SEDAR 64:
Southeastern U.S. Yellowtail Snapper

Joint SSC Meeting, Tampa, FL

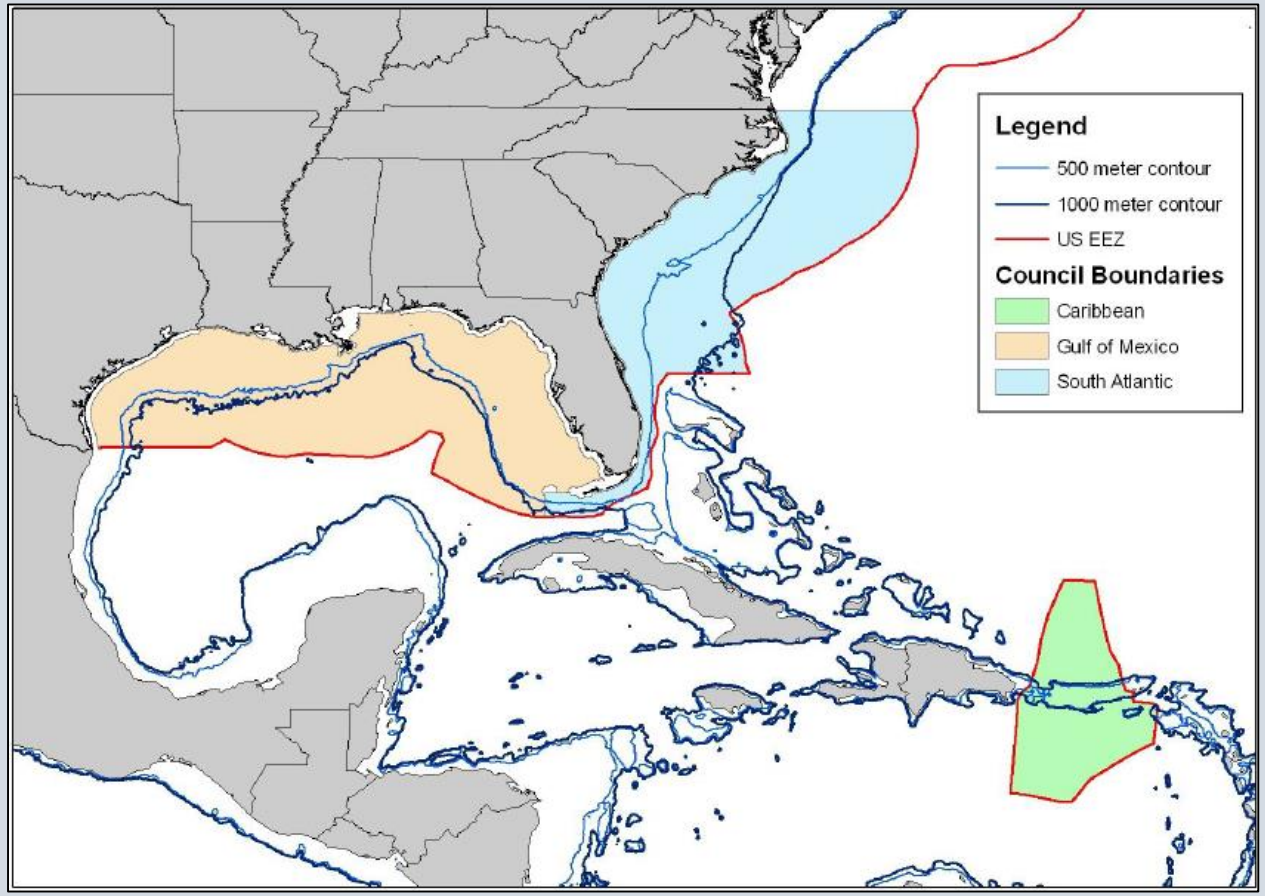
July 21 – 23, 2020

Shanae D. Allen and Christopher E. Swanson

FWRI Stock Assessment Group, St. Petersburg, FL

Introduction:
Stock Unit

- Managed as separate stock units by two councils (SAFMC, GMFMC)
  - Boundary is U.S. Highway 1 in the Florida Keys west to the Dry Tortugas
  - State of Florida also manages in state waters
- Assessments treat South Atlantic and Gulf of Mexico as a single stock unit



Introduction:
Management History - SAFMC

- Snapper-Grouper FMP (8/31/1983)
  - 12” (305mm) TL minimum size limit for commercial and recreational fisheries
    - Florida state waters regulation enacted 7/1/1985
- Amendment 4 (1/1/1992)
  - Aggregate daily bag limit of 10 snappers for recreational fishery
    - Florida state waters regulation enacted 12/1/1986
- Amendment 11B (12/2/1999)
  - MSY-proxy set as 30% static SPR; OY-proxy is 40% static SPR
- Regulatory Amendment 15 (9/12/13)
  - OY = ACL = ABC
- Regulatory Amendment 21 (11/6/2014)
  - Modified MSST to be 75% of the SSB_{MSY}

Introduction:
Management History - GMFMC

- Reef Fish FMP (11/8/1984)
- Reef Fish Amendment 1 (2/21/1990)
  - 12” (305mm) TL minimum size limit for commercial and recreational fisheries
  - Aggregate daily bag limit of 10 snappers for recreational fishery
- Reference points are currently undefined but an amendment is currently under development
  - GMFMC currently defers to SAFMC

Introduction:
Assessment History

- SEDAR 3 (2003)
  - Integrated and Statistical Catch-at-Age model (ICA) for data 1981 – 2001
  - F_{2001}/F_{msy} = 0.57 (not overfishing); SSB_{2001}/SSB_{msy} = 1.43 (not overfished)

- SEDAR 27A (2012)
  - Statistical catch-at-age model (ASAP2) for data 1981 – 2010
  - $F_{msy} \rightarrow F_{30\%SPR}$; MSST = $(1-M)*SSB_{30\%SPR}$
  - $F_{2001}/F_{30\%SPR}$ = 0.15 (not overfishing); SSB_{2001}/MSST= 3.36 (not overfished)

Introduction:
Quota History

Gulf of Mexico	Date	ACL
Commercial and Recreational	Jan 2012 – Sept 2013	725,000 lbs
	Sept 2013 – Current	**901,125 lbs**
South Atlantic	Date	ACL
Commercial	Apr 2012 – Nov 2012	1,142,589 lbs
	Nov 2012 – Current	**1,596,510 lbs**
Closures	10/31/2015 – 12/31/2015	
	6/3/2017 – 8/1/2017	
Recreational	Apr 2012 – Sept 2013	1,031,286 lbs
	Sept 2013 – Current	**1,440,990 lbs**

SEDAR 64:Yellowtail Snapper

Data

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Joint SSC Meeting, Tampa, FL: July 21 – 23, 2020

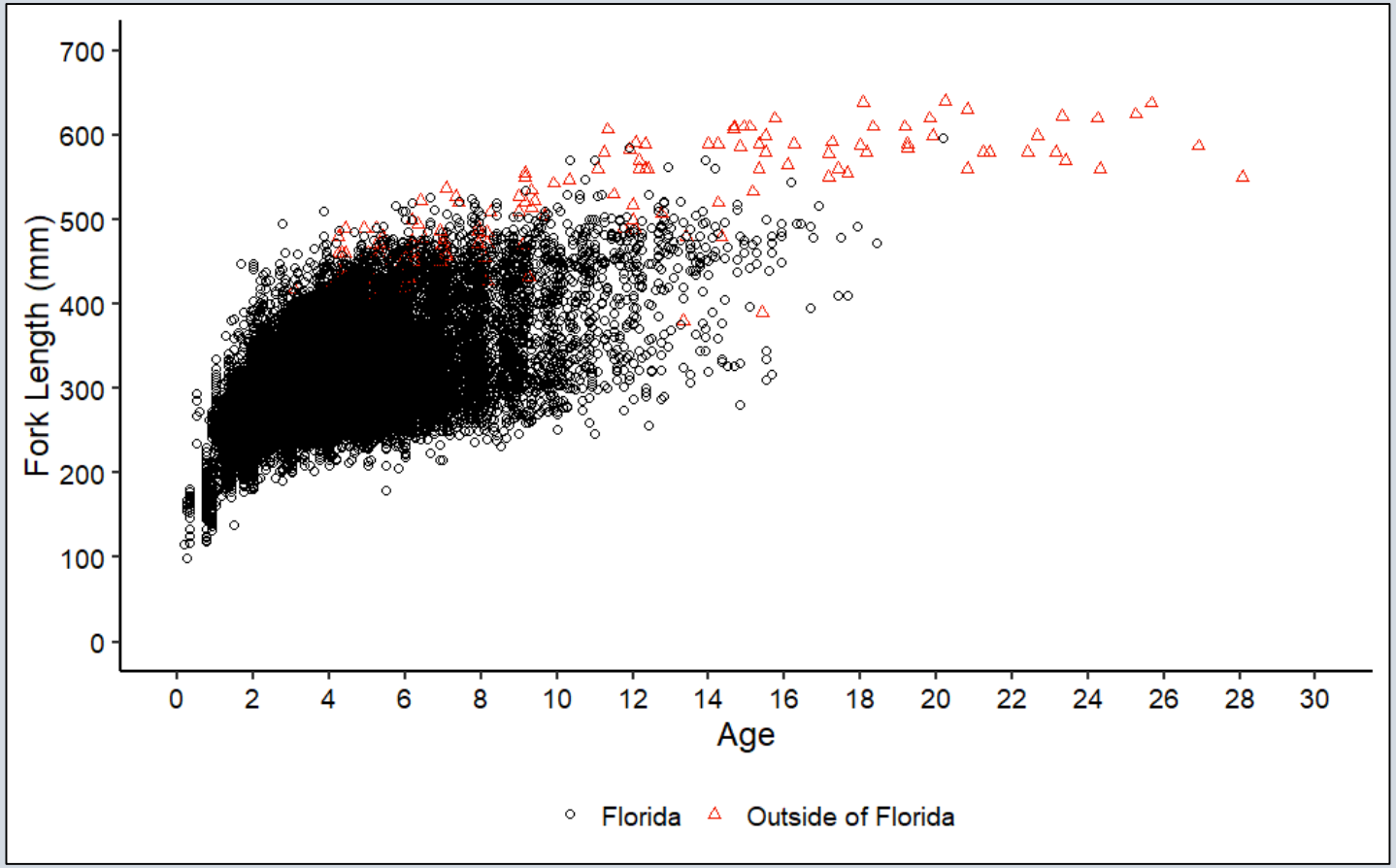
Data:
Life History

Age Structure

- 0 – 20 years in Florida
- Max age-28 off the Carolinas
- 99% of otoliths from FL
- In Florida
  - 58% were age-2 and -3
  - 90% were ages 2 – 6

Location within Florida

- 61% from Florida Keys
- 35% from southeast Florida



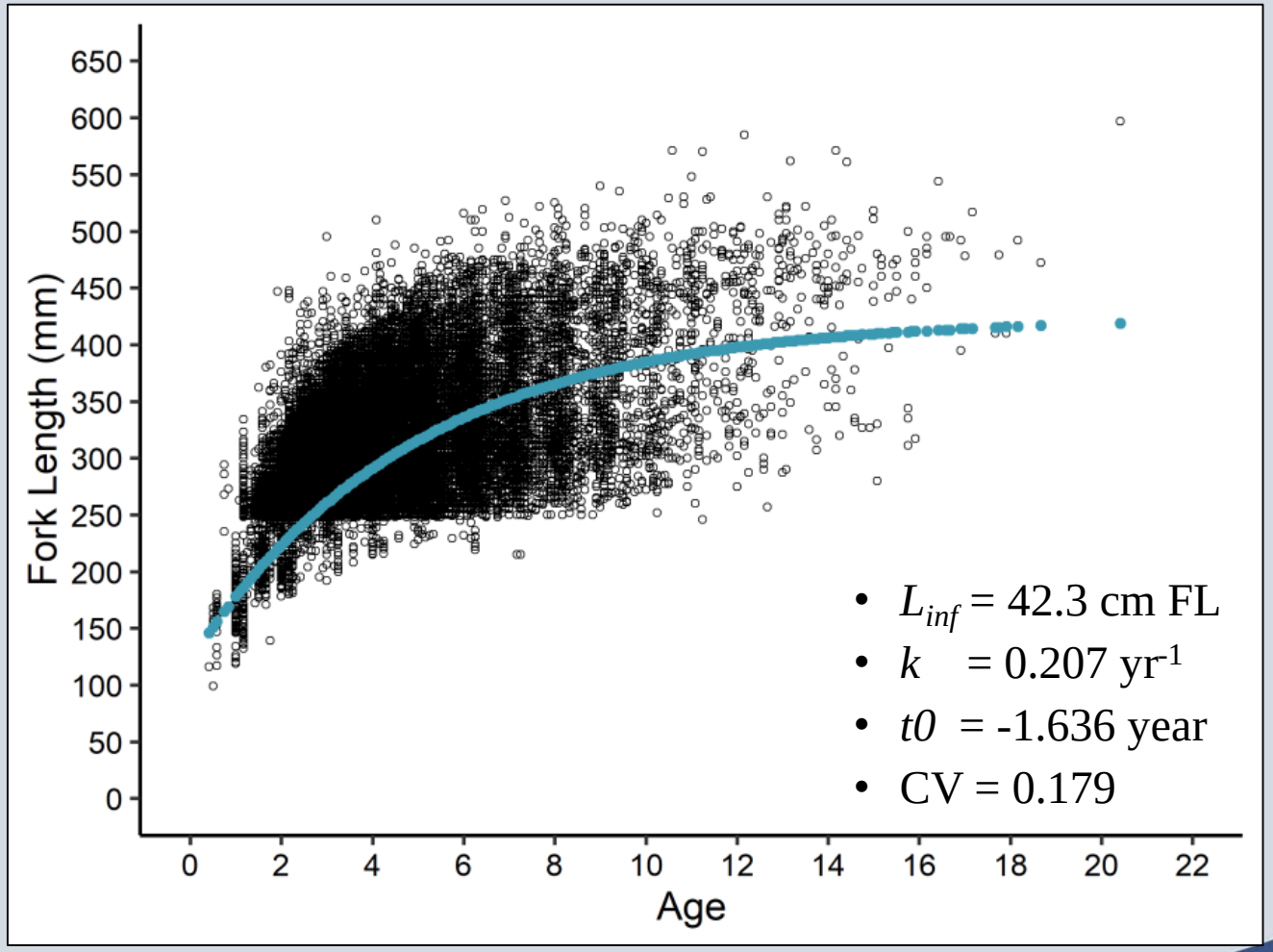
Age Data:

Data Type	Fleet/Survey	Years	Ages	# Otoliths	Weighting
Retained Ages	Com (TIP/Other)	1981 - 2017	1 - 18	21,824	None
	HB (SRHS/Other)	1981 - 2017	1 - 20	21,684	None
	MRIP (GRFS/MARFIN/ Other)	1986 - 2017	1 - 16	2,238	None
Other	FI (FWRI/Other)	1995 - 2015	0 - 13	1,888	None

Data:
Life History

Size-truncated von Bertalanffy growth model (Diaz et al. 2004)

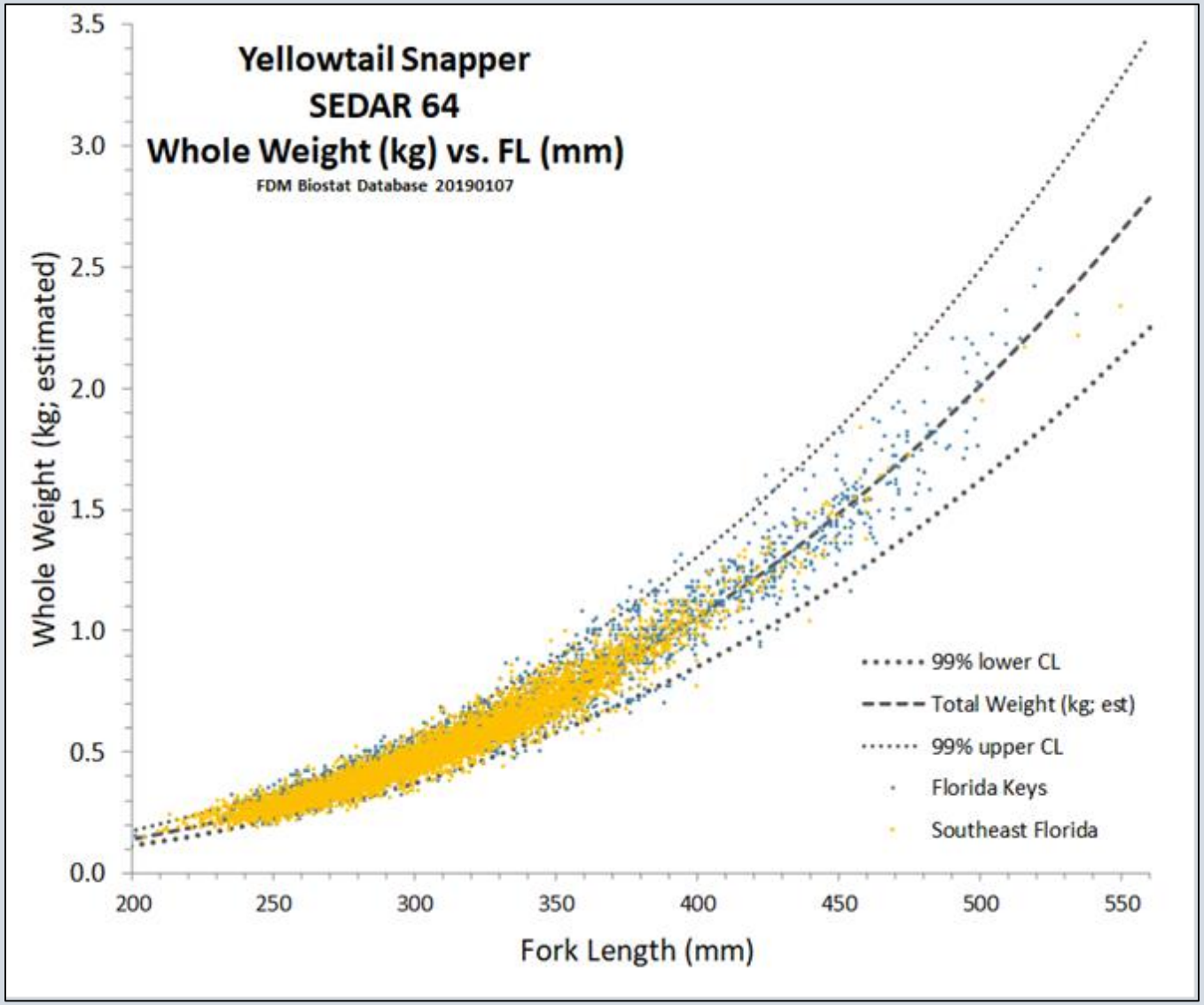
- Truncated at min. size limit (12 inch TL or approx. 24.8 cm FL) for fishery-dependent data starting 8/31/83
  - SAFMC Snapper-Grouper FMP
- Inverse weighted; age 12+ group
- Constant CV for length-at-age
- n = 45,833 otoliths



Length Data:

Data Type	Fleet/Survey	Years	Range (FL)	Sample Size	Weighting
Retained Lengths	Com (TIP)	1984-2017	14 - 68	163,118	By landings
	HB (SRHS)	1981-2017	14 - 58	90,038	By landings
	MRIP	1981-2017	10 - 78	17,929	By landings
Discard Lengths	Com (Reef fish/Shark Observer Prog)	2009 - 2017	12 - 38	868	By discards
	MRIP & HB (HB/CH Observer Prog)	2005 - 2017	10 - 44	7,243	By discards
Survey Lengths	Com CPUE	*Linked to Commercial fleet			
	MRIP CPUE (retained & discarded)	2005 - 2017	10 - 78	22,992	By landings & discards
	RVC Adult	1999 - 2016	19 - 64	44,401	By # of SSUs
	RVC Juvenile	1999 - 2016	2 - 18	41,904	By # of SSUs

Data:
Life History



Source	Y [kg]	a	b	X[cm]	n	Min [cm]	Max [cm]
SEDAR 64	TW	2.574E-05	2.8797	FL	16,540	20.2	55.0
	TW	2.459E-05	2.7487	$TL_{relaxed}$	10,792	24.7	69.7
	TW	1.959E-05	2.7849	TL_{max}	1,763	28.4	65.4

Data:
Life History

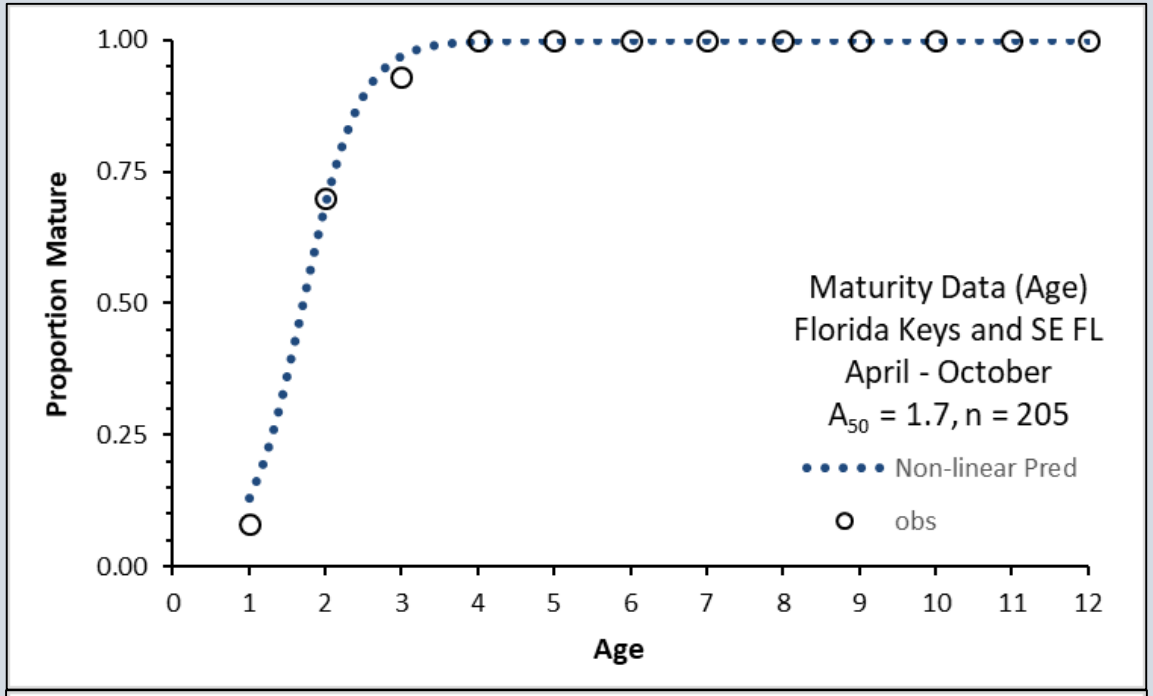
Maturity(Unchanged since SEDAR 27A)

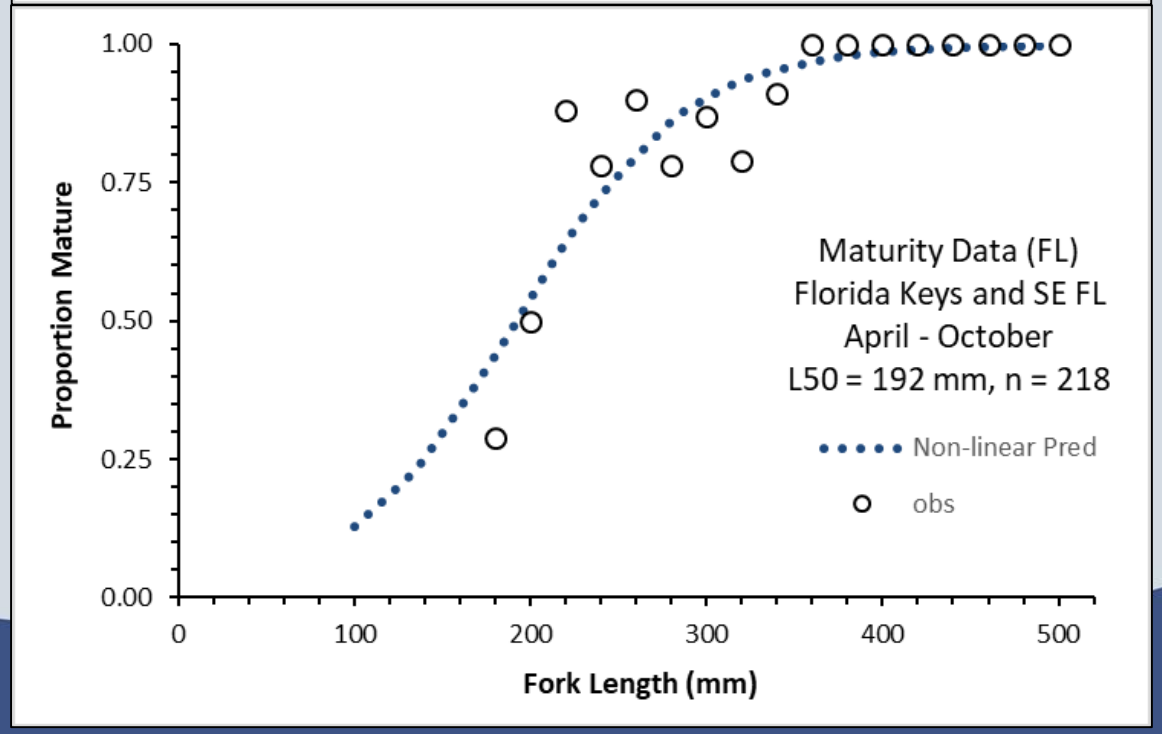
Data source
- Barbieri and Colvocoresses (2003)
- Florida Keys and southeast Florida

Age-at-maturity
- 205 samples
- A_{50} = 1.7 years old; 1.5 – 1.9 yr old 95% CI

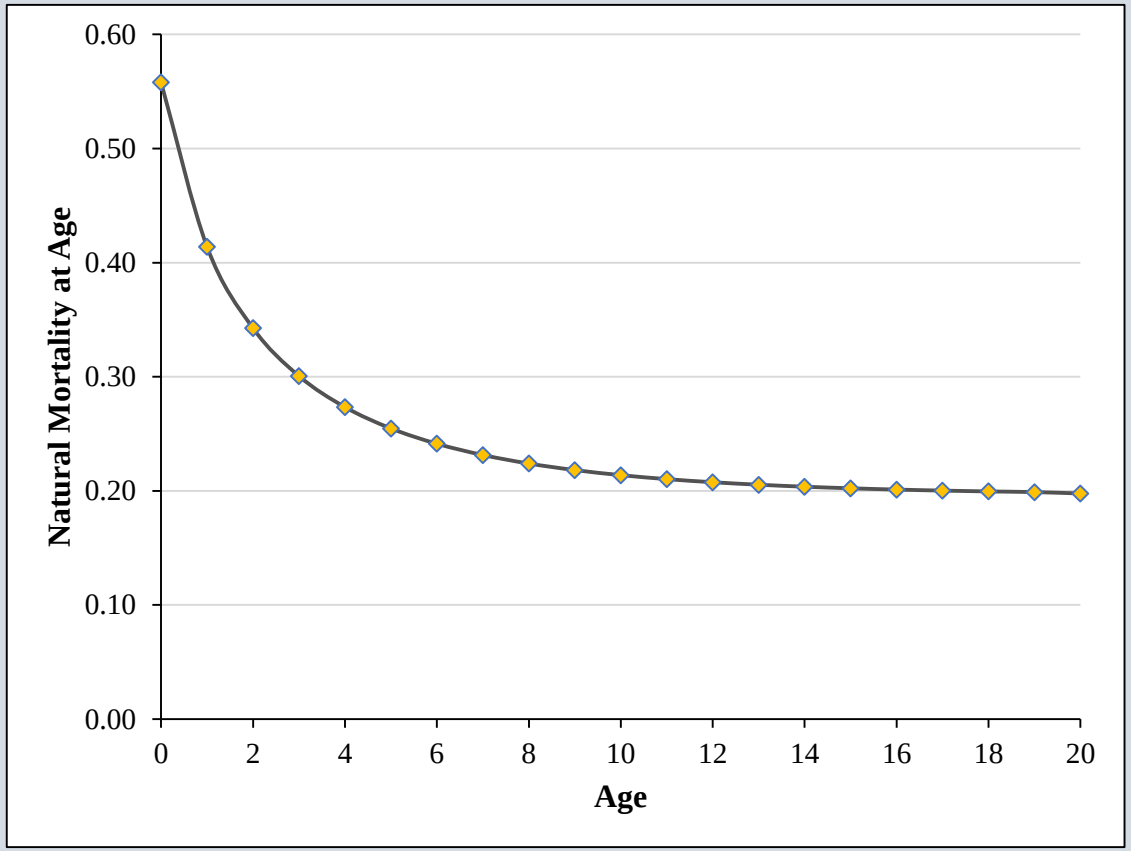
Size-at-maturity
- 218 samples
- L_{50} = 192 mm FL; 162 – 222 mm FL 95% CI

Sex ratios (male:female)
- 1:1.04 in the Florida Keys (Grimes 1987)
- 1:1.3 and 1:1.4 in Jamaica and Cuba (Grimes 1987)
- 1:1 on Campeche Banks (Trejo-Martínez et al. 2011)





Data:
Life History



Instantaneous Natural Mortality

Hoenig$_{\text{all taxa}}$ 1983

- $e^{(1.44-0.982*\ln(t_{max}))}$
  - t_{max} for Florida is age-20
- $M_{Hoenig(\text{all taxa})} = 0.223\ yr^{-1}$

Age-specific Natural Mortality

Lorenzen 2005

- $M(a) = -\ln\left(\frac{L(a)}{L(a)+L_\infty(\exp(k(a_{max}-ac))-1}\right) * \frac{-MrLr}{L_\infty k}$
- $M_r = 0.223\ yr^{-1}$
  - Scaled between ages 3 – 20
- Size-truncated VB growth parameters: L_{inf}, k
- M (a) = 0.558 yr^{-1} – 0.198 yr^{-1} for ages 0 – 20

Data:

- AP recommended start year of 1992
  - High uncertainty in recreational landings and discards prior to 1992
  - Age composition data for fleets become available
  - Indices of abundance or biomass become available
  - 1981 start year (SEDAR 27A) as a sensitivity

Data:

Landings

Commercial Fleet

- Florida's Marine Trip Ticket Program and NOAA ALS
- Florida only data used from 1992 – 2017 (available from 1962)
- Standard errors (in log-space) weighted by landings (0.05 – 0.1)

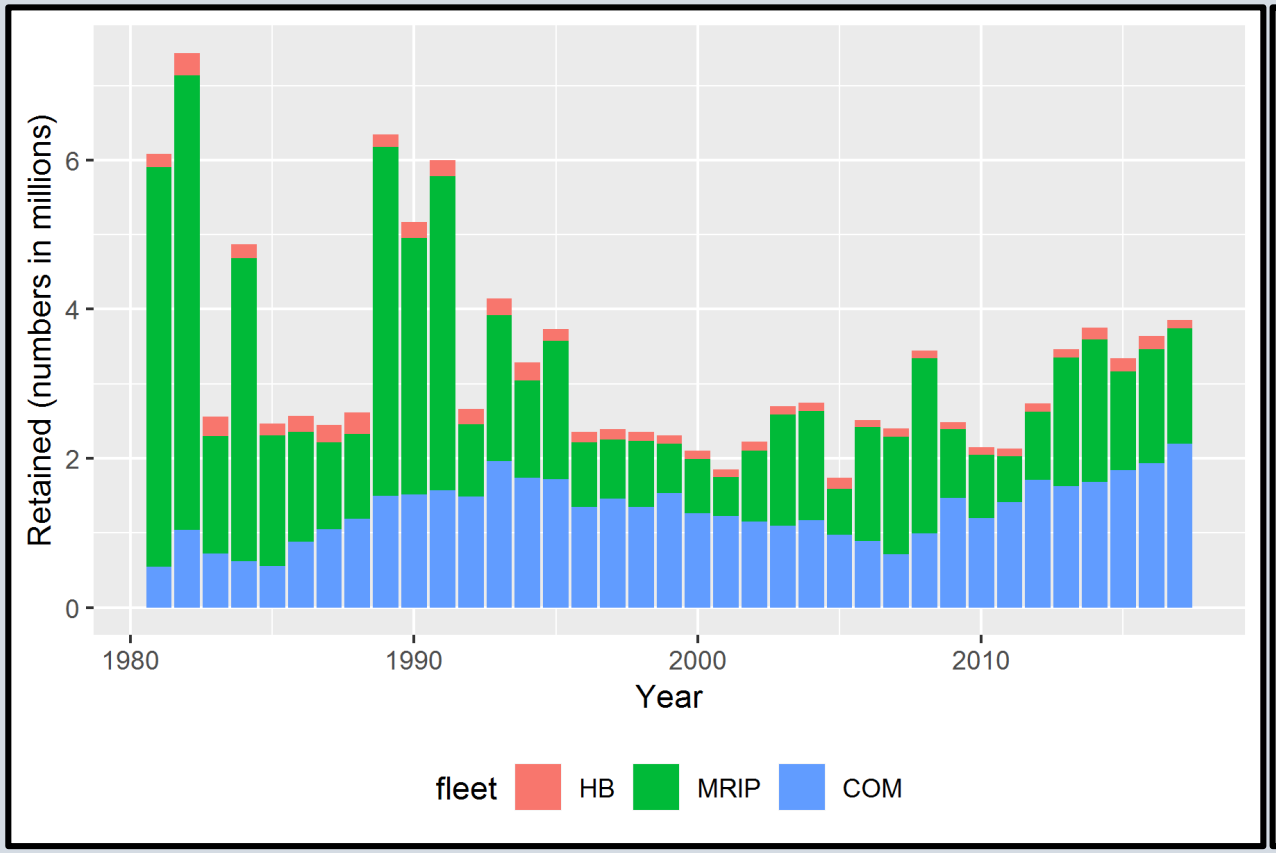
Headboat Fleet

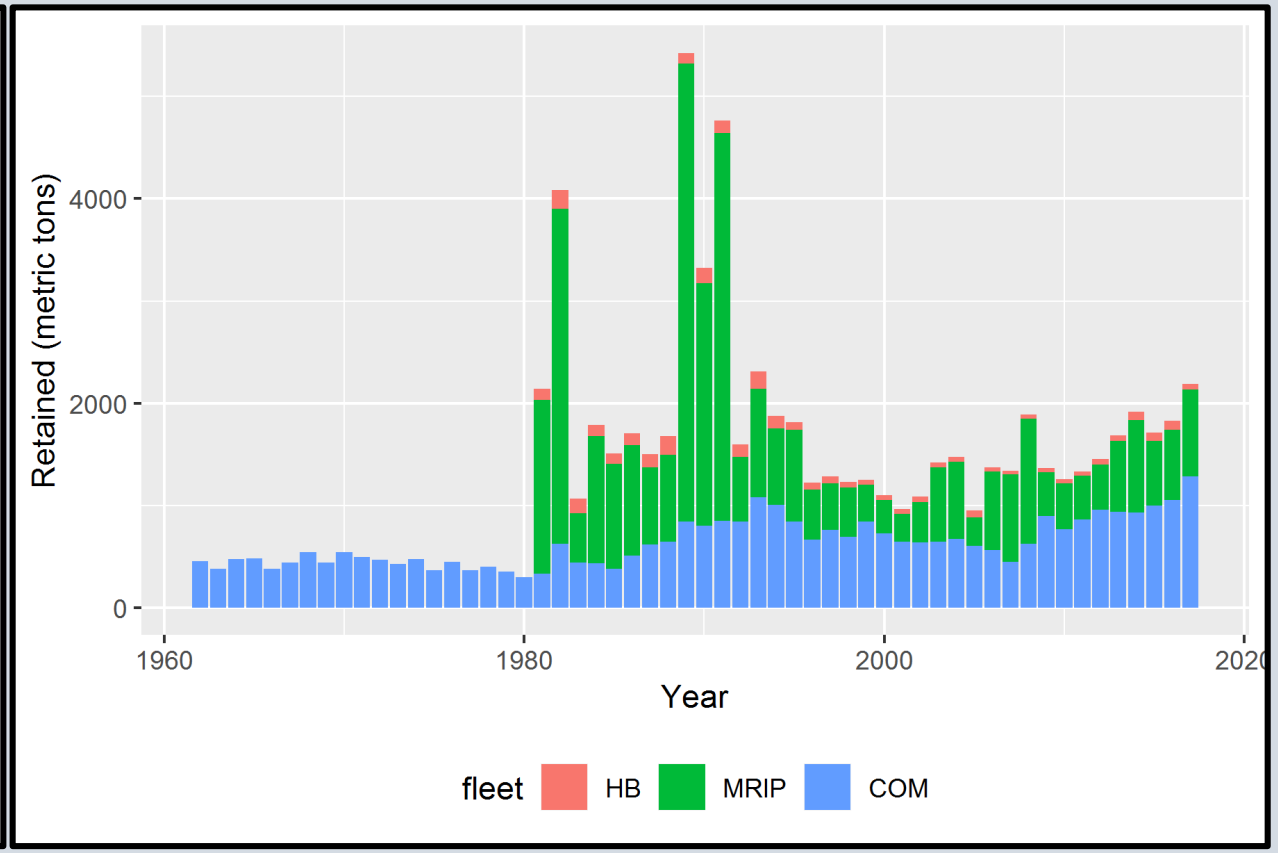
- Southeast Region Headboat Survey (SRHS)
- Florida only data used from 1992 – 2017 (available from 1981)
- Standard errors (in log space) assumed equal to 0.25 and constant through time

MRIP Fleet (modes: private, shore, and charter)

- Marine Recreational Information Program; Fully calibrated (APAIS, FES, and FHS)
- Florida only data used from 1992 – 2017 (available from 1981)
- CVs transformed to standard errors (in log-space; 0.09 – 0.36)

Data:
Landings





Data:
Discards

Commercial Fleet

- Effort and discard rate data from vertical line trips in southern Florida reported in the CFLP between 2002 – 2017
- For years 1993 – 2001, discard rates were averaged for years 2002 – 2006 and used with available effort data
- CVs provided by SEFSC using the ‘standard’ S32 method (CVs = 1.94 – 5.61)

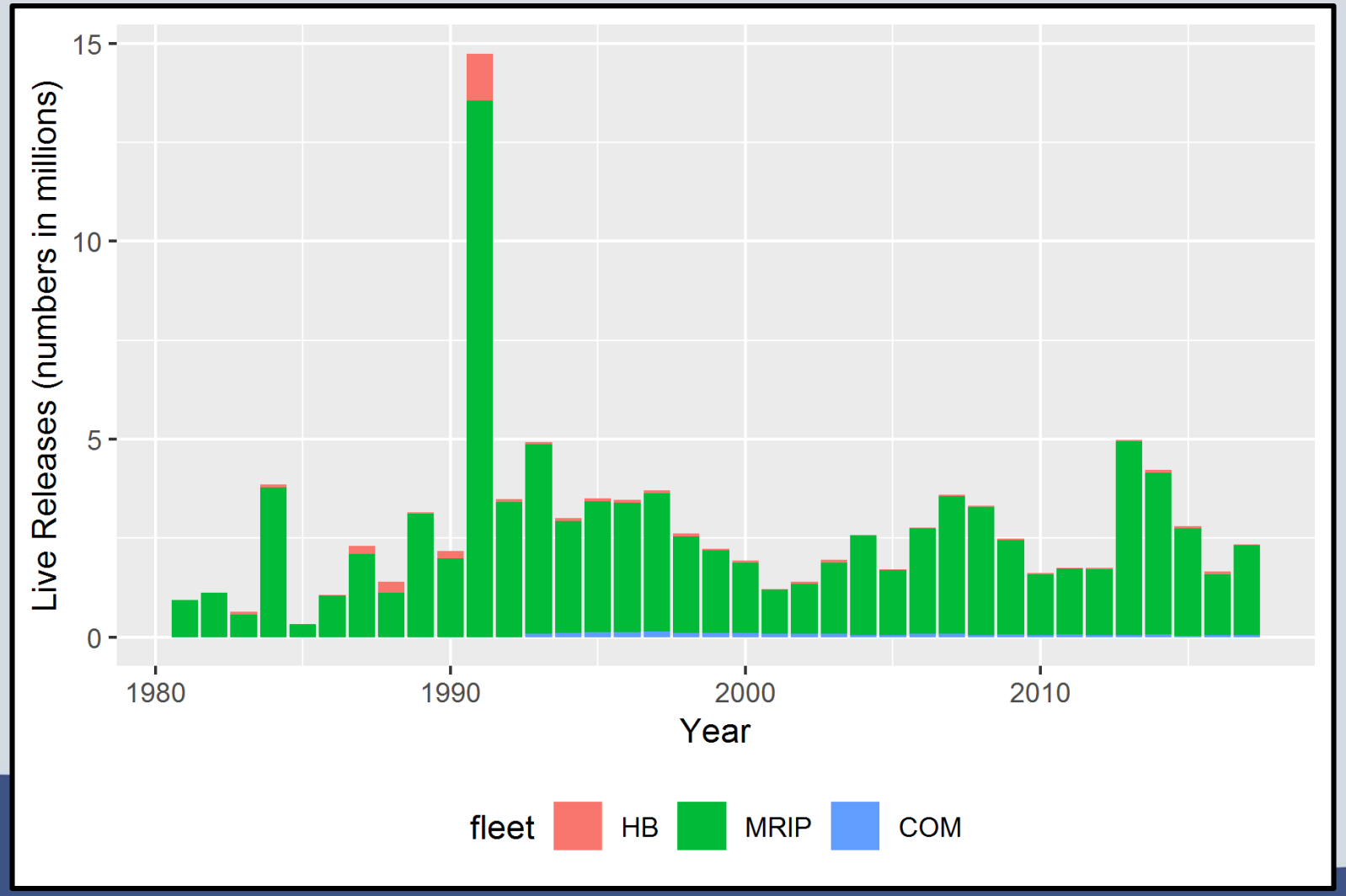
Headboat Fleet

- SRHS logbook data from 2004 – 2017 and validated using Florida At-Sea Observer Program
- Years 1981 – 2003 were hindcasted using MRIP Charterboat:SRHS discard ratio proxy method
- Standard errors (in log space) assumed equal to 0.50 and constant through time

MRIP Fleet

- MRIP data (fully calibrated APAIS, FES, and FHS) used from 1992 – 2017 (available in 1981)
- CVs provided by SEFSC and transformed to standard errors (in log-space; 0.06 – 0.20)

Data:
Discards



Data:
Discard Mortality

Commercial Fleet

- 10% in SEDAR 64 Base Model
- 15% sensitivity run

Headboat and MRIP Fleets

- 10% in SEDAR 64 Base Model
- 20% and 30% sensitivity runs

Data:
Indices of Abundance and Biomass

https://www.fisheries.noaa.gov/southeast/science-data/reef-ecology-unit

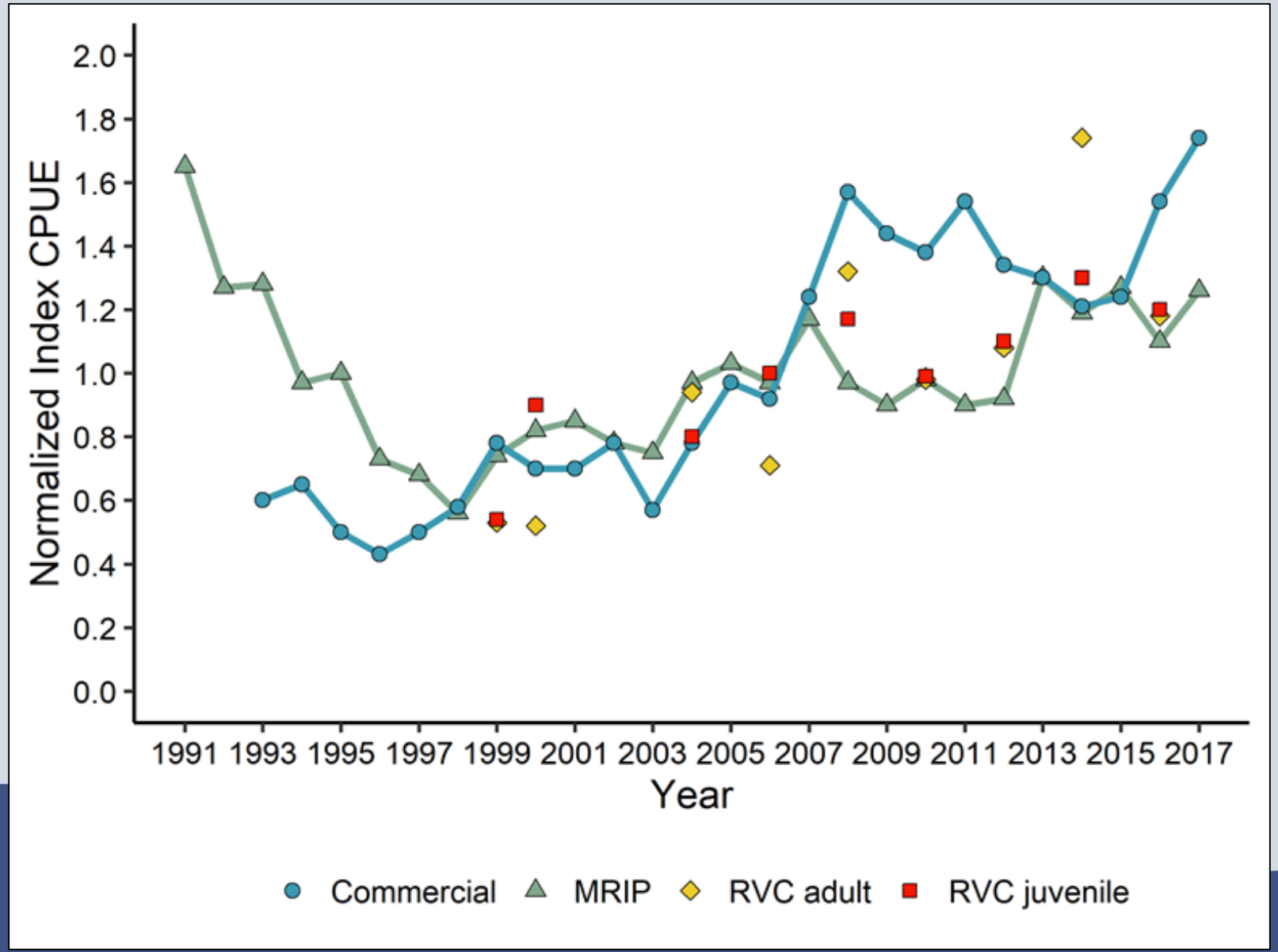
Fishery-Independent

- Reef Fish Visual Census (RVC)
  - Two-stage SRS design using divers in water <30 m
  - combined data in overlapping years for the FL Keys and the Dry Tortugas
  - 1999, 2000, biennially 2004 – 2016
  - Juvenile and subadult (1 – 18 cm); Adult (19+ cm) indices of abundance

Fishery-Dependent

- Commercial vertical line
  - CFLP data from 1993 – 2017
  - Southern Florida (SE Florida through Sarasota and the Dry Tortugas)
  - Index of biomass (lbs of fish/hook hours fished)
- MRIP
  - MRIP total catch (A+B1+B2) data from 1991 – 2017
  - Southeast Florida and the FL Keys (including the Dry Tortugas)
  - Index of abundance (number of fish/trip)

Data:
Indices of Abundance and Biomass



Data:
Modifications/Updates Compared to SEDAR 27A

Data Structure

- MRIP data changed
- Use of Florida-only data to inform assessment model (e.g. landings, life history)
- Addition of seven years of data (2011 – 2017)
- Start year changed to 1992
  - ‘Removal’ of eleven years of early data (1981 – 1991)
  - Still ‘in’ the model but only informs the early recruitment deviations & initial pop size
- Excluded headboat index of abundance
- Inclusion of length composition data to be fit by the model
- Commercial discard mortality rate changed from 11.5% to 10%
  - Recreational fleet discard mortality rate remained at 10%

Data:
Modifications/Updates Compared to SEDAR 27A

Life History

- Length-at-age information doubled
  - Updates to external von Bertalanffy growth parameter estimates and estimated within assessment model
  - Use of FL instead of TL
- Updates to constant and age-varying natural mortality estimates
- Update to length-weight parameter estimates
- Spawning timing changed to Jan 1

Further
Questions about
the Data?

