Status of Yellowtail Rockfish (*Sebastes flavidus*) Along the U.S. Pacific Coast in 2017

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Contents

Executive Summary

Stock

This assessment reports the status of the Yellowtail Rockfish (*Sebastes flavidus*) resource in U.S. waters off the coast of the California, Oregon, and Washington using data through 2016.

The Pacific Fishery Management Council (PFMC) manages the U.S. fishery as two stocks separated at Cape Mendocino, California (40° 10'N). The northern stock has long been assessed on its own; the southern stock is managed as part of the "Minor Shelf Rockfish" complex. This assessment analyzed each stock independently, with the southern stock extending southward to the U.S./Mexico border and the northern stock extending northward to the U.S./Canada border (Figure a).

The Southern model was not robust enough for management purposes, mainly due to lack of data. Therefore although the data and sensitivities investigated for the model are reported in this document, the results of any of those sensitivities should be interpreted with the recognition that the model is not considered suitable for management. We therefore report estimates and projections only for the Northern model.

The most recent fully integrated assessment (Wallace and Lai 2005), following the pattern of prior assessments, included only the Northern stock which it divided into three assessment areas with divisions at Cape Elizabeth (47° 20'N) and Cape Falcon (45° 46'N). The northern stock was assessed most recently using a data-moderate assessment method in 2013 (Cope et al. 2013). The southern stock was also analyzed using the data-moderate method but that model was never reviewed or put forward for management. The contribution of the southern stock to the overfishing limit (OFL) for the Southern Shelf Complex was determined using Depletion-Based Stock Reduction Analysis (Dick and MacCall 2011).

Since the 2005 assessment, reconstruction of historical catch by Washington and Oregon makes any border but the state line (roughly 46° N) incompatible with the data from those states. Additionally, an unknown amount of the groundfish catch landed in northern Oregon is believed to have been caught in Washington waters. This is not an issue that can be resolved at present, and we have elected to address the stock in two areas consistent with the management border at Cape Mendocino. This is consistent, as well, with a recent genetic analysis (Hess et al. 2011) that found distinct stocks north and south of Cape Mendocino but did not find stock differences within the northern area.

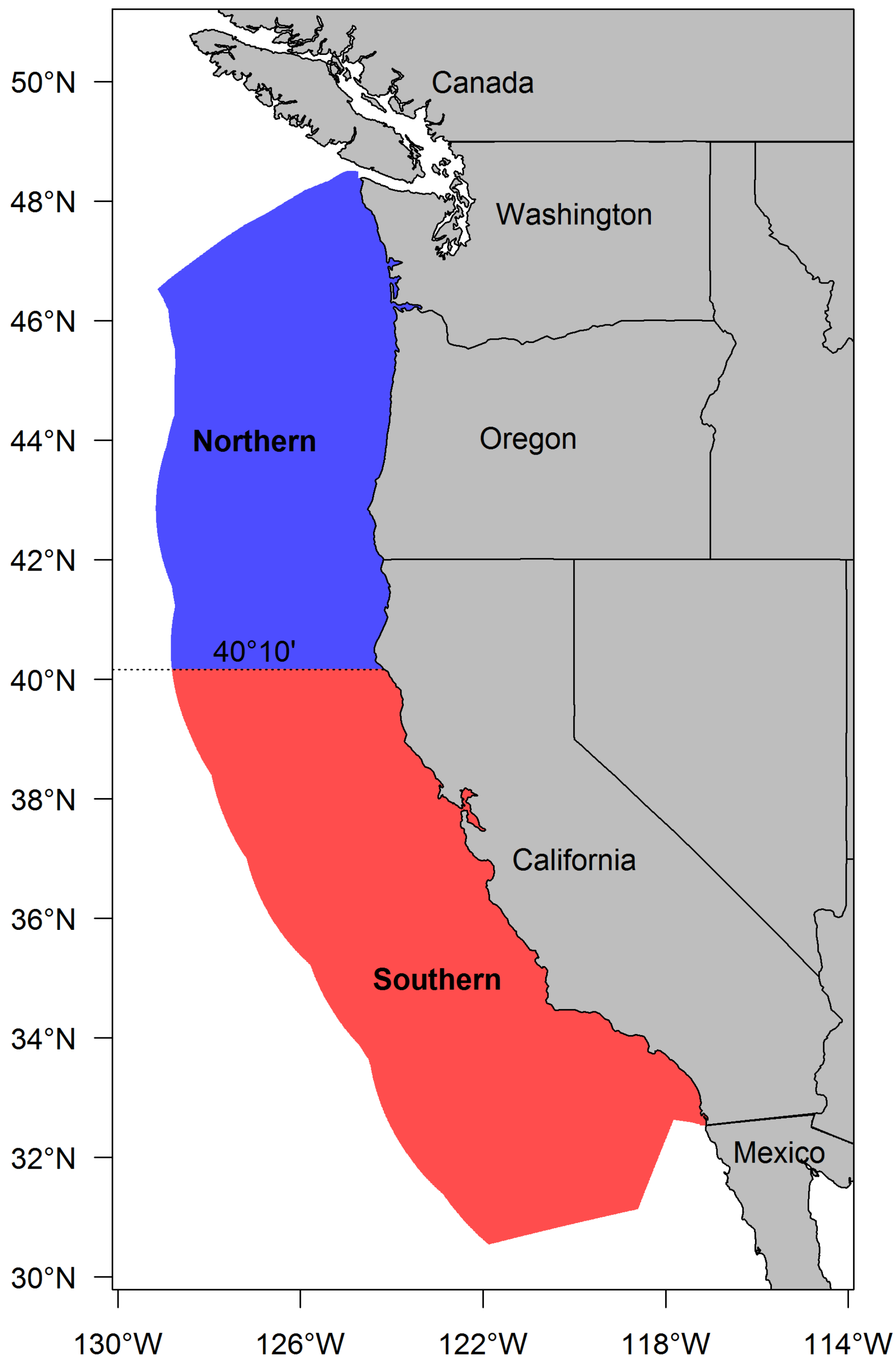

Figure a: Map depicting the boundaries for the base-case model.

Catches

Catches from the Northern stock (Figure b) were divided into four categories: commercial catch, bycatch in the at-sea hake fishery, recreational catch in Oregon and California (north of 40° 10'N), and recreational catch in Washington. The first three of these fleets were entered in metric tons, but the recreational catch from Washington was entered in the model as numbers of fish with the average weight calculated internally in the model from the weight-length relationship and the estimated selectivity for this fleet (which is informed by the length-compositions). Catches have been increasing over the past 10 years (Table a) but remain well below the peak catch due to management measures, included lower catch limits and closed areas.

Catches from the Southern stock (Figure c) were divided into two categories: commercial and recreational catch, both of which were entered as metric tons. Catches over the past 10 years have remained far below the peak levels, with the majority of recent catch coming from the Recreational fishery (Table b)

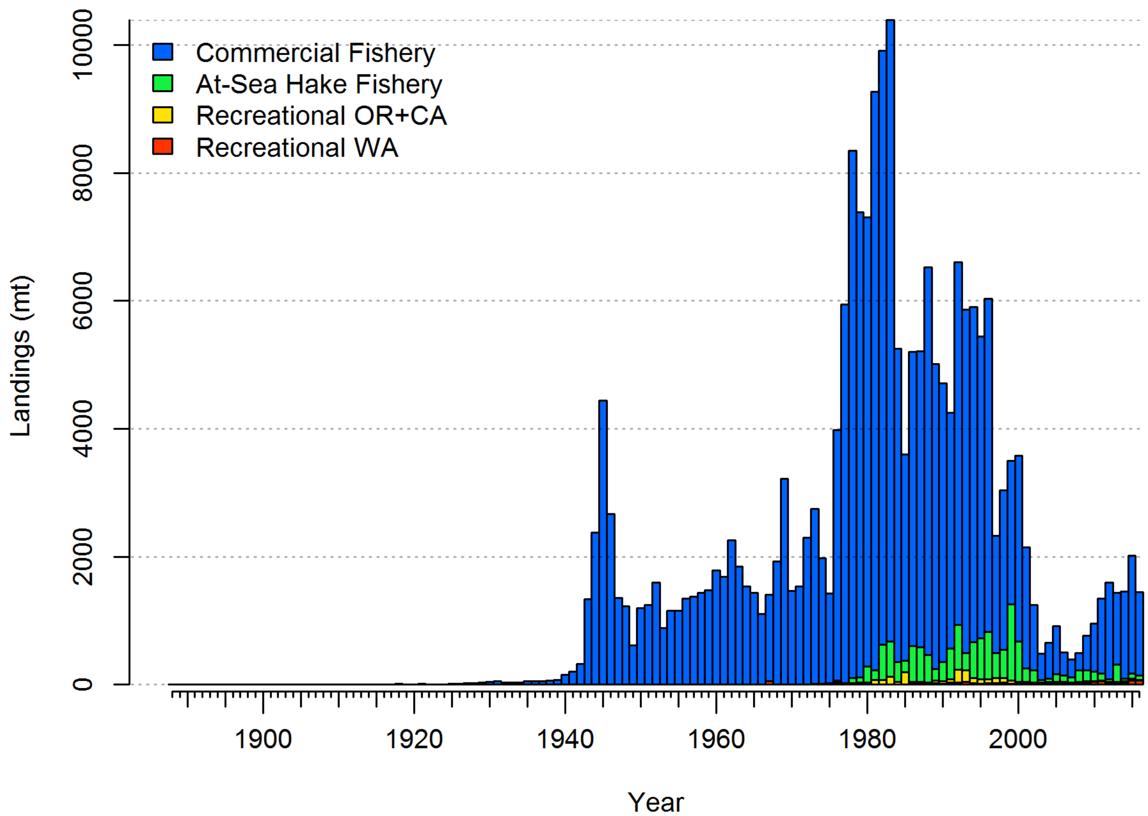

Figure b: Estimated catch history of Yellowtail Rockfish in the Northern model. Recreational catches in Washington are model estimates of total weight converted from input catch in numbers using model estimates of growth and selectivity.

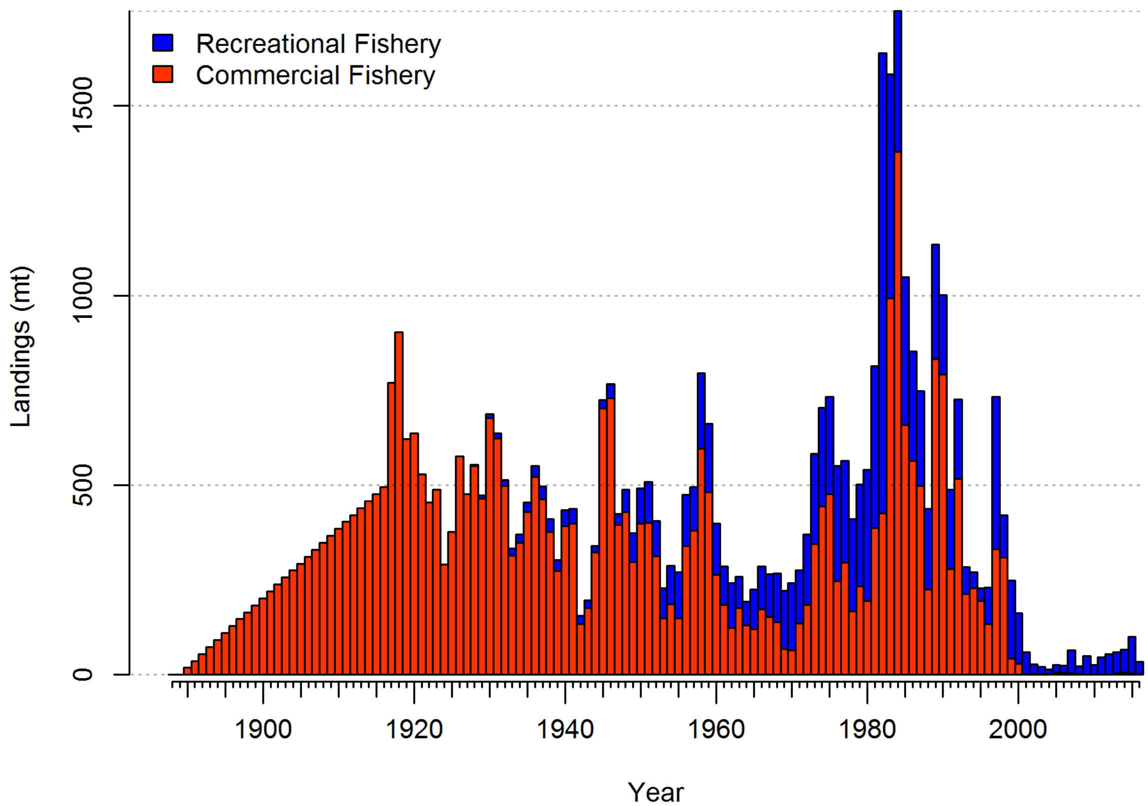

Figure c: Estimated catch history of Yellowtail Rockfish in the Southern model.

Table a: Recent Yellowtail Rockfish catch by fleet for the Northern model (north of 40° 10'N).

Year	Commercial (mt)	At-sea hake bycatch (mt)	Recreational OR+CA (mt)	Recreational WA (1000s)
2006	358	109	23	14
2007	276	79	18	15
2008	276	175	24	18
2009	539	176	17	28
2010	754	150	12	38
2011	1181	101	18	43
2012	1509	43	20	19
2013	1117	269	20	24
2014	1366	42	16	33
2015	1841	86	29	56
2016	1308	62	14	60

Table b: Recent Yellowtail Rockfish catch by fleet for the Southern model (south of 40° 10'N).

Year	Recreational (mt)	Commercial (mt)
2006	19	5
2007	60	4
2008	20	2
2009	48	1
2010	24	1
2011	45	1
2012	53	1
2013	56	4
2014	60	5
2015	96	4
2016	32	2

Data and Assessment

Yellowtail Rockfish north of Cape Mendocino (40° 10'N) was most recently assessed as part of a 2013 data-moderate stock assessment (Cope et al. 2013) that did not include any length or age data. The northern stock was previously assessed in 2000 (Tagart et al. 2000) with that assessment updated in 2003 and 2005 (Lai et al. 2003, Wallace and Lai (2005)). The stock south of 40° 10'N has never been fully assessed due to the lack of data for this area.

Northern model landings are from one recreational and two commercial fisheries: the commercial trawl fishery and the bycatch of Yellowtail Rockfish in the Hake fishery. The Triennial Trawl Survey and the NWFSC Shelf-Slope Survey provide fishery-independent information. A research study and the West Coast Groundfish Observing Program provide data on discards. Length and age samples are available from 1972 to the present (308,133 and 16,781 samples, respectively).

Southern model landings are treated as one recreational and one commercial fishery. Two recreational surveys have been conducted onboard private fishing vessels, and a Hook and Line Survey conducted by the NWFSC provides fishery-independent survey data, although this survey is conducted mainly outside the range of the stock, and has only been sampling since 2004. No discard data are available for the Southern model. Biological sampling since 1980 provides 179,308 length samples, however age sampling was sparse (6,352 samples) and mainly covers the period 1980-1999.

Lack of data for the Southern model contributed heavily to its failure to meet standards for use in management.

This assessment uses Stock Synthesis version 3.30. The Northern model begins in 1889, as does the Southern model. In both cases those starting years were chosen based on the first year of the available catch data and the start of the estimated recruitment deviations was at a later point, so both models were assumed to start at an unfished equilibrium. Steepness was fixed in both models at 0.718. Natural mortality was estmated in the Northern model for females with a male offset, and those estimated values from the Northern model were used as fixed values in the Southern model. Growth parameters, selectivities, equilibrium recruitment and recruitment deviations were estimated in both models.

Stock Biomass

The spawning output for the Northern model was estimated to have fallen below 40% of unfished equilibrium in the early 1980s, to a minimum of 29.3% in 1984 but has rebounded since to 75.2% in 2017 (˜95% asymptotic interval: ± 61.2%-89.2%) (Figures d and e, Table c).

The spawning output and depletion from the final Southern model are shown in the same set of figures for comparison, although this model is not being put forward for management, however most variations of the Southern model explored during development and review showed the stock to be healthy and well above management targets.

Table c: Recent trend in beginning of the year spawning output and depletion for the Northern model for Yellowtail Rockfish.

Year	Spawning Output (trillion eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	12.128	(7.86-16.39)	0.809	(0.604-1.013)
2009	12.569	(8.27-16.87)	0.838	(0.637-1.039)
2010	12.827	(8.53-17.12)	0.855	(0.66-1.051)
2011	12.846	(8.6-17.09)	0.857	(0.668-1.045)
2012	12.740	(8.6-16.88)	0.850	(0.67-1.029)
2013	12.472	(8.46-16.49)	0.832	(0.663-1.001)
2014	12.157	(8.28-16.04)	0.811	(0.651-0.97)
2015	11.841	(8.09-15.6)	0.790	(0.639-0.94)
2016	11.482	(7.83-15.14)	0.766	(0.621-0.91)
2017	11.278	(7.69-14.86)	0.752	(0.612-0.892)

Table d: Recent trend in beginning of the year spawning output and depletion for the Southern model for Yellowtail Rockfish.

Year	Spawning Output (trillion eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	2.801	(0-6.43)	0.636	(0.482-0.79)
2009	2.805	(0-6.41)	0.637	(0.492-0.783)
2010	2.841	(0-6.46)	0.645	(0.506-0.784)
2011	2.915	(0-6.6)	0.662	(0.527-0.797)
2012	3.019	(0-6.8)	0.686	(0.553-0.819)
2013	3.158	(0-7.09)	0.717	(0.583-0.852)
2014	3.316	(0-7.41)	0.753	(0.615-0.891)
2015	3.513	(0-7.83)	0.798	(0.653-0.943)
2016	3.767	(0-8.37)	0.856	(0.699-1.013)
2017	4.099	(0-9.08)	0.931	(0.756-1.106)

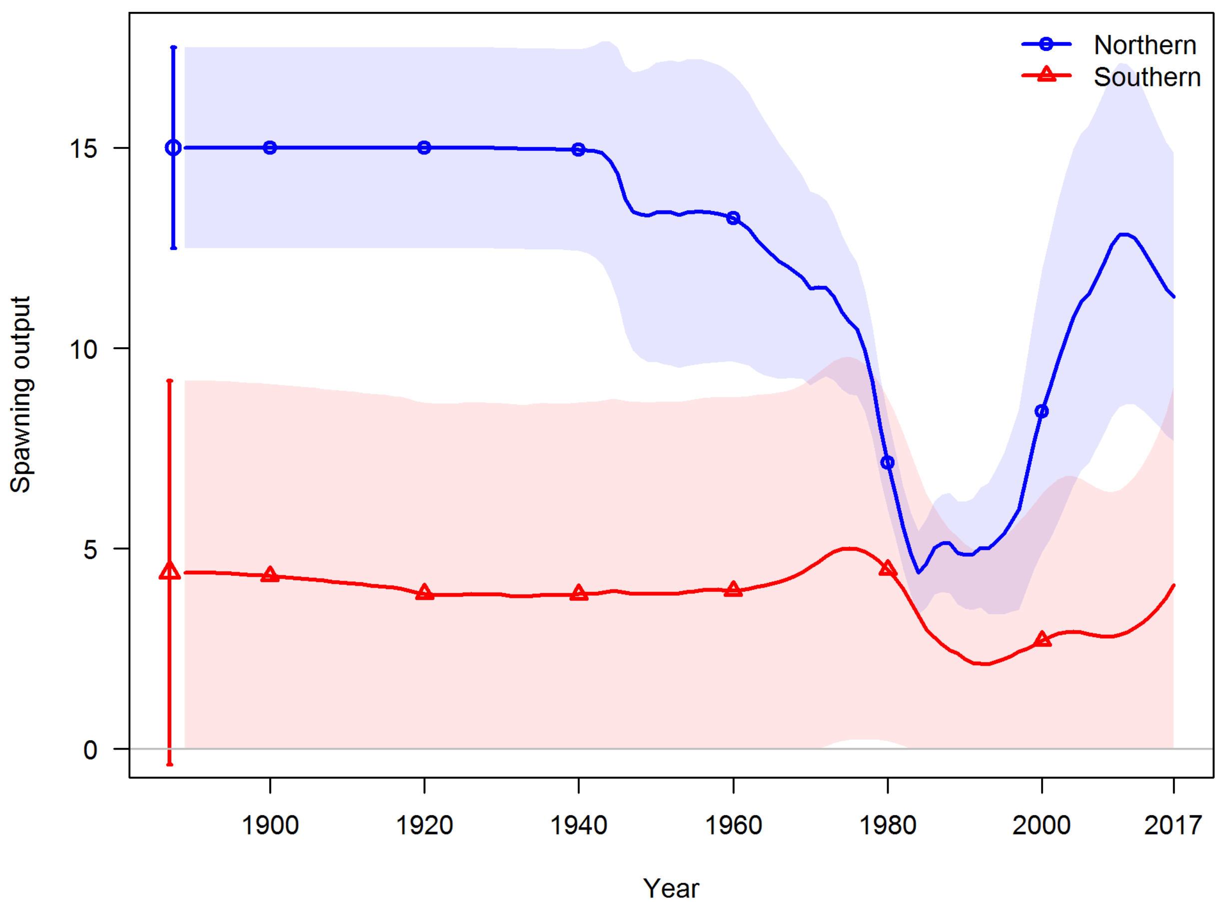

Figure d: Time series of spawning output trajectory (line: median; shaded areas: approximate 95% credibility intervals) for the base case Northern model and final Southern model.

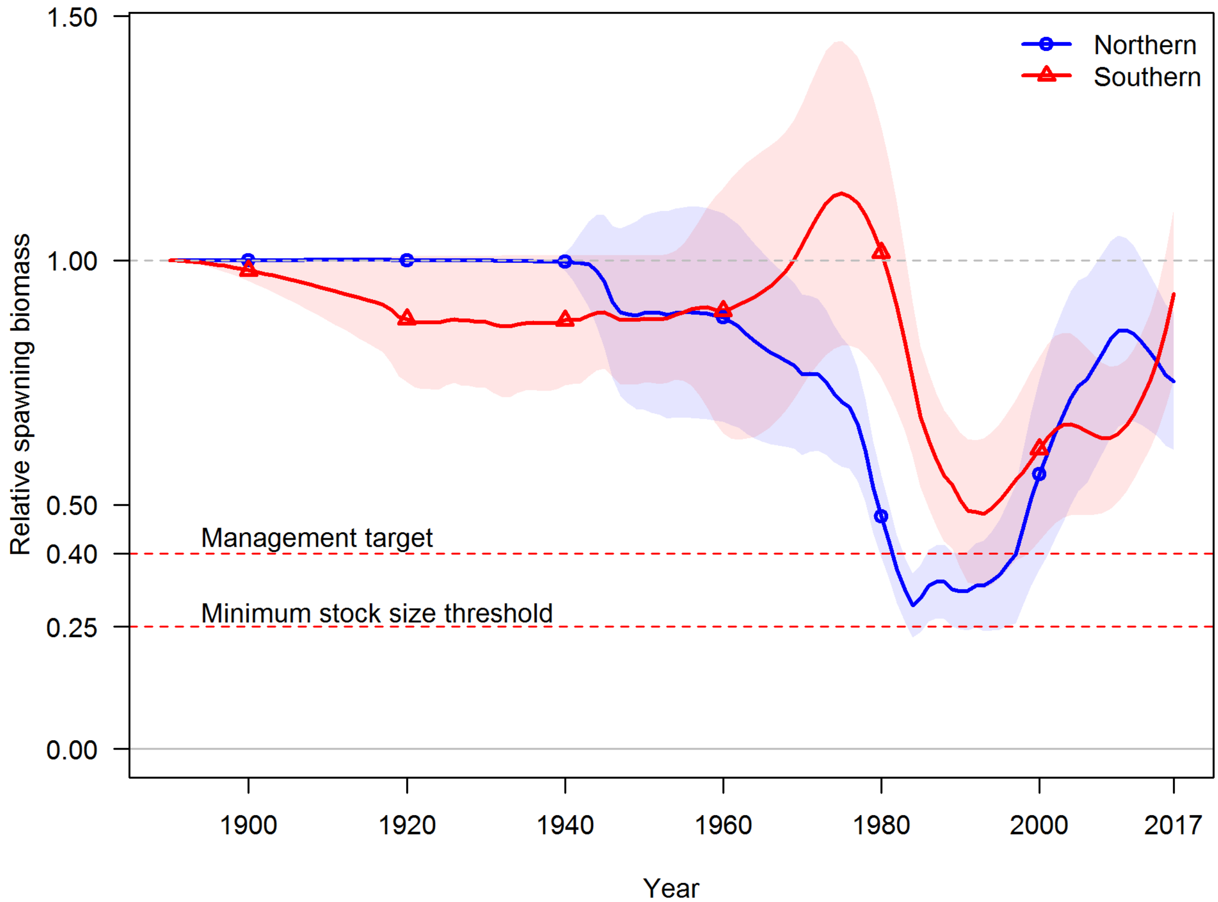

Figure e: Estimated relative depletion with approximate 95% asymptotic confidance intervals (dashed lines) for the base case Northern model and final Southern model.

Recruitment

The Northern model recruitments have ranged from roughly 21 million to 72 million since 2008, although with large uncertainty. Recruitments have shown remarkable consistency since 2013.

Southern model recruitments have ranged from 21 million to 103 million. In 2008 and 2010 it estimates especially large recruitments and extra large recruitment deviations.

Table e: Recent recruitment for the Northern model.

Year	Estimated Recruitment (millions)	˜ 95% confidence interval
2008	66.69	(37.78 - 117.74)
2009	20.82	(9.86 - 43.95)
2010	72.38	(38.52 - 136)
2011	29.34	(12.68 - 67.92)
2012	38.43	(15.07 - 98.01)
2013	53.49	(19.02 - 150.45)
2014	50.06	(17.82 - 140.61)
2015	49.53	(18 - 136.34)
2016	49.20	(17.89 - 135.27)
2017	49.09	(17.86 - 134.94)

Table f: Recent recruitment for the Southern model.

Year	Estimated Recruitment (millions)	˜ 95% confidence interval
2008	103.48	(31.51 - 339.77)
2009	58.70	(16.09 - 214.16)
2010	87.54	(25.05 - 305.87)
2011	51.00	(13.23 - 196.67)
2012	25.48	(6.62 - 97.99)
2013	42.54	(12.66 - 142.92)
2014	33.50	(9.71 - 115.53)
2015	30.74	(8.58 - 110.13)
2016	20.87	(4.91 - 88.65)
2017	25.39	(5.24 - 123.02)

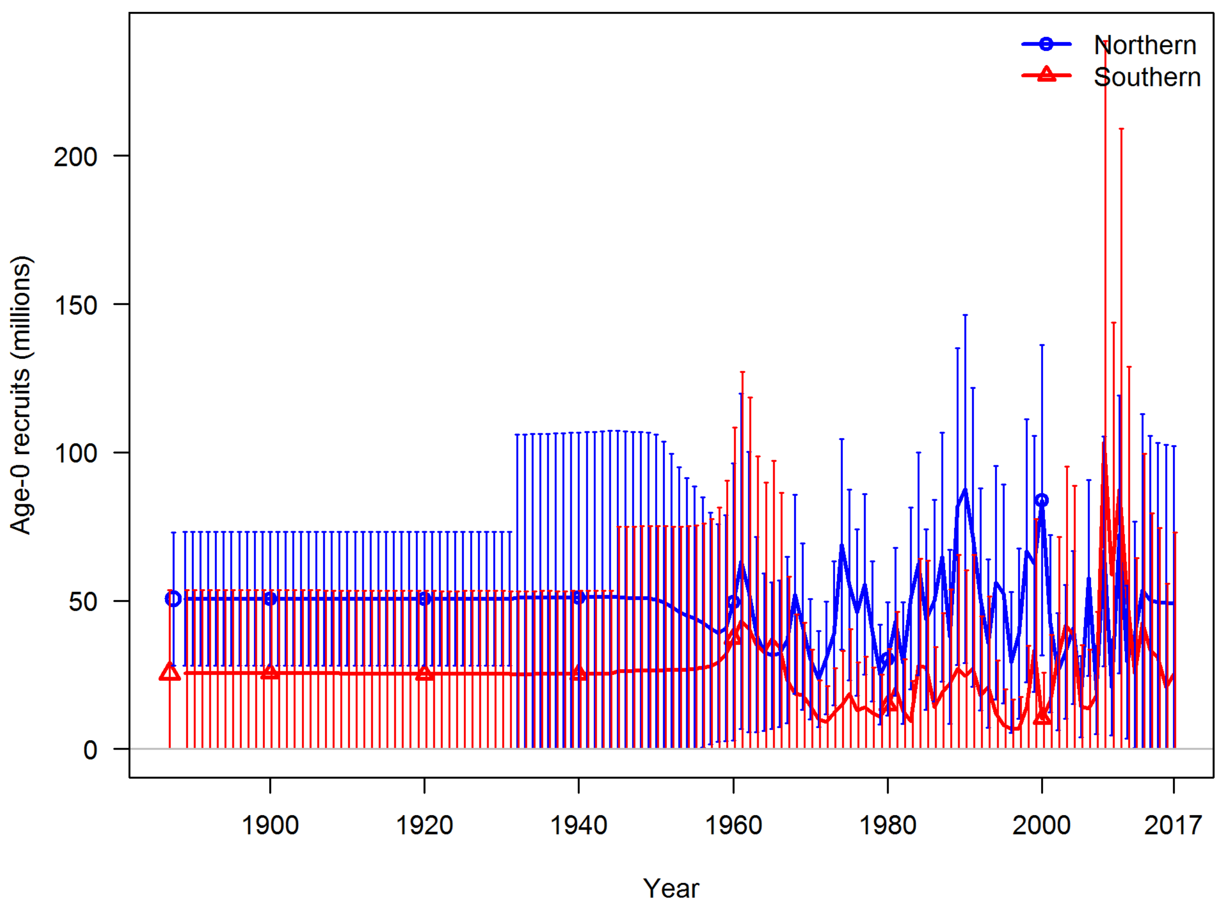

Figure f: Time series of estimated Yellowtail Rockfish recruitments for the base-case Northern model and final Southern Model with 95% confidence or credibility intervals.

Exploitation status

The Northern model is estimated to have experienced overfishing throughout the 1980s and 1990s relative to the current SPR-based harvest limits (Figure g). However, in recent years, the fishing intensity has been well within the management limits and exploitation rates (catch divided by age 4+ biomass) are estimated to have been less than 2% per year (Table g).

A summary of Yellowtail Rockfish exploitation histories for the Northern base model is provided as Figure h.

Table g: Recent trend in spawning potential ratio and exploitation for Yellowtail Rockfish in the Northern model. Fishing intensity is (1-SPR) divided by 50% (the SPR target) and exploitation is catch divided by age 4+ biomass.

Year	Fishing intensity	˜ 95% confidence interval	Exploitation rate	˜ 95% confidence interval
2007	0.172	(0.04-0.3)	0.006	(0.001-0.011)
2008	0.108	(0.06-0.16)	0.004	(0.002-0.005)
2009	0.209	(0.11-0.31)	0.008	(0.004-0.012)
2010	0.292	(0.12-0.47)	0.012	(0.004-0.02)
2011	0.250	(0.16-0.35)	0.010	(0.007-0.014)
2012	0.293	(0.19-0.4)	0.012	(0.008-0.017)
2013	0.277	(0.18-0.38)	0.011	(0.007-0.015)
2014	0.284	(0.18-0.39)	0.011	(0.007-0.015)
2015	0.383	(0.25-0.51)	0.016	(0.01-0.022)
2016	0.294	(0.19-0.4)	0.012	(0.008-0.016)

Table h: Recent trend in spawning potential ratio and exploitation for Yellowtail Rockfish in the Southern model. Fishing intensity is (1-SPR) divided by 50% (the SPR target) and exploitation is catch divided by age 4+ biomass.

Year	Fishing intensity	˜ 95% confidence interval	Exploitation rate	˜ 95% confidence interval
2007	0.038	(0-0.08)	0.001	(0-0.003)
2008	0.013	(0-0.03)	0.000	(0-0.001)
2009	0.027	(0-0.06)	0.001	(0-0.002)
2010	0.013	(0-0.03)	0.000	(0-0.001)
2011	0.021	(0-0.05)	0.001	(0-0.002)
2012	0.022	(0-0.05)	0.001	(0-0.002)
2013	0.022	(0-0.05)	0.001	(0-0.002)
2014	0.023	(0-0.05)	0.001	(0-0.002)
2015	0.032	(0-0.07)	0.001	(0-0.002)
2016	0.011	(0-0.02)	0.000	(0-0.001)

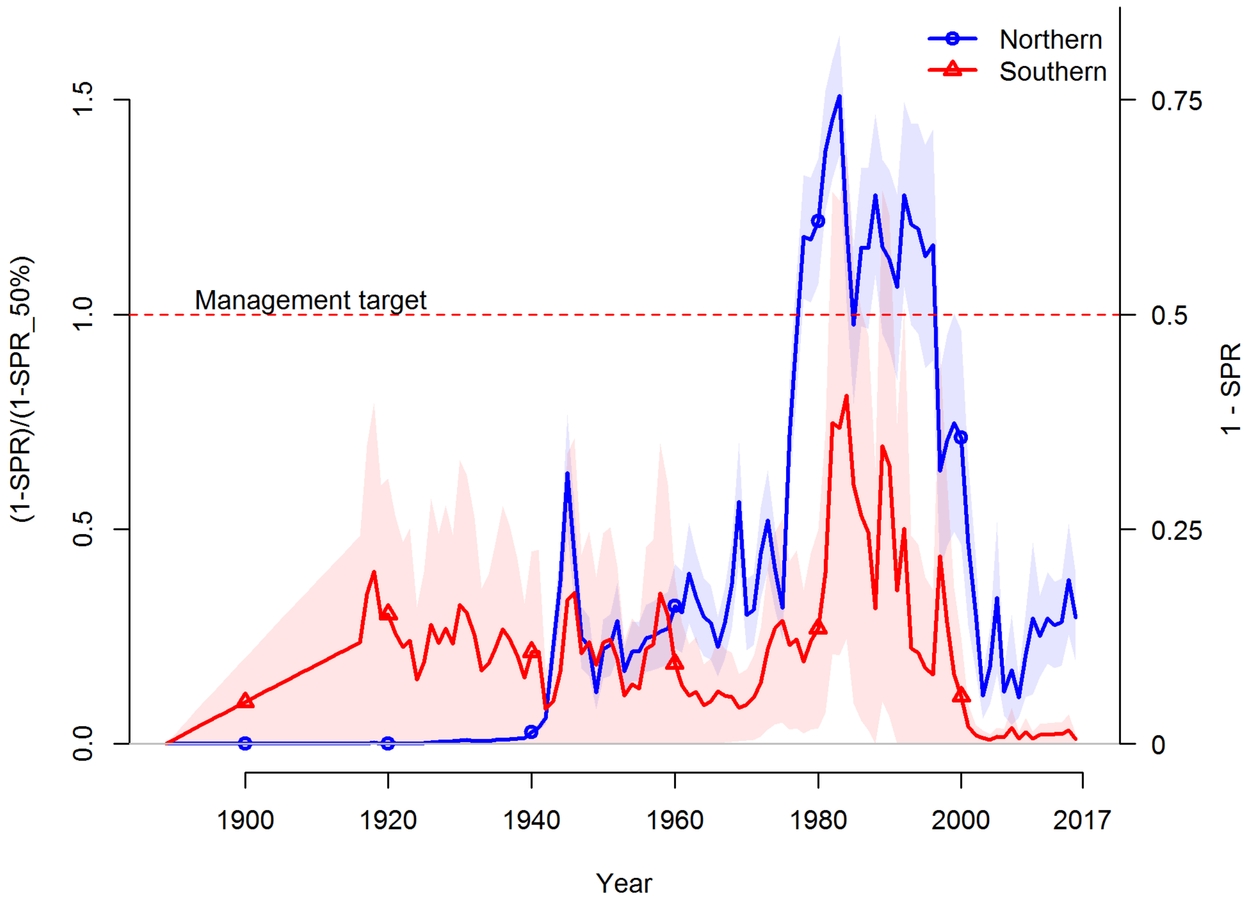

Figure g: Estimated spawning potential ratio (SPR) for the base-case Northern model and final Southern model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$ harvest rate. The last year in the time series is 2016.

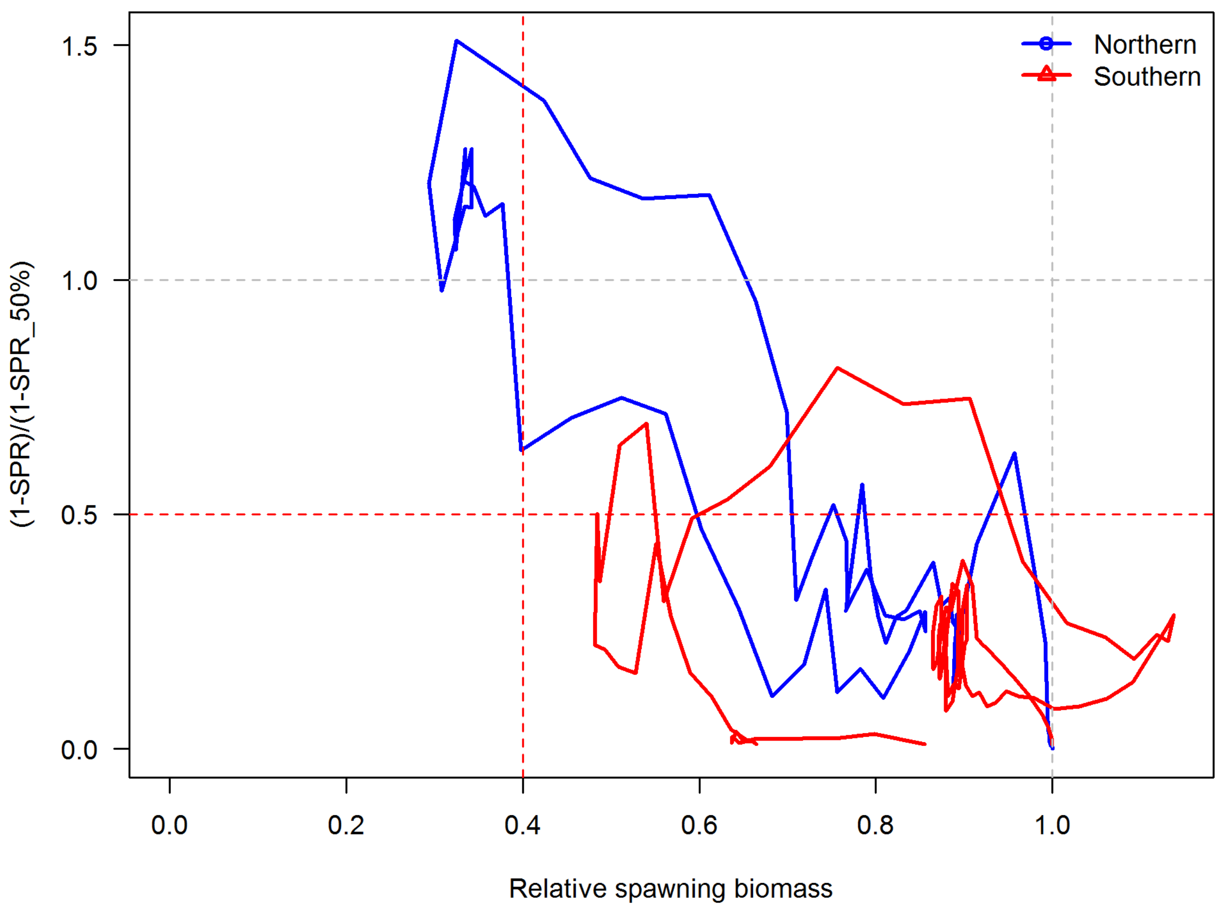

Figure h: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case Northern model and final Southern model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the unfished spawning biomass.

Ecosystem Considerations

Rockfish in general are sensitive to the strength and timing of the upwelling cycle in the Eastern Pacific, which affects where pelagic juveniles settle, and impacts the availability of the zooplankton which the young require.

Yellowtail Rockfish feed mainly on pelagic animals, but are opportunistic, occasionally eating benthic animals as well. Large juveniles and adults eat fish (small Pacific whiting, Pacific herring, smelt, anchovies, lanternfishes, and others), along with squid, krill, and other planktonic organisms. They are prey for Chinook Salmon, Lingcod, Cormorants, Pigeon Guillemots and Rhinoceros Auklets. (Love 2011)

Reference Points

Yellowtail Rockfish are managed relative to biomass reference points at $B_{40\%}$ (the B_{MSY} proxy) and $B_{25\%}$ (the minimum stock-size threshold). Harvest rates are managed relative to an F_{MSY} proxy $SPR = 50\%$ which corresponds to a Relative Fishing Intensity, $(1-SPR)/(1-SPR_{50\%})$, of 100%. This assessment estimates the Northern stock to be above the $B_{40\%}$ threshold with Relative Fishing Intensity below 100% ($SPR > 50\%$ which means the Spawning Potential is greater than 50% of the unfished Spawning Potential).

The estimated relative depletion level for the Northern model in 2017 is 75.2% (˜95% asymptotic interval: ± 61.2%-89.2%, corresponding to an unfished spawning output of 11.3 trillion eggs (˜95% asymptotic interval: 7.69-14.86 trillion eggs) of spawning output in the base model (Table i). Unfished age 4+ biomass was estimated to be 161.6 mt in the base case model. The target spawning output based on the biomass target ($SB_{40\%}$) is 6 trillion eggs, which gives a catch of 5434.5 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 5115 mt.

Estimated equilibrium yield curves for the base-case Northern model is shown in Figure i.

Table i: Summary of reference points and management quantities for the base case Northern model.

Quantity	**Estimate**	**~95% Confidence Interval**
Unfished spawning output (trillion eggs)	15	(12.5-17.5)
Unfished age 4+ biomass (1000 mt)	161.6	(126.4-196.9)
Unfished recruitment (R0, millions)	50.6	(28.1-73.1)
Spawning output(2016 trillion eggs)	11.5	(7.8-15.1)
Relative Spawning Output (depletion)2016)	0.7656	(0.6212-0.9101)
Reference points based on $SB_{40\%}$		
Proxy spawning output ($B_{40\%}$)	6	(5-7)
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.4589	(0.4589-0.4589)
Exploitation rate resulting in $B_{40\%}$	0.0575	(0.0552-0.0598)
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	5434.5	(4035.6-6833.3)
Reference points based on SPR proxy for MSY		
Spawning output	6.7	(5.6-7.8)
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.051	(0.049-0.0531)
Yield with SPR_{proxy} at SB_{SPR} (mt)	5115	(3806.5-6423.5)
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	3.4	(2.8-4)
SPR_{MSY}	0.3043	(0.2984-0.3103)
Exploitation rate at MSY	0.0888	(0.0846-0.093)
MSY (mt)	6123.8	(4501.9-7745.6)

Management Performance

Total catch (including landings and discards) from the Northern stock has remained well below the management limits in recent years (Table j) and harvest specifications for 2017 and 2018 are set at values similar to the previous years.

Table j: Northern model recent total catch relative to the management guidelines. Estimated total catch includes estimated discarded biomass. Note: the OFL was termed the ABC prior to implementation of FMP Amendment 23 in 2011. The ABC was redefined to reflect the uncertainty in estimating the OFL under Amendment 23. Likewise, the ACL was termed the OY prior to 2011.

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Estimated total catch (mt)
2007	4585	-	4585	856
2008	4510	-	4510	520
2009	4562	-	4562	1100
2010	4562	-	4562	1624
2011	4566	4364	4364	1350
2012	4573	4371	4371	1594
2013	4579	4378	4378	1433
2014	4584	4382	4382	1461
2015	7218	6590	6590	2017
2016	6949	6344	6344	1449
2017	6786	6196	6196	-
2018	6574	6002	6002	-

Table k: Southern model recent total catch relative to harvest specifications. The southern stock of yellowtail rockfish has been managed in the Southern Shelf Rockfish complex during this period. The values in this table represent the yellowtail harvest specification contributions to the complex and, as such, are not the reference limits used in managing fisheries catches. There were no harvest specifications for this stock prior to 2011.

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Estimated total catch (mt)
2011	1248.90	1042.20	1042.20	45.9
2012	1248.90	1042.20	1042.20	53.7
2013	1064.40	887.70	887.70	59.9
2014	1064.40	887.70	887.70	65.4
2015	1064.40	887.70	887.70	99.3
2016	1064.40	887.70	887.70	33.6
2017	1064.40	887.70	887.70	-
2018	1064.40	887.70	887.70	-

Unresolved Problems And Major Uncertainties

At the STAR meeting the Northern model underwent a major change in that the two fishery-dependent indices that had been included in the pre-STAR model were withdrawn. Representatives of the Groundfish Advisory Panel and Washington Department of Fish and Wildlife identified mistaken assumptions about the datasets used in developing these indices. In the case of the commercial logbook index, this had to do with underestimating the impact of changes in reporting the species and market categories which was occuring differently among the three reporting states. The Hake bycatch index was developed with inaccurate information about the Hake fleet of the time, which was much more heterogeneous than had been believed. These indices were removed because the biases introduced could not be addressed within the time-frame of the review; however they were influential in the model, and both merit further investigation.

In the past, the Northern stock has been modeled as three stocks assumed to have a latitudinal cline in growth. This was not addressed in the present model, in part because the Hess study (Hess et al. 2011) suggests there is no genetic basis for such a cline, and because of objections raised by Washington and Oregon over boundary assumptions made previously. Future research should examine the assumption that growth is invariant along the coast, and evaluate whether the Northern model is sensitive to alternate assumptions.

Another structural decision in the Northern model was in treating female natural mortality as age-independent. This conflicts with prior assessments of Yellowtail Rockfish and with recent assesments of other rockfish stocks. Sex ratios in the data change definitively with age, and old females are conspicuous in their absence. Assessments have addressed this by increasing female mortality after a certain age. One problem with this approach is in defining the age at which such a change occurs. Another is that this assumes that the disappearance of older females is not due to their retirement to habitat unavailable to the fishery. In any case, this was not investigated during the present assessment, and may have provided further insight had it been.

The Southern model unquestionably had insufficient data to support an age-structured model. The ages were sparse and the period since 1999 was barely represented at all. The only fishery-independent survey (the Hook and Line Survey) is conducted mostly outside of the range of the species, and there is no discard data available for the Southern model. Attempting this separate assessment of the Southern stock is useful in defining what constitutes sufficient data, but also in that discussions engendered by the lack of data has identified an otolith collection at the SWFSC that could be investigated, as well as otoliths collected in the Hook and Line Survey that have not been aged.

A final problem common to all stocks caught in the midwater is the lack of a targeting survey. The STAR panel report accompanying this document suggests several avenues to approach this problem. Because depleted midwater stocks have impeded fishing for many species, the lack of such a survey is an ongoing financial burden on industry that deserves further attention.

Decision Tables

Potential OFL projections for the Northern model are shown in Table l.

A decision table for the Northern model is provided in Table m. The initial catch streams chosen during the STAR panel with input from the GMT and GAP representatives are as follows.

- Base catch stream. Annual catches for each fleet are calculated within Stock Synthesis for from the Base Model by applying the default SPR-based control rule with a 0.956 adjustment from OFL to ACL associated with a P-star of 0.45 and the default 0.36 Sigma for Category-1 stocks
- Historic target opportunity catch stream example. This is based on a calculation by the GMT of the based on an average attainment during a period when there was a mid-water fishery targing Yellowtail. It results in an total annual catch of approximately 4000 mt.
- Recent 5-year average. It results in an total annual catch of approximately 2000 mt.

These are shown in the table in order of increasing average catch.

Allocation of catch among fleets for the years 2019 and beyond was based on an average ratio among fleets over the last 5 years as follows: Commercial, 89.6%; At-sea Hake Bycatch, 6.6%; Recreational Oregon and California, 1.2%; and Recreational Washington, 2.6%. For the years 2017 and 2018, the fleet-specific catches were based on the following calculations.

- Recreational catch of 620 mt in 2017 and 597 mt in 2018 based on the set-asides in the harvest specifications. These were divided among the two recreational fleets based based on the recent 5-year average split among them estimated as 35% to the Oregon and Northern California and 65% to Washington.
- At-sea Hake bycatch of 300 mt based on current set-aside.
- Commercial catch of 5276 and 5105 mt in 2017 and 2018 based on the difference between the ACLs for these two years (6196 and 6002 mt, respectively) and the values for the recreational and At-sea Hake fisheries noted above.

In all these calculations, the catch of the Washington Recreational fleet relative to the other fleets is based on the estimated catch in biomass, but the forecast catches for this fleet are input in numbers of fish to match the inputs of the historic catch in the model. The conversion of biomass to numbers in the forecast is based on an average weight of 1.056 kg calculated from the period since 2003 after the estimated change in selectivity of both recreational fleets. Minor discrepencies between this average and the average weight estimated within the model within the forecast period are the source of the small difference between the catch values shown in the decision table and the 2000 and 4000 mt values for two of the catch streams as well as the difference between the 5979 mt catch for 2018 in these forecasts and the 6002 ACL for that year.

No decision table for the Southern model was developed because this model is not recommended for use in management.

Table l: Projections of potential OFL (mt) for the Northern model, using the base model forecast.

Year	OFL
2017	7462.77
2018	6963.32
2019	6568.18
2020	6261.27
2021	6033.99
2022	5876.95
2023	5776.23
2024	5715.12
2025	5677.99
2026	5652.84
2027	5631.77
2028	5610.41

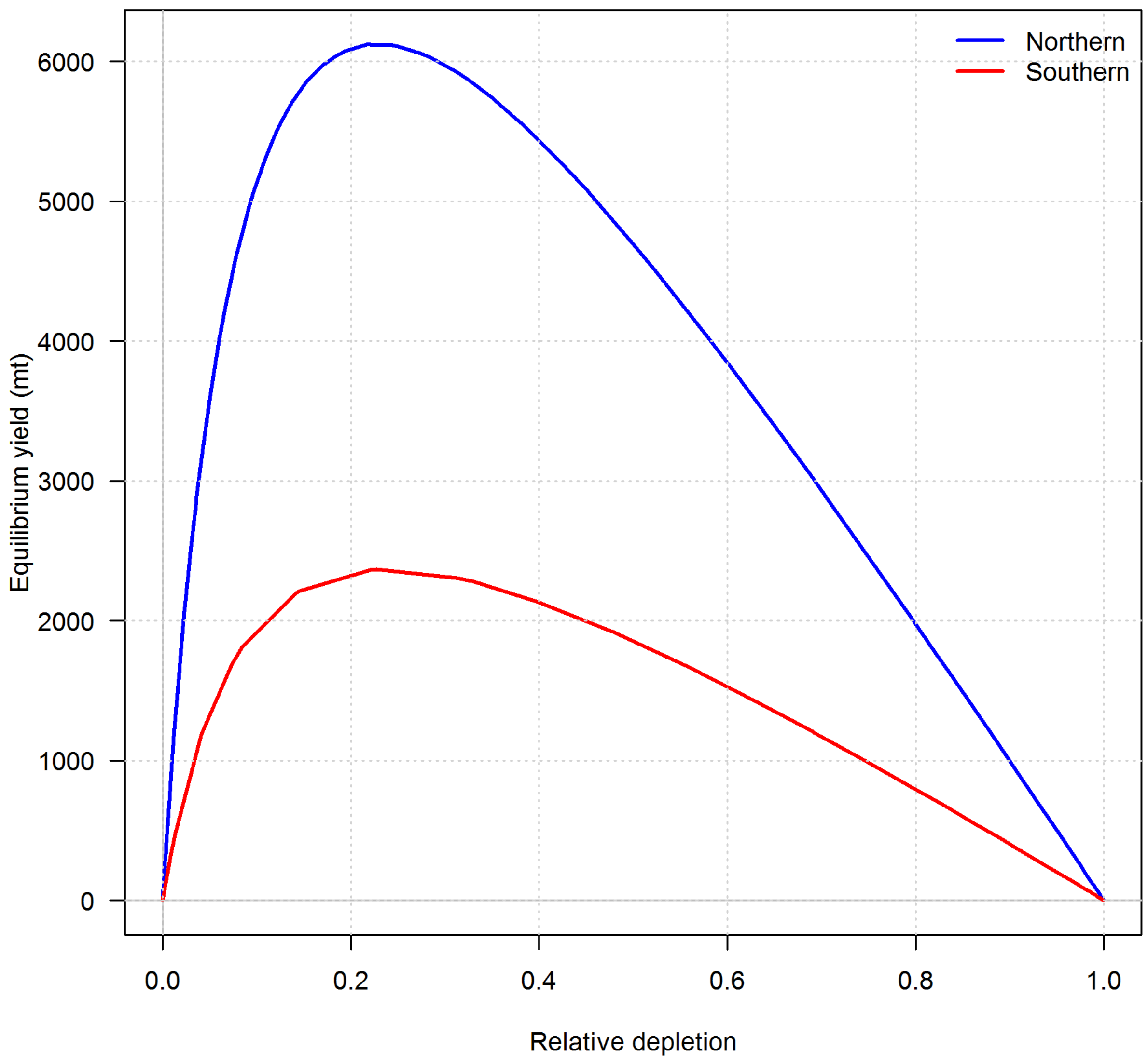

Figure i: Equilibrium yield curve for the base-case Northern model and final Southern model.

Table m: Summary of Spawning Output and Relative Spawning Output (Depletion) over 12-year projections for alternate states of nature based on an axis of uncertainty for the Northern model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. Projections for the years 2017/18 are shown in the first two rows and are used in all catch streams.

			States of nature					
			Low state (M = 0.122)		Base (M = 0.174)		High state (M = 0.249)	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
2017/18	2017	6196	8.30	0.50	11.30	0.75	17.90	0.82
	2018	5979	7.60	0.46	10.50	0.70	16.60	0.76
Recent 5-year average (approx. 2000 mt)	2019	1998	7.00	0.42	9.80	0.65	15.60	0.71
	2020	1997	7.00	0.42	9.80	0.65	15.40	0.70
	2021	1997	7.10	0.43	9.80	0.65	15.50	0.71
	2022	1997	7.20	0.43	9.80	0.65	15.80	0.72
	2023	1997	7.30	0.44	9.90	0.66	16.30	0.74
	2024	1998	7.40	0.44	10.10	0.67	16.80	0.77
	2025	1998	7.60	0.46	10.20	0.68	17.30	0.79
	2026	1998	7.70	0.46	10.40	0.69	17.80	0.81
	2027	1998	7.90	0.48	10.60	0.71	18.10	0.83
	2028	1998	8.20	0.49	10.70	0.71	18.40	0.84
Historic target opportunity catch stream example (approx. 4000 mt)	2019	3996	7.00	0.42	9.80	0.65	15.60	0.71
	2020	3994	6.70	0.40	9.50	0.63	15.20	0.69
	2021	3994	6.50	0.39	9.20	0.61	15.00	0.68
	2022	3993	6.30	0.38	9.00	0.60	15.10	0.69
	2023	3993	6.10	0.37	8.90	0.59	15.40	0.70
	2024	3993	6.00	0.36	8.90	0.59	15.80	0.72
	2025	3993	5.90	0.35	8.90	0.59	16.20	0.74
	2026	3993	5.90	0.35	8.90	0.59	16.60	0.76
	2027	3993	5.90	0.35	8.90	0.59	16.90	0.77
	2028	3994	5.90	0.35	8.90	0.59	17.10	0.78
Base catch stream	2019	6442	7.00	0.42	9.80	0.65	15.60	0.71
	2020	6122	6.40	0.38	9.20	0.61	14.90	0.68
	2021	5881	5.80	0.35	8.60	0.57	14.50	0.66
	2022	5709	5.30	0.32	8.20	0.55	14.50	0.66
	2023	5595	4.90	0.29	8.00	0.53	14.60	0.67
	2024	5522	4.60	0.28	7.80	0.52	15.00	0.68
	2025	5475	4.40	0.26	7.70	0.51	15.30	0.70
	2026	5442	4.30	0.26	7.60	0.51	15.60	0.71
	2027	5416	4.20	0.25	7.50	0.50	15.90	0.73
	2028	5392	4.10	0.25	7.50	0.50	16.10	0.73

Table n: Results summary for base-case Northern model and final Southern model.

Model Region	Quantity	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Northern Model	Landings (mt)	494.2	762.7	957.7	1348.8	1592.7	1432.5	1459.8	2015.4	1447.9	-
	Total Est. Catch (mt)	520.2	1100.2	1624.1	1349.7	1593.8	1433.3	1460.8	2016.8	1448.9	-
	OFL (mt)	4510	4562	4562	4566	4573	4579	4584	7218	6949	6786
	ACL (mt)	4510	4562	4562	4364	4371	4378	4382	6590	6344	6196
Northern Model	(1-SPR)(1-$SPR_{50\%}$)	0.108	0.209	0.292	0.250	0.293	0.277	0.284	0.383	0.294	
Base Case	Exploitation rate	0.004	0.008	0.012	0.010	0.012	0.011	0.011	0.016	0.012	
	Age 4+ biomass (mt)	139.69	138.78	134.91	134.22	129.32	129.70	125.70	127.51	125.63	123.87
	Spawning Output	12.13	12.57	12.83	12.85	12.74	12.47	12.16	11.84	11.48	11.28
	95% CI	(7.86-16.39)	(8.27-16.87)	(8.53-17.12)	(8.6-17.09)	(8.6-16.88)	(8.46-16.49)	(8.28-16.04)	(8.09-15.6)	(7.83-15.14)	(7.69-14.86)
	Depletion	0.81	0.84	0.86	0.86	0.85	0.83	0.81	0.79	0.77	0.75
	95% CI	(0.604-1.013)	(0.637-1.039)	(0.66-1.051)	(0.668-1.045)	(0.67-1.029)	(0.663-1.001)	(0.651-0.97)	(0.639-0.94)	(0.621-0.91)	(0.612-0.892)
	Recruits	66.69	20.82	72.38	29.34	38.43	53.49	50.06	49.53	49.20	49.09
	95% CI	(37.78 - 117.74)	(9.86 - 43.95)	(38.52 - 136)	(12.68 - 67.92)	(15.07 - 98.01)	(19.02 - 150.45)	(17.82 - 140.61)	(18 - 136.34)	(17.89 - 135.27)	(17.86 - 134.94)
Southern Model	(1-SPR)(1-$SPR_{50\%}$)	0.013	0.027	0.013	0.021	0.022	0.022	0.023	0.032	0.011	
Final Model	Exploitation rate	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.000	
	Age 4+ biomass (mt)	49.35	53.47	53.77	53.52	53.68	67.55	75.29	87.65	94.23	95.92
	Spawning Output	2.80	2.81	2.84	2.91	3.02	3.16	3.32	3.51	3.77	4.10
	95% CI	(0-6.43)	(0-6.41)	(0-6.46)	(0-6.6)	(0-6.8)	(0-7.09)	(0-7.41)	(0-7.83)	(0-8.37)	(0-9.08)
	Depletion	0.64	0.64	0.65	0.66	0.69	0.72	0.75	0.80	0.86	0.93
	95% CI	(0.482-0.79)	(0.492-0.783)	(0.506-0.784)	(0.527-0.797)	(0.553-0.819)	(0.583-0.852)	(0.615-0.891)	(0.653-0.943)	(0.699-1.013)	(0.756-1.106)
	Recruits	103.48	58.70	87.54	51.00	25.48	42.54	33.50	30.74	20.87	25.39
	95% CI	(31.51 - 339.77)	(16.09 - 214.16)	(25.05 - 305.87)	(13.23 - 196.67)	(6.62 - 97.99)	(12.66 - 142.92)	(9.71 - 115.53)	(8.58 - 110.13)	(4.91 - 88.65)	(5.24 - 123.02)

Research And Data Needs

The following research will be valuable for future Yellowtail Rockfish assessments:

1. A problem common to assessments of all stocks caught in the midwater is the lack of a targeting survey. Because limits on the take of depleted midwater stocks have impeded fishing for many species, the lack of such a survey is an ongoing financial burden on industry.
2. Research to determine whether old females of a variety of rockfish species actually have a mortality rate different than that of younger females. Assessments variously treat the discrepancies seen in sex ratios of older fish as either mortality-related or due unavailability to the fishery (e.g., ontogenetic movement offshore, or to rockier habitats). As these assumptions impact model outcomes very differently, resolving this issue would greatly improve confidence in the assessments.
3. A hindrance to analysis of the commercial fishery is the inability to distinguish between midwater and trawl gear, particularly in data from the 1980s-1990s. Reliable recording of gear type will ensure that this does not continue to be problematic for future assessments.
4. We recommend that the next assessment of the Northern stock be an update to this assessment, unless fishing patterns change dramatically, or new sources of data are discovered.
5. For the next full assessment, we suggest the following:
    - A commercial index in the North. This is by far the largest segment of the fishery, and the introduction of the trawl rationalization program should mean that an index can be developed for the current fishery when the next full assessment is performed.
    - Further investigation into an index for the commercial logbook dataset from earlier periods.
    - Further analysis of growth patterns along the Northern coast. The previous full assessment subdivided the Northern stock based on research showing differential growth along the coast, and although data for the assessment is no longer available along the INPFC areas used in that analysis, there may be some evidence of growth variability that would be useful to include in a future assessment.
6. The Southern stock cannot be evaluated with a full statistical catch-at-age model unless more data are made available. In particular, we feel that the following are minimally required:
    - A longer timeseries of the juvenile rockfish CPUE in the south, which will of course only be available after several years have elapsed.

- A timeseries of recent ages for the Southern model. The commercial age timeseries currently stops in 2002. Otoliths have been collected for all years in the Hook & Line survey, however only samples from 2004 have been aged. There may also be a collection otoliths associated with research at the SWFSC, and these should be investigated as well.

1 Introduction

1.1 Basic Information

Yellowtail Rockfish, *Sebastes flavidus*, occur off the West Coast of the United States from Baja California to the Aleutian Islands. Yellowtail is a major commercial species, captured mostly in trawls from Central California to British Columbia (Love 2011). Because it is an aggregating, midwater species it is usually caught in the commercial midwater trawl fishery. In California there is a large recreational fishery as well. The center of Yellowtail Rockfish abundance is from southern Oregon through British Columbia (Fraidenburg 1980). Yellowtail Rockfish are colloquially known as "greenies", although *flavidus* is Latin for "yellow" (Love 2011). We briefly summarize Yellowtail Rockfish life history, fisheries, assessment and management here, but in-depth, extensive background information on Yellowtail Rockfish and other managed species is available at (Council 2016).

A number of studies correlate environmental conditions to pelagic juvenile abundance and juvenile recruitment of rockfishes, including Yellowtail Rockfish. Year-class strength is particularly impacted during the early larval phase, and annual pelagic juvenile abundance is correlated with physical conditions, especially upwelling strength along the coast (e.g., (Field and Ralston 2005), (Laidig et al. 2007), (Laidig 2010), (Ralston and Stewart 2013)).

A recent genetic study (Hess et al. 2011) indicates that there are in fact two stocks of Yellowtail Rockfish, with a genetic cline at Cape Mendocino, California, roughly 40°10′ North Latitude. This study of 1013 fish from 21 sites along the West Coast from Mexico through Alaska examined two datasets, one of mitochondrial DNA, and one of nuclear DNA microsattelite loci. Findings in both datasets agreed, and also concur with the findings of Field and Ralston (Field and Ralston 2005) who looked at differences in recruitment trends related to physical forcing and coherence along the coast, and found the greatest differences among the U.S. and Canadian stocks to be defined by Cape Mendocino. Neither the genetic study nor the oceanographic studies definitively identify mechanisms of stock isolation, however they suggest that a combination of physical forcing due to offshore advection and differences in available habitat across Cape Mendocino may together account for the differences observed.

The species has never had a full length and age integrated assessment south of Cape Mendocino, mainly due to a lack of fishery-independent data; this assessment represents an initial attempt to do so.

A map showing the scope of the assessment and depicting boundaries for fisheries or data collection strata is provided in Figure 2.

1.2 Life History

Rockfish are in general long-lived and slow-growing, however Yellowtail Rockfish have a high growth rate relative to other rockfish species, reaching a maximum size of about 55 cm in approximately 15 years (Tagart 1991). Yellowtail are reported to live at least 64 years (Love 2011), however no fish that old occur in data available for this assessment (For the Northern model, the 95th percentile of age is 35 years for females and 45 years for males and for the Southern model, 30 and 40 years respectively for females and males). The maximum age plausibly observed in the north is 60; in the south, 49. There were data we considered to be outliers, for example, three fish in the PacFIN data were reported to be 70, 99, and 101.

ellowtail Rockfish are among those that are fertilized internally and release live young. Spawning aggregations occur in the fall, and parturition in the winter and spring (January-May) (Eldridge et al. 1991). Young-of-the-year recruit to nearshore waters from April through August, migrating to deeper water in the fall. Preferred habitat is the midwater over reefs and boulder fields.

Yellowtail Rockfish are extremely motile, and make rapid and frequent ascents and descents of 40 meters; they also exhibit strong homing tendencies (Love 2011). They are able to quickly release gas from their swim bladders, perhaps making them less susceptible to barotrauma than similar species (Eldridge et al. 1991).

Rockfish Conservation Areas (RCAs) have been closed to fishing since 2002. Following that closure, Yellowtail Rockfish are among the many species that have been seen to increase in both abundance and in average size in Central California (Marks et al. 2015).

Literature values for von Bertallanfy parameters are $L_\infty = 52.2, k = 0.17, t_0 = -0.75$ for females, $L_\infty = 47.6, k = 0.19, t_0 = -1.69$ for males. Length-Weight parameters are $W = 0.0287L^{2.822}$ for females, $W = 0.0359L^{2.745}$ for males (Love 2011). See Section 2.1 for a discussion of the new analysis of the weight-length relationship. Fecundity is represented in the models as: $1.1185^{-11}W^{4.59}$. This is a rescaling of the values provided in (Dick et al. 2017).

Ecosystem Considerations

Rockfish in general are sensitive to the strength and timing of the upwelling cycle in the Eastern Pacific, which affects where pelagic juveniles settle, and impacts the availability of the zooplankton which the young require.

Yellowtail Rockfish feed mainly on pelagic animals, but are opportunistic, occasionally eating benthic animals as well. Large juveniles and adults eat fish (small Pacific Whiting, Pacific Herring, smelt, anchovies, lanternfishes, and others), along with squid, krill, and other planktonic organisms. They are prey for Chinook Salmon, Lingcod, Cormorants, Pigeon Guillemots and Rhinoceros Auklets. (Love 2011)

1.3 Fishery and Management History

There has been a commercial fishery in California for Yellowtail Rockfish since at least 1916, the earliest year for which we have data. Records for recreational fishing start in 1928. In Washington the Recreational data go back to 1889, however in Washington and Oregon the commercial trawl fishery is many times larger than the recreation fishery. In California that has not been the case in recent time; the recreational fishery has been larger than the commercial fishery since the late 1990s.

The rockfish fishery off the U.S. Pacific coast first developed off California in the late 19th century as a hook-and-line fishery (Love et al. 2002). The rockfish trawl fishery was established in the early 1940s, when the United States became involved in World War II and wartime shortage of red meat created an increased demand for other sources of protein (Harry and Morgan 1961, Alverson et al. 1964, Miller et al. 2014).

Until late 2002, Yellowtail Rockfish were harvested as part of a directed mid-water trawl fishery, with fairly high landings in the 1980s and 1990s. Yellowtail commonly co-occur with Canary, Widow Rockfish and several other rockfishes (Tagart 1988); (Rogers and Pikitch 1992). Association with these and other rockfish species has substantially altered fishing opportunity for Yellowtail Rockfish since Canary Rockfish stocks were declared overfished by National Marine Fisheries service in 2000. In order to achieve the necessary reduction in the catch of Canary Rockfish, Widow Rockfish and other overfished species, stringent management measures were adopted, limiting harvest of Yellowtail Rockfish as well as other co-occurring species.

Beginning in 2000, shelf rockfish species could no longer be retained by vessels using bottom trawl footropes with a diameter greater than 8 inches. The use of small footrope gear increases the risk of gear loss in rocky areas. This restriction was intended to provide an incentive for fishers to avoid high-relief, rocky habitat, thus reducing the exposure of many depleted species to trawling. This was reinforced through reductions in landing limits for most shelf rockfish species.

Since September 2002, Rockfish Conservation Areas (RCAs, areas known to be critical habitat) have been closed to fishing. Alongside these closures, limits on landings have been put in place that were designed so as to accommodate incidental bycatch only. These eliminated directed mid-water fishing opportunities for Yellowtail Rockfish in non-tribal trawl fisheries. A somewhat greater opportunity to target Yellowtail Rockfish in the trawl fishery has been available since 2011 under the trawl rationalization program, however quotas for Widow and Canary Rockfish continue to constrain targeting of Yellowtail Rockfish. With the recent improved status of constraining stocks, the industry is developing strategies to better attain allocations of Yellowtail Rockfish and Widow Rockfish.

Yellowtail Rockfish are currently managed with stock-specific harvest specifications north of 40°10′ N. latitude, and as part of the Southern Shelf Rockfish complex south of 40°10′ N.

latitude. The Over Fishing Limit (OFL) contribution of Yellowtail Rockfish to the Southern Shelf Rockfish complex is based on a data-poor analysis (Dick and MacCall 2010).

Total catch (including landings and discards) in both areas has remained well below the management limits and harvest specifications in recent years (Tables 2 and 15)

1.4 Assessment History

Early studies of Yellowtail Rockfish stocks on the U.S. West Coast north of 40°10′ N. latitude (Cape Mendocino, northern California) began in the 1980s with observational surveys. Statistical assessments of Yellowtail Rockfish were conducted in 1982 (Tagart 1982), 1988 (Tagart 1988), 1996 (Tagart et al. 1997), and 1997 (Tagart et al. 1997) to determine harvest specifications for the stock. These early assessments employed a variety of statistical methods, for example, the 1997 assessment used cohort analysis and dynamic pool modeling. Figure 61shows the timeseries of age 4+ biomass for Yellowtail Rockfish across past assessments.

The Yellowtail Rockfish assessment in 2000 (Tagart et al. 2000) was the first that estimated stock status, with an estimated depletion of 60.5 percent at the start of 2000. Lai et al. (Lai et al. 2003) updated the 2000 assessment and estimated that stock depletion was 46 percent at the start of 2003. A second assessment update was prepared in 2005 (Wallace and Lai 2005) with an estimated depletion of 55 percent at the start of 2005. The 2000 assessment and updates were age-structured assessments conducted using AD Model Builder as the software platform for nonlinear optimization (Fournier et al. 2012).

