# South Atlantic King mackerel stock assessment

SEDAR 38 Review workshop

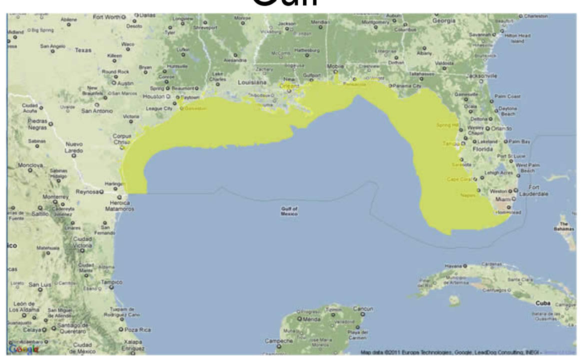
August 12, 2014
SEFSC staff
Miami, FL

# Presentation outline

I. Basic life history, fishery details, stock structure and Gulf and Atlantic model overview
II. SS Atlantic model set up
III. SS Atlantic model results
IV. Atlantic Stock status
V. Atlantic Projections

Atlantic

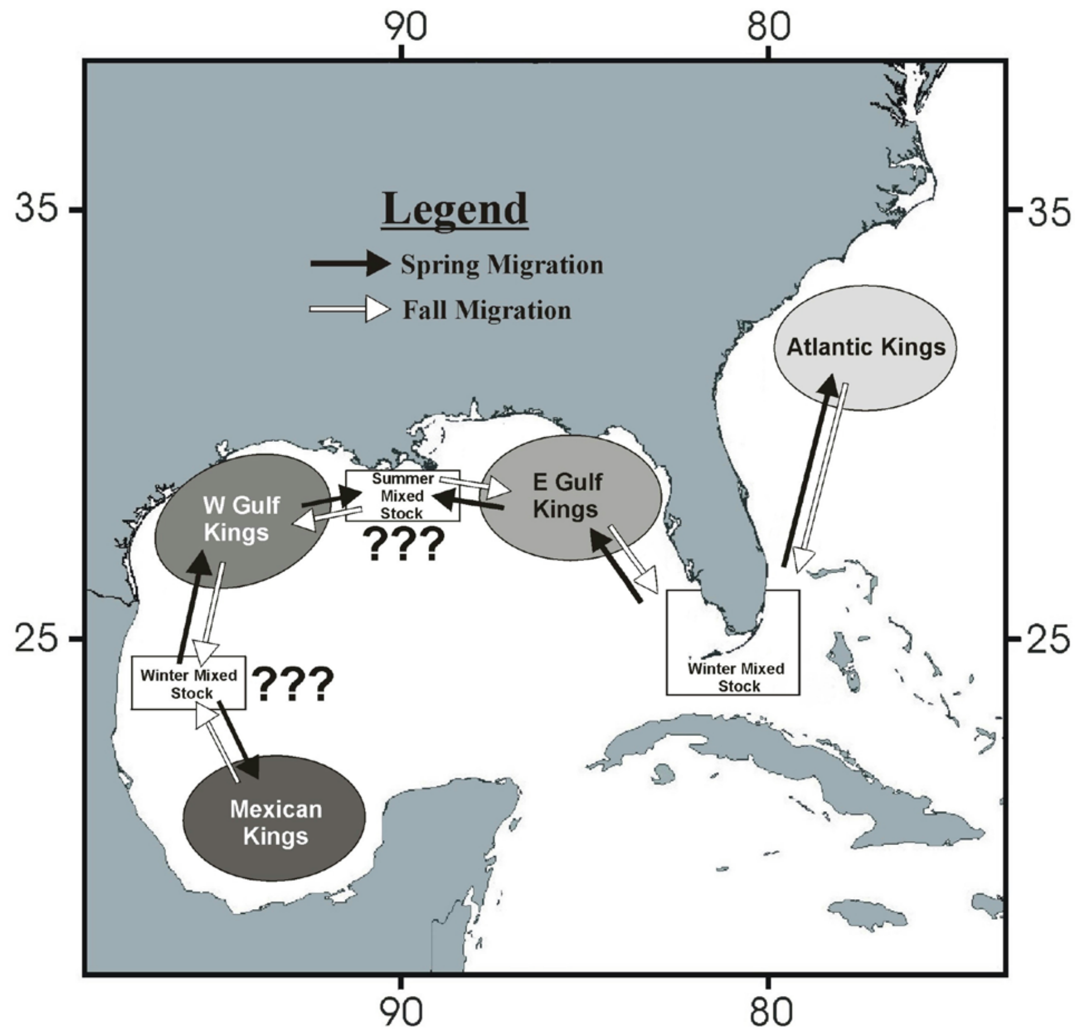

Gulf



# Basic life history

## King mackerel, *Scomberomorous cavalla*

- Schooling, coastal pelagic
- Large size (max 90 lbs, 40kg)
- Sexually dimorphic growth
- Batch spawner (May – Oct)
- Primarily piscivorous
- Modeled as 2 stocks with philopatry but mix in winter in S. Florida – Winter Mixing Zone (WMZ)



# Commercial Fishery

Fish landed gutted

Primarily trolling handlines from smaller vessels


Bryan Fleuch http://collierseagrant.blogspot.com/2012/01/chasing-kings.html

# Recreational/tournament fishery

Large high value tournament fishery targets the largest king mackerel


http://www.fishska.com/

Substantial recreational fishery

http://www.sportfishingmag.com/files/imagecache/enlarged_image/_images/201307/kingfish-boat-prep-01.jpg

# History of assessments

- Pre-SEDAR, Mackerel Stock assessment panel (1990, 1992, 1994, 1996, 1998, 2000, 2002) – ADAPT VPA

- 2004 (**SEDAR 5**) VPA ((VPA-2Box),
  - Not overfished and overfishing not occurring
  - Time varying stock definitions (Winter Mixing zone 100% Gulf)
  - reference points based on MSY proxies (SPR30%)

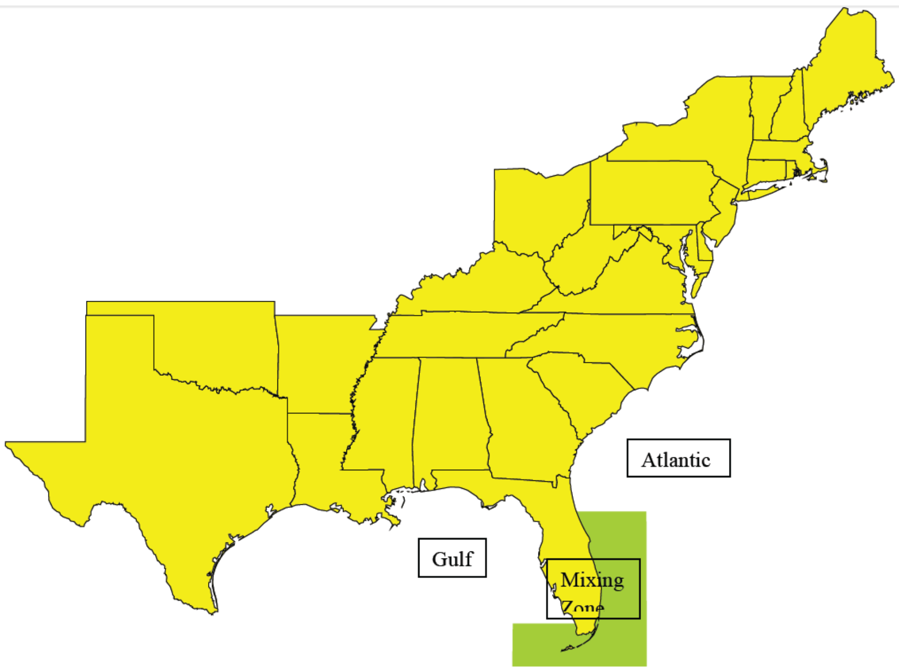
- 2008 (**SEDAR 16**) VPA model (VPA-2Box) and a Statistical Catch at Age model incorporating mixing (SS2),
  - Not overfished and overfishing not occurring
  - Winter Mixing zone 50% Gulf/SA
  - reference points based on MSY proxies (SPR30%)

- **2014 SEDAR 38**, SS3 and VPA for continuity

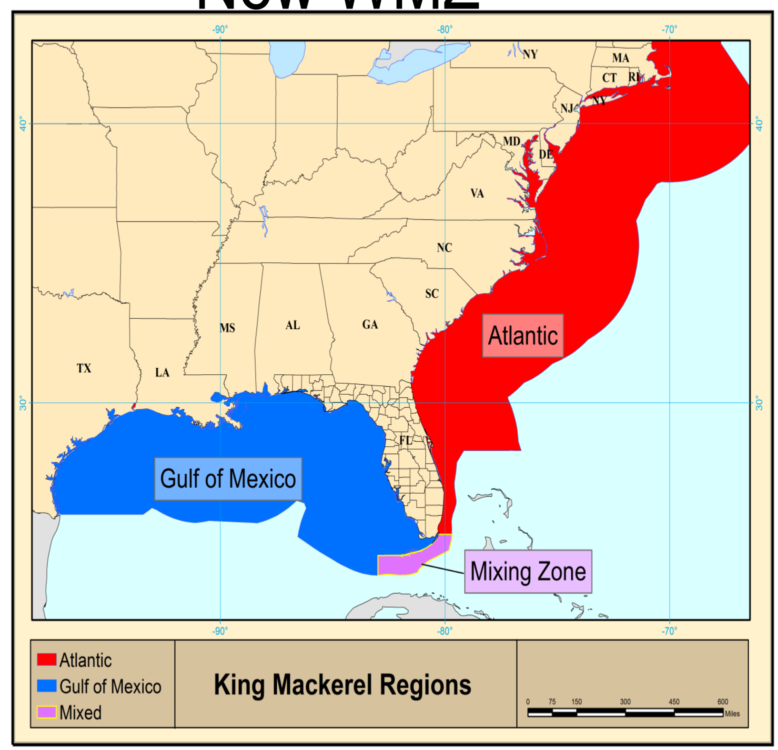
# New information

- Reconfiguration of the winter mixing zone, now much smaller, only ~7% unaccounted landings by stock

Old WMZ

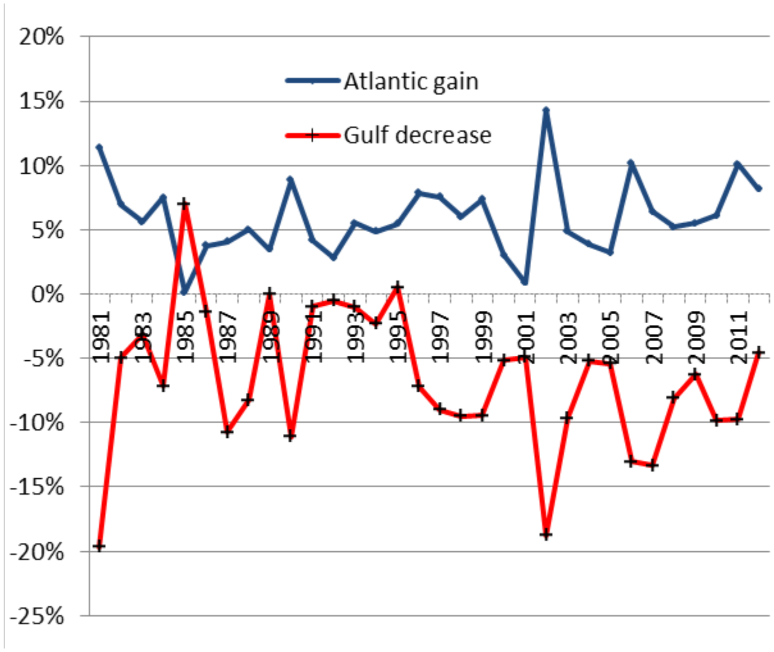



New WMZ

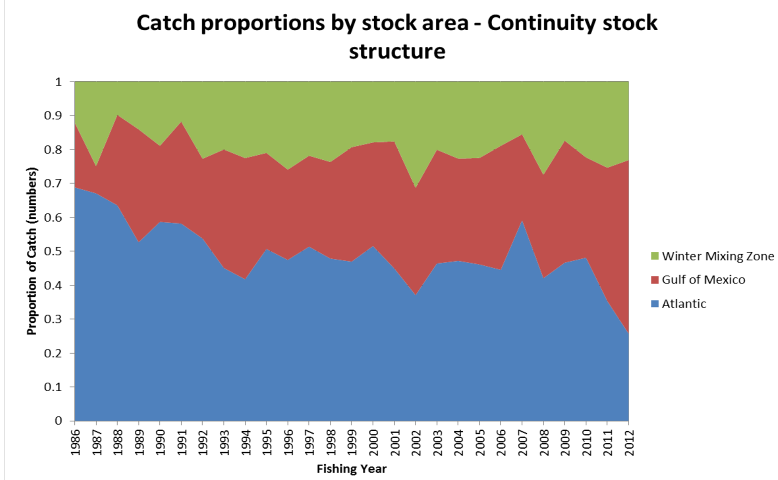


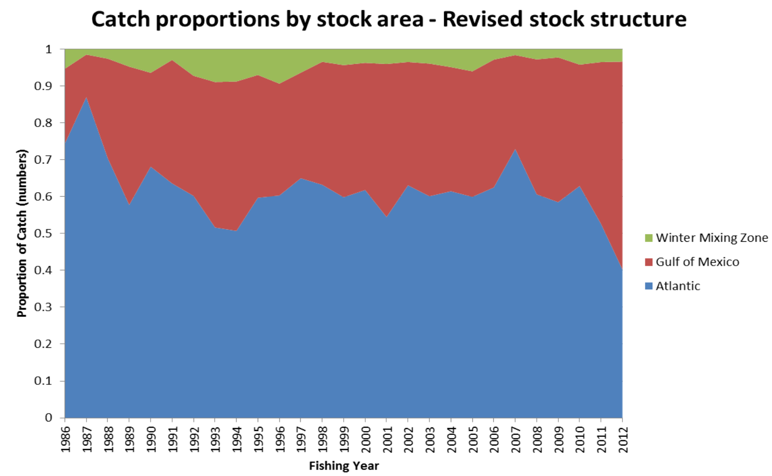
# Reallocation of landings

Average increase of 6% in ATL and decrease of 7% in Gulf




Now unaccounted for WMZ is only 7% of the total as opposed to 24% in S16



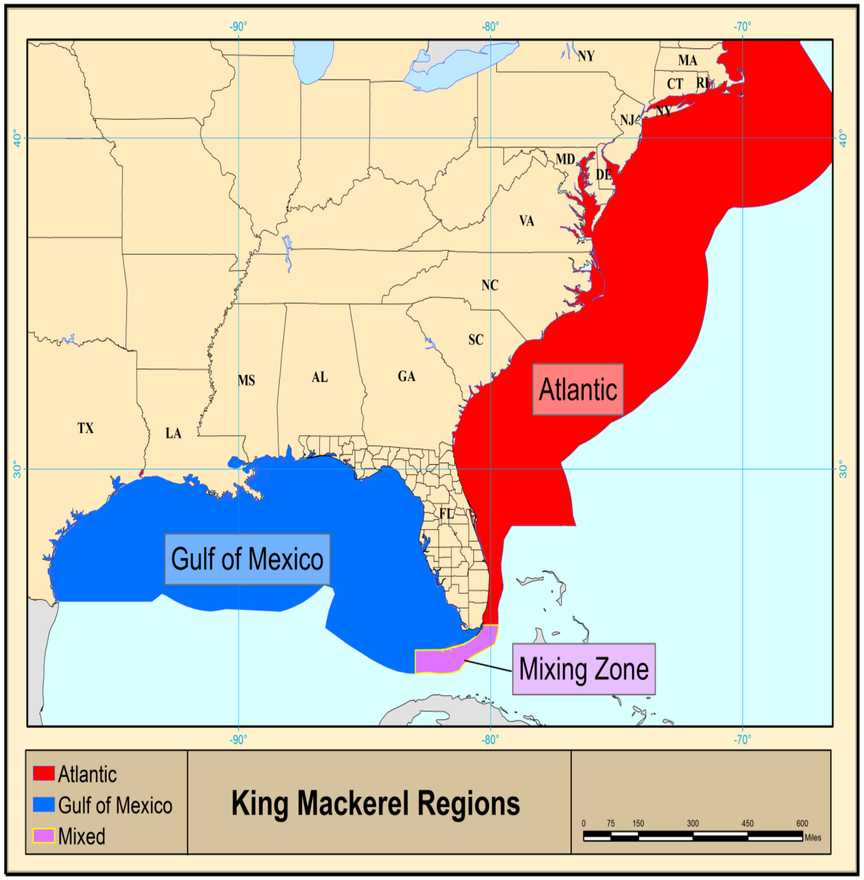
# S38 Assessment models

- Primary assessment model – stock synthesis (Methot)
  - Initially configured to replicate VPA assumptions (S38AWdoc)
  - Configured according to new data assumptions/best practices
  - Integrated catch at age/length model, widely applied

- Secondary/continuity models VPA-2Box (Porch, 2002)
  - Used for advice in S16
  - Continuity model
  - Revised stock structure, primarily used for support

# SS Model(s) structure

- Gulf and SA stocks
- Fishing year
  - Gulf
  - SA
- WMZ partitioned 50/50
  - Only stock specific age and length comps used



# II. SS Atlantic model set up

# Model structure

- 6 fleets (HL, GN, Shrimp bycatch, HB, C/P, Tourn)
- 4 surveys (Comm Troll (Handline), Head Boat, SEAMAP trawl, Shrimp effort) – *MRFSS excluded*
- Tournament fleet selectivity modeled as logistic
- Sex-specific selectivity, Females modeled as offset from males.
- All other Selex modeled as double normal (can be flat or dome)

# Model structure/set up

- Sigma r fixed at 0.6
- Recruitment deviations estimated for 1981-2012 with no ramp on bias correction (full bias correction for all devs)
- CV of 0.2 used for private charter and headboat landings, 0.02 for commercial
- Time series of effort used for shrimp fishery to estimate discards
- Start in 1900, assumed virgin
- Fishing mortality proxy is exploitation rate in number for all ages
- Ageing error vector is constant CV of 0.1 at age

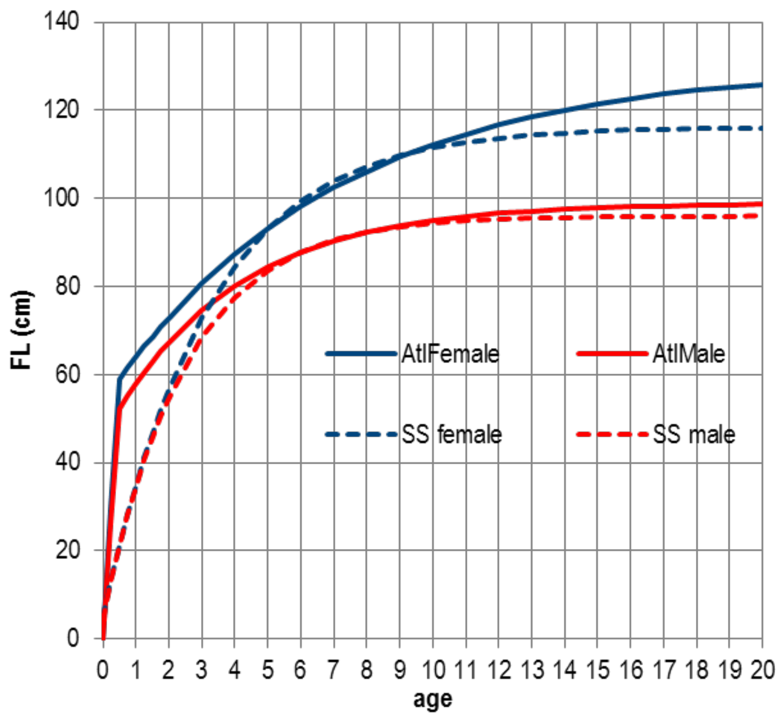
# Biology- growth

Growth estimated internally in SS

external estimates used as initial inputs

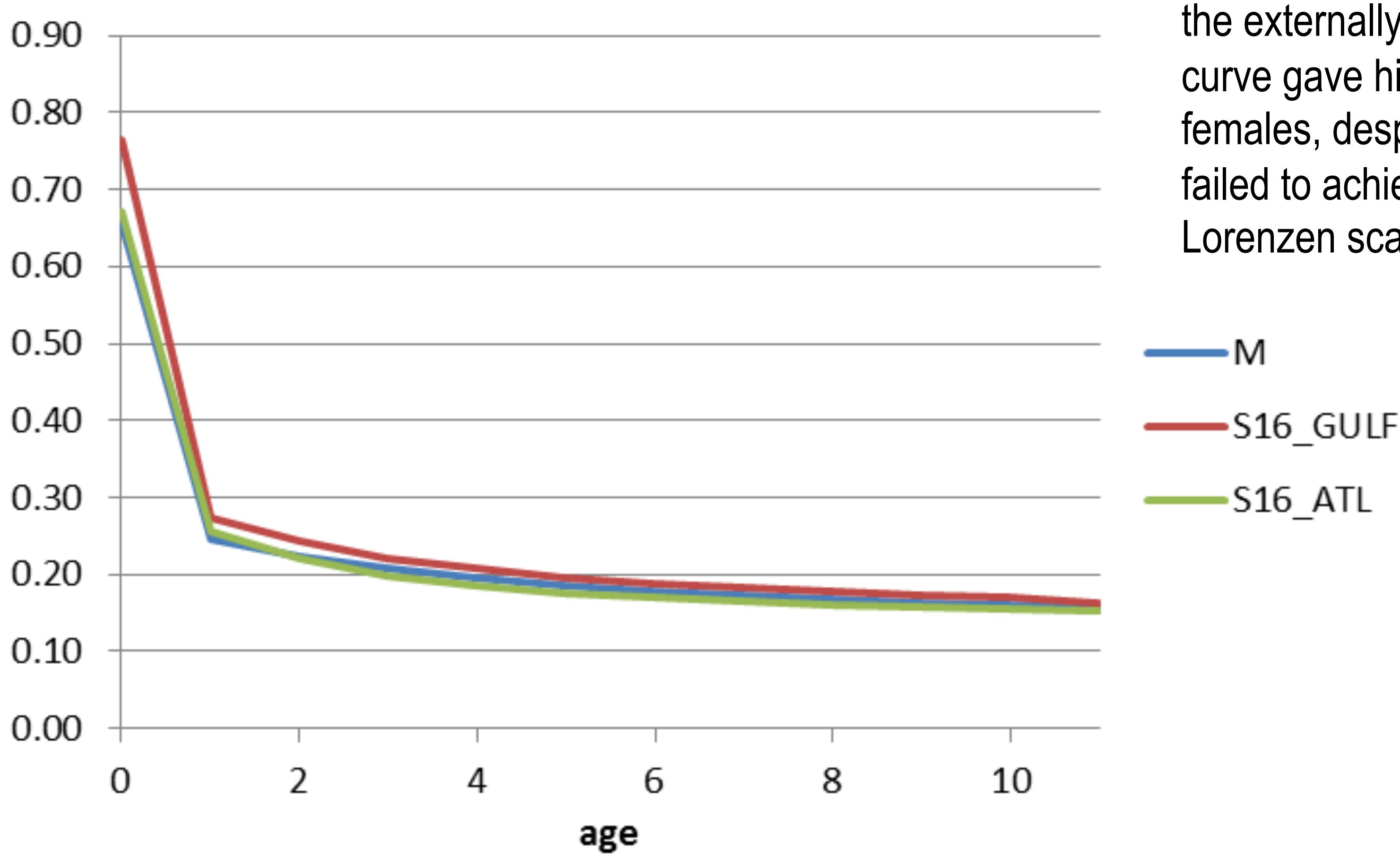
Modeled with linear ramp to assumed size at age 0.5 (21cm)

Model estimates selectivity, resulting in divergence between external estimates



# Biology

## Natural mortality, single Lorenzen vector, derived from external growth curves




Separate vectors, based on the externally derived growth curve gave higher M at age for females, despite greater size, failed to achieve intent of Lorenzen scaling

# Biology

- Length-weight
- Fecundity
- Maturity
- SSB modeled as female eggs

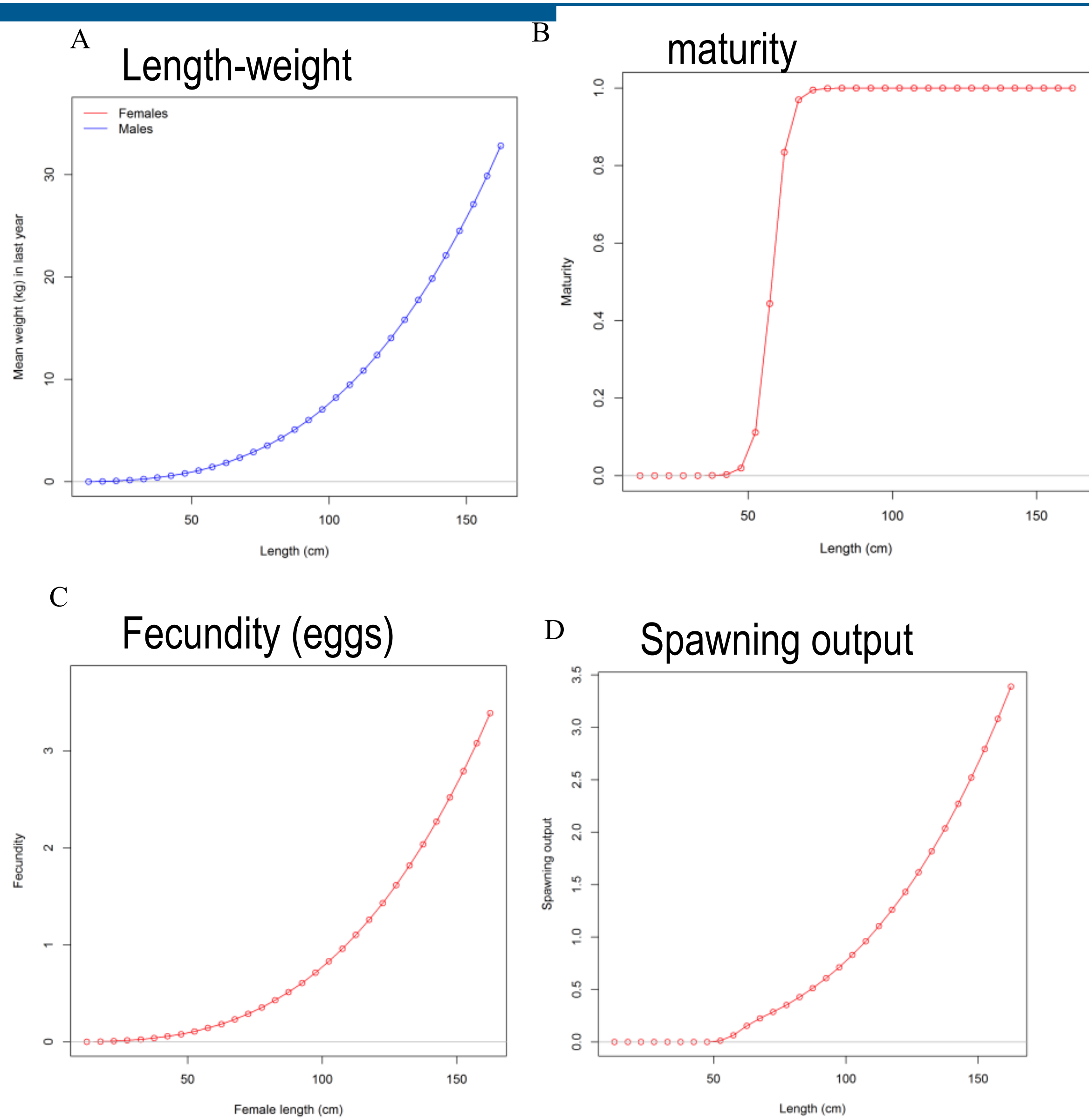
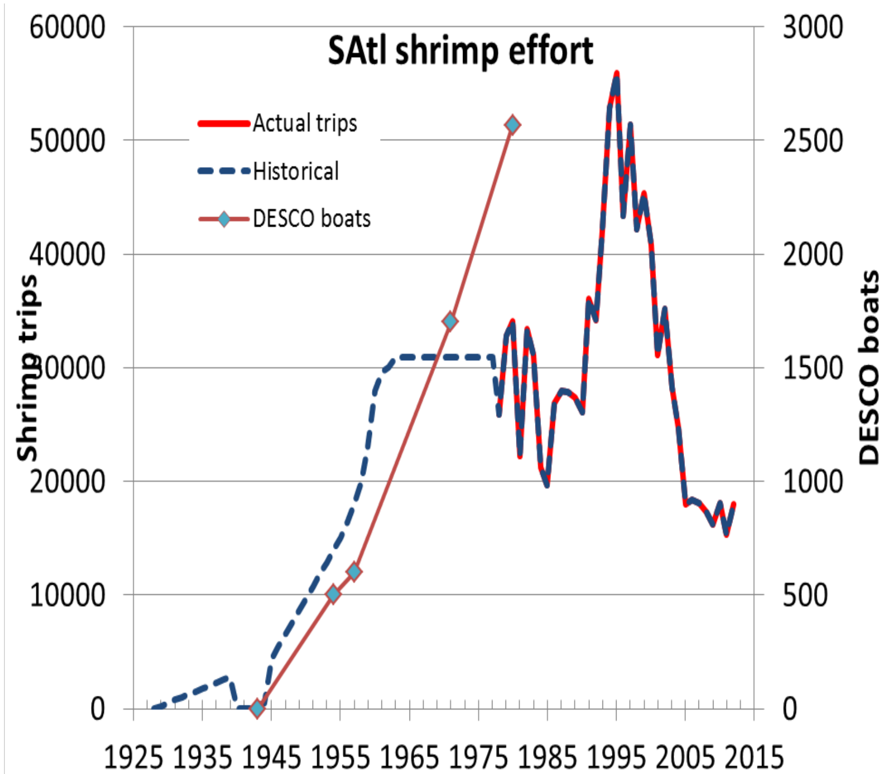



Figure 3.1.2. A. Length-Weight relationship, B. maturity as a function of length, C. fecundity as function of length and D. Spawning output as a function of length (product of maturity and fecundity.