SEDAR 64:Yellowtail Snapper

Base Model Configuration

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Stock Assessment Model:
Base Model Configuration

Stock Synthesis v. 3.30.14

- Moderate complexity
- Years: 1992 – 2017
- Early recruitment devs starting 1981
- 1 season, 1 area
- Spawning: January
- Settlement: January at age 0, 2 cm FL
- Combined sex model with female-only SSB (frac_female = 0.5)

Life History

- Estimated growth using external VB growth model inputs as initial guesses
- 20 ages in the model; Age 12+ group
- Natural mortality: Fixed vector by age (Lorenzen 2005)
- Maturity: Fixed vector by age
- Fecundity = Spawning biomass at length
- Length-Weight: fixed

Stock Assessment Model:
Base Model Configuration

Fleets

- Commercial
  - Landings (mt) and discards (numbers)
- Headboat
  - Landings and discards (numbers)
- MRIP (Charter, Private, Shore modes)
  - Landings and discards (numbers)

Surveys

- Commercial CPUE
  - retained lbs/hook hour
- RVC
  - Juvenile/subadult
  - Adult
  - number of fish/diver ‘cylinder’
- MRIP CPUE
  - total catch/trip (numbers)

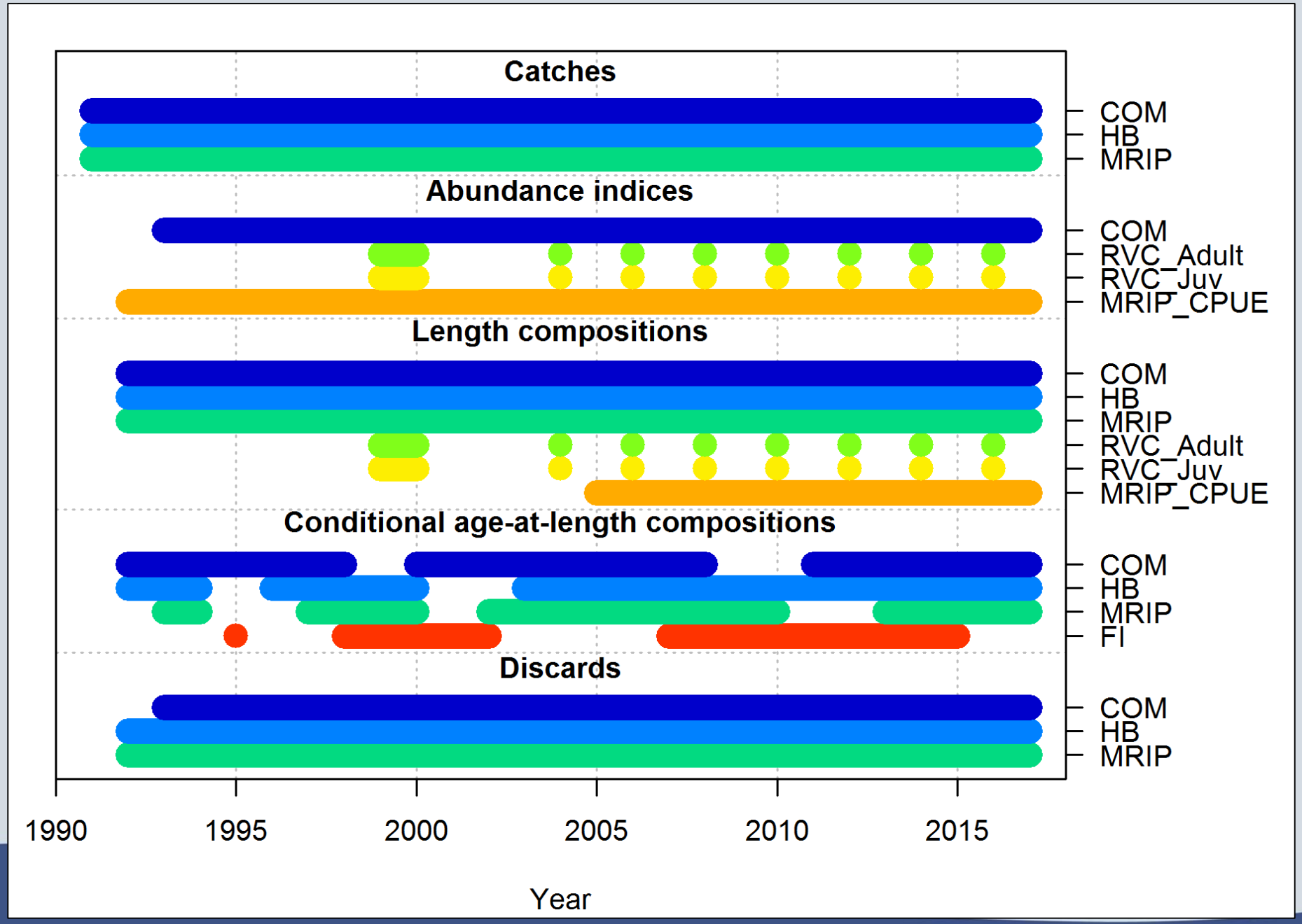
Stock Assessment Model:
Base Model Configuration

Length Composition Data

- Commercial
  - Landings and discards
- Headboat
  - Landings
- MRIP
  - Landings
- Headboat/MRIP Discards
  - Same length compositions
- RVC
  - Juvenile/Subadult
  - Adult

Conditional Age-at-Length Data

- Commercial Landings
- Headboat Landings
- MRIP Landings
- Fishery-independent sources


Catches
COM
HB
MRIP
Abundance indices
COM
RVC_Adult
RVC_Juv
MRIP_CPUE
Length compositions
COM
HB
MRIP
RVC_Adult
RVC_Juv
MRIP_CPUE
Conditional age-at-length compositions
COM
HB
MRIP
FI
Discards
COM
HB
MRIP
1990
1995
2000
2005
2010
2015
Year

Stock Assessment Model:
Base Model Configuration

Fleet Selectivity

- Commercial
  - Selectivity: Simple logistic (flat-topped)
  - Estimated Retention (flat-topped)
  - Discard Mortality = 10%
- Headboat
  - Selectivity: Double normal (dome)
  - Estimated Retention (flat-topped)
  - Discard Mortality = 10%
- MRIP
  - Selectivity: Double normal (dome)
  - Estimated Retention (flat-topped)
  - Discard Mortality = 10%

Index Selectivity

- Commercial CPUE
  - Linked to Commercial fleet
  - Catchability Time Block: 2009 - 2017
- RVC Adult
  - Selectivity: Double normal (dome)
  - Constant catchability
- RVC Juvenile
  - Selectivity: Double normal (dome)
  - Constant catchability
- MRIP CPUE
  - Selectivity: Mirrored to MRIP fleet
  - Constant catchability

Stock Assessment Model:
Base Model Configuration

Recruitment Dynamics

- Beverton-Holt stock-recruitment relationship
  - Virgin recruitment in log-space (*ln(R0)*), the standard deviation of log of recruitment (*sigmaR*), and *steepness* estimated in model
- Simple recruitment deviations
  - no sum-to-zero constraint
- Early recruitment deviations
  - 1981 – 1990 (period of lower data-richness)
- Main recruitment deviations
  - 1991 – 2017 (period of higher data-richness)
- Bias adjustments (following Methot and Taylor 2011)

Stock Assessment Model:
Base Model Configuration

Parameters
- 85 out of 117 parameters estimated

Priors
- Symmetric betas on initial Fishing mortality rates for Commercial, Headboat, and MRIP fleets

Lambda
- No emphasis on model fit (=0)
  - Initial equilibrium catch for all three fleets

Reported Fishing Mortality Rates
- Age 4

Stock Assessment Model:
Base Model Configuration

Model Convergence Criteria

- Total likelihood (sum of individual data source component's likelihoods)
- Invertible Hessian matrix
- Maximum gradient <0.0001

Error Structure

- Assumed log-normal for all landings, indices, and discard data (except commercial discards)

Multinomial Distribution

- Length composition and conditional age-at-length data

Data Weighting

- Length composition and conditional age-at-length data
- Initial sample sizes equal to sqrt (number of trips or number of fish)
- Iterative re-weighting following Francis (2011)

SEDAR 64:Yellowtail Snapper

Base Model Results

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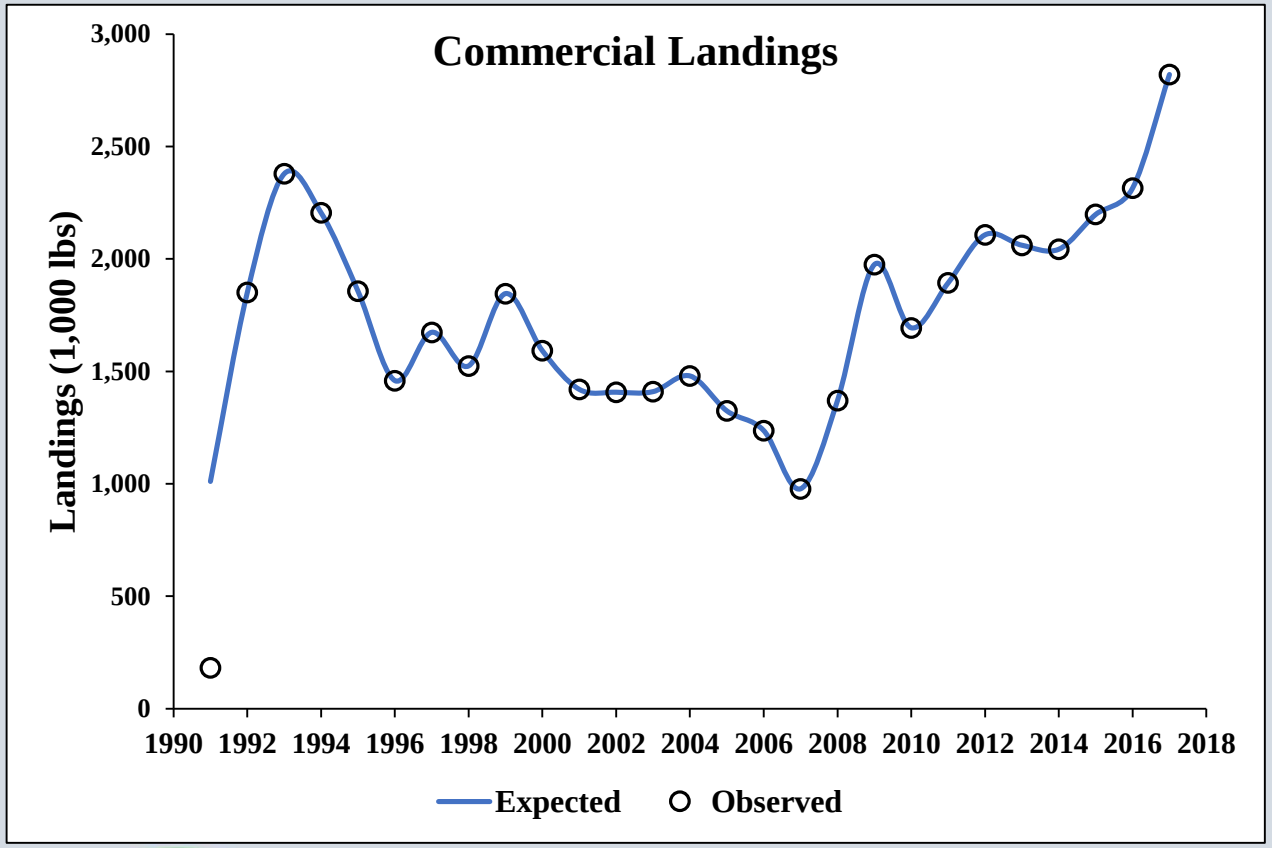
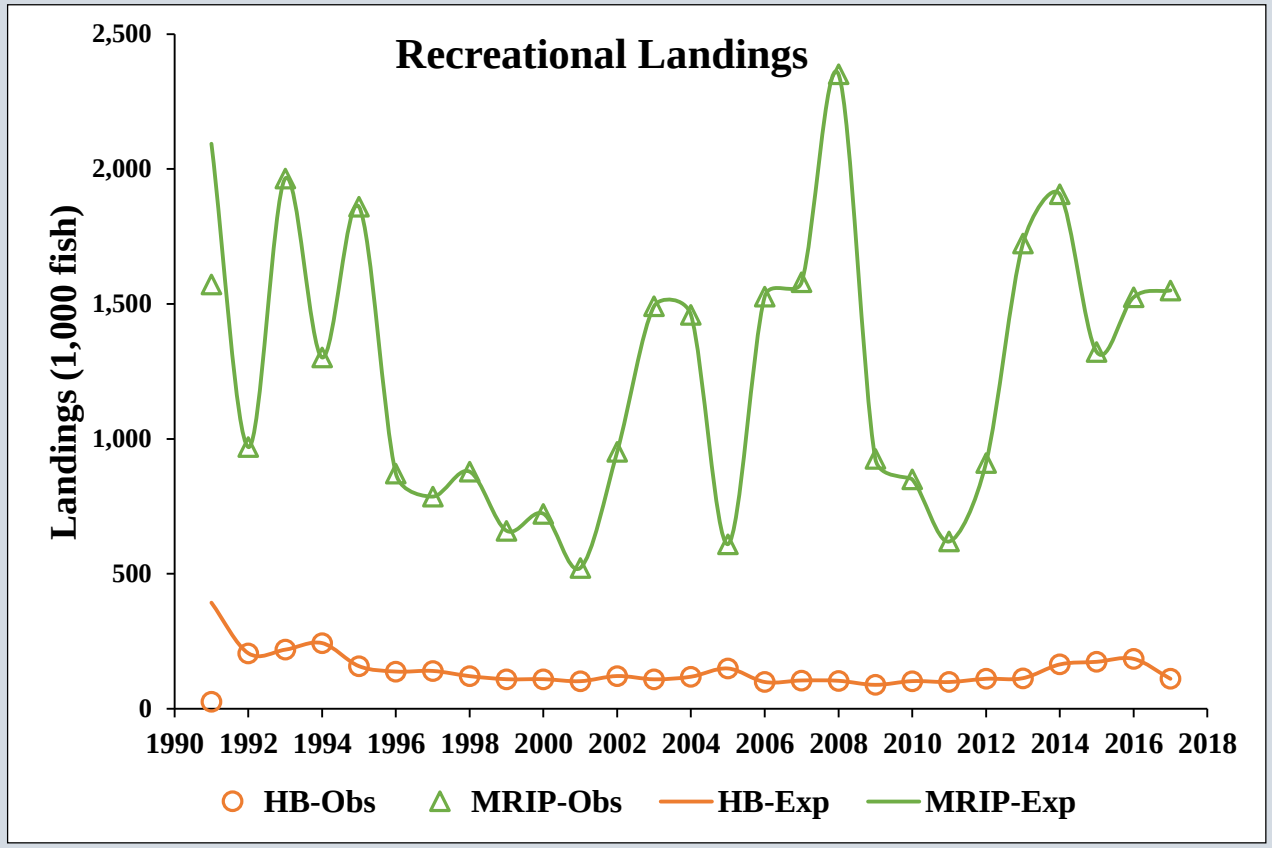
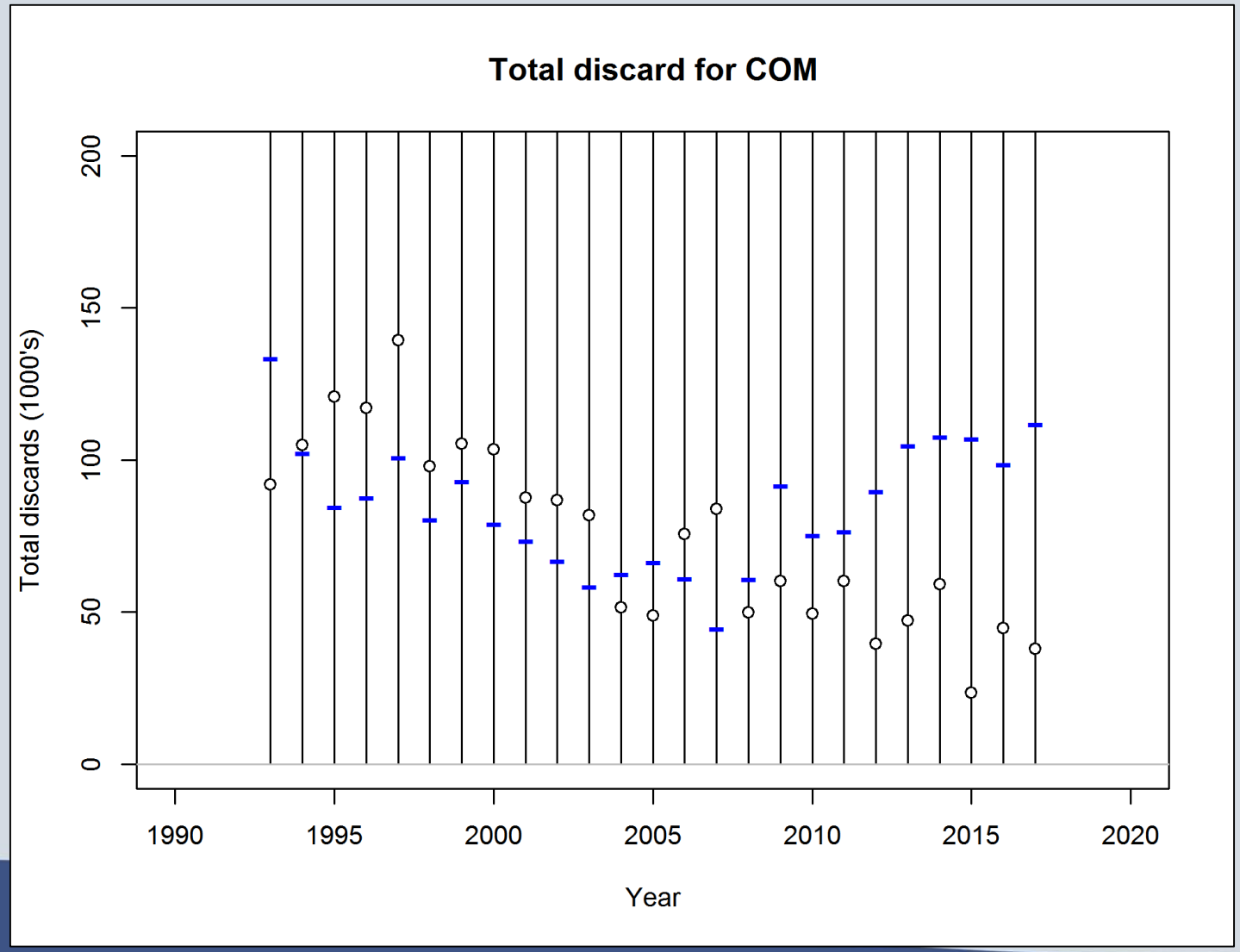
Stock Assessment Model:
Landings

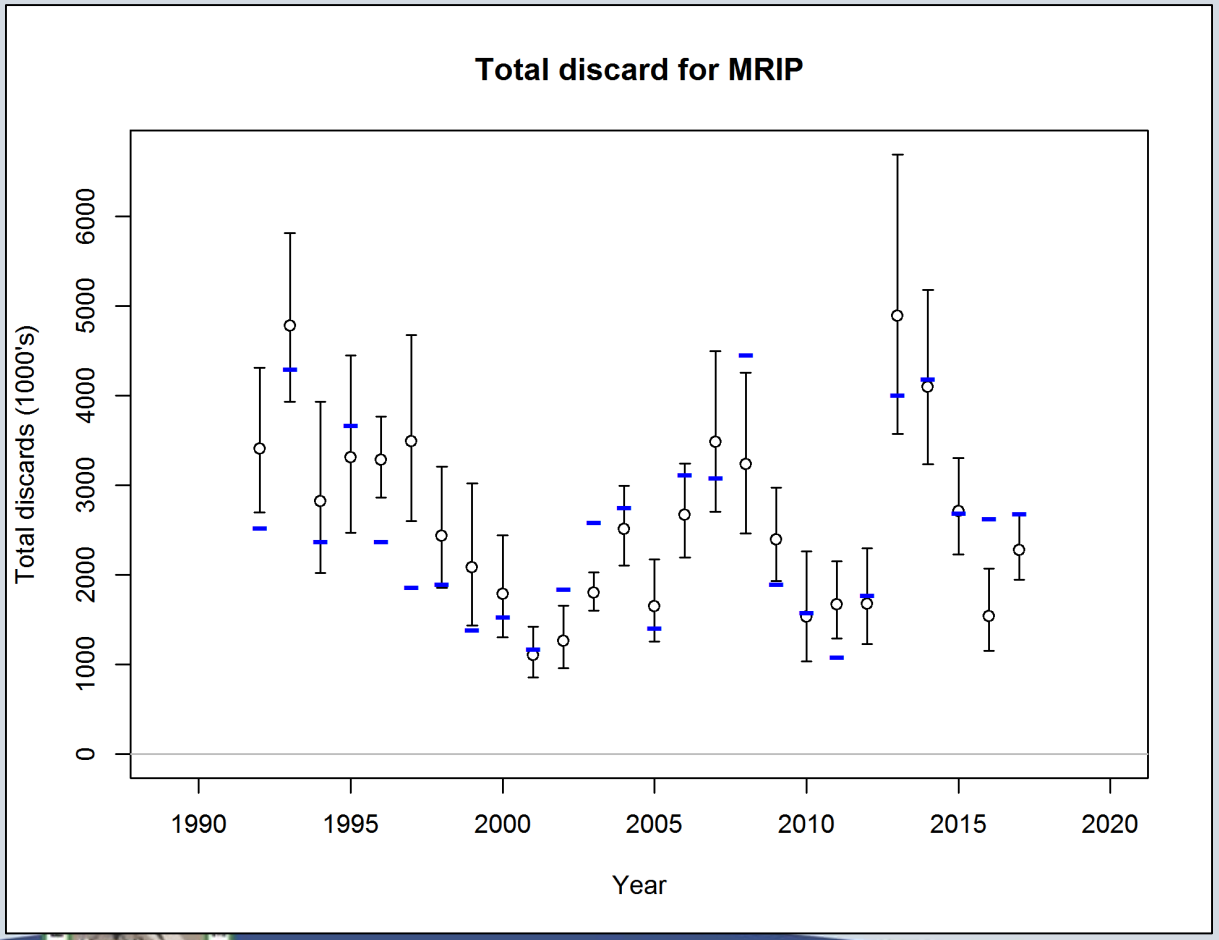


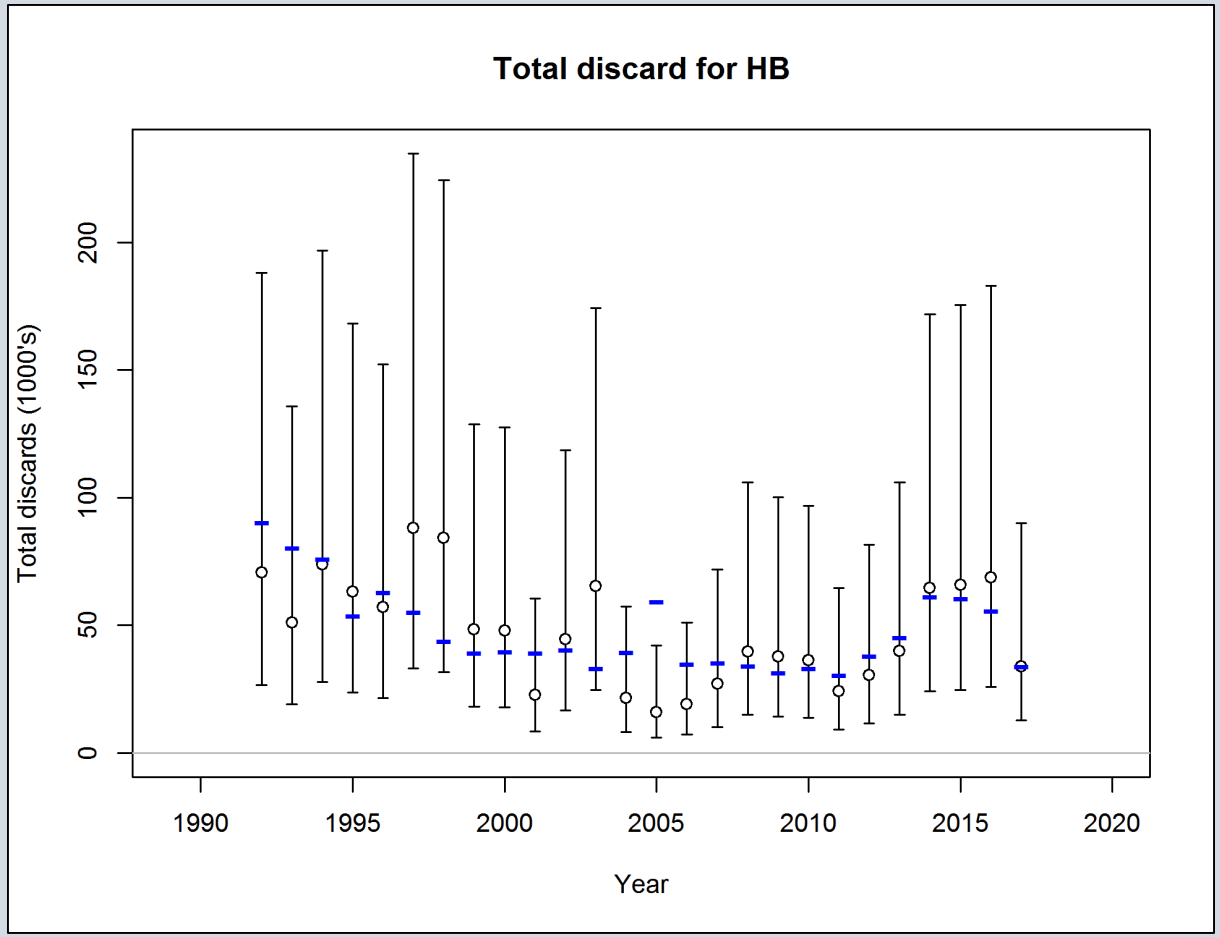


Stock Assessment Model:
Discards

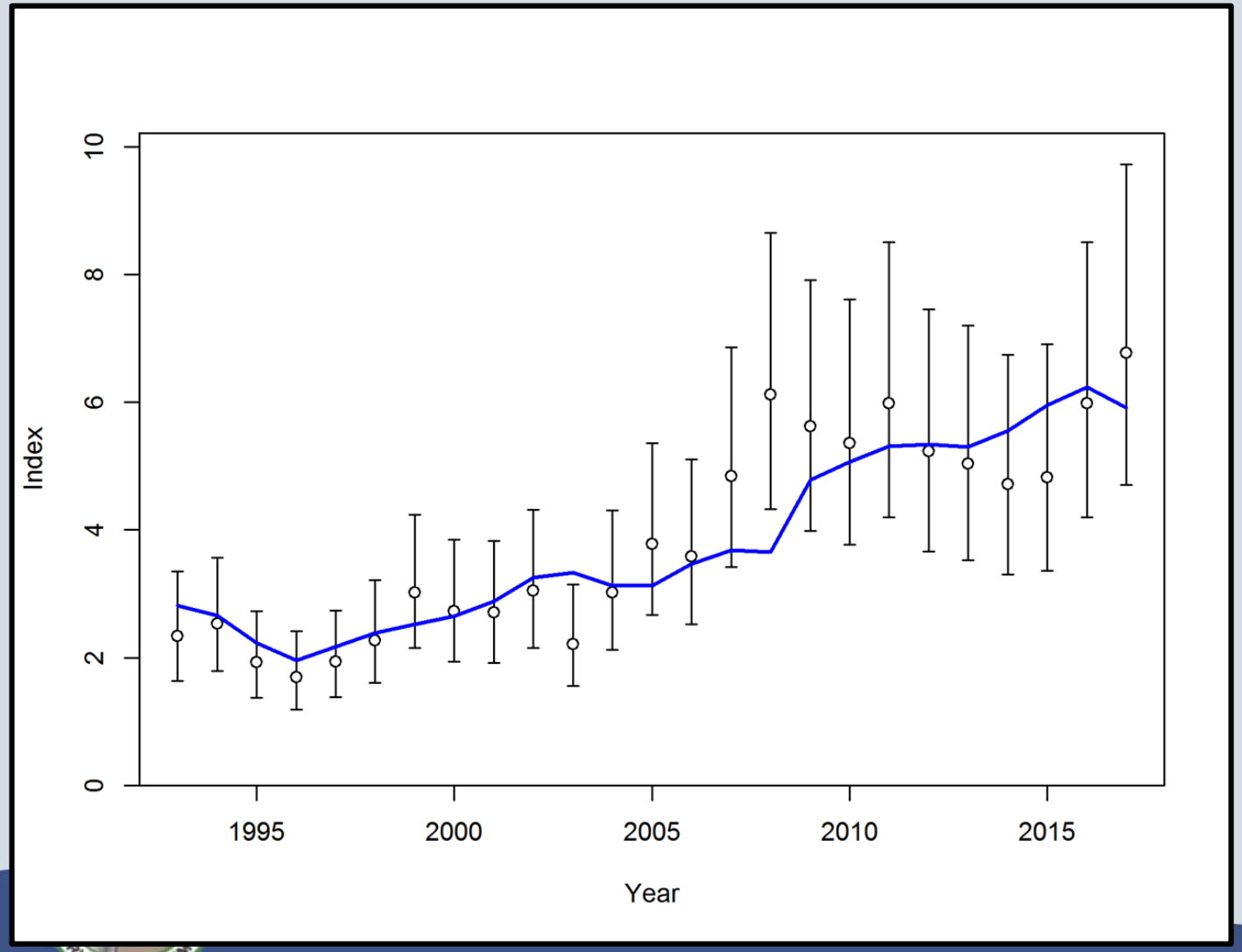


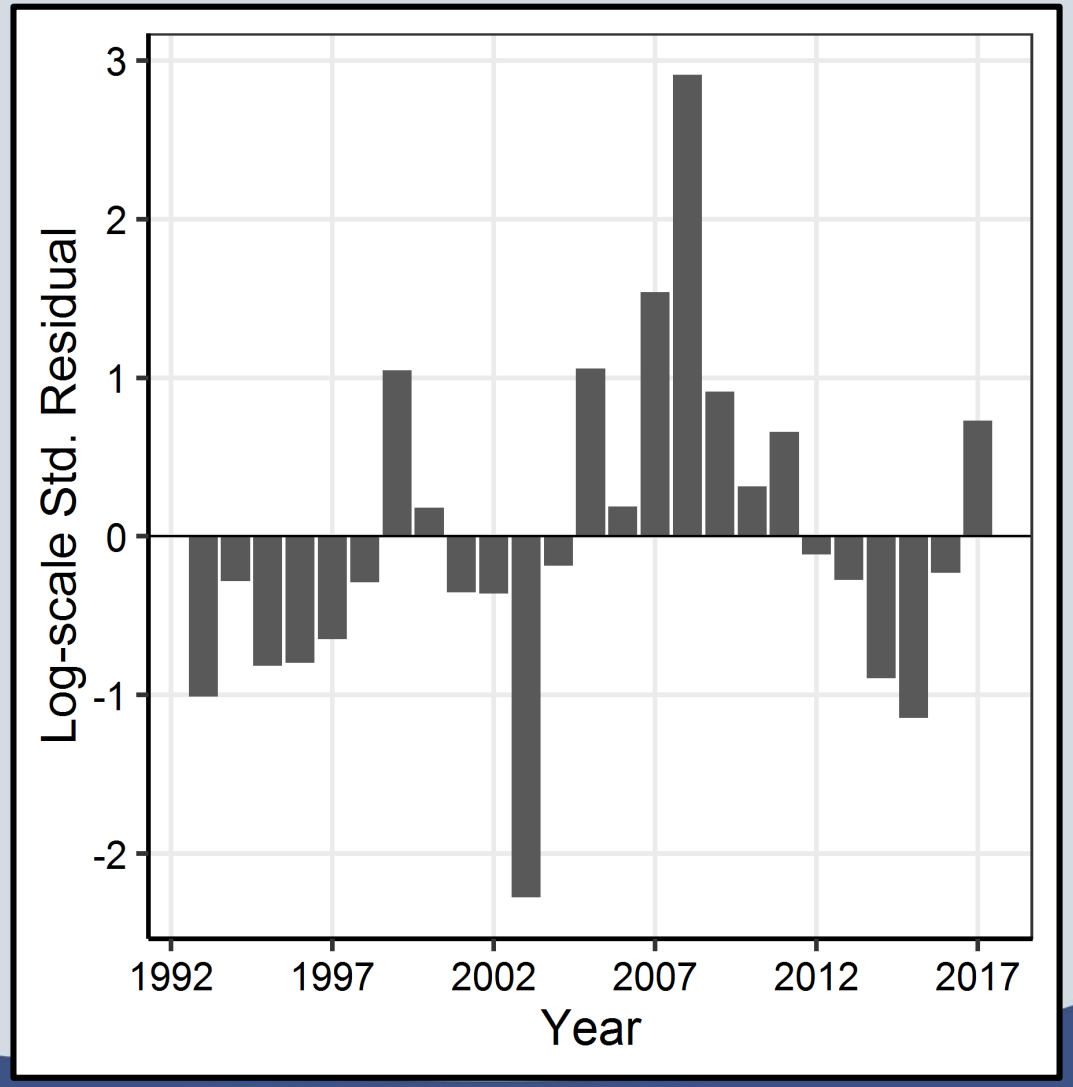
Stock Assessment Model:
Discards



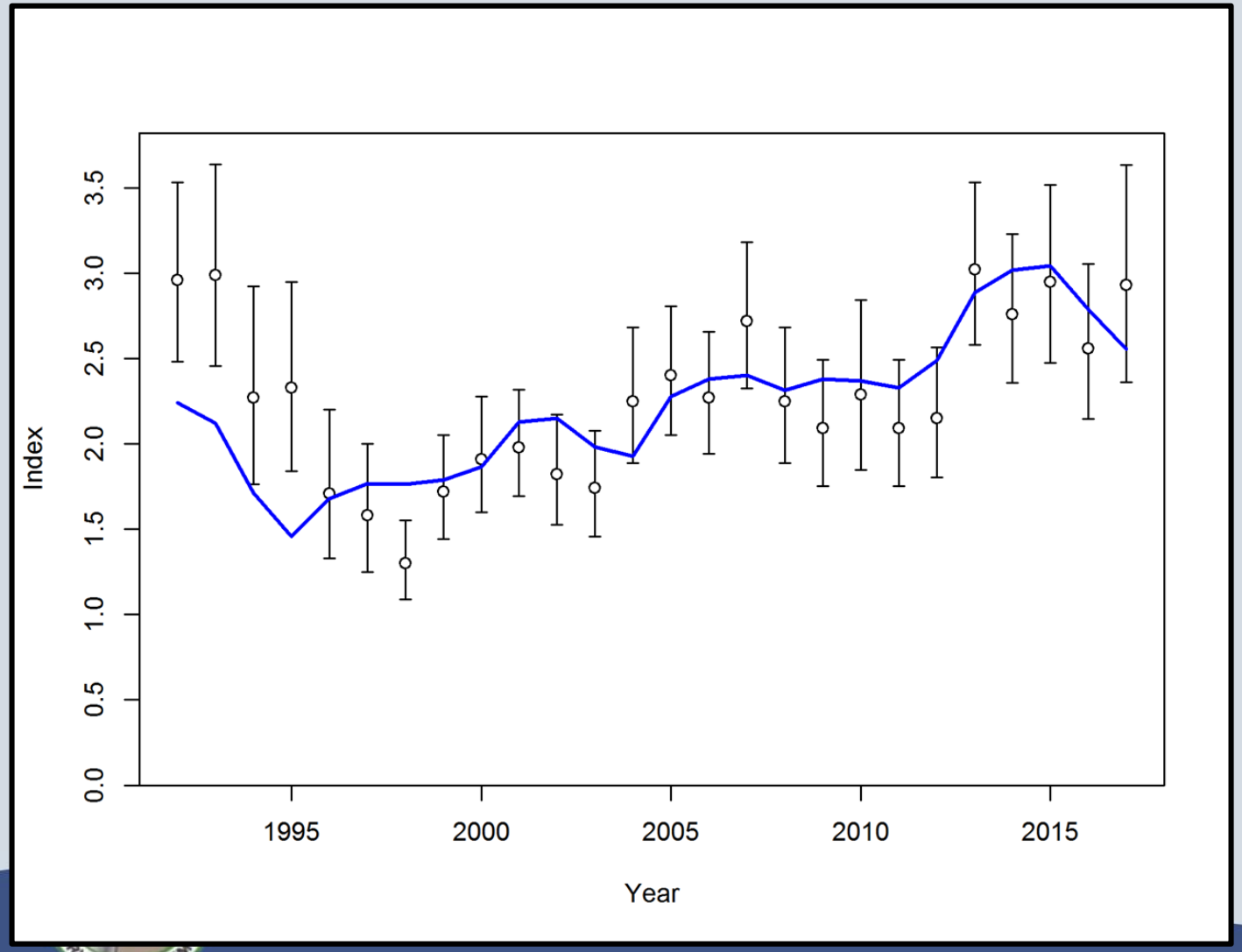


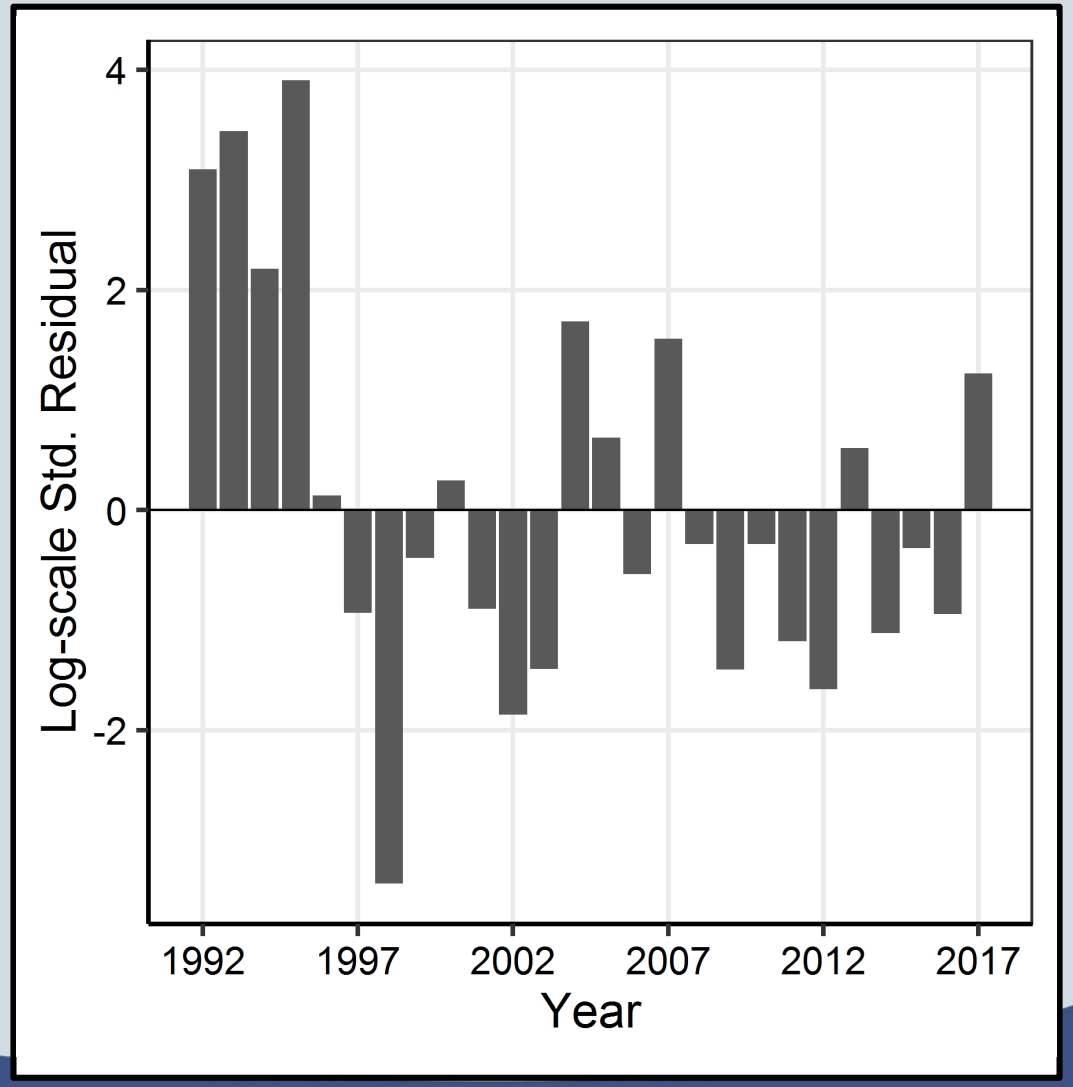
Stock Assessment Model:
Fits to Indices: Commercial



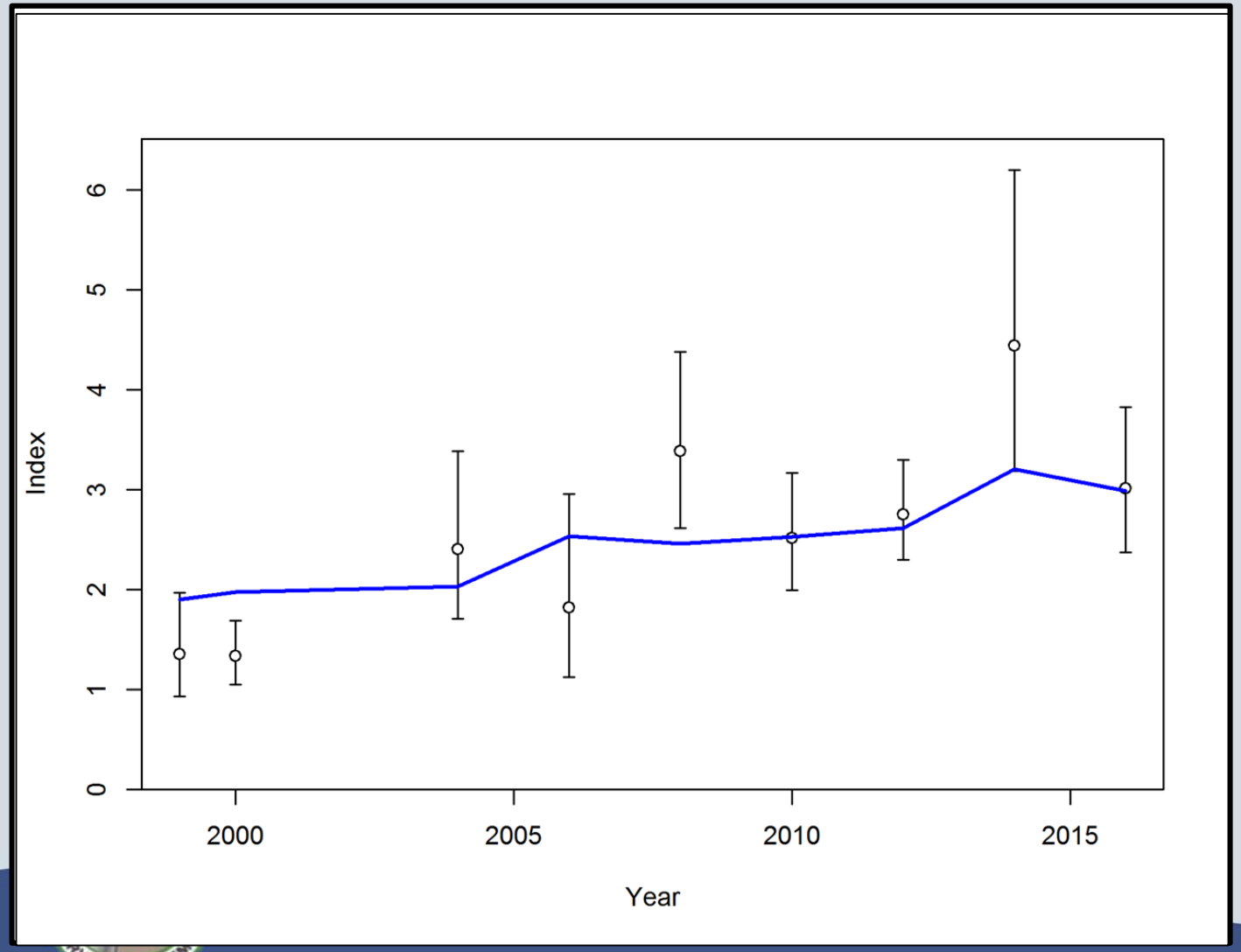


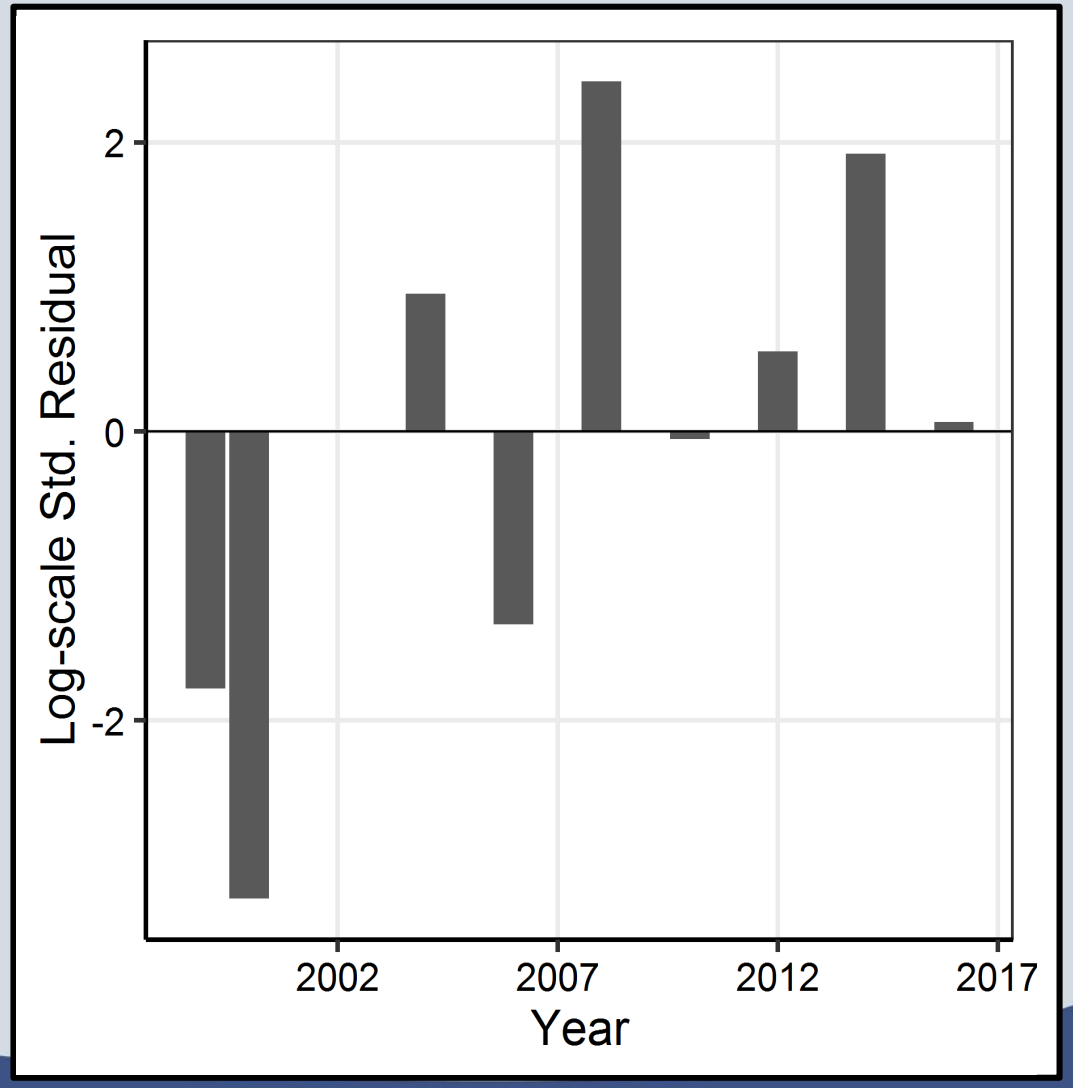
Stock Assessment Model:
Fits to Indices: MRIP



