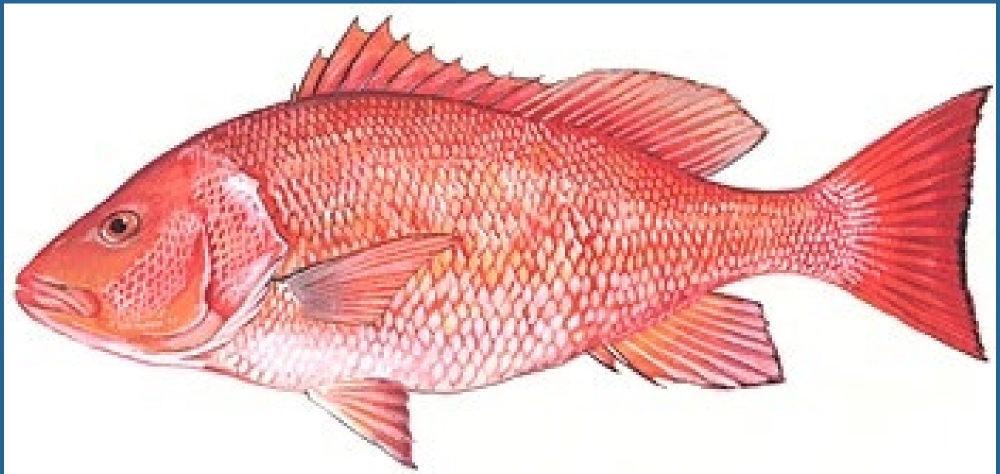
NOAA FISHERIES

Sustainable Fisheries Branch, Beaufort, NC

SEDAR 73
South Atlantic Red Snapper

SSC Review

27 April 2021



Topics

- Background
- Data
- Assessment model
- Assessment results
- Forecasts

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Background – SEDAR41

- The SEDAR41 benchmark (terminal year 2014) found the SA red snapper stock to be overfished and undergoing overfishing
- Proxy for MSY is 30% SPR (codified), also used for SEDAR73
- $F_{2012\text{-}2014}/F30 = 2.84$
- $SSB_{2014}/SSB_{F30} = 0.14$

Background – SEDAR73

- SEDAR73 (terminal year 2019) is an update assessment, with allowance for new data sources
  - New data sources and assessment modifications were discussed by the SSC in January 2021
- SEDAR73 conducted via webinars
  - Selectivity WG met fall of 2020 (focus on SERFS)
  - Data workshop December 1-4, & 16 of 2020
  - Three assessment webinars in January and February of 2021

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Life history

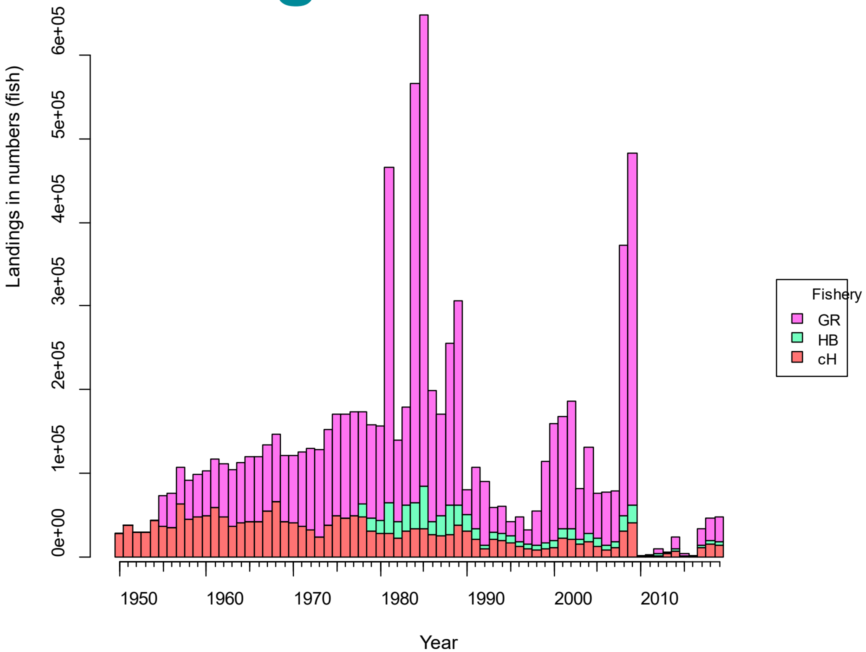
- Von Bertalanffy growth
  - Population growth curve – all data
  - Fishery growth curve1 – fishery samples taken during 20” minimum size limit
  - Fishery growth curve 2 – fishery samples taken outside of the 20” minimum size limit
- Age-based natural mortality (*updated*)
  - Lorenzen curve scaled to Then et al. (lutjanids only)
  - SEDAR-41 used Charnov curve scaled to Then et al. (all fishes)
- Spawning biomass modeled as population fecundity
  - Spawning occurs in mid-summer
  - 50:50 sex ratio
  - Logistic model of female maturity
  - Batch size is a function of body size (*updated*)
  - Age-specific number of batches

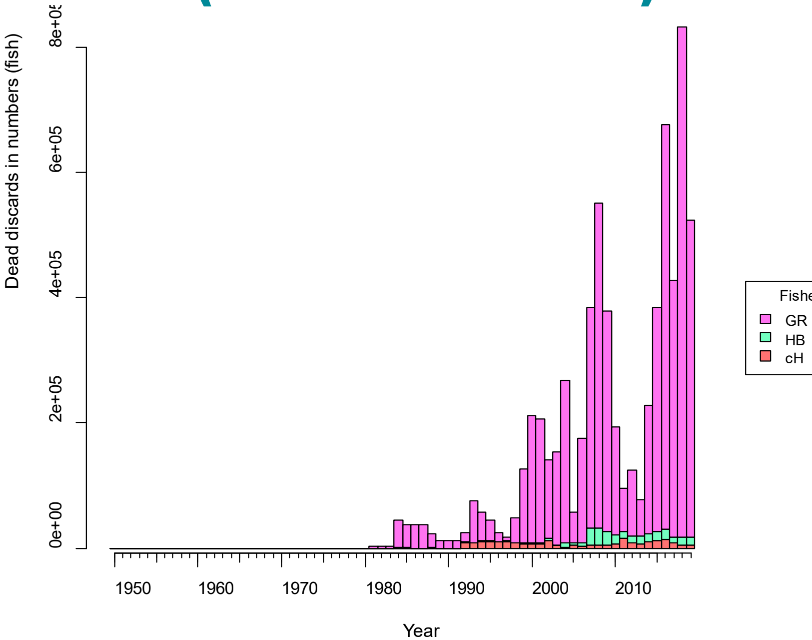
Fleet structure

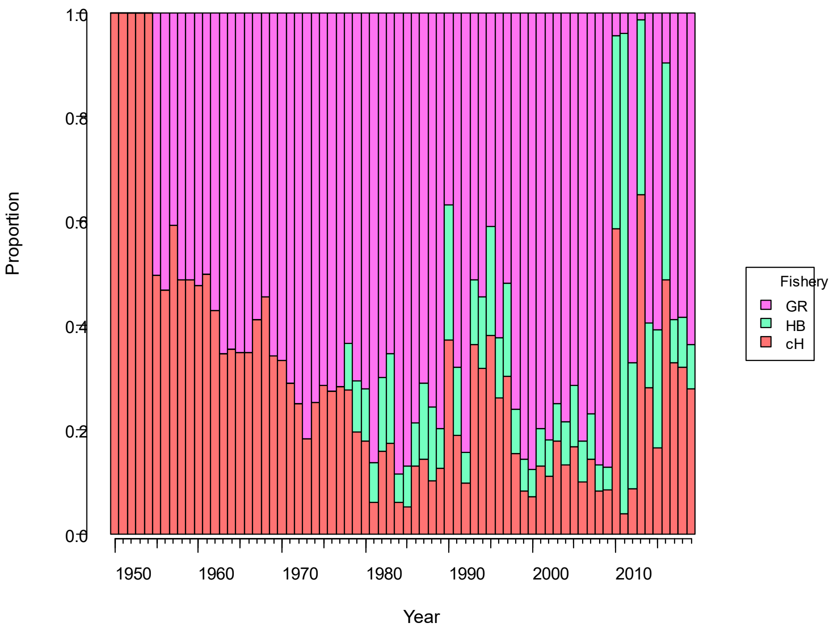
- Commercial handline (pooled with other gears)
- Recreational headboats
- General recreational (private + charterboats)

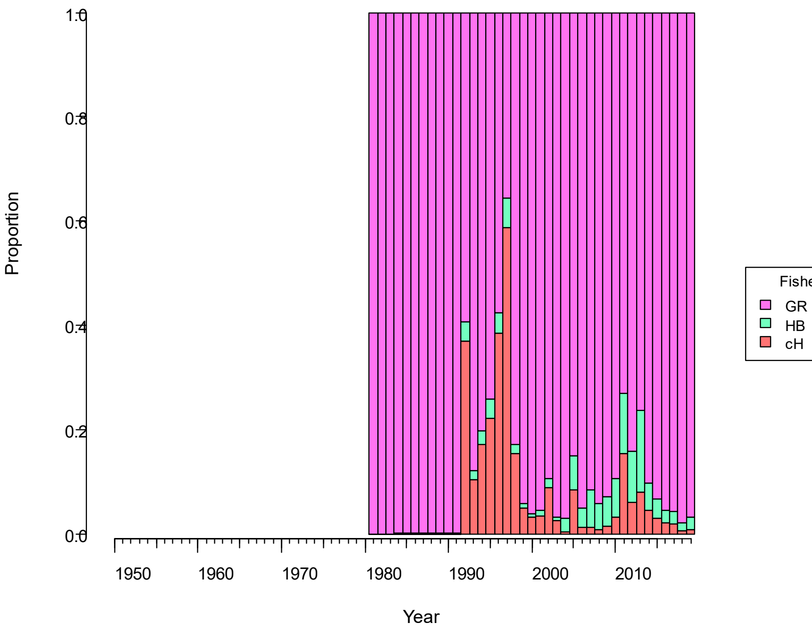
- Landings and dead discards modeled separately for each fleet

Landings and discard mortalities (in numbers)









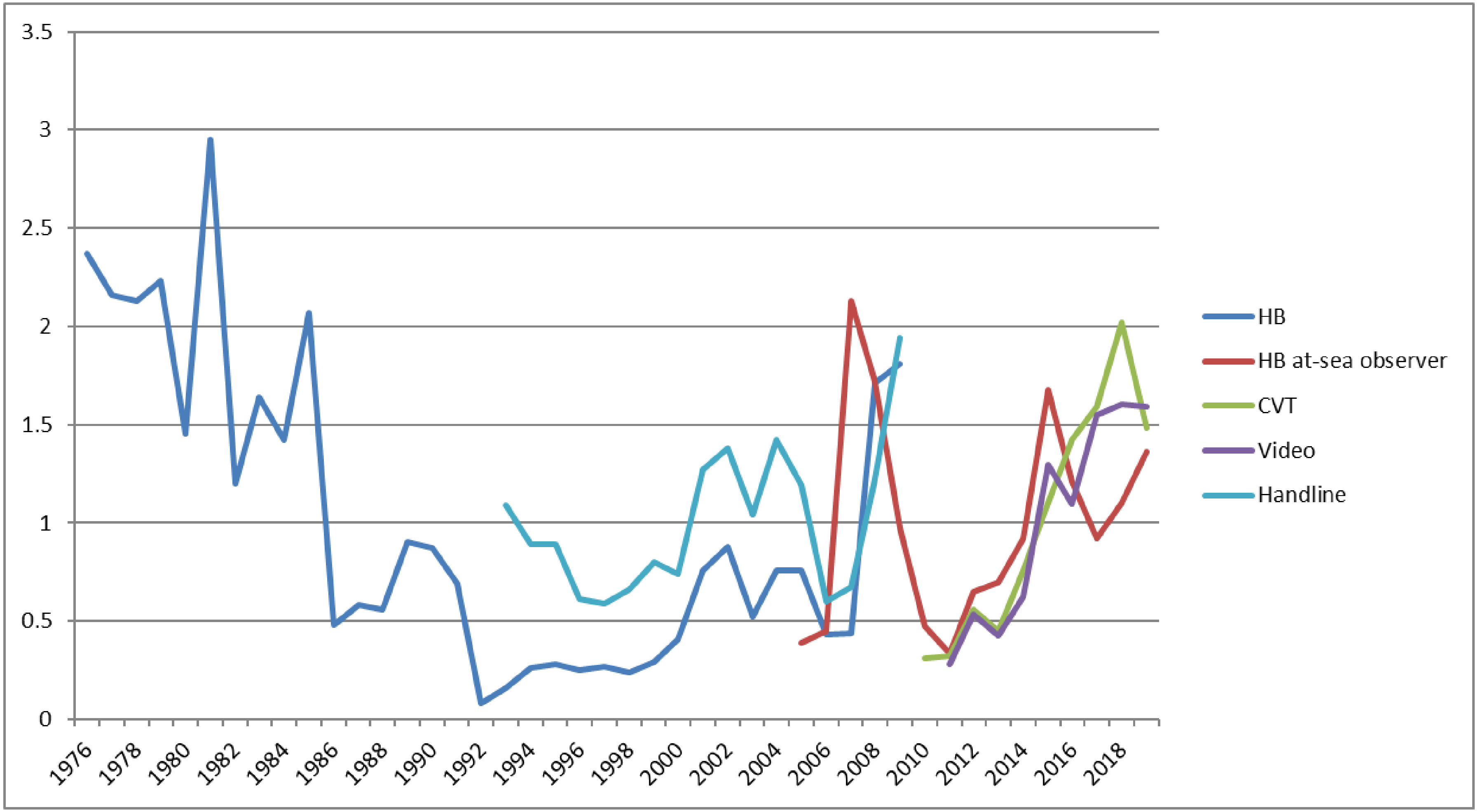
Comps available for S73

- Lengths
  - Commercial landings 1984–1992
  - Commercial discards; pooled into <2010 and ≥2010
  - Headboat discards 2005–2019
  - Gen rec discards (*new data source*)
- Ages
  - Commercial landings 1990–2019
  - Headboat landings 1978–2019
  - General rec landings 2001–2019
  - SERFS chevron trap 2010–2019

Indices of Abundance

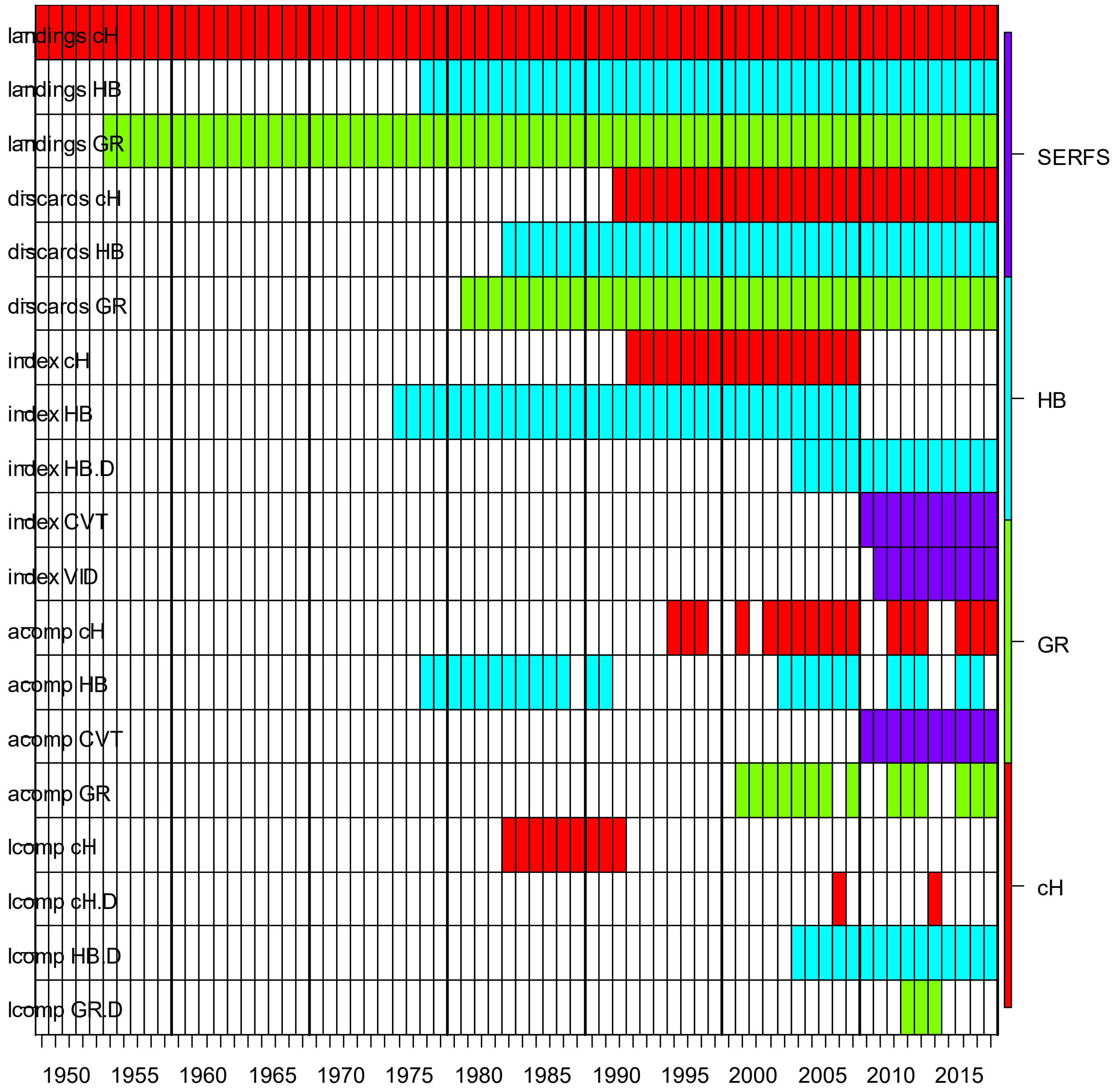
- Three fishery dependent indices of abundance
  - Headboat logbooks (1976–2009)
  - Commercial handline logbooks (1993–2009)
  - Headboat discards, included only fish <20” (2005–2019)
- Logbook indices (landings per effort) were truncated at 2009, because of the regulations starting in 2010
- Two fishery independent index of abundance from SERFS
  - S41 combined the two indices, because of non-independence
  - Chevron traps (2010–2019)
  - Videos (2011–2019)

Indices



3.5
3
2.5
2
1.5
1
0.5
0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
HB
HB at-sea observer
CVT
Video
Handline

SEDAR73 data summary

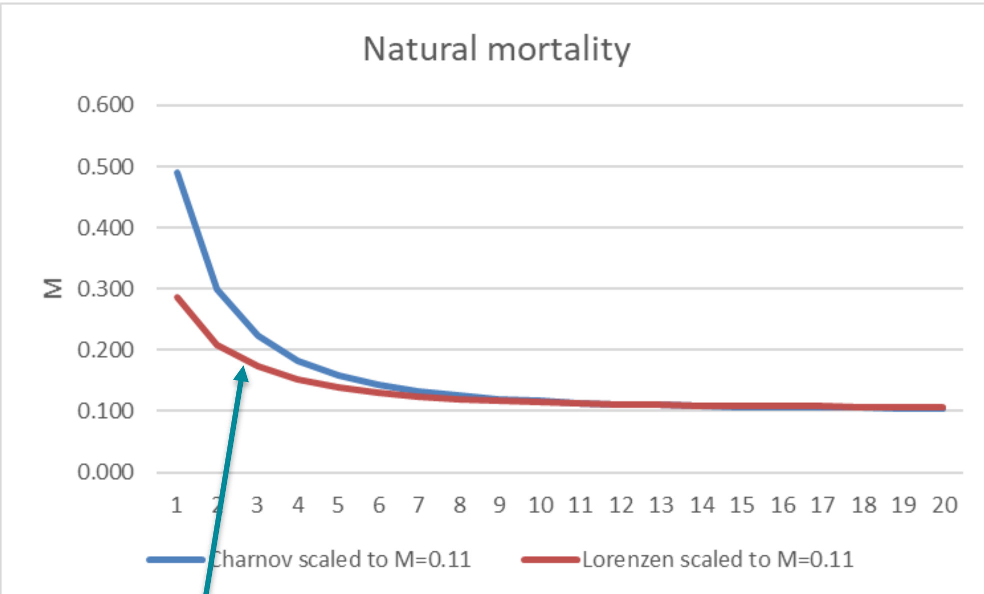


New data/information for SEDAR73

- General recreational landings and discards from current MRIP methodology
- Life history
  - Batch fecundity, natural mortality
- Indices of abundance
  - Trap and video as separate time series
  - FWRI repetitive timed drop survey (hook-and-line) + age comps
- Discard length comps
  - Commercial: shark bottom longline observer program
  - Headboats: Captain Steve Amick measurements
  - Gen rec: FWRI charterboat observers, MyFishCount
- Discard mortality and use of descender devices

Natural mortality

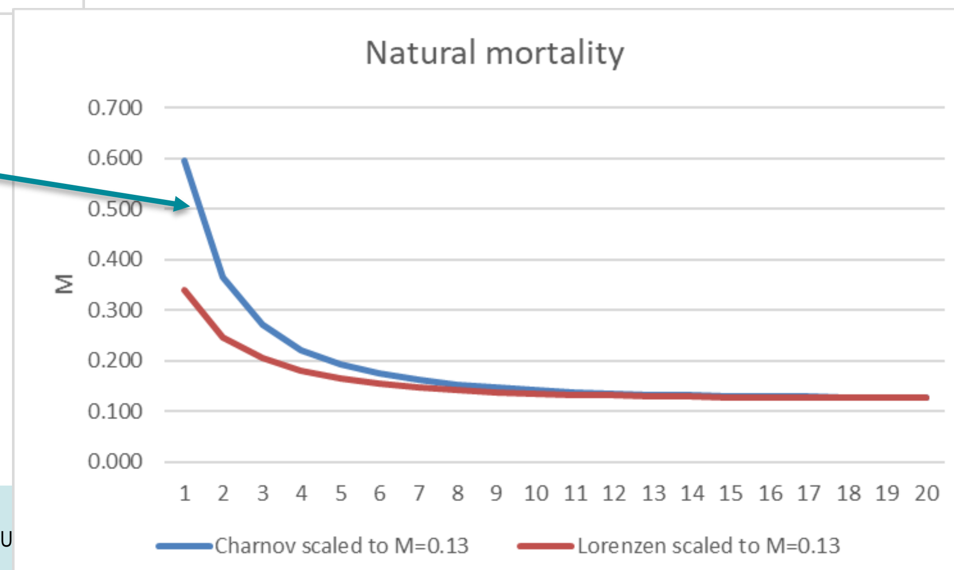
Scaled to Then et al., lutjanids only



SEDAR73

SEDAR41

Scaled to Then et al., all species



Discard Mortality

Fleet	Block 1	Block 2	Block 3	Block 4
cH	$0.48(0.38-0.58)$	$0.38(0.28-0.48)$	$0.36(0.26-0.46)$	$0.32(0.22-0.42)$
HB	$0.37(0.27-0.45)$	$0.26(0.18-0.34)$	$0.25(0.17-0.33)$	$0.22(0.14-0.30)$
GR	$0.37(0.27-0.45)$	$0.28(0.20-0.36)$	$0.26(0.18-0.34)$	$0.23(0.15-0.31)$

Block 1

- Recreational: pre-2011
- Commercial: pre-2007

Block 2 (circle hooks)

- Recreational: 2011-2016
- Commercial: 2007-2016

Block 3 (circle hooks + 25% descender device use)

- All fleets: 2017-2020

Block 4 (circle hooks + 75% descender device use)

- All fleets: post-2020 (forecasts)

➢ Reductions in Blocks 3 and 4 based on Vecchio et al. (S73-WP15)

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BAM: same basic model as in SEDAR41 (1 of 2)

- Integrated catch-age formulation, fit to data using penalized maximum likelihood
- Baranov catch equation
- Spawning stock based on population fecundity
  - Length-dependent batch size
  - Age-dependent number of batches
- Age-based natural mortality (scaled Lorenzen)

BAM: same basic model as in SEDAR41 (2 of 2)

- Initial age structure in 1950 was equilibrium age structure, conditional on F_{init} (estimated)
- Recruitment deviations start in 1978
- Ages modeled: 1-20+
- Constant (estimated) CV of size at age for each growth curve
  - population, fishery 20-inch size limit, fishery no size limit
- Uncertainty characterized by Monte/Carlo Bootstrap Ensemble (MCBE) approach

Selectivity structure

Follows SEDAR41 with the exception of CVT and VID indices

Fleet/survey	Block 1 (1950–1991)	Block 2 (1992–2009)	Block 3 (2010–2019)
L.cH	Flat	Flat	Flat
L.HB	Dome	Dome	Dome
L.GR	Dome	Dome	Flat
D.cH	—	Dome	Flat
D.HB	Dome	Dome	Dome
D.GR	Dome	Dome	Dome
HBD	—	Dome	Dome
CVT	—	—	Dome
VID	—	—	Flat

Modifications to the SEDAR41 model (1 of 3)

- SERFS trap and video indices included as separate time series
  - Selectivity of traps was dome-shaped rather than flat-topped
  - Selectivity of video was flat-topped, with ascending limb mirroring that of traps
  - Video index CVs divided by 3 to achieve closer fit to high observed values in the terminal years
  - Each likelihood multiplied by 0.5 to account for non-independence of sampling
    - Bivariate likelihood attempted but did not converge. More model development time required for this approach to be fully vetted.
- Plus group for fitting age comps is 13+ for commercial and 10+ for headboat, gen rec, and CVT because of many zeros in observed older age classes
  - SEDAR41 used 13+ for commercial, gen rec, and CVT

Modifications to the SEDAR41 model (2 of 3)

- Mean recruitment model, rather than Beverton-Holt with h=0.99
  - lognormal deviations
- Comp data fit using the Dirichlet-multinomial, rather than the robust multinomial distribution
  - Recommended by Francis (2017), Thorson et al. (2017), and Fisch et al. (submitted)
  - Better accounts for overdispersion, which can result from intra-haul correlation
  - Self-weighting
  - Has become standard practice in SEDAR assessments (including GoM assessments using SS)

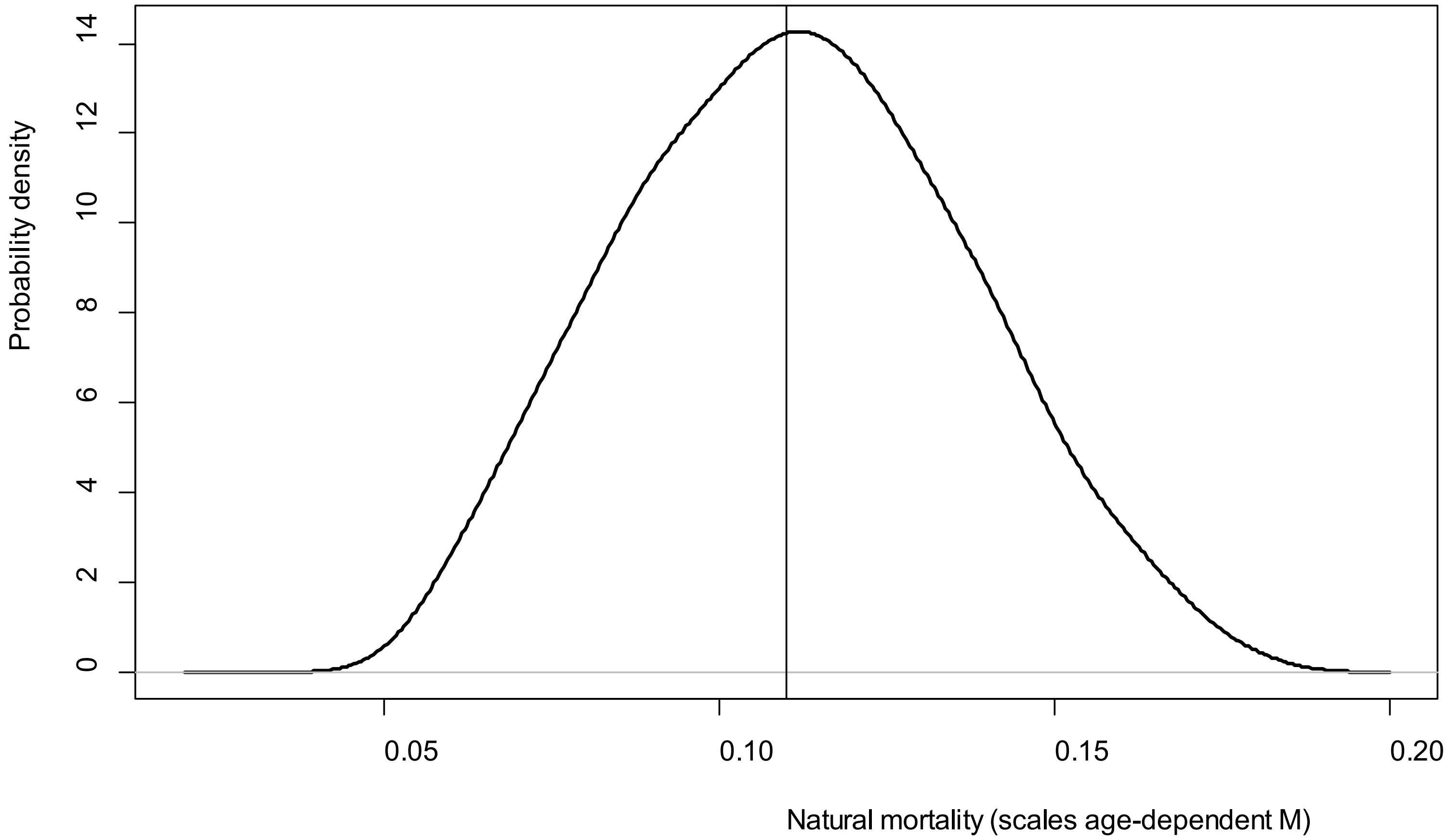
Modifications to the SEDAR41 model (3 of 3)

- Iterative re-weighting not done
  - Not necessary for comps (Dirichlet-multinomial)
  - Degraded fits to indices (undesirable)
- Two measures of fishing intensity, in addition to apical F
  - SPR_F
  - Exploitation rate