A data-moderate assessment of Yellowtail Rockfish south of 40°10′ N. latitude was conducted in 2013 (Cope et al. 2013). This assessment estimated depletion at the start of 2013 at 67 percent, and estimated the spawning biomass at 50,043 mt. This was a large biomass increase relative to previous estimates and may be attributed to the low removals over the previous decade.

The data-poor assessment method, Depletion-Based Stock Reduction Analysis (Dick and MacCall 2011) was applied to the Southern stock in 2011 (Dick and MacCall 2010). This method does not estimate biomass, but did provide the estimate of the OFL contribution for the southern stock to the complex in which it is managed.

1.5 Fisheries off Canada, Alaska, and/or Mexico

Yellowtail Rockfish are a target species in Canada with catches between 4000-6000 mt since the late 1980s. It has the second largest single-species Total Allowable Catch (TAC) among rockfish species under quota management for the Canadian Pacific Coast. In Canada it is caught in similar amounts by bottom and midwater trawl gear. A 2015 Stock Assessment conducted by the Fisheries and Oceans Canada found the stock to be at 50% of unfished spawning biomass, in the "healthy" range (Canadian Science Advisory Secretariat 2015).

The Alaska Fisheries Science Center assesses Yellowtail Rockfish as one of 25 species in the "Other Rockfish" complex in the Gulf of Alaska. The 2015 full assessment of this complex found no evidence of overfishing, which is confirmed in the 2016 SAFE document(Center 2016).

Limited catches of Yellowtail are reported as far south as Baja California(Love 2011).

2 Data

2.1 Biological Parameters

2.1.1 Weight-Length

The weight-length relationship is based on the standard power function: $W = \alpha(L^{\beta})$ where W is individual weight (kg), L is length (cm), and α and β are coefficients used as constants.

To estimate this relationship, 12,778 samples with both weight and length measurements from the fishery independent surveys were analyzed. These included 6,354 samples from the NWFSC Combo survey, 5,085 from the Triennial survey, and 1,339 from the Hook and Line survey. All Hook and Line survey samples were from the Southern area, along with 910 samples from the other two surveys (Figure 4).

A single weight-length relationship was chosen for females and males in both areas after examining various factors that may influence this relationships, including sex, area, year, and season. None of these factors had a strong influence in the overall results. Season was one of the bigger factors, with fish sampled later in the year showing a small increase in weight at a given length (2-6% depending on the other factors considered). However, season was confounded with area because most of the samples from the Southern area were collected from the Hook and Line survey which takes place later in the year (mid-September to mid-November) and the resolution of other data in the model do not support modeling the stock at a scale finer than a annual time step.

Males and females did not show strong differences in either area, and the estimated differences were in opposite directions for the two areas, suggesting that this might be a spurious relationship or confounded with differences timing of the sampling relative to spawning.

The estimated coefficients resulting from this analysis were $\alpha = 1.1843e-05$ and $\beta = 3.0672$.

2.1.2 Maturity And Fecundity

Maturity was estimated from histological analysis of 141 samples collected in 2016. These include 96 from the NWFSC Combo survey, 25 from mid-water catches in the NWFSC acoustic/trawl survey, 13 from the Hook and Line survey, and 7 from Oregon Department of Fish and Wildlife. The sample sizes were not adequate to estimate differences in maturity by area. Length at 50% maturity was estimated at 42.49cm (Figure 3) which was consistent with the range 37-45cm cited in the previous assessment (Wallace and Lai 2005).

2.1.3 Natural Mortality

Hamel (2015) developed a method for combining meta-analytic approaches to relating the natural mortality rate M to other life-history parameters such as longevity, size, growth rate and reproductive effort, to provide a prior on M. In that same issue of ICESJMS, Then et al. (2015), provided an updated data set of estimates of M and related life history parameters across a large number of fish species, from which to develop an M estimator for fish species in general. They concluded by recommending M estimates be based on maximum age alone, based on an updated Hoenig non-linear least squares estimator $M = 4.899A_{max}^{-.916}$.

The approach of basing M priors on maximum age alone was one that was already being used for west coast rockfish assessments. However, in fitting the alternative model forms relating M to Amax, Then et al. did not consistently apply their transformation. In particular, in real space, one would expect substantial heteroscedasticity in both the observation and process error associated with the observed relationship of M to Amax. Therefore, it would be reasonable to fit all models under a log transformation. This was not done.

Re-evaluating the data used in Then et al. (2015) by fitting the one-parameter Amax model under a log-log transformation (such that the slope is forced to be -1 in the transformed space (as in Hamel (2015)), the point estimate for M is $M = 5.4/Amax$

This is also the median of the prior. The prior is defined as a lognormal with mean $ln(5.4/Amax)$ and SE = 0.4384343.

Initial natural mortality priors for these models were based on examination of the 99% quantile of the observed ages from early in the time-series, before the full impact of fishing would have taken place. For the Northern model, these quantiles were approximately 35 years for females and 45 years for males, resulting in median M values of 0.15 and 0.12 for females and males. For the Southern model, the 99% quantile of the early age observations were approximately 30 and 40 years for females and males, resulting in median M prior values of 0.18 and 0.135, respectively. In both models, M for males was represented as an offset from females.

2.1.4 Aging Precision And Bias

Age error matrices were developed for double-reads at the PFMC aging lab in Newport, OR and for double reads within the WDFW aging lab. The Newport lab has done all of the Survey aging for the NWFSC, along with some commercial ages and the 400 fish from the Small Study. WDFW provided the bulk of recreational and commercial ages. Between-lab differences in aging were minute, as were within-lab differences. This result is supported by the primary age reader's assessment: Yellowtail Rockfish are extremely easy to age (B. Kamikawa, pers. comm.).

2.2 Biological Data and Indices

Data used in the Northern and Southern Yellowtail Rockfish assessments are summarized in Figures 6 and 70.

Data sources for the two models are largely distinct. Northern fisheries and surveys had very sparse data (if any) for the south and vice-versa. Among the 12 data sources referenced below, only 2 data sources are common to both models. These are the MRFSS/RecFIN recreational dockside survey, which focuses on California and Oregon, and the CalCOM California commercial dataset, which contributed data from the northern-most California counties (Eureka and Del Norte) to the Northern model. The CalCOM data account for less than five percent of the commercial landings in the Northern model, and less than 1% of the biological samples.

Commercial landings are not differentiated in either model. For the Northern model, this is due to the very small portion (1.15 %) of the landings that are attributed to non-trawl gear. For the Southern model, this is due to the paucity of data.

A description of each model's data sources follows.

2.3 Northern Model Data

Summary of the data sources in the Northern model.

Source	Landings	Lengths	Ages	Indices	Discard	Type
PacFIN	Y	Y	Y	Y		Commercial
WCGOP		Y			Y	Commercial Discards
Hake Bycatch	Y	Y	Y	Y		Commercial
CalCOM	Y	Y	Y			Commercial
WaSport	Y	Y	Y			Recreational
MRFSS	Y	Y				Recreational
RecFIN	Y	Y				Recreational
Triennial		Y	Y	Y		Survey
NWFSCcombo		Y	Y	Y		Survey
Pikitch		Y			Y	Commercial Study
ODFW	Y					Historical data
WDFW	Y					Historical data

2.3.1 Commercial Fishery Landings

Washington and Oregon Landings The bulk of the commercial landings for Washington and Oregon came from the from the Pacific Fisheries Information Network (**PacFIN**) database.

Washington Catch Information
The Washington Department of Fisheries and Wildlife (**WDFW**) provided historical Yellowtail catch for 1889“1980. Landings for 1981-2016 came from the PacFIN database. WDFW also provided catches for the period 1981 2016 to include the re-distribution of the un-speciated”URCK” landings in PacFIN; this information is currently not available from PacFIN.

Oregon Catch Information
The Oregon Department of Fisheries and Wildlife (**ODFW**) provided historical Yellowtail catch from 1892-1985. ODFW also provided estimates of Yellowtail Rockfish in the in the un-speciated PacFIN “URCK” and “POP1” catch categories for recent years, and those estimates were combined with PacFIN landings for 1986-2016.

Northern California Catch
The California Commercial Fishery Database (**CalCOM**) provided landings for the Northern model for the two counties north of $40°10'$ (Eureka and Del Norte) for 1969-2016.

Hake Bycatch
The Alaska Fisheries Science Center (**AFSC**) provided data for Yellowtail bycatch in the hake fishery from 1976-2016.

2.3.2 Sport Fishery Removals

Washington Sport Catch
WDFW provided recreational catches for 1967 and 1975-2016.

Oregon Sport Catch
ODFW provided recreational catch data for 1979-2016.

MRFSS and RecFIN Data from Northern California came from the Marine Recreational Fisheries Statistical Survey (**MRFSS**) and from the Recreational Fisheries Information Network (**RecFIN**). These are dockside surveys focused on California and Oregon. MRFSS was conducted from 1980-1989 and 1993-2003, RecFIN from 2004 to the present.

2.3.3 Estimated Discards

Commercial Discards
The West Coast Groundfish Observing Program (**WCGOP**) is an onboard observer program that has extensively surveyed fishing practices since 2002, with nearly 100% observer coverage

in the trawl sector in recent years. WCGOP provided discard ratios for Yellowtail Rockfish from 2002 to 2015.

Pikitch Study

The Pikitch study was conducted between 1985 and 1987 (Pikitch et al. 1988). The northern and southern boundaries of the study were 48°42′ N latitude and 42°60′ N. latitude respectively, which is primarily within the Columbia INPFC area (Pikitch et al. 1988 , Rogers and Pikitch 1992).

Participation in the study was voluntary and included vessels using bottom, midwater, and shrimp trawl gears. Observers of normal fishing operations on commercial vessels collected the data, estimated the total weight of the catch by tow and recorded the weight of species retained and discarded in the sample.

Pikitch study discards were aggregated due to small sample size and included in the data as representing a single year mid-way through the study.

2.3.4 Abundance Indices

Two fishery-dependent abundance indices were developed for this analysis that were discovered in course of review to be based on incomplete information about how the commercial trawl and Hake fisheries were operated in the late 1980s through the late 1990s. Representatives from WDFW and from the Council's Groundfish Advisory Panel raised numerous concerns about the Commercial Trawl Index and the Hake Bycatch Index, respectively, and they were ultimately removed from the model.

The commercial trawl index used the species composition of catch to infer the potential for Yellowtail Rockfish in each haul, however the way in which market categories were changing throughout the period of interest made the species composition of catch led to concerns about the consistency of the resolution of catch reporting over time (Theresa Tsou, pers. comm.). The Hake fishery was explained to have had greater heterogeneity among the boats used in the fishery than had been assumed in developing the index (Dan Waldeck, pers. comm.).

Give the unknown impact of incomplete information used in developing these indices which could not be adequately addressed during the review, and that there were fishery-independent indices covering the period in question, the decision was made to withdraw these two indices. They are described in Appendix B for completeness.

2.3.5 Fishery-Independent Data

Alaska Fisheries Science Center (AFSC) Triennial Shelf Survey

Research surveys have been used since the 1970s to provide fishery-independent information about the abundance, distribution, and biological characteristics of Yellowtail Rockfish. A coast-wide survey was conducted in 1977 (Gunderson and Sample 1980) by the Alaska Fisheries Science Center, and repeated every three years through 2001. The final year of this survey, 2004, was conducted by the NWFSC according to the AFSC protocol. We refer to this as the **Triennial Survey**.

The survey design used equally-spaced transects from which searches for tows in a specific depth range were initiated. The depth range and latitudinal range was not consistent across years, but all years in the period 1980-2004 included the area from 40° 10'N north to the Canadian border and a depth range that included 55-366 meters, which spans the range where the vast majority of Yellowtail encountered in all trawl surveys. Therefore the index was based on this depth range. The survey as conducted in 1977 had incomplete coverage and is not believe to be comparable to the later years, and is not used in the index.

An index of abundance was estimated based on the VAST delta-GLMM model as described for the NWFSCcombo Index above. In this case as well, Q-Q plots indicated slightly better performance of the lognormal over gamma models for positive tows (Figure 17). The index shows a gradual decline from 1980 to 1992 followed by high variability in the final 4 points spanning 1995-2004. The distribution of estimated densities was more variable that in the NWFSCcombo survey, but the relatively higher densities in the northern part of the coast were similar (Figure 16).

Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey

In 2003, the NWFSC took over an ongoing slope survey the AFSC had been conducting, and expanded it spatially to include the continental shelf. This survey, referred to in this document as the **NWFSCcombo Survey**, has been conducted annually since. It uses a random-grid design covering the coastal waters from a depth of 55 m to 1,280 m from late-May to early-October (Bradburn et al. 2011 , Keller et al. 2017). Four chartered industry vessels are used each year (with the exception of 2013 when the U.S. federal-government shutdown curtailed the survey).

The data from the NWFSCcombo survey was analyzed using a spatio-temporal delta-model (Thorson et al. 2015), implemented as an R package VAST (Thorson and Barnett 2017) and publicly available online (https://github.com/James-Thorson/VAST). Spatial and spatio-temporal variation is specifically included in both encounter probability and positive catch rates, a logit-link for encounter probability, and a log-link for positive catch rates. Vessel-year effects were included for each unique combination of vessel and year in the database.

The patterns of estimated density for each year showed consistently higher biomass in the Northern part of the Northern area (Figure 16). Both lognormal and gamma distributions were explored for the positive tows and produced similar results with the lognormal model showing slightly better patterns in Q-Q plot (Figure 17). The index shows variability with an overall gradual increase from 2003 to 2013 with high estimates near the end of the time series in 2014 and 2016 (Figure 18). A design-based index extrapolated from swept area densities without any geostatistical standardization shows a more dramatic increase from 2015 to 2016 (Figure 18)

Length and age compositions were also developed from this survey.

2.3.6 Biological Samples

Length And Age Compositions
Length composition data were compiled from PacFIN for Oregon and Washington for the Northern model and combined with raw (unexpanded) length data from CalCOM for the two California counties north of 40° 10'N (Eureka and Del Norte counties).

Length compositions were provided from the following sources:

Summary of the time series of lengths used in the stock assessment.

Source	Type	Lengths	Tows	Years
PacFIN	commercial	186161	3830	1968-2016
CalCOM	commercial	2340		1978-2015
MRFSS	recreational	4125		1980-2003
RecFIN	recreational	432		2004-2016
WASport	recreactional	11099		1975-2015
Triennial	survey	16262	465	1977-2004
NWFSCcombo	survey	940	564	2004-2016

The expanded table detailing the length data is Table 4. The names in this table are truncated so that the data can be compared side-by-side, but should be obvious: "C.Trawl" is the Commercial Trawl fishery.

Age structure data were available from the following sources:

Summary of the time series of age data used in the stock assessment.

Source	Type	Ages	Tows	Years
PacFIN	commercial	138854		1972-2016
CalCOM	commercial	3546		1980-2002
WASport	recreational	4027		1997-2016
Triennial	survey	6553	278	1997-2004
NWFSCcombo	survey	2990	544	2003-2016

The expanded table detailing the ages can be found in Table 5

2.4 Southern Model Data

Summary of the data source in the Southern model.

Source	Landings	Lengths	Ages	Indices	Discard	Type
CalCOM	Y	Y	Y			Commercial
MRFSS	Y	Y				Recreational
RecFIN	Y	Y				Recreational
HookandLine		Y	Y	Y		Survey
Onboard		Y	Y	Y		Survey
JuvenilePelagic				Y		Study
SmallResearch		Y	Y			Study

2.4.1 Commercial Fishery Landings

California Commercial Landings
The California Commercial Fishery Database (**CalCOM**) provided landings in California south of 40° 10'N for 1969-2016. Because this fishery is known to have begun in the 1880s, we added catch as a linear ramp from 1889 (the earliest catch in the Northern model) to the 2016 value.

Historical Data A reconstruction of the historical commercial fishery south of Cape Mendocino was provided by the Southwest Fisheries Science Center (**SWFSC**) for 1916-1968 (Ralston et al. 2010).

2.4.2 Sport Fishery Removals

MRFSS Estimates and RecFIN
The California Department of Fish and Wildlife (**CDFW**) provided estimated Yellowtail removals for the Marine Recreational Fisheries Statistical Survey (**MRFSS**) from 1980-1989, 1993-2003. The Recreational FIsheries Information Network, (**RecFIN**) provided landings for 2004-2016.

Historical Data A reconstruction of the historical recreational fishery south of Cape Mendocino was provided by the Southwest Fisheries Science Center (**SWFSC**) for 1928-1980 (Ralston et al. 2010). Yellowtail Rockfish have been identified as a sigificant component of the catch since the earliest days of the fishery. The catch at Monterey in 1935 was 7.9% Yellowtail Rockfish (with Bocaccio and Chillipepper Rocfish comprising 70.2%) (FishBull 1936), at a time of rapid expansion in the fishery (Phillips 1939).

Small Research Study California Cooperative Groundfish Survey CPFV Sampling, 1978-1984. Commercial port samplers with the California Cooperative Groundfish Survey sampled landings from CPFVs operating north of Point Conception in the late 1970s and early 1980s. This data set represents the only source of sex-specific length information available for Yellowtail Rockfish in California.

2.4.3 Estimated Discards

No discard data were available for the Southern model.

2.4.4 Abundance Indices

MRFSS Index

From 1980-2003, the Marine Recreational Fisheries Statistics Survey (MRFSS) executed a dockside (angler intercept) sampling program in Washington, Oregon, and California. Data from this survey are available from the Recreational Fisheries Information Network (RecFIN). The Recreational Fishieries Information Network (RecFIN) serves as a repository for recreational fishery data for California, Oregon, and Washington (http://www.recfin.org). RecFIN is currently undergoing a transition to a relational database design. Catch estimates for years 1980-2003 were downloaded prior to the transition.

MRFSS-era recreational removals for California were estimated for two regions: north and south of Point Conception. No finer-scale estimates of landings are available for this period. Catches were downloaded in weight. MRFSS sampling was temporarily suspended from 1990-1992, and we left the catch in these years as missing values rather than performing any interpolation.

MRFSS was replaced with the California Recreational Fisheries Survey (CRFS) beginning January 1, 2004. Among other improvements to MRFSS, CRFS provides higher sampling intensity, finer spatial resolution (6 districts vs. 2 regions), and onboard CPFV sampling. Estimates of catch from 2004-2016 were provided by RecFIN staff. We and aggregated CRFS data to match the structure of the MRFSS data.

California Onboard Surveys

1987-1998 This assessment uses two indices derived from onboard CPFV observer data and collected during different time periods of the fishery. The primary advantage of onboard observer data is that catch and effort data are based on individual fishing stops (or drifts), rather than aggregated at the trip level, and information about actual fishing locations is available, rather than port of landing or interview site. This location information, when combined with recent maps of rocky reef habitat, allows us to associate catch rates with reefs of known area and produce habitat area-weighted CPUE indices.

The CDFW (formerly CDFG) Central California Marine Sport Fish Project sampled the Northern and Central California CPFV fleet using onboard observers from 1987-1998. Observers recorded the total catch (kept and released fish) of a subset of anglers during each fishing drift. Catches from drifts occurring at a single CDFW fishing site were aggregated into a fishing stop. Each stop in the database is associated with the closest reef structure. Retained fish were measured at the end of the fishing day. Additional details about the survey design, data collected, spatial associations between fishing stops and reef habitat, and the structure of the relational database are described in (Monk et al. 2016).

1999-2016 California onboard CPFV observer data, spanning the years 1999-2016 was provided by the SWFSC (Monk et al. 2014). Each observation included a unique trip and drift identifier, and a subset of anglers was observed at each drift. Drift-level information included catch of blue rockfish in numbers (kept and discarded) including zeros, number of observed anglers, time fished (in minutes), location where drift began (latitude and longitude), year, month, county, CRFS district, depth (in feet), distance from nearest reef habitat (in meters), and unique reef identified.

Indices from these datasets were provided by the SWFSC according to the methods described in (Monk et al. 2016).

Juvenile Pelagic Index The Fishery Ecology Division of the Southwest Fishery Science Center has conducted a standardized pelagic juvenile trawl survey during May-June every year since 1983 (Williams and Ralston 2002). The primary purpose of the survey is to estimate the abundance of pelagic juvenile rockfishes (Sebastes spp.) and to develop indices of year-class strength for use in groundfish stock assessments on the U. S. West Coast. The survey samples young-of-the-year rockfish when they are ~100 days old, an ontogenetic stage that occurs after year-class strength is established, but well before cohorts recruit to commercial and recreational fisheries (Ralston and Stewart 2013),(Sakuma et al. 2016).

The survey has encountered tremendous interannual variability in the abundance of the ten species that are routinely indexed, as well as high apparent synchrony in abundance among the ten most frequently encountered species (Ralston and Stewart 2013).

The abundance index was developed using a delta-GLM within a hierarchical Bayesian framework using the R package *rstanarm*, and used as an indicator of age-0 fish. Further details of the analysis are available in Appendix C.

2.4.5 Fishery-Independent Data

Hook and Line Survey

The NWFSC Hook and Line survey provided data for an index in the Southern California Bight from 2004-2016. The Yellowtail index of abundance is based on numbers of fish provided by the Northwest Fisheries Science Centers Hook and Line survey in the Southern California

Bight. This index used survey data from 2004-2016 and was created following the methods put forth in (Harms et al. 2010), after those methods were updated to create models with greater parsimony. In addition, the final index is averaged over all crew staff and sites. (Note that vessels are confounded with crew staff.) Two vessels were employed for the survey in 2004-12 and three vessels in 2013-16. Data from inside the Cowcod Conservation Area (CCA) was not used in this index.

The 2016 index value differs from previous years in that certain variables such as sea surface temperature and tide flow were not available for this analysis, due to an ongoing upgrade in data collection software.

Variables in the binomial model with logit link:

NumYTRK ~ Year + SiteName + CrewStaff + DropNum + HookNum + poly(WaveHt.m,3) + poly(SwellHt.m, 3) + poly(PctLiteR, 2) + poly(MoonPct, 3)

Where poly(, X) identifies the Xth degree polynomials for continuous variables, and a colon (:) represents an interaction term. PctLite is the percent of daylight that has passed at the time the drop occurs on a given day.

The posterior median index values and their associated posterior log-SD are from a converged, 2.5 million draw MCMC.

2.4.6 Biological Samples

Length composition samples were available for the Southern model from 5 sources, and ages from 3.

Length compositions were provided from the following sources:

Summary of the time series of lengths used in the stock assessment.

Source	Type	Lengths	Tows	Years
CalCOM	commercial	16160	1543	1978-2015
MRFSS	recreational	39425		1980-2003
RecFIN	recreational	49136		2004-2016
Onboard	recreational	76740		1987-2016
Small Study	recreational	909		1978-1984
Hook and Line	survey	1339	174	2004-2016

The expanded table with detailed lengths is Table 16

Age structure data were available from the following sources:

Summary of the time series of age data used in the stock assessment.

Source	Type	Ages	Years
CalCOM	commercial	7875	1980-2004
Small Study	recreational	400	1978-1984
Hook and Line	survey	248	2004

The expanded table with detailed age information is Table 17

2.4.7 Environmental Or Ecosystem Data Included In The Assessment

No environmental or ecosystem data were included in either model.

3 Assessment

3.1 History Of Modeling Approaches Used For This Stock

Yellowtail Rockfish was previously modeled as an age-structured, 3-area stock north of 40°10′ in 1999 (Tagart et al. 2000) using a model written in ADMB (Fournier et al. 2012); an update of this assessment was last conducted in 2004 (Wallace and Lai 2005). That assessment divided the stock into 3 INPFC areas based on the suggestion that there might be biological differences in the stock, however recent genetic studies don't support that (Hess et al. 2011). The INPFC area boundaries are not coincident with state boundaries; this is a concern in that recent reconstructions of historical catch are state-by-state along the West Coast. Because we cannot produce data that conform to the areas previously assessed, we have made no effort to reproduce the previous model.

A data-moderate approach was used to evaluate stock status in 2013 (Cope et al. 2013). The data-moderate model used only indices of abundance and made simplifying assumptions about selectivity and growth since no length or age data were included in the model. This approach is also incompatible with the current model, and we have made no attempt to reproduce it, either. The same data-moderate was initially applied to the Southern model as well but due to a shortage of time during the review process, that model was never reviewed or put forward for management.

A data-poor assessment method, Depletion-Based Stock Reduction Analysis (Dick and MacCall 2011) was applied to the Southern stock in 2011 (Dick and MacCall 2010). This method doesn't estimate biomass but provided the estimate of the OFL contribution for the southern stock to the complex in which it is managed.

3.1.1 Previous Assessment Recommendations

The STAR Panel report for the 2005 Yellowtail Rockfish update assessment (for the area North of 40°10′ included three recommendations for future assessments:

1. *Figure out the root cause of the low average weight at age in South Vancouver in 2002 and 2003. The actual cause of this problem is unclear, but may involve instability in fitting von Bertalanffy parameters, sampling, ageing, or penalties in the model.* The Northern model is no longer divided into sub-stocks and no longer uses empirical weights because weight at age is modeled using an internally estimated growth curve. The length compositions for 2002 and 2003 do not show anomolously small fish.

2. *The major hindrance to Yellowtail stock assessments is lack of a credible abundance index. A major effort should be made to develop a credible abundance index for Yellowtail*

Rockfish. This may need to involve new survey technology. The abundance indices used in both the Northern and Southern models in this assessment are all newly analyzed using updated statistical approaches, but there is no fishery independent survey that samples fish in the mid-water. In 2005, the NWFSC shelf-slope bottom trawl survey had only been in place for 2 years whereas it now represents a 14-year timeseries for the Northern stock. However, there remains the challenge of using bottom trawl gear to sample a rockfish often associated with mid-water or untrawable bottom habitat.

3. *Considering that the last full assessment of Yellowtail was conducted in 2000, and the stock assessment model software currently in use is no longer being updated or maintained, a full assessment of Yellowtail should be considered in the next assessment cycle.* This is a full assessment conducting using the actively maintained Stock Synthesis software.

3.2 Model Description

3.2.1 Transition To The Current Stock Assessment

These are the main changes from the previous model, and our rationale for them:

1. Transition to Stock Synthesis. *Rationale*: The Pacific Fishery Management Council's preferred modeling platform for stock assessments is Stock Synthesis (Methot 2015), developed since the last full assessment of Yellowtail Rockfish.

2. Addition of Southern model. *Rationale*: Hess, et al. determined that the West Coast Yellowtail stocks show a genetic cline occurring near Cape Mendocino, which is roughly $40°10'$ north latitude (Hess et al. 2011). This divides the stock into two genetically distinct substocks which we model independently.

3. Availability of recent data. *Rationale*: Ten years of data collection have occurred since the last update assessment, and the data necessary for an assessment of the southern stock is now available.

4. Historical catch reconstructions. *Rationale*: Reconstruction of catch timeseries in California, Washington and Oregon clarify stock history as far back as 1889.

5. Collapsing the stock north of $40°10'$ into one, heterogeneous stock. *Rationale*: the previous full assessment of the Northern stock used three INPFC areas as proxies for sub-stocks thought to exhibit differential growth. No attempt was made in this assessment to evaluate growth in those areas because the areas themselves have become obsolete with respect to data availability. In addition, the Hess, et al. study (Hess et al. 2011) found that although there was notable heterogeneity in the Southern stock, there was very little in the North. This suggests that differences in growth might be due to environmental factors that could change over time. Evaluating growth patterns along the Northern Coast is among the recommendations for future research.

3.2.2 Definition of Fleets and Areas

The Northern model comprises the area between Cape Mendocino, California, and the Canadian border. The Southern model runs from Cape Mendocino to the Mexican border (Figure 2).

Northern Model

Commercial: The commercial fleet consists primarily of bottom and midwater trawl. No attempt was made to analyze the fishery separately by gear, particularly since it seems that in the fishery in the 1980s and 1990s, "bottom trawl" gear was used in the midwater as well as on the bottom, and "midwater gear" was sometimes dragged across soft bottom (Craig Goode, ODFW Port Sampler, pers. comm).

The data associated with the commercial fleet includes age- and length-composition data from PacFIN and CalCOM, historical catch timeseries from CDFW, ODFW and WDFW. Observations of discards from the Pikitch research study provide lengths and discard rates; discard lengths and rates calculated from WCGOP data. Sex was available for the comps in the retained catch, which is by-sex in the model, but was not available for the discards, so they are undifferentiated by sex.

The PacFIN logbook (fish ticket) index developed for the commercial fishery is in fish/tow. Further information about how the data for the index was worked up is in the Abundance Indices section (2.3.4) above.

At-Sea Hake Fishery: Yellowtail Rockfish are frequently caught in mid-water trawls associated with the At-Sea Hake Fishery (consisting of the Catcher-Processor and Mothership sectors). This fishery requires separate analysis than the shore-based commercial fishery because the at-sea catches are processed at sea (typically into fish meal). The catches are recorded and biological sampling takes place but the data are housed in a different database. The At-Sea Hake fishery provides catches, length compositions by sex, and an index of abundance.

Recreational: The recreational fleet includes data from sport fisheries off Oregon, and northern California (Eureka and Del Norte counties), from MRFSS and RecFIN. The index of abundance for the recreational fleet is in fish per angler-hour. Length data for this fleet are undifferentiated by sex.

Washington-Sport: The Washington data (WA_Sport) provides catches, lengths and ages, and was treated as a separate fleet because the WA_Sport landings are not available by weight, so they are entered in the model as numbers, and Stock Synthesis internally converts them to weight using the combination of estimated selectivity for this fleet (informed by the length compositions), estimated growth, and the weight-length relationship. Sex was available for the biological data, however many lengthed fish were not sexed, so the lengths for this fleet are undifferentiated by sex, although the ages are.

Research: The Alaska Fisheries Science Center's Triennial Trawl survey, provides age- and length-compositions, and an index of abundance. This survey was conducted every third year from 1977-2004.

The Northwest Fisheries Science Center's NWFSCcombo survey provides age- and length-compositions, as well as an index of abundance.

Conditional Age-at-Length: Only the NWFSCcombo ages were used as conditional age-at-length in the model. All other aged fleets (Commercial, Washington_Sport, and Triennial) are present in the model as marginal ages due to the amount of noise in the age data for those fleets.

Indices: The NWFSCcombo and Triennial surveys provide indices based on biomass per area-towed. The logbook survey for the commercial fleet is in units of biomass per tow and the At-Sea Hake Bycatch index is in units of relative biomass per hour.

Southern Model

Commercial: The commercial fleet consists primarily of hook and line and trawl gear. Hook and line gear account for 78% of the landings by weight in the recent period (1978-2016). Commercial data were sexed, although there are many unsexed lengths. To preserve the large numbers of lengths, the length data are entered in the model as undifferentiated, however the ages are sexed and provide the sole conditional age-at-length timeseries in the Southern Model.

Recreational: The recreational fleet includes data from sport fishery off the California coast south of Cape Mendocino. The recreational lengths are unsexed. The index is in fish per angler-hour. Further information about how the index was worked up is included below. Changes in catchability and selectivity were estimated to have occurred in 1993 associated with a gap in the sampling.

California Onboard Recreational Survey: Research derived-data include observations from the California Onboard recreational survey. The length-compositions from this survey are undifferentiated by sex. The index is in fish per angler-hour. This index included a sudden drop from 1998 to 1999 associated with a large change in the average length. This change appears to be more consistent with changes in sampling or fishing behavior than abundance so changes in catchability and selectivity were estimated associated with this time period.

NWFSC Hook-and-Line Survey: The data from this survey are used in the model as an index of fish per angler-hour, a single year of marginal age data by sex, and sexed length compositions.

Small Fish Study: Length comps and a single year of ages reflect a small study of juvenile fish conducted by the SWFSC.

Juvenile Pelagic Survey: The SWFSC conducts an annual larval fish survey, and this provides an index of abundance of age-0 fish for the Southern Model.

3.2.3 Modeling Software

The STAT team used Stock Synthesis (Methot 2015), which is the Pacific Fishery Management Council's preferred modeling platform for assessments. Version 3.30.03.05 (dated May 11, 2017) was primarily used, but tests with newer versions 3.30.03.07 and 3.30.04.02 produced identical results.

3.2.4 Data Weighting

Commercial and survey length composition and marginal age composition data are weighted according to the method of Ian Stewart (pers.comm):

Sample Size = 0.138 * Nfish + Ntows if Nfish/Ntows < 44, and Ntows * 7.06 otherwise.

Age-at-Length samples are unwieghted; that is, each fish is assumed to represent an independent sample.

Recreational trips (the analogue of tows in the commercial fishery) are difficult to define in most cases. Since much of the recreational data are from the dockside interview MRFSS program, which didn't anticipate the need to delineate samples as belonging to particular trips, we chose to use all recreational data "as-is", with the initial weights entered as number of fish.

Weighting among fleets used the Francis method (Francis 2011) which is based on the model fit to the mean length or age relative to the expected variability for a given (adjusted) input sample size. The one exception was the age data from the Southern model's Hook and Line survey, where only a single year of ages were available and the Francis method cannot be used. For this single age-composition, the sample size was tuned using the McAllister-Ianelli harmonic mean method (McAllister and Ianelli 1997). As a sensitivity analysis, the McAllister-Ianelli method was applied to all fleets in each model (described below).

3.2.5 Priors

Log-normal priors for natural mortality were developed based on the method of Hamel (2015) as discussed under "Natural Mortality" in Section 2.1.3 with point estimates for M of 0.15 and 0.12 for females and males for the Northern model and 0.18 and 0.135 for females and males in the Southern model. In the Northern model, both female mortality (with the prior) and male mortality as an offset (without a prior) were estimated. For the southern model, M was fixed at the median prior values for the two sexes.

The prior for steepness (h) assumes a beta distribution with parameters based on an update of the Thorson-Dorn rockfish prior (Thorson et al. (2017), commonly used in past West

Coast rockfish assessments) which was reviewed and endorsed by the Scientific and Statistical Committee in 2017. The prior is a beta distribution with μ=0.718 and σ=0.158.

3.2.6 General Model Specifications

Fecundity is represented in the models as: $1.1185^{-11}W^{4.59}$. This is a rescaling of the values provided in (Dick et al. 2017).

Model data, control, starter, and forecast files can be found at ftp://ftp.pcouncil.org/pub/GF_STAR2_2017_Ytail_Yeye/.

3.2.7 Estimated And Fixed Parameters

The Northern model has a total of 127 estimated parameters in the following categories:

- equilibrium recruitment ($log(R_0)$) and 85 recruitment deviations,
- 2 natural mortality parameters,
- 8 growth parameters,
- 1 index extra standard deviation parameter,
- 16 selectivity parameters and 13 retention parameters.

The Southern model has a total of 104 estimated parameters in the following categories:

- equilibrium recruitment($log(R_0)$) and 72 recruitment deviations,
- 8 growth parameters,
- 1 index extra standard deviation parameter, and
- 16 selectivity parameters.

The estimated parameters are described in greater detail below, and a full list of all estimated and fixed parameters is provided in Table 10 (Northern model) and Table 20 (Southern model).

Growth Five parameters for female growth are estimated in each model: three von Bertalanffy parameters and two parameters for CV as a function of length at age related to variability in length at age for small and large fish.

Three parameters are estimated for male growth in each model as offset from female growth. The size for small fish and CV for small fish were assumed equal to females.

Natural Mortality Natural mortality is estimated in the Northern model with an offset for males from females. After much exploration of alternatives, natural mortality was fixed in the Southern model at the values estimated by the Northern model.

Selectivity Selectivity for all fleets was initially estimated as a 4-parameter double normal, which allows selectivity to be dome shaped, with parameters controlling the position of the peak selectivity, the width of the peak, and the ascending and descending slopes.

For all fleets where the estimated patterns were asymptotic, we fixed the parameters related to the dome, leaving only the position of the peak and the ascending slope as estimated parameters. For a few fleets, the position of the peak hit the upper bound, and was fixed at 55cm.

The two recreational fleets in the Northern model had a block on selectivity beginning in 2003 to allow a change in selectivity associated with management measures which constrained the depth range of recreational fishing.

The early and late Onboard Indices in the Southern model were treated as a single fleet with blocks on selectivity in earlier versions of the model. However, in the Final Southern Model, the Onboard survey from these two periods was split into separate fleets with independent selectivity.

Retention Retention for commercial fishery in Northern model is a logistic function of size, with three parameters estimated: length at 50% retention, the slope of the curve, and the asymptotic retention fraction. The asymptote was allowed to be time-varying, with one value applied for the early years through 2001. From 2002 through 2011 we applied annual time-blocks for theses years when the WCGOP program observed high discards. The final block runs from 2012 forward, reflecting the current period in which the implementation of the IFQ program has led to low discard rates.

Other Estimated Parameters Log(R0) is the equilibrium recruitment, which is estimated in each model.

Recruitment deviations for the Northern model are estimated from 1932 to 2016. For the Southern model recruitment deviations are estimated from 1945 to 2016. Both models also included estimated recruitment devations for the forecast years, although these have no impact on the model estimates for the current year.

A parameter representing extra standard deviation added to all years was estimated for each index that was included in the likelihood to allow the model to appropriately weight these data sources compared to other data types.

3.3 Model Selection and Evaluation

3.3.1 Key Assumptions and Structural Choices

Selectivity in both models is asymptotic, with the exception of the OR-CA MRFSS recreational fleet in the Northern model, and the Onboard recreational fleet in the Southern model.

For the Northern model, several options for developing a CPUE series for the recreational fishery were considered but rejected as sparse and noisy. Similarly, the Washington_Sport fishery data was evaluated a a possible source for an index, but the data was not available in a form useful for a recreational index, i.e., there was no data that provided for a trip-level analysis of catch and effort, as was used for the MRFSS index in the Southern model (Stephens and MacCall 2004).

3.3.2 Alternate Models Considered

The indices based on the Commercial Logbook CPUE and At-Sea Hake Bycatch were included during initial development of the Northern model but removed after further considerations and investigation at the STAR panel as described elsewhere.

Alternative structures for the time-blocked selectivity and retention were investigated in the Northern model, as were domed selectivities.

We also explored time-blocks on selectivity in the Southern model, and domed selectivity for the MRFSS/RecFIN data. For early versions of the model, we allowed the model to estimate natural mortality. There is very little discard of Yellowtail in the Onboard Survey, however it is the only information on discards in the south, so we attempted to include it in the model.

These approaches resulted in models that didn't converge, and so they were rejected.

Finally, we evaluated different assumptions pertaining to maturity ogives, modeling these parameters from the literature:

- Parameters in (Gunderson and Sample 1980): L50% = 45.0, slope = -0.5315
- Parameters in (Echeverria 1987): L50% = 36.36, slope = - 0.4331

which we discovered made no significant changes in model outcomes.

3.3.3 Convergence

Convergence testing through use of dispersed starting values often requires extreme values to explore new areas of the multivariate likelihood surface. Stock Synthesis provides a jitter option that generates random starting values from a normal distribution logistically transformed into each parameter's range (Methot 2015). We used this function to find parameter values for convergence in the Southern model.

The jitter analysis of the final Southern model post-tuning was run 100 times, and resulted in 75 models that returned to the base case. No model resulted in a lower likelihood than the base model.

The Northern jitter analysis was run 100 times, and resulted in 88 models that returned to the base case. No model resulted in a lower likelihood than the base model.

3.4 Response To The Current STAR Panel Requests

The comprehensive explorations of the models conducted by the STAR panel are detailed in Appendix D.

3.5 Life History Results for both models

Maturity at length and mean weight at length are both estimated externally as described in Section 2.1 above (and shown in Figures 3 and 4).

The growth at the beginning of the year estimated by the models for the Northern and Southern stocks is shown in Figure 5. Females grow faster in each case, but the Northern stock grows faster and attains larger maximum size.

3.6 Northern Model Base Case Results

The data used in the Northern model by fishery is shown in Figure 6. Estimated catches are shown in Figure 7; estimated discards are in Figure 8. These show the large catches in the 1980s and 90s are being predicted by the model. The large discards in latter years match the data well for those years.

The timeseries of estimated spawning output in trillions of eggs is shown in Figure 55. The model is estimating two periods of decline, one beginning in the forties and a steeper decline in the 1970s and 1980s, followed by an increase since 2000 to pre-1980 levels. There is a decrease in the final years of the timeseries coincident with increased uncertainty.

Figure 56 shows the total biomass following a similar pattern; the ending value is 130219 metric tonnes.

The relative spawning output (Figure 57) went below the 40% target in the early 1980s, and may have been below the minimum stock size limit of 25% in the late 1990s, but has rebounded since to 75% (see Table 12).

Figures 58 and 59 address recruitments estimated the the model. The first of these shows the age-0 recruits, and the second the recruitment deviations. There are no strong patterns in recruitment and the variability of the recruitment deviations was tuned to be 0.546 (based on the method of Methot & Taylor (2011)) which is similar to what has been assumed or estimated for other rockfish in the California Current. The stock-recruit curve, Figure 60 shows a shallow relationship between stock size and recruitment.}

3.6.1 Selectivities, Indices and Discards

Selectivities in the Northern model (Figure 9) show the difference between the recreational fisheries and the commercial fishery and survey sampling. All of the fish are fully selected by 50 cm, but the recreational fish are fully selected at 30 cm.

Retention by length (Figure 10) varies over time between 40% and 100%, with no clear pattern of interannual variation, except for the trawl-rationalization era 2011-present.

Discarding in the commercial fleet (Figure 11) is fit only by putting blocks on retention in the Northern model. Discards were very low except during the 1990s and 2000s, until the trawl-rationalization program implementation.

Fits to the indices for the northern model (Figure 23) demonstrate the utility of the NWFSC-combo survey. Although the model misses the uptick at the end of the timeseries, it is the only recent index and is well-fit by the model. The other indices are noisier. Most of the indices are fairly flat, indicating little change in abundance during each time-period. Although the fit to the Triennial index is poor, the data nicely reflects the changes in management during it's tenure: the CPUE was falling during the 1980s and 1990s, then rising after stringent restrictions began in 2000.

3.6.2 Lengths

Bubble plots for the lengths in the fishery (Figure 24) show the constancy of the commercial fleet, and the differences in growth between males and females; the females are larger, the males smaller. The recreational fleet is represented by two different sampling regimes, and the changeover in the mid-2000s is clear in that panel.

Commercial length comps are very well fit (Figures 26 and 27). Commercial discards are noiser and not well fit (Figure 28) although the fit to the mean length (which is lower than for the retained fish), is reasonable (Figure 27).

Lengths in the early period of the Hake Bycatch fishery are noisy (doubtless due to small sample sizes). By 1992, the model is able to fit the data well (Figures 30 and 31).

The recreation OR+N.CA timeseries of lengths demonstrates the difference between the MRFSS sampling and RecFIN sampling. The fits in the early period are good, those in the later period are noisy and model uncertainty is high (Figures 32 and 33).

The WA_Sport length fits might have been improved with a better choice of maximum size bin for the model (Figures 34 and 35), however the data are noisy throughout the size range represented.

The Triennial lengths Figures 36 and 37 are fit well in some years and not in others. The data is not noisy, however the intermittency of data collection may mean that the model is unable to capture interannual variation as well as for an annual timeseries.

NWFSCcombo lengths are not well fit, particularly in 2013, where the data show a large number of small fish that may represent a good recruitment several years earlier Figures 38 and 39.

Figure 40 shows the relative fits among the data sources, aggregated across time. The timeseries of presence-absence residuals indicated by filled- and open-bubbles Figure 41 and Figure 42 demonstrates the relative disappointment in model fits; the smaller the bubble, the better the match between the data and the model expectation.

3.6.3 Ages

The NWFSCcombo survey was the only datasource used to inform growth as conditional age-at-length data for the Northern model; ages for other fleets were treated as marginal ages.

The fits to the marginal commercial Figure 43 are quite good from about 1979 on, even fitting the tail where the ages beyond 55 are lumped. The weightings panel Figure 44 shows the same thing: fits are good after about 1979, and the decrease in mean age in the population corresponds with high catches in the 1980s and 1990s, with mean age increasing after 2000 as catches were curtailed.

The Washington Sport ages are noisy, and the fit is poor throughout the timeseries, see Figure 45 and Figure 46.

The Triennial ages are noisy but are fit surprisingly well 47; 48. That the model misses the influx of young fish in 1986 may be due to the timing of the survey; three-year surveys may not provide enough data for the model to fit recruitment events.

Aggregated age comps for the Commercial, Washington Sport and Triennial fleets are shown in Figure 49, for comparison. Agreggated fits for the Commercial and Triennial fleets are very satisfying.

The implied marginal age comps for the NWFSCcombo survey (Figure 50) are the conditional-age-at-length compositions for the survey aggregated over length. This figure is included for informational purposes only; the marginal "ghost" comps are not included in the likelihood calculations.

Pearson residuals for the marginal age comps, are shown in the bubble plots in Figure 51. The filled bubbles represent estimates greater than observations, and the open bubbles observations greater than estimates. The large filled bubbles at age 25 in a few years suggest that we might have chosen a slightly older age as the compilation age.

The residuals for the conditional age-at-length from the NWFSCcombo survey show that growth appears to be reasonably estimated with no strong patterns suggesting consistently older or younger fish than expected in any year (Figure 52). However, the mean age aggregated across length bins shows more variability in the observations than expected by the model (Figure 53). This may represent young fish recruiting to the fishery, which would happen approximately 5 years after a biological recruitment event. The conditional age-at-length fits are also shown in Figure 53. These plots explain the reason this survey was chosen to represent conditional age-at-length; the model was able to fit these data much better than other datasets, and improved fit, lower likelihood values and increased parsimony all contributed to a better model.

3.6.4 Northern Model Parameters

For the Base model, the parameter estimates are given in Table 10. Status for all of the estimated parameters is good although the parameter for peak selectivity of the Triennial survey is estimated close to the 55 cm upper bound with a value of NA.

3.6.5 Northern Model Uncertainty and Sensitivity Analyses

The following sensitivity analyses were conducted for the Northern model:

McAllister-Ianelli weights We investigated tuning the model according to the method of McAllister and Ianelli [-@McAllister1997].

M prior Age64 The literature value for maximum age is 64. We centered the prior for female mortality at 0.0844, the value associated with that age, and estimated M for both females and males (with no prior on the offset for males).

M prior Age64 The literature value for maximum age is 64. We centered the prior for female mortality at 0.0844, the value associated with that age, and estimated M for both females and males (with no prior on the offset for males).

M fixed Age64 We fixed mortality at 0.0844, the value associated with maximum age of 64, for both females and males.

Add commercial index We included the index based on commercial fishery logbook CPUE.

Add hake bycatch index We included the index based on bycatch in the at-sea hake fishery.

Add commercial and hake indices We included both the commercial CPUE and hake bycatch indices.

In general, the Northern model showed little change under these sensitivity analyses (Figures 62 and 63 and Table 11). The McCallister-Ianelli weighting method to the length and age composition data resulting in a higher overall scale of the population, with spawning output in 2017 at 82% compared to 75% for the base model. Applying the natural mortality prior centered at 0.0844 based on the maximum age of 64 reported in the literature instead of the base model prior centered at 0.15 had little impact on the estimated female natural mortality, reducing it from $M = 0.174$ to $M = 0.173$. However, fixing female and male natural mortality at 0.0844 had the largest impact of any of the sensitivity analyses explored for the Northern model. The likelihood profile over female natural (described below) indicated that there was information in the length and age data that strongly supported higher natural mortality than the value based on maximum age of 64. Furthermore, among the collection of over 138,000 ages available from the Commercial fishery, only 7 (0.005% of the total) were older than 55 (including one listed as 110), suggesting that some of these outliers could have been data entry errors and applying a quantile to the distribution of ages to get an approximate maximum age for development of the prior is a more reliable method than taking the maximum of all observations. Adding either the index based on commercial logbook CPUE or bycatch in the at-Sea hake fishery, decreased the scale of the population a similar small amount and the combination of adding both of these indices resulted in a larger decrease (from 75% of unfished spawning output in 2017 down to 63%, Figure 63 and Table 11).

3.6.6 Northern Model Likelihood Profiles

We profiled the change in negative log likelihood for the data sources and model total likelihood for critical parameters in the model: $log(R_0)$, the log of equilibrium recruitment; female natural mortality, **MF**; male natural mortality, **MM**; and steepness, **h**, the parameter that reflects how quickly the stock-recruit relationship allows the stock to rebound from depleted stock size.

The likelihood profile over a range of values (from 9 to 11) $log(R_0)$ are shown in Figure 64. This plot shows the tension between the index data and the other data sources. The indices are better fit with a smaller value of $log(R_0)$, near 9.6, while all other data sources are better fit at larger values. The overall likelihood in the model is lowest at the estimated MLE value of 10.8. The likelihood contribution of the discard fractions is small over this range of $log(R_0)$, while the recruitments, ages and lengths are all best fit at values larger than 10.5.

The likelihood profile over female natural mortality, MF, is over a range from 0.10 to 0.24 (Figure 65). In this figure, the indices are fit best when MF is 0.1, the ages and lengths are fit nearer 0.18, and the recruitments and total log likelihoods are minimized at 0.15.

Figure 66 shows the likelihood profile for male natural mortality, MM, over a range of negative values that are the offset from female mortality (FM). Male natural mortality is represented as an offset from that for females based on the equation $MM = MF * e^{offset}$, such that an offset of 0 results in equal mortality for males and females, and an offset of -0.3 results in a male natural mortality which is about 74% of the female mortality ($exp(-0.3) = 0.7408$). The index data are at odds with the other data sources but would not be expected to be informative about natural mortality and show relatively little changes over the range of values considered. Both the age and length data support male mortality lower than female mortality (an offset less than 0).

The profile over values of steepness, h, from 0.5 to 0.9, Figure 67, shows the index data for once in the majority as all data sources except the lengths support 0.9 as minimizing the likelihood, while the lengths support a value closer to 0.5. The scale of this plot differs from the others showing that the that the choice of h within this range has far less impact on likelihood in the model than choices for the other profiled parameters. This suggests the stock is not depleted; the choice of steepness would have a much greater impact on a depleted stock. The MLE occurring at the maximum h value also supports the choice to fix the steepness at the mean of the prior $h = 0.718$.

3.6.7 Northern Model Retrospective Analysis

The Northern model shows little influence of removing up to 5 years of data (Figure 68). Examination of the contributions of each index to the likelihood profile over $log(R_0)$ indicated that the NWFSCcombo survey, which is the only index available within the most recent data, had the least influence on the scale of the model, so shortening this time series wouldn't be expected to have a large contribution on the population estimates.

3.6.8 Northern Model Reference Points

The estimated relative depletion level for the Northern model in 2017 is 75.2% (~95% asymptotic interval: ± 61.2%-89.2%, corresponding to an unfished spawning output of 11.3 trillion eggs (~95% asymptotic interval: 7.69-14.86 trillion eggs) of spawning output in the base model (Table i). Unfished age 4+ biomass was estimated to be 161.6 mt in the base case model. The target spawning output based on the biomass target ($SB_{40\%}$) is 6 trillion eggs, which gives a catch of 5434.5 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 5115 mt.

3.7 Final Southern Model Results

The results offered here are for a version of the Southern model that was thought to be the most robust among sensitivites, and is not a "Base Case", as the model was deemed too uncertain for management. The model was unable to estimate natural mortality (M), and was very sensitive to a range of alternates evaluated, responding to plausible values with large shifts in the scale of the population. We investigated using the NWFSCcombo Survey as an index, however Yellowtail Rockfish do not occur in the survey trawls in large numbers in the south as they do in the north, therefore the Hook and Line Survey was the sole fishery-independent index available to inform the model.

Data used in the Southern model is shown in Figure 70.

Estimated catches are shown in Figure 71.

The estimated spawning biomass in Figure 100 shows the size of the uncertainty in this model. Total biomass (Figure 101) shows a sharp upward trend in recent years, the decade in which there is only one year of age data, 2004, from the Hook-and-Line Survey. Spawning depletion has likely never been below the 40% management target (Figure 102), since almost all variations of the model explored show a healthy stock well above that level.

Recruitments have been constant, except 2008 and 2010, when the model sees extra large recruitments with extra large recruitment deviations (Figures 103 and 104). The spawner-recruit curve, Figure 105 shows a shallow relationship between stock size and recruitment, much like that in the Northern model.

3.7.1 Final Southern Model Selectivities, Indices and Discards

Selectivity by fleet is shown in Figure 72. Selectivities for all but the recreational Onboard fishery are modeled as asymptotic; both recreational fleets (MRFSS/RecFIN and Onboard) are fully selected at 30cm; the remaining fleets show full selectivity at 45cm, except for the Commercial fishery, which isn't fully selected until the maximum size, 55cm.

Index fits are shown in 74. The estimated change in catchability in 1993 for the MRFSS index is small and both the observed and expected index values show little trend. The Onboard survey fits to the two periods are flat in each period with a large change in catchability estimated between the two periods. The Hook-and-Line survey fit does not seem to capture trends in time. However, the model fits the data from the Juvenile Pelagic remarkably well, capturing the downward trend at the end of the period, which the other fits for the current period do not. During model tuning, we tried introducing a time-blocked index for the two periods of the MRFSS and the two periods of the Onboard survey, however it didn't improve the fit to the index until we also introduced the Northern model's estimates of natural mortality. These two changes had to be made in concert, since either in isolation destabilized the model further.

There was little information to inform this model of discard behavior, except in the Onboard survey, where it was represented by extremely small numbers. We included these discards in the retained fishery, since attempts to include it as a type-1 "retained plus discards" fishery prevented the model from converging.

3.7.2 Final Southern Model Lengths

Lengths in the Southern model were entered as unsexed, except for the Hook-and-Line fishery. There were sexes for the Commercial lengths, however there were also large numbers of unsexed lengths, and we chose to model the lengths as unsexed, to include as much of the data as possible. This was true of the Small-Fish study, as well.

Bubble plots of the lengths by year in each fishery are in Figure 75. The plot for the recreational fishery clearly shows the transition from the MRFSS sampling program to RecFIN in 2003/2004, as well as suggesting the existence of larger fish in the 1980s. The Commercial fishery data has been sparse in recent years; however the fish taken in the Commercial catch are consistently larger than those in the recreational fishery, no doubt reflecting trawling in deeper waters. The Onboard survey lengths reflect two eras of sampling, again with larger fish in the earlier period. The panel for the Hook-and-Line survey shows that the females landed are always larger than the males, in agreement with the model estimates of growth: Figure 5.

The fits to the lengths in the Recreational fishery Figure 76 show variable fits through the years, with the noisy and sparse data in 2004 heralding the transition between MRFSS sampling and RecFIN. Overall, the timeseries of mean lengths is fit fairly well (Figure 77).

The Commercial length comps are fit well through 2005, when data becomes sparse and noisy Figure 78; and Figure 79.

Fits for the Onboard Survey lengths are reasonable for both the early and late periods (Figures 80 - 83. Previous attempts to apply a time-block to this data resulted in poor convergence, but splitting the onboard index into separate fleets (along with revising the indices) during the STAR panel resulted in better fits and model performance.

The Hook-and-Line Survey lengths are noisy (Figure 84), but the fits are acceptable, and follow the trend of the data better than those for the other datasets: Figure 85.

The Small Fish Study lengths are not fit badly (Figures 86 and 87), and it is perhaps a shame that there are so few years to this timeseries.

The aggregate fits to the length comps for all five datasets is shown in Figure 88, and Pearson residuals for the lengths in Figure 89. Filled bubbles represent under-estimation of the data, open bubbles represent overestimation.

3.7.3 Final Southern Model Ages

There are few marginal ages in the model. Bubble plots for the Southern model ages (Figure 90) show the small sample from the Small Fish Study and the single year of ages from the Hook-and-Line Survey. The samples are too small to show any inter-annual variation, and are noisy within-year.

Figure 92 shows the fit to the Recreational Fishery samples, which is poor in all four years. The mean age in this data is shown in Figure 93, at 10 years.

The Hook-and-Line Survey age fit is shown in Figure 91. The Francis tuning method could not be applied in this case as it depends on the fit to multiple years of data.

The aggregated fits for the marginal ages are shown in Figure 94.

The implied marginal age distribution from the commercial conditional-age-at-length compositions is shown in Figure 95. This figure is included for informational purposes only; as it does not contribute to the model likelihood calculations. The fits here are quite good 1981-1999, however the last three years of data are very sparse and not well fit.

Pearson residuals for the Small Fish Study and the Hook-and-Line Survey are shown in Figure 96. Bubble size indicates the amount of disappointment in the fits. The filled bubbles indicate underestimates by the model; the open bubbles indicate overestimates.

The good news age-data comes from the commercial fleet, as was foreshadowed by the implied marginal ages. Figure 98 shows the interannual fits to the mean age in the commercial age-at-length data. Except for 1981, 1982 and 1989, the model is able to fit the data reasonably well, detecting the downward trend in the late 1980s and into the mid-1990s.

The annual plots of age-at-length fits (Figure 99) show good fits in all years except 2001-2002.

3.7.4 Final Southern Model Parameters

For the Final Southern model, the parameter estimates are given in Table 20. Status for all of the 161 estimated parameters is good.

3.7.5 Southern Model Uncertainty and Sensitivity Analyses

The Southern model was investigated in these 16 analyses:

- **Drop Biological Datasets** The data from each source in turn was dropped from the model.
- **Drop Indices** Each index in turn was dropped from the model.
- **Changes to M** Two sensitivities to M were run: we let the model estimate M and we fixed M at a value that Hamel (2015) estimated for a maximum age of 64, the value reported in (Love 2011).
- **add NWFSCcombo** Samples South of Cape Mendocino in the NWFSCcombo shelf-slope bottom trawl survey were too sparse to create an index, but as a sensitivity, the VAST analysis that produced the index for the Northern model was re-run at a coastwide scale with the output stratified at Cape Mendocino. The estimates for the Southern area were input to the Southern model as an additional fleet with catchability and selectivity assumed equal to the estimated values from the Northern model.
- **Tuning** We investigated tuning the model according to the method of McAllister and Ianelli(1997).

The Southern model is very reactive to many of these sensitivity analyses (Tables 21 and 22), and not so much to others. Removing different subsets of the biological data (Figures 106 and 107) had a large impact only in a few cases: removing all ages or removing all lengths resulted in large changes as expected. Commercial Fishery biological data and removing the Recreational (MRFSS) biological data also had large changes, which. In Figures 108 and 109 we can see that the model is not very sensitive to removal of the indices. The remaining fleets (all of which had shorter time-series of biological data) had much smaller impacts.

Removing all indices of abundance has relatively little impact on the model results, with removal of the Hook and Line index causing the largest impact (though still small). However, removing the Juvenile Index (or all indices, including this one) resulted in large changes to the estimates of recruitment in the most recent years 110. This is likely caused by recent recruitment getting information from the Juvenile Survey which is assumed to index only age-0 fish.

The impact of the remaining sensitivies on estimates of spawning output are shown in Figures 111 and 112.

Adding an index from the NWFSCcombo Survey with catchability fixed at the value estimated in the Northern model resulted in a low biomass at the end of the time series, and in order to sustain the observed history of removals, the model estimated very high recruitment causing an implausible increase in biomass prior to the period of peak removals in the 1980s.

Estimating M resulted in estimates of $M = 0.21$ for females and $M = 0.23$ for males, along with a much highest stock size. Fixing mortality at the low $M = 0.08$ (the value associated with a maximum age of 64) resulted in a much lower estimate of the scale of the model. Tuning based on the McAllister-Ianelli method had very little impact.

3.7.6 Final Southern Model Likelihood Profiles

The Southern model likelihood profiles shown here are those for one of the many sensitivities, and may be slightly different than those that would be the result of profiles on the "final" Southern model. These likelihood profiles show the general pattern of likelihood profiles for the Southern model, which was not found to be sufficient for management purposes.

We profiled the change in negative log likelihood for the data sources and model total likelihood for critical parameters fixed in the model: $log(R_0)$, the log of equilibrium recruitment; female natural mortality, **MF**; male natural mortality, **MM**; and steepness, **h** the parameter that reflects how quickly the stock-recruit relationship allows the stock to rebound from depleted stock size.

The likelihood profile for $log(R_0)$ is shown in Figure 113. The parameter $log(R_0)$ was profiled over values from 8.6-11.0. The figure shows that best fit to the age and length data all occur in the range of 9.0 to 9.6 but the indices are best fit at the upper end of the range: 11.0. The overall negative-log-likelihood is minimized at 10.1.

The female natural mortality (FM) profile, 114 ranges from 0.1 to 0.24. This shows that the indices and length data show the greatest change in likelihood associated with changing M and all support a higher value (consistent with the sensitivitiy analysis where mortality was estimated).

Male natural mortality (MM) is profiled over a range from -0.4 to 0. Male natural mortality is represented as an offset from that for females based on the equation $MM = MF * e^{offset}$, such that an offset of 0 results in equal mortality for males and females, and an offset of -0.3 results in a male natural mortality which is about 74% of the female mortality ($exp(-0.3) = 0.7408$). All roads lead to Rome in this figure (Figure 115); since all data sources and the overall likelihood are minimized at zero. Likelihoods for recruitments and indices are flat over the range of MM; the other data sources show changes of about 20 (lengths) and 40 (ages) likelihood values. However, given the larger amount of data available to the Northern model supporting lower mortality for males than females (Figure 66), the choice to fix the male mortality at the value from the Northern model, resulting in lower mortality for males than females, seems reasonable.

The profile over stock-recruit steepness (Figure 116) shows little information about steepness, with the change in total likelihood less than 0.7, over a range of $h = 0.5$ to $h = 0.9$. This supports the conclusion that the stock was never at a very low biomass. For a more depleted stock, steepness would have a larger impact on the likelihood. The lack of information on steepness supports the choice to fix the value at the mean of the prior: $h = 0.718$.

3.7.7 Final Southern Model Retrospective Analysis

The Southern model retrospectives shown here are those for one of the many sensitivities, and may be slightly different than those that would be the result of arun on the "final" Southern model. These retrospectives show the general pattern of retrospectives for the Southern model, which was not found to be sufficient for management purposes.

The Southern model shows a retrospective pattern in which removing one year of data at a time leads to slightly higher estimates of spawning output (Figure 117). The changes associated with 1 or 2 years of data removed are relatively small, but removing years of data had a larger impact on spawning output, with equilibrium value increasing from 2.8 trillion eggs to 3.5 trillion eggs when 5 years of data were removed.

3.7.8 Final Southern Model Reference Points

Reference points are not reported for the Southern model because it is not being recommended for management of the species.

4 Harvest Projections and Decision Tables

Potential OFL projections for each model are shown in Table 13 for the Northern model and Table 24 for the Southern model.

These values can be compared to recent regulations shown in Tables 2 and 15.

Decision tables will be completed during the STAR panel after determination of the axis of uncertainty and catch streams to include.

5 Regional Management Considerations

Management of the Yellowtail Rockfish northern stock has always been delineated by the 40° 10' line and the Canadian border. That the stock's genetic cline was found at Cape Mendocino is a happy accident that reinforces 40° 10' as the appropriate management line.

This assessment was not designed to test that choice. Given that the data for commercial and recreational fisheries is collected by the individual states (WA, OR, CA), it might have been interesting to investigate a management line at the California/Oregon border, had the STAT team the time and managers the interest in investigating a change.

6 Research and Data Needs

The following research will be valuable for future Yellowtail Rockfish assessments:

1. A problem common to assessments of all stocks caught in the midwater is the lack of a targeting survey. Because limits on the take of depleted midwater stocks have impeded fishing for many species, the lack of such a survey is an ongoing financial burden on industry.

2. Research to determine whether old females of a variety of rockfish species actually have a mortality rate different than that of younger females. Assessments variously treat the discrepancies seen in sex ratios of older fish as either mortality-related or due unavailability to the fishery (e.g., ontogenetic movement offshore, or to rockier habitats). As these assumptions impact model outcomes very differently, resolving this issue would greatly improve confidence in the assessments.

3. A hindrance to analysis of the commercial fishery is the inability to distinguish between midwater and trawl gear, particularly in data from the 1980s-1990s. Reliable recording of gear type will ensure that this does not continue to be problematic for future assessments.

4. We recommend that the next assessment of the Northern stock be an update to this assessment, unless fishing patterns change dramatically, or new sources of data are discovered.

5. For the next full assessment, we suggest the following:

    - A commercial index in the North. This is by far the largest segment of the fishery, and the introduction of the trawl rationalization program should mean that an index can be developed for the current fishery when the next full assessment is performed.
    - Further investigation into an index for the commercial logbook dataset from earlier periods.
    - Further analysis of growth patterns along the Northern coast. The previous full assessment subdivided the Northern stock based on research showing differential growth along the coast, and although data for the assessment is no longer available along the INPFC areas used in that analysis, there may be some evidence of growth variability that would be useful to include in a future assessment.

6. The Southern stock cannot be evaluated with a full statistical catch-at-age model unless more data are made available. In particular, we feel that the following are minimally required:

    - A longer timeseries of the juvenile rockfish CPUE in the south, which will of course only be available after several years have elapsed.

- A timeseries of recent ages for the Southern model. The commercial age timeseries currently stops in 2002. Otoliths have been collected for all years in the Hook & Line survey, however only samples from 2004 have been aged. There may also be a collection otoliths associated with research at the SWFSC, and these should be investigated as well.

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8 Tables

8.1 Northern Model Tables

Table 1. Catch timeseries for the Northern model. Commercial discards are estimated within the model based on estimated selectivity and retention functions. Numbers for the Recreational catch in Washington are converted to weight in the model based on the weight-length relationships combined with estimated growth and selectivity for this fleet.

Year	Comm (retain, mt)	Comm (discard, mt)	Comm (total, mt)	Hake Bycatch (mt)	Rec CA and OR (mt)	Rec WA (1000s)	Rec WA (mt)	Total (mt)
1889	0.1	0.0	0.1	0.0	0.0	0	0.0	0.1
1890	0.1	0.0	0.1	0.0	0.0	0	0.0	0.1
1891	0.2	0.0	0.3	0.0	0.0	0	0.0	0.3
1892	2.4	0.1	2.5	0.0	0.0	0	0.0	2.5
1893	2.1	0.1	2.2	0.0	0.0	0	0.0	2.2
1894	2.1	0.1	2.2	0.0	0.0	0	0.0	2.2
1895	0.6	0.0	0.6	0.0	0.0	0	0.0	0.6
1896	0.1	0.0	0.1	0.0	0.0	0	0.0	0.1
1897	0.1	0.0	0.1	0.0	0.0	0	0.0	0.1
1898	0.1	0.0	0.1	0.0	0.0	0	0.0	0.1
1899	0.1	0.0	0.1	0.0	0.0	0	0.0	0.1
1900	0.2	0.0	0.2	0.0	0.0	0	0.0	0.2
1901	0.2	0.0	0.2	0.0	0.0	0	0.0	0.2
1902	0.3	0.0	0.3	0.0	0.0	0	0.0	0.3
1903	0.3	0.0	0.3	0.0	0.0	0	0.0	0.3
1904	0.7	0.0	0.7	0.0	0.0	0	0.0	0.7
1905	0.4	0.0	0.5	0.0	0.0	0	0.0	0.5
1906	0.5	0.0	0.5	0.0	0.0	0	0.0	0.5
1907	0.5	0.0	0.6	0.0	0.0	0	0.0	0.6
1908	0.7	0.0	0.8	0.0	0.0	0	0.0	0.8
1909	0.6	0.0	0.7	0.0	0.0	0	0.0	0.7
1910	0.7	0.0	0.7	0.0	0.0	0	0.0	0.7
1911	0.7	0.0	0.8	0.0	0.0	0	0.0	0.8
1912	0.8	0.0	0.8	0.0	0.0	0	0.0	0.8
1913	0.8	0.0	0.9	0.0	0.0	0	0.0	0.9
1914	0.9	0.0	0.9	0.0	0.0	0	0.0	0.9
1915	1.0	0.0	1.1	0.0	0.0	0	0.0	1.1
1916	3.5	0.2	3.6	0.0	0.0	0	0.0	3.6
1917	5.9	0.3	6.2	0.0	0.0	0	0.0	6.2
1918	15.0	0.7	15.6	0.0	0.0	0	0.0	15.6

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Table 1. Catch timeseries for the Northern model. Commercial discards are estimated within the model based on estimated selectivity and retention functions. Numbers for the Recreational catch in Washington are converted to weight in the model based on the weight-length relationships combined with estimated growth and selectivity for this fleet.

Year	Comm (retain, mt)	Comm (discard, mt)	Comm (total, mt)	Hake Bycatch (mt)	Rec CA and OR (mt)	Rec WA (1000s)	Rec WA (mt)	Total (mt)
1919	4.7	0.2	4.9	0.0	0.0	0	0.0	4.9
1920	5.5	0.2	5.7	0.0	0.0	0	0.0	5.7
1921	7.2	0.3	7.5	0.0	0.0	0	0.0	7.5
1922	5.6	0.2	5.8	0.0	0.0	0	0.0	5.8
1923	3.1	0.1	3.3	0.0	0.0	0	0.0	3.3
1924	6.0	0.3	6.3	0.0	0.0	0	0.0	6.3
1925	14.2	0.6	14.8	0.0	0.0	0	0.0	14.8
1926	15.0	0.7	15.7	0.0	0.0	0	0.0	15.7
1927	25.8	1.1	27.0	0.0	0.0	0	0.0	27.0
1928	23.6	1.0	24.6	0.0	0.1	0	0.0	24.7
1929	31.3	1.4	32.6	0.0	0.3	0	0.0	32.9
1930	44.5	1.9	46.4	0.0	0.3	0	0.0	46.7
1931	51.8	2.3	54.1	0.0	0.4	0	0.0	54.5
1932	34.4	1.5	35.9	0.0	0.5	0	0.0	36.4
1933	31.8	1.4	33.2	0.0	0.6	0	0.0	33.8
1934	30.6	1.3	31.9	0.0	0.7	0	0.0	32.6
1935	49.2	2.1	51.3	0.0	0.8	0	0.0	52.1
1936	49.3	2.1	51.5	0.0	0.9	0	0.0	52.4
1937	54.5	2.4	56.9	0.0	1.1	0	0.0	58.0
1938	66.1	2.9	69.0	0.0	1.0	0	0.0	70.0
1939	76.3	3.3	79.6	0.0	0.9	0	0.0	80.5
1940	149.4	6.5	156.0	0.0	1.3	0	0.0	157.3
1941	200.4	8.7	209.1	0.0	1.2	0	0.0	210.3
1942	323.9	14.1	338.0	0.0	0.6	0	0.0	338.6
1943	1338.8	58.3	1397.1	0.0	0.6	0	0.0	1397.7
1944	2374.3	103.4	2477.7	0.0	0.5	0	0.0	2478.2
1945	4438.2	193.2	4631.4	0.0	0.7	0	0.0	4632.1
1946	2666.8	116.1	2783.0	0.0	1.2	0	0.0	2784.2
1947	1351.2	58.8	1410.0	0.0	0.9	0	0.0	1410.9
1948	1222.4	53.2	1275.6	0.0	1.8	0	0.0	1277.4
1949	611.3	26.6	638.0	0.0	2.4	0	0.0	640.4
1950	1191.6	51.9	1243.5	0.0	2.9	0	0.0	1246.4
1951	1242.7	54.1	1296.8	0.0	3.3	0	0.0	1300.1
1952	1593.9	69.4	1663.3	0.0	2.9	0	0.0	1666.2
1953	883.6	38.5	922.1	0.0	2.5	0	0.0	924.6

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Table 1. Catch timeseries for the Northern model. Commercial discards are estimated within the model based on estimated selectivity and retention functions. Numbers for the Recreational catch in Washington are converted to weight in the model based on the weight-length relationships combined with estimated growth and selectivity for this fleet.