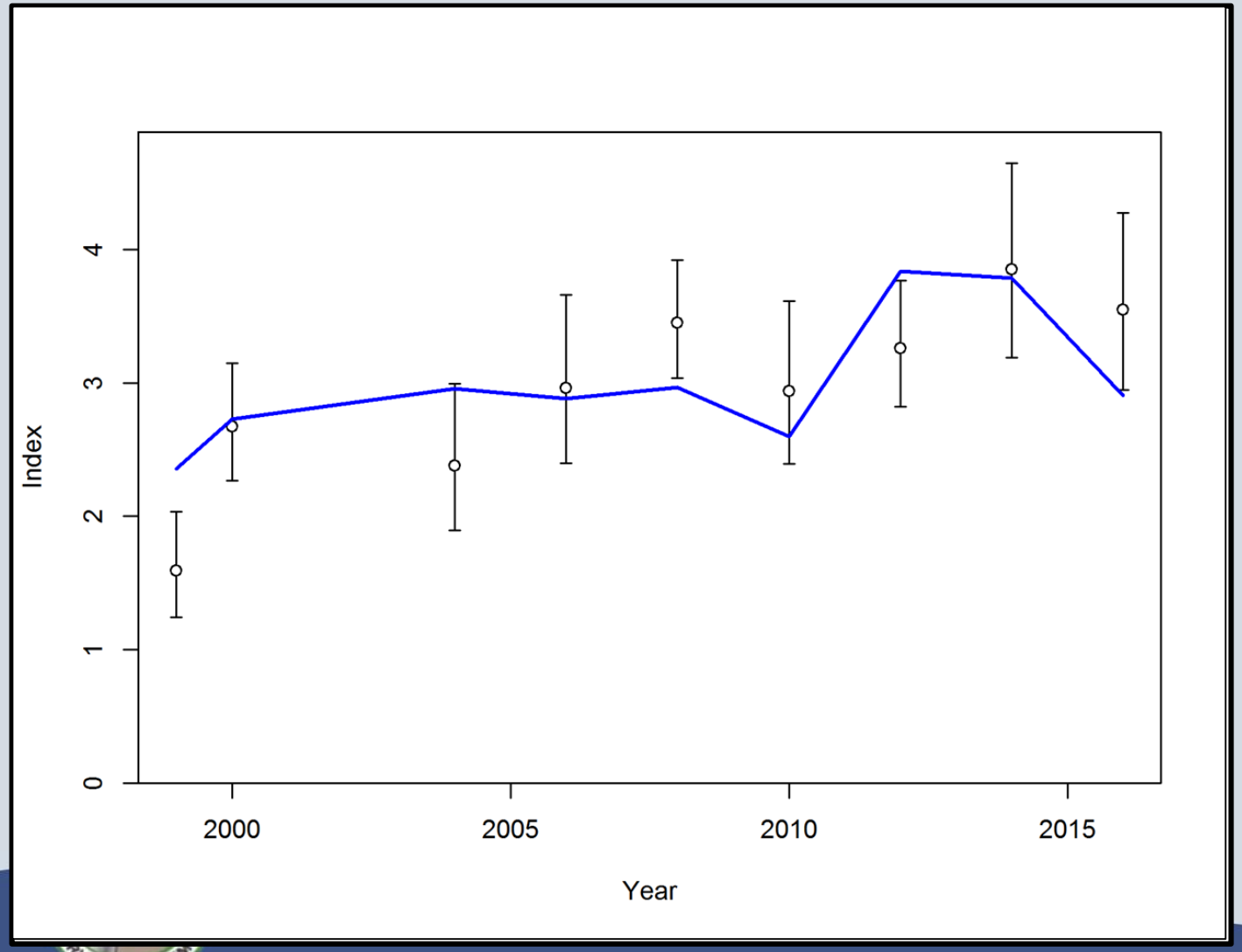


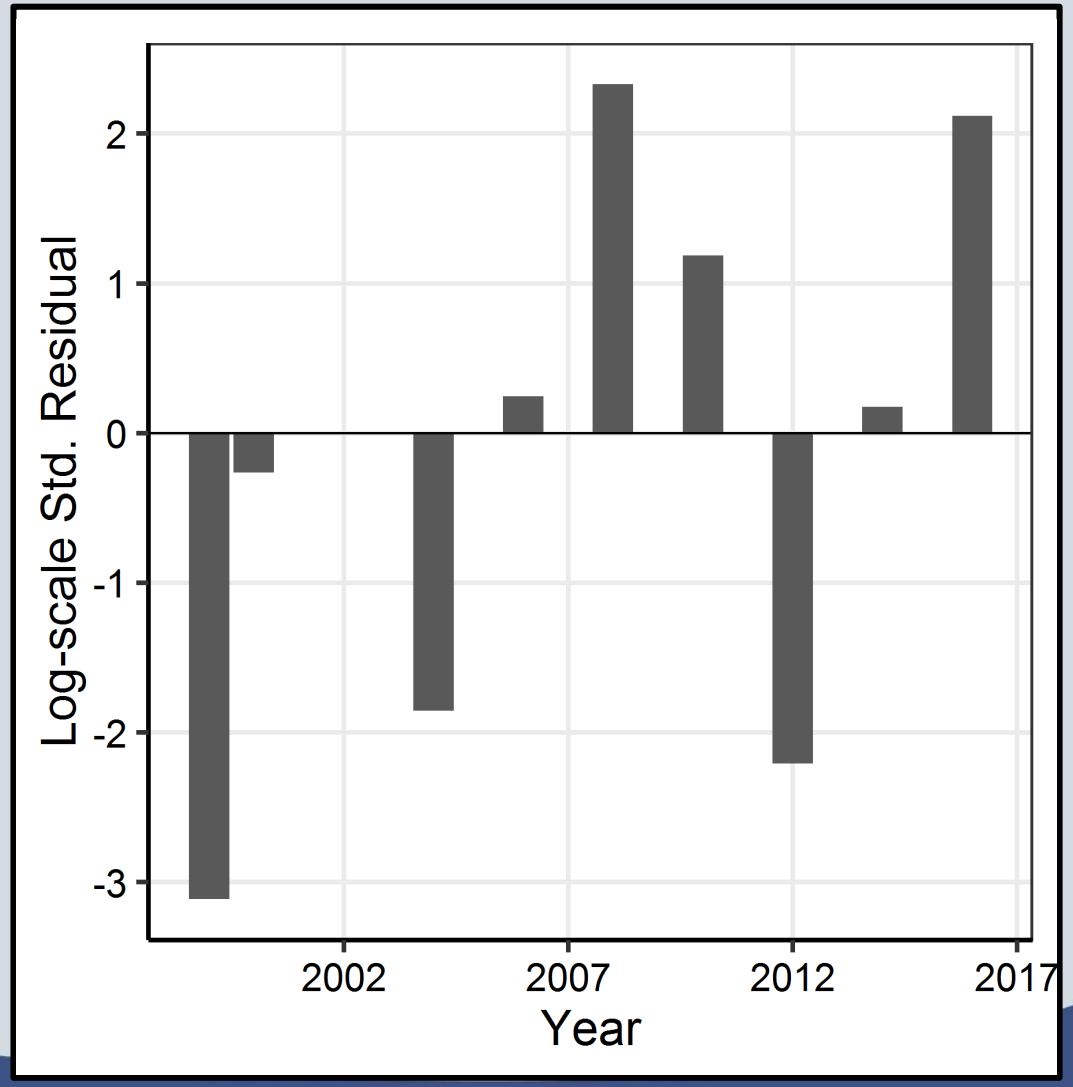
Stock Assessment Model:
Fits to Indices: RVC Adult



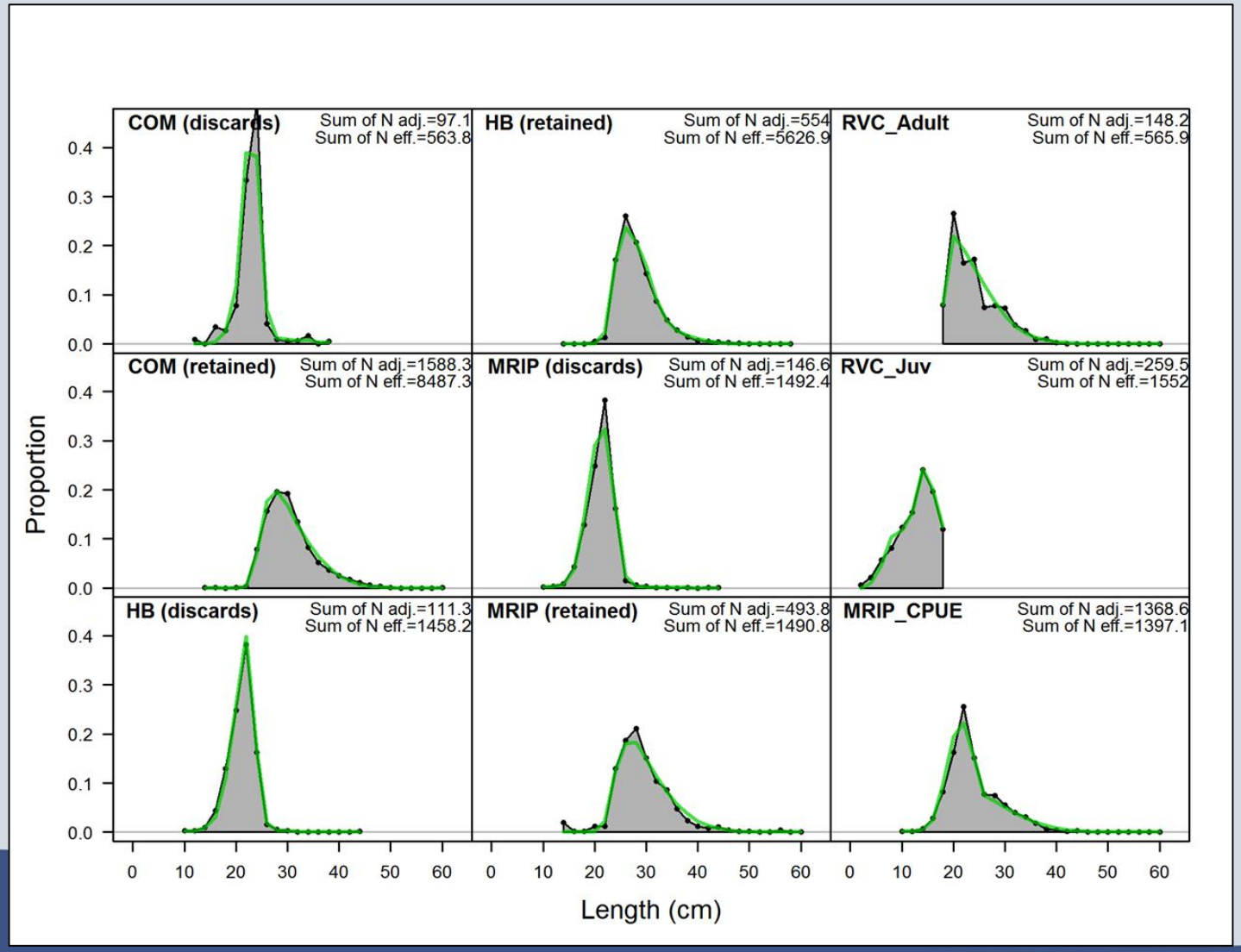


Stock Assessment Model:
Fits to Indices: RVC Juvenile

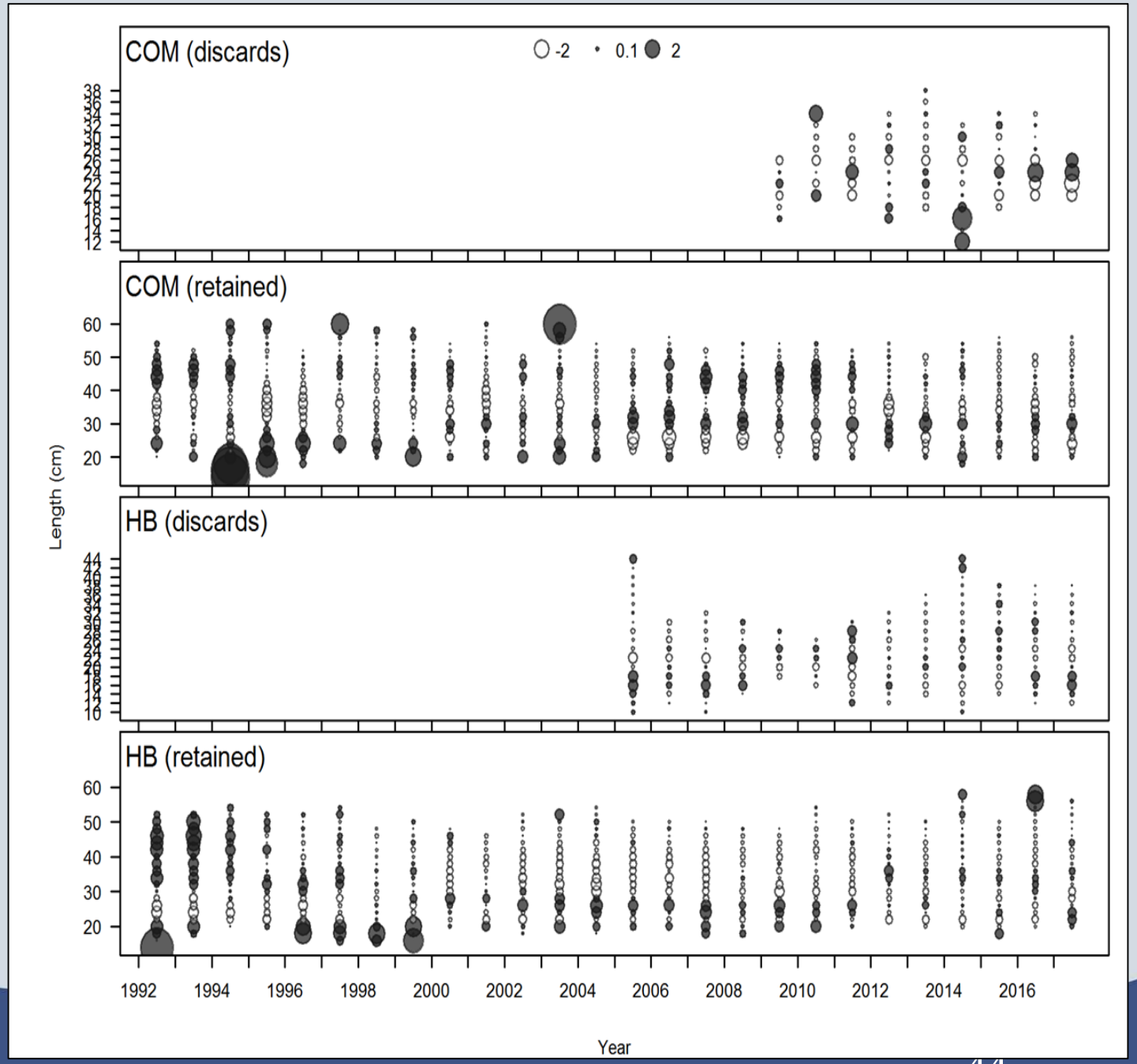




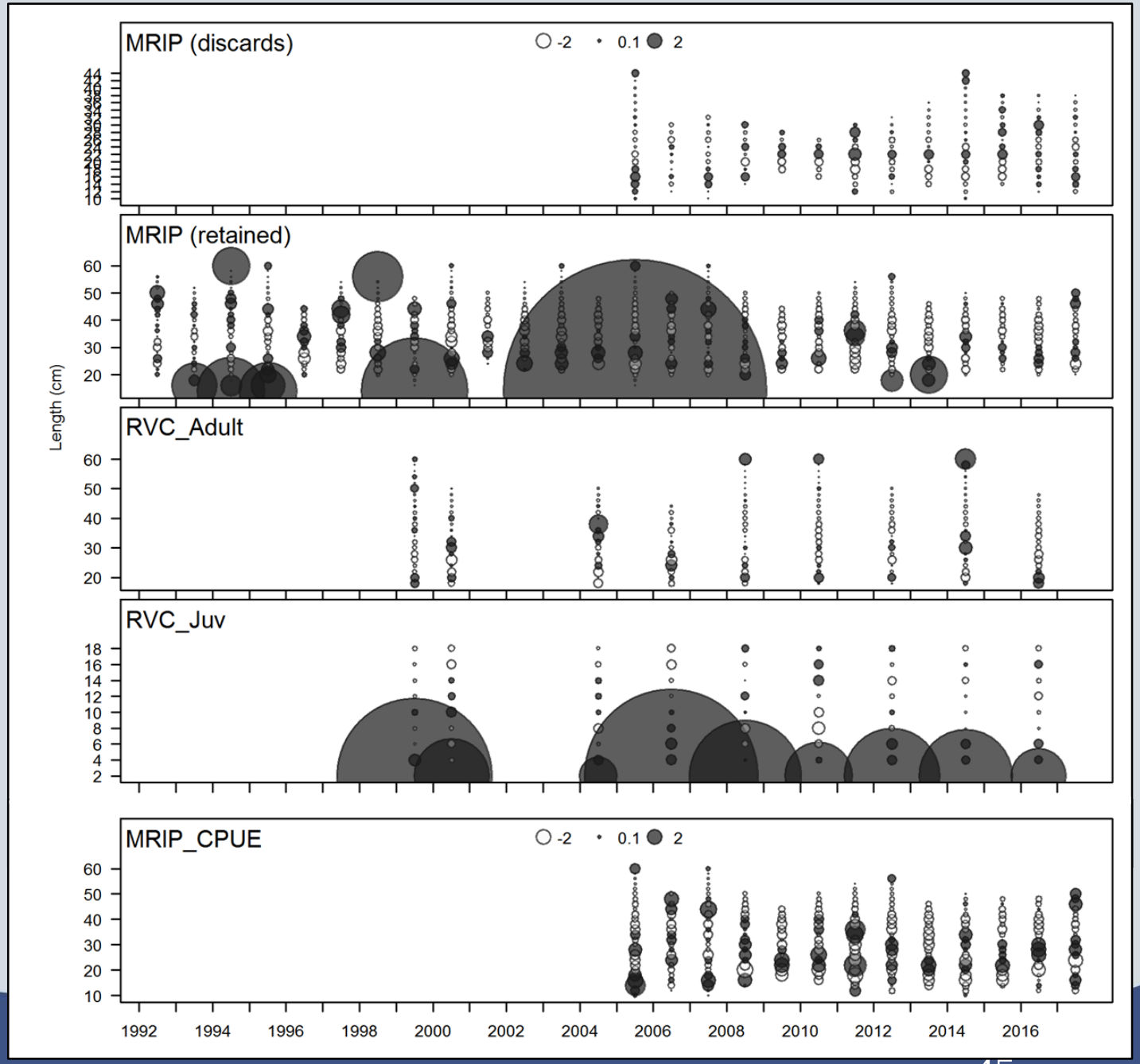
Stock Assessment Model:
Fits to Length Comps



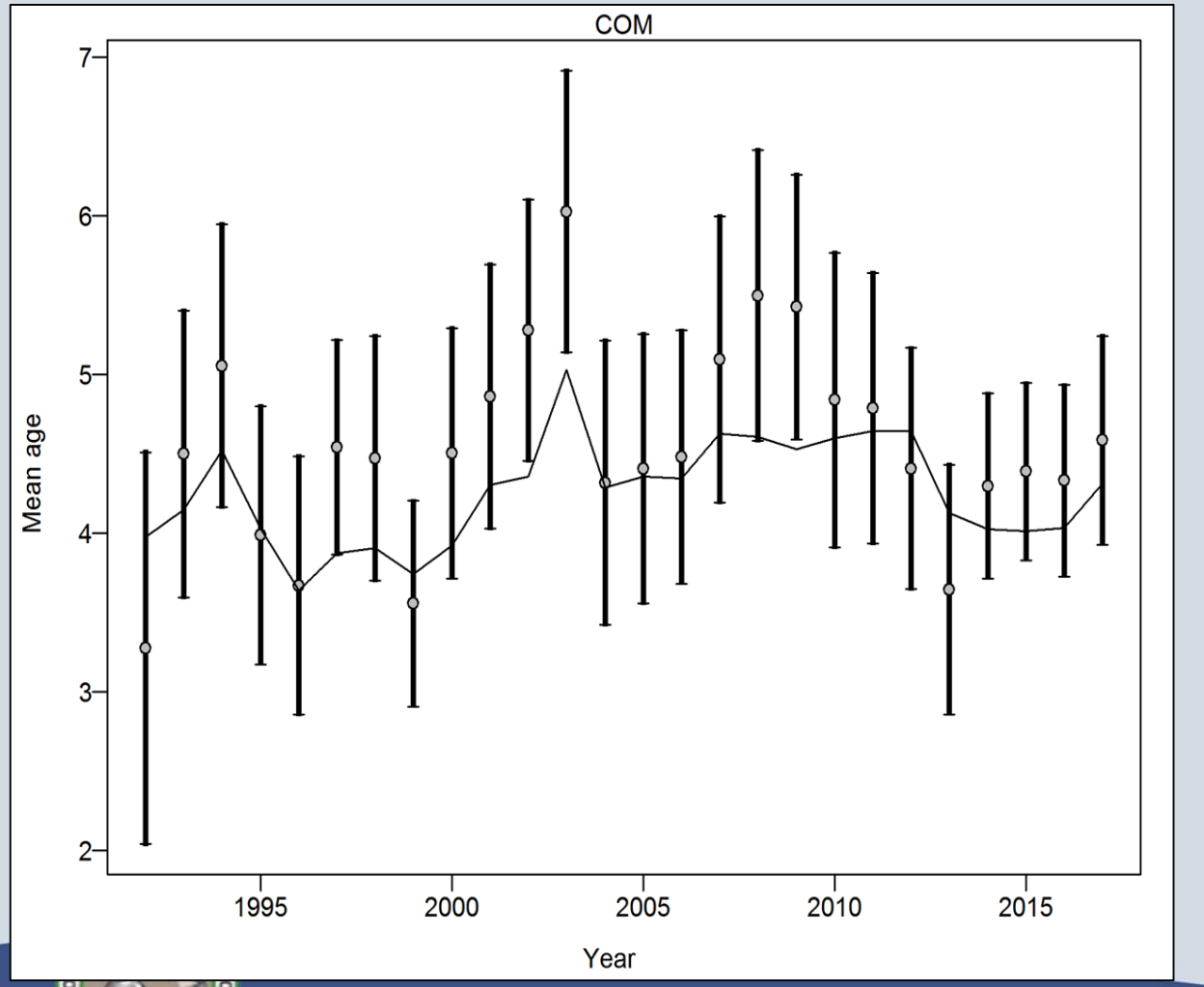
Stock Assessment Model:
Fits to Length Comps

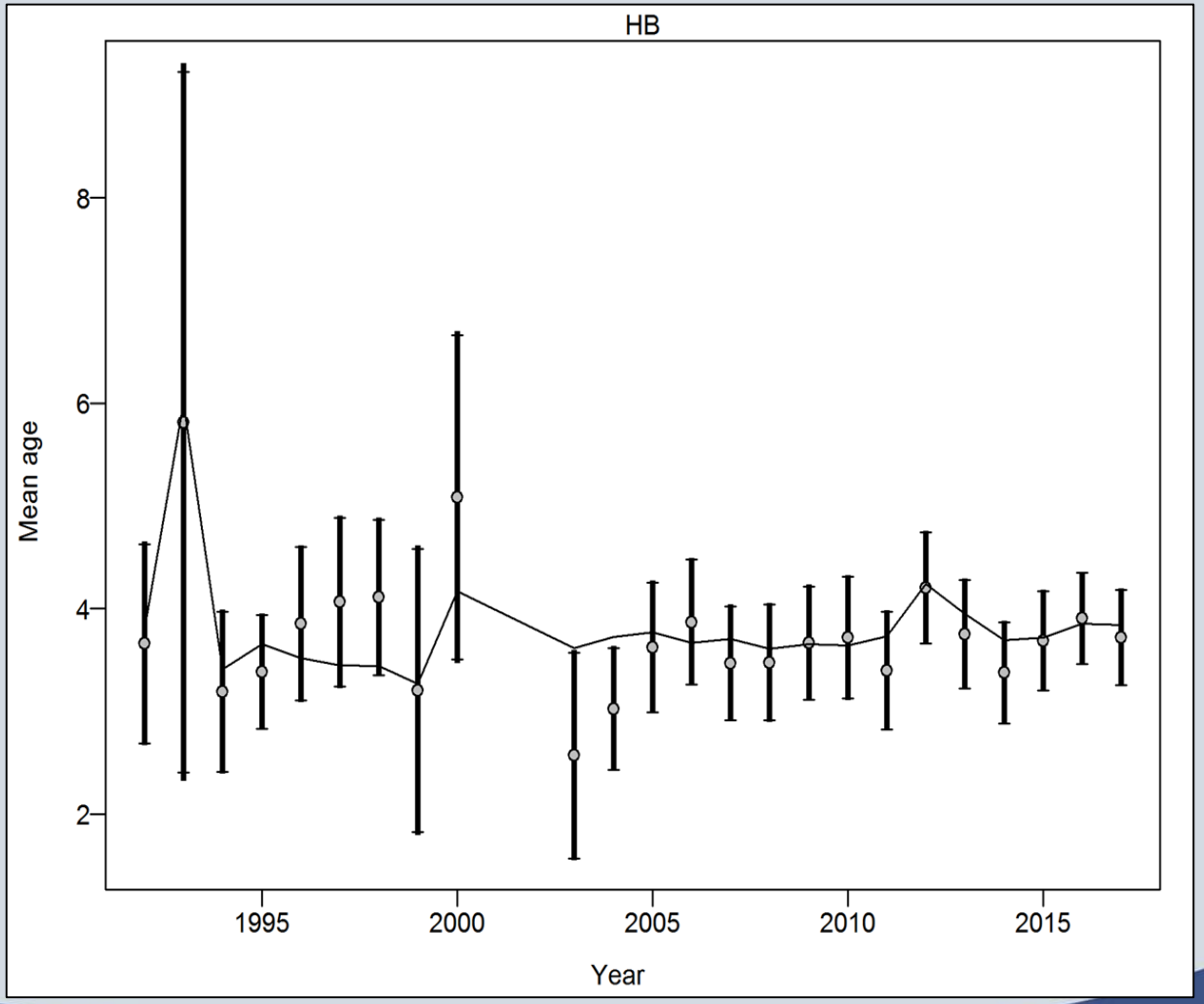


Stock Assessment Model:
Fits to Length Comps

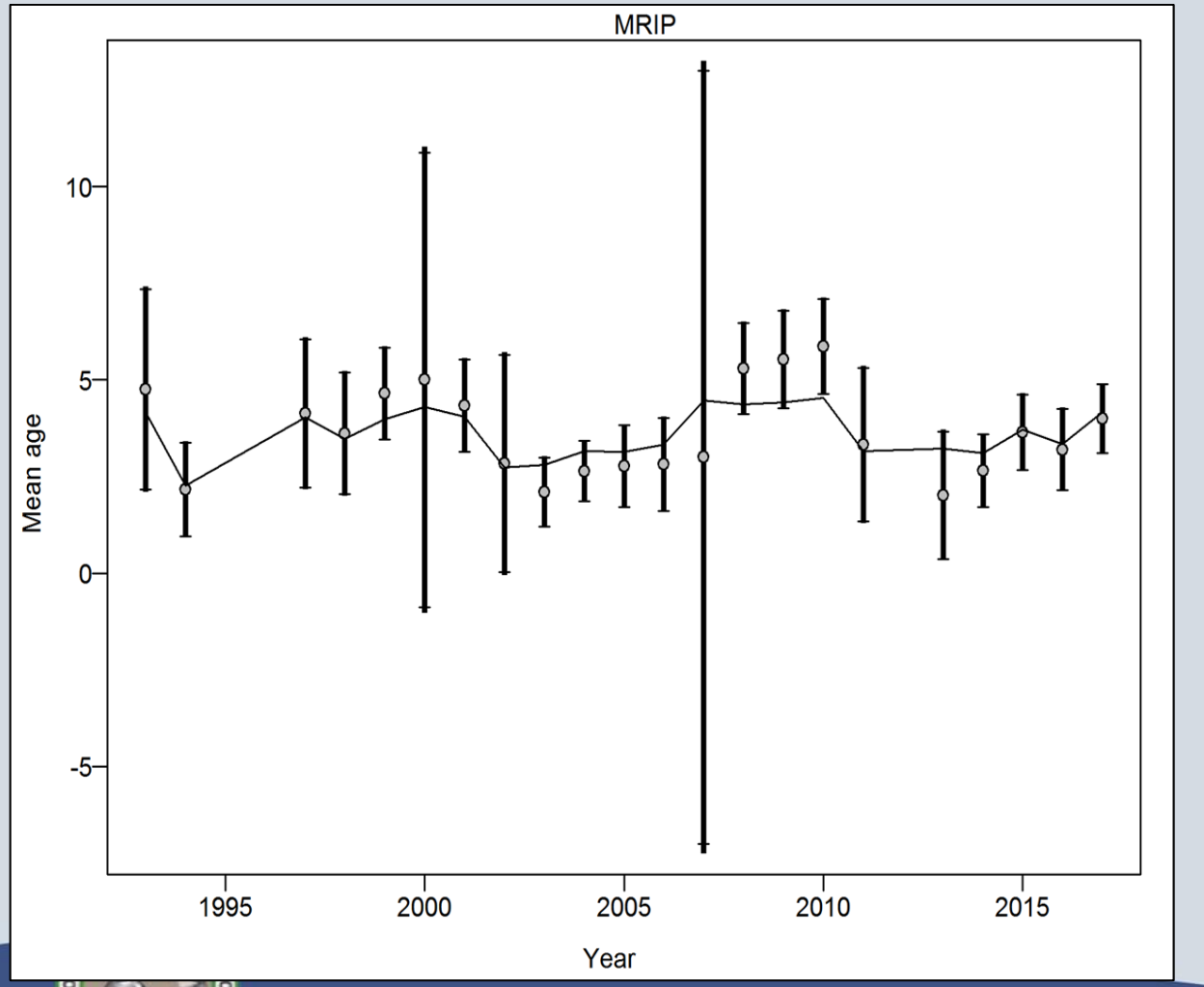


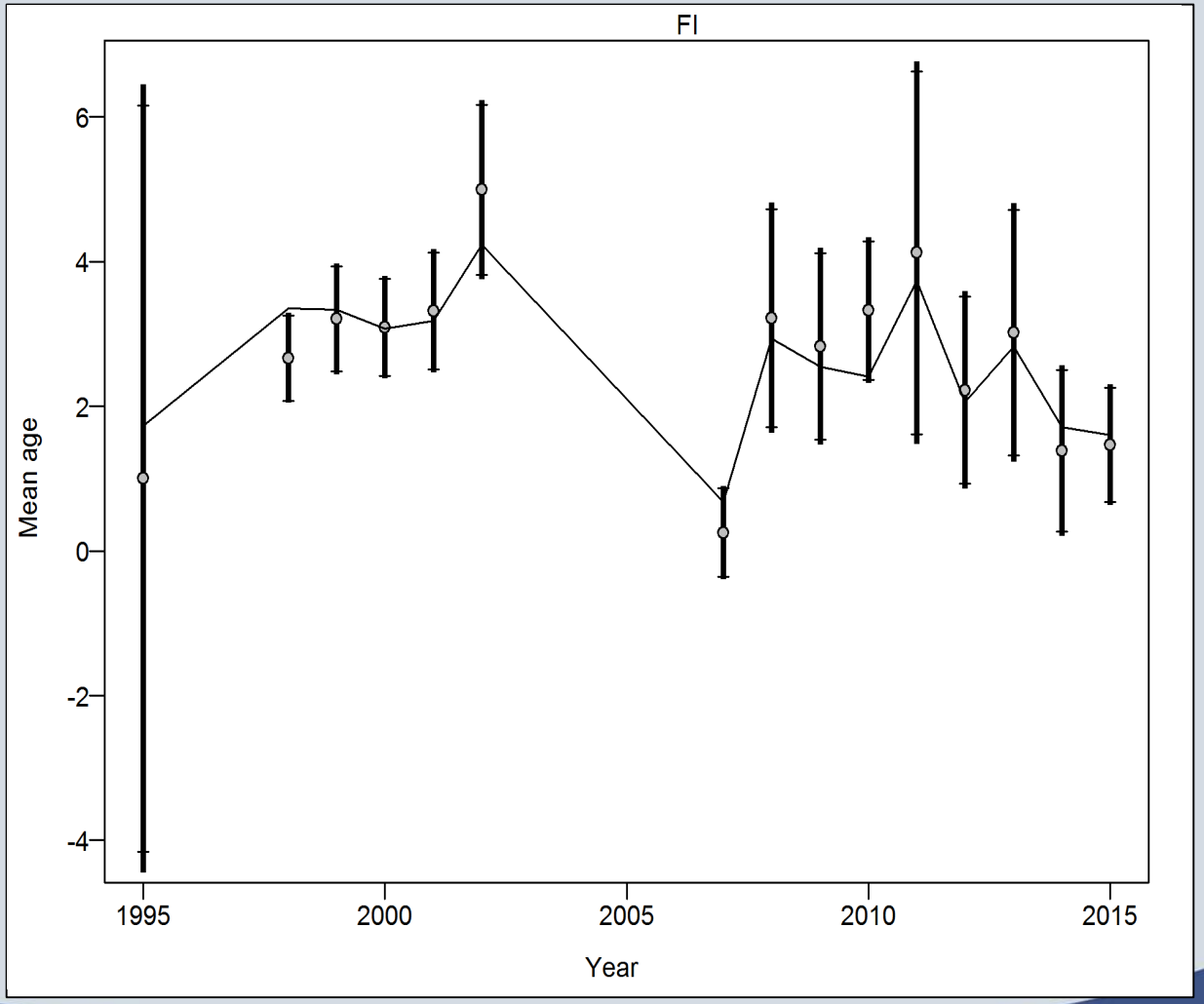
Stock Assessment Model:
Fits to Age Comps



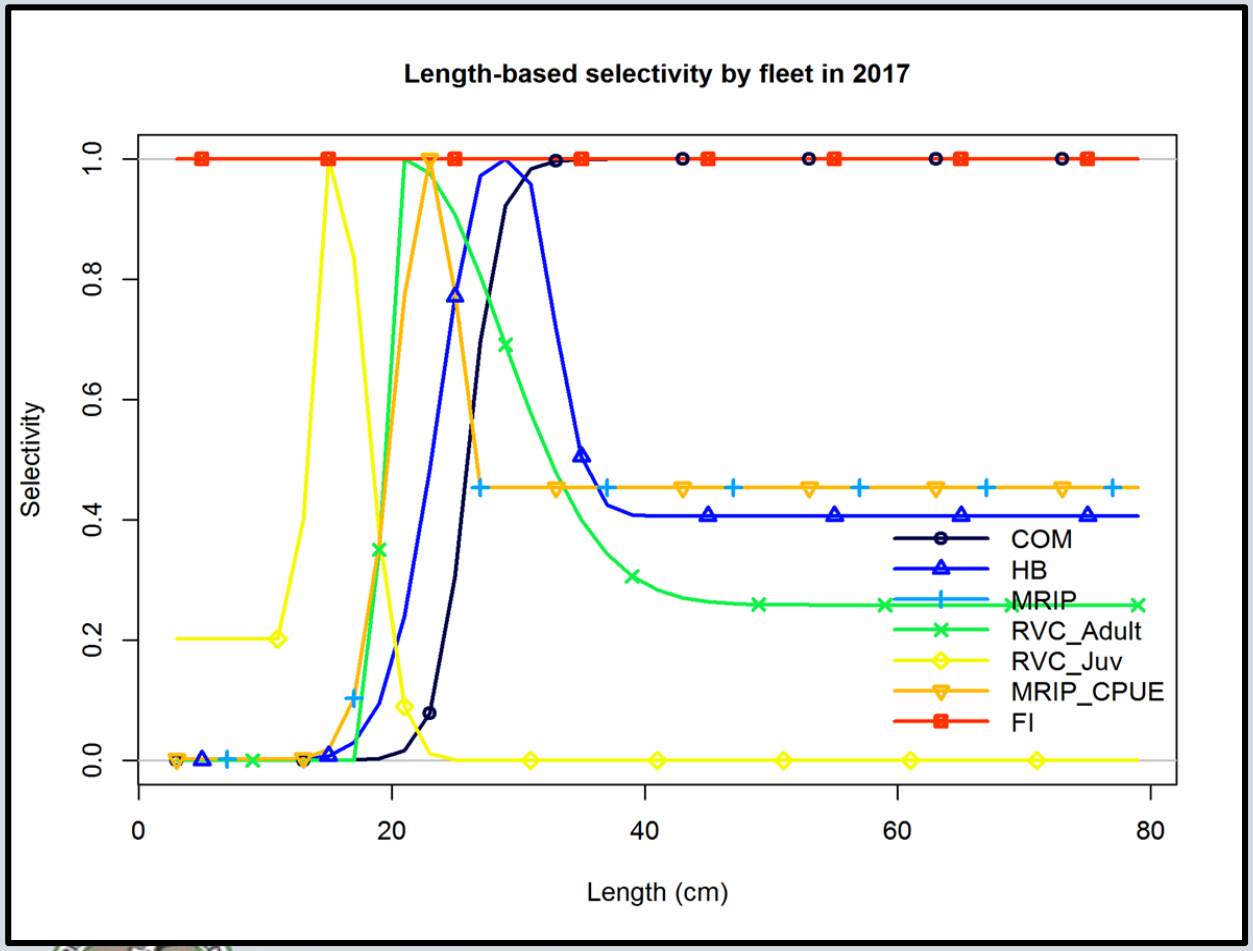


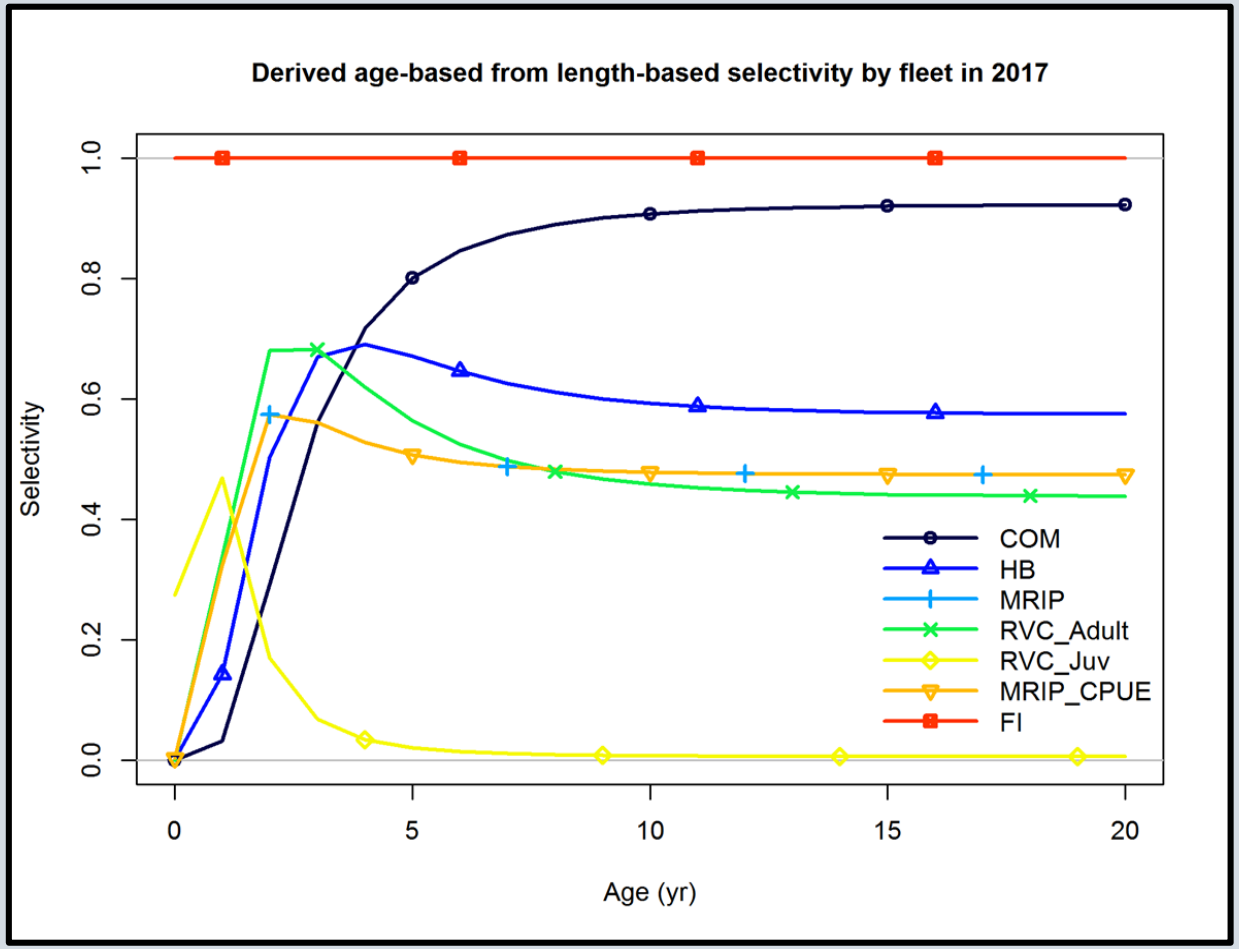
Stock Assessment Model:
Fits to Age Comps