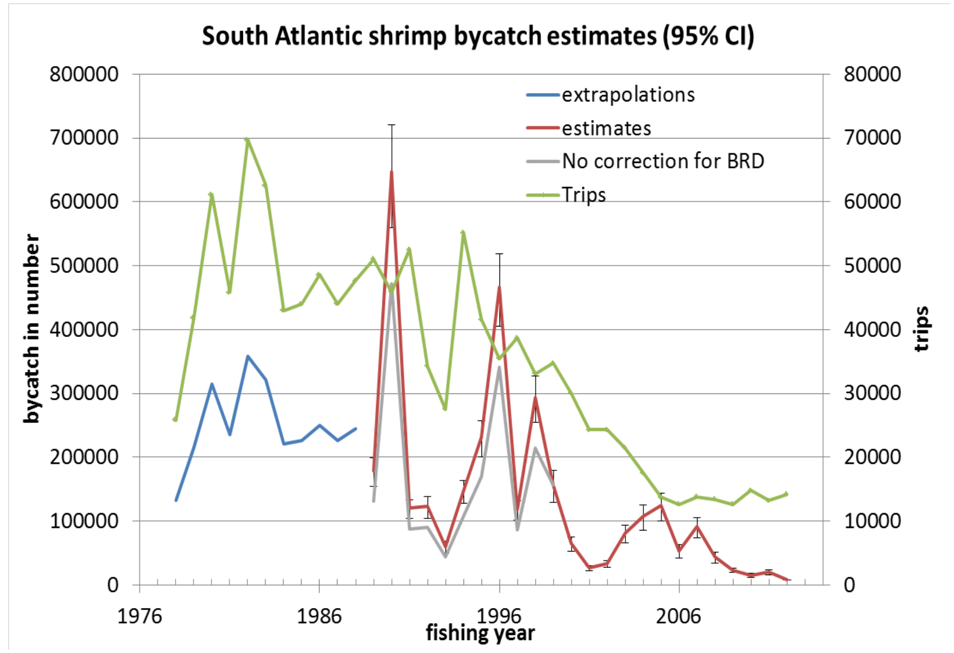
# Shrimp bycatch


1. Vector of shrimp fishing effort




South Atlantic shrimp effort showing historical build up from 1925 and increases after WWII commensurate with boat building in DESCO shipyard: http://www.staugustinelighthouse.org/LAMP/Hertiage_Boatbuilding/

2. Median bycatch in number input to SS (Derived from GLM of BCPUE)

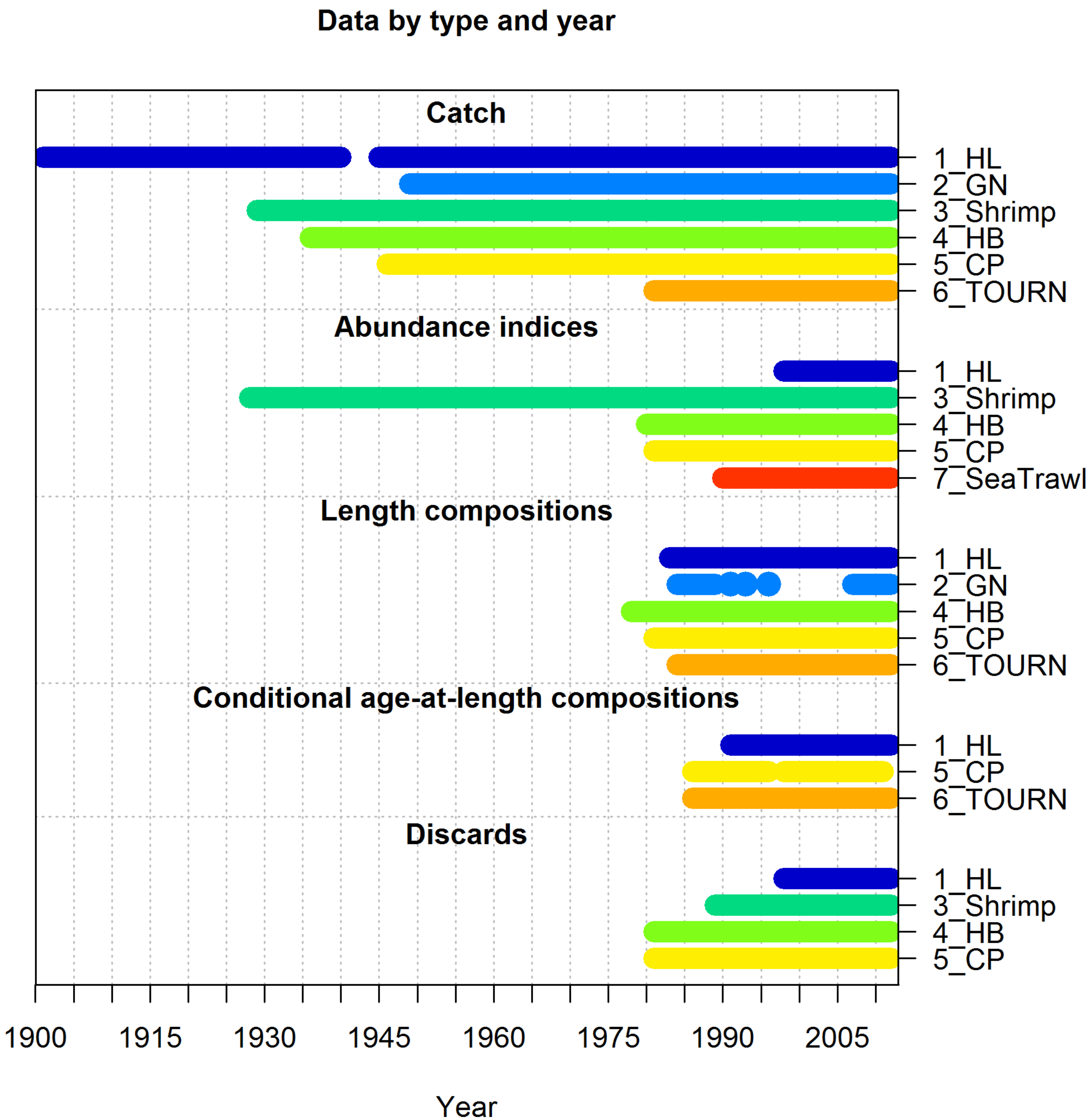



South Atlantic shrimp fishery discards (95%CI) and effort in numbers of trips (green line). Time series in blue is derived from an average catch rate per trip multiplied by the number of trips and are not model-derived estimates. Estimates include correction for a 27% BRD reduction in 1999. The grey line indicates the estimates with no correction.

# Data treatments

- Tournament landings (3% Charter/Private) ramped from 0 in 1980 to 3% from 1991-2012 (FishSmart project estimates tournaments ~3% of rec)
- Outlier fish below size limits removed, primarily for diagnostic purposes
- Shrimp discards input as the median number for 1989-2012: SS “super-year” approach used
- Predicted shrimp fishery discards estimated by fitting to vector of shrimp effort
- Knife edge retention above size limits assumed for other fleets
- Time blocks for change in tournament selectivity in 1997 due to targeting largest single fish
- Time blocks for size limit changes:

| years | inches |
|---|---|
| 1930-1985 | 14 |
| 1990-1991 | 20 |
| 1992-1998 | 24 |



Data by type and year
Catch
1_HL
2_GN
3_Shrimp
4_HB
5_CP
6_TOURN
Abundance indices
1_HL
3_Shrimp
4_HB
5_CP
7_SeaTrawl
Length compositions
1_HL
2_GN
4_HB
5_CP
6_TOURN
Conditional age-at-length compositions
1_HL
5_CP
6_TOURN
Discards
1_HL
3_Shrimp
4_HB
5_CP
1900
1915
1930
1945
1960
1975
1990
2005
Year


# III. SS Atlantic model results

# Model diagnostics, jitter start values

Some alternate solutions, but the range of estimated parameters is very low.

This is due to the relatively high CV on >50% of the removals

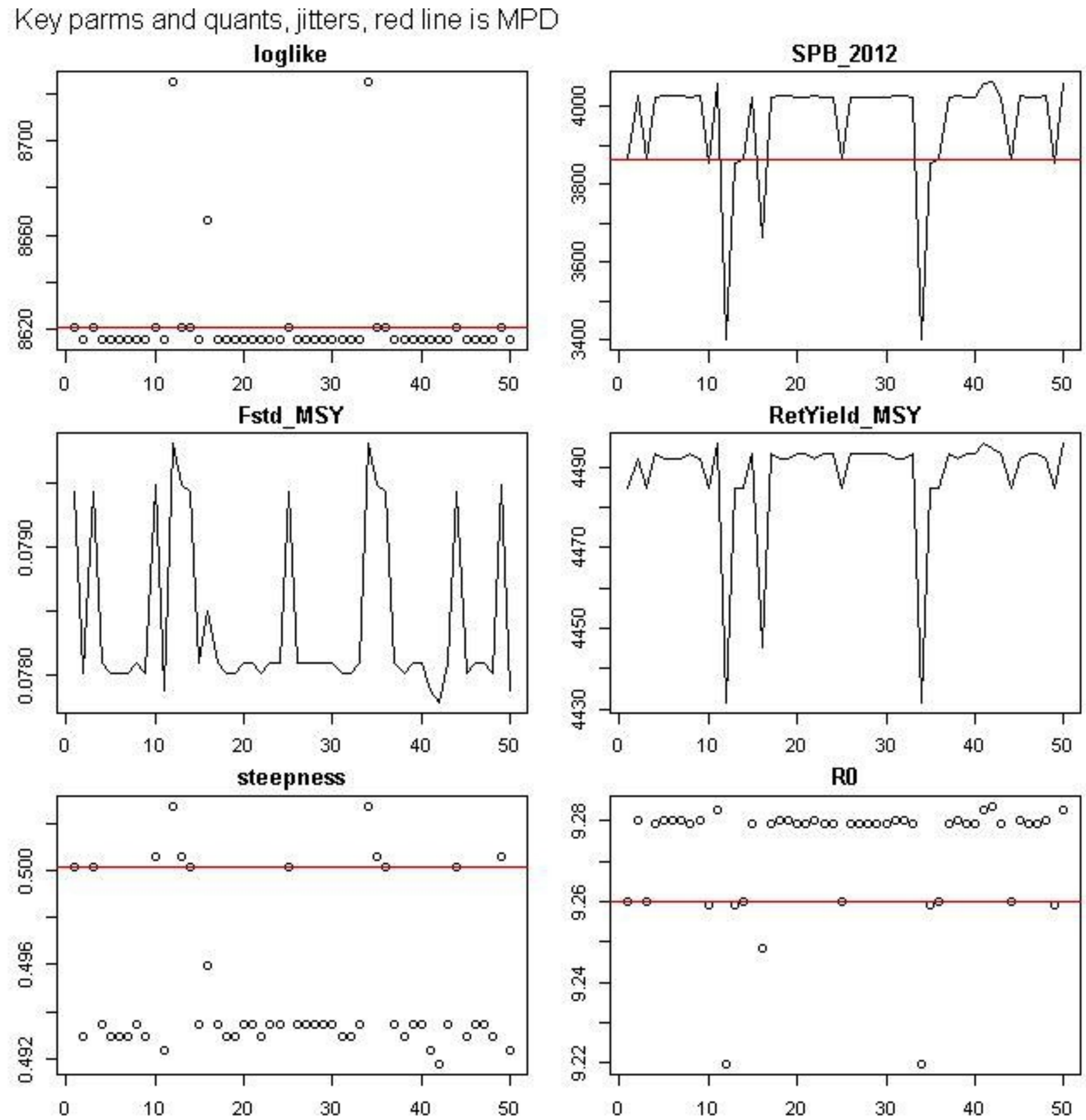



Figure 3.2.1. Analysis of results of jittering starting values by 10%. Red line is maximum posterior density estimate.

# Model diagnostics jitter start values

Population level impacts are minor, however

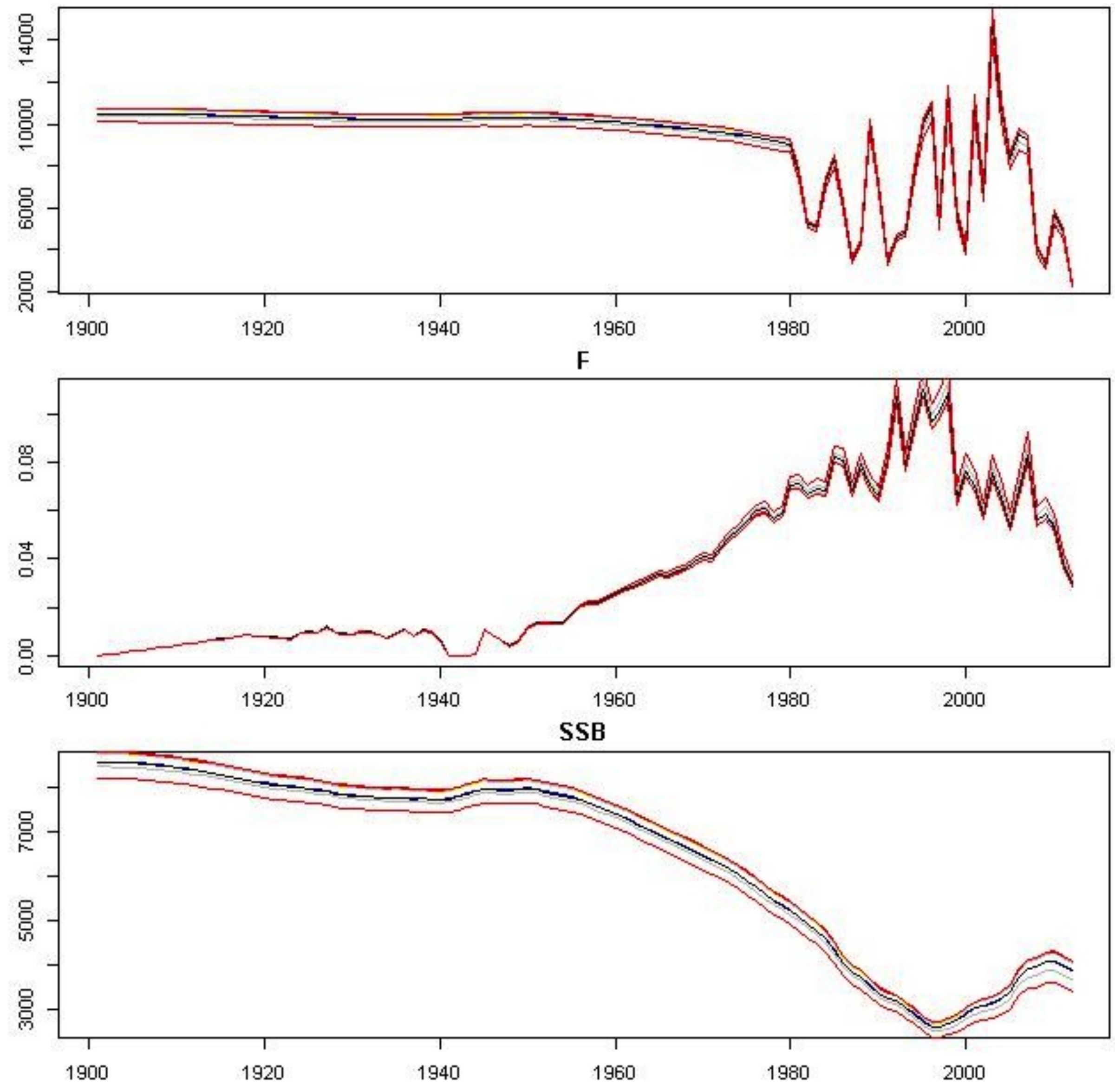



Figure 3.2.2. Time series of jitter runs.

# Model diagnostics, likelihood profile on R0

Evaluate influence of each likelihood component on key parms

Fairly well estimated
Some conflict between the age (high R0) and the length data (lower R0)

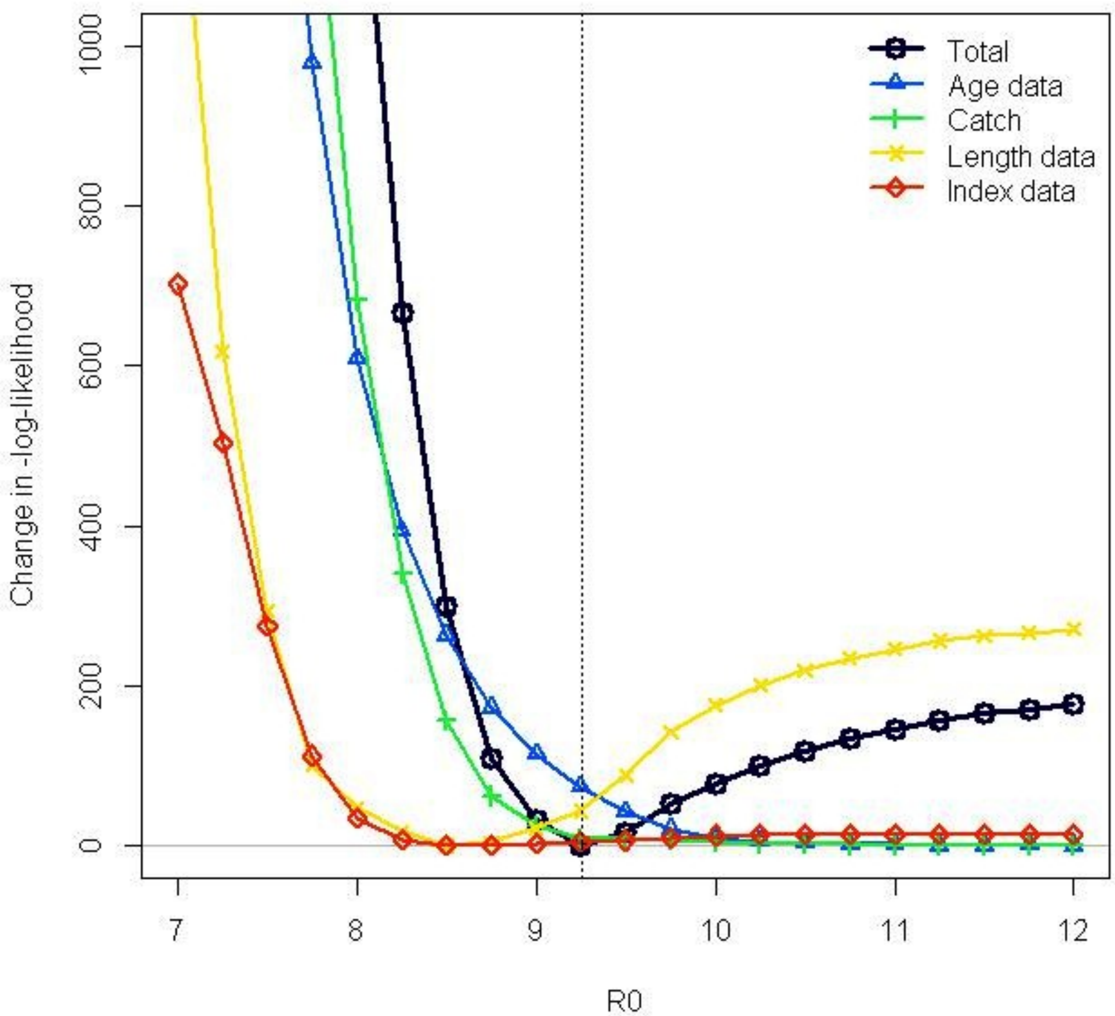



Figure 3.2.4. Likelihood profile for virgin recruitment. The dotted line represents the point estimate from the base model. The values represent the change in negative log-likelihood, by component.

# Model diagnostics, likelihood profile on steepness

Conflict between the age and the length data

Fairly strong evidence that steepness is not at upper bound

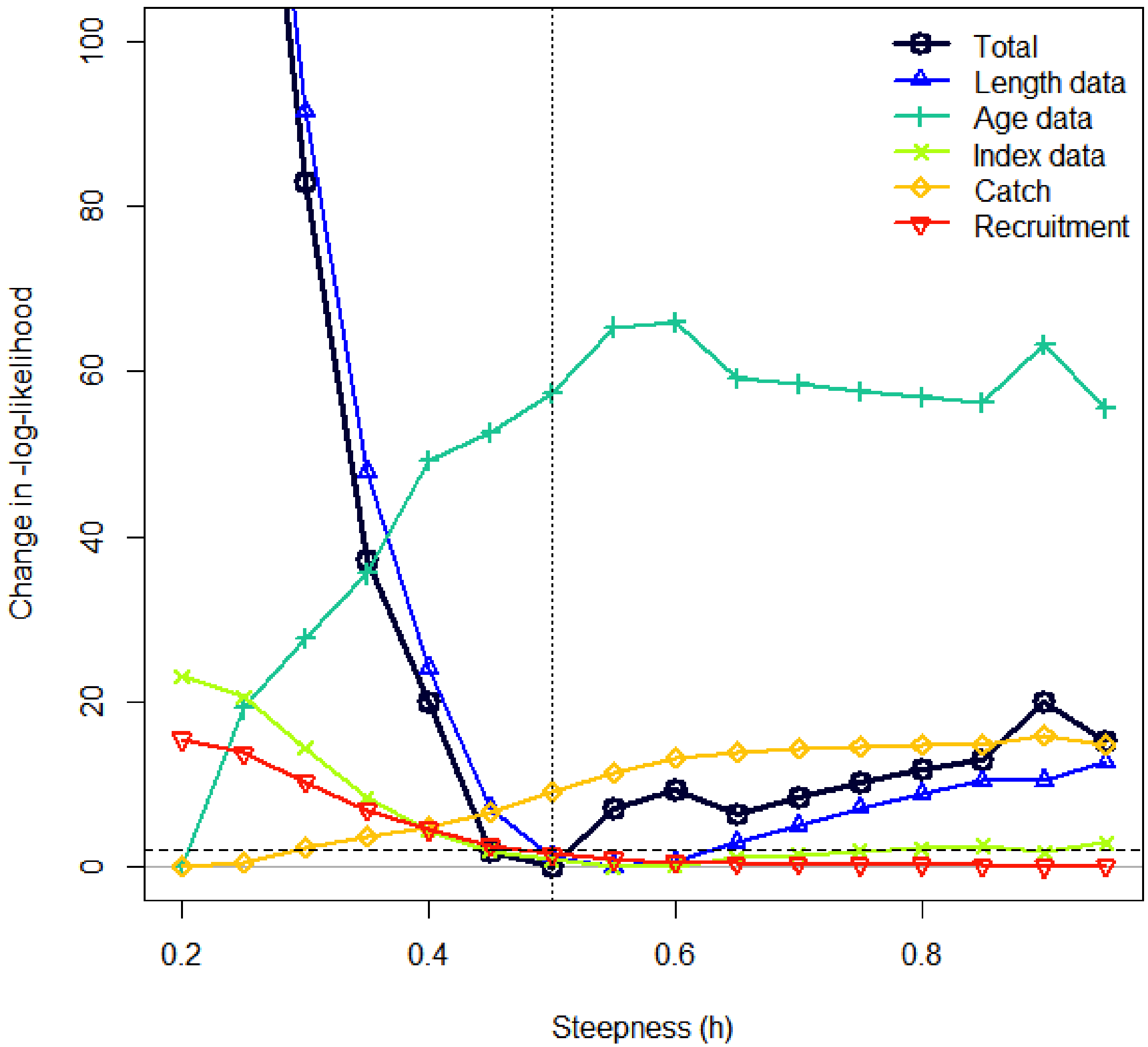
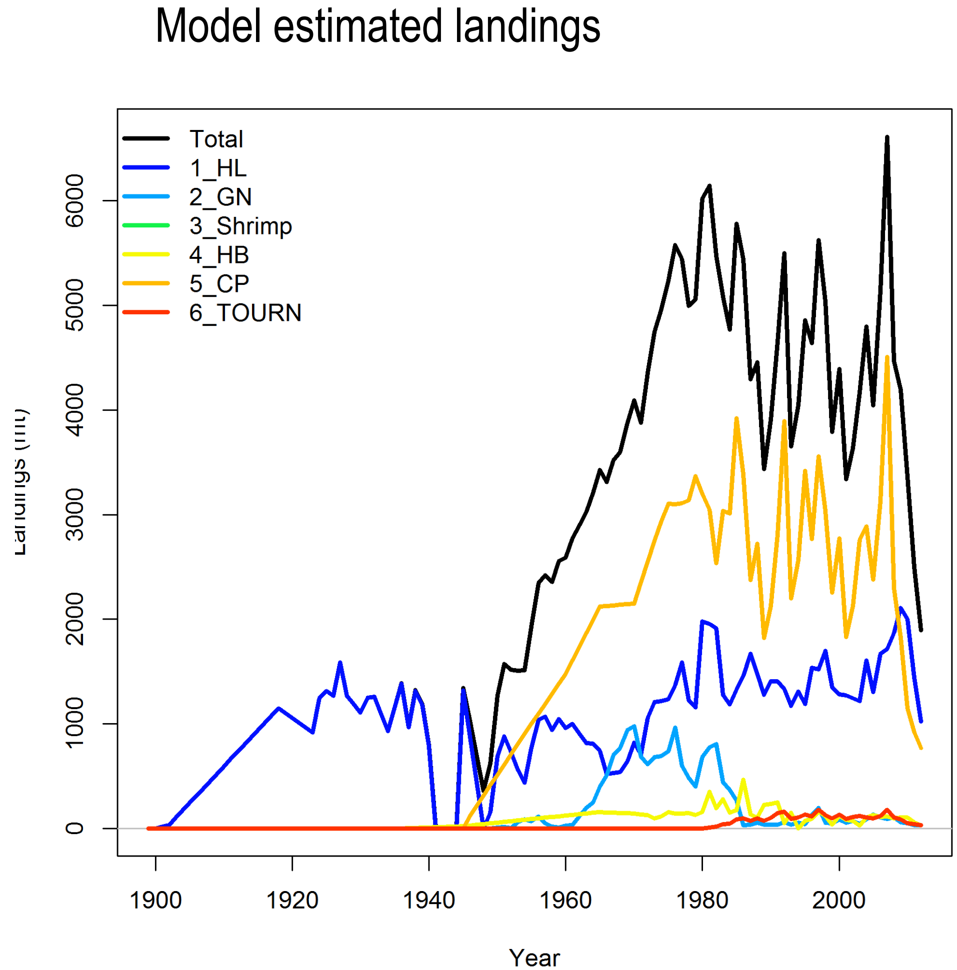



Figure 3.2.3. Likelihood profile for Beverton-Holt steepness. The dotted line represents the point estimate from the base model. The values represent the change in negative log-likelihood, by component.