Year	Comm (retain, mt)	Comm (discard, mt)	Comm (total, mt)	Hake Bycatch (mt)	Rec CA and OR (mt)	Rec WA (1000s)	Rec WA (mt)	Total (mt)
1954	1151.7	50.1	1201.8	0.0	3.1	0	0.0	1204.9
1955	1152.7	50.2	1202.9	0.0	3.7	0	0.0	1206.6
1956	1339.5	58.3	1397.9	0.0	4.2	0	0.0	1402.1
1957	1372.9	59.8	1432.7	0.0	3.6	0	0.0	1436.3
1958	1424.6	62.0	1486.6	0.0	6.1	0	0.0	1492.7
1959	1470.1	64.0	1534.1	0.0	5.6	0	0.0	1539.7
1960	1785.5	77.7	1863.3	0.0	4.1	0	0.0	1867.4
1961	1678.2	73.1	1751.3	0.0	3.1	0	0.0	1754.4
1962	2248.7	97.9	2346.5	0.0	3.6	0	0.0	2350.1
1963	1844.9	80.3	1925.2	0.0	2.5	0	0.0	1927.7
1964	1532.2	66.7	1598.9	0.0	1.9	0	0.0	1600.8
1965	1430.0	62.3	1492.3	0.0	3.2	0	0.0	1495.5
1966	1099.0	47.9	1146.9	0.0	3.5	0	0.0	1150.4
1967	1348.3	58.7	1407.0	0.0	3.5	52	51.5	1462.0
1968	1925.6	83.9	2009.4	0.0	3.9	0	0.0	2013.3
1969	3214.3	139.9	3354.2	0.0	4.8	0	0.0	3359.0
1970	1461.7	63.6	1525.3	0.0	5.5	0	0.0	1530.8
1971	1527.2	66.5	1593.7	0.0	4.3	0	0.0	1598.0
1972	2293.8	99.8	2393.7	0.0	5.8	0	0.0	2399.5
1973	2737.7	119.2	2856.9	0.0	7.4	0	0.0	2864.3
1974	1964.1	85.5	2049.6	0.0	8.0	0	0.0	2057.6
1975	1402.0	61.0	1463.0	0.0	8.0	16	16.5	1487.5
1976	3921.9	170.7	4092.6	29.5	9.4	22	22.0	4153.5
1977	5913.9	257.5	6171.4	7.4	8.3	11	10.9	6198.0
1978	8248.3	359.3	8607.6	75.5	7.5	17	17.5	8708.1
1979	7270.4	316.9	7587.3	82.0	25.2	5	5.2	7699.7
1980	7022.5	306.2	7328.7	255.3	24.0	4	3.8	7611.8
1981	9045.7	394.6	9440.3	152.6	69.1	5	4.9	9666.9
1982	9283.5	405.0	9688.5	551.2	69.5	2	2.4	10311.6
1983	9714.9	423.8	10138.6	548.3	123.3	3	3.5	10813.7
1984	4896.4	213.5	5110.0	312.0	37.4	3	3.4	5462.8
1985	3231.2	140.9	3372.1	174.2	190.5	6	5.8	3742.6
1986	4599.8	200.5	4800.3	560.1	29.1	11	10.6	5400.1
1987	4623.2	201.6	4824.9	541.4	23.9	19	18.9	5409.1
1988	6062.3	264.5	6326.8	423.4	17.8	19	18.8	6786.8

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Table 1. Catch timeseries for the Northern model. Commercial discards are estimated within the model based on estimated selectivity and retention functions. Numbers for the Recreational catch in Washington are converted to weight in the model based on the weight-length relationships combined with estimated growth and selectivity for this fleet.

Year	Comm (retain, mt)	Comm (discard, mt)	Comm (total, mt)	Hake Bycatch (mt)	Rec CA and OR (mt)	Rec WA (1000s)	Rec WA (mt)	Total (mt)
1989	4764.7	208.0	4972.7	184.6	41.7	19	18.5	5217.5
1990	4367.4	190.7	4558.0	295.1	37.7	16	16.0	4906.8
1991	3690.0	161.1	3851.1	478.1	52.4	34	33.9	4415.5
1992	5669.3	247.5	5916.8	694.8	200.8	36	36.0	6848.4
1993	5366.2	234.4	5600.6	273.4	177.9	47	46.6	6098.5
1994	5239.4	229.0	5468.4	560.4	80.7	20	19.8	6129.3
1995	4713.2	206.0	4919.1	646.8	65.2	16	16.4	5647.5
1996	5209.5	227.5	5437.0	746.2	60.2	22	21.9	6265.3
1997	1836.3	80.1	1916.4	396.3	76.6	22	22.2	2411.5
1998	2490.2	108.6	2598.8	438.1	70.6	34	34.3	3141.8
1999	2241.0	97.7	2338.7	1198.6	45.4	13	12.9	3595.6
2000	2905.6	126.6	3032.2	635.3	27.4	16	15.7	3710.6
2001	1898.9	82.7	1981.7	213.4	26.1	11	11.1	2232.3
2002	1024.7	111.2	1135.9	189.9	27.3	5	5.0	1358.1
2003	413.7	10.2	423.9	36.6	20.1	11	11.1	491.7
2004	568.3	185.2	753.5	47.6	18.8	22	21.7	841.6
2005	752.1	846.4	1598.5	112.2	26.9	20	19.5	1757.1
2006	357.6	61.6	419.2	108.7	23.4	14	13.9	565.2
2007	276.4	467.9	744.3	78.7	17.8	16	15.5	856.3
2008	276.0	26.0	302.0	175.0	23.9	19	19.3	520.2
2009	538.7	337.5	876.3	176.2	16.9	31	30.8	1100.2
2010	753.6	666.4	1420.0	150.1	11.6	42	42.4	1624.1
2011	1181.3	0.9	1182.2	101.2	18.4	48	47.9	1349.7
2012	1508.6	1.1	1509.7	43.0	20.1	21	21.0	1593.8
2013	1117.1	0.8	1118.0	269.0	20.2	26	26.1	1433.3
2014	1366.5	1.0	1367.5	42.0	15.8	36	35.5	1460.8
2015	1840.8	1.4	1842.2	86.4	29.1	59	59.1	2016.8
2016	1308.4	1.0	1309.4	62.3	14.0	63	63.2	1448.9

Table 2. Northern model recent total catch relative to the management guidelines. Estimated total catch includes estimated discarded biomass. Note: the OFL was termed the ABC prior to implementation of FMP Amendment 23 in 2011. The ABC was redefined to reflect the uncertainty in estimating the OFL under Amendment 23. Likewise, the ACL was termed the OY prior to 2011.

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Estimated total catch (mt)
2007	4585	-	4585	856
2008	4510	-	4510	520
2009	4562	-	4562	1100
2010	4562	-	4562	1624
2011	4566	4364	4364	1350
2012	4573	4371	4371	1594
2013	4579	4378	4378	1433
2014	4584	4382	4382	1461
2015	7218	6590	6590	2017
2016	6949	6344	6344	1449
2017	6786	6196	6196	-
2018	6574	6002	6002	-

Table 4. Time series of length composition sample sizes for the Northern model. Numbers of fish sampled and number of tows with samples are provided for all but the recreational fleets where only the number of fish was available. "Comm." refers to the Commercial fishery. "Hake" to the bycatch in the At-Sea Hake fish" and "Tri." to the triennial survey.

Year	Comm. Fish	Comm. Tows	Hake Fish	Hake Tows	Tri. Fish	Tri. Tows	NWFSC Fish	NWFSC Tows	Rec-WA Fish	Rec-OR+CA Fish
1972	994	14								
1973	341	5								
1974	384	4								
1975	405	4								
1976	1771	19	120	14						
1977	1620	17	0	0	1919	21				
1978	972	11	276	14						
1979	2548	26	5	2					59	
1980	4520	46	3104	88	1171	24			247	384
1981	4729	48	0	0					201	160
1982	5010	51	177	9					92	105
1983	2644	28	0	0	3506	58			46	93
1984	4383	45	0	0					1	376

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Table 4. Time series of length composition sample sizes for the Northern model. Numbers of fish sampled and number of tows with samples are provided for all but the recreational fleets where only the number of fish was available. "Comm." refers to the Commercial fishery. "Hake" to the bycatch in the At-Sea Hake fish" and "Tri." to the triennial survey.

Year	Comm. Fish	Comm. Tows	Hake Fish	Hake Tows	Tri. Fish	Tri. Tows	NWFSC Fish	NWFSC Tows	Rec-WA Fish	Rec-OR+CA Fish
1985	5685	57	43	3					3	254
1986	4365	45	0	0	3076	42			364	164
1987	4083	79	0	0					343	129
1988	3315	67	0	0					279	138
1989	3696	75	13	4	1774	57			296	161
1990	3663	74	0	0					239	
1991	3132	76	0	0					310	
1992	4170	104	3651	201	2355	72			527	
1993	3779	89	2435	176					550	404
1994	4384	104	5020	374					678	639
1995	4203	100	2568	179	1090	67			1074	567
1996	3836	89	4127	297					952	307
1997	5506	139	5199	388					648	304
1998	5009	123	2898	417	4287	130			520	611
1999	5561	138	5530	557					572	372
2000	5107	130	3835	443					671	247
2001	4743	126	1571	322	1159	58			721	97
2002	3154	76	832	148					1313	186
2003	2204	58	2133	327			167	3	2298	31
2004	3029	73	2858	481	1668	54	92	2	1996	1
2005	2001	56	5093	536			209	5	2498	3
2006	1954	52	5799	533			117	5	1544	7
2007	1869	62	5551	717			189	4	1420	3
2008	1650	62	4731	620			209	3	789	11
2009	1578	67	3570	404			144	5	1342	11
2010	1960	70	5708	645			250	4	1043	7
2011	1816	87	4807	620			279	4	1463	16
2012	2584	105	1482	234			215	5	1282	125
2013	1846	113	1840	204			117	4	1010	114
2014	2534	177	1314	137			373	6	1724	57
2015	3050	159	1646	129			336	5	1448	53
2016	2836	139	4213	481			293	5	2006	24

Table 3. Timeseries of observed discard fractions and the estimated CV for the commercial fleet in the Northern model.

Year	Discard fraction	CV
1981	0.0349	2.9300
1982	0.0327	3.0200
1983	0.0325	3.0100
1984	0.0354	3.1300
1985	0.0319	3.2200
1986	0.0333	3.0800
1987	0.0361	2.9700
1988	0.0363	2.8600
1989	0.0358	3.1000
1990	0.0376	2.9600
1991	0.0399	2.9300
2002	0.0981	0.4090
2003	0.0241	0.7330
2004	0.2469	0.3920
2005	0.5334	0.1890
2006	0.1473	0.2210
2007	0.6366	0.2360
2008	0.0907	0.6650
2009	0.3906	0.3030
2010	0.4872	0.3630
2011	0.0010	0.0010
2012	0.0010	0.0010
2013	0.0010	0.0010
2014	0.0010	0.0010
2015	0.0002	1.7000

Table 5. Age timeseries for the Northern model.

Year	Trawl	Tows	Triennial	Tows	NWFSCcombo	Tows	Rec WA
1972	994	14					
1973	341	5					
1974	384	4					
1975	405	4					
1976	1771	19					
1977	1620	17	1426	17			
1978	972	11					
1979	2548	26					32
1980	4520	46	755	14			228
1981	4729	48					14
1982	5010	51					19

Continued on next page

Table 5. Age timeseries for the Northern model.

Year	Trawl	Tows	Triennial	Tows	NWFSCcombo	Tows	Rec WA
1983	2644	28	1699	21			40
1984	4383	45					
1985	5685	57					3
1986	4365	45	1216	22			345
1987	4083	79					278
1988	3315	67					250
1989	3696	75	399	11			227
1990	3663	74					207
1991	3132	76					247
1992	4170	104	467	13			504
1993	3779	89					537
1994	4384	104					452
1995	4203	100	369	44			655
1996	3836	89					537
1997	5506	139					541
1998	5009	123	1436	89			441
1999	5561	138					528
2000	5107	130					
2001	4743	126	746	50			
2002	3154	76					654
2003	2204	58			53	3	624
2004	3029	73	452	53	27	2	584
2005	2001	56			73	5	575
2006	1954	52			41	5	426
2007	1869	62			76	4	498
2008	1650	62			74	3	447
2009	1578	67			37	5	352
2010	1960	70			66	4	419
2011	1816	87			70	4	319
2012	2584	105			79	5	272
2013	1846	113			74	4	352
2014	2534	177			93	6	1234
2015	3050	159			75	5	1127
2016	2836	139			102	5	1635

Table 6. Number of hauls by year and area in total and with Yellowtail Rockfish for the Triennial bottom trawl survey.

Year	Hauls in Northern area	Hauls with Yellowtail in Northern area	Hauls in Southern area	Hauls with Yellowtail in Southern area
1977	312	87	263	9
1980	299	96	50	4
1983	453	181	68	9
1986	412	128	72	12
1989	355	67	150	8
1992	361	81	121	12
1995	354	58	158	14
1998	361	127	167	3
2001	339	55	167	3
2004	256	53	127	1
Average	350	93	134	8

Table 7. Number of hauls by year and area in total and with Yellowtail Rockfish for the NWFSCcombo bottom trawl survey.

Year	Hauls in Northern area	Hauls with Yellowtail in Northern area	Hauls in Southern area	Hauls with Yellowtail in Southern area
2003	311	32	196	3
2004	231	22	213	5
2005	314	42	276	5
2006	309	30	297	5
2007	344	45	298	0
2008	321	31	321	6
2009	322	35	319	5
2010	332	44	335	3
2011	327	46	320	2
2012	339	40	313	6
2013	261	20	178	10
2014	317	50	310	5
2015	281	57	328	2
2016	301	78	311	2
average:	308	41	287	4

Table 8. Summary of the biomass/abundance time series used in the Northern model.

Years	Name	Fishery ind.	Method	Used in model
1987-1998	Commercial Logbook	No	delta-GLM (bin-lognormal)	No
1985-1999	Hake Bycatch	No	VAST with catchability adjustment	No
1977-2004	Triennial	Yes	VAST	Yes
2003-2016	NWFSCcombo	Yes	VAST	Yes

Table 9. CPUE timeseries for the Northern model. The SE values represent standard error on a log scale, which is similar to a CV. The Commercial Trawl and Hake Bycatch indices were not included in the likelihood of the final model.

Year	Commercial Trawl	SE	Hake Bycatch	SE	NWFSCcombo	SE	Triennial	SE
1977							11368.40	0.22
1978								
1979								
1980							7818.55	0.27
1981								
1982								
1983							10135.00	0.17
1984								
1985			1.01	0.43				
1986			1.36	0.39			7729.08	0.18
1987	641.15	0.35	0.99	0.39				
1988	514.98	0.30	1.16	0.39				
1989	368.74	0.30	0.88	0.41			5821.89	0.29
1990	357.04	0.25	1.17	0.41				
1991	402.15	0.22	1.64	0.48				
1992	359.75	0.24	1.69	0.44			8009.17	0.27
1993	304.50	0.22	1.77	0.47				
1994	317.44	0.21	0.65	0.42				
1995	295.22	0.19	0.67	0.47			2765.16	0.30
1996	424.16	0.17	0.58	0.43				
1997	136.88	0.21	0.40	0.45				
1998	223.35	0.19	0.43	0.49			20868.20	0.21
1999			0.62	0.45				
2000								
2001							4532.19	0.30
2002								
2003					21414.20	0.40		
2004					15615.80	0.48	15724.00	0.27
2005					28766.70	0.36		
2006					11758.60	0.42		
2007					20075.30	0.36		
2008					15379.40	0.41		
2009					9939.86	0.40		
2010					29371.70	0.36		
2011					23241.60	0.35		
2012					21824.60	0.39		
2013					15938.20	0.51		
2014					45904.30	0.34		
2015					30202.00	0.33		
2016					62864.10	0.30		

Table 10. List of parameters used in the base Northern model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
1	NatM_p_1_Fem_GP_1	0.174	2	(0.02, 0.25)	OK	0.012	Log_Norm (-2.12, 0.438)
2	L_at_Amin_Fem_GP_1	14.689	3	(1, 25)	OK	0.572	None
3	L_at_Amax_Fem_GP_1	53.580	2	(35, 70)	OK	0.224	None
4	VonBert_K_Fem_GP_1	0.140	3	(0.1, 0.4)	OK	0.004	None
5	CV_young_Fem_GP_1	0.105	5	(0.03, 0.16)	OK	0.010	None
6	CV_old_Fem_GP_1	0.040	5	(0.03, 0.16)	OK	0.003	None
7	Wtlen_1_Fem	0.000	-50	(0, 3)			None
8	Wtlen_2_Fem	3.067	-50	(2, 4)			None
9	Mat50%_Fem	42.490	-50	(30, 56)			None
10	Mat_slope_Fem	-0.401	-50	(-2, 1)			None
11	Eggs_scalar_Fem	0.000	-50	(0, 6)			None
12	Eggs_exp_len_Fem	4.590	-50	(2, 7)			None
13	NatM_p_1_Mal_GP_1	-0.149	2	(-3, 3)	OK	0.015	None
14	L_at_Amin_Mal_GP_1	0.000	-2	(-1, 1)			None
15	L_at_Amax_Mal_GP_1	-0.145	2	(-1, 1)	OK	0.005	None
16	VonBert_K_Mal_GP_1	0.352	3	(-1, 1)	OK	0.025	None
17	CV_young_Mal_GP_1	0.000	-5	(-1, 1)			None
18	CV_old_Mal_GP_1	0.243	5	(-1, 1)	OK	0.072	None
19	Wtlen_1_Mal	0.000	-50	(0, 3)			None
20	Wtlen_2_Mal	3.067	-50	(2, 4)			None
24	CohortGrowDev	1.000	-50	(0, 2)			None
25	FracFemale_GP_1	0.500	-99	(0.001, 0.999)			None
26	SR_LN(R0)	10.832	1	(5, 20)	OK	0.227	None
27	SR_BH_steep	0.718	-6	(0.2, 1)			None
28	SR_sigmaR	0.500	-6	(0.5, 1.2)			None
29	SR_regime	0.000	-50	(-5, 5)			None

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Table 10. List of parameters used in the base Northern model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
30	SR_autocorr	0.000	-50	(0, 2)			None
140	LnQ_base_CommercialTrawl(1)	-4.748	-1	(-30, 15)			None
141	LnQ_base_HakeByCatch(2)	-10.003	-1	(-30, 15)			None
142	LnQ_base_Triennial(5)	-1.315	-1	(-30, 15)			None
143	Q_extraSD_Triennial(5)	0.282	1	(0, 0.5)	OK	0.127	None
144	LnQ_base_NWFSCcombo(6)	-1.056	-1	(-30, 15)			None
145	Q_extraSD_NWFSCcombo(6)	0.155	1	(0, 0.5)	OK	0.099	None
146	SizeSel_P1_CommercialTrawl(1)	49.319	1	(20, 55)	OK	0.766	None
147	SizeSel_P2_CommercialTrawl(1)	70.000	-4	(-20, 70)			None
148	SizeSel_P3_CommercialTrawl(1)	4.293	3	(-5, 20)	OK	0.093	None
149	SizeSel_P4_CommercialTrawl(1)	70.000	-4	(-5, 70)			None
150	SizeSel_P5_CommercialTrawl(1)	-999.000	-99	(-999, 25)			None
151	SizeSel_P6_CommercialTrawl(1)	-999.000	-99	(-999, 25)			None
152	Retain_P1_CommercialTrawl(1)	24.762	3	(20, 55)	OK	3.367	None
153	Retain_P2_CommercialTrawl(1)	1.608	3	(0.1, 40)	OK	0.704	None
154	Retain_P3_CommercialTrawl(1)	3.136	3	(-10, 20)	OK	0.739	None
155	Retain_P4_CommercialTrawl(1)	0.000	-4	(-3, 3)			None
156	SizeSel_P1_HakeByCatch(2)	52.914	1	(20, 55)	OK	0.947	None
157	SizeSel_P2_HakeByCatch(2)	70.000	-4	(-20, 70)			None
158	SizeSel_P3_HakeByCatch(2)	4.312	3	(-5, 20)	OK	0.114	None
159	SizeSel_P4_HakeByCatch(2)	70.000	-4	(-5, 70)			None
160	SizeSel_P5_HakeByCatch(2)	-999.000	-99	(-999, 25)			None
161	SizeSel_P6_HakeByCatch(2)	-999.000	-99	(-999, 25)			None
162	SizeSel_P1_RecORandCA(3)	31.131	6	(20, 55)	OK	0.787	None
163	SizeSel_P2_RecORandCA(3)	-20.000	-4	(-20, 70)			None
164	SizeSel_P3_RecORandCA(3)	3.214	6	(-5, 20)	OK	0.232	None
165	SizeSel_P4_RecORandCA(3)	20.000	-4	(-5, 20)			None

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Table 10. List of parameters used in the base Northern model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
166	SizeSel_P5_RecORandCA(3)	-999.000	-99	(-999, 25)			None
167	SizeSel_P6_RecORandCA(3)	-999.000	-99	(-999, 25)			None
168	SizeSel_P1_RecWA(4)	55.000	-6	(20, 55)			None
169	SizeSel_P2_RecWA(4)	-20.000	-4	(-20, 70)			None
170	SizeSel_P3_RecWA(4)	5.373	6	(-5, 20)	OK	0.326	None
171	SizeSel_P4_RecWA(4)	20.000	-4	(-5, 70)			None
172	SizeSel_P5_RecWA(4)	-999.000	-99	(-999, 25)			None
173	SizeSel_P6_RecWA(4)	-999.000	-99	(-999, 25)			None
174	SizeSel_P1_Triennial(5)	55.000	-1	(20, 55)			None
175	SizeSel_P2_Triennial(5)	70.000	-4	(-20, 70)			None
176	SizeSel_P3_Triennial(5)	5.070	3	(-5, 20)	OK	0.102	None
177	SizeSel_P4_Triennial(5)	70.000	-4	(-5, 70)			None
178	SizeSel_P5_Triennial(5)	-999.000	-99	(-999, 25)			None
179	SizeSel_P6_Triennial(5)	-999.000	-99	(-999, 25)			None
180	SizeSel_P1_NWFSCcombo(6)	50.169	1	(20, 55)	OK	2.988	None
181	SizeSel_P2_NWFSCcombo(6)	70.000	-4	(-20, 70)			None
182	SizeSel_P3_NWFSCcombo(6)	4.541	3	(-5, 20)	OK	0.422	None
183	SizeSel_P4_NWFSCcombo(6)	70.000	-4	(-5, 70)			None
184	SizeSel_P5_NWFSCcombo(6)	-999.000	-99	(-999, 25)			None
185	SizeSel_P6_NWFSCcombo(6)	-999.000	-99	(-999, 25)			None
186	Retain_P3_CommercialTrawl(1)_BLK1repl_2002	2.222	6	(-10, 20)	OK	0.455	None
187	Retain_P3_CommercialTrawl(1)_BLK1repl_2003	3.707	6	(-10, 20)	OK	0.755	None
188	Retain_P3_CommercialTrawl(1)_BLK1repl_2004	1.122	6	(-10, 20)	OK	0.522	None
189	Retain_P3_CommercialTrawl(1)_BLK1repl_2005	-0.118	6	(-10, 20)	OK	0.401	None
190	Retain_P3_CommercialTrawl(1)_BLK1repl_2006	1.760	6	(-10, 20)	OK	0.260	None
191	Retain_P3_CommercialTrawl(1)_BLK1repl_2007	-0.526	6	(-10, 20)	OK	0.630	None
192	Retain_P3_CommercialTrawl(1)_BLK1repl_2008	2.363	6	(-10, 20)	OK	0.806	None

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Table 10. List of parameters used in the base Northern model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
193	Retain_P3_CommercialTrawl(1)_BLK1repl_2009	0.468	6	(-10, 20)	OK	0.496	None
194	Retain_P3_CommercialTrawl(1)_BLK1repl_2010	0.123	6	(-10, 20)	OK	0.687	None
195	Retain_P3_CommercialTrawl(1)_BLK1repl_2011	7.312	6	(-10, 20)	OK	0.654	None
196	SizeSel_P1_RecORandCA(3)_BLK3repl_2003	31.244	6	(20, 55)	OK	1.520	None
197	SizeSel_P3_RecORandCA(3)_BLK3repl_2003	2.908	6	(-5, 20)	OK	0.605	None
198	SizeSel_P4_RecORandCA(3)_BLK3repl_2003	4.265	6	(-5, 20)	OK	0.445	None
199	SizeSel_P1_RecWA(4)_BLK3repl_2003	33.634	6	(20, 55)	OK	1.186	None
200	SizeSel_P3_RecWA(4)_BLK3repl_2003	2.771	6	(-5, 20)	OK	0.517	None
201	SizeSel_P4_RecWA(4)_BLK3repl_2003	11.496	6	(-5, 70)	OK	87.330	None

Table 12. Time-series of population estimates from the Northern model base-case.

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1889	161631	15.00	0.00	50657	0	0.00	1.00
1890	161632	15.00	1.00	50657	0	0.00	1.00
1891	161633	15.00	1.00	50657	0	0.00	1.00
1892	161635	15.00	1.00	50657	2	0.00	1.00
1893	161637	15.00	1.00	50656	2	0.00	1.00
1894	161640	15.00	1.00	50656	2	0.00	1.00
1895	161645	15.00	1.00	50656	1	0.00	1.00
1896	161652	15.00	1.00	50656	0	0.00	1.00
1897	161660	15.00	1.00	50656	0	0.00	1.00
1898	161668	15.00	1.00	50656	0	0.00	1.00
1899	161675	15.00	1.00	50657	0	0.00	1.00
1900	161682	15.00	1.00	50657	0	0.00	1.00
1901	161688	15.00	1.00	50657	0	0.00	1.00
1902	161694	15.00	1.00	50657	0	0.00	1.00
1903	161699	15.00	1.00	50658	0	0.00	1.00
1904	161704	15.00	1.00	50658	1	0.00	1.00
1905	161708	15.00	1.00	50658	0	0.00	1.00
1906	161711	15.00	1.00	50658	1	0.00	1.00
1907	161715	15.00	1.00	50658	1	0.00	1.00
1908	161717	15.00	1.00	50659	1	0.00	1.00
1909	161720	15.00	1.00	50659	1	0.00	1.00
1910	161722	15.00	1.00	50659	1	0.00	1.00
1911	161724	15.00	1.00	50659	1	0.00	1.00
1912	161726	15.00	1.00	50659	1	0.00	1.00
1913	161727	15.00	1.00	50659	1	0.00	1.00
1914	161729	15.00	1.00	50659	1	0.00	1.00
1915	161730	15.00	1.00	50659	1	0.00	1.00
1916	161731	15.00	1.00	50659	4	0.00	1.00
1917	161729	15.00	1.00	50659	6	0.00	1.00
1918	161725	15.00	1.00	50659	16	0.00	1.00
1919	161714	15.00	1.00	50658	5	0.00	1.00
1920	161713	15.00	1.00	50658	6	0.00	1.00
1921	161711	15.00	1.00	50658	8	0.00	1.00
1922	161709	15.00	1.00	50658	6	0.00	1.00
1923	161708	15.00	1.00	50658	3	0.00	1.00
1924	161709	15.00	1.00	50658	6	0.00	1.00
1925	161708	15.00	1.00	50658	15	0.00	1.00
1926	161699	15.00	1.00	50657	16	0.00	1.00

Table 12. Time-series of population estimates from the Northern model base-case.

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1927	161690	15.00	1.00	50657	27	0.00	1.00
1928	161671	14.99	1.00	50656	25	0.00	1.00
1929	161657	14.99	1.00	50655	33	0.00	1.00
1930	161637	14.99	1.00	50654	47	0.00	1.00
1931	161607	14.98	1.00	50652	54	0.00	1.00
1932	161573	14.98	1.00	50941	36	0.00	1.00
1933	161561	14.97	1.00	50963	34	0.00	1.00
1934	161561	14.97	1.00	50985	33	0.00	1.00
1935	161576	14.97	1.00	51004	52	0.00	1.00
1936	161589	14.97	1.00	51020	52	0.00	1.00
1937	161619	14.96	1.00	51035	58	0.00	0.99
1938	161659	14.96	1.00	51050	70	0.00	0.99
1939	161699	14.95	1.00	51069	81	0.00	0.99
1940	161739	14.95	1.00	51095	157	0.00	0.99
1941	161718	14.93	1.00	51125	210	0.00	0.98
1942	161663	14.91	0.99	51166	339	0.00	0.97
1943	161508	14.88	0.99	51215	1398	0.01	0.89
1944	160419	14.69	0.98	51228	2478	0.02	0.81
1945	158479	14.35	0.96	51205	4632	0.03	0.68
1946	154811	13.72	0.91	50981	2784	0.02	0.78
1947	153245	13.41	0.89	50831	1411	0.01	0.88
1948	153128	13.34	0.89	50787	1277	0.01	0.89
1949	153168	13.31	0.89	50690	640	0.00	0.94
1950	153790	13.39	0.89	50356	1246	0.01	0.89
1951	153789	13.38	0.89	49430	1300	0.01	0.89
1952	153710	13.38	0.89	47929	1666	0.01	0.86
1953	153239	13.32	0.89	46232	925	0.01	0.92
1954	153364	13.38	0.89	44924	1205	0.01	0.89
1955	153018	13.40	0.89	43989	1207	0.01	0.89
1956	152429	13.41	0.89	42649	1402	0.01	0.88
1957	151394	13.39	0.89	40621	1436	0.01	0.87
1958	150061	13.36	0.89	39135	1493	0.01	0.87
1959	148393	13.31	0.89	40733	1540	0.01	0.87
1960	146410	13.24	0.88	49575	1867	0.01	0.84
1961	143990	13.11	0.87	63353	1754	0.01	0.85
1962	141935	12.97	0.86	52961	2350	0.02	0.80
1963	140051	12.72	0.85	38489	1928	0.01	0.83
1964	139307	12.52	0.83	32710	1601	0.01	0.85

Table 12. Time-series of population estimates from the Northern model base-case.

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1965	139115	12.34	0.82	31490	1496	0.01	0.86
1966	138726	12.16	0.81	32152	1150	0.01	0.89
1967	138025	12.04	0.80	36763	1462	0.01	0.86
1968	136326	11.91	0.79	52158	2013	0.02	0.81
1969	133714	11.76	0.78	41311	3359	0.03	0.72
1970	130023	11.49	0.77	30215	1531	0.01	0.85
1971	128371	11.52	0.77	23667	1598	0.01	0.84
1972	126600	11.49	0.77	30656	2399	0.02	0.78
1973	123749	11.27	0.75	38964	2864	0.02	0.74
1974	120222	10.91	0.73	68934	2058	0.02	0.80
1975	117671	10.65	0.71	55369	1487	0.01	0.84
1976	116634	10.48	0.70	45986	4153	0.04	0.64
1977	114343	9.96	0.66	55622	6198	0.06	0.52
1978	111429	9.17	0.61	39635	8708	0.08	0.41
1979	107415	8.05	0.54	25145	7700	0.08	0.41
1980	105102	7.14	0.48	30353	7612	0.08	0.39
1981	102805	6.36	0.42	42932	9667	0.10	0.31
1982	98256	5.53	0.37	28943	10312	0.11	0.27
1983	93017	4.87	0.33	50734	10814	0.12	0.24
1984	87305	4.40	0.29	62424	5463	0.07	0.40
1985	86940	4.62	0.31	43636	3743	0.05	0.51
1986	88723	5.01	0.33	50040	5400	0.07	0.42
1987	89484	5.13	0.34	64726	5409	0.07	0.42
1988	90845	5.13	0.34	37864	6787	0.08	0.36
1989	91623	4.90	0.33	81741	5218	0.06	0.42
1990	94339	4.84	0.32	87677	4907	0.06	0.44
1991	98274	4.86	0.32	71462	4416	0.05	0.47
1992	103949	5.02	0.33	50521	6848	0.07	0.36
1993	108341	5.01	0.33	35638	6098	0.06	0.40
1994	113547	5.16	0.34	56097	6129	0.06	0.40
1995	117888	5.36	0.36	52366	5647	0.05	0.43
1996	121638	5.66	0.38	29236	6265	0.05	0.42
1997	123678	5.97	0.40	38923	2412	0.02	0.68
1998	127773	6.83	0.46	66847	3142	0.03	0.65
1999	129732	7.68	0.51	62432	3595	0.03	0.63
2000	130694	8.42	0.56	83820	3711	0.03	0.64
2001	131712	9.04	0.60	42268	2232	0.02	0.77
2002	134815	9.66	0.64	26123	1358	0.01	0.85

Table 12. Time-series of population estimates from the Northern model base-case.

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
2003	138733	10.23	0.68	32801	492	0.00	0.94
2004	142488	10.77	0.72	40941	842	0.01	0.91
2005	144490	11.14	0.74	17583	1757	0.01	0.83
2006	144235	11.34	0.76	57647	565	0.00	0.94
2007	143732	11.73	0.78	19891	856	0.01	0.91
2008	142176	12.13	0.81	66692	520	0.00	0.95
2009	140357	12.57	0.84	20818	1100	0.01	0.90
2010	138108	12.83	0.86	72381	1624	0.01	0.85
2011	135511	12.85	0.86	29344	1350	0.01	0.87
2012	133896	12.74	0.85	38427	1594	0.01	0.85
2013	132423	12.47	0.83	53491	1433	0.01	0.86
2014	131351	12.16	0.81	50057	1461	0.01	0.86
2015	130645	11.84	0.79	49535	2017	0.02	0.81
2016	129912	11.48	0.77	49199			

Table 11. Results of sensitivity analyses for the Northern model.

Quantity	Base Model	McAllister-Ianelli weights	M prior Age64	M fixed Age64	Include commercial index	Include hake bycatch index	Include commercial and hake indices
TOTAL_like	960.70	1422.57	961.70	1016.99	956.81	958.43	953.61
Survey_like	-3.10	-1.01	-3.15	-2.83	-7.60	-6.26	-12.61
Length_comp_like	326.79	471.71	326.86	346.38	327.22	327.22	327.86
Age_comp_like	729.94	1035.96	730.04	751.75	731.31	731.88	733.61
Parm_priors_like	0.36	0.66	1.33	0.00	0.29	0.27	0.21
Recr_Virgin_millions	50.62	88.59	49.33	10.72	43.69	42.02	36.13
SR_LN(R0)	10.83	11.39	10.81	9.28	10.68	10.65	10.49
NatM_p_1_Fem_GP_1	0.17	0.20	0.17	0.08	0.17	0.17	0.16
NatM_p_1_Mal_GP_1	-0.15	-0.15	-0.15	-0.11	-0.15	-0.15	-0.15
SPB_Virgin_thousand_mt	0.01	0.02	0.01	0.02	0.01	0.01	0.01
SPB_2017_thousand_mt	0.01	0.01	0.01	0.00	0.01	0.01	0.01
Bratio_2017	0.75	0.82	0.75	0.23	0.70	0.69	0.63
SPRratio_2016	0.29	0.20	0.30	1.01	0.33	0.35	0.40
TotYield_MSY_thousand_mt	6.12	8.79	6.04	3.14	5.58	5.45	4.98

Table 13. Projection of potential OFL, spawning output, and depletion for the Northern model.

Yr	OFL contribution (mt)	ACL landings (mt)	Age 4+ biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output
2017	7462.77	6864.71	124456.00	11.28	0.75
2018	6963.32	6405.34	120024.00	10.31	0.69
2019	6568.18	6041.94	116830.00	9.54	0.64
2020	6261.27	5759.69	114593.00	8.92	0.60
2021	6033.99	5550.67	113084.00	8.45	0.56
2022	5876.95	5406.23	112040.00	8.09	0.54
2023	5776.23	5313.55	111280.00	7.85	0.52
2024	5715.12	5257.30	110670.00	7.70	0.51
2025	5677.99	5223.11	110119.00	7.60	0.51
2026	5652.84	5199.93	109579.00	7.54	0.50
2027	5631.77	5180.52	109034.00	7.50	0.50
2028	5610.41	5160.85	108486.00	7.47	0.50

8.2 Southern Model Tables

Table 14. Catch timeseries for the Southern model.

Year	Commercial (mt)	Recreational (mt)	Total (mt)
1889	1.0	0.0	1.0
1890	18.3	0.0	18.3
1891	36.6	0.0	36.6
1892	54.9	0.0	54.9
1893	73.2	0.0	73.2
1894	91.6	0.0	91.6
1895	109.9	0.0	109.9
1896	128.2	0.0	128.2
1897	146.5	0.0	146.5
1898	164.8	0.0	164.8
1899	183.1	0.0	183.1
1900	201.4	0.0	201.4
1901	219.7	0.0	219.7
1902	238.0	0.0	238.0
1903	256.4	0.0	256.4
1904	274.7	0.0	274.7
1905	293.0	0.0	293.0
1906	311.3	0.0	311.3
1907	329.6	0.0	329.6
1908	347.9	0.0	347.9
1909	366.2	0.0	366.2
1910	384.5	0.0	384.5
1911	402.8	0.0	402.8
1912	421.2	0.0	421.2
1913	439.5	0.0	439.5
1914	457.8	0.0	457.8
1915	476.1	0.0	476.1
1916	494.4	0.0	494.4
1917	769.5	0.0	769.5
1918	903.6	0.0	903.6
1919	622.0	0.0	622.0
1920	635.6	0.0	635.6
1921	527.6	0.0	527.6
1922	453.8	0.0	453.8
1923	488.7	0.0	488.7
1924	290.1	0.0	290.1
1925	377.1	0.0	377.1
1926	576.2	0.0	576.2
1927	476.4	0.0	476.4

Continued on next page

Table 14. Catch timeseries for the Southern model.

Year	Commercial (mt)	Recreational (mt)	Total (mt)
1928	549.7	4.2	553.9
1929	463.8	8.4	472.2
1930	677.5	9.6	687.1
1931	623.5	12.8	636.3
1932	497.4	16.0	513.4
1933	313.8	19.2	333.0
1934	347.6	22.5	370.1
1935	428.7	25.7	454.4
1936	522.0	28.9	550.9
1937	461.9	34.2	496.1
1938	376.1	33.7	409.8
1939	273.4	29.4	302.8
1940	392.1	42.4	434.5
1941	398.9	39.2	438.1
1942	134.1	20.8	154.9
1943	176.2	19.9	196.1
1944	322.5	16.3	338.8
1945	702.4	21.8	724.2
1946	729.1	37.5	766.6
1947	394.5	29.8	424.3
1948	428.5	59.4	487.9
1949	296.5	77.0	373.5
1950	398.0	93.8	491.8
1951	400.9	107.8	508.7
1952	311.8	93.9	405.7
1953	148.0	80.2	228.2
1954	186.3	100.2	286.5
1955	149.7	120.3	270.0
1956	340.3	134.5	474.8
1957	379.9	115.2	495.1
1958	596.5	197.9	794.4
1959	481.7	180.1	661.8
1960	264.0	133.9	397.9
1961	184.7	100.6	285.3
1962	123.5	117.7	241.2
1963	175.9	81.9	257.8
1964	130.8	62.6	193.4
1965	120.5	103.5	224.0
1966	171.9	112.9	284.8
1967	152.0	113.5	265.5
1968	139.4	127.3	266.7

Continued on next page

Table 14. Catch timeseries for the Southern model.

Year	Commercial (mt)	Recreational (mt)	Total (mt)
1969	67.2	154.2	221.4
1970	65.0	177.5	242.5
1971	135.9	139.9	275.8
1972	184.0	186.3	370.3
1973	344.1	238.4	582.5
1974	444.1	259.3	703.4
1975	475.9	257.4	733.3
1976	245.9	303.7	549.6
1977	295.6	268.2	563.8
1978	167.1	243.6	410.7
1979	233.6	267.3	500.9
1980	193.6	346.0	539.6
1981	386.4	427.0	813.4
1982	425.5	1213.0	1638.5
1983	992.9	590.0	1582.9
1984	1378.6	371.0	1749.6
1985	658.5	390.0	1048.5
1986	564.6	288.0	852.6
1987	498.6	249.0	747.6
1988	224.1	213.0	437.1
1989	831.5	302.0	1133.5
1990	792.2	208.6	1000.8
1991	279.0	208.6	487.6
1992	516.9	208.6	725.5
1993	212.9	71.0	283.9
1994	228.9	42.0	270.9
1995	194.5	33.0	227.5
1996	133.6	96.0	229.6
1997	331.1	402.0	733.1
1998	309.2	112.0	421.2
1999	42.9	205.0	247.9
2000	28.2	134.0	162.2
2001	2.8	56.0	58.8
2002	2.4	25.0	27.4
2003	1.2	19.0	20.2
2004	1.2	13.0	14.2
2005	5.0	20.2	25.2
2006	5.1	18.8	23.9
2007	4.3	59.8	64.1
2008	2.4	20.0	22.4
2009	1.1	48.2	49.3

Continued on next page

Table 14. Catch timeseries for the Southern model.

Year	Commercial (mt)	Recreational (mt)	Total (mt)
2010	0.9	24.1	25.0
2011	0.7	45.2	45.9
2012	0.8	52.8	53.6
2013	4.4	55.5	59.9
2014	5.3	60.1	65.4
2015	3.5	95.8	99.3
2016	1.8	31.9	33.7

Table 15. Southern model recent total catch relative to harvest specifications. The southern stock of yellowtail rockfish has been managed in the Southern Shelf Rockfish complex during this period. The values in this table represent the yellowtail harvest specification contributions to the complex and, as such, are not the reference limits used in managing fisheries catches. There were no harvest specifications for this stock prior to 2011.

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Estimated total catch (mt)
2011	1248.90	1042.20	1042.20	45.9
2012	1248.90	1042.20	1042.20	53.7
2013	1064.40	887.70	887.70	59.9
2014	1064.40	887.70	887.70	65.4
2015	1064.40	887.70	887.70	99.3
2016	1064.40	887.70	887.70	33.6
2017	1064.40	887.70	887.70	-
2018	1064.40	887.70	887.70	-

Table 16. length timeseries for the Southern model.

Year	Commercial Trawl	Tows	Hook-and-Line	Sites	Small Fish	MRFSS/RecFIN	Onboard
1978	152	30			112		
1979	126	17			194		
1980	86	35			112	1000	
1981	262	35			90	723	
1982	198	61			186	1529	
1983	298	77			141	1116	
1984	246	64			74	1729	
1985	885	80				3280	
1986	608	68				2049	
1987	184	33				920	1230
1988	284	36				632	4129
1989	671	86				1517	7869
1990	400	55					2451
1991	705	43					3506
1992	2602	134					7210
1993	1802	133				999	5952
1994	2310	132				632	5166
1995	783	52				895	8949
1996	829	79				2047	6113
1997	866	61				9213	10433
1998	726	51				5315	5127
1999	308	34				3802	
2000	162	12				861	
2001	149	25				402	
2002	4	4				764	
2003	34	3					242
2004			13	126		639	584
2005	41	3	14	122		466	1042
2006	83	2	6	88		1212	1633
2007	90	17	18	119		3063	1381
2008	78	11	15	139		1353	314
2009	67	8	15	80		2570	232
2010		7	12	60		1618	566
2011			13	126		3479	712
2012	33	6	11	106		5472	438
2013	16	13	13	96		6527	941
2014	26	16	17	110		6137	545
2015	46	20	13	78		6824	494
2016			14	89		2688	451

Table 17. Age timeseries for the Southern model.

Year	Commercial Trawl	Tows	Hook-and-Line	Sites	Small Fish
1980	54	35			31
1981	113	35			88
1982	114	61			167
1983	240	77			116
1984	161	64			
1985	382	80			
1986	500	68			
1987	65	33			
1988	141	36			
1989	458	86			
1990	213	55			
1991	263	43			
1992	379	134			
1993	141	133			
1994	216	132			
1995	76	52			
1996	332	79			
1997	169	61			
1998	122	51			
1999	169	34			
2000	10	12			
2001	2	2			
2002	3	3			
2003					
2004			248	13	

Table 18. Summary of the biomass/abundance time series used in the Southern model.

Years	Name	Fishery ind.	Method	Endorsed
1981-2003	Dockside CPUE	No	delta-GLM (bin-lognormal)	SSC
1987-2006	Onboard CPUE	No	Polygon	SSC
2004-2016	Hook-and-Line	Yes	Binomial GLM	
2001-2016	Juvenile CPUE	Yes	Delta-GLM	

Table 19. CPUE timeseries for the Southern model. The SE values represent standard error on a log scale, which is similar to a CV. The two time periods for the onboard survey were treated as independent indices.

Year	Hook and Line	SE	Onboard	SE	Recreational	SE	Juvenile Survey	SE
1980					0.17	0.17		
1981					0.14	0.20		
1982					0.34	0.15		
1983					0.33	0.17		
1984					0.34	0.13		
1985					0.38	0.11		
1986					0.37	0.13		
1987			0.81	0.13	0.12	0.24		
1988			0.63	0.10	0.13	0.20		
1989			0.85	0.08	0.31	0.21		
1990			0.91	0.13				
1991			0.81	0.12				
1992			0.75	0.09				
1993			0.49	0.09	0.50	0.45		
1994			0.53	0.08	0.43	0.31		
1995			0.65	0.08	0.47	0.20		
1996			0.58	0.08	0.28	0.13		
1997			0.70	0.07	1.18	0.13		
1998			0.55	0.09	0.72	0.17		
1999					0.32	0.15		
2000					0.20	0.29		
2001			0.16	0.19	0.09	0.22	2.72	0.40
2002			0.26	0.14	0.11	0.23	3.66	0.32
2003			0.20	0.10	0.08	0.25	4.55	0.30
2004	0.11	0.36	0.21	0.09			12.87	0.29
2005	0.14	0.32	0.29	0.08			1.54	0.75
2006	0.12	0.34	0.47	0.07			1.22	0.83
2007	0.17	0.32	0.62	0.06			1.35	0.80
2008	0.07	0.39	0.23	0.08			4.65	0.28
2009	0.09	0.40	0.34	0.08			4.98	0.30
2010	0.06	0.45	0.21	0.08			3.90	0.44
2011	0.05	0.42	0.62	0.07			2.99	0.47
2012	0.07	0.40	0.35	0.08			2.71	0.69
2013	0.09	0.42	0.76	0.07			8.96	0.30
2014	0.06	0.40	0.66	0.07			5.96	0.32
2015	0.09	0.37	0.60	0.07			5.03	0.39
2016	0.05	0.43	0.22	0.09			1.75	0.82

Table 20. List of parameters used in the Southern base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
1	NatM_p_1_Fem_GP_1	0.174	-2	(0.02, 0.25)			None
2	L_at_Amin_Fem_GP_1	18.448	3	(1, 25)	OK	0.643	None
3	L_at_Amax_Fem_GP_1	49.651	2	(35, 70)	OK	0.328	None
4	VonBert_K_Fem_GP_1	0.109	3	(0.1, 0.4)	OK	0.005	None
5	CV_young_Fem_GP_1	0.078	5	(0.03, 0.16)	OK	0.014	None
6	CV_old_Fem_GP_1	0.057	5	(0.03, 0.16)	OK	0.006	None
7	Wtlen_1_Fem	0.000	-50	(0, 3)			None
8	Wtlen_2_Fem	3.067	-50	(2, 4)			None
9	Mat50%_Fem	42.490	-50	(30, 56)			None
10	Mat_slope_Fem	-0.401	-50	(-2, 1)			None
11	Eggs_scalar_Fem	0.000	-50	(0, 6)			None
12	Eggs_exp_len_Fem	4.590	-50	(2, 7)			None
13	NatM_p_1_Mal_GP_1	-0.149	-2	(-3, 3)			Normal (0, 99)
14	L_at_Amin_Mal_GP_1	0.000	-2	(-1, 1)			None
15	L_at_Amax_Mal_GP_1	-0.112	2	(-1, 1)	OK	0.011	None
16	VonBert_K_Mal_GP_1	0.163	3	(-1, 1)	OK	0.059	None
17	CV_young_Mal_GP_1	0.000	-5	(-1, 1)			None
18	CV_old_Mal_GP_1	0.119	5	(-1, 1)	OK	0.125	None
19	Wtlen_1_Mal	0.000	-50	(0, 3)			None
20	Wtlen_2_Mal	3.067	-50	(2, 4)			None
24	CohortGrowDev	1.000	-1	(1, 1)			None
25	FracFemale_GP_1	0.500	-99	(0.001, 0.999)			None
26	SR_LN(R0)	10.147	1	(8, 12)	OK	0.560	None
27	SR_BH_steep	0.718	-6	(0.2, 1)			None
28	SR_sigmaR	0.770	-6	(0.5, 1.2)			None
29	SR_regime	0.000	-50	(-5, 5)			None

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Table 20. List of parameters used in the Southern base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
30	SR_autocorr	0.000	-50	(0, 2)			None
129	LnQ_base_OnboardSurvey_Early(3)	-11.487	-1	(-30, 15)			None
130	Q_extraSD_OnboardSurvey_Early(3)	0.150	1	(0, 0.5)	OK	0.057	None
131	LnQ_base_OnboardSurvey_Late(4)	-12.311	-1	(-30, 15)			None
132	Q_extraSD_OnboardSurvey_Late(4)	0.313	1	(0, 0.5)	OK	0.074	None
133	LnQ_base_HookAndLineSurvey(5)	-12.890	-1	(-30, 15)			None
134	Q_extraSD_HookAndLineSurvey(5)	0.198	1	(0, 0.5)	OK	0.117	None
135	LnQ_base_JuvenilePelagic(6)	-8.989	-1	(-30, 15)			None
136	Q_extraSD_JuvenilePelagic(6)	0.235	1	(0, 0.5)	OK	0.129	None
144	SizeSel_P1_CommercialCatch(2)	55.000	1	(20, 55)	HI	0.000	None
145	SizeSel_P2_CommercialCatch(2)	20.000	-4	(-20, 20)			None
146	SizeSel_P3_CommercialCatch(2)	5.283	3	(-5, 20)	OK	0.044	None
147	SizeSel_P4_CommercialCatch(2)	20.000	-4	(-5, 20)			None
148	SizeSel_P5_CommercialCatch(2)	-999.000	-99	(-999, 25)			None
149	SizeSel_P6_CommercialCatch(2)	-999.000	-99	(-999, 25)			None
150	SizeSel_P1_OnboardSurvey_Early(3)	30.024	1	(20, 55)	OK	1.076	None
151	SizeSel_P2_OnboardSurvey_Early(3)	-20.000	-4	(-20, 7)			None
152	SizeSel_P3_OnboardSurvey_Early(3)	3.164	3	(-5, 20)	OK	0.342	None
153	SizeSel_P4_OnboardSurvey_Early(3)	19.961	4	(-5, 20)	HI	193.002	None
154	SizeSel_P5_OnboardSurvey_Early(3)	-999.000	-99	(-999, 25)			None
155	SizeSel_P6_OnboardSurvey_Early(3)	-999.000	-99	(-999, 25)			None
156	SizeSel_P1_OnboardSurvey_Late(4)	30.003	1	(20, 55)	OK	0.937	None
157	SizeSel_P2_OnboardSurvey_Late(4)	-20.000	-4	(-20, 7)			None
158	SizeSel_P3_OnboardSurvey_Late(4)	4.199	3	(-5, 20)	OK	0.299	None
159	SizeSel_P4_OnboardSurvey_Late(4)	3.123	4	(-5, 20)	OK	0.440	None
160	SizeSel_P5_OnboardSurvey_Late(4)	-999.000	-99	(-999, 25)			None
161	SizeSel_P6_OnboardSurvey_Late(4)	-999.000	-99	(-999, 25)			None

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Table 20. List of parameters used in the Southern base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
162	SizeSel_P1_HookAndLineSurvey(5)	48.191	1	(20, 55)	OK	3.740	None
163	SizeSel_P2_HookAndLineSurvey(5)	20.000	-4	(-20, 20)			None
164	SizeSel_P3_HookAndLineSurvey(5)	5.141	3	(-5, 20)	OK	0.298	None
165	SizeSel_P4_HookAndLineSurvey(5)	20.000	-4	(-5, 20)			None
166	SizeSel_P5_HookAndLineSurvey(5)	-999.000	-99	(-999, 25)			None
167	SizeSel_P6_HookAndLineSurvey(5)	-999.000	-99	(-999, 25)			None
168	SizeSel_P1_SmallFish(7)	46.393	1	(20, 55)	OK	2.167	None
169	SizeSel_P2_SmallFish(7)	20.000	-4	(-20, 20)			None
170	SizeSel_P3_SmallFish(7)	5.189	3	(-5, 20)	OK	0.198	None
171	SizeSel_P4_SmallFish(7)	20.000	-4	(-5, 20)			None
172	SizeSel_P5_SmallFish(7)	-999.000	-99	(-999, 25)			None
173	SizeSel_P6_SmallFish(7)	-999.000	-99	(-999, 25)			None
174	AgeSel_P1_JuvenilePelagic(6)	0.000	-1	(0, 40)			None
175	AgeSel_P2_JuvenilePelagic(6)	0.000	-1	(0, 40)			None

Table 23. Time-series of population estimates from the final Southern model .

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1889	76342	4.40	0.00	25564	1	0.00	1.00
1890	76345	4.40	1.00	25564	18	0.00	1.00
1891	76335	4.40	1.00	25563	37	0.00	0.99
1892	76312	4.40	1.00	25561	55	0.00	0.99
1893	76277	4.39	1.00	25558	73	0.00	0.98
1894	76231	4.38	1.00	25553	92	0.00	0.98
1895	76175	4.37	0.99	25549	110	0.00	0.97
1896	76109	4.36	0.99	25543	128	0.00	0.97
1897	76034	4.35	0.99	25536	146	0.00	0.96
1898	75951	4.34	0.99	25530	165	0.00	0.96
1899	75861	4.33	0.98	25522	183	0.00	0.96
1900	75764	4.31	0.98	25514	201	0.00	0.95
1901	75660	4.30	0.98	25506	220	0.00	0.95
1902	75550	4.28	0.97	25497	238	0.00	0.94
1903	75434	4.27	0.97	25488	256	0.00	0.94
1904	75314	4.25	0.97	25478	275	0.00	0.93
1905	75189	4.23	0.96	25468	293	0.00	0.93
1906	75059	4.22	0.96	25458	311	0.00	0.93
1907	74926	4.20	0.95	25448	330	0.00	0.92
1908	74790	4.18	0.95	25437	348	0.01	0.92
1909	74650	4.16	0.95	25426	366	0.01	0.91
1910	74507	4.14	0.94	25414	385	0.01	0.91
1911	74361	4.12	0.94	25403	403	0.01	0.90
1912	74213	4.10	0.93	25391	421	0.01	0.90
1913	74062	4.08	0.93	25378	439	0.01	0.89
1914	73910	4.06	0.92	25366	458	0.01	0.89
1915	73755	4.04	0.92	25354	476	0.01	0.89
1916	73599	4.02	0.91	25341	494	0.01	0.88
1917	73441	4.00	0.91	25328	769	0.01	0.83
1918	73052	3.96	0.90	25296	904	0.01	0.80
1919	72580	3.90	0.89	25257	622	0.01	0.85
1920	72406	3.87	0.88	25240	636	0.01	0.85
1921	72235	3.85	0.87	25224	528	0.01	0.87
1922	72177	3.84	0.87	25218	454	0.01	0.89
1923	72189	3.84	0.87	25219	489	0.01	0.88
1924	72167	3.84	0.87	25217	290	0.00	0.93
1925	72322	3.86	0.88	25231	377	0.01	0.91
1926	72384	3.87	0.88	25238	576	0.01	0.86
1927	72260	3.86	0.88	25230	476	0.01	0.88

Table 23. Time-series of population estimates from the final Southern model .

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1928	72237	3.86	0.88	25229	554	0.01	0.87
1929	72146	3.85	0.87	25223	472	0.01	0.88
1930	72136	3.85	0.87	25224	687	0.01	0.84
1931	71934	3.83	0.87	25208	636	0.01	0.85
1932	71797	3.81	0.87	25196	513	0.01	0.87
1933	71782	3.81	0.86	25195	333	0.01	0.92
1934	71930	3.83	0.87	25208	370	0.01	0.91
1935	72029	3.84	0.87	25217	454	0.01	0.89
1936	72043	3.84	0.87	25220	551	0.01	0.87
1937	71968	3.84	0.87	25215	496	0.01	0.88
1938	71948	3.84	0.87	25214	410	0.01	0.90
1939	72008	3.84	0.87	25220	303	0.00	0.92
1940	72157	3.86	0.88	25234	434	0.01	0.89
1941	72173	3.87	0.88	25237	438	0.01	0.89
1942	72184	3.87	0.88	25239	155	0.00	0.96
1943	72448	3.90	0.89	25261	196	0.00	0.95
1944	72651	3.93	0.89	25278	339	0.01	0.92
1945	72707	3.94	0.89	26225	724	0.01	0.83
1946	72488	3.90	0.89	26265	767	0.01	0.82
1947	72295	3.87	0.88	26308	424	0.01	0.89
1948	72473	3.87	0.88	26371	488	0.01	0.88
1949	72620	3.86	0.88	26424	373	0.01	0.91
1950	72895	3.87	0.88	26470	492	0.01	0.88
1951	73071	3.87	0.88	26514	509	0.01	0.88
1952	73245	3.87	0.88	26566	406	0.01	0.90
1953	73522	3.88	0.88	26657	228	0.00	0.94
1954	73960	3.91	0.89	26822	286	0.00	0.93
1955	74333	3.94	0.89	27048	270	0.00	0.94
1956	74721	3.96	0.90	27380	475	0.01	0.89
1957	74938	3.97	0.90	27947	495	0.01	0.88
1958	75196	3.98	0.90	29192	794	0.01	0.82
1959	75308	3.96	0.90	31941	662	0.01	0.85
1960	75842	3.95	0.90	37250	398	0.01	0.91
1961	77184	3.97	0.90	43118	285	0.00	0.93
1962	79364	4.00	0.91	40719	241	0.00	0.94
1963	81798	4.04	0.92	35077	258	0.00	0.94
1964	84008	4.07	0.93	32564	193	0.00	0.95
1965	86028	4.12	0.94	37136	224	0.00	0.95
1966	88170	4.17	0.95	34139	285	0.00	0.94

Table 23. Time-series of population estimates from the final Southern model .

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1967	89937	4.23	0.96	23235	265	0.00	0.94
1968	90666	4.31	0.98	18645	267	0.00	0.95
1969	90466	4.41	1.00	18212	221	0.00	0.96
1970	89607	4.54	1.03	14487	242	0.00	0.95
1971	87854	4.67	1.06	9962	276	0.00	0.95
1972	85149	4.80	1.09	9194	370	0.00	0.93
1973	81728	4.92	1.12	12124	582	0.01	0.89
1974	77925	4.99	1.13	14653	703	0.01	0.87
1975	74072	5.01	1.14	18655	733	0.01	0.86
1976	70599	4.98	1.13	13022	550	0.01	0.89
1977	67169	4.92	1.12	14116	564	0.01	0.88
1978	63977	4.81	1.09	12182	411	0.01	0.90
1979	61002	4.67	1.06	10791	501	0.01	0.88
1980	58004	4.47	1.02	14700	540	0.01	0.87
1981	55414	4.25	0.97	20474	813	0.02	0.80
1982	53315	3.99	0.91	12735	1638	0.03	0.63
1983	50325	3.66	0.83	9443	1583	0.04	0.63
1984	47438	3.33	0.76	28059	1750	0.04	0.59
1985	46015	3.00	0.68	27438	1049	0.03	0.70
1986	45931	2.78	0.63	14097	853	0.02	0.73
1987	45573	2.61	0.59	18958	748	0.02	0.75
1988	45723	2.46	0.56	22147	437	0.01	0.84
1989	46521	2.38	0.54	27061	1134	0.03	0.65
1990	47222	2.24	0.51	24619	1001	0.03	0.68
1991	48184	2.15	0.49	27124	488	0.01	0.82
1992	49969	2.13	0.48	17904	726	0.02	0.75
1993	50959	2.12	0.48	21019	284	0.01	0.89
1994	52392	2.17	0.49	11873	271	0.01	0.89
1995	52962	2.24	0.51	7990	227	0.00	0.91
1996	52801	2.32	0.53	6683	230	0.00	0.92
1997	51977	2.42	0.55	6966	733	0.01	0.78
1998	50189	2.50	0.57	14165	421	0.01	0.86
1999	48911	2.59	0.59	33240	248	0.01	0.92
2000	49258	2.70	0.61	10164	162	0.00	0.94
2001	48552	2.80	0.64	16301	59	0.00	0.98
2002	48301	2.88	0.65	30999	27	0.00	0.99
2003	49299	2.92	0.66	41635	20	0.00	0.99
2004	51675	2.93	0.66	38536	14	0.00	1.00
2005	54635	2.90	0.66	14306	25	0.00	0.99

Table 23. Time-series of population estimates from the final Southern model .

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
2006	56256	2.86	0.65	13674	24	0.00	0.99
2007	57432	2.83	0.64	18080	64	0.00	0.98
2008	58429	2.80	0.64	103477	22	0.00	0.99
2009	65827	2.81	0.64	58704	49	0.00	0.99
2010	72212	2.84	0.65	87542	25	0.00	0.99
2011	81633	2.91	0.66	51002	46	0.00	0.99
2012	89562	3.02	0.69	25476	54	0.00	0.99
2013	95273	3.16	0.72	42544	60	0.00	0.99
2014	100994	3.32	0.75	33499	65	0.00	0.99
2015	105187	3.51	0.80	30739	99	0.00	0.98
2016	108046	3.77	0.86	20871			

Table 21. Sensitivity of the Southern model to a variety of alternative assumptions (first of two tables).

Label	Base	No_Ages	No_Lengths	No_Comm	No_HnL	No_MRFSS	No_Onboard	No_Small
TOTAL_like	519.58	289.02	173.12	424.52	453.55	405.61	471.18	476.98
Survey_like	5.78	2.46	-17.56	9.60	3.06	-11.68	5.85	5.97
Length_comp_like	289.10	277.76	0.00	203.16	240.72	205.83	238.48	258.20
Age_comp_like	216.53	0.00	188.93	205.73	202.53	209.21	217.63	205.00
Parm_priors_like	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recr_Virgin_millions	10.43	15.90	9.11	5.12	10.06	0.00	9.92	10.27
SR_LN(R0)	9.25	9.67	9.12	8.54	9.22	9.86	9.20	9.24
SR_BH_steep	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
NatM_p_1_Fem_GP_1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
NatM_p_1_Mal_GP_1	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14
L_at_Amax_Fem_GP_1	49.64	48.86	47.39	48.99	49.62	49.68	49.59	49.64
L_at_Amax_Mal_GP_1	-0.11	-0.12	-0.08	-0.10	-0.10	-0.11	-0.11	-0.12
VonBert_K_Fem_GP_1	0.10	0.10	0.17	0.11	0.10	0.11	0.10	0.10
VonBert_K_Mal_GP_1	0.14	-0.10	0.14	0.14	0.17	0.19	0.13	0.17
SPB_Virgin_thousand_mt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bratio_2017	0.74	0.76	0.71	0.44	0.74	0.00	0.73	0.72
SPRratio_2016	0.03	0.02	0.04	0.07	0.03	0.99	0.03	0.03

Table 22. Sensitivity of the Southern model to a variety of alternative assumptions (second of two tables).

Label	Base	No_CPUEs	No_HnL.1	No_Juv	No_Rec	No_Onboard	M_Age_64	M_Est	Add_Combo	M.I_Tune
TOTAL_like	519.58	500.49	514.99	514.10	517.49	517.68	543.47	480.67	524.95	1189.54
Survey_like	5.78	0.00	5.36	8.66	4.00	5.47	16.37	-1.13	3.39	26.23
Length_comp_like	289.10	269.25	283.12	280.15	289.02	286.56	304.50	268.57	287.90	443.52
Age_comp_like	216.53	215.55	216.01	216.43	216.09	216.52	212.31	202.75	221.57	699.04
Parm_priors_like	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recr_Virgin_millions	10.43	9.83	9.76	10.54	10.49	10.30	0.00	162.76	4.29	11.79
SR_LN(R0)	9.25	9.19	9.19	9.26	9.26	9.24	8.00	12.00	8.36	9.37
SR_BH_steep	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
NatM_p_1_Fem_GP_1	0.15	0.15	0.15	0.15	0.15	0.15	0.08	0.21	0.15	0.15
NatM_p_1_Mal_GP_1	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	0.00	0.07	-0.14	-0.14
L_at_Amax_Fem_GP_1	49.64	49.75	49.65	49.66	49.65	49.64	49.10	49.32	49.59	49.48
L_at_Amax_Mal_GP_1	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.10	-0.10	-0.10	-0.11
VonBert_K_Fem_GP_1	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.12
VonBert_K_Mal_GP_1	0.14	0.13	0.13	0.14	0.14	0.14	0.16	0.22	0.08	0.16
SPB_Virgin_thousand_mt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Bratio_2017	0.74	0.85	0.75	0.77	0.75	0.74	0.00	0.75	0.46	0.90
SPRratio_2016	0.03	0.02	0.02	0.02	0.02	0.02	0.96	0.00	0.09	0.01

Table 24. Projection of potential OFL, spawning output, and depletion for the Southern base case model.

Yr	OFL contribution (mt)	ACL landings (mt)	Age 4+ biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output
2017	4560.98	4360.30	99352.70	4.10	0.93
2018	4433.10	4238.05	96545.10	4.29	0.98
2019	4259.28	4071.87	92935.30	4.50	1.02
2020	4056.53	3878.05	87601.60	4.68	1.06
2021	3847.28	3678.00	82927.30	4.80	1.09
2022	3646.27	3485.83	78472.60	4.83	1.10
2023	3459.55	3307.33	74347.00	4.79	1.09
2024	3289.49	3144.76	70608.20	4.68	1.06
2025	3136.96	2998.94	67276.10	4.51	1.02
2026	3001.89	2869.81	64344.60	4.31	0.98
2027	2883.48	2756.60	61790.70	4.09	0.93
2028	2780.44	2658.10	59581.00	3.87	0.88

9 Figures

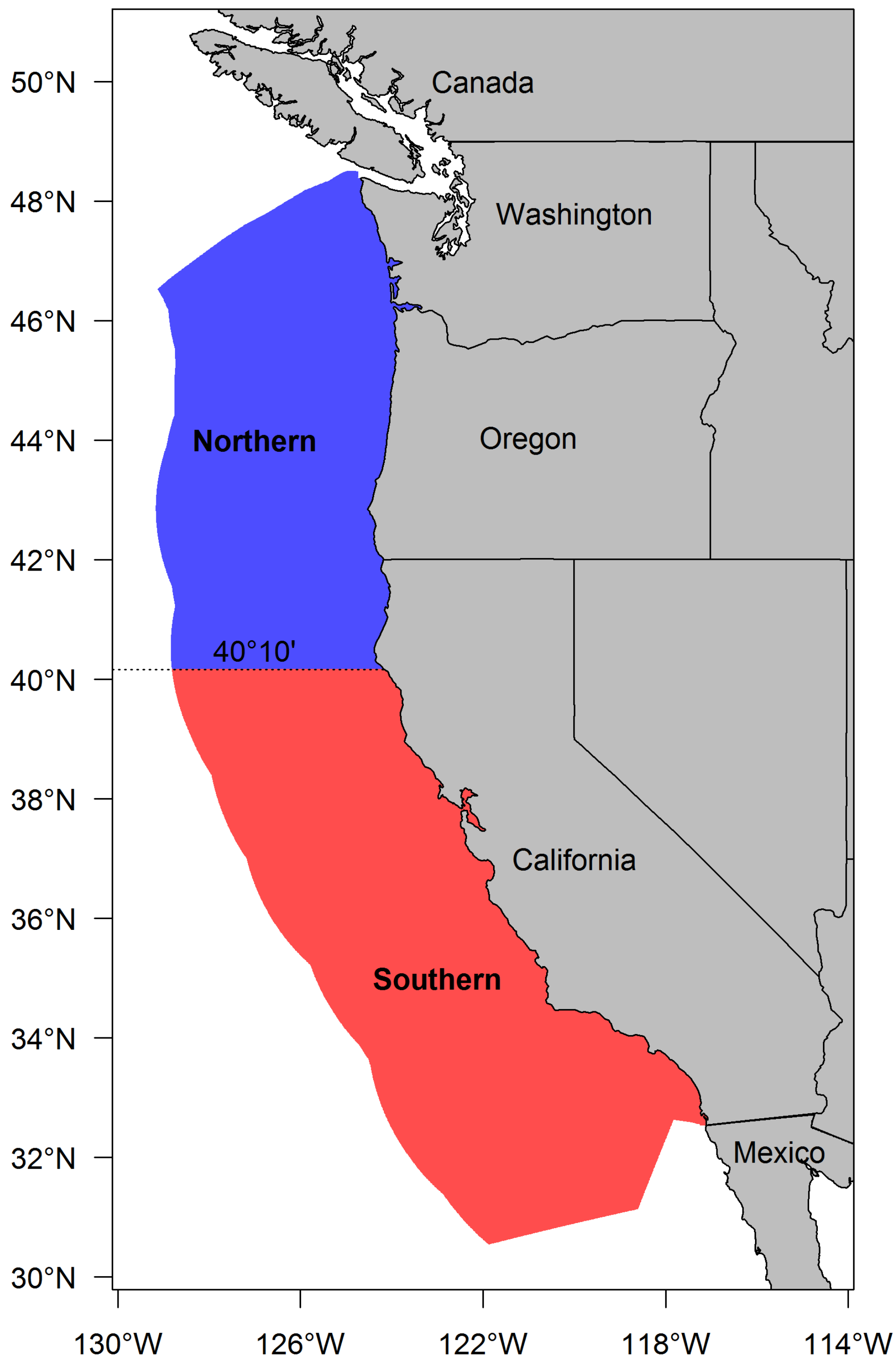


Figure 1: Map depicting the boundaries for the base-case model.