Stock Assessment Model:
Estimated Selectivity

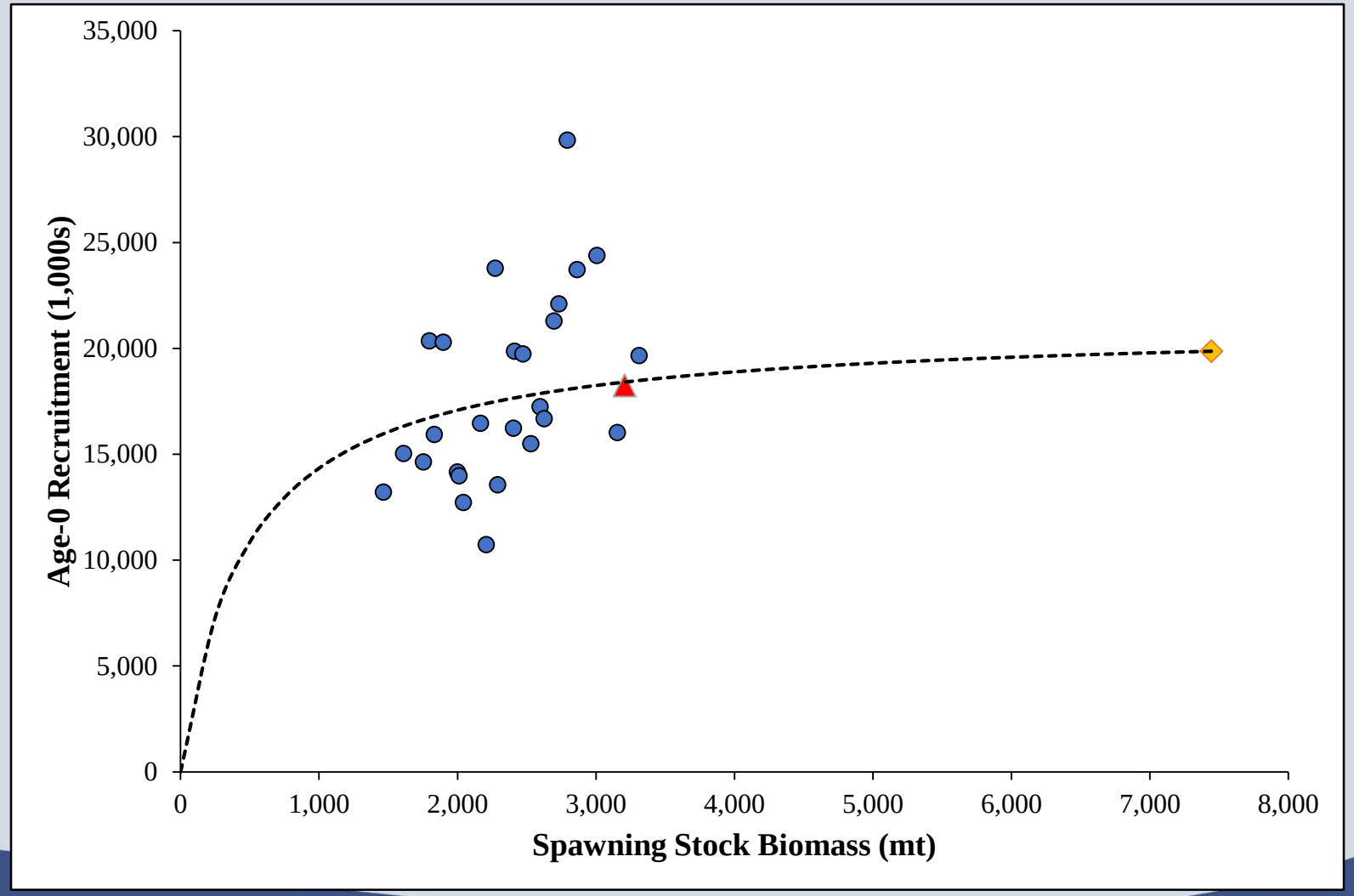




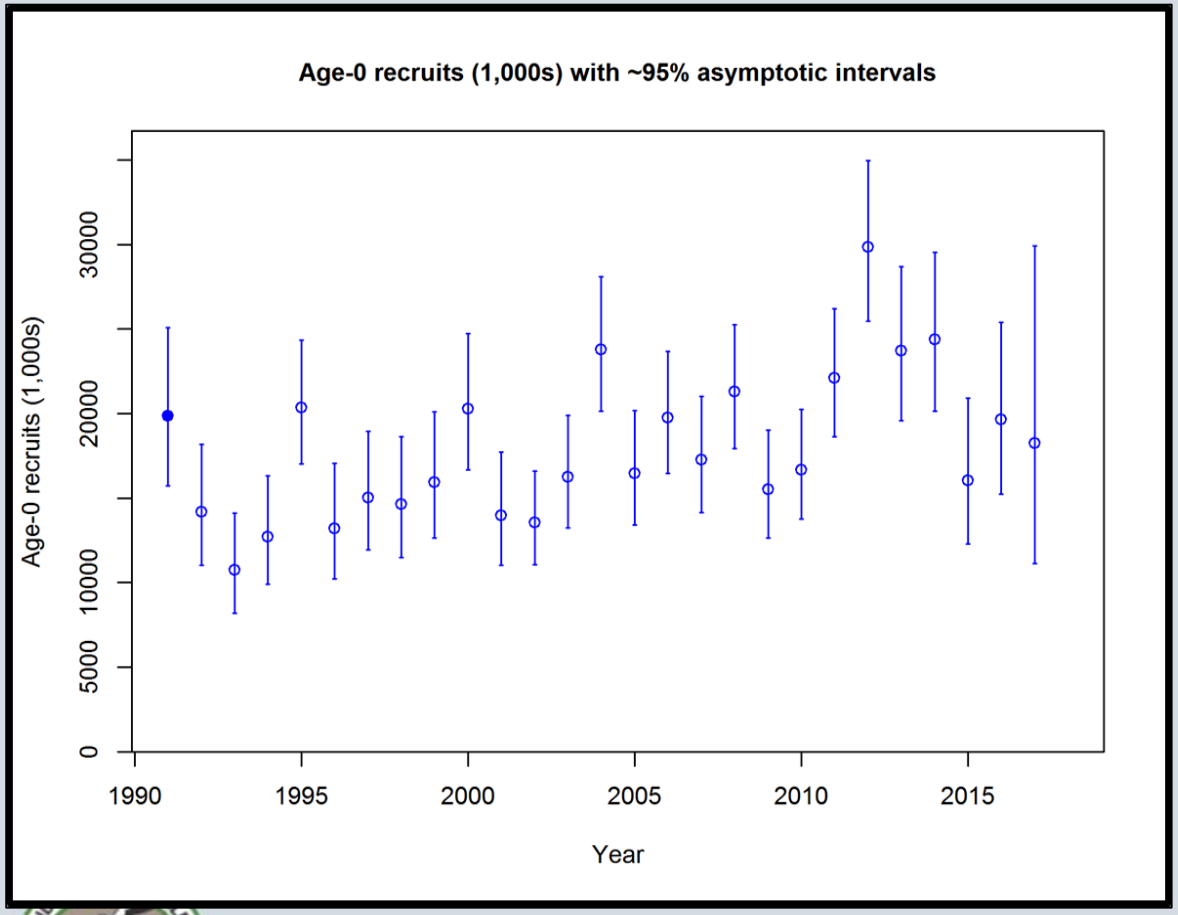
Stock Assessment Model:
Stock-Recruitment Curve

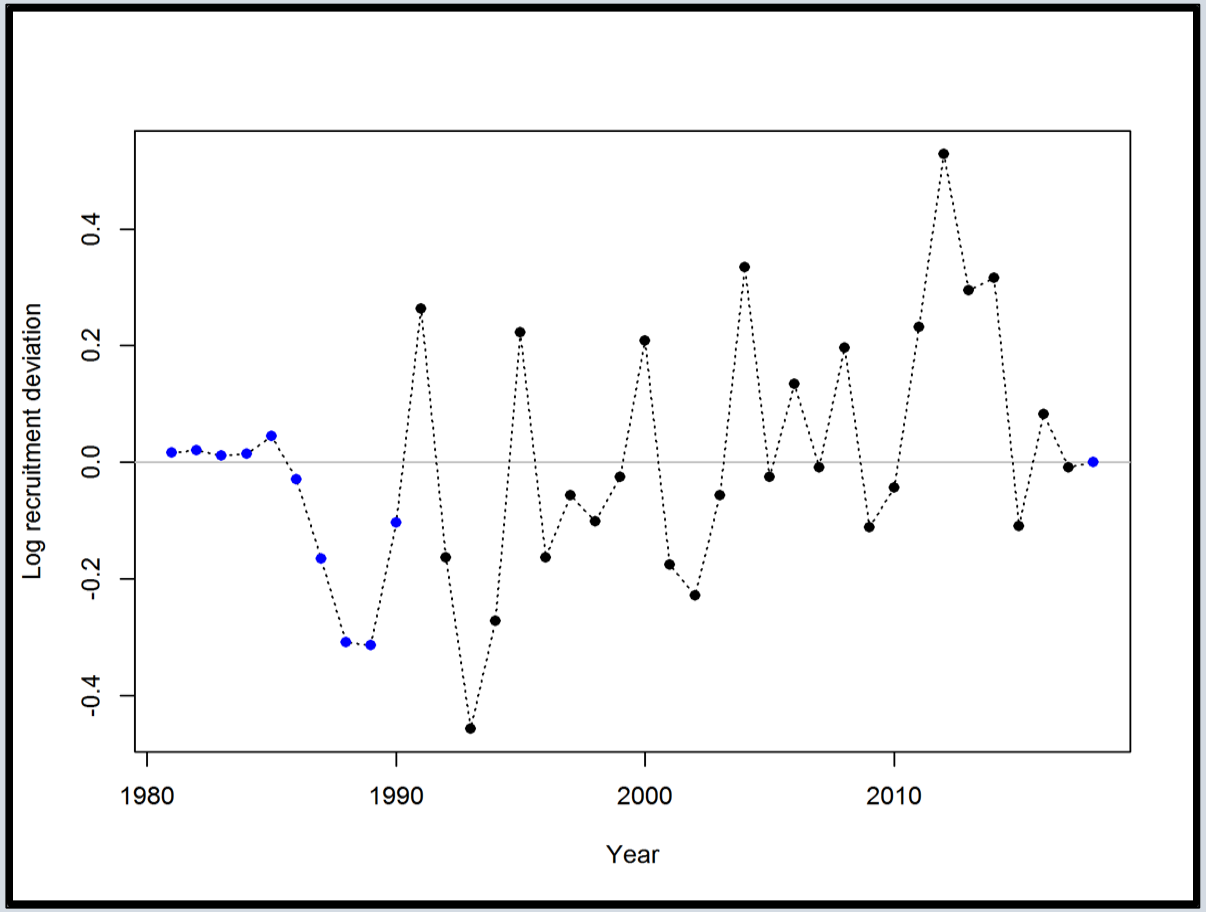
Parameter Estimates

- SSB0: 7,446.26 mt
- *R0*: 19.864 million
- *steepness*: 0.808
- Beverton-Holt
  - a: 21,127.61
  - b: 473.52



Stock Assessment Model:
Estimated Recruitment





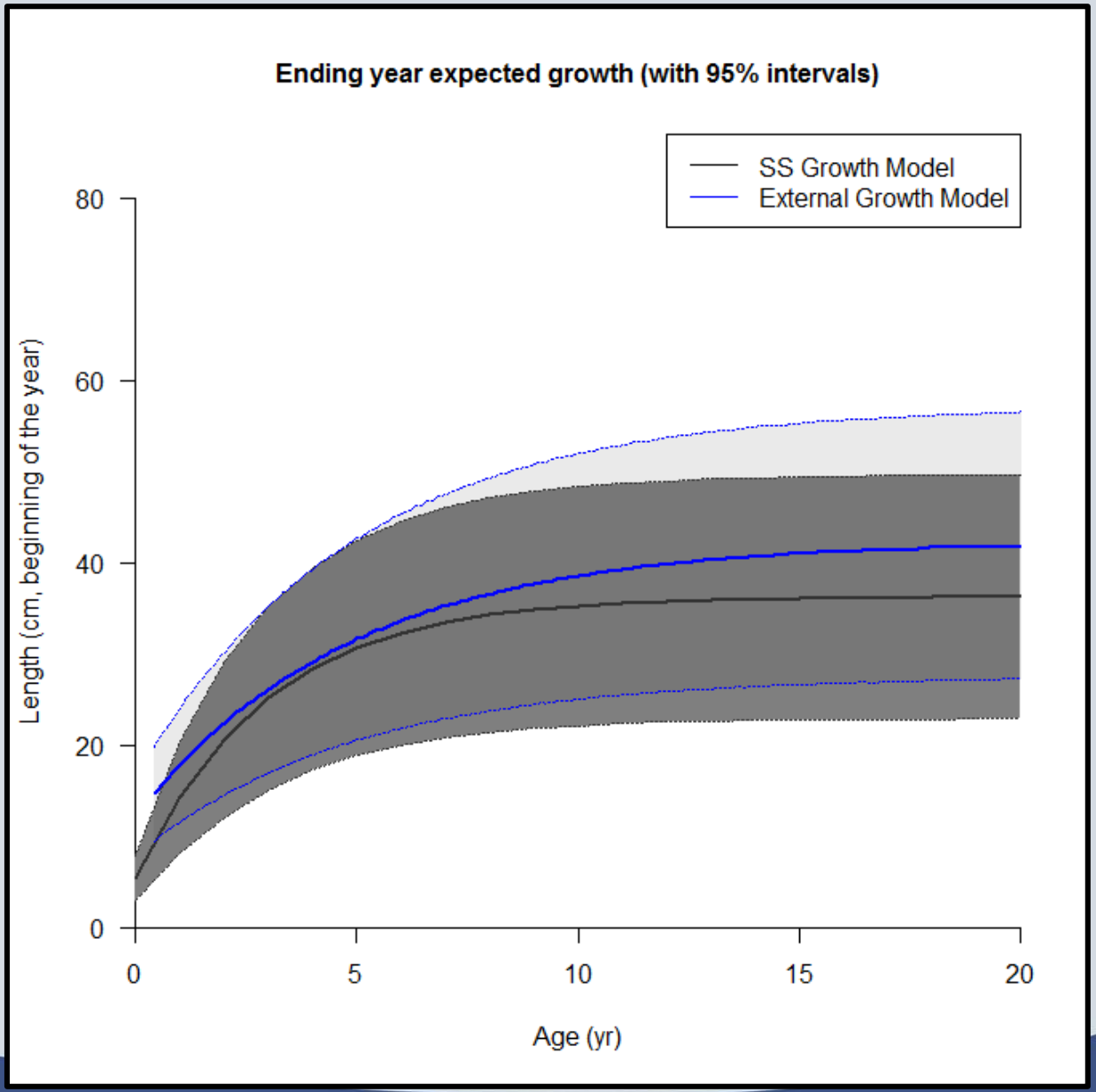
Stock Assessment Model: Growth

SS Model (black)

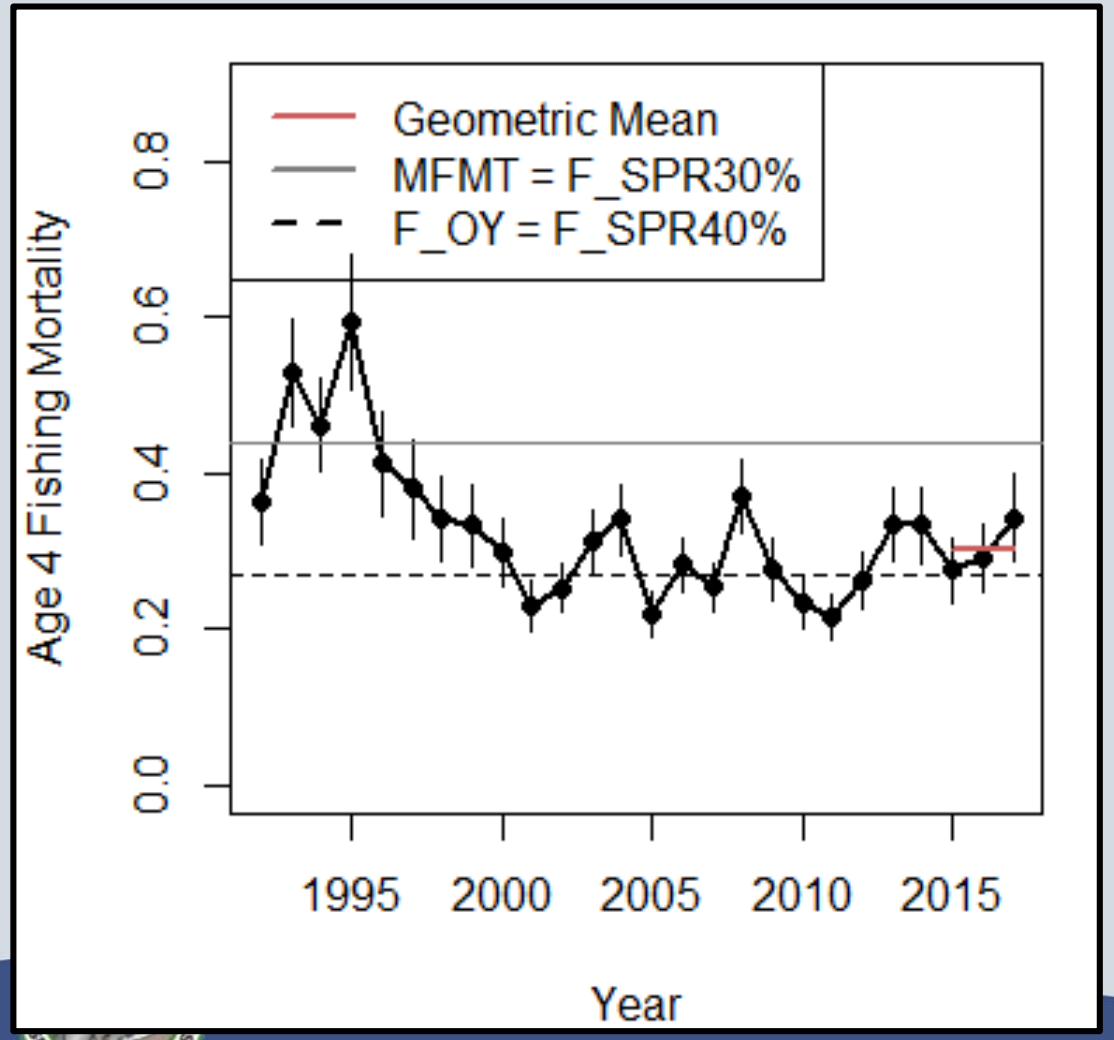
- L_{inf}: 36.2 cm
- k: 0.34 year^{-1}
- CV_{young}: 0.23
- CV_{old}: 0.19

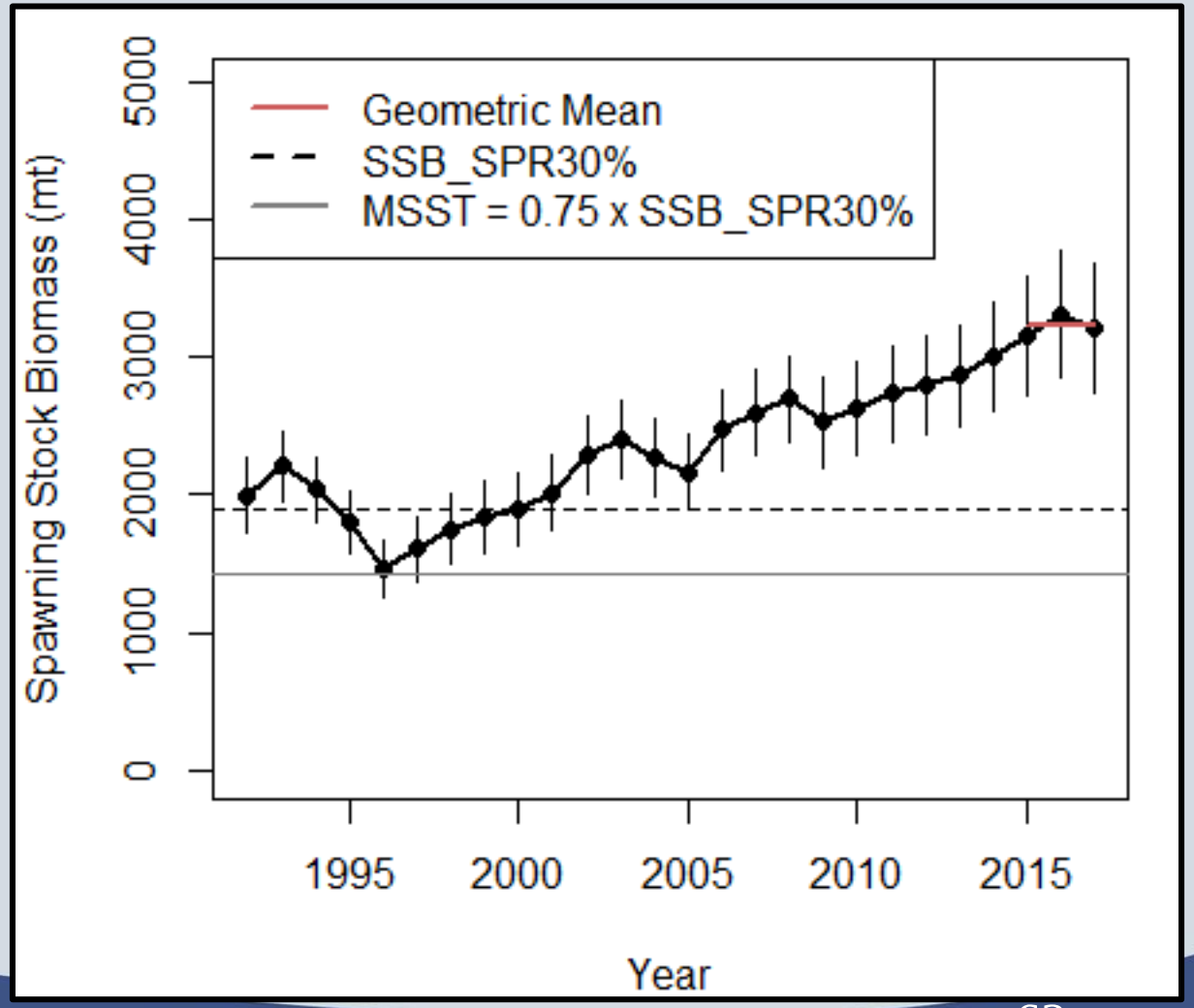
Size-truncated external model (blue)

- L_{inf}: 42.3 cm
- k: 0.21 year^{-1}
- CV_{young}: 0.18
- CV_{old}: 0.18

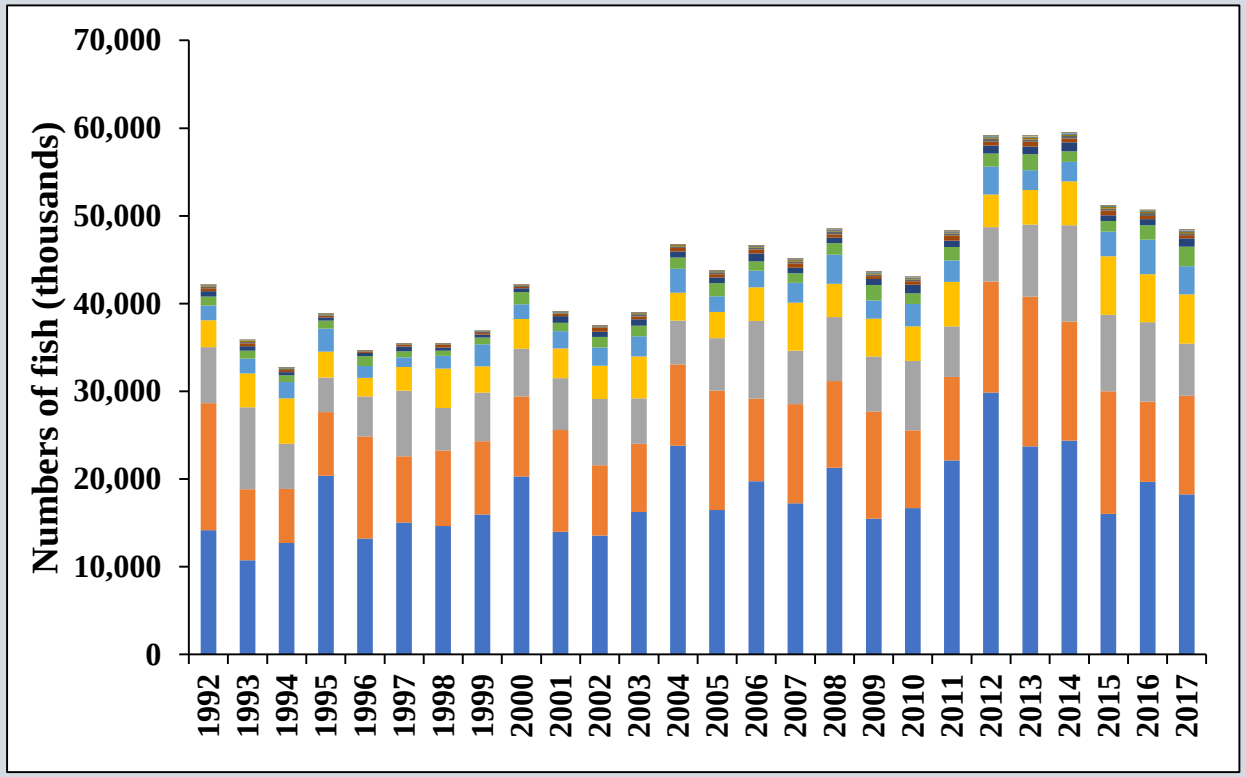


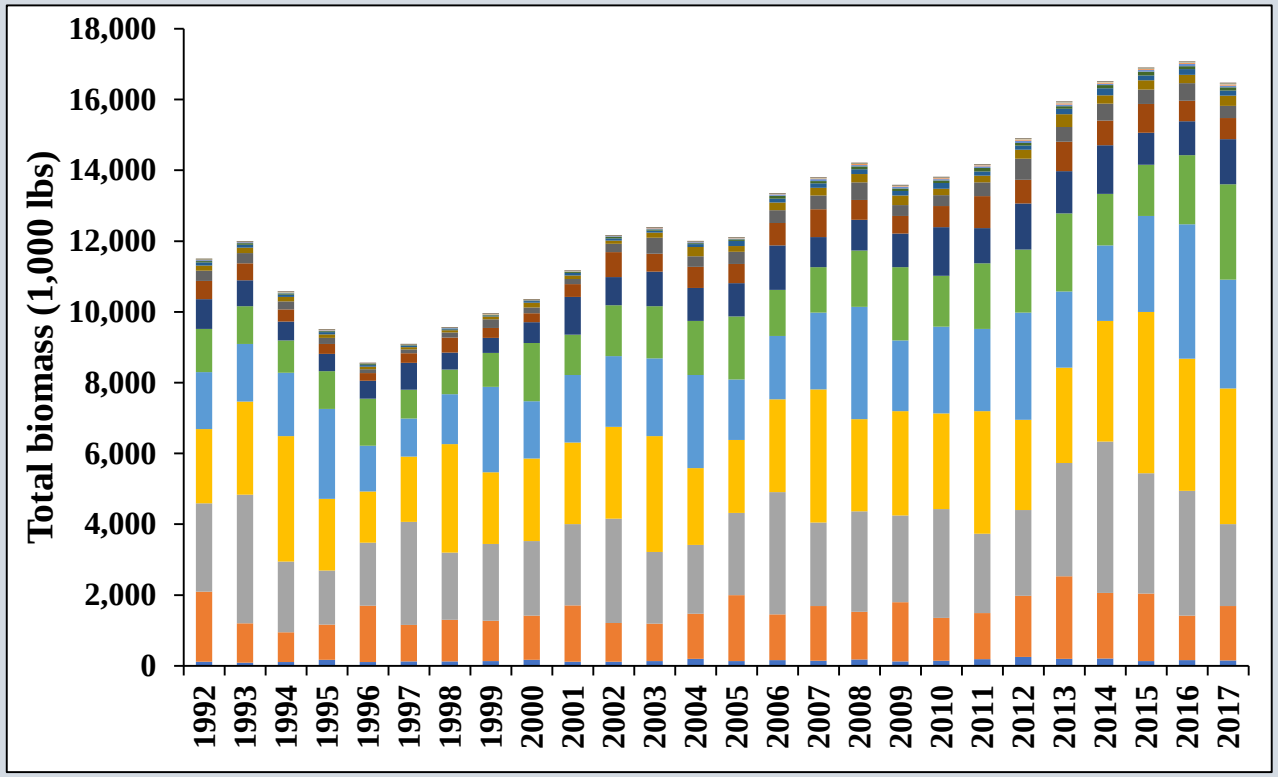
Stock Assessment Model:
Estimated Fishing mortality and SSB





Stock Assessment Model:
Numbers and Biomass at age





0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Stock Assessment Model:
Management Quantities

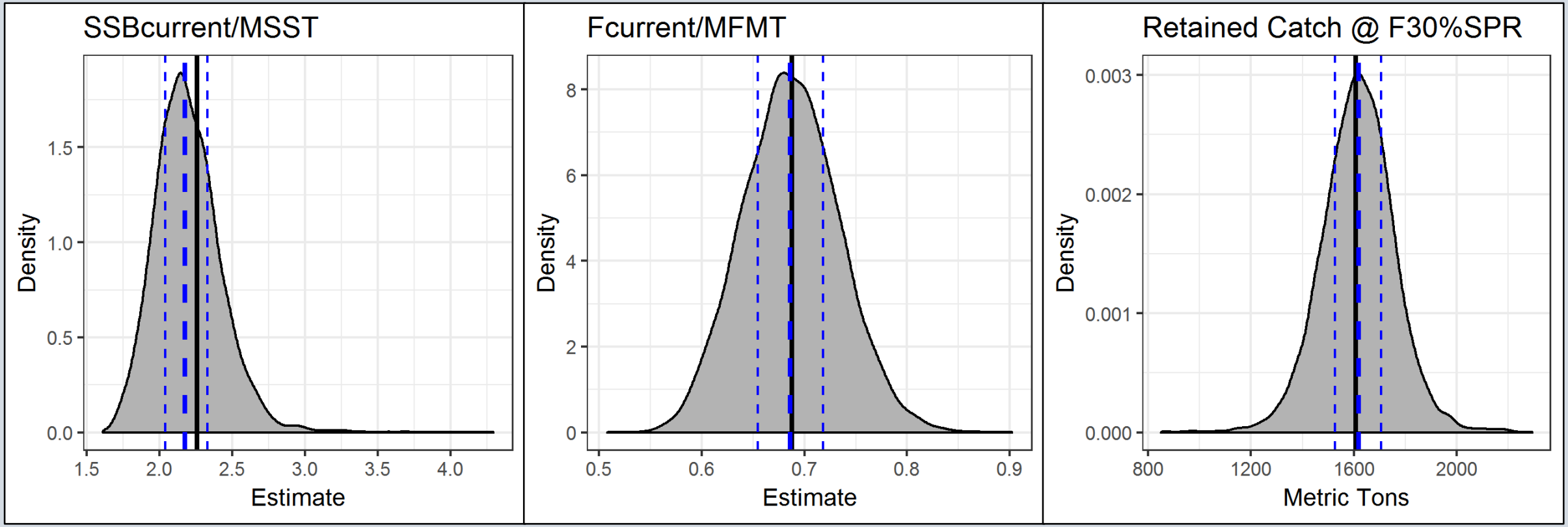
South Atlantic and Gulf of Mexico Fishery Management Councils			
Criteria	**Definition**	**Value**	**Pounds (lbs)**
MSST (Minimum Stock Size Threshold)	$0.75*SSB_{F30\%SPR}$	1,428 mt	3,148,201 lbs
$SSB_{F30\%SPR}$	The estimated spawning stock biomass associated with F at 30% SPR	1,904 mt	4,197,601 lbs
$SSB_{current}$	The geometric mean of SSB for 2015 - 2017	3,223 mt	7,105,499 lbs
MFMT (Maximum Fishing Mortality Threshold)	$F_{30\%\ SPR}$	0.438 yr^{-1}	
OFL (Overfishing Limit)	Retained Yield at MFMT	1,608 mt	3,545,033 lbs
$F_{current}$	The geometric mean of F on age-4 fish for 2015 - 2017	0.295 yr^{-1}	
OY (Optimum Yield)	Retained Yield at F_{OY}	1,497 mt	3,300,320 lbs
F_{OY} (Fishing Mortality Rate at OY)	$F_{40\%\ SPR}$	0.271 yr^{-1}	

Uncertainty: Markov Chain Monte-Carlo

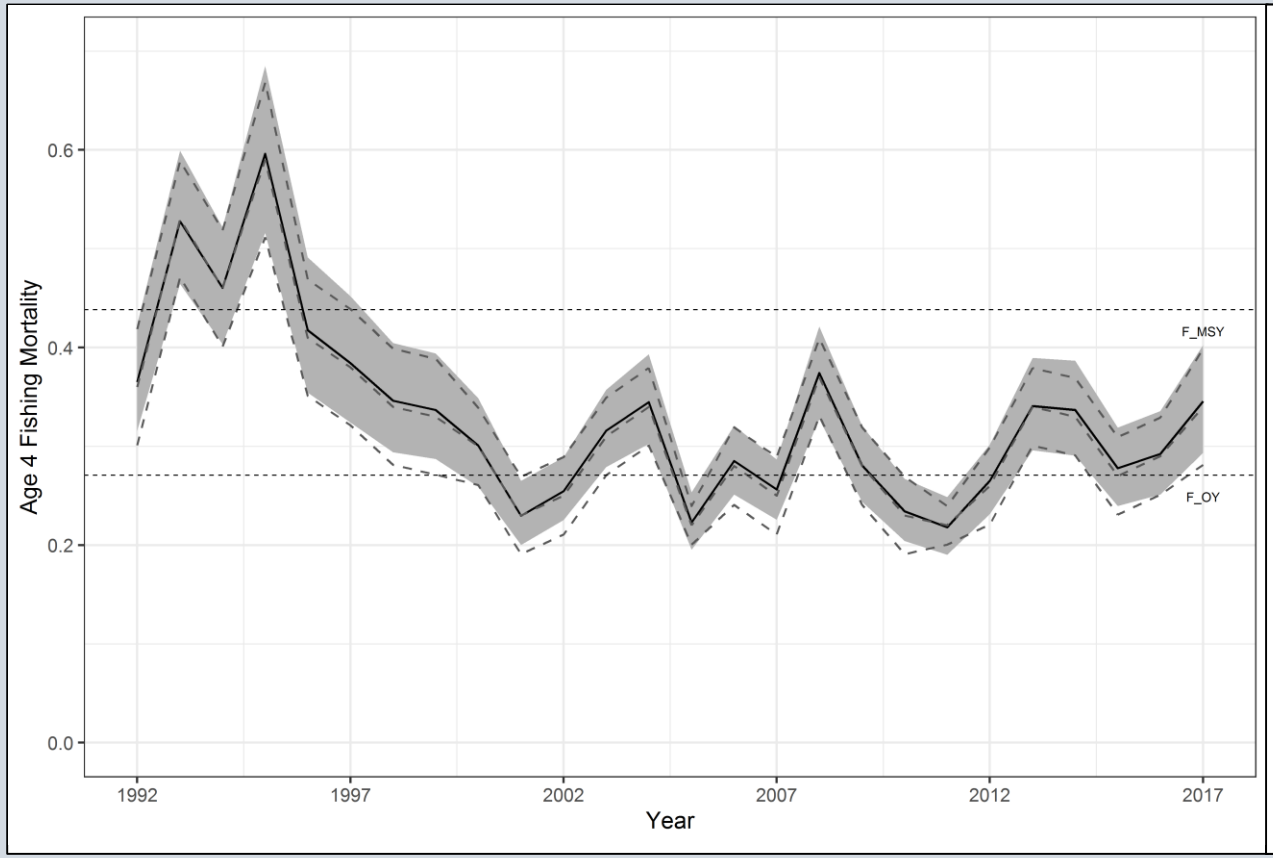
MCMC Analysis

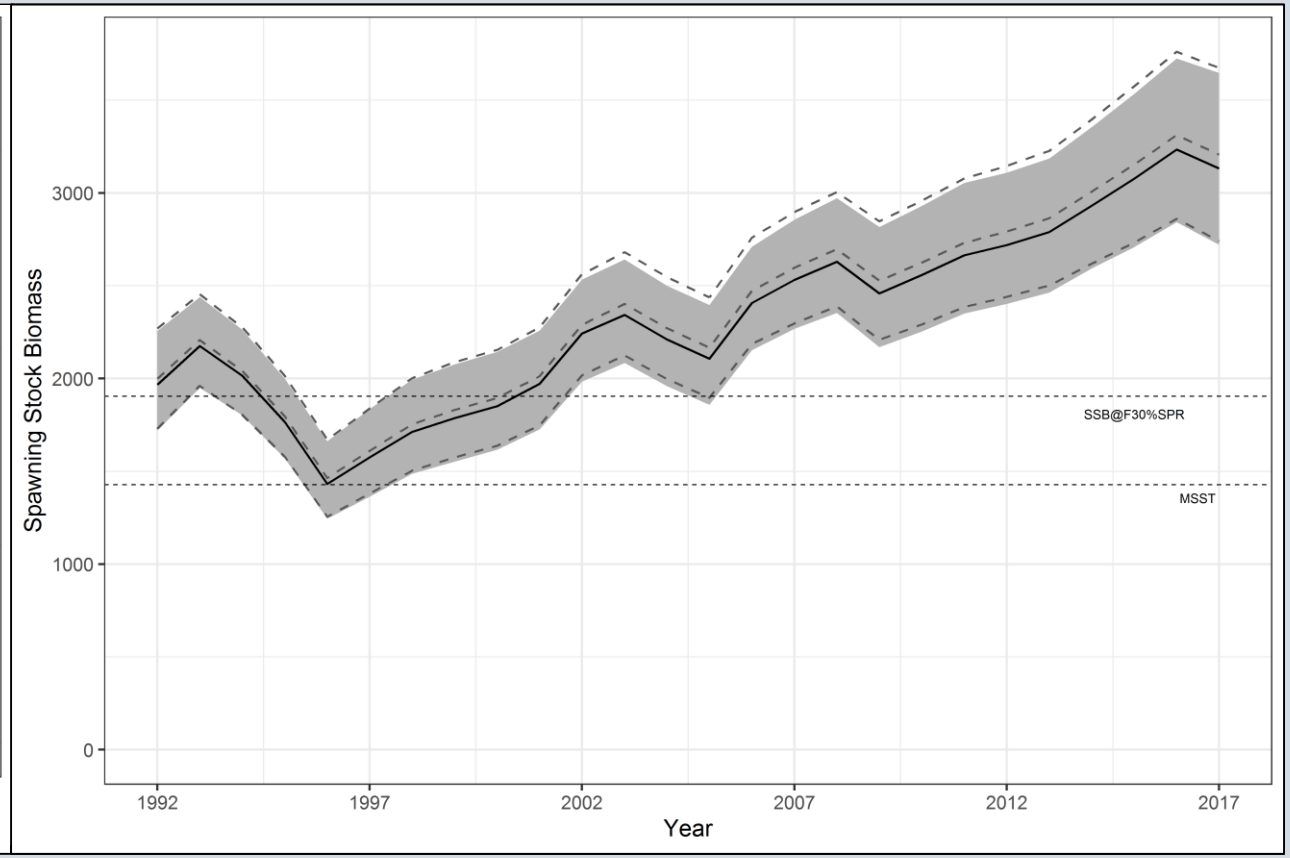
- Generate posterior distributions of model parameters and derived quantities
- Two chains
  - 1) 2,500 iterations saved from 5,000,000 (2,000 burn in)
  - 2) 2,500 iterations saved from 10,000,000 (5,002,000 burn in)
- Two-chain convergence assessed using Gelman and Rubin's (1992) potential reduction scale factor

Uncertainty: Markov Chain Monte-Carlo



Uncertainty: Markov Chain Monte-Carlo





SEDAR 64:Yellowtail Snapper

Base Model Sensitivity Runs

Shanae D. Allen and Christopher E. Swanson

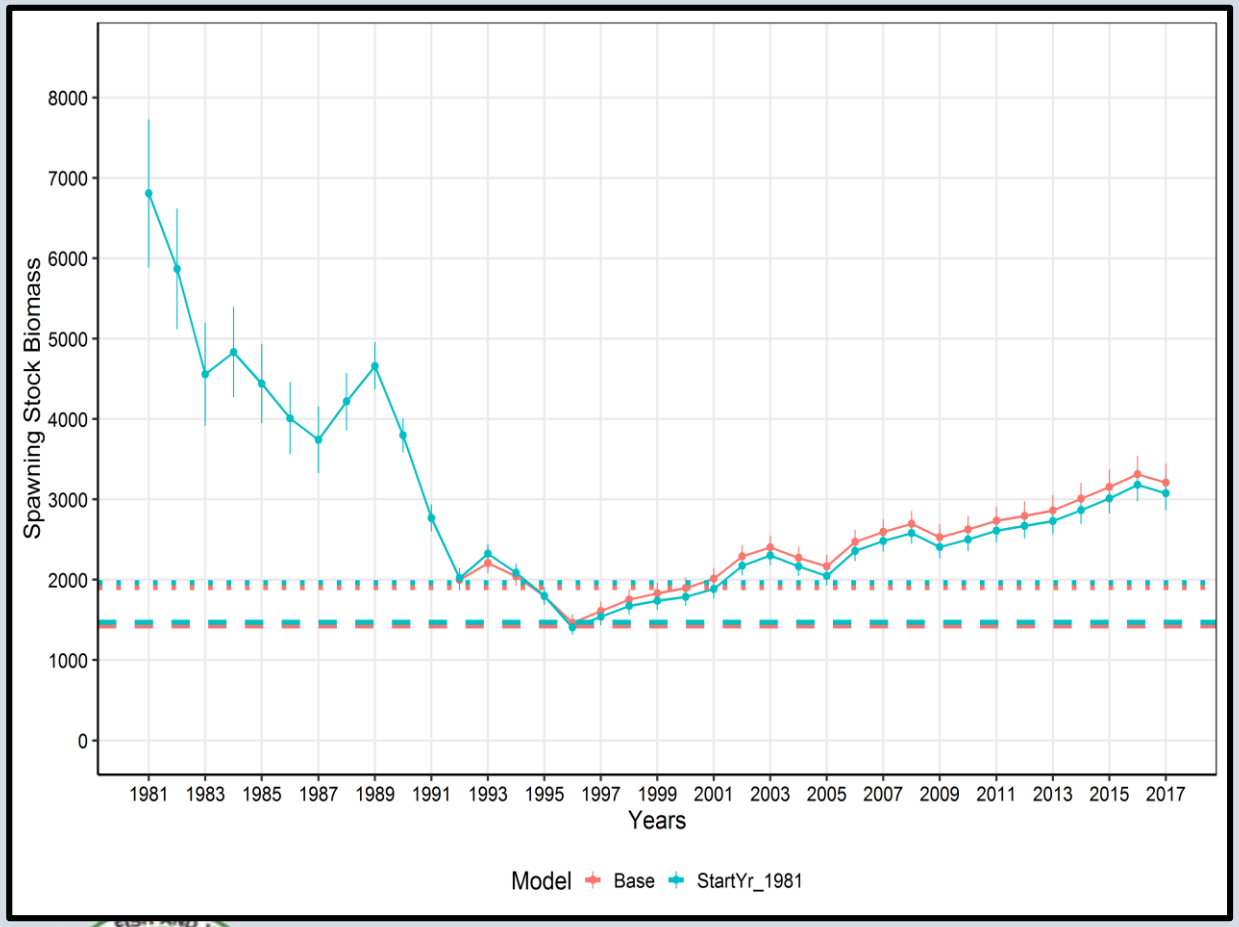
FWRI Stock Assessment Group, St. Petersburg, FL

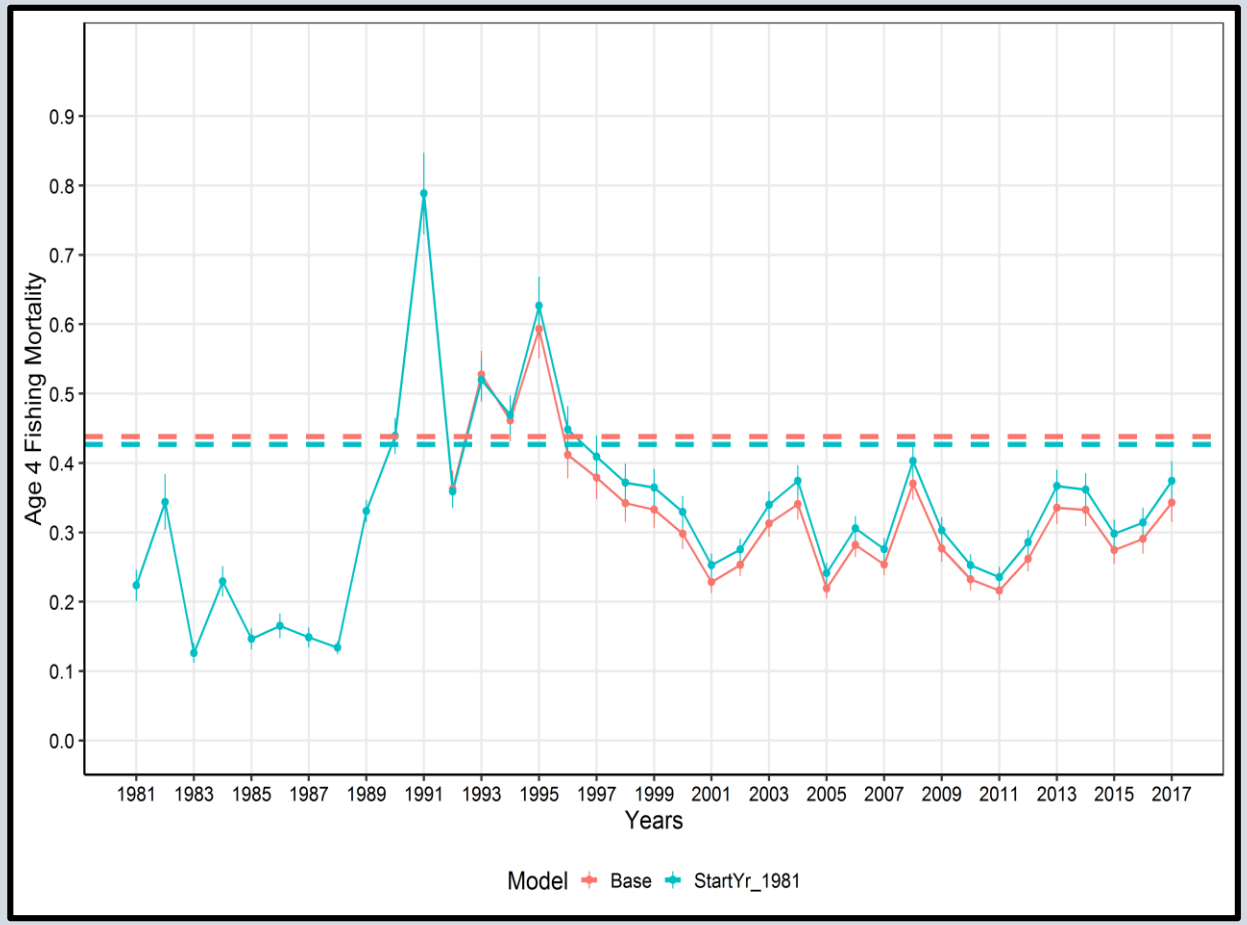
Joint SSC Meeting, Tampa, FL: July 21 – 23, 2020

Sensitivity Runs:

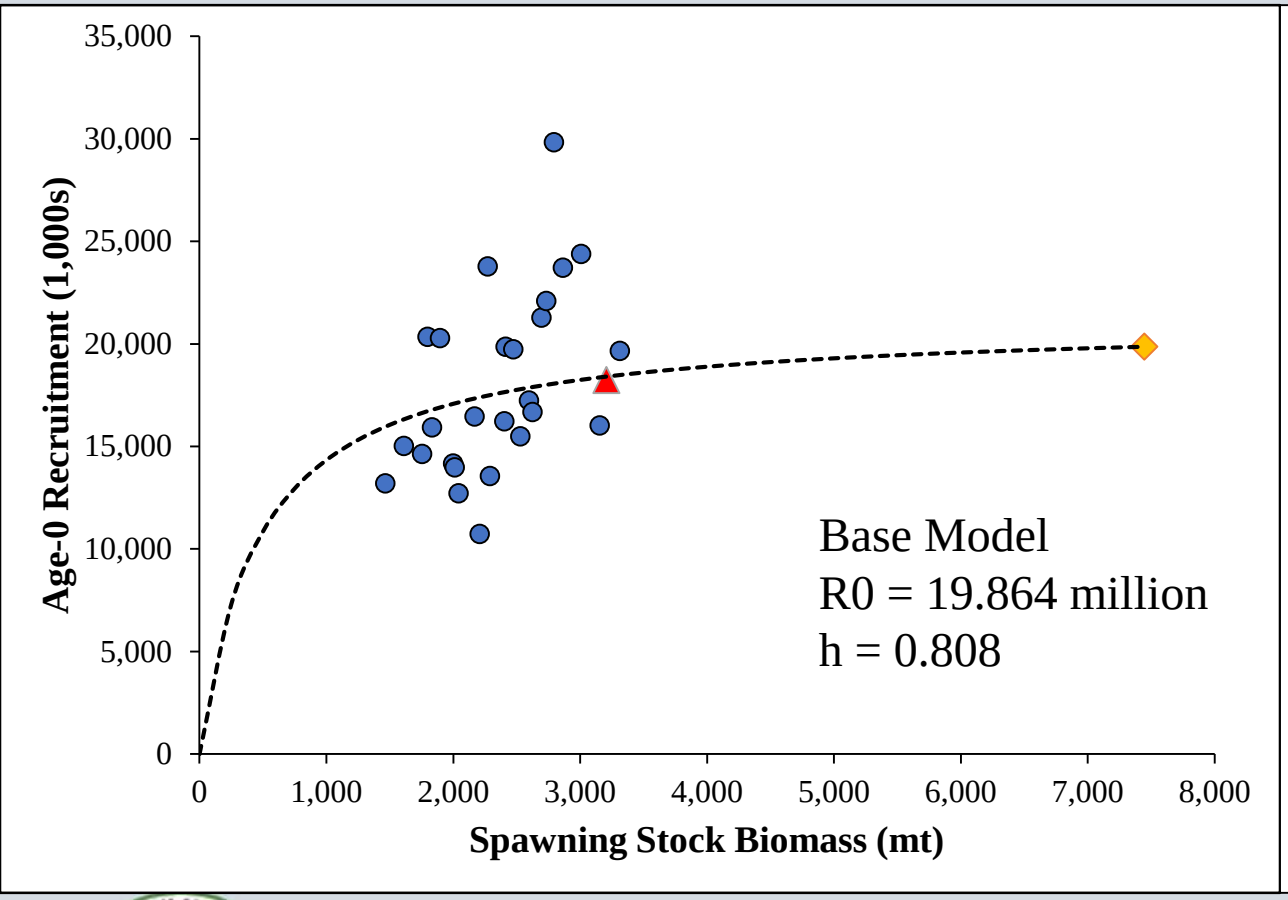
1. Change start year to 1981
2. Remove Francis (2011) weights on composition data
3. Lower natural mortality by increasing maximum age to 28
4. Change MRIP fleet selectivity to flat top
5. Alter Commercial and Recreational discard mortality