# Landings and F by fleet



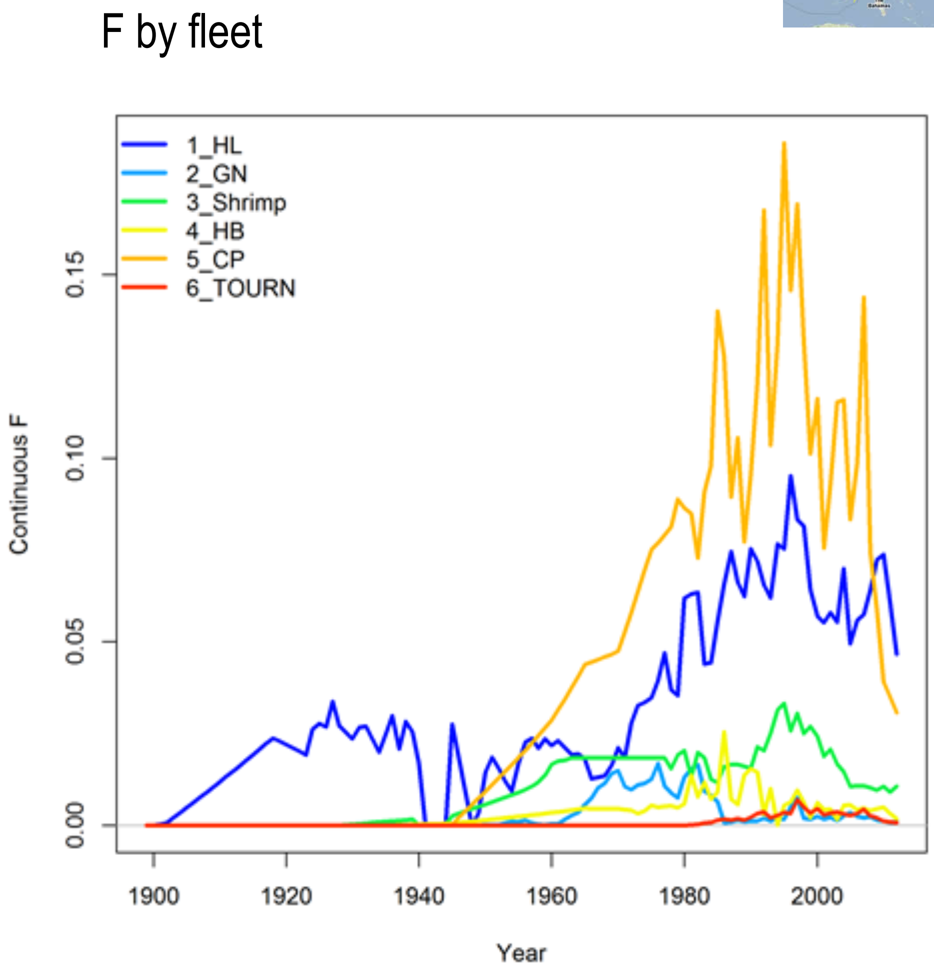
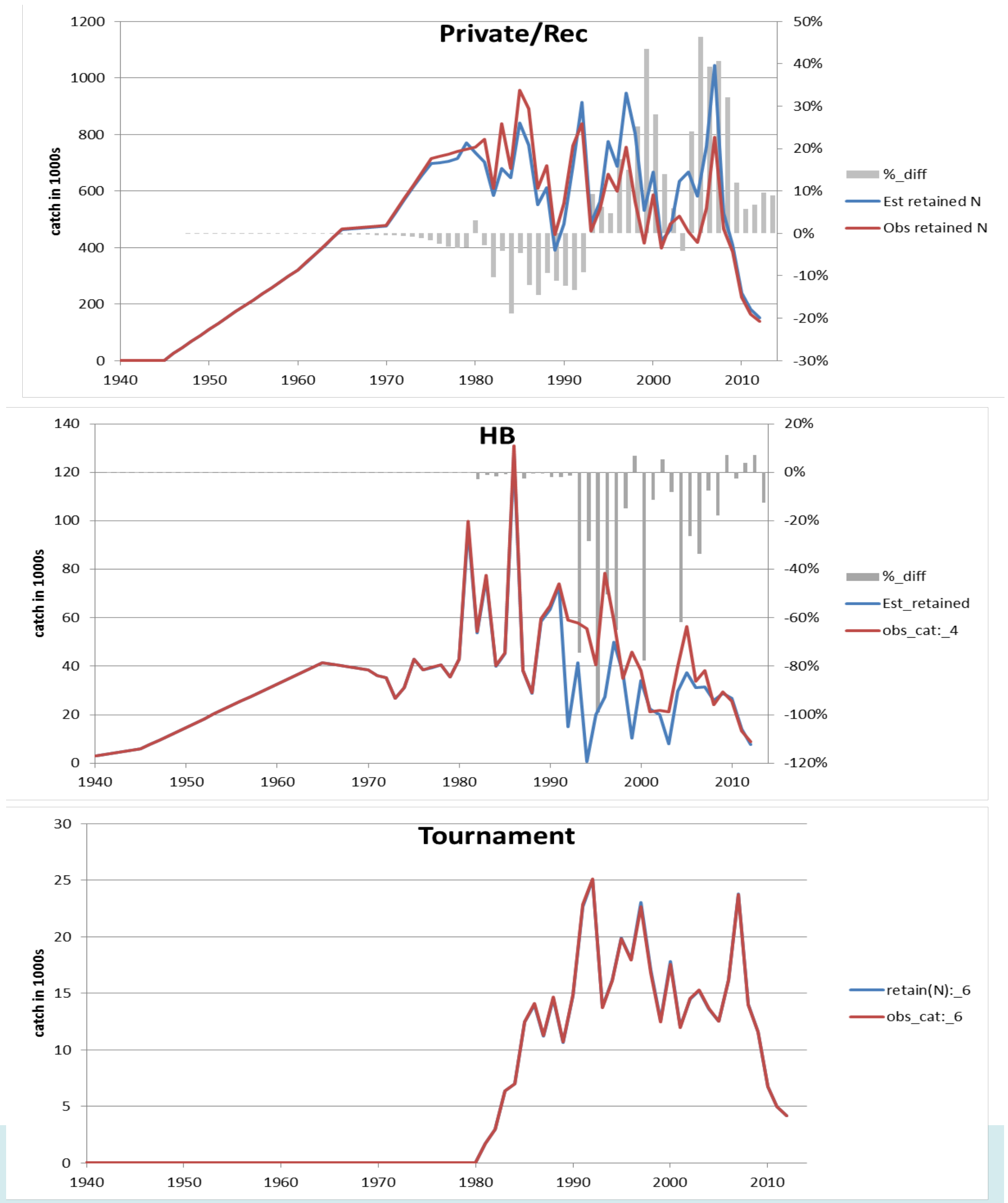




Figure 3.2.6. Model estimated landings by fleet and year.

# Fits to catch

- Figure 3.2.5. Observed (red) versus estimated (blue) retained catch.
- 20% CV on the input catch.
- Bars on are % diff

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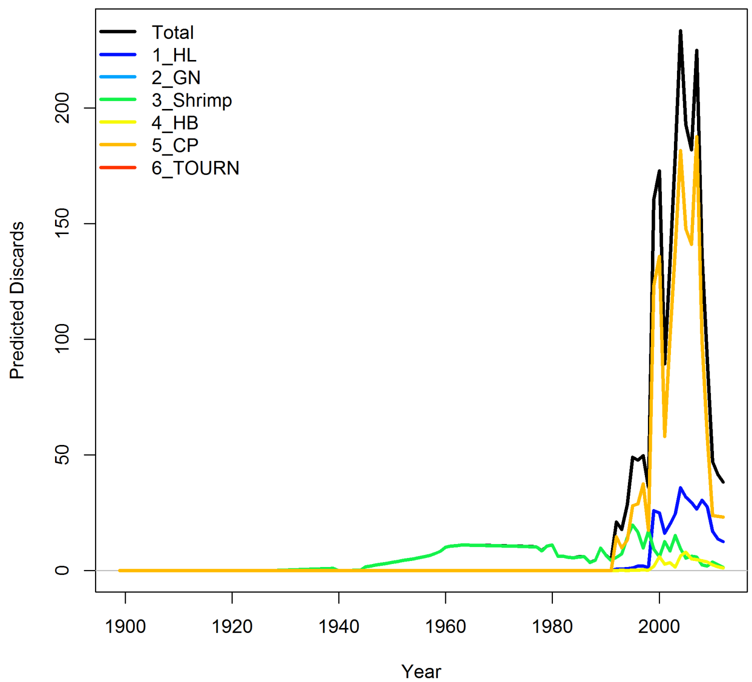
# Discards




## Fits to discards

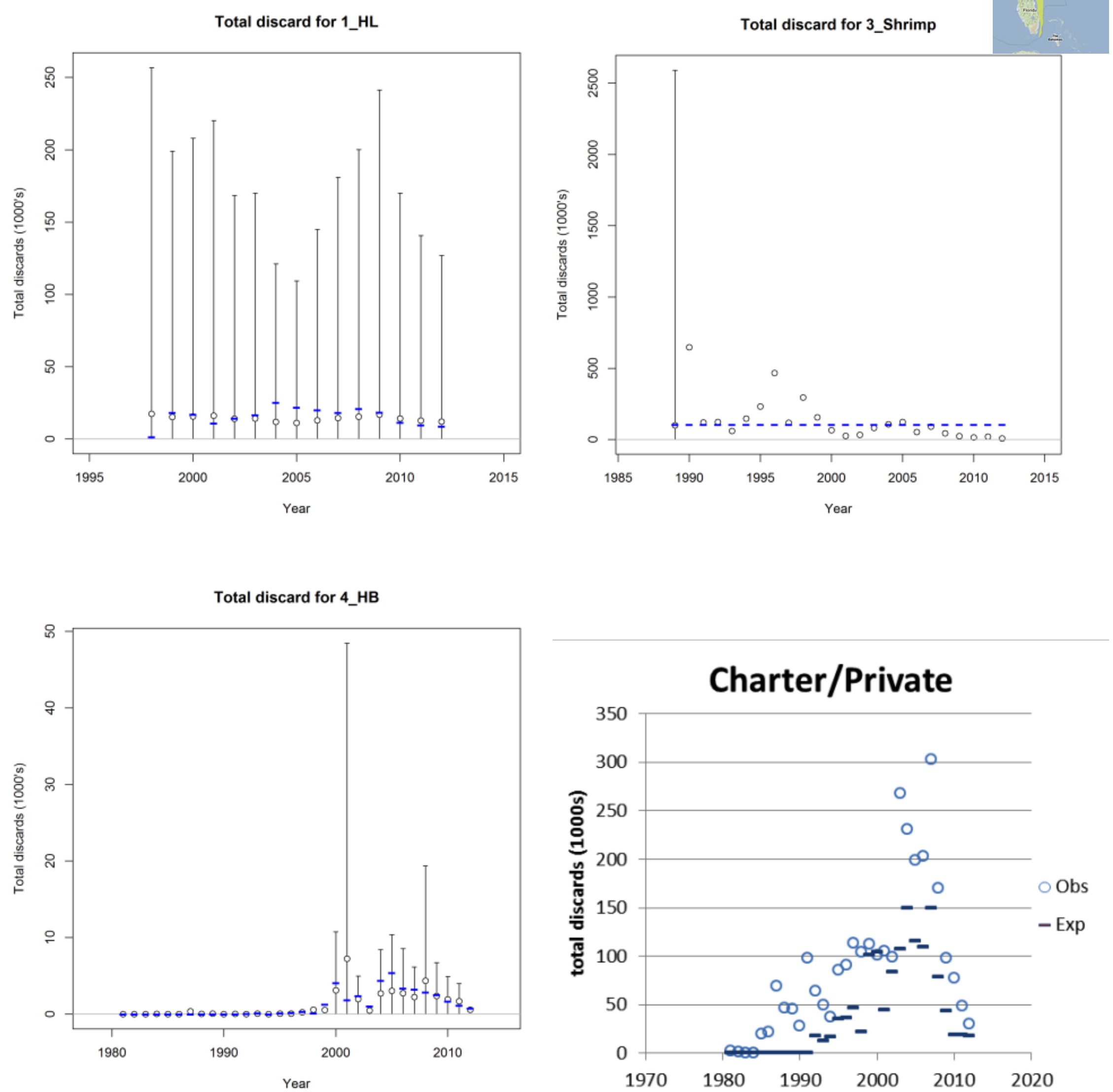
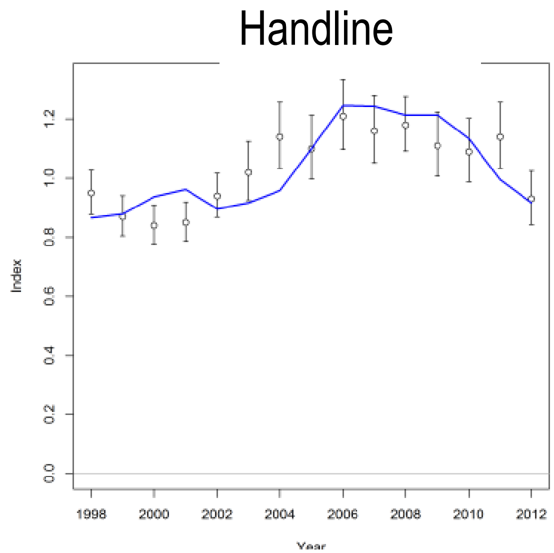


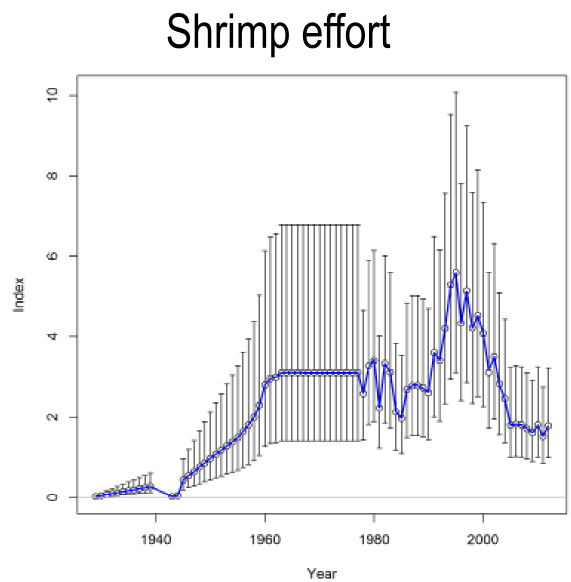

Figure 3.2.8. Observed (open circles) and predicted discards (blue dashes) (mt) of South Atlantic King Mackerel from the commercial handline line fishing fleet, shrimp bycatch, headboat and charter/private fleets.

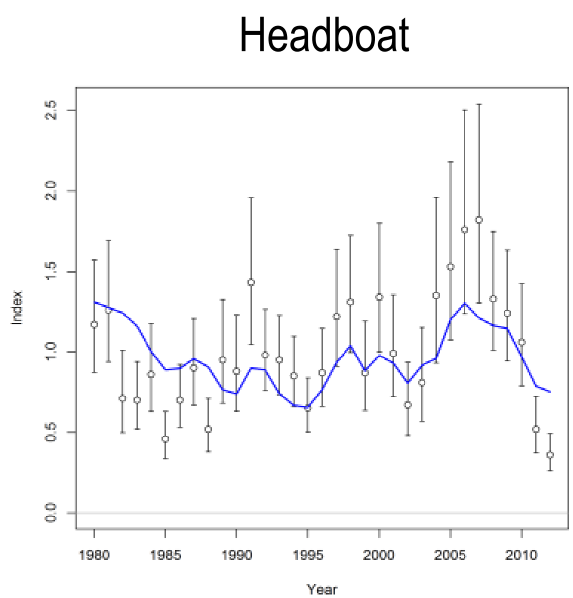
# Fits to indices

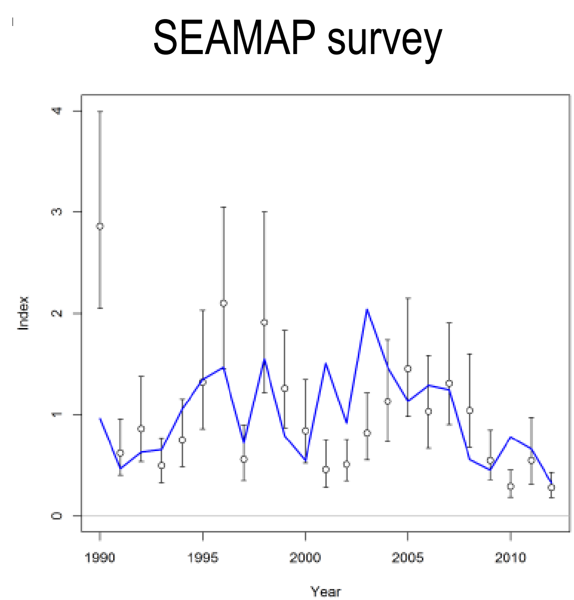
Shrimp effort not strictly a 'survey'

Error bars are 95% CI



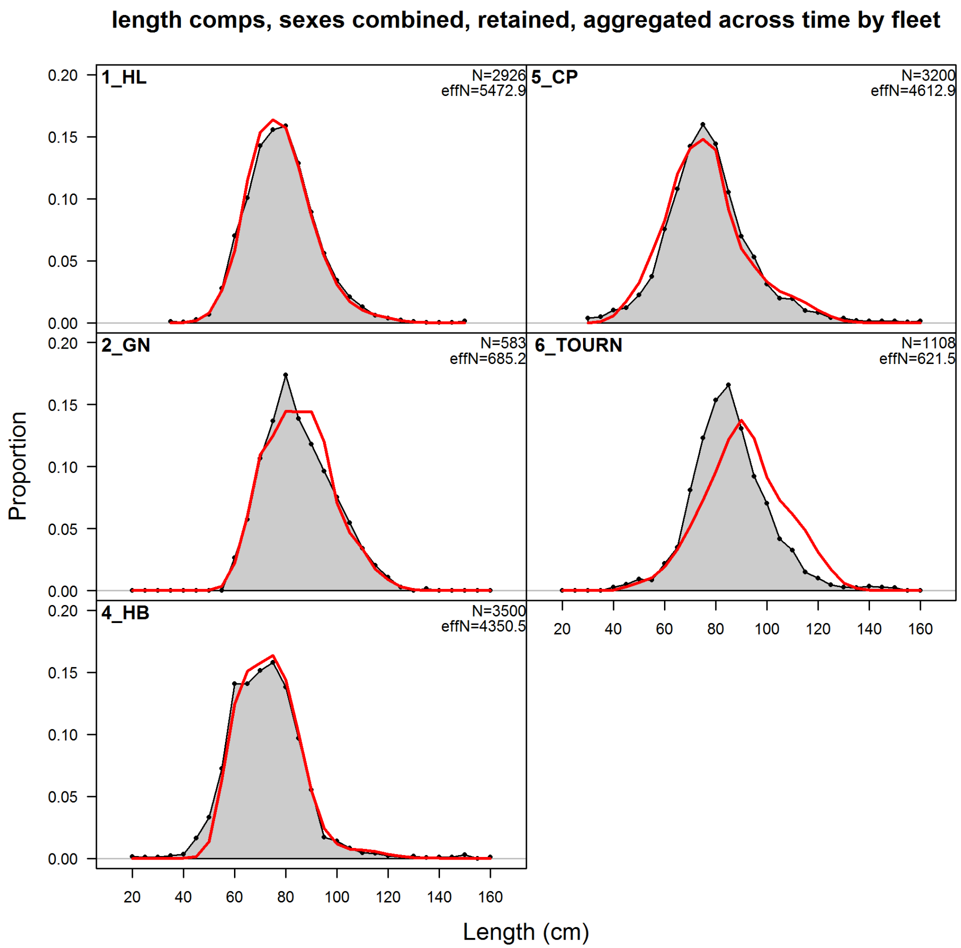



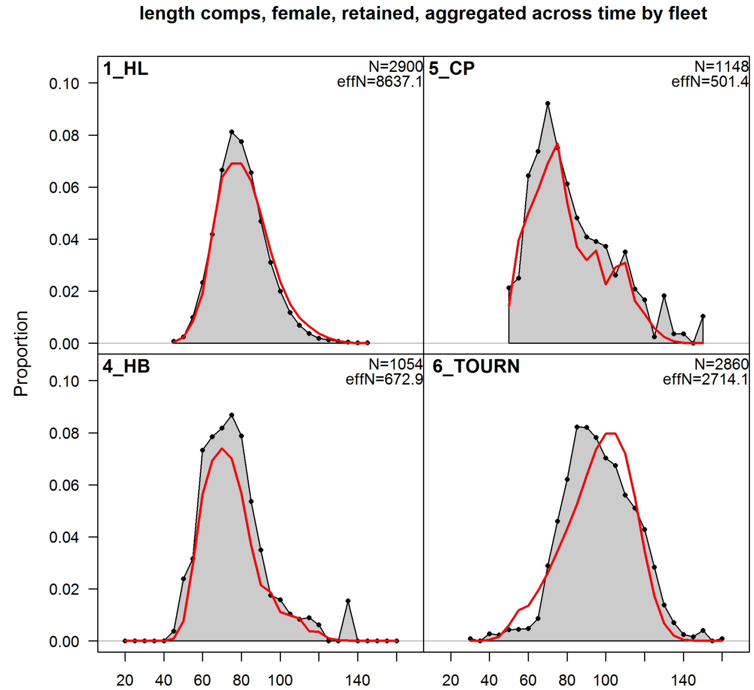



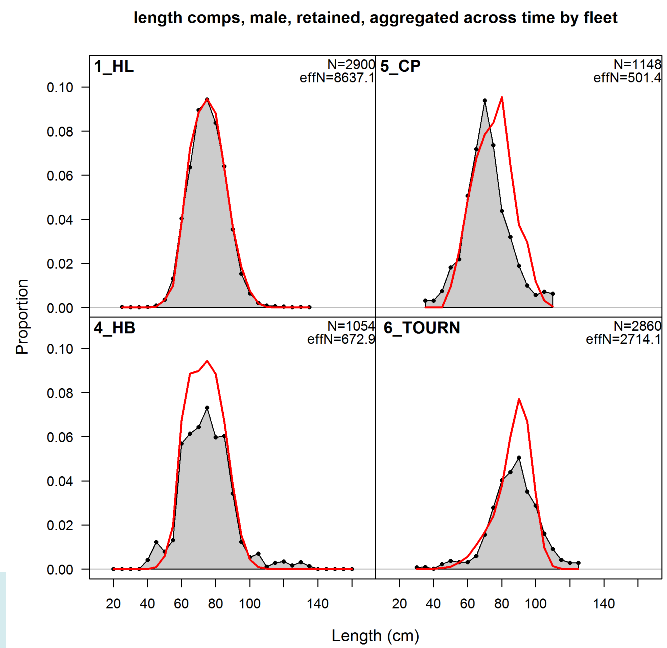
# Fits to length comps

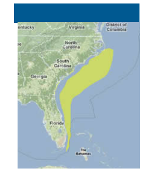
Red is expected




Full comp output is listed as extra material at end of presentation



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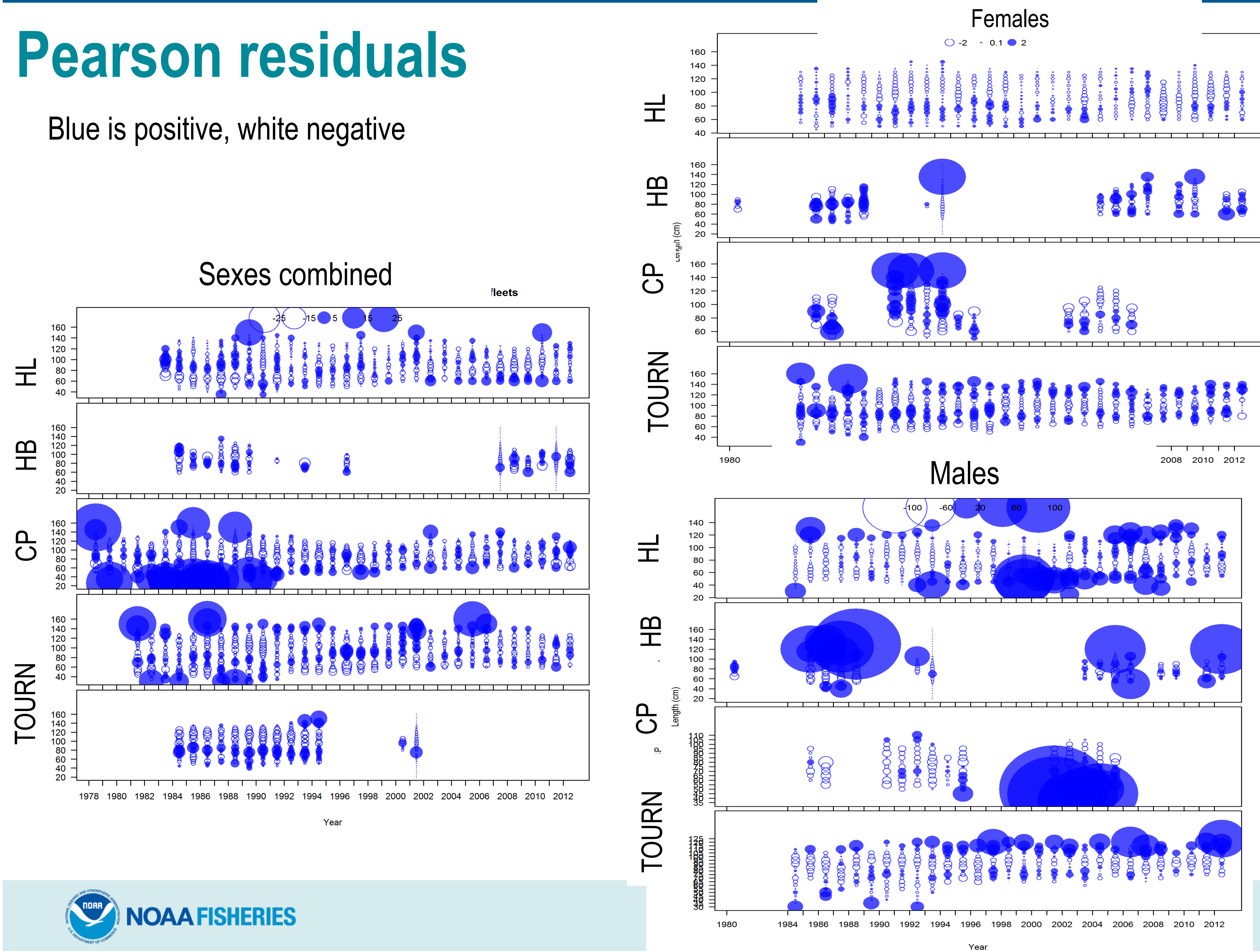
# Pearson residuals

Blue is positive, white negative



# Age composition data (modeled as conditional age at length, similar to age-length key)

Left: Observed (black) and expected (blue) length at age with 90% intervals

Right: Observed and expected standard deviation of age at length

constant CV of 0.1 at age

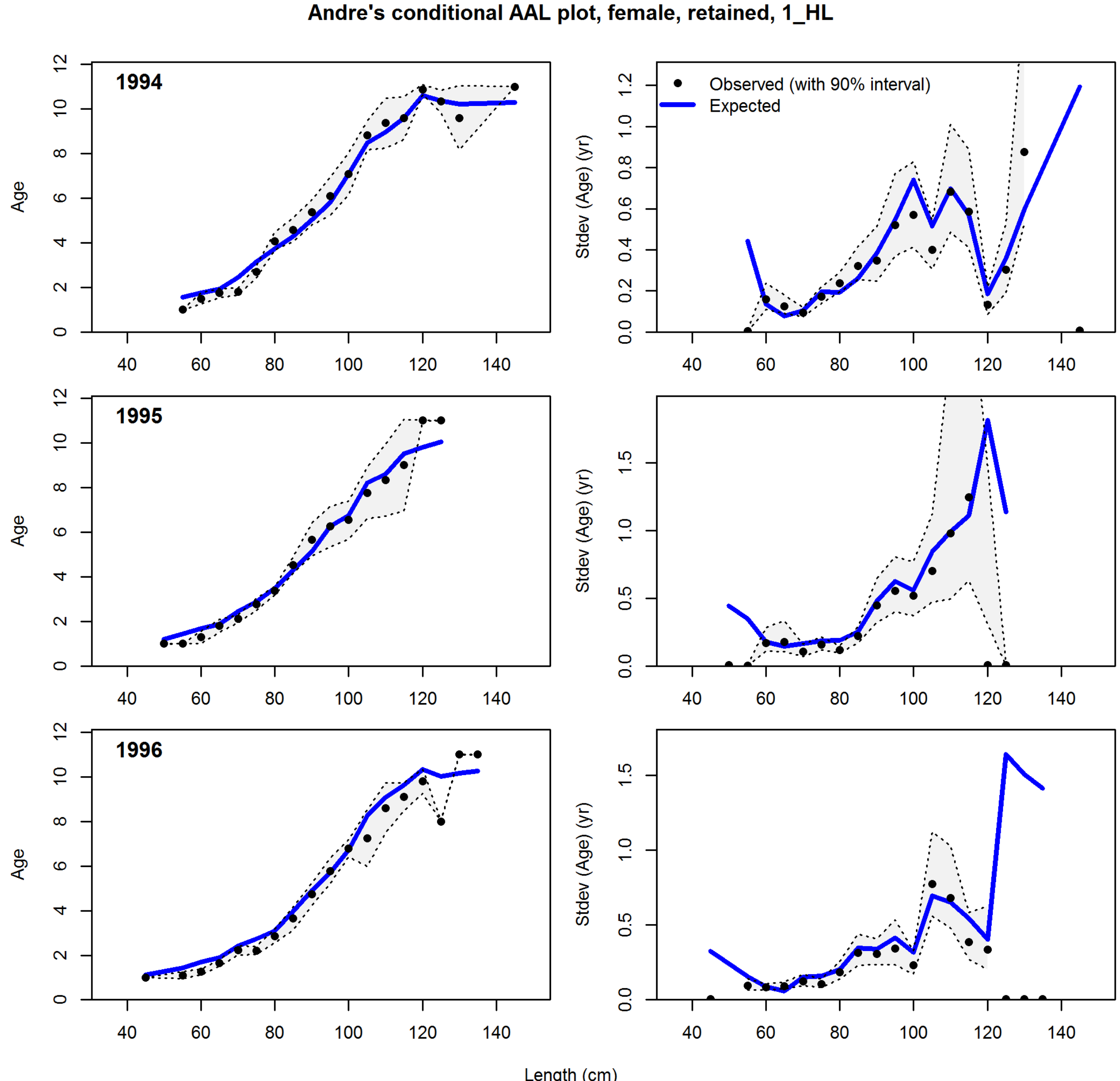



Figure 3.3.24. Observed and expected female handline mean age-at-length with 90% intervals about observed age at length (left panels) and observed and expected standard deviation in age-at-length (right panels). The years 1994-1996 were chosen randomly for illustrative purposes.

