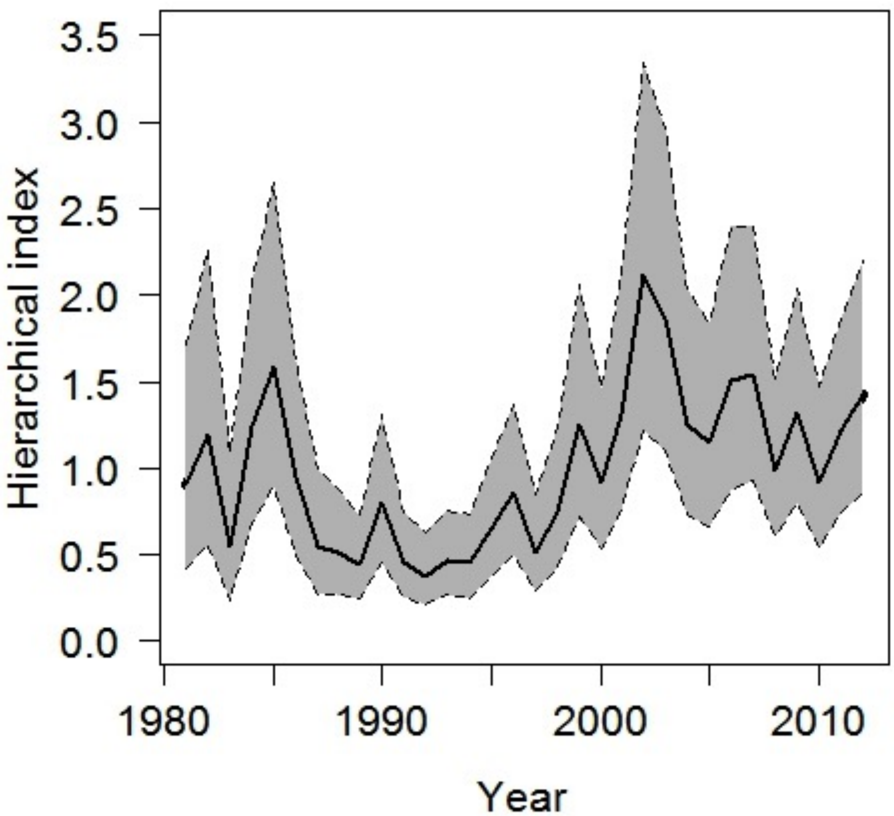


Figure 4.3. Hierarchical index of abundance used in sensitivity scenarios. The shaded area is the 95% CI band.

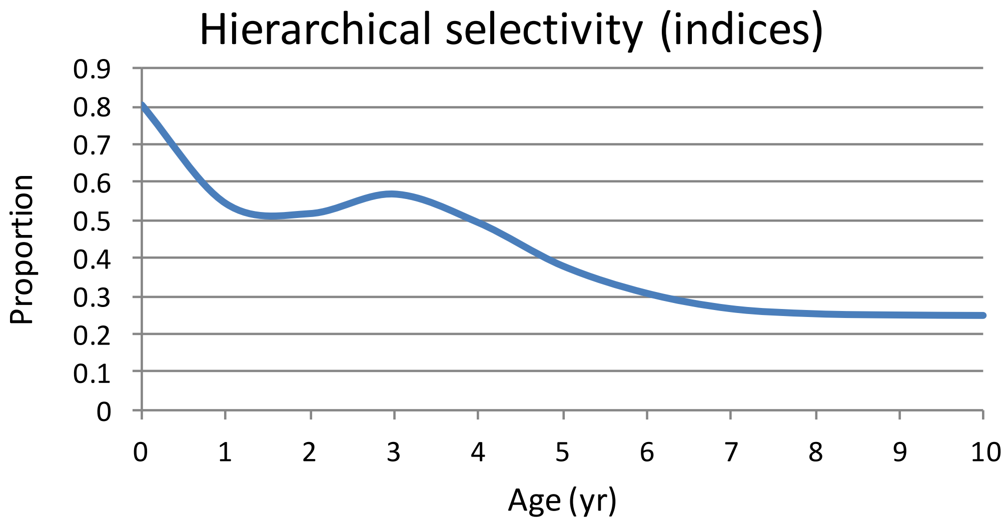


Figure 4.4. Selectivity for the hierarchical index. Selectivity was obtained by weighting the base run selectivities by the inverse variance selectivity weights reported in SEDAR39-AW-02.

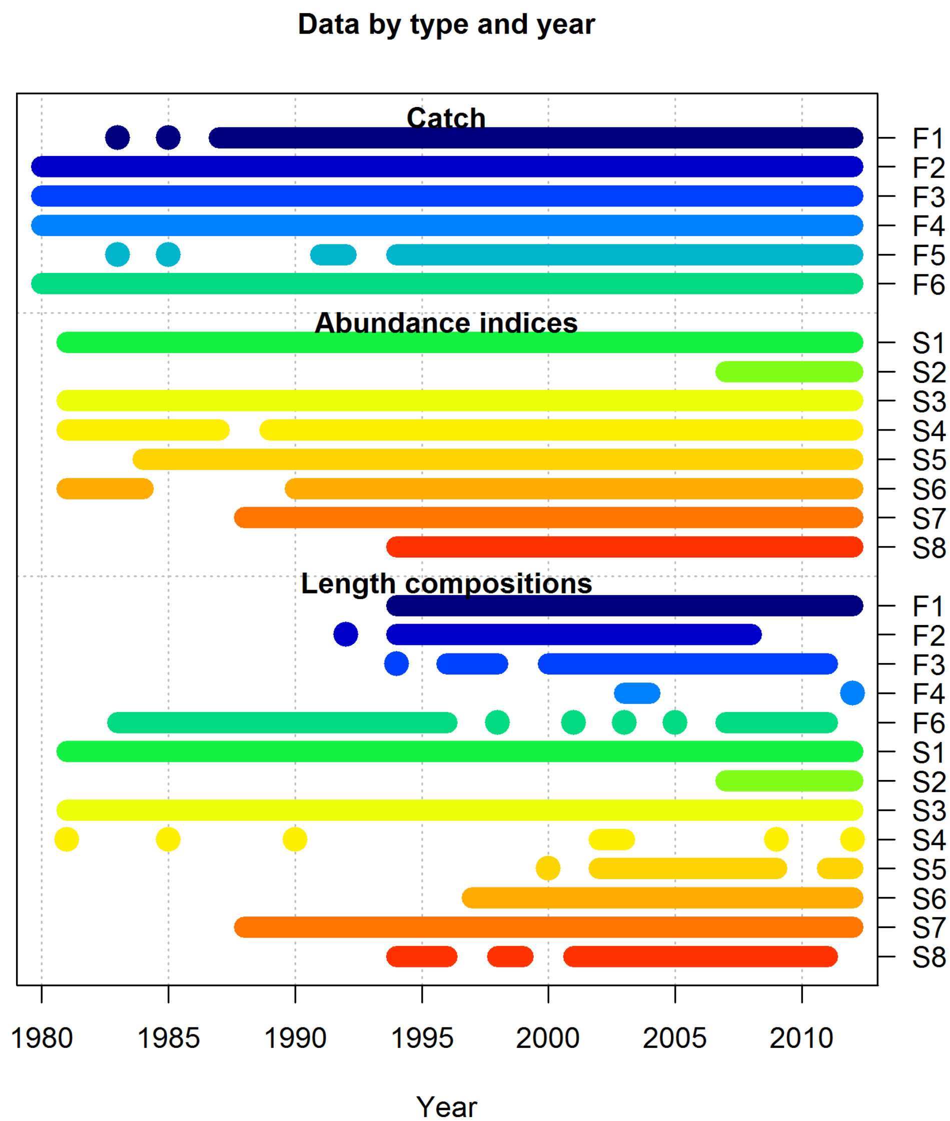
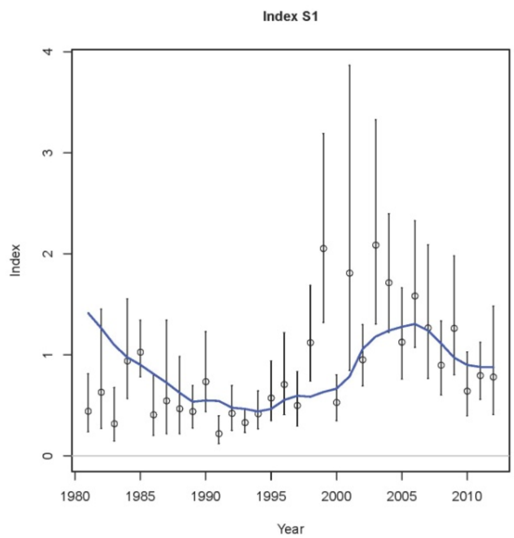


Figure 4.5. Data sources used in this assessment under both proposed base model configurations (Sel-1 and Sel-2).



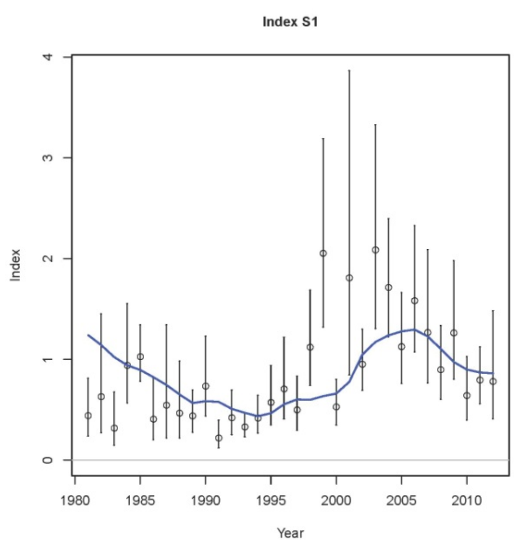
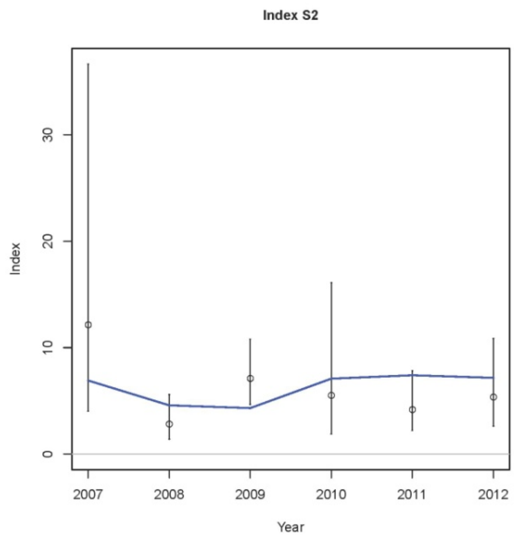
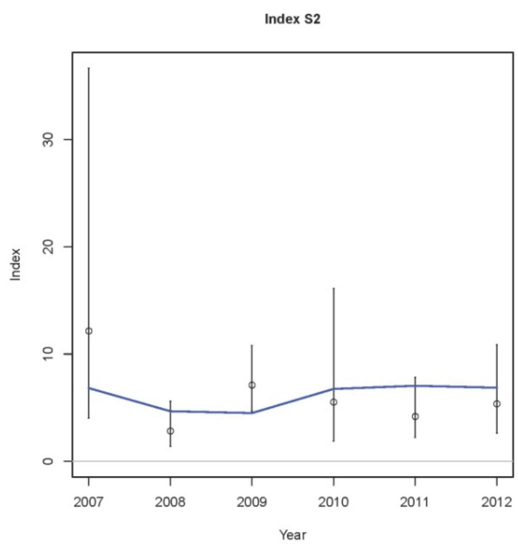


Figure 4.6. Model fits (blue line) to standardized indices of relative abundance (open circles with 95% confidence intervals assuming lognormal error) for both proposed base model configurations (Sel-1 top panel and Sel-2 bottom panel). See Section 3.2 and **Tables 2.5** and **2.6** for a description of the data sources for each index of relative abundance (surveys S1 – S8).





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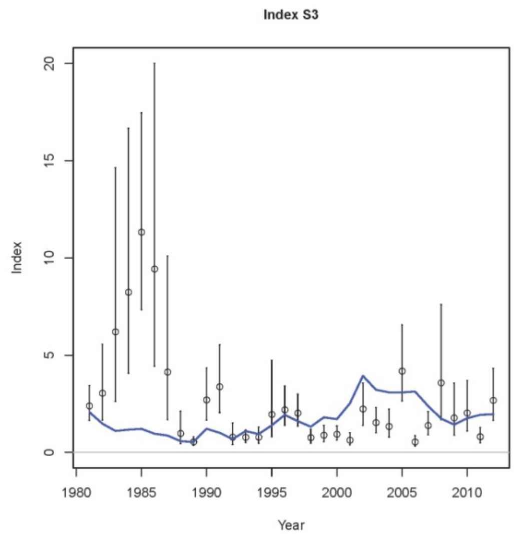

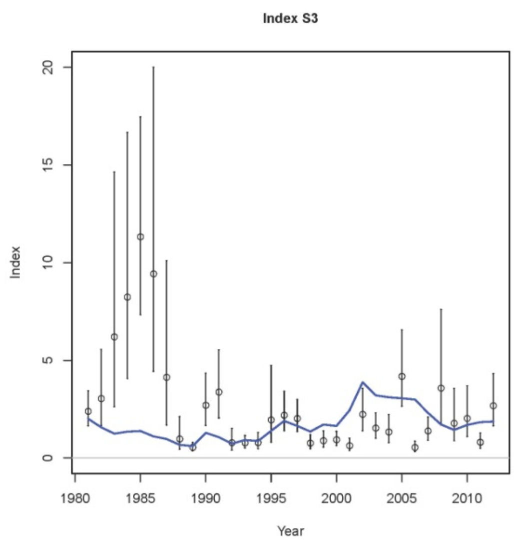

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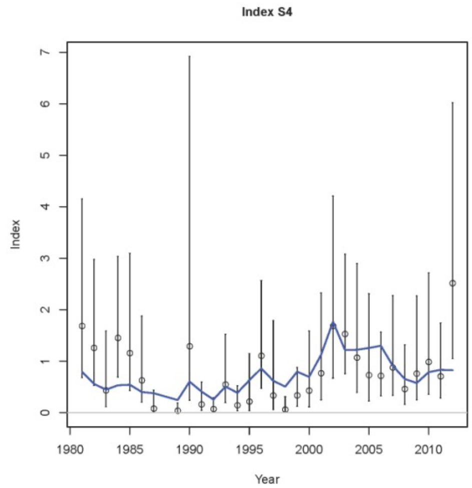

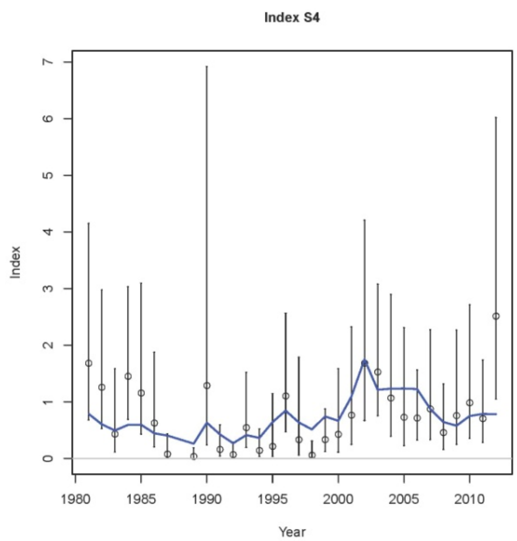

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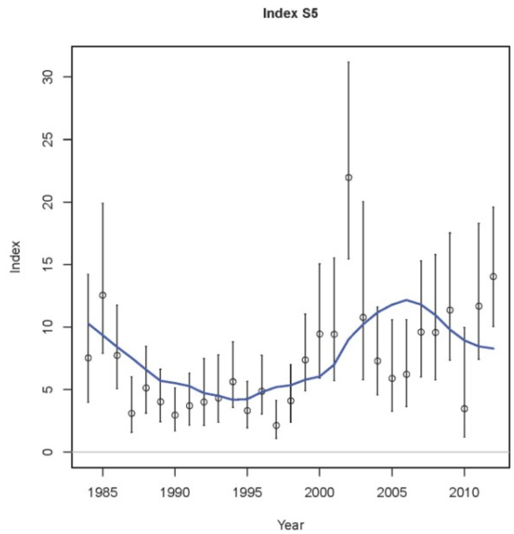

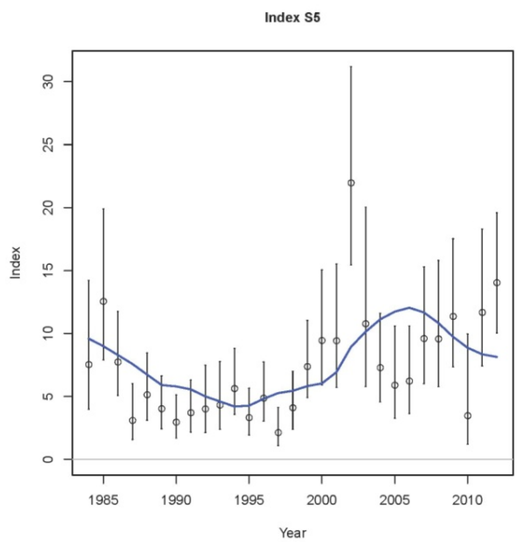

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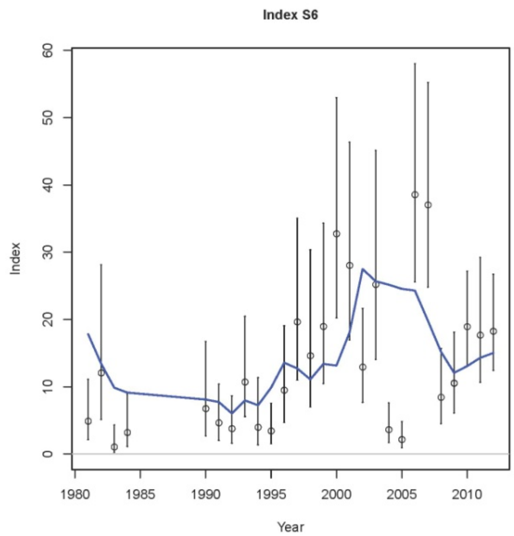

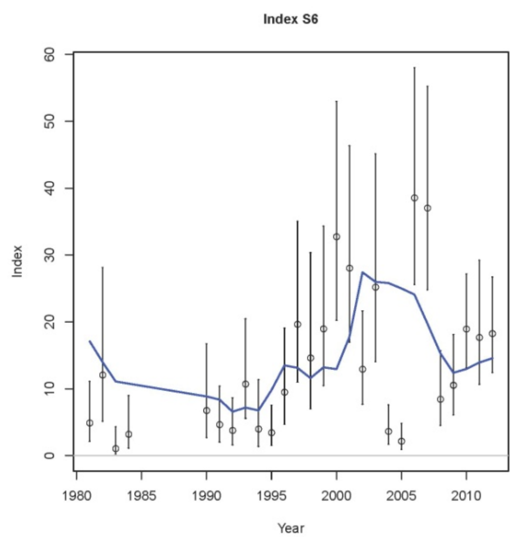

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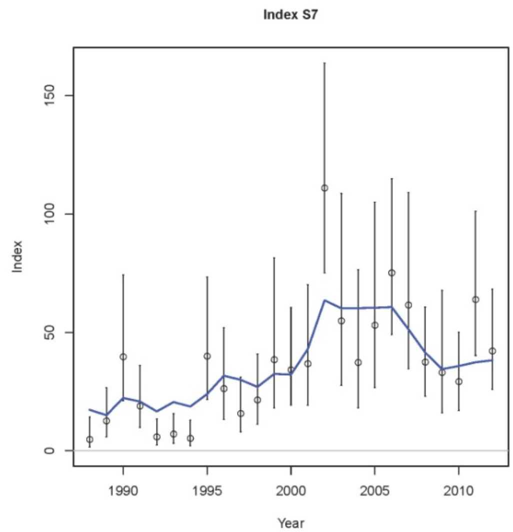

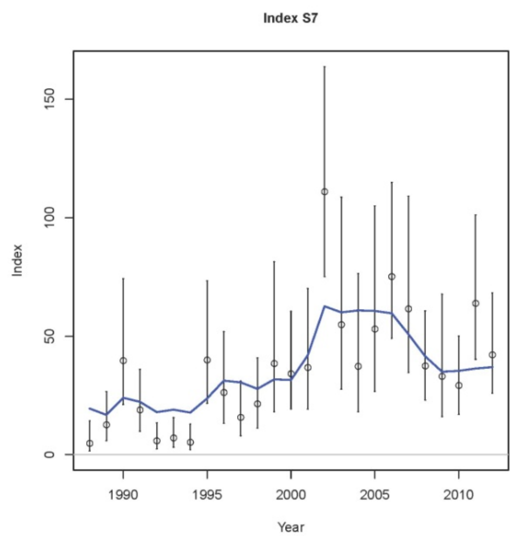

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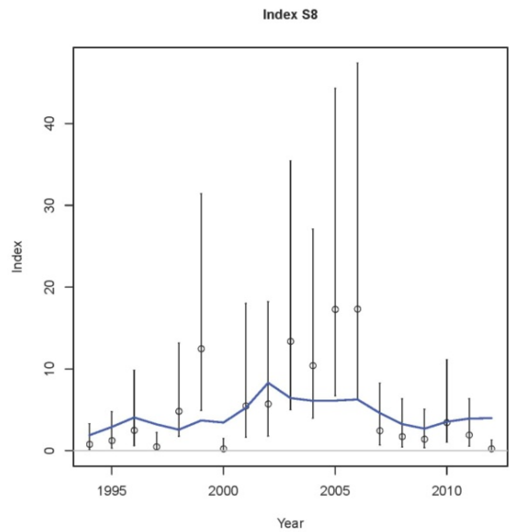


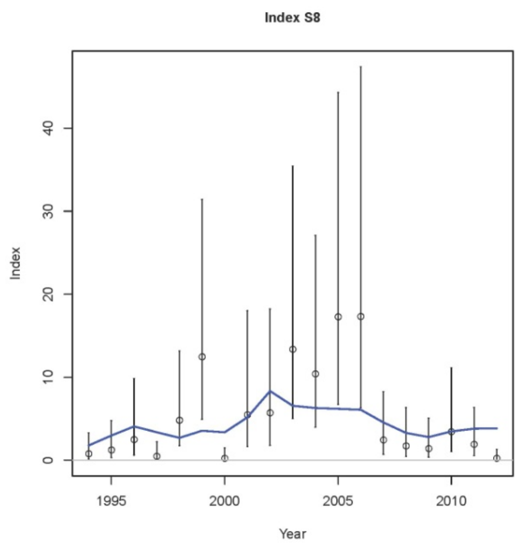


Figure 4.6. Continued.

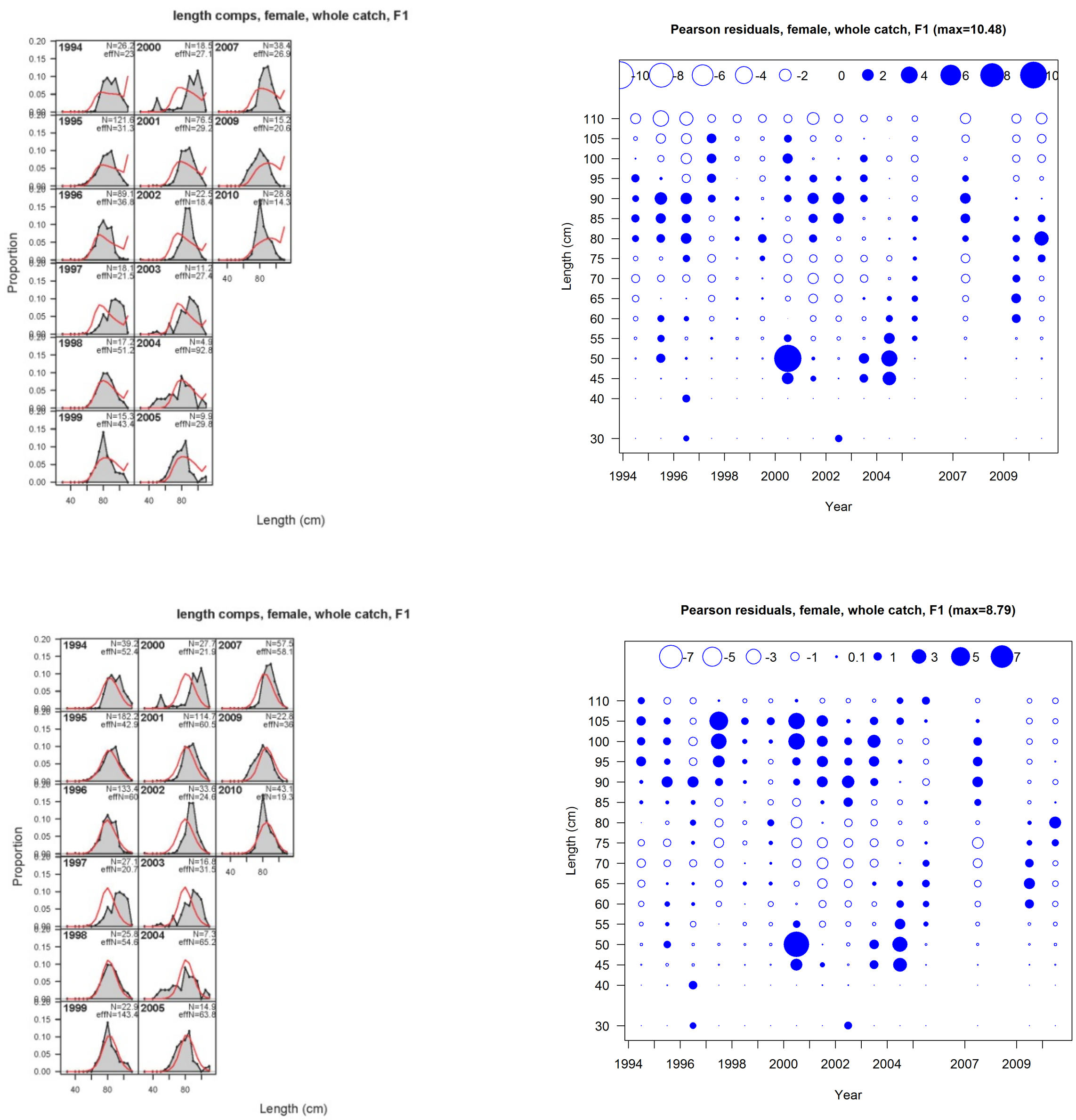


Figure 4.7. Observed and model predicted female annual length compositions for the main targeted fishery (fleet F1 – NE Gillnet Kept) under both proposed base model configurations (Sel-1 upper panels and Sel-2 lower panels). Length compositions shown start in 1994 (upper left graph) and continue to 2010. Diameter of Pearson residuals (circles) indicates relative error; predicted < observed (solid), predicted > observed (transparent). The maximum diameter width of the plot for Pearson residuals changed between Sel-1 (Max = 10.48) and Sel-2 (Max = 8.79).

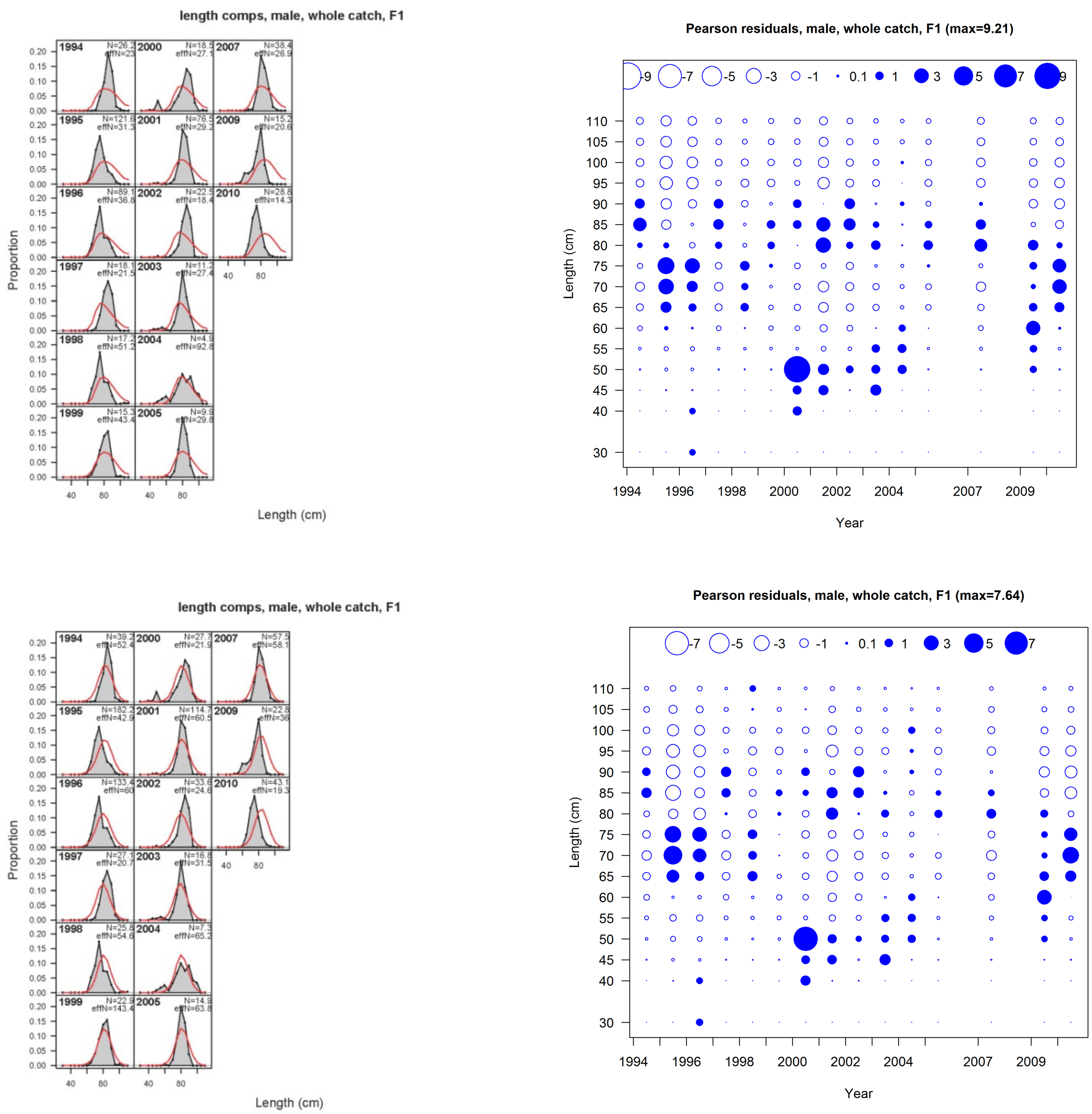
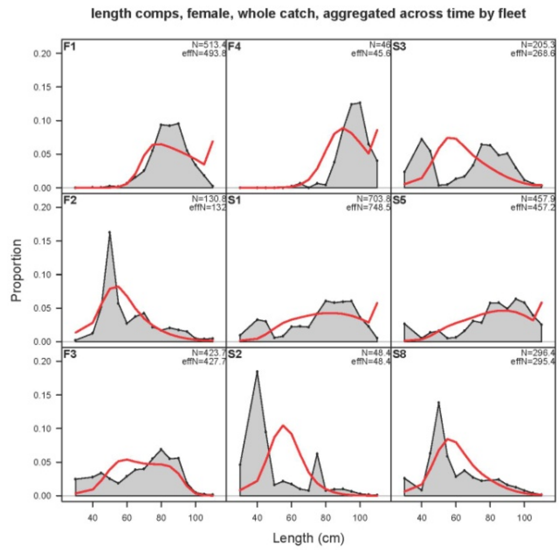


Figure 4.8. Observed and model predicted male annual length compositions for the main targeted fishery (fleet F1 – NE Gillnet Kept) under both proposed base model configurations (Sel-1 upper panels and Sel-2 lower panels). Length compositions shown start in 1994 (upper left graph) and continue to 2010. Diameter of Pearson residuals (circles) indicates relative error; predicted < observed (solid), predicted > observed (transparent). The maximum diameter width of the plot for Pearson residuals changed between Sel-1 (Max = 9.21) and Sel-2 (Max = 7.64).



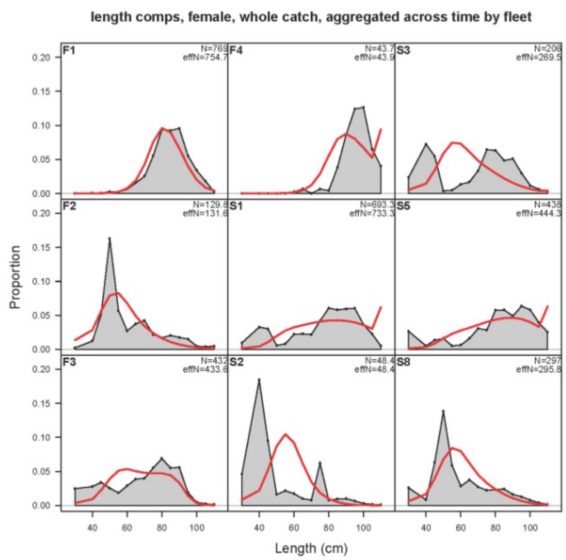
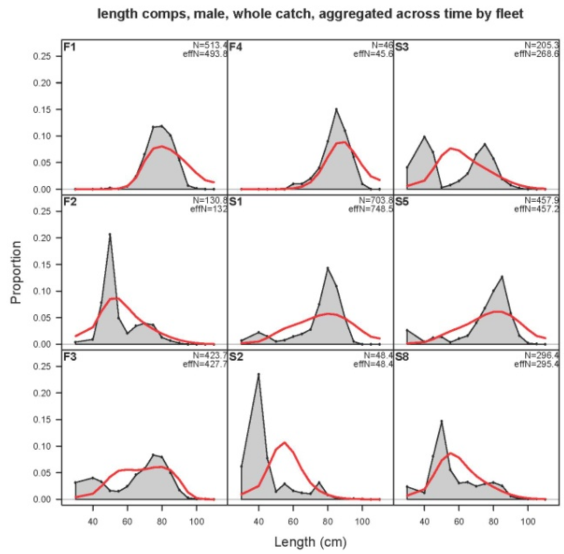


Figure 4.9. Model fits to aggregated female length compositions for data sources with sex specific length compositions are provided for both proposed based model configurations (Sel-1 upper panel and Sel-2 lower panel). See Section 3.2 and (and **Tables 2.3 - 2.5)** for a description of the length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8).



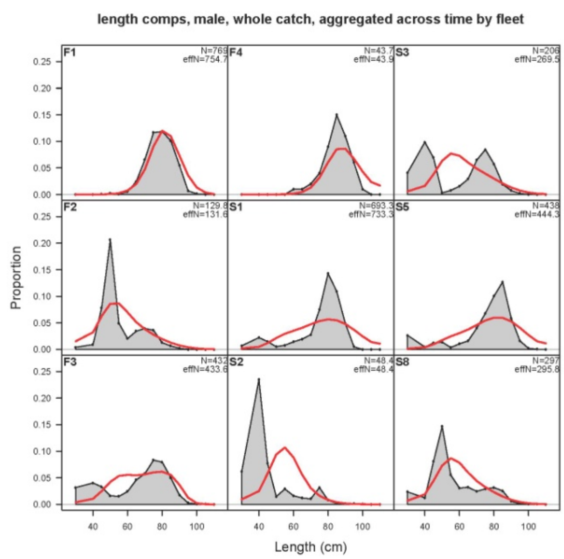
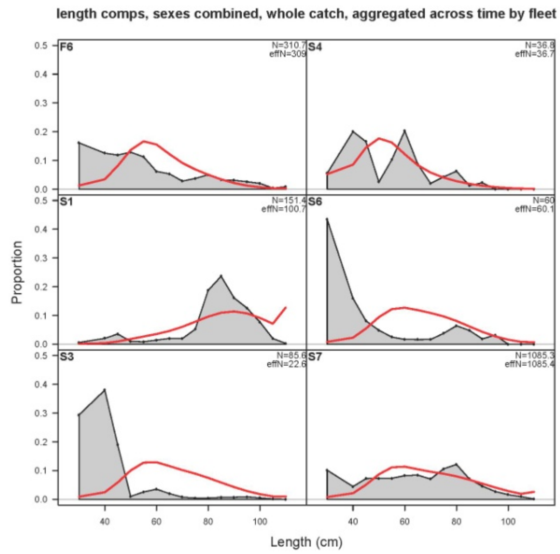


Figure 4.10. Model fits to aggregate male length compositions for data sources with sex specific length compositions are provided for both proposed based model configurations (Sel-1 and Sel-2). See Section 3.2 and (and **Tables 2.3 - 2.5)** for a description of the length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8).



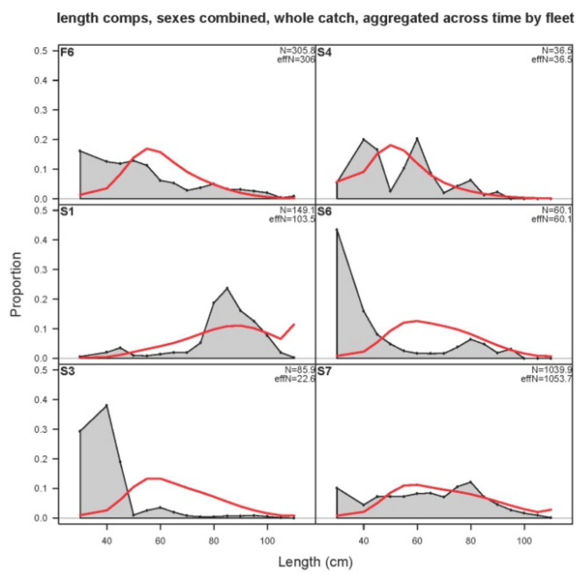


Figure 4.11. Model fits to aggregate combined or unknown sex length compositions for data sources without sex specific length compositions are provided for both proposed based model configurations (Sel-1 and Sel-2). See Section 3.2 and (and **Tables 2.3 - 2.5)** for a description of the length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8).

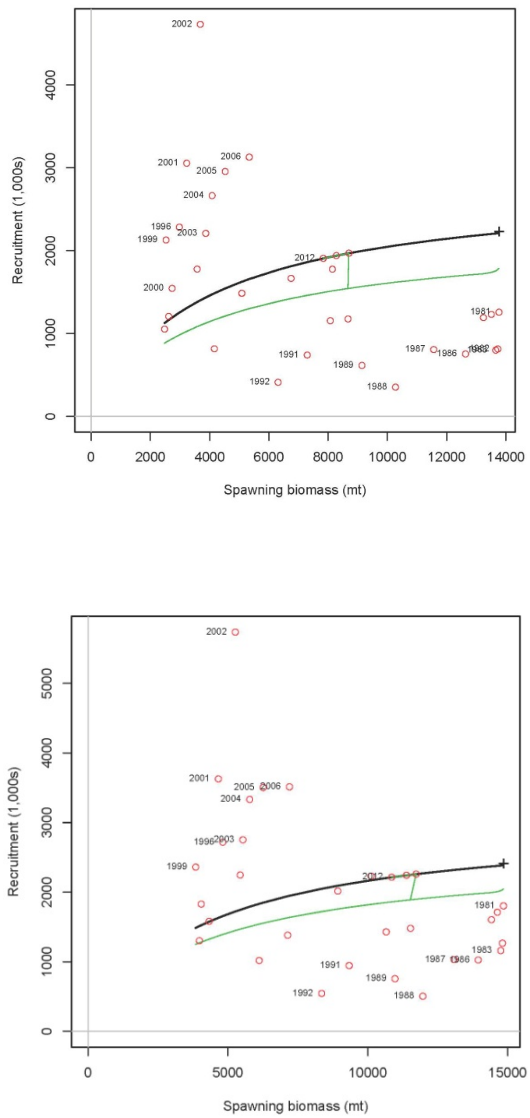


Figure 4.12. Predicted stock-recruitment relationship for the Atlantic stock of *Mustelus canis* under both proposed base model configurations (Sel-1 top panel and Sel-2 bottom panel). Plotted are predicted annual recruitments from SS (circles), expected recruitment from the stock-recruitment relationship (black line),and bias adjusted recruitment from the stock-recruitment relationship (green line).

