SEDAR 41 Benchmark Assessment:

Gray Triggerfish

(*Balistes capriscus*)

NOAA FISHERIES

Southeast Fisheries Science Center

Review Workshop

March 14 2016

Outline

NOAA FISHERIES
Southeast Fisheries Science Center

I. Stock definition and life history characteristics

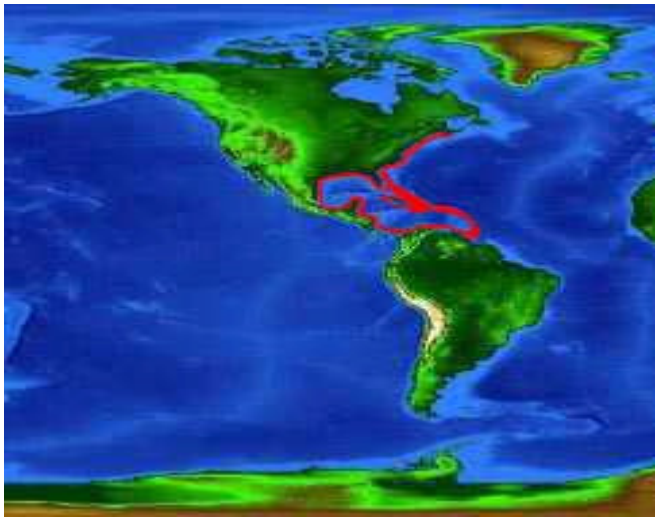
II. Data Sources
- Landings and discards
- Age and length compositions
- Indices of abundance

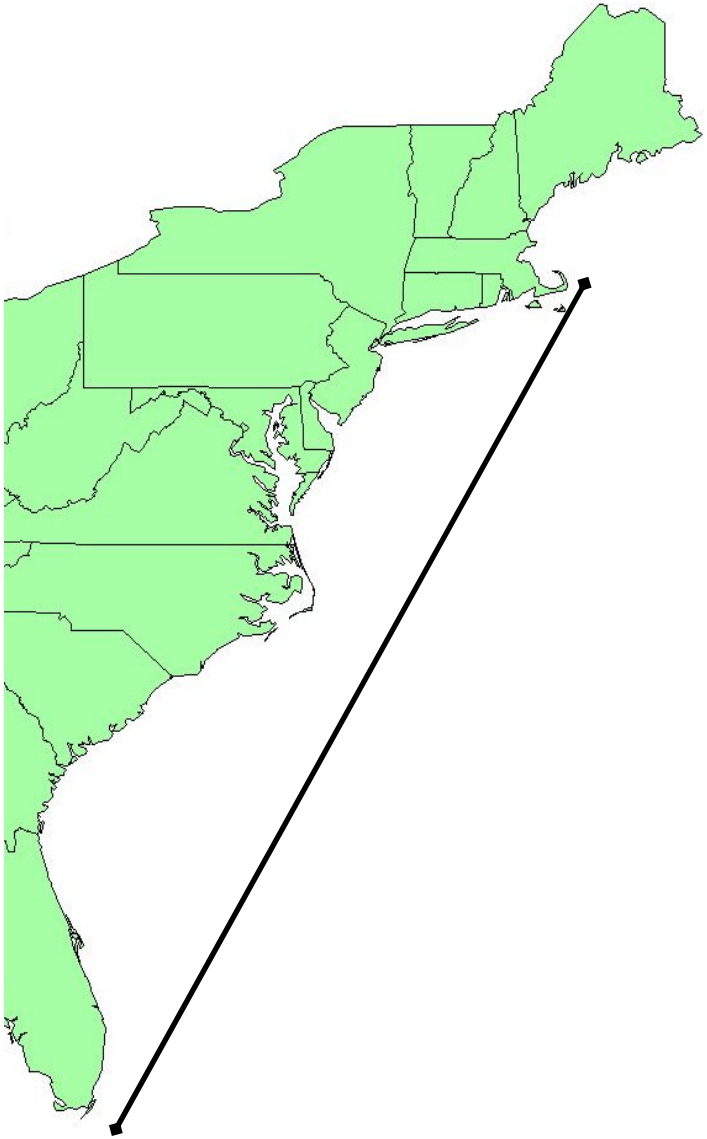
III. Catch curve analysis

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

V. Supplementary model
- Age-aggregated surplus production model

Gray Triggerfish Geographic Distribution

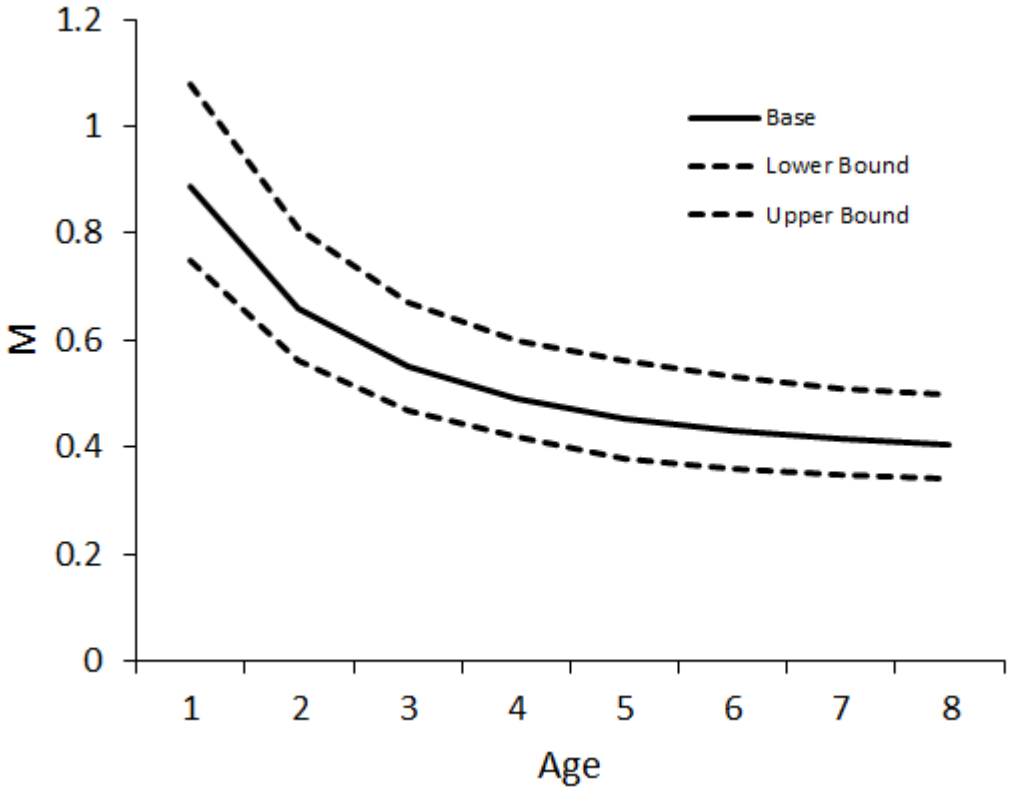




- Distributed along US East Coast, the Gulf of Mexico, and Carribbean
- Associated with snapper-grouper complex (50-300 ft)
- Genetically homogenous throughout US region (Gulf and South Atlantic)
- Most landings from NC to Florida, but landed as far north as Massachusetts
- Stock boundaries from Florida Keys as far north as landings reported (Massachusetts)

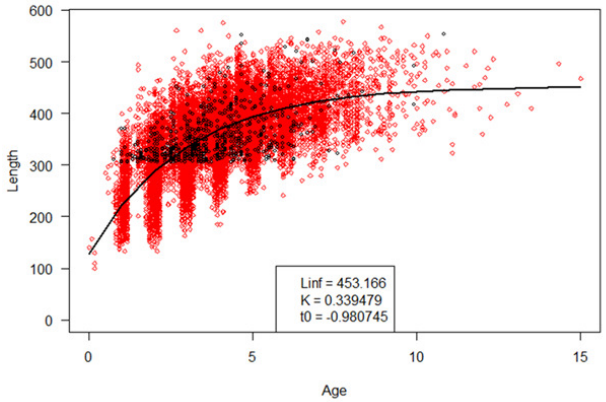
Natural Mortality

- Age-dependent M (constant in time)
- Based on L_{age}, L_{∞}, and k (Charnov et al. 2012)
- Scaled to point estimate M=0.41 (tmax = 15 yrs; Then et al. 2014)
- Bootstrap on tmax (using ageing error matrix) and Then et al. (2014) dataset to get upper and lower bounds

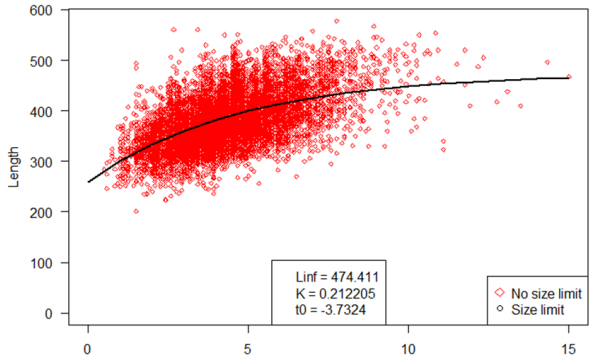


Von Bertalannffy Growth

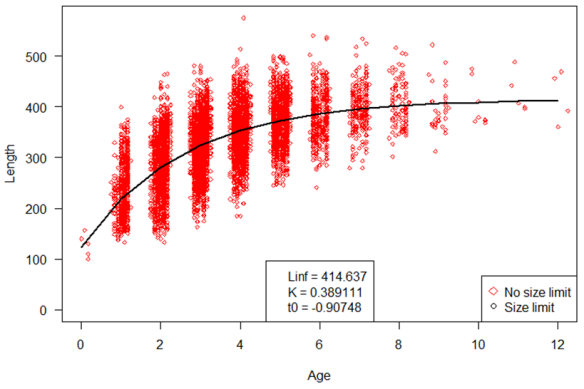
Population Growth Curve
- Fixed at externally estimated values
- Inverse weighted by sample size
- Diaz corrected (black, Florida length limit)



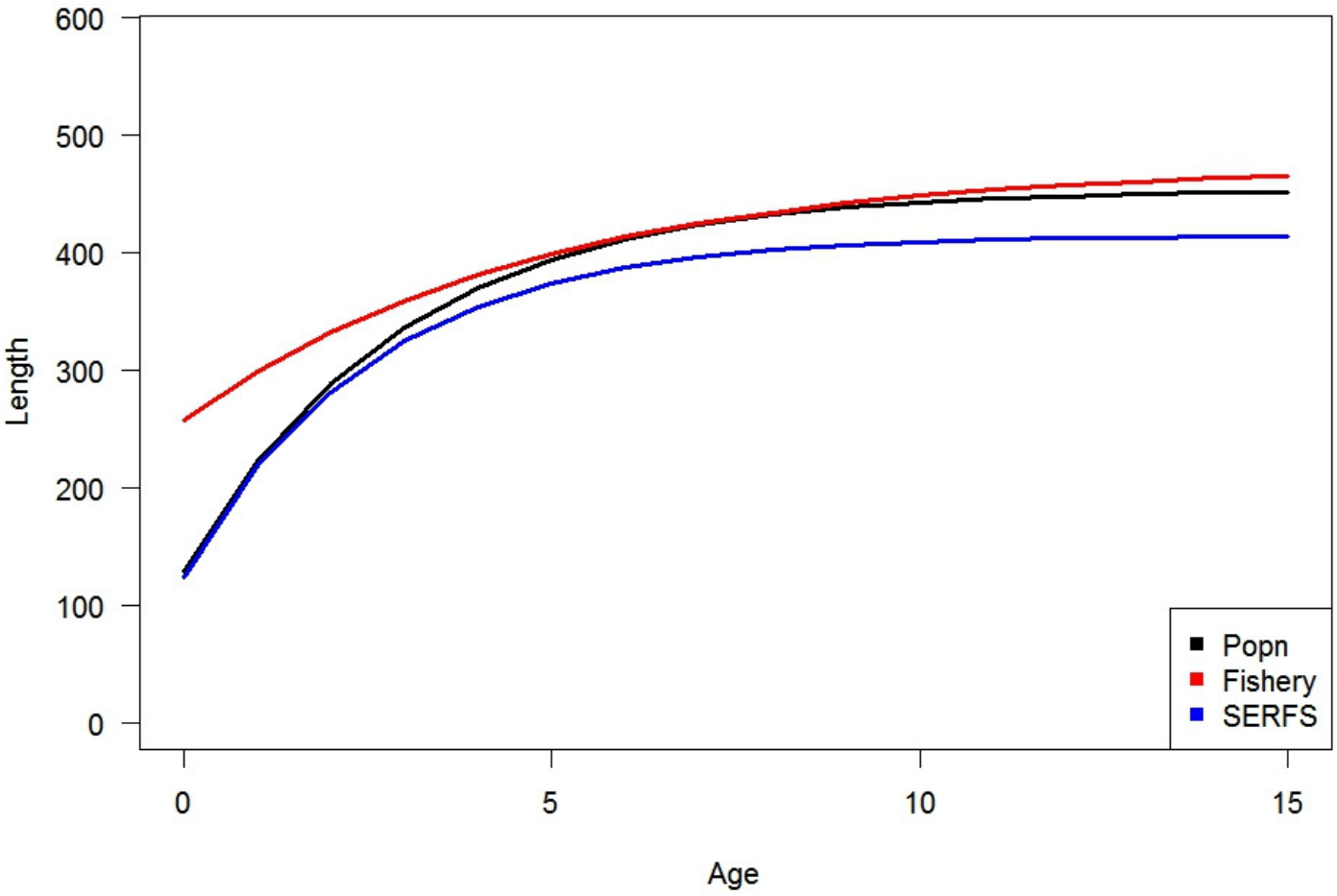
Fishery Dependent Growth Curve
- All fishery-dependent data
- Inverse weighted by sample size
- Used to compute mean length of landings
- Estimated by catch-age model from starting values



Fishery Independent Growth Curve
- All fishery-independent data
- Inverse weighted by sample size
- Used to match fishery-independent length comps
- Estimated from catch-age model from starting values



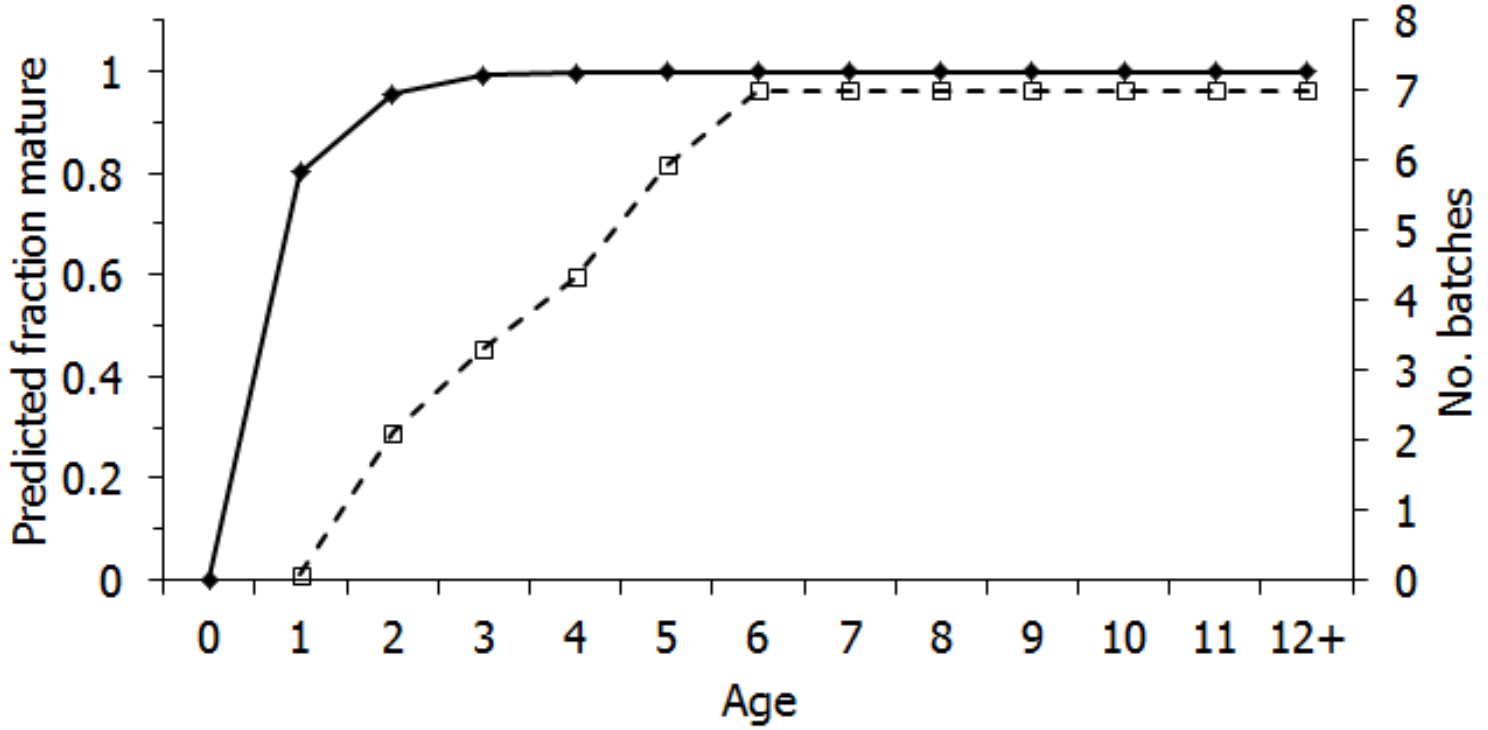
Growth Curves



	Popn	Fishery	SERFS trap
Linf	453.2	474.4	414.6
K	0.34	0.21	0.39
t_0	-0.98	-3.73	-0.91

Maturity and Reproduction

- Maturity: Logistic model for age 1-12
- Assume 50:50 sex ratio
- Age-dependent number of batches per year (due to age-dependent spawning interval)
- Size dependent batch fecundity (Lang and Fitzhugh 2015)
- Recommended measure of reproductive potential from the DW:
  Population fecundity=No. fish x %female x %mature x No. batches/ind x batch fecundity



Discard Mortality

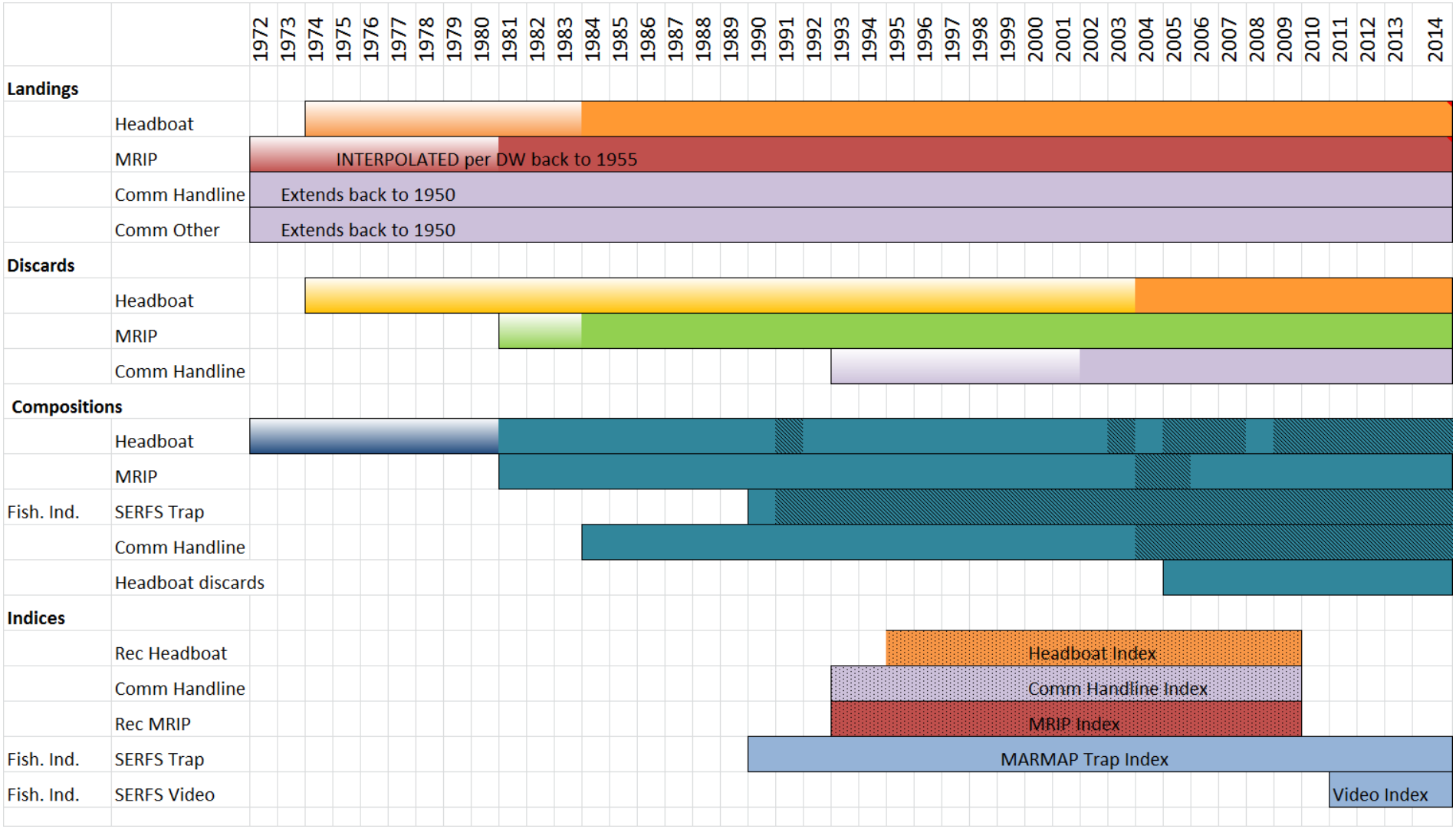
DW Recommendation:

- Discard mortality rate = 0.125
- Range for sensitivities and MCB = 0.05 – 0.20
- Constant in time

Table 2.4 Sedar 41 DW Report

Source	Discard Mortality Rate
SEDAR 32-DW14	0.12
SEDAR 32-DW11	0.12
Rudershausen et al. (201)	0.15
Collins (1994)	0.17
Patterson et al. (2002), SEDAR 9	0.0

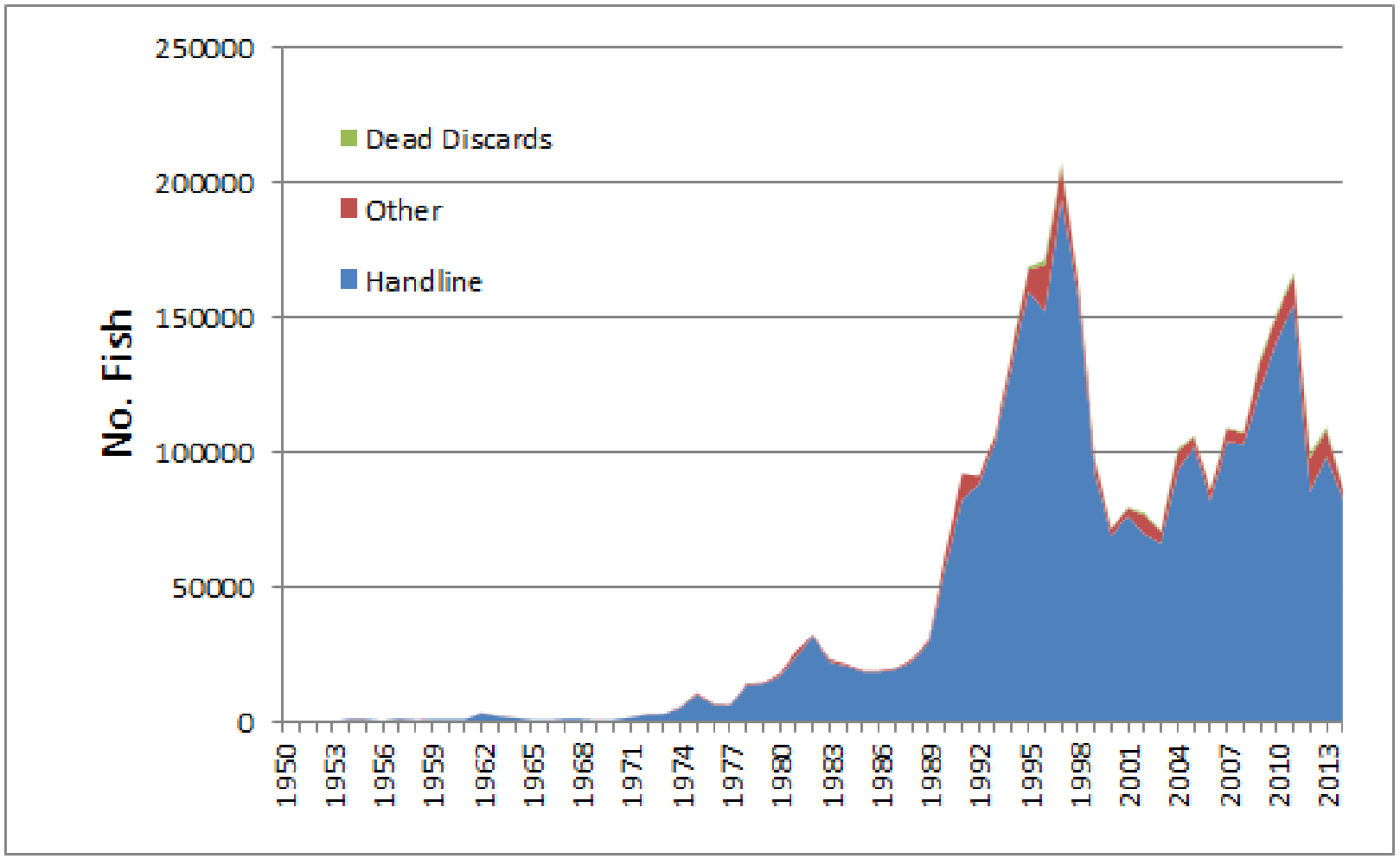
Time Series



light: limited spatial coverage, data estimated/re-constructed, low sample sizes

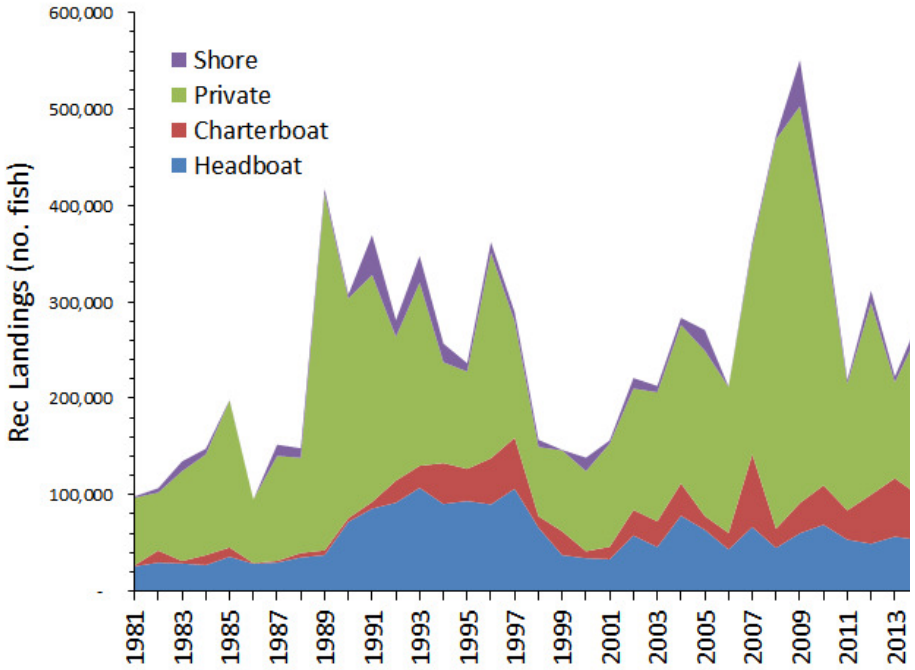
Compositions: blue length comps, dark shading age comps

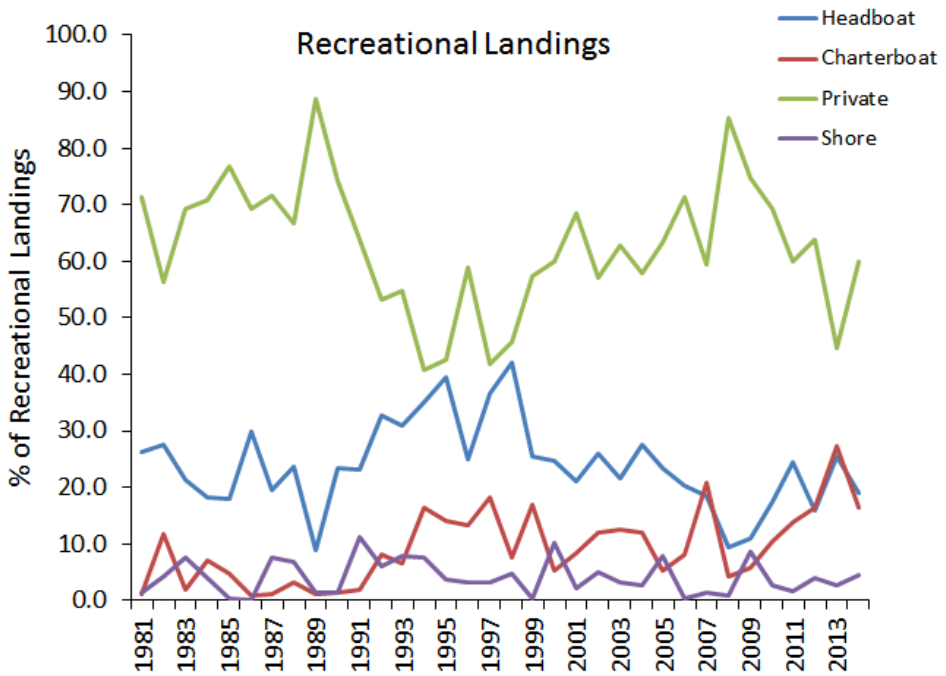
Commercial Removals



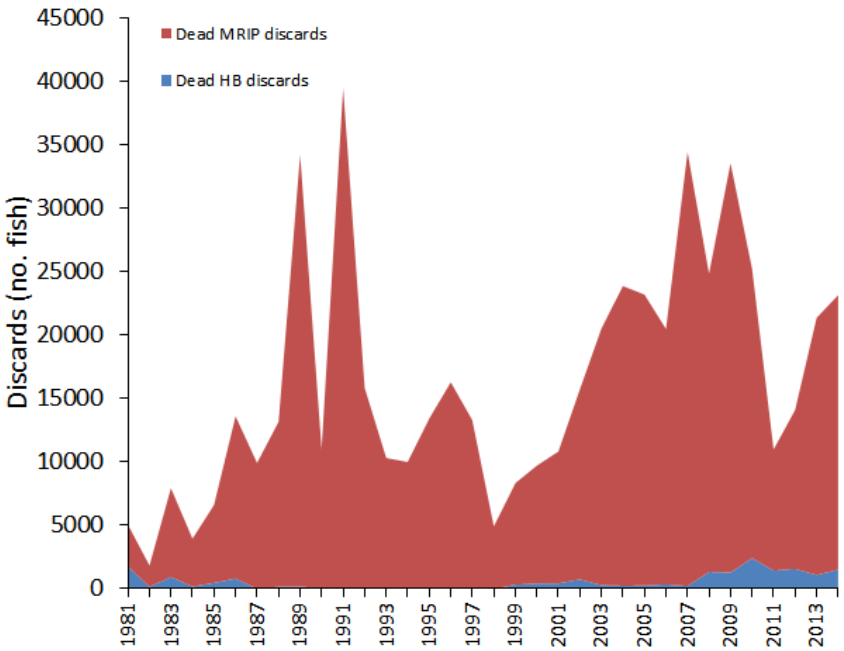
- 'Other' as % of handline landings: mean = 5.7% , range= 1.6 - 14.9%
- Dead discards as % of landings: mean = 0.73%, range= 0.31 - 1.62% landings

Recreational Landings

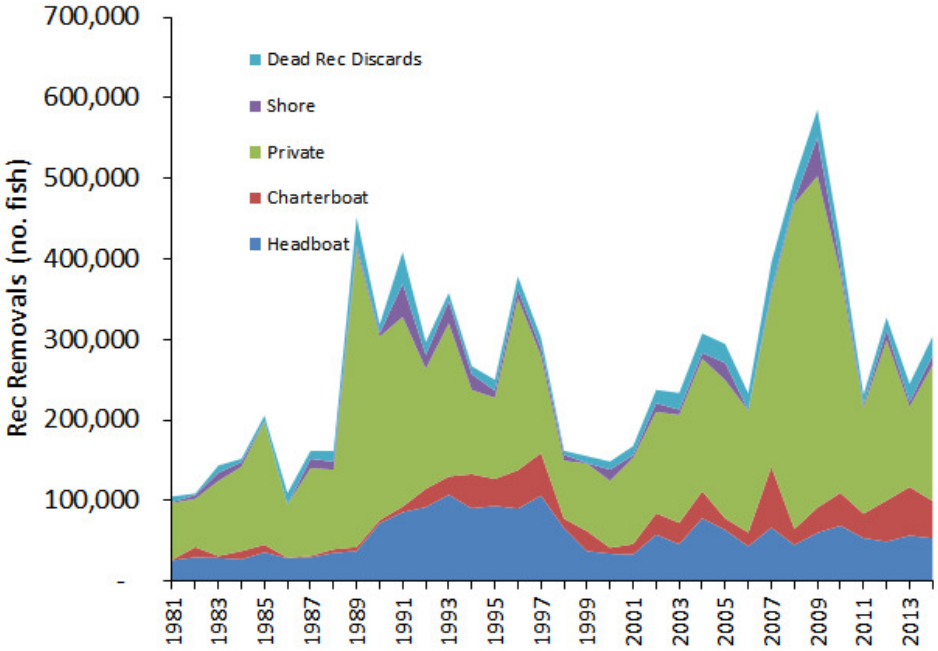




Recreational Discards

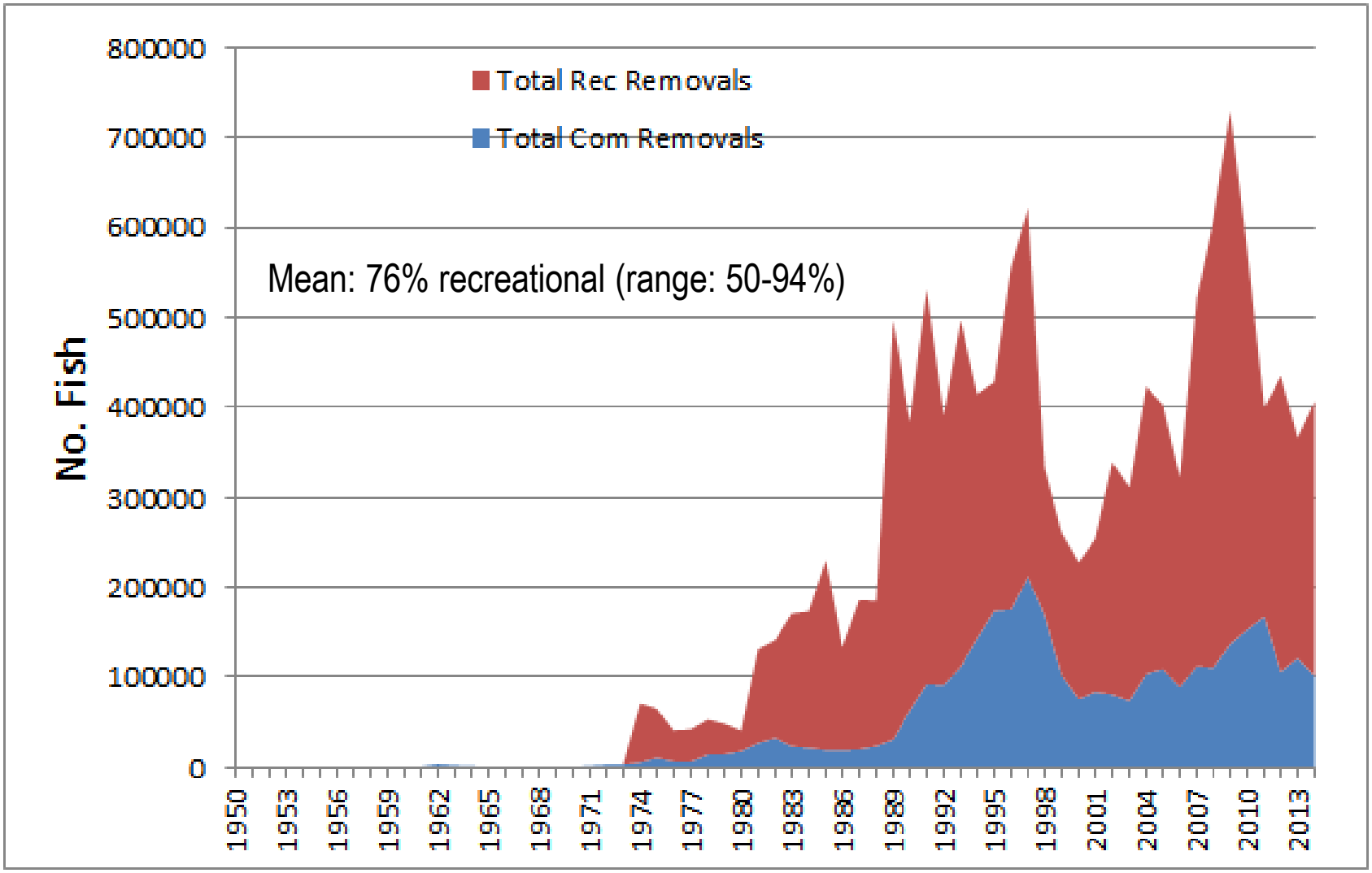


On average, 95.4% discards are from general recreational (MRIP)



On average, dead discards are 6.7% of recreational landings (range: 1.9-15.1%)

Recreational and Commercial Removals



Regulations

Fleet	Year	Region
12 in TL	1995	Fl. state and federal waters; comm, rec
Agg. bag lt.	1999	S. Atlantic; rec only
12 in FL	2006	Fl. State and federal waters; comm, rec

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- Regulations limited to particular regions or sectors of the fishery
- Appear mostly to be driven by market conditions
- Do not appear to have strong effects on composition data

Length Composition Sample Sizes

LENGTH COMPOSITIONS														
	MRIP Charterboat		MRIP Private		MRIP Total		Headboat		Headboat Discards		Com Handline		Chevron Trap	
Year	n.fish	n.trips	n.fish	n.trips	n.fish	n.trips	n.fish	n.trips	n.fish	n.trips	n.fish	n.trips	n.fish	n.trips
1981			8	6	8	6	476	232						
1982			14	5	14	5	550	241						
1983	1	1	12	5	13	6	975	417						
1984	2	2	12	6	14	8	851	418			282	42		
1985	1	1	22	13	23	14	963	430			650	61		
1986	4	3	31	22	35	25	719	336			209	35		
1987	3	3	31	17	34	20	552	286			409	46		
1988	8	7	23	19	31	26	431	228			212	32		
1989	22	12	63	37	85	49	696	252			339	38		
1990	17	12	45	22	62	34	793	251			650	38	78	41
1991	17	13	50	27	67	40	586	187			572	36	398	134
1992	38	24	53	29	91	53	738	241			487	34	204	88
1993	34	16	94	39	128	55	807	265			1107	77	298	118
1994	208	38	56	24	264	62	1025	239			1480	66	447	154
1995	103	33	22	18	125	51	868	247			3131	136	669	156
1996	172	25	91	35	263	60	1021	189			1789	78	1198	179
1997	87	28	53	17	140	45	1554	301			906	51	958	194
1998	50	18	21	15	71	33	954	348			1338	65	519	124
1999	124	40	64	29	188	69	707	261			1822	95	190	62
2000	33	16	27	12	60	28	416	187			2565	154	269	92
2001	100	42	50	23	150	65	489	200			2020	137	258	99
2002	162	69	104	30	266	99	579	225			1429	93	348	112
2003	182	71	52	21	234	92	961	298			2230	78	67	34
2004	271	88	111	25	382	113	1248	311			3478	148	262	96
2005	139	52	54	22	193	74	948	253	108	42	2678	136	382	108
2006	103	43	56	41	159	84	760	262	77	43	2706	220	174	75
2007	197	60	93	44	290	104	917	282	86	42	2130	285	423	123
2008	142	59	66	39	208	98	655	186	92	30	1583	269	334	72
2009	259	70	82	48	341	118	837	259	129	51	1831	242	319	90
2010	471	89	121	51	592	140	1313	325	90	49	2447	269	586	216
2011	376	46	54	30	430	76	1068	310	43	32	3162	297	595	169
2012	233	66	65	33	298	99	1233	290	49	36	1992	202	1148	341
2013	431	45	85	60	516	105	2516	394	135	43	1594	148	1270	367
2014	370	102	125	63	495	165	1660	363	212	49	406	51	1658	464
Average:	**136**	**37**	**59**	**29**	**195**	**66**	**933**	**283**	**102**	**41.7**	**1537**	**118**	**522**	**148**

- Most lengths from com cHL and HB; ~ 5X greater sampling for HB survey than for MRIP
- Headboat has the only compositions for discards

Age Composition Sample Sizes

	AGE COMPOSITIONS									
	MRIP Charterboat		MRIP Private		Headboat		Com Handline		Chevron Trap	
Year	n.fish	n.trips	n.fish	n.trips	n.fish	n.trips	n.fish	n.trips	n.fish	n.trips
1990					18	10				
1991					42	24			389	47
1992									209	70
1993									308	112
1994					1	1			465	142
1995									686	134
1996									1219	166
1997					2	2			963	164
1998									530	118
1999									202	60
2000									268	86
2001			2	1					273	78
2002	5	4							361	102
2003	5	3	1	1	37	20			74	33
2004	47	18	4	2	9	4	188	25	212	74
2005	90	35			68	19	386	47	358	99
2006	28	9			83	30	463	86	186	64
2007	10	1			69	47	681	196	352	96
2008	3	2			21	13	736	205	272	64
2009	1	1			31	30	686	180	238	79
2010	1	1			97	55	965	215	197	97
2011	1	1			61	36	1237	211	338	116
2012					123	35	756	110	450	190
2013	5	5			489	129	563	97	909	281
2014	29	9			557	187	431	69	976	304
	19	**7**	**2**	**1**	**107**	**40**	**645**	**131**	**435**	**116**

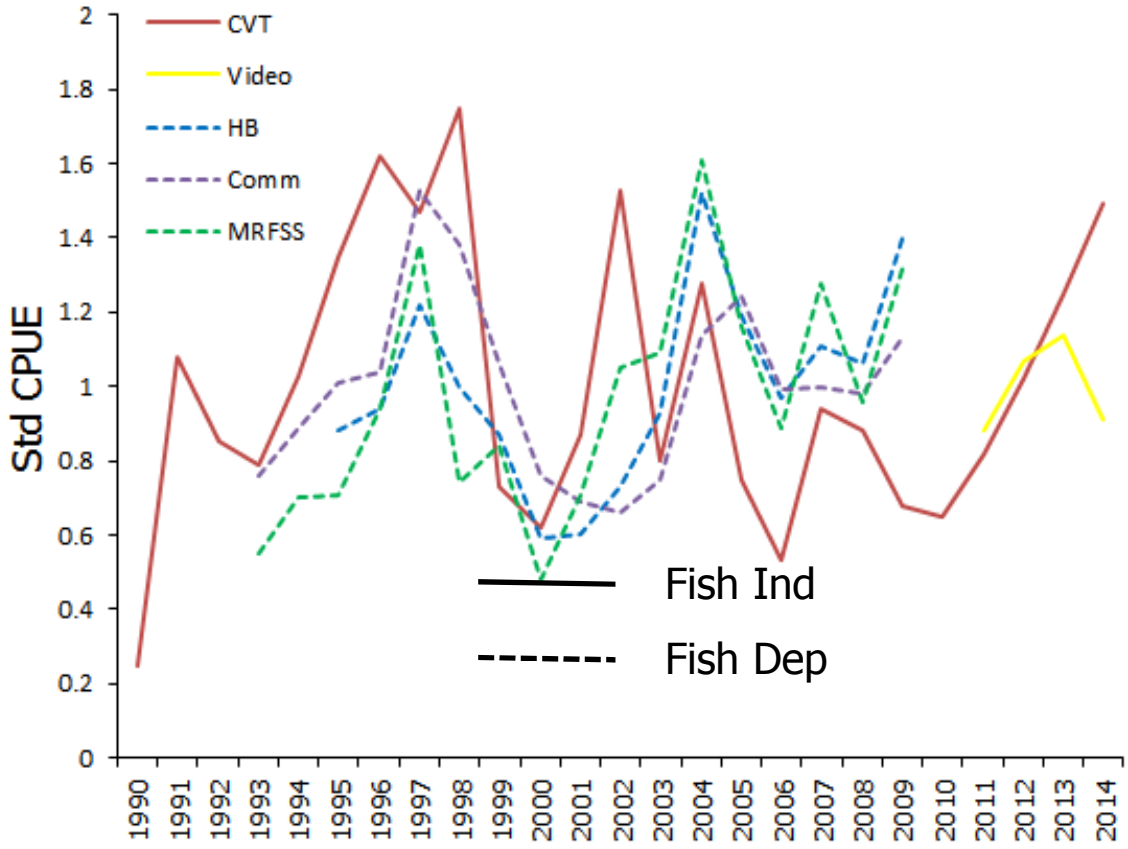
- Limited age samples from MRIP (mostly from Charterboat)
- 11 years of age comps for cHL and HB; 24 years of age comps from SERFS trap survey

Indices

From DW:
3 Fishery-dependent indices: Headboat, General Recreational (MRIP), commercial handline

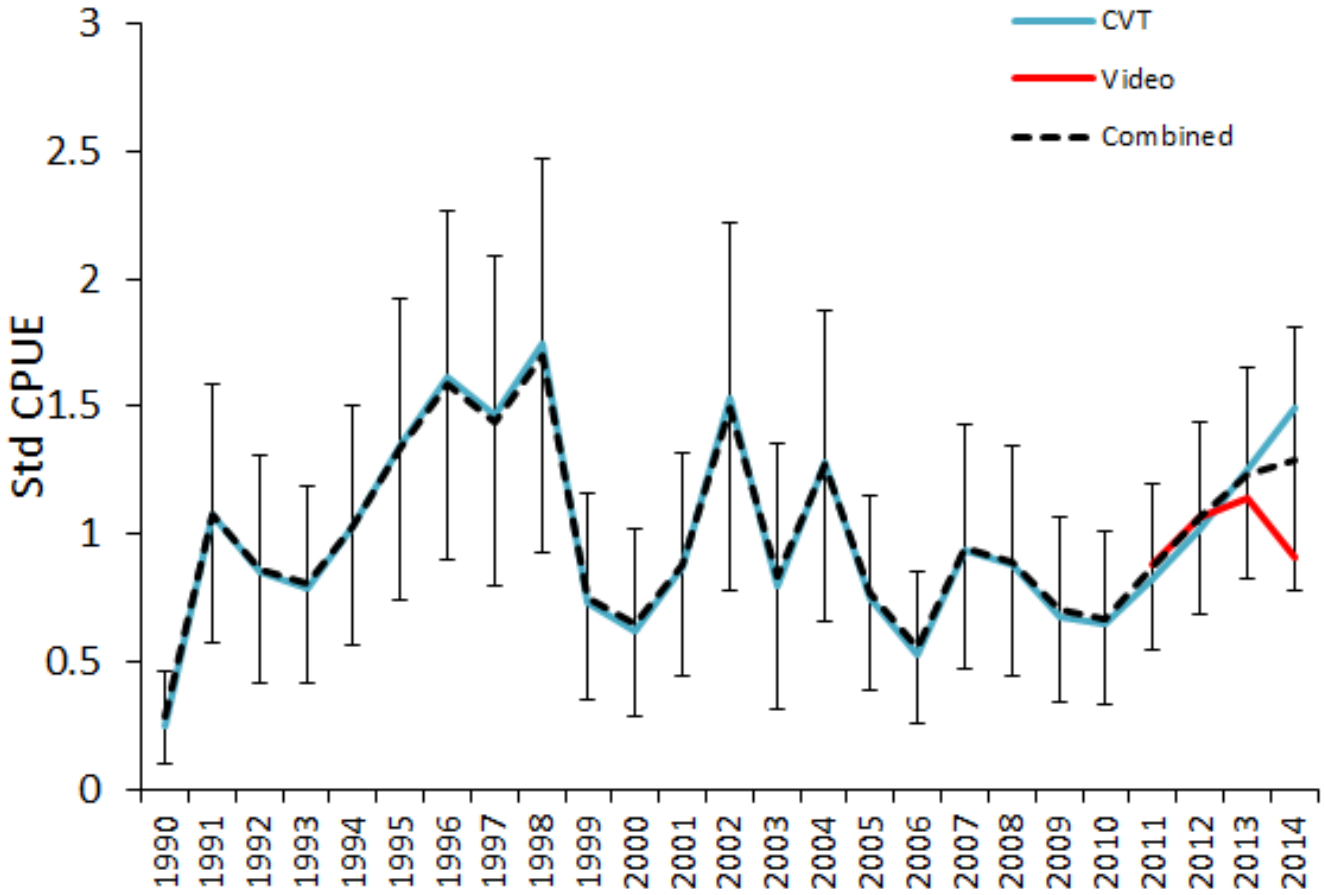
2 Fishery-independent indices: SERFS chevron trap, SERFS video survey

Pearson Correlation					
	HB	**CVT**	**Video**	**Comm**	**MRFSS**
HB	1				
CVT	0.073	1			
Video	NA	0.12	1		
Comm	0.663	0.37	NA	1	
MRFSS	0.862	0.161	NA	0.476	1



Indices

- Chevron Trap index: 1990-2014
- Video index: 2011-2014
- Trap and video observations are from the same sampling program (cameras mounted on traps)
- AW recommendation: combine using Conn (2010) method



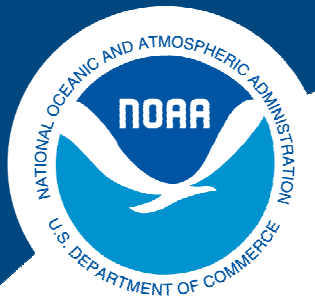
Conn (2010)

Ageing Error Matrix

- 1,383 samples and two readers
- Average Percent Error (APE) = 7.5%
- Developed using AGEMAT software (Punt 2008)

AGE	1	2	3	4	5	6	7	8
1	0.982	0.018	0.000	0.000	0.000	0.000	0.000	0.000
2	0.018	0.963	0.018	0.000	0.000	0.000	0.000	0.000
3	0.000	0.089	0.822	0.089	0.000	0.000	0.000	0.000
4	0.000	0.001	0.150	0.699	0.150	0.001	0.000	0.000
5	0.000	0.000	0.005	0.189	0.611	0.189	0.005	0.000
6	0.000	0.000	0.000	0.012	0.213	0.550	0.213	0.012
7	0.000	0.000	0.000	0.000	0.020	0.227	0.505	0.248
8	0.000	0.000	0.000	0.000	0.001	0.029	0.235	0.735

(SEDAR 41-DW47)



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Questions about the data?

ASSESSMENT – Gray Triggerfish 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
- Alternative Model
  - Age-aggregated surplus production model

Beaufort Assessment Model (BAM)

- Forward projecting statistical catch-age model

- Fit by maximum likelihood
  - Robust multinomial likelihoods for age and length composition data
  - lognormal likelihoods for landings and index data
  - Plus priors and penalty terms
  - Likelihood weights to control model fit (from iterative re-weighting, Francis 2011)
- AD Model Builder for optimization

- Baranov catch equation to predict landings
- Beverton-Holt spawner-recruit model with steepness fixed at 0.99; estimate annual recruitment deviations (1988-2014) about the mean recruitment
- Von Bertanlanffy (VB) growth curve assuming normal distn of size-at-age to model growth of the population (estimated external to the model)
- Age-length conversions (using separate VB curves) assuming normal distribution of length at age to match fishery landings and survey length comps (estimated from starting values)
- Catchability options: constant, linear change, random walk, density dependence
- Selectivity options: flat-topped (logistic); dome-shaped (double logistic, logistic exponential, double gaussian)
- F30% benchmarks from the expected spawner-recruit curve

Initial Decisions (Assessment workshop)

1. Start date
2. Plus group
3. Fleet structure
4. Selectivity

Model Start Year

Recommendation: 1988 as a start year

"…gray triggerfish became more desirable as a food fish in the late 1970s and early 1980s throughout the South Atlantic." (SEDAR 41 DW report).

Gray triggerfish are associated with the snapper-grouper complex so that early (e.g., pre-1980s) discards could be substantial.