# Selectivities

Tournament modeled as logistic

All others are double normal models

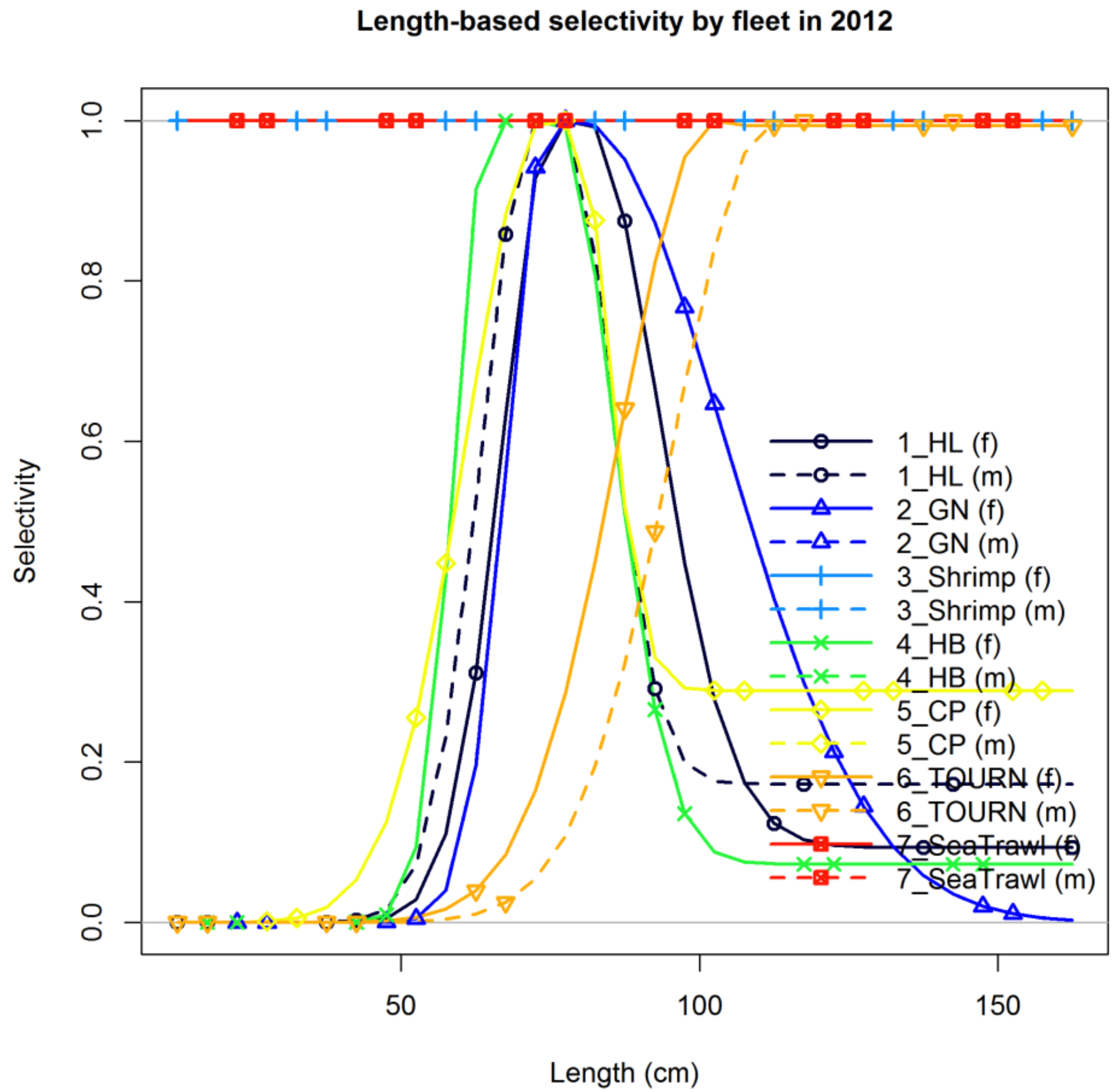
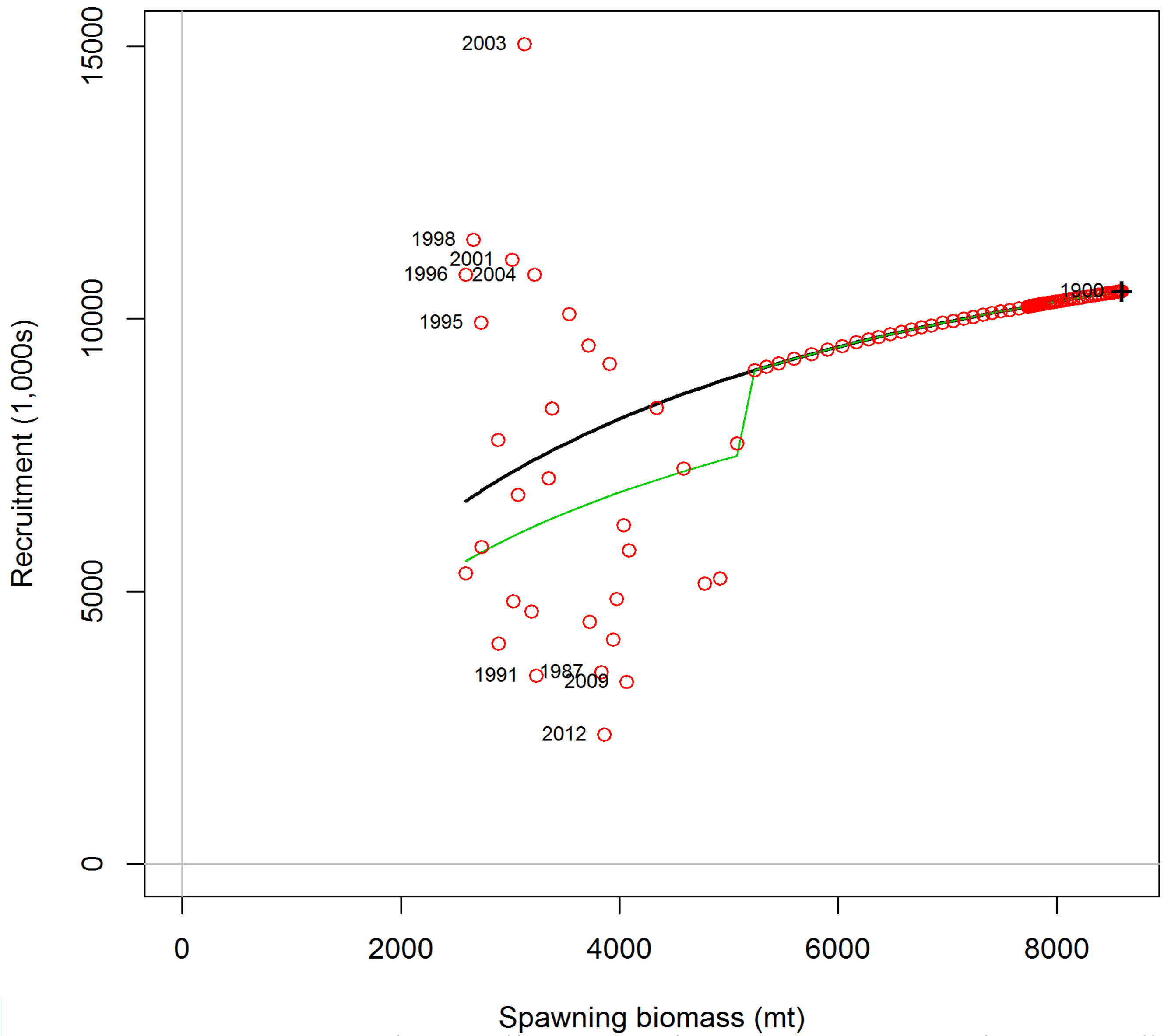



Figure 3.3.25. Estimated fleet selectivities-at-length by fleet and sex.

# Stock recruitment relationship

Beverton-holt model, steepness estimated 0.50 (sd= 0.03)

Ricker model tested but 1.4 logLik points worse

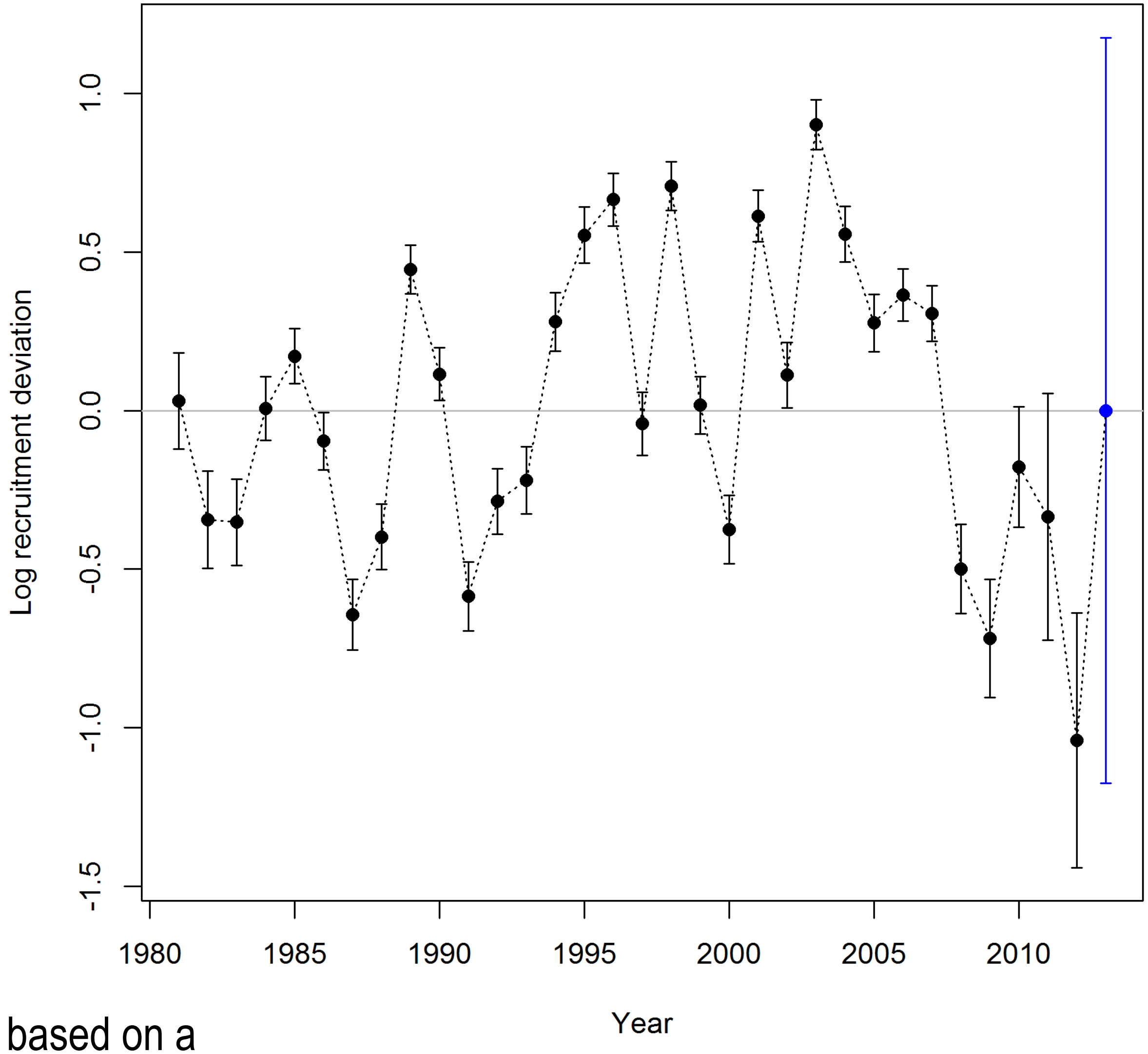


# Recruitment deviations

Estimated to sum to zero, min/max (-5,5)

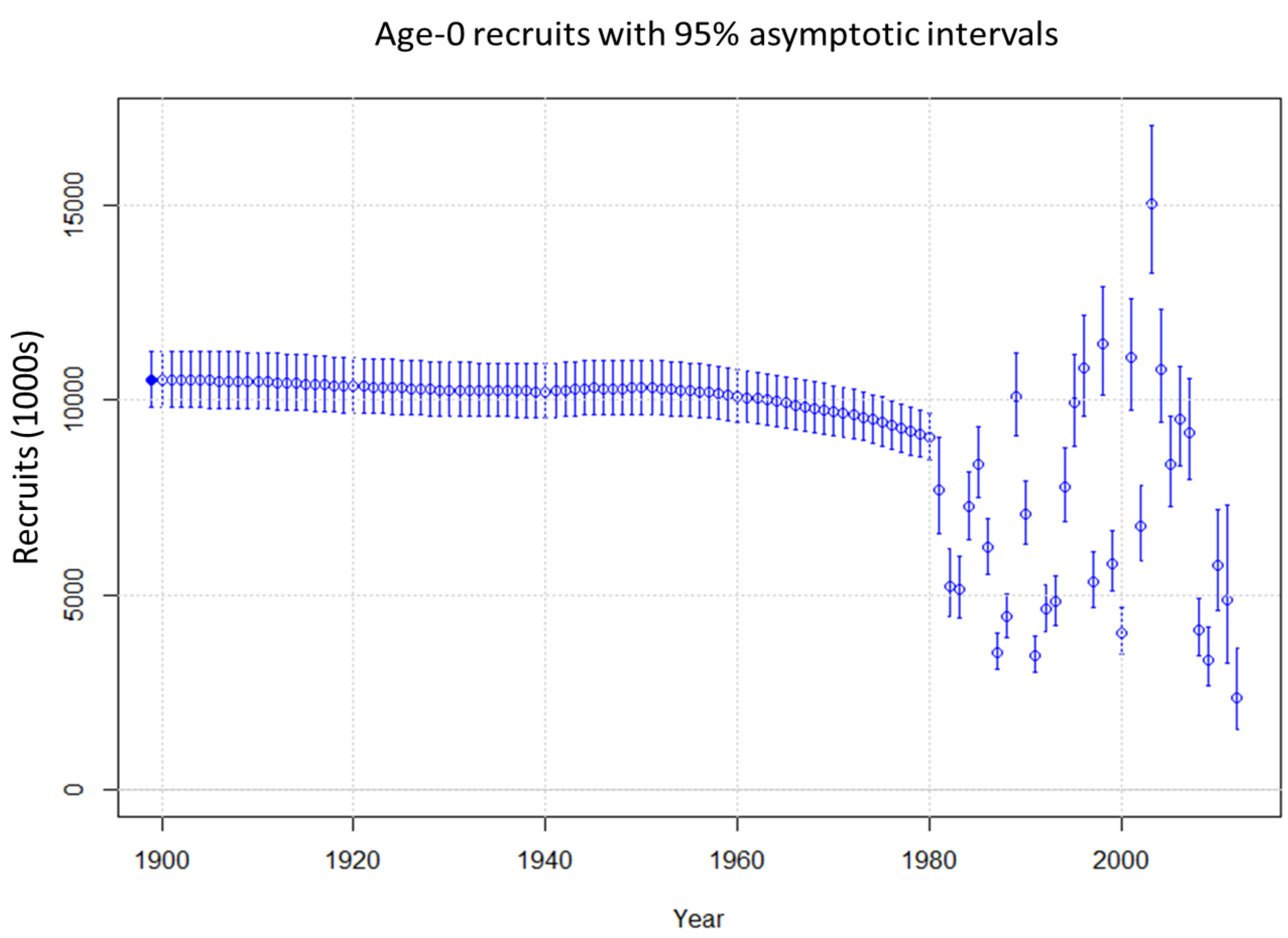
Assumed to be N(0,0.6)

Sigma r fixed at 0.6


*2013 point is future prediction based on a recruitment deviation of zero.

# Recruitment




# SSB and total biomass

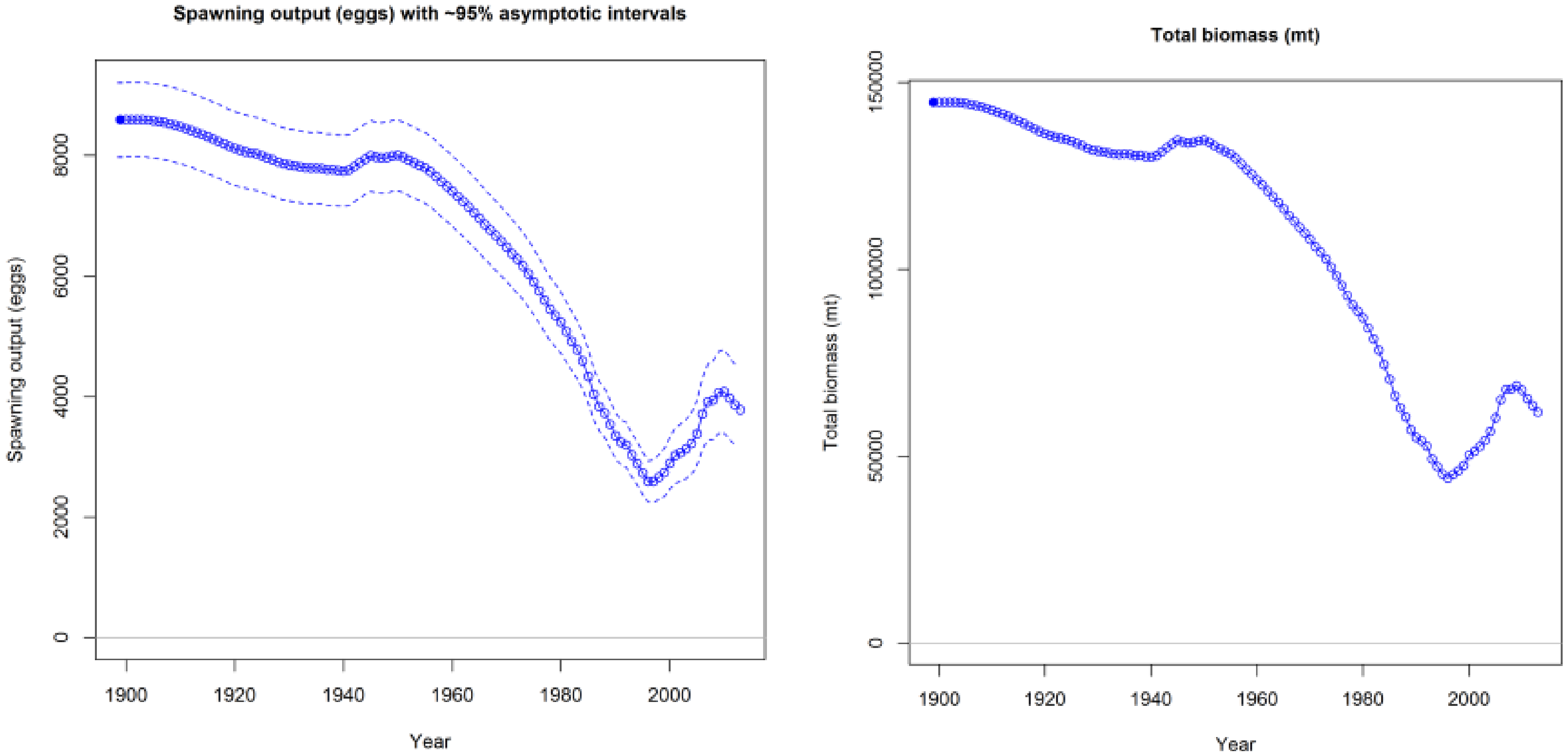
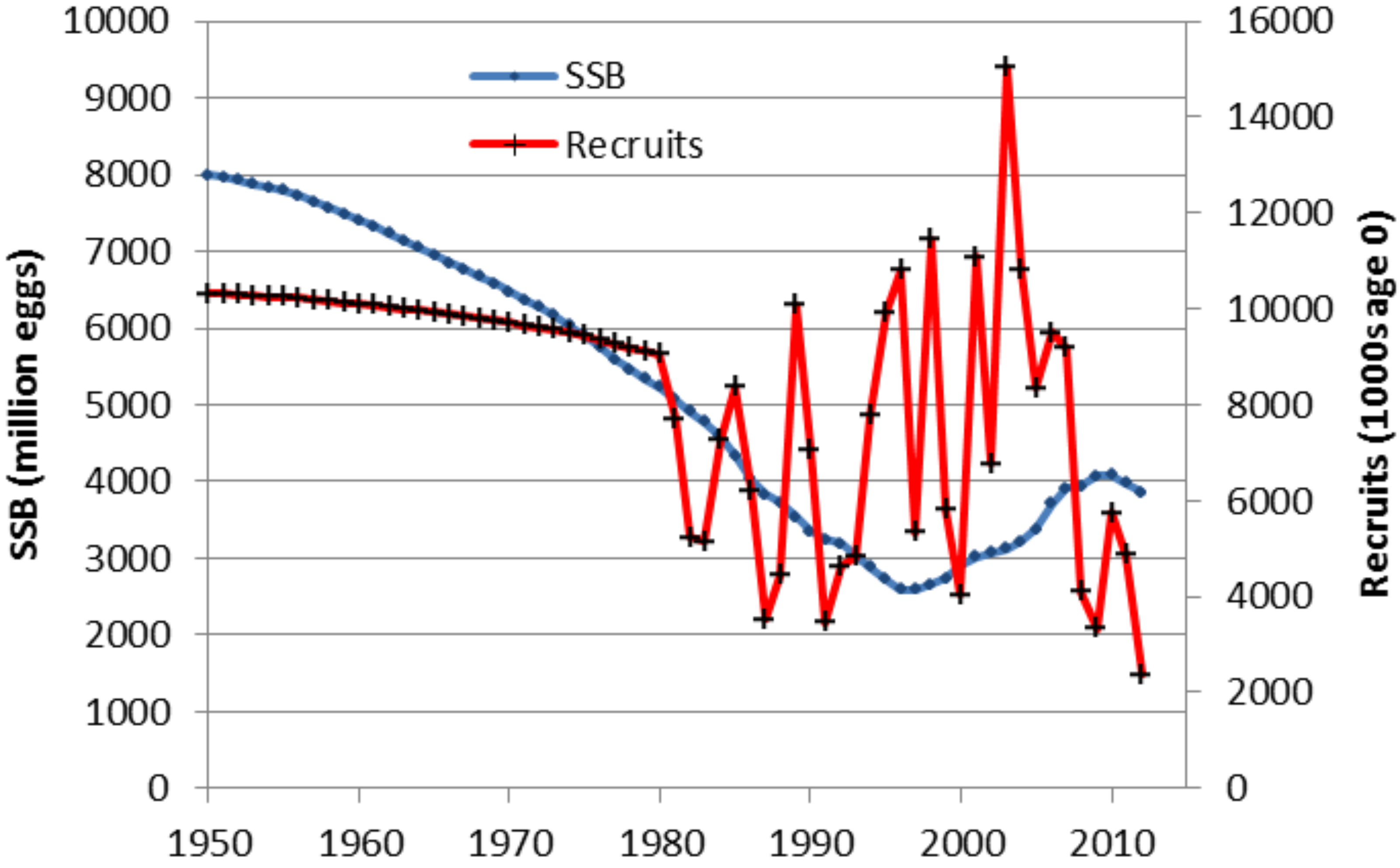



Figure 3.2.34. Predicted spawning biomass (female eggs in millions) with 95% CI and total biomass in whole metric tons.

