SEDAR 28 Stock Assessment:

U.S. South Atlantic Cobia

(*Rachycentron canadum*)

SEDAR 28 Review Workshop

Atlanta, GA

October 29-31, 2012

Outline

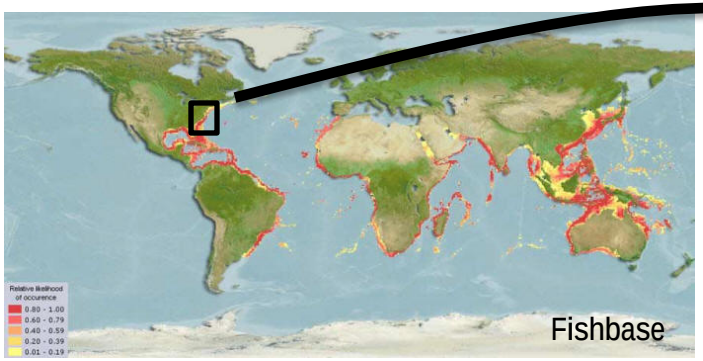
I. Stock definition and life history characteristics

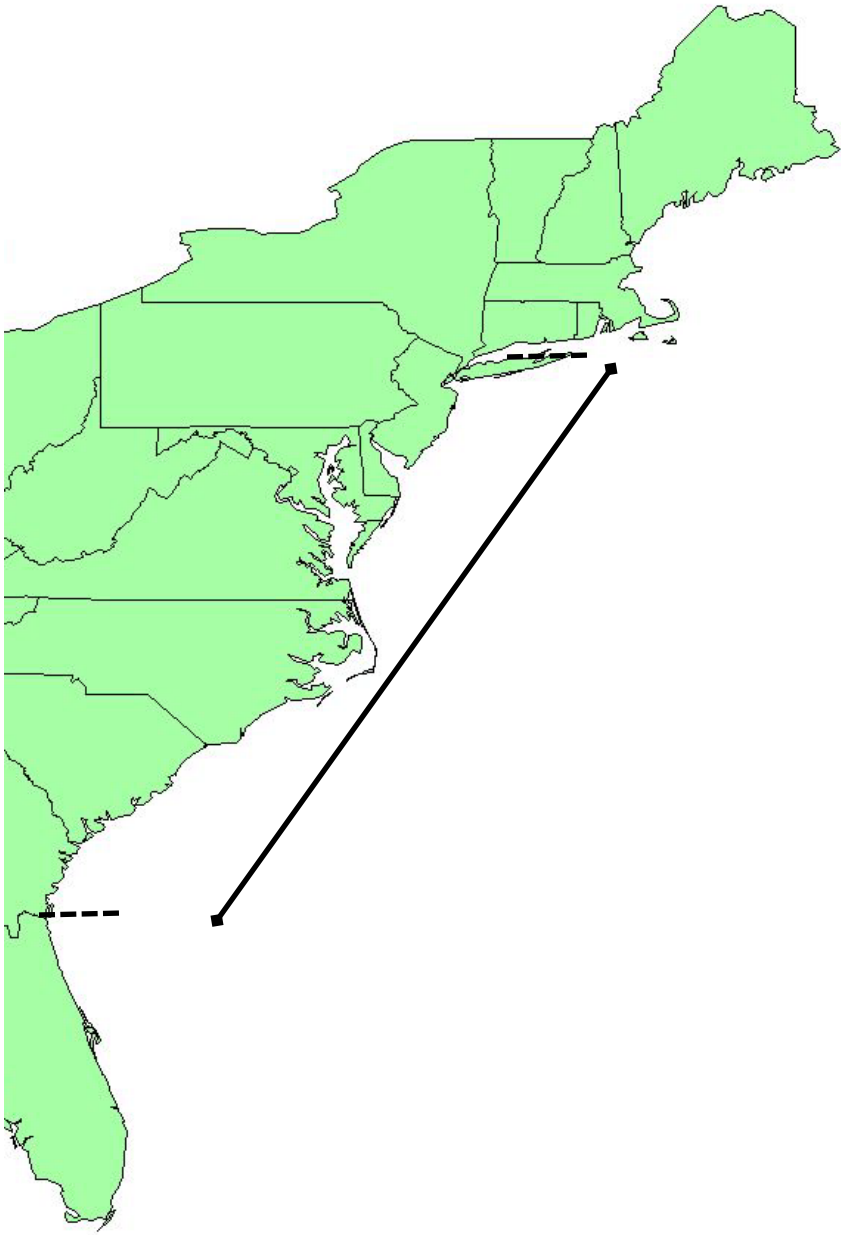
II. Data Sources
- Landings and discards
- Age and length compositions
- Indices of abundance

III. Statistical catch-age model (BAM) and associated analyses

IV. Supplementary methods
- Mortality estimation (catch curves, mean length estimator)
- Surplus production model

Cobia Geographic Distribution





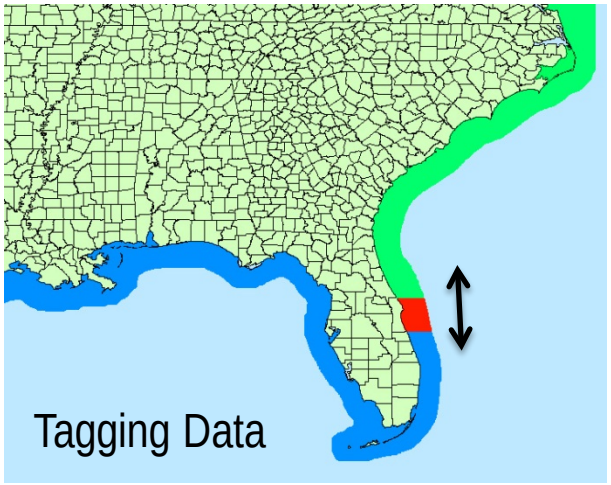
- Globally distributed
- U.S. distribution extends along Gulf and East coast
- Stock boundaries from New York to Ga-Fl border

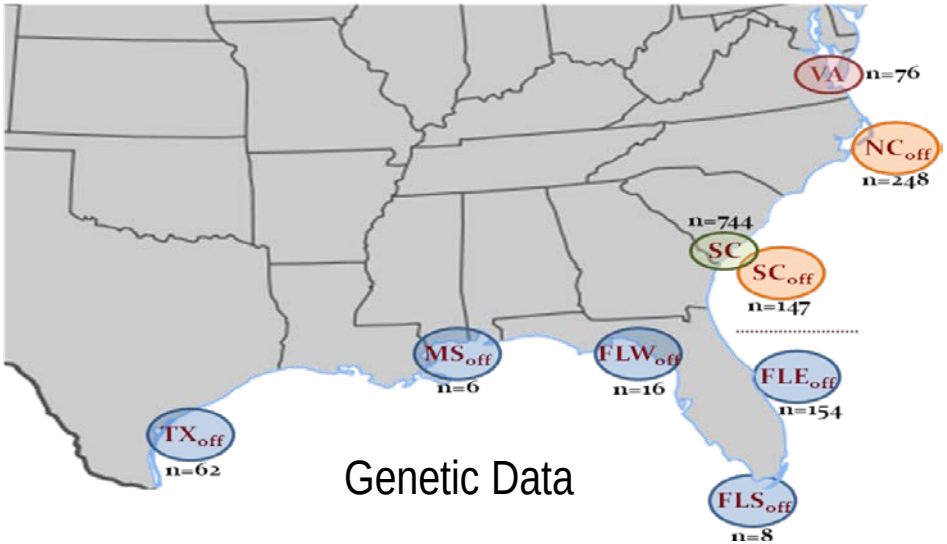
Stock Definition

Northern boundary: Through New York, northern extent of landings

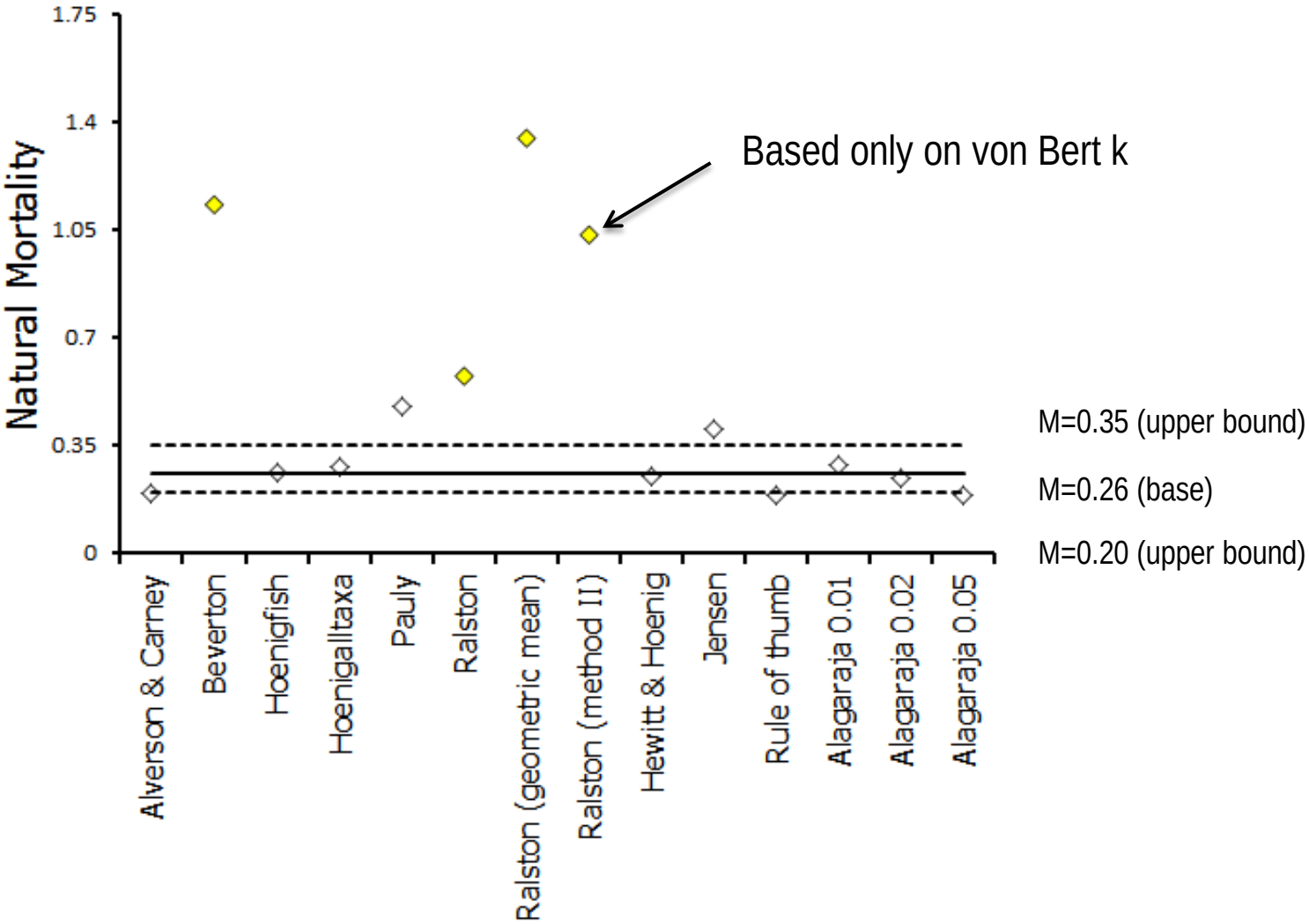
Southern boundary:

- Tagging data suggest a mixing zone off east coast of Florida
- Recent genetic (microsatellite) data suggest a boundary north of the proposed mixing zone, but not clear how far north
- Limited genetic data suggest some inshore-offshore structure of adult fish
- DW recommended Fl-Ga border as southern boundary; combine purported inshore/offshore “stocks”





Natural Mortality



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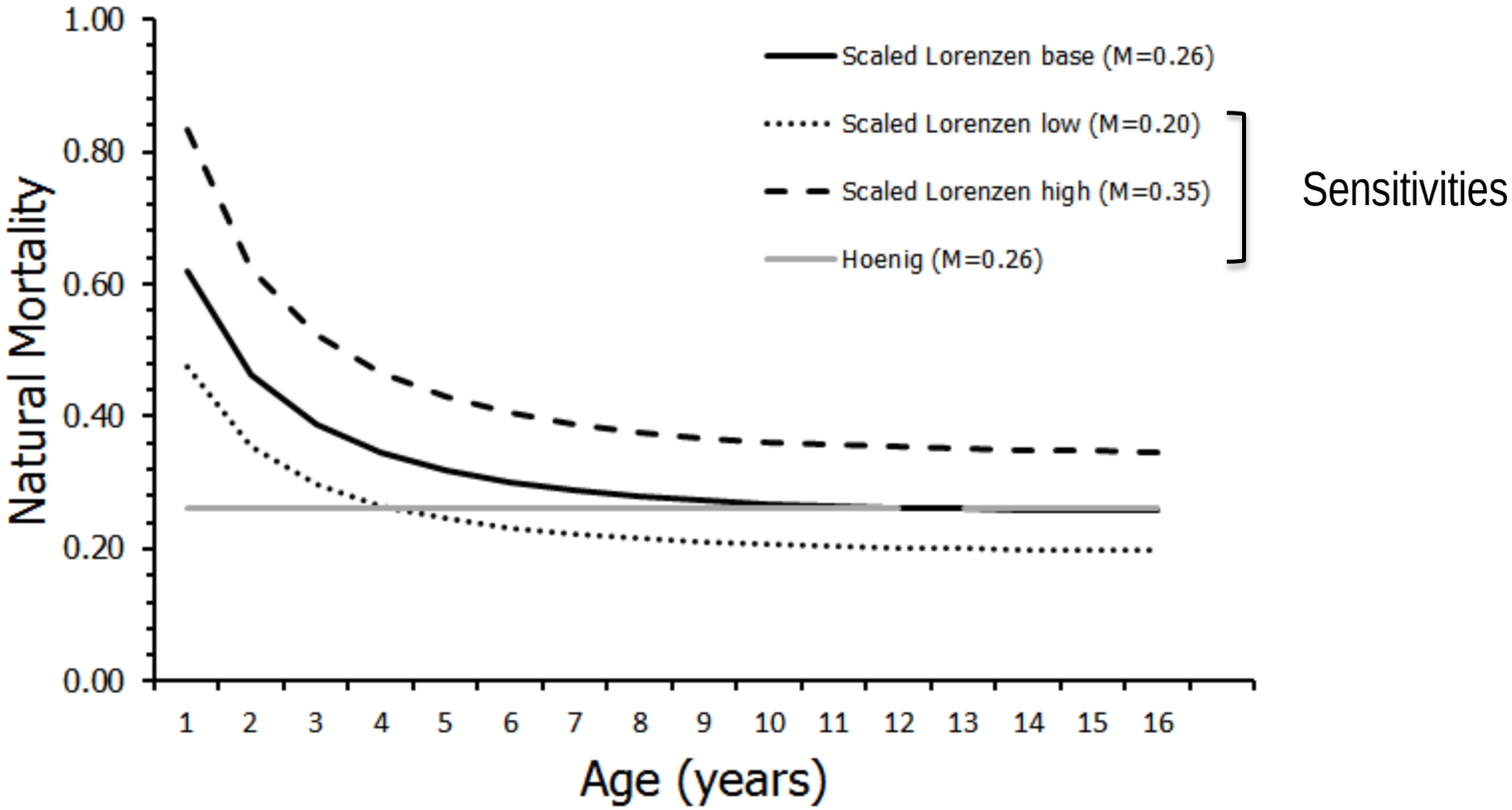
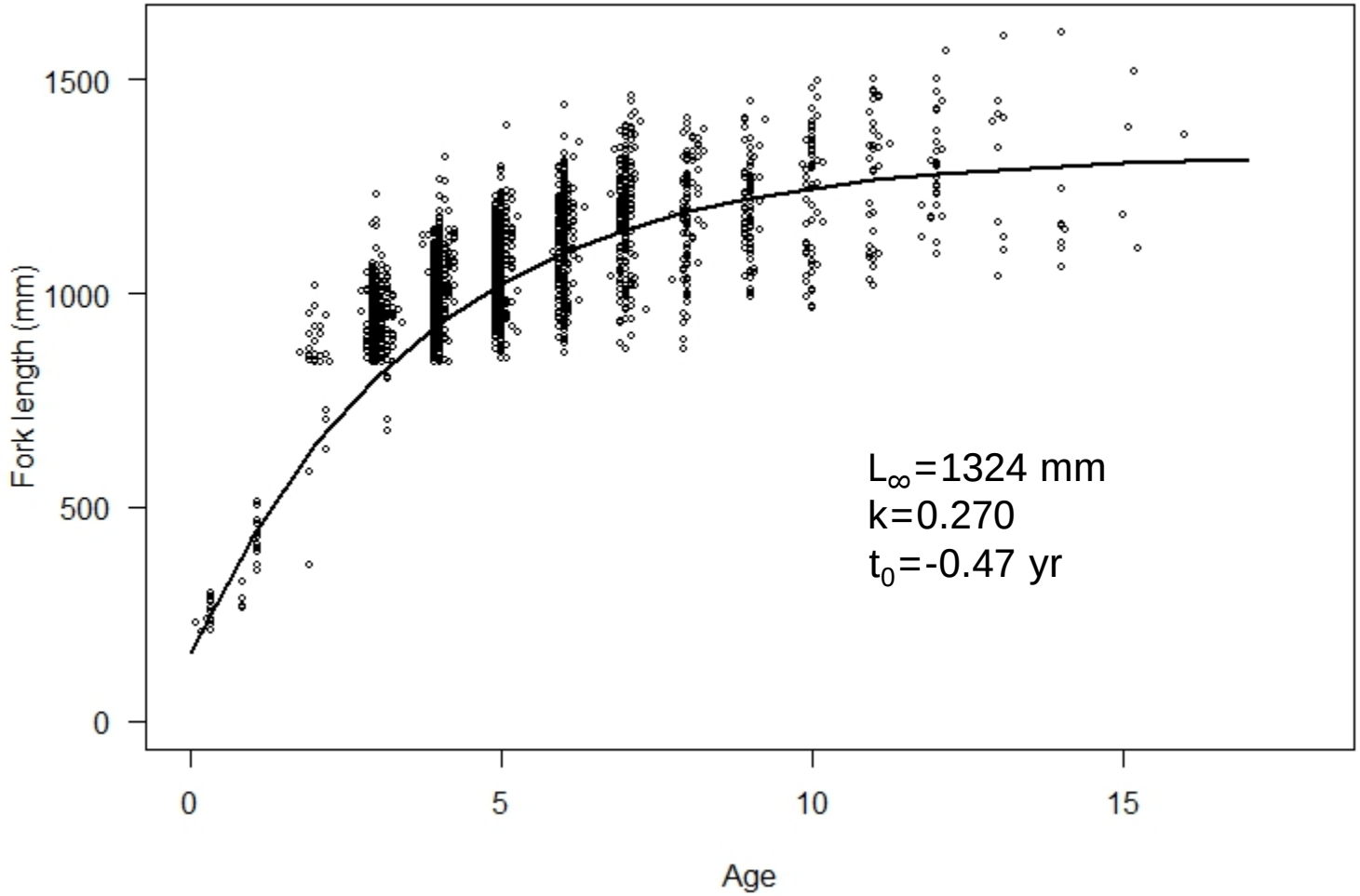


- Scaled to provide same fraction fish surviving to max age as for constant M
- Age-based mortality assumed constant in time

Growth



- Assumed Von Bertalanffy growth
- Corrected for size-selectivity (Diaz correction)
- Inverse weighted by sample size at calendar age

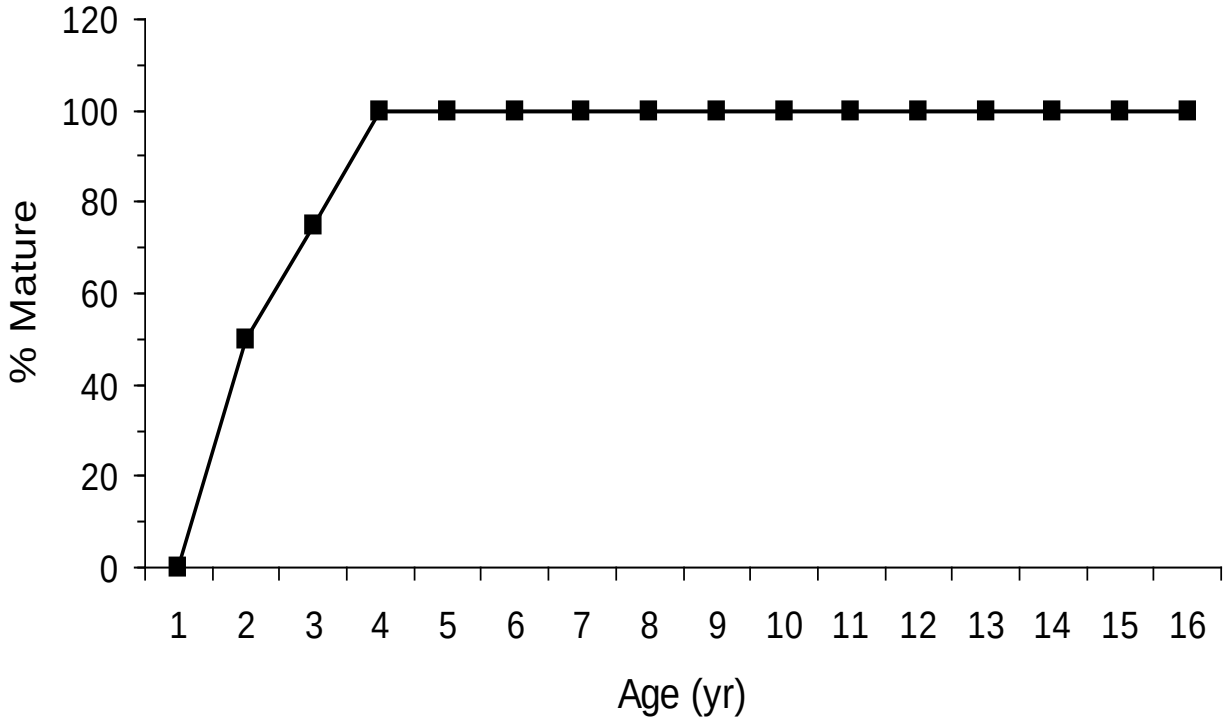
Female Maturity

DW Recommendation: Age 50% maturity = 2 yrs

Female FL (mm)	% Mature	n	
≤350	0	0	<1 yr (assume 0% mature)
351-400	0%	2	
401-450	0%	3	
451-500	0%	2	
551-600	0%	1	2 yr (assumed 50% mature)
601-650	33%	3	
651-700	100%	1	
701-750	44%	9	3 yr (assume 75% mature)
751-800	75%	4	
801-850	100%	24	
851-900	100%	53	>4 yr (assumed 100% mature)
901-950	100%	73	
951-1000	100%	89	
1001-1050	100%	93	
1051-1100	100%	67	
1101-1150	100%	89	
1151-1200	100%	80	
1201-1250	100%	55	
1251-1300	100%	52	
1301-1350	100%	27	
1351-1400	100%	18	
1401-1450	100%	8	
1451-1500	100%	10	
1551-1600	100%	1	
1601-1650	100%	1	
Total	**98%**	**765**	

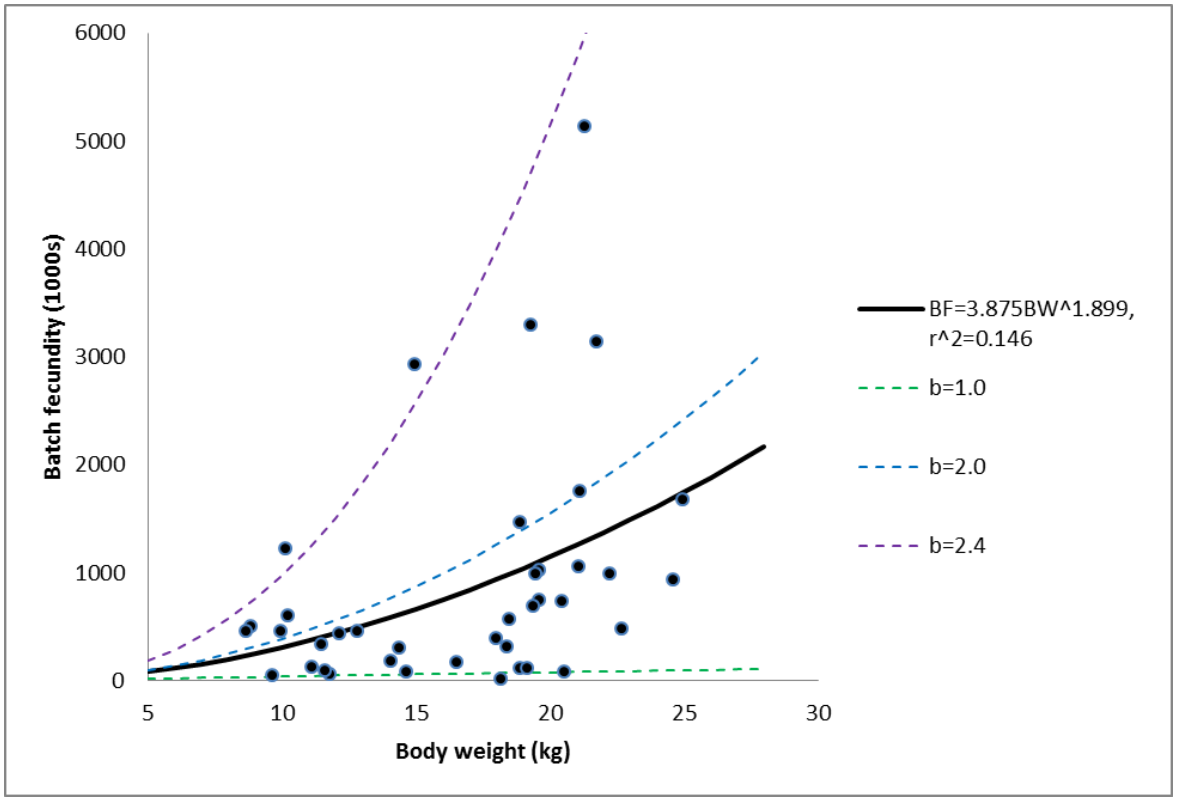
Age	Sample Size	% mature
0	1	0
1	7	0
2	27	70
3	240	100
4	136	100
5	114	100
6	92	100
7	67	100
8	37	100
9	27	100
10	19	100
11	15	100
12	13	100
13	4	100
14	2	100
15	0	NA
16	1	100

Female Maturity Vector



- Used to compute total mature female biomass (measure of spawning stock)

Female Fecundity



Base Run: Mature female biomass as measure of spawning potential

Sensitivity: Limited information on batch fecundity

Assume spawning frequency of every 6-d and spawning duration of 4 months

Fishing Fleets

Recreational (combined as general recreational)

- Charterboat, private recreational, shore (MRFSS/MRIP)
- Headboats (Southeast Regional Headboat Survey)

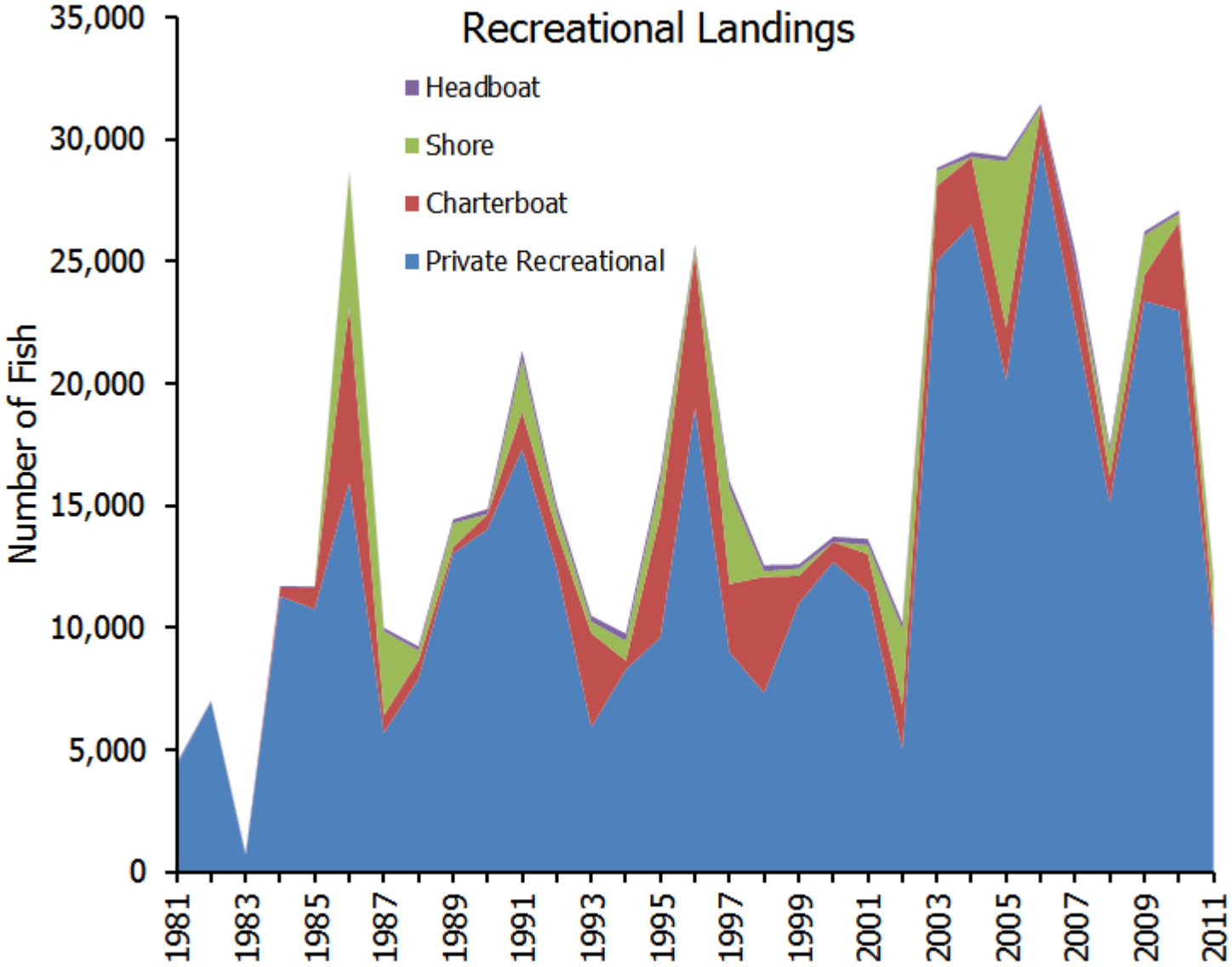
Commercial (combined as general commercial)

- Handlines
- Gillnets
- Pound nets
- Seines, trawls, miscellaneous

Summary of Regulations:

Year		Recreational	Commercial
1983	Min. size limit	33 in. (838 mm) FL	33 in. (838 mm) FL
1990	Bag limit	2 fish/person/day	2 fish/person/day

