NOAA FISHERIES

SEFSC

Atlantic Smooth Dogfish (*Mustelus canis*) Stock Synthesis Model

Dean Courtney

SEDAR 39 (Review Workshop): Stock Synthesis Base Model Configuration, Alternative Model Configurations (Model Sensitivities), and Projections

February 10, 2015

Outline

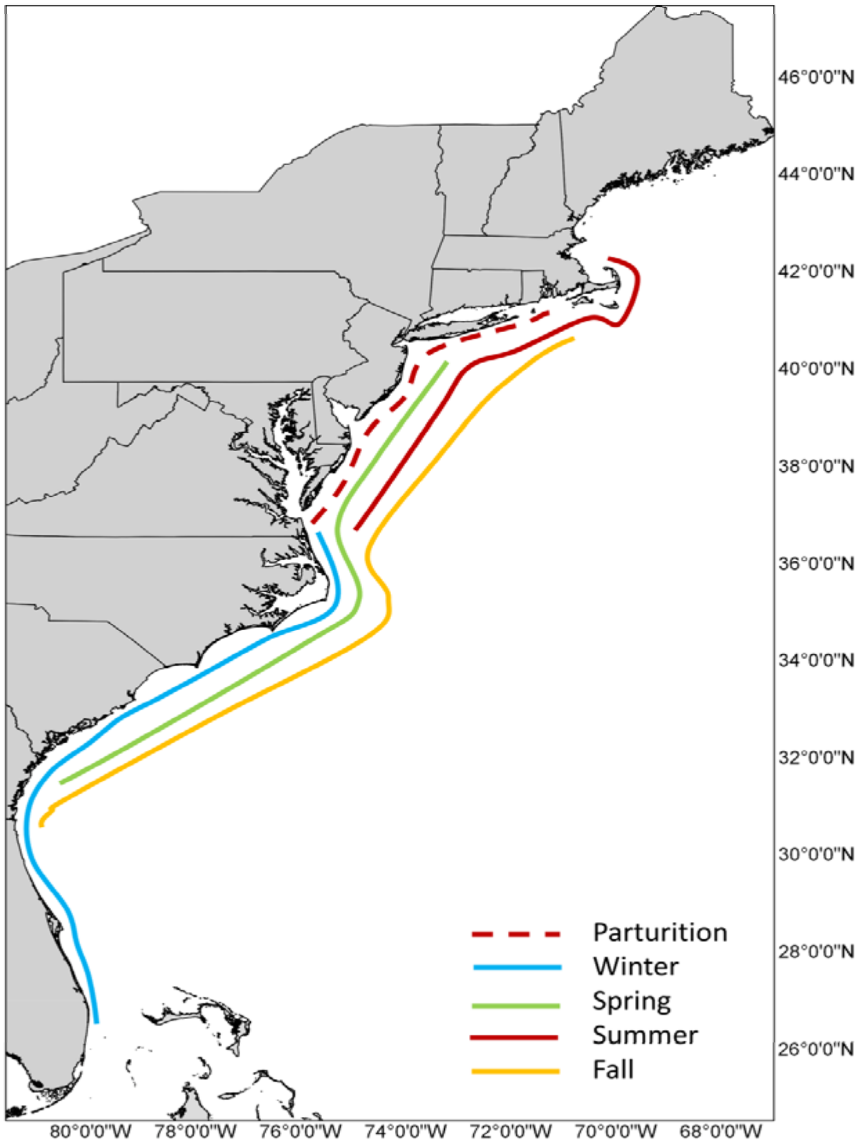
- Data
- Selectivity
- Stock Synthesis model results
- Model sensitivity results
- Projection model results

Data

- Distribution
- Catch
- Indices of relative abundance
- Length composition
- Life history
  - Growth in length and weight at age
  - Fecundity
  - Stock-recruitment steepness

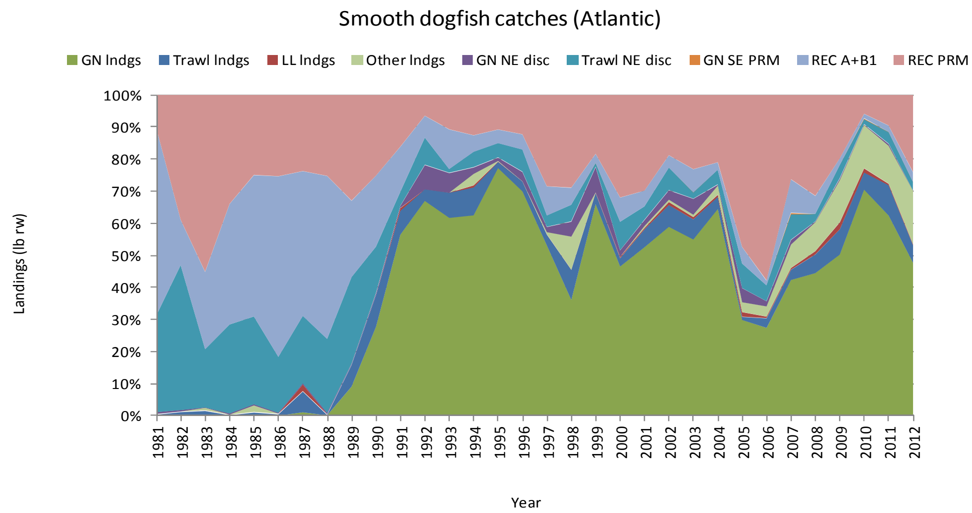
Distribution

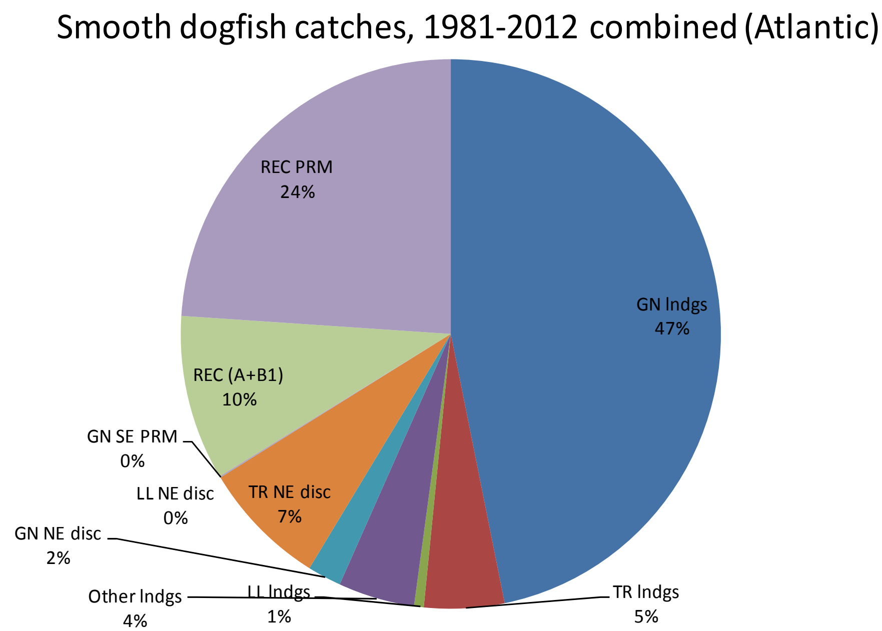
- Figure 2.5. Approximate seasonal distribution pattern of *Mustelus canis* along the east coast of the United States obtained from the SEDAR 39 Data Workshop report (see SEDAR39-DW28



Catch

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

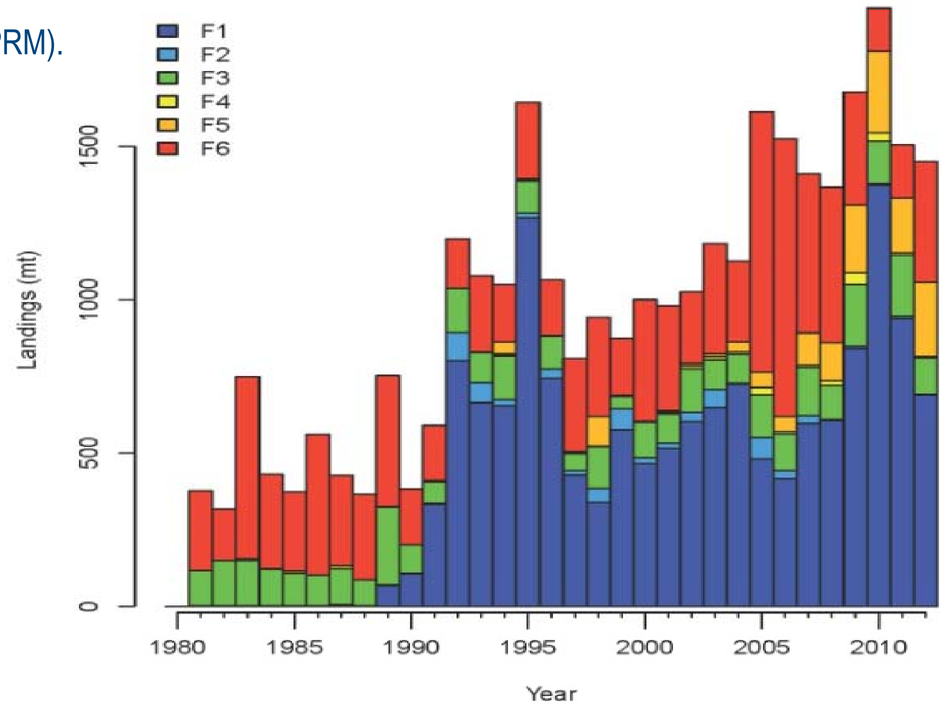




Aggregated Catch

- Table 2.2. Total catches of *Mustelus canis* in the Atlantic Ocean (in mt whole weight) were aggregated into six fleets (F1 – F6) for use in the assessment model as follows:

- Aggregated total catch of *Mustelus canis* in the Atlantic Ocean (in mt whole weight)
- F1 (Com-GN Kept) = Com-GN Landings;
- F2 (Com-GN Discard) = Com-GN-NE (PRM) + Com-GN-SE (PRM);
- F3 (Com-TR) = Com-TR Landings + Com-TR-NE (PRM);
- F4 (Com-LL) = Com-LL Landings + updated Com-LL-NE (PRM);
- F5 (Com-Other) = Com-Other Landings; and
- F6 (Recreational) = Recreational (A+B1) + Recreational (PRM).



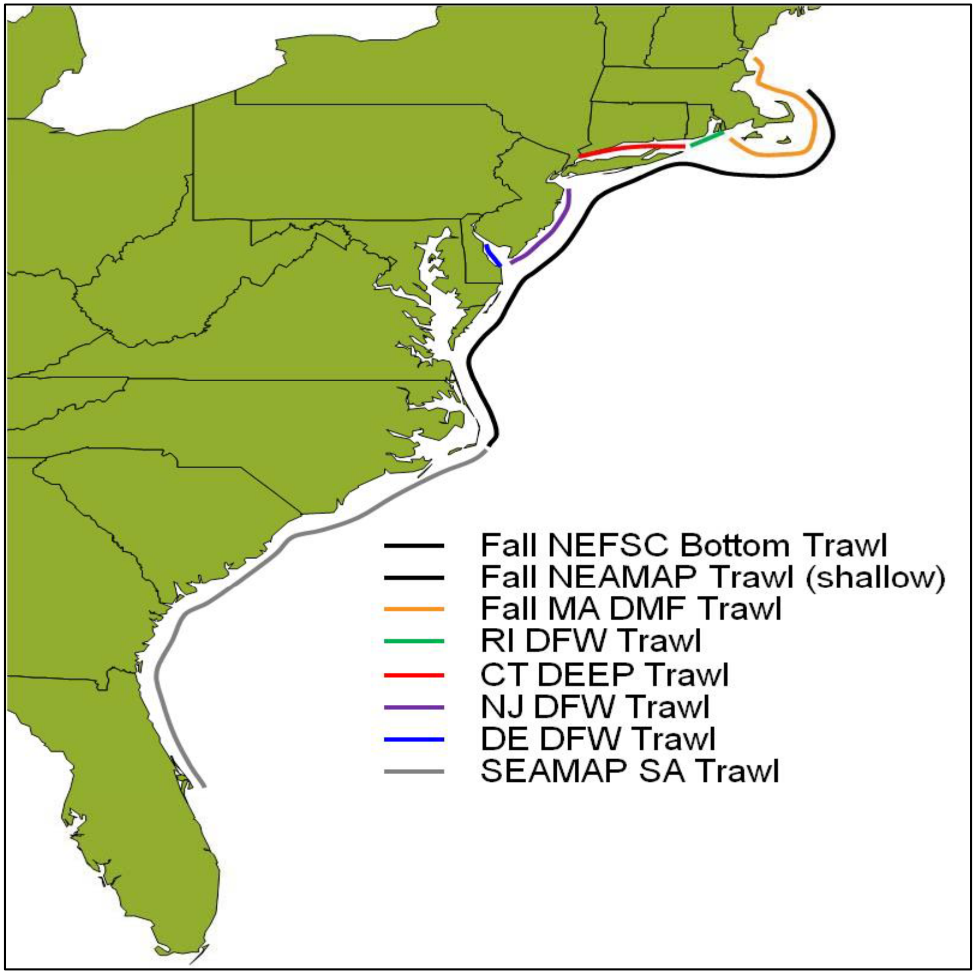
Indices of Relative Abundance

- Table 2.6. Indices of relative abundance recommended by the Index Working Group of the SEDAR 39 Data Workshop for the Atlantic stock of *Mustelus canis* (see SEDAR 39 Data Workshop report).

SS3	Index Name	SEDAR Document Number	Rank
S1	NEFSC Fall Trawl-N	SEDAR39-DW-24	1
S2	NEAMAP Fall Trawl	SEDAR39-DW-30	2
S3	MA DMF Fall Trawl	SEDAR39-DW-24	3
S4	RI DEM Seas. Trawl	SEDAR39-DW-10	3
S5	CT DEEP Trawl	SEDAR39-DW-12	3
S6	DE DFW Trawl	SEDAR39-DW-15	3
S7	NJ DFW Trawl	SEDAR39-DW-14	3
S8	SEAMAP-SA Trawl	SEDAR39-DW-02	4

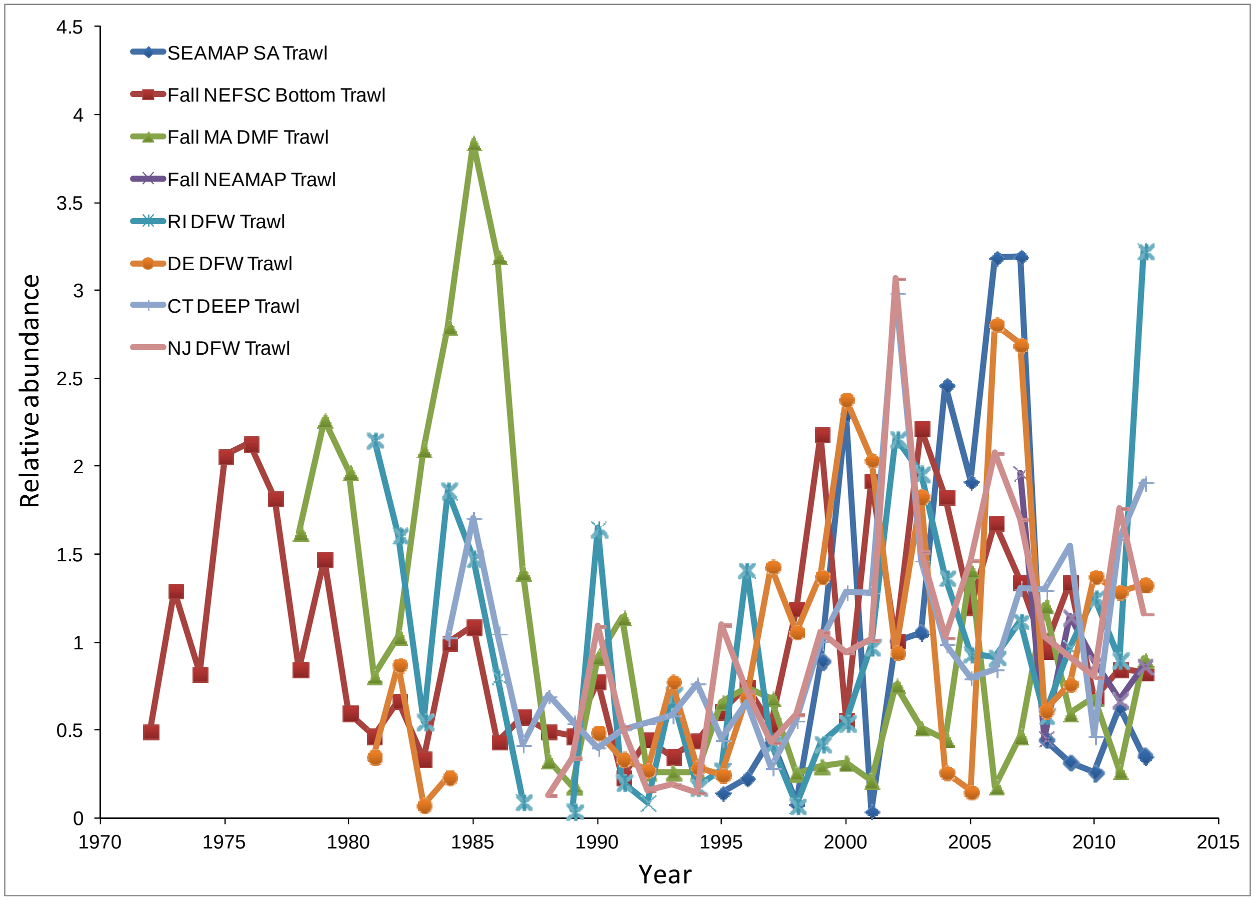
Linear Coverage of Abundance Indices

- Figure 2.4. Approximate linear coverage of abundance indices recommended for the Atlantic stock of *Mustelus canis* by the Index Working Group of the SEDAR 39 Data Workshop (see SEDAR 39 Data Workshop report)



Annual Relative Abundance Indices

- Figure 2.6. Annual indices of relative abundance for each time series recommended for the Atlantic stock of *Mustelus canis* by the Index Working Group of the Data Workshop (see SEDAR 39 Data Workshop report); Each index is standardized to its mean.



Length Composition Data

- Fishery-independent and fishery-dependent length composition data submitted for the Atlantic stock of Mustelus canis during the SEDAR 39 Data Workshop, reviewed for use in the stock assessment model during the SEDAR 39 Assessment Webinars, and summarized in SEDAR39-AW-01

- Length composition data recommended for use in the stock assessment model (ATL Assessment Report Tables 2.3 and 2.4) were associated with each aggregated catch time series (fleets F1 – F6) and each index of abundance (surveys S1 – S8), and summarized in ATL Assessment Report Table 2.5

- Catch aggregation and the association of length composition data with catch and survey data were based on a review of the available length composition data during the SEDAR 39 Assessment Webinars as described in the ATL Assessment Report Section 2.2 and in SEDAR39-AW-01