# SSB and recruits



# Numbers at age

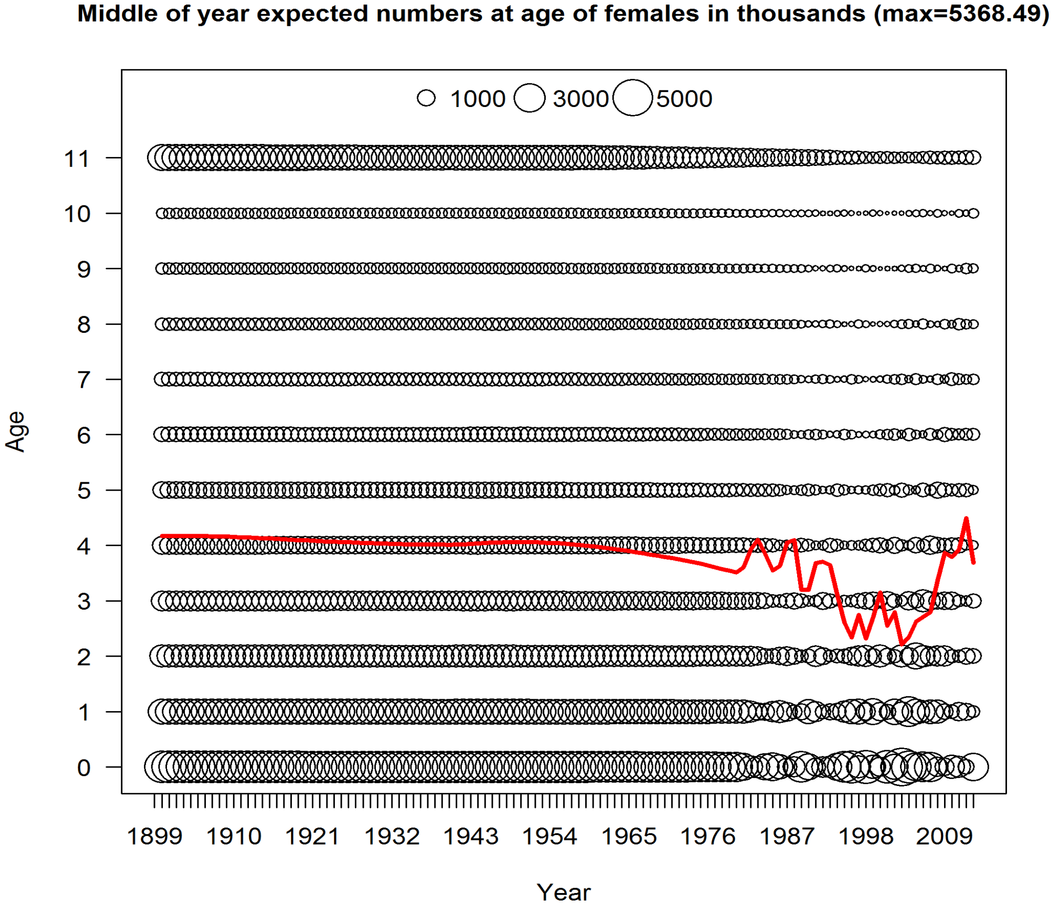
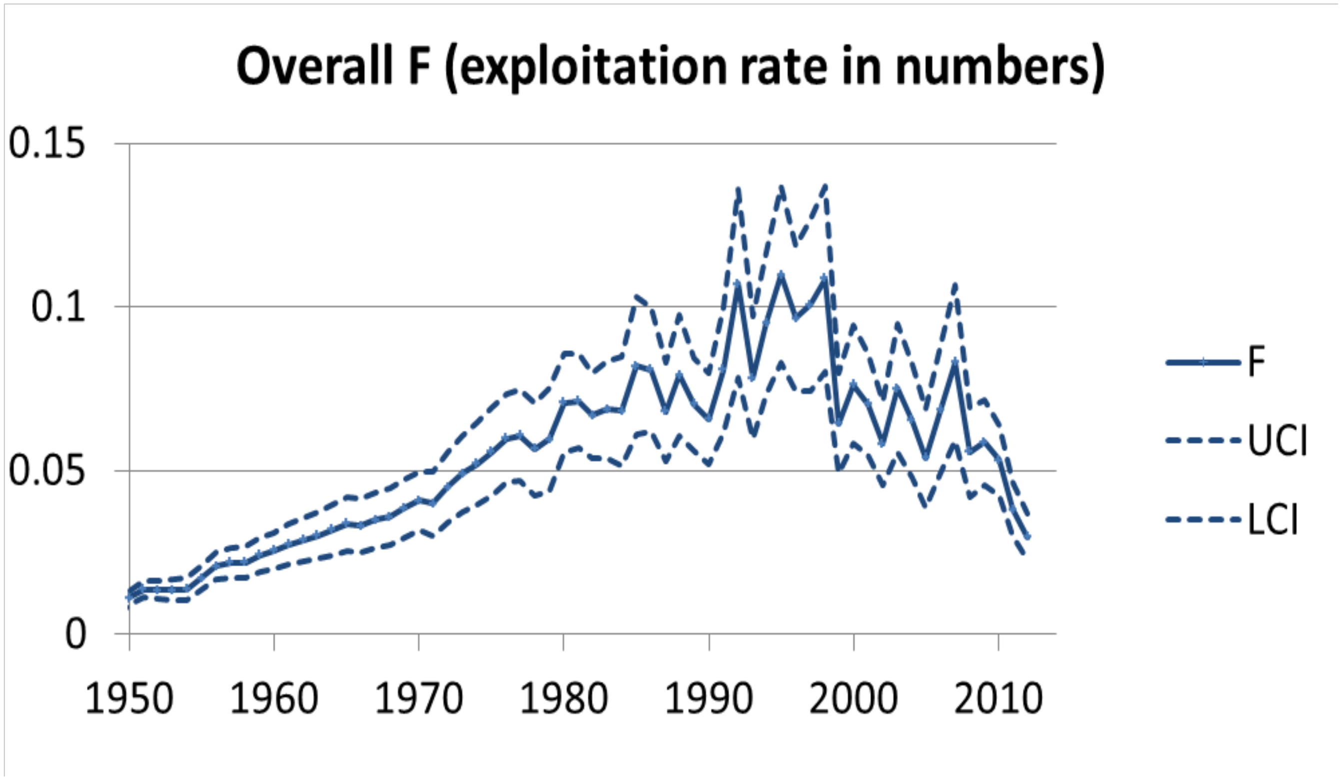
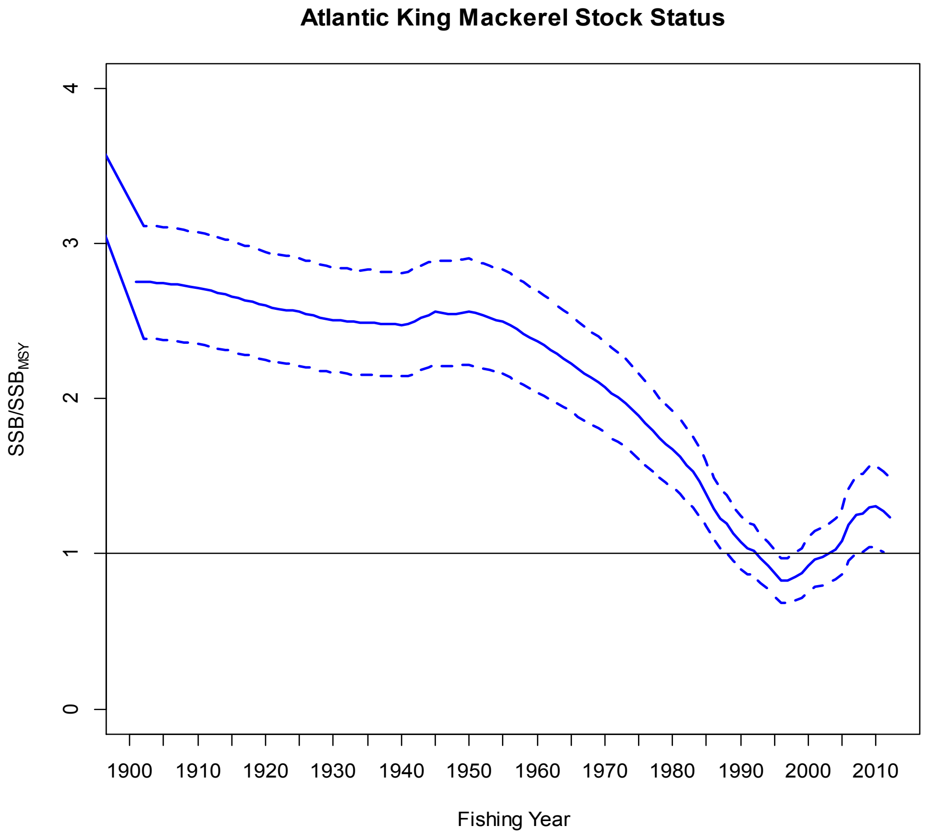


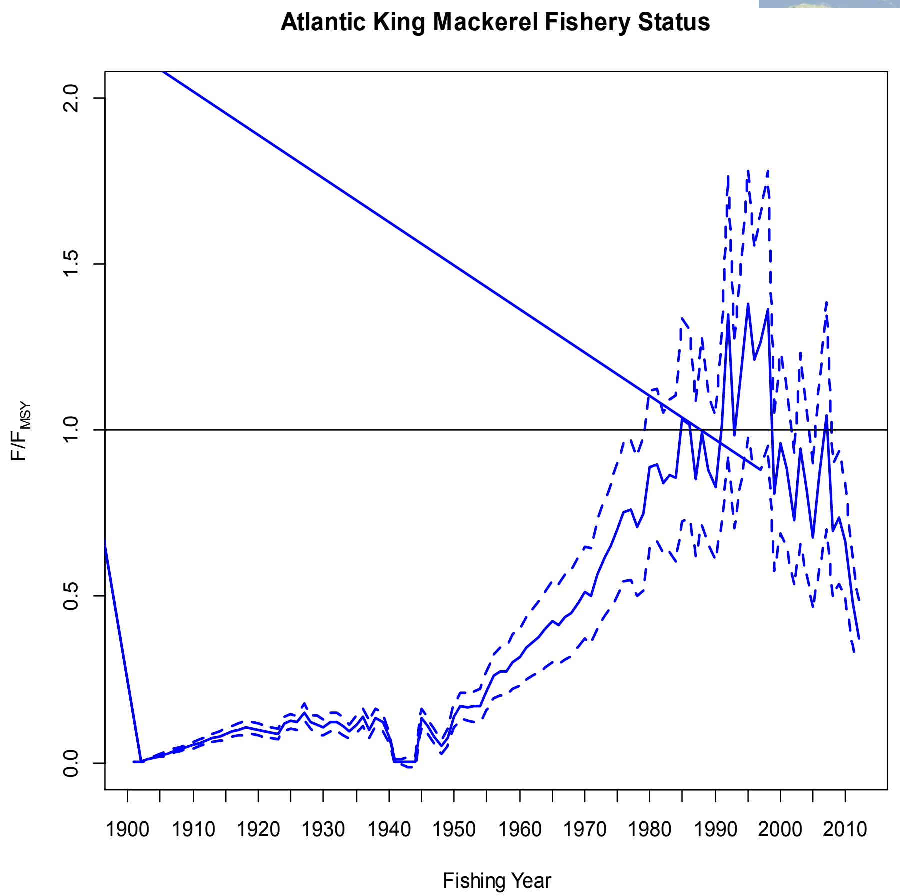

Figure 3.2.36. Predicted female numbers-at-age (bubbles) and mean age (red line).

# Exploitation rate



# Stock status, relative to $SSB_{msy}$ and $F_{msy}$



# Benchmarks, base model

| parameter/derived quantity | 4. BASE | SE |
|---|---|---|
| SR_LN(R0) | 9.26 | 0.04 |
| SR_BH_steep | 0.50 | 0.03 |
| SSB_Unfished | 8596 | 314 |
| TotBio_Unfished | 144664 | 5247 |
| Recr_Unfished | 10508 | 371 |
| SSB_BB40% | 3438 | 126 |
| SPR_BB40% | 0.55 | 0.02 |
| Fstd_BB40% | 0.07 | 0.004 |
| TotYield_B40% | 4461 | 208 |
| SSB_SPRB40% | 1720 | 212 |
| Fstd_SPR40% | 0.12 | 0.00 |
| TotYield_SPRB40% | 3871 | 472 |
| SSB_MSY | 3123 | 178 |
| SPR_MSY | 0.52 | 0.02 |
| Fstd_MSY | 0.08 | 0.01 |
| TotYield_MSY | 4484.7 | 219.6 |
| RetYield_MSY | 4446.2 | 216.8 |

# III. SS Atlantic model sensitivity runs

1. Indices only
2. Indices and length composition
3. Indices, length composition and conditional age at length
4. Base model

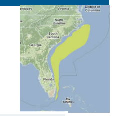
5/6. Natural mortality rate

7. Removing tournament data
8. Equal index weighting
9. low CV on recreational landings
10. Jack-knife of abundance indices
11. Retrospective analysis

# Likelihood components

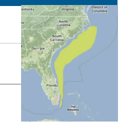
| | 1. ind only | 2. ind and length | 3. Indices, length and age | 4. BASE | 5. HiM | 6. LoM | 7. No Tourn ament | 8. Index = wt | 9. Low error on catch |
|---|---|---|---|---|---|---|---|---|---|
| max grad component | 3.054 | 0.077 | 1.739 | 0.023 | 0.073 | 1.501 | 0.217 | 0.276 | 0.271 |
| LIKELIHOOD | -180.13 | 4086 | 9448 | 8621 | 8610 | 8689 | 4764 | 9028 | 8976 |
| Catch | 0.0 | 1.4 | 2.1 | 140.3 | 132.1 | 152.4 | 137.2 | 2.1 | 2.1 |
| Survey | -176.9 | -62.8 | -68.0 | -65.4 | -52.8 | -74.3 | -72.1 | -22.4 | -62.6 |
| Discard | - | 233.8 | 262.9 | 149.7 | 151.8 | 148.2 | 153.8 | 264.2 | 263.6 |
| Length_comp | - | 3910.1 | 3521.9 | 2826.4 | 2852.7 | 2846.3 | 2085.5 | 3174.2 | 3183.8 |
| Age_comp | - | - | 5733.2 | 5572.6 | 5522.8 | 5620.9 | 2463.5 | 5612.0 | 5592.1 |
| Recruitment | -3.6 | -1.8 | -7.5 | -6.9 | -4.9 | -8.1 | -7.0 | -6.4 | -6.9 |
| Parm softbounds | - | 0.0240 | 0.0047 | 0.0052 | 0.0058 | 0.0066 | 0.0042 | 0.005 | 0.006 |

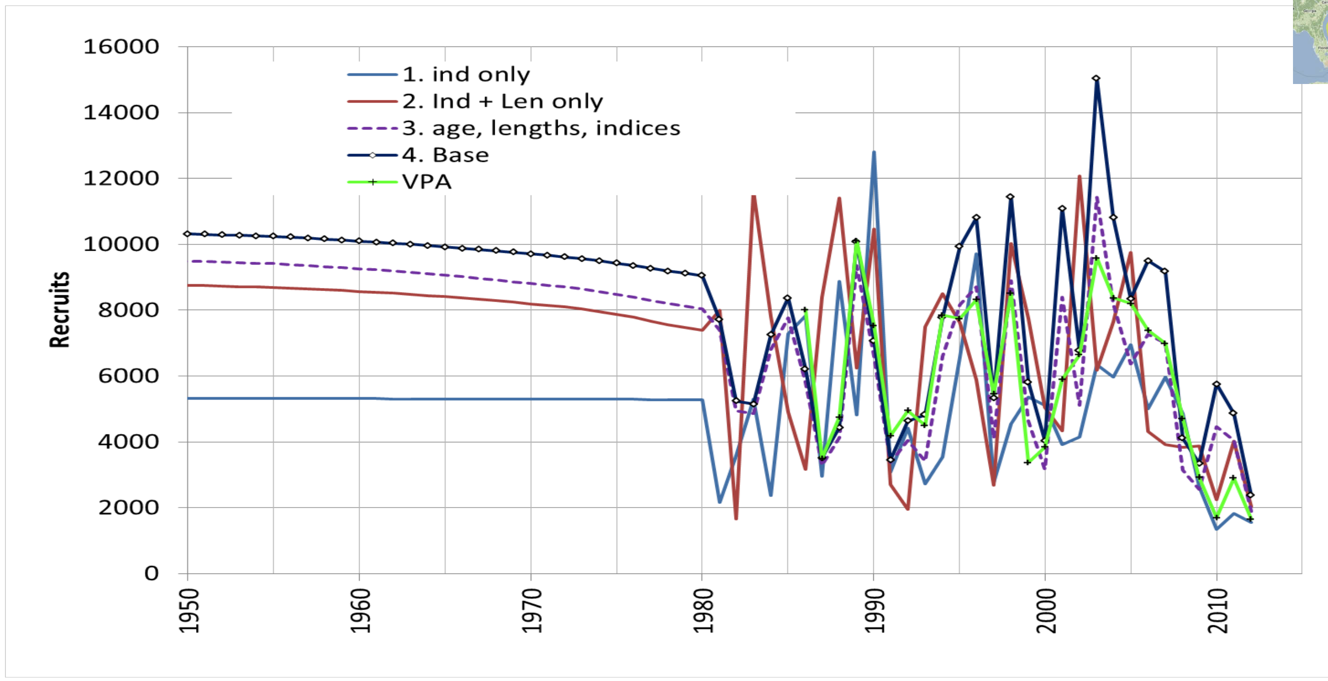
# Parameters/estimated quantities



| | 1. ind only | 2. ind and length | 3. ind, len and wt, | BASE | HiM | LoM | No Tourn | Index = wt | Low cv on catch |
|---|---|---|---|---|---|---|---|---|---|
| SR_LN(R0) | 8.579 (0.01) | 9.089 (0.02) | 9.175 (0.02) | 9.26 (0.04) | 10.59 (0.12) | 8.47 (0.033) | 9.05 (0.05) | 9.311 (0.03) | 9.312 (0.03) |
| SR_BH_steep | 0.99 (0) | 0.639 (0.03) | 0.474 (0.02) | 0.5 (0.03) | 0.26 (0.01) | 0.91 (0.061) | 0.57 (0.04) | 0.442 (0.02) | 0.466 (0.02) |
| SSB_Unfished | 3317.16 (36.75) | 5102.03 (107.57) | 7868.6 (167.02) | 8595.62 (314.32) | 20392.8 (2568.91) | 6913.59 (232.94) | 6954.74 (348.57) | 9081.1 (258.17) | 9093.96 (271) |
| Recr_Unfished | 5316.44 (58.9) | 8857.88 (186.76) | 9655.73 (193.47) | 10507.7 (370.62) | 39739.3 (4941.15) | 4765.39 (159.116) | 8548.46 (399.5) | 11058 (294.53) | 11070.6 (310.27) |
| SSB_SPR40% | 1321.82 (14.65) | 1536.97 (43.38) | 1329.91 (134.52) | 1720.35 (211.86) | 0 (0) | 2666.11 (64.4) | 1814.18 (128.55) | 1120 (217.96) | 1448.96 (223.34) |
| Fstd_SPR40% | 0.082 (0) | 0.073 (0.002) | 0.123 (0) | 0.115 (0.003) | 0.13 (0.004) | 0.09 (0.002) | 0.12 (0.003) | 0.116 (0.002) | 0.117 (0.003) |
| TotYield SPR40% | 2591.62 (28.71) | 3992.06 (113.3) | 3179.17 (319.66) | 3871.04 (472.25) | 0 (0) | 4287.17 (103.821) | 4310.9 (297.52) | 2510.02 (484.76) | 3229.51 (492.22) |
| SSB_MSY | 710.004 (7.87) | 1644.12 (80.06) | 3105.37 (105.54) | 3123.32 (177.82) | 9511.61 (1267.89) | 1420.07 (261.779) | 2353.12 (193.65) | 3497.41 (143.29) | 3420.85 (152) |
| SPR_MSY | 0.216 (0) | 0.418 (0.02) | 0.563 (0.01) | 0.522 (0.02) | 0.85 (0.02) | 0.22 (0.046) | 0.46 (0.03) | 0.579 (0.02) | 0.555 (0.02) |
| Fstd_MSY | 0.146 (0) | 0.07 (0) | 0.076 (0) | 0.079 (0.01) | 0.02 (0) | 0.16 (0.027) | 0.1 (0.01) | 0.066 (0) | 0.072 (0) |
| TotYield_MSY | 2869.95 (31.8) | 3999.48 (99.05) | 4228.99 (99.57) | 4484.72 (219.64) | 3660.87 (561.08) | 4763.55 (249.916) | 4436.51 (193.14) | 4045.97 (138.08) | 4317.93 (180.48) |
| RetYield_MSY | 2869.95 (31.8) | 3972.4 (97.82) | 4195.88 (98.62) | 4446.15 (216.8) | 3630.09 (555.79) | 4715.8 (241.817) | 4398.53 (190.33) | 4014.24 (136.42) | 4281.99 (178.23) |

# Comparison of other model runs

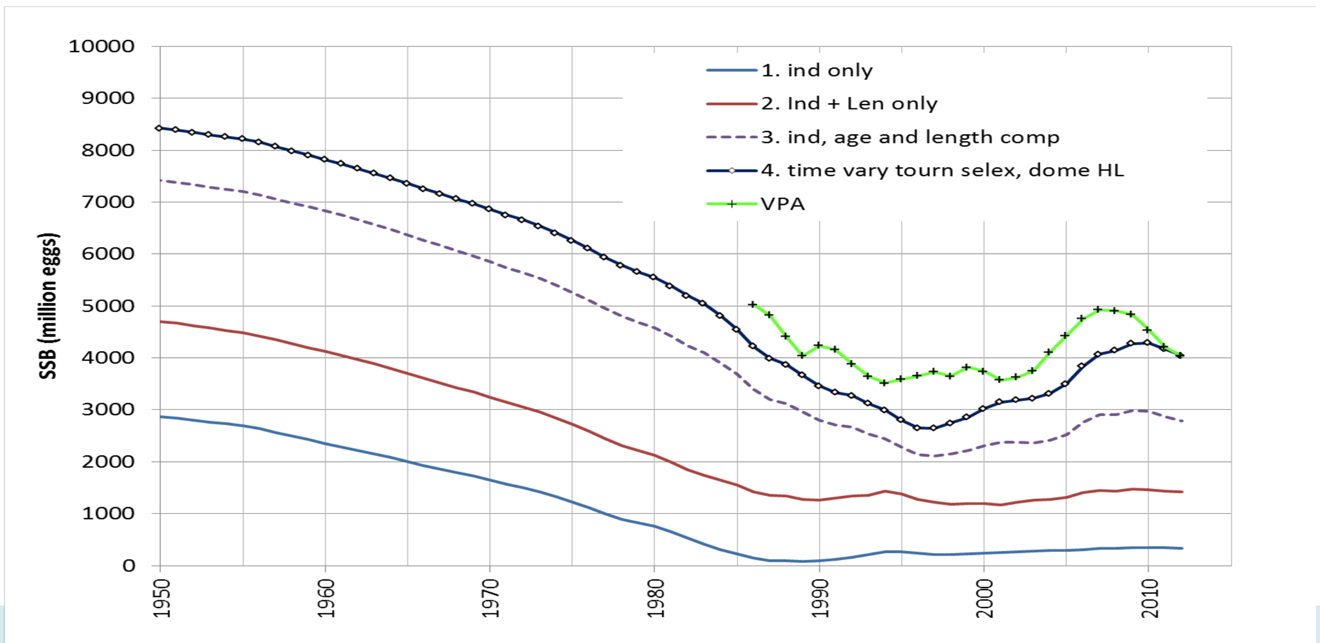





KMK_ATL_1: CPUE only with no length or age-at-length(AAL);
Two length bins (i.e. one big plus group)
Allows recruitment deviations;
Fixed sex-specific growth at Data Workshop values

KMK_ATL_2: This starts with #1
Add only lengths and selectivity

KMK_ATL_3: This starts with #2
Adds AAL
Freely estimates constant growth (i.e. no informed priors)




NOAA FISHERIES

# Sensitivity runs, compare with VPA

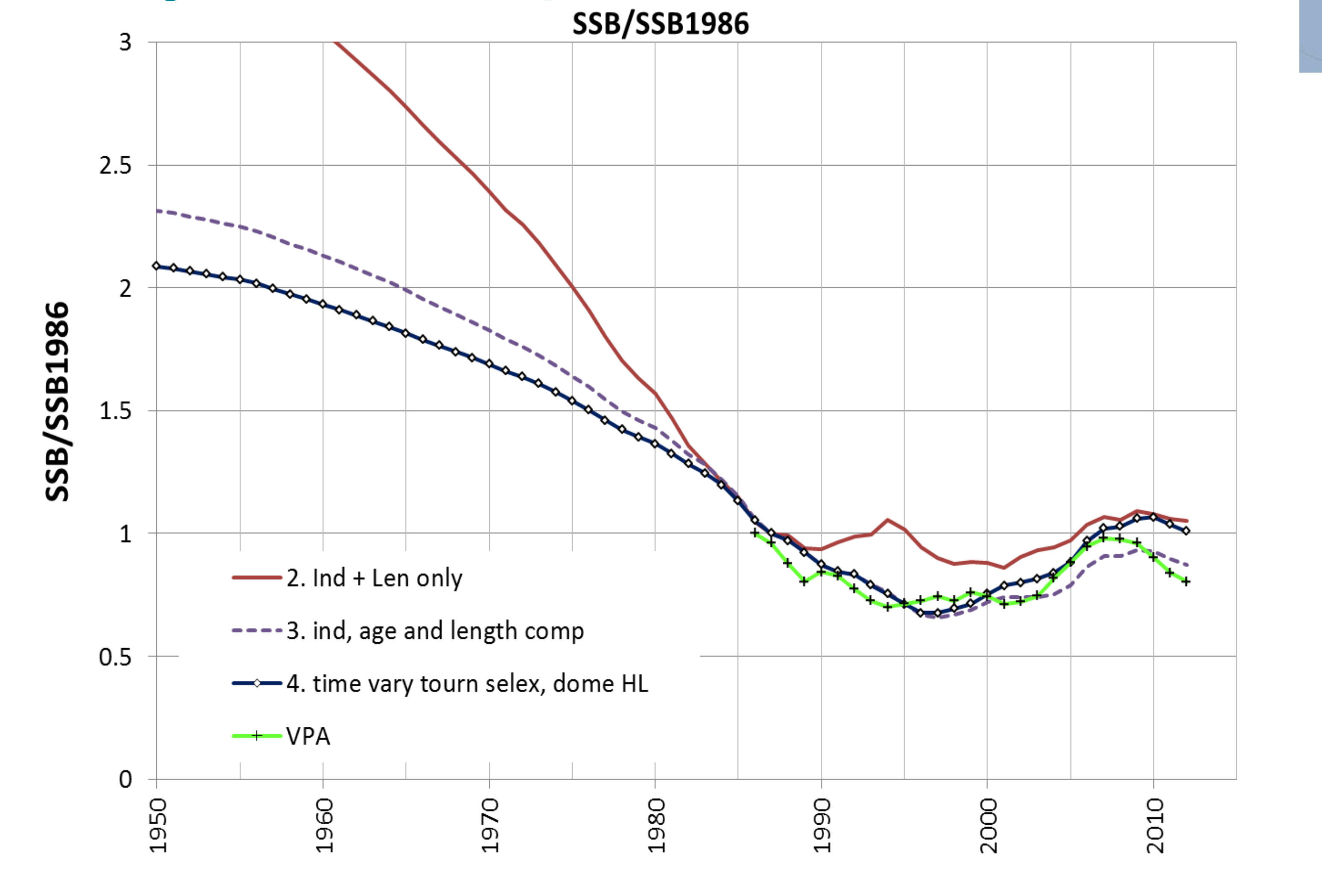



Figure 3.2.43. $SSB/SSB_{1986}$ for models 2-4 and the VPA.