Data to characterize discards is limited prior to early 2000s and no data prior to 1981

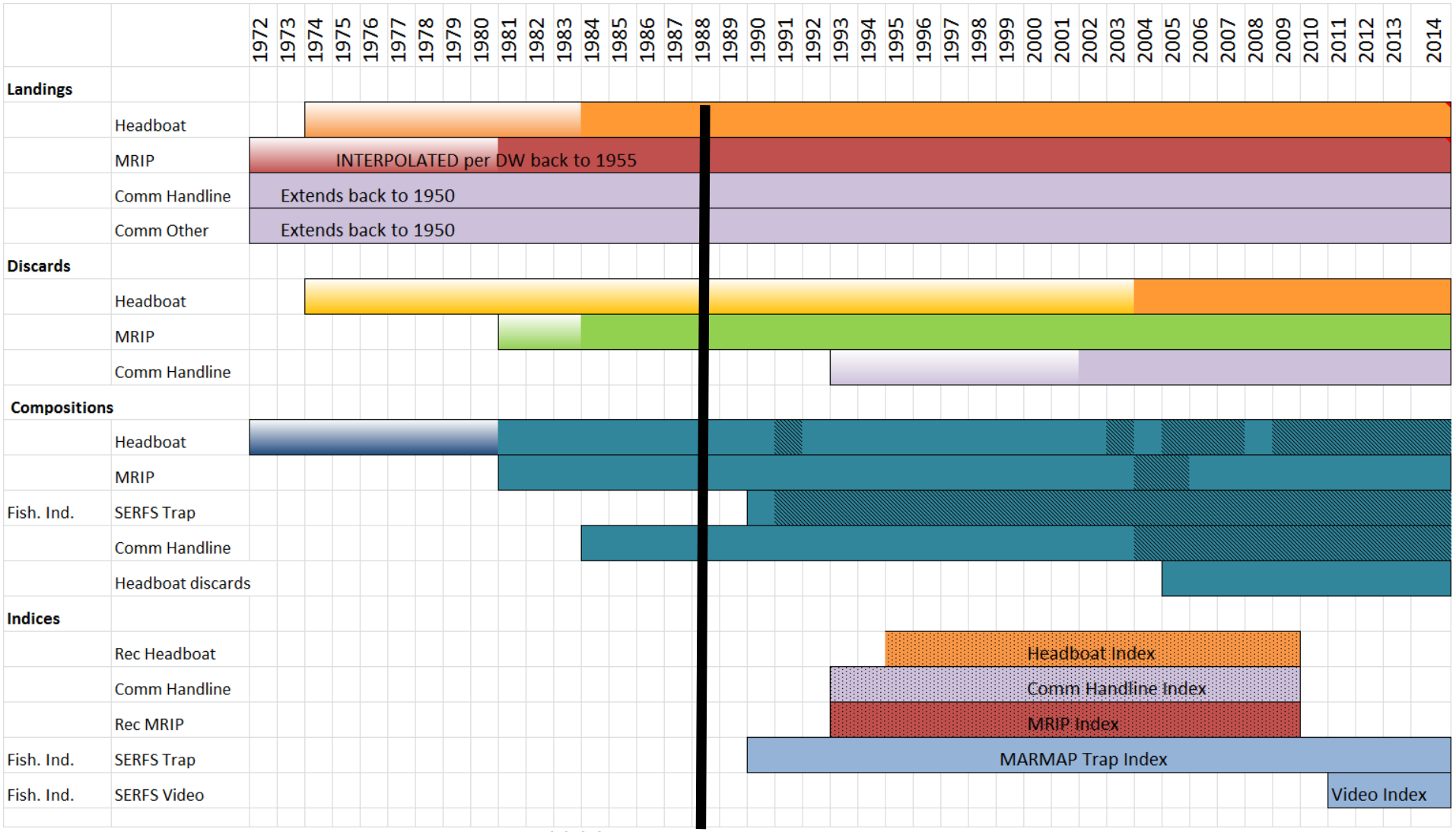
- Commercial discards observed 2002-2014; estimated 1993-2001
- MRIP discard estimates 1981-2014 (self-reported, no validation, sparse sampling)
- Headboat discards observed 2004-2014; estimated from 1981-2003 (using MRIP)

Landings are less certain early in the time series due to species identification:

Headboat survey had universal logbook form that included gray triggerfish beginning in 1984 ("Unclassified triggerfish" included on form beginning in 1974)

"More confidence in later time frame (i.e., 1990s) in the species identification [MRIP survey]"

Time Series



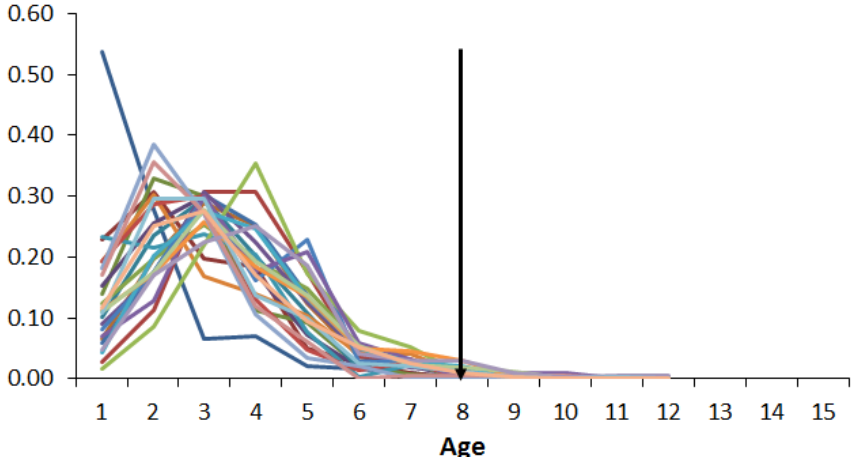
All age comps and indices begin post-1988

Some length comps pre 1988 (i.e., 1981-1987)

Estimate initial F to reflect fishing mortality prior to 1988 (length comps, chevron trap age comps)

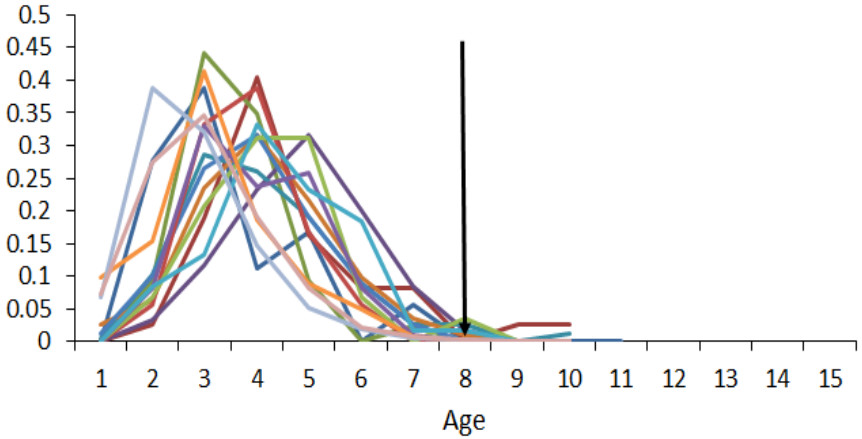
Plus Group

AW recommendation: Model ages 1 to 8+



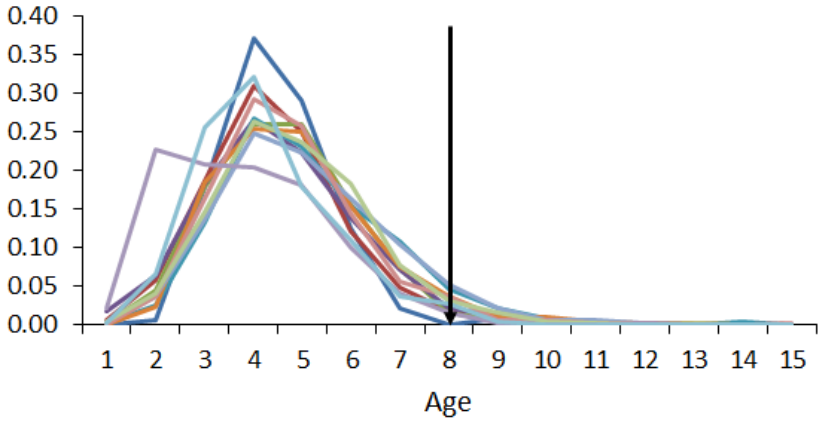
SERFS Chevron Trap

- Ages 2-4 common
- Avg proportion catch age 8+ is 1.4%



Recreational (pooled)

- Ages 3-5 common
- Avg proportion catch age 8+ is 1.2%



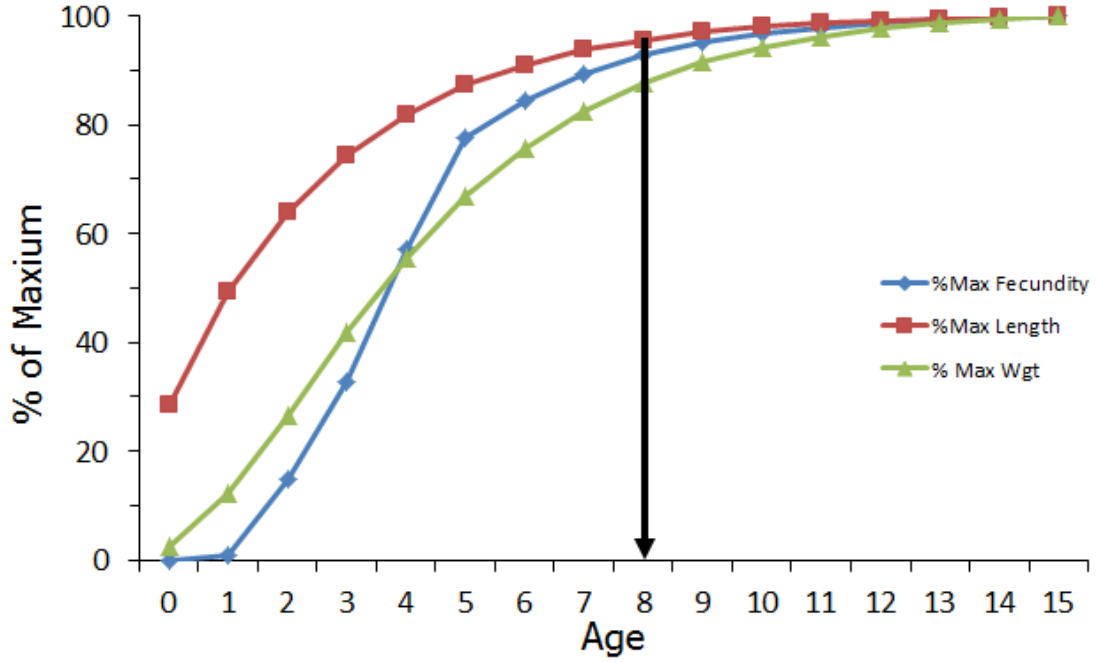
Commercial Handline

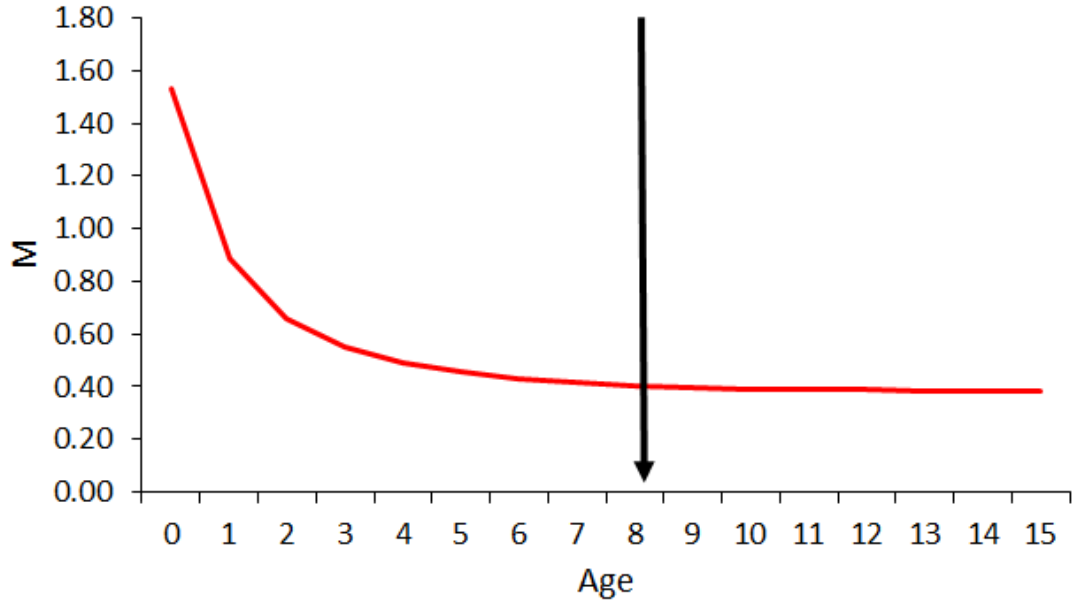
- Ages 3-5 common
- Avg proportion catch age 8+ is 4.3%

Plus Group

AW recommendation: Model ages 1 to 8+

- Life history parameters saturate by age 8





Fishing Fleets

Commercial

- Single commercial fleet (pooled handline, other, and discards)

Recreational

Option 1:

- **Two recreational fleets (headboat, pooled general recreational (MRIP))**
- **Two discard fleets (headboat discards; pooled MRIP discards**)
- Justification: Headboat is separate survey with strongest age/length comps—information on year class strength; discard length comps available

Option 2:

- Single recreational fleet (pooled over headboat and general recreational (MRIP))
- Single discard fleet (pooled over headboat and general recreational (MRIP))
  - Issues: -Ignores structure in recreational fleet (depth-related patterns in fishing)
    -Contamination of headboat compositions

Option 3:

- Three recreational fleets (headboat, MRIP charterboat, MRIP private)
- Two discard fleets (headboat--has discard length compositions; pooled MRIP discards)
  - Issues: -lack of composition data to estimate separate selectivities
    -sampling bias at high level of disaggregation

Selectivity Recommendations (AW)

Fleet	Recommended
SERFS Chevron Trap	Logistic
Commercial Handline	Logistic
Headboat	Domed
General Recreational	Domed
Headboat (HB) Discards	Domed
General Rec Discards	=HB Discards

Selectivity

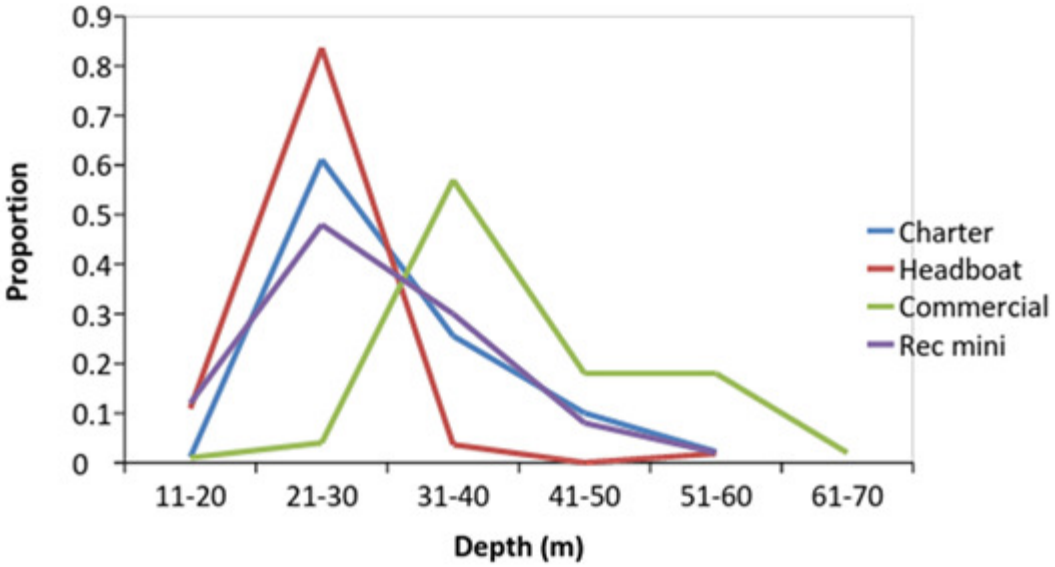
Gear Selectivity and Availability:

- No effect of hook size or hook type (Sedar 41-DW43)

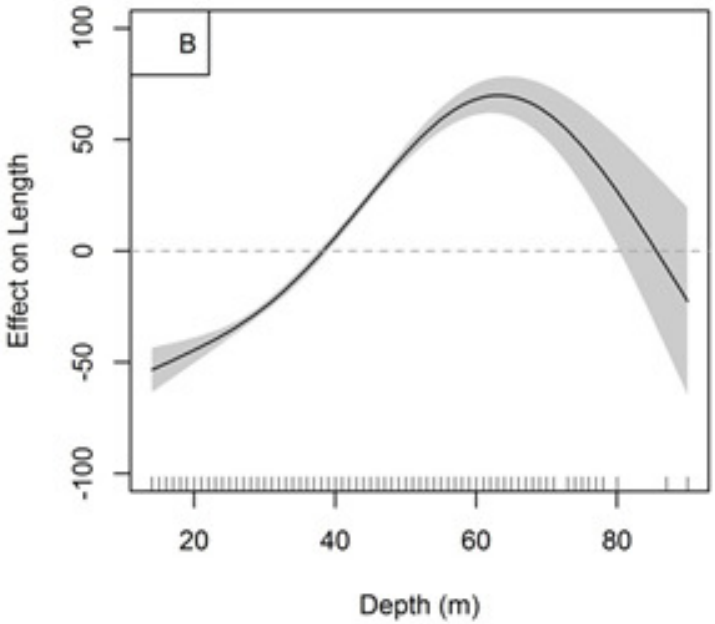
- Largest (oldest) fish occur at ~ 60 m depth
- SERFS Chevron trap encompasses depth range
- Max depth of cHL deeper than recreational
- Headboats shallower than general recreational (GR)

- Expectation: Largest (oldest) fish most available to cHL > GR > HB

Depth Distn of Fleets



Depth Distn of Gray Triggerfish

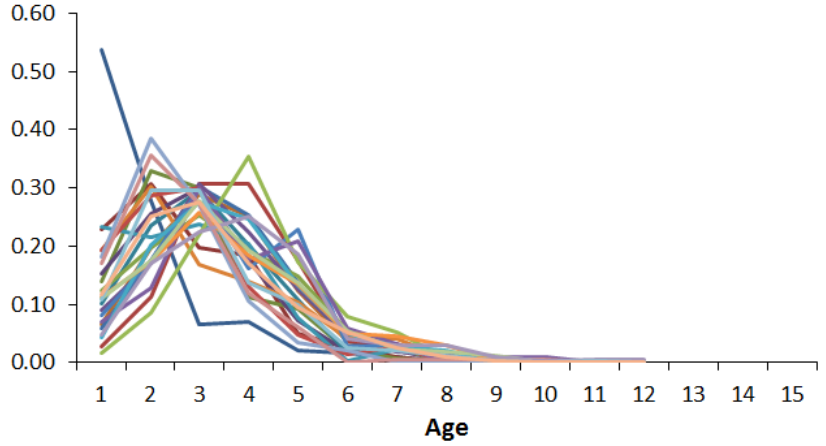


Smart et al. (2015);
SERFS trap survey

Logistic Selectivity (Trap and cHL)

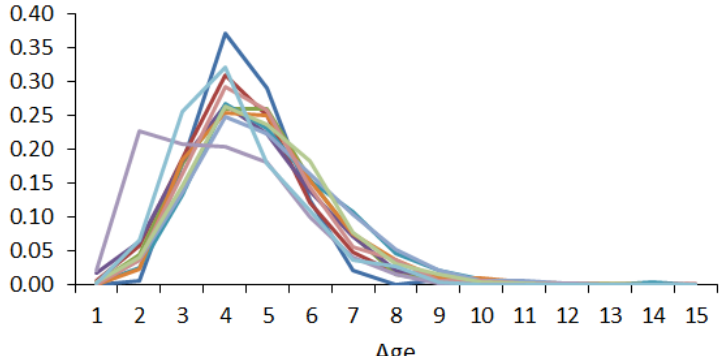
SERFS Chevron trap

- Encompasses full depth range
- Captures all ages out to age 12



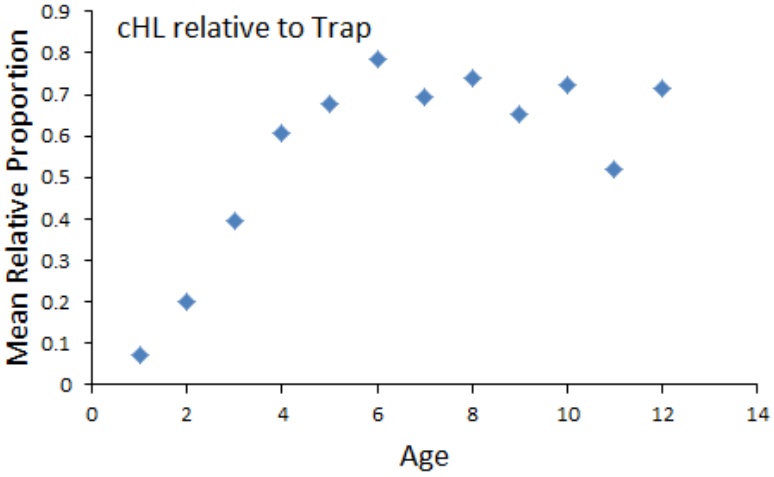
Comm Handline

- Fishes deeper than other fleets
- Captures all ages out to age 15



Mean Relative Age composition (cHL to trap)

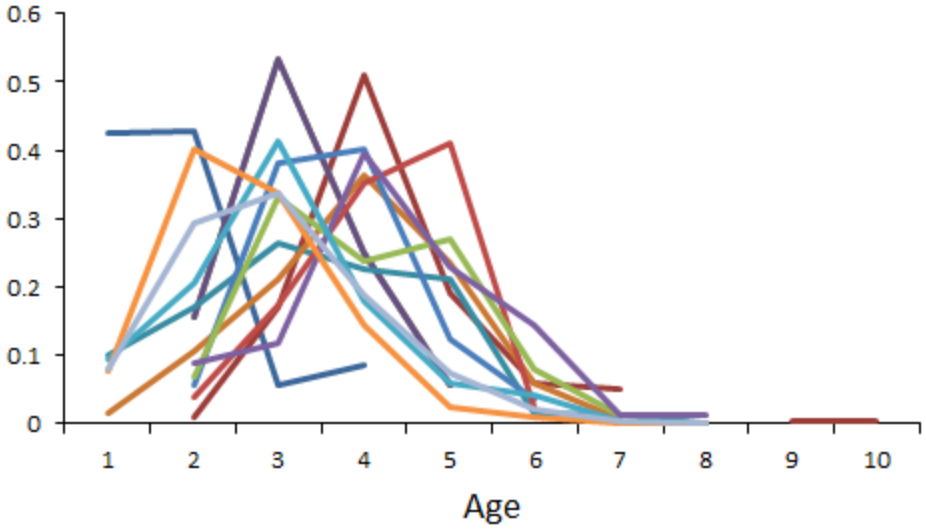
- Proportion $cHL_{age}/(CHL_{age} + Trap_{age})$
- Average by age 2004-2014
- Expect decline at age if cHL domed relative to trap



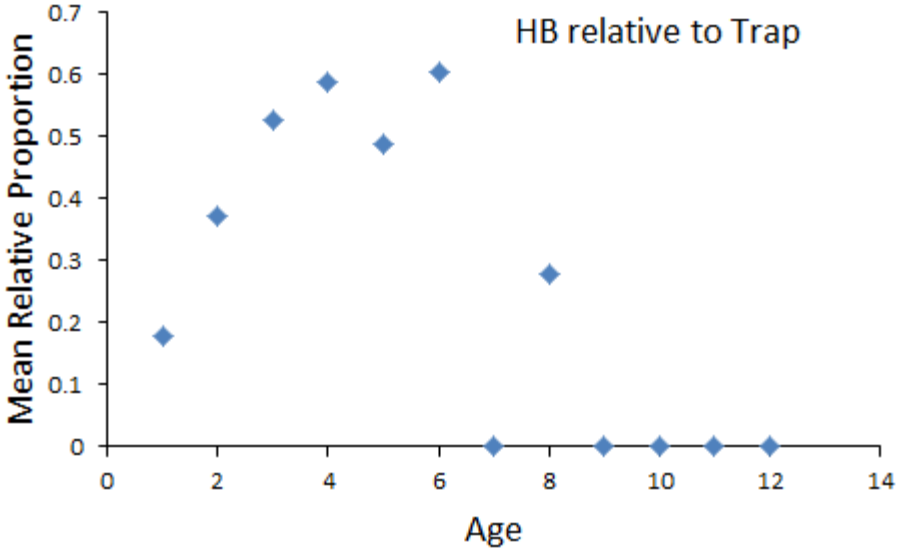
Dome-Shaped Selectivity (Headboat)

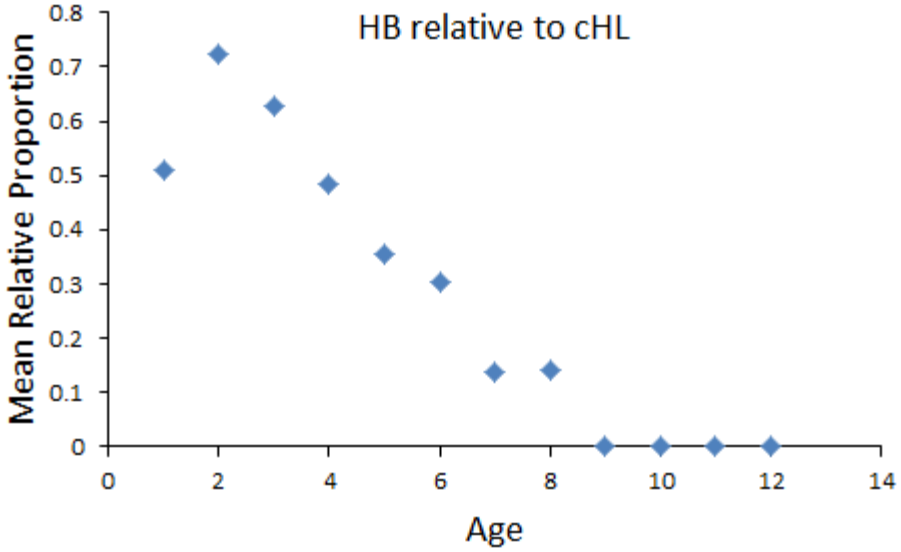
Headboat

- Primarily shallow water (< 30 m)
- Captures mostly < age 6



Dome-shaped





Dome-Shaped Selectivity (Headboat)

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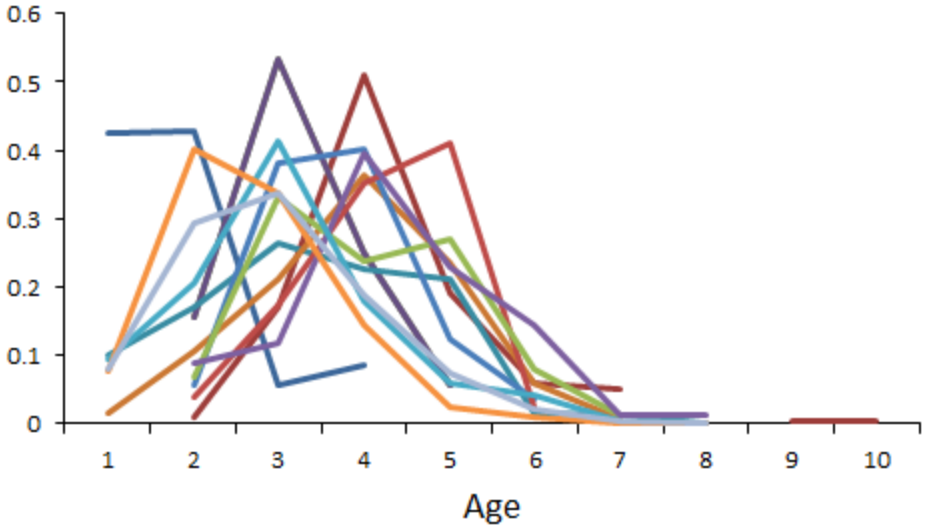
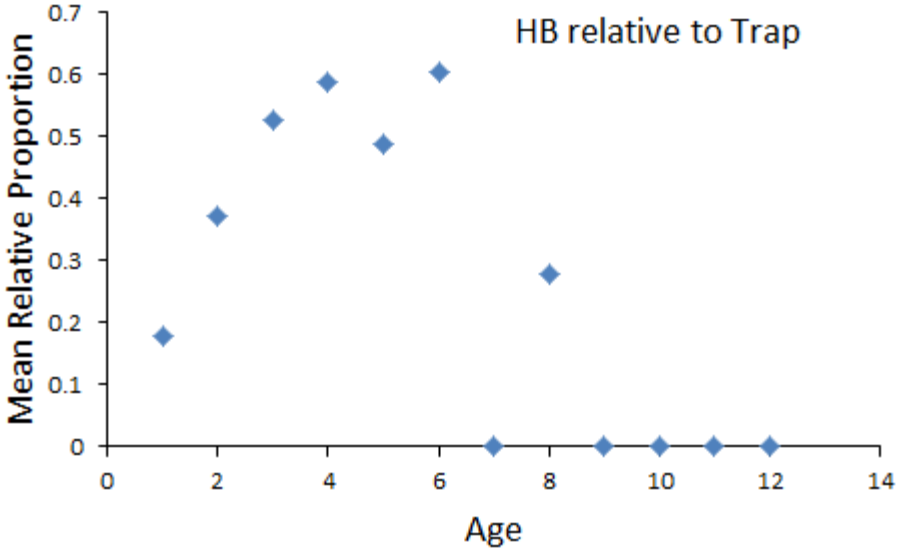
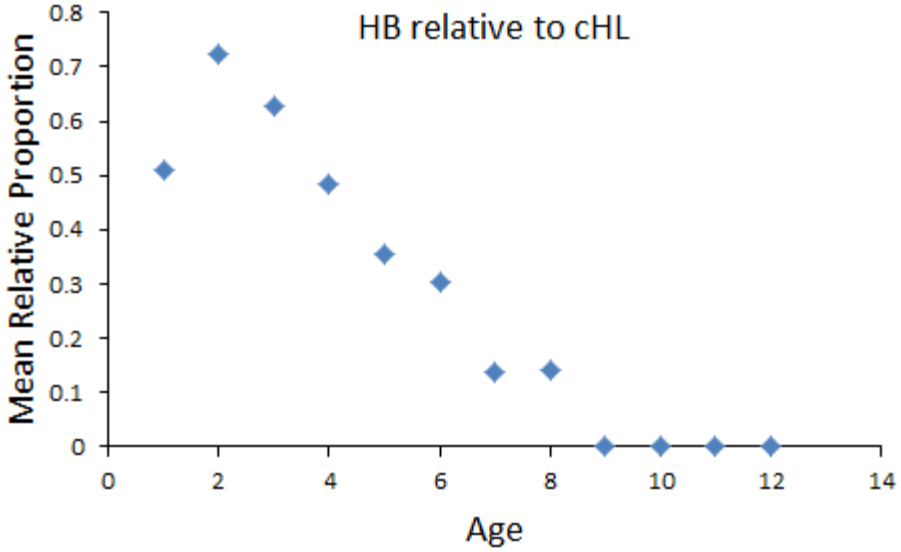


Dome-shaped

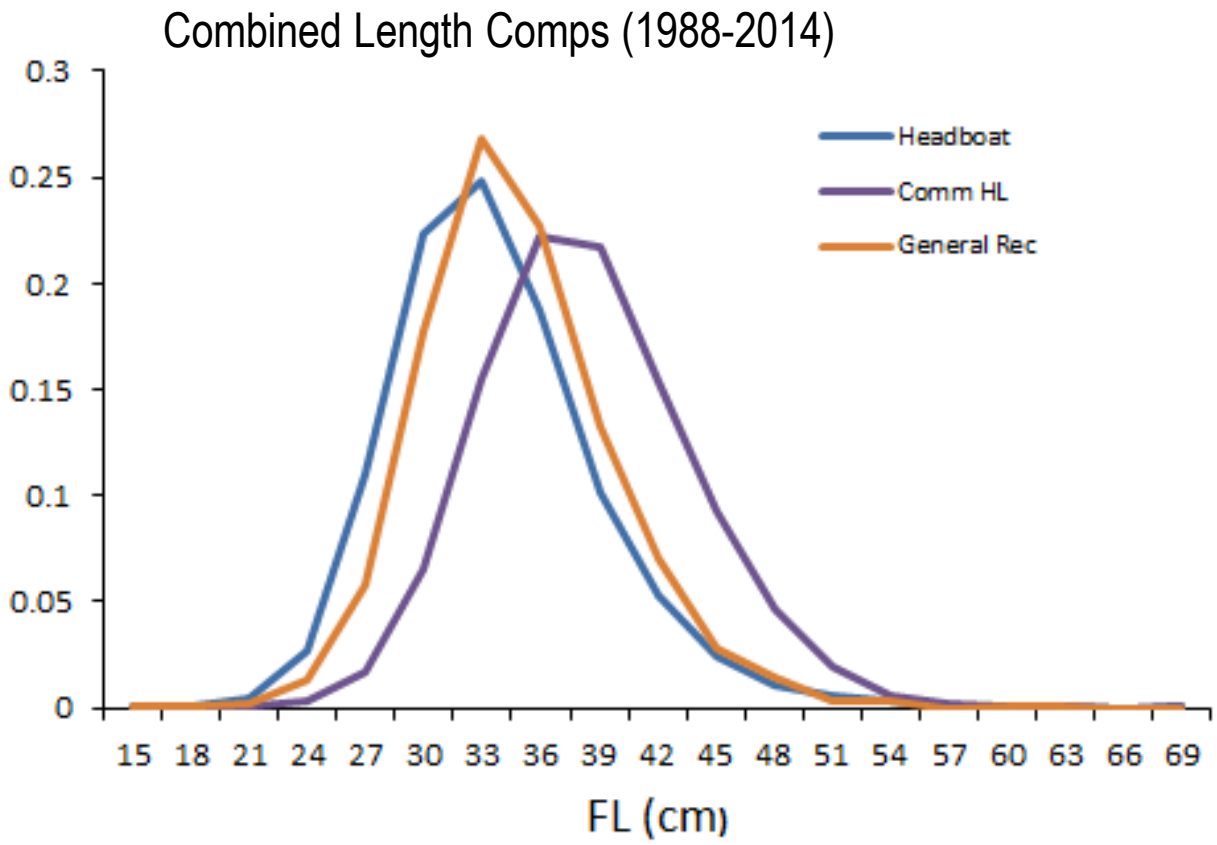




Dome-Shaped Selectivity (General Recreational)

General Recreational

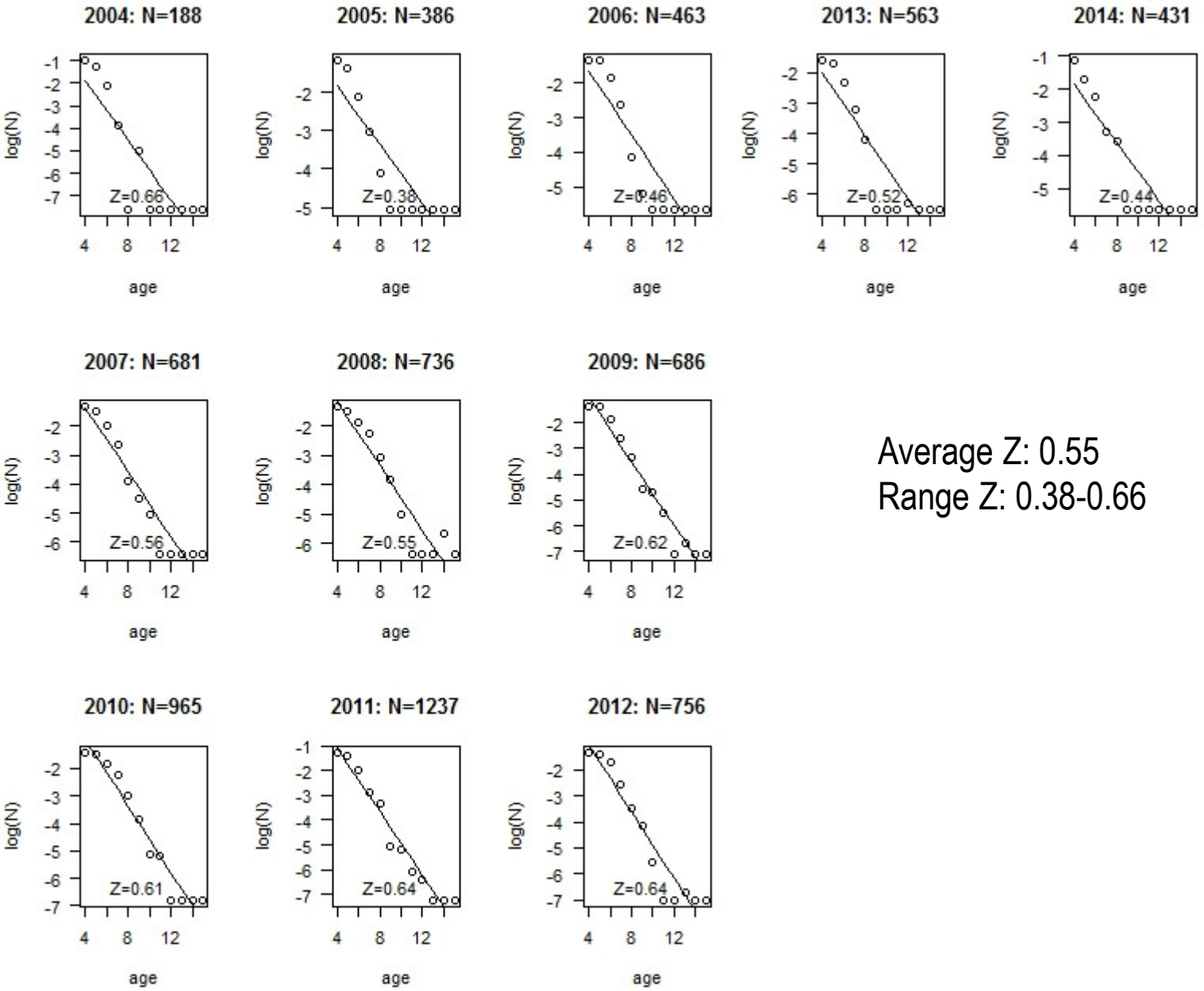
- Intermediate depths (< 50 m)
- GR Length comps intermediate to HB and cHL



Preliminary Analysis

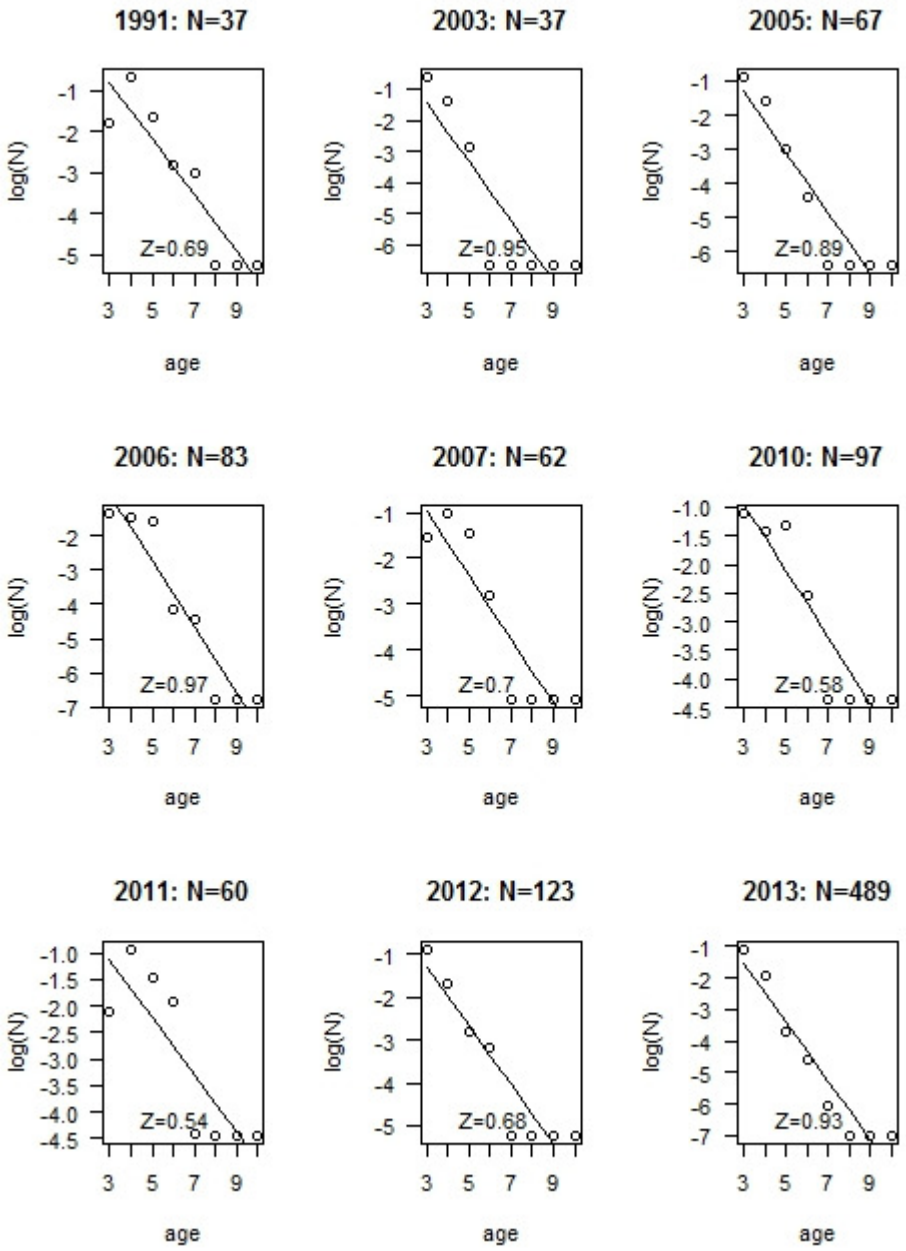
Catch Curves

Commercial Handline



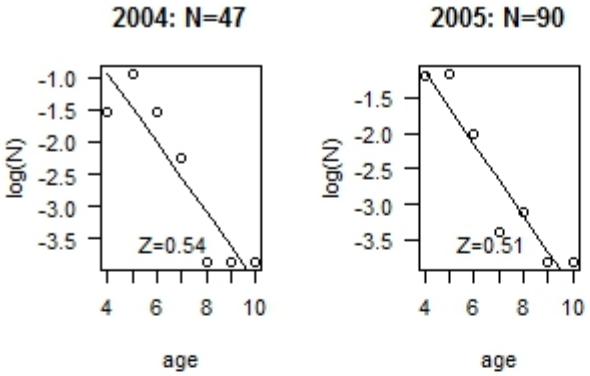
Average Z: 0.55
Range Z: 0.38-0.66

Recreational Headboat



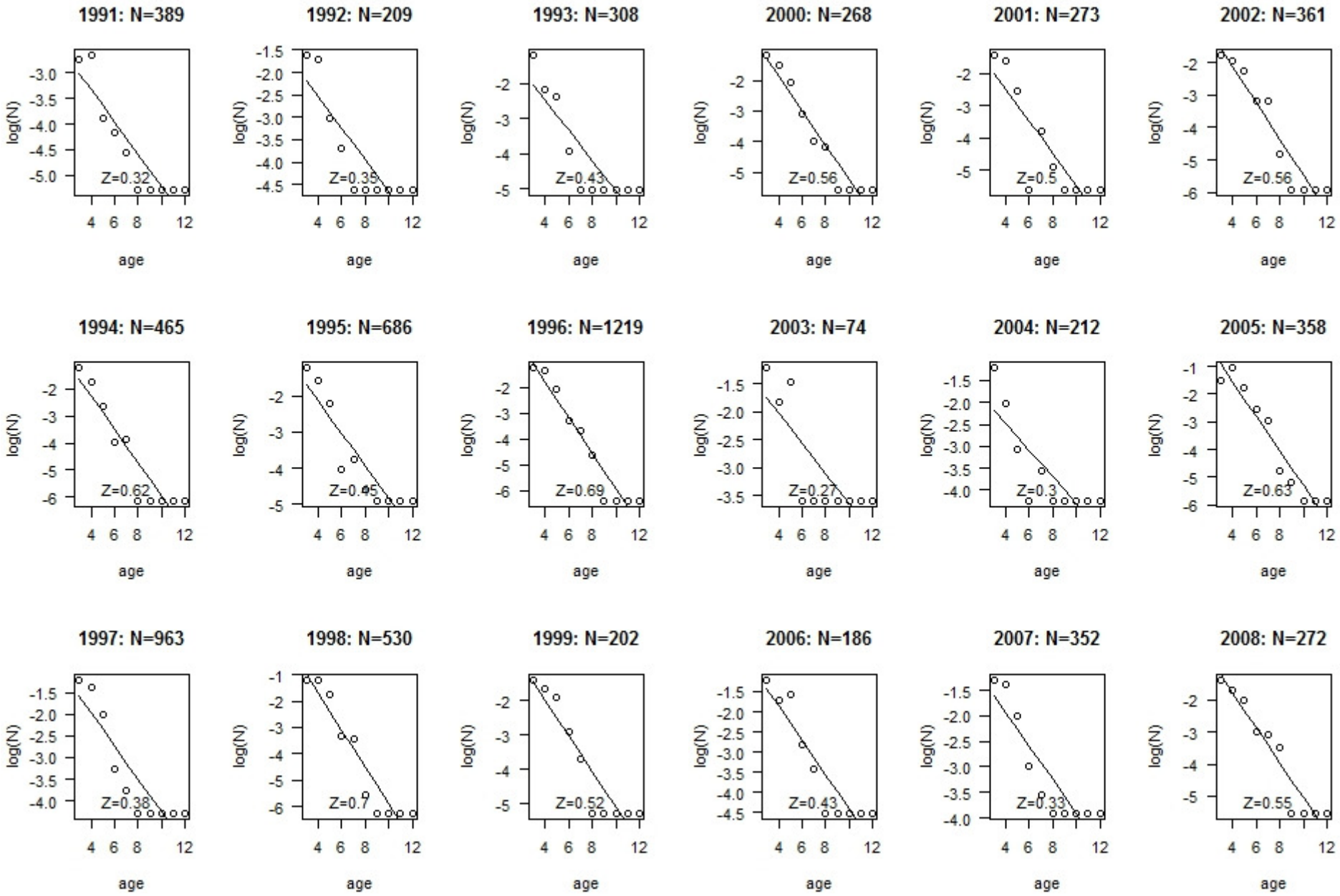
Average Z: 0.78
Range Z: 0.54-0.97

Recreational MRIP

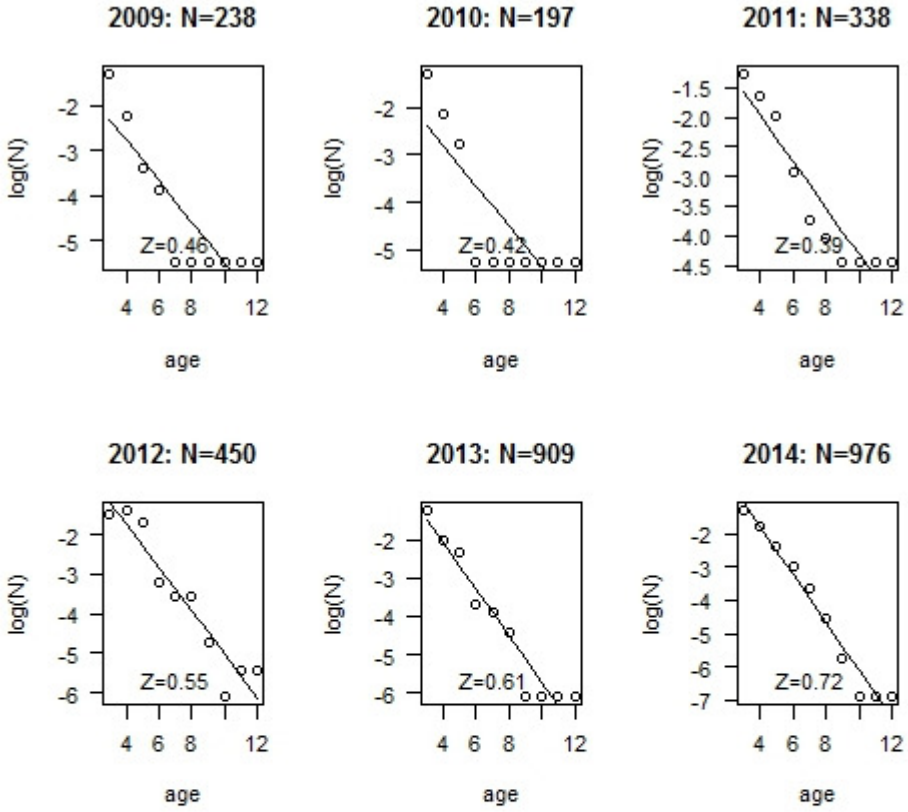


Average Z: 0.53
Range Z: 0.51-0.54

SERFS Chevron Trap

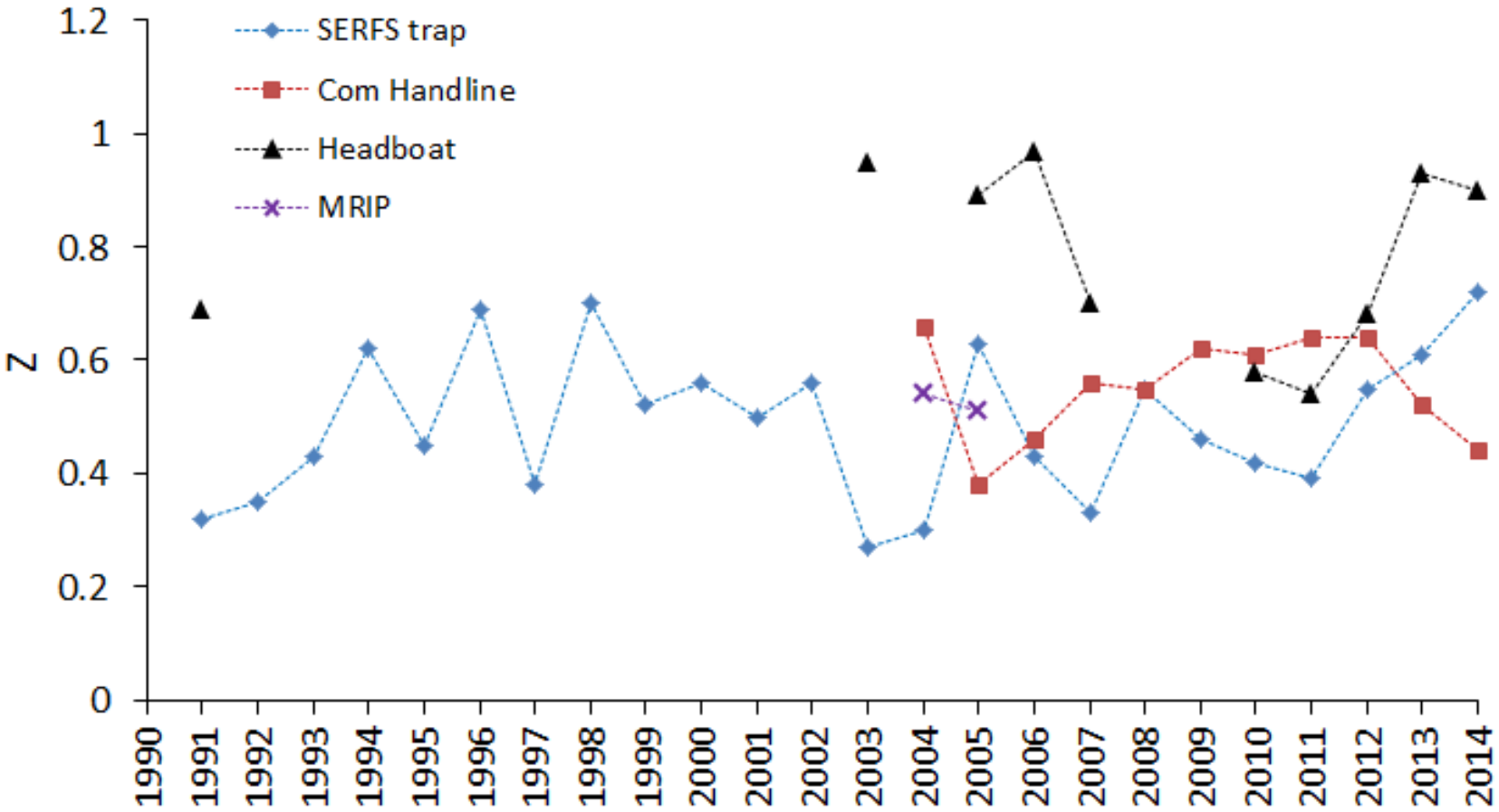


SERFS Chevron Trap



Average Z: 0.49
Range Z: 0.27-0.72

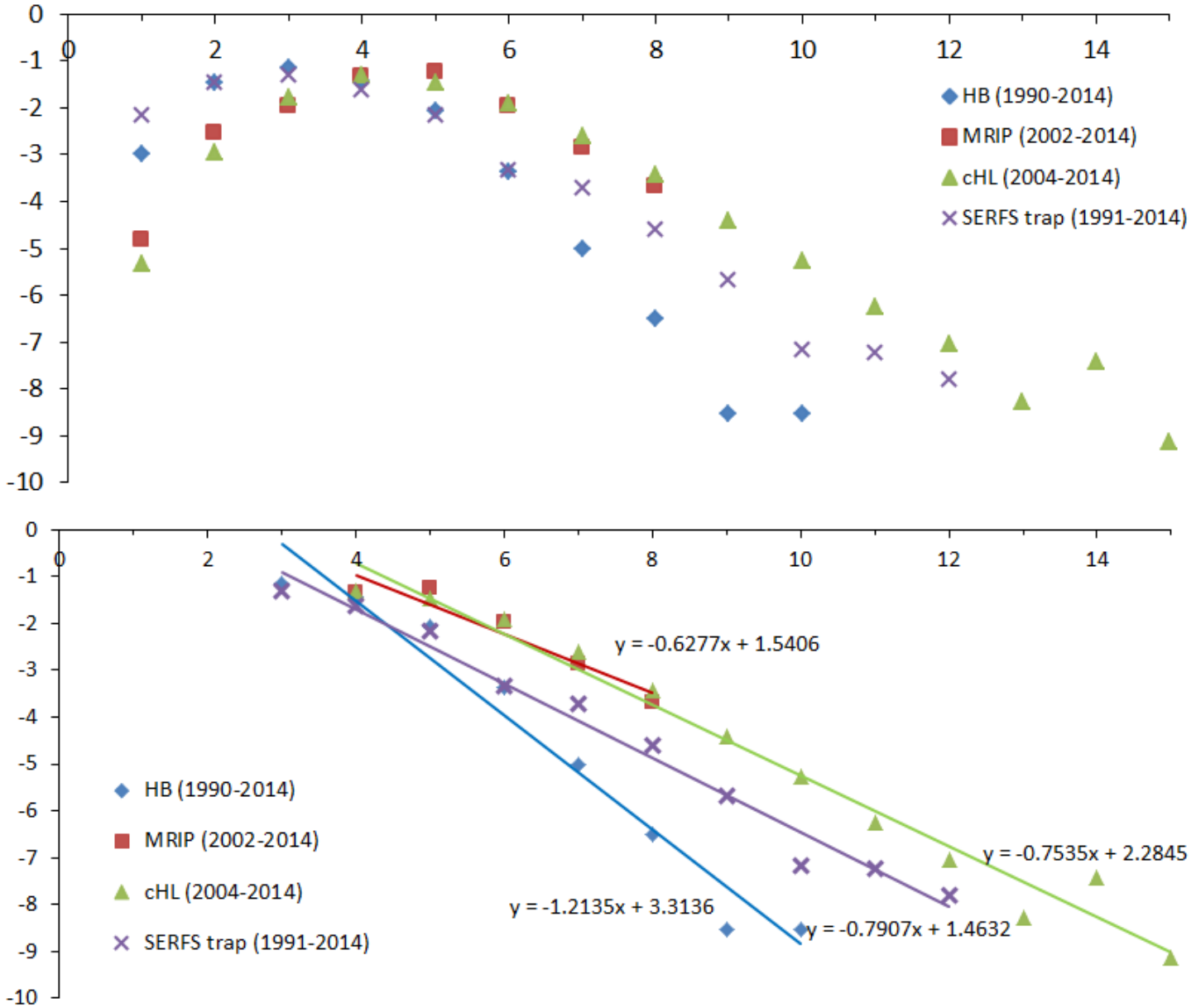
Catch Curve Summary



- No pattern in total mortality over time
- Loss rates from headboat > other fleets

Mortality Rates

(pooled over years and weighted by ntrips)



Catch-Age Model Configuration (Data Inputs)

Removals

- General recreational landings (Pooled over modes): 1988-2014
- Headboat landings: 1988-2014
- General recreational discards (pooled over modes): 1988-2014
- Headboat discards: 1988-2014
- Commercial removals (handline, other, and dead discards): 1988-2014

Age Compositions

- Annual commercial handline age comps: 2004-2014
- Annual headboat age comps: 1990-91, 2003, 2005-2014
- Annual SERFS chevron trap age comps: 1991-2014

Length Compositions

- Annual commercial handline length comps:1988-2014
- Headboat length comps: 1988-2014
- General recreational length comps: 1989-2014
- Headboat discard length comps: 2005-2014
- Annual SERFS chevron trap length comps: 1990-2014

Catch-Age Model Configuration (Data Inputs, cont.)