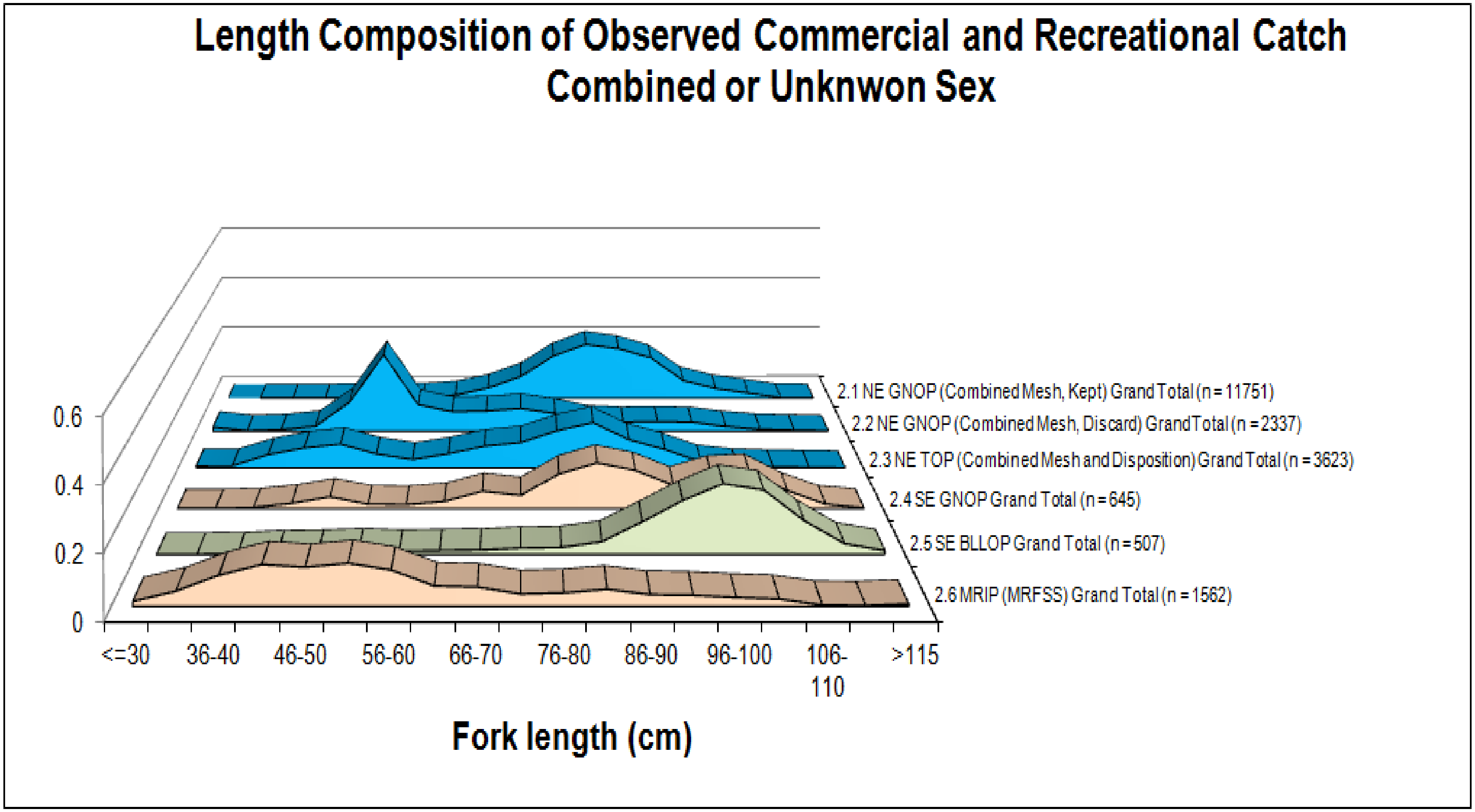
Length Composition Data

- ATL Assessment Report Table 2.5

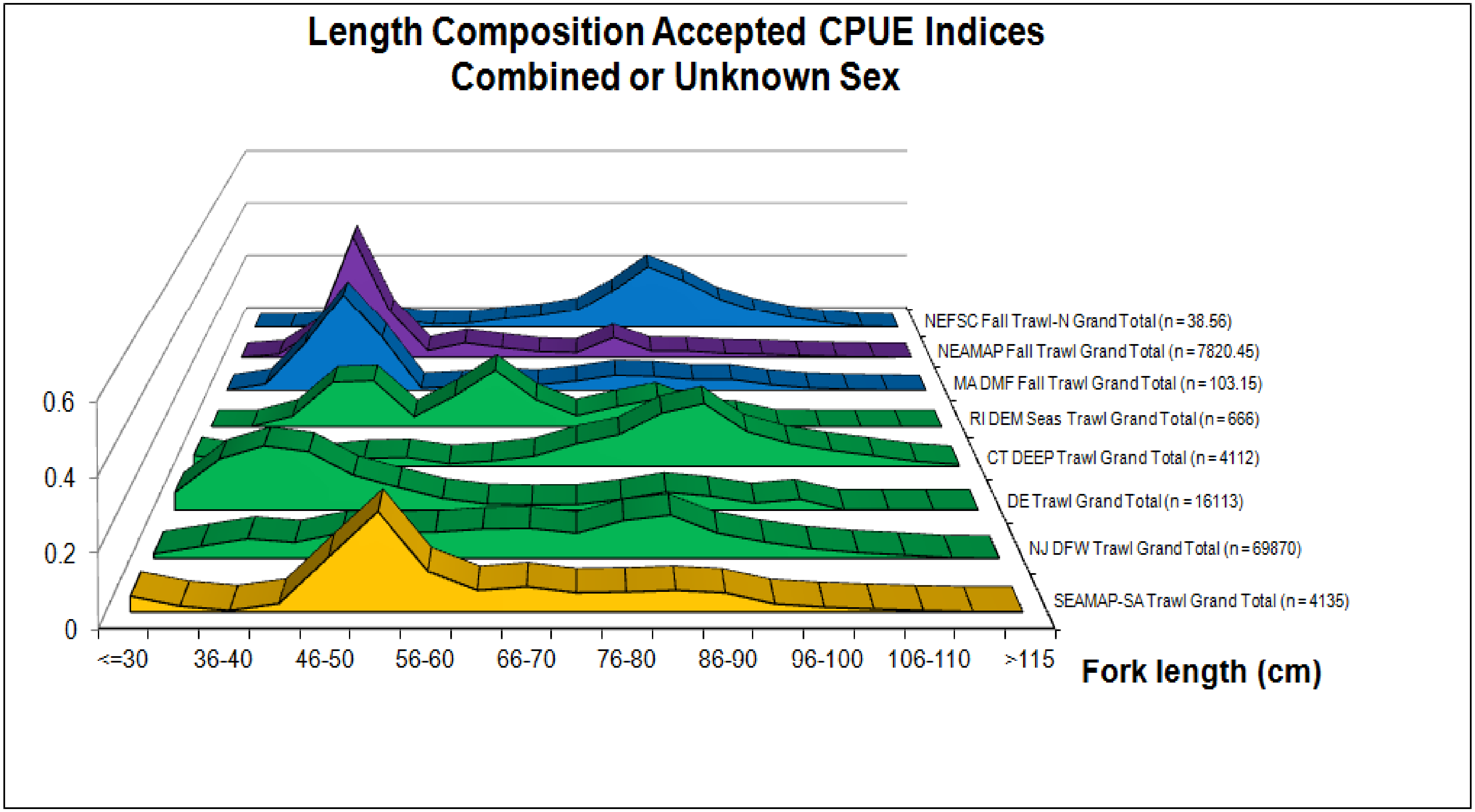
Time series	Series type	Series name	Associated length composition data source
F1	Catch	Com-GN Kept	2.1 NE GNOP (Combined Mesh, Kept)
F2	Catch	Com-GN Discard	2.2 NE GNOP (Combined Mesh, Discard)
F3	Catch	Com-TR	2.3 NE TOP (Combined Mesh and Disposition)
NA[1]			2.4 SE GNOP
F4	Catch	Com-LL	2.5 SE BLLOP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

[1] Associated length data were not representative of any catch time series used in the assessment.
[2] Associated length data were not available for fleet 5 (F5).
(The length composition for fleet 3 (F3) was assumed to be representative of the length composition for F5)

Fisheries Dependent Length Composition Data



Fisheries Independent Length Composition Data



Life History (Growth in Length and Weight at Age)

- ATL Assessment Report Table 2.8. The von Bertalanffy growth (VBG) parameters recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean were converted here to cm fork length (cm FL) separately for females and males for input into the stock assessment model (see ATL Assessment Report Section 2.4.1).

- The minimum and maximum ages in the stock assessment model were set to age-0 and age-18, respectively. Length at age-0 (L_{Amin} cm FL) and length at age-18 (L_{Amax} cm FL) along with the VBG growth coefficient (k) were input separately for females and males in the stock assessment model.

- The sex-specific fixed length-weight relationships recommended in the SEDAR 39 Data Workshop report for *Mustelus canis* in the Atlantic Ocean was used in the stock assessment model to convert body length (cm FL) to body weight (kg).

- The approximate size at birth (c. 32.5 cm FL) is also provided from the scientific literature (see SEDAR39-RD01).

Life History (Growth in Length and Weight at Age)

- ATL Assessment Report Table 2.8

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

Life History (Fecundity)

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

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

Life History (Stock-Recruitment Steepness)

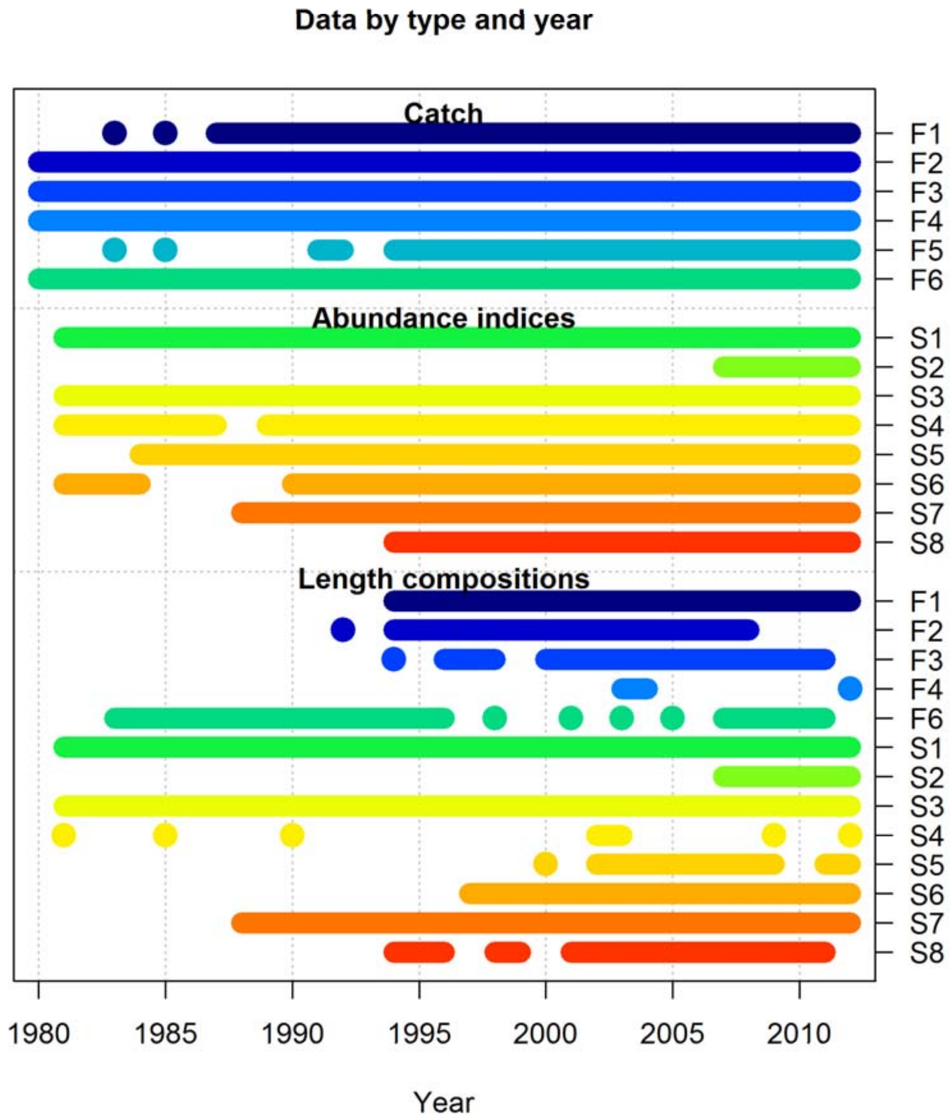
- Table 2.10. Life history inputs used to calculate steepness for developing a prior distribution for *Mustelus canis* for the base run

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

Life History (Stock-Recruitment Steepness)

- Biological Inputs for M. *canis* (Atlantic): Base
- Female von Bertalanffy growth curve:
  L_∞ = 123.57 cm STL, K = 0.292 yr^{-1}, t_0 = -1.943 yr
- Lifespan = 16 yr; a_{50} = 4.4 yr
- Length-weight relationship: W (kg) = $6x10^{-6}FL^{3.0084}$
- Pup-production: pups = $-31.31+42.47(1-e^{-0.496a})$
- Parturition frequency: annual (1 yr)
- Natural Mortality = 0.26 (age-0) → 0.20 (a_{max})
- r = 0.23 yr^{-1}
- Steepness = 0.54

Stock Synthesis (SS3) Base Model Structure



- Catch
  - 6 Fleets (F1 – F6)
- Abundance
  - 8 Surveys (S1 – S8)
- Length composition
  - 5 Fleets (F1 – F6, excluding F5)
  - 8 Surveys (S1 – S8)
  - Sex combined and sex specific data where available
  - Length composition of F5 set equal to that of F3

Selectivity

Selectivity

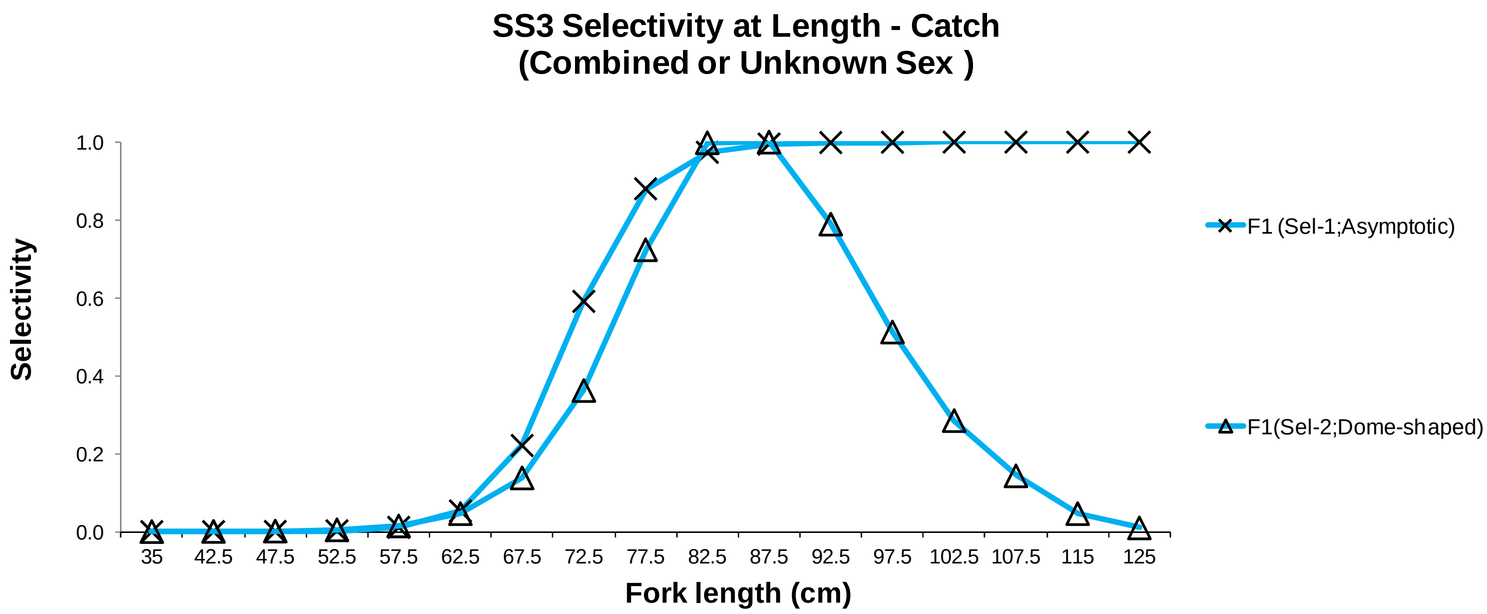
- Preliminary selectivity
  - Preliminary parameter values and the approximate shape for selectivity at age were obtained from length composition data obtained for *Mustelus canis* in the northwest Atlantic externally of the stock assessment model, based on methods used in previous HMS shark assessments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

Two Scenarios for Selectivity (F1)

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

Two Scenarios for Selectivity (F1)

- Two scenarios were explored with the base model structure for selectivity of fleet F1 (NE Gillnet kept)
  - Sel-1; Asymptotic F1– simple logistic (2 parameters)
  - Sel-2; Dome-shaped F1 – double logistic (4 parameters)
  - Selectivity parameters were estimated in SS3 in both scenarios



Two Scenarios for Selectivity (F1)

- Based on Assessment Panel recommendations, several model diagnostics were evaluated to compare model fits to data between the two alternative base model configurations (Sel-1 and Sel-2)
  - Akaike's information criterion (AIC) was used to compare model fits to data given the number of estimated parameters for Sel-1 and Sel-2
  - The root mean squared error (RMSE) was used to compare model fits to length comps and Indices of abundance for Sel-1 and Sel-2
  - A Kolmogorov-Smirnov (K-S) test to compare the length frequency distribution of fleet F1 to the other data sources used in this assessment to determine if large sharks occurred in relatively higher proportions in any of the other data sources

AIC – Results (Table 4.6)

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

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

RMSE – Results

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

K-S Test Results

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

Other Considerations

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

Conclusions Based on Diagnostics for Sel-1 vs Sel-2

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

- The proposed base model under the Sel-2 configuration (dome-shaped selectivity for fleet F1) had a substantially better fit to the data based on the minimum AIC value (5633.5) than the proposed base model under the Sel-1 configuration (asymptotic-shaped selectivity for fleet F1 (Sel-1) (Δ_i = 100.1) (See Section 4.1.1 and Table 4.6).

- The Sel-2 configuration had a better fit (smaller RMSE) to the length composition data for fleet F1 (NE Gillnet Kept) than the Sel-1 configuration (See Section 4.1.2; Table 4.7), and fits to female length composition data for the largest size bins were improved under the Sel-2 configuration (Figures 4.7 and 4.9).

Stock Synthesis Model Results

Stock Synthesis Model Results

- Assessment base model selectivity (Sel-2)
- Model fits to abundance indices
- Model fits to length composition data
- Assessment base model results (Sel-2)
- MCMC results for assessment base model (Sel-2)

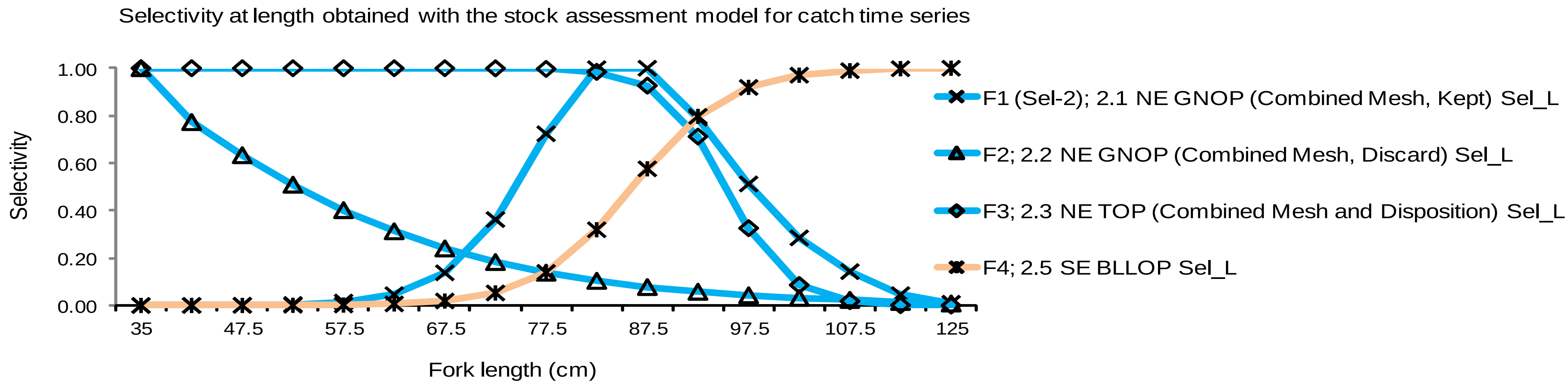
Assessment Base Model Selectivity (Sel-2)

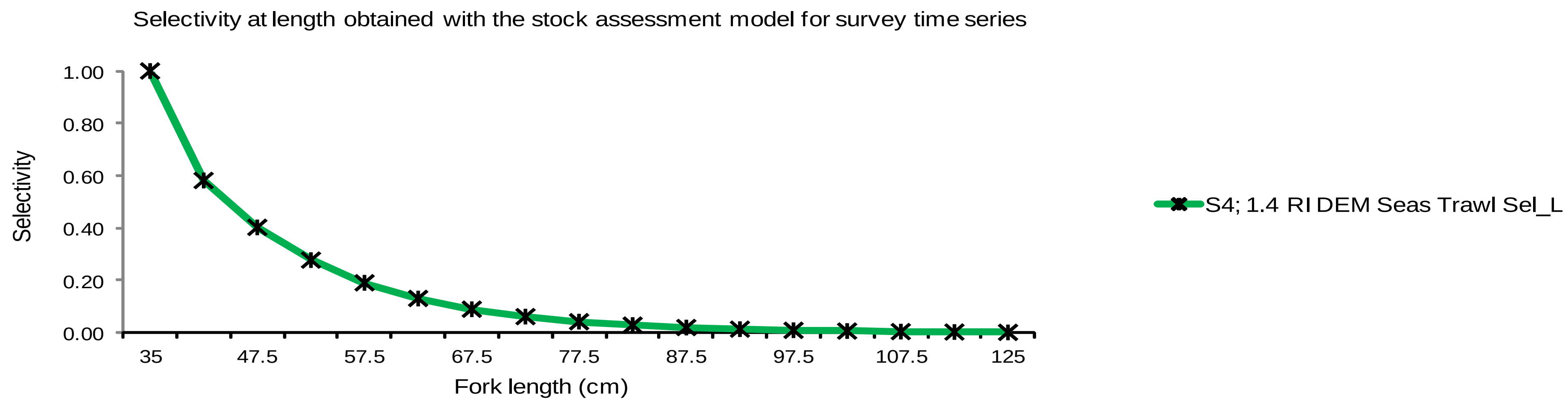
- ATL Assessment Report Table 4.A.2. Final selectivity parameters (both estimated and fixed) for the base model configuration (Sel-2)

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

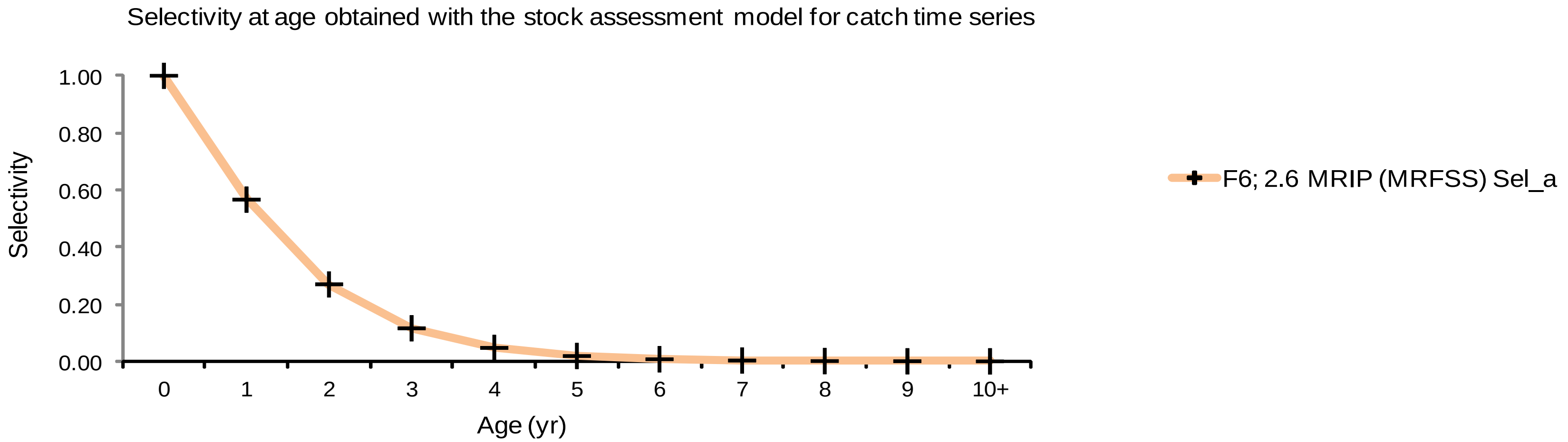
* Fixed parameter.