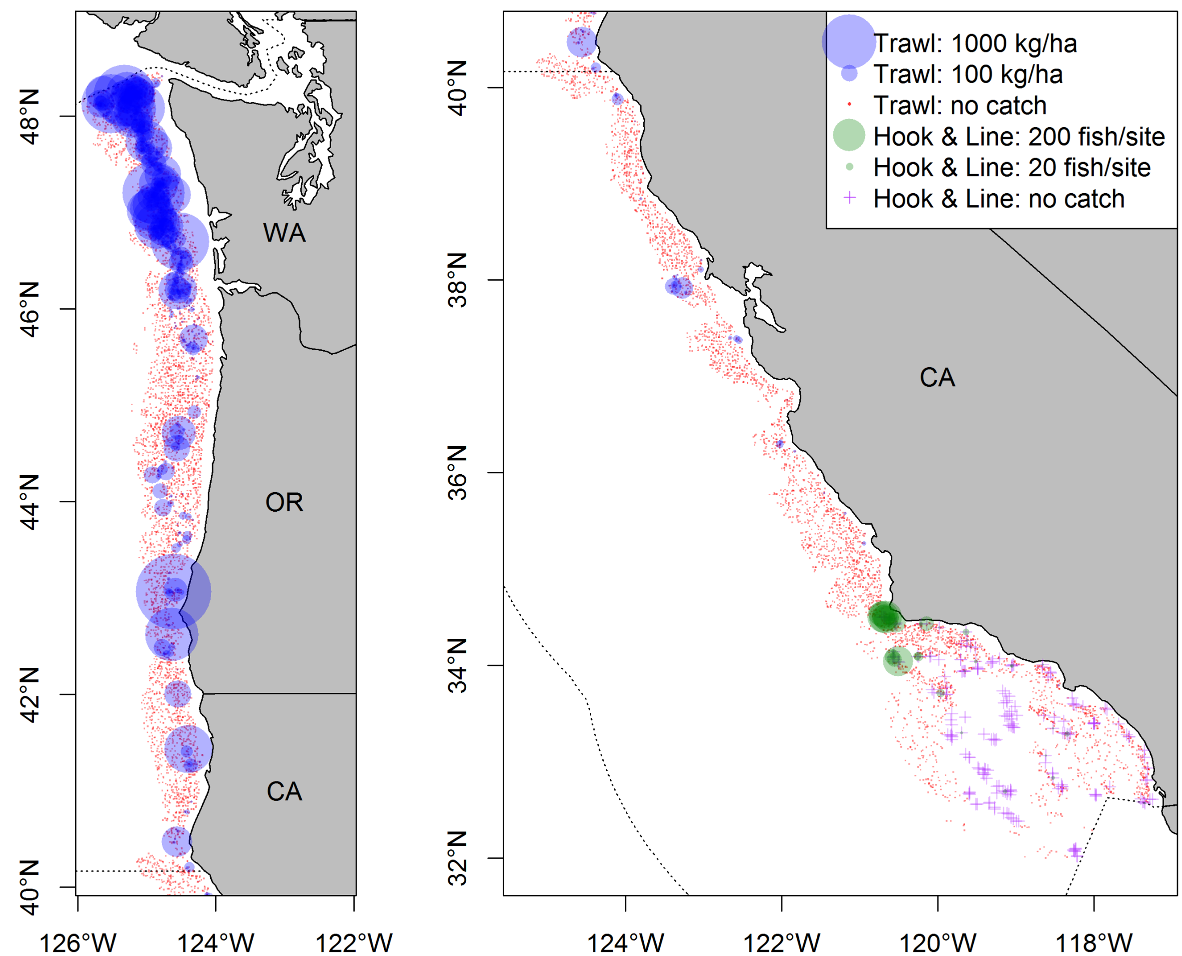


Figure 2: Map showing observations of Yellowtail Rockfish in the NWFSCcombo trawl survey and Hook & Line survey.

1570 9.1 Life history (maturity, fecundity, and growth) for both models

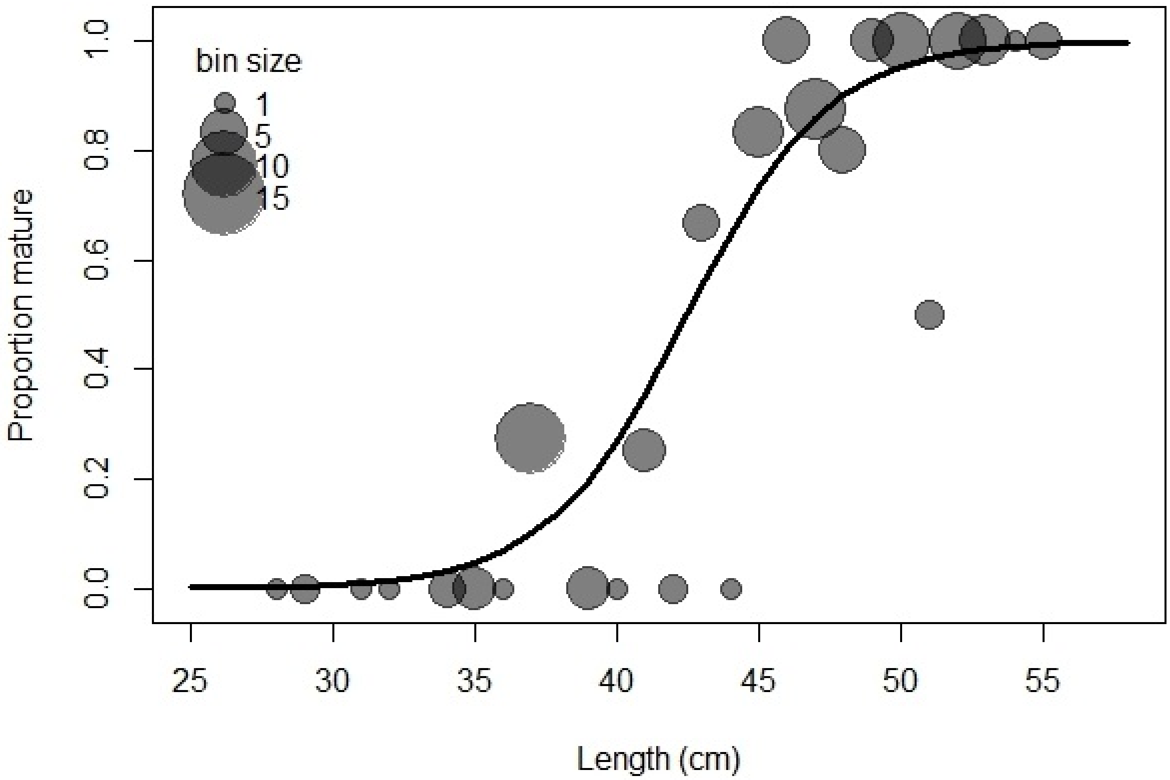


Figure 3: Estimated maturity relationship for Yellowtail Rockfish used in both models. Gray points indicate average observed functional maturity within each length bin with point size proportional to the number of samples.

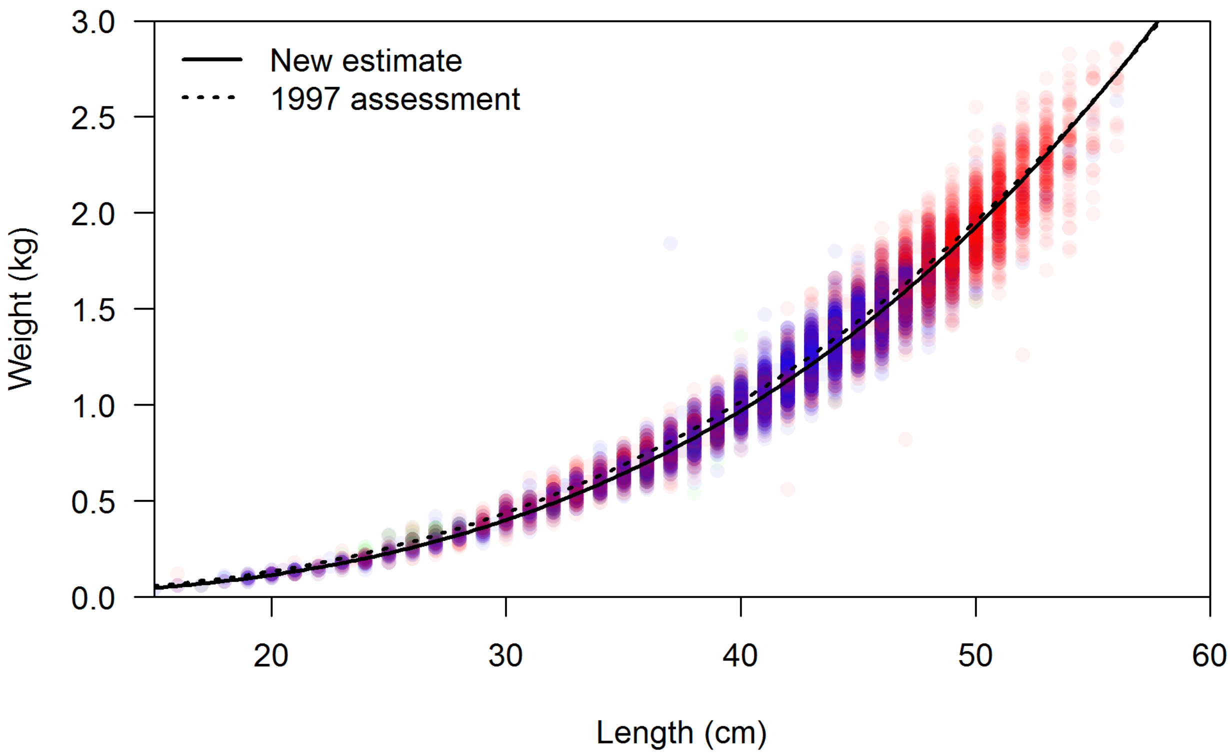


Figure 4: Estimated weight-length relationship for Yellowtail Rockfish used in both models. Colored points show observed values (red for females, blue for males, and green for unsexed). The black line indicates the estimated relationship $W = 0.000011843L^{3.0672}$.

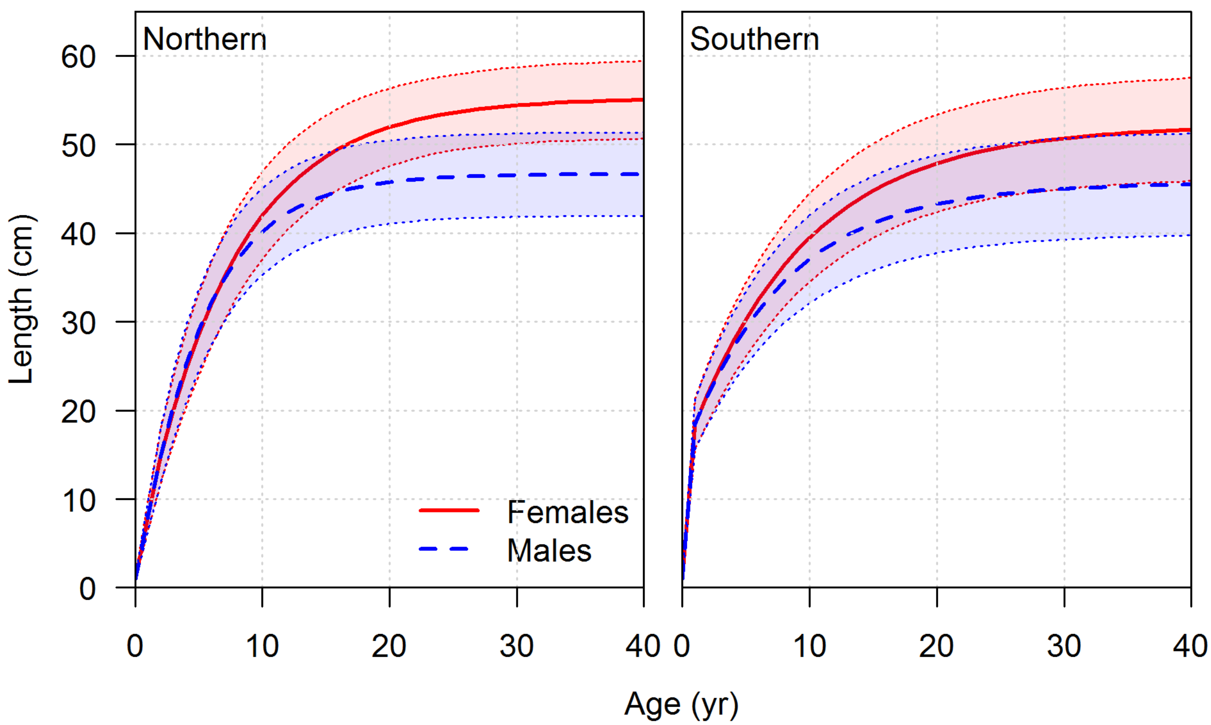


Figure 5: Estimated length-at-age for female and male Yellowtail Rockfish in each model. Shaded areas indicate 95% intervals for distribution of lengths at each age. Values represent beginning-of-year growth.

1571 9.2 Data and model fits for the Northern model

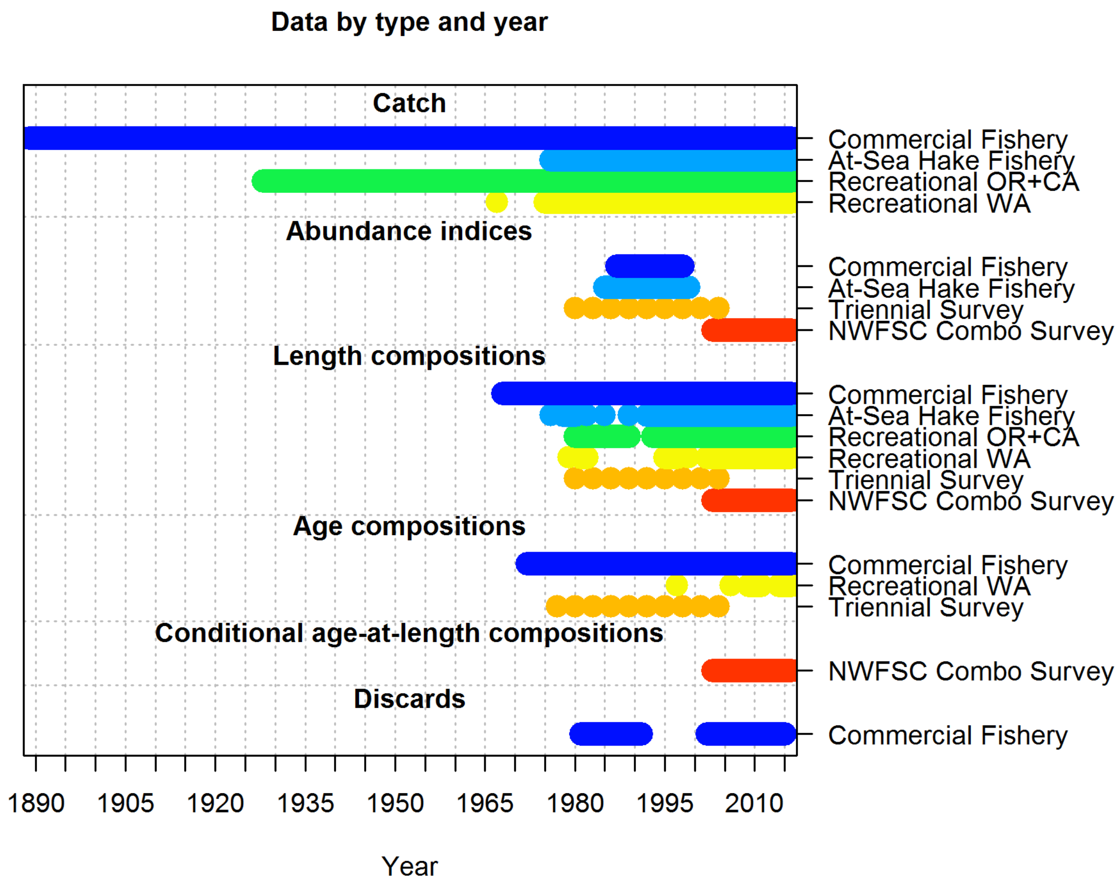


Figure 6: Summary of data sources used in the Northern model.

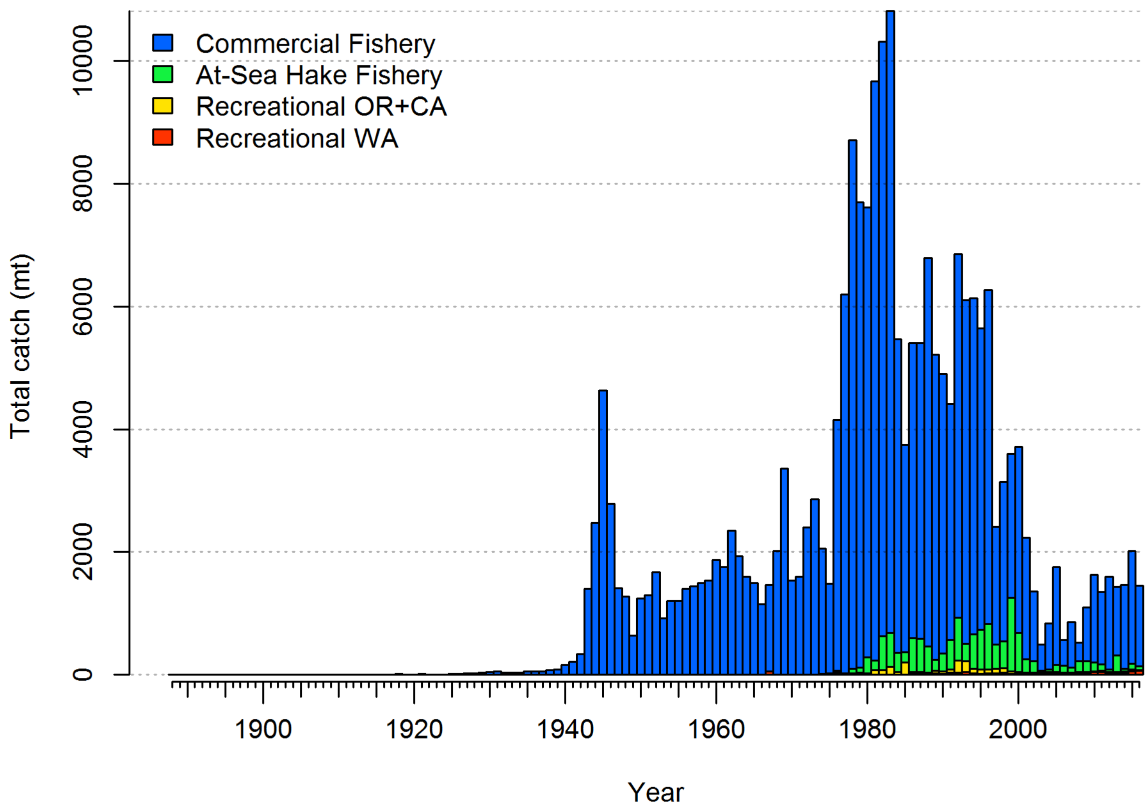


Figure 7: Estimated catch history of Yellowtail Rockfish in the Northern model. Recreational catches in Washington are model estimates of total weigth converted from input catch in numbers using model estimates of growth and selectivity. Catches for the Commercial Fishery include estimated discards.

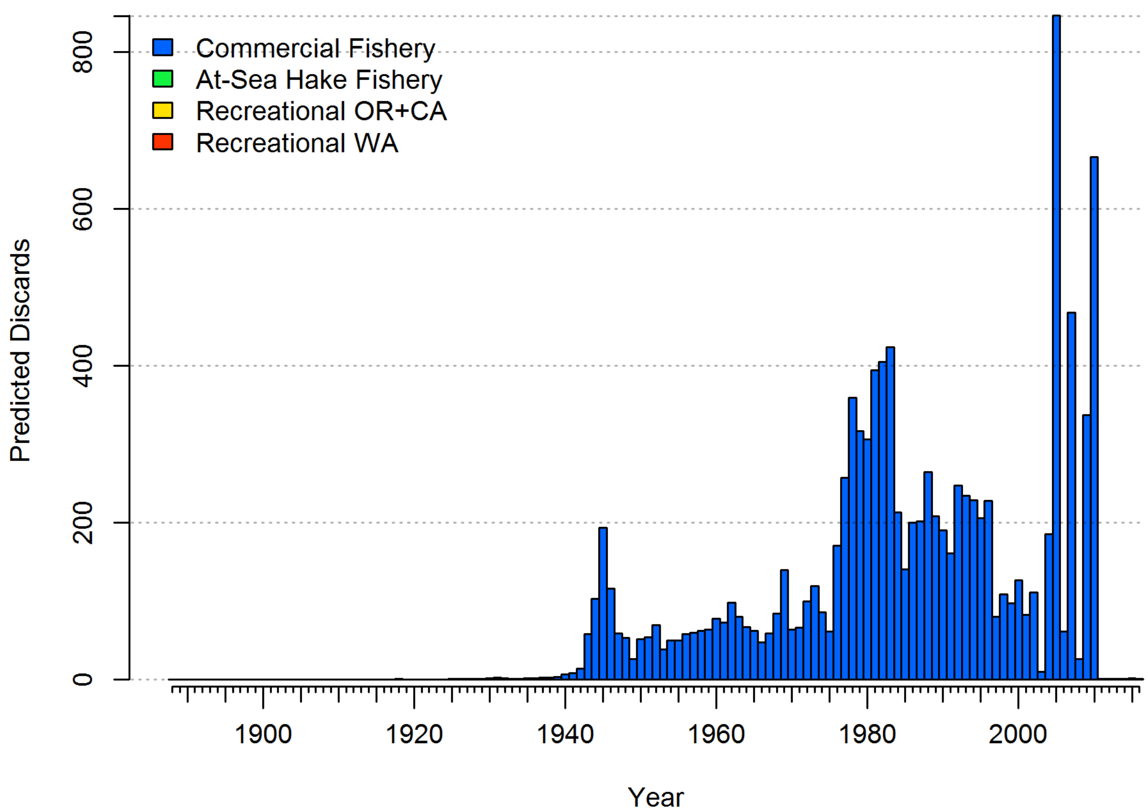


Figure 8: Estimated discards in the Commercial Fishery in the Northern model. Estimates are influenced by the data for landings, discard ratios, and discard length combines and depend on the estimated parameters controlling selectivity and retention.

1572 ### 9.2.1 Selectivity, retention, and discards for Northern model

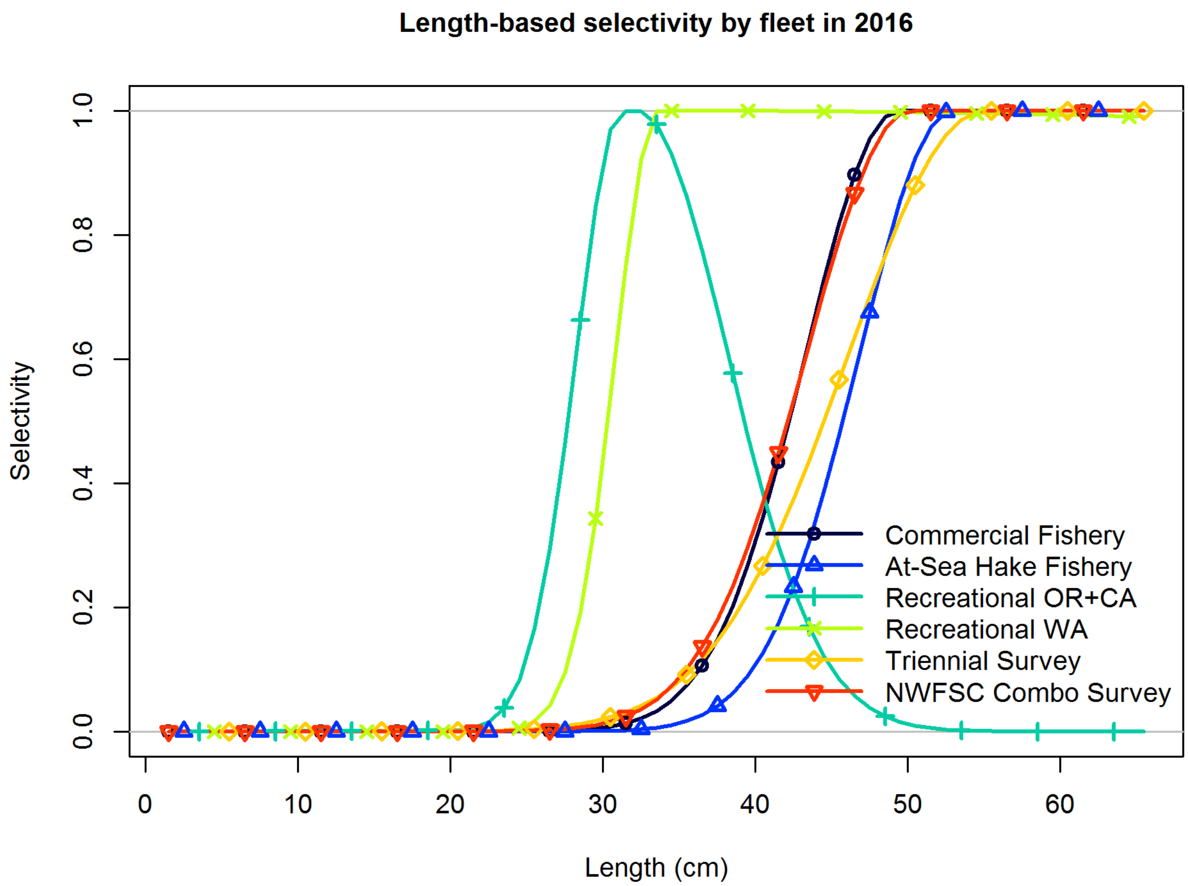


Figure 9: Estimated selectivity by length for each fishery and survey in the Northern model.

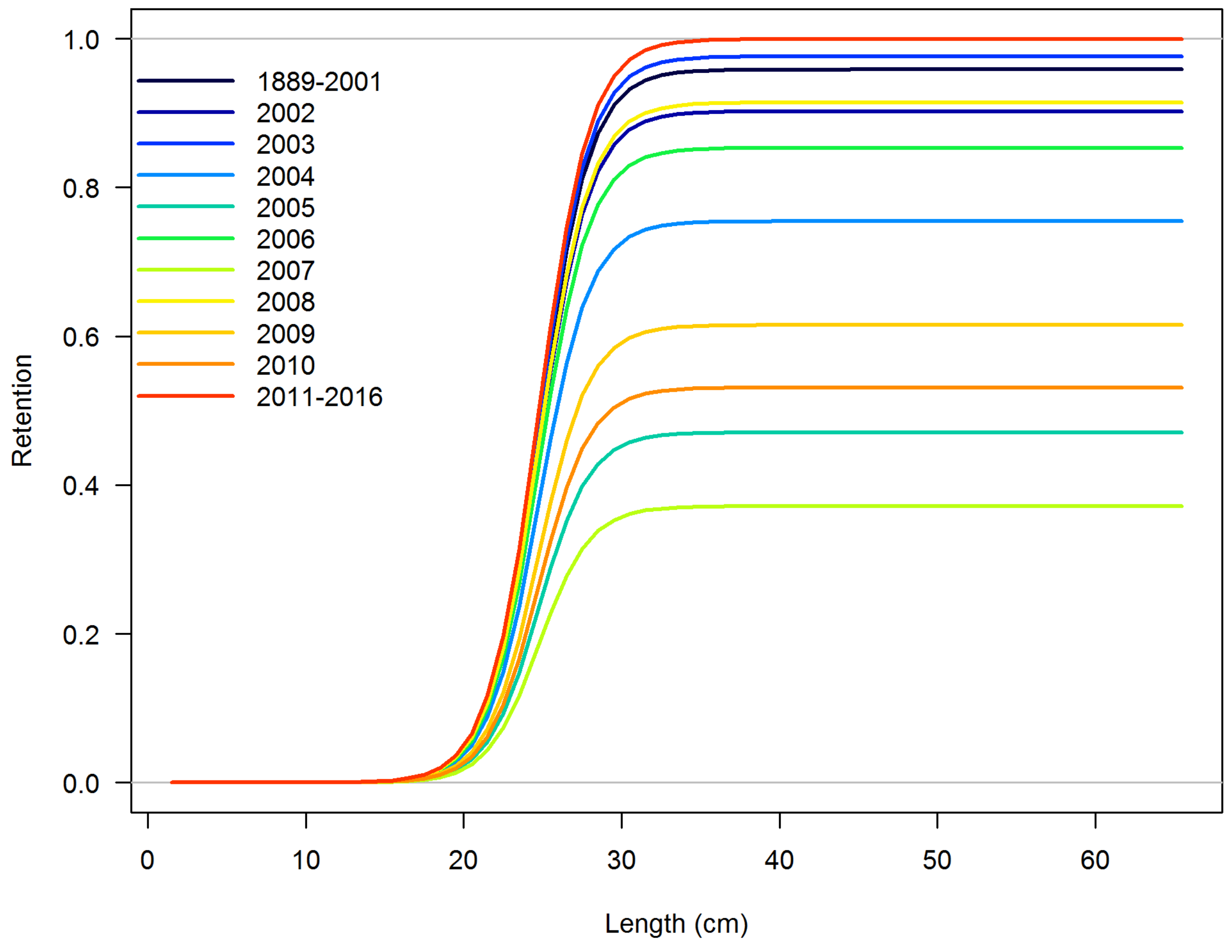


Figure 10: Estimated retention by length by the Commercial Fishery in the Northern model.

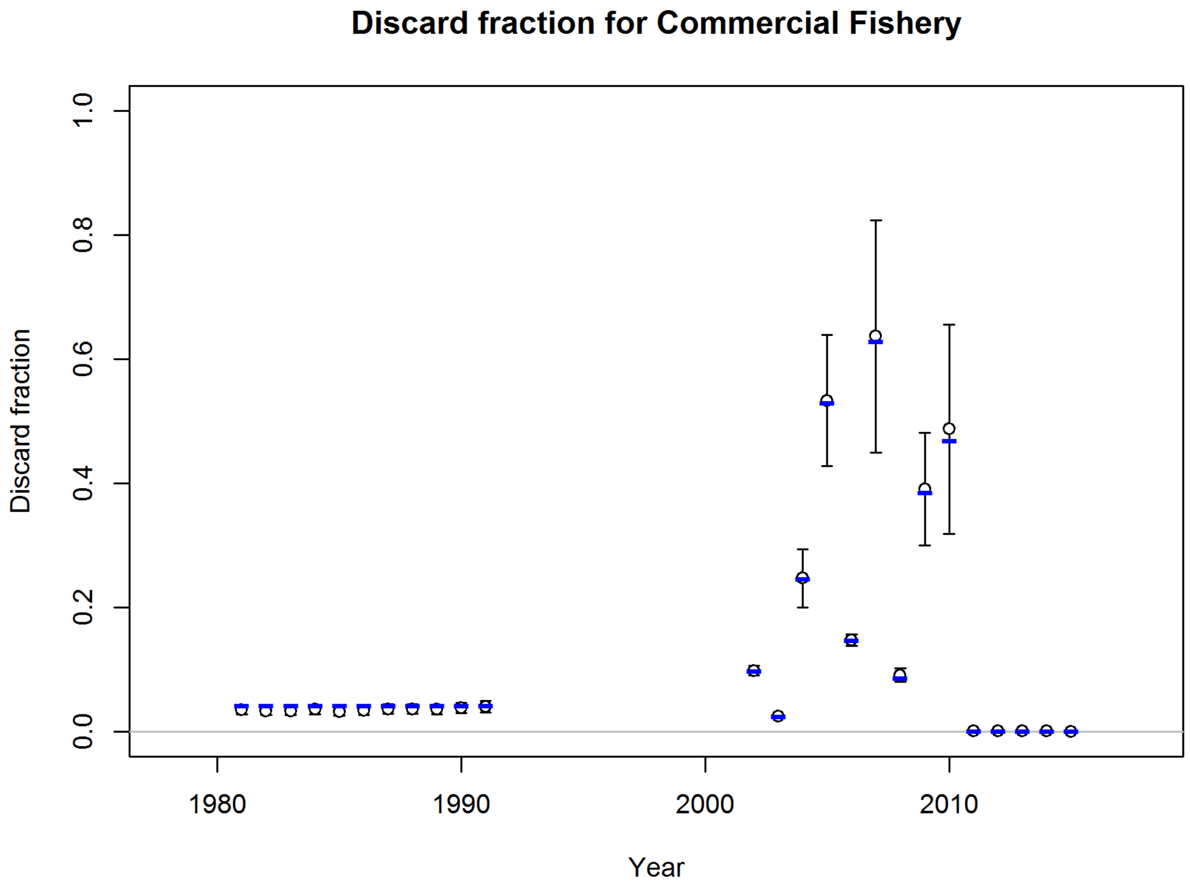


Figure 11: Fit to discard fractions for the commercial fishery in the Northern model.

9.2.2 At-Sea Hake Bycatch Index

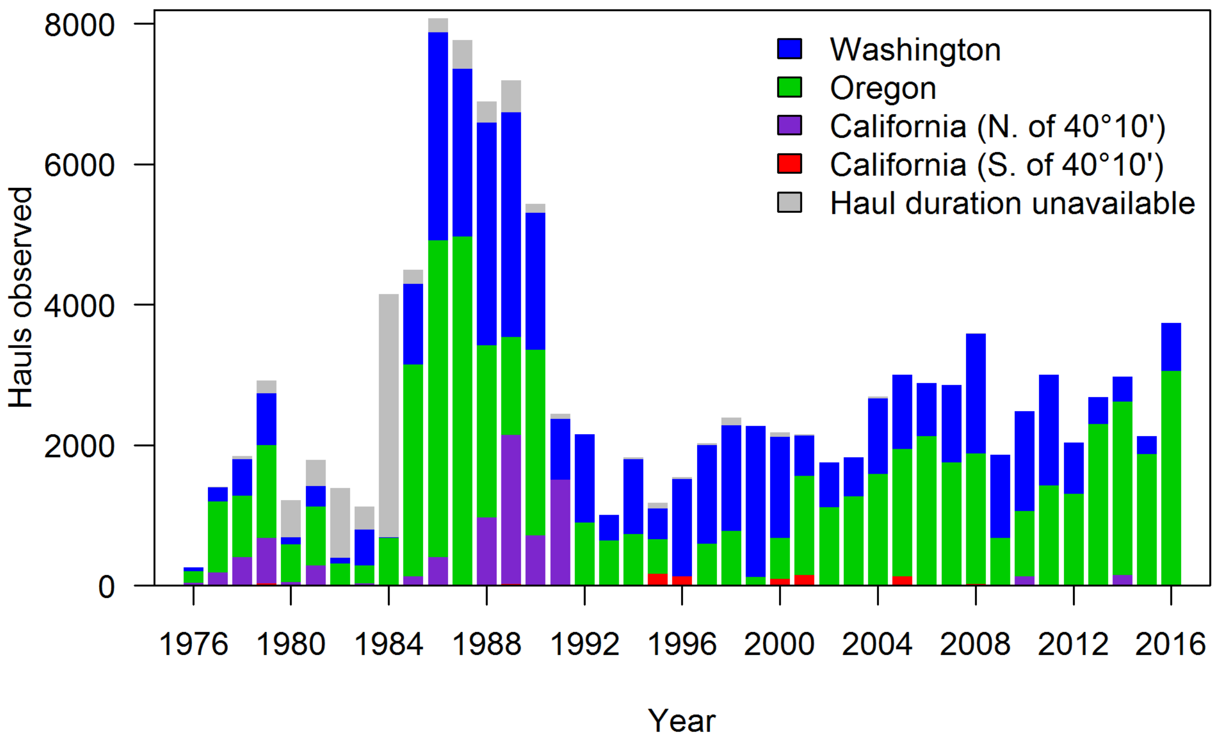


Figure 12: Number of observed hauls (with or without bycatch of Yellowtail Rockfish) from the at-sea hake fishery classified by location relative to Washington, Oregon, and California (north and south of 40-10). Grey bars indicate observed tows with no haul duration available which were excluded from the CPUE analysis for the Northern model.

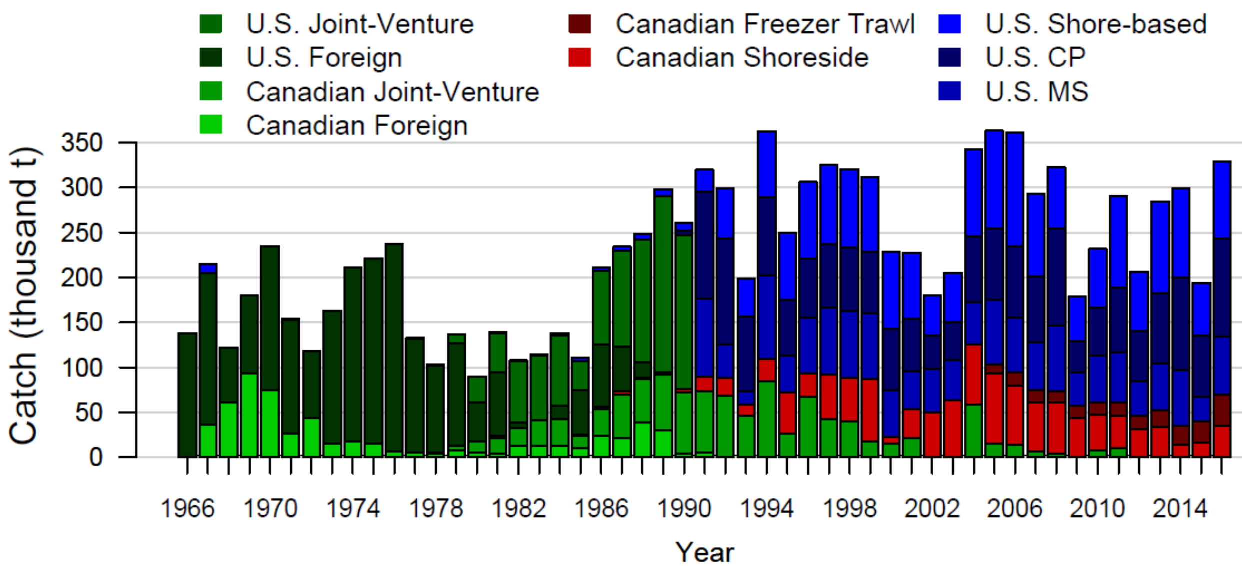


Figure 13: Catch history for Pacific Hake by sector. Data used in the CPUE analysis for the NOrthern model are from the "U.S. Joint-Venture" and "U.S. Foreign sectors" through 1990 and from the Catcher-Processor ("U.S. CP") and Mothership ("U.S. MS") sectors from 1990 onward.

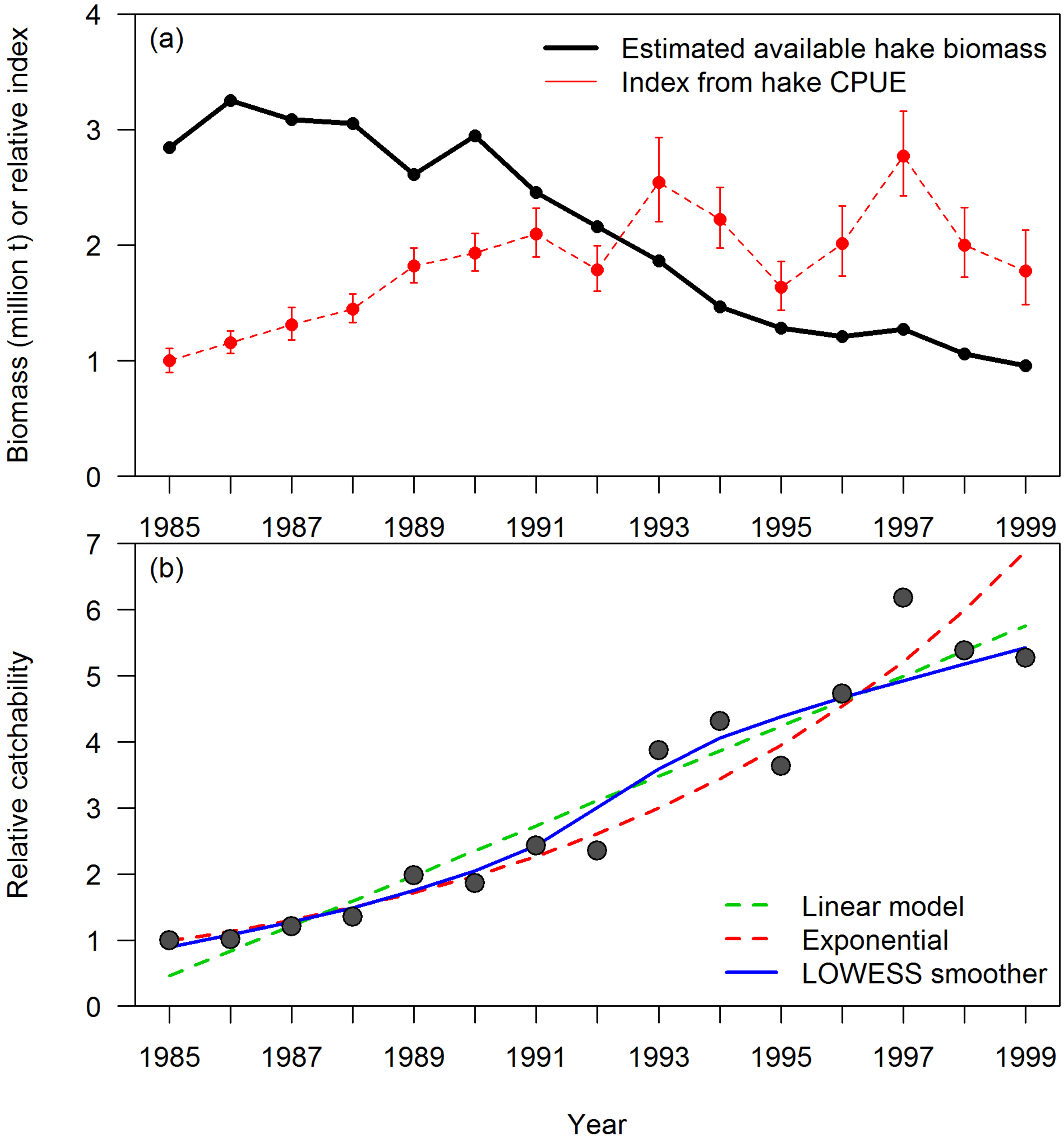


Figure 14: Geostatical index for Pacific Hake developed using VAST compared to the estimated avaialble hake biomass.

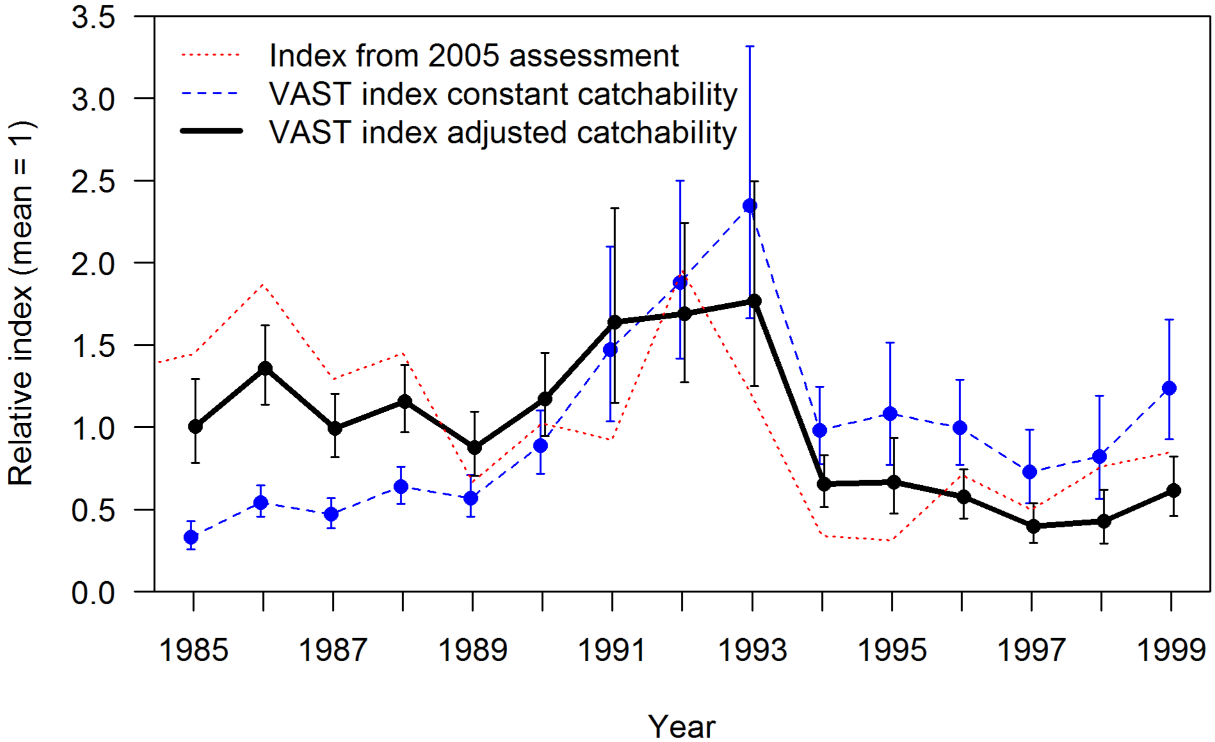


Figure 15: Index for the Northern model from the geostatistical model VAST with constant catchability and adjusted for the estimated increase in catchability (previous figure). These are compared to the index used in recent yellowtail assessments (Wallace and Lai, 2005).

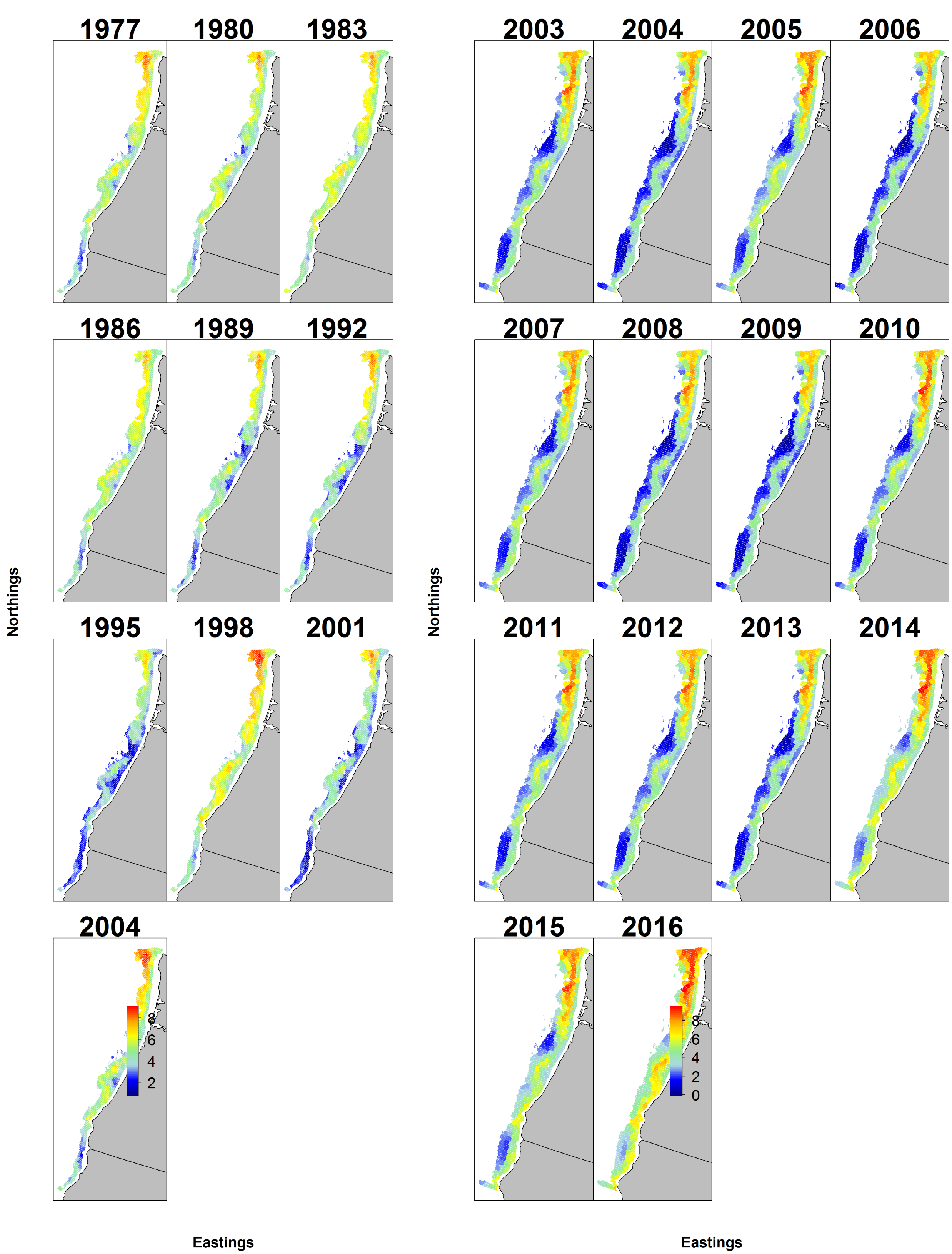


Figure 16: Estimated density from the VAST model for the Triennial and NWFSCcombo trawl surveys for the Northern area.

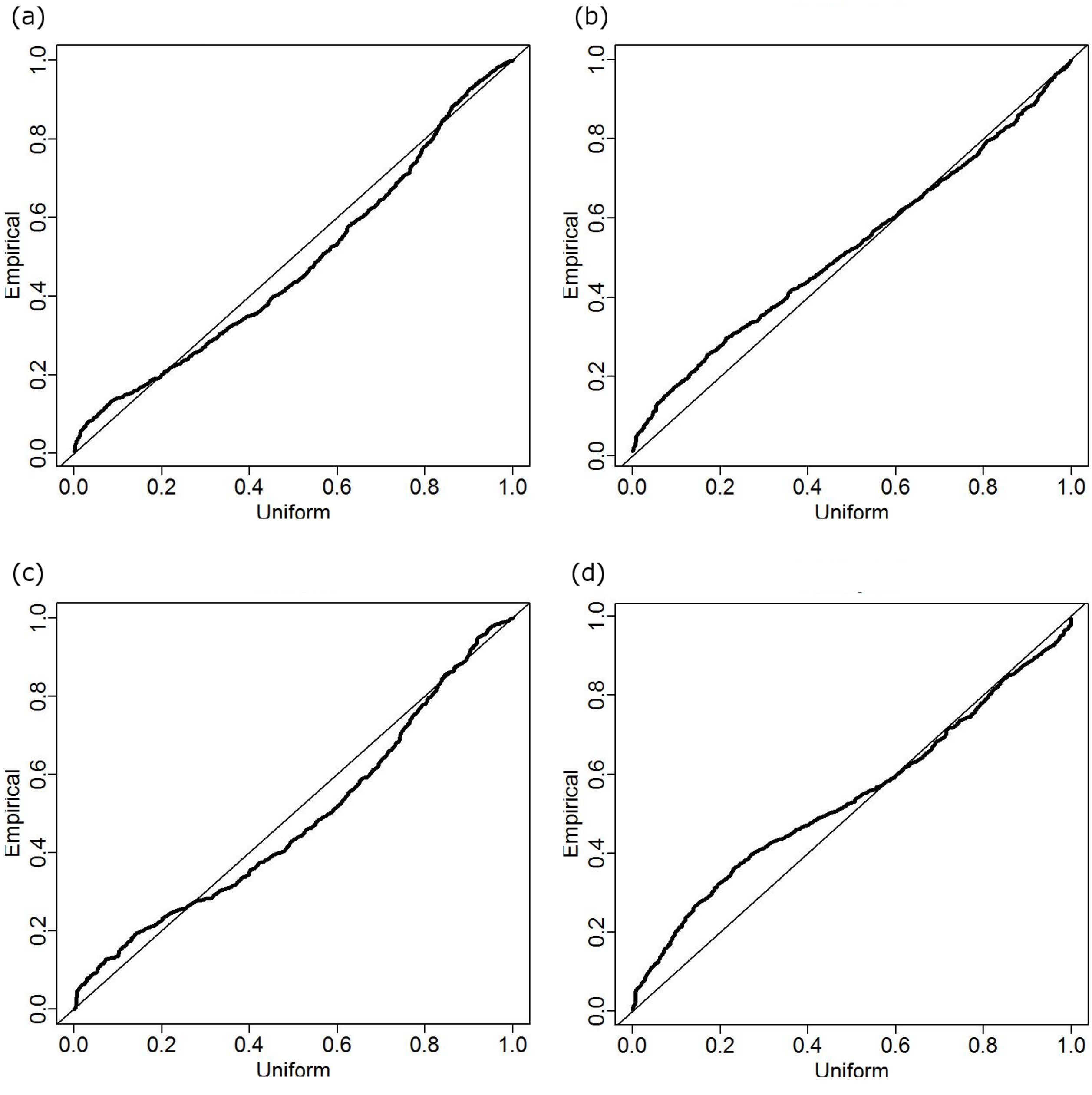


Figure 17: Quantile-Quantile plot for the VAST models for the Triennial and NWFSCcombo bottom trawl surveys for the Northern area. Panels are (a) Triennial with log-normal error distribution, (b) Trienial with gama error distribution, (c) NWFSCcombo with log-normal error distribution, and (d) NWFSCcombo with gama error distribution.

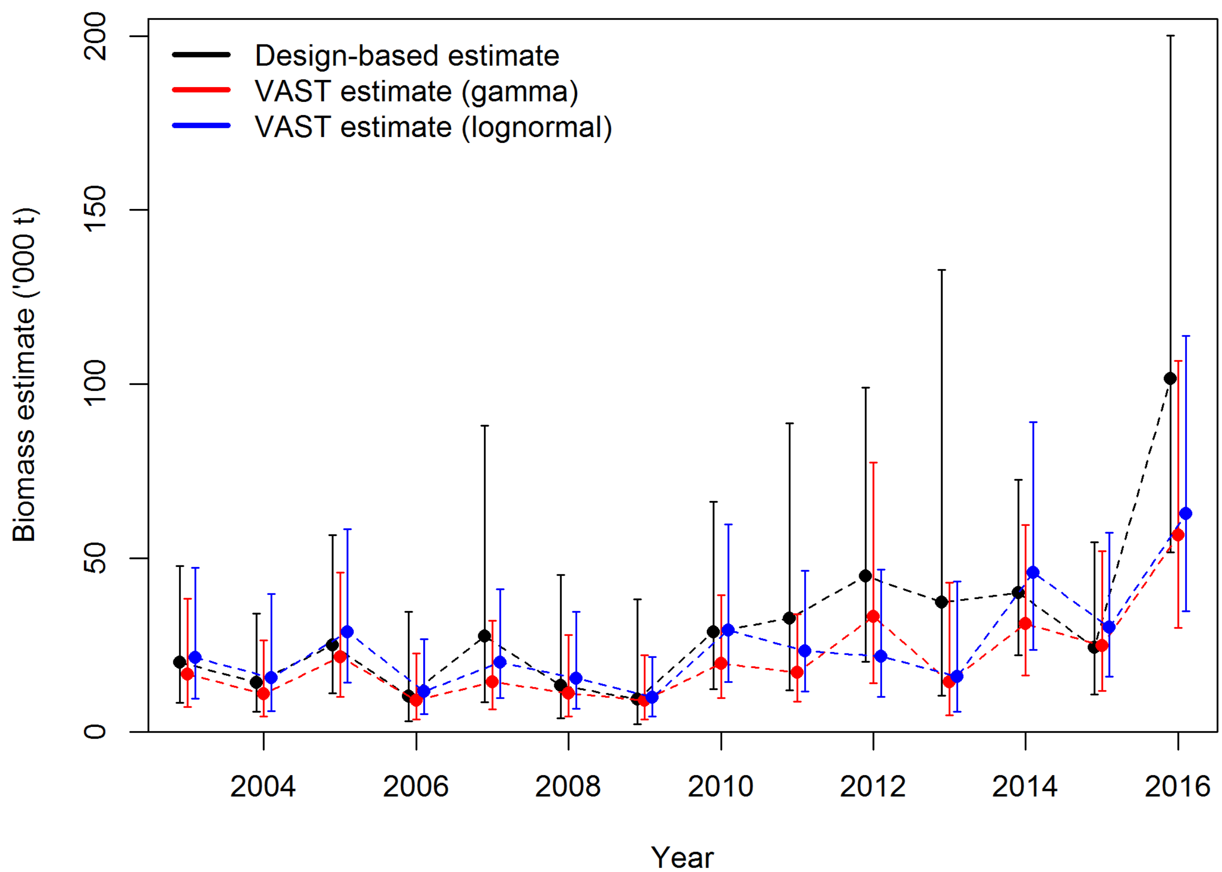


Figure 18: Comparison of estimated indices for the Northern model calculated from the VAST model for the NWFSCcombo shelf-slope trawl survey with log-normal and gamma error distributions and the the design-based estimate that doesn't depend on the geostatistical analysis included in VAST.

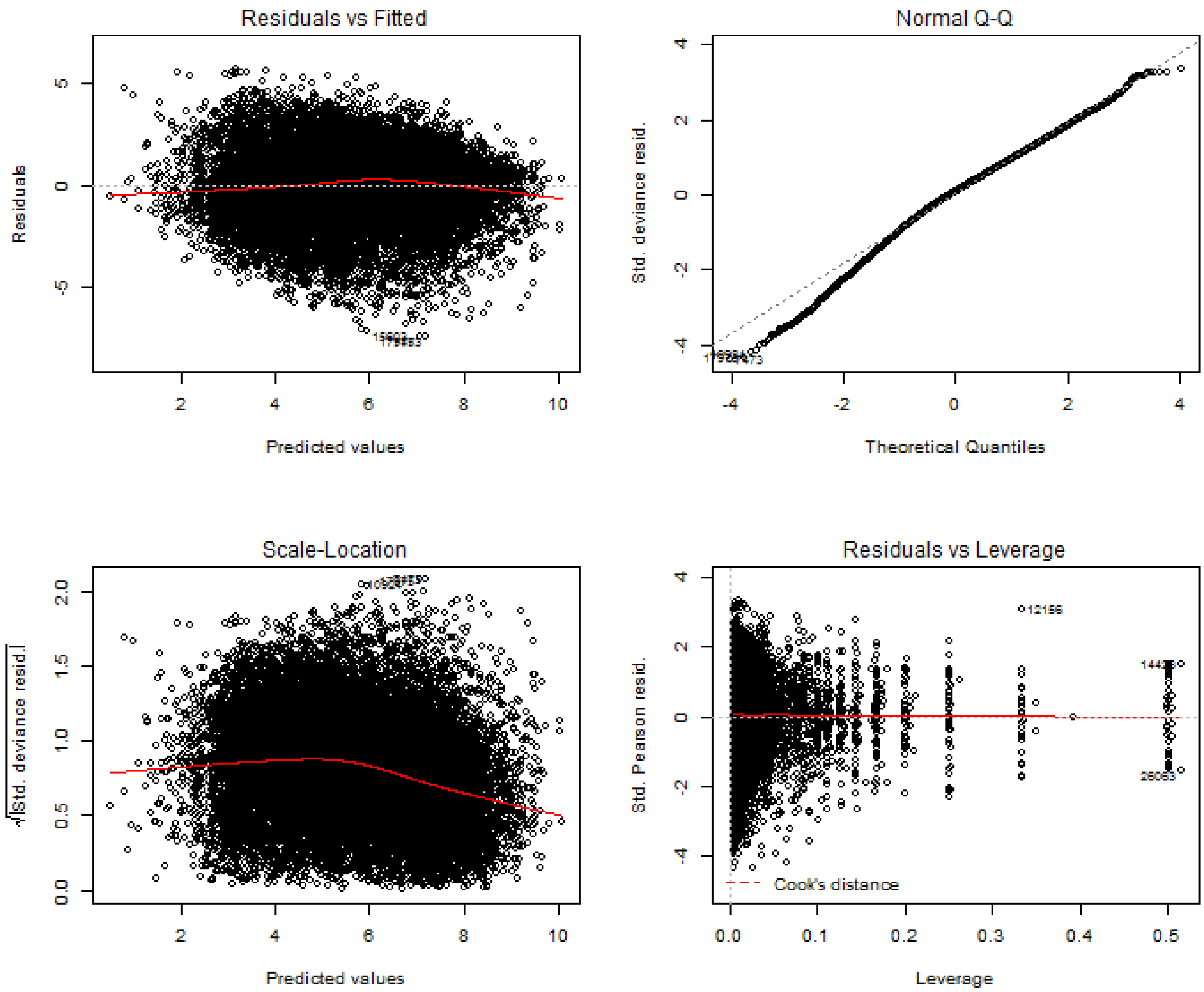


Figure 19: Quantile-Quantile plot for the Northern model Logbook CPUE model with a log-normal error distribution applied to PacFIN data from 1989 - 1998.

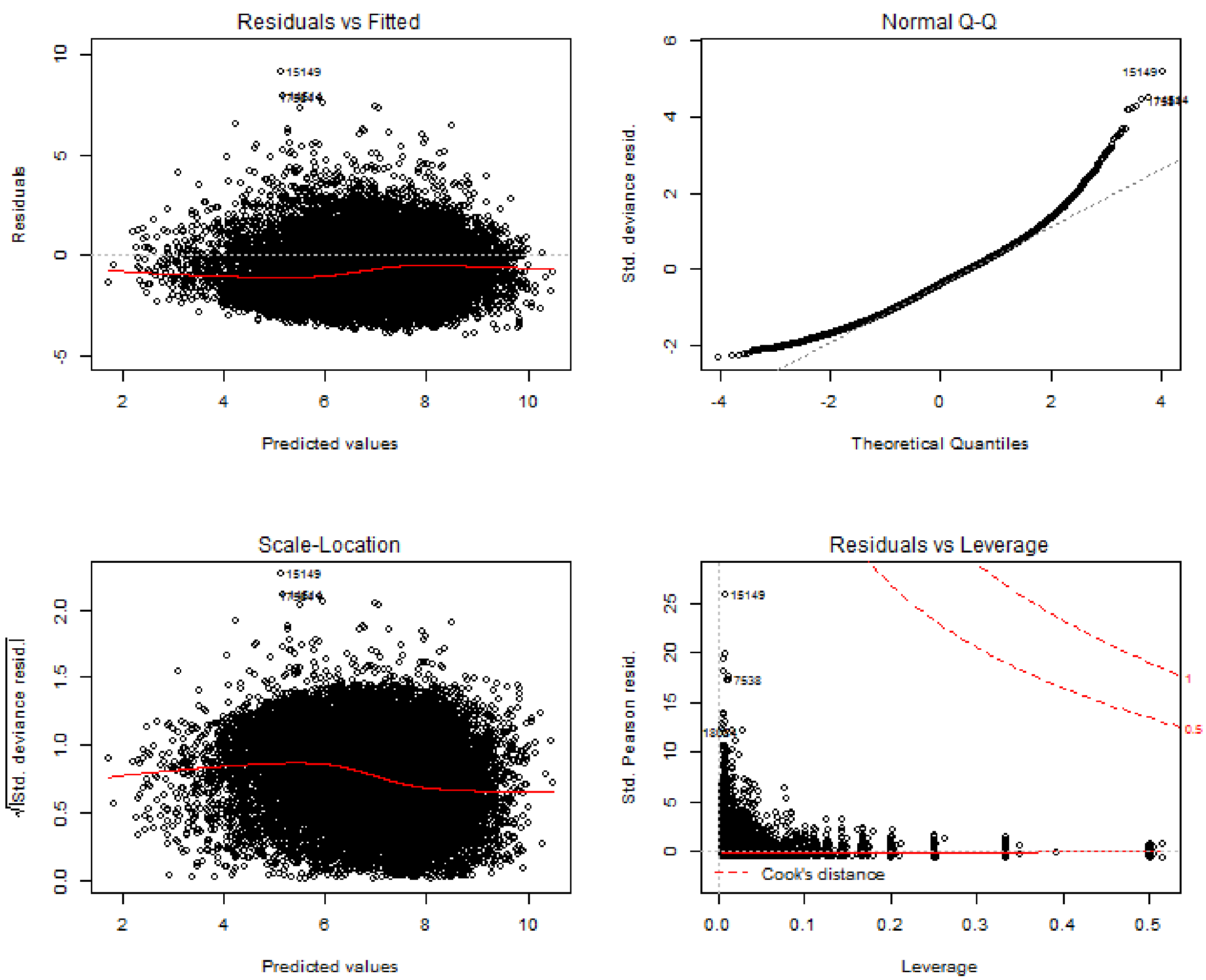


Figure 20: Quantile-Quantile plot for the Northern model Logbook CPUE model with a gamma error distribution applied to PacFIN data from 1989 - 1998.

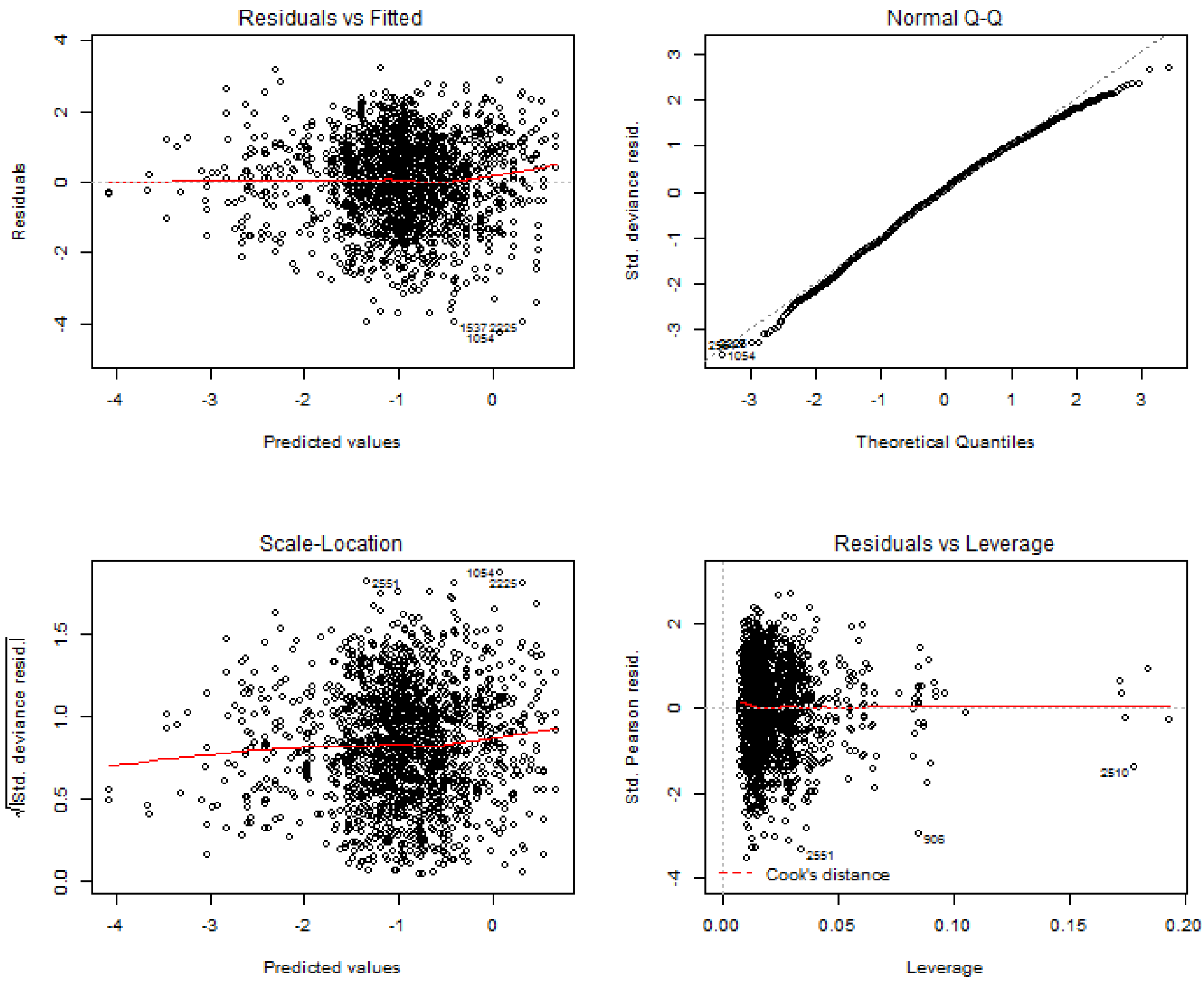


Figure 21: Quantile-Quantile plot for the Northern model MRFSS model with a lognormal error distribution applied to California dockside survey data.