# Sensitivity runs

- High and low M

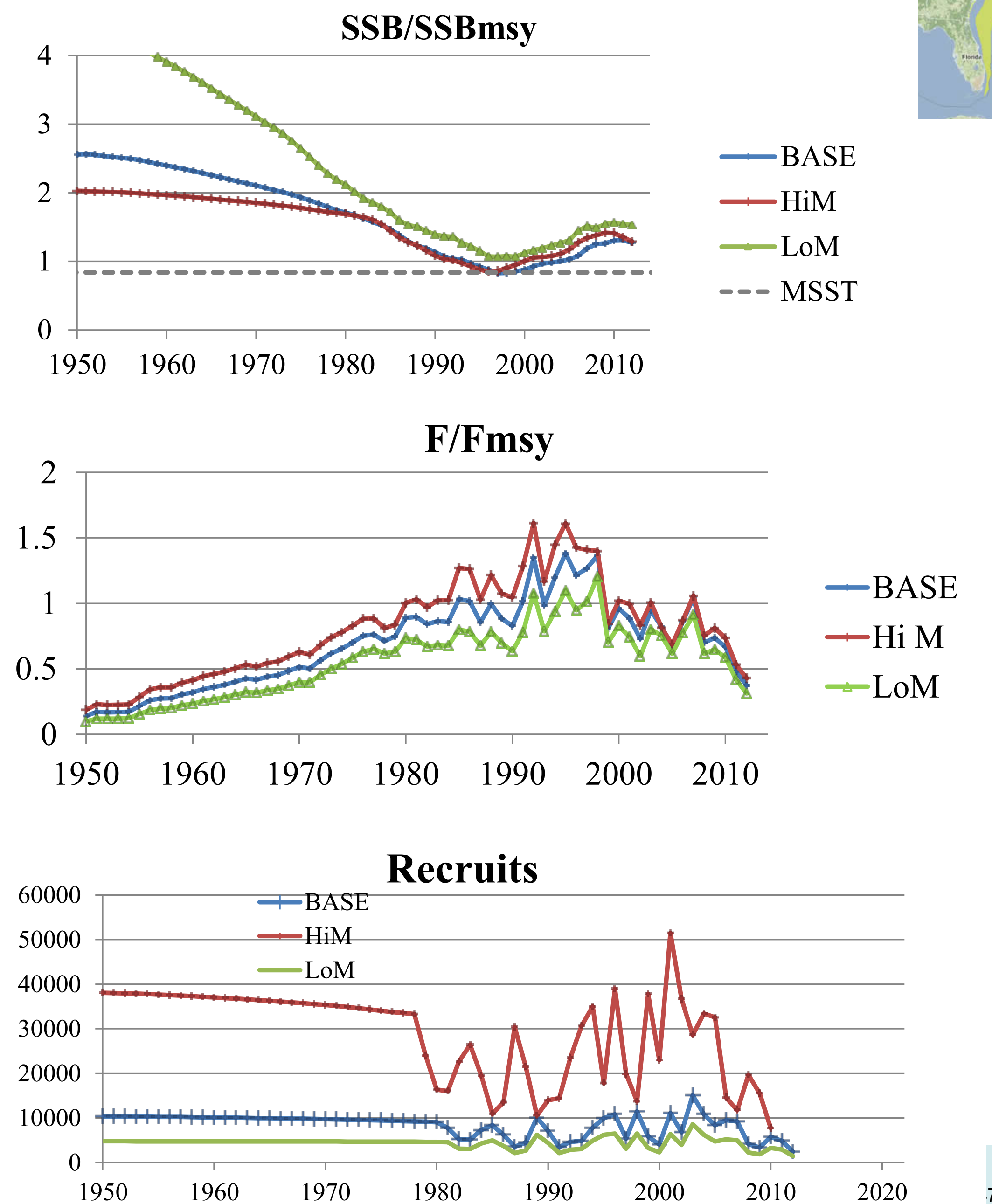



Figure 3.2.44. $SSB/SSB_{MSY}$ and $F/F_{MSY}$ rate and recruits across sensitivity for high and low M

# Sensitivity runs

- No error on catch
- Equal weight on indices

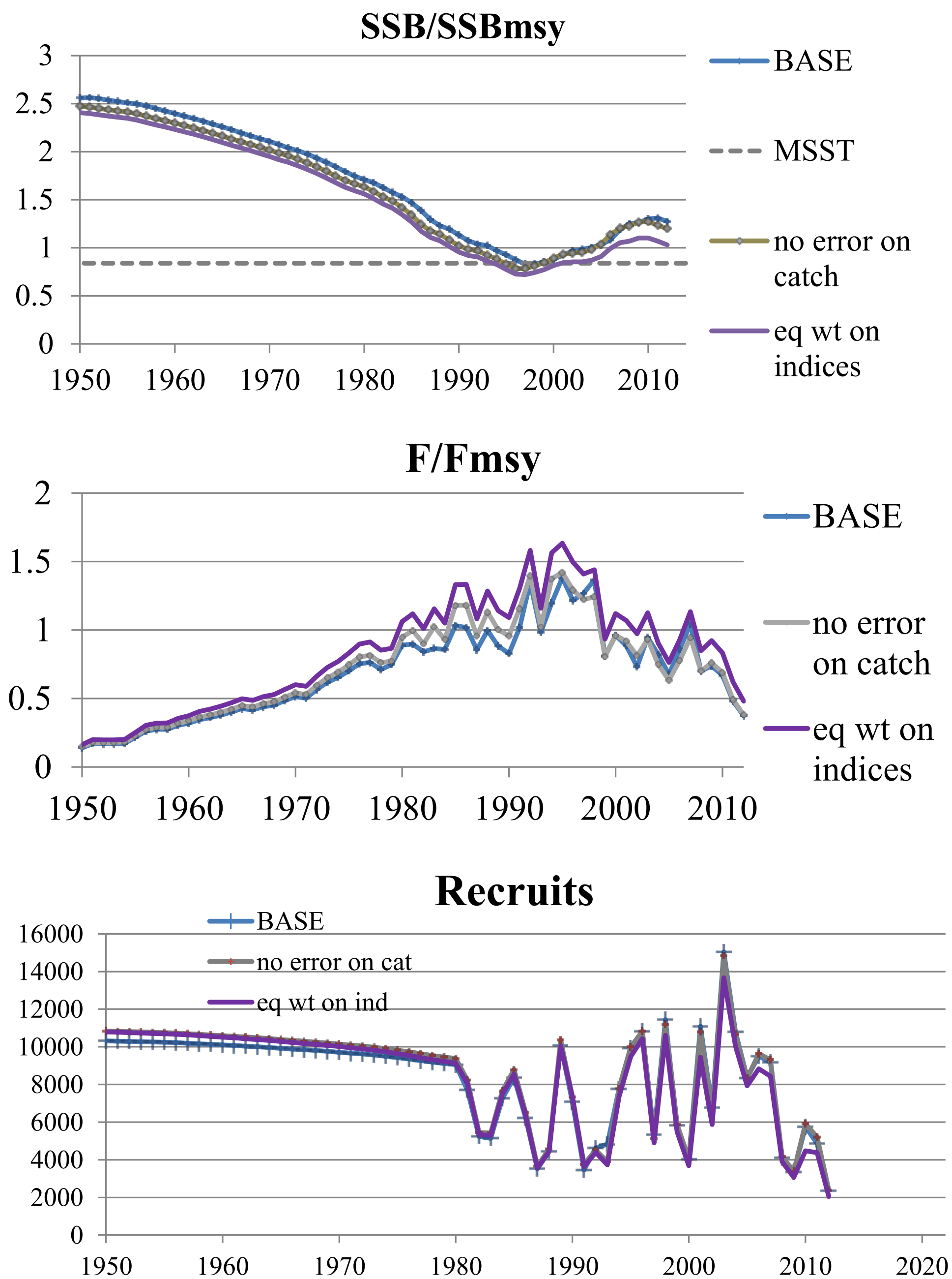



Figure 3.2.45. SSB/SSB$_{MSY}$ and F/F$_{MSY}$ rate and recruits across sensitivity runs with low error on recreational catch (cv~0.01) and with indices equally weighted.

# Sensitivity runs

- No tournament data

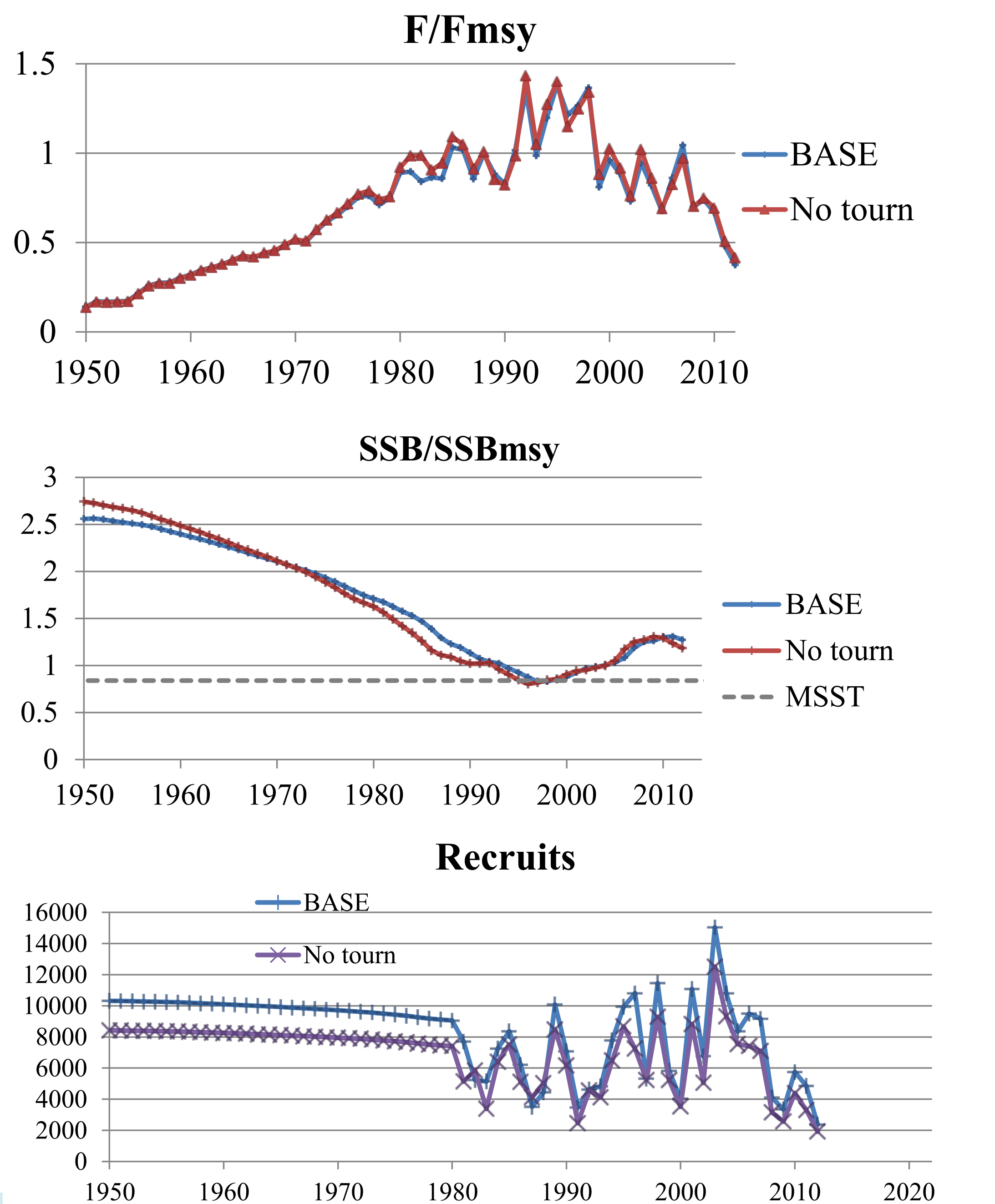



Figure 3.2.46. $F/F_{MSY}$ and $SSB/SSB_{MSY}$ and estimated recruitment for sensitivity run with and without tournament composition data.

# Jacknife of indices

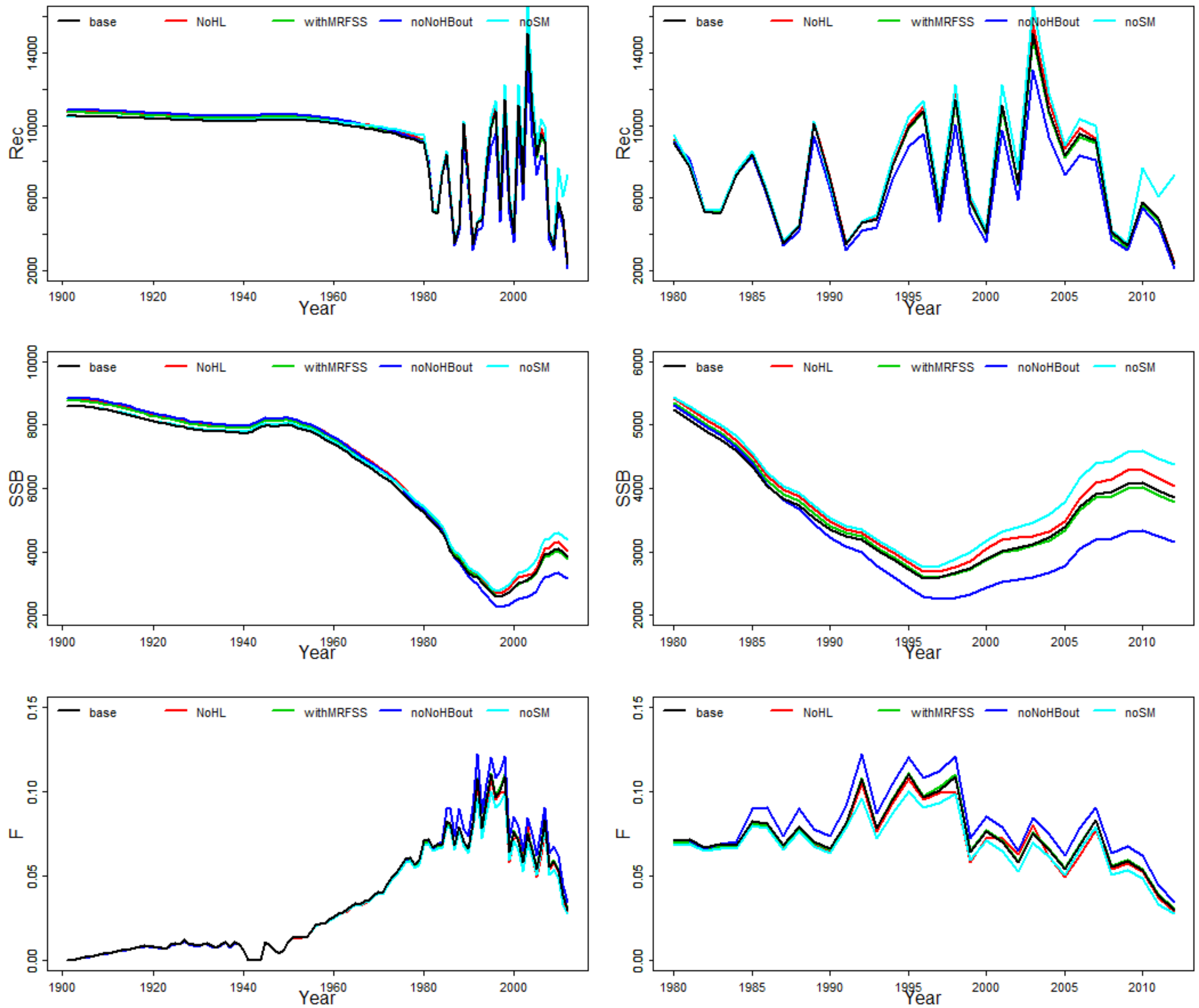



Figure 3.2.47. Predicted age-0 recruitment, spawning stock biomass (female SSB) and fishing mortality (exploitation rate in numbers) from jack-knife of abundance indices.

# Retrospectives

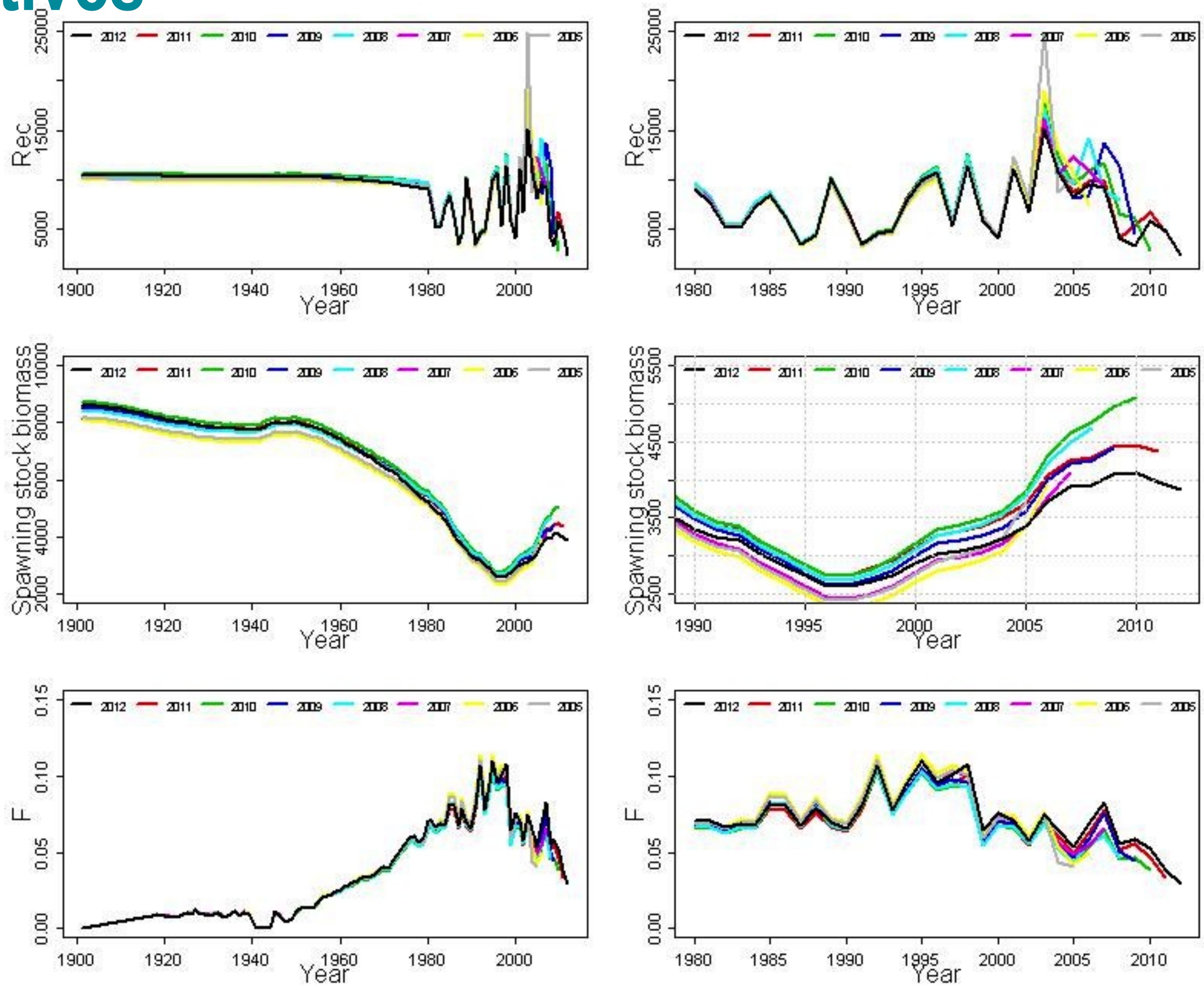



Figure 3.2.48. Predicted age-0 recruitment, spawning stock biomass (female SSB) and fishing mortality (exploitation rate in numbers) from the retrospective analysis for the entire time series and expanded to1980-2012.

# 20 year retrospective patterns in steepness

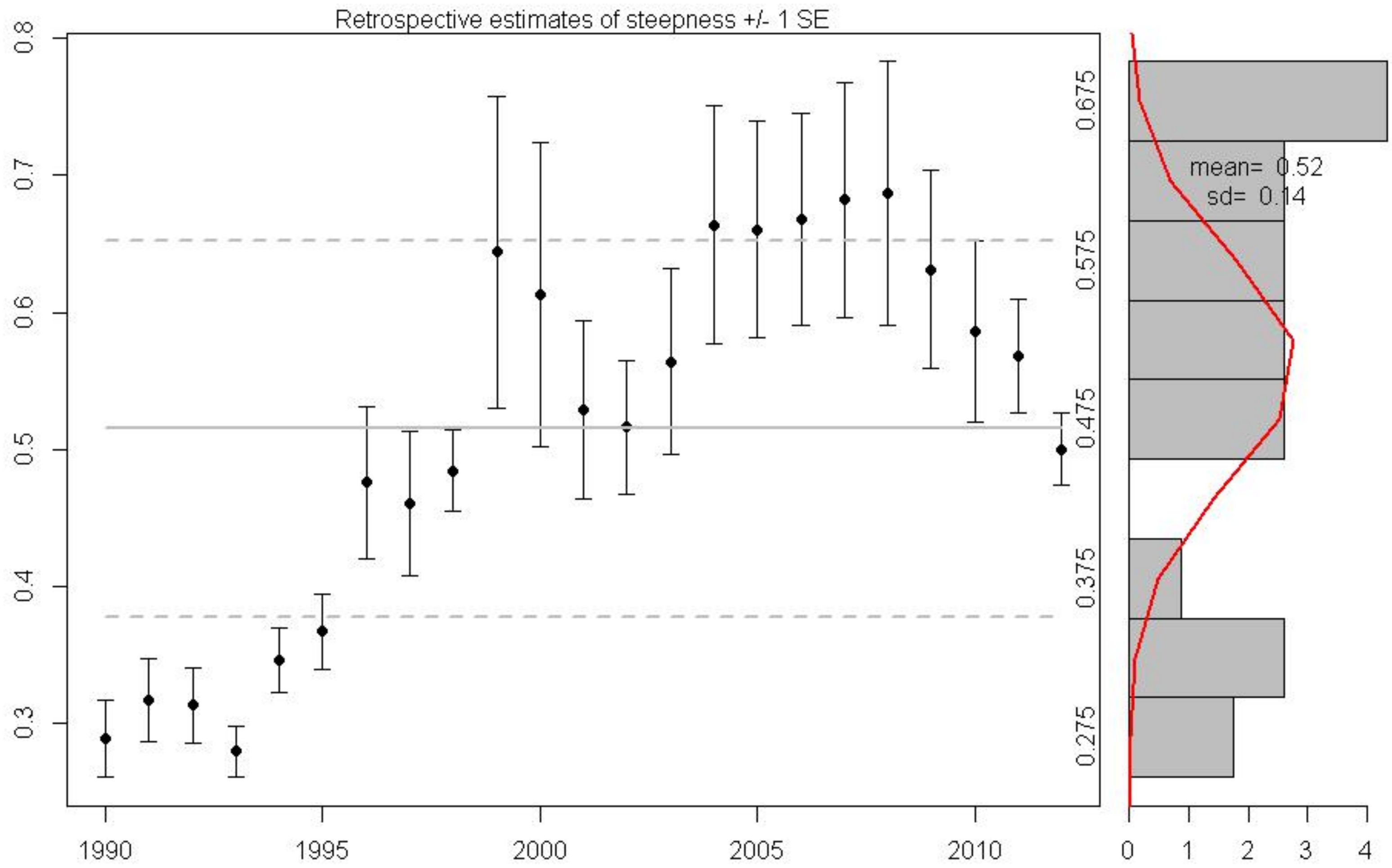
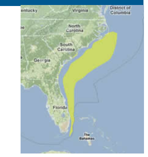


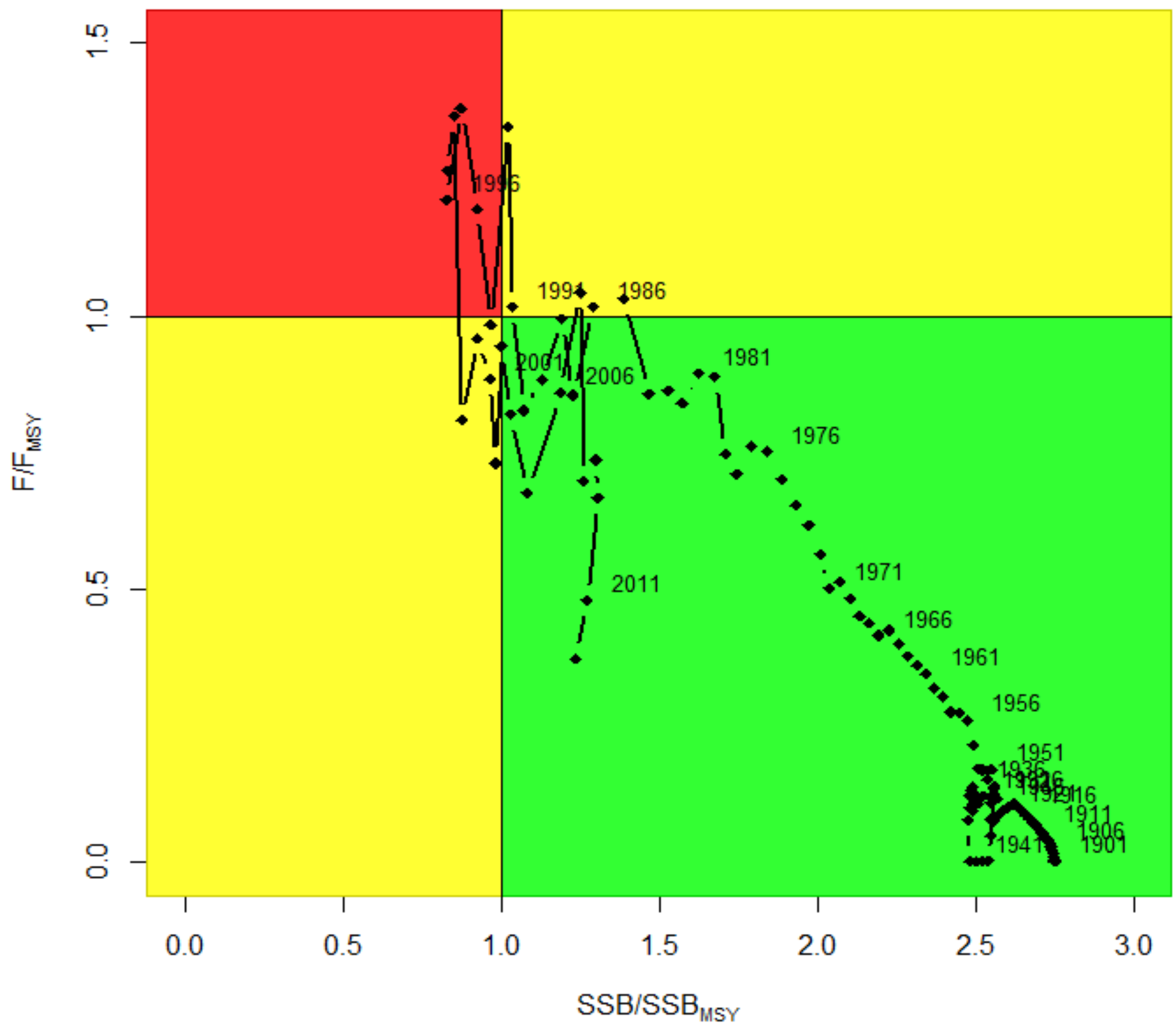

Figure 3.2.50. Retrospective estimates of steepnesss +/- 1 SE from 23 years of retrospective peels.