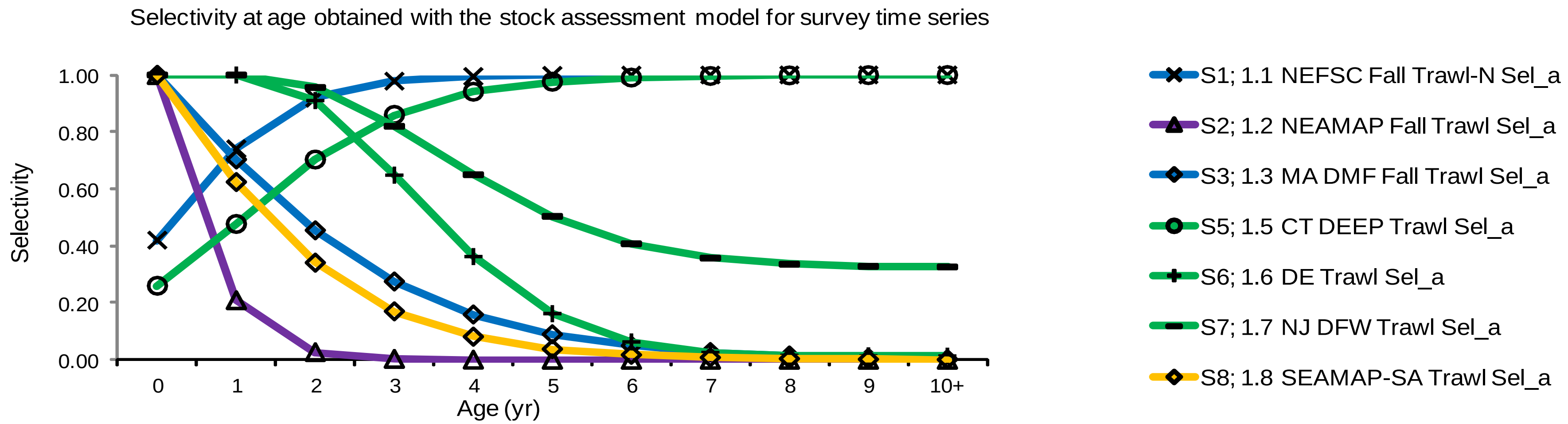
Assessment Base Model Selectivity (Sel-2)
Selectivity at Length





Assessment Base Model Selectivity (Sel-2)
Selectivity at Age

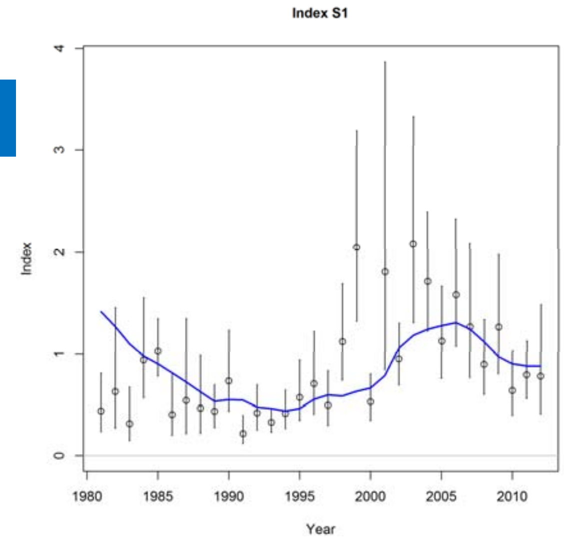




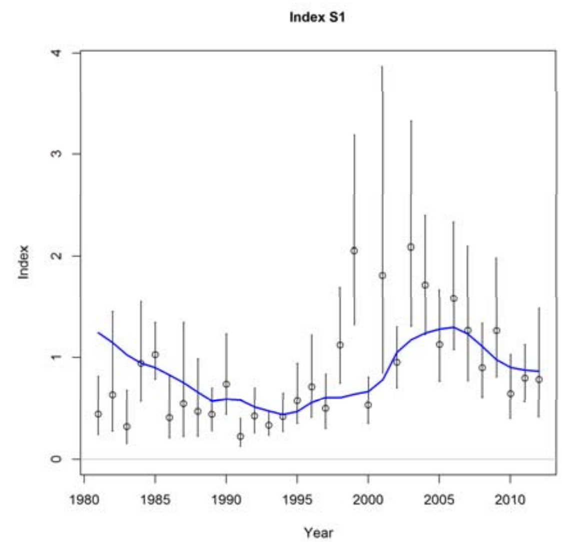
Model Fits to Abundance Indices

S1 1.1 NEFSC Fall Trawl-N

- Both selectivity scenarios resulted in similar fits to survey S1
  - Reasonable fit in most recent years
  - Poor fit to peak in middle years
  - Poor fit in earliest years



Sel-1;
Asymptotic F1

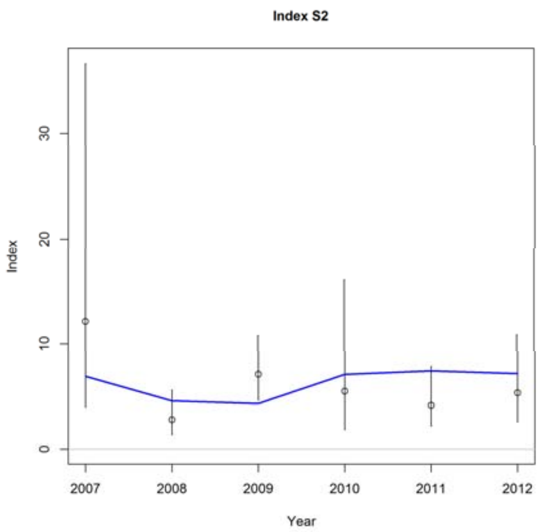


Sel-2;
Dome-shaped F1

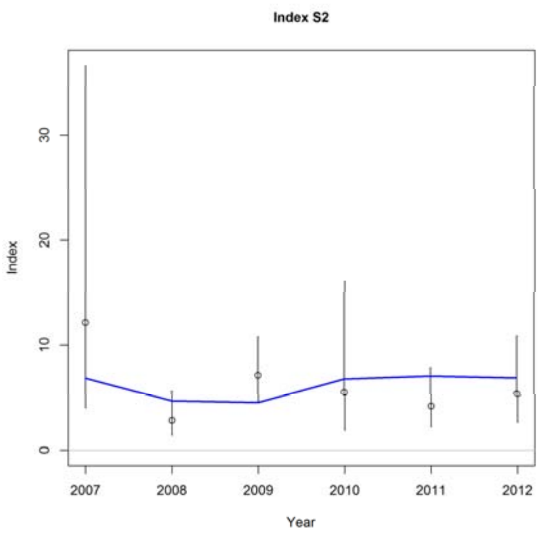
Model Fits to Abundance Indices

S2 1.2 NEAMAP Fall Trawl

- Both selectivity scenarios resulted in similar fits to survey S2
  - Reasonable fit in all years



Sel-1;
Asymptotic F1

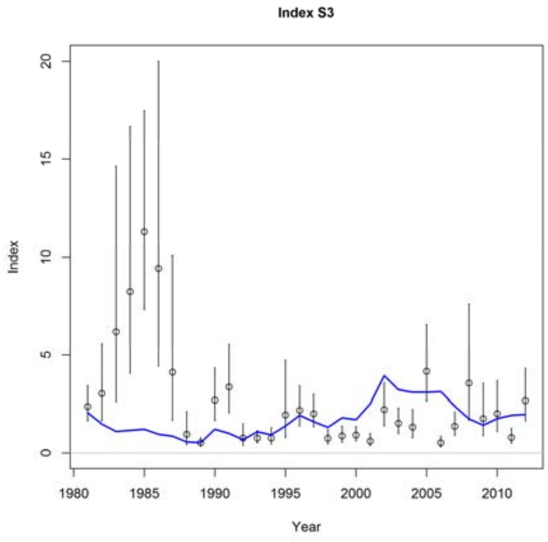


Sel-2;
Dome-shaped F1

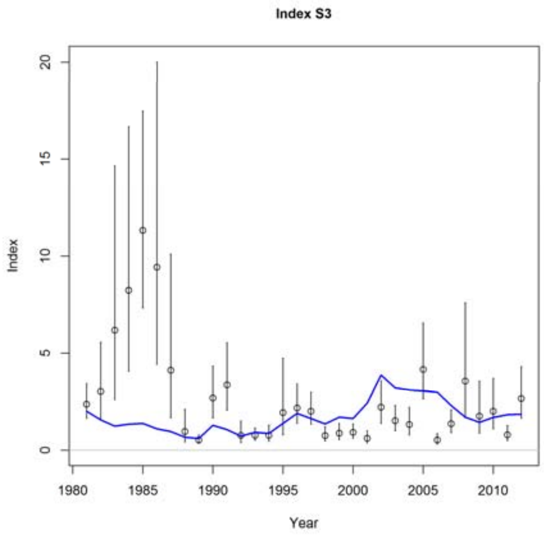
Model Fits to Abundance Indices

S31.3 MA DMF Fall Trawl

- Both selectivity scenarios resulted in similar fits to survey S3
  - Reasonable fit in most recent years
  - Poor fit in early years



Sel-1;
Asymptotic F1

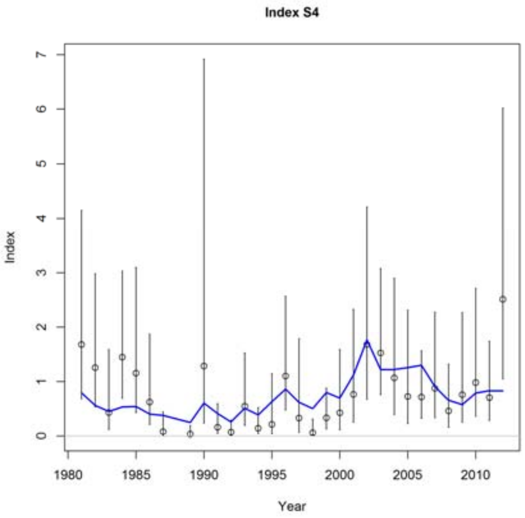


Sel-2;
Dome-shaped F1

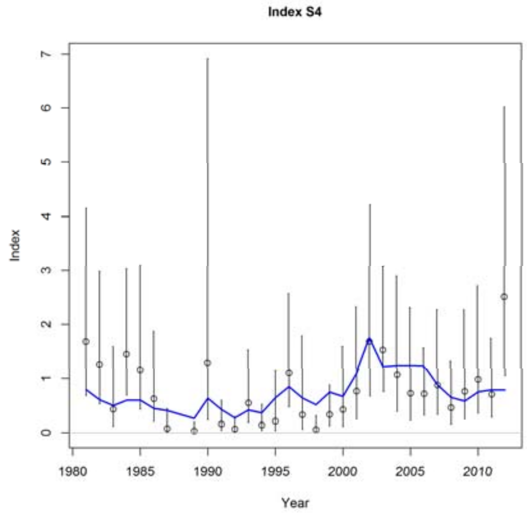
Model Fits to Abundance Indices

S4 1.4 RI DEM Seas Trawl

- Both selectivity scenarios resulted in similar fits to survey S4
  - Reasonable fit in most recent years
  - Poor fit in early years



Sel-1;
Asymptotic F1

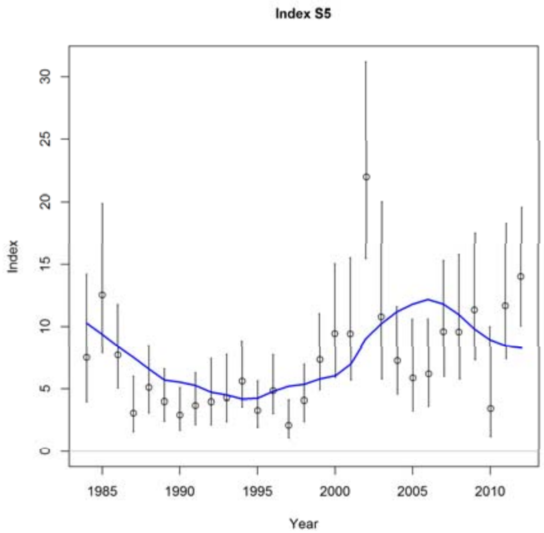


Sel-2;
Dome-shaped F1

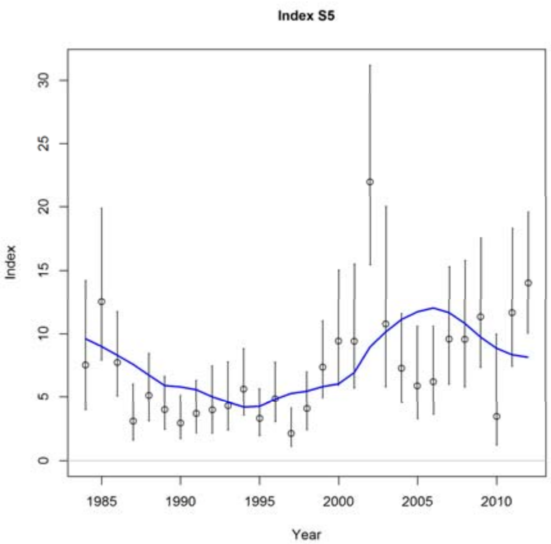
Model Fits to Abundance Indices

S51.5 CT DEEP Trawl

- Both selectivity scenarios resulted in similar fits to survey S5
  - Reasonable fit early years
  - Did not follow trend in recent years



Sel-1;
Asymptotic F1

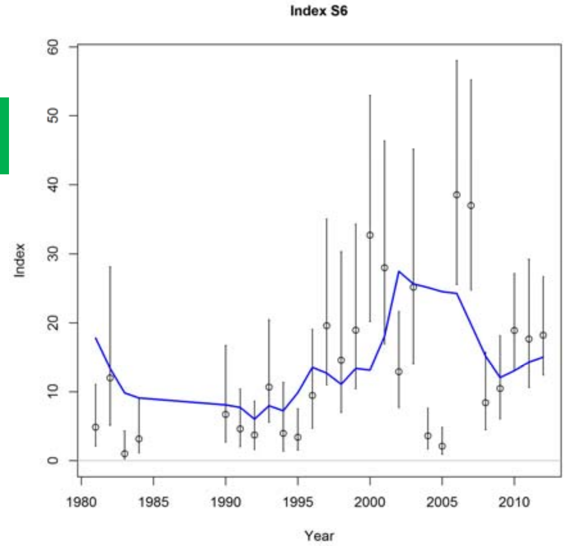


Sel-2;
Dome-shaped F1

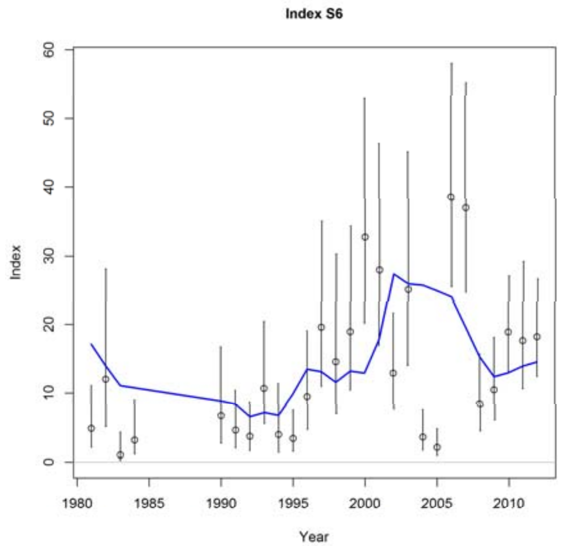
Model Fits to Abundance Indices

S61.6 DE Trawl

- Both selectivity scenarios resulted in similar fits to survey S6
  - Reasonable fit in most recent years
  - Poor fit in early years
  - Middle years have high inter annual variability



Sel-1;
Asymptotic F1

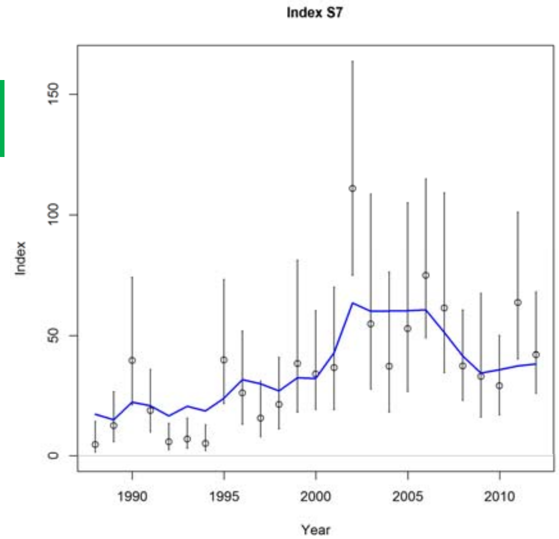


Sel-2;
Dome-shaped F1

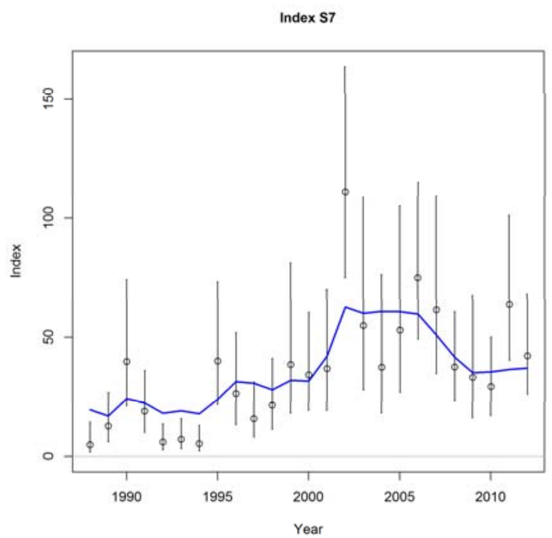
Model Fits to Abundance Indices

S7 1.7 NJ DFW Trawl

- Both selectivity scenarios resulted in similar fits to survey S7
  - Best fit



Sel-1;
Asymptotic F1

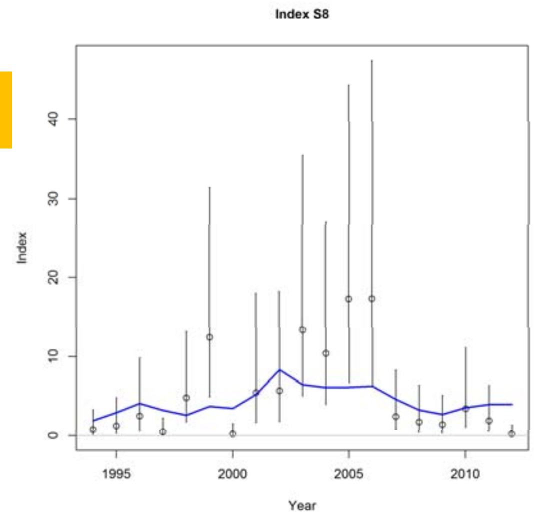


Sel-2;
Dome-shaped F1

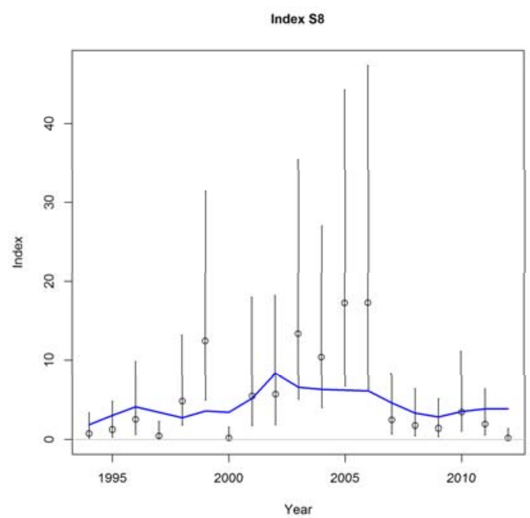
Model Fits to Abundance Indices

S8 1.8 SEAMAP-SA Trawl

- Both selectivity scenarios resulted in similar fits to survey S8
  - Reasonable fit early and recent years
  - Did not fit peak in middle years