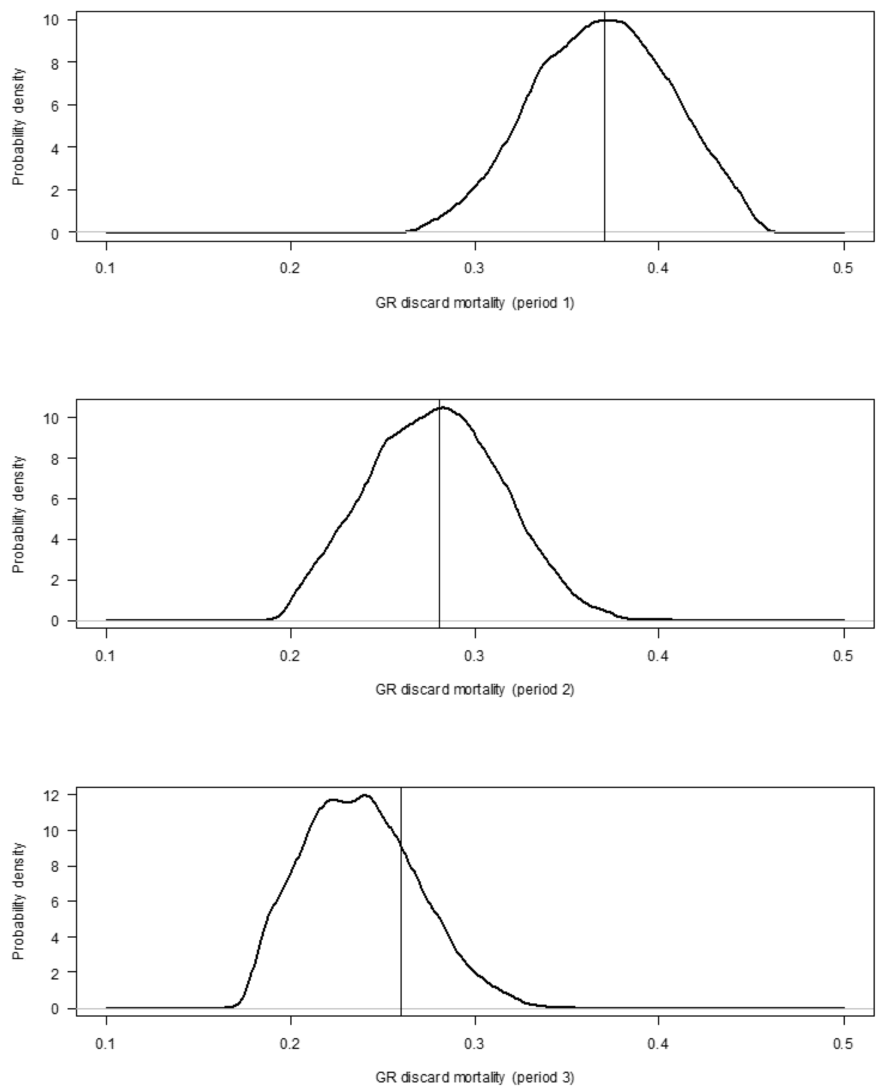
Characterizing uncertainty: Monte Carlo/Bootstrap Ensemble (MCBE)

- Bootstrap the data
  - Multinomial resampling of age and length comps
  - Multiplicative lognormal error on indices, landings, and discards
- Monte Carlo draws
  - Natural mortality: Bootstrap Then et al. data paired with Tmax~U[48,53]
  - Discard mortality: Normal deviates by fleet and time-block, decreasing
  - Batch fecundity: Bootstrap the raw data
  - Batch number: Bootstrap the raw data
  - Scale of historic recreational landings: Truncated normal deviate with mean = 1 and CV=0.59 from data providers
- 4000 model fits
  - 8% culled because didn't converge or a parameter hit a bound

Natural mortality

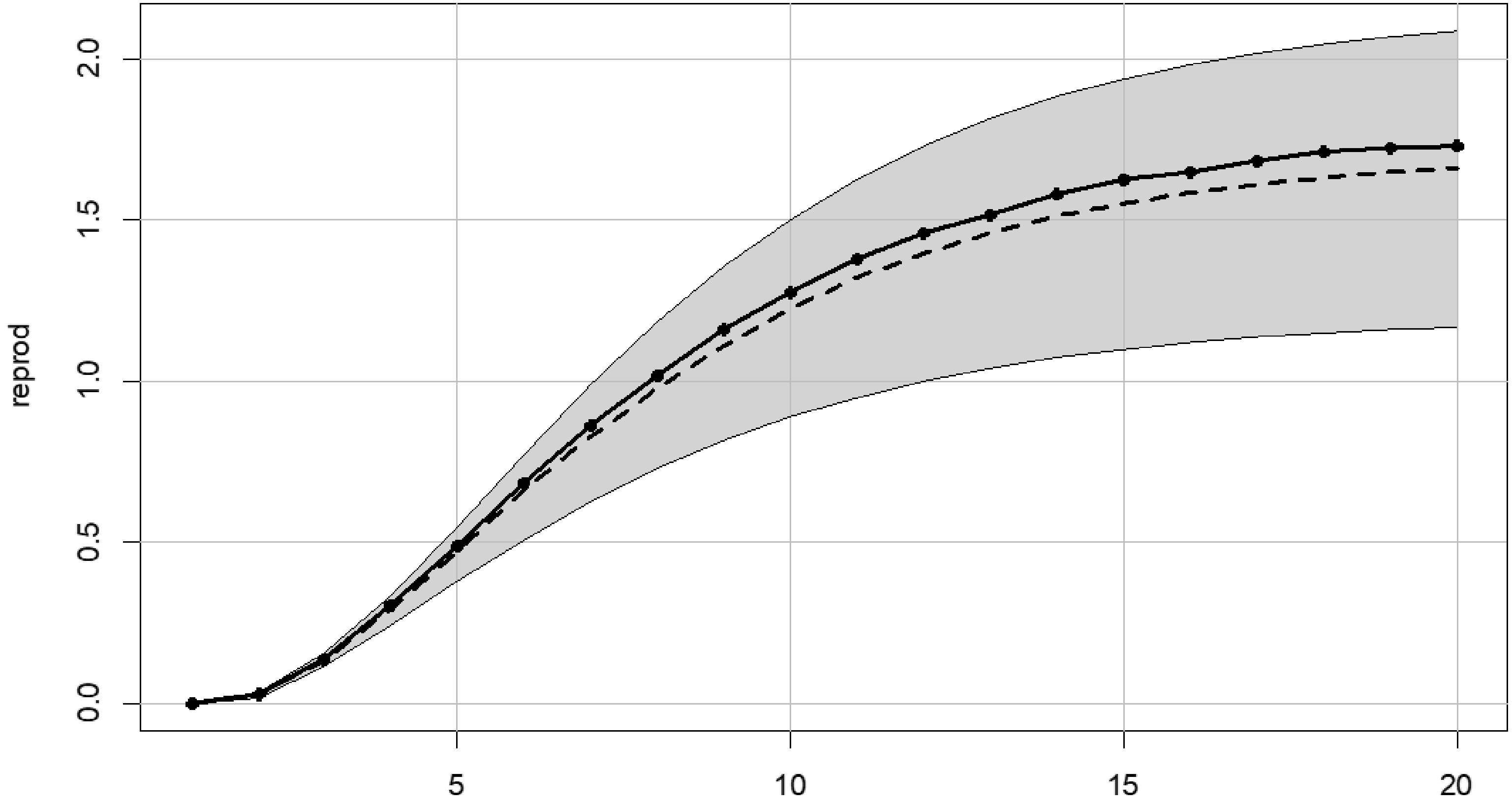


Discard mortality (e.g., general rec)

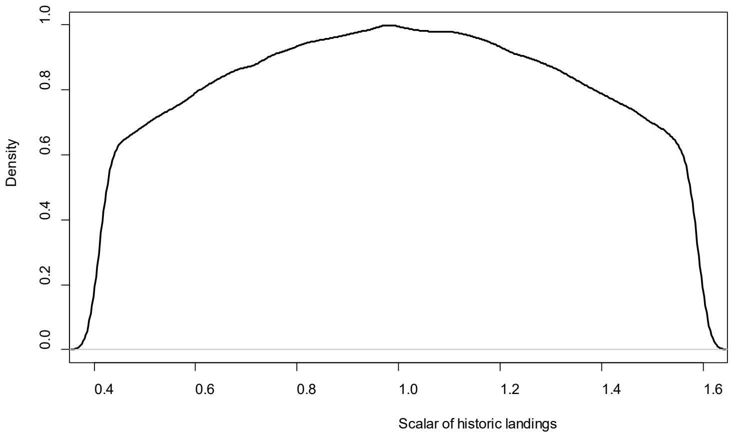


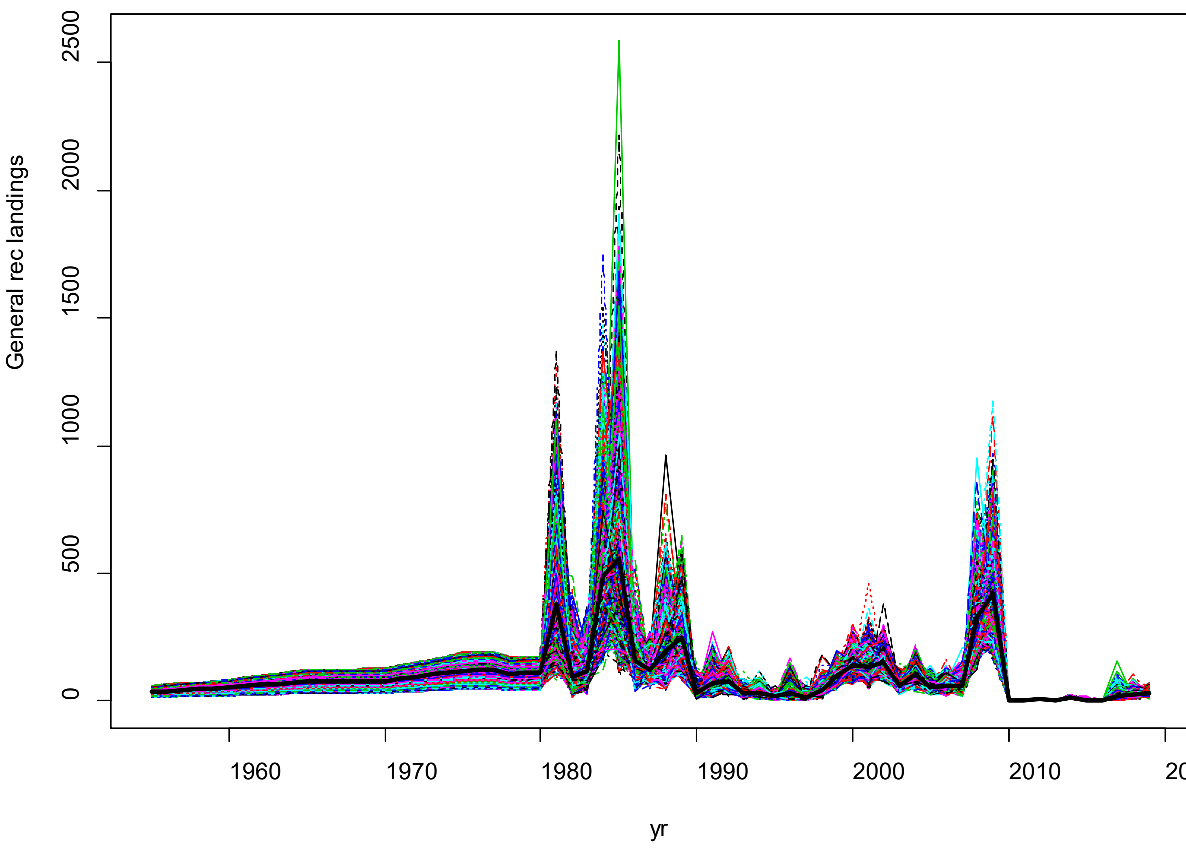
Reproductive output (scaled) of mature females

- combines uncertainty in batch fecundity and number of batches



Scale of historic recreational landings + bootstrap





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Sensitivity runs

- MyFishCount comp data included
- RTD index included, with corresponding age comps
- Drop SERFS CVT index
- Drop SERFS video index, with upweighting on CVT index
- Drop HB.D index
- High video index wgt=4
- Low video index wgt=2
- High M = 0.15 (implies max age of 38)
- Low M = 0.07 (implies max age of 87)
- SEDAR41 M (Charnov scaled to M = 0.13)
- Charnov M scaled to M = 0.11
- Robust multinomial likelihood for comp data, with iterative re-weighting
- Discards starting in 2010 adjusted downward to 10% of observed values (hypothetical)
- M adjusted upward until stock is considered rebuilt (hypothetical)
- Retrospective analyses

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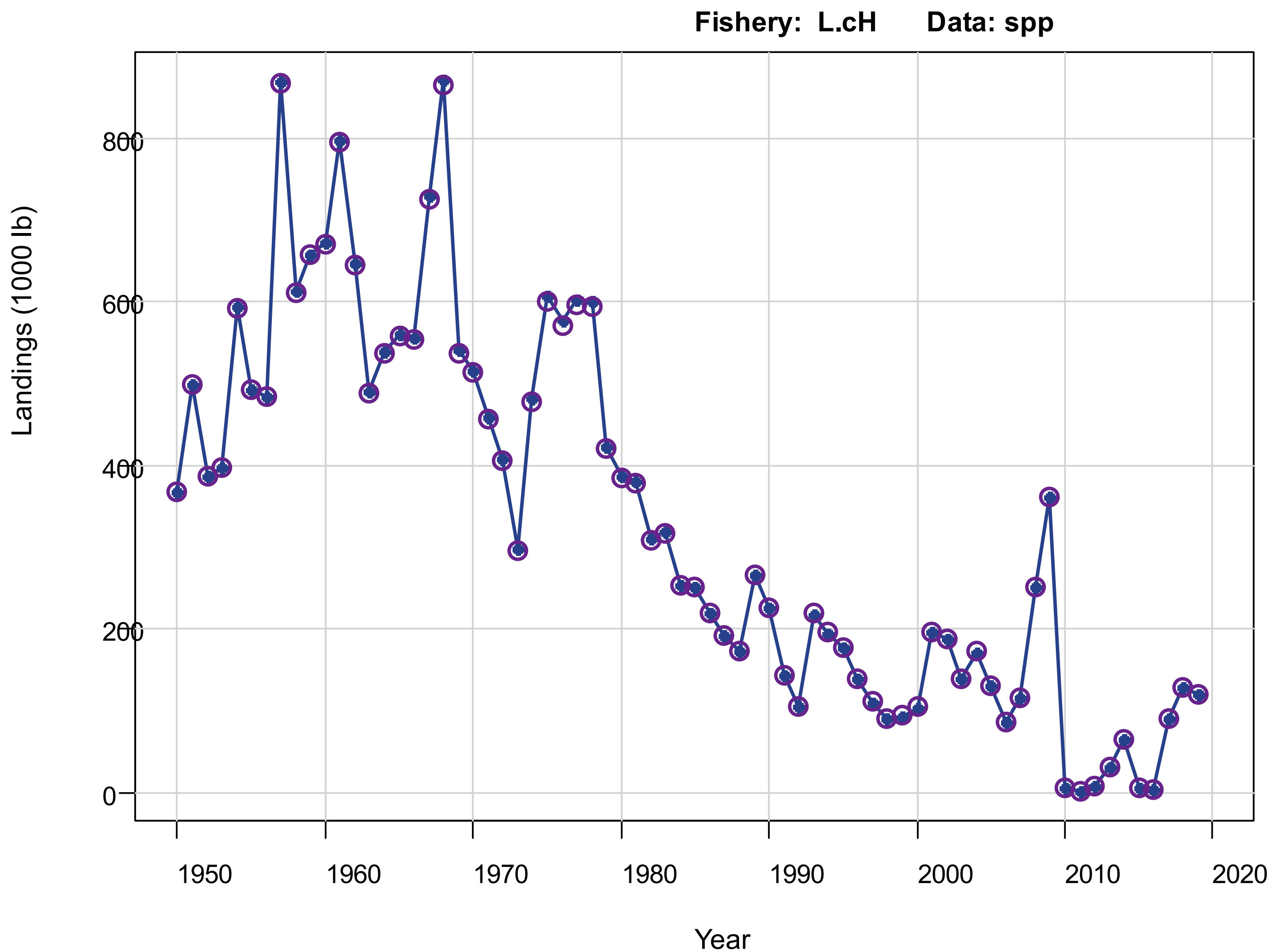
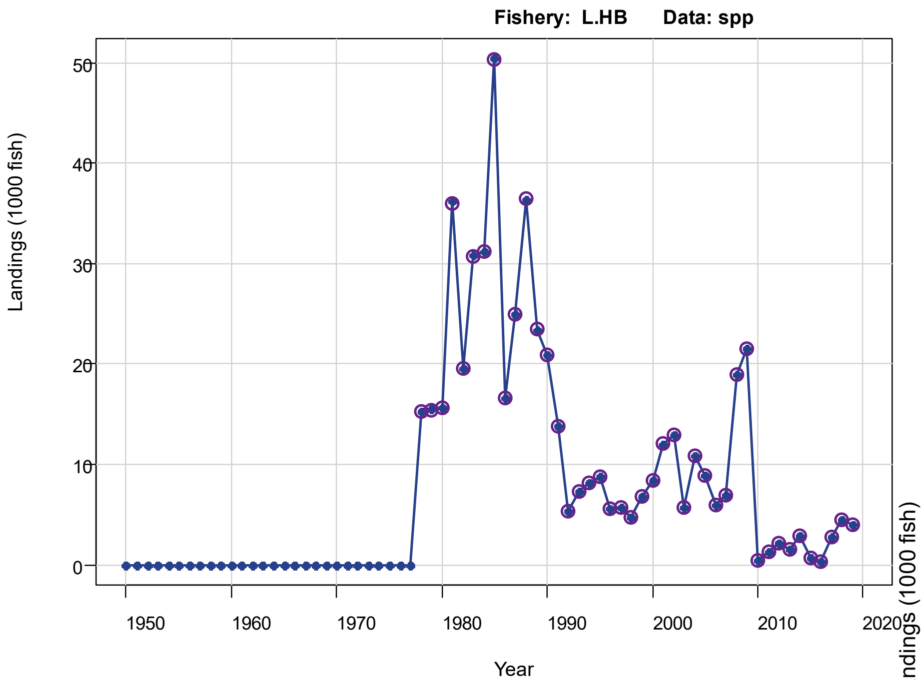
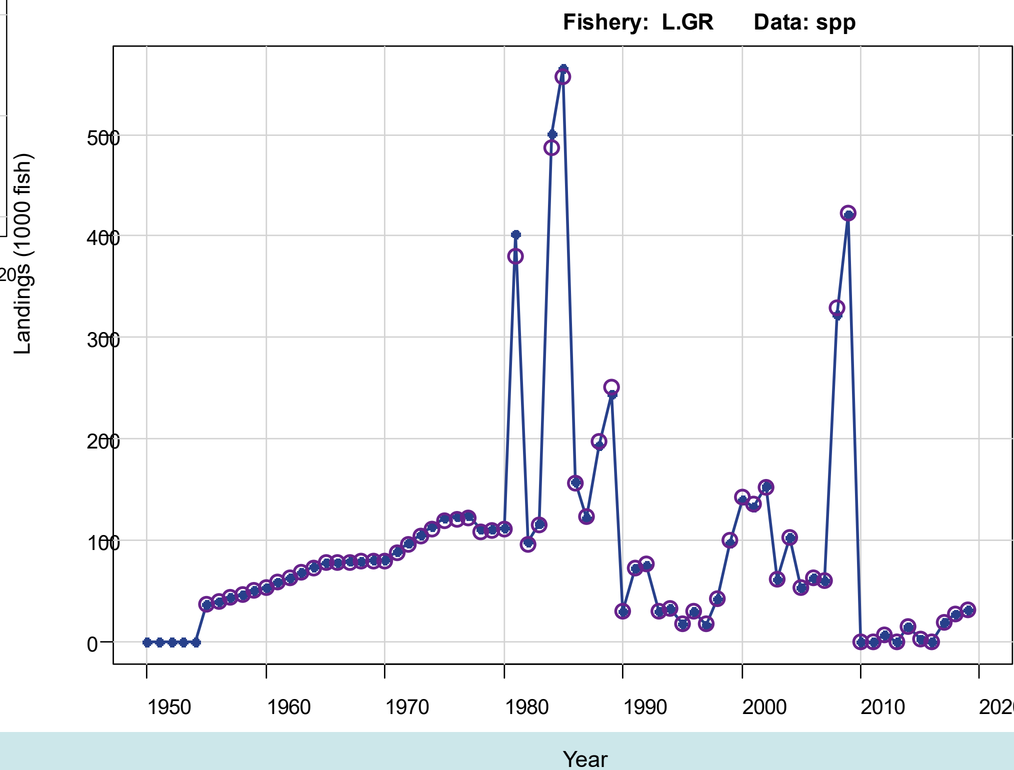
BAM base run – fits to data (comm landings)

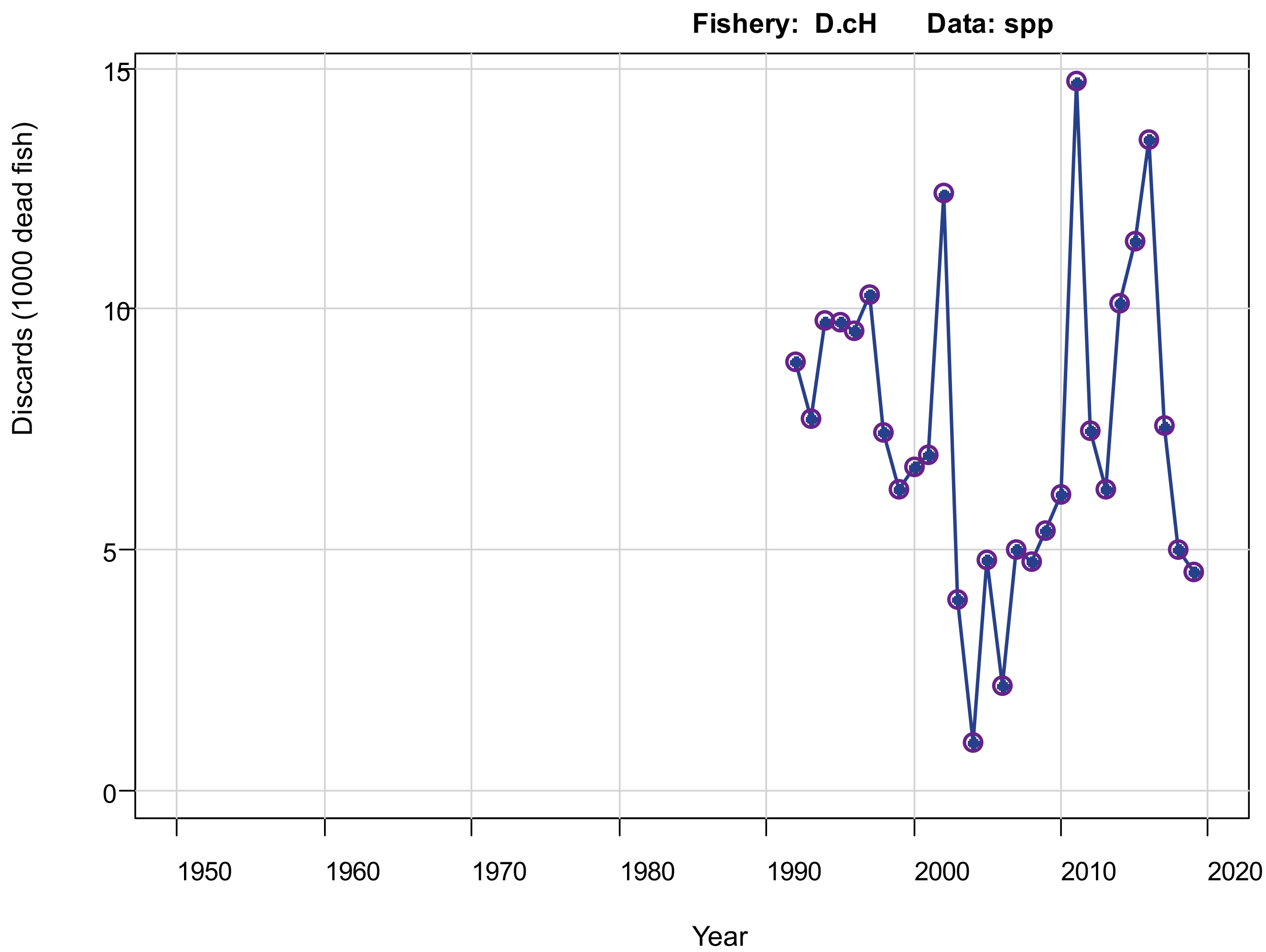


BAM base run – fits to data (HB & rec landings)

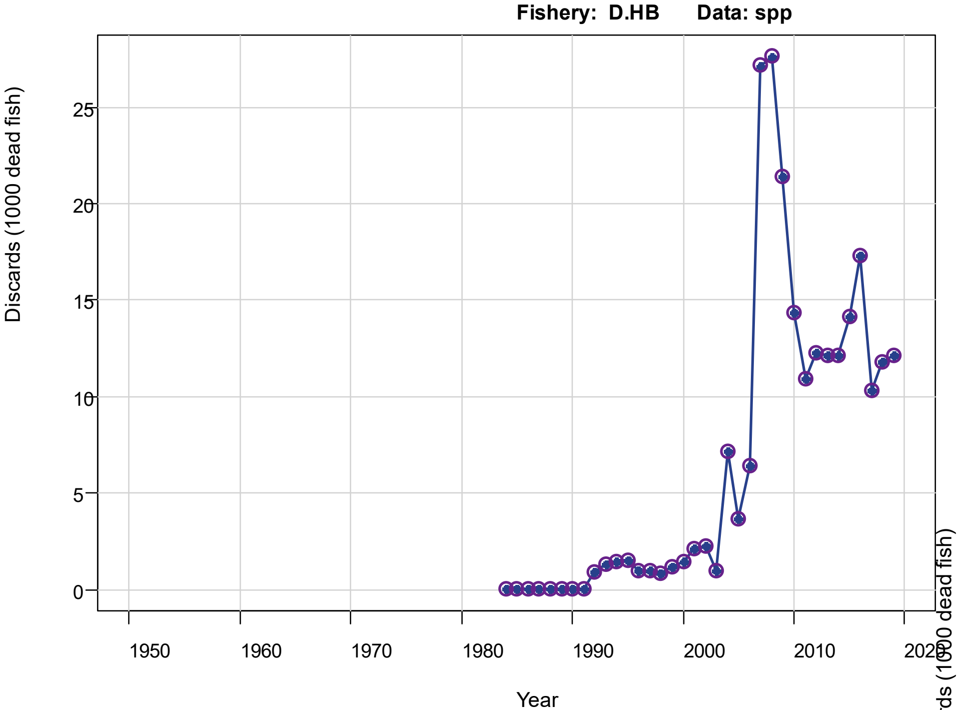


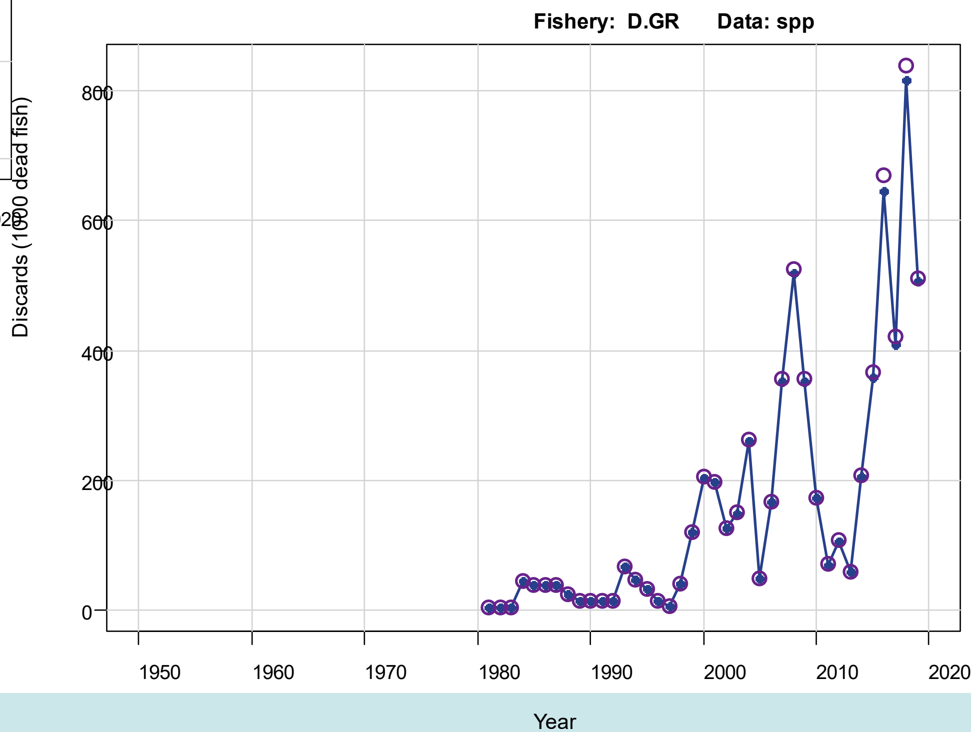


BAM base run – fits to data (comm dead discards)



BAM base run – fits to data (HB & rec dead discards)





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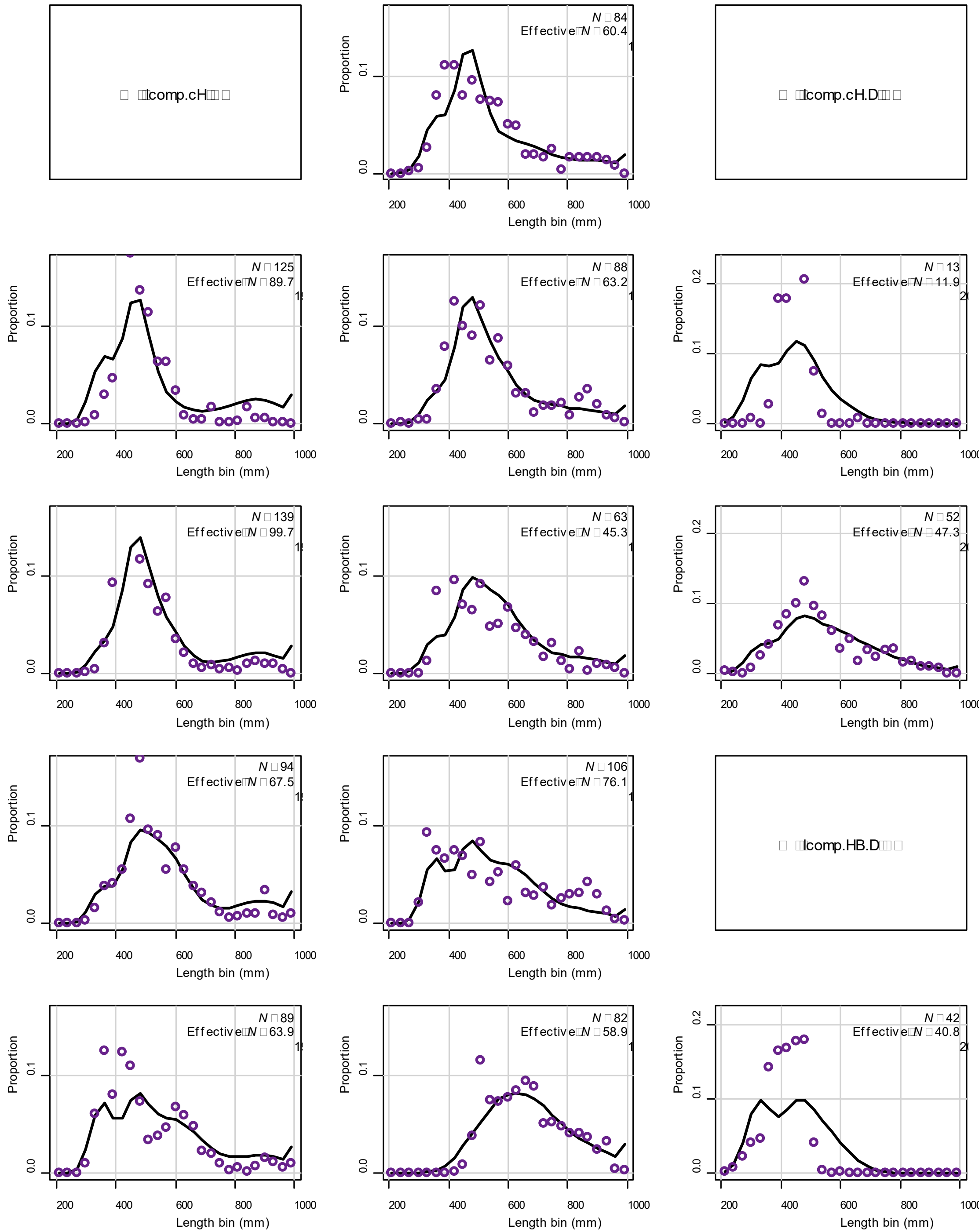