Indices

- AW panel recommended combining SERFS chevron trap and video index (CVID)

- AW panel recommended excluding fishery-dependent indices
  - Do not extend to end of times series (end in 2009)
  - Concerns about changes in targeting due to regulations on other species and changes in market value
  - Could not fit all 4 indices simultaneously

  - Gray Triggerfish available to the trap
  - Fishery-independent index covers center of geographic (NC – N. Florida), full depth range, and extends over nearly entire time series (1990-2014)

AW panel recommended up-weighting fishery-independent trap index 6X

  - Capture general trend in the index
  - Minor loss of fit to other data components

- Effects of included indices and index weights evaluated via sensitivity analysis

Catch-Age Model Configuration (Base Run)

- Assessment period: 1988-2014 (~ 90% of removals after 1988)
- Model ages 1 to 8+
- Initialization: Estimated historical fishing mortality rate (F_init) and deviations around equilibrium age structure
- Growth curves:
  - Population growth curve (fixed from DW; t0, K, Linf, len_cv)
  - Fishery-dependent and survey growth curve (estimated from starting values provided by DW)
- Recruitment:
  - Beverton-Holt recruitment. Steepness fixed at 0.99; Recs devs estimated around mean recruitment
  - Standard deviation of recruitment (rec_sigma), R0 estimated
- Fleets and Selectivities
  - Commercial handline: Logistic selectivity (2 parameters, A50 and slope)
  - Combined SERFS video-trap index: Logistic selectivity (2 parameters, A50 and slope)
  - Headboat: dome-shaped selectivity (double logistic; 4 parameters, ascending and descending limbs)
  - General rec dome-shaped selectivity (double logistic; 4 parameters, ascending and descending limbs)
  - Headboat discards: dome-shaped selectivity (logistic exponential, 3 parameters)
  - MRIP discards: assumed same selectivity as headboat discards (no composition data)
- Catchability (assumed constant):
  - SERFS fishery-independent survey
- Estimate annual *F* for each fleet; Age-specific *F* product of full *F* and selectivity at age

BAM Estimated Parameters

Estimated Parameters =201

Fishery growth curve and SERFS trap growth curve (8): t0, k, Linf, CV

Deviations around initial age structure (7)

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

Annual R devs (27): 1988-2014

Selectivity (15): Headboat fleet (4)
Handline fleet (2)
SERFS trap survey (2)
Headboat discards (3)
General rec fleet (4)

Catchability (1): q for SERFS trap index

Fishing mortality (140): average F + annual deviations for each fleet (landings and discards, 1988-2014))

Initial F (1)

Key Assumption

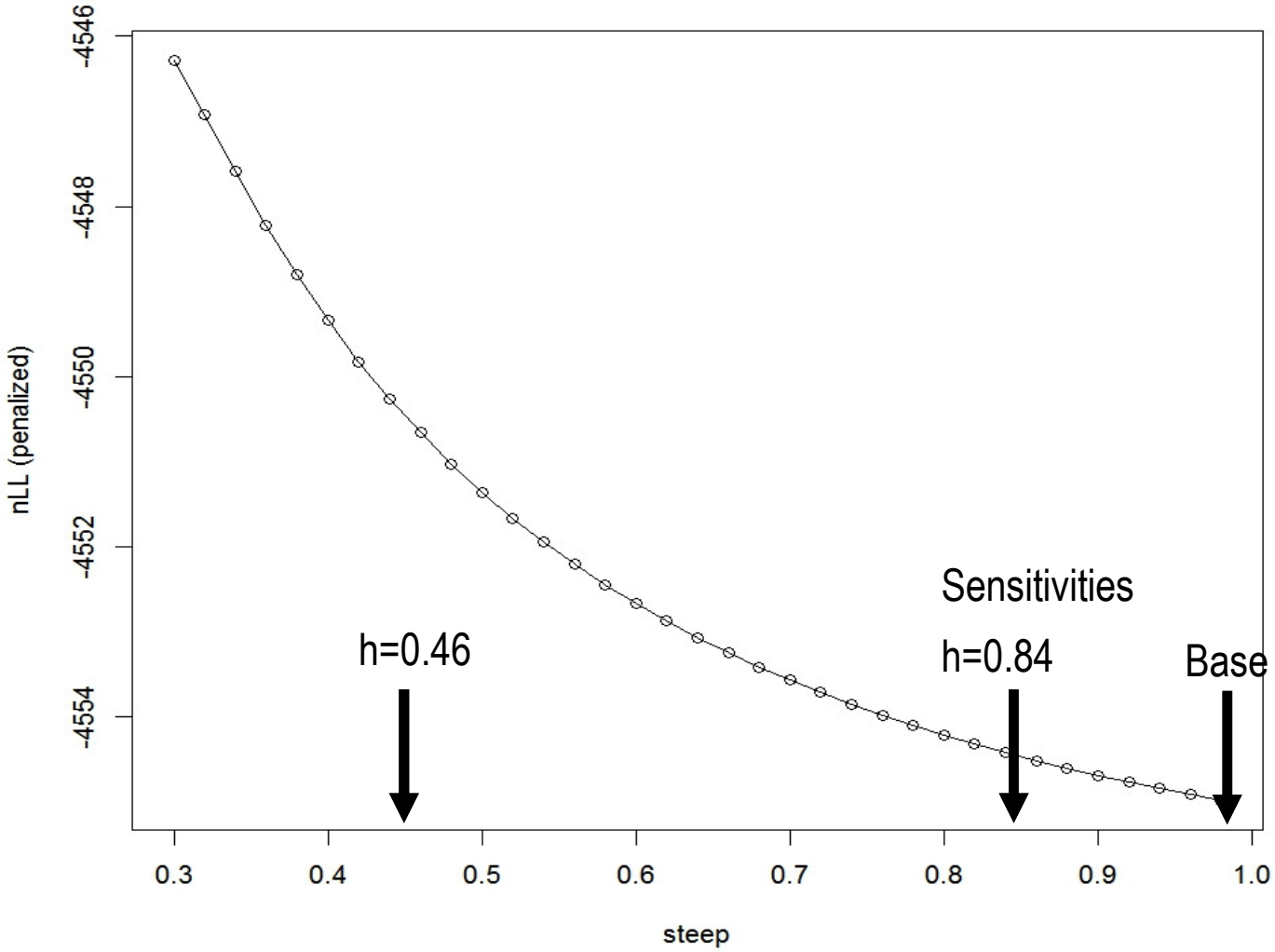
- Could not estimate steepness; hit upper bound; prior with CV < 5% to move off bound
- AW panel recommended fixing steepness (h) at 0.99 to assume an average recruitment
- Recruitment deviations estimated around this average (1988-2014)

==========

- Use F30% proxies for MSY-related benchmarks

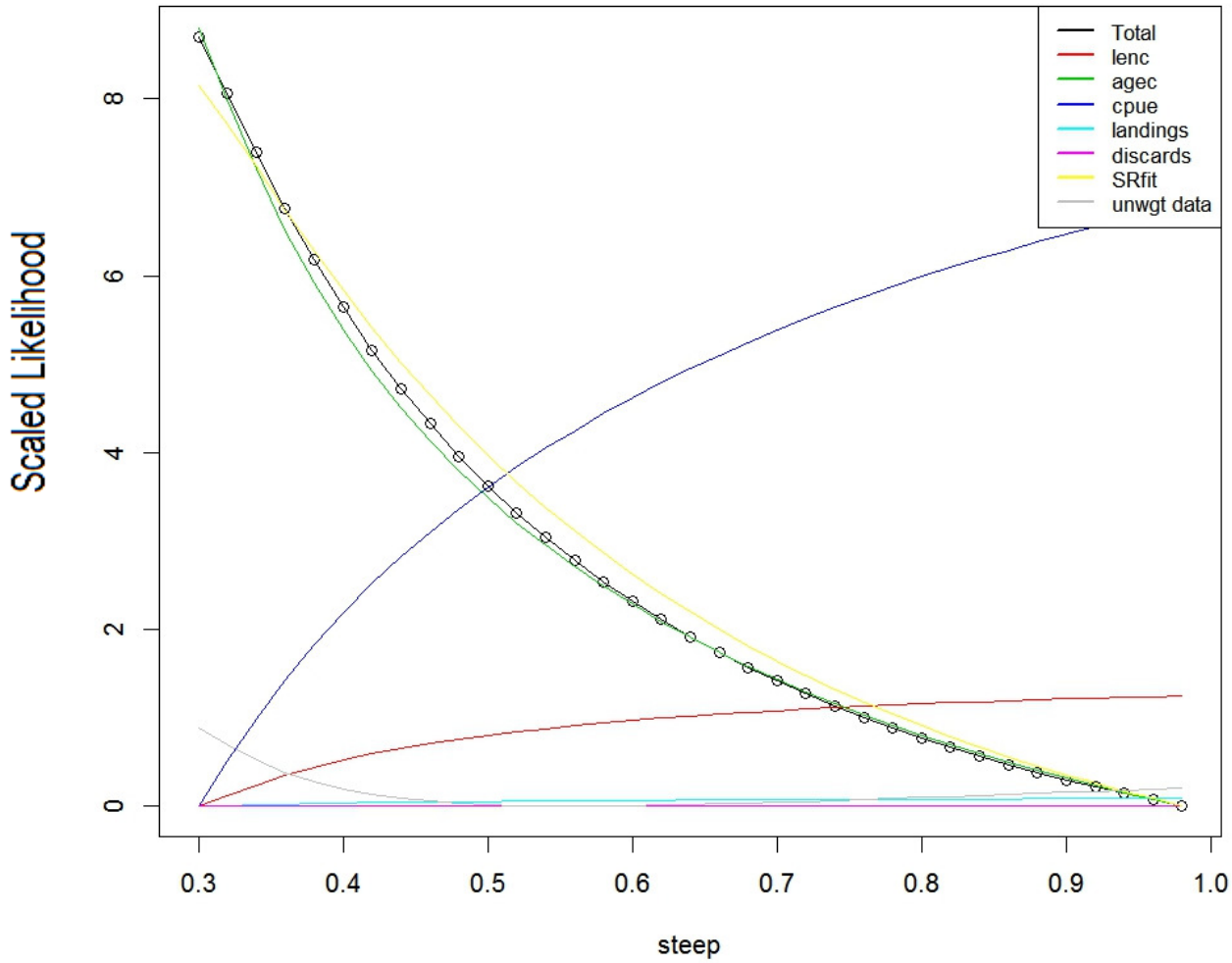
Steepness Profile

- Little evidence for low recruitment at low popn size
- No well-defined minimum

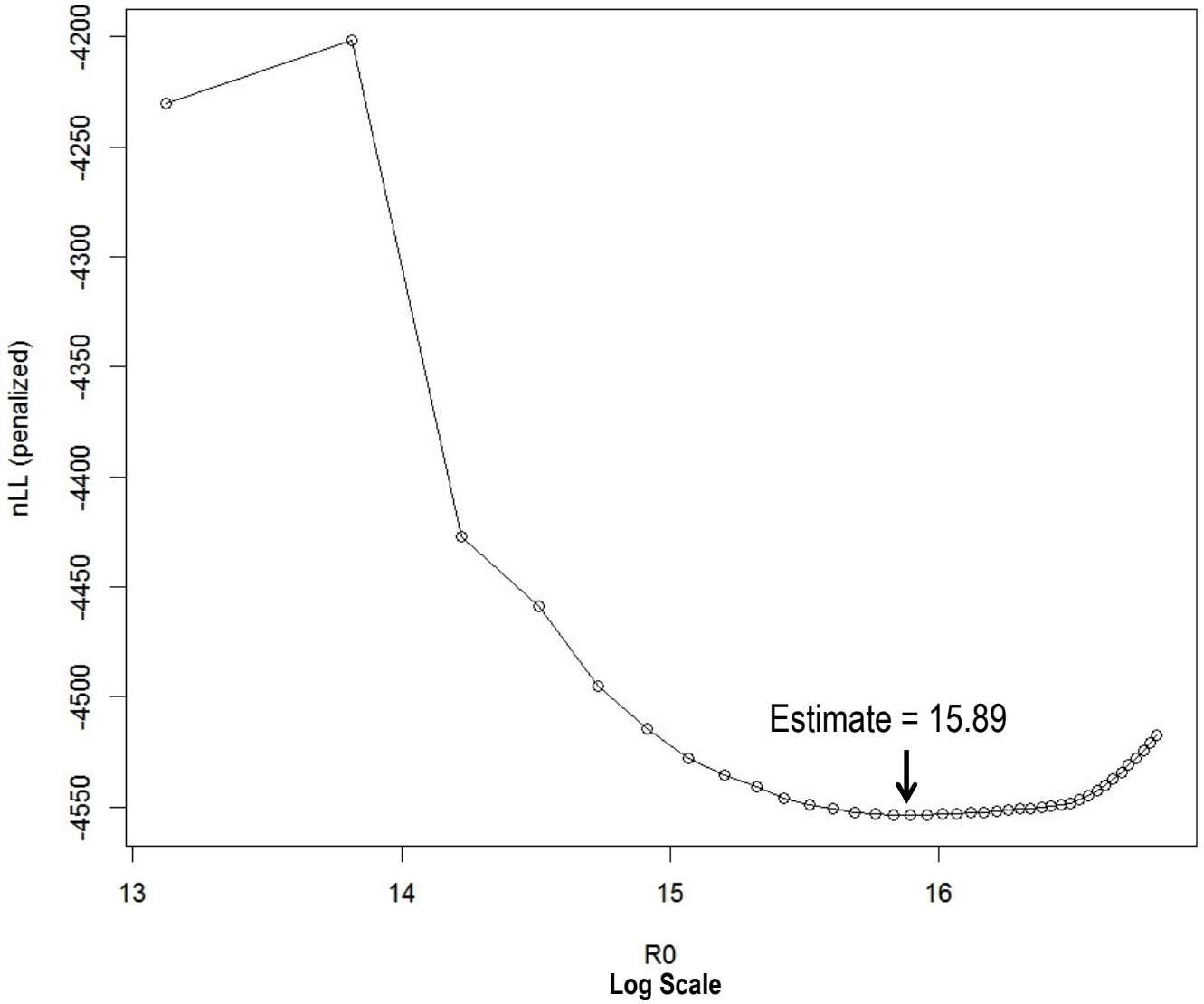


Steepness Profile

- Steepness profile driven by age comps and recruitments
- Other data in conflict regarding value for steepness

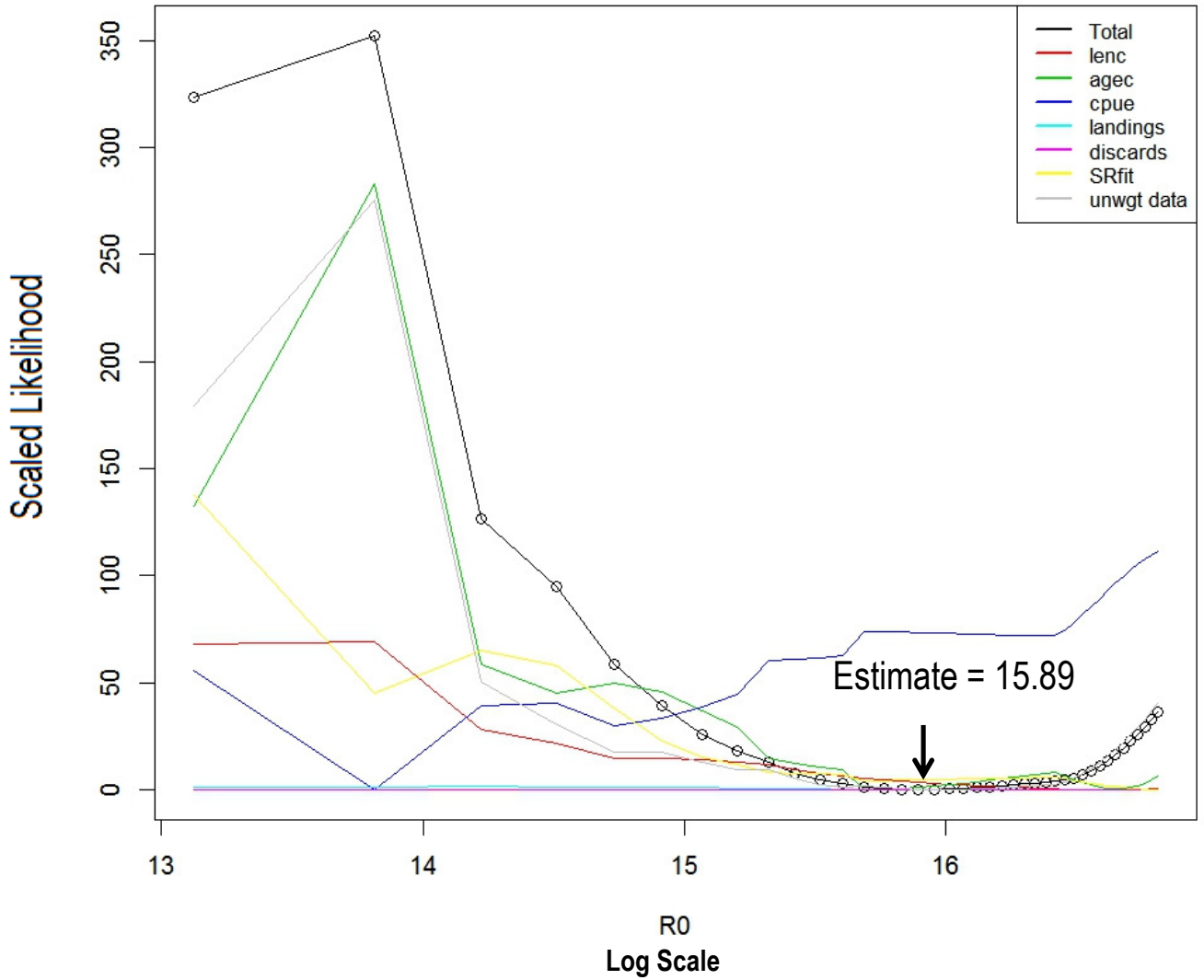


R0 Profile


nLL (penalized)
-4200
-4250
-4300
-4350
-4400
-4450
-4500
-4550
13
14
15
16
R0
Log Scale
Estimate = 15.89

R0 Profile

- Most data in agreement regarding estimate of R0
- CPUE index suggests lower value of R0



Random Re-starts

Setup
- 200 random re-starts
- Uniform distn (+/- 25% initial value)
- Base = Run 201

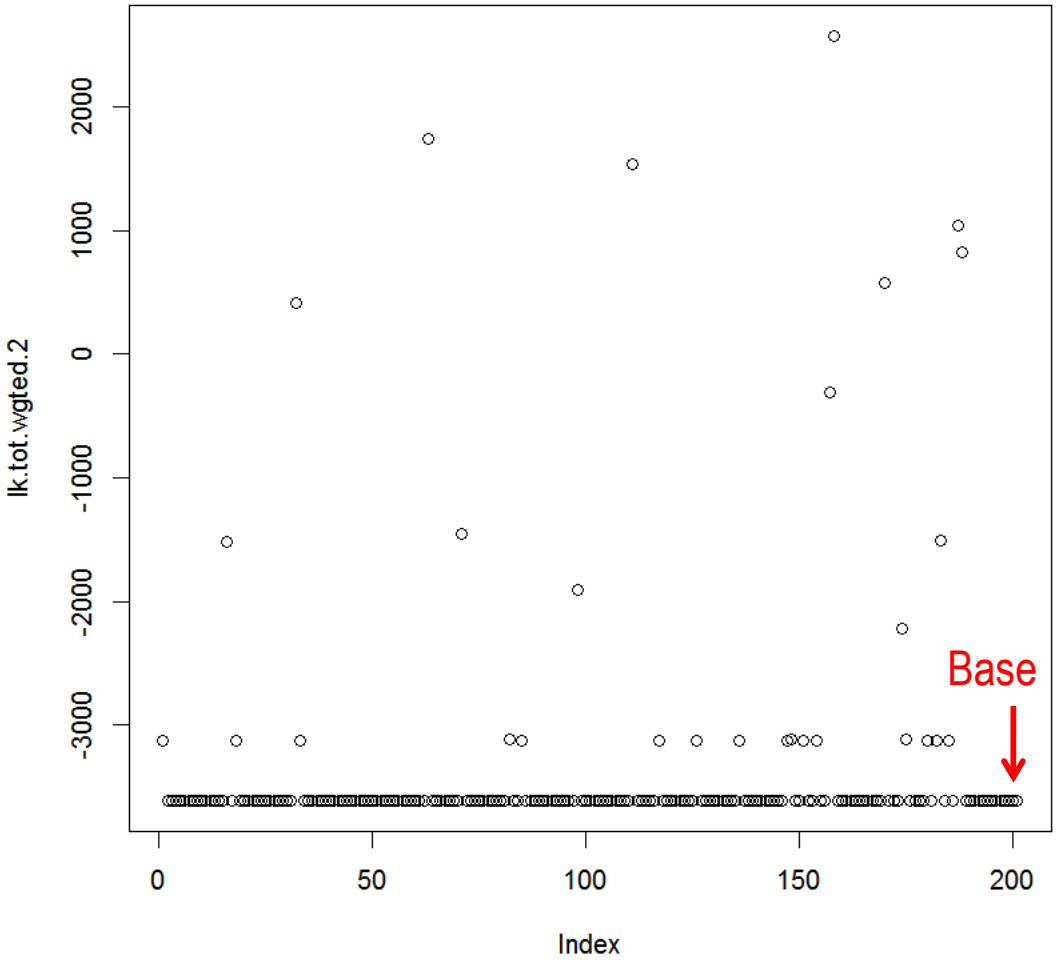
Growth curves
- Fishery: Linf, k, t0, len_cv
- SERFS trap: Linf, k, t0, len_cv

Recruitment
- R0
- Rec_sigma

Selectivities
- cHL: L50, slope
- SERFS trap: L50, slope
- HB: L51, slope1, L52, slope 2
- HB discards: L50, slope, sigma
- GR: L51, slope1, L52, slope 2

Initialization
- Finit

- Model relatively insensitive to starting values
- Base run has lowest neg log likelihood

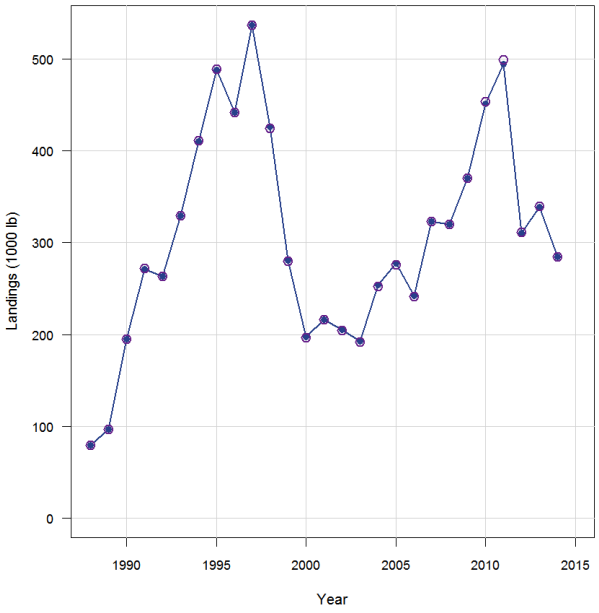


Model Fits

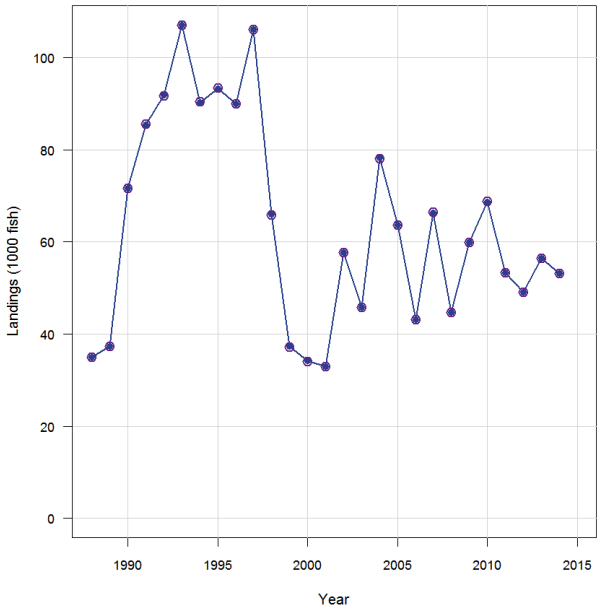
Model Fits: Fishery Landings

BAM Base Run

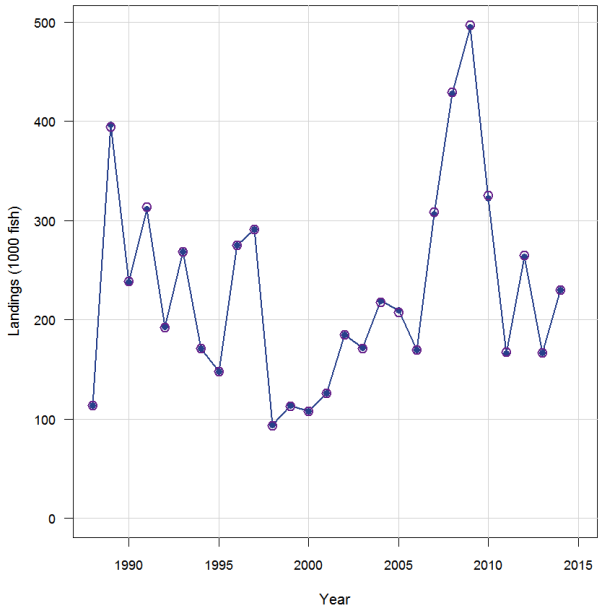
Commercial Handline



General Recreational



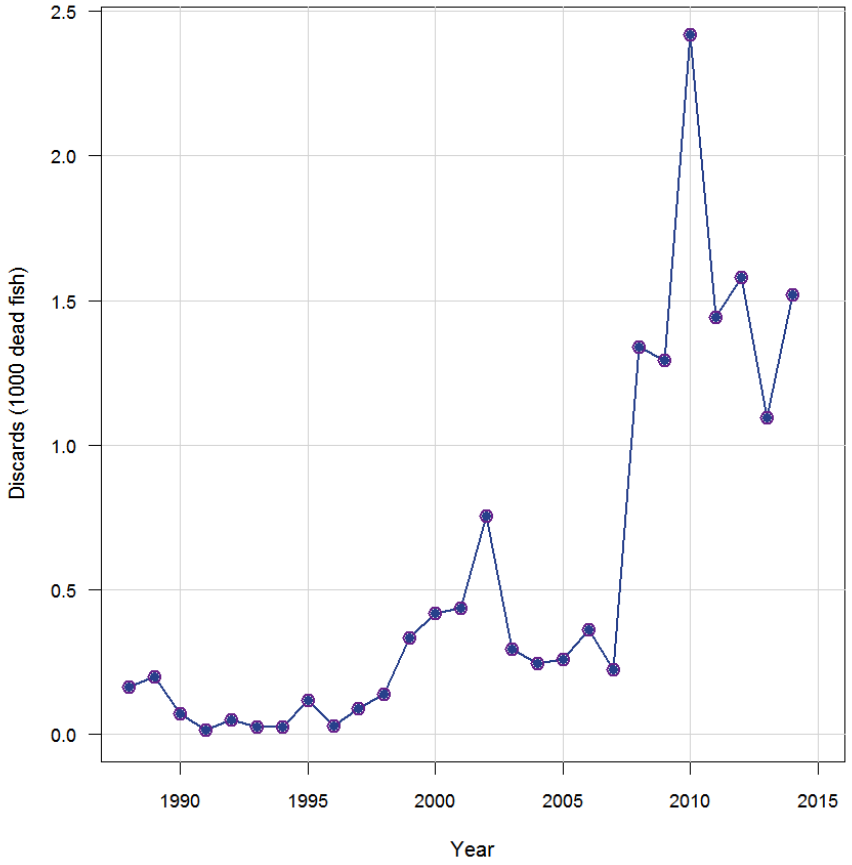
Headboat



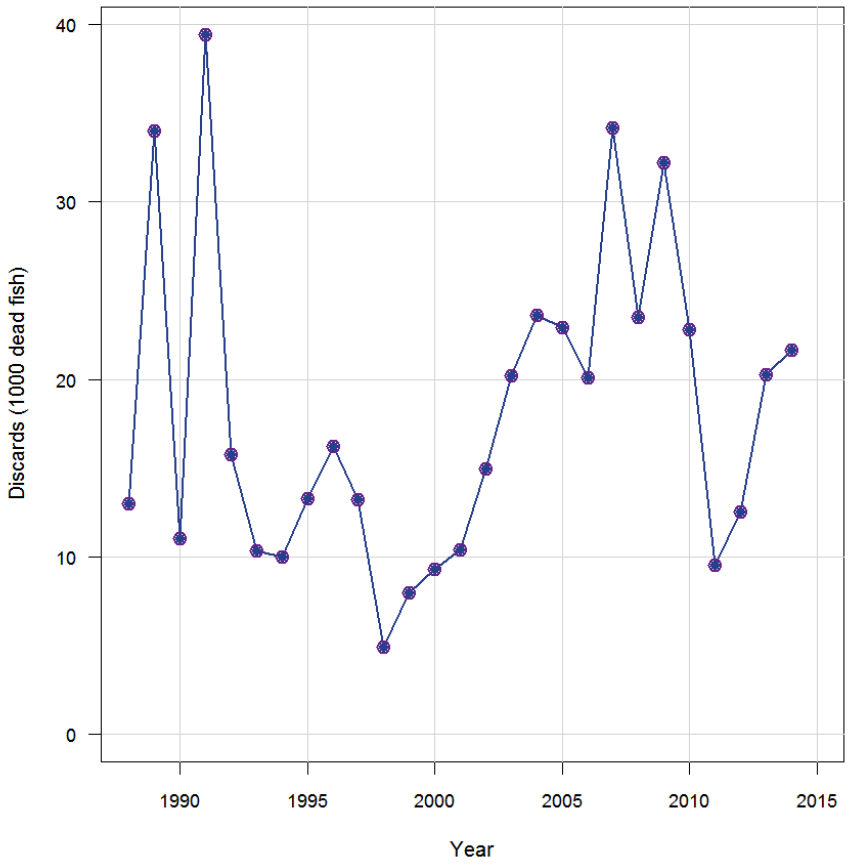
Model Fits: Fishery Discards

BAM Base Run

Headboat Discards

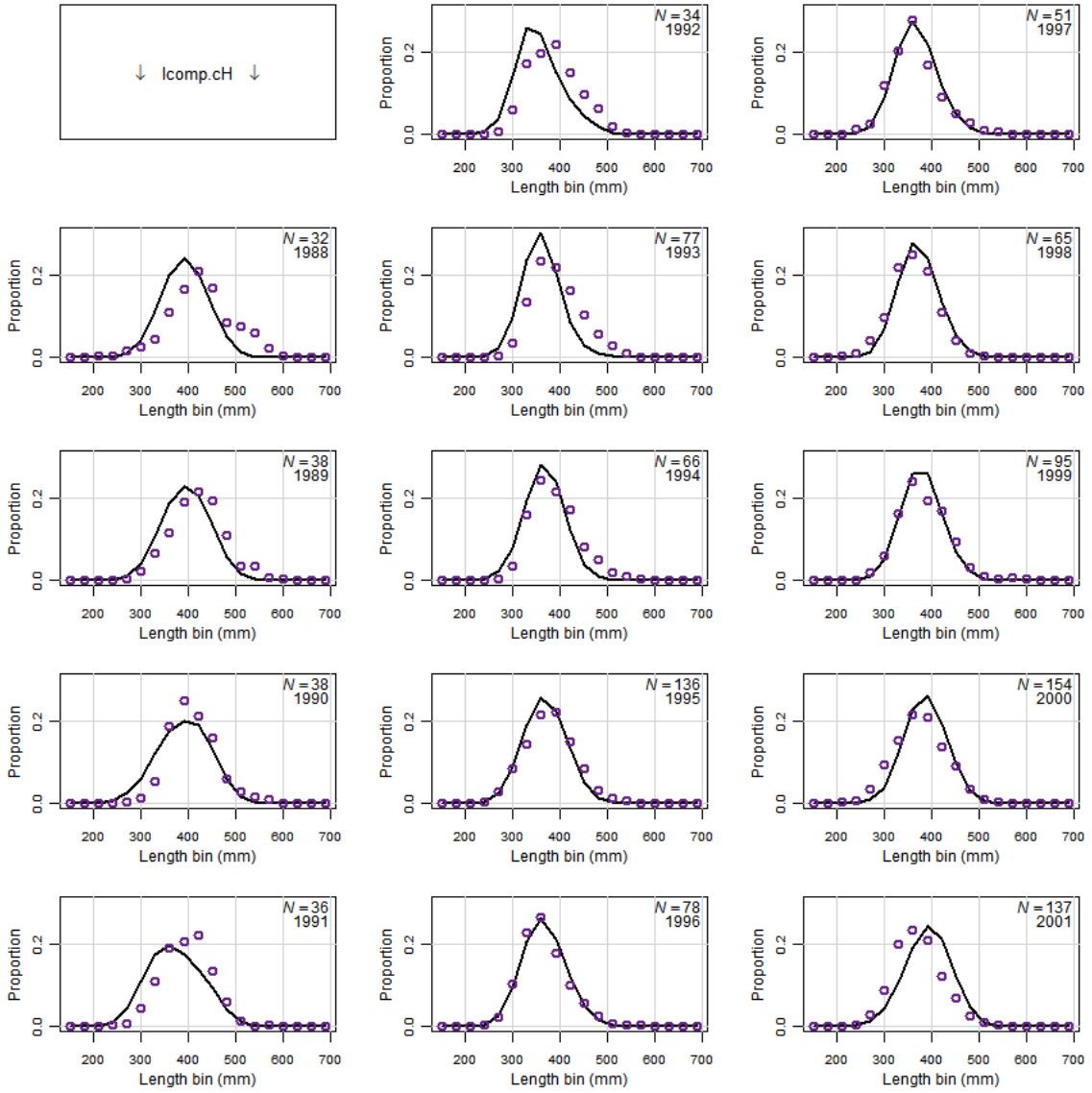


General Recreational Discards



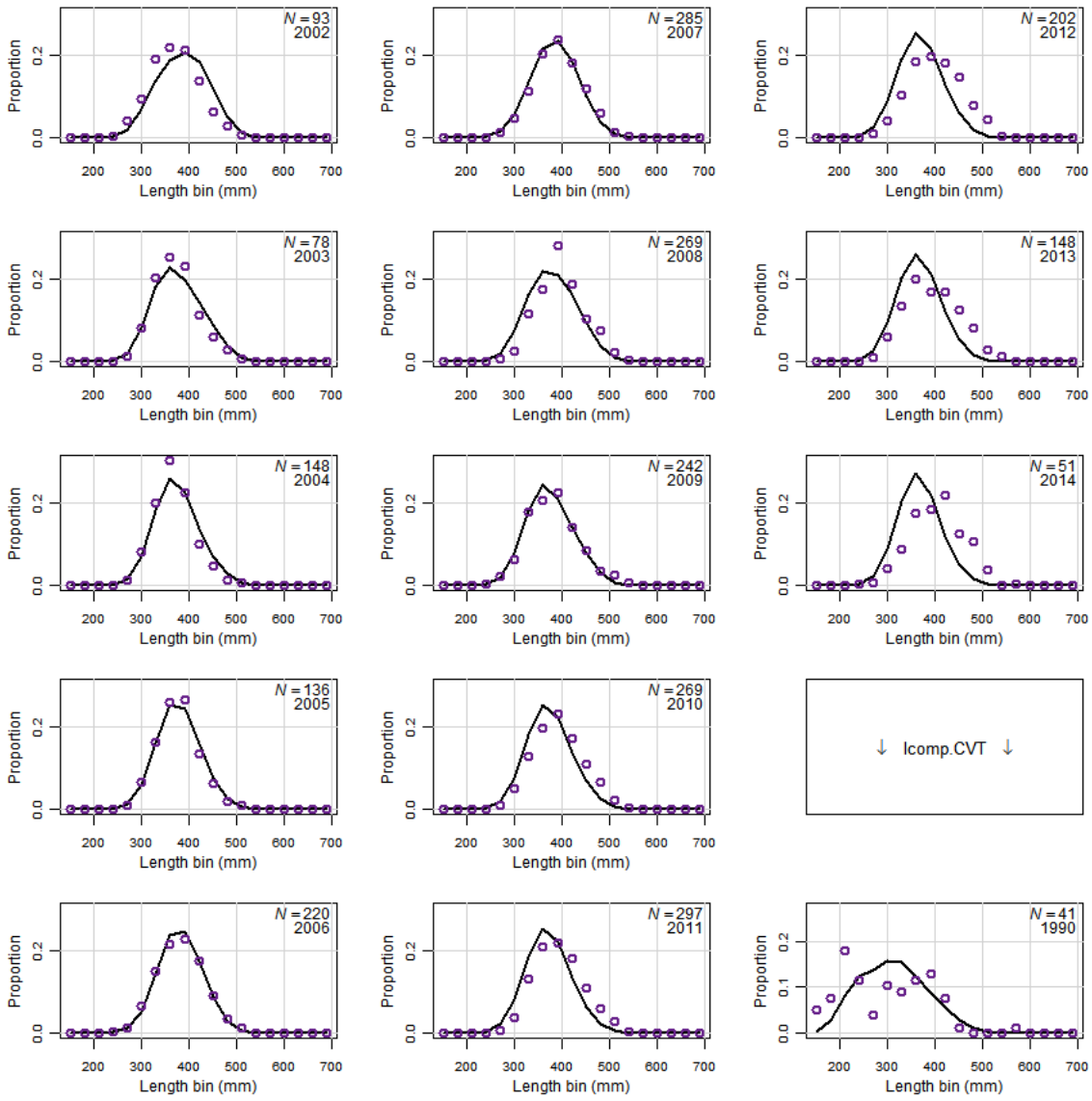
Model Fits: Length Compositions

BAM Base Run



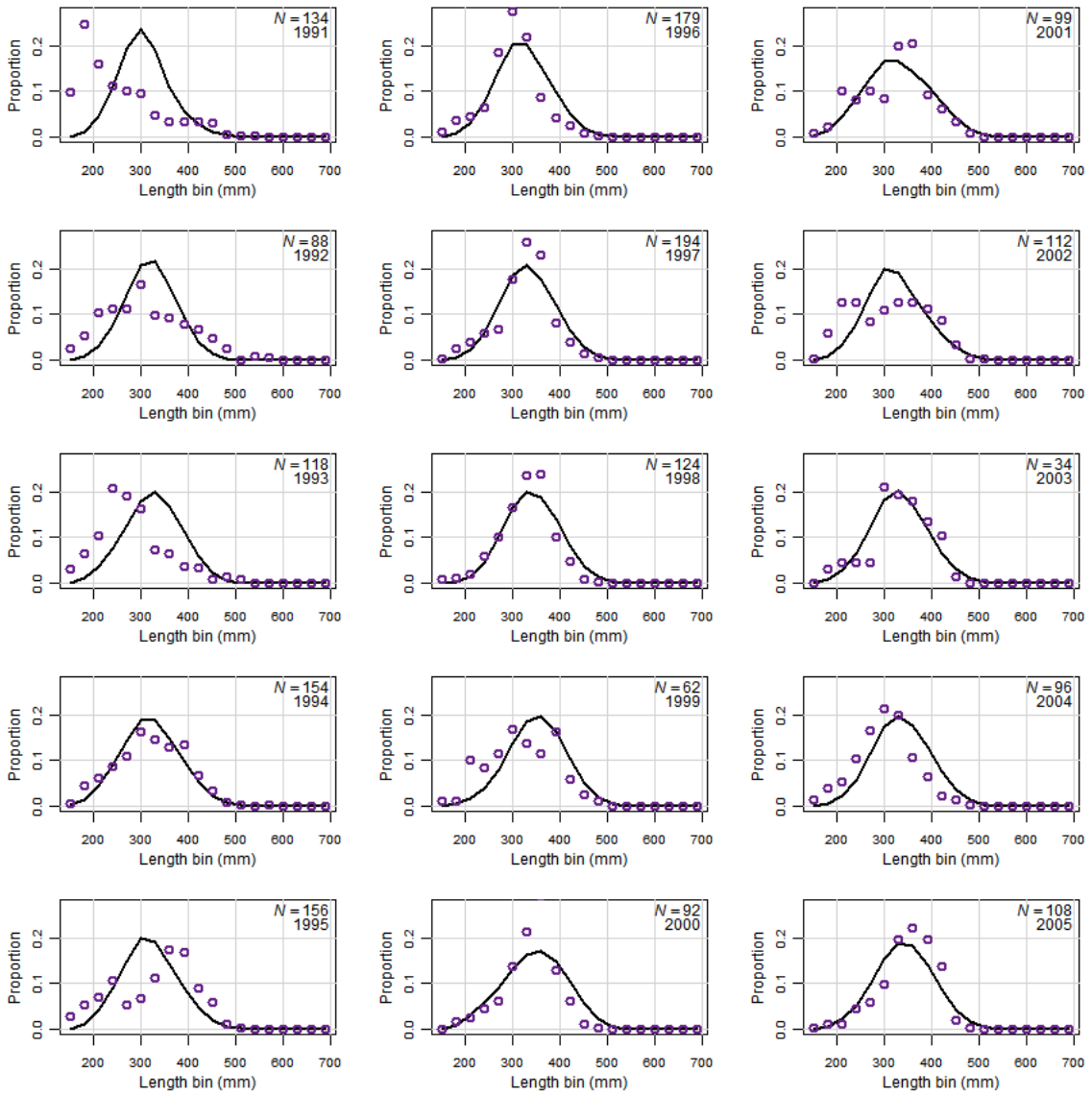
Model Fits: Length Compositions (cont.)

BAM Base Run



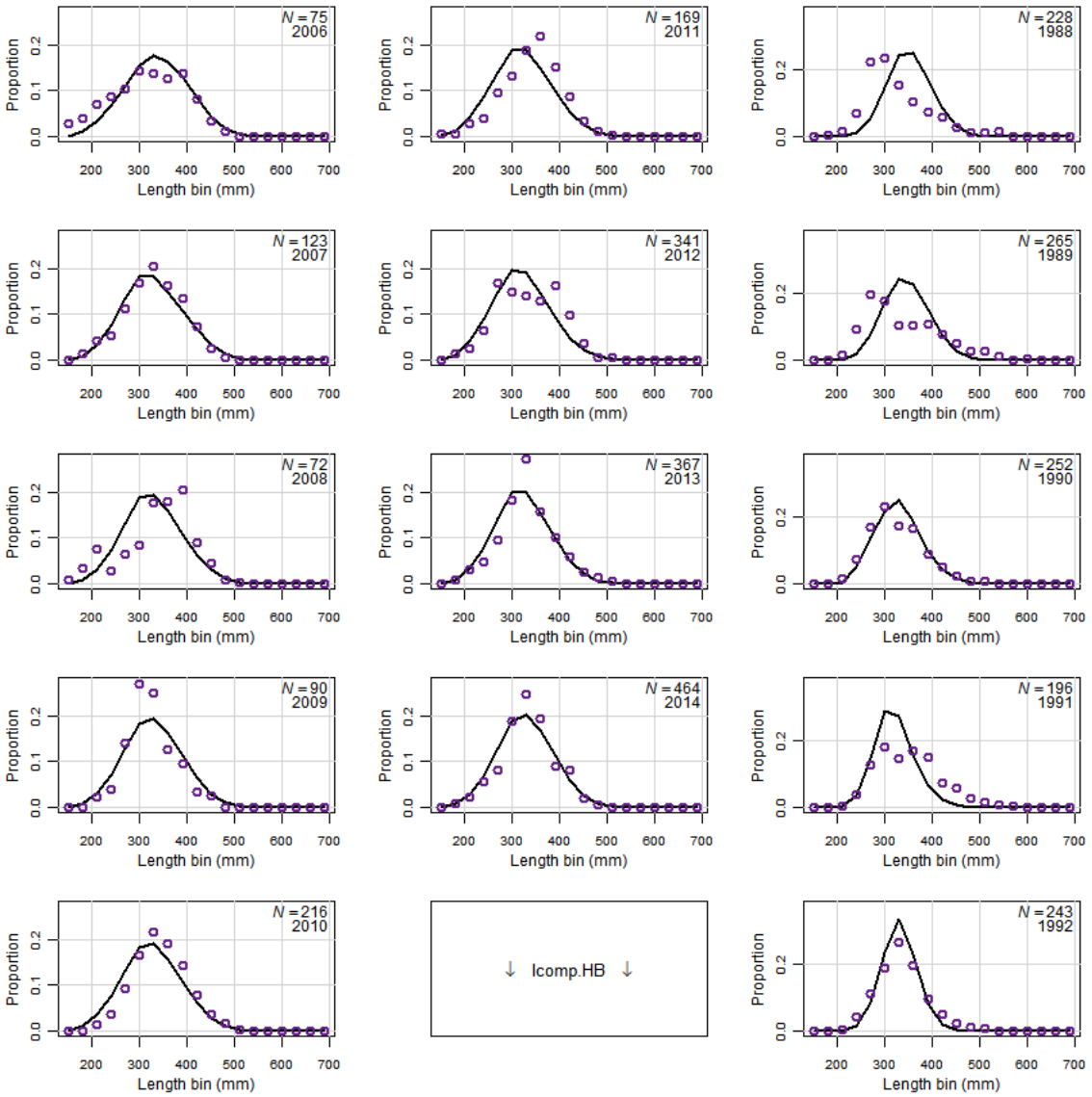
Model Fits: Length Compositions (cont.)

BAM Base Run



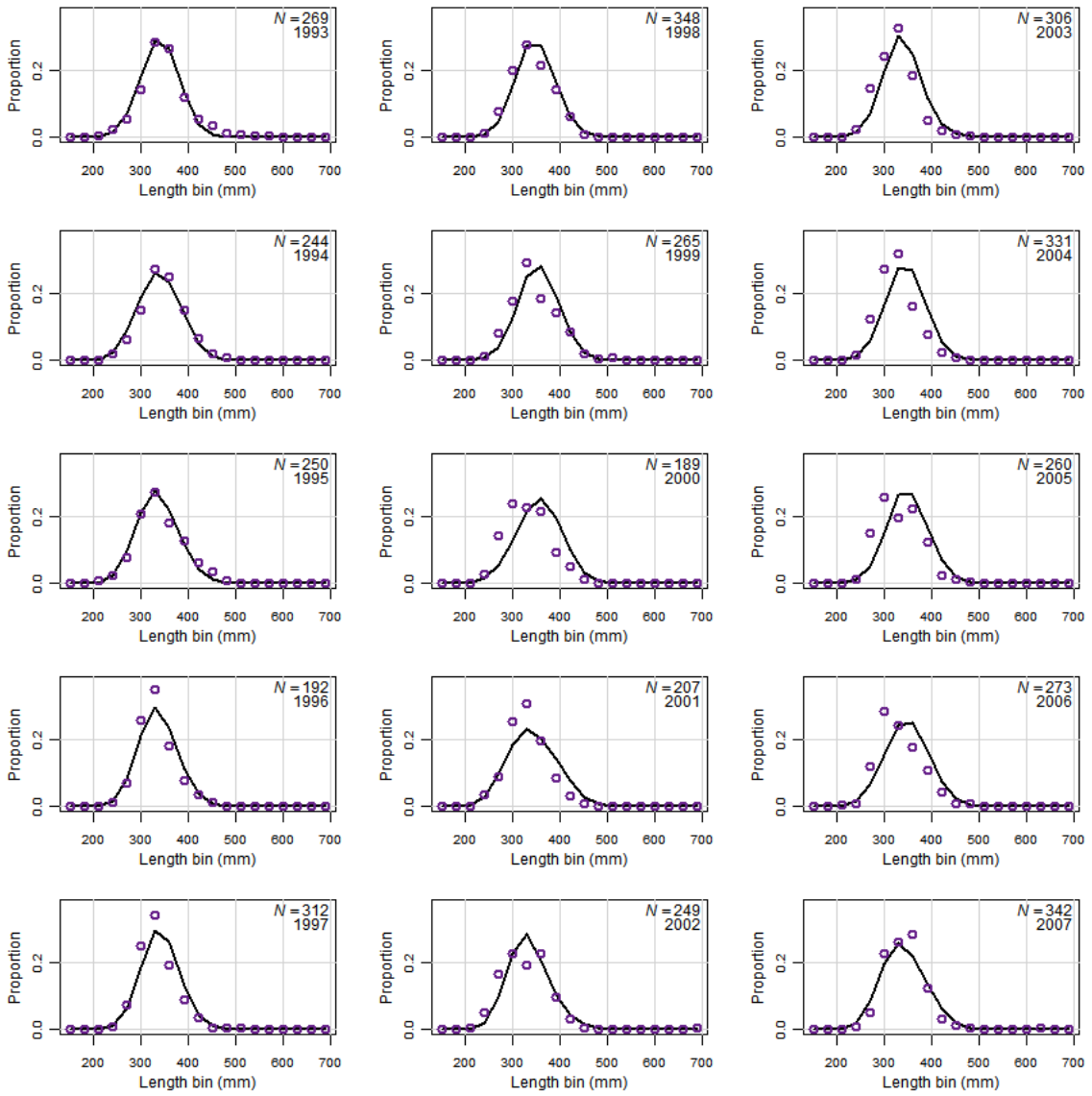
Model Fits: Length Compositions (cont.)

BAM Base Run



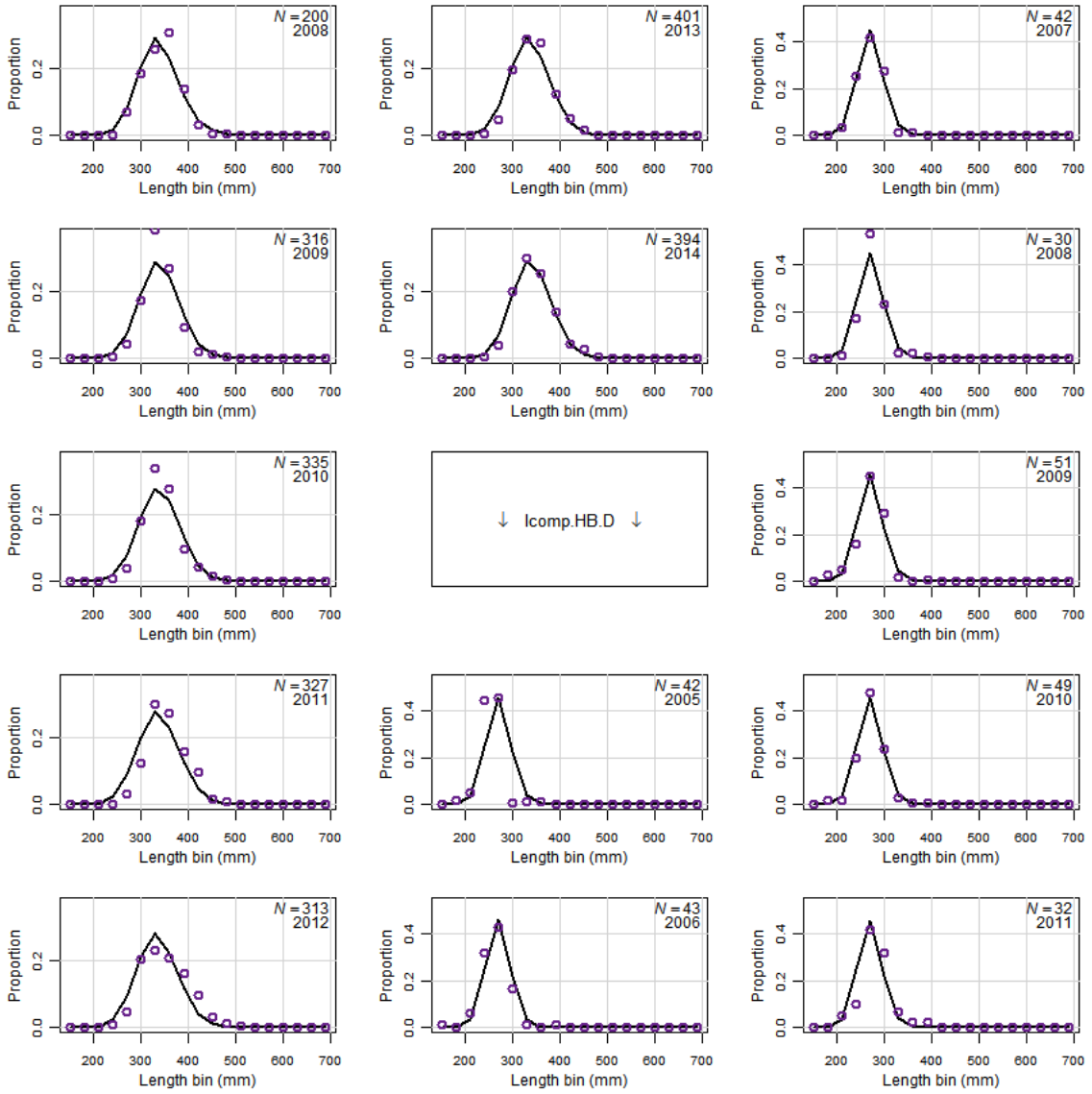
Model Fits: Length Compositions (cont.)

BAM Base Run



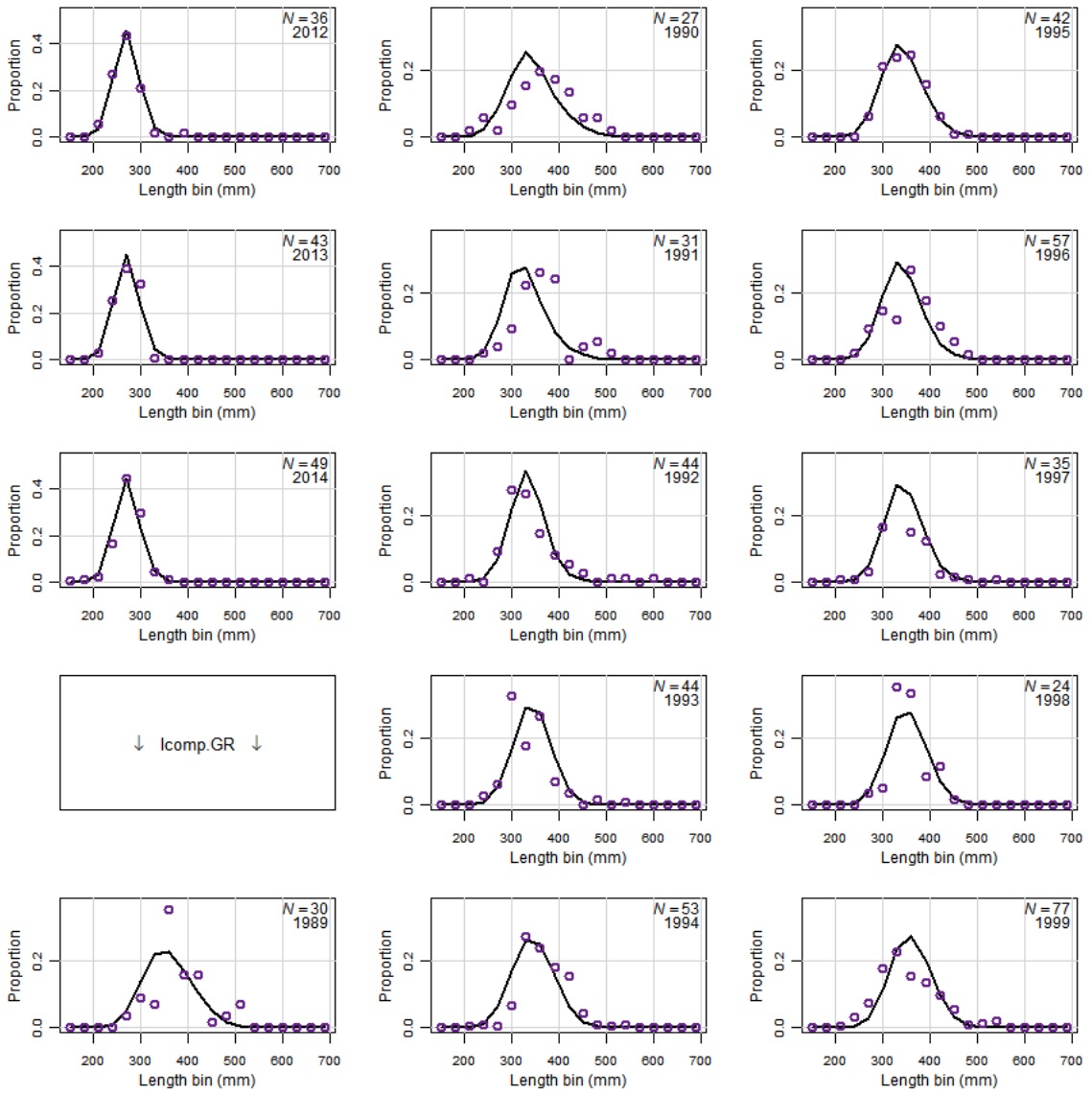
Model Fits: Length Compositions (cont.)