Sel-1;
Asymptotic F1



Sel-2;
Dome-shaped F1

Model Fits to Length Composition Data

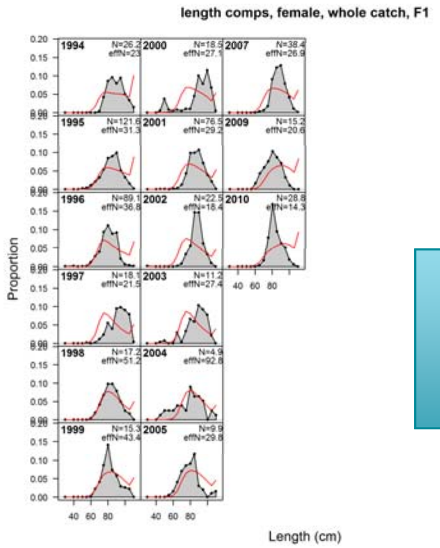
- Annual length compositions observed (grey) and model predicted (red line); Diameter of Pearson residuals (circles) indicates relative error; predicted < observed (solid), predicted > observed (transparent)

F1 2.1 NE GNOP (Combined Mesh, Kept)

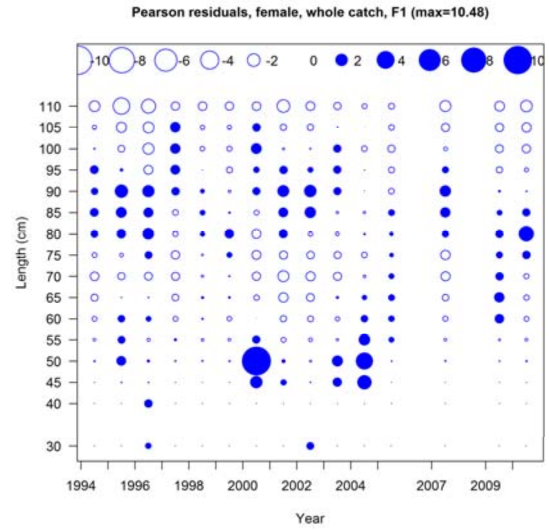
F1 Female

2.1 NE GNOP (Combined Mesh, Kept)

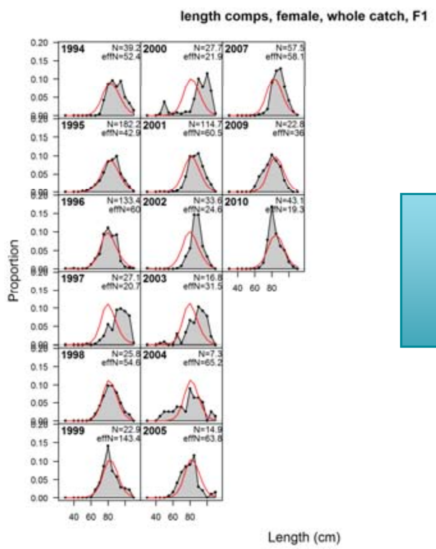
Sel-1;
Asymptotic F1



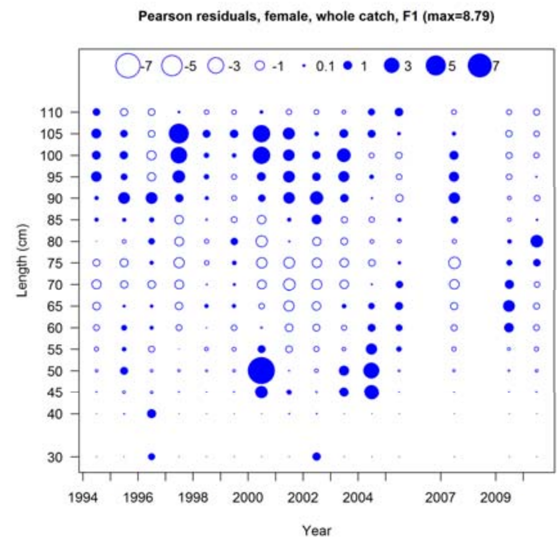
Max (10.48) relatively worse fit



Sel-2;
Dome-shaped F1



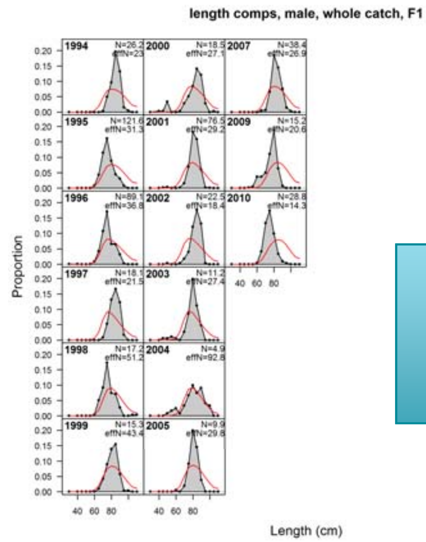
Max (8.79) relatively better fit



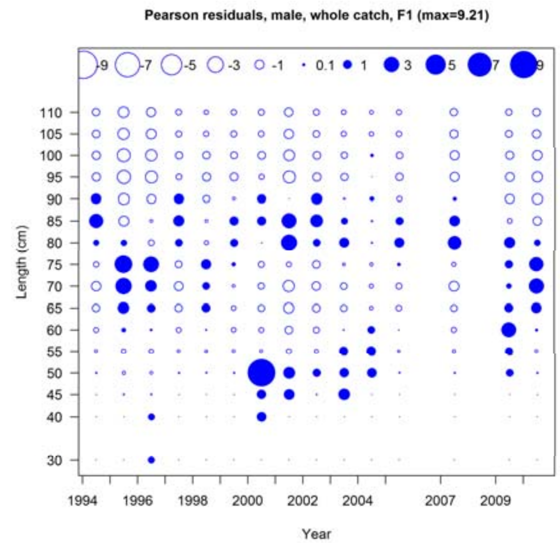
F1 Male

2.1 NE GNOP (Combined Mesh, Kept)

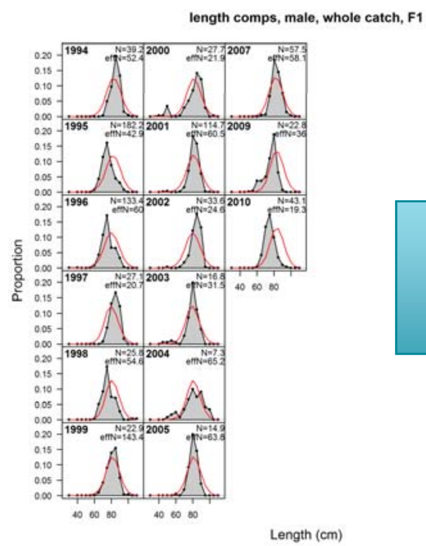
Sel-1;
Asymptotic F1



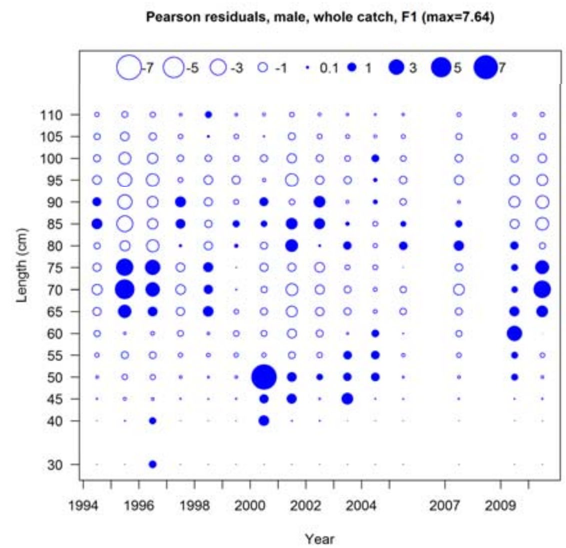
Max (9.21) relatively worse fit



Sel-2;
Dome-shaped F1



Max (7.64) relatively better fit

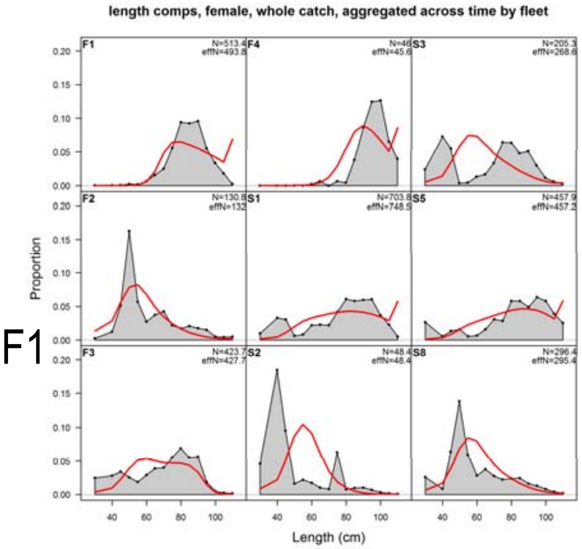


Model Fits to Aggregated Length Compositions

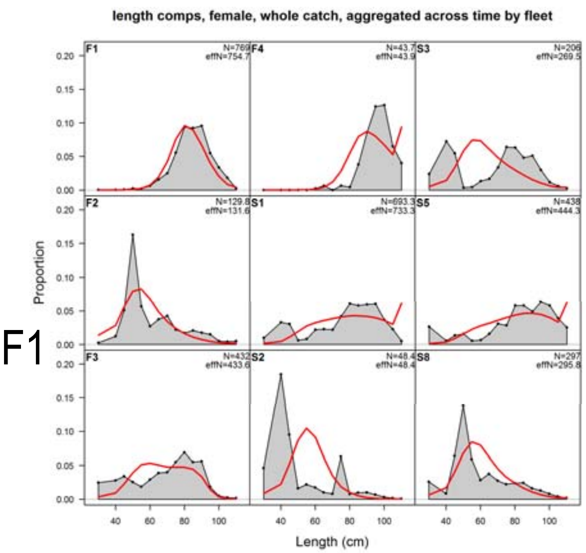
Female

- Fits to NE GNOP Combined Mesh, Kept improved with dome-shaped selectivity (F1; Sel-2) relative to asymptotic selectivity (F1; Sel-1)
- Both selectivity scenarios resulted in similar fits to other length data
- Some large sizes overestimated
  - F1 (NE GNOP Combined Mesh, Kept) Sel-1; Asymptotic
  - F4 (SE BLLOP)
  - S1 (NEFSC Fall Trawl-N)
  - S5 (CT DEEP Trawl)
- Some small sizes underestimated
  - S2 (NEAMAP Fall Trawl)
  - S3 (MA DMF Fall Trawl)

Sel-1;
Asymptotic F1



Sel-2;
Dome-shaped F1

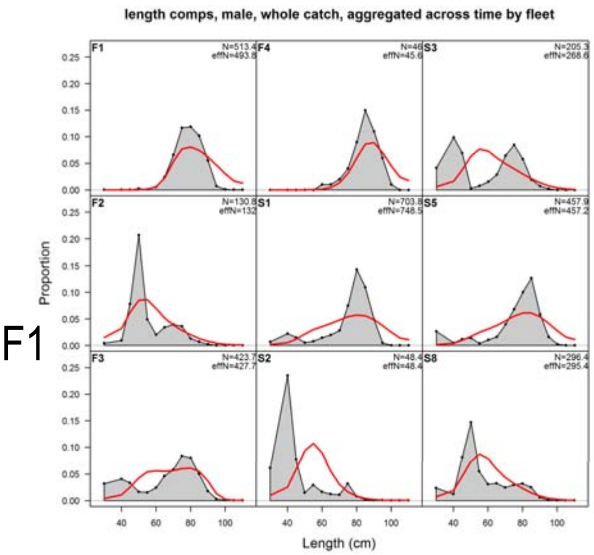


Model Fits to Aggregated Length Compositions

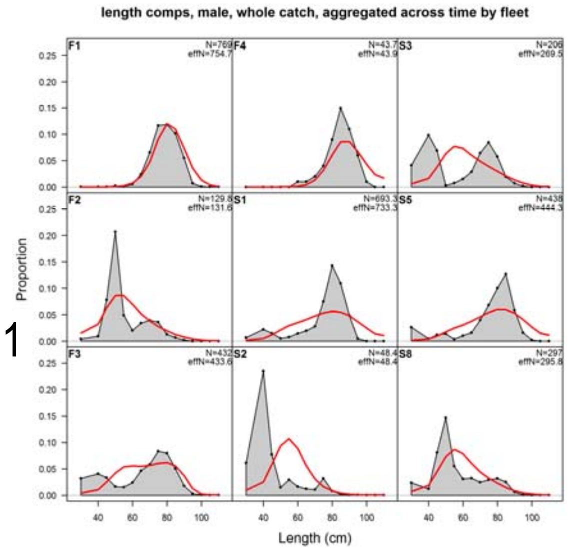
Male

- Fits to NE GNOP Combined Mesh, Kept improved with dome-shaped selectivity (F1; Sel-2) relative to asymptotic selectivity (F1; Sel-1)
- Both selectivity scenarios resulted in similar fits to other length data
  - F1 (NE GNOP Combined Mesh, Kept)
  - F2 (NE GNOP Combined Mesh, Discard)
  - F3 (NE TOP Combined Mesh and Disposition)
  - F4 (SE BLLOP)
  - S1 (NEFSC Fall Trawl-N)
  - S5 (CT DEEP Trawl)
  - S8 (SEAMAP-SA Trawl)
- Some small sizes underestimated
  - S2 (NEAMAP Fall Trawl)
  - S3 (MA DMF Fall Trawl)
  - S8 (SEAMAP-SA Trawl)

Sel-1;
Asymptotic F1



Sel-2;
Dome-shaped F1



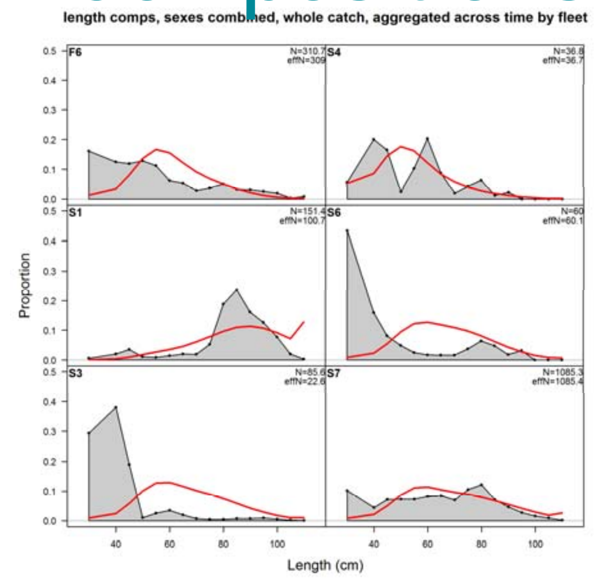
Model Fits to Aggregated Length Compositions

Combined or Unknown Sex

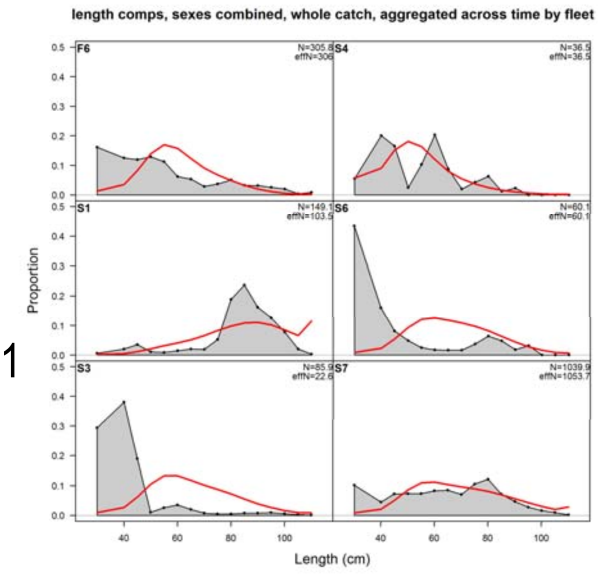
- Both selectivity scenarios resulted in similar fits length data
  - S1 (NEFSC Fall Trawl-N)
  - S7 (NJ DFW Trawl)

- Some small sizes underestimated
  - F6 MRIP (MRFSS)
  - S3 (MA DMF Fall Trawl)
  - S4 (RI DEM Seas Trawl)
  - S6 (DE Trawl)
  - S7 (NJ DFW Trawl)

Sel-1;
Asymptotic F1



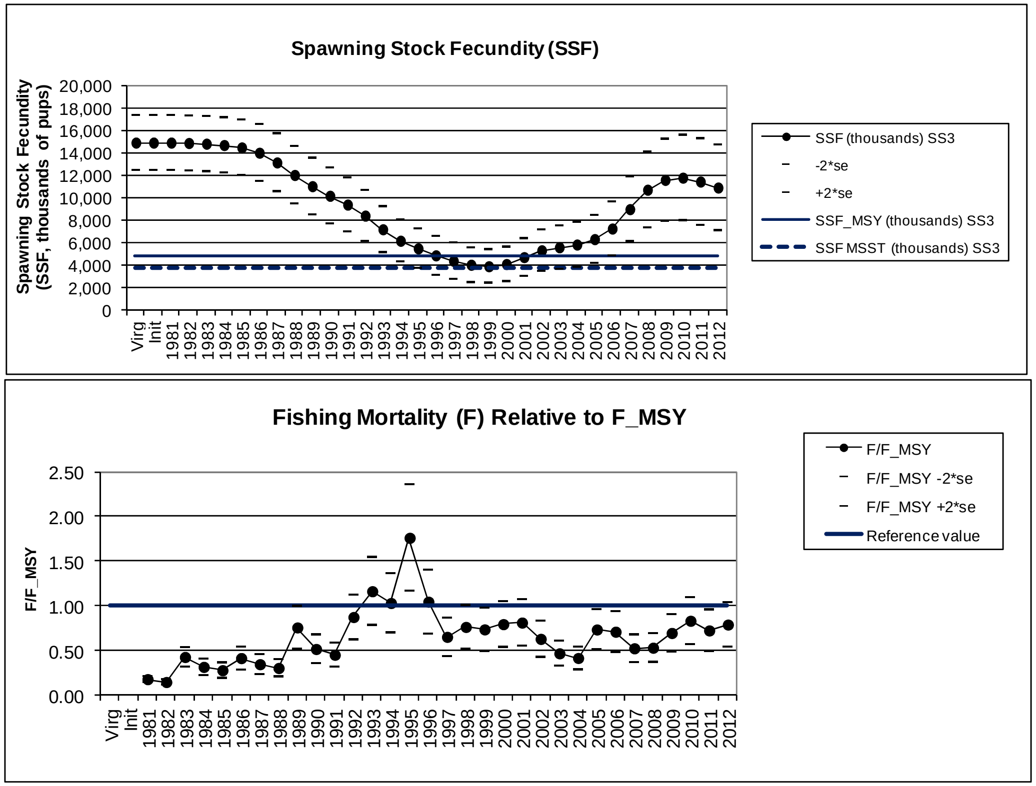
Sel-2;
Dome-shaped F1



Assessment Base Model Results (Sel-2)

Assessment Base Model Results (Sel-2)

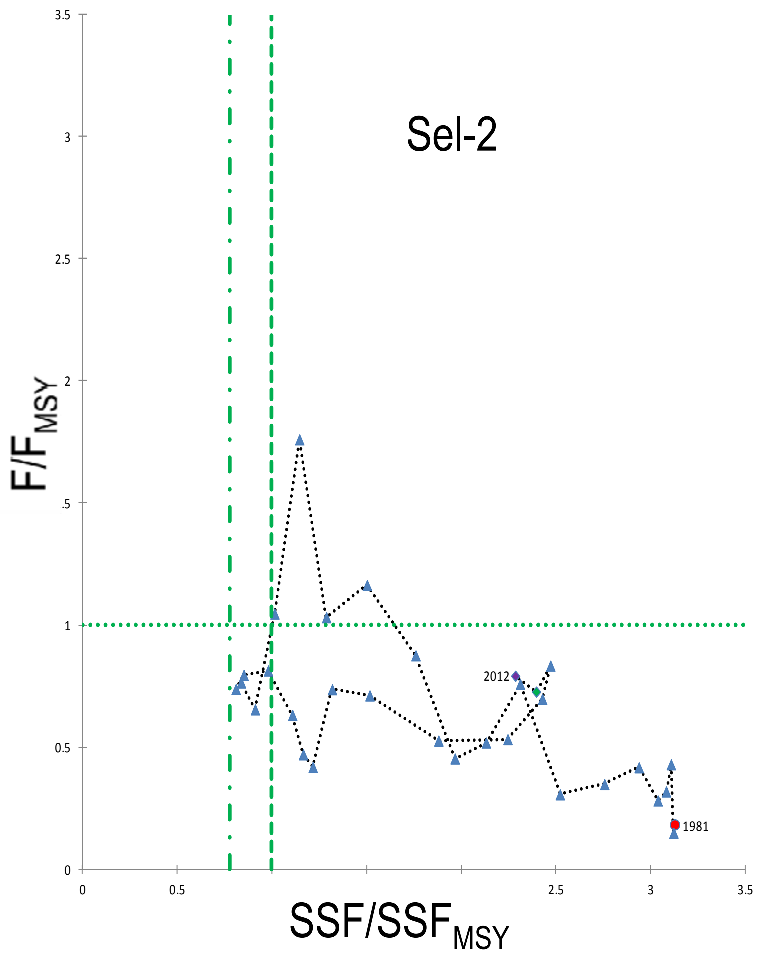
- The base model configuration Sel-2 predicted that the stock was not overfished and that there was an almost negligible chance of overfishing occurring (ATL Assessment Report Figure 4.17)



Approximate 95% intervals based on ± 2*(asymptotic SE)
The SSF minimum stock size threshold MSST (stippled line top panel) is calculated as (1-average *M*)*SSF_{MSY}.

