SEDAR
Southeast Data, Assessment, and Review

SEDAR 39
Stock Assessment Report

HMS Gulf of Mexico Smoothhound Sharks

March 2015

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

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(Note: Individual sections are numbered independently)

SEDAR

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:

- Species identification issues: The Data Workshop Panel discussed the difficulty of correctly identifying the three species for smoothhounds that occur within the Gulf of Mexico. Due to this issue, the Panel recommended that the assessment be conducted as a complex, using the information available for the three species as appropriate.

- Single-species assessment vs. complex: Given the difficulty with identifying the individual species of smoothhound occurring in the Gulf of Mexico, a smoothhound complex assessment was conducted. Both the Data workshop and Review workshop panelists noted that this approach may not accurately represent the information or status of any individual species within the Gulf of Mexico, and managers should consider this uncertainty when making decisions.

- Shrimp trawl fishery bycatch estimation: The majority of the landings incorporated into this assessment are derived from the estimation of shrimp trawl fishery bycatch. Much discussion centered on the approach used to derive the estimated values used in the model, and it was suggested that alternatives ways to produce these estimates be examined for future assessments.

- Lack of quantitative measures of uncertainty in shrimp bycatch estimation: The Review Panel noted that a lack of measures of uncertainty regarding the shrimp bycatch estimates might be an issue, as the catch data are considered error-free in the model formulation.

- Inclusion of commercial landings in the assessment: The Data Workshop panel explored the GulfFIN database to determine the commercial removals of these species. Only very small quantities were discovered, and it was noted it was common practice for GOM bottom longline fishermen to use smoothhound as bait; therefore, since they were not landed they would not be included on reports as landings. Given the very small magnitude of commercial landings, the Catch WG opted not to consider this data set.

- Stock Status: The reliability of the stock status determination is dependent on the accuracy of the shrimp trawl bycatch estimates for these species, which have a high level uncertainty associated with them.

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*.

Smooth Dogfish Management History

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.

State-by-State

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

Florida Smoothhound Management History

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*

Gulf Smoothhound Management History

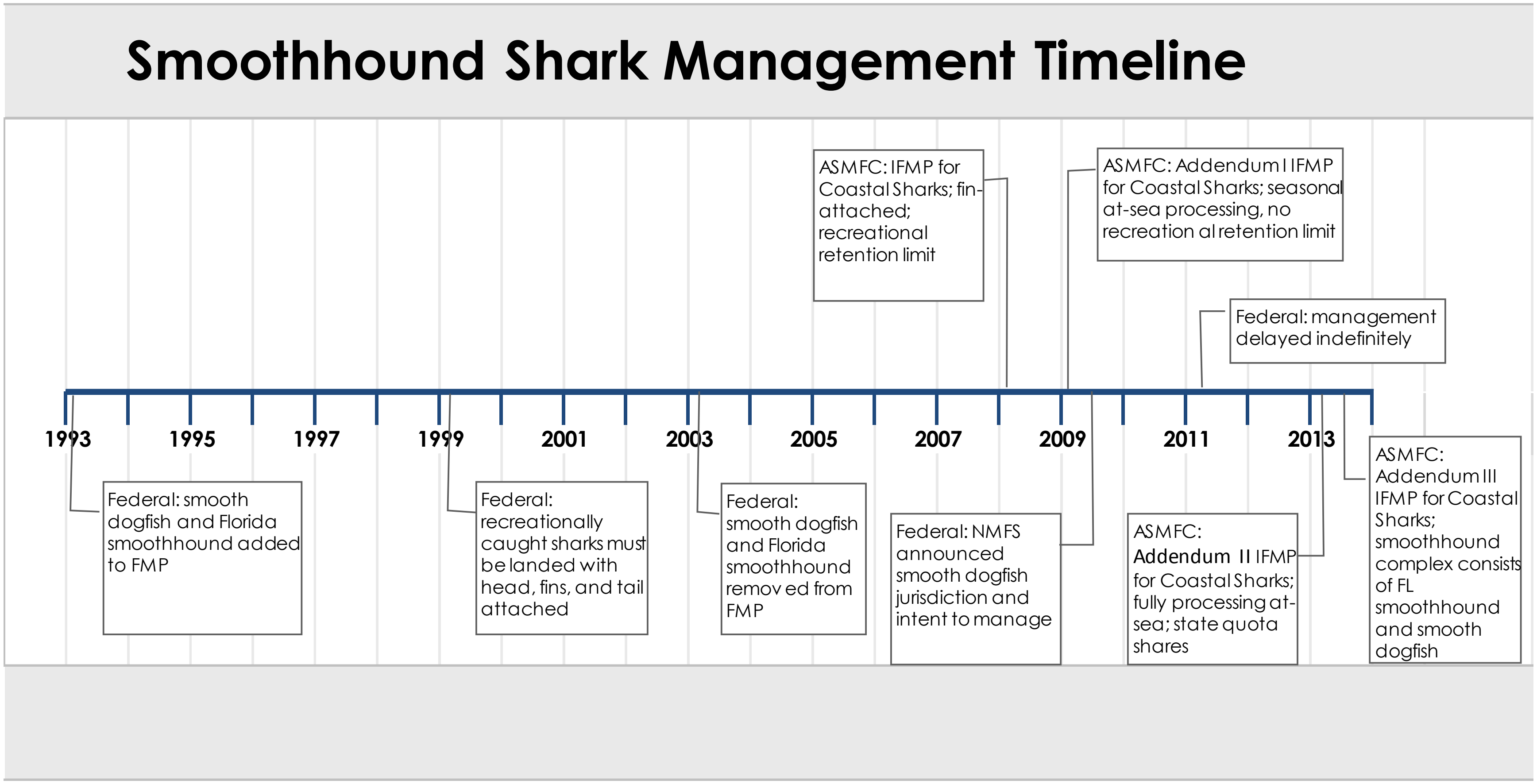
Although there are no management measures specific to the Gulf smoothhound, the species is very difficult to distinguish from smooth dogfish. Thus, past smooth dogfish management measures likely impacted Gulf smoothhound.

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

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

ASMFC: Addendum I IFMP for Coastal Sharks; seasonal at-sea processing, no recreational retention limit

Federal: NMFS announced smooth dogfish jurisdiction and intent to manage

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

3. 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.

4. 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.

5. ASSESSMENT HISTORY AND REVIEW

The Gulf of Mexico smoothhound sharks complex have not be assessed prior to SEDAR 39.

6. 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
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

Southeast Data, Assessment, and Review

SEDAR 39

HMS Gulf of Mexico Smoothhound Sharks

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	
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
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Additional Participants via Webinars/Conference Calls

Shane Cantrell	Industry
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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 data collected in the reeffish bottom longline fishery	John Carlson and Elizabeth Scott-Denton	30 April 2014
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	C.T. McCandless	17 June 2014

	survey conducted by the Graduate School of Oceanography.		
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	N. E. Kohler, P. A. Turner, M. Pezzullo, and C.	19 May 2014 Updated 17 June 2014

	Cooperative Shark Tagging Program	T. McCandless	
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,	22 May 2014

		Jim Gelsleichter, Robert Latour	

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 Ocean, with descriptions of two new species and a new subspecies	Phillip C. Heemstra
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-22: Identification, life History and distribution of *Mustelus canis*, *M. norrisi* and *M. sinusmexicanus* in the northern Gulf of Mexico.
L.M. Jones, W.B. Driggers III, J. Gelsleichter, M. Giresi, R.D. Grubbs, K.M. Hannan, E.R. Hoffmayer and C.M. Jones

Life history data for *Mustelus canis*, *M. norrisi* and *M. sinusmexicanus* were collected from various sources and used to describe the age, growth, reproductive biology and distribution of the three species in the northern Gulf of Mexico. Close morphological similarities among the three species limited the amount of reliable species-specific data that were available. As a result, when available, genetically verified specimens were utilized to generate life history parameter estimates. Parameter estimates for age and growth models and maturity ogives are provided. Information on the basic reproductive biology of each species are presented based on data collected from various source, including fisheries-independent surveys, personal observation, unpublished data and primary literature. Additionally, species and sex-specific length-length and length-weight relationships are summarized and the distribution of each species within the northern Gulf of Mexico is discussed.

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.

2.3 Stock Definition and Description

Two mark and recapture documents were presented that showed no movement of tagged *M. canis, norrisi and sinusmexicanus* between the Gulf of Mexico and Atlantic Ocean (SEDAR39-DW-01, SEDAR39-DW-20). Preliminary evidence of genetic stock structure of *M. canis* was presented by Giresi et al. (SEDAR39-DW-29) and showed significant differences in haplotype frequencies between the Gulf of Mexico and Atlantic Ocean. Based on tagging and genetic data presented, there was a consensus that *M. canis* in the Gulf of Mexico and the Atlantic Ocean represent two distinct stocks. *Mustelus norrisi and M. sinusmexicanus* only occur in the Gulf of Mexico.

Decision 1: Tagging shows no movement of *M. canis*, *M. norrisi* and *M. sinusmexicanus* between the Gulf of Mexico and Atlantic Ocean. Furthermore, tagging and genetic data strongly support the existence of separate stocks of *M. canis* in the Gulf of Mexico and Atlantic Ocean.

Decision 2: After considering identification problems associated with life history data from the northern Gulf of Mexico and that corresponding data from the Atlantic Ocean are robust for *M. canis*, we strongly recommend assessment of *M. canis* in the Atlantic and assessment of all *Mustelus* spp. in the Gulf of Mexico as a single complex.

2.4 Natural mortality

Natural mortality estimates will be discussed during the assessment process.

2.5 Age & growth

Age and growth data were presented by Jones et al. (SEDAR39-DW-22) (Tables 2.12.1, 2.12.2 and 2.12.3). Due to limited samples from female *M. norrisi* and both sexes of *M. sinusmexicanus*, growth models for both sexes were only available for *M. canis*. Growth models for male *M. norrisi* and combined sexes of *M. sinusmexicanus* were provided. Genetic analyses of a subset of specimens used for age and growth analyses indicated that there were numerous identification issues among the three species, bringing into question the reliability of species-specific models, with the exception of *M. sinusmexicanus*. Because of the identification problems associated with the NMFS samples used for vertebral analyses or in the case of *M. sinusmexicanus*, limited sample size, it was not possible to present a reliable growth model for any of the species. Therefore, the group felt the growth of the three species was best described by the lowest and highest biologically realistic values of von Bertalanffy Growth Function parameter estimates found for any of the three species. The growth models selected to represent these low and high values were associated with the combined sex model for *M. canis* (L_∞ =113.78, k = 0.13, t_0 = -3.87) and *M. norrisi* (L_∞ =95.05, k = 0.25, t_0 = -2.03), respectively (Figures 2.13.1 and 2.13.2). Maximum observed ages for female *M. canis*, *M. norrisi,* and *M. sinusmexicanus* were 13, 6, and 14 years, respectively. Maximum observed ages for male *M. canis*, *M. norrisi*, and *M. sinusmexicanus* were 11, 9, and 13 years, respectively.

Decision 3: Use low and high VBGF parameter estimates from SEDAR39-DW-22 to capture variability in growth dynamics among species (*M. canis*: L_∞ =113.78, k = 0.13, t_0 = -3.87) and *M. norrisi:* L_∞ =95.05, k = 0.25, t_0 = -2.03).

Decision 4: Use maximum observed ages reported in SEDAR39-DW-22 (*M. canis / M. sinusmexicanus* group = 14 years, *M. norrisi* = 9 years)

2.6 Maturity and Reproduction

Reproductive data for the three species of *Mustelus* occurring in the northern Gulf of Mexico were presented by Jones et al. (SEDAR39-DW-22) (Table 2.12.1 and 2.12.2). Based on identification issues and biological similarities (e.g. maximum observed age and length), age and size at maturity data for *M. canis* and *M. sinusmexicanus* were combined (Figures 2.13.3 and 2.13.4, Table 2.12.3). Size and age at 50% maturity for this group were 69.2 cm FL and 3.3 years for males, 75.1 cm FL and 4.1 years for females. However, no nominal *M. sinusmexicanus* specimens had both maturity and age data. Therefore, age at maturity for *M. canis* was used as a surrogate for *M. sinusmexicanus*. For *M. norrisi*, reliable sizes at maturity data were only available for males (53.9 cm FL) (Figure 2.13.5, Table 2.12.4). Age data were not available for *M. norrisi* specimens. Therefore, the group chose to use age at maturity data from the combined *M. canis* / *M. sinusmexicanus* estimates as a conservative surrogate for *M. norrisi* (age at 50% maturity = 3.3 years for males and 4.1 years for females). Age and size at maturity schedules are listed in Tables 5, 6 and 7. Brood sizes were reported for all species and based on a combination of fisheries-independent data, unpublished data and reports from the primary literature. Mean brood size for *M. canis*, *M. sinusmexicanus* and *M. norrisi* were 15.5, 5.0, and 11.3, respectively. There was no significant relationship between maternal fork length and brood size for any of the three species. Based on similar data sources, pupping occurred for each species during the early summer with mature females reproducing annually (Tables 2.12.1 and 2.12.2).

Decision 5: Use reproductive parameters presented in SEDAR39-DW-22 and Tables 2.12.1 and 2.12.2.

2.7 Movements and migrations

Two mark and recapture documents were presented that showed no movement of tagged *M. canis, norrisi and sinusmexicanus* between the Gulf of Mexico and Atlantic Ocean (SEDAR39-DW-01, SEDAR39-DW-20). Preliminary evidence of genetic stock structure of *M. canis* was presented by Giresi et al. (SEDAR39-DW-29) and showed significant differences in haplotype frequencies between the Gulf of Mexico and Atlantic Ocean. Based on tagging and genetic data presented, there was a consensus that *M. canis* in the Gulf of Mexico and the Atlantic Ocean represent two distinct stocks. *Mustelus norrisi and M. sinusmexicanus* only occur in the Gulf of Mexico.

Decision 6: All available data indicate that the three species of *Mustelus* occurring in the Gulf of Mexico do not move outside of the bounds of the region.

2.8 Meristics & conversion factors

Meristic relationships for lengths and body weight were calculated for *M. canis*, *M. norrisi* and *M. sinusmexicanus* captured in the northern Gulf of Mexico (Table 12.2.1 and 12.2.2). There was no significant difference among length relationships between *M. canis* and *M. sinusmexicanus*. As a result of this finding data were combined to calculate length relationships for these two species. There was a significant difference between length relationships for *M. norrisi* and the *M. canis*/*sinusmexicanus* group, therefore, species-specific relationships for *M. norrisi* were calculated (Table 12.2.2). Among the four length measurements commonly taken for sharks (precaudal, fork, total and stretch total), only fork length was consistently recorded across data sources. As a result, the amount of available data for specific length relationships varied. Linear regression was used to calculate conversions among lengths. Because of differences in maximum observed sizes and fecundity estimates, species-specific length-weight relationship were generated (Tables 12.2.1 and 12.2.2) utilizing non-linear regression.

2.9 Comments on the Adequacy of data for assessment analyses

There were two significant issues associated with life history data for the three species of *Mustelus* occurring in the northern Gulf of Mexico. The first issue was related to misidentifications of specimens used for analyses and the second was related to limited data for estimating some life history characteristics. Genetic analyses of a subset of specimens used for age, growth and reproductive analyses indicated that there were numerous identification issues among the three species, bringing into question the reliability of species-specific data, with the exception of *M. sinusmexicanus*. Tissue samples from 184 randomly selected individuals of *Mustelus* spp. collected in the northern Gulf of Mexico were genetically identified based on sequences of the NADH-2 gene (M. Giresi, unpublished data). Results of genetic assays indicated that 68% of *M. canis*, 40% of *M. norrisi* and 97% of *M. sinusmexicanus* were properly identified. Of the specimens incorrectly identified as *M. canis*, 91% of those were genetically determined to be *M. sinusmexicanus*. Therefore, based on the similarity in maximum size and maximum observed age, these two species were combined to generate von Bertalanffy growth parameter estimates for the two species treated as a group.

To further compound the problem, several life history parameter estimates were based on limited sample sizes. For example, brood size estimates for *M. norrisi* and *M. sinusmexicanus* were based on the collection of seven and five gravid females, respectively. Similarly, maturity data for *M. norrisi* were only available for 24 males and no females. While all estimates fell within expected ranges based on the limited knowledge of each species, it is apparent that the life histories of *Mustelus* spp. in the northern Gulf of Mexico remain poorly understood. As a result, it should be considered a priority to obtain accurate and reliable species-specific life history data on *M. canis*, *M. norrisi* and *M. sinusmexicanus* before the next assessment of this group.

2.10 Research Recommendations

1. Identify external characters from genetically verified specimens that will definitively differentiate among the three *Mustelus* species occurring in the northern Gulf of Mexico.

2. Increase tagging effort on the three *Mustelus* species occurring in the northern Gulf of Mexico to gain knowledge pertaining to movement patterns and seasonally mediated distribution.

3. Reexamine all aspects of the species-specific life histories of the three *Mustelus* species occurring in the Gulf of Mexico.

4. Encourage collection of the full suite of body length measurements (i.e. precaudal length, fork length, total length and stretch total length) of all *Mustelus* species occurring in the northern Gulf of Mexico to generate length-length relationships based on a robust sample size.

2.11 Literature Cited

Bethea, D.M. and W.B. Driggers. 2014. Tag and recapture data for smoothhound sharks, *Mustelus* spp., in the Gulf of Mexico and US South Atlantic: 1998-2012. SEDAR39-DW-01. SEDAR, North Charleston, SC. 11 pp.

Giresi, M.M. and D.S. Portnoy. 2014. Seasonal Distribution of *Mustelus canis* off the Atlantic coast of the U.S. SEDAR39-DW-29. SEDAR, North Charleston, SC. 3 pp.

Jones, L.M., W.B. Driggers III, K.M. Hannan, E.R. Hoffmayer, and C.M. Jones. 2014. Identification, Life History and Distribution of *Mustelus canis*, *M. norrisi* and *M. sinusmexicanus* in the northern Gulf of Mexico. SEDAR39-DW-22. SEDAR, North Charleston, SC. 24 pp.

Kohler, N.E., P.A. Turner, M. Pezzullo, and C.T. McCandless. 2014. Mark/Recapture Data for the Smooth Dogfish, *Mustelus Canis*, in the western North Atlantic from the NEFSC Cooperative Shark Tagging Program. SEDAR39-DW-20. SEDAR, North Charleston, SC. 24 pp.

2.12 Tables

Table 2.12.1. Summary of Recommended Life History Parameters for *Mustelus canis* / *M. sinusmexicanus* group

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

Life history Workgroup	**Gulf of Mexico**				
Pupping month	May-July				SEDAR39-DW-22
Growth parameters	Low	*M. canis* and *M. sinusmexicanus* combined sexes	High	*M. canis* combined	
L_∞ (cm FL)	101.13	109.65	118.16	113.78	SEDAR39-DW-22
K	0.12	0.15	0.19	0.13	SEDAR39-DW-22
t_o	-4.07	-3.41	-2.76	-3.87	SEDAR39-DW-22
Maximum observed age	*M. canis*: 13 female, 11 male, *M. sinusmexicanus*: 14 female, 9 male				SEDAR39-DW-22
Sample size	932 (682 female, 250 male)				SEDAR39-DW-22
Length-weight relationships	Combined: FL= 1.0532(PCL) + 1.9399 r^2 = 0.99 (n=87)				SEDAR39-DW-22
FL in cm	Combined: FL= 0.8532(STL) + 0.655 r^2 = 0.97 (n=43)				SEDAR39-DW-22
WT in kg	Combined FL= 0.8856(TL) - 0.2375 r^2 = 0.97 (n=864)				SEDAR39-DW-22
	M. canis female: WT = (2.0*10^-6)*FL^3.258 r^2 = 0.95 (n=398)				
	M. canis male: WT = (3.0*10^-6)*FL^3.108 r^2 = 0.90 (n=148)				
	M. sinusmexicanus female: WT = (3.0*10^-6)*FL^3.135 r^2 = 0.88 (n=250)				
	M. sinusmexicanus male: WT = (2.0*10^-6)*FL^3.213 r^2 = 0.90 (n=76)				SEDAR39-DW-22
Size at maturity (FL)	Males 69.2 cm, females 75.1 cm, combined 71.5 cm				
Median age (years) at maturity	males 3.3, females 4.1, combined 3.6				SEDAR39-DW-22
Reproductive cycle	Annual				
Fecundity	No relationship btw maternal size and brood size for *M. canis* or *M. sinusmexicanus; M. canis* mean = 15.5 (S.D. = 2.80, range =11-20),*M. sinusmexicanus* mean=5 (S.D. = 2.80, range 3-10)				SEDAR39-DW-22
Gestation	10-11 months				SEDAR39-DW-22
Sex-ratio	1:1				SEDAR39-DW-22
Stock structure	No exchange between Atlantic and Gulf based on tagging data, genetic information suggests one stock				SEDAR39-DW-01

Table 2.12.2. Summary of Recommended Life History Parameters for *Mustelus norrisi*

Table 2.12.2. Summary of *Mustelus norrisi* -- Biological Inputs for 2014 Assessment

Life history Workgroup	**Gulf of Mexico**	
Pupping month	April	SEDAR39-DW-22
Growth parameters	Combined sexes	
L_∞ (cm FL)	95.05	SEDAR39-DW-22
K	0.25	SEDAR39-DW-22
t_o	-2.03	SEDAR39-DW-22
Maximum observed age	9 female, 9 male	SEDAR39-DW-22
Sample size	60 (34 female, 26 male)	SEDAR39-DW-22
Length-weight relationships	Combined: FL=1.0351(PCL) + 3.7305 r^2 =0.99 (n=10)	SEDAR39-DW-22
FL in cm	Combined: FL=0.8895(STL) - 2.4015 r^2 =1.00 (n=4)	SEDAR39-DW-22
WT in kg	Combined FL=0.9157(TL) - 2.3258 r^2 =0.97 (n=62) *M. norrisi* female: WT = (2.0*10^-6)*FL^3.2486 r^2 = 0.92 (n=34) *M. norrisi* male: WT = (2.0*10^-5)*FL^2.6353 r^2 = 0.85 (n=26)	SEDAR39-DW-22
		SEDAR39-DW-22
Size at maturity (FL)	Males 53.9 cm, females 58.5 cm	
Median age (years) at maturity	males 3.3, females 4.1, combined 3.6	SEDAR39-DW-22
Reproductive cycle	Annual	
Fecundity	mean = 11.3 (S.D. = 2.10, range =8-14	SEDAR39-DW-22
Gestation	10-11 months	SEDAR39-DW-22
Sex-ratio	1:1	SEDAR39-DW-22
Stock structure	No exchange between Atlantic and Gulf based on tagging data, genetic information suggests one stock	SEDAR39-DW-01

Table 2.12.3: von Bertalanffy Growth Function parameter estimates for *Mustelus canis*, *M. norrisi* and *M. sinusmexicanus* from the northern Gulf of Mexico. L_∞ and t_o are reported in cm FL and years, respectively. Models considered to represent low and high values for *Mustelus* spp. are highlighted in gray.

Species	Sex	L_∞	*k*	t_o	*N*	r^2
Combined	Combined	109.62	0.15	-3.42	518	0.74
Combined	Female	130.32	0.12	-3.50	224	0.78
Combined	Male	93.89	0.23	-2.70	293	0.75
M. canis	Combined	113.78	0.13	-3.87	369	0.75
M. canis	Female	128.95	0.12	-3.65	166	0.80
M. canis	Male	96.88	0.19	-3.23	203	0.76
M. norrisi	Combined	95.05	0.25	-2.03	94	0.64
M. norrisi	Male	85.86	0.4	-1.40	57	0.74
M. sinusmexicanus	Combined	104.58	0.16	-3.99	54	0.58

Table 2.12.4. Summary of age and size at maturity for *Mustelus canis* / *M. sinusmexicanus* group and *M. norrisi* in the northern Gulf of Mexico.

Species	Sex	Age (years) at 50% maturity (a, b, n)	Size (cm FL) at 50% maturity (a, b, n)
M. canis / sinusmexicanus	Combined	3.61 (-5.67, 1.57, 346)	71.54 (-23.62, 0.33, 656)
	Female	4.11 (-6.31, 1.54, 145)	75.09 (-55.54, 0.74, 303)
	Male	3.28 (-5.36, 1.63, 201)	69.20 (-21.98, 0.32, 353)
M. norrisi	Combined	3.61 (-5.67, 1.57, 346)	-
	Female	4.11 (-6.31, 1.54, 145)	58.50
	Male	3.28 (-5.36, 1.63, 201)	53.86 (-74.15, 1.38, 39)

Table 2.12.5. Recommended sex-specific size at maturity schedules for the *Mustelus canis* / *M. sinusmexicanus* group in the northern Gulf of Mexico.

Fork 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	0.01
60	0.00	0.05
65	0.00	0.21
70	0.02	0.56
75	0.48	0.86
80	0.97	0.97
85	1.00	0.99
90	1.00	1.00
95	1.00	1.00
100	1.00	1.00
105	1.00	1.00
110	1.00	1.00
115	1.00	1.00
120	1.00	1.00
125	1.00	1.00
130	1.00	1.00

Table 2.12.6. Recommended sex-specific age at maturity schedules for the *Mustelus canis* / *M. sinusmexicanus* group in the northern Gulf of Mexico.

Age (years)	Female	Male
0	0.00	0.00
0.5	0.00	0.01
1	0.01	0.02
1.5	0.02	0.05
2	0.04	0.11
2.5	0.08	0.22
3	0.15	0.39
3.5	0.28	0.59
4	0.46	0.76
4.5	0.65	0.88
5	0.80	0.94
5.5	0.89	0.97
6	0.95	0.99
6.5	0.98	0.99
7	0.99	1.00
7.5	0.99	1.00
8	1.00	1.00
8.5	1.00	1.00
9	1.00	1.00
9.5	1.00	1.00
10	1.00	1.00
10.5	1.00	1.00
11	1.00	1.00
11.5	1.00	1.00
12	1.00	1.00
12.5	1.00	1.00
13	1.00	1.00
13.5	1.00	1.00
14	1.00	1.00

Table 2.12.7. Recommended size at maturity schedule for male *Mustelus norrisi* in the northern Gulf of Mexico:

Fork length (cm)	Male
30	0.00
35	0.00
40	0.00
45	0.00
50	0.00
55	0.83
60	1.00
65	1.00
70	1.00
75	1.00
80	1.00

2.13 Figures

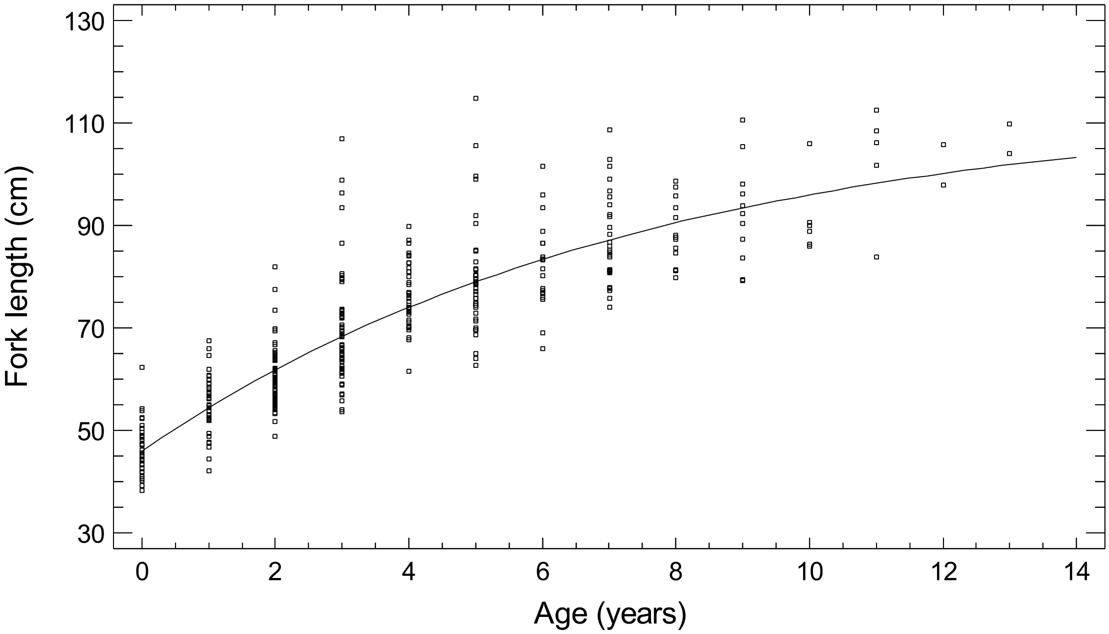

Figure 2.13.1. von Bertalanffy Growth Function (VBGF) for combined *Mustelus canis* in the northern Gulf of Mexico. See Table 2.12.1 for a summary of VBGF parameter estimates.

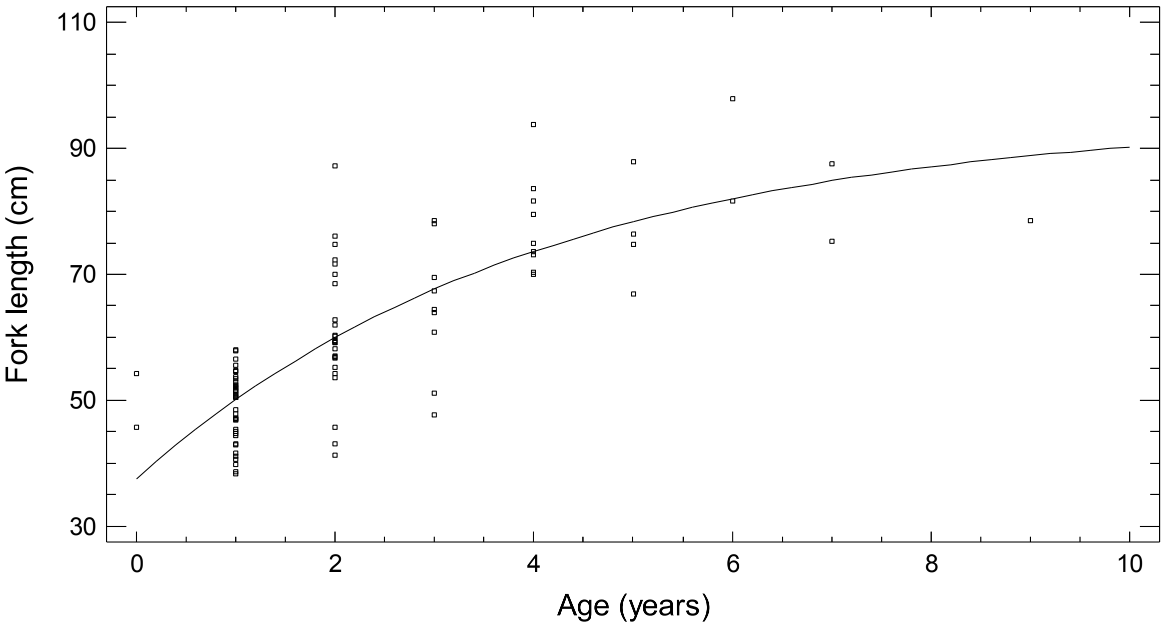

Figure 2.13.2. von Bertalanffy Growth Function (VBGF) for combined *Mustelus norrisi* in the northern Gulf of Mexico. See Table 2.12.2 for a summary of VBGF parameter estimates.

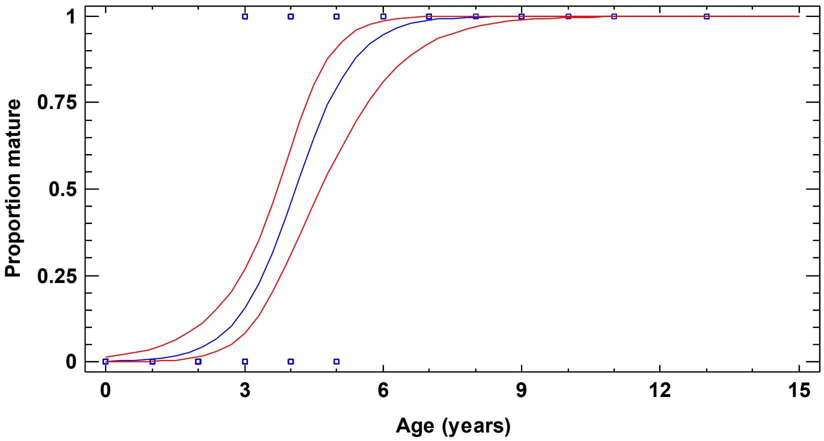

Figure 2.13.3. Age at maturity ogive for females within the *Mustelus canis / M. sinusmexicanus* group in the northern Gulf of Mexico. 95% confidence intervals are indicated by red lines.

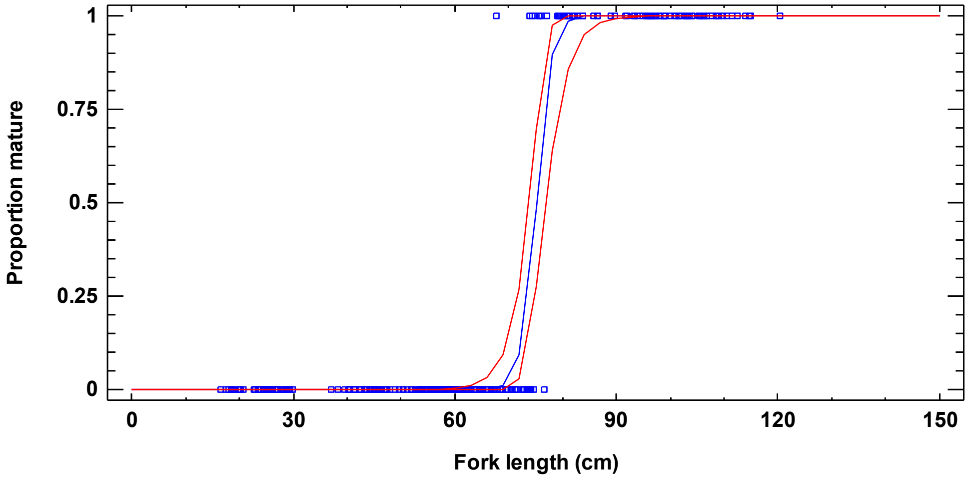

Figure 2.13.4. Size at maturity ogive for females within the *Mustelus canis / M. sinusmexicanus* group in the northern Gulf of Mexico. 95% confidence intervals are indicated by red lines.

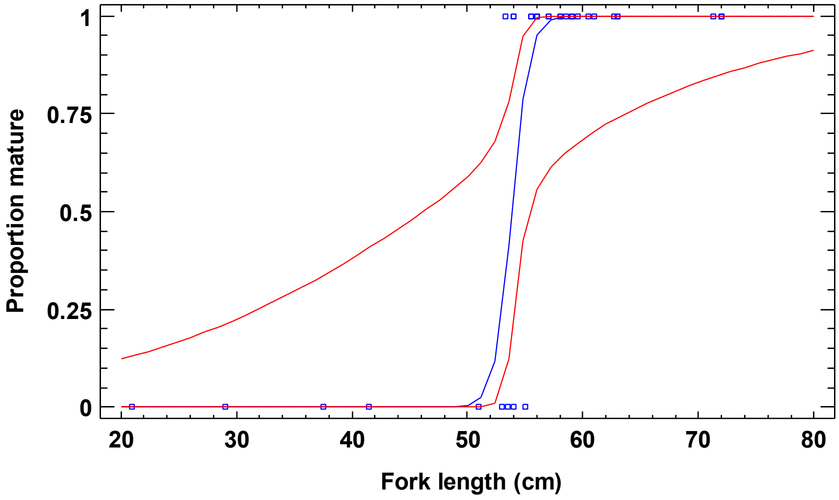

Figure 2.13.5. Size at maturity ogive for male *Mustelus norrisi* in the northern Gulf of Mexico. 95% confidence intervals are indicated by red lines.

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) commercial landings; 2) setting the year for virgin biomass; 3) commercial discards in longline fishery; 4) post-release live-discard mortality rates; and 5) 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-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
Shrimp bycatch estimates for Gulf of Mexico smoothhound sharks were generated using the same approach developed in the SEDAR 34 HMS Gulf of Mexico Atlantic sharpnose and bonnethead shark assessments (Zhang et al 2013a, 2013b; Cortes et al 2013). The estimated shrimp bycatch for

smoothhound sharks is about 100,000 sharks during 2009-2012, but can be as high as 400,000 sharks in the earlier years when shrimp fishery effort was high.

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-26 Discards of *Mustelus* spp. in the Gulf of Mexico reeffish bottom longline fishery.
John Carlson, Elizabeth Scott-Denton, and Kevin McCarthy
Observer reported *Mustelus* spp. discard rates from 2006-2012, along with self reported commercial fishing effort data, were used to calculate *Mustelus* spp. live and dead discards from the reeffish bottom longline fishery in the Gulf of Mexico. Fishing effort data were available from the coastal logbook program for the years 1990-2012. Beginning in 1993 all commercial vessels with Federal fishing permits (other than those for swordfish, tunas, and shrimp) were required to report landings and effort to the coastal logbook program. Only effort defined as targeting reefish (trips with reefish landings >2/3 of total landings for the trip) was included in the discard calculations. Total discards were calculated as the product of observer reported yearly mean discard rates and the yearly total targeted fishing effort (sets fished) 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. To calculate discards for the years 1990-2005 the mean discard rate across the years 2006-2012 was used. Yearly total dead discards prior to 2006

were calculated as the product of the median discard rate and the year-specific targeted effort. Total live discards for *Mustelus* spp. were higher than the total discard dead.

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 were compiled from GulfFIN (Gulf Fisheries Information Network) for the Gulf of Mexico region. Initial extractions found essentially no landings of *Mustelus* spp. reported in that database. Additional extractions from GulfFIN during the workshop revealed very small quantities of *M. canis* landings from 2010 to present and small quantities of unclassified dogfish under a code for the Family Squalidae intermittently between 2000 and 2007 for the Gulf of Mexico (GOM). It was shared by a member of the WG that it was common practice for GOM bottom longline fishermen to immediately use smoothhound as bait; therefore, since they were not landed they would not be included on reports as landings. This may explain the disparity between commercial landings and the abundance reflected in observer and research data. Given the very small magnitude of commercial landings, the Catch WG opted not to consider this data set.

Decision 1. Treat Gulf of Mexico catches for the smoothhound complex and Atlantic catches for smooth dogfish separately.

Decision 2. Do not consider commercial landings of smoothhounds in the Gulf of Mexico given their very small magnitude.

Discussions between all WGs (Catches, Life History, Indices of abundance) resulted in setting the year of virgin biomass in the Gulf of Mexico to 1982. This choice was based on a combination of available data from indices, commercial discards, recreational catches, and observer data as well as an understanding of the fishery.

Decision 3. Set the year of virgin biomass for the smoothhound complex in the Gulf of Mexico at 1982.

3.4 Commercial Fishery Discards

The Panama City Laboratory Bottom Longline Observer Program has collected extensive fishery and biological data from the fleet of bottom longline federally permitted vessels since 2005. The NMFS-

Galveston Laboratory also began observer coverage of this fishery in 2006 as part of the observer program to monitor the reeffish fishery in the Gulf of Mexico. Both programs have continued observations of this fishery since 2006. During some hauls, *Mustelus* spp., are caught as bycatch and retained and landed.

Total discards of *Mustelus* spp. in the reeffish bottom longline fishery were originally calculated for 2006-2012. Discard rates (alive and dead) in 2008 were substantially larger than those rates for all other years presented. Discussions with the panel reflected concerns of using possibly erroneous data in back-calculating rates. Therefore, additional data were acquired from the Coastal Fishery Logbook Program (CFLP) back to 1990 containing bottom longline effort data. A median bycatch rate was calculated from the observer data for the years 2006-2012. Total discards were calculated using the median discard rate multiplied by the year-specific effort data from the CFLP. 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 bottom longline fishery are presented in **Tables 3.13.1 and 3.13.2**, respectively. **Figure 3.14.1** shows all annual catches stacked (top) and as a proportion (middle), and catches for the entire time period (1982-2012) as proportions (bottom). Total commercial longline discards accounted for a very small proportion of catches in any given year and for ca. 2% of all catches for the entire time period (see also **Table 3.13.3**).

Decision 4. Use the median discard bycatch rate for smoothhound sharks in the Gulf of Mexico calculated from the observer programs and bottom longline fishery effort for 2006-2012 and apply it to the remainder of the time series (back to 1990) to generate discards for 1990-2005.

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 3.13.4**) 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 % (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 3.13.4**).

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 3.13.4**) obtained from the scientific literature for *Mustelus* spp.: 27.0% (Frick et al. 2010b); and for *S. acanthias* from the northwest Atlantic: 29% (Mandelman and Farringdon 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 3.13.4**).

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 3.13.4**) 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 3.13.4**, SEDAR 39-DW-21). A high PRLDM rate for hook and line fisheries (High-$PRLDM_{\text{hook and line}}$ = 24 %; **Table 3.13.4**) 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 3.13.4**).

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 $_{\text{longline}}$ = 8 %; **Table 3.13.4**). 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 $_{\text{longline}}$ = 19 %; **Table 3.13.4**). 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 $_{\text{longline}}$ = 13.5 %; **Table 3.13.4**).

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. The panel recommended using the GOM SEAMAP summer CPUE to scale the mean 2009-2012 bycatch CPUE based on Observer data for 1982-2008. To avoid the large interannual variability in the SEAMAP summer CPUE, the panel recommended using a linear or nonlinear trend of the SEAMAP summer CPUE vs. year (**Figure 3.14.2**), and the ratio of the mean 2009-2012 bycatch CPUE and the mean 2009-2012 SEAMAP summer CPUE to scale the bycatch CPUE for 1982-2008 (**Figure 3.14.3**).

Calculation of the annual bycatch during 1982-2008 was based on the scaled bycatch CPUE (1982-2008) multiplied by estimated shrimp effort during 1982-2008, and by the estimated number of nets per vessel (NPV) for the shrimp fishery during 1982-2008. The difference between the linear and nonlinear global trends is negligible as can be seen in **Figure 3.14.4**. The approach is being referred to as “Option 2B Linear” and “Option 2B Nonlinear” and is defined as:

Step 1:

$\text{Pred\_SEAMAP\_CPUE}_{[yr]}$ = linear or nonlinear regression of SEAMAP CPUE vs. Year

where yr = 1982-2012

Step 2:

$\text{Scaled\_CPUE}_{[yr]} =$

$(\text{2009\_2012\_Mean\_CPUE}/\text{2009\_2012\_Mean\_SEAMAP\_CPUE}) * \text{Pred\_SEAMAP\_CPUE}_{[yr]}$

where yr = 1982-2008

Step 3:

$\text{Bycatch}_{[yr]} = \text{Scaled\_CPUE}_{[yr]} * \text{Effort}_{[yr]} * \text{NPV}_{[yr]}$

where yr = 1982-2008

Shrimp trawl fishery discards accounted for an overwhelming majority of the catches in any given year and over the entire time period (96%; **Figure 3.14.1 bottom panel**).

Decision 9: Gulf of Mexico shrimp bycatch CPUE and bycatch for 2009-2012 based on Observer data reported in SEDAR 39-DW-05 are reasonable estimates. However, determine Gulf of Mexico shrimp bycatch CPUE and bycatch for 1982-2008 using a linear or nonlinear trend of the SEAMAP summer CPUE, and the ratio of the mean 2009-2012 bycatch CPUE and the mean 2009-2012 SEAMAP summer CPUE.

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

Age and growth, reproductive, and length-weight information for the three species of *Mustelus (M. canis*, *M. norrisi*, and *M. sinusmexicanus*) were available from the NMFS MS Laboratories, albeit greatly limited by identification problems and limited sample sizes (see Life History section).

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

No age composition information was available. In contrast, several datasets were made available that contained individual lengths. **Table 3.13.5** 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 the catches.

3.10 Comments on the adequacy of data for assessment analyses

Catch data for smoothhounds in the Gulf of Mexico were considered to be adequate to characterize total removals but only when treated as catches for a complex of *Mustelus* spp. This is because three species of *Mustelus* occur in the GOM and there is a high likelihood of mis-identification in the different catch data streams even when animals are identified to species level. Commercial landings data are essentially inexistent and the catches are overwhelmingly dominated by shrimp trawl discards. These discards are uncertain because they are estimated.

3.11 Research Recommendations

1. Given the high difficulty in differentiating among the three species of *Mustelus* occurring in the Gulf of Mexico, even by experienced shark researchers, we feel it is not appropriate to recommend any species-specific identification by fishermen, observers, port samplers, or dealers. Collection of vertebral samples for systematic characterization of age compositions would also require that the whole specimen or a tissue sample be kept for subsequent macroscopic identification or for genetic analysis, respectively.

2. Increase temporal/spatial/fleet-specific shrimp fleet Observer Program coverage to improve bycatch estimates of *Mustelus* species in the shrimp trawl fishery.

3. Conduct research to explore and test the relationship between CPUEs based on shrimp fleet Observer Program and survey (SEAMAP) to indirectly estimate pre-2009 shrimp bycatch CPUE for *Mustelus* species when Observer program data were very limited.

3.12 Literature Cited

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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.

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3.13 Tables

Table 3.13.1. Estimated live discards of *Mustelus* spp. from the bottom longline fishery in the Gulf of Mexico based on the Panama City and Galveston Bottom Longline 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
1990	10963		0.5501	6,031	2,355	15,287
1991	19159		0.5501	10,540	4,115	26,715
1992	10826		0.5501	5,956	2,325	15,096
1993	34019		0.5501	18,715	7,307	47,435
1994	40785		0.5501	22,437	8,760	56,870
1995	36416		0.5501	20,034	7,822	50,778
1996	39941		0.5501	21,973	8,579	55,693
1997	46073		0.5501	25,347	9,896	64,243
1998	38713		0.5501	21,297	8,315	53,980
1999	40260		0.5501	22,149	8,647	56,138
2000	38945		0.5501	21,425	8,365	54,304
2001	38112		0.5501	20,967	8,186	53,142
2002	35414		0.5501	19,483	7,606	49,380
2003	38636		0.5501	21,255	8,298	53,873
2004	36276		0.5501	19,957	7,792	50,582
2005	27697		0.5501	15,237	5,949	38,620
2006	29738	228	0.1228	3,652	0	3,952
2007	25770	372	0.1237	3,187	0	23,670
2008	27047	274	2.7701	74,922	0	463,496
2009	16753	804	1.2898	21,608	0	111,878
2010	13337	2019	0.5503	7,339	0	21,841
2011	19408	2542	0.1987	3,856	0	17,667
2012	16647	1087	0.5501	9,158	0	44,737

Table 3.13.2. Estimated dead discards of *Mustelus* spp. from the bottom longline fishery in the Gulf of Mexico based on the Panama City and Galveston Bottom Longline Observer Program and Costal Fishery Logbook Program data. Discards are reported as number of fish.

Year	Total sets	Total Observer Sets	Mean per set discard dead	MEAN TOTAL DISCARDS	LCL	UCL
1990	10963		0.0249	273	81	755
1991	19159		0.0249	477	141	1,319
1992	10826		0.0249	269	80	745
1993	34019		0.0249	846	250	2,342
1994	40785		0.0249	1,015	300	2,808
1995	36416		0.0249	906	268	2,507
1996	39941		0.0249	994	294	2,750
1997	46073		0.0249	1,146	339	3,172
1998	38713		0.0249	963	285	2,665
1999	40260		0.0249	1,001	296	2,772
2000	38945		0.0249	969	286	2,681
2001	38112		0.0249	948	280	2,624
2002	35414		0.0249	881	260	2,438
2003	38636		0.0249	961	284	2,660
2004	36276		0.0249	902	267	2,497
2005	27697		0.0249	689	204	1,907
2006	29738	228	0.0044	130	0	
2007	25770	372	0.0000	0	0	0
2008	27047	274	0.1350	3,652	0	26,595
2009	16753	804	0.0249	417	0	4,466
2010	13337	2019	0.0583	778	0	
2011	19408	2542	0.0063	122	0	
2012	16647	1087	0.0434	722	0	

Table 3.13.3. Total catches of smoothhounds in the Gulf of Mexico (all in numbers). The first column are estimated dead discards from the shrimp trawl fishery (option 2B Nonlinear); the second column includes dead discards estimated from reeffish observer programs and effort data from the Coastal Fishery Logbook Program; the third column are live discard estimates from the same source multiplied by the proportion believed to die in longlines (average post-release live discard mortality rate of 13.5%); the fourth and fifth columns are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 x post-release live discard mortality rate for hook and line of 17%). Directed commercial landings are very low, and thus not included in the table.

Year	Com-TR-GOM Disc	Com-RFLL-SE Disc	Com-RFLL-SE (PRM)	Recreational (A+B1)	Recreational (PRM)
1982	64706			0	0
1983	61225			1718	0
1984	66130			3168	0
1985	66963			5841	534
1986	76547			3659	0
1987	84872			5010	93
1988	73644			37	0
1989	81618			7710	0
1990	82550	273	814	5105	0
1991	95380	477	1423	53	0
1992	92963	269	804	1913	1957
1993	91958	846	2527	1833	0
1994	92718	1015	3029	1745	0
1995	94439	906	2705	432	0
1996	111850	994	2966	419	181
1997	130361	1146	3422	775	0
1998	138946	963	2875	2	0
1999	143473	1001	2990	115	0
2000	147426	969	2892	0	0
2001	161907	948	2831	501	0
2002	184941	881	2630	691	0
2003	161454	961	2869	0	16
2004	147112	902	2694	1	0
2005	104376	689	2057	1889	0
2006	105472	130	493	2	0
2007	94656	0	430	0	0
2008	77533	3652	10114	0	0
2009	108711	417	2917	0	0
2010	73837	778	991	190	0
2011	110435	122	521	0	0
2012	95951	722	1236	1258	0

Table 3.13.4. 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.

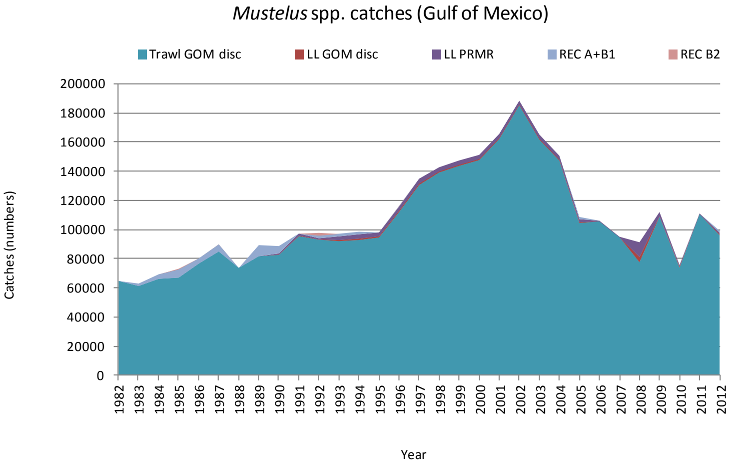
PRLDM rate	Longline	Hook and line	Gillnet	Trawl
Low	8%	10%	13%	0%
Base	13.5%	17%	27%	19%
High	19%	24%	40%	37%

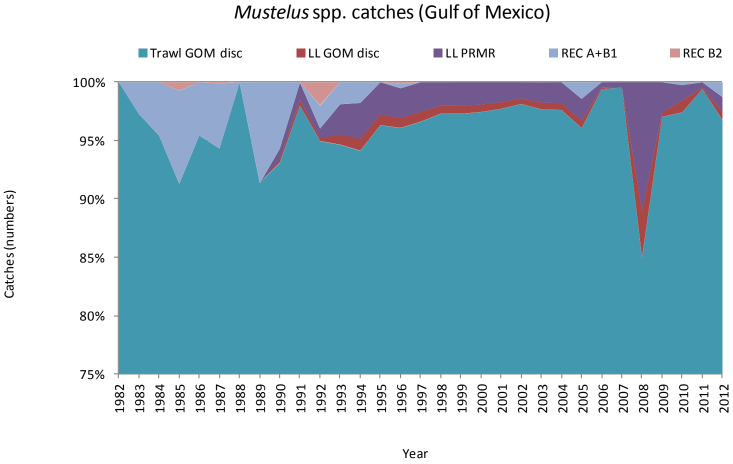
Table 3.13.5. Length compositions available for smoothhounds in the Gulf of Mexico.

Name	Acronym	Years of coverage	Species	Area	Subarea	State	Sex	N	Index used?
NMFS Mississippi Labs Bottom Longline	NMFS SE BLL	1995-96; 00-09; 11-12	*Mustelus canis*	GOM		FL-TX	Yes	572	yes
NMFS Mississippi Labs Bottom Longline	NMFS SE BLL	2000-2008; 2011-2012	*Mustelus norrisi*	GOM		FL-TX	Yes	59	yes
NMFS Mississippi Labs Bottom Longline	NMFS SE BLL	2000; 2007-2012	*Mustelus sinusmexicanus*	GOM		FL-TX	Yes	384	yes
NMFS Mississippi Labs Bottom Longline	NMFS SE BLL	2007; 2009-2012	*Mustelus spp.*	GOM		FL-TX	Yes	136	yes
NMFS Mississippi Labs Small Pelagics Trawl	NMFS Small Pel Trawl	2002-2012	*Mustelus canis*	GOM		FL-TX	Yes	163	yes
NMFS Mississippi Labs Small Pelagics Trawl	NMFS Small Pel Trawl	2002-03; 06-08; 10-12	*Mustelus norrisi*	GOM		FL-TX	Yes	16	yes
NMFS Mississippi Labs Small Pelagics Trawl	NMFS Small Pel Trawl	2007-2011	*Mustelus sinusmexicanus*	GOM		FL-TX	Yes	95	yes
NMFS Mississippi Labs Small Pelagics Trawl	NMFS Small Pel Trawl	2006: 2008-2011	*Mustelus spp.*	GOM		FL-TX	Yes	27	yes
NMFS SEAMAP Groundfish Summer Trawl survey	SEAMAP Groundfish Trawl (Summer)	1989-2012	*Mustelus canis*	GOM		FL-TX	No	352	yes
NMFS SEAMAP Groundfish Summer Trawl survey	SEAMAP Groundfish Trawl (Summer)	1988; 91-99; 01-02; 04-07; 11-12	*Mustelus norrisi*	GOM		FL-TX	No	61	yes
NMFS SEAMAP Groundfish Summer Trawl survey	SEAMAP Groundfish Trawl (Summer)	2007-2008	*Mustelus sinusmexicanus*	GOM		FL-TX	No	28	yes
NMFS SEAMAP Groundfish Fall Trawl survey	SEAMAP Groundfish Trawl (Fall)	1988-2012	*Mustelus canis*	GOM		FL-TX	No	240	yes
NMFS SEAMAP Groundfish Fall Trawl survey	SEAMAP Groundfish Trawl (Fall)	1989-90; 92-97; 03-07; 12	*Mustelus norrisi*	GOM		FL-TX	No	47	yes
NMFS SEAMAP Groundfish Fall Trawl survey	SEAMAP Groundfish Trawl (Fall)	2012	*Mustelus sinusmexicanus*	GOM		FL-TX	No	2	yes
Bottom Longline Observer Program*	BLLOP	1996; 98-99; 03-12	*Mustelus spp.*	GOM		FL-TX	Yes	1483	no
Louisiana SEAMAP Bottom Longline*	LA SEAMAP BL	2011-2012	*Mustelus spp.*	GOM		LA	Yes	498	no
Marine Recreational Information Program*	MRIP	Various 1984-2012	*Mustelus spp.*	GOM		FL-LA	No	91	no
Reeffish BLLOP*	Reeffish BLLOP	2006-2012	*Mustelus spp.*	GOM		NA	No	301	no
Total								4555	

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

3.14 Figures





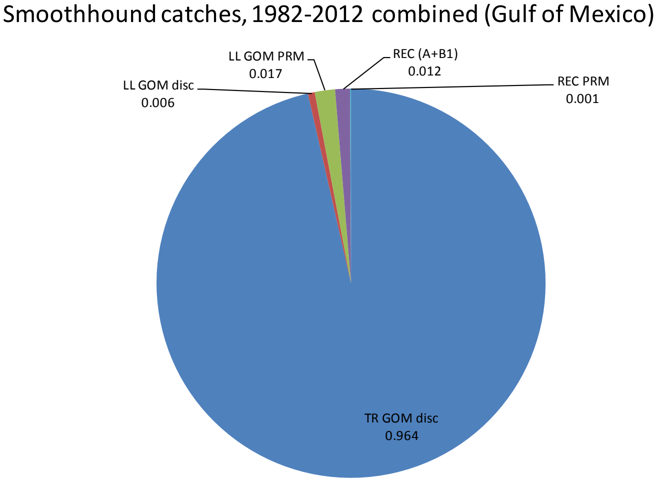


Figure 3.14.1. Catches of smoothhounds in the Gulf of Mexico, 1982-2012: stacked (top), as a proportion (middle), and as a proportion for all years combined (bottom).

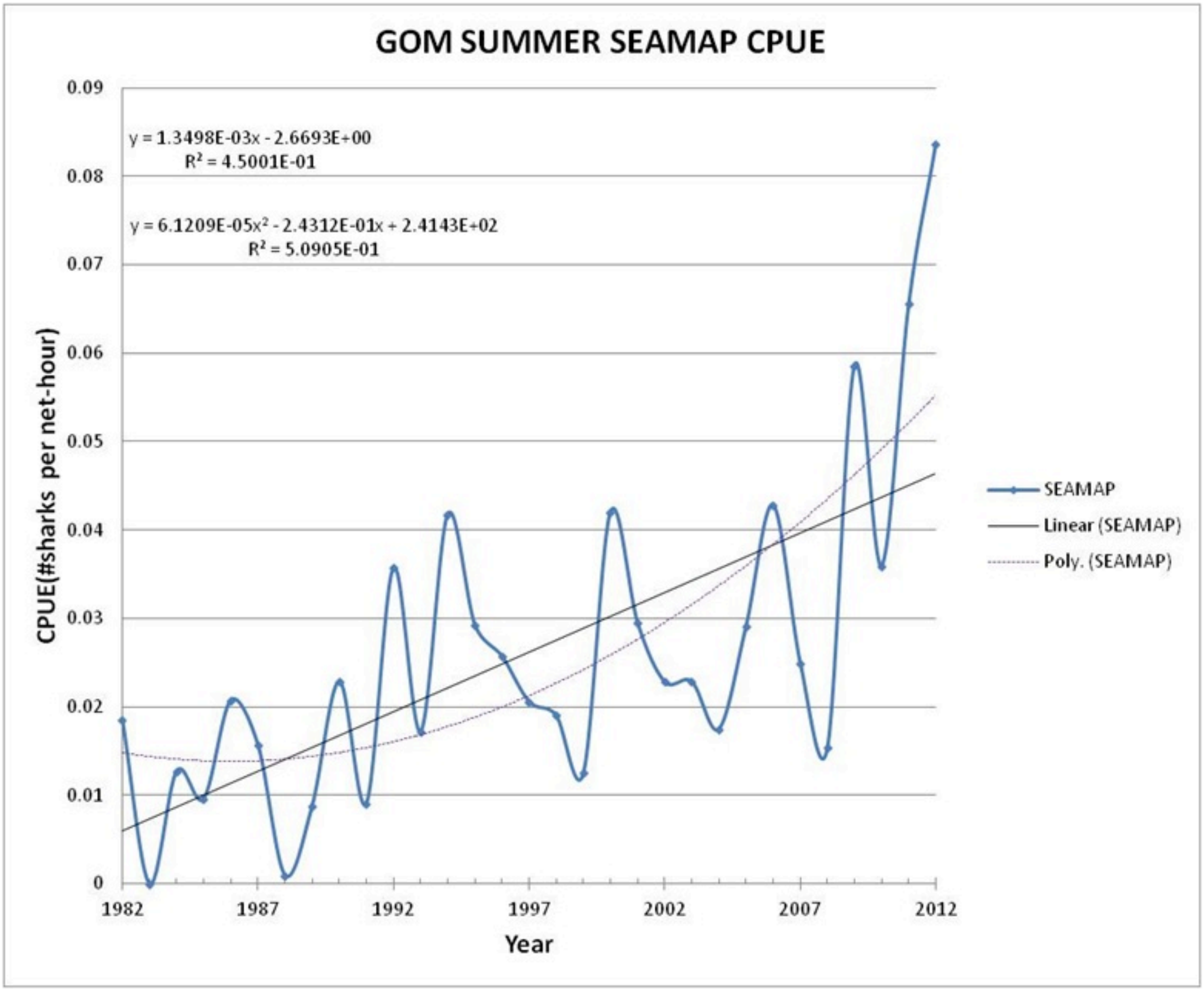


Figure 3.14.2. Gulf of Mexico SEAMAP summer CPUE (SEAMAP). The equations are linear or nonlinear regressions of SEAMAP CPUE vs. year during 1982-2012, which are used to calculate predicted SEAMAP CPUE in Step 1 (y is pred_SEAMAP_CPUE and x is Year, see Section 3.6. for details).

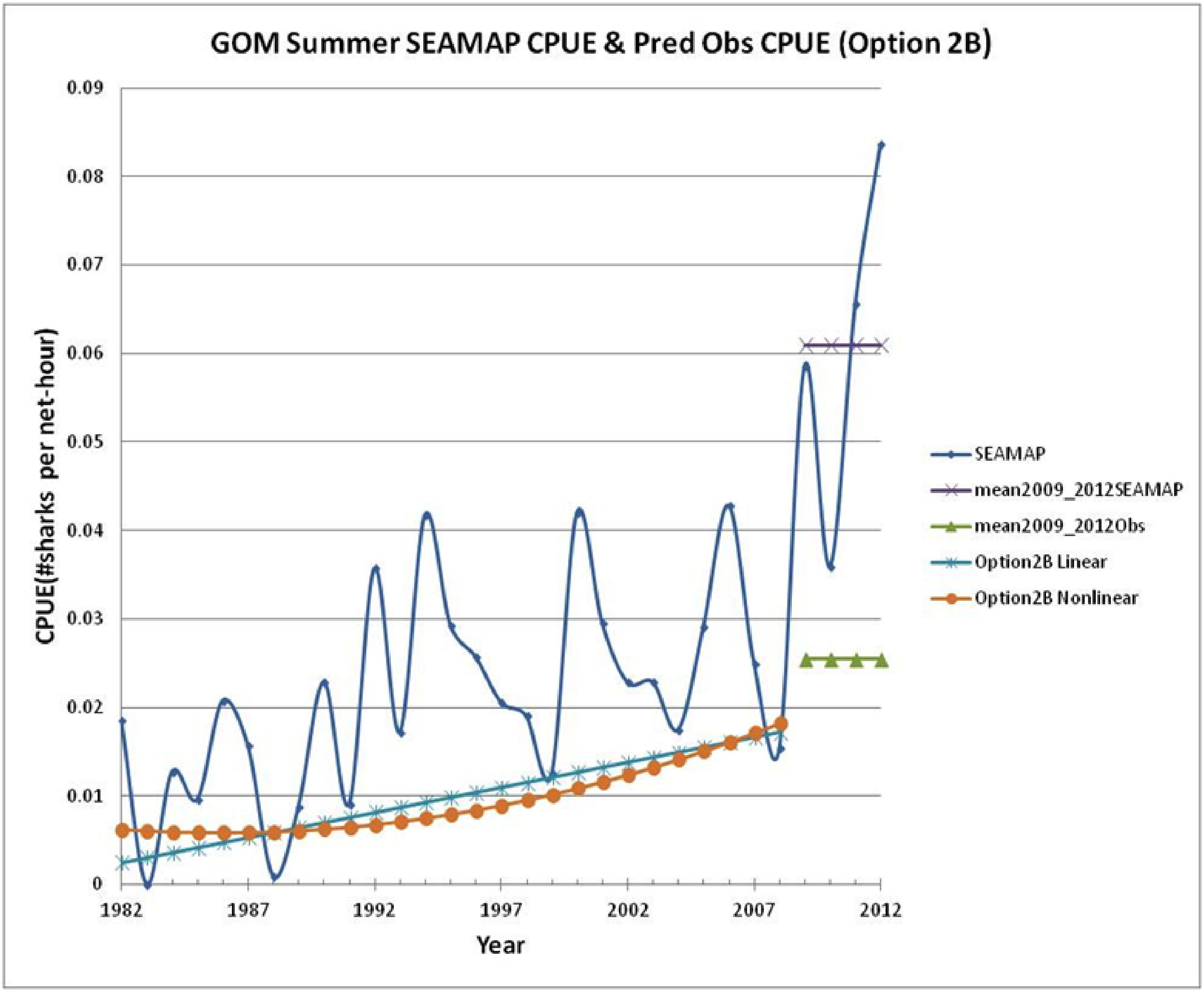


Figure 3.14.3. Gulf of Mexico SEAMAP summer CPUE (SEAMAP) and scaled bycatch CPUE for 1982-2008 (Option2B Linear and Option2B Nonlinear, see Section 3.6. for details). The ratio of the mean 2009-2012 bycatch CPUE (mean2009_2012Obs) and the mean 2009-2012 SEAMAP summer CPUE (mean2009_2012SEAMAP) is 0.41771.

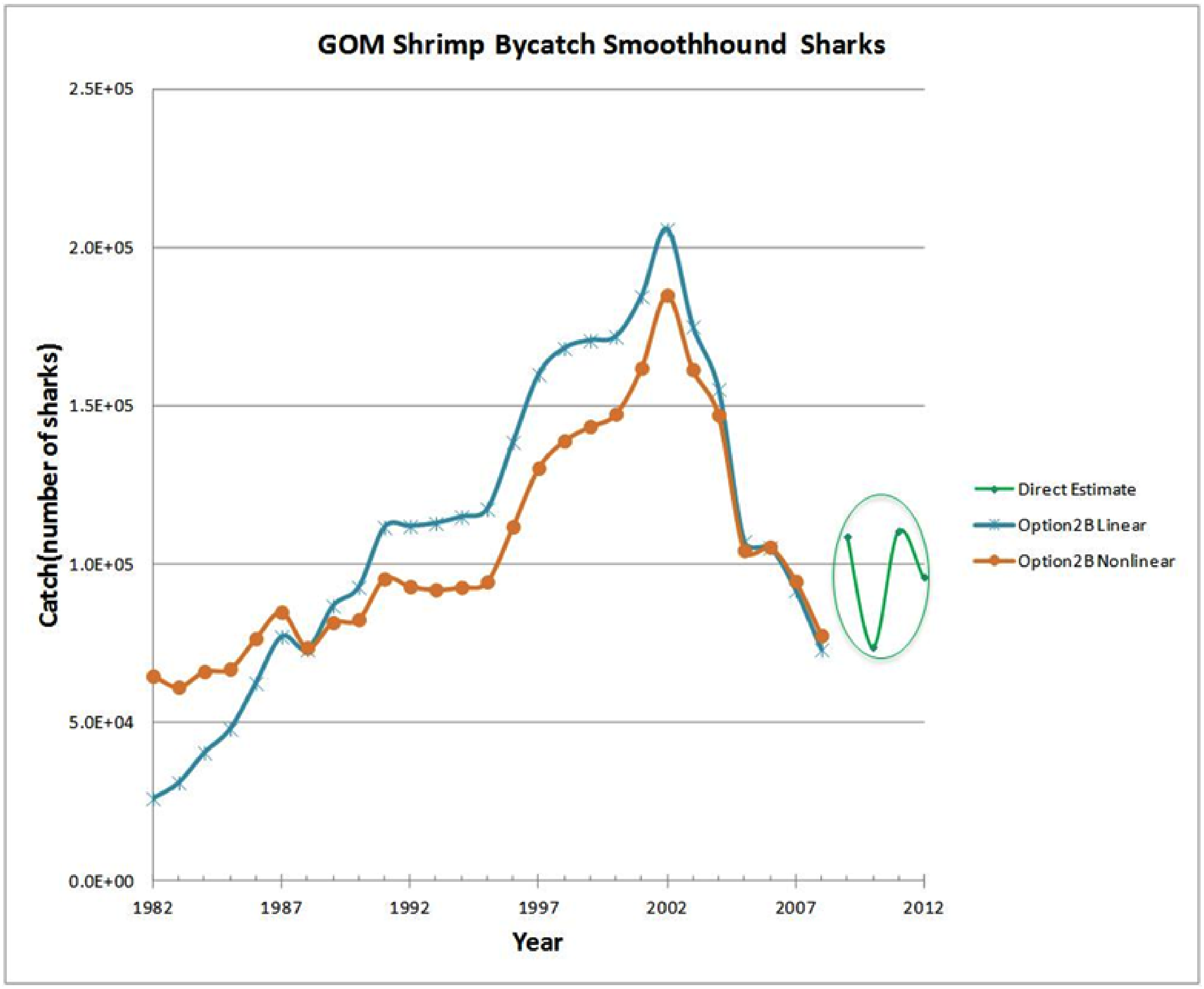


Figure 3.14.4. Bycatch estimate for 2009-2012 (Direct Estimate, see SEDAR 39-DW-05 for details) and bycatch estimate for 1982-2008 based on Option2B Linear and Option2B Nonlinear (see Section 3.6. for details).

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 catch working group (WG), including: 1) assessing recreational catches, 2) post-release live discard mortality rates; and 3) 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

Recreational catches of smoothhound sharks correspond to estimates from three data collection programs: the Marine Recreational Information Program (MRIP), the NMFS Headboat Survey (HBOAT) operated by the SEFSC Beaufort Laboratory, and the Texas Parks and Wildlife Department Recreational Fishing Survey (TXPWD). 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 smoothhound sharks were computed as the sum of the MRIP (A+B1, where A=fished landed and B1=dead discards), HBOAT (fish landed), and TXPWD (fish landed) survey estimates as appropriate.

In the Gulf of Mexico, the vast majority of catches was of smooth dogfish and came predominantly from the MRIP. There were also some isolated catches of *M. norrisi* reported in the MRIP totaling ca. 10,000 animals over 1995, 1997, 1999, 2001, 2002, 2004, and 2005. With the exception of a peak of almost 24,000 animals (120,000 lb ww) in 1984, annual catches never exceeded 8,000 animals (55,000 lb ww) (**Table 4.12.1, Figure 4.13.1 top panel**). Most of the catches both in numbers and weight were from the west coast of Florida (**Figure 4.13.2**). **Table 4.12.1** shows all catches of smoothhounds in the Gulf of Mexico, including recreational landings and dead discards (A+B1) and live recreational releases in the last two columns. **Figure 4.13.3** shows all annual catches stacked (top) and as a proportion (middle), and catches for the entire time period (1982-2012) as proportions (bottom). Recreational landings and dead discards accounted for only ca. 1% of the total catches.

Confidence intervals for A+B1 catches of smoothhounds in the Gulf of Mexico were calculated based on CVs and are presented in **Figure 4.13.4.**

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 smoothhounds (see Post-release live discard mortality section). The sporadic live releases (B2) were mostly from Louisiana (**Figure 4.13.5**). **Table 4.12.1** also shows recreational discards released alive (B2) assumed to die (B2 in numbers x post-release live discard mortality rate for hook and line) in the last column. **Figure 4.13.**3 (bottom panel) shows that these recreational discards were almost negligible.

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 4.12.4, 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 1: 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 is not 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 4.12.3).

4.9 Comments on the adequacy of data for assessment analyses

Catch data for smoothhounds in the Gulf of Mexico were considered to be adequate to characterize total removals but only when treated as catches for a complex of *Mustelus* spp. This is because three species of *Mustelus* occur in the GOM and there is a high likelihood of mis-identification in the different catch data streams even when animals are identified to species level. Recreational landings, dead discards, and live releases are all estimated, but represent a very small fraction of total estimated catches of smoothhounds in the Gulf of Mexico.

4.10 Research Recommendations

1. Given the high difficulty in differentiating among the three species of *Mustelus* occurring in the Gulf of Mexico, even by experienced shark researchers, we feel it is not appropriate to recommend any species-specific identification by fishermen or port samplers. Collection of vertebral samples for systematic characterization of age compositions would also require that the whole specimen or a tissue sample be kept for subsequent macroscopic identification or for genetic analysis, respectively.

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.

SEDAR32-WP-02. Matter, V.M. and A. Rios. 2013. MRFSS to MRIP adjustment ratios and weight estimation procedures for South Atlantic and Gulf of Mexico managed species. SEDAR, North Charleston, SC.

4.12 Tables

Table 4.12.1. Total catches of smoothhounds in the Gulf of Mexico (all in numbers). The first column are estimated dead discards from the shrimp trawl fishery; the second column includes dead discards estimated from reeffish observer programs and effort data from the Coastal Fishery Logbook Program; the third column are live discard estimates from the same source multiplied by the proportion believed to die in longlines (average post-release live discard mortality rate of 13.5%); the fourth and fifth columns are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 x post-release live discard mortality rate for hook and line of 17%).

	Com-TR-GOM	Com-RFLL-SE	Com-RFLL-SE	Recreational	Recreational
Year	Disc	Disc	(PRM)	(A+B1)	(PRM)
1982	64706			0	0
1983	61225			1718	0
1984	66130			3168	0
1985	66963			5841	534
1986	76547			3659	0
1987	84872			5010	93
1988	73644			37	0
1989	81618			7710	0
1990	82550	273	814	5105	0
1991	95380	477	1423	53	0
1992	92963	269	804	1913	1957
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1994	92718	1015	3029	1745	0
1995	94439	906	2705	432	0
1996	111850	994	2966	419	181
1997	130361	1146	3422	775	0
1998	138946	963	2875	2	0
1999	143473	1001	2990	115	0
2000	147426	969	2892	0	0
2001	161907	948	2831	501	0
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2003	161454	961	2869	0	16
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2006	105472	130	493	2	0
2007	94656	0	430	0	0
2008	77533	3652	10114	0	0
2009	108711	417	2917	0	0
2010	73837	778	991	190	0
2011	110435	122	521	0	0
2012	95951	722	1236	1258	0

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 ± 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.

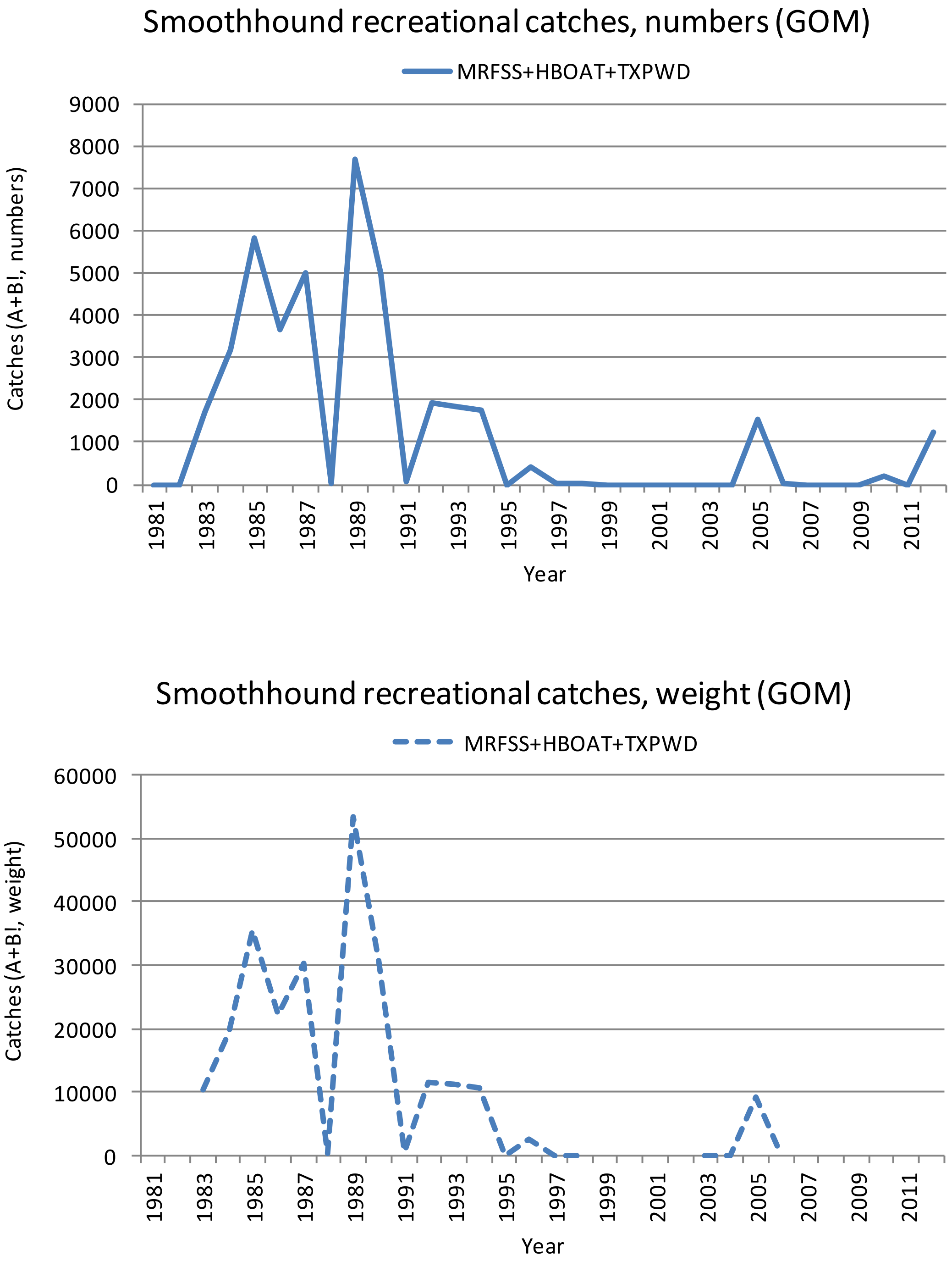
PRLDM rate	Longline	Hook and line	Gillnet	Trawl
Low	8%	10%	13%	0%
Base	13.5%	17%	27%	19%
High	19%	24%	40%	37%

Table 4.12.3. Length compositions available for smoothhounds in the Gulf of Mexico.

Name	Acronym	Years of coverage	Species	Area	Subarea	State	Sex	N	Index used?
NMFS Mississippi Labs Bottom Longline	NMFS SE BLL	1995-96; 00-09; 11-12	*Mustelus canis*	GOM		FL-TX	Yes	572	yes
NMFS Mississippi Labs Bottom Longline	NMFS SE BLL	2000-2008; 2011-2012	*Mustelus norrisi*	GOM		FL-TX	Yes	59	yes
NMFS Mississippi Labs Bottom Longline	NMFS SE BLL	2000; 2007-2012	*Mustelus sinusmexicanus*	GOM		FL-TX	Yes	384	yes
NMFS Mississippi Labs Bottom Longline	NMFS SE BLL	2007; 2009-2012	*Mustelus spp.*	GOM		FL-TX	Yes	136	yes
NMFS Mississippi Labs Small Pelagics Trawl	NMFS Small Pel Trawl	2002-2012	*Mustelus canis*	GOM		FL-TX	Yes	163	yes
NMFS Mississippi Labs Small Pelagics Trawl	NMFS Small Pel Trawl	2002-03; 06-08; 10-12	*Mustelus norrisi*	GOM		FL-TX	Yes	16	yes
NMFS Mississippi Labs Small Pelagics Trawl	NMFS Small Pel Trawl	2007-2011	*Mustelus sinusmexicanus*	GOM		FL-TX	Yes	95	yes
NMFS Mississippi Labs Small Pelagics Trawl	NMFS Small Pel Trawl	2006: 2008-2011	*Mustelus spp.*	GOM		FL-TX	Yes	27	yes
NMFS SEAMAP Groundfish Summer Trawl survey	SEAMAP Groundfish Trawl (Summer)	1989-2012	*Mustelus canis*	GOM		FL-TX	No	352	yes
NMFS SEAMAP Groundfish Summer Trawl survey	SEAMAP Groundfish Trawl (Summer)	1988; 91-99; 01-02; 04-07; 11-12	*Mustelus norrisi*	GOM		FL-TX	No	61	yes
NMFS SEAMAP Groundfish Summer Trawl survey	SEAMAP Groundfish Trawl (Summer)	2007-2008	*Mustelus sinusmexicanus*	GOM		FL-TX	No	28	yes
NMFS SEAMAP Groundfish Fall Trawl survey	SEAMAP Groundfish Trawl (Fall)	1988-2012	*Mustelus canis*	GOM		FL-TX	No	240	yes
NMFS SEAMAP Groundfish Fall Trawl survey	SEAMAP Groundfish Trawl (Fall)	1989-90; 92-97; 03-07; 12	*Mustelus norrisi*	GOM		FL-TX	No	47	yes
NMFS SEAMAP Groundfish Fall Trawl survey	SEAMAP Groundfish Trawl (Fall)	2012	*Mustelus sinusmexicanus*	GOM		FL-TX	No	2	yes
Bottom Longline Observer Program*	BLLOP	1996; 98-99; 03-12	*Mustelus spp.*	GOM		FL-TX	Yes	1483	no
Louisiana SEAMAP Bottom Longline*	LA SEAMAP BL	2011-2012	*Mustelus spp.*	GOM		LA	Yes	498	no
Marine Recreational Information Program*	MRIP	Various 1984-2012	*Mustelus spp.*	GOM		FL-LA	No	91	no
Reeffish BLLOP*	Reeffish BLLOP	2006-2012	*Mustelus spp.*	GOM		NA	No	301	no
Total								4555	

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

4.13 Figures


Smoothhound recreational catches, numbers (GOM)

Smoothhound recreational catches, weight (GOM)

Figure 4.13.1. Recreational catches of smoothhounds in the Gulf of Mexico in numbers (A+B1, top) and weight (lb ww, A+B1, bottom)

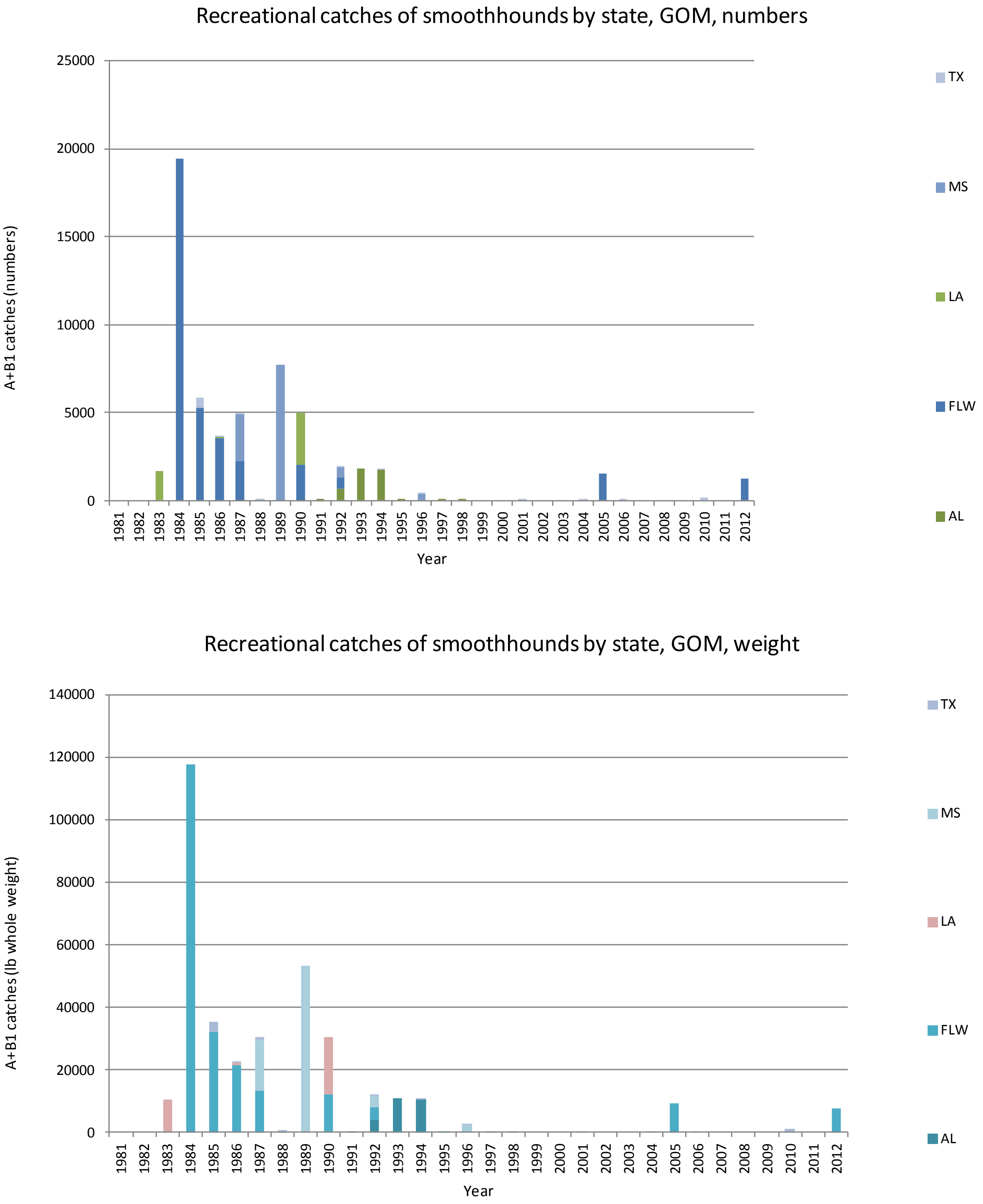
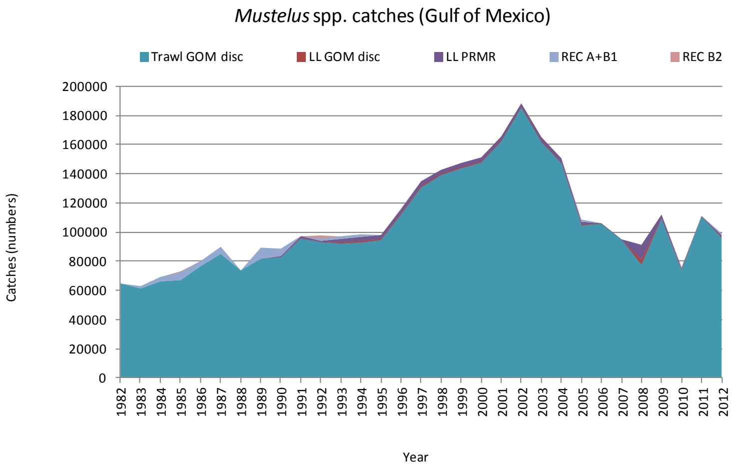
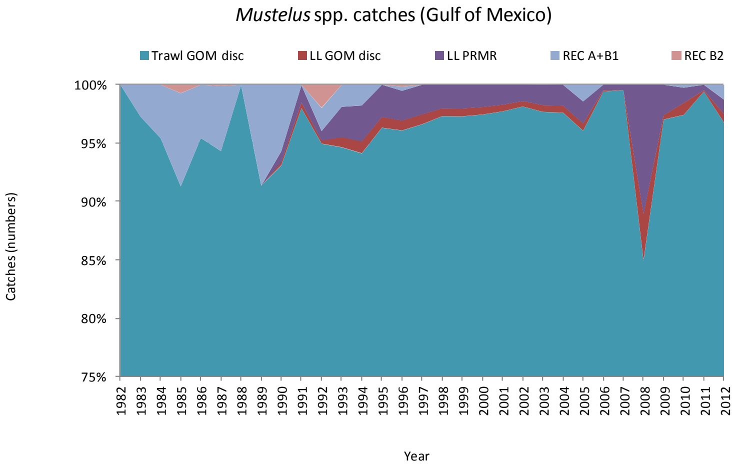


Figure 4.13.2. Recreational catches of smoothhounds in the Gulf of Mexico by state in numbers (A+B1, top) and weight (lb ww, A+B1, bottom).





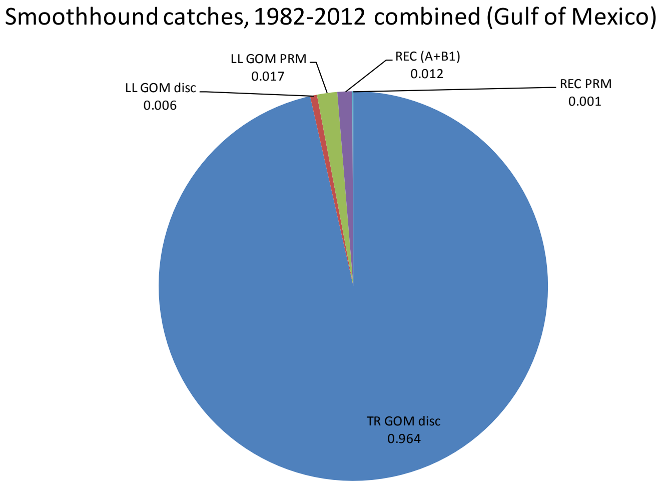


Figure 4.13.3. Catches of smoothhounds in the Gulf of Mexico, 1982-2012: stacked (top), as a proportion (middle), and as a proportion for all years combined (bottom).