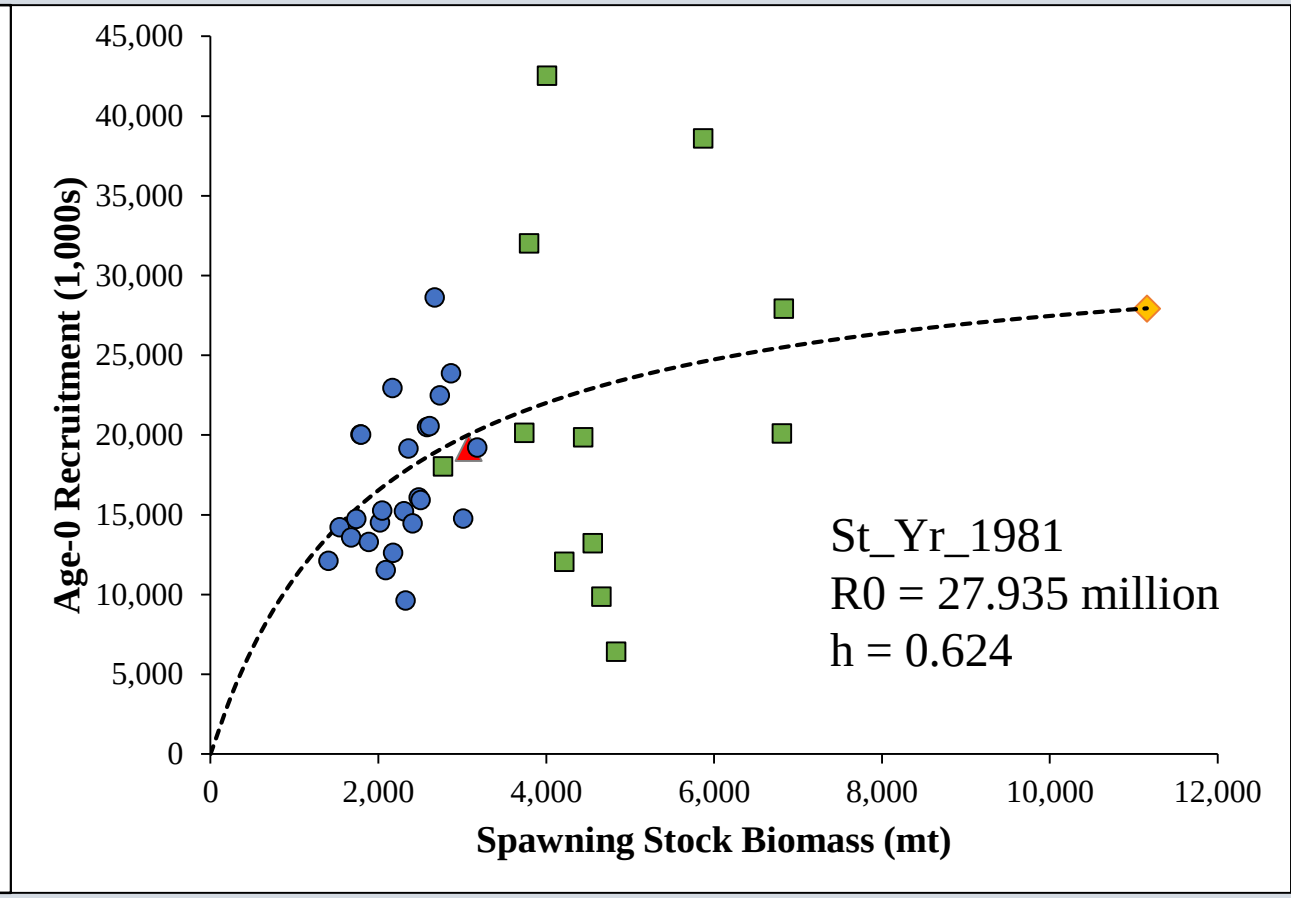
Sensitivity Run:1981 Start Year



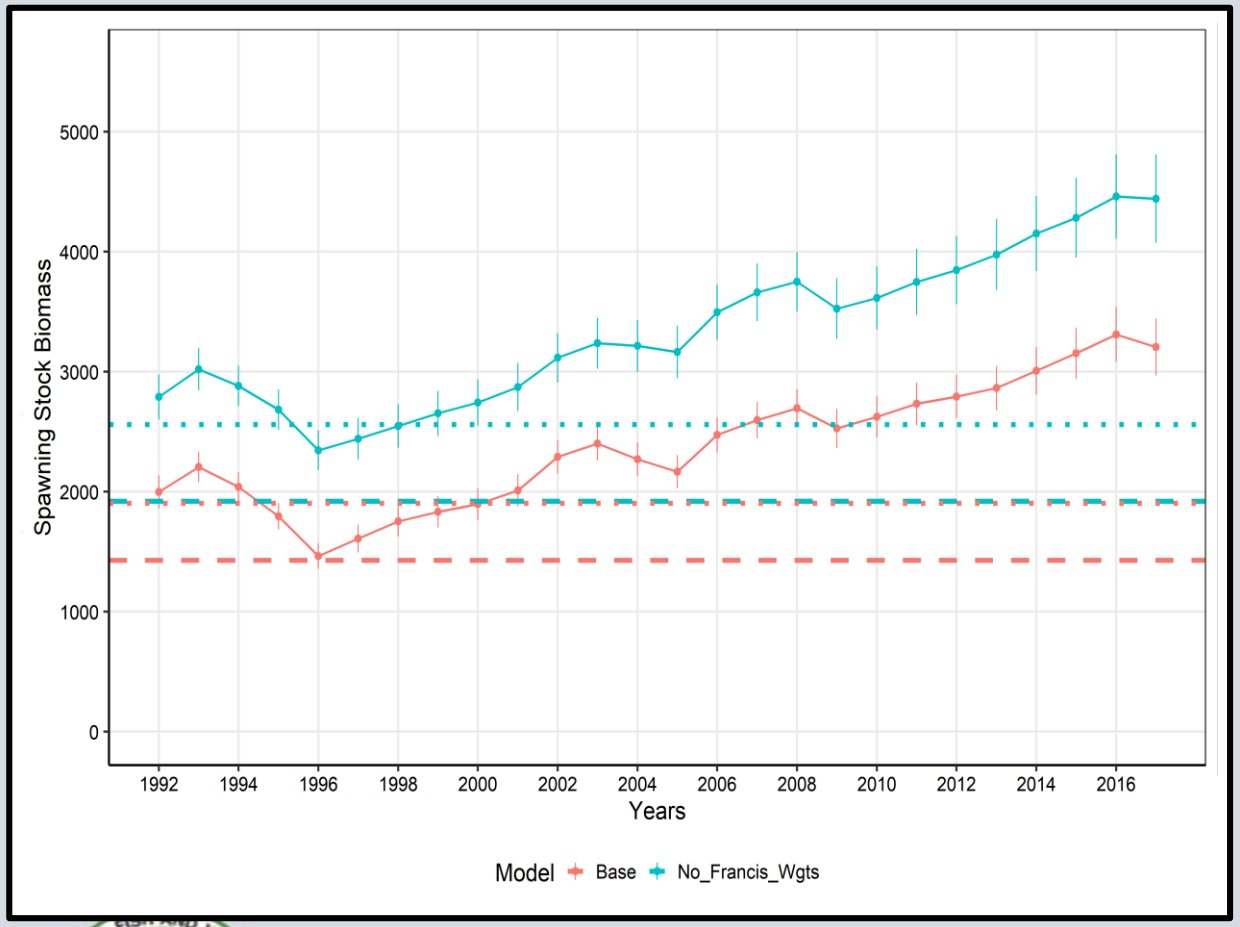


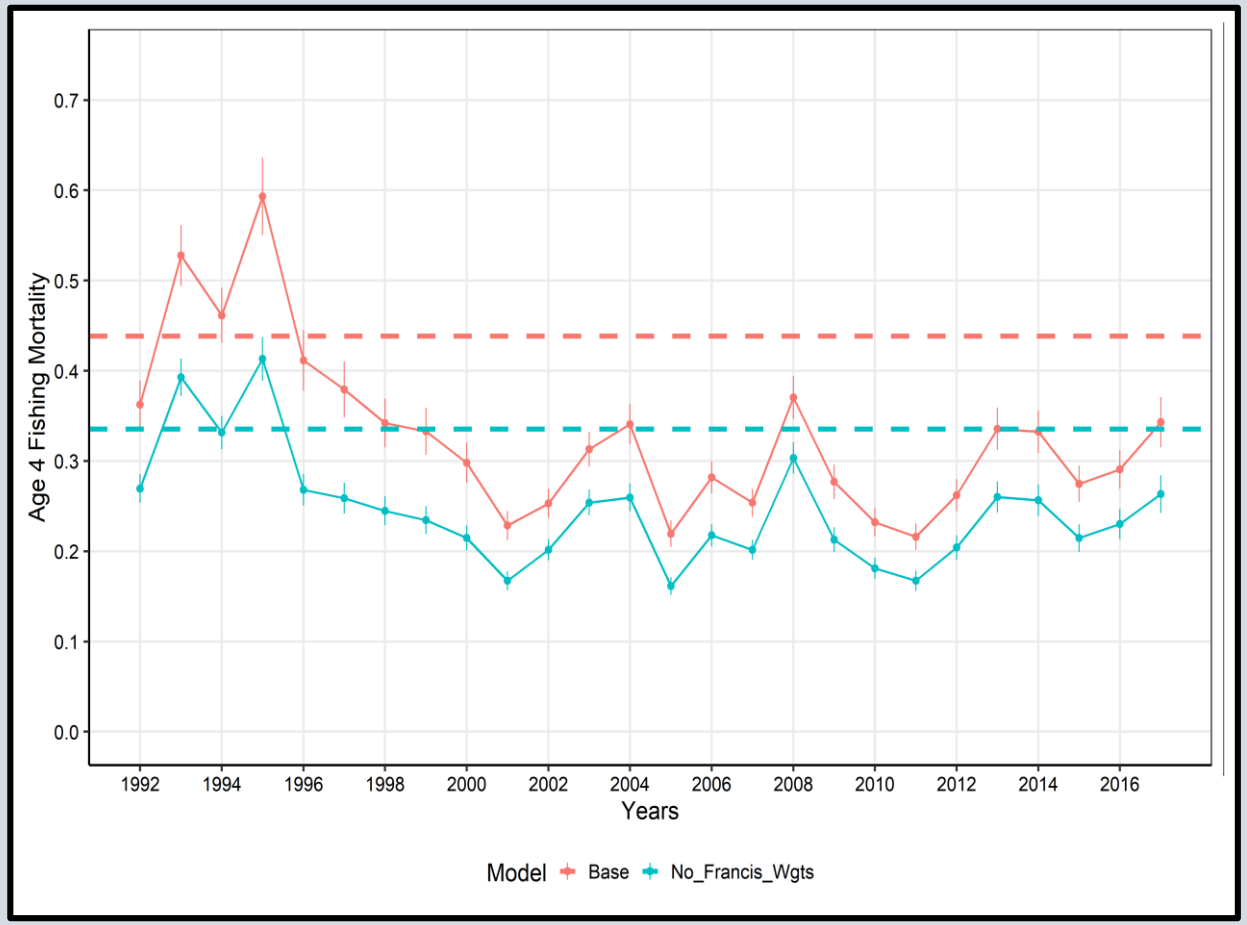
Sensitivity Run:1981 Start Year





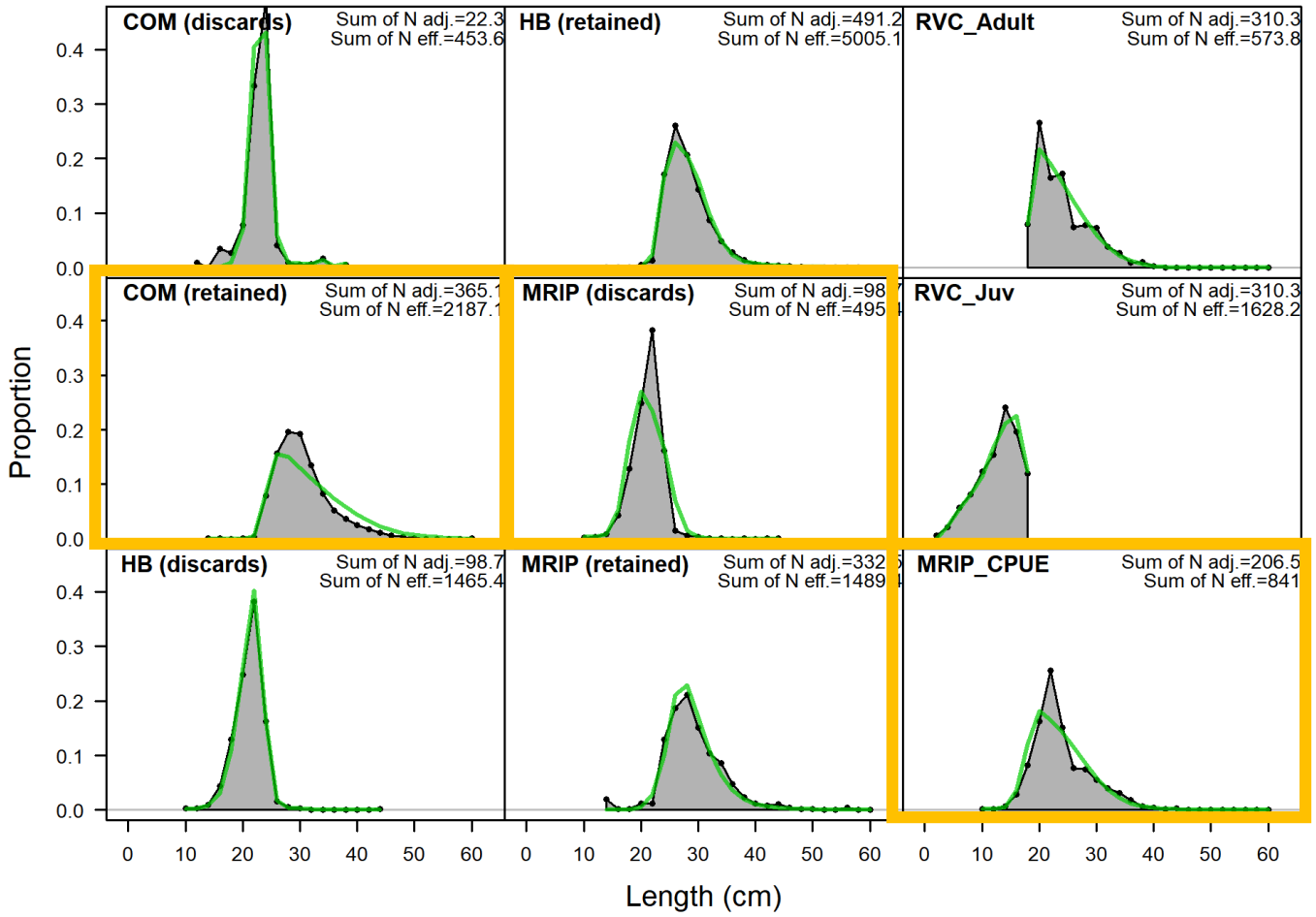
Sensitivity Run: Removing Francis Weights on Composition Data



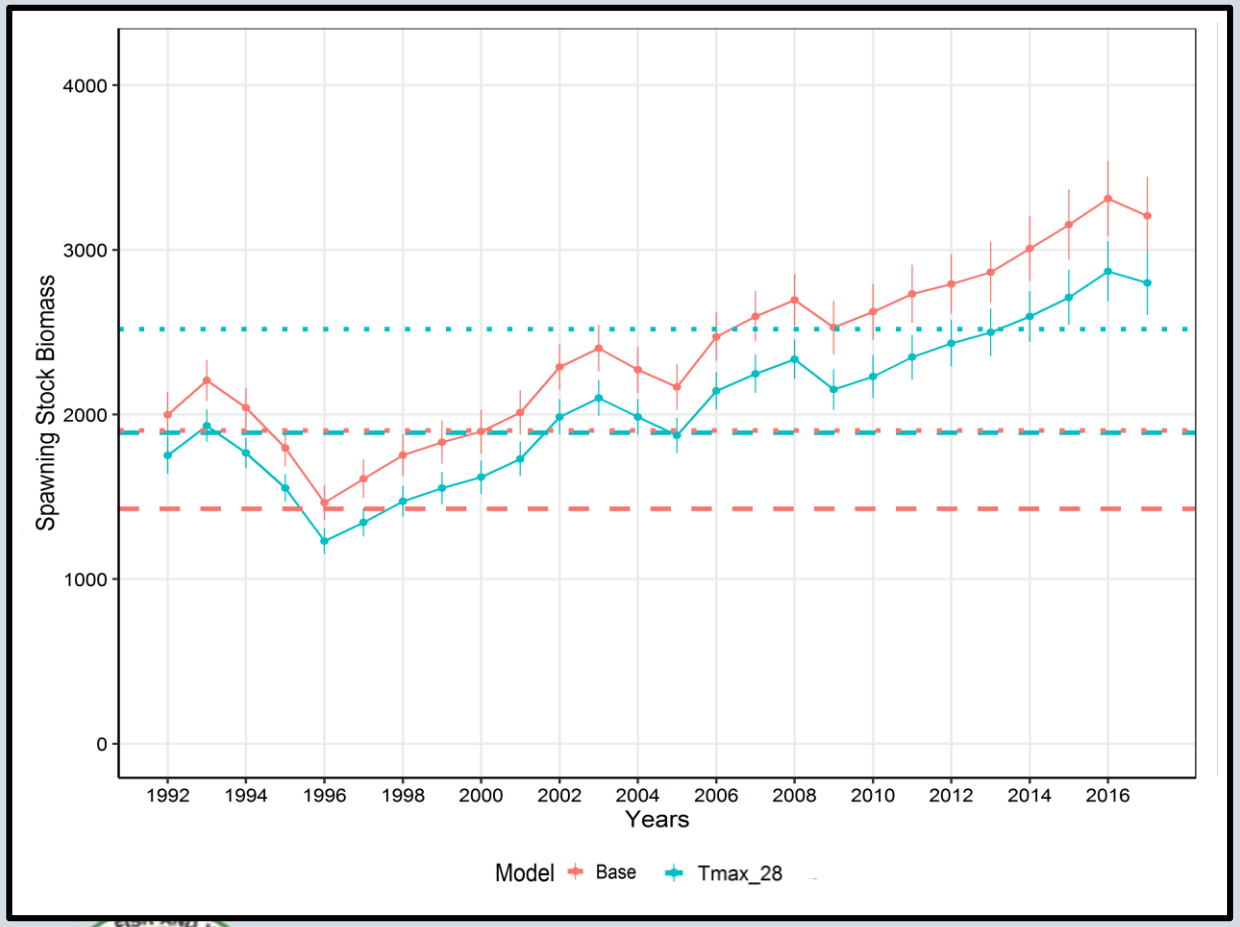


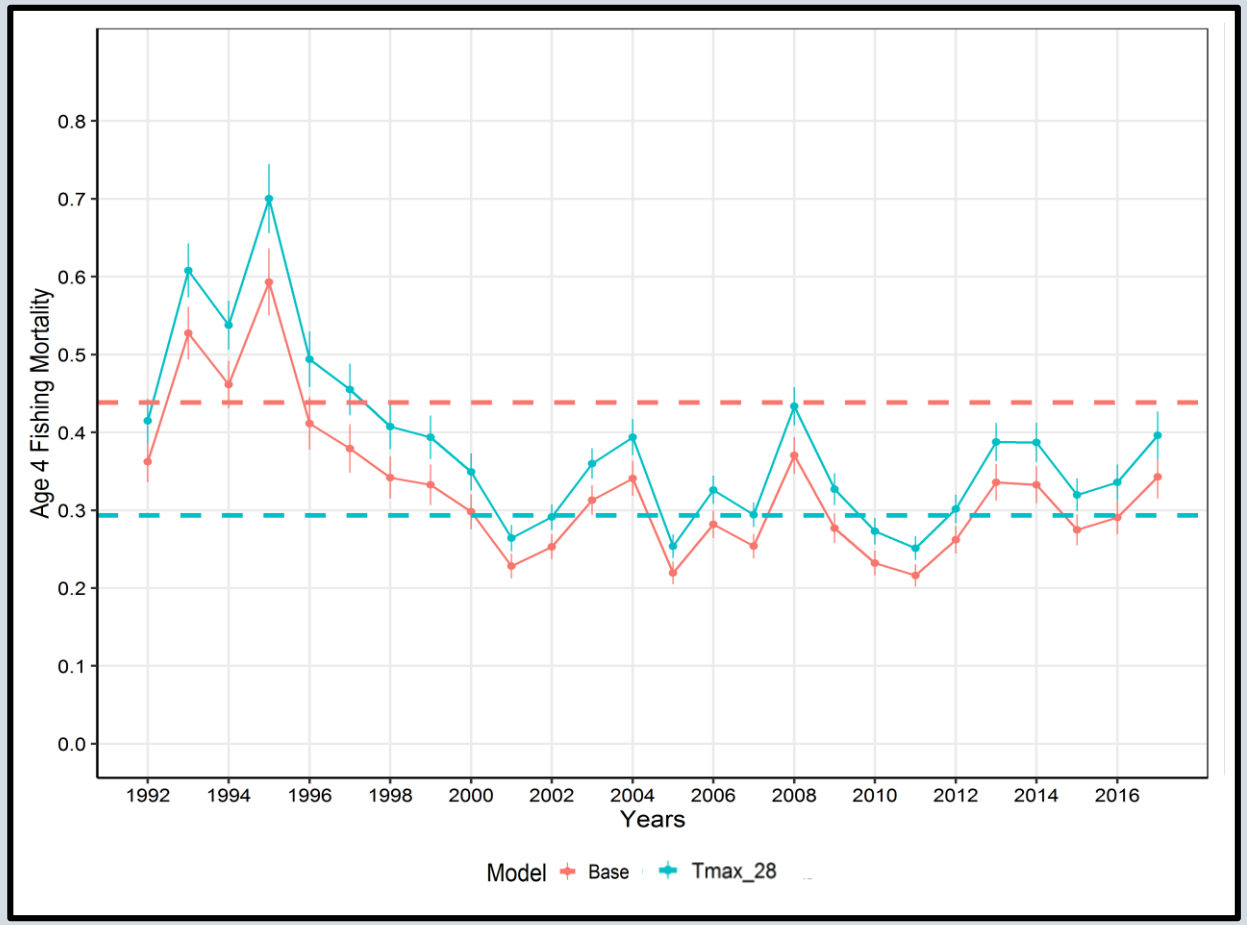
Sensitivity Run: Removing Francis Weights on Composition Data

Log-Likelihood Components	Base	No Weights
Commercial CPUE	-30.2	-28.7
RVC Adult Index	-4.2	-2.4
RVC Juvenile Index	-6.5	-5.9
MRIP CPUE	-22.9	-27.6
Commercial Discards	130.7	130.4
Headboat Discards	-8.9	-9.2
MRIP Discards	18.9	55.4

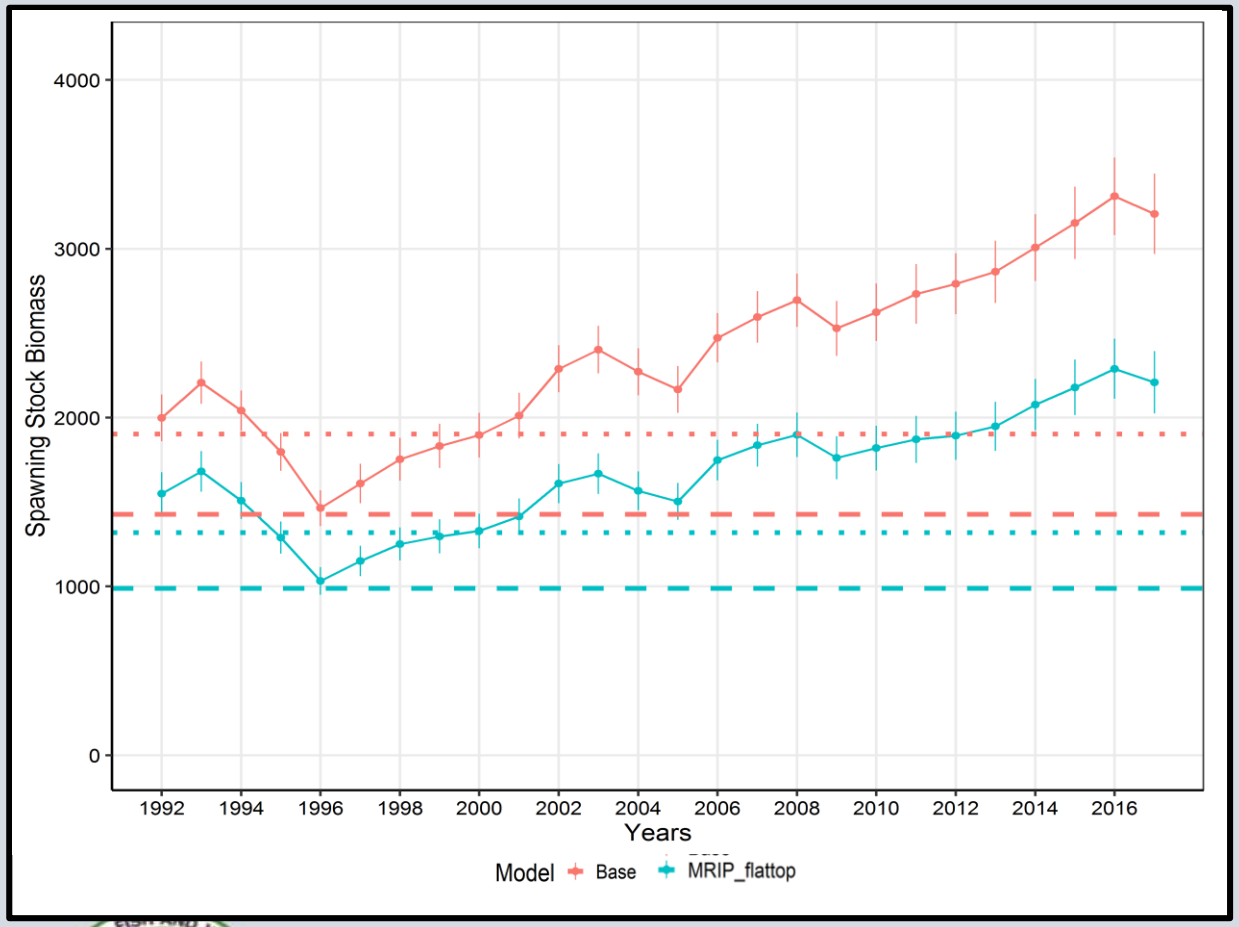


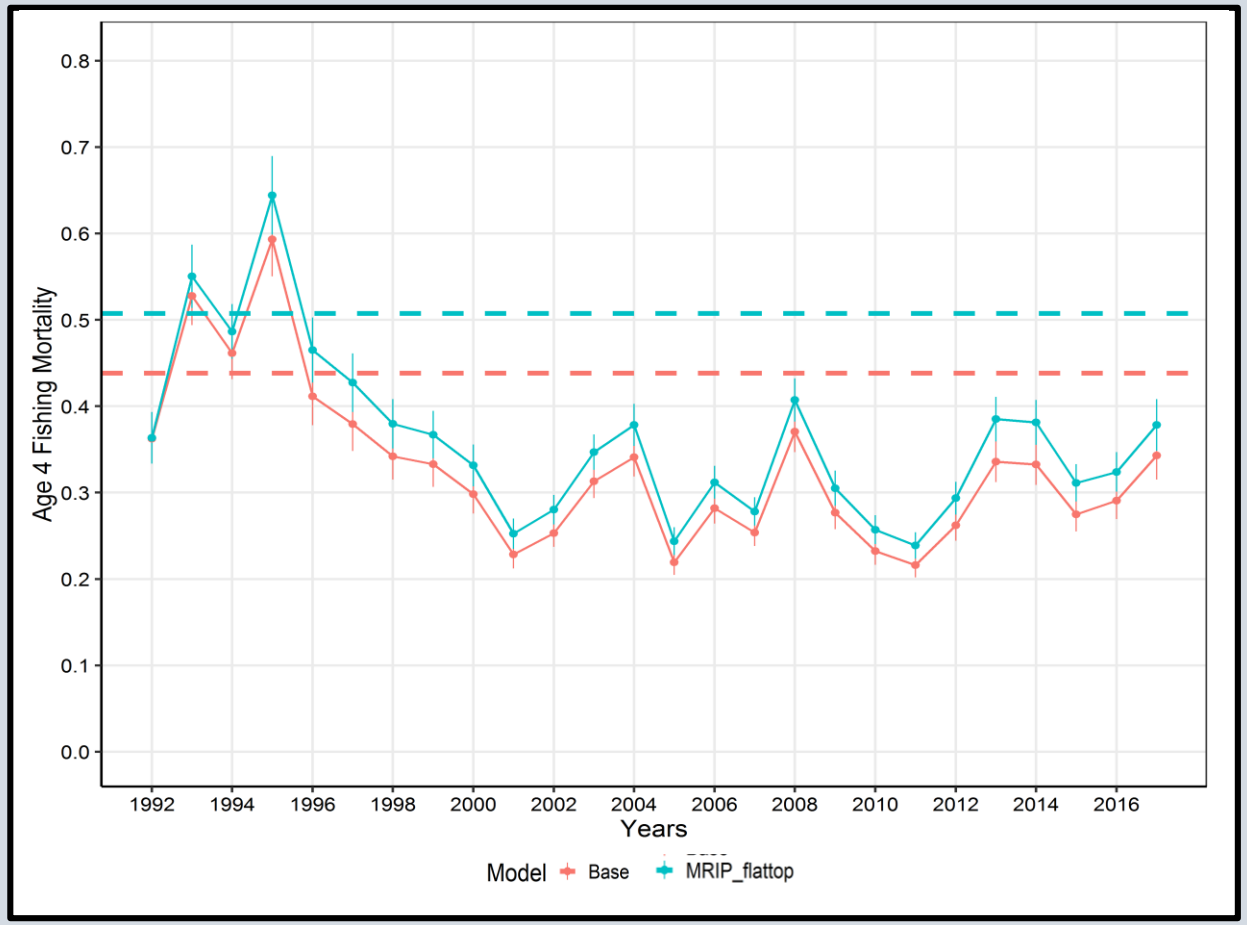
Sensitivity Run: Lowered Natural Mortality by Increasing Tmax to 28



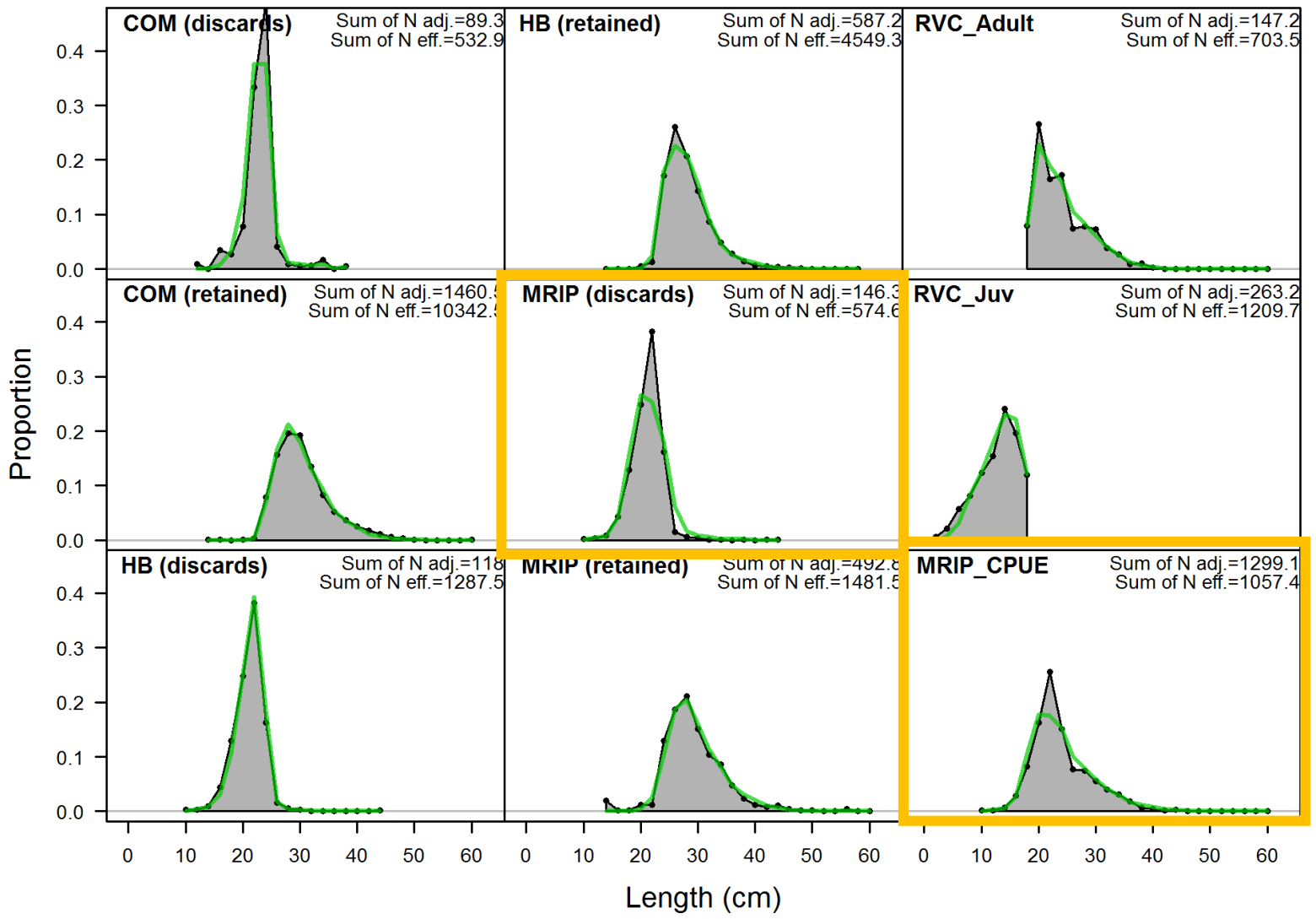


Sensitivity Run: MRIP selectivity changed to logistic (flat top)

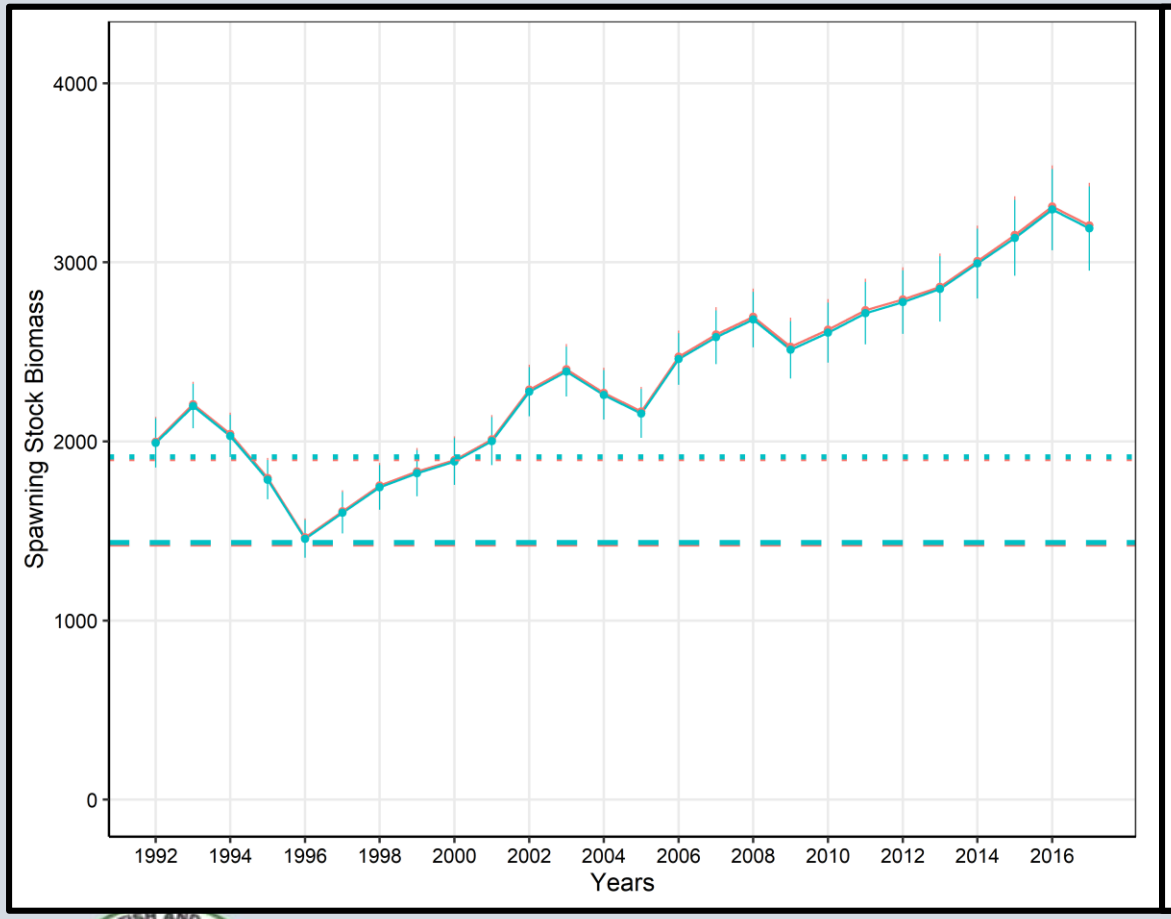


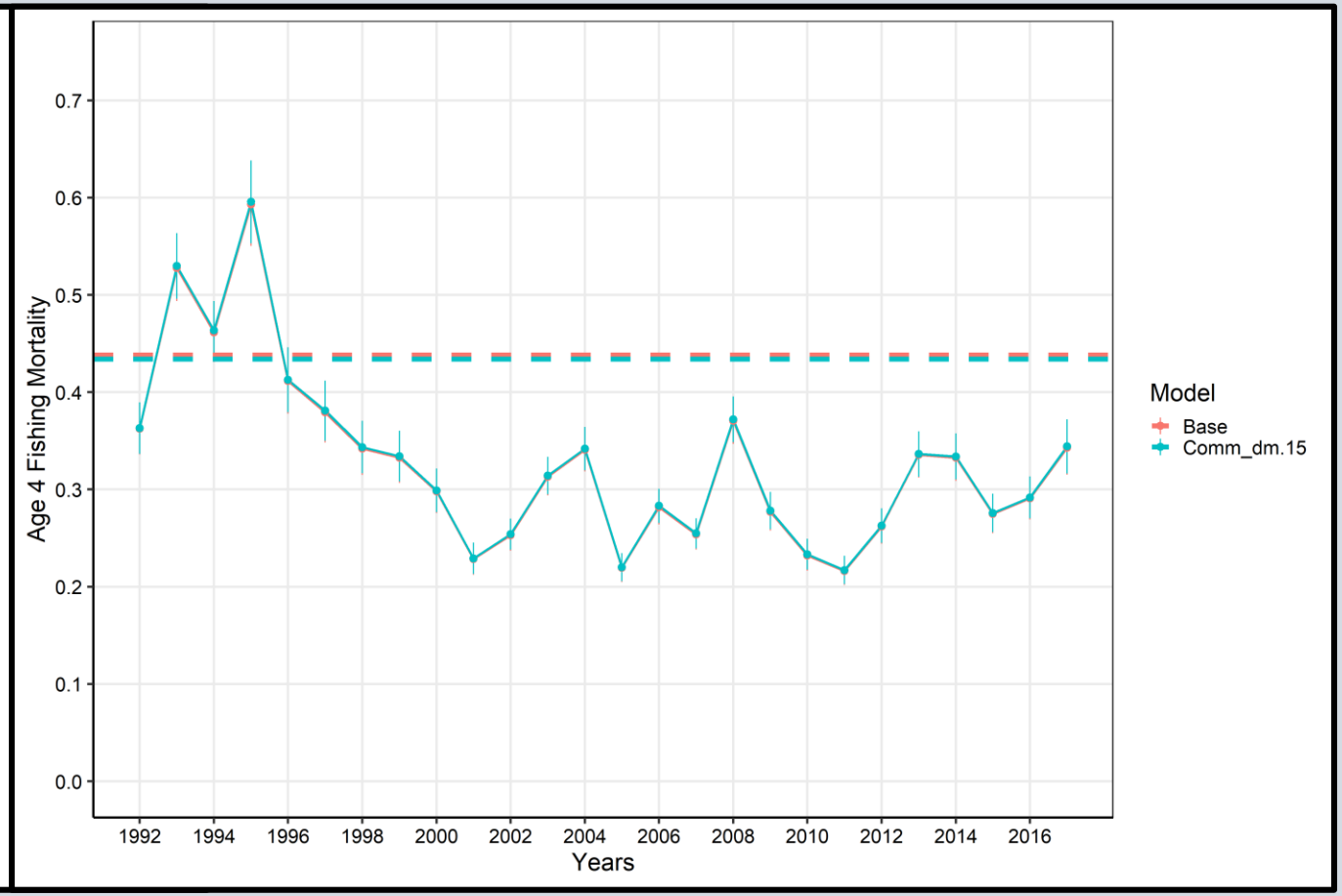


MRIP Flat top Fits: Overall length compositions per fleet

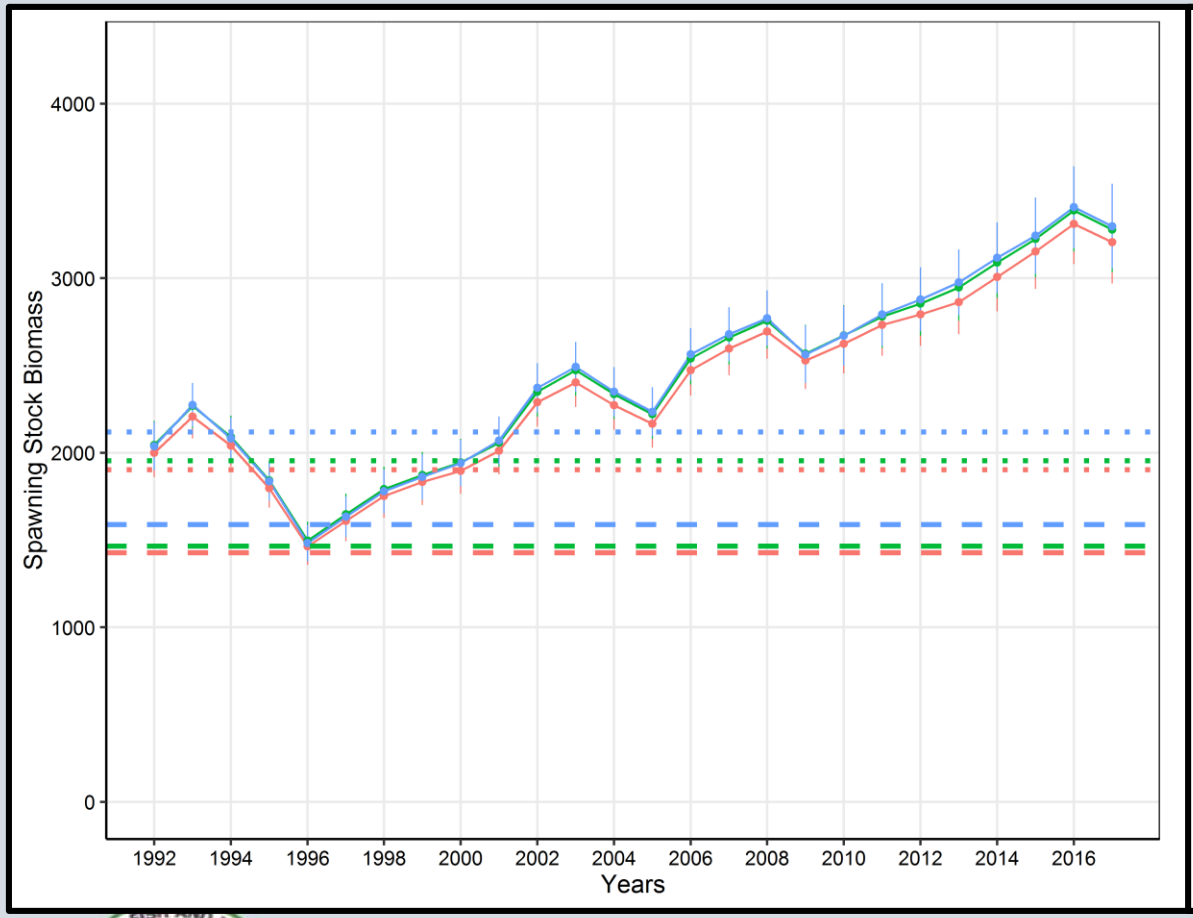


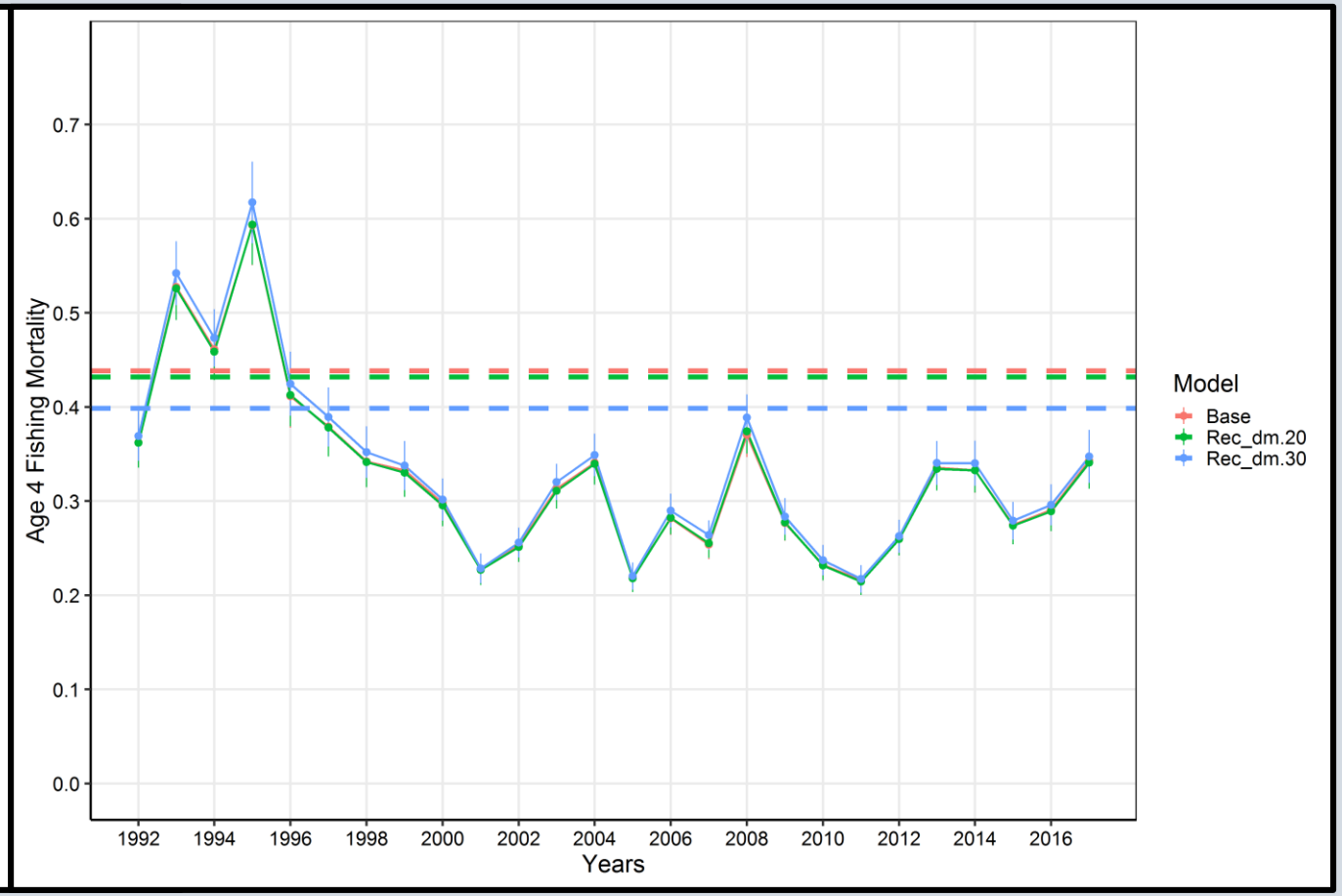
Sensitivity Run: 15% Commercial Discard Mortality