BAM Base Run



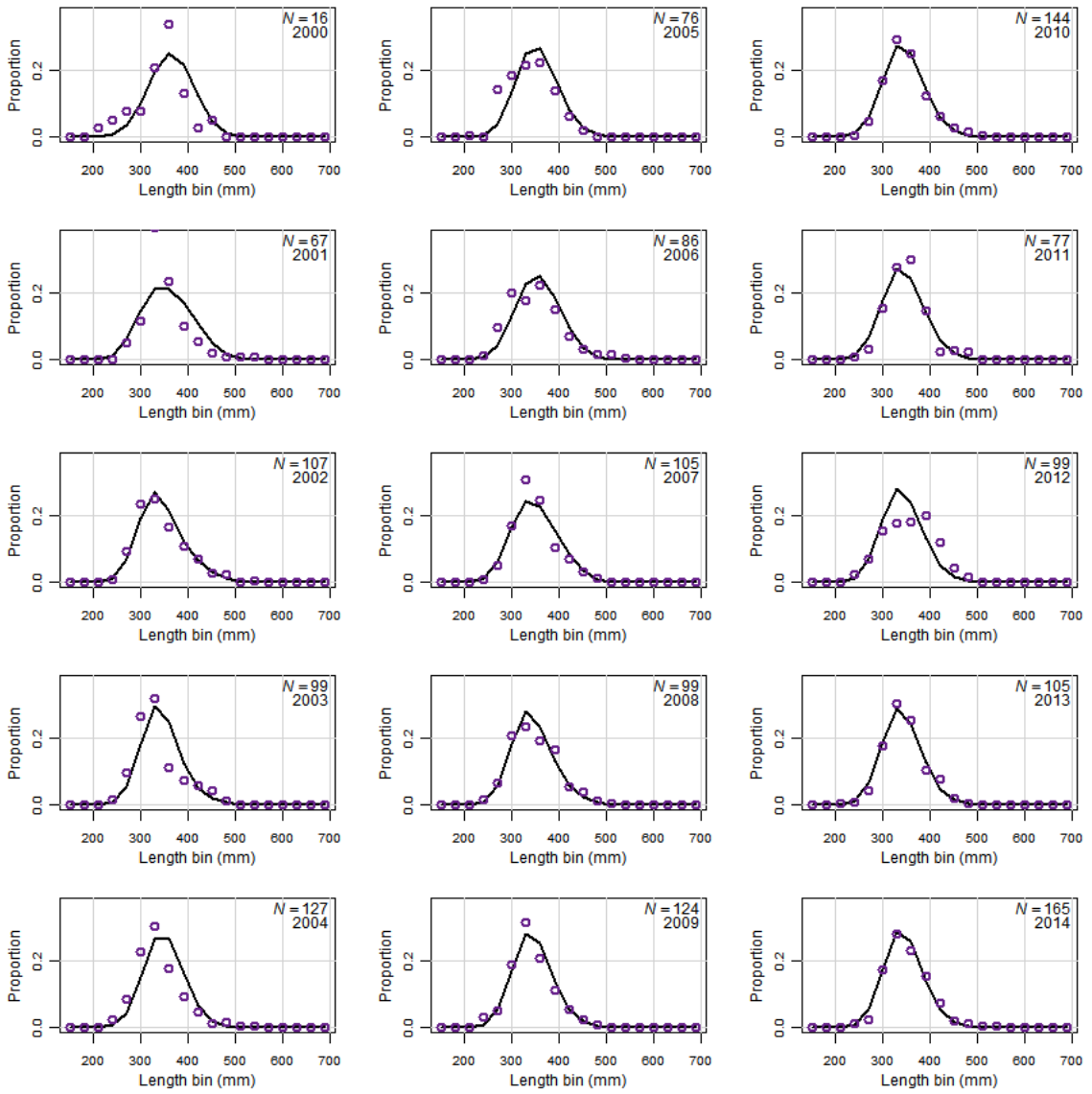
Model Fits: Length Compositions (cont.)

BAM Base Run



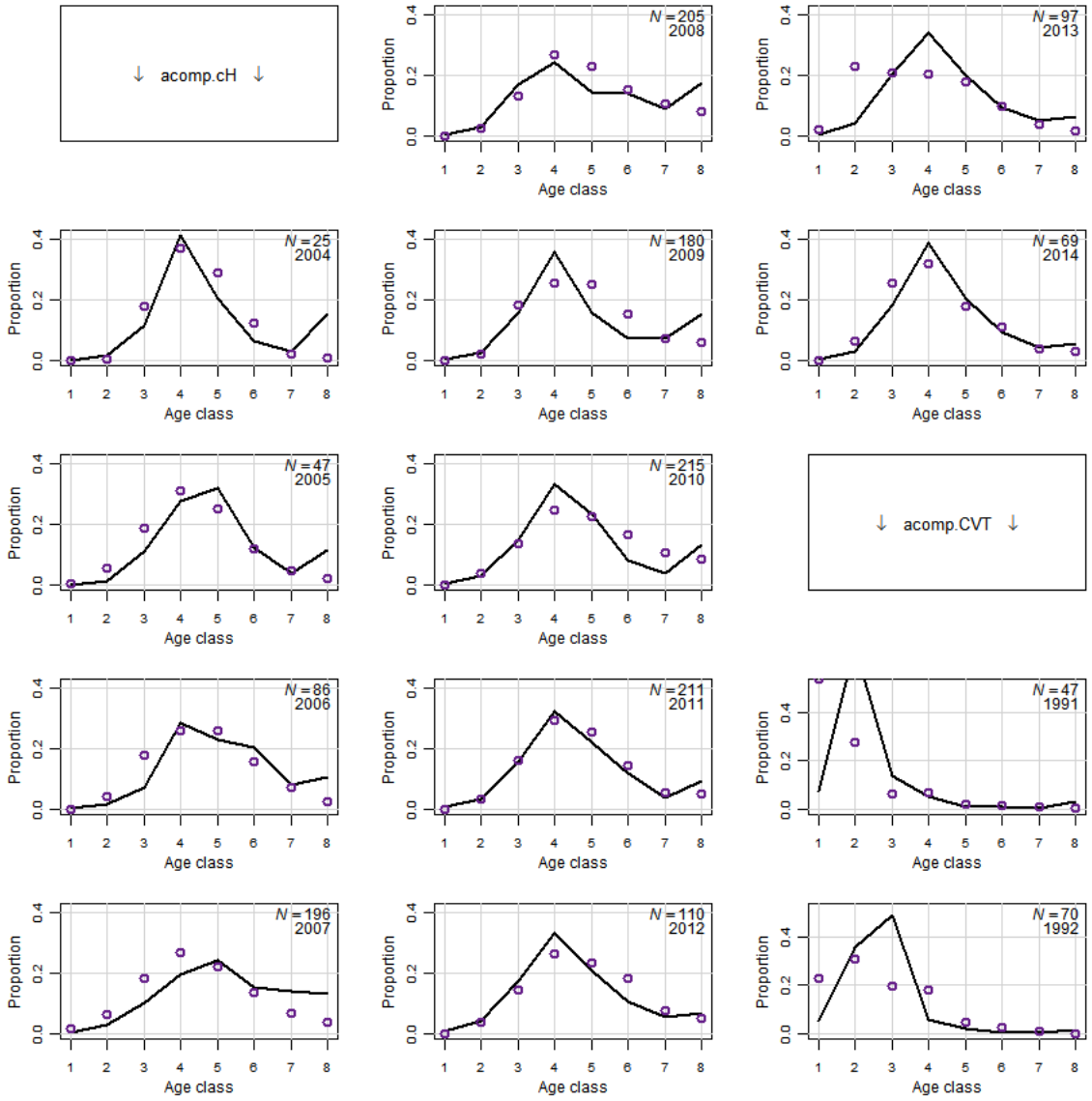
Model Fits: Length Compositions (cont.)

BAM Base Run



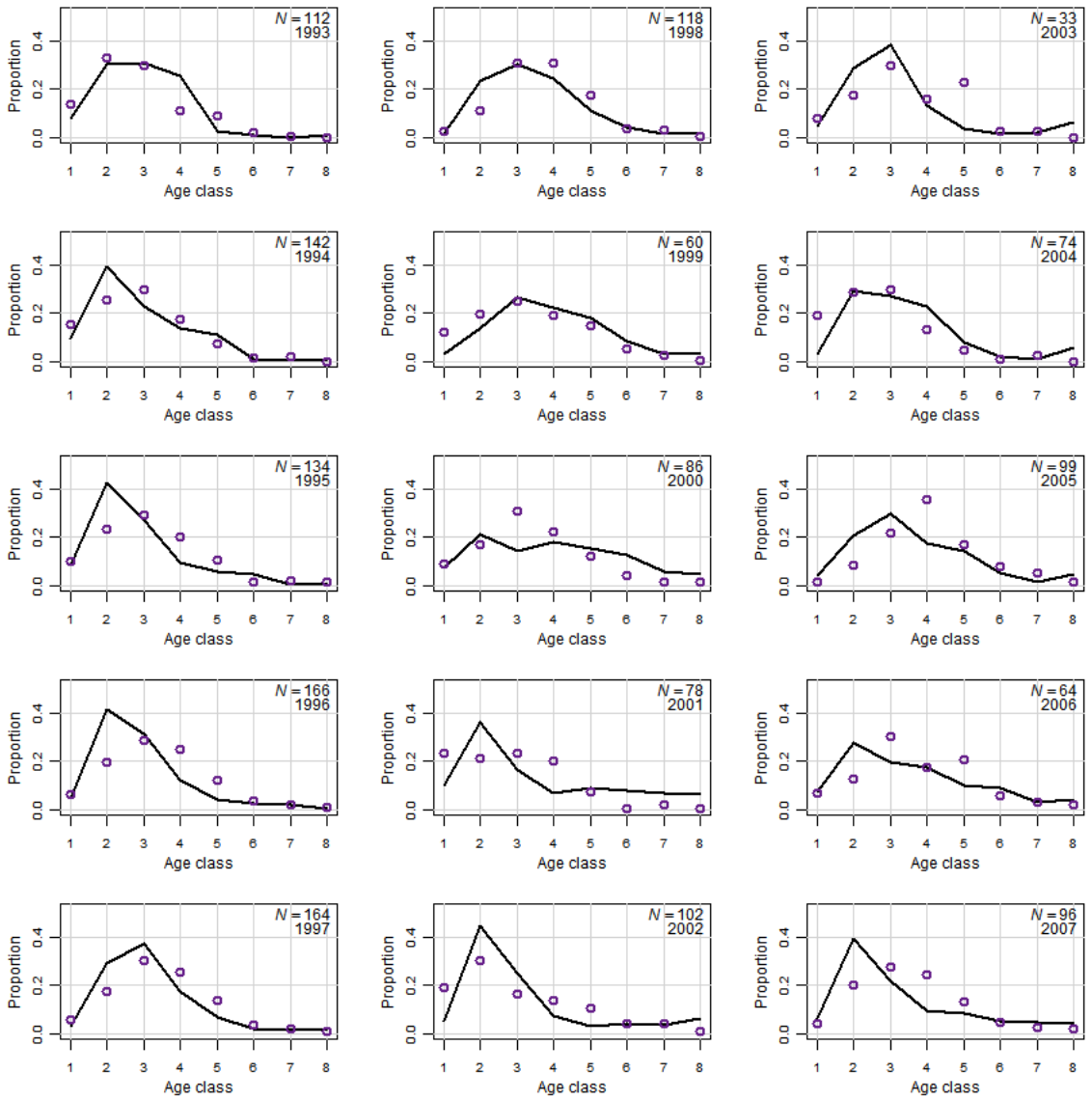
Model Fits: Age Compositions

BAM Base Run



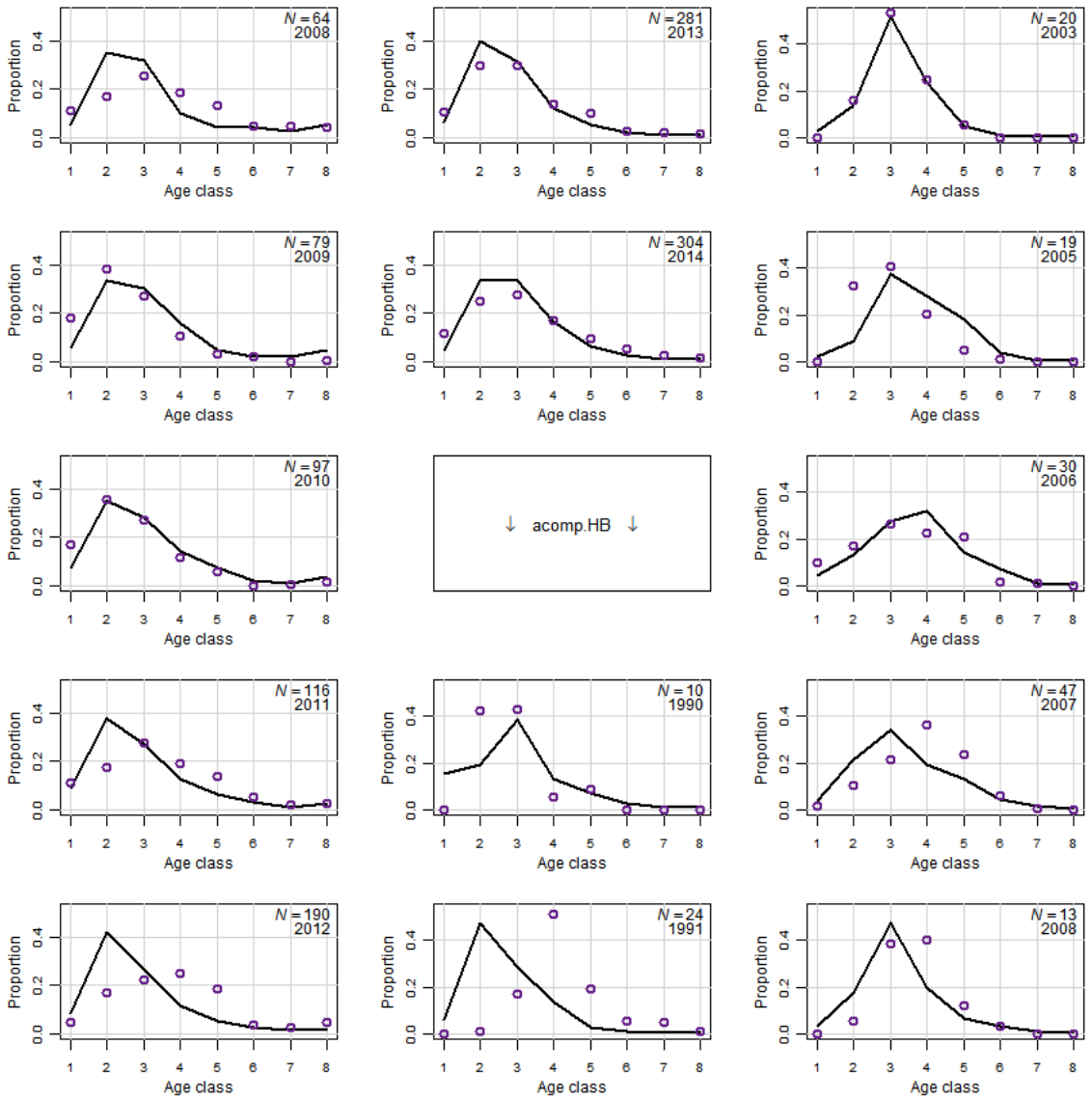
Model Fits: Age Compositions (cont.)

BAM Base Run



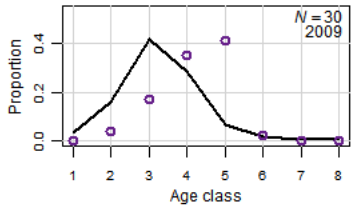
Model Fits: Age Compositions (cont.)

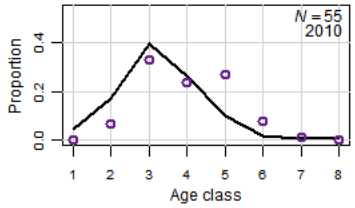
BAM Base Run

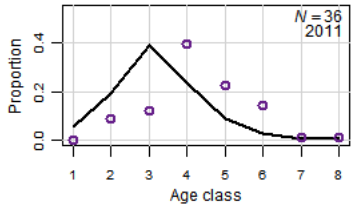


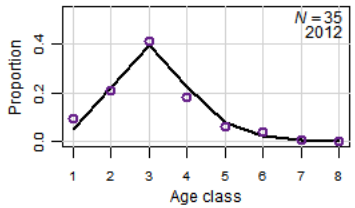
Model Fits: Age Compositions (cont.)

BAM Base Run



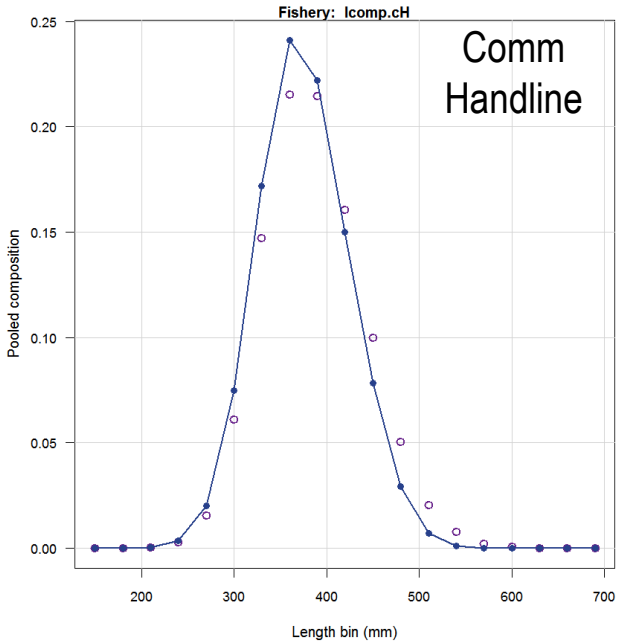


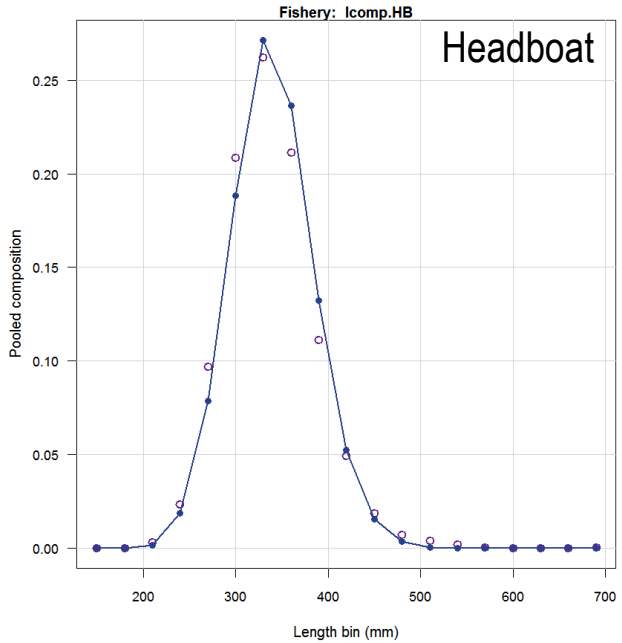


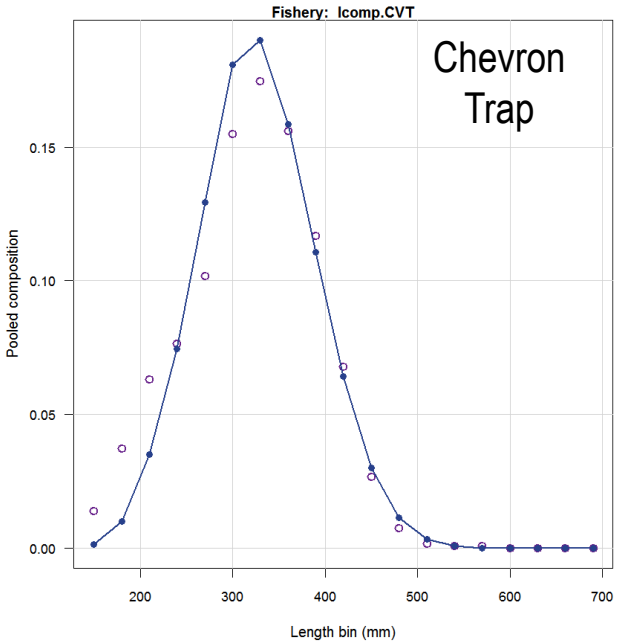


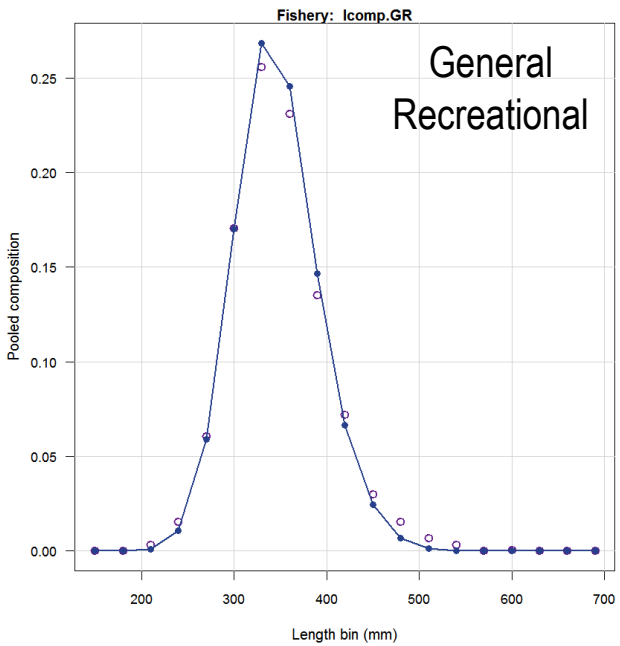
Model Fits: Pooled Length Compositions

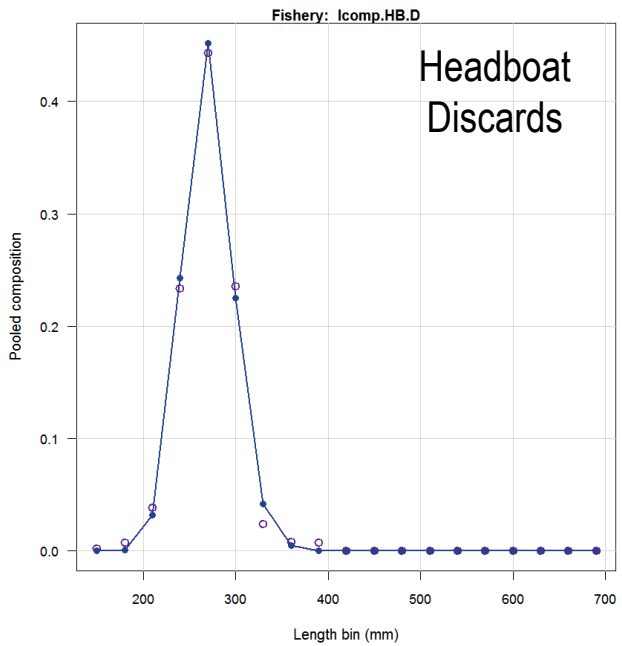
BAM Base Run







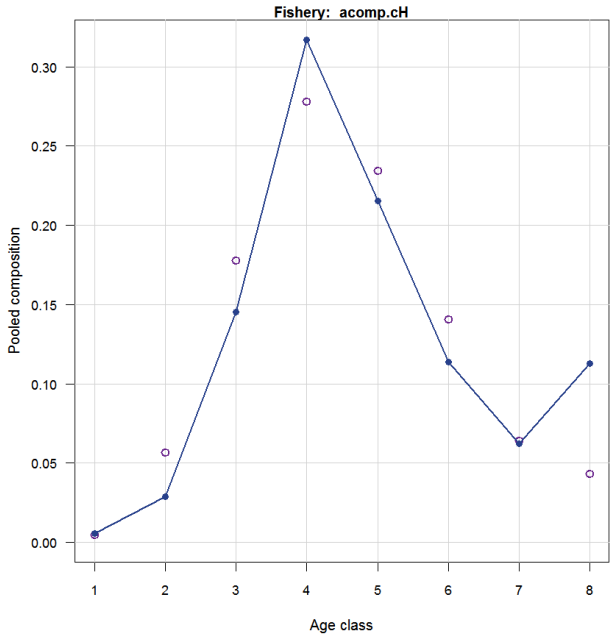




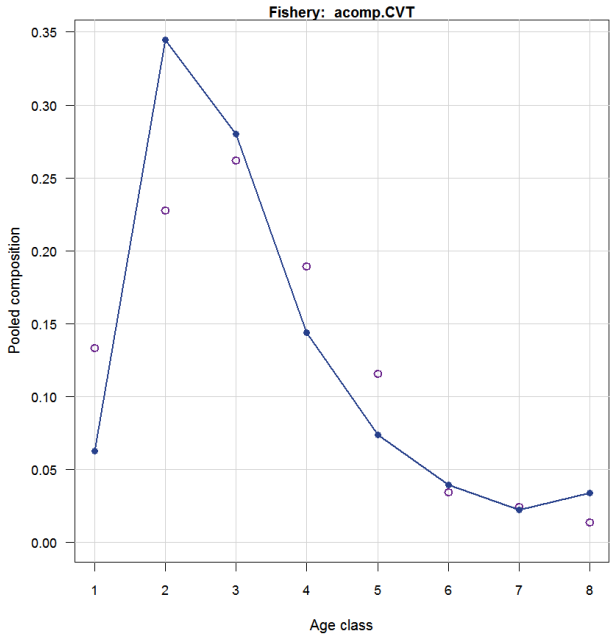
Model Fits: Pooled Age Compositions

BAM Base Run

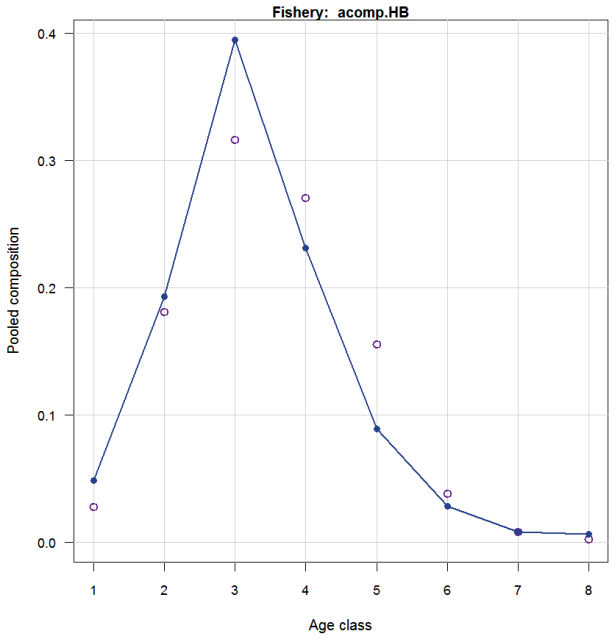
Commercial Handline



Chevron Trap



Headboat

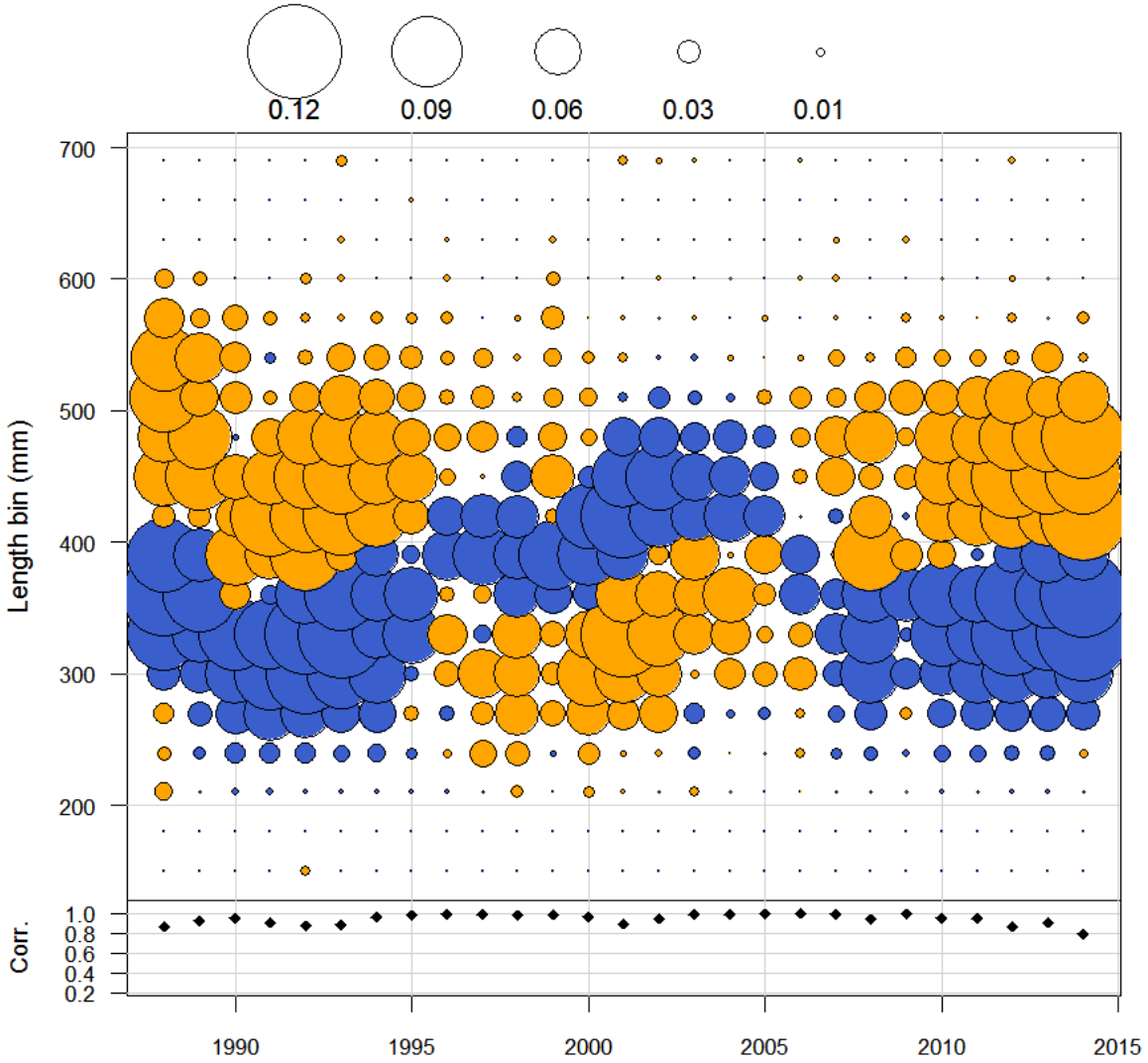


Model Fits: Length Comp Residuals

BAM Base Run

Commercial Handline

Orange=underestimate, Blue=overestimate



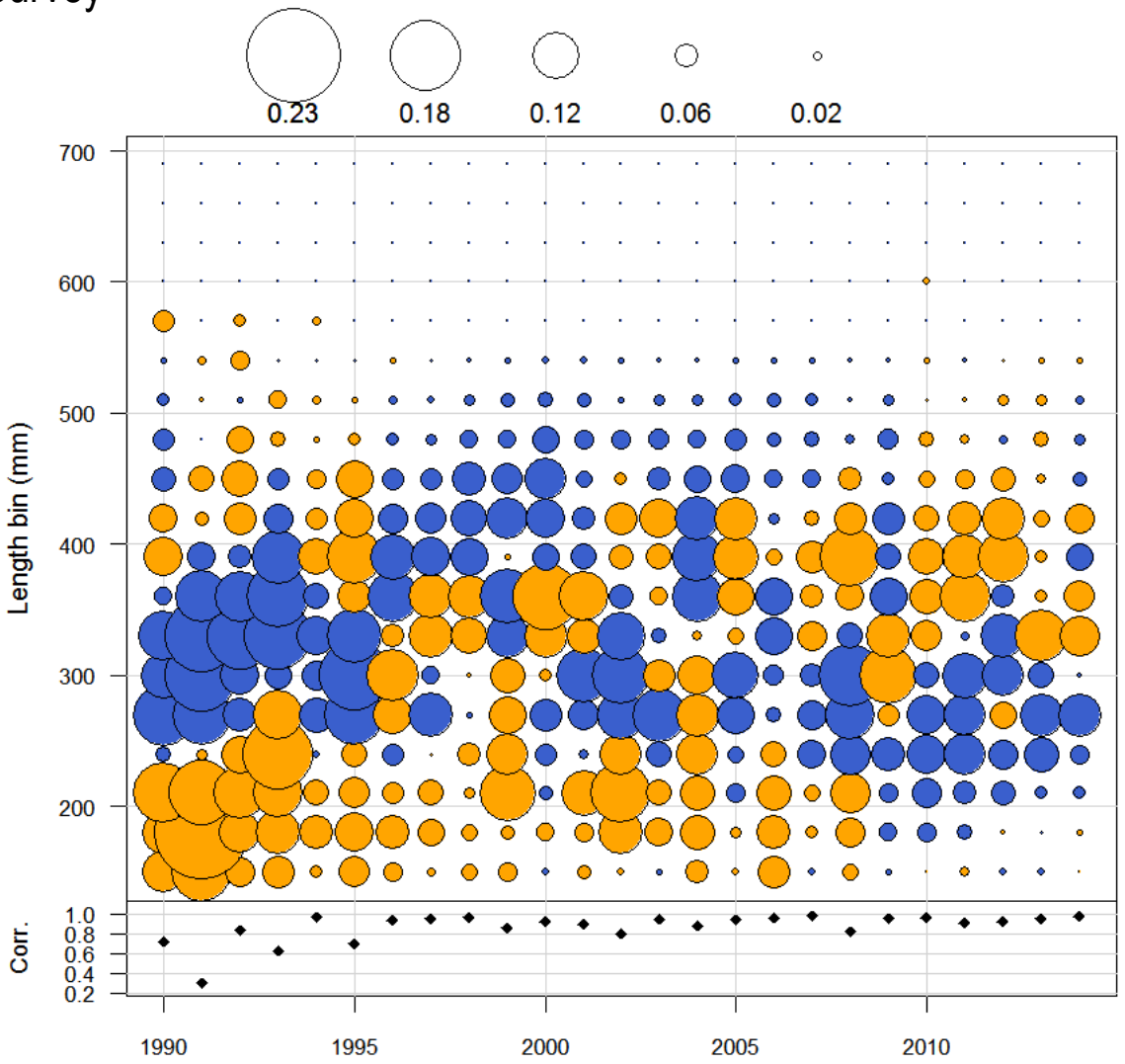
Slight residual pattern
Opposite to expected effect of a size limit

Model Fits: Length Comp Residuals

BAM Base Run

Chevron Trap Survey

Orange=underestimate, Blue=overestimate

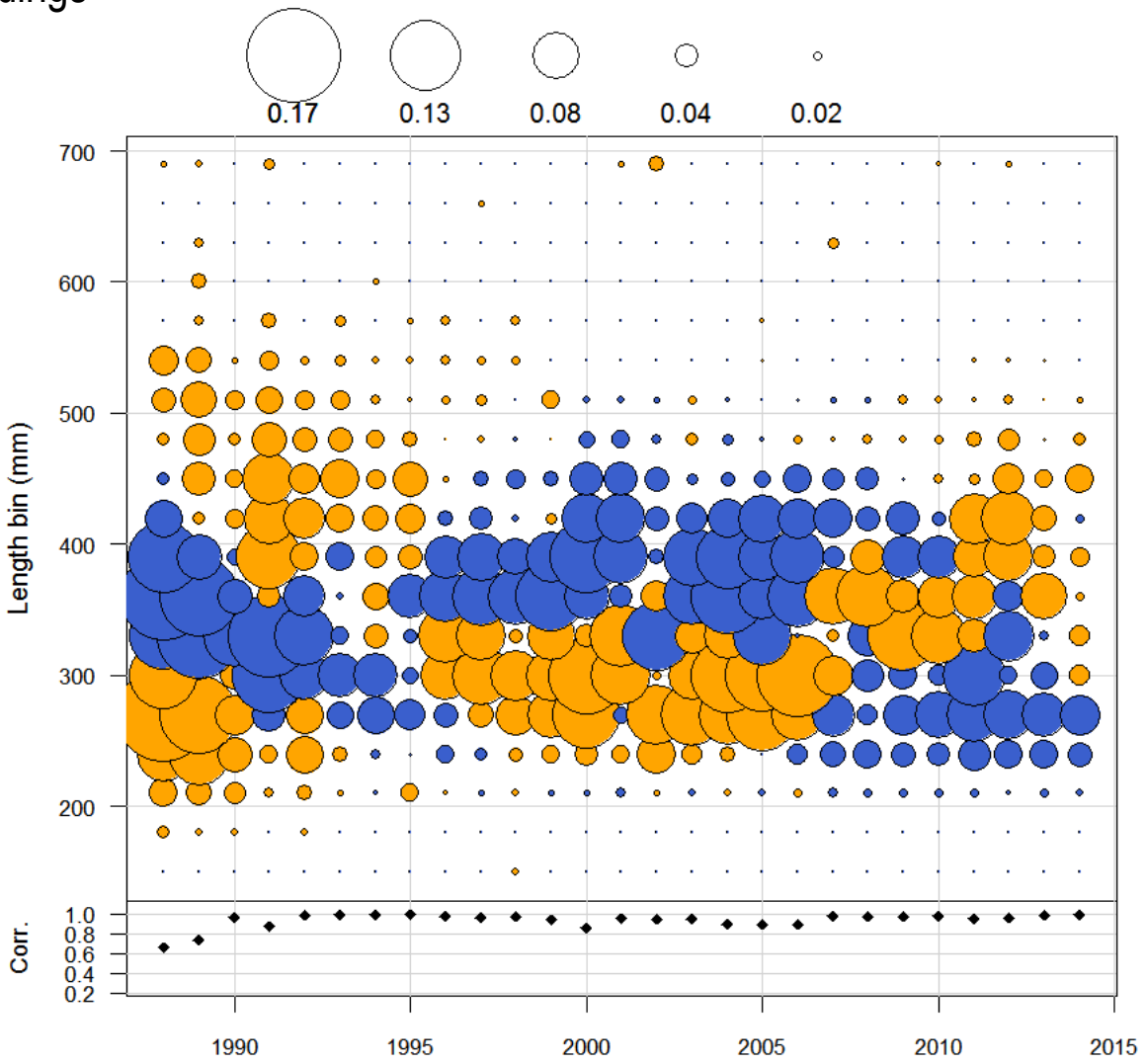


Model Fits: Length Comp Residuals

BAM Base Run

Headboat Landings

Orange=underestimate, Blue=overestimate

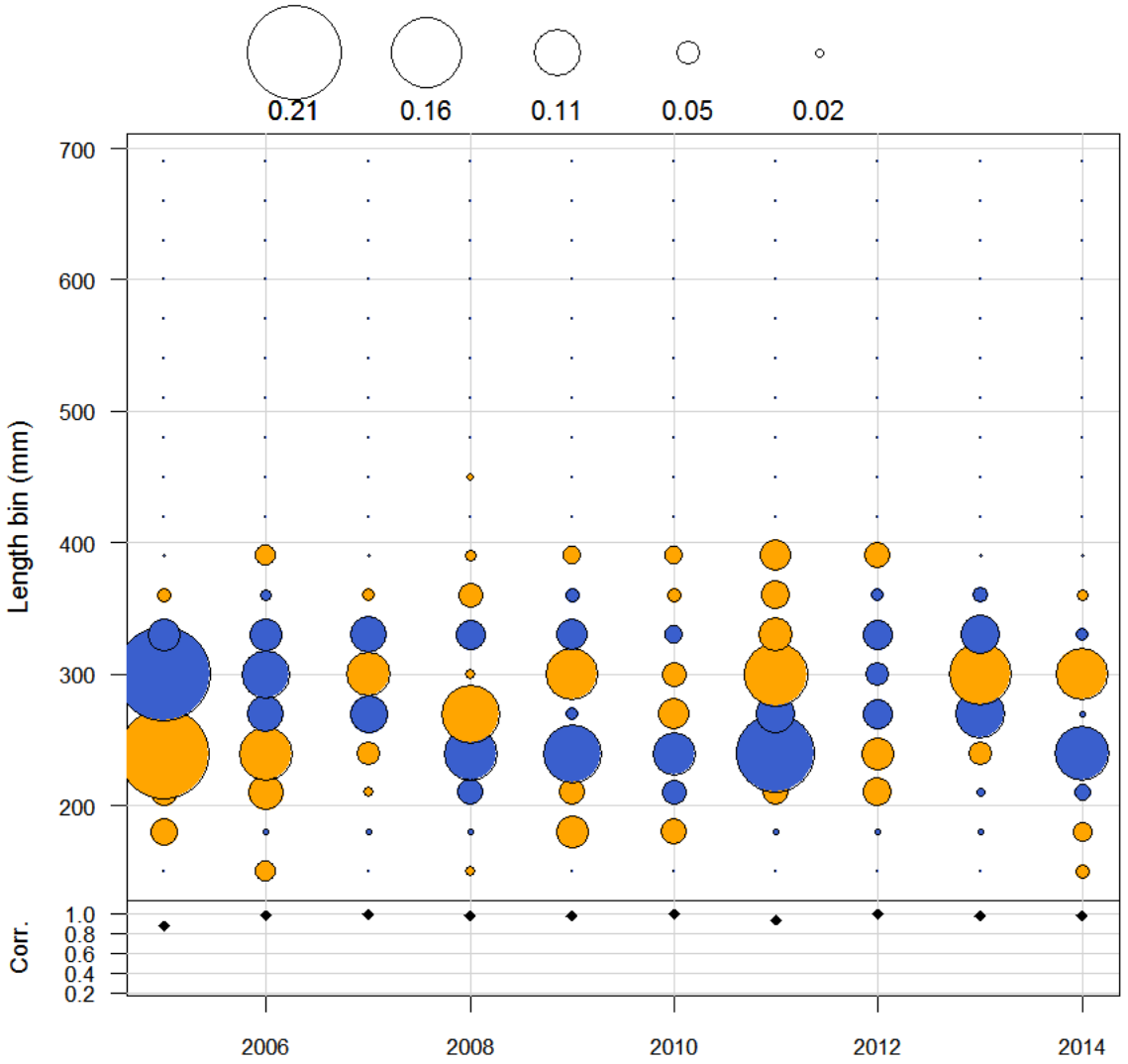


Model Fits: Length Comp Residuals

BAM Base Run

Headboat Discards

Orange=underestimate, Blue=overestimate

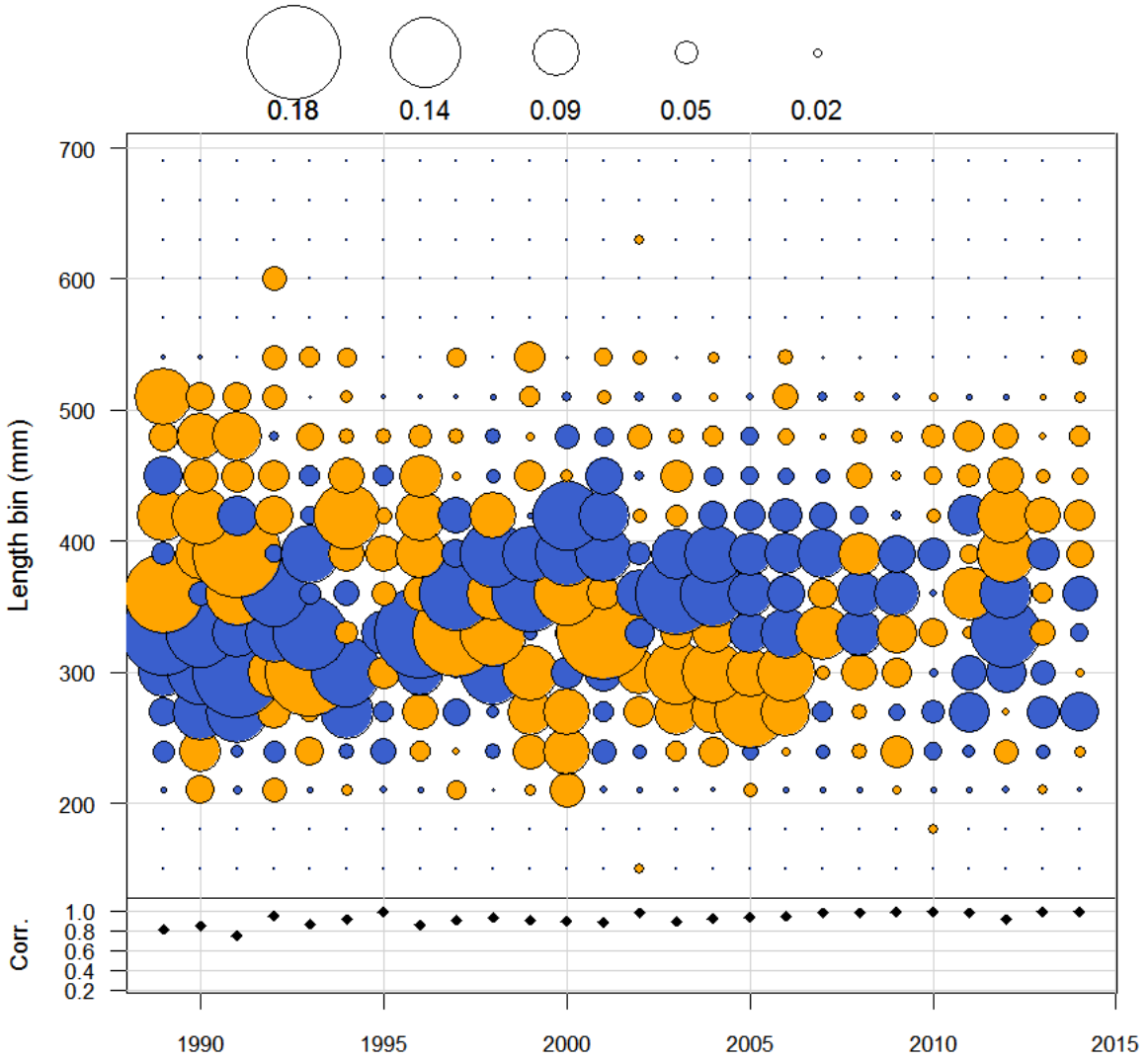


Model Fits: Length Comp Residuals

BAM Base Run

General Recreational

Orange=underestimate, Blue=overestimate

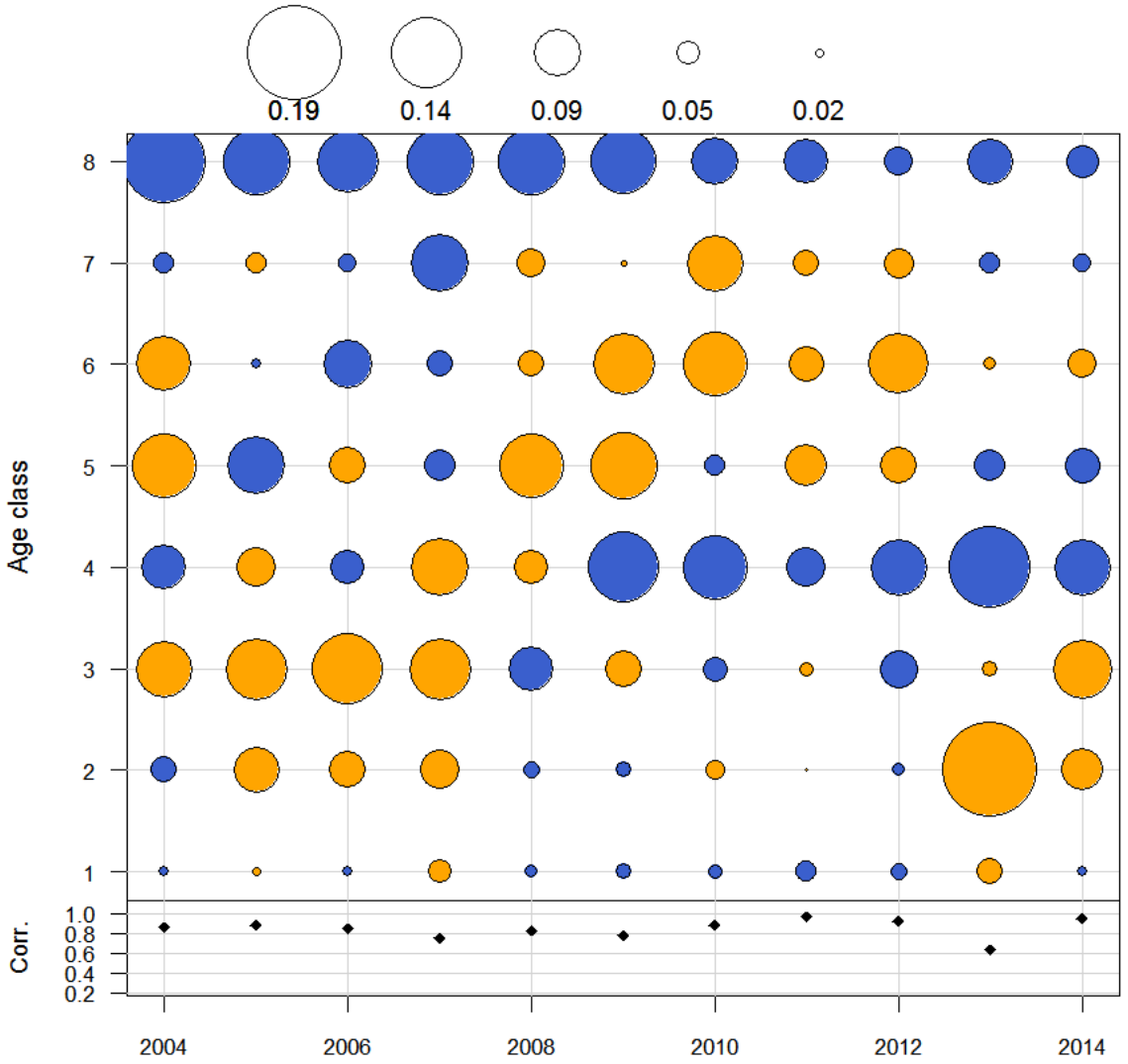


Model Fits: Age Comp Residuals

BAM Base Run

Commercial Handline

Orange=underestimate, Blue=overestimate

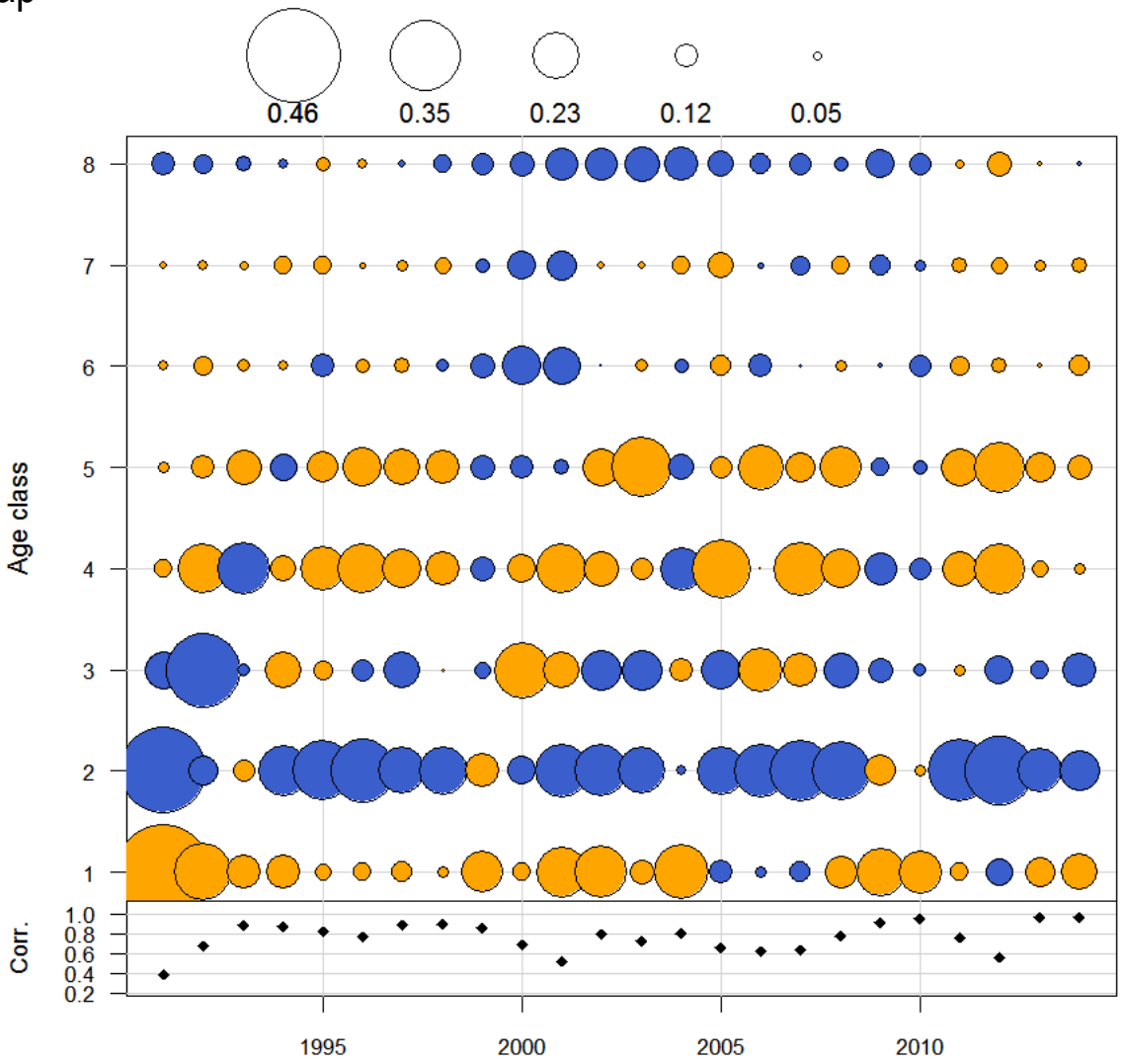


Model Fits: Age Comp Residuals

BAM Base Run

Chevron Trap

Orange=underestimate, Blue=overestimate

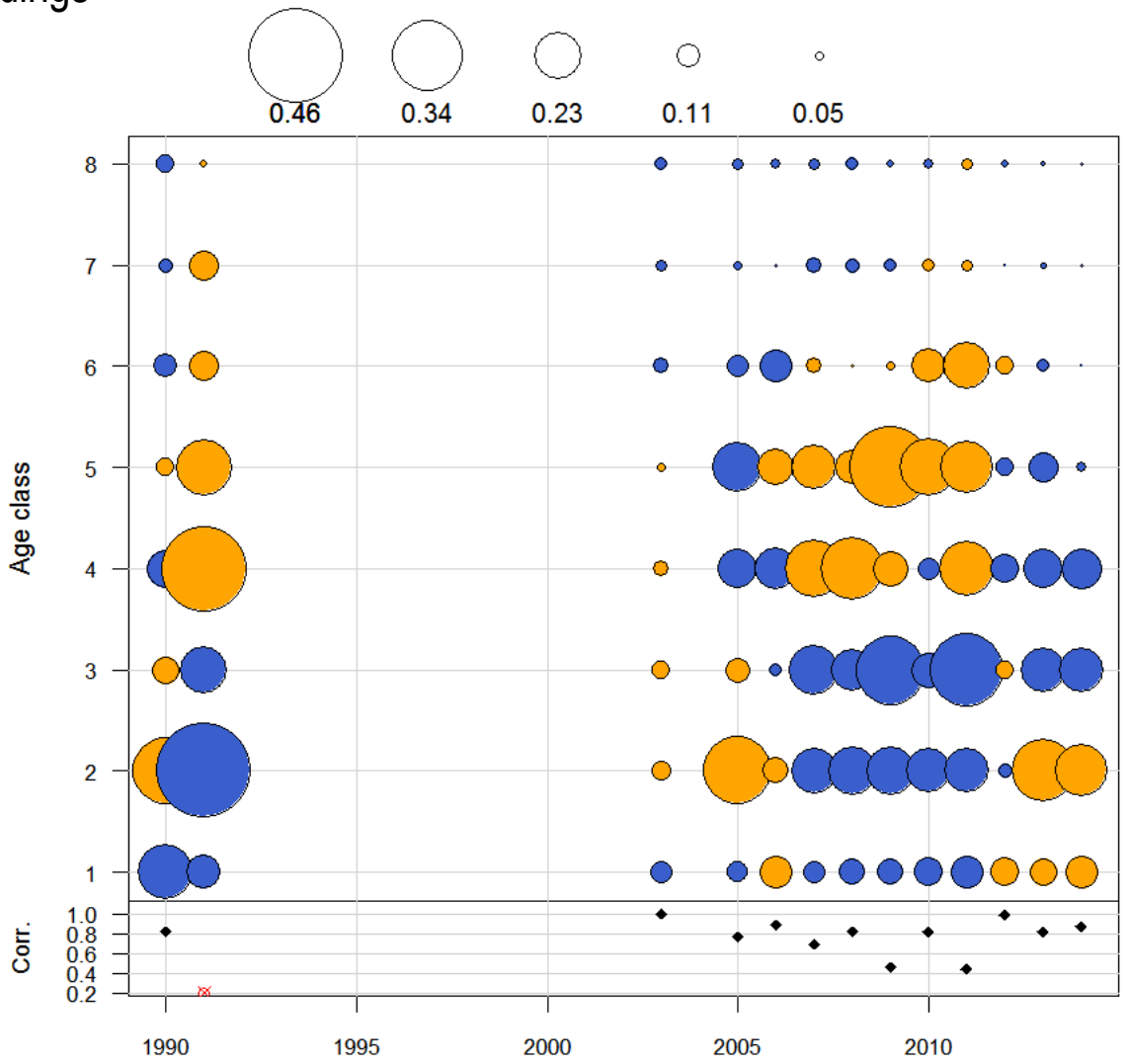


Model Fits: Age Comp Residuals

BAM Base Run

Headboat Landings

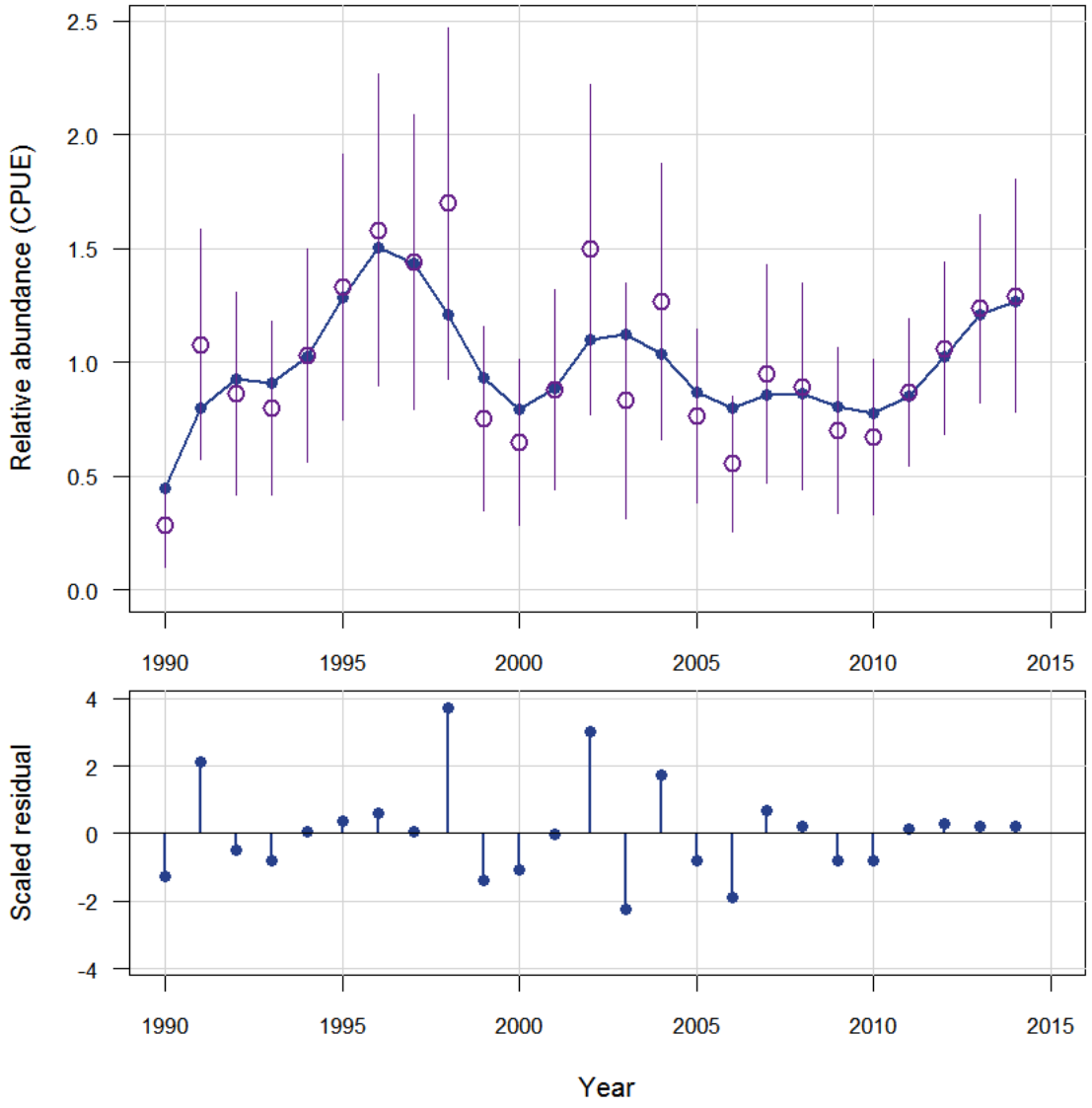
Orange=underestimate, Blue=overestimate



Model Fits: Indices

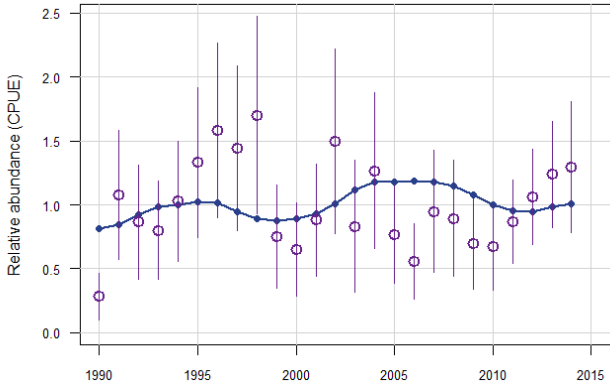
BAM Base Run

SERFS Fishery Independent Trap-Video Index (1990-2014)