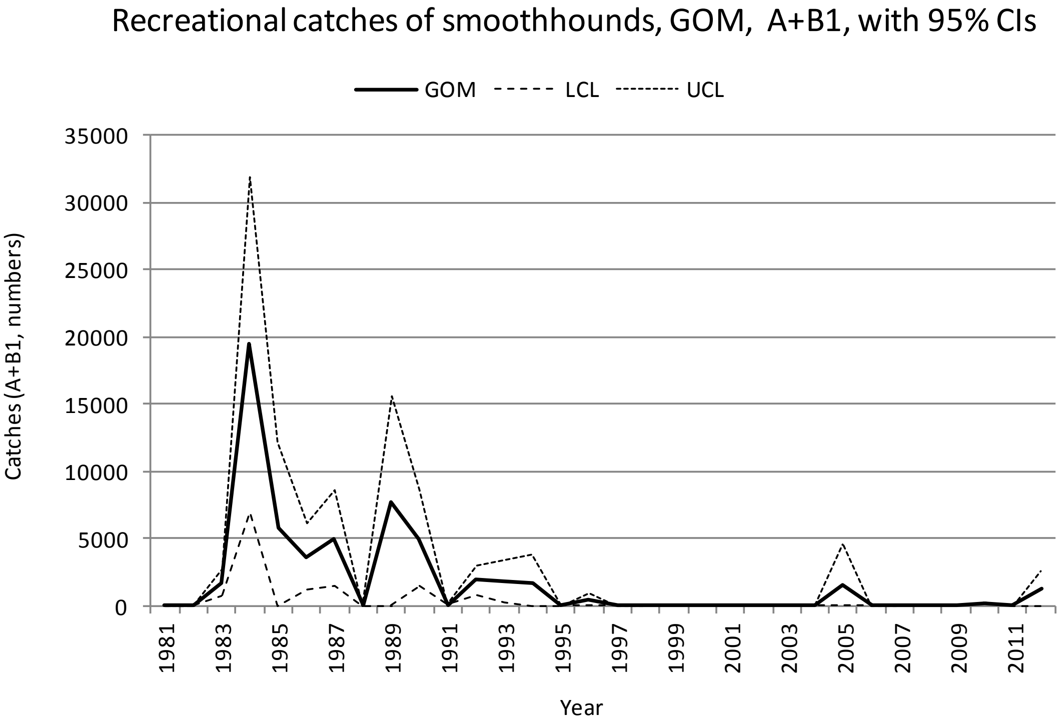


Figure 4.13.4. Variability (as 95% CIs) in estimates of recreational catches of smoothhounds in the Gulf of Mexico (A+B1, numbers).

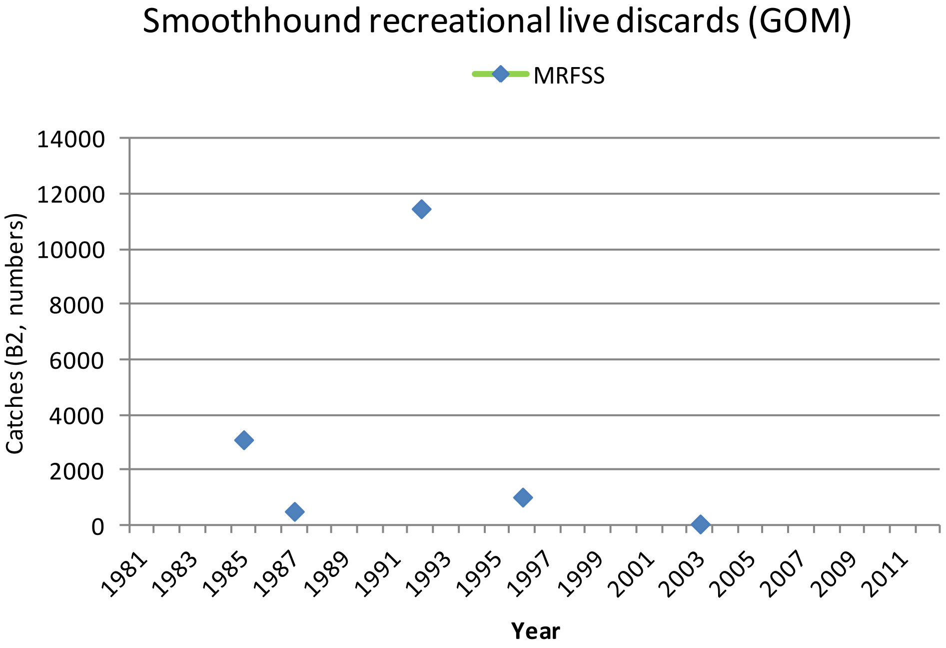


Figure 4.13.5. Recreational live releases (B2) of smoothhounds in the Gulf of Mexico.

5 MEASURES OF POPULATION ABUNDANCE

5.1 Overview

Six indices of abundance were considered for use in the assessment models for *Mustelus* spp. Indices were constructed using both fishery independent and dependent data. For the stock complex of *Mustelus* spp., the Indices Working Group recommended the following indices for use in the stock assessment model for the base run: NMFS Small Pelagics Trawl Survey (SEDAR39-DW-08), NMFS Southeast (SE) Bottom Longline (SEDAR39-DW-06), NMFS SEAMAP Groundfish Trawl Summer, and NMFS SEAMAP Groundfish Trawl Fall (1988-2012) series (SEDAR39-DW-07). Two indices were reviewed, but not recommended for use: the NMFS SEAMAP Groundfish Trawl Fall (1972-1986) series and the Reeffish Bottom Longline Observer series (SEDAR39-DW-04). These indices were not recommended for use because of high coefficients of variation due to sporadic catches and sampling in spatial strata where 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 four working papers describing index construction:

SEDAR39-DW-04	Reeffish Bottom Longline Observer series
SEDAR39-DW-06	NMFS SE Bottom Longline Survey
SEDAR39-DW-07	NMFS SEAMAP Groundfish Trawl Surveys
SEDAR39-DW-08	NMFS Small Pelagics Trawl Survey

5.3 Fishery Independent Indices

5.3.1 Smoothhound Abundance Indices from NMFS Bottom Longline Surveys in the Western North Atlantic and Northern Gulf of Mexico (SEDAR39-DW-06).

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories has conducted standardized bottom longline surveys in the Gulf of Mexico (GOM), Caribbean, and Western North Atlantic Ocean (Atlantic) since 1995. Additionally in 2011, the Congressional Supplemental Sampling Program (CSSP) was conducted where high levels of bottom longline survey effort were maintained from April through October. Data from the SEFSC Bottom Longline Survey and the CSSP Survey were used to produce abundance indices for smoothhound sharks. An abundance index was only produced for the GOM since there were only 3 stations with captures of smoothhound sharks in the Atlantic. All smoothhound sharks captured (*Mustelus spp., Mustelus canis* (smooth dogfish)*, Mustelus norrisi* (Florida smoothhound)*,* and *Mustelus sinusmexicanus* (Gulf smoothhound)) were grouped together and treated as a species complex. Of the 1185 smoothhound captured during the GOM survey, a total of 1151 were measured from 1995 – 2012 with an average fork length of 925 mm. The index was produced with the delta-lognormal method described by Lo *et al.* (1992), and used data from 2000 - 2012. The early years of the survey (1995 – 1999) were dropped because of lack of survey coverage in the deeper depths. The overall trend of the index appeared to be slightly positive. The index was recommended for use in the base run in the stock assessment model (with a ranking of 1). The pros of the index were that it was a fishery independent survey with good spatial (entire GOM) and temporal (12 years) coverage and covered the entire depth range of smoothhound. The one con was the shorter time series, especially when compared to the SEAMAP Groundfish Survey, but the working group felt the spatial and depth coverage outweighed the shorter time series.

5.3.2 Smoothhound Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico (SEDAR39-DW07).

The Southeast Fisheries Science Center Mississippi Laboratories and state partners have conducted groundfish surveys since 1972 in the northern Gulf of Mexico during the summer and fall under several sampling programs. In 1987, both groundfish surveys were brought under the Southeast Area Monitoring and Assessment Program (SEAMAP). These fisheries independent data were used to develop abundance indices for smoothhound. All smoothhound sharks captured (*Mustelus spp., Mustelus canis* (smooth dogfish)*, Mustelus norrisi* (Florida smoothhound)*,* and *Mustelus sinusmexicanus* (Gulf smoothhound)) were grouped together and treated as a species complex. Of the 487 smoothhound captured during the summer survey, a total of 441 were measured from 1988 – 2012 with an average total length of 637 mm. While during the fall survey 379 smoothhound were captured, with 289 measured, with an average total length of 701 mm. Separate indices were produced with the delta-lognormal method described by Lo *et al.* (1992) and used the summer and fall SEAMAP groundfish survey data. Only fall SEAMAP data from 1988 – 2012 was used in the Fall SEAMAP Survey index because of major changes in survey design and survey coverage between 1972 – 1986 and 1987 – 2012 (no smoothhound were captured in 1987). Both the Summer SEAMAP Survey index (1982 – 2012) and Fall SEAMAP Survey index (1988 – 2012) were recommended for use in the stock assessment in the base run with a ranking of 1. The pros of both indices were that they are fishery independent surveys that they have good spatial (entire GOM) and temporal (31 and 25 years for the summer and fall, respectively) coverage. The cons were that it does not cover the entire depth range of smoothhound and it had low catches of smoothhound, but the working group felt the long time series outweighed the lack of coverage and catch.

5.3.3 Smoothhound Abundance Indices from NMFS Small Pelagics Surveys in the Northern Gulf of Mexico (SEDAR39-DW08).

The Southeast Fisheries Science Center Mississippi Laboratories Small Pelagics Survey began in October of 2002 as an outer shelf and upper slope survey in order to investigate if the distributional range of many of species collected in Southeast Area Monitoring and Assessment Program (SEAMAP) groundfish surveys extended beyond the geographical boundaries of the commercial shrimping grounds. By 2004, the survey became a mid to outer shelf and upper slope survey in order to overlap some of the area covered by the SEAMAP Groundfish Survey. All smoothhound sharks captured (*Mustelus spp., Mustelus canis* (smooth dogfish)*, Mustelus norrisi* (Florida smoothhound)*,* and *Mustelus sinusmexicanus* (Gulf smoothhound)) were grouped together and treated as a species complex. Of the 366 smoothhound captured during the survey, a total of 301 were measured from 2002 – 2012 with an average total length of 807 mm. The index was produced with the delta-lognormal method described by Lo *et al.* (1992) and used data from 2002 – 2012. The annual abundance index shows a slight increase in abundance over the course of the time series. The index was recommended for use as a base model in the stock assessment (with a ranking of 1). The pros of the index were that it was a fishery independent survey with good spatial (entire GOM) and temporal (10 years) coverage and cover the entire depth range of smoothhound. The one con was the shorter time series, especially when compared to the SEAMAP Groundfish Survey, but the working group felt the spatial and depth coverage outweighed the shorter time series.

5.4 Fishery Dependent Indices

5.4.1 SEFSC Reeffish Bottom Longline Observer Program (SEDAR39-DW-04).

This reeffish fishery in the Gulf of Mexico consists of approximately 890 federally permitted vessels. Primary gears used in this fishery include bottom longline, vertical line (bandit or handline) and more recently buoy gear. Data collected by at-sea observers of this fishery began in 2005 by the NMFS-Panama City Laboratory and in 2006 by the NMFS-Galveston Laboratory. During some hauls, *Mustelus* spp., are caught as bycatch and discarded or retained and landed. Using combined data from both the Panama City and Galveston Laboratory observer programs, a relative abundance index for *Mustelus* spp. was developed using the Delta-Lognormal approach. Several covariates were used in the analysis including year, depth, hook type, and season. The final models for both the binomial and lognormal models included year, set depth and season. The standardized index was relatively flat with individual years exhibiting high levels of variation.

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 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 recommended 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 that the SEAMAP groundfish data (SEDAR39-DW-07) should be analyzed as three separate indices of abundance for smoothhound. The SEAMAP Fall Survey was originally one long index (1972-2012), but major changes in survey design and expansion of the survey area makes combining the early years (1976-1986) with the recent years (1987-2012) difficult. Thus, three indices were developed during the workshop; SEAMAP Summer Survey (1982-2012), Early SEAMAP Fall Survey (1972-1986) and SEAMAP Fall Survey (1988-2012). However, the working group decided not to recommend the Early SEAMAP Fall Survey (1972-1986) for use due to sporadic catches, with four years of zero catch and three years of one positive catch. The Reeffish Bottom Longline observer program series was also not recommended for use because of high coefficients of variation due to sporadic catches and the working group felt the time series was not very informative. See the evaluation worksheets compiled in SEDAR39-DW-27 for detailed information by time series.

The working group, for the purpose of potentially 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 important for the ranking process. Short time series or limited spatial coverage frequently reduced the ranking of an index.

The working group felt that all indices merited equal weight and subsequently all series were given a score=1.

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

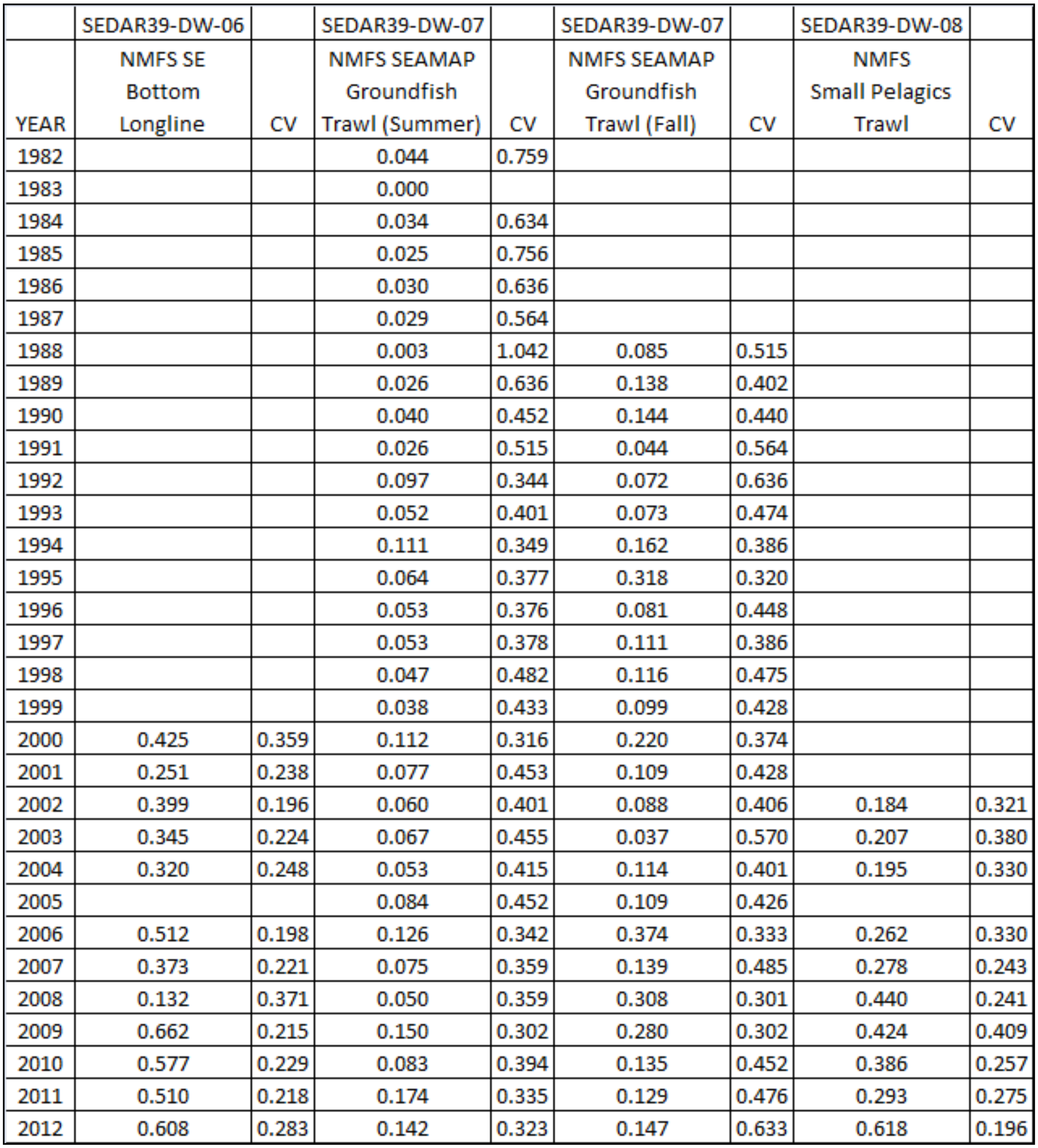
- Monitor/record bottom temperature, salinity, DO on all fishery independent surveys

5.8 Tables

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

Index Name	SEDAR Document Number	Index Type	Rank
NMFS SE Bottom Longline	SEDAR39-DW-06	Independent	1
NMFS SEAMAP Groundfish Trawl (Summer)	SEDAR39-DW-07	Independent	1
NMFS SEAMAP Groundfish Trawl (Fall)	SEDAR39-DW-07	Independent	1
NMFS Small Pelagics Trawl	SEDAR39-DW-08	Independent	1

Table 5.8.2. Recommended indices of abundance for a model base run for the Gulf of Mexico stock of *Mustelus spp.*, including index name and SEDAR document number. CV is the coefficient of variation for the annual index value.



	SEDAR39-DW-06		SEDAR39-DW-07		SEDAR39-DW-07		SEDAR39-DW-08	
YEAR	NMFS SE Bottom Longline	CV	NMFS SEAMAP Groundfish Trawl (Summer)	CV	NMFS SEAMAP Groundfish Trawl (Fall)	CV	NMFS Small Pelagics Trawl	CV
1982			0.044	0.759				
1983			0.000					
1984			0.034	0.634				
1985			0.025	0.756				
1986			0.030	0.636				
1987			0.029	0.564				
1988			0.003	1.042	0.085	0.515		
1989			0.026	0.636	0.138	0.402		
1990			0.040	0.452	0.144	0.440		
1991			0.026	0.515	0.044	0.564		
1992			0.097	0.344	0.072	0.636		
1993			0.052	0.401	0.073	0.474		
1994			0.111	0.349	0.162	0.386		
1995			0.064	0.377	0.318	0.320		
1996			0.053	0.376	0.081	0.448		
1997			0.053	0.378	0.111	0.386		
1998			0.047	0.482	0.116	0.475		
1999			0.038	0.433	0.099	0.428		
2000	0.425	0.359	0.112	0.316	0.220	0.374		
2001	0.251	0.238	0.077	0.453	0.109	0.428		
2002	0.399	0.196	0.060	0.401	0.088	0.406	0.184	0.321
2003	0.345	0.224	0.067	0.455	0.037	0.570	0.207	0.380
2004	0.320	0.248	0.053	0.415	0.114	0.401	0.195	0.330
2005			0.084	0.452	0.109	0.426		
2006	0.512	0.198	0.126	0.342	0.374	0.333	0.262	0.330
2007	0.373	0.221	0.075	0.359	0.139	0.485	0.278	0.243
2008	0.132	0.371	0.050	0.359	0.308	0.301	0.440	0.241
2009	0.662	0.215	0.150	0.302	0.280	0.302	0.424	0.409
2010	0.577	0.229	0.083	0.394	0.135	0.452	0.386	0.257
2011	0.510	0.218	0.174	0.335	0.129	0.476	0.293	0.275
2012	0.608	0.283	0.142	0.323	0.147	0.633	0.618	0.196

5.9 Figures

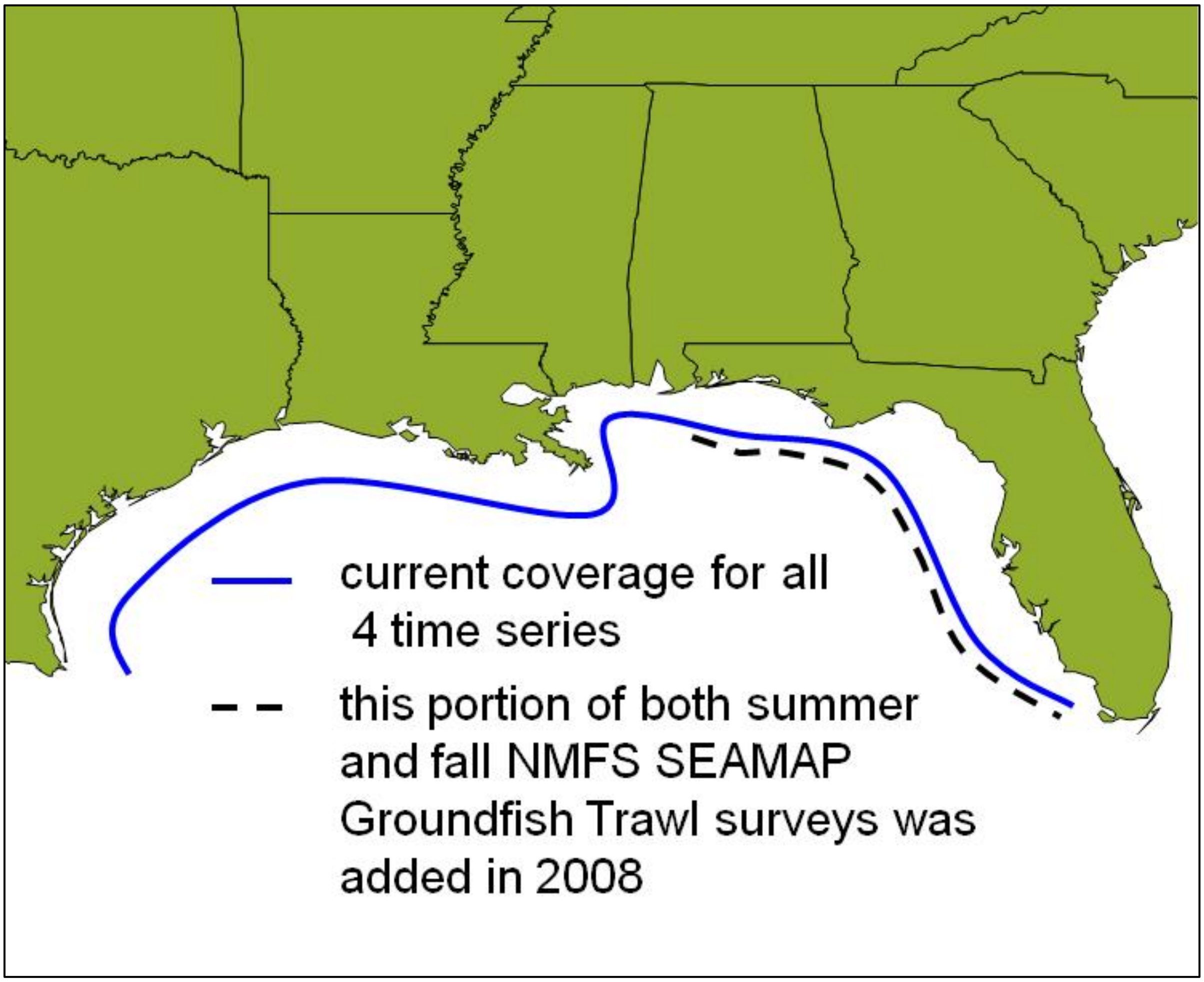


Figure 5.9.1. Approximate linear coverage of specific abundance indices for *Mustelus spp.* in the Gulf of Mexico.

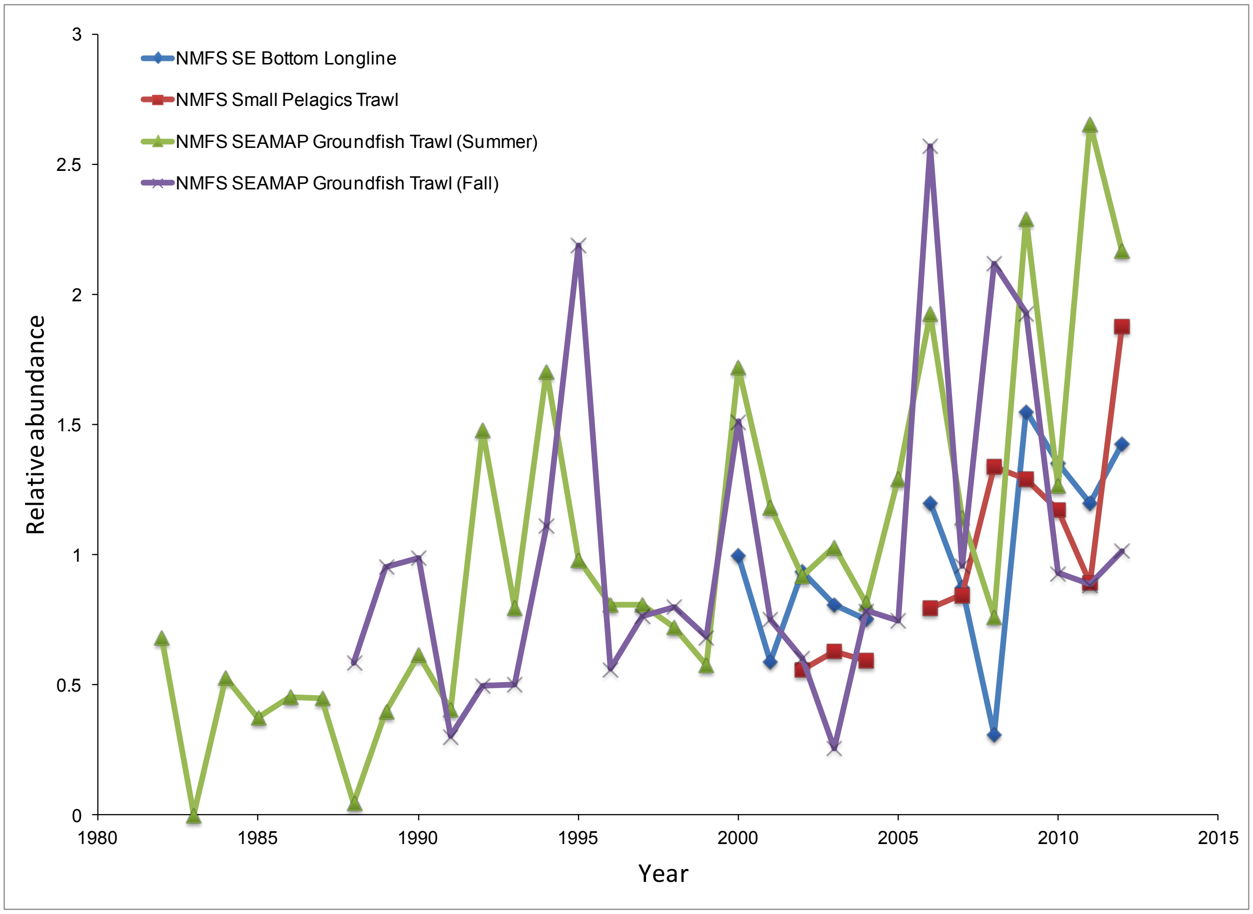


Figure 5.9.2. Plot of mean annual indices of relative abundance for each time series recommended for the Gulf of Mexico stock complex of *Mustelus spp.* by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that time series.

6 ANALYTIC APPROACH

6.1 Suggested analytic approach given the data

It is apparent from the conclusions of the Life History and Catch Working Groups that a mix of three *Mustelus* species occurs in the Gulf of Mexico. However, given the problems with species identification and very limited and uncertain life history information identified by the Life History WG, species-specific assessments are not feasible at this time. The remaining option as recommended by the Catch and Life History WGs is to undertake an assessment of a *Mustelus* spp. complex in the Gulf of Mexico.

To that end we plan on using Bayesian surplus production models (McAllister and Babcock 2006; Meyer and Millar 1999; Spiegelhalter et al. 2000) to assess the status of the *Mustelus* complex. We believe this is the appropriate approach because the lack of species-specific data precludes us from using more complex models.

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

Meyer R., Millar R.B. 1999. BUGS in Bayesian stock assessments. Can J Fish Aquat Sci 56:1078–1086.

Spiegelhalter, D., Thomas, A., and Best, N. 2000. WinBUGS User Manual Version 1.4. MRC Biostatistics Unit, Cambridge, UK.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 39

HMS Gulf of Mexico Smoothhound complex

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 $F=0_{p70}$)
   - Target rebuilding year (Year $F=0_{p70}$ + 1 generation time if Year $F=0_{p70}>10$) ($\text{Year}_{rebuild}$)
   - F resulting in 50% and 70% probability of rebuilding by $\text{Year}_{rebuild}$
   - 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	NOAA/NMFS

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

<table>
<tr><th colspan="4">Documents Prepared for the Assessment Process</th></tr>
<tr><td>SEDAR39-AW-01</td><td>Review of Available Length Composition Data Submitted for use in the SEDAR 39 <i>Mustelus canis</i> Atlantic Stock Assessment</td><td>Dean Courtney</td><td>10 Sept 2014</td></tr>
<tr><td>SEDAR39-AW-02</td><td>Hierarchical analysis of U.S Atlantic Smooth dogfish and Gulf of Mexico smoothhound species indices of abundance</td><td>Cami McCandless</td><td>15 Oct 2014</td></tr>
<tr><th colspan="4">Reference Documents</th></tr>
<tr><td>SEDAR39-RD06</td><td>A review of integrated analysis in fisheries stock assessment</td><td colspan="2">Mark N. Maunder and Andre A. Punt</td></tr>
<tr><td>SEDAR39-RD07</td><td>Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management</td><td colspan="2">Richard D. Methot Jr, and Chantell R. Wetzel</td></tr>
<tr><td>SEDAR39-RD08</td><td>Appendix A: Technical Description of the Stock Synthesis assessment program</td><td colspan="2">Richard D. Methot Jr, and Chantell R. Wetzel</td></tr>
<tr><td>SEDAR39-RD09</td><td>Model selection for selectivity in fisheries stock assessments</td><td colspan="2">Andre E. Punt, F. Hurtado-Ferro, F. and A.R. Whitten</td></tr>
</table>

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, Chantel Wetzel, James Thorson,Yukio Takeuchi, Cole Monnahan, and other contributors
SEDAR39-RD13	User Manual for Stock Synthesis - Model Version 3.24s	Richard D. Methot Jr.
SEDAR39-RD14	FINAL REPORT FOR THE ASSESSMENT METHODS WORKING GROUP SUMMARIZING THE DOMESTIC SHARK P* STANDARDIZATION WORKSHOP	DEAN L. COURTNEY ENRIC CORTÉS 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.

There were no changes in the catch series and indices of abundance recommended by the Data Workshop (DW), which are summarized in Section 2. The DW report, however, contained no information on catch in weight. Since this information is required for management and given that catches are overwhelmingly dominated by shrimp trawl discards, we obtained length composition data for the Gulf of Mexico smoothhound complex from the shrimp observer program. Lengths were subsequently converted to weights with the length-weight relationships recommended by the DW. This information is reported in Section 2.

The life history information recommended by the DW was used to develop a prior for the intrinsic rate of population growth (r_{max}). Details of the procedure can be found in Section 2. 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).

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.

The original intent was to use the Bayesian surplus production model (McAllister and Babcock 2006) for this assessment. However, initial runs revealed that this model was unable to fit the indices of abundance. It was then decided to use the WinBUGS state-space surplus production model (SSSPM; Cortés 2002, Jiao et al. 2009, Brodziak and Ishimura 2011), which, unlike the BSP, also takes account of process error. All analyses were thus conducted with the SSSPM. The model and its configuration are fully described in Section 3.1.3.

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 Sections 3.2.3 to 3.2.6. We estimated abundance (exploitable numbers) because imputed catches were in numbers and the model estimates harvest rates. Since this is a production model, no selectivities or stock-recruit relationship were estimated.

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 at length in Section 3.2.5. Fits to abundance indices, residual plots, convergence diagnostics of the MCMC algorithm, and measures of goodness-of-fit (performance) are provided in Sections 3.2.1 and 3.2.2.

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.

The modeling platform used (production model) does not consider per-recruit or yield measures. 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, H_{MSY}, N_{MSY}, H/H_{MSY}, N/N_{MSY}) are provided in Sections 3.2.3 to 3.2.6.

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 reported in Section 3.2.6.

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.

Posterior distributions for the main model parameters and stock status metrics (N/N_{MSY}, H/H_{MSY}) are reported in Sections 3.2.3 to 3.2.6.

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 assessment can be characterized as data-limited because of the impossibility of differentiating between species in the complex (in catches and indices of abundance) due to mis-identification, which precluded use of age-structured models for individual species. However, we developed probabilistic projections of future stock conditions that carried forward uncertainty in estimated parameters and calculated probabilities of both the stock being overfished and overfishing occurring at different catch levels. A detailed description of the projection methodology, along with estimated generation time, is provided in Section 3.1.7 and projection results are provided in Section 3.2.7.

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 3.4.

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

No changes were introduced to the catch streams presented and approved at the DW. Catches are imputed into the model as a single series but are overwhelmingly dominated by shrimp trawl discards (**Table 2.5.1**; **Figure 2.6.1**). 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 3.1.5.

Since the DW report contained no information on catch in weight and this information is required for management, given that catches are overwhelmingly dominated by shrimp trawl discards we obtained length composition data for the Gulf of Mexico smoothhound complex from the shrimp trawl observer program. Lengths obtained were subsequently converted to weights with the two length-weight relationships recommended by the DW (one for females, one for males; see their Table 2.12.1). Unfortunately, the shrimp trawl observer program does not report the sex of sharks observed; therefore we report summary statistics and weight composition data obtained from assuming that all lengths corresponded to either males or females (**Table 2.5.2**, **Figure 2.6.2**). A total of 882 *Mustelus* spp. were measured in the shrimp trawl observer program, but only for the years 2010-2012.

2.2. INDICES OF ABUNDANCE

The standardized indices of abundance used in the assessment are presented in **Table 2.5.3** and **Figure 2.6.3**. The Index Working Group (WG) of the DW recommended the use of four indices, all of which were fishery independent: NMFS SE Bottom Longline, NMFS SEAMAP Groundfish Trawl (Summer), NMFS SEAMAP Groundfish Trawl (Fall), and NMFS Small Pelagics Trawl. All these indices were standardized by the respective authors through GLM techniques (see SEDAR 39 DW Report). The base scenario used equal weighting of the CPUE indices, but the coefficients of variation (CV) associated with the standardized indices (used in the inverse weighting scenario; see Section 3.1.5) are also listed in **Table 2.5.3**.

2.3. LIFE HISTORY INPUTS

The life history inputs used to develop an informative prior distribution for productivity (r_{max}) are presented in **Table 2.5.4**. The Life History WG recommended using the biological values for the *M. canis-M. sinusmexicanus* grouping and those for *M. norrisi* to capture variability in the biology of the *Mustelus* spp. complex, but did not specify values. To generate a value of productivity for the *Mustelus* spp. complex, we used a life table approach with the Euler-Lotka equation (Lotka 1907) to calculate values of r_{max} for both the *M. canis-M. sinusmexicanus* grouping and *M. norrisi* . We then used the mid-point of these two values to develop the prior distribution (see Section 3.1.5).

Briefly, the Euler-Lotka equation has the following form:

$$\sum_{x=\alpha}^{\omega} l_x m_x e^{-rx} = 1$$

where α is age at first breeding, ω is maximum age, l_x is cumulative survival from age 0 to x, m_x is age-specific fecundity (the number of female offspring produced per breeding female of age x on an annual basis), and r (indistinctly referred to here as $r_{\max}$) is obtained by iteratively solving the equation.

Biological input values in **Table 2.5.4** are as reported in the DW 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 simulate a maximum compensatory response in an effort to estimate r_{max}.

The value of productivity for the *M. canis-M. sinusmexicanus* grouping was $r = 0.281$ yr^{-1} and that for *M. norrisi* was 0.183 yr^{-1}. The mid-point (0.23 yr^{-1}) was thus used to develop the prior for the base run. The values of 0.28 and 0.18 were subsequently used for the high and low productivity scenarios, respectively (see Section 3.1.5).

2.4. REFERENCES

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2.5. TABLES

Table 2.5.1. Total catch of smoothhounds in the Gulf of Mexico (all in numbers) used in the base model run. The first column shows estimated dead discards from the shrimp trawl fishery; the second column includes dead discards estimated from reeffish observer programs and effort data from the Coastal Fishery Logbook Program; the third column are live discard estimates from the same source multiplied by the proportion believed to die in longlines (average post-release live discard mortality rate of 13.5%); the fourth and fifth columns are recreational landings and dead discards (A+B1) and recreational discards released alive (B2) assumed to die (B2 x post-release live discard mortality rate for hook and line of 17%). Directed commercial landings are very low, and thus not included in the table. The sixth column shows the total catch stream imputed into the model base run.

	Com-TR-GOM	Com-RFLL-SE	Com-RFLL-SE	Recreational	Recreational	TOTAL
Year	Disc	Disc	(PRM)	(A+B1)	(PRM)	catches
1982	64706			0	0	64706
1983	61225			1718	0	62942
1984	66130			3168	0	69297
1985	66963			5841	534	73338
1986	76547			3659	0	80206
1987	84872			5010	93	89976
1988	73644			37	0	73681
1989	81618			7710	0	89328
1990	82550	273	814	5105	0	88742
1991	95380	477	1423	53	0	97333
1992	92963	269	804	1913	1957	97906
1993	91958	846	2527	1833	0	97163
1994	92718	1015	3029	1745	0	98507
1995	94439	906	2705	432	0	98482
1996	111850	994	2966	419	181	116409
1997	130361	1146	3422	775	0	135704
1998	138946	963	2875	2	0	142787
1999	143473	1001	2990	115	0	147579
2000	147426	969	2892	0	0	151288
2001	161907	948	2831	501	0	166187
2002	184941	881	2630	691	0	189143
2003	161454	961	2869	0	16	165300
2004	147112	902	2694	1	0	150710
2005	104376	689	2057	1889	0	109011
2006	105472	130	493	2	0	106097
2007	94656	0	430	0	0	95086
2008	77533	3652	10114	0	0	91299
2009	108711	417	2917	0	0	112045
2010	73837	778	991	190	0	75795
2011	110435	122	521	0	0	111078
2012	95951	722	1236	1258	0	99167

Table 2.5.2. Summary statistics of lengths measured in the shrimp trawl observer program (2010-2012) and resulting converted whole weights for Gulf of Mexico *Mustelus* spp. (using the length-weight equation for females (3rd column) or males (4th column)).

Yr 2010-2012	combined FL in cm	WW in lb Female_Eq	WW in lb Male_Eq
Min	8.71	0.01	0.01
Max	102.50	15.65	11.72
Mean	48.12	1.57	1.29
SD	10.07	1.36	1.05
Median	45.90	1.14	0.96
N	882	882	882

Table 2.5.3. Indices of abundance recommended in the DW Report for the base model run. The base run used equal weighting, but CVs (coefficients of variation) are listed and were used in the inverse CV weighting sensitivity run.

Year	NMFS SE Bottom Longline	CV	NMFS SEAMAP Groundfish Trawl (Summer)	CV	NMFS SEAMAP Groundfish Trawl (Fall)	CV	NMFS Small Pelagics Trawl	CV
1982			0.044	0.759				
1983			0.000					
1984			0.034	0.634				
1985			0.025	0.756				
1986			0.030	0.636				
1987			0.029	0.564				
1988			0.003	1.042	0.085	0.515		
1989			0.026	0.636	0.138	0.402		
1990			0.040	0.452	0.144	0.440		
1991			0.026	0.515	0.044	0.564		
1992			0.097	0.344	0.072	0.636		
1993			0.052	0.401	0.073	0.474		
1994			0.111	0.349	0.162	0.386		
1995			0.064	0.377	0.318	0.320		
1996			0.053	0.376	0.081	0.448		
1997			0.053	0.378	0.111	0.386		
1998			0.047	0.482	0.116	0.475		
1999			0.038	0.433	0.099	0.428		
2000	0.425	0.359	0.112	0.316	0.220	0.374		
2001	0.251	0.238	0.077	0.453	0.109	0.428		
2002	0.399	0.196	0.060	0.401	0.088	0.406	0.184	0.321
2003	0.345	0.224	0.067	0.455	0.037	0.570	0.207	0.380
2004	0.320	0.248	0.053	0.415	0.114	0.401	0.195	0.330
2005			0.084	0.452	0.109	0.426		
2006	0.512	0.198	0.126	0.342	0.374	0.333	0.262	0.330
2007	0.373	0.221	0.075	0.359	0.139	0.485	0.278	0.243
2008	0.132	0.371	0.050	0.359	0.308	0.301	0.440	0.241
2009	0.662	0.215	0.150	0.302	0.280	0.302	0.424	0.409
2010	0.577	0.229	0.083	0.394	0.135	0.452	0.386	0.257
2011	0.510	0.218	0.174	0.335	0.129	0.476	0.293	0.275
2012	0.608	0.283	0.142	0.323	0.147	0.633	0.618	0.196

Table 2.5.4. Life history inputs used to calculate productivity for developing a prior distribution for the base run. The left panel shows the inputs for the *Mustelus canis*-*M. sinusmexicanus* group and the right panel the inputs for *M. norrisi*. Productivity values resulting from the two panels were averaged and used as input for the base run. The productivity resulting from using the biological inputs on the right panel (*M. norrisi*) was used for the low productivity scenario and that resulting from using the biological inputs on the left panel (*M. canis*-*M. sinusmexicanus*) was used for the high productivity scenario.

Mustelus canis-M. sinusmexicanus combined					*Mustelus norrisi*			
Age	Proportion mature	M	Fecundity (female pups)		Age	Proportion mature	M	Fecundity (female pups)
0	0.003	0.300	5.000		0	0.003	0.468	5.650
1	0.016	0.277	5.000		1	0.016	0.376	5.650
2	0.074	0.244	5.000		2	0.074	0.325	5.650
3	0.277	0.220	5.000		3	0.277	0.295	5.650
4	0.648	0.168	5.000		4	0.648	0.275	5.650
5	0.898	0.168	5.000		5	0.898	0.262	5.650
6	0.977	0.168	5.000		6	0.977	0.253	5.650
7	0.995	0.168	5.000		7	0.995	0.246	5.650
8	0.999	0.168	5.000		8	0.999	0.241	5.650
9	1.000	0.168	5.000		9	1.000	0.237	5.650
10	1.000	0.168	5.000					
11	1.000	0.168	5.000					
12	1.000	0.168	5.000					
13	1.000	0.168	5.000					
14	1.000	0.168	5.000					
Maturity ogive:		1/(1+EXP(5.67-1.57*age))			Maturity ogive:		1/(1+EXP(5.67-1.57*age))	
Sex ratio:		1:1			Sex ratio:		1:1	
Reproductive frequency:		1 yr			Reproductive frequency:		1 yr	
Fecundity:		10 (mean of 15 and 5)			Fecundity:		10 (mean of 15 and 5)	
L_{inf}		113.78	(cm FL)		L_{inf}		95.05	(cm FL)
k		0.130			k		0.250	
t_0		-3.87			t_0		-2.03	
Weight vs length relation:		$W=0.000002L^{3.258}$			Weight vs length relation:		$W=0.000002L^{3.2486}$	
(W is in kg; L is cm FL)					(W is in kg; L is cm FL)			

2.6. FIGURES

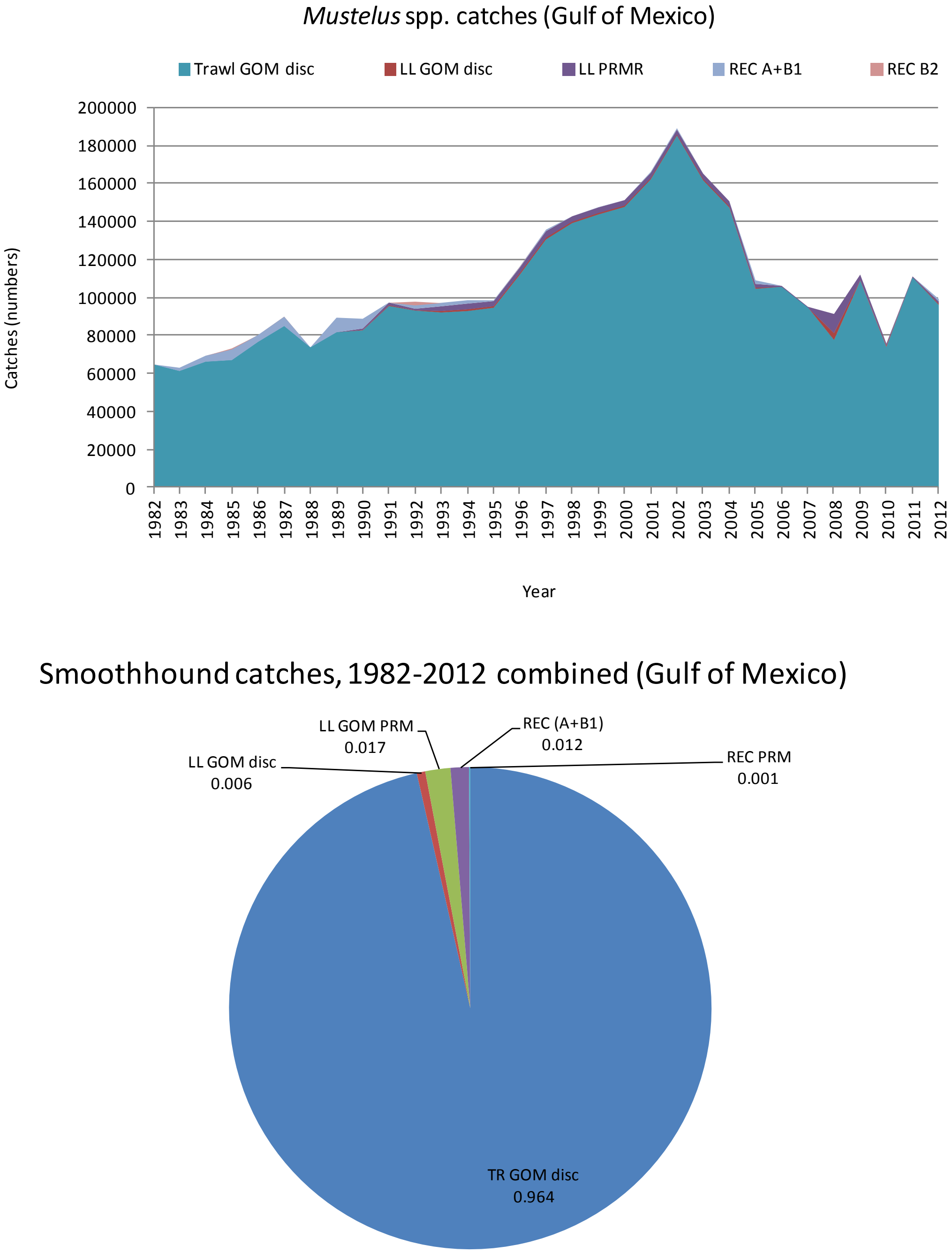

Figure 2.6.1. Catches of smoothhounds in the Gulf of Mexico, 1982-2012 (top) and as a proportion for all years combined (bottom). “Trawl GOM disc” are dead discards from the shrimp trawl fleet.

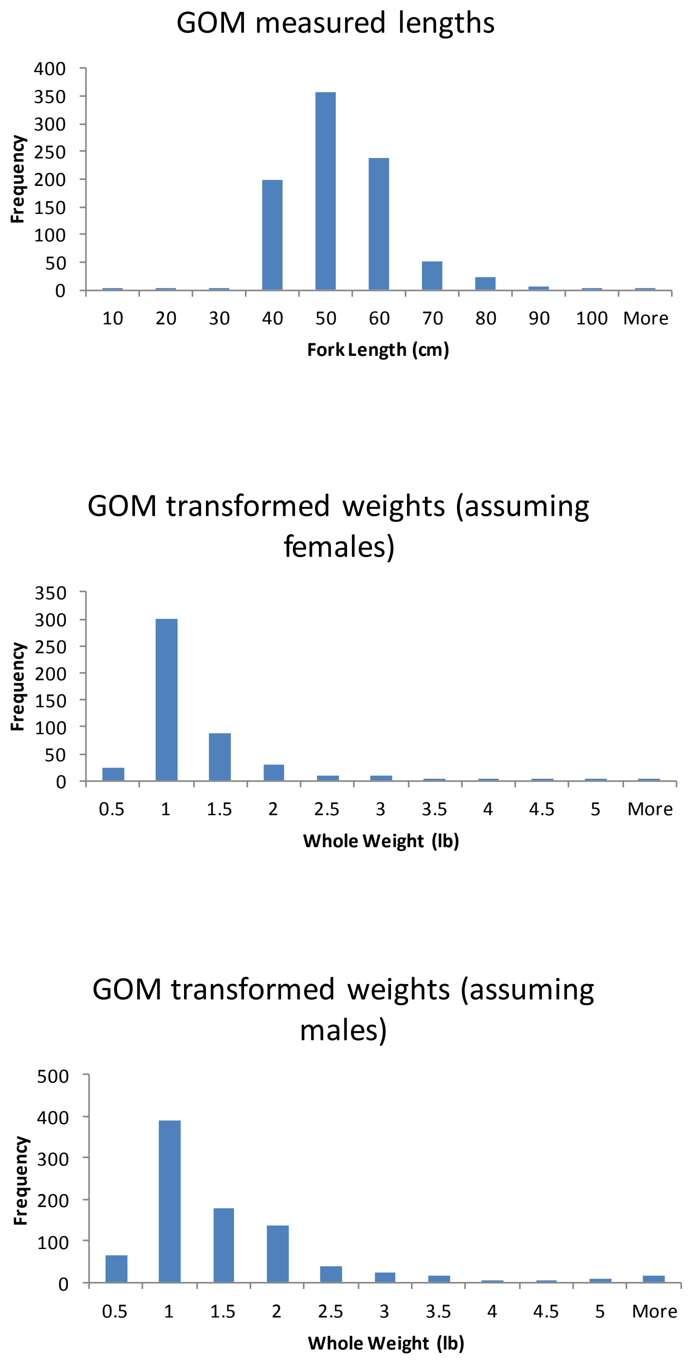

Figure 2.6.2. Length and weight composition of Gulf of Mexico *Mustelus* spp. from the shrimp trawl observer program (2010-2012). Top panel: measured lengths; middle panel: weights obtained by using the female weight/length equation (WT = (2.0*10^-6)*FL^3.258, $r^2 = 0.95$, n=398) recommended by the DW for the *Mustelus canis* / *M. sinusmexicanus* group; bottom panel: weights obtained by using the male weight/length equation (WT = (3.0*10^-6)*FL^3.108, $r^2 = 0.90$, n=148) recommended by the DW for the *Mustelus canis* / *M. sinusmexicanus* group.

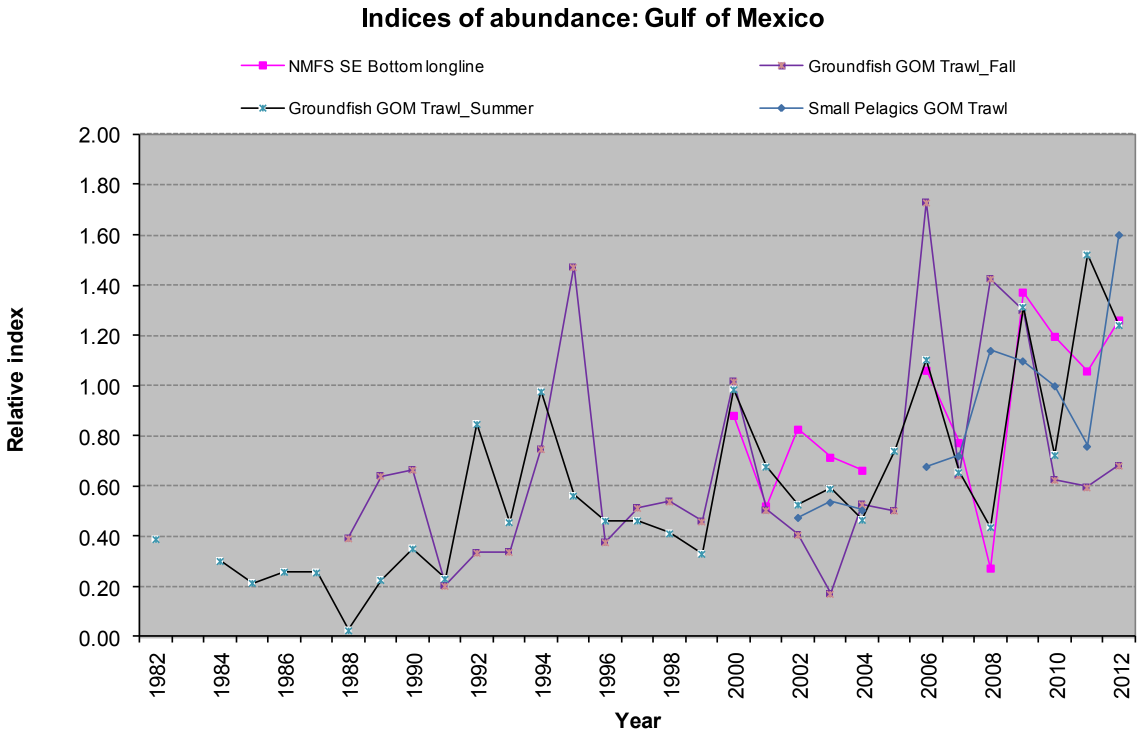

Figure 2.6. 3. Indices of abundance used for the base scenario. All indices are statistically standardized and scaled (divided by the respective mean for the overlapping years of all indices for plotting purposes).

3. STOCK ASSESSMENT MODEL(S) AND RESULTS

Although we initially attempted to use the Bayesian Surplus Production (BSP) model (McAllister and Babcock 2006), the model was not able to fit the indices of abundance (it showed flat trends) and the Assessment Panel (AP) recommended using an alternative approach. We thus decided to use a different form of production model, which in addition to considering observation error (like the BSP), also considers process error. The model is described below.

3.1. MODEL 1 METHODS: STATE- SPACE SURPLUS PRODUCTION MODEL (SSSPM)

3.1.1. Overview

The state-space Bayesian surplus production model (SSSPM) implements a Schaefer production model in a Bayesian framework. This implementation was done in WinBUGS, which uses Gibbs sampling, an MCMC method of numerical integration, to sample from the posterior distribution (Spiegelhalter et al. 2007). The model was originally developed by Meyer and Millar (1999a) and modified by Cortés (2002) to apply it to small coastal sharks. Further modifications were later used by Jiao et al. (2009) for hammerhead sharks and by Brodziak and Ishimura (2011) for North Pacific swordfish. Briefly, the model is fitted to the indices of abundance and catch is treated as a known constant.

3.1.2. Data sources

The catch stream, indices of abundance, and biological inputs used to derive productivity in the application of the SSSPM are described in Section 2. Catch data (in numbers) were available from 1982 to 2012 (**Table 2.1**) and of the four CPUE series used in the base run, the earliest year represented was 1982 (**Table 2.2**).

3.1.3. Model configuration

The model started in 1982 and ended in 2012. The first year in which both CPUE and catch data were available was 1982. Estimated parameters were r, K, the abundance (in numbers) in 1982 relative to K (N_{82}/K or initial depletion at the beginning of the model), process and observation error variances, and the time series of proportions of carrying capacity (P_t terms; see eq. 4 below). In the base run, each individual index of abundance value was weighted equally (which is equivalent to no weighting). We refer to this weighting scheme as “equal weighting” in contrast to “inverse CV weighting” which will be described later for one of the sensitivity runs.

Production model, process error model, and observation error model

To minimize correlations between model parameters and speed mixing of the Gibbs sampler, the surplus production model is reparameterized by expressing the annual biomass or abundance as a proportion of carrying capacity:

$$P_t = \left(P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_{t-1}}{K} \right) e^{P\varepsilon_t} \tag{1}$$

where $P_t = N_t/K$. The model is a state-space model, which relates the observed catch rates (I_t) to unobserved states (P_t) through a stochastic observation model for I_t given P_t (Millar and Meyer 1999, Meyer and Millar 1999b):

$$I_t = qKP_t e^{O\varepsilon_t} \tag{2}$$

The model assumes lognormal error structures for both process and observation errors (e^{P_ε} and e^{O_ε}), with $P\varepsilon_t \sim N(0,\sigma^2)$ and $O\varepsilon_t \sim N(0,\tau^2)$. The process error model relates the dynamics of exploitable biomass (abundance) to natural variability in biological and environmental processes affecting the stock. Thus, the population dynamics are subject to natural variation (eq. 1), which is expressed in the form of independent and lognormally distributed random variables (e^{P_ε}). The observation error model relates the observed indices of abundance (indistinctly also referred to here as CPUE) to the exploitable biomass (abundance) of the stock. The CPUE dynamics are subject in this case to sampling or observation variability (eq. 2), which is expressed in the form of independent and lognormally distributed random variables (e^{O_ε}). Note that the annual observation errors include a year-specific weighting factor (w_t). This weighting factor was set to 1 for the base run (equal weighting scenario), but differed for the inverse CV weighting scenario described later (see Section 3.1.5).

In the present implementation, the catchability coefficient for each index of abundance (q_j) is taken as the MLE (closed form):

$$\hat{q}_j = e^{\left(\frac{\sum_{t=1}^{t=y} \left(\ln(I_{j,t}) - \ln(\hat{N}_t) \right)}{n_j} \right)} \qquad (3)$$

where n_j is the number of observations for each index.

The crucial equation for Bayesian inference is the joint posterior distribution of the unobservable states given the data, which is equal to the product of the joint prior distribution and the sampling distribution (likelihood of the CPUE data) by virtue of Bayes' theorem:

$$\begin{aligned} & p(K, r, P_{82}, \sigma^2, \tau^2, P_1, \ldots, P_n \mid I_1, \ldots, I_n) = \\ & p(K) p(r) p(P_{82}) p(\sigma^2) p(\tau^2) p(P_1 \mid P_{82}, \sigma^2) \\ & \times \prod_{i=2}^{i=n} p(P_t \mid P_{t-1}, K, r, \sigma^2) \prod_{t=1}^{t=n} p(I_t \mid P_t, \tau^2) \end{aligned} \qquad (4)$$

where $P_{82} = N_{82}/K$ or the initial depletion at the start of the model.

3.1.4. Parameter estimation

Prior distributions

Prior distributions were used to quantify the degree of existing knowledge on each of the model parameters to be estimated under the Bayesian approach.

Carrying capacity—The prior for *K* was uniform on log (*K*), with a range of 10^4 to $50\text{x}10^6$ (ca. 250 times the maximum observed catch) individuals. These values were chosen to reflect a reasonable range of exploitable numbers likely needed to support observed removals.

Intrinsic rate of growth —An informative, lognormally distributed prior was used for *r* to take advantage of the biological information reported in Section 2. The mean of the lognormal distribution was 0.23. Since WinBUGS specifies precision (1/variance) for most of the distributions, a precision value of 4, equivalent to a variance of 0.25 or an SD of 0.5, was used, which corresponds to a CV of 0.5 on the arithmetic scale.

Initial depletion—An informative prior was also used for N_{82}/K, with the mean set equal to 0.7 to reflect some depletion with respect to virgin levels, and the precision at 25, equivalent to a variance of 0.04 or an SD of 0.2, which corresponds to a CV of 0.2 on the arithmetic scale. Considering initial depletion in 1982 is justified because the shrimp trawl fishery had been in operation long before that year yet no discard estimates were available for years preceding 1982.

Priors for error variances—Priors for both the observation error variance (τ^2) and process error variance (σ^2) were specified as inverse gamma distributions as used in previous stock assessments (Millar and Meyer 1999, Cortés 2002, Brodziak and Ishimura 2011). For the observation error variance prior, the scale parameter was set to λ=2 and the shape parameter to k=0.1. This set of parameters yields an inverse gamma distribution variance prior with a mean=0.099, a median=0.060, and a 95% credible interval of 0.018 - 0.396 (approximately equivalent to a log variance=0.05, a log SD=0.22, and a CV=0.22 on the arithmetic scale). For the process error variance prior, the scale parameter was set to λ=4 and the shape parameter to k=0.5. This set of parameters yields an inverse gamma distribution variance prior with a mean=0.167, median=0.136, and a 95% credible interval of 0.057 - 0.463 (approximately equivalent to a log variance=0.125, a log SD=0.354, and a CV=0.354 on the arithmetic scale).

Priors for proportions of carrying capacity—Priors for the P_t (N_t/K) terms were lognormally distributed (see Process error model above).

Posterior distribution

The posterior distribution is given in equation (4) above.

Parameter estimation and convergence diagnostics

WinBUGS uses an MCMC method called Gibbs sampling (Gilks et al. 1996) to generate a large number of samples from the joint posterior distribution. All runs were based on two chains of initial values (where the P_t values were set equal to 0.5 and 1.0, respectively) to account for over-dispersed initial values (Spiegelhalter et al. 2007), and included a 50,000 sample burn-in phase that was removed to eliminate any potential dependence of the MCMC samples on the initial conditions. This was followed by a 20,000 iteration phase with a thinning rate of 5 to reduce autocorrelation where every fifth sample was used for inference. A total of 8,000 samples from the posterior distribution were thus used for summarizing results.

Convergence of the MCMC algorithm for the two chains was tested by 1) examining the time series history of the two MCMC chains to determine whether mixing was good, 2) monitoring parameter autocorrelations, 3) using the convergence diagnostic of Gelman and Rubin (Gelman and Rubin 1992), and 4) examining the Monte Carlo error of parameter estimates (as a rule of thumb this error should be <5% of the estimated SD). These convergence diagnostics were monitored for the key model parameters.

Goodness of fit criteria

Goodness of fit of alternative model formulations was assessed by visual inspection of the model fit to the CPUE series and examination of residual patterns. Residuals for the CPUE series were the observation errors on the normal scale.

We also used the root mean-squared error (RMSE) of the CPUE fit as an additional diagnostic (Brodziak and Ishimura 2011), with lower RMSE values indicating a better fit. For overall model comparison, we used the DIC (Deviance Information Criterion), with lower values of DIC also indicating a better model fit (Lunn et al. 2012):

$$DIC = \bar{D} + p_D \tag{5}$$

and $p_D = \bar{D} - \hat{D}$, where Dbar is the posterior mean of the deviance and Dhat is the deviance of the posterior mean (Spiegelhalter et al. 2007). Both RMSE and DIC can only be used to compare model configurations that use the same data.

3.1.5. Uncertainty analysis

Uncertainty in data inputs and model configuration was examined through the use of sensitivity scenarios. Some of these scenarios (1-6) were believed to correspond to plausible states of nature, alternative to the base run. Thirteen sensitivity runs in total are included in this report in addition to the baseline run. No continuity analysis was conducted because this is the first time this stock complex is assessed. We also performed retrospective analyses of the baseline run, wherein the model was refit while sequentially dropping the last four years of data to look for systematic bias in key model output quantities over time.

We now specifically describe how each of the 13 sensitivity runs was implemented.

Scenario 1: *Hierarchical index*—The motivation for this scenario, which uses the same inputs as the base run, but only a single hierarchical index of abundance (see document SEDAR39-AW-02 and Conn (2010) for a full description of the method; **Table 3.1, Figure 3.1**) 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.

Scenario 2: *Inverse CV weighting*—Same as the base run, but using the inverse of the CV to weight each CPUE series (**Table 2.2**). As mentioned in Section 3.1.3, a weighting factor (w_t) is included in the variance of the $O\varepsilon_t$ terms (normally distributed random variables). These annual weighting factors were calculated based on the relative CVs of each annual CPUE index and the minimum observed CV of CPUE (Brodziak and Ishimura 2011) such that:

$$w_t = \frac{CV(CPUE_t)}{\min\left\{CV(CPUE)\right\}} \qquad (6)$$

Scenarios 3 and 4: *Low and high catch*—Same as the base run, but using a low and high catch scenario, respectively. 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 the catches were overwhelmingly dominated by the shrimp trawl discards (See Section 2.1), we used only the lower and upper 95% confidence limits of the estimated shrimp trawl discards to generate the low and high catch scenarios, respectively (**Table 3.2** and **Figure 3.2**). The low and high catch scenarios varied widely with respect to the base run catches, with all values of shrimp trawl discards being 0 in the low catch scenario, except for the 2010 value.

Scenarios 5 and 6: *Low and high productivity*—Same as the base run, but using low and high productivity estimates (r=0.18 and 0.28 yr^{-1}) as detailed in Section 2.3.

Scenarios 7, 8, and 9: *Large prior for process error variance, large prior for observation error variance, and both simultaneously* —Same as the base run, but increasing the prior value of the variance (equivalent to decreasing the precision in WinBUGS) for process error, observation error, and both process and observation error. For the process error variance prior, the scale parameter was changed from λ=4 in the base run to λ=0.16 and the shape parameter from k=0.5 in the base run to k=0.02. For the observation error variance prior, the scale parameter was changed from λ=2 in the base run to λ=0.16 and the shape parameter from k=0.1 in the base run to k=0.02. This set of parameters yields an inverse gamma distribution process and/or observation error variance prior with a mean=1,944, a median=1.293, and a very large 95% credible interval of 0.015 - 26,010.

Scenarios 10 and 11: *High and low initial depletion*—Same as the base run, but varying the mean value of initial depletion (N_{82}/K) from 0.7 in the base run to 0.9 and 0.5, respectively, to test whether these different hypotheses about initial conditions affected model outcome.

Scenarios 12 and 13: *High and low carrying capacity*—Same as the base run, but varying the range of the prior for K from 10^4 - $50\text{x}10^6$ in the base run to 10^4 - $500\text{x}10^6$ individuals in the high K scenario (increasing the upper bound by a factor of 10), and from 10^4 - $50\text{x}10^6$ in the base run to 10^4 - $5\text{x}10^6$ individuals in the low K scenario (decreasing the upper bound by a factor of 10)

3.1.6. Benchmark/Reference points

Benchmarks included estimates of absolute population levels and harvest rates for the last year of data, 2012 (N_{2012}, H_{2012}), reference points based on MSY (H_{MSY}, N_{MSY}), current status relative to MSY levels, and depletion estimates (current status relative to carrying capacity). In addition, trajectories for H_{year}/H_{MSY}, N_{year}/N_{MSY}, and predicted abundance (N_{year}) and harvest rate (H_{year}), were produced and plotted. Phase plots of stock status, including MSST (Minimum Stock Size Threshold) were also included. Because M<0.5, MSST is computed as $(1\text{-M})\text{SSF}_{\text{MSY}}$ (Restrepo et al. 1998). The means of the age-specific (ages 1-max) values of M corresponding to the two values of productivity (for the *M. canis-M. sinusmexicanus* grouping and *M. norrisi*; see Section 2.3) used for the base run were averaged to produce a single value of M (0.232). Phase plots depicting the combined H_{year}/H_{MSY} and N_{year}/N_{MSY} trajectories were also produced, as well as time series plots of the probability of the stock being overfished and of overfishing occurring for every year considered in the model.

3.1.7. Projection methods

Projections were governed by the same population dynamics (eq. 1) used to fit the model during 1982-2012, but without process error. Unknown parameters and unobservable states were estimated given the data and priors during the fitting of the model using MCMC, and then the estimated values of K, r, P_{2012}, and a fixed catch (TAC; Total Allowable Catch) were used for projections. Variability in estimated K, r, and P_{2012} is thus propagated into the future through each MCMC iteration.

Generation time was calculated using a life table approach (see Section 2.3) through the equation:

$$\bar{A} = \sum_{x=0}^{\omega} x e^{-rx} l_x m_x \qquad (7)$$

As explained in Section 2.3, ω is maximum age, l_x is cumulative survival from age 0 to x, m_x is age-specific fecundity (the number of female offspring produced per breeding female of age x on an annual basis), and r is the intrinsic rate of increase obtained by iteratively solving the Euler-Lotka equation. This generation time (6.5 yr) is defined as the mean age of parents of offspring (Caswell 2001).

The model was projected forward 10 years (ca. 1.5 generation times) using a fixed TAC strategy with six different levels of catches: no catch (0), the catch in 2012 (C_{2012}), 2* C_{2012}, 3* C_{2012}, 4* C_{2012}, and MSY. We thus projected the population dynamics from 2013 to 2022 and calculated the probability of the stock being overfished and of overfishing occurring for each of the 10 projected years. Projections were conducted for the base run and the “plausible states of nature”, which included sensitivity scenarios 1-6.

3.2. MODEL RESULTS

3.2.1. Measures of model fit

All four indices of abundance were fit reasonably well, with the exception of large interannual fluctuations, but in all cases the increasing trend of the observed series was captured by the model fit (**Figure 3. 3**). Thus, the fit to the NMFS SE Bottom Longline index was satisfactory, except for the very low value in 2008; the fit to the NMFS SEAMAP Groundfish Trawl (Fall) index was also reasonable, except for the more extreme values in 1999, 2005, 2008, and 2009; the fit to the SEAMAP Groundfish Trawl (Summer) index, which was the longest series, was also satisfactory, except for 7 high fluctuations from 1992 to 2012; and the fit to the NMFS Small Pelagics Trawl index, the shortest series, was fairly good with only the 2012 value being outside the 95% credible intervals. According to the RMSE, the best fit corresponded to the SEAMAP Groundfish Trawl (Summer) index whereas the NMFS SE Bottom Longline had the poorest fit (**Table 3.3**). Examination of residual plots further revealed that the SEAMAP Groundfish Trawl (Summer) index had a pattern of consecutive positive residuals from 2000 to 2007 that did not appear to be random (**Figure 3.4**). The NMFS SE Bottom Longline index also appeared to have two sets of suspect consecutive positive residuals. The only index that had a significant increasing trend in residuals was the SEAMAP Groundfish Trawl (Summer) (slope=0.002, P<0.01). Overall, the fits appeared to be adequate.

3.2.2. Convergence to posterior distribution

Examination of the time series history revealed that there was good mixing of the two chains for key parameters (carrying capacity, intrinsic rate of increase, and initial depletion) (**Figure 3.5**). Autocorrelations for all parameters quickly decreased after an initial lag (**Figure 3.6**). The Gelman-Rubin diagnostic indicated good convergence for the main parameters of interest because the ratio of the width of the central 80% interval of the pooled runs and the average width of the 80% intervals within the individual runs converged to 1 and both the pooled and within interval widths stabilized (**Figure 3.7**). Empirical estimation of MC error also indicated that these errors were about 1% of the estimated SD for the key parameters, well below the recommended threshold of 5%.

3.2.3. Parameter estimates and reference points for the base run

Estimated model parameters and benchmarks for the base run with their associated CVs are presented in **Table 3.3**. Carrying capacity (*K*) was estimated at ca. 14×10^6 individuals, the intrinsic rate of increase (r) at 0.21 yr^{-1}, and initial depletion (P_{82}) at 59% of virgin levels. The posterior distribution for K thus tended to favor larger values than the prior (**Figure 3.8**), the posterior for r predicted slightly lower values than the prior (**Figure 3.9**), and the posterior for P_{82} also predicted lower values than the prior (**Figure 3.10**). The posteriors for observation error variances (τ^2) differed to different degrees from the priors depending on the index. The posteriors for the NMFS SEAMAP Groundfish Trawl (Fall) and NMFS SE Bottom Longline indices τ^2 were fairly similar to the priors, but the posterior for the NMFS SEAMAP Groundfish Trawl (Fall) index τ^2 was substantially larger and that for the NMFS SEAMAP Groundfish Trawl (Fall) index τ^2 was lower (**Figure 3.11**). The posterior for process variance (σ^2) favored lower values (**Figure 3.12**). In all, there appeared to be information in the data since the posteriors for most parameters were different from the priors.

Mean estimates of reference points were about $7\text{x}10^5$ animals for MSY, $7.2\text{x}10^6$ for N_{MSY}, and 0.106 for H_{MSY} (**Figure 3.13**). Stock abundance in the terminal year of the model, 2012 (N_{2012}) was substantially greater than $N_{MSY.}$ The predicted stock status was that it is not overfished ($N_{2012}/N_{MSY} = 1.78$) and that overfishing is not occurring ($H_{2012}/H_{MSY} = 0.18$). Overall, parameters were estimated reasonably well, with all CVs <1.

3.2.4. Exploitable stock abundance and exploitation rate

The predicted exploitable stock abundance trajectory showed an increasing trend from 1982 to 2012 with wide 95% credible intervals (**Figure 3.14 top**). The predicted exploitation rate fluctuated but generally remained stable, never exceeding the estimated H_{MSY} of 0.106 (**Figure 3.14 bottom**). The model predicted that the stock had been overfished ($N<N_{MSST}$) from 1982 to 1991, but not thereafter (**Figure 3.15 top**) and that overfishing had never taken place, although the credible intervals were very wide (**Figure 3.15 bottom**). The reason for the model predicting that the stock was in an overfished condition for a number of years at the start of the time series (1982-1989) is likely the combination of the assumed initial depletion and the fact that the two abundance indices available for that period (the NMFS SEAMAP Groundfish Trawl (Summer) starting in 1982 and the NMFS SEAMAP Groundfish Trawl (Fall) starting in 1988) showed decreasing trends from 1982 to 1988 and from 1988 to 1991, respectively. The probability of the stock being overfished was >50% during 1982-1992, decreased to <30% in 1993-1994, and remained well below 30% thereafter, except for 2003 (**Figure 3.16 top**). The probability of overfishing occurring never exceeded 30% (**Figure 3.16 bottom**). **Table 3.4** lists the values for these four series (predicted exploitable number, exploitation rate, relative abundance, and relative exploitation rate).

3.2.5. Evaluation of uncertainty

Results of sensitivity analyses 1 to 4 are summarized in **Table 3.5**, those of sensitivity runs 5 to 13 in **Table 3.6**, and those of the retrospective analyses in **Table 3.7**. **Appendix 3.8.1** contains fits to indices for all sensitivity runs; **Appendix 3.8.2** has residual plots for all sensitivity runs; **Appendix 3.8.3** has the exploitable number and exploitation rate trajectories for all sensitivity runs; **Appendix 3.8.4** has the relative exploitable number and exploitation rate trajectories for all sensitivity runs; **Appendix 3.8.5** has the trajectories for the probability of the stock being overfished and overfishing occurring for all sensitivity runs; **Appendix 3.8.6** has the probability of the stock becoming overfished and overfishing occurring for the projection scenarios considered (1-6); **Appendix 3.8.7** has the convergence diagnostic plots for the key model parameters for all sensitivity runs; and **Appendix 3.8.8** has the prior-posterior plots of the key model parameters for all sensitivity runs.

Note that comparison of fits to indices through the RMSE and of overall model fit through DIC could not be undertaken for sensitivity runs 1-4 and the base run because they used different data inputs (**Table 3.5**).

Sensitivity run 1 (Hierarchical index)—The model fit the single hierarchical index better than the base run likely because of lower interannual variability. All observed index values were within the 95% credible intervals. Predicted trends were very similar and stock status predictions were only slightly more pessimistic than in the base run.

Sensitivity run 2 (Inverse CV weighting)—Using the inverse CVs to weight the indices led to a slightly more optimistic stock status. The visual fit to indices was slightly improved in some cases with respect to the base run. Predicted trends were very similar to those from the base run.

Sensitivity runs 3 and 4 (Low and high catch)— Considering a catch lower than that in the base run did not have a perceptible effect on the fit to indices but led to a lower predicted abundance. Stock status with respect to the overfished condition was identical to the base run and improved with respect to the overfishing condition. This scenario resulted in the most imprecise estimation, with CVs of several parameters >1 (**Table 3.5**). A catch higher than in the base run led to very similar fits to indices and predicted abundance and exploitation trends, but higher estimated abundance. Overfished status was as in the base run and overfishing status worsened slightly compared to the base run.

The next set of sensitivity runs (5-13) allowed comparison of fits to indices through the RMSE and of overall model fit through DIC because they used the same data inputs (**Table 3.6**).

Sensitivity runs 5 and 6 (Low and high productivity)—The low productivity run obviously resulted in a less productive stock, which was compensated by a higher predicted K and a slightly higher abundance than in the base run. Stock status relative to overfished and overfishing conditions barely changed compared to the base run. The exact opposite trend was found when considering a high productivity stock. Stock status predictions compared to the base run also did not vary. Note that the MSST reference line was 0.722 (1-0.278) for the low productivity run (where M=0.278) and 0.815 (1-0.185) for the high productivity run (where M=0.185). Fits to indices and predicted abundance and exploitation trends with both scenarios were very similar to those of the base run.

Sensitivity runs 7, 8, and 9 (Large process error variance, large observation error variance, and both simultaneously) —Use of these three different options for process and observation errors produced very similar fits to indices and predicted abundance and exploitation trends. Comparison of RMSE values from these scenarios and the base run revealed that only the NMFS Small Pelagics Trawl index was fit marginally better in the large observation error run than in the base run. The difference in DIC values among runs was <5, with the combined large process and observation error run having the best fit. These scenarios had very little effect on stock status predictions.

Sensitivity runs 10 and 11 (High and low initial depletion)—With the obvious exception of the starting conditions of the predicted abundance trends, considering higher and lower P_{82} values had very little effect on results. Fits to indices and most parameter estimates were very similar. Compared to the base run, the overfishing condition was very similar and the overfished condition slightly improved and worsened with the higher P_{82} (less depletion) and lower P_{82} (more depletion), respectively.

Sensitivity runs 12 and 13 (High and low carrying capacity)—Although the fits to indices and predicted abundance and exploitation trends were similar to those in the base run, increasing the upper bound of *K* by an order of magnitude resulted in ca. a 6-fold increase in predicted abundance compared to the base run. Stock status with respect to the overfished condition remained very similar to that in the base run but stock status with respect to overfishing improved by almost 40%. Decreasing the upper bound of *K* by an order of magnitude also led to similar fits to indices as in the base run, but the posterior for *K* hit an upper bound, indicating that the prior did not include all plausible values. This scenario was also the only one where the exploitation rate trajectory was closer to the reference line (1) and exceeded it in some years. Stock status with respect to the overfished condition remained similar to that in the base run but stock status with respect to overfishing worsened by almost a factor of 2, although it still indicated no overfishing.

Differences in model fit between sensitivity runs 5 to 13 and the base run were very small. The RMSE ranged from 0.114 to 0.121 for the NMFS SE Bottom Longline index, from 0.070 to 0.075 for the NMFS SEAMAP Groundfish Trawl (Fall) index, from 0.031 to 0.035 for the NMFS SEAMAP Groundfish Trawl (Summer) index, and from 0.064 to 0.077 for the NMFS Small Pelagics Trawl index. DIC value differences among all model runs were <5, except for the difference between the best fitting model (DIC=-199.297 for sensitivity run 11) and the worst fitting model (DIC=-194.221 for sensitivity run 9), which was barely above 5 units.

Retrospective analysis

Results of the retrospective analysis are presented in **Table 3.7** and **Figures 3.16-3.18**. Four model output quantities were examined in the analysis: 1) exploitable number 2) exploitation rate, 3) relative exploitable number, and 4) relative exploitation rate. The abundance trajectories for the 2011, 2010, and 2009 retrospective runs overlapped among themselves and ran parallel to the base run, estimating a slightly higher abundance. The abundance trajectory for the 2008 retrospective run also ran parallel to the base run but did not overlap with the other retrospective runs, estimating an even higher abundance than those (**Figure 3.17**).

The exploitation rate trajectories for the 2011, 2010, and 2009 retrospective runs overlapped among themselves and ran parallel to the base run, overlapping it for most of the 1990s and several years in the 2000s, and estimating a slightly lower exploitation rate for the rest of the time series. The exploitation rate trajectory for the 2008 retrospective run ran parallel to the base run and the 2011, 2010, and 2009 retrospective runs but never fully overlapped with any of them, estimating a lower exploitation rate than the other retrospective runs (**Figure 3.17**). The same trends noted for the absolute abundance and exploitation rate trajectories were observed for the corresponding relative trajectories (N/N_{MSY} and $H/_{MSY}$) (**Figure 3.18**). **Figure 3.19** shows the probability of the stock being overfished for all the retrospective runs compared to the base run. Although there were some differences in the probability of the stock being overfished for some of the earlier years, all probabilities for almost the last two decades were <30%. In terms of overfishing, all probabilities remained below 30% throughout the time series.

3.2.6. Benchmarks/Reference points

The base run predicted that the stock had been overfished until about 1991 but not thereafter, ending in the most optimistic status in the final year of data, 2012, whereas overfishing never occurred (**Figure 3.20**). Results of all sensitivity runs explored agreed with the prediction of a not overfished/no overfishing status (**Figure 3.21**). Combined results from all model runs indicated that the probability of the stock being overfished was high during the first decade of the time series (1980s), generally declined to less than 30% by the mid-1990s, and further declined to very low levels by the mid-2000s, nearing 0 by the end of the time series (**Figure 3.22 top**). With the exception of several occurrences for sensitivity run 13 (low *K*) and one instance for sensitivity run 4 (high catch), the probability of overfishing never exceeded 30% throughout the entire time series (**Figure 3.22 bottom**).

3.2.7. Projections

Figure 3.23 shows the projected exploitable number for the base run at six different levels of fixed catch. Only the projection at catch=MSY resulted in more than a 30% probability of the stock being overfished during the projected time horizon of 10 years (starting in 2018) (**Figure 3.24 top**). Both the MSY and 4* C_{2012} catch strategies resulted in more than a 30% probability of overfishing occurring by 2014 (**Figure 3.24 bottom**).

Projections with the other plausible states of nature (scenarios 1-6) did not generally deviate much from those of the base run (**Appendix 3.8.6**). **Table 3.8** summarizes the catch levels that would result in both <30% probability of the stock becoming overfished and of overfishing occurring from all projection scenarios examined. Projections with the hierarchical run (scenario 1) predicted that a two-fold increase in the 2012 catch level would still yield <30% probability of overfishing occurring. In contrast, projections with the high catch run (scenario 4) predicted that a four-fold increase in the 2012 catch level would still allow for <30% probability of overfishing. Only the low catch run (scenario 3) predicted that not even the 2012 catch level would allow for <30% probability of the stock becoming overfished or of overfishing occurring. We further explored this case by adding two additional catch levels to the low catch scenario projections: 0.5*C_{2012} and 0.25*C_{2012}. Results showed that halving the 2012 catch level would still allow for <30% probability of the stock becoming overfished, but that only 0.25*C_{2012} would allow for <30% probability of overfishing (**Appendix 3.8.6**).

Figure 3.25 summarizes the probabilities of the stock being overfished and of overfishing occurring for all scenarios and catch levels considered.

3.3. DISCUSSION

This assessment can be considered data poor, or at least data limited, because of the inability to differentiate among species, which made it necessary to conduct the analyses on the complex of three species of *Mustelus*. The fishery is essentially a bycatch fishery, with shrimp trawl discards accounting for over 95% of the catches during 1982-2012. Since observer program coverage of the fishery is low, biological and fishery information is very scarce.

Four indices of abundance, all of them fishery independent, were available. These indices cover the entire northern Gulf of Mexico (GOM), although coverage of the eastern GOM from the two longest running indices (SEAMAP Groundfish Trawl) started only in 2008. All four indices of abundance, which were standardized through GLM techniques, showed an increasing trend. The stock assessment model fit captured this increasing trend in the four indices. Of the model formulations that were directly comparable, i.e., used the same data inputs, differences in DIC values were <5, indicating that none of the model runs performed substantially better than the others (Lunn et al. 2012).

The uncertainty analysis conducted revealed that stock status results relative to MSY-based reference points were rather insensitive to assumptions about catch level, stock productivity, initial conditions, carrying capacity, and other model definitions and all model formulations coincided in predicting a negligible probability of the stock being overfished or overfishing occurring in 2012 and at least the six preceding years. Only the low *K* sensitivity run showed a consistently higher probability of overfishing than all other scenarios during most of the time series, but that scenario hit the upper bound of *K*. The retrospective analysis revealed that there were some retrospective patterns, but stock status results were not affected. In all, the Bayesian estimation approach used allowed us to transparently specify the degree of uncertainty and confidence in the quantities estimated.

Similarly, the Bayesian projection approach allowed us to specify the risk levels of implementing different catch-based strategies. Projections under varying catch levels based on what were considered more plausible states of nature all predicted, except the low catch scenario, that the 2012 catch could be increased by a factor of 4 and still allow for less than a 30% probability of the stock being overfished during any of the 10 years in the projection horizon. Similarly, all projected scenarios, except the low catch scenario, predicted that the 2012 catch could be increased by a factor of 2, 3, or 4 and still allow for less than a 30% probability of overfishing occurring during any of the 10 years in the projection horizon. Because the low catch scenario predicted that the 2012 catch would lead to both more than a 30% probability of the stock being overfished and overfishing occurring, we explored the use of two additional catch levels (half and a quarter the 2012 catch), which indicated that halving the 2012 catch would still allow for less than a 30% probability of the stock being overfished, but that the 2012 catch would have to be reduced by ¼ for the probability of overfishing to remain below 30%. However, the low catch scenario is likely not very plausible because the lower confidence limit of the shrimp trawl discard series was 0 in all years except 2010. In all, it appears that doubling the 2012 catches would still provide a sufficient buffer from the overfishing limit, such that the probability of overfishing occurring in any given year during 2013-2022 would be less than 30%.

Despite the limitations of the data available, the known life-history characteristics of at least some of the species making up the complex, in combination with the fishery-independent indicators of relative abundance suggest that this species complex can support current levels of exploitation. As recommended by the Life History WG (see Data Workshop report), the life histories of the three *Mustelus* species that compose the complex should be investigated more in depth. However, species-specific assessments will likely still not be possible in the future because of the great difficulty in correct identification of specimens.

3.4. RECOMMENDATION FOR DATA COLLECTION AND FUTURE RESEARCH

We list below research recommendations that are more feasible and would allow improvement of future stock assessments of this stock:

- Since catches are dominated by shrimp trawl fishery discards, increase the spatio-temporal observer coverage of the shrimp fleet
- Explore the relationship between catch rates derived from the shrimp fleet observer program and those based on the SEAMAP survey to indirectly estimate shrimp bycatch CPUE prior to 2009 when observer program data were especially limited
- Reexamine and/or investigate all aspects of the life histories of the three *Mustelus* species occurring in the Gulf of Mexico

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3.6. TABLES

Table 3.1. Standardized hierarchical index of abundance used in sensitivity scenario 1 with associated CVs. The index is scaled (divided by the mean).

Year	Index
1982	0.834
1983	1.464
1984	0.664
1985	0.564
1986	0.597
1987	0.563
1988	0.373
1989	0.736
1990	0.798
1991	0.422
1992	1.116
1993	0.703
1994	1.405
1995	1.420
1996	0.731
1997	0.810
1998	0.801
1999	0.663
2000	1.467
2001	0.843
2002	0.895
2003	0.817
2004	0.836
2005	1.021
2006	1.578
2007	1.067
2008	1.097
2009	1.915
2010	1.389
2011	1.470
2012	1.943

Table 3.2. Low and high catch scenarios for Gulf of Mexico smoothhounds (all in numbers) compared to base run catches.

Year	Base catch	Low catch	High catch
1982	64706	0	152313
1983	62942	1718	145837
1984	69297	3168	158832
1985	73338	6375	164002
1986	80206	3659	183845
1987	89976	5104	204887
1988	73681	37	173391
1989	89328	7710	199834
1990	88742	6192	200510
1991	97333	1953	226471
1992	97906	4943	223773
1993	97163	5205	221668
1994	98507	5789	224042
1995	98482	4043	226347
1996	116409	4560	267847
1997	135704	5343	312205
1998	142787	3840	330911
1999	147579	4106	341832
2000	151288	3861	350893
2001	166187	4280	385398
2002	189143	4202	439541
2003	165300	3846	383899
2004	150710	3597	349890
2005	109011	4635	250329
2006	106097	625	248898
2007	95086	430	223244
2008	91299	13766	196273
2009	112045	3334	227126
2010	75795	15550	136041
2011	111078	643	226534
2012	99167	3216	203591

Table 3.3. Summary of results (mean and CV) for base run. N_{2013} ratio is N_{2013}/K. All abundance metrics refer to exploitable number. H is the exploitation rate. P_{1982} is N_{1982}/K. M is the average (age 1-max) natural mortality rate.

Run	**Base**	
	Mean	CV
K	1.44E+07	0.88
r	0.212	0.40
MSY	6.89E+05	0.95
N_{2012}	1.27E+07	0.90
H_{2012}	0.018	0.96
N_{2013}ratio	0.787	0.24
N_{1982}	5.28E+06	0.98
H_{2012}/H_{MSY}	**0.179**	**0.89**
N_{2012}/N_{MSY}	**1.776**	**0.16**
N_{MSY}	7.19E+06	0.88
H_{MSY}	0.106	0.40
P_{1982}	0.589	0.20
MSST ((1-M)*N_{MSY})	5.53E+06	
Convergence diagnostics		
Chain mixing	Good	
Autocorrelations	Low	
Gelman-Rubin	Good	
(MC error)/(posterior sd)	<5%	
Abundance index	**RMSE**	
NMFS SE Bottom LL	0.115	
NMFS SEAMAP Gr Tr (F)	0.071	
NMFS SEAMAP Gr Tr (S)	0.032	
NMFS Small Pel Tr	0.069	

Table 3.4. Mean predicted exploitable number, exploitation rate, relative exploitable number, and relative exploitation rate by year for the base run.