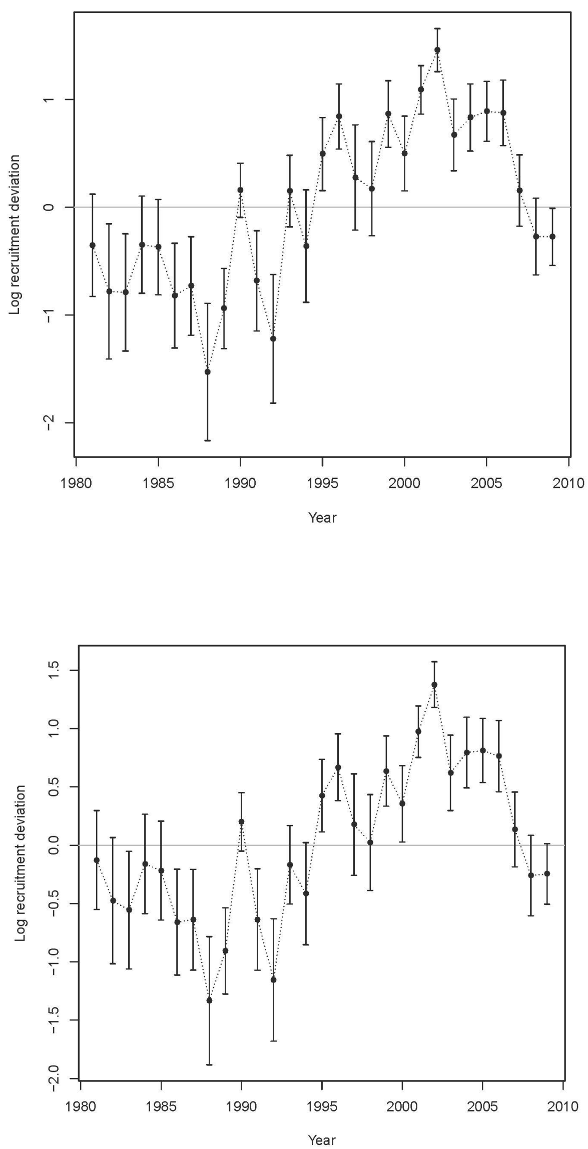


Figure 4.13. Predicted log recruitment deviations with associated 95% asymptotic intervals for the Atlantic stock of *Mustelus canis* under both proposed base model configurations (Sel-1 top panel and Sel-2 bottom panel).

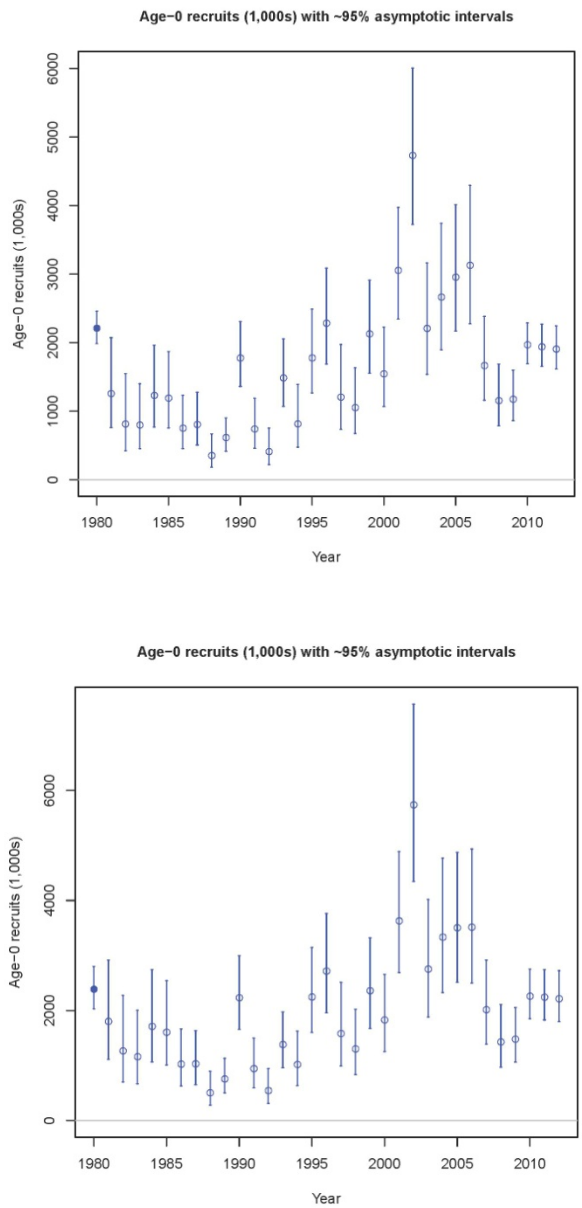


Figure 4.14. Predicted age-0 recruits with associated 95% asymptotic intervals for the Atlantic stock of *Mustelus canis* under both proposed base model configurations (Sel-1 top panel and Sel-2 bottom panel).

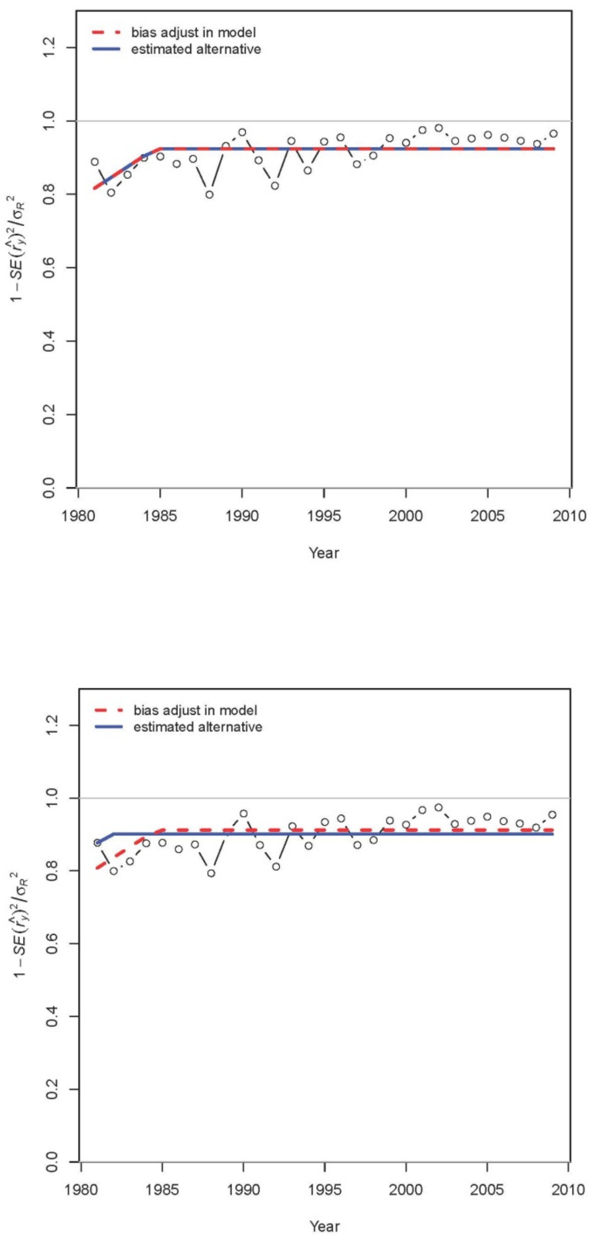


Figure 4.15. Bias adjustment applied to the stock-recruitment relationship under both proposed base model configurations (Sel-1 top panel and Sel-2 bottom panel).

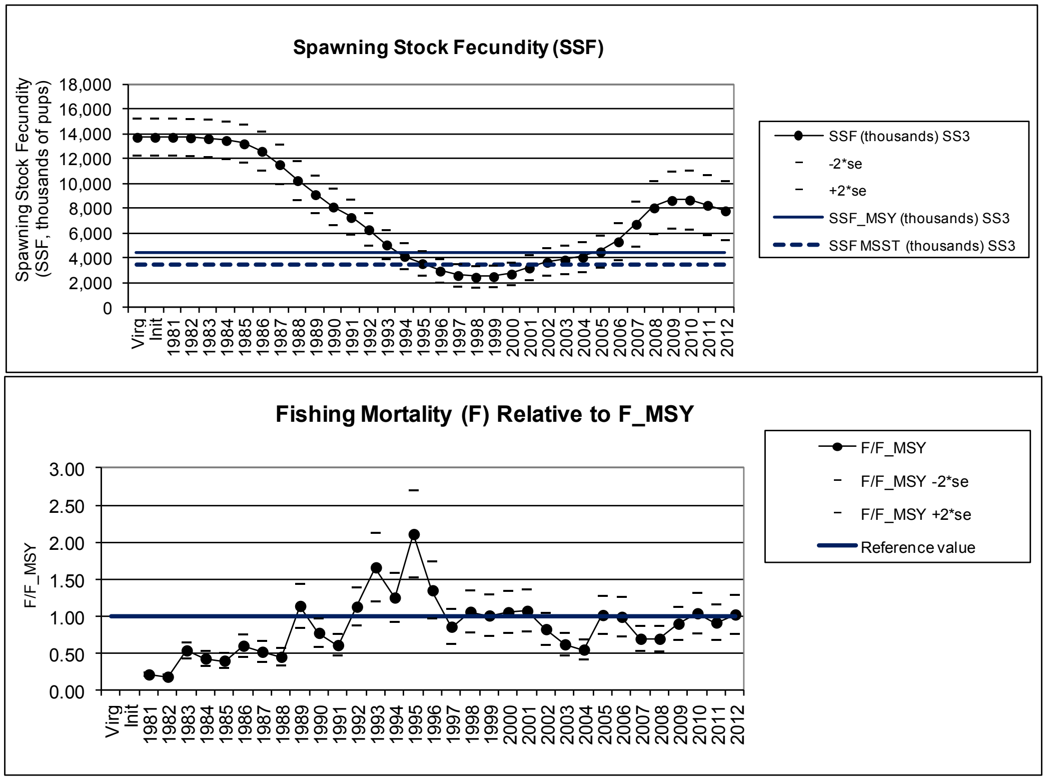


Figure 4.16. Spawning stock fecundity (SSF top panel) and annual fishing mortality, calculated as overall exploitation rate in numbers, relative to fishing mortality at MSY (F/F_{MSY}) obtained from the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the asymptotic-shaped functional form of length based selectivity (Sel-1) for the main targeted fishery (fleet F1 – NE Gillnet Kept), along with approximate 95% asymptotic confidence intervals. The SSF minimum stock size threshold MSST (stippled line top panel) is calculated as (1-average M)*SSF_{MSY}.

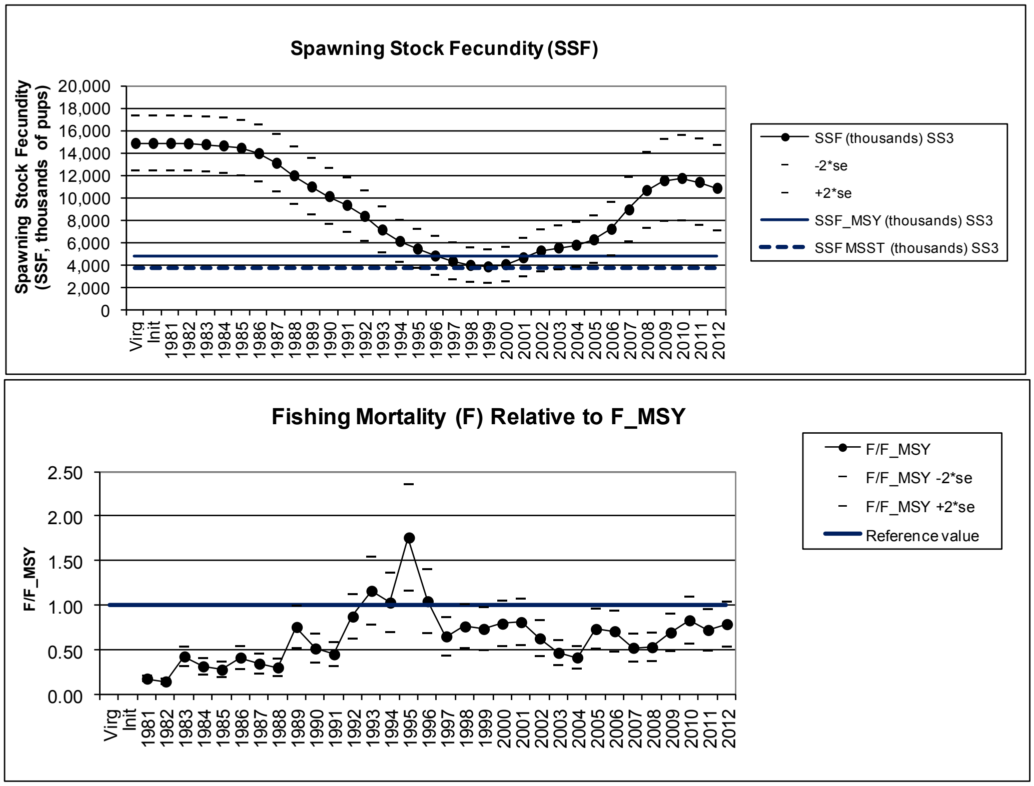


Figure 4.17. Spawning stock fecundity (SSF top panel) and annual fishing mortality, calculated as overall exploitation rate in numbers, relative to fishing mortality at MSY (F/F_{MSY}) obtained from the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the dome-shaped functional form of length based selectivity (Sel-2) for the main targeted fishery (fleet F1 – NE Gillnet Kept), along with approximate 95% asymptotic confidence intervals. The SSF minimum stock size threshold MSST (stippled line top panel) is calculated as (1-average M)*SSF_{MSY}.

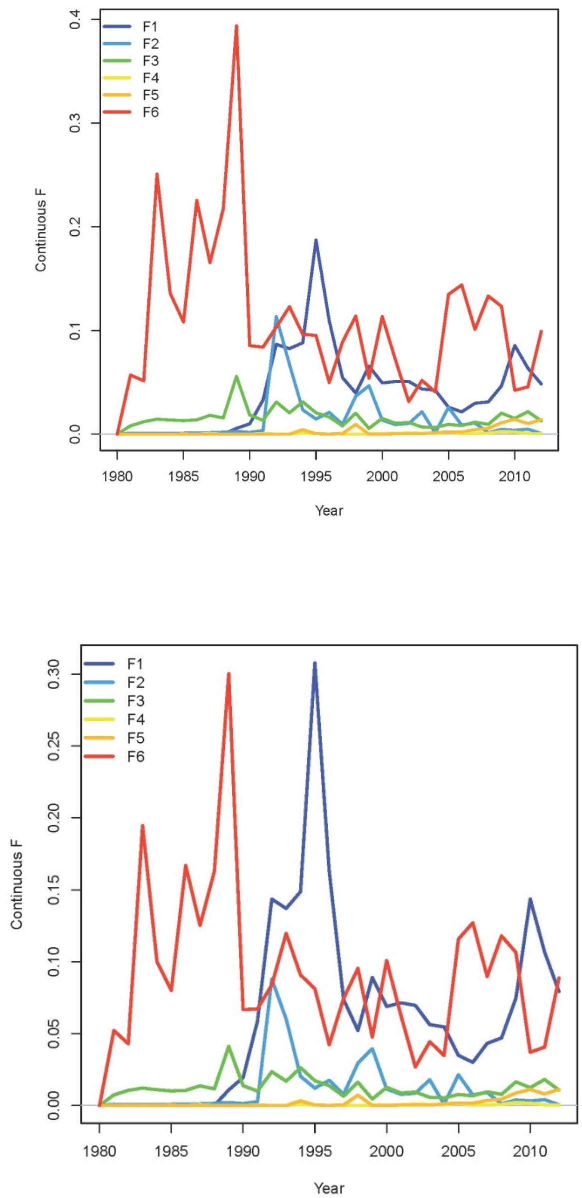
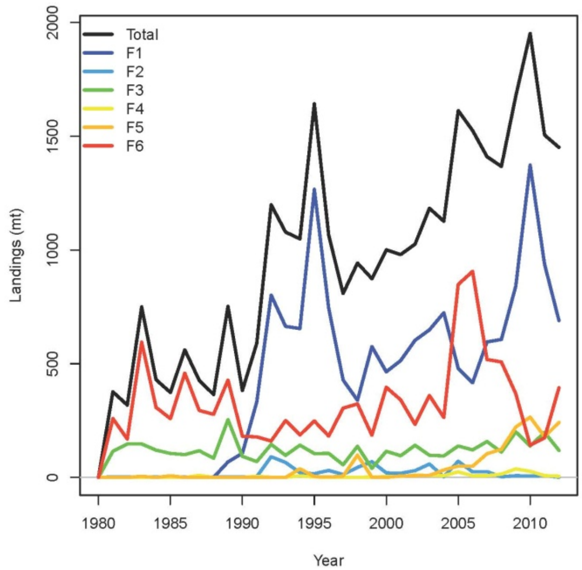


Figure 4.18. Continuous fishing mortality rates *F* obtained with iterative adjustment to observed catch for each fleet (F1 – F6) under both of the proposed base model configurations (Sel-1 top panel and Sel-2 bottom panel).



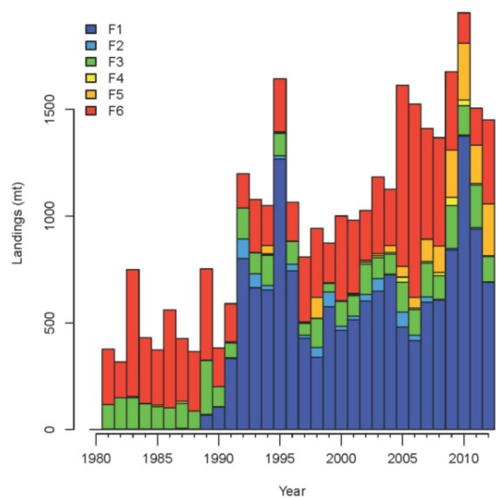


Figure 4.19. The same catch streams (see Sections 2 and 3 and **Tables 2.2 and 2.5**) were associated with each fleet (F1 – F6) under both proposed base model configurations (Sel-1 and Sel-2). For comparison, the catch streams associated with each fleet (Sel-2) are reported here.

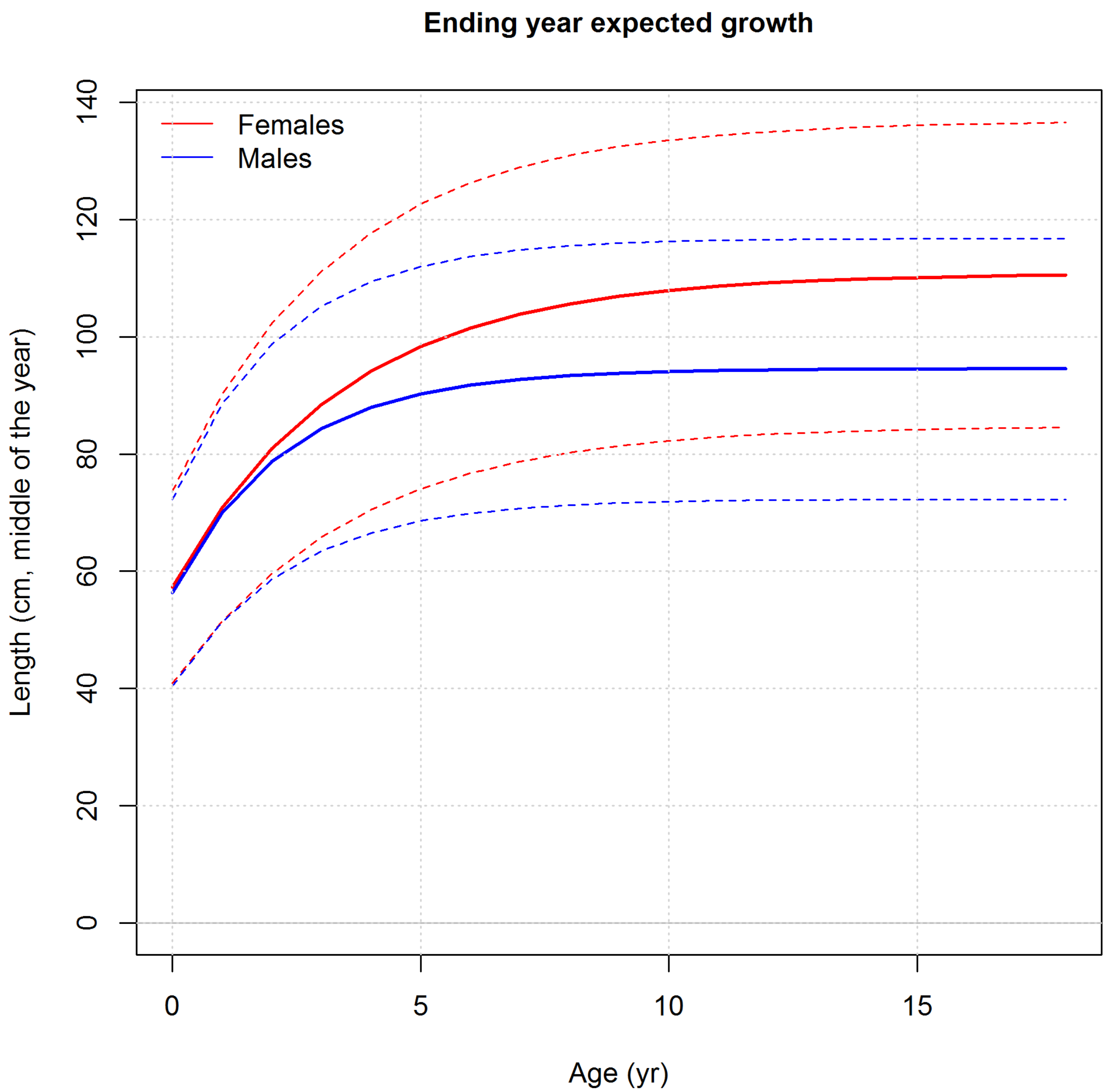


Figure 4.20. Growth relationship and 95% intervals for females (red) and males (blue) under both of the proposed base model configurations (Sel-1 and Sel-2) as described above (see Sections 2 and 3; **Table 2.8**).

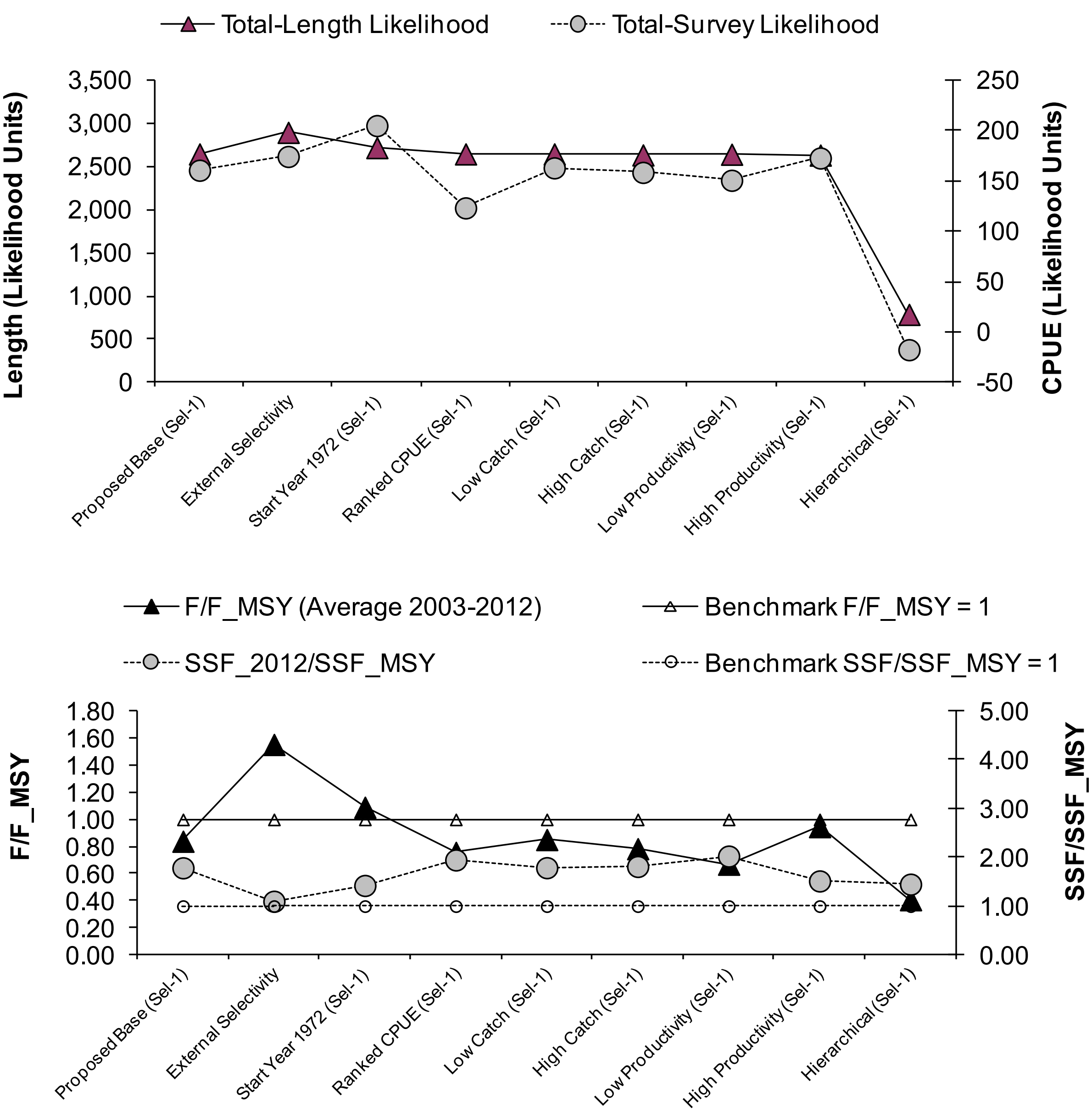


Figure 4.21. Summary of model results for the proposed base configuration under Sel-1and sensitivity scenarios conducted with either externally derived selectivity or under the same model configuration as Sel-1 (asymptotic-shaped functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept)). For the sensitivity analyses, F/F_{MSY} was calculated as the aggregate annual fishing mortality, F, averaged over the most recent 10 years and then divided by F_{MSY}.

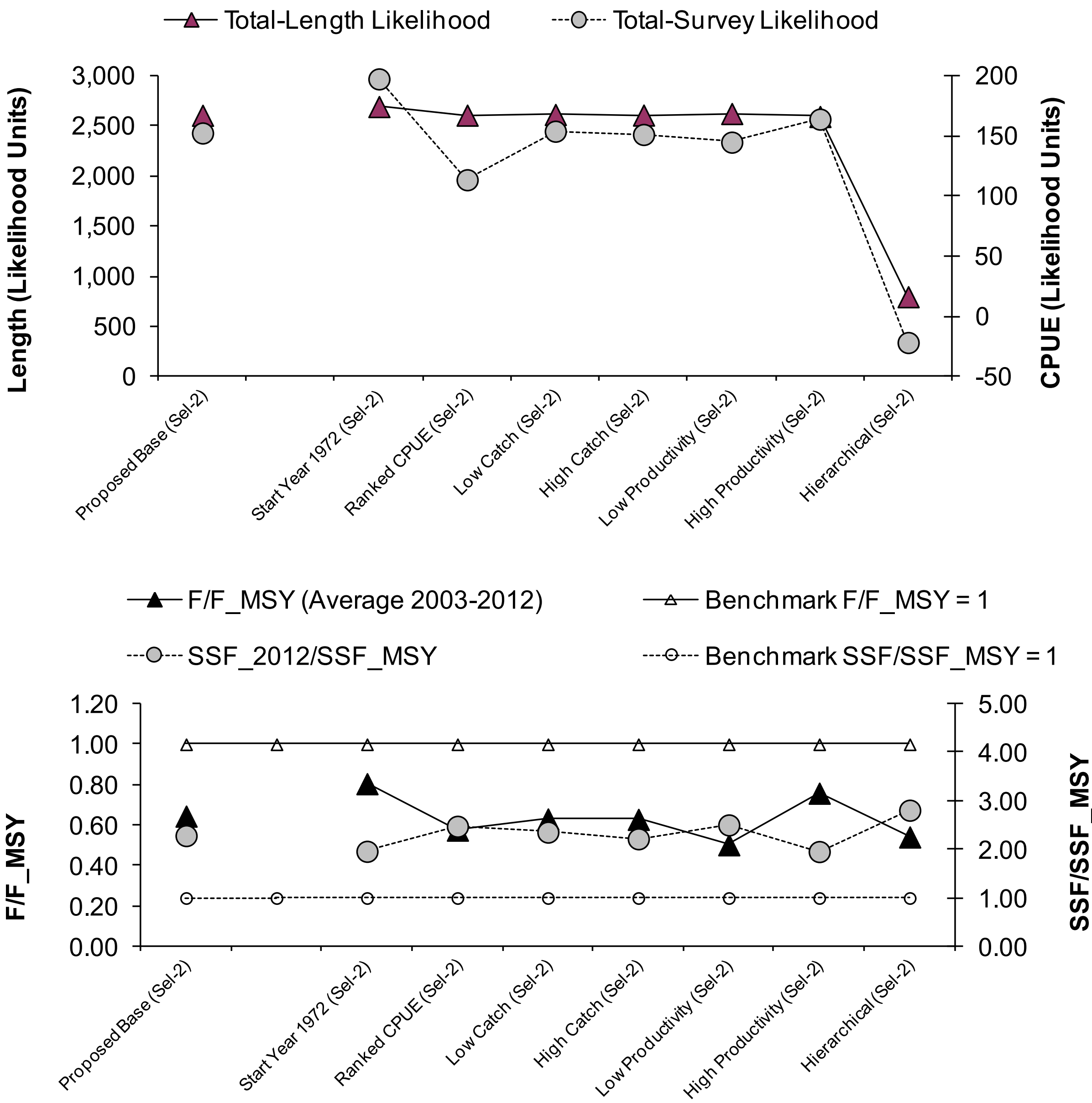


Figure 4.22. Summary of model results for the proposed base configuration under Sel-2 and sensitivity scenarios conducted with either externally derived selectivity or under the same model configuration as Sel-2 (asymptotic-shaped functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept)). For the sensitivity analyses, F/F_{MSY} was calculated as the aggregate annual fishing mortality, F, averaged over the most recent 10 years and then divided by F_{MSY}.

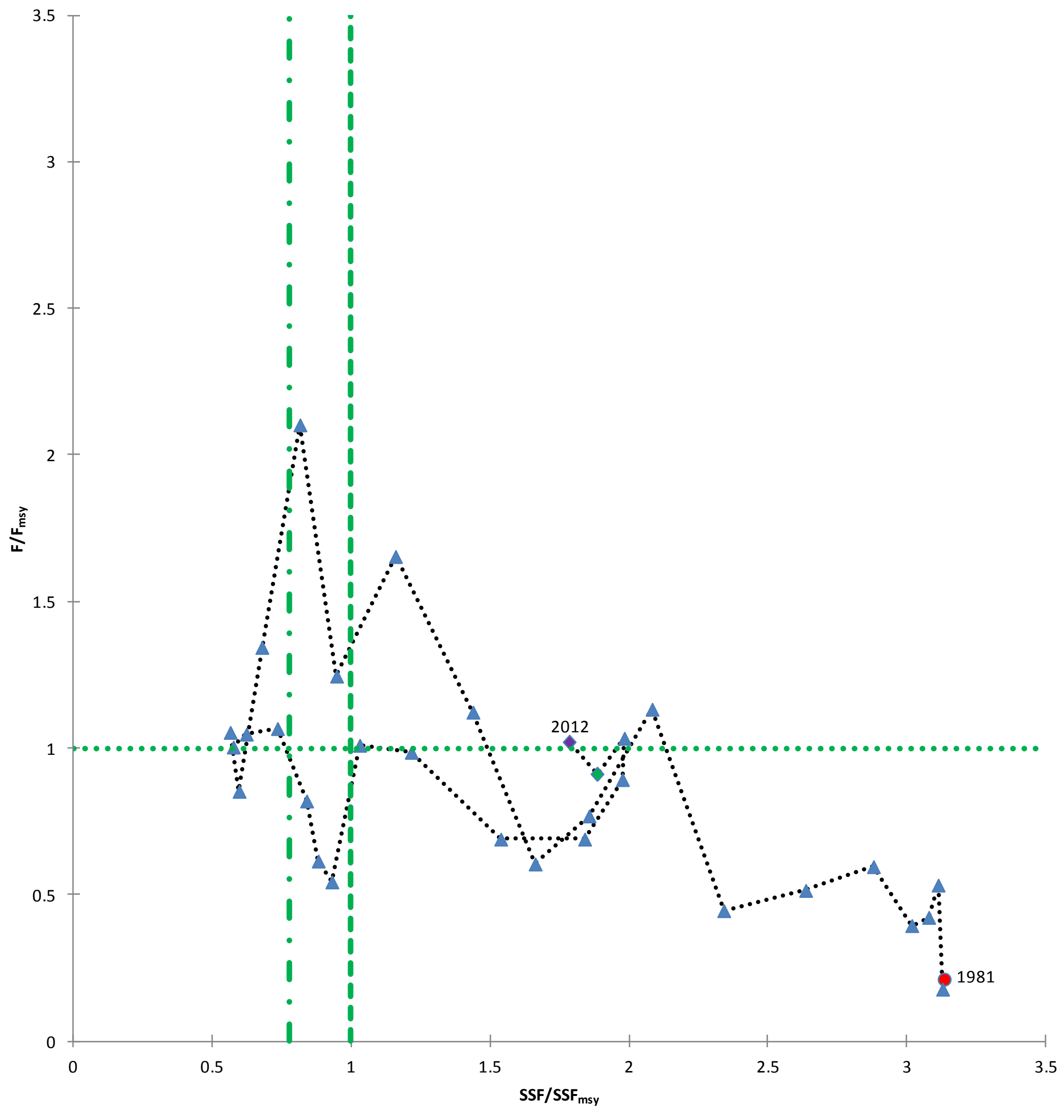


Figure 4.23.a. Phase plot of the relative spawning stock fecundity and relative fishing mortality trajectories by year from 1981 to 2012 for the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the asymptotic-shaped functional form of length based selectivity (Sel-1) for the main targeted fishery (fleet F1 – NE Gillnet Kept). The dotted horizontal line indicates F_{MSY}, the dashed vertical line indicates SSF_{MSY}, and the dot-dashed vertical line indicates MSST ((1-M)*SSF_{MSY}, with M calculated as the average natural mortality at age used in the assessment model configuration).

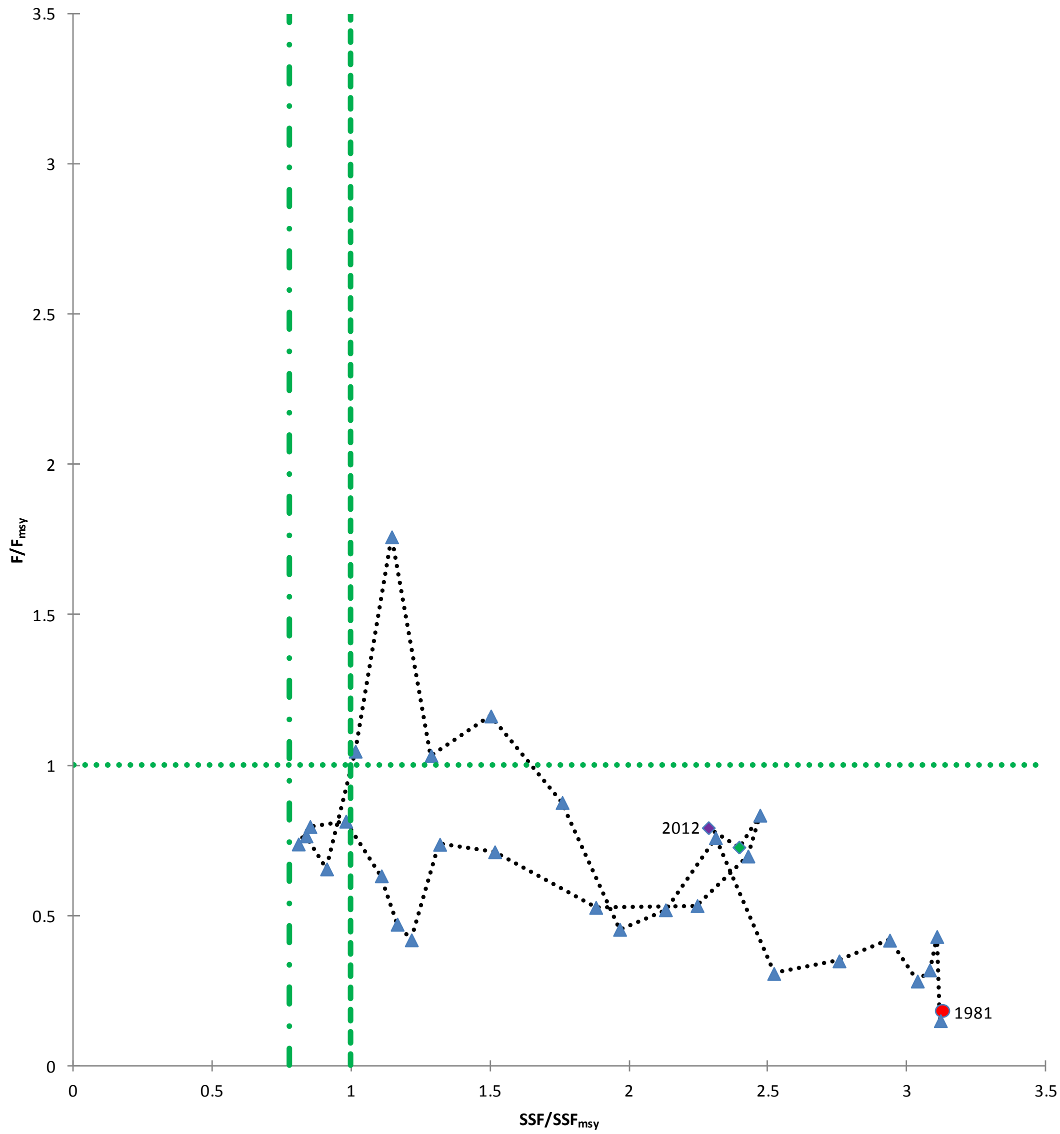


Figure 4.23.b. Phase plot of the relative spawning stock fecundity and relative fishing mortality trajectories by year from 1981 to 2012 for the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the dome-shaped functional form of length based selectivity (Sel-2) for the main targeted fishery (fleet F1 – NE Gillnet Kept). The dotted horizontal line indicates F_{MSY}, the dashed vertical line indicates SSF_{MSY}, and the dot-dashed vertical line indicates MSST ((1-*M*)*SSF_{MSY}, with *M* calculated as the average natural mortality at age used in the assessment model configuration).

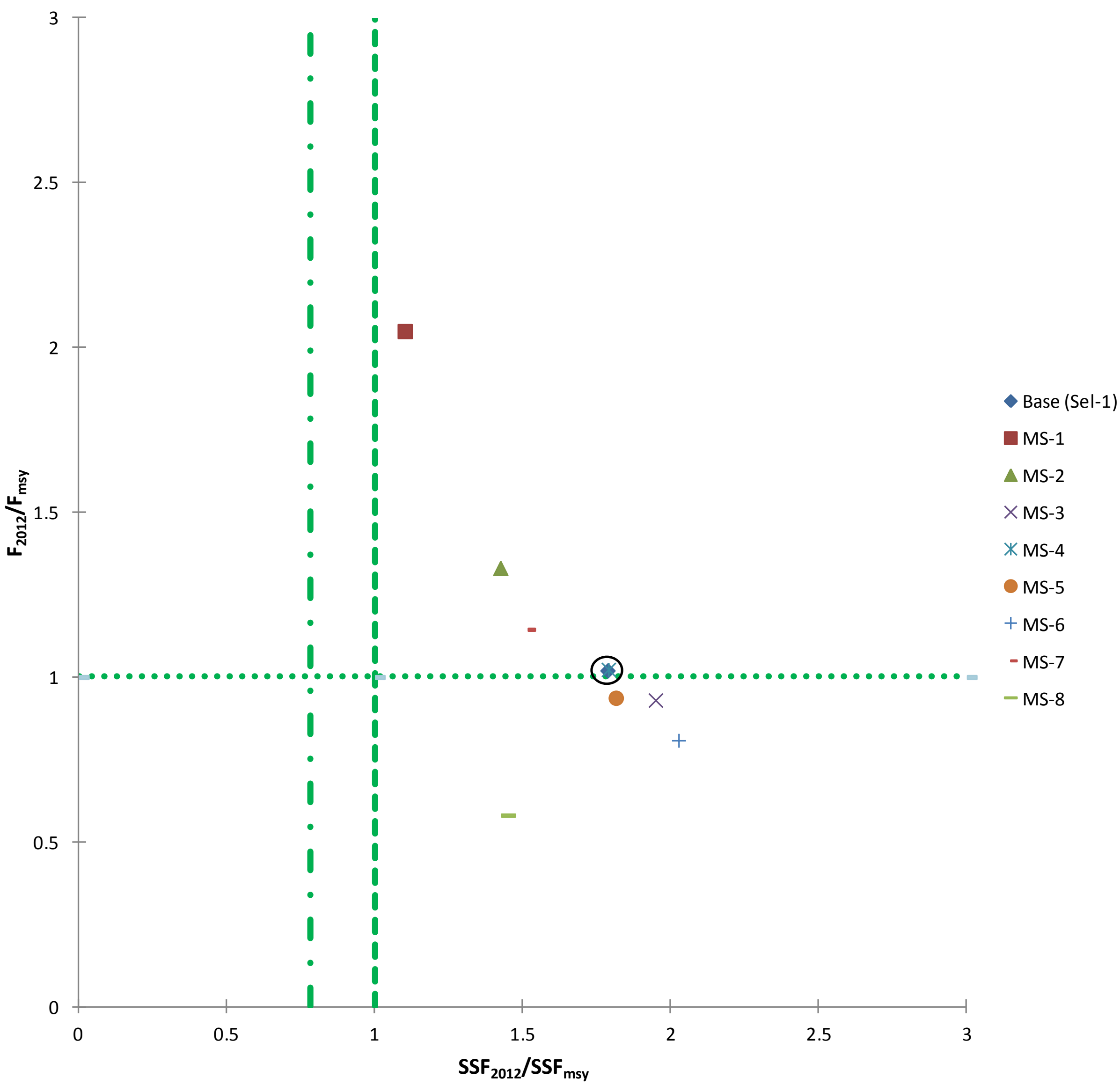


Figure 4.24.a. Phase plot for the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the asymptotic-shaped functional form of length based selectivity (Sel-1) for the main targeted fishery (fleet F1 – NE Gillnet Kept). Results are shown for the proposed base configuration under Sel-1and eight model sensitivities conducted either with externally derived selectivity (MS-1) or selectivity under the same model configuration as Sel-1 (sensitivity runs are defined in **Table 4.12**). The circle indicates the position of the base run, which overlaps with that of other sensitivity runs. The dotted horizontal line indicates F_{MSY}, the dashed vertical line indicates SSF_{MSY}, and the dot-dashed vertical line indicates MSST ((1-M)*SSF_{MSY}, with M calculated as the average natural mortality at age used in the assessment model configuration).