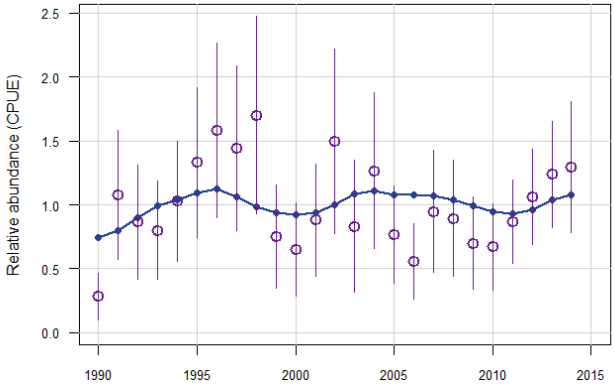


Alternative Index Wgts

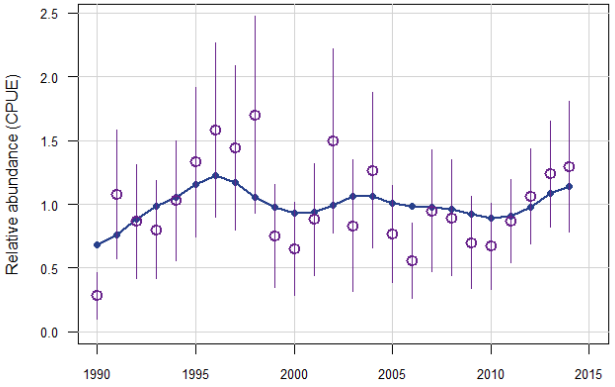
No upweighting



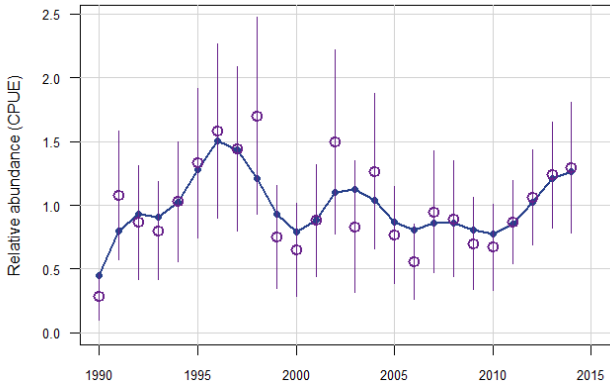
2X upweighting



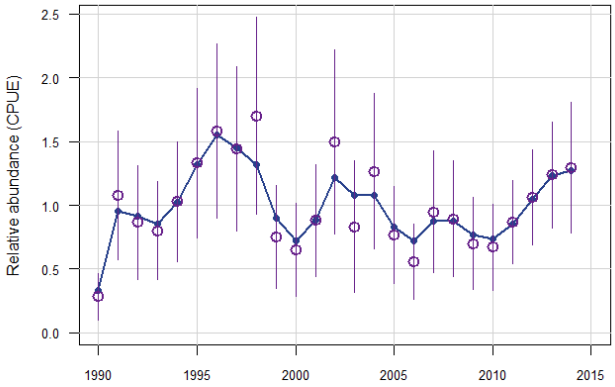
4X upweighting



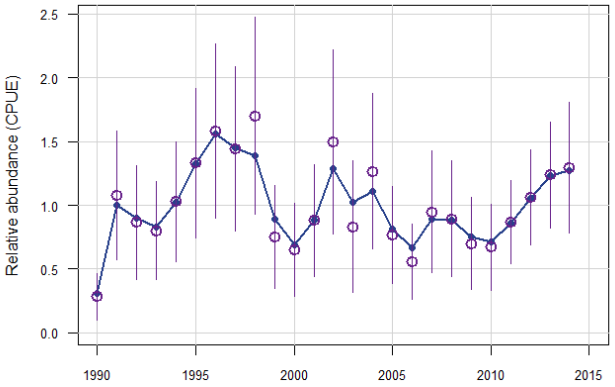
6X upweighting



8X upweighting

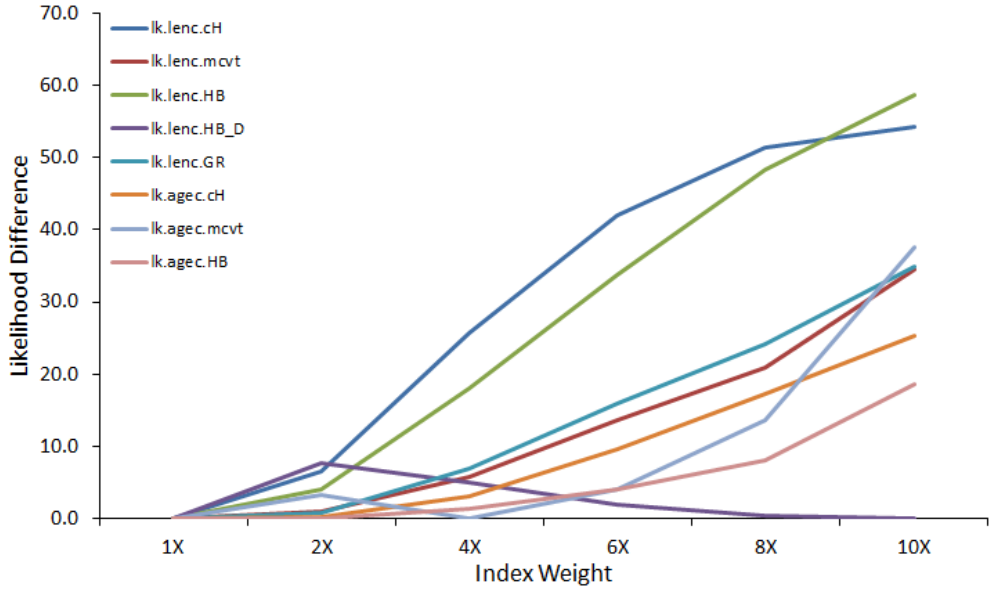


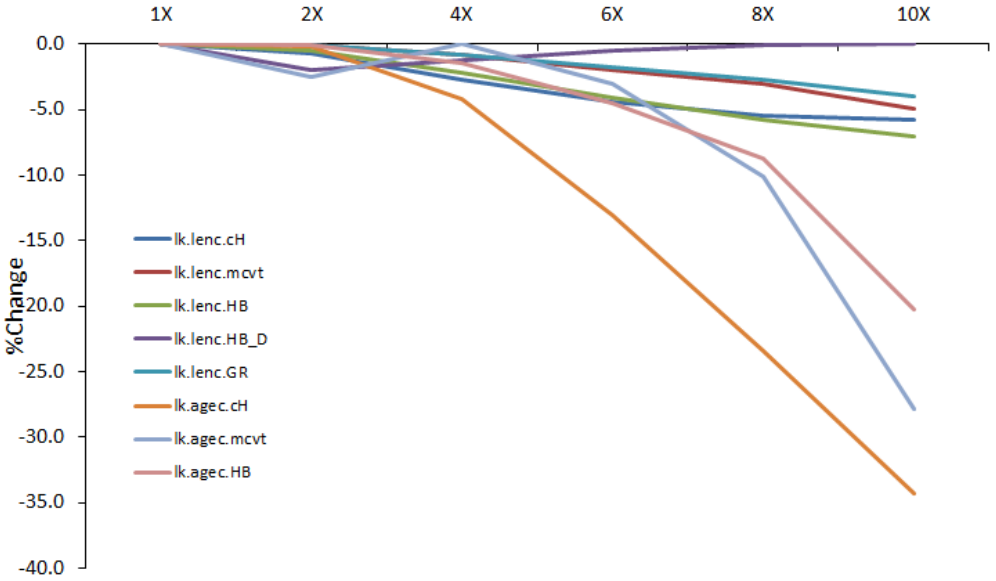
10X upweighting



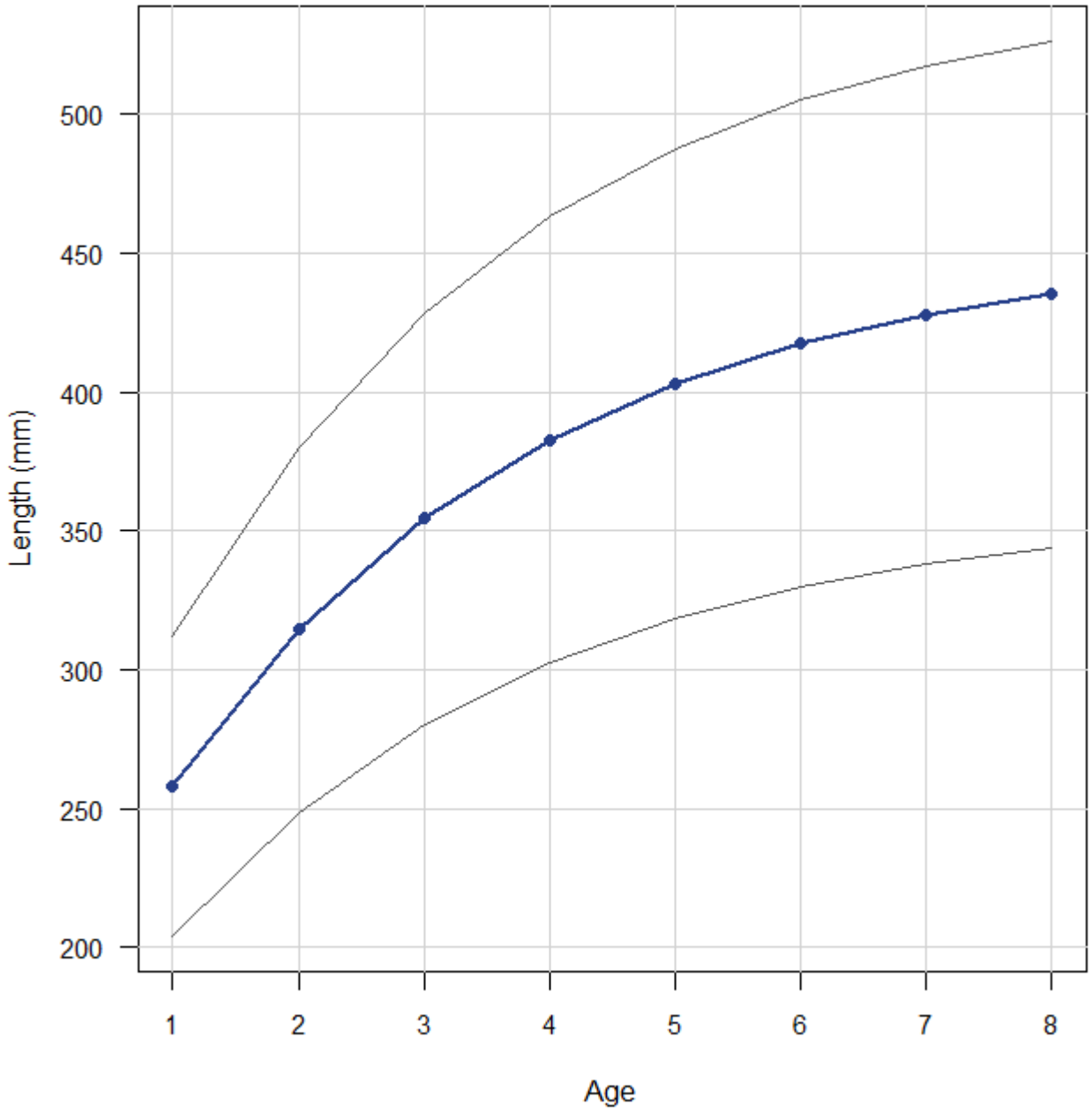
AW recommendation: Upweight 6X

Index Weighting

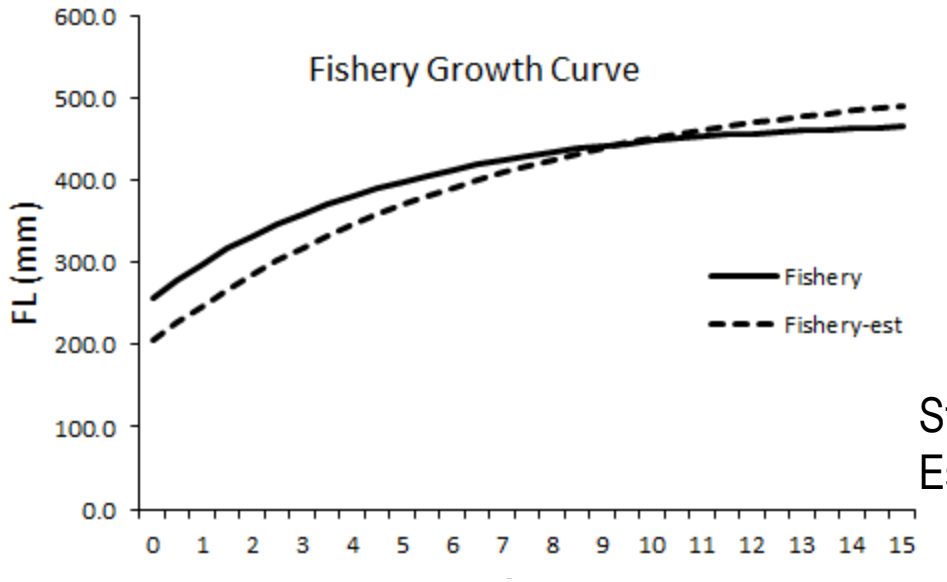




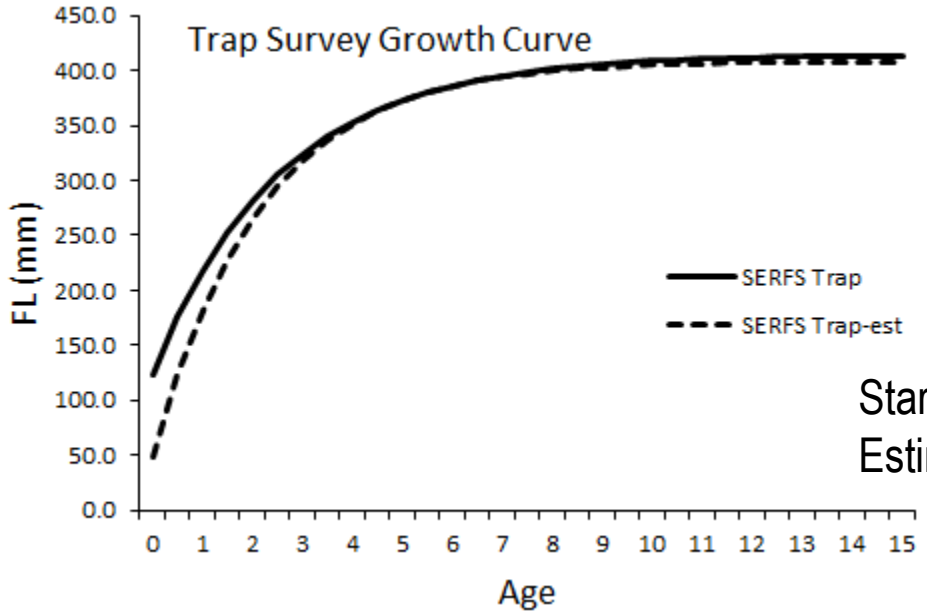
Model Outputs


Length (mm)
500
450
400
350
300
250
200
1
2
3
4
5
6
7
8
Age

Estimated Growth Curves



Starting: len_cv=0.096
Estimated: len_cv = 0.088

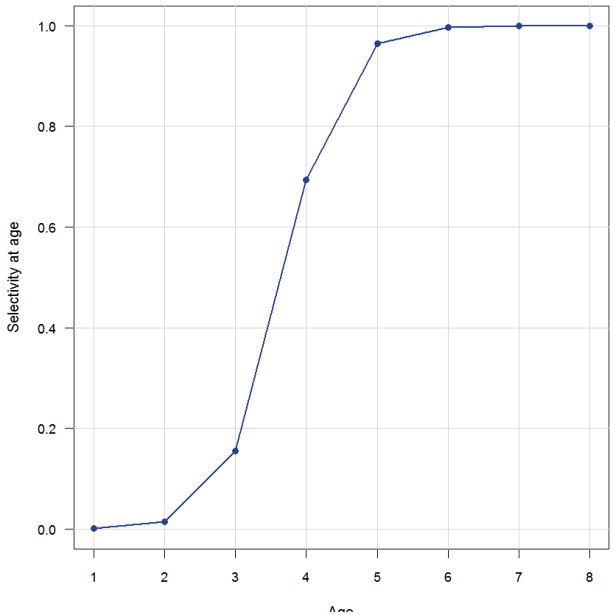


Starting: len_cv = 0.110
Estimated: len_cv = 0.132

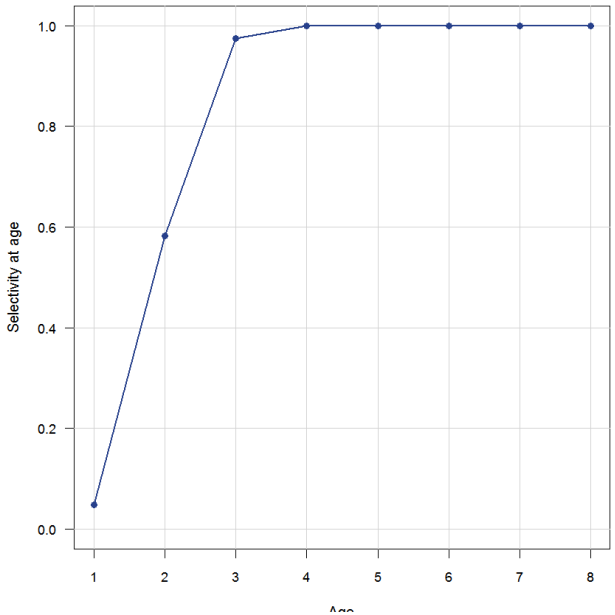
Model Outputs: Selectivity

BAM Base Run

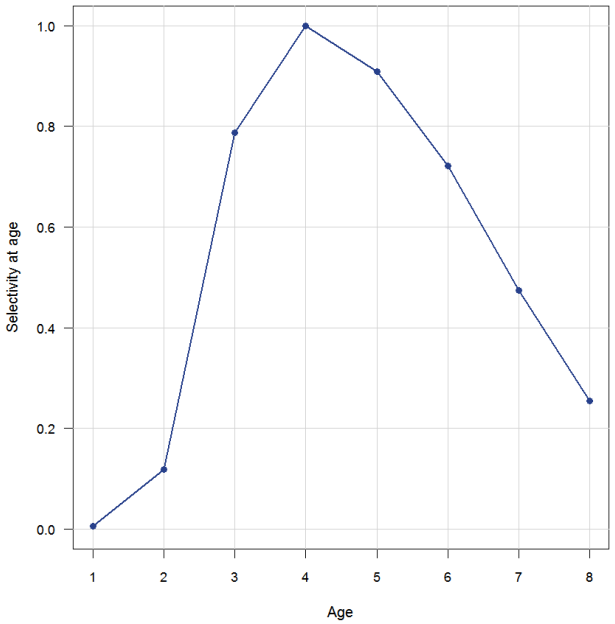
Commercial Handline

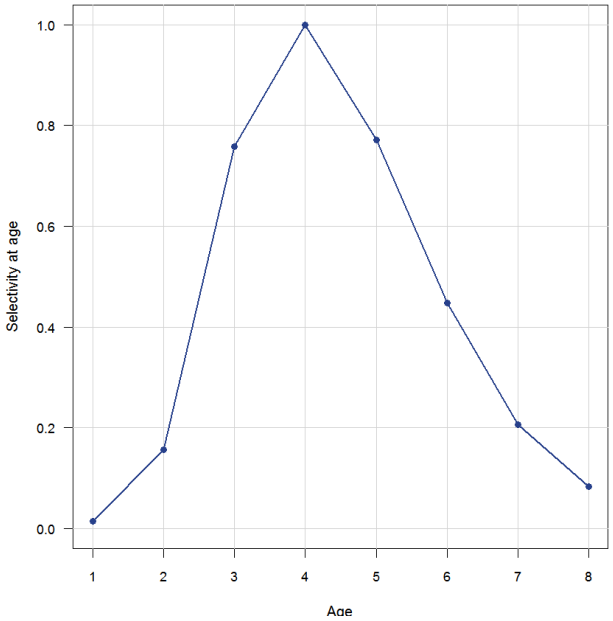


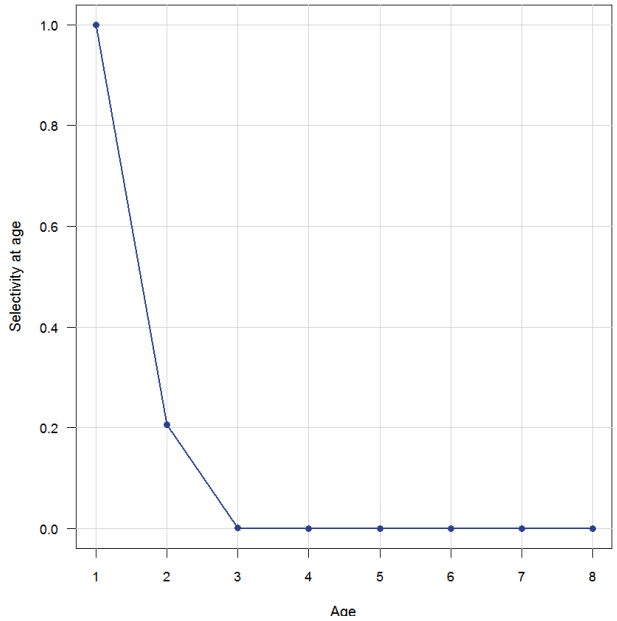
Chevron Trap



General Recreational



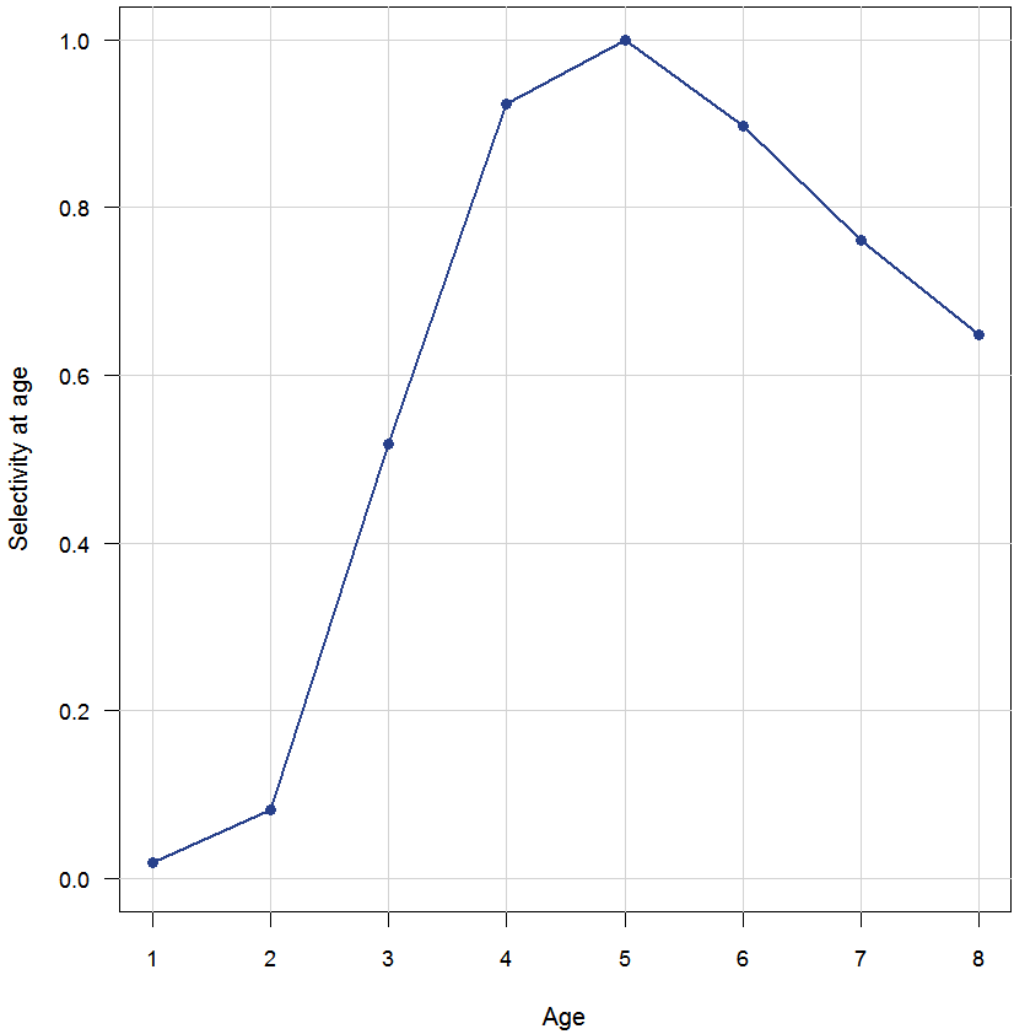




Model Outputs: Selectivity

BAM Base Run

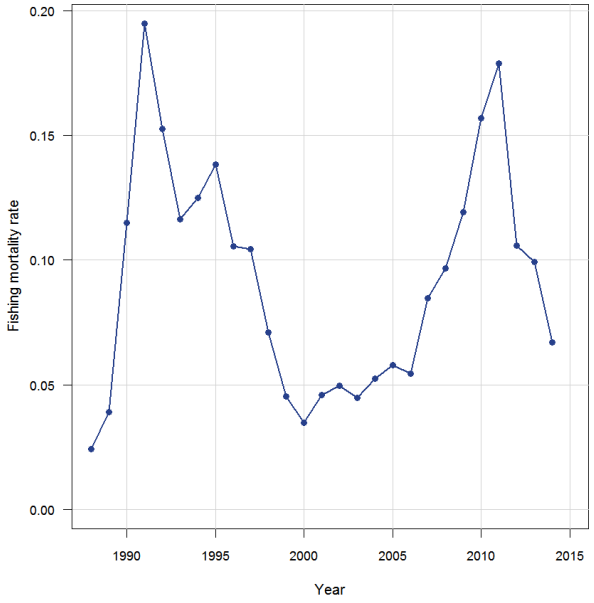
- Average selectivity in terminal assessment yr (2014)
- Weighted by geometric mean F in last 3 yrs
- Used to compute benchmarks and in projections



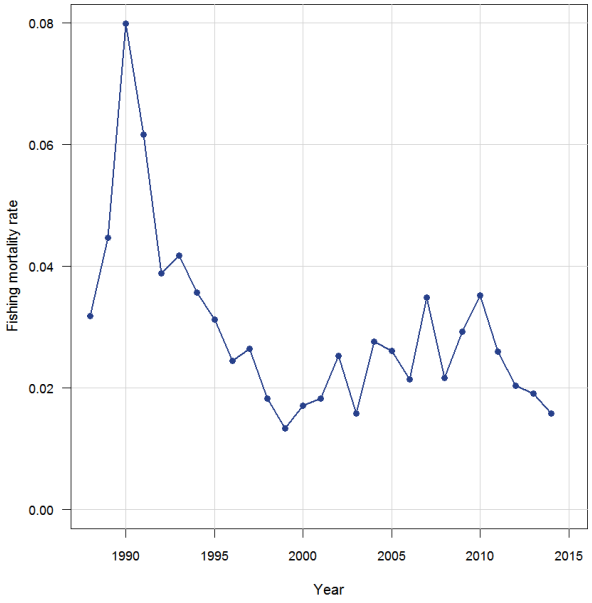
Model Outputs: Fishing Mortality

BAM Base Run

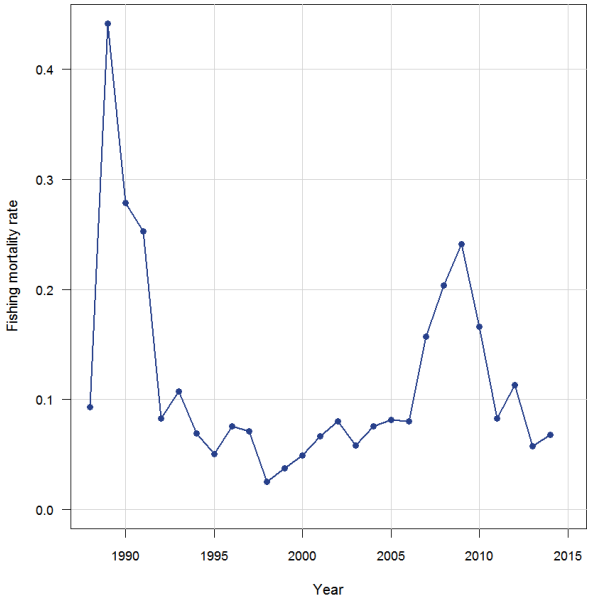
Commercial handline



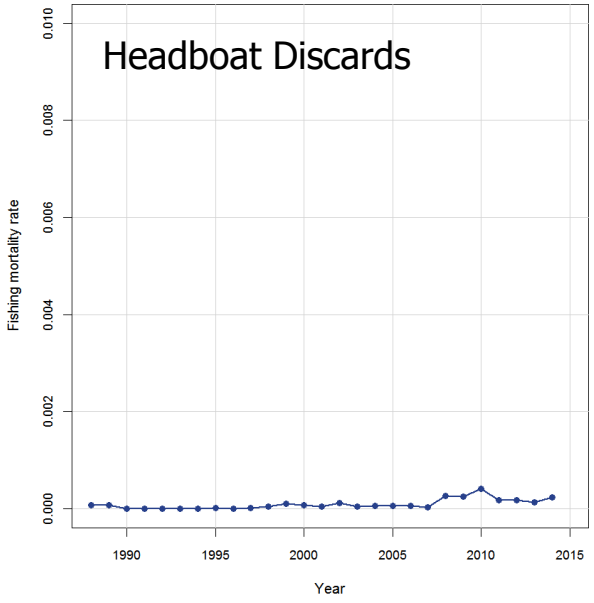
Headboat



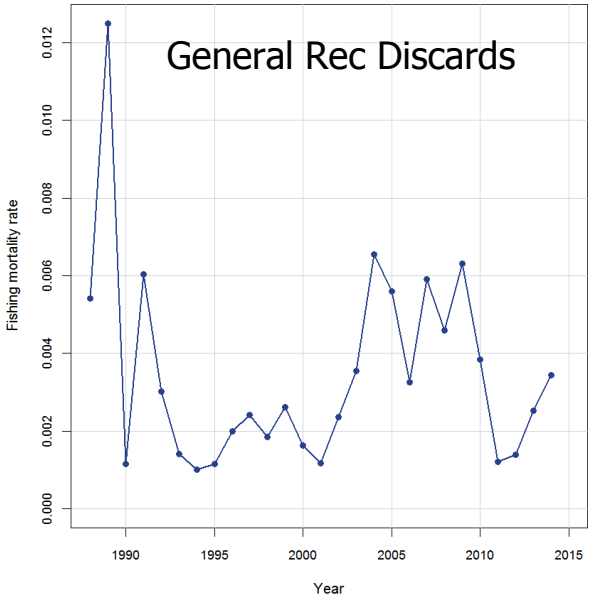
General Recreational



Headboat Discards



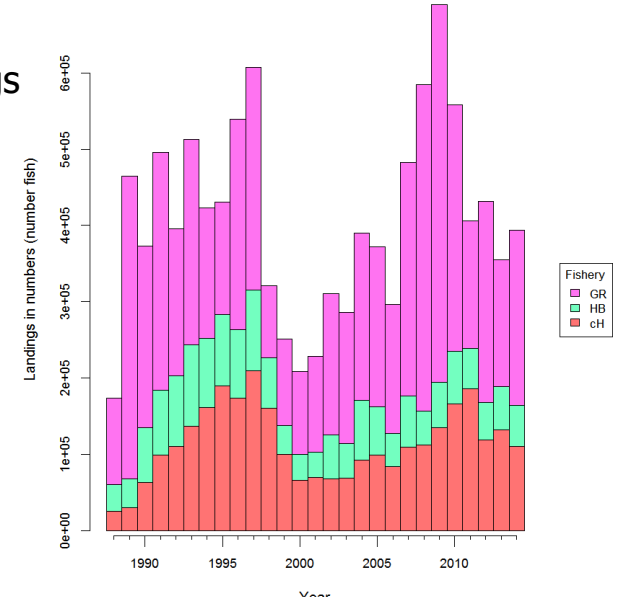
General Rec Discards



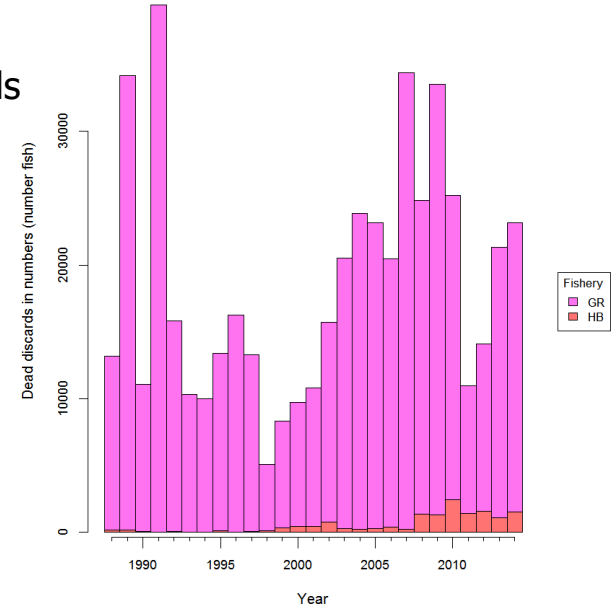
Model Outputs: Landings & Fishing Mortality BAM Base Run