# IEA working group environmental/ecosystem considerations

- Evaluated climate effects (SST and NAO) on Comm HL CPUE and landings- Little detectable effect at spatial and temporal scales (Harford et al S38RW paper)
- Tested effects of 3 temperature metrics (mean SST, degree days and upwelling) on comm HL and HB residuals, and rec devs –no sig. effect
- Spatial shifts in population evaluated- little evidence detected
- Predator-prey interactions noted but little data to evaluated.
- Signs of a correlation between rec devs and location of the Florida current; needs more clarification but promising research area to potentially explain low recruitments

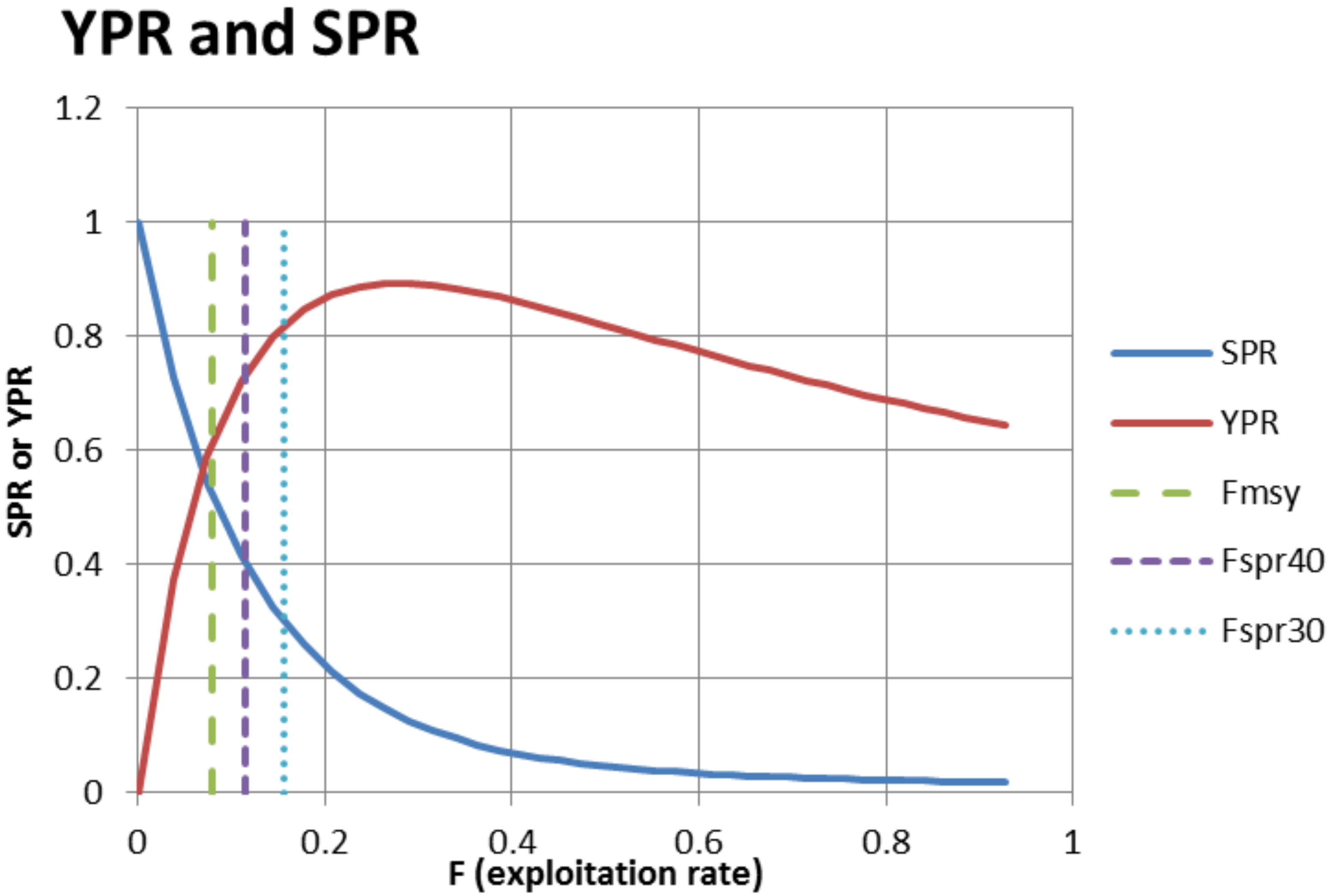
# IV. Atlantic Stock status






| | |
|---|---|
| $SSB_{2012}$/ $SSB_{MSY}$ | **1.24** |
| $F_{2012}$/ $F_{MSY}$ | 0.37 |
| **Stock Status** | Not Overfished |
| **Fishery Status** | Not Undergoing Overfishing |

# YPR/SPR


YPR and SPR
SPR or YPR
F (exploitation rate)
0
0.2
0.4
0.6
0.8
1
1.2
SPR
YPR
Fmsy
Fspr40
Fspr30

# Quantification of uncertainty

| | Bootstraps | | | Deterministic | | |
|---|---|---|---|---|---|---|
| parameter/derived quantity | median | sd | CV | estimate | sd | CV |
| R0 | 9.29 | 0.06 | 1% | 9.26 | 0.04 | 0% |
| H | 0.47 | 0.05 | 11% | 0.50 | 0.03 | 5% |
| SPB_Virgin | 8939.34 | 580.94 | 6% | 8595.62 | 370.62 | 4% |
| Recr_Virgin | 10780.65 | 690.42 | 6% | 10507.70 | 370.62 | 4% |
| Fstd_MSY | 0.074 | 0.02 | 28% | 0.079 | 0.01 | 8% |
| RetYield_MSY | 4176.66 | 728.74 | 17% | 4446.15 | 216.80 | 5% |
| SSB_MSY | 3347.32 | 429.70 | 13% | 3861.94 | 342.84 | 9% |
| SPB_2012 | 4227.66 | 906.85 | 21% | 3861.94 | 342.84 | 9% |
| ForeCatchret_2013 | 1841.04 | 54.44 | 3% | 1838.19 | 16.15 | 1% |
| ForeCatchret_2014 | 1862.69 | 38.00 | 2% | 1864.97 | 19.36 | 1% |
| ForeCatchret_2015 | 4070.62 | 2249.23 | 55% | 4270.27 | 749.82 | 18% |
| ForeCatchret_2016 | 4241.32 | 1857.68 | 44% | 4446.65 | 1091.05 | 25% |
| ForeCatchret_2017 | 4376.53 | 1580.21 | 36% | 4578.69 | 1206.40 | 26% |
| ForeCatchret_2018 | 4421.91 | 1388.60 | 31% | 4635.68 | 1254.69 | 27% |
| | | | | | | |
| | Total boostraps | loglikelihood >2*median LL | Hit steepness bound | Total 'good' boots | | |
| | 343 | 30 | 12 | 312 | | |

Table 3.11. Mean and standard deviation of parameter estimates and key derived quantities from 314 bootstrap samples compared with deterministic quatities.

# Parametric bootstrapping

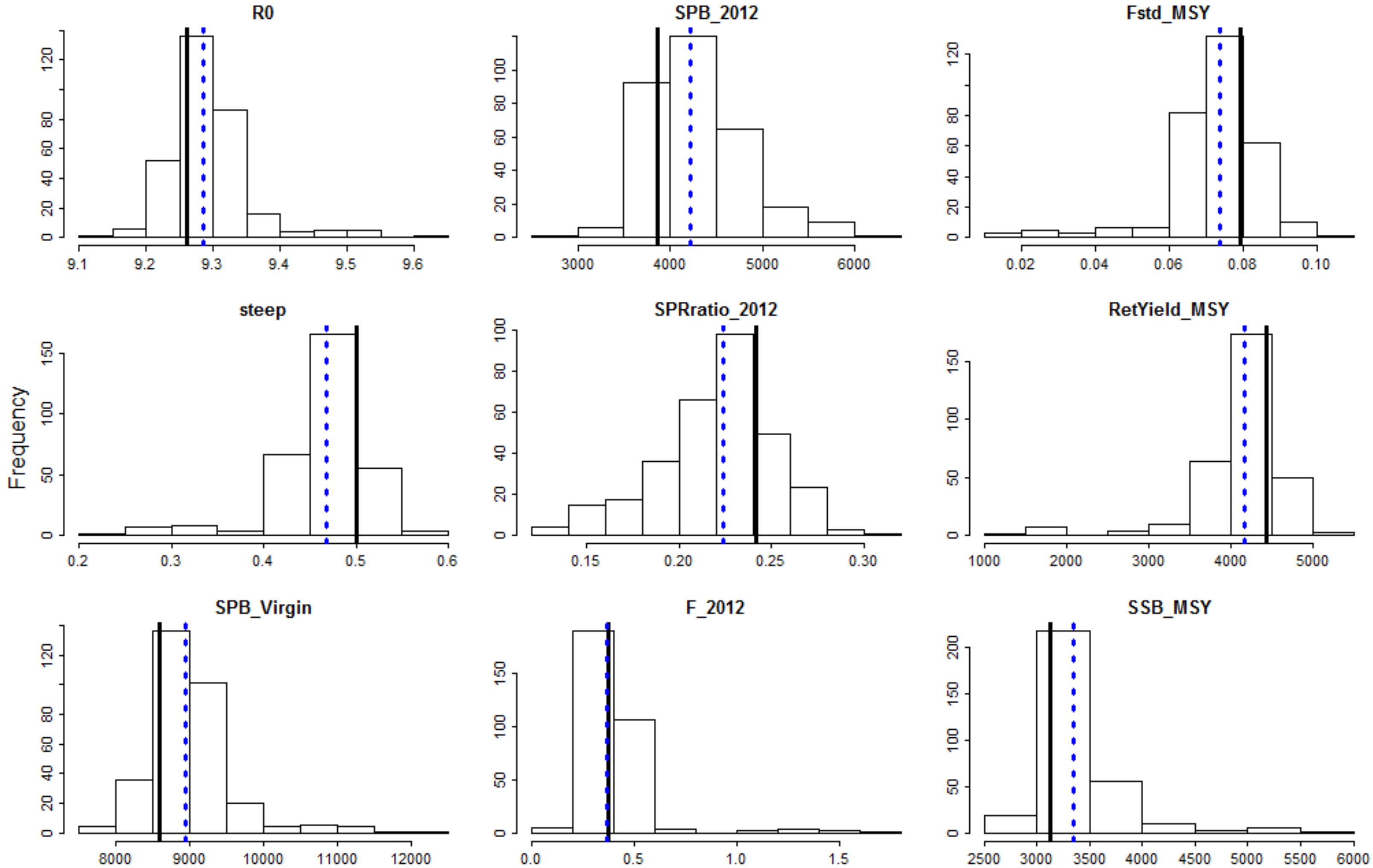



Figure 3.2.60. Histograms of key estimated parameters and key derived quantities from bootstraps. Blue line is the bootstrap median and black line is the deterministic estimate.

# V. Atlantic Projections

# Projection specifications

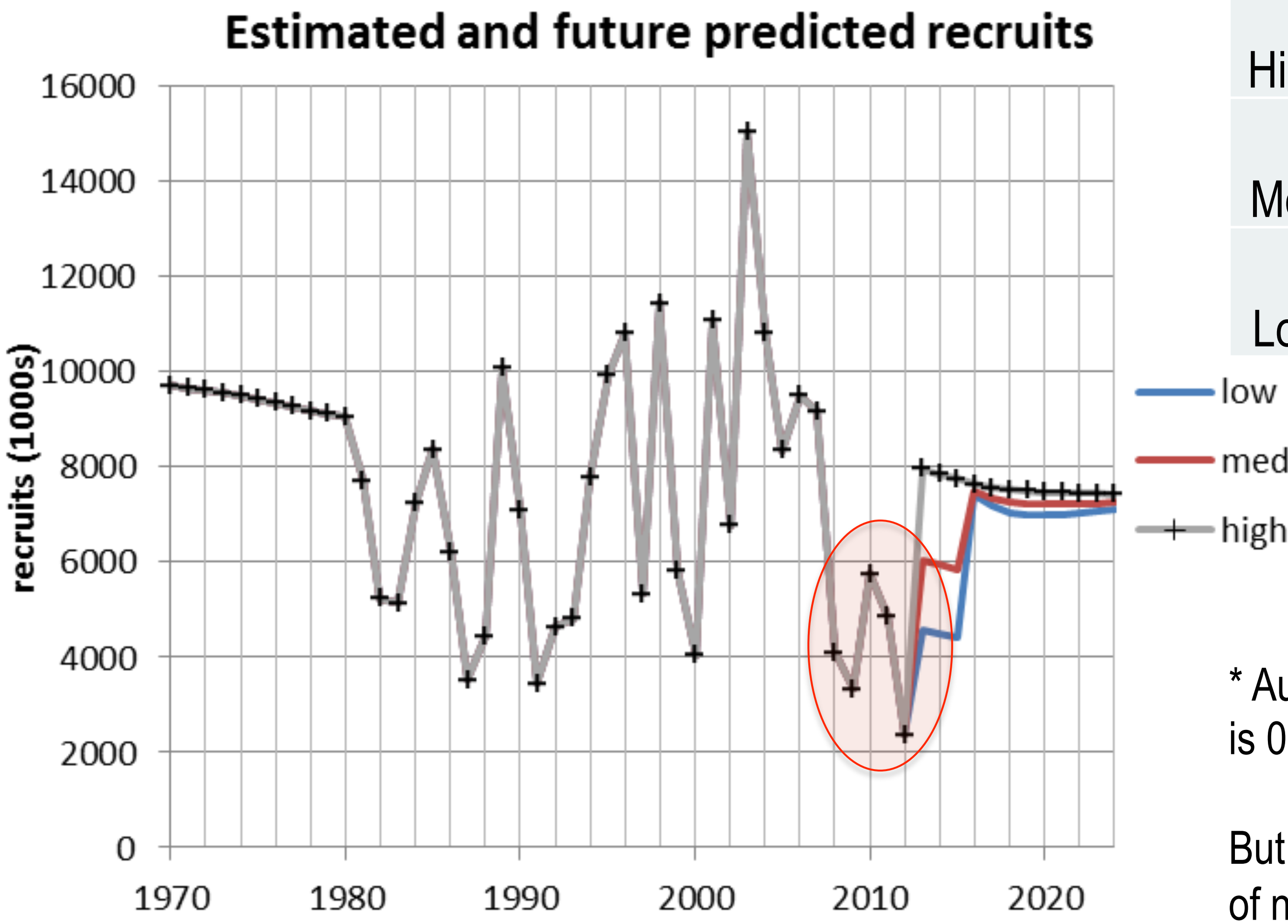
1. Use FMSY for benchmarks

2. Selectivity and relative F averaged over 2010-12?

3. Input 2013 and 2014 landings
   - Carry over 2012-13 FY for both or input ACLs?

4. Future recruitment

# Future recruitment

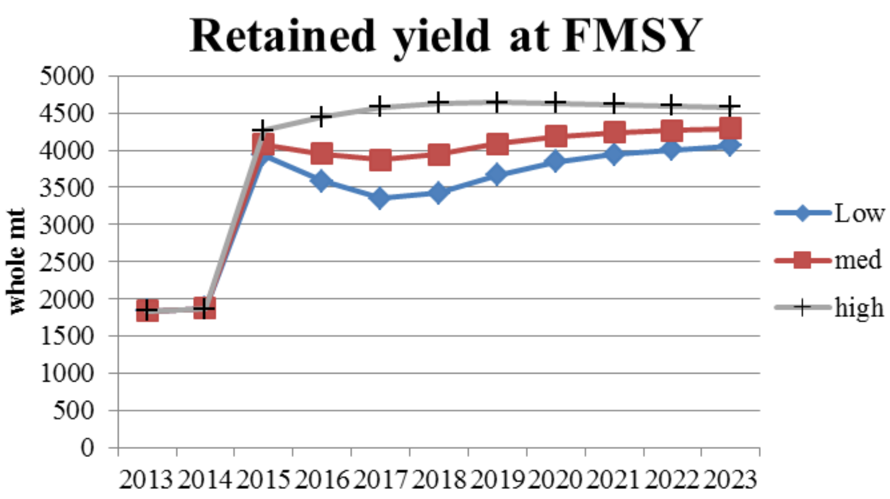


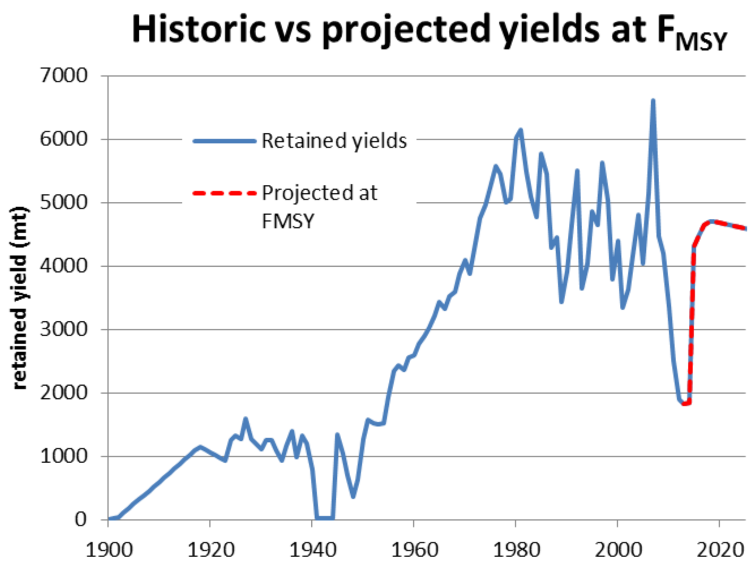

| | | |
|---|---|---|
| High | 0 | Long term avg |
| Med | -0.27 | 50% of avg 2008-2012 |
| Low | -0.55 | avg 2008-2012 |

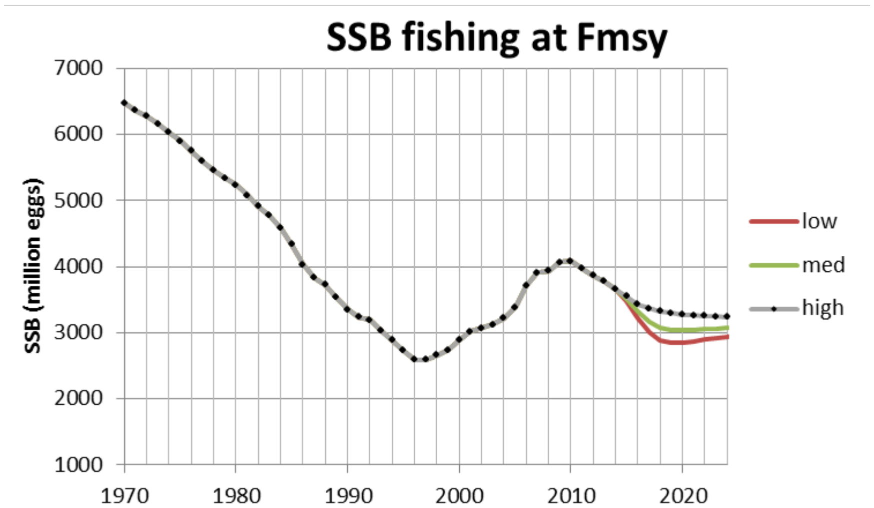
* Autocorrelation AR(1) estimate is 0.35, could use AR(1) process.

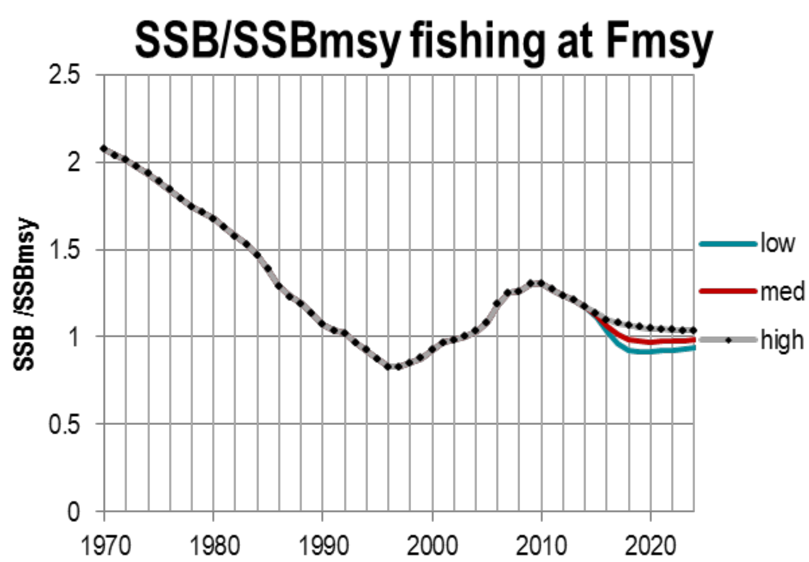
But estimates show no evidence of non-linear time series predictability (Sugihara and May 1990)*

# Projections at $F_{MSY}$



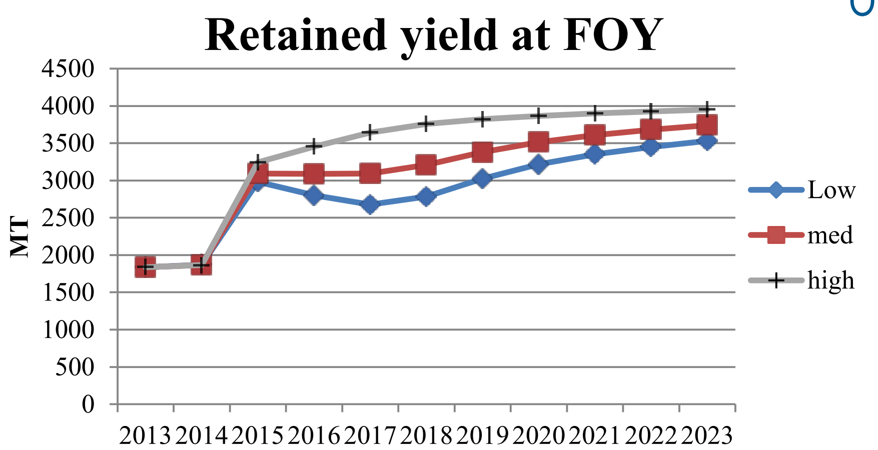



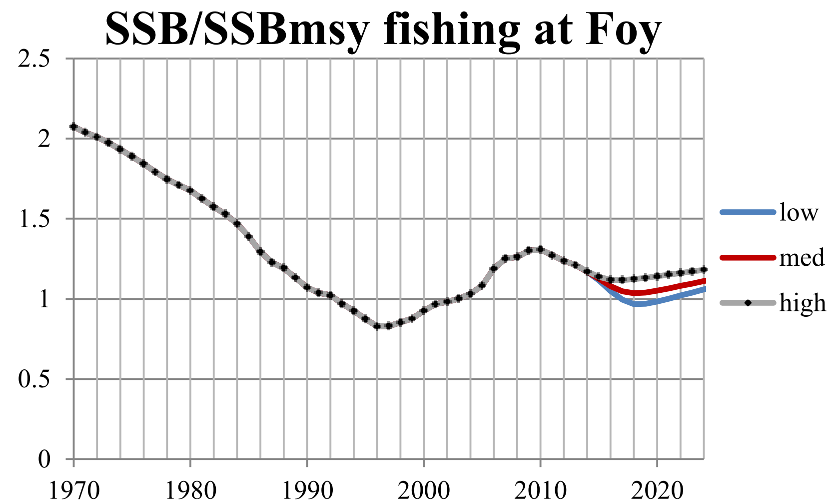



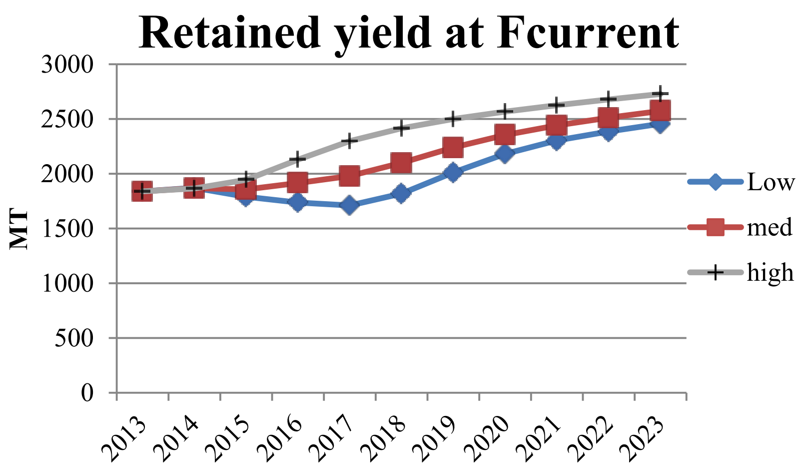
# Projections at $F_{OY}$ and $F_{current}$