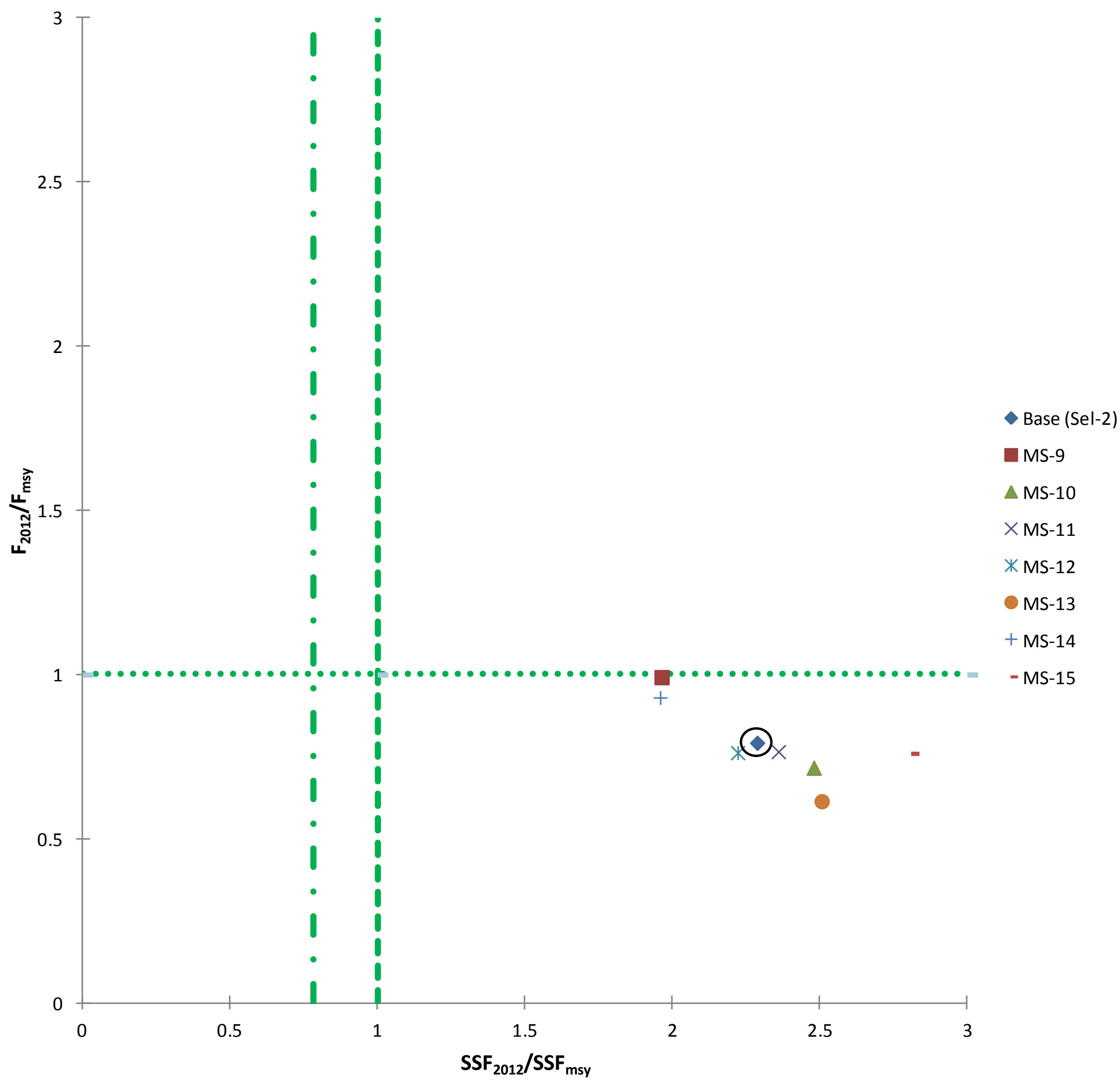


Figure 4.24.b. Phase plot for the proposed SEDAR 39 Atlantic *Mustelus canis* SS3 base model configuration with the dome-shaped functional form of length based selectivity (Sel-2) for the main targeted fishery (fleet F1 – NE Gillnet Kept). Results are shown for the proposed base configuration under Sel-2 and seven model sensitivities conducted under the same model configuration as Sel-2 (sensitivity runs are defined in **Table 4.13**). The circle indicates the position of the base run, which overlaps with that of other sensitivity runs. The dotted horizontal line indicates F_{MSY}, the dashed vertical line indicates SSF_{MSY}, and the dot-dashed vertical line indicates MSST ((1-M)*SSF_{MSY}, with M calculated as the average natural mortality at age used in the assessment model configuration).

Appendix 4.A. *Algorithm used to identify the final functional forms used in the assessment model*

The final functional forms used to model selectivity in the assessment model included the simple logistic, double logistic, and double normal selectivity functions. Functional forms were chosen based on the following algorithm:

1. Either a simple logistic or a double logistic selectivity function was evaluated for each fleet and survey in the proposed base model configuration;
2. A functional form was chosen which was consistent with the approximate shape of the selectivity curve obtained from the externally derived double normal selectivity function (**Appendix 2.A**);
3. Model diagnostics were evaluated for both age based and length based selectivity for each functional form, and the final functional form for selectivity was obtained based on the following criteria:
    a. Improved fit to the available length composition data based on a visual examination of the predicted versus observed length compositions from the stock assessment model output;
    b. Smooth selectivity curve (no sharp breaks);
    c. Maximum selectivity equal to one;
    d. Selectivity parameters not estimated at a boundary condition;
    e. Selectivity parameters not estimated above or below a correlation threshold;
4. If neither age based or length based selectivity was accepted based on the model diagnostics described above, then the number of estimated parameters was reduced by fixing one or more parameters of the selectivity function at an approximate value consistent with the shape of the selectivity curve obtained from the externally derived double normal selectivity function (**Appendix 2.A**); and
5. If the reduced age or length based selectivity parameter estimation was not accepted based on the model diagnostics described above, then the double normal selectivity at age curve obtained derived externally of the stock assessment model (**Appendix 2.A**) was implemented.

Implementation of the simple logistic and double logistic selectivity functions in Stock Synthesis

The simple logistic selectivity function is implemented in Stock Synthesis with selectivity patterns 1 (size) and 12 (age):

$S(a) = \dfrac{1}{1+e^{\left(\frac{-\log(19)(a-p1)}{p2}\right)}}$ (e.g., user manual for Stock Synthesis; Methot Jr. R. D., 2013).

The double logistic selectivity function is implemented in Stock Synthesis with selectivity patterns 9 (size) and 19 (age):

$$S(a) = \left[\left(\frac{1}{1+e^{\left(-p2(a-p1)\right)}} \right) \left(1 - \frac{1}{1+e^{\left(-p4(a-p3)\right)}} \right) \right] \Big/ Max \quad \text{(e.g., Methot 1990)}$$

The simple logistic and double logistic selectivity function parameters in Stock Synthesis are described below (excerpted from the user manual for Stock Synthesis; Methot Jr. R. D., 2013):

> "…
> <u>9.3.19 Selectivity Details</u>
> …
> Patterns 1 (size) and 12 (age) -- simple logistic
> p1 – size (age) at inflection
> p2 – width for 95% selection; a negative width causes a descending curve
> …
> Pattern 9 (size) and 19 (age) – simple double logistic with no defined peak
> p1 – ascending inflection age/size
> p2 – ascending slope
> p3 – descending inflection age/size
> p4 – descending slope
> p5 – age or size at first selection; this is a specification parameter, so must not be estimated. Enter integer that is age for pattern 19 and is bin number for pattern 9
> p6 – (0/1) where a value of 0 causes the descending inflection to be a standalone parameter, and a value of 1 causes the descending inflection to be interpreted as an offset from the ascending inflection. This is a specification parameter, so must not be estimated.
> A value of 1.0e-6 is added to the selectivity for all ages, even those below the min. age.
> …"

Implementation of parameter estimation with a normal prior

Parameter estimation for ln(R_0) and selectivity utilized a normal prior with a large standard deviation (Prior_stddev) and independent minimum and maximum boundary conditions for each parameter. Implementation of a normal prior in Stock Synthesis is described below (excerpted from the user manual for Stock Synthesis; Methot Jr. R. D., 2013):

"…

9.3.28 Parameter Priors

…

PR_Type	PR_value, Pr	PR_stddev, Psd	Description
0	Pr	Psd	Normal prior. Note that this function is independent of the parameter bounds.

Prior_Like = 0.5*square((Pval-Pr)/Psd);

…

where:

Pval is value of the parameter for which a prior is being calculated;

Pmin and Pmax are the bounds on the parameter;

Pr is the value of the parameter prior, or the first of 2 factors controlling the calculation of the prior;

Psd is the value of the prior's standard deviation, or the second of 2 factors controlling the calculation of the prior;

Pconst is a small constant, 0.0001;

Prior_Like is the calculated value of the prior's contribution to the logL.

…"

Table 4.A.1. Final selectivity parameters (both estimated and fixed) selected for use in this assessment model for the proposed base model configuration with the asymptotic-shaped functional form of length based selectivity (Sel-1) for the main targeted fishery (fleet F1 – NE Gillnet Kept). Final selectivity parameters (both estimated and fixed) were obtained using the algorithm described above.

Series	Associated length data source	Functional form of selectivity	Stock Synthesis selectivity pattern	Estimated Parameters	p1	p2	p3	p4	p5	p6
F1 (Sel-1)	2.1 NE GNOP (Combined Mesh, Kept)	Simple logistic (size)	1	2	71.37	9.05				
F2	2.2 NE GNOP (Combined Mesh, Discard)	Double logistic (size)	9	2	31.88	-0.06	100.04*	0*	1	0
F3	2.3 NE TOP (Combined Mesh, Combined Disposition)	Double logistic (size)	9	4	32.02	4.82	95.58	0.33	1	0
F4	2.5 SE BLLOP	Simple logistic (size)	1	2	86.56	14.07				
F5	NA	Assume same selectivity as F3	15	0						
F6	2.6 MRIP	Double logistic (age)	19	1	0.01*	-0.87	10*	2*	0	0
S1	1.1 NEFSC Fall Trawl-N	Simple logistic (age)	12	2	0.30	2.17				
S2	1.2 NEAMAP Fall Trawl	Double logistic (age)	19	1	0.01*	-2.17	10*	2*	0	0
S3	1.3 MA DMF Fall Trawl	Double logistic (age)	19	1	0.01*	-0.59	10*	2*	0	0
S4	1.4 RI DEM Seas Trawl	Double logistic (size)	9	2	60.84*	0*	0.21	0.07	1	0
S5	1.5 CT DEEP Trawl	Simple logistic (age)	12	2	1.20	3.11				
S6	1.6 DE Trawl	Externally derived double normal at age	20	0	0.09*	-6*	4.09*	2.07*	9*	-4.34*
S7	1.7 NJ DFW Trawl	Externally derived double normal at age	20	0	0.09*	-6*	5.37*	2.42*	9*	-0.73*
S8	1.8 SEAMAP-SA Trawl	Double logistic (age)	19	1	0.01*	-0.78	10*	2*	0	0

* Fixed parameter.

Table 4.A.2. Final selectivity parameters (both estimated and fixed) selected for use in this assessment model for the proposed base model configuration with the dome-shaped functional form of length based selectivity (Sel-2) for the main targeted fishery (fleet F1 – NE Gillnet Kept). Final selectivity parameters (both estimated and fixed) were obtained using the algorithm described above.

Series	Associated length data source	Functional form of selectivity	Stock Synthesis selectivity pattern	Estimated Parameters	p1	p2	p3	p4	p5	p6
F1 (Sel-2)	2.1 NE GNOP (Combined Mesh, Kept)	Double logistic (size)	9	4	77.24	0.23	93.40	0.16	1	0
F2	2.2 NE GNOP (Combined Mesh, Discard)	Double logistic (size)	9	2	34.50	-0.06	100.04*	0*	1	0
F3	2.3 NE TOP (Combined Mesh, Combined Disposition)	Double logistic (size)	9	4	45.50	0.00	95.27	0.33	1	0
F4	2.5 SE BLLOP	Simple logistic (size)	1	2	86.06	13.85				
F5	NA	Assume same selectivity as F3	15	NA						
F6	2.6 MRIP	Double logistic (age)	19	1	0.01*	-0.93	10*	2*	0	0
S1	1.1 NEFSC Fall Trawl-N	Simple logistic (age)	12	2	0.24	2.14				
S2	1.2 NEAMAP Fall Trawl	Double logistic (age)	19	1	0.01*	-2.16	10*	2*	0	0
S3	1.3 MA DMF Fall Trawl	Double logistic (age)	19	1	0.01*	-0.61	10*	2*	0	0
S4	1.4 RI DEM Seas Trawl	Double logistic (size)	9	2	60.84*	0*	0.25	0.08	1	0
S5	1.5 CT DEEP Trawl	Simple logistic (age)	12	2	1.10	3.09				
S6	1.6 DE Trawl	Externally derived double normal at age	20	0	0.09*	-6*	4.09*	2.07*	9*	-4.34*
S7	1.7 NJ DFW Trawl	Externally derived double normal at age	20	0	0.09*	-6*	5.37*	2.42*	9*	-0.73*
S8	1.8 SEAMAP-SA Trawl	Double logistic (age)	19	1	0.01*	-0.79	10*	2*		

* Fixed parameter.

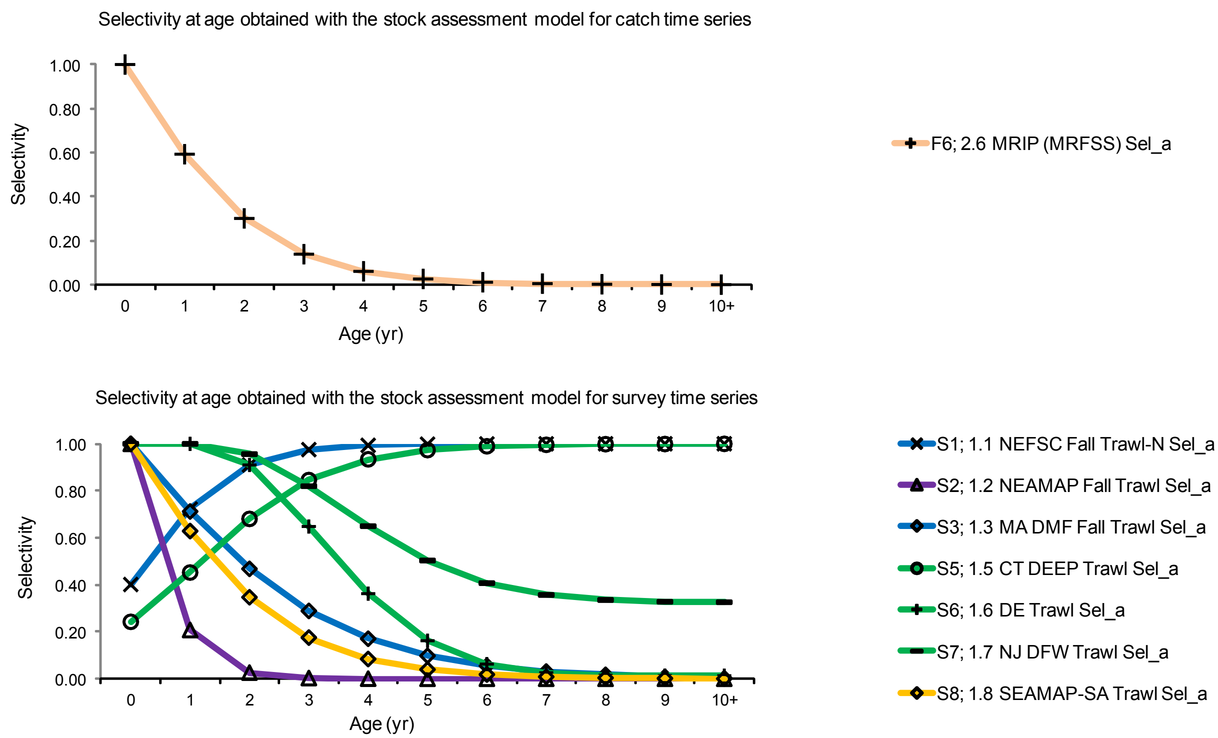


Figure 4.A.1. Final selectivity at age obtained for time series of catch (top panel) and relative abundance (survey; lower panel) in the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configuration evaluated with the asymptotic-shaped (Sel-1) functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept).

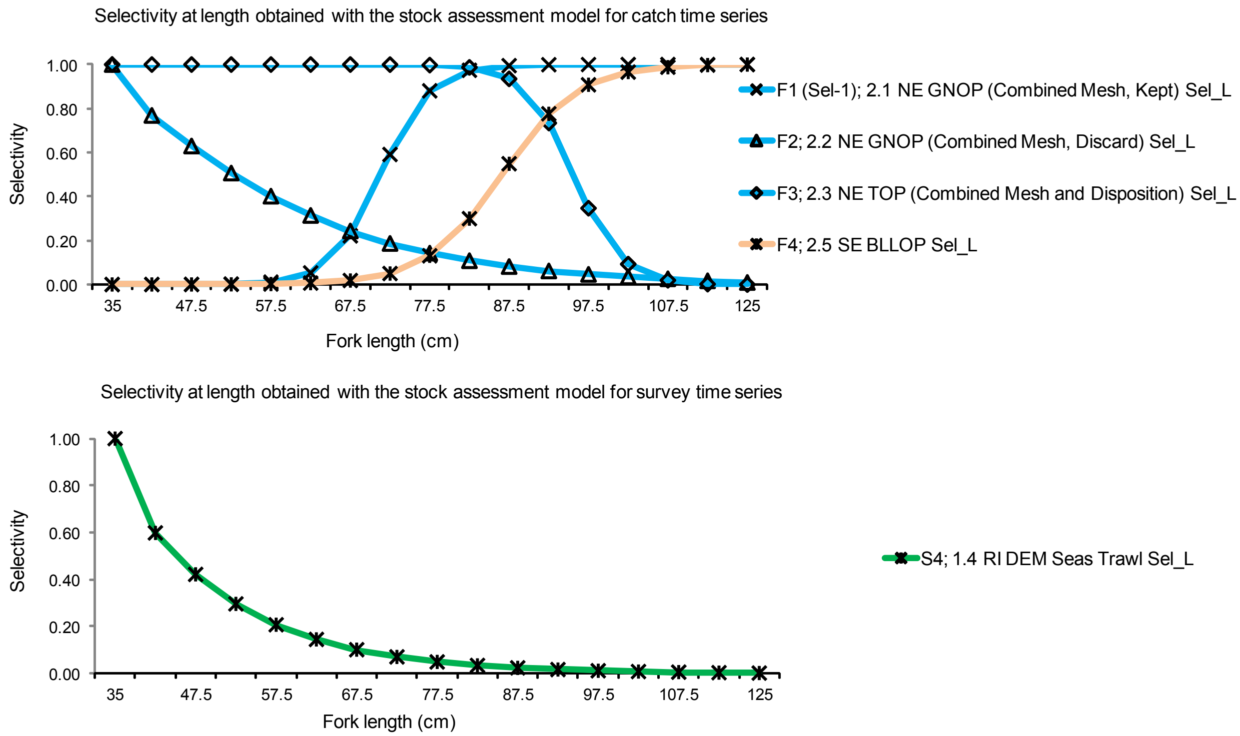


Figure 4.A.2. Final selectivity at length obtained for time series of catch (top panel) and relative abundance (survey; lower panel) in the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configuration evaluated with the asymptotic-shaped (Sel-1) functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept).

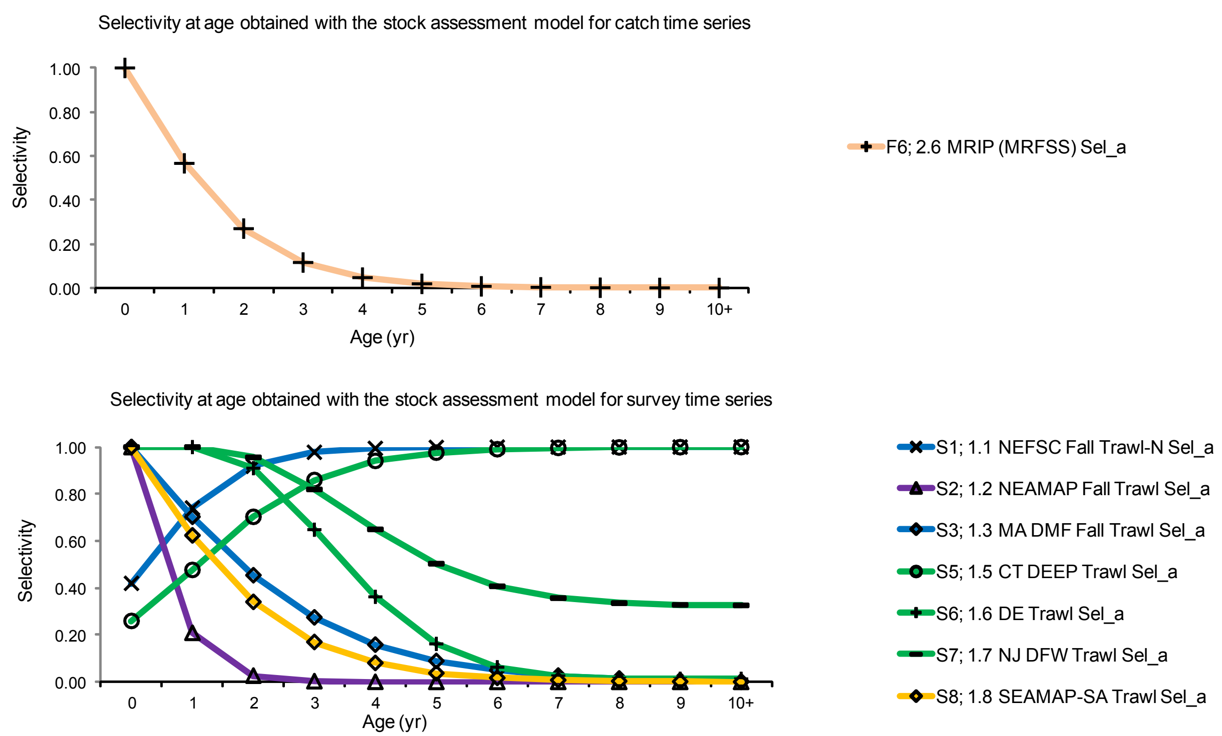


Figure 4.A.3. Final selectivity at age obtained for time series of catch (top panel) and relative abundance (survey; lower panel) in the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configuration evaluated with the dome-shaped (Sel-2) functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept).

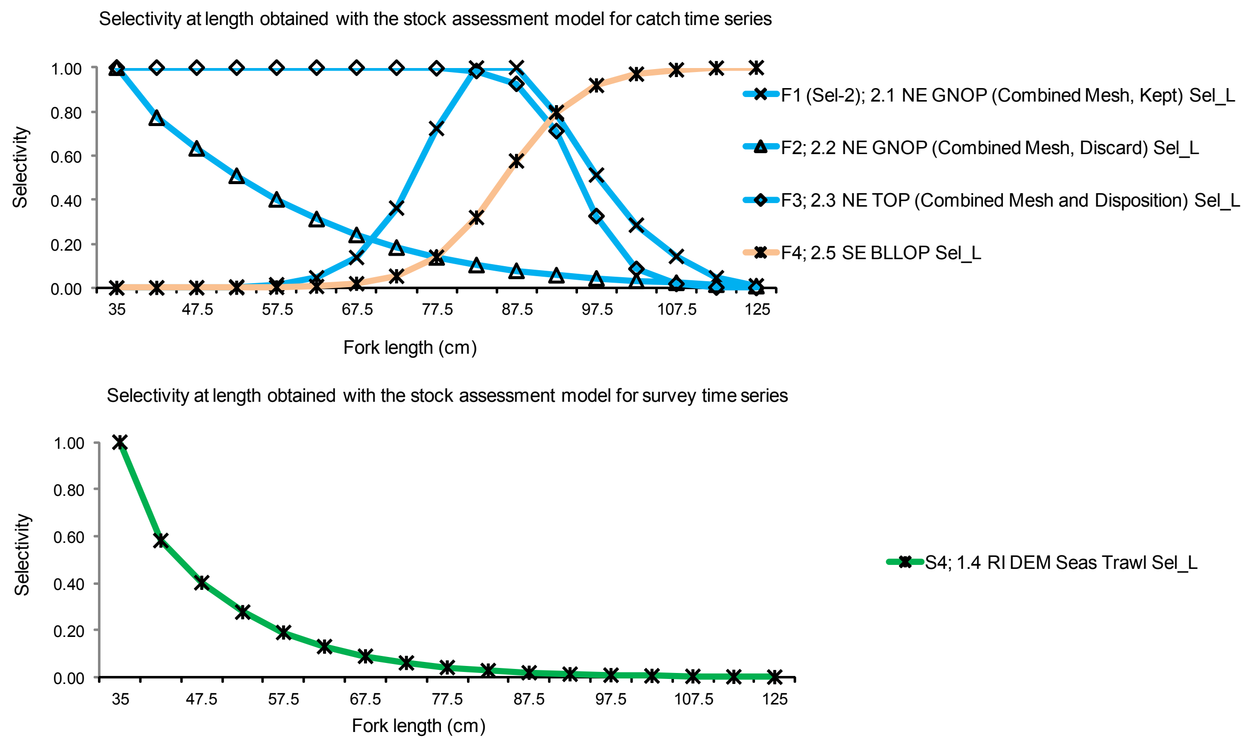


Figure 4.A.4. Final selectivity at length obtained for time series of catch (top panel) and relative abundance (survey; lower panel) in the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configuration evaluated with the dome-shaped (Sel-2) functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept).

Figure 4.A.5. Final selectivity curves obtained for the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configuration with the asymptotic-shaped functional form of length based selectivity (Sel-1) for the main targeted fishery (fleet F1 – NE Gillnet Kept). Selectivity (black line; either left or middle panel); age-frequency sample data (middle panel) obtained by back-transforming the available length frequency sample data (left panel) through the sex-specific von Bertalanffy growth equation; and the observed (right panel) and predicted (red line in right panel) length distribution obtained from the stock assessment model with the final selectivity.

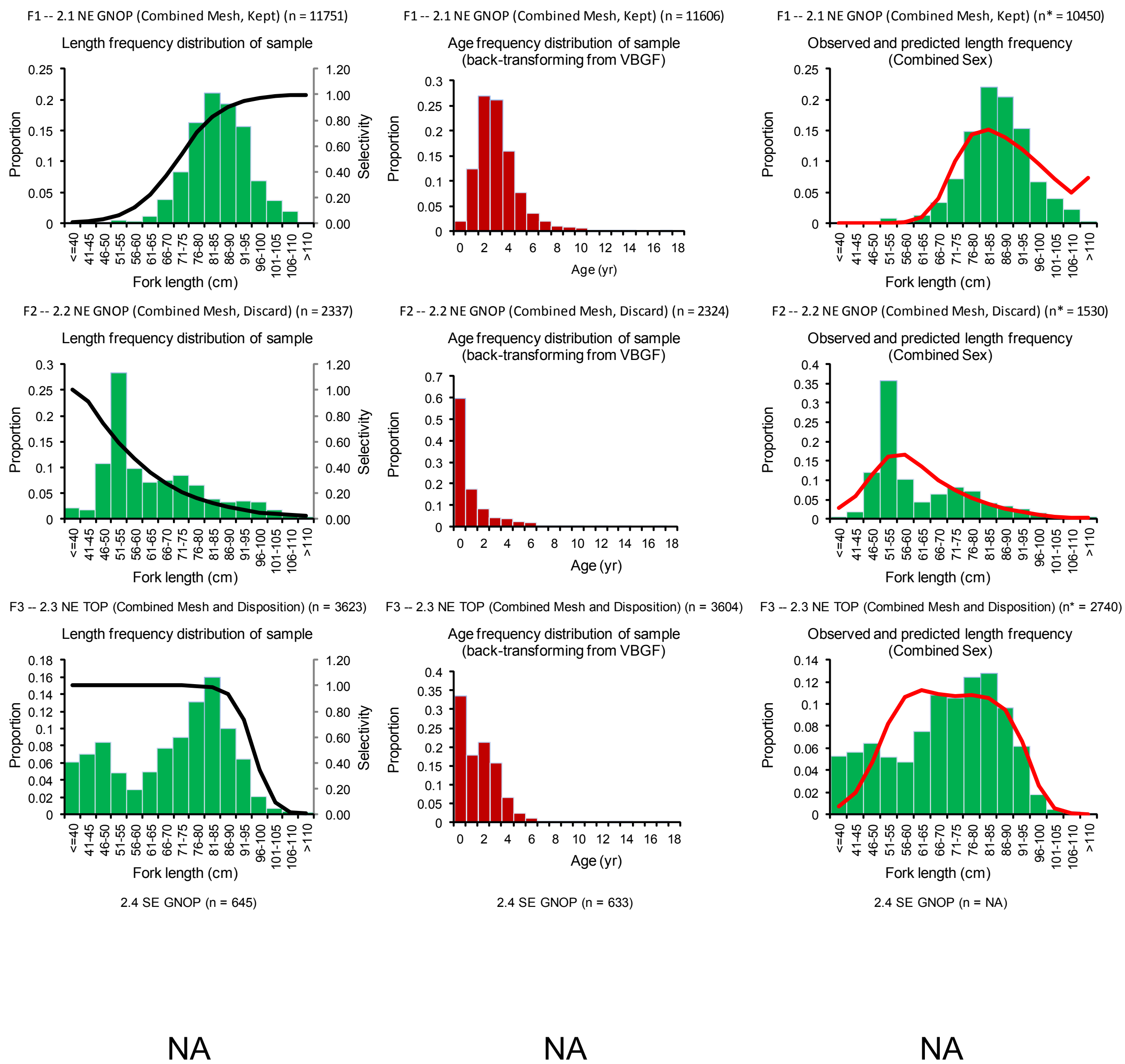


Figure 4.A.5. Continued.

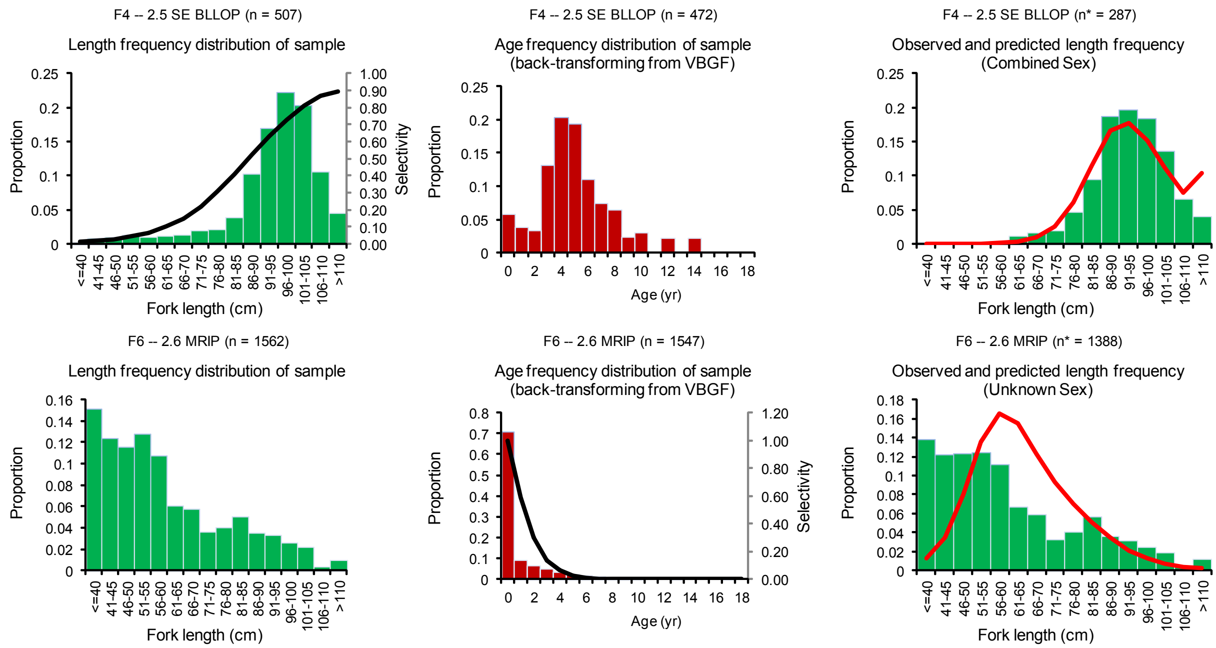


Figure 4.A.5. Continued.

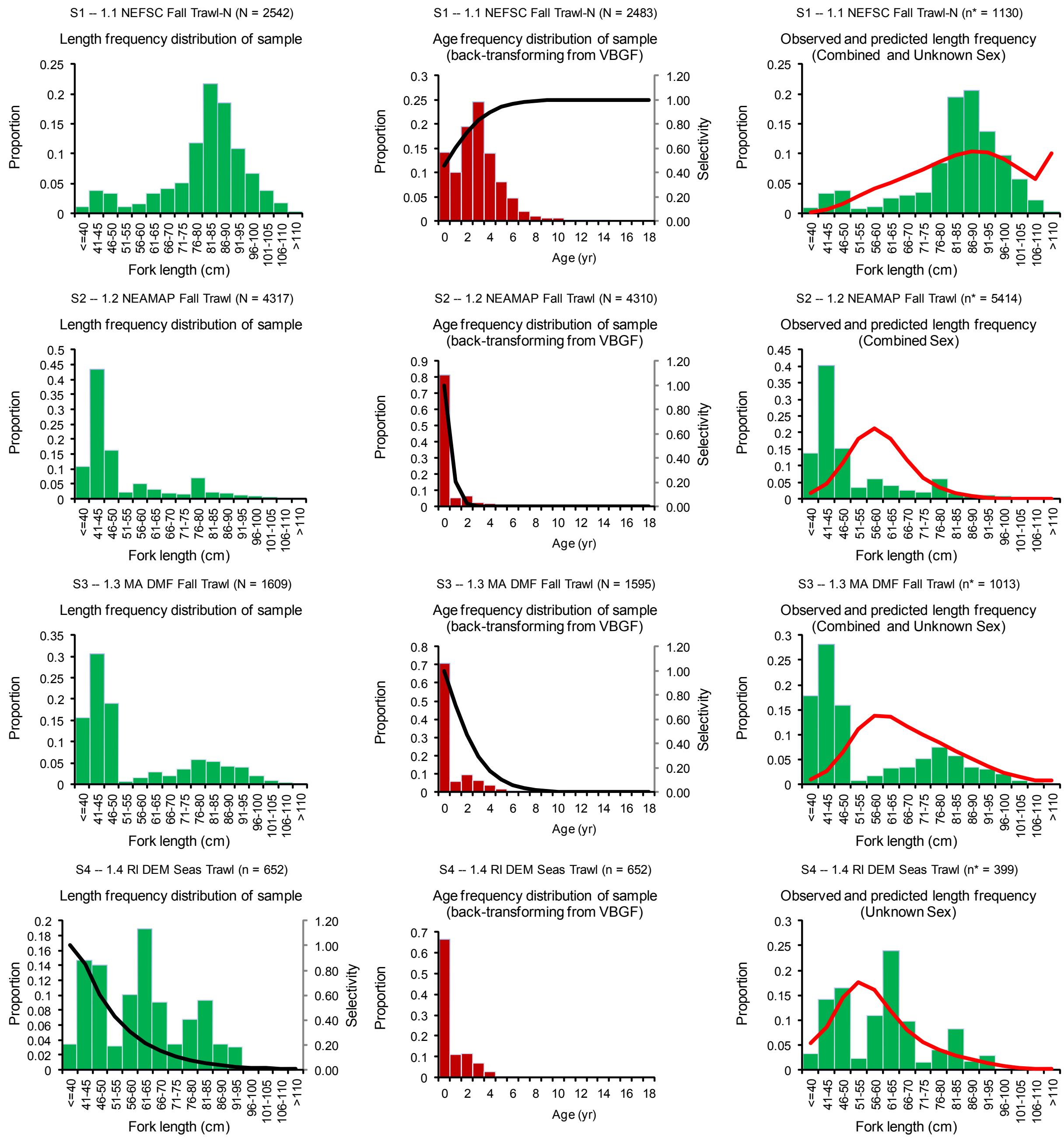
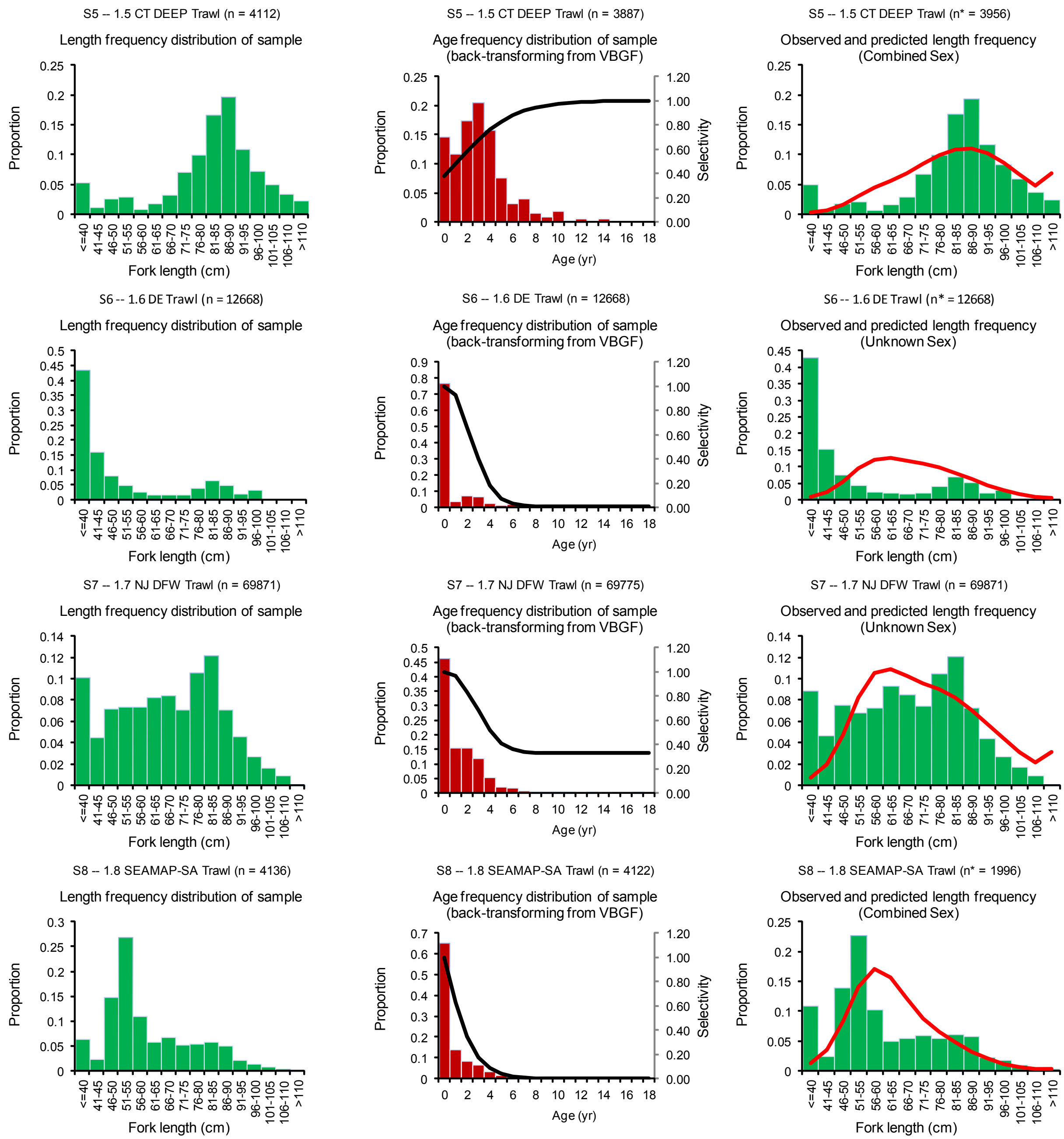


Figure 4.A.5. Continued.