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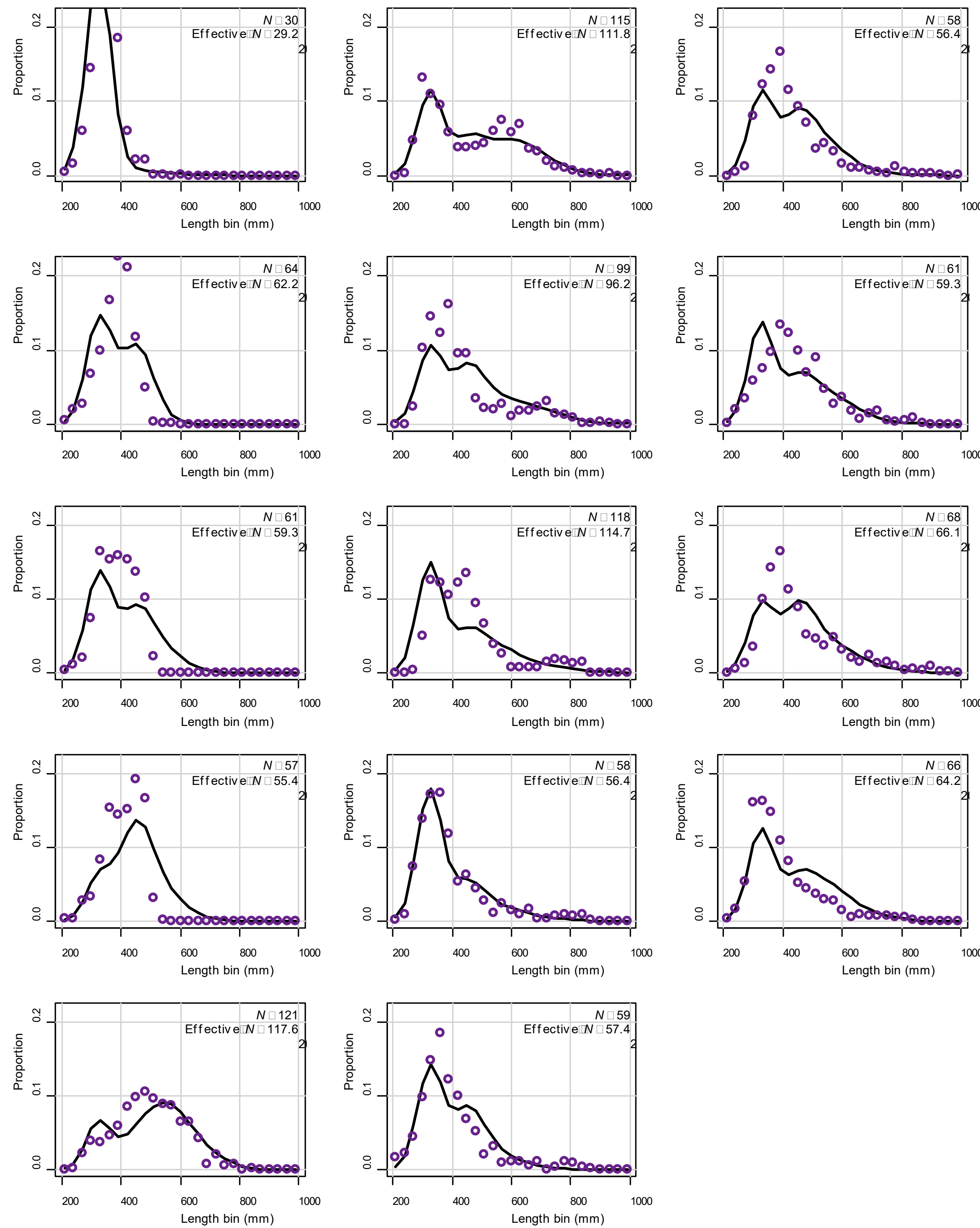

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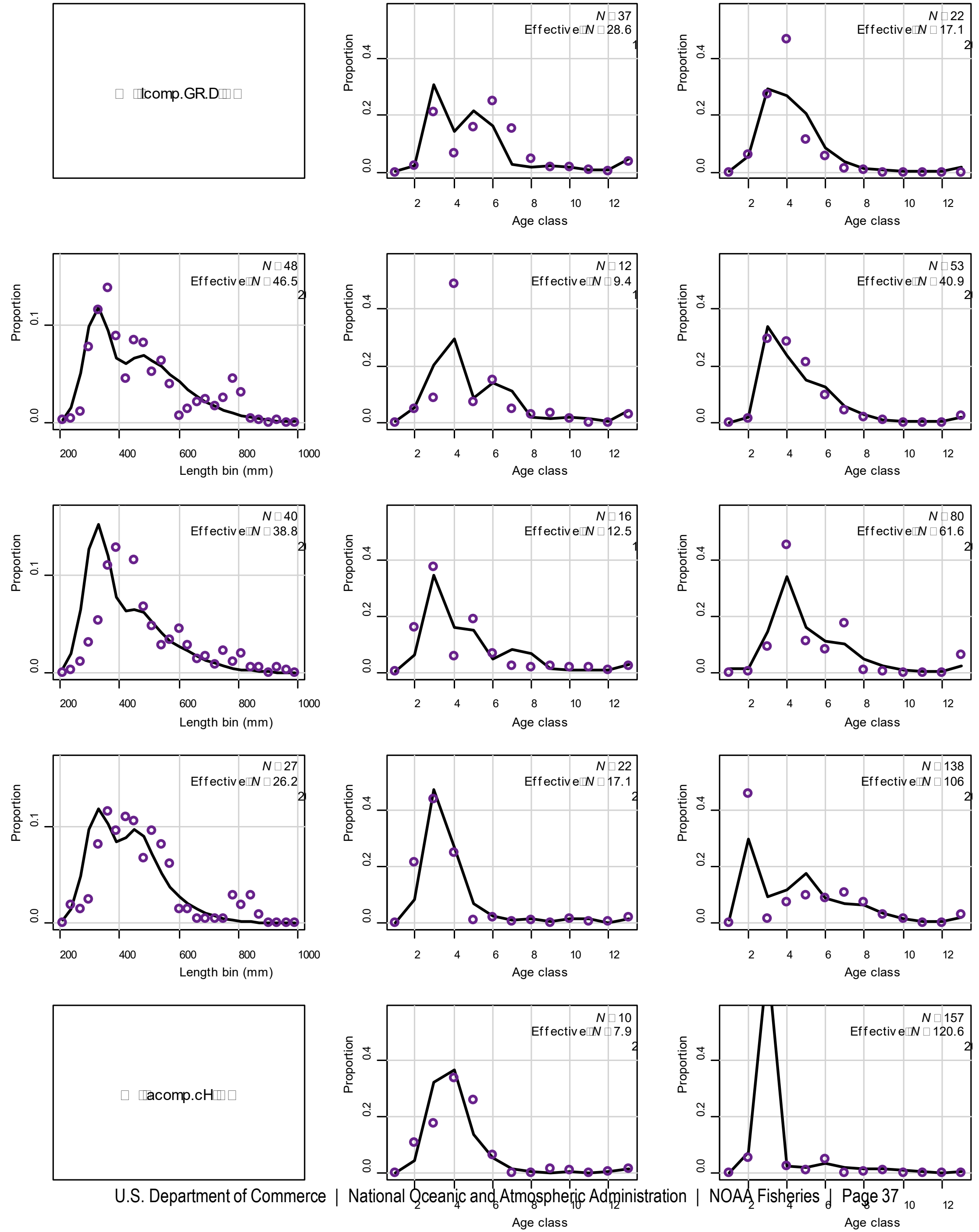

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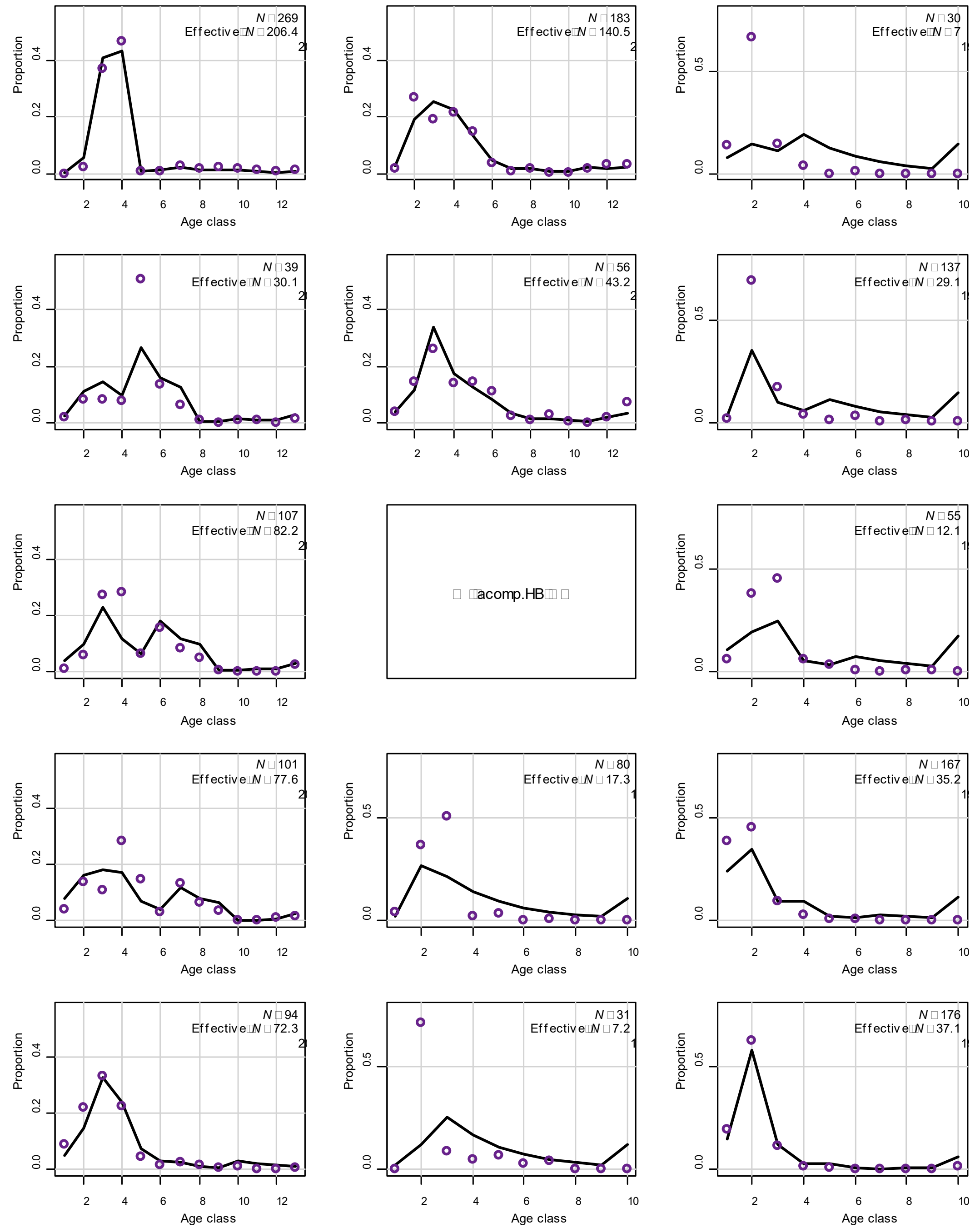

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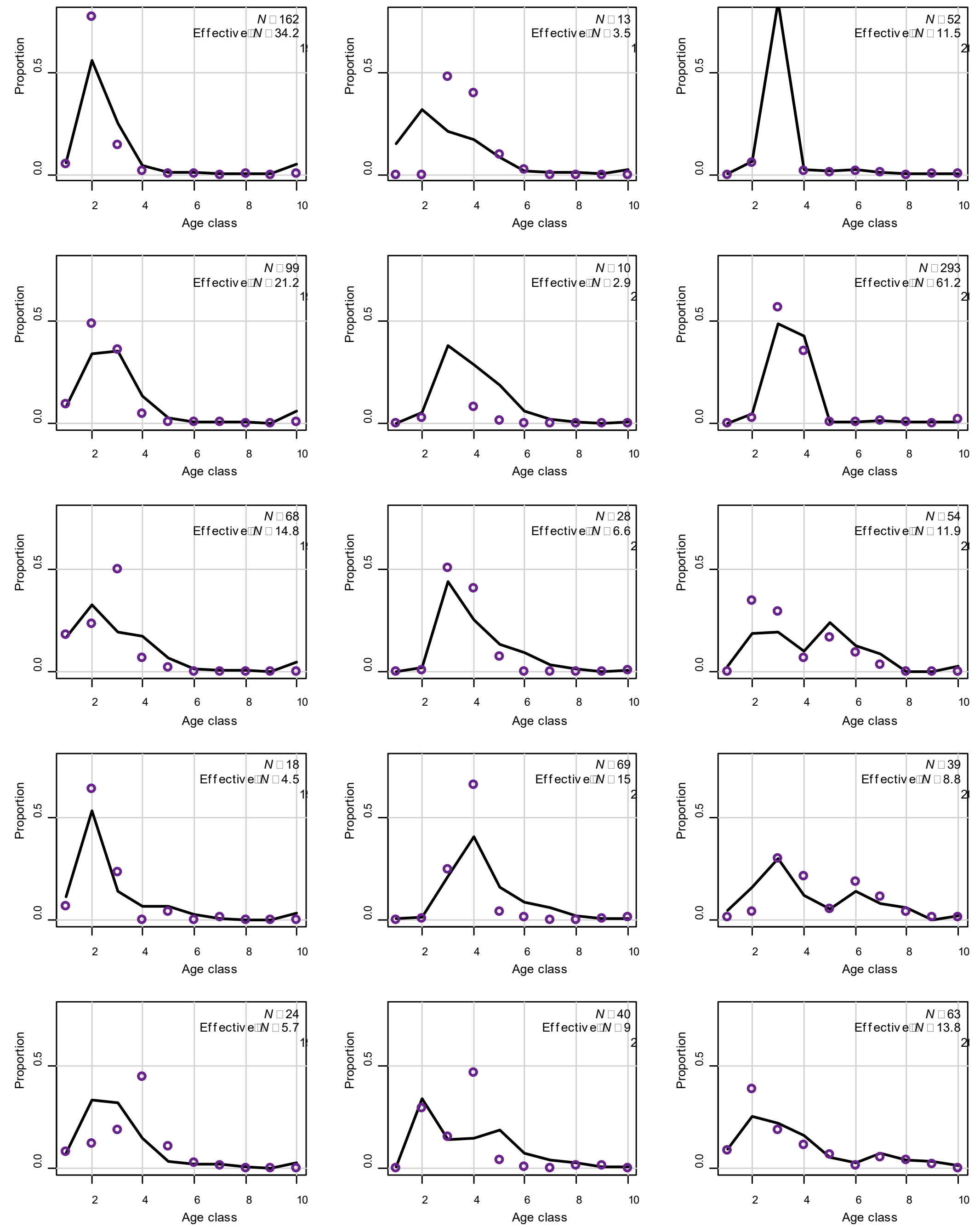

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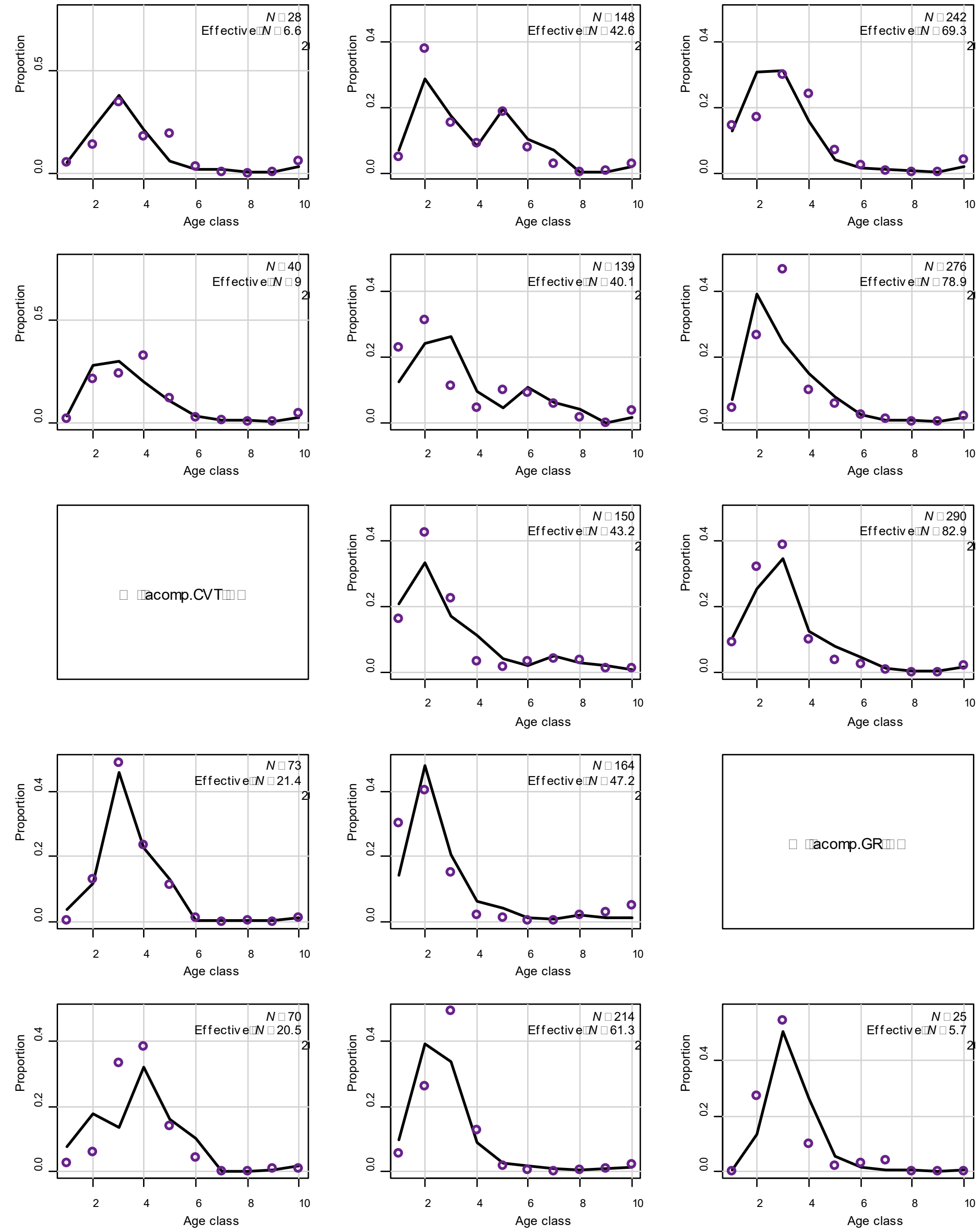

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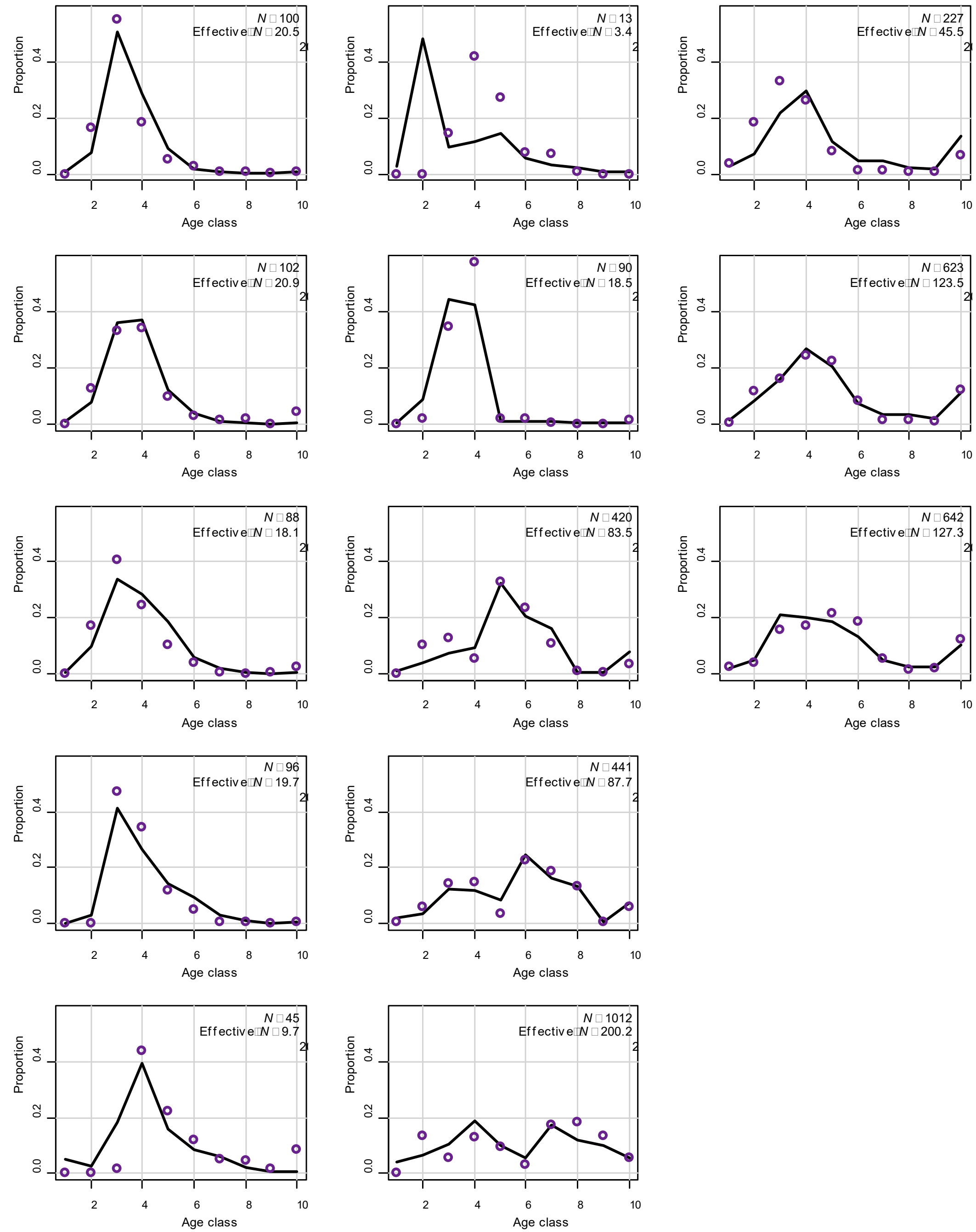

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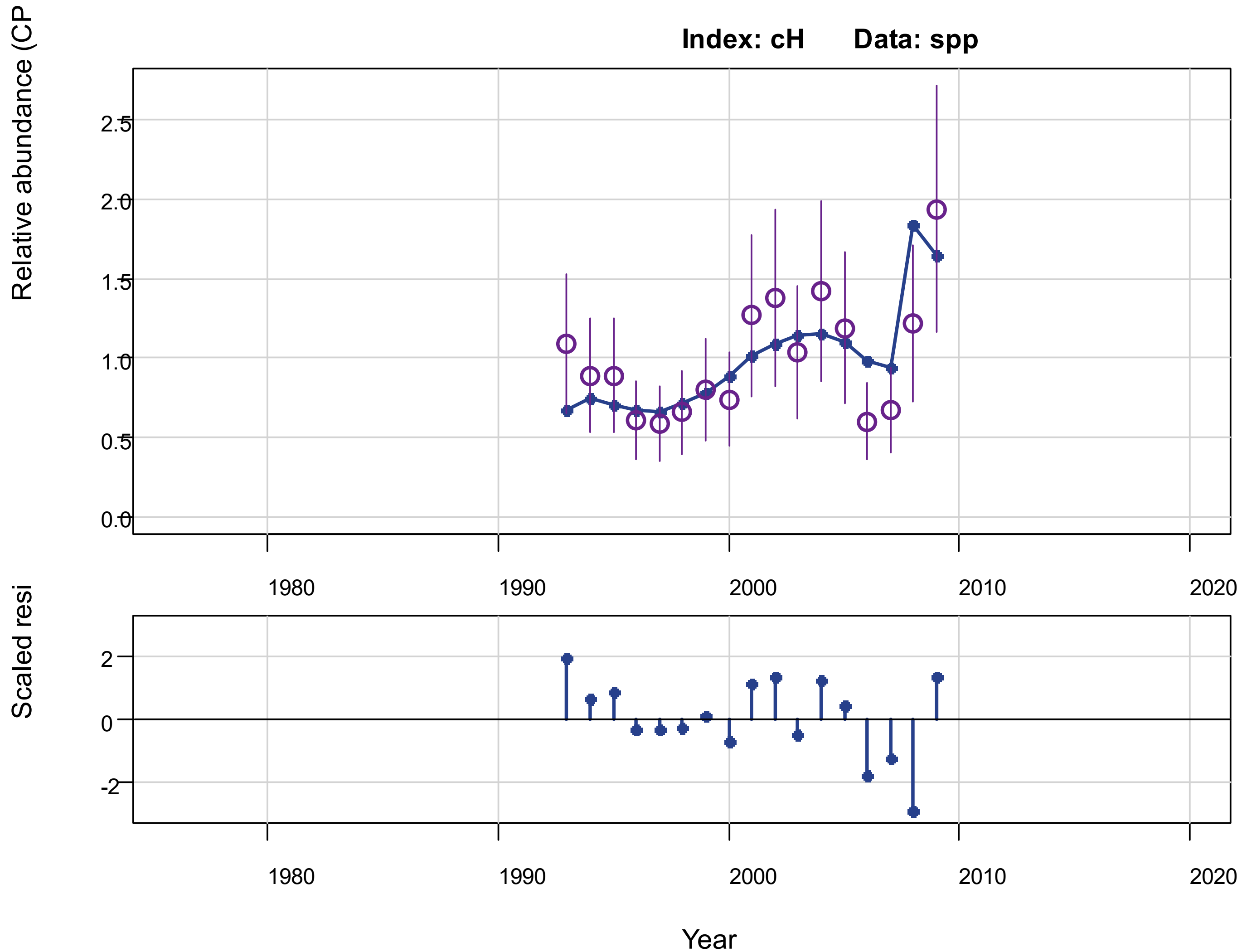

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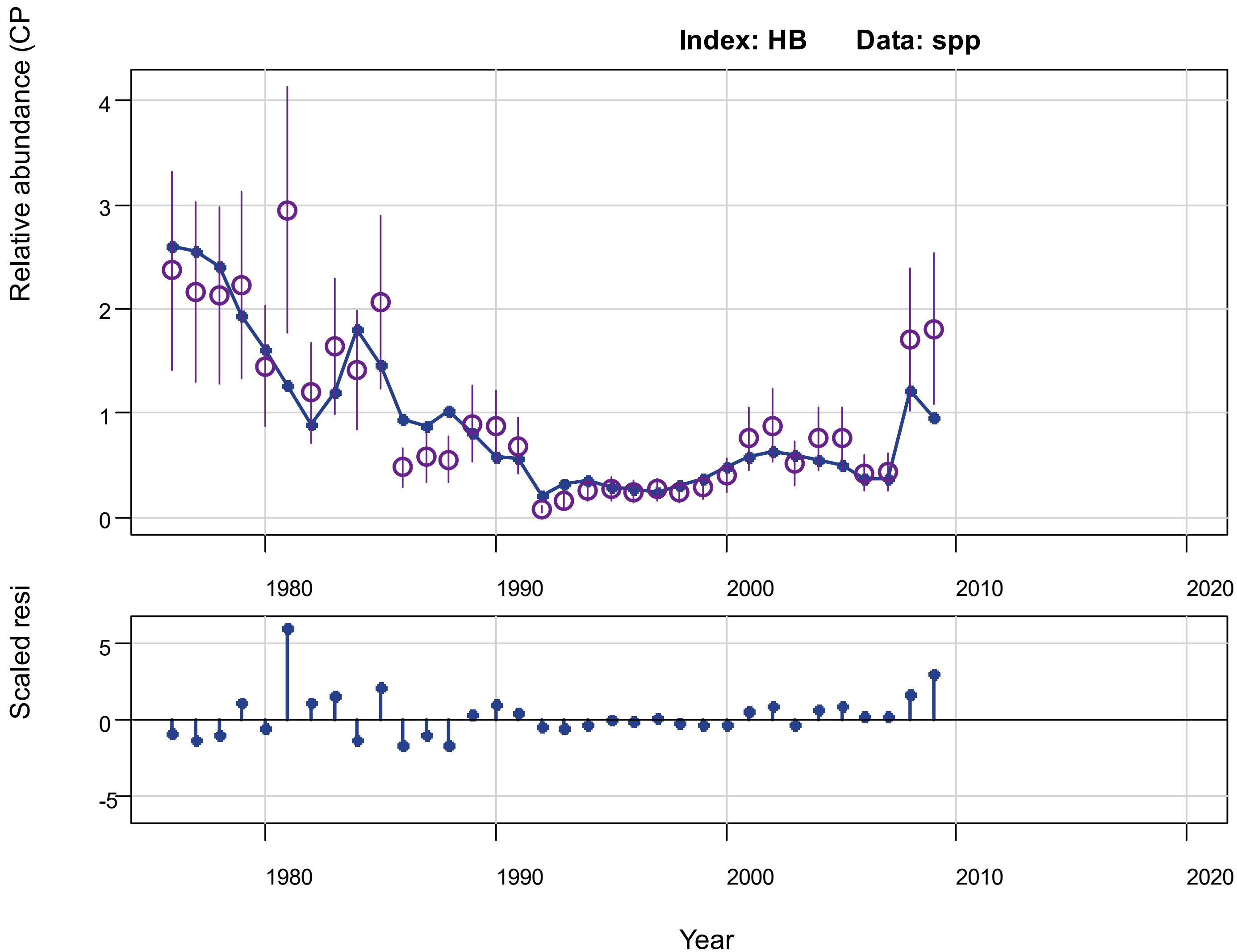