Sensitivity Run: 20% and 30% MRIP Discard Mortality





SEDAR 64: Yellowtail Snapper

Retrospective Analysis

Shanae D. Allen and Christopher E. Swanson

FWRI Stock Assessment Group, St. Petersburg, FL

Joint SSC Meeting, Tampa, FL: July 21 – 23, 2020

Retrospective Analysis (7-yr peel):

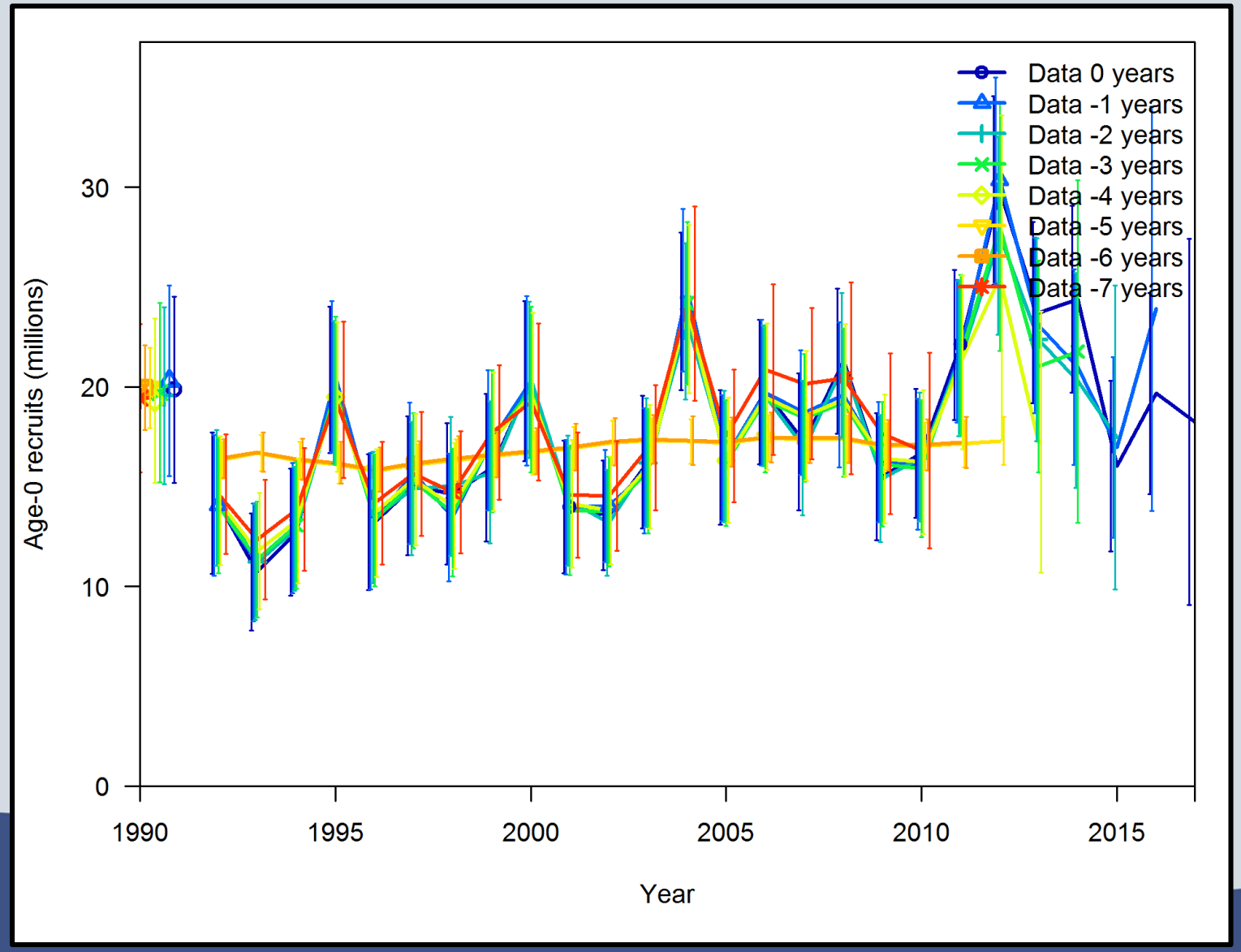
Parameter	AFSC Mohn's Rho (Hurtado et al. 2015)
SSB	-0.04
Recruitment	-0.10
Age-4 F	0.06

Retrospective Analysis

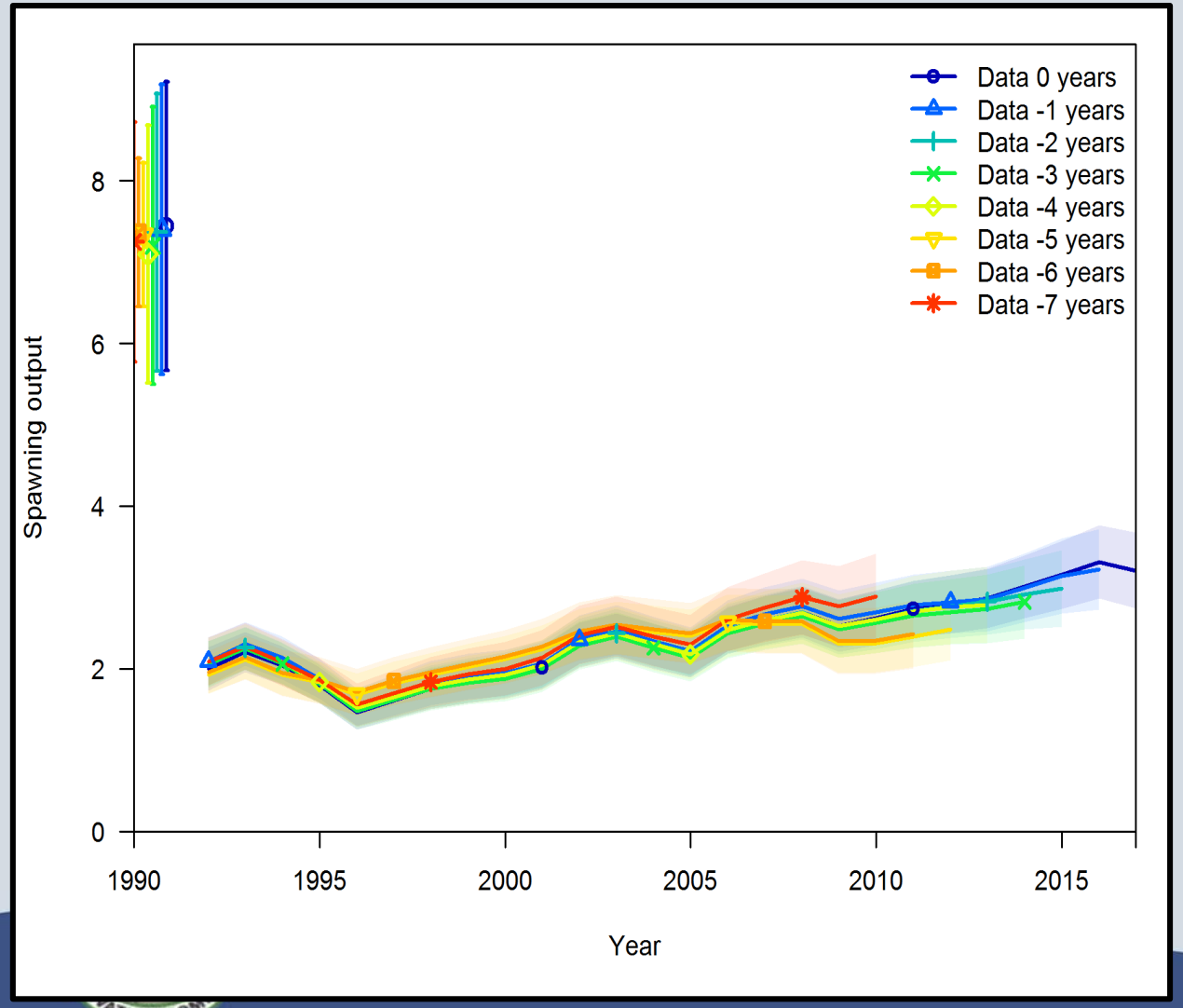
- Seven-year peel
- Helps evaluate the effect of the final year on model results
- Patterns can indicate model misspecification or temporal dynamics
- Evaluated visually and quantitatively
  - Mohn's Rho
  - Hurtado et al (2015) "Rule of thumb"
    - - 0.15 – 0.20 for longer-lived species

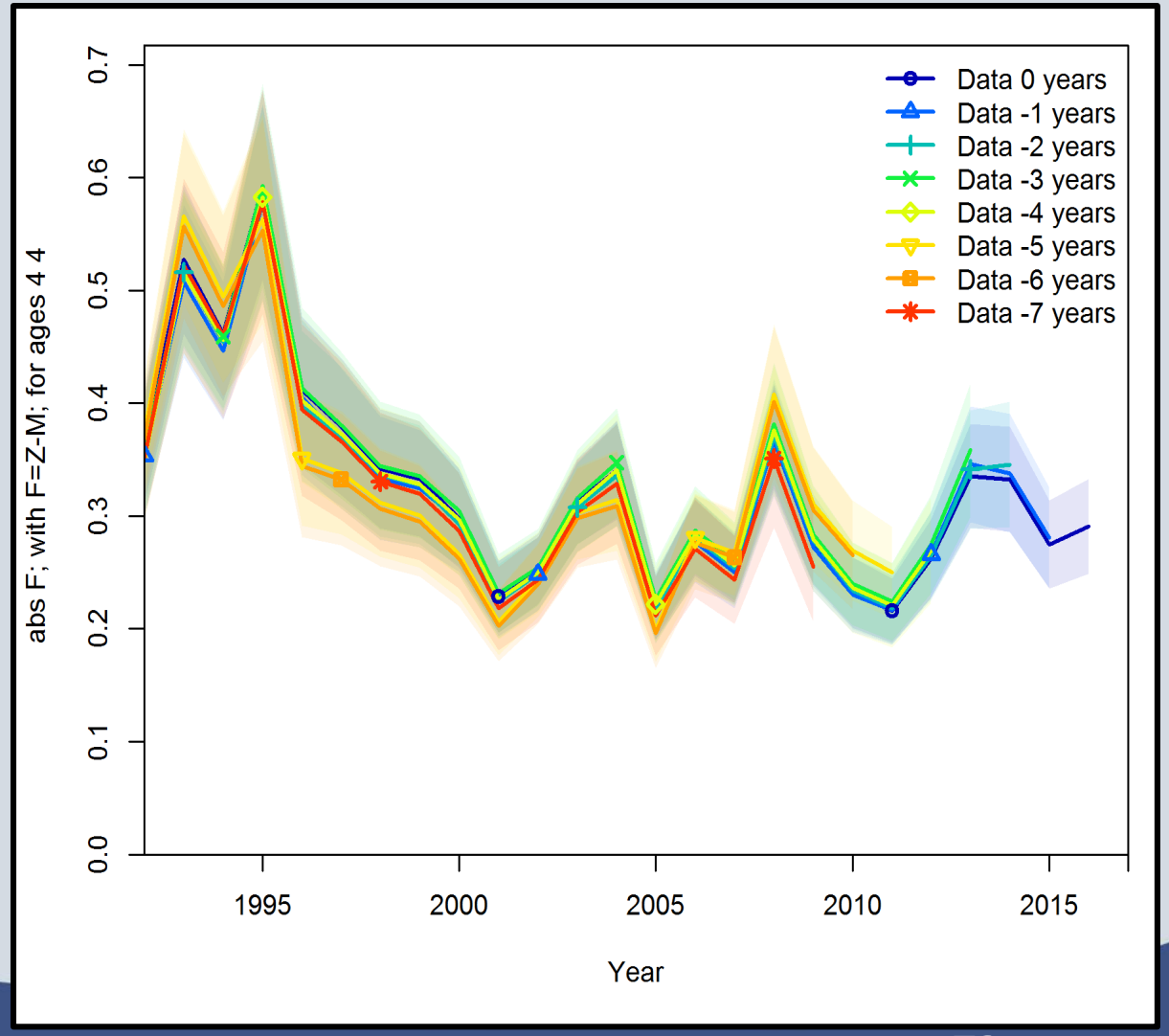
Peel	Gradient	Number of parameters near bounds
Base	<0.0001	0
- 1 yr	<0.0001	0
- 2 yrs	<0.0001	0
- 3 yrs	**0.0003**	0
- 4 yrs	**0.0002**	0
- 5 yrs	<0.0001	0
- 6 yrs	<0.0001	**1**
- 7 yrs	<0.0001	**1**

Retrospective Analysis (7-yr peel):



Retrospective Analysis (7-yr peel):





Additional Analyses of Convergence and Uncertainty

- Parametric Bootstrap
  - Sensitive to effective sample sizes which must be integer
  - Many runs did not converge
- Profiling on R0, sigmaR, steepness, and initial Fs
  - Suggested little model sensitivity to these quantities
  - Likelihood is flat for steepness > 0.65
- Jitter Analysis (varied starting points by 20%)
  - Suggested the model converged to a global solution rather than a local minima
- Jack-knife Analysis on Indices of Abundance
  - All indices had similar influence on trends in fishing mortality rates and SSB
  - Removing MRIP index lowered fishing mortality rates and increased SSB

SEDAR 64:Yellowtail Snapper

Projections

Shanae D. Allen and Christopher E. Swanson

FWRI Stock Assessment Group, St. Petersburg, FL

Joint SSC Meeting, Tampa, FL: July 21 – 23, 2020

Projections:

Methodology

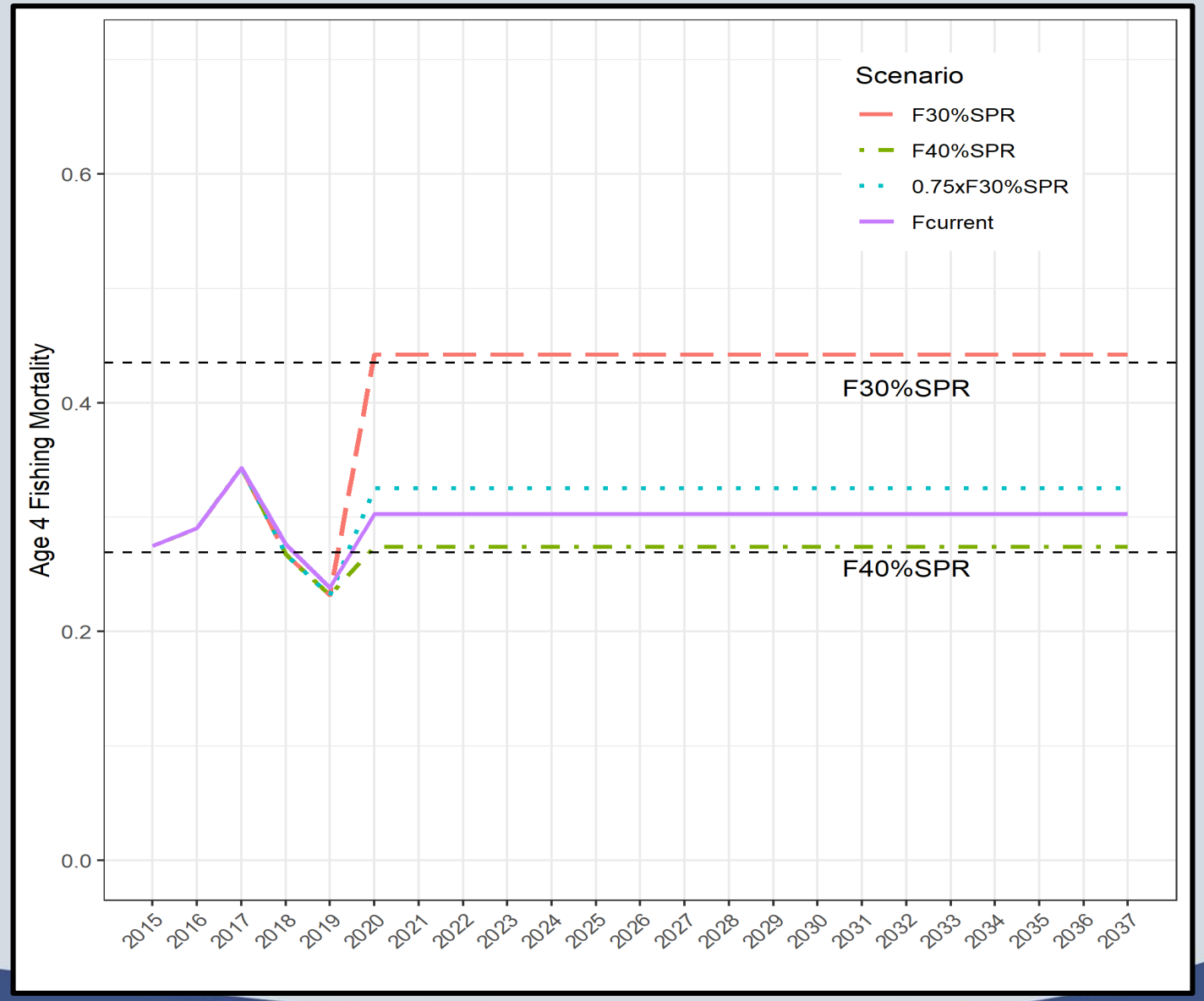
- Deterministic projections were run to estimate sustainable landings for years 2020-2037, retained landings in metric tons were inputted for interim years 2018 and 2019
- Structure and parameters of the projection model same as assessment model
- Recruitment for first year of projection equal to 2015 – 2017 average (~18 million)
- Fishing rates that define the projections were assumed to start in 2020.

Projections:

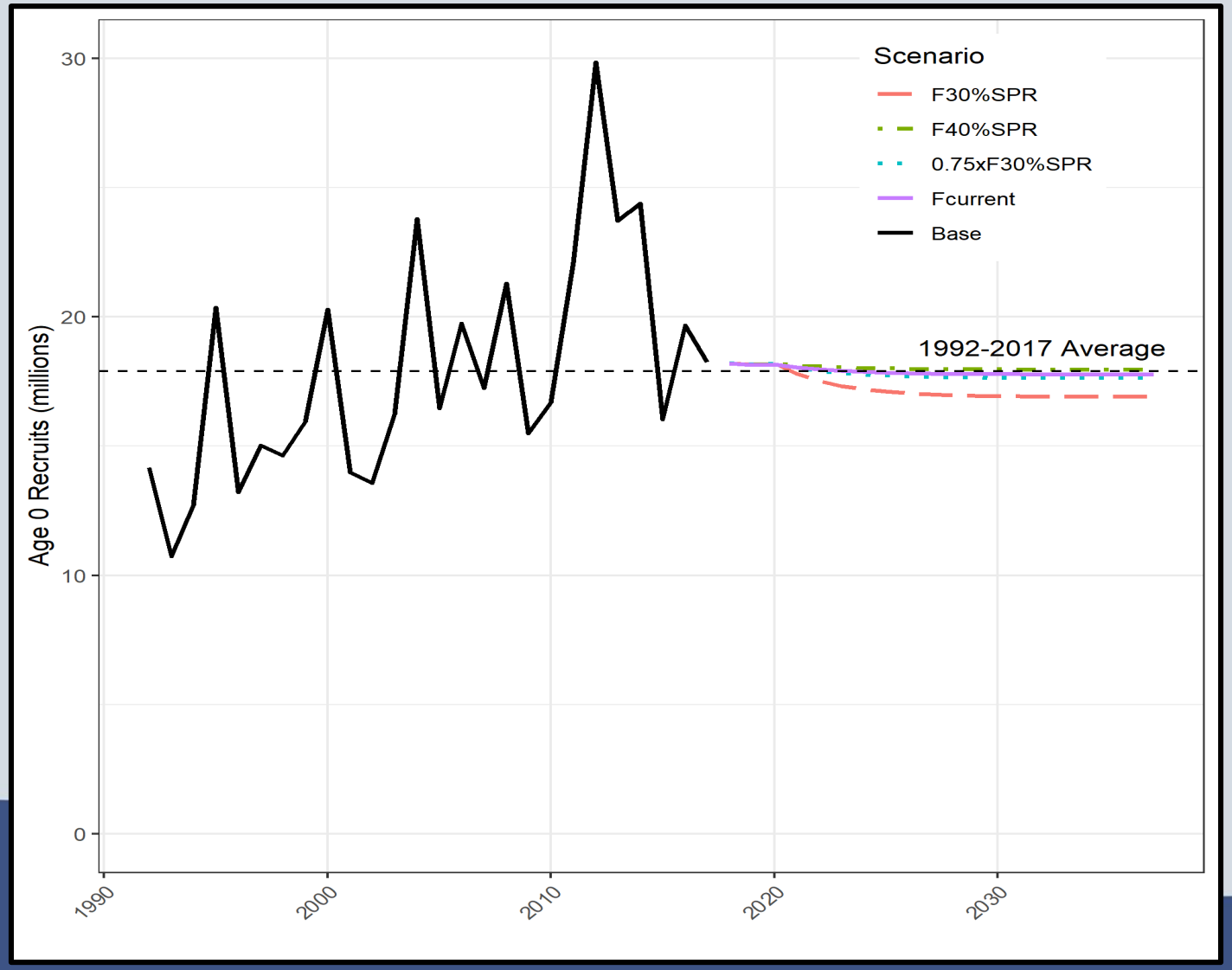
Projection Scenarios

1. $F = F_{Current}$ (geometric mean of last 3 years)
2. $F = F_{MSY} = F_{30\%SPR}$
3. $F = 75\%$ of FMSY

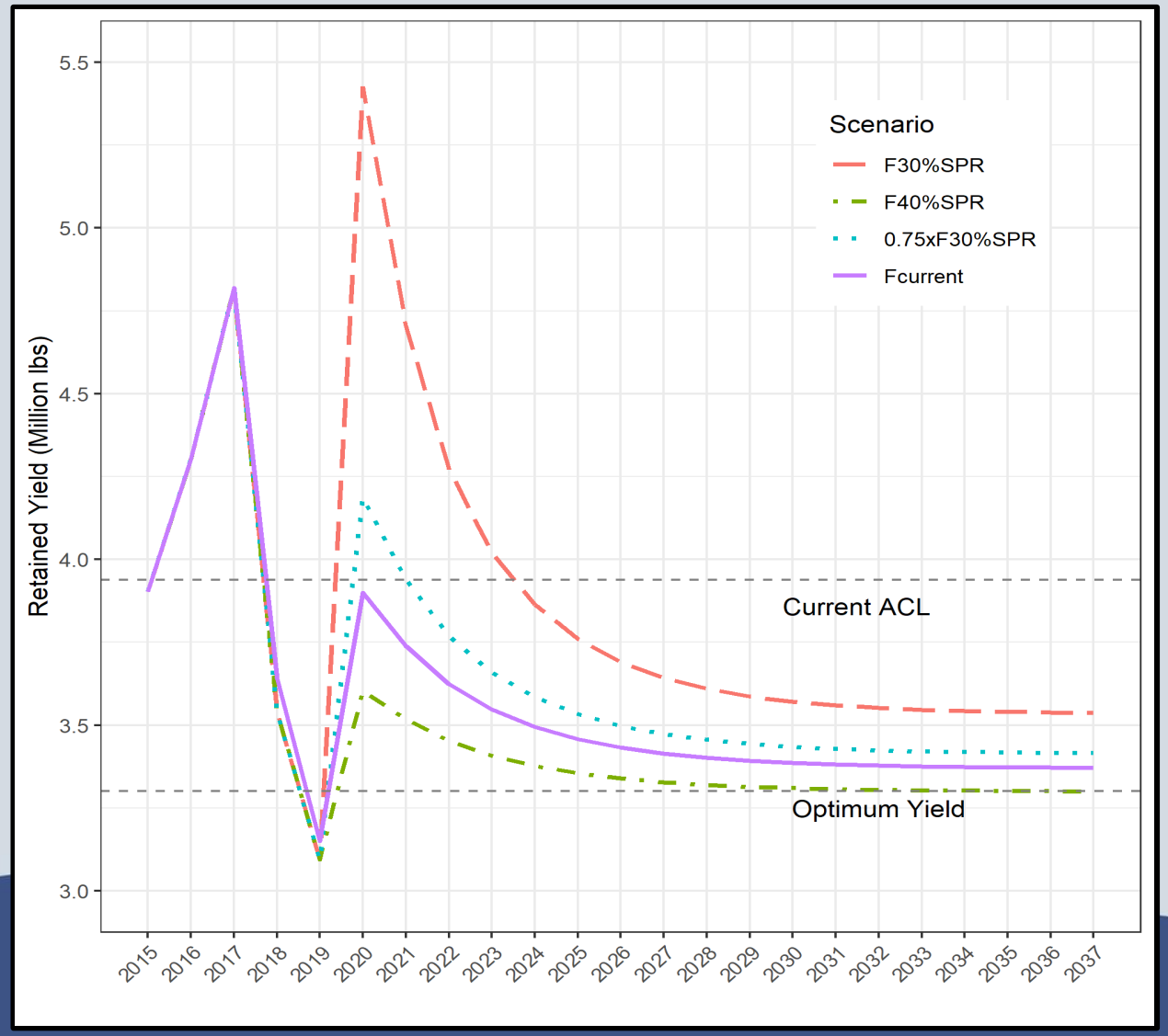
4* $F = F_{OY} = F_{40\%SPR}$

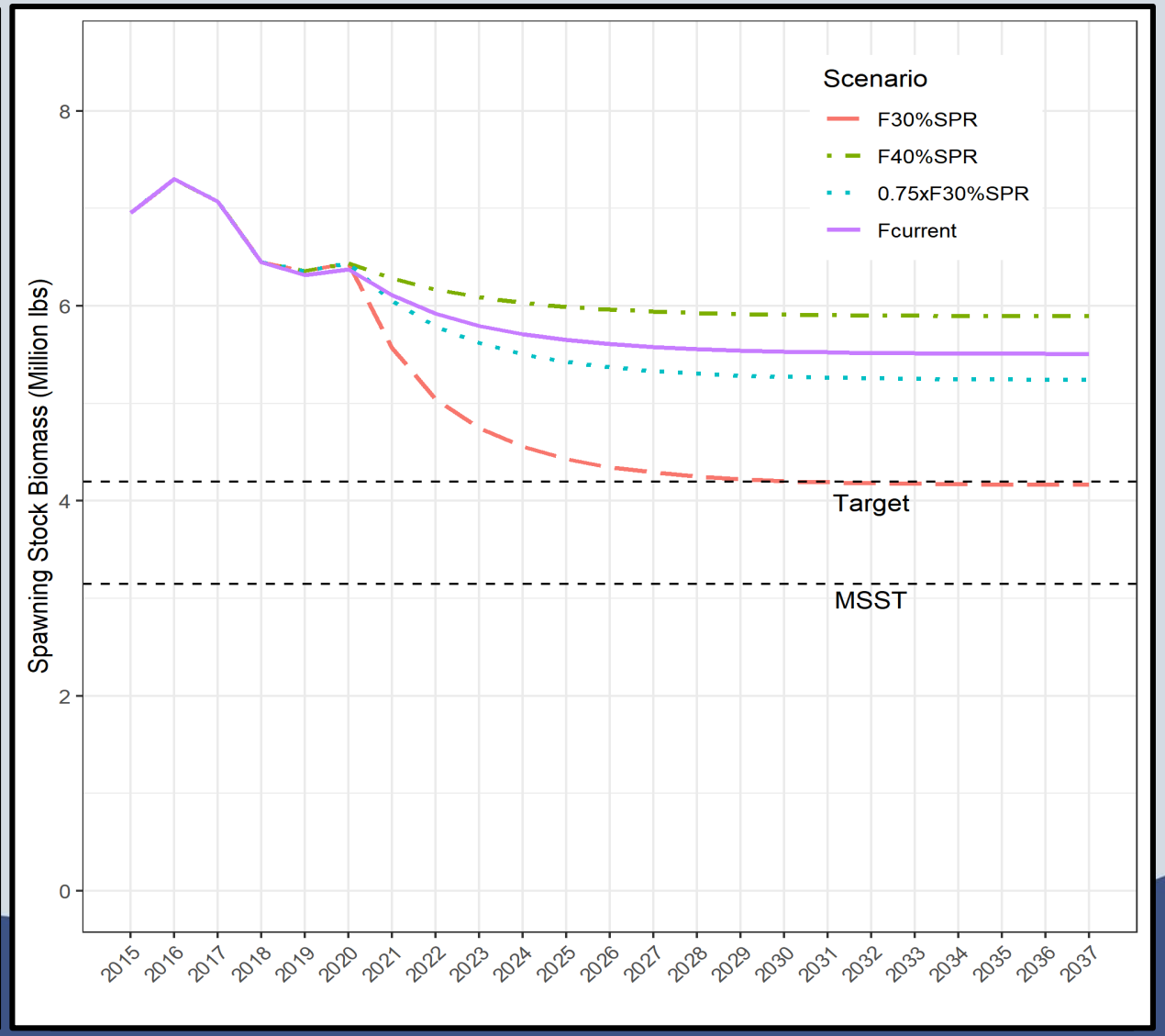


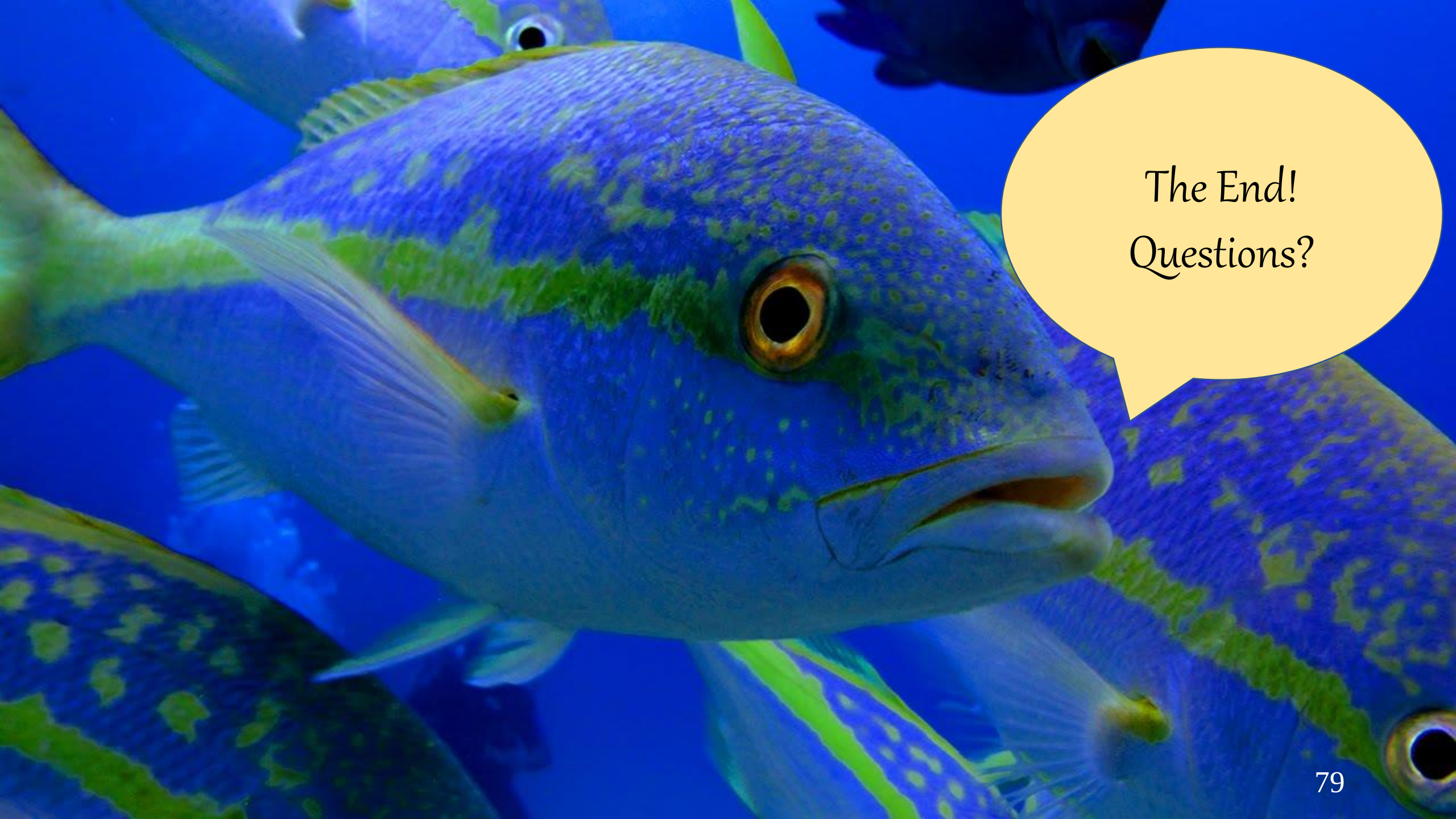
20 Year Projections: Recruitment



20 Year Projections:






The End!
Questions?

Yellowtail Snapper Natural Mortality

Beverton-Holt life history invariants

- M/k ratio (Jensen 1996)
  - $M = 1.5k$ → $M = 1.5(0.207)$ → $M = 0.311\ yr^{-1}$
- Yellowtail Snapper $M/k = 1.076$
  - Hordyk et al. (2015) describes M/k ratios ranging from 0.12 – 3.52 for several species

Charnov et al. (2013)

- $M(a) = k\left(\frac{L\infty}{L(a)}\right)^{1.5}$

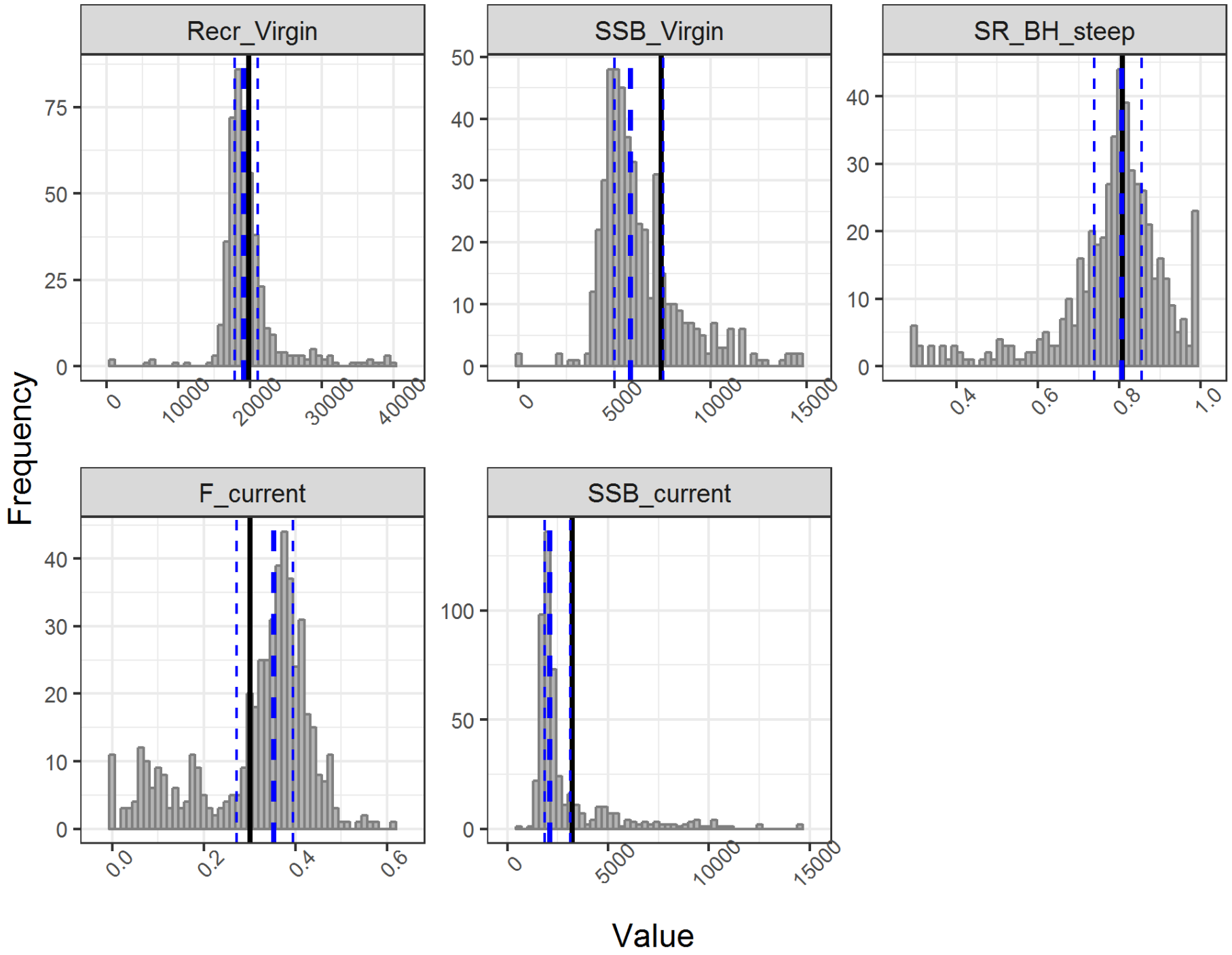
These and other *k*-based methods explored were found unreasonable and estimated high mortality rates at young ages

		M-at-age	Survival proportions-at-age		
Age	**Length (cm)**	**Base Model**	**Base Model**	**Jensen (1996)**	**Charnov et al. (2013)**
0	12	0.558	1.000	1.000	1.000
1	18	0.414	0.572	0.446	0.261
2	22	0.343	0.378	0.245	0.122
3	26	0.301	0.269	0.149	0.071
4	29	0.273	0.199	0.097	0.046
5	32	0.255	0.151	0.065	0.032
6	34	0.241	0.117	0.045	0.023
7	35	0.231	0.092	0.032	0.018
8	37	0.224	0.073	0.023	0.013
9	38	0.218	0.058	0.016	0.010
10	38	0.214	0.047	0.012	0.008
11	39	0.210	0.038	0.009	0.006
12	40	0.208	0.031	0.006	0.005
13	40	0.205	0.025	0.005	0.004
14	41	0.204	0.020	0.004	0.003
15	41	0.202	0.017	0.003	0.003
16	41	0.201	0.014	0.002	0.002
17	41	0.200	0.011	0.001	0.002
18	42	0.200	0.009	0.001	0.001
19	42	0.199	0.007	0.001	0.001
20	42	0.198	0.006	0.001	0.001

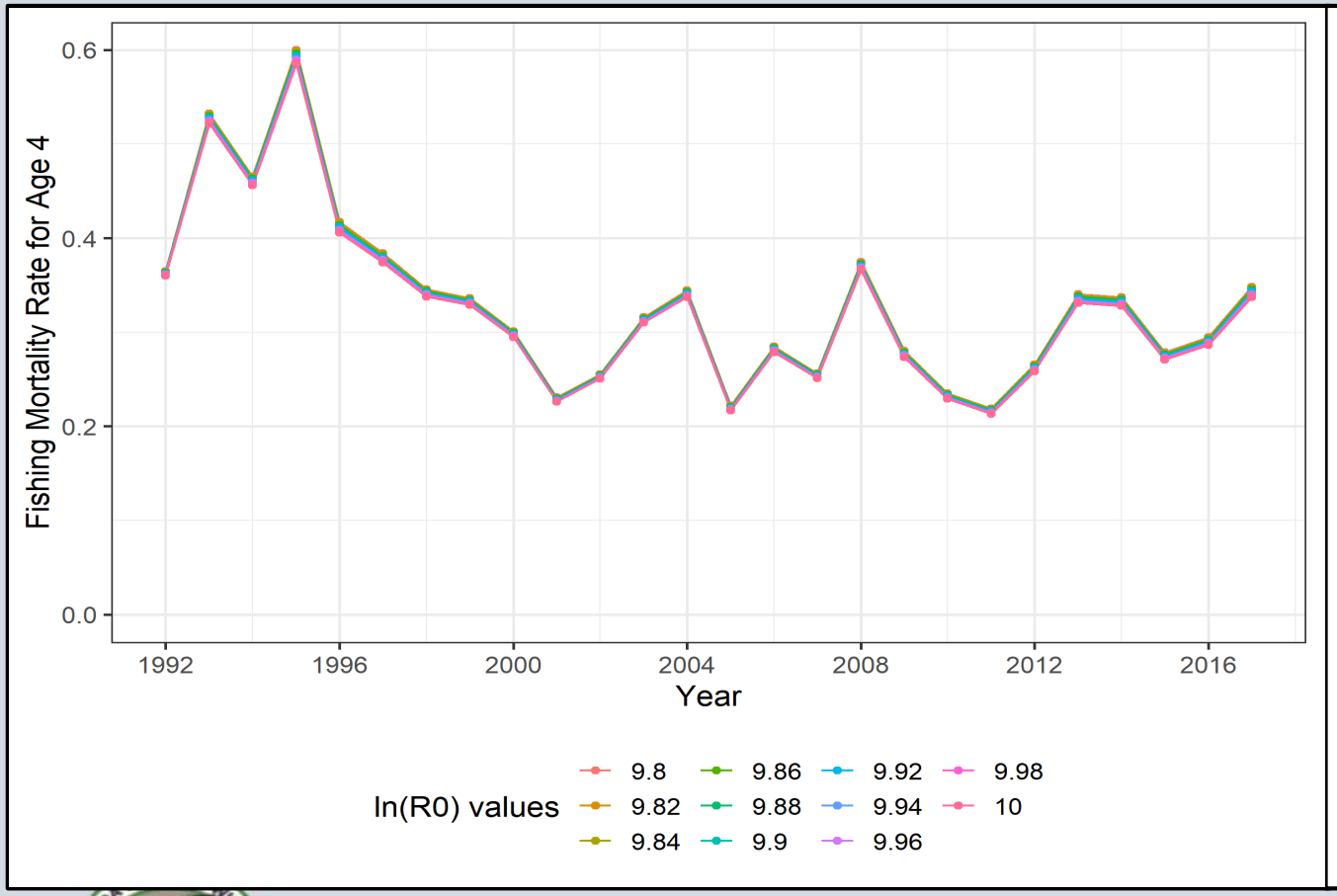
Uncertainty: Parametric Bootstrap

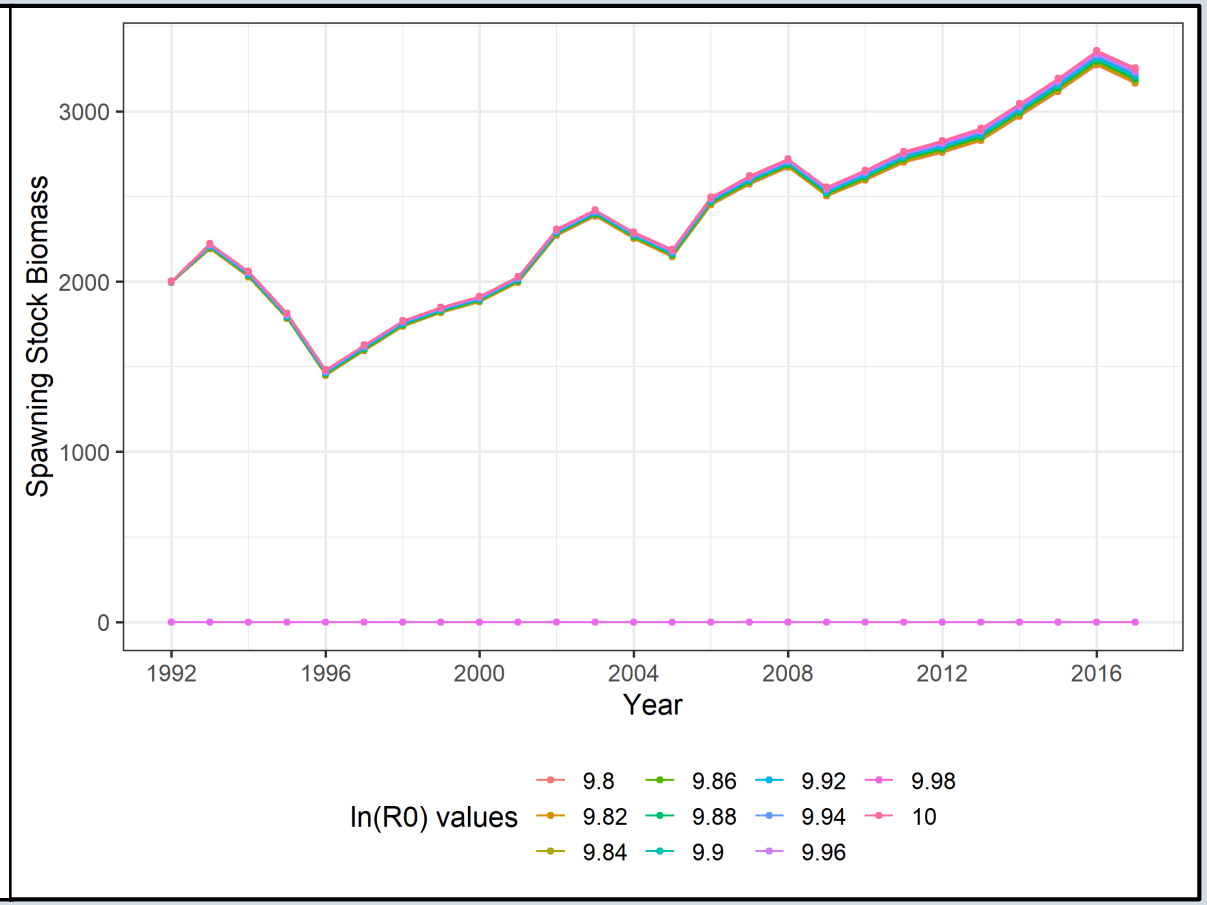
- Resampling method to analyze uncertainty associated with the data
- 500 bootstrapped datasets
  - Error distributions centered on fitted values
- ESS must be integer
  - Multiplied age-at-length ESS by Francis weight, rounded to lowest integer, removed zero bins.