Year	N	H	N/N_{MSY}	F/F_{MSY}
1982	5,282,000	0.031	0.744	0.297
1983	3,426,000	0.049	0.488	0.472
1984	3,786,000	0.048	0.535	0.465
1985	3,925,000	0.049	0.554	0.475
1986	4,063,000	0.051	0.574	0.497
1987	4,086,000	0.057	0.578	0.550
1988	4,014,000	0.046	0.567	0.447
1989	5,239,000	0.043	0.736	0.415
1990	5,640,000	0.040	0.789	0.385
1991	4,680,000	0.052	0.656	0.505
1992	5,557,000	0.044	0.775	0.432
1993	6,250,000	0.039	0.878	0.376
1994	8,423,000	0.029	1.179	0.284
1995	9,415,000	0.026	1.320	0.252
1996	7,306,000	0.039	1.026	0.383
1997	7,137,000	0.047	1.004	0.457
1998	7,125,000	0.050	1.001	0.483
1999	7,241,000	0.050	1.017	0.489
2000	8,715,000	0.043	1.213	0.419
2001	6,937,000	0.059	0.967	0.572
2002	6,133,000	0.075	0.858	0.724
2003	5,782,000	0.069	0.808	0.670
2004	6,314,000	0.058	0.882	0.561
2005	7,690,000	0.035	1.067	0.343
2006	9,381,000	0.028	1.307	0.267
2007	8,674,000	0.027	1.209	0.258
2008	9,873,000	0.022	1.379	0.217
2009	11,970,000	0.022	1.674	0.216
2010	10,800,000	0.017	1.513	0.162
2011	9,982,000	0.027	1.399	0.258
2012	12,710,000	0.018	1.776	0.179

Table 3.5. Summary of results (mean and CV) for sensitivity runs 1-4. N_{2013} ratio is N_{2013}/K. All abundance metrics refer to exploitable number. H is the exploitation rate. P_{1982} is N_{1982}/K. M is the average (age 1-max) natural mortality rate.

Run	**Base**		**Hierarchical**		**Inv CV**		**Low Catch**		**High Catch**	
	Mean	CV	EV	CV	EV	CV	EV	CV	EV	CV
K	1.44E+07	0.88	1.37E+07	0.90	1.52E+07	0.84	7.65E+06	1.50	1.88E+07	0.67
r	0.212	0.40	0.204	0.40	0.210	0.39	0.195	0.39	0.223	0.39
MSY	6.89E+05	0.95	6.27E+05	0.98	7.21E+05	0.90	3.48E+05	1.64	9.61E+05	0.74
N_{2012}	1.27E+07	0.90	1.15E+07	0.94	1.38E+07	0.86	6.77E+06	1.54	1.67E+07	0.70
H_{2012}	0.018	0.96	0.021	0.97	0.016	0.97	0.007	1.60	0.021	0.81
N_{2013}ratio	0.787	0.24	0.767	0.24	0.789	0.23	0.790	0.24	0.785	0.24
N_{1982}	5.28E+06	0.98	6.84E+06	0.95	5.16E+06	0.95	2.77E+06	1.61	6.95E+06	0.79
H_{2012}/H_{MSY}	**0.179**	0.89	**0.211**	0.89	**0.159**	0.87	**0.071**	1.51	**0.196**	0.73
N_{2012}/N_{MSY}	**1.776**	0.16	**1.680**	0.19	**1.826**	0.15	**1.776**	0.17	**1.778**	0.16
N_{MSY}	7.19E+06	0.88	6.84E+06	0.90	7.60E+06	0.84	3.82E+06	1.50	9.42E+06	0.67
H_{MSY}	0.106	0.40	0.102	0.40	0.105	0.39	0.098	0.39	0.112	0.39
P_{1982}	0.589	0.20	0.638	0.18	0.584	0.20	0.590	0.20	0.588	0.20
MSST ($(1-M)*N_{MSY}$)	5.53E+06		5.26E+06		5.84E+06		2.94E+06		7.24E+06	
Convergence diagnostics										
Chain mixing	Good		Good		Good		Good		Good	
Autocorrelations	Low		Low		Low		Low		Low	
Gelman-Rubin	Good		Good		Good		Good		Good	
(MC error)/(posterior sd)	<5%		<5%		<5%		<5%		<5%	

Table 3.6. Summary of results (mean and CV) for sensitivity runs 5-13. N_{2013} ratio is N_{2013}/K. All abundance metrics refer to exploitable number. H is the exploitation rate. P_{1982} is N_{1982}/K. M is the average (age 1-max) natural mortality rate.

Run	**Base**		**Low r**		**High r**		**Large ProErr**		**Large ObsErr**		**Large Pro&ObsErr**	
	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV
K	1.44E+07	0.88	1.58E+07	0.82	1.34E+07	0.93	1.30E+07	0.93	1.44E+07	0.89	1.31E+07	0.93
r	0.212	0.40	0.182	0.42	0.241	0.37	0.199	0.40	0.210	0.39	0.195	0.40
MSY	6.89E+05	0.95	6.59E+05	0.92	7.28E+05	1.00	5.70E+05	0.98	6.80E+05	0.96	5.61E+05	0.98
N_{2012}	1.27E+07	0.90	1.39E+07	0.85	1.19E+07	0.96	1.20E+07	0.95	1.27E+07	0.91	1.20E+07	0.95
H_{2012}	0.018	0.96	0.016	0.99	0.021	0.97	0.020	0.93	0.019	0.97	0.020	0.92
N_{2013}ratio	0.787	0.24	0.785	0.24	0.736	0.35	0.848	0.19	0.793	0.23	0.847	0.19
N_{1982}	5.28E+06	0.98	5.85E+06	0.93	4.85E+06	1.04	5.48E+06	1.00	5.56E+06	0.99	5.72E+06	1.00
H_{2012}/H_{MSY}	**0.179**	0.89	**0.186**	0.92	**0.175**	0.86	**0.196**	0.79	**0.180**	0.87	**0.198**	0.77
N_{2012}/N_{MSY}	**1.776**	0.16	**1.768**	0.17	**1.777**	0.16	**1.834**	0.14	**1.782**	0.16	**1.828**	0.14
N_{MSY}	7.19E+06	0.88	7.90E+06	0.82	6.71E+06	0.93	6.51E+06	0.93	7.19E+06	0.89	6.57E+06	0.93
H_{MSY}	0.106	0.40	0.091	0.42	0.120	0.37	0.099	0.40	0.105	0.39	0.097	0.40
P_{1982}	0.589	0.20	0.588	0.19	0.587	0.20	0.562	0.20	0.593	0.19	0.568	0.20
MSST ((1-M)*N_{MSY})	5.53E+06		5.71E+06		5.47E+06		5.01E+06		5.53E+06		5.05E+06	
Convergence diagnostics												
Chain mixing	Good		Good		Good		Good		Good		Good	
Autocorrelations	Low		Low		Low		Low		Low		Low	
Gelman-Rubin	Good		Good		Good		Good		Good		Good	
(MC error)/(posterior sd)	<5%		<5%		<5%		<5%		<5%		<5%	
Abundance index	**RMSE**		**RMSE**		**RMSE**		**RMSE**		**RMSE**		**RMSE**	
NMFS SE Bottom LL	0.115		0.114		0.114		0.117		0.120		0.121	
NMFS SEAMAP Gr Tr (F)	0.071		0.071		0.071		0.075		0.072		0.075	
NMFS SEAMAP Gr Tr (S)	0.032		0.032		0.032		0.034		0.033		0.035	
NMFS Small Pel Tr	0.069		0.069		0.069		0.077		0.064		0.074	
DIC for model comparison	-197.906		-197.973		-197.571		-196.532		-195.252		-194.221	

Table 3.6. (Continued)

Run	**High P_{82}**		**Low P_{82}**		**High K**		**Low K**	
	EV	CV	EV	CV	EV	CV	EV	CV
K	1.43E+07	0.88	1.45E+07	0.88	8.61E+07	1.38	3.11E+06	0.33
r	0.215	0.40	0.214	0.39	0.201	0.40	0.260	0.35
MSY	6.97E+05	0.96	7.03E+05	0.94	3.96E+06	1.51	1.93E+05	0.40
N_{2012}	1.29E+07	0.91	1.27E+07	0.90	7.62E+07	1.42	2.78E+06	0.36
H_{2012}	0.019	1.00	0.019	0.97	0.012	1.44	0.042	0.44
N_{2013}ratio	0.786	0.24	0.789	0.23	0.786	0.24	0.786	0.23
N_{1982}	6.25E+06	0.99	4.25E+06	0.97	3.11E+07	1.51	1.19E+06	0.47
H_{2012}/H_{MSY}	**0.179**	0.91	**0.177**	0.88	**0.111**	1.31	**0.345**	0.47
N_{2012}/N_{MSY}	**1.796**	0.15	**1.753**	0.17	**1.769**	0.17	**1.795**	0.15
N_{MSY}	7.17E+06	0.89	7.26E+06	0.88	4.30E+07	1.38	1.56E+06	0.33
H_{MSY}	0.107	0.40	0.107	0.39	0.101	0.40	0.130	0.35
P_{1982}	0.740	0.18	0.430	0.20	0.588	0.20	0.590	0.20
MSST ((1-M)*N_{MSY})	5.51E+06		5.58E+06		3.31E+07		1.20E+06	
Convergence diagnostics								
Chain mixing	Good		Good		Good		Good	
Autocorrelations	Low		Low		Low		Low	
Gelman-Rubin	Good		Good		Good		Good	
(MC error)/(posterior sd)	<5%		<5%		<5%		<5%	
Abundance index	**RMSE**		**RMSE**		**RMSE**		**RMSE**	
NMFS SE Bottom LL	0.114		0.114		0.114		0.115	
NMFS SEAMAP Gr Tr (F)	0.070		0.071		0.071		0.071	
NMFS SEAMAP Gr Tr (S)	0.033		0.032		0.032		0.032	
NMFS Small Pel Tr	0.070		0.068		0.068		0.070	
DIC for model comparison	-195.799		-199.297		-197.855		-197.843	

Table 3.7. Summary of results (mean and CV) for the retrospective runs. N_{cur+1} ratio is N_{cur+1}/K. All abundance metrics refer to exploitable number. H is the exploitation rate. P_{1982} is N_{1982}/K. M is the average (age 1-max) natural mortality rate.

Run	**Base**		**Retro2011**		**Retro2010**		**Retro2009**		**Retro2008**	
	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV
K	1.44E+07	0.88	1.41E+07	0.90	1.42E+07	0.89	1.42E+07	0.90	1.39E+07	0.91
r	0.212	0.40	0.214	0.39	0.213	0.40	0.216	0.39	0.224	0.40
MSY	6.89E+05	0.95	6.84E+05	0.98	6.88E+05	0.97	7.00E+05	0.98	7.16E+05	1.00
N_{cur}	1.27E+07	0.90	1.03E+07	0.93	1.16E+07	0.92	1.27E+07	0.92	1.12E+07	0.95
H_{cur}	0.018	0.96	0.027	0.99	0.016	1.00	0.022	0.98	0.021	1.04
N_{cur+1}ratio	0.787	0.24	0.715	0.27	0.762	0.25	0.787	0.24	0.753	0.26
N_{cur}	5.28E+06	0.98	5.52E+06	0.99	5.55E+06	1.00	5.53E+06	1.02	5.76E+06	1.01
Hcur/H_{MSY}	**0.179**	0.89	**0.257**	0.91	**0.155**	0.89	**0.204**	0.89	**0.196**	0.99
Ncur/N_{MSY}	**1.776**	0.16	**1.462**	0.20	**1.635**	0.19	**1.794**	0.16	**1.622**	0.21
N_{MSY}	7.19E+06	0.88	7.06E+06	0.90	7.10E+06	0.89	7.09E+06	0.90	6.95E+06	0.91
H_{MSY}	0.106	0.40	0.107	0.39	0.106	0.40	0.108	0.39	0.112	0.40
P_{1982}	0.589	0.20	0.594	0.19	0.594	0.19	0.599	0.20	0.607	0.19
MSST ((1-M)*N_{MSY})	5.53E+06		5.43E+06		5.46E+06		5.45E+06		5.35E+06	
Convergence diagnostics										
Chain mixing	Good		Good		Good		Good		Good	
Autocorrelations	Low		Low		Low		Low		Low	
Gelman-Rubin	Good		Good		Good		Good		Good	
(MC error)/(posterior sd)	<5%		<5%		<5%		<5%		<5%	
cur = 2012 for base, 2011 for Retro2011, 2010 for Retro2010, 2009 for Retro2009, and 2008 for Retro2008										

Table 3.8. Level of 2012 catches that allow for less than a 30% probability of the stock being overfished and overfishing occurring in 2022 with the projected base run and six alternative scenarios (1-6) corresponding to plausible states of nature. Conclusions that differ from those of the base run are highlighted in yellow.

Scenario	Pr(Overfished)<0.3	Pr(Overfishing<0.3)
Base	Catch$_{2012}$ x 4	Catch$_{2012}$ x 3
Hierarchical	Catch$_{2012}$ x 4	Catch$_{2012}$ x 2
Inverse CV weights	Catch$_{2012}$ x 4	Catch$_{2012}$ x 3
Low catch	Catch$_{2012}$ x 0	Catch$_{2012}$ x 0
High catch	Catch$_{2012}$ x 4	Catch$_{2012}$ x 4
Low productivity	Catch$_{2012}$ x 4	Catch$_{2012}$ x 3
High productivity	Catch$_{2012}$ x 4	Catch$_{2012}$ x 3

3.7. FIGURES

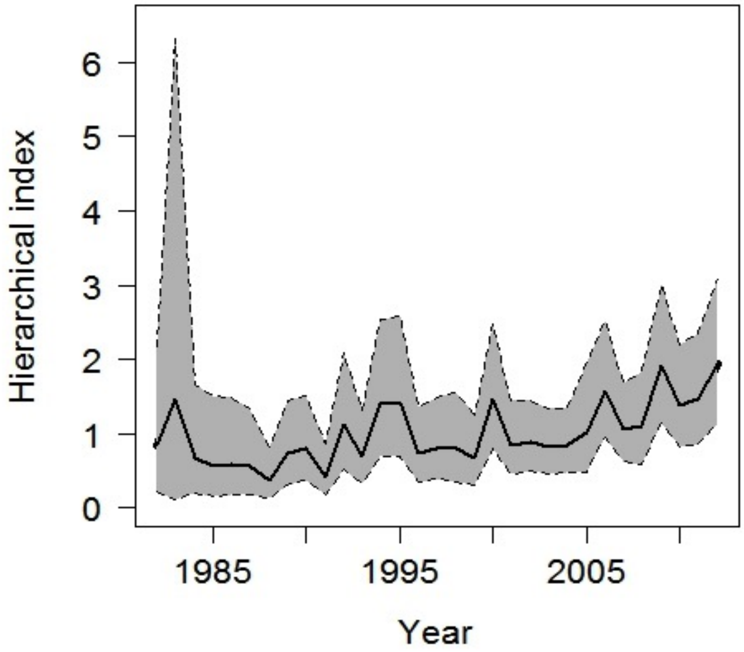


Figure 3.1. Hierarchical index of abundance used in sensitivity run 1. The shaded area is the 95% CI band.

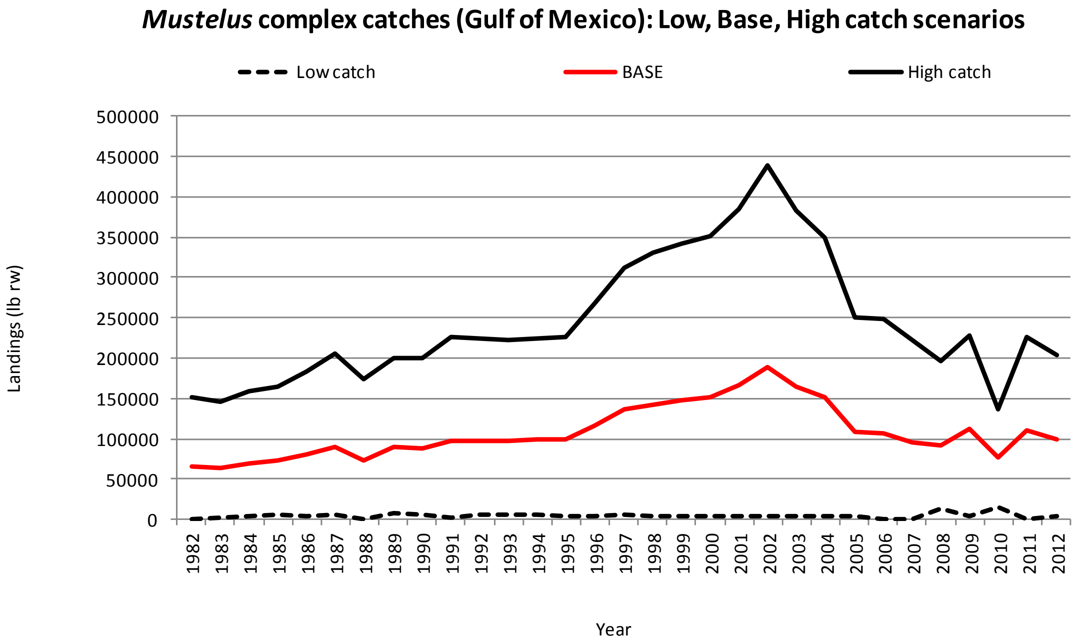
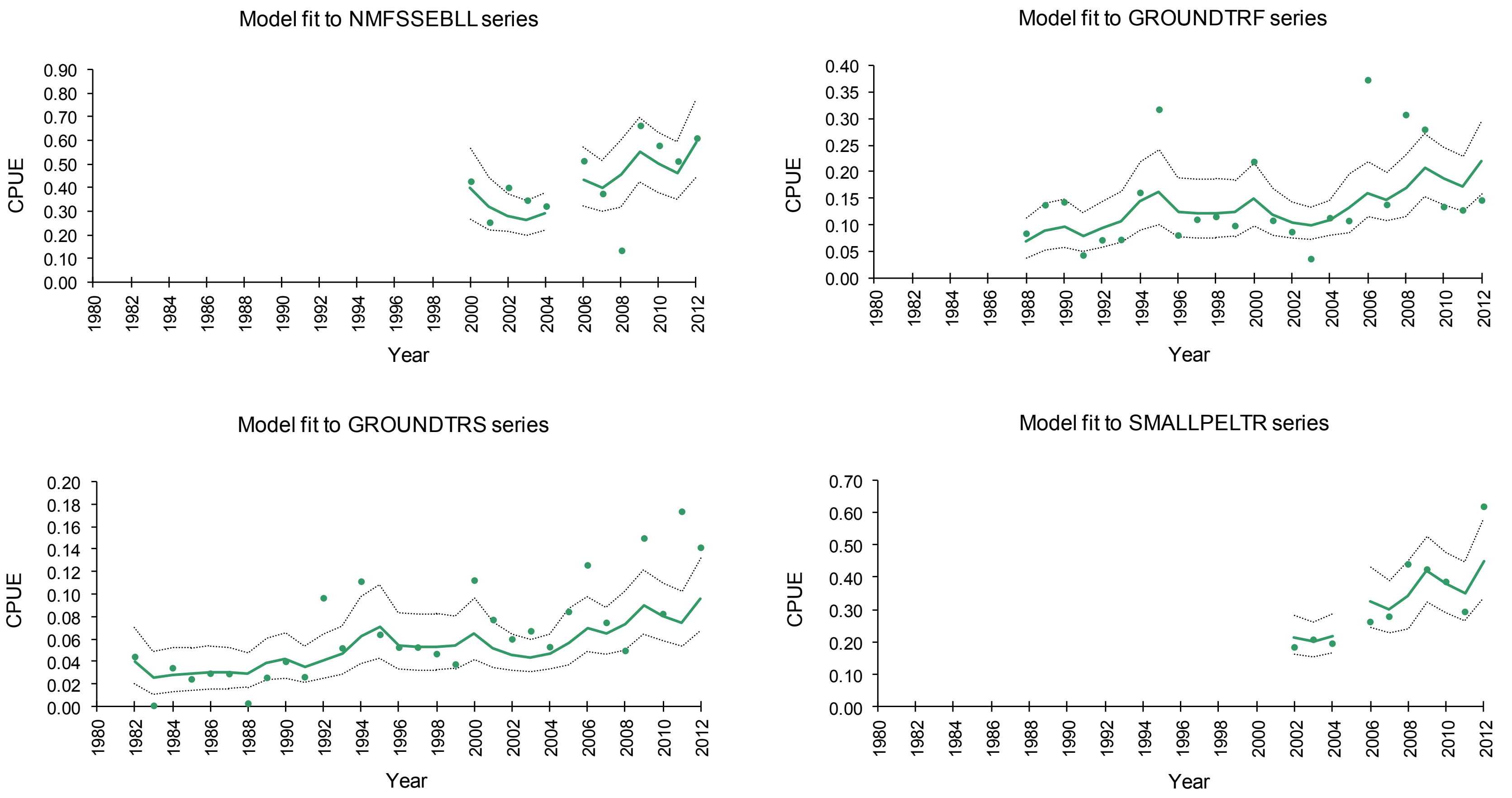


Figure 3.2. Low and high catches used in the low and high catch sensitivity runs (3 and 4). The base run catches are shown for reference.


Model fit to NMFSSEBLL series

Model fit to GROUNDTRF series

Model fit to GROUNDTRS series

Model fit to SMALLPELTR series

Figure 3.3. Predicted fits to the four indices of abundance in the base run. Solid circles are observed CPUEs, solid lines are mean predicted CPUEs, and dotted lines are 95% credible intervals.

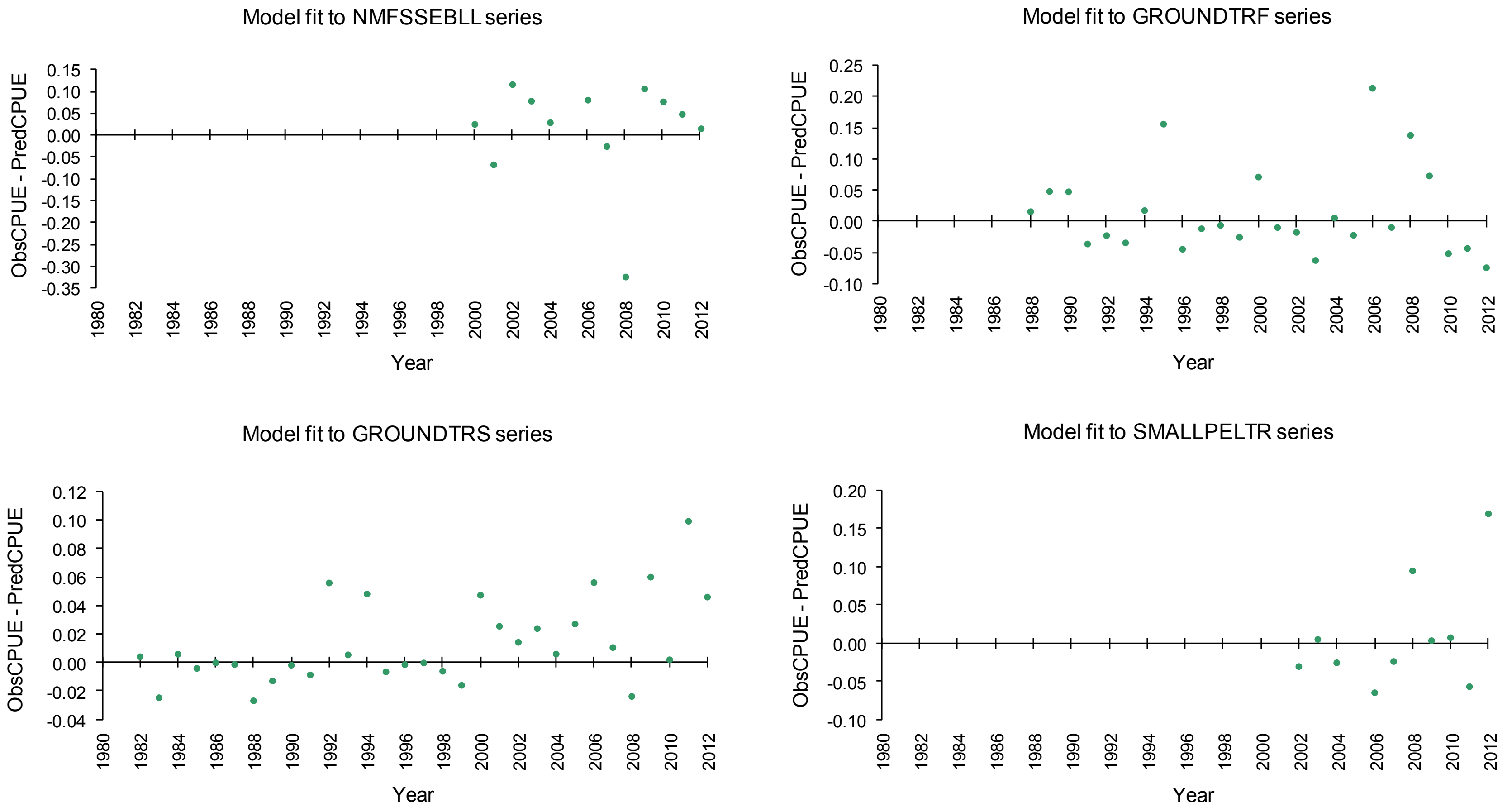


Figure 3.4. Residual plots (normal scale) of the CPUE fits for the base run.

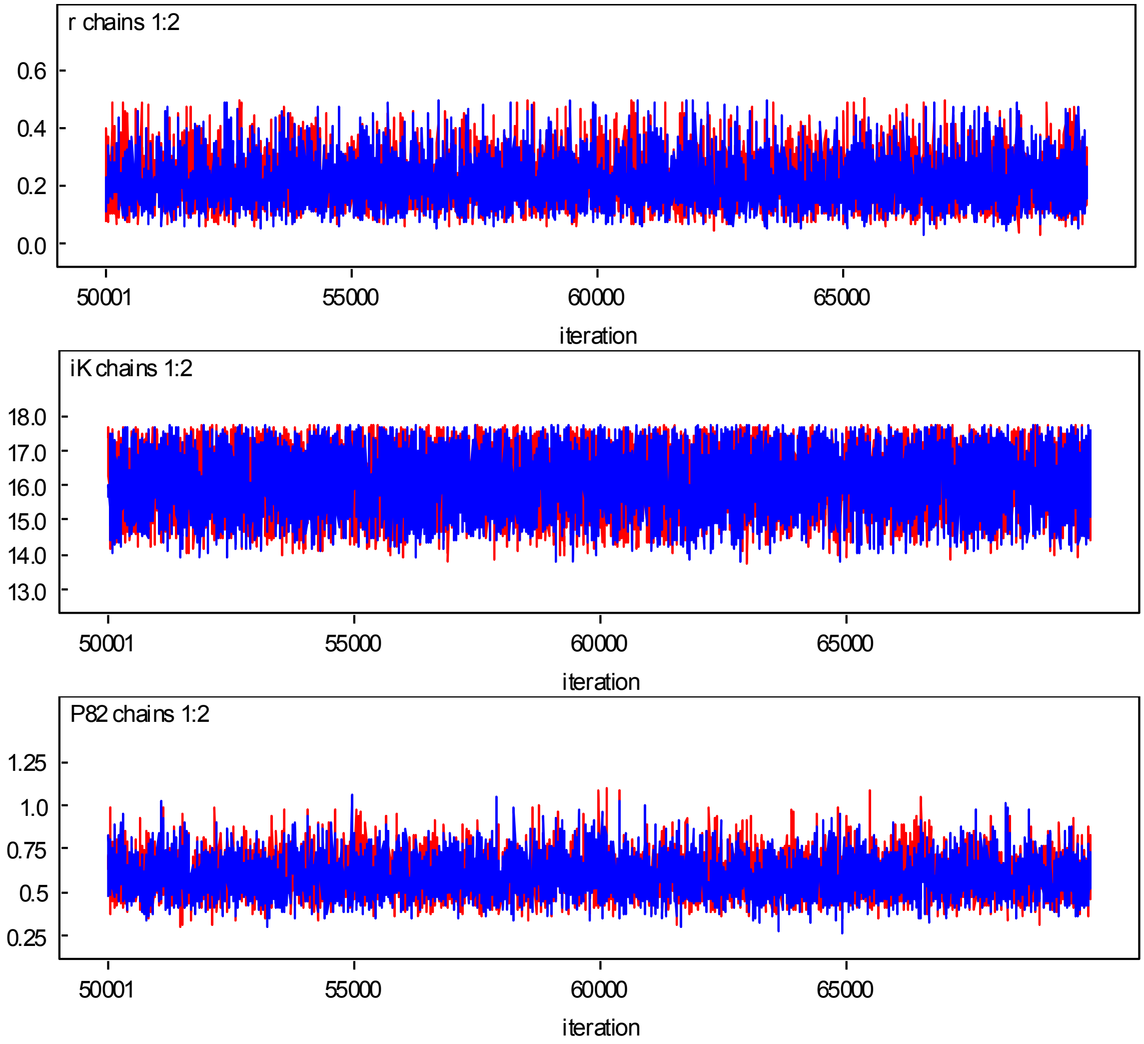


Figure 3.5. Convergence diagnostic for the base run showing the time series history of mixing for the two chains for the key model parameters (r, K, and P_{82}).

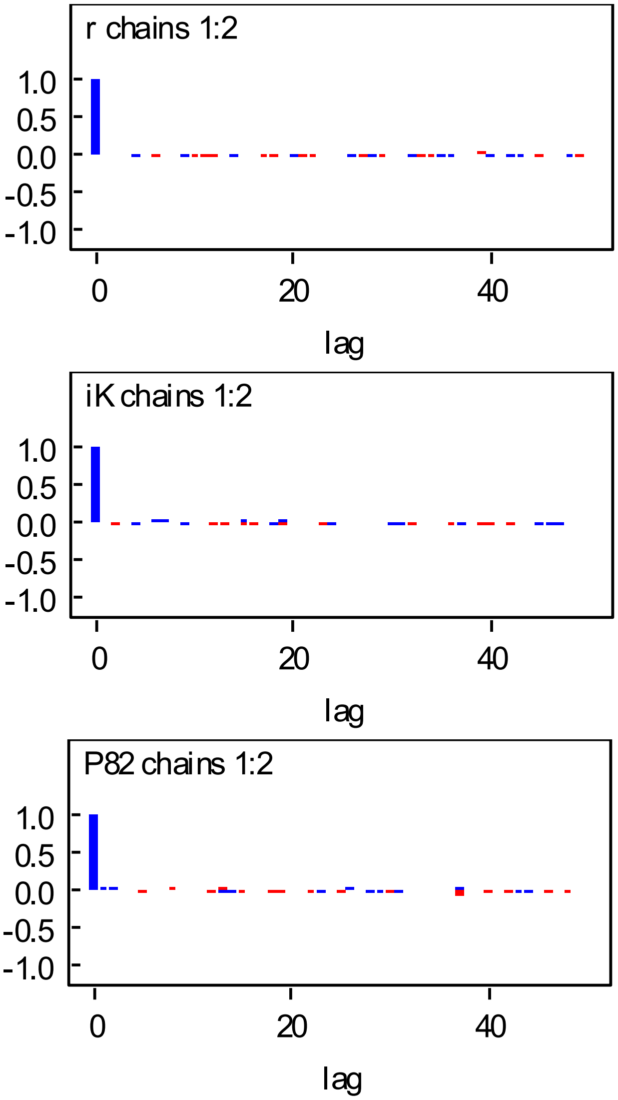


Figure 3.6. Convergence diagnostic for the base run showing the autocorrelation for the two chains for the key model parameters (r, K, and P_{82}).

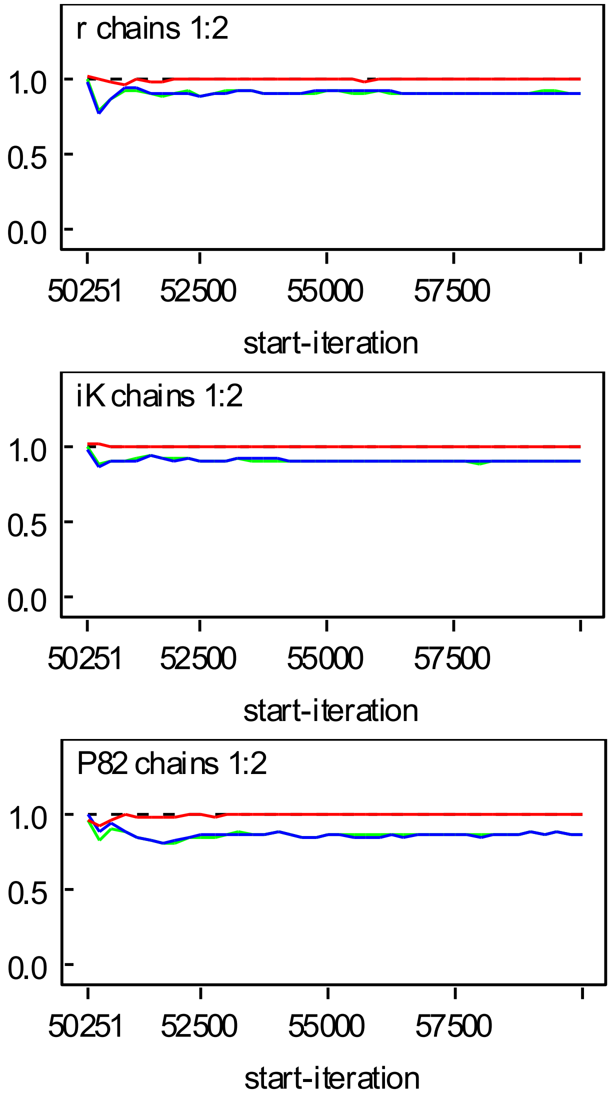


Figure 3.7. Convergence diagnostic for the base run showing the Gelman-Rubin statistic for the two chains for the key model parameters (*r, K,* and P_{82}).

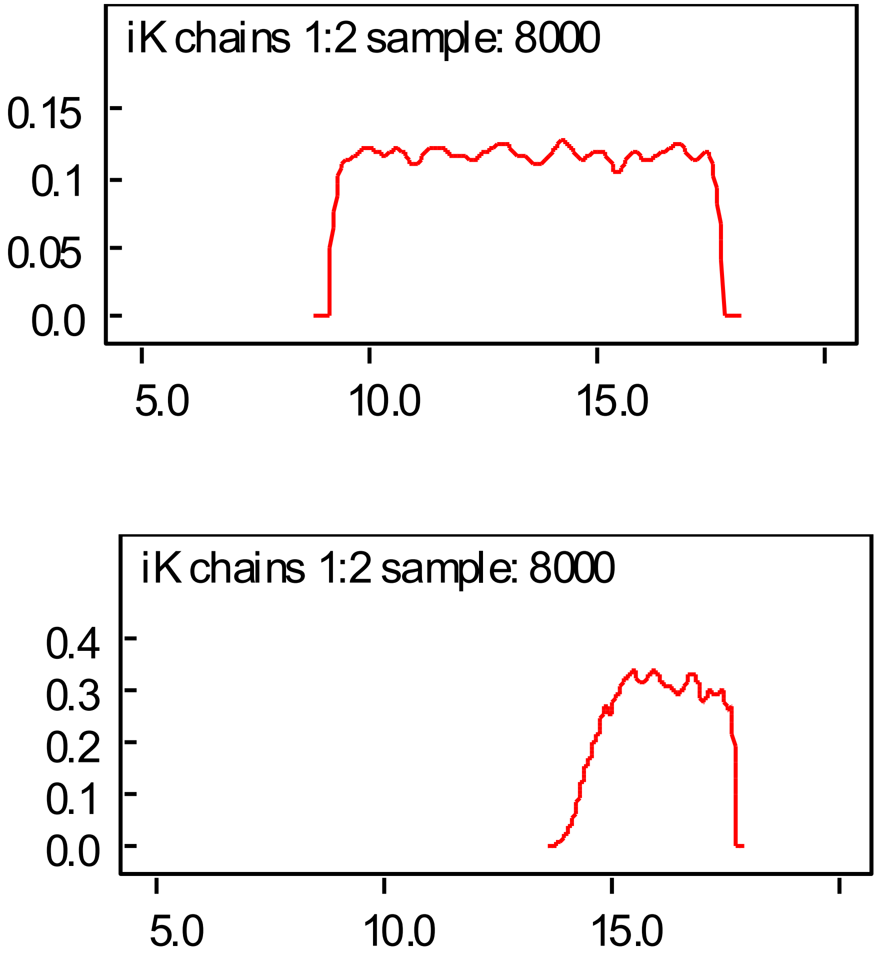


Figure 3.8. Prior and posterior distribution for carrying capacity (*K=exp(iK)*) in the base run.

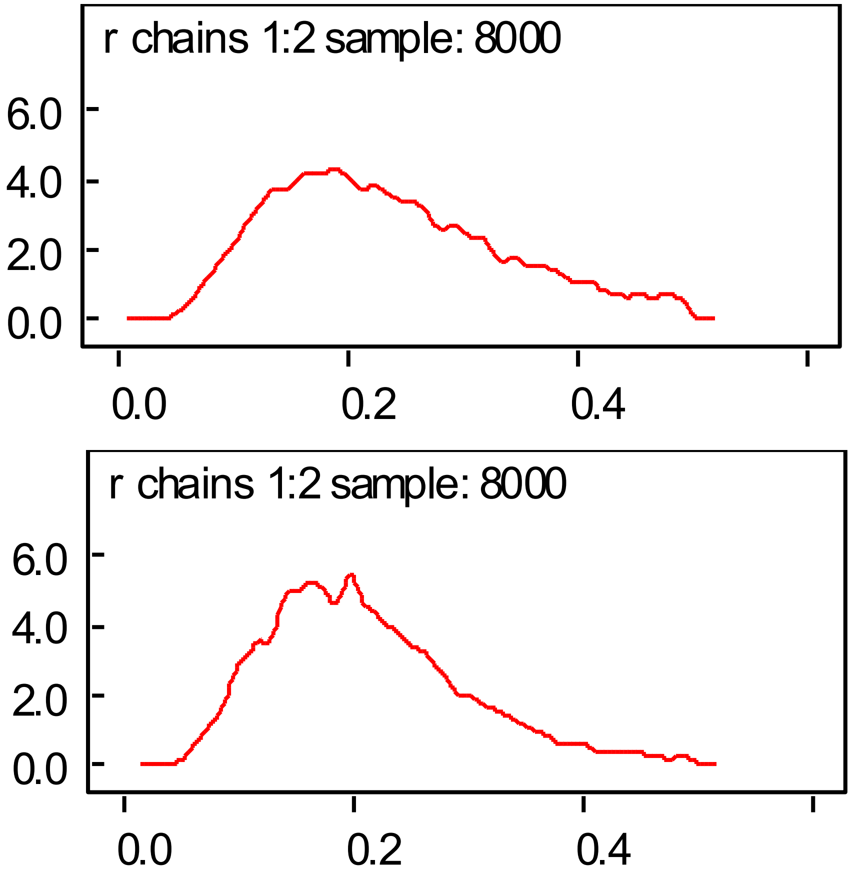


Figure 3.9. Prior and posterior distribution for the intrinsic rate of increase (*r*) in the base run.

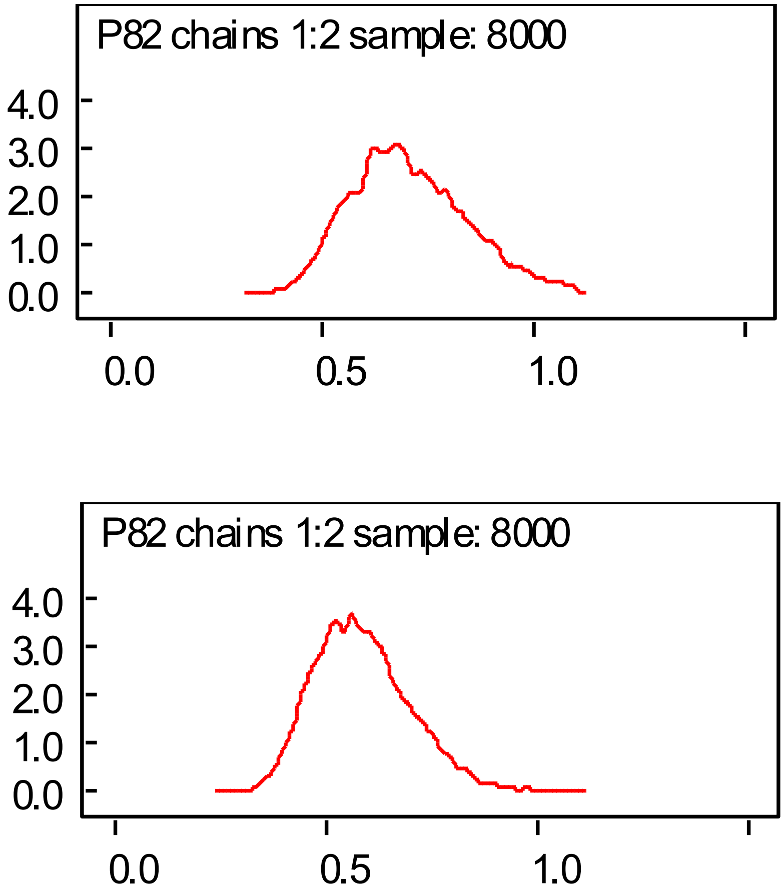


Figure 3.10. Prior and posterior distribution for initial depletion (P_{82}) in the base run.

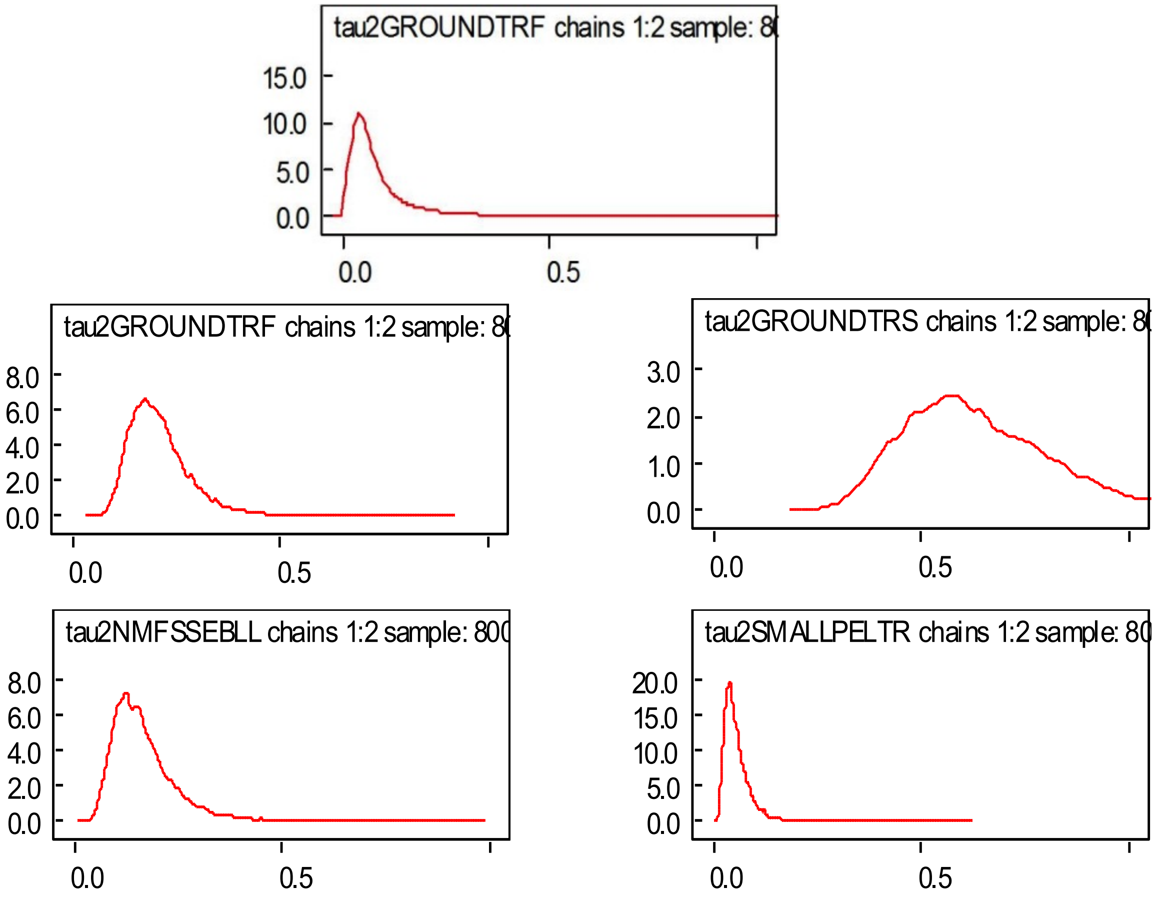


Figure 3.11. Prior and posterior distribution for the observation error variance (τ^2) in the base run. The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

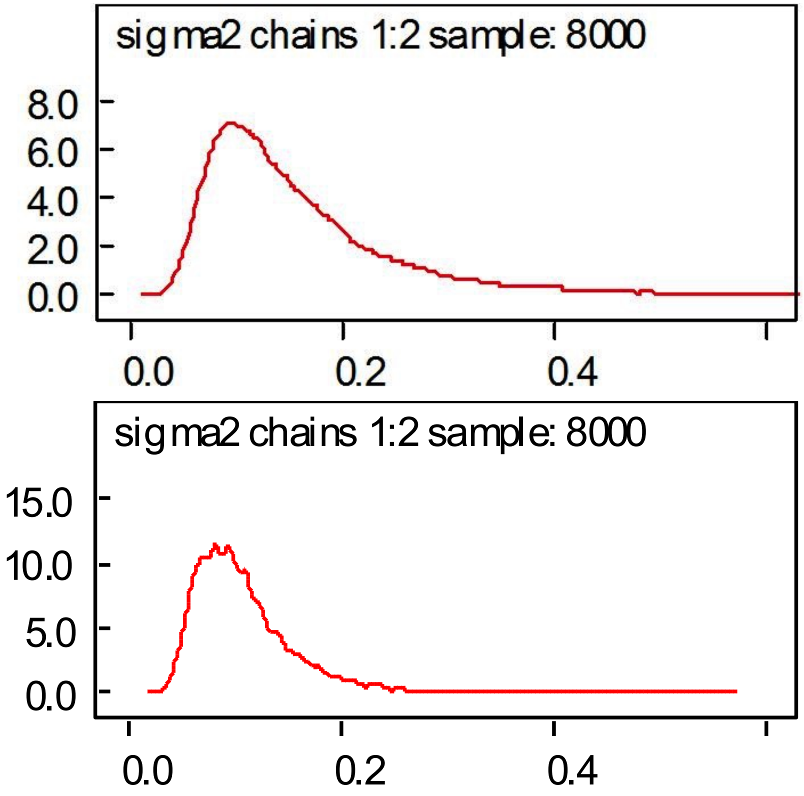
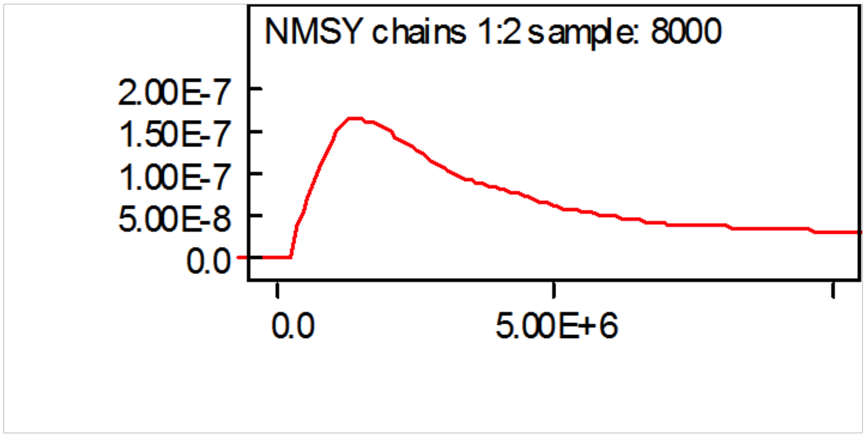


Figure 3.12. Prior and posterior distribution for the process error variance (σ^2) in the base run.



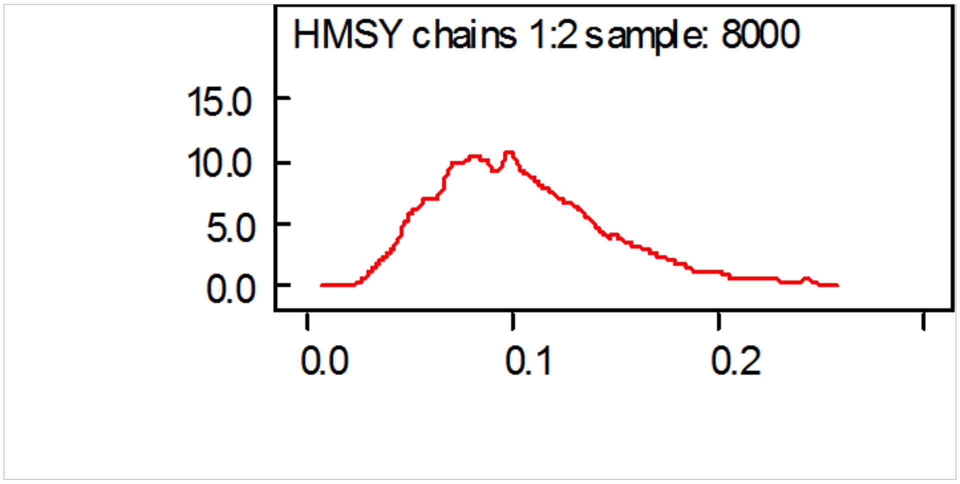
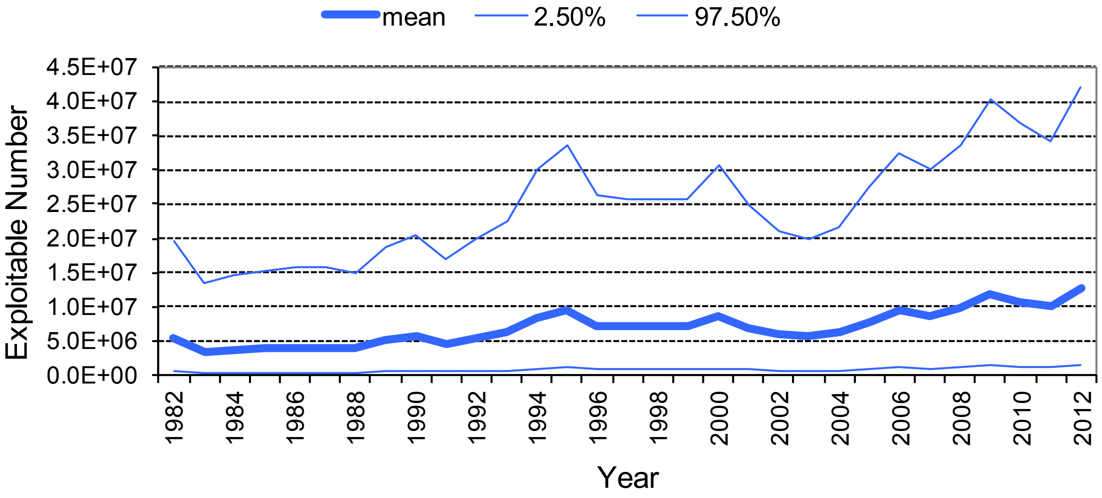


Figure 3.13. Prior and posterior distribution for the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy}) in the base run.



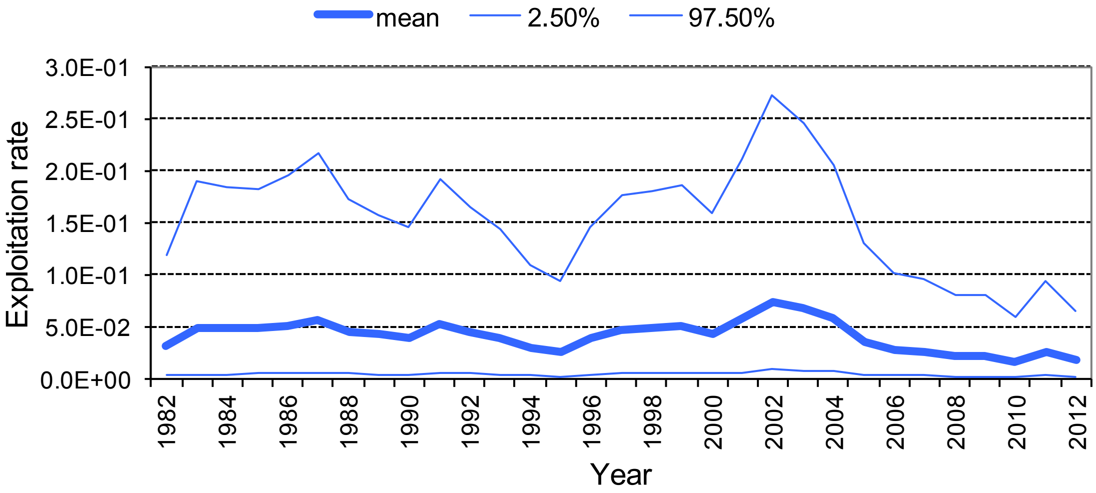
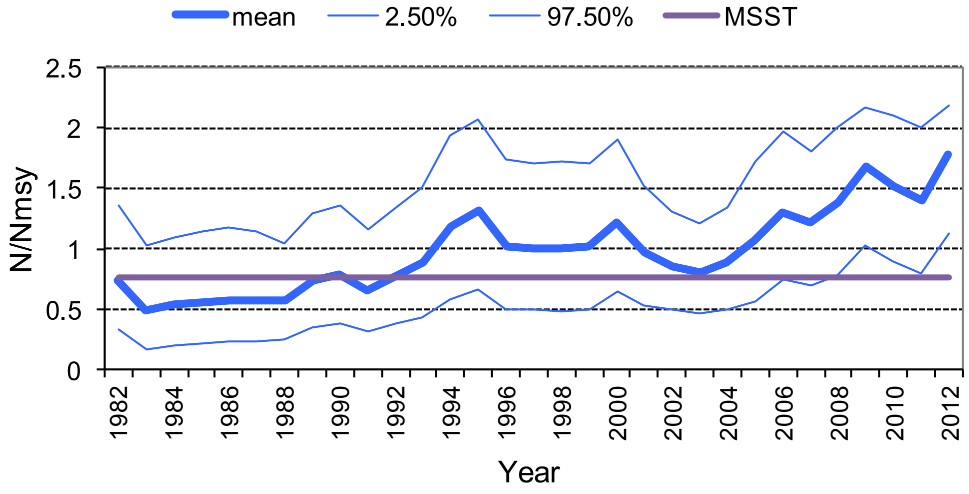


Figure 3.14. Mean predicted exploitable number (top) and exploitation rate (bottom) trajectories (with 95% credible intervals) for the base run.



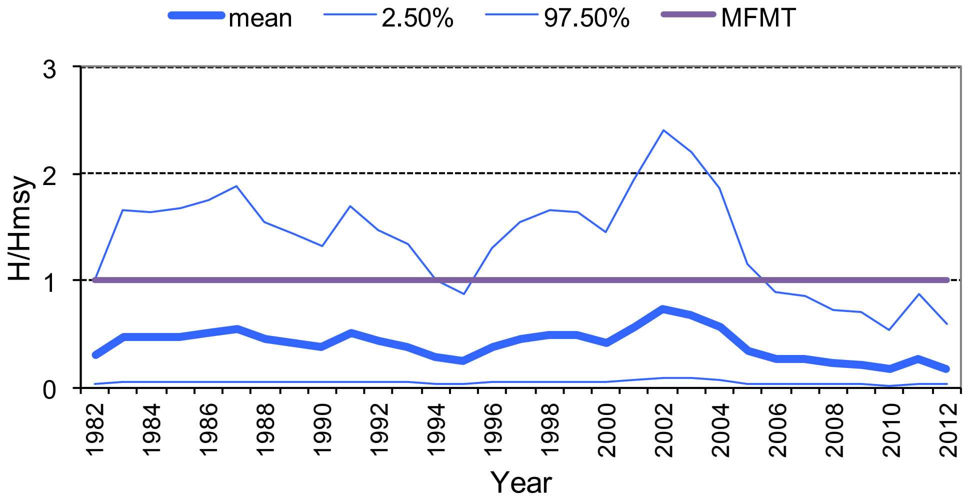
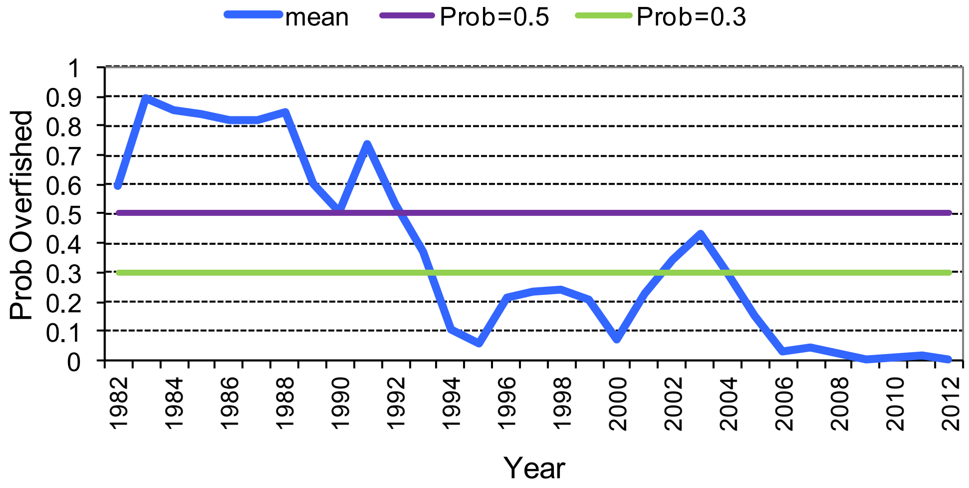


Figure 3.15. Mean relative predicted exploitable number (top) and relative exploitation rate (bottom) trajectories (with 95% credible intervals) for the base run. In the top panel, MSST is the Minimum Stock Size Threshold ($(1-M)N_{MSY}$) reference line; in the bottom panel, MFMT is the maximum fishing mortality threshold (H_{MSY}).



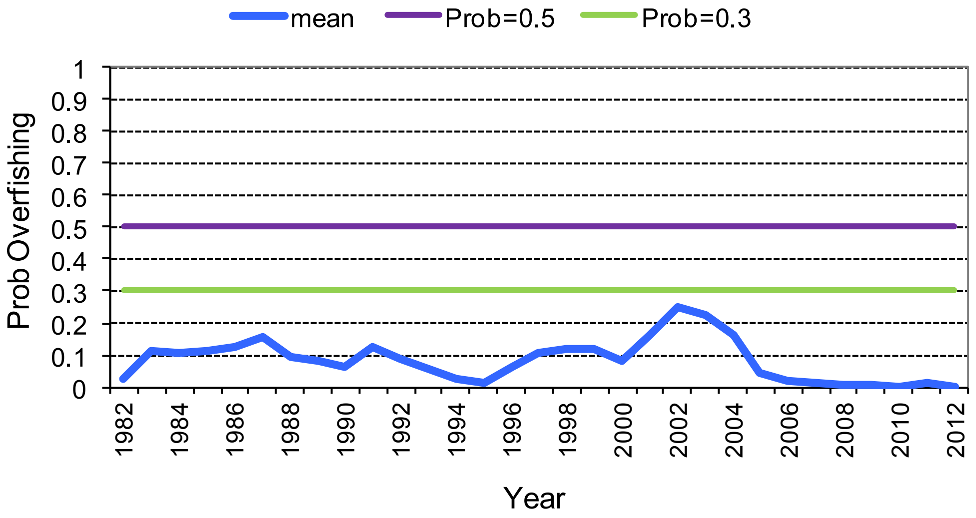
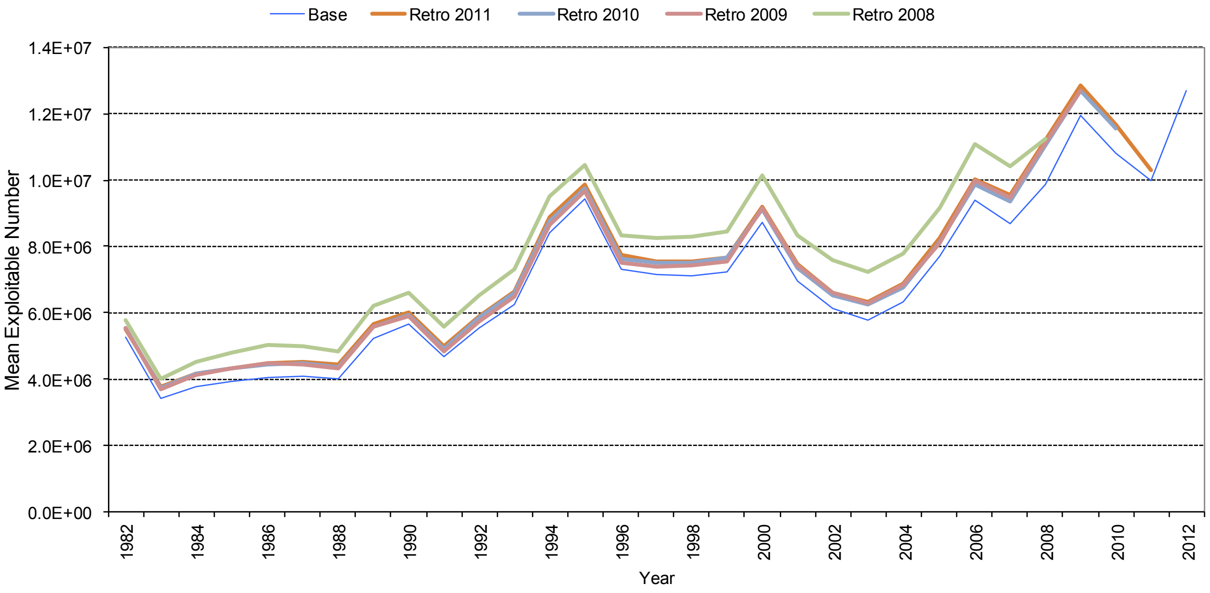


Figure 3.16. Probability of exploitable number being smaller than MSST (overfished condition; top) and probability of exploitation rate being larger than H_{MSY} (overfishing condition; bottom) for the base run. The two reference lines denote a 50% and 30% probability of an overfished and overfishing condition occurring.



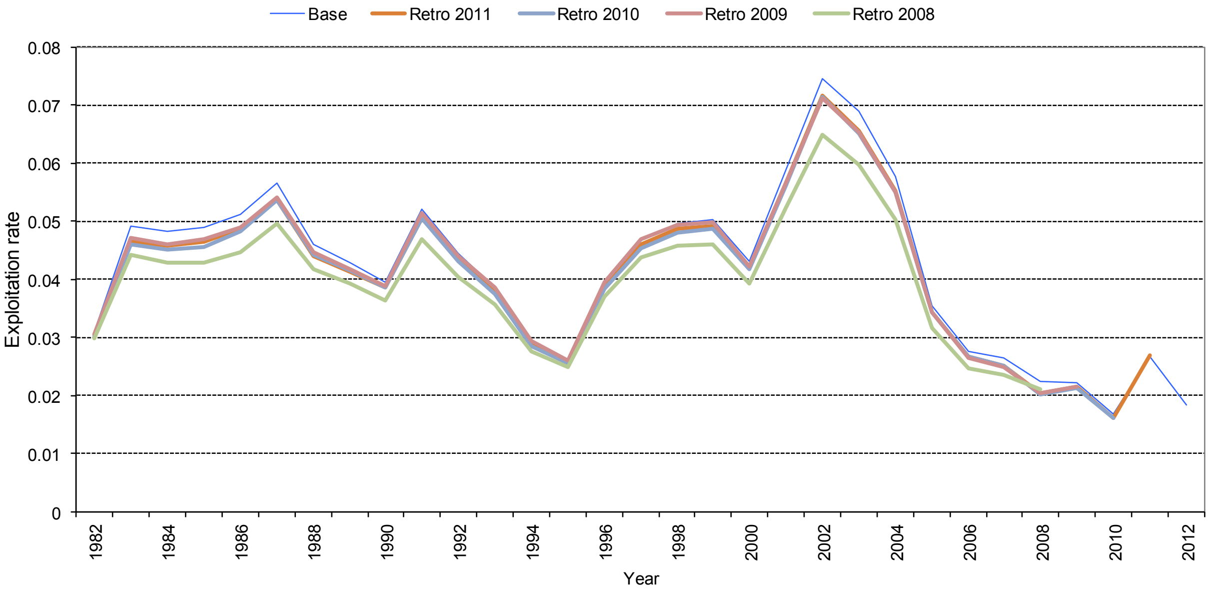
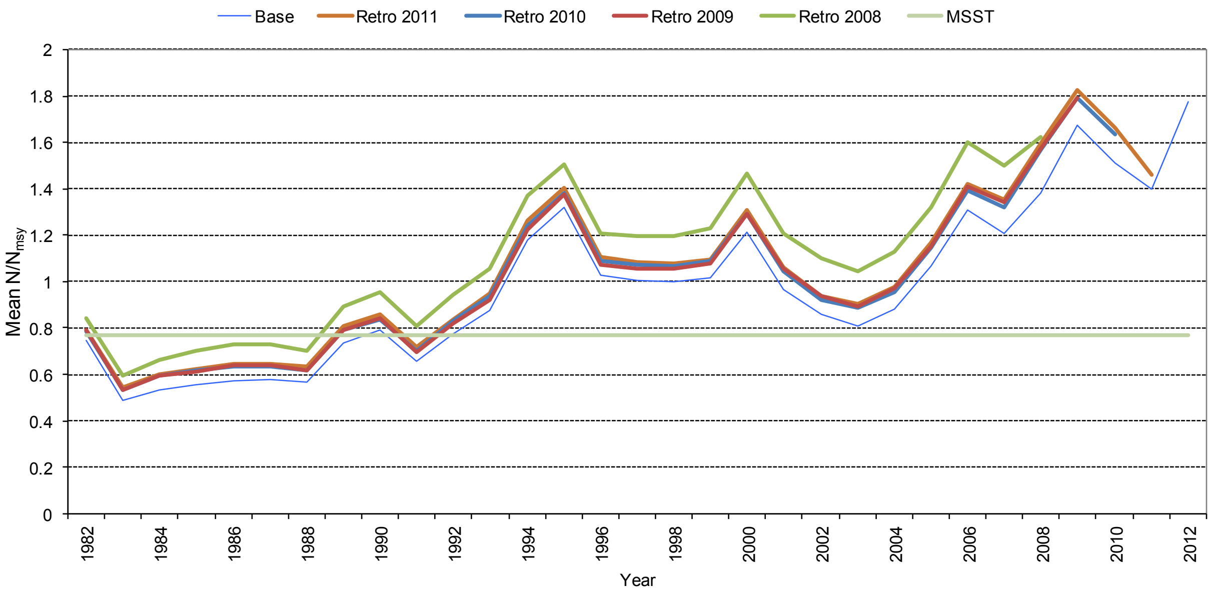


Figure 3.17. Mean predicted exploitable number (top) and exploitation rate (bottom) trajectories for the retrospective analysis. Retro11 fit the model by removing 2012 data, Retro10 by removing 2012-2011 data, Retro09 by removing 2012-2010 data, and Retro08 by removing 2012-2009 data.



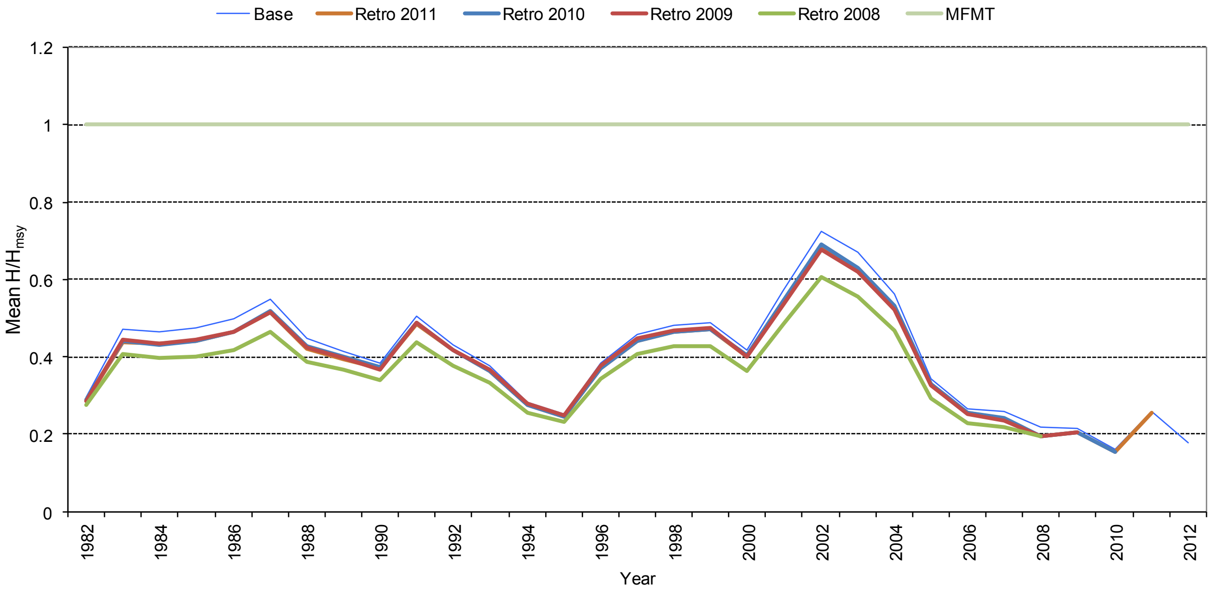
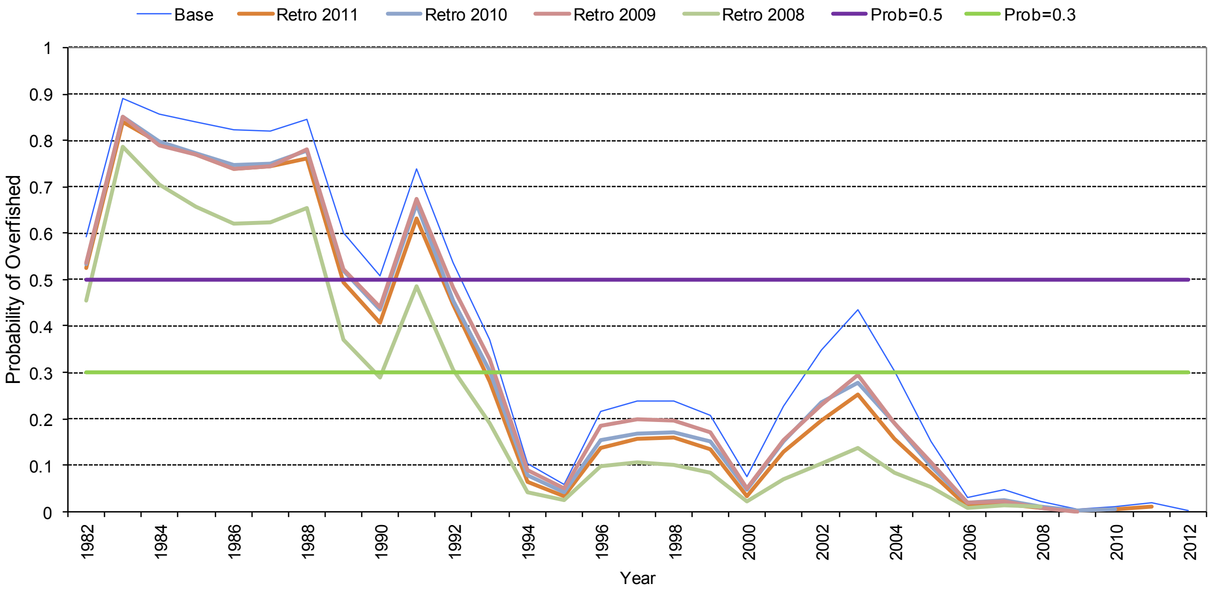


Figure 3.18. Mean relative predicted exploitable number (top) and relative exploitation rate (bottom) trajectories for the retrospective analysis. In the top panel, MSST is the Minimum Stock Size Threshold ($(1-M)N_{MSY}$) reference line; in the bottom panel, MFMT is the maximum fishing mortality threshold (H_{MSY}). Retro11 fit the model by removing 2012 data, Retro10 by removing 2012-2011 data, Retro09 by removing 2012-2010 data, and Retro08 by removing 2012-2009 data.



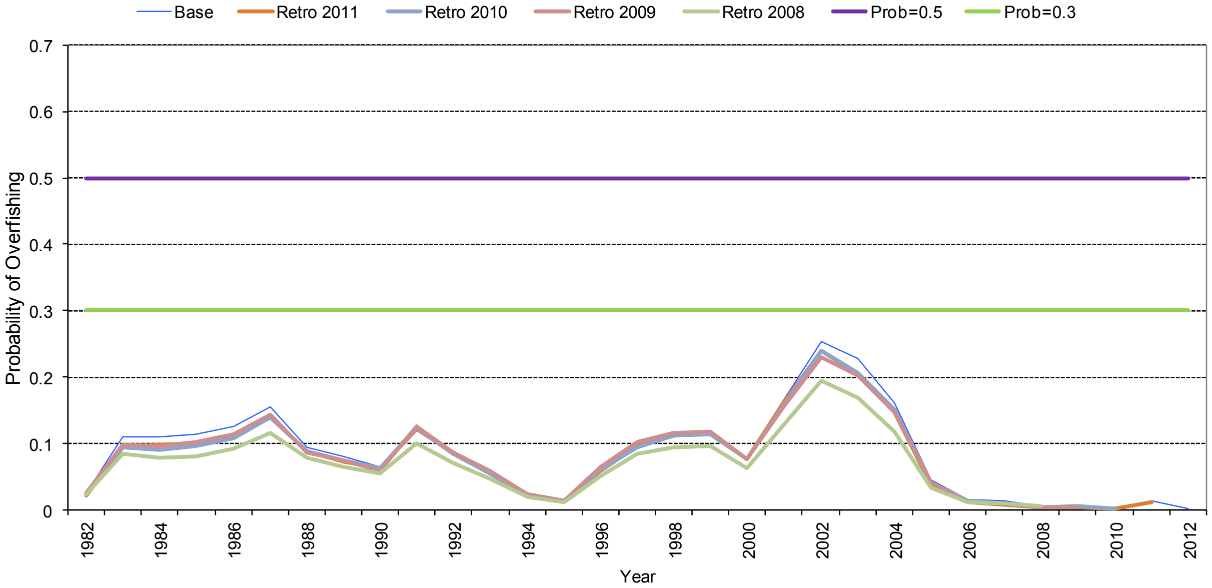


Figure 3.19. Probability of exploitable number being smaller than MSST (overfished condition) (top) and probability of exploitation rate being larger than H_{MSY} (bottom) for the retrospective analysis. The two reference lines denote a 50% and 30% probability of an overfished and overfishing condition occurring. Retro11 fit the model by removing 2012 data, Retro10 by removing 2012-2011 data, Retro09 by removing 2012-2010 data, and Retro08 by removing 2012-2009 data.

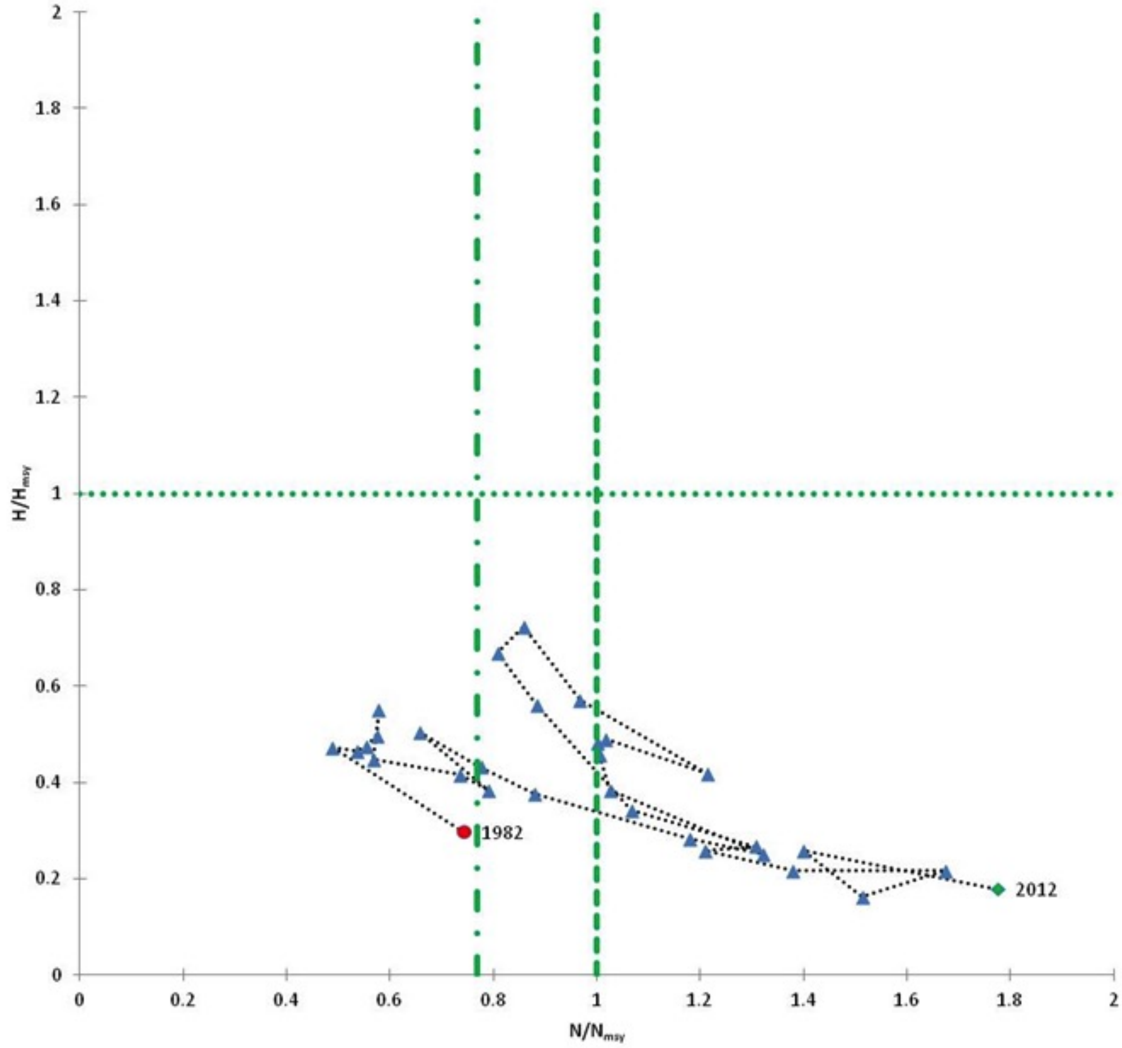


Figure 3.20. (A) Combined relative exploitable number and exploitation rate trajectory for the base run. The dotted horizontal line indicates H_{MSY}, the dashed vertical line indicates N_{MSY}, and the dot-dashed vertical line indicates MSST ((1-M)*N_{MSY}).

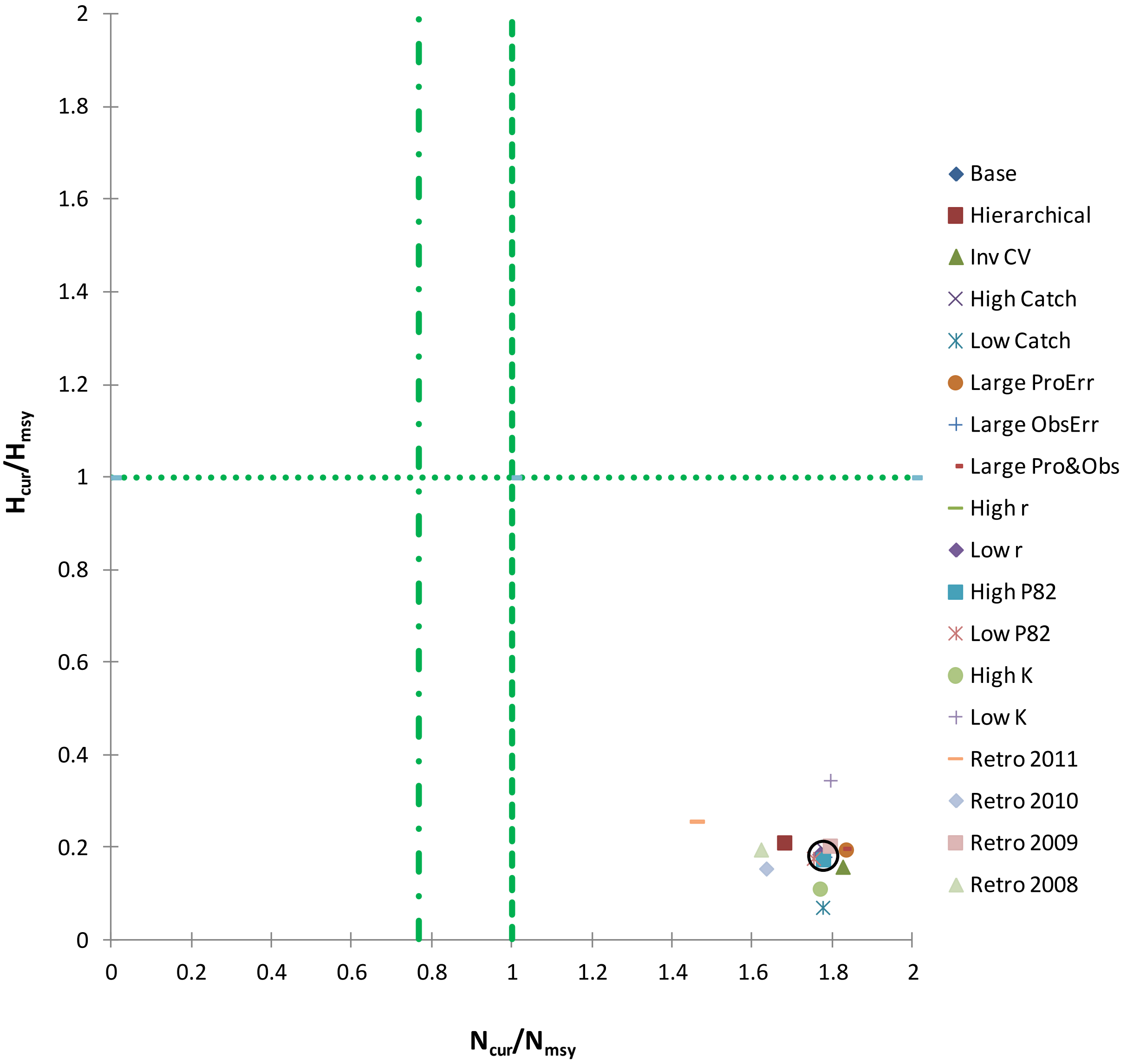
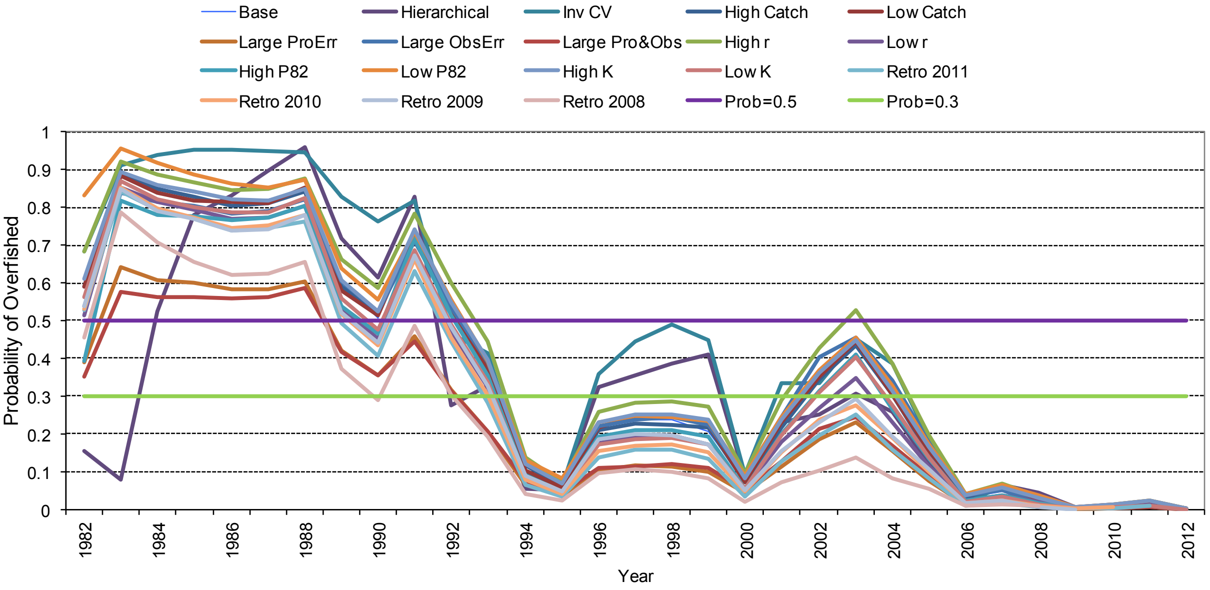


Figure 3.21. Phase plot of Gulf of Mexico *Mustelus* spp. complex stock status. Results are shown for all runs: base, 13 sensitivity scenarios, and retrospective runs. The circle indicates the position of the base run, which overlaps with that of several sensitivity runs. The dotted horizontal line indicates H_{MSY}, the dashed vertical line indicates N_{MSY}, and the dot-dashed vertical line indicates MSST ($(1-M)*N_{MSY}$).



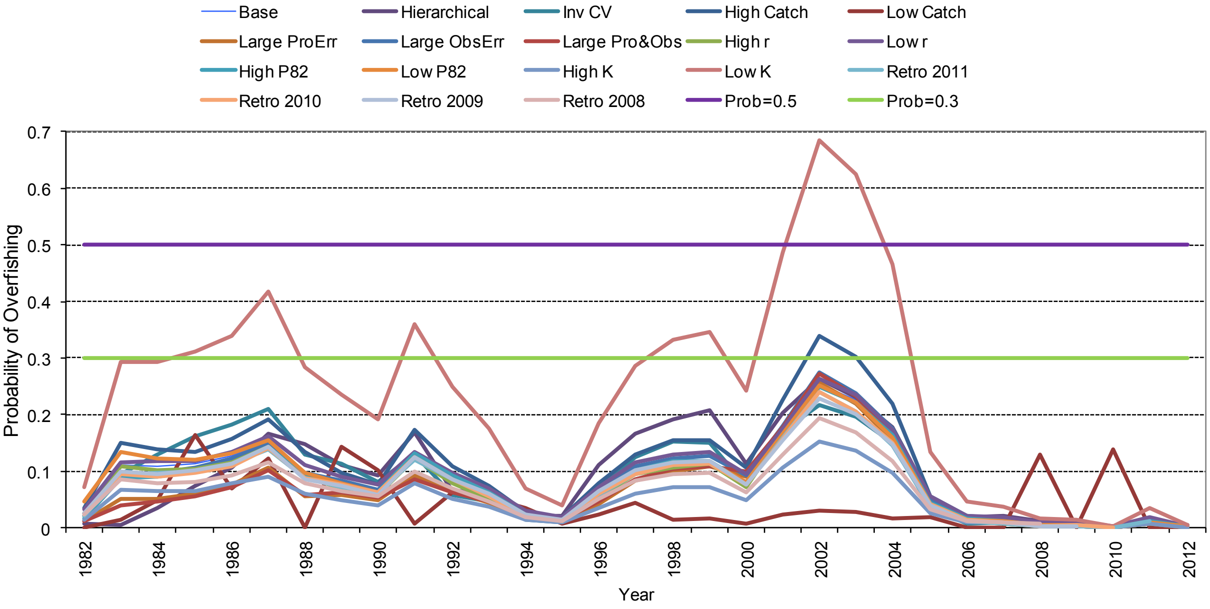


Figure 3.22. Probability of exploitable number being smaller than MSST (overfished condition) (top) and probability of exploitation rate being larger than H_{MSY} (bottom) for all runs: base, 13 sensitivity scenarios, and retrospective runs. The two reference lines denote a 50% and 30% probability of an overfished and overfishing condition occurring.