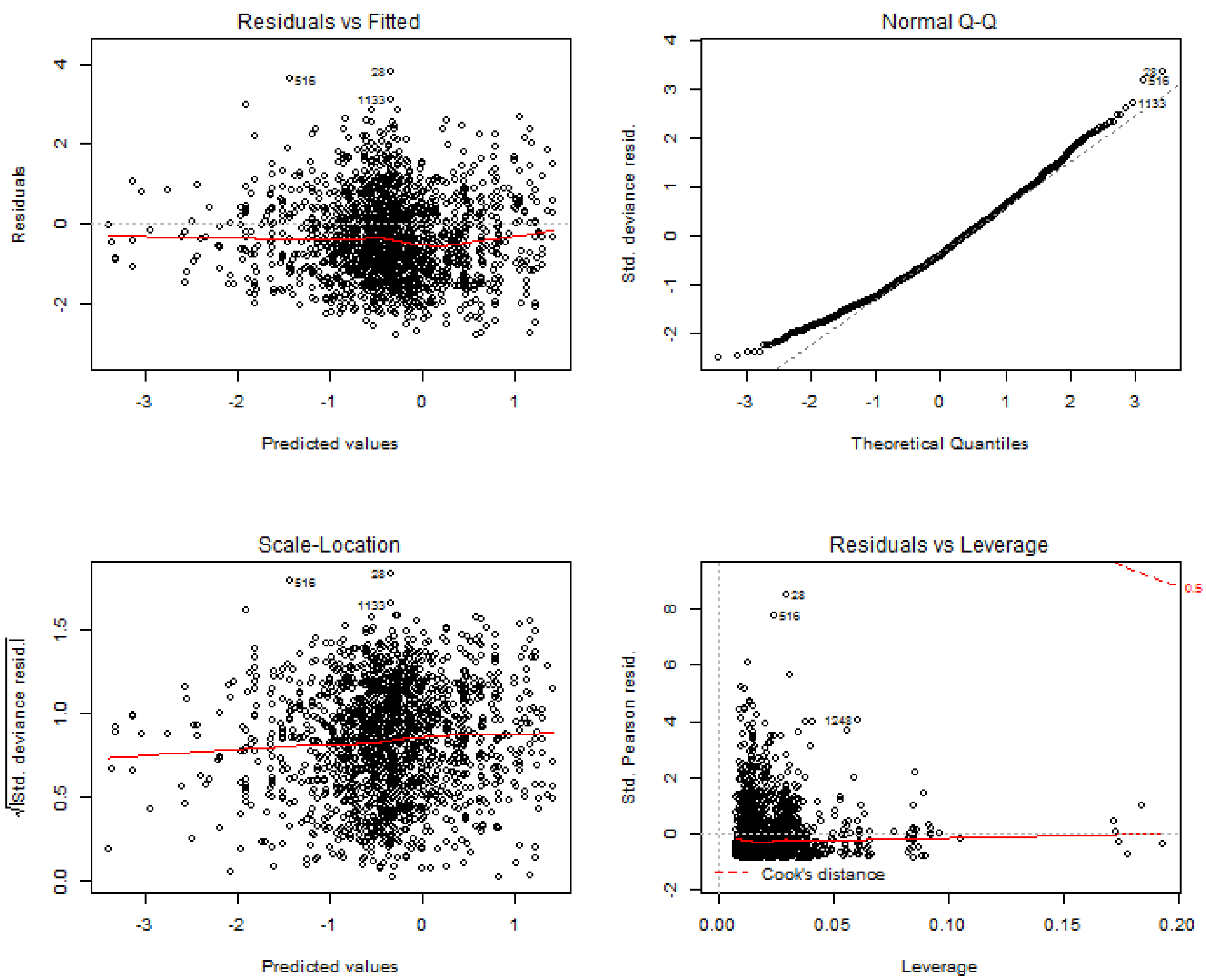


Figure 22: Quantile-Quantile plot for the Northern model MRFSS model with a lognormal error distribution applied to California dockside survey data.

9.2.3 Fits to indices of abundance for Northern model

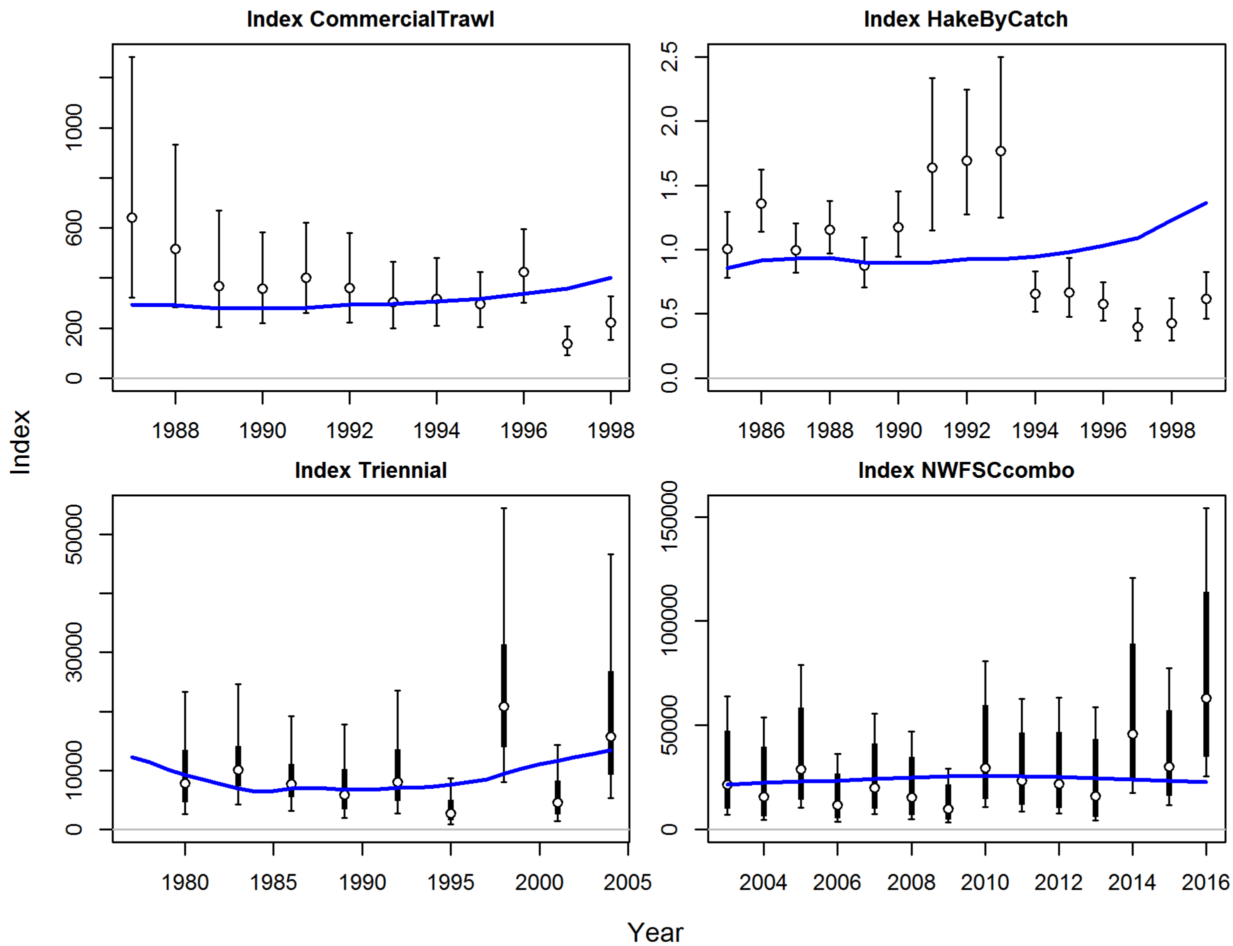


Figure 23: Estimated fits to the CPUE and survey indices for the Northern model. The Commercial Trawl Logbook and Hake Bycatch indices are not included in the likelihood so the fits shown here are shown only for comparison purposes.

9.2.4 Length compositions for Northern model

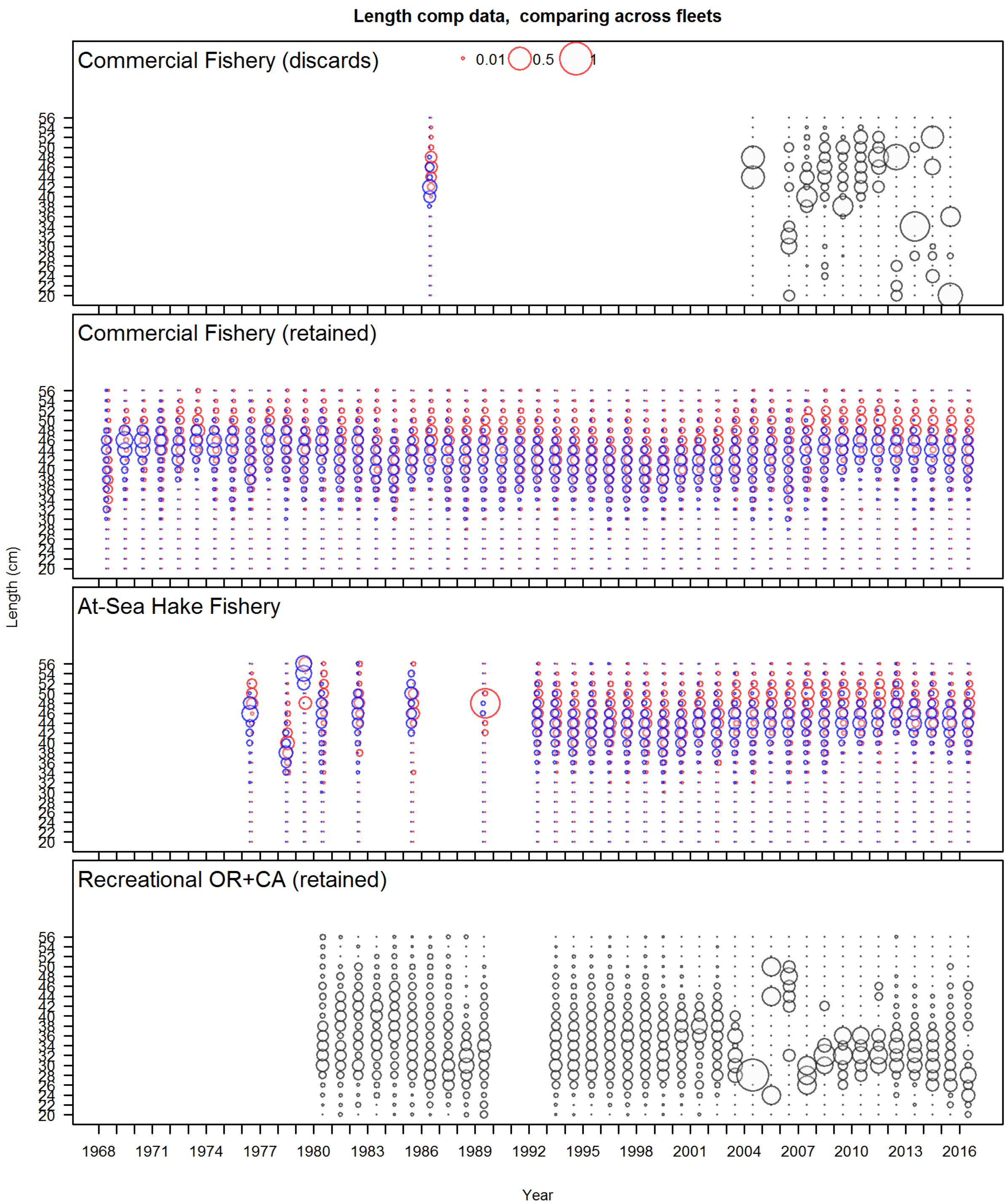


Figure 24: Length compositions for all fleets in the Northern model (figure 1 of 2). Bubble size is proportional to proportions within each year. Bubble colors indicate unsexed fish (gray), females (red), and males (blue).

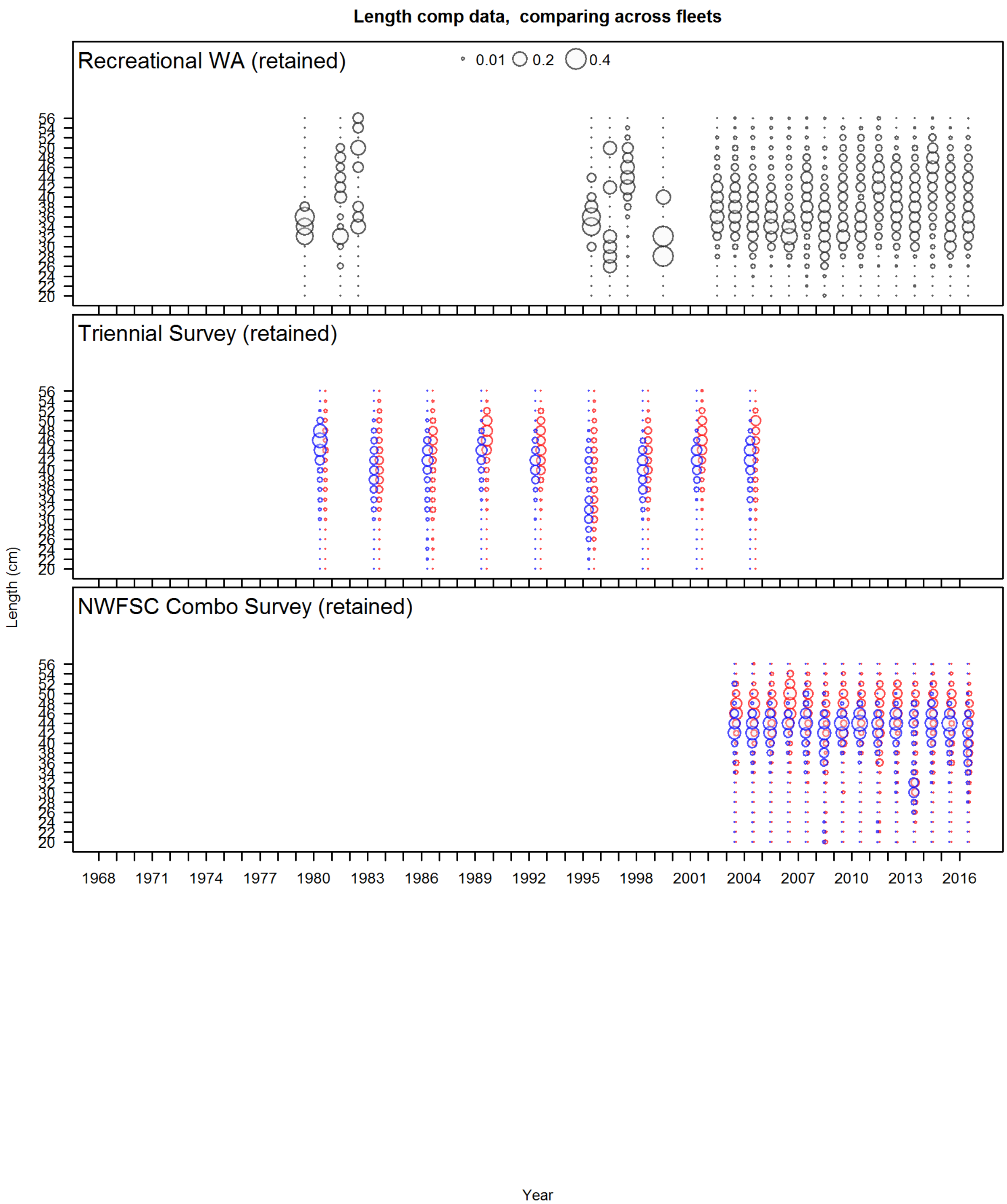


Figure 25: Length compositions for all fleets in the Northern model (figure 2 of 2).

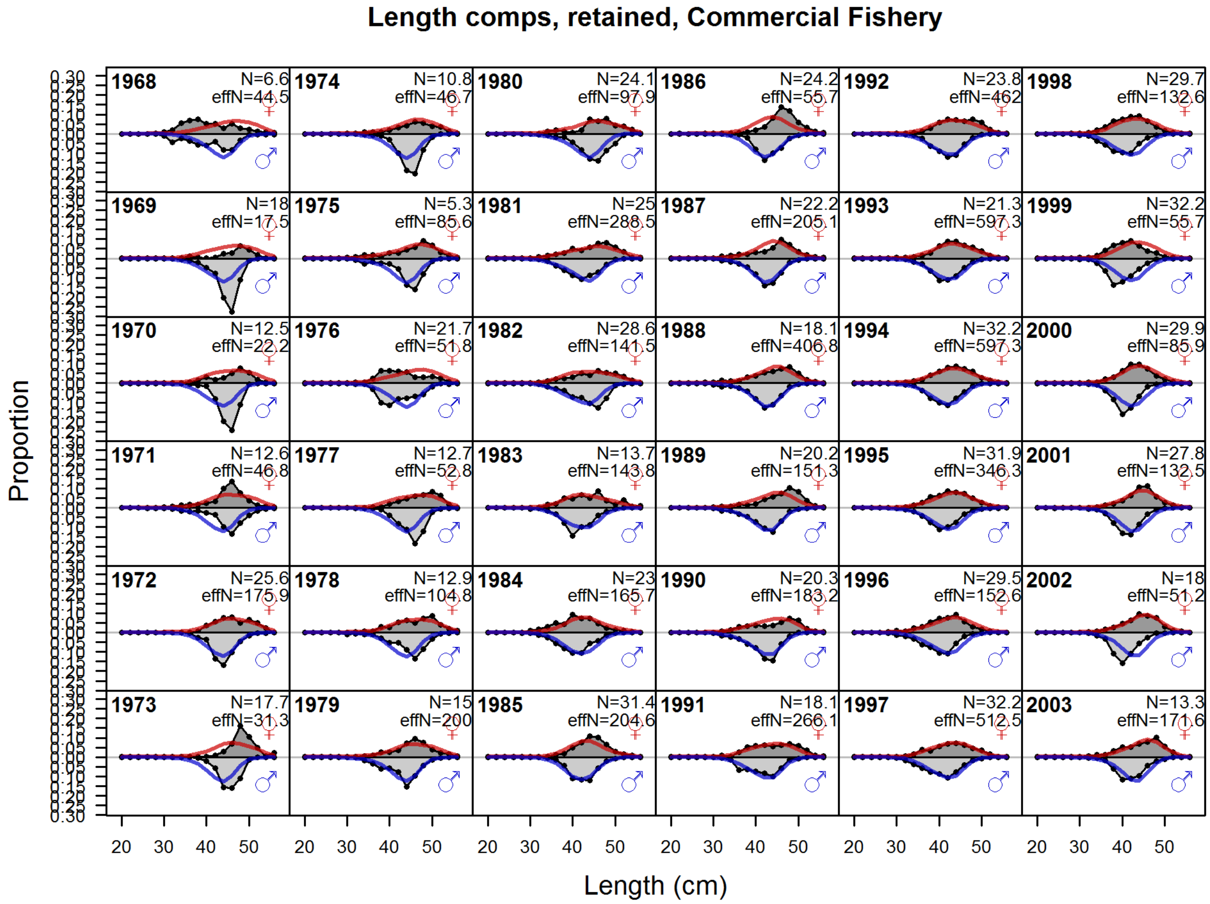
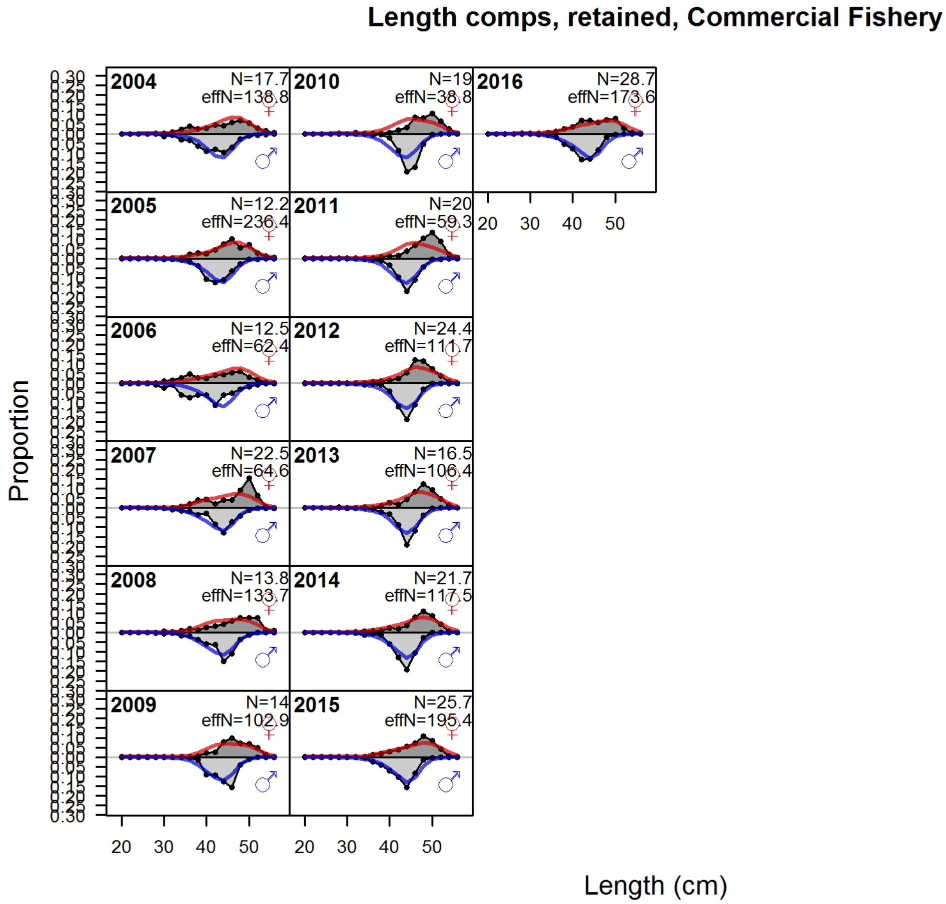


Figure 26: **Northern model** Length comps, retained, Commercial Fishery (plot 1 of 2)



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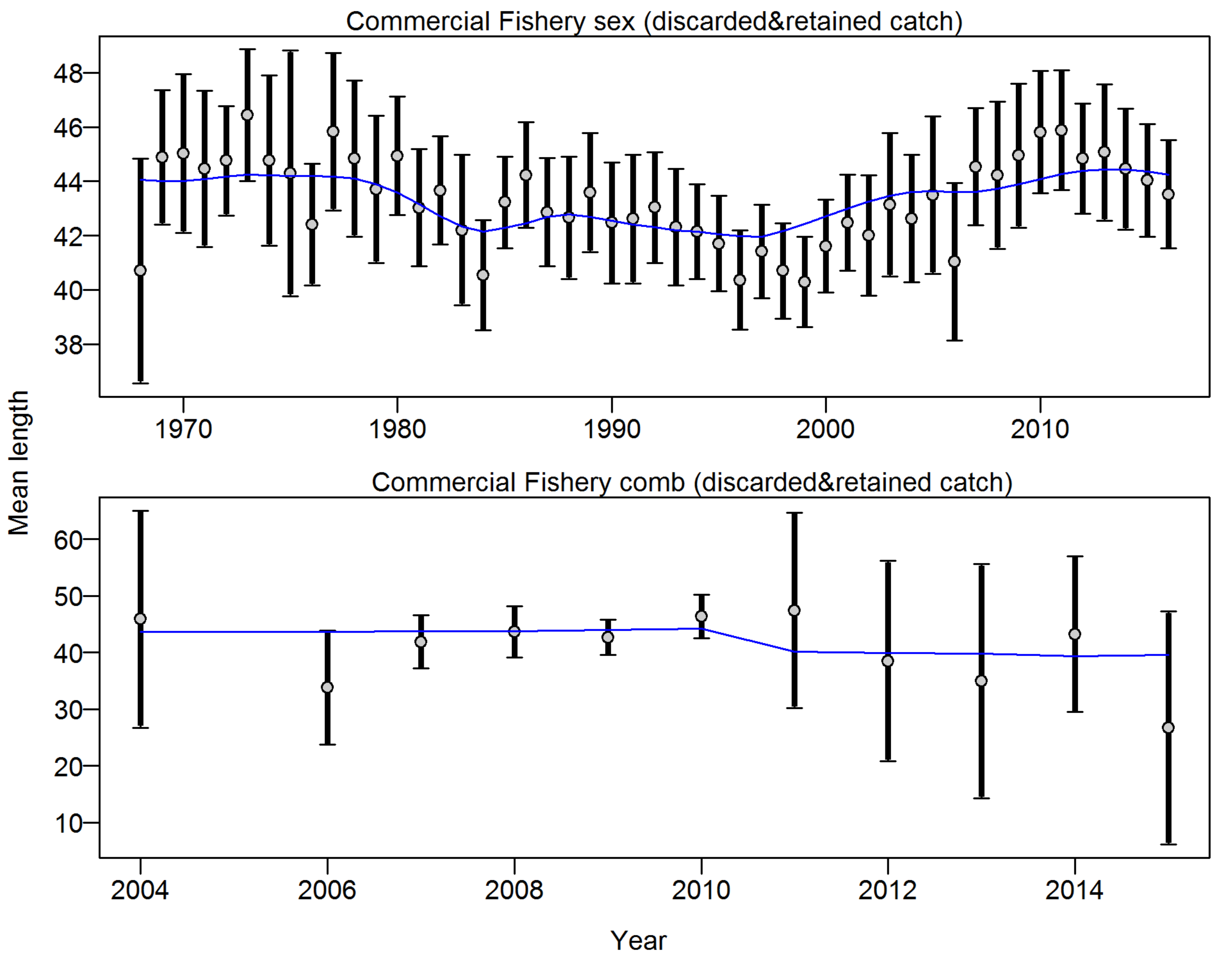


Figure 27: **Northern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Commercial Fishery: 0.9716 (0.7433_1.399) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

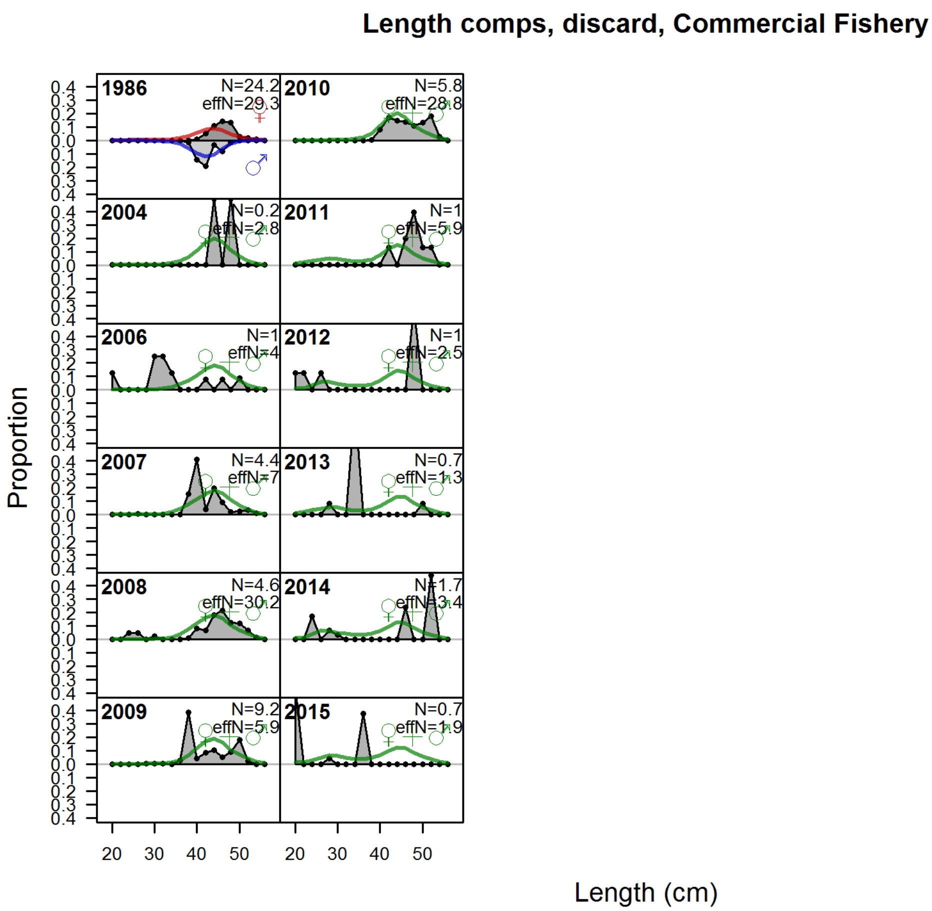


Figure 28: **Northern model** Length comps, discard, Commercial Fishery

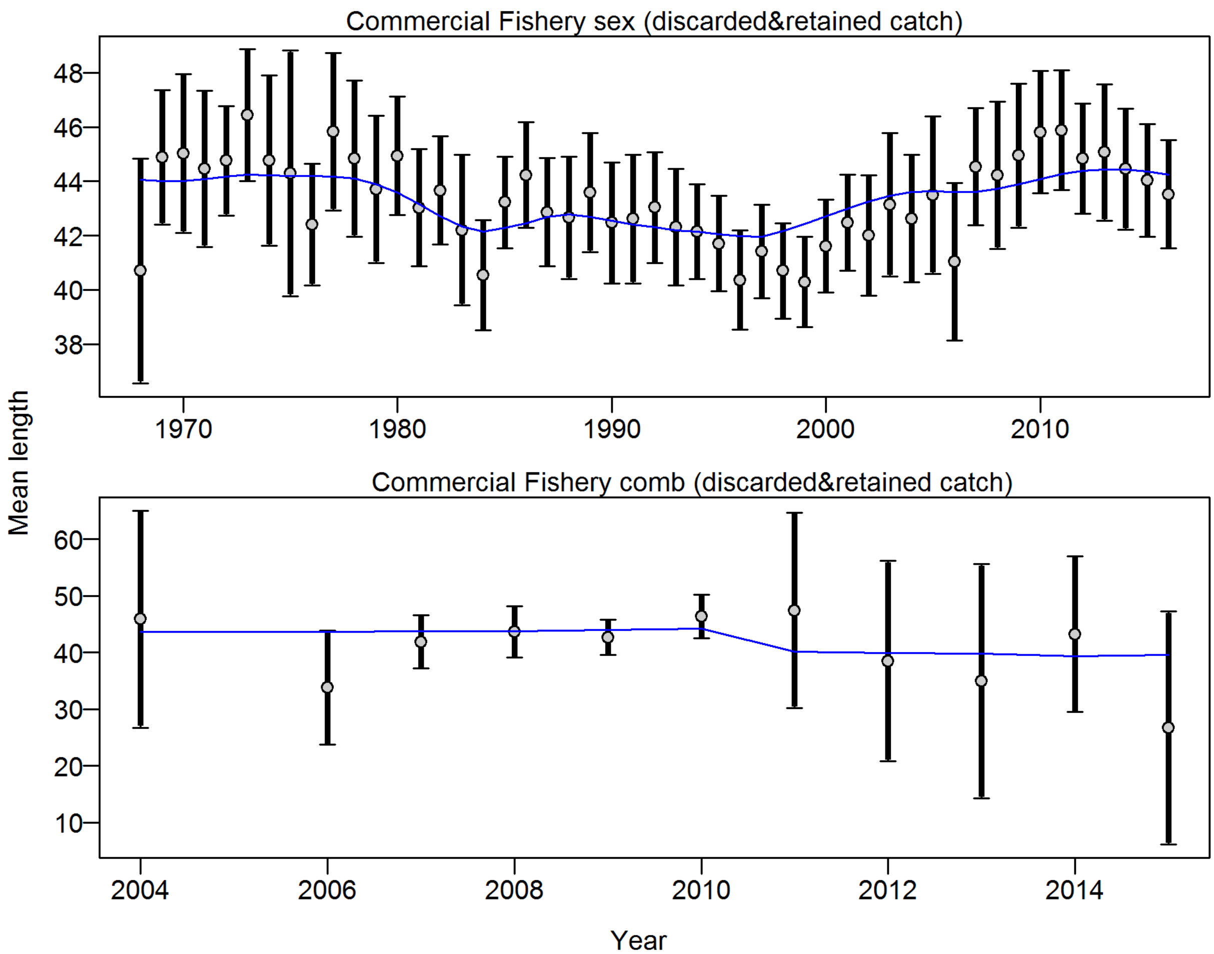


Figure 29: **Northern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Commercial Fishery: 0.9716 (0.7438_1.4283) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

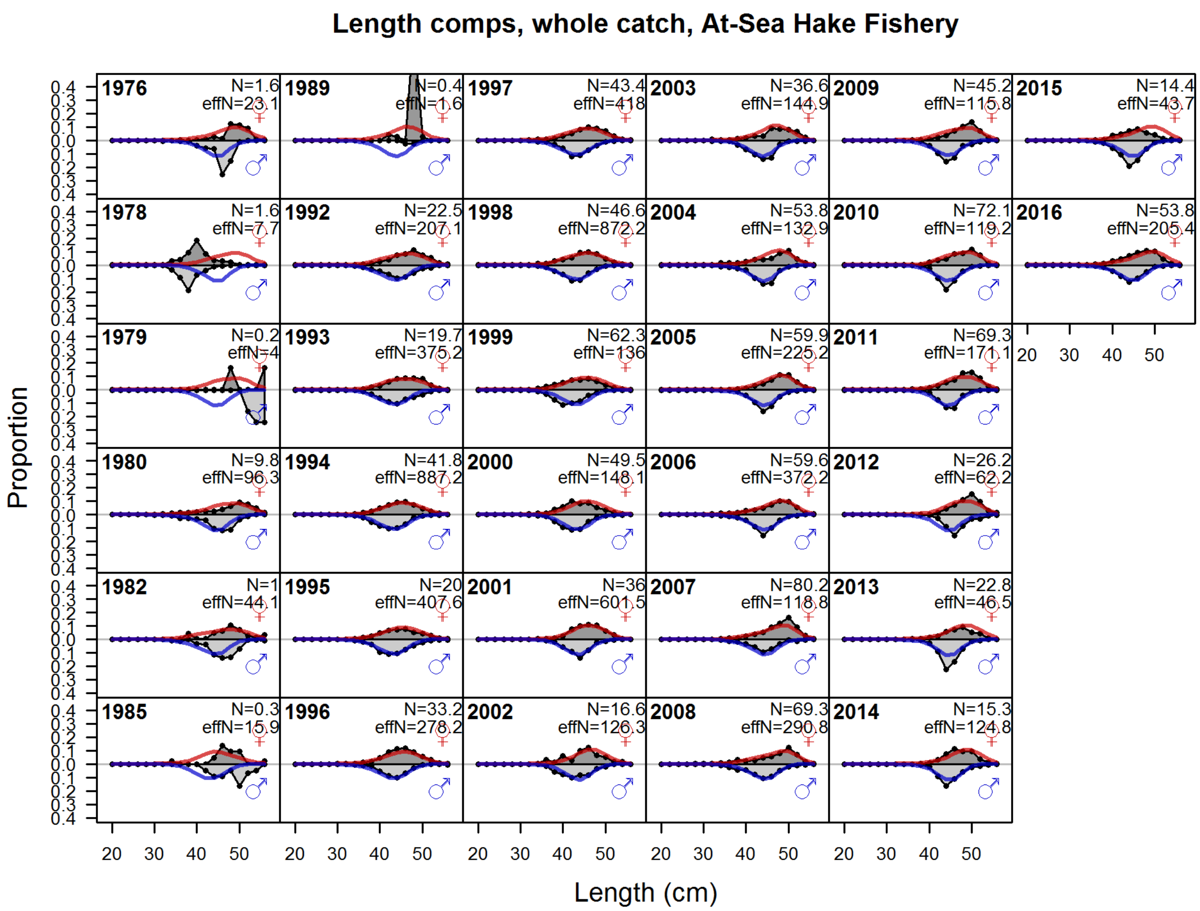


Figure 30: **Northern model** Length comps, whole catch, At_Sea Hake Fishery

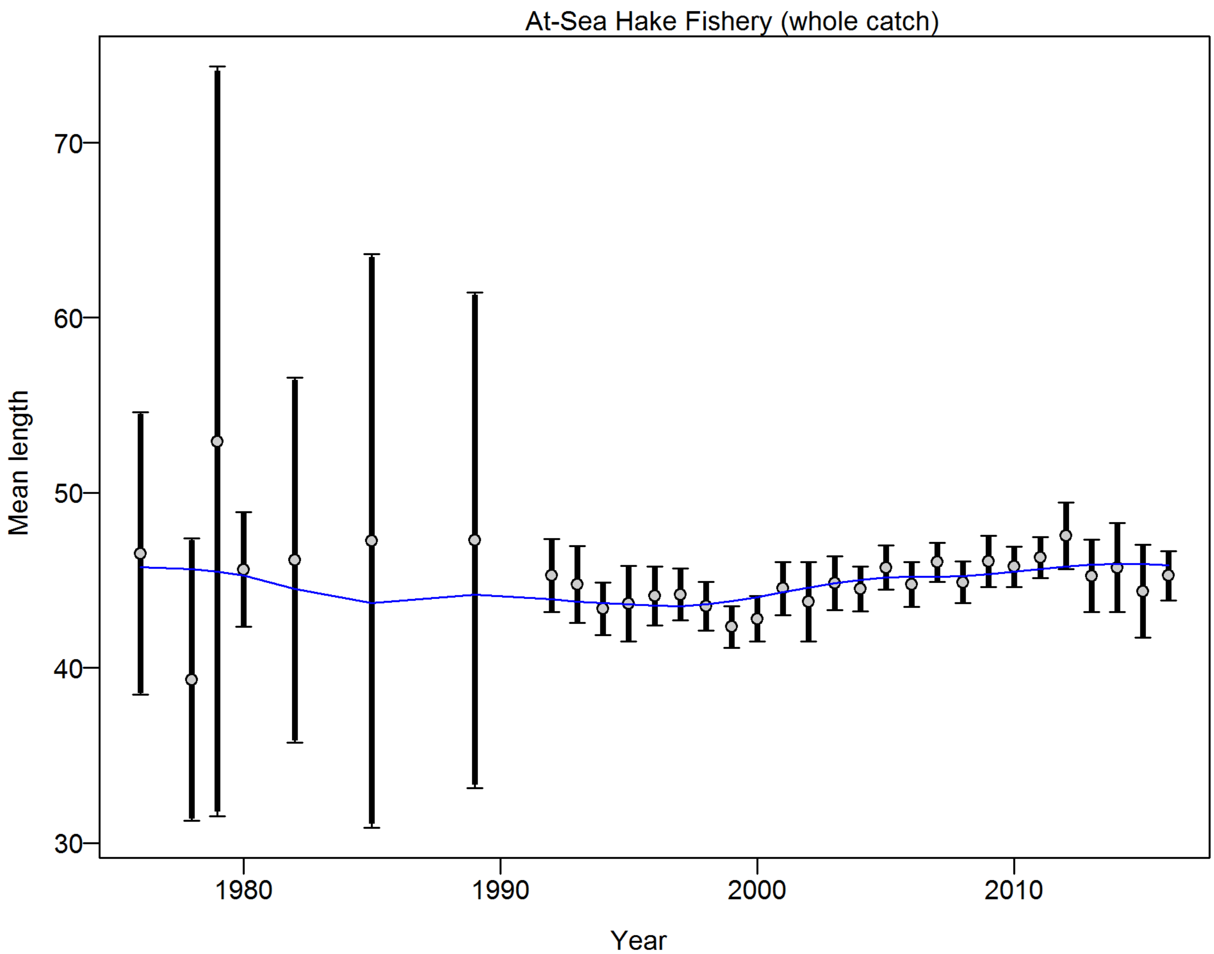


Figure 31: **Northern model** Mean length for At_Sea Hake Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from At_Sea Hake Fishery: 0.9755 (0.6537_1.8738) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

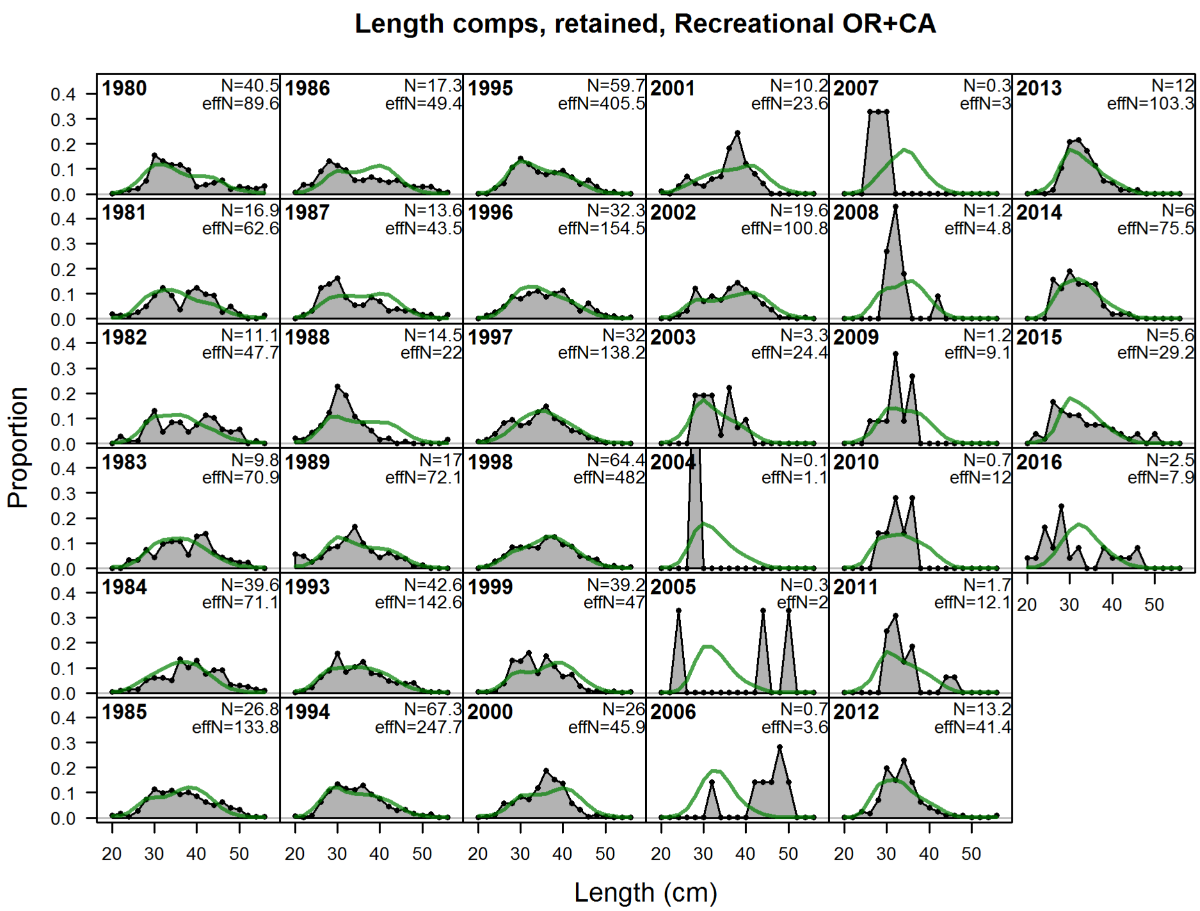


Figure 32: **Northern model** Length comps, retained, Recreational OR+CA

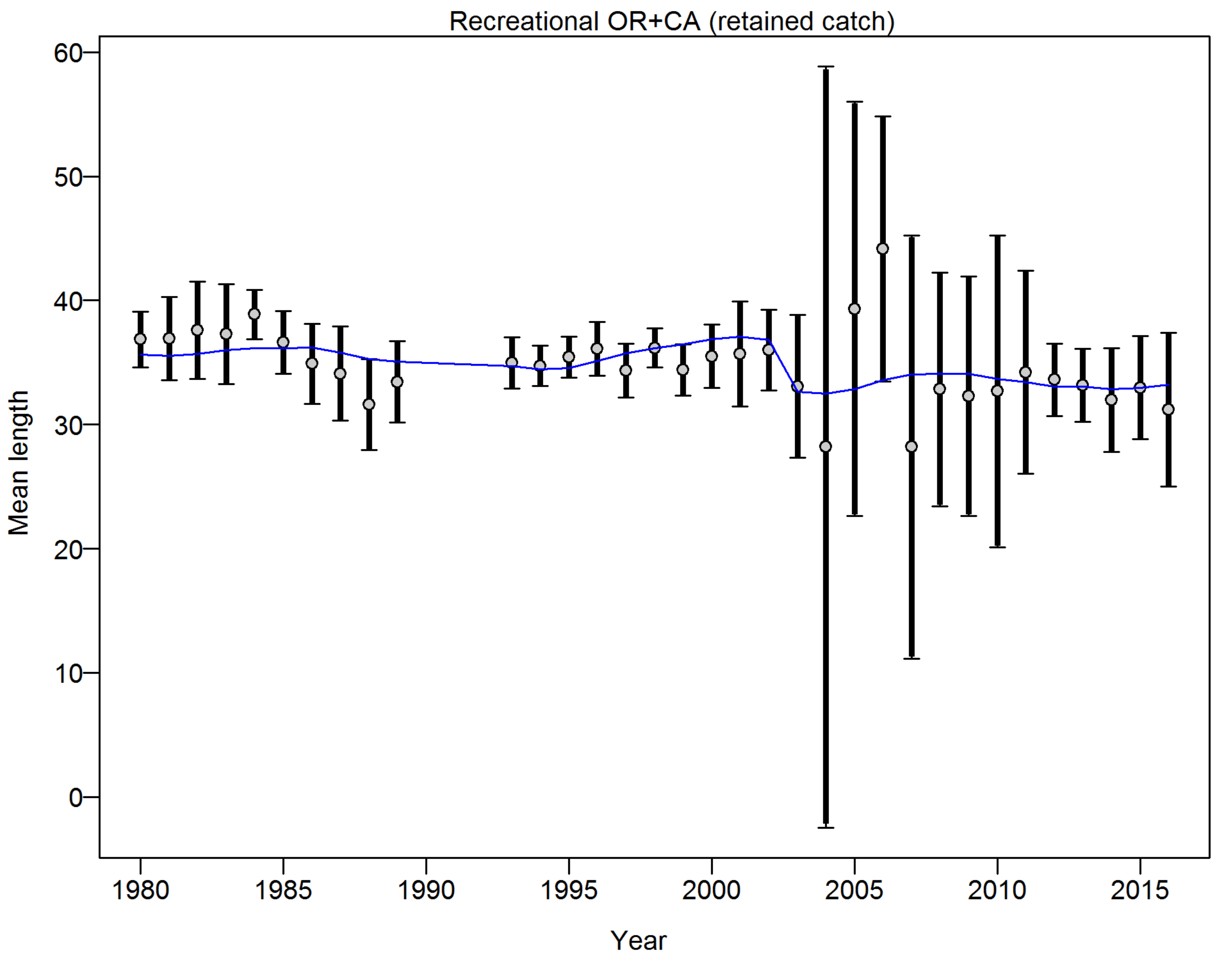


Figure 33: **Northern model** Mean length for Recreational OR+CA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Recreational OR+CA: 0.9823 (0.6151_1.9161) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

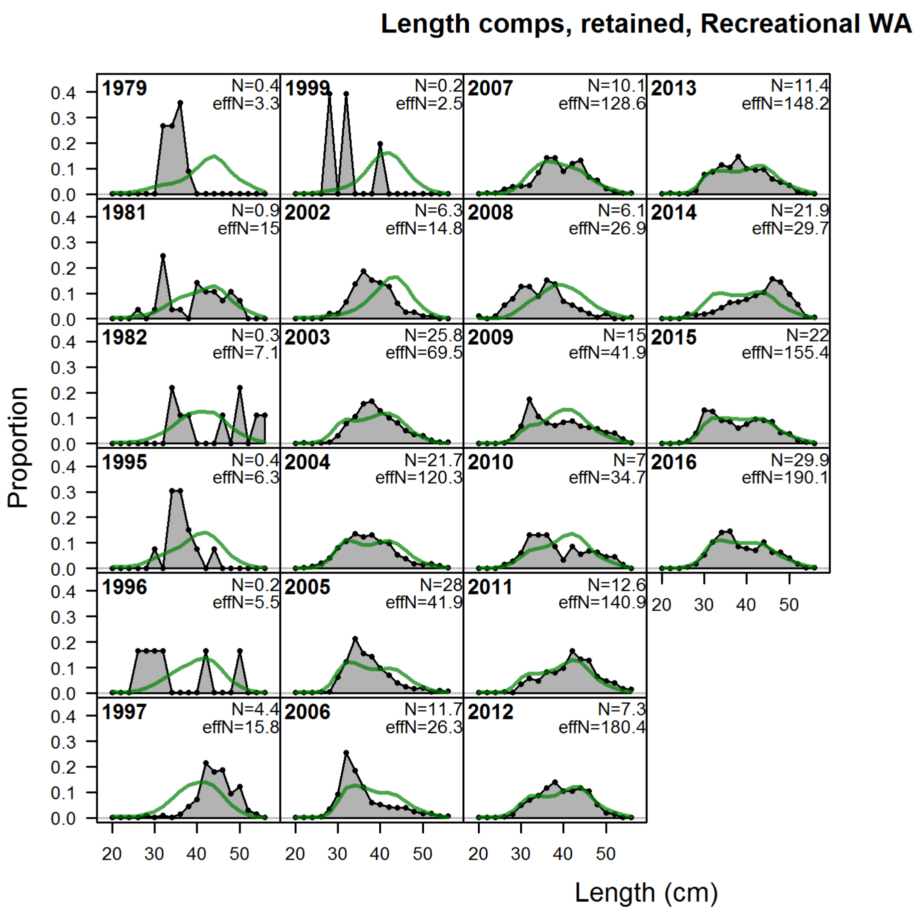


Figure 34: **Northern model** Length comps, retained, Recreational WA

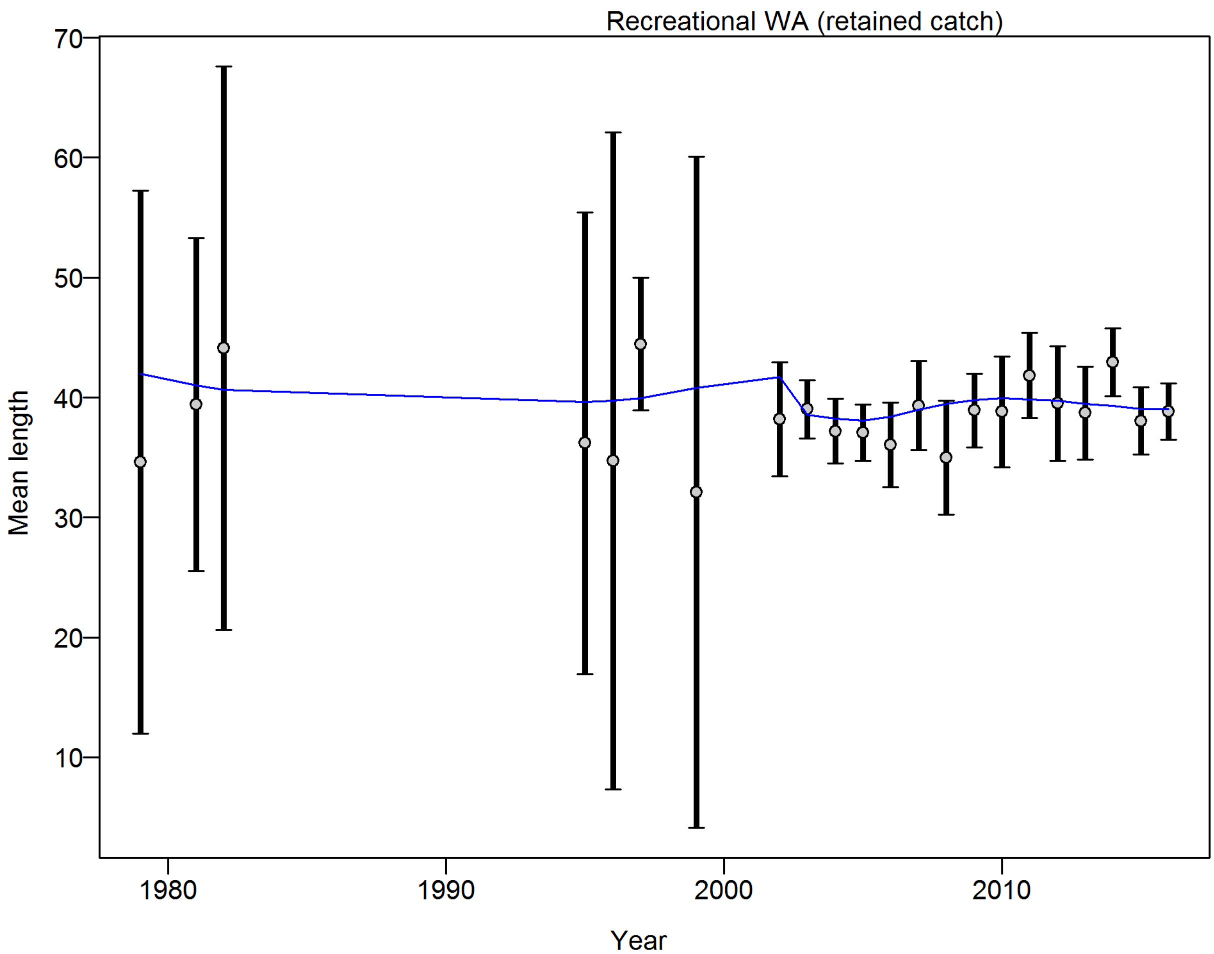


Figure 35: **Northern model** Mean length for Recreational WA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Recreational WA: 0.9978 (0.5546_3.3788) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

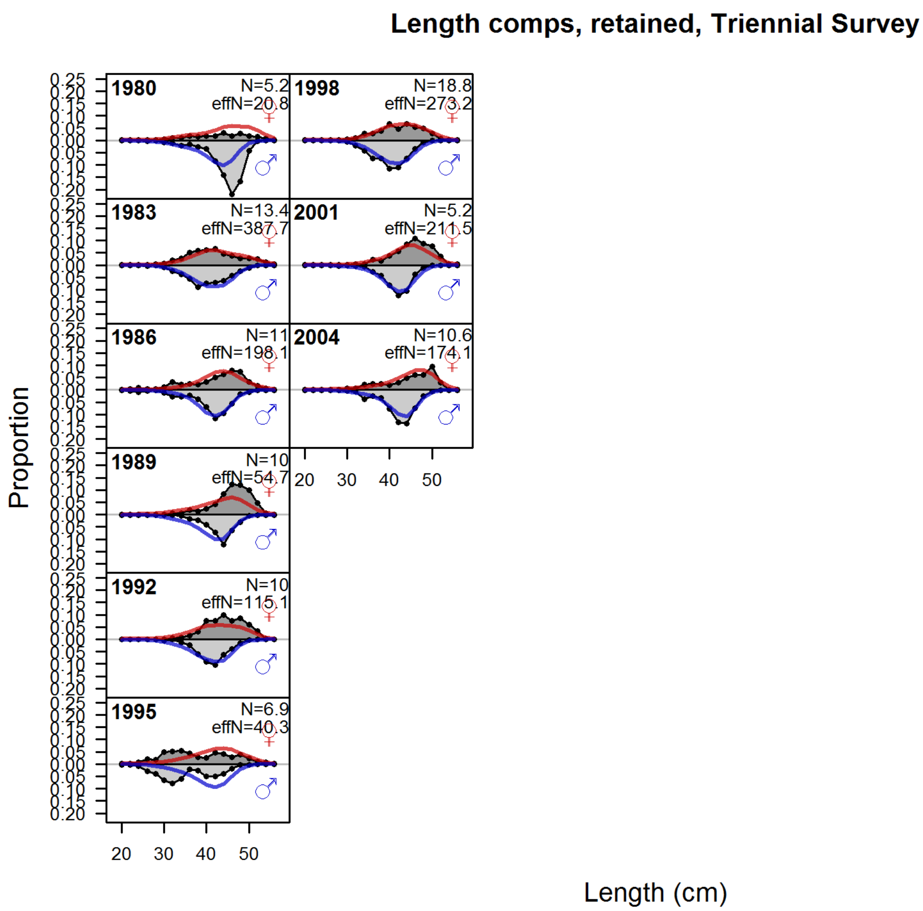


Figure 36: **Northern model** Length comps, retained, Triennial Survey

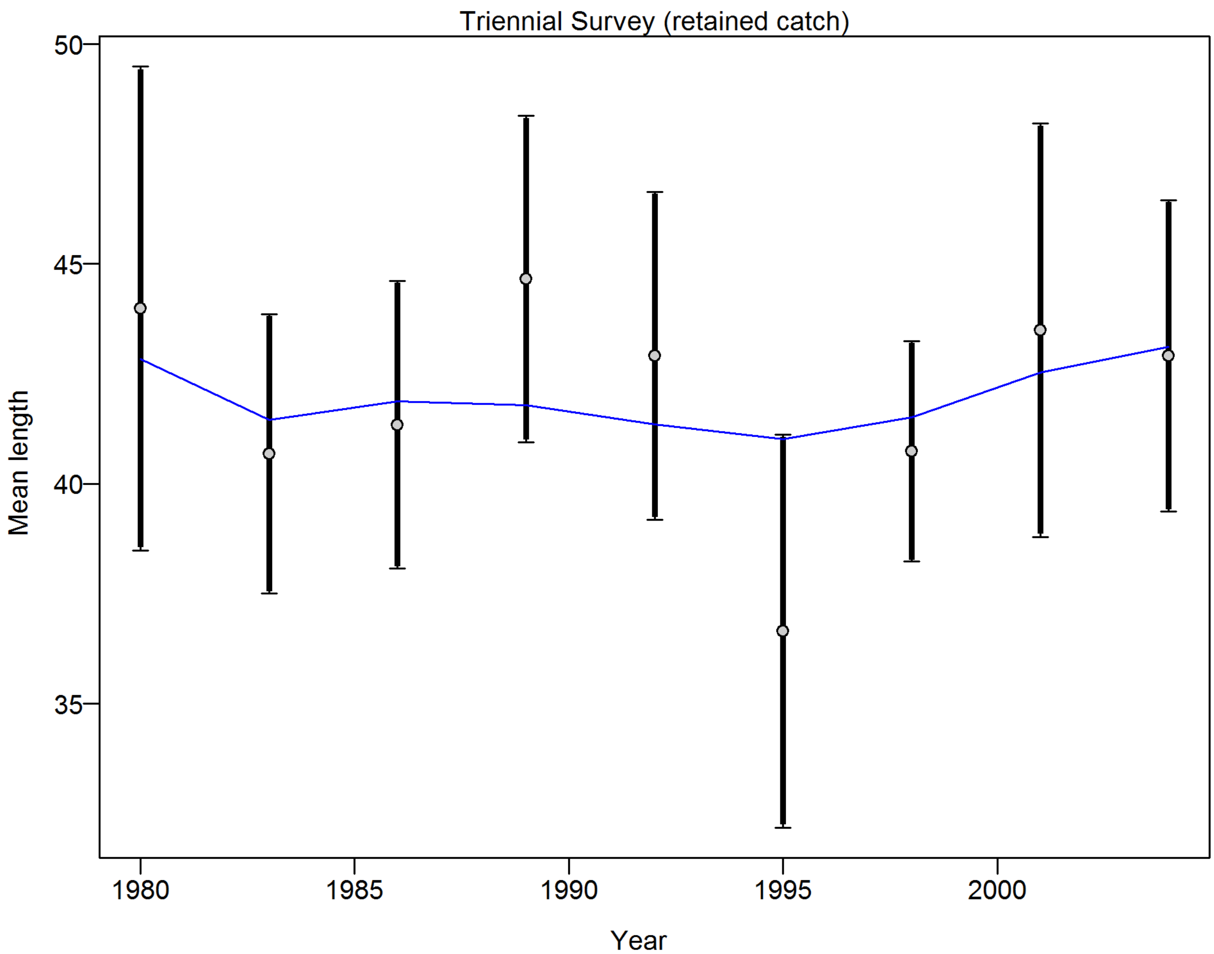


Figure 37: **Northern model** Mean length for Triennial Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Triennial Survey: 0.9723 (0.5456_5.0031) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

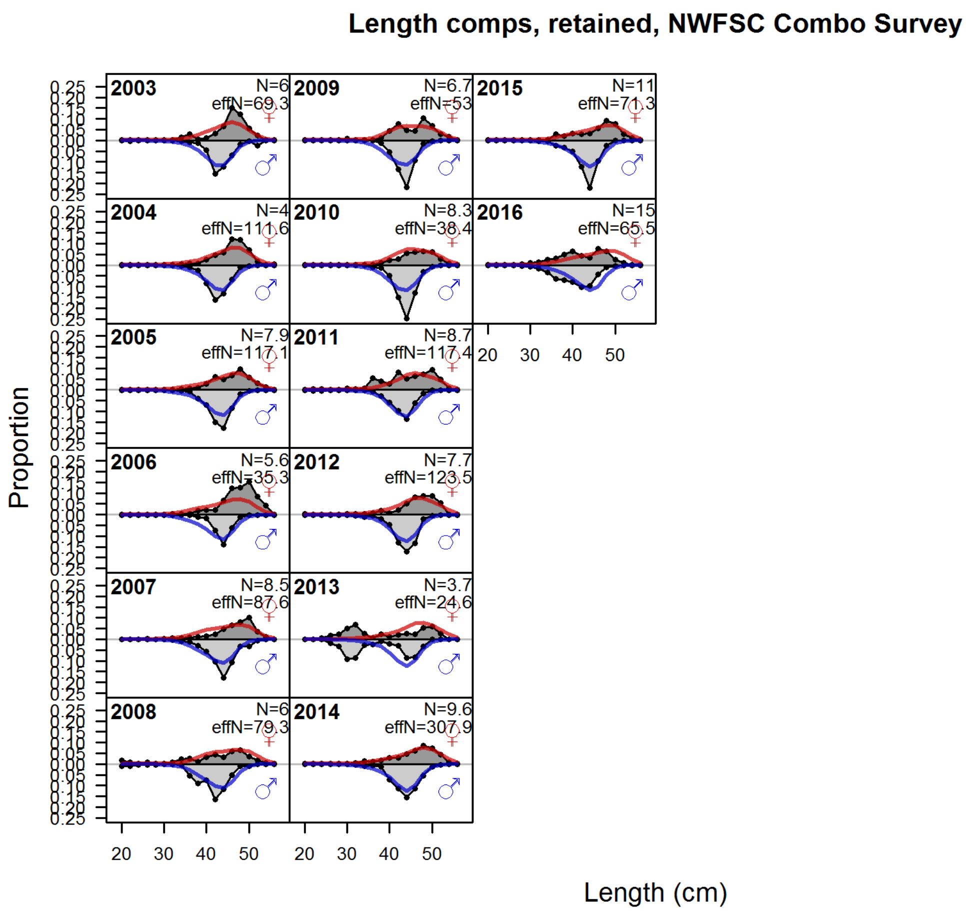


Figure 38: **Northern model** Length comps, retained, NWFSC Combo Survey

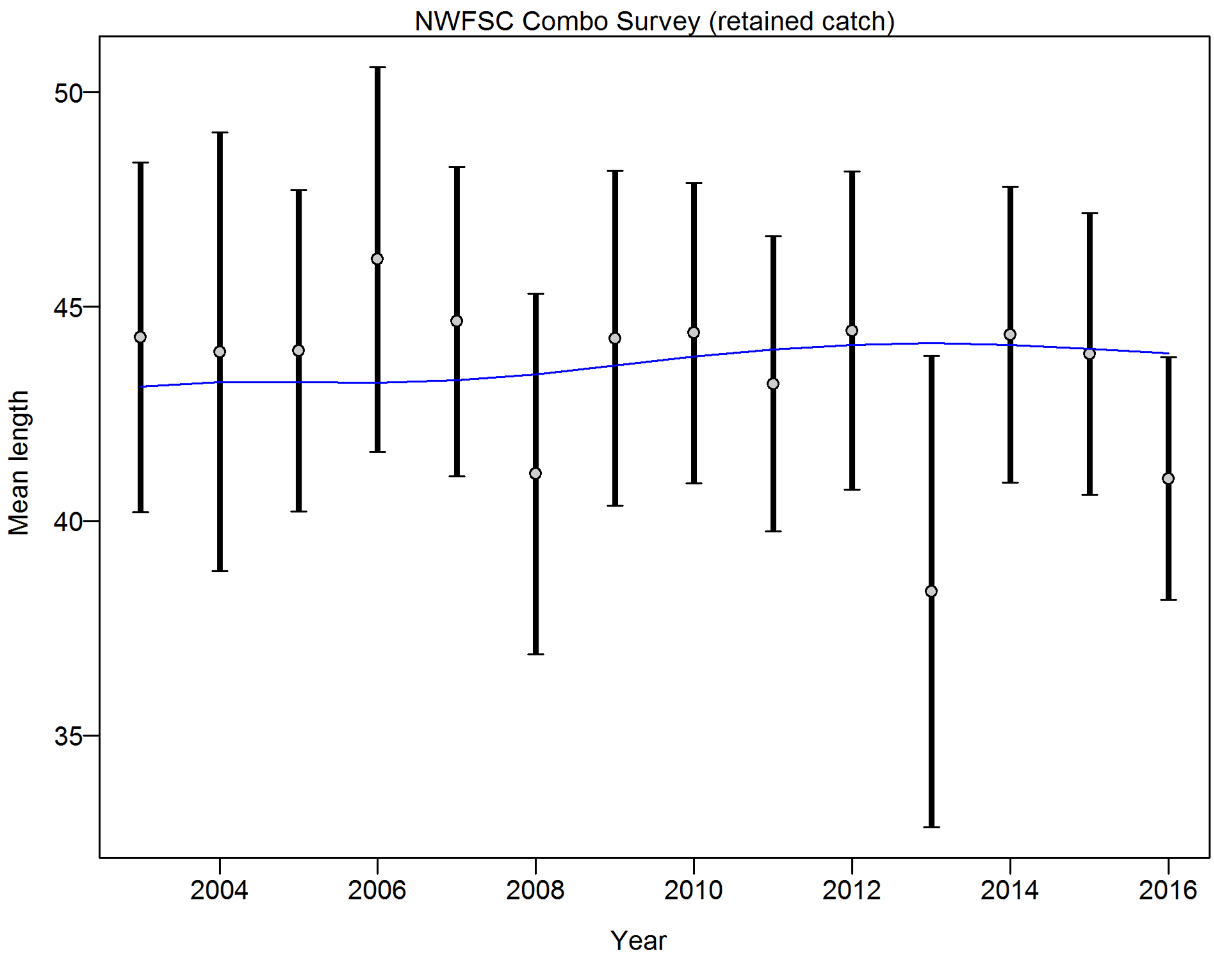


Figure 39: **Northern model** Mean length for NWFSC Combo Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from NWFSC Combo Survey: 1.0053 (0.6094_4.8354) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

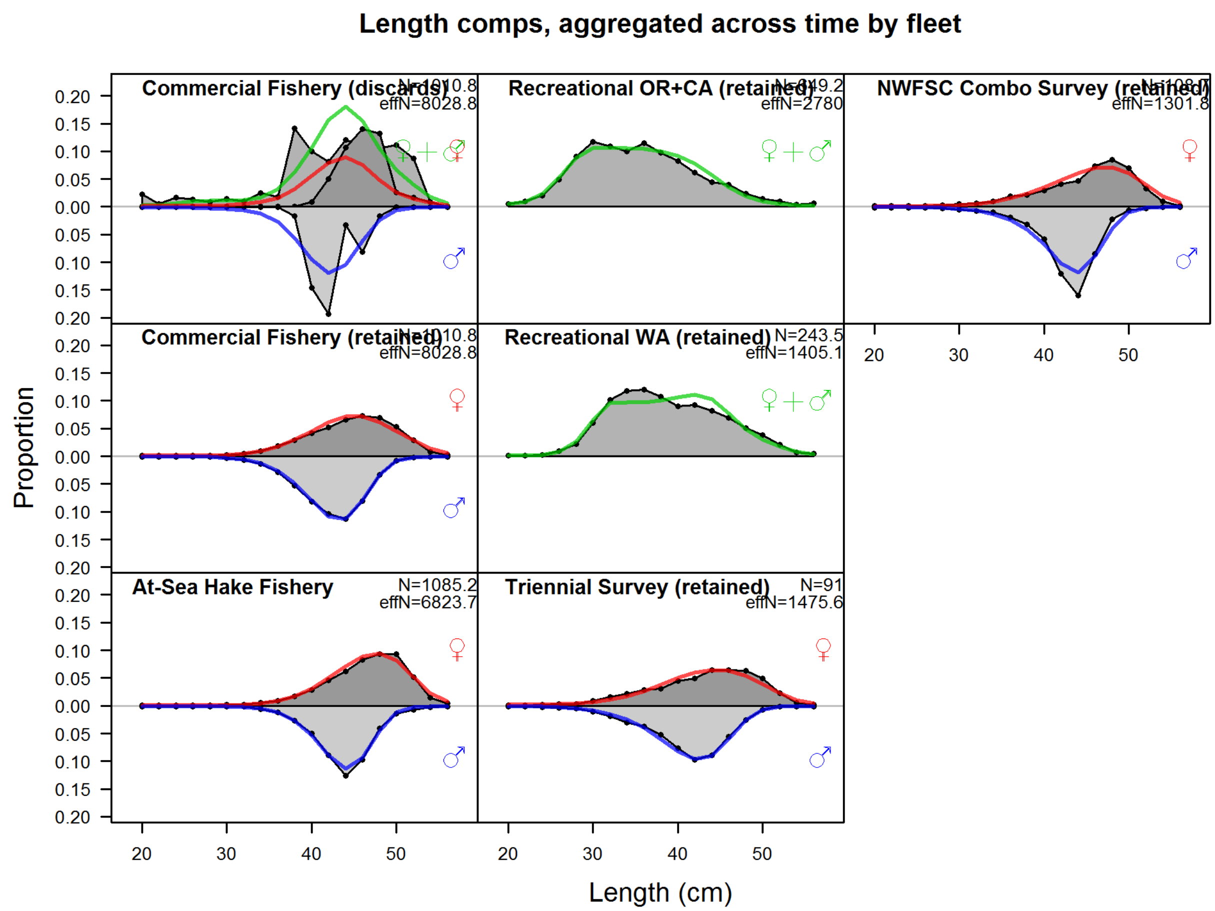


Figure 40: **Northern model** Length comps, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch.