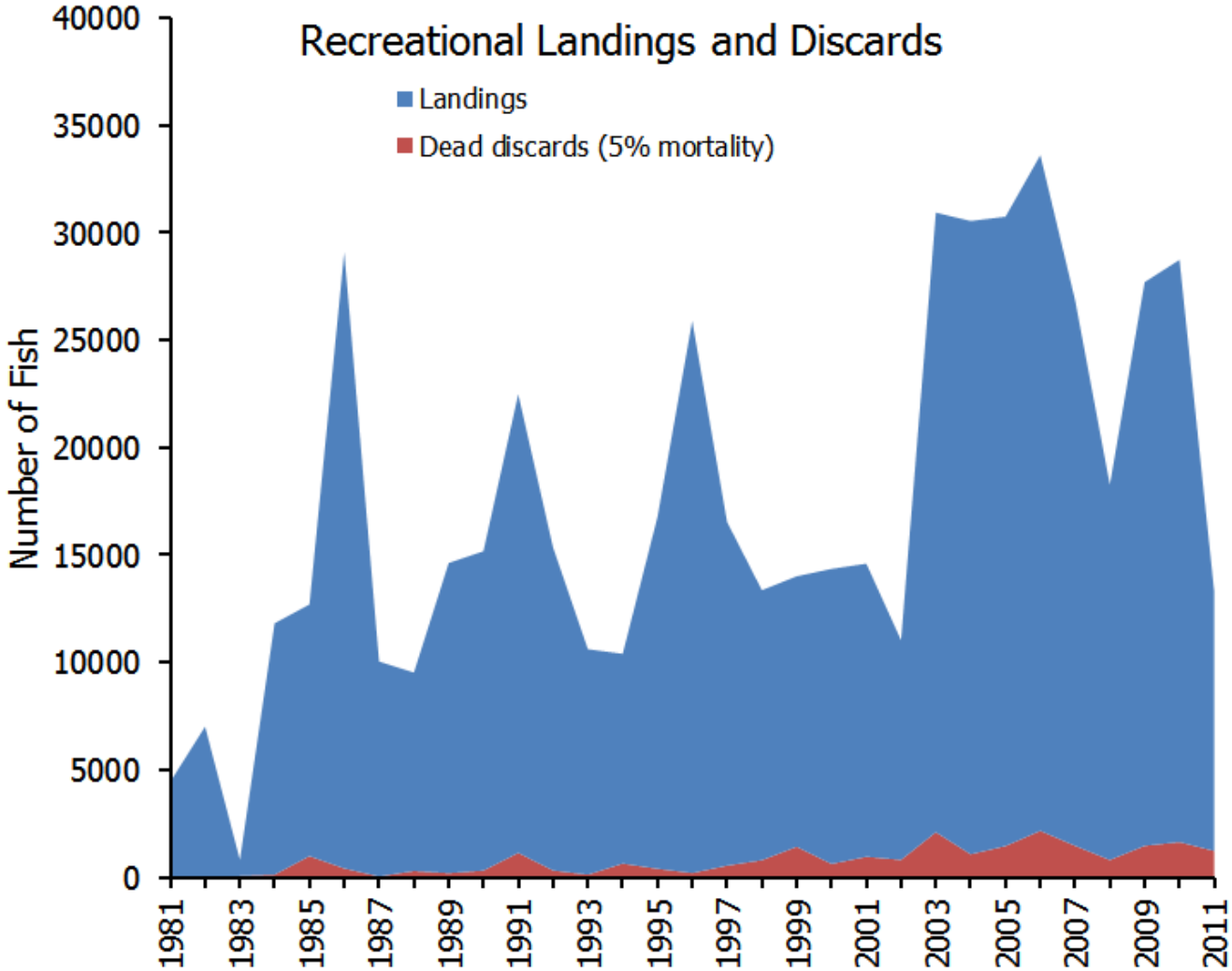
Recreational Landings



Recreational Removals

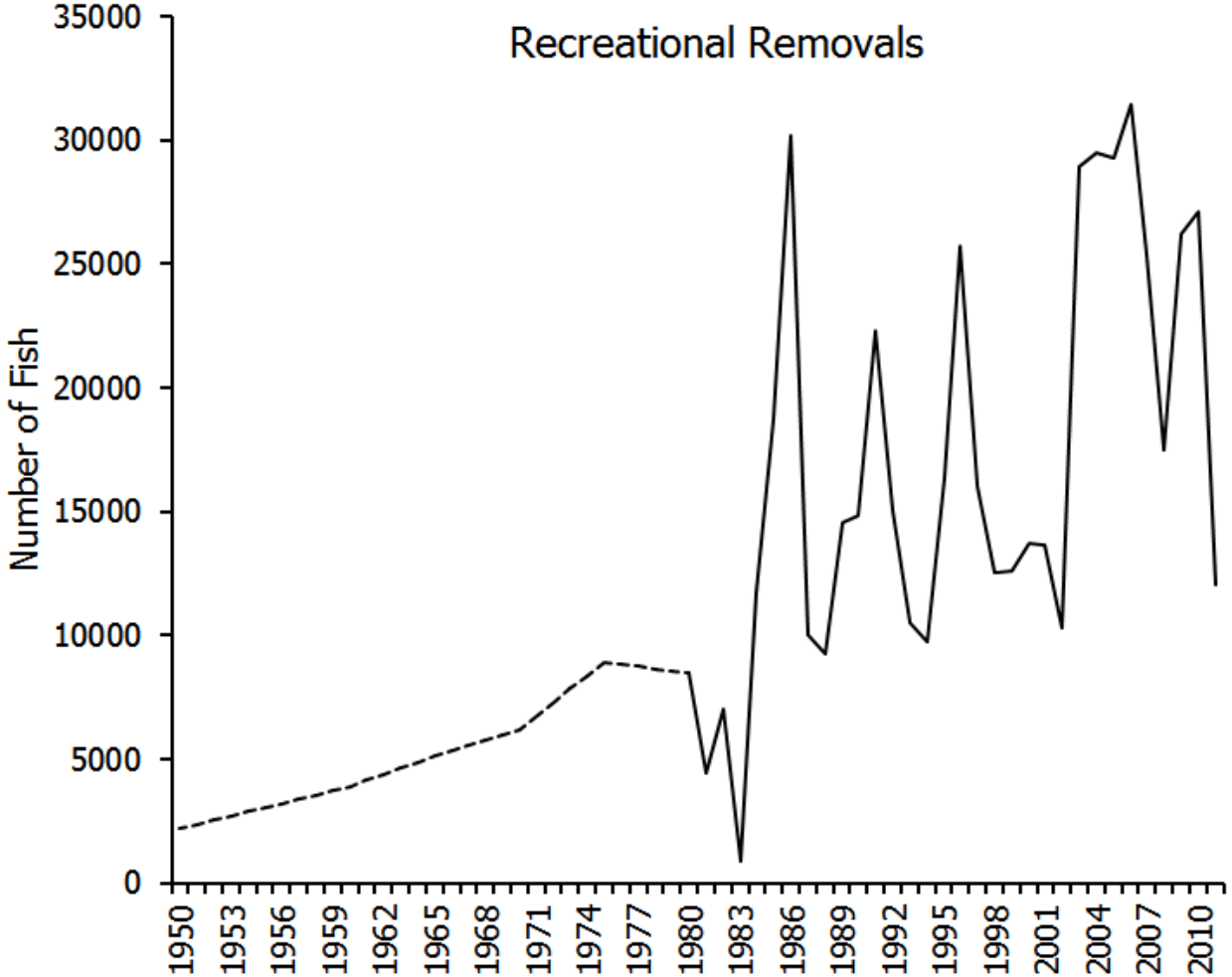
Discards

- 5% mortality rate from lines (range: 2-8%)
- Dead discards average < 5% landings
- Combined as recreational removals
- Assume no discards prior to regulation (1983)

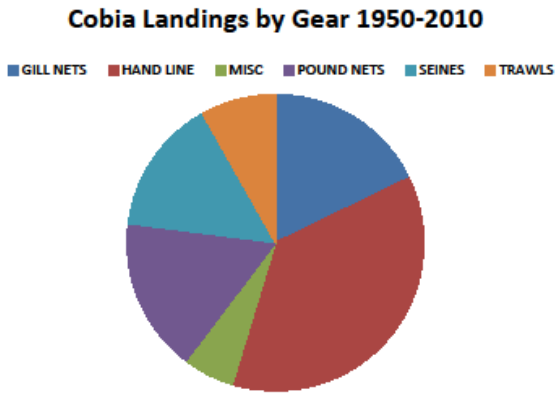


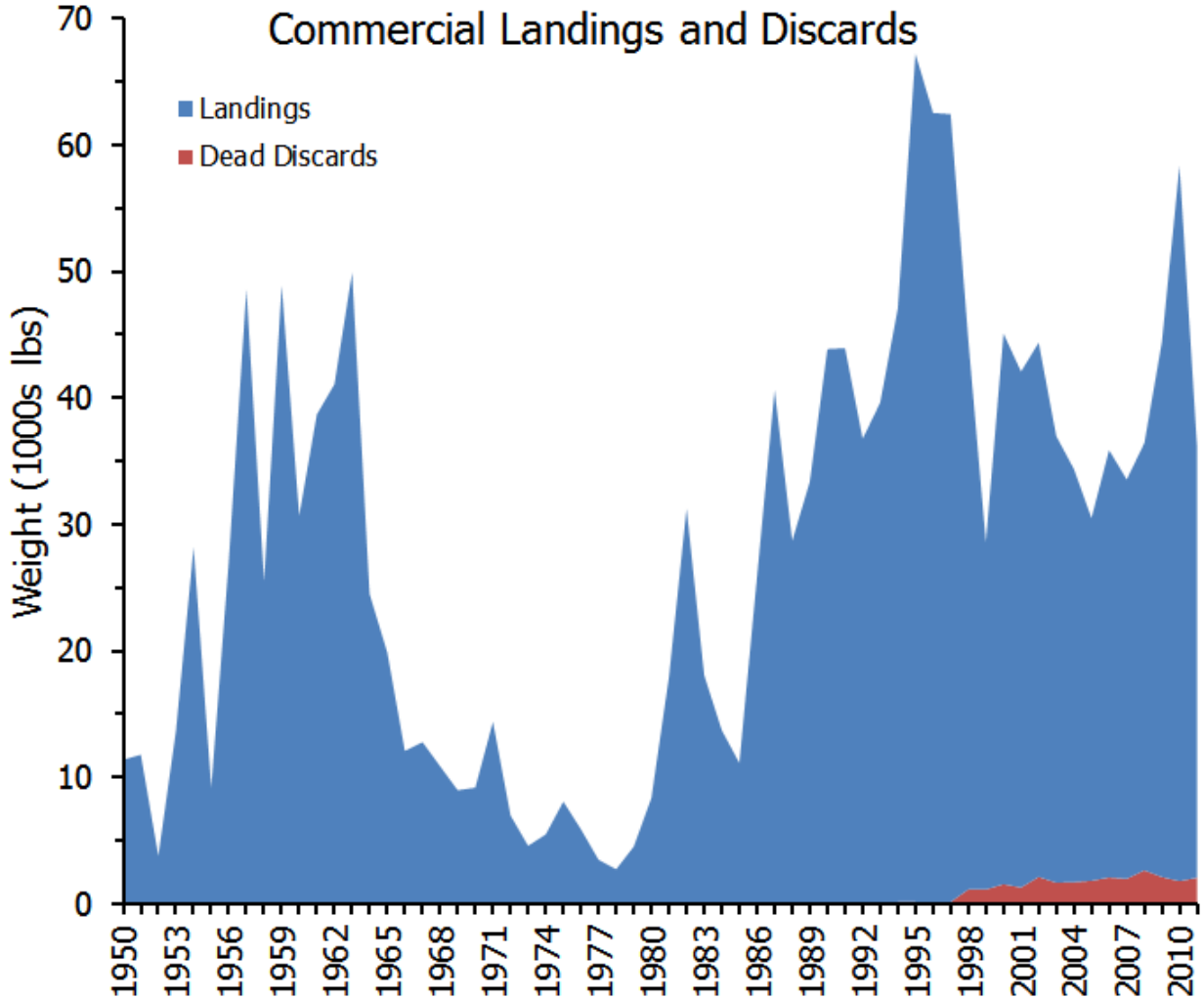
Historical Recreational Landings

- Historical time period pre- 1981
- Historical landings=Avg cobia CPUE (1981-85) x historical effort
- Historical effort base on:
  - Estimated number SW anglers
  - Estimated number SW angler days
  - Accounted for re-call bias



Commercial Landings



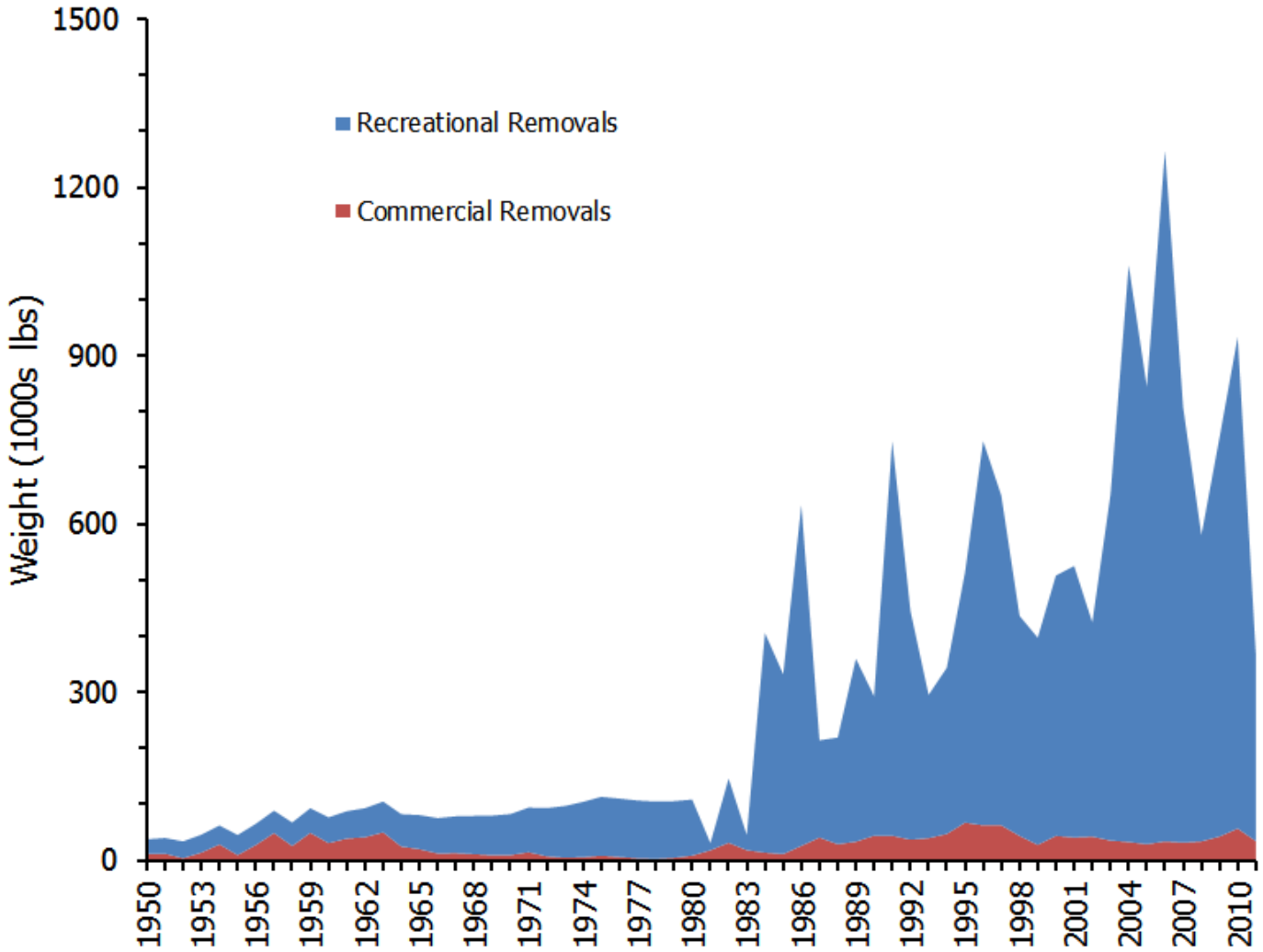


Discard Mortality

- 5% lines (range: 2-8%)
- 51% gillnets (range: 36-77%)
- Dead discards average < 2.5% landings
- Combined as commercial removals
- Assume no discard prior to regulation (1983)

Recreational and Commercial Removals

Since 1981, 92% recreational and 8% Commercial



Age and Length Compositions

- Annual recreational length and age comps
- Pooled commercial length and age comps and weighted by sample size

	Recreational				Commercial			
	Length Comps		Age Comps		Length Comps		Age Comps	
YEAR	Number Fish	Number Trips	Number Fish	Number Trips	Number Fish	Number Trips	Number Fish	Number Trips
1981	3	3						
1982	9	9			12	2		
1983	6	5						
1984	15	14	3	NA	12	12		
1985	30	25	2	NA	12	9		
1986	31	28	22	NA			1	NA
1987	34	30	18	NA	5	5		
1988	29	28	17	NA	15	14		
1989	45	41	78	NA	10	4	4	NA
1990	47	39	103	NA	24	3	3	NA
1991	42	41	16	NA	13	10	1	NA
1992	51	42	20	NA	1	1		
1993	35	30	16	NA	10	5		
1994	40	32	16	NA	7	6		
1995	48	43	10	NA	5	3		
1996	55	39	31	NA				
1997	37	30	20	NA	9	3		
1998	56	37					5	NA
1999	55	38	130	NA	12	5	9	NA
2000	22	17	111	NA	11	4	7	NA
2001	37	33	72	NA	11	7	7	NA
2002	49	41	27	NA	5	3	36	NA
2003	50	45	7	NA	13	6	2	NA
2004	57	42	7	NA	42	17	2	NA
2005	64	45	125	NA	39	21	6	NA
2006	41	36	81	NA	23	13	2	NA
2007	112	62	397	NA	21	12	11	NA
2008	85	52	327	NA	75	33	5	NA
2009	61	50	311	NA	30	18	3	NA
2010	100	69	330	NA	7	7	5	NA
2011	52	38	307	NA	14	14	11	NA
Mean:	45	35	96		17	9	7	
Range:	(3-112)	(3-69)	(2-397)		(1-75)	(1-33)	(1-36)	

33 in size limit

2 fish bag limit

Sample Sizes Recreational Age Comps by Region

1984 to 1997 mostly NC fish

1999 to 2004 all Va fish

2005 to 2011 mostly SC-Ga & Va
(either end of stock range)

Assume sampled from unit stock

- sampled from lt geographic range
- sampled on migratory route

		STATE		
YEAR	Va	NC	SC-Ga	Total
1984		3		3
1985		2		2
1986		22		22
1987		18		18
1988		16	1	17
1989		78		78
1990		101	2	103
1991		16		16
1992		20		20
1993		16		16
1994		16		16
1995		10		10
1996		31		31
1997		20		20
1998				0
1999	130			130
2000	111			111
2001	72			72
2002	27			27
2003	7			7
2004	7			7
2005	10	1	114	125
2006	25	1	55	81
2007	56		341	397
2008	47		280	327
2009	106		205	311
2010	106	9	215	330
2011	89		218	307

NC only

Va only

SC-Va

Age Compositions from Va and SC (2005-2011)

YEAR	Va	STATE NC	SC-Ga	Total
1984		3		3
1985		2		2
1986		22		22
1987		18		18
1988		16	1	17
1989		78		78
1990		101	2	103
1991		16		16
1992		20		20
1993		16		16
1994		16		16
1995		10		10
1996		31		31
1997		20		20
1998				0
1999	130			130
2000	111			111
2001	72			72
2002	27			27
2003	7			7
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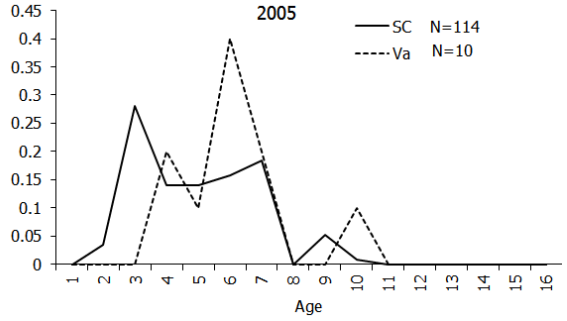
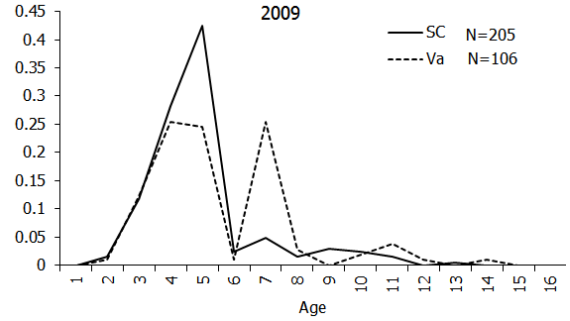
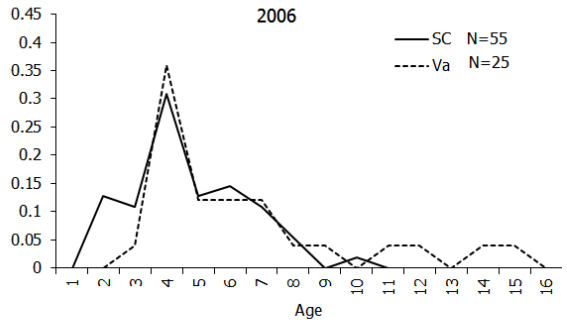
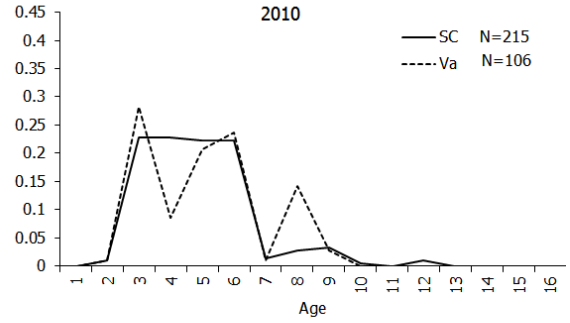
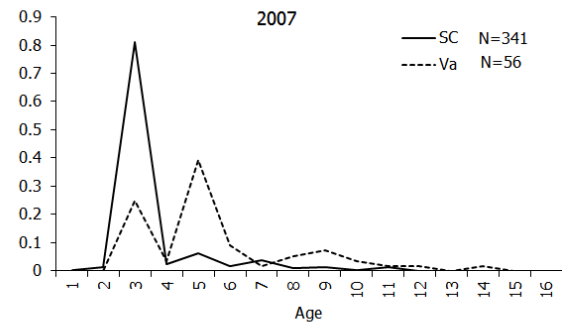
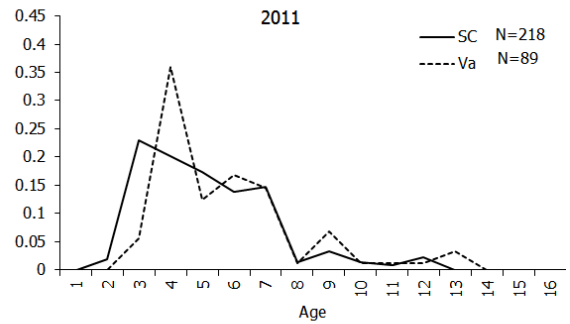


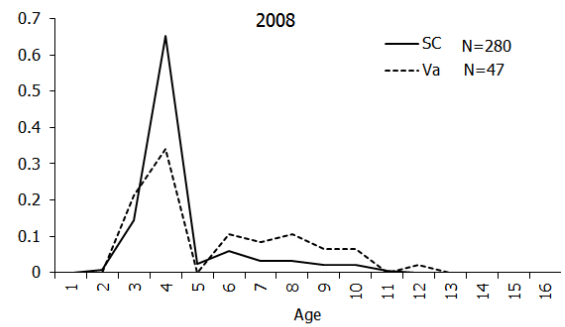


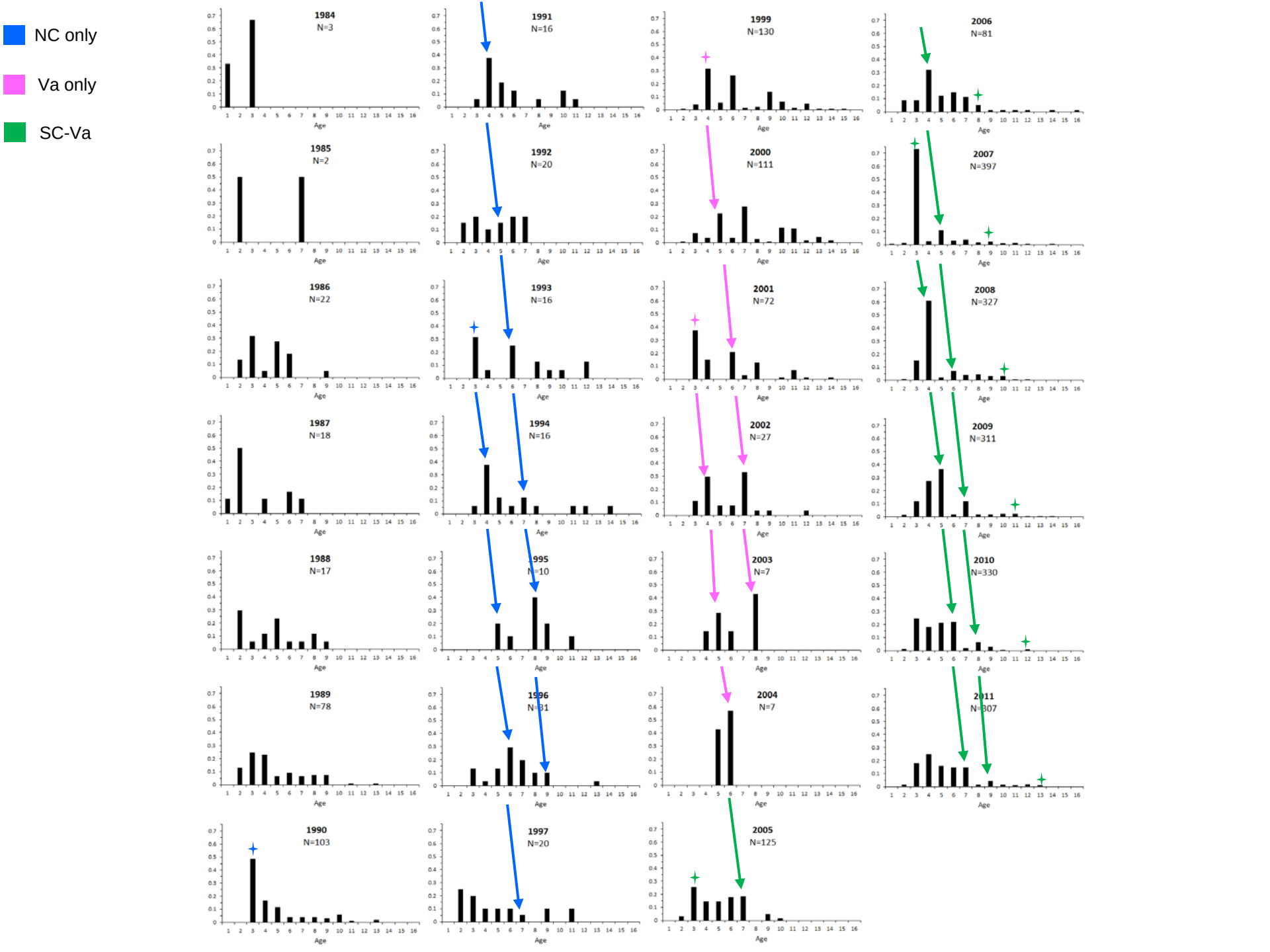











NC only
Va only
SC-Va
1984
N=3
1985
N=2
1986
N=22
1987
N=18
1988
N=17
1989
N=78
1990
N=103
1991
N=16
1992
N=20
1993
N=16
1994
N=16
1995
N=10
1996
N=31
1997
N=20
1999
N=130
2000
N=111
2001
N=72
2002
N=27
2003
N=7
2004
N=7
2005
N=125
2006
N=81
2007
N=397
2008
N=327
2009
N=311
2010
N=330
2011
N=307
Age

Year Class Strength

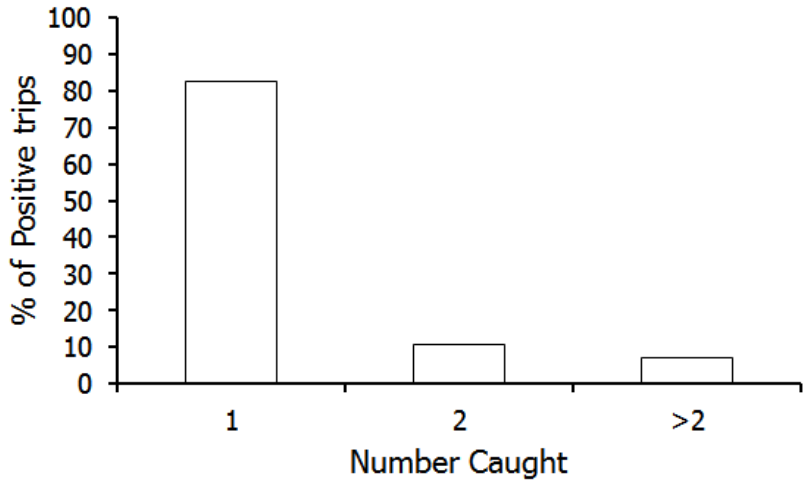
- 6-7 strong year classes (every 2-3 years)
- Distributed throughout the time series but never in consecutive years
- Strong year classes occur in each region (Va, NC, SC-Ga)
- Some limited evidence for “crossing over” among regions
- Most recent years (2005-2011) includes samples from either end of range
- Suggest age compositions reflect stock wide patterns in yr class strength

Indices of Abundance

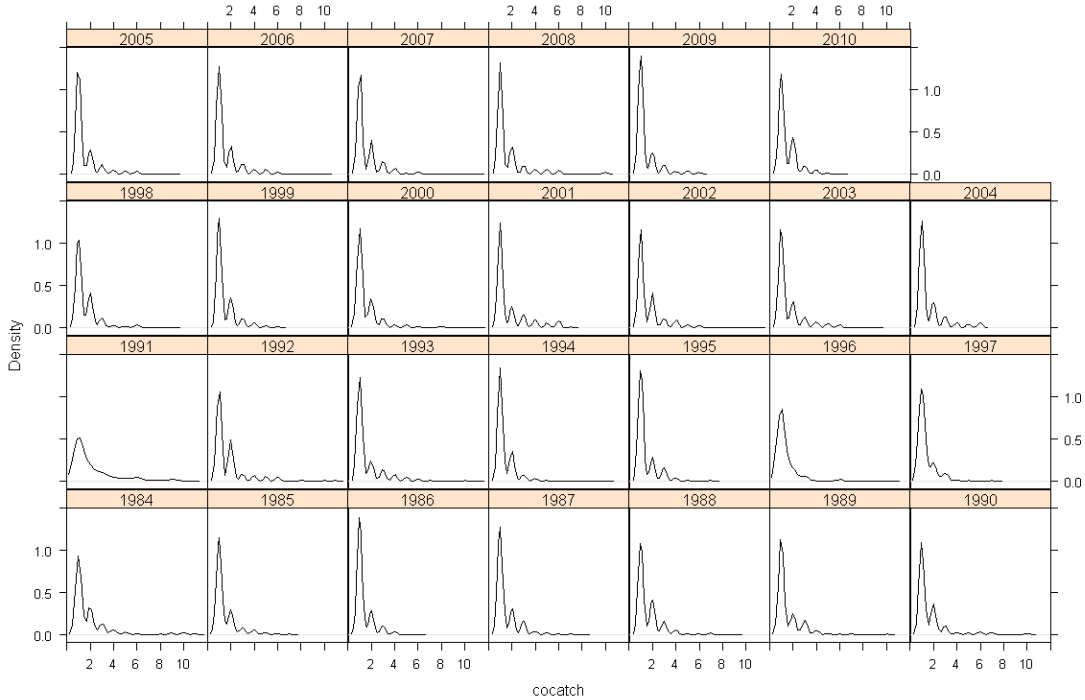
- Three potential indices of abundance recommended by DW
- All indices are fishery-dependent
- All indices based on recreational hook and line gear
- All indices standardized using Delta-GLMs