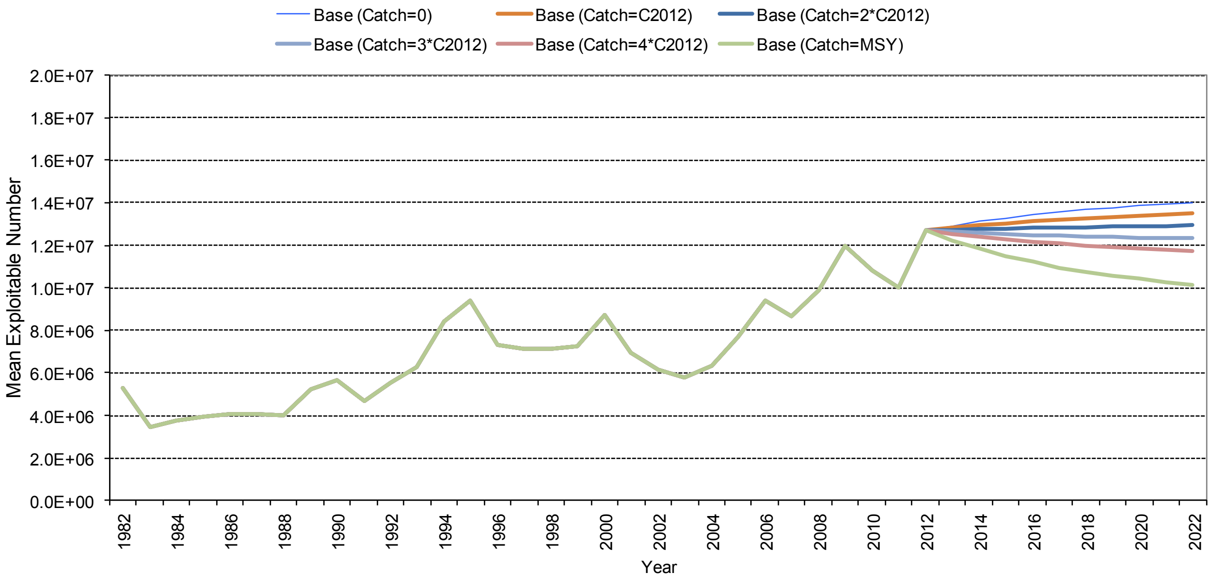
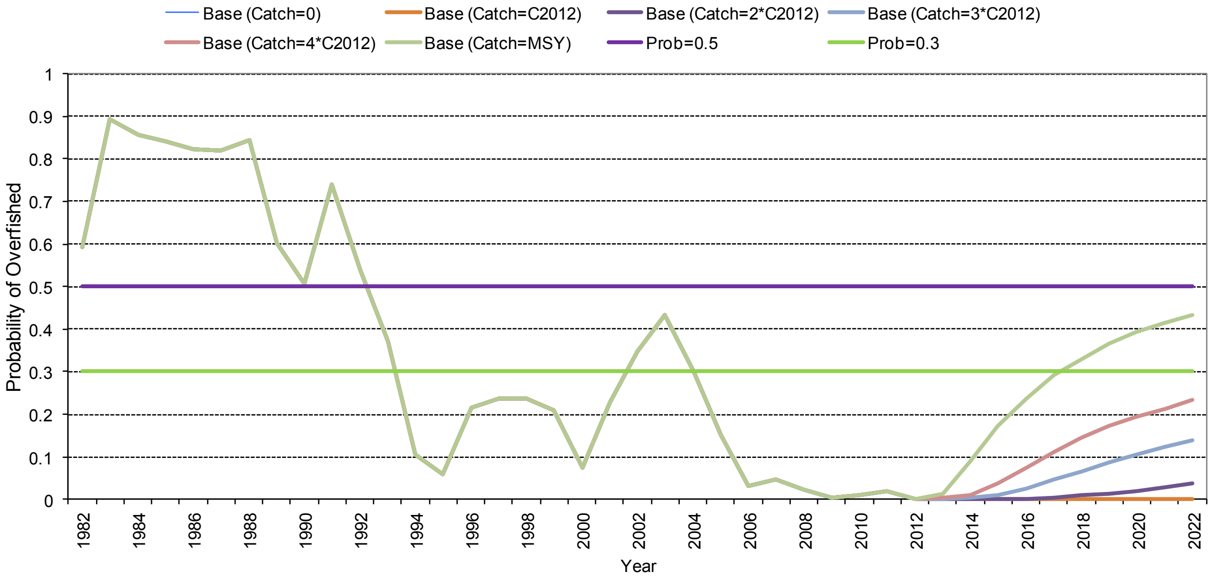


Figure 3.23. Mean projected exploitable number under six alternative constant catch level harvesting strategies for the base run.



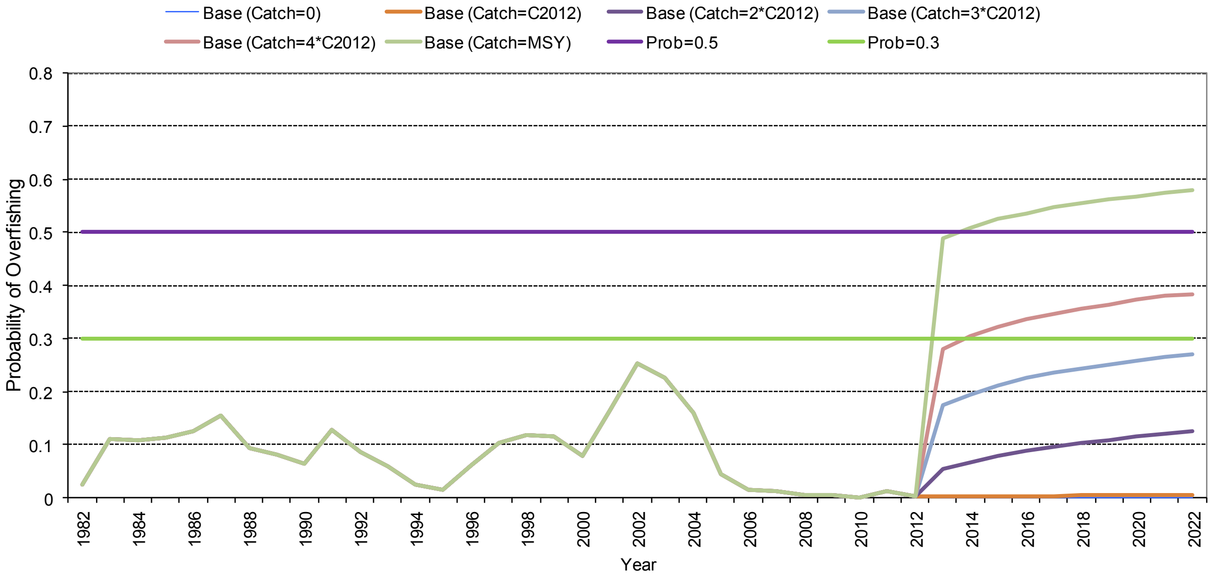


Figure 3.24. Probability of exploitable number being smaller than MSST (overfished condition; top) and probability of exploitation rate being larger than H_{MSY} (overfishing condition; bottom) under six alternative constant catch level harvesting strategies for the base run. The two reference lines denote a 50% and 30% probability of an overfished and overfishing condition occurring.

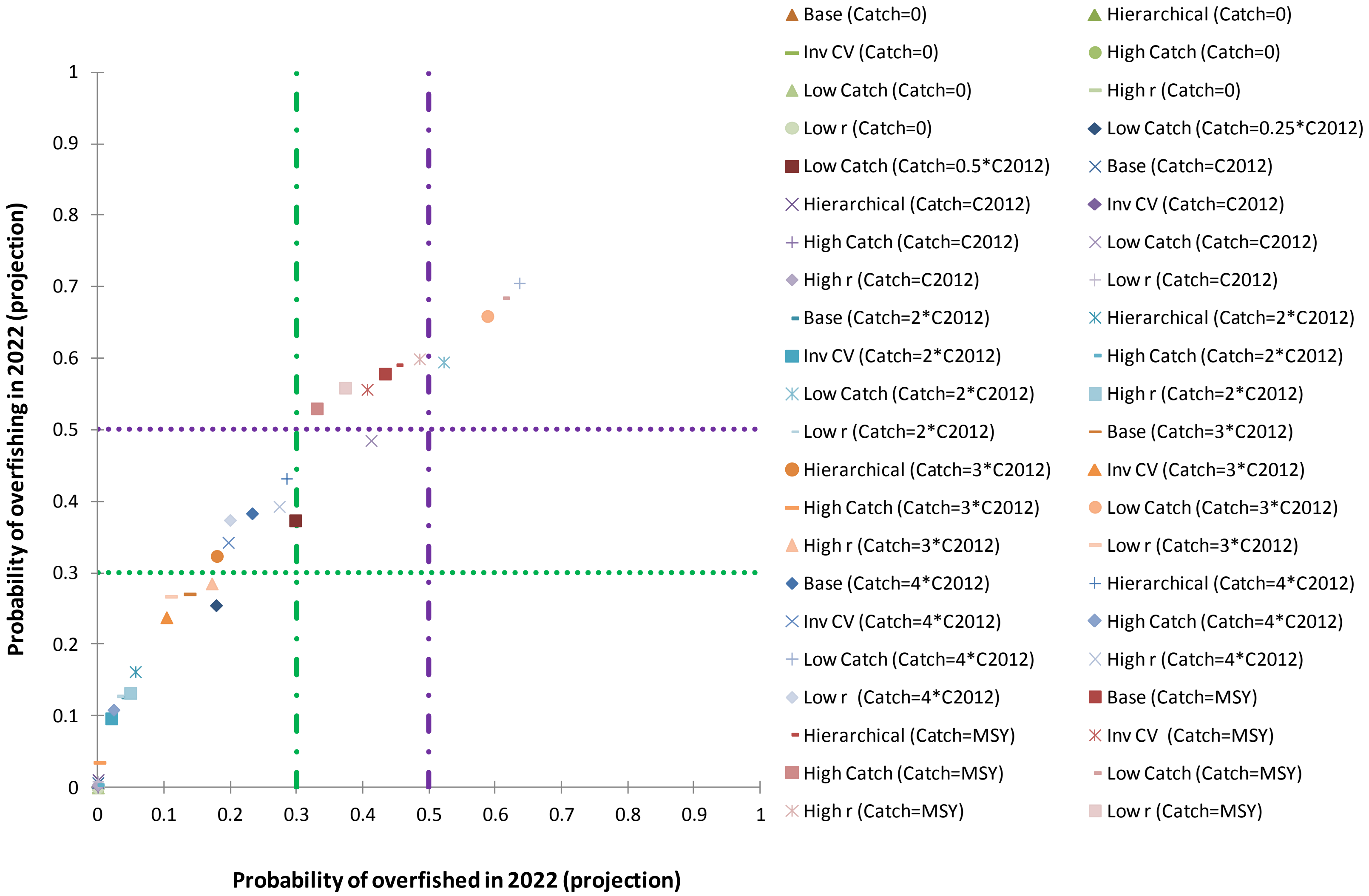
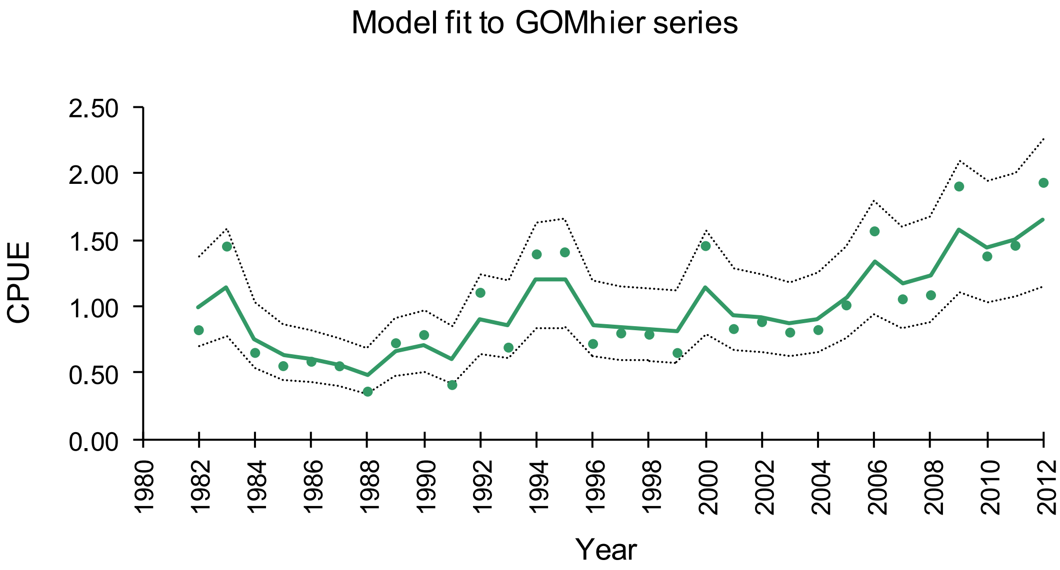


Figure 3.25. Phase plot of the probability of the stock being overfished and of overfishing occurring under six alternative constant catch level harvesting strategies for all projection runs (base + six plausible states of nature). The two sets of reference lines denote a 50% and 30% probability of an overfished (vertical lines) and overfishing (horizontal lines) condition occurring.

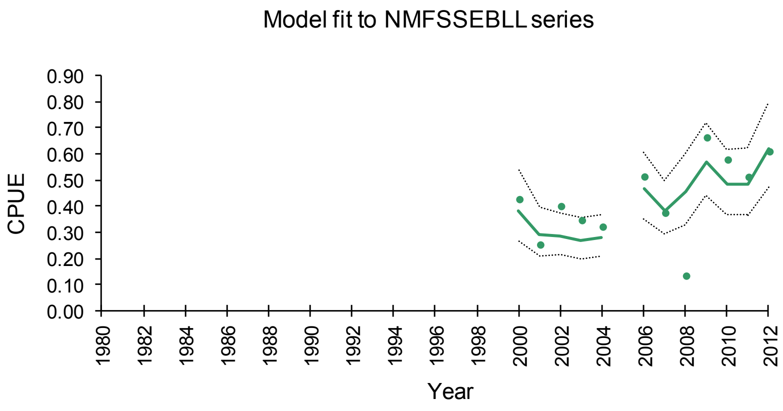
3.8. APPENDICES

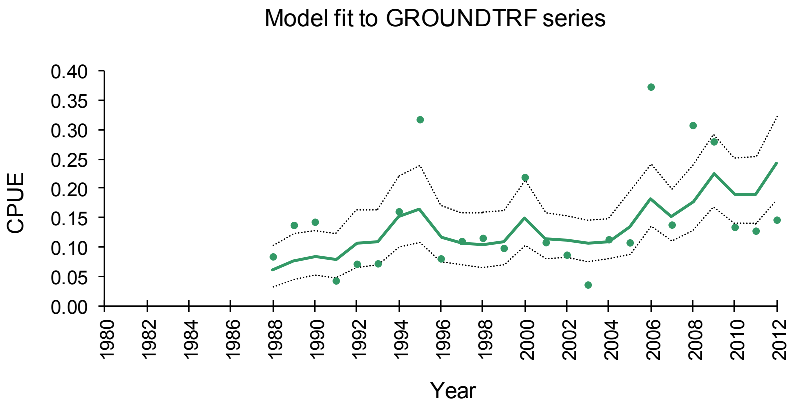
Appendices 3.8.1, 3.8.2, 3.8.7, and 3.8.8 include plots for all the sensitivity scenarios in the following order: 1) hierarchical run, 2) inverse CV weighting, 3) low catch, 4) high catch, 5) low r, 6) high r, 7) large process error, 8) large observation error, 9) large process and observation error, 10) high initial depletion, 11) low initial depletion, 12) high K, and 13) low K.

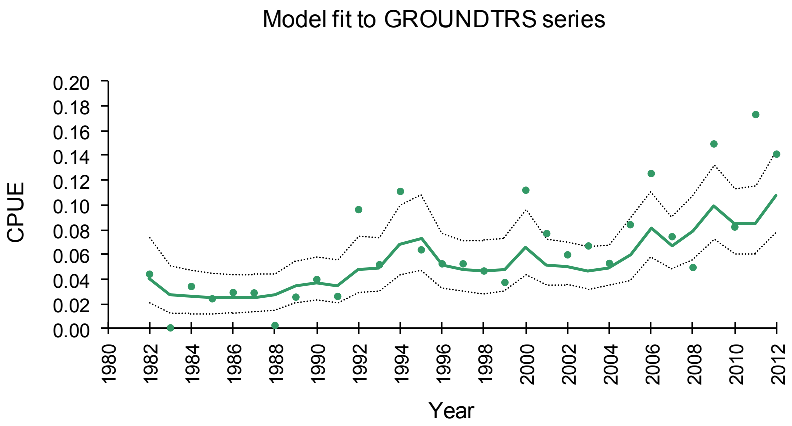
Appendix 3.8.1: Predicted fits to the indices of abundance for each of the 13 sensitivity runs.

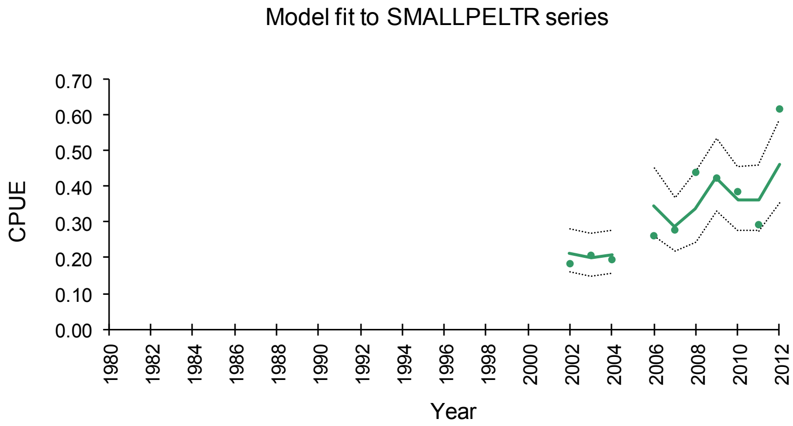


Hierarchical index run model fit



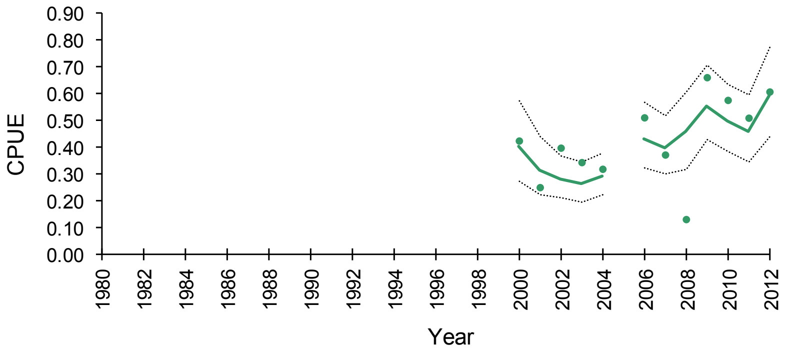




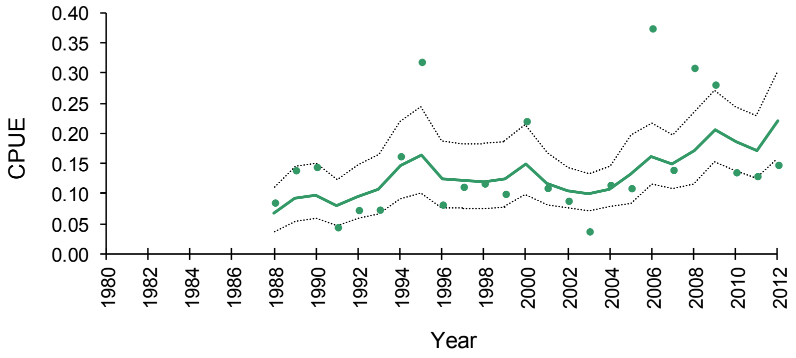


Inverse CV run model fits

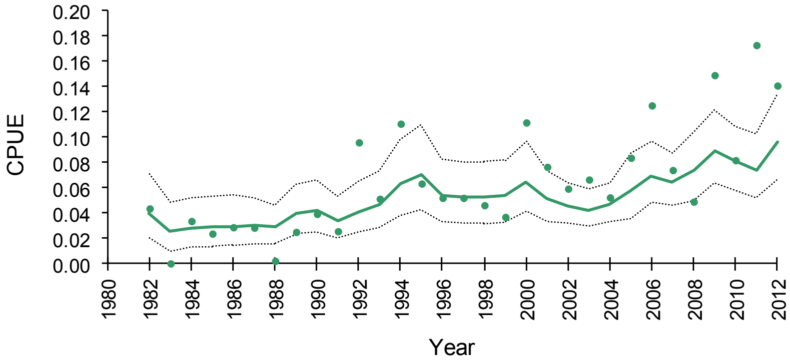
Model fit to NMFSSEBLL series



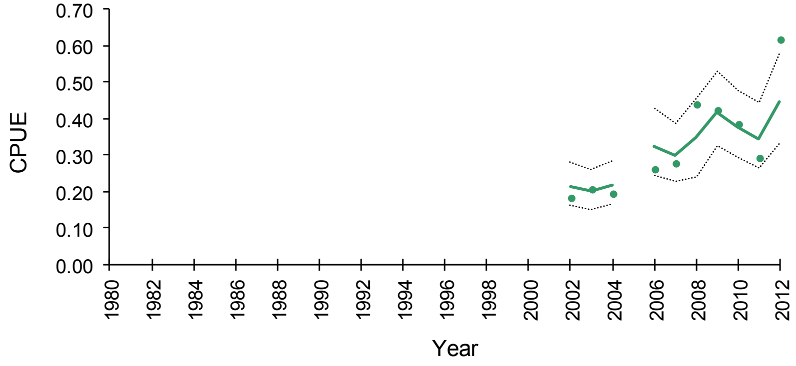
Model fit to GROUNDTRF series



Model fit to GROUNDTRS series

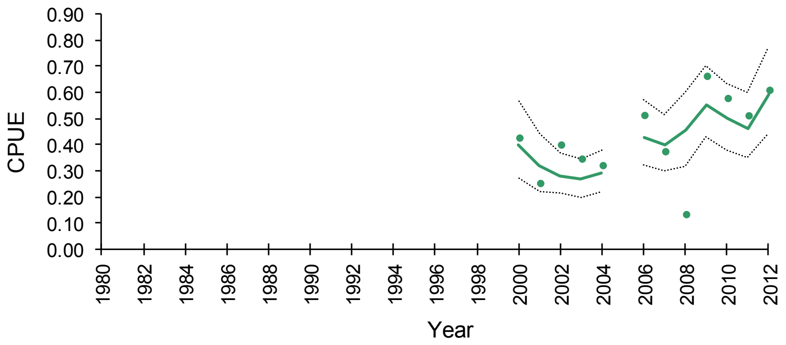


Model fit to SMALLPELTR series

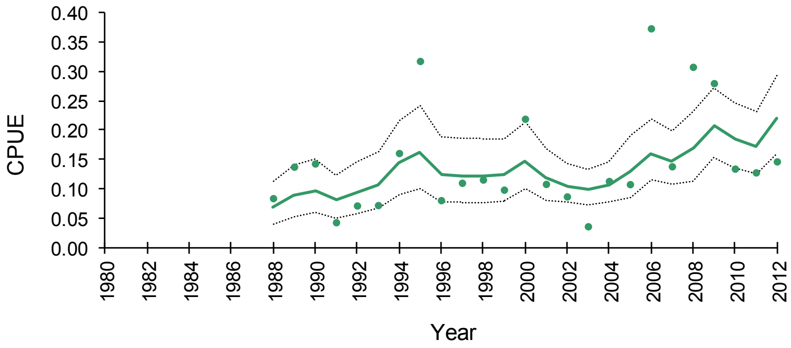


Low catch run model fits

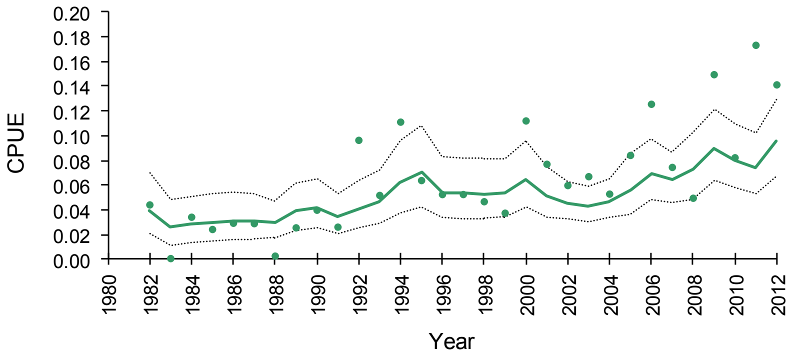
Model fit to NMFSSEBLL series



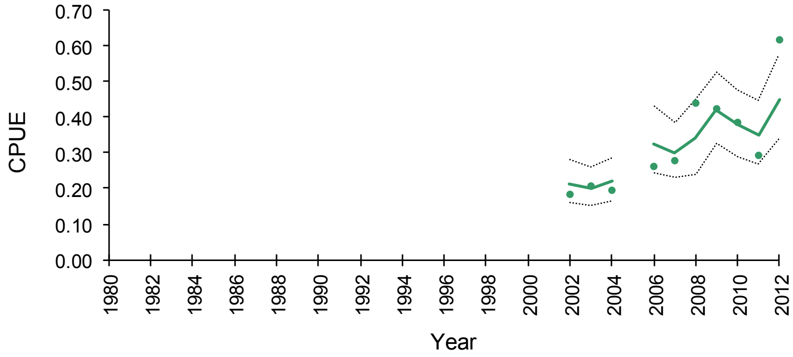
Model fit to GROUNDTRF series



Model fit to GROUNDTRS series

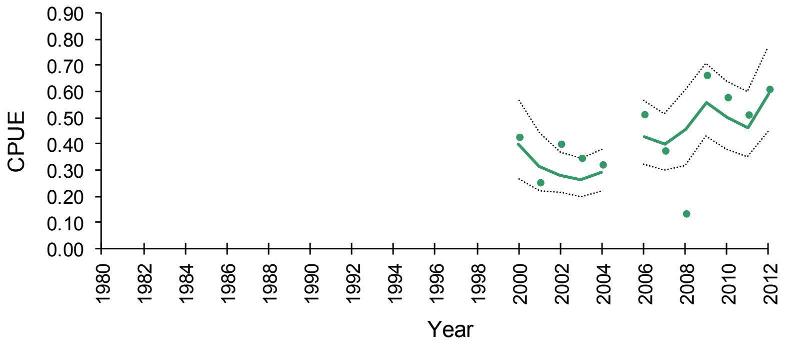


Model fit to SMALLPELTR series

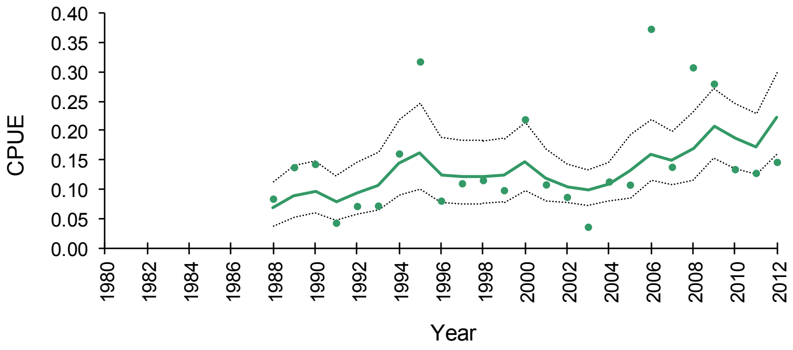


High catch run model fits

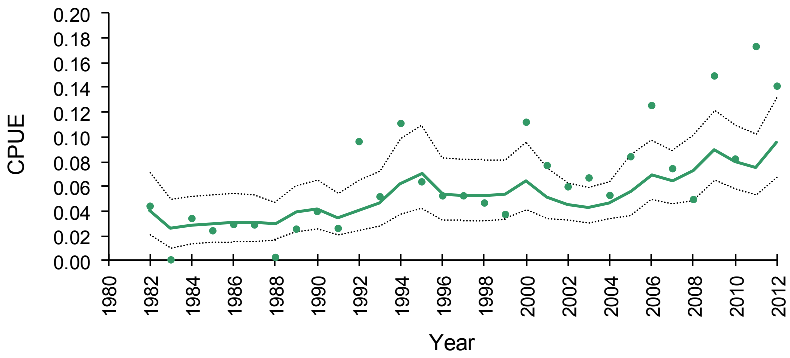
Model fit to NMFSSEBLL series



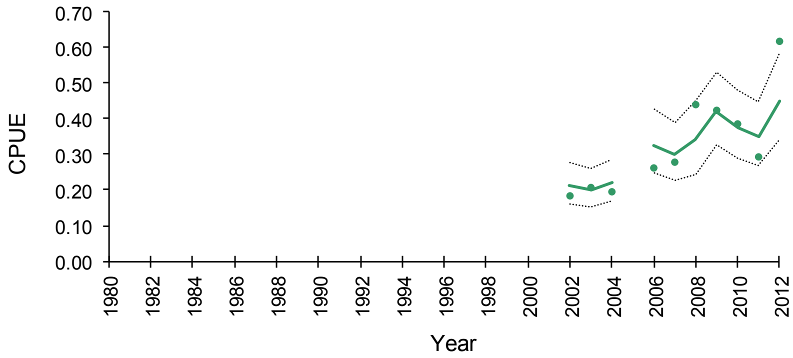
Model fit to GROUNDTRF series



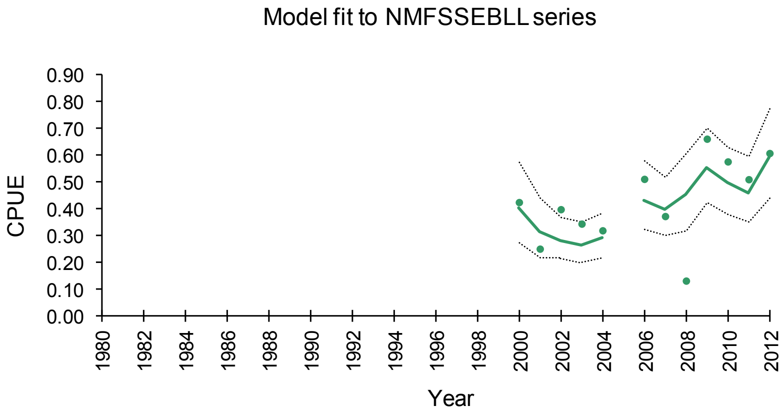
Model fit to GROUNDTRS series

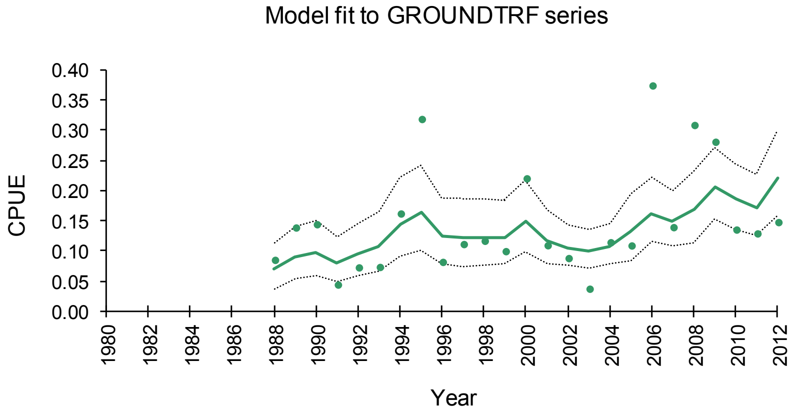


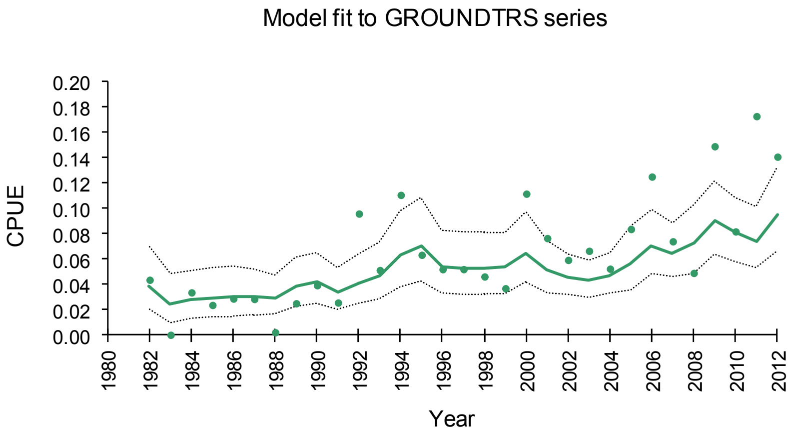
Model fit to SMALLPELTR series

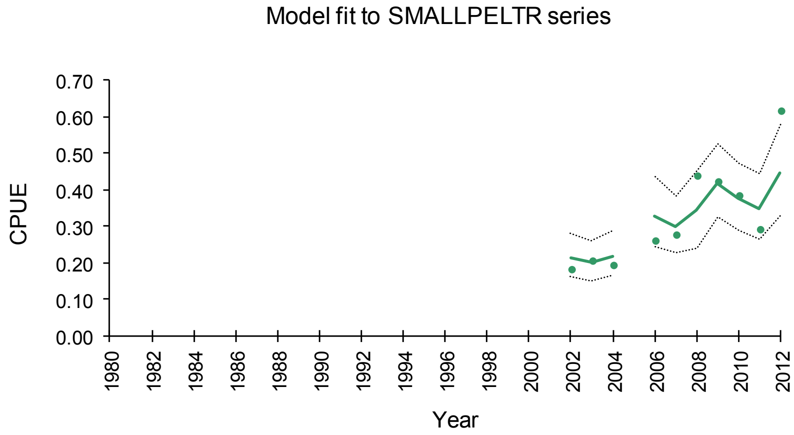


Low r run model fits

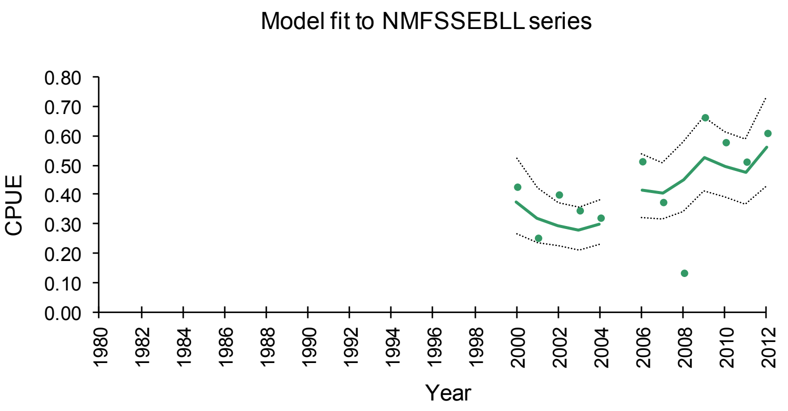


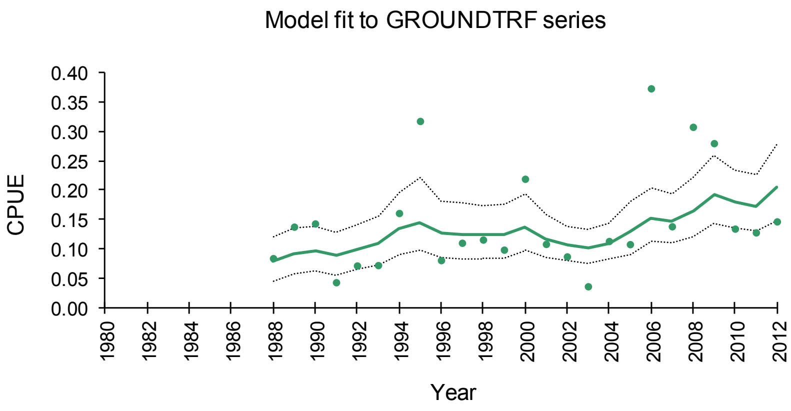


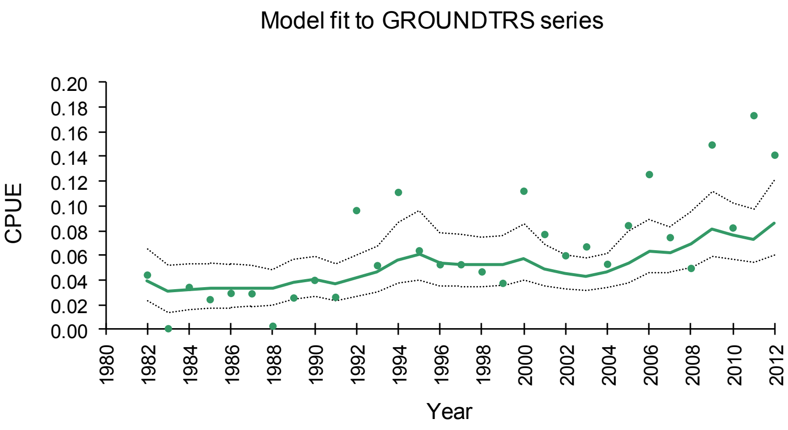


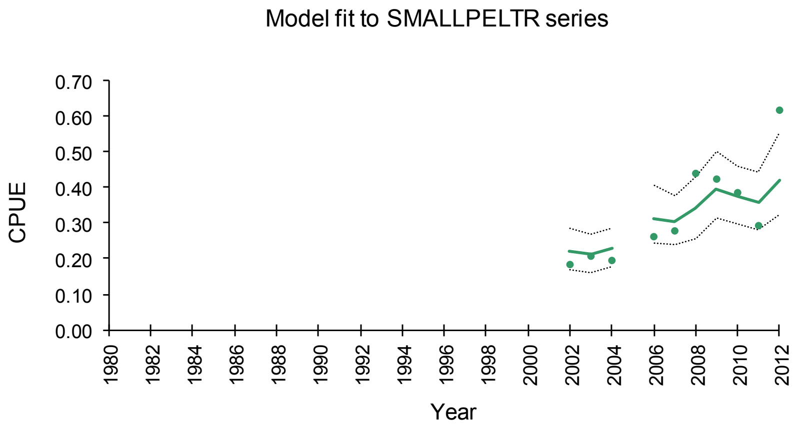


High r run model fits

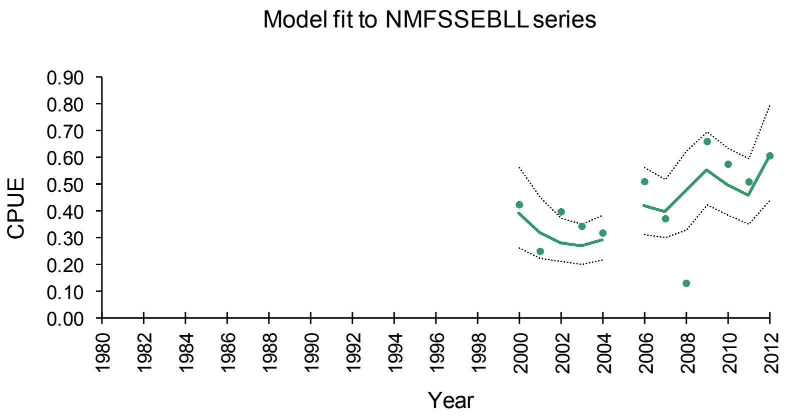

Model fit to NMFSSEBLL series

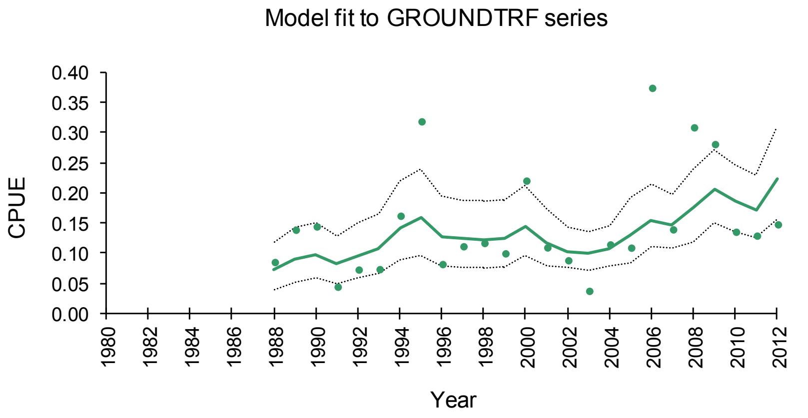

Model fit to GROUNDTRF series

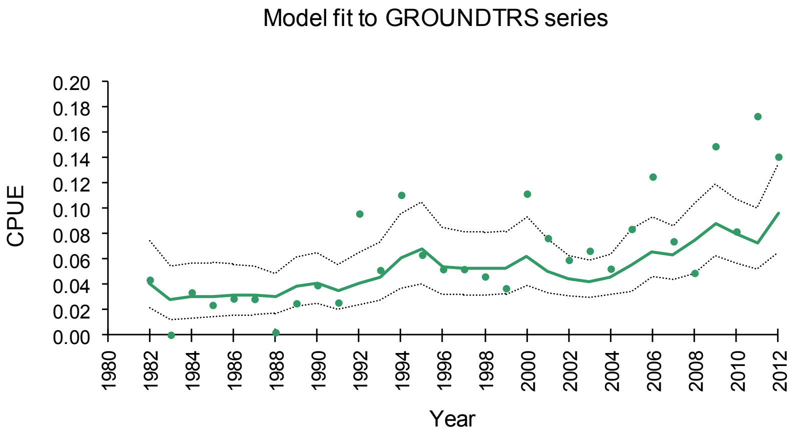

Model fit to GROUNDTRS series

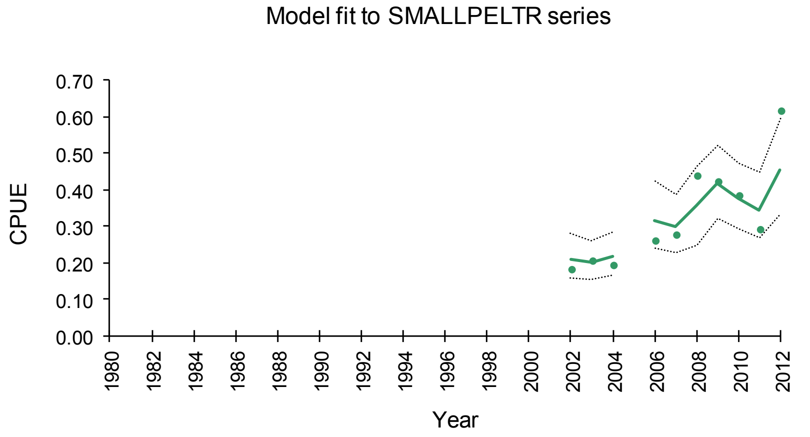

Model fit to SMALLPELTR series

Large process error run model fits

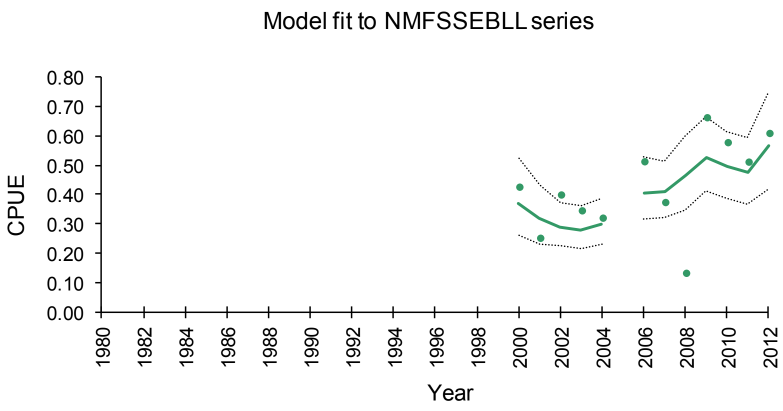

Model fit to NMFSSEBLL series

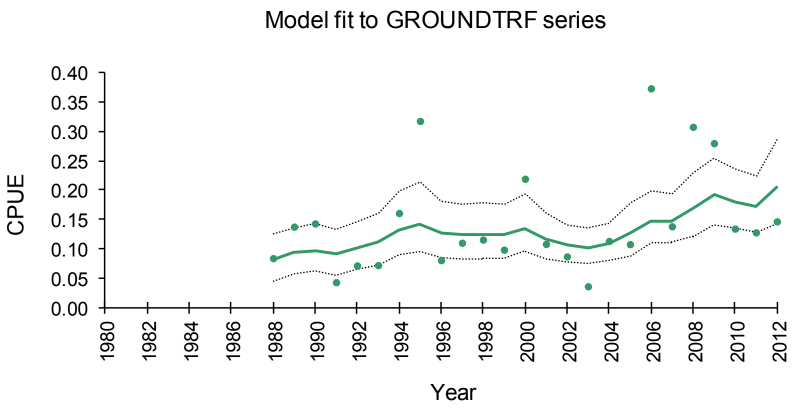

Model fit to GROUNDTRF series

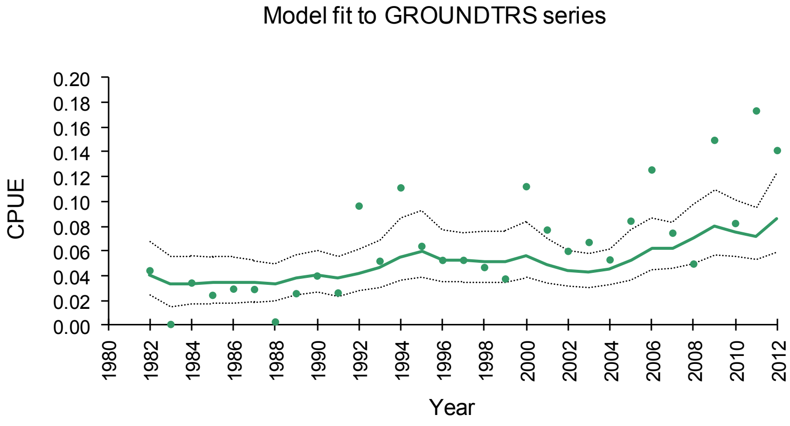

Model fit to GROUNDTRS series

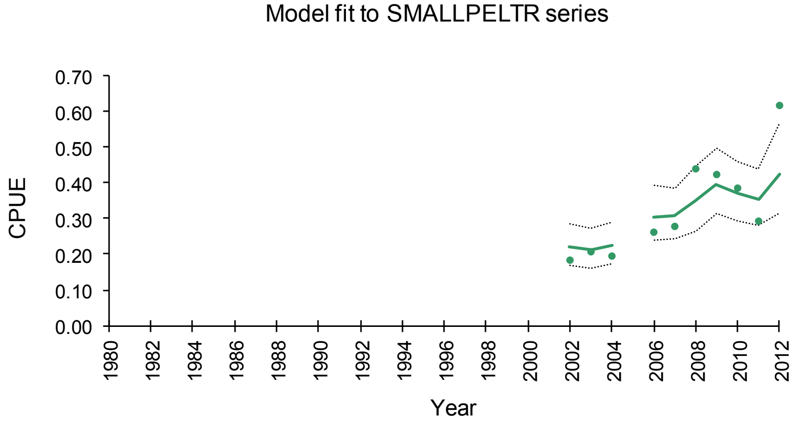

Model fit to SMALLPELTR series

Large observation error run model fits

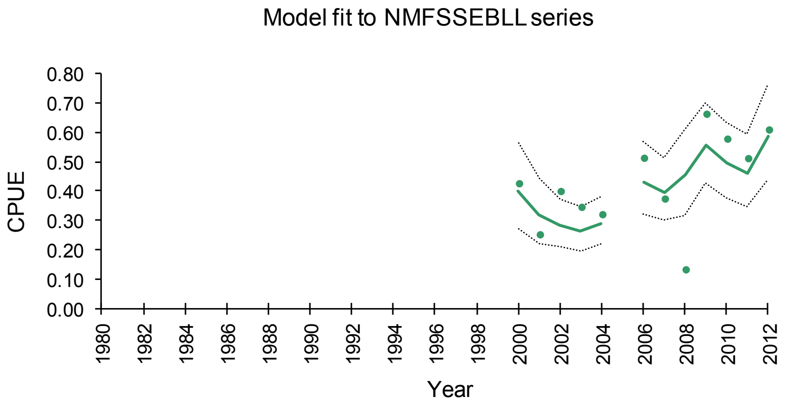


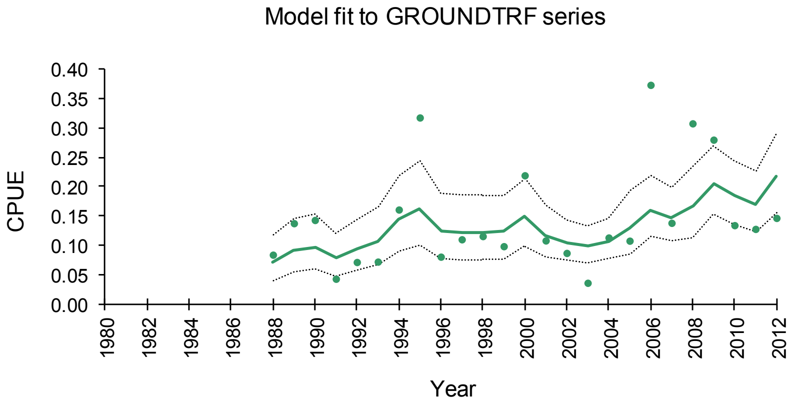


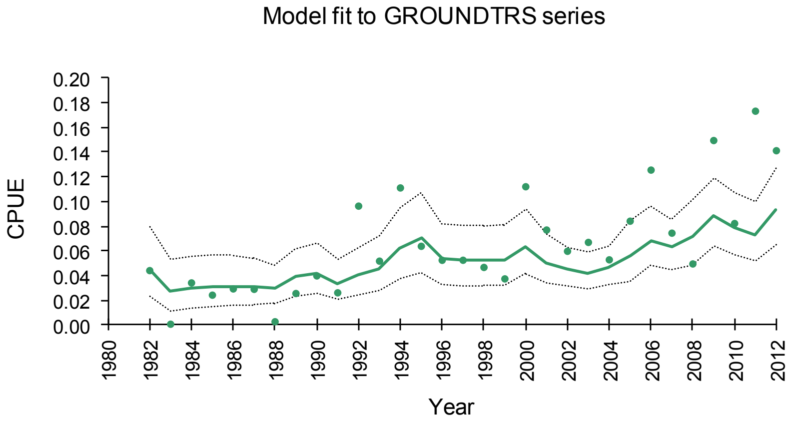


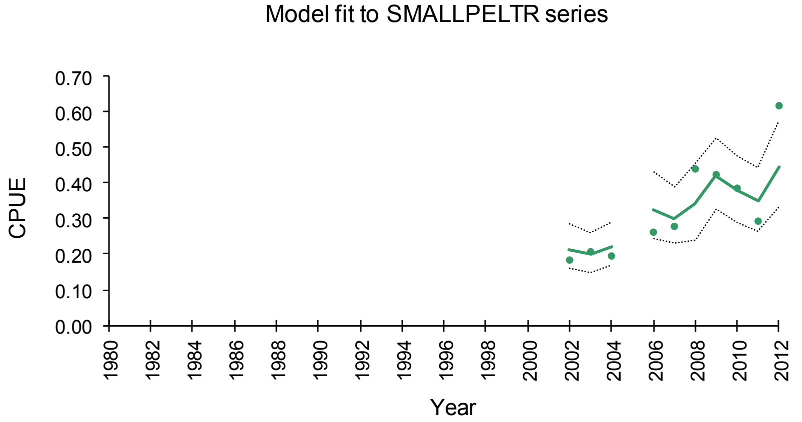


Large process and observation error run model fits

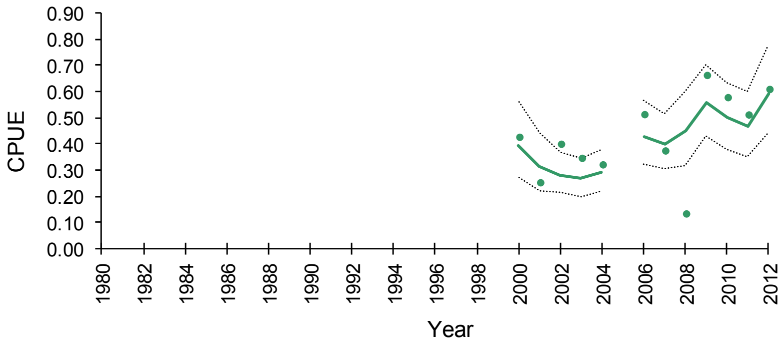

Model fit to NMFSSEBLL series


Model fit to GROUNDTRF series

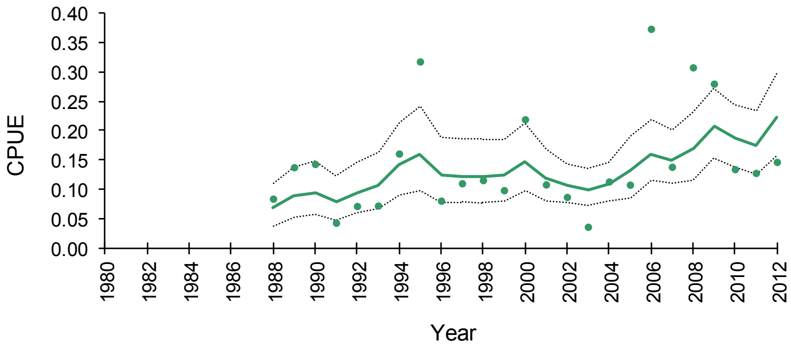

Model fit to GROUNDTRS series


Model fit to SMALLPELTR series

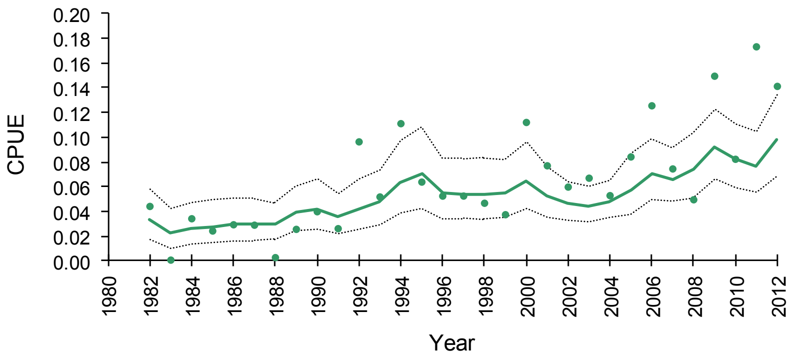
High P_{82} run model fits



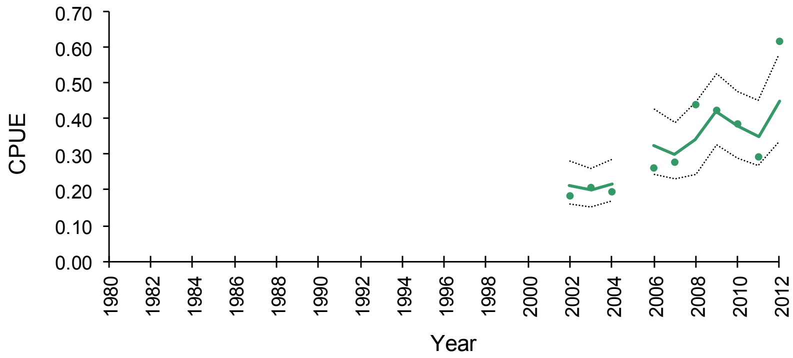
Model fit to NMFSSEBLL series



Model fit to GROUNDTRF series

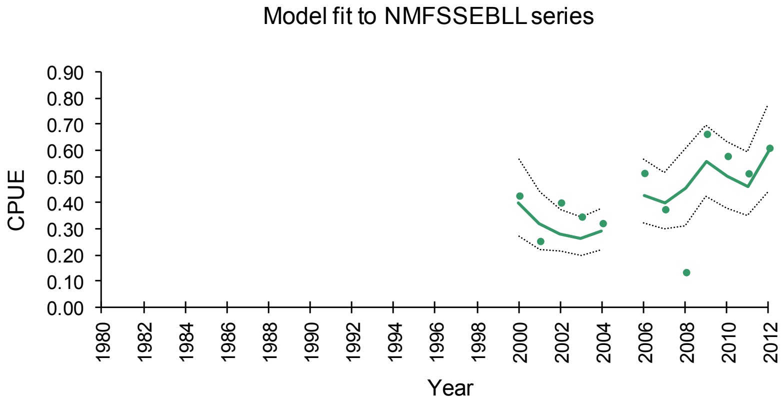


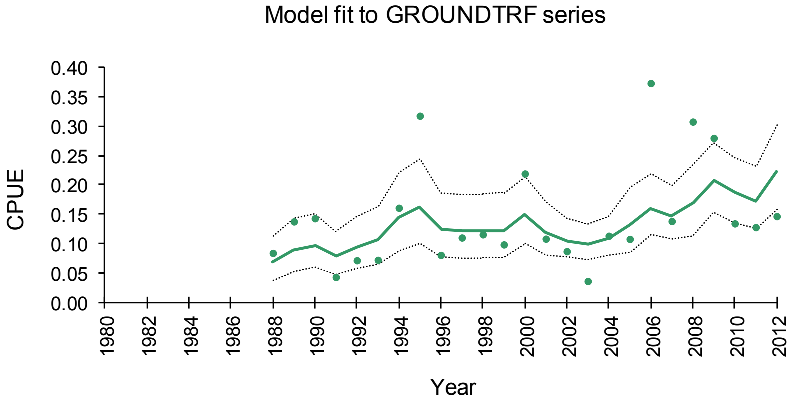
Model fit to GROUNDTRS series

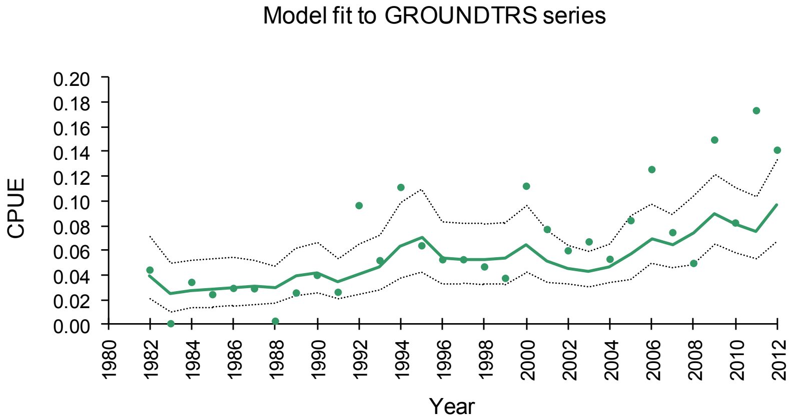


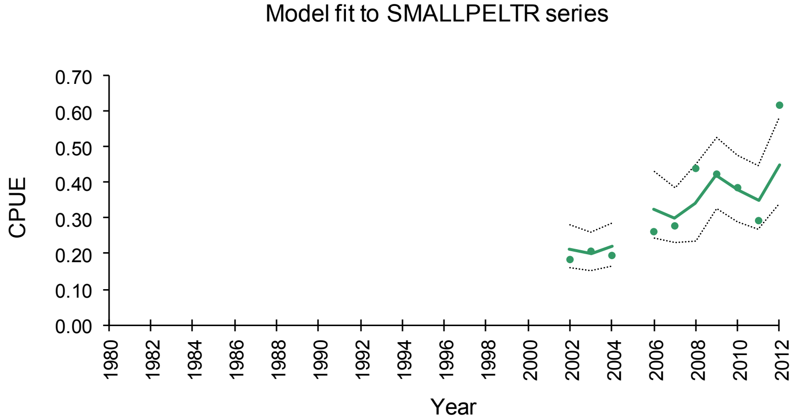
Model fit to SMALLPELTR series

Low P_{82} run model fits

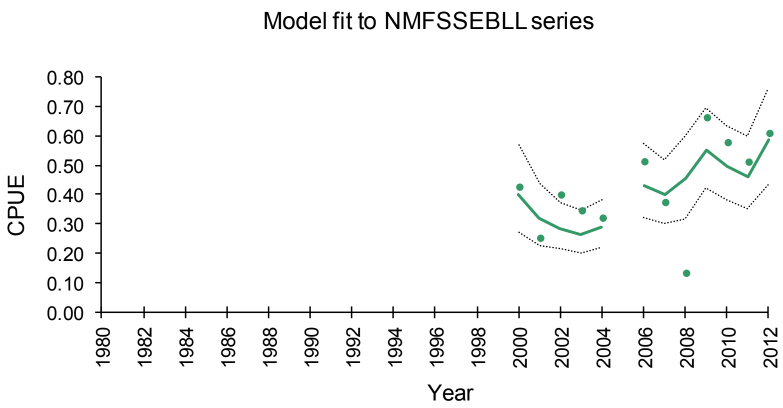

Model fit to NMFSSEBLL series


Model fit to GROUNDTRF series

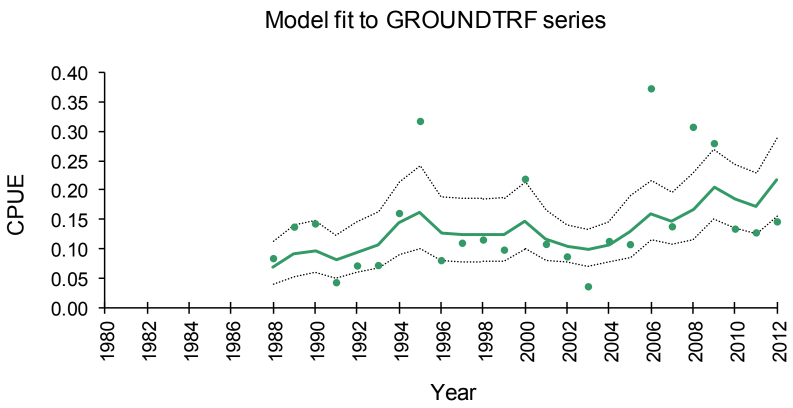

Model fit to GROUNDTRS series


Model fit to SMALLPELTR series

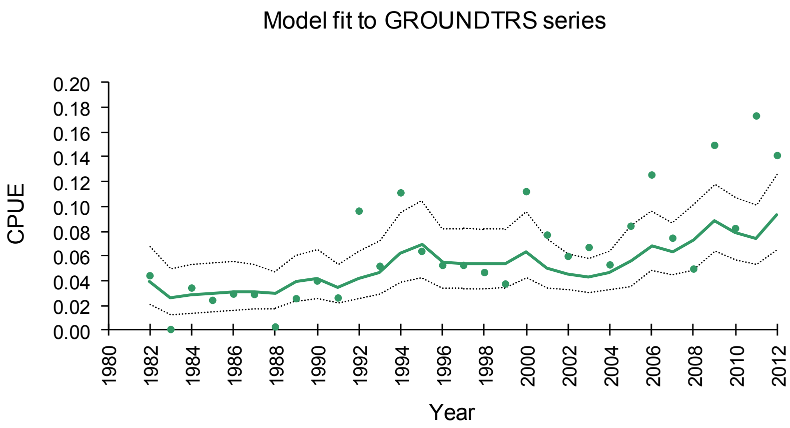
High K run model fits



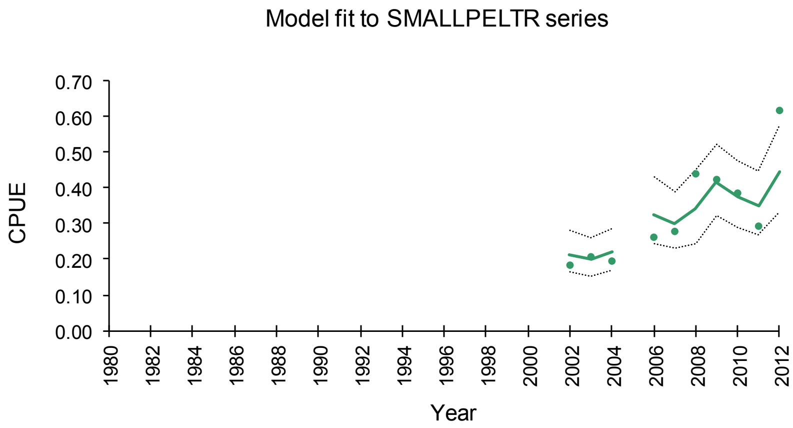
Model fit to NMFSSEBLL series



Model fit to GROUNDTRF series



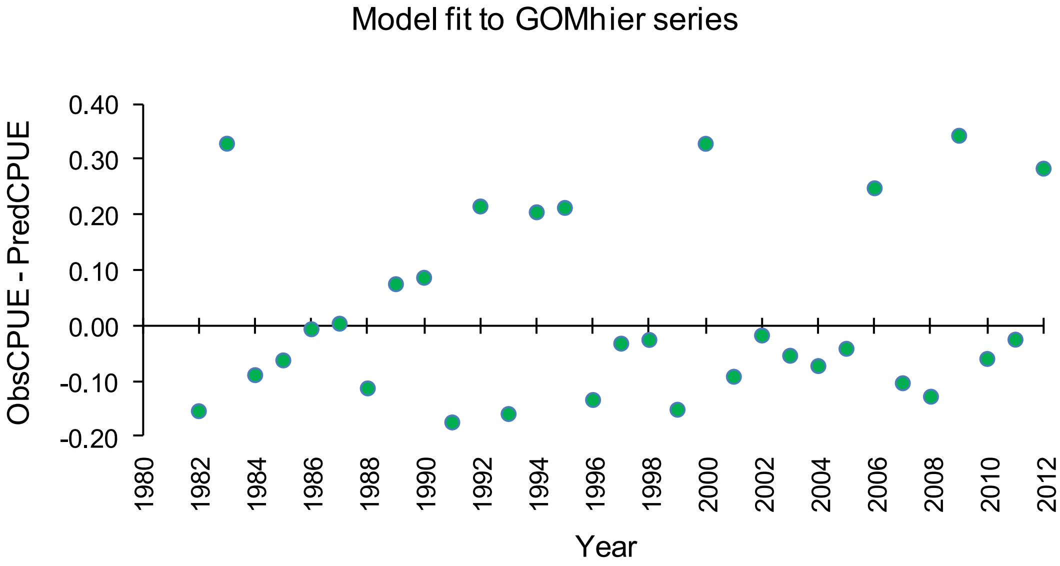
Model fit to GROUNDTRS series



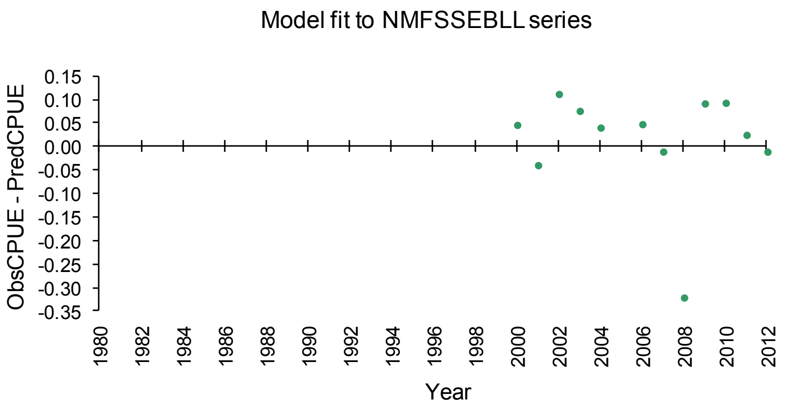
Model fit to SMALLPELTR series

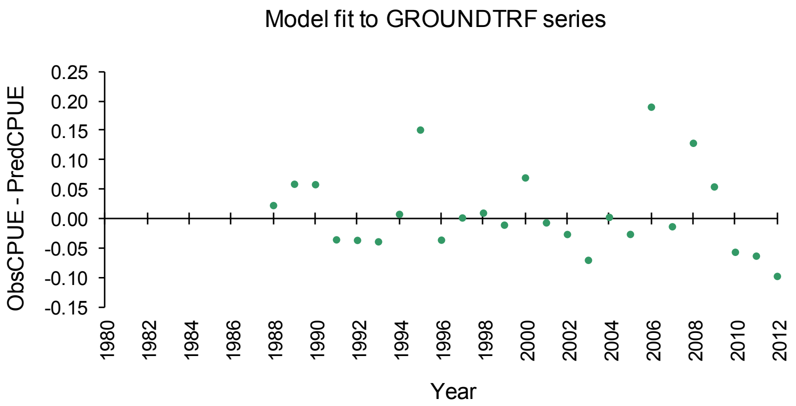
Low K run model fits

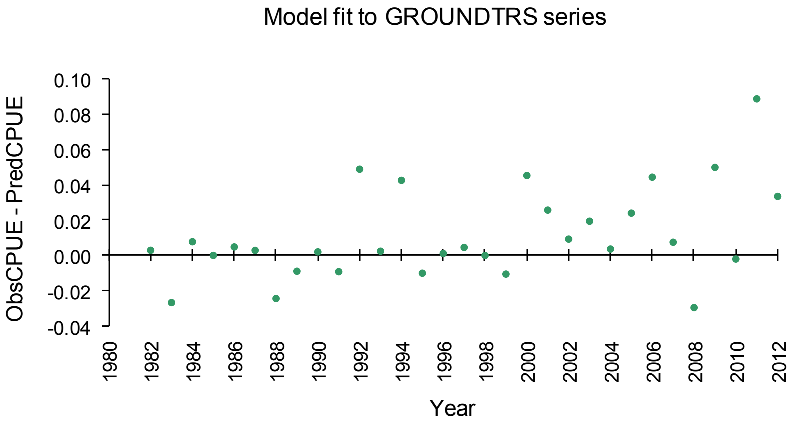
Appendix 3.8.2: Residuals of the CPUE fits for each of the 13 sensitivity runs.