* The observed length composition data input in the stock assessment model (right panel) were reduced relative to those in the sample (left panel) because length measurements with unknown sex were not included in the assessment model in a given year if sex specific length measurements were available from the same data source in the same year; Length measurements were also not included from a data source in a given year if less than 30 sharks (either sex specific or unknown sex) were measured in that year.

Figure 4.A.6. Final selectivity curves obtained for the proposed SEDAR 39 Atlantic *Mustelus canis* Stock Synthesis base model configuration with the dome-shaped functional form of length based selectivity (Sel-2) for the main targeted fishery (fleet F1 – NE Gillnet Kept). Selectivity (black line; either left or middle panel); age-frequency sample data (middle panel) obtained by back-transforming the available length frequency sample data (left panel) through the sex-specific von Bertalanffy growth equation; and the observed (right panel) and predicted (red line in right panel) length distribution obtained from the stock assessment model with the final selectivity.

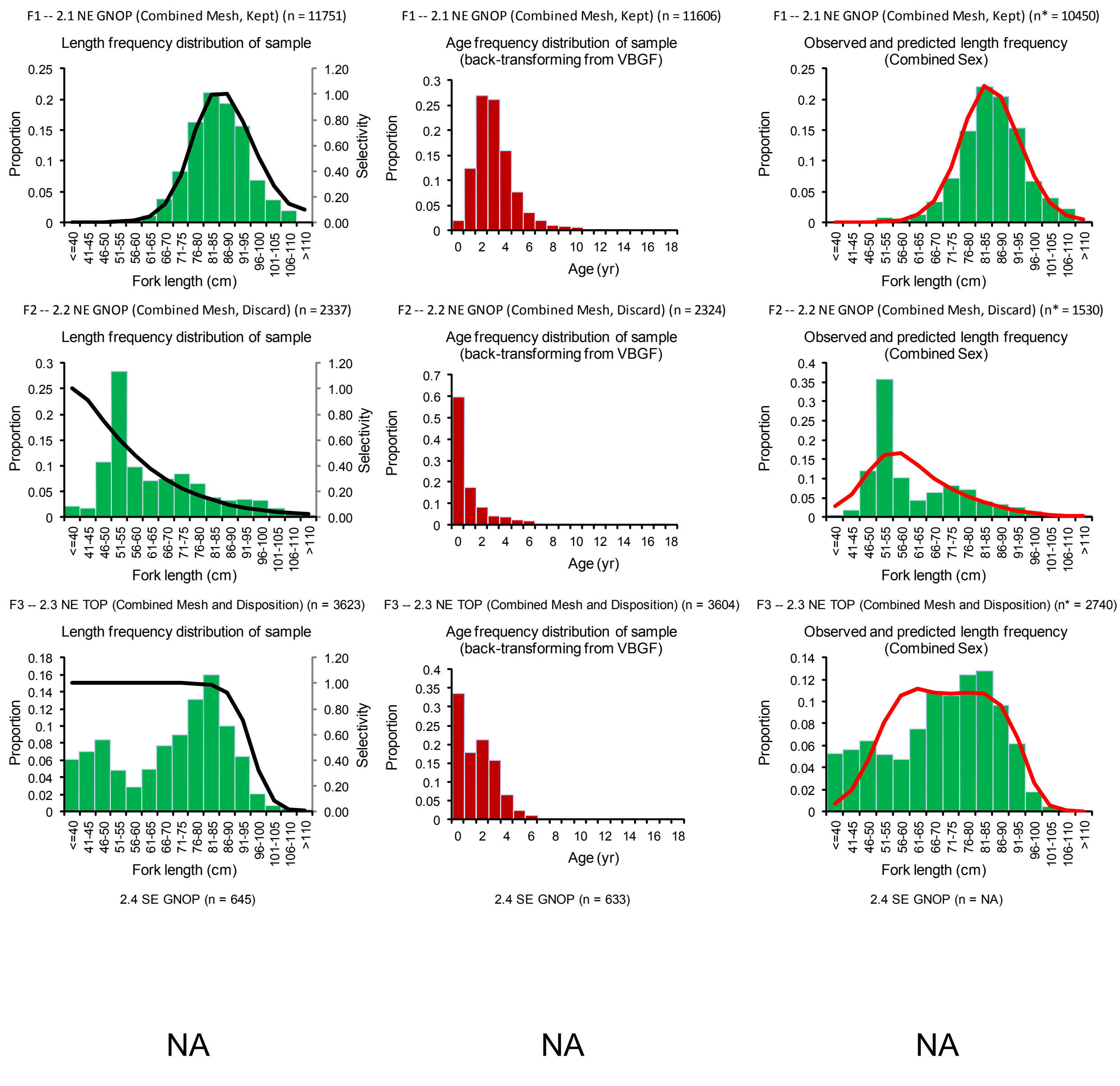


Figure 4.A.6. Continued.

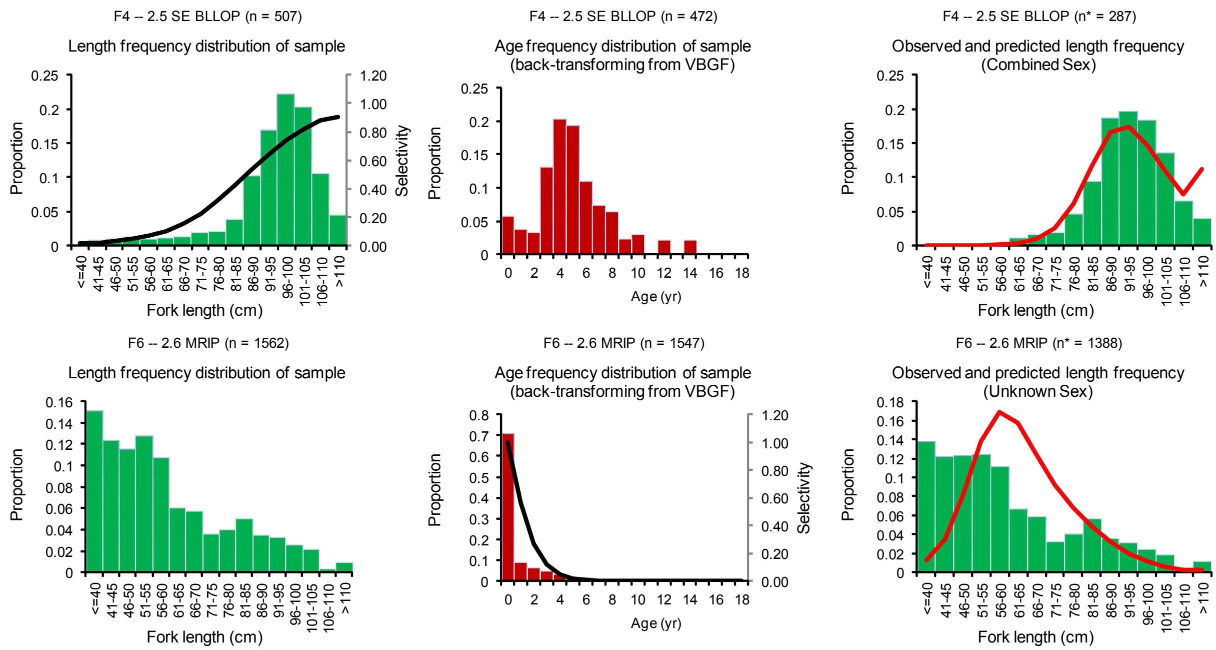


Figure 4.A.6. Continued.

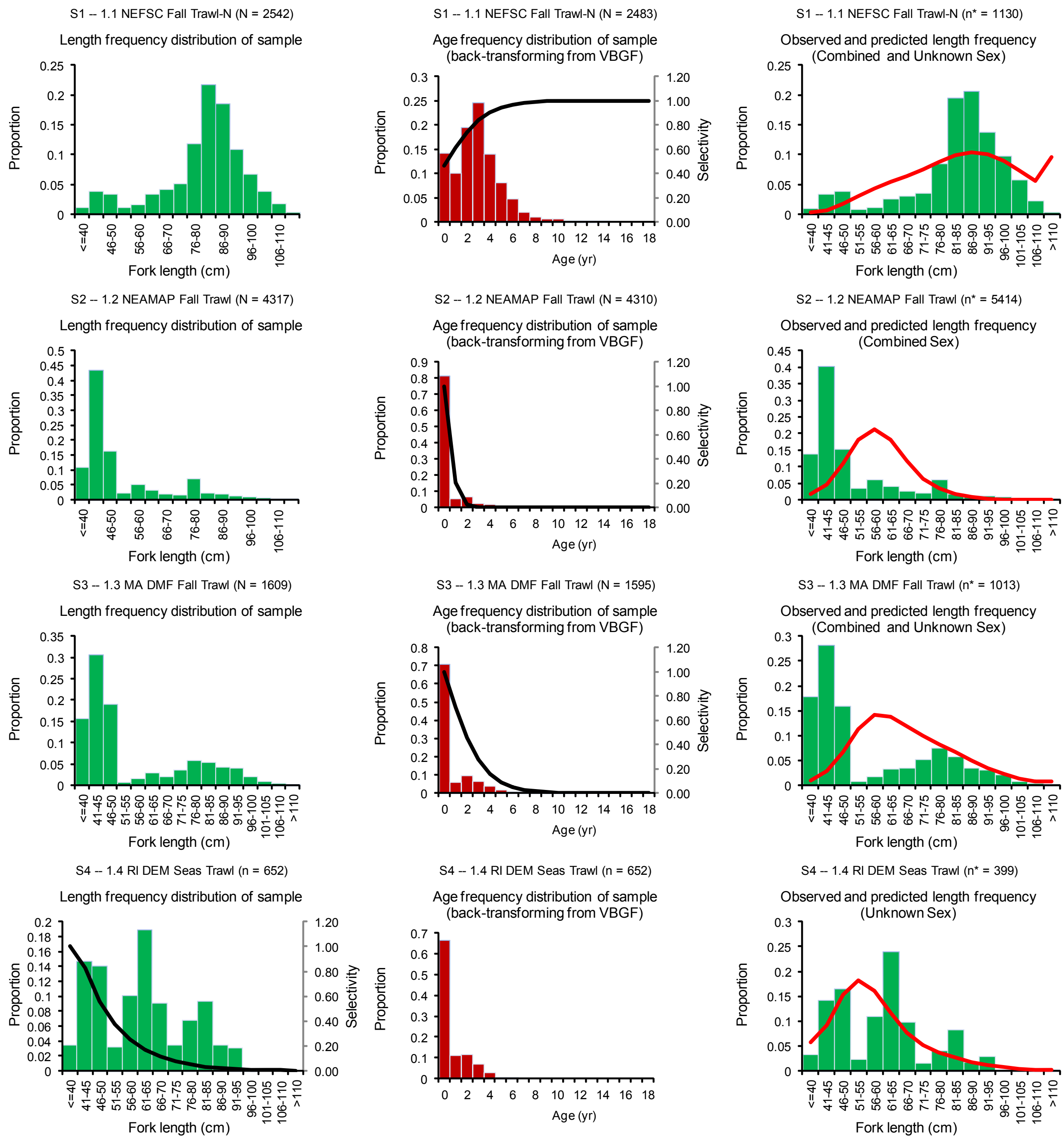
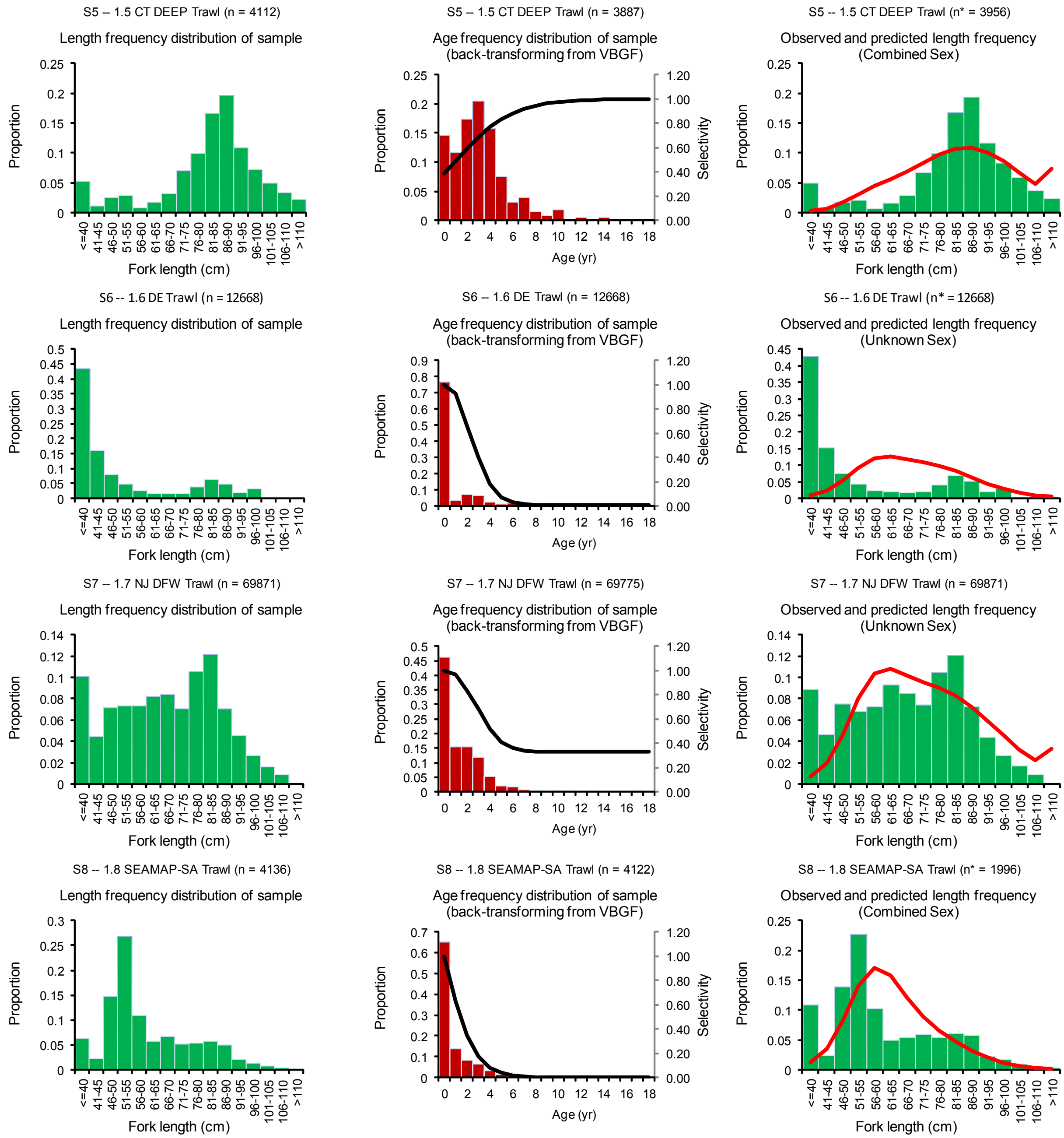


Figure 4.A.6. Continued.



* The observed length composition data input in the stock assessment model (right panel) were reduced relative to those in the sample (left panel) because length measurements with unknown sex were not included in the assessment model in a given year if sex specific length measurements were available from the same data source in the same year; Length measurements were also not included from a data source in a given year if less than 30 sharks (either sex specific or unknown sex) were measured in that year.

Appendix 4.B. Aggregated length frequency distributions compared with the K-S test

Figure 4.B.1. Sex specific aggregated proportions at length (left panels) and cumulative proportions at length (right panels) compared with the K-S test.

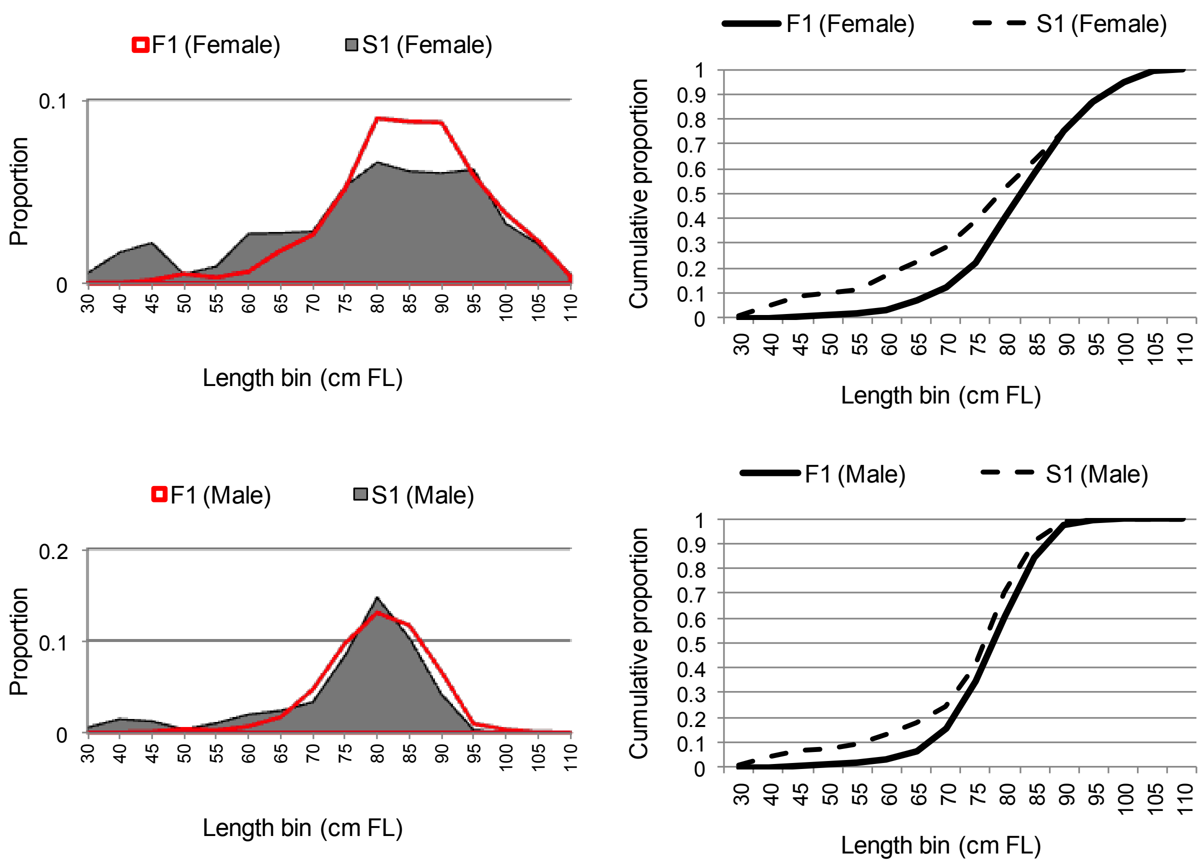


Figure 4.B.1. Continued**.**

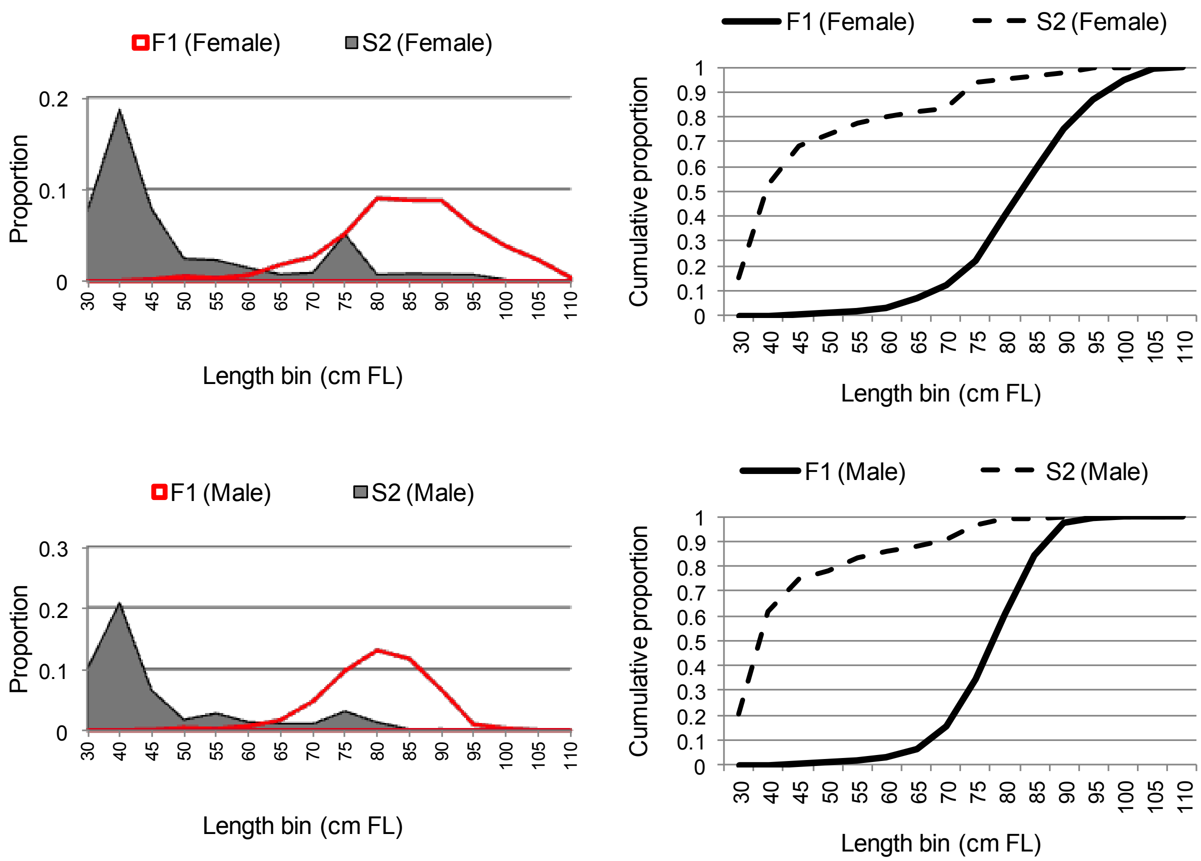

F1 (Female)
S2 (Female)
Proportion
Length bin (cm FL)
Cumulative proportion
F1 (Male)
S2 (Male)

Figure 4.B.1. Continued.

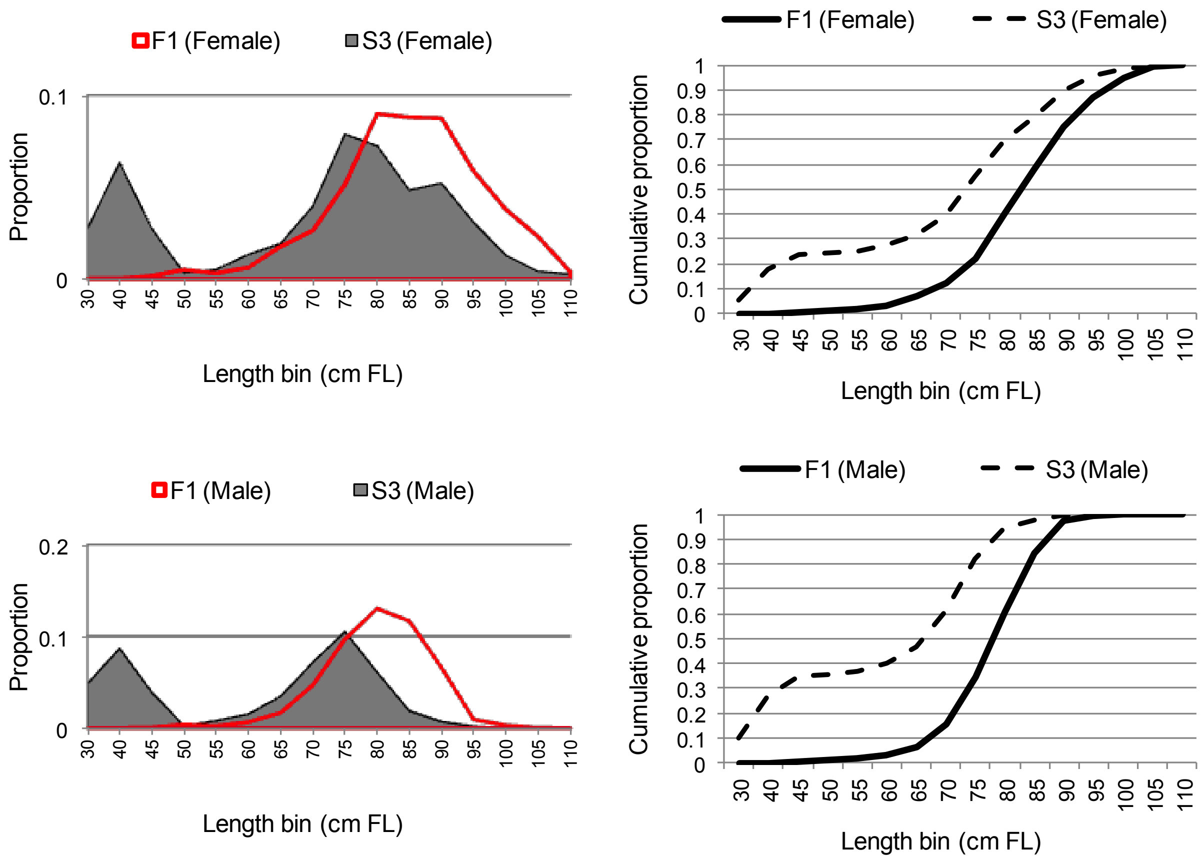


Figure 4.B.1. Continued.

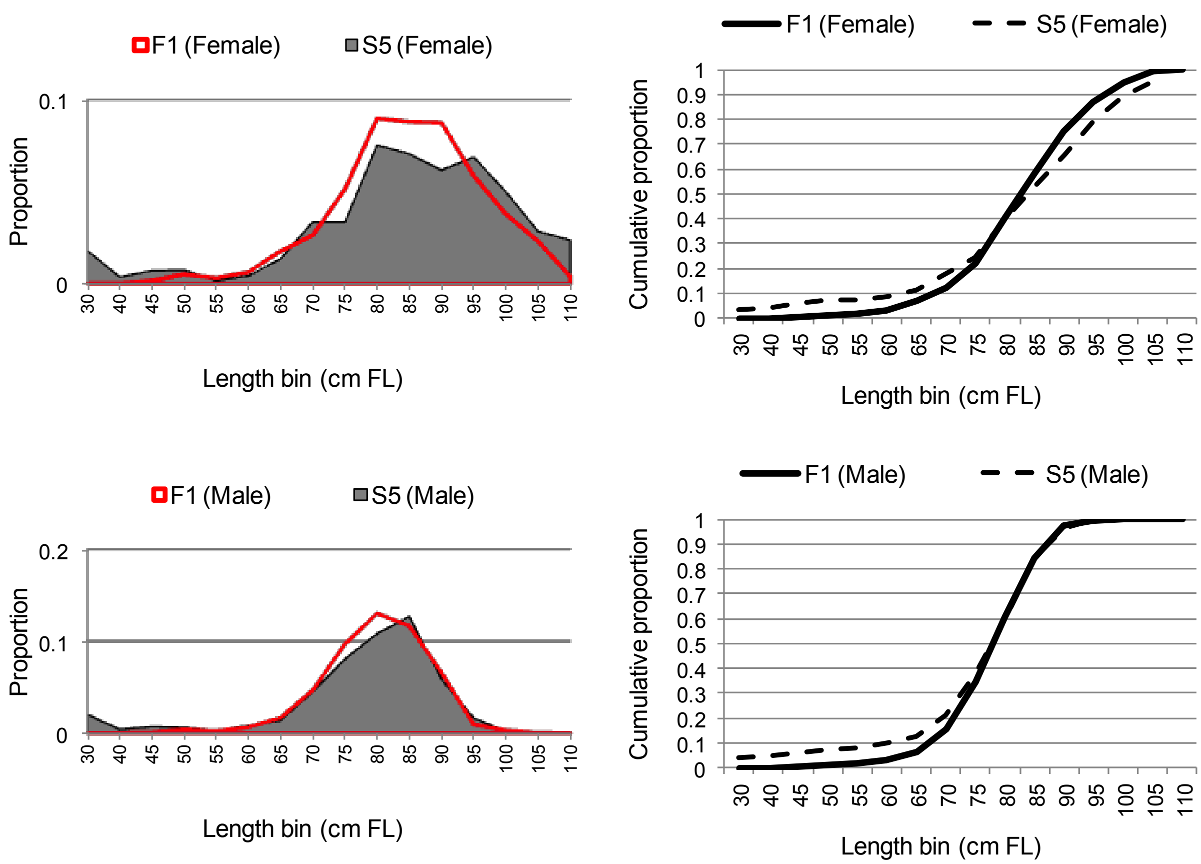


Figure 4.B.1. Continued.

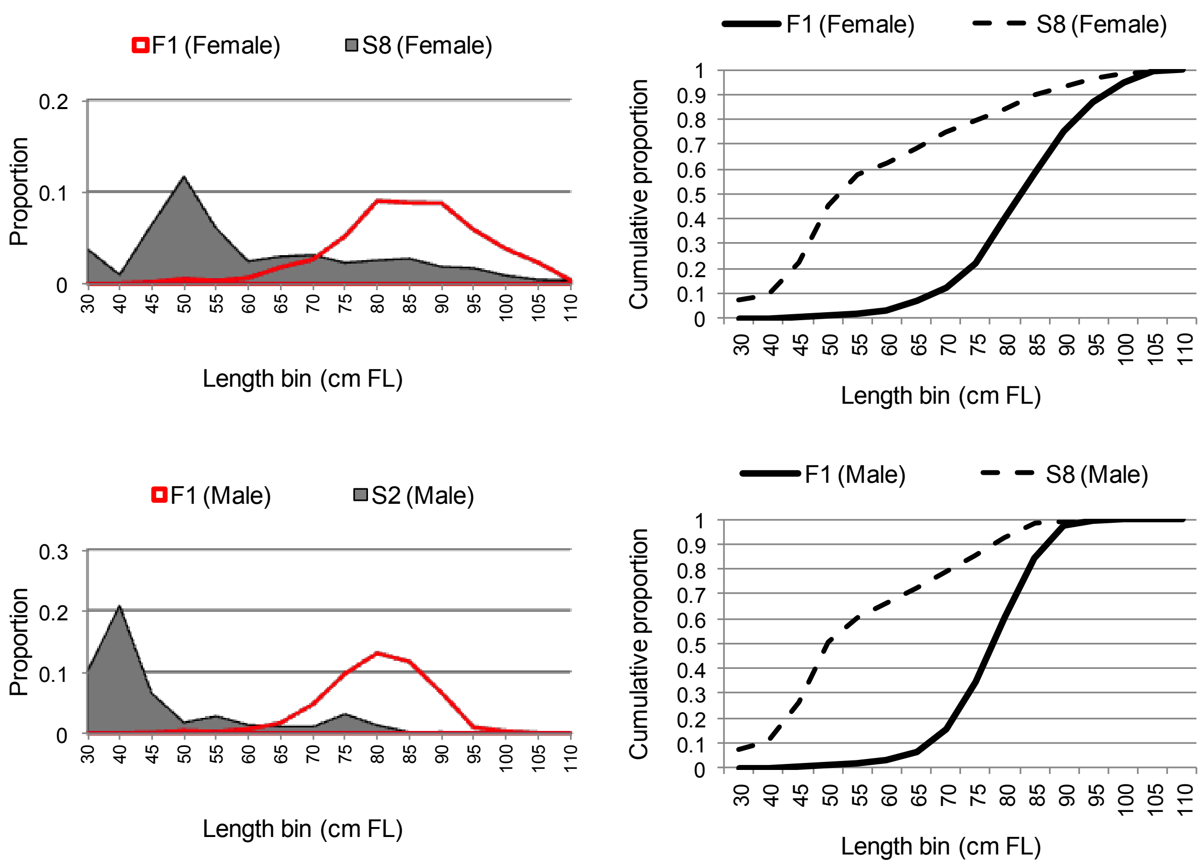


Figure 4.B.1. Continued**.**

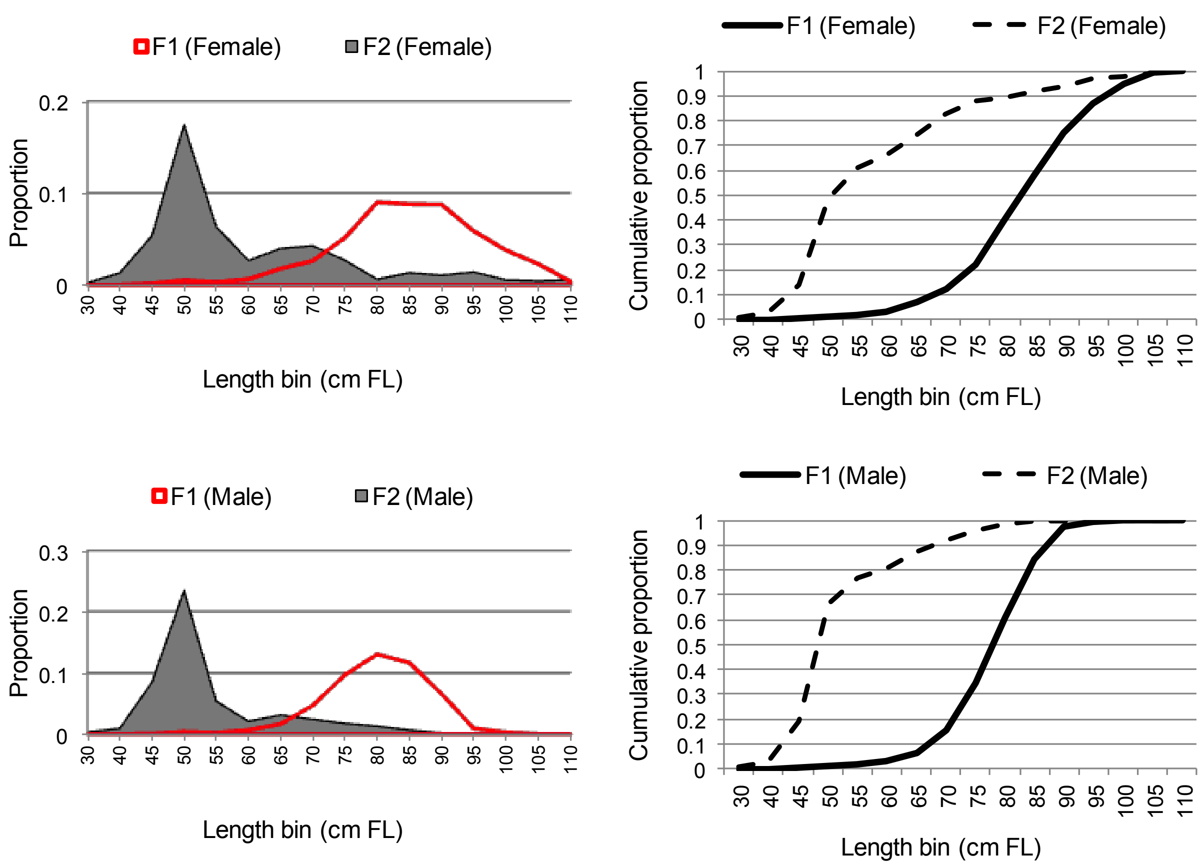


Figure 4.B.1. Continued.

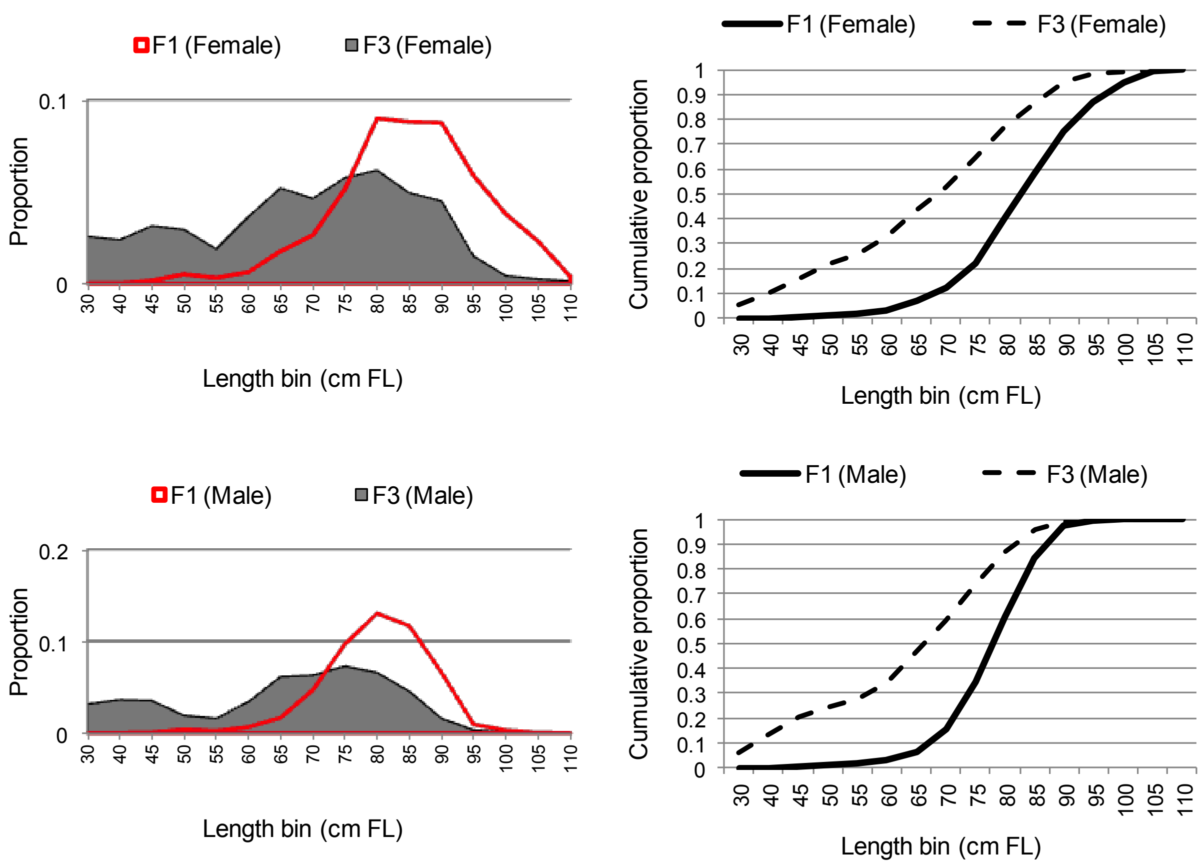


Figure 4.B.1. Continued.

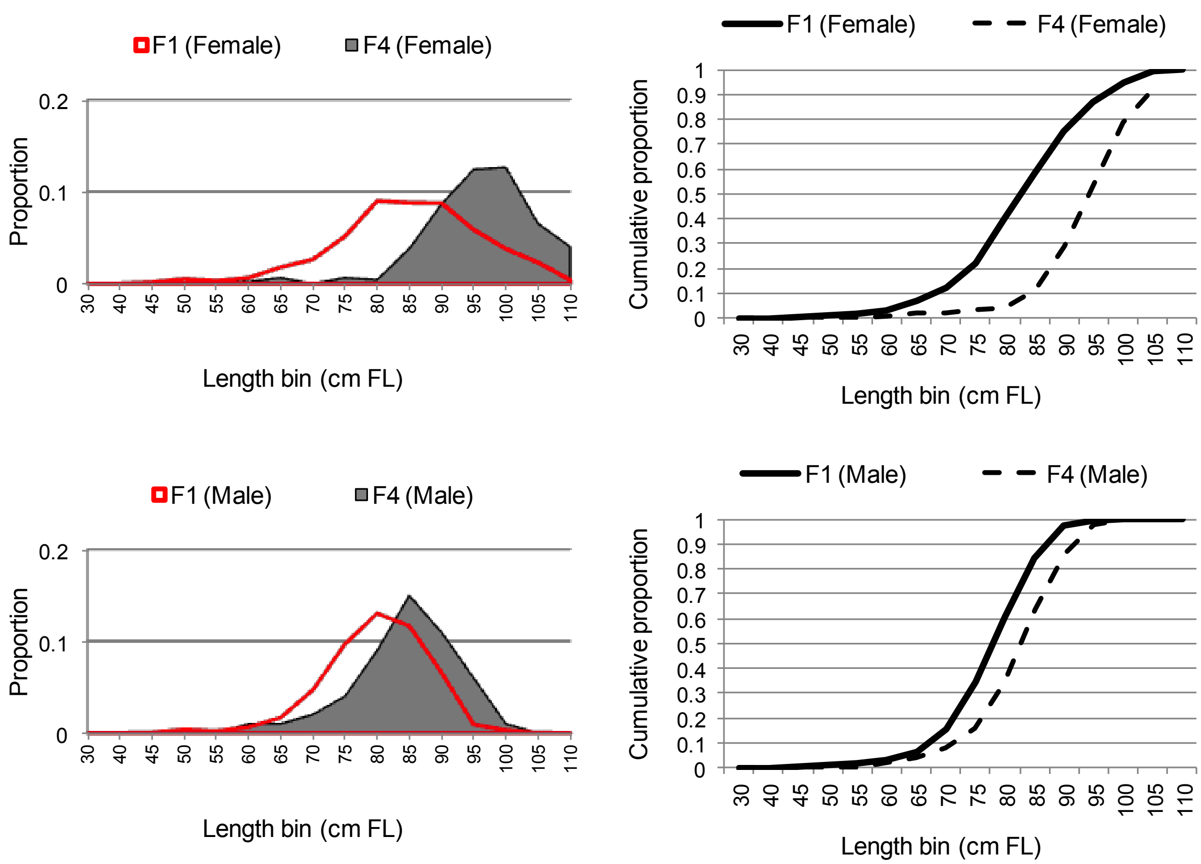


Figure 4.B.2. Sex combined aggregated proportions at length (left panels) and cumulative proportions at length (right panels) compared with the K-S test.