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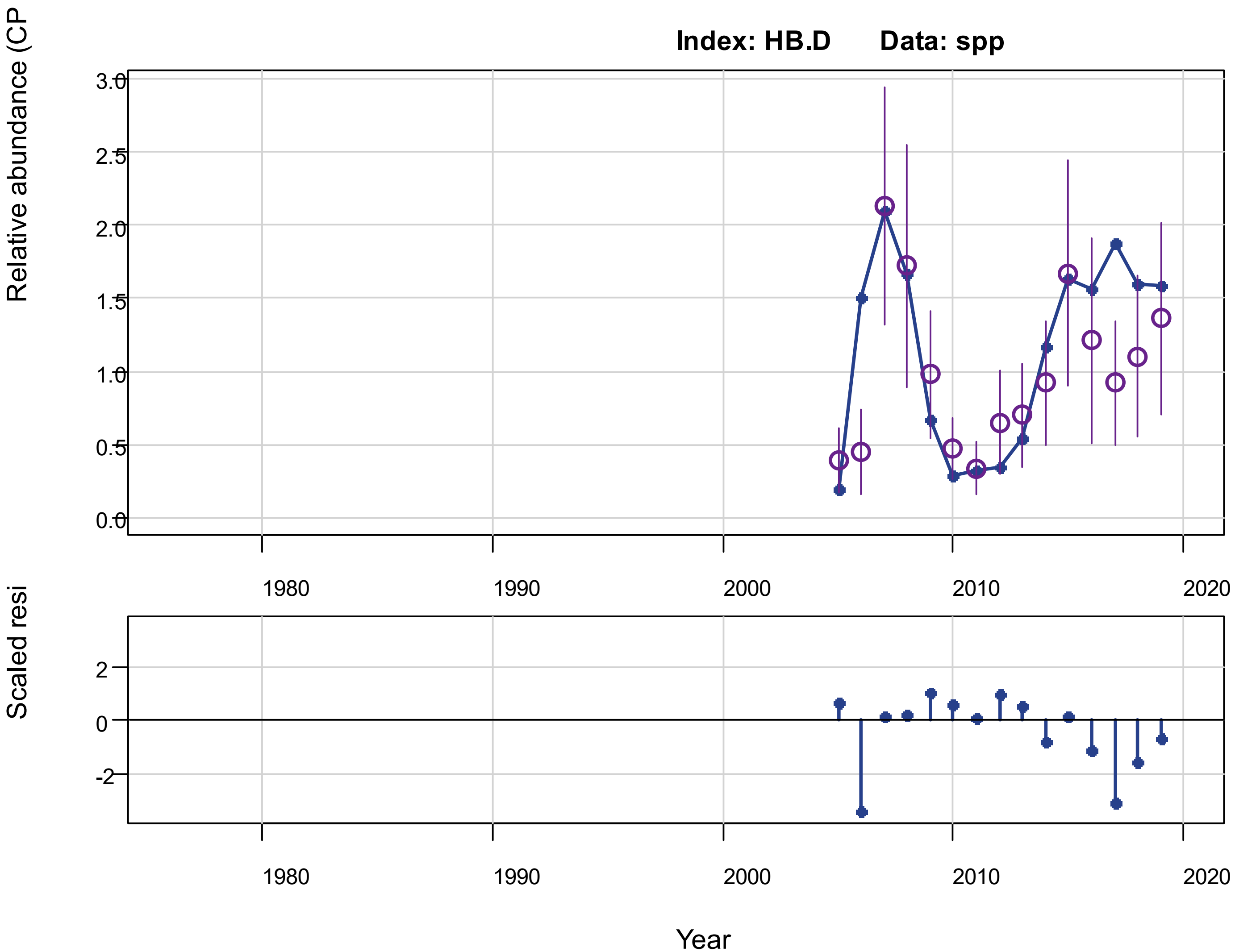

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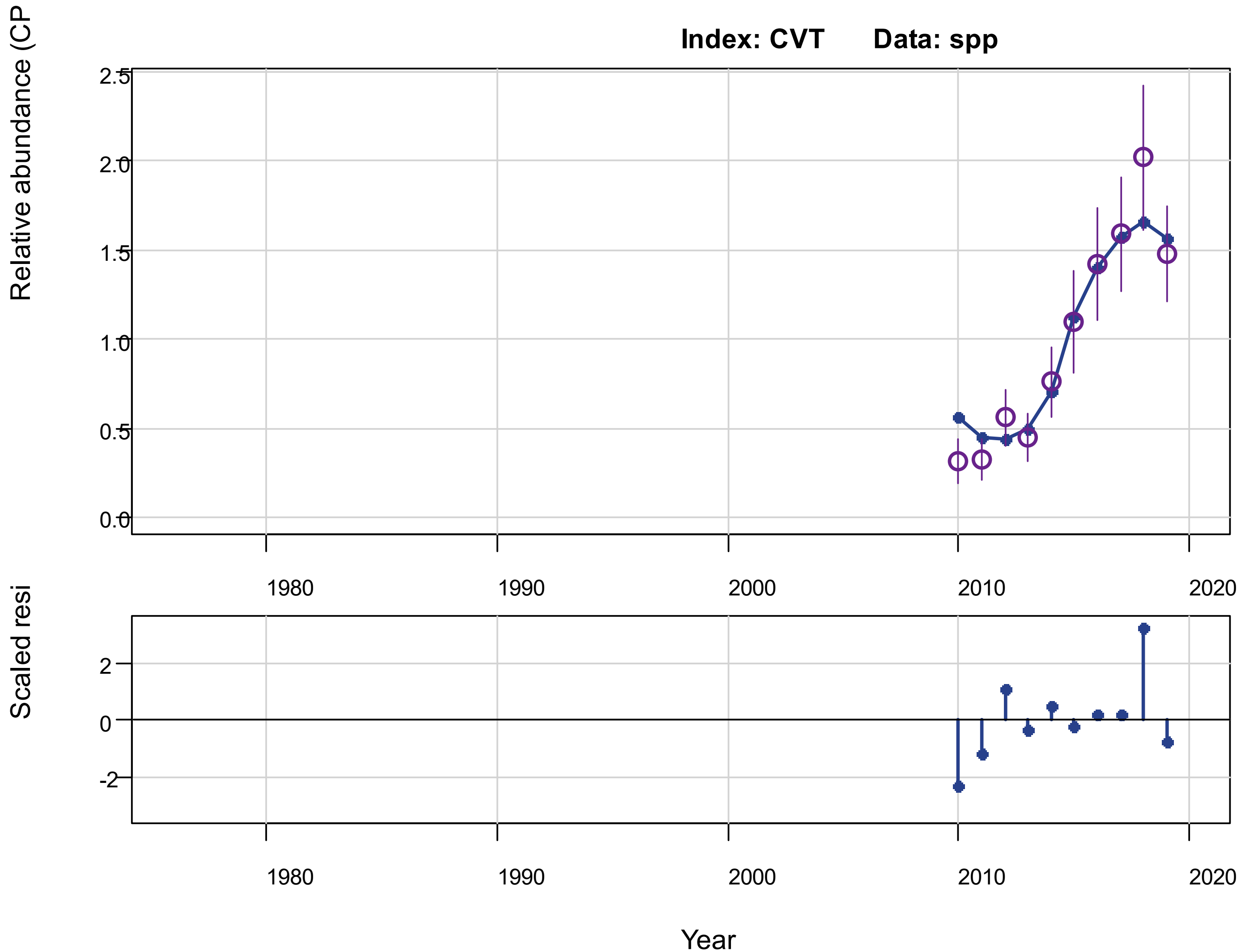

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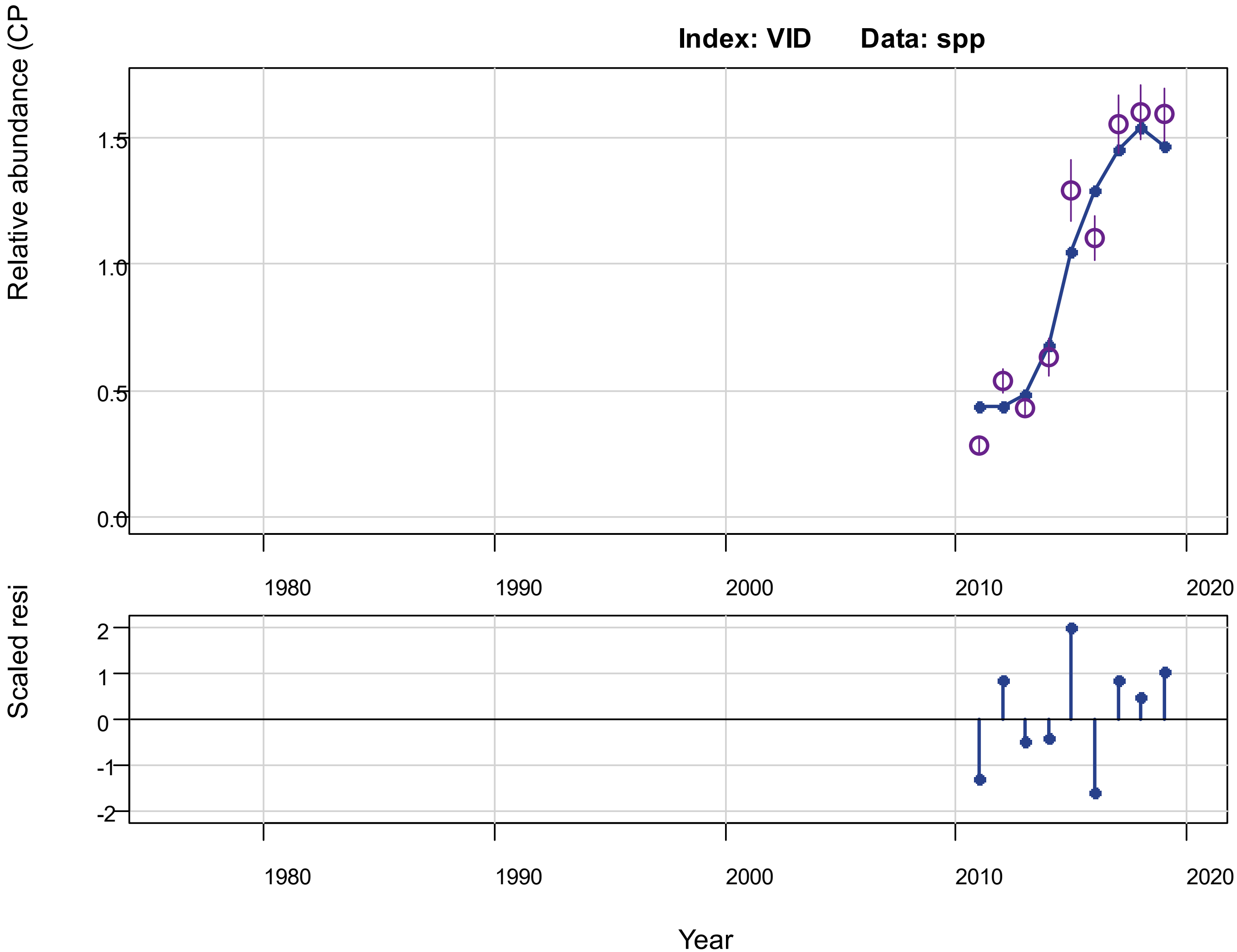
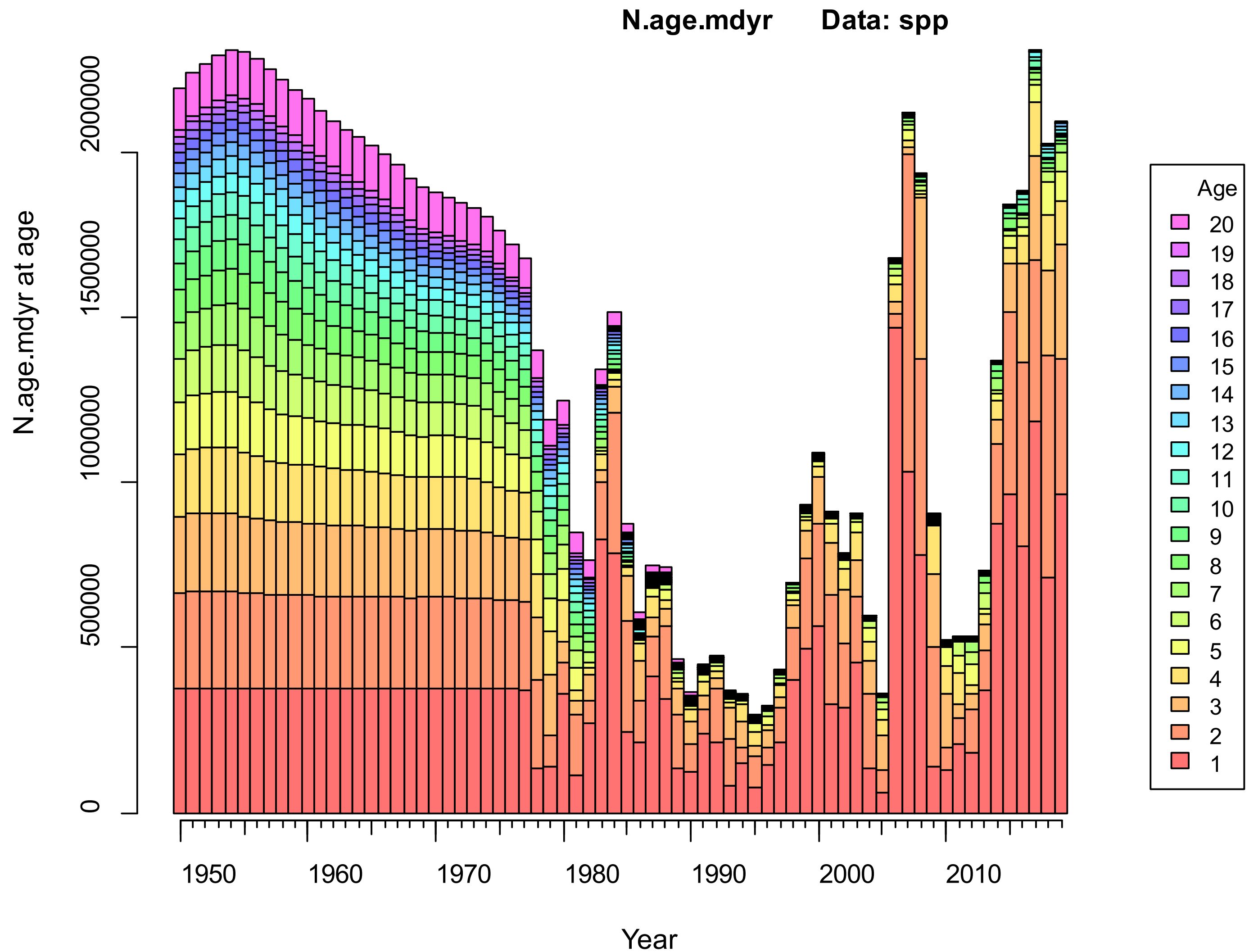
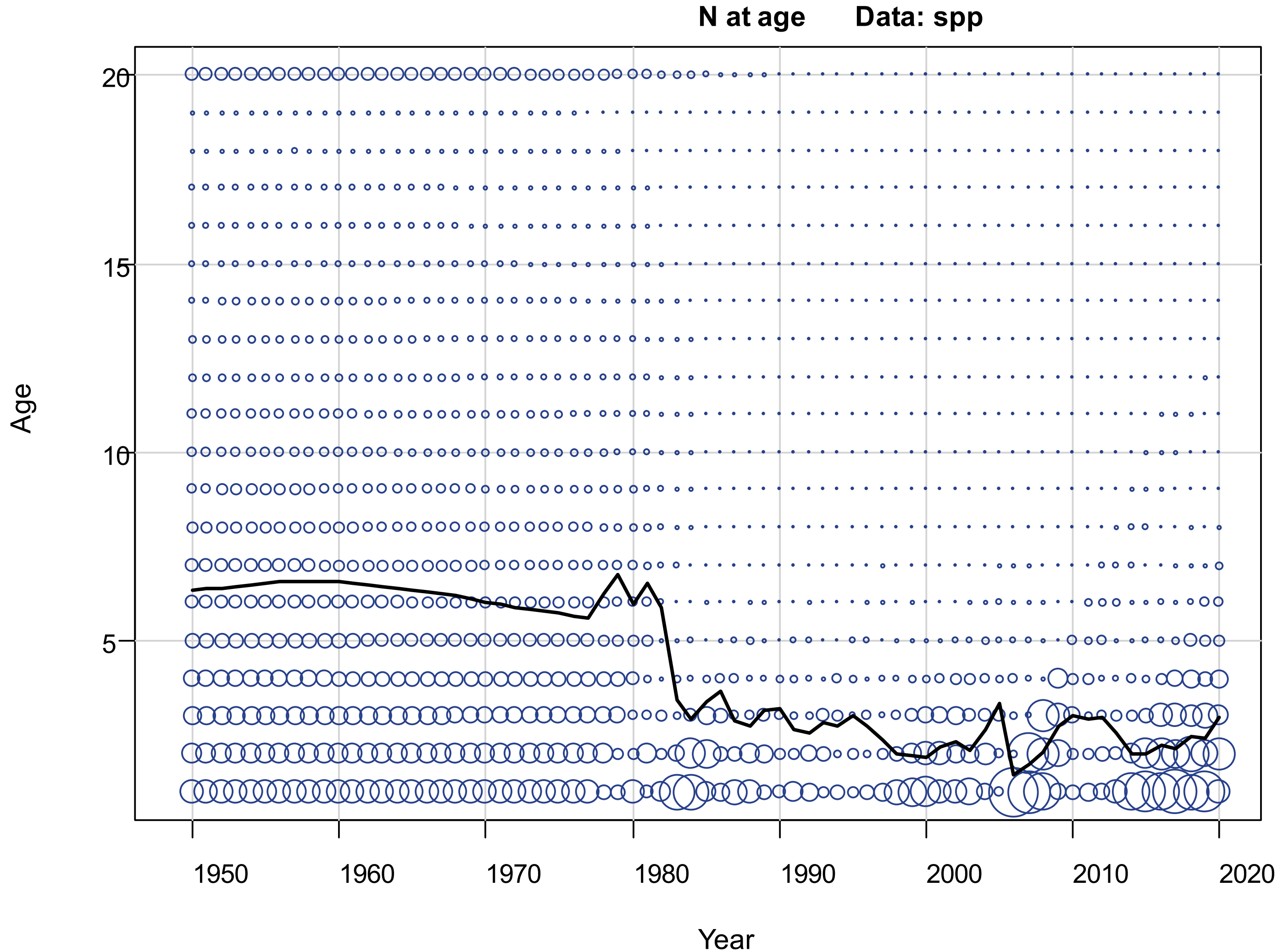


BAM base run – abundance



BAM base run – abundance age structure



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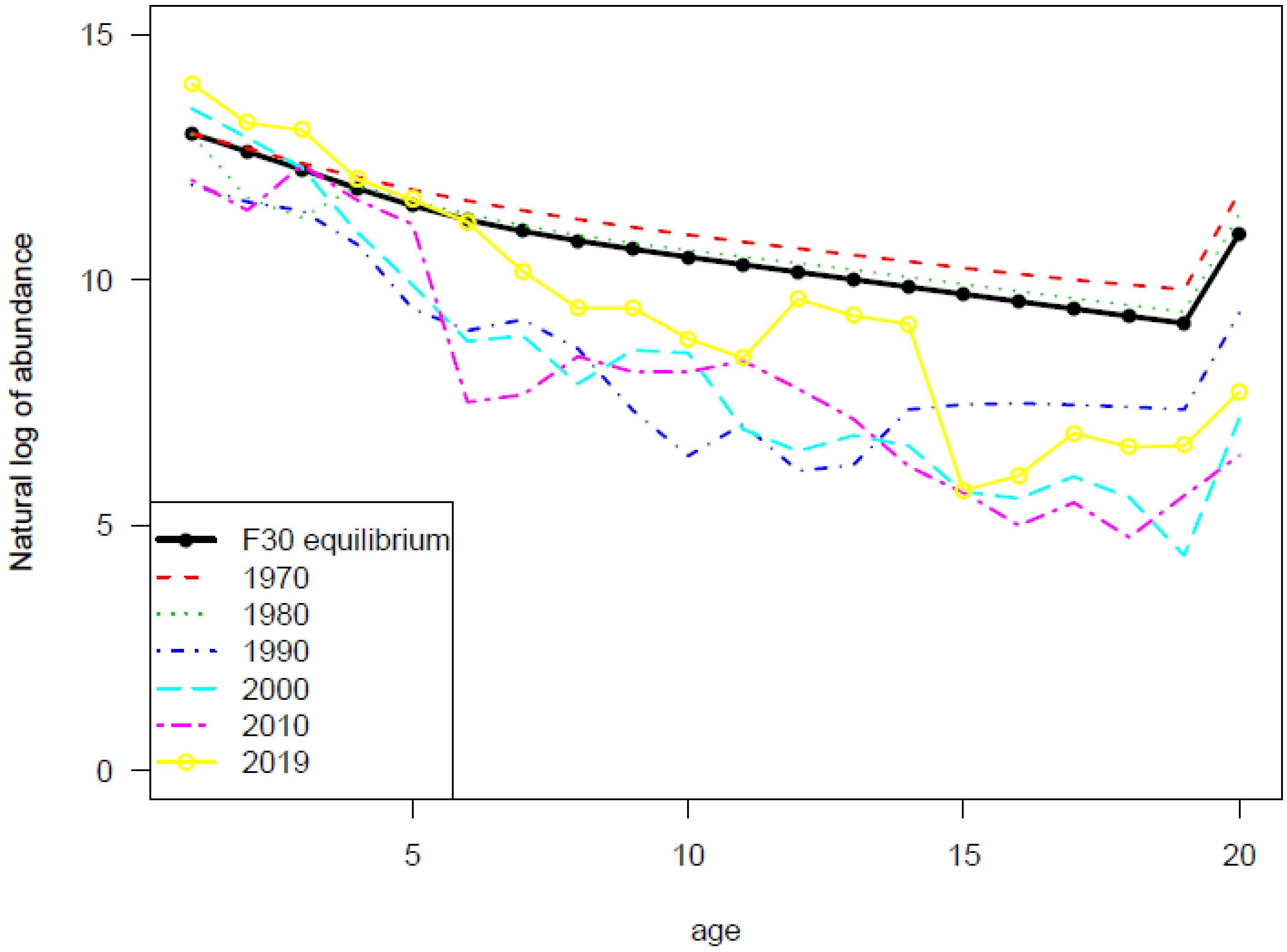
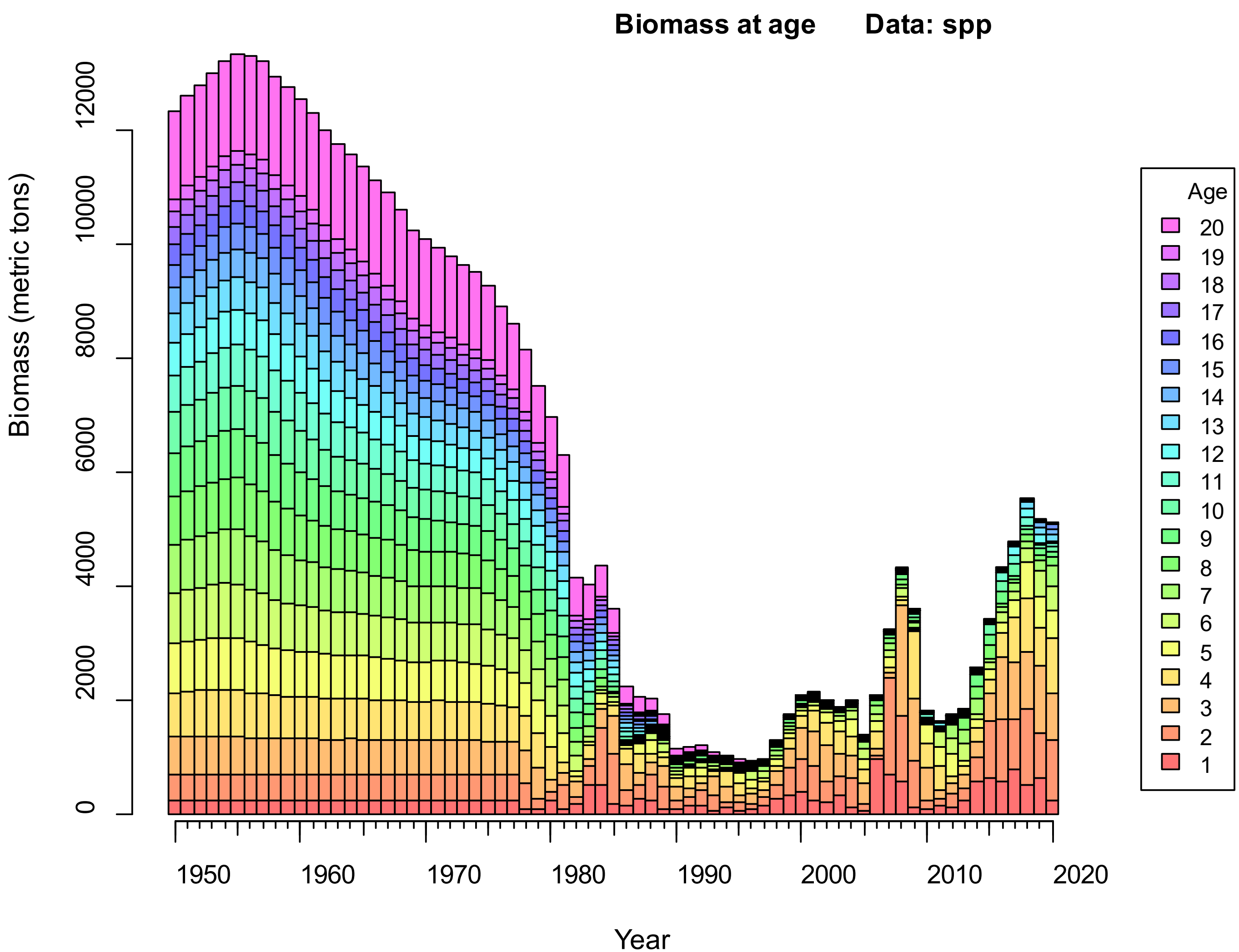
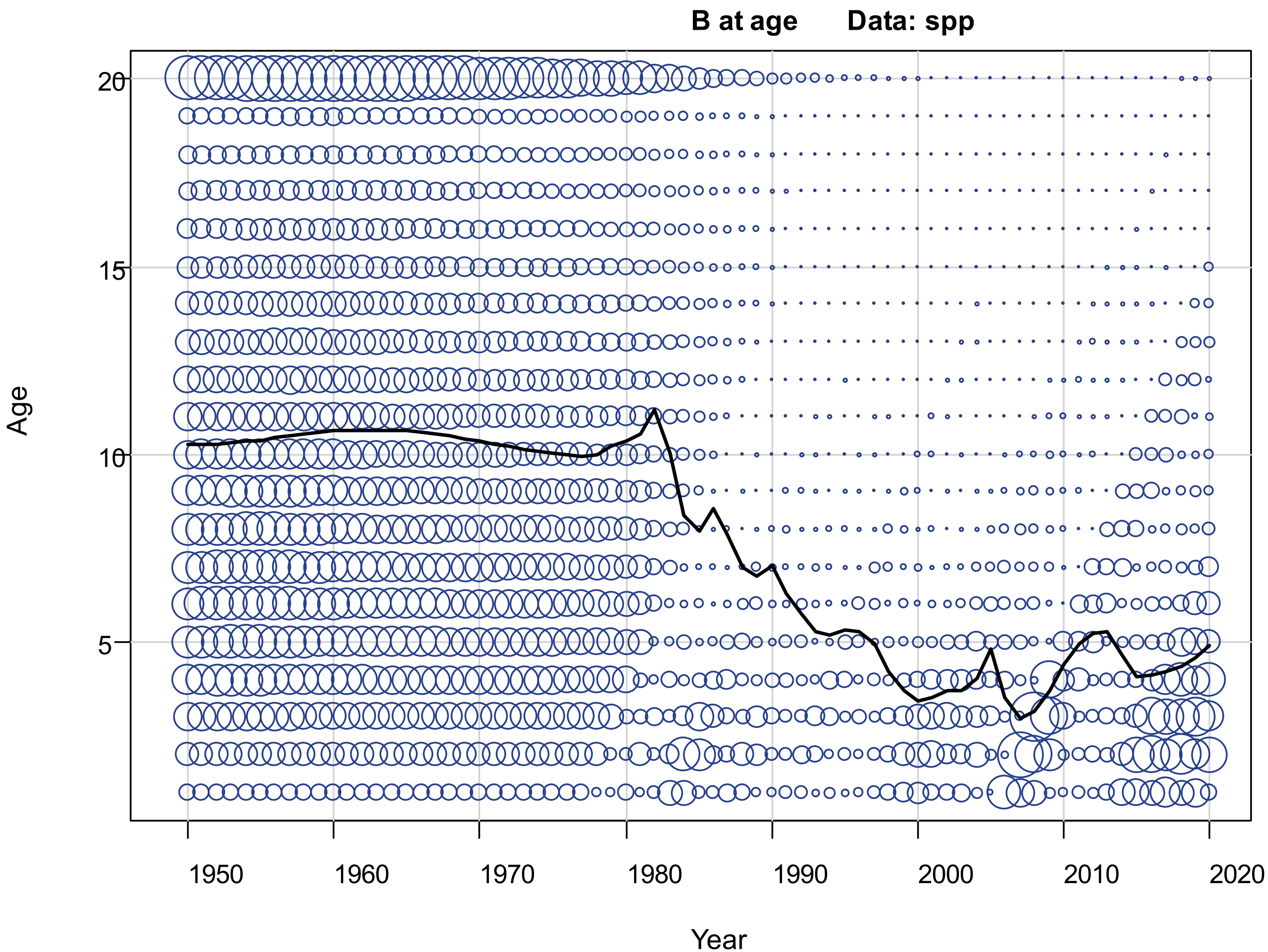