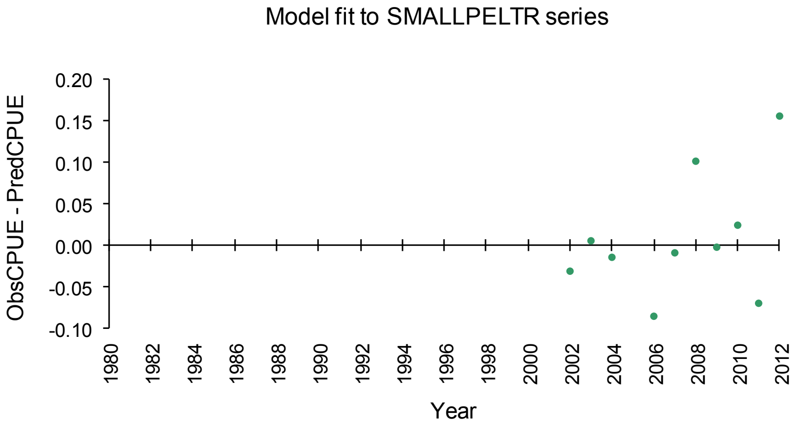


Hierarchical index run model fit residuals

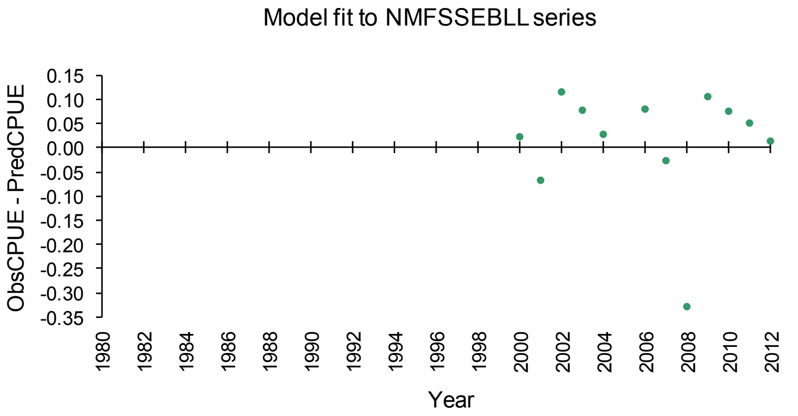

Model fit to NMFSSEBLL series

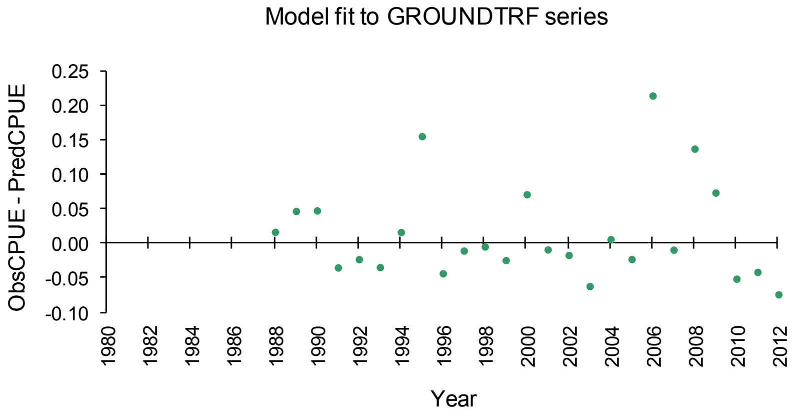

Model fit to GROUNDTRF series

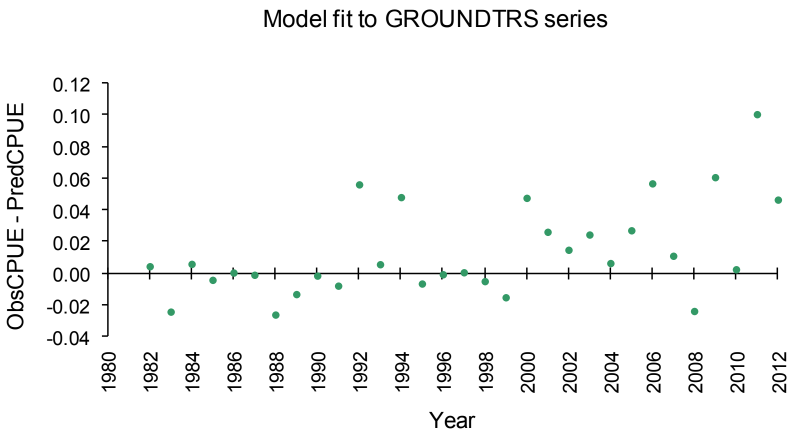

Model fit to GROUNDTRS series

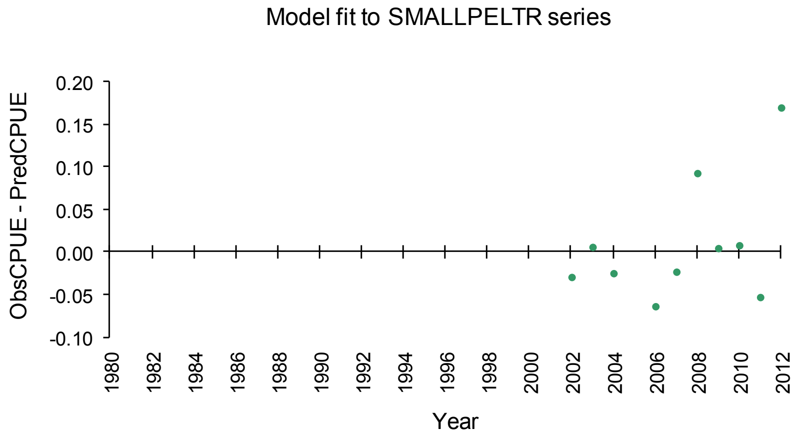

Model fit to SMALLPELTR series

Inverse CV run model fit residuals

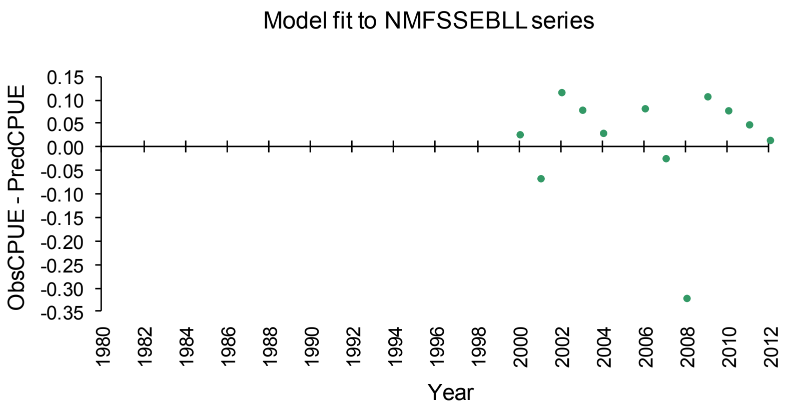

Model fit to NMFSSEBLL series

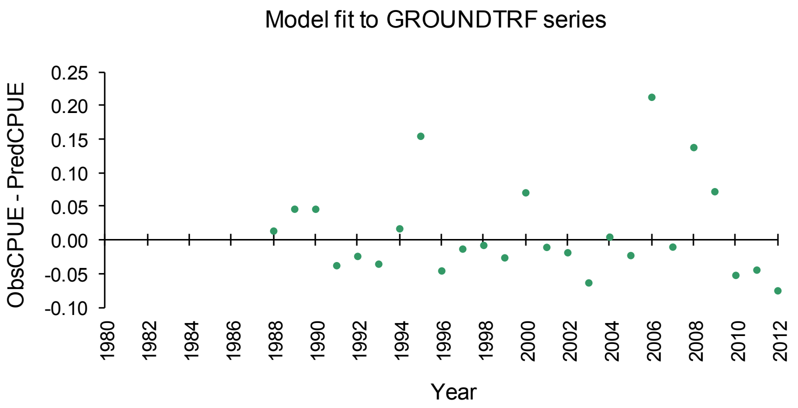

Model fit to GROUNDTRF series

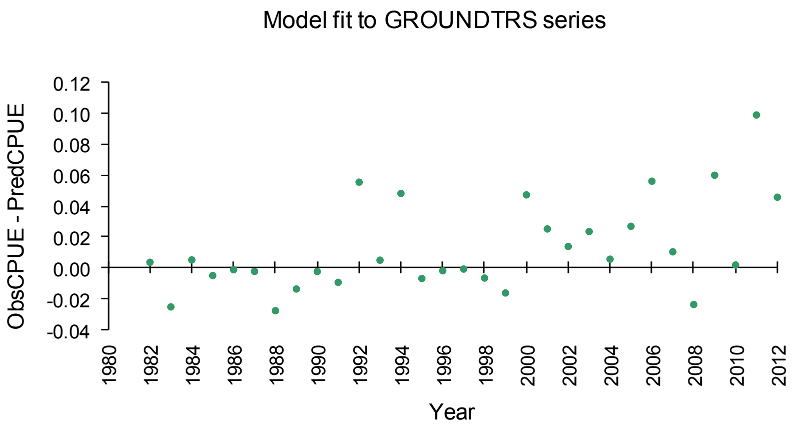

Model fit to GROUNDTRS series

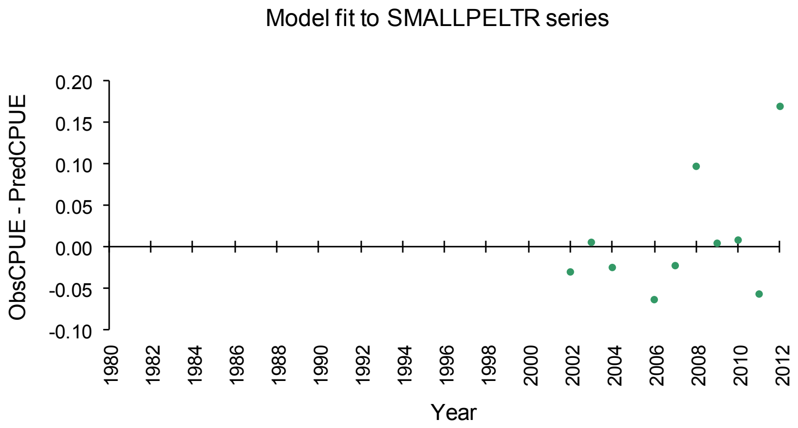

Model fit to SMALLPELTR series

Low catch run model fit residuals

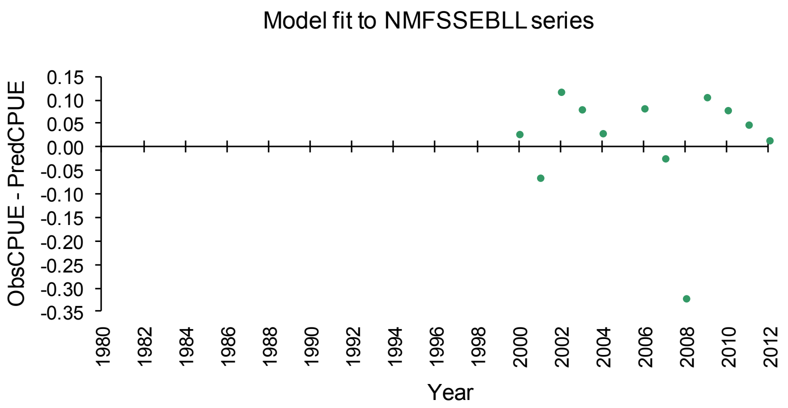

Model fit to NMFSSEBLL series

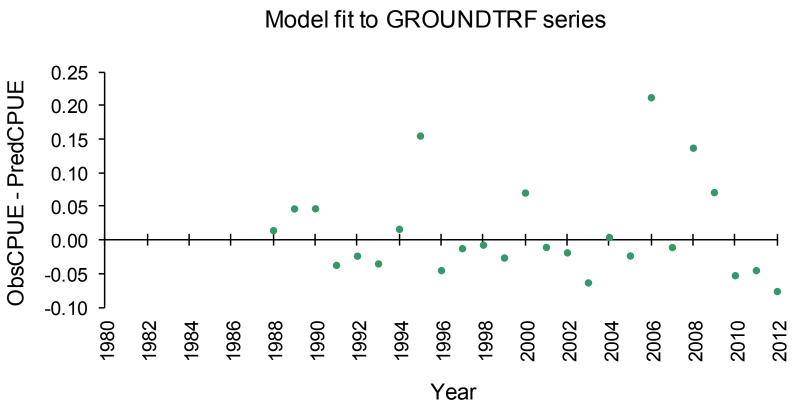

Model fit to GROUNDTRF series

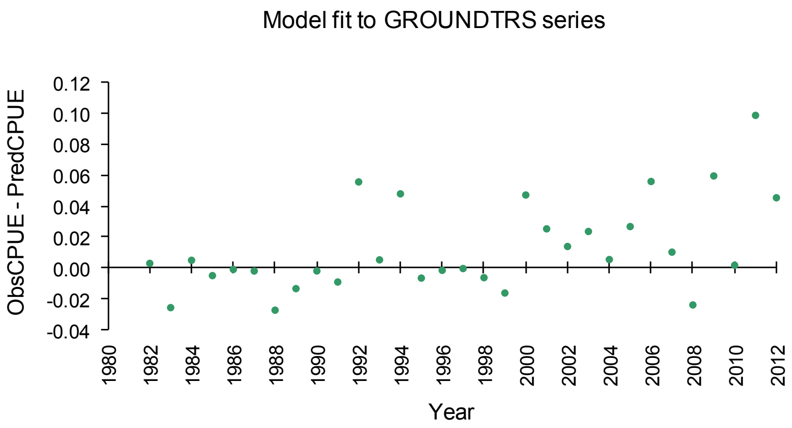

Model fit to GROUNDTRS series

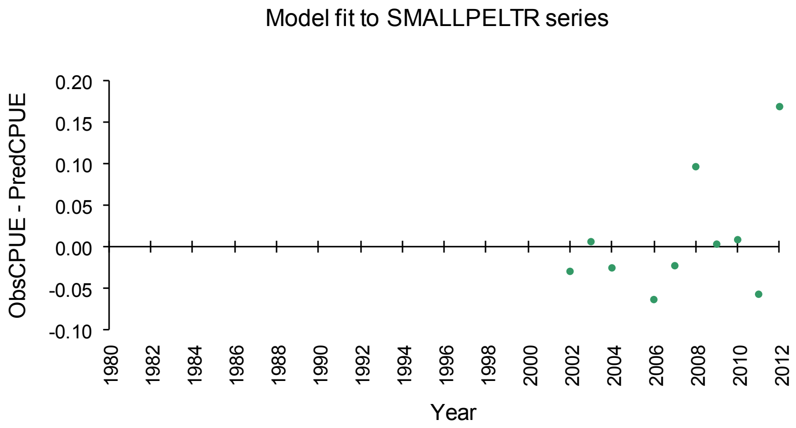

Model fit to SMALLPELTR series

High catch run model fit residuals

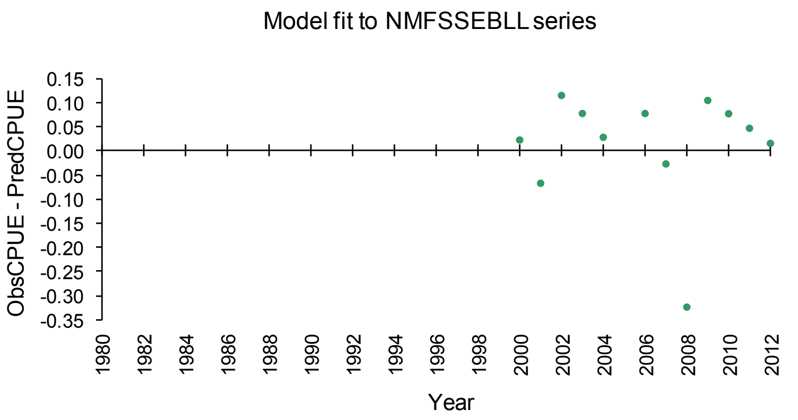


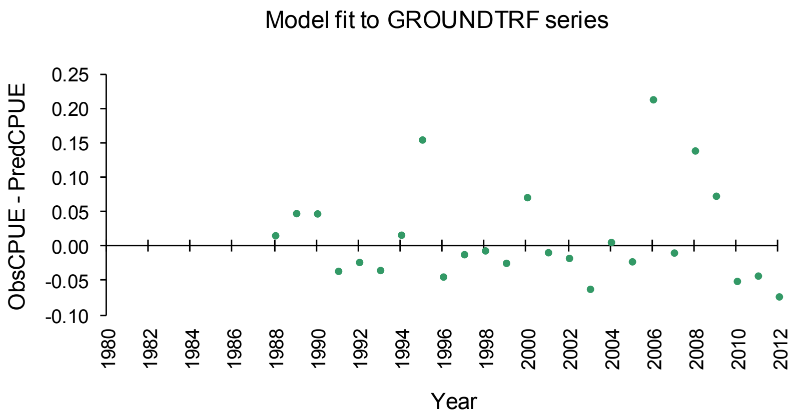


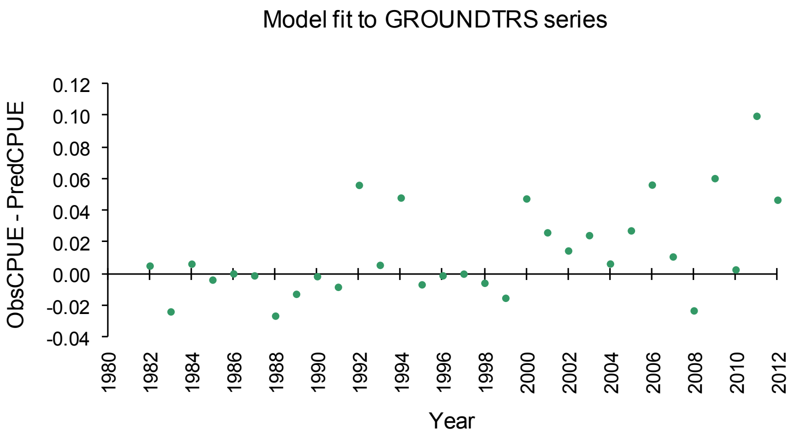


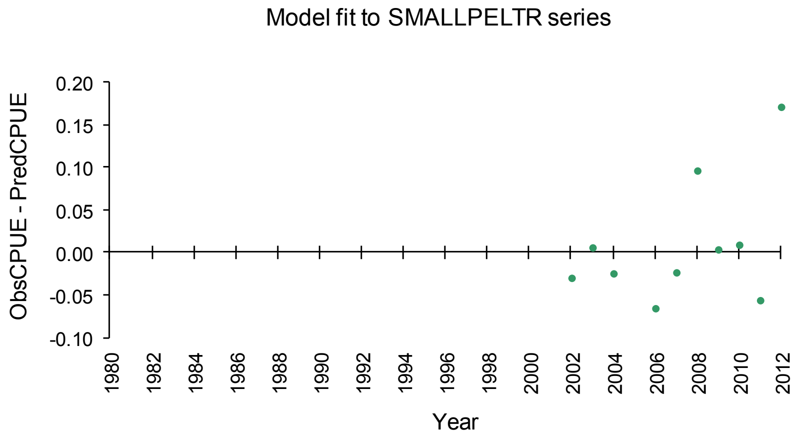


Low r run model fit residuals

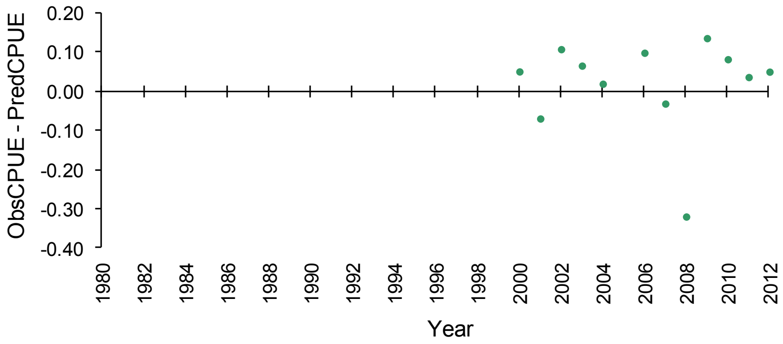

Model fit to NMFSSEBLL series

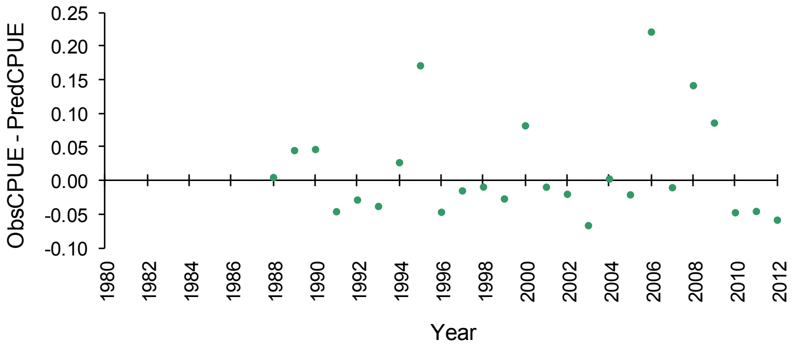

Model fit to GROUNDTRF series

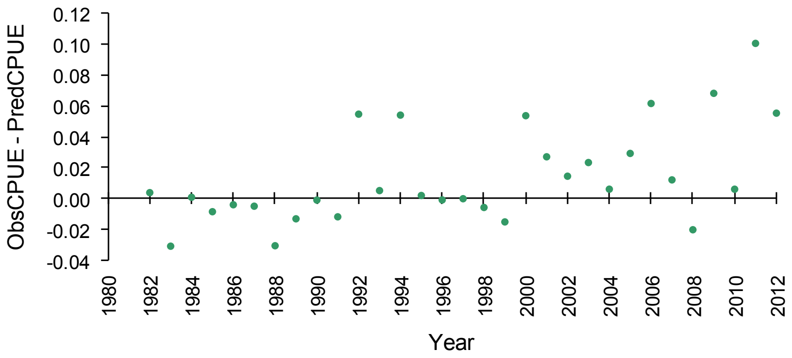

Model fit to GROUNDTRS series

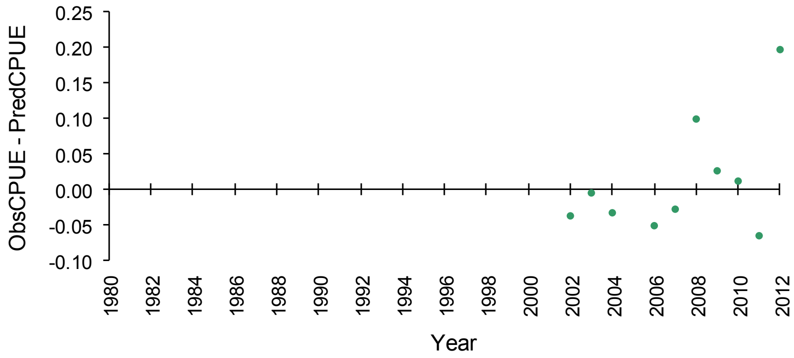

Model fit to SMALLPELTR series

High r run model fit residuals

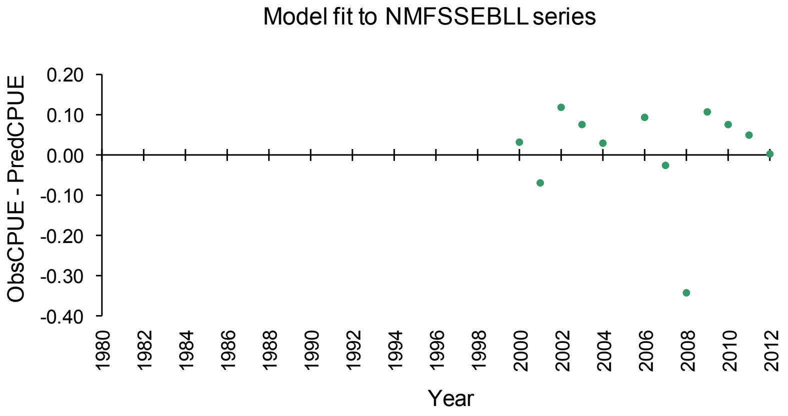

Model fit to NMFSSEBLL series

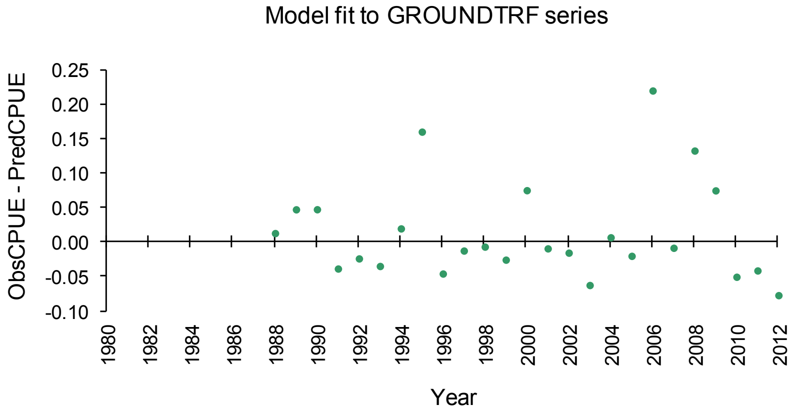

Model fit to GROUNDTRF series

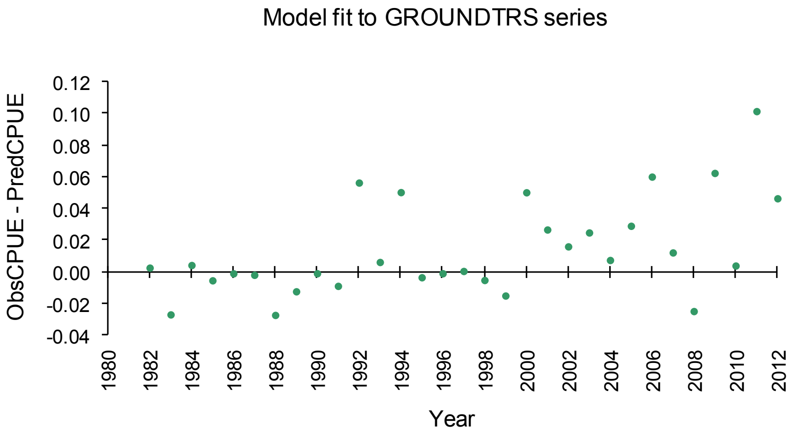

Model fit to GROUNDTRS series

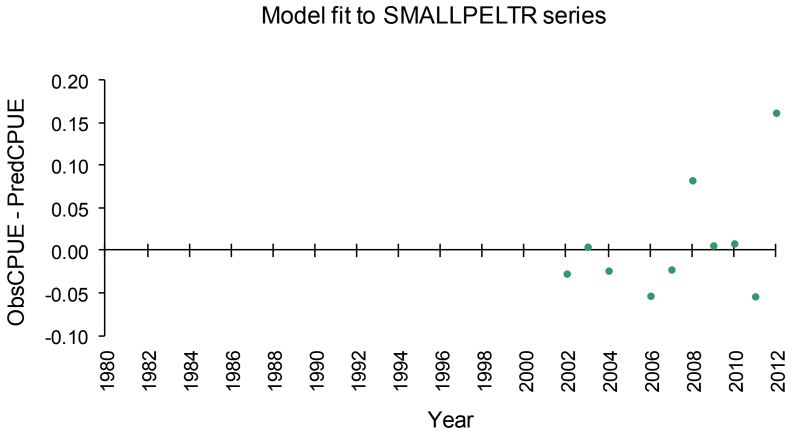

Model fit to SMALLPELTR series

Large process error run model fit residuals

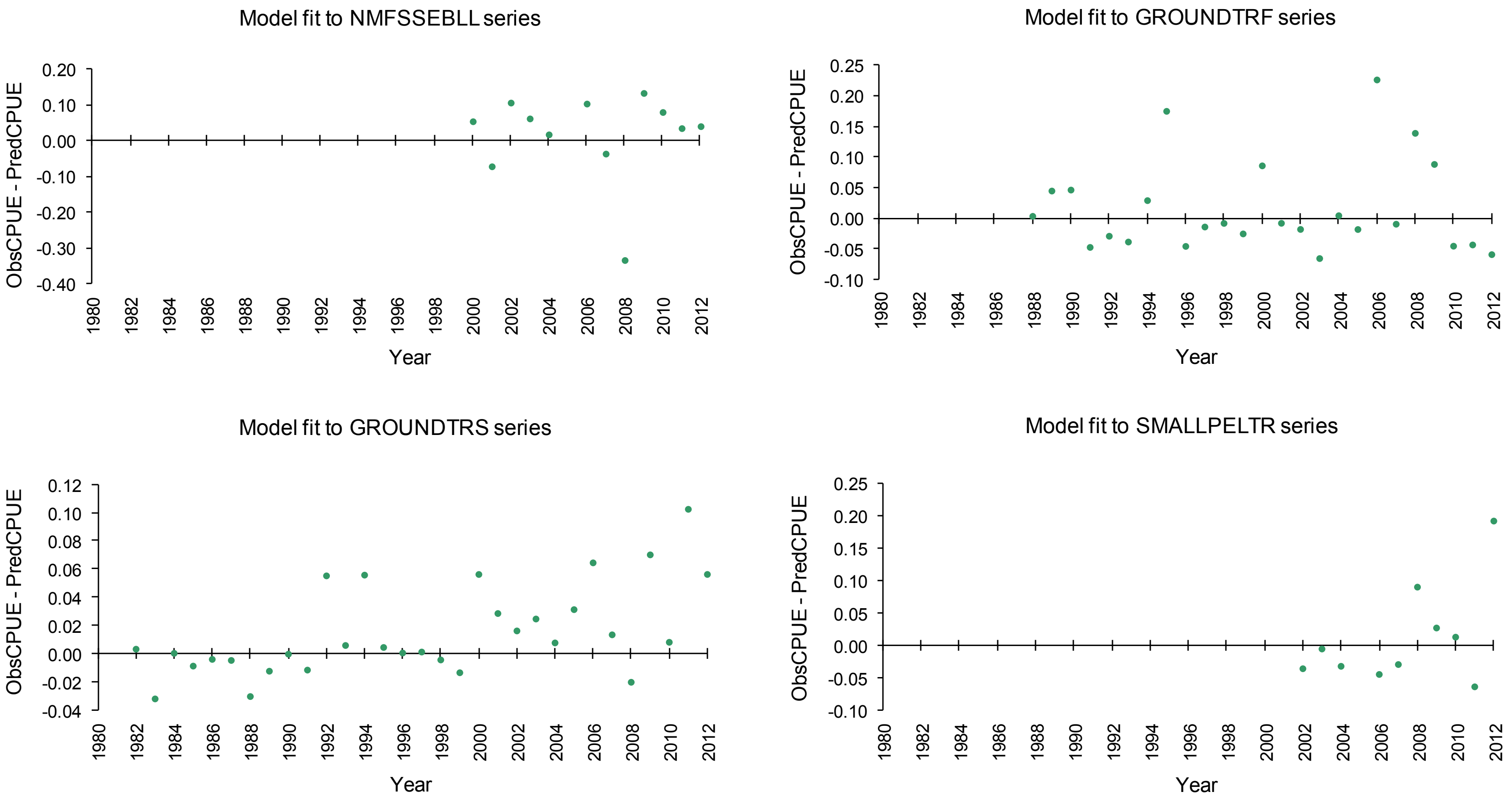

Model fit to NMFSSEBLL series


Model fit to GROUNDTRF series

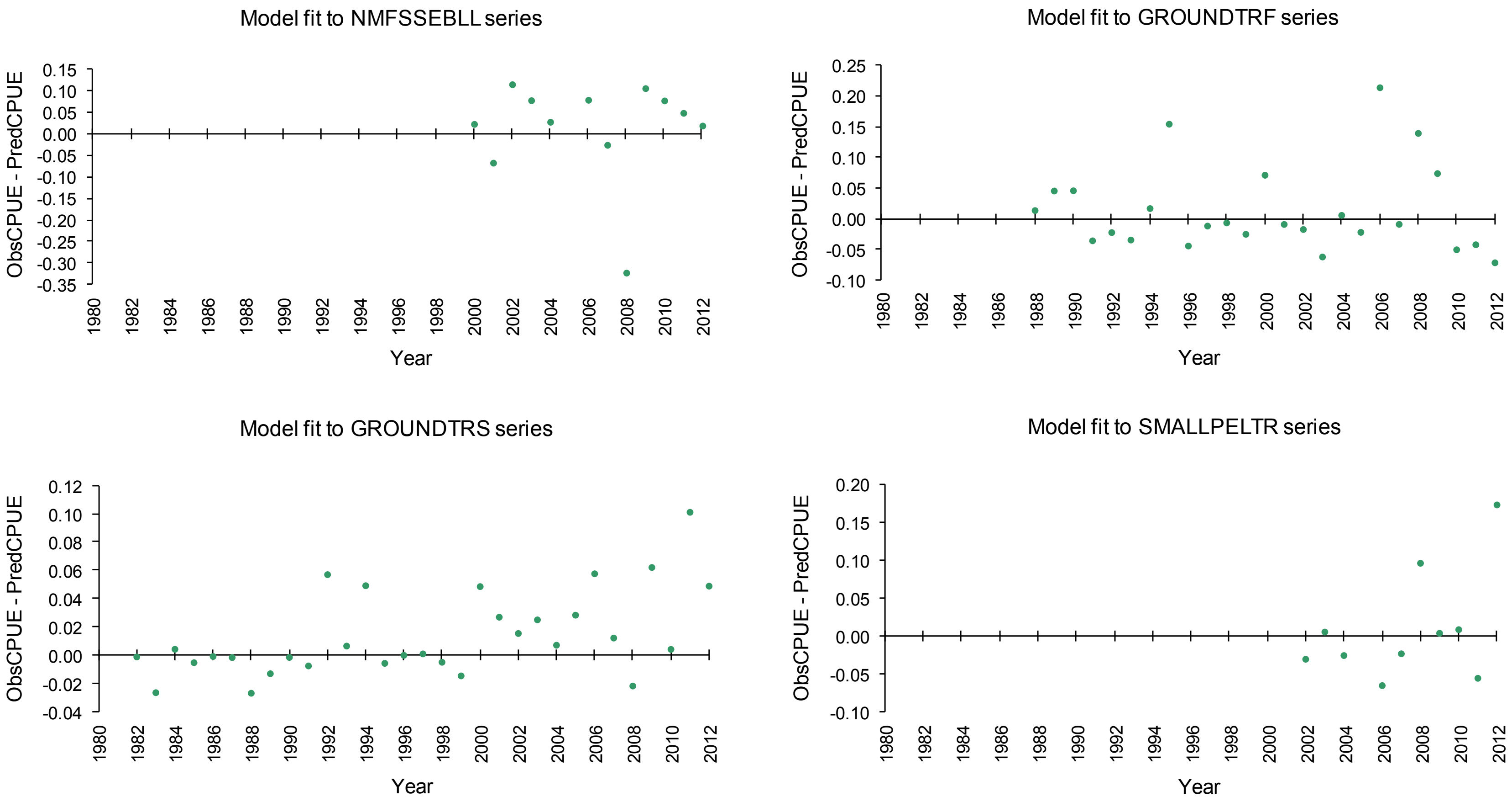

Model fit to GROUNDTRS series


Model fit to SMALLPELTR series

Large observation error run model fit residuals



Large process and observation error run model fit residuals

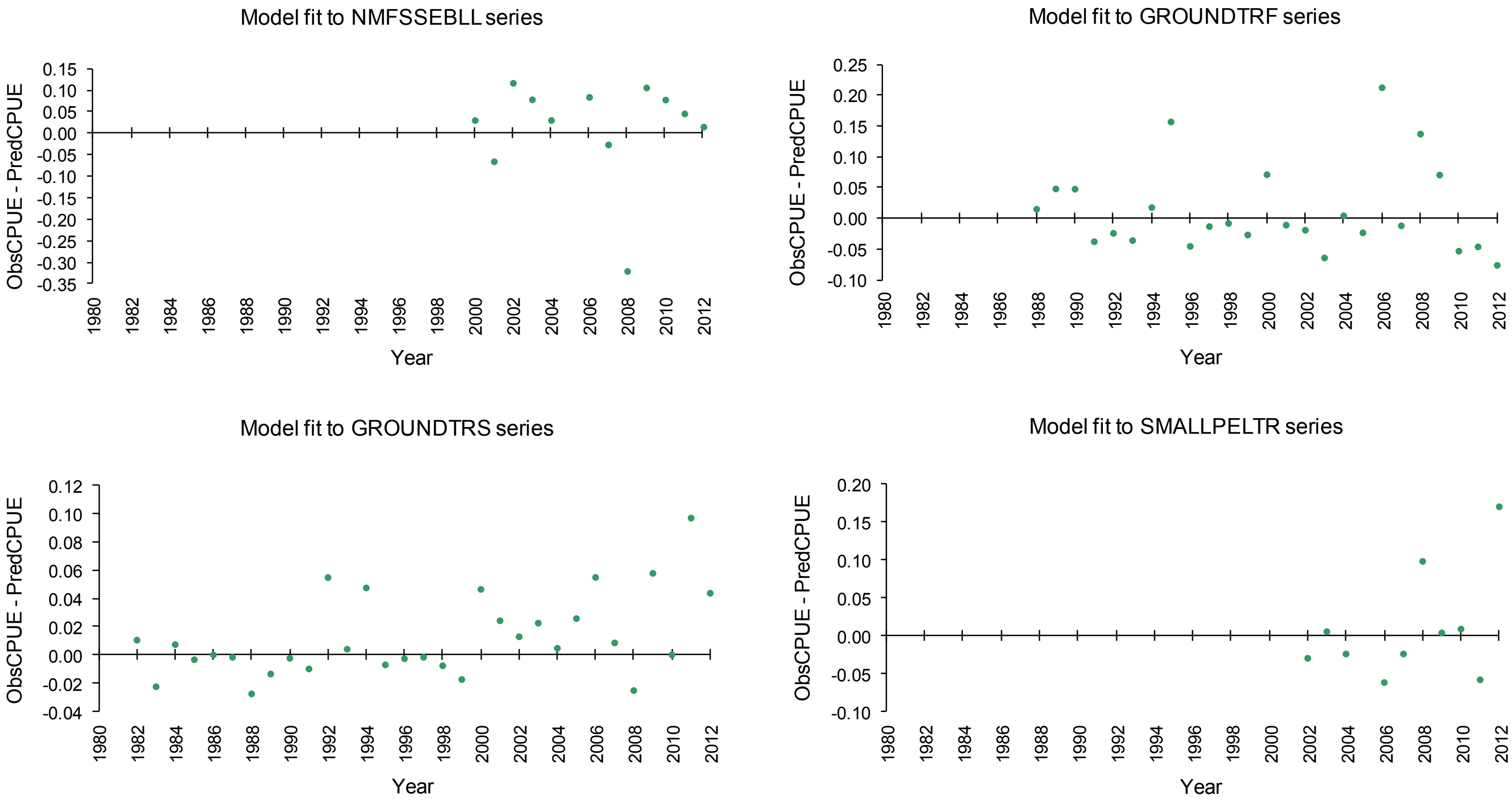

Model fit to NMFSSEBLL series

Model fit to GROUNDTRF series

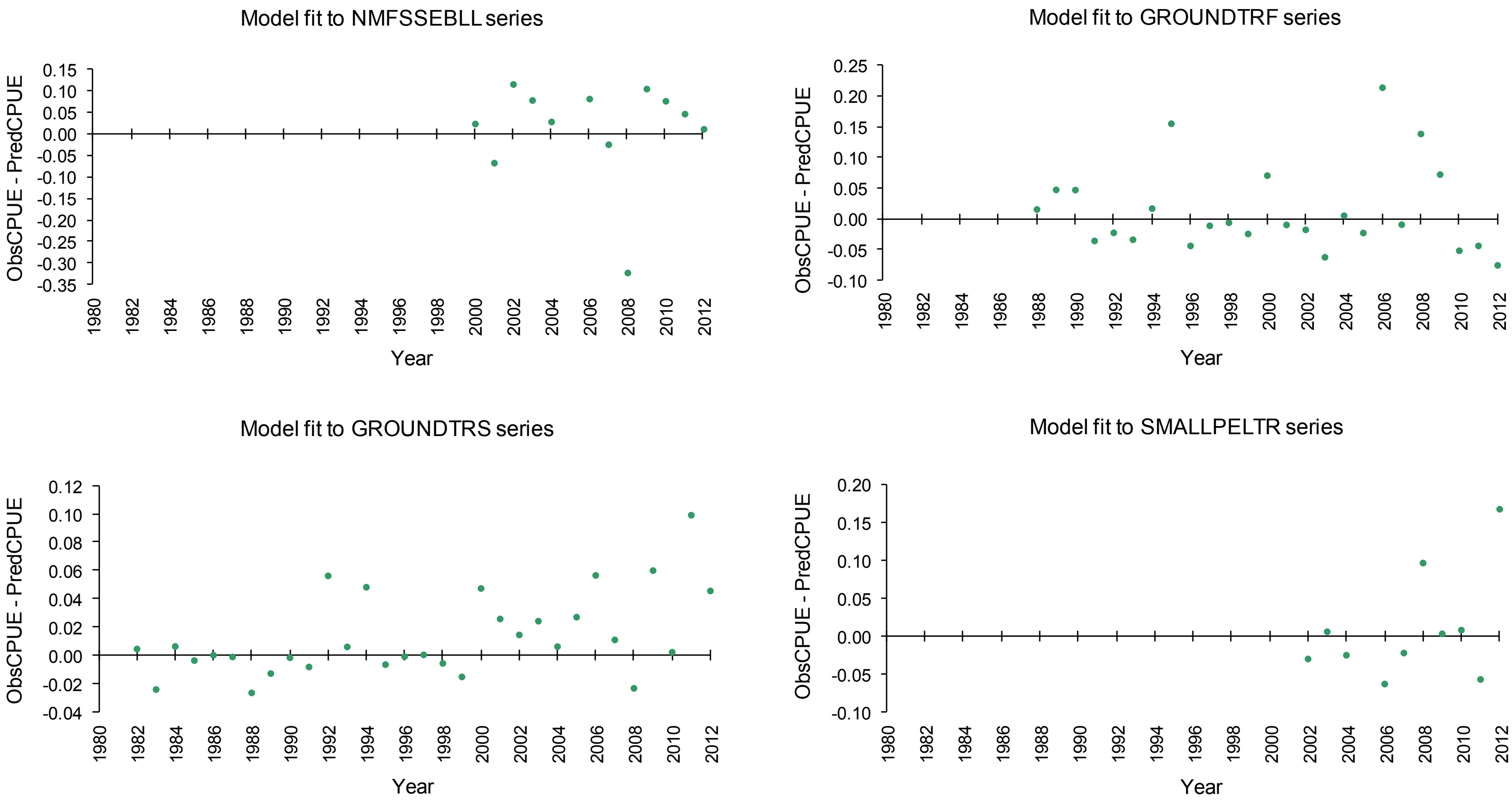
Model fit to GROUNDTRS series

Model fit to SMALLPELTR series

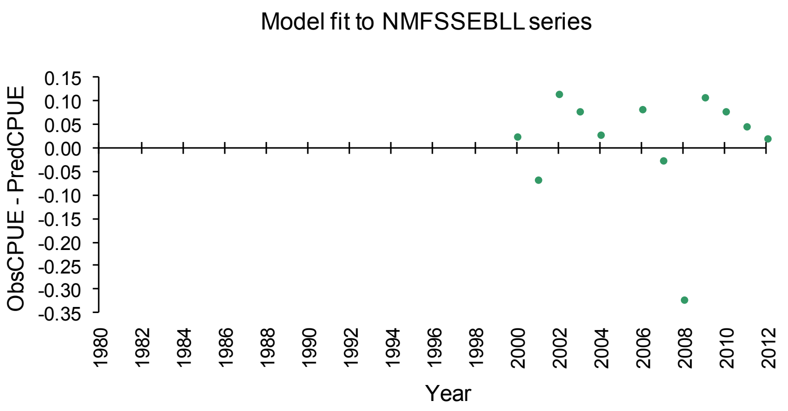
High P_{82} run model fit residuals

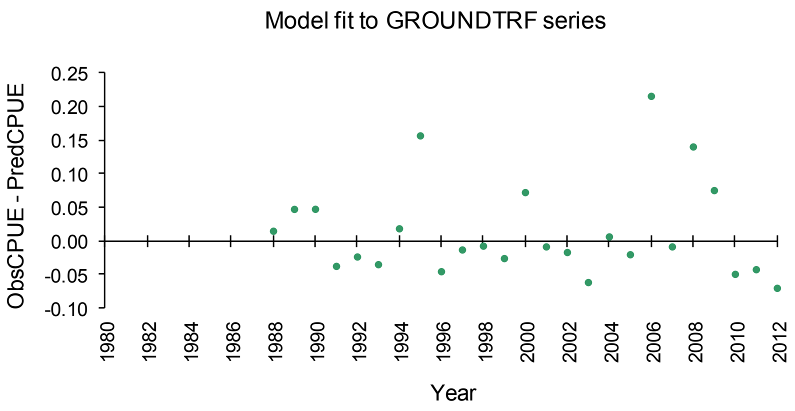


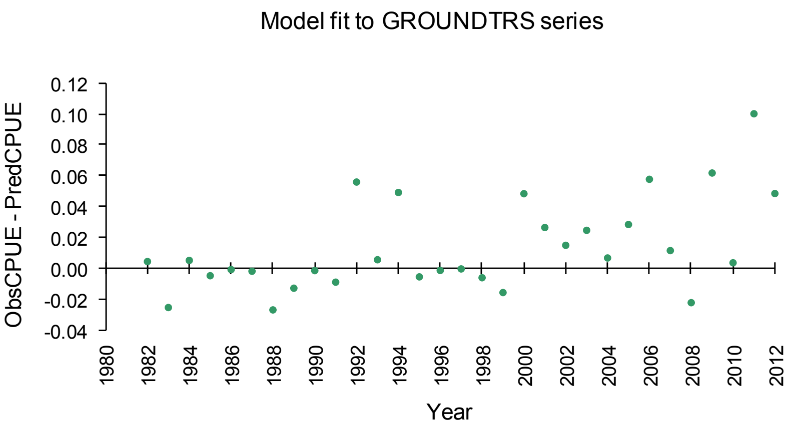
Low P_{82} run model fit residuals

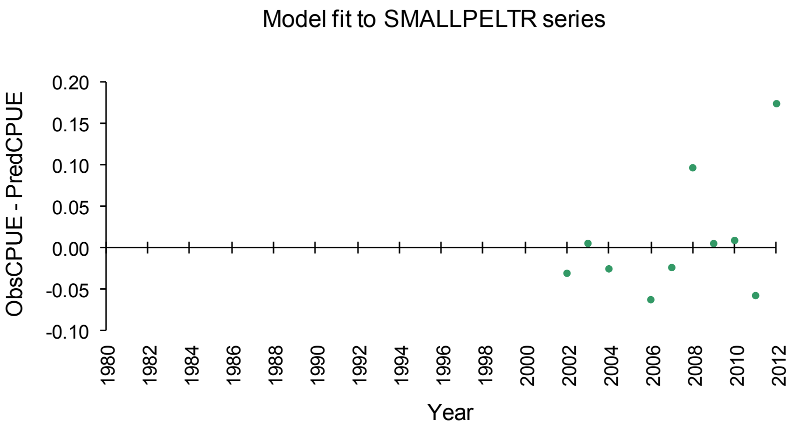


High K run model fit residuals



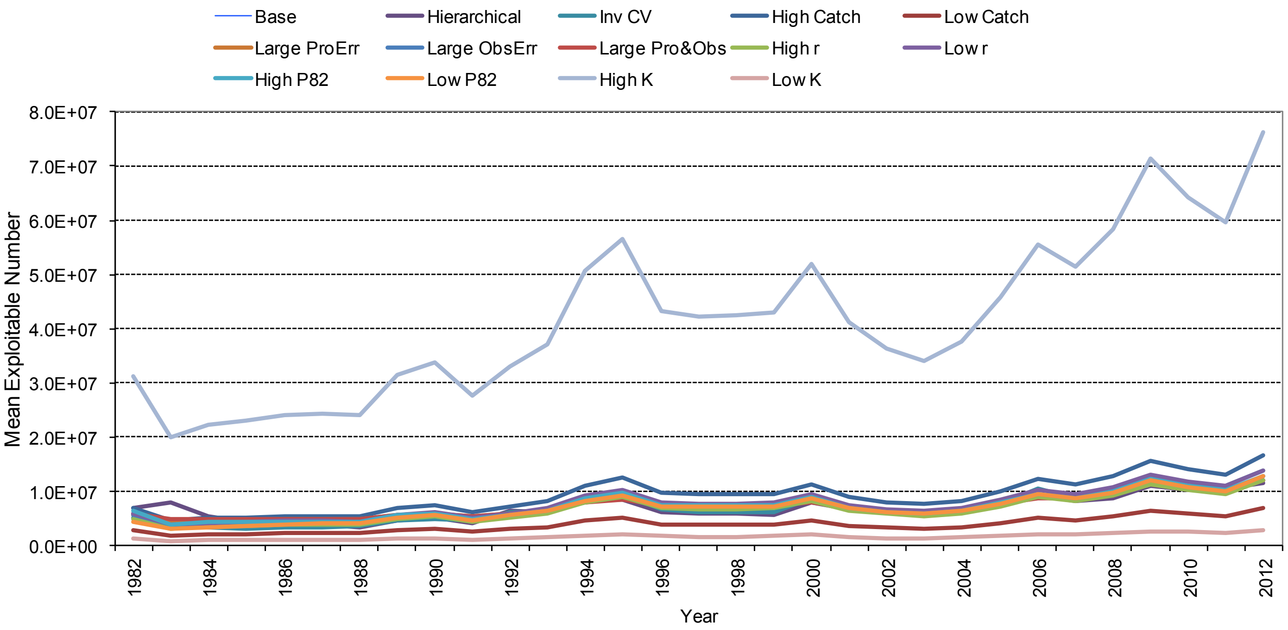


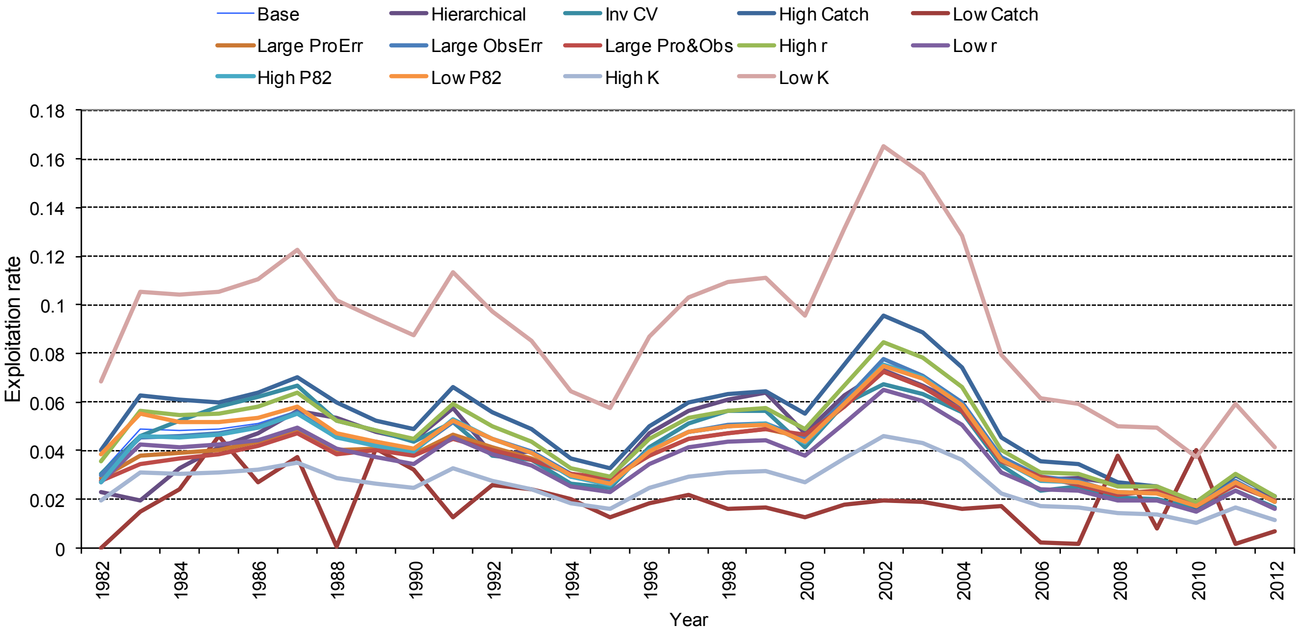




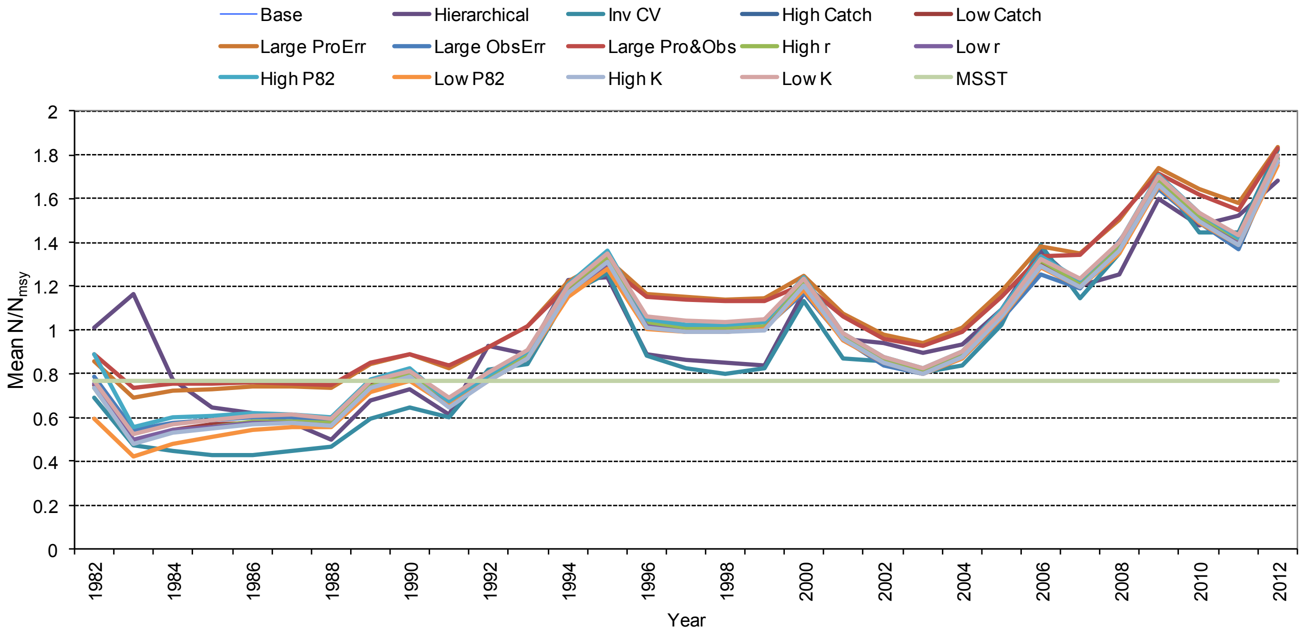
Low K run model fit residuals

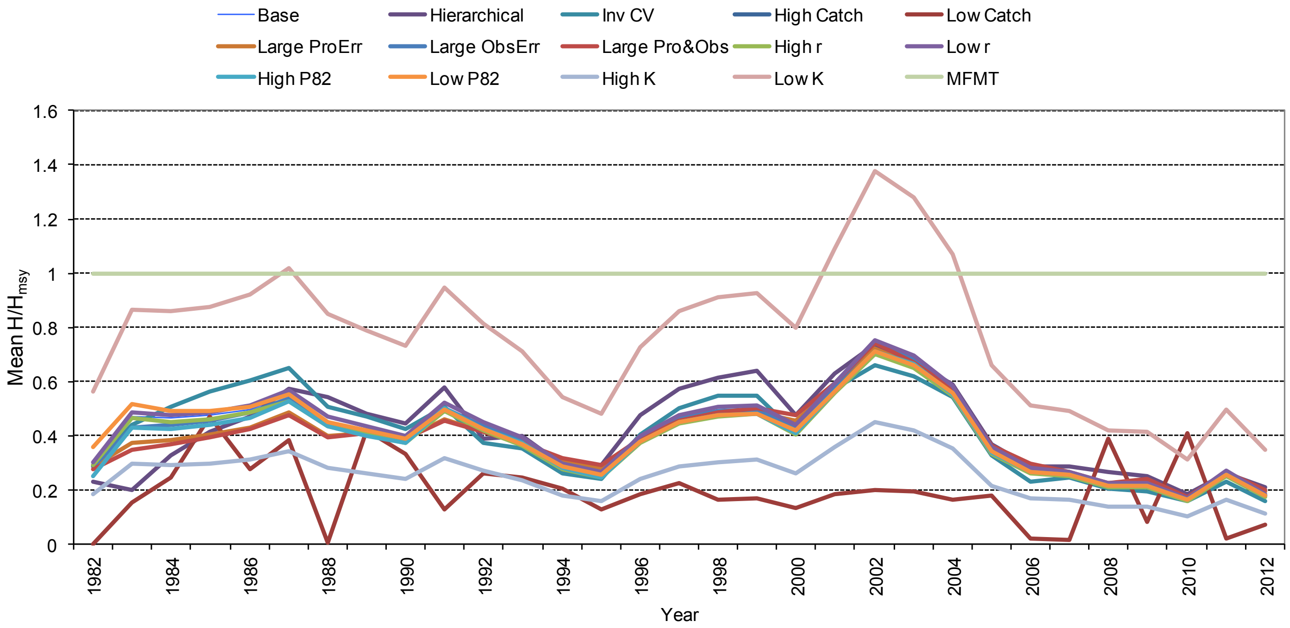
Appendix 3.8.3: Mean predicted exploitable number (top) and exploitation rate (bottom) trajectories for each of the 13 sensitivity runs (combined plots).



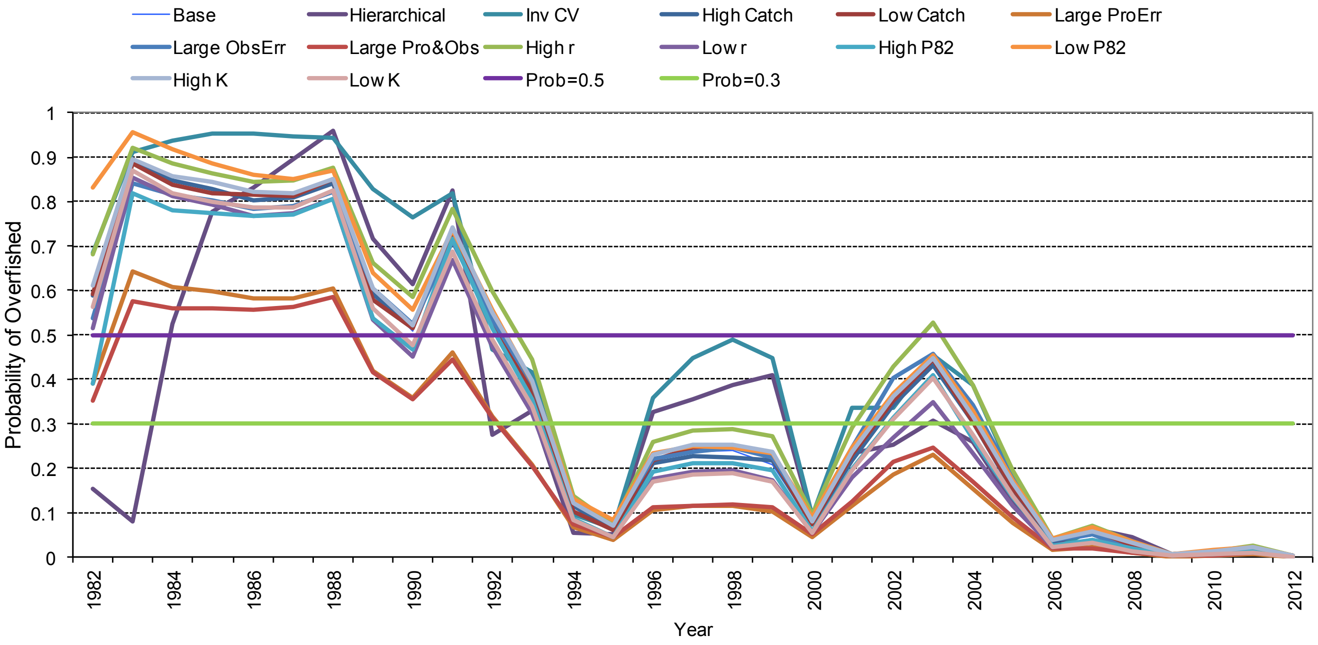


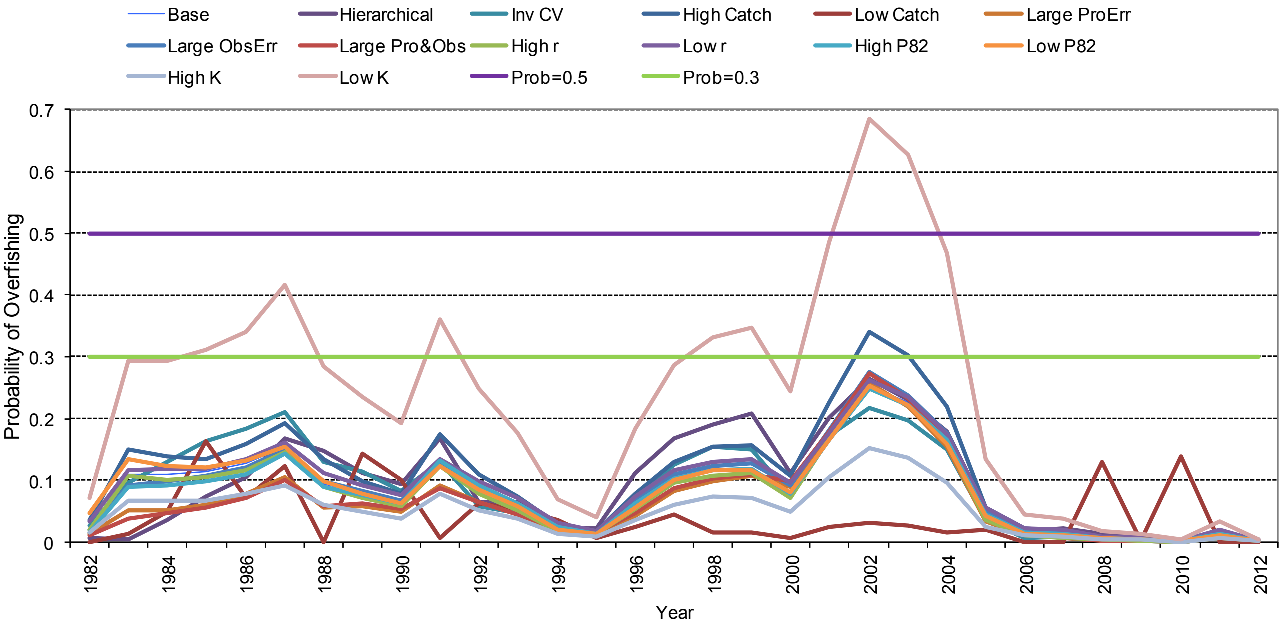
Appendix 3.8.4: Mean relative predicted exploitable number (top) and relative exploitation rate (bottom) trajectories for each of the 13 sensitivity runs (combined plots).





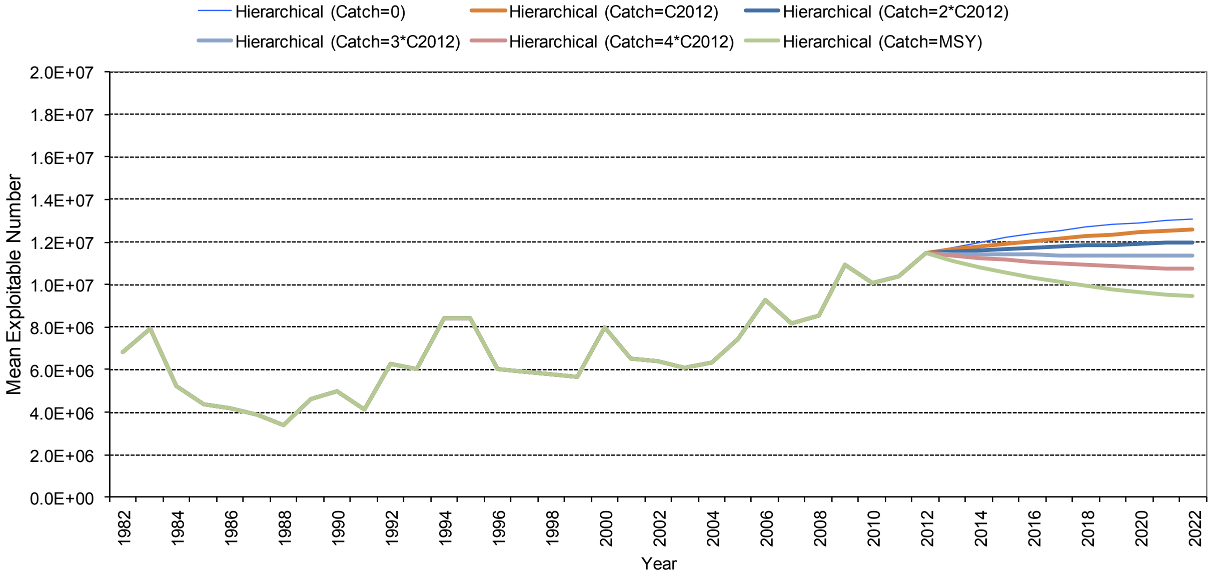
Appendix 3.8.5: Probability of exploitable number being smaller than MSST (overfished condition; top) and probability of exploitation rate being larger than H_{MSY} (overfishing condition; bottom) for each of the 13 sensitivity runs.

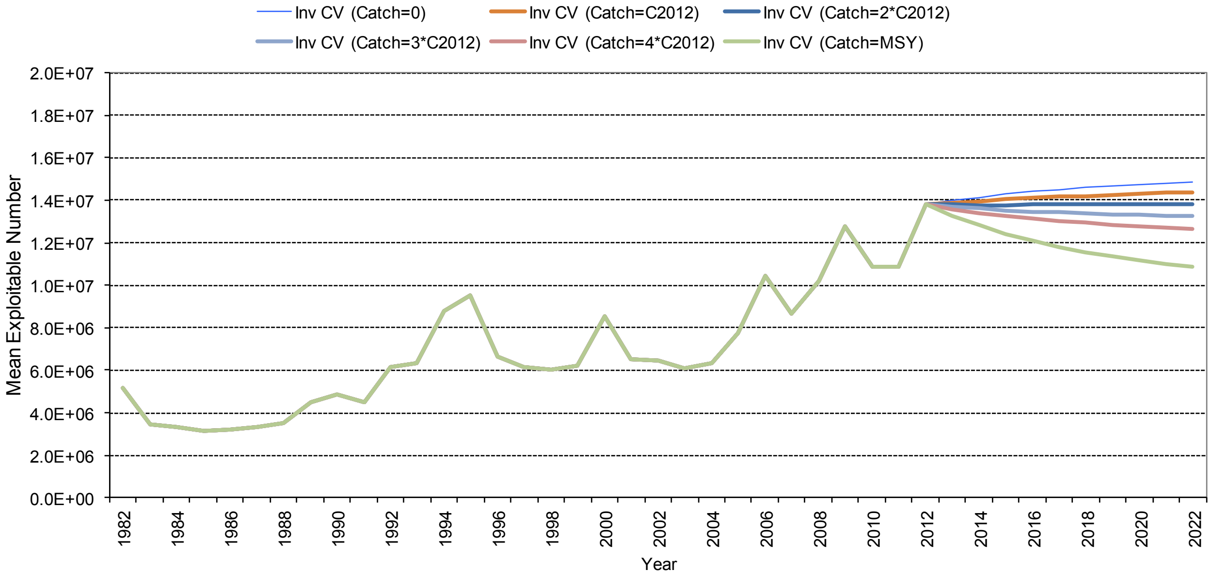


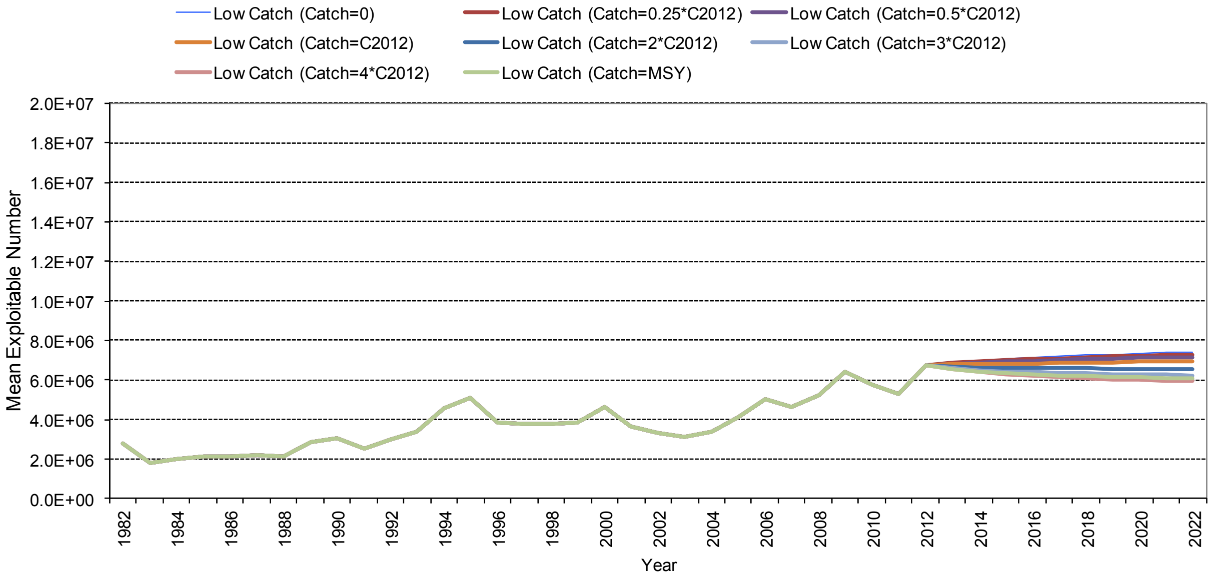


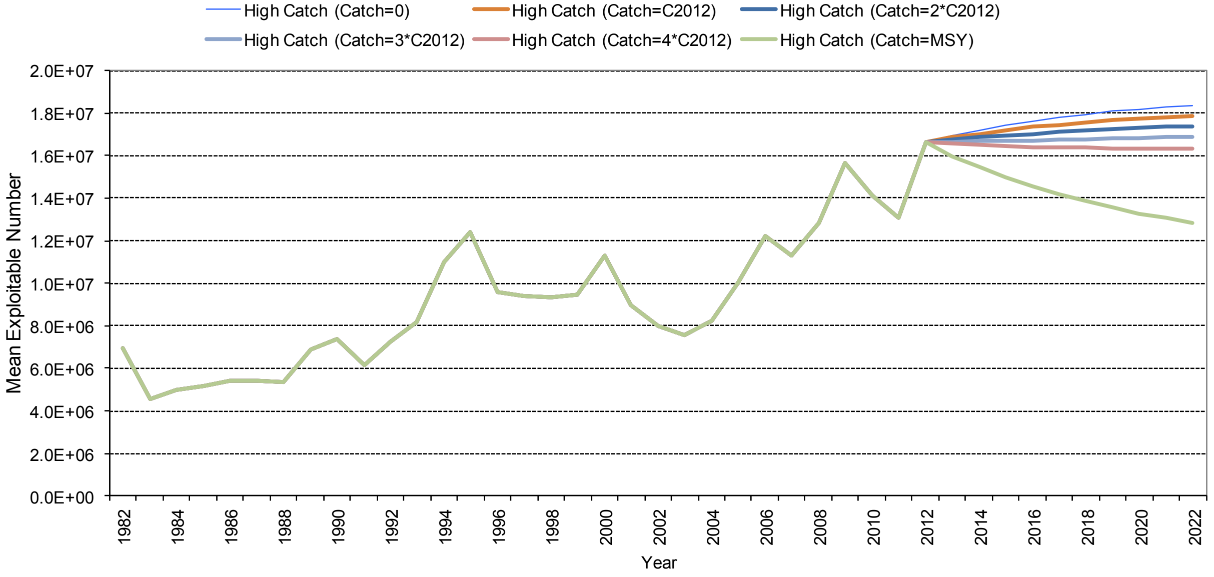
Appendix 3.8.6: Projections for each of 6 runs representing plausible states of nature: 1) hierarchical, 2) inverse CV weighting, 3) low catch, 4) high catch, 5) low r, and 6) high r, under six alternative constant catch level harvesting strategies: no catch (0), the catch in 2012 (C_{2012}), 2* C_{2012}, 3* C_{2012}, 4* C_{2012}, and MSY. Two additional harvesting strategies (0.5* C_{2012}, 0.25* C_{2012}) were added for the low catch scenario.

Appendix 3.8.6.1: Mean projected exploitable number.






Low Catch (Catch=0)
Low Catch (Catch=0.25*C2012)
Low Catch (Catch=0.5*C2012)
Low Catch (Catch=C2012)
Low Catch (Catch=2*C2012)
Low Catch (Catch=3*C2012)
Low Catch (Catch=4*C2012)
Low Catch (Catch=MSY)
Mean Exploitable Number
2.0E+07
1.8E+07
1.6E+07
1.4E+07
1.2E+07
1.0E+07
8.0E+06
6.0E+06
4.0E+06
2.0E+06
0.0E+00
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Year


High Catch (Catch=0)
High Catch (Catch=C2012)
High Catch (Catch=2*C2012)
High Catch (Catch=3*C2012)
High Catch (Catch=4*C2012)
High Catch (Catch=MSY)
Mean Exploitable Number
2.0E+07
1.8E+07
1.6E+07
1.4E+07
1.2E+07
1.0E+07
8.0E+06
6.0E+06
4.0E+06
2.0E+06
0.0E+00
1982
1984
1986
1988
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2006
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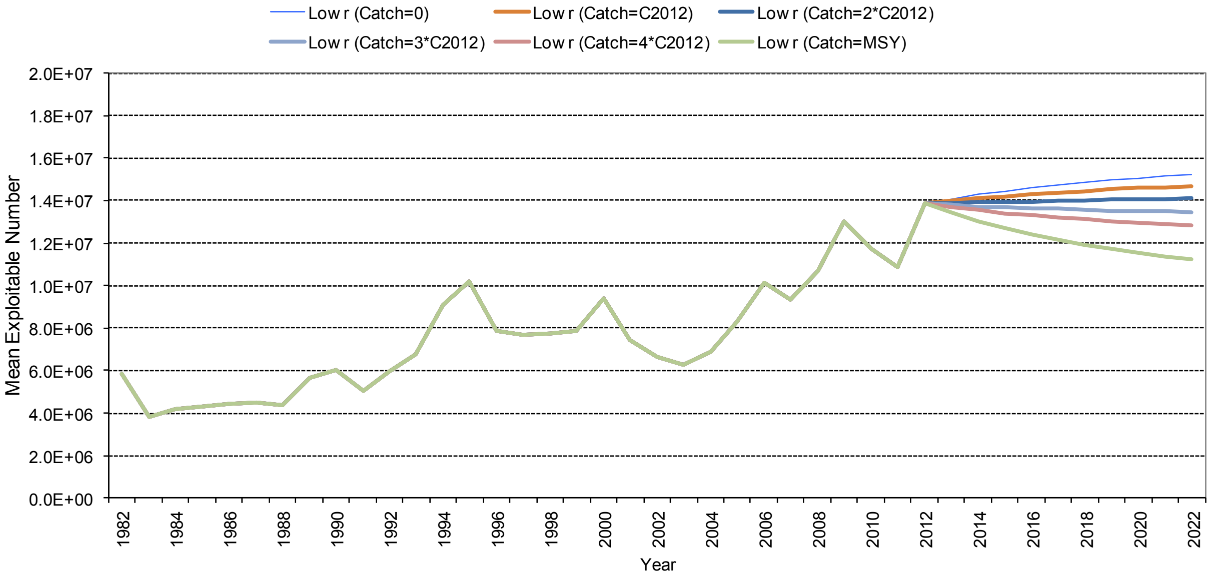
2012
2014
2016
2018
2020
2022
Year


Low r (Catch=0)
Low r (Catch=C2012)
Low r (Catch=2*C2012)
Low r (Catch=3*C2012)
Low r (Catch=4*C2012)
Low r (Catch=MSY)
Mean Exploitable Number
2.0E+07
1.8E+07
1.6E+07
1.4E+07
1.2E+07
1.0E+07
8.0E+06
6.0E+06
4.0E+06
2.0E+06
0.0E+00
1982
1984
1986
1988
1990
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1994
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1998
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2002
2004
2006
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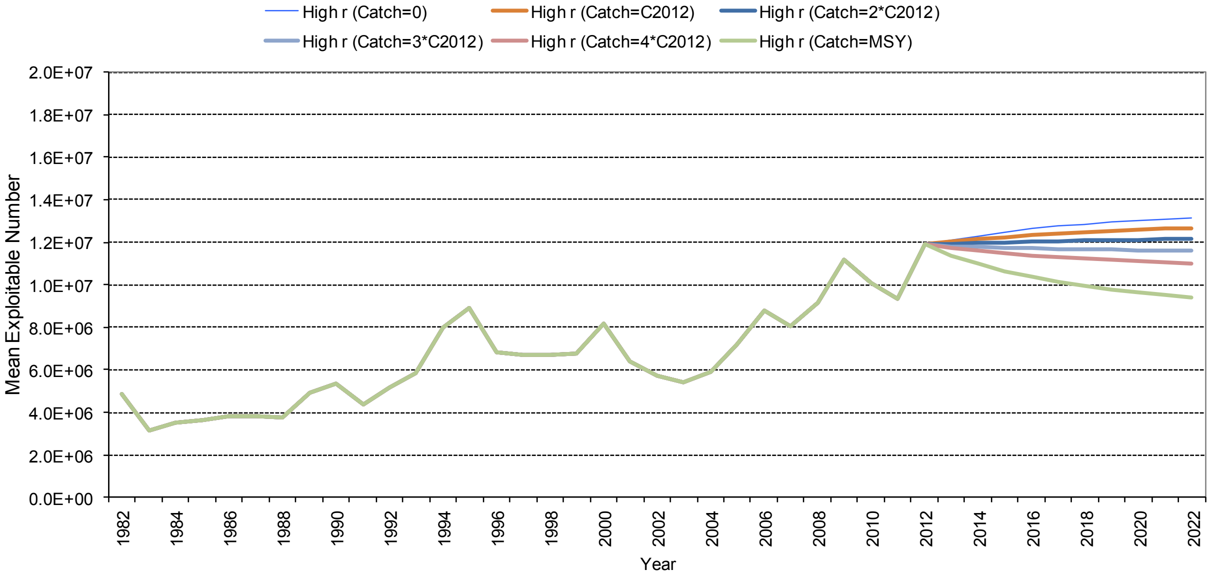
2010
2012
2014
2016
2018
2020
2022
Year


High r (Catch=0)
High r (Catch=C2012)
High r (Catch=2*C2012)
High r (Catch=3*C2012)
High r (Catch=4*C2012)
High r (Catch=MSY)
Mean Exploitable Number
2.0E+07
1.8E+07
1.6E+07
1.4E+07
1.2E+07
1.0E+07
8.0E+06
6.0E+06
4.0E+06
2.0E+06
0.0E+00
1982
1984
1986
1988
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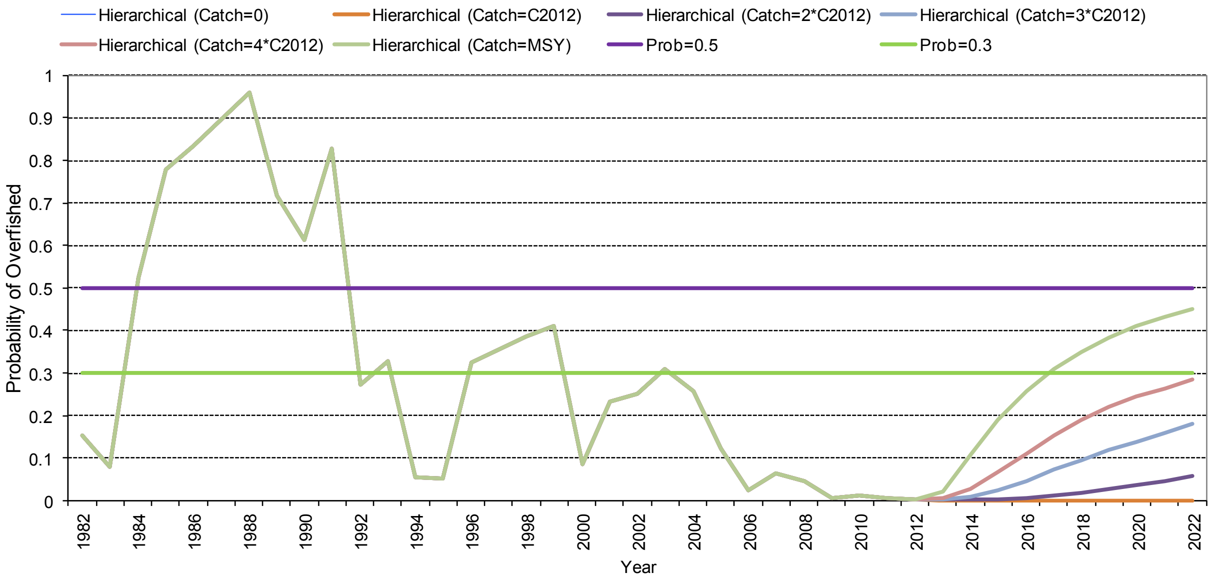
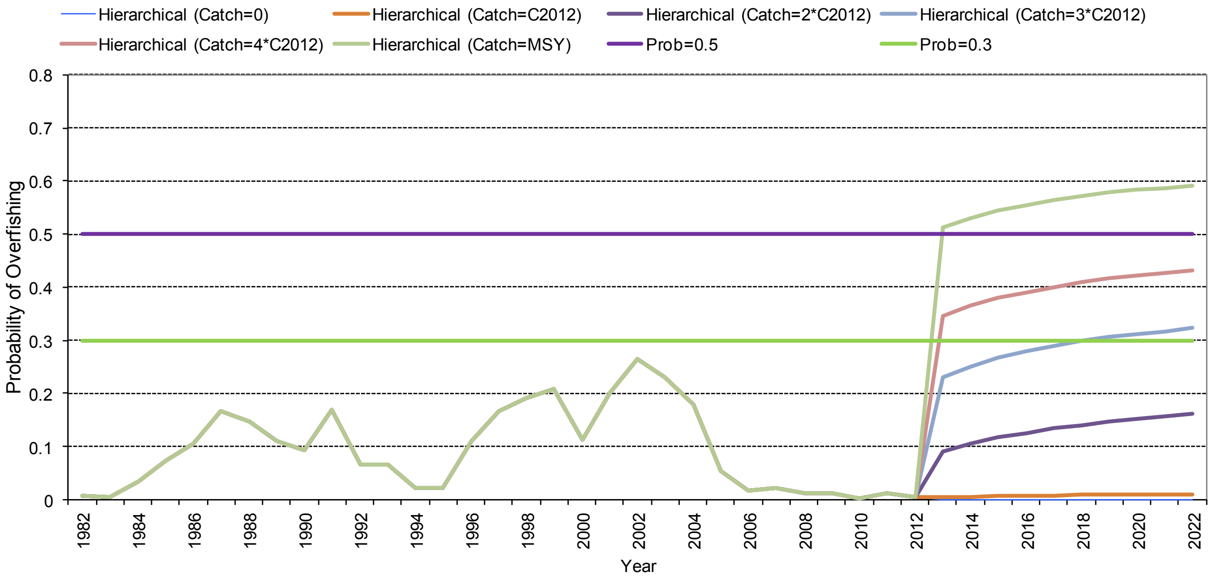
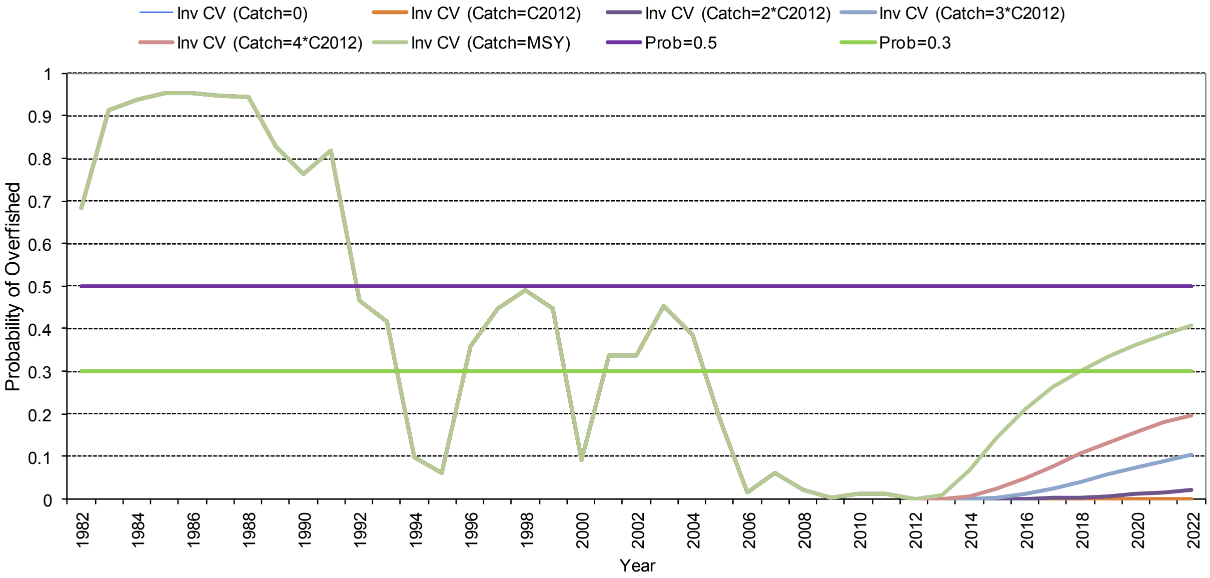
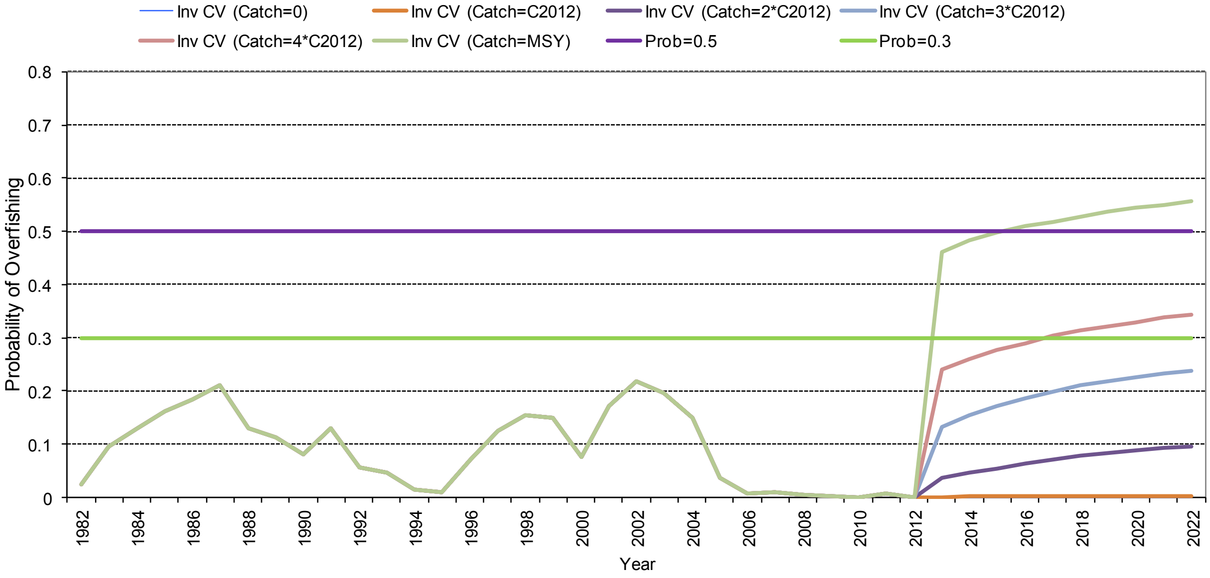
2022
Year

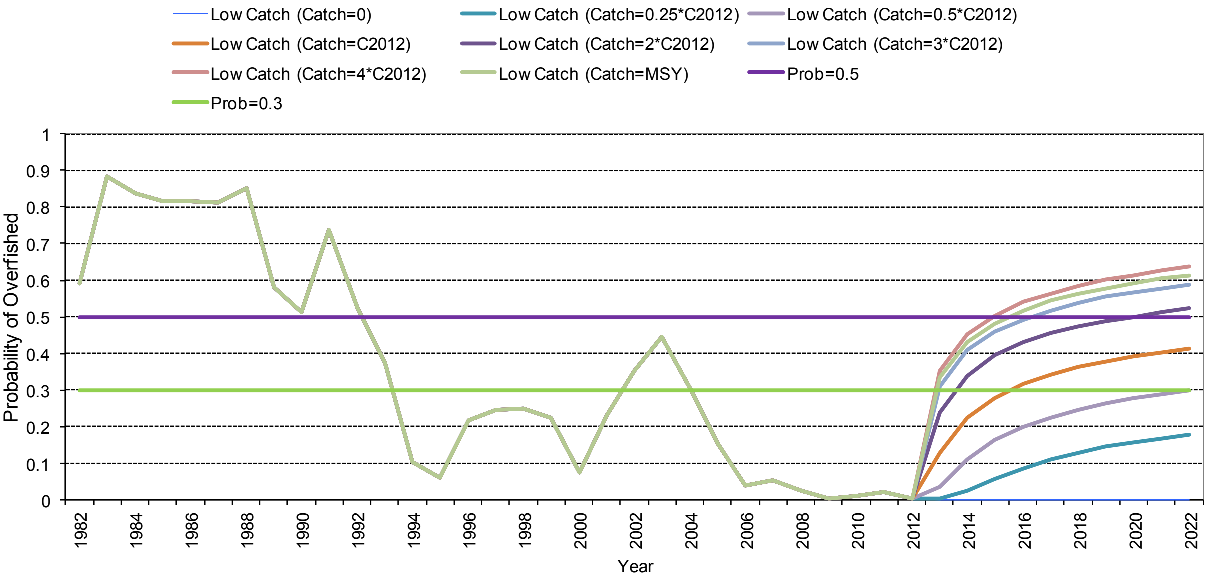
Appendix 3.8.6.2: Probability of exploitable number being smaller than MSST (overfished condition; top) and probability of exploitation rate being larger than H_{MSY} (overfishing condition; bottom).






Inv CV (Catch=0)
Inv CV (Catch=C2012)
Inv CV (Catch=2*C2012)
Inv CV (Catch=3*C2012)
Inv CV (Catch=4*C2012)
Inv CV (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfished
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Year


Inv CV (Catch=0)
Inv CV (Catch=C2012)
Inv CV (Catch=2*C2012)
Inv CV (Catch=3*C2012)
Inv CV (Catch=4*C2012)
Inv CV (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfishing
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Year


Low Catch (Catch=0)
Low Catch (Catch=0.25*C2012)
Low Catch (Catch=0.5*C2012)
Low Catch (Catch=C2012)
Low Catch (Catch=2*C2012)
Low Catch (Catch=3*C2012)
Low Catch (Catch=4*C2012)
Low Catch (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfished
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1982
1984
1986
1988
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2008
2010
2012
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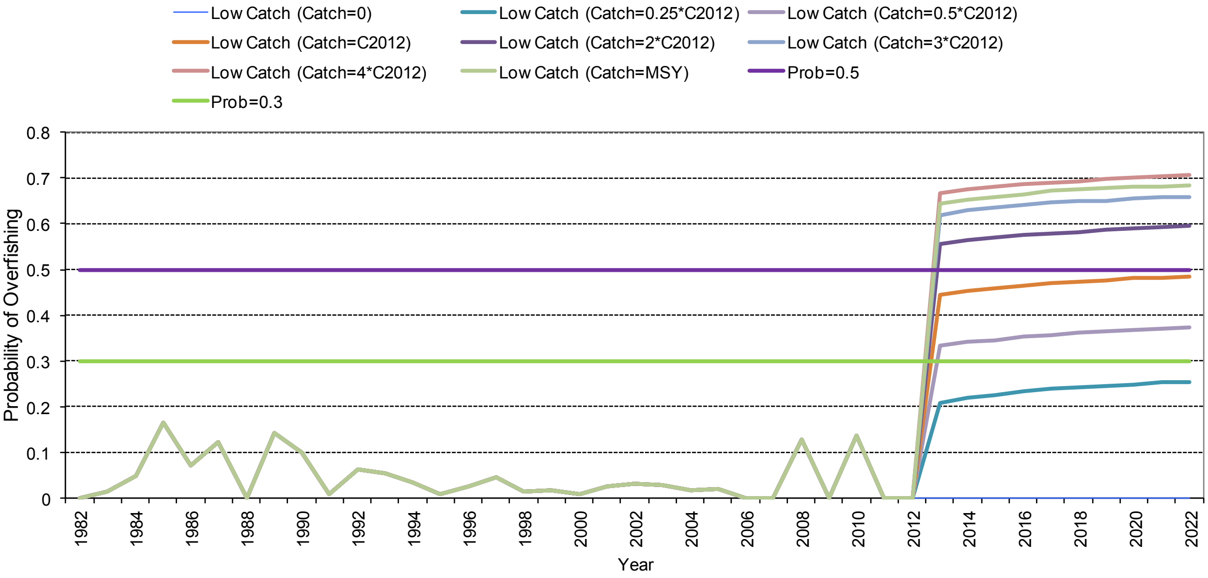
2016
2018
2020
2022


Low Catch (Catch=0)
Low Catch (Catch=0.25*C2012)
Low Catch (Catch=0.5*C2012)
Low Catch (Catch=C2012)
Low Catch (Catch=2*C2012)
Low Catch (Catch=3*C2012)
Low Catch (Catch=4*C2012)
Low Catch (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfishing
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1982
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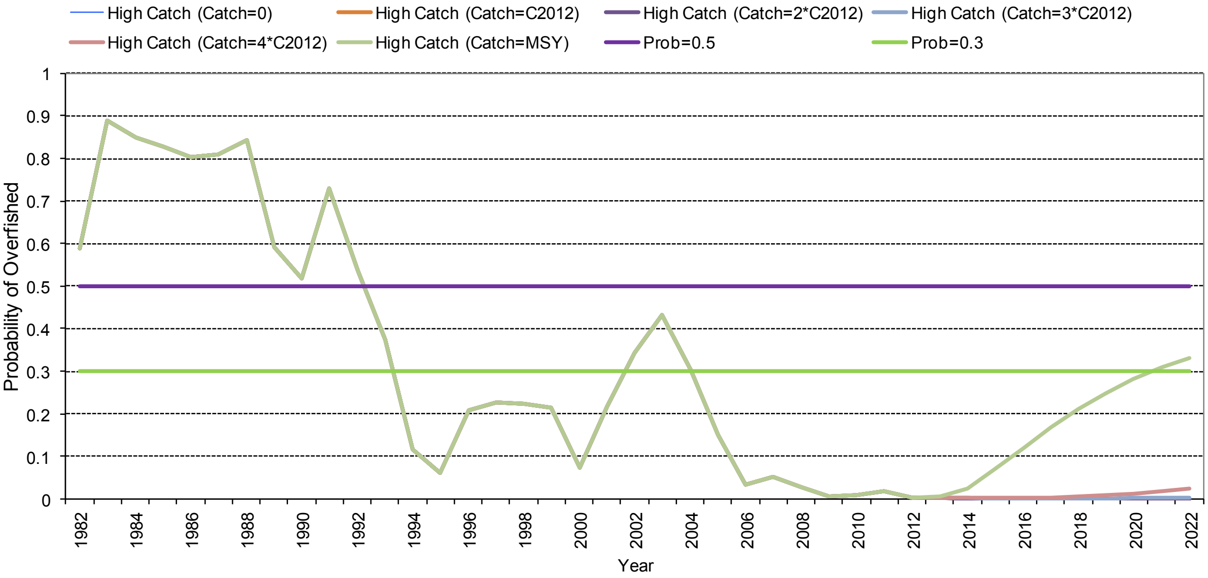
2022


High Catch (Catch=0)
High Catch (Catch=C2012)
High Catch (Catch=2*C2012)
High Catch (Catch=3*C2012)
High Catch (Catch=4*C2012)
High Catch (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfished
1
0.9
0.8
0.7
0.6
0.5
0.4
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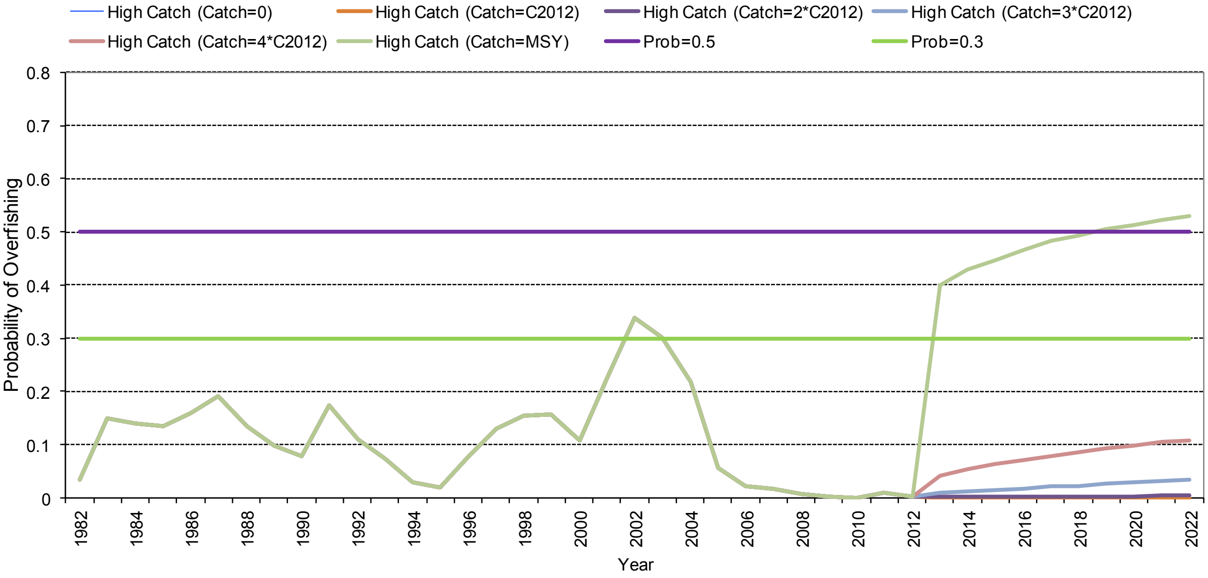
High Catch (Catch=0)
High Catch (Catch=C2012)
High Catch (Catch=2*C2012)
High Catch (Catch=3*C2012)
High Catch (Catch=4*C2012)
High Catch (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfishing
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
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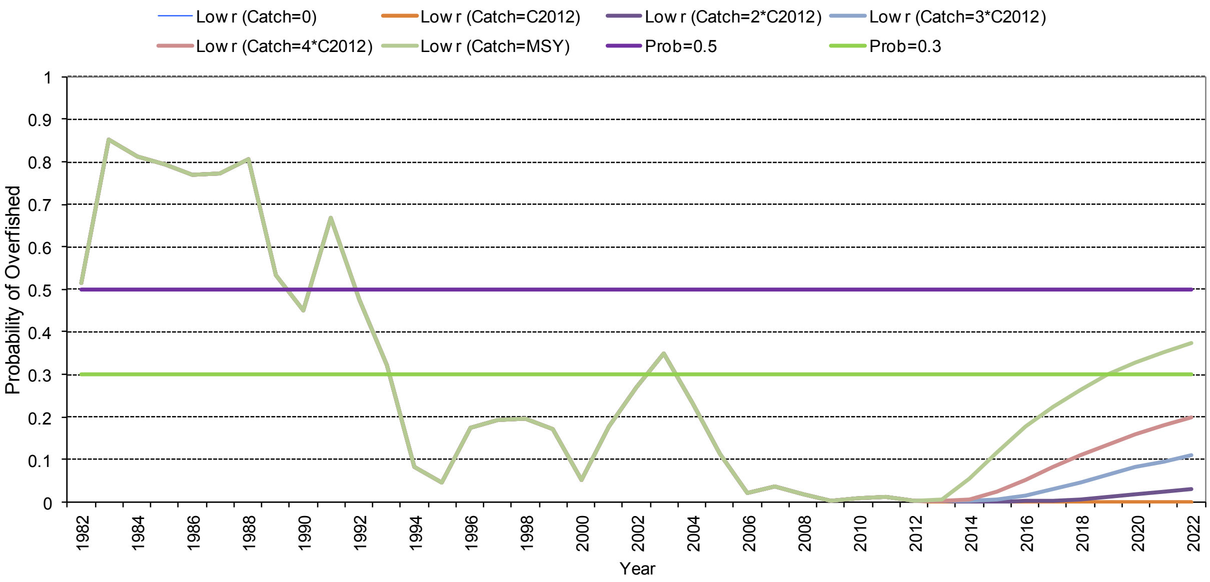
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Low r (Catch=C2012)
Low r (Catch=2*C2012)
Low r (Catch=3*C2012)
Low r (Catch=4*C2012)
Low r (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfished
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
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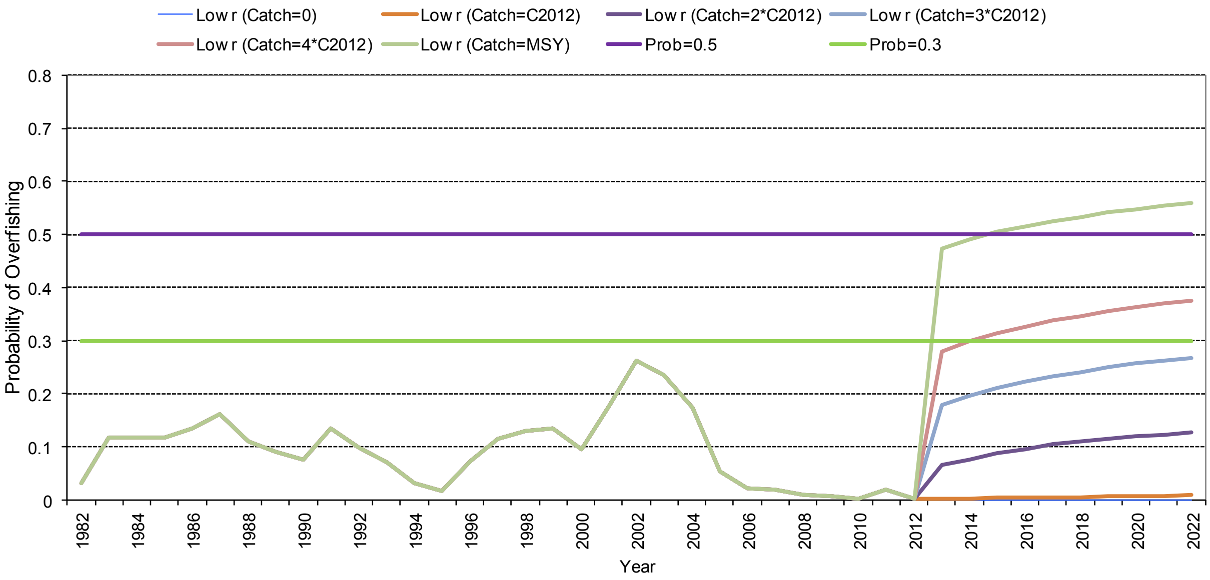
Low r (Catch=0)
Low r (Catch=C2012)
Low r (Catch=2*C2012)
Low r (Catch=3*C2012)
Low r (Catch=4*C2012)
Low r (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfishing
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0.1
0.2
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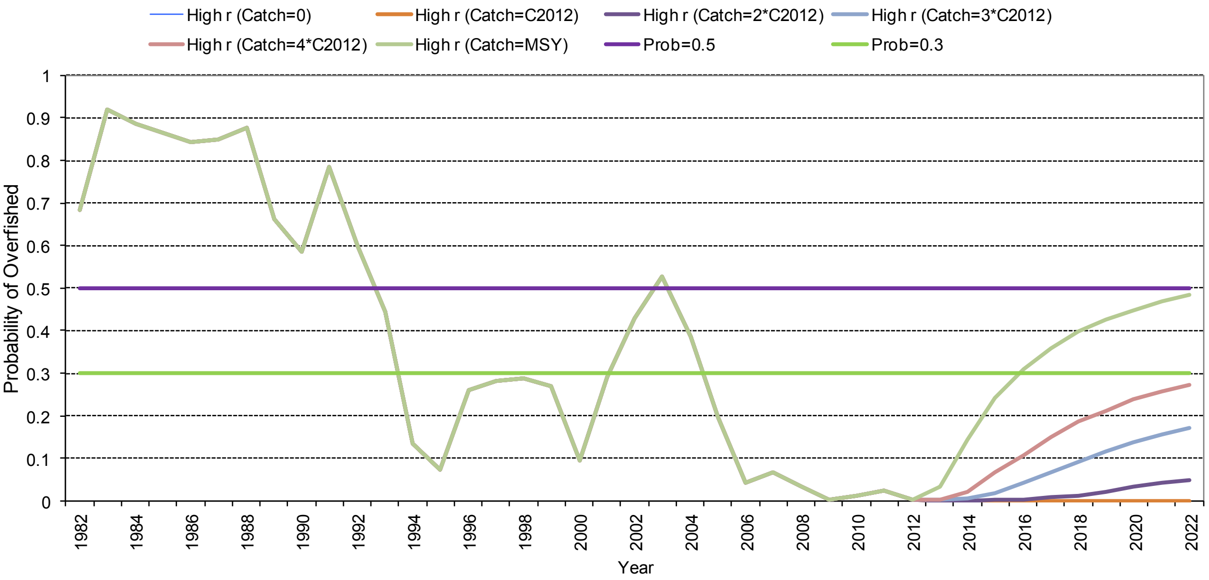
High r (Catch=0)
High r (Catch=C2012)
High r (Catch=2*C2012)
High r (Catch=3*C2012)
High r (Catch=4*C2012)
High r (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfished
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0.1
0.2
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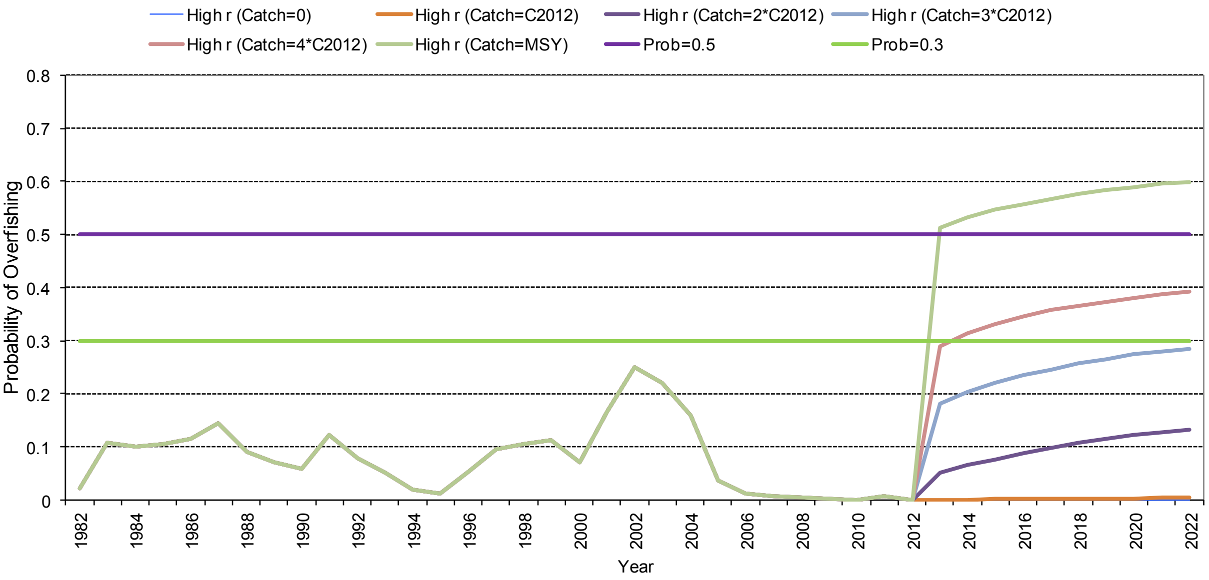
High r (Catch=0)
High r (Catch=C2012)
High r (Catch=2*C2012)
High r (Catch=3*C2012)
High r (Catch=4*C2012)
High r (Catch=MSY)
Prob=0.5
Prob=0.3
Probability of Overfishing
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1982
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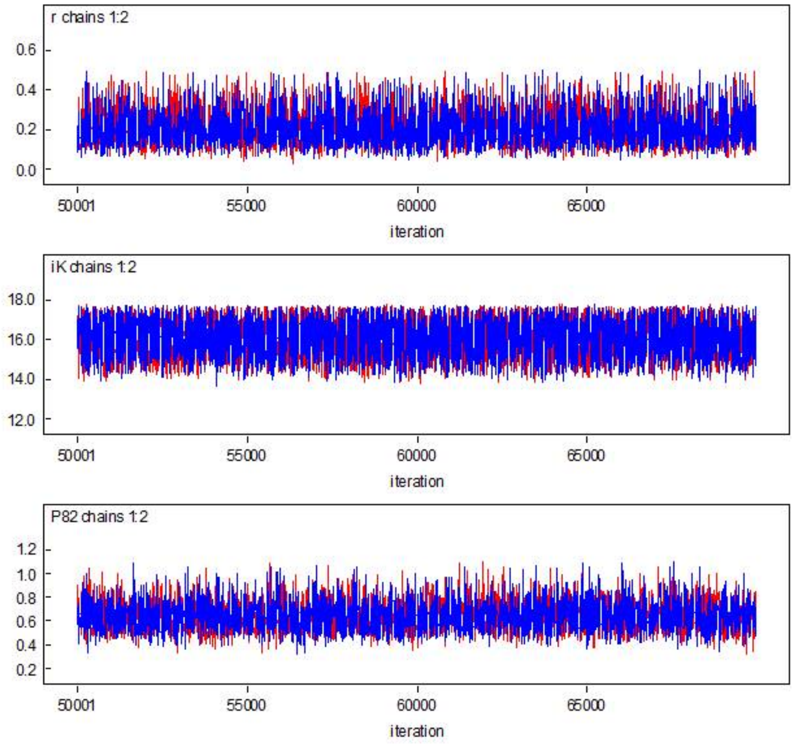
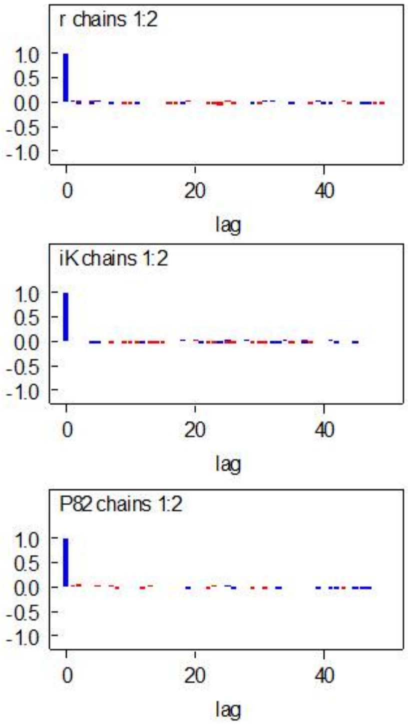
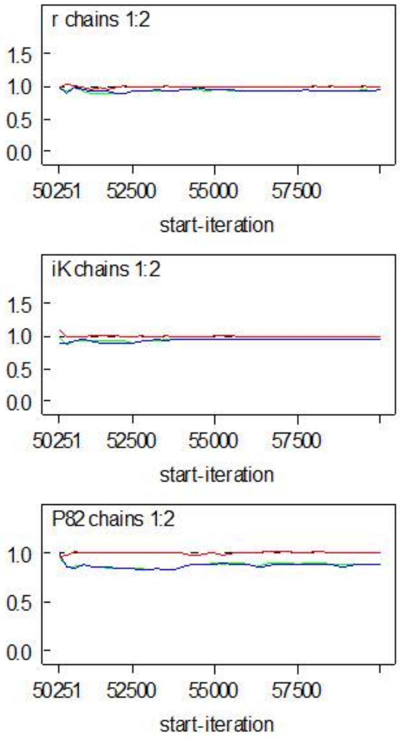
Appendix 3.8.7: Convergence diagnostics for the key model parameters (*r*, *K*, and P_{82}) for the two chains for each of the 13 sensitivity runs.