Assessment Base Model Results (Sel-2)

- The base model configuration (Sel-2) predicted that the stock was not overfished and that overfishing was not occurring (ATL Assessment Report Figure 4.23b)



The dotted horizontal line indicates F_{MSY}, the dashed vertical line indicates SSF_{MSY}
The dot-dashed vertical line indicates MSST ((1-M)*SSF_{MSY})
M is calculated as the average natural mortality at age used in the assessment model configuration).

Assessment Base Model Results Sel-2

ATL Assessment Report Table 4.13

- Stock is not overfished **SSF_{2012} > SSF_{MSY}**
- Overfishing is not occurring **F_{2012} < F_{MSY}**

	Base Model (Sel-2)	
AIC	5633.5	
Parameters	52	
Objective function	2764.7	
Gradient	2.19E-06	
(1-avgM)	0.78	
Steepness	0.54	
	Est	CV
SSF_{2012}	10,847	18%
F_{2012}	0.102	---
R_{2012}	2,213	11%
SSF_0	14,849	8%
R_0	2,385	8%
MSY	1,125	8%
SSF_{MSY}	4,746	8%
F_{MSY}	0.129	2%
SSF_{2012}/SSF_{MSY}	**2.286**	---
F_{2012}/F_{MSY}	**0.792**	16%
Stock status	**SSF_{2012} > SSF_{MSY}**	
Fishery status	**F_{2012} < F_{MSY}**	

MCMC

- Markov chain Monte Carlo (MCMC) was implemented in AD Model Builder (ADMB) for the SEDAR 39 Atlantic smooth dogfish base model configuration (Sel-2; ATL Assessment Report Table 4.13).

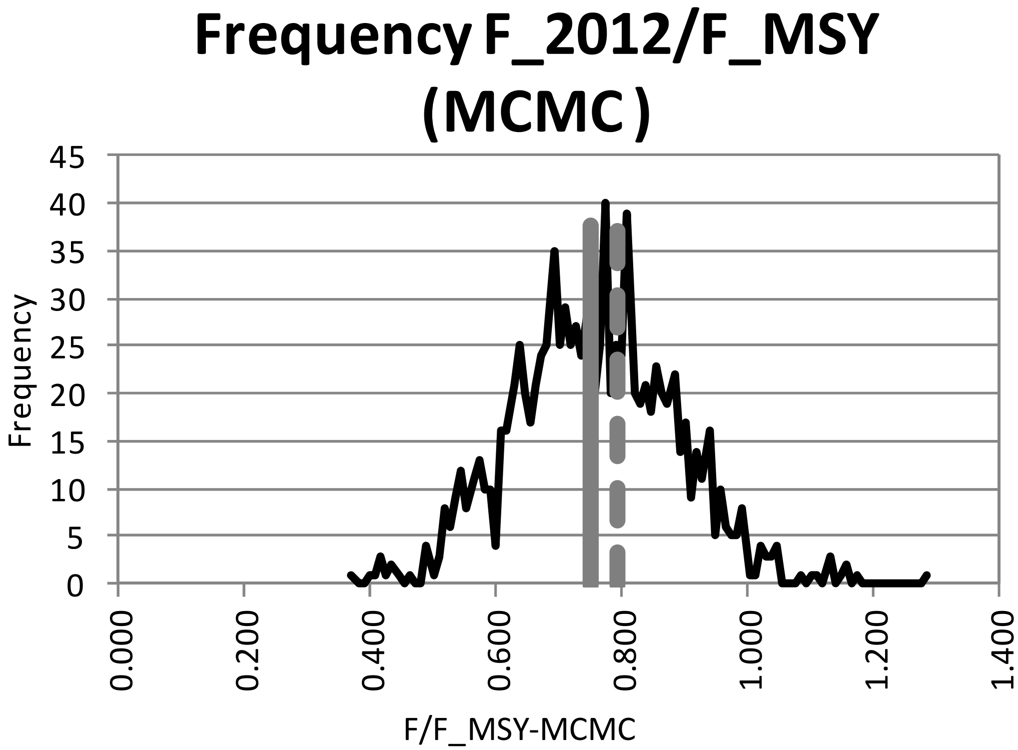
- MCMC was implemented with 1 million draws, with every 1000th saved and with a burn in of 1,000 (n = 990 saved draws) (Methot R. D. 2011; e.g., Methot 2013 and A guide for Bayesian Analysis in AD Model Builder)

References

- Methot R. D. 2011. User manual for Stock Synthesis model version 3.21d, updated May 12, 2011. NOAA Fisheries, Seattle, WA.
- Methot R. D. 2013. User manual for Stock Synthesis model version 3.24s, updated November 21, 2013. NOAA Fisheries, Seattle, WA. Available: http://nft.nefsc.noaa.gov/SS3.html. (October, 2014).
- A Guide for Bayesian Analysis in AD Model Builder. Cole C. Monnaha, Melissa L. Muradian, Peter T. Kuriyama, November 7, 2014. corresponding author; monnahc@uw.edu Available: http://www.admb-project.org/developers/mcmc/mcmc-guide-for-admb/view (Feb 2015)

MCMC Results Assessment Base Model (Sel-2)

- MCMC results are provided for the base configuration (Sel-2)
- The stippled line represents the parameter estimate obtained from SS3
- The solid line represents the median of saved MCMC draws (n = 990)
- F_2012 > F_MSY in 3% of saved draws



Model Sensitivity Run Results

SS3 Model Sensitivity Runs

- Model uncertainty
  - Sensitivity run-1: Externally derived selectivity for all fleets and surveys (analogous to SSASPM); start year in 1981; equilibrium conditions assumed prior to 1981
  - Sensitivity run-2: Start year 1972; Equilibrium fishing mortality prior to 1972
  - Sensitivity run-3: Sensitivity to CPUE ranks assigned at Data Workshop
  - Sensitivity run-4: Fit one abundance index (CPUE) at a time
- Plausible states of nature
  - Sensitivity run-5: Low and high catch
  - Sensitivity run-6: Low and high productivity
  - Sensitivity run-7: Fit the hierarchical index of abundance

SS3 Model Sensitivity Run Methods

- Model fits to data (Likelihood)
  - Smaller values (likelihood units) imply better fit to data
    - Evaluate relative changes in fits to length composition data (Length)
    - Evaluate relative changes in fits to abundance indices (CPUE)

- Management implications
  - F/F_MSY
  - SSF/SSF_MSY

Sensitivity-1: Selectivity

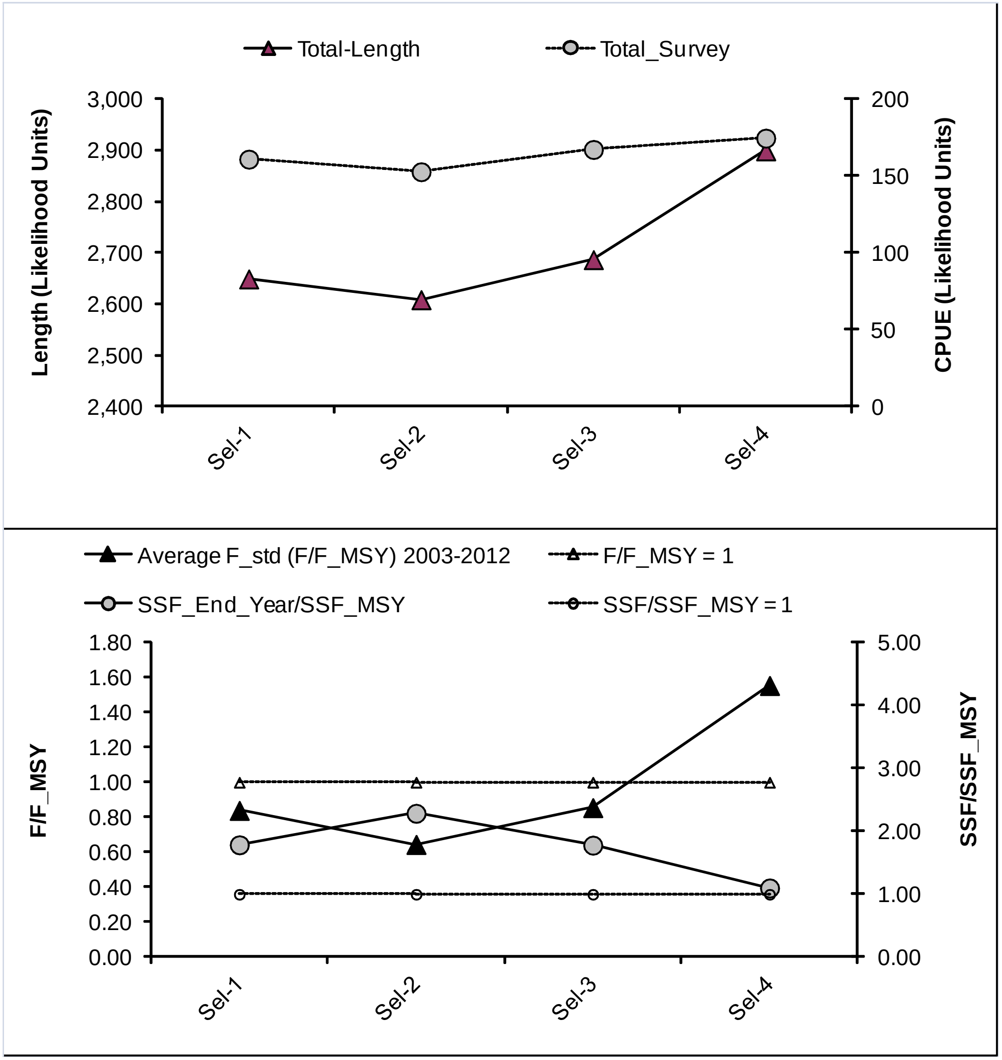
- Sensitivity run-1
  - Externally derived selectivity for all fleets and surveys (analogous to SSASPM); start year in 1981; equilibrium conditions assumed prior to 1981

Sensitivity-1: Selectivity

- Model sensitivity to selectivity
  - Base (Sel-1): Asymptotic F1– simple logistic (2 parameters)
  - Base (Sel-2): Dome-shaped F1 – double logistic (4 parameters)
  - Sel-3: Externally derived selectivity F1
  - Sel-4: Externally derived selectivity all fleets and surveys, analogous to methods used in previous HMS shark assessments conducted with a state spaced age structured production model (SSAPSM)

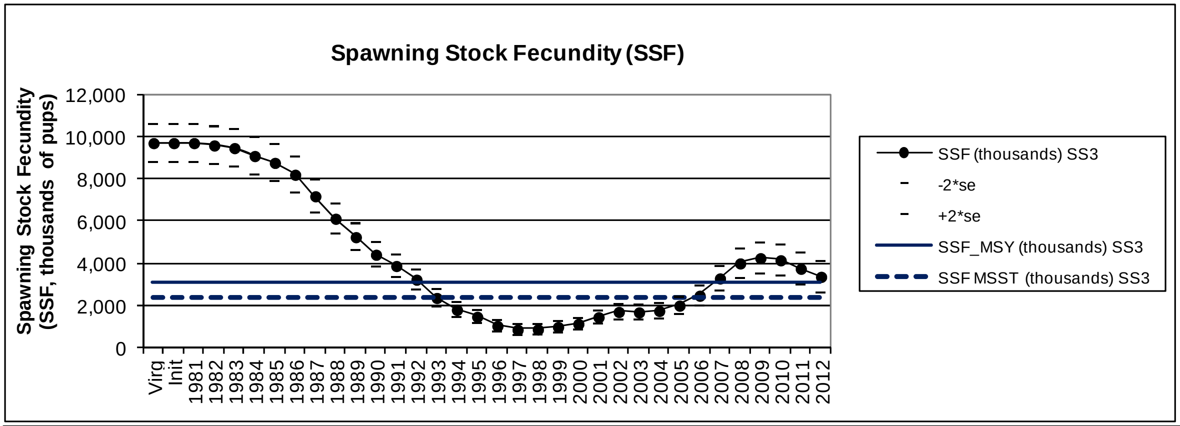
Sensitivity-1: Selectivity

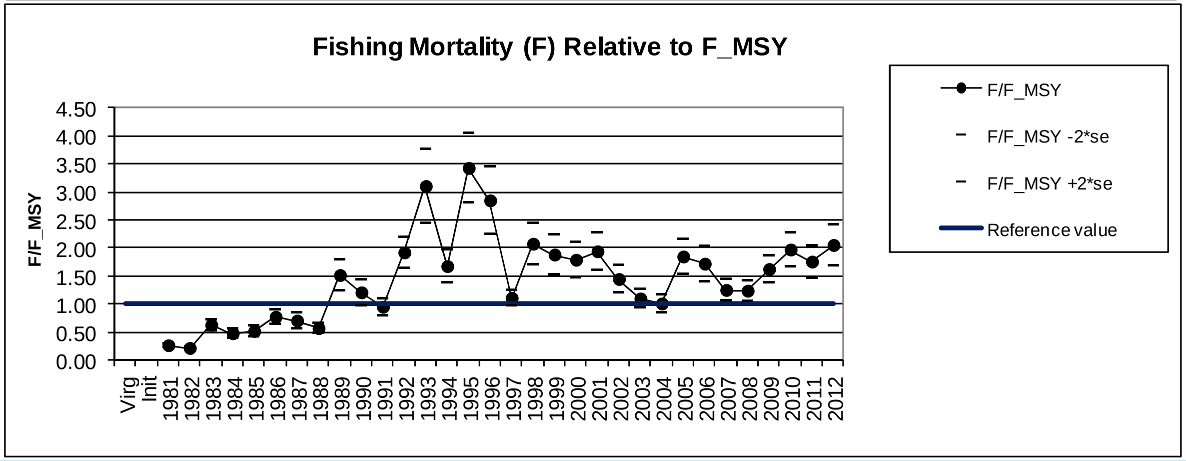
- Model results were sensitive to selectivity
- Estimating dome-shaped selectivity in SS3 for F1 (Sel-2) resulted in a slightly improved fit to the length composition data and to the abundance indices relative to estimating asymptotic selectivity in SS3 for F1 (Sel-1) as indicated by the relatively lower likelihood units for length and CPUE respectively
- Externally derived selectivity for F1 (Sel-3) resulted in about the same fit to length and CPUE as asymptotic selectivity for F1 (Sel-1)
- The use of externally derived selectivity for all fleets and surveys (Sel-4) resulted in a large change in F/F_MSY and SFF/SSF_MSY relative to base model structure (Sel-1 and Sel-2) and relative to the bench marks (1.0) for F/F_MSY and SFF/SSF_MSY



Sensitivity-1: Selectivity

- Sel-4: Externally derived selectivity for all fleets and surveys (analogous to SSASPM); start year in 1981; equilibrium conditions assumed prior to 1981
  - SSF_2012 slightly above SSF_MSY (solid line) and above SSF_MSST (dashed line)
  - F_2012 above F_MSY (solid line) in recent years





Sensitivity-2: Equilibrium Prior to 1981

- Sensitivity run-2
  - Start year 1972; Equilibrium fishing mortality prior to 1972

Sensitivity-2: Equilibrium Prior to 1981

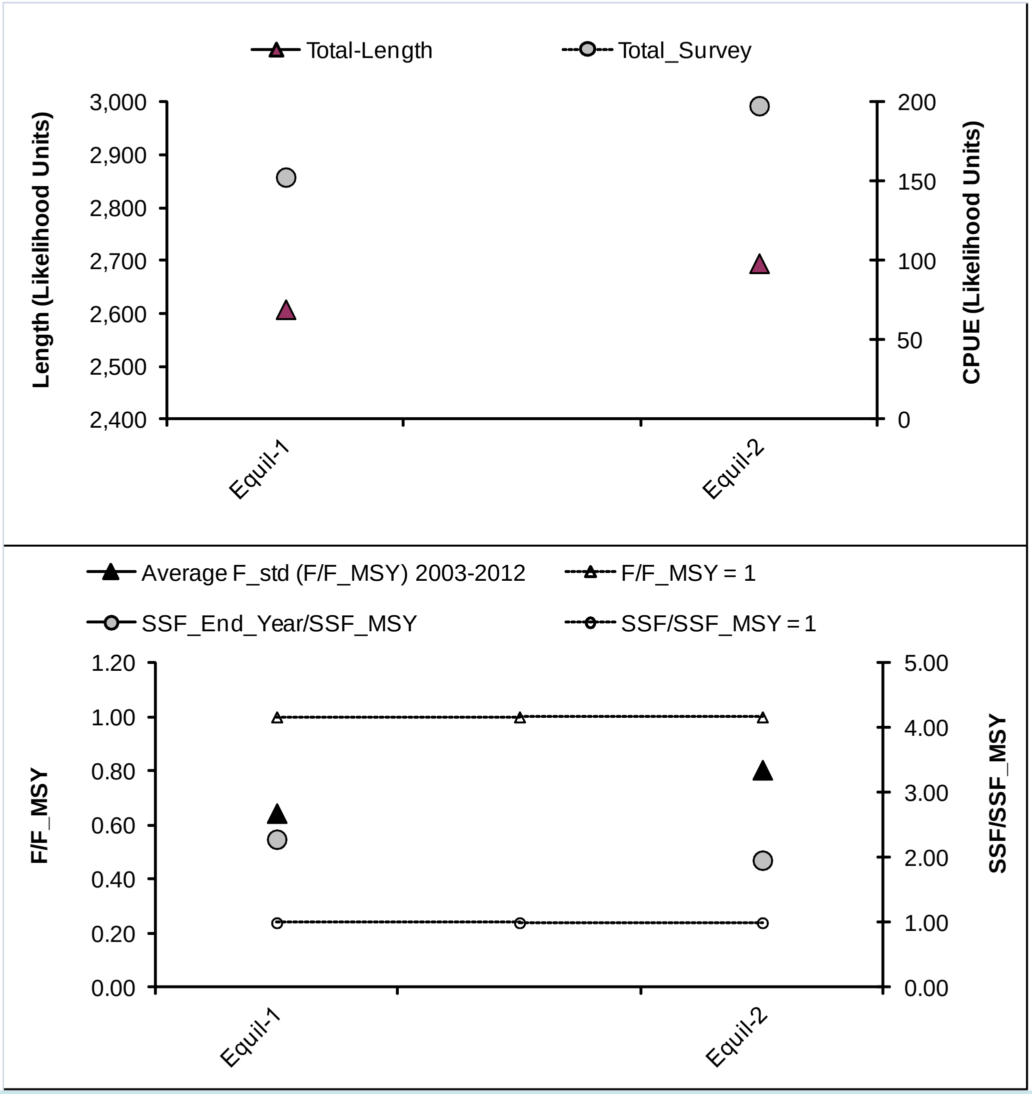
- Model sensitivity to assumed equilibrium conditions prior to model start year (1981)
  - Base (Equil-1)
    - Model start year 1981
    - Assume no catch prior to 1981
    - Assume equilibrium (unfished) conditions prior to 1981
  - Equil-2
    - Change model start year 1972
    - Include extrapolated catch from Data Workshop (1980 –> 1972)
    - Estimate equilibrium fishing mortality prior to 1972 in SS3

Sensitivity-2: Equilibrium Prior to 1981

- Model results were sensitive to the assumption of unfished equilibrium conditions prior to 1981

- Starting the model in 1972 and estimating equilibrium fishing mortality prior to 1972 (Equil-2) resulted in a moderate change in F/F_MSY and SFF/SSF_MSY relative to the base model structure (Equil-1)

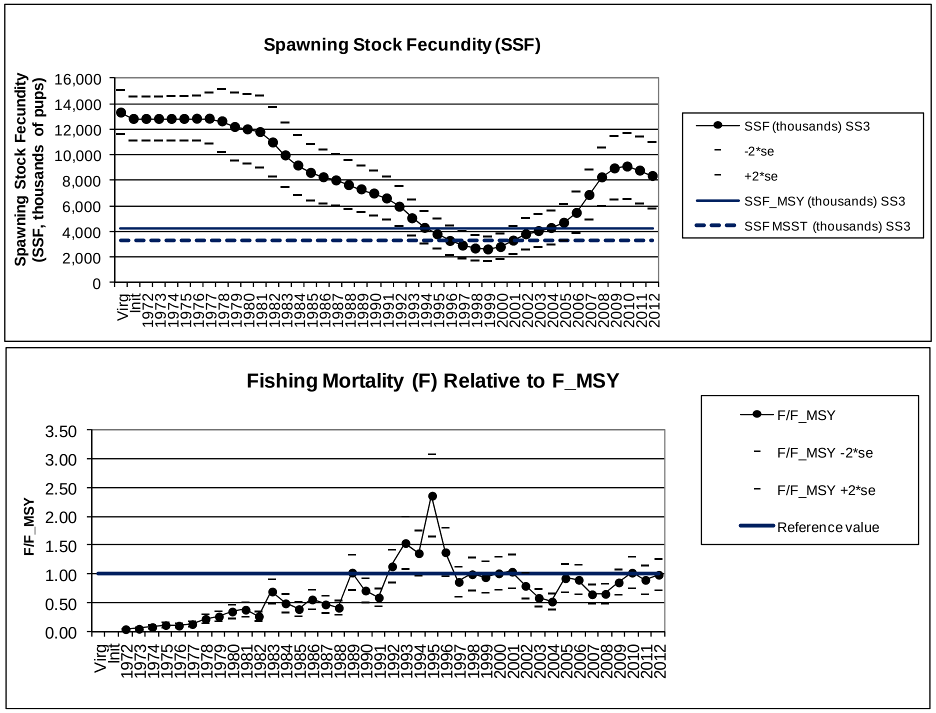
Sel-2; Dome-shaped F1



Sensitivity-2: Equilibrium Prior to 1981

- Equil-2: Start year 1972; Equilibrium fishing mortality prior to 1972
  - SSF_2012 above SSF_MSY and SSF_MSST
  - F_2012 ≈ F_MSY