Removals by Fishery

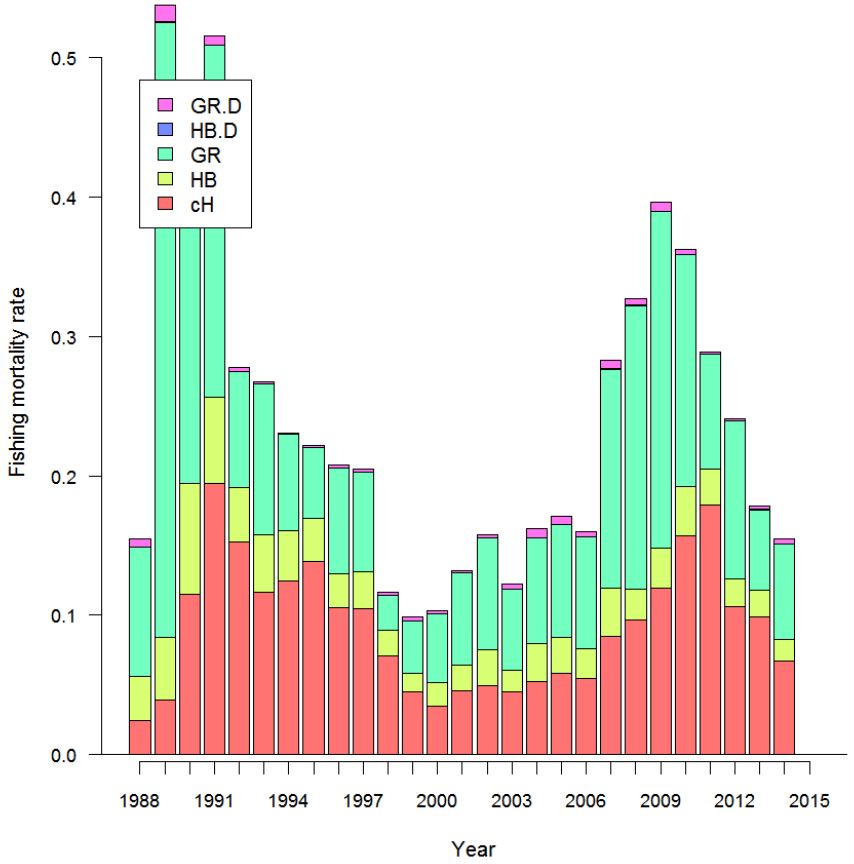
Landings



Dead Discards

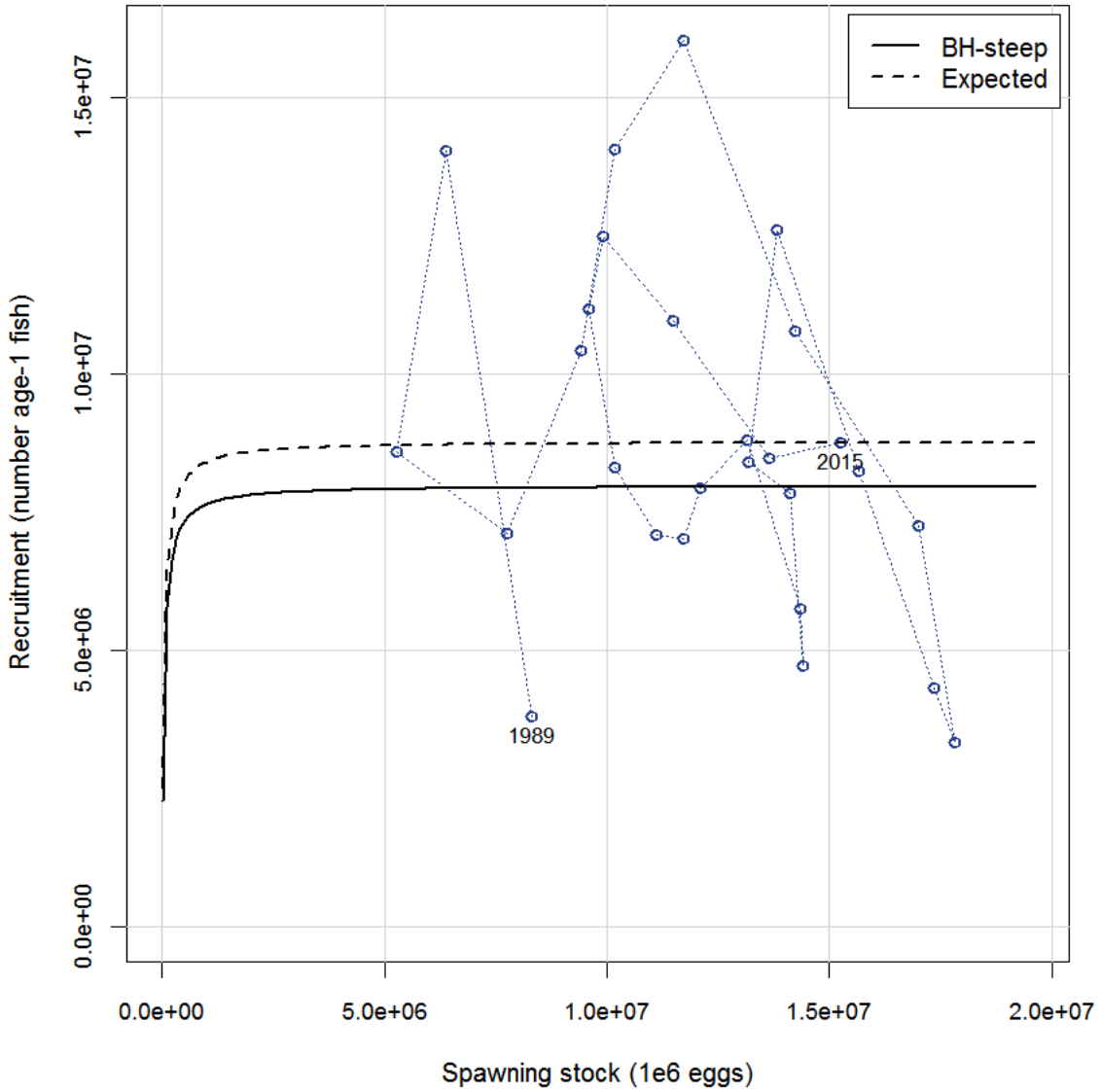


F by Fishery



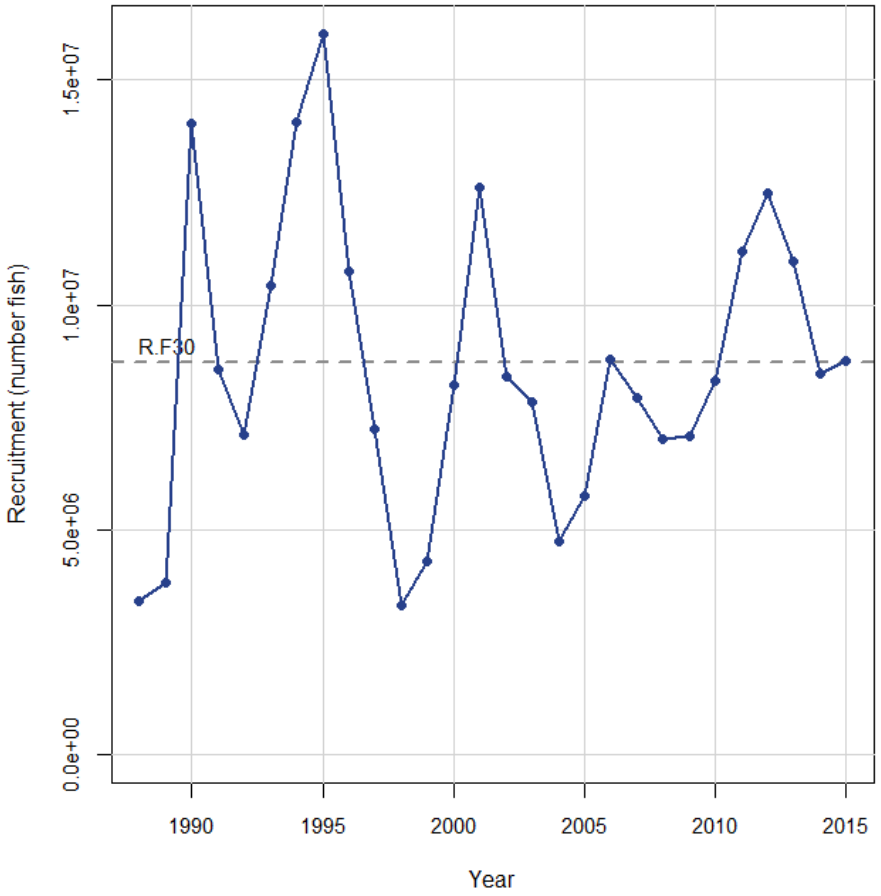
Model Outputs: Stock-Recruitment

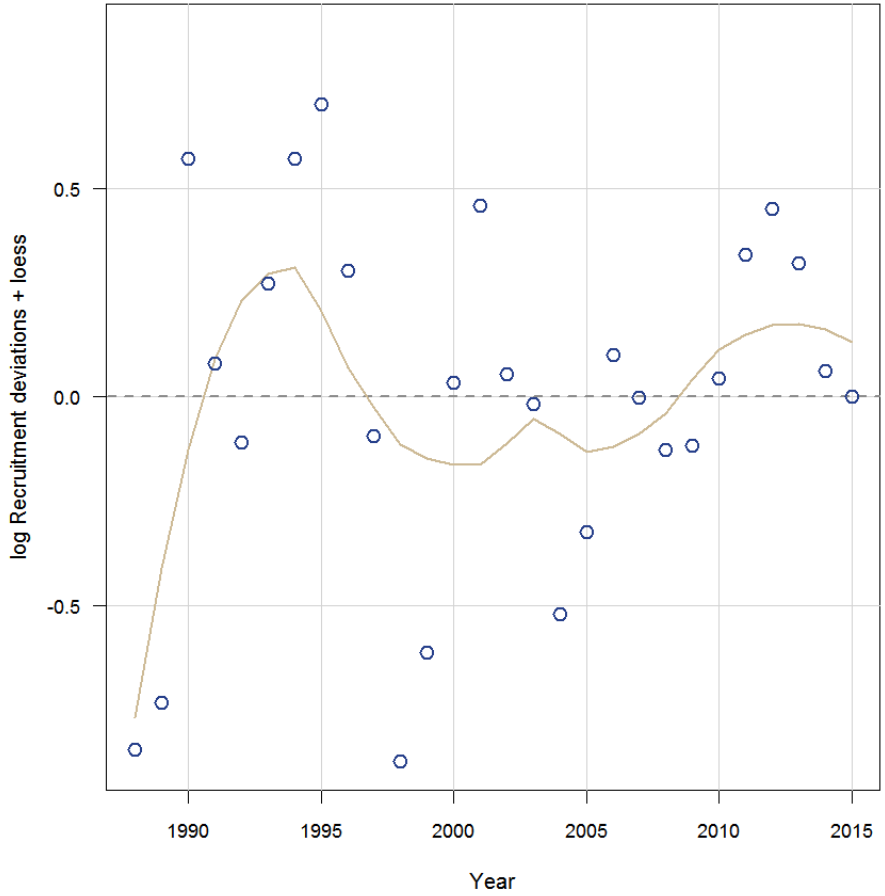
BAM Base Run



Model Outputs: Age-1 Recruitment

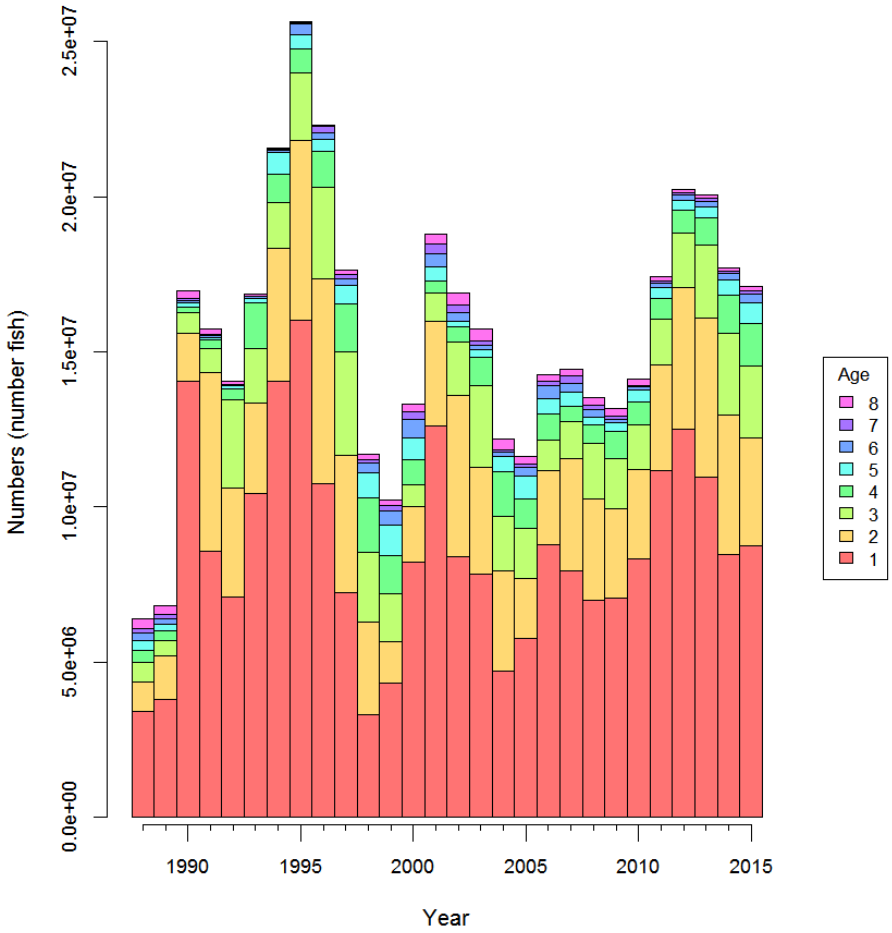
BAM Base Run

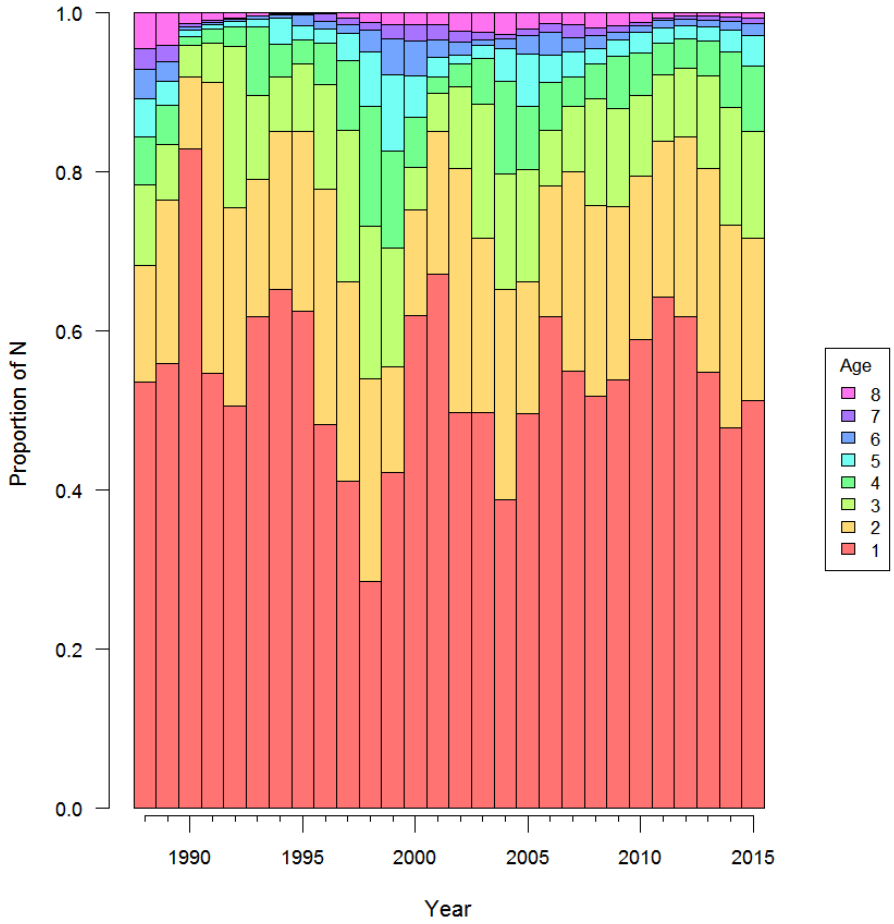




Model Outputs: Numbers at Age

BAM Base Run

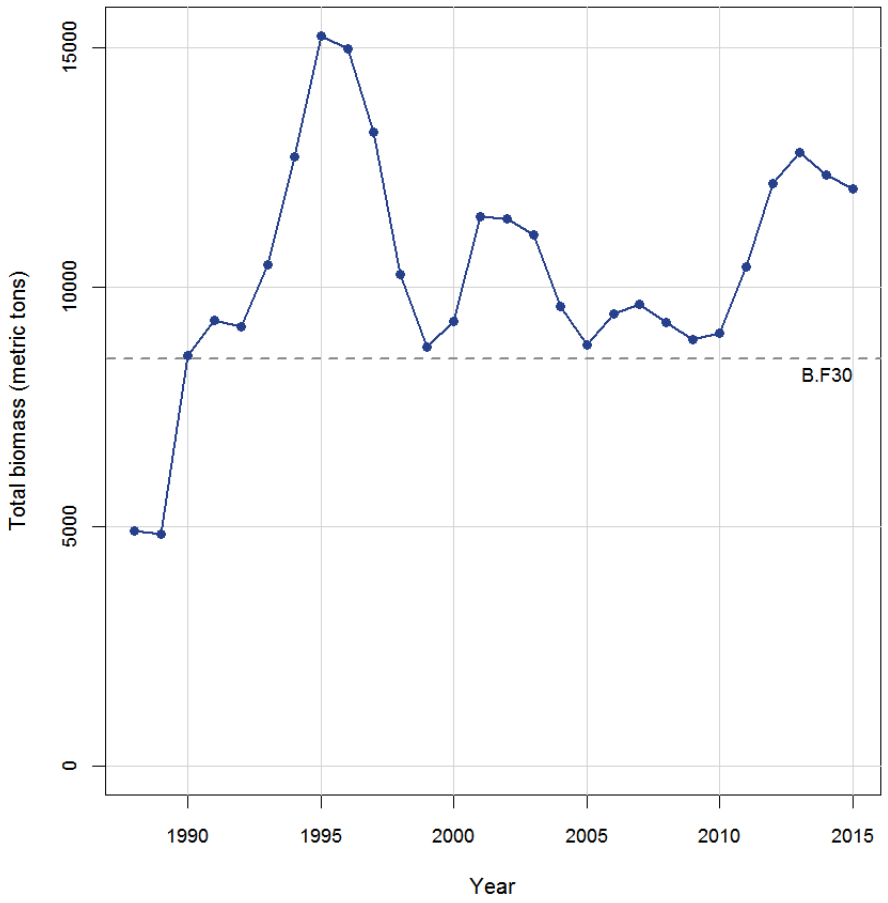




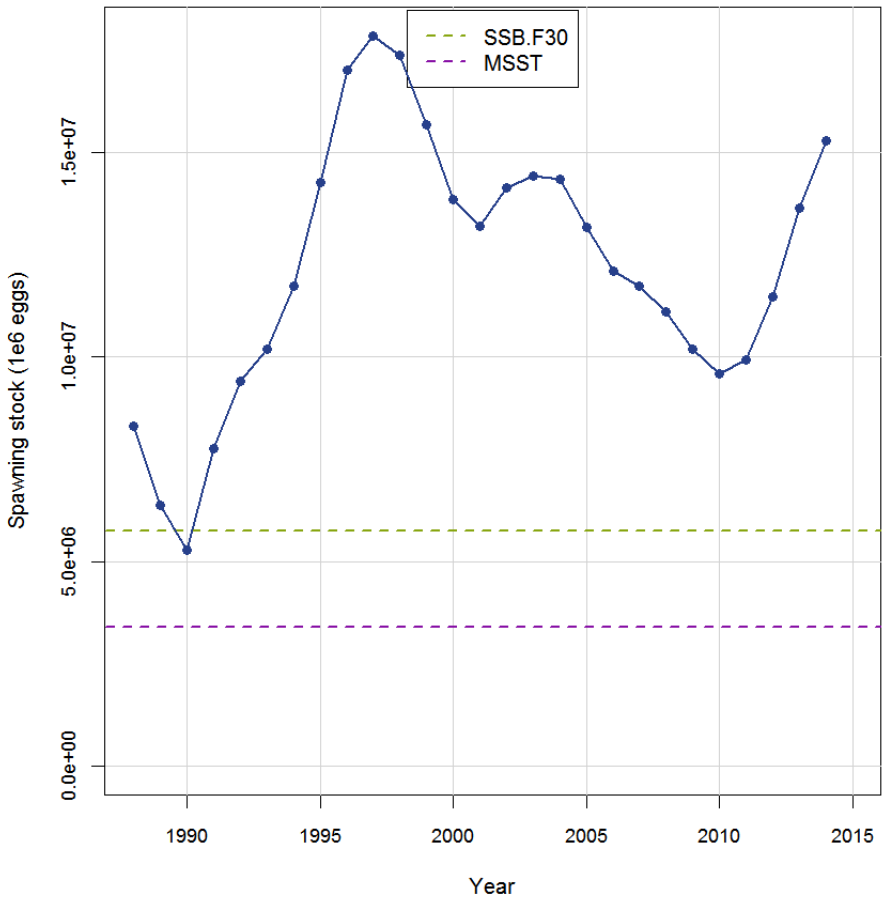
Model Outputs: Biomass

BAM Base Run

Total Biomass



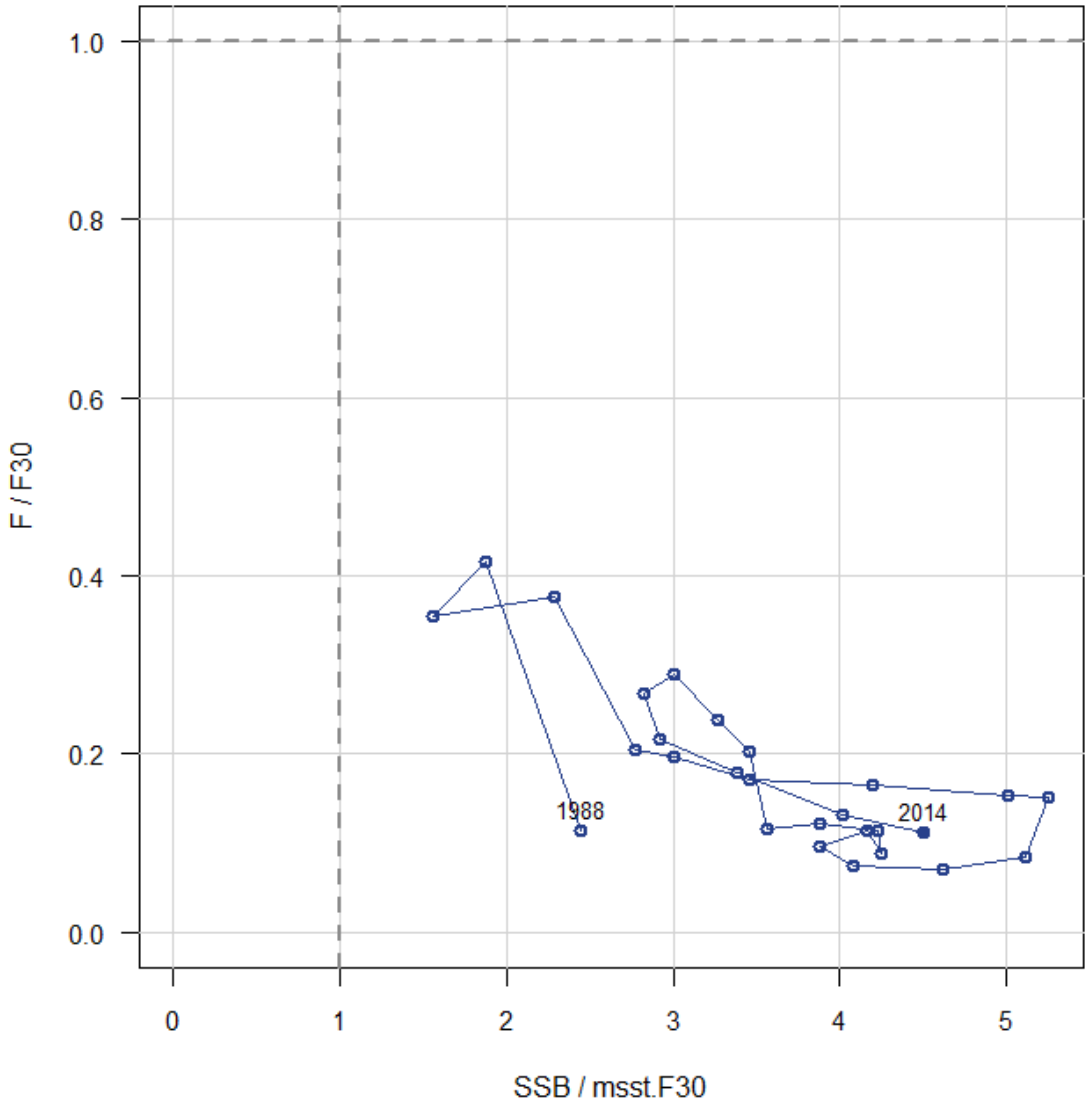
Spawning Biomass



Model Outputs: Biomass

BAM Base Run

Not Overfished or Overfishing



Model Outputs: Management Quantities

BAM Base Run

Table 22. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort catch-age model, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap analysis. Measures of yield describe total removals, of which ~ 97.3% were estimated to be landings, and the remainder, dead discards. 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) is measured as population fecundity (number of eggs)

Quantity	Units	Estimate	Median	SE
$F_{30\%}$	y^{-1}	1.24	1.24	0.62
$85\%F_{30\%}$	y^{-1}	1.05	1.05	0.53
$75\%F_{30\%}$	y^{-1}	0.93	0.93	0.47
$65\%F_{30\%}$	y^{-1}	0.80	0.81	0.41
$F_{30\%}$	y^{-1}	1.24	1.24	0.62
$F_{40\%}$	y^{-1}	0.71	0.72	0.38
$B_{F30\%}$	metric tons	8515	8389	4448
$SSB_{F30\%}$	1e6 eggs	5751203	5570736	1610871
MSST	1e6 eggs	3393210	3241071	779326
$L_{F30\%}$	1000 lb whole	2379	2339	1090
$R_{F30\%}$	number fish	8710621	8607344	6364635
$L_{85\%F30\%}$	1000 lb whole	2282.41	2245	1045
$L_{75\%F30\%}$	1000 lb whole	2204.00	2165	1010
$L_{65\%F30\%}$	1000 lb whole	2109.81	2075	970
$F_{2012-2014}/F_{30\%}$	—	0.14	0.14	0.13
$SSB_{2014}/MSST$	—	4.50	4.57	1.28
$SSB_{2014}/SSB_{F30\%}$	—	2.65	2.65	0.51

Sensitivity Runs

<u>39 sensitivities</u>

Natural mortality (5): Low M (scaled to 5th %tile of M bootstraps)
High M (scaled to 905h %tile of M bootstrap)
Low M (scaled to Then et al. growth estimator M=0.27)
Constant M = 0.41
Constant M = 0.27

Batch number (3): age-independent batch number
low batch number (5th %tile of bootstrap estimates)
high batch number (95th %tile of bootstrap estimates)

Stock Recruitment (3): Ricker SR curve, steepness fixed h=0.46, steepness fixed 0.84

Recruitment deviations (5): estimate rec devs starting in 1993, 1998, 2003, 2008, 2013

Discard mortality (2): low discard mortality (0.05), high discard mortality (020); from DW

Initialization (3): Low Finit = 0.01, high Finit = 0.1, higher Finit = 0.2

Catchability (1): Random walk (RW) on fishery-independent trap index

Sensitivity Runs (cont.)

Selectivities (3): All selectivities logistic (including discards)
All fishery selectivities dome-shaped
Force fit to GR pooled age comp (do not fit to GR length comps)

Selectivity blocks (3): Blocking around implementation of length limit off Florida (1995)
Blocking around implementation and change in Florida length limit (1995, 2006)
Blocking around inclusion of GT in aggregate snapper-grouper bag limit (1999)

FI and FD indices (2): Include all FI and FD indices (with iterative reweighting)
Include FD indices only (with iterative reweighting)

Video index (2): Separate video and trap indices (with iterative reweighting and trap upweighted)
Separate video and trap indices (with iterative reweighting and video index upweighted)

Likelihood weights (6): All wgts set to 1.0, wgts set to those from iterative reweighting (trap not upweighted),
upweighted trap index 2X, 4X, 8X, 10X

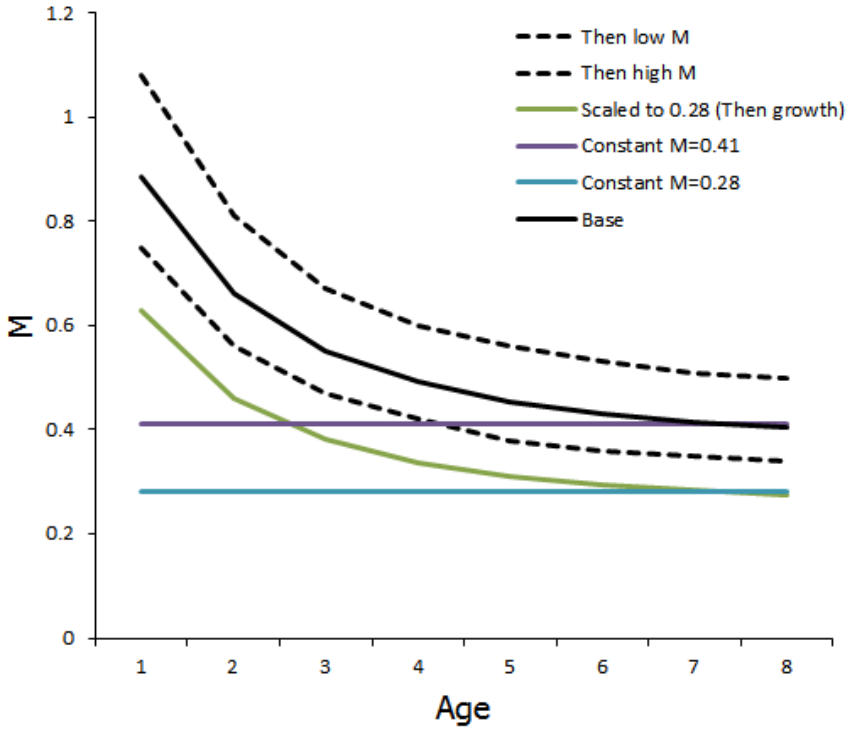
Ageing error matrix (1): Use ageing error matrix

Retrospectives (5): Data through 2013, 2012, 2011, 2010, 2009 (5 year retrospective)

Sensitivity—Natural Mortality

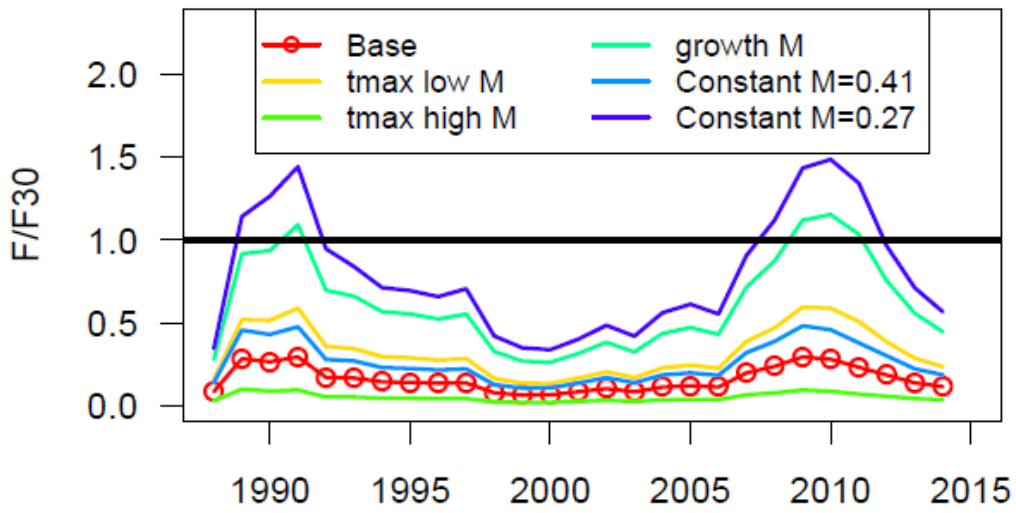
Approach

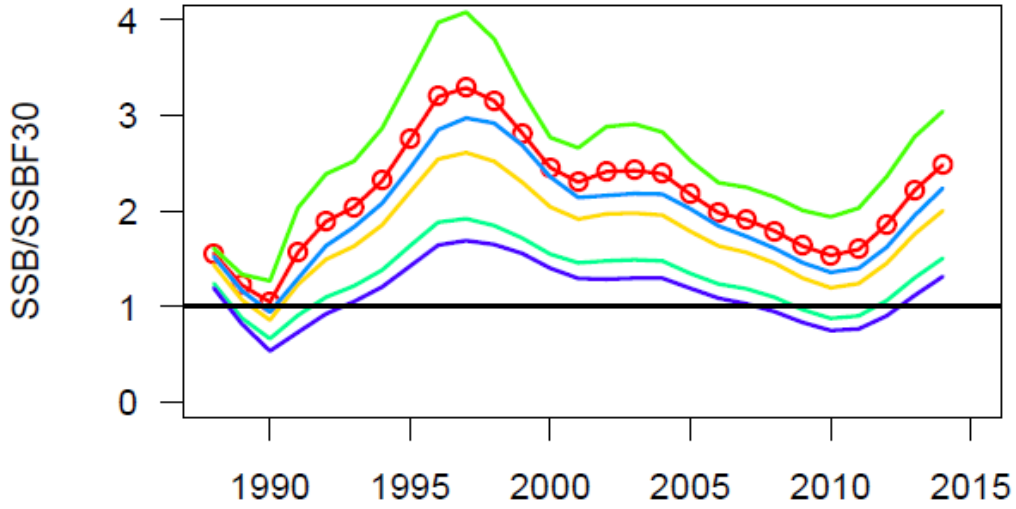
- Randomly select tmax based on ageing error matrix (age 10)
- Randomly select pairs of estimates from the 2 parameters of the Then et al. M vs. tmax fct (based on bootstrapping with replacement)
- Predict constant M from tmax
- Estimate age-dependent M from Charnov relationship



	0	1	2	3	4	5	6	7	8	9	10
0	0.93	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.07	0.86	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.10	0.80	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.13	0.73	0.13	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.17	0.65	0.17	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.01	0.21	0.56	0.21	0.01	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.03	0.23	0.47	0.23	0.03	0.00	0.00
7	0.00	0.00	0.00	0.00	0.01	0.06	0.24	0.39	0.24	0.06	0.01
8	0.00	0.00	0.00	0.00	0.00	0.02	0.09	0.23	0.31	0.23	0.11
9	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.11	0.21	0.25	0.37
10	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.07	0.12	0.18	0.60

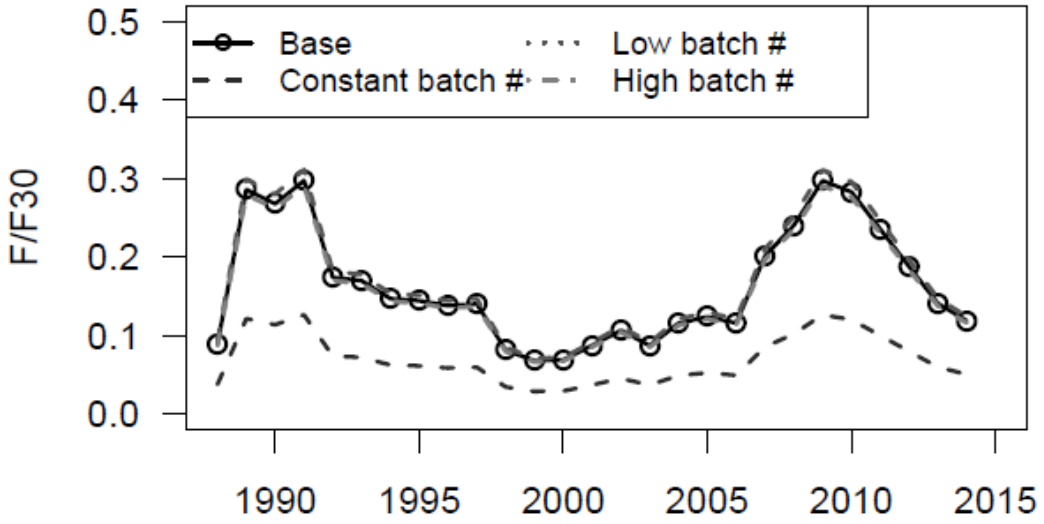
Sensitivity—Natural Mortality



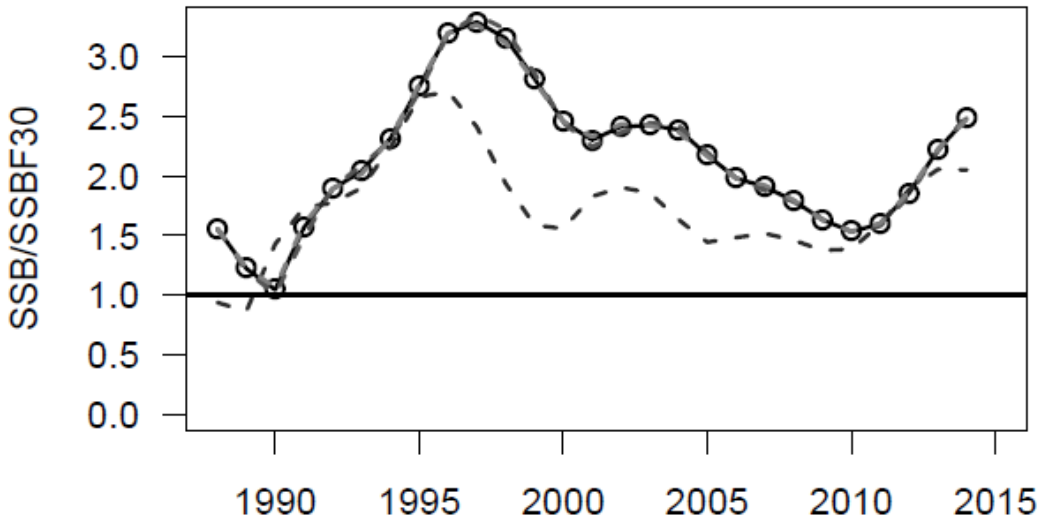


Sensitivity—Batch Number

Young age classes contributing earlier than in base run

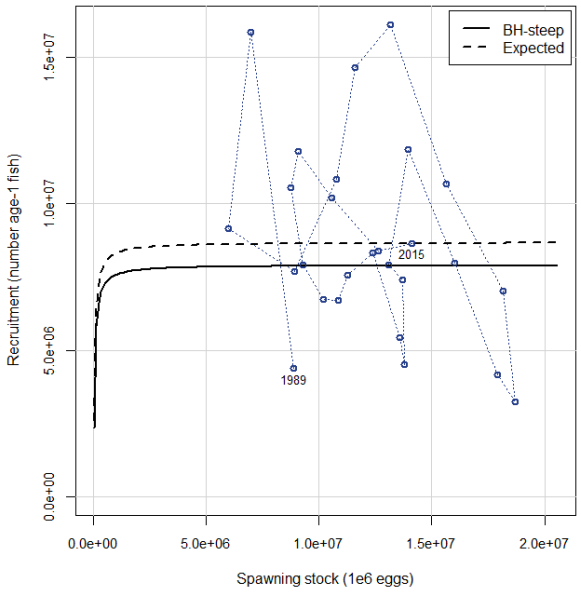


No differential effect of older age classes on popn fecundity

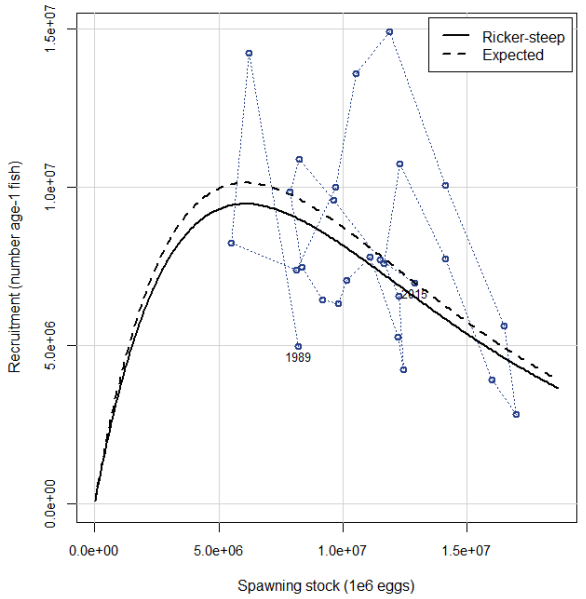


Sensitivity—Recruitment

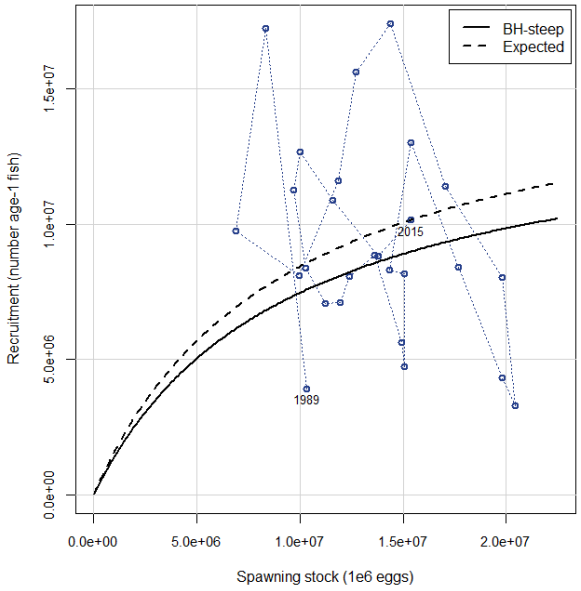
Base
BH
(h=0.99)



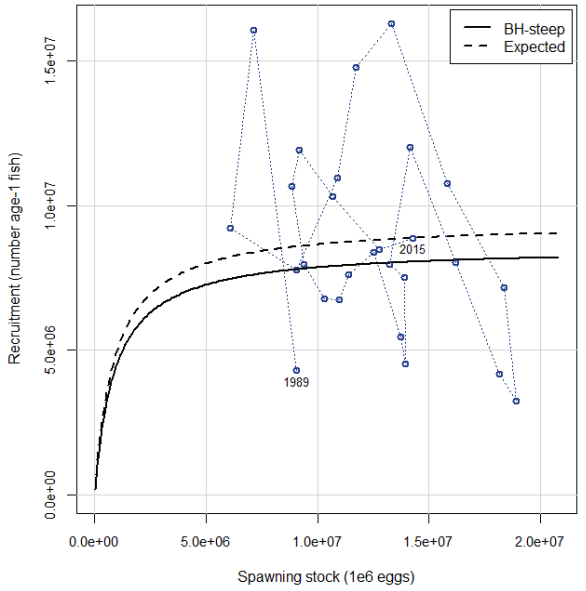
Ricker



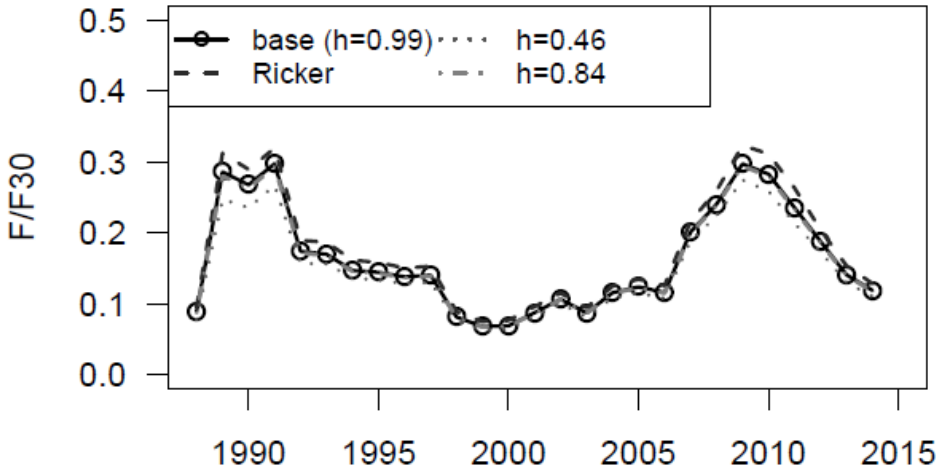
BH
(h=0.46)

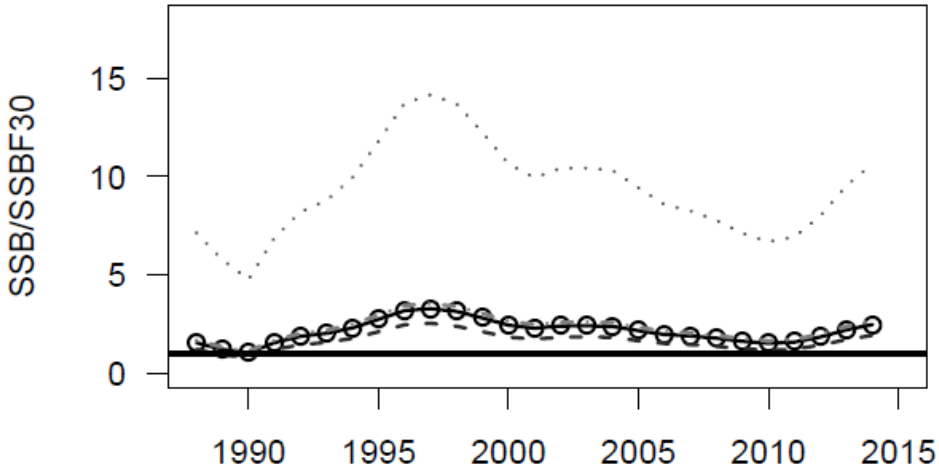


BH
(h=0.84)



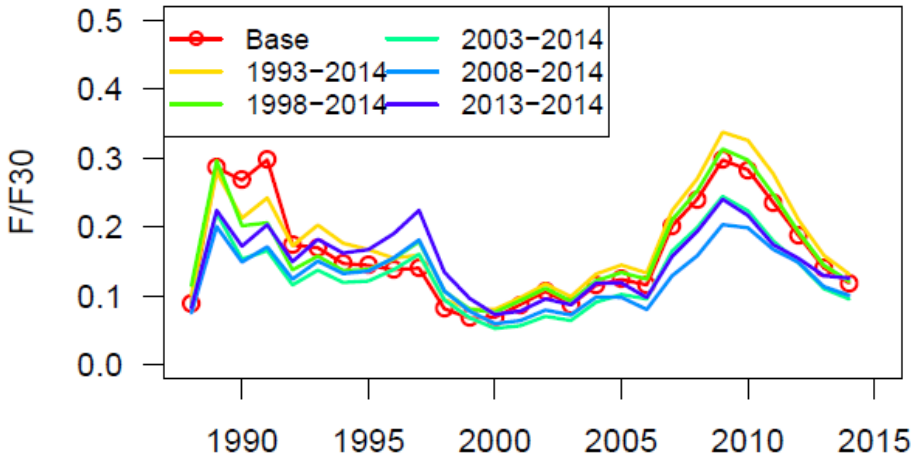
Sensitivity—Recruitment

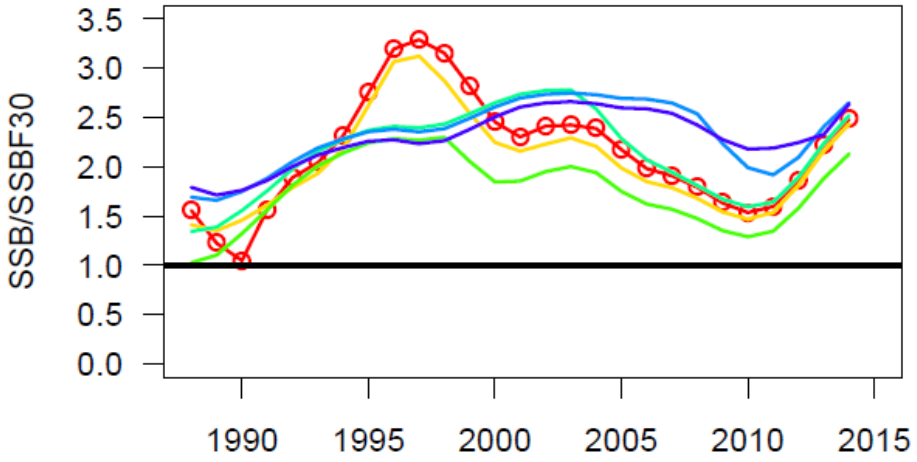




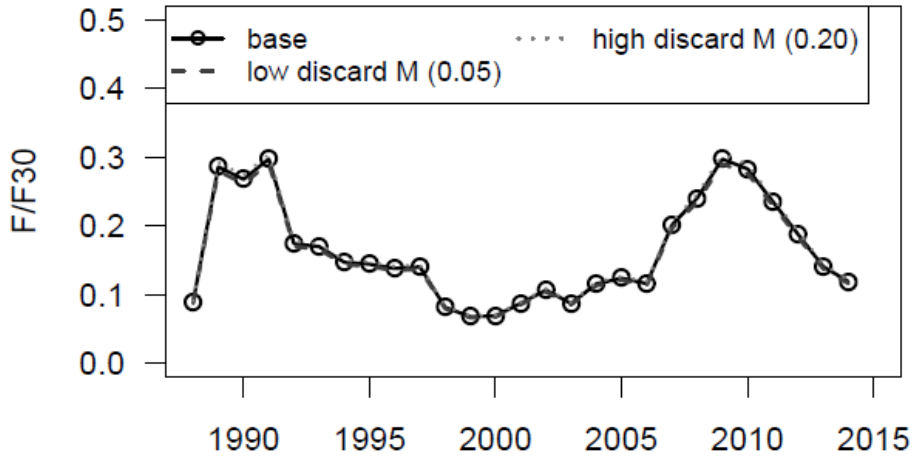
Higher R0 to support landings given lower steepness (h=0.46)

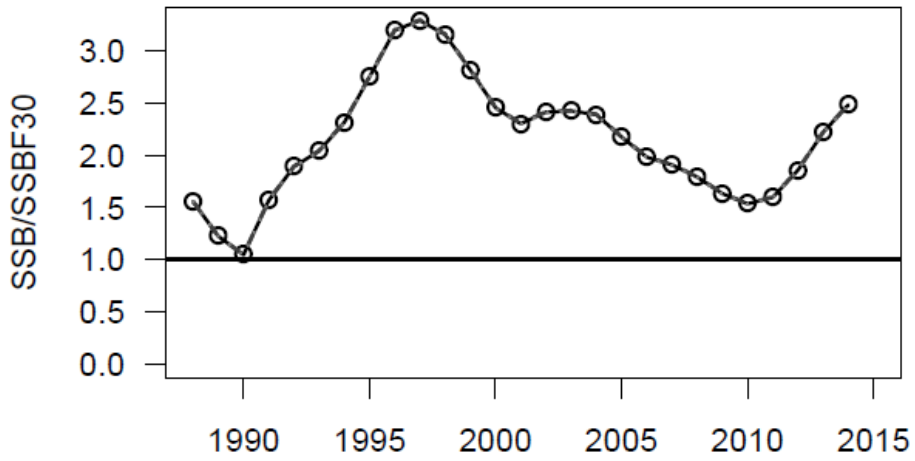
Sensitivity—Rec Devs



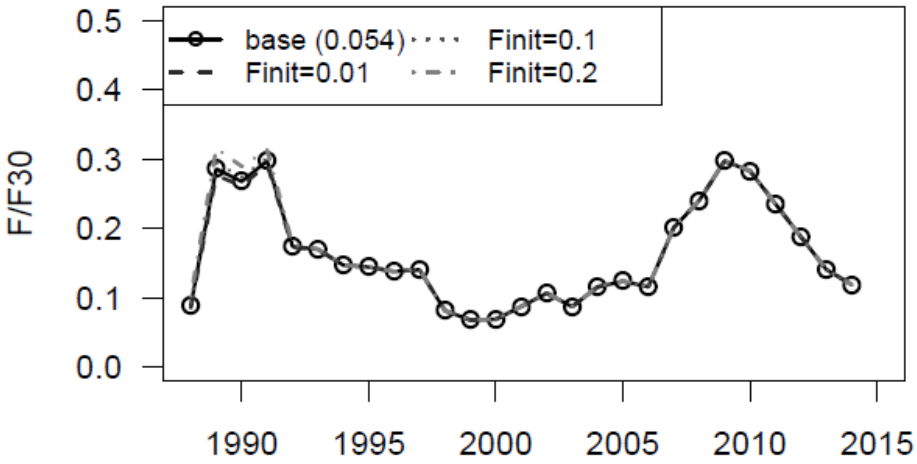


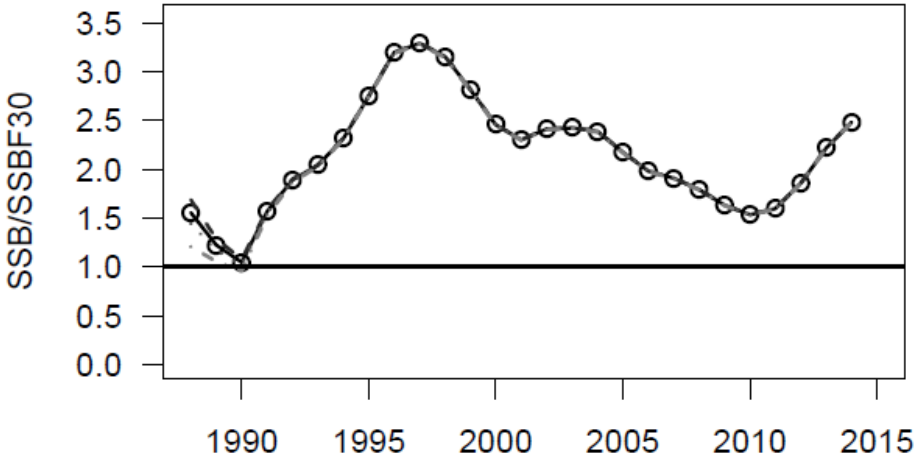
Sensitivities—Discard M



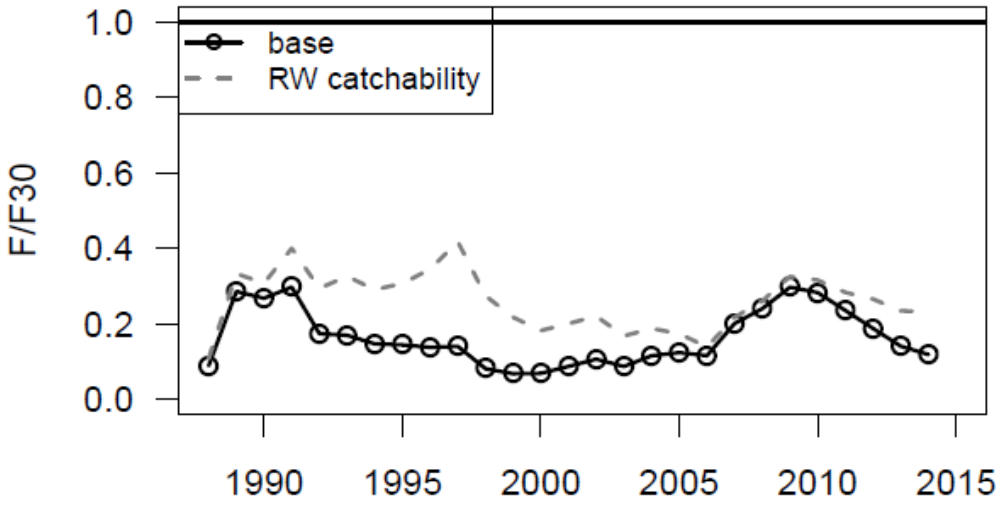


Sensitivity—Initialization

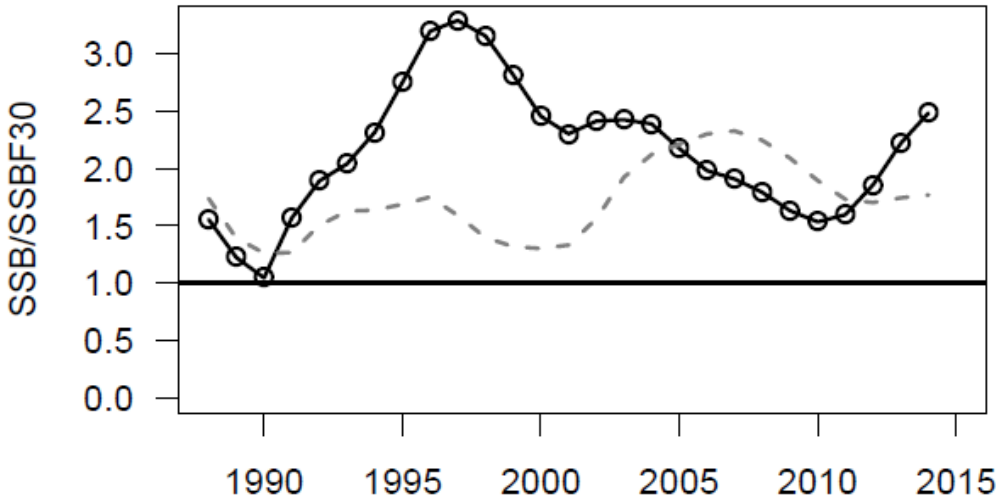




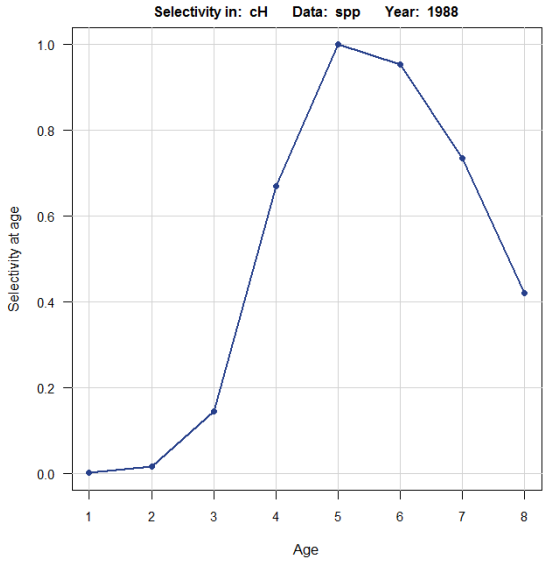
Sensitivity—Catchability

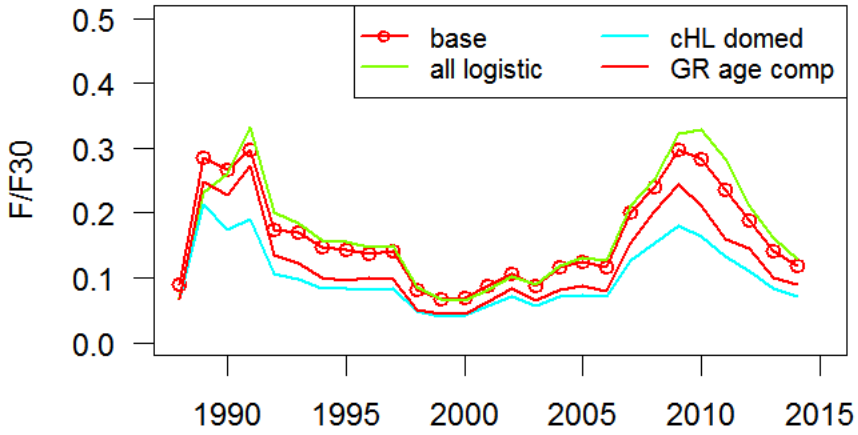


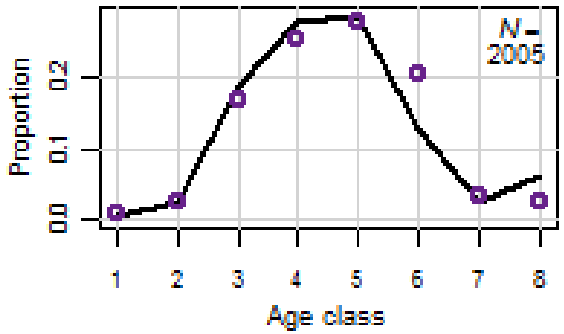
- Negates influence of FI trap index
- Similar patterns when trap index downweighted or excluded