Number Cobia Caught per Trip

General recreational

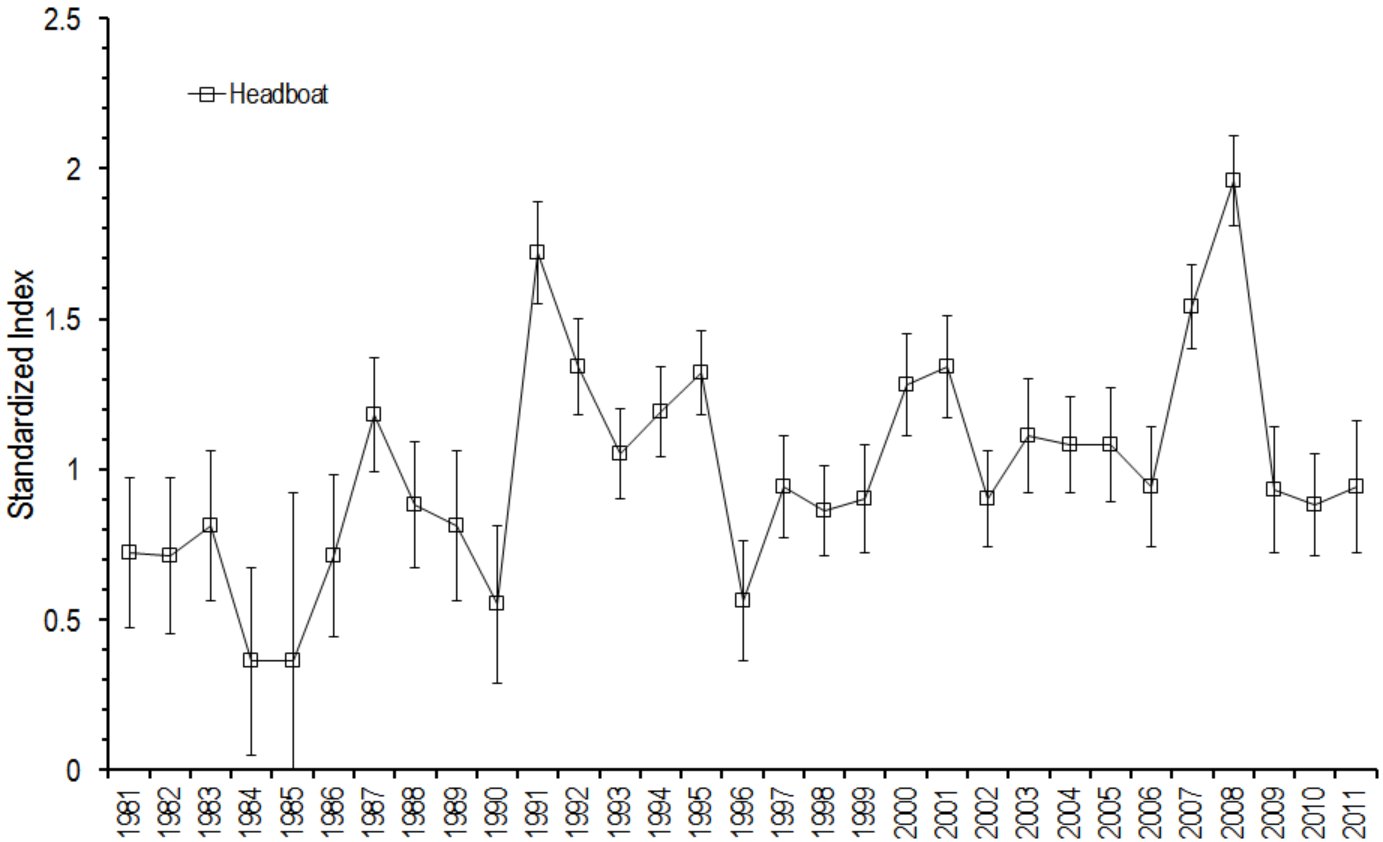


Headboat



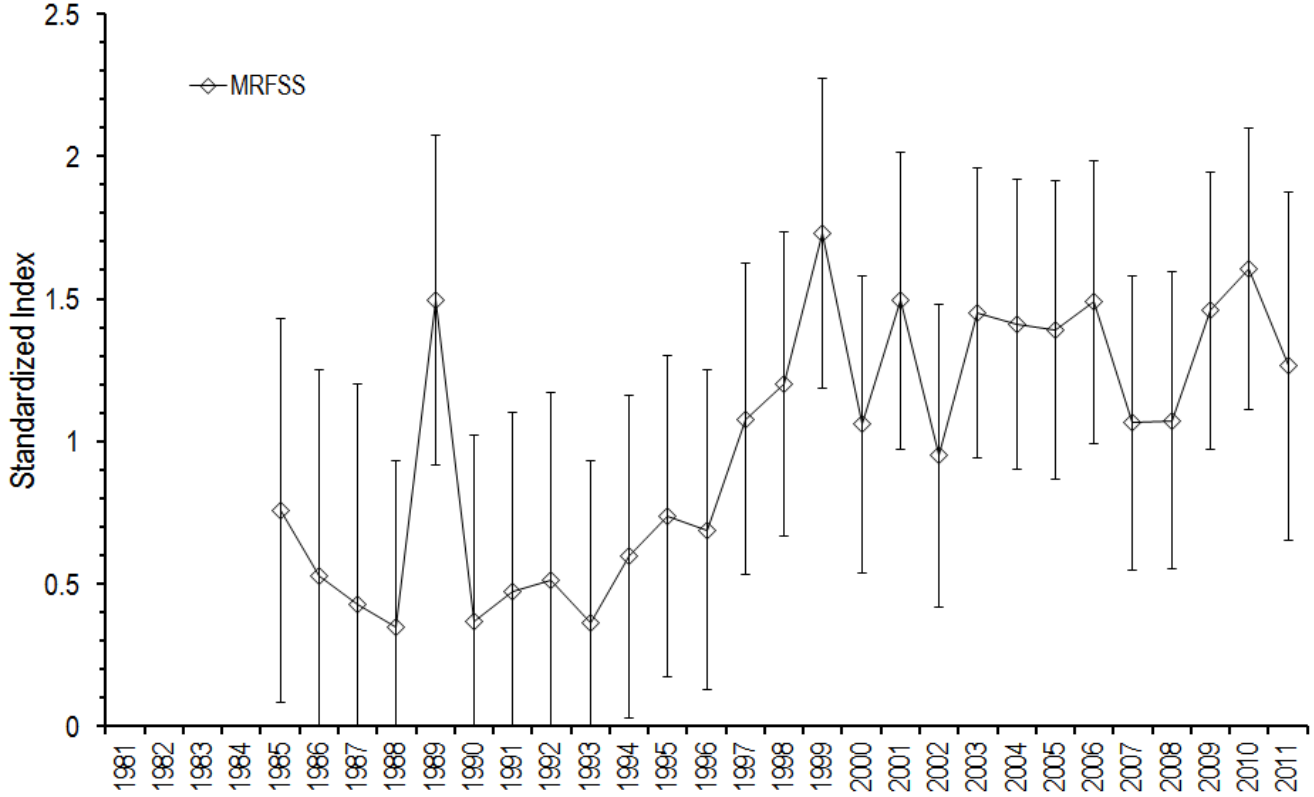
Headboat Index

- 1981-2011
- Covers entire stock range of cobia
- Complete census of headboats
- Not influenced by the bag limi
- Index based on subset of core vessels that caught ~ 90% of cobia



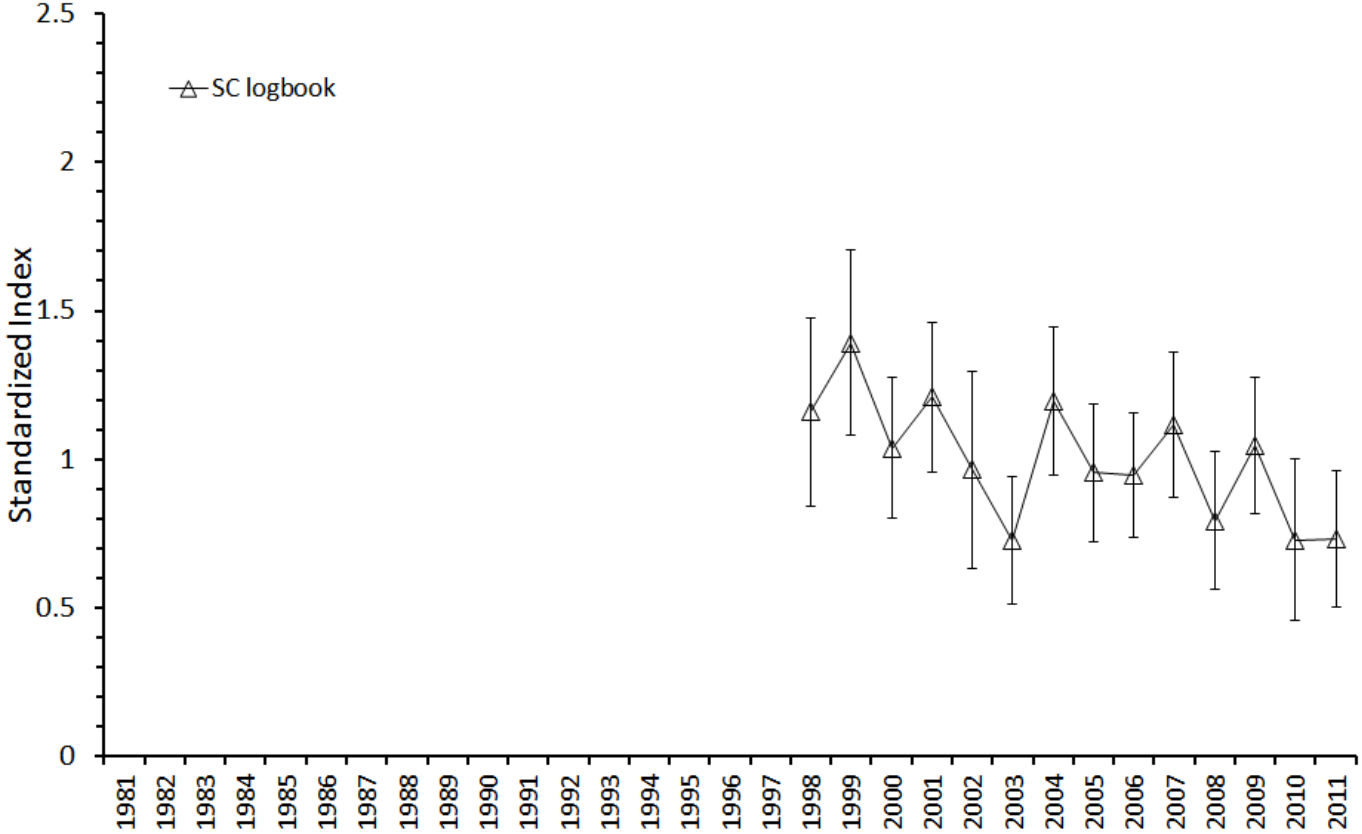
MRFSS Index

- 1985-2011
- Covers entire stock range of cobia
- Index based on private recreational and shore modes using hook and line
- Retained and discarded fish (not sensitive to bag limit)
- Sampling may be insufficient for rare species
- Difficult to define relevant effort
  - Must catch or report target cobia
  - Only anglers on vessel who contributed to catch included



SC Charterboat Logbook Index

- 1998-2011
- Covers portion of (center of) stock range
- Complete census of South Carolina charterboats
- Not influenced by the bag limit
    - retained and discarded fish
    - Typically 6 fisher per trip
- Index based on bottom fishing trips using hook and line gear

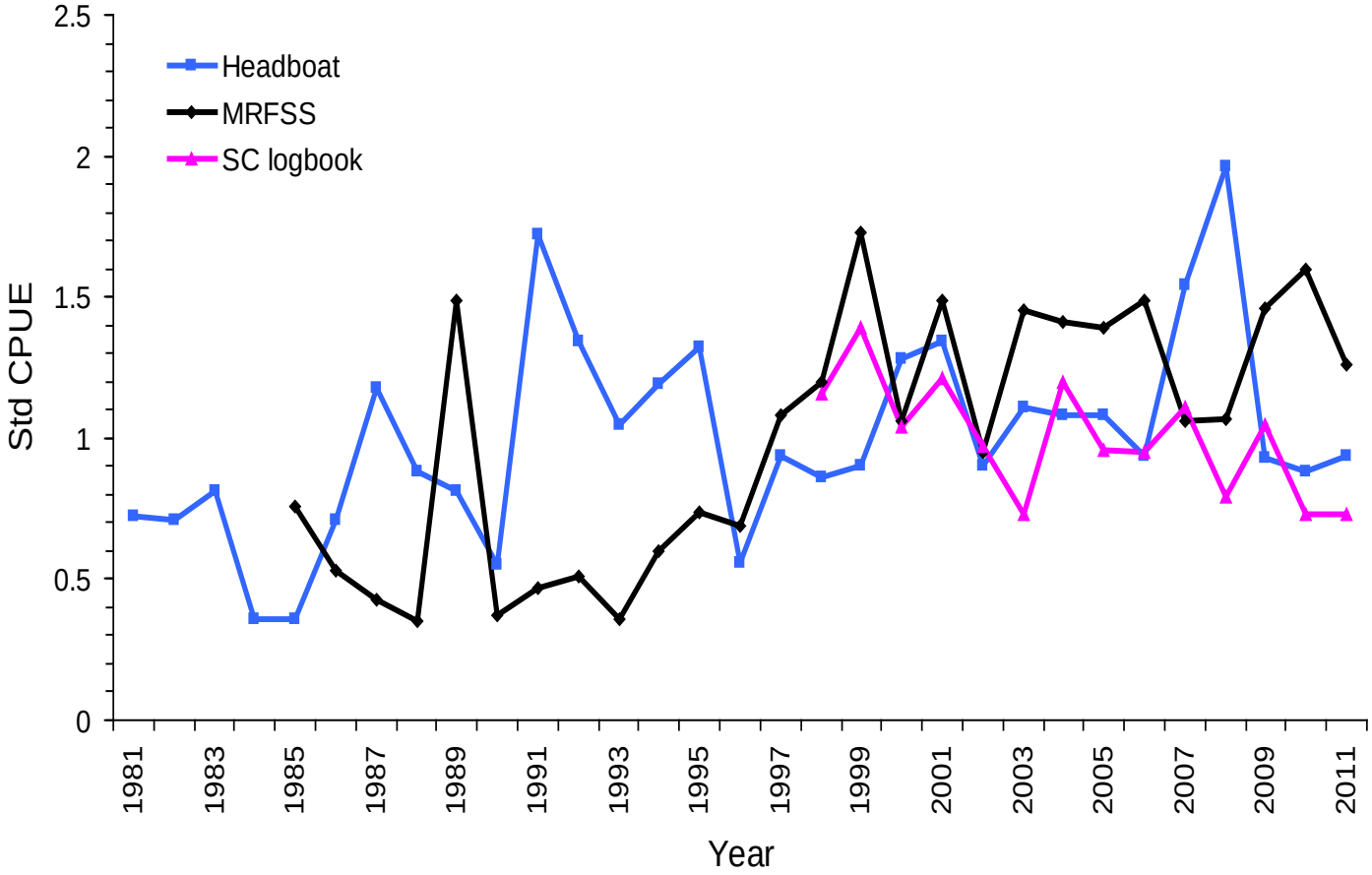


Indices

Index Correlations

	Pearson	Kendall's	Spearman
Headboat-MRFSS:	0.002	-0.026	-0.035
Headboat-SC log:	-0.11	-0.011	-0.024
MRFSS-SC log:	0.19	0.11	0.12

95% Confidences intervals: ~ -0.35 – 0.35



Indices

- Three indices could not be fit simultaneously
- AW panel recommended exclusion of MRFSS index

Basis:

- MRFSS survey may not adequately sample rare species
    - mean: 0.18% positives
    - Sampling survey vs. census
- MRFSS index did not reflect strong year classes from age comps to same extent as other indices
- Index showed a strong residual pattern in initial model runs
- Some concerns about changes in MRFSS sampling effort effort over time
- Evaluate consequences of excluding MRFSS via sensitivity analysis

Ageing Error Matrix

- 4 readers, 3 labs (NMFS Beaufort, SCDNR, ODU), 106 otoliths
- Average percent agreement (93.8%, range: 89.6 – 97.2%)
- 85% of errors were of one year; no obvious bias
- ‘Agemat’ to develop the matrix (Punt et al. 2008)

							TRUE AGE						
		1	2	3	4	5	6	7	8	9	10	11	12
	1	0.982	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000
READ AGE	5	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000	0.000
	6	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000
	7	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000
	8	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000
	9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000
	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000
	11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018
	12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.982

Questions about the data?

ASSESSMENT - Cobia
Beaufort Assessment Model (BAM)

Outline

- Model description
  - Model configuration
  - Model inputs
  - Estimated parameters

- Base Run
  - Model fits
  - Model outputs
  - Model Diagnostics
    - -profiling
    - -retrospective analysis
  - Model Uncertainty
    - -Sensitivity analysis
    - -Monte Carlo-Bootstrap

(MCB) analysis
  - Projections

- Additional methods
  - Catch curve analysis
  - Mean length estimator
  - Surplus production model

Beaufort Assessment Model (BAM)

- Forward projecting statistical catch-age model

- Fit by maximum likelihood
  - Robust multinomial for age and length composition data
  - lognormal for landings and index data
  - Plus priors and penalty terms
  - Likelihood weights to control model fit (derived from iterative re-weighting)
- AD Model Builder for optimization

- Baranov catch equation to predict landings
- Beverton-Holt spawner-recruit model, with annual deviations assumed to be distributed lognormally
- Age-length conversion matrix assuming normal distribution of length at age with estimated CV
- Catchability options: constant, linear change, random walk, density dependence
- Selectivity options: logistic, double logistic, joined logistic, double gaussian
- MSY-benchmarks from the expected spawner-recruit curve (bias corrected)

BAM Configuration for Cobia

- Assessment years: 1950–2011 (Earliest year consistent data was available)

- Modeled ages: 0–12+

  -Plus group based on inspection of age compositions and where growth and natl mortality reach asymptotes

- Von Bertalannfy growth and Lorenzen age-based natural mortality

- Initial numbers at age: computed from assumed equilibrium age structure and a historical fishing mortality rate (geo. mean F from 1950-52)

- Spawner-recruit: Beverton-Holt curve with lognormal recruitment deviations
  - Data poor period: 1950-1974: follow S-R curve exactly
  - Data rich period: 1984-2009 age composition and other data available
  - 1975-1983: transition period between data poor and data rich period

- Spawning potential: mature female biomass (N x wgt x fraction female) at time of peak spawning (May)

BAM Configuration for Cobia (cont)

- Two Fleets: general recreational, general commercial; discards pooled with landings
- Abundance Indices: headboat (HB), South Carolina Charterboat logbook (SC)
- Catchability: separate q for each fleet, assumed constant in time
- Selectivity: logistic functions for landings and indices. Constant in time.
- Fishing mortality: annual estimates (free parameters) for each fleet. Age-specific F computed as product full F and selectivity at age

BAM Data Inputs

- Recreational removals (landings + discards)
  - -Observed: 1981-2011
  - -Reconstructed: 1950-1980

- Commercial removals (1950-2011)

- Recreational age compositions
  - -annual 1984-2011

- Recreational length compositions (annual: 1981-2011)

- Commercial length compositions (pooled, 1982-2011)
- Commercial age compositions (pooled, 1986-2011)

- Headboat index (1981-2011)
- SC logbook index (1998-2011)

- Iterative re-weighting for data components

BAM Estimated Parameters

Estimated Parameters (169)

- S-R parameters (2): R0, sigma-R (steepness fixed)

- Annual R devs (35): 1975-2009

- Selectivity (4): Recreational (A50, slope)
  Commercial (A50, slope)
  A50 free; prior for slopes based on catch curves

- Catchability (2): q for each abundance index (assumed constant in time)

- Fishing mortality (126): average F + annual deviations for each fleet (landings and discards)

- Length-at-age (1): CV of length-at-age conversion matrix

Key Assumption

- Could not estimate steepness; hit upper bound; prior with CV < 10% to move off bound

- Steepness (h) fixed at 0.75

==========

LITERATURE SOURCES

- h=0.747

  mode of “Domain 2 nonanadromous” species, h=0.747 (Myers et al. 2002)

  age at maturity 2-5 yrs (cobia mature at 2-4 yrs)

  natural mortality 0.2-0.5/yr (cobia M=0.26; range 0.2-0.35)

  longevity 5-15 yrs (cobia max age=16 yrs)

- h=0.75

  sample mean from meta analysis of marine demersal fishes (Shertzer and Conn 2012)

- h=0.77

  mean from SW and FW species (Rose et al. 2001)

- h=0.69

  14 Pacific rockfishes (2010)

- h=0.70

  Prior SEDAR assessments (Shertzer and Conn 2012)

BAM Likelihood Components

- Landings and discards: Lognormal with assumed CV=0.05
- Indices: Lognormal with annual CVs from catch rate standardization (data workshop)
- Age Compositions: Robust multinomial with annual n = number of sampled fish
- Length Compositions: Robust multinomial with annual n = number of sampled trips
- Recruitment deviations: Lognormal with estimated variance of rec devs (sigma-R)
- Prior penalties:
  - Slope of selectivity parameters: normal with mean taken from catch curve analysis (Thorson and Prager 2011) and CV = 0.5 (recreational) or 0.25 (commercial)

BAM Likelihood Weights

- Iterative re-weighting (Francis 2011)

- Stage 1 weights based on characteristics of the data inputs:
  - for indices are the CVs estimated from catch rate standardization
  - for compositions are the effective sample sizes (number of trips, or number of fish)

- Stage 2 weights based on characteristics of the model run:
  - Start with all stage 2 weights on data components set to 1.0
  - Calculate SDNRs (standard deviation of normalized residuals)
  - Re-compute weights as 1/SDNR for indices or $1/(\text{SDNR})^2$ for compositions
  - Iterate until SDNRs approach 1.0

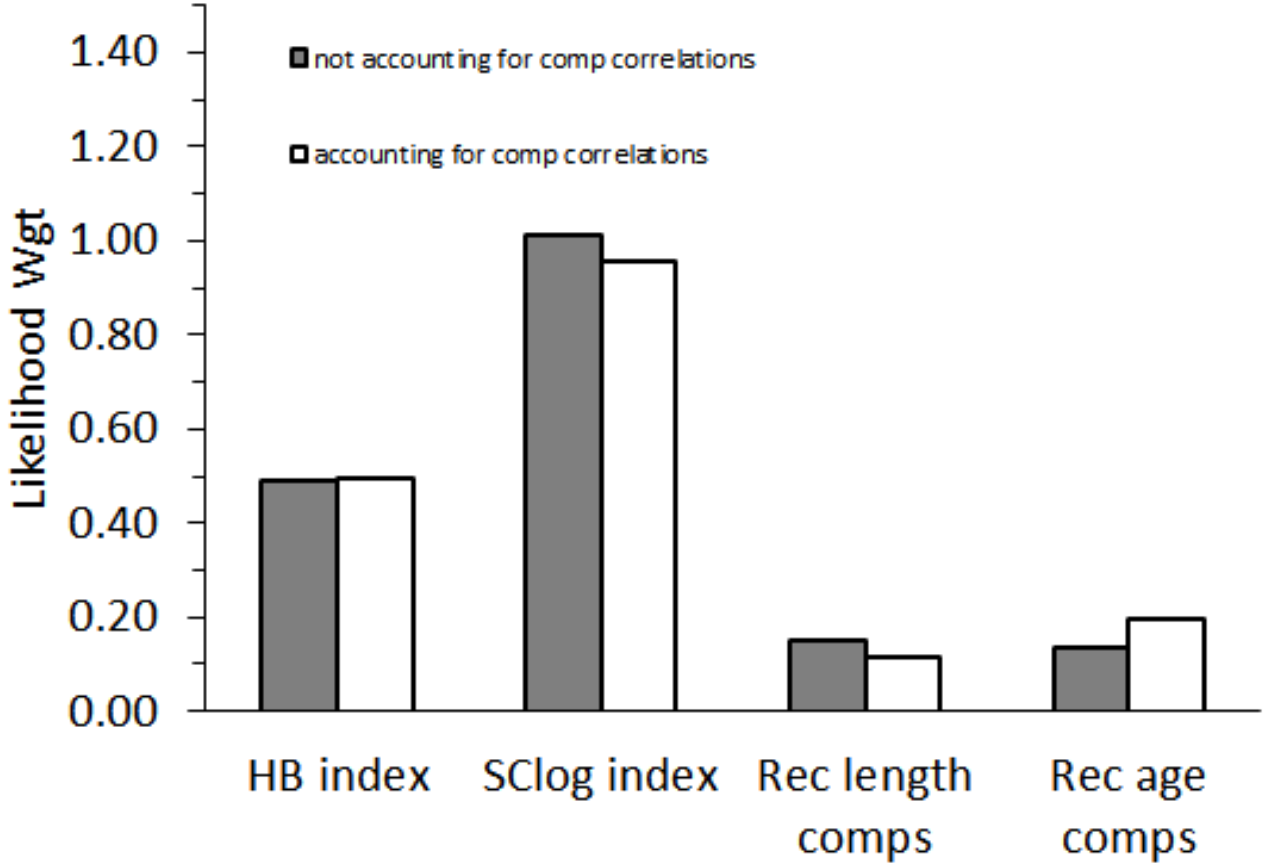
- Method accounts for potential correlations in the composition data (TA 1.8 in Francis (1011))

- Did not re-weight landings

- Commercial length and age comps given same weights as corresponding recreational data

- Evaluated weighting assumptions via sensitivity analysis

Iterative Re-weighting

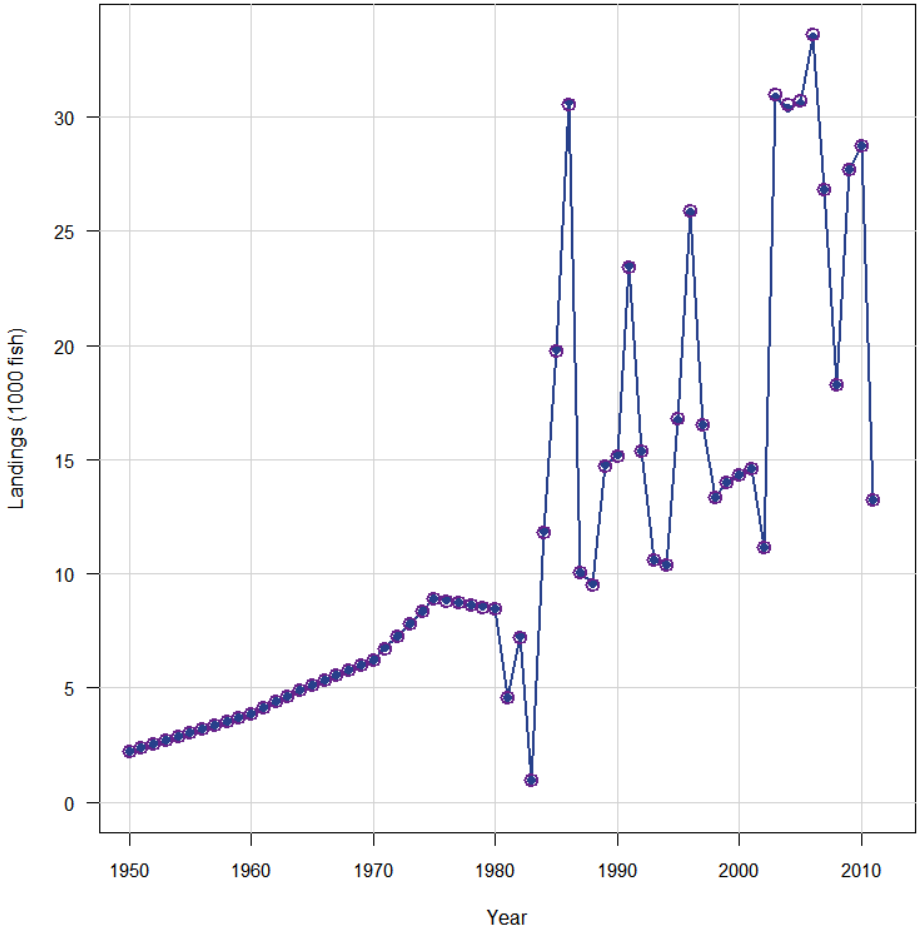


- Length and age compositions down-weighted relative to indices
- HB index down-weighted relative to SC logbook index
- Accounting for correlations had little effect