Number of runs	Base LL	Min LL	Max LL	Runs with parameters near bounds	Runs above gradient threshold	Number of failed runs
500	744.4	1773.8	14881.8	445	500	0

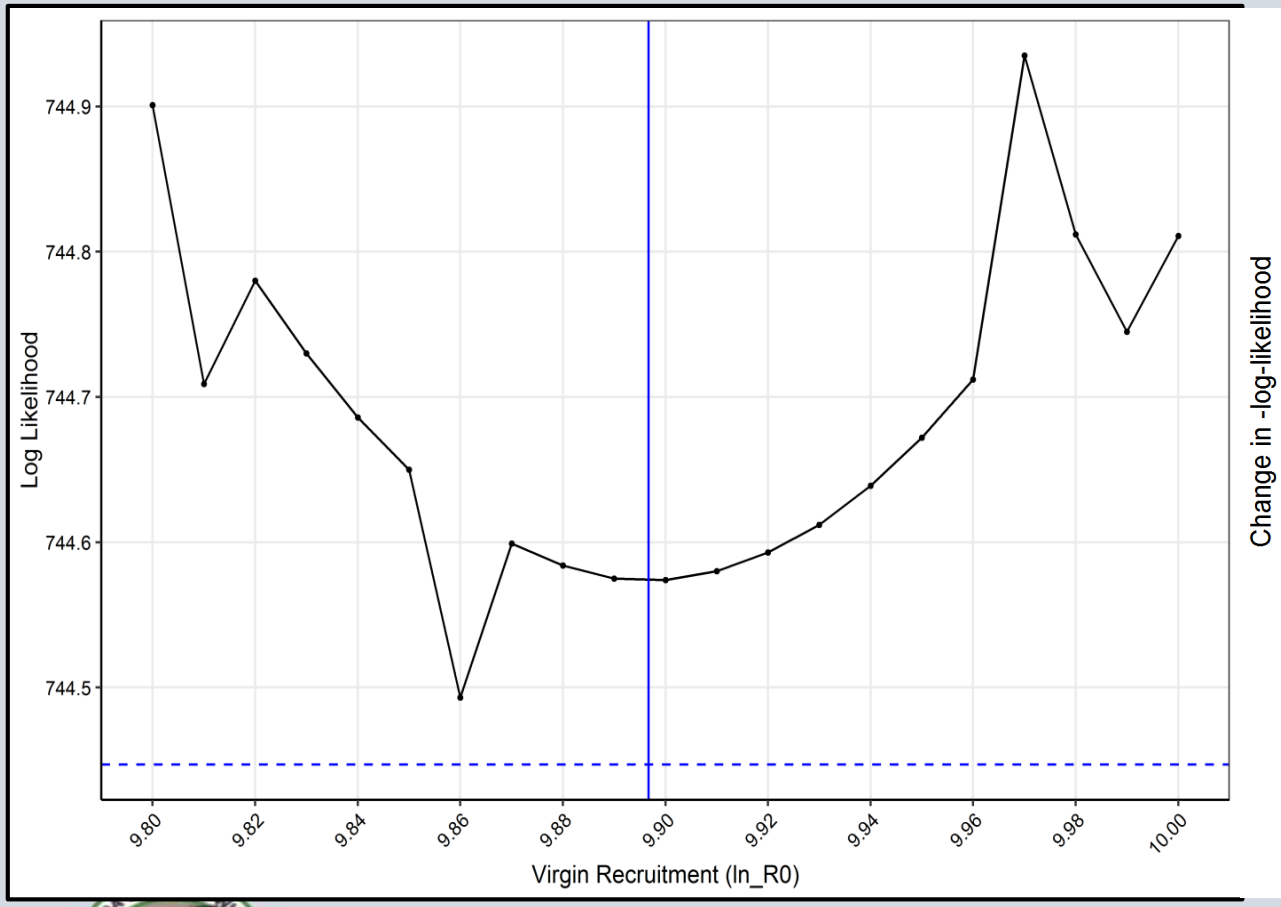

Recr_Virgin
SSB_Virgin
SR_BH_steep
F_current
SSB_current
Frequency
Value
0
25
50
75
10
20
30
40
100
10000
20000
30000
40000
5000
15000
0.4
0.6
0.8
1.0
0.0
0.2

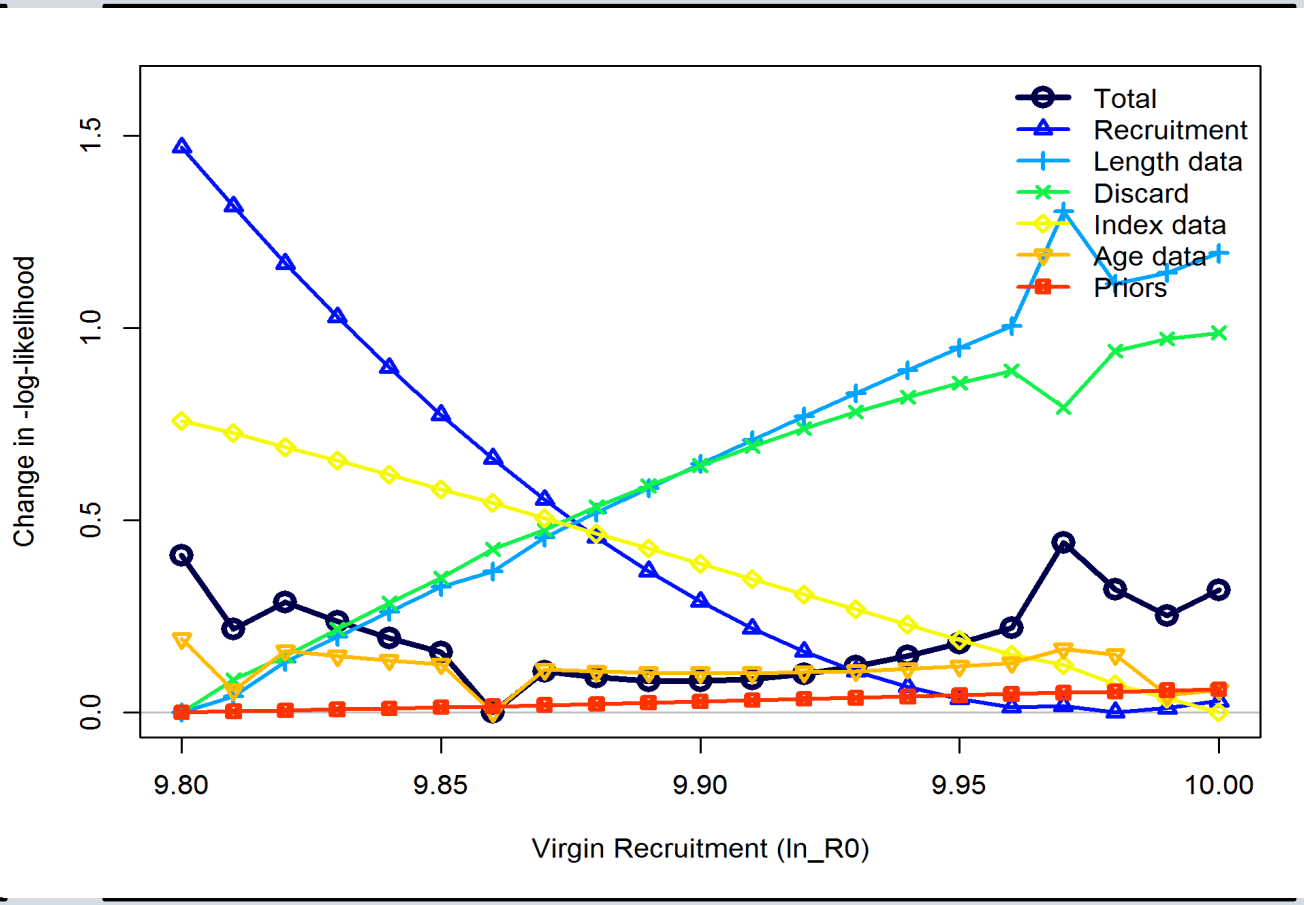
Likelihood Profile – Unfished Recruitment (R0)



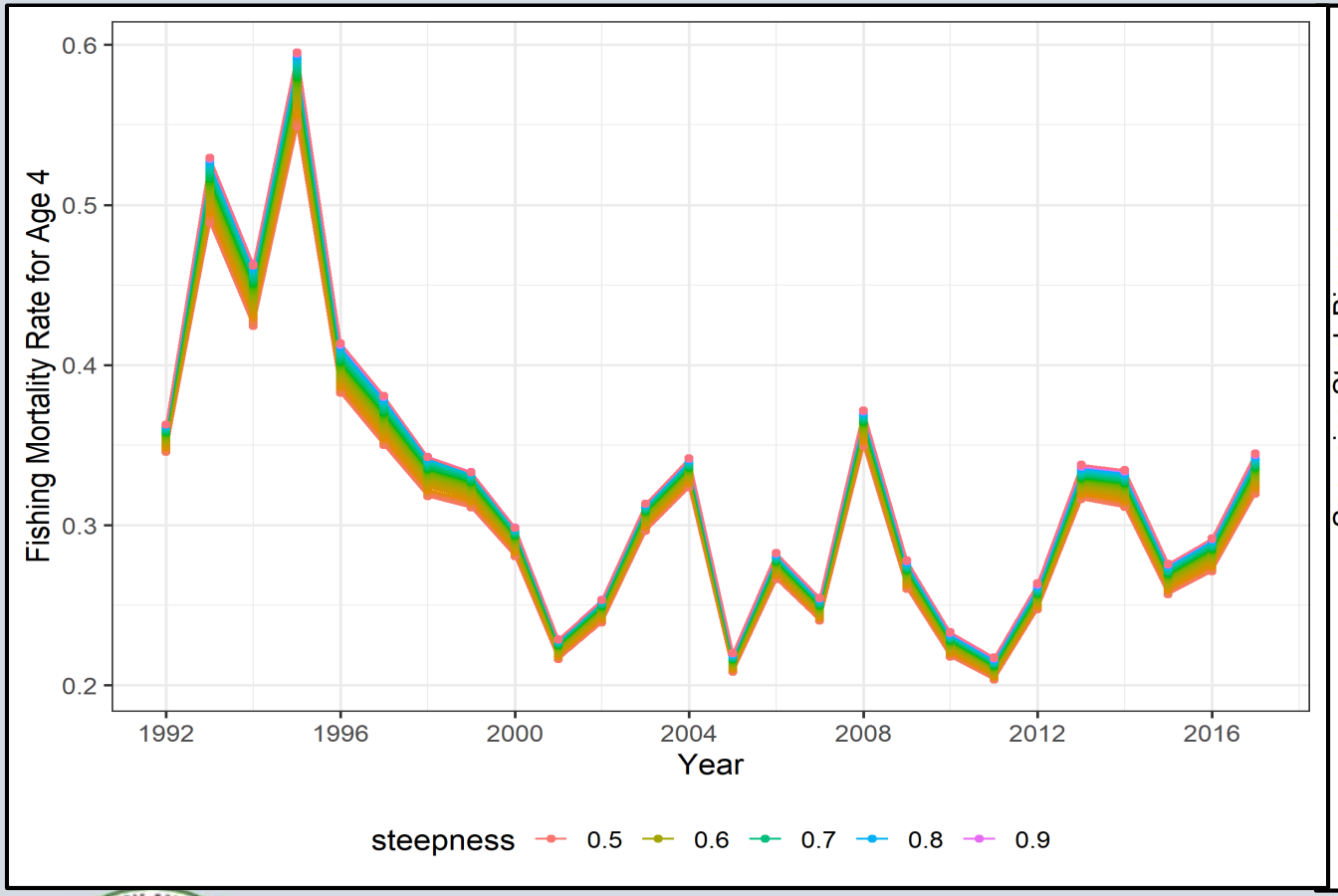


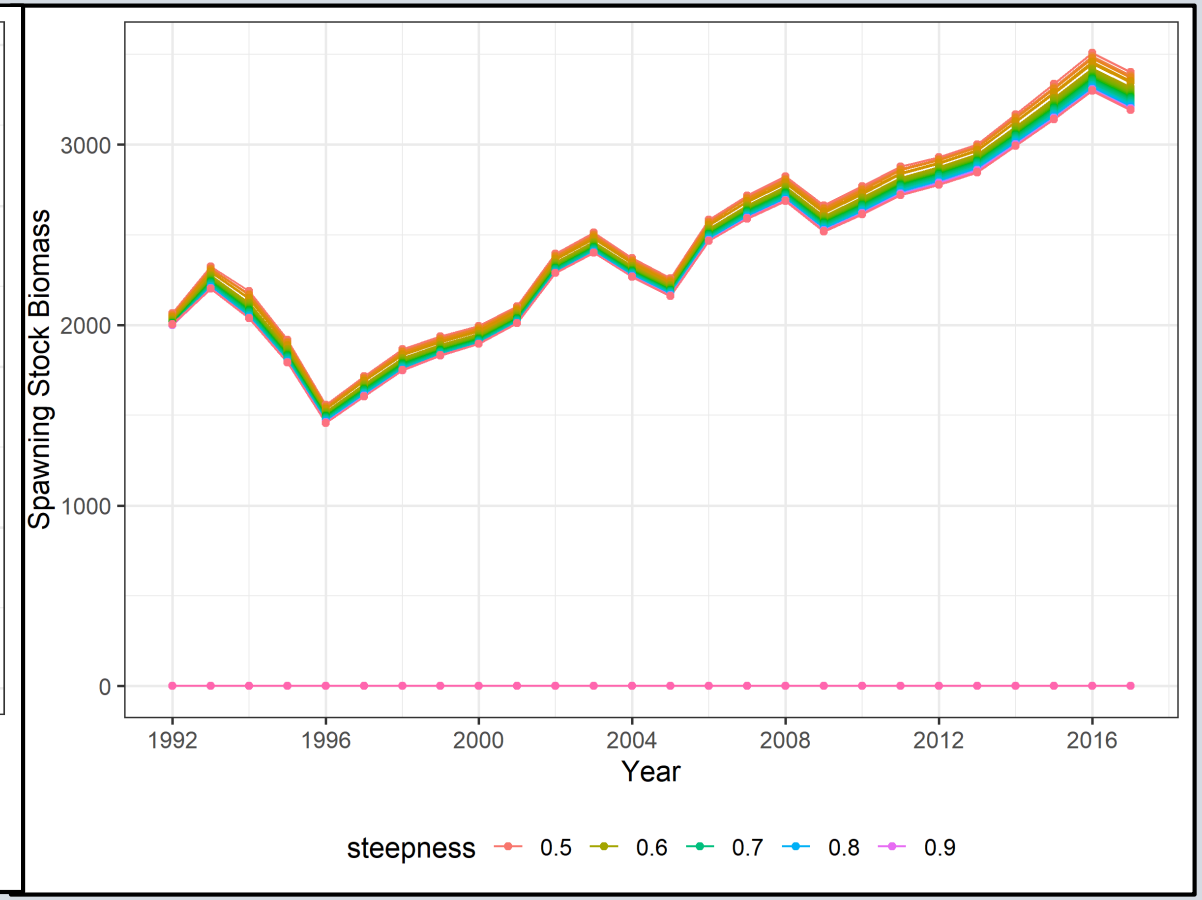
Likelihood Profile – Unfished Recruitment (R0)



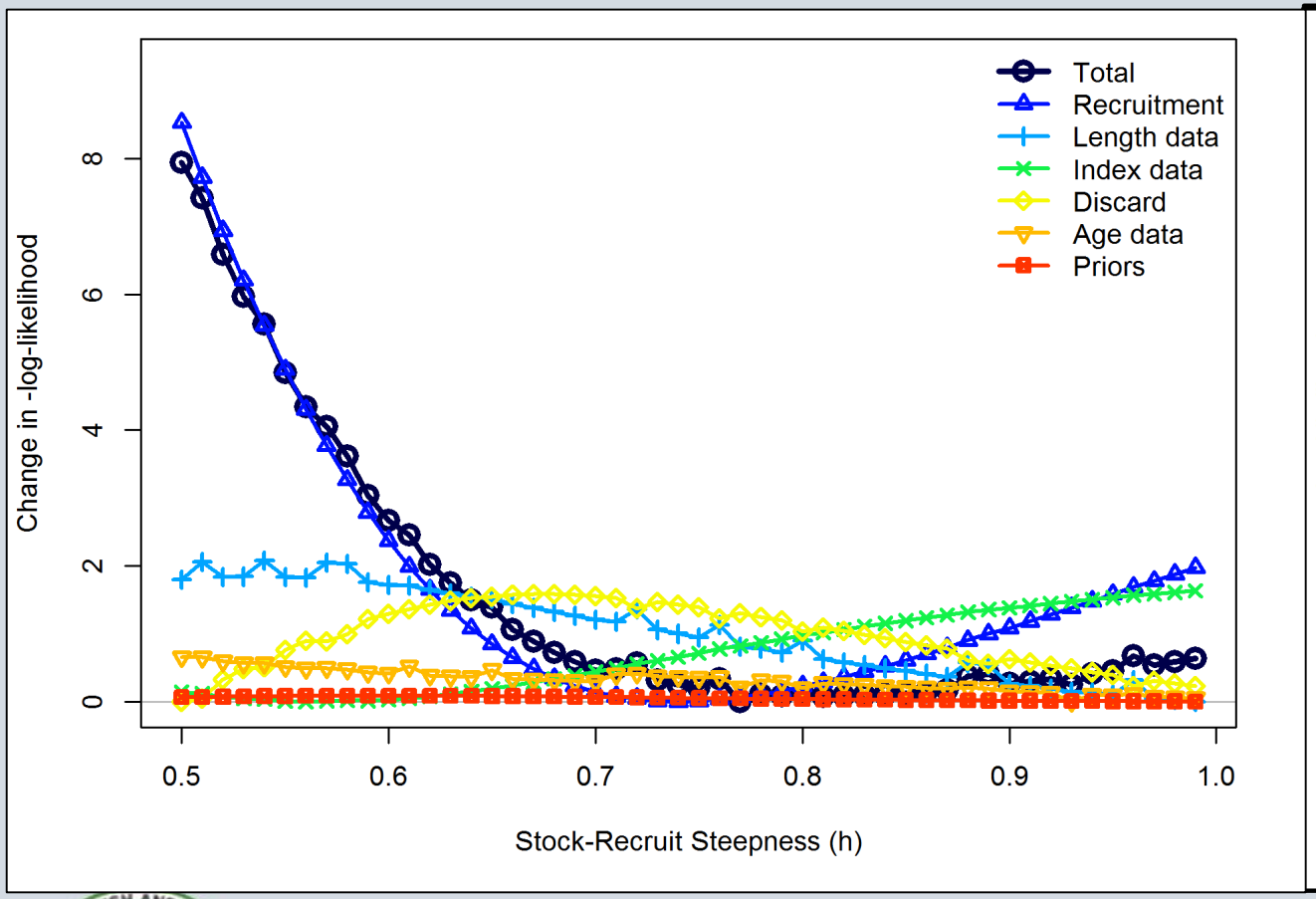


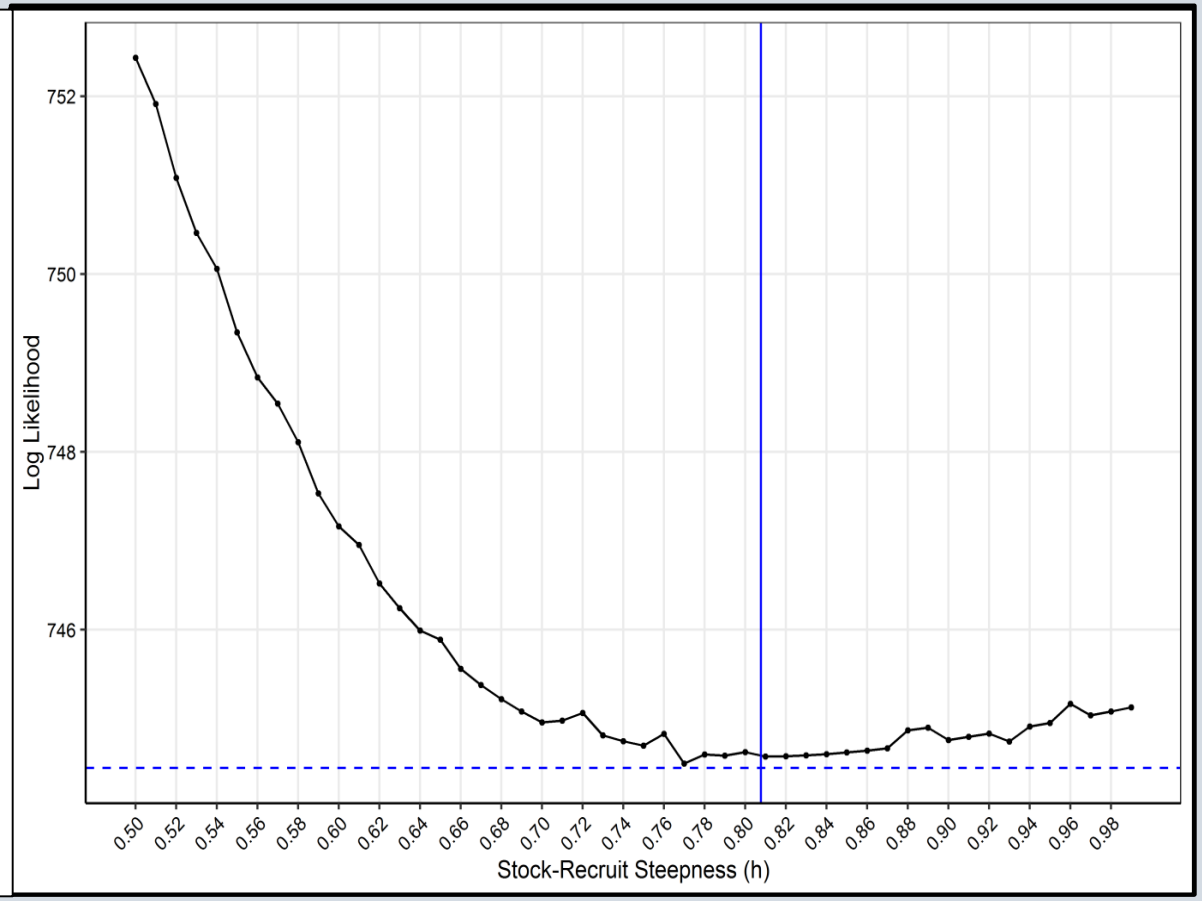
Likelihood Profile - Steepness



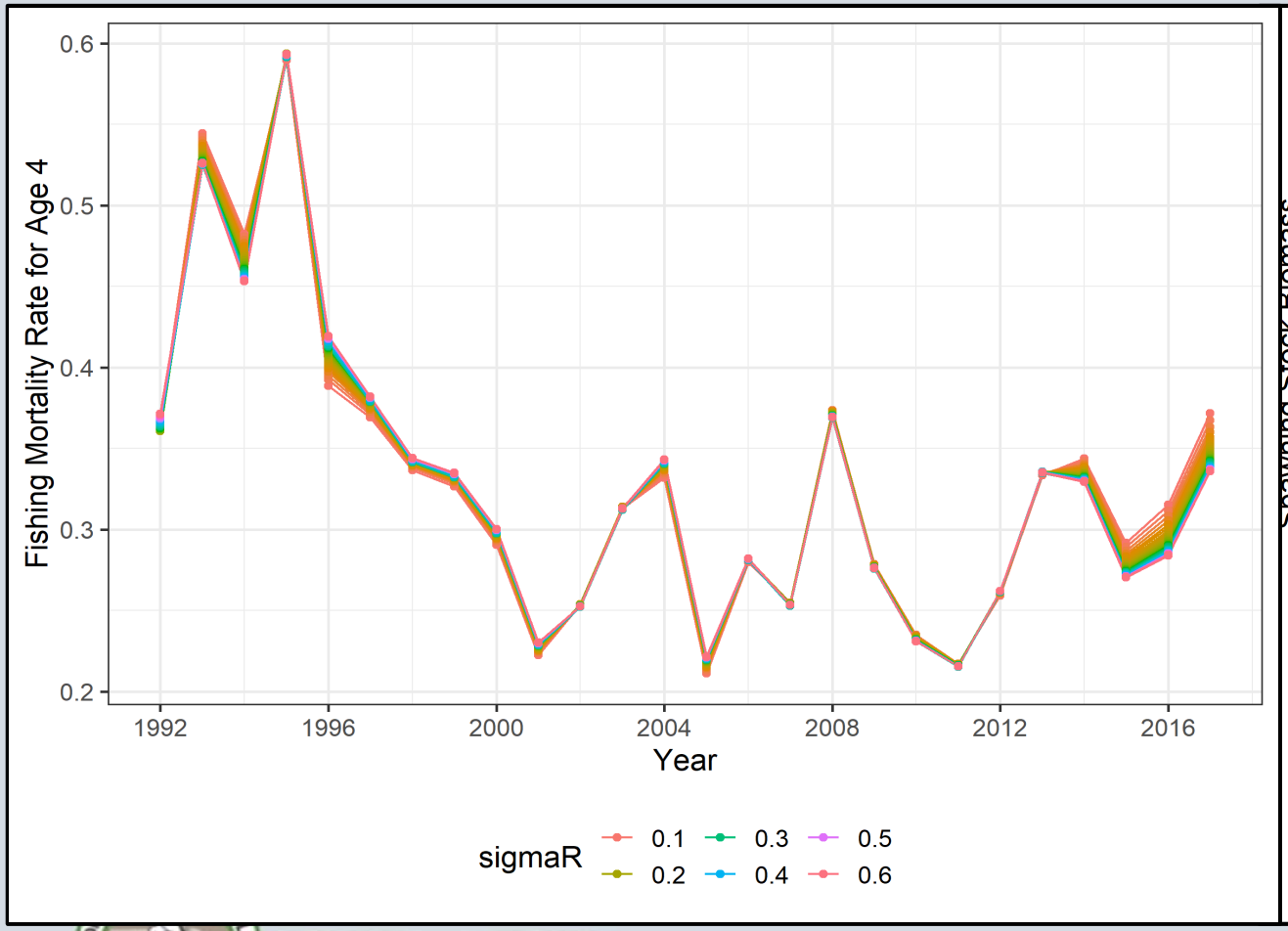


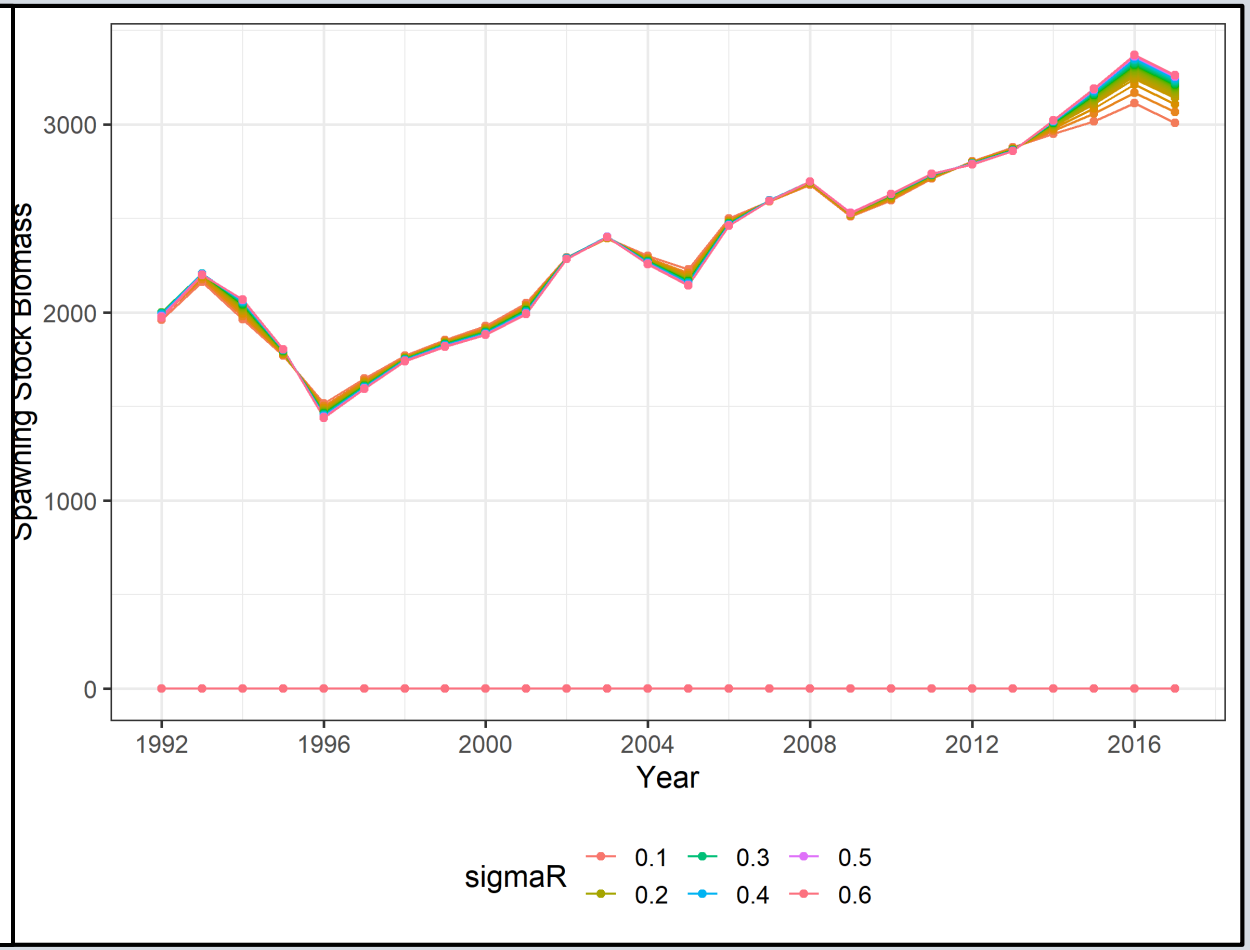
Likelihood Profile - Steepness



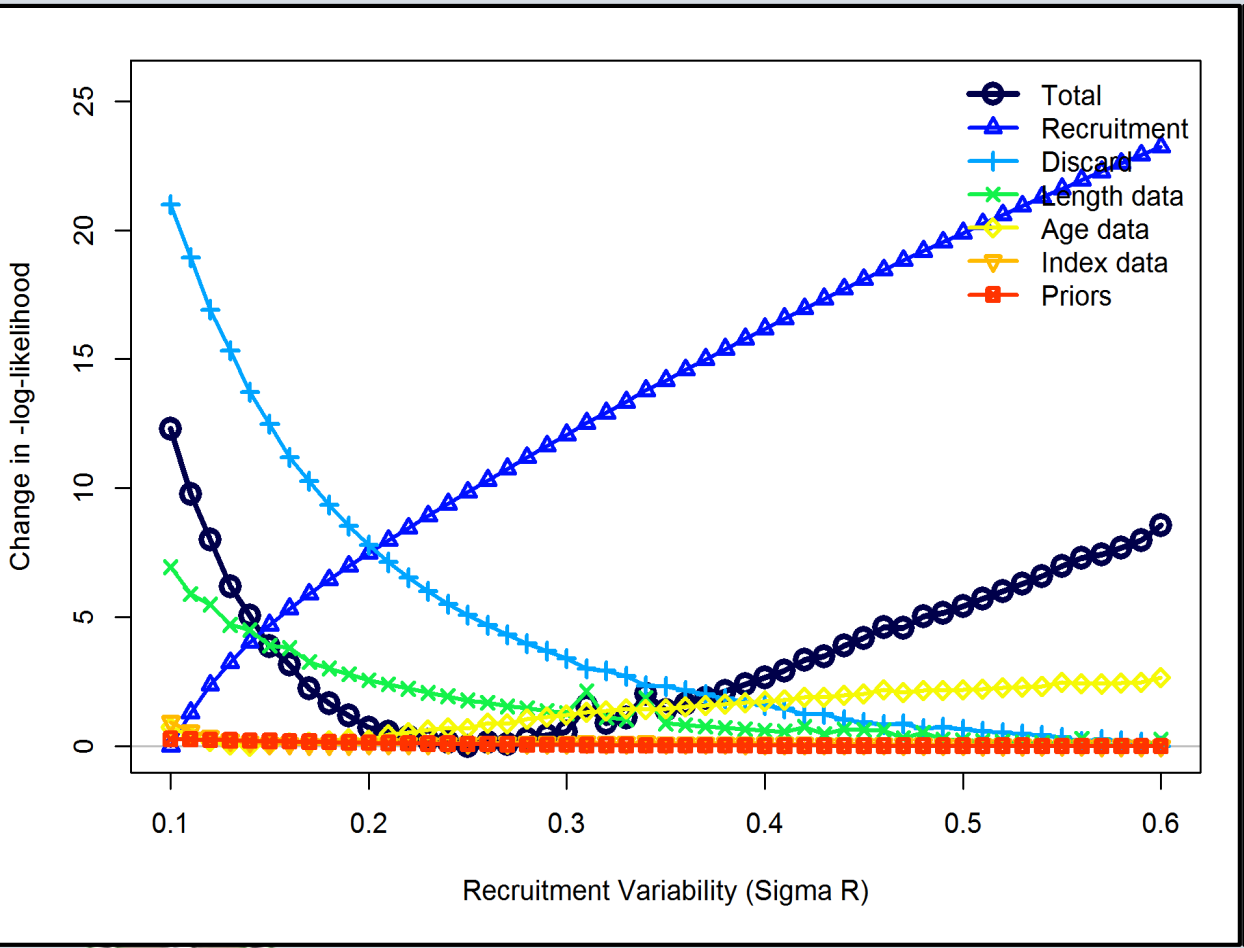


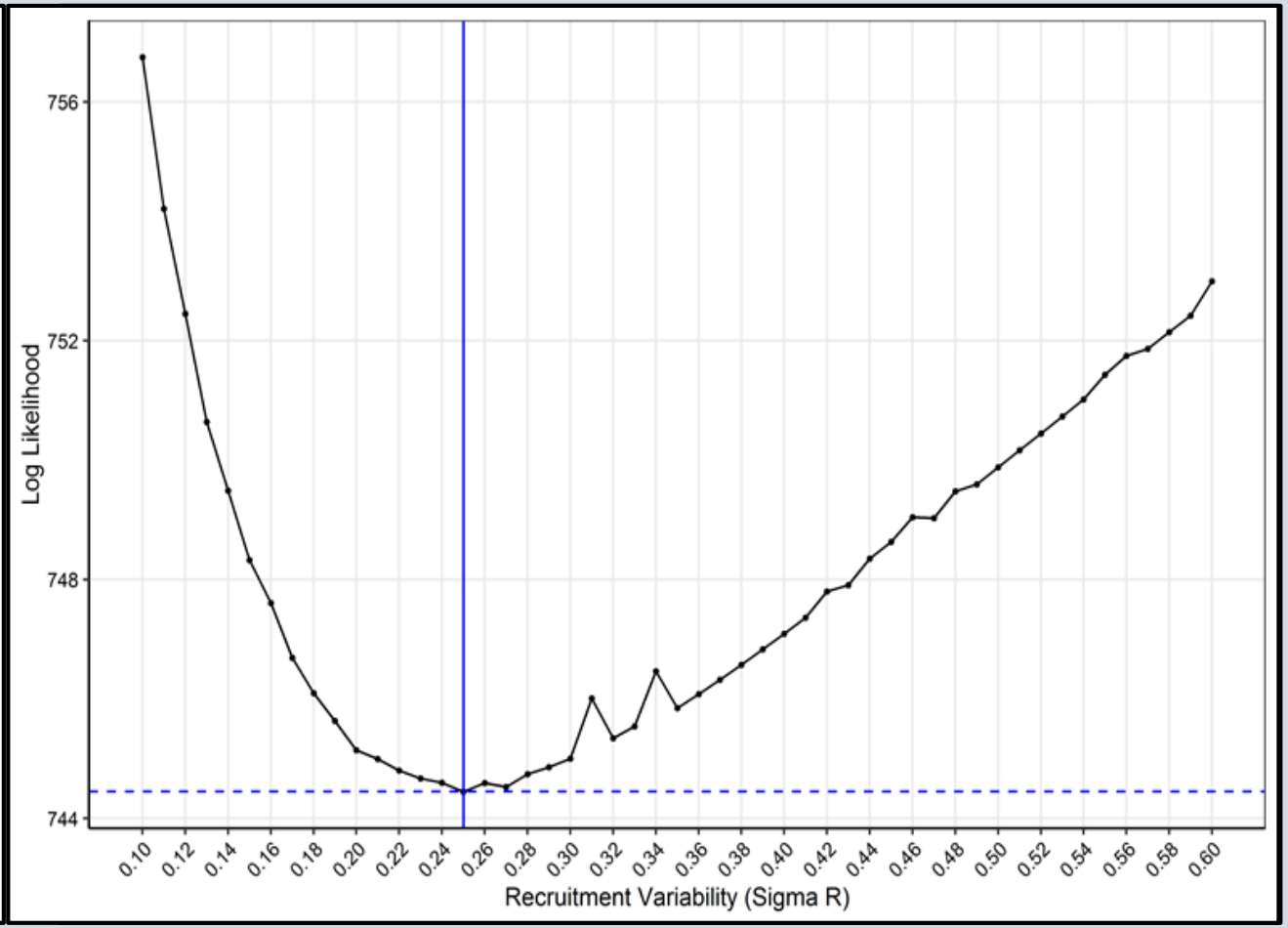
Likelihood Profile – Recruitment Variability



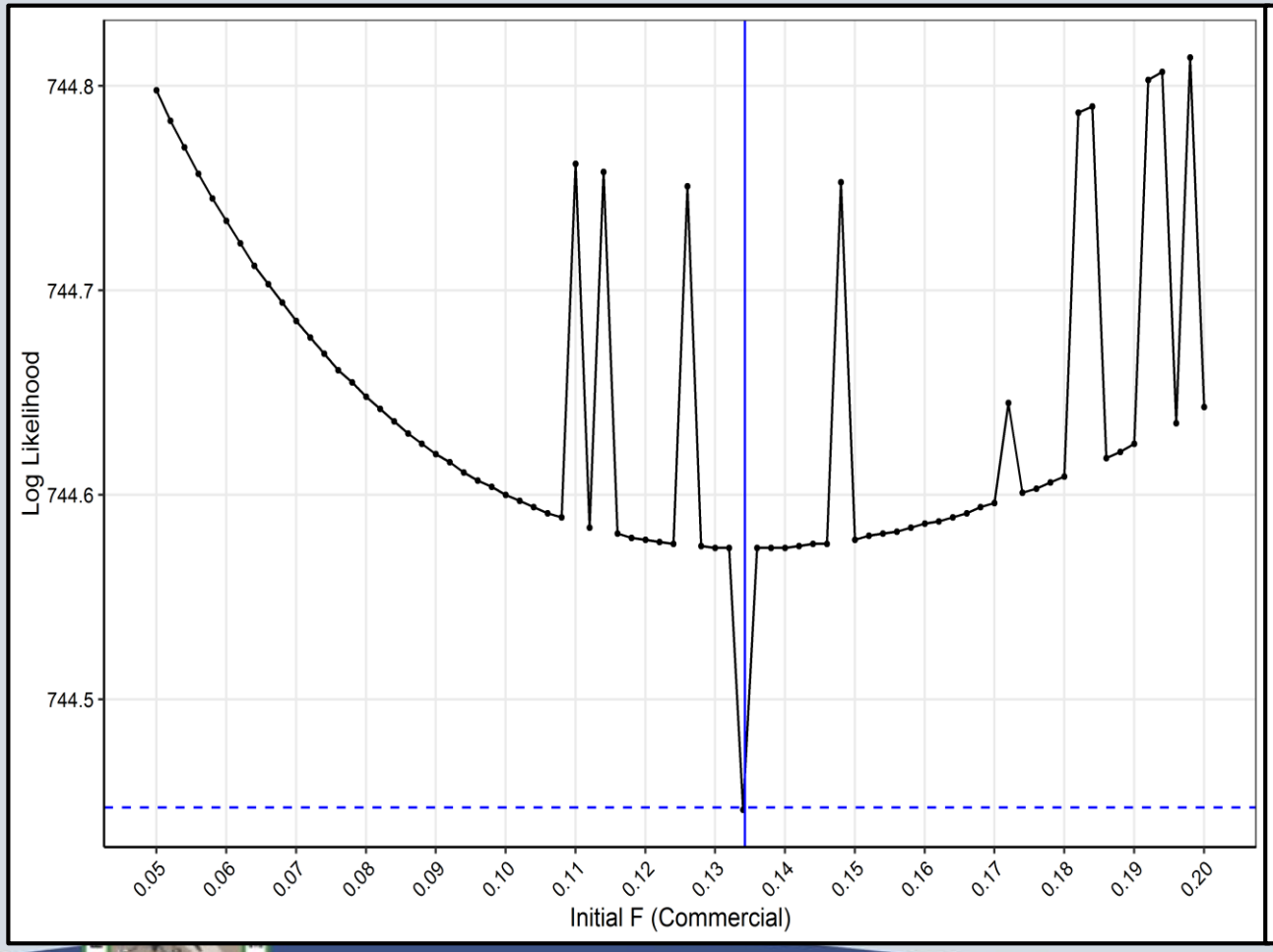


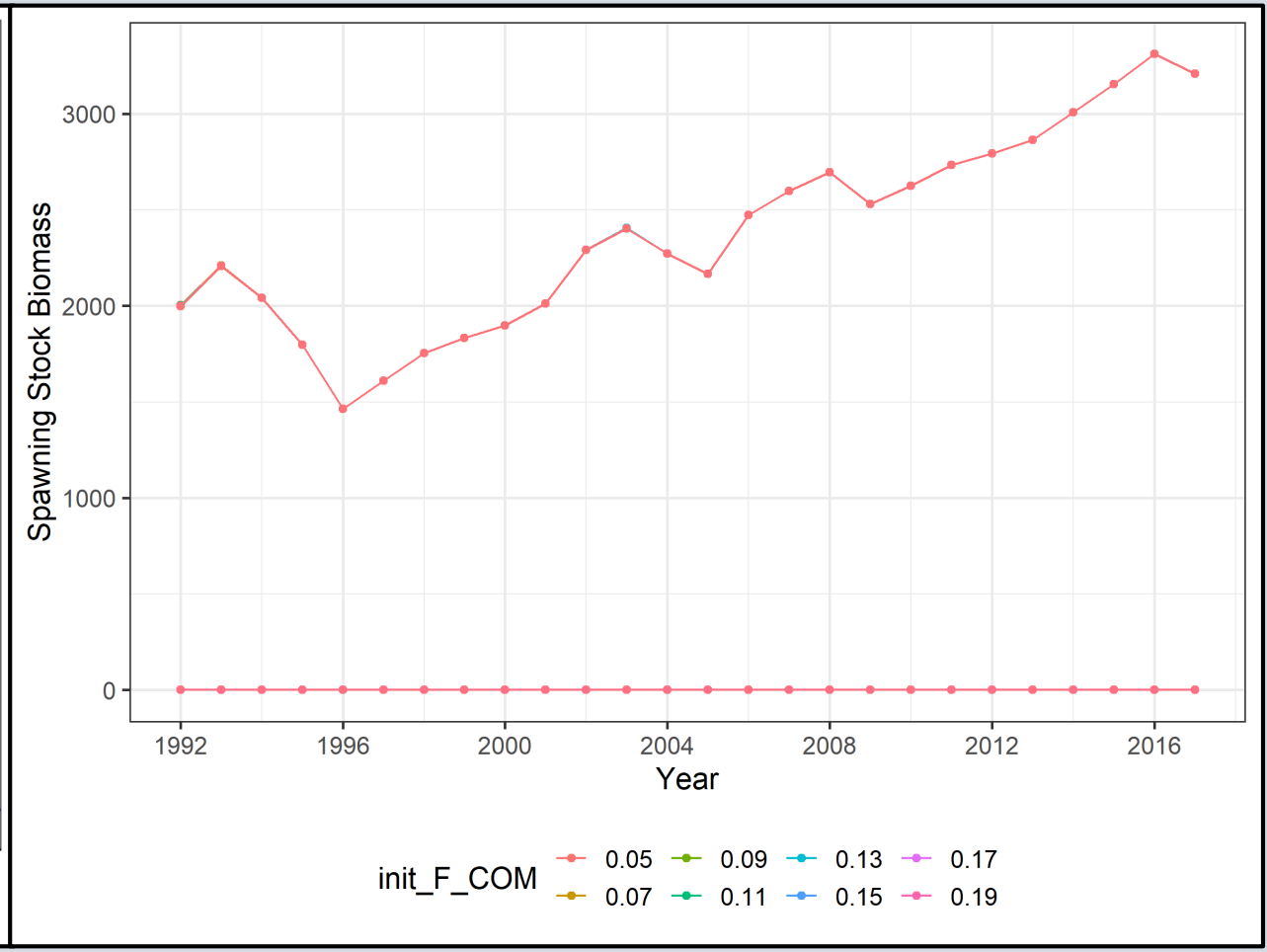
Likelihood Profile – Recruitment Variability