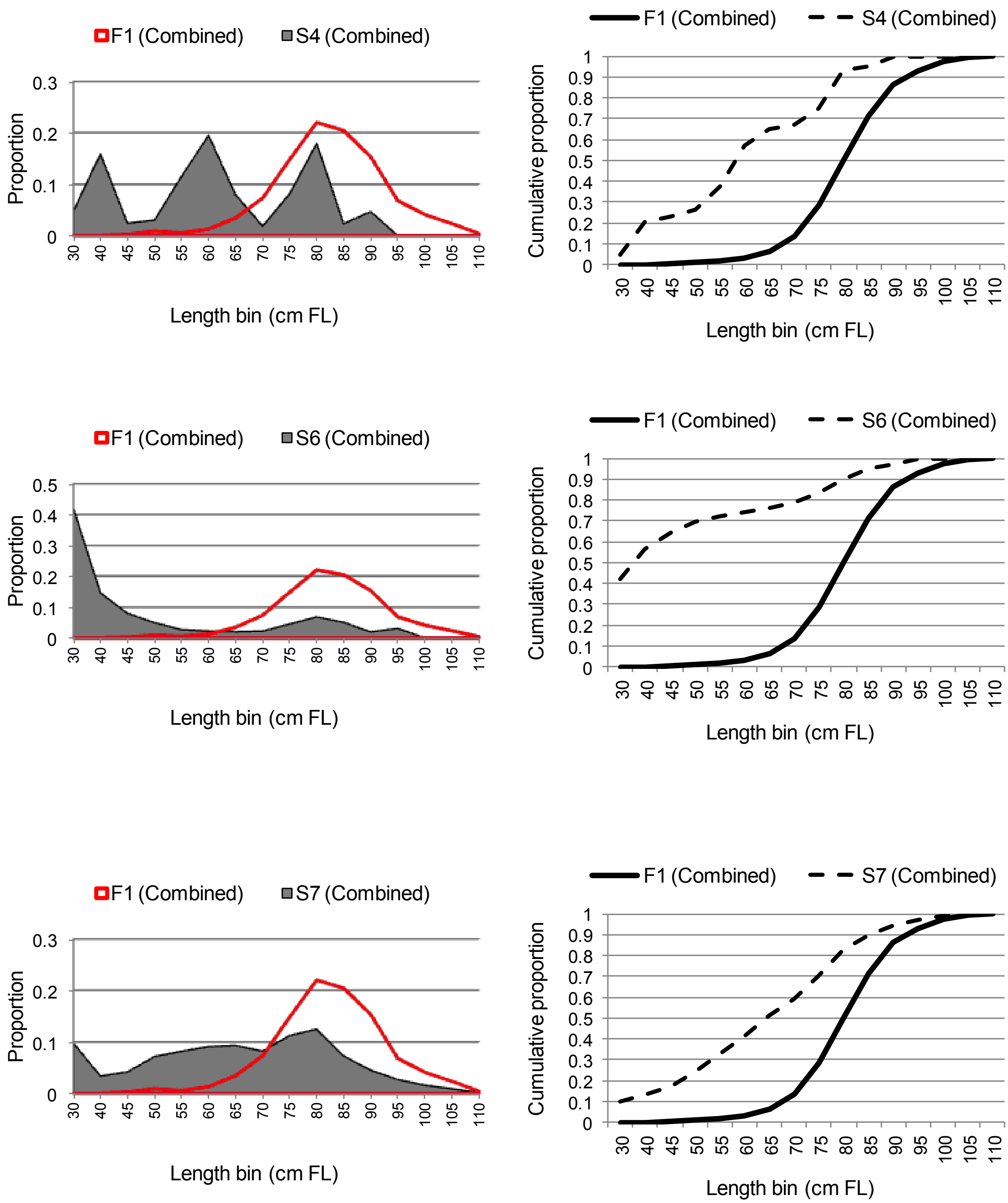
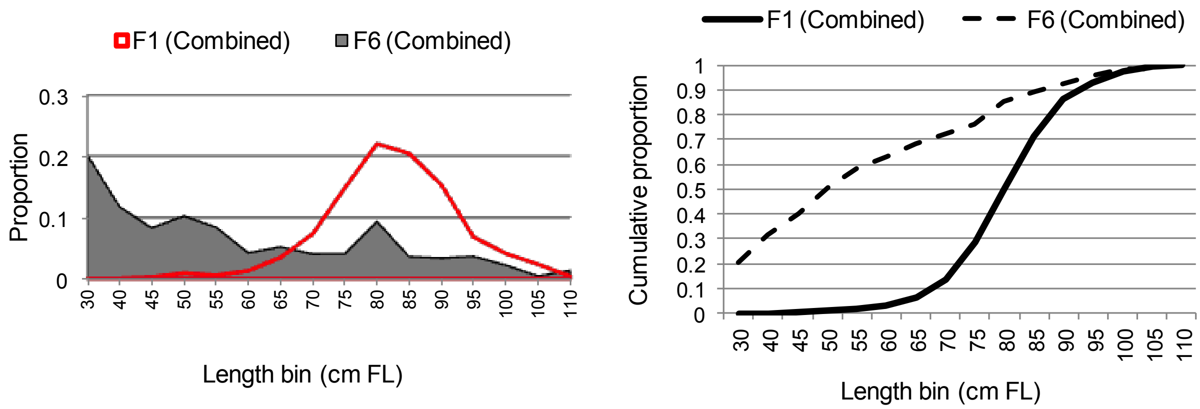


Figure 4.B.2. Continued.



SEDAR

Southeast Data, Assessment, and Review

SEDAR 39

HMS Atlantic Smooth Dogfish Shark

SECTION IV: Research Recommendations

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

1. DATA WORKSHOP RESEARCH RECOMMENDATIONS

1.1 Life History Working Group Recommendations

- Increase tagging effort to examine if there is fine scale structure within *M. canis* off the east coast of the United States to determine if the stock is homogeneous or if it would be more accurately described by northern and southern groupings.
- Conduct genetic analyses in support of Research Recommendation 1.
- Better define seasonal distribution, including regional sex ratios, and identify nursery areas.
- Continue to monitor life history characteristics of *M. canis* off the east coast of the United States to detect potential temporal changes, density-dependent effects or clinal variability among individuals throughout the range.

1.2 Commercial Fisheries Working Group Recommendations

- Increase temporal/spatial/fleet-specific shrimp fleet Observer Program coverage to improve bycatch estimates of *Mustelus* species in the shrimp trawl fishery.
- Conduct research to explore and test the relationship between CPUEs based on shrimp fleet Observer Program and survey (SEAMAP) to indirectly estimate shrimp bycatch CPUE for *Mustelus* species when Observer program data were very limited.

1.3 Recreational Fisheries Working Group Recommendations

No research recommendations relative to recreational fisheries were formulated.

1.4 Indices of Relative Abundance Working Group Recommendations

- Monitor/record bottom temperature, salinity, DO on all fishery independent surveys

2. ASSESSMENT WORKSHOP RESEARCH RECOMMENDATIONS

1. Modeling considerations.

Improve the fits to length composition data. For example Stock Synthesis allows for the estimation of sex specific selectivity and includes options to utilize parameter offset approaches in the estimation of selectivity parameters in order to improve parameter estimation. Several methods are also available for selecting among alternative functional forms for selectivity (e.g., Helu et al 2000; Maunder and Harley 2011; Punt et al. 2014). For example, the use of Akaike's information criterion (AIC) (Akaike 1973; Burnham and Anderson 2002; e.g., Hilborn and Mangel 1997) is appropriate for comparing alternative forms of selectivity, as implemented here for comparing proposed base runs Sel-1 and Sel-2, if models compared use the same data and have the same data structure (Helu et al 2000). Alternative methods would be required for selecting among models with different data or with different data structure. For example, the hold-out cross validation has been used for comparison of models run with different data sets (Maunder and Harley 2011).

2. Data Considerations.

Obtain age composition data from existing surveys in order to not have to rely solely only length composition data in the model.

Update age and growth studies in order to resolve potential differences in observed and predicted size at birth.

3. REVIEW PANEL RESEARCH RECOMMENDATIONS

TOR 6. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.

a) Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.

The research recommendations provided by the Data and Assessment Workshops are considered to be reasonable and would strengthen any future assessment. Research recommendations from the data workshop regarding commercial fisheries (point 1.2 in the Research Recommendations Report) focus on developing CPUE and catch estimates from the *Mustelus* bycatch in the Atlantic shrimp fishery. This is a good recommendation because currently the fishery is poorly accounted for in the assessment. However the data workshop indicated that due to the low spatial/temporal overlap (6.5% of the tow hours overlapped with the *M. canis* distribution) there was low probability of significant interaction and inadequate data to develop a catch history. Developing data from this fishery may be impractical given the uncertainty, in addition sampling from the edge of the distribution can be heavily influenced by factors other than abundance, especially in low information situations (SEAMAP recorded only 5 positive tows from 630 over the years 2001 – 2012). A more important research avenue would be to develop better data streams from the gillnet fishery. An additional research recommendation that would assist the

SEDAR process from the data standpoint is to increase the monitoring on the gillnet fishery as it is currently the major source of fishing mortality.

Research is required into how to appropriately use the rankings of the CPUE series as weights in the modeling process. An additional need is to conduct research on the estimation of the effective sample size (appropriate weights) of the length compositions outside the model. Research avenues that would directly assist the stock assessment process are: 1) to consider alternative recruitment functions; 2) using the equivalent of steepness for the Ricker model (as per the Brooks et al. paper) and potentially the low fecundity stock recruitment function which was developed by Ian Taylor for spiny dogfish in the Pacific. Additionally, investigate the modeling of initial depletion in the model (i.e. using estimated fishing mortalities, catches or recruitment offset), and to investigate projections from within SS3. These recommendations are in line with the DW and AW's recommendations of research on how to weight the length composition data, and improving the fits to the selectivities and to obtain age data.

b) Provide recommendations on possible ways to improve the SEDAR process.

The general SEDAR process is fairly well structured with the development of data workshops and assessment workshops. It is helpful to have the copious documentation. One note is that the rationale for why the decisions were made is often as important as what the decision was. For abundance indices this was often documented in the index worksheets, but not all the decisions were listed in the data workshop report.

Some of the panel's comments regarding the assessment were unable to be addressed because they dealt directly initial model formulation and/or with preliminary analysis. The SEDAR, and in particular the assessment process would have benefited from additional outside input during the assessment workshop (and webinars) from scientists particularly experienced with integrated models such as SS3.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 39

Atlantic Smooth Dogfish Shark

SECTION V: Review Workshop Report

March 2015

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

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1. INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 39 Review Workshop was held February 10-12, 2015 in Panama City, Florida.

1.2 TERMS OF REFERENCE

1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following:
   a) Are data decisions made by the DW and AW sound and robust?
   b) Are data uncertainties acknowledged, reported, and within normal or expected levels?
   c) Are data applied properly within the assessment model?
   d) Are input data series reliable and sufficient to support the assessment approach and findings?
2. Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data, and considering the following:
   a) Are methods scientifically sound and robust?
   b) Are assessment models configured properly and used consistent with standard practices?
   c) Are the methods appropriate for the available data?
3. Evaluate the assessment findings and consider the following:
   a) Are abundance, exploitation, and biomass estimates reliable, consistent with input data and population biological characteristics, and useful to support status inferences?
   b) Is the stock overfished? What information helps you reach this conclusion?

c) Is the stock undergoing overfishing? What information helps you reach this conclusion?

d) Is there an informative stock recruitment relationship? Is the stock recruitment curve reliable and useful for evaluation of productivity and future stock conditions?

e) Are the quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and conditions?

4. Evaluate the stock projections, including discussing strengths and weaknesses, and consider the following:

   a) Are the methods consistent with accepted practices and available data?

   b) Are the methods appropriate for the assessment model and outputs?

   c) Are the results informative and robust, and useful to support inferences of probable future conditions?

   d) Are key uncertainties acknowledged, discussed, and reflected in the projection results?

5. Consider how uncertainties in the assessment, and their potential consequences, are addressed.

   - Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods.
   - Ensure that the implications of uncertainty in technical conclusions are clearly stated.

6. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.

   - Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.
   - Provide recommendations on possible ways to improve the SEDAR process.

7. Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.

8. Provide guidance on key improvements in data or modeling approaches which should be considered when scheduling the next assessment.

9. Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report and that reported results are consistent with Review Panel recommendations. If there are differences between the AW and RW due to the reviewer's request for changes and/or additional model runs, etc. describe those reasons and results.

10. Prepare a Peer Review Summary summarizing the Panel’s evaluation of the stock assessment and addressing each Term of Reference.

1.3 LIST OF PARTICIPANTS

Workshop Panel
Carolyn Belcher, Chair .... HMS AP
Robin Cook .... CIE Reviewer
Neil Klaer .... CIE Reviewer
Joel Rice .... CIE Reviewer

Analytic Representation
Enric Cortés .... SEFSC, Panama City
Dean Courtney .... SEFSC, Panama City
Xinsheng Zhang .... SEFSC, Panama City

Council Representation
Anna Beckwith .... SAFMC
Ben Hartig .... SAFMC

Appointed Observers
Peter Barile .... SFA
Kathy Sosebee .... NEFSC

Staff
Julie Neer .... SEDAR
Julie O'Dell .... SAFMC Staff
Karyl Brewster-Geisz .... HMS

1.4 LIST OF REVIEW WORKSHOP WORKING PAPERS AND DOCUMENTS

Documents Prepared for the Review Workshop			
SEDAR39-RW-01	Projections for the SEDAR 39 Atlantic Smooth Dogfish (*Mustelus canis*) Stock Assessment Report Base Model Configuration	Dean Courtney	30 Jan 2015

2. REVIEW PANEL REPORT

EXECUTIVE SUMMARY

The decisions made by the SEDAR 39 data and assessment workshops for Atlantic dogfish were deemed sound. The data uncertainties associated with the catch estimates, life history and length composition data were acknowledged. Overall, the review panel did not find the assessment to be data poor. The selected CPUE indices included in the model are all fishery-independent. One concern from the review panel was the decision made by the data workshop where B_o was set in 1981, given there were catches prior to that year. However, understanding the need to estimate initial F values and the uncertainty associated with catches prior to 1981, the choice seemed reasonable. The data were properly integrated into the assessment model; however, one suggested area of improvement would be the inclusion of directly observed ages. The assessment findings are sufficiently supported by the data.

Atlantic smooth dogfish were assessed using Stock Synthesis 3 (SS3). For comparative purposes, the SS3 model was constructed as a bridging analysis for the previously applied state-space Bayesian surplus production model (SSPASM); however, the SS3 model was used to produce the base case and sensitivities under review. Both modeling approaches have been used in previously accepted stock assessments. One area of difficulty acknowledged by the review panel was the apparent difficulty in relative weighting of the different data sources in SS3. Additionally, it was noted that the base case was more strongly directed at estimation of selectivity for the differing fleets and surveys, which may not always be the approach for a new SS3 model. Patterns in recruitment deviations indicate a systematic effect outside of the stock-recruitment model or a mis-specification of the model itself. At present, a simple solution does not exist to remedy this issue; therefore the base case remained unchanged. Given the available data and the associated issues, SS3 was still found to be appropriate for use as the primary assessment method.

The review panel indicated that the range of sensitivities appropriately captured the uncertainty regarding the states of nature and the potential implications for the reference points. Based on the accepted base case and range of associated sensitivities, it is likely that the stock is not overfished, nor experiencing overfishing. The review panel cautioned about inferences drawn about stock status because of the level of uncertainty associated with the stock-recruitment relationship and uncertainty in the catches. The review panel also noted that the fishing level for the most recent year is close to F_{MSY} for some sensitivity runs. The panel also recommended looking at proxies such as 40%SPR or $F_{0.1}$, which may avoid the problems with the uncertainty in the stock-recruitment relationship.

The stock assessment for Atlantic smooth dogfish was considered the best scientific information available, and it included plausible states of nature as sensitivity analyses. Although there are areas that merit additional research (i.e., the initial depletion, appropriate weights to the data) there were no obvious omissions or major contradictions in the data or assessment methodology.

Key improvements recommended by the review panel for future assessments included research on better fits to the length composition data using different functional forms and fitting of growth parameters, closer integration of projections with the assessment, looking at different approaches for weighting length compositions, and investigating model uncertainty using alternative models with different structural assumptions.

SEDAR 39 HMS Terms of Reference: Atlantic Smooth Dogfish

1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following:

General Panel Comments.

The data used in this assessment consist of biological information, catch estimates, length frequency inputs and indices of abundance. In general this is not a data poor assessment, and for some inputs (i.e. length composition) there is a large amount of data. However some aspects of the data limit the utility, such as inconsistent data recording methods. However the indices of abundance (as a whole) could be considered low information due to the relative shortness of many series, inconsistent trends and high variability. The selected CPUE indices are all fishery independent. They generally cover the range of the species abundance in the western north Atlantic, with particular coverage in New England where parturition is known to occur. All of the selected indices of abundance came from trawl surveys, however gillnet catch is large and there is no index of abundance from this fishery due to data deficiencies with the gillnet CPUE standardization. The CPUE series based on the observer data from the gillnet fleet was recommended to be removed by the DW. The recommendation to remove the CPUE series associated with the largest source of mortality is sound given that the species is a bycatch component of the gillnet fishery and therefore may not reflect trends in abundance of the stock.

a) Are data decisions made by the DW and AW sound and robust?

The majority of the decisions made by the DW and AW are sound, some decisions (i.e. used published studies for life history information and ignored the shrimp trawl fishery bycatch) were made because they were the best available science. The decision by the DW to set B_O to 1981 is questionable as there are documented and undocumented catch prior to that year. However, as assessments may be set to estimate initial F values, and catches prior to 1981 are uncertain, this choice seems reasonable.

b) Are data uncertainties acknowledged, reported, and within normal or expected levels?

The uncertainties with respect to the data are acknowledged in relation to the catch estimates, life history and length composition data. The selection and ranking of the CPUE series was fairly well documented but there is a lack of clarity as to how to use the ranks. Rankings were useful however, particularly for highlighting the index ranked 1, ensuring that work would be done in the assessment to fit that index in particular.

c) Are data applied properly within the assessment model?

The data are applied properly within the assessment model. Age-structured stock assessments are normally improved if age composition data are available. Stock synthesis (SS3) is fundamentally an age-structured model, so this also applies to here. Even single years of representative age-at-length data can allow a model such as SS3 to better characterize fitted growth parameters in particular. Unfortunately, direct age composition information is not available for this assessment, but assessment models for this stock in future could potentially be improved if such data were collected and made available, particularly from the fishing fleets that account for most of the catch. Age data from vertebrae of similar shark species (e.g. *Mustelus antarcticus* in Australia) are collected by fishery observers, demonstrating that it should be technically achievable, depending on available resources.

d) Are input data series reliable and sufficient to support the assessment approach and findings?

The data are sufficient to support the assessment approach (integrated model) and support the assessment findings. One of the benefits of this assessment is that this species is well studied with respect to the biology, helping to constrain the model. However the catch statistics rely in part on catch reconstruction rather than actual catch records (commercial), and the estimate of recreational post release mortality. Further there is no reliable information regarding the catch prior to 1981 and this makes estimation of the initial depletion somewhat problematic.

2. Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data, and considering the following:

a) Are methods scientifically sound and robust?

SS3 is available from the NOAA toolbox, has been extensively used, tested and validated elsewhere, and can accept a large variety of catch, abundance index and age/length composition data sources. In particular, age/length composition is used at the raw annual sampled level, rather than as a derivative source such as a catch at age matrix or an age-length key. A weakness of SS3 is in the complexity of the model itself and the vast range of choices available to the analyst on how to configure any particular implementation. This means that analysts require considerable training and experience to make best use of the platform, and to acquire knowledge of the latest best-practice for some configuration choices. A particular area of difficulty is in relative weighting of different data sources (in this case length or survey abundance) both within and among each series.

b) Are assessment models configured properly and used consistent with standard practice?

The SS3 assessment has been carried out with two main objectives. Firstly as a bridging analysis for comparison with results from the more traditionally applied state-space Bayesian surplus production model (SSPASM), and secondly to apply a method most appropriate to the available data. The first objective has led to an SS3 implementation that has placed more emphasis on the derivation and estimation of selectivity parameters for the various fleets and surveys than might otherwise have been the case with an entirely new SS3 model.

The base model was configured to estimate a starting biomass (via an initial equilibrium recruitment level R_0), recruitment deviations in each year, and a large number of selectivity parameters. To take full advantage of SS3, some important biological parameters such as natural mortality or growth would also be estimated by the model. However, as the base model has been constructed to concentrate particularly on selectivity, the additional estimation of these other parameters has proved difficult. The base model cannot fit all available abundance indices well as they conflict in some cases. Fits to available length data are poor particularly for young fish and the plus group in many years. Length fits for the main gillnet fishery were much improved by the shift to dome-shaped selectivity for the base model.

Common practice is that recruitment deviations are estimated by the model for recruitment prior to the starting year based on the estimated CV of those earlier deviations. An objective method is to allow deviations to be estimated for those early years where the estimated CV is low. Examination of the estimated CVs for a minimally modified base model show that deviations appear to be well estimated after about 1974, giving a period of 7 years prior to the model start year for which deviations should be estimated. Implementation of this procedure was examined in sensitivity analyses developed during the RW, which proved to have minimal impact on the management implications of the base case.

Common practice is also to attempt to estimate initial F values for fishing fleets that have non-zero catches historically prior to the start of the model. Implementation of this procedure was also examined for the effect on management implications of the base case as sensitivity analyses during the RW, which also proved to be minimal.

Standard practice for relative weighting among data sources within an SS3 model recommends ensuring that abundance indices are fitted in preference to age or length composition data as composition data are often noisy, and the primary source of signal for population abundance should be from abundance indices. In recent years there has been much work towards the development of a precise standardized method to carry this out, but at present such a procedure is not generally available. The procedure used by the assessment team does ensure that abundance indices are given more weight than they would receive if standard iterative re-weighting input CVs and sample sizes were applied to all sources, so the recommendation is satisfied.

Estimated recruitment deviations generally show a pattern of negative deviations earlier in the series and positive later, with a high degree of autocorrelation. The pattern indicates either a systematic effect not accounted for by the model (e.g. cycling environmental conditions affecting recruitment strength), or model mis-specification of the stock-recruitment relationship. There is not currently a simple stock recruitment relationship in SS3 that would easily account for such behavior, so no simple change to the base case could be recommended at this time as a remedy. Recent recruitment deviations have been near zero, and the overall variability in estimated deviations is currently treated as random noise. Further work is required to investigate how best to account for the systematic pattern, but the RP agrees that there are no candidates currently available in SS3, and that the current base is the best that can be achieved with the available model.

Model convergence was assumed if the standard error of parameter estimates could be derived from the inverted Hessian matrix. Other diagnostics were also examined including excessive CVs on estimated quantities, parameters on bounds, patterns in length composition, unusually large individual likelihood components and high or non-informative parameter correlations. Model AIC, RMSE and K-S tests were used for comparison among alternative models. These are standard and recommended practice for SS3 models. An additional method that requires a great increase in model run time is the use of MCMC – both as a confirmation of convergence, and also as a method of construction and analysis of the posterior distribution for estimated quantities. The use of MCMC is encouraged, although the additional time and analysis required for each individual assessment is also acknowledged.

c) Are the methods appropriate for the available data?

Use of SS3 as the primary assessment method is appropriate given the available data which includes various conflicting fishery independent survey abundance indices with different associated selectivity patterns, and also a great deal of length-frequency data either collected directly from the fisheries, or associated with survey indices.

3. Evaluate the assessment findings and consider the following:

a) Are abundance, exploitation, and biomass estimates reliable, consistent with input data and population biological characteristics, and useful to support status inferences?

The base case assessment abundance, biomass and exploitation estimates are consistent with the majority of the input data (note that there are some inconsistent CPUE series and some poor fits to the length frequency data) and are useful to support perceptions of stock trends. Inferences about the stock status need to be interpreted with care given the uncertainty in the stock recruitment relationship.

b) Is the stock overfished? What information helps you reach this conclusion? & c) Is the stock undergoing overfishing? What information helps you reach this conclusion?

Based on the accepted base case and sensitivities presented (SEL2 and internally estimated selection parameters) the range of sensitivity models indicate that the population is above MSY and the exploitation rate is lower that F_{MSY} (see figure 4.24.b in the assessment report). It is likely that the stock is not overfished nor is it experiencing overfishing, but this is conditioned on the stock recruitment relationship which may be unreliable. The RP is of the opinion that the range of sensitivities investigated appropriately captures the uncertainty regarding the states of nature and therefore the implications regarding the reference points. The RP does note however that the recent year's stock status is near the $F_{CURRENT} / F_{MSY}$ =1 bound for some of the sensitivities.

d) Is there an informative stock recruitment relationship? Is the stock recruitment curve reliable and useful for evaluation of productivity and future stock conditions?

The stock recruitment curve is largely set by the steepness value which was not estimated in the model but rather calculated by demographic methods. Steepness is the main driver of productivity and appears to be acceptably calculated. The RP notes that in comparison to many teleost species this is a relatively robust method for sharks as they have well studied fecundity. The RP notes that the currently implemented stock recruitment relationship is the best available at this point but does not appear to capture the pattern of natural variability estimated by the model.

e) Are the quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and conditions?

The estimates of the stock status appear reliable assuming the stock and recruitment is adequately modeled, especially when the sensitivities are taken into account. Additionally the model estimated that the stock is more lightly exploited in the terminal year (2012) than in the two previous years. The RP agrees with the methods used and the determination of the stock status, however the RP notes that the use of 40%SPR or $F_{0.1}$ proxies for MSY may avoid the problems of uncertainty in the stock-recruitment relationship.

The RP notes that common SEDAR practice is to define stock status as the average of the last few (often 3) years of the assessment, and that this assessment reports the terminal year.

4. Evaluate the stock projections, including discussing strengths and weaknesses, and consider the following:

a) Are the methods consistent with accepted practices and available data?

Accepted practice for stock projection is to account for as much of the uncertainty characterized by the stock assessment into forward stochastic simulations. The method employed by the assessment team achieves this standard through Monte Carlo simulations drawn from the asymptotic standard errors and parameter correlations estimated by the SS3 assessment.

b) Are the methods appropriate for the assessment model and outputs?

Besides annual recruitment deviations and selectivity, the base case stock assessment only estimates the value for one simple population parameter, R_0 (initial equilibrium unexploited recruitment). The resulting error for R_0, F_{2012} (terminal year fishing mortality - a derived quantity) and the standard deviation of recruitment deviations were used in projections from a stock assessment to propagate uncertainty into the future. The standard error of the estimated deviations was used to generate random bias-adjusted log-normal variability in future recruitments, assuming the fitted stock-recruitment relationship.

Alternative commonly used procedures include formulating projections directly from MCMC draws, or from alternative population states derived from re-fitting the model to bootstrapped re-sampling of the input data. These alternatives are superior to the method used as they do not assume that the errors in estimated parameters are characterized by normal distributions, as do the approximate asymptotic ones calculated via inversion of the Hessian. However, examination of the range of variation achieved by the applied procedure indicates adequate performance, assuming that the recruitment variability has been appropriately modelled.

c) Are the results informative and robust, and useful to support inferences of probable future conditions?

Projection results for an assessment examine the stock condition indicators of principal interest to managers, and also the variation in those quantities in a robust and informative manner. Results are provided as key summary statistics and also as time series for 21 alternative fixed catch scenarios for the projection period of 10 years.

d) Are key uncertainties acknowledged, discussed, and reflected in the projection results?

Uncertainty due to plausible alternative states of nature was characterized through the projection of the selected plausible sensitivity analyses. There were other sensitivity analyses examined as model diagnostics (e.g. the model based on externally estimated selectivities) that were not included in the set of plausible states of nature, and the RP agrees with the choices made in this selection.

5. Consider how uncertainties in the assessment, and their potential consequences, are addressed.

a) Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods.

The key uncertainties in the Atlantic smooth dogfish assessment are: a) the historical catch series (which impacts the initial depletion); b) the indices of abundance; and c) the life history parameterization, including the productivity and the post release delayed mortality. This was noted by the assessment team which undertook multiple alternative runs to characterize the uncertainty associated with the alternative states of nature. Although the presented sensitivity runs show the effect of single changes to the inputs or parameterizations, to better characterize the shape of the uncertainty (with respect to the MSY based reference points) a full grid of interactions would need to be run. Note that this is non-trivial and that the RP requested an additional “worst case scenario” run (i.e., low productivity, high catch) the results of which did not indicate a major departure from the selected base case.

b) Ensure that the implications of uncertainty in technical conclusions are clearly stated.

The impact of the uncertainty considered in the stock assessment on the technical conclusions does not change the status of the stock (the considered alternatives indicate that the population is above MSY and the exploitation rate is lower than F_{MSY}). The extremes of the considered uncertainty also indicate that population may be near parity with respect to the $F_{CURRENT}/ F_{MSY}$ reference point.

TOR 6. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.

a) Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.

The research recommendations provided by the Data and Assessment Workshops are considered to be reasonable and would strengthen any future assessment. Research recommendations from the data workshop regarding commercial fisheries (point 1.2 in the Research Recommendations Report) focus on developing CPUE and catch estimates from the *Mustelus* bycatch in the Atlantic shrimp fishery. This is a good recommendation because currently the fishery is poorly accounted for in the assessment. However the data workshop indicated that due to the low spatial/temporal overlap (6.5% of the tow hours overlapped with the *M. canis* distribution) there was low probability of significant interaction and inadequate data to develop a catch history. Developing data from this fishery may be impractical given the uncertainty, in addition sampling from the edge of the distribution can be heavily influenced by factors other than abundance, especially in low information situations (SEAMAP recorded only 5 positive tows from 630 over the years 2001 – 2012). A more important research avenue would be to develop better data streams from the gillnet fishery. An additional research recommendation that would assist the SEDAR process from the data standpoint is to increase the monitoring on the gillnet fishery as it is currently the major source of fishing mortality.

Research is required into how to appropriately use the rankings of the CPUE series as weights in the modeling process. An additional need is to conduct research on the estimation of the effective sample size (appropriate weights) of the length compositions outside the model. Research avenues that would directly assist the stock assessment process are: 1) to consider alternative recruitment functions; 2) using the equivalent of steepness for the Ricker model (as per the Brooks et al. paper) and potentially the low fecundity stock recruitment function which was developed by Ian Taylor for spiny dogfish in the Pacific. Additionally, investigate the modeling of initial depletion in the model (i.e. using estimated fishing mortalities, catches or recruitment offset), and to investigate projections from within SS3. These recommendations are in line with the DW and AW's recommendations of research on how to weight the length composition data, and improving the fits to the selectivities and to obtain age data.

b) Provide recommendations on possible ways to improve the SEDAR process.

The general SEDAR process is fairly well structured with the development of data workshops and assessment workshops. It is helpful to have the copious documentation. One note is that the rationale for why the decisions were made is often as important as what the decision was. For abundance indices this was often documented in the index worksheets, but not all the decisions were listed in the data workshop report.

Some of the panel's comments regarding the assessment were unable to be addressed because they dealt directly initial model formulation and/or with preliminary analysis. The SEDAR, and in particular the assessment process would have benefited from additional outside input during the assessment workshop (and webinars) from scientists particularly experienced with integrated models such as SS3.

7. Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.

The stock assessment is considered the best scientific information available. We note that this is the first assessment of this species in the Atlantic and also that the assessment included plausible states of nature as sensitivity analyses. While there are areas that merit additional research (the initial depletion, appropriate weights to the data) there are no obvious omissions or major contradictions in the data or assessment methodology. All details of the assessment were made available to the RP during the workshop.

8. Provide guidance on key improvements in data or modeling approaches which should be considered when scheduling the next assessment.

With respect to the next assessment the RP recommends the following research avenues.

- Closer integration of projections with the SS3 assessment
- Better fit to the length comp via different functional forms and fitting of growth parameters
- Examine approaches to appropriately weight the length compositions
- Investigate model uncertainty by applying alternative models that make different structural assumptions to test robustness of the assessment

9. Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report and that reported results are consistent with Review Panel recommendations. If there are differences between the AW and RW due to the reviewer's request for changes and/or additional model runs, etc. describe those reasons and results.

The RP did request additional runs as part of its review however none of the plausible runs resulted in a change in stock status. The RP considers the base case as presented along with the sensitivity runs to adequately capture the best available science and the status of the stock.

10. CIE Reviewer may contribute to a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference.

All three CIE reviewers provided consensus on the language that appears in the Peer Review Summary Report.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 39

HMS Atlantic Smooth dogfish

SECTION IV: Addendum and Post-Review Workshop Updates

February 2015

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

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1. POST REVIEW ADDENDUM

1.1. SUMMARY

Corrections were provided for the SEDAR 39 HMS Atlantic Smooth Dogfish Section III: Assessment Process Report (ATL Assessment Report) **Table 4.13** during the CIE Review Workshop (RW). Eleven topics of additional information were provided during the CIE RW which were either not available or were not sufficiently documented in the ATL Assessment Report. Two stock assessment model sensitivity runs were developed during the CIE RW in response to CIE Review Panel recommendations to evaluate the effect of including several standard stock assessment practices within the smooth dogfish base model configuration from the ATL Assessment Report (ATL Base Sel-2). A summary of projection model results was provided for the base model configuration from the ATL Assessment Report (ATL Base Sel-2) and for model sensitivities associated with the base model configuration (Sel-2) from the ATL Assessment Report.

1.2. CORRECTIONS

Corrections for the SEDAR 39 HMS Atlantic Smooth Dogfish Section III: Assessment Process Report (ATL Assessment Report) **Table 4.13** are reported in **Table 1** (highlighted in yellow).

1.3. ADDITIONAL INFORMATION

1.3.1. Item 1. Estimate Some Growth Parameters within the Stock Assessment Model

Model fits to aggregate length compositions were poor for some length composition data sources at the smallest and largest length bins for the smooth dogfish base model configuration (ATL Base Sel-2; see ATL Assessment Report **Figures 4.9 – 4.11**). The von Bertalanffy growth (VBG) parameters recommended for *Mustelus canis* in the Atlantic Ocean also resulted in a relatively large length at age-0 (L_{Amin}) for males and females (46.94 and 48.84 cm FL, respectively; see ATL Assessment Report Sections 2.4 and 3.3.1.1), relative to the approximate size at birth (c. 32.5 cm FL) obtained from the scientific literature (SEDAR39-RD01). It was noted that it may be possible to improve the fits for the smallest length bins by estimating the growth parameter for L_{Amin} within the stock assessment model. In the smooth dogfish base model configuration from the ATL Assessment Report (ATL Base Sel-2), the distribution of mean length at each age was modeled with a normal distribution and the CV in mean length at age was modeled as a linear function of length with the CVs fixed at L_{Amin} (0.15) and at L_{Amax} (0.12) (see ATL Assessment Report Section 3.3.1.1). It was noted that it may also be possible to improve the fits for the smallest and largest length bins by estimating the CVs at L_{Amin} and at L_{Amax} within the stock assessment model.

Preliminary attempts to estimate L_{Amin} and the CVs at L_{Amin} and at L_{Amax} within the stock assessment model were not successful (see ATL Assessment Report Section 4.11). Because growth parameters may be highly correlated with selectivity parameters, the CIE Review Panel recommended evaluating model sensitivity to the estimation of growth parameters within the stock assessment model by fixing some of the selectivity parameters in the stock assessment model at their estimated values.

As a first step, model sensitivity to the effect of estimating growth parameters within the stock assessment model was evaluated with the model sensitivity MS-1 (External Selectivity) from the ATL Assessment Report (see the ATL Assessment Report **Table 4.12**). Model sensitivity MS-1 was chosen because all of the selectivity parameters in MS-1 were fixed at externally derived values (see the ATL Assessment Report **Table 2.A.1)**. Three growth parameters were estimated within MS-1: the length at age-0, L_{Amin} cm FL, and the coefficient of variation, CV, in mean length at age at both the minimum age, CV L_{Amin}, and the maximum age, CV L_{Amax} (**Table 2**). Growth parameters were estimated separately for males and females. The model with estimated growth parameters resulted in a better fit to the aggregate length composition data of some data sources for the smallest and largest size bins compared to both MS-1 and the base model configuration (ATL Base Sel-2) (**Figures 1 – 3**). However, the model with estimated growth parameters also resulted in a worse fit for the smallest size bins for some data sources (e.g., Fleet F2) compared to both MS-1 and the base model configuration (ATL Base Sel-2) (**Figures 1 – 3**). The ATL Assessment Report Section 3.2 and **Tables 2.3 - 2.5** provide a description of the length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8).

1.3.2. Item 2. Down-weight Length Composition Data within the Stock Assessment Model

The effect of down-weighting the length composition data within the stock assessment model was evaluated by applying a weight of $\lambda = \frac{1}{4}$ to all length composition data within the base assessment model (ATL Base Sel-2). The model with a weight of $\lambda = \frac{1}{4}$ applied to the length composition data resulted in similar fits to indices of relative abundance, annual length compositions for the main targeted fishery (fleet F1 – NE Gillnet Kept), and aggregate length composition data compared to the base assessment model (ATL Base Sel-2) (**Figures 4 – 16**).

1.3.3. Item 3. Evaluate the Correlation File from the Stock Assessment Model

The program r4ss (Taylor et al. 2014) was used to evaluate parameter correlations after each model run. The correlation matrix was examined for highly correlated (> 0.95) and non-informative (< 0.01) parameters. A list of model parameters and their associated asymptotic standard errors for the base model configuration (ATL Base Sel-2) is available in the ATL Assessment Report **Table 4.2.b**. All estimated parameters were within reasonable correlation thresholds (≥ 0.01, and ≤ 0.95) and no parameters were estimated at boundary conditions, based on diagnostics completed after each run with the program r4ss (not shown). However, some parameters were estimated at values very close to their boundary conditions (e.g., SizeSel_3P_2_F3; ATL Assessment Report **Table 4.2.b**). Parameters estimated near boundary conditions may have been kept off the boundary condition by the use of the soft boundary option in SS3. Three estimated selectivity parameters (SizeSel_3P_1_F3, SizeSel_3P_2_F3, and SizeSel_10P_3_S4) also had very large standard errors (SEs) relative to the parameter estimates, indicating that these parameters were poorly estimated (ATL Stock Assessment Report **Table 4.2.b)**.

1.3.4. Item 4. Provide a Table of Likelihood Component Values from the Stock Assessment Model

Likelihood component values were provided for fits to each index of relative abundance (surveys S1 – S8) and for fits to each length composition data source associated with fleets F1 – F6 and surveys S1 – S8 (**Tables 3** and **4,** and **Figures 17** and **18**). Likelihood component values were provided for the base model configuration (ATL Base Sel-2) and for the model sensitivities associated with the base model configuration (Sel-2) (**Tables 3** and **4,** and **Figures 17** and **18**). The ATL Assessment Report Section 3.7 and **Table 4.13** provide a description of the model sensitivities associated with the base model configuration (sel-2), which included the following: MS-9 Start Year 1972 (Sel-2), MS-10 Ranked CPUE (Sel-2), MS-11 Low Catch (Sel-2), MS-12 High Catch (Sel-2), MS-13 Low Productivity (Sel-2), MS-14 High Productivity (Sel-2), and MS-15 Hierarchical (Sel-2). The ATL Assessment Report Section 3.2 and **Tables 2.3 - 2.5** provide a description of the length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8). The ATL Assessment Report Section 3.2 and **Tables 2.5** – **2.7** provide a description of the data sources for each index of relative abundance (surveys S1 – S8). Likelihood component values were also provided for results of model sensitivity runs conducted during the CIE Review Workshop (RW Sensitivity Run 01 and RW Sensitivity Run 02), which are described below.