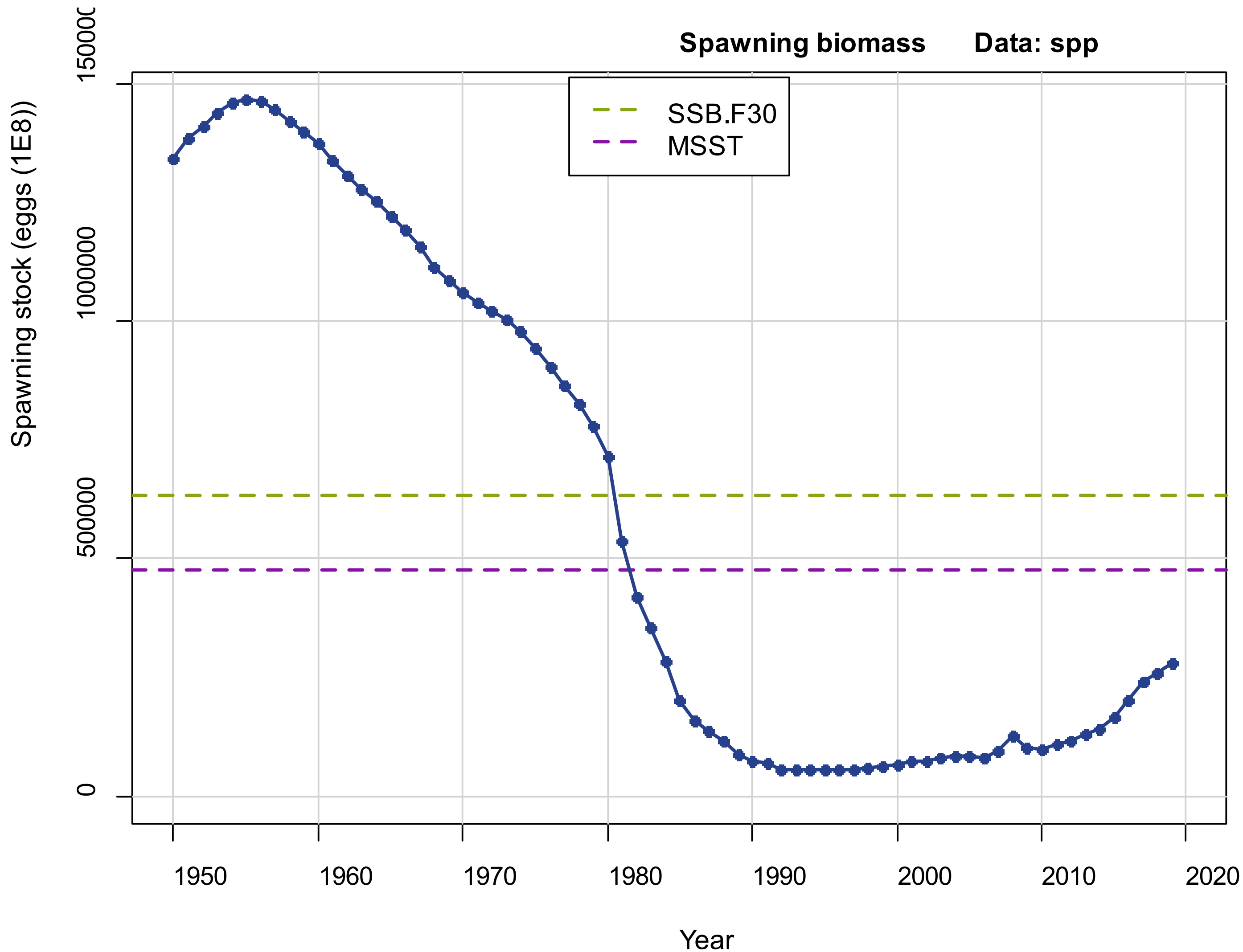
BAM base run – biomass



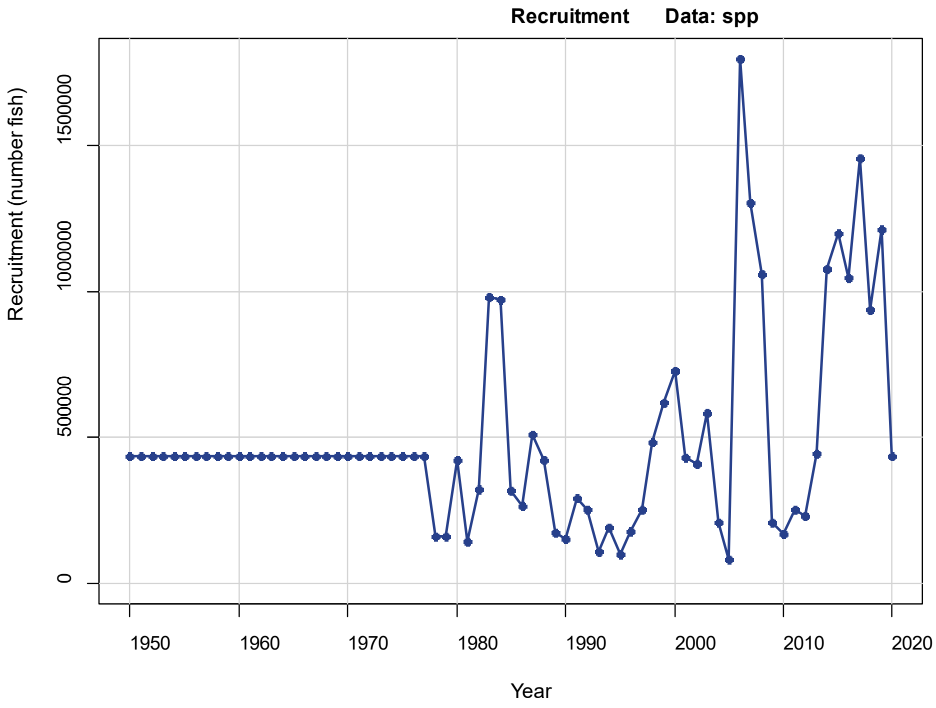
BAM base run – biomass age structure

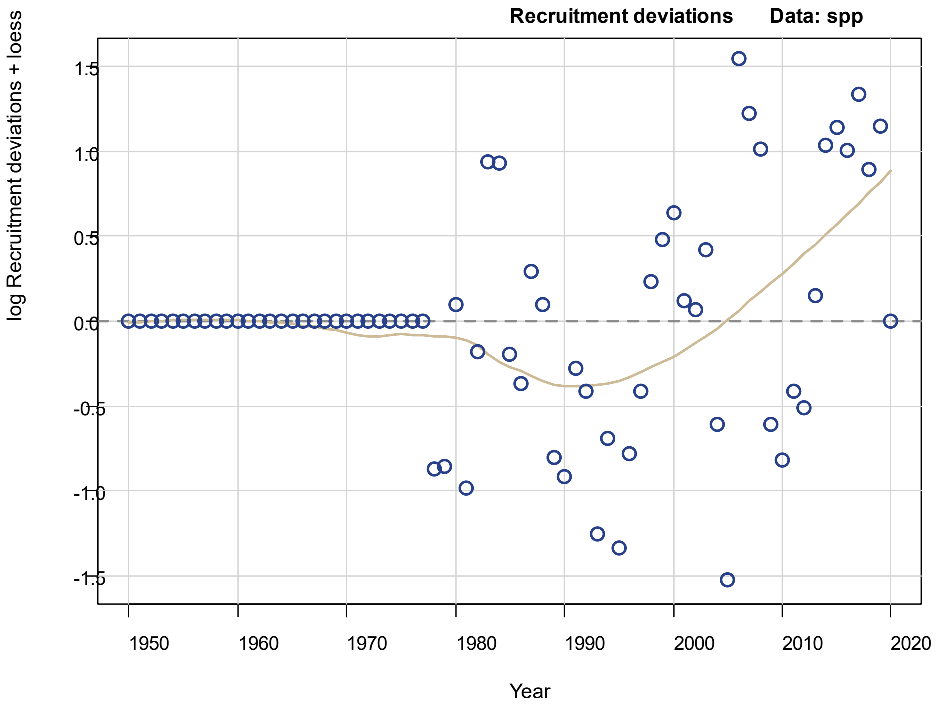


BAM base run – Spawning stock

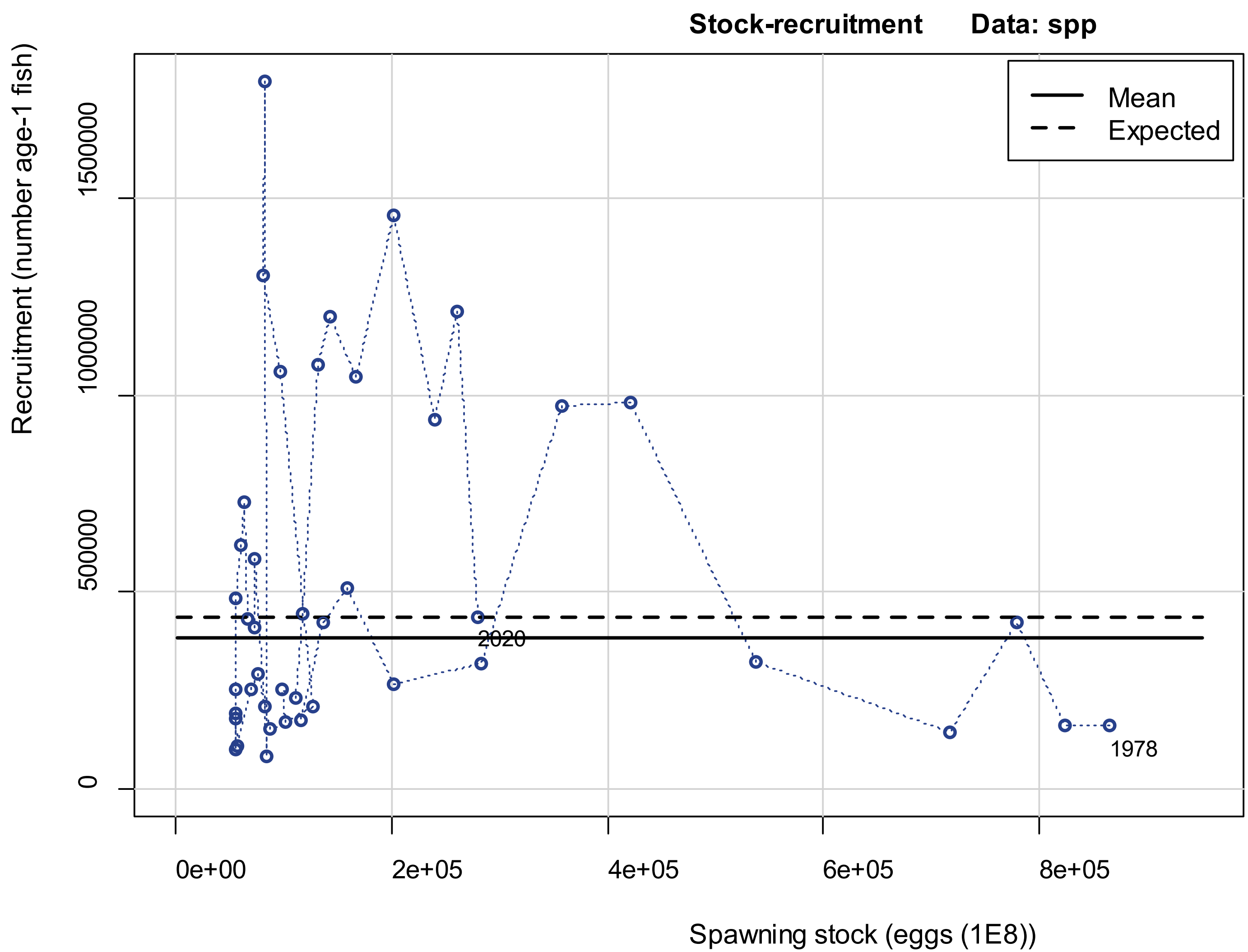


BAM base run – Recruitment

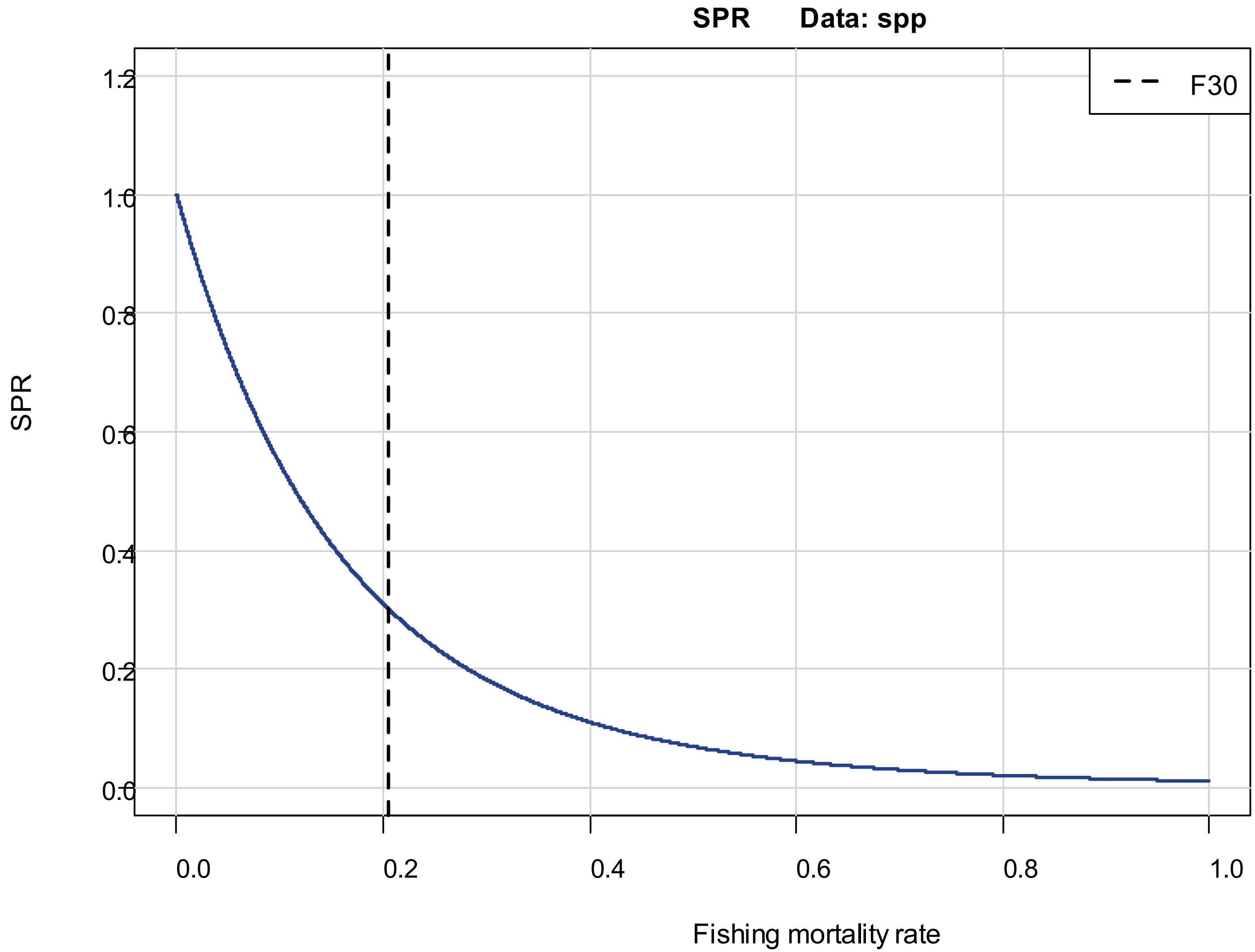




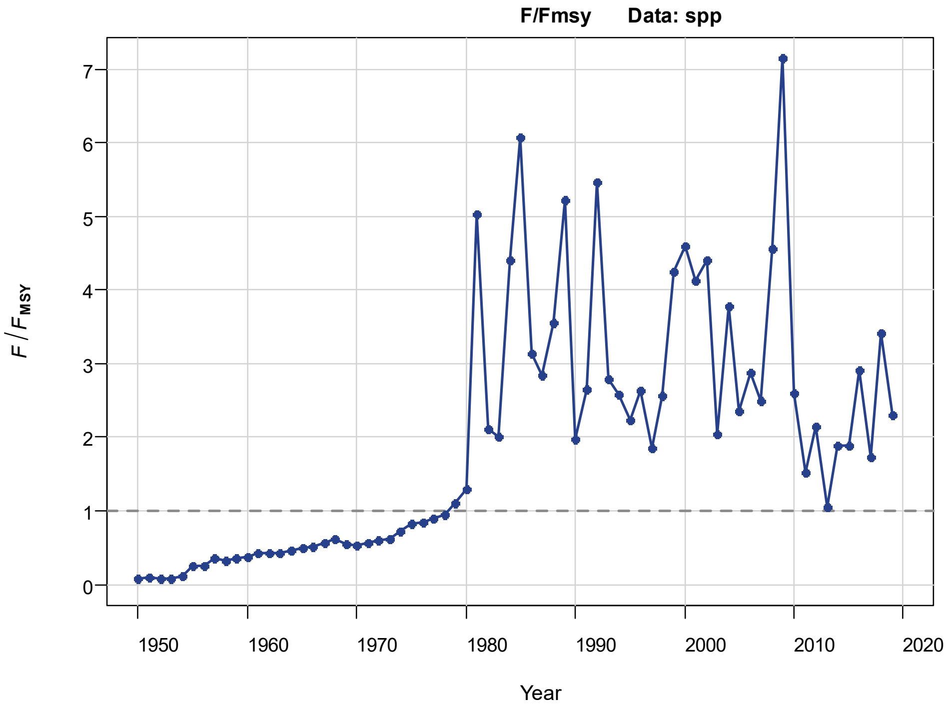
BAM base run – Spawners-recruits

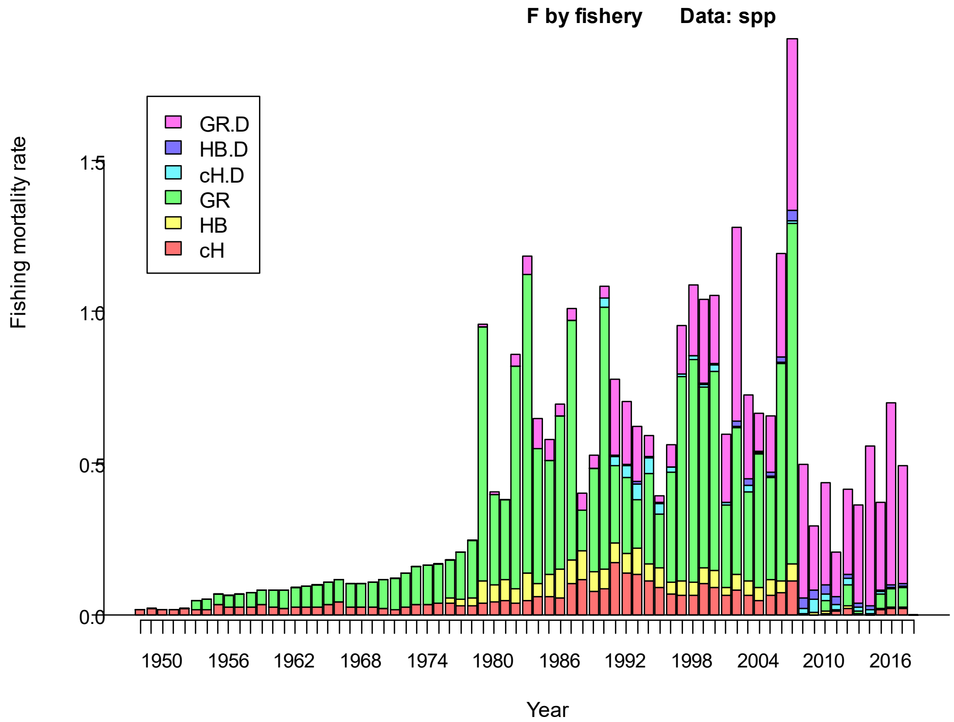


BAM base run – Spawning potential ratio

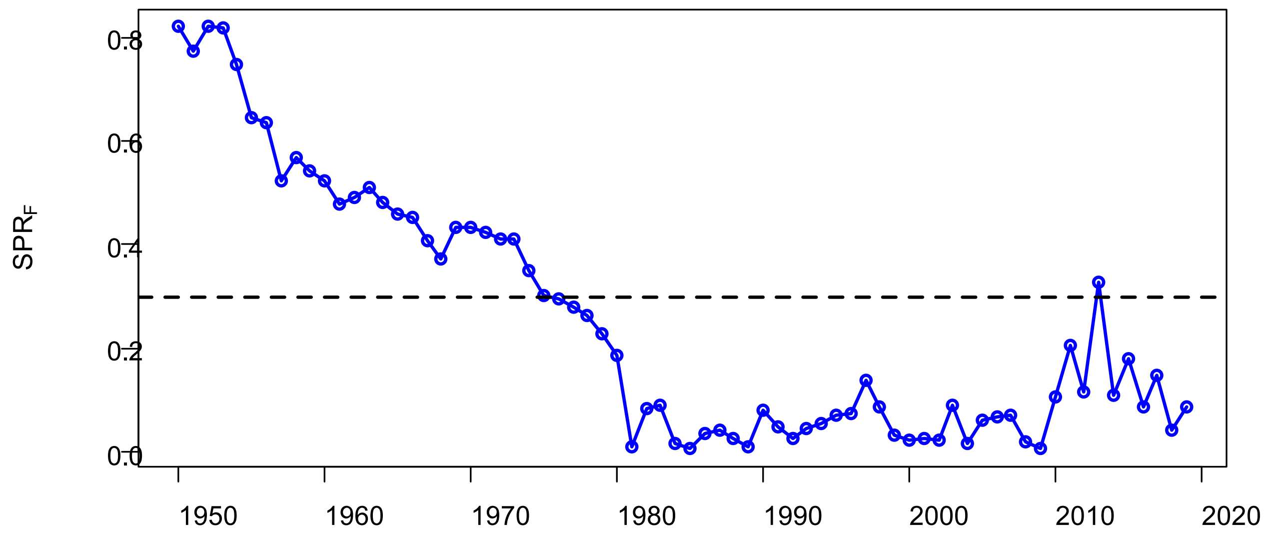


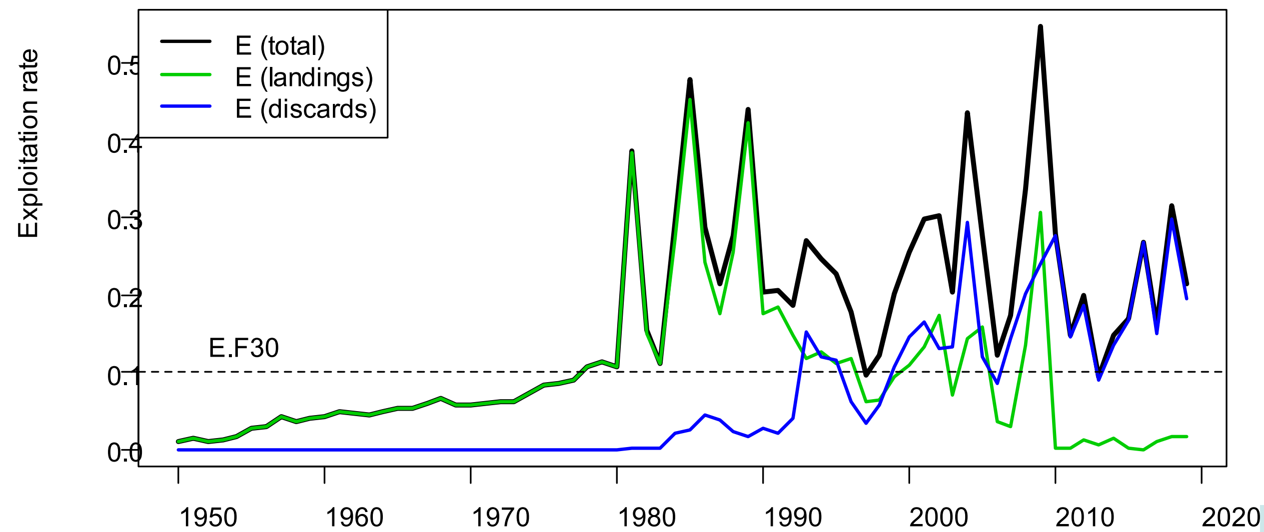
BAM base run – Fishing mortality



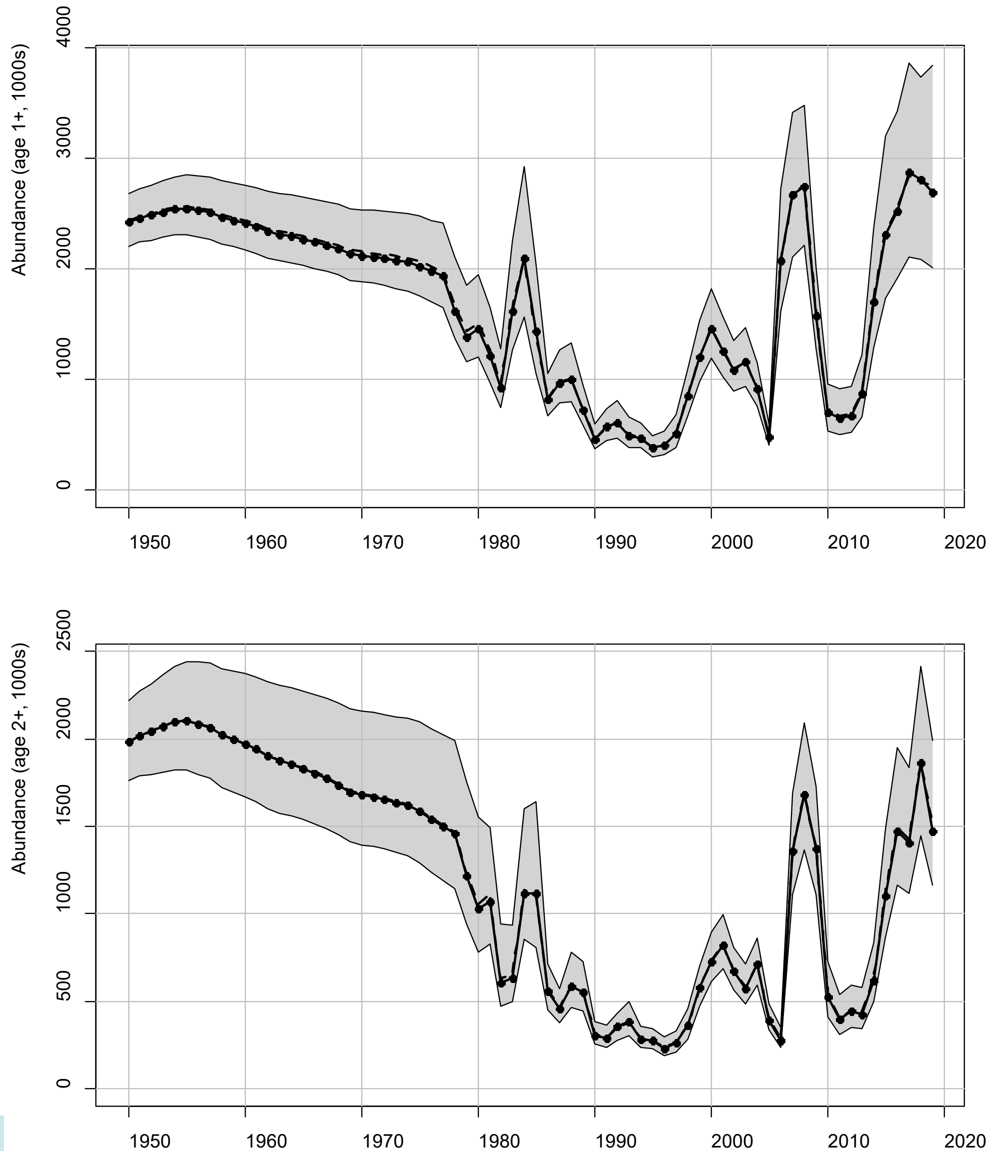


BAM base run – Fishing mortality (alternative metrics)