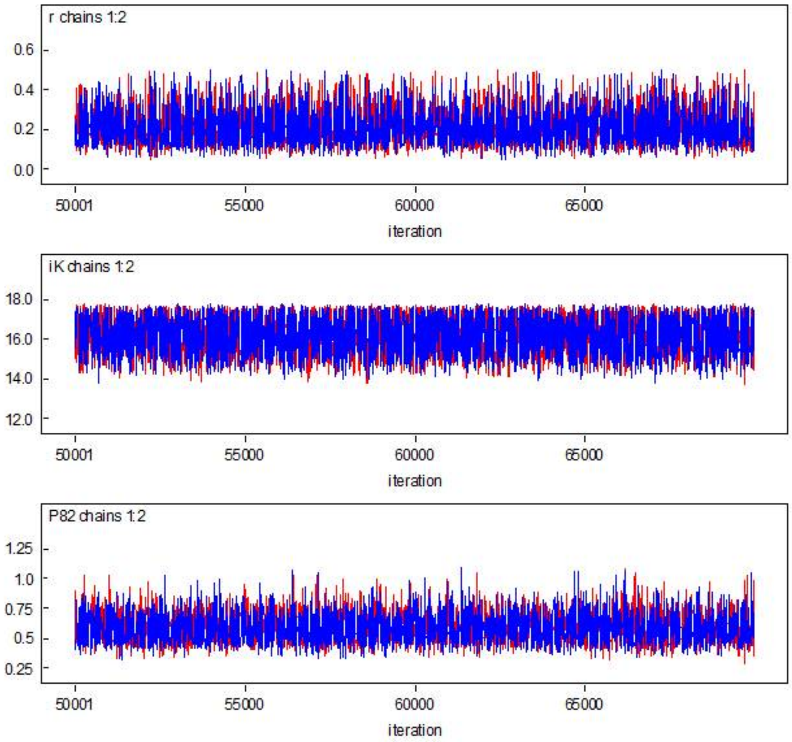
Hierarchical index run showing the time series history of mixing



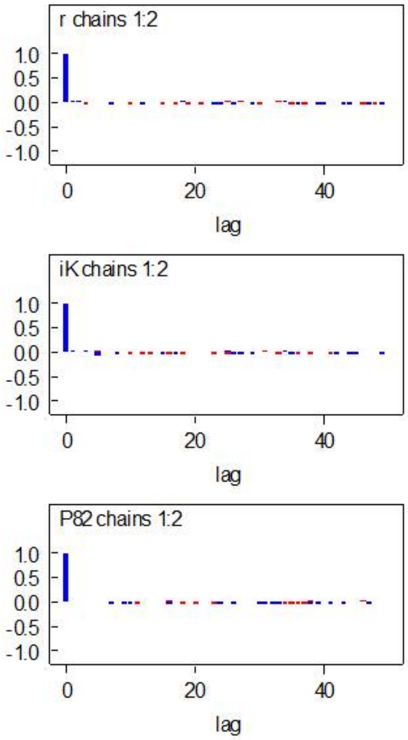
Hierarchical index run showing the autocorrelation



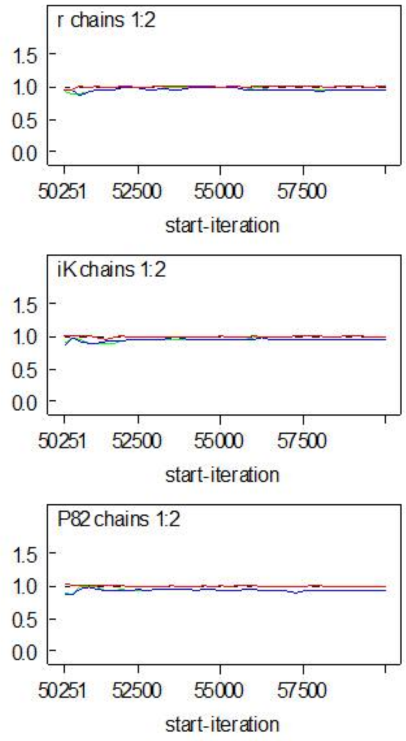
Hierarchical index run showing the Gelman-Rubin statistic



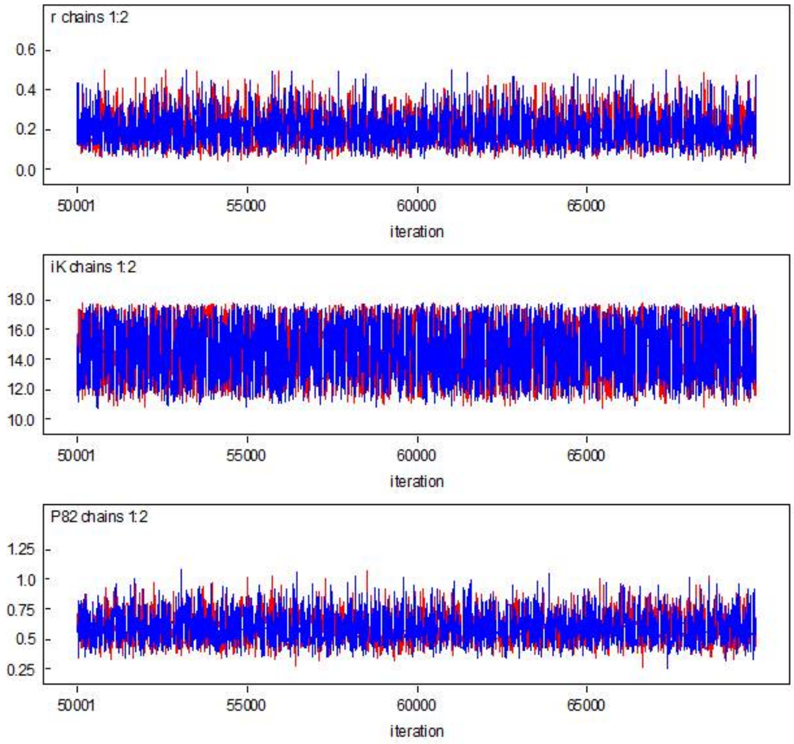
Inverse CV run showing the time series history of mixing



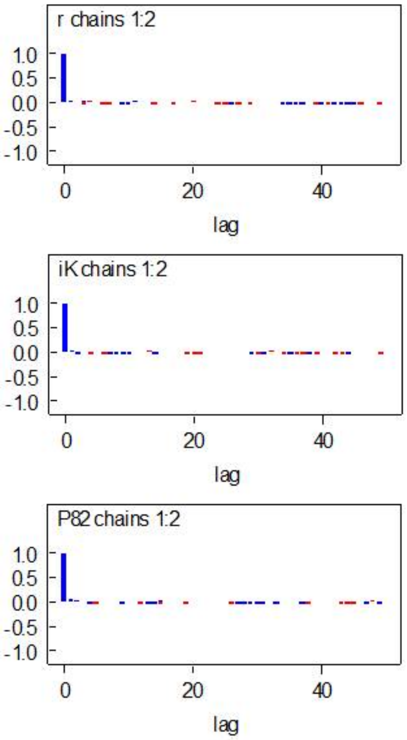
Inverse CV run showing the autocorrelation



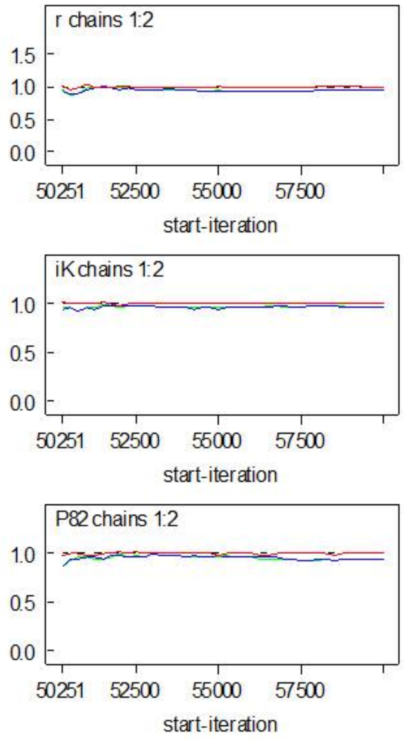
Inverse CV run showing the Gelman-Rubin statistic



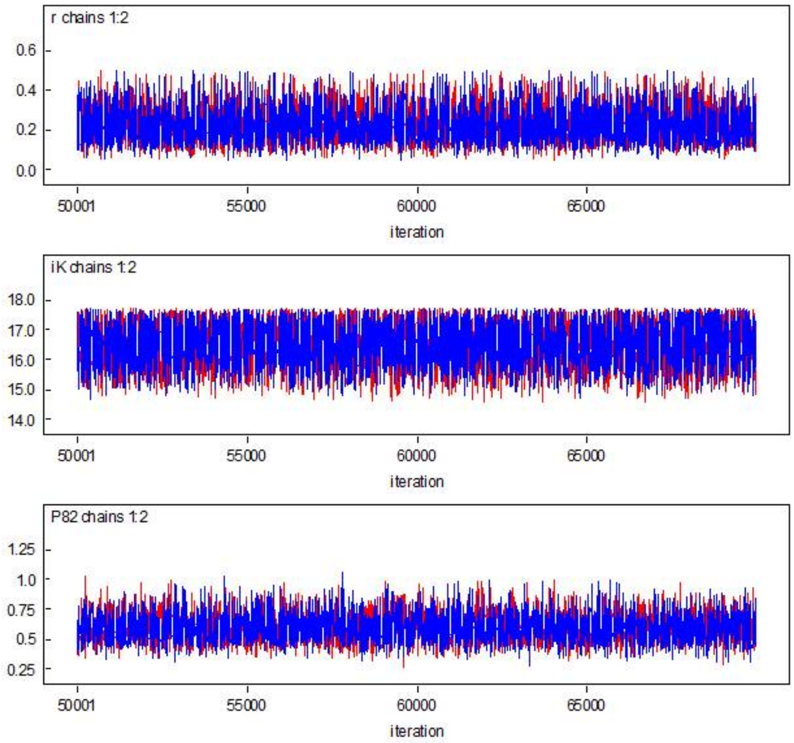
Low catch run showing the time series history of mixing



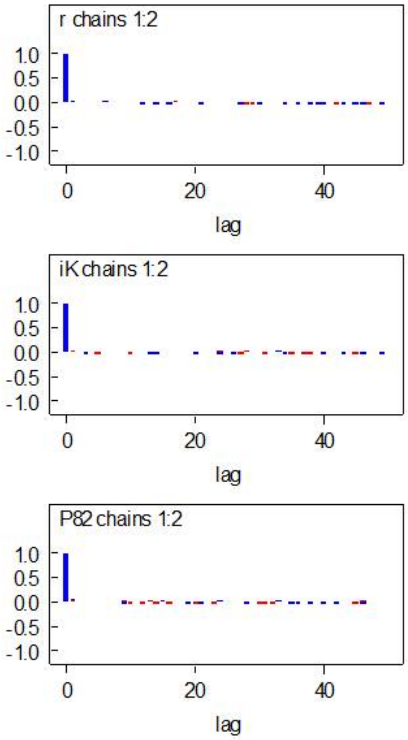
Low catch run showing the autocorrelation



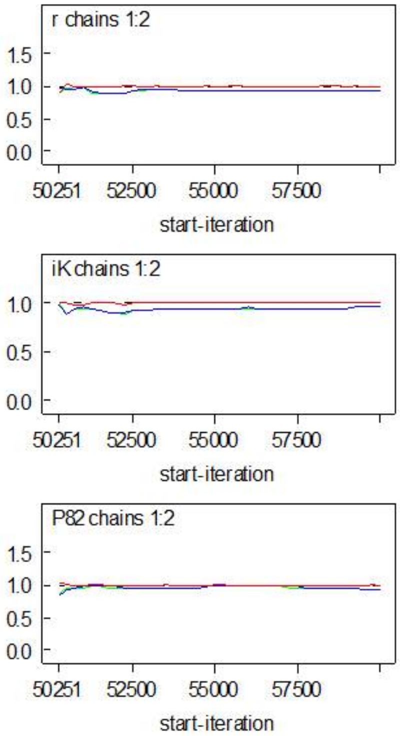
Low catch run showing the Gelman-Rubin statistic



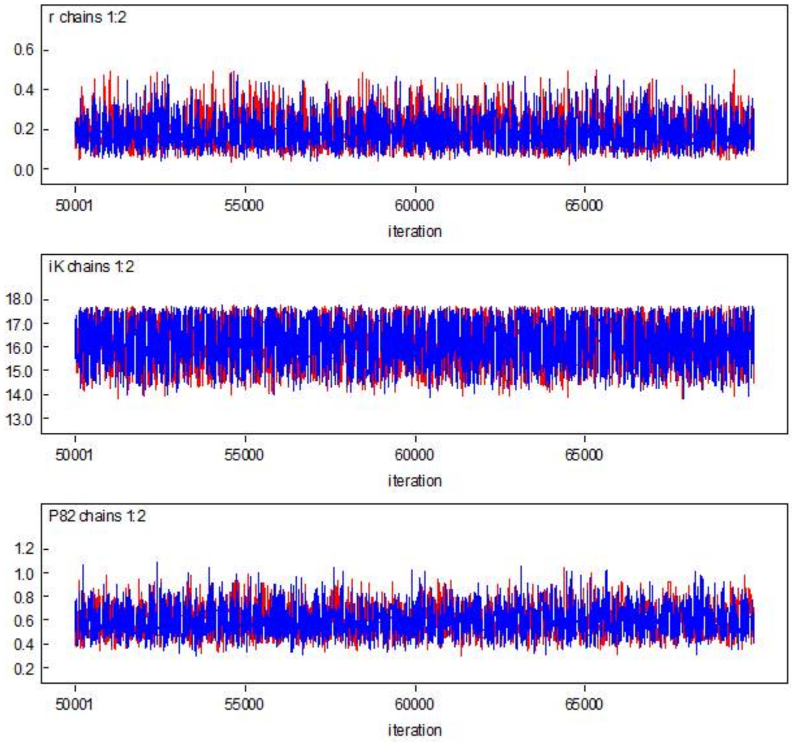
High catch run showing the time series history of mixing



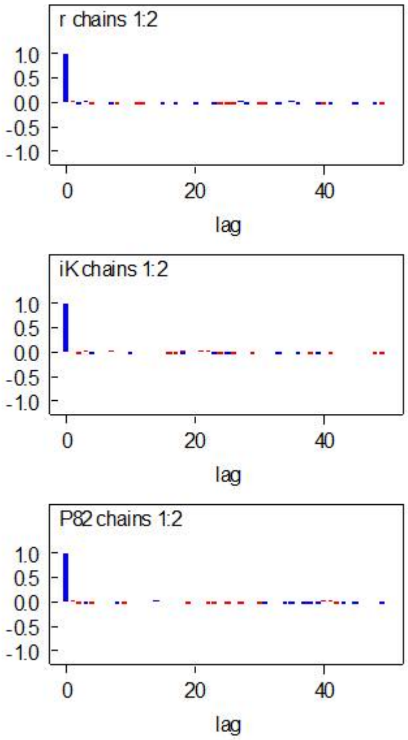
High catch run showing the autocorrelation



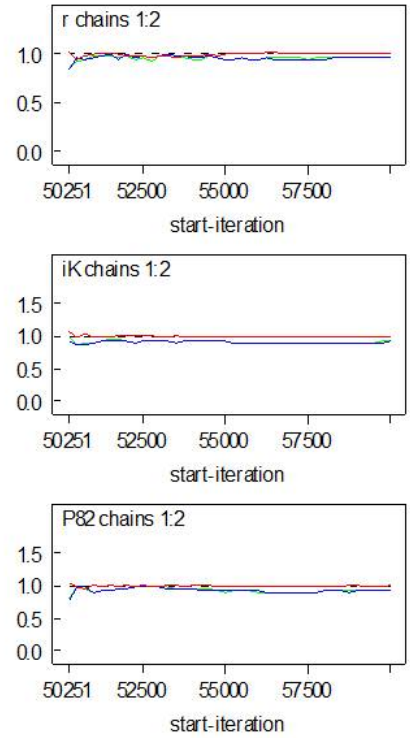
High catch run showing the Gelman-Rubin statistic



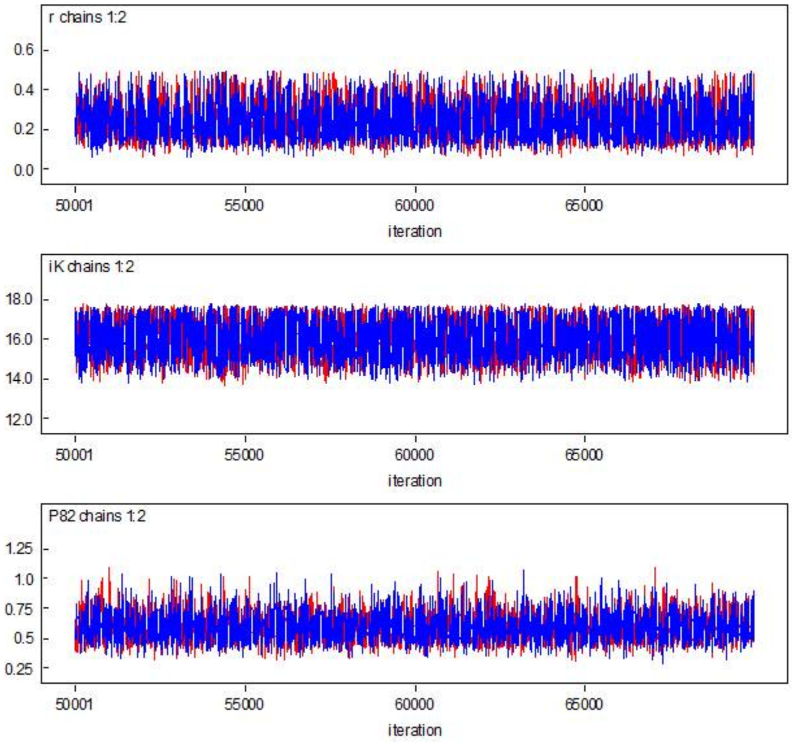
Low r run showing the time series history of mixing



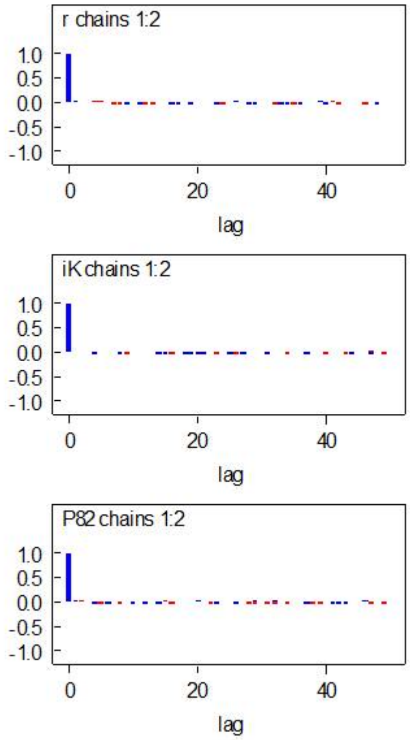
Low r run showing the autocorrelation



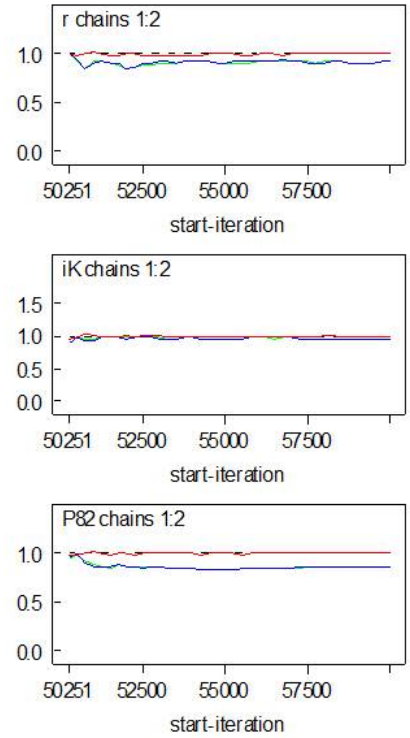
Low r run showing the Gelman-Rubin statistic



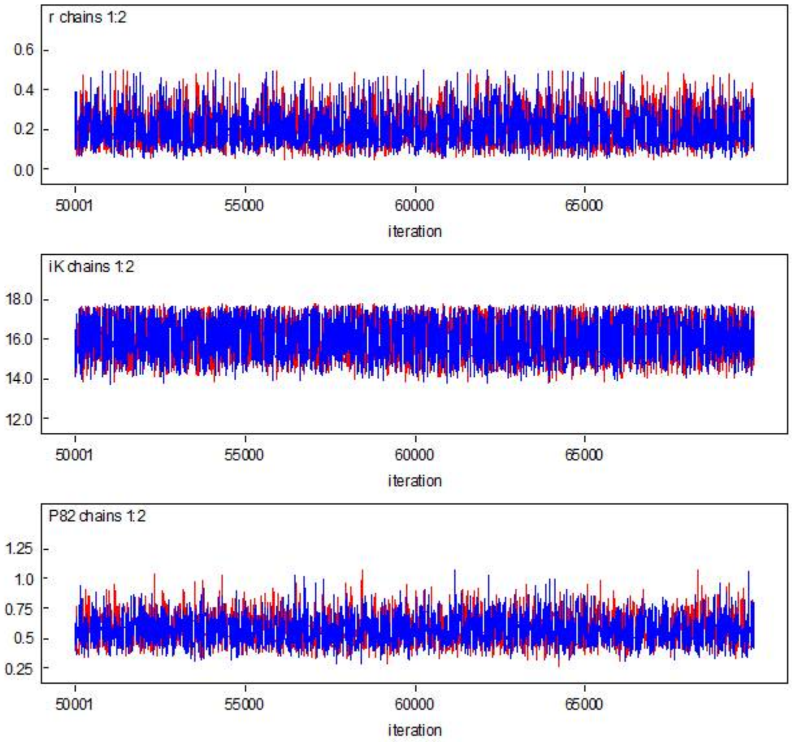
High r run showing the time series history of mixing



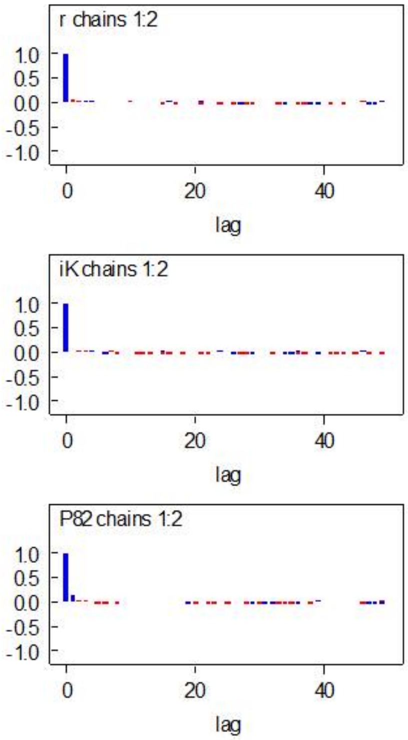
High r run showing the autocorrelation



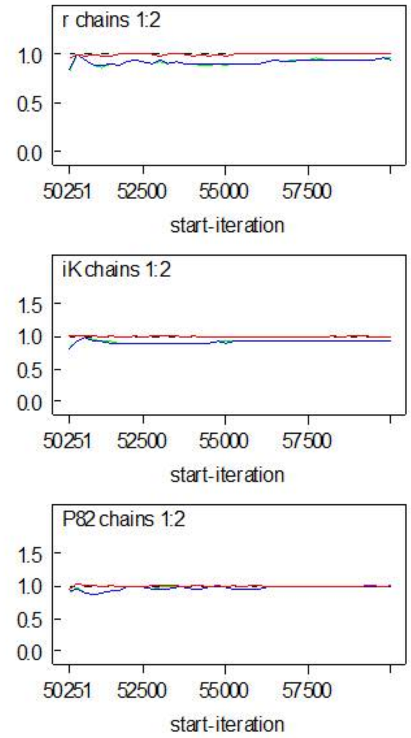
High r run showing the Gelman-Rubin statistic



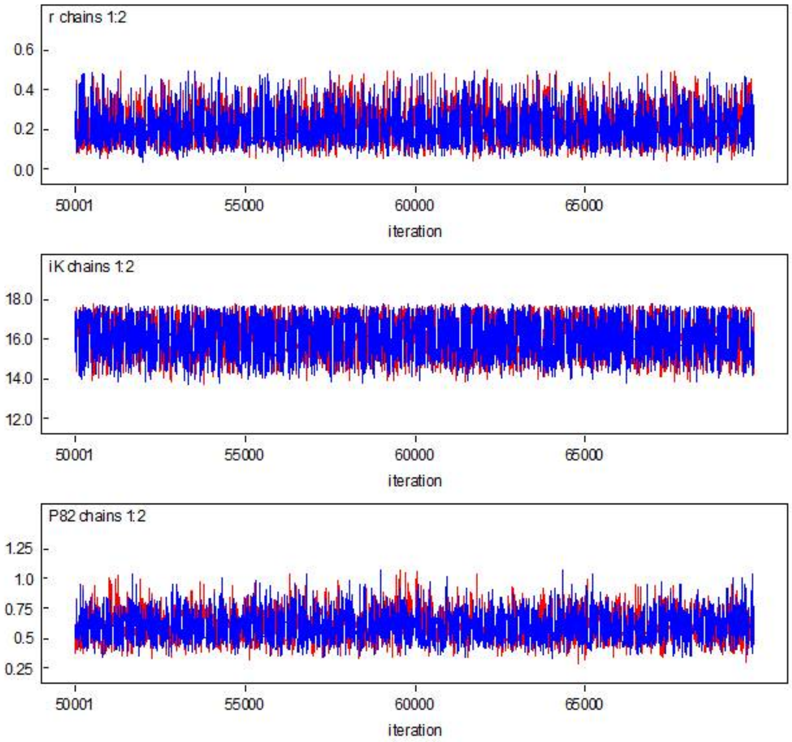
Large process error run showing the time series history of mixing



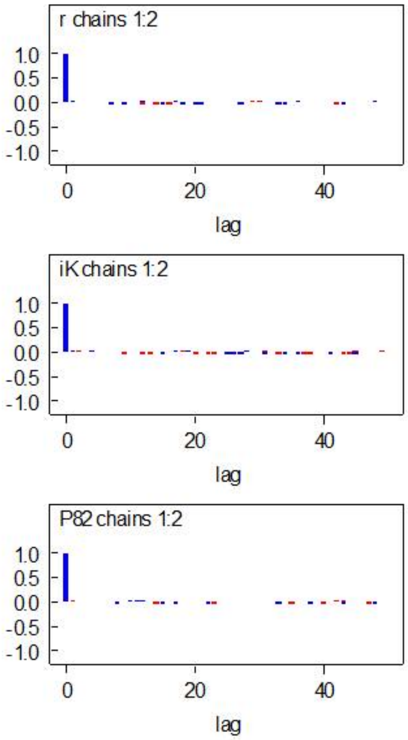
Large process error run showing the autocorrelation



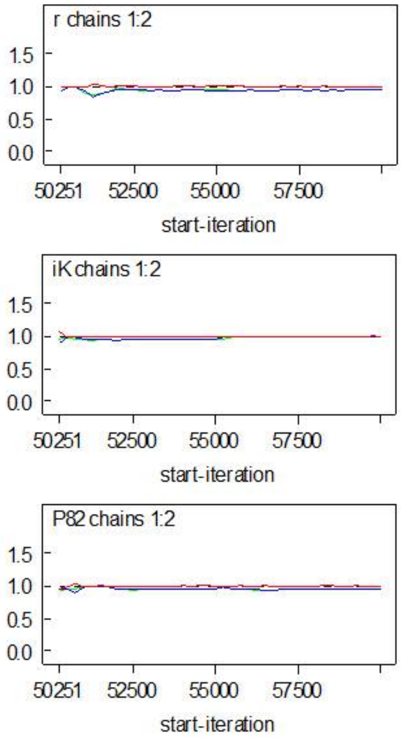
Large process error run showing the Gelman-Rubin statistic



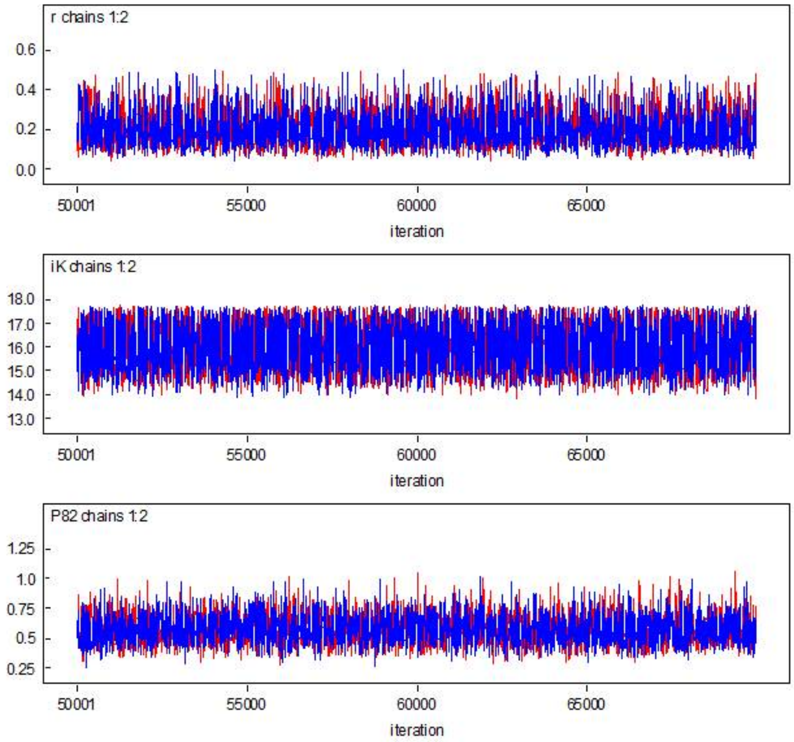
Large observation error run showing the time series history of mixing



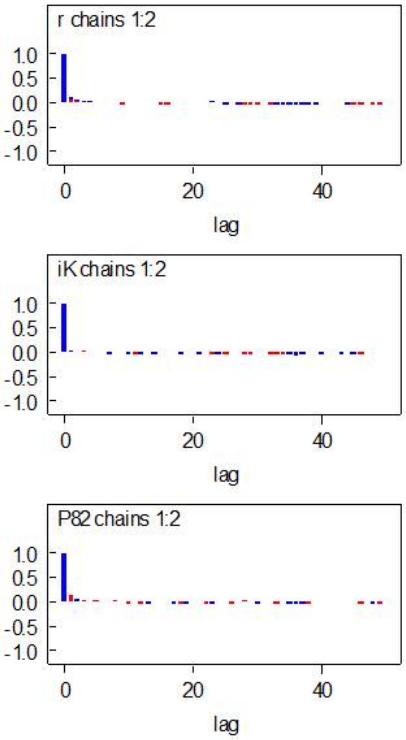
Large observation error run showing the autocorrelation



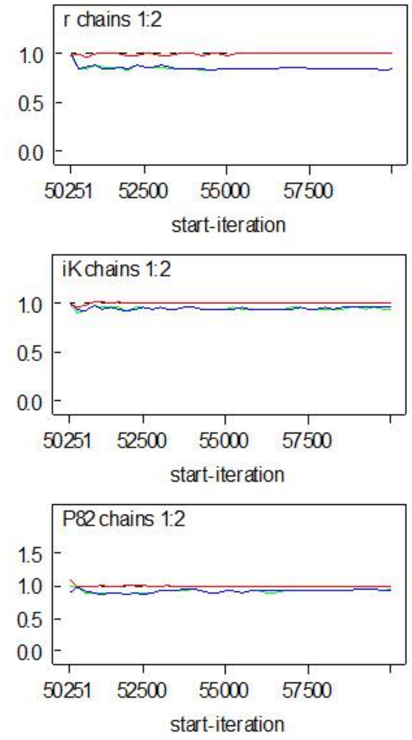
Large observation error run showing the Gelman-Rubin statistic



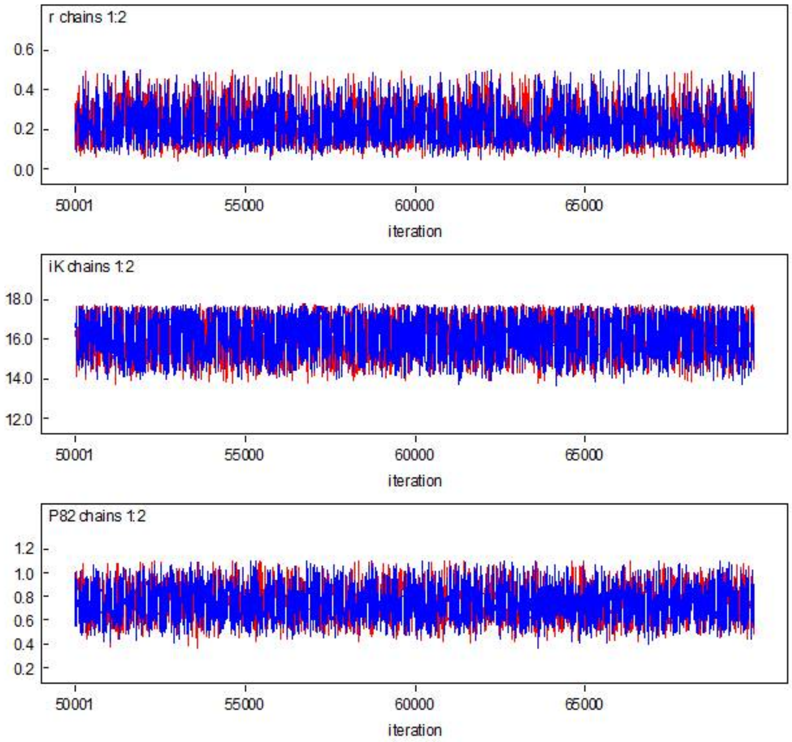
Large process and observation error run showing the time series history of mixing



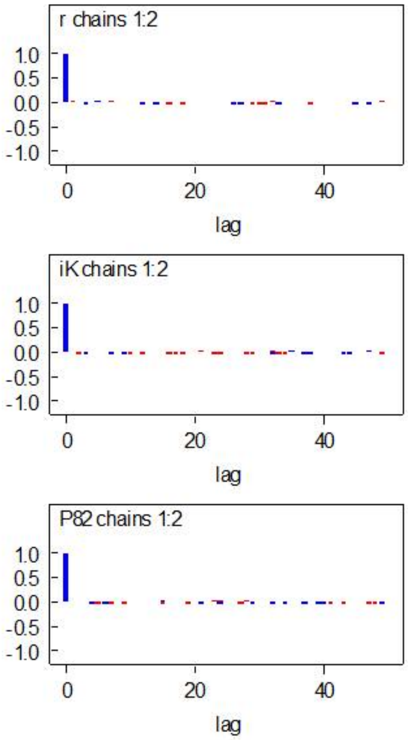
Large process and observation error run showing the autocorrelation



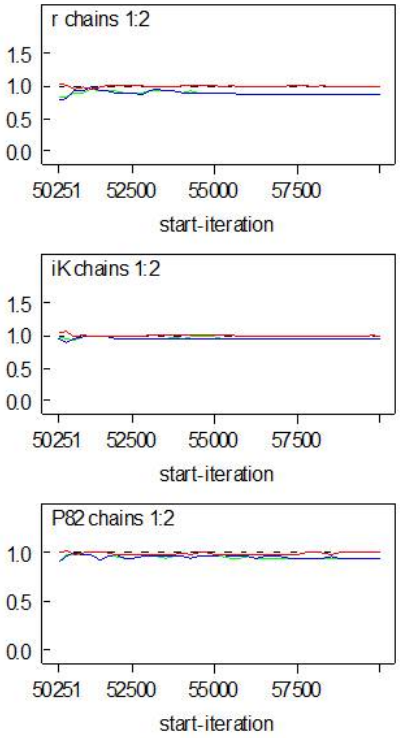
Large process and observation error run showing the Gelman-Rubin statistic



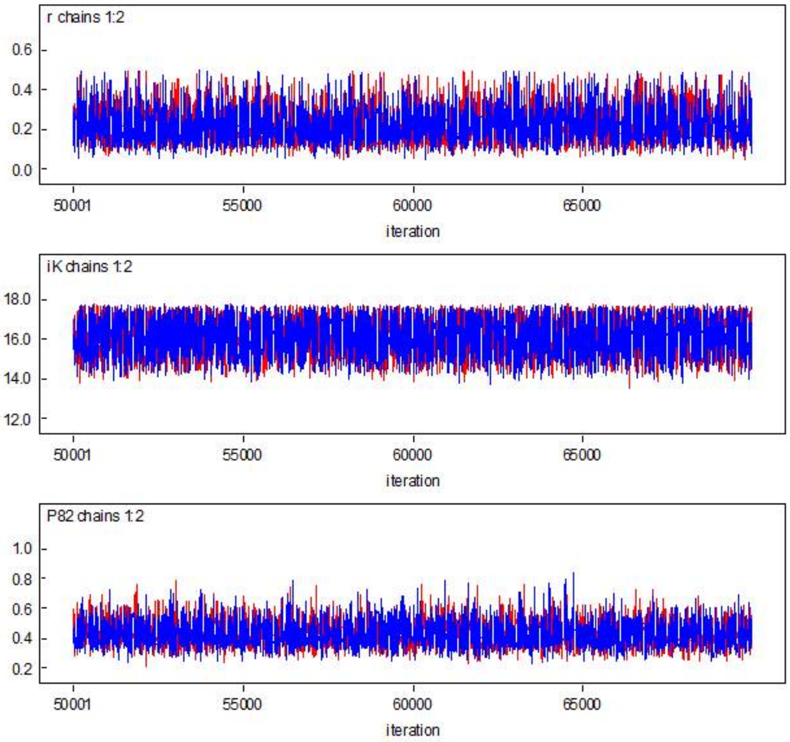
High P_{82} run showing the time series history of mixing



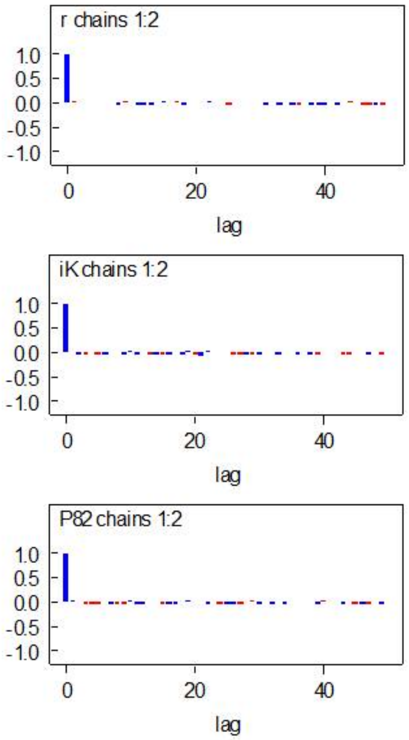
High P_{82} run showing the autocorrelation



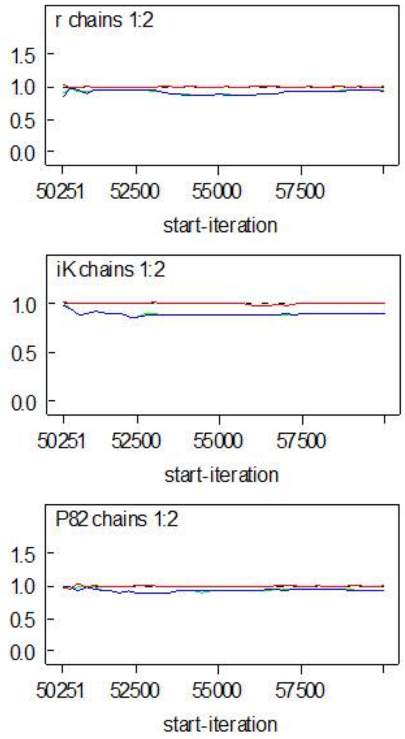
High P_{82} run showing the Gelman-Rubin statistic



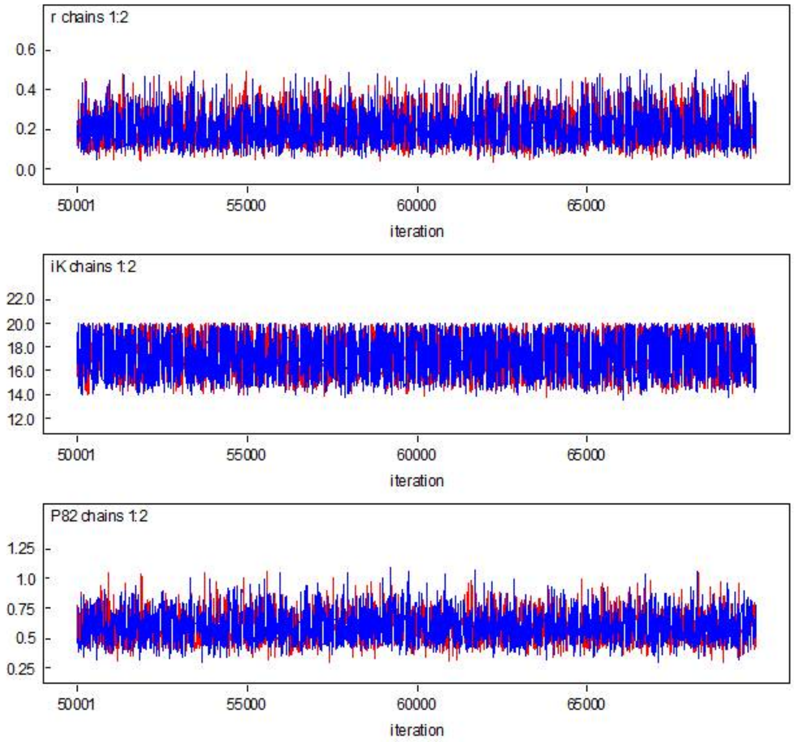
Low P_{82} run showing the time series history of mixing



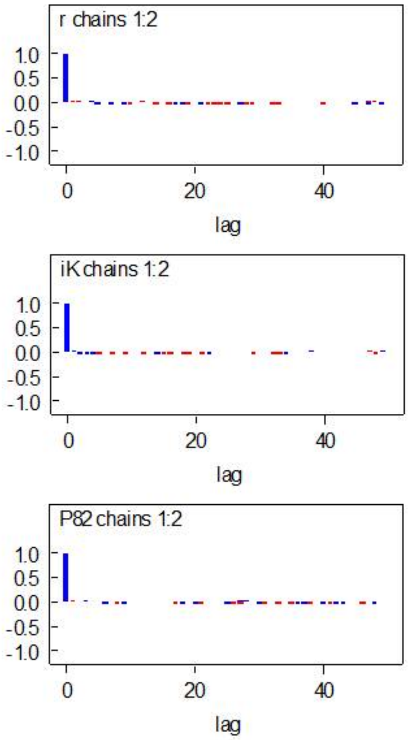
Low P_{82} run showing the autocorrelation



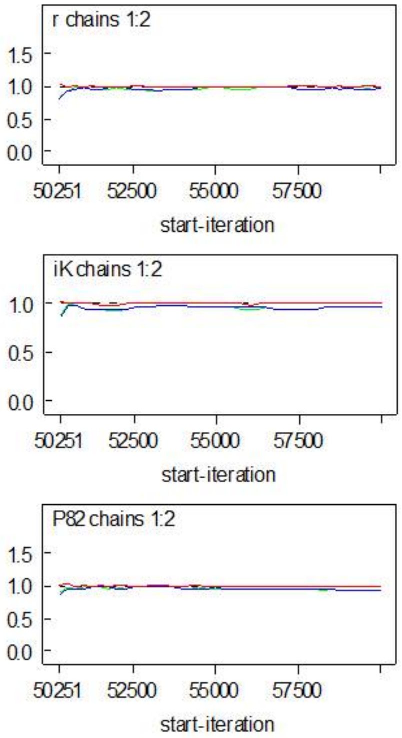
Low P_{82} run showing the Gelman-Rubin statistic



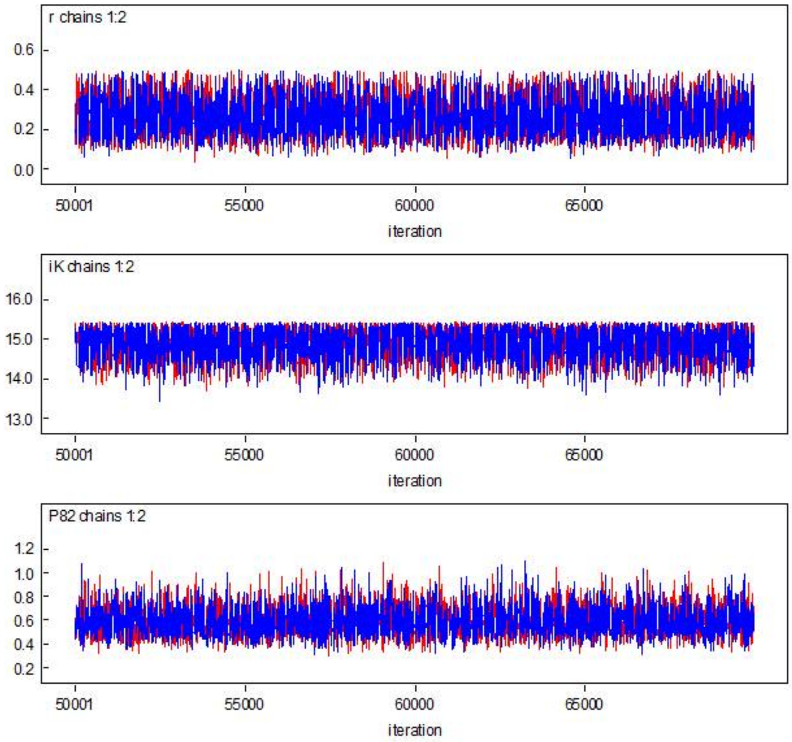
High K run showing the time series history of mixing



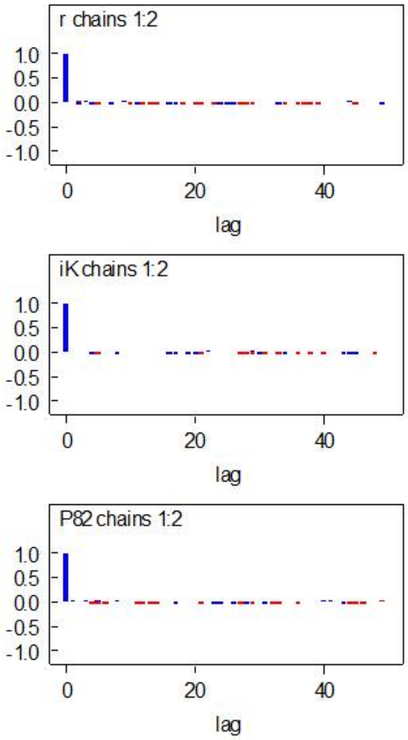
High K run showing the autocorrelation



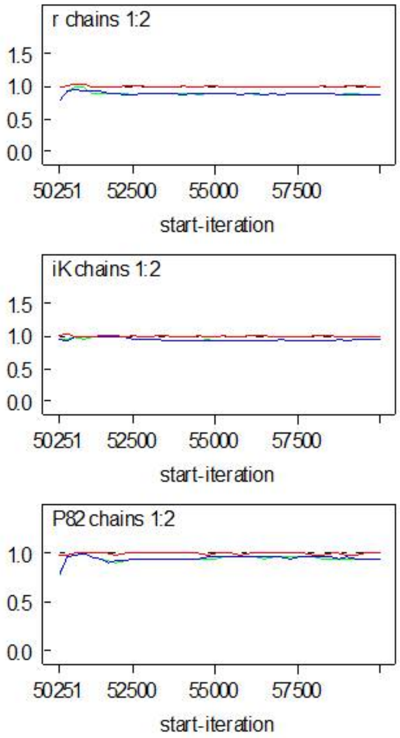
High K run showing the Gelman-Rubin statistic



Low K run showing the time series history of mixing

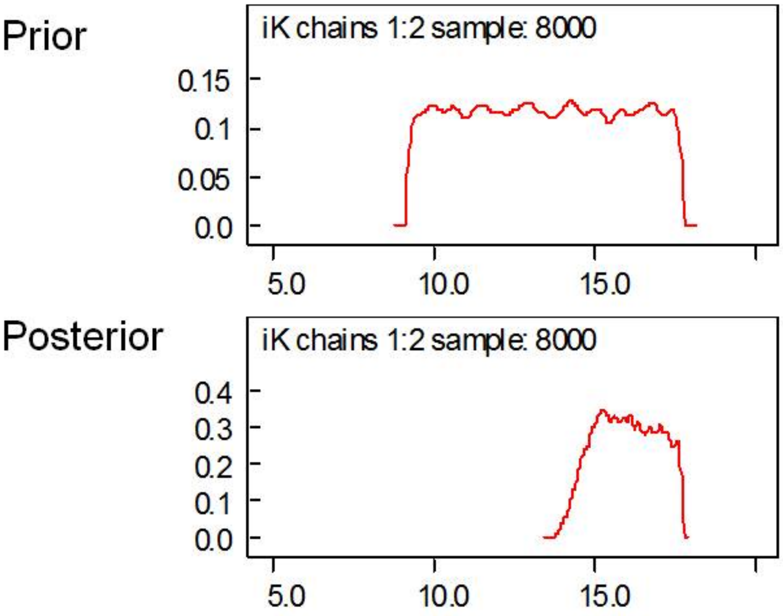


Low K run showing the autocorrelation



Low K run showing the Gelman-Rubin statistic

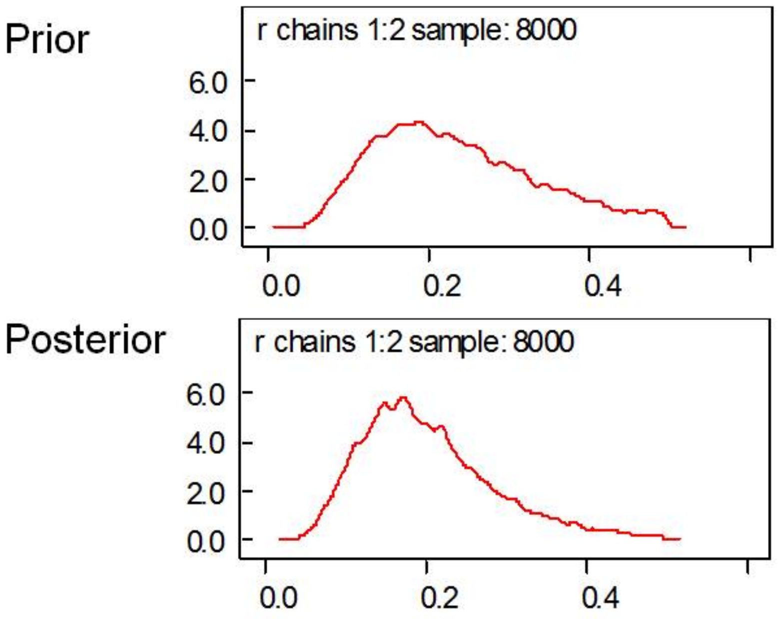
Appendix 3.8.8: Prior and/or posterior distribution for each of the 13 sensitivity runs.



```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
iK	13.47	2.462	0.02572	9.406	13.45	17.53	50001	8000
Posterior								
iK	16.0	0.9605	0.01064	14.3	15.99	17.63	50001	8000

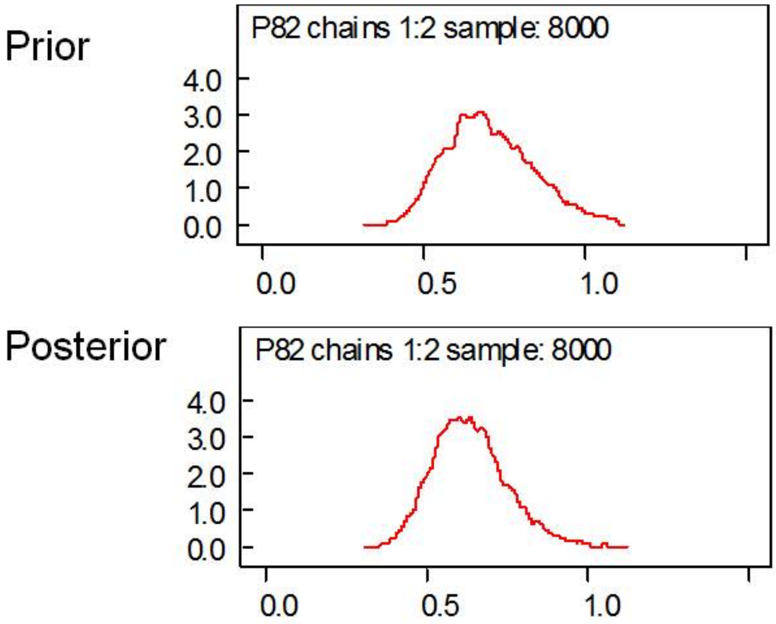
Hierarchical index run showing the carrying capacity (*K=exp(iK)*)




r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
r	0.236	0.09876	0.001084	0.08492	0.2215	0.4596	50001	8000
Posterior								
r	0.2037	0.08232	9.991E-4	0.08022	0.1897	0.4058	50001	8000

Hierarchical index run showing the intrinsic rate of increase (*r*)

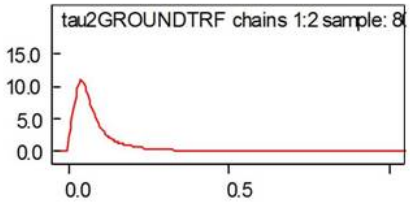


P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

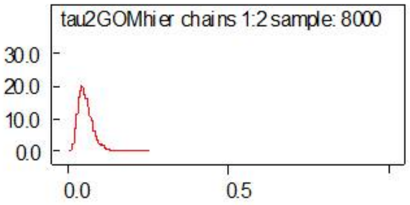
node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.6382	0.1163	0.001573	0.4392	0.6292	0.8995	50001	8000

Hierarchical index run showing the initial depletion (P_{82})

Prior



Posterior

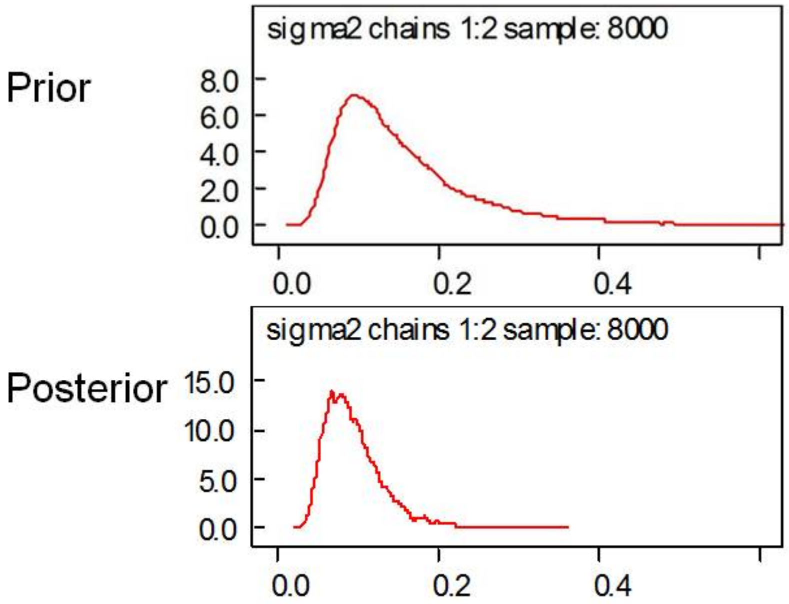


```
itau2GROUNDTRF<-dgamma(2.0, 0.1)
tau2GROUNDTRF=1/itau2GROUNDTRF
```

The hierarchical index prior (top panel) was the same as the four indices, but posterior (lower panel) differed.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GOMhier	0.05547	0.02388	3.169E-4	0.02092	0.05145	0.1134	50001	8000

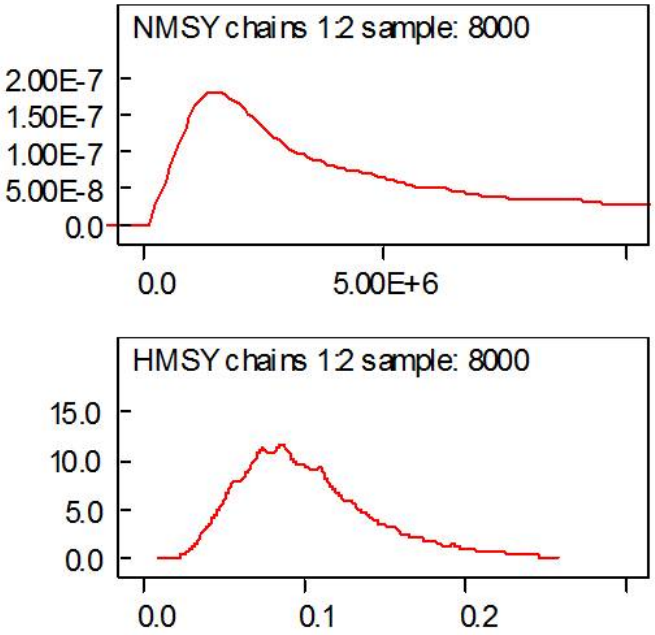
Hierarchical index run showing the observation error variance (τ^2)

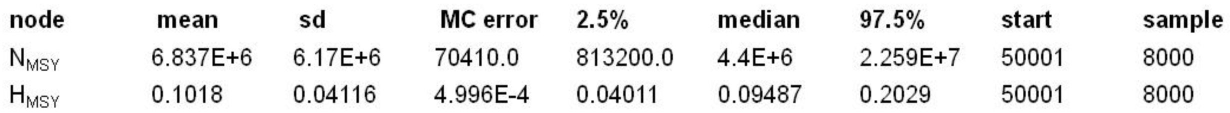


```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.09477	0.03464	5.094E-4	0.04607	0.08856	0.1808	50001	8000

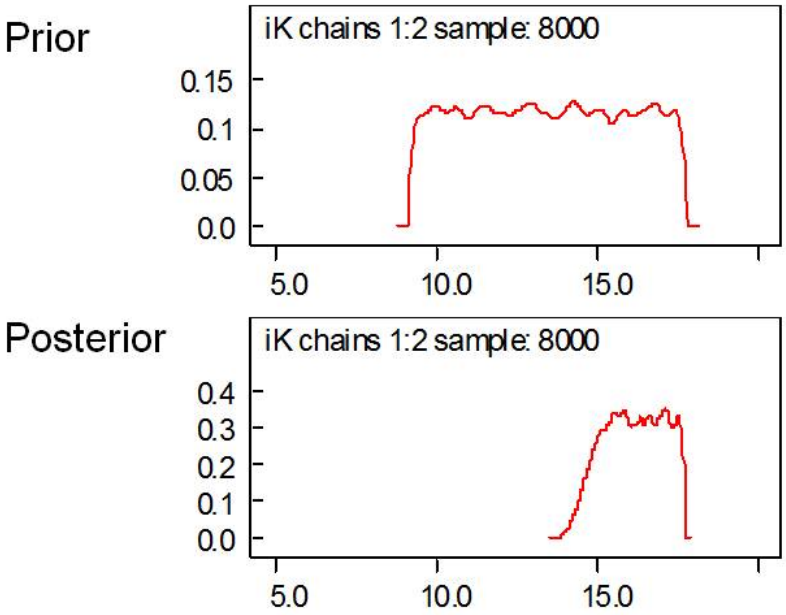
Hierarchical index run showing the process error variance (σ^2)





node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	6.837E+6	6.17E+6	70410.0	813200.0	4.4E+6	2.259E+7	50001	8000
H_{MSY}	0.1018	0.04116	4.996E-4	0.04011	0.09487	0.2029	50001	8000

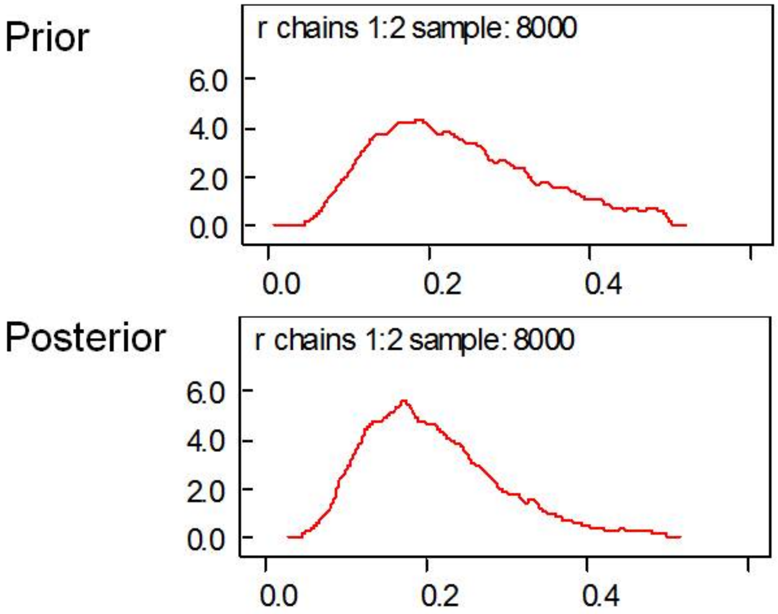
Hierarchical index run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})



```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

```
node       mean     sd       MC error   2.5%     median   97.5%    start    sample
Prior
iK         13.47    2.462    0.02572    9.406    13.45    17.53    50001    8000
Posterior
iK         16.15    0.9296   0.01111    14.43    16.17    17.64    50001    8000
```

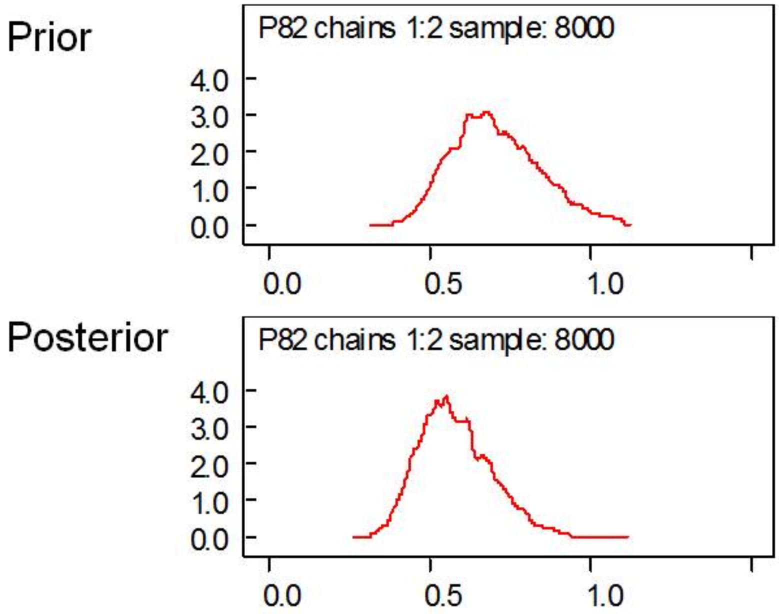
Inverse CV run showing the carrying capacity (*K=exp(iK)*)



r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
r	0.236	0.09876	0.001084	0.08492	0.2215	0.4596	50001	8000
Posterior								
r	0.2097	0.08278	9.49E-4	0.08581	0.1963	0.4078	50001	8000

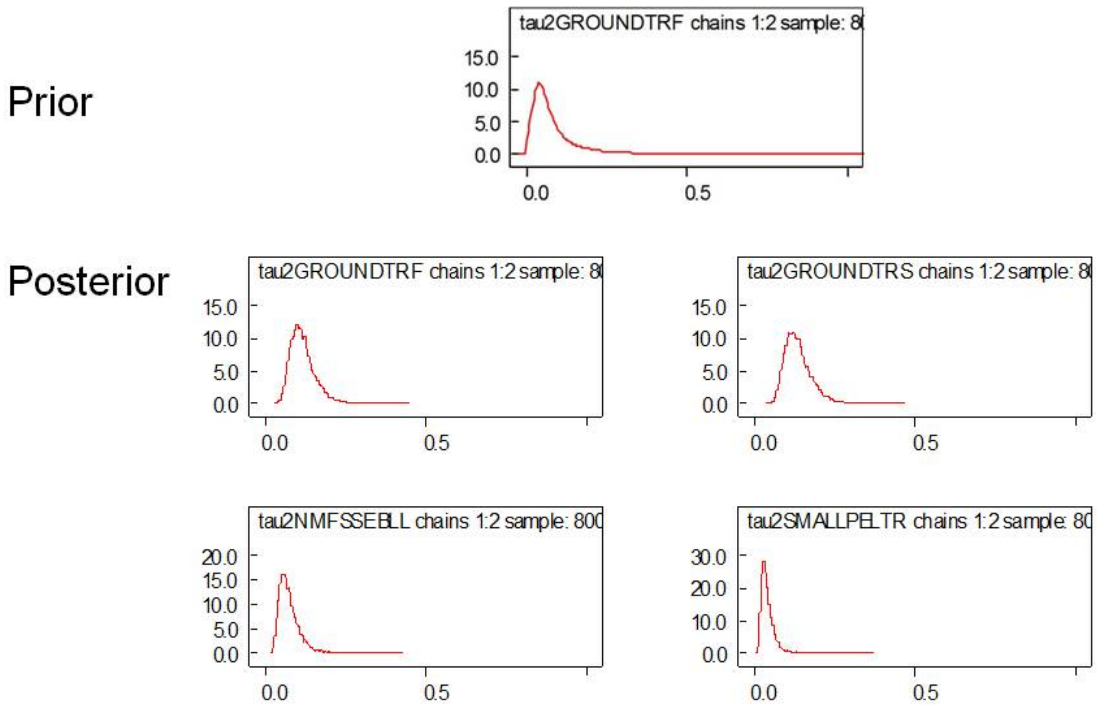
Inverse CV run showing the intrinsic rate of increase (*r*)



P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.5839	0.115	0.001298	0.3942	0.5709	0.8376	50001	8000

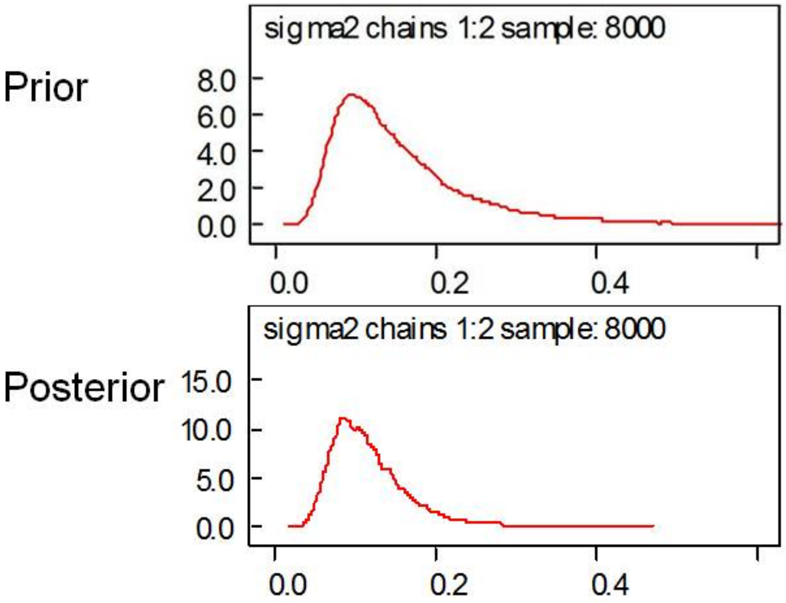
Inverse CV run showing the initial depletion (P_{82})



itau2GROUNDTRF<-dgamma(2.0, 0.1)
tau2GROUNDTRF=1/itau2GROUNDTRF
The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.1167	0.04022	4.919E-4	0.05864	0.1098	0.2158	50001	8000
tau2GROUNDTRS	0.1366	0.04292	5.042E-4	0.07363	0.1297	0.2405	50001	8000
tau2NMFSSEBLL	0.07405	0.03338	3.669E-4	0.03077	0.06668	0.1614	50001	8000
tau2SMALLPELTR	0.04084	0.02198	2.879E-4	0.01561	0.03589	0.0957	50001	8000

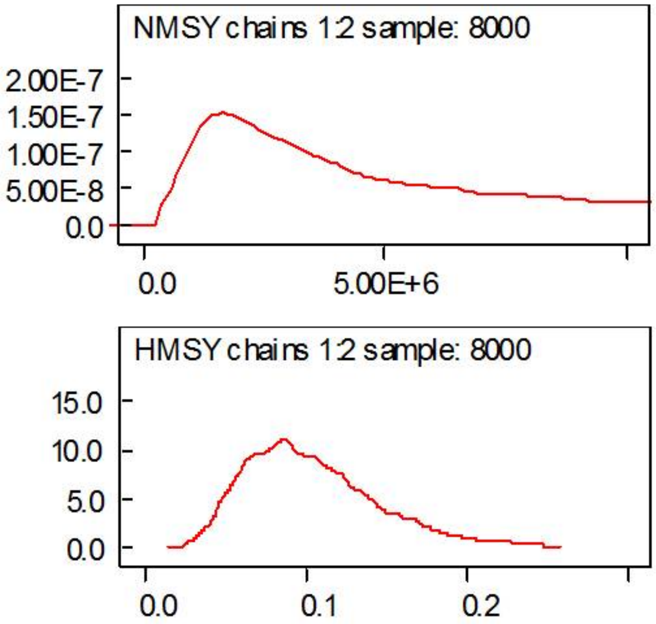
Inverse CV run showing the observation error variance (τ^2)

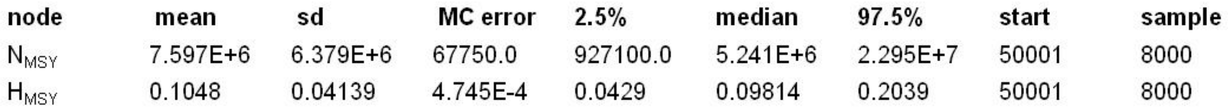


```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.1185	0.04716	7.688E-4	0.05532	0.1091	0.2384	50001	8000

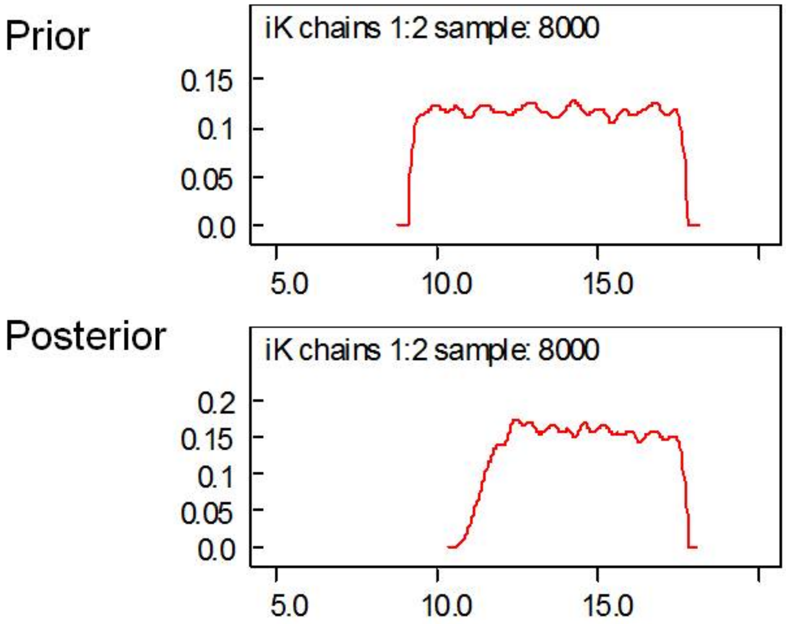
Inverse CV run showing the process error variance (σ^2)





node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	7.597E+6	6.379E+6	67750.0	927100.0	5.241E+6	2.295E+7	50001	8000
H_{MSY}	0.1048	0.04139	4.745E-4	0.0429	0.09814	0.2039	50001	8000

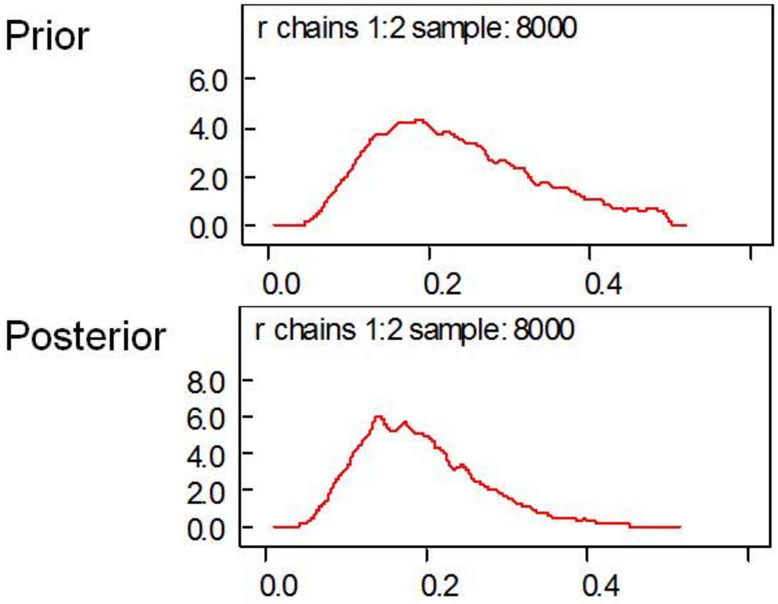
Inverse CV run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})



```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

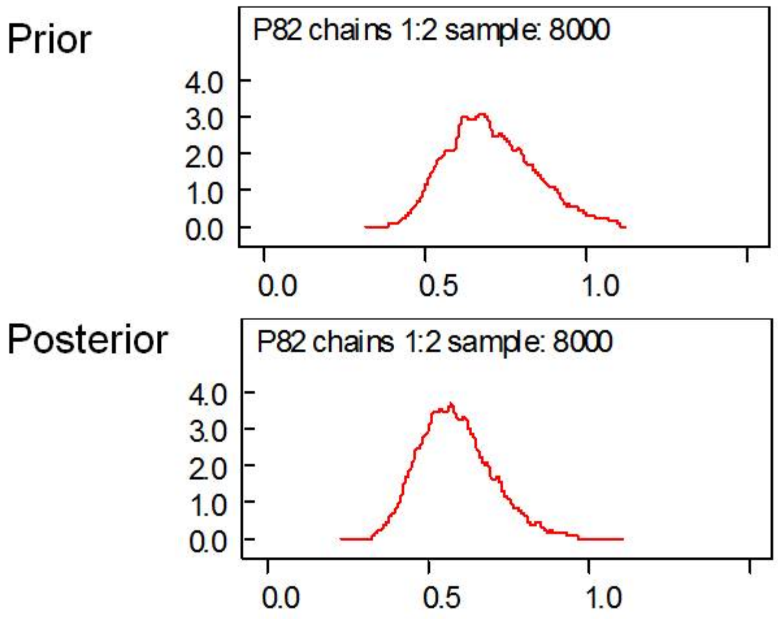
node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
iK	13.47	2.462	0.02572	9.406	13.45	17.53	50001	8000
Posterior								
iK	14.52	1.829	0.02374	11.43	14.52	17.56	50001	8000

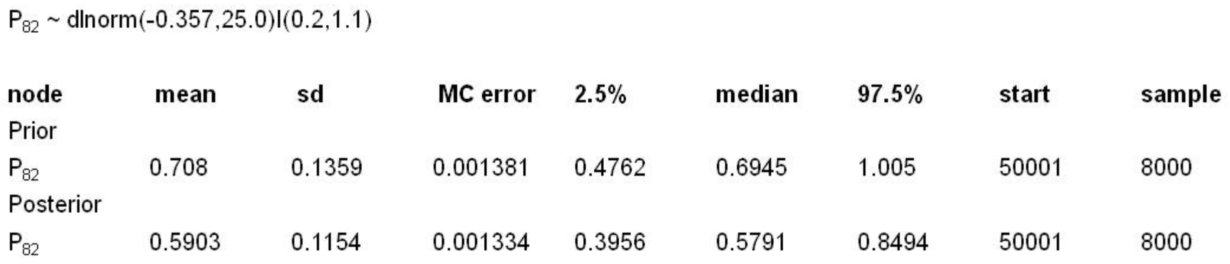
Low catch run showing the carrying capacity (*K=exp(iK)*)



```
r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node       mean     sd        MC error   2.5%      median   97.5%    start   sample
Prior
r          0.236    0.09876   0.001084   0.08492   0.2215   0.4596   50001   8000
Posterior
r          0.1951   0.07693   9.937E-4   0.07952   0.1831   0.3803   50001   8000
```

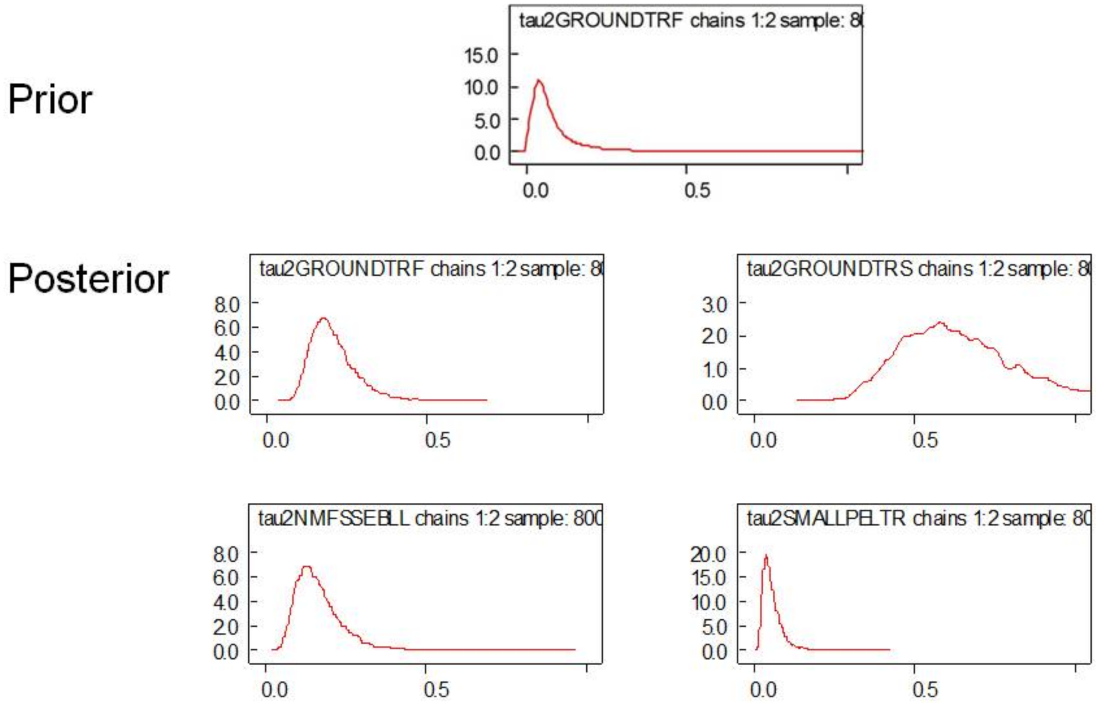
Low catch run showing the intrinsic rate of increase (*r*)




P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.5903	0.1154	0.001334	0.3956	0.5791	0.8494	50001	8000

Low catch run showing the initial depletion (P_{82})



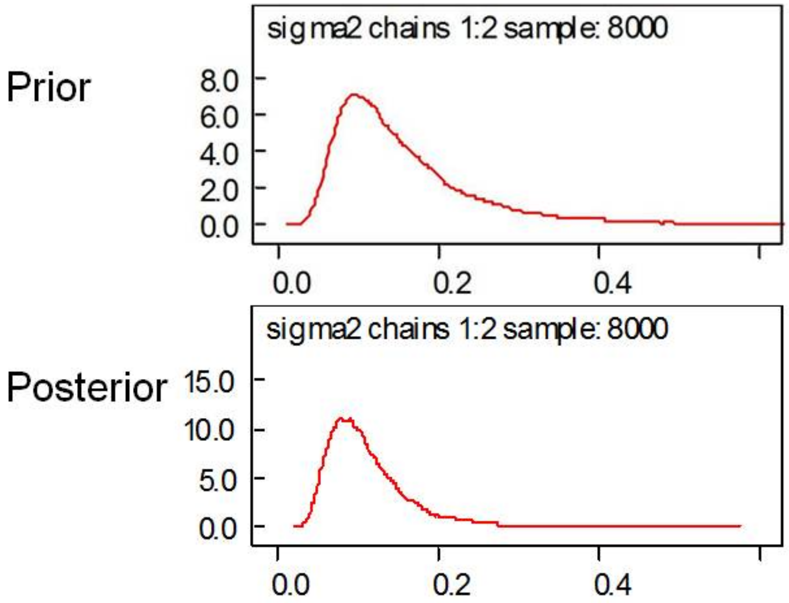
itau2GROUNDTRF<-dgamma(2.0, 0.1)

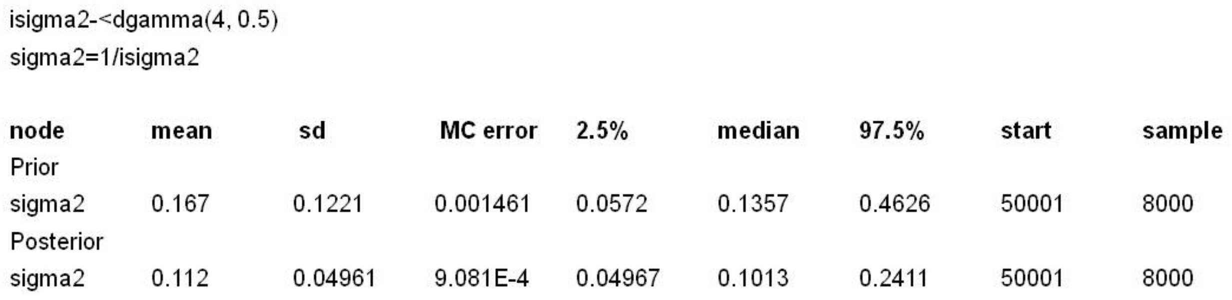
tau2GROUNDTRF=1/itau2GROUNDTRF

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.2085	0.07256	7.631E-4	0.1057	0.1953	0.3869	50001	8000
tau2GROUNDTRS	0.646	0.1927	0.002309	0.3468	0.6191	1.099	50001	8000
tau2NMFSSEBLL	0.1696	0.07961	9.115E-4	0.06839	0.1533	0.3703	50001	8000
tau2SMALLPELTR	0.05565	0.0321	4.0E-4	0.01859	0.04768	0.1408	50001	8000

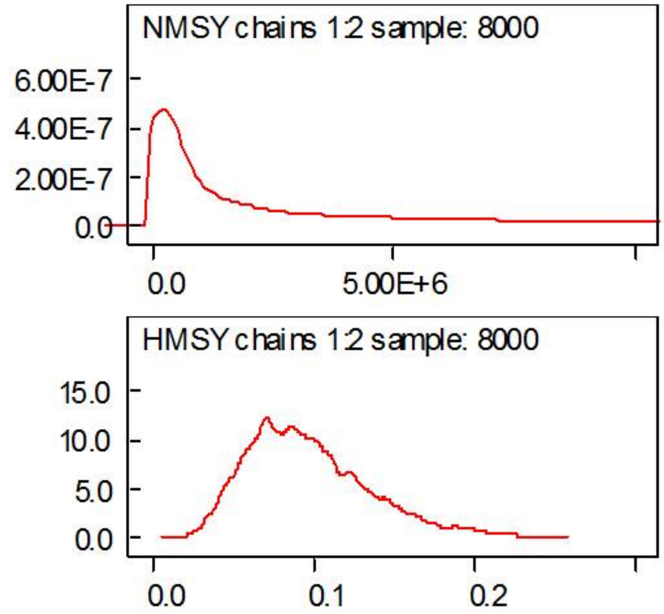
Low catch run showing the observation error variance (τ^2)





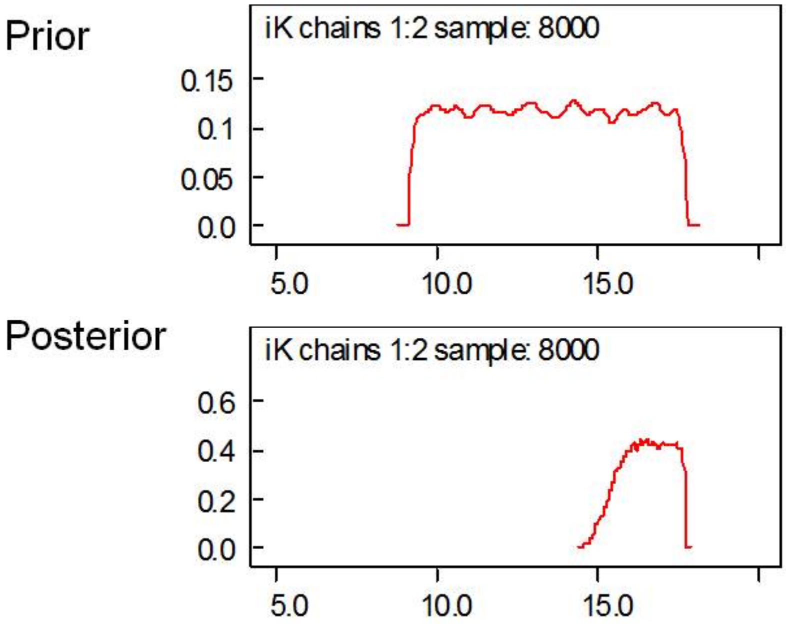
```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2

node      mean     sd        MC error   2.5%      median   97.5%    start   sample
Prior
sigma2    0.167    0.1221    0.001461   0.0572    0.1357   0.4626   50001   8000
Posterior
sigma2    0.112    0.04961   9.081E-4   0.04967   0.1013   0.2411   50001   8000
```

Low catch run showing the process error variance (σ^2)



node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	3.823E+6	5.74E+6	69020.0	45950.0	1.014E+6	2.12E+7	50001	8000
H_{MSY}	0.09753	0.03846	4.969E-4	0.03976	0.09153	0.1901	50001	8000

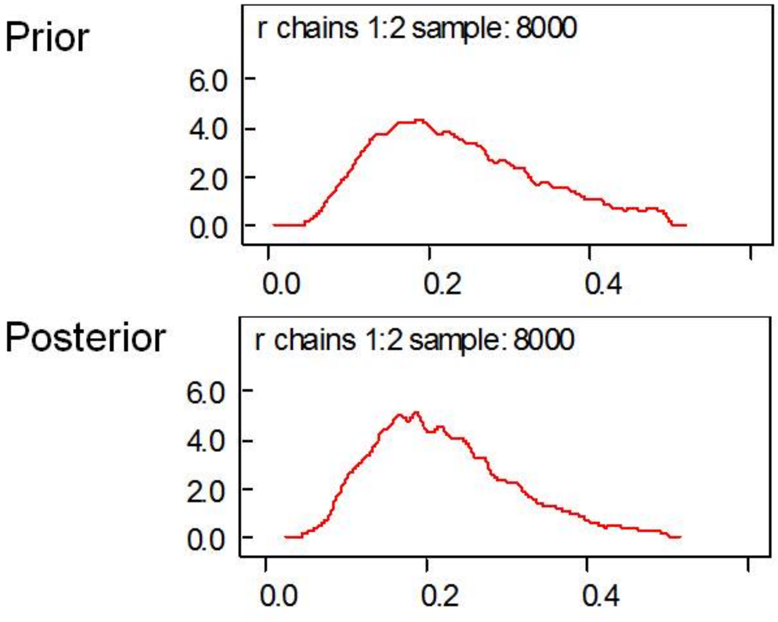
Low catch run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})

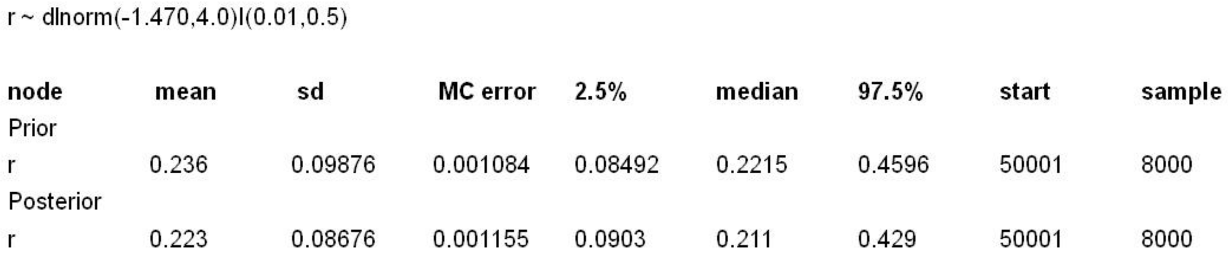