Sel-2; Dome-shaped F1



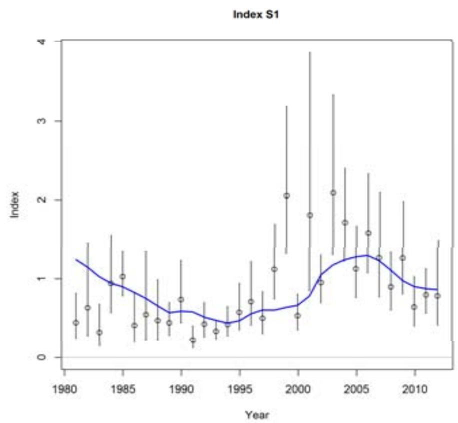
Sensitivity-2: Equilibrium Prior to 1981

- Fits to S1 not very sensitive to start year

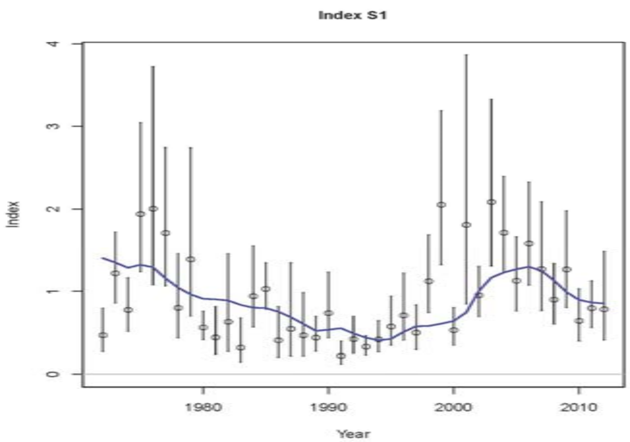
S1 1.1 NEFSC Fall Trawl-N

Sel-2;
Dome-shaped F1

Base (Start year 1981)



Alt. (Start year 1972)



Sensitivity-3: Sensitivity to CPUE Ranks

- Sensitivity run-3
  - Sensitivity to CPUE ranks assigned at Data Workshop

Sensitivity-3: Sensitivity to CPUE Ranks

- Sensitivity run-3
  - Base = inverse CV weighting
  - Alternative = (inverse CV weighting)*Weight
    - Alt-1: Weight = 1/(survey rank)
    - Alt-2: Weight = 1/(survey rank); standardized sum = 1.0
    - Alt-3: Weight = 1/(survey rank); standardized average = 1.0

Sensitivity-3: Sensitivity to CPUE Ranks

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

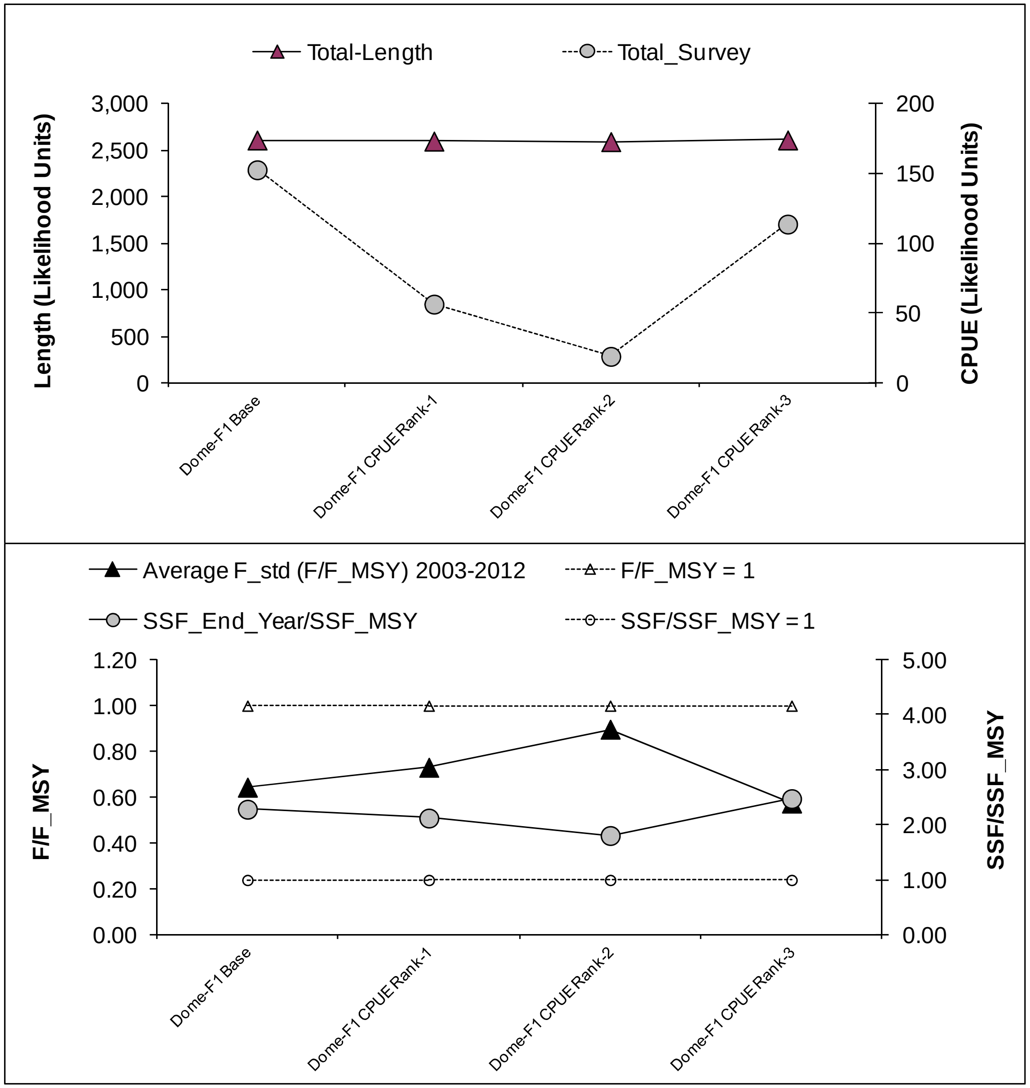
Sensitivity-3: Sensitivity to CPUE Ranks

- Model results were sensitive to the method used to implement assigned CPUE ranks from Data Workshop

- Use of alternative methods to implement ranks derived from the Data Workshop recommendations resulted in moderate changes in F/F_MSY and SFF/SSF_MSY relative to base model structure (Dome F1 Base)

- Use of ranks standardized to an average = 1.0 resulted in the smallest changes in F/F_MSY and SFF/SSF_MSY relative to base model structure (Dome F1 Base)

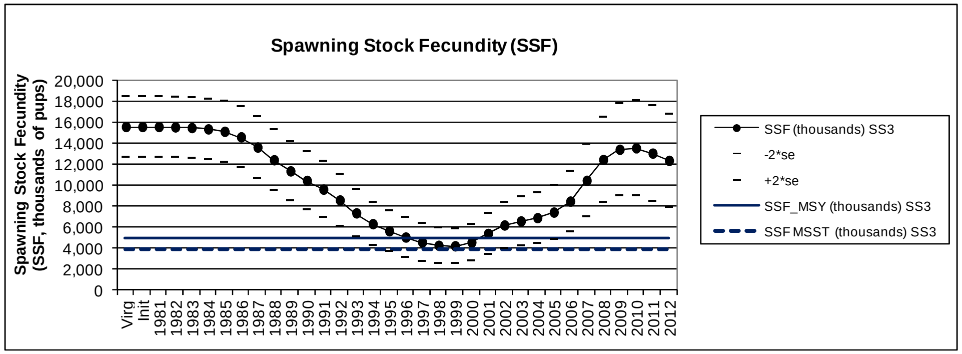
Sel-2; Dome-shaped F1

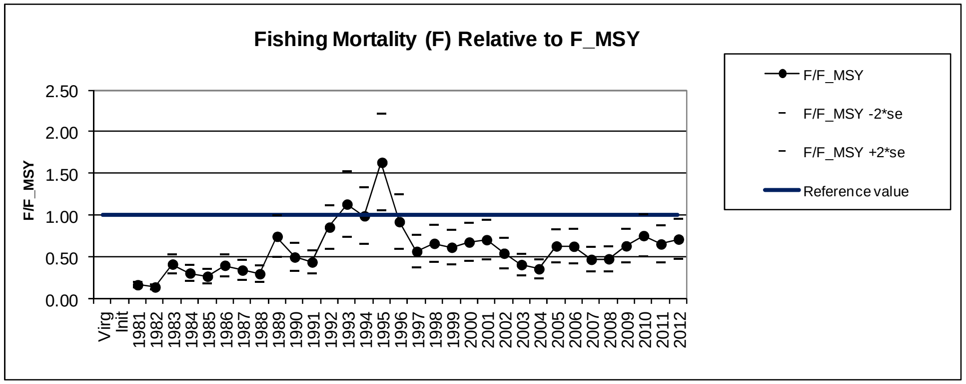


Sensitivity-3: Sensitivity to CPUE Ranks

- Alt-3: Weight = 1/(survey rank); standardized average = 1.0
  - SSF_2012 above SSF_MSY and SSF_MSST
  - F_2012 below F_MSY

Sel-2; Dome-shaped F1



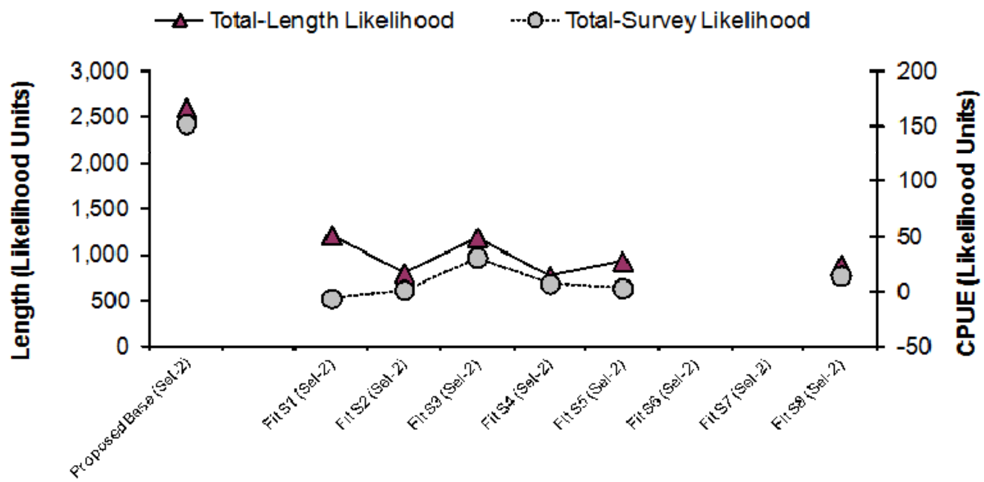


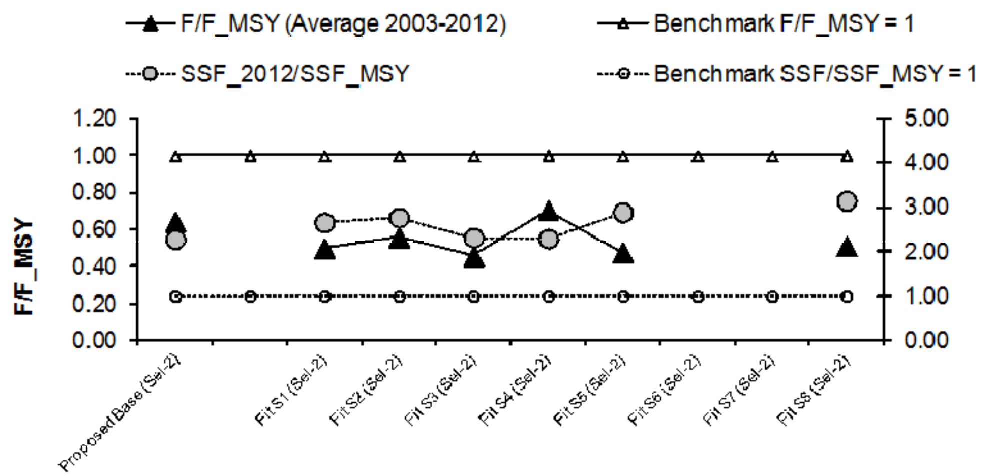
Sensitivity-4: Fit One CPUE at a Time

- Sensitivity run-4
  - Fit one abundance index (CPUE) at a time

Sensitivity-4: Fit One CPUE at a Time

- Model results were sensitive to fitting one CPUE at a time
- Resulted in large changes in total length and CPUE likelihoods (because of the different amount of data used)
- Resulted in moderate changes in F/F_MSY and SFF/SSF_MSY relative to base model structure (Dome F1 Base) and to benchmarks
- Models fit to S6 and S7 failed to converge





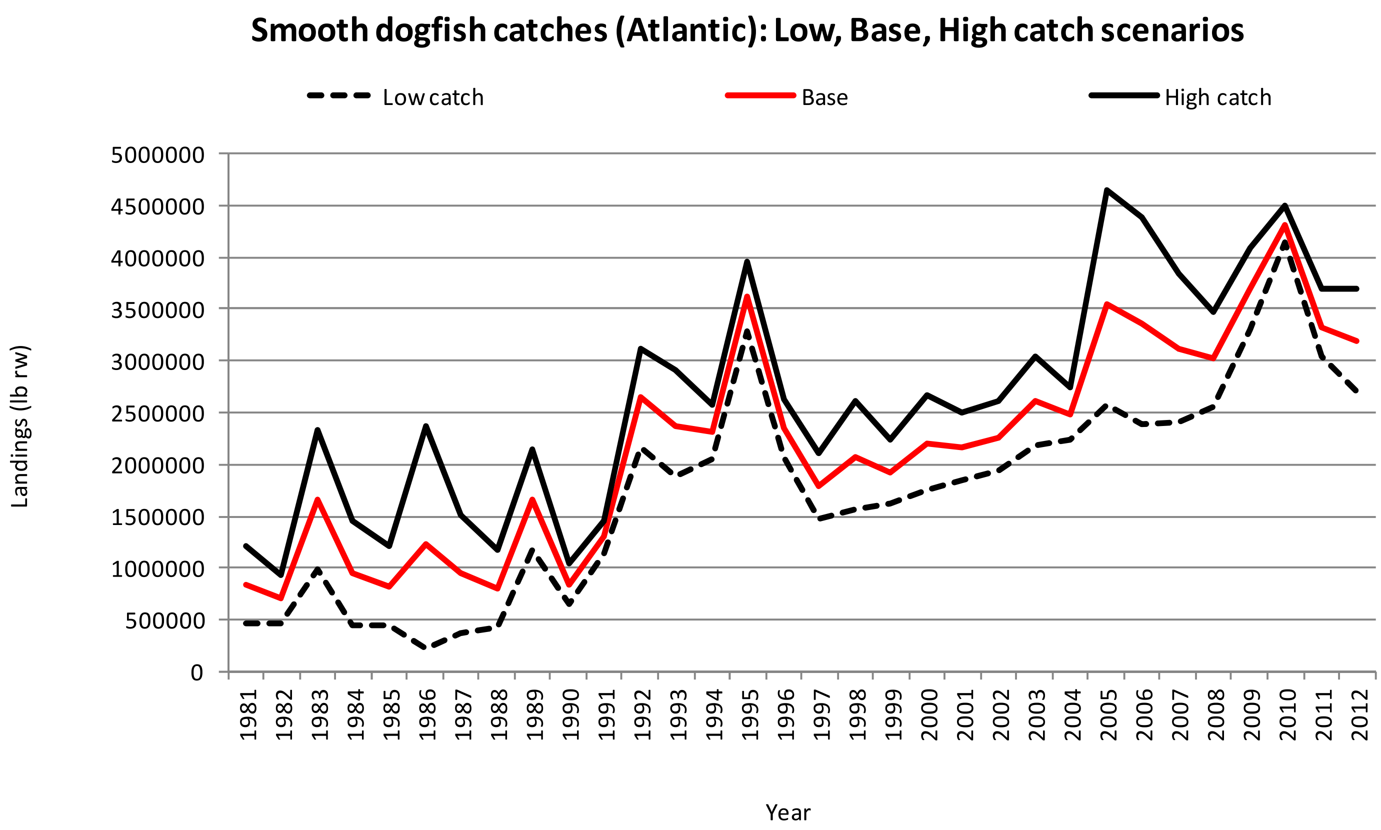
Sensitivity-5: Low and High Catch

- Sensitivity run-5
  - Low and high catch

Sensitivity-5: Low and High Catch

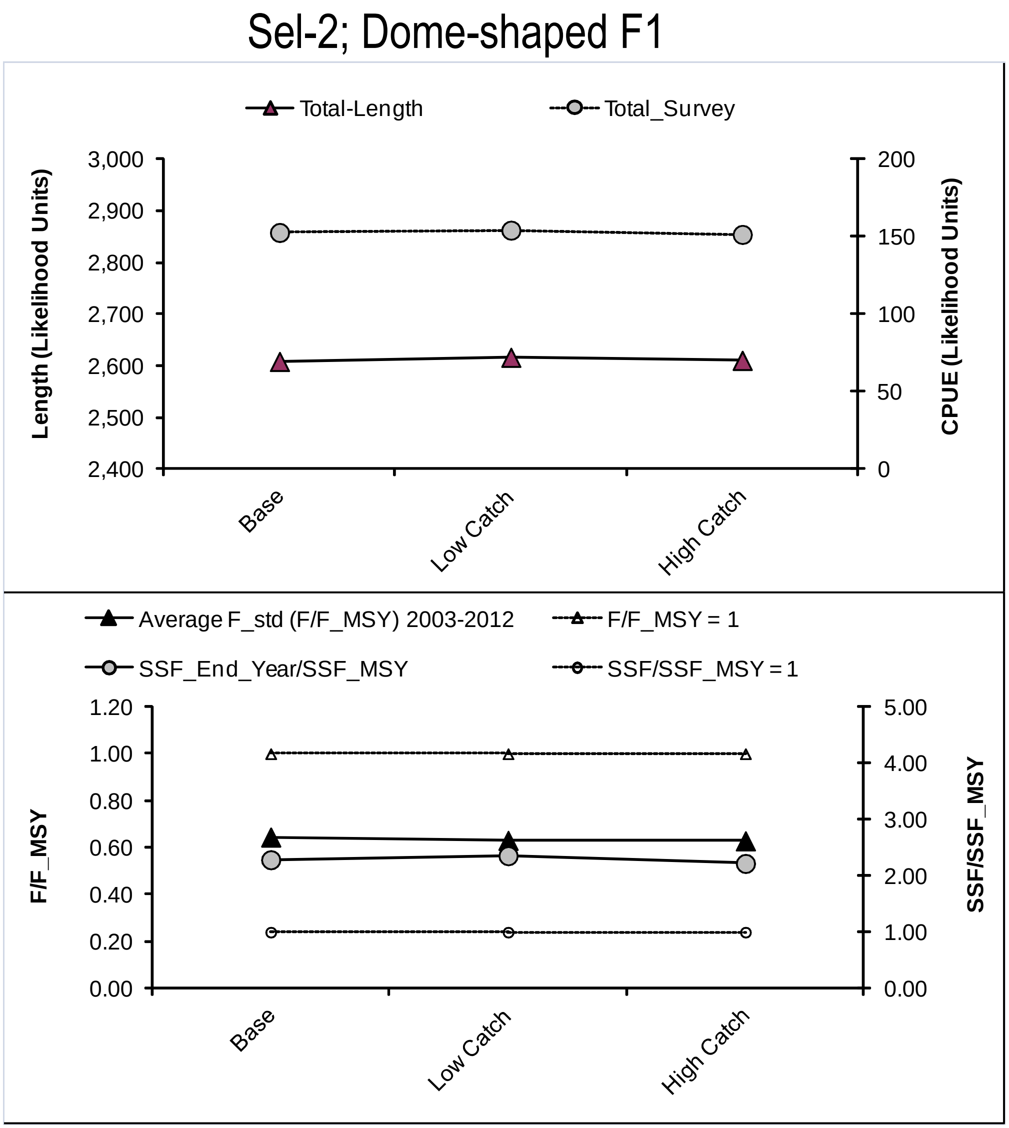
- Commercial landings are census-like; no variability
- Variability introduced (via CVs) in:
  - Commercial discards:
    - Gillnet, trawl, and longline NE
    - Gillnet SE
  - Recreational catches:
    - Landings + dead discards (A+B1)
    - Released alive (B2)