1.3.5. Item 5. Review Iterative Re-weighting Used in the Stock Assessment Model

The likelihood component weighting philosophy implemented in the current assessment was consistent with examples provided in the scientific literature (e.g., Punt et al. 2014): "…(a) the model should fit the trends in the abundance indices as well as possible, and (b) the effective sample sizes and CVs assigned to the data should match the variation implied by the residuals…" In the current assessment, model sensitivity was explored to down-weighted data sets by increasing the variance or reducing the sample size in the corresponding likelihood component (e.g., Maunder and Punt 2013). In particular, the base assessment model (ATL Base Sel-2) was implemented with the input CVs provided for abundance indices, and the input sample sizes provided for length composition data, obtained during the SEDAR 39 Data Workshop. The effective sample sizes for length data were then modified (once) within the stock assessment model, based on the effective sample size determined for each data source from Stock Synthesis output (e.g., see Punt et al. 2014 citing the approach of McAllister and Ianelli 1997). The input CVs for abundance indices were not modified. This approach resulted in down-weighted length composition data relative to the abundance indices by reducing the sample size in the corresponding likelihood component for each length composition data source to match the effective sample size implied by the variation in residuals.

Iterative re-weighting for recruitment variability was described in the ATL Assessment Report Section 3.3.2. The initial value of the parameter representing the standard deviation in recruitment, σ_R, was input as a fixed value (0.4), and the final value was obtained by iteratively re-weighting σ_R (once) based on the RMSE of recruitment residuals determined from Stock Synthesis output. This approach resulted in a value of 0.62 for σ_R in the base assessment model (ATL Base Sel-2). See the ATL Assessment Report **Table 4.2.b** for a description of all model parameters in the base assessment model (ATL Base Sel-2).

1.3.6. Item 6. Review Initial Sample Size used in the Stock Assessment Model

The initial sample sizes used in the stock assessment model were described in the ATL Assessment Report Section 3.3.5. Initial annual sample sizes input in the assessment model for length composition data associated with surveys S1and S3 were the annual numbers of positive tows for each survey obtained from the working document submitted with the respective indices obtained from SEDAR 39-DW-24 (their Table 2) and SEDAR 39-DW-24 (their Table 6), respectively. The annual sample sizes input in the assessment model for the remainder of the length composition data sources were the numbers of sharks measured for length in each sample, obtained during the SEDAR 39 Data Workshop. The annual number of sharks measured for length for survey S2 was calculated based on sub-sampling expansion factors obtained from the working document submitted with the index for the same data source (SEDAR 39-WP-30). Annual length compositions were not included in the assessment from a data source if there were less than 30 sharks measured for length (either separately by sex, or for combined sex, depending upon which data were used in the assessment).

1.3.7. Item 7. Estimate Initial Fishing Mortality within the Stock Assessment Model

The effect of estimating initial fishing mortality within the stock assessment model was evaluated for the base assessment model (ATL Base Sel-2). Initial fishing mortality was estimated for fleets F3 (Com-TR) and F6 (Recreational), which had nonzero catch in the start year of the assessment model (1981). The ATL Assessment Report Sections 2 and 3 and **Tables 2.2 and 2.5** provide a description of the data sources associated with each catch time series. Initial fishing mortality rates were estimated by assuming an average historical catch in weight for fleets F3 and F6 during the years 1972-1980 equal to 99.3 mt and 123 mt, respectively (ATL Assessment Report **Table 2.2)**. The resulting values estimated for initial fishing mortality in Stock Synthesis (F3 = 0.01 and F6 = 0.02) were consistent with the continuous fishing mortality rates obtained for fleets F3 and F6 in subsequent years (**Figure 19**). Based on Akaike's information criterion (AIC; Akaike 1973; Burnham and Anderson 2002; e.g., Hilborn and Mangel 1997), there was some evidence for an improved fit to data for the model with estimated initial fishing mortality (AIC = 5630.58) relative to the base assessment model (ATL Base Sel-2, AIC = 5633.46; ATL Stock Assessment Report **Table 4.13**). However, the difference in AIC values was not substantial. Time series results for stock status also did not differ substantially between the model with estimated initial fishing mortality and the base assessment model (ATL Base Sel-2) (**Figure 20**).

1.3.8. Item 8. Provide Plots of the Spawning Potential Ratio (SPR)

Spawning potential ratio (SPR) plots are provided below with the results of model sensitivity runs conducted during the Review Workshop (RW Sensitivity Run 02).

1.3.9. Item 9. Compare Stock Biomass Trajectories Obtained from the Stock Assessment Model and from the Main Targeted Fishery

Stock biomass trajectories were compared from the base assessment model (ATL Base Sel-2) and the main targeted fishery during overlapping years 1995 – 2012 (**Figure 21**). The stock biomass trajectory obtained from the base assessment model (ATL Base Sel-2) was consistent with a period of high exploitation and stock depletion in the 1990s followed by a period of relatively lower exploitation and stock recovery in the recent 2000s (ATL Assessment Report **Figure 4.17**). In contrast, the standardized relative abundance index obtained for smooth dogfish caught during observed anchored sink gillnet trips resulted in an overall decreasing trend across the time series (years 1995 – 2012; SEDAR-DW-09, their Table 2 and Figure 3).

1.3.10. Item 10. Change L-min from Age-0 to Age 0.5 in the Stock Assessment Model

The effect of changing the minimum length (L_{Amin} cm FL) from the length at age-0 to the length at age-0.5 was evaluated with the base assessment model (ATL Base Sel-2). The minimum length in the base assessment model, L_{Amin}, was changed from the length at age-0 (Female 48.84 cm FL; Male 46.96 cm FL) to the length at age-0.5 (Female 57.25 cm FL; Male 56.35 cm FL). Time series results for stock status obtained for the base assessment model (ATL Base Sel-2) did not differ substantially from those modeled with the minimum length changed from the length at age-0 to the length at age-0.5 (**Figure 22**).

1.3.11. Item 11. Evaluate the Effect of Increasing and Decreasing Trends in Recent Relative Abundance

The effects of increasing and decreasing trends in relative abundance were evaluated by fitting one index of relative abundance at a time within the base assessment model (ATL Base Sel-2). Model results indicated that the assessment model was sensitive to fitting one index of relative abundance at a time. There were large changes in likelihood values for length and survey data because of the differences in the amount of data used in each model (**Figure 23**). However, there were only moderate changes in relative stock status (F/F_{MSY} and SFF/SSF$_{\text{MSY}}$) compared to both the base assessment model (ATL Base Sel-2) and to the bench marks (1.0) for both F/F_{MSY} and SFF/SSF$_{\text{MSY}}$ (**Figure 23**). Models fit to surveys S6 and S7 failed to converge (**Figure 23**).

1.4. MODEL SENSITIVITY RUNS

1.4.1. RW Sensitivity Run 01

Review Workshop, RW, Sensitivity Run 01 was developed by sequentially including a set of CIE RW recommended standard practices within the base assessment model (ATL Base Sel-2) (**Table 5**).

- **Run 1) R1 offset**. Estimate offset for initial equilibrium recruitment, log (R1), relative to virgin recruitment.

- **Run 2) Run 1 + Estimate initial *F* for fleets F3 and F6**. Initial fishing mortality was estimated for fleets F3 (Com-TR) and F6 (Recreational), which had nonzero catch in the start year of the assessment model (1981), analogously to Item 7 above.

- **Run 3) Run 2 + Change L-min from age-0 to age 0.5**. Change the minimum length, L_{Amin} cm FL, from the length at age-0 to the length at age-0.5, analogously to Item 10 above.

- **Run 4) Run 3 + Fix selectivity to parameter estimates, except fleet F1**. All selectivity parameters, except those for the main targeted fishery (Fleet F1), were fixed at their final values obtained from the base model (ATL Base Sel-2; ATL Stock Assessment Report **Tables 4.2.b** and **4.A.2** provide lists of the parameter values used).

- **Run 5) Run 4 + Estimate growth parameters Lmin and CV at Lmin and Lmax**. The following three growth parameters were estimated: The length at age-0 (L_{Amin} cm FL) and the coefficient of variation, CV, in mean length at age at both the minimum age (CV L_{Amin}) and the maximum age (CV L_{Amax}), analogously to Item 1 above.

- **Run 6) Run 5 + Down-weight S3 and S6 from Stock Synthesis estimate**. An examination of the likelihood component values (Item 4 above) identified a consistent pattern of relatively large likelihood values (poor fit) for surveys S3 and S6 in both the base model (ATL Base Sel-2) and the model sensitivities conducted for the base model (Sel-2). The ATL

Assessment Report Section 3.2 and **Tables 2.5 – 2.7** provide a description of the data sources for each index of relative abundance (surveys S1 – S8). The ATL Assessment Report Section 3.7 and **Table 4.13** provide a description of the model sensitivities associated with the base model (Sel-2). Consequently, the CVs assigned to the surveys S3 and S6 were iteratively re-weighted (once) to match the variation implied by the residuals from model Run 5, as obtained from Stock Synthesis output. This approach resulted in down-weighting the fit to surveys S3 and S6 in the model likelihood for Run 6 by increasing the CV in the corresponding likelihood component for each survey data source to match the CV implied by the variation in residuals from Run 5.

- **Run 7) Run 6 + Estimate early recruitment deviations (starting in year 1981 minus the age at 50% maturity).** Age at maturity may approximate the number of years that early recruitment deviations (recruitment prior to the start year of the assessment model) can be modeled in an assessment. Age at maturity was obtained from the ATL Assessment Report **Appendix 2.B** as 2.5 years for males, and 4.4 years for females. Consequently, early recruitment deviations were estimated for five years (1976 – 1980) prior to the start year of the assessment model.

- **Run 8) Run 7 + Down weight length comp by ¾ (i.e. multiply by ¼)**. Down-weight the length composition data within the stock assessment model by applying a weight of $\lambda = 1/4$ to all length composition data within the model, analogously to Item 2 above.

- **Run 9) Run 8 + Include estimated maximum bias adjustment in σ_R**. For Run 9, recruitment deviations were implemented with full bias adjustment applied during the years 1983 – 2010 and the maximum annual bias adjustment parameter (b_y; Methot and Taylor 2011) was set equal to 0.77, as obtained from Stock Synthesis output for model Run 8 with the program r4ss (Taylor et al 2014; e.g., see ATL Assessment Report Section 3.2).

Using the approach outlined above, the final model for RW Sensitivity Run 01 (i.e. Run 9) resulted in a better fit to the aggregate length composition data for the smallest and largest size bins of some data sources compared to the base model configuration (ATL Base Sel-2) (**Figures 24 – 26**). However, RW Sensitivity Run 01 also resulted in a worse fit to the aggregate length composition data for the smallest size bins of some data sources (i.e. fleet F2-female and male, survey S4-sexes combined, and survey S8-female and male) compared to the base model configuration (ATL Base Sel-2) (**Figures 24 – 26**).

1.4.2. RW Sensitivity Run 02

Review Workshop, RW, Sensitivity Run 02 was developed by sequentially including externally estimated growth parameters obtained from Item 1 above along with a subset of the CIE RW recommended standard practices within the base assessment model (ATL Base Sel-2) (**Table 6**).

- **Run 1) Estimate Lmin and the CV at Lmin and Lmax**. For Run 1, the estimated parameter values obtained for L_{Amin}, CV at L_{Amin}, and CV at L_{Amax} with model sensitivity MS-1 (External Selectivity) from Item 1 above (**Table 2**) were implemented in the base assessment model (ATL Base Sel-2) as fixed parameters.

- **Run 2) Run 1 + Down weight S3 and S6 based on CV from Stock Synthesis**. For Run 2, the CVs assigned to the surveys S3 and S6 were iteratively re-weighted (once) to match the variation implied by the residuals from model Run 1, as described above for RW Sensitivity Run 01.

- **Run 3) Run 2 + Estimate initial fishing mortality for fleets F3 and F6**. For Run 3, initial fishing mortality was estimated for fleets F3 (Com-TR) and F6 (Recreational), as described above for RW Sensitivity Run 01.

- **Run 4) Run 3 + Estimate early recruitment deviations estimated for 15 years**. For Runs 4 and 5, a two step process was used to determine the number of years with estimated early recruitment deviations. In the first step, (Run 4) early recruitment deviations were estimated within the model for an arbitrarily long number of years (in this case, 15 years). In the second step, the bias adjustment ramp for estimated recruitment deviations from model Run 4 was examined with the program r4ss (Taylor et al 2014; e.g., Methot and Taylor 2011). Maximum bias adjustment recommendations range from 0 – 1. Values near 0 indicate that there is very little information in the data to estimate recruitment deviations. An examination of the bias adjustment ramp for model Run 4 with the program r4ss (**Figure 27**) indicated that the information in the data to estimate early recruitment deviations dropped off quickly and was at about 50% of its maximum in year 1974 (i.e., seven years of estimated early recruitment deviations).

- **Run 5) Run 3 + Estimate early recruitment deviations for 7 years (years 1974 – 1980)**. For Run 5, early recruitment deviations were estimated for 7 years (years 1974 – 1980), based on information in the data obtained from Run 4, as described above.

Using the approach outlined above, the final model for RW Sensitivity Run 02 (i.e. Run 5) resulted in a better fit to the aggregate length composition data for the smallest and largest size bins of some data sources compared to the base model configuration (ATL Base Sel-2) (**Figures 28 – 30**). However, the model for RW Sensitivity Run 02 also resulted in a worse fit to the aggregate length composition data for the smallest size bins of some data sources (i.e. fleet F2-female and male, survey S4-sexes combined, and survey S8-female and male) compared to the base model configuration (ATL Base Sel-2) (**Figures 28 – 30**).

At the request of the CIE Review Panel, the spawning-potential ratio (SPR) was provided from Stock Synthesis output for both the base model configuration (ATL Base Sel-2) and the RW Sensitivity Run 02 (**Figure 31**). In Stock Synthesis, the spawning-potential ratio, SPR (Goodyear 1993), is defined as the equilibrium level of spawning biomass-per-recruit that would occur with the current year's level of fishing intensity relative to the unfished level of spawning biomass-per-recruit (Methot and Wetzel 2013). A difference in the current assessment model is that SPR is defined in terms of spawning stock fecundity-per-recruit rather than spawning biomass-per-recruit. In Stock Synthesis the SPR metric is reported as one minus SPR (1 – SPR) to create a metric that increases as fishing intensity increases (Methot and Wetzel 2013).

For comparison to annual fishing mortality (*F*) relative to F_{MSY} (e.g., see the SEDAR 39 Atlantic smooth dogfish Stock Assessment Report **Figure 4.17)**, the 1 – SPR metric was reported here relative to 1 – SPR_{MSY} (**Figure 31**), where SPR_{MSY} obtained from the base model configuration (ATL Base Sel-2) and the RW Sensitivity Run 02 was 0.46 and 0.47, respectively. The 1-SPR metric obtained from the RW Sensitivity Run 02 in the final assessment year (2012) was within the approximate 95% confidence intervals obtained for the 1-SPR metric with the base model configuration (ATL Base Sel-2), based on the asymptotic standard errors obtained for (1 – SPR)/(1 – SPR_{MSY}) from Stock Synthesis (**Figure 31**).

1.5. SUMMARY OF PROJECTION MODEL RESULTS

A summary of projection model results for the base model configuration (ATL Base Sel-2) and model sensitivities associated with the base model configuration (Sel-2) was provided during the CIE RW (**Table 7**). Projection results provide examples of a given fixed level of total annual removals due to fishing (1,000s of sharks) during the years (2013 – 2022) which resulted in the $Pr(SSF_t > SSF_{MSY}) \geq 70\%$ in the year 2022 from 10,000 Monte Carlo projections (**Table 7**). Projection methods and results for the base model configuration (ATL Base Sel-2) were provided in the RW document SEDAR39-RW-01. The ATL Assessment Report Section 3.7 and **Table 4.13** provide a description of the model sensitivities associated with the base model configuration (Sel-2), which were used for projections: MS-9 Start Year 1972 (Sel-2), MS-10 Ranked CPUE (Sel-2), MS-11 Low Catch (Sel-2), MS-12 High Catch (Sel-2), MS-13 Low Productivity (Sel-2), MS-14 High Productivity (Sel-2), and MS-15 Hierarchical (Sel-2).

1.6. REFERENCES

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1.7. TABLES

Table 1 (Corrections for the ATL Assessment Report **Table 4.13;** Highlighted in yellow**)**. Summary of model results for the proposed base configuration under Sel-2 and seven model sensitivities conducted under the same model configuration as Sel-2 (dome-shaped functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept)). Parameters are the MSY (mt) obtained directly from Stock Synthesis as the equilibrium yield at F_{MSY}, spawning stock fecundity, SSF (1,000s), recruits, R (1,000s), and aggregate annual fishing mortality, F, calculated as overall exploitation rate in numbers. Model sensitivities (MS) are described above and defined here as follows: MS-9 Start Year 1972 (Sel-2), MS-10 Ranked CPUE (Sel-2), MS-11 Low Catch (Sel-2), MS-12 High Catch (Sel-2), MS-13 Low Productivity (Sel-2), MS-14 High Productivity (Sel-2), and MS-15 Hierarchical (Sel-2). Values are also provided for the Akaike information criteria (AIC), total objective function, final gradient, 1 - average natural mortality at age ($1-\bar{M}_a$), MSST = $(1-\bar{M}_a)\times \mathrm{SSF}_{\mathrm{MSY}}$, and stock-recruitment steepness for each model. AIC values are not comparable among models with different data inputs.

	Proposed Base (Sel-2)		MS-9		MS-10		MS-11		MS-12		MS-13		MS-14		MS-15	
AIC	5633.5		5918.4		5559.5		5654.1		5634.5		5651.6		5632.7		1654.5	
Parameters	52		62		52		52		52		52		52		43	
Objective function	2764.7		2897.2		2727.7		2775.1		2765.3		2773.8		2764.3		784.2	
Gradient	**8.91E-05**		3.68E-05		4.06E-05		4.07E-05		4.34E-05		1.46E-05		2.59E-04		8.06E-06	
$(1-\bar{M}_a)$	0.78		0.78		0.78		0.78		0.78		0.74		0.80		0.78	
Steepness	0.54		0.54		0.54		0.54		0.54		**0.49**		**0.62**		**0.54**	
MSST	3,701		3,311		3,866		3,103		4,595		4,169		3,062		3,557	
	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV
SSF_{2012}	10,847	18%	8,329	16%	12,283	18%	9,380	19%	13,081	17%	14,115	23%	7,490	14%	12,809	37%
F_{2012}	0.102	---	0.126	---	0.093	---	0.092	---	0.104	---	0.071	---	0.145	---	0.101	---
R_{2012}	2,213	11%	1,896	9%	2,360	11%	1,876	12%	2,720	10%	3,293	16%	1,405	7%	2,235	22%
SSF_0	14,849	8%	12,793	7%	15,506	9%	12,503	9%	18,383	8%	16,538	13%	12,893	5%	14,245	17%
R_0	2,385	8%	2,135	7%	2,491	9%	2,008	9%	2,953	8%	3,440	13%	1,560	5%	2,288	18%
MSY	1,125	8%	1,011	6%	1,173	9%	966	9%	1,371	8%	1,363	13%	1,065	4%	1,071	18%
$\mathrm{SSF}_{\mathrm{MSY}}$	4,746	8%	4,245	7%	4,958	9%	3,979	9%	5,892	8%	5,634	13%	3,827	5%	4,560	18%
$\mathrm{F}_{\mathrm{MSY}}$	0.129	2%	0.127	2%	0.130	2%	0.120	2%	0.136	2%	0.116	2%	0.156	2%	0.133	3%
$\mathrm{SSF}_{2012}/\mathrm{SSF}_{\mathrm{MSY}}$	2.286	---	1.962	---	2.478	---	2.358	---	2.220	---	2.505	---	1.957	---	2.809	---
$\mathrm{F}_{2012}/\mathrm{F}_{\mathrm{MSY}}$	0.792	16%	0.992	14%	0.716	17%	0.765	17%	0.762	16%	0.614	21%	0.930	12%	0.760	34%
Stock status	$\mathrm{SSF}_{2012} > \mathrm{SSF}_{\mathrm{MSY}}$		$\mathrm{SSF}_{2012} > \mathrm{SSF}_{\mathrm{MSY}}$		$\mathrm{SSF}_{2012} > \mathrm{SSF}_{\mathrm{MSY}}$		$\mathrm{SSF}_{2012} > \mathrm{SSF}_{\mathrm{MSY}}$		$\mathrm{SSF}_{2012} > \mathrm{SSF}_{\mathrm{MSY}}$		$\mathrm{SSF}_{2012} > \mathrm{SSF}_{\mathrm{MSY}}$		$\mathrm{SSF}_{2012} > \mathrm{SSF}_{\mathrm{MSY}}$		$\mathrm{SSF}_{2012} > \mathrm{SSF}_{\mathrm{MSY}}$	
Fishery status	$\mathrm{F}_{2012} < \mathrm{F}_{\mathrm{MSY}}$		$\mathrm{F}_{2012} \approx \mathrm{F}_{\mathrm{MSY}}$*		$\mathrm{F}_{2012} < \mathrm{F}_{\mathrm{MSY}}$		$\mathrm{F}_{2012} < \mathrm{F}_{\mathrm{MSY}}$		$\mathrm{F}_{2012} < \mathrm{F}_{\mathrm{MSY}}$		$\mathrm{F}_{2012} < \mathrm{F}_{\mathrm{MSY}}$		$\mathrm{F}_{2012} < \mathrm{F}_{\mathrm{MSY}}$		$\mathrm{F}_{2012} < \mathrm{F}_{\mathrm{MSY}}$	

*Either $F_{2012} < F_{\mathrm{MSY}}$ or $F_{2012} = F_{\mathrm{MSY}}$, depending upon how rounding is calculated.

Table 2. *Item 1.*—Growth parameters for length at age-0 (L_{Amin} cm FL) and the coefficient of variation (CV) in mean length at age at both the minimum age (CV L_{Amin}) and the maximum age (CV L_{Amax}), along with asymptotic standard errors (S.E.), obtained from MS-1 (External Selectivity) modeled with estimated growth parameters. For comparison, the fixed growth parameters from the base model configuration (ATL Base Sel-2) and MS-1 (External Selectivity) are also provided.

	ATL Base Sel-2	MS-1 (External Selectivity)	MS-1 (External Selectivity) modeled here with estimated growth parameters	
Growth parameters	Fixed	Fixed	Estimated	S.E.
Female				
L_{Amin} (cm FL)	48.84	48.84	35.02	0.743
CV L_{Amin}	0.15	0.15	0.22	0.015
CV L_{Amax}	0.12	0.12	0.02	0.006
Male				
L_{Amin} (cm FL)	46.96	46.96	31.39	0.677
CV L_{Amin}	0.15	0.15	0.19	0.011
CV L_{Amax}	0.12	0.12	0.04	0.004

Table 3. *Item 4.*—Likelihood component values for fits to each index of relative abundance (surveys S1 – S8) for the base assessment model (ATL Base Sel-2) and for the model sensitivities associated with the base model configuration (Sel-2). The ATL Assessment Report Section 3.7 and **Table 4.13** provide a description of the model sensitivities associated with the base model configuration (Sel-2), which are defined as follows: MS-9 Start Year 1972 (Sel-2), MS-10 Ranked CPUE (Sel-2), MS-11 Low Catch (Sel-2), MS-12 High Catch (Sel-2), MS-13 Low Productivity (Sel-2), MS-14 High Productivity (Sel-2), and MS-15 Hierarchical (Sel-2). The ATL Assessment Report Section 3.2 and **Tables 2.5** and **2.6** provide a description of the data sources for each index of relative abundance (surveys S1 – S8). Likelihood component values were also provided for the results of model sensitivity runs conducted during the Review Workshop (RW Sensitivity Run 01 and RW Sensitivity Run 02), as described in the text of this addendum.

Model run	S1	S2	S3	S4	S5	S6	S7	S8
ATL Base (Sel-2)	2.40	-0.53	88.45	8.88	3.99	35.19	-1.49	15.74
RW Sensitivity Run 02	0.31	-0.14	16.04	17.32	1.01	7.53	0.80	17.57
RW Sensitivity Run 01	-5.07	-2.43	14.71	8.83	-2.61	7.37	-2.95	16.45
MS-9 Start Year 1972 (Sel-2)	5.21	-0.70	111.11	16.72	3.57	48.04	-2.08	15.75
MS-10 Ranked CPUE (Sel-2)	-4.95	-0.58	75.24	7.92	1.48	26.89	-1.46	9.20
MS-11 Low Catch (Sel-2)	2.41	-0.63	89.11	8.98	4.73	35.04	-1.29	15.75
MS-12 High Catch (Sel-2)	2.63	-0.23	88.63	8.51	3.15	34.94	-1.99	15.75
MS-13 Low Productivity (Sel-2)	0.68	0.02	84.76	7.80	2.10	35.48	-1.83	15.99
MS-14 High Productivity (Sel-2)	6.46	-0.87	93.03	9.91	5.86	34.80	-0.93	15.89
MS-15 Hierarchical (Sel-2)	-21.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4. *Item 4. Continued*—Likelihood component values for fits to length composition data sources associated with each fleet (F1 – F6; upper panel) and index of relative abundance (surveys S1 – S8; lower panel) for the base assessment model (ATL Base Sel-2) and for the model sensitivities associated with the base model configuration (Sel-2). The ATL Assessment Report Section 3.7 and **Table 4.13** provide a description of the model sensitivities associated with the base model configuration (Sel-2), which are defined as follows: MS-9 Start Year 1972 (Sel-2), MS-10 Ranked CPUE (Sel-2), MS-11 Low Catch (Sel-2), MS-12 High Catch (Sel-2), MS-13 Low Productivity (Sel-2), MS-14 High Productivity (Sel-2), and MS-15 Hierarchical (Sel-2). The ATL Assessment Report Section 3.2 and **Tables 2.3 - 2.5** provide a description of the length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8). Likelihood component values were also provided for the results of model sensitivity runs conducted during the Review Workshop (RW Sensitivity Run 01 and RW Sensitivity Run 02), as described in the text of this addendum.

Fleets (F1 – F6)

Model run	F1	F2	F3	F4	F5	F6
ATL Base (Sel-2)	179.78	78.97	261.53	10.17	0.00	236.19
RW Sensitivity Run 02	178.51	81.05	192.01	9.63	0.00	189.26
RW Sensitivity Run 01	47.76	18.05	44.15	2.30	0.00	50.85
MS-9 Start Year 1972 (Sel-2)	174.59	80.12	259.59	10.29	0.00	236.14
MS-10 Ranked CPUE (Sel-2)	177.64	79.42	259.37	10.21	0.00	236.18
MS-11 Low Catch (Sel-2)	176.90	79.89	263.44	10.24	0.00	236.73
MS-12 High Catch (Sel-2)	177.03	79.92	261.64	10.22	0.00	236.35
MS-13 Low Productivity (Sel-2)	178.70	80.81	258.86	10.94	0.00	233.74
MS-14 High Productivity (Sel-2)	172.93	79.09	268.07	9.58	0.00	238.50
MS-15 Hierarchical (Sel-2)	177.93	83.30	289.02	10.10	0.00	237.34

Surveys (S1 – S8)

Model run	S1	S2	S3	S4	S5	S6	S7	S8
ATL Base (Sel-2)	467.43	61.83	432.71	27.61	195.48	116.97	389.35	150.29
RW Sensitivity Run 02	411.51	65.34	358.59	27.59	139.96	70.71	207.36	165.98
RW Sensitivity Run 01	108.13	14.77	85.73	6.35	35.97	17.10	57.39	41.98
MS-9 Start Year 1972 (Sel-2)	520.95	61.91	450.59	27.58	200.15	123.84	400.19	149.23
MS-10 Ranked CPUE (Sel-2)	468.65	61.80	432.22	27.56	194.94	117.44	393.01	151.17
MS-11 Low Catch (Sel-2)	465.16	61.87	434.80	27.57	197.92	117.43	394.72	149.72
MS-12 High Catch (Sel-2)	464.03	61.90	432.72	27.58	198.19	116.69	394.29	149.86
MS-13 Low Productivity (Sel-2)	480.85	61.89	433.45	27.33	202.36	114.22	392.68	149.86
MS-14 High Productivity (Sel-2)	451.07	62.03	434.13	22.85	193.83	120.95	393.04	150.03
MS-15 Hierarchical (Sel-2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5. *RW Sensitivity Run 01.*—Review Workshop (RW) Sensitivity Run 01 was developed by sequentially including the following set of CIE RW recommended standard practices within the base assessment model (ATL Base Sel-2).

- Run 1) R1 offset *
- Run 2) Run 1 + Estimate initial *F* for fleets F3 and F6
- Run 3) Run 2 + Change L-min from age-0 to age 0.5
- Run 4) Run 3 + Fix selectivity to parameter estimates, except fleet F1
- Run 5) Run 4 + Estimate growth parameters Lmin and CV at Lmin and Lmax
- Run 6) Run 5 + Down-weight S3 and S6 from Stock Synthesis estimate
- Run 7) Run 6 + Estimate early rec devs (starting in 1981 – age at 50% maturity)
- Run 8) Run 7 + Down weight length comp by ¾ (i.e. multiply by ¼)
- Run 9) Run 8 + Include estimated maximum bias adjustment in σ_R

*The model runs implemented here were not considered "standard practice" by all CIE Review Panelists, and may be better described as "common practices".

Table 6. *RW Sensitivity Run 02.*—Review Workshop (RW) Sensitivity Run 02 was developed by sequentially including estimated growth parameters (obtained from item 1 above) and a subset of the CIE RW recommended standard practices within the base assessment model (ATL Base Sel-2).

- Run 1) Estimate Lmin and the CV at Lmin and Lmax (Obtained from Item 1 above)
- Run 2) Run 1 + Down-weight S3 and S6 based on CV from Stock Synthesis
- Run 3) Run 2 + Estimate initial fishing mortality for fleets F3 and F6
- Run 4) Run 3 + Estimate early rec devs for 15 years
- Run 5) Run 3 + Estimate early rec devs for 7 years

Table 7. *Summary of Projection Model Results.*—A summary of projection model results for the base model configuration (ATL Base Sel-2) and model sensitivities associated with the base model configuration (Sel-2) was provided during the CIE RW. Projection results provide examples of a given fixed level of total annual removals due to fishing (1,000s of sharks) during the years (2013 – 2022) which resulted in the Pr($SSF_t > SSF_{MSY}$) ≥ 70% in the year 2022 from 10,000 Monte Carlo projections. Projection methods and results for the base model configuration (ATL Base Sel-2) were provided in the RW document SEDAR39-RW-01. The ATL Assessment Report Section 3.7 and **Table 4.13** provide a description of the model sensitivities associated with the base model configuration (Sel-2), which were used for projections: MS-9 Start Year 1972 (Sel-2), MS-10 Ranked CPUE (Sel-2), MS-11 Low Catch (Sel-2), MS-12 High Catch (Sel-2), MS-13 Low Productivity (Sel-2), MS-14 High Productivity (Sel-2), and MS-15 Hierarchical (Sel-2).

Projection scenario	Model configuration	Example of fixed removals (1000s)
1	Base Model Configuration (Sel-2)	550
2	MS-9 Start Year 1972 (Sel-2)	350
3	MS-10 Ranked CPUE (Sel-2)	650
4	MS-11 Low Catch (Sel-2)	450
5	MS-12 High Catch (Sel-2)	650
6	MS-13 Low Productivity (Sel-2)	850
7	MS-14 High Productivity (Sel-2)	350
8	MS-15 Hierarchical (Sel-2)	500

1.8. FIGURES

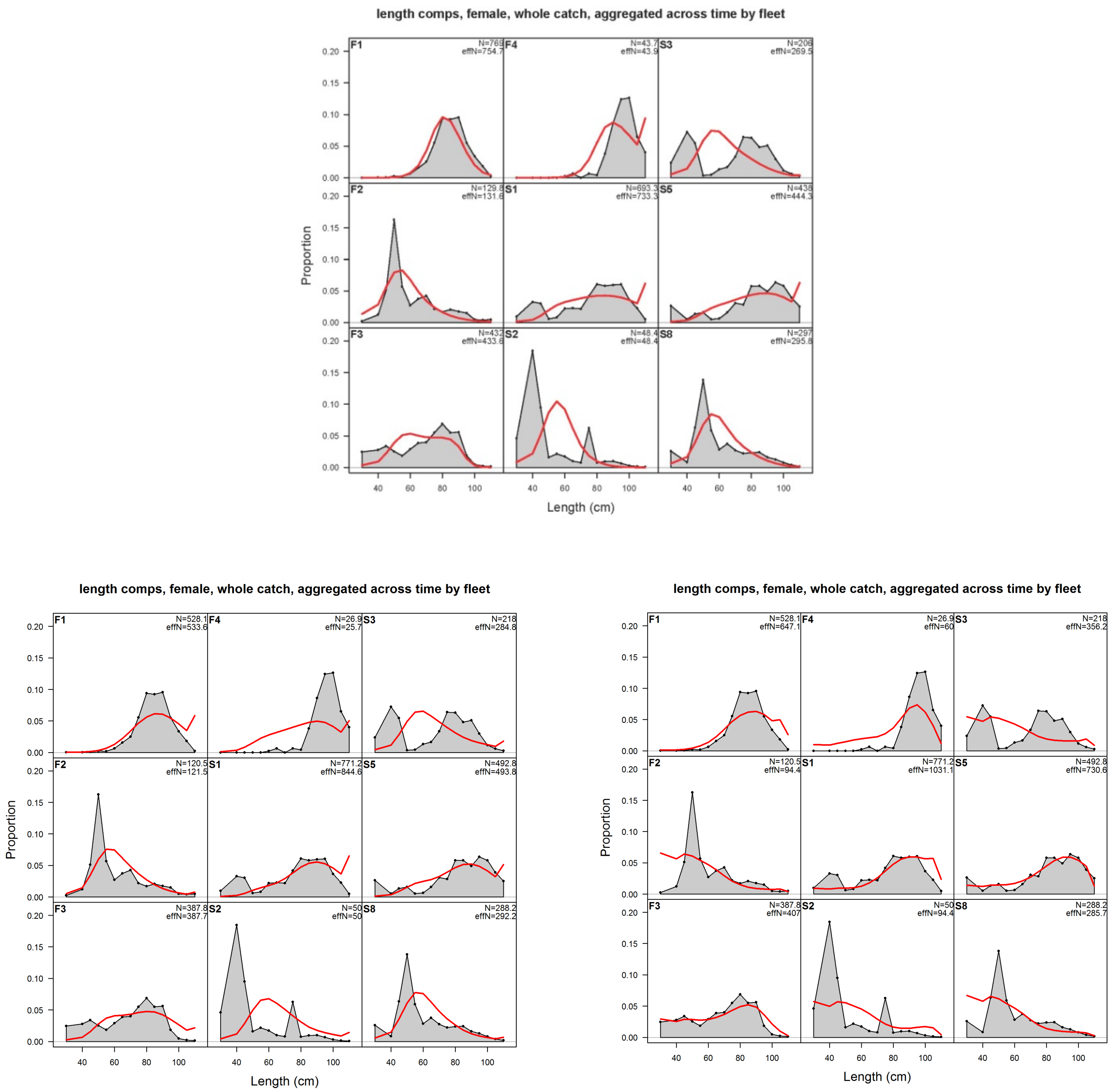


Figure 1. *Item 1*.—Model fits to aggregate female length composition data for the base assessment model (ATL Base Sel-2; upper panels; ATL Stock Assessment Report **Figures 4.9 – 4.11**), model sensitivity MS-1 (External Selectivity; lower left panels; see the ATL Assessment Report **Table 4.12**), and MS-1 (External Selectivity) modeled here with estimated growth parameters (lower right panels). See the ATL Assessment Report Section 3.2 and **Tables 2.3 - 2.5** for a description of the length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8).

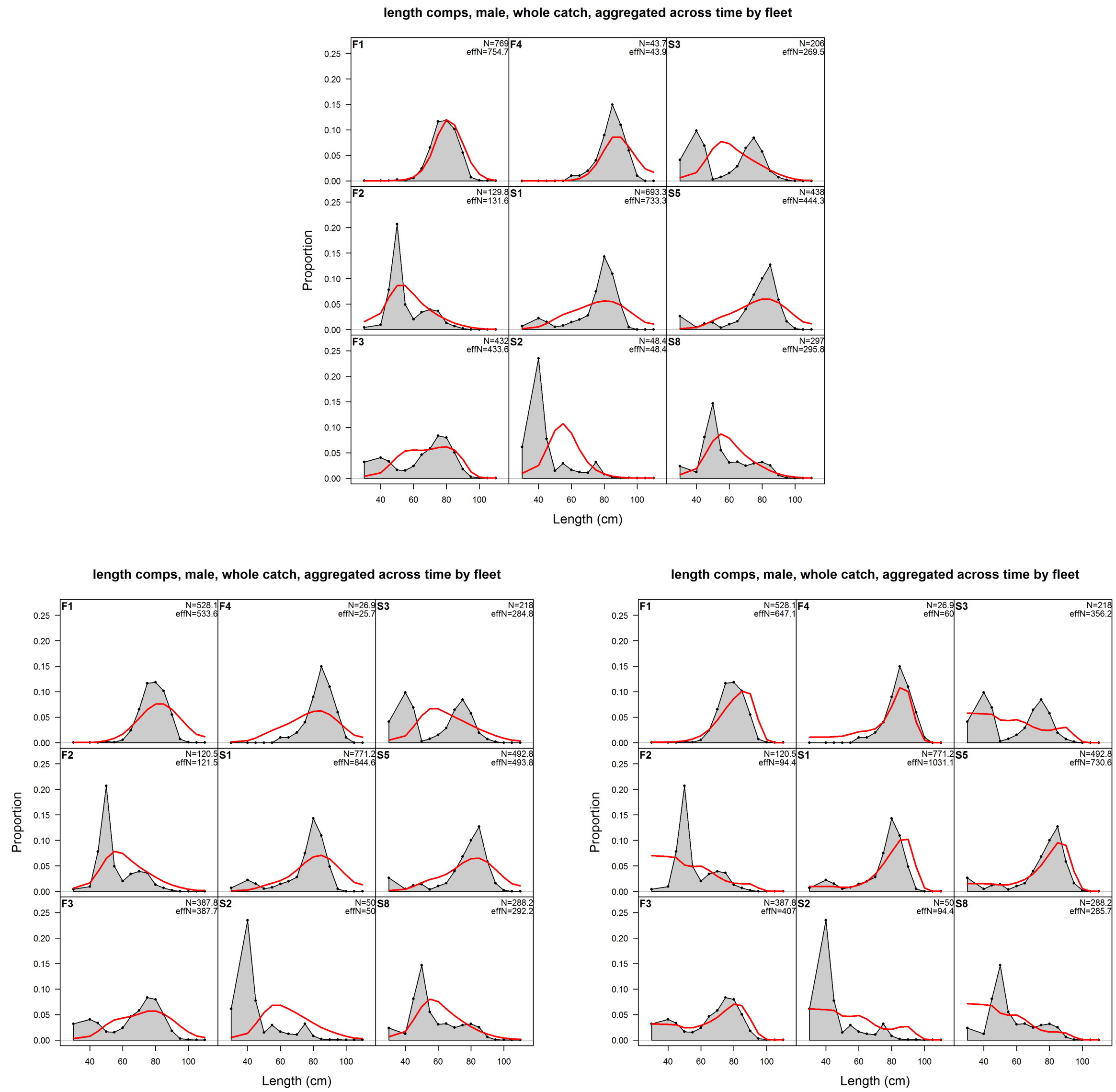


Figure 2. *Item 1. Continued.*—Model fits to aggregate male length composition data for the base assessment model (ATL Base Sel-2; upper panels), MS-1 (lower left panels), and MS-1 modeled here with estimated growth parameters (lower right panels).