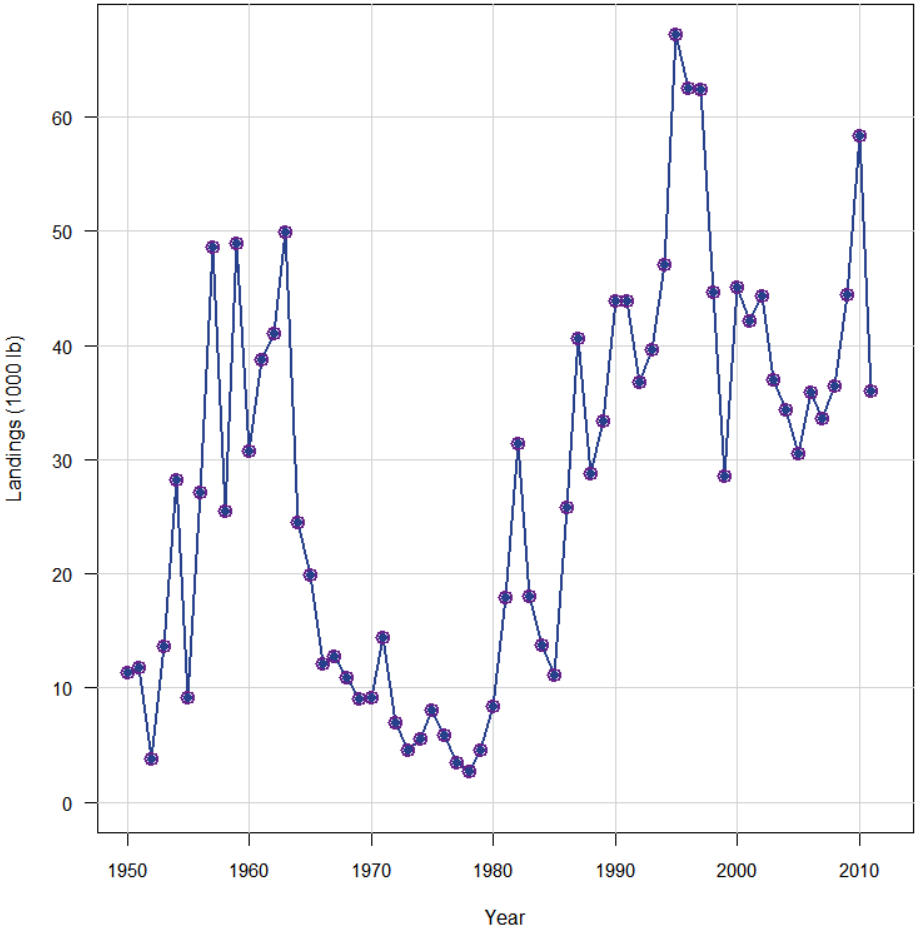
Model Fits: Fishery Landings

BAM Base Run

Recreational

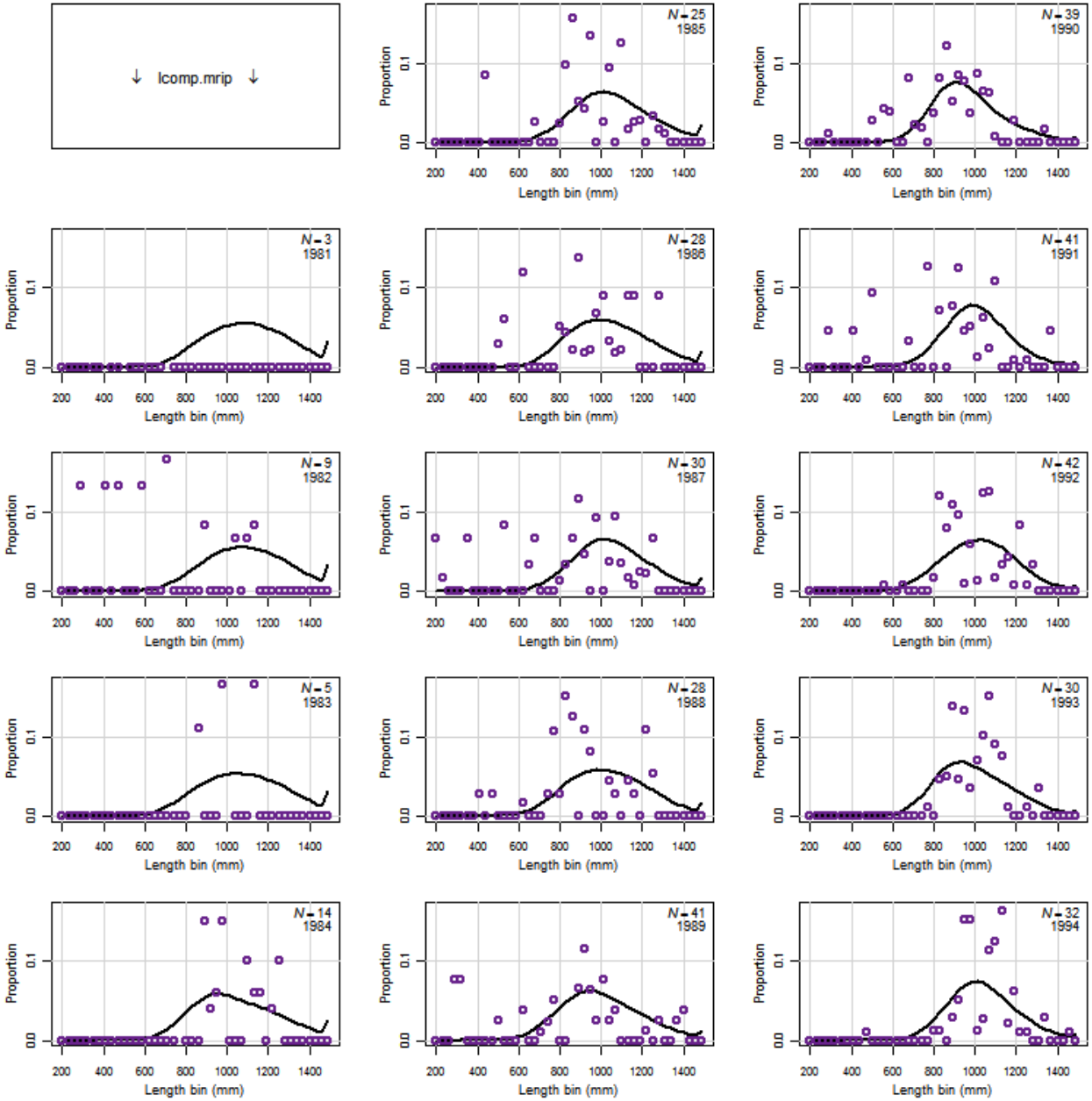


Commercial



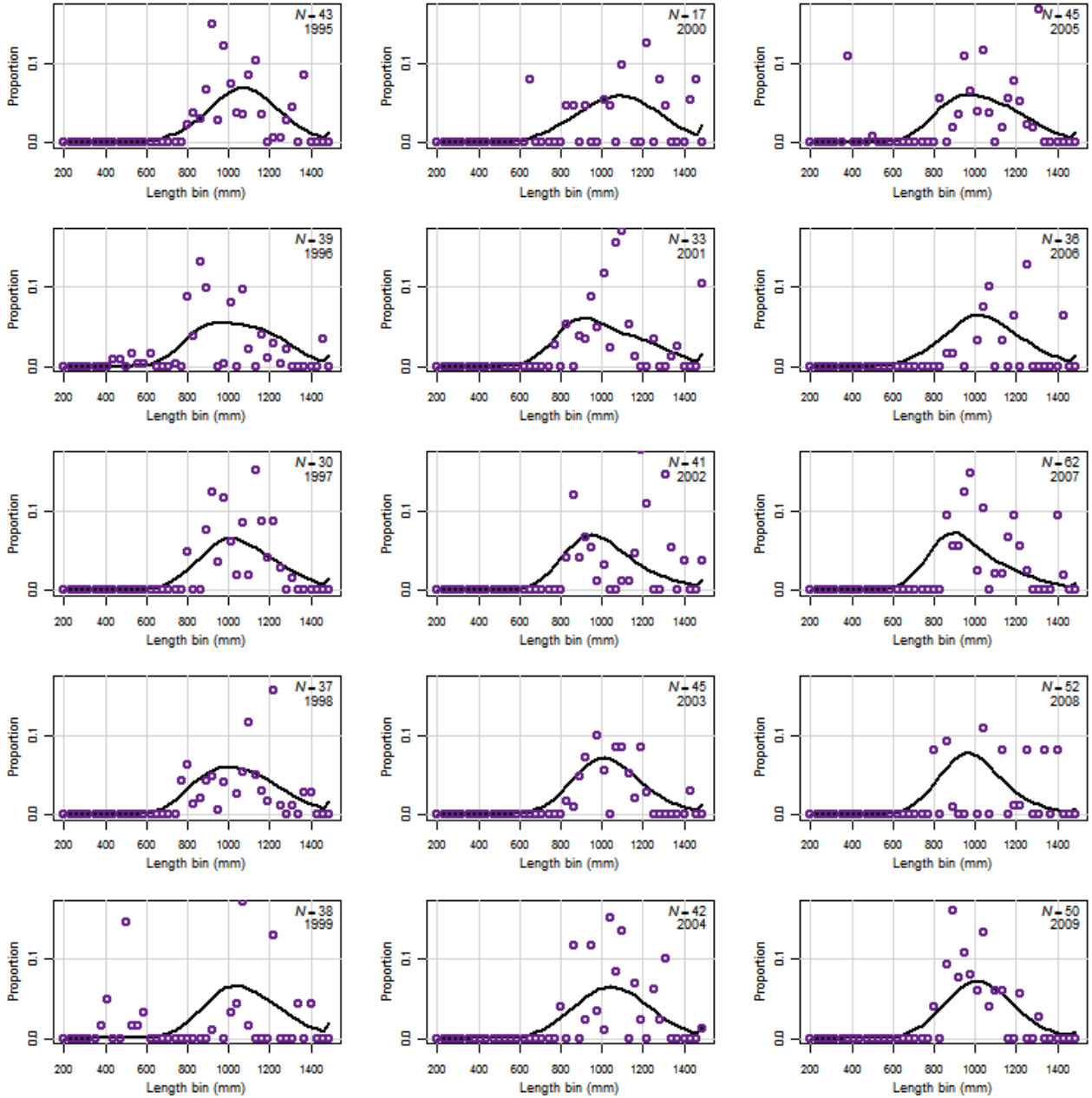
Model Fits: Length and Age Compositions

BAM Base Run



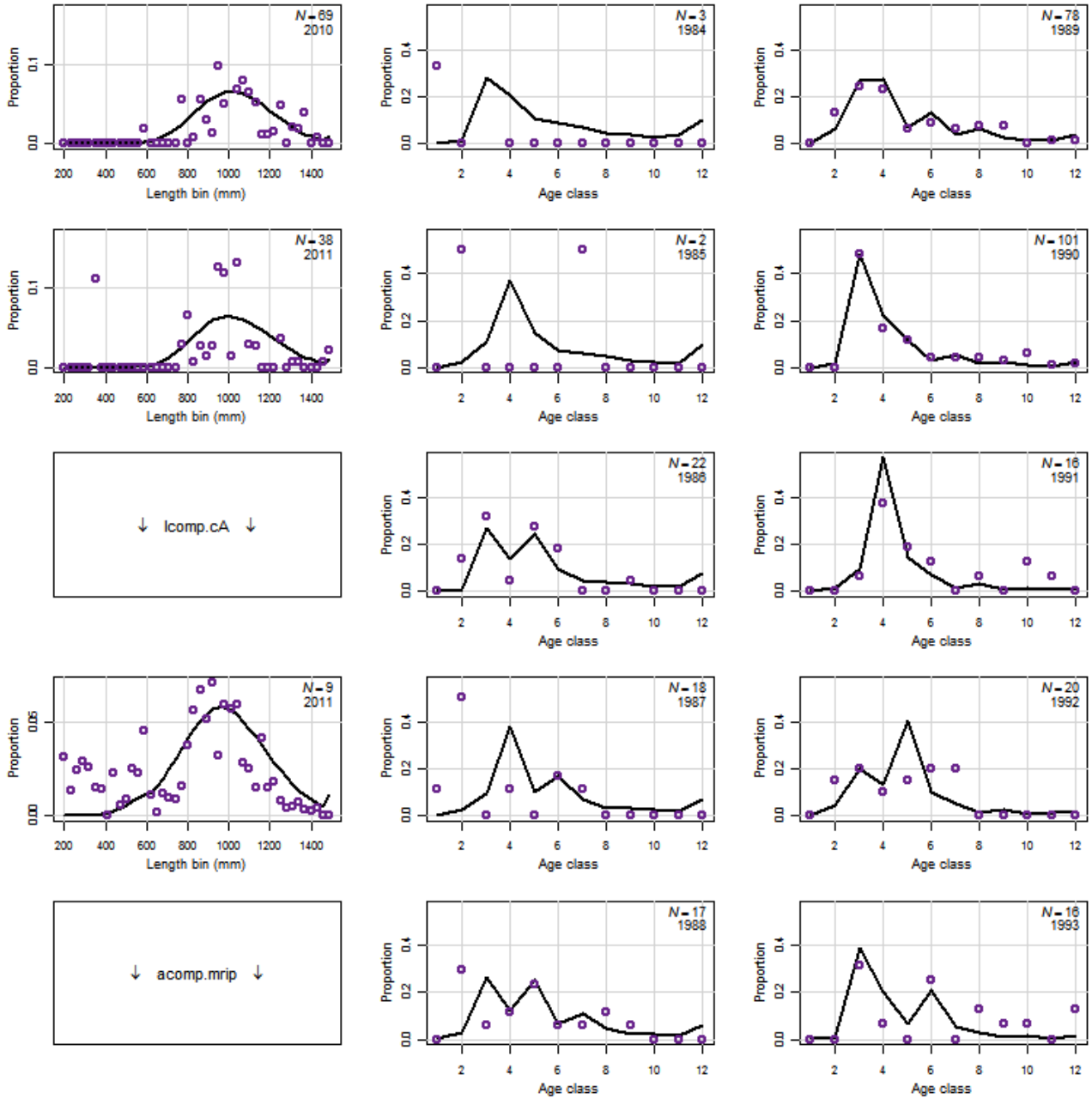
Model Fits: Length and Age Compositions

BAM Base Run



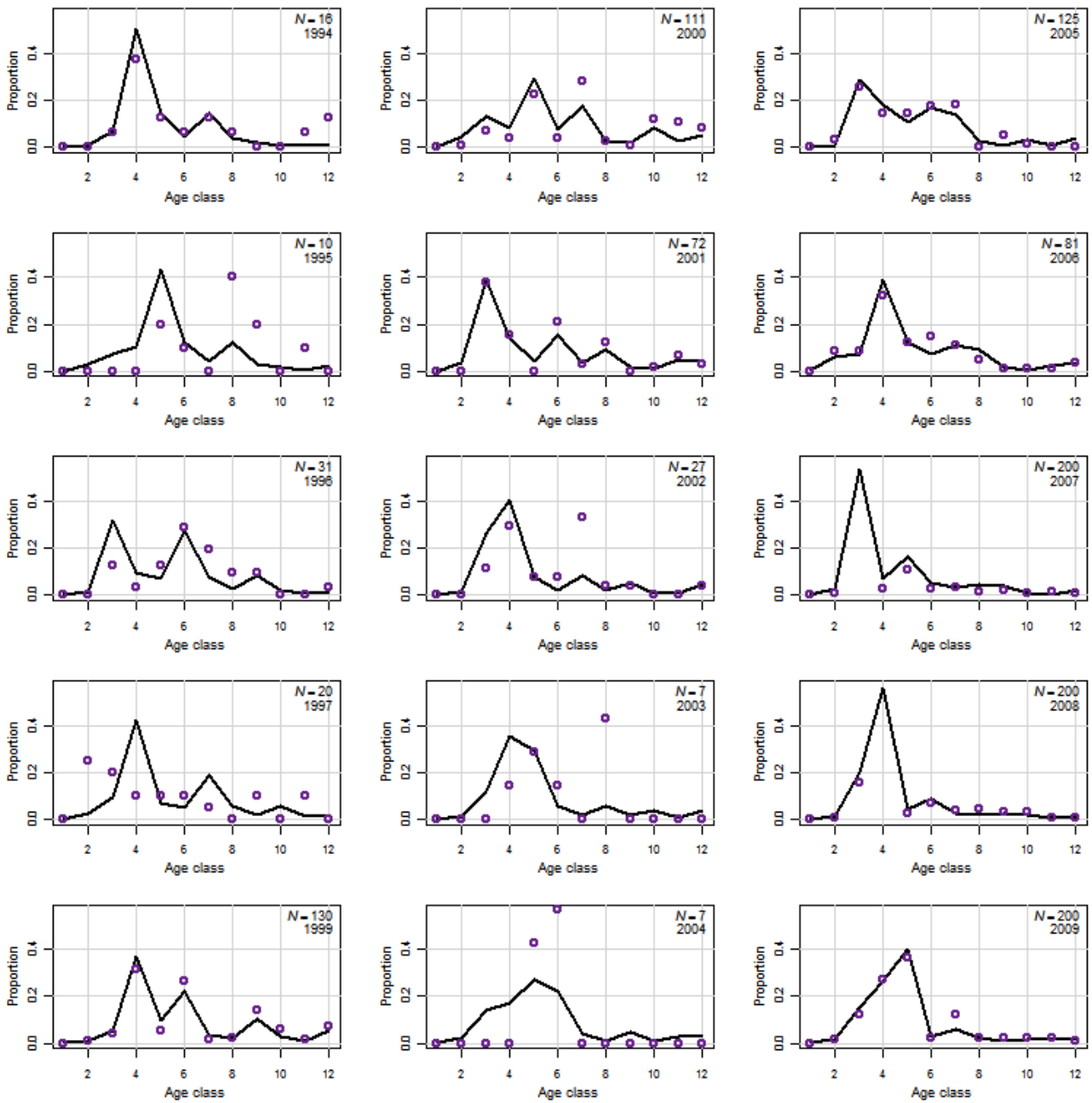
Model Fits: Length and Age Compositions

BAM Base Run



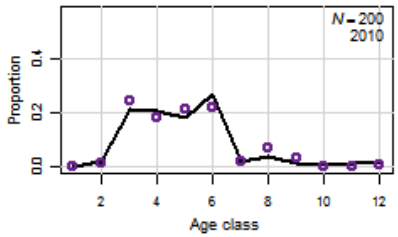
Model Fits: Length and Age Compositions

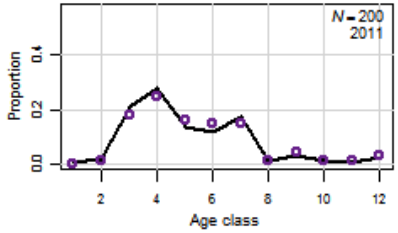
BAM Base Run



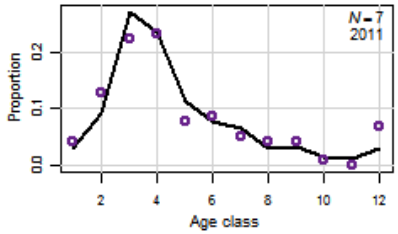
Model Fits: Length and Age Compositions

BAM Base Run





↓ acomp.cA ↓



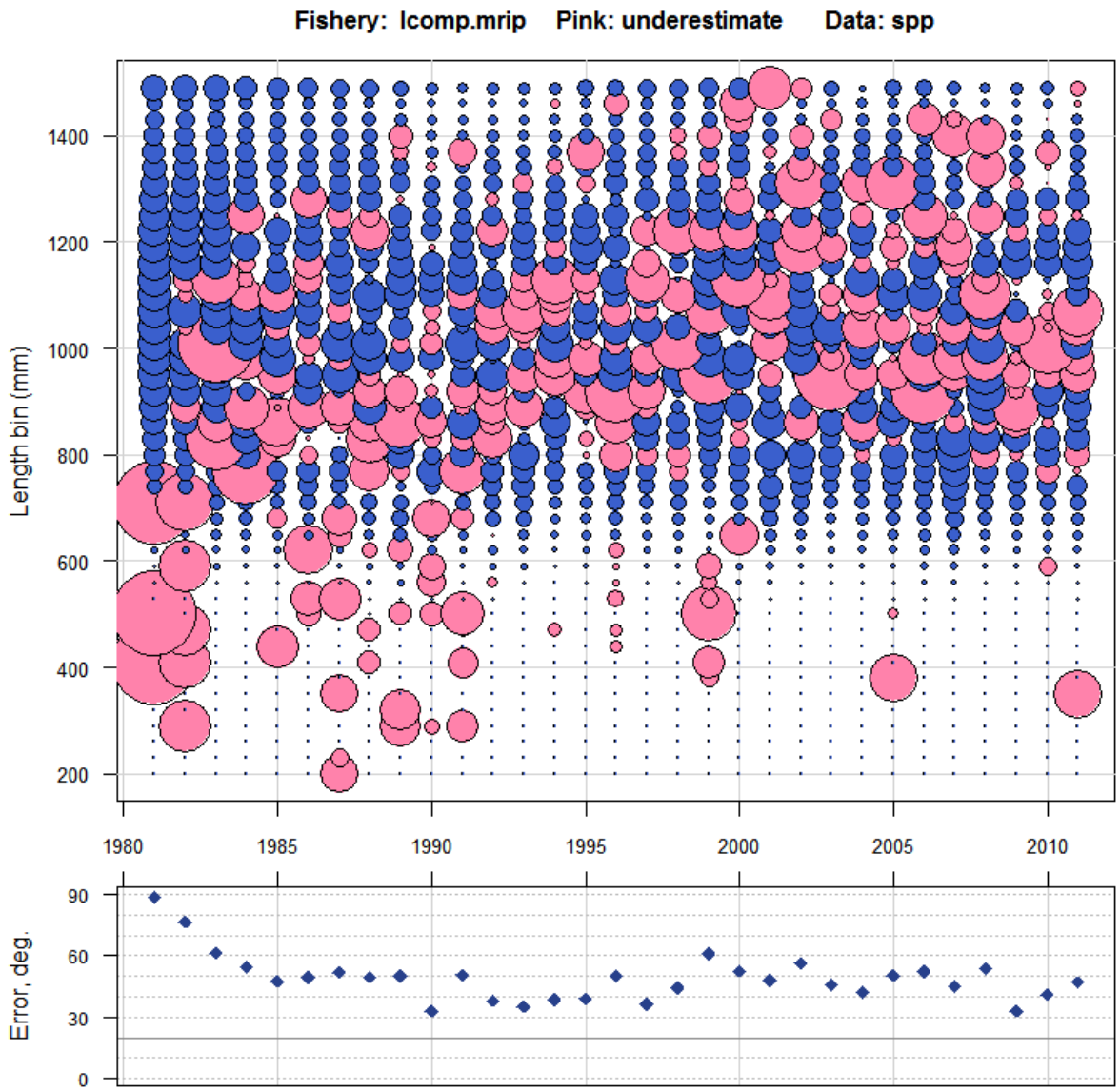
Model Fits: Recreational Length Comps

BAM Base Run

YEAR	Length Comps Number Fish	Length Comps Number Trips
1981	3	3
1982	9	9
1983	6	5
1984	15	14
1985	30	25
1986	31	28
1987	34	30
1988	29	28
1989	45	41
1990	47	39
1991	42	41
1992	51	42
1993	35	30
1994	40	32
1995	48	43
1996	55	39
1997	37	30
1998	56	37
1999	55	38
2000	22	17
2001	37	33
2002	49	41
2003	50	45
2004	57	42
2005	64	45
2006	41	36
2007	112	62
2008	85	52
2009	61	50
2010	100	69
2011	52	38

33 in. min

2 fish bag



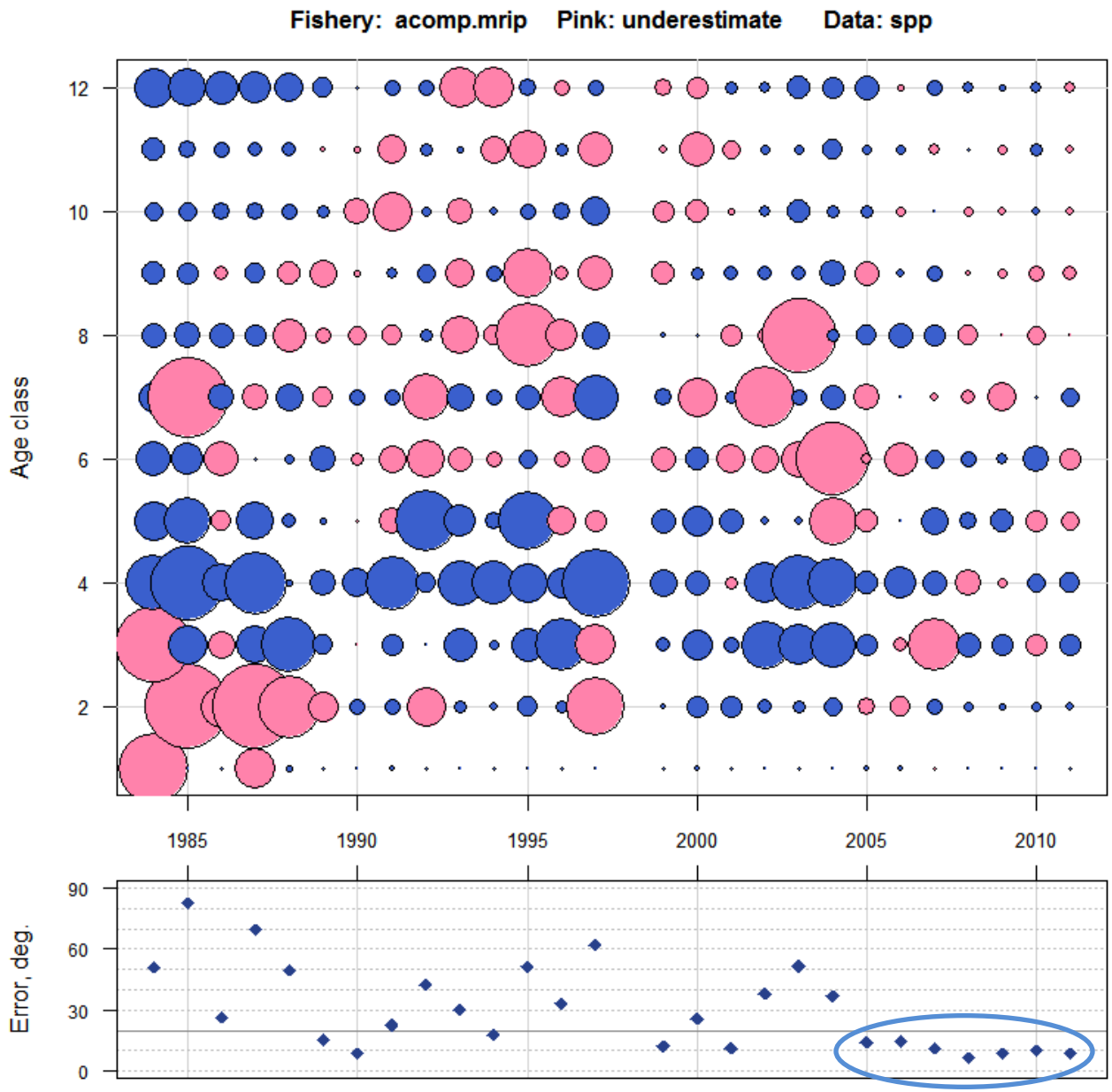
Model Fits: Recreational Age Comps

BAM Base Run

YEAR	Age Comps Number Fish
1981	
1982	
1983	
1984	3
1985	2
1986	22
1987	18
1988	17
1989	78
1990	103
1991	16
1992	20
1993	16
1994	16
1995	10
1996	31
1997	20
1998	
1999	130
2000	111
2001	72
2002	27
2003	7
2004	7
2005	125
2006	81
2007	397
2008	327
2009	311
2010	330
2011	307

33 in. min

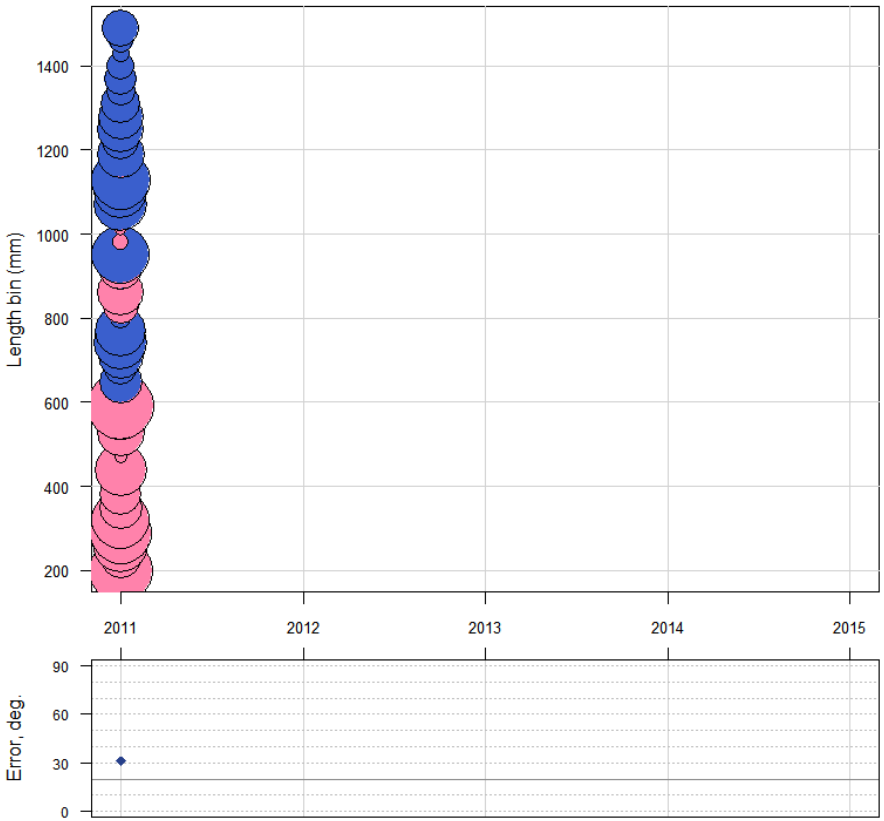
2 fish bag



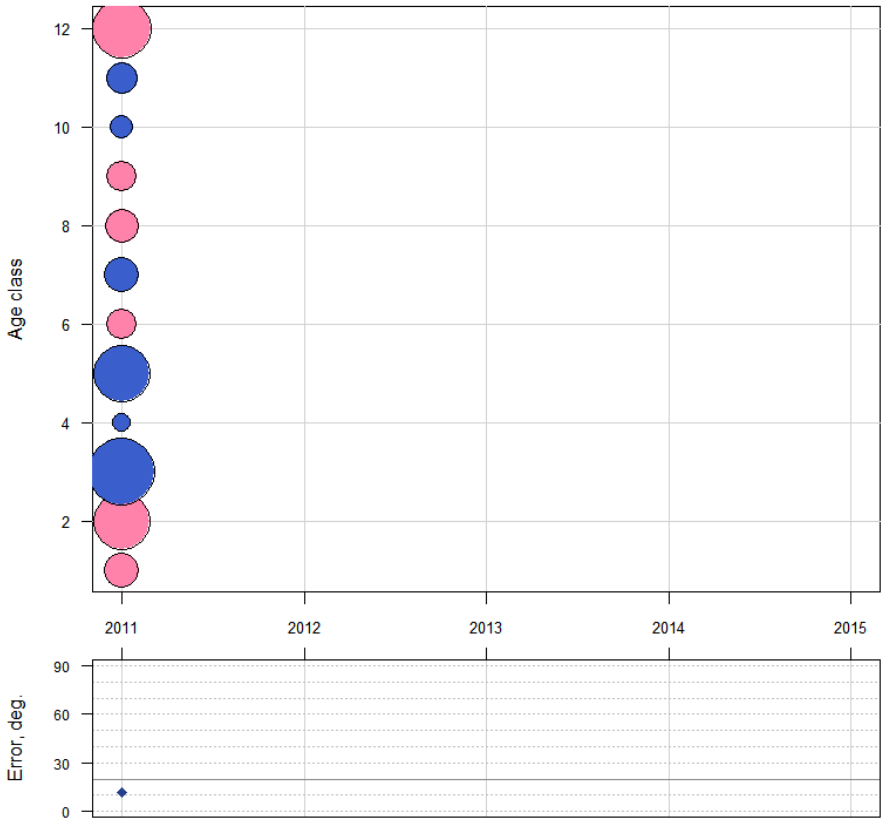
Model Fits: Commercial Compositions

BAM Base Run

Commercial Length Comps



Commercial Age Comps



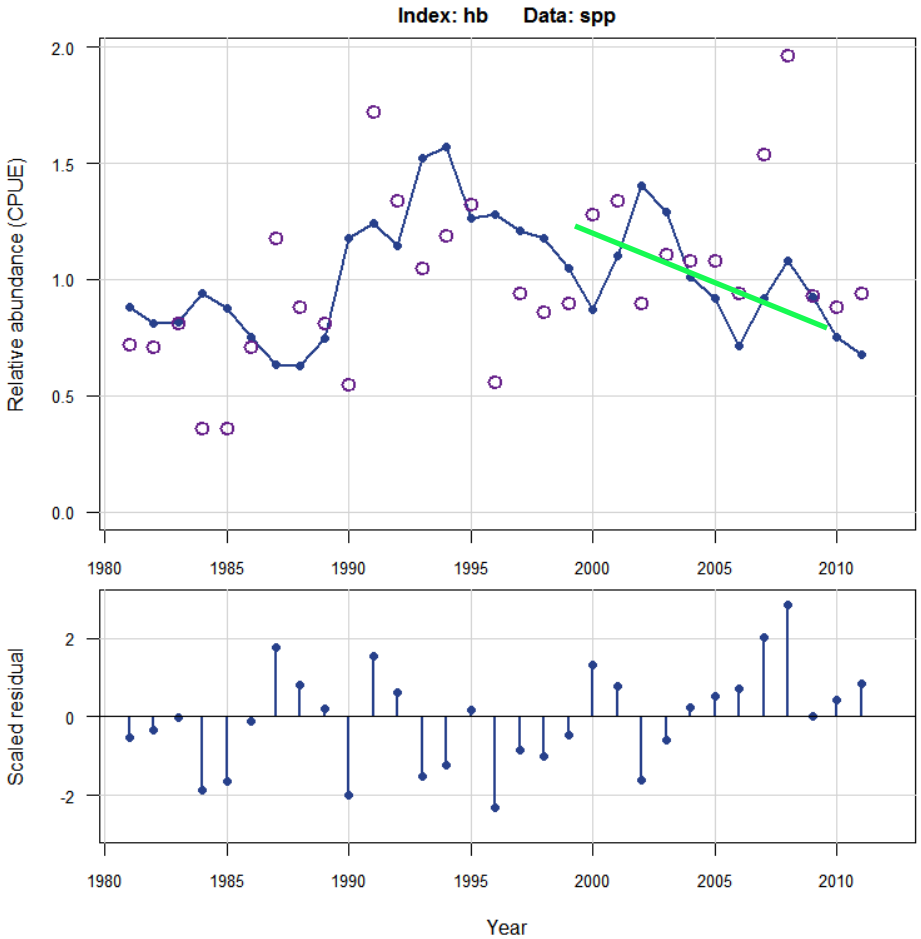
<u>1982-2011</u>
Avg num trips: 9
Total num fish: 438