```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

```
node       mean      sd       MC error   2.5%    median   97.5%   start   sample
Prior
iK         13.47     2.462    0.02572    9.406   13.45    17.53   50001   8000
Posterior
iK         16.5      0.7364   0.009174   15.07   16.54    17.67   50001   8000
```

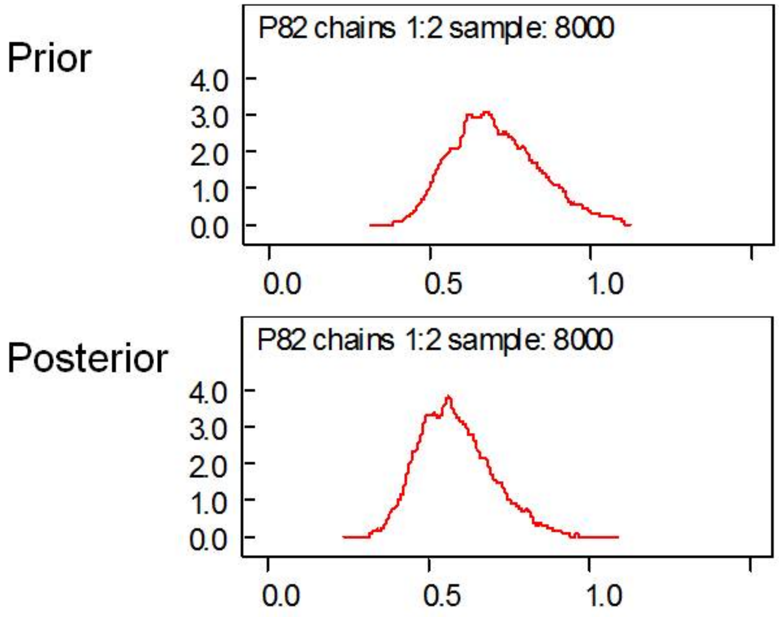
High catch run showing the carrying capacity (*K=exp(iK)*)




r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
r	0.236	0.09876	0.001084	0.08492	0.2215	0.4596	50001	8000
Posterior								
r	0.223	0.08676	0.001155	0.0903	0.211	0.429	50001	8000

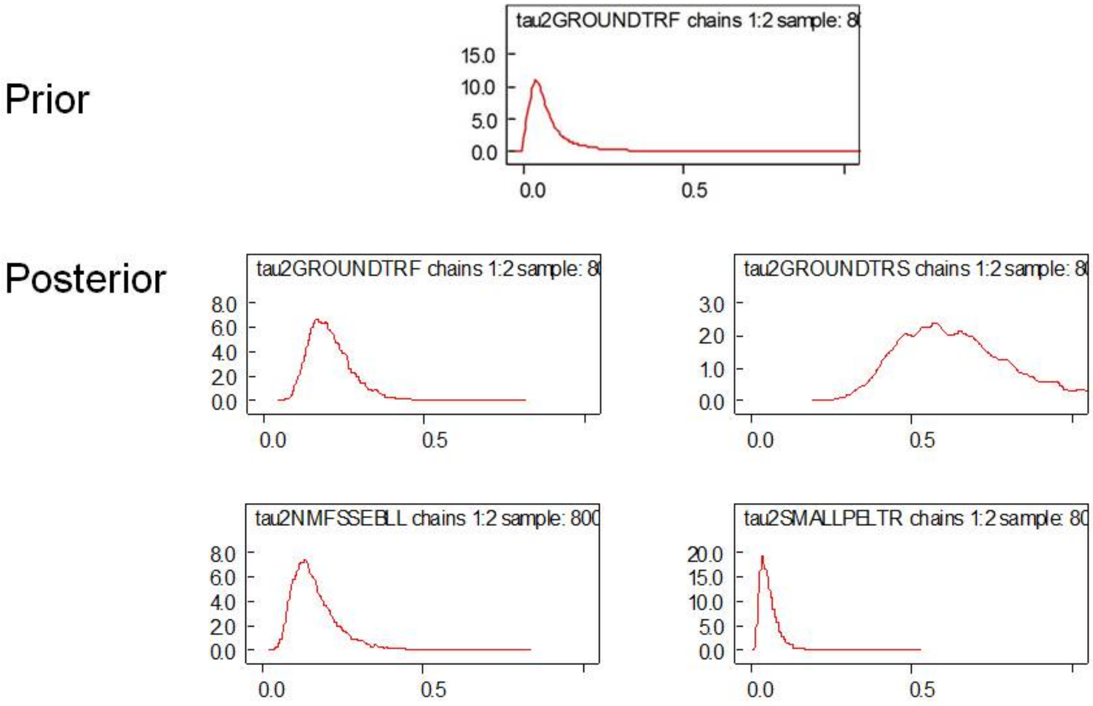
High catch run showing the intrinsic rate of increase (*r*)



P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.588	0.1157	0.001485	0.3917	0.5755	0.8458	50001	8000

High catch run showing the initial depletion (P_{82})

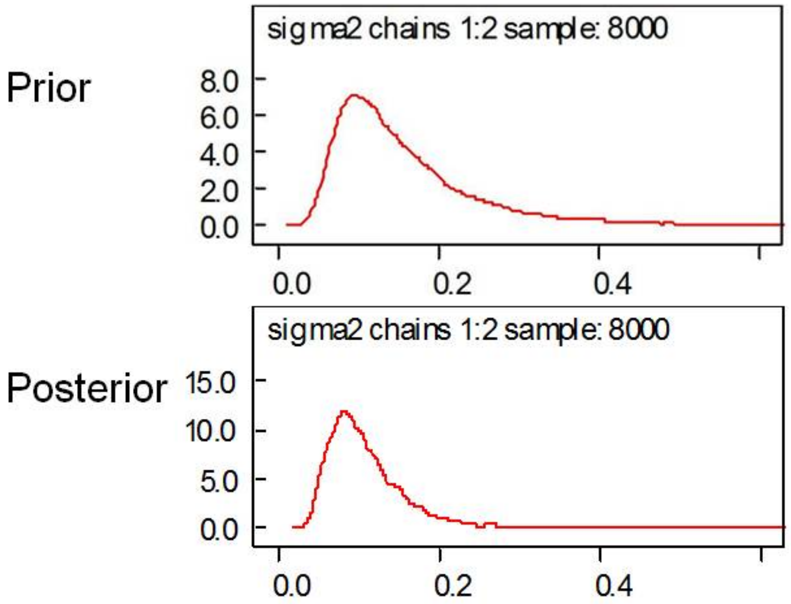


```
itau2GROUNDTRF<-dgamma(2.0, 0.1)
tau2GROUNDTRF=1/itau2GROUNDTRF
```

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.2102	0.07343	8.685E-4	0.1048	0.1974	0.3888	50001	8000
tau2GROUNDTRS	0.6522	0.1976	0.002708	0.3572	0.6231	1.124	50001	8000
tau2NMFSSEBLL	0.1659	0.07679	7.2E-4	0.06846	0.1487	0.3659	50001	8000
tau2SMALLPELTR	0.05595	0.03283	4.304E-4	0.01898	0.0484	0.1412	50001	8000

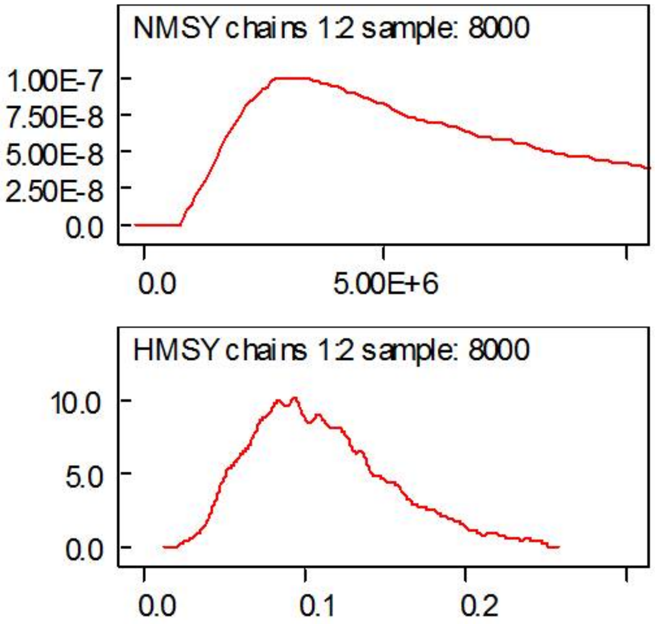
High catch run showing the observation error variance (τ^2)

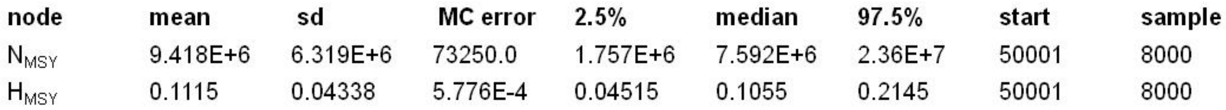


```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.1079	0.04611	7.978E-4	0.04864	0.09805	0.2225	50001	8000

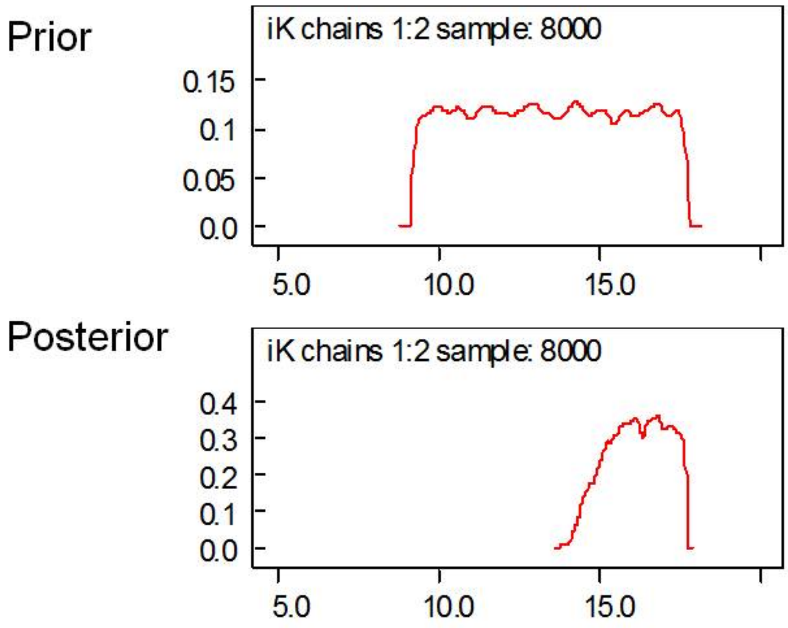
High catch run showing the process error variance (σ^2)

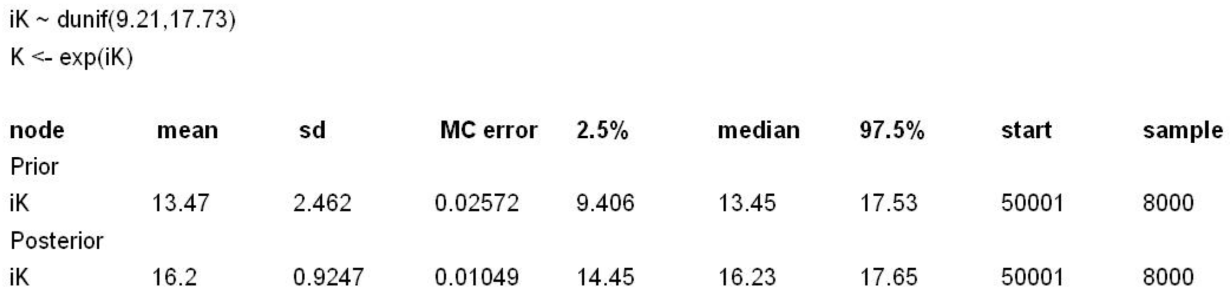




node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	9.418E+6	6.319E+6	73250.0	1.757E+6	7.592E+6	2.36E+7	50001	8000
H_{MSY}	0.1115	0.04338	5.776E-4	0.04515	0.1055	0.2145	50001	8000

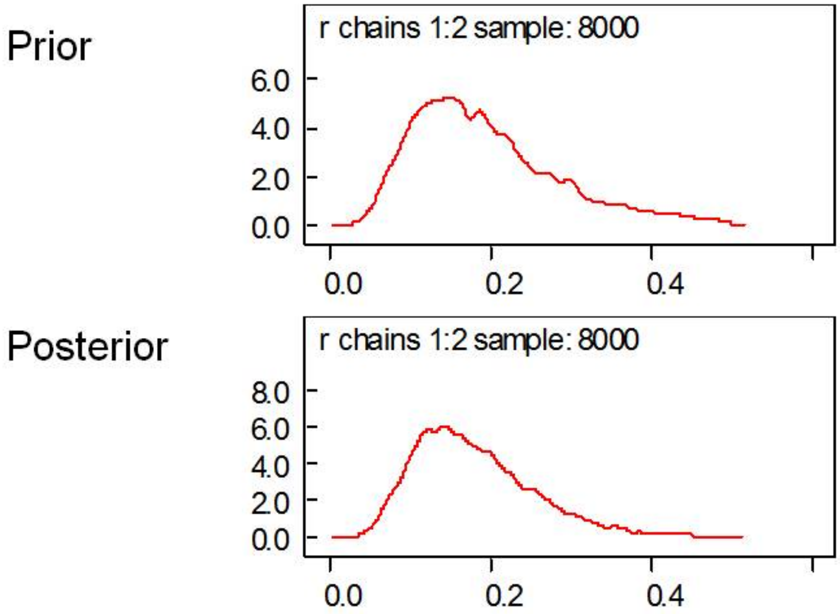
High catch run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})





```
iK ~ dunif(9.21,17.73)
K <- exp(iK)

node      mean    sd       MC error  2.5%    median  97.5%   start   sample
Prior
iK        13.47   2.462    0.02572   9.406   13.45   17.53   50001   8000
Posterior
iK        16.2    0.9247   0.01049   14.45   16.23   17.65   50001   8000
```

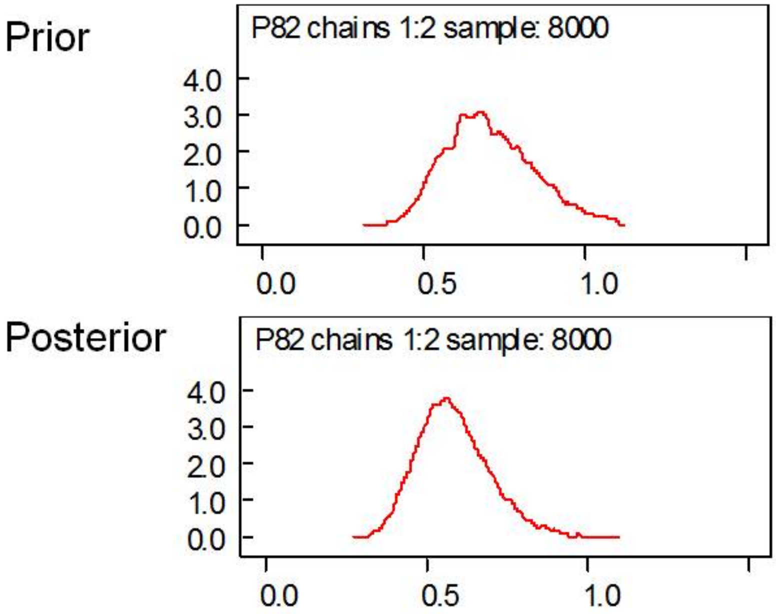
Low r run showing the carrying capacity (*K=exp(iK)*)



r ~ dlnorm(-1.715,4.0)I(0.01,0.5)

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
r	0.1961	0.09105	9.322E-4	0.06559	0.1791	0.4237	50001	8000
Posterior								
r	0.1823	0.07678	8.963E-4	0.06787	0.1692	0.3664	50001	8000

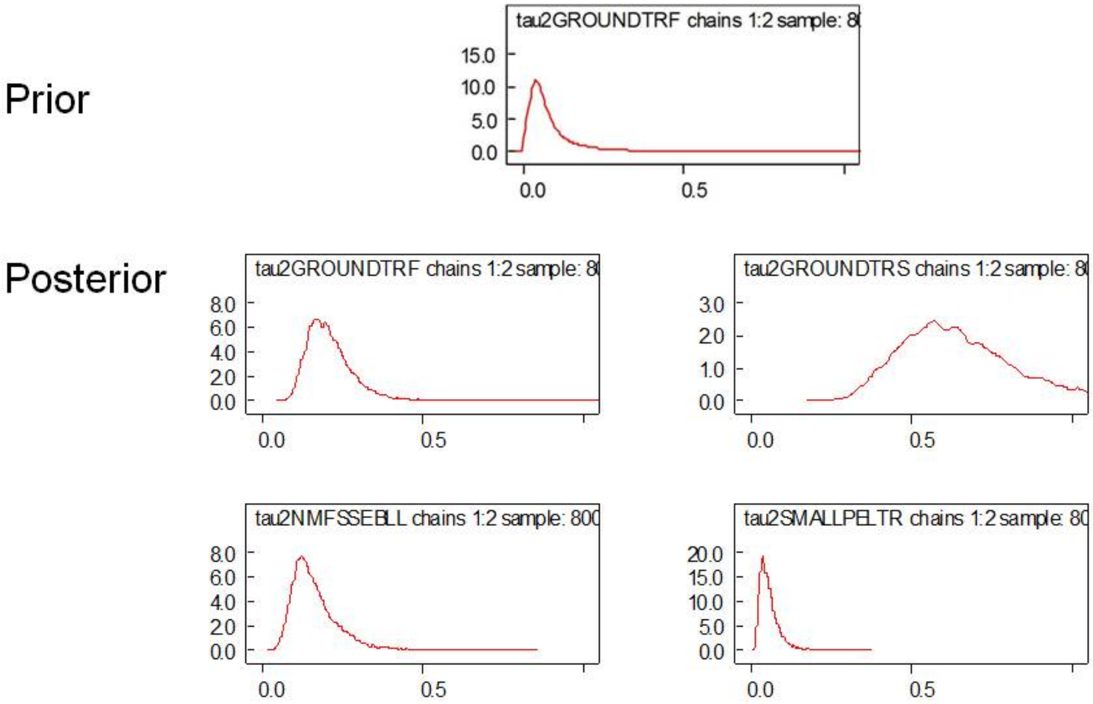
Low r run showing the intrinsic rate of increase (*r*)



P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.5876	0.1138	0.001224	0.3989	0.5739	0.8498	50001	8000

Low r run showing the initial depletion (P_{82})

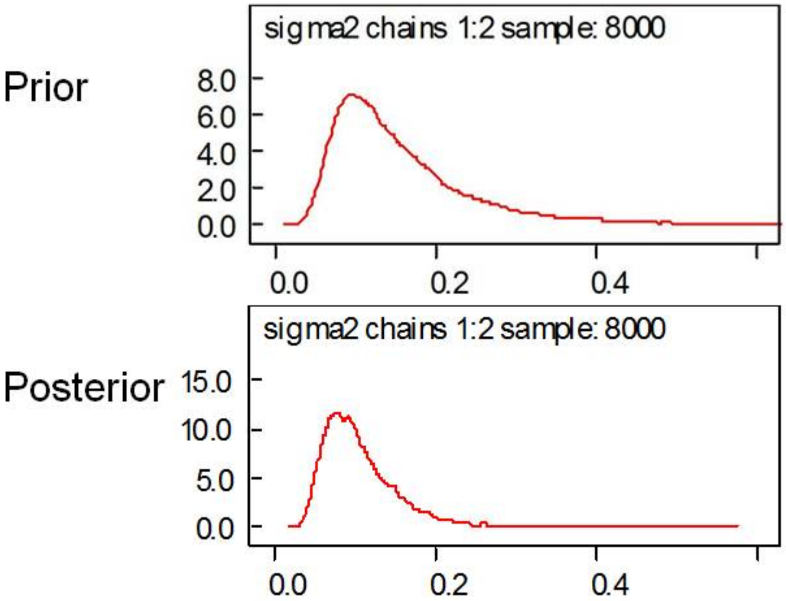


```
itau2GROUNDTRF<-dgamma(2.0, 0.1)
tau2GROUNDTRF=1/itau2GROUNDTRF
```

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.2089	0.07295	9.043E-4	0.1062	0.1958	0.3908	50001	8000
tau2GROUNDTRS	0.6569	0.2025	0.00249	0.3512	0.6277	1.152	50001	8000
tau2NMFSSEBLL	0.1661	0.07638	7.881E-4	0.06726	0.1508	0.3577	50001	8000
tau2SMALLPELTR	0.0559	0.03182	3.464E-4	0.01907	0.04805	0.1349	50001	8000

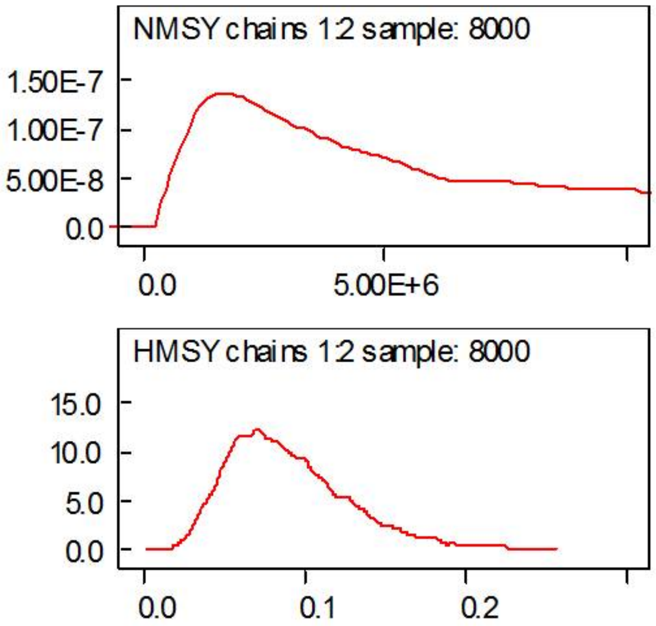
Low r run showing the observation error variance (τ^2)

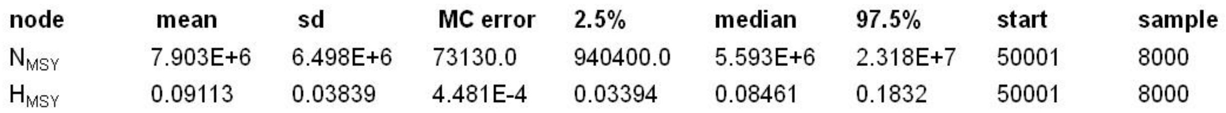


```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.1083	0.04811	8.861E-4	0.04884	0.09761	0.2288	50001	8000

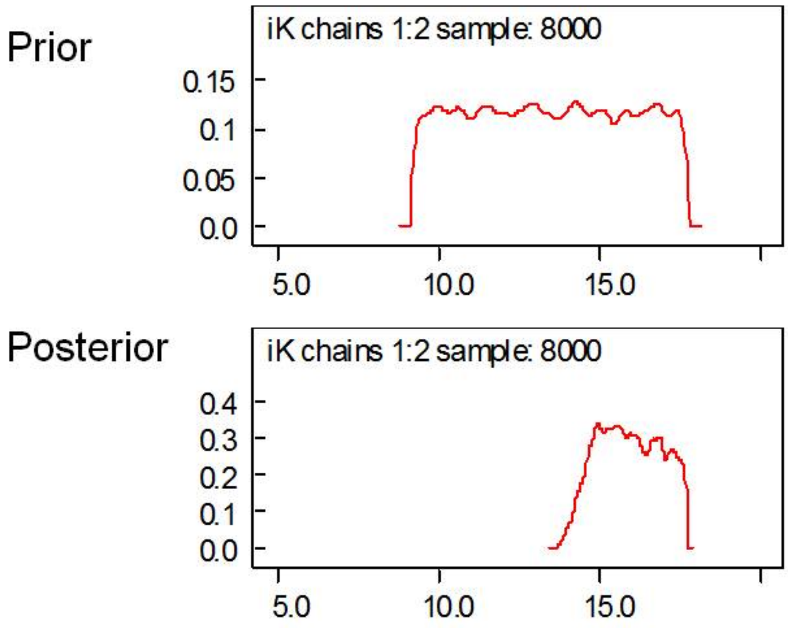
Low r run showing the process error variance (σ^2)

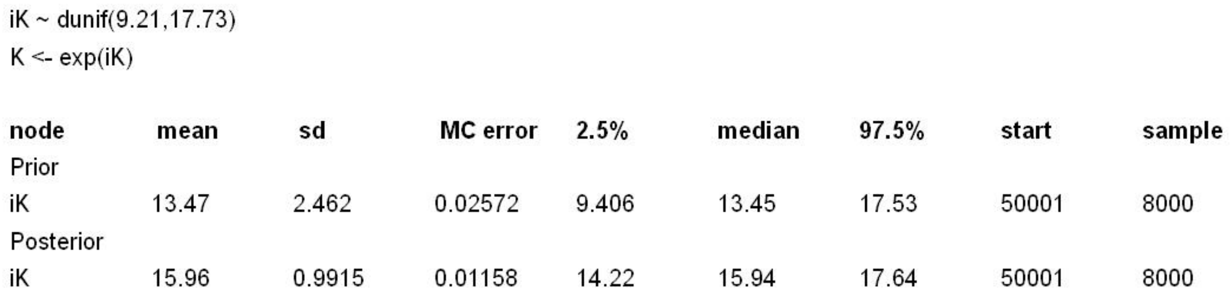




node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	7.903E+6	6.498E+6	73130.0	940400.0	5.593E+6	2.318E+7	50001	8000
H_{MSY}	0.09113	0.03839	4.481E-4	0.03394	0.08461	0.1832	50001	8000

Low r run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})

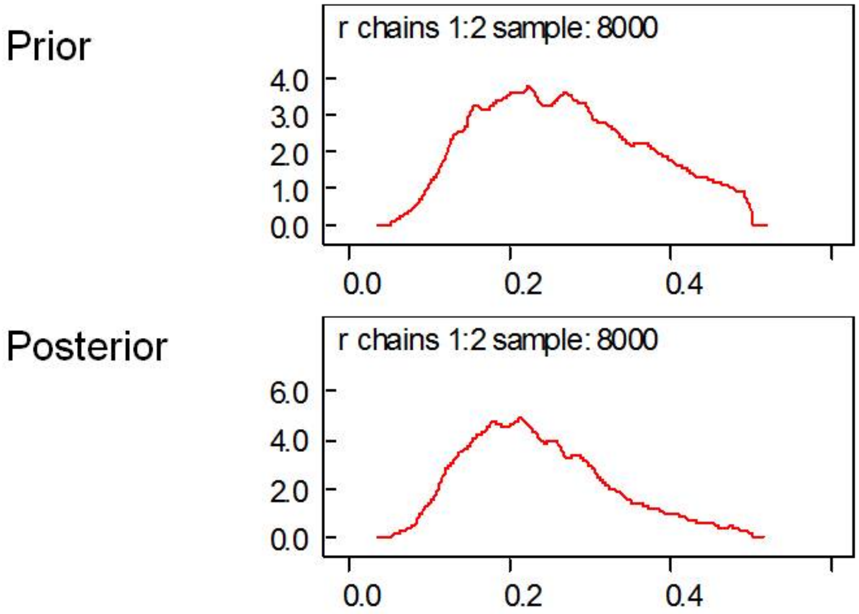




```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
iK	13.47	2.462	0.02572	9.406	13.45	17.53	50001	8000
Posterior								
iK	15.96	0.9915	0.01158	14.22	15.94	17.64	50001	8000

High r run showing the carrying capacity (*K=exp(iK)*)

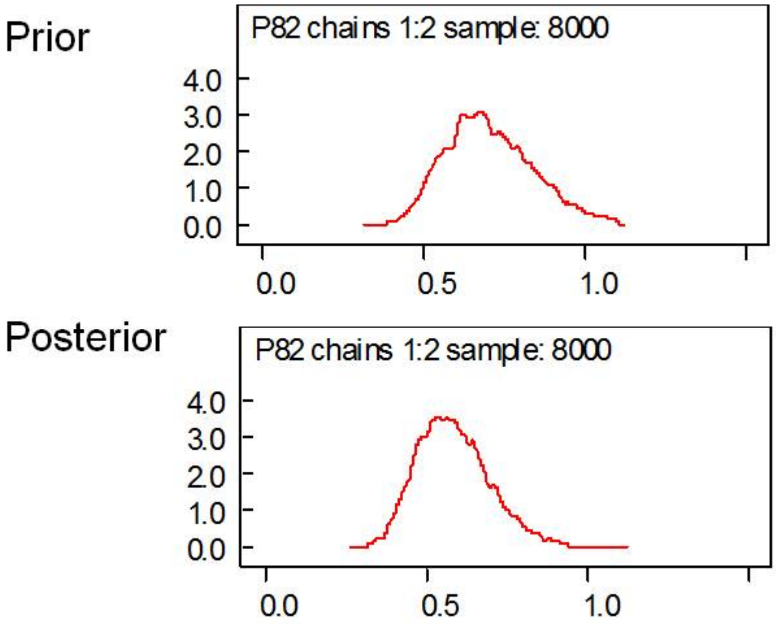


r ~ dlnorm(-1.273,4.0)I(0.01,0.5)

Prior

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
r	0.2695	0.1022	0.001193	0.1015	0.2609	0.475	50001	8000
Posterior								
r	0.2407	0.08915	9.902E-4	0.1	0.2286	0.4456	50001	8000

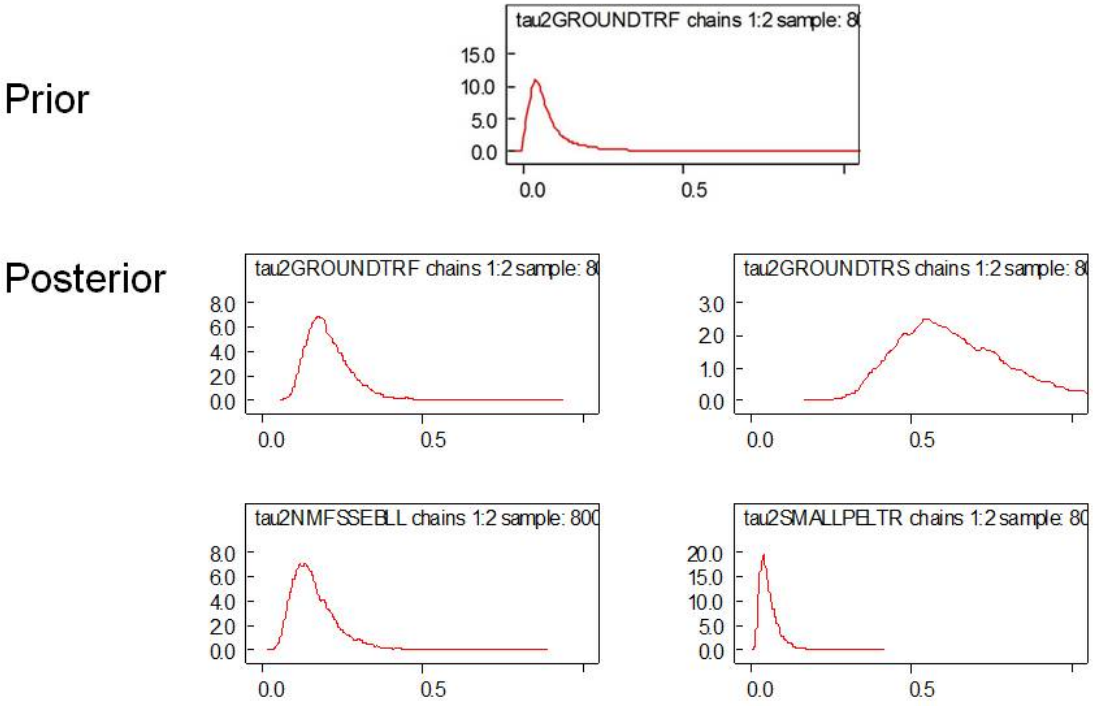
High r run showing the intrinsic rate of increase (*r*)



P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.5873	0.1146	0.00149	0.3959	0.5764	0.8444	50001	8000

High r run showing the initial depletion (P_{82})

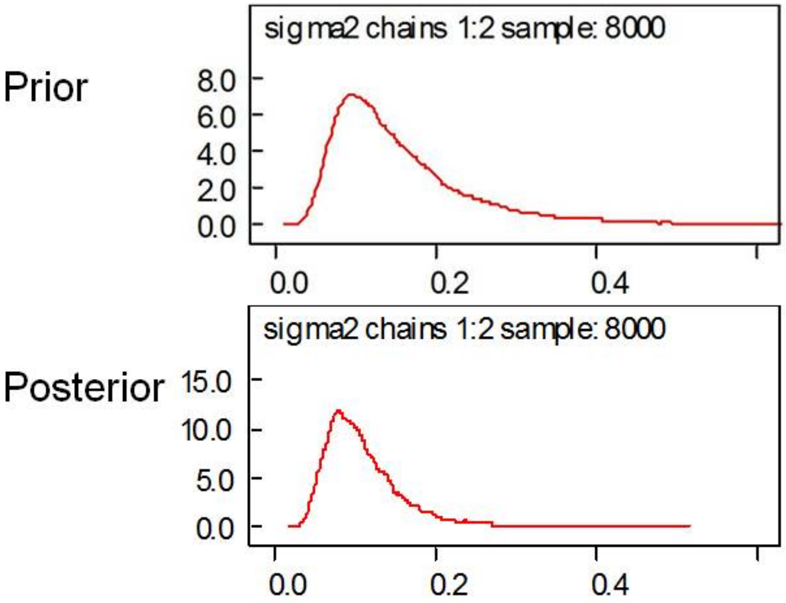


```
itau2GROUNDTRF<-dgamma(2.0, 0.1)
tau2GROUNDTRF=1/itau2GROUNDTRF
```

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.2084	0.07262	8.251E-4	0.1046	0.1962	0.3796	50001	8000
tau2GROUNDTRS	0.6465	0.1972	0.00237	0.3519	0.6143	1.125	50001	8000
tau2NMFSSEBLL	0.1665	0.07843	8.343E-4	0.0683	0.1502	0.3643	50001	8000
tau2SMALLPELTR	0.05607	0.03134	4.482E-4	0.01916	0.04875	0.1374	50001	8000

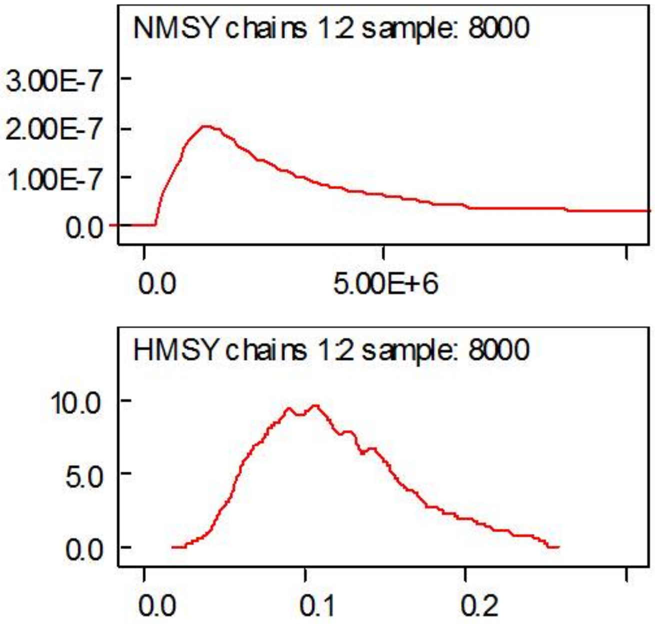
High r run showing the observation error variance (τ^2)

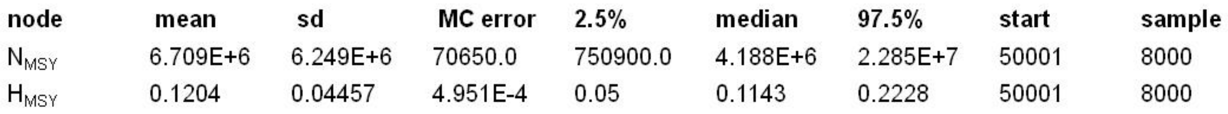


```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.1116	0.0481	8.405E-4	0.04934	0.1018	0.2332	50001	8000

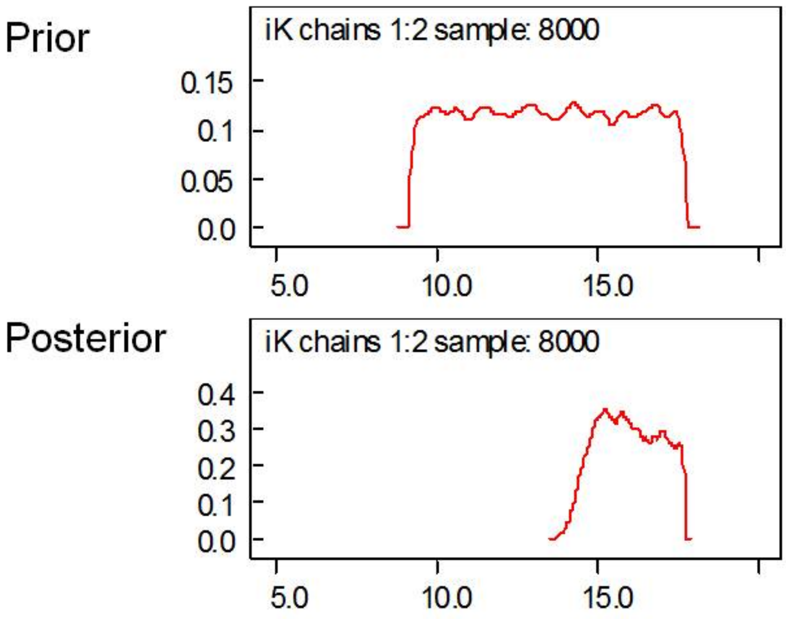
High r run showing the process error variance (σ^2)

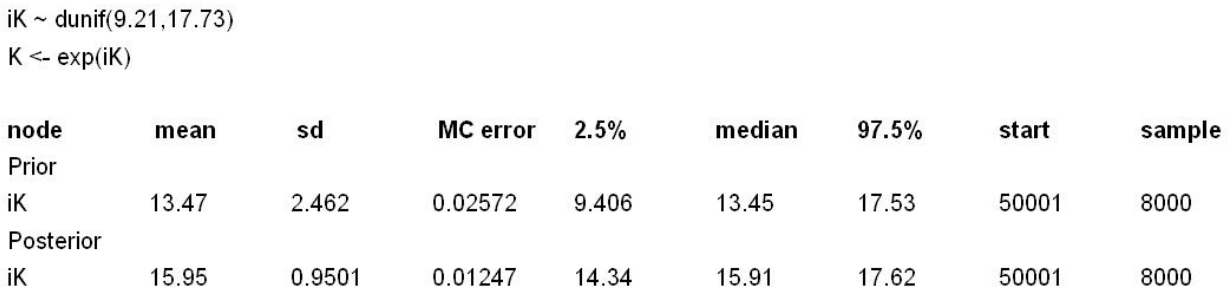




node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	6.709E+6	6.249E+6	70650.0	750900.0	4.188E+6	2.285E+7	50001	8000
H_{MSY}	0.1204	0.04457	4.951E-4	0.05	0.1143	0.2228	50001	8000

High r run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})

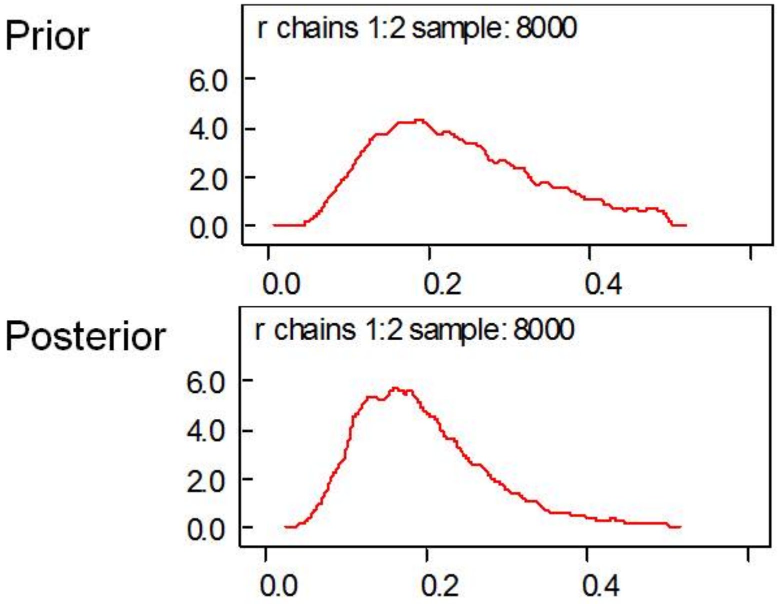




```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
iK	13.47	2.462	0.02572	9.406	13.45	17.53	50001	8000
Posterior								
iK	15.95	0.9501	0.01247	14.34	15.91	17.62	50001	8000

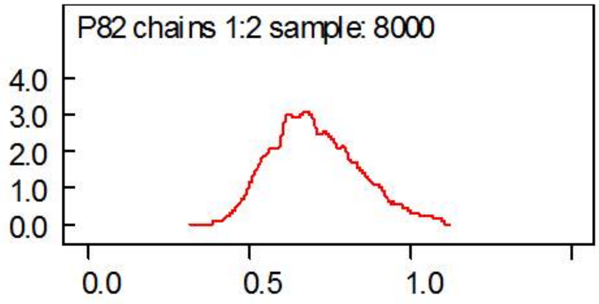
Large process error run showing the carrying capacity (*K=exp(iK)*)



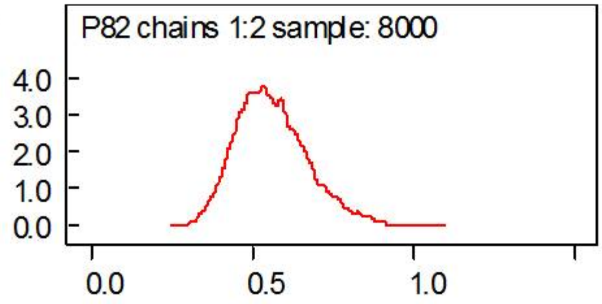
```
r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node       mean    sd        MC error   2.5%      median   97.5%    start   sample
Prior
r          0.236   0.09876   0.001084   0.08492   0.2215   0.4596   50001   8000
Posterior
r          0.199   0.08001   0.001097   0.08088   0.1852   0.3891   50001   8000
```

Large process error run showing the intrinsic rate of increase (*r*)

Prior



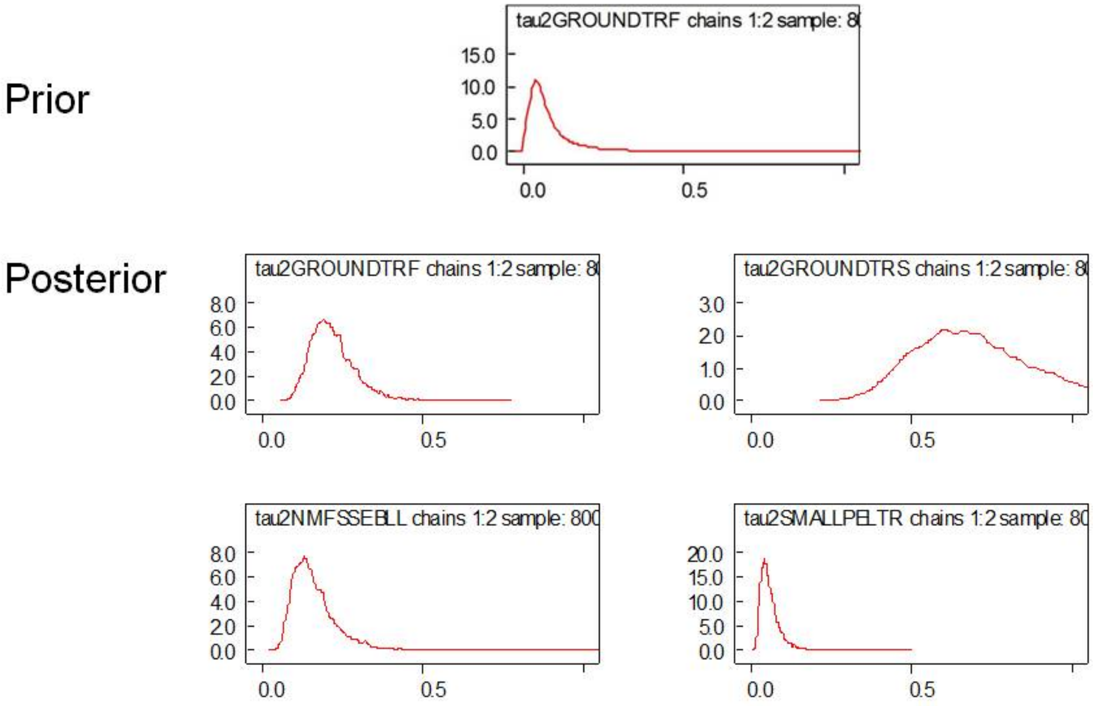
Posterior



P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.5623	0.1125	0.001649	0.3765	0.5499	0.8115	50001	8000

Large process error run showing the initial depletion (P_{82})



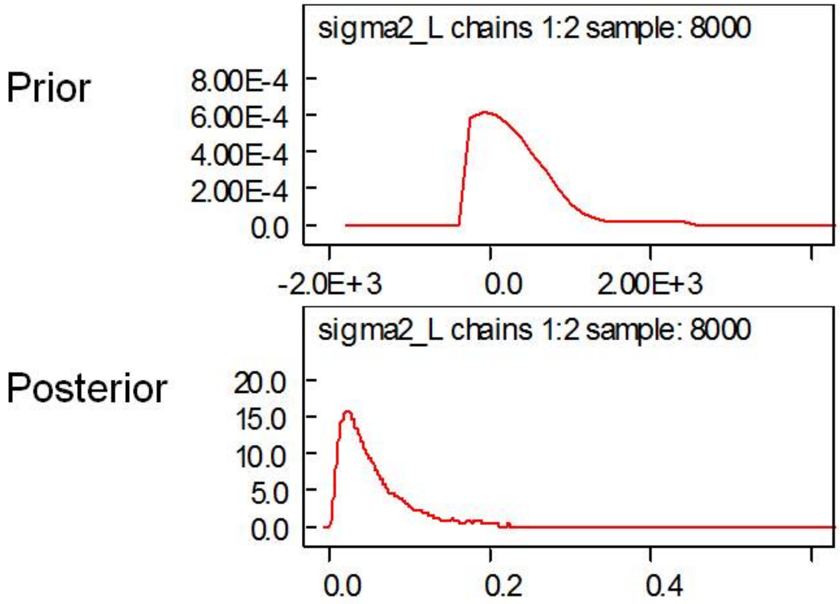
itau2GROUNDTRF<-dgamma(2.0, 0.1)

tau2GROUNDTRF=1/itau2GROUNDTRF

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.2205	0.06996	8.318E-4	0.1155	0.21	0.3862	50001	8000
tau2GROUNDTRS	0.7188	0.2138	0.003492	0.3884	0.6889	1.215	50001	8000
tau2NMFSSEBLL	0.1618	0.07289	8.297E-4	0.07065	0.1462	0.3438	50001	8000
tau2SMALLPELTR	0.0592	0.03293	4.353E-4	0.02073	0.05191	0.1453	50001	8000

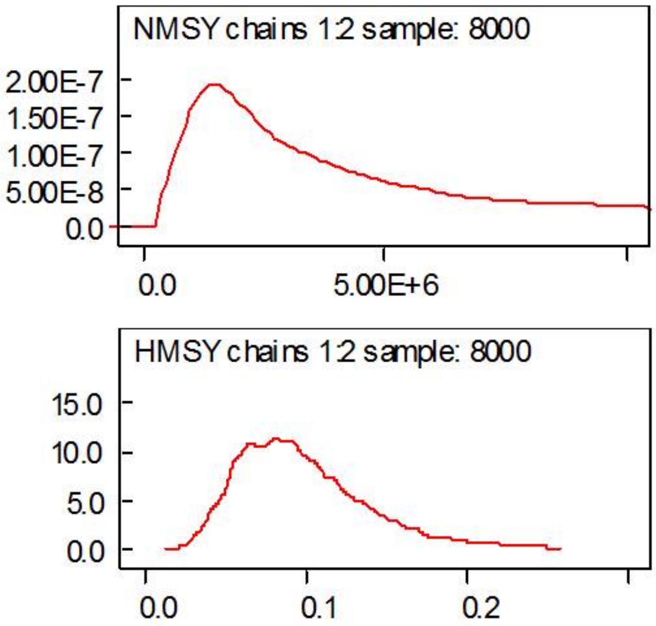
Large process error run showing the observation error variance (τ^2)

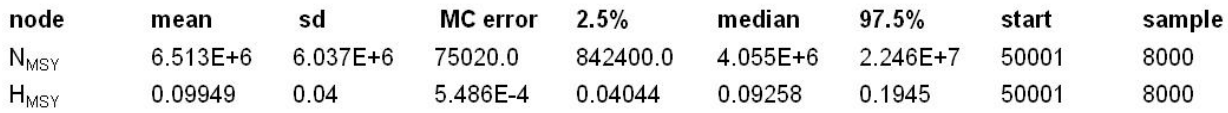


```
isigam2_L-<dgamma(0.16,0.02)I(0.00001,)
sigma2_L=1/isigma2_L
```

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
sigma2_L	1944.0	9413.0	94.4	0.01496	1.293	26010.0	50001	8000
Posterior								
sigma2_L	0.05807	0.05131	0.001578	0.009993	0.04254	0.1959	50001	8000

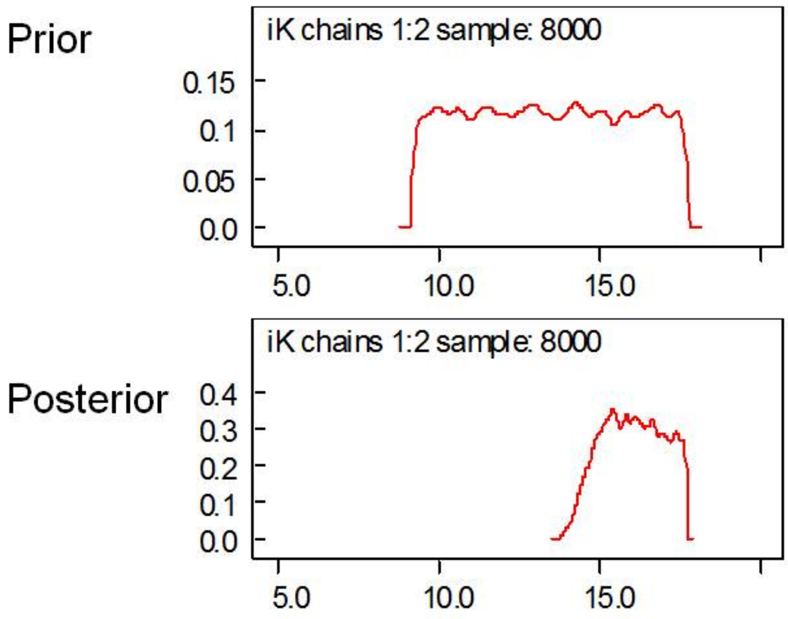
Large process error run showing the process error variance (σ^2)





node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	6.513E+6	6.037E+6	75020.0	842400.0	4.055E+6	2.246E+7	50001	8000
H_{MSY}	0.09949	0.04	5.486E-4	0.04044	0.09258	0.1945	50001	8000

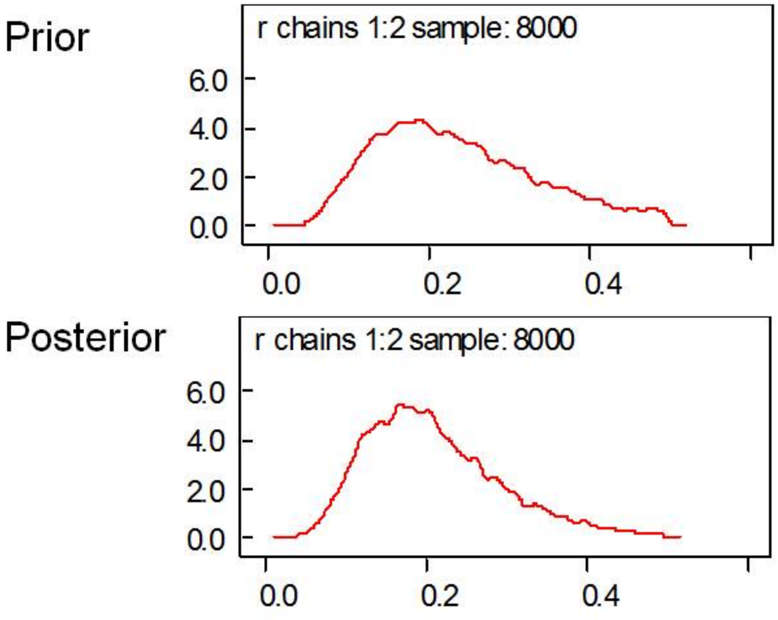
Large process error run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})



```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
iK	13.47	2.462	0.02572	9.406	13.45	17.53	50001	8000
Posterior								
iK	16.06	0.9632	0.01066	14.34	16.05	17.63	50001	8000

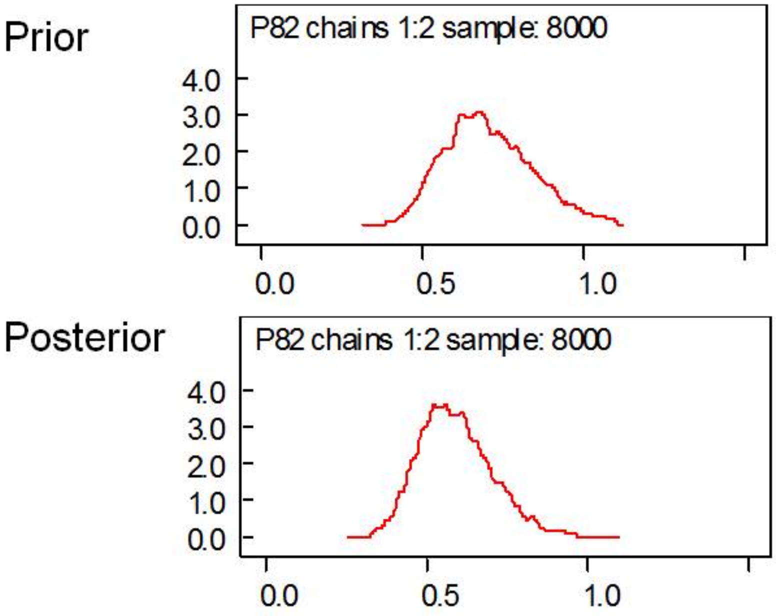
Large observation error run showing the carrying capacity (*K=exp(iK)*)



r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
r	0.236	0.09876	0.001084	0.08492	0.2215	0.4596	50001	8000
Posterior								
r	0.21	0.08231	9.717E-4	0.08407	0.197	0.4033	50001	8000

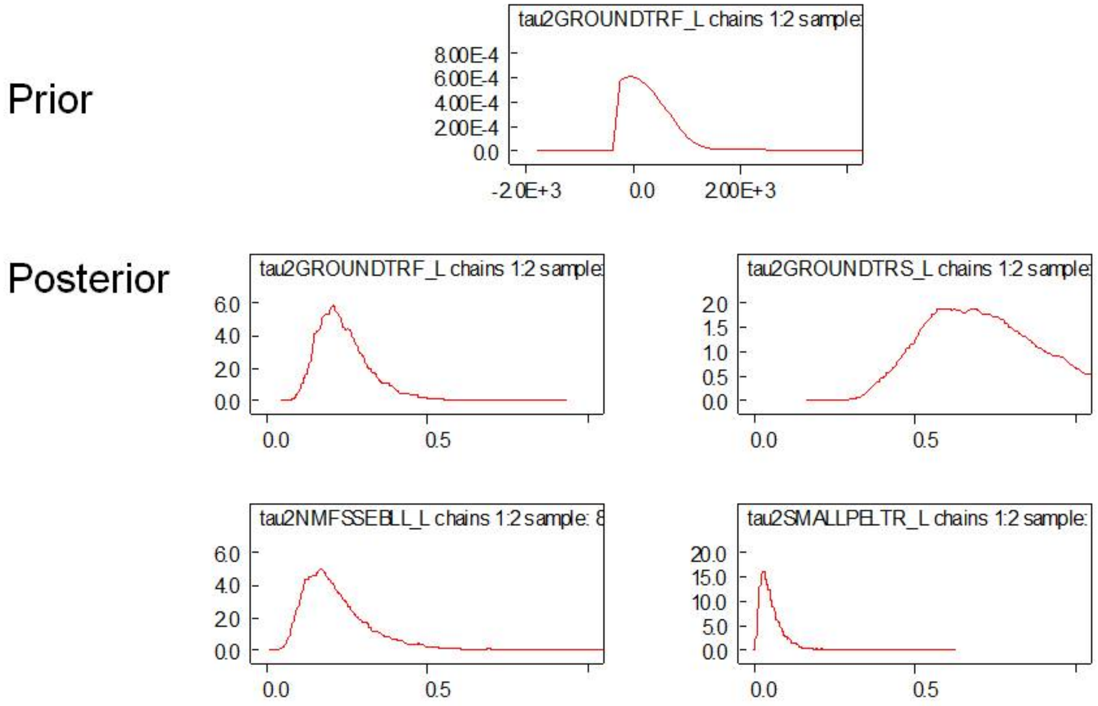
Large observation error run showing the intrinsic rate of increase (*r*)



P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.5928	0.1151	0.001486	0.3972	0.5829	0.8498	50001	8000

Large observation error run showing the initial depletion (P_{82})

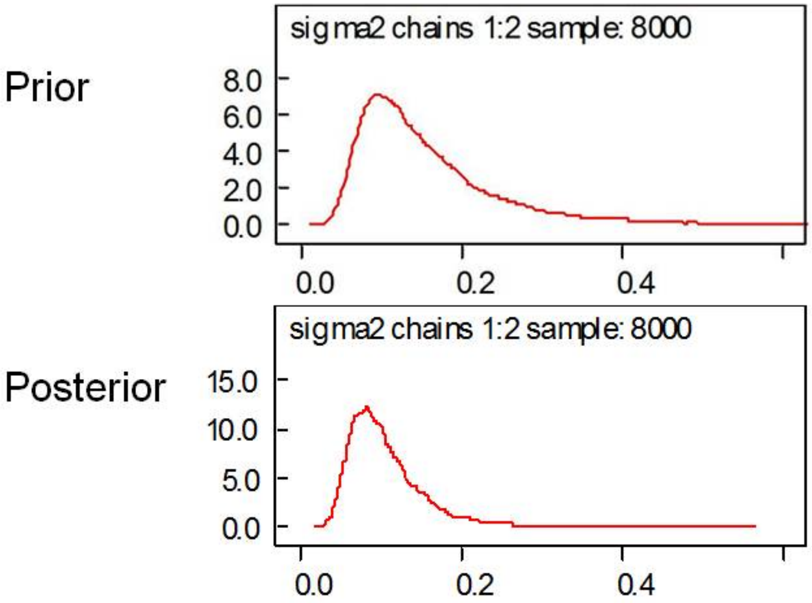


```
itau2GROUNDTRF_L<-dgamma(0.16,0.02)I(0.00001,)
tau2GROUNDTRF_L=1/itau2GROUNDTRF_L
```

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
tau2GROUNDTRF_L	1944.0	9413.0	94.4	0.01496	1.293	26010.0	50001	8000
Posterior								
tau2GROUNDTRF_L	0.2426	0.0869	9.914E-4	0.119	0.2287	0.4583	50001	8000
tau2GROUNDTRS_L	0.7607	0.2459	0.003403	0.4119	0.7186	1.369	50001	8000
tau2NMFSSEBLL_L	0.2243	0.1206	0.001348	0.08196	0.1968	0.5301	50001	8000
tau2SMALLPELTR_L	0.05617	0.0475	6.157E-4	0.009964	0.04352	0.178	50001	8000

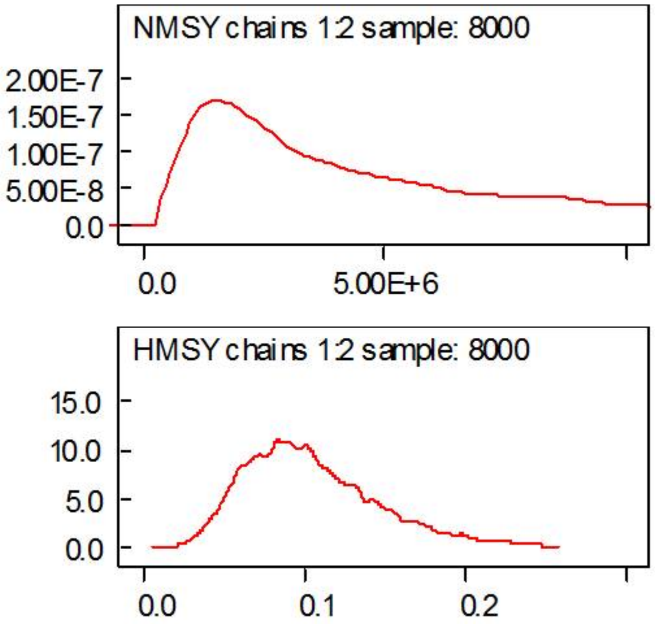
Large observation error run showing the observation error variance (τ^2)



```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

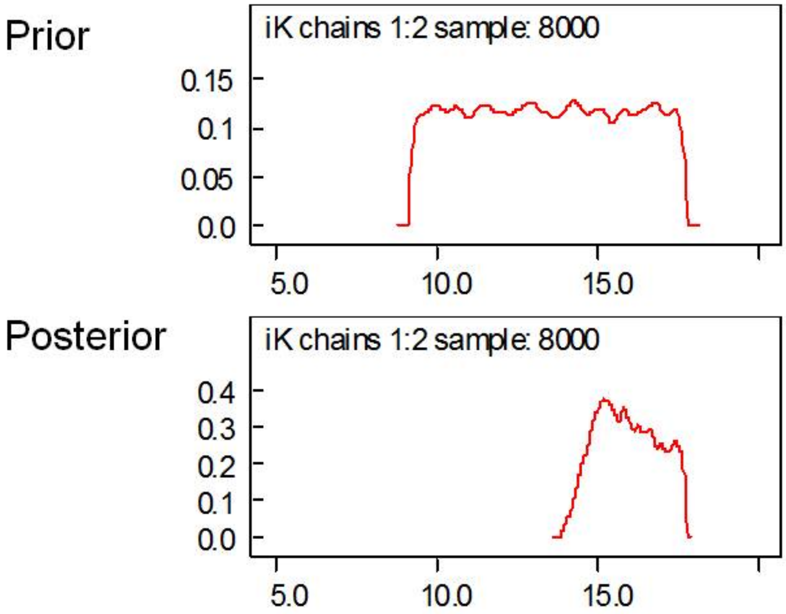
node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.104	0.04345	7.511E-4	0.04832	0.09468	0.2149	50001	8000

Large observation error run showing the process error variance (σ^2)



node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	7.186E+6	6.365E+6	67960.0	845600.0	4.682E+6	2.277E+7	50001	8000
H_{MSY}	0.105	0.04115	4.858E-4	0.04203	0.09849	0.2016	50001	8000

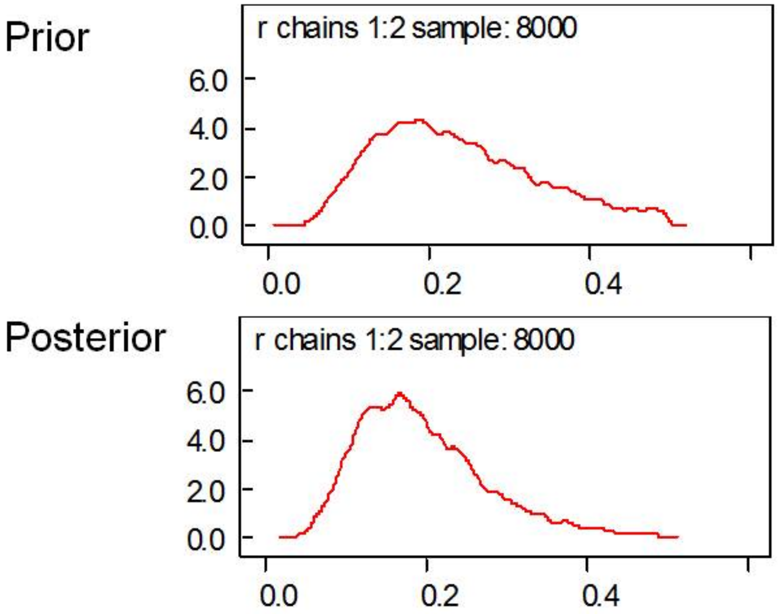
Large observation error run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})



```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
iK	13.47	2.462	0.02572	9.406	13.45	17.53	50001	8000
Posterior								
iK	15.96	0.9495	0.01257	14.36	15.9	17.63	50001	8000

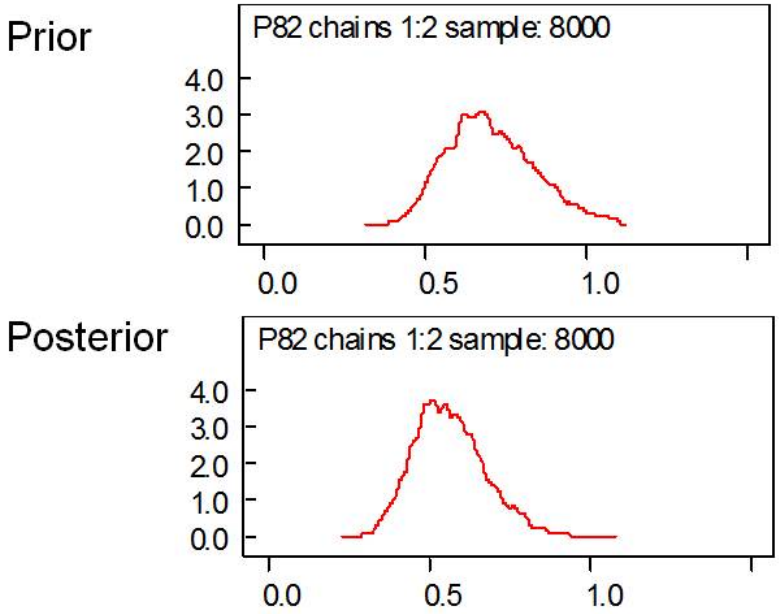
Large process and observation error run showing the carrying capacity (*K=exp(iK)*)

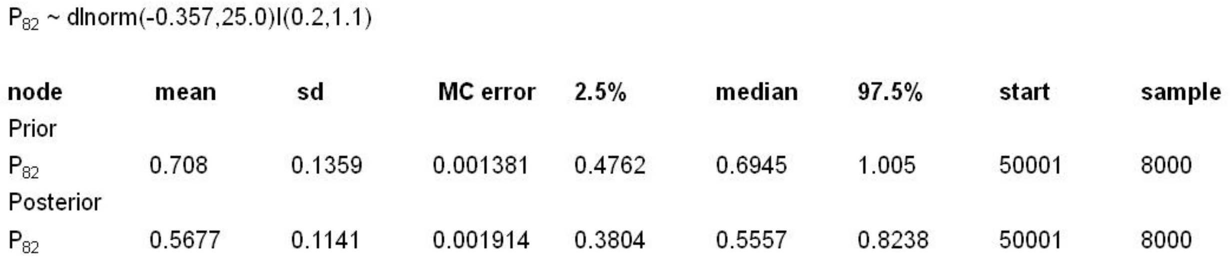


r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
r	0.236	0.09876	0.001084	0.08492	0.2215	0.4596	50001	8000
Posterior								
r	0.1945	0.07822	0.001076	0.08082	0.1805	0.3887	50001	8000

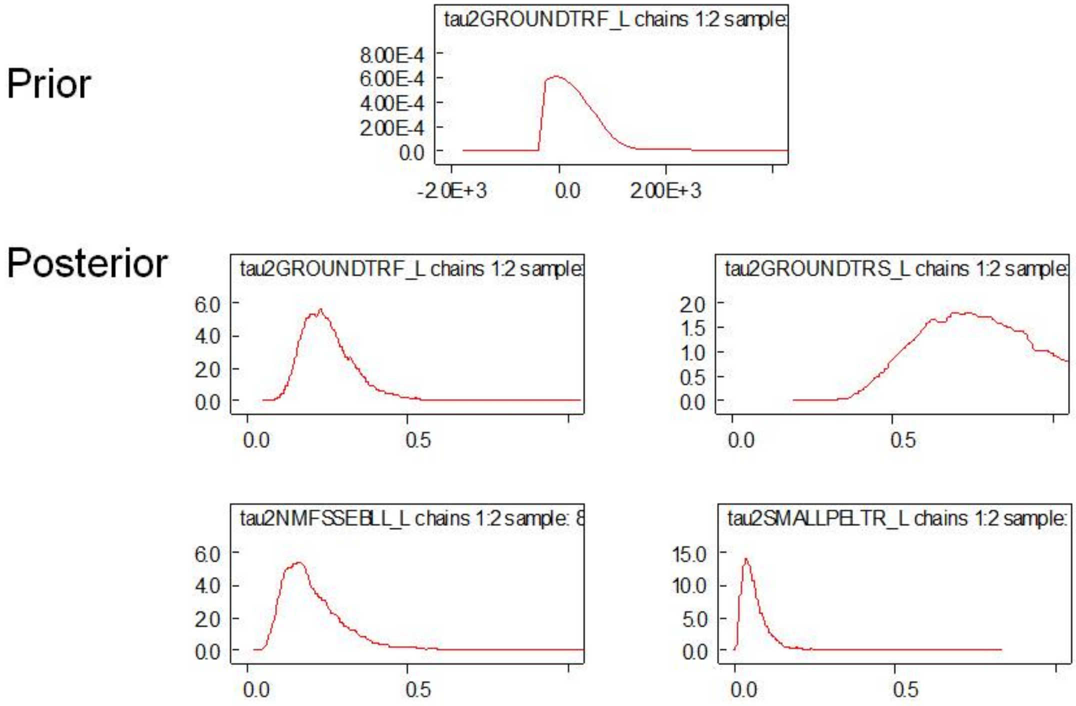
Large process and observation error run showing the intrinsic rate of increase (*r*)




P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.5677	0.1141	0.001914	0.3804	0.5557	0.8238	50001	8000

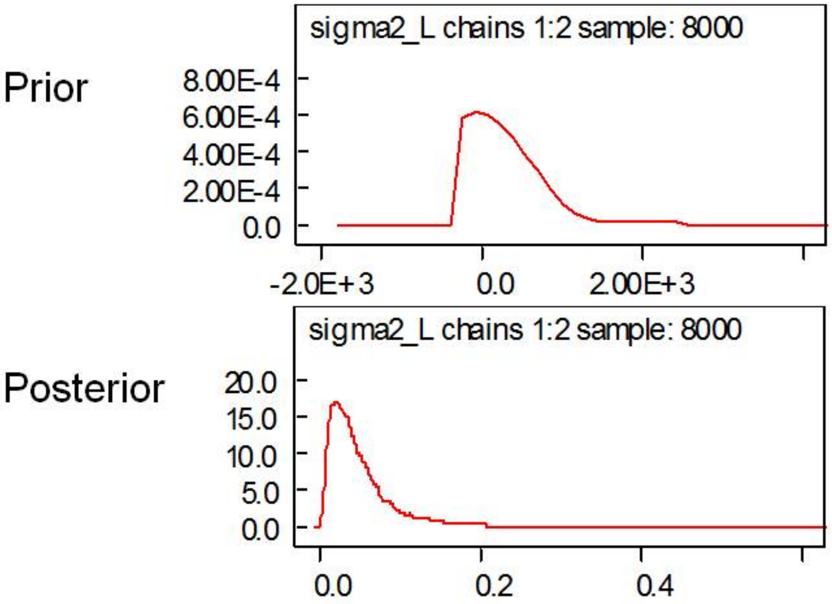
Large process and observation error run showing the initial depletion (P_{82})



itau2GROUNDTRF_L<-dgamma(0.16,0.02)I(0.00001,)
tau2GROUNDTRF_L=1/itau2GROUNDTRF_L
The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
tau2GROUNDTRF_L	1944.0	9413.0	94.4	0.01496	1.293	26010.0	50001	8000
Posterior								
tau2GROUNDTRF_L	0.2544	0.08859	0.00108	0.1293	0.2386	0.4669	50001	8000
tau2GROUNDTRS_L	0.8321	0.2583	0.004233	0.4499	0.7897	1.46	50001	8000
tau2NMFSSEBLL_L	0.2134	0.1147	0.001284	0.08285	0.1871	0.5043	50001	8000
tau2SMALLPELTR_L	0.0634	0.0501	8.657E-4	0.01288	0.05065	0.1923	50001	8000

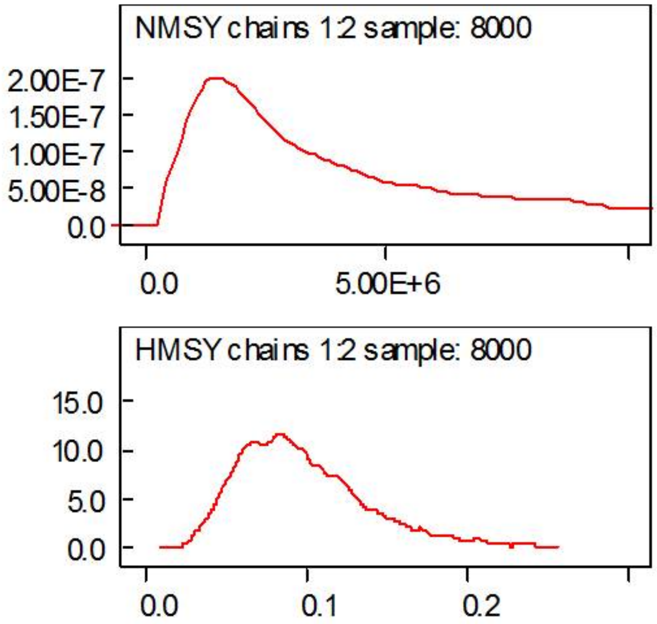
Large process and observation error run showing the observation error variance (τ^2)



```
isigam2_L-<dgamma(0.16,0.02)I(0.00001,)
sigma2_L=1/isigma2_L
```

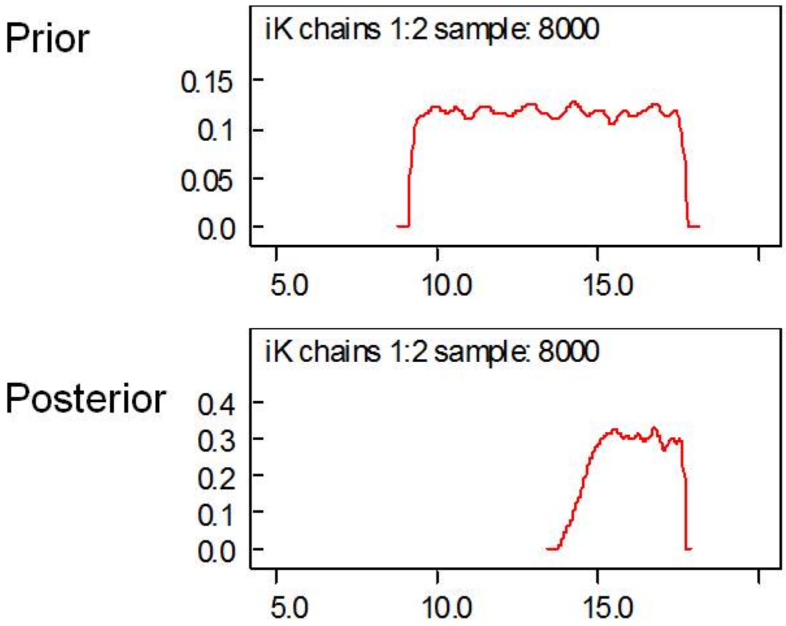
node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
sigma2_L	1944.0	9413.0	94.4	0.01496	1.293	26010.0	50001	8000
Posterior								
sigma2_L	0.05494	0.04753	0.001455	0.009722	0.04173	0.184	50001	8000

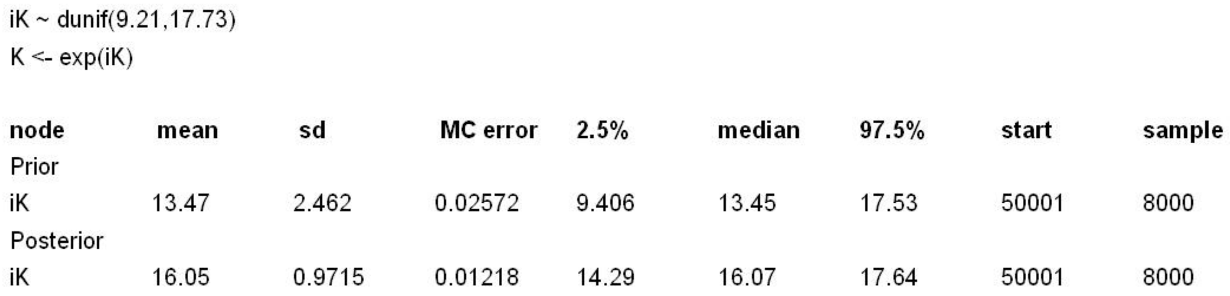
Large process and observation error run showing the process error variance (σ^2)



node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	6.568E+6	6.117E+6	75990.0	857600.0	4.03E+6	2.272E+7	50001	8000
H_{MSY}	0.09724	0.03911	5.379E-4	0.04041	0.09024	0.1943	50001	8000

Large process and observation error run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})

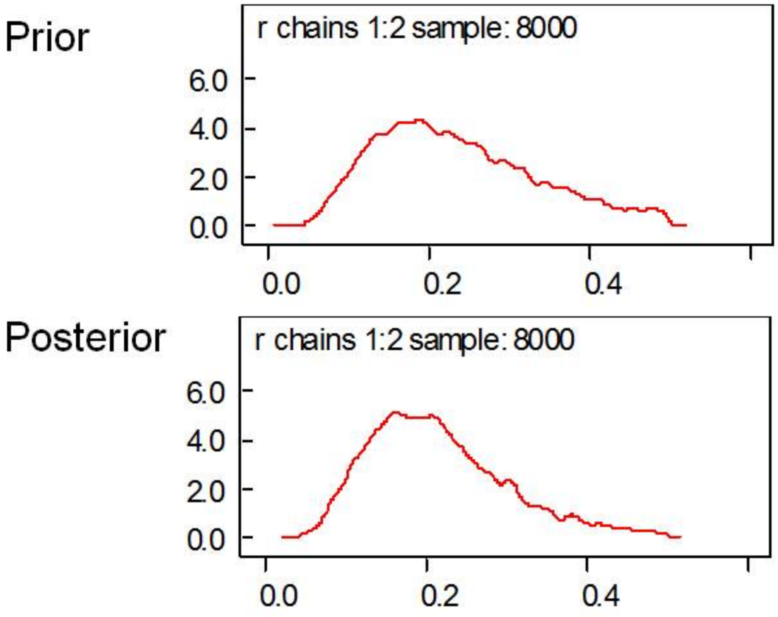




```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
iK	13.47	2.462	0.02572	9.406	13.45	17.53	50001	8000
Posterior								
iK	16.05	0.9715	0.01218	14.29	16.07	17.64	50001	8000

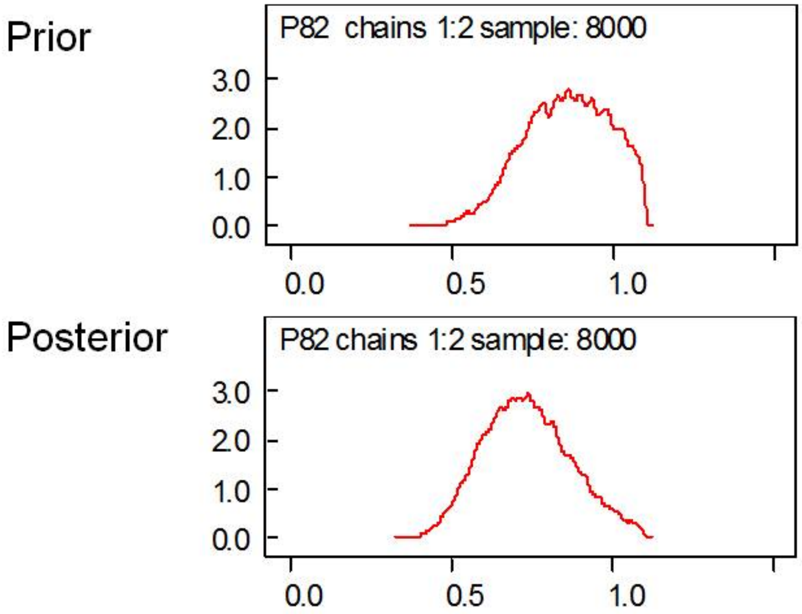
High P_{82} run showing the carrying capacity (*K=exp(iK)*)



r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
r	0.236	0.09876	0.001084	0.08492	0.2215	0.4596	50001	8000
Posterior								
r	0.2149	0.08545	0.001069	0.08642	0.2002	0.4189	50001	8000

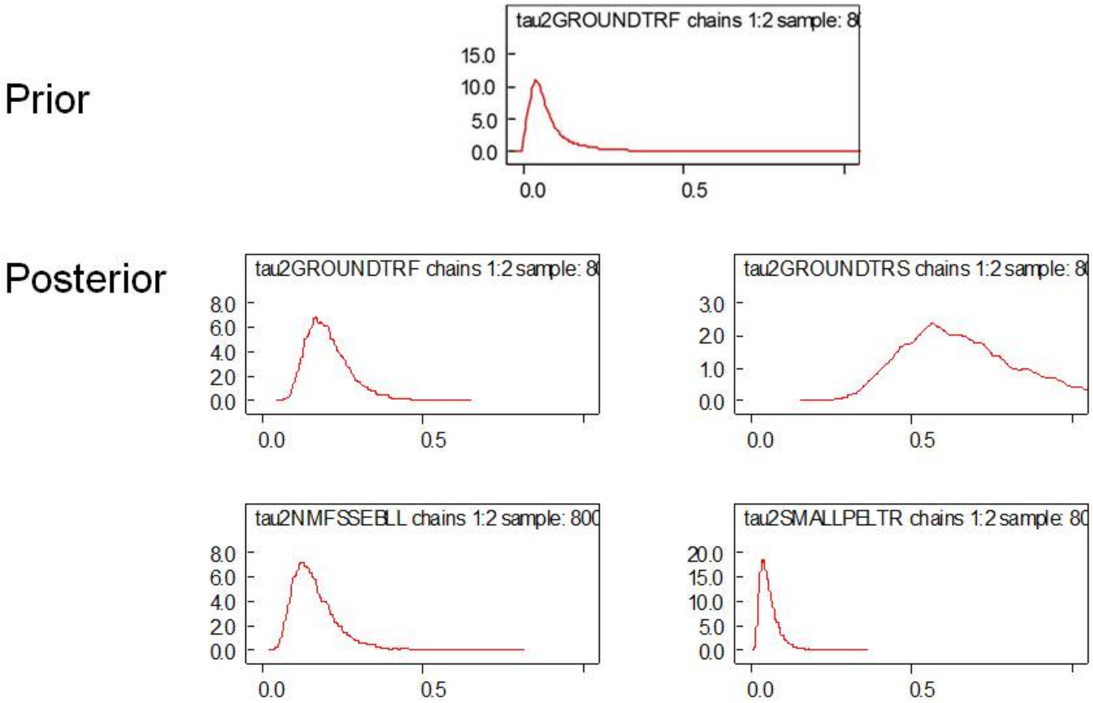
High P_{82} run showing the intrinsic rate of increase (*r*)



P_{82} ~ dlnorm(-0.105,25.0)I(0.2,1.1)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
P_{82}	0.8602	0.1313	0.001512	0.5958	0.865	1.081	50001	8000
Posterior								
P_{82}	0.7399	0.135	0.00159	0.5017	0.7304	1.025	50001	8000

High P_{82} run showing the initial depletion (P_{82})

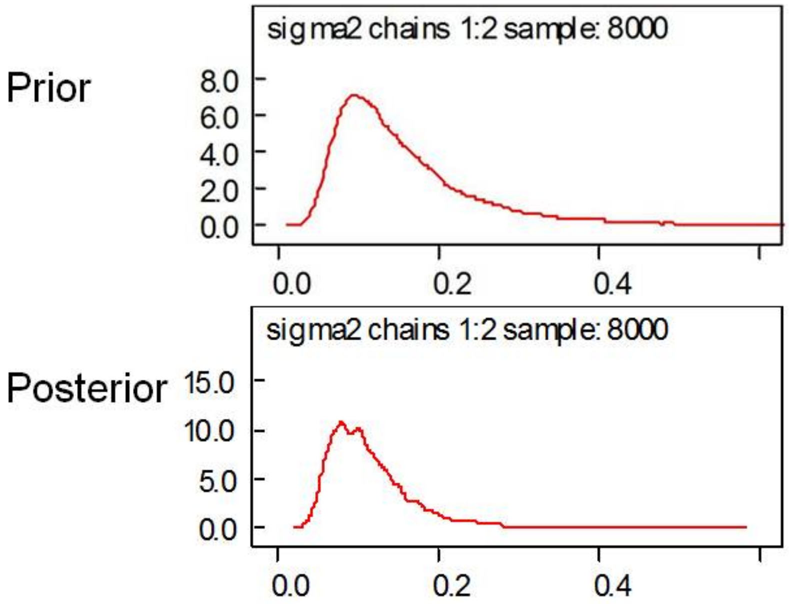