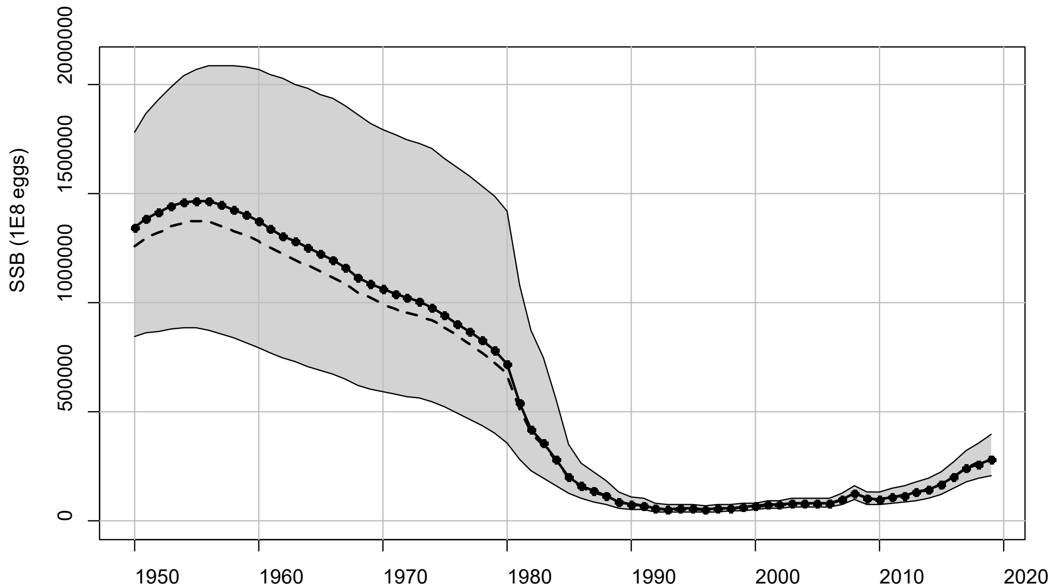


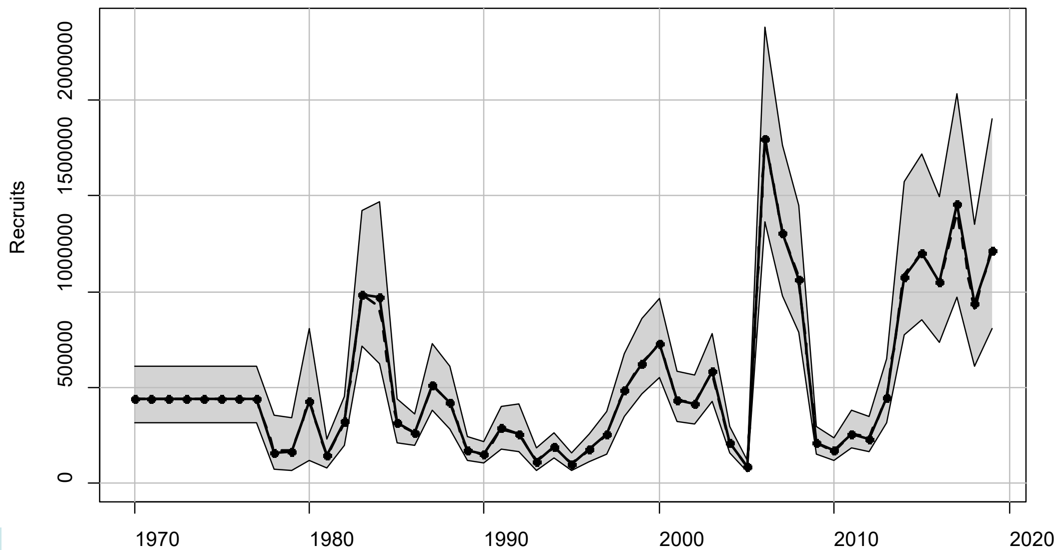


MCBE – Abundance estimates



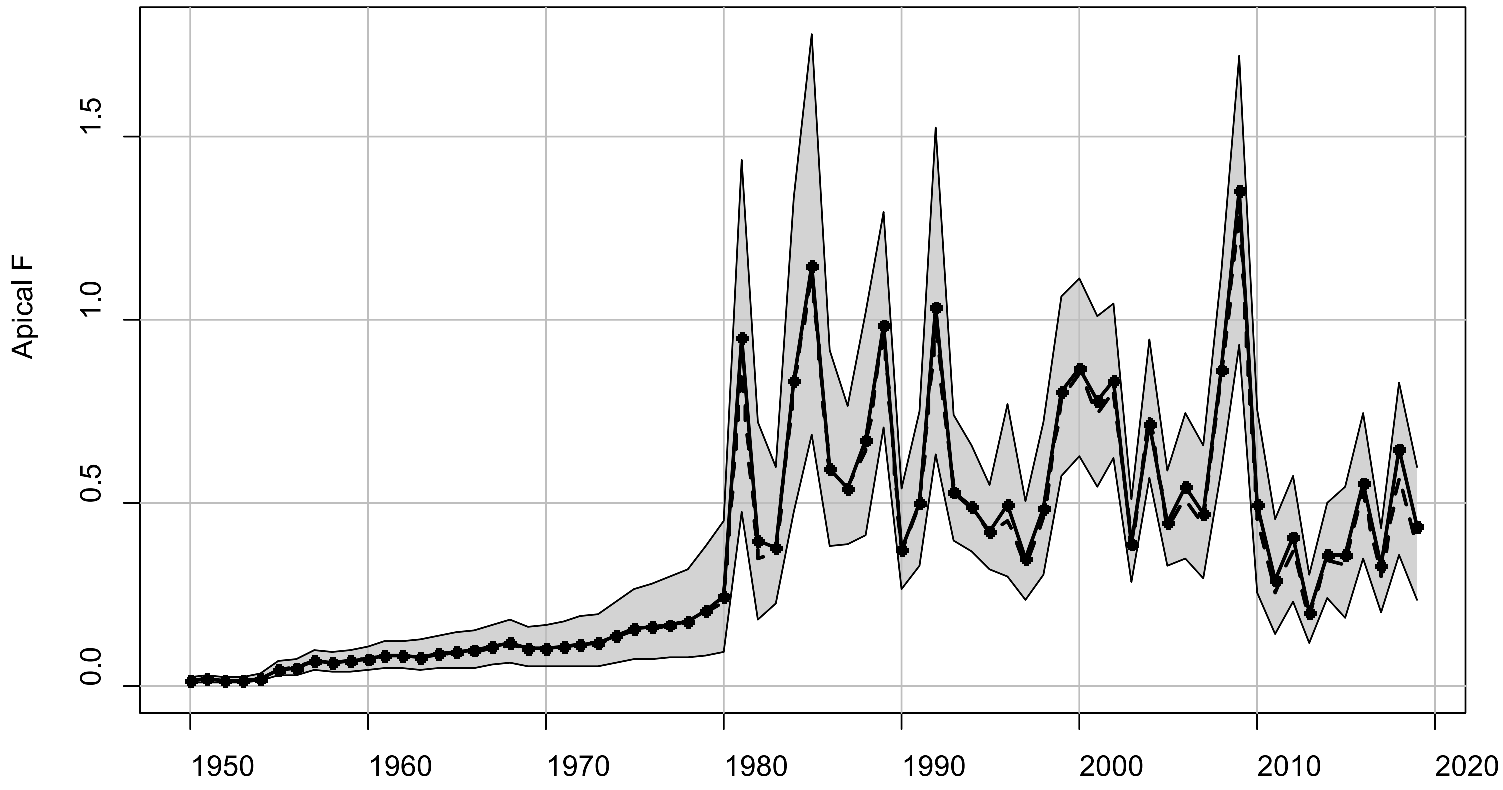
MCBE – Spawners and recruits



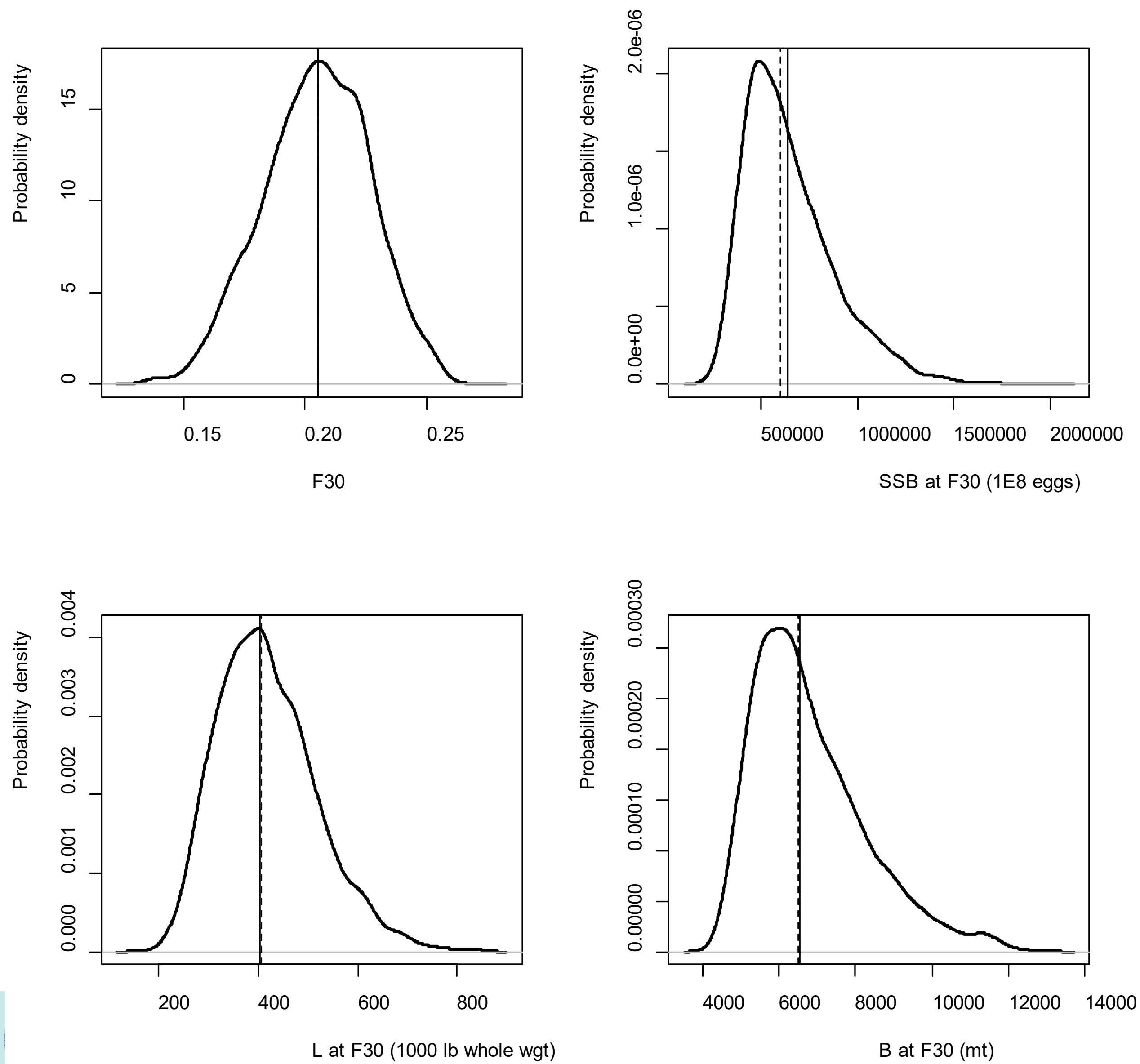


Note, different scale of X-axes

MCBE – Fishing mortality

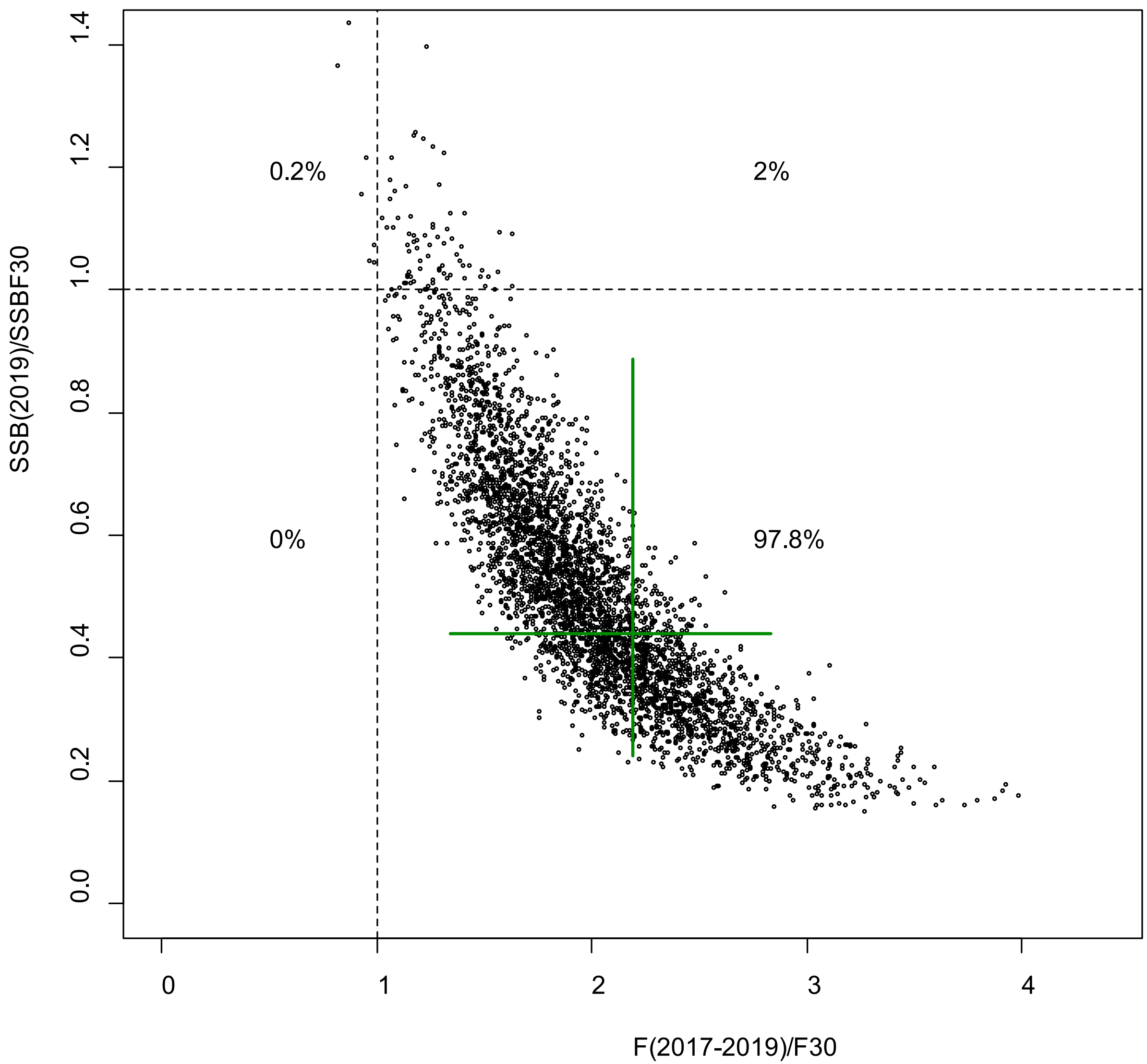


MCBE – Uncertainty in benchmarks



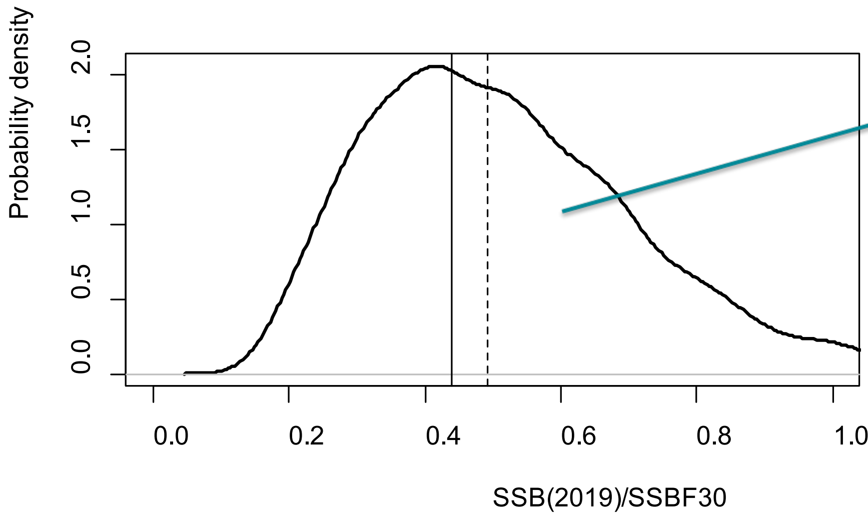
Solid=MLE (base)
Dash=Median

MCBE – Status indicators

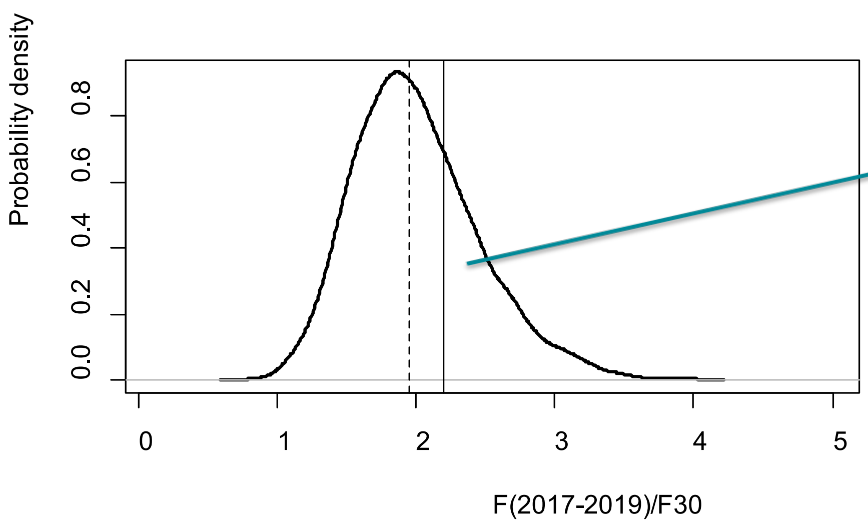


MCBE – Status indicators

Solid=MLE (base)
Dash=Median



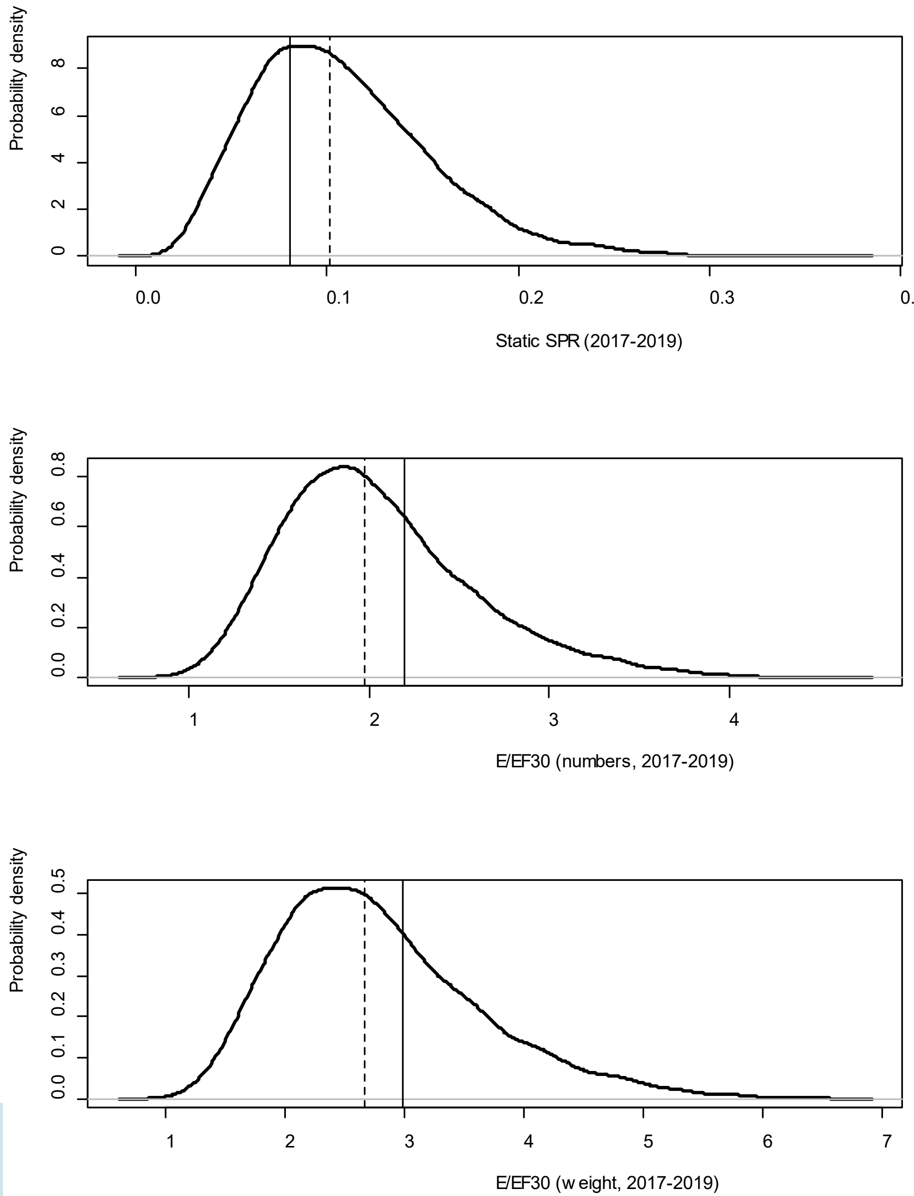
97.8% of distribution below 1.0 (i.e., not yet rebuilt)



~99.8% of distribution exceeds 1.0 (i.e., overfishing)

MCBE – Status indicators (alternative fishing intensity metrics)

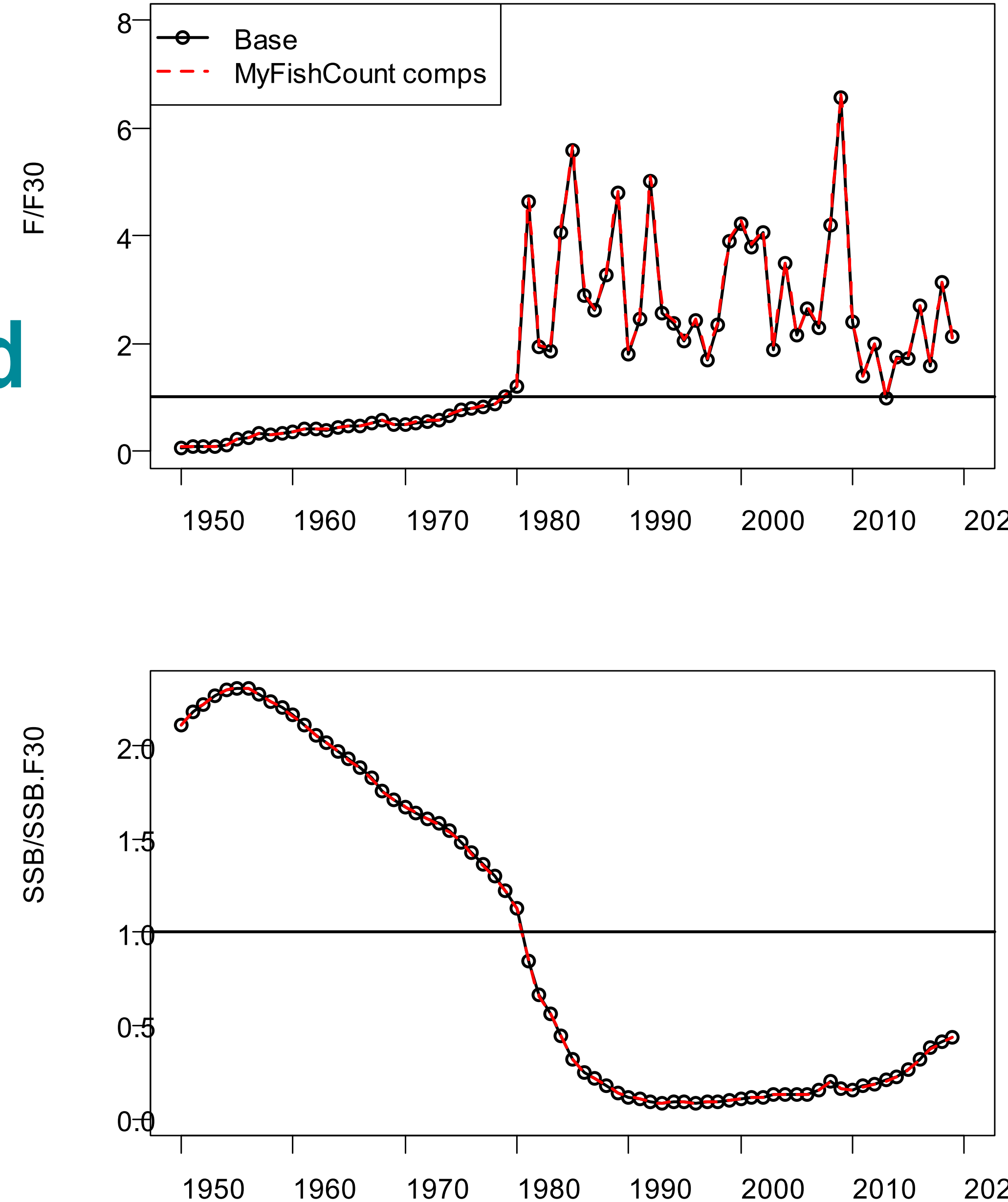
Solid=MLE (base)
Dash=Median



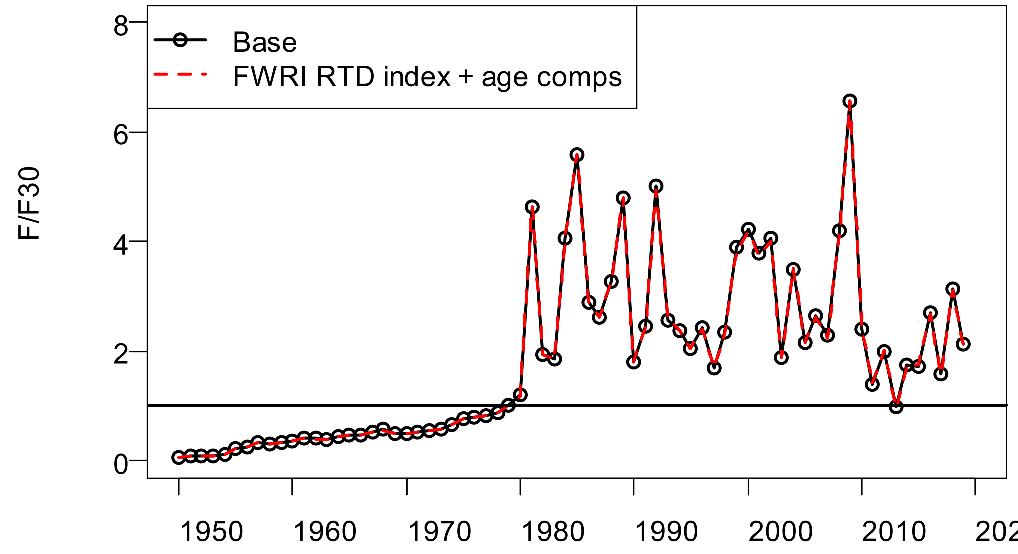
BAM results – Management quantities

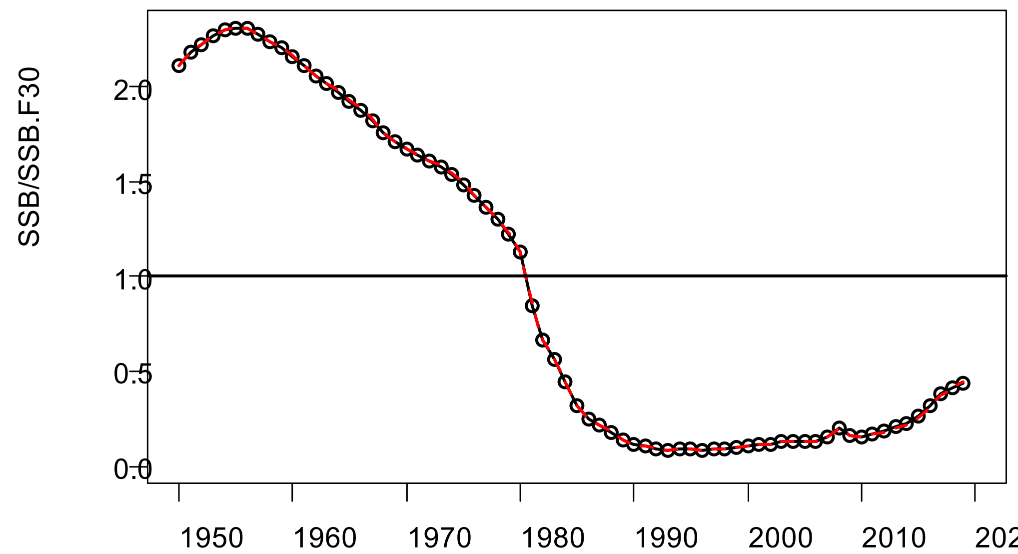
Quantity	Units	Estimate	Median	SE	SEDAR41
$F_{30\%}$	y^{-1}	0.21	0.21	0.02	
$85\%F_{30\%}$	y^{-1}	0.17	0.17	0.02	
$75\%F_{30\%}$	y^{-1}	0.15	0.15	0.02	
$65\%F_{30\%}$	y^{-1}	0.13	0.13	0.01	
$F_{40\%}$	y^{-1}	0.15	0.15	0.02	
$E_{F30\%}$	—	0.10	0.10	0.01	
$B_{F30\%}$	metric tons	6530.71	6483.54	1475.32	
$SSB_{F30\%}$	eggs (1E8)	635426.40	594630.20	233432.64	
MSST	eggs (1E8)	476569.80	445972.60	175074.48	
$L_{F30\%}$	1000 lb whole	404.70	407.78	99.69	
$R_{F30\%}$	number fish	436868.50	439823.20	89925.13	
$L_{85\%F30\%}$	1000 lb whole	404.85	407.88	98.99	
$L_{75\%F30\%}$	1000 lb whole	398.97	401.84	97.18	
$L_{65\%F30\%}$	1000 lb whole	386.75	389.45	93.96	
$F_{2017-2019}/F_{30\%}$	—	2.20	1.95	0.45	2.84
$E_{2017-2019}/E_{F30\%}$	—	2.20	1.97	0.53	
$SSB_{2019}/MSST$	—	0.59	0.66	0.27	
$SSB_{2019}/SSB_{F30\%}$	—	0.44	0.49	0.20	0.14