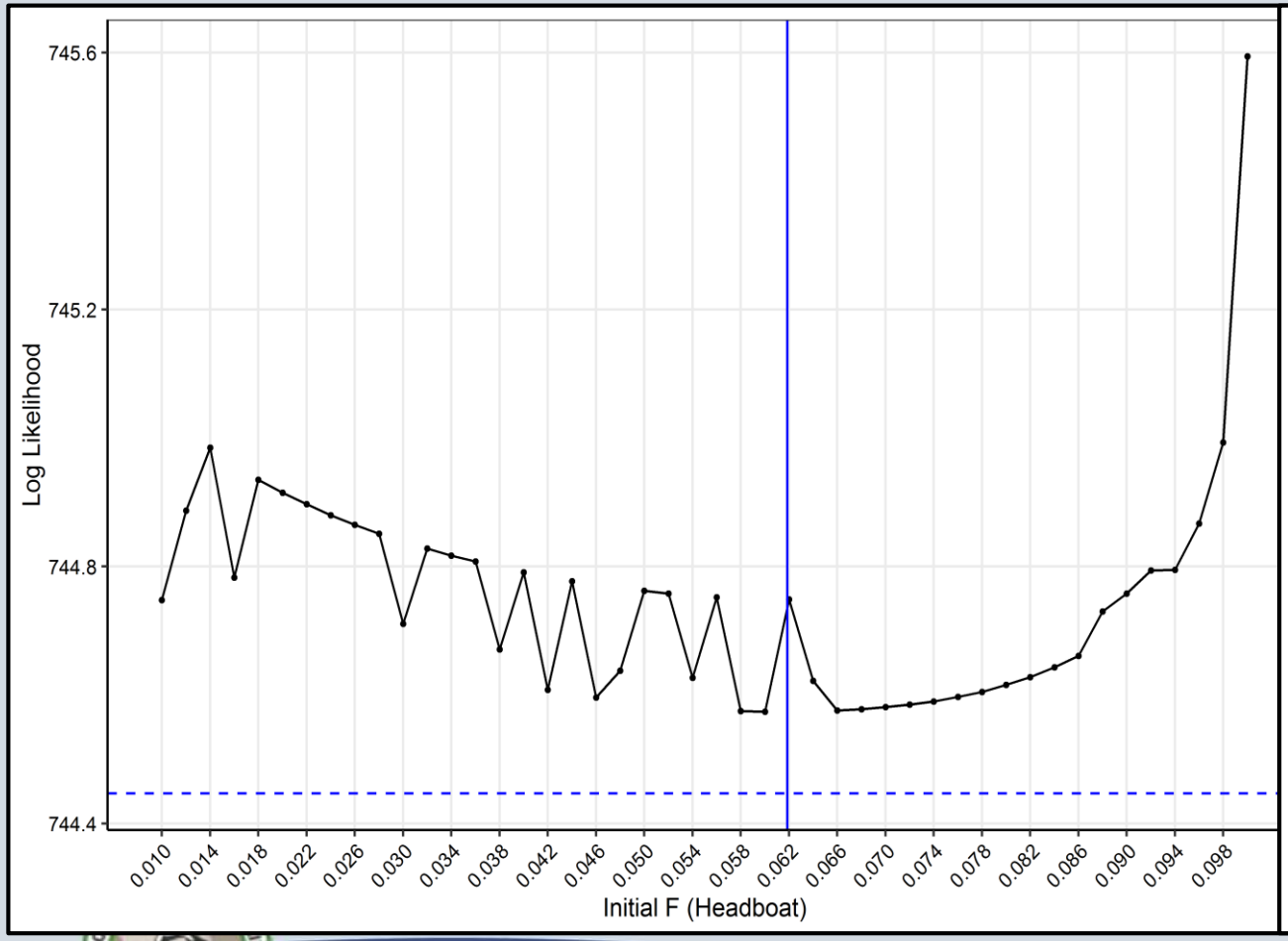


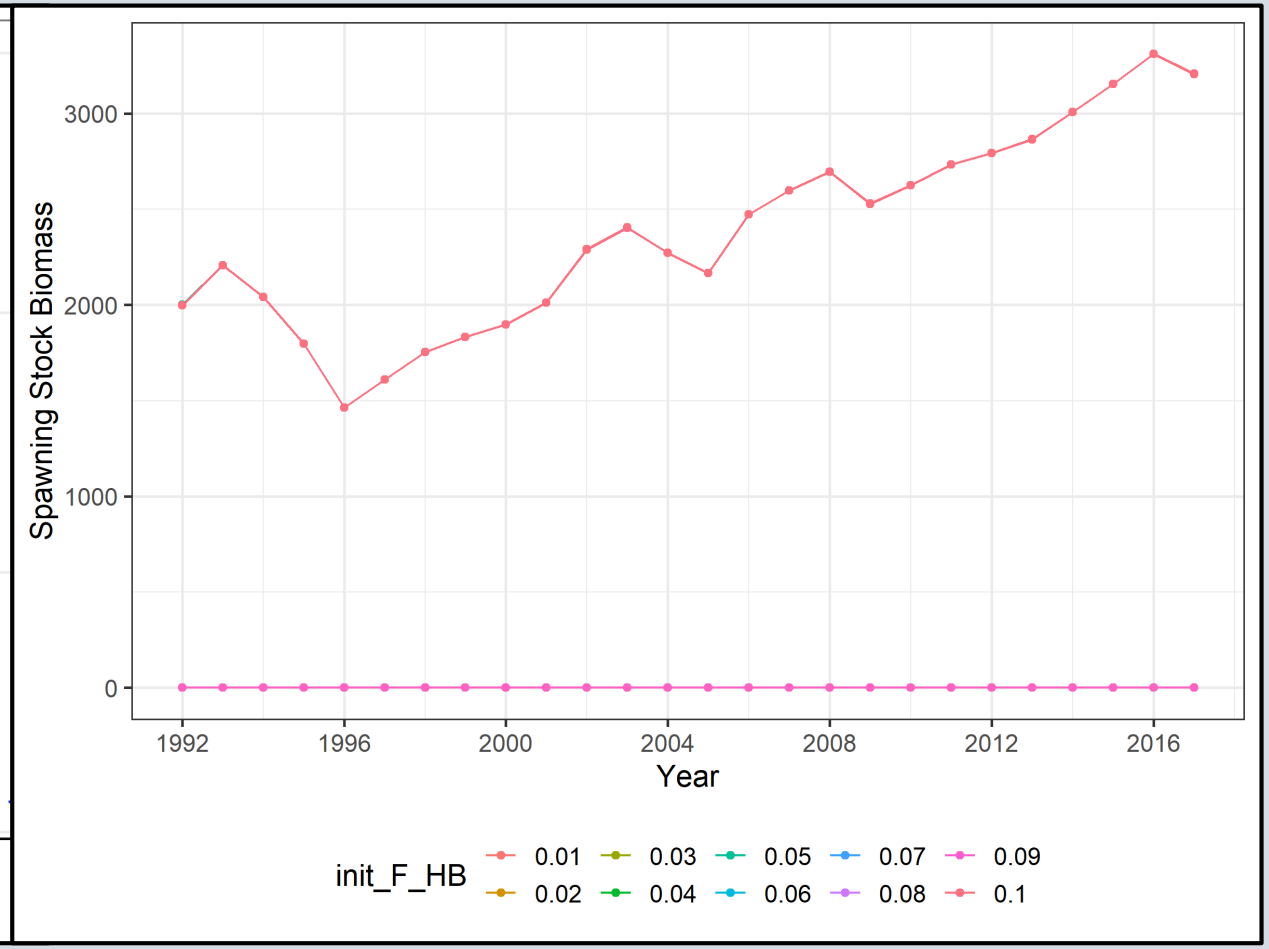
Likelihood Profile – Initial Commercial F



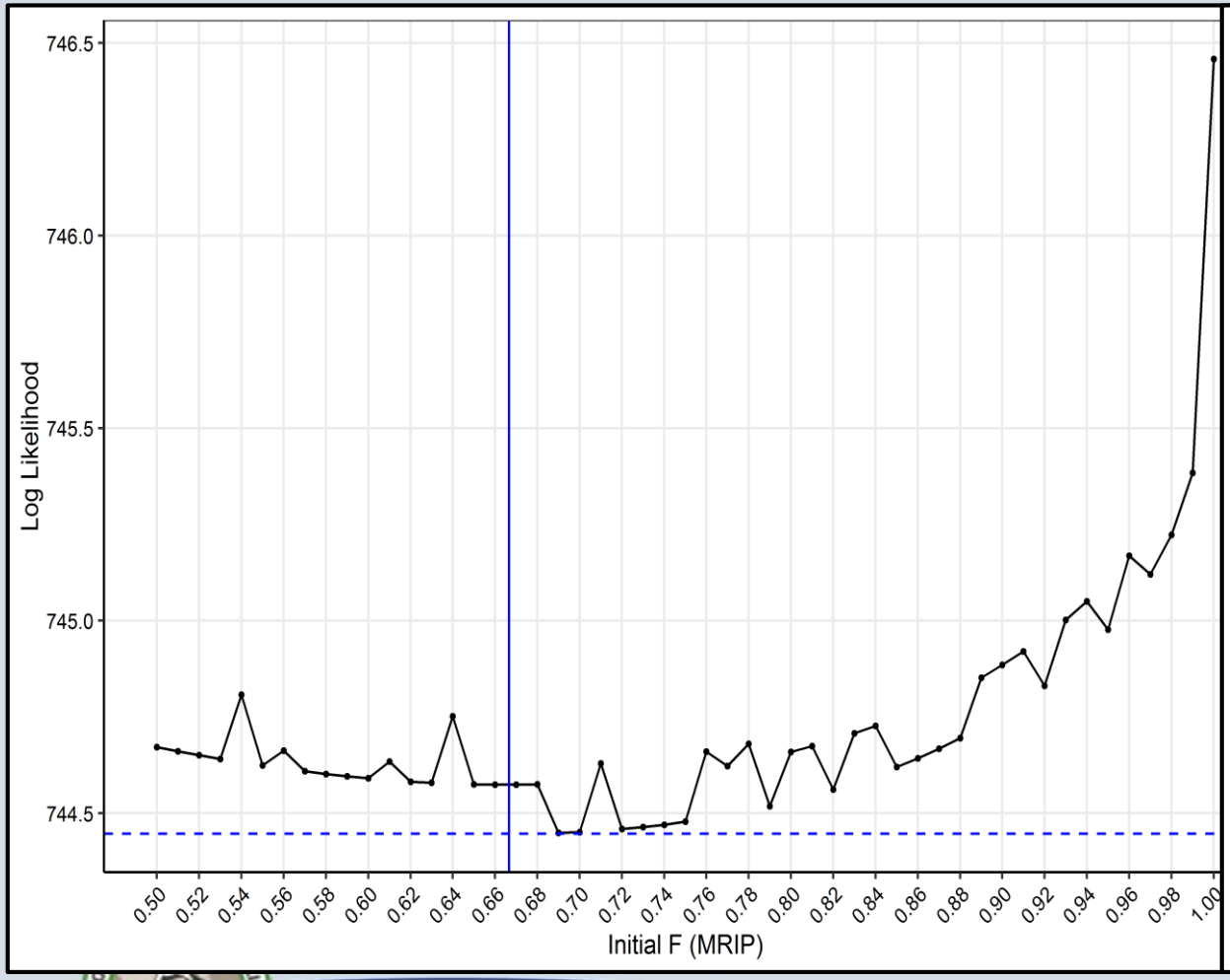


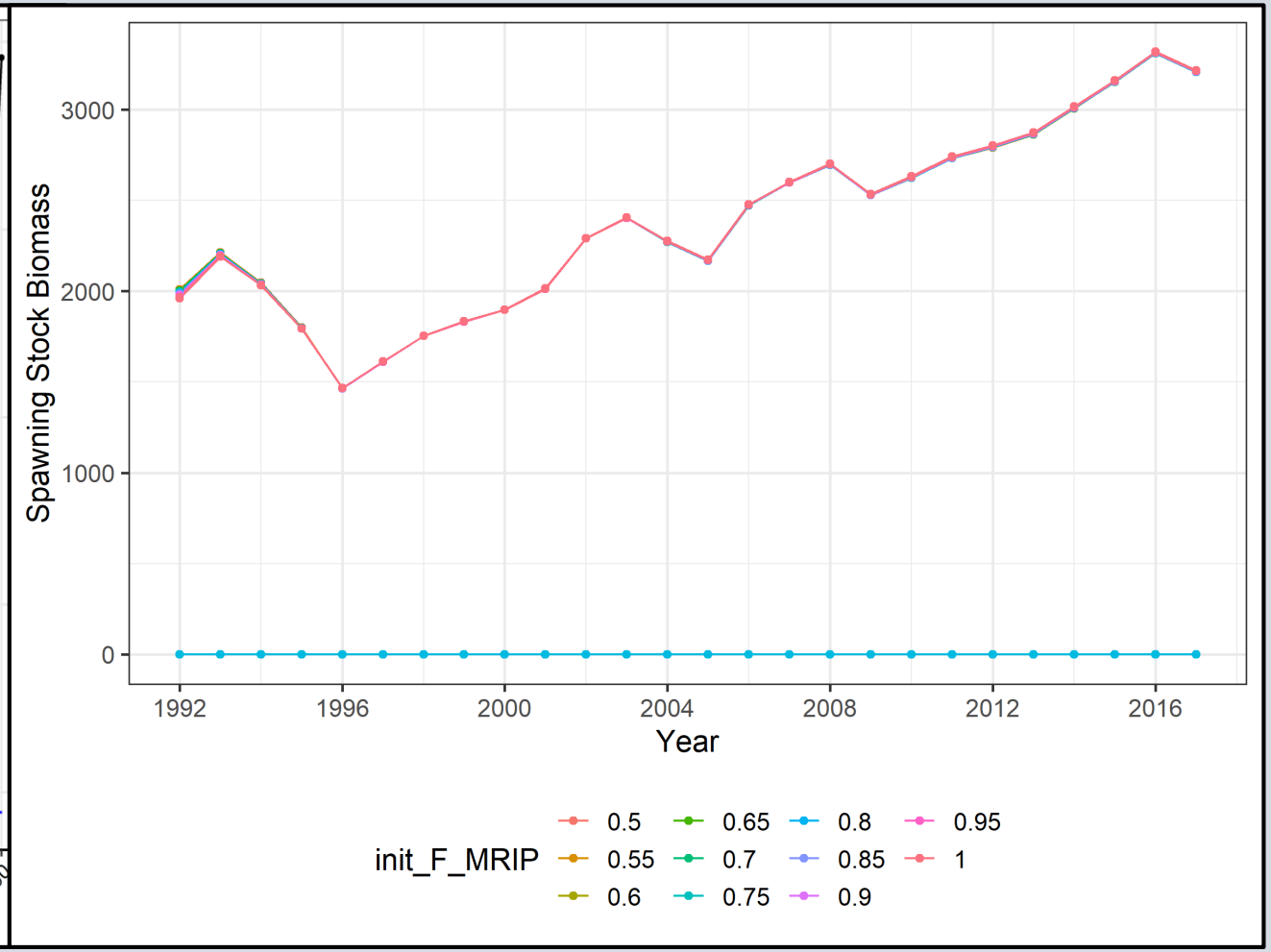
Likelihood Profile – Initial Headboat F



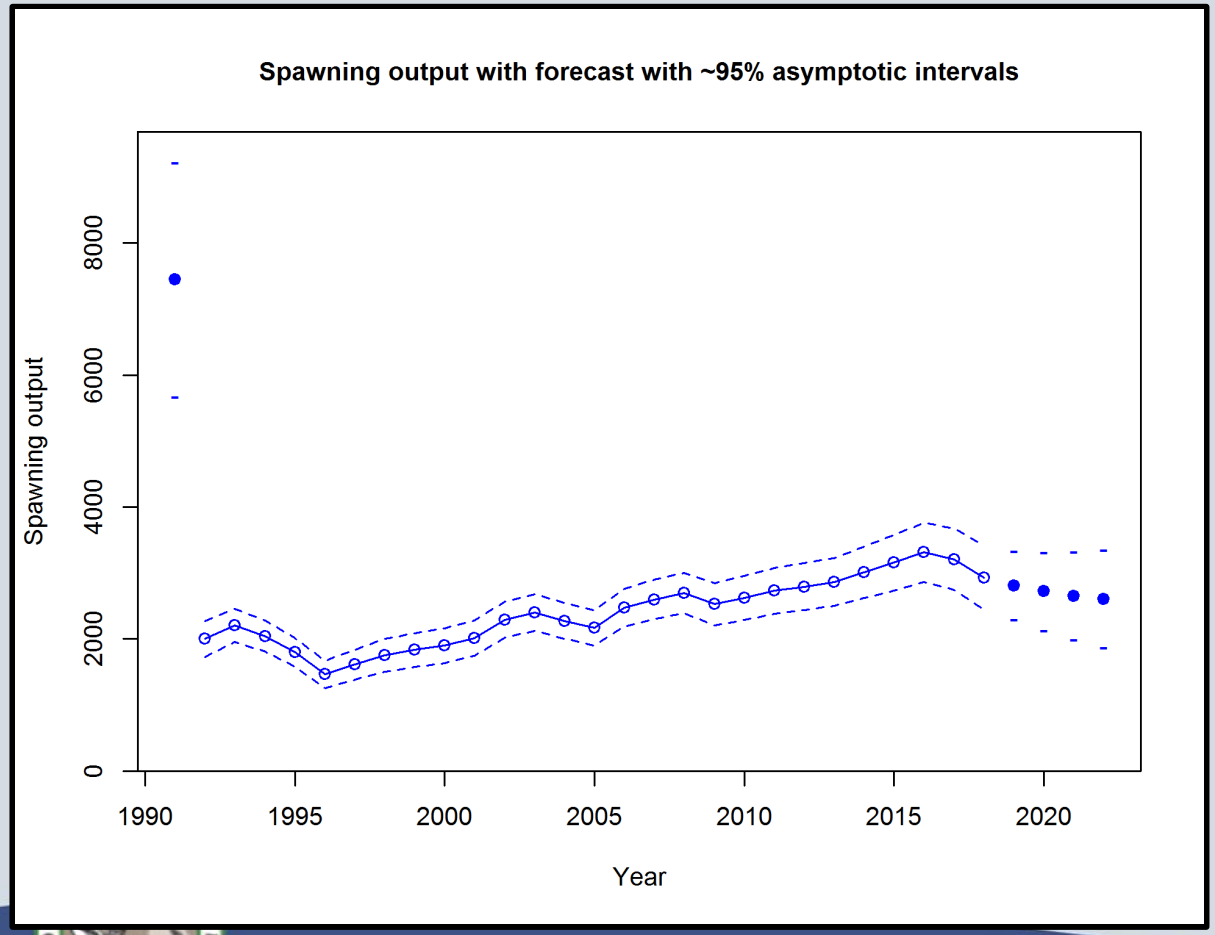


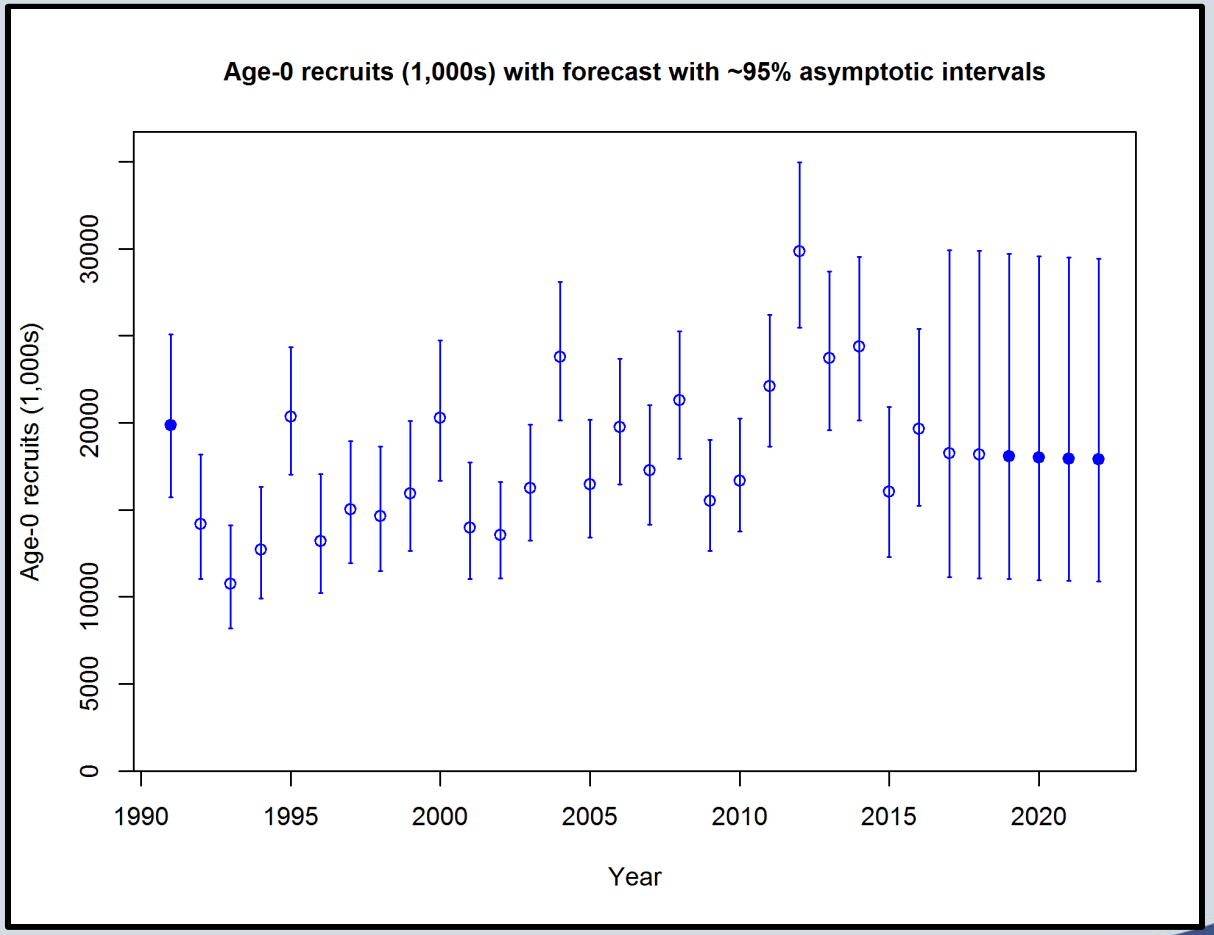
Likelihood Profile – Initial MRIP F



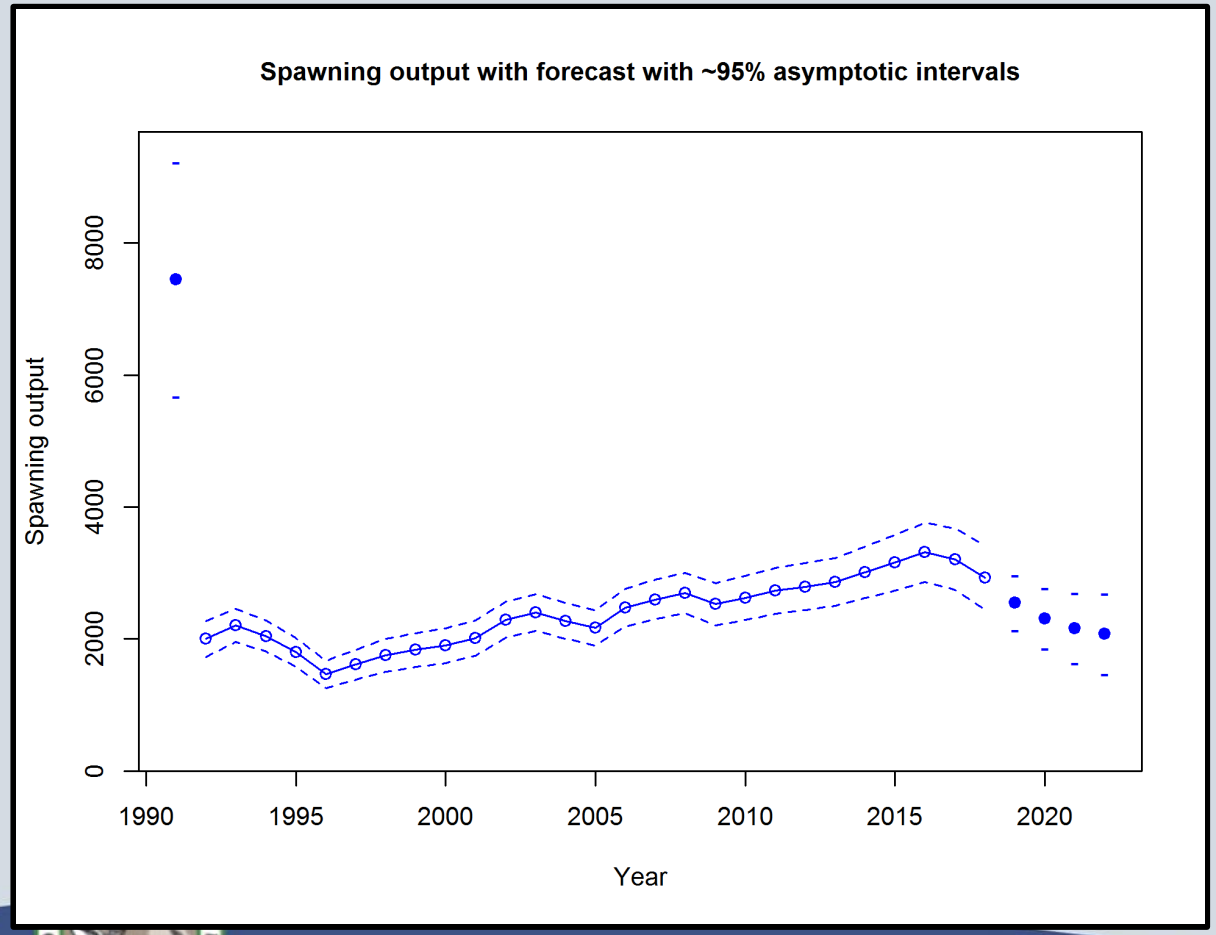


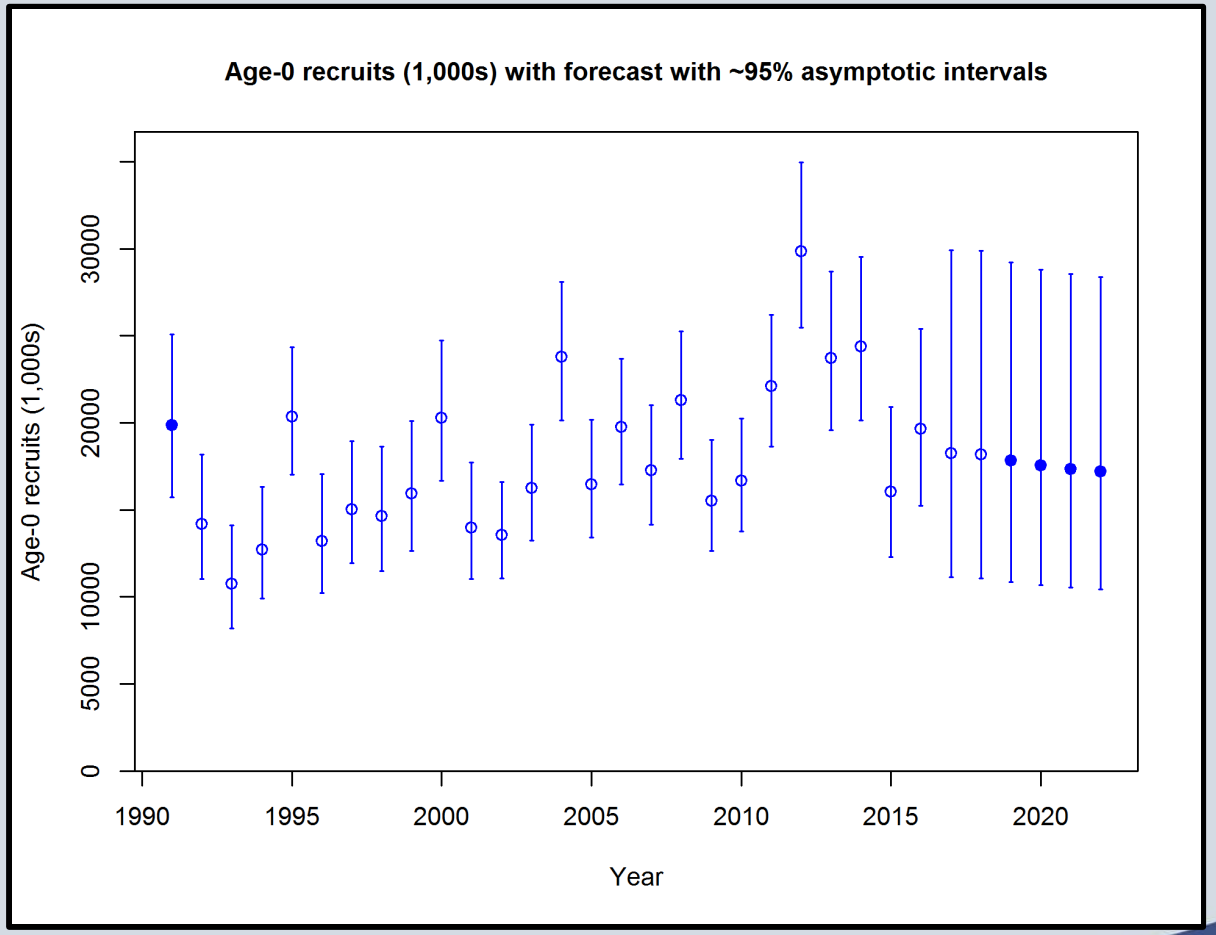
Stock Assessment Model:
Projections, Scenario 1: $F = F_{current}$



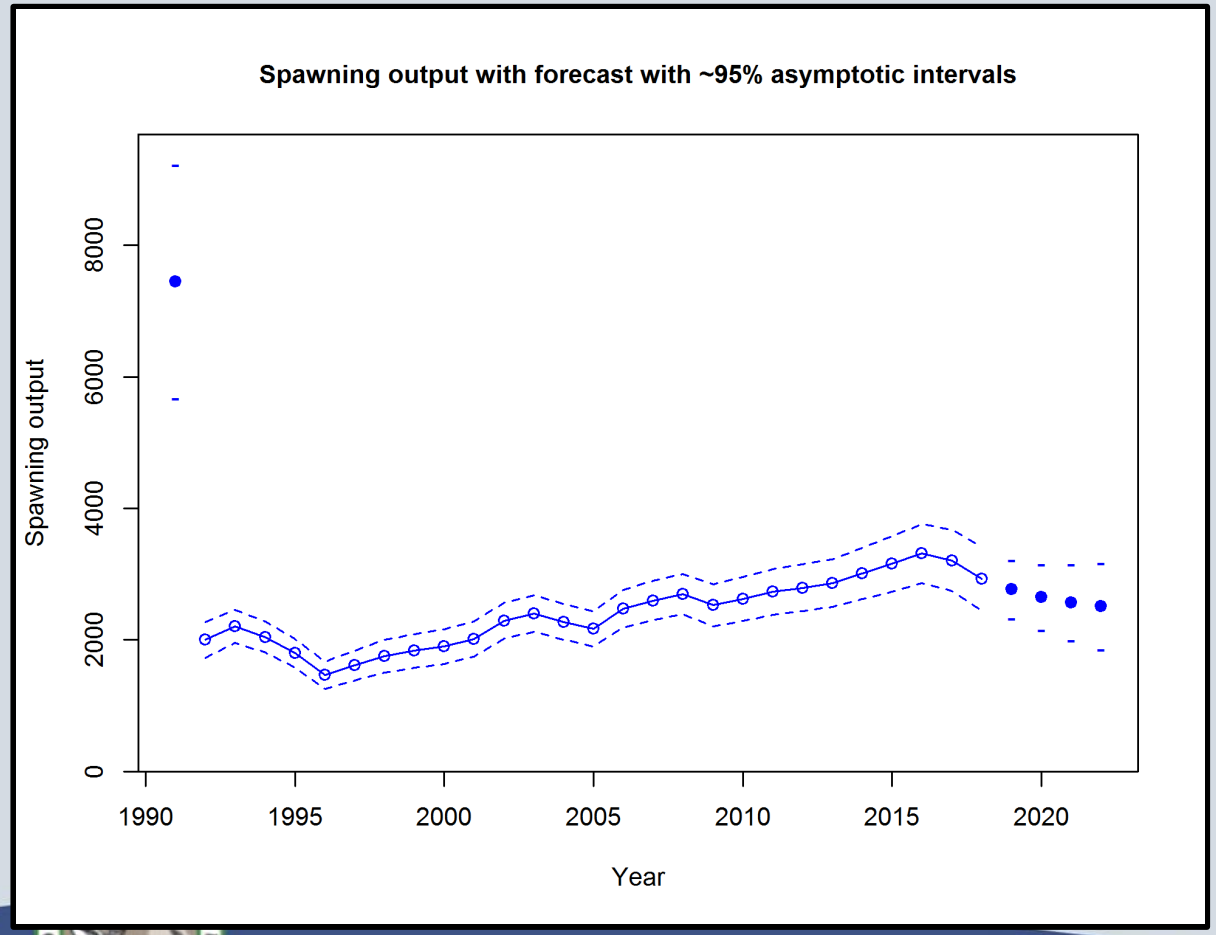


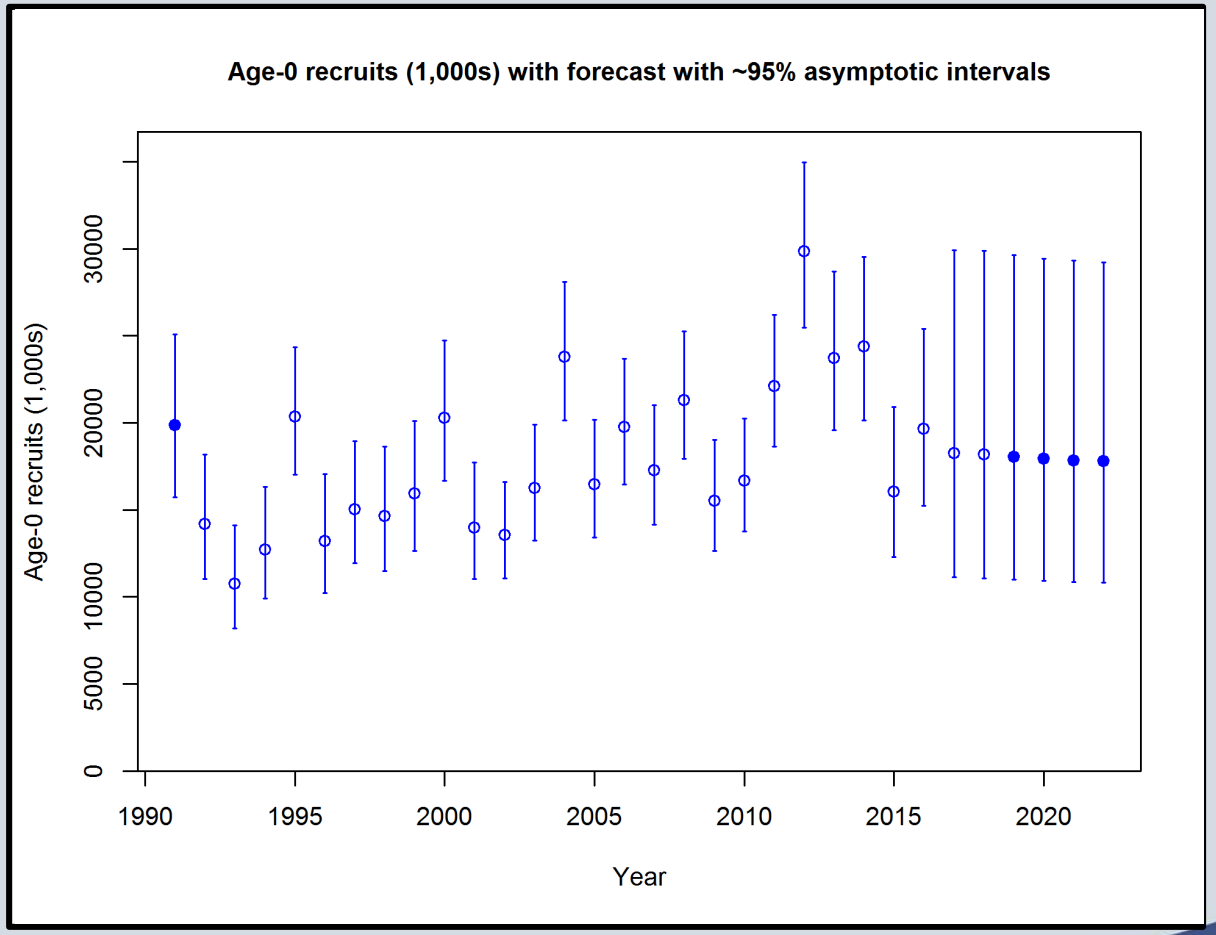
Stock Assessment Model:
Projections, Scenario 2: $F = F_{30\%SPR}$



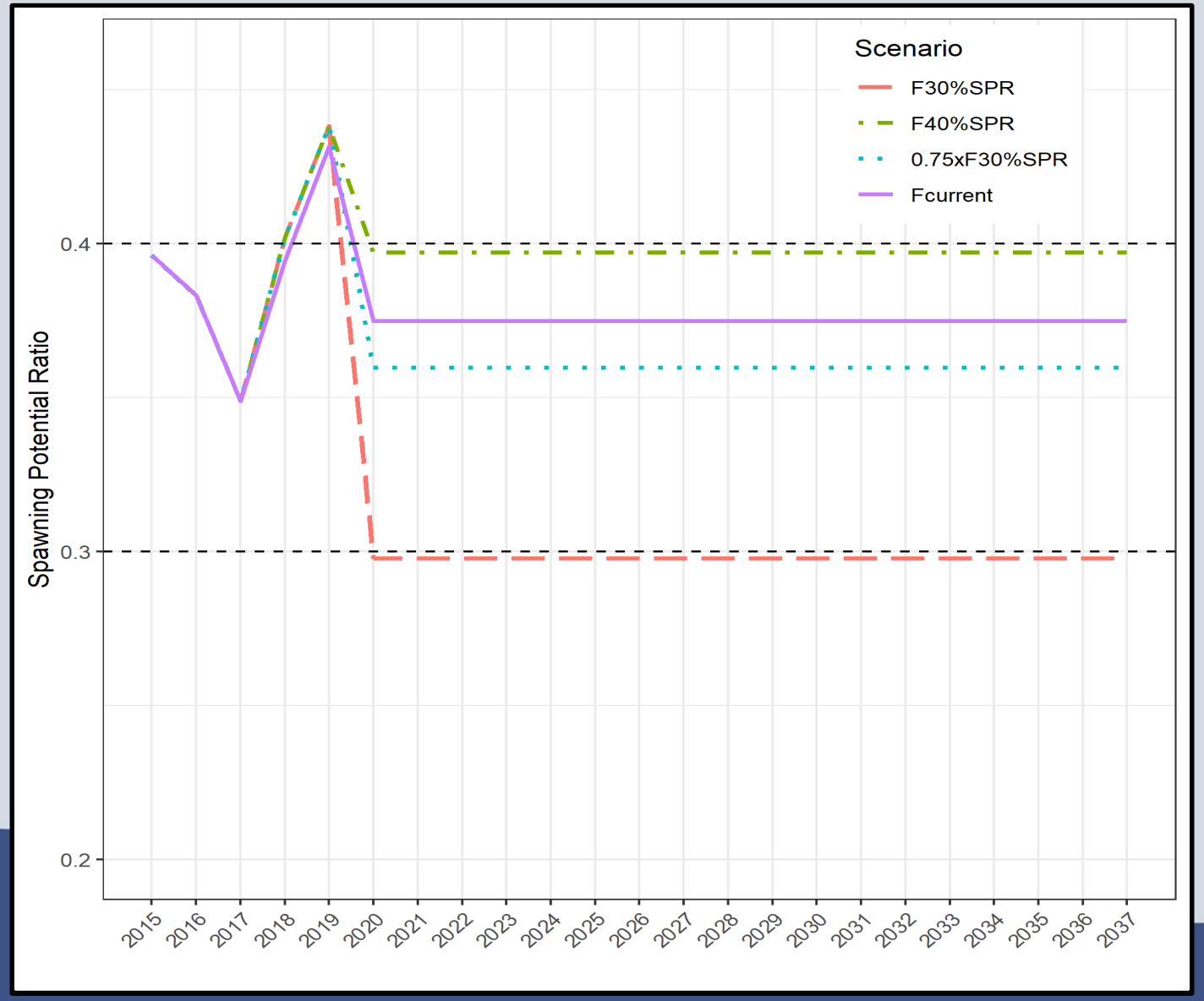


Stock Assessment Model:
Projections, Scenario 3: $F = 0.75 * F_{30\%SPR}$

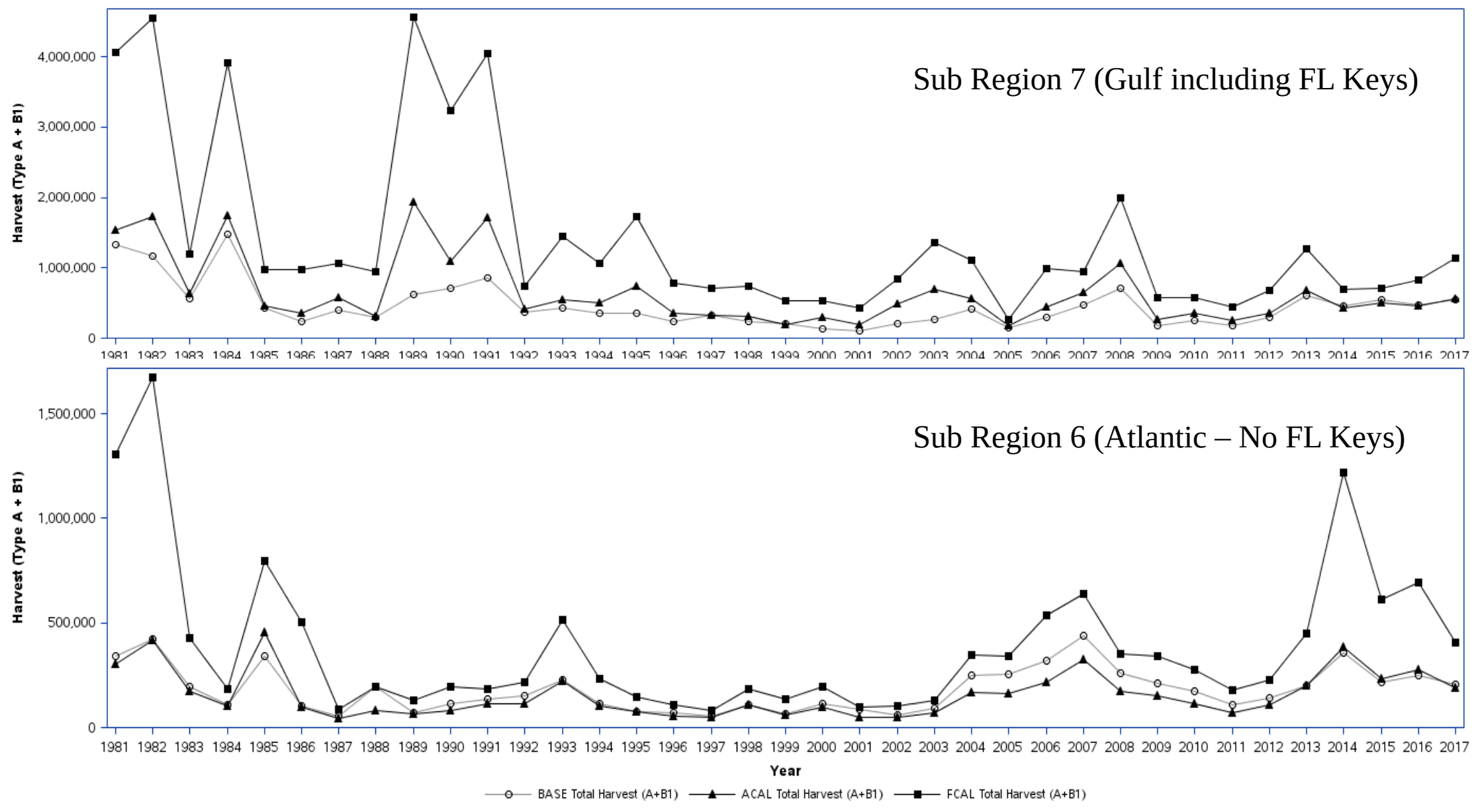
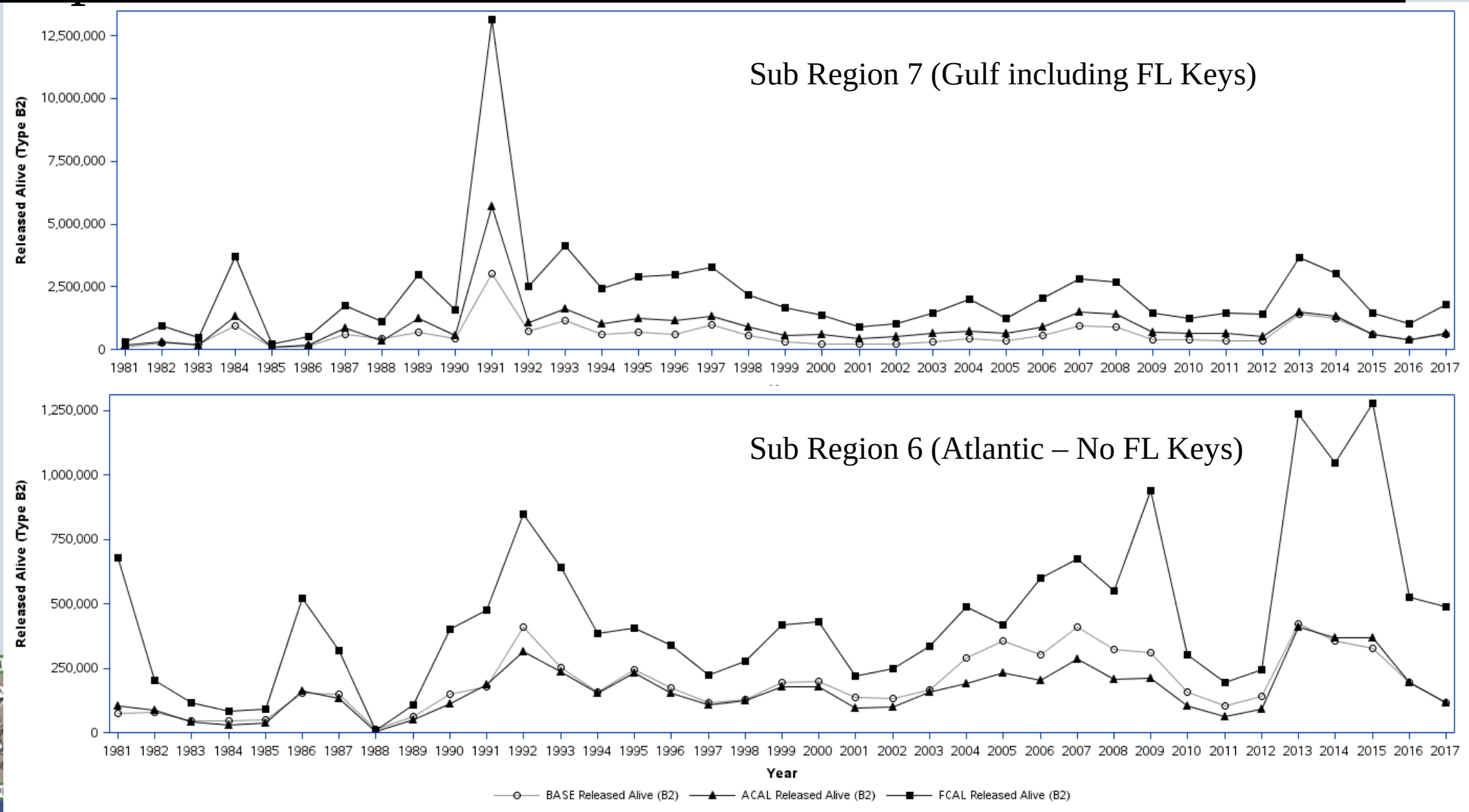




20 Year Projections: Spawning Potential Ratio



Comparison of non-calibrated vs calibrated Rec Landings



Comparison of non-calibrated vs calibrated Rec Discards