<u>1986-2011</u>
Avg num trips: 7
Total num fish: 120

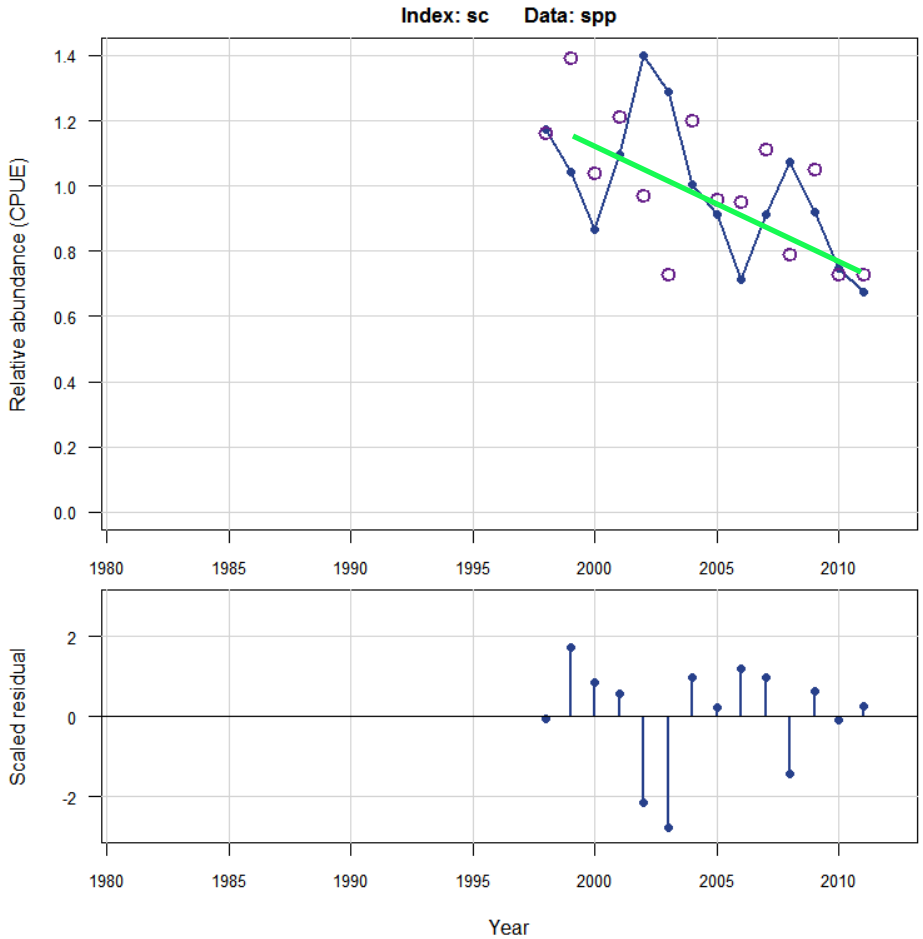
Model Fits: Indices

BAM Base Run

Headboat



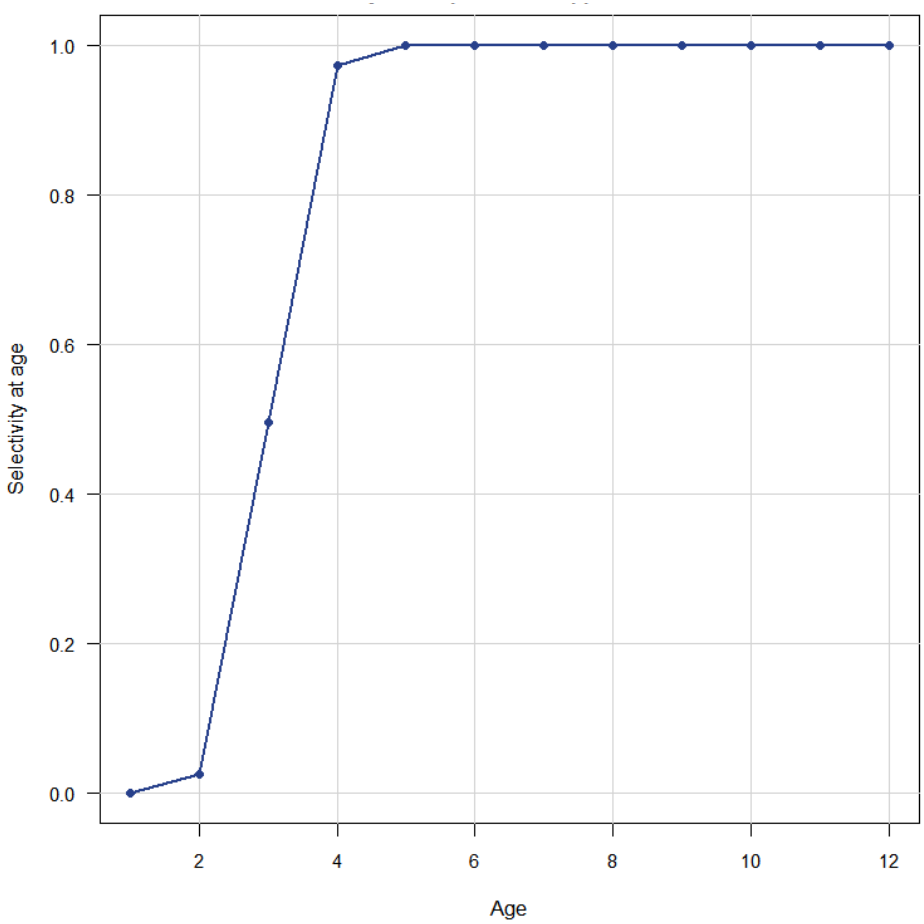
SC logbook



Model Outputs: Selectivity

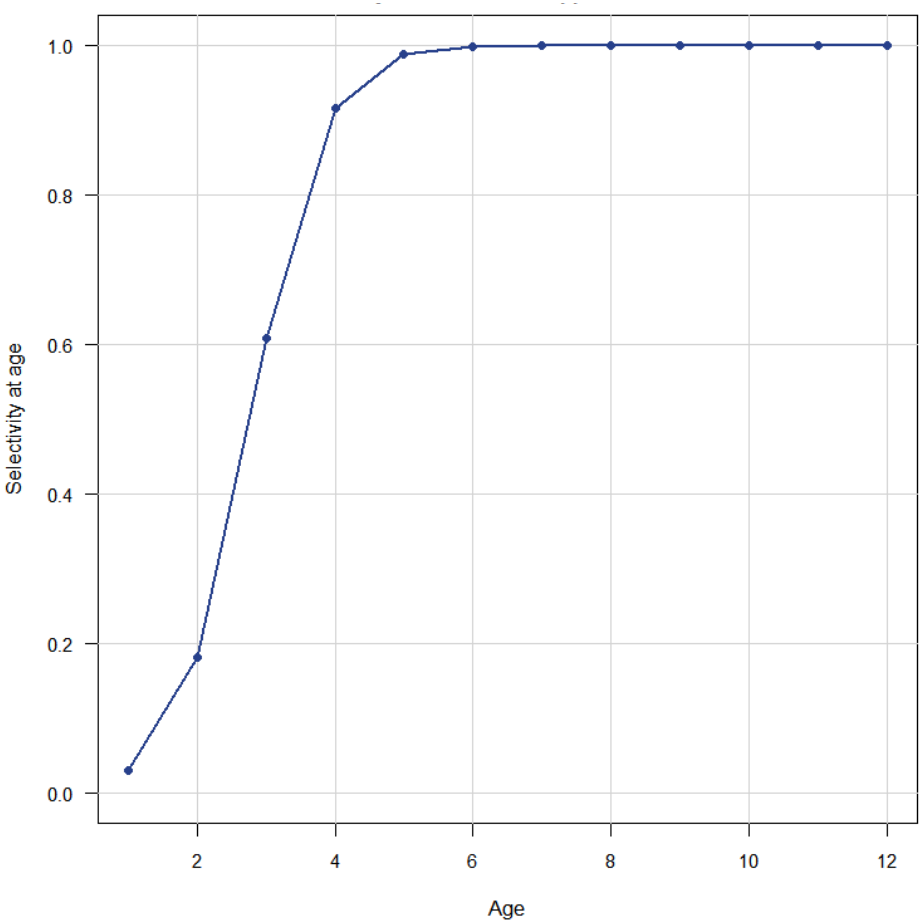
BAM Base Run

Recreational



A_{50}: 3.01 yr
Age at full selection: 4 yr

Commercial

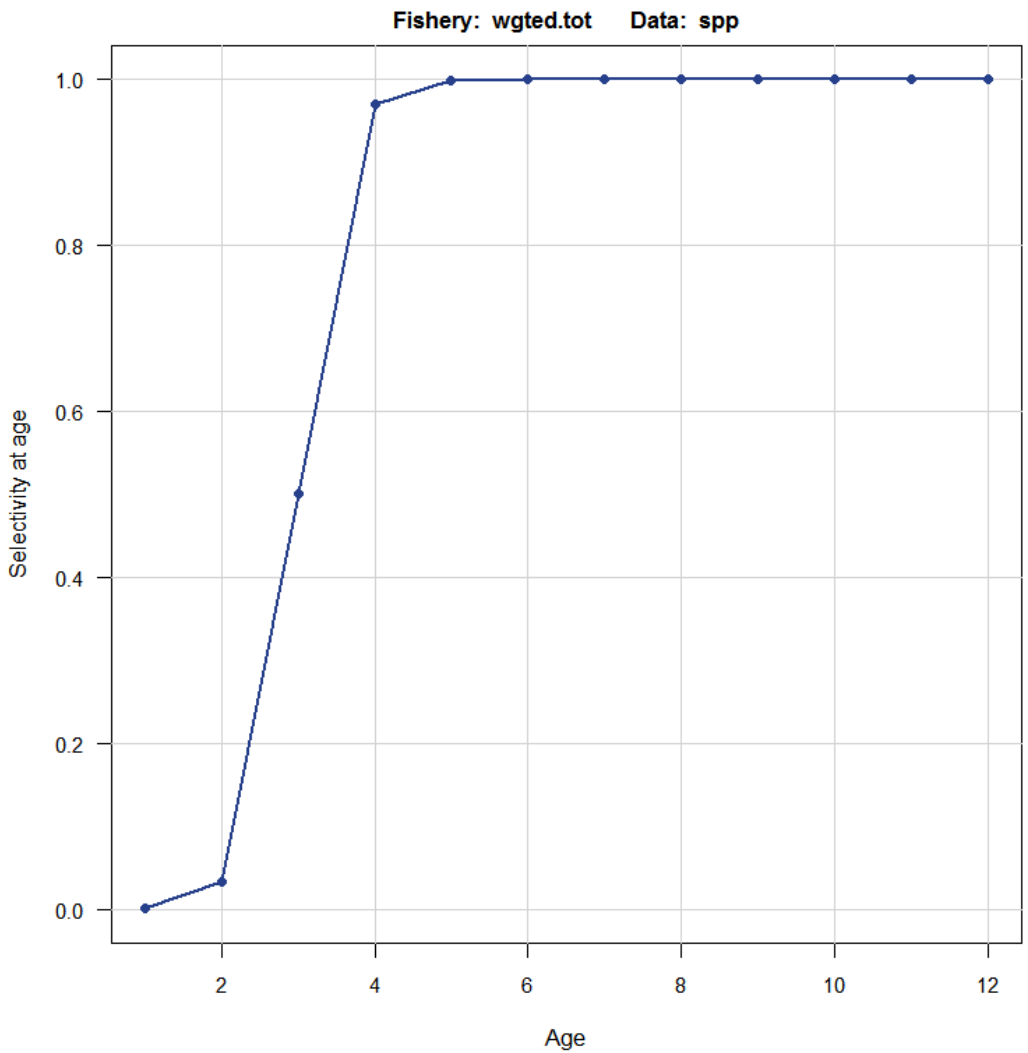


A_{50}: 2.77 yr
Age at full selection: 5 yr

Model Outputs: Selectivity

BAM Base Run

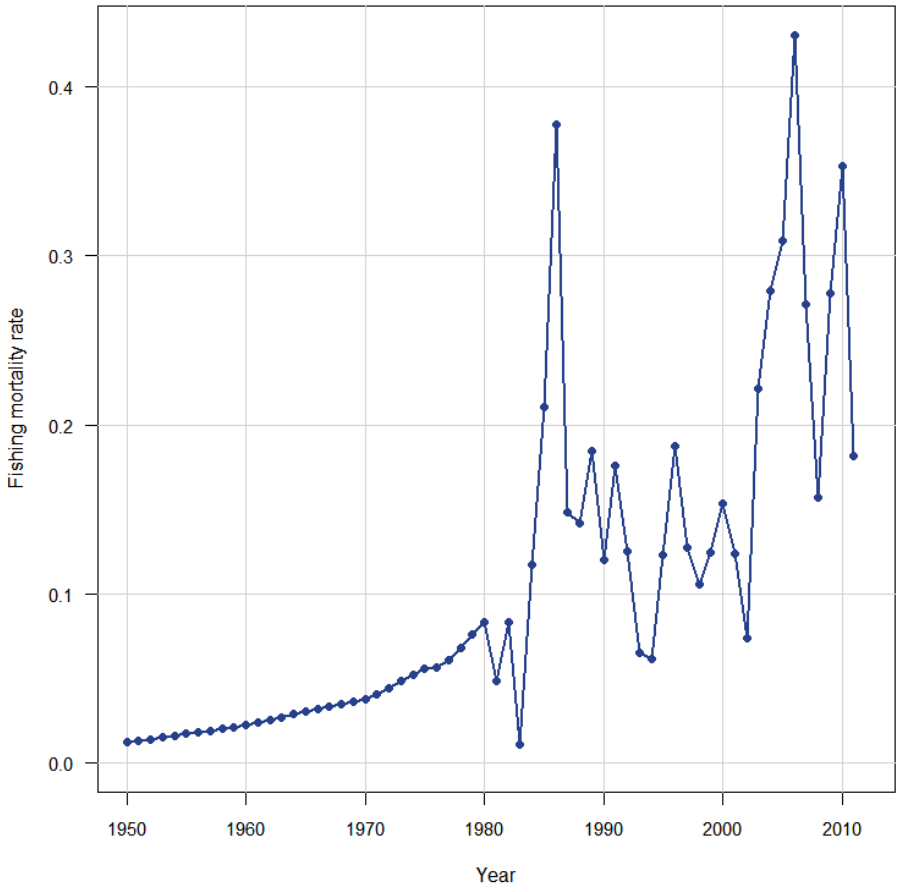
- Average selectivity in terminal assessment yr (2011)
- Weighted by geometric mean F in last 3 yrs
- Used to compute benchmarks and in projections



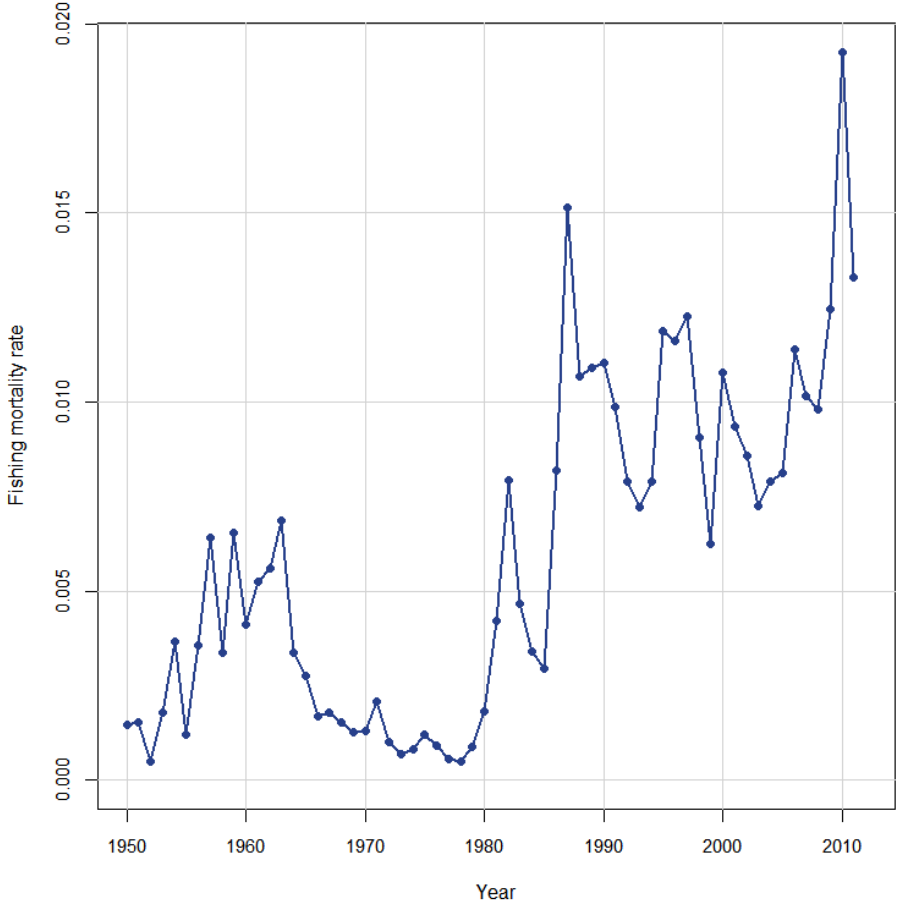
Model Outputs: Fishing Mortality

BAM Base Run

Recreational

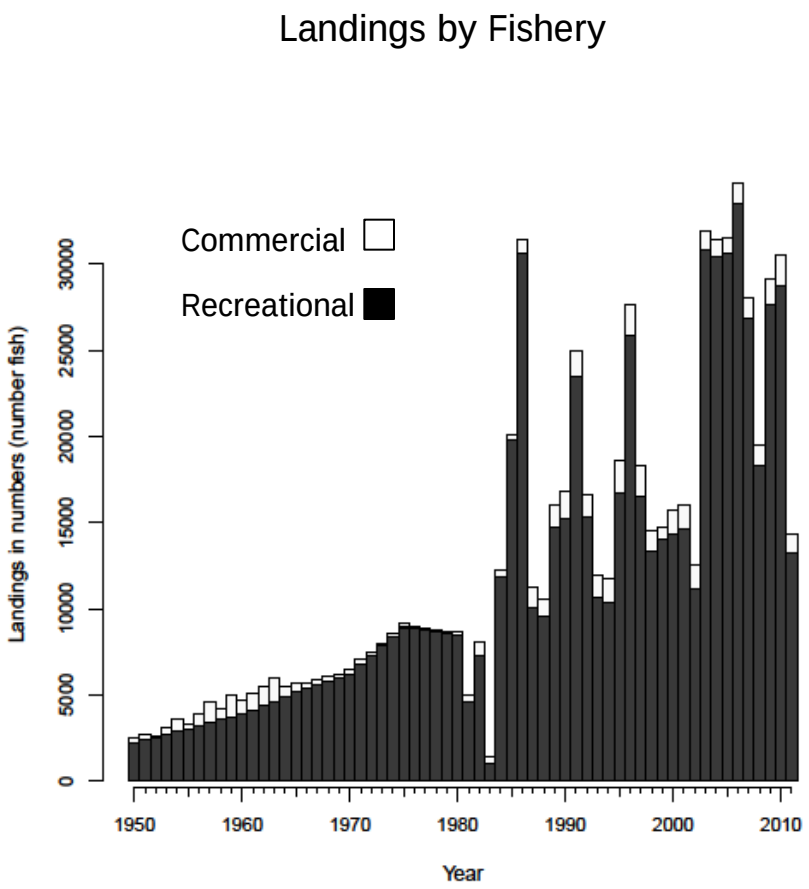


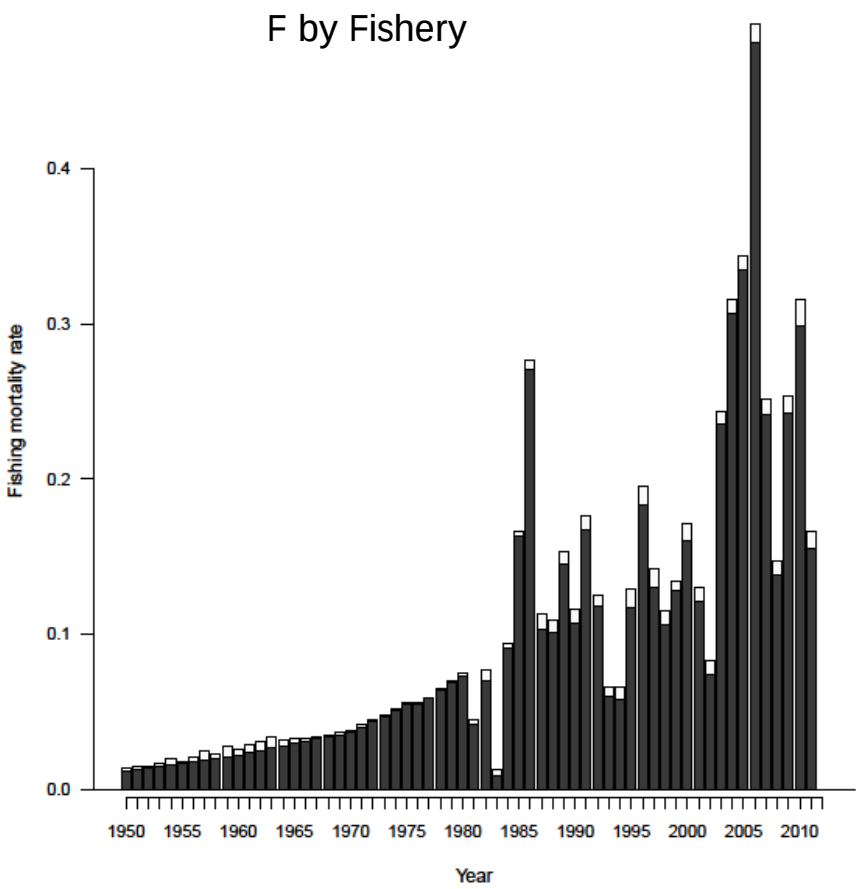
Commercial



Model Outputs: Landings & Fishing Mortality

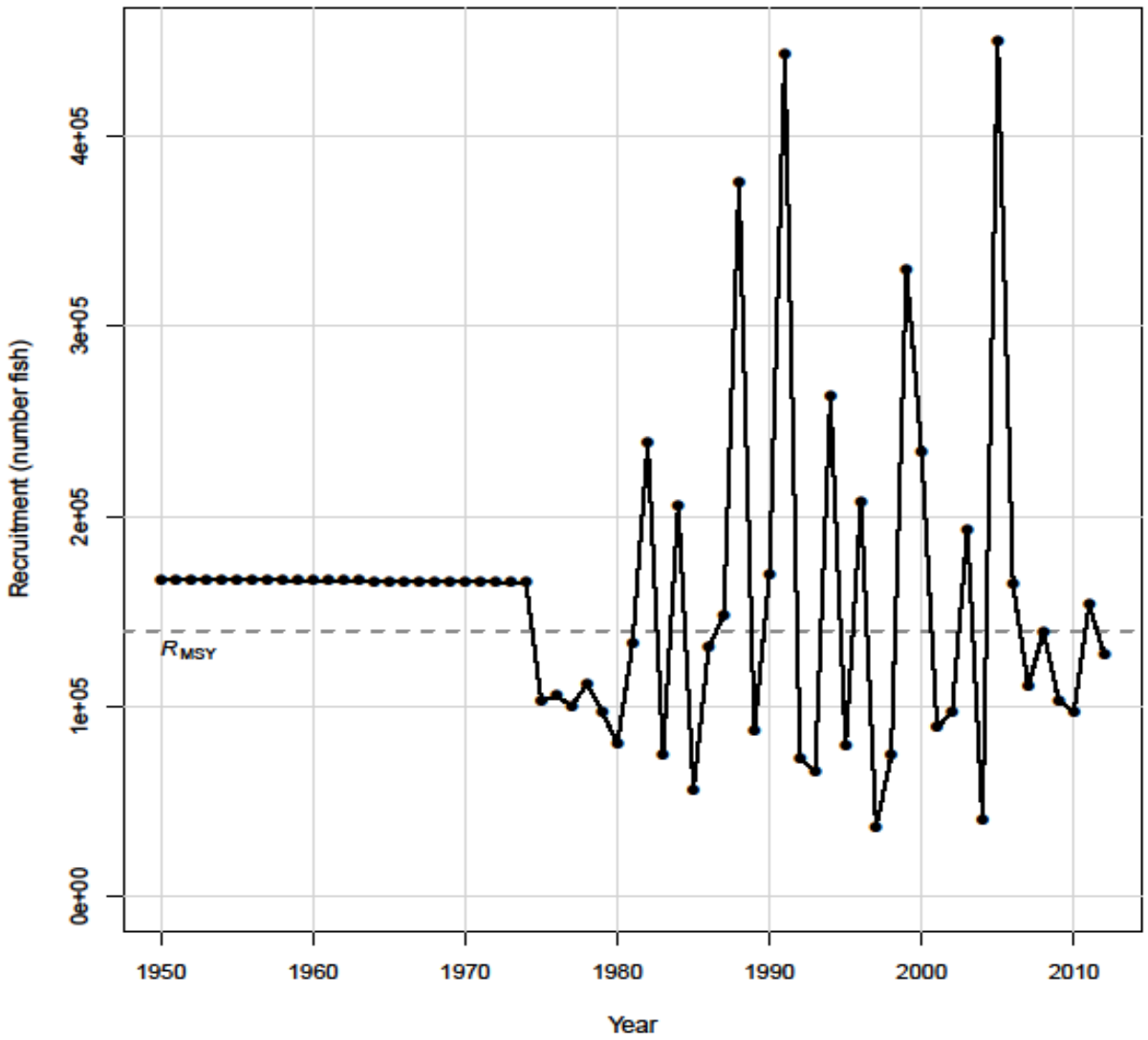
BAM Base Run





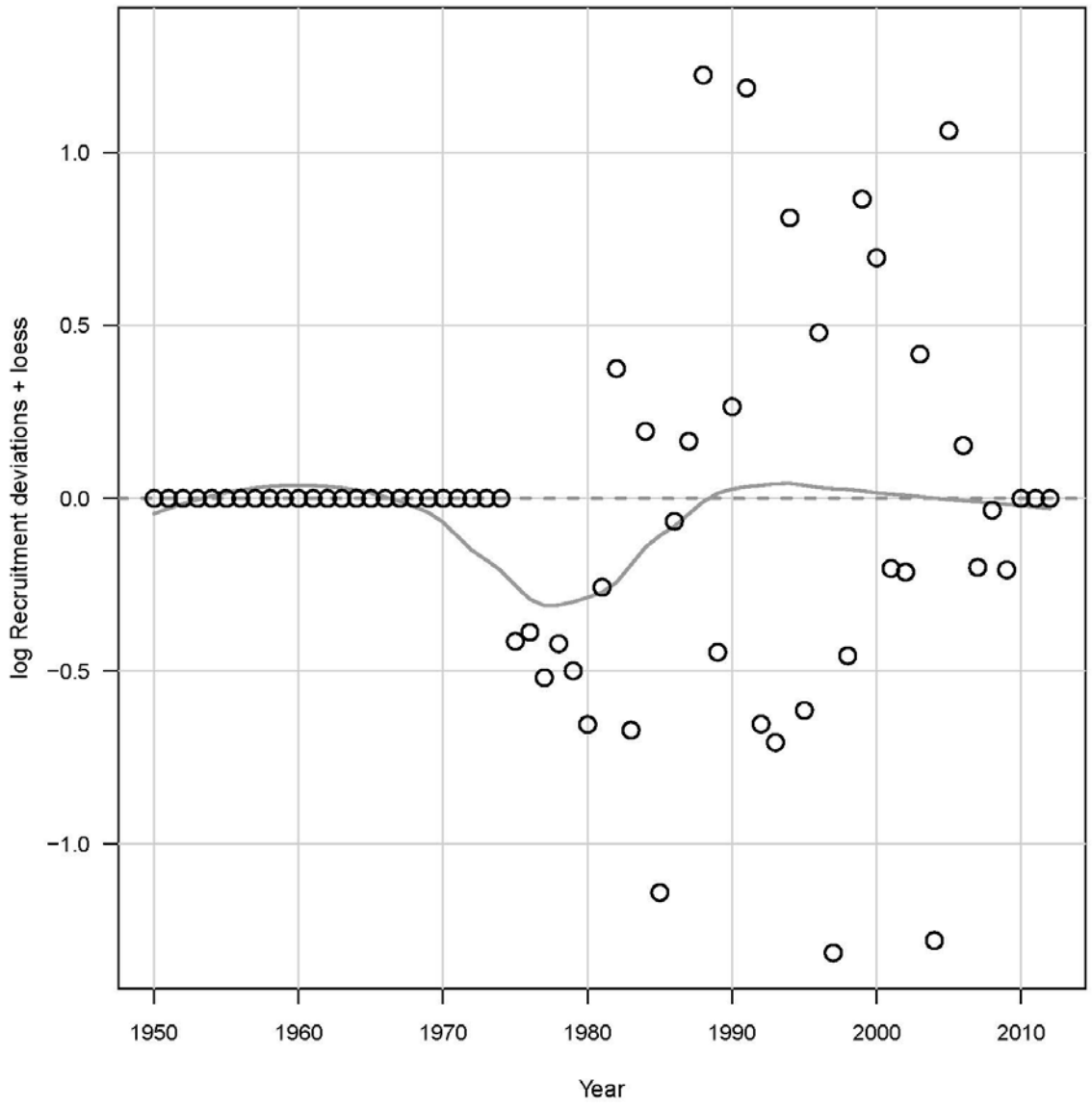
Model Outputs: Age-1 Recruitment

BAM Base Run



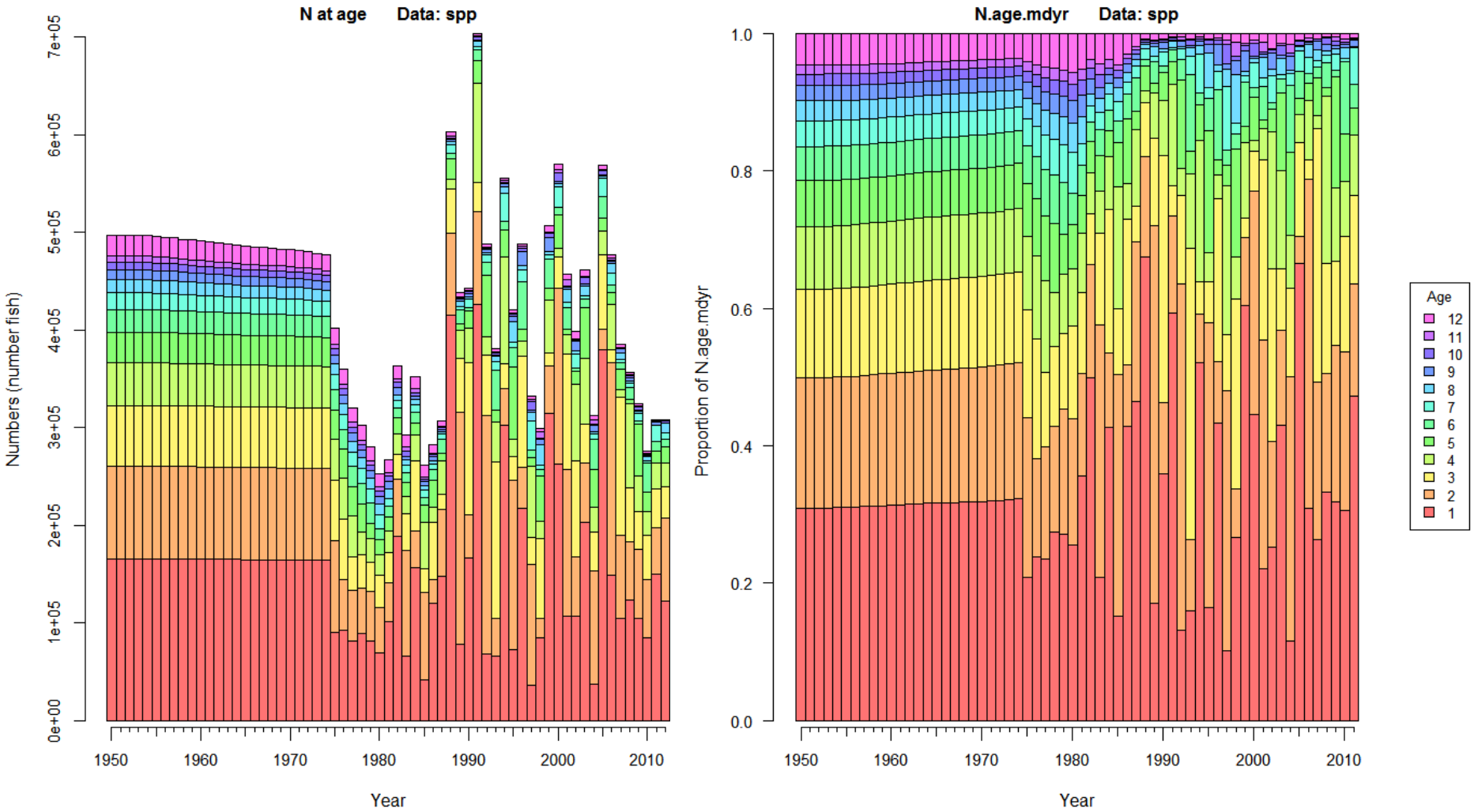
Model Outputs: Age-1 Recruitment Residuals