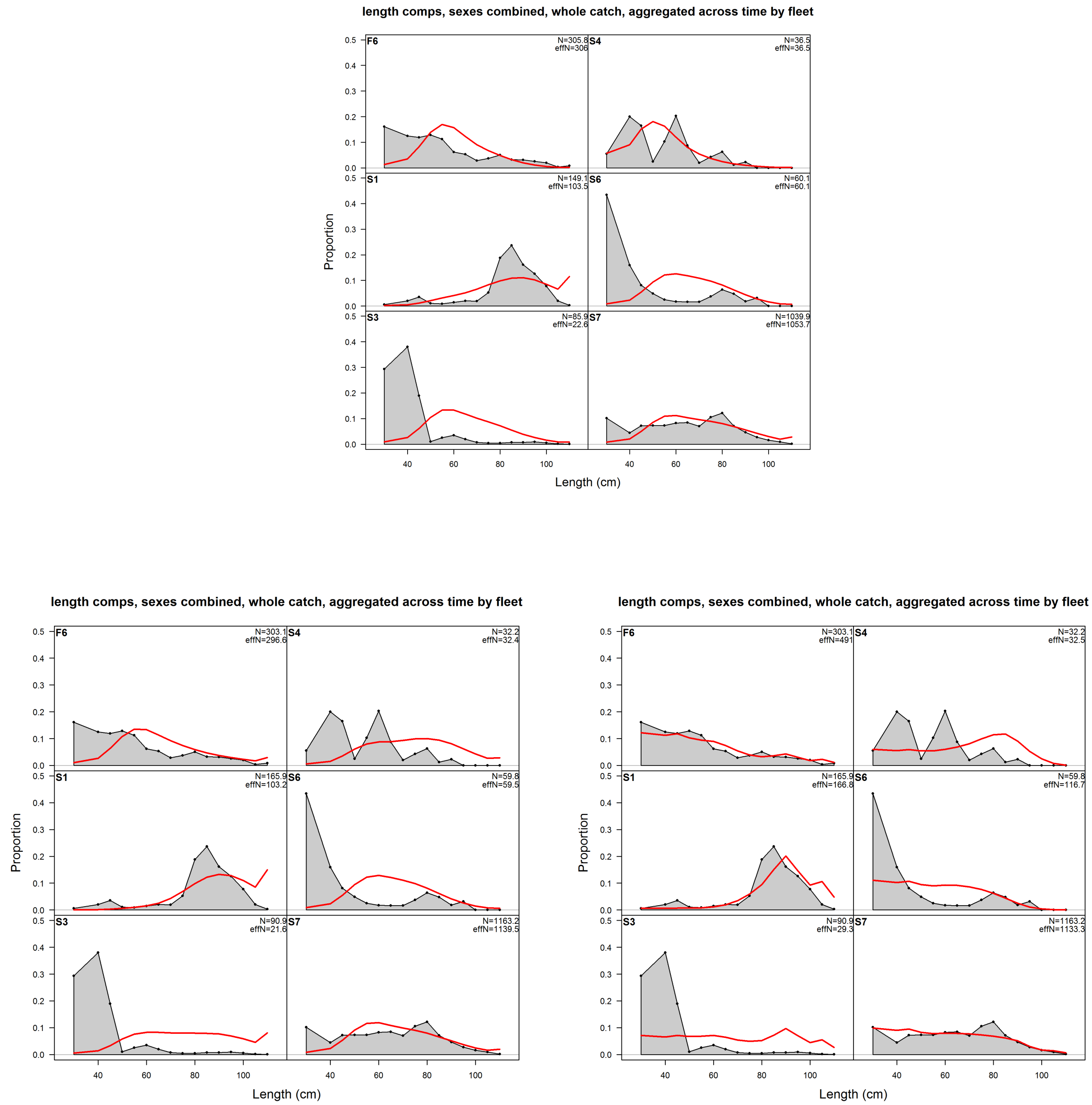
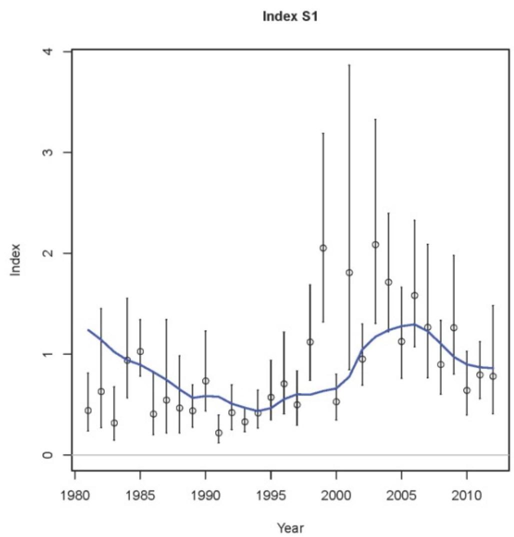


Figure 3. *Item 1. Continued.*—Model fits to aggregate combined sex (or unknown sex) length composition data for the base assessment model (ATL Base Sel-2; upper panels), MS-1 (lower left panels), and MS-1 modeled here with estimated growth parameters (lower right panels).



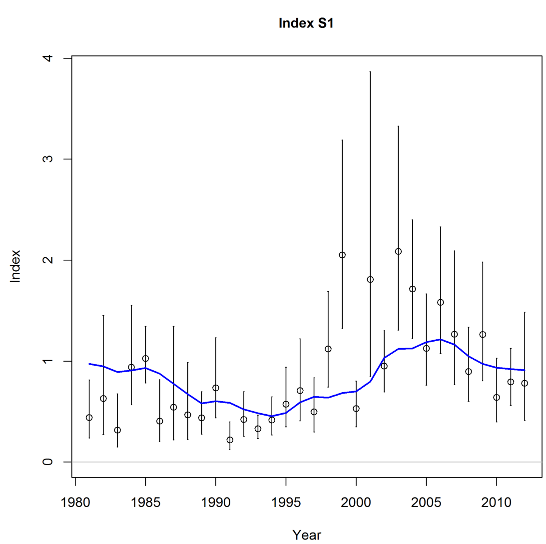
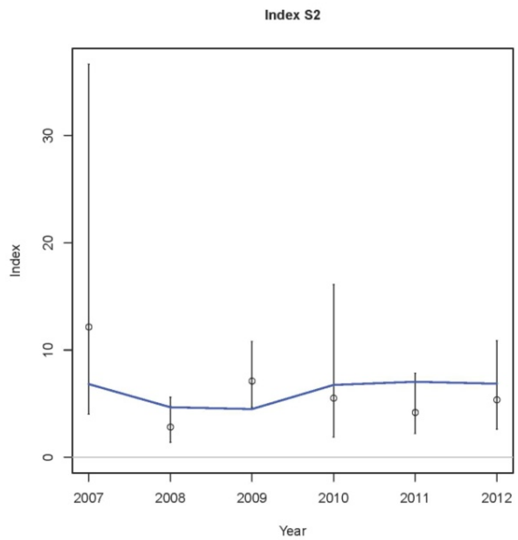


Figure 4. *Item 2.*—Model fits (blue line) to standardized indices of relative abundance (open circles with 95% confidence intervals assuming lognormal error) for the base assessment model (ATL Base Sel-2; upper panel; ATL Assessment Report **Figure 4.6**), and the base model configuration modeled here with length composition data down weighted by 3/4 (λ=1/4; lower panel). See the ATL Assessment Report Section 3.2 and **Tables 2.5** – **2.7** for a description of the data sources for each index of relative abundance (surveys S1 – S8).



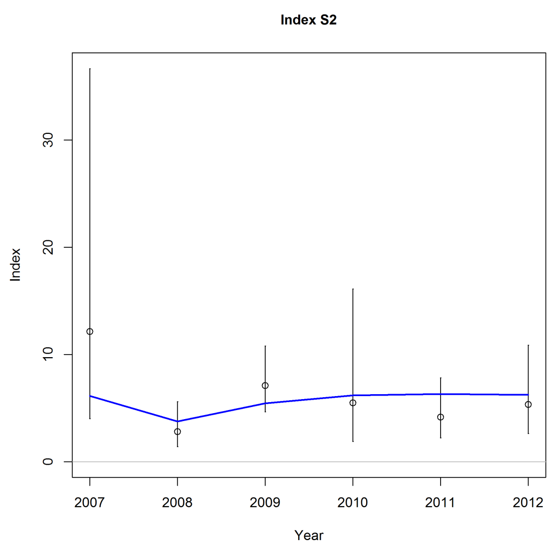
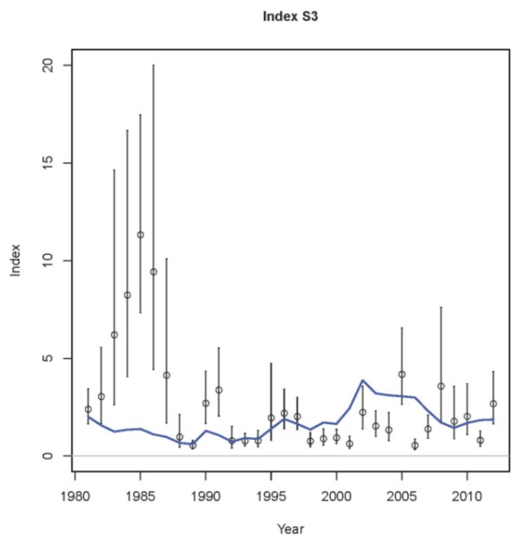


Figure 5. *Item 2. Continued—.*



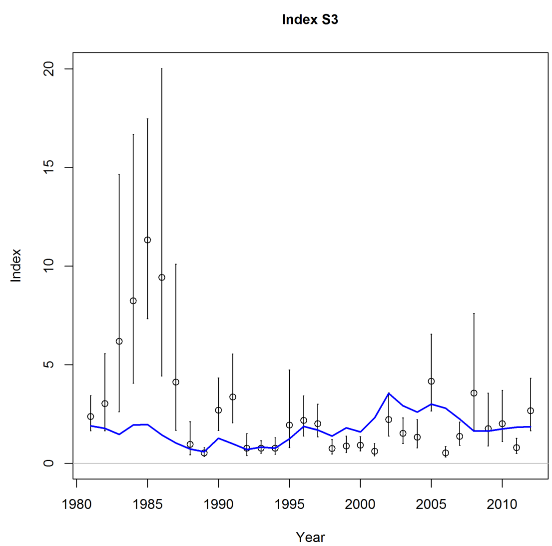
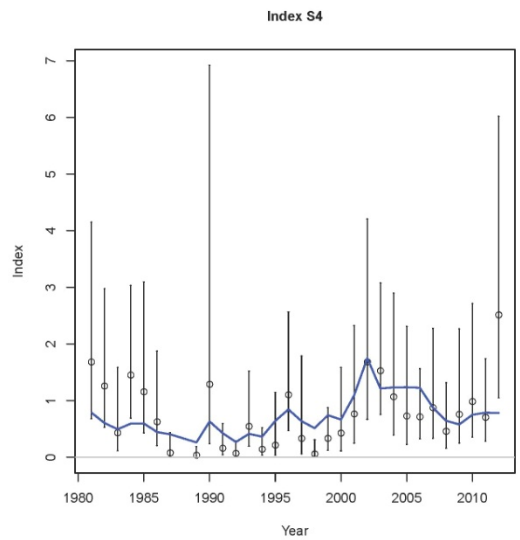


Figure 6. *Item 2. Continued—.*



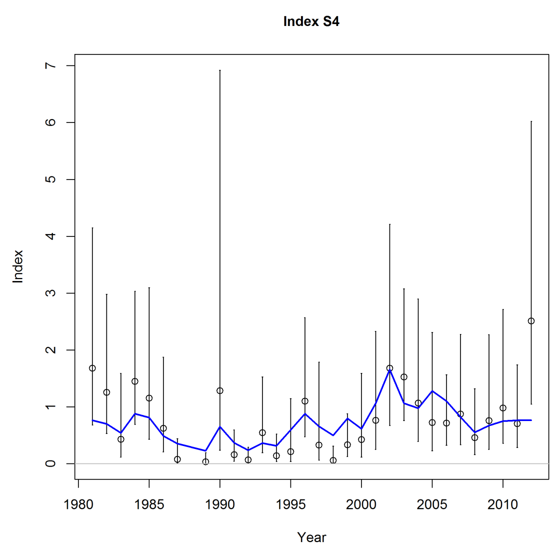
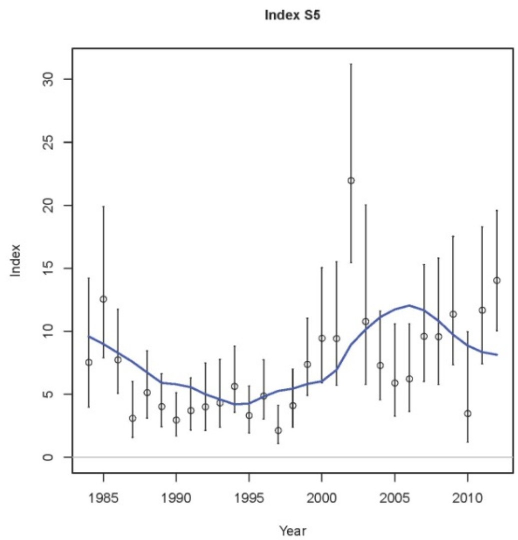


Figure 7. *Item 2. Continued—.*



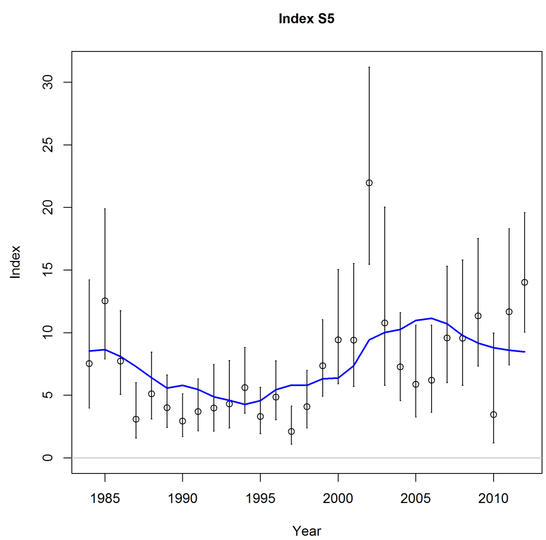
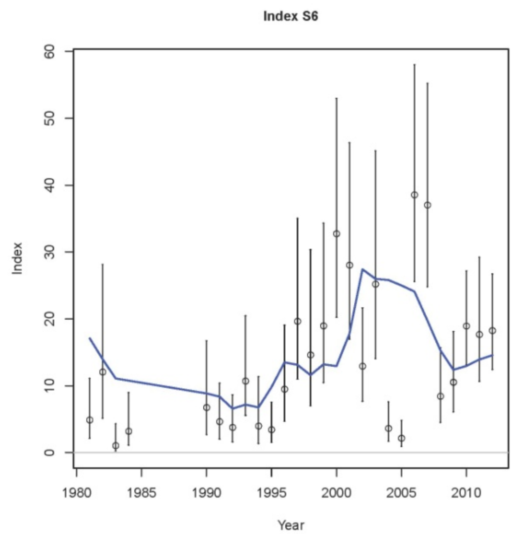


Figure 8. *Item 2. Continued—.*



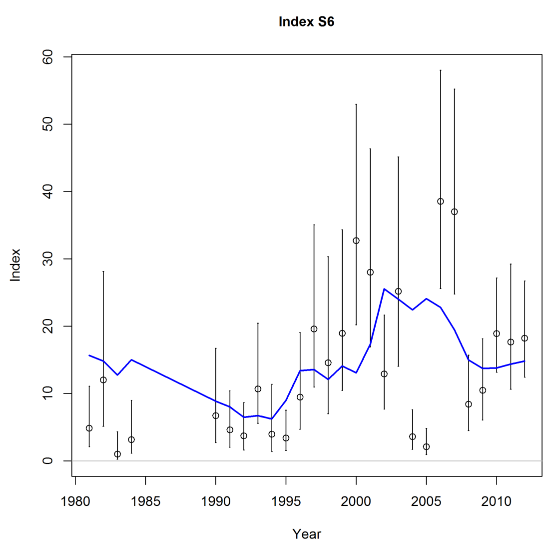
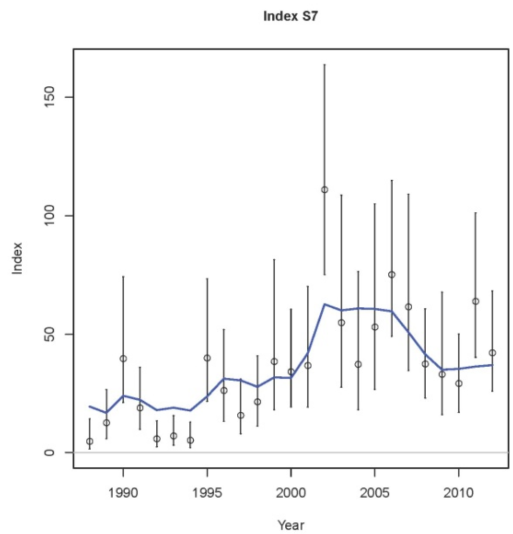


Figure 9. *Item 2. Continued—.*



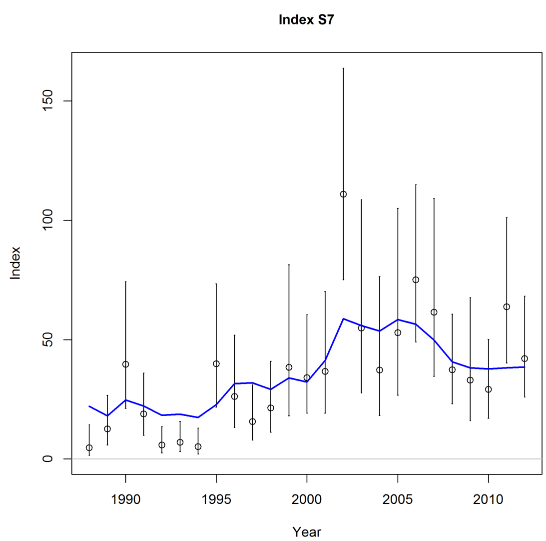
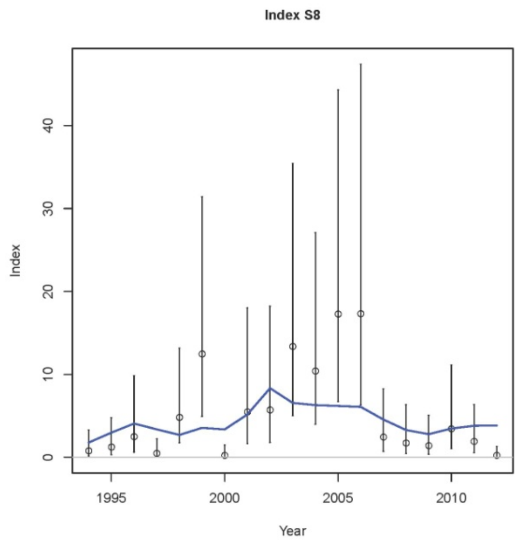


Figure 10. *Item 2. Continued—.*



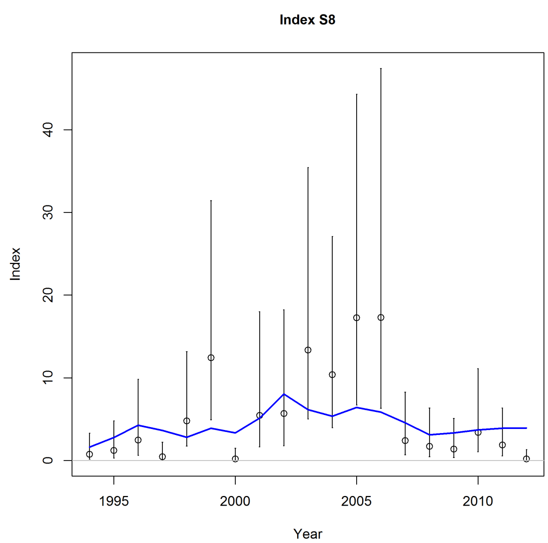


Figure 11. *Item 2. Continued—.*

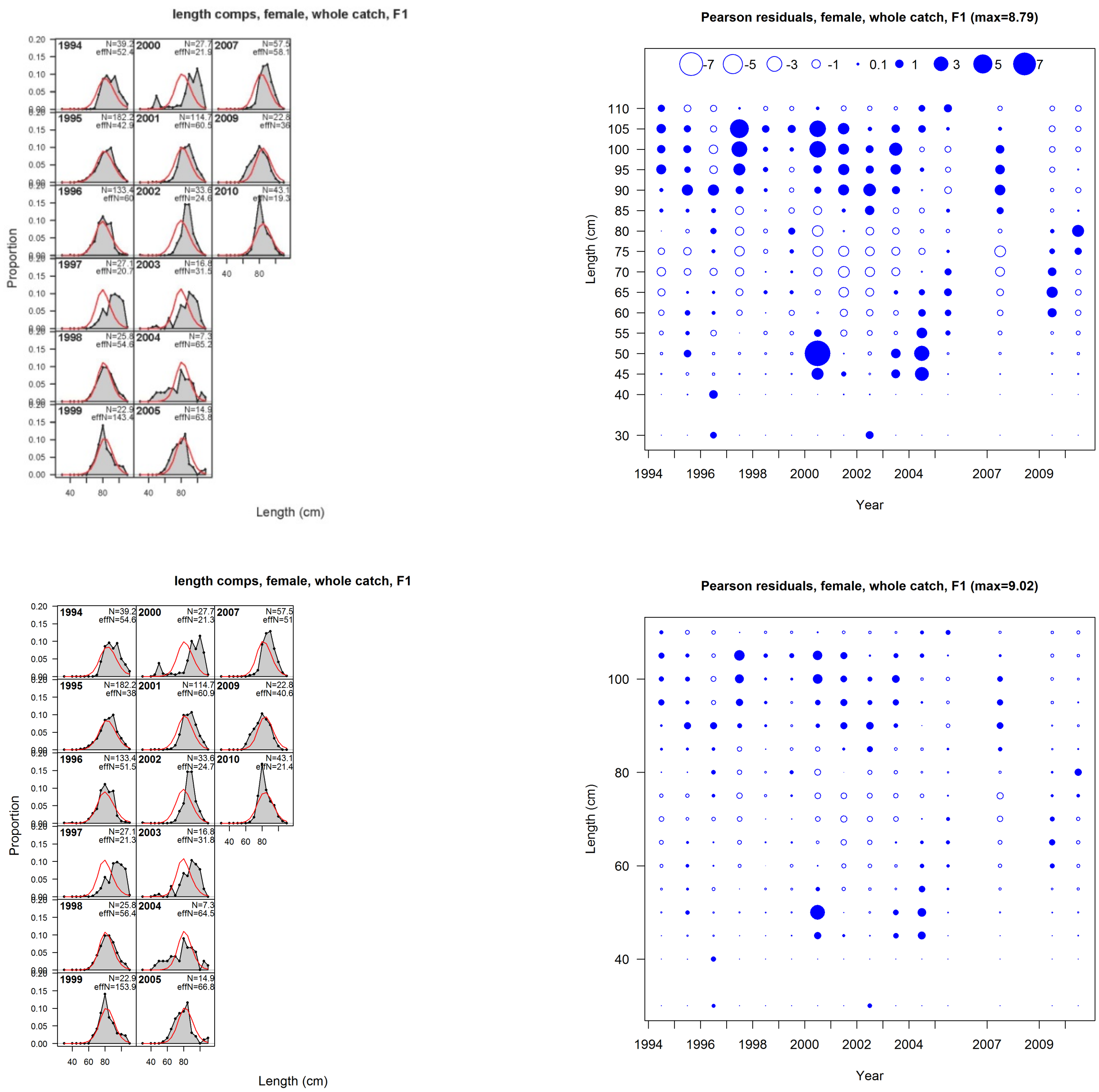


Figure 12. *Item 2. Continued*— Observed and model predicted female annual length compositions for the main targeted fishery (fleet F1 – NE Gillnet Kept) for the base assessment model (ATL Base Sel-2; upper panels; ATL Assessment Report **Figure 4.7**), and the base model configuration modeled here with length composition data down weighted by 3/4 (λ=1/4; lower panels). Length compositions shown start in 1994 (upper left graph) and continue to 2010. Diameter of Pearson residuals (circles) indicates relative error; predicted < observed (solid), predicted > observed (transparent). The maximum diameter width of the plot for Pearson residuals changed between ATL Base Sel-2 (Max = 8.79; upper right panel) and the model with λ=1/4 (Max = 9.02; lower right panel).

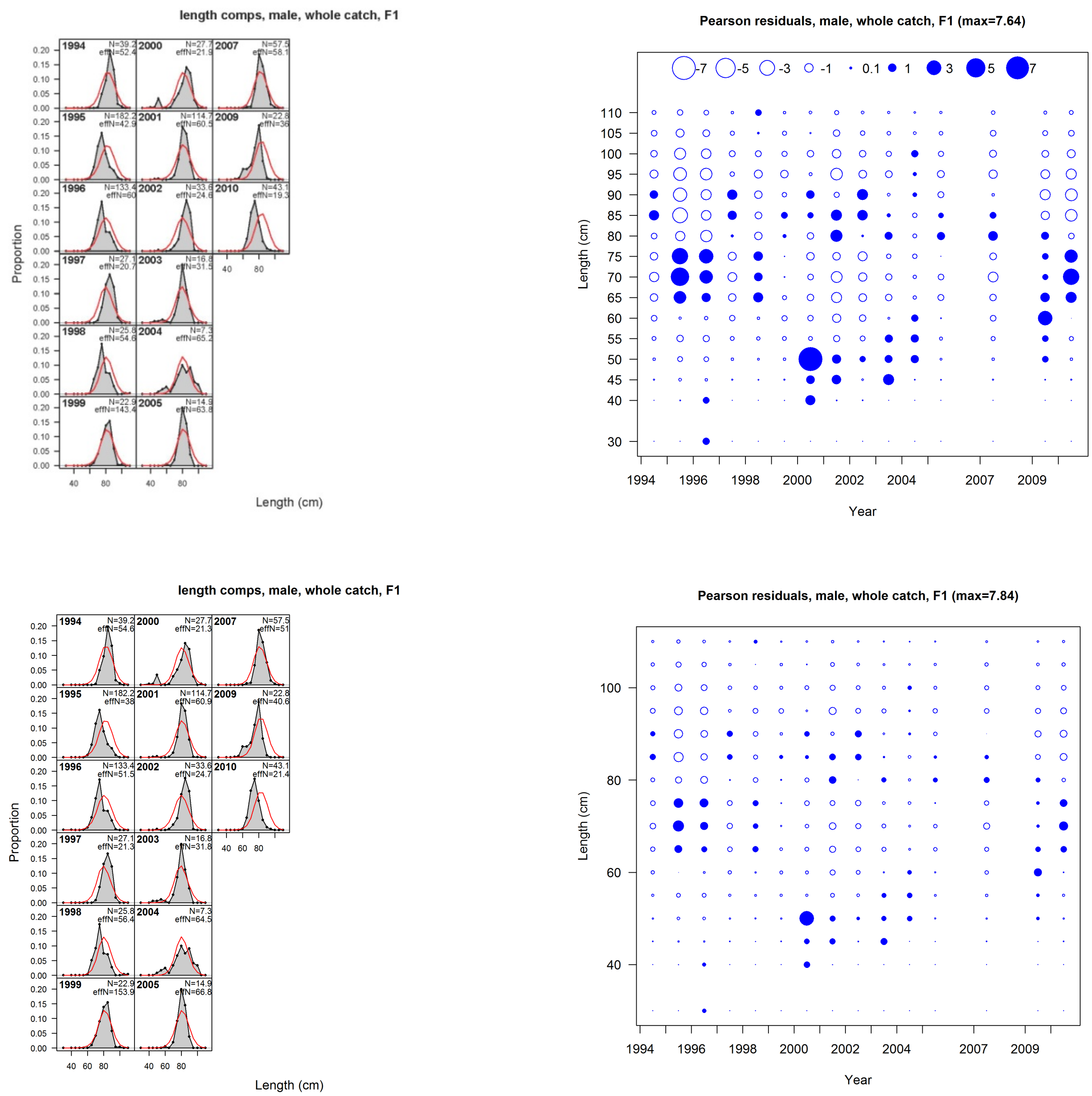
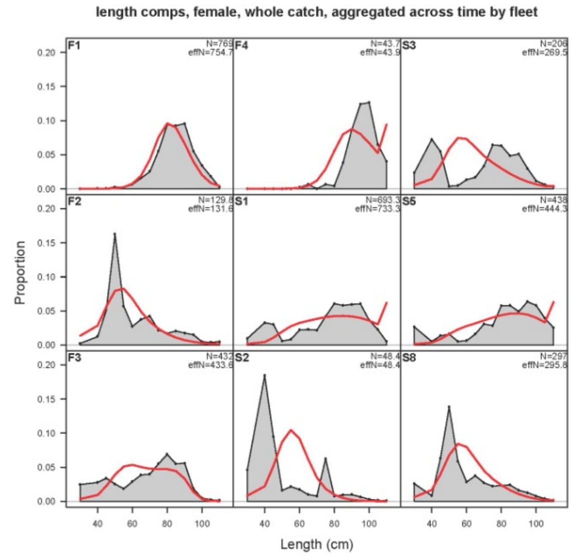


Figure 13. *Item 2. Continued*—Observed and model predicted male annual length compositions for the main targeted fishery (fleet F1 – NE Gillnet Kept) for the base assessment model (ATL Base Sel-2; upper panels; ATL Assessment Report **Figure 4.8**), and for the base model configuration modeled here with length composition data down weighted by 3/4 (λ=1/4; lower panels). Length compositions shown start in 1994 (upper left graph) and continue to 2010. Diameter of Pearson residuals (circles) indicates relative error; predicted < observed (solid), predicted > observed (transparent). The maximum diameter width of the plot for Pearson residuals changed between ATL Base Sel-2 (Max = 7.64; upper right panel) and the model with λ=1/4 (Max = 7.84; lower right panel).



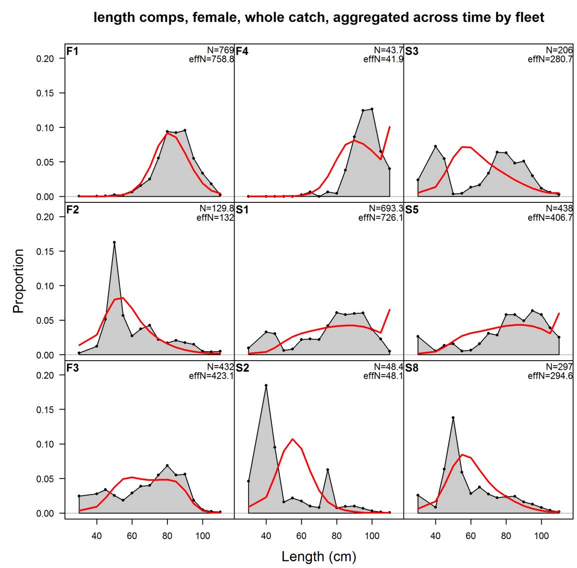
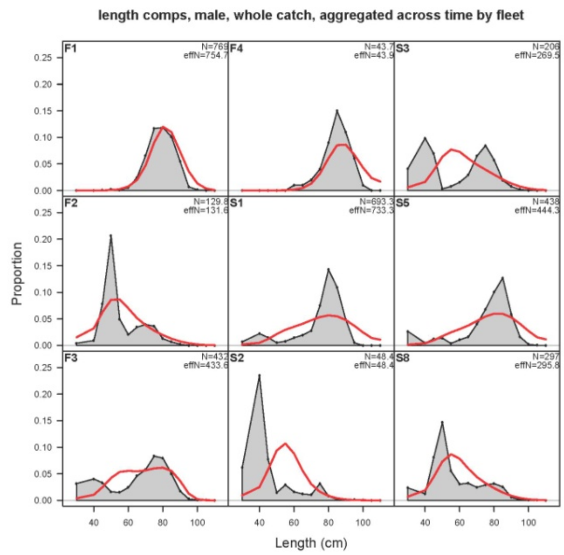


Figure 14. *Item 2. Continued*—Model fits to aggregate female length composition data for the base assessment model (ATL Base Sel-2; upper panels; ATL Stock Assessment Report **Figures 4.9 – 4.11**) and the base model configuration modeled here with length composition data down weighted by 3/4 (λ=1/4; lower panels). See the ATL Assessment Report Section 3.2 and **Tables 2.3 – 2.5** for a description of the length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8).



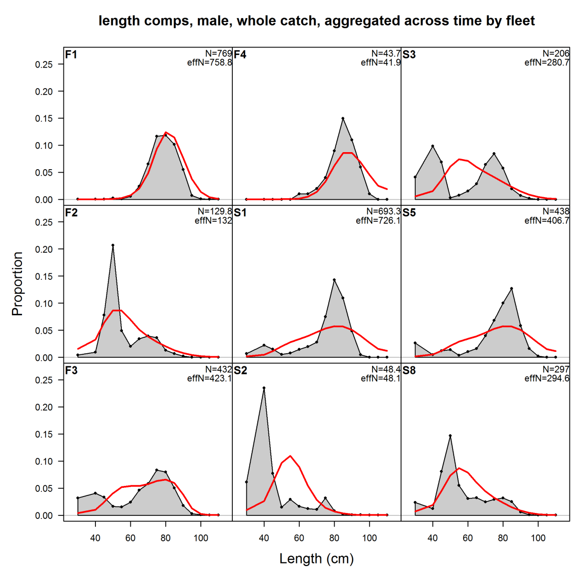
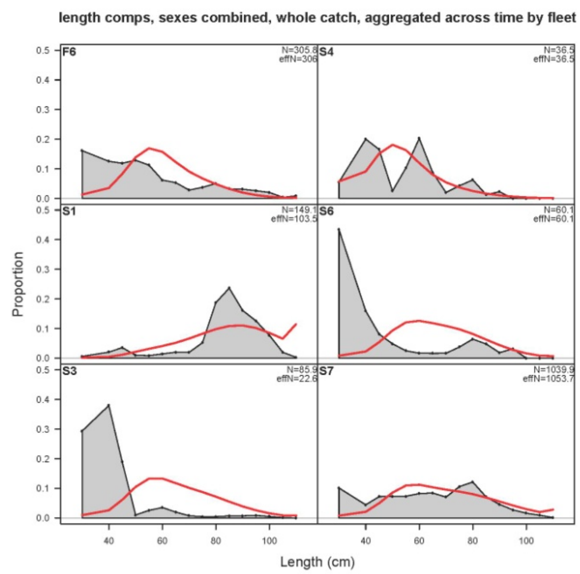


Figure 15. *Item 2. Continued*—Model fits to aggregate male length composition data for the base assessment model (ATL Base Sel-2; upper panels) and the base model configuration modeled here with length composition data down weighted by 3/4 (λ=1/4; lower panels).



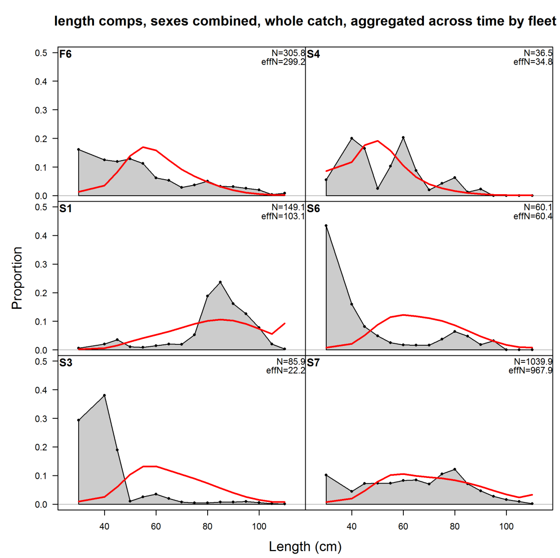


Figure 16. *Item 2. Continued*—Model fits to aggregate combined sex (or unknown sex) length composition data for the base assessment model (ATL Base Sel-2; upper panels) and the base model configuration modeled here with length composition data down weighted by 3/4 (λ=1/4; lower panels).

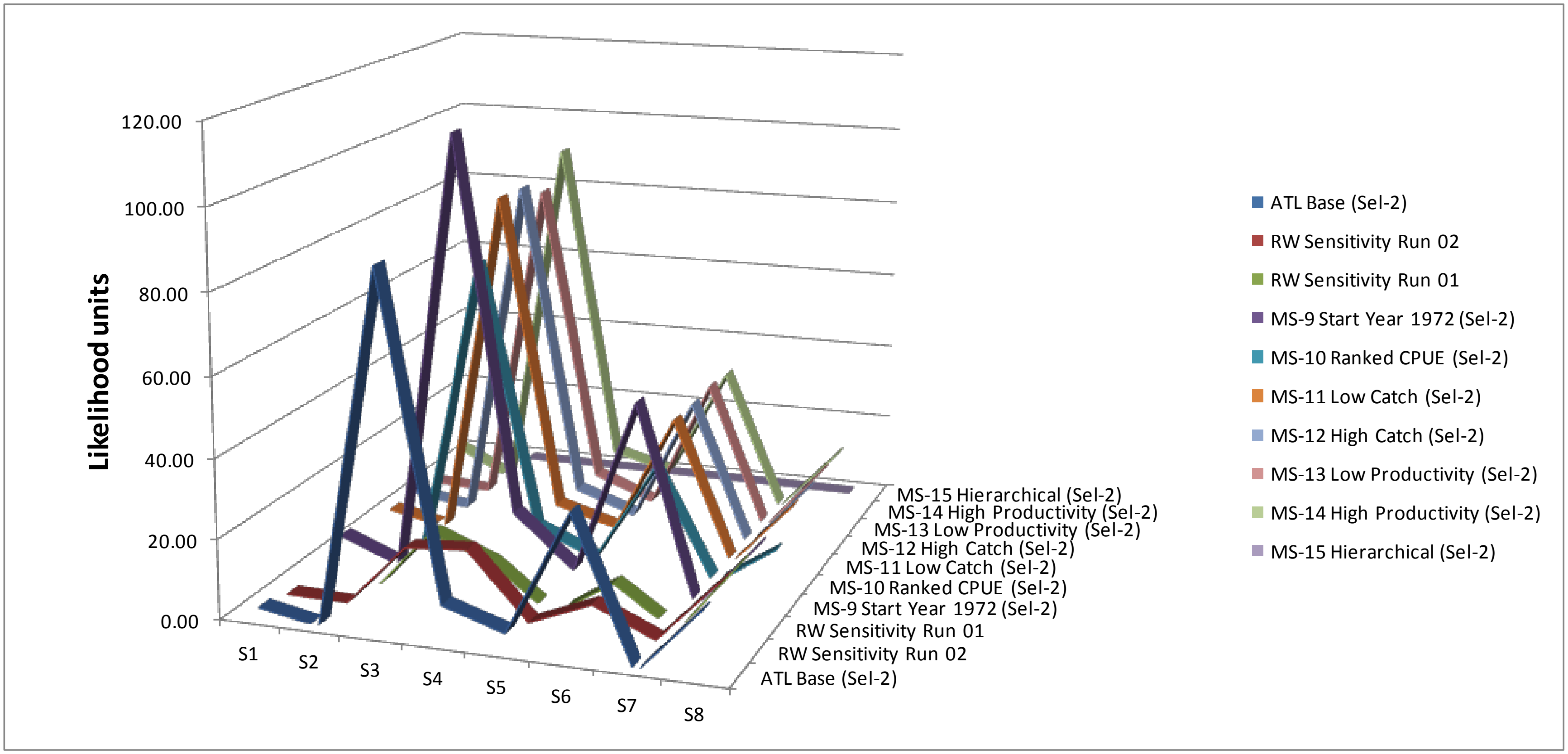


Figure 17. *Item 4.*—Likelihood component values for fits to each index of relative abundance (surveys S1 – S8) for the base assessment model (ATL Base Sel-2) and for the model sensitivities associated with the base model configuration (Sel-2). A description of each data source is provided in **Table 3**. Likelihood component values were also provided for results of model sensitivity runs conducted during the CIE Review Workshop (RW Sensitivity Run 01 and RW Sensitivity Run 02), which are described in the text of this addendum.