Sensitivity-5: Low and High Catch



Sensitivity-5: Low and High Catch

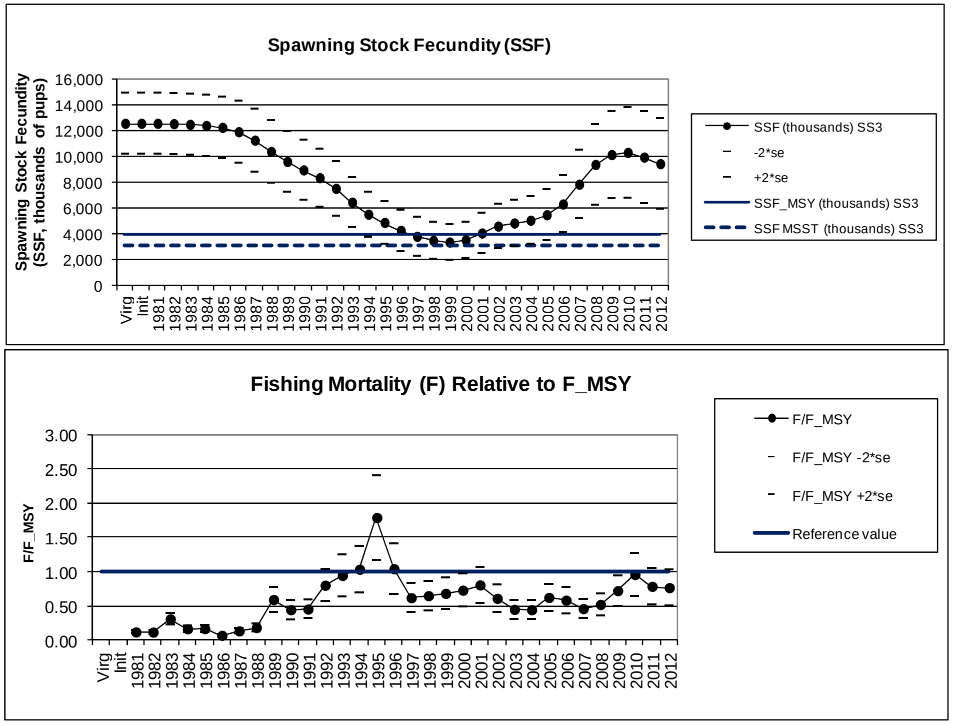
- Model results were not very sensitive to the low and high catch scenarios
- Both the low and high catch scenarios resulted in about the same fits to length and CPUE as the base model structure
- Both the low and high catch scenarios resulted in little change in F/F_MSY and SFF/SSF_MSY relative to the base model structure



Sensitivity-5: Low Catch

- Low catch
  - Results similar to those obtained under the base model structure

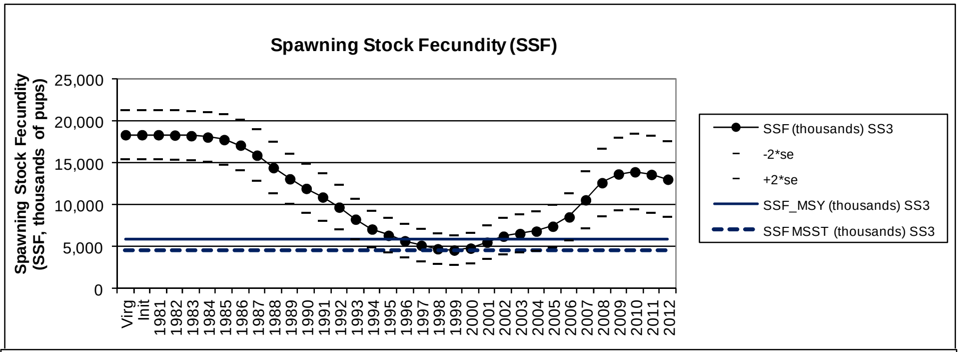
Sel-2; Dome-shaped F1

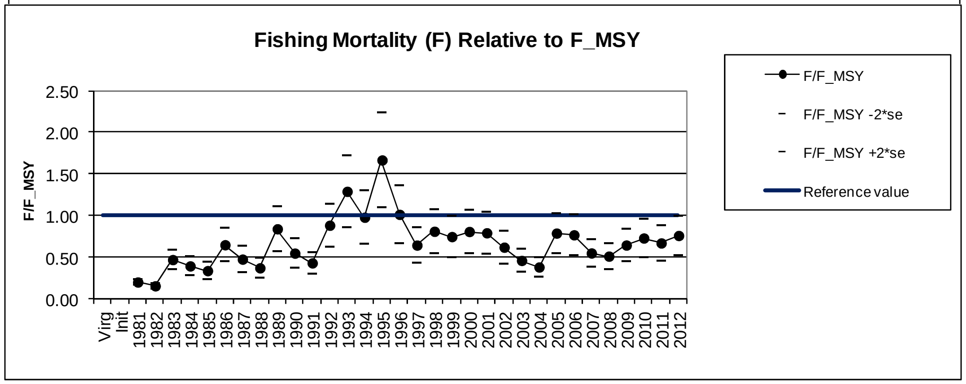


Sensitivity-5: High Catch

- High catch
  - Results similar to those obtained under the base model structure

Sel-2; Dome-shaped F1





Sensitivity-6: Low and High Productivity

- Sensitivity run-6
  - Low and High Productivity

Biological Inputs for M. *canis* (Atlantic): Low Productivity

- Female von Bertalanffy growth curve: LCL
  $L_\infty = 122.13$ cm STL, $K = 0.275\ yr^{-1}$, $t_0 = -2.069$ yr
- Lifespan = 16 yr; $a_{50} = 4.4$ yr
- Length-weight relationship: $W\ (kg) = 6x10^{-6}FL^{3.0084}$
- Pup-production: $-31.31+42.47(1-e^{-0.496a})$
- Parturition frequency: annual (1 yr)
- Natural Mortality = constant → 0.26 (a_0)
- $r = 0.211\ yr^{-1}$
- Steepness = 0.49

Biological Inputs for M. *canis* (Atlantic): High Productivity

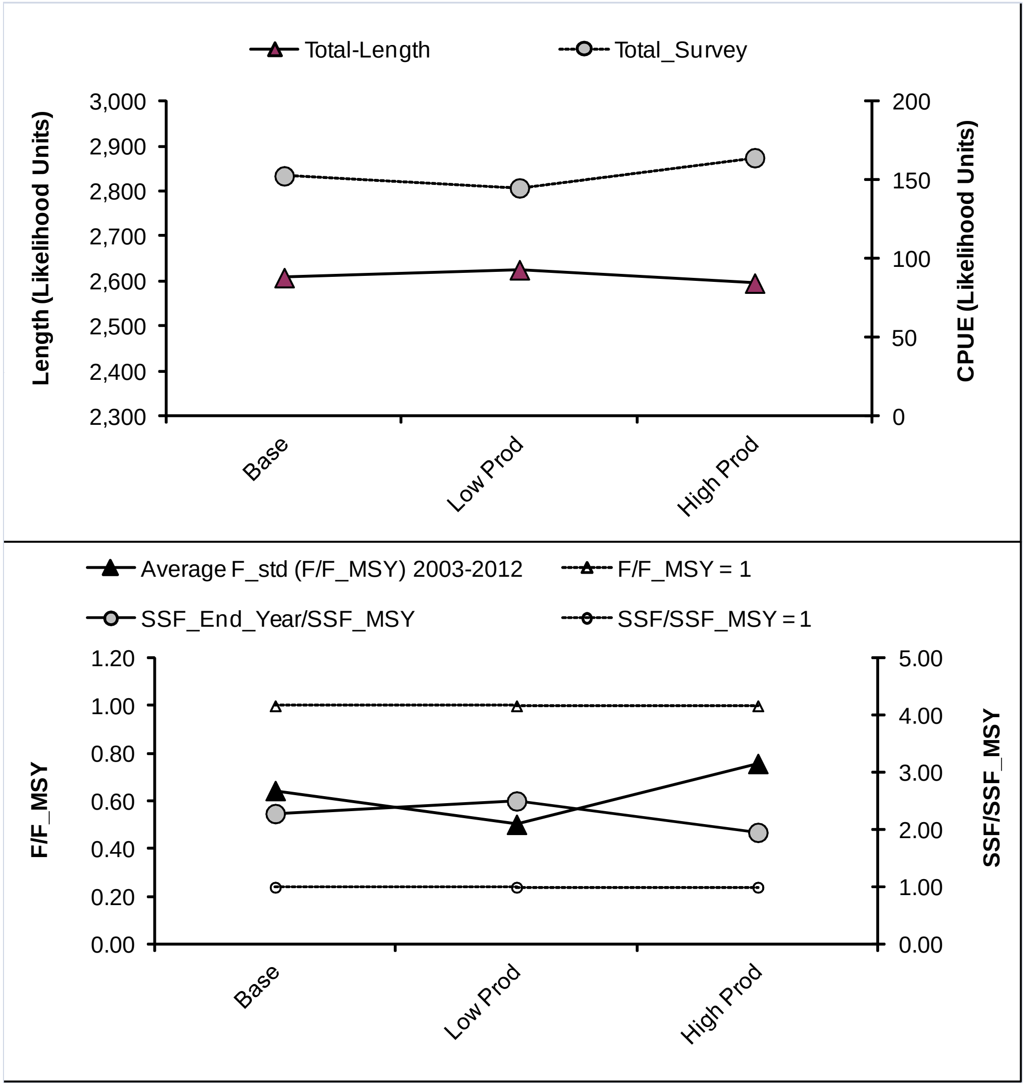
- Von Bertalanffy growth curve: UCL

  L_∞ = 125.01 cm STL, K = 0.309 yr^{-1}, t_0 = -1.817 yr
- Lifespan = 16 yr; a_{50} = 4.4 yr
- Length-weight relationship: W (kg) = $6x10^{-6}FL^{3.0084}$
- Pup-production: pups = constant (9.53)
- Parturition frequency: annual (1 yr)
- Natural Mortality = constant → 0.20 (a_{max})
- r = 0.276 yr^{-1}
- Steepness = 0.62

Sensitivity-6: Low and High Productivity

- Model results were sensitive to the low and high productivity scenarios
- The high productivity scenario resulted in a worse fit to CPUE than the base model structure
- Both the low and high productivity scenarios resulted in a moderate change in F/F_MSY and SFF/SSF_MSY relative to the base model structure

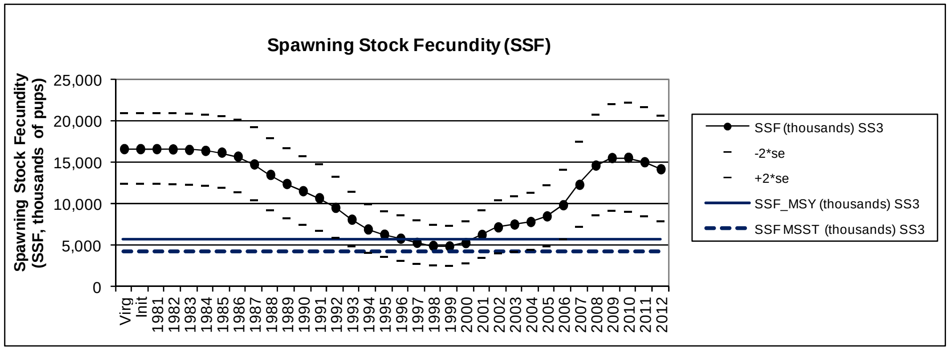
Sel-2; Dome-shaped F1

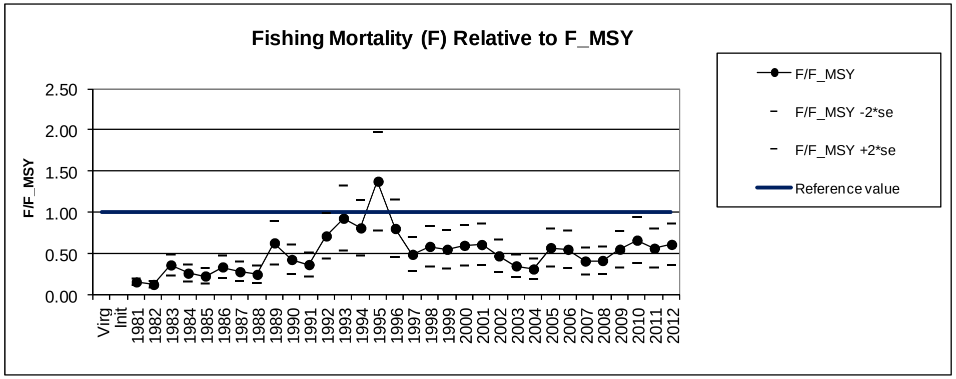


Sensitivity-6: Low Productivity

- Low productivity
  - SSF_2012 above SSF_MSY (solid line) and SSF_MSST (dashed line)
  - F_2012 below F_MSY (solid line)

Sel-2; Dome-shaped F1

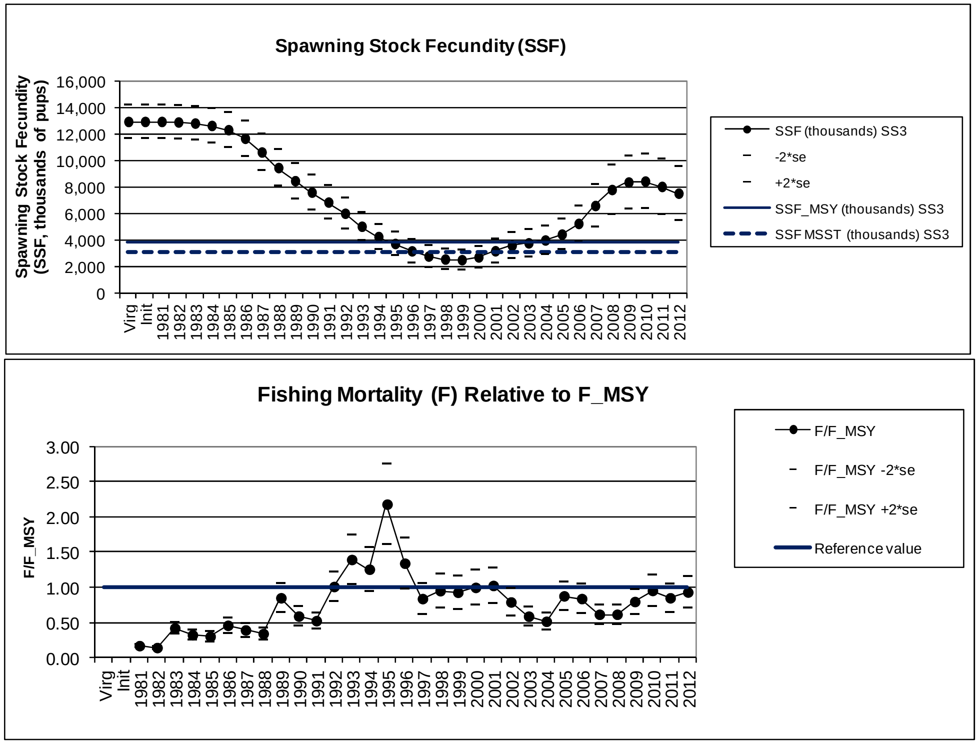




Sensitivity-6: High Productivity

- High productivity
  - SSF_2012 above SSF_MSY (solid line) and SSF_MSST (dashed line)
  - F_2012 below F_MSY (Sel-2; Dome-shaped F1)

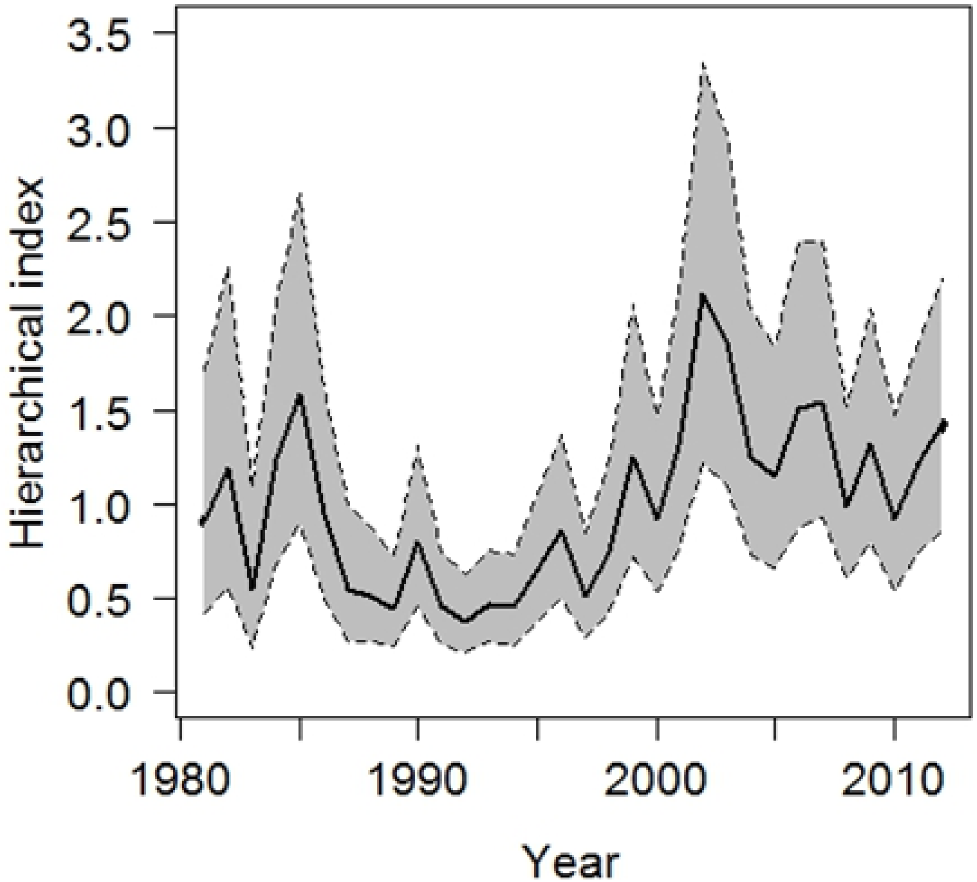
Sel-2; Dome-shaped F1



Sensitivity-7: Hierarchical Index

- Sensitivity run-7
  - Fit the hierarchical index of abundance

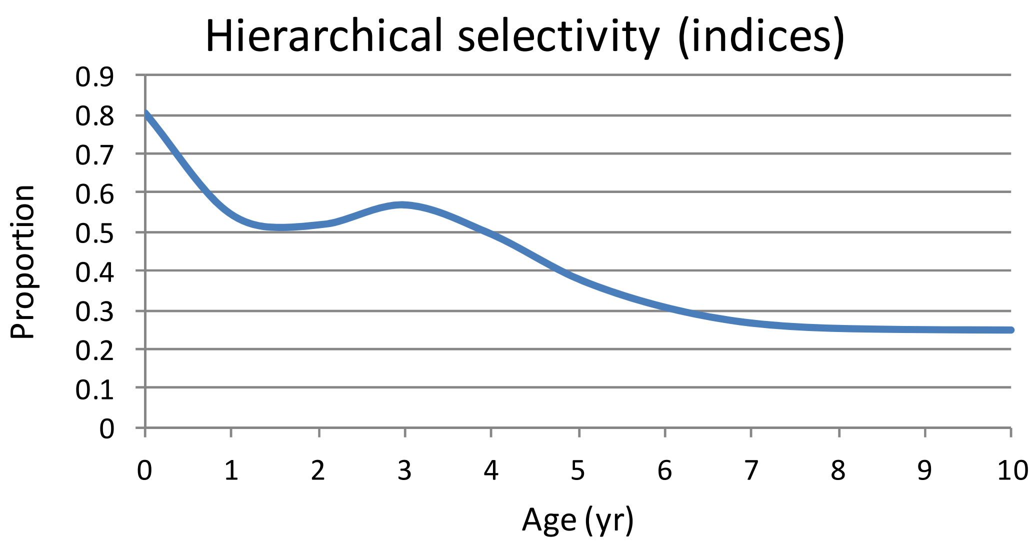
Sensitivity-7: Hierarchical Index



McCandless, C. T. Hierarchical analysis of U.S Atlantic smooth dogfish and Gulf of Mexico smoothhound species indices of abundance. SEDAR39-AW-02

Sensitivity-7: Hierarchical Index

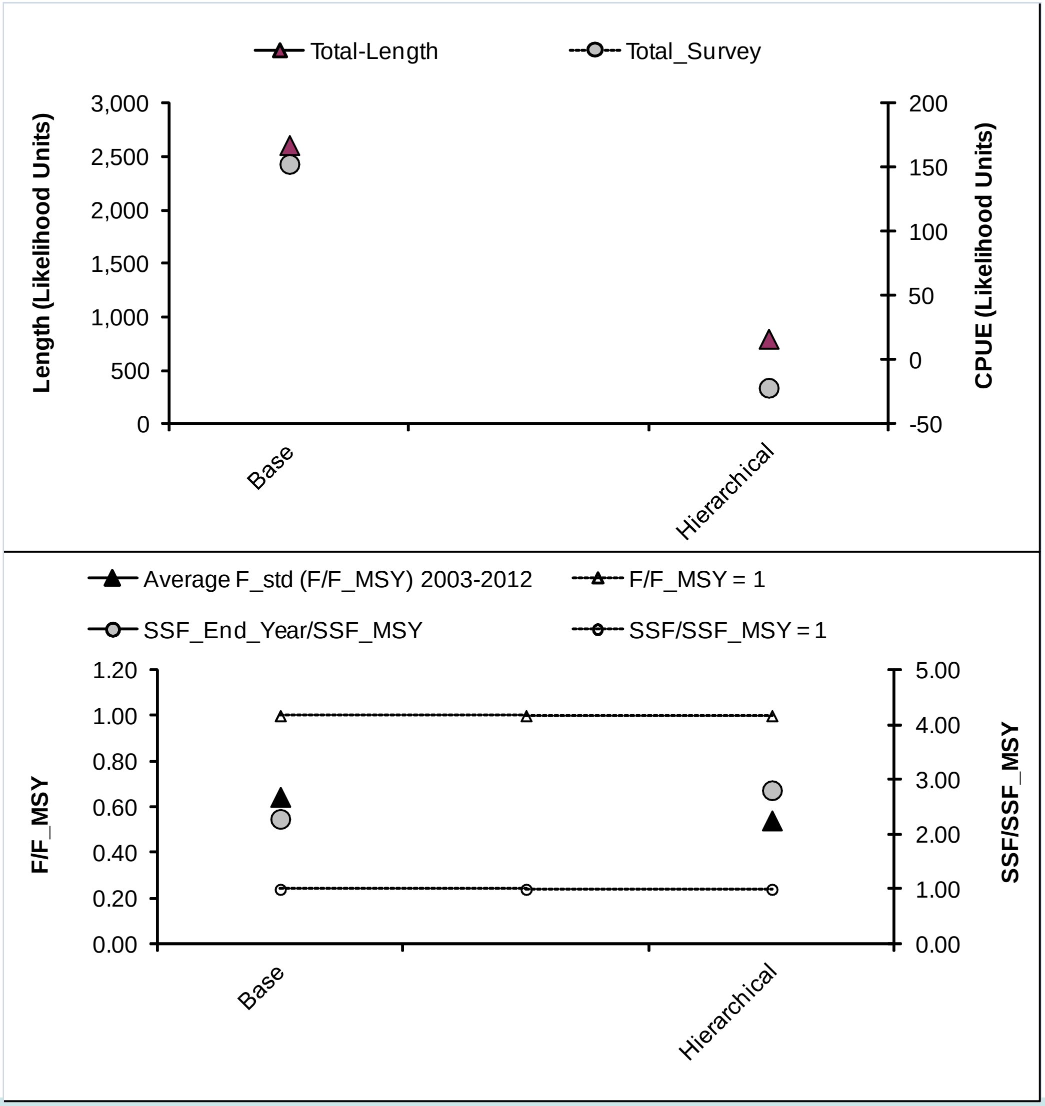
- The selectivity used for the hierarchical index was computed as a weighted sum (at age) of the selectivities associated with the individual indices (weighted by the inverse variance weights)