BAM Base Run



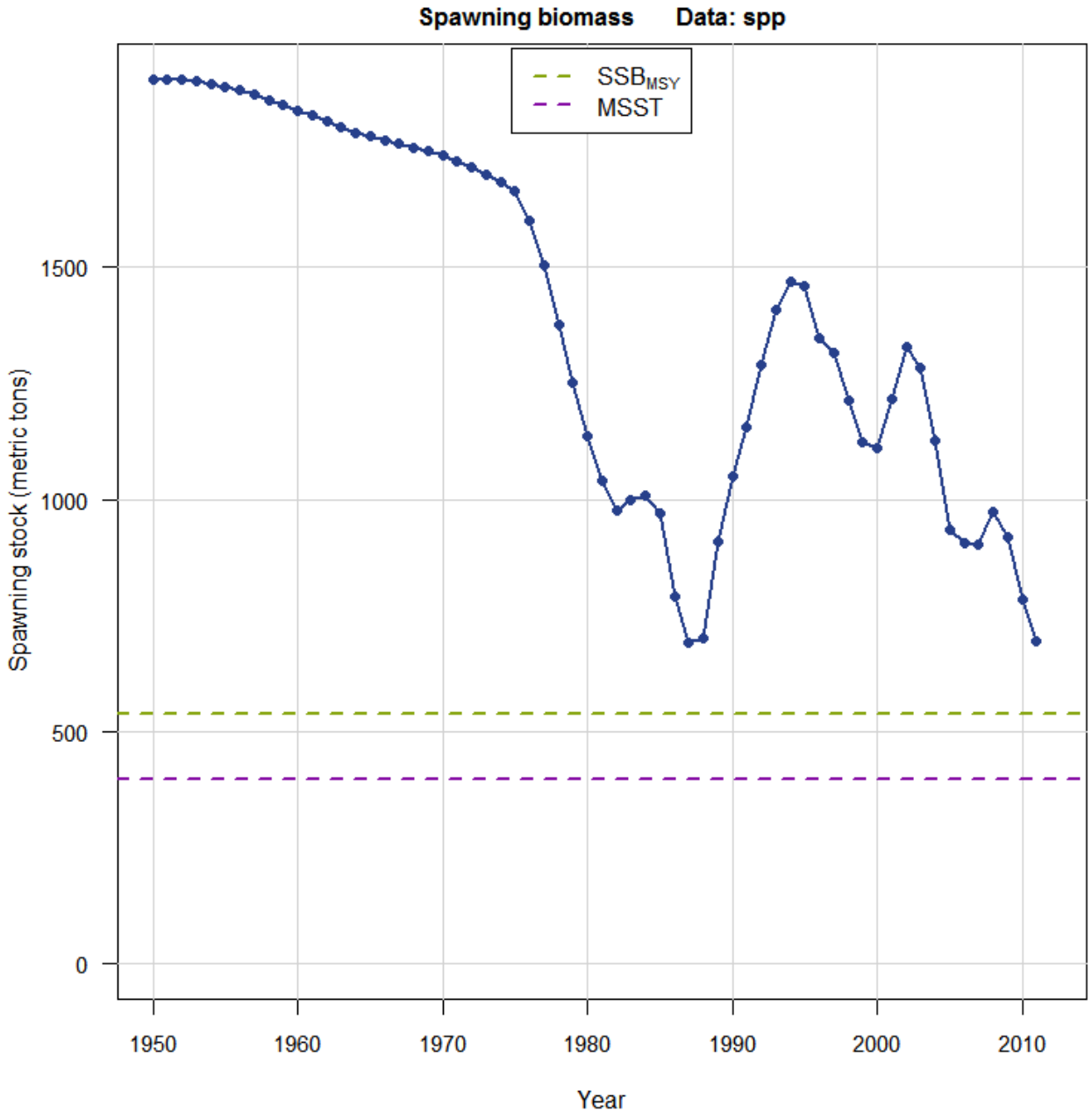
Model Outputs: Numbers at Age

BAM Base Run



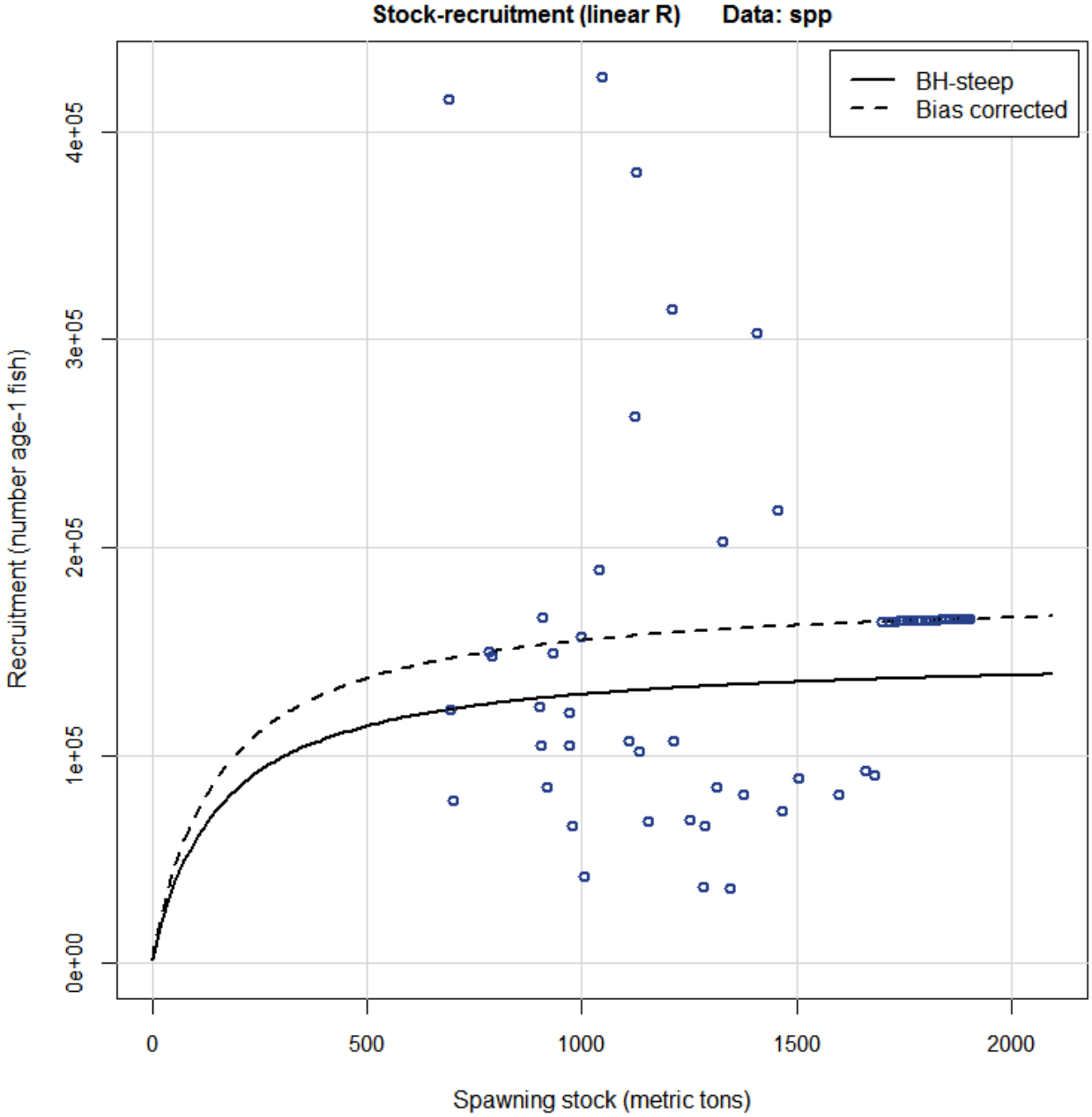
Model Outputs: Spawning Biomass

BAM Base Run



Model Outputs: Stock-Recruitment

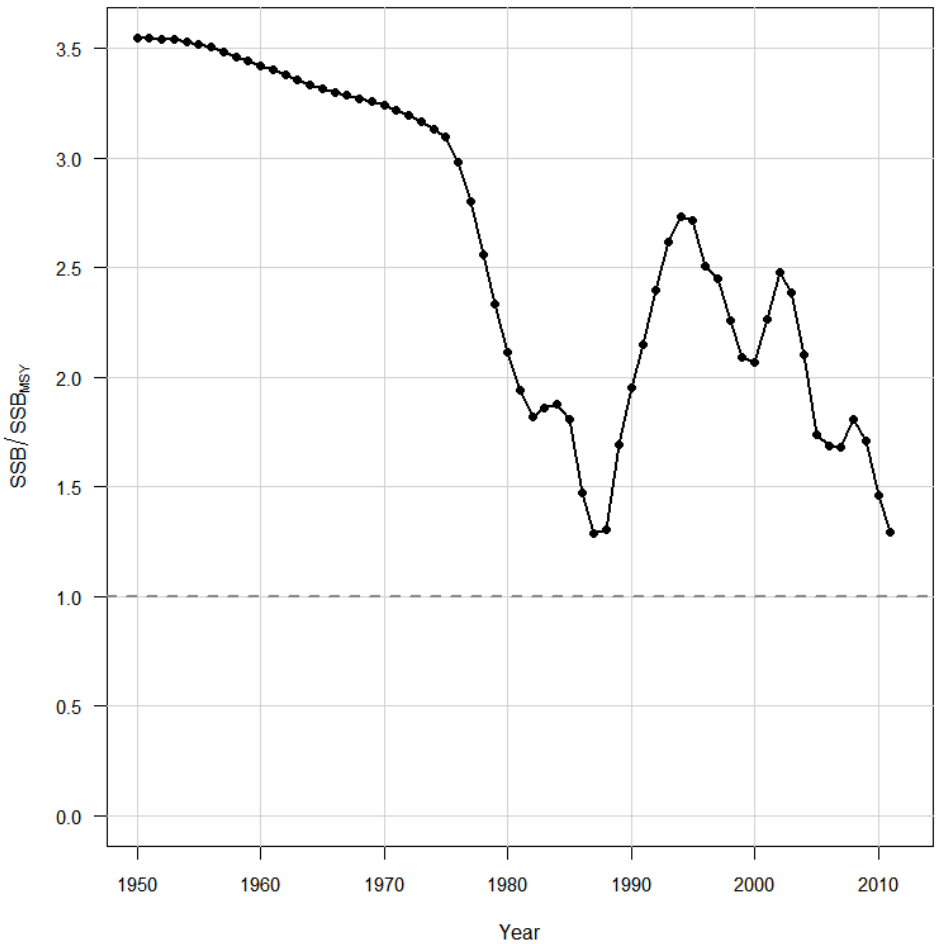
BAM Base Run



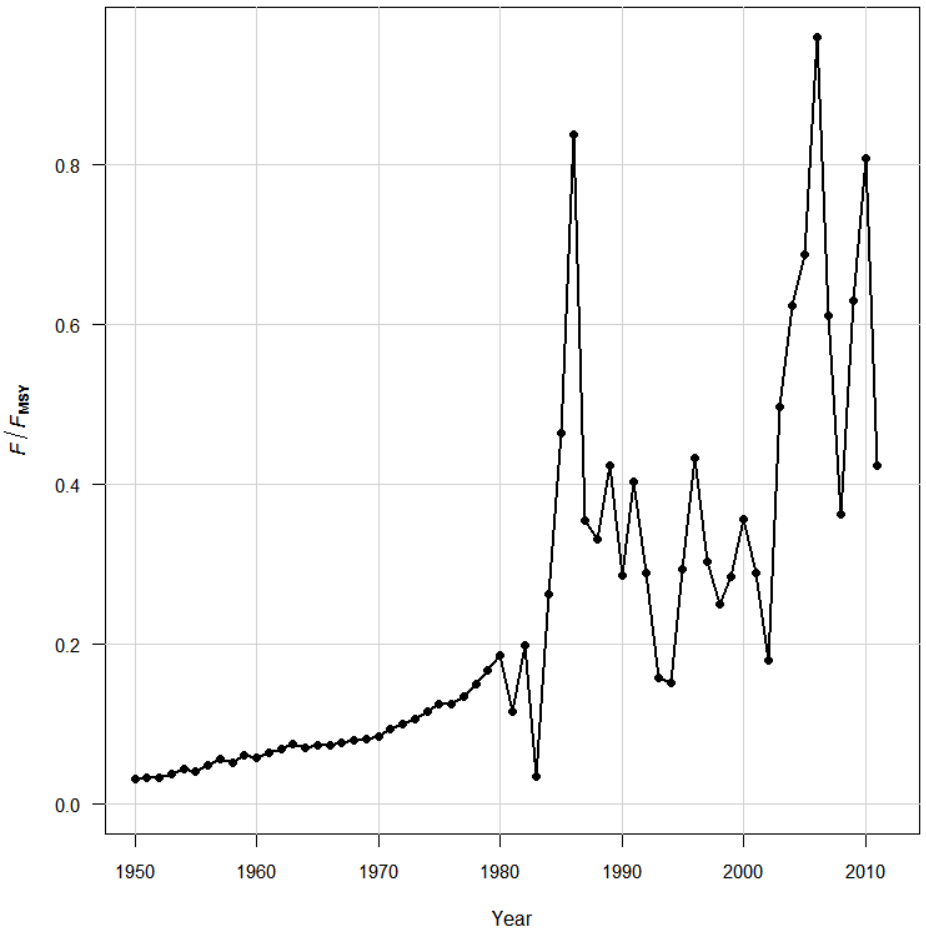
Model Outputs: Status Indicators

BAM Base Run

Biomass Status



Exploitation Status



Model Outputs: Management Quantities

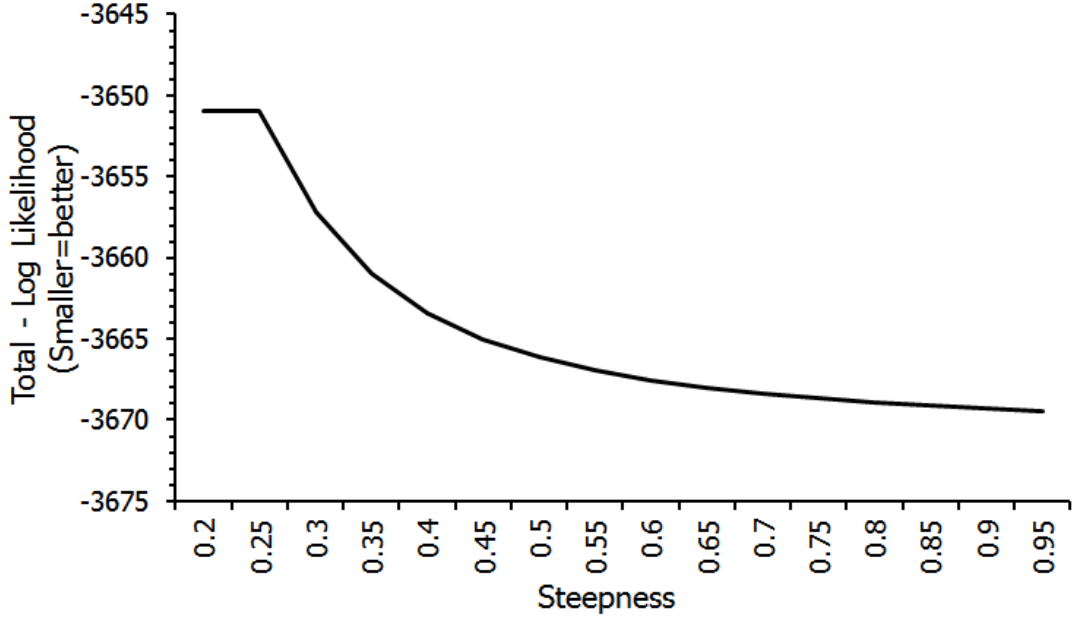
BAM Base Run

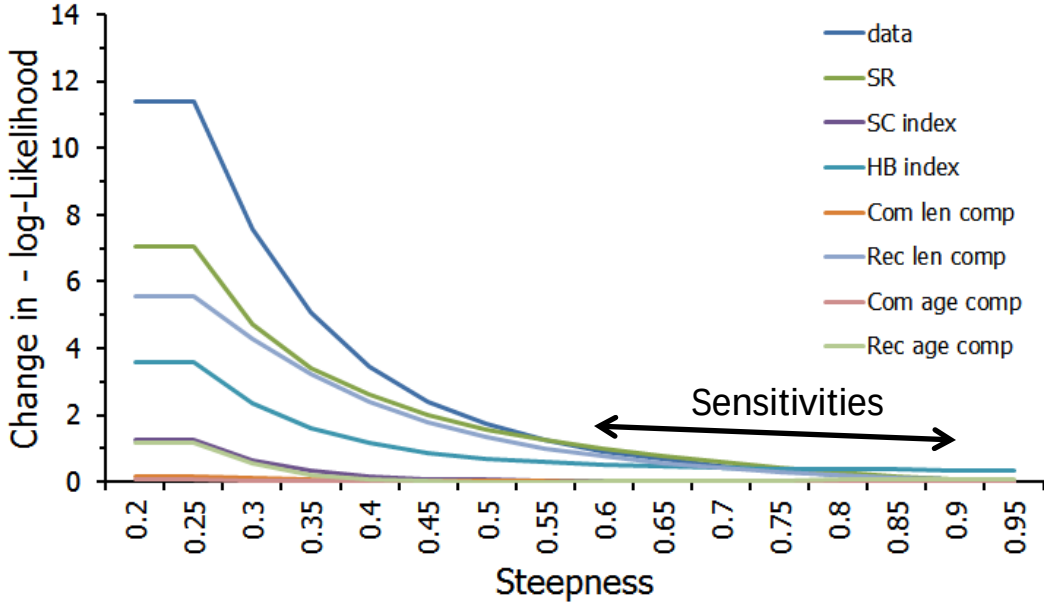
Table 3.12. Estimated status indicators, benchmarks, and related quantities from the Beaufort catch-age model, conditional on estimated current selectivities averaged across fisheries. Rate estimates (F) are in units of y^{-1}; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) and minimum stock size threshold (MSST) are measured by total weight of mature females. Symbols, abbreviations, and acronyms are listed in Appendix A.

Quantity	Units	Estimate
F_{MSY}	y^{-1}	0.461
$85\%F_{MSY}$	y^{-1}	0.391
$75\%F_{MSY}$	y^{-1}	0.345
$65\%F_{MSY}$	y^{-1}	0.299
$F_{30\%}$	y^{-1}	0.493
$F_{40\%}$	y^{-1}	0.309
$F_{50\%}$	y^{-1}	0.205
B_{MSY}	mt	1991.6
SSB_{MSY}	mt	536.8
MSST	mt	397.2
MSY	1000 lb	808
R_{MSY}	1000 age-1 fish	139
Y at $85\%F_{MSY}$	1000 lb	803
Y at $75\%F_{MSY}$	1000 lb	794
Y at $65\%F_{MSY}$	1000 lb	777
$F_{2009-2011}/F_{MSY}$	—	0.599
F_{2011}/F_{MSY}	—	0.423
$SSB_{2011}/MSST$	—	1.75

Model Diagnostics: Steepness Profile

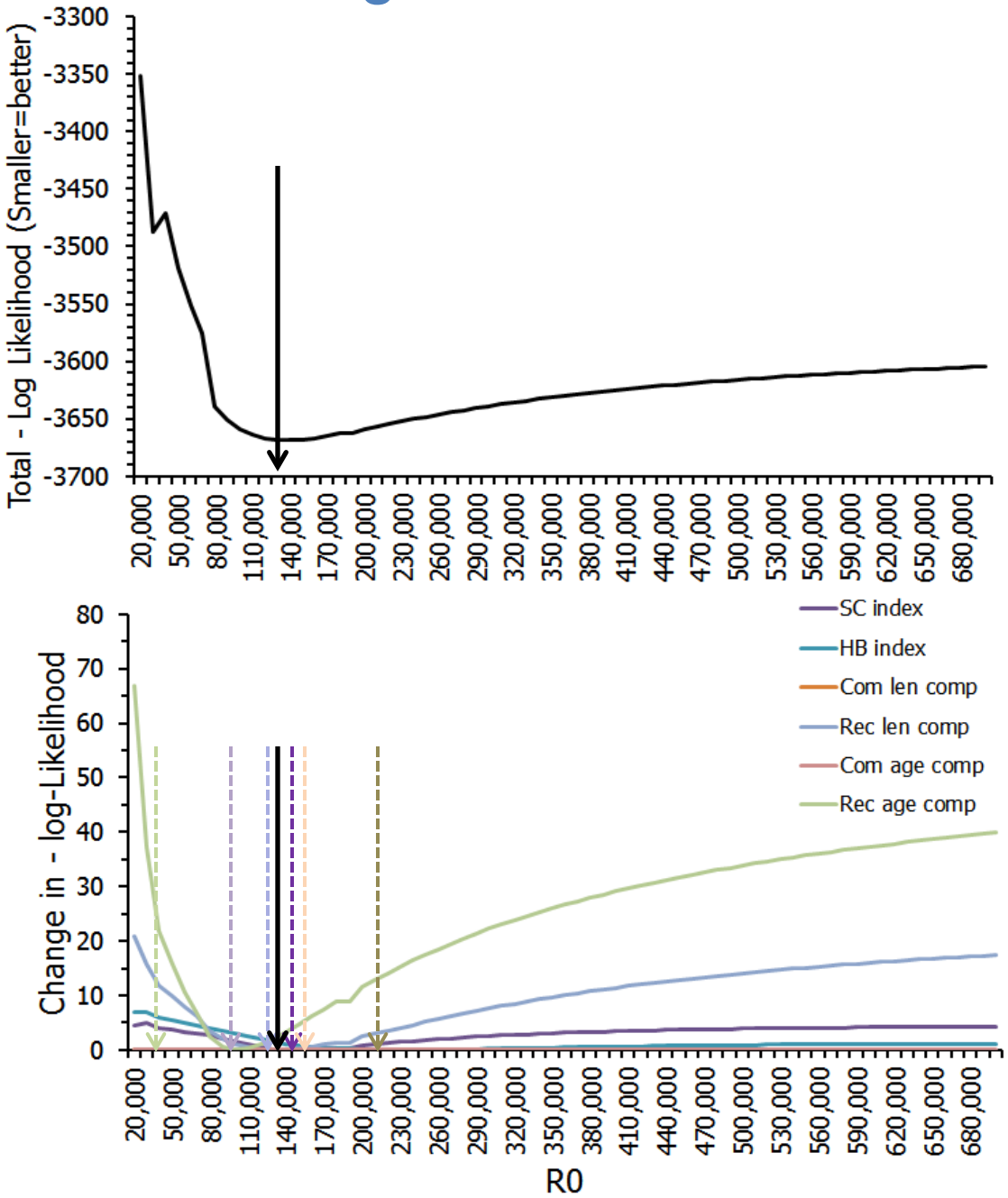
BAM Base Run





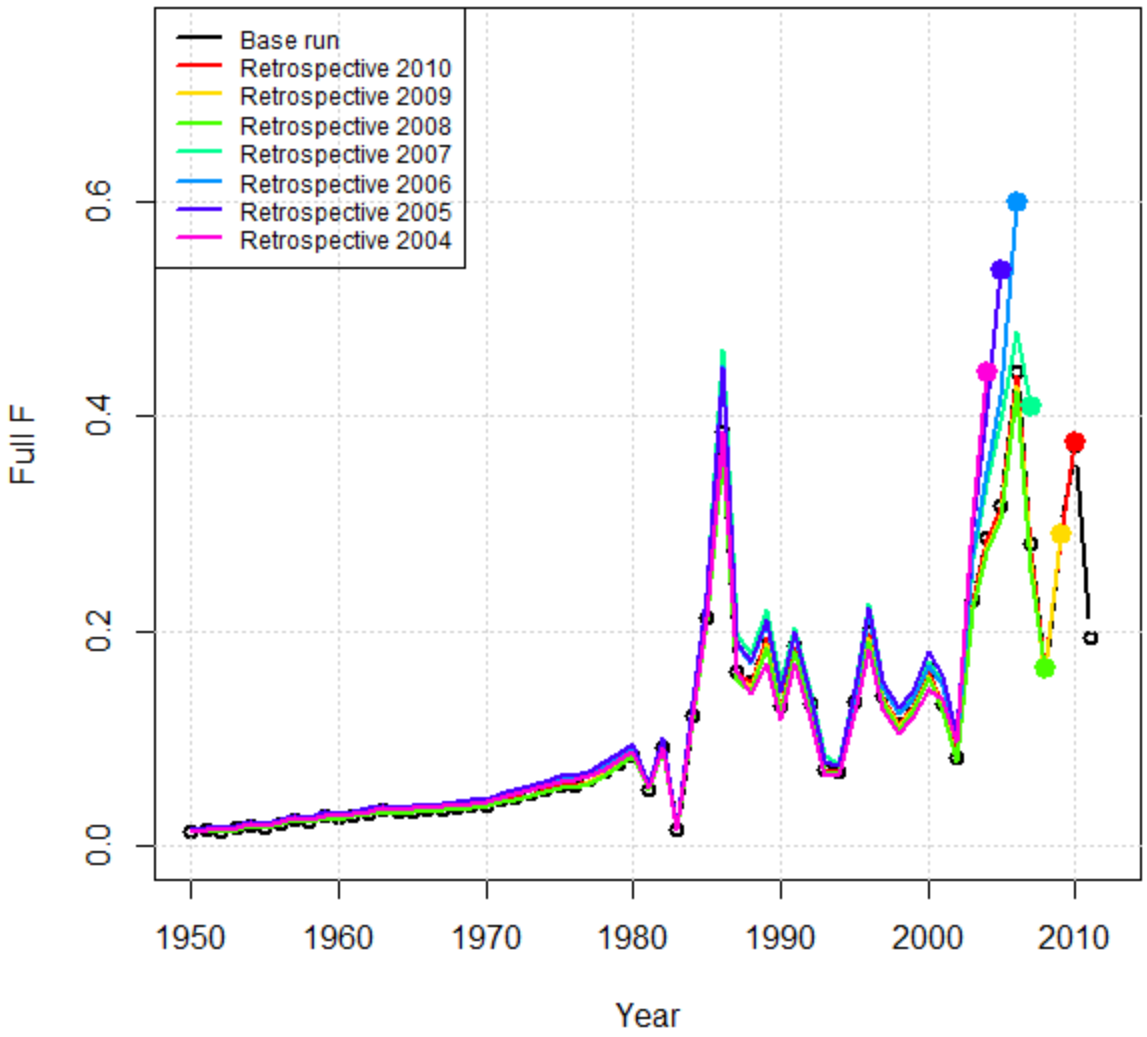
Model Diagnostics: R0 Profile

BAM Base Run



Model Diagnostics: Retrospective Analysis

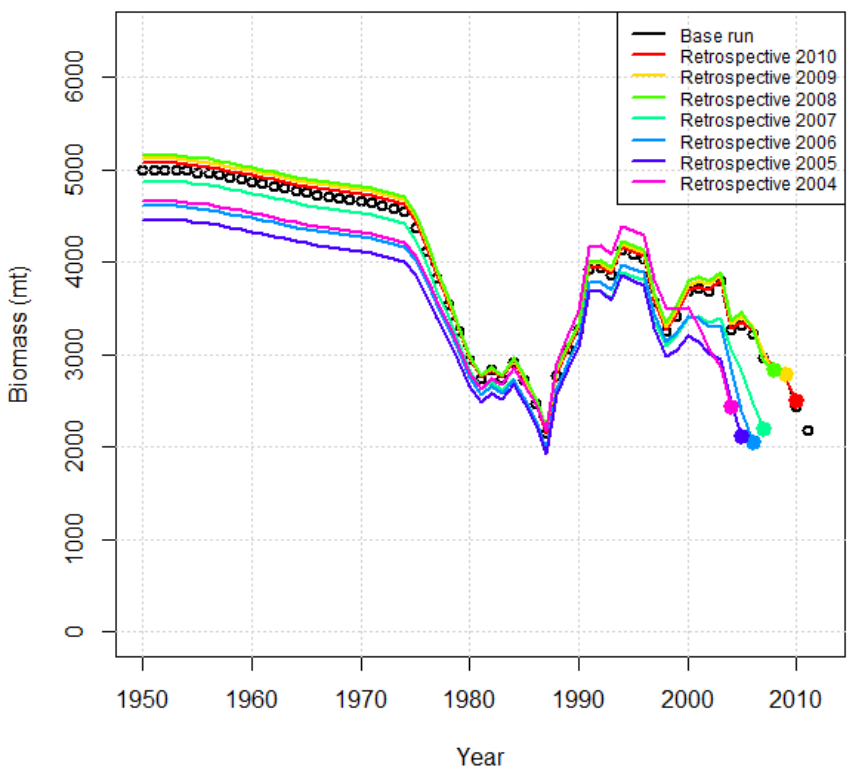
BAM Base Run



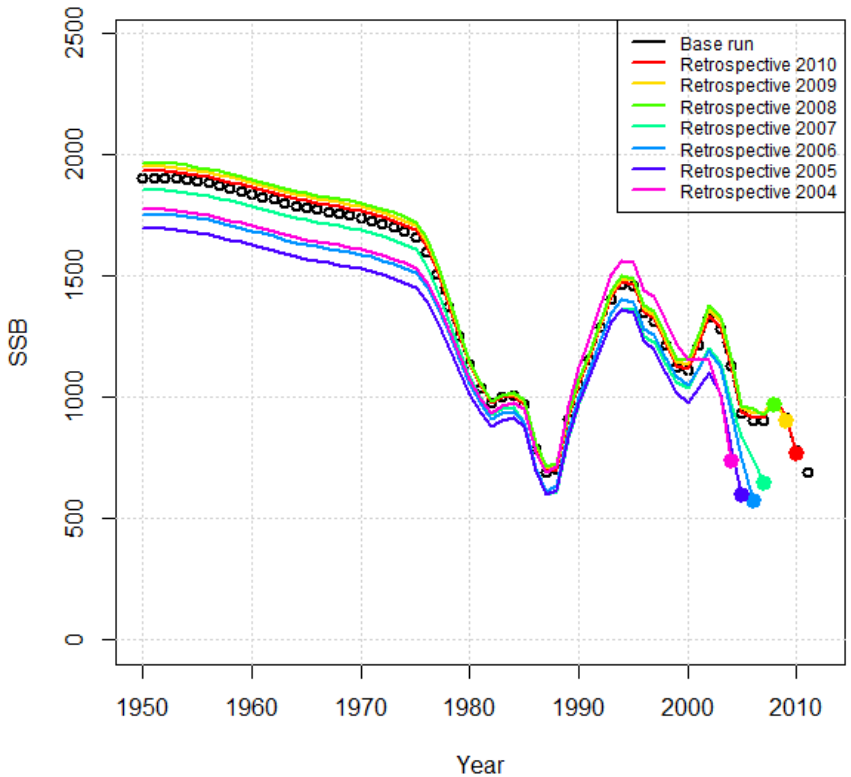
Model Diagnostics: Retrospective Analysis

BAM Base Run

Biomass

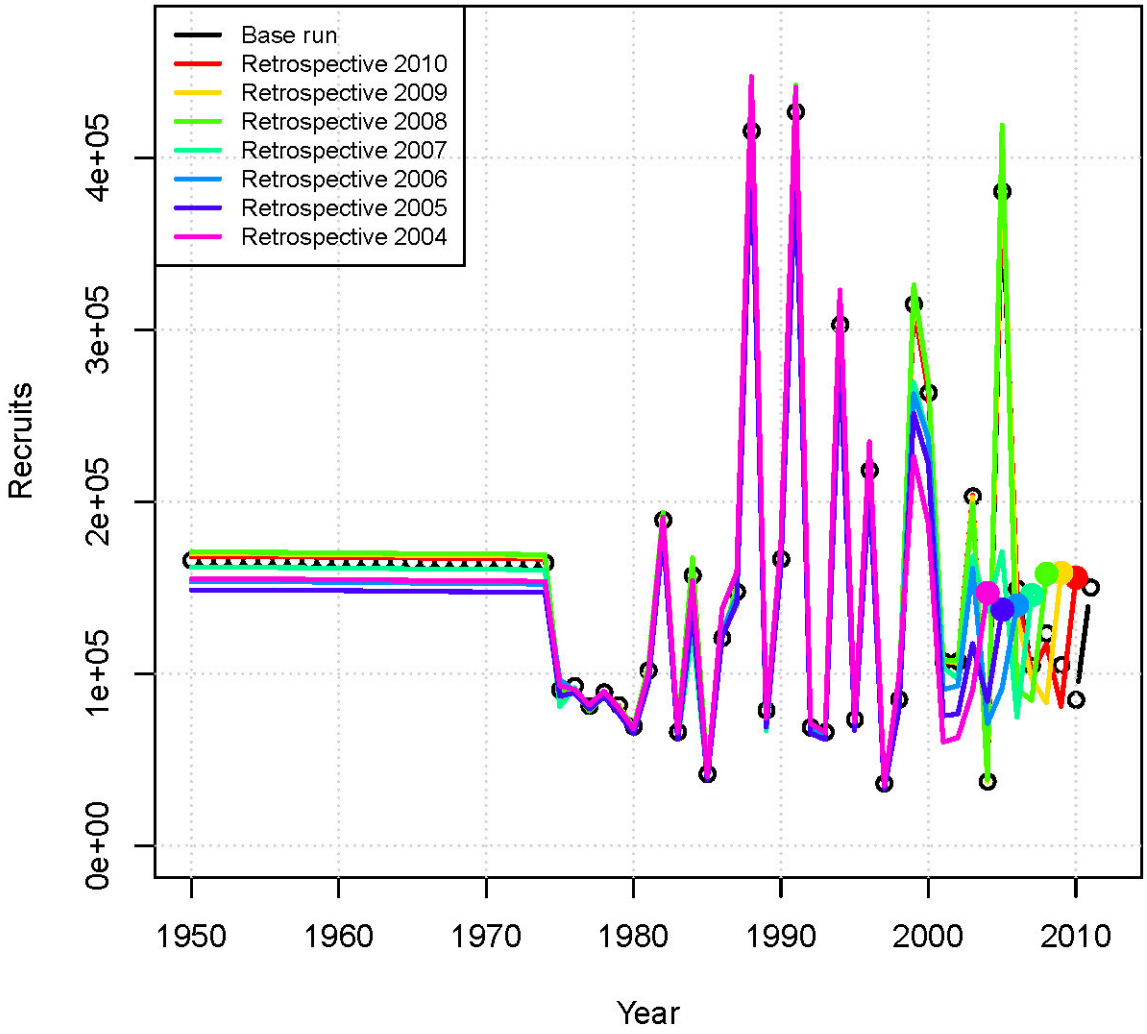


Spawning Biomass



Model Diagnostics: Retrospective Analysis

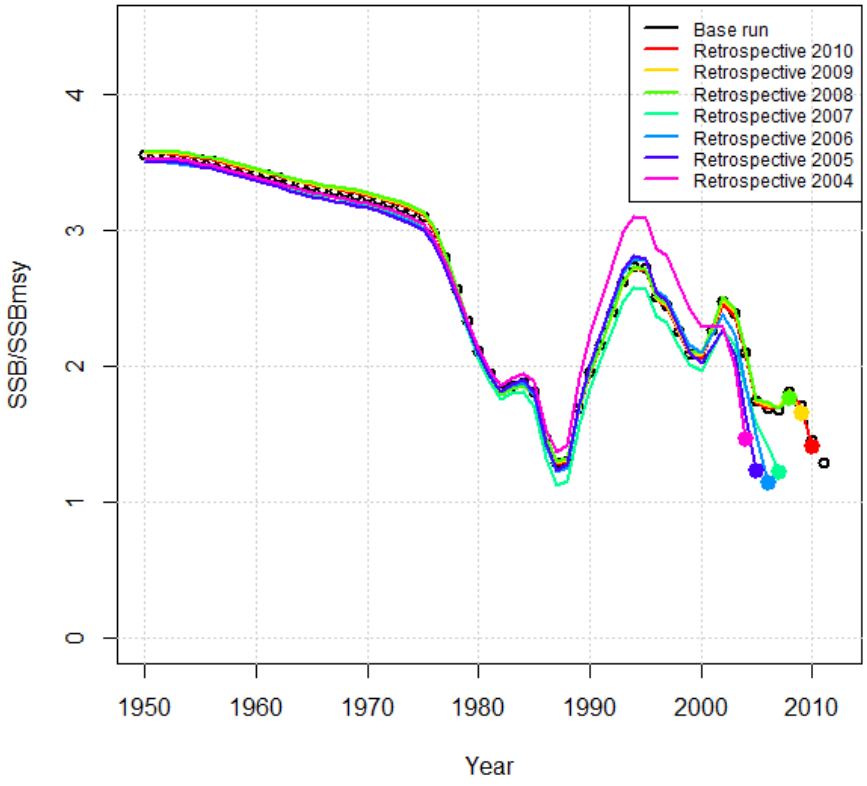
BAM Base Run



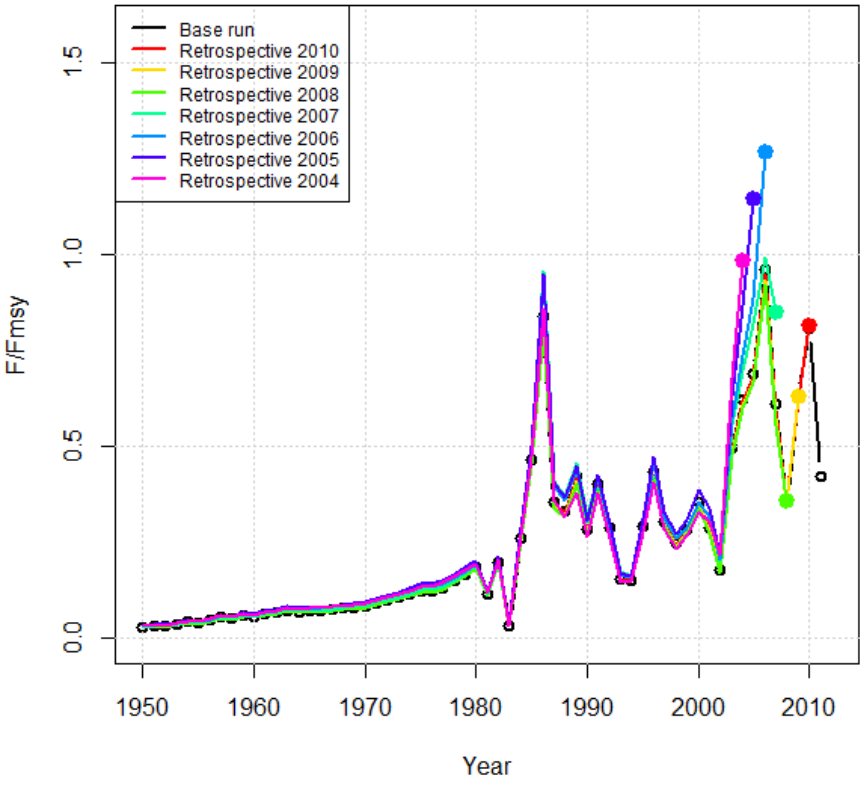
Model Diagnostics: Retrospective Analysis