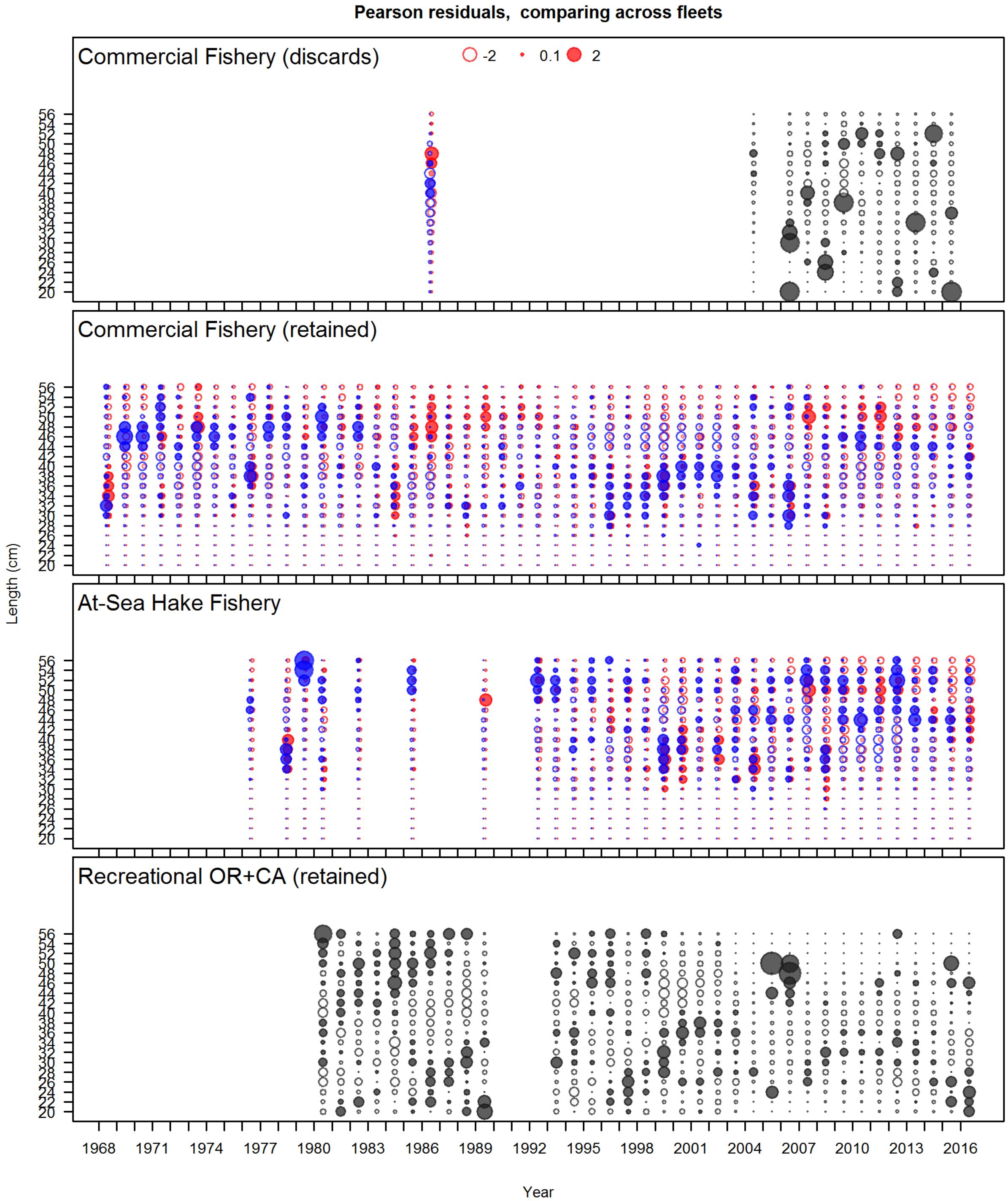


Figure 41: Length composition Pearson residuals for all fleets in the Northern model (Figure 1 of 2). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble colors indicate unsexed fish (gray), females (red), and males (blue).

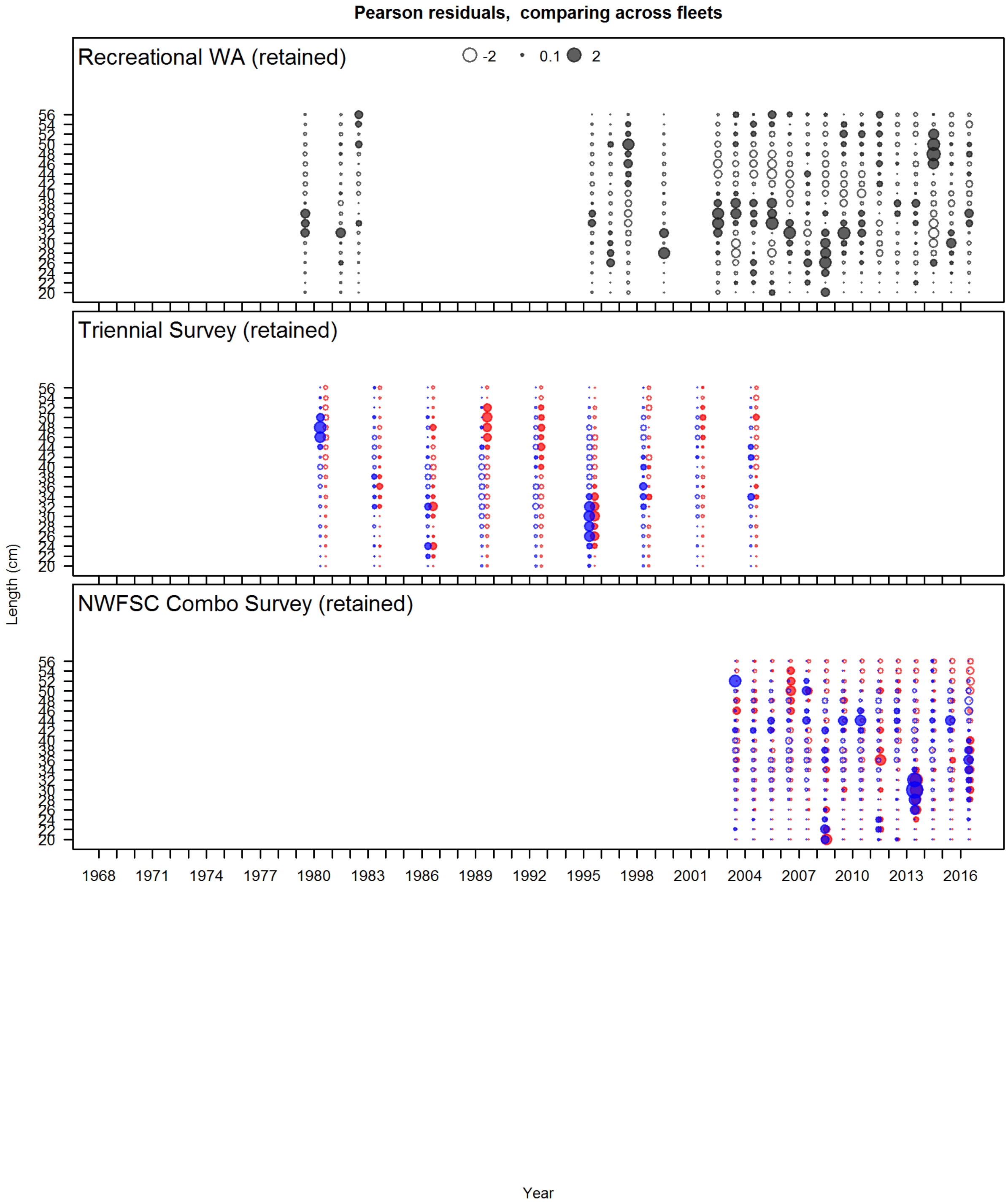


Figure 42: Length composition Pearson residuals for all fleets in the Northern model (Figure 2 of 2).

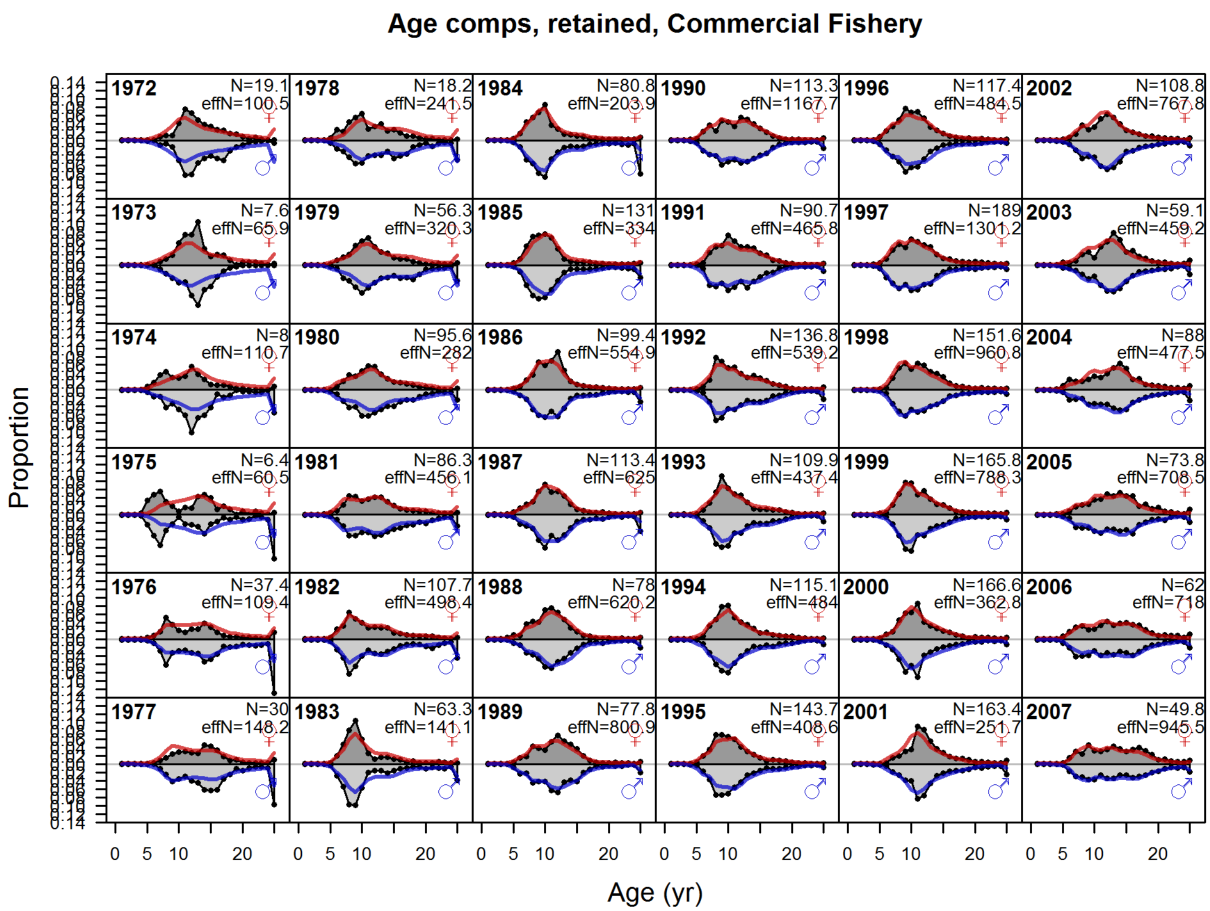
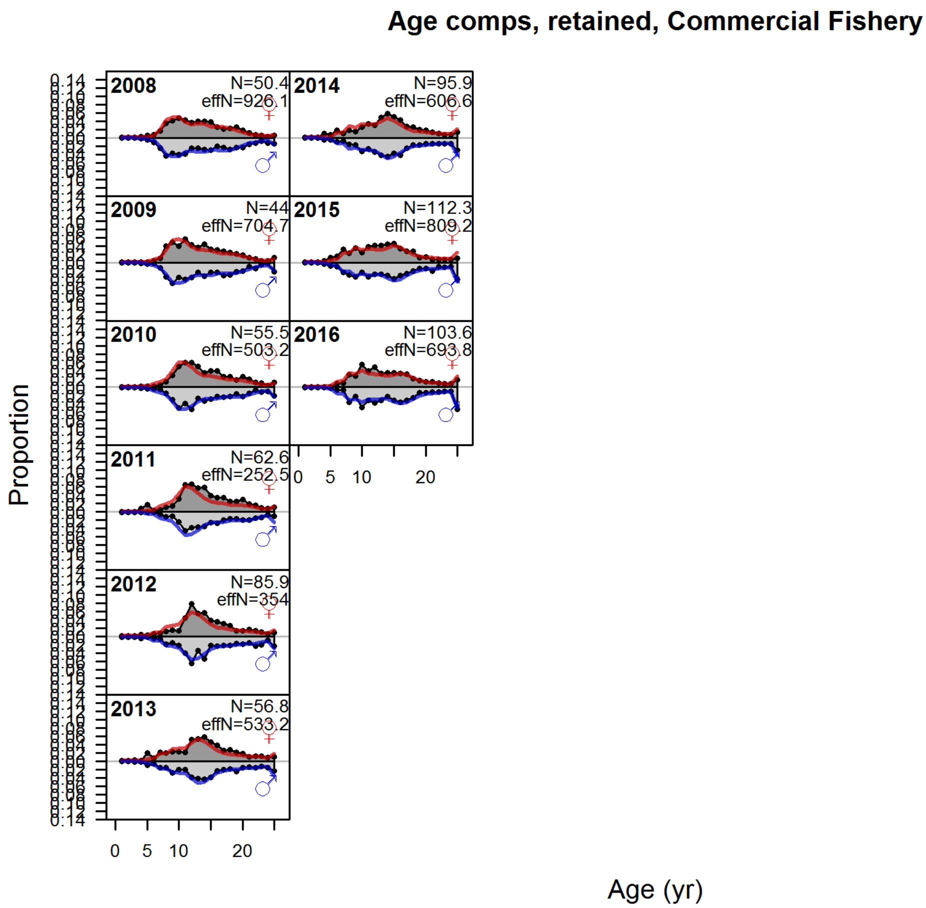


Figure 43: **Northern model** Age comps, retained, Commercial Fishery (plot 1 of 2)

9.2.5 Fits to age compositions for Northern model



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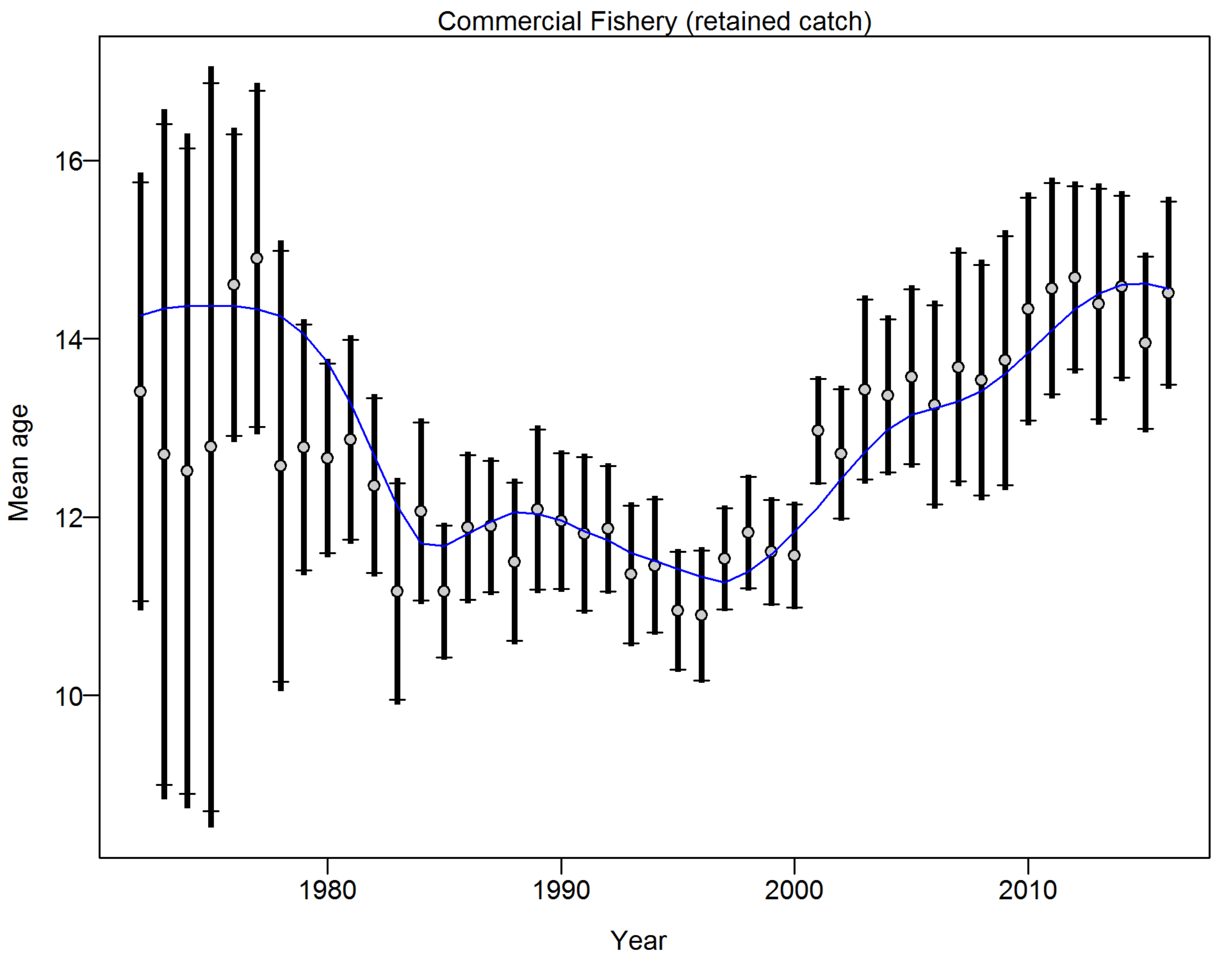


Figure 44: **Northern model** Mean age for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data from Commercial Fishery: 1.0925 (0.7652_1.7859) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

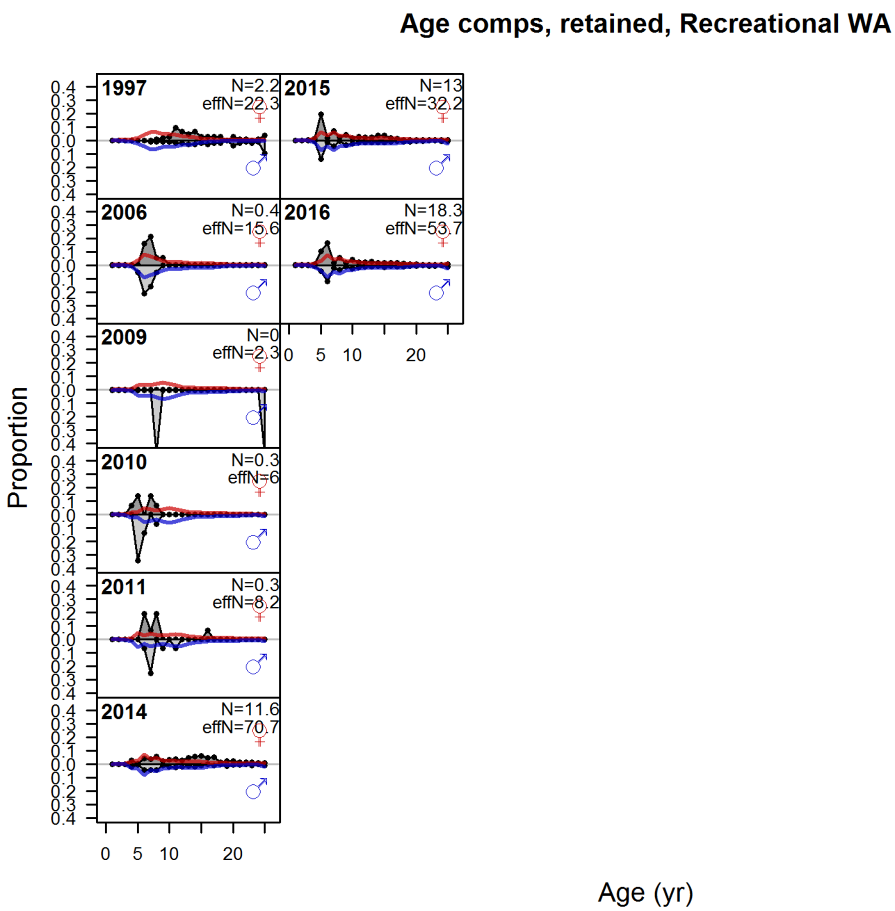


Figure 45: **Northern model** Age comps, retained, Recreational WA

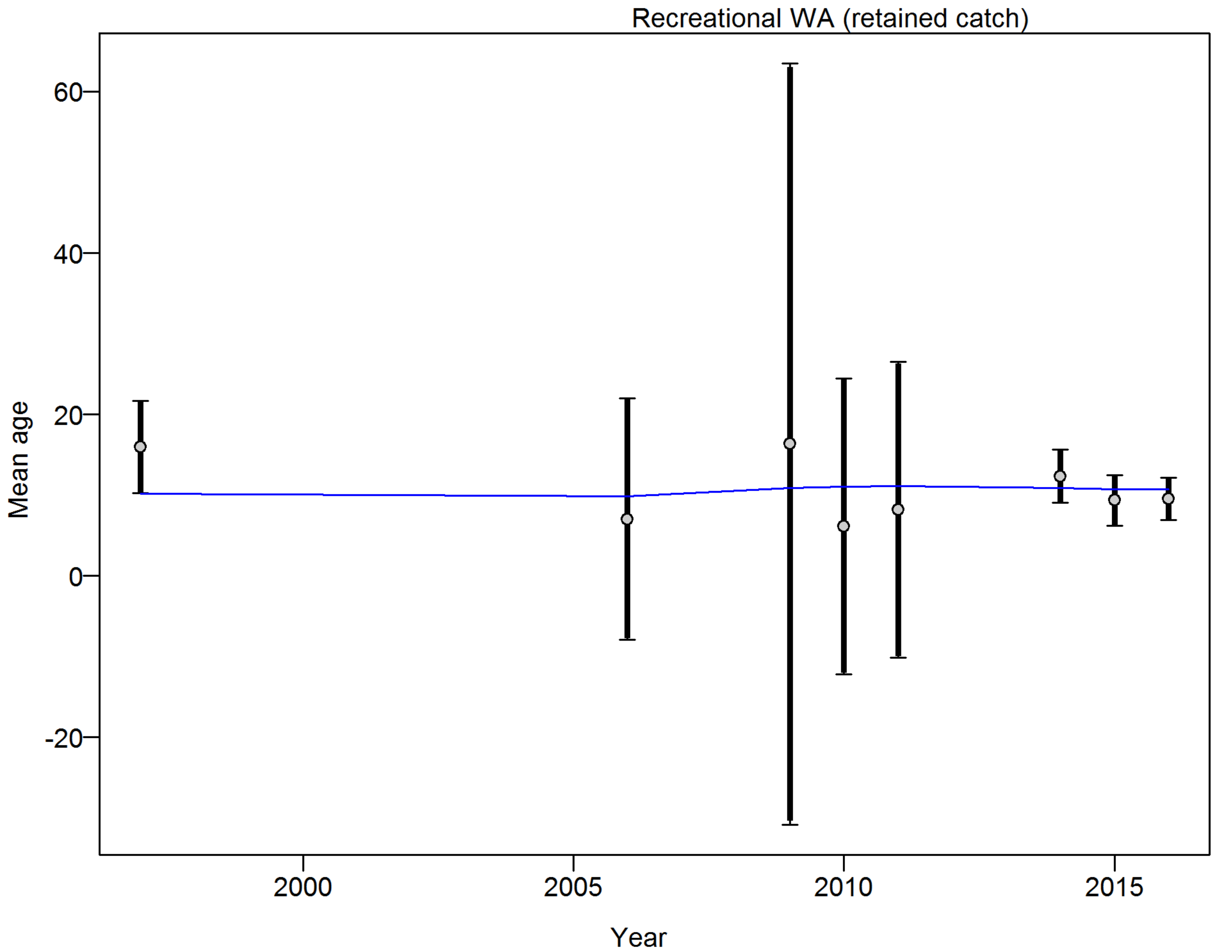


Figure 46: **Northern model** Mean age for Recreational WA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data from Recreational WA: 0.9798 (0.5722_13.3318) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

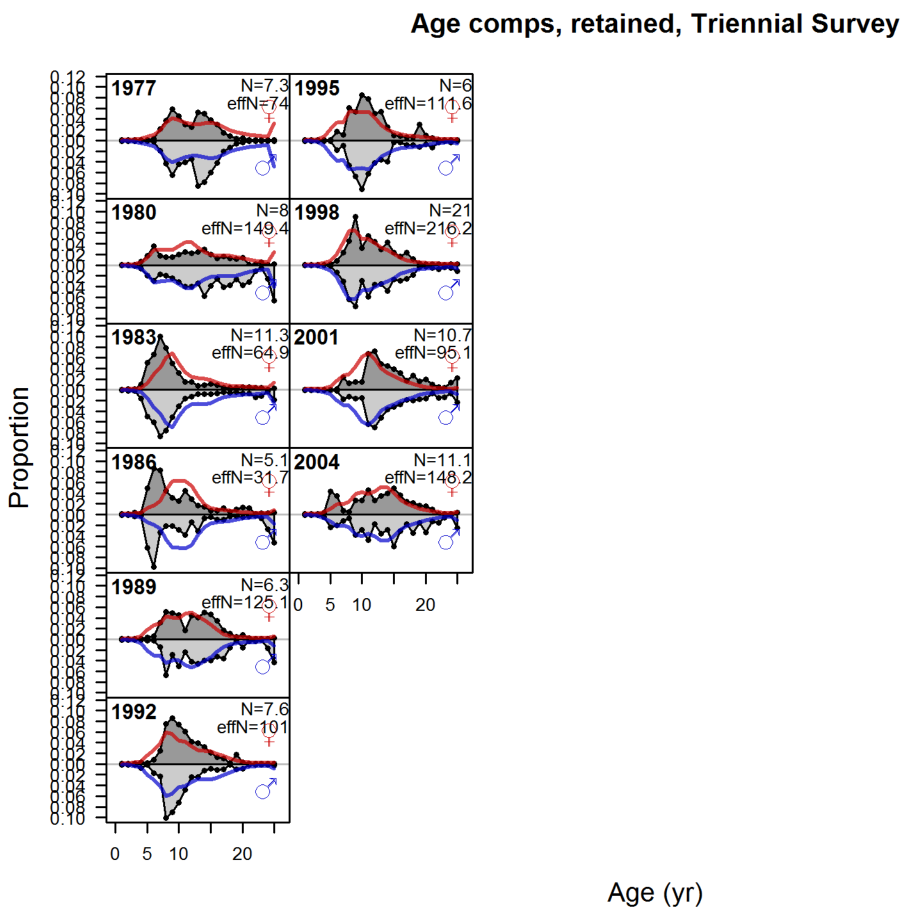


Figure 47: **Northern model** Age comps, retained, Triennial Survey

Figure 48: **Northern model** Mean age for Triennial Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data from Triennial Survey: 1.0397 (0.6408_3.8318) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

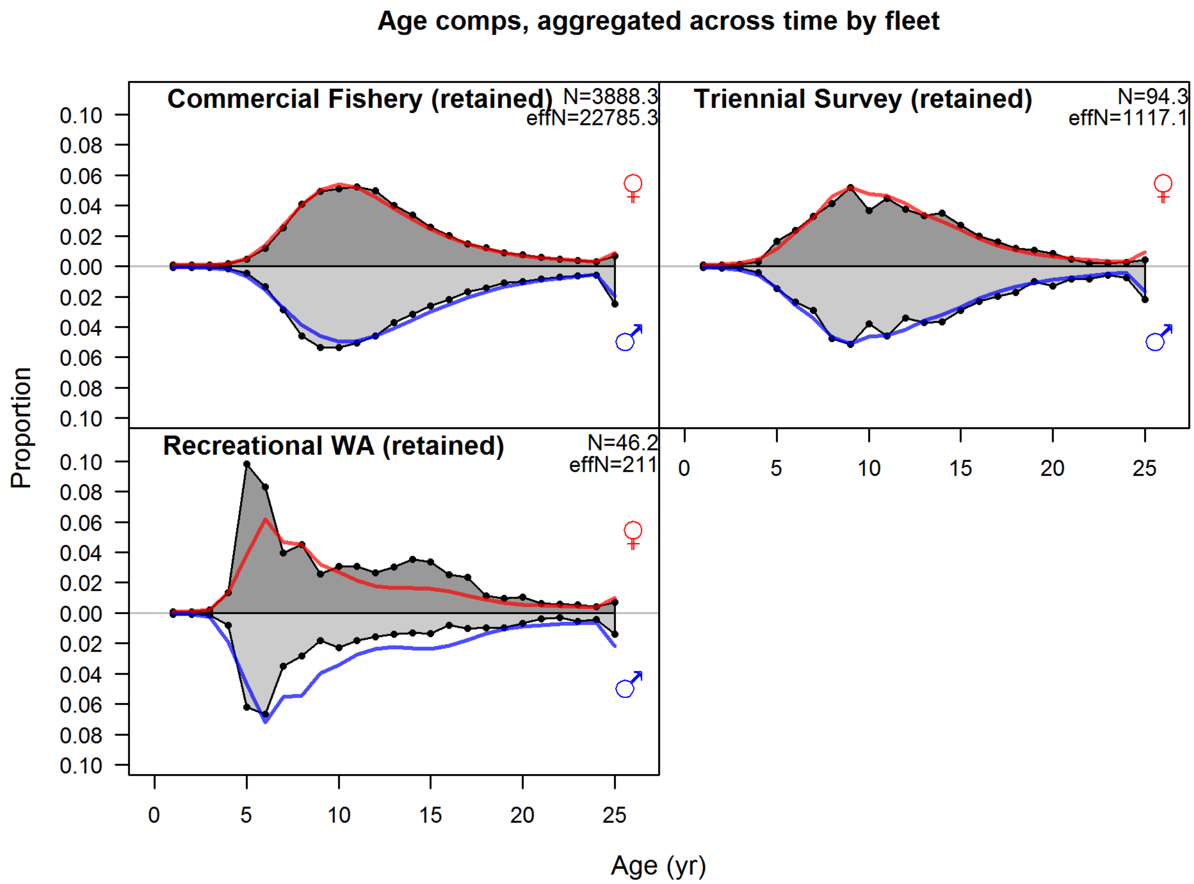


Figure 49: **Northern model** Age comps, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch.

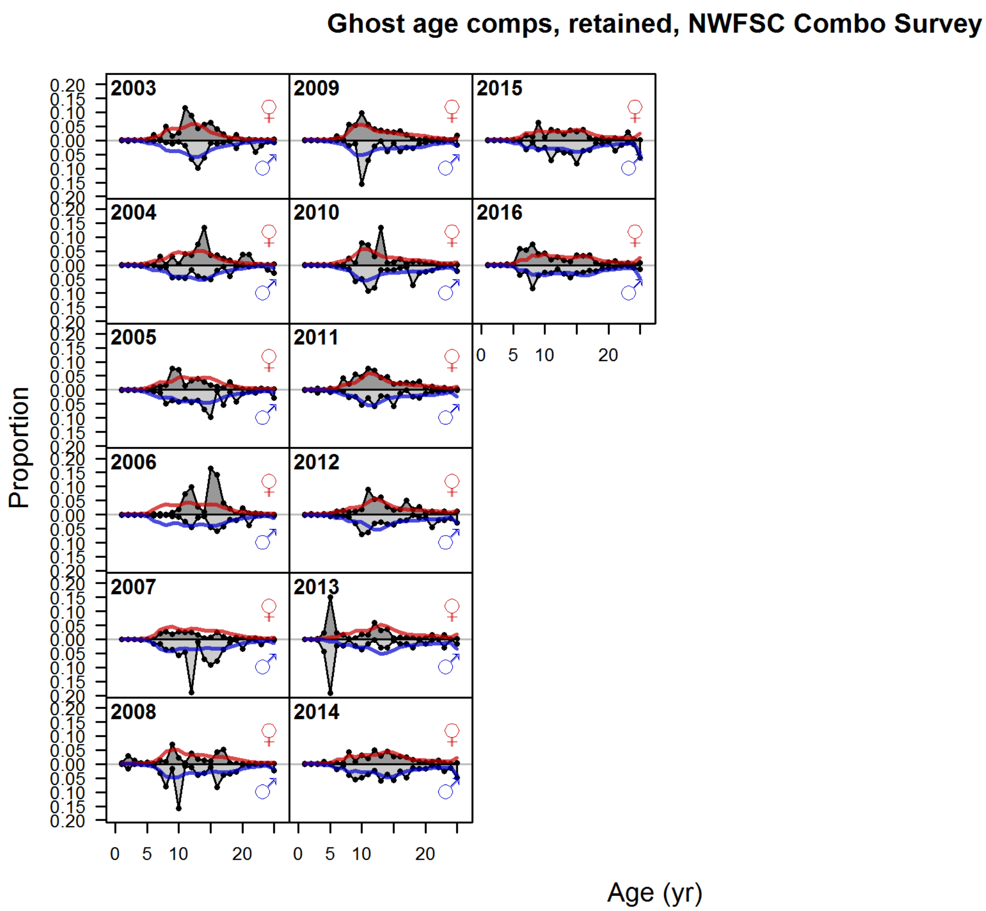


Figure 50: **Northern model** Ghost age comps, retained, NWFSC Combo Survey

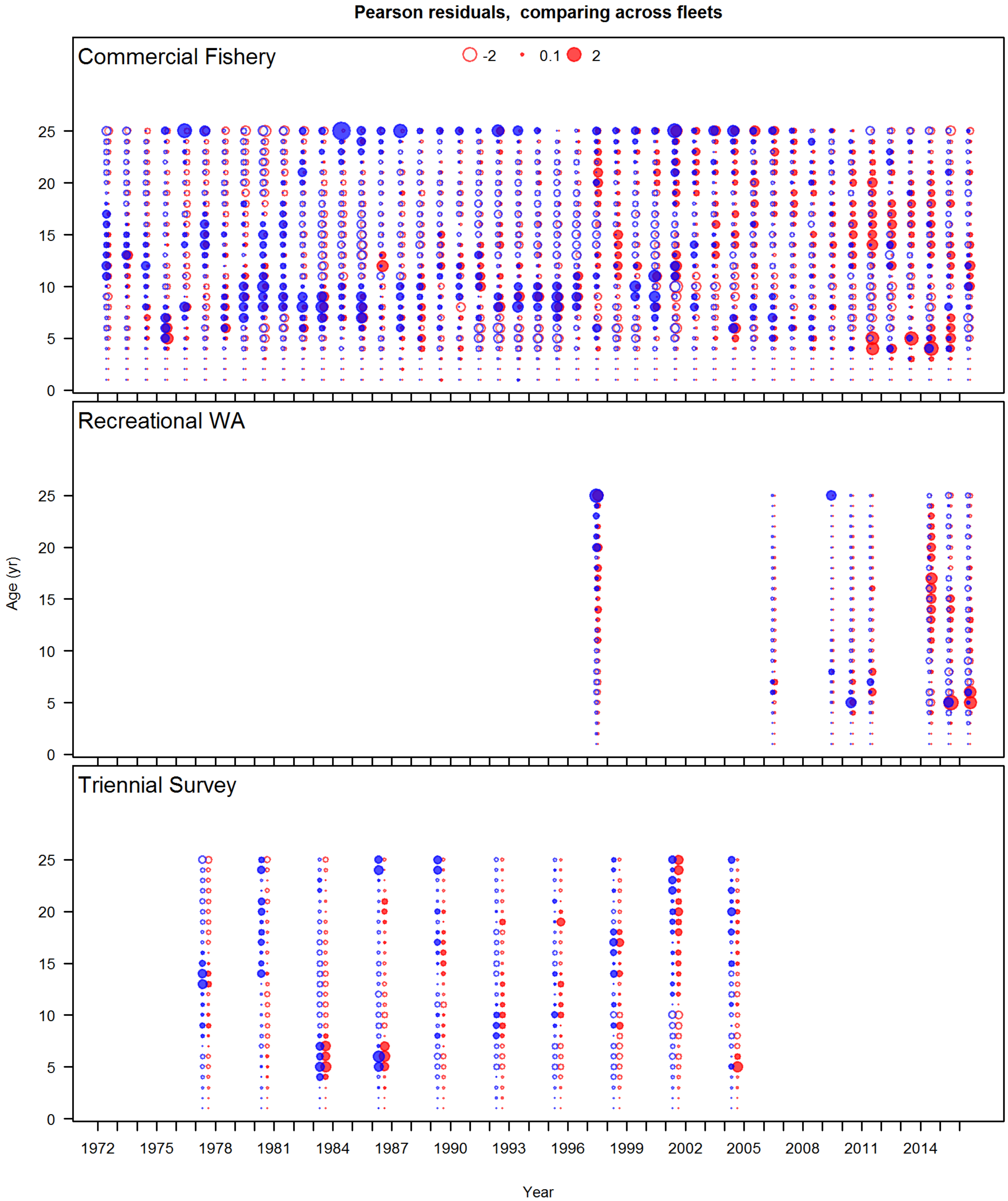


Figure 51: Age composition Pearson residuals for all fleets in the Northern model. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble colors indicate unsexed fish (gray), females (red), and males (blue).

1581 ### 9.2.6 Fits to conditional-age-at-length compositions for Northern model

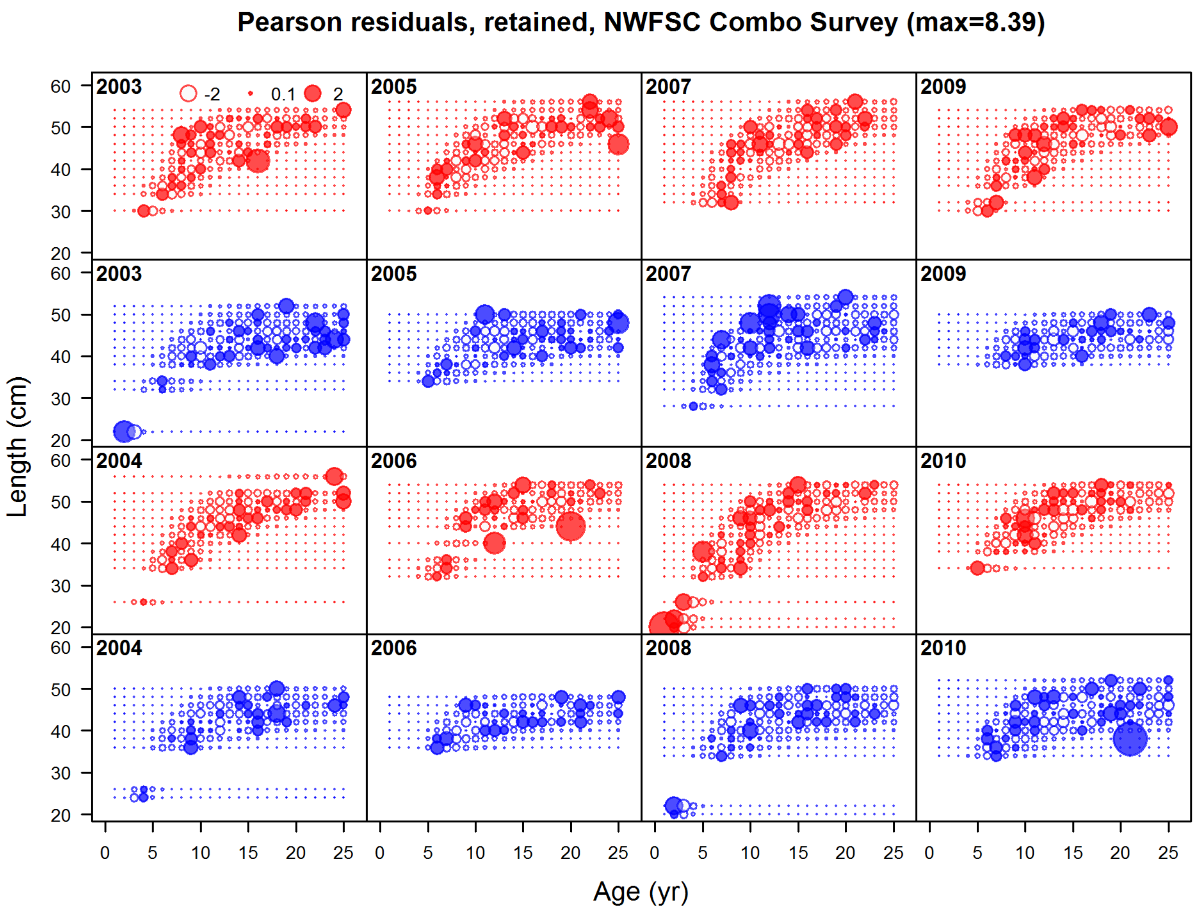
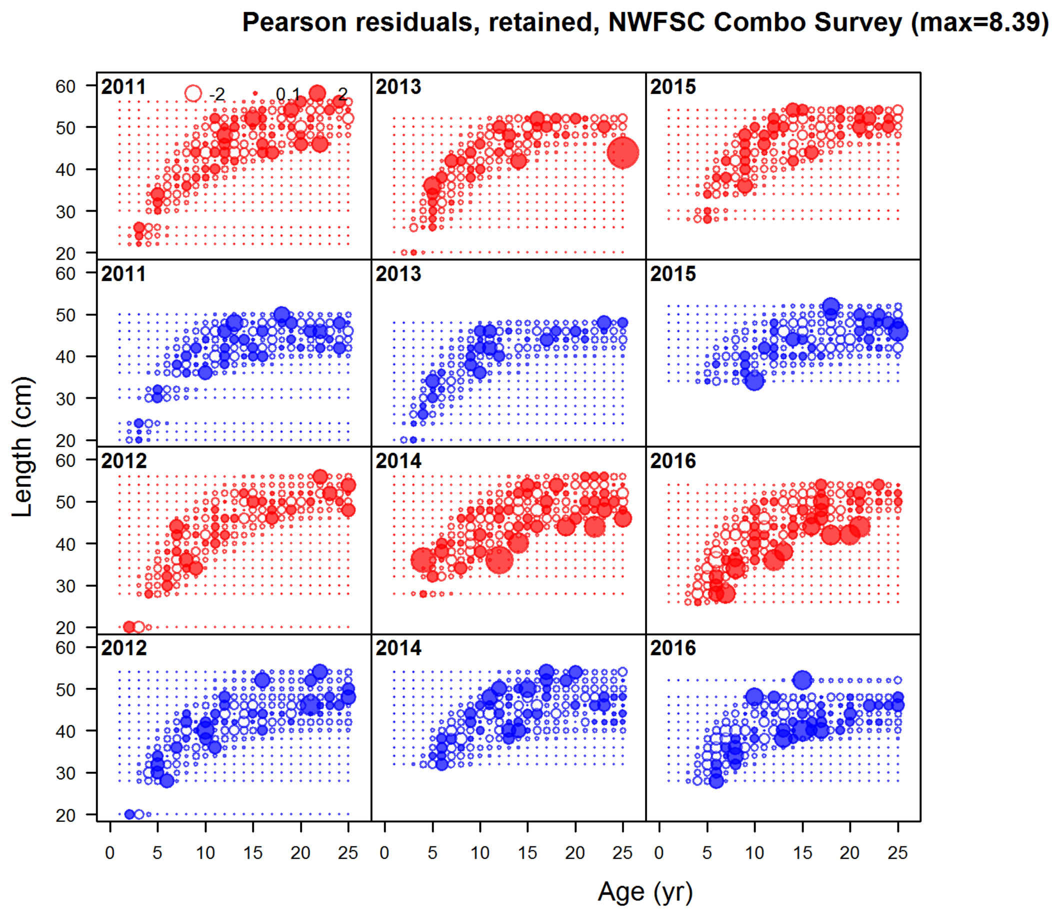


Figure 52: **Northern model** Pearson residuals, retained, NWFSC Combo Survey (max=8.39) (plot 1 of 2)



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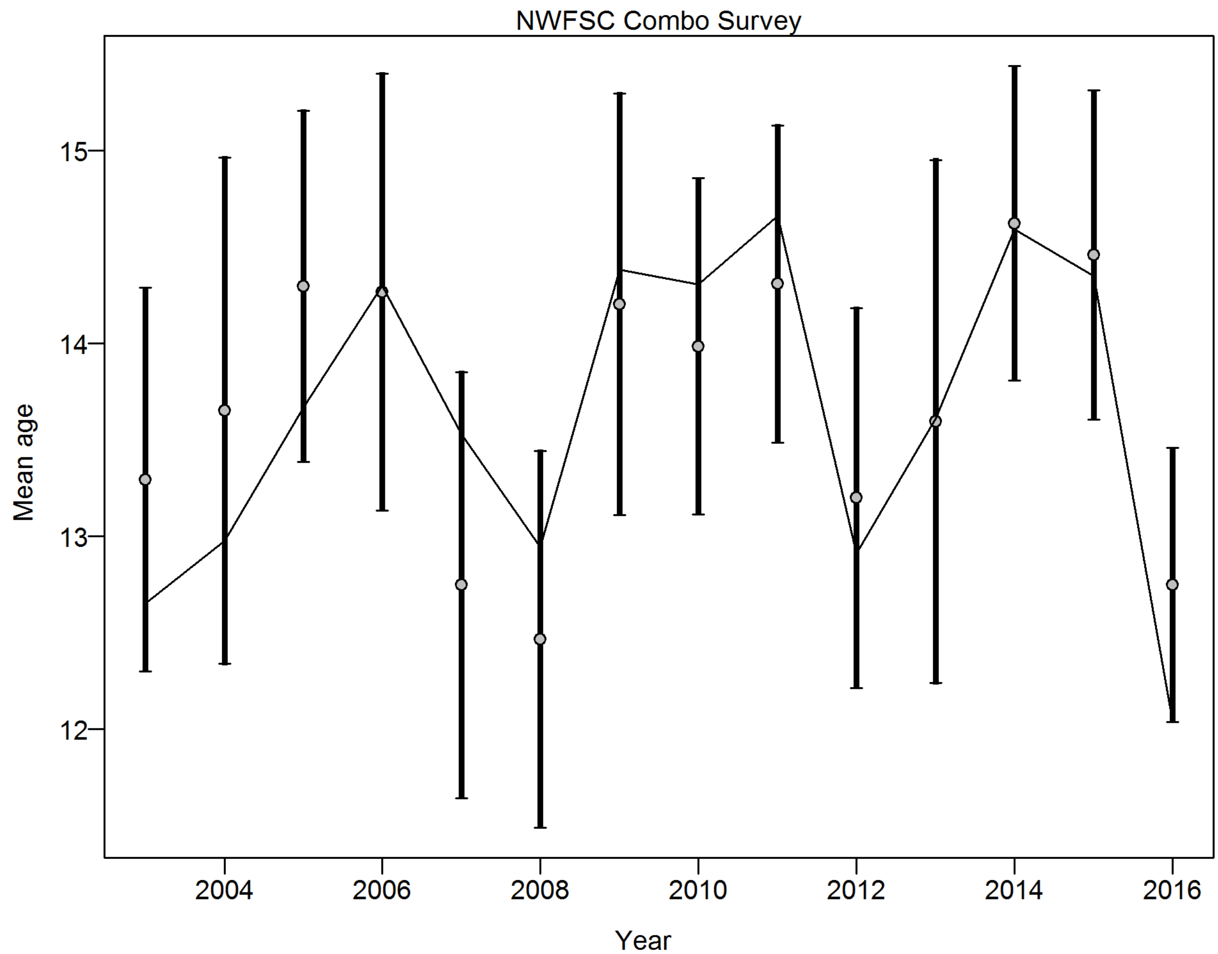


Figure 53: **Northern model** Mean age from conditional data (aggregated across length bins) for NWFSC Combo Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for conditional age_at_length data from NWFSC Combo Survey: 1.0123 (0.6662_2.3339) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

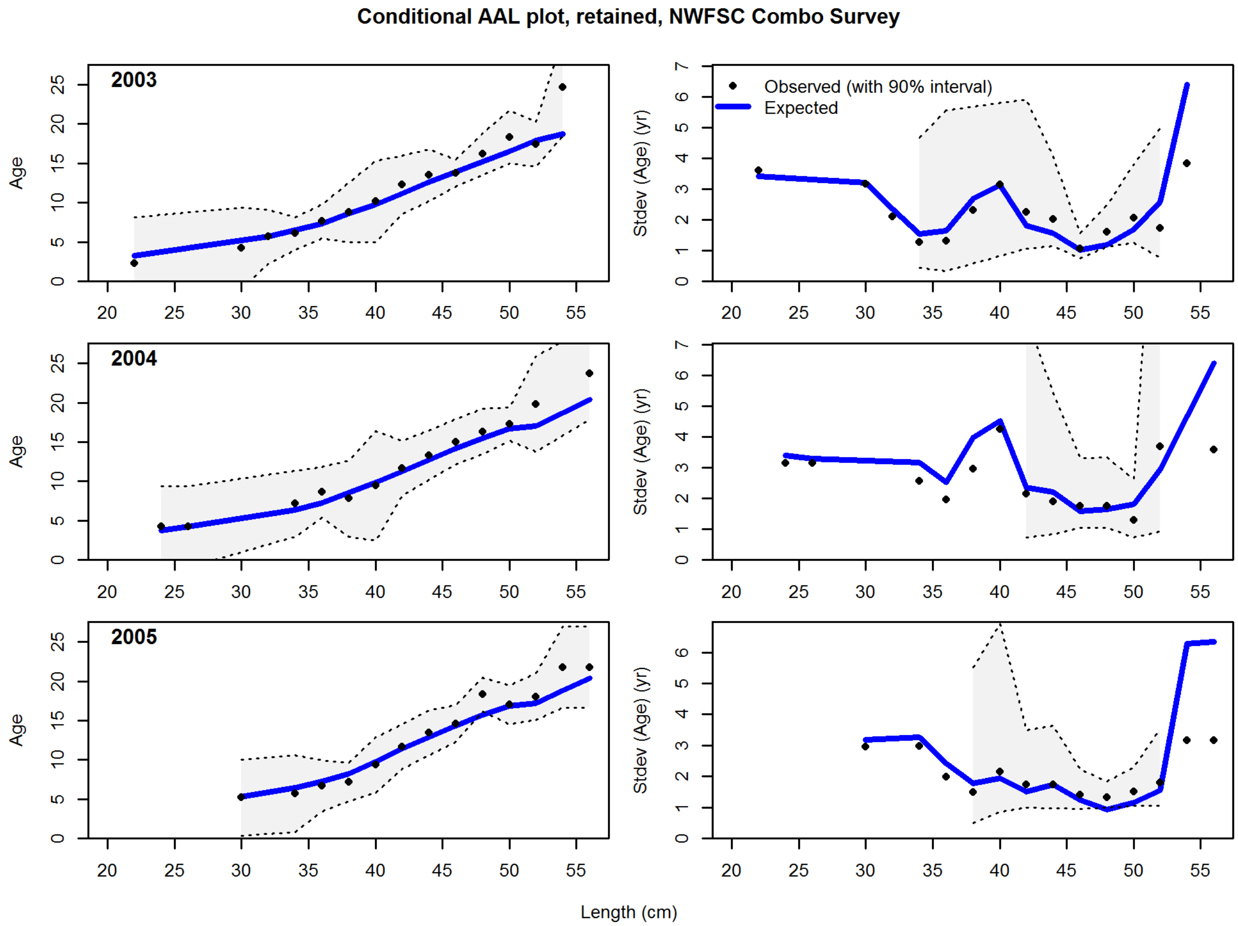
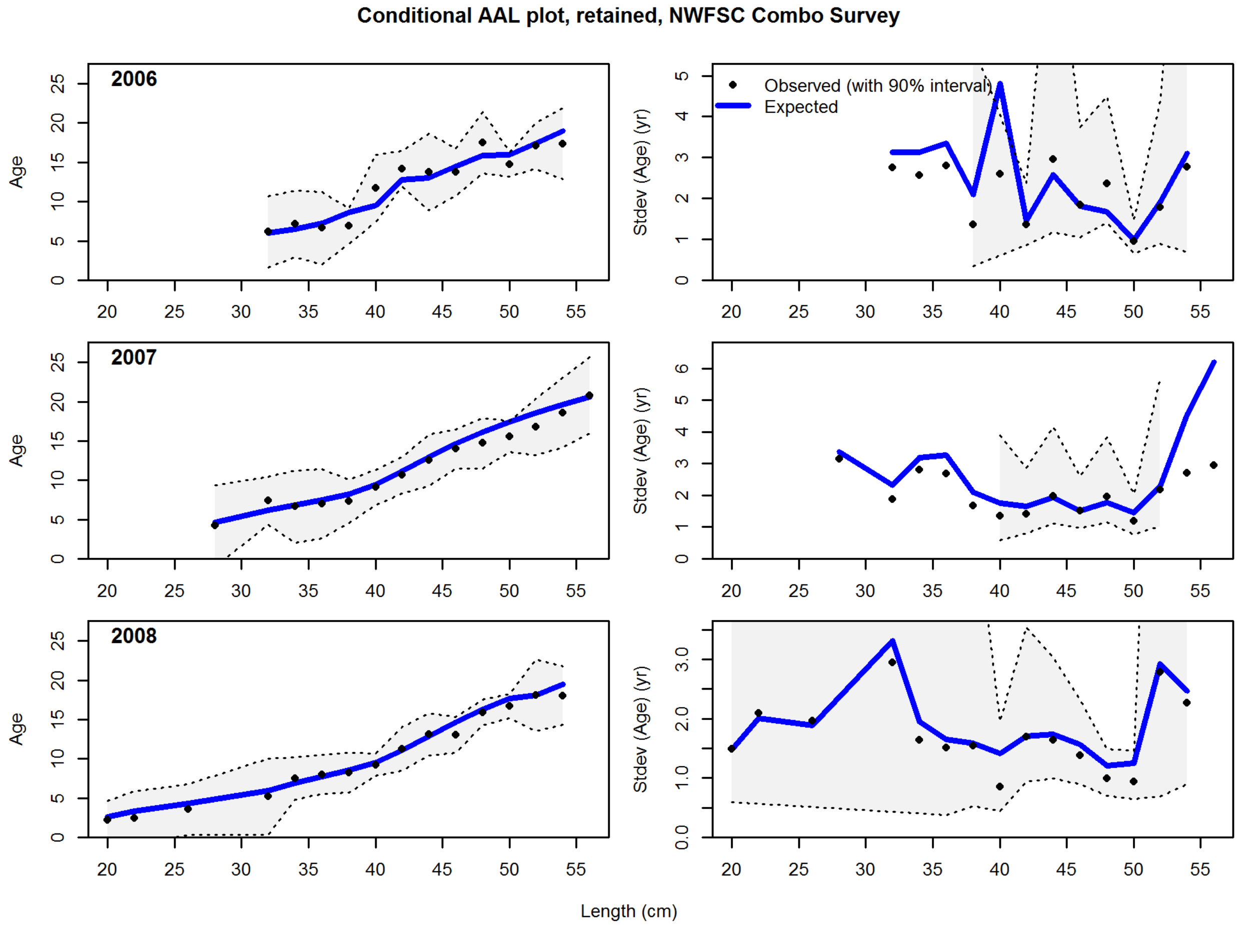


Figure 54: **Northern model** Conditional AAL plot, retained, NWFSC Combo Survey (plot 1 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution.



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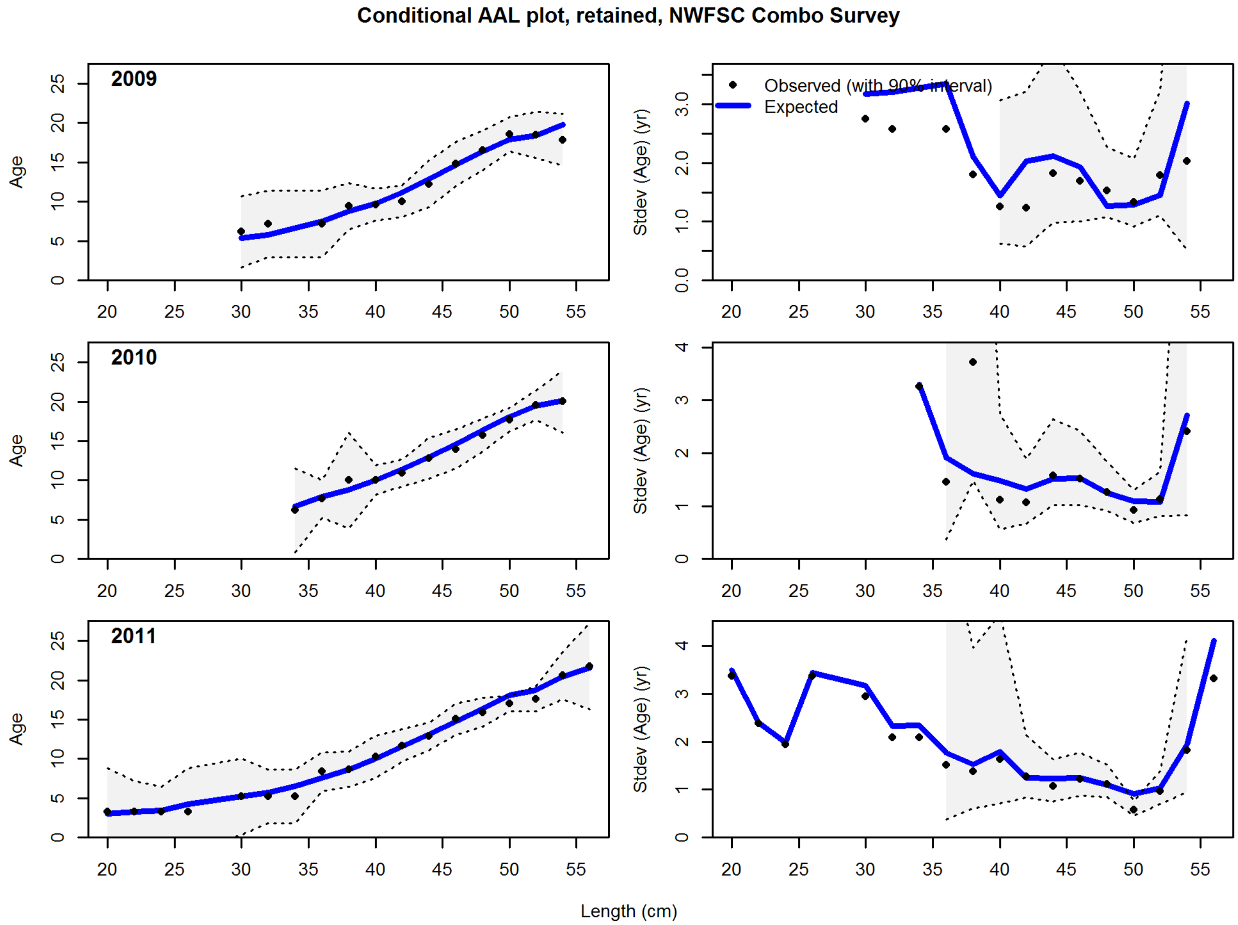

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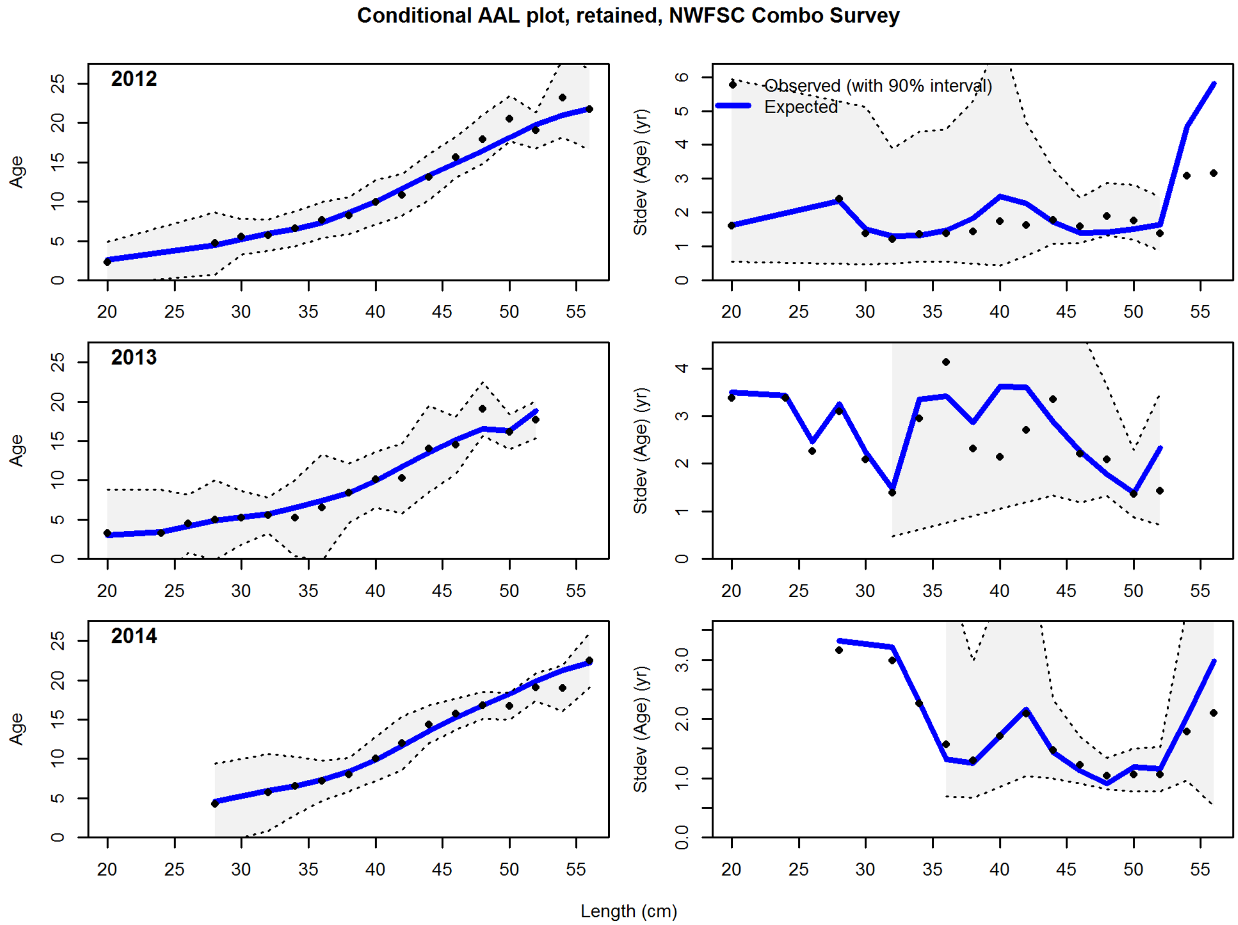

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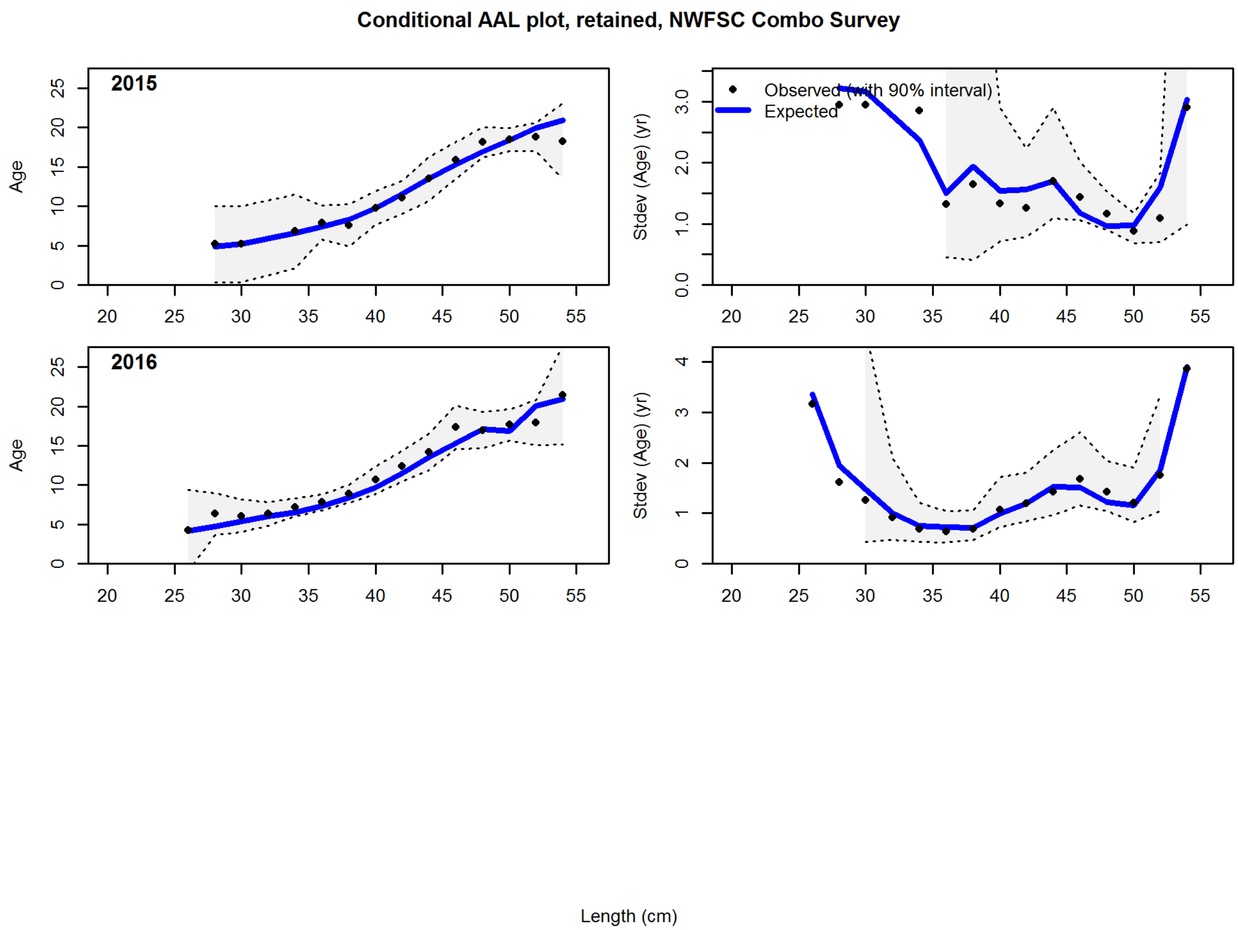

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9.3 Model results for Northern model

9.3.1 Base model results for Northern model

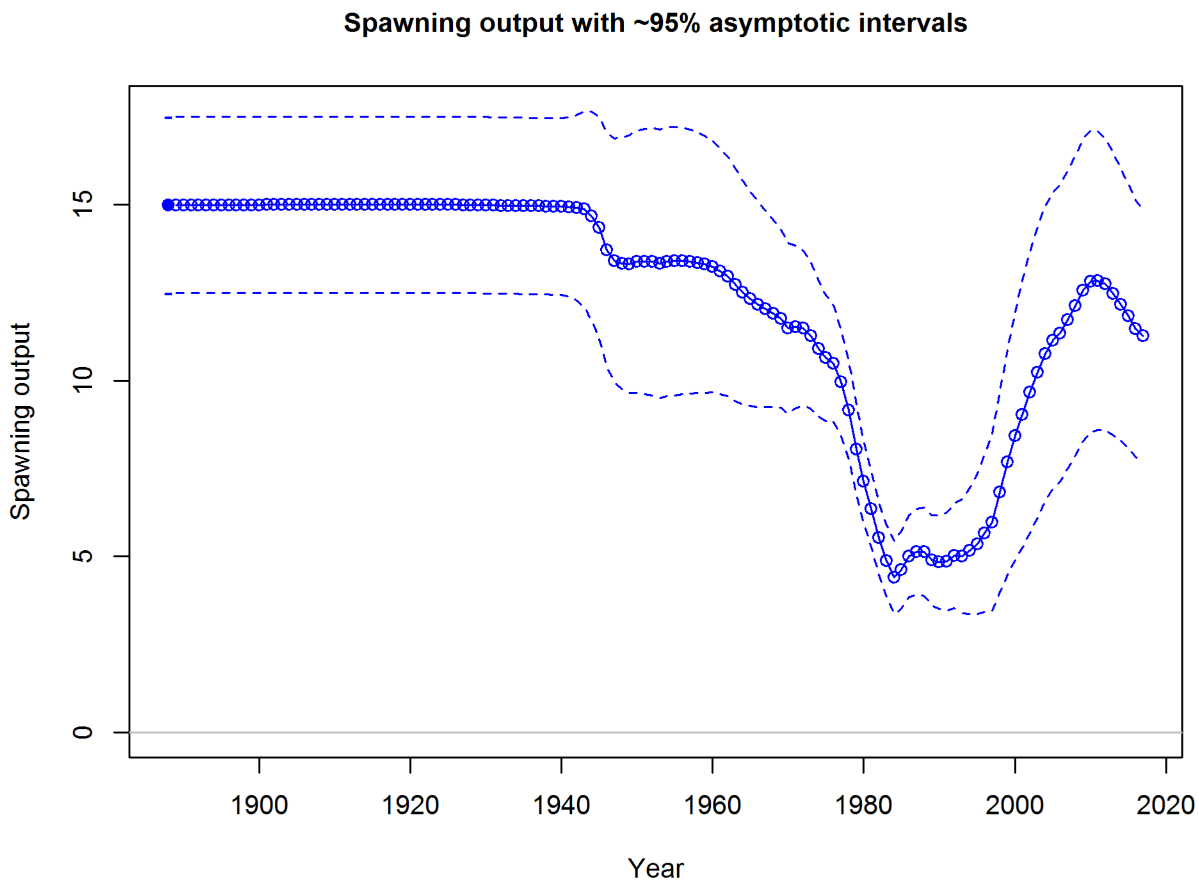


Figure 55: Estimated time-series of spawning output for Northern model.