Sensitivity-7: Hierarchical Index

- Model results were sensitive to use of the hierarchical index
- The hierarchical index scenario utilized a single abundance index and no length composition data, consequently, the likelihood units for length and CPUE fits are not comparable with the base model
- The hierarchical index scenario resulted in a moderate change in F/F_MSY and SFF/SSF_MSY relative to the base model structure

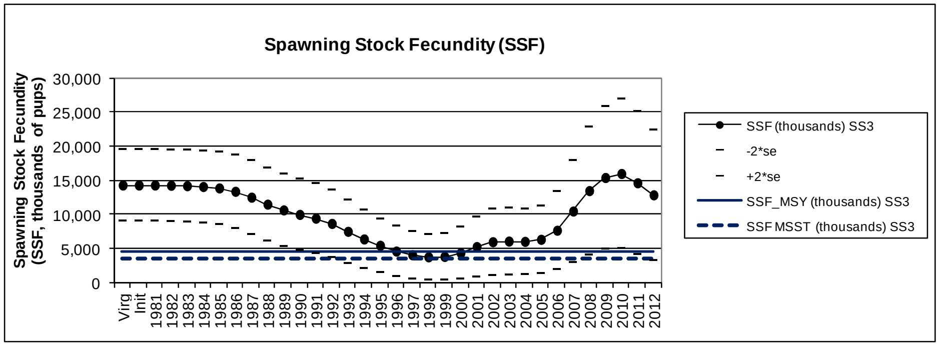
Sel-2; Dome-shaped F1

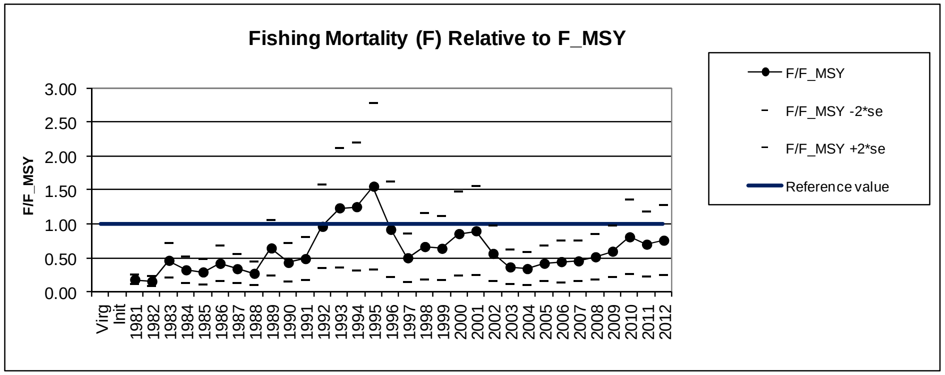


Sensitivity-7: Hierarchical Index

- Fit the hierarchical index of abundance
    - SSF_2012 above SSF_MSY (solid line) and SSF_MSST (dashed line)
    - F_2012 below F_MSY

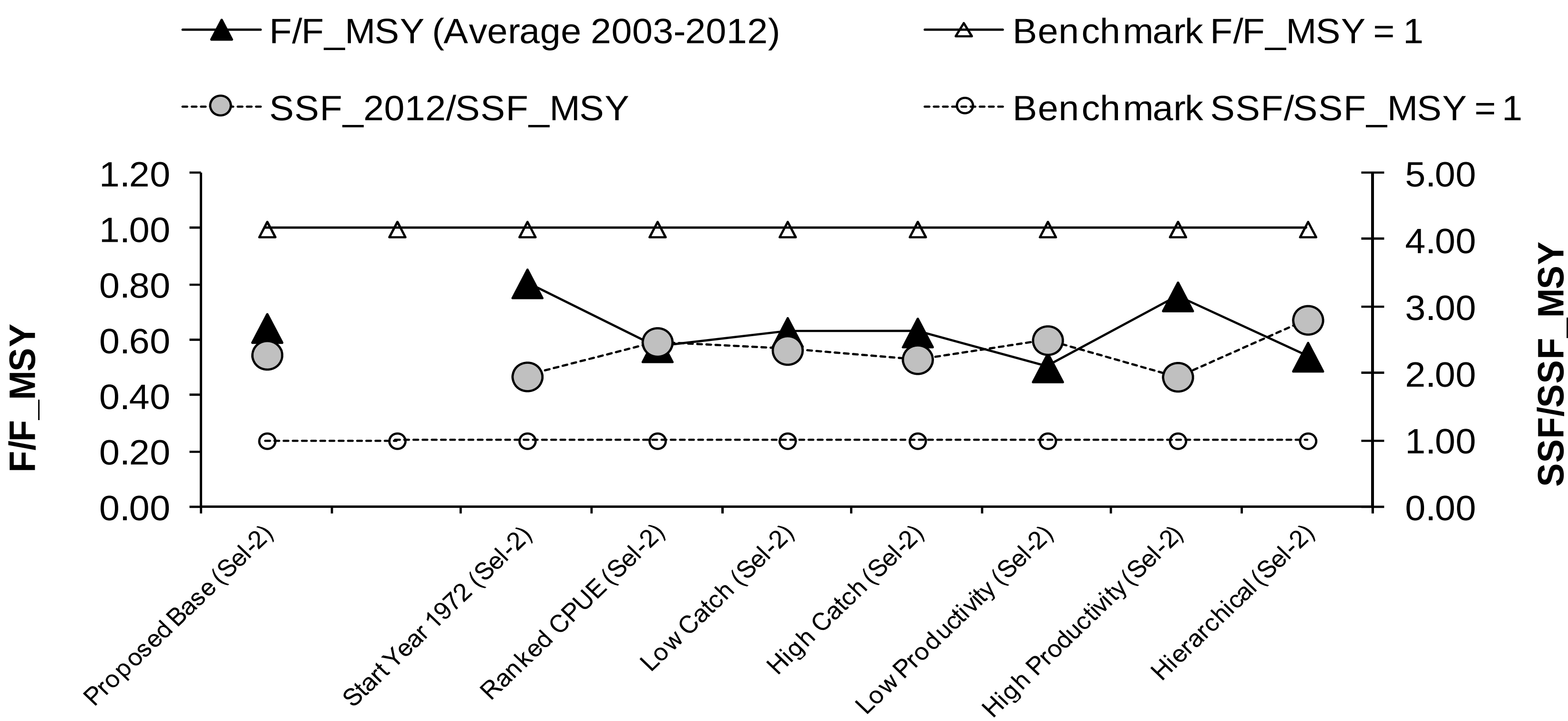
Sel-2; Dome-shaped F1





Summary of Sensitivity Run Results Under Sel-2

- Sel-2 Dome-shaped selectivity for fleet F1 (NE Gillnet Kept)
- The range of model and data configurations explored with sensitivity analyses resulted in moderate changes in F/F_MSY and SFF/SSF_MSY relative to the base model structure and to benchmarks



Sensitivity Model Results and Conclusions

- All of the sensitivity scenarios examined in this assessment estimated that the stock was not overfished
- In contrast, the sensitivity scenario with externally derived selectivity and two sensitivity scenarios conducted under model configuration Sel-1 estimated that the stock was in an overfishing condition, and one sensitivity scenario conducted under model configuration Sel-1 estimated that the stock was close to being in an overfishing condition ($F_{2012} \approx F_{MSY}$; i.e., either $F_{2012} > F_{MSY}$ or $F_{2012} = F_{MSY}$ depending upon how rounding is calculated) (Table 4.12; Figure 4.24.a)

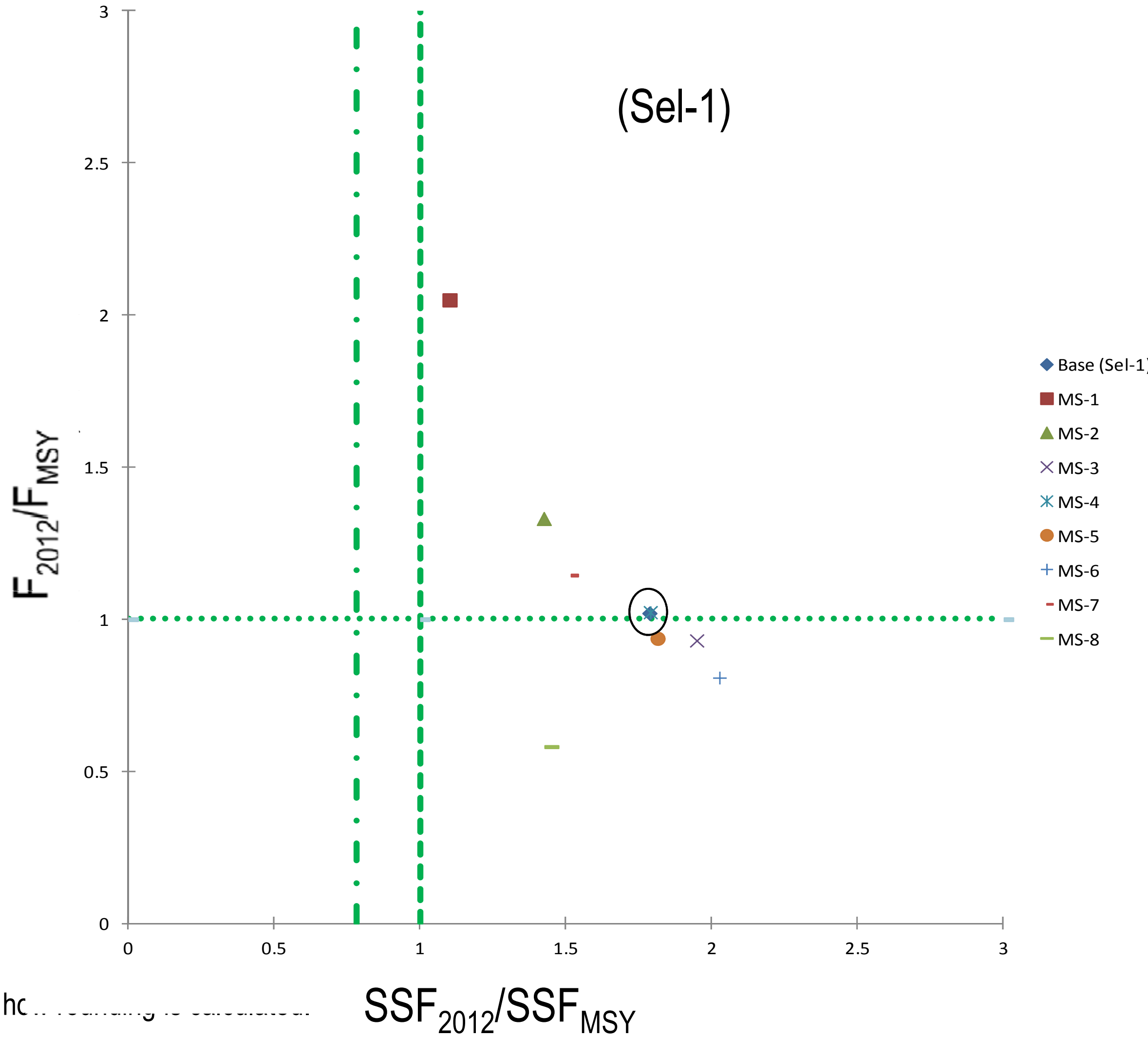
Sensitivity Results Under Sel-1 (Figure 4.24.a)

- Base (Sel-1)[2]
- MS-1 External Selectivity[1]
- MS-2 Start Year 1972 (Sel-1)[1]
- MS-3 Ranked CPUE (Sel-1)
- MS-4 Low Catch (Sel-1)[2]
- MS-5 High Catch (Sel-1)
- MS-6 Low Productivity (Sel-1)
- MS-7 High Productivity (Sel-1)[1]
- MS-8 Hierarchical (Sel-1)

[1] $F_{2012} > F_{MSY}$

[2] $F_{2012} \approx F_{MSY}$*

*Either $F_{2012} > F_{MSY}$ or $F_{2012} = F_{MSY}$, depending upon hc



$1-\bar{M}_a$

Sensitivity Results Under Sel-1 (Table 4.12)

- Summary of model results for eight model sensitivities conducted either with externally derived selectivity or selectivity under the same model configuration as Sel-1 (asymptotic-shaped functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept)).

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

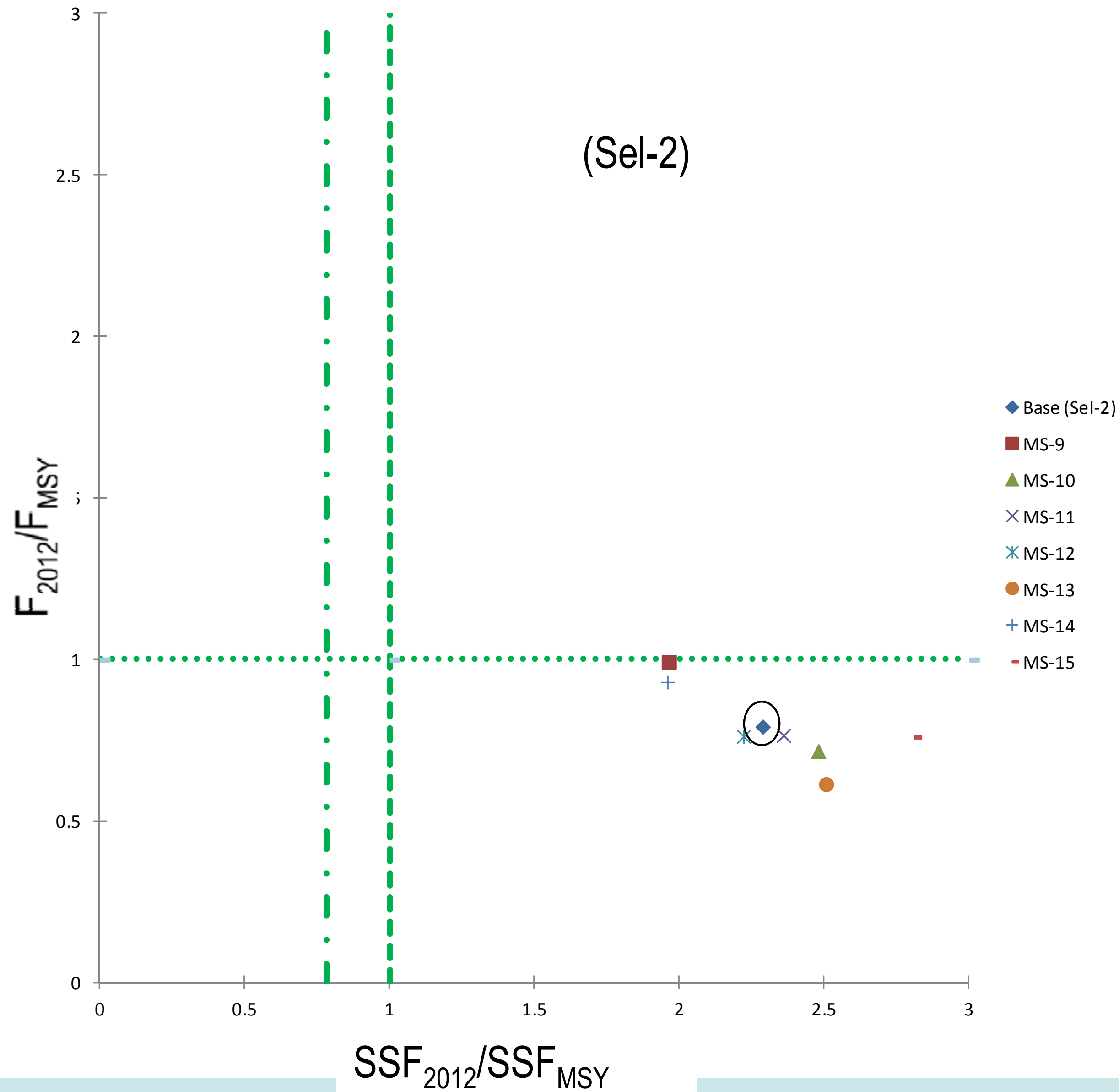
*Either $F_{2012} > F_{MSY}$ or $F_{2012} = F_{MSY}$, depending upon how rounding is calculated.

Sensitivity Model Results Under Sel-2

- All of the sensitivity scenarios conducted under model configuration Sel-2 estimated that the stock was not in an overfishing condition, although one scenario was estimated close to an overfishing condition ($F_{2012} \approx F_{MSY}$; i.e., either $F_{2012} < F_{MSY}$ or $F_{2012} = F_{MSY}$ depending upon how rounding is calculated) (Tables 4.12 and 4.13; Figures 4.24.a and 4.24.b).

Sensitivity Results Under Sel-2 (Figure 4.24.b)

- Base (Sel-2)
- MS-9 Start Year 1972 (Sel-2)
- MS-10 Ranked CPUE (Sel-2)
- MS-11 Low Catch (Sel-2)
- MS-12 High Catch (Sel-2)
- MS-13 Low Productivity (Sel-2)
- MS-14 High Productivity (Sel-2)
- MS-15 Hierarchical (Sel-2)



$1-\bar{M}_a$

Sensitivity Results Under Sel-2 (Table 4.13)

- Summary of model results for seven model sensitivities conducted under the same model configuration as Sel-2 (dome-shaped functional form of length based selectivity for the main targeted fishery (fleet F1 – NE Gillnet Kept))

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

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

Projections

- Courtney, D. 2015. Projections for the SEDAR 39 Atlantic Smooth Dogfish (*Mustelus canis*) Stock Assessment Report Base Model Configuration. SEDAR39-RW-01. SEDAR, North Charleston, SC. 17 pp.

Projections at Alternative Fixed Removals

- SEDAR39-RW-01 Table 1. Simulations were conducted for 21 alternative fixed levels of total annual removals due to fishing (1000s of sharks) ranging from zero to 1,000 in increments of 50.

Fixed level of total annual removals due to fishing (1000s of sharks)	Alternative
0	1
50	2
100	3
150	4
200	5
250	6
300	7
350	8
400	9
450	10
500	11
550	12
600	13
650	14
700	15
750	16
800	17
850	18
900	19
950	20
1000	21

Projection Methods

- Projection results were reported for a given fixed level of total annual removals due to fishing (1,000s of sharks).

- Projection results were reported as the proportion of times that spawning stock fecundity in projection year *t* (SSF_t) was above spawning stock fecundity at maximum sustainable yield (SSF_{MSY}), $Pr(SSF_t > SSF_{MSY})$

- The $Pr(SSF_t > SSF_{MSY})$ was color coded as:
  - $Pr \geq 0.70$ (green),
  - $0.50 \leq Pr < 0.70$ (yellow), and
  - $Pr < 0.50$ (red).

Projection Results for Assessment Base Model (Sel-2)

- Projection results from 10,000 Monte Carlo simulations over the range of fixed removals levels evaluated here (SEDAR39-RW-01 Table 1) indicated that levels of fixed removals less than or equal to 550 (1000s of sharks) resulted in at least a 70% probability of maintaining SSF_t, above SSF_{MSY} during the years 2013 – 2022 (SEDAR39-RW-01 Table 2).

Projection Results for Assessment Base Model (Sel-2)

- SEDAR39-RW-01 Table 2

Alternative	Fixed level of total annual removals due to fishing (1000s of sharks)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	150	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	250	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	350	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
9	400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.96
10	450	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.95	0.91
11	500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.90	0.84
12	550	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.83	0.74
13	600	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.88	0.75	0.63
14	650	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.81	0.65	0.51
15	700	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.72	0.54	0.38
16	750	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.64	0.43	0.28
17	800	1.00	1.00	1.00	1.00	1.00	1.00	0.84	0.54	0.34	0.18
18	850	1.00	1.00	1.00	1.00	1.00	1.00	0.77	0.46	0.24	0.10
19	900	1.00	1.00	1.00	1.00	1.00	0.99	0.70	0.37	0.17	0.05
20	950	1.00	1.00	1.00	1.00	1.00	0.98	0.62	0.29	0.10	0.02
21	1000	1.00	1.00	1.00	1.00	1.00	0.96	0.53	0.21	0.06	0.01

Thank you