BAM Base Run

Biomass status



Exploitation status



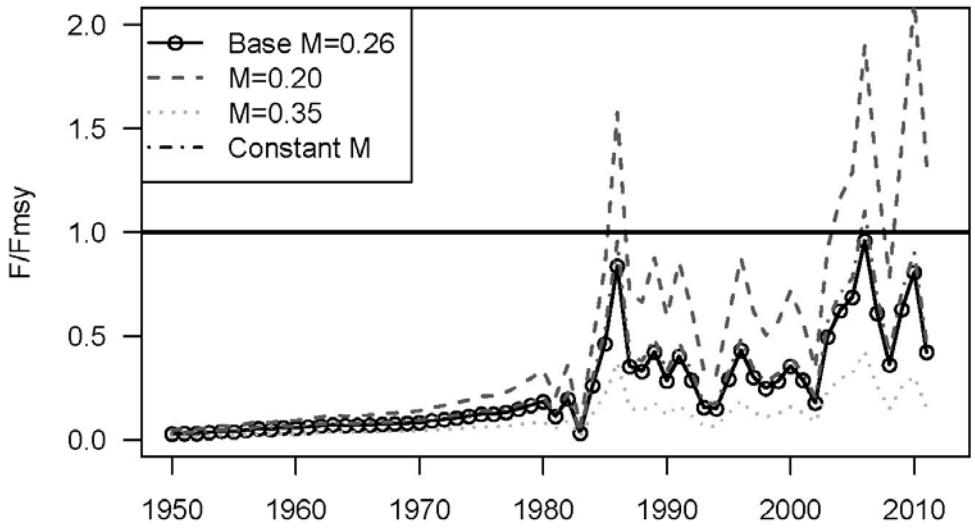
Model Diagnostics: Sensitivity Analysis

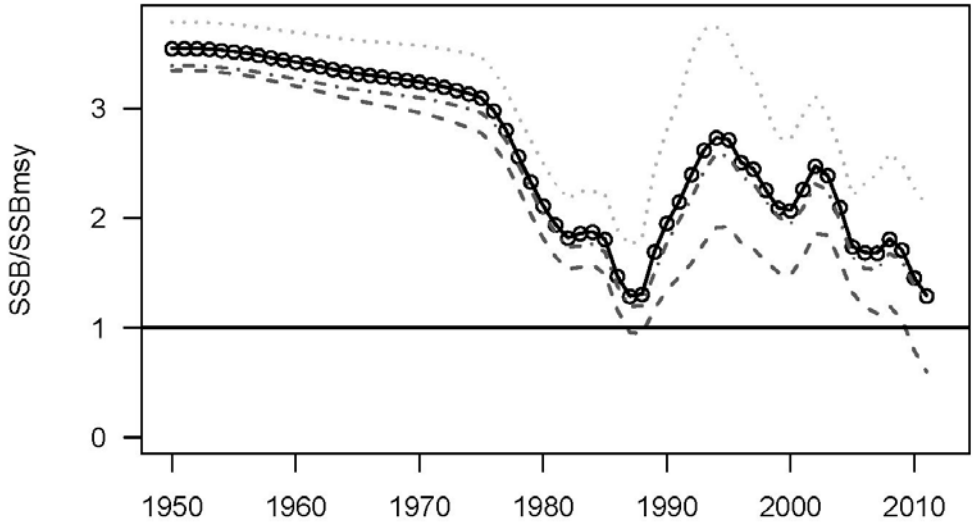
BAM Base Run

Run	Description	F_{MSY}	SSB_{MSY} (mt)	B_{MSY} (mt)	MSY(1000 lb)	$F_{2009-2011}/F_{MSY}$	SSB_{2011}/MSST	SSB_{2011}/SSB_{MSY}	steep	R0(1000)
Base	—	0.46	537	1992	808	0.6	1.75	1.29	0.75	137
S1	M=0.20	0.31	549	1693	617	1.59	0.75	0.6	0.75	74
S2	M=0.35	0.697	612	2806	1207	0.23	3.26	2.12	0.75	275
S3	constant M=0.26	0.403	559	1826	795	0.67	1.67	1.24	0.75	76
S4	h=0.6	0.299	677	2264	708	0.96	1.31	0.97	0.6	142
S5	h=0.9	1.046	340	1639	953	0.26	2.86	2.12	0.95	132
S6	Unweighted	0.538	320	1224	526	1.03	1.07	0.79	0.75	71
S7	upweight indices	0.446	620	2286	917	0.41	2.41	1.79	0.75	160
S8	q 0.02	0.46	534	1981	804	0.62	1.68	1.25	0.75	136
S9	RW q	0.462	522	1938	787	0.7	1.49	1.1	0.75	133
S10	SC stocking	0.461	534	1983	805	0.58	1.84	1.36	0.75	136
S11	Low discard mortality	0.461	523	1939	787	0.59	1.76	1.31	0.75	133
S12	High discard mortality	0.461	549	2039	827	0.61	1.73	1.28	0.75	140
S13	HB index only	0.462	526	1951	793	0.63	1.66	1.23	0.75	133
S14	SC logbook index only	0.464	515	1912	778	0.72	1.44	1.06	0.75	130
S15	HB, SC logbook, MRFSS indices	0.46	545	2020	819	0.55	1.91	1.41	0.75	139
S16	Fecundity	0.321		2254	738	0.87	1.58	1.17	0.75	140

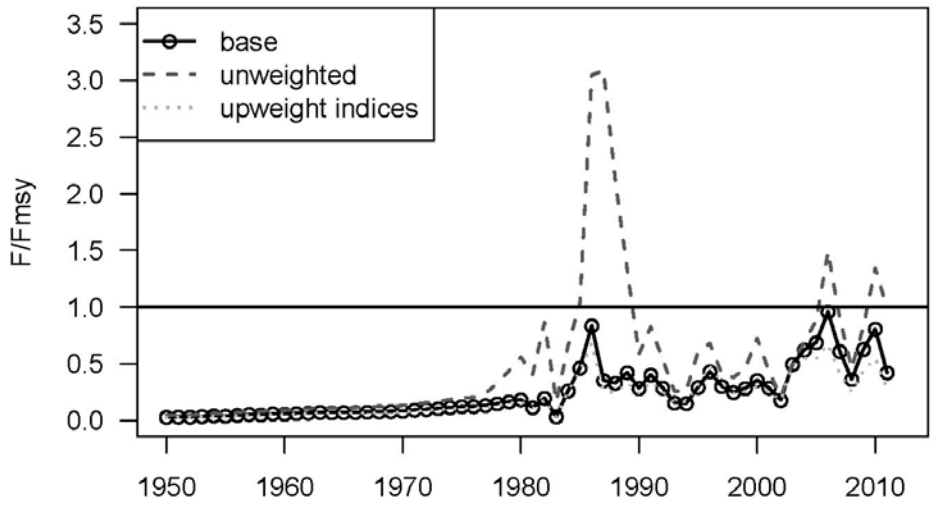
Model Diagnostics: Sensitivity Analysis

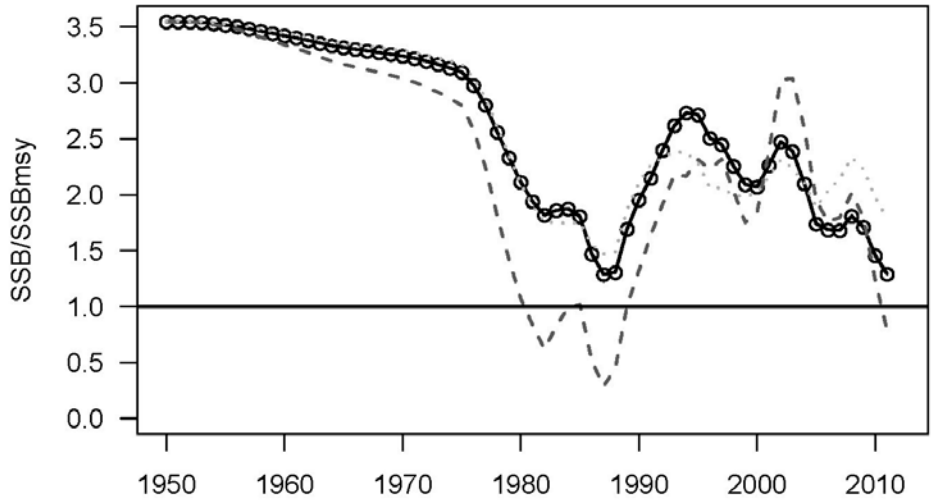
BAM Base Run



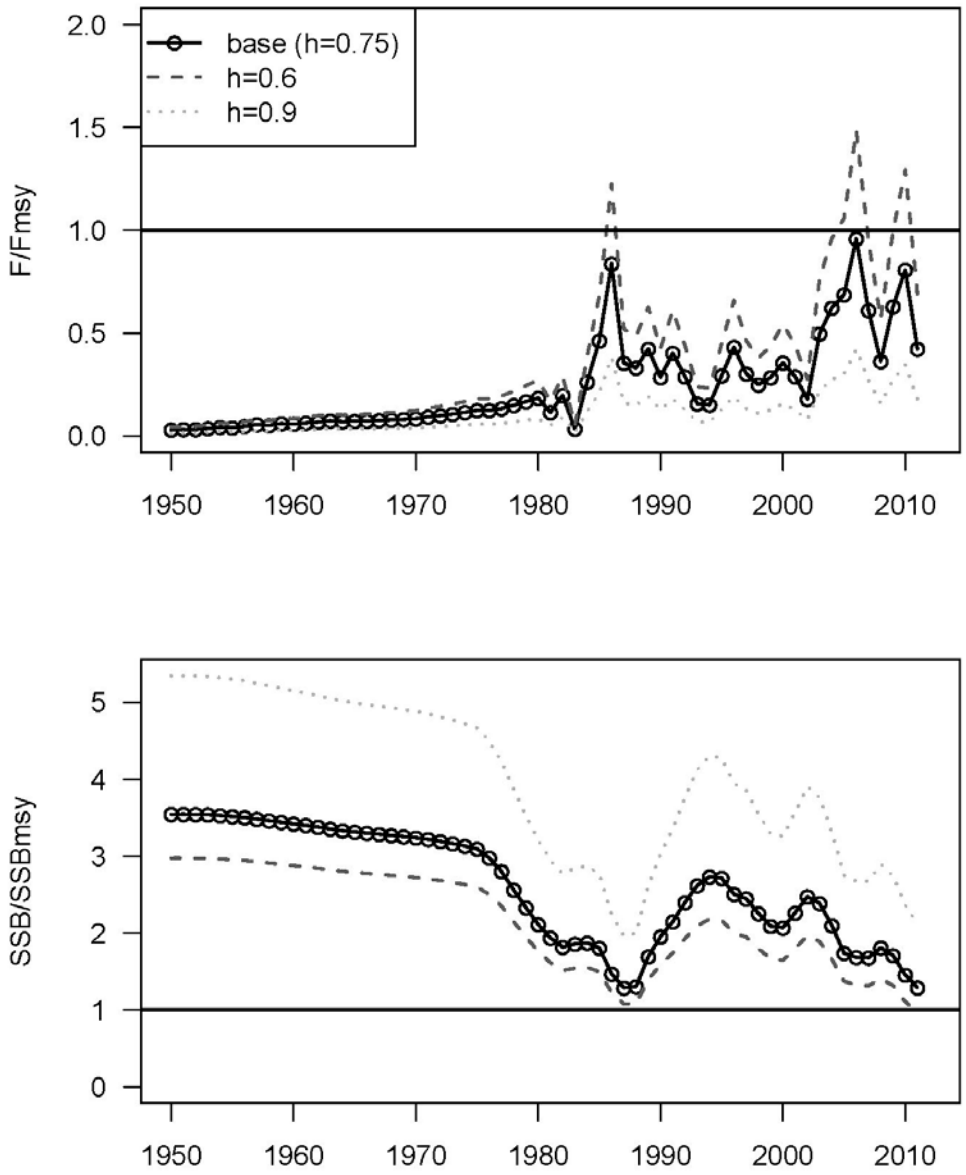


Model Diagnostics: Sensitivities

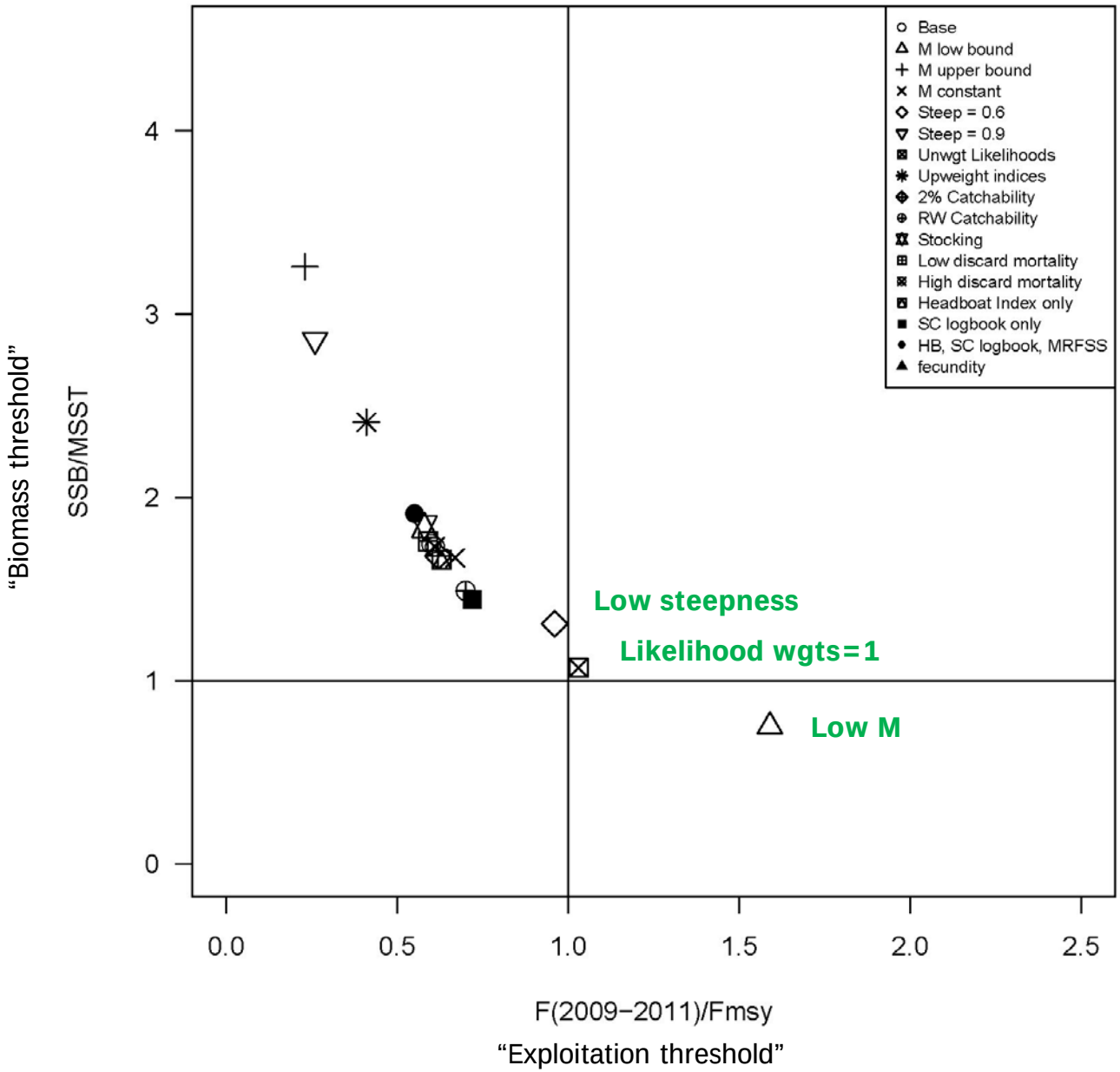




Model Diagnostics: Sensitivities



Model Diagnostics: Sensitivity Phase Plot



Model Diagnostics: Uncertainty Analysis

Monte-Carlo Bootstrap (MCB)

Bootstrap Component:

- Landings and Indices (Lognormal likelihood components): a parametric bootstrap to original data, with CVs as applied in the fitting procedure
- Length and Age Compositions (Multinomial likelihood components): resample Nfish and assign them to bins with probabilities equal to those from original data

Monte-Carlo Component:

- Natural Mortality (M)
- Steepness
- Multiplier on ‘historical’ recreational landings

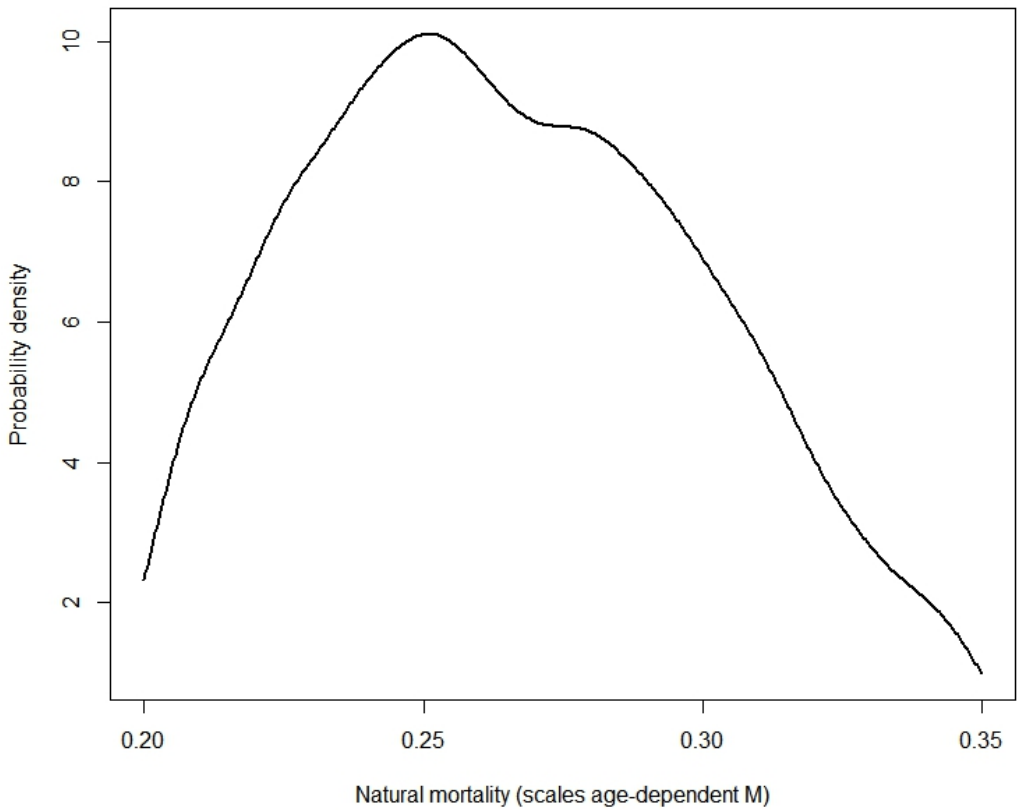
MCB trials:

- n=3200 MCB trials attempted; n=3196 retained

Model Diagnostics: MCB Analysis

Natural Mortality (M):

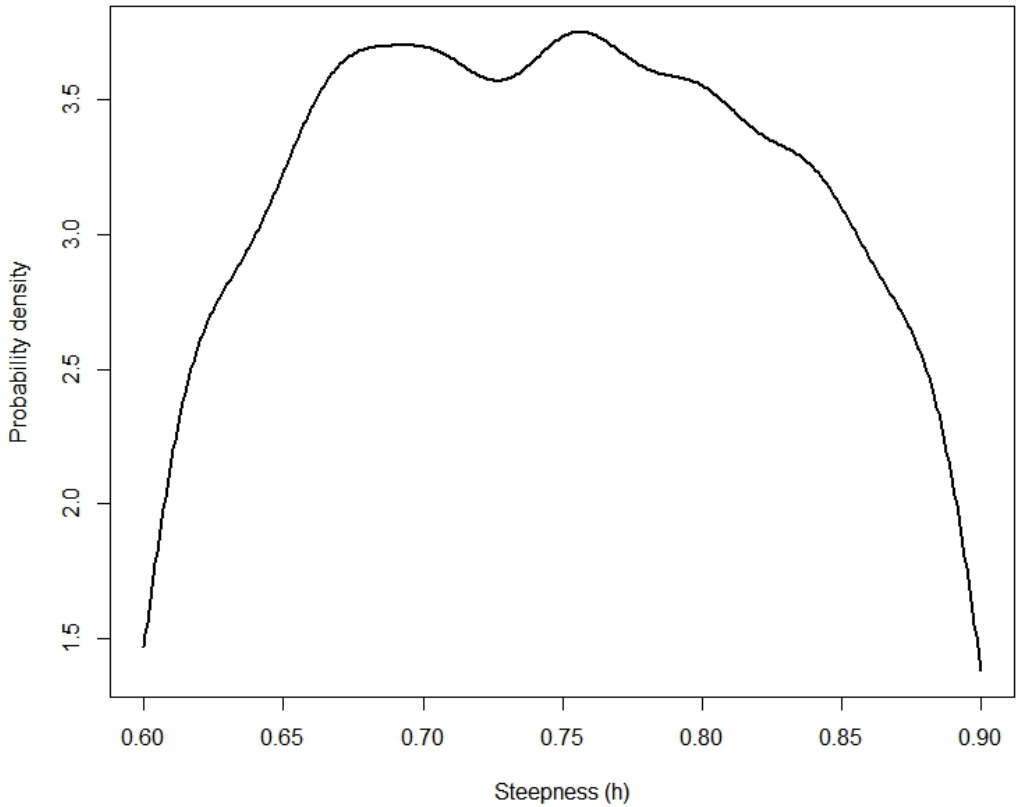
- truncated normal
- mean = 0.26
- lower bound=0.20
- upper bound=0.35;
- st dev derived from the upper bound



Model Diagnostics: MCB Analysis

Steepness

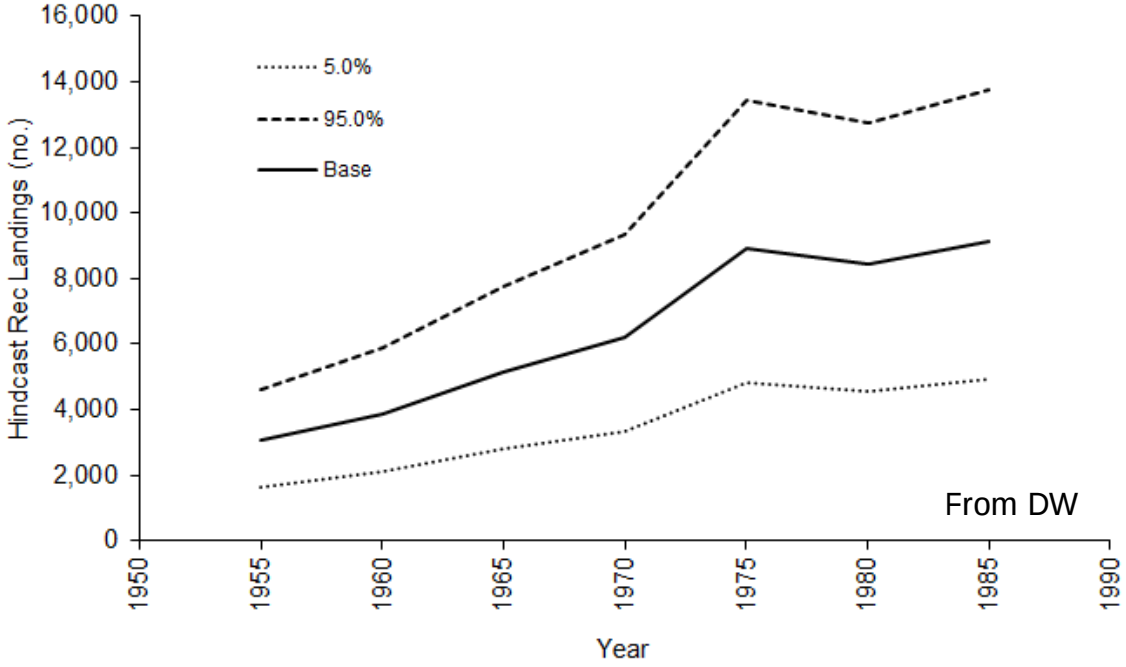
- truncated normal
- mean = 0.75
- lower bound=0.60
- upper bound=0.90
- st dev = 0.19 from meta-analysis

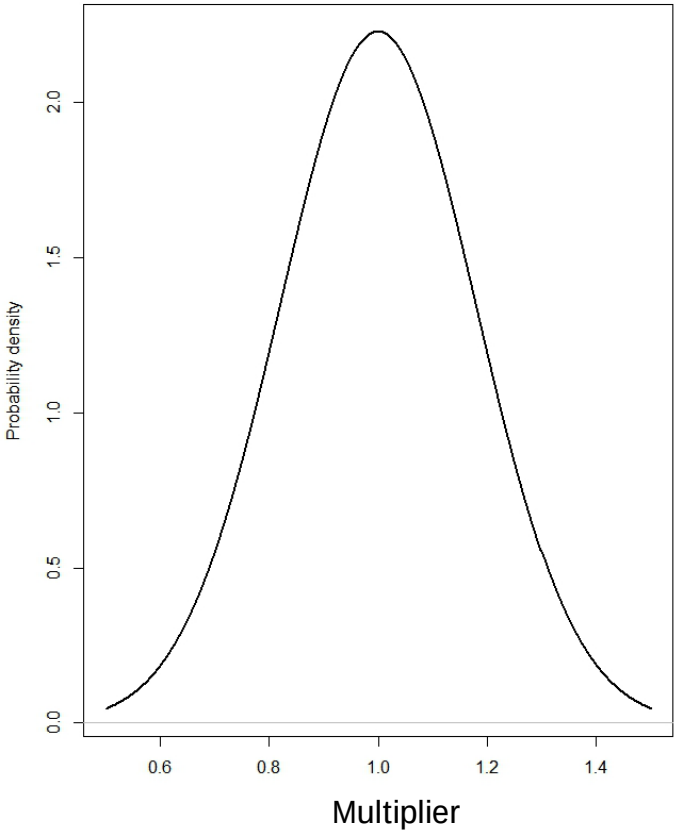


Model Diagnostics: MCB Analysis

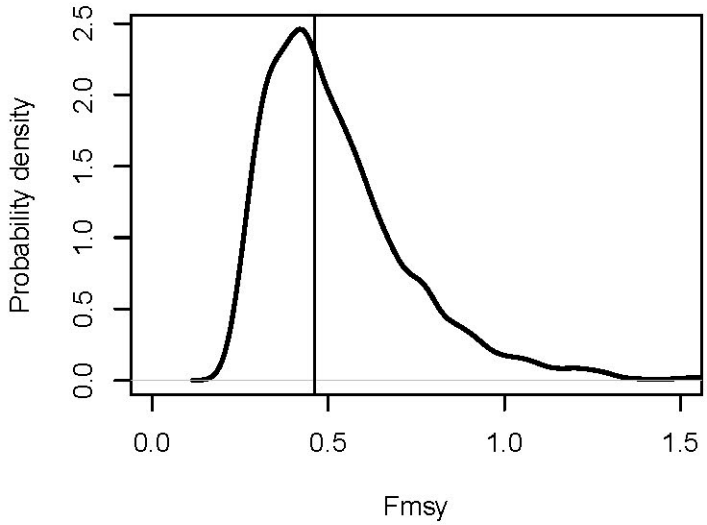
Multiplier on Historical (1950-1981) Recreational Landings

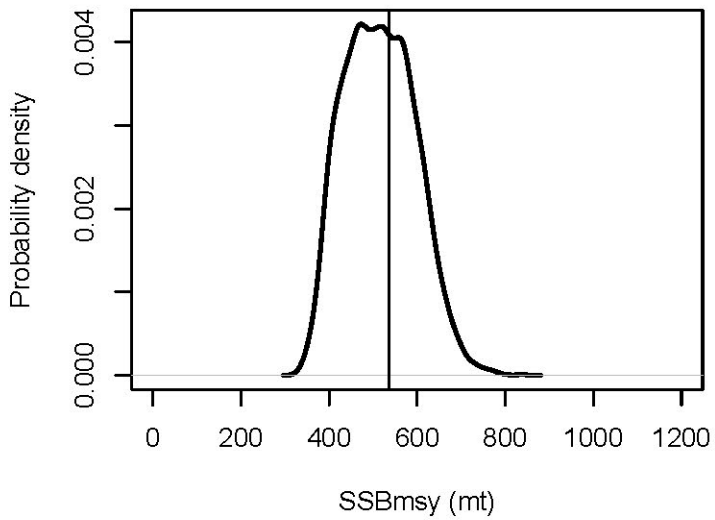
- truncated normal with mean=1.0
- upper bound=1.46, lower bound= 0.54
- st dev =0.24 (derived from 95% CIs supplied by DW)