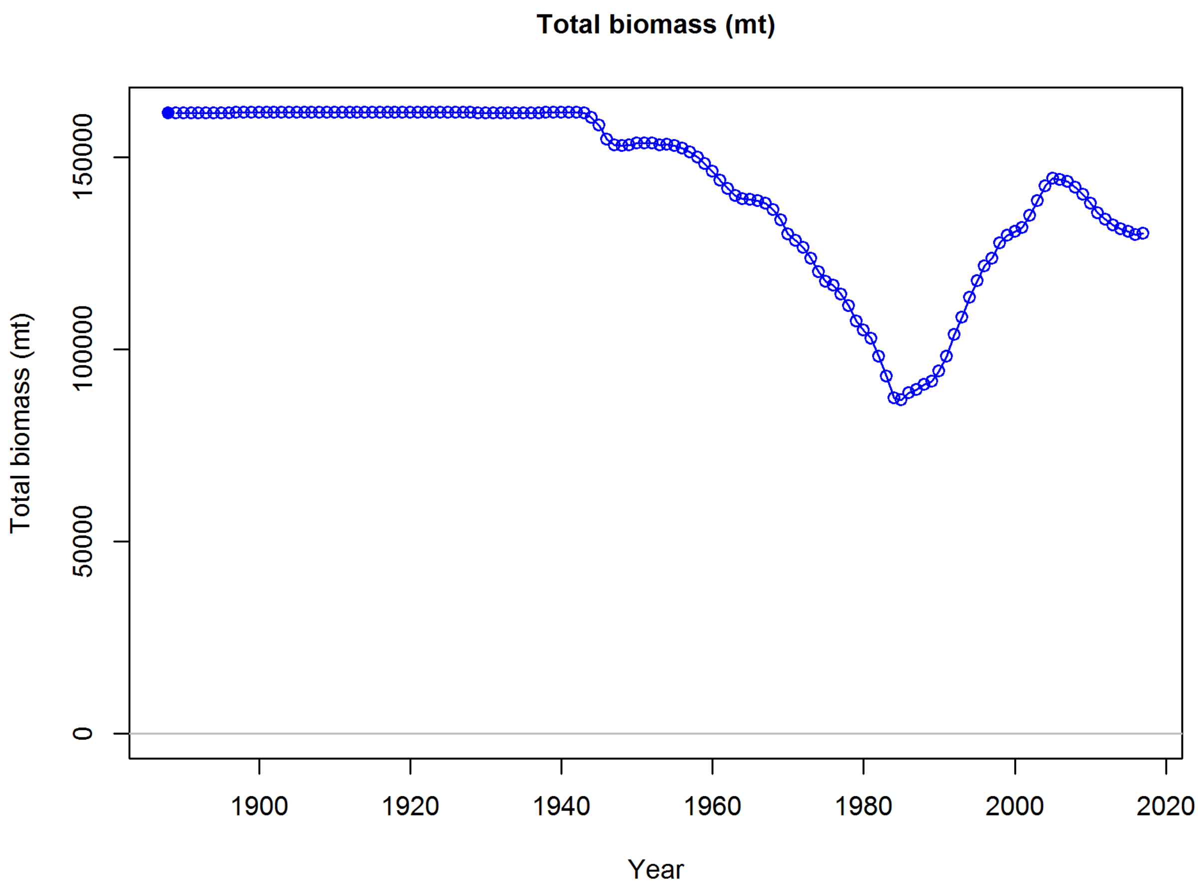


Figure 56: Estimated time-series of total biomass for Northern model.

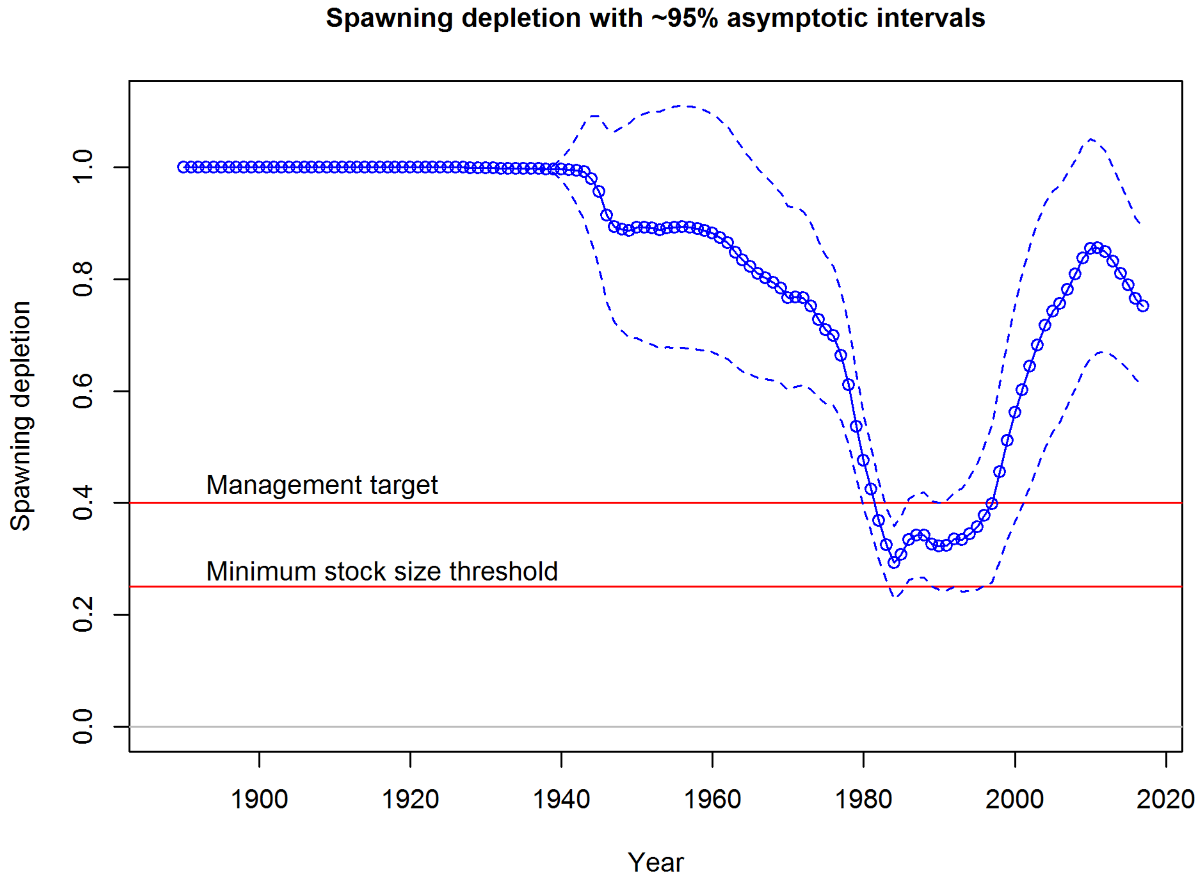


Figure 57: Estimated time-series of relative biomass for Northern model.

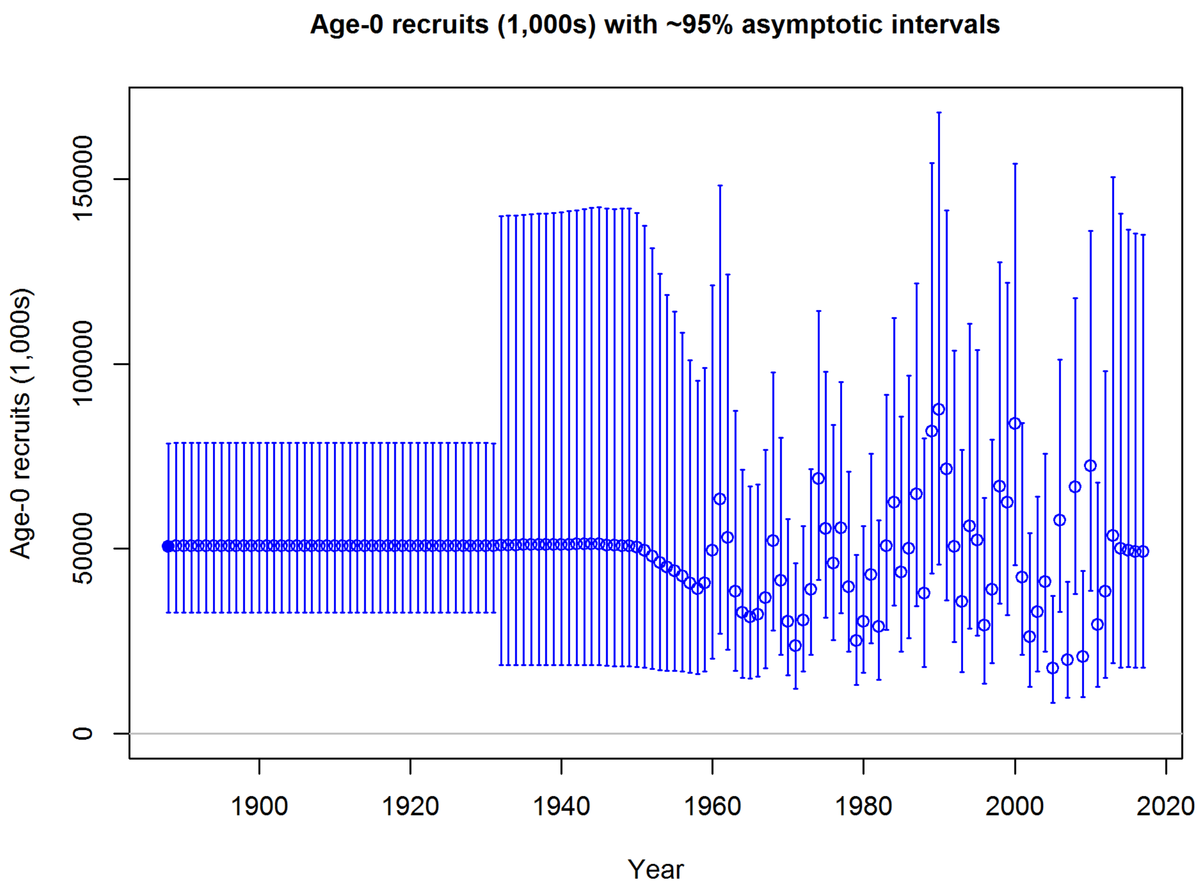


Figure 58: Estimated time-series of recruitment for the Northern model.

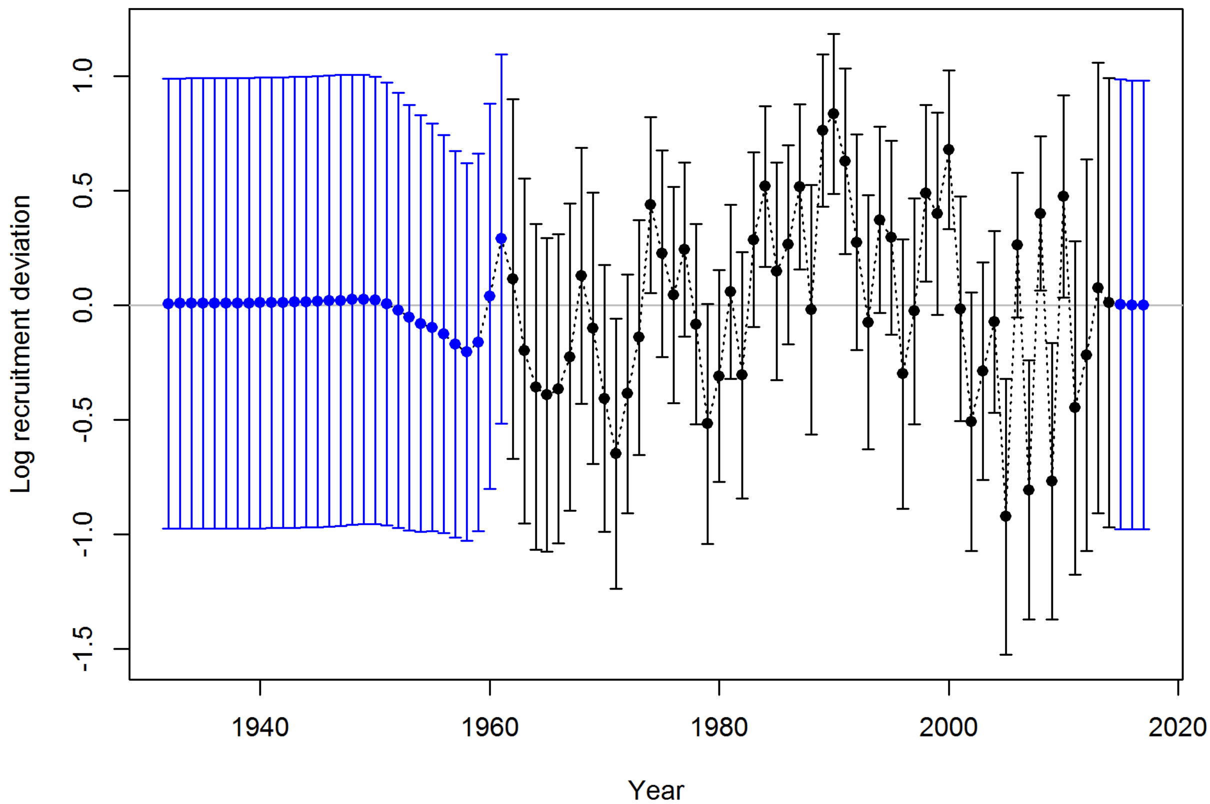


Figure 59: Estimated time-series of recruitment deviations for the Northern model.

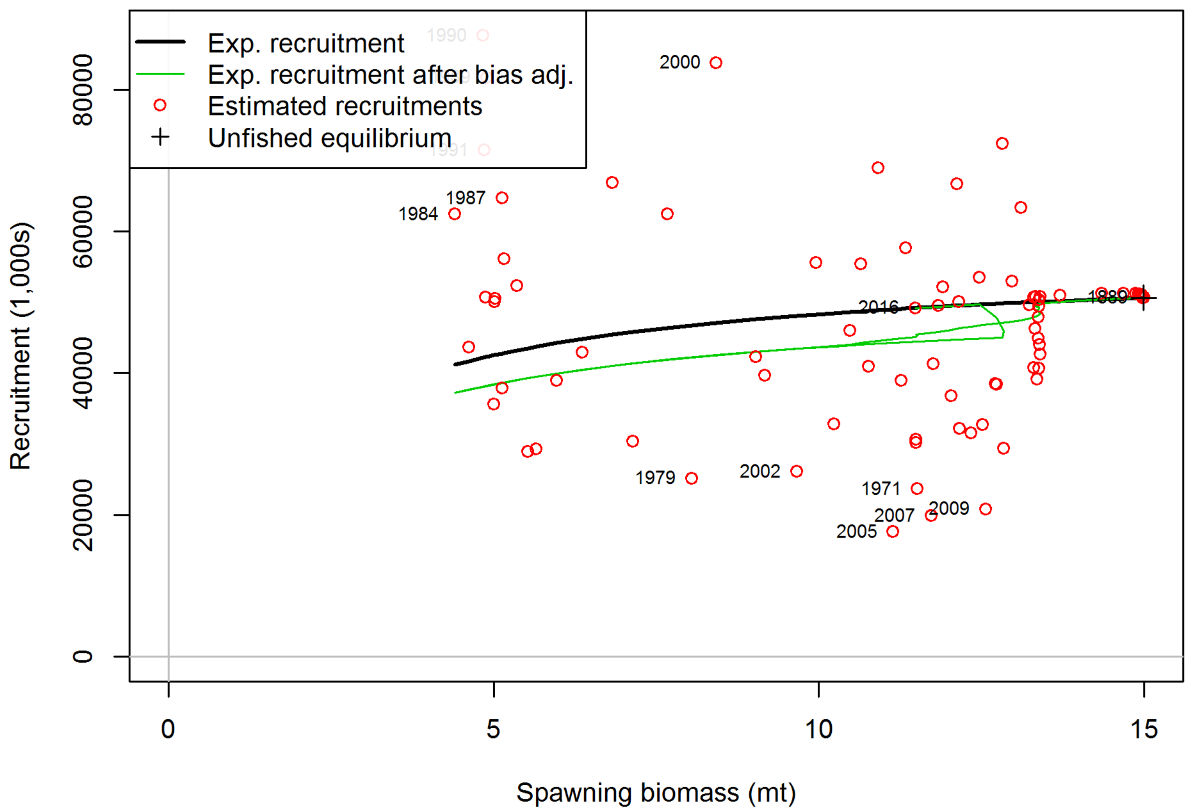


Figure 60: Estimated recruitment (red circles) for the Northern model relative to the stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution

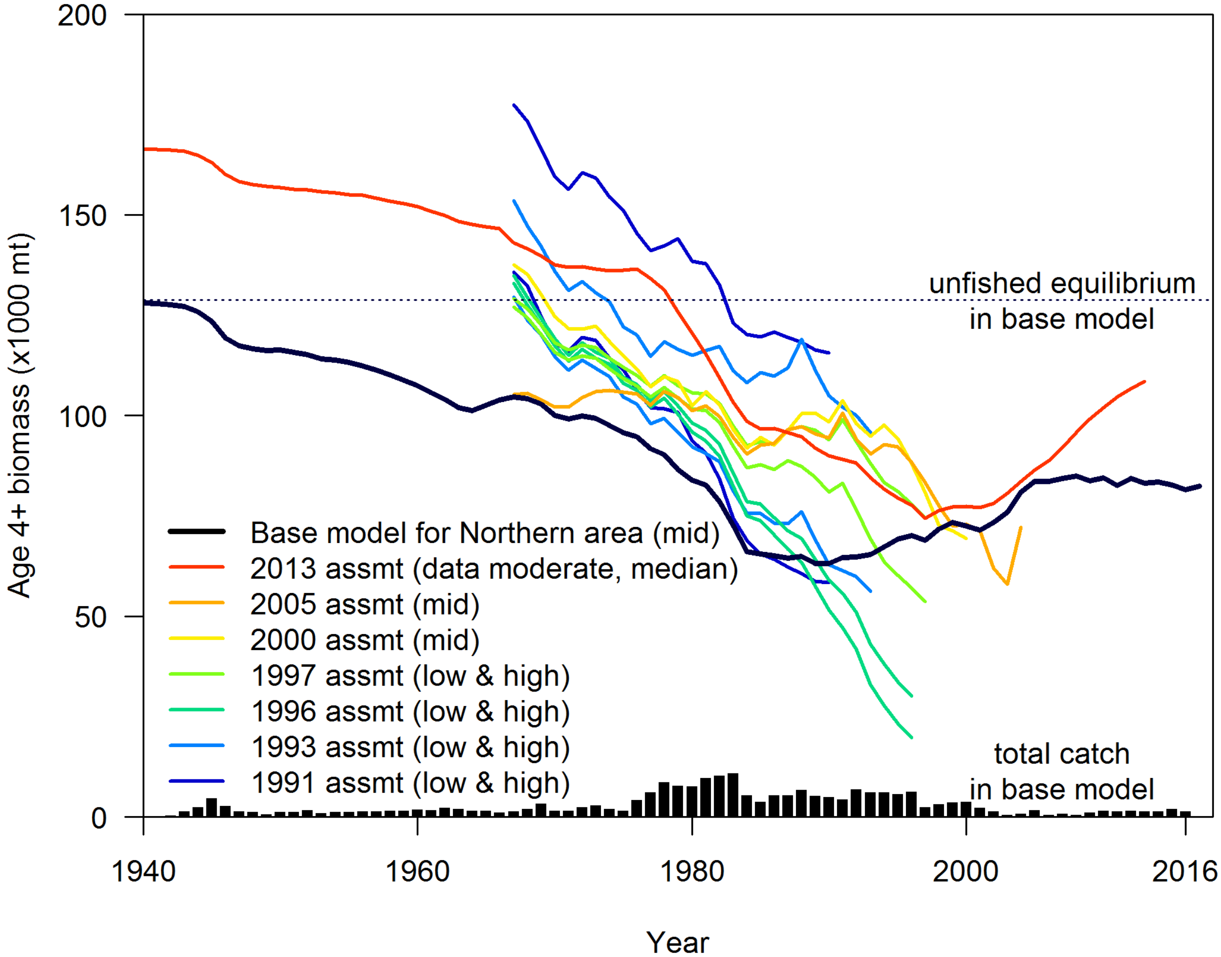


Figure 61: Comparison of time series of age 4+ biomass for Yellowtail Rockfish across past assessments. Previous assessments were focused only on the area north of 40°10′, but also included a small area within Canada.

9.3.2 Sensitivity analyses for Northern model

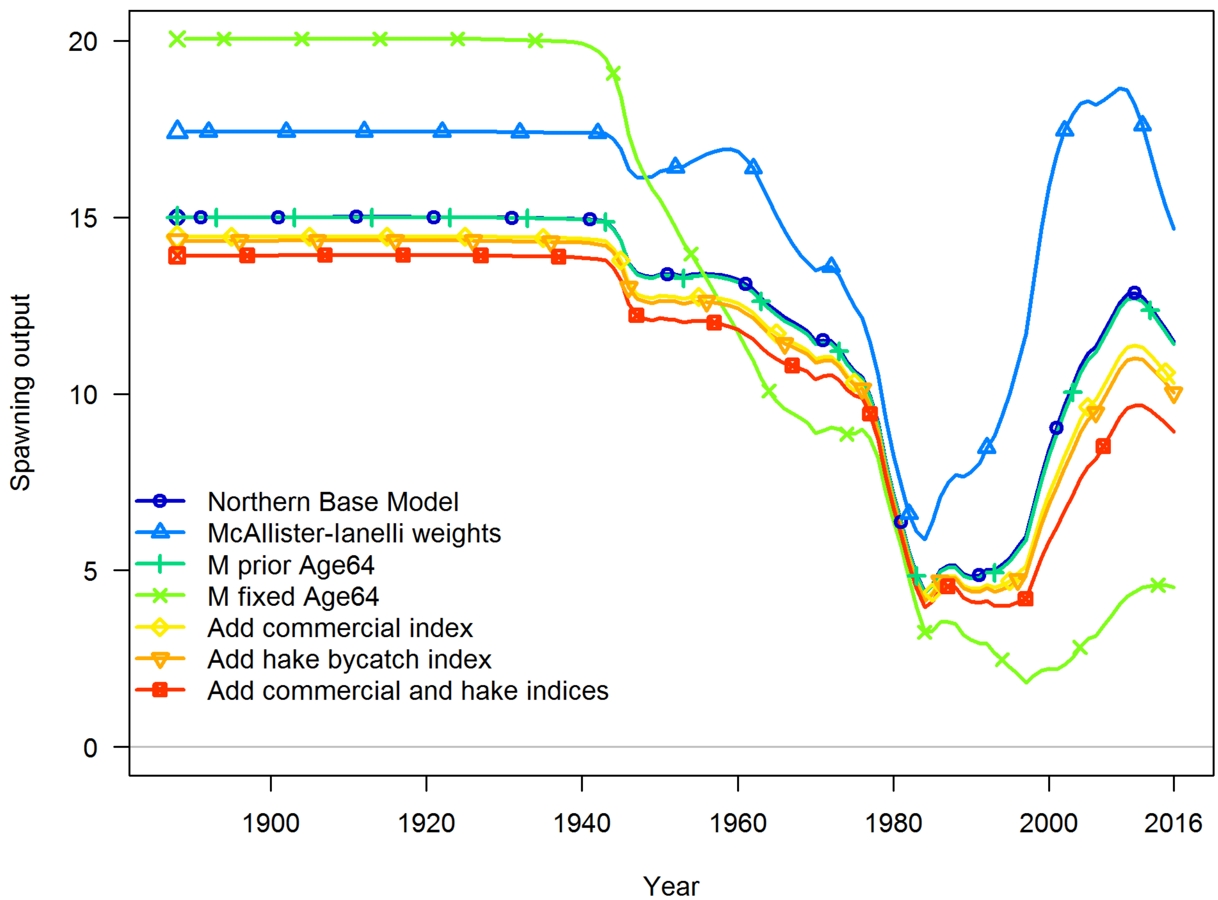


Figure 62: Time series of spawning output (in trillions of eggs) estimated in sensitivity analyses for the Northern model.

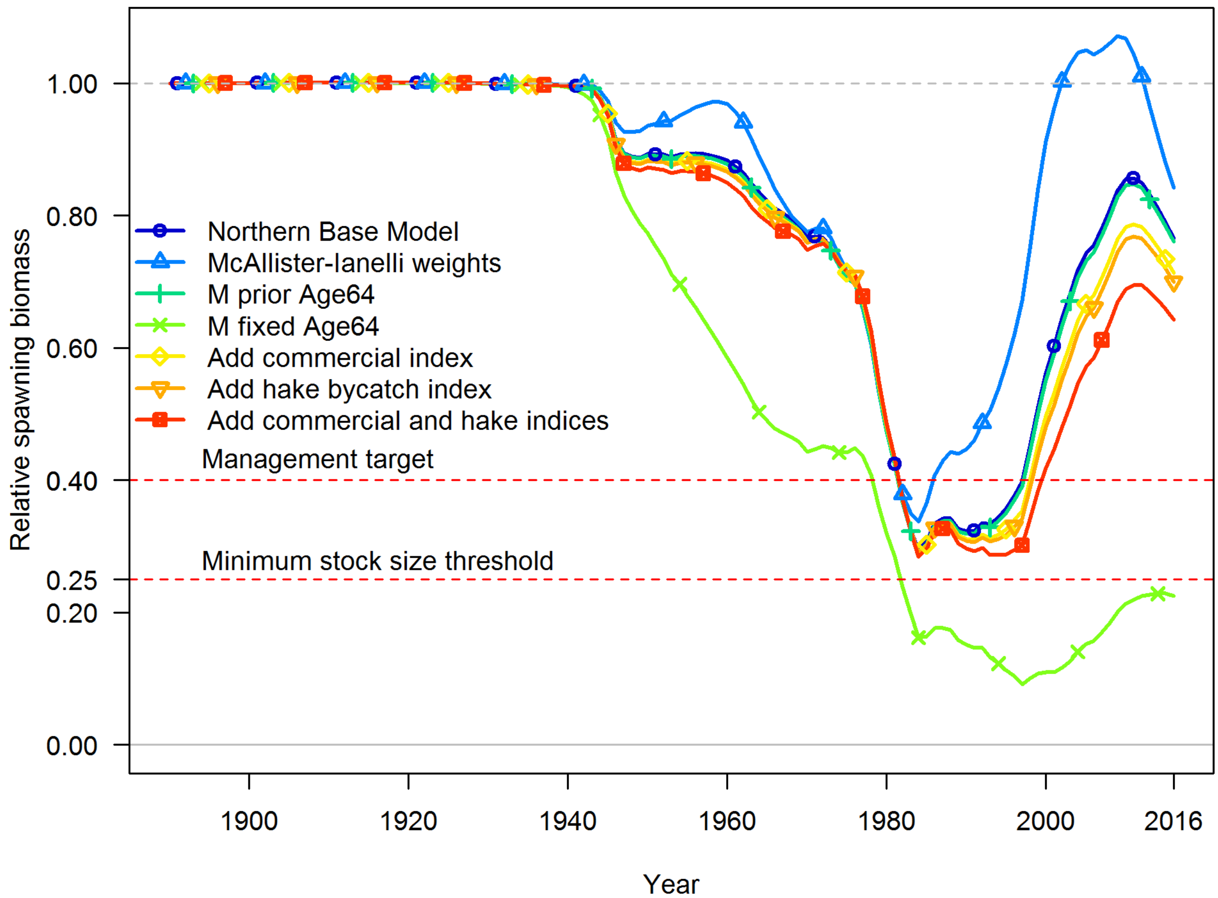


Figure 63: Time series of relative spawning output estimated in sensitivity analyses for the Northern model.

1595 ### 9.3.3 Likelihood profiles for Northern model

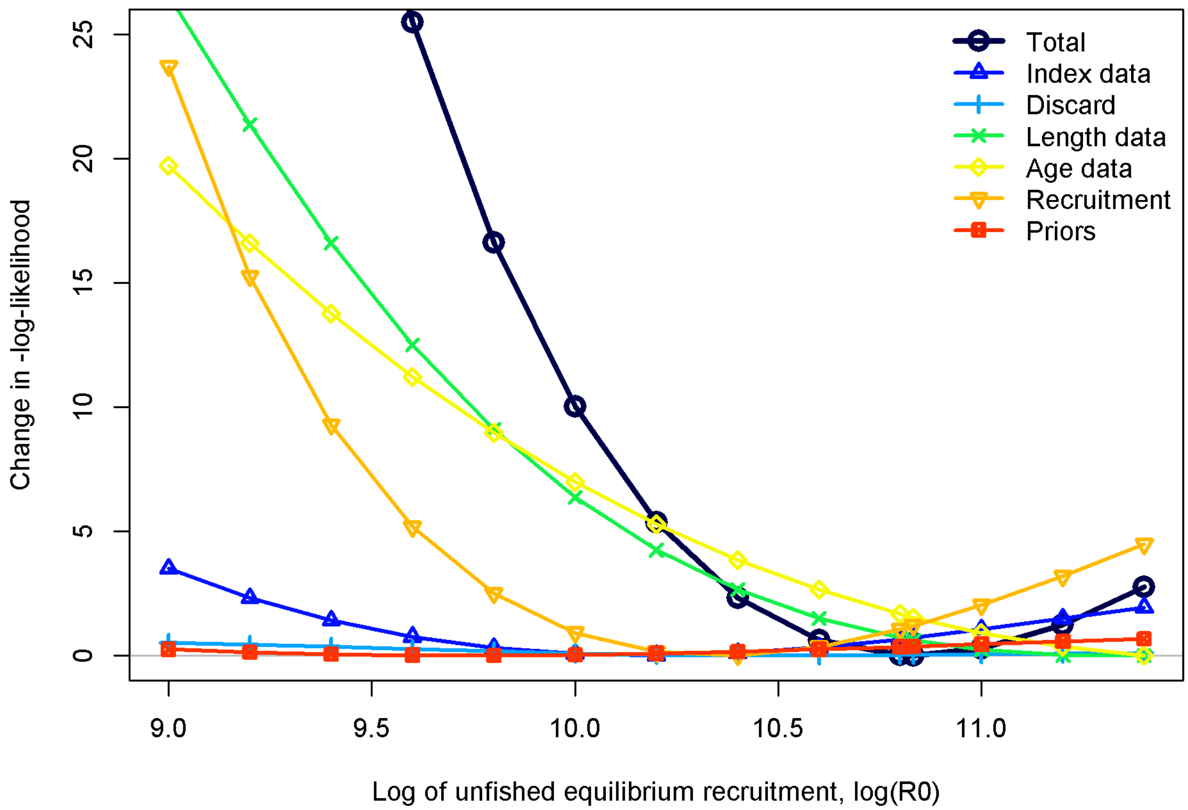


Figure 64: Likelihood profile over the log of equilibrium recruitment (R_0) for the Northern model.

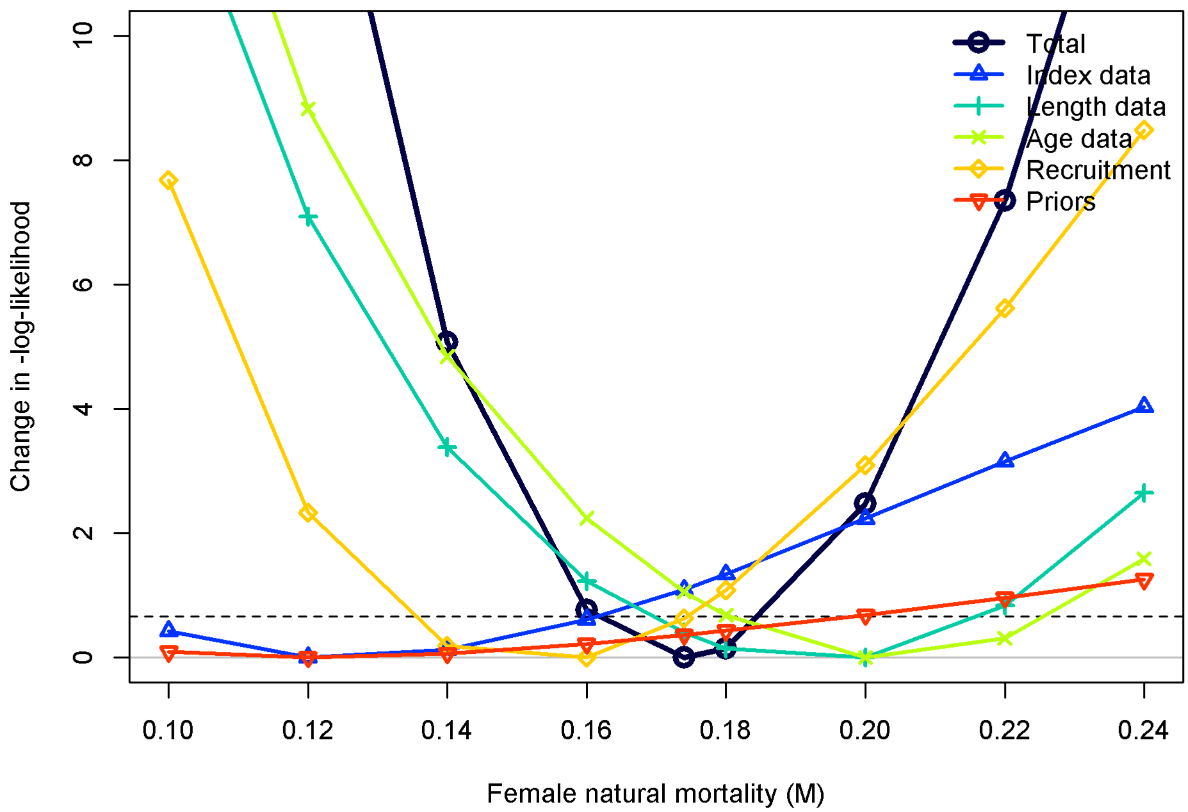


Figure 65: Likelihood profile over female natural mortality for the Northern model.

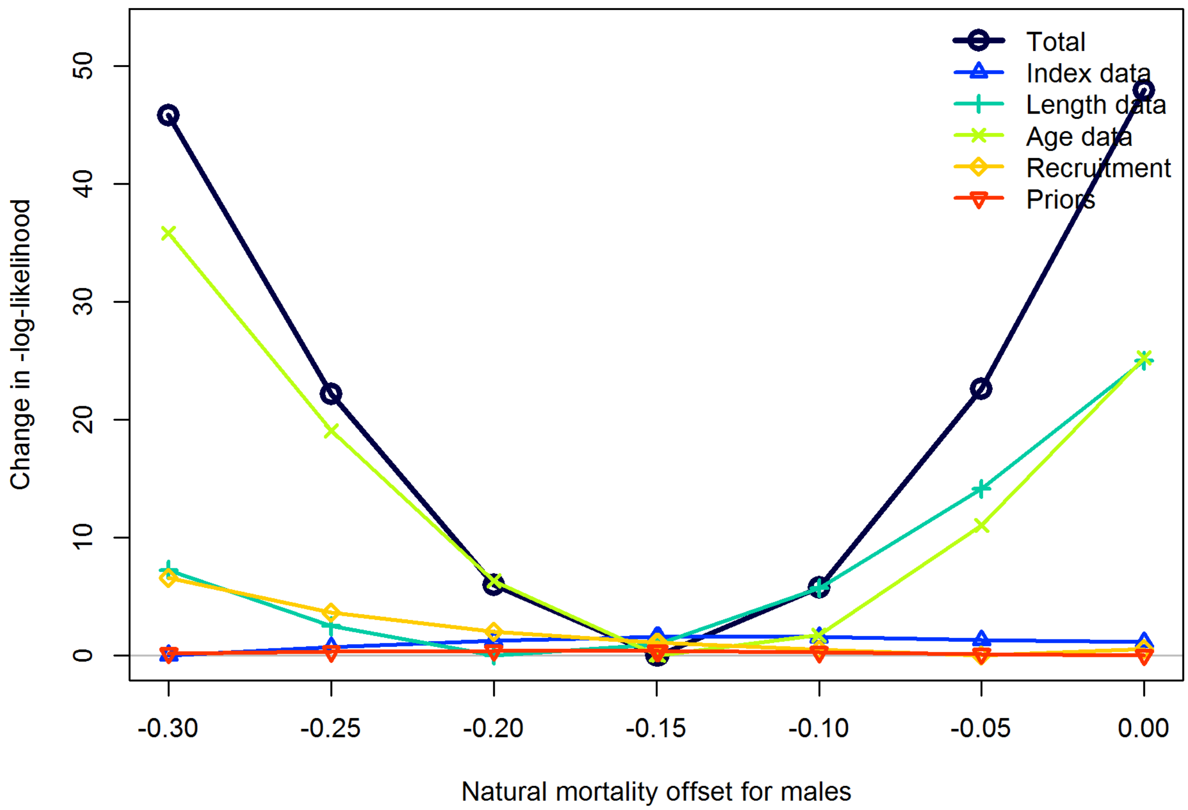


Figure 66: Likelihood profile over the male offset for natural mortality for the Northern model. Negative values are associated with natural mortality being lower for males than females.

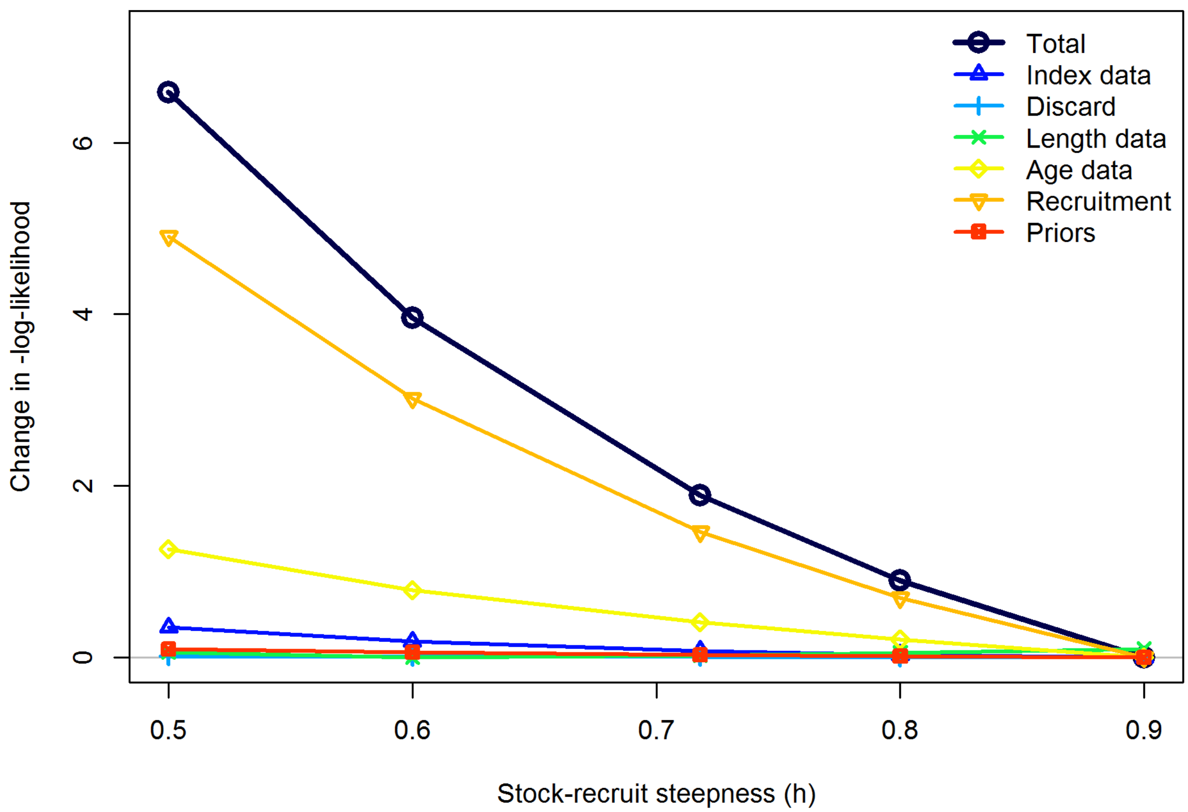


Figure 67: Likelihood profile over stock-recruit steepness (h) for the Northern model.

9.3.4 Retrospective analysis for Northern model

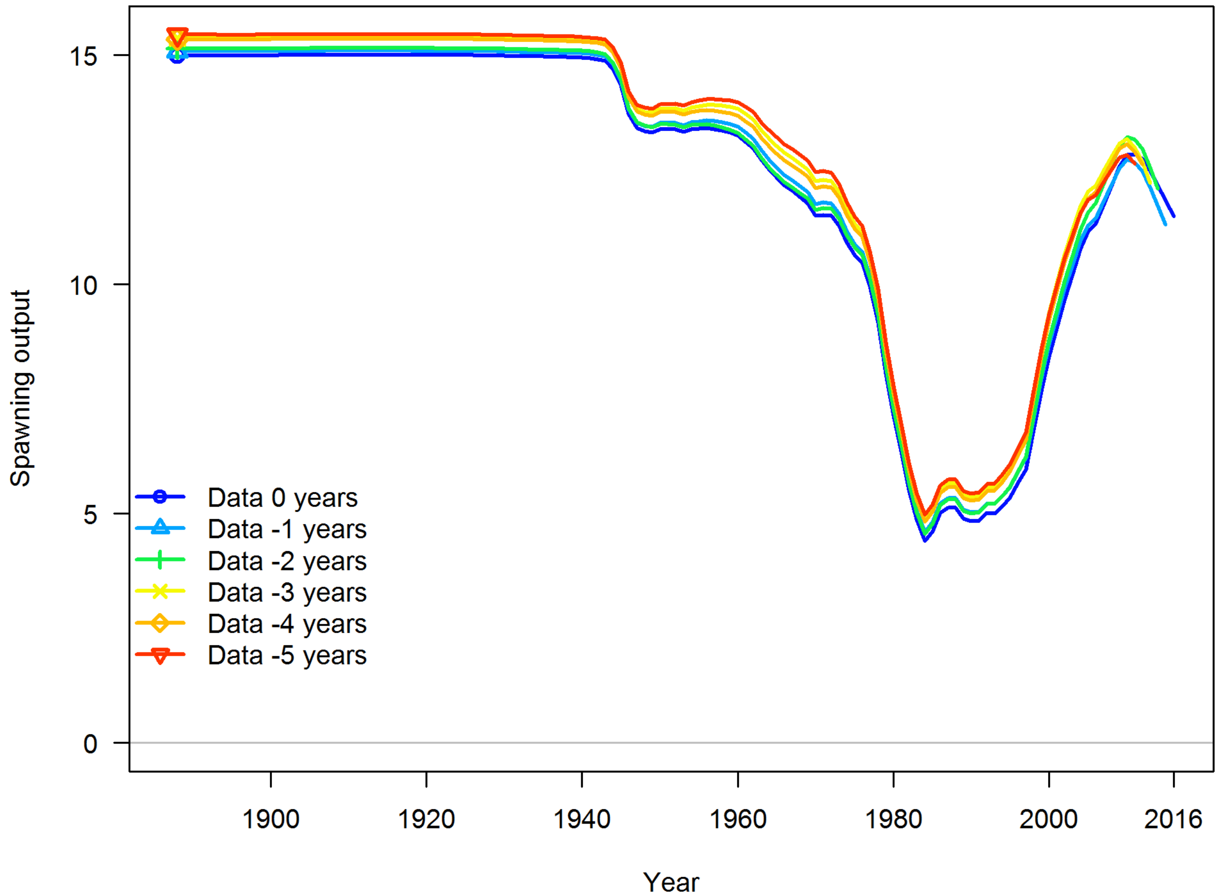


Figure 68: Retrospective analysis of spawning output for the Northern model.

9.3.5 Forecasts for Northern model

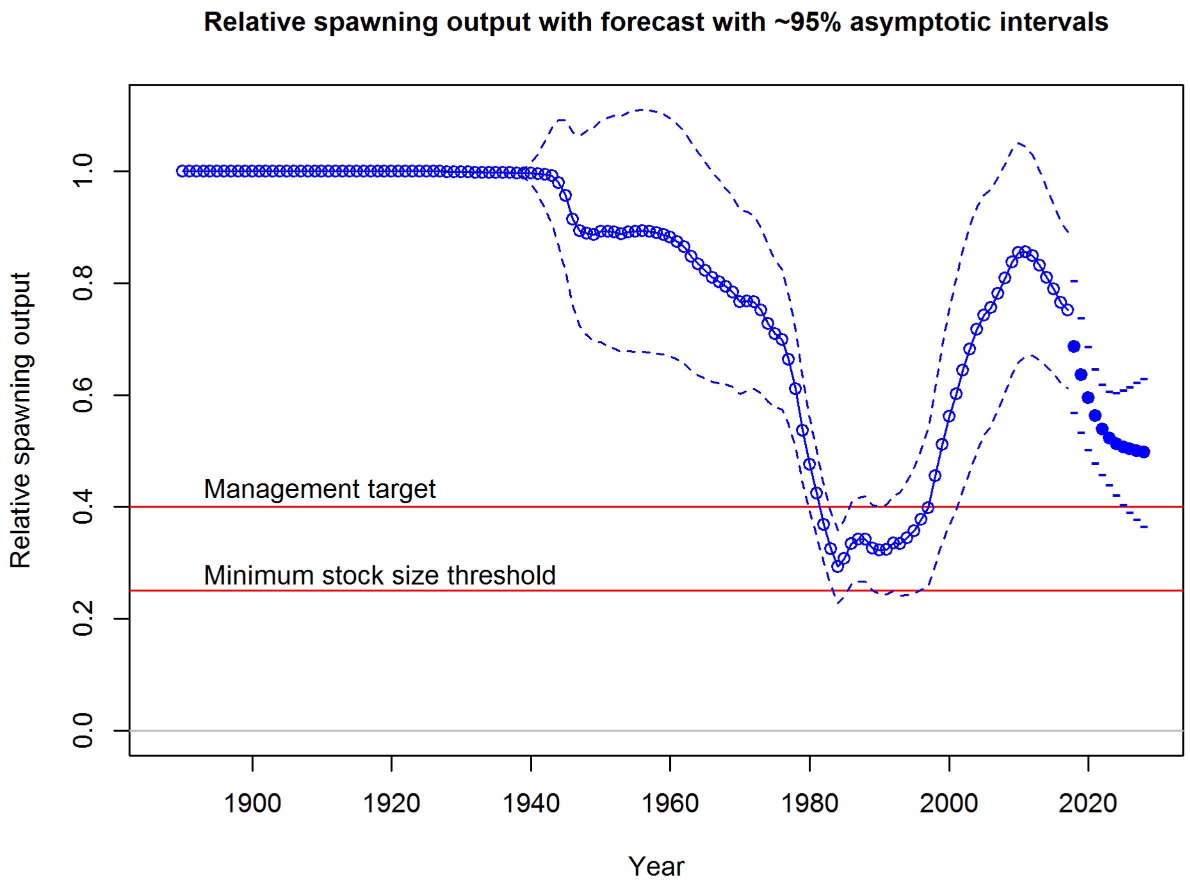


Figure 69: Forecast of relative spawning output for the Northern model. Filled circles for the years 2017 indicate forecast years.

1598 ## 9.4 Data and model fits for Southern model

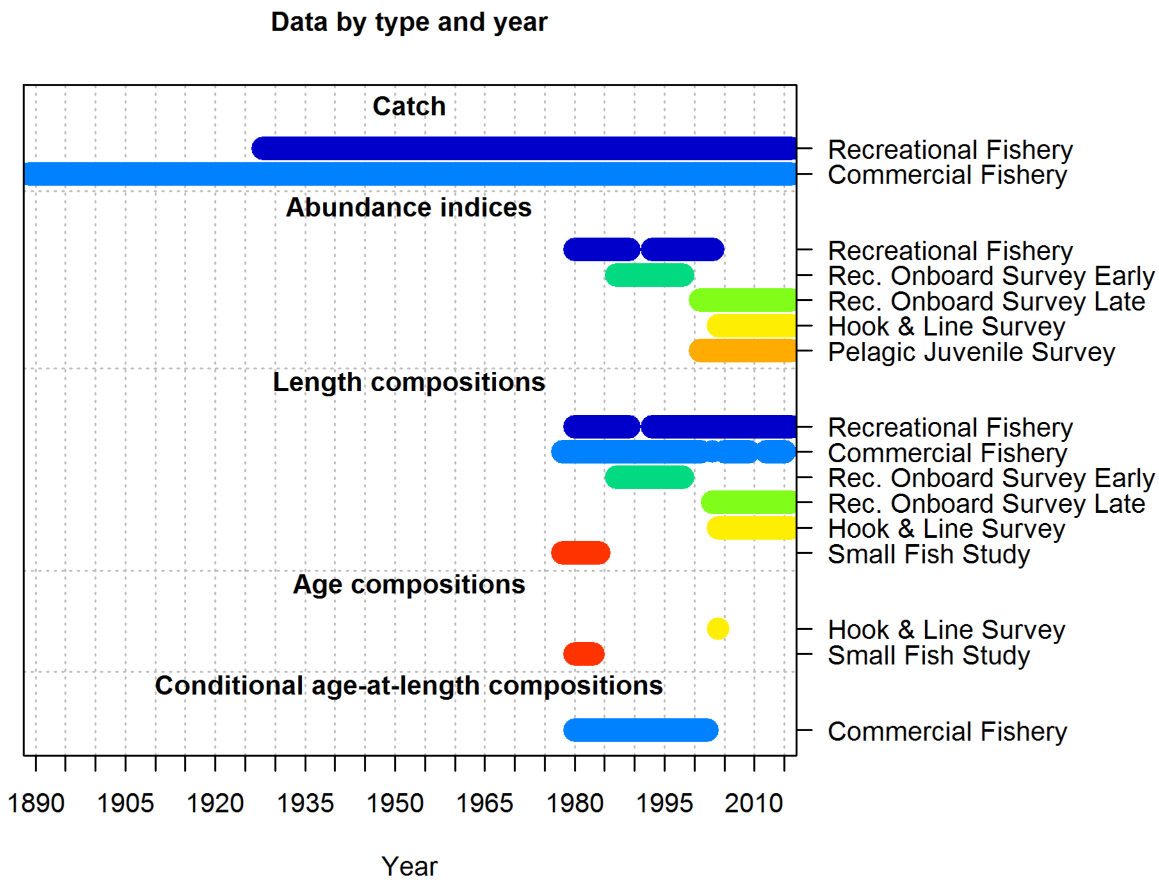


Figure 70: Summary of data sources used in the Southern model.

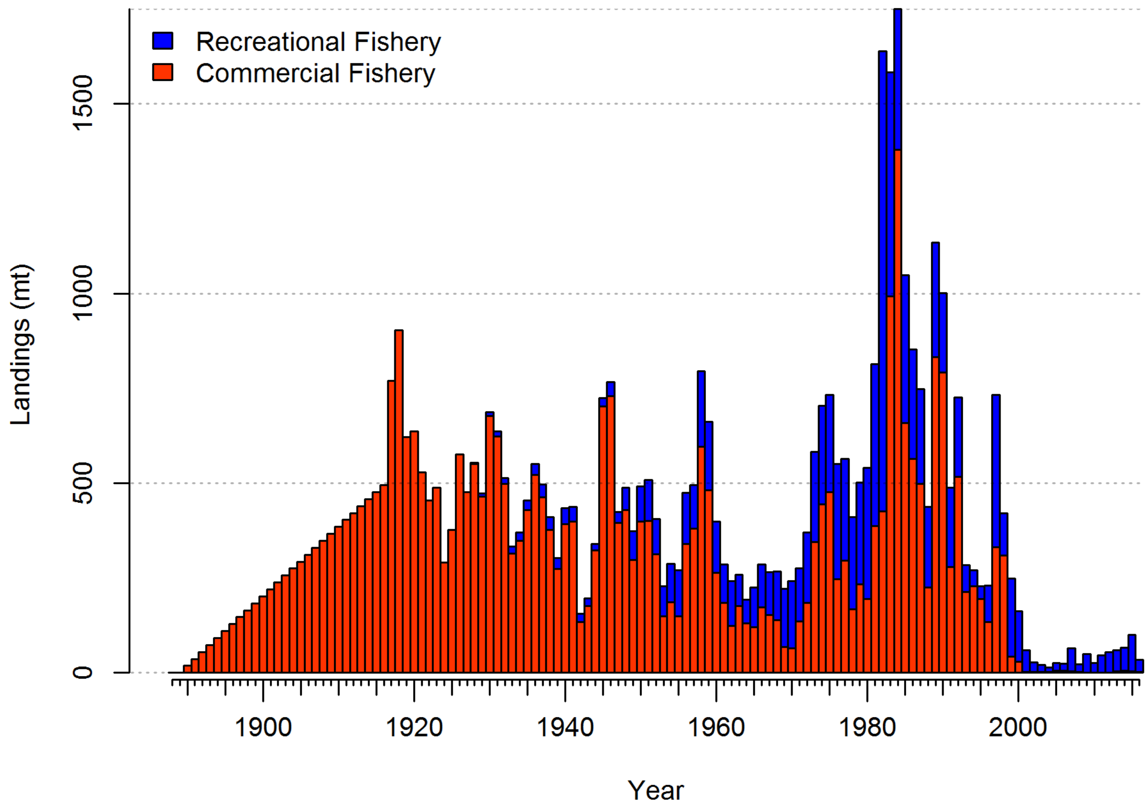


Figure 71: Estimated catch history of Yellowtail Rockfish in the Southern model.

9.4.1 Selectivity, retention, and discards for Southern model

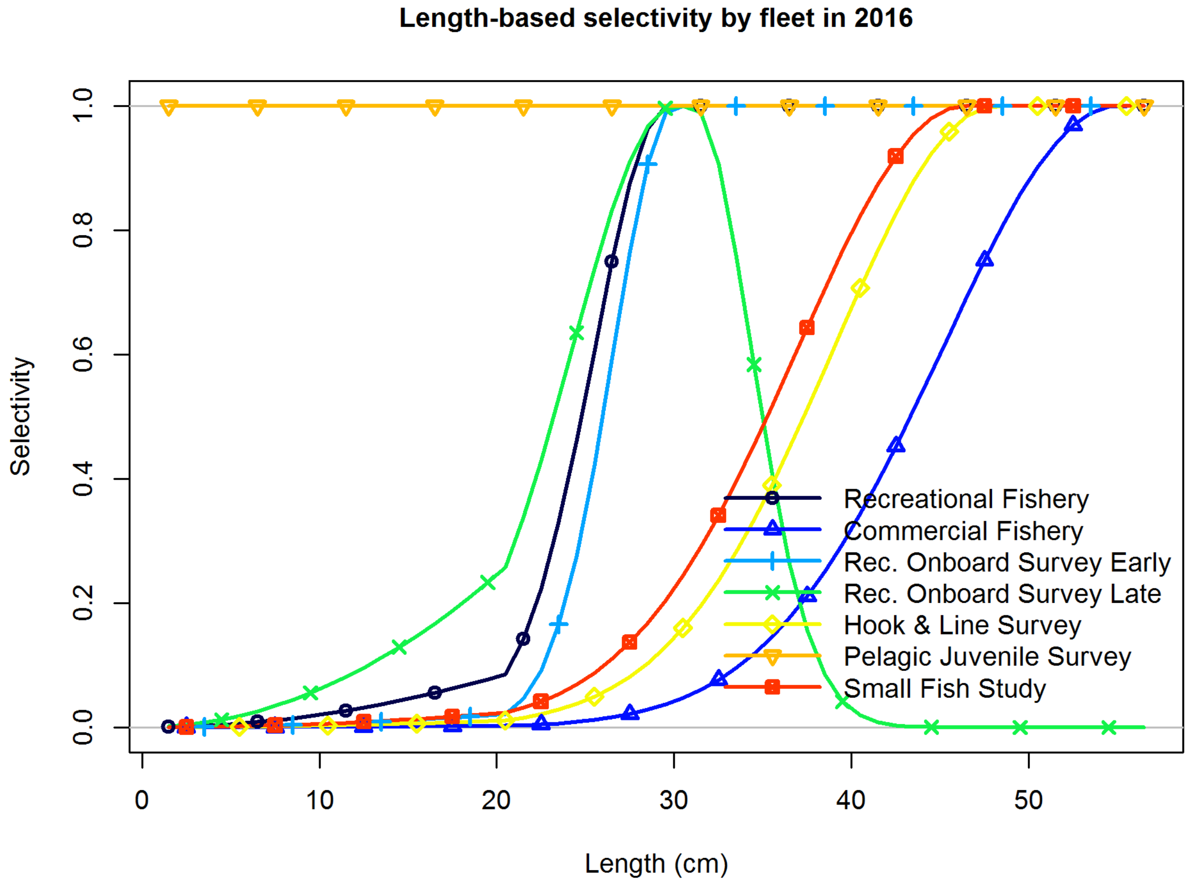


Figure 72: Estimated selectivity by length for each fishery and survey in the Southern model. The Pelagic Juvenile Survey has age-based selectivity as shown in the following figure.

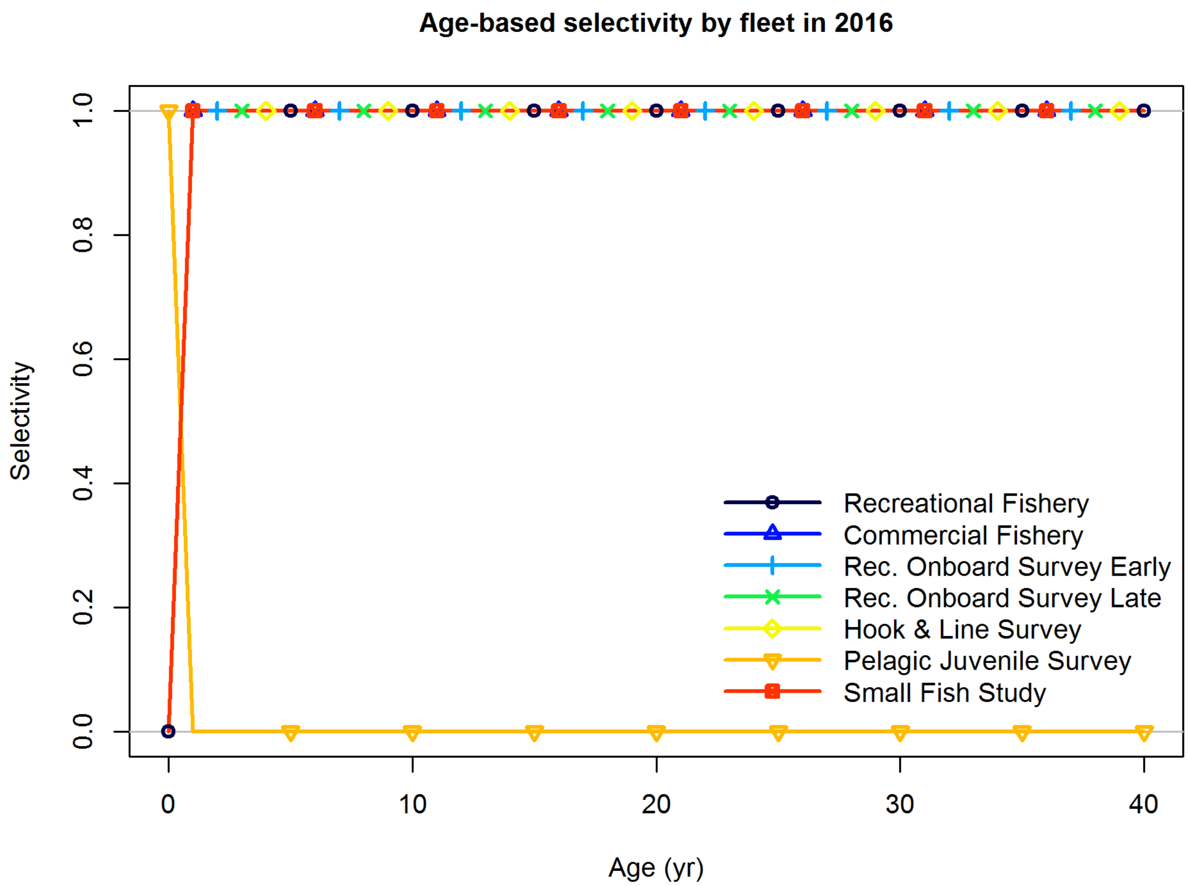


Figure 73: Fixed age-based component of selectivity for each fishery and survey in the Southern model. The Pelagic Juvenile Survey is assumed to select only age-0 fish while all other fleets are assumed to not select any age-0 fish.

9.4.2 Fits to indices of abundance for Southern model

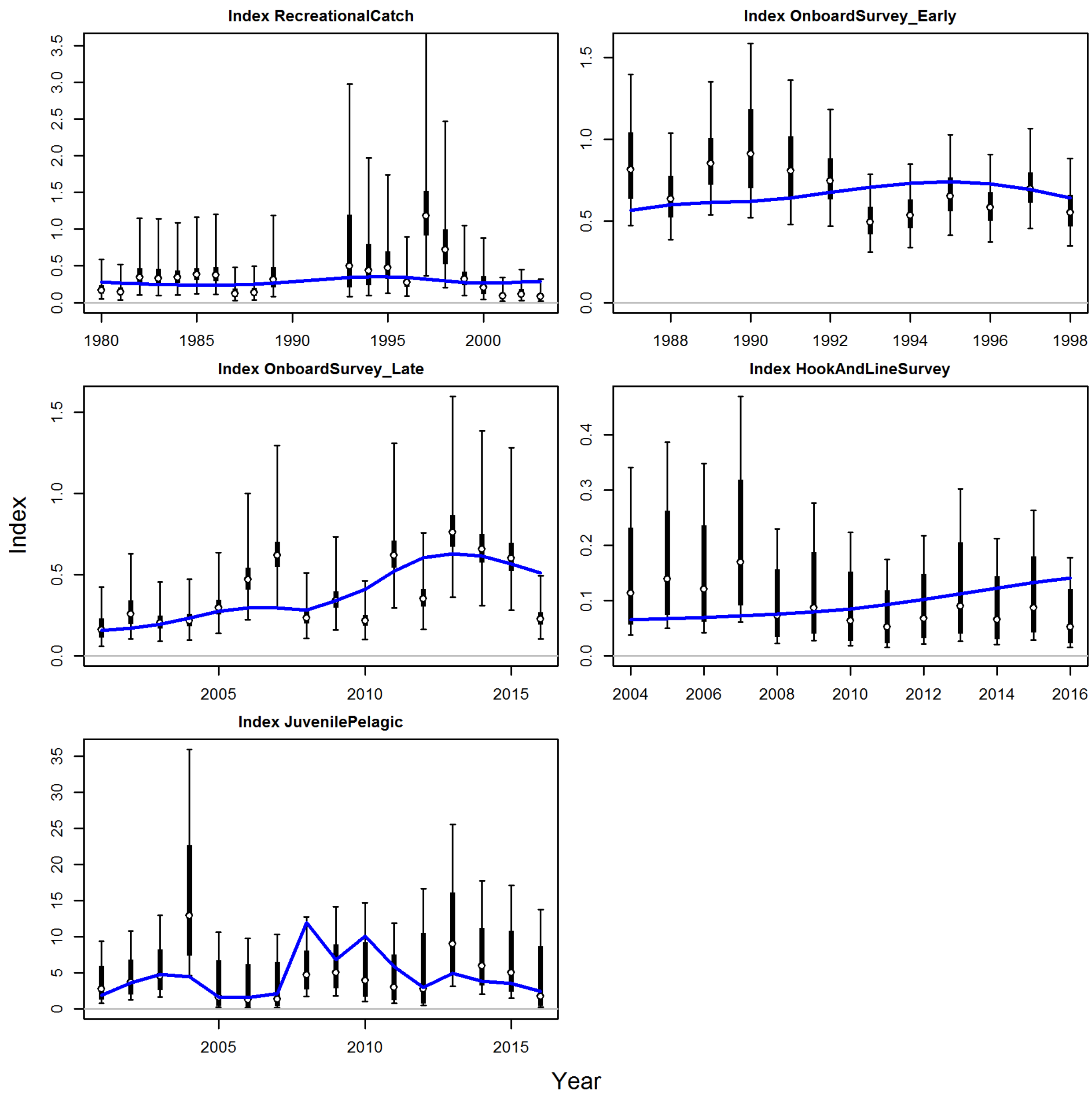


Figure 74: Estimated fits to the CPUE and survey indices for the Southern model.

9.4.3 Length compositions for Southern model

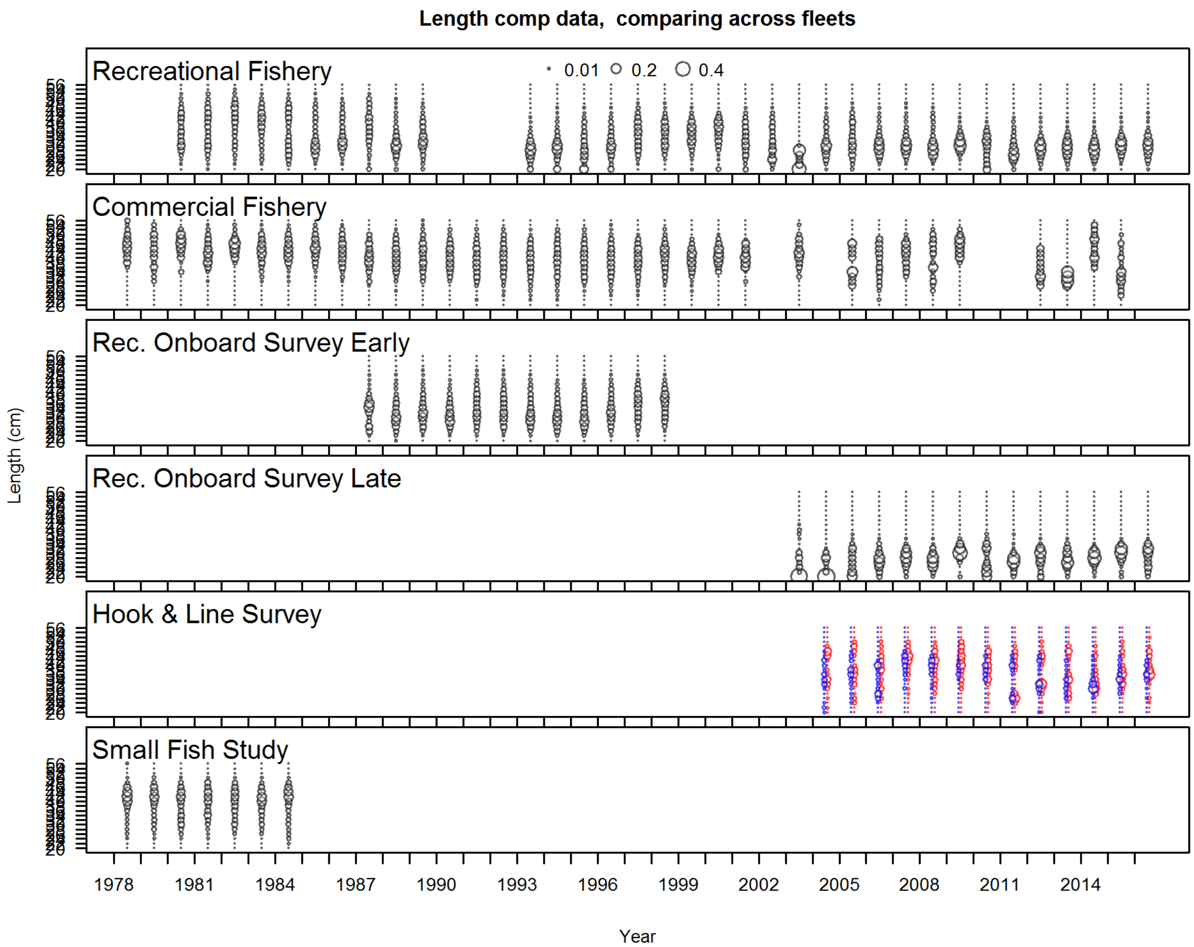


Figure 75: Length compositions for all fleets in the Southern model. Bubble size is proportional to proportions within each year.