BAM results – Sensitivity to MyFishCount discard length comps

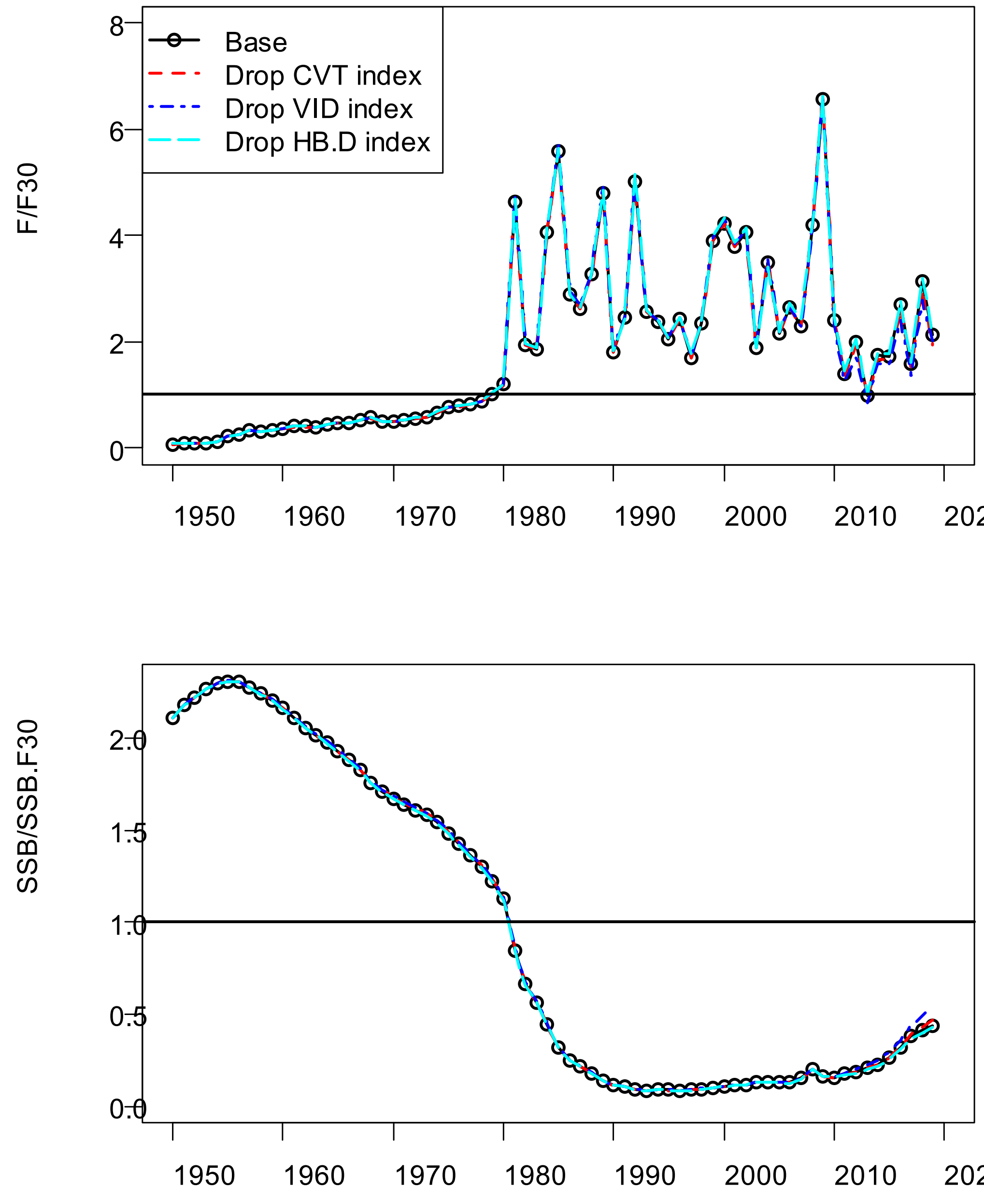


BAM results – Sensitivity to FWRI RTD index + age comps

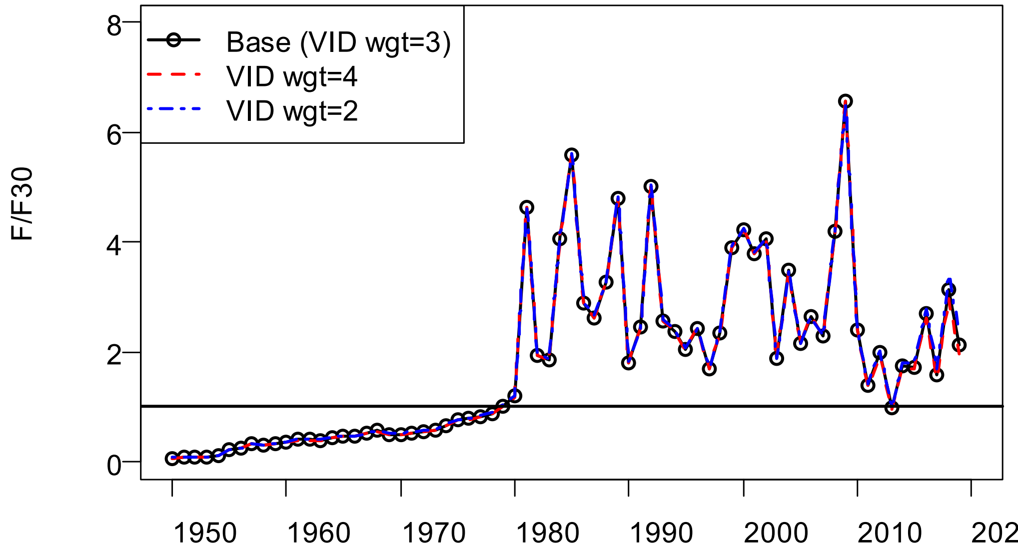


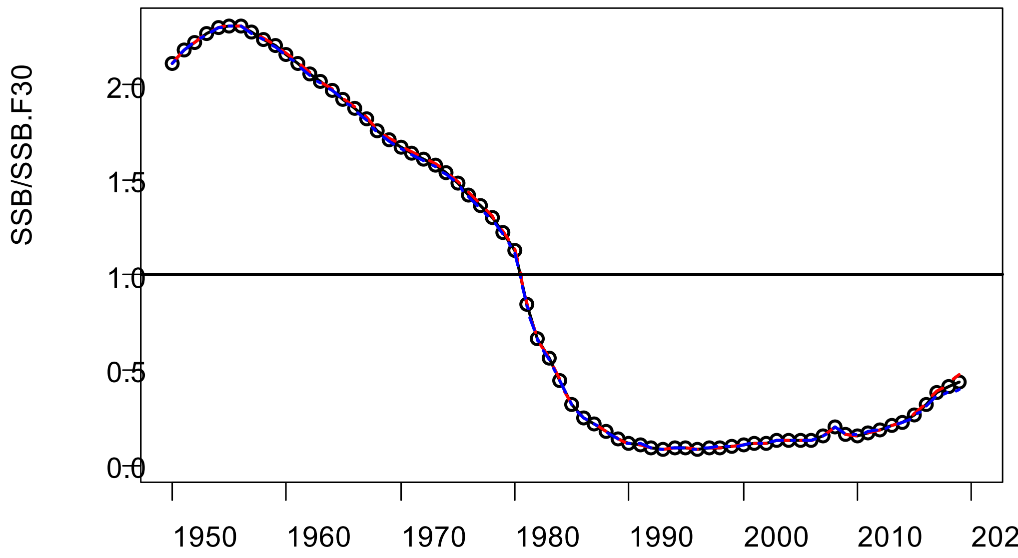


BAM results – Sensitivity to dropping indices

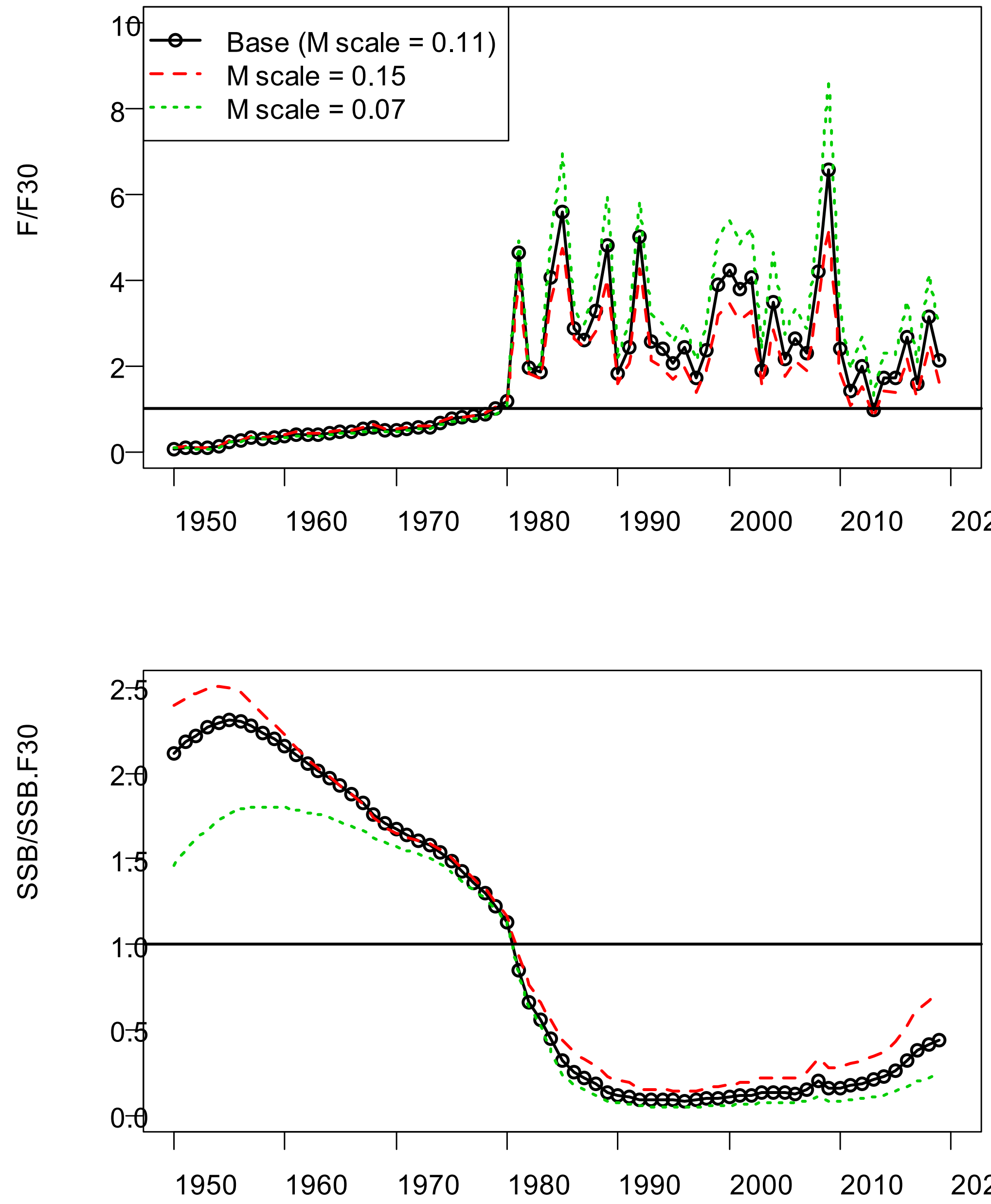


BAM results – Sensitivity to weight on video index

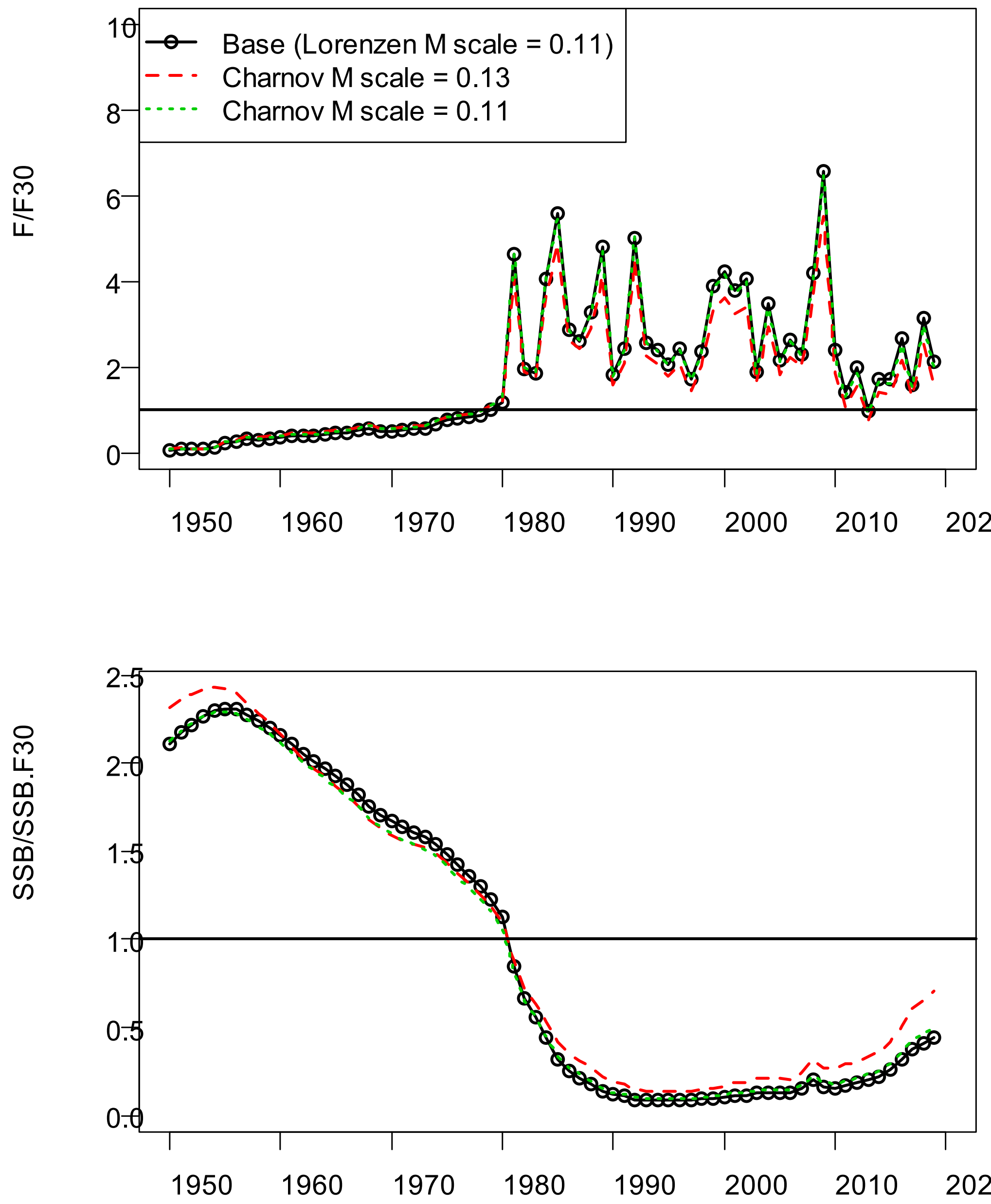




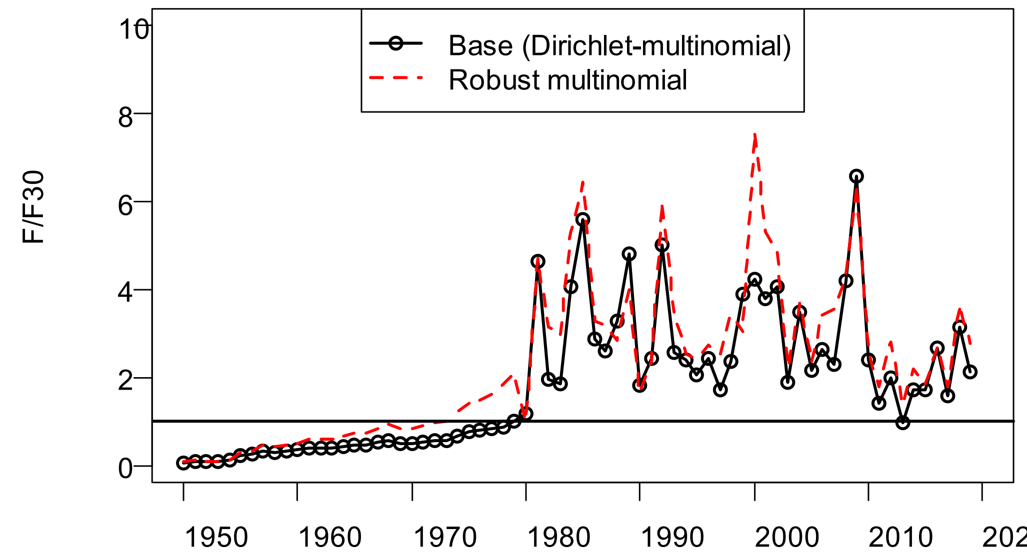
BAM results – Sensitivity to scale of M

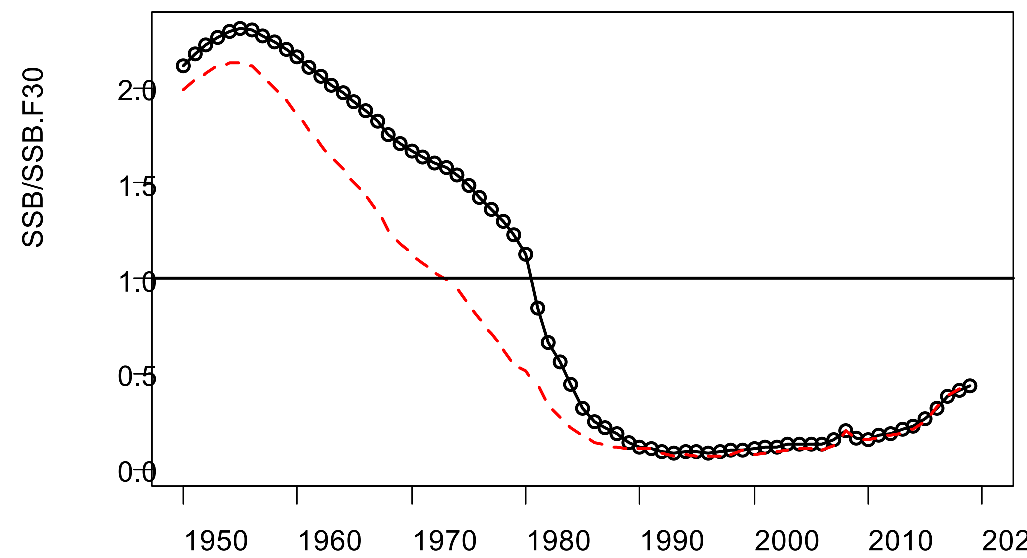


BAM results – Sensitivity to shape and scale of M

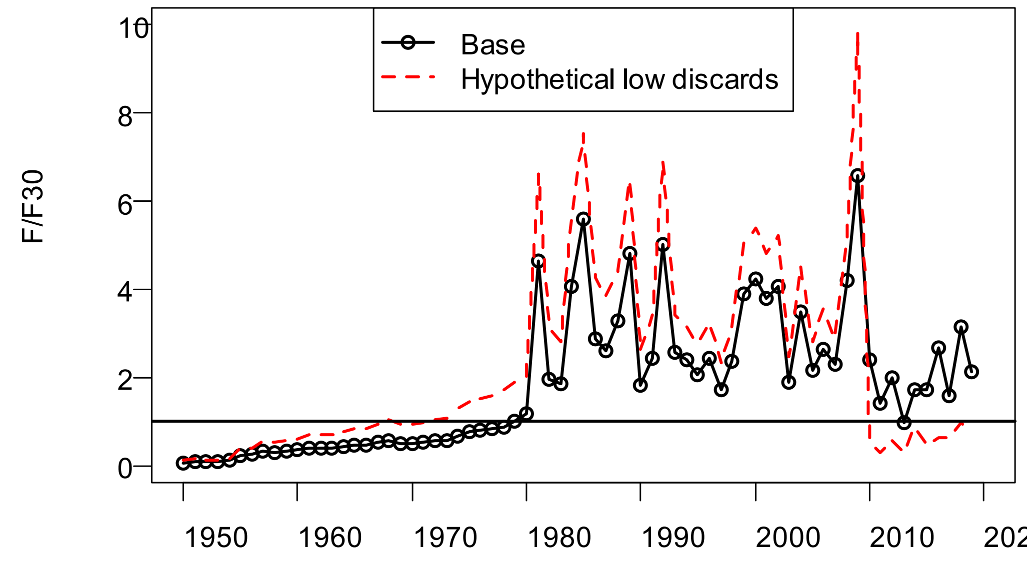


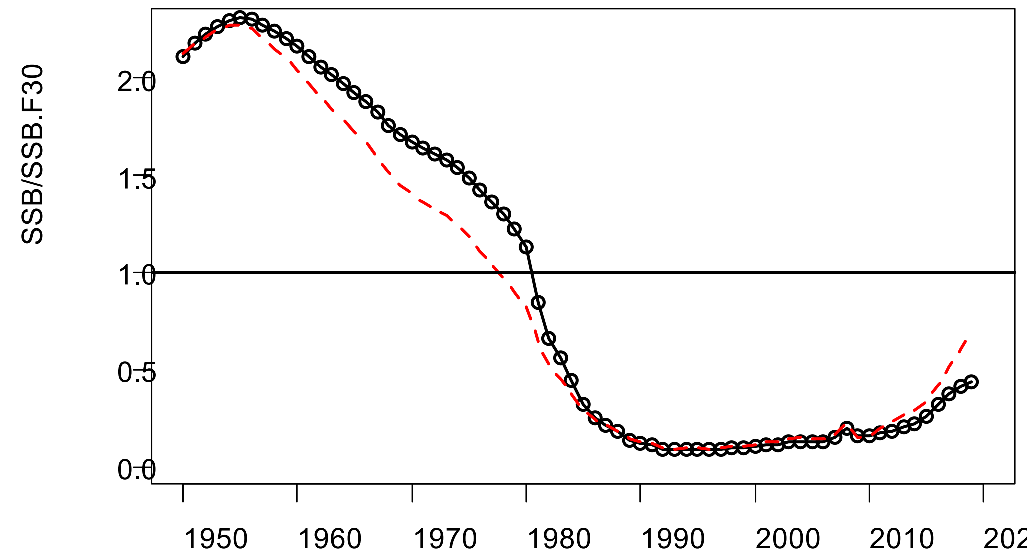
BAM results – Sensitivity to comp likelihood



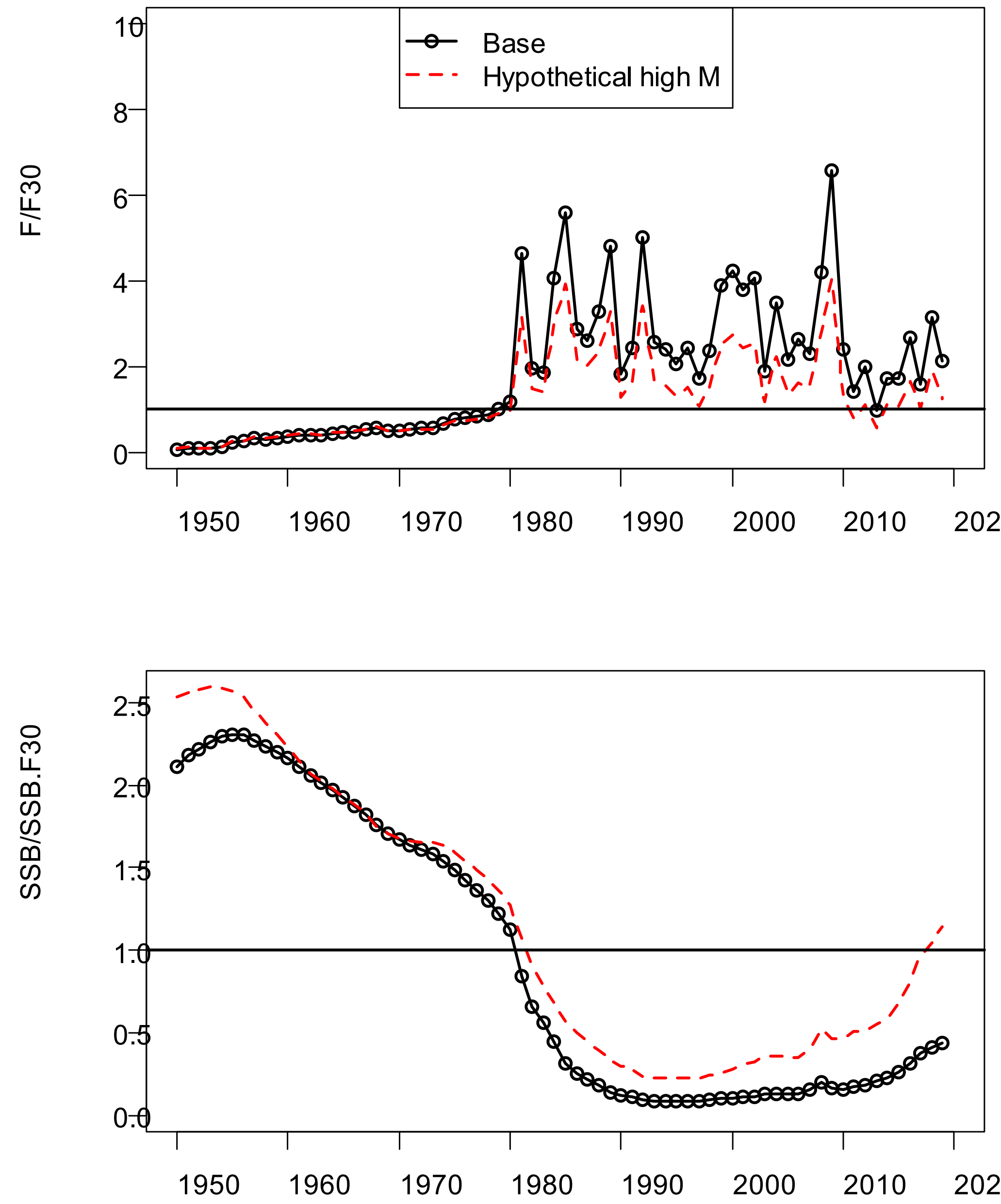


BAM results – Sensitivity to low recent discards (HYPOTHETICAL)

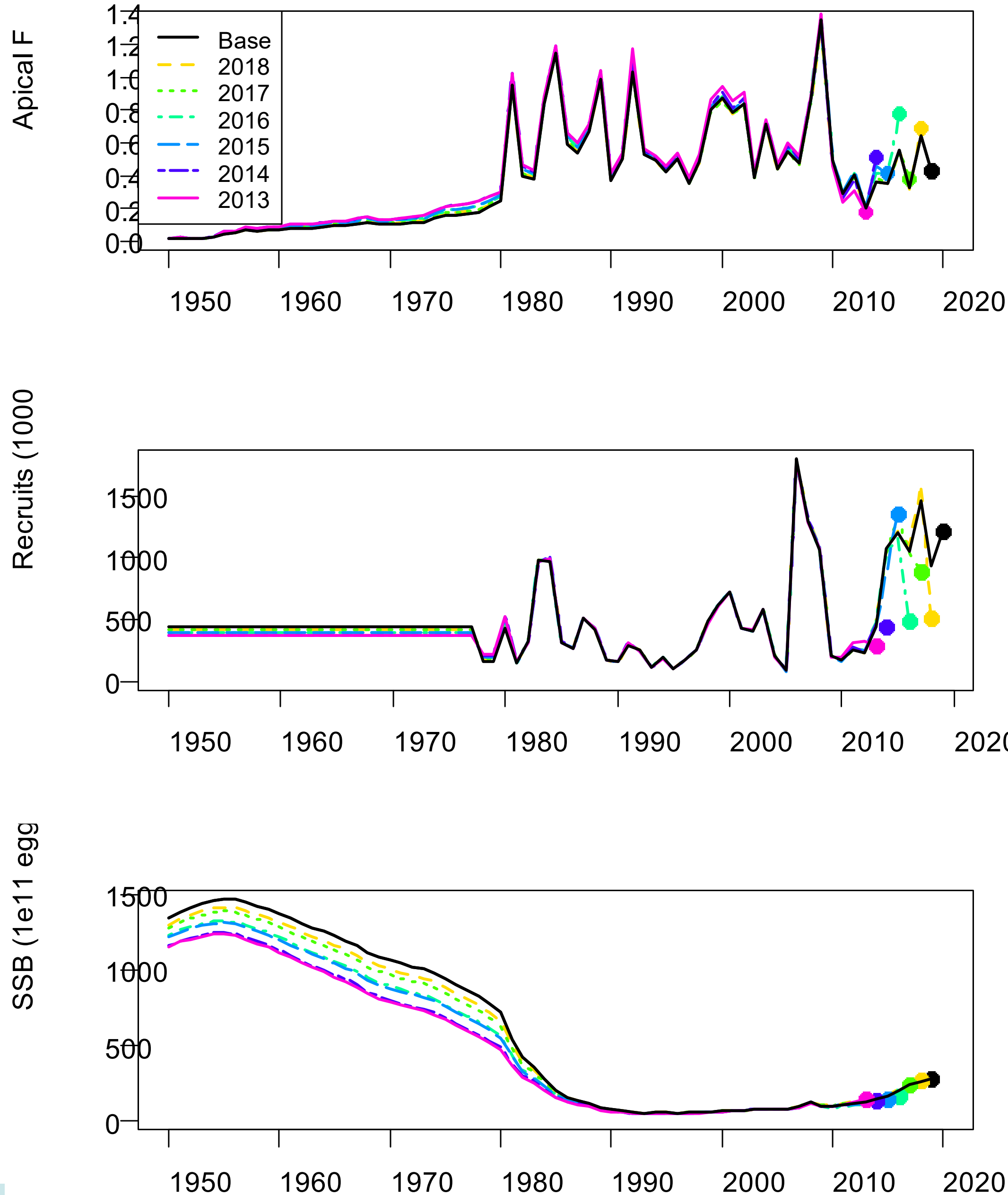




BAM results – Sensitivity to high M; M=0.2 implies max age of 28 (HYPOTHETICAL)



BAM results – Retrospective analysis



Summary of assessment results

- SA red snapper are not yet rebuilt (robust result)
- Overfishing continued through 2019 (robust result)
  - Overfishing resulted primarily from gen rec discards
  - Alternative fishing intensity metrics tell the same story
- Estimated red snapper abundance has increased substantially in recent years, and is highest at the end of the time series
  - This result is driven by high, recent recruitment
- The age structure has filled out, but not yet to the level expected at F30%
- Natural mortality remains a key source of uncertainty in this assessment
  - Though results are robust to range used in this assessment

Topics

- Background
- Data
- Assessment model
- Assessment results
- **Forecasts**

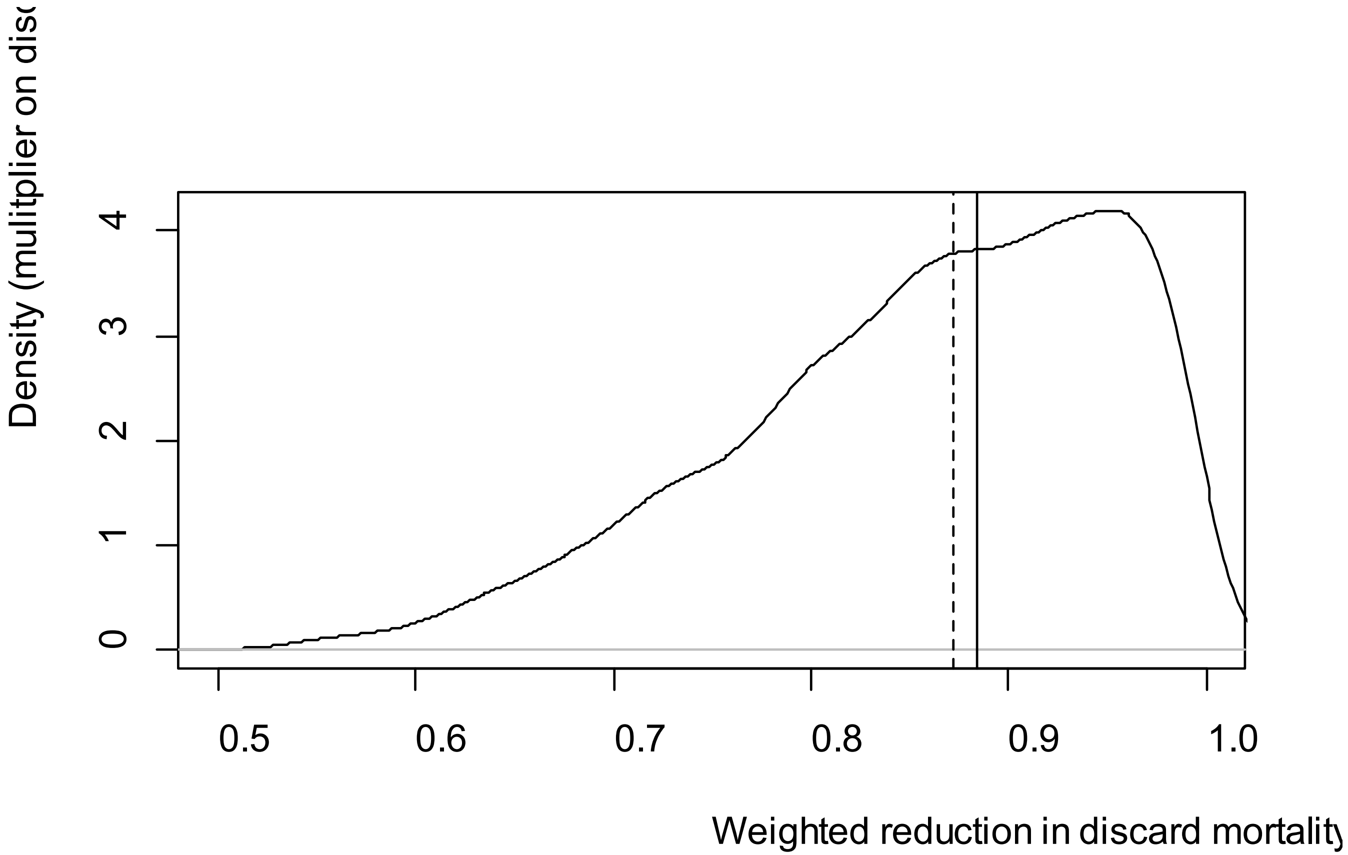
Forecasts

- Six scenarios identified by the SSC working group, 3 F scenarios X 2 recruitment scenarios
- F scenarios
  - $F=F_{30\%}$
  - Frebuild with 0.500 probability
  - Frebuild with 0.675 probability
- Recruitment scenarios
  - Long-term average recruitment
  - Recent high recruitment

Forecasts, other details

- New F starts in 2023
  - Will be revised to start in 2021 (4/21 Council request)
- Interim period (2020-2022) applies average landings from 2017-2019
  - Just 2020 in the forthcoming revision
- Reduction in discard mortality (more descender device usage) starts in 2021
  - Applied as proportional reduction to discard F
  - F-weighted average of fleet-specific discard mortality rates

Forecasts, discard mortality reduction



Forecasts, technical issue

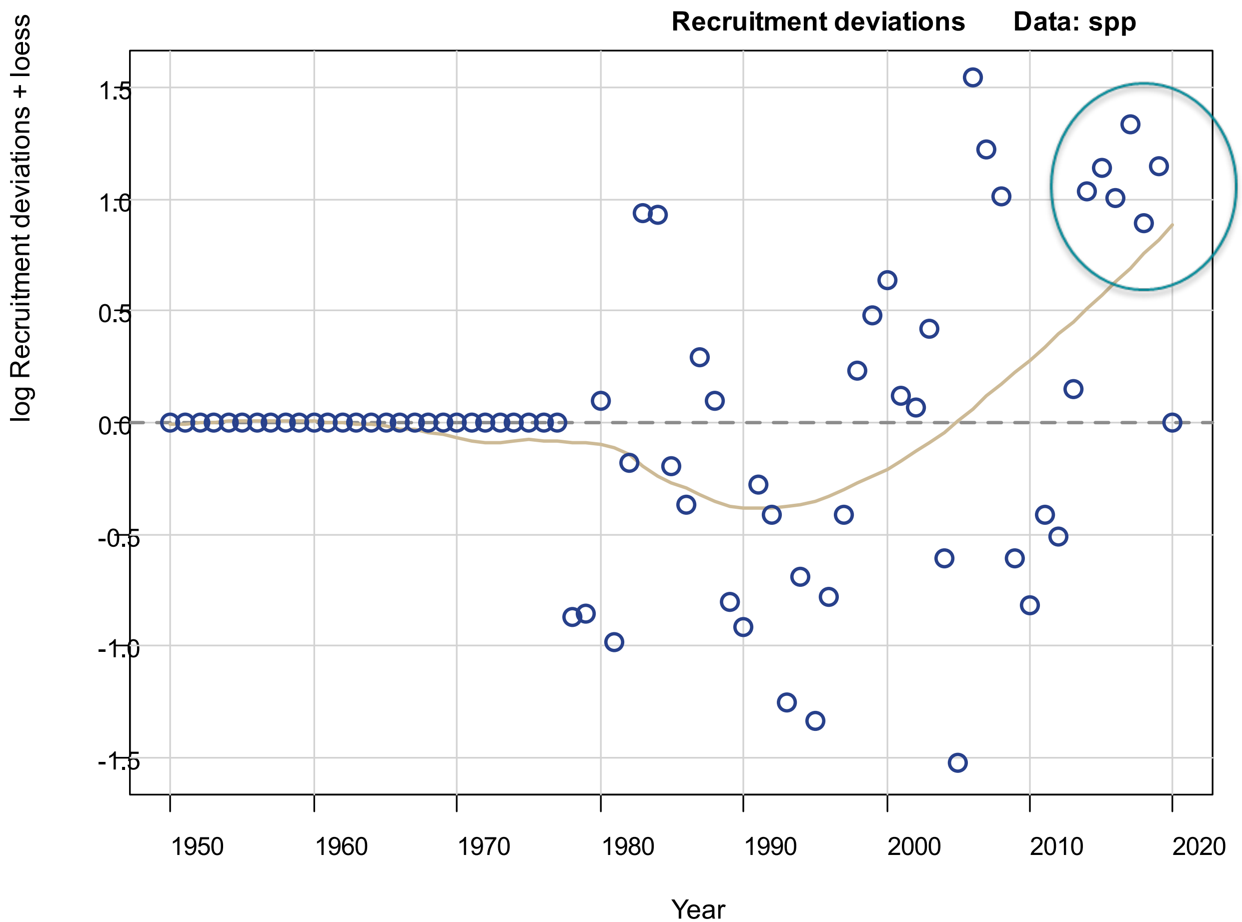
- Change in discard mortality would result in different benchmarks
- For internal consistency, forecasts in the report have a different set of benchmarks than the assessment