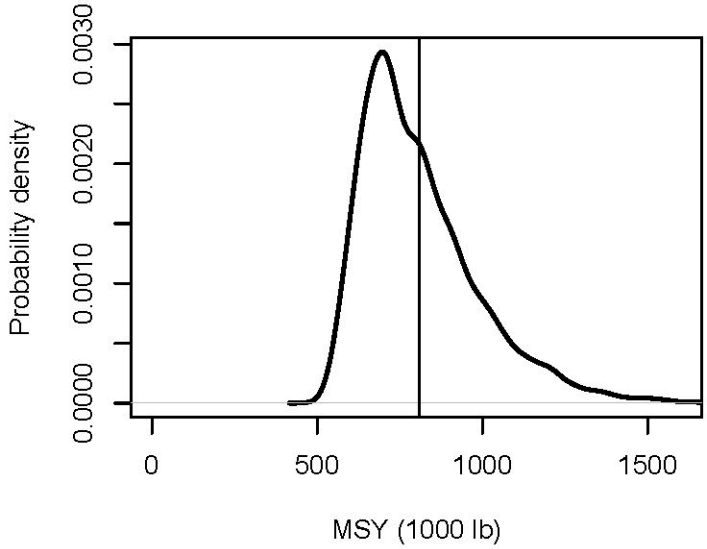




Model Diagnostics: MCB Results

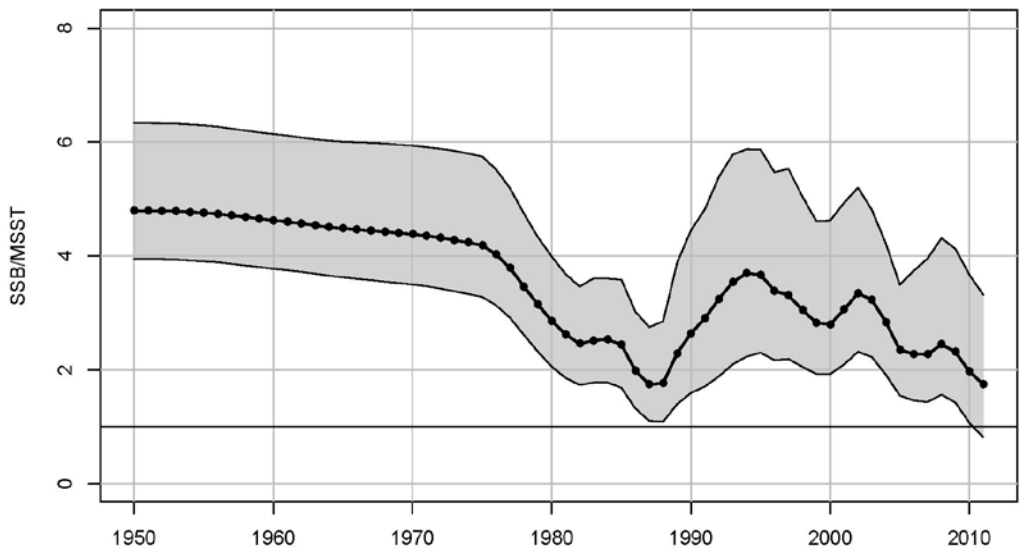


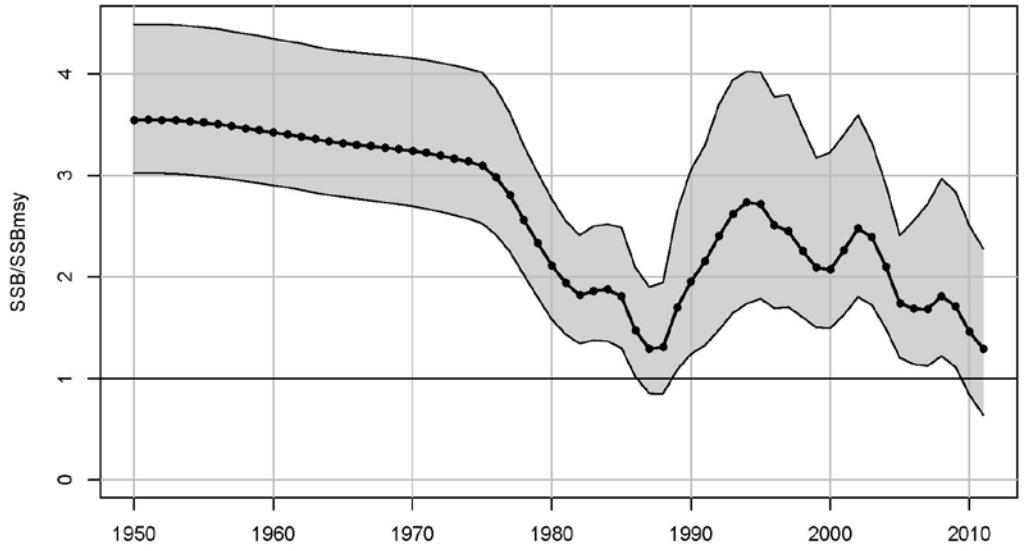




Model Diagnostics: MCB Results

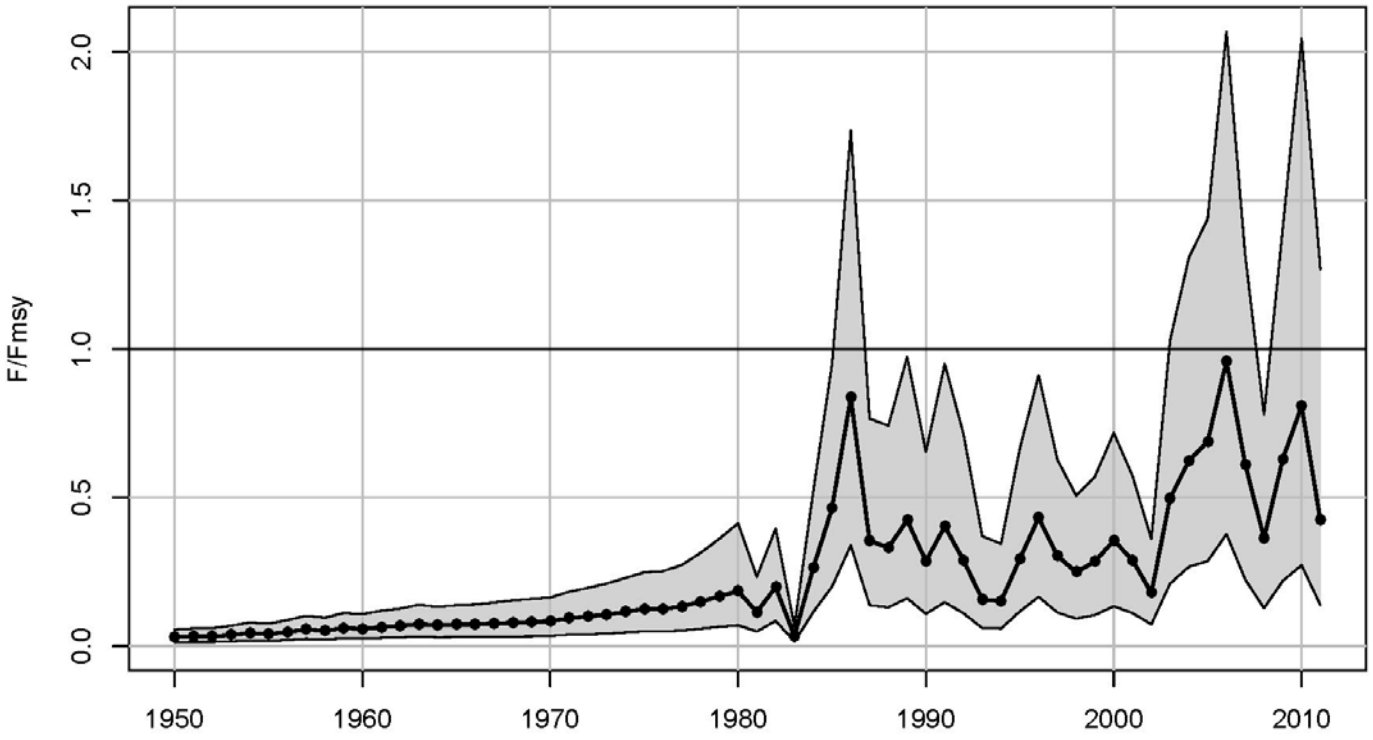
Biomass Status



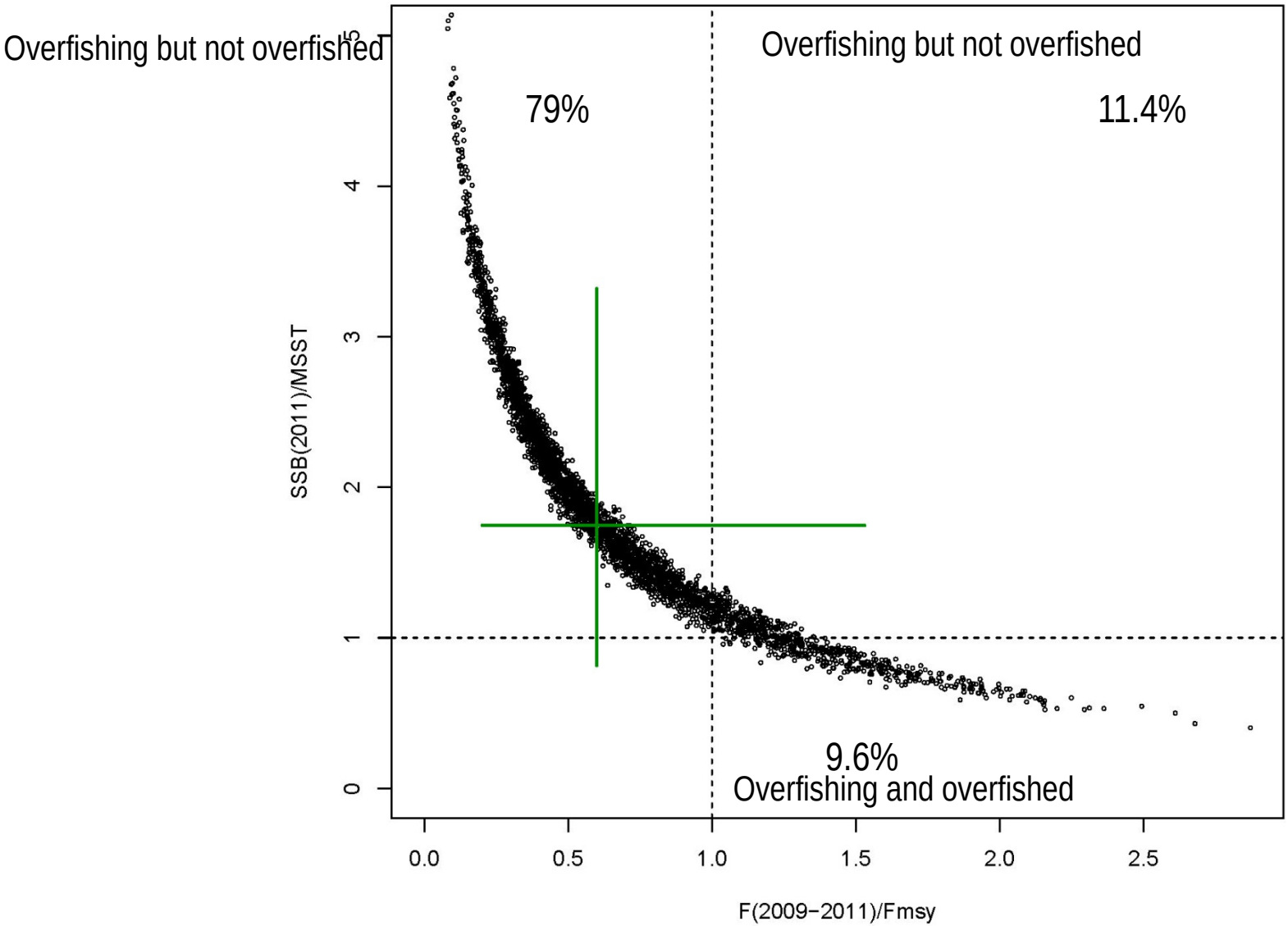


Model Diagnostics: MCB Results

Exploitation Status



Model Diagnostics: MCB Results



Projections

Age-based projection model

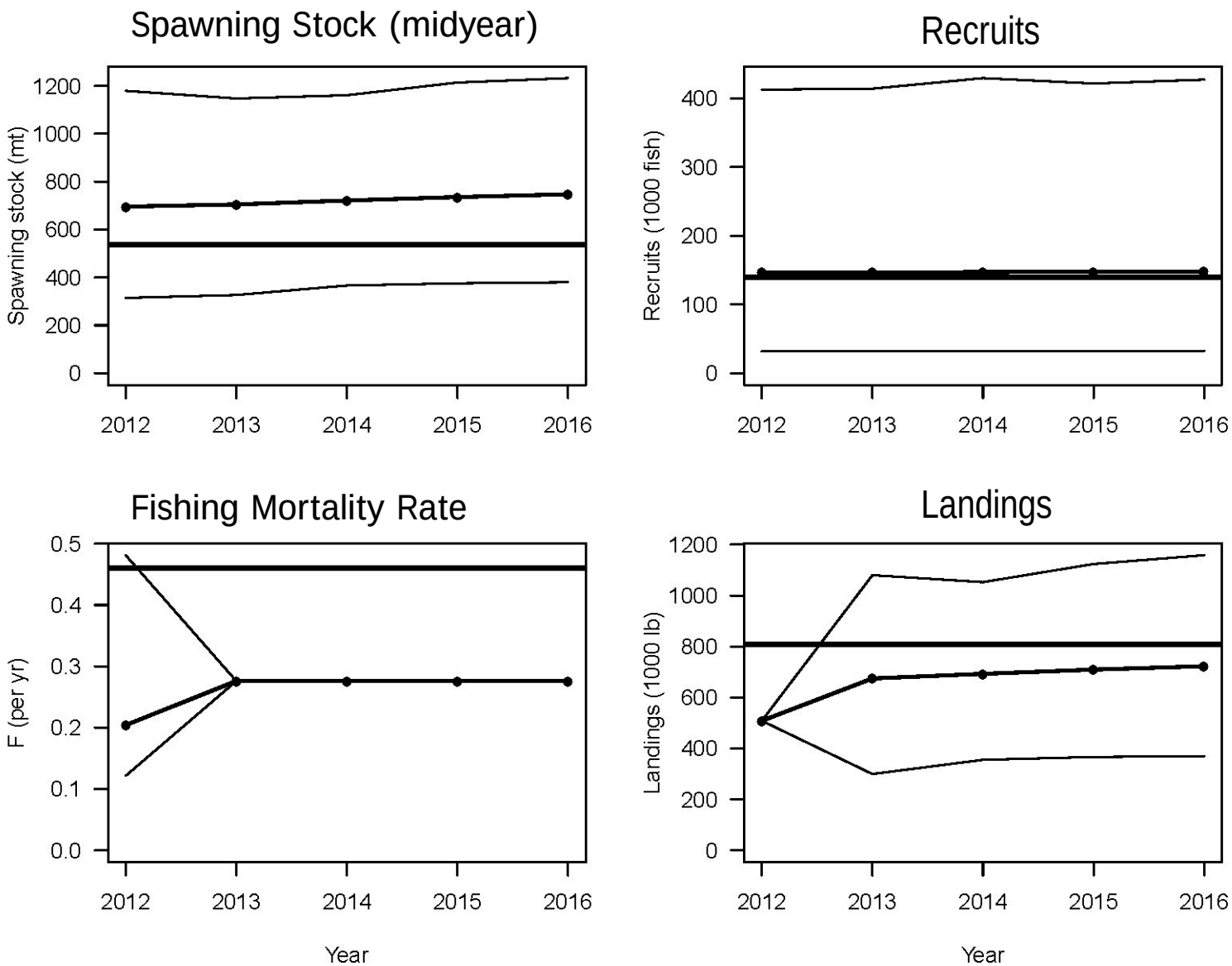
- 5 year projection (2012-2016)
- Same structure as assessment model
- Initialization:
  - Initial (2012) numbers at age (2-12^{+}) based on 2011 estimates discounted by Z
  - Initial recruits (age-1 in 2012) computed from S-R model and 2011 spawning biomass
  - Terminal two years of recruitment did not deviate from S-R curve
  - Lognormal stochasticity added to age-1 and age-2 abundance in 2011
  - During initialization period (2012) fully selected F taken as geo. mean F 2009-2011
- New management assumed to start in 2013
- n= 10,000 projected time series
- Each time series based on a single MCB run chosen at random (includes uncertainty and in data and parameters estimates)

Projection Scenarios

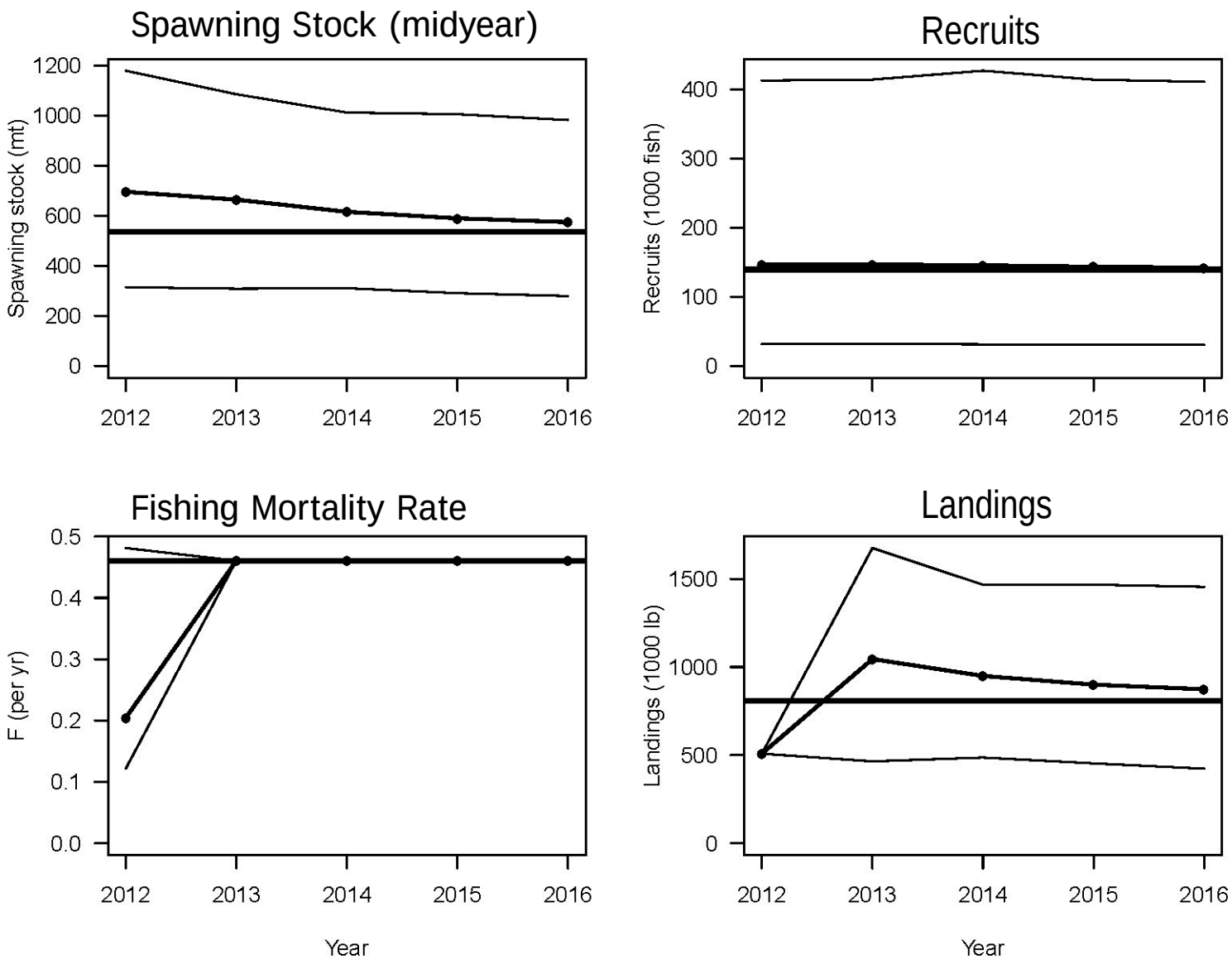
Five Constant F Projection Scenarios:

1. $F=F_{msy}$
2. $F=F_{current}$ (geometric mean F from 2009-2011)
3. $F=65\%\ F_{msy}$
4. $F=75\%\ F_{msy}$
5. $F=85\%\ F_{msy}$

Projection Scenario $F=F_{current}$



Projection Scenario $F=F_{msy}$



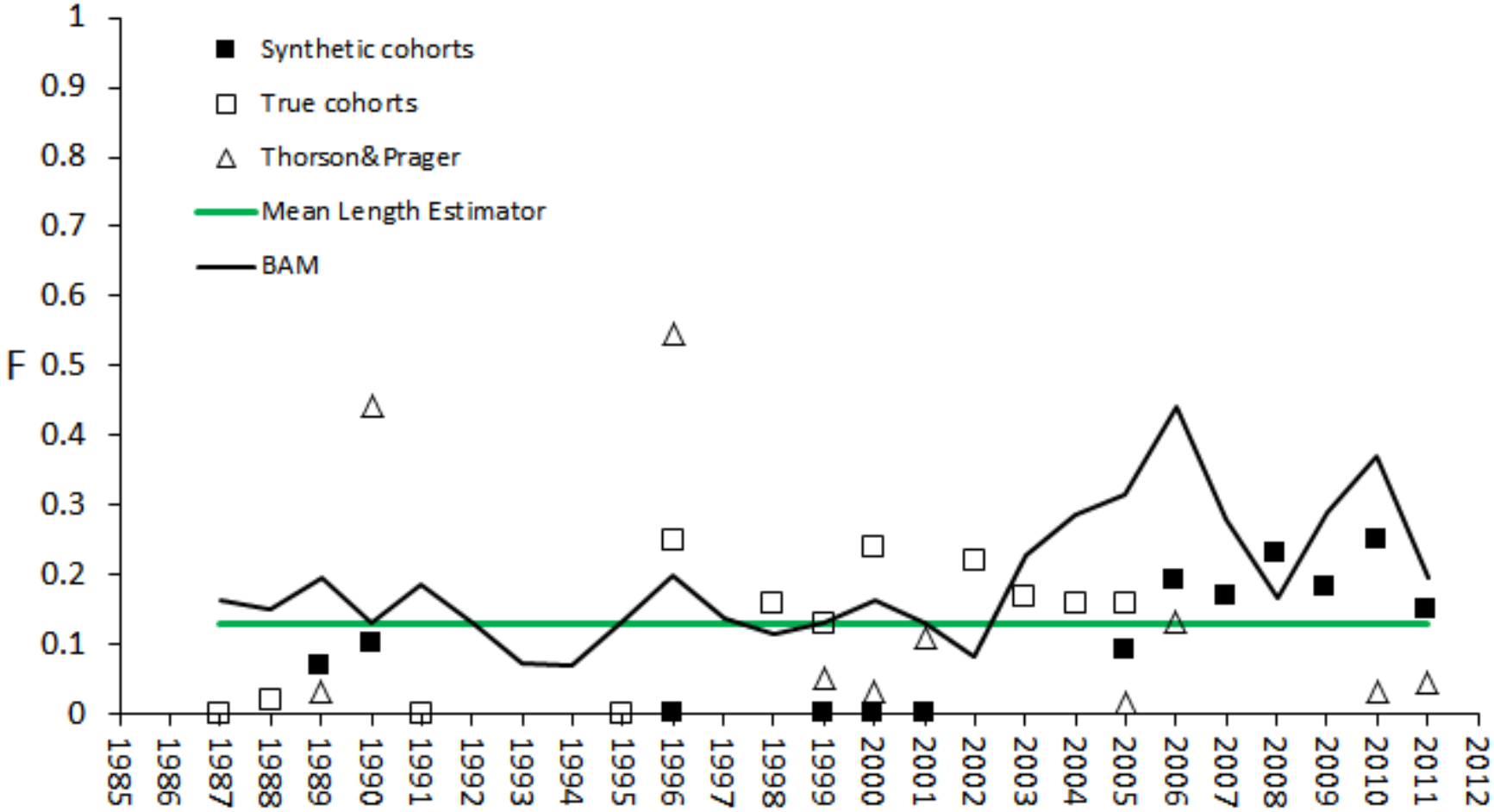
Alternative Methods

Total Mortality Estimation

- Traditional catch curve analysis
- Thorson and Prager (2011) catch curves
- Mean length estimator (Gedamke and Hoenig 2006)

Total Mortality Estimation

(F computed as Z-M) where M=0.26



Surplus Production Model

Age-aggregated Surplus production model

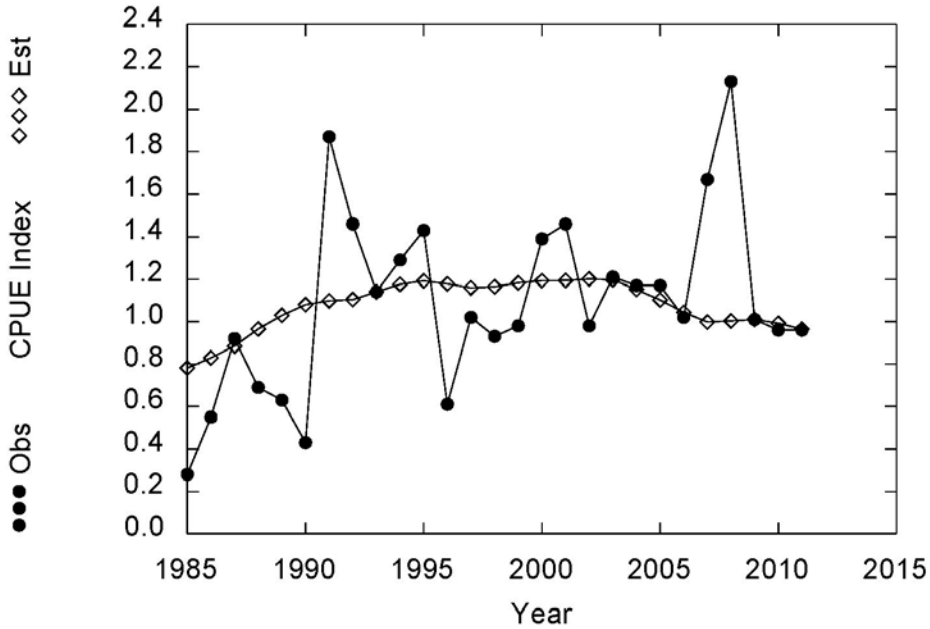
- Graham-Schaefer logistic (nonequilibrium) formulation
- Conditioned on yield (landings and discards)
- Fit to headboat and SC logbook indices
- Implementing in ASPIC (Prager 1994)

Lack of contrast in data led to:

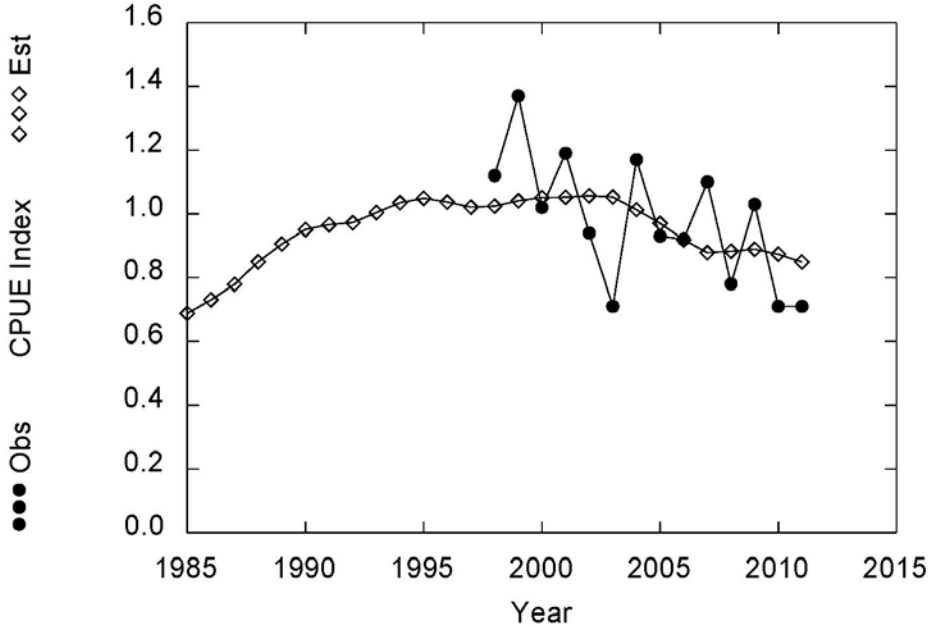
- convergence problems
- unrealistic estimates of B_1/K
- AW panel recommended not pursuing further for this assessment
- could fit with much later start date (1985)

Surplus Production Model

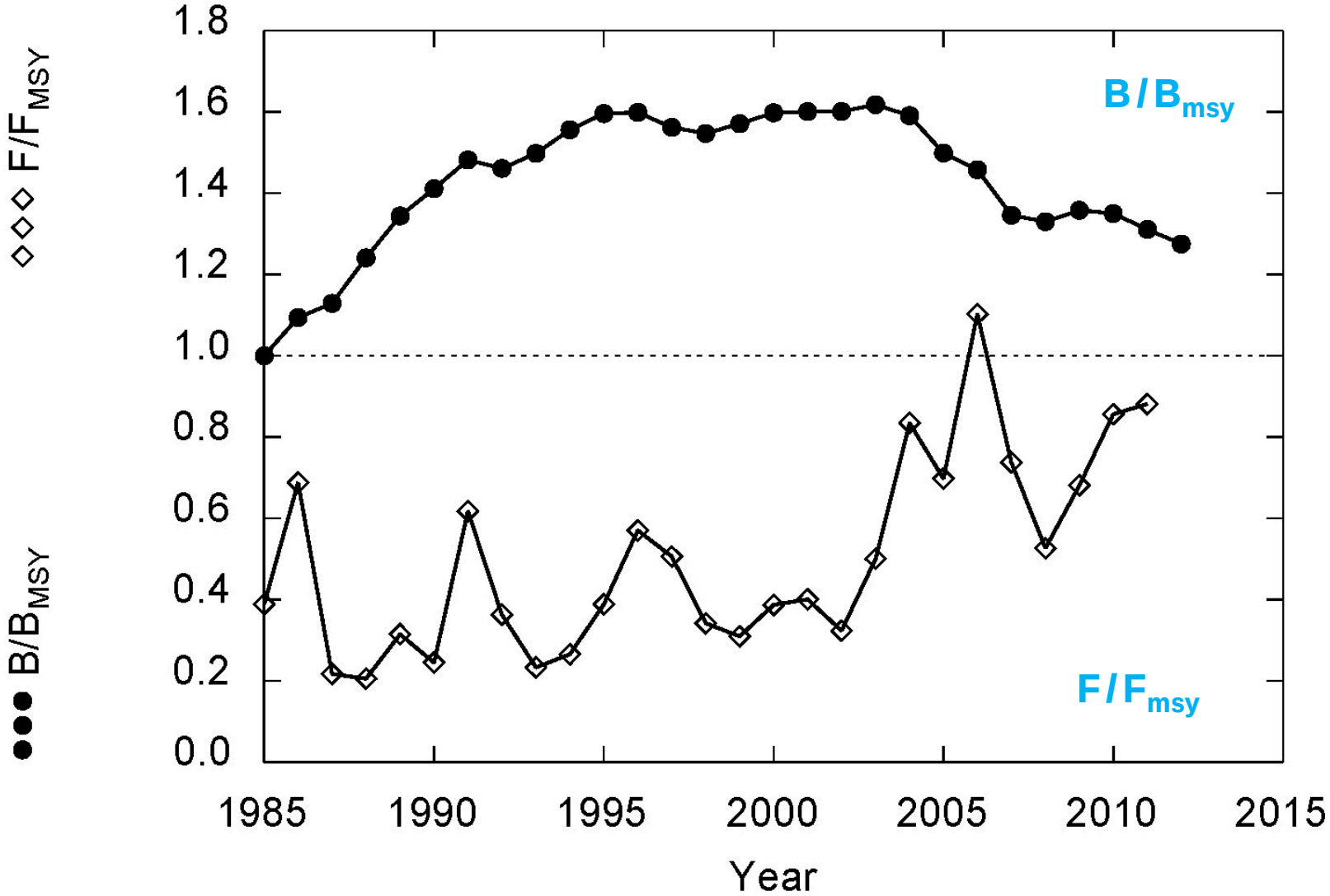
Headboat Index



SC logbook Index



Surplus Production Model



THE END