```
itau2GROUNDTRF<-dgamma(2.0, 0.1)
tau2GROUNDTRF=1/itau2GROUNDTRF
```

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.2053	0.06996	8.572E-4	0.1027	0.1942	0.3755	50001	8000
tau2GROUNDTRS	0.6706	0.2045	0.003052	0.3605	0.6408	1.151	50001	8000
tau2NMFSSEBLL	0.1674	0.07757	9.097E-4	0.06741	0.1515	0.3613	50001	8000
tau2SMALLPELTR	0.057	0.03288	4.224E-4	0.01856	0.04922	0.1386	50001	8000

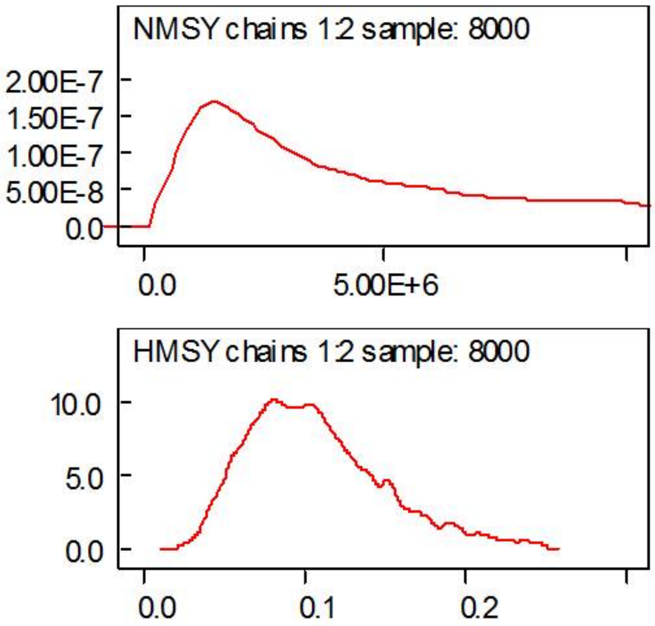
High P_{82} run showing the observation error variance (τ^2)



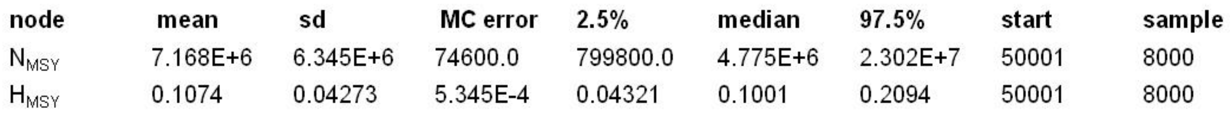
```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.1149	0.05034	9.203E-4	0.05119	0.1037	0.2463	50001	8000

High P_{82} run showing the process error variance (σ^2)

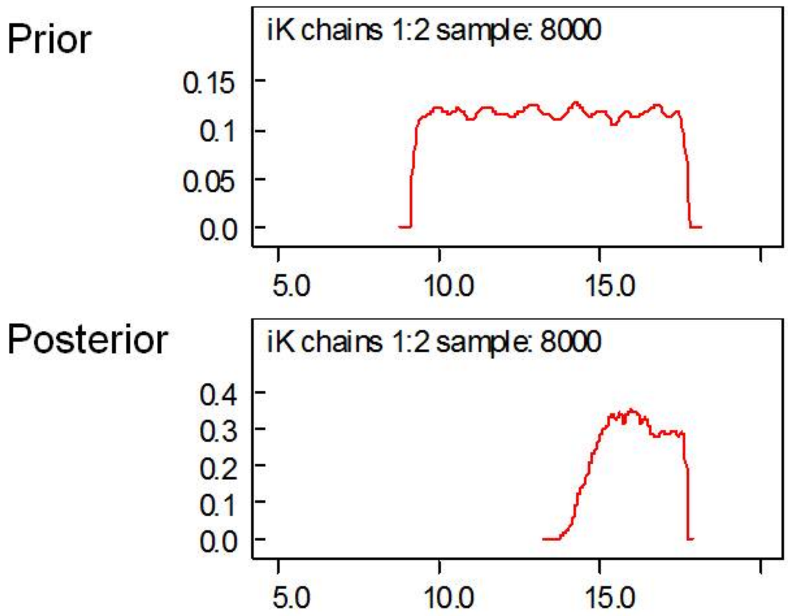

NMSY chains 1:2 sample: 8000

HMSY chains 1:2 sample: 8000



node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	7.168E+6	6.345E+6	74600.0	799800.0	4.775E+6	2.302E+7	50001	8000
H_{MSY}	0.1074	0.04273	5.345E-4	0.04321	0.1001	0.2094	50001	8000

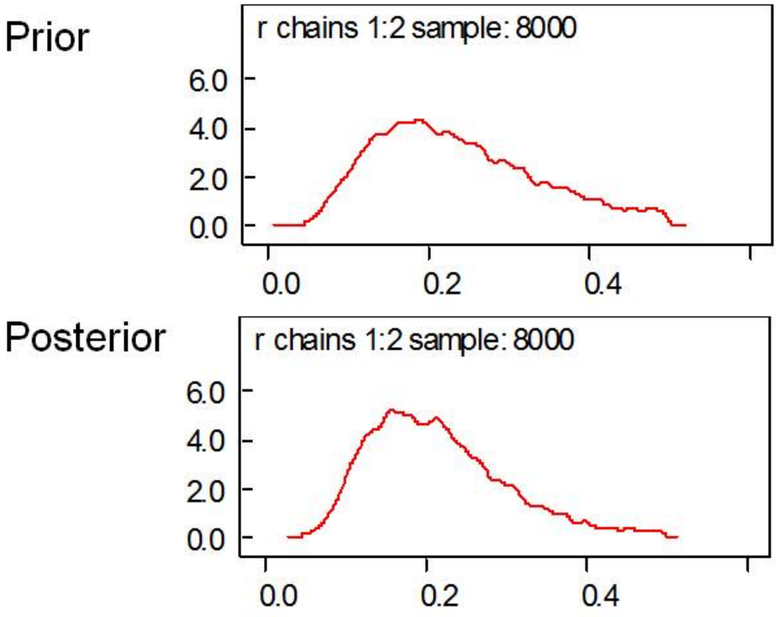
High P_{82} run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})



```
iK ~ dunif(9.21,17.73)
K <- exp(iK)
```

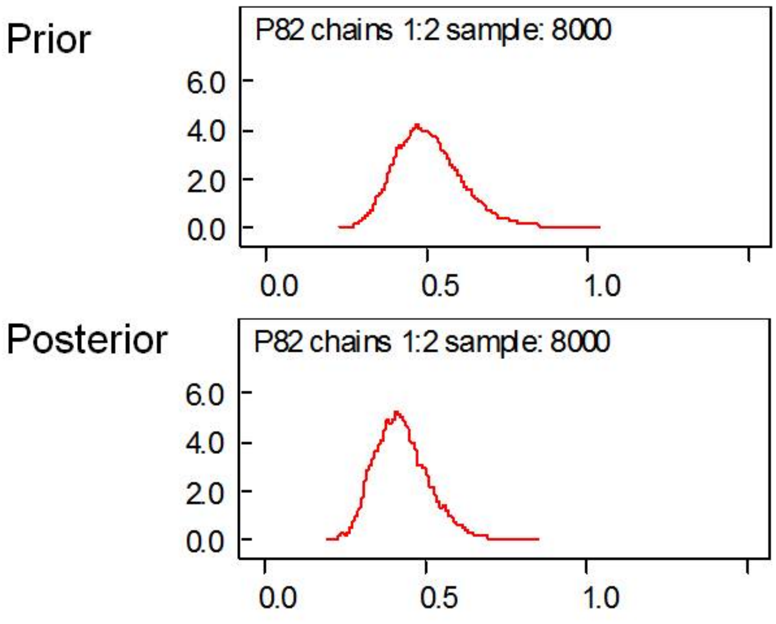
node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
iK	13.47	2.462	0.02572	9.406	13.45	17.53	50001	8000
Posterior								
iK	16.08	0.9558	0.01194	14.36	16.08	17.64	50001	8000

Low P_{82} run showing the carrying capacity (*K=exp(iK)*)



node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
r	0.236	0.09876	0.001084	0.08492	0.2215	0.4596	50001	8000
Posterior								
r	0.2143	0.08301	0.001158	0.0872	0.2017	0.41	50001	8000

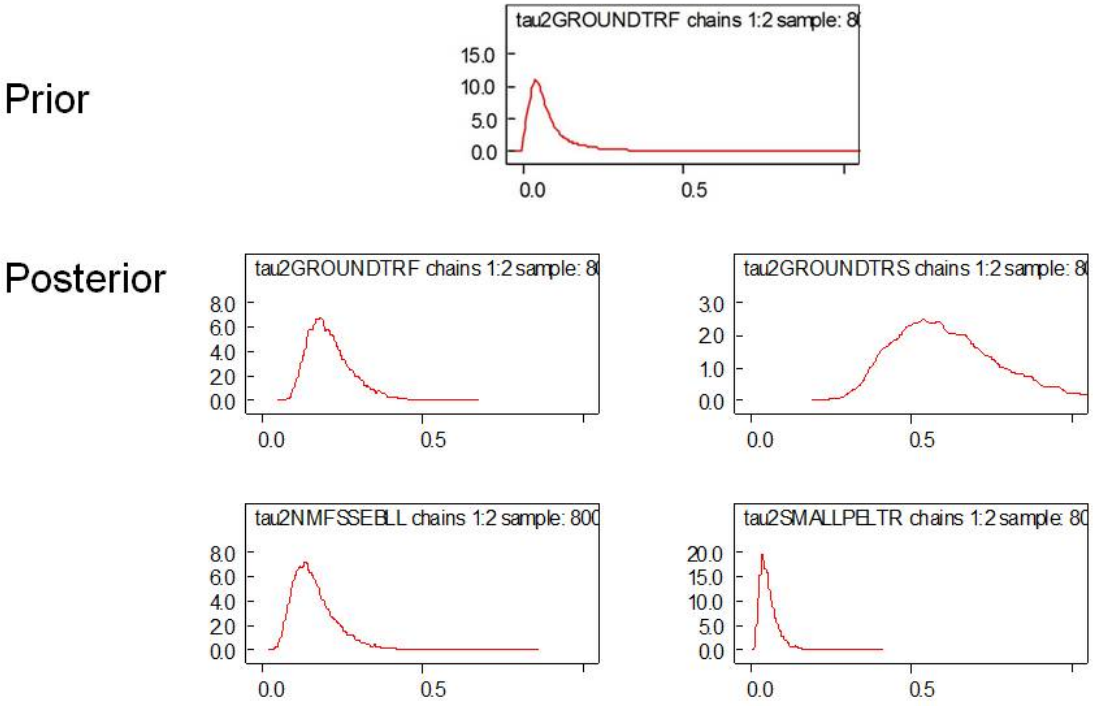
Low P_{82} run showing the intrinsic rate of increase (*r*)



P_{82} ~ dlnorm(-0.693,25.0)I(0.2,1.1)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
P_{82}	0.5093	0.1031	0.001307	0.3374	0.4995	0.7426	50001	8000
Posterior								
P_{82}	0.4301	0.08399	0.001164	0.2896	0.4214	0.6188	50001	8000

Low P_{82} run showing the initial depletion (P_{82})



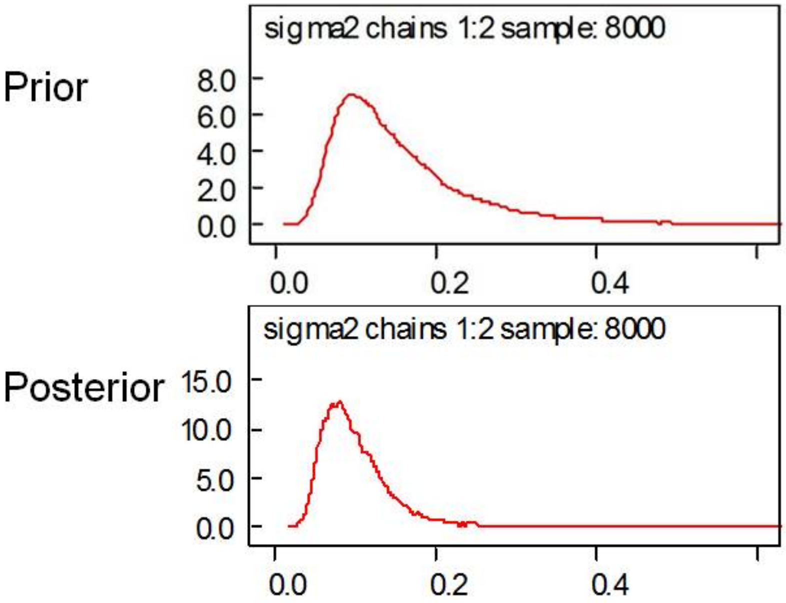
itau2GROUNDTRF<-dgamma(2.0, 0.1)

tau2GROUNDTRF=1/itau2GROUNDTRF

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.2105	0.0714	8.476E-4	0.106	0.1994	0.3839	50001	8000
tau2GROUNDTRS	0.6265	0.1894	0.002649	0.3448	0.5988	1.092	50001	8000
tau2NMFSSEBLL	0.1644	0.07432	8.346E-4	0.06655	0.1494	0.3494	50001	8000
tau2SMALLPELTR	0.05586	0.03264	4.015E-4	0.01884	0.04797	0.141	50001	8000

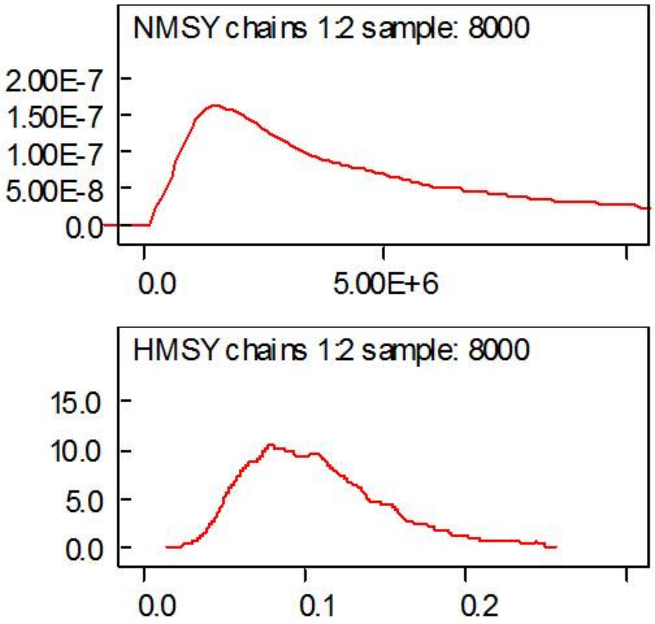
Low P_{82} run showing the observation error variance (τ^2)

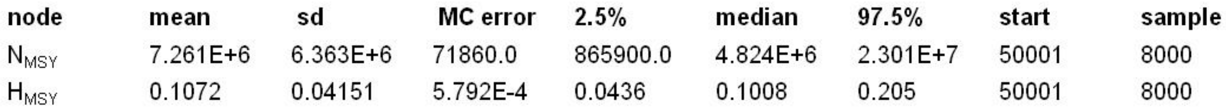


```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.1001	0.04208	7.802E-4	0.04685	0.09143	0.2033	50001	8000

Low P_{82} run showing the process error variance (σ^2)

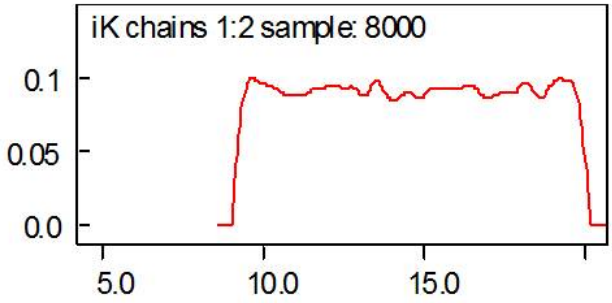




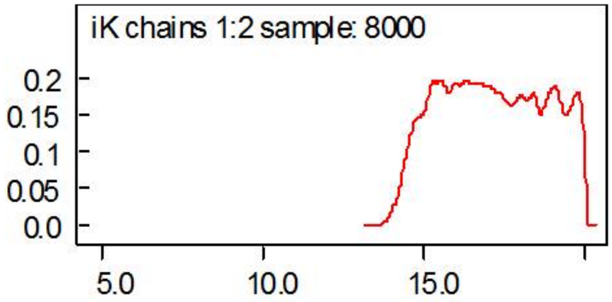
node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	7.261E+6	6.363E+6	71860.0	865900.0	4.824E+6	2.301E+7	50001	8000
H_{MSY}	0.1072	0.04151	5.792E-4	0.0436	0.1008	0.205	50001	8000

Low P_{82} run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})

Prior



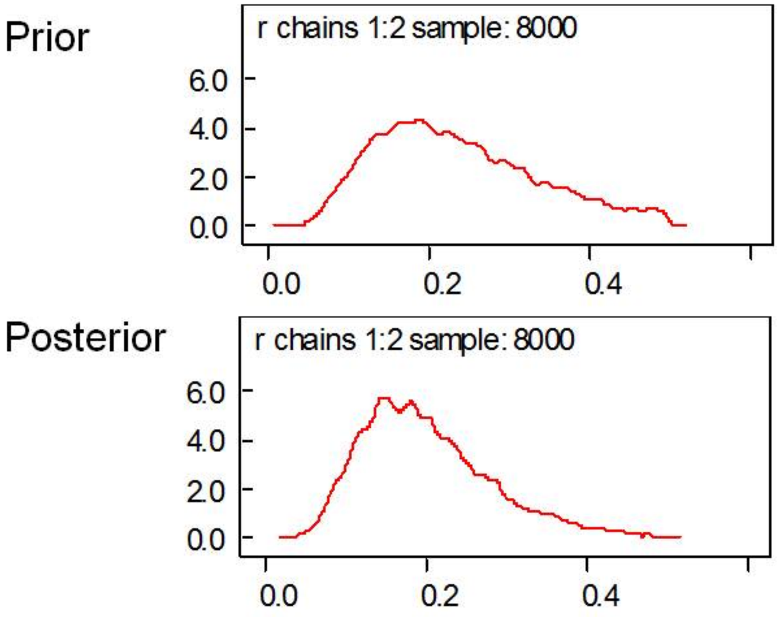
Posterior



```
iK ~ dunif(9.21,20.03)
K <- exp(iK)
```

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
iK	14.62	3.147	0.03243	9.49	14.61	19.75	50001	8000
Posterior								
iK	17.19	1.612	0.01858	14.47	17.13	19.89	50001	8000

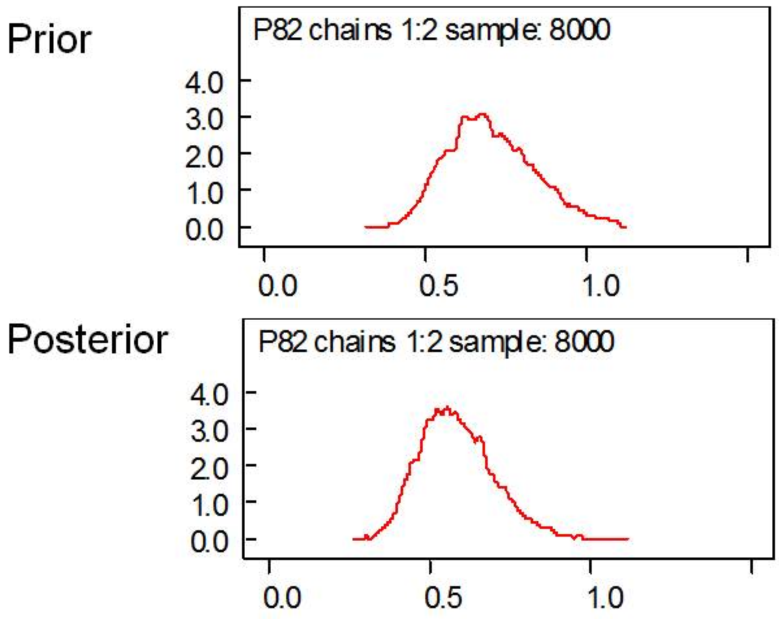
High K run showing the carrying capacity (*K=exp(iK)*)

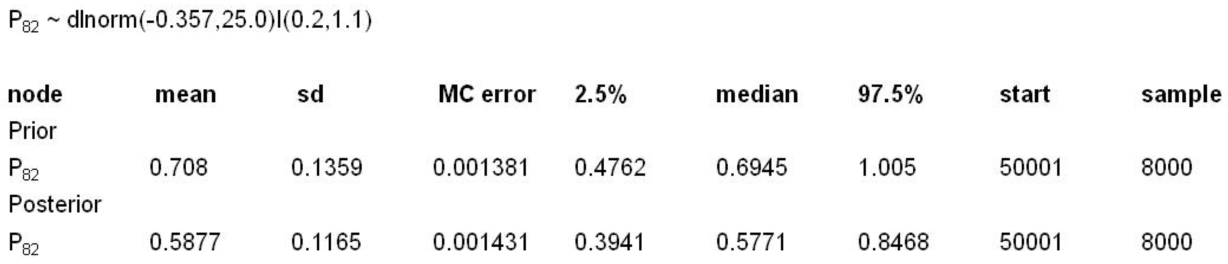


r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
r	0.236	0.09876	0.001084	0.08492	0.2215	0.4596	50001	8000
Posterior								
r	0.2014	0.07956	9.76E-4	0.08118	0.189	0.3898	50001	8000

High K run showing the intrinsic rate of increase (*r*)

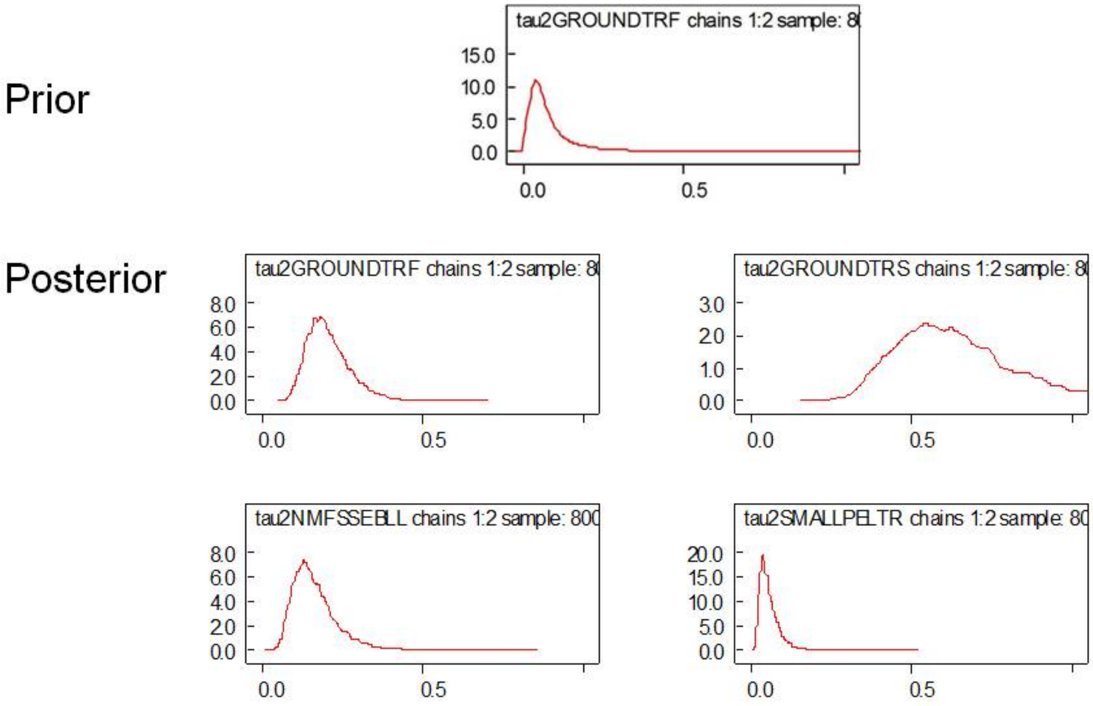




P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.5877	0.1165	0.001431	0.3941	0.5771	0.8468	50001	8000

High K run showing the initial depletion (P_{82})

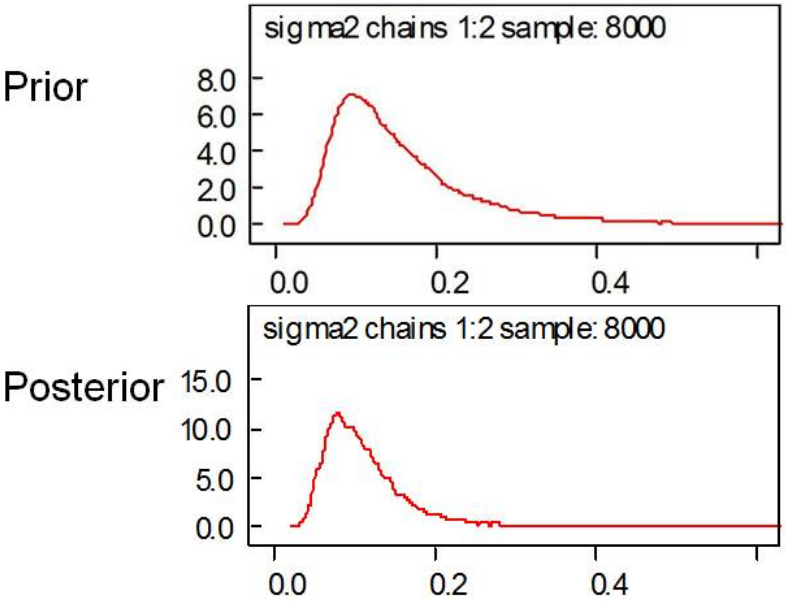


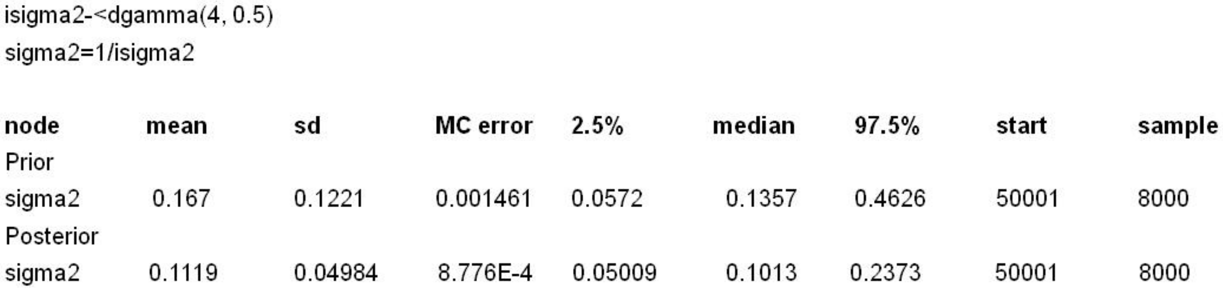
```
itau2GROUNDTRF<-dgamma(2.0, 0.1)
tau2GROUNDTRF=1/itau2GROUNDTRF
```

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.2076	0.07106	8.358E-4	0.1045	0.1953	0.3782	50001	8000
tau2GROUNDTRS	0.644	0.197	0.002815	0.3521	0.6151	1.112	50001	8000
tau2NMFSSEBLL	0.1667	0.07649	8.046E-4	0.06939	0.1507	0.359	50001	8000
tau2SMALLPELTR	0.05637	0.03317	4.122E-4	0.01869	0.04849	0.1387	50001	8000

High K run showing the observation error variance (τ^2)

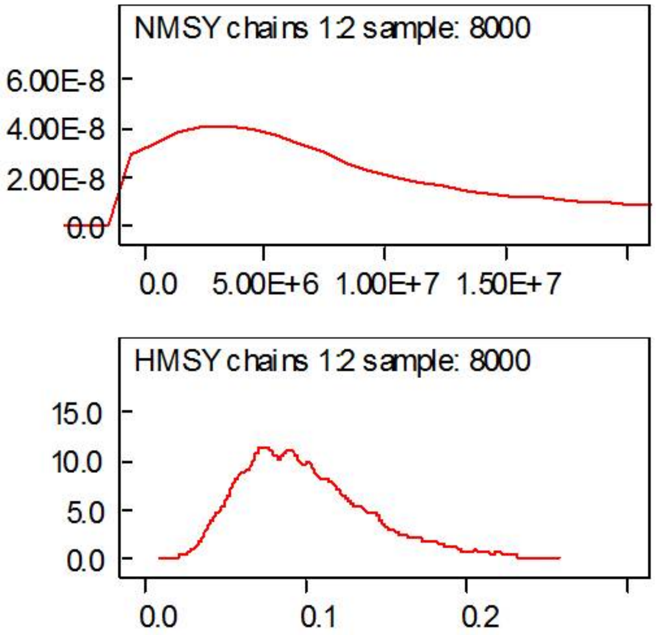




```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

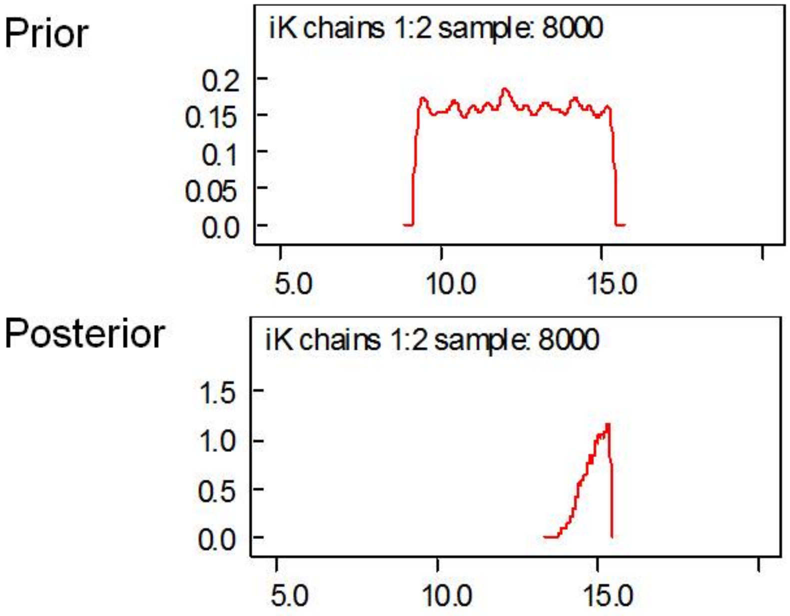
node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.1119	0.04984	8.776E-4	0.05009	0.1013	0.2373	50001	8000

High K run showing the process error variance (σ^2)



node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	4.303E+7	5.945E+7	7.12E+5	9.6E+5	1.377E+7	2.166E+8	50001	8000
H_{MSY}	0.1007	0.03978	4.88E-4	0.04059	0.09449	0.1949	50001	8000

High K run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})

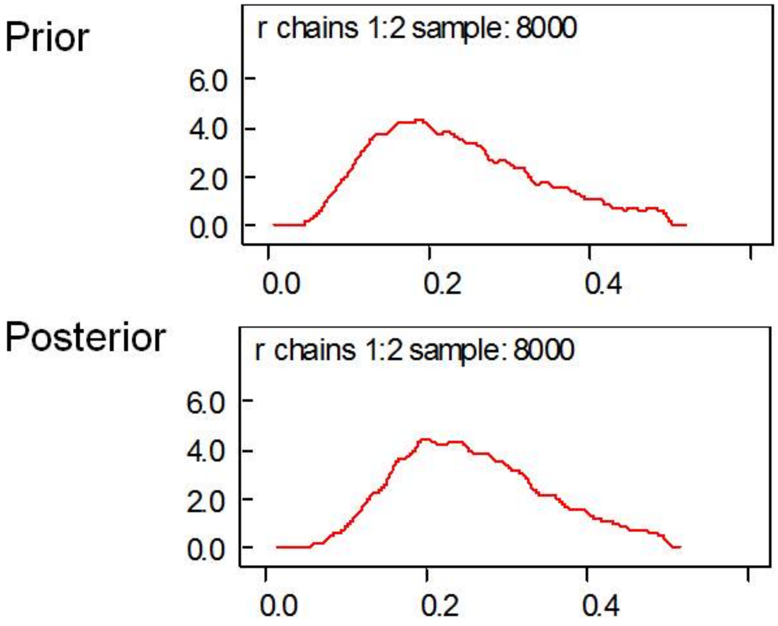


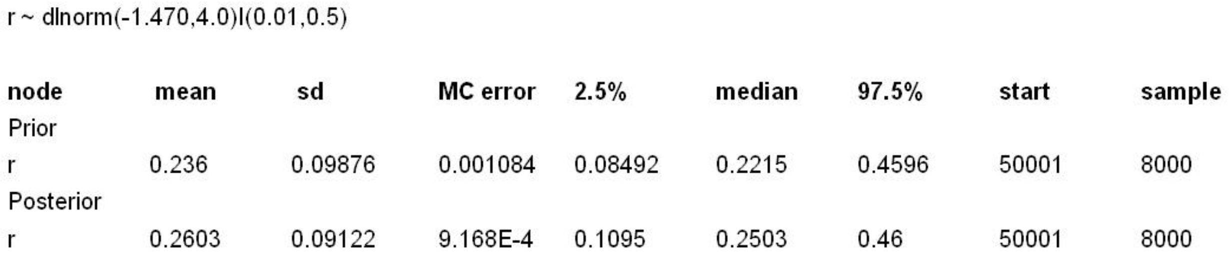
Upper bound of uniform iK does NOT cover all possible values for iK

```
iK ~ dunif(9.21,15.42)
K <- exp(iK)
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
iK	12.31	1.788	0.01926	9.368	12.29	15.27	50001	8000
Posterior								
iK	14.89	0.3688	0.004262	14.08	14.95	15.4	50001	8000

Low K run showing the carrying capacity (*K=exp(iK)*)

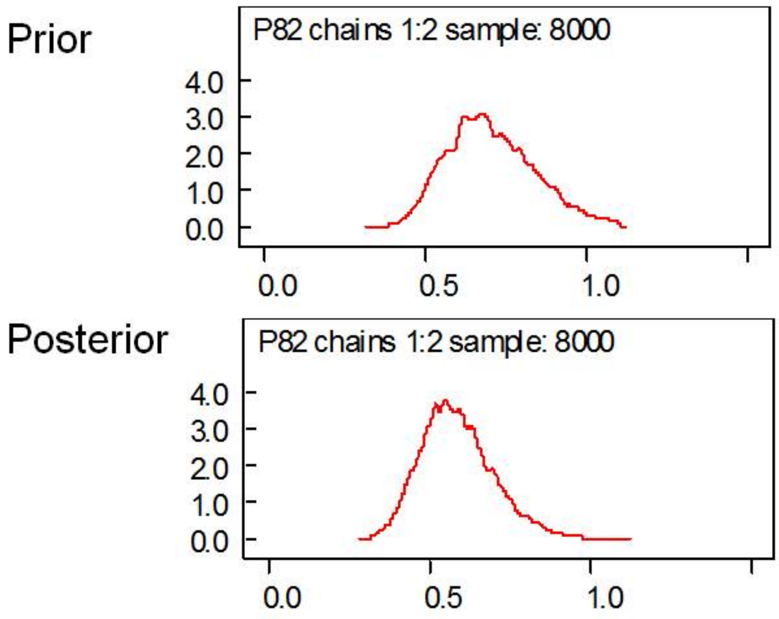




r ~ dlnorm(-1.470,4.0)I(0.01,0.5)

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
Prior								
r	0.236	0.09876	0.001084	0.08492	0.2215	0.4596	50001	8000
Posterior								
r	0.2603	0.09122	9.168E-4	0.1095	0.2503	0.46	50001	8000

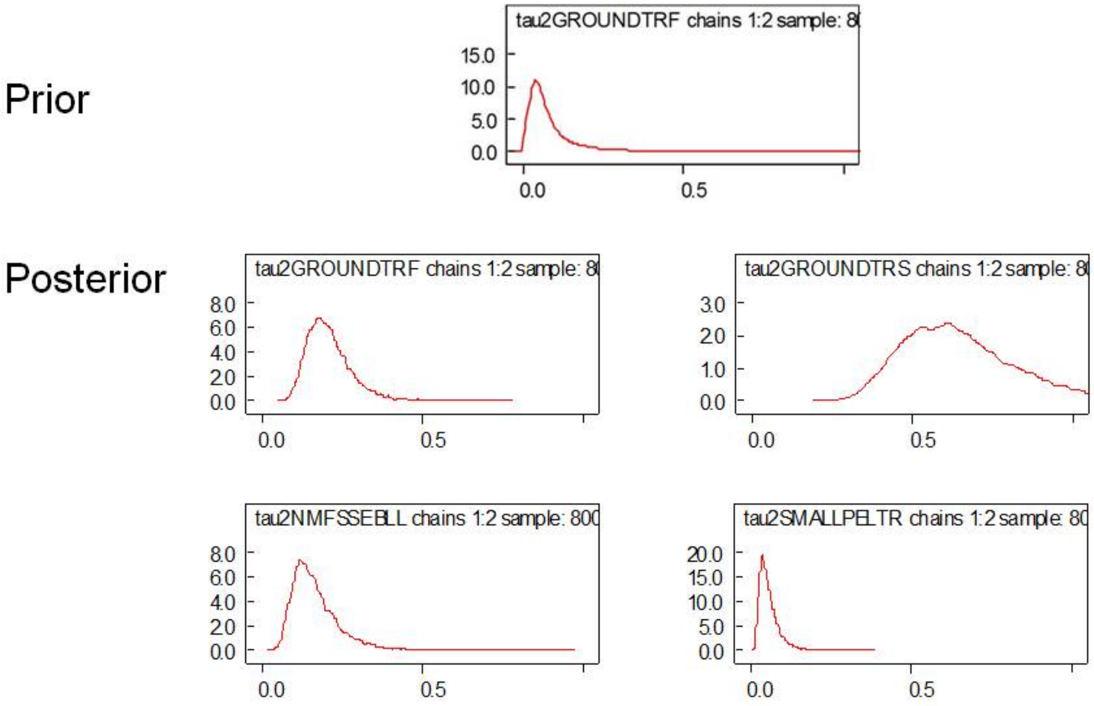
Low K run showing the intrinsic rate of increase (*r*)



P_{82} ~ dlnorm(-0.357,25.0)I(0.2,1.1)

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
P_{82}	0.708	0.1359	0.001381	0.4762	0.6945	1.005	50001	8000
Posterior								
P_{82}	0.5895	0.1154	0.001346	0.3956	0.578	0.8489	50001	8000

Low K run showing the initial depletion (P_{82})



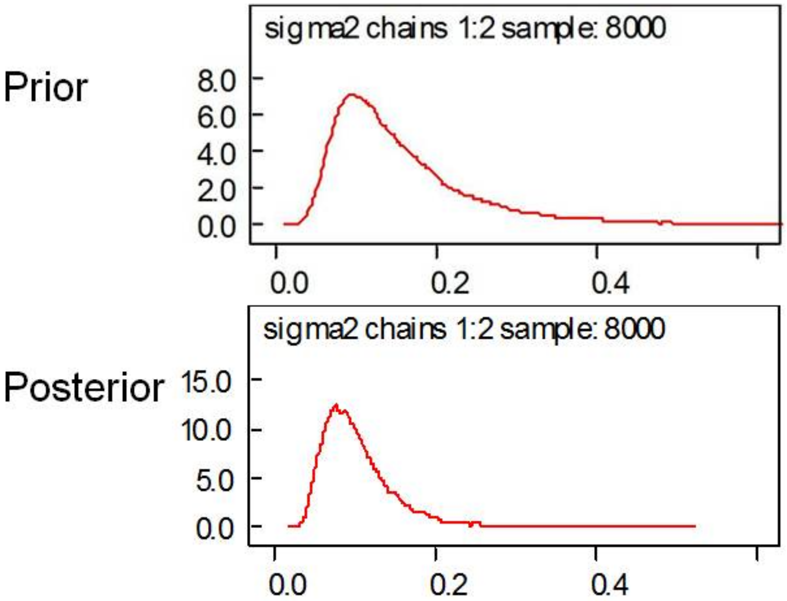
itau2GROUNDTRF<-dgamma(2.0, 0.1)

tau2GROUNDTRF=1/itau2GROUNDTRF

The prior (top panel) was the same for the four indices, but posteriors (four lower panels) differed.

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
prior								
tau2GROUNDTRF	0.09917	0.2513	0.002924	0.01795	0.05974	0.3957	50001	8000
Posterior								
tau2GROUNDTRF	0.2091	0.07083	8.636E-4	0.106	0.1976	0.3802	50001	8000
tau2GROUNDTRS	0.6596	0.1991	0.002879	0.3682	0.628	1.145	50001	8000
tau2NMFSSEBLL	0.167	0.07808	8.687E-4	0.06923	0.1502	0.36	50001	8000
tau2SMALLPELTR	0.05667	0.03285	4.171E-4	0.01899	0.04858	0.1418	50001	8000

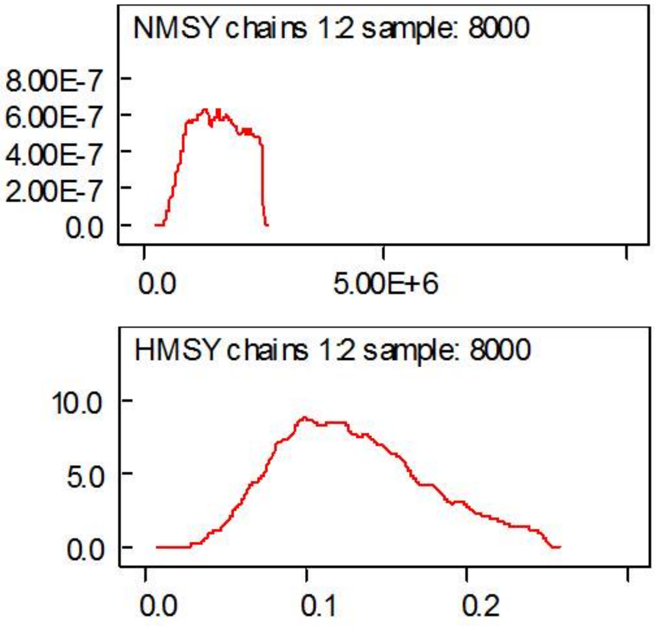
Low K run showing the observation error variance (τ^2)



```
isigma2-<dgamma(4, 0.5)
sigma2=1/isigma2
```

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
Prior								
sigma2	0.167	0.1221	0.001461	0.0572	0.1357	0.4626	50001	8000
Posterior								
sigma2	0.1038	0.04339	7.383E-4	0.04789	0.09476	0.2134	50001	8000

Low K run showing the process error variance (σ^2)



node	mean	sd	MC error	2.5%	median	97.5%	start	sample
N_{MSY}	1.556E+6	517200.0	5967.0	651600.0	1.552E+6	2.436E+6	50001	8000
H_{MSY}	0.1301	0.04561	4.584E-4	0.05474	0.1251	0.23	50001	8000

Low K run showing the predicted exploitable number at MSY (N_{msy}) and exploitation rate at MSY(H_{msy})

SEDAR

Southeast Data, Assessment, and Review

SEDAR 39

HMS Gulf of Mexico Smoothhound Shark Complex

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

1. Identify external characters from genetically verified specimens that will definitively differentiate among the three *Mustelus* species occurring in the northern Gulf of Mexico.

2. Increase tagging effort on the three *Mustelus* species occurring in the northern Gulf of Mexico to gain knowledge pertaining to movement patterns and seasonally mediated distribution.

3. Reexamine all aspects of the species-specific life histories of the three *Mustelus* species occurring in the Gulf of Mexico.

4. Encourage collection of the full suite of body length measurements (i.e. precaudal length, fork length, total length and stretch total length) of all *Mustelus* species occurring in the northern Gulf of Mexico to generate length-length relationships based on a robust sample size.

1.2 Commercial Fisheries Working Group Recommendations

1. Given the high difficulty in differentiating among the three species of *Mustelus* occurring in the Gulf of Mexico, even by experienced shark researchers, we feel it is not appropriate to recommend any species-specific identification by fishermen, observers, port samplers, or dealers. Collection of vertebral samples for systematic characterization of age compositions would also require that the whole specimen or a tissue sample be kept for subsequent macroscopic identification or for genetic analysis, respectively.

2. Increase temporal/spatial/fleet-specific shrimp fleet Observer Program coverage to improve bycatch estimates of *Mustelus* species in the shrimp trawl fishery.

3. Conduct research to explore and test the relationship between CPUEs based on shrimp fleet Observer Program and survey (SEAMAP) to indirectly estimate pre-2009 shrimp bycatch CPUE for *Mustelus* species when Observer program data were very limited.

1.3 Recreational Fisheries Working Group Recommendations

Given the high difficulty in differentiating among the three species of *Mustelus* occurring in the Gulf of Mexico, even by experienced shark researchers, we feel it is not appropriate to recommend any species-specific identification by fishermen or port samplers. Collection of vertebral samples for systematic characterization of age compositions would also require that the whole specimen or a tissue sample be kept for subsequent macroscopic identification or for genetic analysis, respectively.

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

We list below research recommendations that are more feasible and would allow improvement of future stock assessments of this stock:

- Since catches are dominated by shrimp trawl fishery discards, increase the spatio-temporal observer coverage of the shrimp fleet
- Explore the relationship between catch rates derived from the shrimp fleet observer program and those based on the SEAMAP survey to indirectly estimate shrimp bycatch CPUE prior to 2009 when observer program data were especially limited
- Reexamine and/or investigate all aspects of the life histories of the three *Mustelus* species occurring in the Gulf of Mexico

3. REVIEW PANEL RESEARCH RECOMMENDATIONS

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 Review Panel concurred with the research recommendations of the DW an AW. It is particularly important to maintain the ability to estimate the shrimp trawl bycatch for the future. As more years of data accumulate there will be an improvement in the ability to assess the stock.

The present model software requires that complete catch data are input to the assessment and that they are treated as known error free values. In principle it should be possible to use the shrimp fishery effort data along with the more reliable estimates of catch from 2009 onwards within the model to estimate historical catch and the uncertainties relating to it. It would be desirable to develop such a model which would have wider applicability to stocks that are affected by the same catch data problems.

While it is acknowledged that the species within the smoothhound complex are quite similar biologically, it has been recognised by studies elsewhere (e.g. Gaichas et al. 2012) that individual more vulnerable species within a complex can be adversely affected by aggregated management. This vulnerability may be due to particular species interactions or environmental sensitivity and not just individual species productivity characteristics. Such simulation work could be carried out for the Gulf smoothhound complex to determine whether any of the species may be particularly at risk. The three species in the Gulf smoothhound complex have thus-far proved impossible to tell apart visually, and there does not appear to be plans to allow for future estimation of annual total catch per species due to this problem (unless diagnostic morphological features are found). It would be advantageous for future assessments to have such information. Simple and cost effective methods to allow catch estimation per species should be investigated (e.g. random genetic sampling of the catch by observers).

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.

SEDAR
Southeast Data, Assessment, and Review

SEDAR 39

Gulf of Mexico Smoothhound Sharks Complex

SECTION V: Review Workshop Report

March 2015

SEDAR
4055 Faber Place Drive, Suite 201
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Table of Contents

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 Gulf of Mexico smoothhounds were deemed sound by the review panel. The data uncertainties were acknowledged; however, the catch data are predominantly derived from shrimp bycatch data that lack quantitative measures of uncertainty. Given that the catch data are considered error free in the model, it is important to have some measure of uncertainty for this information. An additional source of uncertainty that needs to be addressed in the future is the stock boundary as catches from the Mexican fishery may have an unrealized influence. The review panel agreed that the data were applied appropriately. The indices of abundance included in the model showed a high level of variability, but tended to show the same general agreement in the upward trend in recent years.

Gulf of Mexico smoothhounds were assessed as a species complex using a Bayesian Schaefer production model using WinBUGS. The Schaefer model is widely used and the review panel found the method to be appropriate and sufficiently robust. Given the assessment was conducted on a grouping of three species, the review panel noted issues could occur if the biology and population dynamics differed significantly between species. However, the review panel did not believe this was an issue for the current assessment.

The stock is most likely neither overfished, nor undergoing overfishing as the base case and all sensitivity runs result in current biomass ratios above 1 and exploitation ratios below 1. The model fits the CPUE data adequately, but this is dependent on the error-free assumption associated with the catch. The reliability of the stock status determination is dependent on the accuracy of the shrimp trawl bycatch estimates for these species.

Because of the high level of uncertainty associated with the derived shrimp trawl bycatch, the review panel suggested further exploration of alternative catch streams to help assess this uncertainty. Additionally, because the Schaefer model was used exclusively, it was not possible to provide insight into model uncertainty. Overall, the review panel believed that the model and associated sensitivities captured the principle uncertainties associated with the assessment.

The review panel considers the base case and corresponding sensitivity runs the best scientific information available.

Key improvements recommended by the review panel for future assessments included the exploration of a model that allows catch estimation given information on fishing effort, inclusion of process error in projections, simulation studies to determine if any species may be at particular risk if managed as part of a complex, and looking into simple and cost effective methods to estimate the proportion of each species represented in the catch.

SEDAR 39 HMS Terms of Reference: Gulf of Mexico Smoothhound complex

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?

The panel agreed with the majority of the decisions reached at the Data Workshop which included the decision to treat the Gulf smoothhound as a separate complex from the Atlantic. The DW also suggested discard survival rates for the calculation of dead discards to be used for the catches. These values are likely to be the best available but, nevertheless, are subject to high uncertainty and need to be treated with caution as they may have a large effect on the estimated catch.

The DW also recommended the reconstruction of shrimp trawl bycatch using the summer SEAMAP CPUE with a linear or non-linear trend. The panel felt that the use of these coarse smoothers may not offer the best way of reducing the noise in the time series but agreed that they were adequate for the present assessment as there is a clear upward trend in the time series. This is an improvement over earlier methods used in SEDAR 34 that assumed constant CPUE in the years prior to 2009.

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

In general, data uncertainties are discussed and acknowledged. Ranges are given for the biological parameters and a rationale given for the choice of values used. However, the catch data are dominated by the shrimp bycatch data and no quantitative estimates of uncertainty are provided. This is a difficult task, but some of the uncertainty could be captured from the GLM models used to model effort and the CVs of the SEAMAP survey to provide minimum estimates of variance. Given that the catch data are treated as error free in the model, it is important to try to quantify the uncertainty in these data.

An uncertainty that deserves some acknowledgement is stock boundary within the Gulf, currently assumed to be the US EEZ, and possible catches outside that boundary (e.g. by Mexico) that might influence the complex.

c) Are data applied properly within the assessment model?

The assessment model is a Schaefer model implemented in Bayesian framework using WinBUGS. The model is fit to survey indices that are assumed to be observed with error while the catch data are treated as known. One potential statistical problem is that the SEAMAP summer index is used to derive the catch data and is also used as an abundance index in the model and it, therefore, may unduly weight model results towards this index. The panel felt this is unlikely to be a significant issue but that ways of avoiding this problem in the future would be desirable. Overall the panel agreed that the data had been applied appropriately.

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

The indices used in the model show a great deal of variability but do show some general agreement in the long term upward trend in recent years. This is also reflected in the hierarchical index that seeks to identify the common signal in the survey data. It seems likely that the indices are adequate to estimate general stock trends.

It is more difficult to assess the adequacy of the catch data as these are derived from discard estimates that are inherently uncertain and the use of a survey index that is clearly noisy. The trend in the catches is driven by the effort of the shrimp trawl fleet and as this signal is very strong, the gross trend in catches is likely to be adequately reflected in the data. What is more uncertain is the scale of the catches and inter-annual variability.

Sensitivity testing of the assessment making different assumptions about the surveys and the level of catch suggests that the data do provide a basis for supporting 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?

The assessment model used was a Schaefer production model that includes process error in the annual biomass. The inclusion of process error is an important feature since attempts to fit the model without it proved unsuccessful. Including process error is more realistic than implementations without it but the fact that is was found to be critical to fit the model successfully may be an indication of lack of real information in the data. However, overall the panel felt the method was appropriate and sufficiently robust for the purpose.

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

The model was configured properly and is consistent with standard practices. The main elements of configuration relate to the choice of priors. Those chosen were generally moderately informative reflecting prior belief in the range of possible values of the parameters. The sensitivity to the choice of priors was investigated. Typically the results did not show undue sensitivity to the priors but the degree to which the priors were updated by the data in the posterior distributions was quite small suggesting that the data are not particularly informative. In the case of carrying capacity for example, a bounded uniform prior was used but in the posterior distributions the upper bound was always reached. This suggests there was little information in the data to estimate K.

c) Are the methods appropriate for the available data?

The Schaefer model is widely used and is appropriate for the available data. One feature that merits comment is that usually such a model would be used to describe the dynamics of a single stock. In this assessment a species complex has in effect been treated as a uniform stock and problems affecting one of the components could be hidden if the species concerned exhibited markedly different biology and dynamics. The panel had no reason to believe that this was a problem, however.

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 abundance, exploitation, and biomass estimates are consistent with the estimated catches and the general trend seen in the indices. To some degree the consistency between the indices and the estimated catch is produced by the fact that the catches are derived from the trend in the SEAMAP summer survey. Most sensitivity runs suggest the same stock status implying the assessment results are insensitive to a range of alternative assumptions. This offers some reassurance in making inferences about stock status.

b) Is the stock overfished? What information helps you reach this conclusion?

The stock is most likely not overfished since the base run and all the sensitivity runs all lie in the region where the ratio N_{cur}/N_{msy} is >1. Addition runs requested at the review meeting that included alternative catch series did not alter this conclusion.

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

The stock is most likely not experiencing overfishing since the base run and all the sensitivity runs all lie in the region where the ratio H_{cur}/H_{msy} is <1. Additional runs requested at the review meeting that included alternative catch series did not alter 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?

The assessment method does not explicitly estimate a stock-recruitment relationship. The growth of the stock is captured by the r parameter that expresses the rate at which the population approaches the carrying capacity, K, of the environment. The model estimates of these parameters are influenced by the priors in the model. In the case of r this was derived using plausible biological information and provides a credible basis for evaluating future stock conditions. In the case of carrying capacity, the data do not appear informative as the posterior distributions are constrained by the upper bound specified in the prior. It is more difficult to judge the usefulness of this estimate.

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 status determination criteria are expressed as the ratio of current stock numbers or harvest rate relative to the MSY values calculated within the Schaefer model. Such estimators are more robust than absolute values as they will be less sensitive to changes in scale that might result, for example, from uncertainty in K. The model fits the CPUE indices adequately but this is conditioned on the assumption that the catch data are more or less error free. Hence the reliability of the stock status indicators is dependent on the veracity of the shrimp bycatch estimates.

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?

The projections are based directly on the MCMC samples taken from the model fit and are then run forward using the same Schaefer model formulation but without the associated process error applied to the population. The core method is consistent with accepted practices and data.

The method assumes a fixed catch (at various levels) for a 10 year forward projection period. As the fishery is largely a bycatch fishery this may not best capture likely scenarios since the actual catch will be driven by effort in shrimp fishery rather than a catch constraint. However, fixed catch scenarios may better reflect management preference and the projections are likely to capture adequately the effects of a range of possible fishing regimes.

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

The methods are appropriate for the assessment model and outputs.

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

The methods are useful to support inference of probable future conditions as they are limited to a time period where the initial conditions (which are the best known) inform the outcome of the projections. Longer projections would be less useful as they become dominated by populations generated entirely from the population dynamics parameters (rather than observations) and are subject to cumulative errors. Given the large distance of the evaluated stock status from the MSY reference points it likely that the projections are robust since only assumptions of very large fixed catches are sufficient to change the perceived status of the stock. Large catches seem less likely in the future given the current status of the shrimp fishery.

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

Uncertainties in the model parameters are captured in the MCMC samples used in the projections and the sensitivity runs give insight into the uncertainties about a range of model assumptions. An important source of uncertainty that is not included in the projections is the process error estimated in the assessment model. Technical problems with the WinBUGS software appear to have prevented the inclusion of this aspect of population variation. It does mean that the range of projected outcomes will be smaller than the range that would otherwise occur of process error was included and could affect the perceived risk of overfishing.

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 Bayesian model framework and sensitivity analysis go a long way to capturing the principal uncertainties associated with the assessment. Perhaps the most important source of uncertainty in the data relates to the shrimp trawl bycatch as this has been derived from effort data and the SEAMAP summer survey. The implications of the uncertainty in these data were explored using high and low catch scenarios. While this is helpful in considering uncertainty in the scale of the catches, it does not consider alternative trends in the catch which may have a larger effect on the estimated population trend. It would be worth investigating alternative but plausible catch streams to explore this uncertainty.

The assessment relies almost entirely on the Schaefer model and while some model assumptions were subject to sensitivity analysis, it is not really possible to evaluate model uncertainty without comparison to alternative structural models.

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}).

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 panel concurred with the research recommendations of the DW an AW. It is particularly important to maintain the ability to estimate the shrimp trawl bycatch for the future. As more years of data accumulate there will be an improvement in the ability to assess the stock.

The present model software requires that complete catch data are input to the assessment and that they are treated as known error free values. In principle it should be possible to use the shrimp fishery effort data along with the more reliable estimates of catch from 2009 onwards within the model to estimate historical catch and the uncertainties relating to it. It would be desirable to develop such a model which would have wider applicability to stocks that are affected by the same catch data problems.

While it is acknowledged that the species within the smoothhound complex are quite similar biologically, it has been recognised by studies elsewhere (e.g. Gaichas et al. 2012) that individual more vulnerable species within a complex can be adversely affected by aggregated management. This vulnerability may be due to particular species interactions or environmental sensitivity and not just individual species productivity characteristics. Such simulation work could be carried out for the Gulf smoothhound complex to determine whether any of the species may be particularly at risk. The three species in the Gulf smoothhound complex have thus-far proved impossible to tell apart visually, and there does not appear to be plans to allow for future estimation of annual total catch per species due to this problem (unless diagnostic morphological features are found). It would be advantageous for future assessments to have such information. Simple and cost effective methods to allow catch estimation per species should be investigated (e.g. random genetic sampling of the catch by observers).

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.

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 input data were subject to review and appear to offer the best information available. Work has been done to try to improve the catch estimates from the shrimp fishery by using the SEAMAP CPUE data. This is an important change from the assumption of constant CPUE used in SEDAR 34 but more work is required to make better use of the available data (see section 6). Nevertheless the assessment makes good use of currently available software and data. In the interests of transparency the WinBUGS code used in the assessment should be included in the assessment report.

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

See section 6. The Schaefer modelling software needs to be developed to allow incomplete catch data and indices of fishing effort to be included in the model.

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 panel requested additional runs as part of its review. The panel 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.

References

Gaichas S, Gamble R, Fogarty M, Benoit H and others (2012) Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. Mar Ecol Prog Ser 459:275–292

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HMS Gulf of Mexico Smoothhound Shark Complex

Section VI: Addenda and Post-Review Updates

February 2015

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4. Revisions

This addendum documents the results of three additional runs requested by the CIE reviewers at the SEDAR 39 Review Workshop (RW) for Gulf of Mexico Smoothhound Complex. In addition to the base and sensitivity scenarios previously run, the reviewers identified three additional sensitivity analyses to run to provide verification that the results of the assessment were robust.

4.1. Three additional sensitivity analyses

The three additional sensitivity runs were:

- Base run with 3 chains for MCMC
- Using a linear trend of the SEAMAP summer CPUE vs. year, and ratio of the mean 2009-2012 bycatch CPUE and the mean 2009-2012 SEAMAP summer CPUE to scale the bycatch CPUE for 1982-2008.
- Very pessimistic scenario with combination of high catch, low productivity, and high initial depletion.

Other than these changes, assessment methods were identical to those presented in section 3 of the Assessment Report.

4.2. Sensitivity results

Convergence diagnostics for the base run with 3 chains for MCMC show 1) time series history revealing that there was good mixing of the three chains for key parameters (carrying capacity, intrinsic rate of increase, and initial depletion) (**Figure 4.1**), 2) autocorrelations for key parameters quickly decreasing after an initial lag (**Figure 4.2**), and 3) the Gelman-Rubin diagnostic indicating good convergence for the key parameters of interest because the ratio of the width of the central 80% interval of the pooled runs and the average width of the 80% intervals within the individual runs converged to 1 and both the pooled and within interval widths stabilized (**Figure 4.3**).

Catches of smoothhounds in the Gulf of Mexico, 1982-2012 were constructed using a linear trend of the SEAMAP summer CPUE to scale the bycatch CPUE for 1982-2008 for the additional bycatch sensitivity run identified by the reviewers. The most noticeable differences are that catches are lower in the initial years and higher around the maximum catch years (around 2002) than corresponding catches used for the base run (**Figure 4.4**).

Summary of results (mean and CV) for the three additional three sensitivity runs identified by the reviewers are provided in **Table 4.1**. The results of the base run with 3 chains are almost identical to the results of the base run with 2 chains. The results of the very pessimistic scenario run (i.e. combination of high catch, low productivity, and high initial depletion) are very similar to the high catch sensitivity scenario previously run. None of these three additional sensitivity runs altered the results or conclusions of the base run, predicting that the stock was not overfished (N_{2012}/N_{MSY} = 1.78 for base run and N_{2012}/N_{MSY} = 1.76-1.78 for the three additional sensitivity runs) and that overfishing was not occurring (H_{2012}/H_{MSY} = 0.18 for base run and H_{2012}/H_{MSY} = 0.16-0.21 for the three additional sensitivity runs). Overall, parameters were estimated reasonably well, with all CVs <1.

4.3. Corrections/changes

Page 22: All "ε_t" of the Assessment Report should be "ε"

Page 22: Equation 1 of the Assessment Report should have two state equations for the initial time period (two-level hierarchical approach) and one state equation for subsequent periods.

$$P_{82} = \left(P_{Assumed\_initial\_mean\_depletion\_prior\_1982}\right)e^{\varepsilon 82}$$

$$P_1 = \left(P_{82}\right)e^{P\varepsilon}$$

$$P_t = \left(P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_{t-1}}{K}\right)e^{P\varepsilon} \qquad t=2,\ldots,N \qquad (1)$$

Page 23: “hats” were incorrectly printed in equation 3 of the Assessment Report. “hats” in equation 3 should be:

$$\hat{q}_j = e^{\left(\frac{\sum_{t=1}^{t=y}\left(\ln(I_{j,t}) - \ln(\hat{N}_t)\right)}{n_j}\right)}$$

Page 26: "Both observation and process errors of individual indices of abundance were captured in the single hierarchical index of abundance." should be added to end of Scenario 1 description of the Assessment Report.

Page 29: "According to the RMSE, the best fit corresponded to the SEAMAP Groundfish Trawl (Summer) index whereas the NMFS SE Bottom Longline had the poorest fit (**Table 3.3**)." in the first paragraph of the Assessment Report should be "According to the RMSE/(Index Mean), the fits corresponding to the SE Bottom Longline index and NMFS Small Pelagics Trawl index were better than the fits from the NMFS SEAMAP Groundfish Trawl (Fall) index and SEAMAP Groundfish Trawl (Summer) index (**Table 4.3** herein)."

Page 30: "The posteriors for the NMFS SEAMAP Groundfish Trawl (Fall) and NMFS SE Bottom Longline indices τ^2 were fairly similar to the priors, but the posterior for the NMFS SEAMAP Groundfish Trawl (Fall) index τ^2 was substantially larger and that for the NMFS SEAMAP Groundfish Trawl (Fall) index τ^2 was lower **(Figure 3.11**). The posterior for process variance (σ^2) favored lower values (**Figure 3.12**)." in the first paragraph of the Assessment Report should be "The posteriors for the NMFS SEAMAP Groundfish Trawl (Fall) and NMFS SE Bottom Longline indices τ^2 were fairly similar to the priors, but the posterior for the NMFS SEAMAP Groundfish Trawl (Summer) index τ^2 was substantially larger and that for the NMFS Small Pelagics Trawl index τ^2 was smaller **(Figure 3.11**). The posterior for process error variance (σ^2) favored lower values (**Figure 3.12**)."

Page 31: "RMSE" in the 3 third paragraph of the Assessment Report should be "RMSE/(Index Mean)"

Page 32: "RMSE" in the 2 second and the fourth paragraphs of the Assessment Report should be "RMSE/(Index Mean)"

Page 33: "The RMSE ranged from 0.114 to 0.121 for the NMFS SE Bottom Longline index, from 0.070 to 0.075 for the NMFS SEAMAP Groundfish Trawl (Fall) index, from 0.031 to 0.035 for the NMFS SEAMAP Groundfish Trawl (Summer) index, and from 0.064 to 0.077 for the NMFS Small Pelagics Trawl index." in the third paragraph of the Assessment Report should be "The RMSE/(Index Mean) ranged from 0.268 to 0.284 for the NMFS SE Bottom Longline index, from 0.485 to 0.517 for the NMFS SEAMAP

Groundfish Trawl (Fall) index, from 0.485 to 0.535 for the NMFS SEAMAP Groundfish Trawl (Summer) index, and from 0.194 to 0.226 for the NMFS Small Pelagics Trawl index."

Page 39: CVs were missing in **Table 3.1** of the Assessment Report and have been added in **Table 4.2** herein.

Page 41: RMSE in **Table 3.3** of the Assessment Report have been changed to RMSE/ (Index Mean) in **Table 4.3** herein.

Page 42: "F/F_{msy}" in **Table 3.4** of the Assessment Report should be "H/H_{msy}".

Page 43: All "EV" in **Table 3.5** of the Assessment Report on page 43 should be "Mean".

Pages 44-45: RMSE in **Table 3.6** of the Assessment Report have been changed to RMSE/(Index Mean) in **Table 4.4** herein.

Page 46: All "EV" in **Table 3.7** of the Assessment Report should be "Mean".

Page 49: "*Landings(lb rw)*" of **Figure 3.2** y-axis label of the Assessment Report should be "*Landings(numbers)*".

Page 60: "Prior and" should be deleted from **Figure 3.13** legend of the Assessment Report.

Page 67: "(A)" should be deleted from **Figure 3.20** legend of the Assessment Report.

4.4. Tables

Table 4.1. Summary of results (mean and CV) for the three additional three sensitivity runs identified by the reviewers (3 chains, Linear Bycatch, and High Catch + Low r + Low P_{82}). N_{2013} ratio is N_{2013}/K. All abundance metrics refer to exploitable number. H is the exploitation rate. P_{1982} is N_{1982}/K. M is the average (age 1-max) natural mortality rate.

	Base		**3 chains**		**Linear Bycatch**		**H Catch & L r & LP$_{82}$**		**High Catch**	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
K	1.44E+07	0.88	1.44E+07	0.89	1.54E+07	0.83	2.06E+07	0.61	1.88E+07	0.67
r	0.212	0.40	0.215	0.39	0.210	0.39	0.188	0.42	0.223	0.39
MSY	6.89E+05	0.95	7.02E+05	0.96	7.45E+05	0.91	8.91E+05	0.69	9.61E+05	0.74
N_{2012}	1.27E+07	0.90	1.28E+07	0.91	1.37E+07	0.85	1.80E+07	0.64	1.67E+07	0.70
H_{2012}	0.018	0.96	0.019	0.99	0.016	0.97	0.018	0.77	0.021	0.81
N_{2013}ratio	0.787	0.24	0.788	0.24	0.787	0.24	0.7885	0.23	0.785	0.24
N_{1982}	5.28E+06	0.98	5.27E+06	0.99	5.65E+06	0.94	6.03E+06	0.71	6.95E+06	0.79
H_{2012}/H_{MSY}	**0.179**	**0.89**	**0.179**	**0.91**	**0.161**	**0.92**	**0.208**	**0.72**	**0.196**	**0.73**
N_{2012}/N_{MSY}	**1.776**	**0.16**	**1.777**	**0.17**	**1.777**	**0.16**	**1.755**	**0.17**	**1.778**	**0.16**
N_{MSY}	7.19E+06	0.88	7.21E+06	0.89	7.71E+06	0.83	1.03E+07	0.61	9.42E+06	0.67
H_{MSY}	0.106	0.40	0.107	0.39	0.105	0.39	0.094	0.42	0.112	0.39
P_{1982}	0.589	0.20	0.587	0.20	0.586	0.20	0.428	0.19	0.588	0.20
MSST ((1-M)*N_{msy}	5.53E+06		5.55E+06		5.93E+06		7.43E+06		7.24E+06	
Convergence diagnostic										
Chain mixing	Good		Good		Good		Good		Good	
Autocorrelations	Low		Low		Low		Low		Low	
Gelman-Rubin	Good		Good		Good		Good		Good	
(MC error)/(posterior sd)	<5%		<5%		<5%		<5%		<5%	

Table 4.2. Standardized hierarchical index of abundance with CVs used in sensitivity scenario 1. The highlighted column indicates the previously missing CVs added.

Year	Index	CV
1982	0.834	0.629
1983	1.464	1.322
1984	0.664	0.587
1985	0.564	0.644
1986	0.597	0.582
1987	0.563	0.536
1988	0.373	0.486
1989	0.736	0.403
1990	0.798	0.372
1991	0.422	0.416
1992	1.116	0.363
1993	0.703	0.367
1994	1.405	0.336
1995	1.420	0.344
1996	0.731	0.356
1997	0.810	0.346
1998	0.801	0.387
1999	0.663	0.370
2000	1.467	0.289
2001	0.843	0.298
2002	0.895	0.267
2003	0.817	0.279
2004	0.836	0.264
2005	1.021	0.376
2006	1.578	0.255
2007	1.067	0.253
2008	1.097	0.289
2009	1.915	0.250
2010	1.389	0.257
2011	1.470	0.260
2012	1.943	0.255

Table 4.3. Summary of results (mean and CV) for base run. N_{2013} ratio is N_{2013}/K. All abundance metrics refer to exploitable number. H is the exploitation rate. P_{1982} is N_{1982}/K. M is the average (age 1-max) natural mortality rate. Highlighted fields indicate fields in which data have been changed.

Run	**Base**	
	Mean	CV
K	1.44E+07	0.88
r	0.212	0.40
MSY	6.89E+05	0.95
N_{cur}	1.27E+07	0.90
$H_{2012cur}$	0.018	0.96
N_{cur+1}ratio	0.787	0.24
N_{1982}	5.28E+06	0.98
H_{cur}/H_{MSY}	**0.179**	**0.89**
$Ncur/N_{MSY}$	**1.776**	**0.16**
N_{MSY}	7.19E+06	0.88
H_{MSY}	0.106	0.40
P_{1982}	0.589	0.20
MSST ((1-M)*N_{msy}	5.53E+06	
Convergence diagnostics		
Chain mixing	Good	
Autocorrelations	Low	
Gelman-Rubin	Good	
(MC error)/(posterior sd)	<5%	
Abundance index	**RMSE/(Index Mean)**	
NMFS SE Bottom LL	0.269	
NMFS SEAMAP Gr Tr (F)	0.487	
NMFS SEAMAP Gr Tr (S)	0.487	
NMFS Small Pel Tr	0.210	

Table 4.4. Summary of results (mean and CV) for sensitivity runs 5-13. N_{2013} ratio is N_{2013}/K. All abundance metrics refer to exploitable number. *H* is the exploitation rate. P_{1982} is N_{1982}/K. *M* is the average (age 1-max) natural mortality rate. Highlighted fields indicate fields in which data have been changed.

Run	**Base**		**Low r**		**High r**		**Large ProErr**		**Large ObsErr**		**Large Pro&Obs**	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
K	1.44E+07	0.88	1.58E+07	0.82	1.34E+07	0.93	1.30E+07	0.93	1.44E+07	0.89	1.31E+07	0.93
r	0.212	0.40	0.182	0.42	0.241	0.37	0.199	0.40	0.210	0.39	0.195	0.40
MSY	6.89E+05	0.95	6.59E+05	0.92	7.28E+05	1.00	5.70E+05	0.98	6.80E+05	0.96	5.61E+05	0.98
N_{2012}	1.27E+07	0.90	1.39E+07	0.85	1.19E+07	0.96	1.20E+07	0.95	1.27E+07	0.91	1.20E+07	0.95
H_{2012}	0.018	0.96	0.016	0.99	0.021	0.97	0.020	0.93	0.019	0.97	0.020	0.92
N_{2013}ratio	0.787	0.24	0.785	0.24	0.736	0.35	0.848	0.19	0.793	0.23	0.847	0.19
N_{1982}	5.28E+06	0.98	5.85E+06	0.93	4.85E+06	1.04	5.48E+06	1.00	5.56E+06	0.99	5.72E+06	1.00
H_{2012}/H_{MSY}	**0.179**	**0.89**	**0.186**	**0.92**	**0.175**	**0.86**	**0.196**	**0.79**	**0.180**	**0.87**	**0.198**	**0.77**
N_{2012}/N_{MSY}	**1.776**	**0.16**	**1.768**	**0.17**	**1.777**	**0.16**	**1.834**	**0.14**	**1.782**	**0.16**	**1.828**	**0.14**
N_{MSY}	7.19E+06	0.88	7.90E+06	0.82	6.71E+06	0.93	6.51E+06	0.93	7.19E+06	0.89	6.57E+06	0.93
H_{MSY}	0.106	0.40	0.091	0.42	0.120	0.37	0.099	0.40	0.105	0.39	0.097	0.40
P_{1982}	0.589	0.20	0.588	0.19	0.587	0.20	0.562	0.20	0.593	0.19	0.568	0.20
MSST ((1-M)*N_{msy}	5.53E+06		6.08E+06		5.16E+06		5.01E+06		5.53E+06		5.05E+06	
Convergence diagnostics												
Chain mixing	Good		Good		Good		Good		Good		Good	
Autocorrelations	Low		Low		Low		Low		Low		Low	
Gelman-Rubin	Good		Good		Good		Good		Good		Good	
(MC error)/(posterior sd)	<5%		<5%		<5%		<5%		<5%		<5%	
Abundance index	**RMSE/(Index Mean)**		**RMSE/(Index Mean)**		**RMSE/(Index Mean)**		**RMSE/(Index Mean)**		**RMSE/(Index Mean)**		**RMSE/(Index Mean)**	
NMFS SE Bottom LL	0.269		0.268		0.268		0.275		0.282		0.284	
NMFS SEAMAP Gr Tr (F)	0.487		0.487		0.485		0.514		0.494		0.517	
NMFS SEAMAP Gr Tr (S)	0.487		0.487		0.486		0.525		0.501		0.535	
NMFS Small Pel Tr	0.210		0.209		0.211		0.235		0.194		0.226	
DIC for model comparison	-197.906		-197.973		-197.571		-196.532		-195.252		-194.221	

Table 4.4. (Continued)

Run	Base		High P_{82}		Low P_{82}		High K		Low K	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
K	1.44E+07	0.88	1.43E+07	0.88	1.45E+07	0.88	8.61E+07	1.38	3.11E+06	0.33
r	0.212	0.40	0.215	0.40	0.214	0.39	0.201	0.40	0.260	0.35
MSY	6.89E+05	0.95	6.97E+05	0.96	7.03E+05	0.94	3.96E+06	1.51	1.93E+05	0.40
N_{2012}	1.27E+07	0.90	1.29E+07	0.91	1.27E+07	0.90	7.62E+07	1.42	2.78E+06	0.36
H_{2012}	0.018	0.96	0.019	1.00	0.019	0.97	0.012	1.44	0.042	0.44
N_{2013}ratio	0.787	0.24	0.786	0.24	0.789	0.23	0.786	0.24	0.786	0.23
N_{1982}	5.28E+06	0.98	6.25E+06	0.99	4.25E+06	0.97	3.11E+07	1.51	1.19E+06	0.47
H_{2012}/H_{MSY}	**0.179**	**0.89**	**0.179**	**0.91**	**0.177**	**0.88**	**0.111**	**1.31**	**0.345**	**0.47**
N_{2012}/N_{MSY}	**1.776**	**0.16**	**1.796**	**0.15**	**1.753**	**0.17**	**1.769**	**0.17**	**1.795**	**0.15**
N_{MSY}	7.19E+06	0.88	7.17E+06	0.89	7.26E+06	0.88	4.30E+07	1.38	1.56E+06	0.33
H_{MSY}	0.106	0.40	0.107	0.40	0.107	0.39	0.101	0.40	0.130	0.35
P_{1982}	0.589	0.20	0.740	0.18	0.430	0.20	0.588	0.20	0.590	0.20
MSST ((1-M)*N_{msy}	5.53E+06		5.51E+06		5.58E+06		3.31E+07		1.20E+06	
Convergence diagnostics										
Chain mixing	Good		Good		Good		Good		Good	
Autocorrelations	Low		Low		Low		Low		Low	
Gelman-Rubin	Good		Good		Good		Good		Good	
(MC error)/(posterior sd)	<5%		<5%		<5%		<5%		<5%	
Abundance index	**RMSE/(Index Mean)**		**RMSE/(Index Mean)**		**RMSE/(Index Mean)**		**RMSE/(Index Mean)**		**RMSE/(Index Mean)**	
NMFS SE Bottom LL	0.269		0.269		0.268		0.268		0.269	
NMFS SEAMAP Gr Tr (F)	0.487		0.485		0.487		0.487		0.490	
NMFS SEAMAP Gr Tr (S)	0.487		0.498		0.485		0.485		0.495	
NMFS Small Pel Tr	0.210		0.213		0.208		0.208		0.213	
DIC for model comparison	-197.906		-195.799		-199.297		-197.855		-197.843	

4.5. Figures

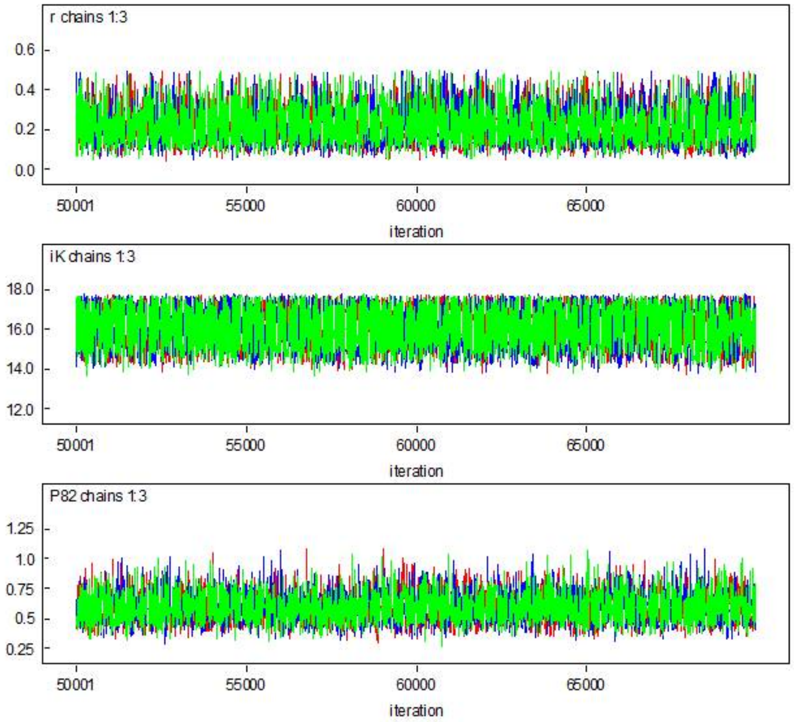

Figure 4.1. Convergence diagnostic for the base run (with three chains) showing the time series history of mixing for the three chains for the key model parameters (*r*, *K*, and P_{82}).

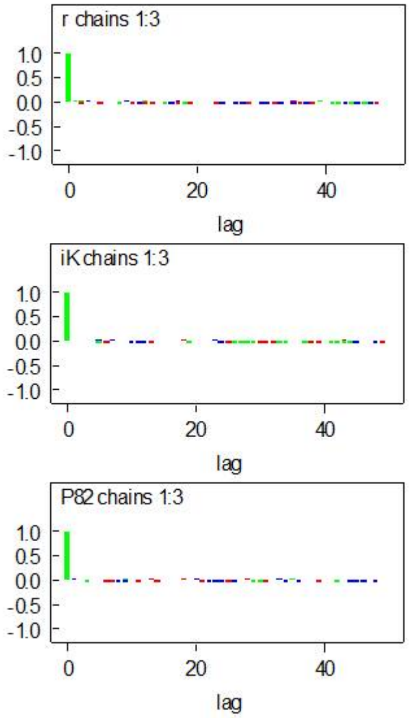

Figure 4.2. Convergence diagnostic for the base run (with three chains) showing the autocorrelation for the three chains for the key model parameters (r, K, and P_{82}).

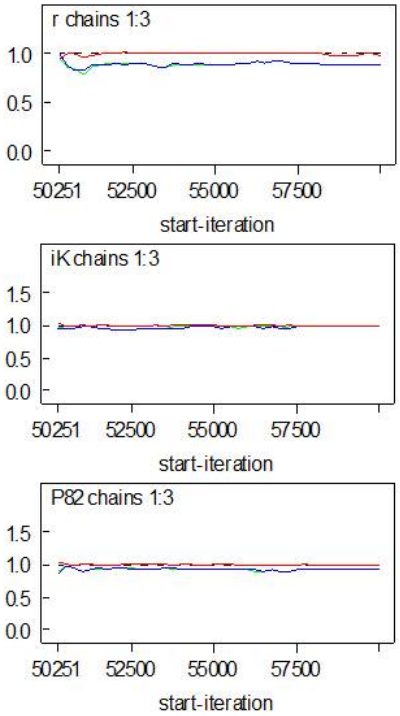

Figure 4.3. Convergence diagnostic for the base run (with three chains) showing the Gelman-Rubin statistic for the three chains for the key model parameters (*r, K,* and P_{82}).

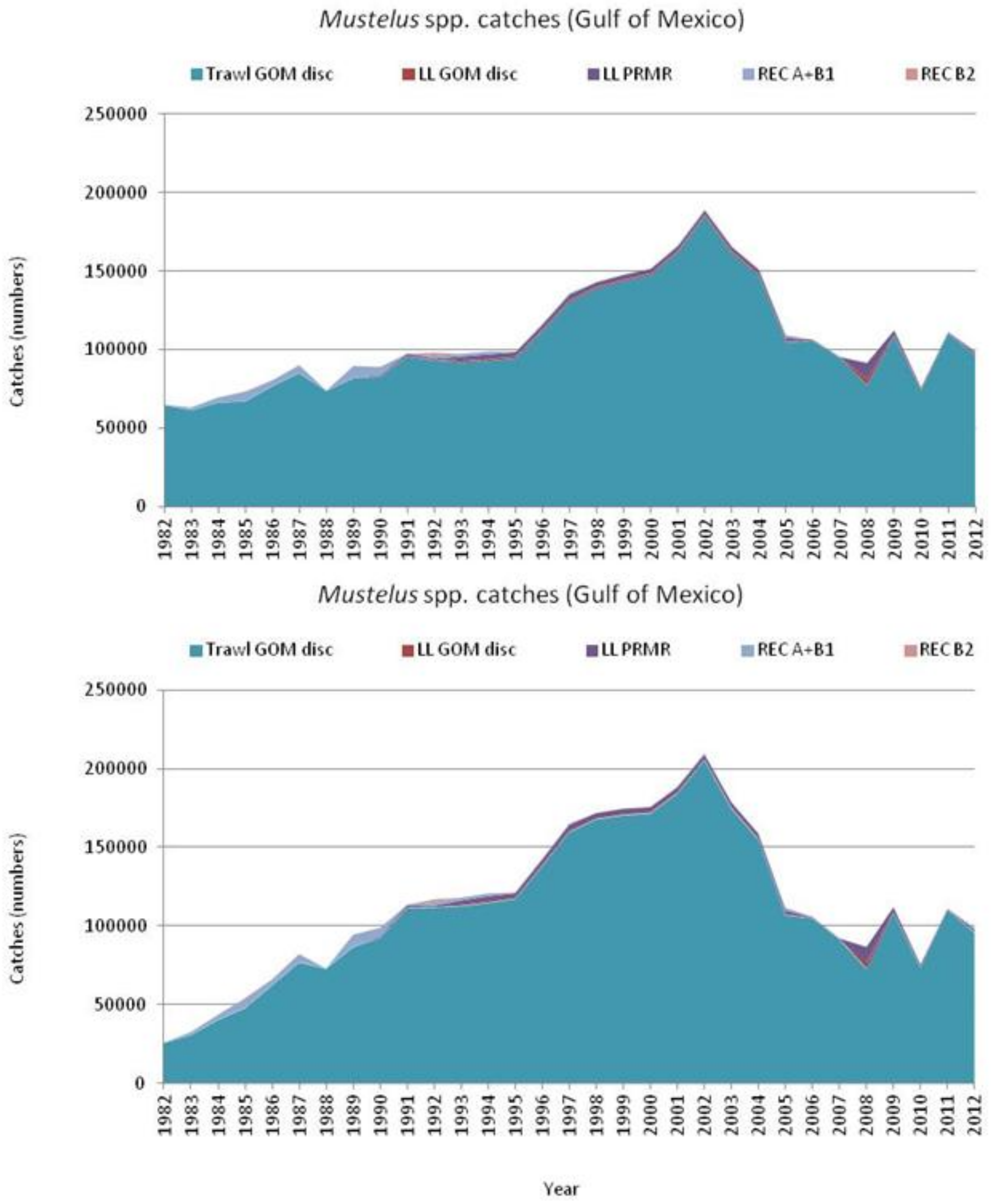

Figure 4.4. Catches of smoothhounds in the Gulf of Mexico, 1982-2012 using a nonlinear trend of the SEAMAP summer CPUE to scale the bycatch CPUE for 1982-2008 for base model run (top) and using a linear trend of the SEAMAP summer CPUE to scale the bycatch CPUE for 1982-2008 for the additional bycatch sensitivity run identified by the reviewers (bottom). "Trawl GOM disc" are dead discards from the shrimp trawl fleet.