Assessment benchmarks	Reduced discard mortality
F30=0.21 MSY=405 klb SSBmsy=635,426	F30=0.22 MSY=442 klb SSBmsy=635,583

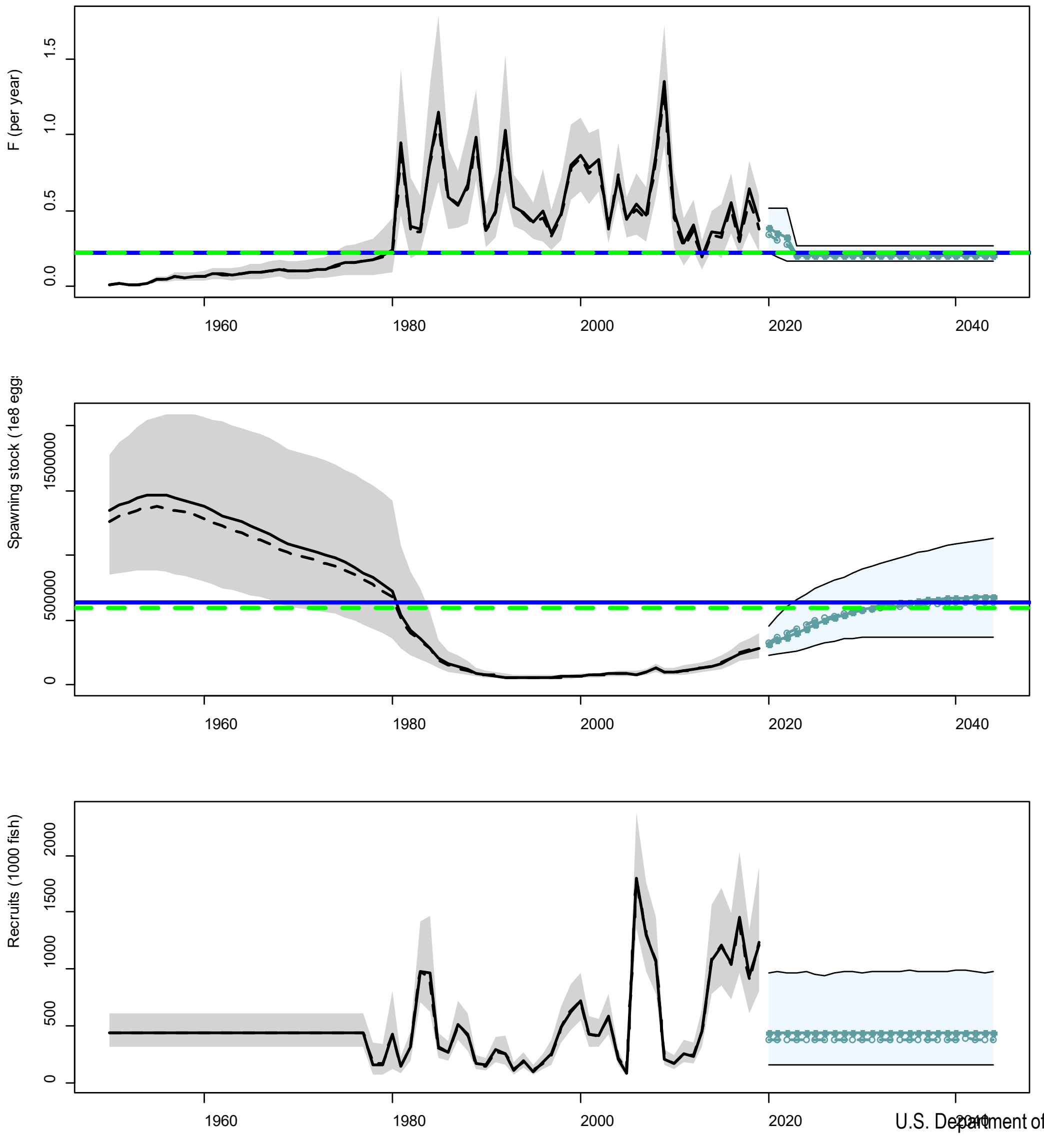
- However, since the report, SEFSC and SERO have considered an alternative approach (more later)

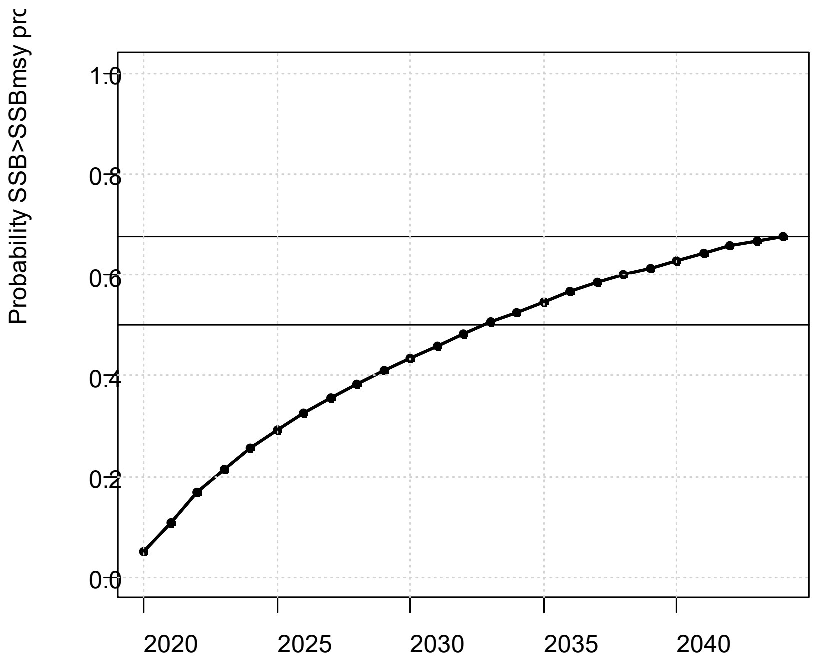
High recruitment scenarios

- Use geomean recruitment from terminal six years

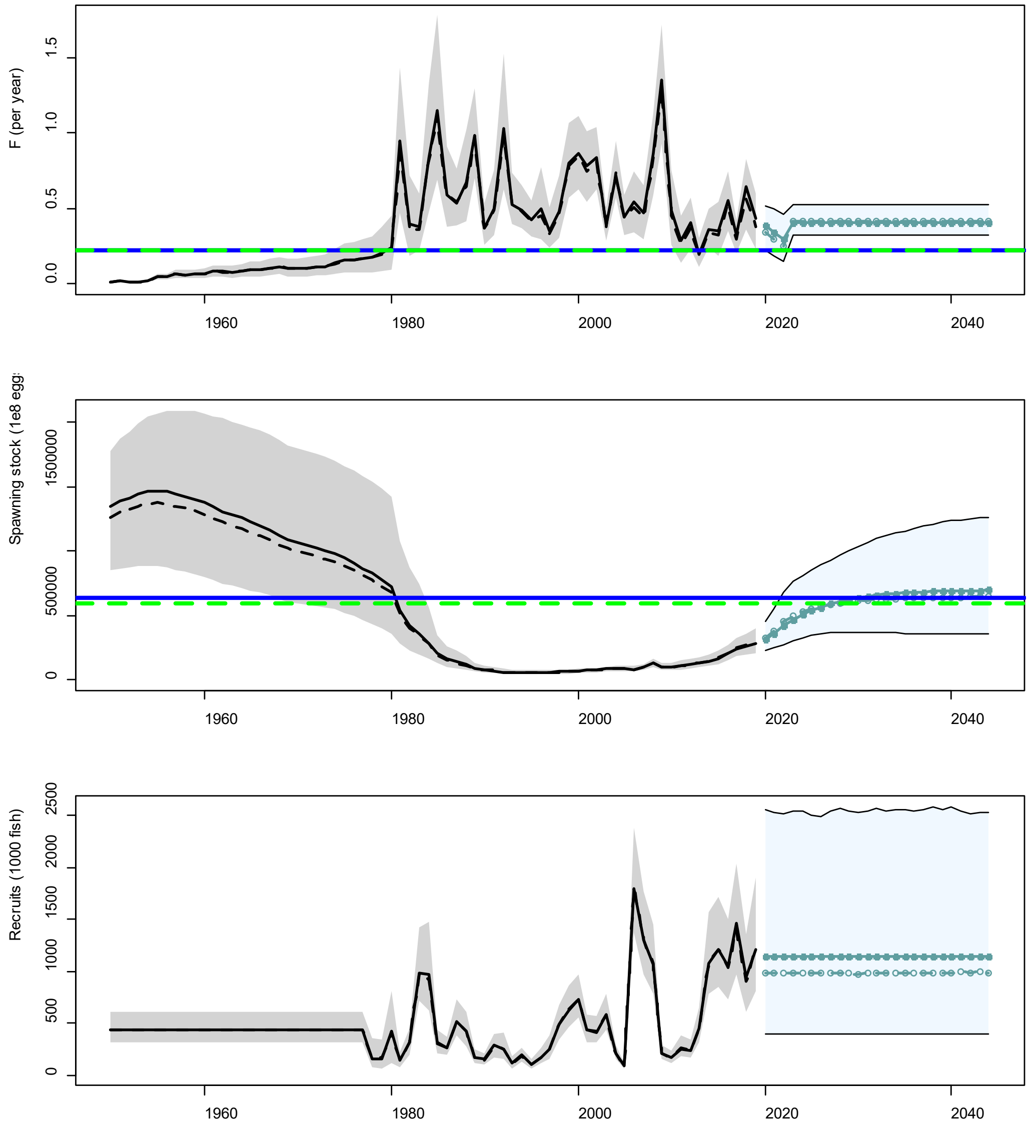


Example forecast (Frebuild with 0.675 prob and mean recruitment)

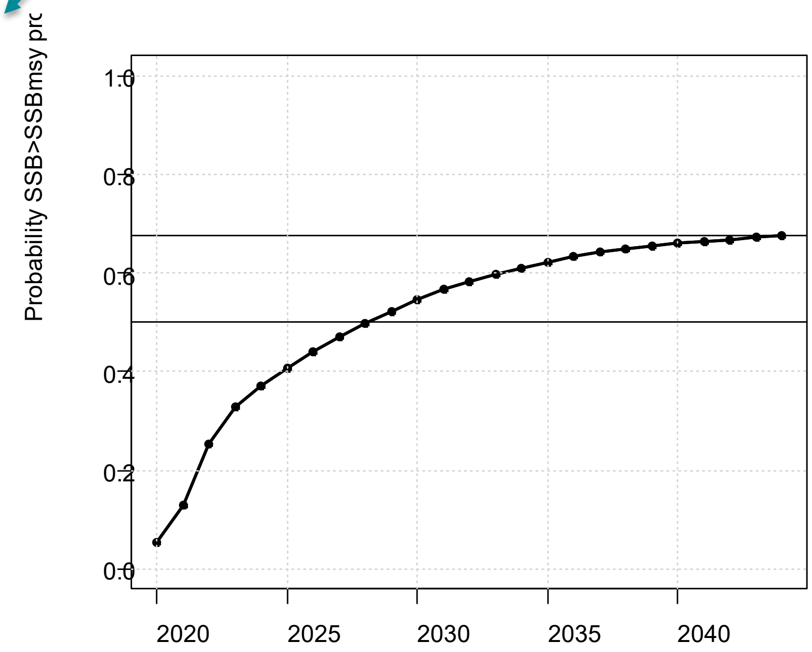




Example forecast (Frebuild with 0.675 prob and high recruitment)



Note, overfishing. Is this acceptable in the short-term?



Additional forecast consideration

- Given reduction in future discard mortality (descender devices), should forecast benchmarks differ from assessment benchmarks?
  - Yes, if forecast scenarios require internal consistency with benchmarks
  - No, if a positive management action simply raises the bar for rebuilding
- An alternative approach (not in the report) reduces discard mortality in the future, while allowing the additional fish to be caught as landings
  - This approach has support of SEFSC and SERO leadership

Alternative, two-step approach to forecasts

- Step One: Forecast using prevailing conditions (assessment benchmarks) to compute Frebuild
- Step Two: Forecast using Frebuild from step one, but reduce discard F to account for descender devices, while iteratively increasing landings F to still achieve rebuilding in 2044

- Preliminary investigation: compared to previous (report) forecasts, this two-step approach has similar trajectories of SSB and total kills, but lower discard mortalities and higher landings (~21% higher)

What forecast scenarios does the SSC need for catch advice?

- Management start year of 2021? Yes.
- Longterm average or recent high recruitment?
- Use the two-step process?
  - Frebuild is based on prevailing conditions
  - For ABCs, project at Frebuild but with reduced discard F and increased landings F
- Other modifications?
- To be continued …

Extras

Forecast tables

Projection F=F30, mean recruitment

Table 30. Projection results with fishing mortality rate fixed at $F = F_{30\%}$ starting in 2023 and long-term, average recruitment. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1e8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1e8)	S.med(1e8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2020	437	380	0.39	0.34	306993	324501	40	39	416	409	408	378	1980	1874	0.052
2021	437	380	0.35	0.31	342360	367864	38	37	420	413	272	240	1499	1369	0.107
2022	437	381	0.33	0.28	369131	401377	35	35	419	412	213	185	1219	1108	0.168
2023	437	380	0.22	0.23	398103	431220	24	28	302	353	136	136	752	793	0.210
2024	437	381	0.22	0.23	429163	458171	24	27	318	368	135	131	723	730	0.244
2025	437	381	0.22	0.23	457019	480318	25	27	333	379	136	129	718	705	0.272
2026	437	377	0.22	0.23	481357	499146	25	28	348	390	136	129	721	696	0.293
2027	437	382	0.22	0.23	503100	514885	26	28	361	399	137	129	726	696	0.308
2028	437	381	0.22	0.23	521476	526457	26	28	372	407	137	129	730	696	0.322
2029	437	380	0.22	0.23	537402	536710	26	28	382	413	137	129	733	699	0.333
2030	437	378	0.22	0.23	551144	543529	27	28	390	418	137	130	734	701	0.339
2031	437	378	0.22	0.23	562901	550883	27	28	397	423	137	130	735	703	0.346
2032	437	380	0.22	0.23	573246	556824	27	29	404	426	137	130	736	705	0.352
2033	437	380	0.22	0.23	582035	562116	27	29	409	430	137	130	737	707	0.356
2034	437	381	0.22	0.23	589522	566207	28	29	414	433	137	130	737	706	0.365
2035	437	380	0.22	0.23	596094	570590	28	29	418	435	137	130	737	706	0.371
2036	437	379	0.22	0.23	601727	573432	28	29	421	437	137	130	738	707	0.377
2037	437	380	0.22	0.23	606443	576438	28	29	424	440	137	130	738	708	0.385
2038	437	381	0.22	0.23	610514	579022	28	29	426	442	137	131	739	709	0.392
2039	437	379	0.22	0.23	613991	581361	28	29	429	444	137	130	739	712	0.400
2040	437	381	0.22	0.23	617005	583259	28	29	430	445	137	130	739	711	0.407
2041	437	385	0.22	0.23	619606	584483	28	29	432	446	137	130	739	710	0.414
2042	437	381	0.22	0.23	621844	585966	28	29	433	447	137	130	739	710	0.420
2043	437	382	0.22	0.23	623769	587483	28	30	435	448	138	130	739	709	0.426
2044	437	380	0.22	0.23	625424	588026	28	30	436	449	138	130	740	709	0.433

Projection F=F30, high recruitment

Table 91. Projection results with fishing mortality rate fixed at $F = F_{30\%}$ *starting in 2023 and recent average recruitment.* R *= number of age-1 recruits (in 1000s),* F *= fishing mortality rate (per year),* S *= spawning stock (1e8 eggs),* L *= landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and* D *= dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with* $\text{SSB} \geq \text{SSB}_{MSY}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1e8)	S.med(1e8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2020	1145	980	0.39	0.34	308482	326178	40	40	416	409	496	447	2079	1961	0.054
2021	1145	982	0.34	0.30	354122	379262	40	39	420	413	421	356	1813	1615	0.129
2022	1145	984	0.29	0.25	416135	448412	40	39	419	412	387	325	1739	1523	0.252
2023	1145	984	0.22	0.23	497494	527371	36	40	383	439	319	307	1499	1491	0.386
2024	1145	983	0.22	0.23	592020	613831	41	45	456	510	339	321	1660	1607	0.530
2025	1145	985	0.22	0.23	690331	701264	46	50	530	581	349	327	1769	1688	0.673
2026	1145	975	0.22	0.23	787833	786625	51	53	600	645	355	330	1833	1735	0.795
2027	1145	986	0.22	0.23	882353	866607	54	57	666	705	357	331	1867	1757	0.884
2028	1145	985	0.22	0.23	971484	942264	57	59	725	760	358	334	1885	1771	0.941
2029	1145	987	0.22	0.23	1054133	1011250	60	62	779	807	359	334	1895	1783	0.972
2030	1145	974	0.22	0.23	1129813	1074781	62	64	827	853	359	334	1902	1788	0.989
2031	1145	977	0.22	0.23	1197981	1132538	64	65	870	891	359	334	1907	1794	0.996
2032	1145	984	0.22	0.23	1258871	1183522	66	67	908	926	359	335	1911	1799	0.999
2033	1145	981	0.22	0.23	1312855	1227167	67	68	942	958	359	335	1915	1807	1.000
2034	1145	987	0.22	0.23	1360287	1265945	68	69	971	985	360	336	1918	1813	1.000
2035	1145	984	0.22	0.23	1401799	1300445	69	70	996	1008	360	336	1921	1817	1.000
2036	1145	981	0.22	0.23	1438041	1331793	70	71	1019	1028	360	337	1924	1822	1.000
2037	1145	987	0.22	0.23	1469513	1358375	71	72	1038	1047	360	338	1926	1827	1.000
2038	1145	984	0.22	0.23	1496803	1379877	71	72	1054	1064	360	338	1928	1832	1.000
2039	1145	982	0.22	0.23	1520378	1400793	72	73	1069	1078	360	337	1930	1832	1.000
2040	1145	985	0.22	0.23	1540703	1418726	72	73	1081	1089	360	336	1931	1832	1.000
2041	1145	990	0.22	0.23	1558198	1431597	73	74	1092	1098	360	336	1932	1831	1.000
2042	1145	982	0.22	0.23	1573246	1443670	73	74	1101	1110	360	337	1933	1832	1.000
2043	1145	989	0.22	0.23	1586186	1454091	73	75	1109	1118	360	337	1934	1832	1.000
2044	1145	983	0.22	0.23	1597313	1464902	74	75	1116	1124	360	337	1935	1832	1.000

Projection F=Frebuild 50% prob, mean recruitment

Table 32. Projection results with fishing mortality rate fixed at $F = F_{\text{rebuild}}$ (P=0.5) starting in 2023 and long-term, average recruitment. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1e8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\text{SSB} \geq \text{SSB}_{\text{MSY}}$. The extension b indicates expected values (deterministic) from the base run; the extension med indicates median values from the stochastic projections.

Year	R.b	R.med	F.b	F.med	S.b(1e8)	S.med(1e8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2020	437	380	0.39	0.34	306993	324501	40	39	416	409	408	378	1980	1874	0.052
2021	437	380	0.35	0.31	342360	367864	38	37	420	413	272	240	1499	1369	0.107
2022	437	381	0.33	0.28	369131	401377	35	35	419	412	213	185	1219	1108	0.168
2023	437	380	0.22	0.22	398610	431801	23	27	296	346	133	133	738	778	0.211
2024	437	381	0.22	0.22	430561	459717	24	27	312	362	133	129	712	719	0.247
2025	437	381	0.22	0.22	459395	482866	24	27	328	374	134	127	708	695	0.277
2026	437	377	0.22	0.22	484754	502549	25	27	343	385	134	127	712	687	0.302
2027	437	382	0.22	0.22	507530	519328	25	28	357	395	135	127	718	688	0.320
2028	437	381	0.22	0.22	526910	531966	26	28	368	403	135	127	722	689	0.338
2029	437	380	0.22	0.22	543798	542940	26	28	379	409	135	128	725	692	0.352
2030	437	378	0.22	0.22	558439	550611	27	28	387	415	135	128	726	694	0.365
2031	437	378	0.22	0.22	571024	558782	27	28	395	420	135	128	727	696	0.374
2032	437	380	0.22	0.22	582125	565559	27	28	402	424	135	128	728	697	0.385
2033	437	380	0.22	0.22	591593	571155	27	29	407	428	135	128	729	699	0.394
2034	437	381	0.22	0.22	599686	576077	28	29	412	432	135	128	729	698	0.405
2035	437	380	0.22	0.22	606797	580821	28	29	416	434	136	128	730	698	0.416
2036	437	379	0.22	0.22	612907	583952	28	29	420	436	136	128	730	699	0.425
2037	437	380	0.22	0.22	618040	587443	28	29	423	439	136	128	731	701	0.433
2038	437	381	0.22	0.22	622478	590483	28	29	426	441	136	129	731	702	0.444
2039	437	379	0.22	0.22	626274	592779	28	29	428	443	136	128	731	705	0.455
2040	437	381	0.22	0.22	629568	594990	28	29	430	445	136	128	731	704	0.464
2041	437	385	0.22	0.22	632412	596449	28	29	432	446	136	128	732	702	0.472
2042	437	381	0.22	0.22	634862	598117	28	29	433	447	136	128	732	703	0.482
2043	437	382	0.22	0.22	636971	599956	28	29	434	448	136	128	732	702	0.491
2044	437	380	0.22	0.22	638786	600537	28	29	436	449	136	129	732	702	0.498

Projection F=Frebuild 50% prob, high recruitment

Table 33. Projection results with fishing mortality rate fixed at $F = F_{\text{rebuild}}$ (P=0.5) starting in 2023 and recent average recruitment. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1e8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\text{SSB} \geq \text{SSB}_{\text{MSY}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1e8)	S.med(1e8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2020	1145	980	0.39	0.34	308482	326178	40	40	416	409	496	447	2079	1961	0.054
2021	1145	982	0.34	0.30	354122	379262	40	39	420	413	421	356	1813	1615	0.129
2022	1145	984	0.29	0.25	416135	448412	40	39	419	412	387	325	1739	1523	0.252
2023	1145	984	0.43	0.43	465234	493777	64	72	691	795	569	547	2657	2646	0.325
2024	1145	983	0.43	0.43	497755	518102	65	72	734	825	551	523	2587	2514	0.354
2025	1145	985	0.43	0.43	524199	535478	66	71	764	845	539	505	2513	2410	0.378
2026	1145	975	0.43	0.43	545916	549697	66	70	787	856	534	496	2464	2341	0.397
2027	1145	986	0.43	0.43	564370	559689	66	70	806	865	532	493	2441	2303	0.411
2028	1145	985	0.43	0.43	579562	567432	67	70	822	871	531	494	2431	2292	0.422
2029	1145	987	0.43	0.43	591943	573021	67	70	835	876	531	494	2428	2290	0.434
2030	1145	974	0.43	0.43	602056	578873	67	70	846	881	531	495	2428	2288	0.441
2031	1145	977	0.43	0.43	610109	582618	68	70	855	886	531	494	2429	2294	0.449
2032	1145	984	0.43	0.43	616597	584424	68	70	862	889	531	495	2430	2292	0.455
2033	1145	981	0.43	0.43	621859	586777	68	70	868	893	531	495	2431	2297	0.458
2034	1145	987	0.43	0.43	626074	587104	68	70	873	894	531	496	2431	2303	0.466
2035	1145	984	0.43	0.43	629480	589123	68	70	877	894	531	495	2432	2300	0.467
2036	1145	981	0.43	0.43	632268	589800	69	70	880	897	531	496	2432	2303	0.473
2037	1145	987	0.43	0.43	634523	590534	69	71	883	899	531	497	2432	2311	0.476
2038	1145	984	0.43	0.43	636360	591833	69	71	885	902	531	496	2433	2309	0.484
2039	1145	982	0.43	0.43	637845	592481	69	71	887	902	531	496	2433	2310	0.489
2040	1145	985	0.43	0.43	639055	592295	69	71	888	903	531	496	2433	2306	0.490
2041	1145	990	0.43	0.43	640049	592269	69	71	889	905	531	496	2433	2304	0.495
2042	1145	982	0.43	0.43	640868	593256	69	71	890	906	531	496	2433	2305	0.497
2043	1145	989	0.43	0.43	641545	594306	69	71	891	907	531	497	2433	2302	0.501
2044	1145	983	0.43	0.43	642105	594782	69	71	892	908	531	495	2433	2306	0.502

Projection F=Frebuild 67.5% prob, mean recruitment

Table 34. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{rebuild}}$ (P=0.675) starting in 2023 and long-term, average recruitment. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1e8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with SSB $\geq$ SSB$_{\mathrm{MSY}}$. The extension b indicates expected values (deterministic) from the base run; the extension med indicates median values from the stochastic projections.

Year	R.b	R.med	F.b	F.med	S.b(1e8)	S.med(1e8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2020	437	380	0.39	0.34	306993	324501	40	39	416	409	408	378	1980	1874	0.052
2021	437	380	0.35	0.31	342360	367864	38	37	420	413	272	240	1499	1369	0.107
2022	437	381	0.33	0.28	369131	401377	35	35	419	412	213	185	1219	1108	0.168
2023	437	380	0.21	0.21	400085	433465	22	26	279	327	126	126	698	735	0.215
2024	437	381	0.21	0.21	434647	464134	22	26	297	343	126	123	678	684	0.256
2025	437	381	0.21	0.21	466375	490157	23	26	314	357	127	122	679	666	0.293
2026	437	377	0.21	0.21	494778	512937	24	26	330	370	128	122	686	662	0.326
2027	437	382	0.21	0.21	520646	532326	25	27	344	381	129	122	693	663	0.356
2028	437	381	0.21	0.21	543054	547922	25	27	357	390	129	122	697	665	0.383
2029	437	380	0.21	0.21	562848	561743	26	27	369	399	130	122	701	668	0.410
2030	437	378	0.21	0.21	580221	572076	26	27	379	405	130	123	702	671	0.433
2031	437	378	0.21	0.21	595329	582301	26	28	387	411	130	122	704	672	0.460
2032	437	380	0.21	0.21	608742	591054	27	28	395	417	130	123	704	674	0.482
2033	437	380	0.21	0.21	620292	598873	27	28	401	422	130	123	705	677	0.505
2034	437	381	0.21	0.21	630247	605272	27	28	407	426	130	123	706	676	0.525
2035	437	380	0.21	0.21	639023	611412	27	28	412	429	130	123	706	676	0.546
2036	437	379	0.21	0.21	646607	616002	27	28	416	432	130	123	707	677	0.566
2037	437	380	0.21	0.21	653035	620116	28	29	420	435	130	123	707	678	0.585
2038	437	381	0.21	0.21	658612	624417	28	29	423	438	130	124	708	679	0.600
2039	437	379	0.21	0.21	663408	628110	28	29	426	440	130	123	708	682	0.613
2040	437	381	0.21	0.21	667577	630823	28	29	428	442	130	123	708	681	0.628
2041	437	385	0.21	0.21	671185	632568	28	29	430	444	130	123	708	680	0.642
2042	437	381	0.21	0.21	674301	634816	28	29	432	445	130	123	709	680	0.657
2043	437	382	0.21	0.21	676990	637421	28	29	433	447	130	123	709	680	0.667
2044	437	380	0.21	0.21	679310	638047	28	29	435	448	130	123	709	680	0.677

Projection F=Frebuild 67.5% prob, high recruitment

Table 35. Projection results with fishing mortality rate fixed at $F = F_{\text{rebuild}}$ (P=0.675) starting in 2023 and recent average recruitment. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (1e8 eggs), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), and D = dead discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\text{SSB} \geq \text{SSB}_{\text{MSY}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(1e8)	S.med(1e8)	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2020	1145	980	0.39	0.34	308482	326178	40	40	416	409	496	447	2079	1961	0.054
2021	1145	982	0.34	0.30	354122	379262	40	39	420	413	421	356	1813	1615	0.129
2022	1145	984	0.29	0.25	416135	448412	40	39	419	412	387	325	1739	1523	0.252
2023	1145	984	0.41	0.41	468024	496608	61	69	665	764	548	527	2560	2548	0.330
2024	1145	983	0.41	0.41	505427	525943	63	70	713	801	535	507	2520	2448	0.370
2025	1145	985	0.41	0.41	536977	548193	64	70	749	828	526	492	2468	2366	0.406
2026	1145	975	0.41	0.41	563629	566870	65	69	778	845	522	484	2431	2308	0.439
2027	1145	986	0.41	0.41	586708	581399	66	70	802	860	520	482	2413	2274	0.471
2028	1145	985	0.41	0.41	606157	593091	67	70	823	871	519	483	2405	2266	0.497
2029	1145	987	0.41	0.41	622400	601949	67	70	840	880	519	483	2404	2265	0.523
2030	1145	974	0.41	0.41	635969	610792	68	70	855	890	519	484	2404	2265	0.547
2031	1145	977	0.41	0.41	647069	617334	68	70	867	897	519	483	2406	2271	0.566
2032	1145	984	0.41	0.41	656212	621566	69	71	877	904	519	484	2407	2270	0.582
2033	1145	981	0.41	0.41	663767	625693	69	71	885	909	519	484	2408	2275	0.598
2034	1145	987	0.41	0.41	669943	627813	69	71	892	912	519	484	2408	2282	0.610
2035	1145	984	0.41	0.41	675017	631221	69	71	898	915	519	484	2409	2279	0.620
2036	1145	981	0.41	0.41	679221	633207	69	71	902	918	519	485	2410	2282	0.632
2037	1145	987	0.41	0.41	682670	634966	70	71	906	922	519	485	2410	2290	0.642
2038	1145	984	0.41	0.41	685512	636991	70	71	909	926	519	485	2410	2288	0.648
2039	1145	982	0.41	0.41	687839	638503	70	72	912	928	519	485	2411	2289	0.655
2040	1145	985	0.41	0.41	689754	638449	70	72	914	929	519	485	2411	2286	0.660
2041	1145	990	0.41	0.41	691336	638980	70	72	916	931	519	485	2411	2283	0.664
2042	1145	982	0.41	0.41	692646	640312	70	72	917	933	519	485	2411	2286	0.668
2043	1145	989	0.41	0.41	693733	641355	70	72	919	934	519	486	2411	2283	0.673
2044	1145	983	0.41	0.41	694635	642512	70	72	920	936	519	484	2412	2287	0.675