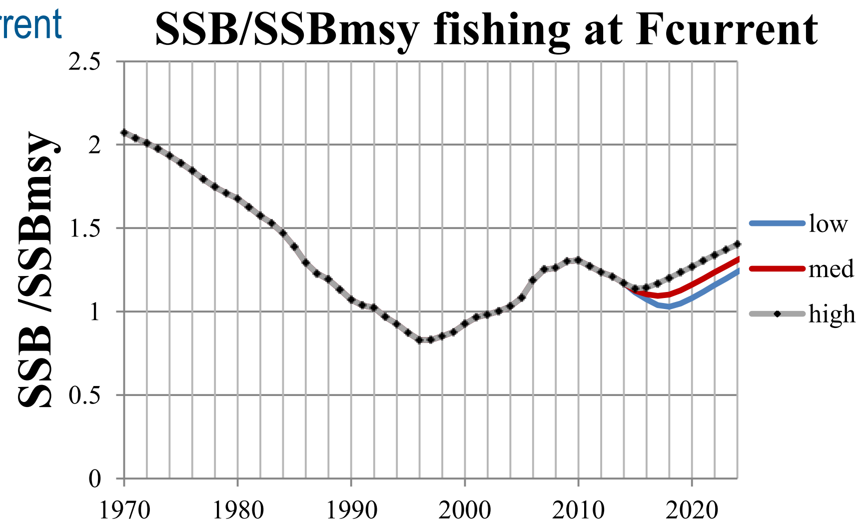
$F_{OY}$



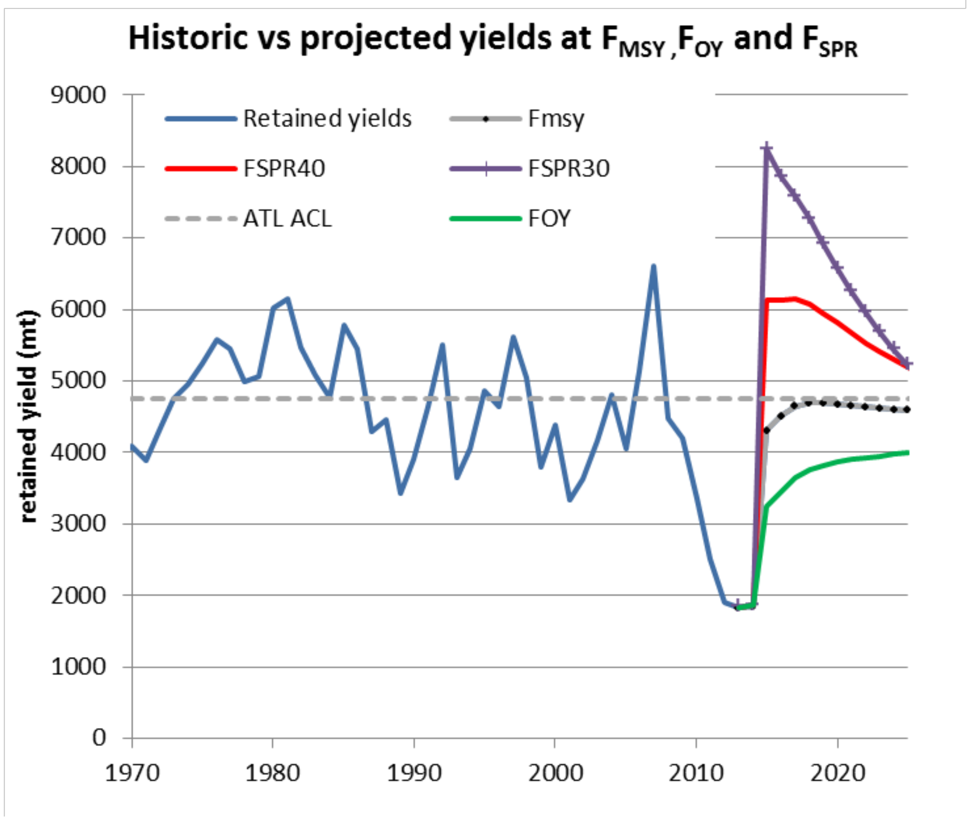

$F_{current}$

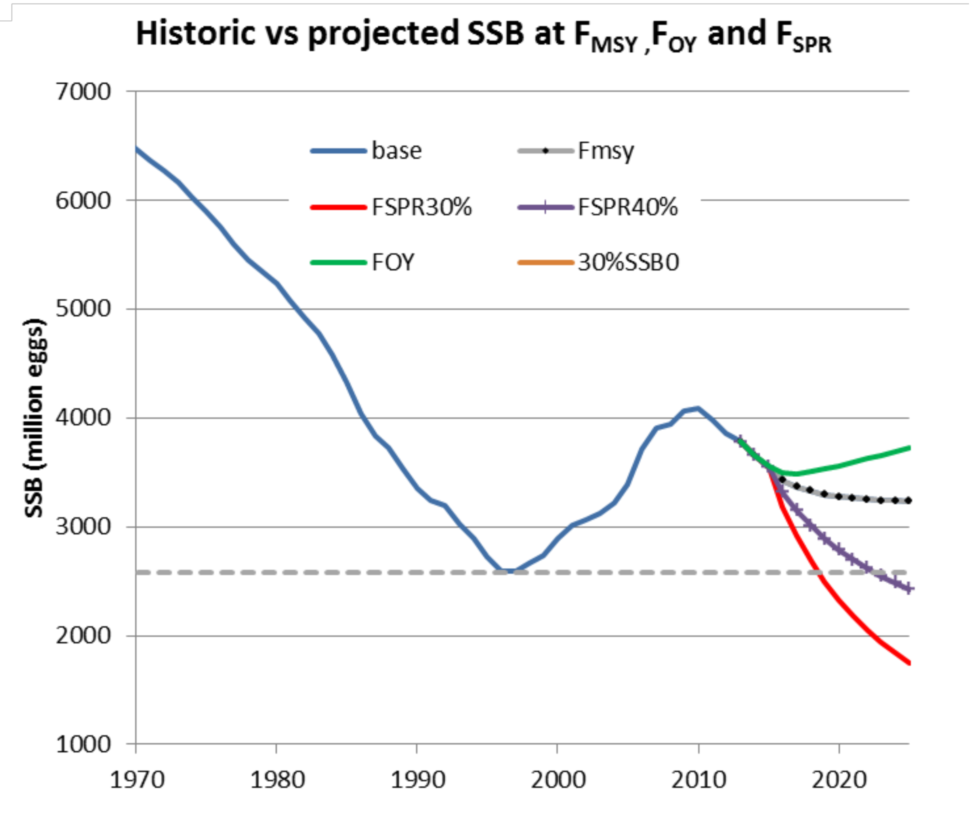


# Projections at $F_{MSY}$, $F_{OY}$ and $F_{SPR}$

## under ‘high’ future recruitment



# Parametric bootstrapping projections

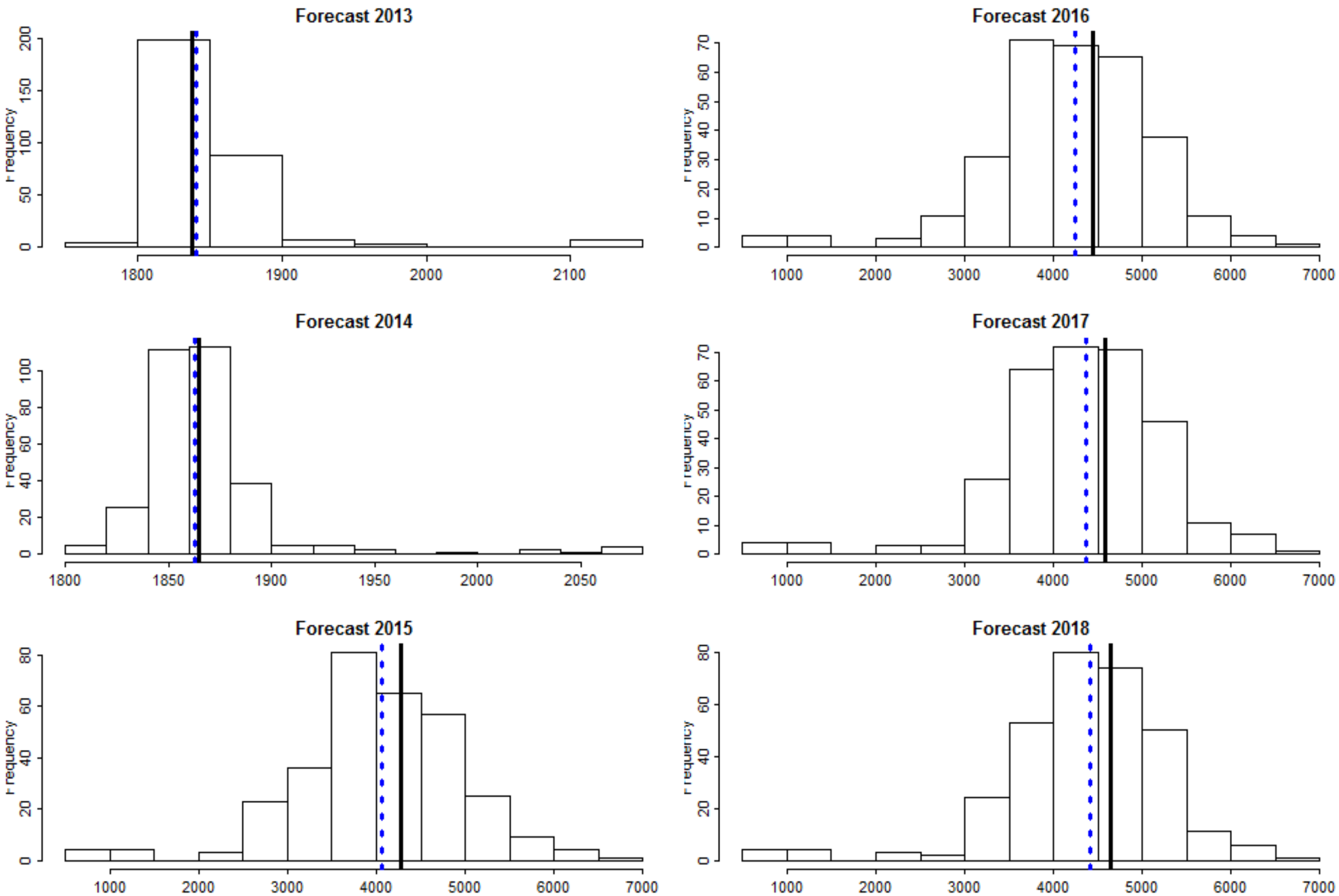



Figure 3.2.61. Histograms of forecasted yields. Blue line is the bootstrap median and black line is the deterministic estimate.

# Remaining considerations for projections

- Movement toward SPR metrics requires replacing recruitments with some constant recruitment (SPR 30% and 40% both lead to reductions in SSB below 30% of virgin.
- Consider autocorrelation in recruitments
- Final (or best preliminary) 2013 and 2014 landings

# Challenges

- Retrospective patterns
  - Likely due to changing est. of steepness
- Future recruitment prediction
  - What levels of recruitment are likely in future
  - Fisheries are recruitment driven
- Why declines in recruitment?
  - Research recommendations

# Strengths

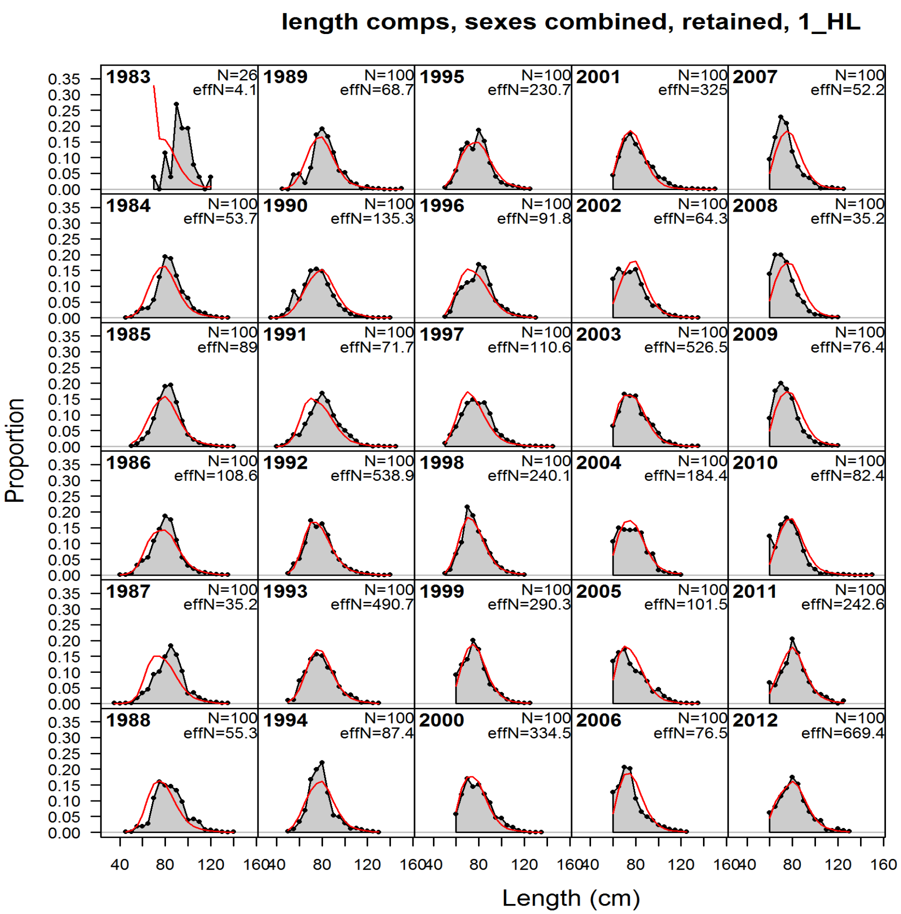
- Unaccounted for removals in the new WMZ only 7% compared with 24% in S16, greatly reducing largest axis of uncertainty
- long time series of landings that begin at virgin conditions.
- high volume of age and length composition information, a juvenile trawl survey
- substantial biological research to precisely characterize growth and fecundity.
- model estimated $R_0$ and steepness allowing for MSY-based reference points rather than proxies
- Almost all sensitivity runs indicate that stock is not overfished nor is overfishing occurring

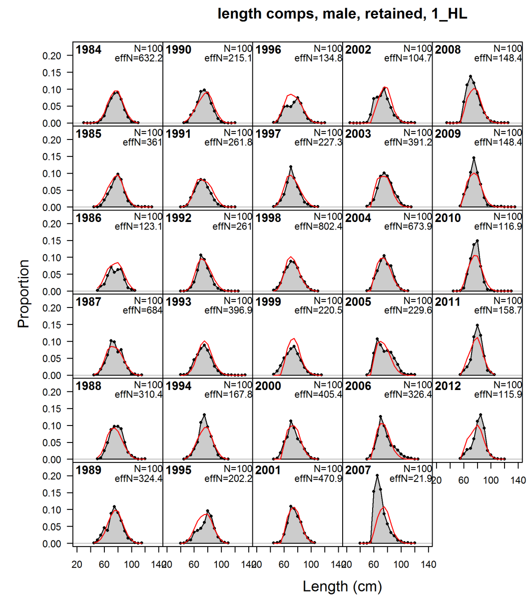
# Acknowledgements

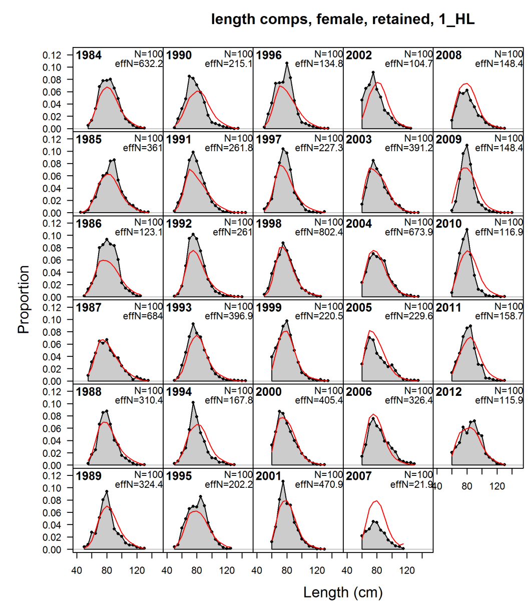
Many people at various state and federal agencies assisted with assembling the data sources included in this stock assessment. The FISHSMART project PIs (Tom Idhe, Tom Miller, David Secor and Mike Wilberg) provided substantial assistance and data for how to model the tournament fishery. Harvey Walsh, Jon Hare, Katrin Marancik and Dave Richardson provided NEFSC larval data. Chris Bonzek at VIMS provided NEAMAP trawl survey data. Ian Taylor has greatly improved the R code for plotting and diagnostics of Stock Synthesis models with which many of the figures in this document were created.

# Extras

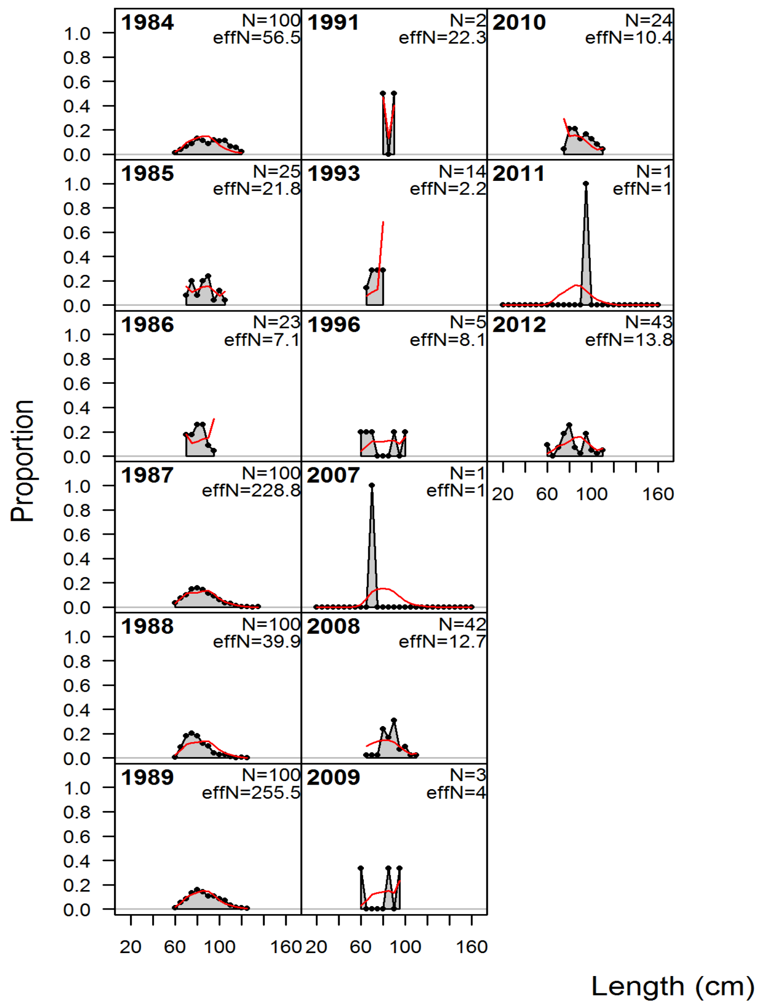

Virginia
District of Columbia
North Carolina
South Carolina
Georgia
Florida
The Bahamas

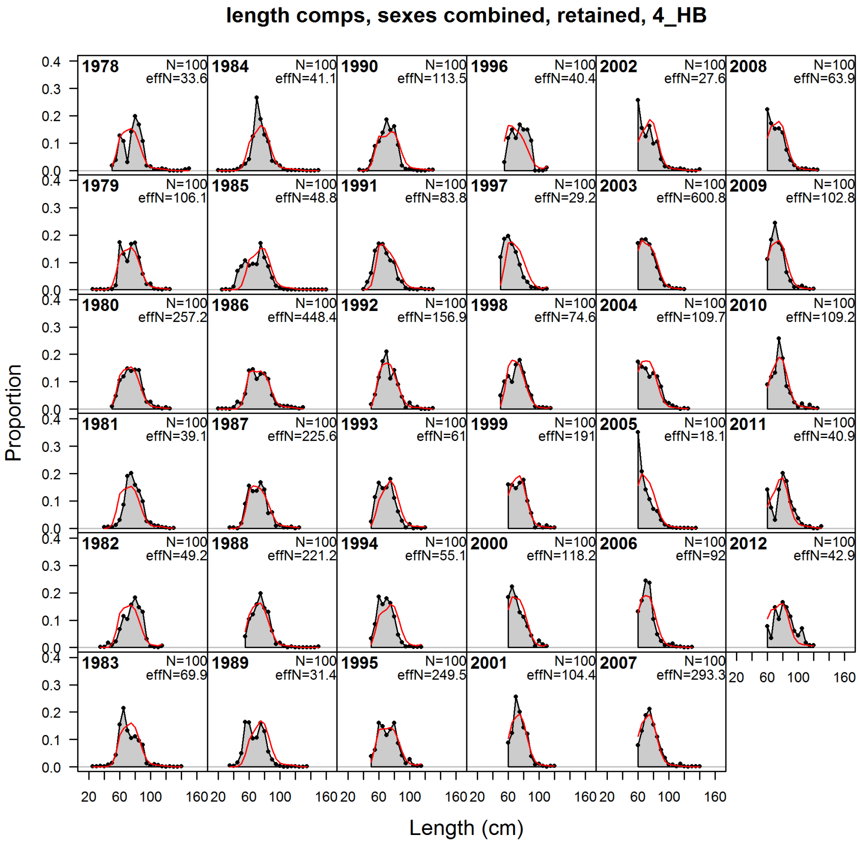

length comps, sexes combined, retained, 1_HL
Proportion
Length (cm)

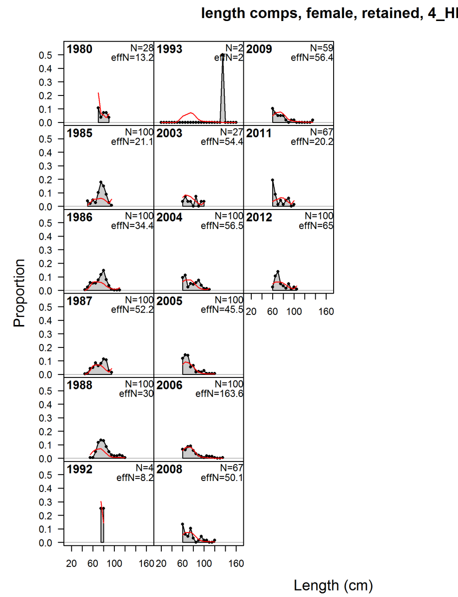

length comps, male, retained, 1_HL
Proportion
Length (cm)

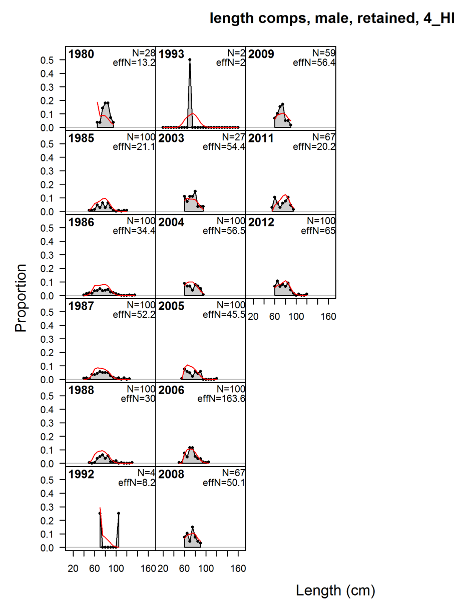

length comps, female, retained, 1_HL
Proportion
Length (cm)

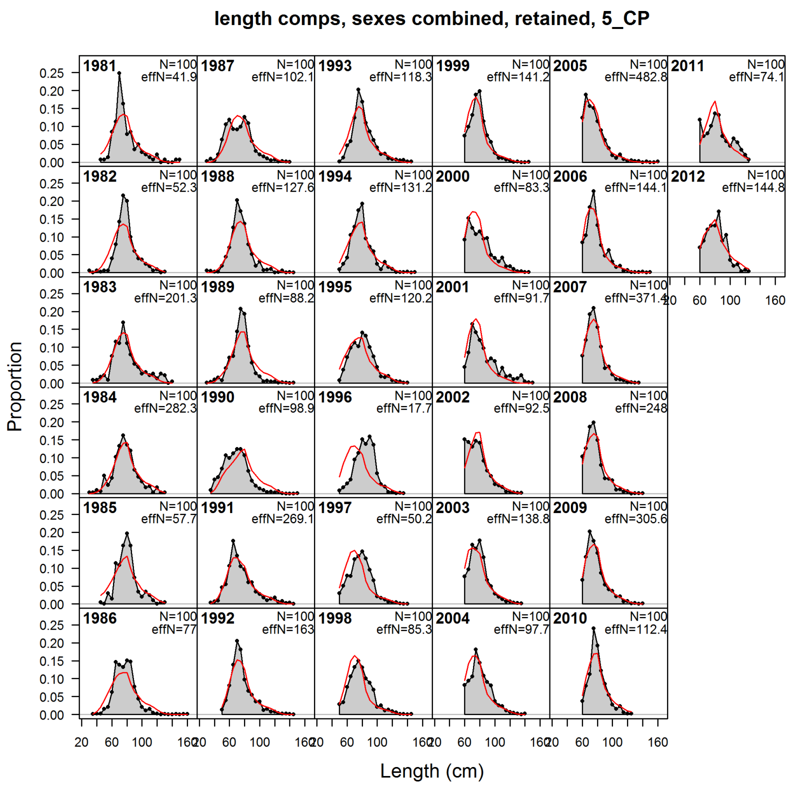
## length comps, sexes combined, retained, 2_GN

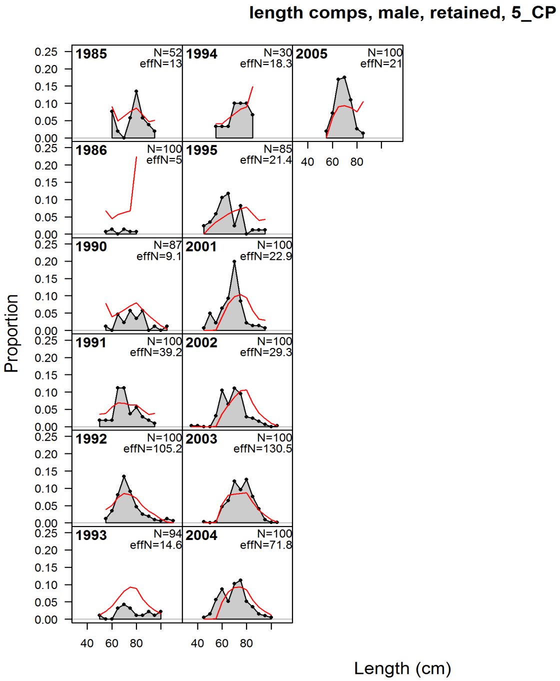


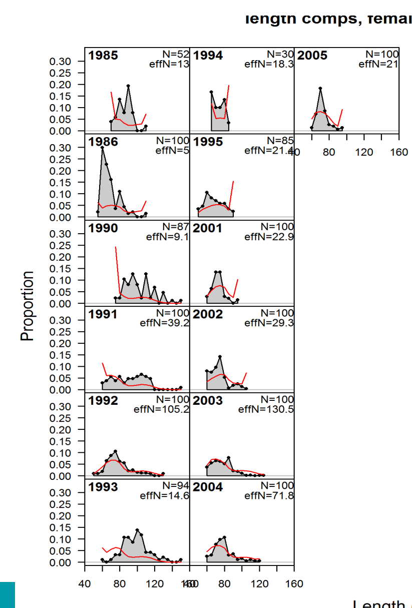

length comps, sexes combined, retained, 4_HB
1978 N=100 effN=33.6
1984 N=100 effN=41.1
1990 N=100 effN=113.5
1996 N=100 effN=40.4
2002 N=100 effN=27.6
2008 N=100 effN=63.9
1979 N=100 effN=106.1
1985 N=100 effN=48.8
1991 N=100 effN=83.8
1997 N=100 effN=29.2
2003 N=100 effN=600.8
2009 N=100 effN=102.8
1980 N=100 effN=257.2
1986 N=100 effN=448.4
1992 N=100 effN=156.9
1998 N=100 effN=74.6
2004 N=100 effN=109.7
2010 N=100 effN=109.2
1981 N=100 effN=39.1
1987 N=100 effN=225.6
1993 N=100 effN=61
1999 N=100 effN=191
2005 N=100 effN=18.1
2011 N=100 effN=40.9
1982 N=100 effN=49.2
1988 N=100 effN=221.2
1994 N=100 effN=55.1
2000 N=100 effN=118.2
2006 N=100 effN=92
2012 N=100 effN=42.9
1983 N=100 effN=69.9
1989 N=100 effN=31.4
1995 N=100 effN=249.5
2001 N=100 effN=104.4
2007 N=100 effN=293.3
Proportion
Length (cm)


length comps, female, retained, 4_HB
1980 N=28 effN=13.2
1993 N=2 effN=2
2009 N=59 effN=56.4
1985 N=100 effN=21.1
2003 N=27 effN=54.4
2011 N=67 effN=20.2
1986 N=100 effN=34.4
2004 N=100 effN=56.5
2012 N=100 effN=65
1987 N=100 effN=52.2
2005 N=100 effN=45.5
1988 N=100 effN=30
2006 N=100 effN=163.6
1992 N=4 effN=8.2
2008 N=67 effN=50.1
Proportion
Length (cm)

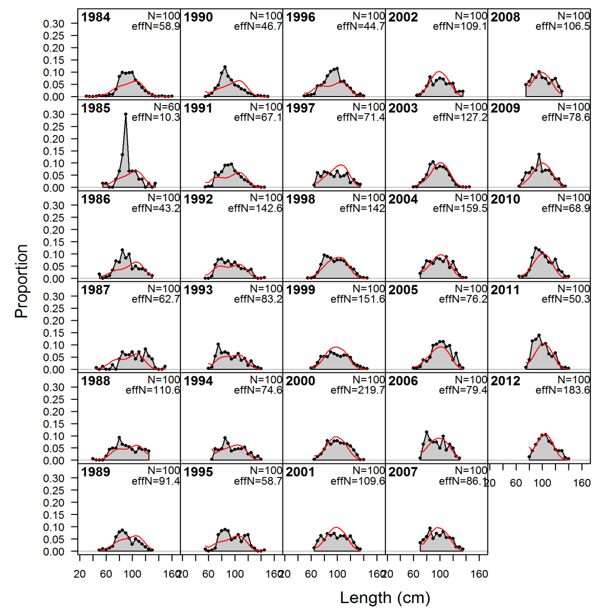

length comps, male, retained, 4_HB
1980 N=28 effN=13.2
1993 N=2 effN=2
2009 N=59 effN=56.4
1985 N=100 effN=21.1
2003 N=27 effN=54.4
2011 N=67 effN=20.2
1986 N=100 effN=34.4
2004 N=100 effN=56.5
2012 N=100 effN=65
1987 N=100 effN=52.2
2005 N=100 effN=45.5
1988 N=100 effN=30
2006 N=100 effN=163.6
1992 N=4 effN=8.2
2008 N=67 effN=50.1
Proportion
Length (cm)


length comps, sexes combined, retained, 5_CP
Proportion
Length (cm)

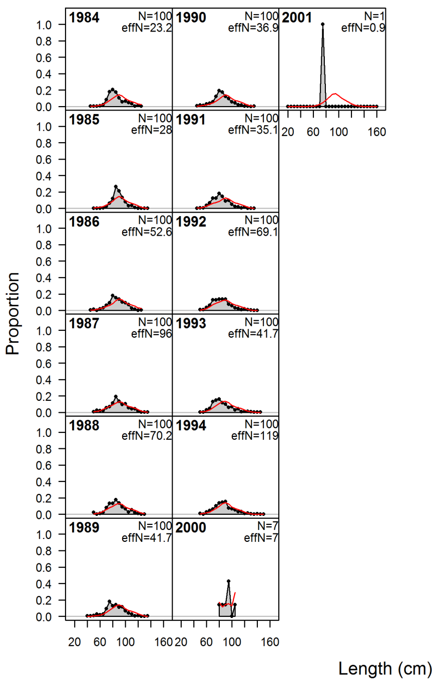

length comps, male, retained, 5_CP
Proportion
Length (cm)


length comps, female, retained, 5_CP
Proportion
Length (cm)

length comps, female, retained, 6_TOURN




length comps, sexes combined, retained, 6_TOURN




length comps, male, retained, 6_TOURN