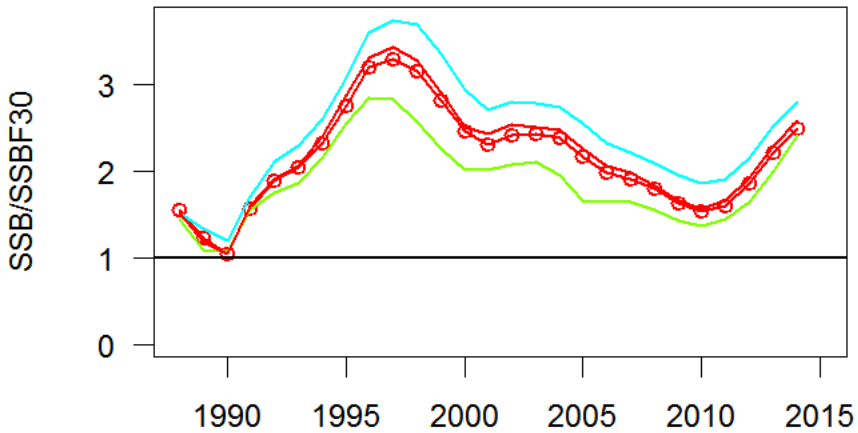


Sensitivity—Form of Selectivity







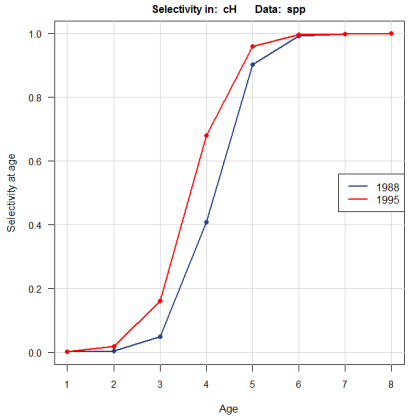


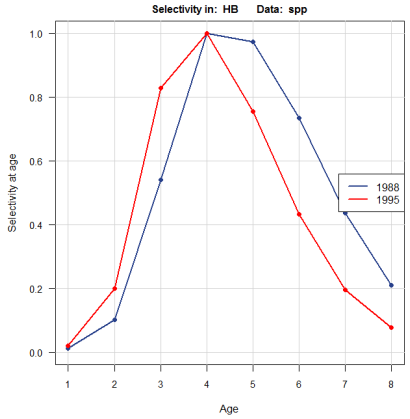
Pooled age comp from CH mode

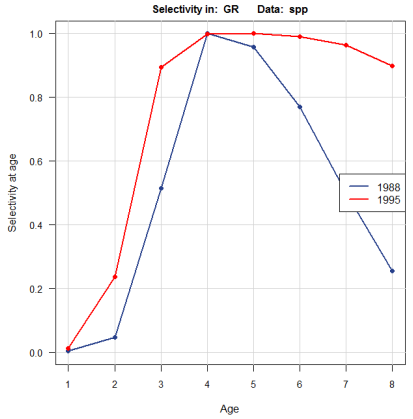
Year	Ntrips	Nfish
2004	18	47
2005	35	90

Sensitivity—Selectivity blocking

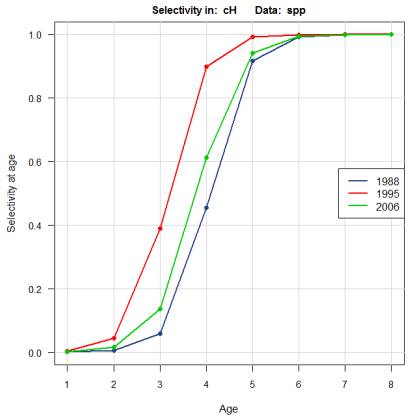
1995 Florida 12 inch TL limit

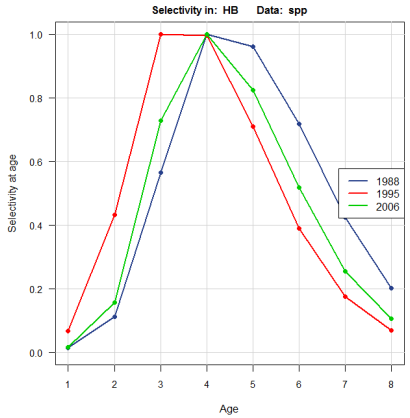


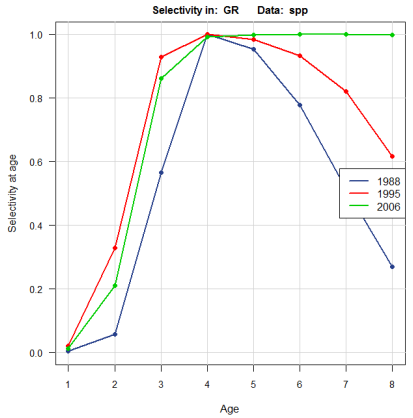




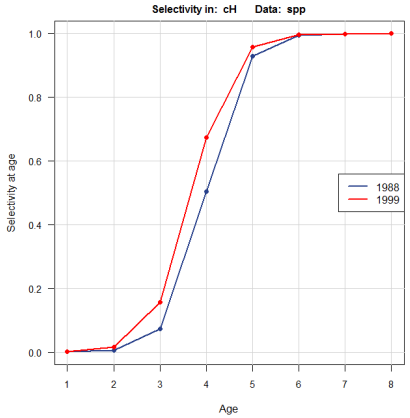
2006 Florida 12 inch FL limit

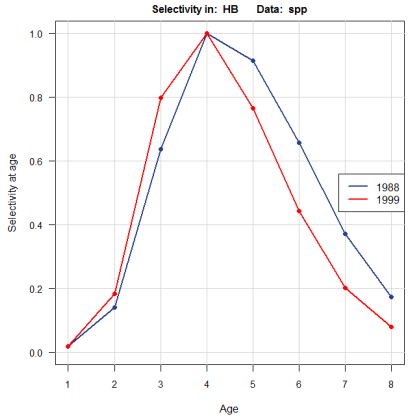


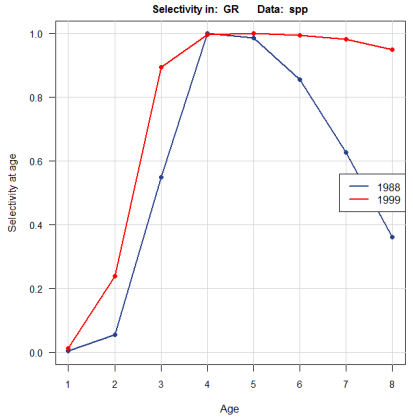




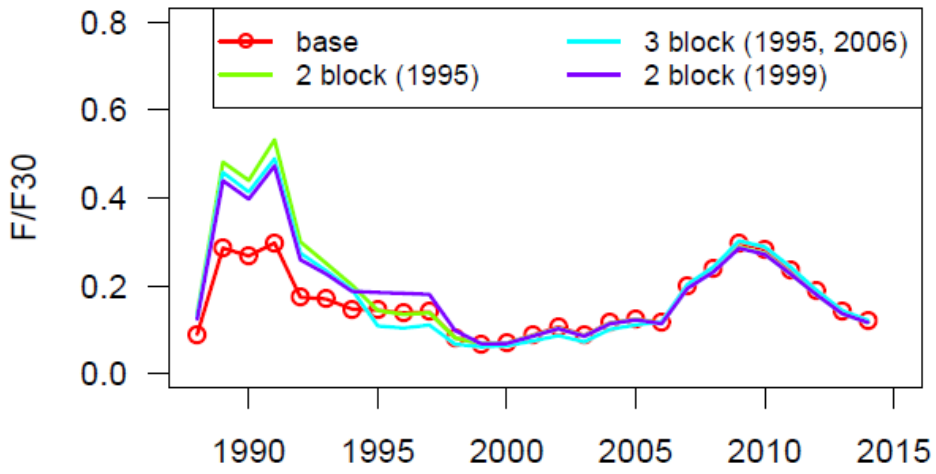
1996 20 fish aggregate bag limit

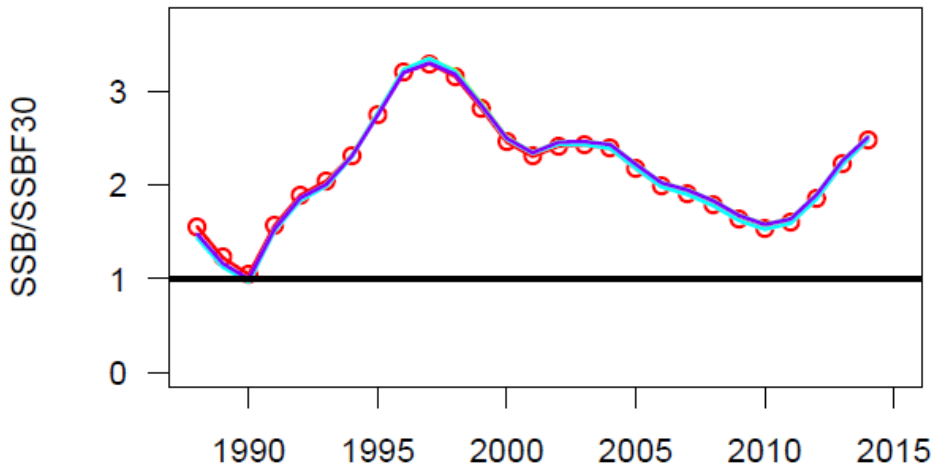






Sensitivity—Selectivity blocking

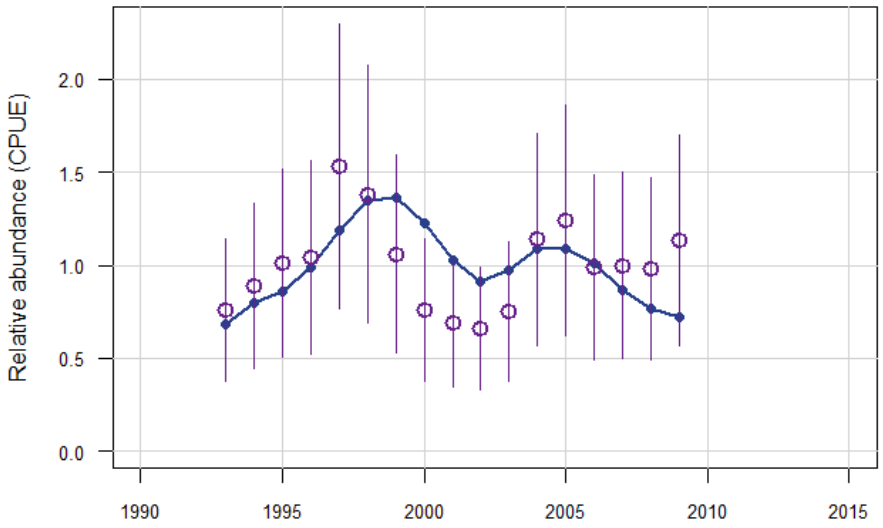




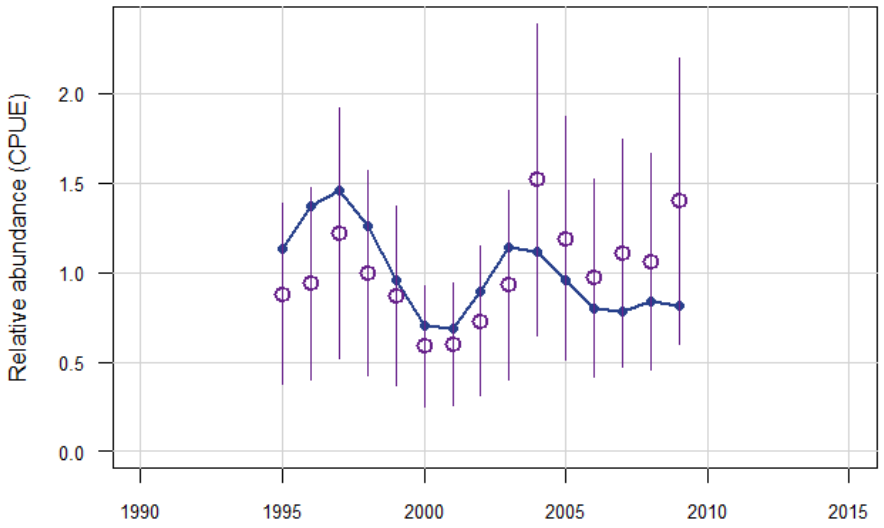
Sensitivity—FI and FD Indices

Iteratively reweighted and then upweight CVID 6X

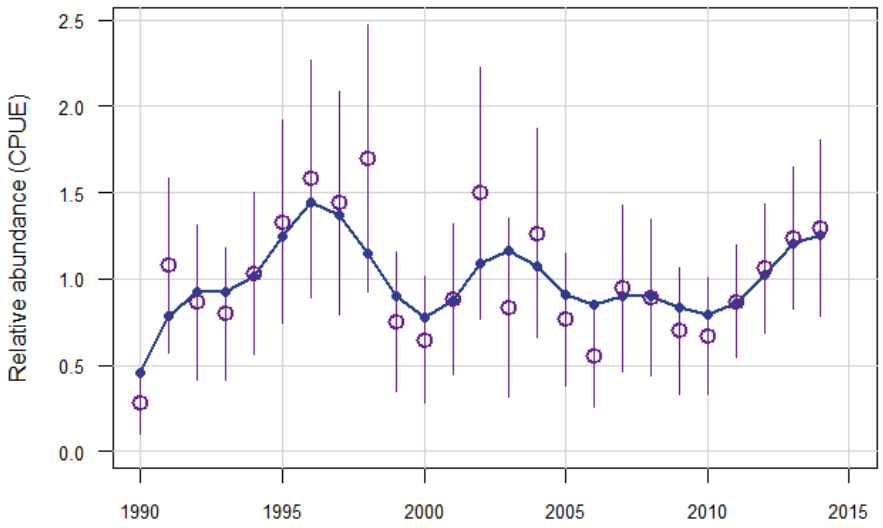
Comm Handline



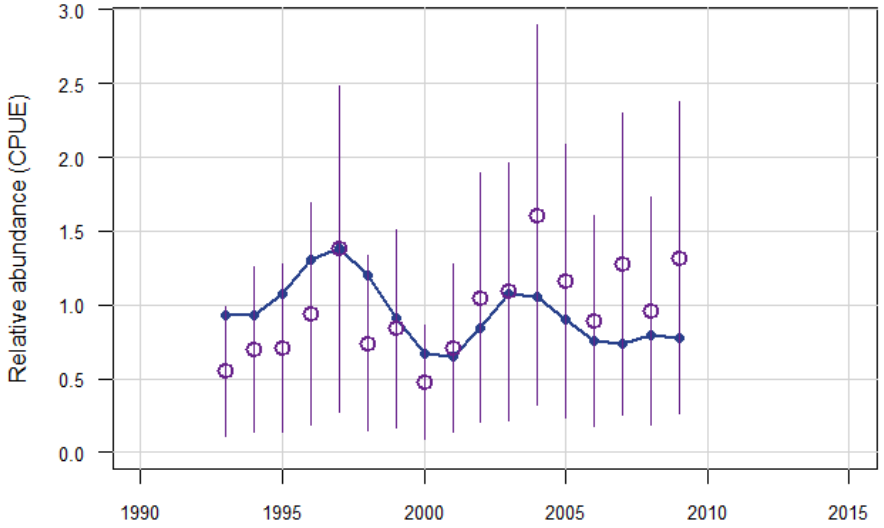
Headboat



CVID

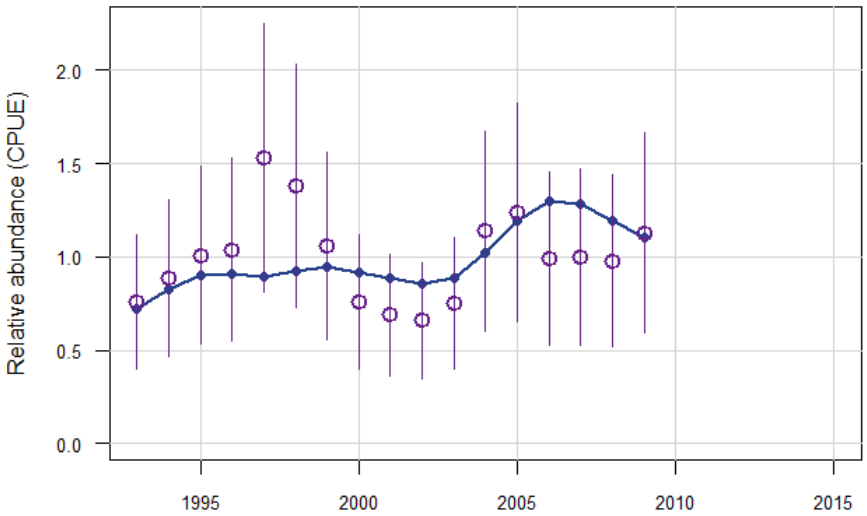


General Rec

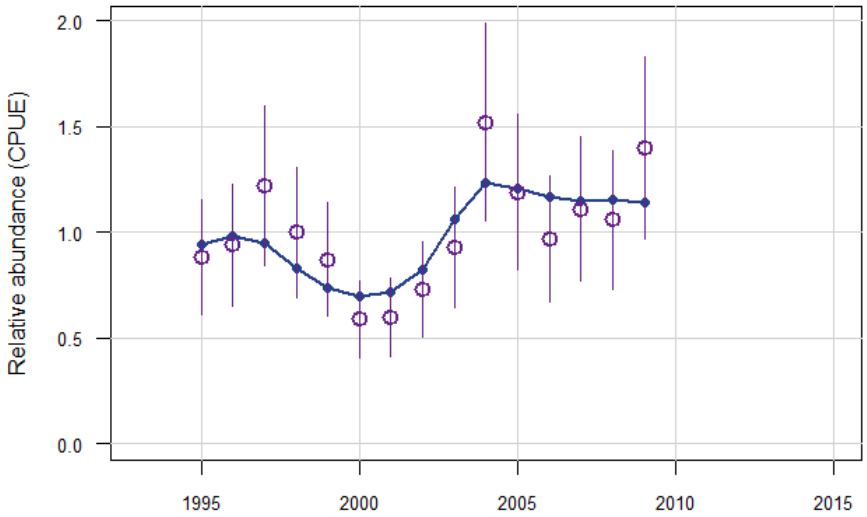


Sensitivity—FD Indices Only

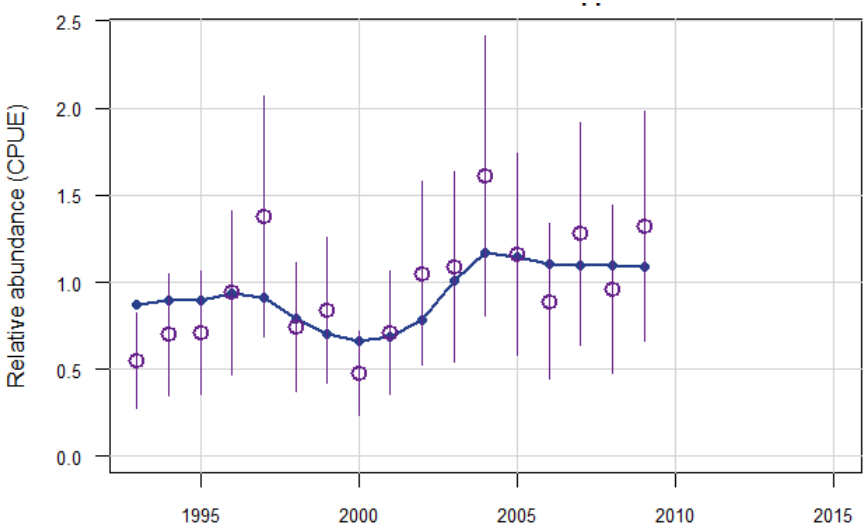
Comm Handline



Headboat

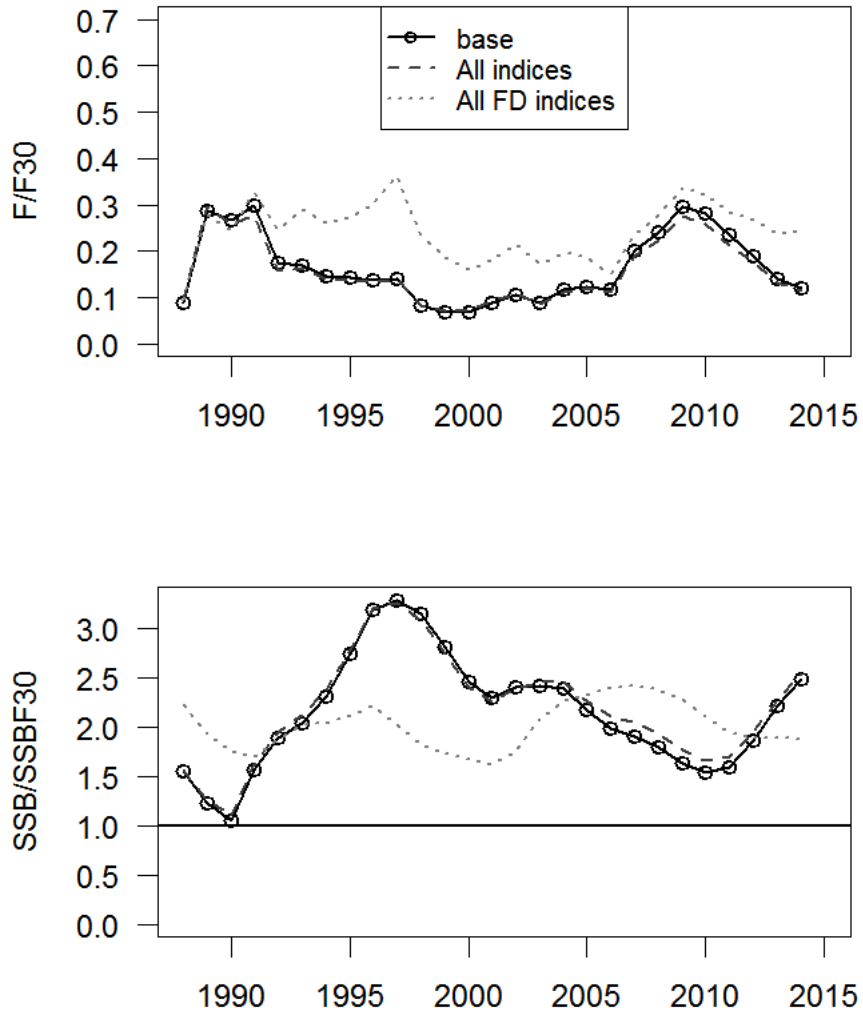


General Rec



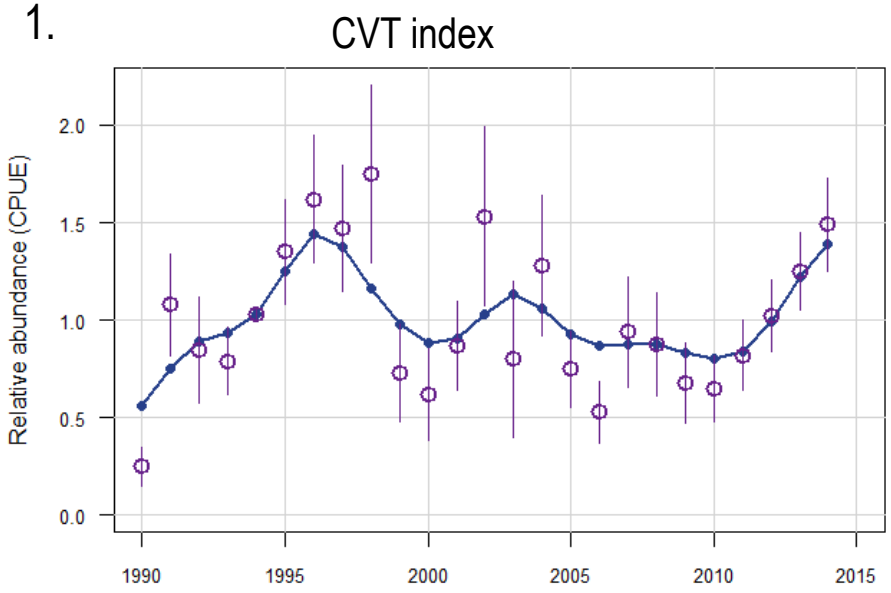
Iteratively reweighted starting from weights = 1

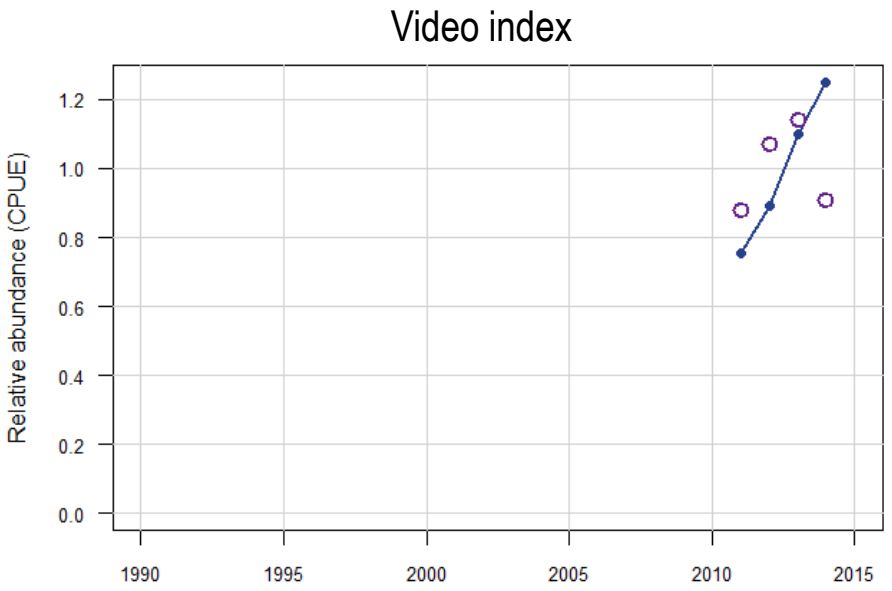
Sensitivity—FI and FD Indices



Sensitivity—Video Index

1.





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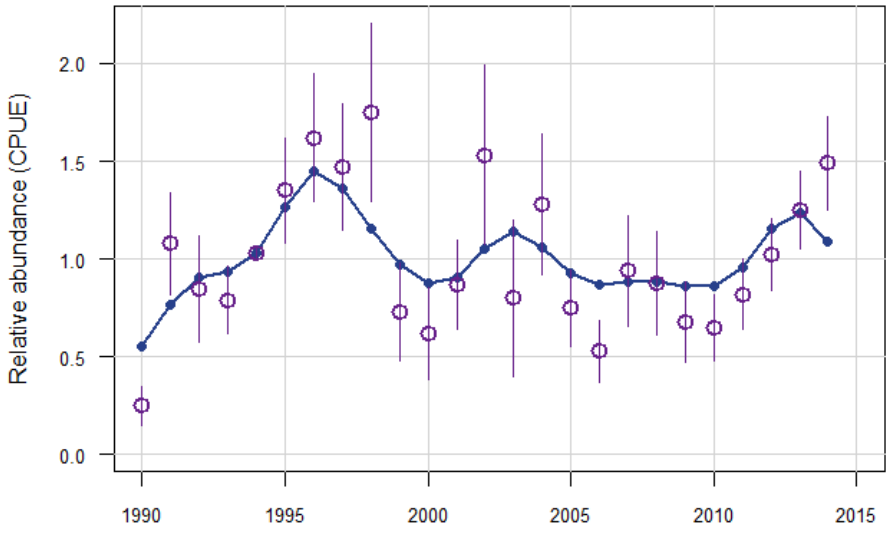
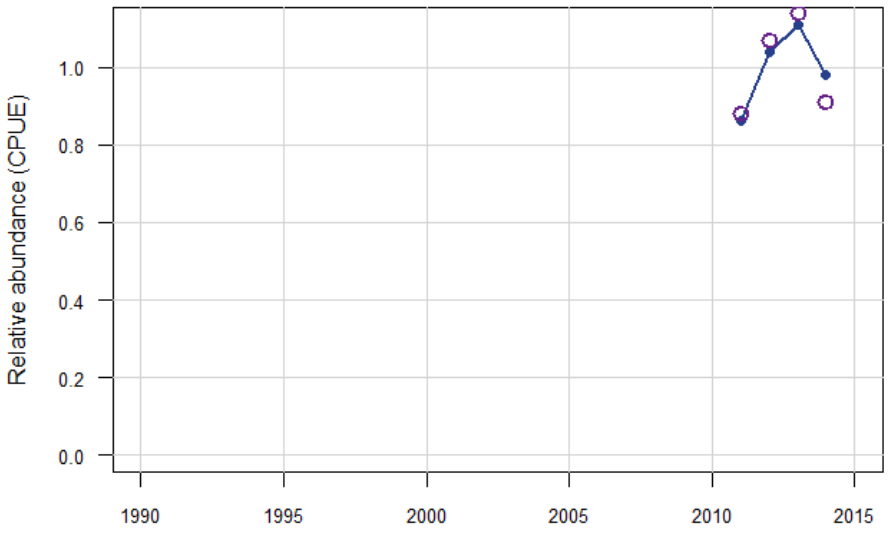
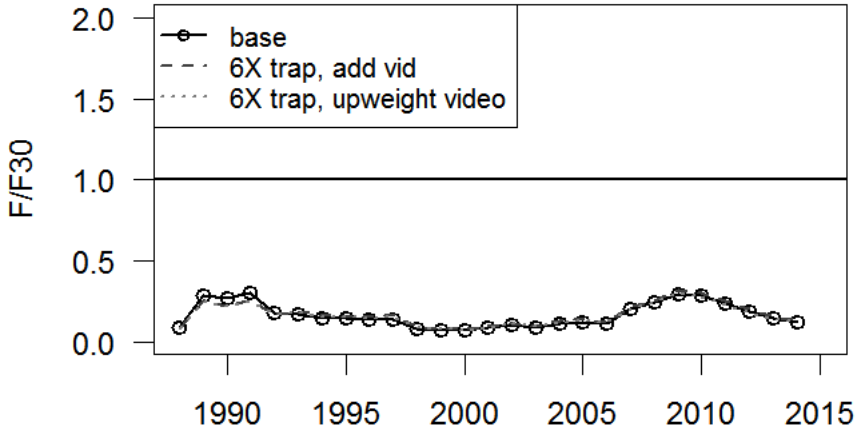
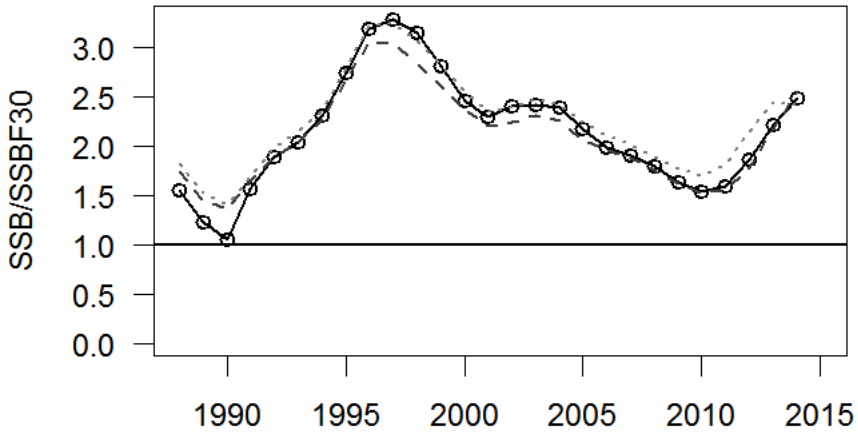


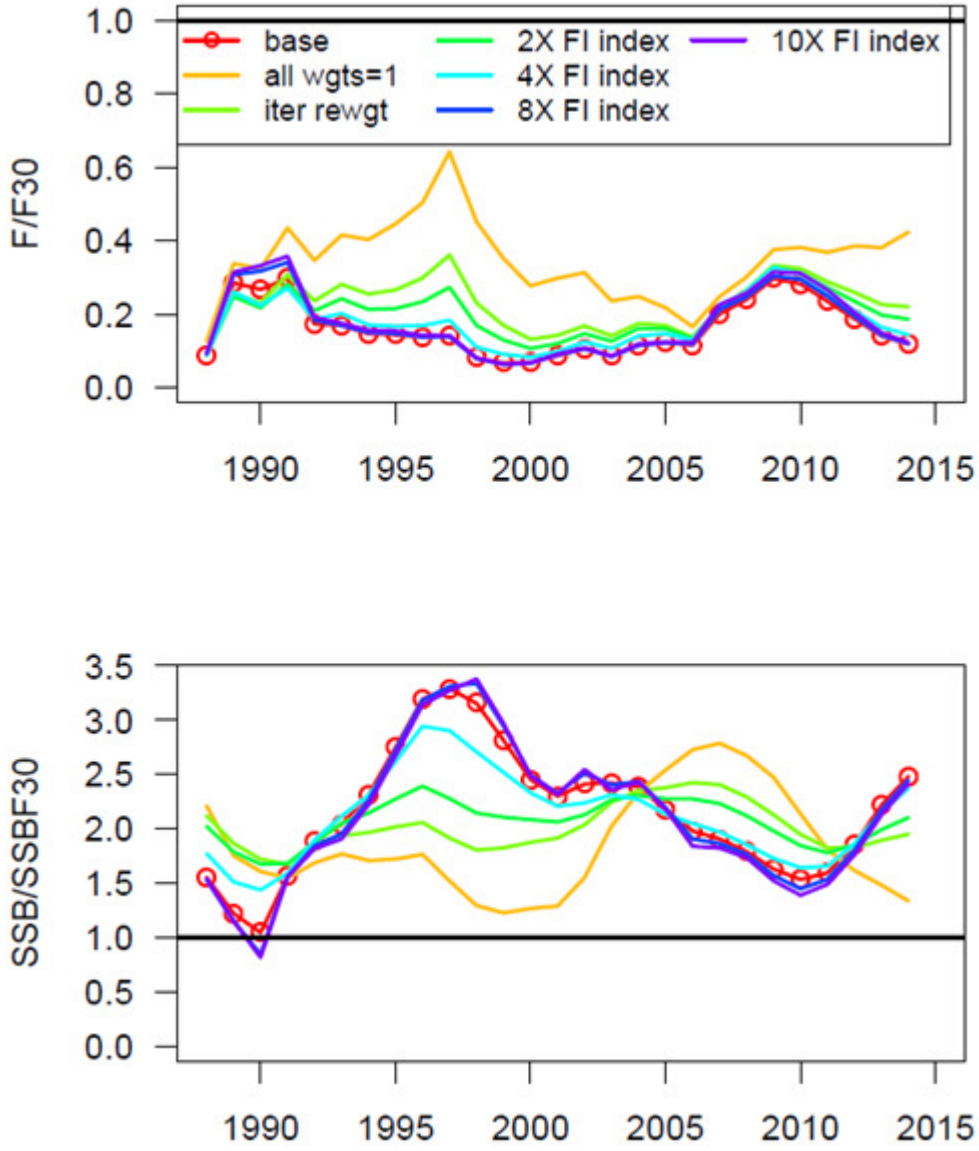


Sensitivity—Video Index

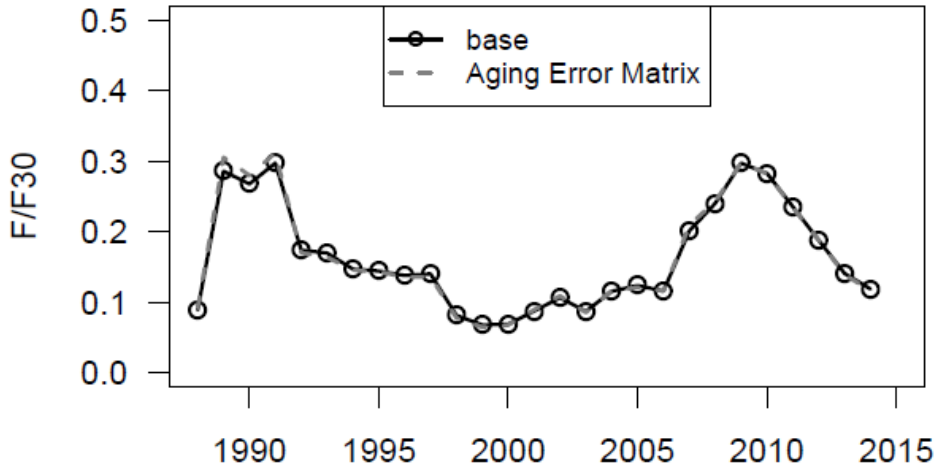


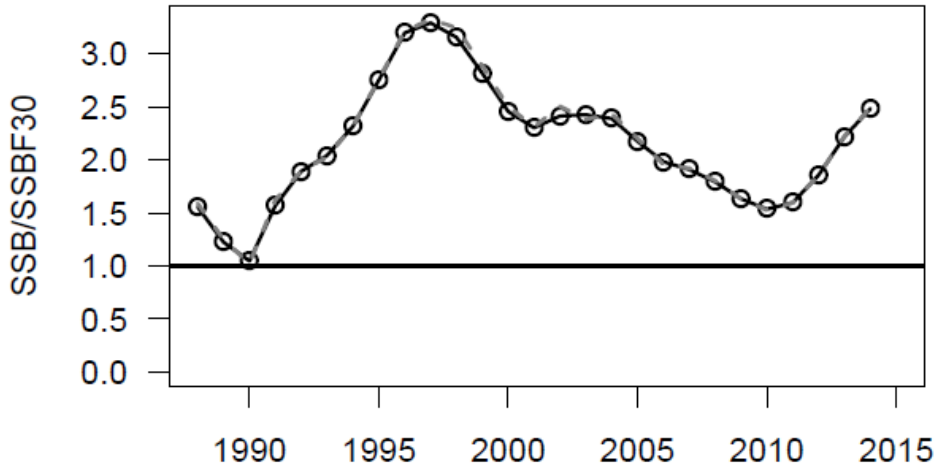


Sensitivity—Likelihood wgts

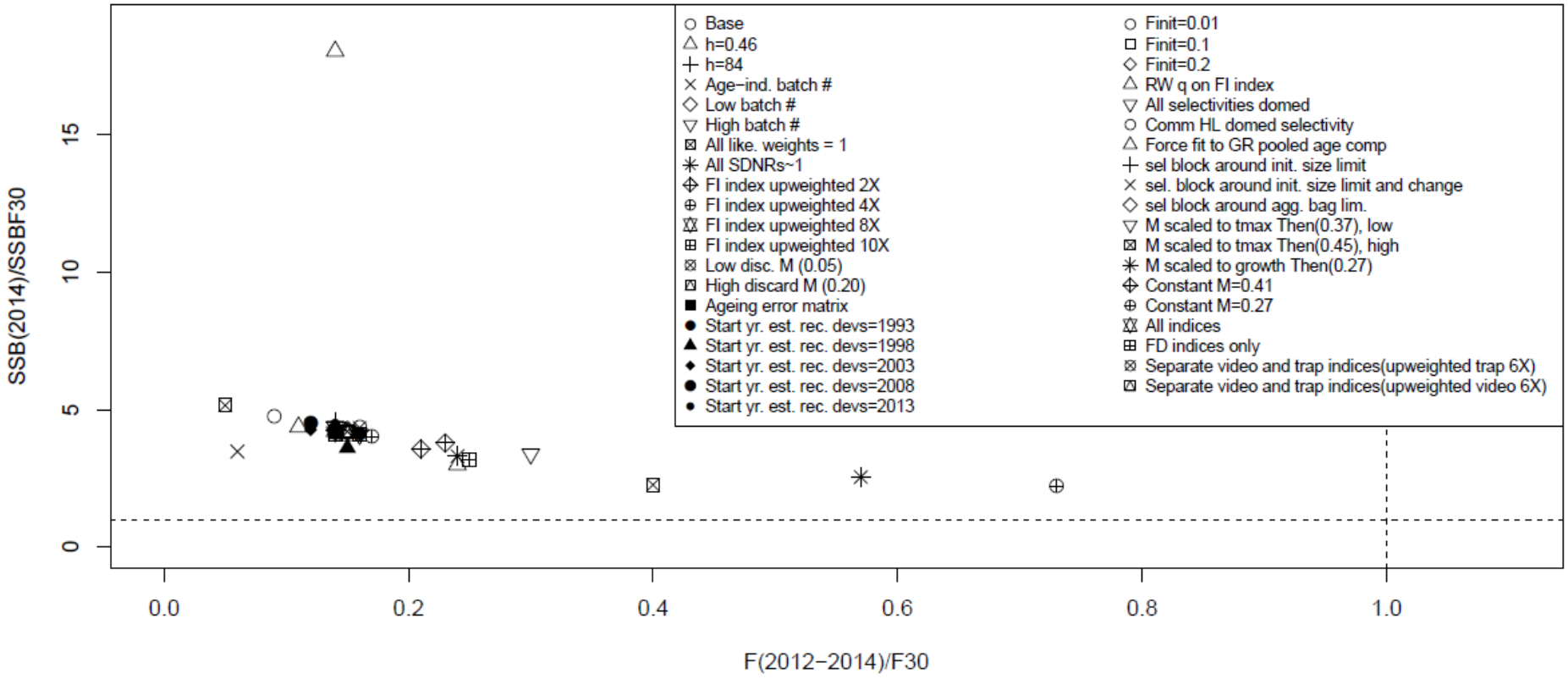


Sensitivities—Aging Error





Sensitivities

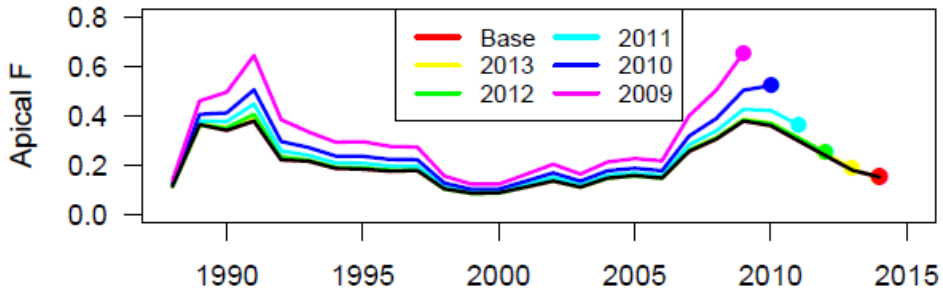


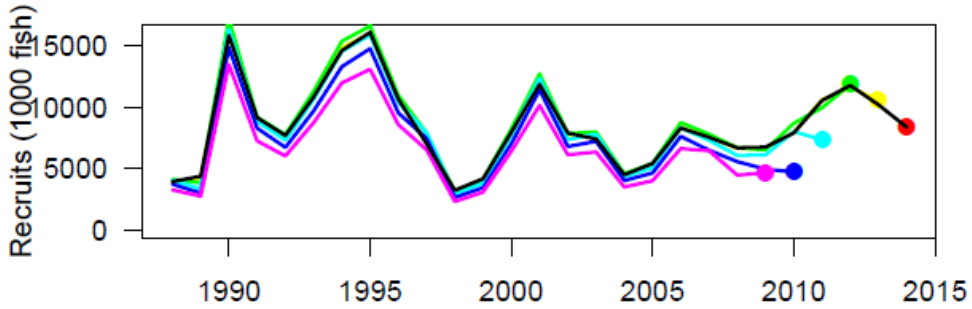
General Conclusions--Sensitivity Analysis

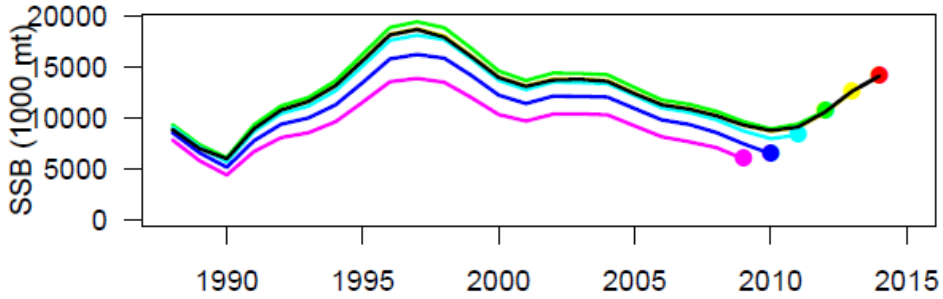
- Most sensitive to natural mortality, likelihood weighting, catchability
- Moderate sensitivity to batch number, rec devs, selectivity assumptions, indices
- Insensitive to discard mortality, initialization, and ageing error
- In general, biomass benchmarks (SSB/SSB_{F30}) were more sensitive than fishing benchmarks (F/F_{30})
- Terminal status did not change from the base run for any sensitivity (though the time series of status did vary)

Retrospective Analysis

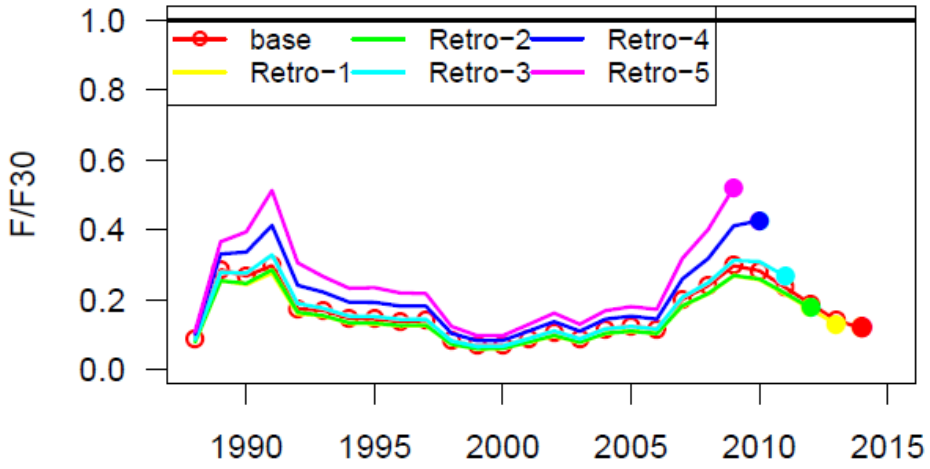
Retrospective

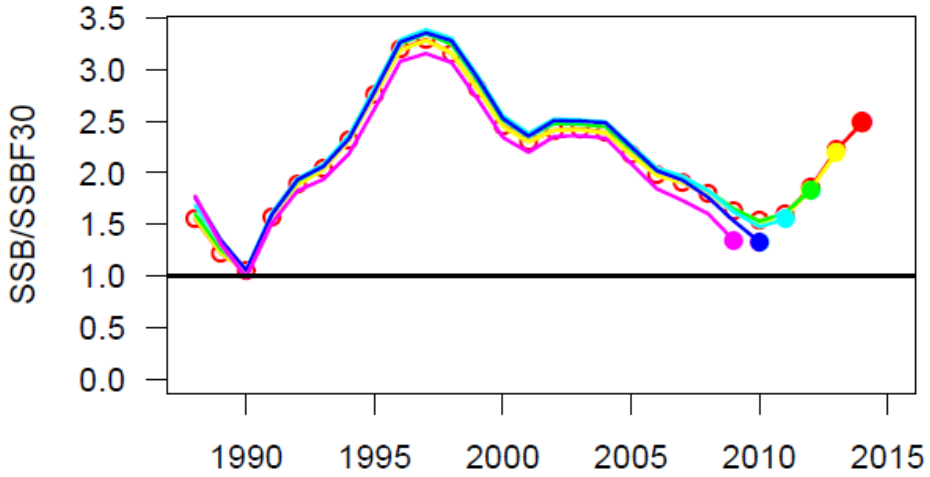






Retrospective—Status





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 or supplied by the DW

- Age and Length Compositions (Multinomial likelihood components): resample Nfish and assign them to bins with probabilities equal to those from original data

New time series of :

- Removals: cHL landings, GR landings, HB landing, GR discards, HB discards

- Indices: SERFS trap-video CPUE (CV from Conn (2010) method)

- Annual Compositions: GR lengths, cHL lengths/ages, HB lengths/ages, HB discard lengths, SERFS trap lengths/ages (fish drawn at random with replacement based on bin probabilities and sample sizes (N_{fish}))

Monte Carlo Bootstrap (MCB)

CVs for Bootstrap Component on Removals

cHL landings:

- CVs provided by commercial WG (based on increases in reporting over time)

HB landings:

CVs based on improvements in sampling and compliance

- 1988-95: before mandatory reporting and full compliance
- 1996-2007: mandatory reporting
- 2008-2014: full compliance

HB discards:

- Assumed 0.2 (larger than landings, less than MRIP discard uncertainty)

GR landings and discards:

- Annual CVs provided by recreational WG (derived from MRIP uncertainty estimates)
- Capped CV at 1.0 to avoid data streams that lead to convergence issues

yr	cv.L.cH	cv.L.HB	cv.L.GR	cv.D.HB	cv.D.GR
1988	0.1	0.15	0.93	0.2	0.74
1989	0.1	0.15	1	0.2	0.36
1990	0.1	0.15	0.86	0.2	0.44
1991	0.1	0.15	0.56	0.2	0.28
1992	0.1	0.15	0.44	0.2	0.25
1993	0.1	0.15	0.45	0.2	0.6
1994	0.075	0.15	0.44	0.2	0.9
1995	0.075	0.15	0.56	0.2	1
1996	0.075	0.1	0.73	0.2	0.54
1997	0.075	0.1	0.62	0.2	0.35
1998	0.075	0.1	1	0.2	0.46
1999	0.075	0.1	0.7	0.2	0.52
2000	0.075	0.1	0.75	0.2	0.29
2001	0.075	0.1	0.86	0.2	0.32
2002	0.05	0.1	0.51	0.2	0.27
2003	0.05	0.1	0.7	0.2	0.31
2004	0.05	0.1	0.41	0.2	0.69
2005	0.05	0.1	0.36	0.2	0.24
2006	0.05	0.1	0.43	0.2	0.29
2007	0.05	0.1	0.21	0.2	0.33
2008	0.05	0.05	0.38	0.2	0.43
2009	0.05	0.05	0.31	0.2	0.37
2010	0.05	0.05	0.31	0.2	0.46
2011	0.05	0.05	0.31	0.2	0.41
2012	0.05	0.05	0.25	0.2	0.71
2013	0.05	0.05	0.13	0.2	0.24
2014	0.05	0.05	0.17	0.2	0.17

Monte Carlo Bootstrap

1. Natural Mortality (M)
   - Uncertainty in tmax (based on ageing error matrix, age-10)
   - Re-sample Then et al. (2014) data with replacement to draw paired parameters, *a* and *b* (M vs. tmax relationship: $M = aT_{max}^{b}$)
   - Calculate new age-dependent Charnov mortality vector scaled to new M

2. Discard Mortality (truncated normal distribution; 0.05 to 0.20 from the DW)

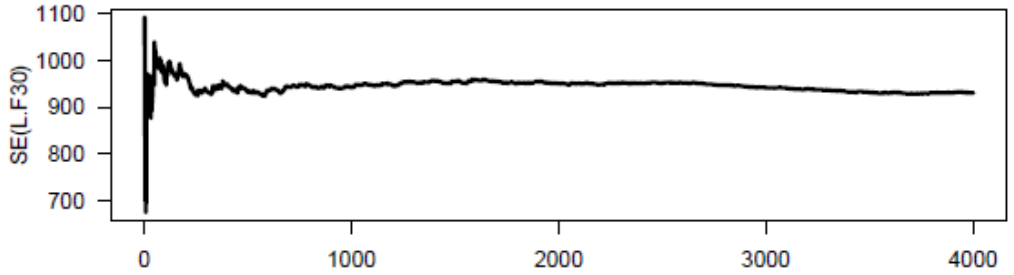
3. Reproduction
   - Batch fecundity
     - paired parameter estimates (*a* and *b*) drawn with replacement from 10,000 bootstraps of the batch fecundity relationship, $a*\text{length}^{b}$
     - Trimmed values where *a* or *b* outside of its 95% CI

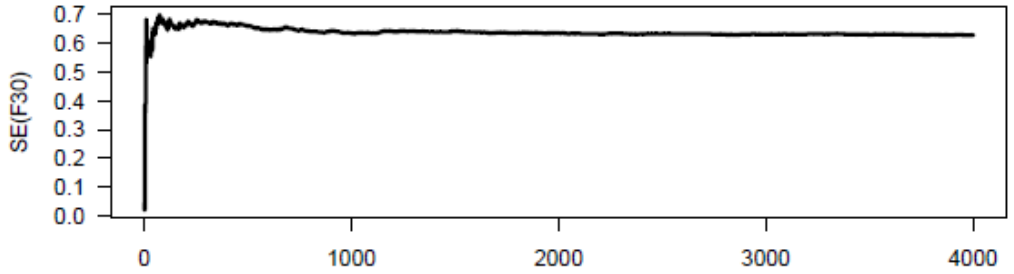
   - Batch number
     - 10,000 bootstrap of raw data from DW (spawning indicator, age, day of year)
     - Re-compute batch number as in the base run (spawning fraction at age x spawning period at age)

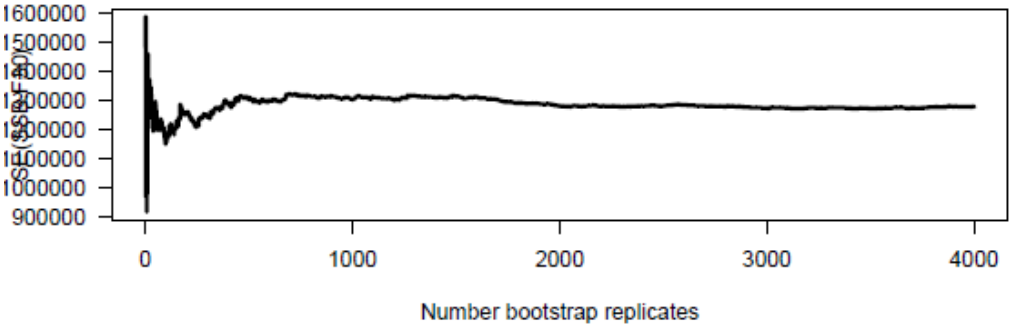
4. Weighting of FI trap index
   draw from uniform distn from 4X to 8X the increase in index weight

MCB--Convergence

- 4000 MCB runs
- 3690 retained (92.3%)
- 7.7% did not converge or parameters hit bounds

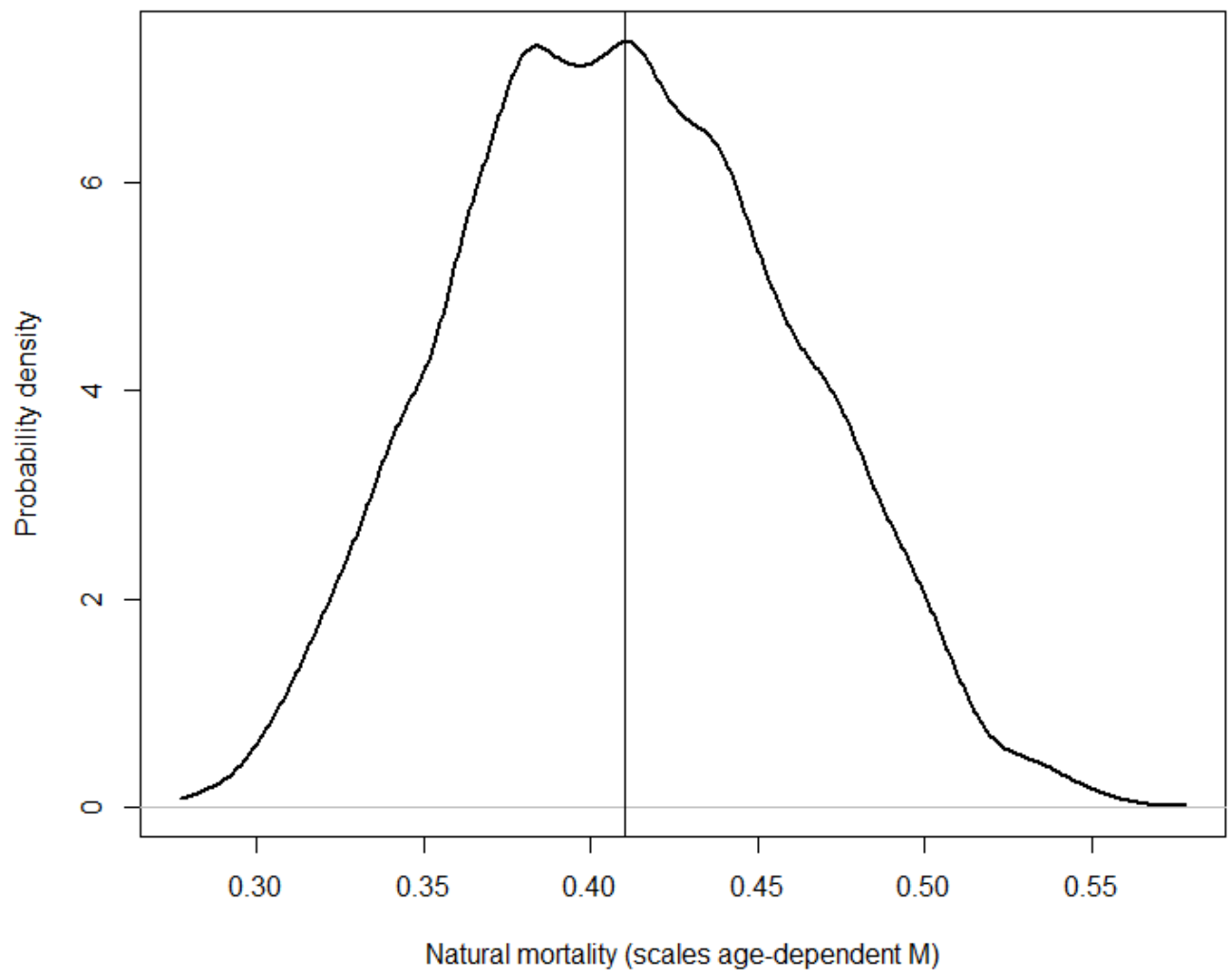






Monte Carlo Draws (M)

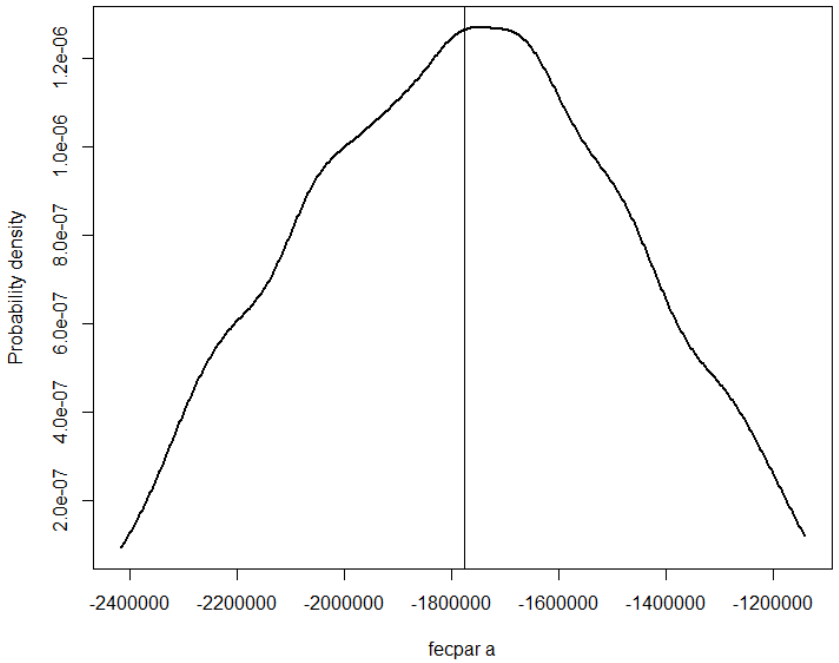
Line = base run

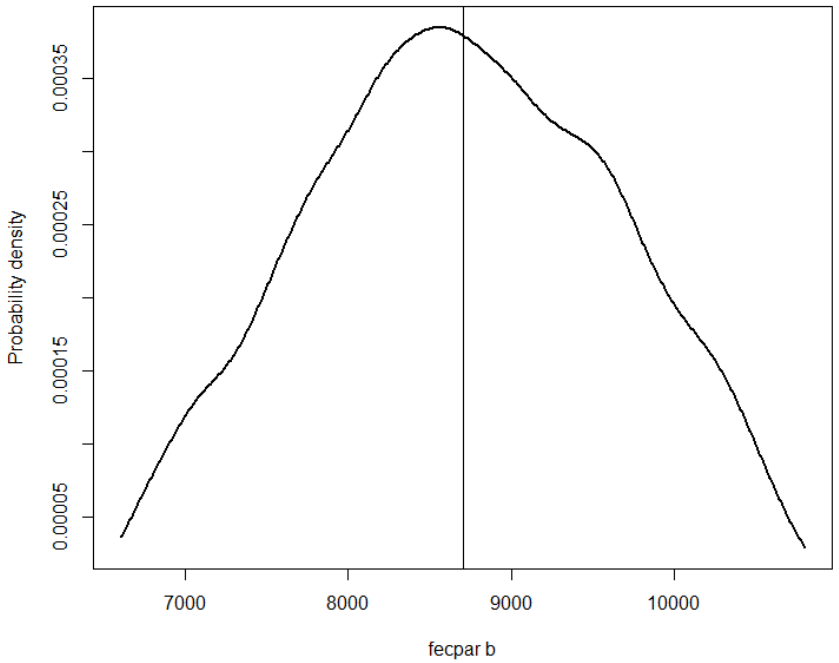


Monte Carlo Draws (Batch fecundity)