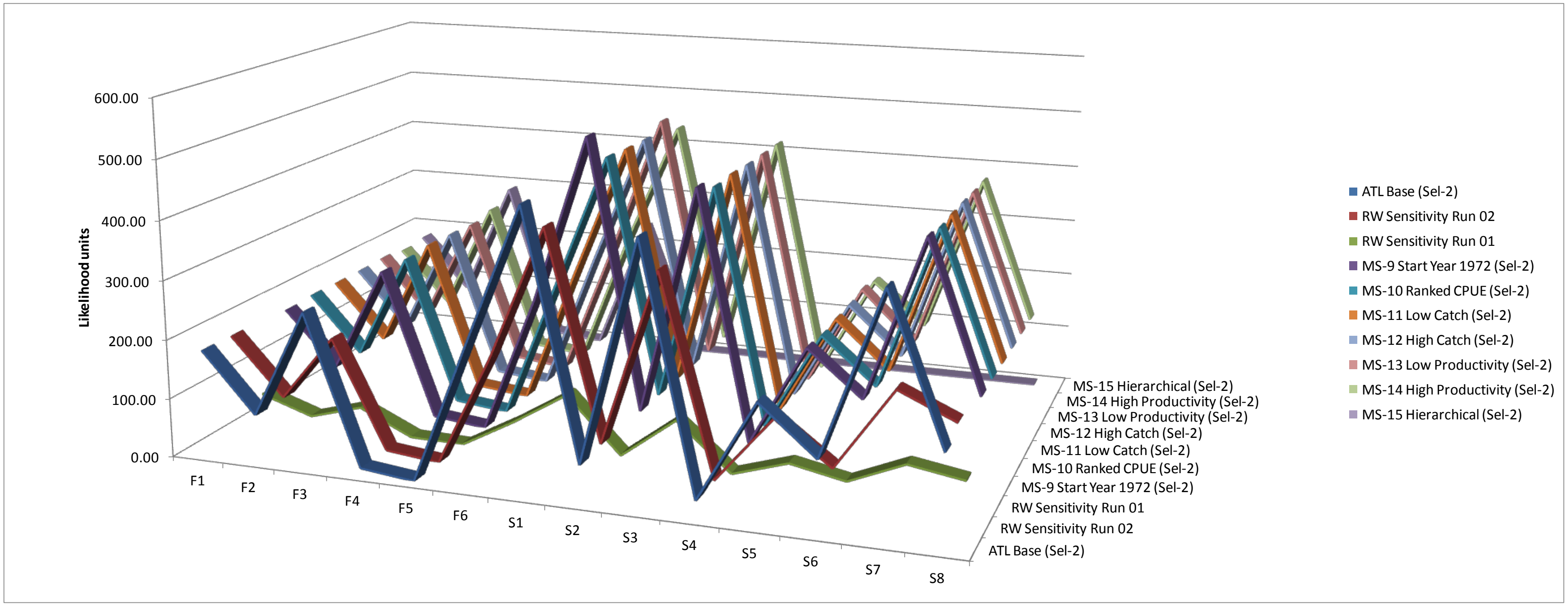


Figure 18. *Item 4. Continued*—Likelihood component values for fits to length composition data sources associated with each fleet (F1 – F6) and index of relative abundance (surveys S1 – S8) for the base assessment model (ATL Base Sel-2) and for the model sensitivities associated with the base model configuration (Sel-2). A description of each data source is provided in **Table 4**. Likelihood component values were also provided for results of model sensitivity runs conducted during the CIE Review Workshop (RW Sensitivity Run 01 and RW Sensitivity Run 02), which are described in the text of this addendum.

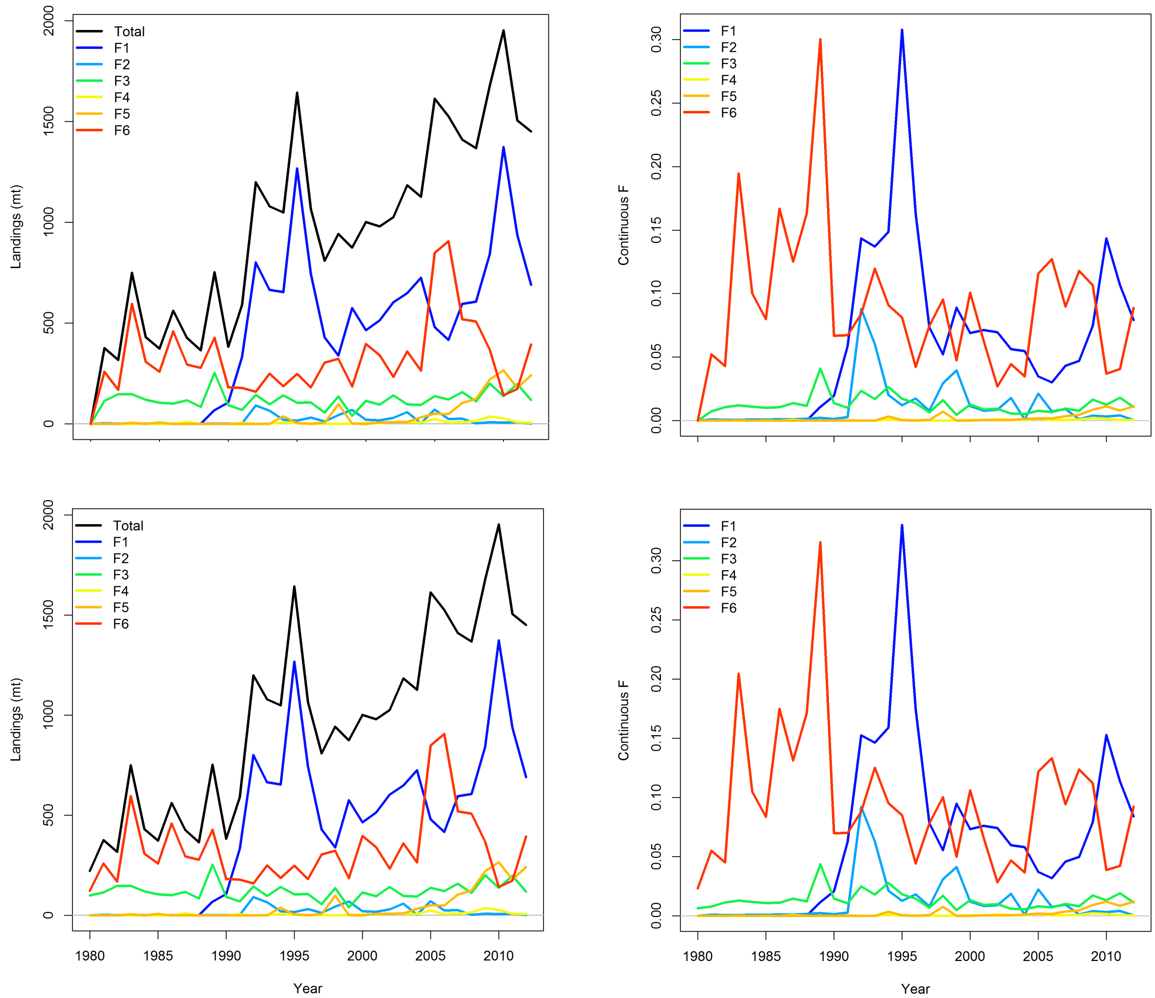


Figure 19. *Item 7*.—Catch time series and continuous fishing mortality rates (*F*) associated with each fleet (F1 – F6) in the base model configuration (ATL Base Sel-2; upper panels; see the ATL Stock Assessment Report **Table 4.13**) and in the base model configuration modeled here with estimated initial fishing mortality for fleets F3 and F6 (lower panels). The ATL Assessment Report Sections 2 and 3 and **Tables 2.2 and 2.5** provide a description of the data sources associated with each catch time series.

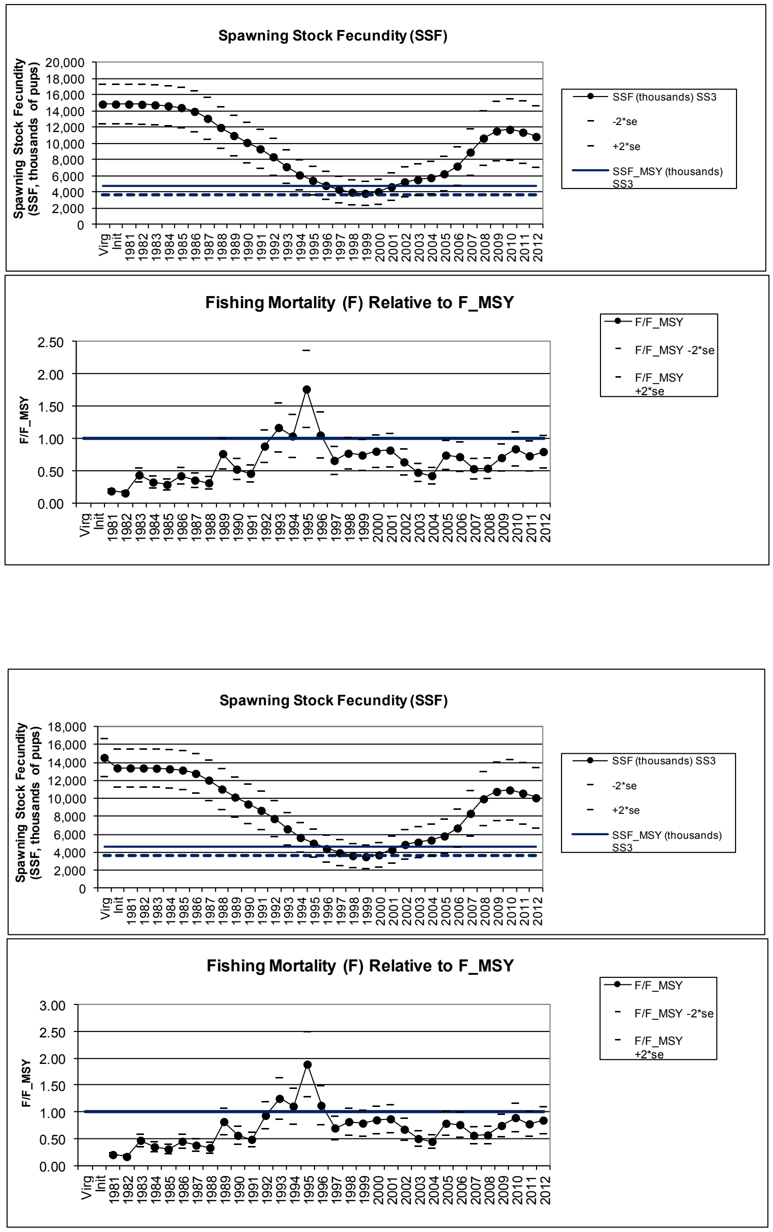


Figure 20. *Item 7. Continued.*—Time series results for stock status from the base assessment model (ATL Base Sel-2; upper two panels; ATL Assessment Report **Figure 4.17**) and the base model modeled here with estimated initial fishing mortality (lower two panels).

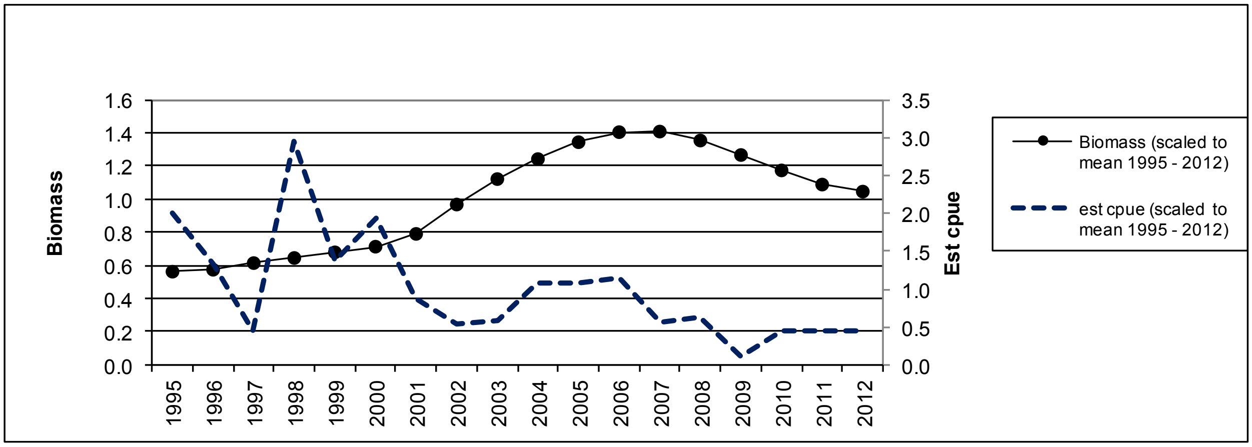


Figure 21. *Item 9.*—Total biomass (Biomass, scaled to the mean) from the base assessment model (ATL Base Sel-2; see the ATL Assessment Report **Table 4.13**) compared to the standardized relative abundance index obtained for smooth dogfish caught during observed anchored sink gillnet trips (Est cpue, scaled to the mean; obtained from SEDAR-DW-09 their Table 2 and Figure 3).

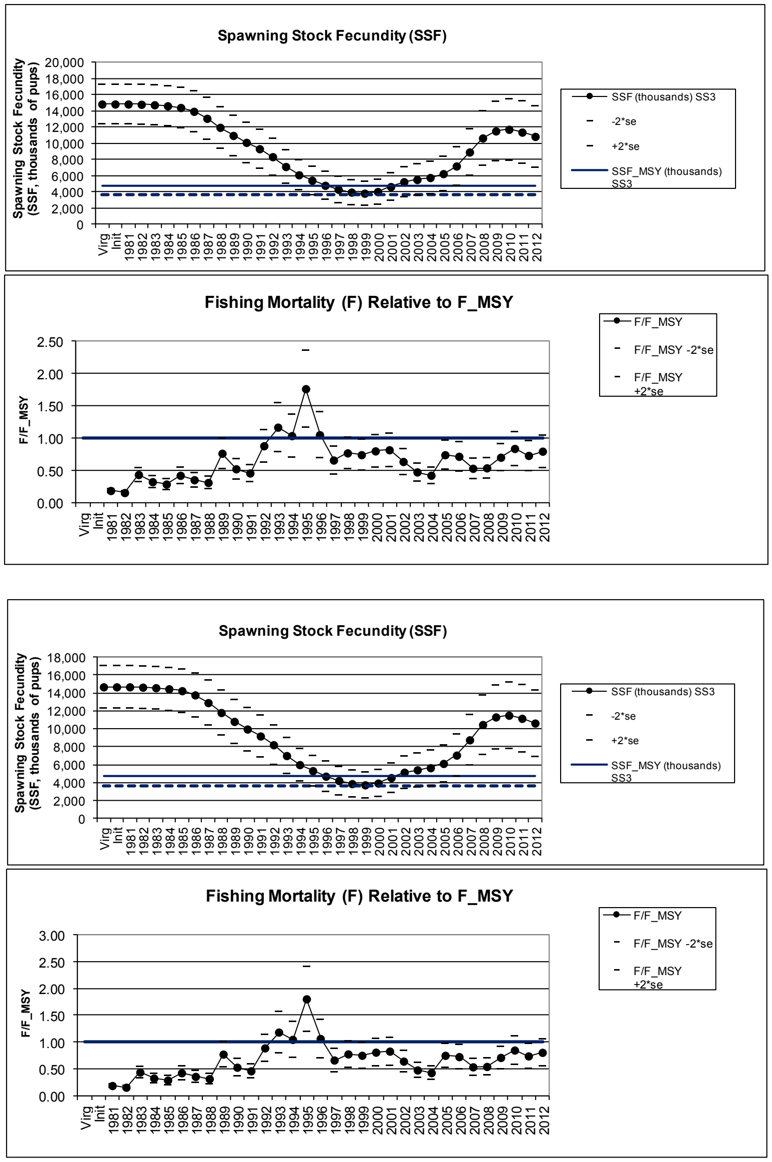


Figure 22. *Item 10.*—Time series results for stock status from the base assessment model (ATL Base Sel-2; upper two panels; ATL Assessment Report **Figure 4.17**) and the base model modeled here with the minimum length, L_{Amin}, changed from the length at age-0 to the length at age-0.5 (lower two panels).

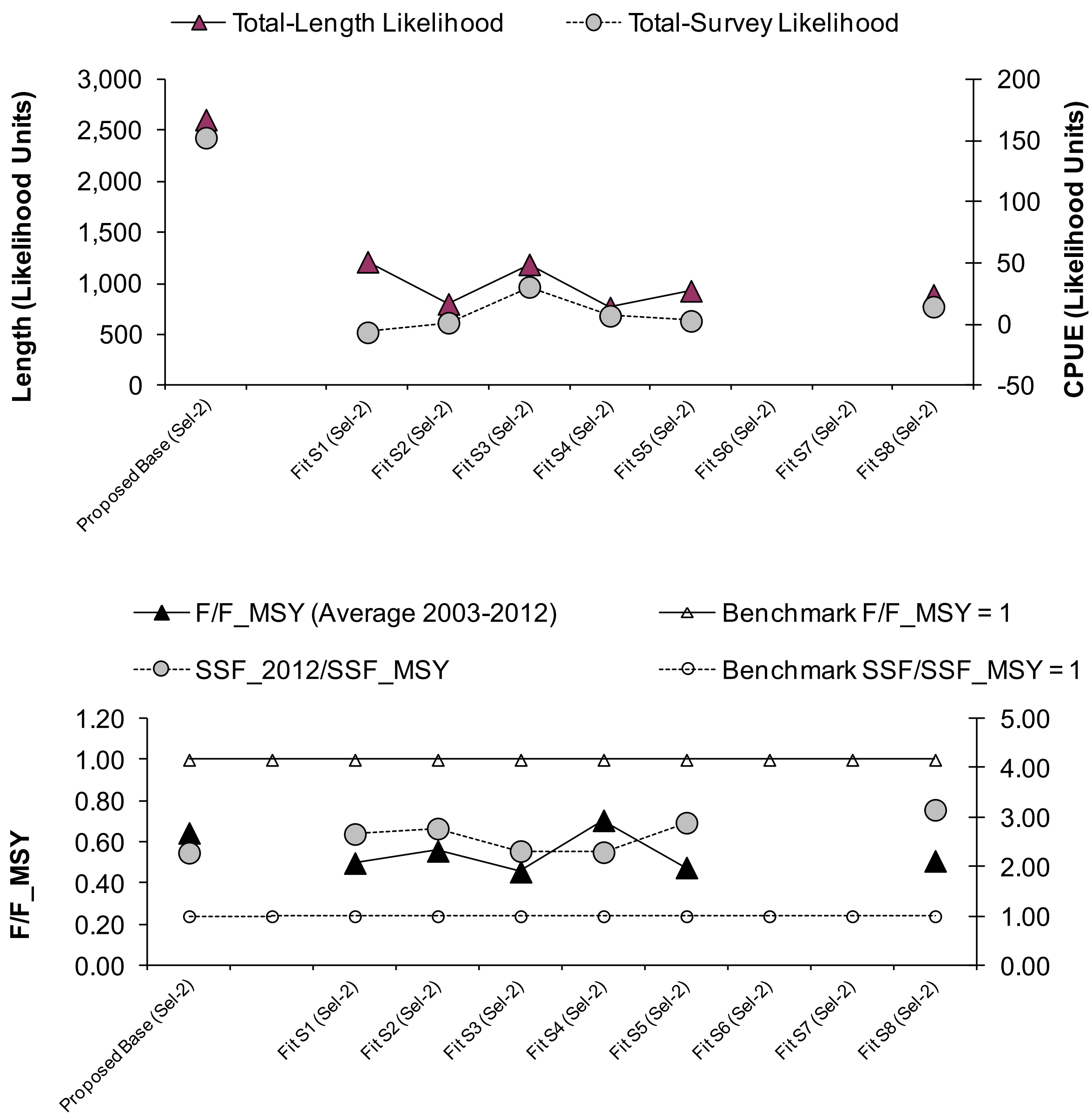
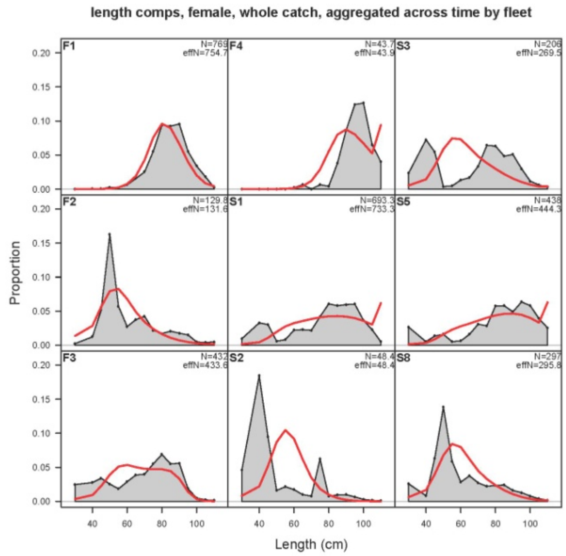


Figure 23. *Item 11.*—Summary of model sensitivity results obtained from fitting each index of relative abundance (CPUE) one at a time within the base assessment model (ATL Base Sel-2; see the ATL Assessment Report **Table 4.13)**. The values for F/F_{MSY} were calculated as the average annual fishing mortality, F, over the most recent 10 years divided by F_{MSY}. The ATL Stock Assessment Report Section 3.2 and **Tables 2.5** – **2.7** provide a description of the data sources for each index of relative abundance (surveys S1 – S8).



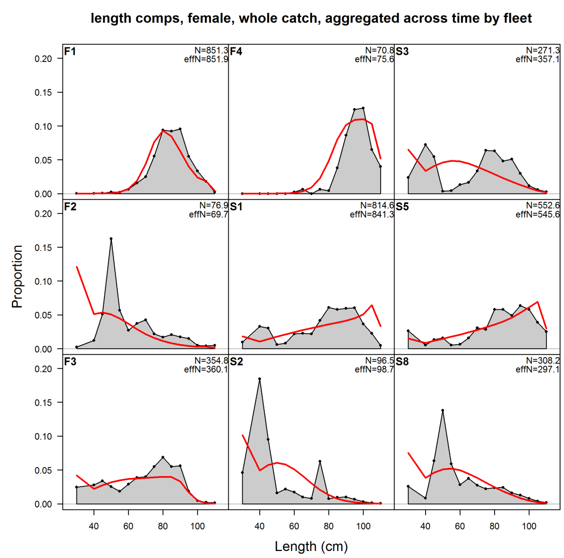
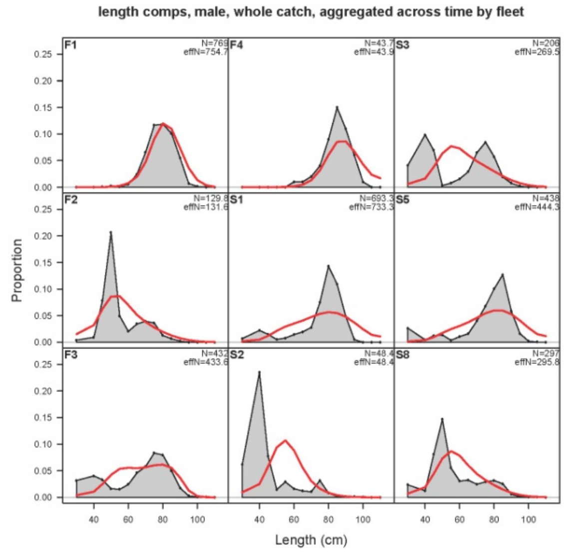


Figure 24. *RW Sensitivity Run 01.*—Model fits to aggregate female length composition data for the base assessment model (ATL Base Sel-2; upper panels; ATL Stock Assessment Report **Figures 4.9 – 4.11**) and RW Sensitivity Run 01 (lower panels), as described above in the text of this addendum.



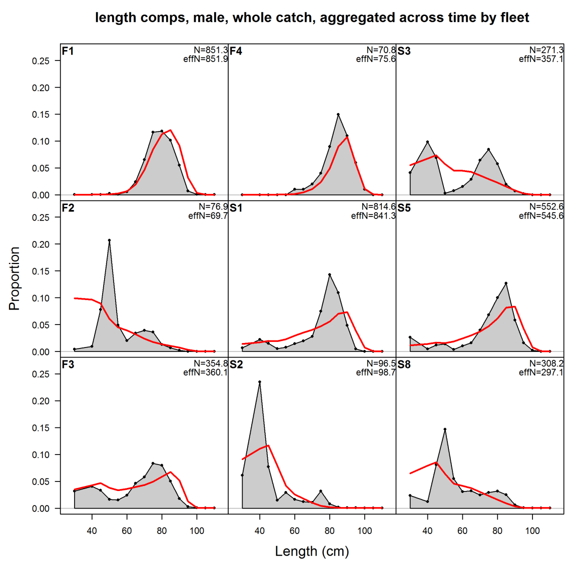
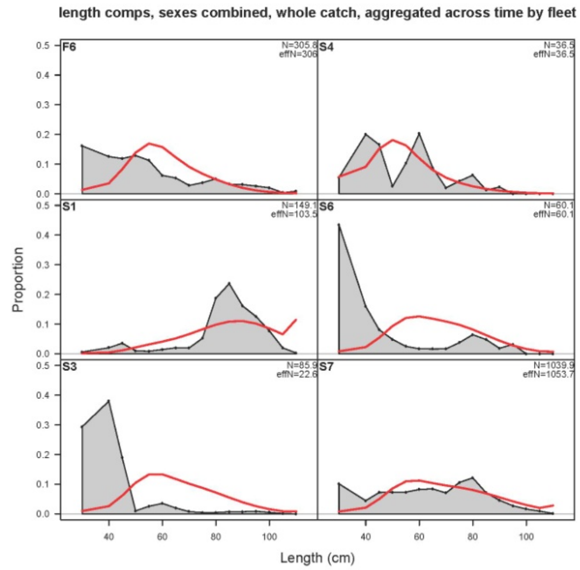


Figure 25. *RW Sensitivity Run 01. Continued*—Model fits to aggregate male length composition data for the base assessment model (ATL Base Sel-2; upper panels) and RW Sensitivity Run 01 (lower panels), as described above in the text of this addendum.



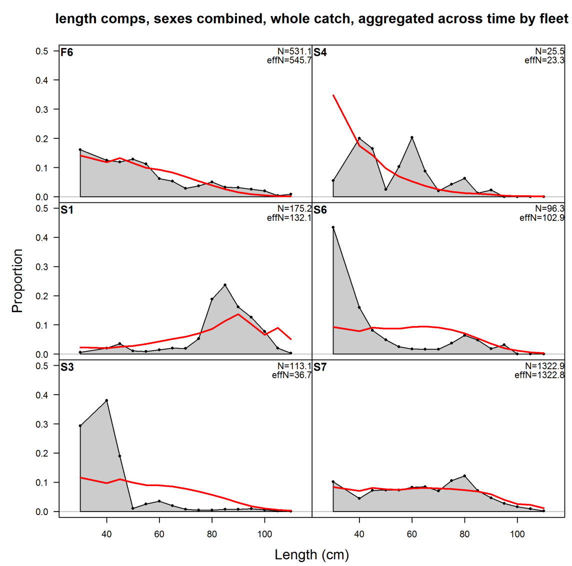


Figure 26. *RW Sensitivity Run 01. Continued*—Model fits to aggregate combined sex (or unknown sex) length composition data for the base assessment model (ATL Base Sel-2; upper panels) and RW Sensitivity Run 01 (lower panels), as described above in the text of this addendum.

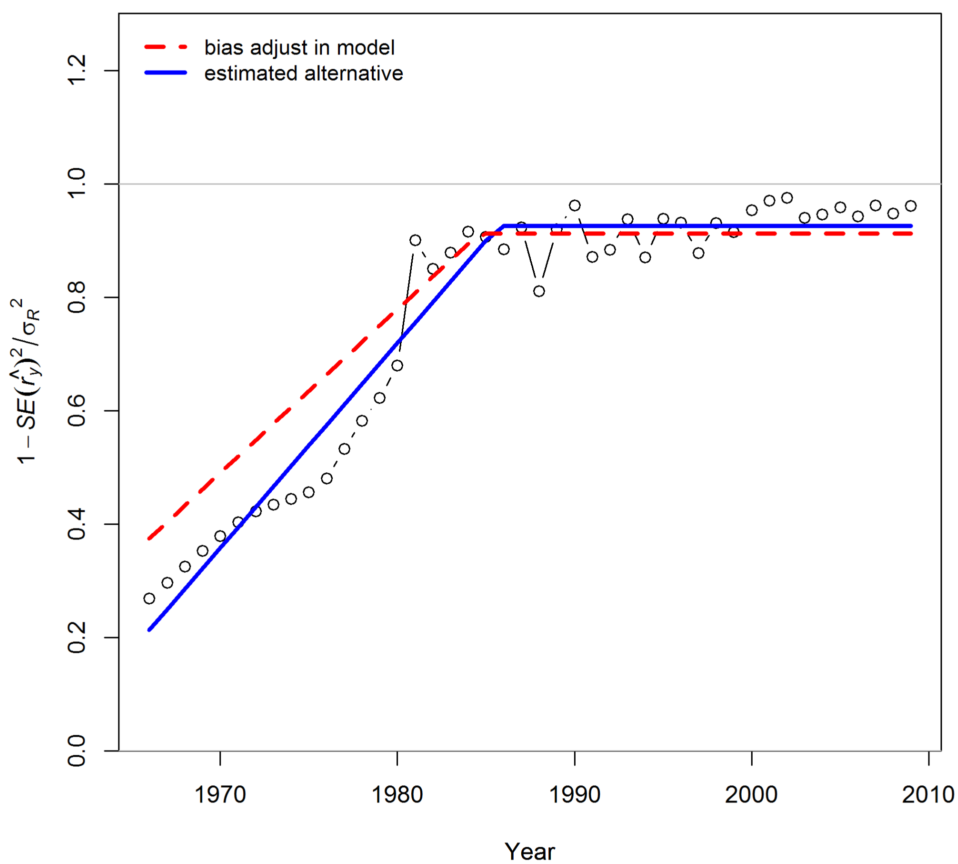


Figure 27. The bias adjustment ramp for recruitment deviations obtained with the program r4ss (Taylor et al 2014; e.g., Methot and Taylor 2011) for model Run 4 of RW Sensitivity Run 02.

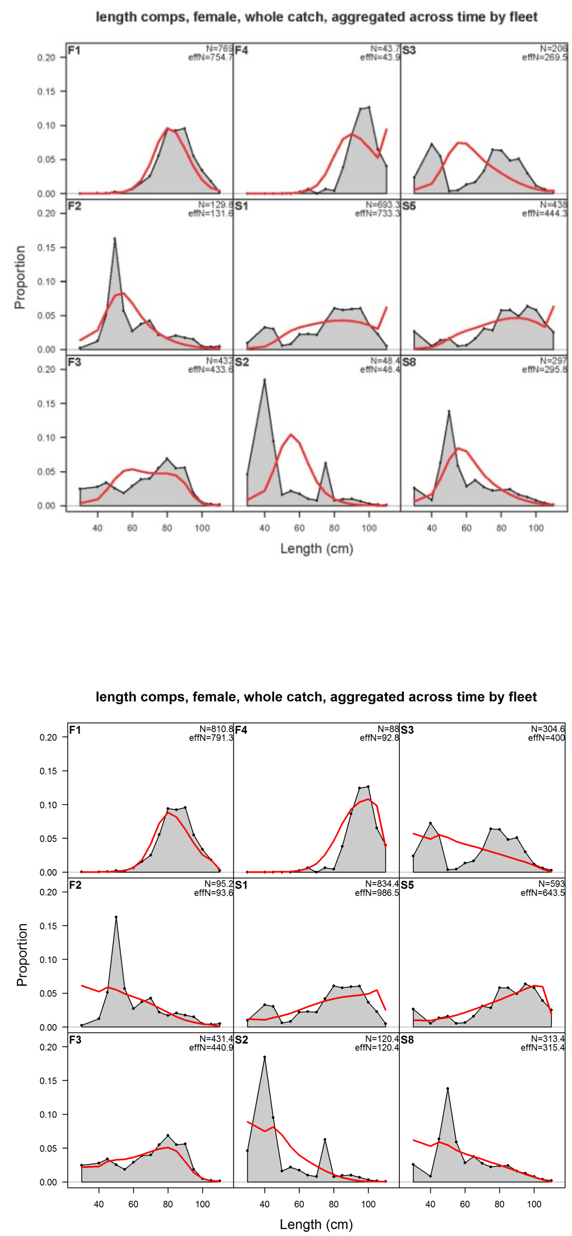
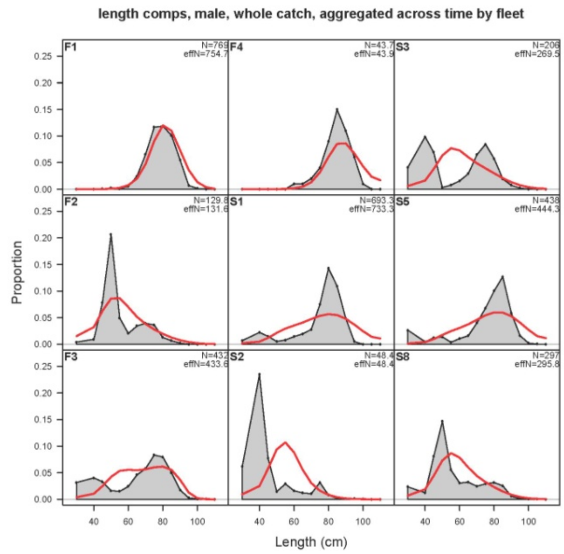


Figure 28. *RW Sensitivity Run 02.*—Model fits to aggregate female length composition data for the base assessment model (ATL Base Sel-2; upper panels; ATL Stock Assessment Report **Figures 4.9 – 4.11**) and RW Sensitivity Run 02 (lower panels), as described above in the text of this addendum.



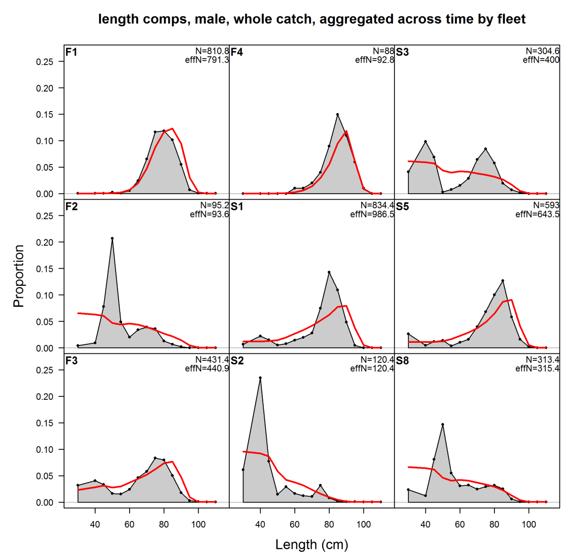
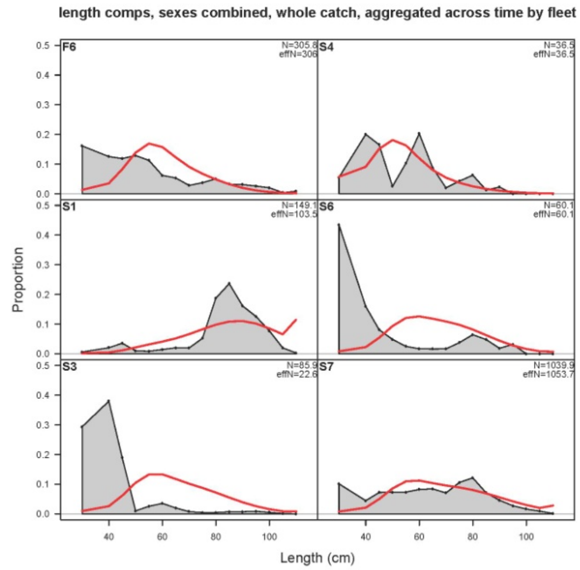


Figure 29. *RW Sensitivity Run 02. Continued*—Model fits to aggregate male length composition data for the base assessment model (ATL Base Sel-2; upper panels) and for RW Sensitivity Run 02 (lower panels), as described above in the text of this addendum.



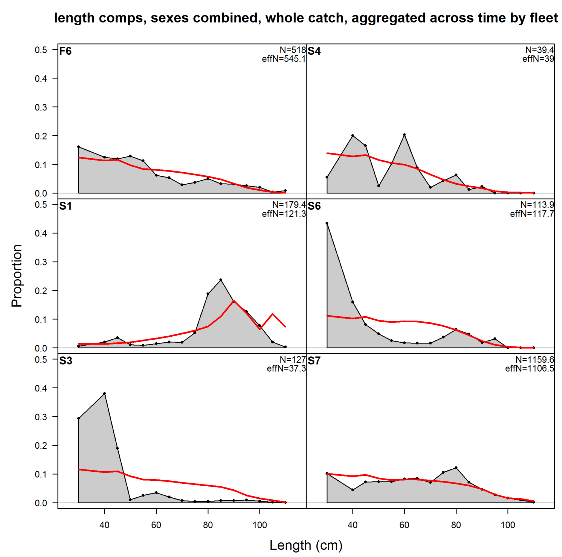
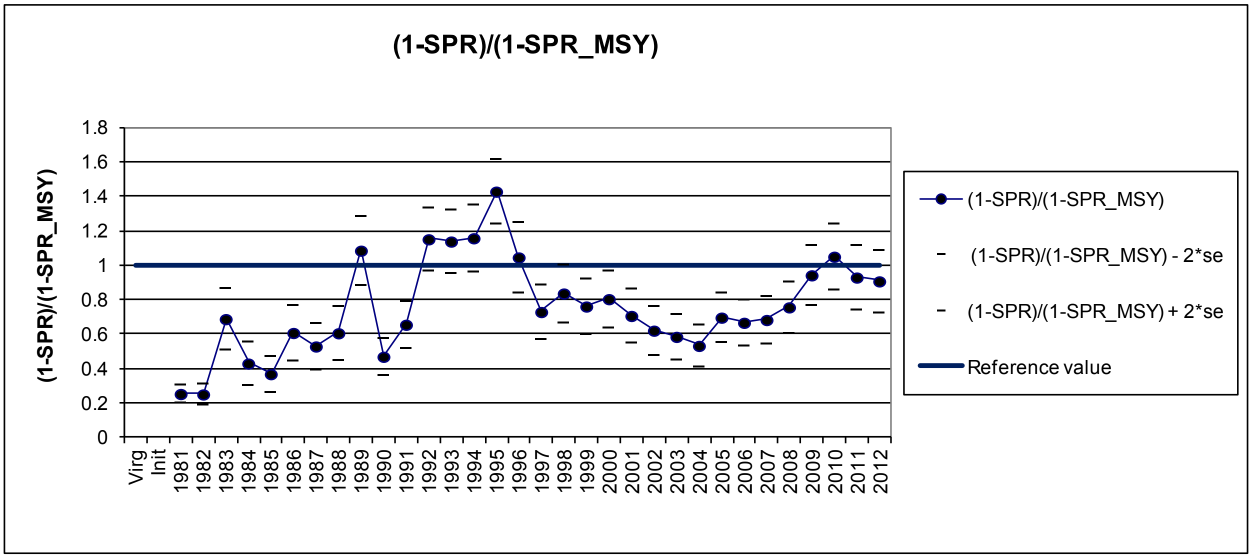


Figure 30. *RW Sensitivity Run 02. Continued*—Model fits to aggregate combined sex (or unknown sex) length composition data for the base assessment model (ATL Base Sel-2; upper panels) and RW Sensitivity Run 02 (lower panels), as described above in the text of this addendum.



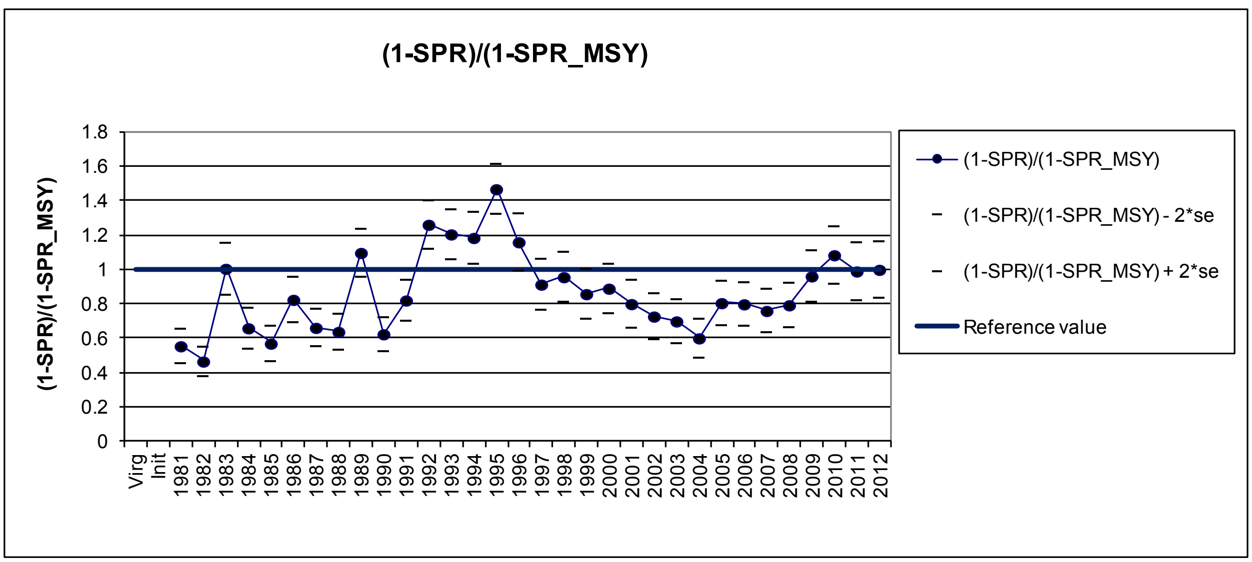


Figure 31. The spawning-potential ratio (SPR) obtained from Stock Synthesis output for both the base model configuration (ATL Base Sel-2; upper panel) and RW Sensitivity Run 02 (lower panel). For comparison to annual fishing mortality (*F*) relative to F_{MSY} (e.g., see the SEDAR 39 Atlantic smooth dogfish Stock Assessment Report **Figure 4.17)**, the 1 – SPR (one minus SPR) metric is reported relative to 1 – $\mathrm{SPR}_{\mathrm{MSY}}$ along with approximate 95% confidence intervals based on the asymptotic standard errors (se) obtained for (1 – SPR)/(1 – $\mathrm{SPR}_{\mathrm{MSY}}$) from Stock Synthesis.