Batch Fecundity = a*length^b

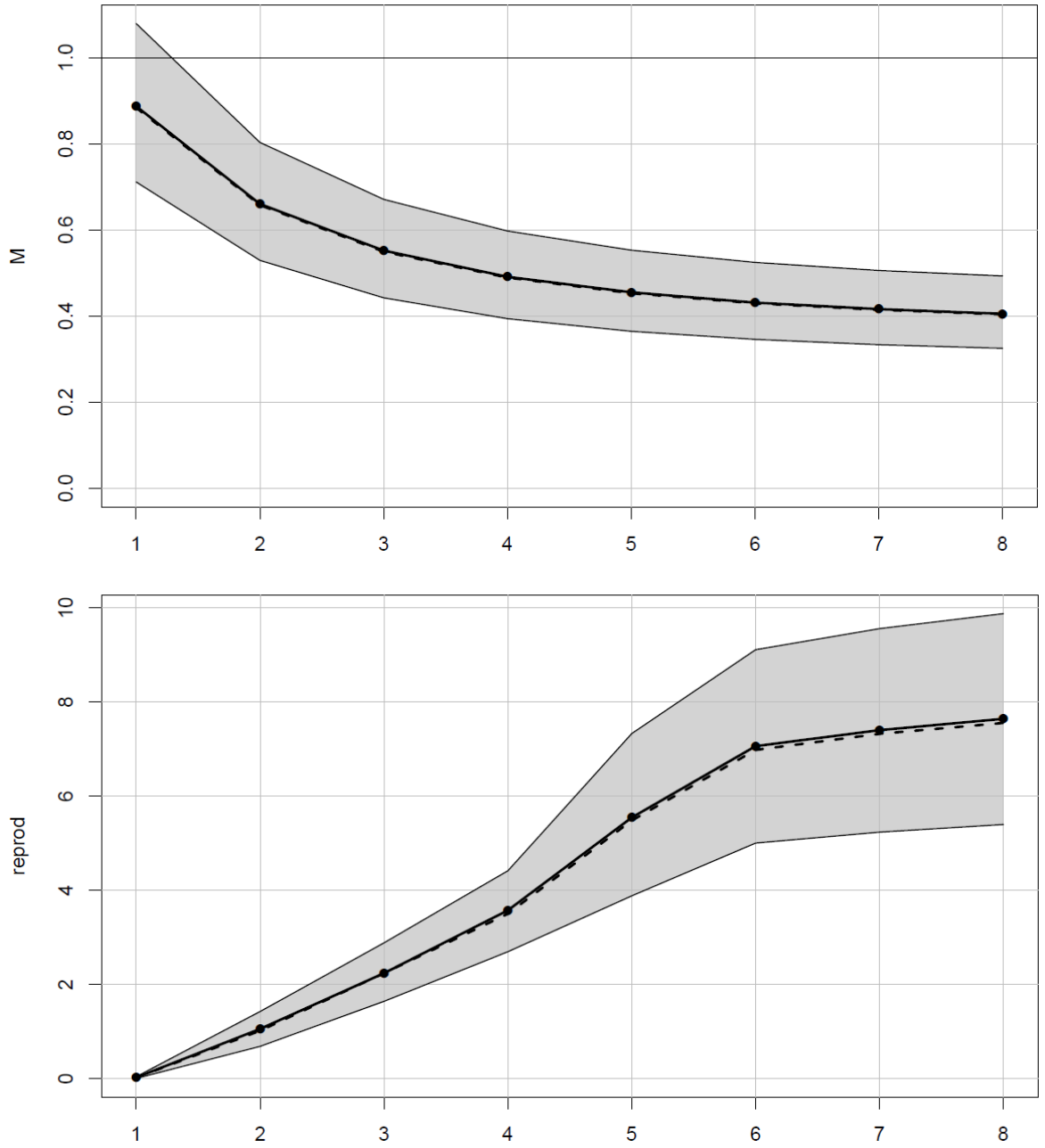
Line = base run





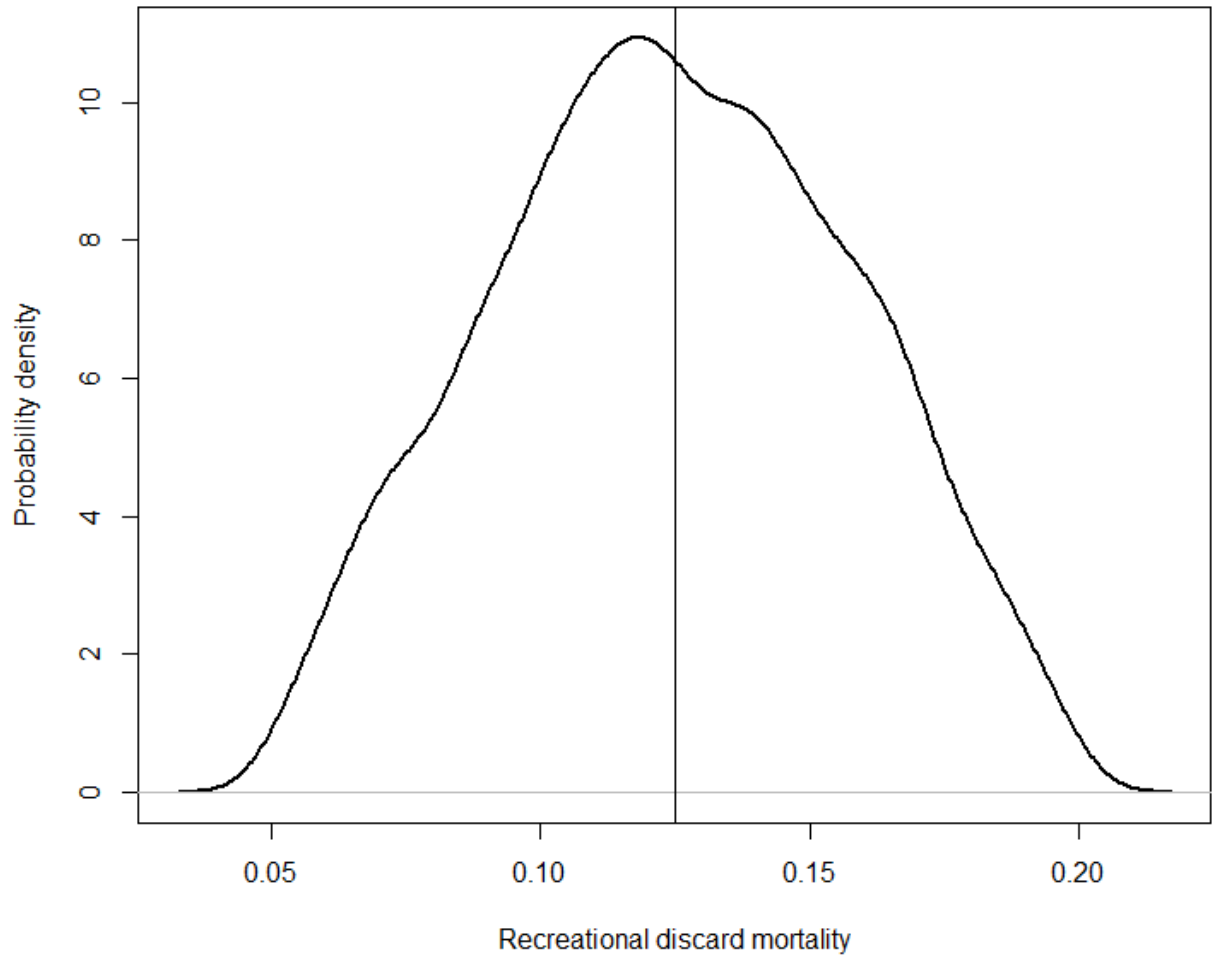
Monte Carlo (Natural Mortality and Reproduction)

Dash: MCB median
Solid: Base run



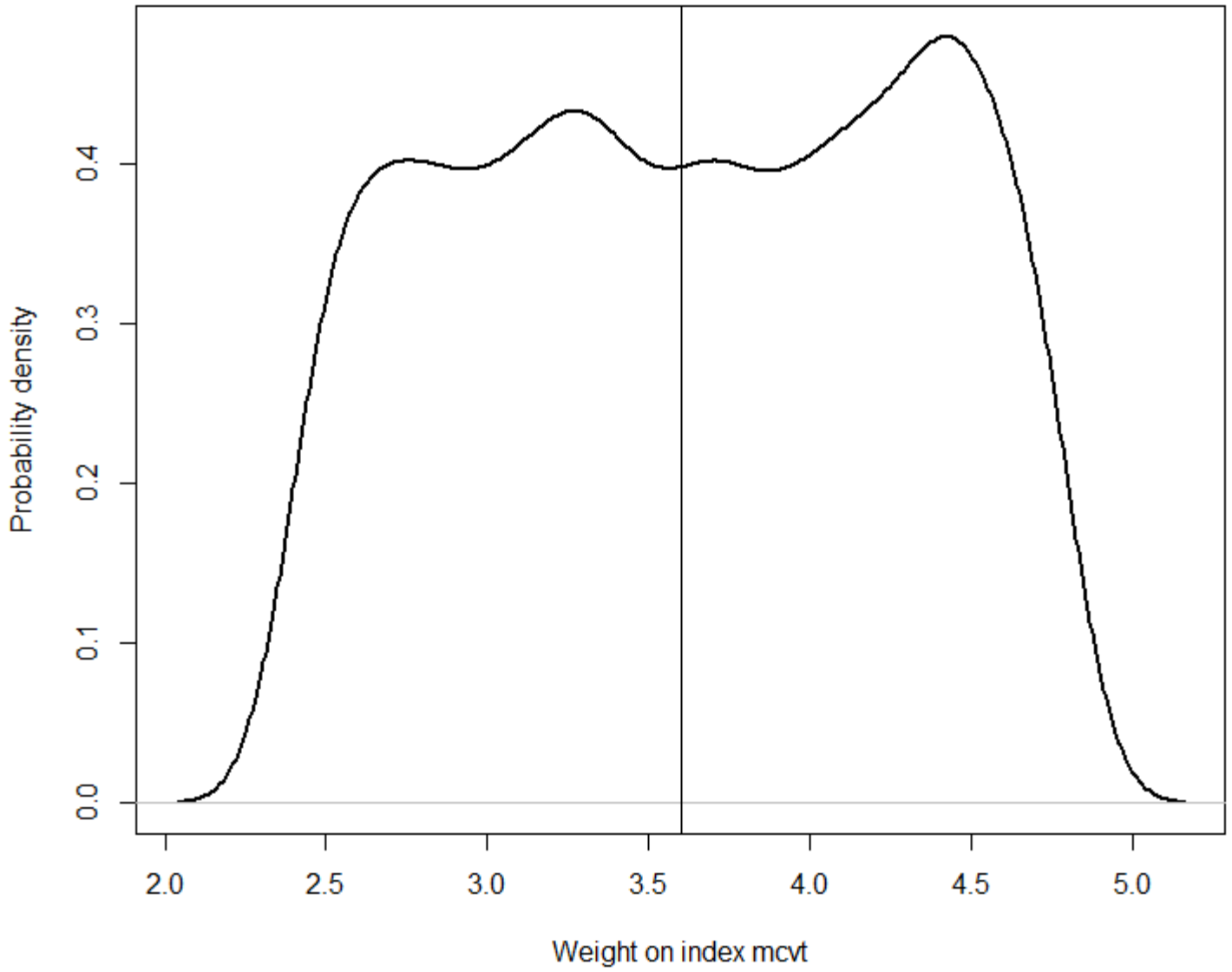
Monte Carlo Draws (Discard Mortality)

Line = base run



Monte Carlo Draws (Index Weight)

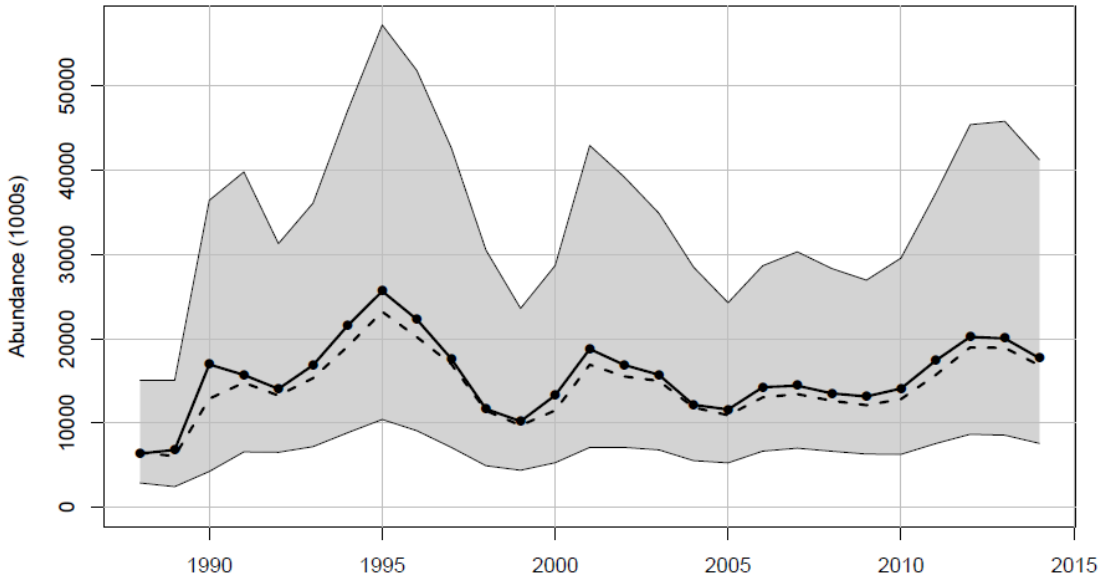
Line = base run



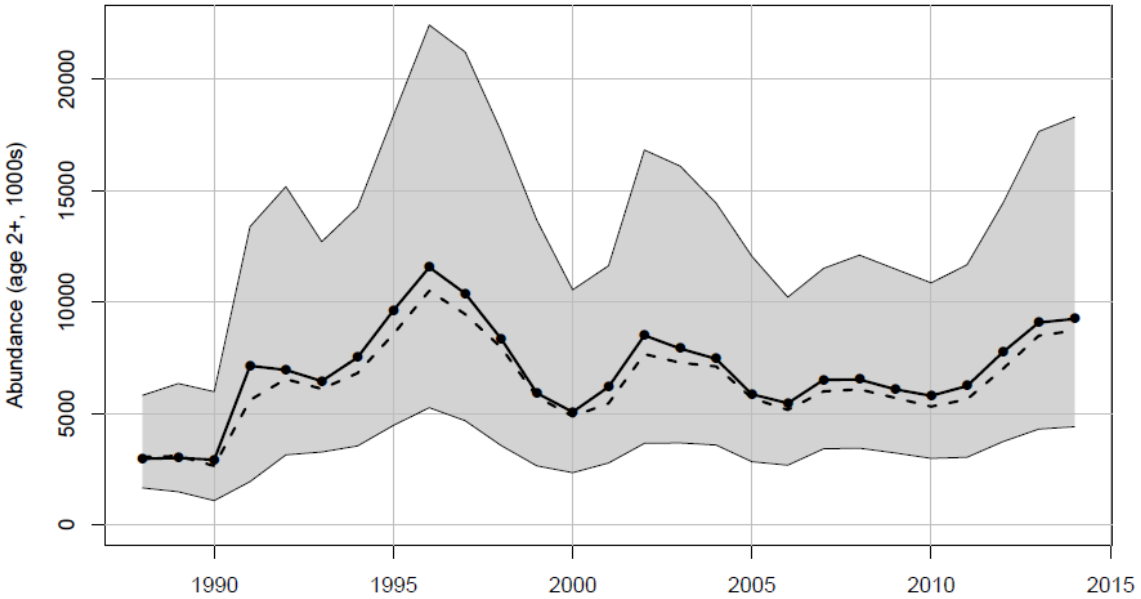
MCB—Abundance and Biomass

solid line = base run
dash =MCB median

Total Abundance

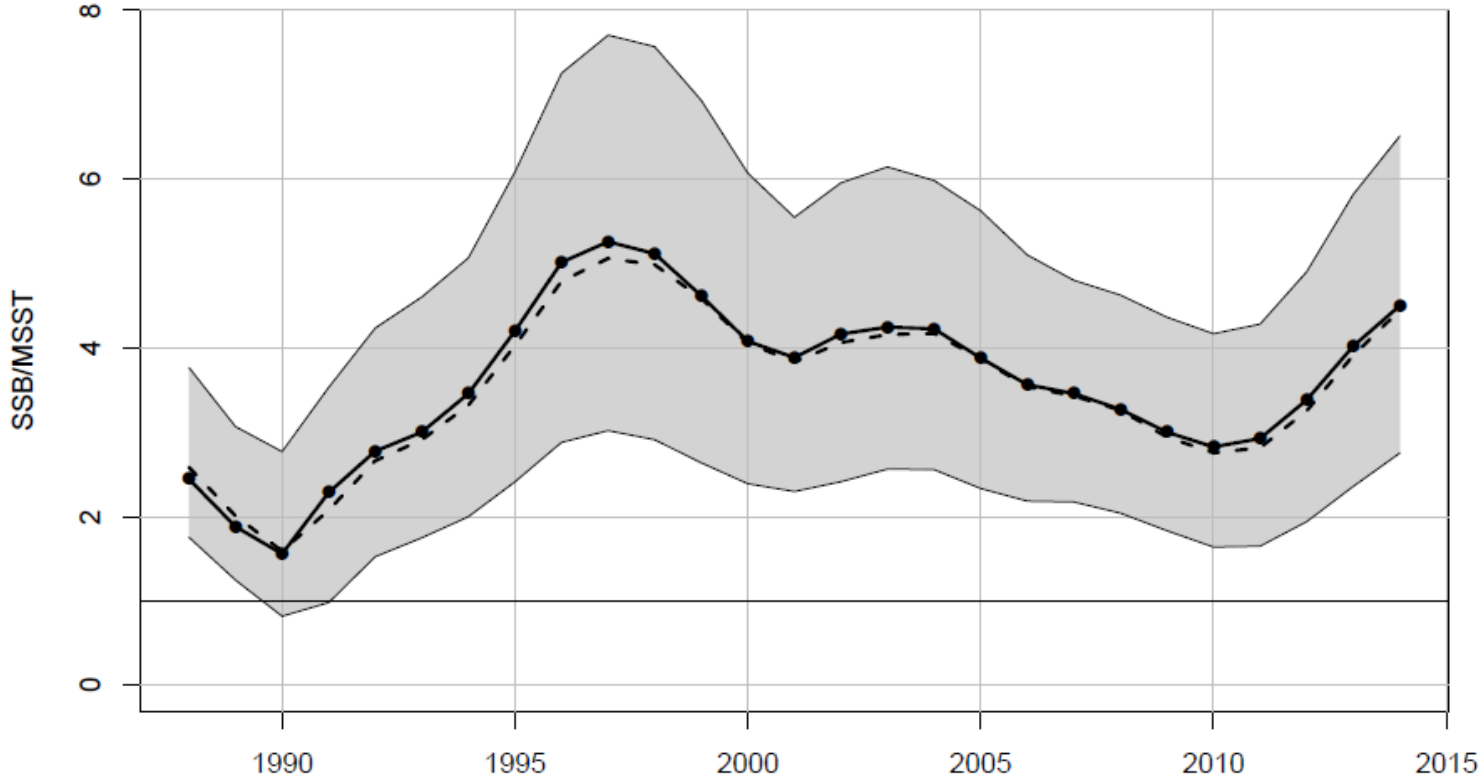


2+ Total Abundance



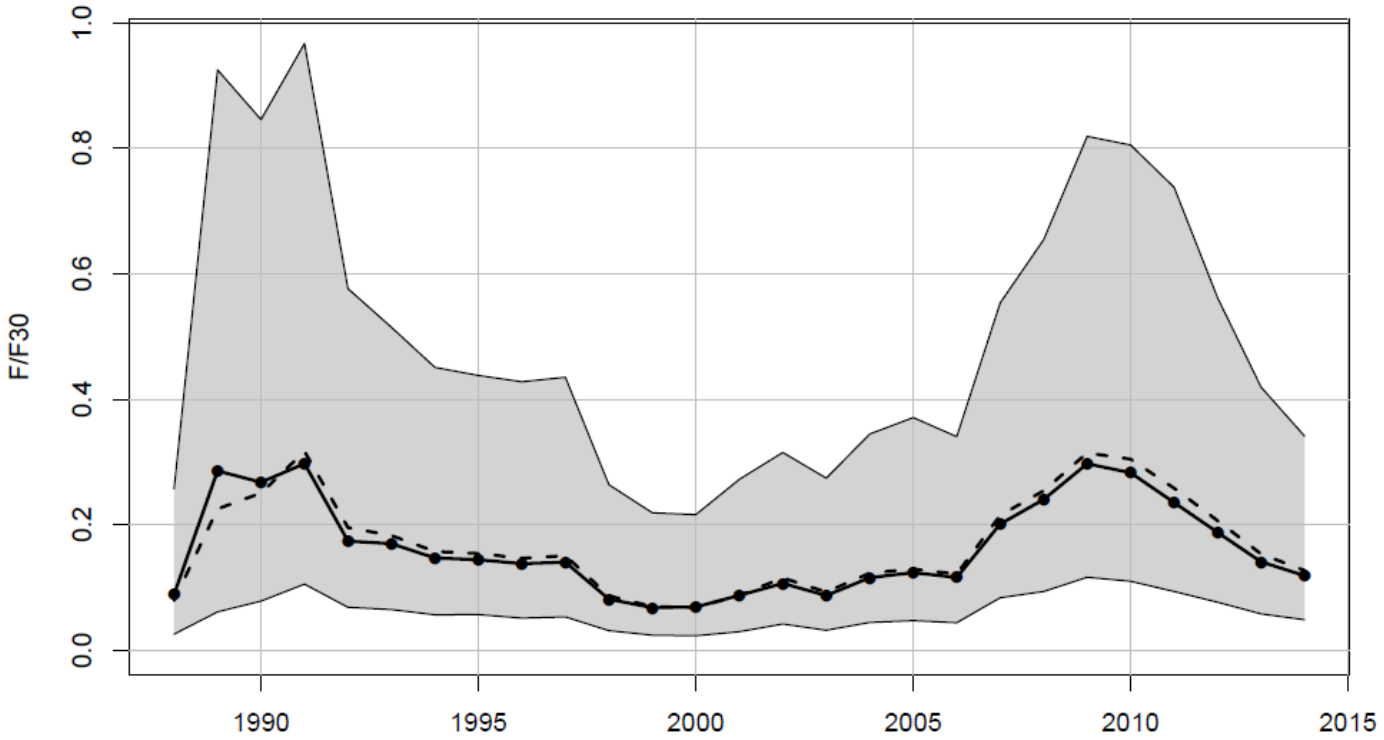
MCB—Biomass Status

solid line = base run
dash =MCB median



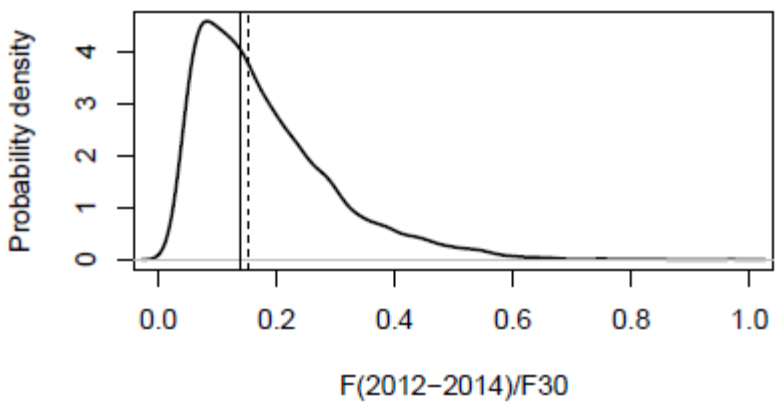
MCB—Exploitation Status

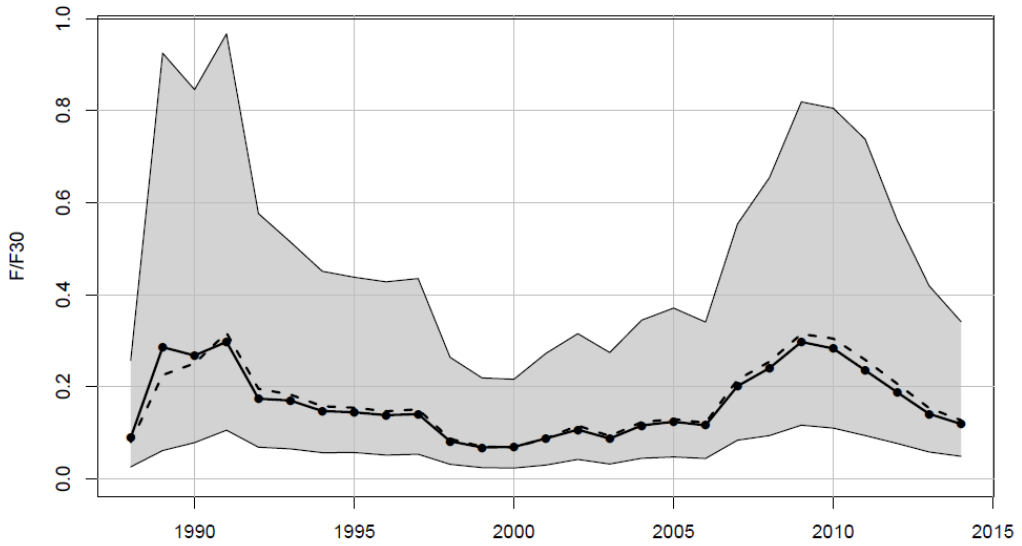
solid line = base run
dash =MCB median

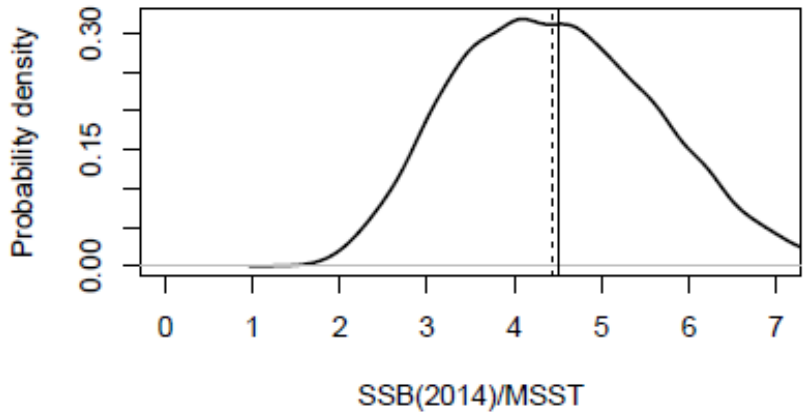


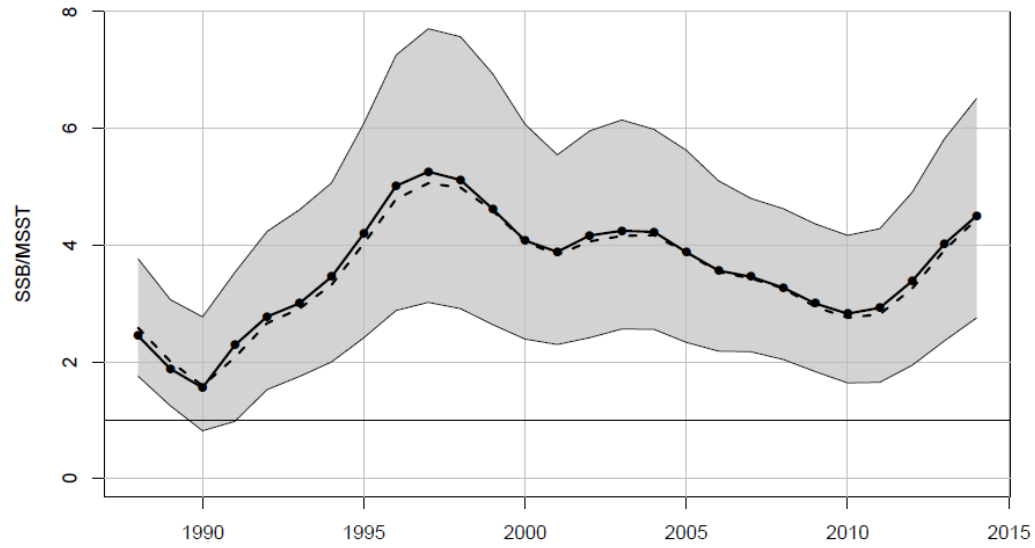
MCB—Status and Uncertainty

solid line = base run
dash =MCB median



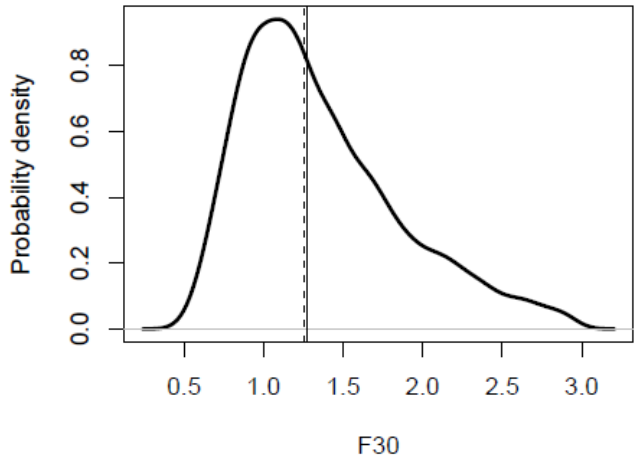


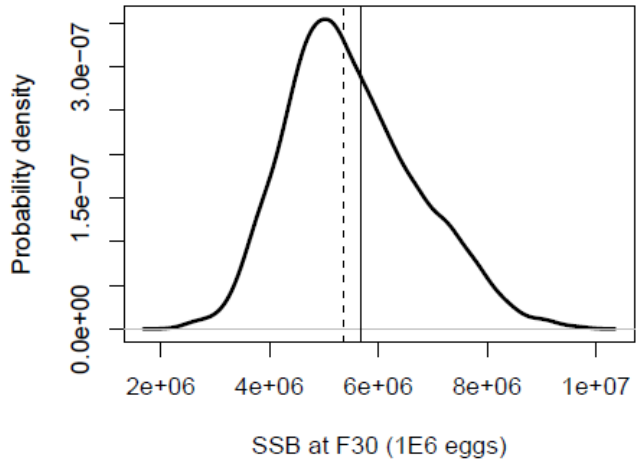


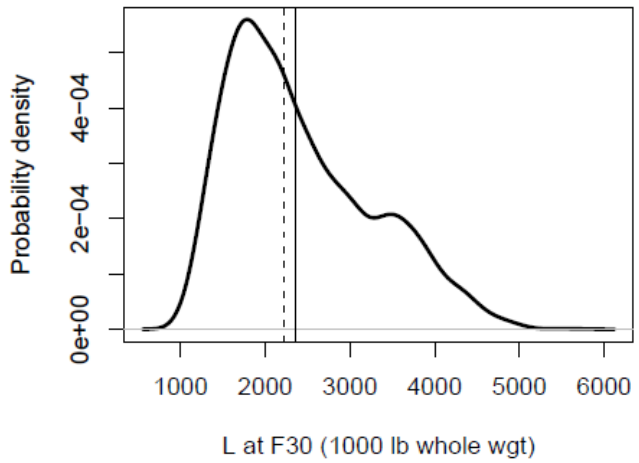


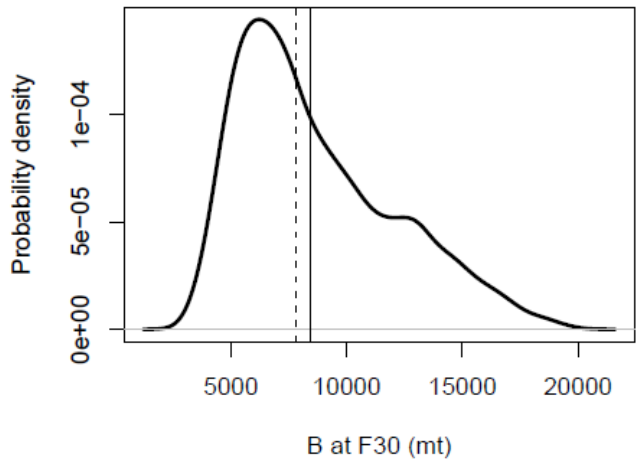
MCB--Results

Distribution of Management Quantities (solid line = base run, dash =MCB median)

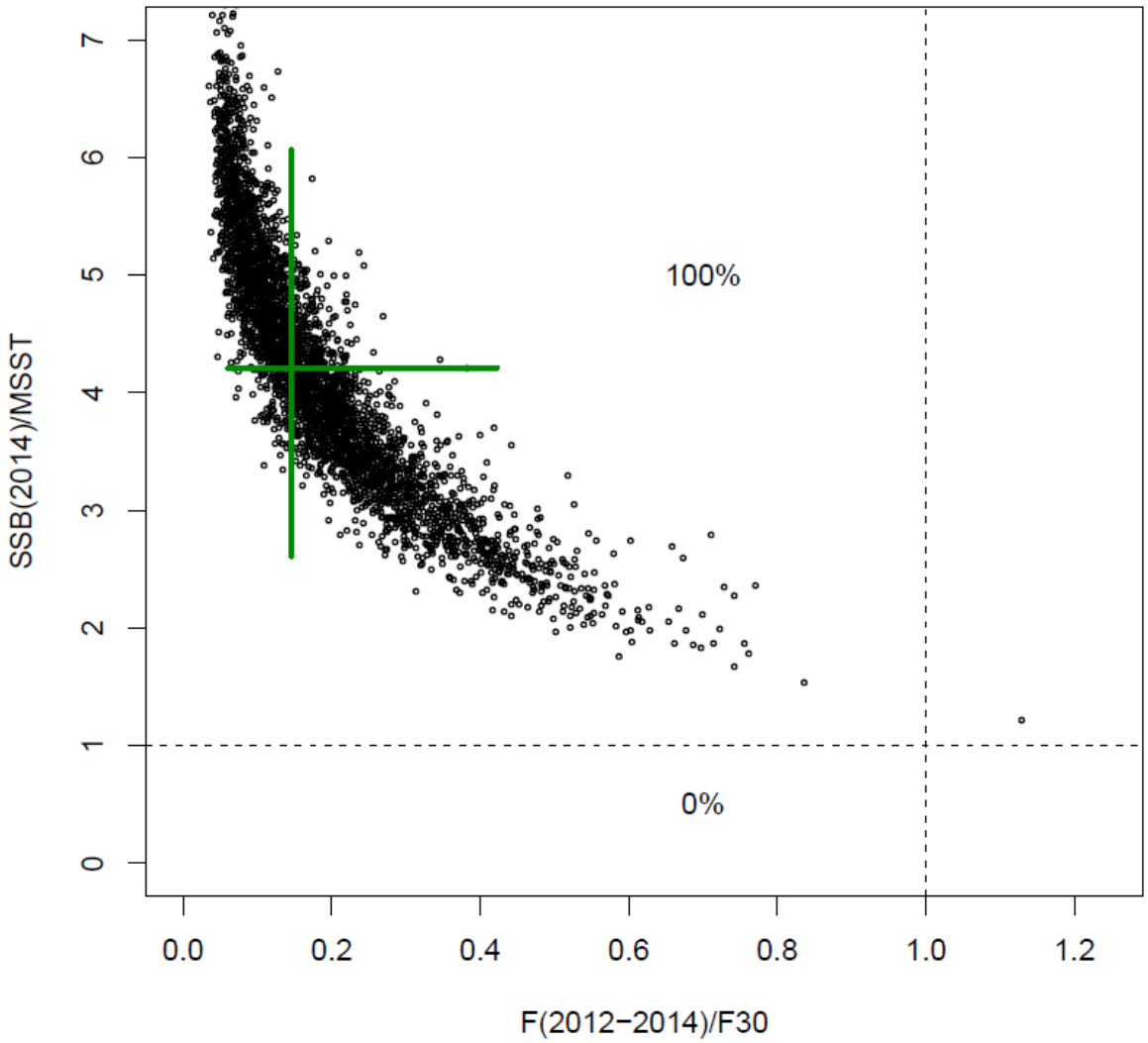








MCB—Phase Plot



Intersection: Base run estimate
Lines: 5th and 95th %tile MCB runs

Projections

Projections

- 10 year projections (2015-2024)
- Same structure as assessment model
- Initialization:
  - Initial (2015) numbers at age (2-8^{+}) based on 2014 estimates discounted by Z
  - Initial recruits (age-1 in 2015) computed from S-R model and 2014 spawning biomass
  - Assume avg selectivity across fleets from last 3 years of the assessment (2012-2014)

  - Interim period: 2015 and 2016 landings matched to $L_{current}$ (mean of 2012-2014 landings)
  - New management assumed to start in 2017
  - Projection period: Constant F from 2017-2024 indicated by the projection scenario

- n= 20,000 projected time series
- Each time series based on a single MCB run chosen at random with replacement (includes uncertainty in data and parameters estimates)

Projections Scenarios

Three Constant F Projection Scenarios:

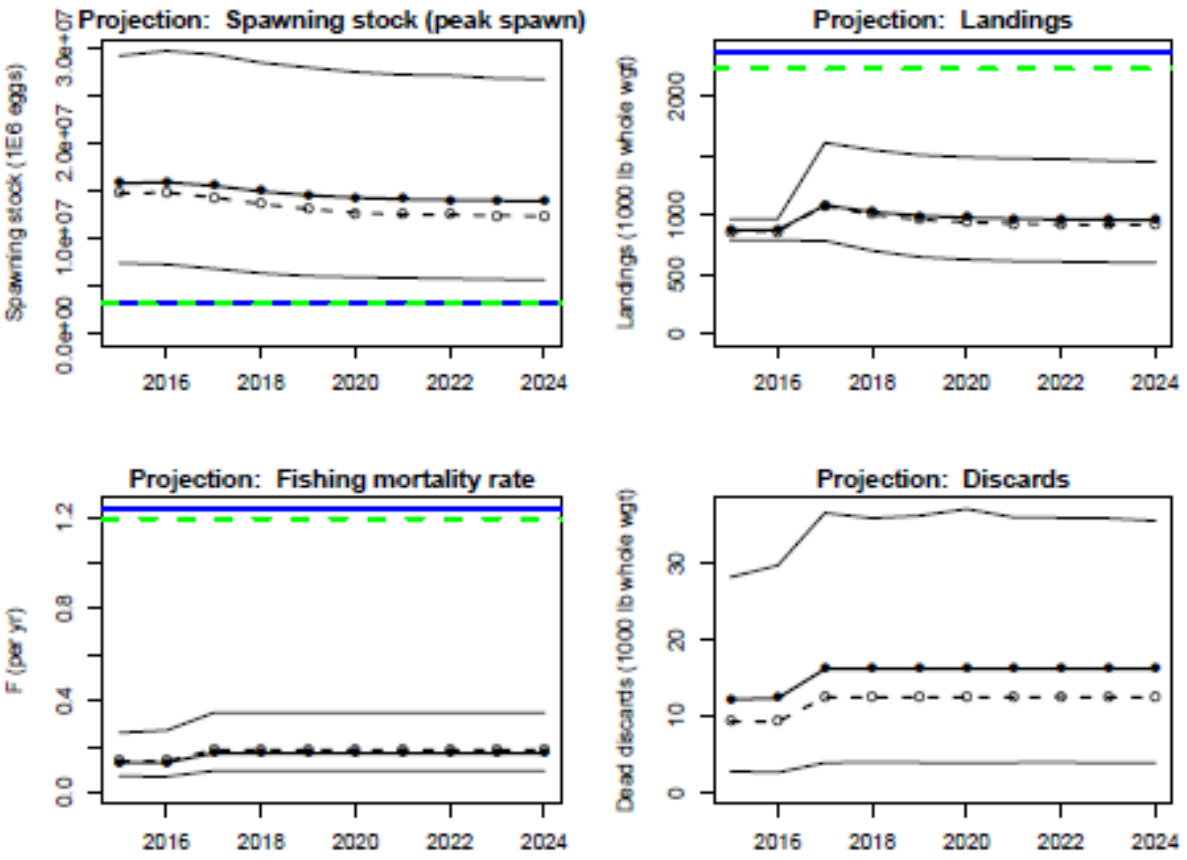
1. $F=F_{current}$
2. $F=75\%\ F_{30}$
3. $F=F_{30}$

Projection F = $F_{current}$

Base: solid black
MCB median: dashed black
(with 5th and 95th CI)

<u>Benchmarks</u>
Base (blue)
MCB median (dash green)

(F_{30}, L_{F30}, $MSST_{F30}$)

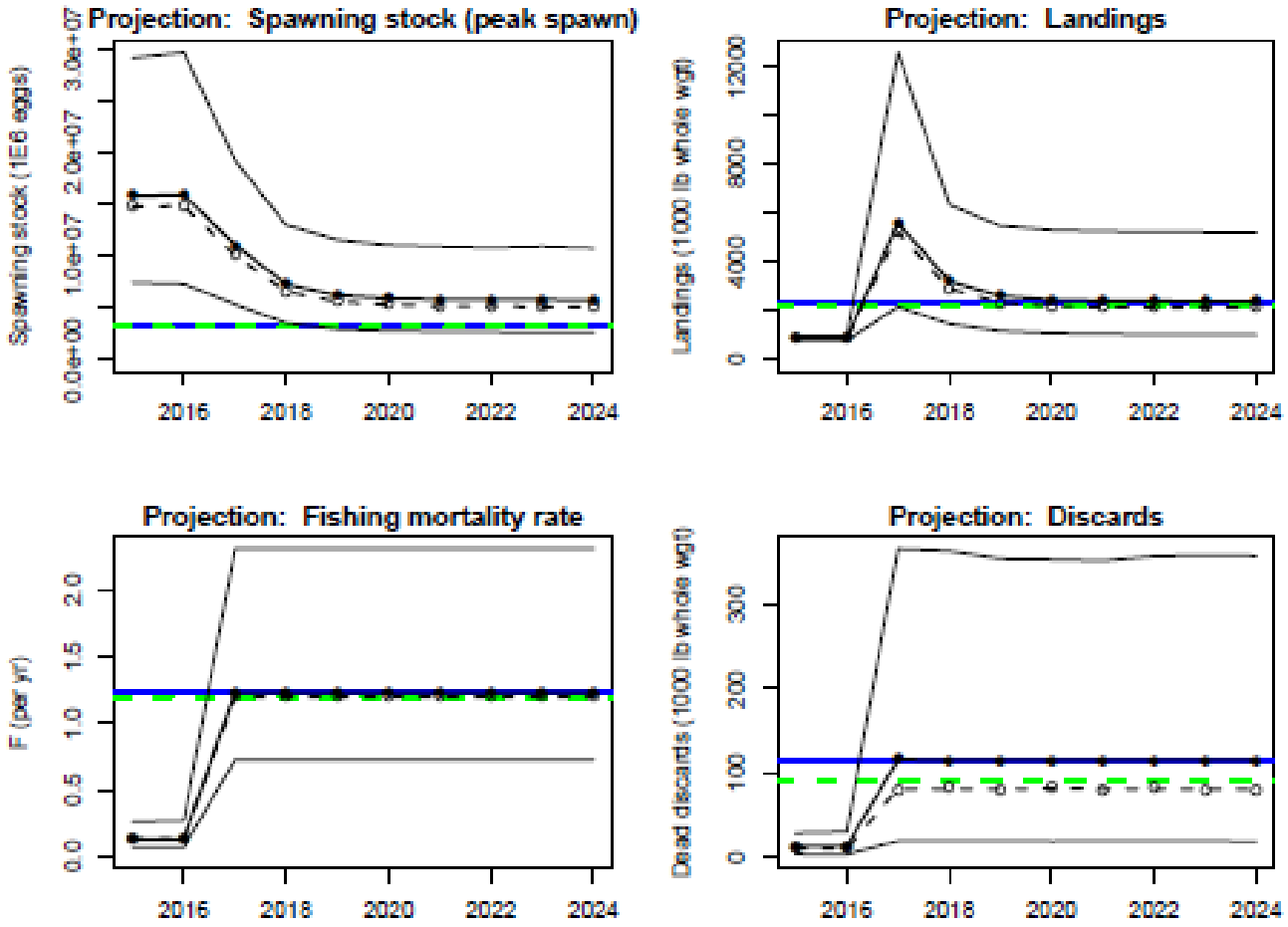


Projection F = F_{30}

Base: solid black
MCB median: dashed black
(with 5th and 95th CI)

<u>Benchmarks</u>
Base (blue)
MCB median (dash green)

(F_{30}, L_{F30}, $MSST_{F30}$)

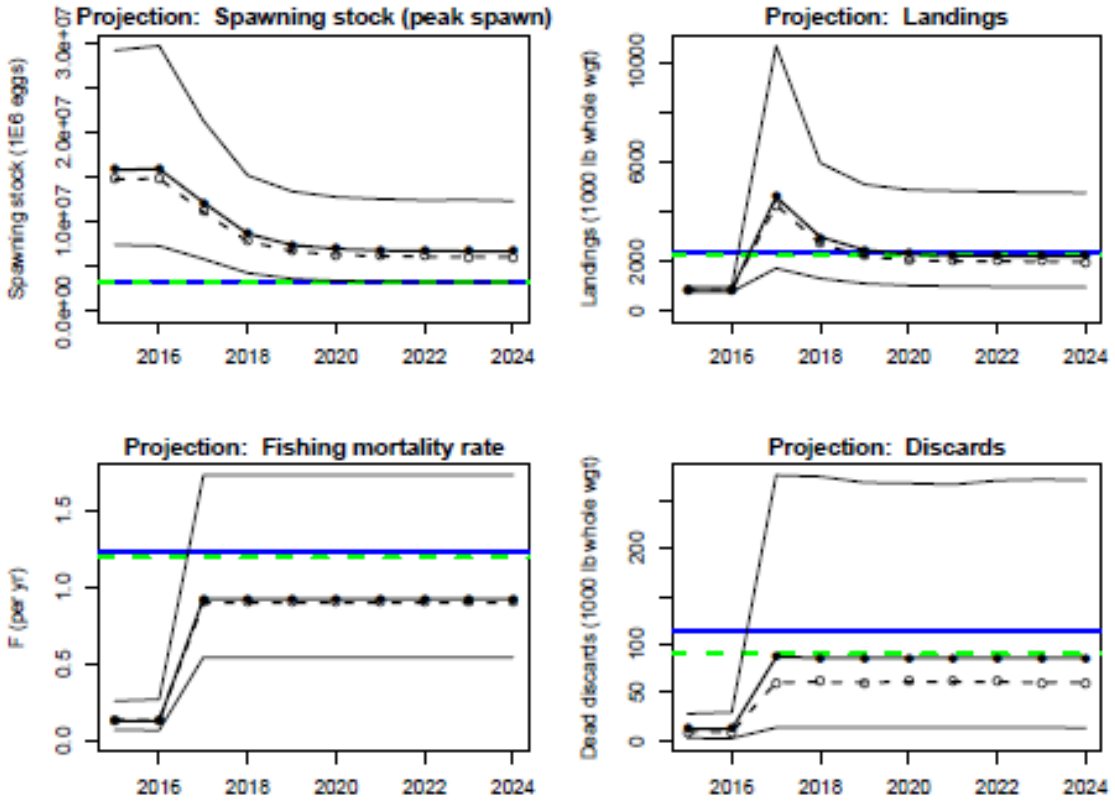


Projection F = 75% F_{30}

Base: solid black
MCB median: dashed black
(with 5th and 95th CI)

<u>Benchmarks</u>
Base (blue)
MCB median (dash green)

(F_{30}, L_{F30}, $MSST_{F30}$)



Surplus Production Model

Age-Aggregated Surplus Production Model

- Response variable: Age-aggregated annual biomass
- Assumes recruitment + growth – natl mortality = 'surplus' production
- Graham-Schaefer logistic formulation:

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2 - F_tB_t$$

- Assumes surplus production symmetric about B_{msy} = 0.5 K (shape param=0.5)
- Conditioned on yield (pooled landings and dead discards)
- Fit to CPUE indices of abundance
- Model estimates K, MSY, B_1/K, q_i's
- Implemented in ASPIC (Prager 1994)

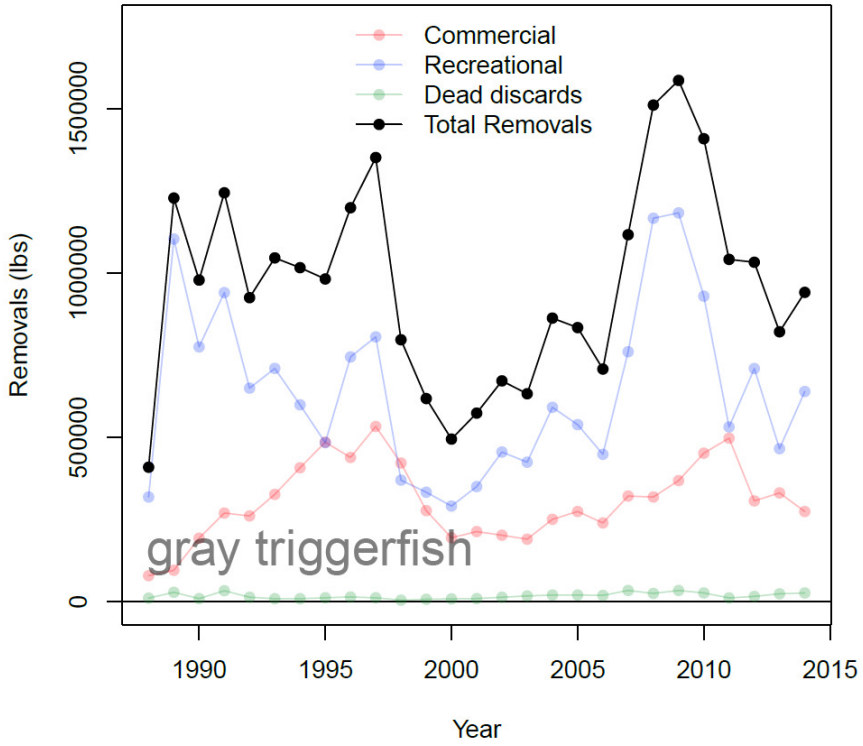
Surplus Production Model (Inputs)

- Removals (1988-2014)
  - Comm handline +other (lbs)
  - Headboat + General Rec (lbs)
  - Dead discards
    - Comm Handline, Headboat, General Rec
    - Converted from no. to wgt using mean wgts of headboat discards

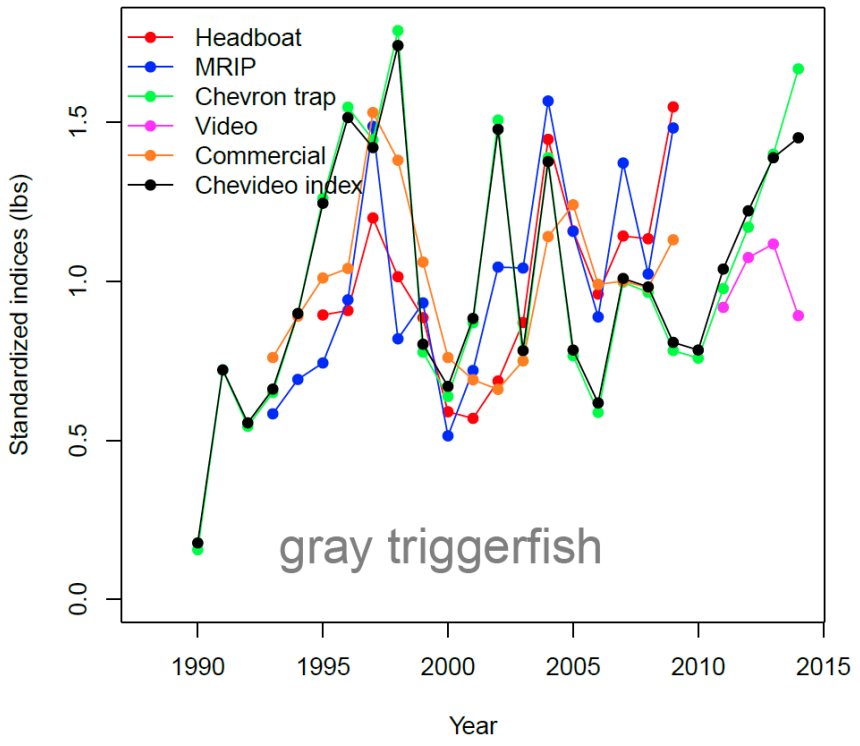
- Indices
  - Chevron trap, video, general rec (MRIP), headboat, comm HL
  - Converted to wgt (using fleet specific mean wgts) and re-standardized to mean 1.0

Surplus Production Model (Inputs)

Removals



Indices



Surplus Production Model

- Best configuration
  - Truncated time series (2000-2014)
  - Comm HL, Headboat, General Rec (MRIP), and CVID indices
  - Status qualitatively similar to BAM catch-age model

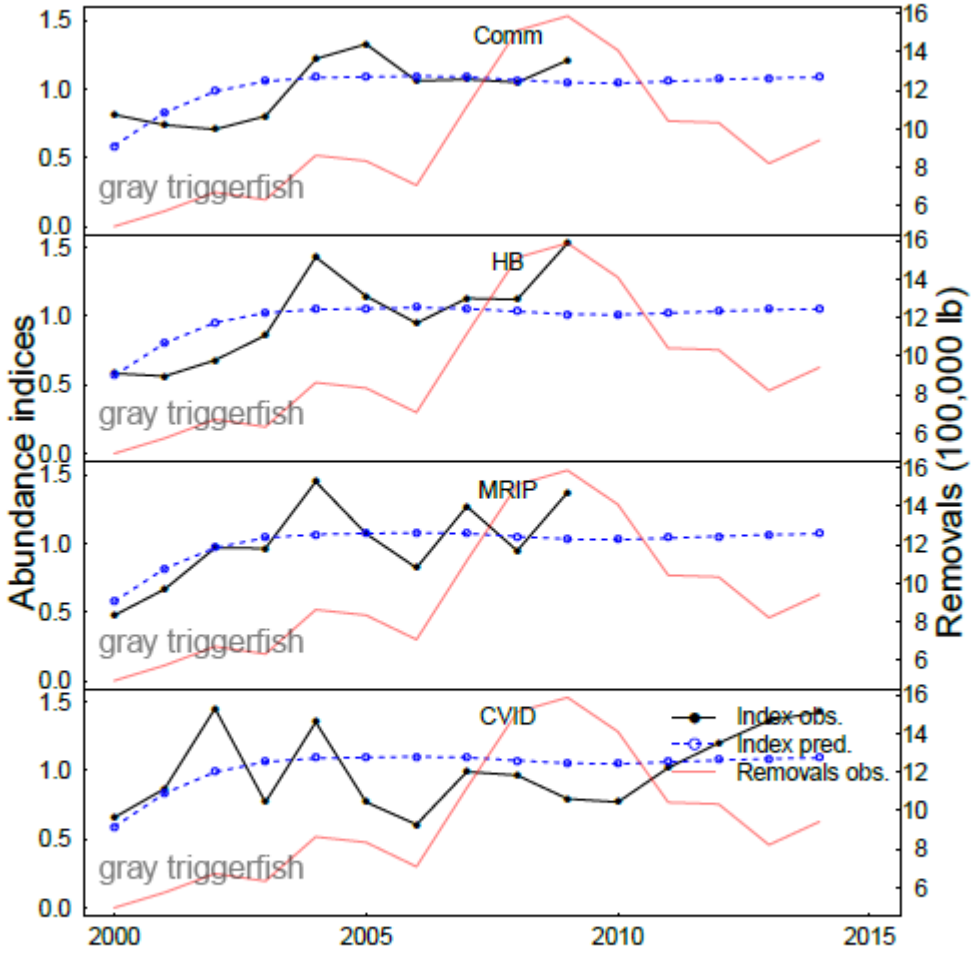
  Issues:
  - Little contrast in removal and index times series (Most contrast in last ~ 10 years)
  - B1/K unlikely—suggests depleted stock in 2000 that increases over time

Table 27. Parameter estimates from ASPIC surplus production model run 213 (best possible configuration) All parameter values are rounded to 3 significant digits. MSY, B_1, and K are in units of 1000 pounds. Catchability parameters correspond to the commercial (q_1), headboat (q_2), GR (q_3), and CVID (q_4) indices.

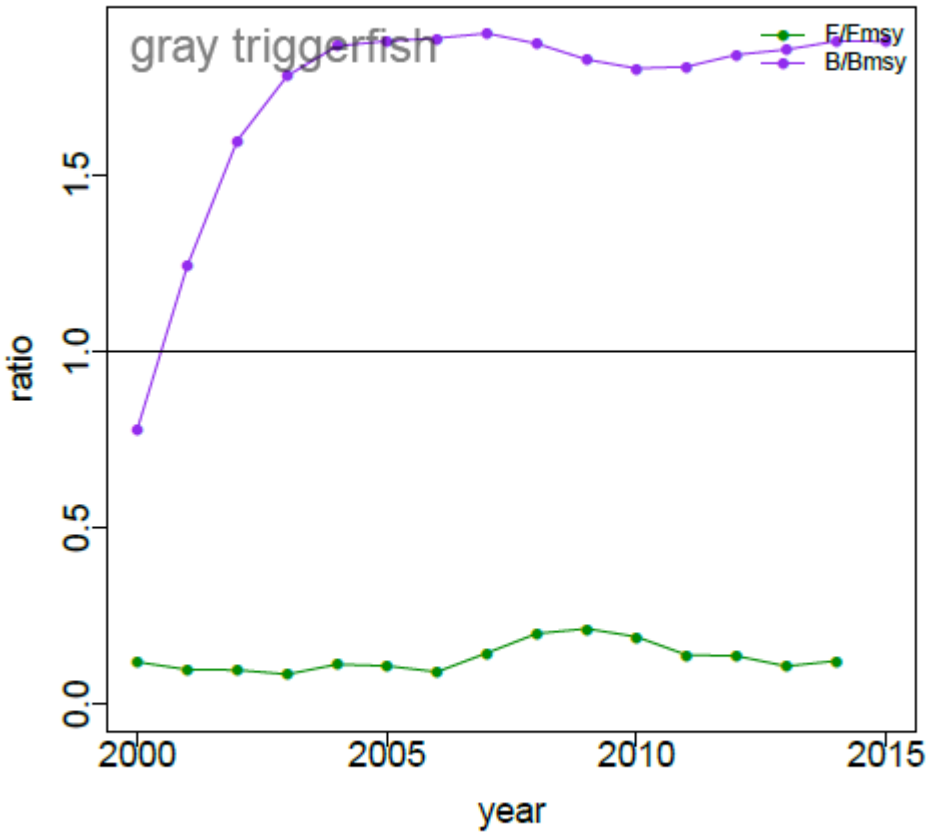
Run	F/F_{MSY}	B/B_{MSY}	B_1/K	MSY	F_{MSY}	q_1	q_2	q_3	q_4	B_1	K
213	0.122	1.88	0.39	4100	0.537	7.57e-08	7.34e-08	7.45e-08	7.62e-08	5960	15300

Fits to Indices

Black: observed index
Red: removals
Blue: model fit



Stock Status



The End