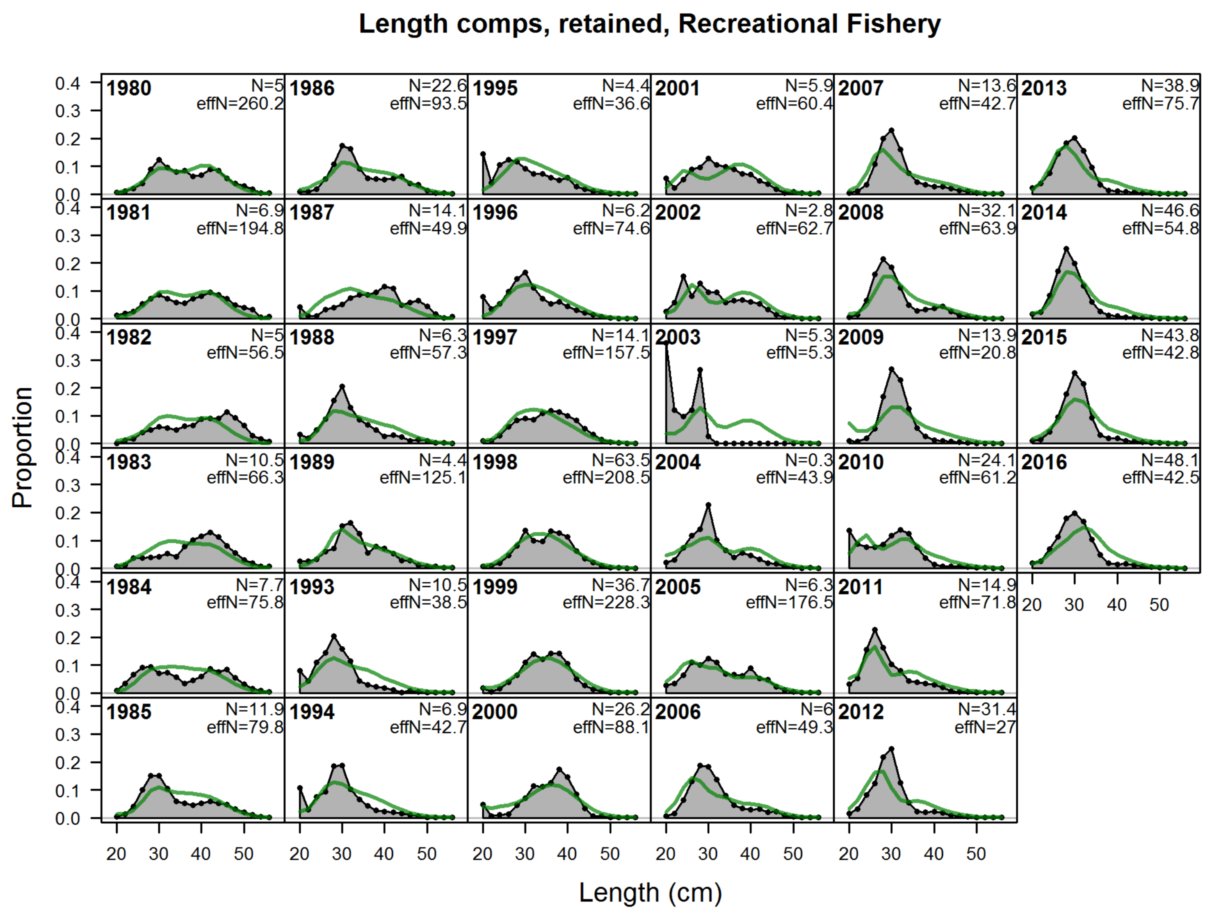


Figure 76: **Southern model** Length comps, retained, Recreational Fishery

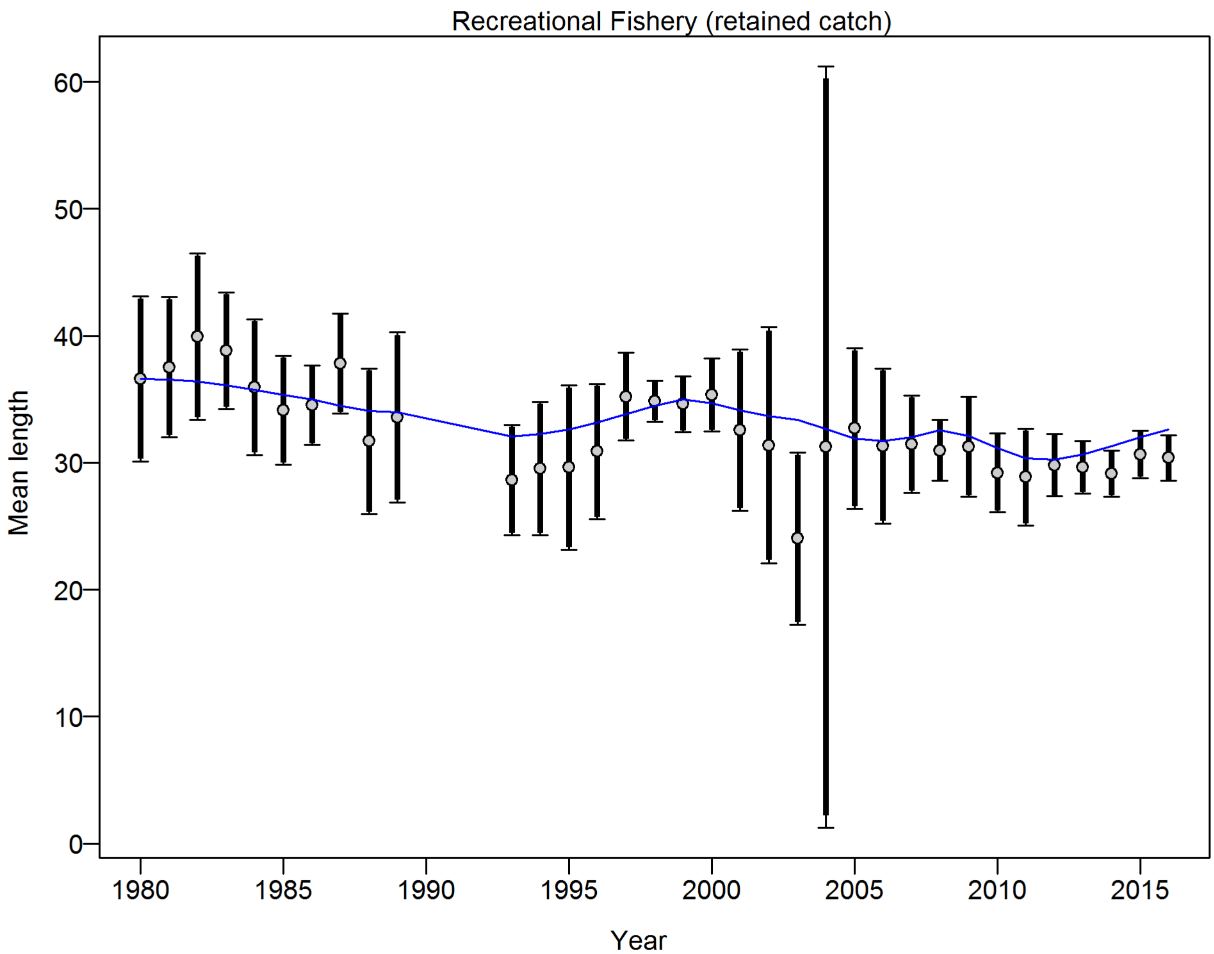


Figure 77: **Southern model** Mean length for Recreational Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Recreational Fishery: 0.9375 (0.6263_1.7408) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

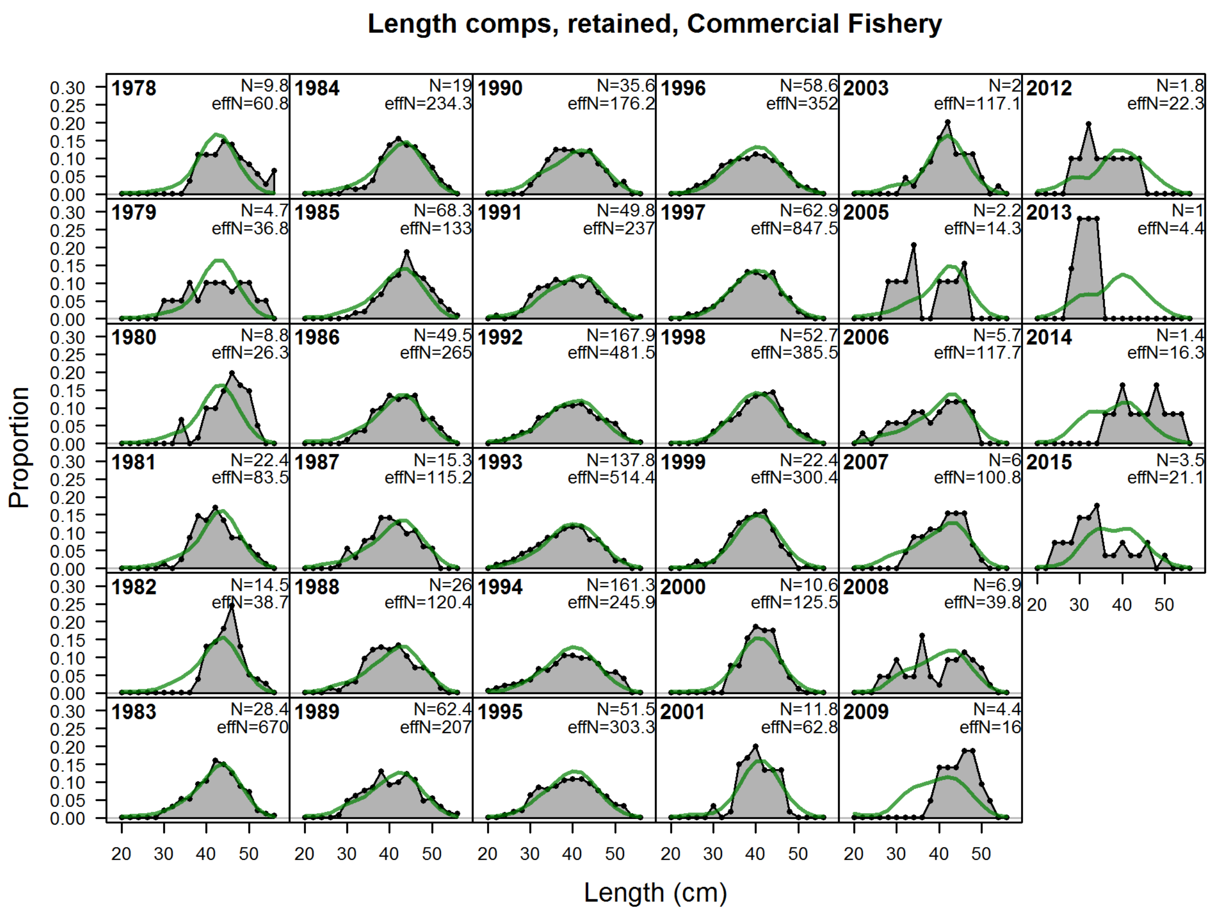


Figure 78: **Southern model** Length comps, retained, Commercial Fishery

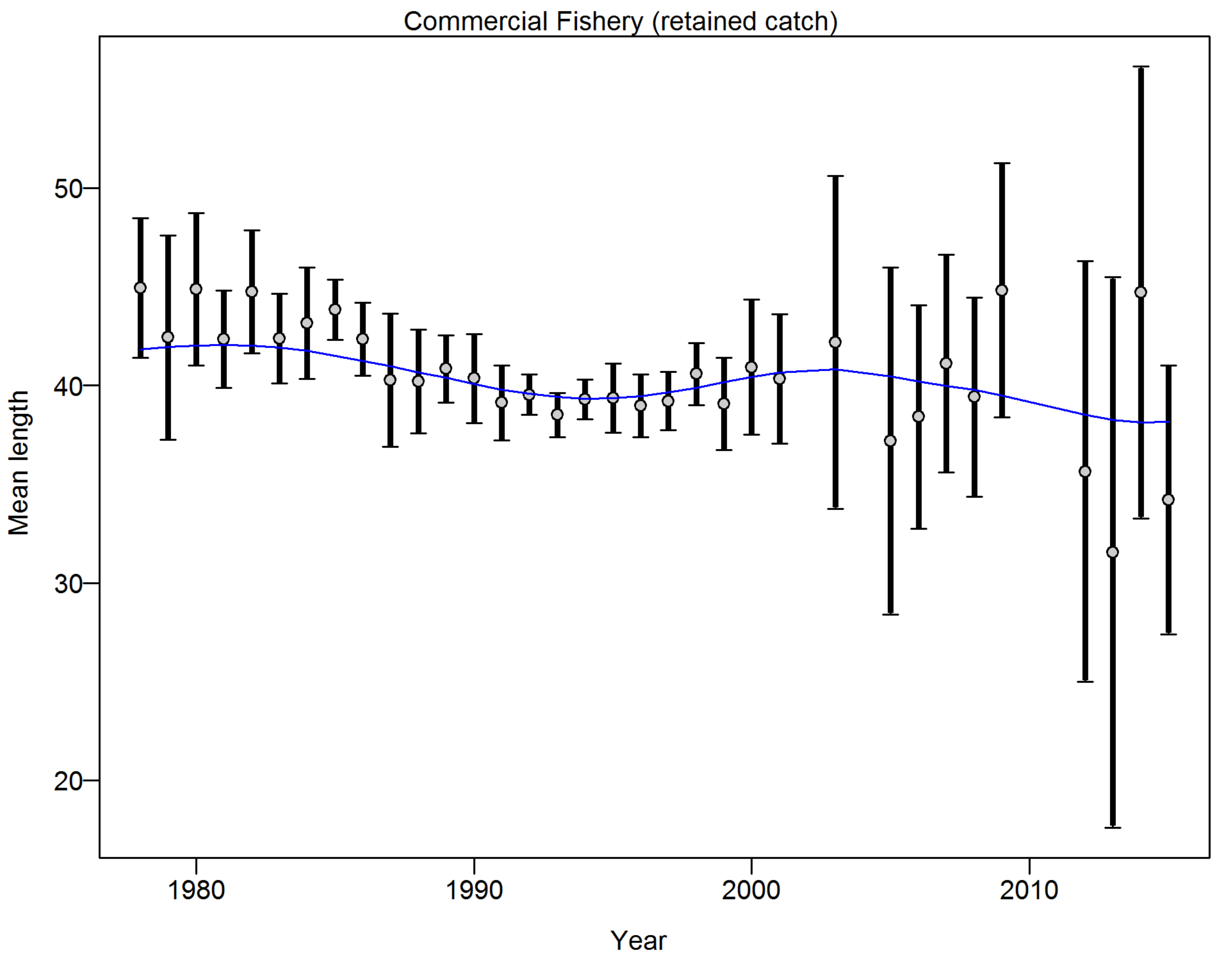


Figure 79: **Southern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Commercial Fishery: 0.9859 (0.6576_1.954) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

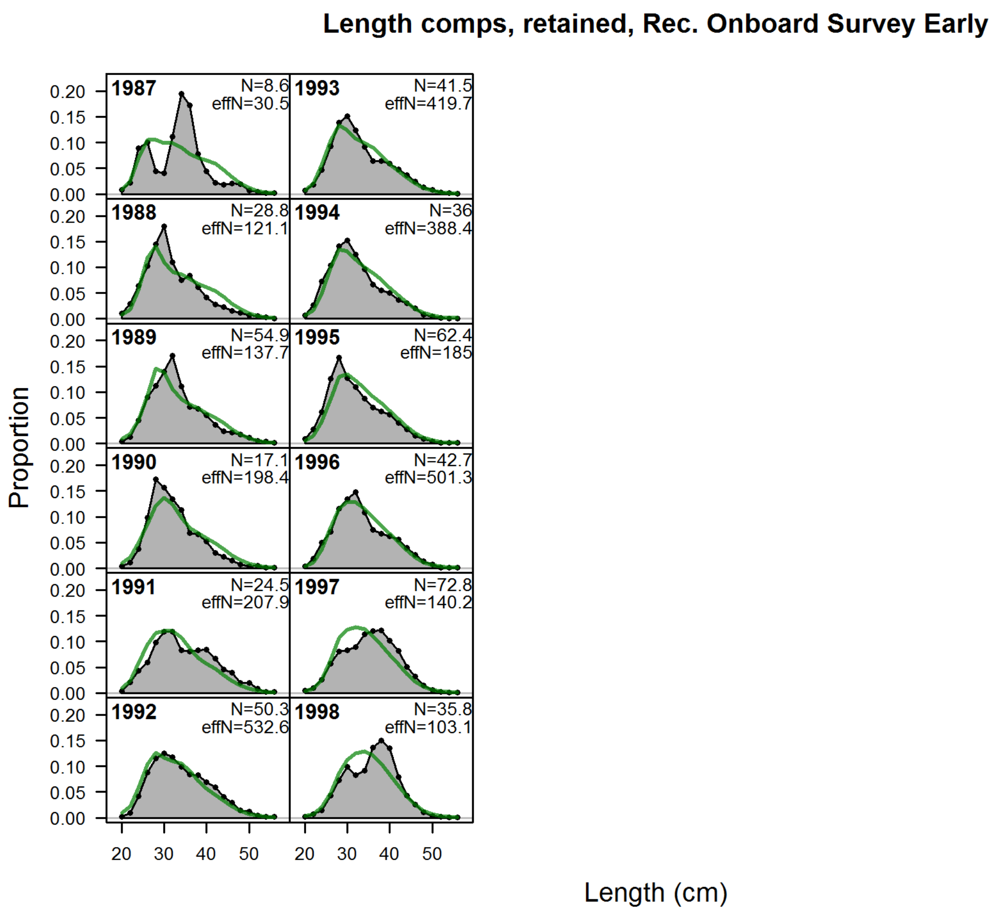


Figure 80: **Southern model** Length comps, retained, Rec. Onboard Survey Early

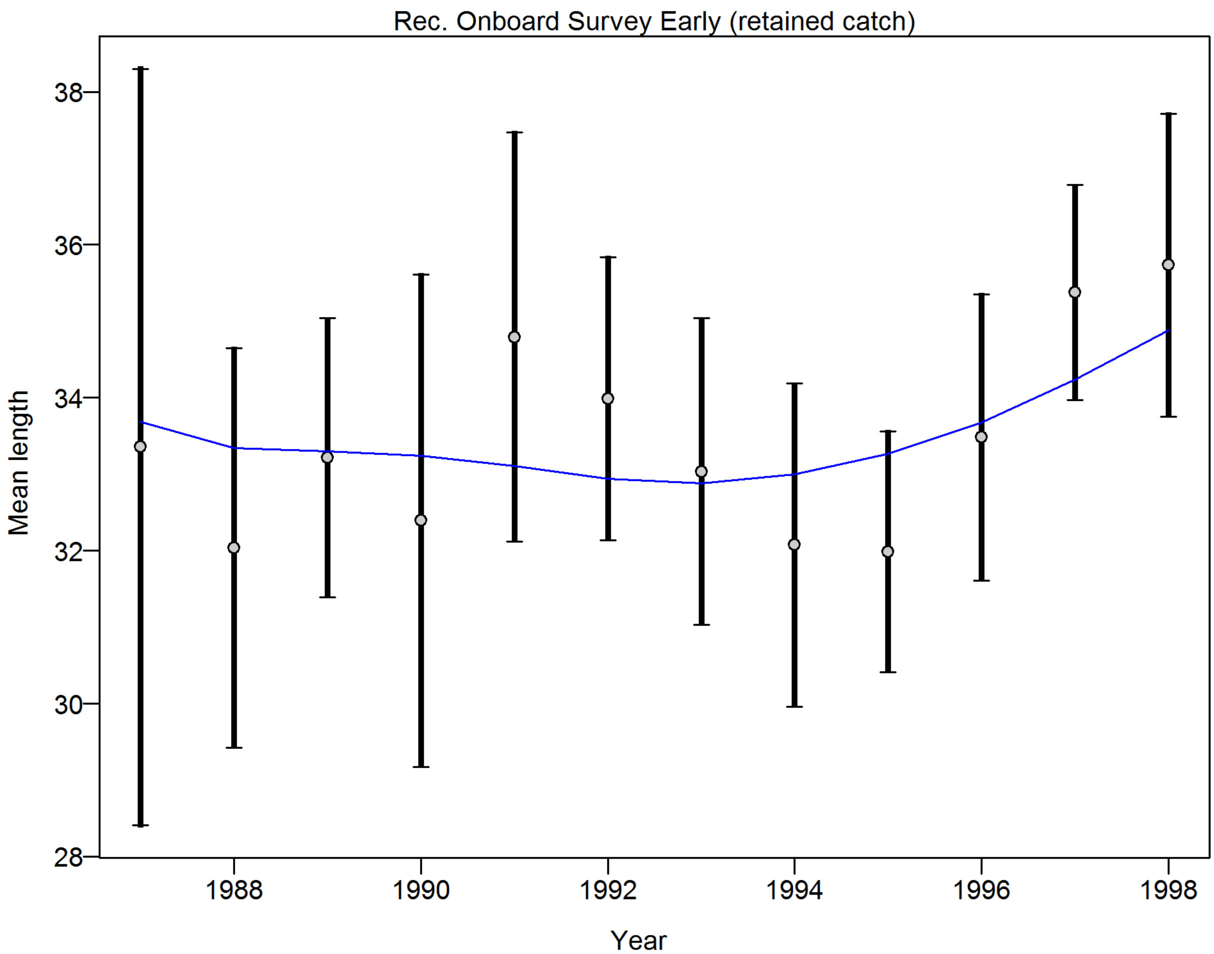


Figure 81: **Southern model** Mean length for Rec. Onboard Survey Early with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Rec. Onboard Survey Early: 1.0132 (0.6845_2.3516) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

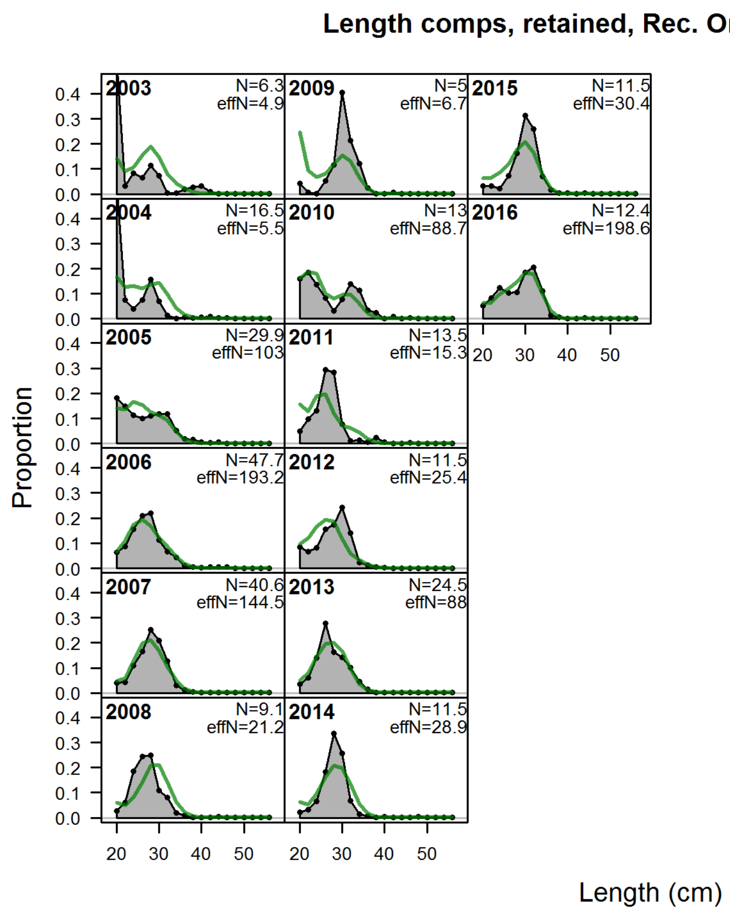


Figure 82: **Southern model** Length comps, retained, Rec. Onboard Survey Late

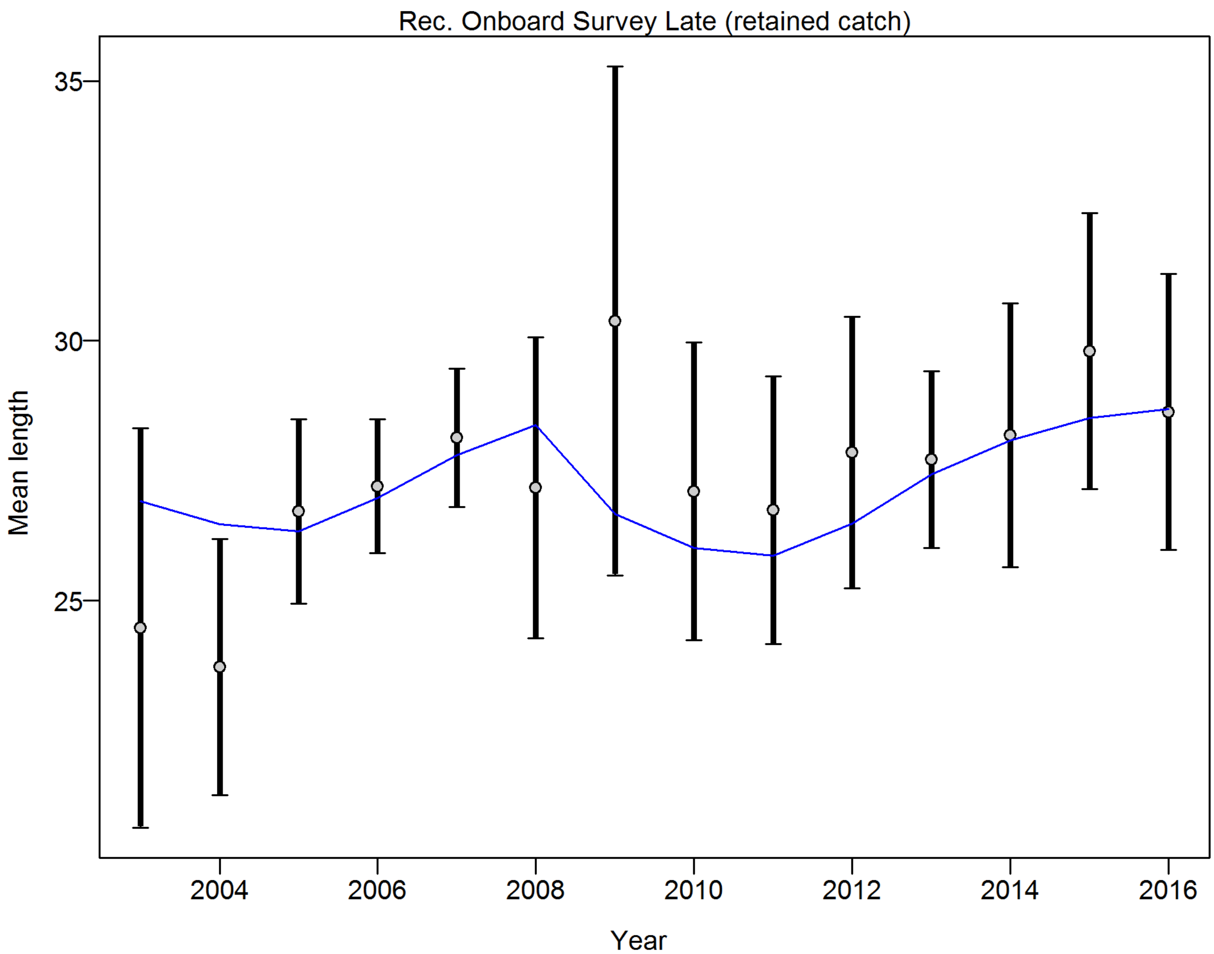


Figure 83: **Southern model** Mean length for Rec. Onboard Survey Late with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Rec. Onboard Survey Late: 0.992 (0.5506_5.0035) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

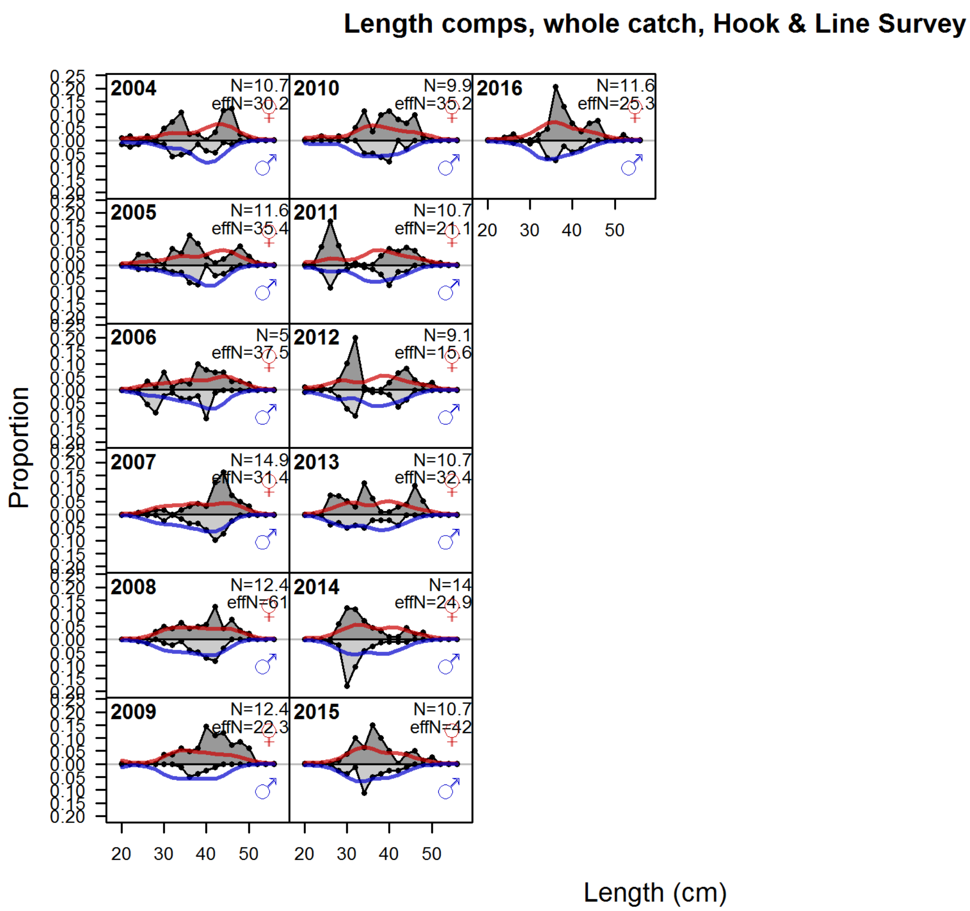


Figure 84: **Southern model** Length comps, whole catch, Hook & Line Survey

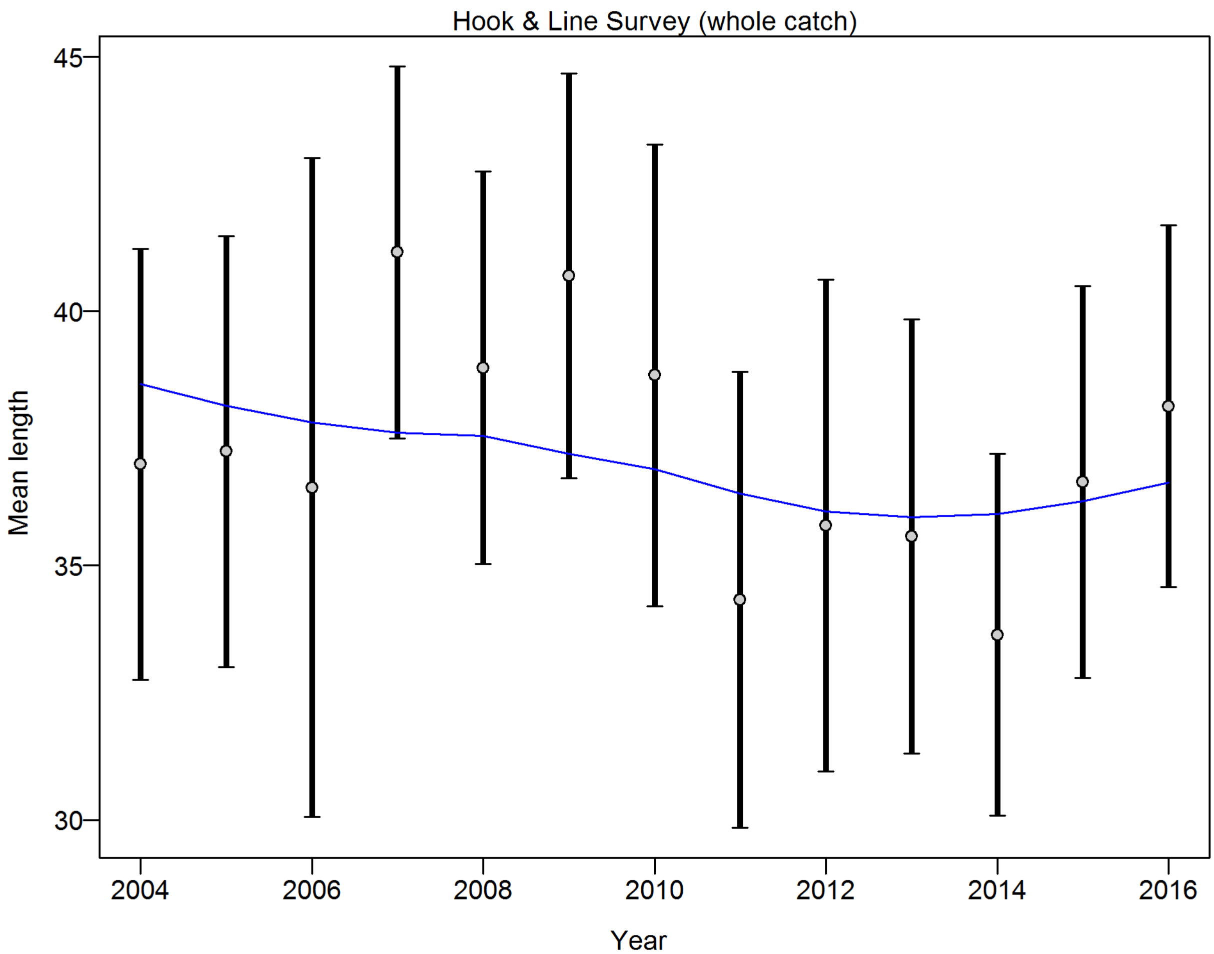


Figure 85: **Southern model** Mean length for Hook & Line Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Hook & Line Survey: 0.9982 (0.6578_2.9651) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

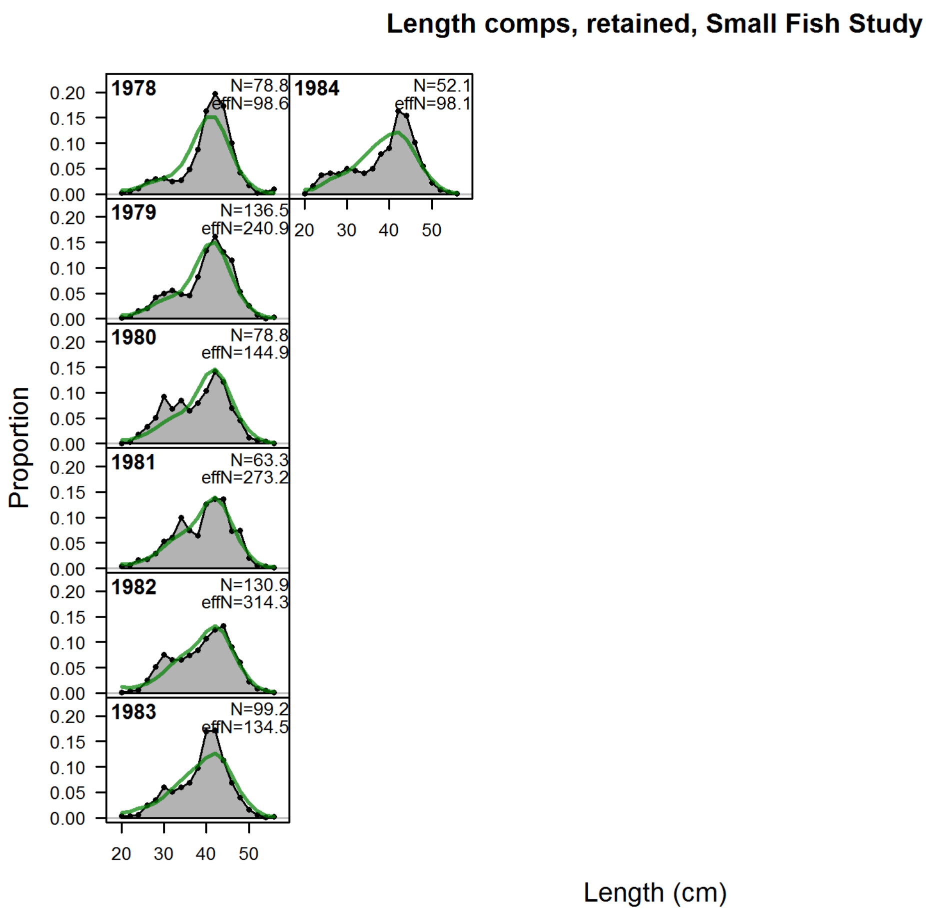


Figure 86: **Southern model** Length comps, retained, Small Fish Study

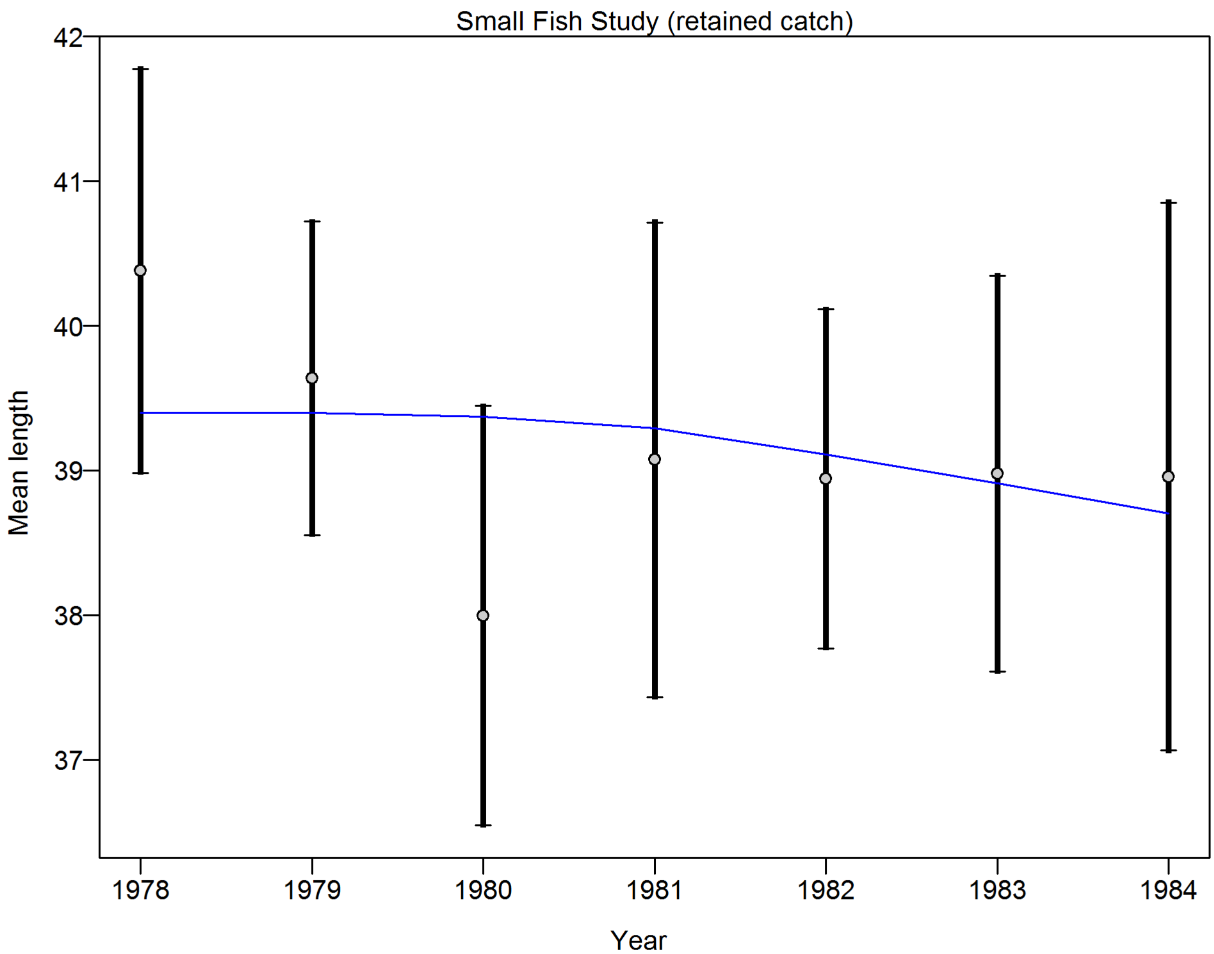


Figure 87: **Southern model** Mean length for Small Fish Study with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Small Fish Study: 1.024 (0.5413_16.4371) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

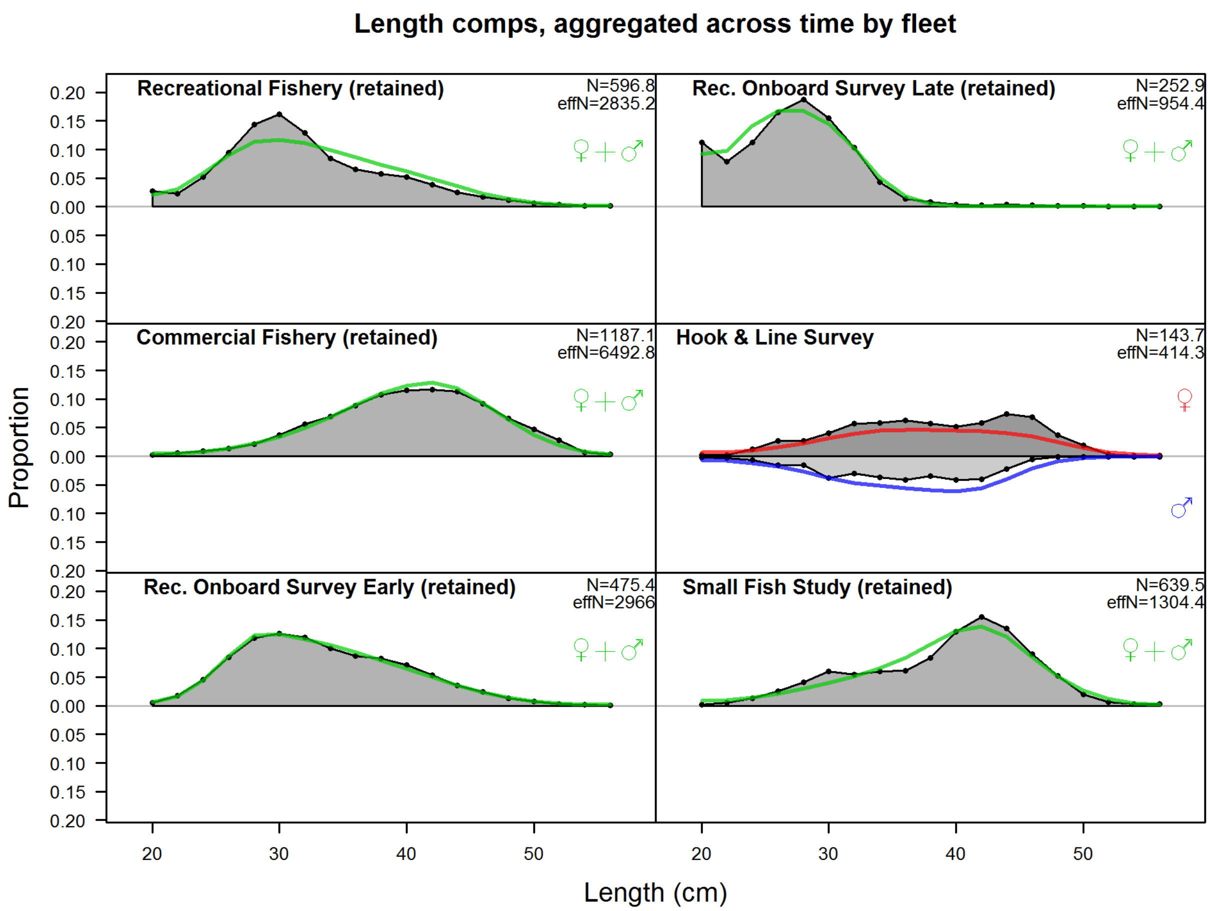


Figure 88: **Southern model** Length comps, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch.

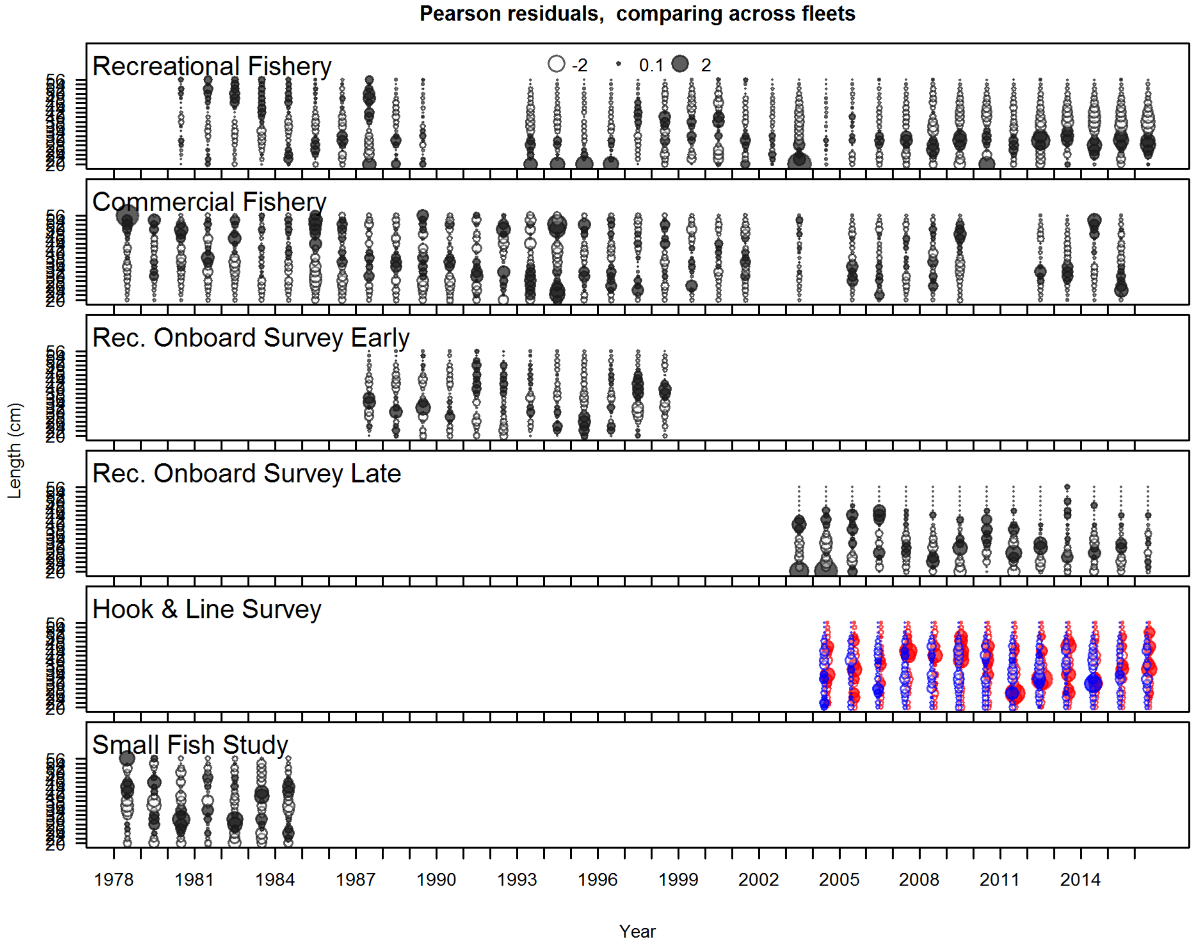


Figure 89: Length composition Pearson residuals for all fleets in the Southern model. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

9.4.4 Age compositions for Southern model

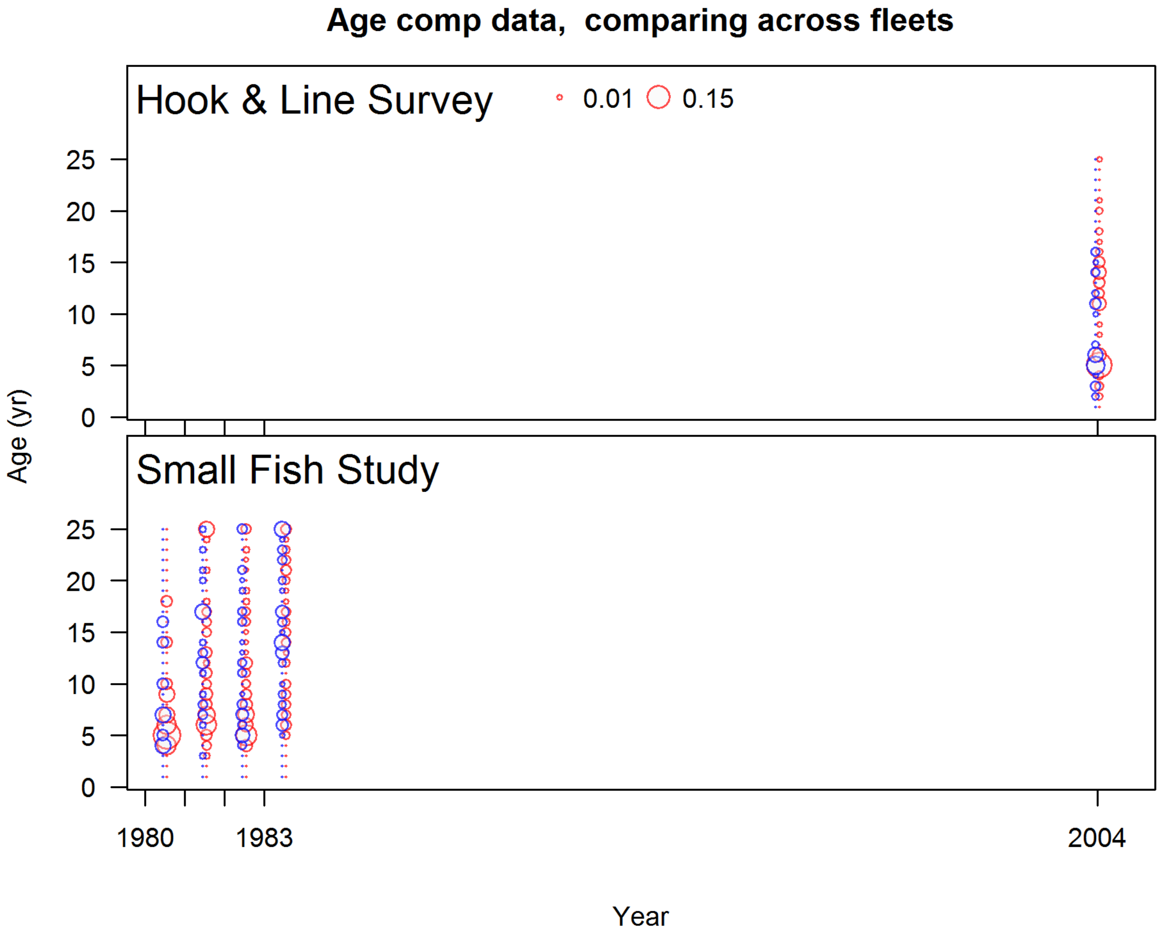


Figure 90: Age compositions for all fleets in the Southern model. Bubble size is proportional to proportions within each year.

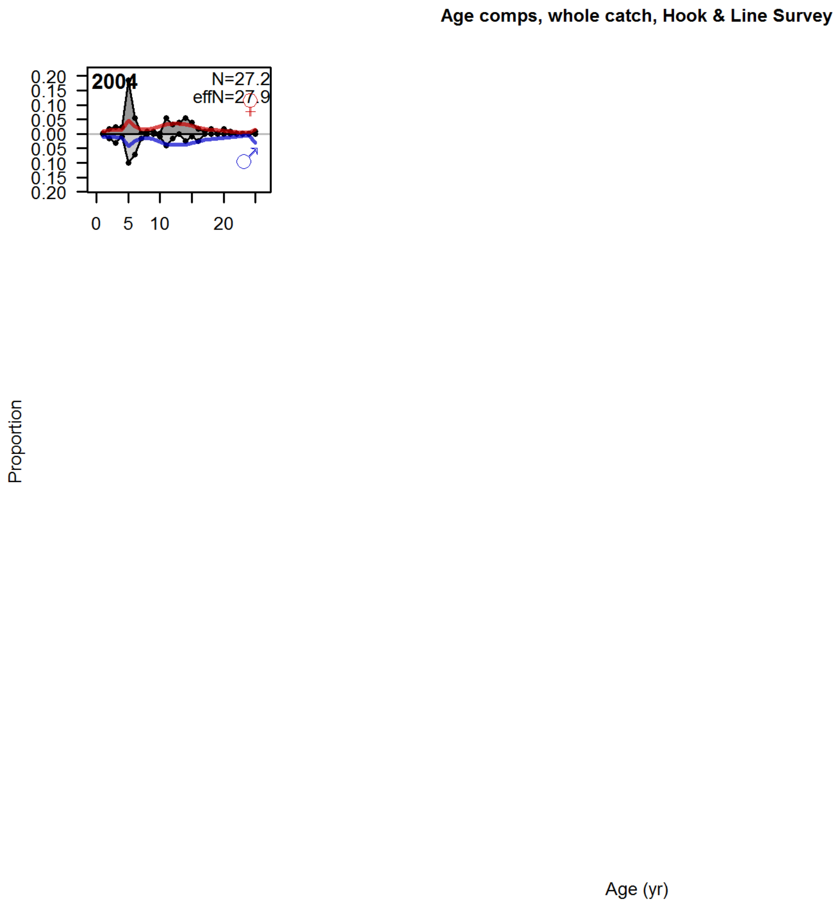


Figure 91: **Southern model** Age comps, whole catch, Hook & Line Survey

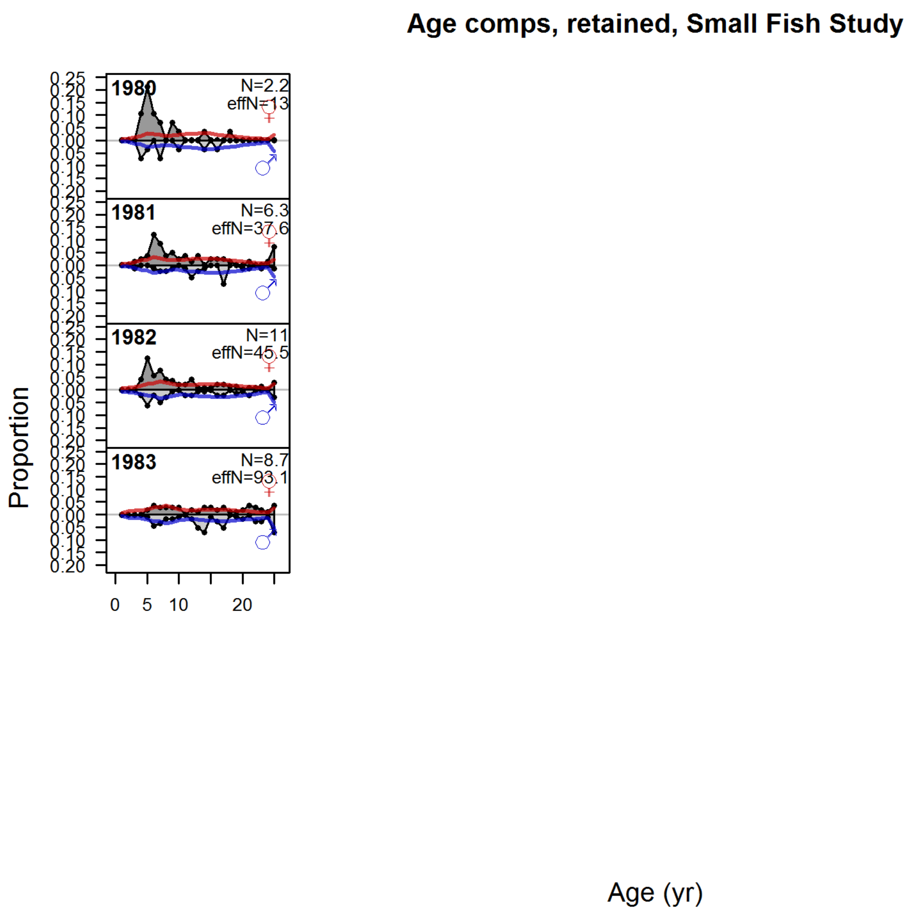


Figure 92: **Southern model** Age comps, retained, Small Fish Study

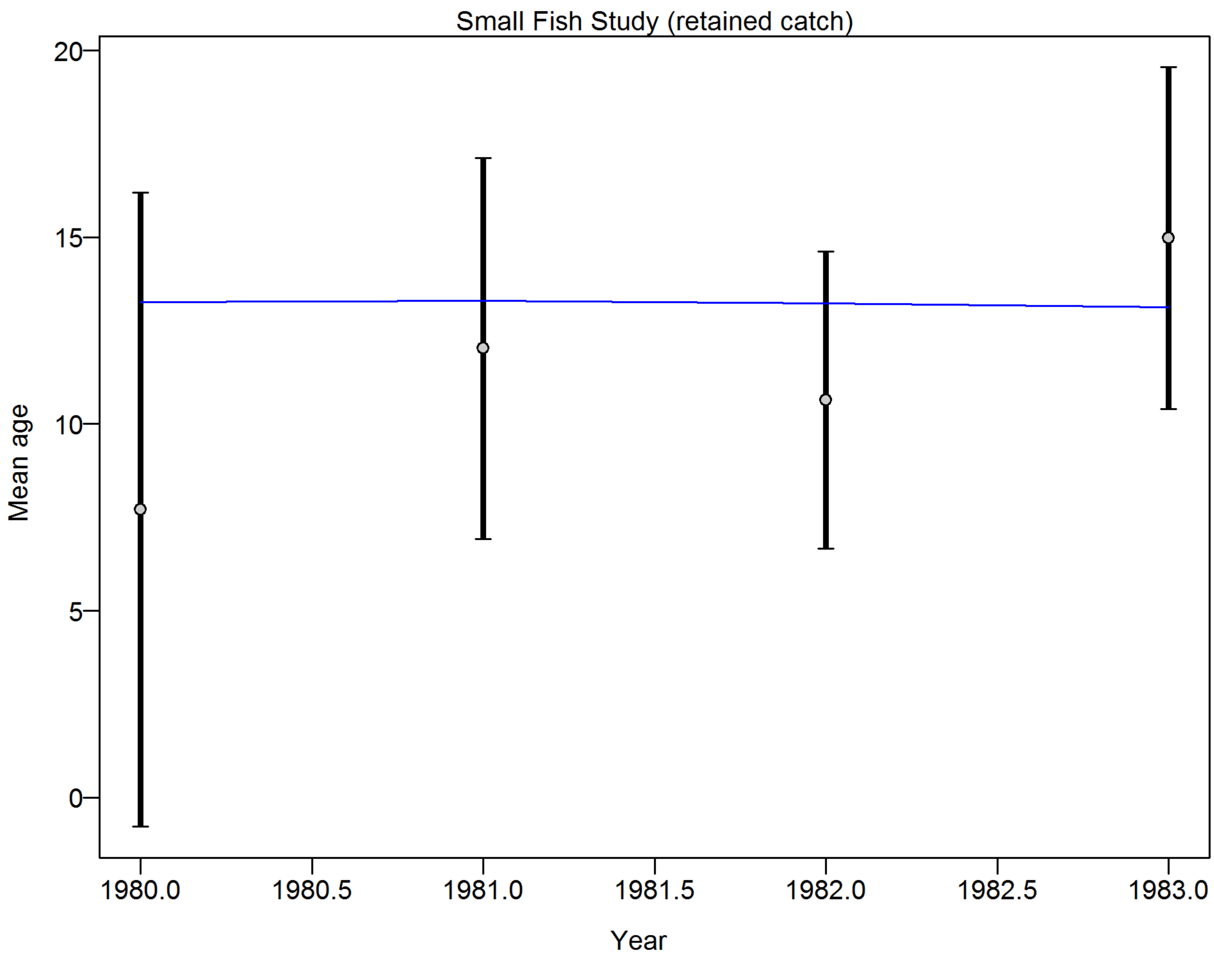


Figure 93: **Southern model** Mean age for Small Fish Study with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data from Small Fish Study: 1.0056 (0.6721_538246.4101) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

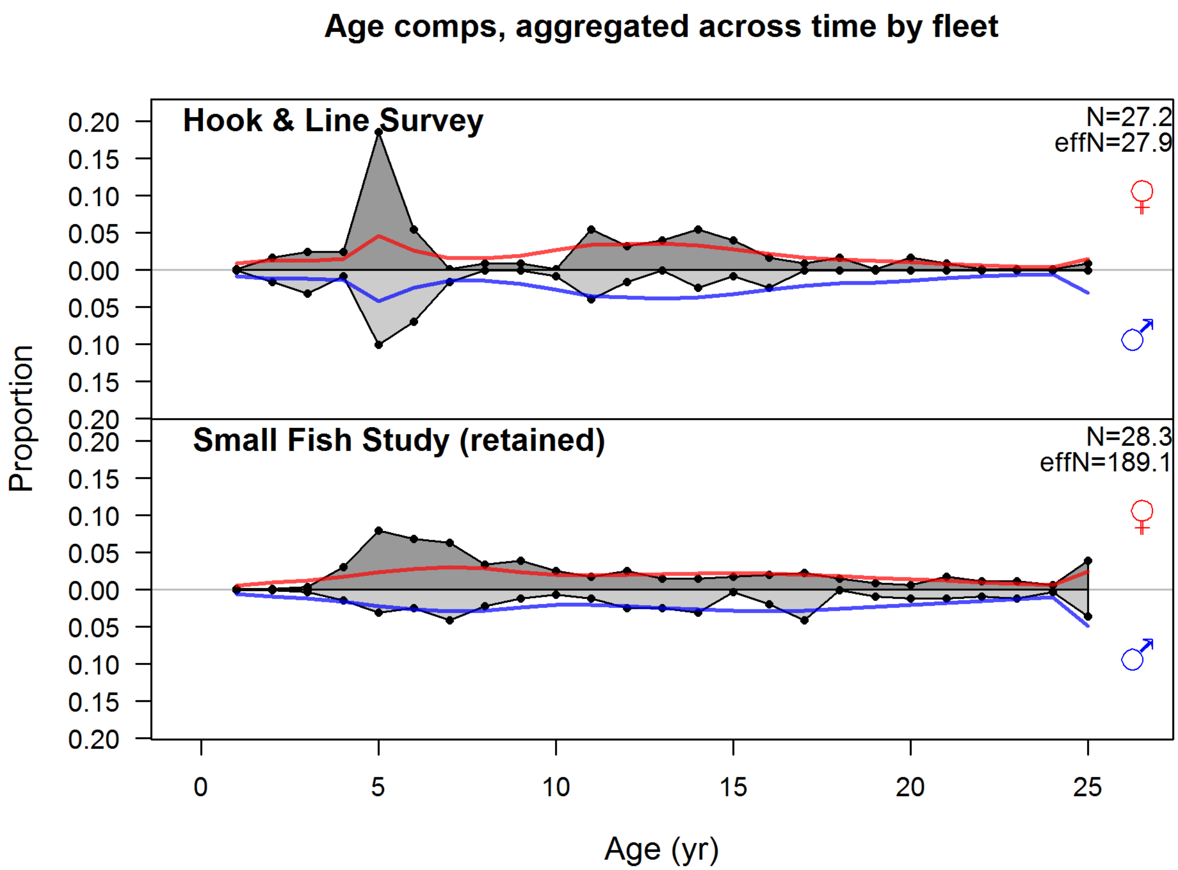


Figure 94: **Southern model** Age comps, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch.

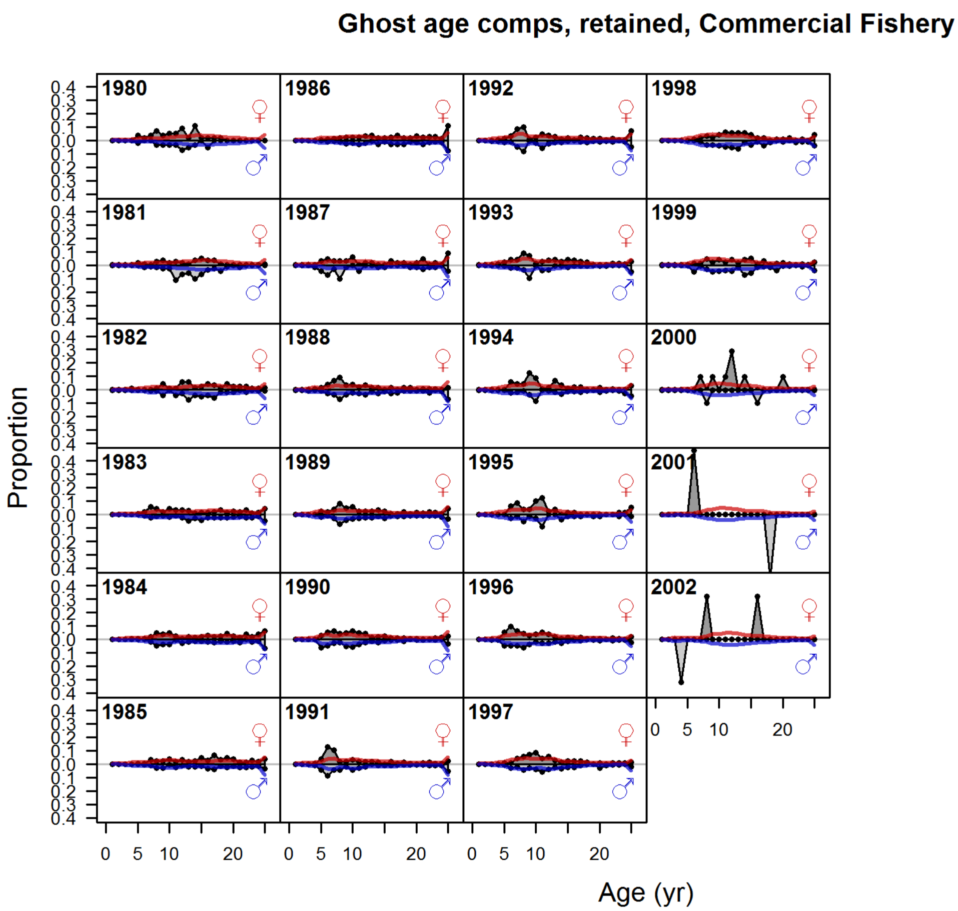


Figure 95: **Southern model** Ghost age comps, retained, Commercial Fishery

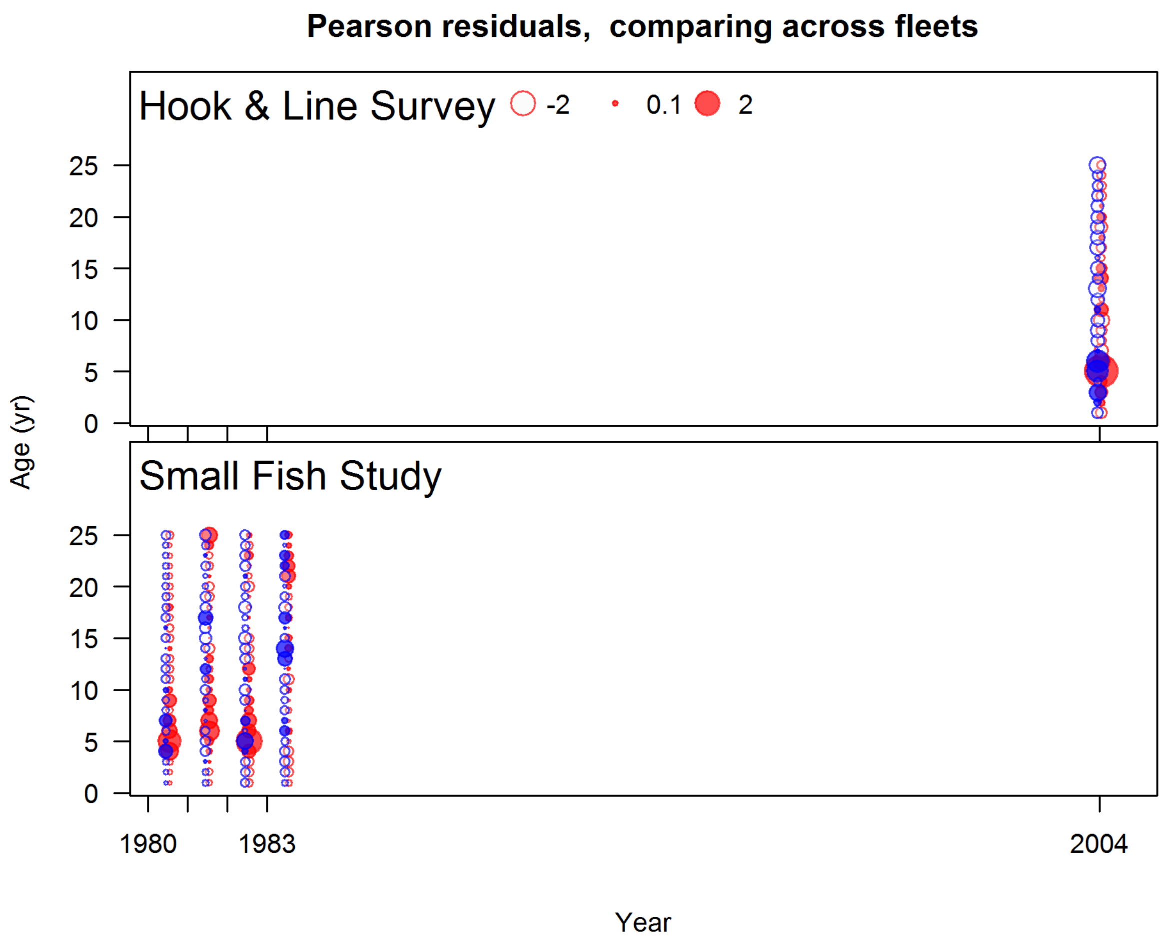


Figure 96: Age composition Pearson residuals for all fleets in the Southern model. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

1603 ### 9.4.5 Fits to conditional-age-at-length compositions for Southern model

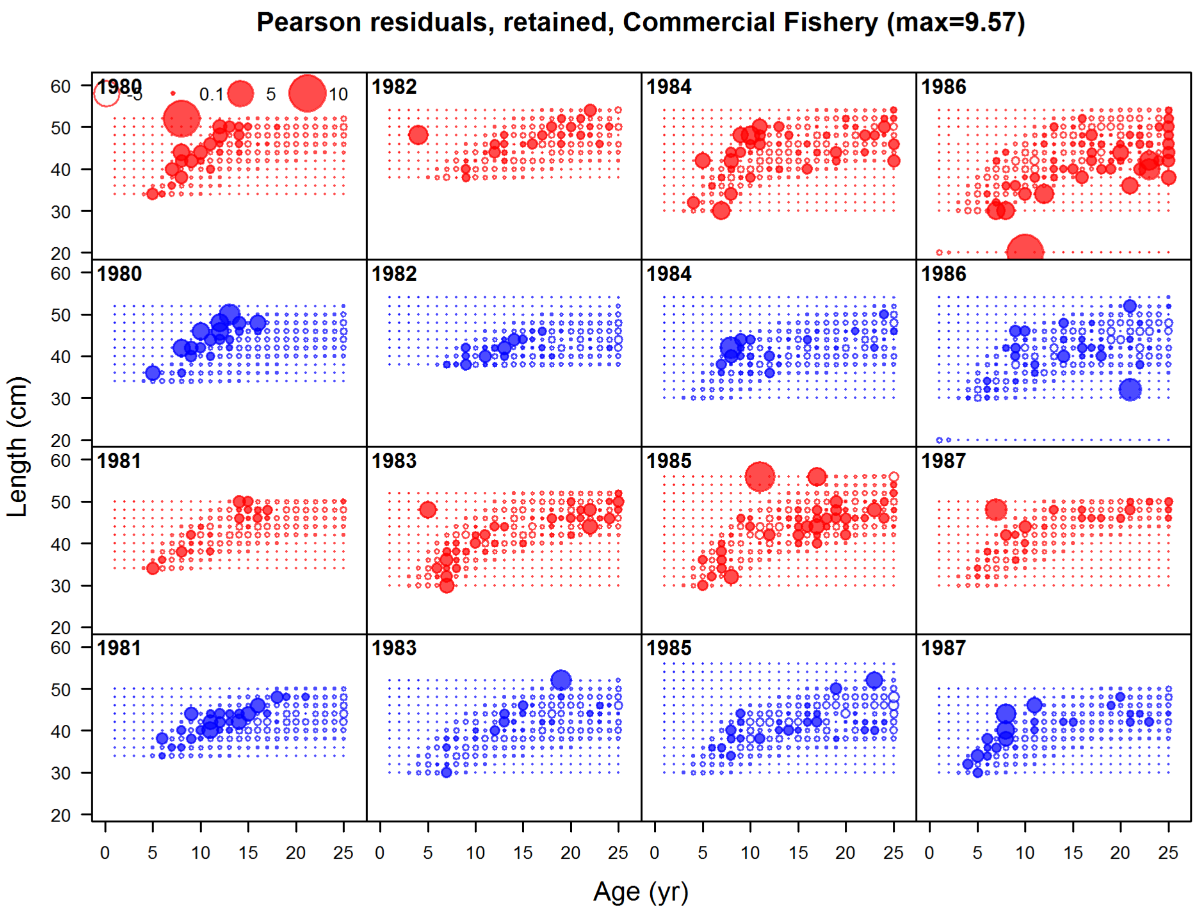
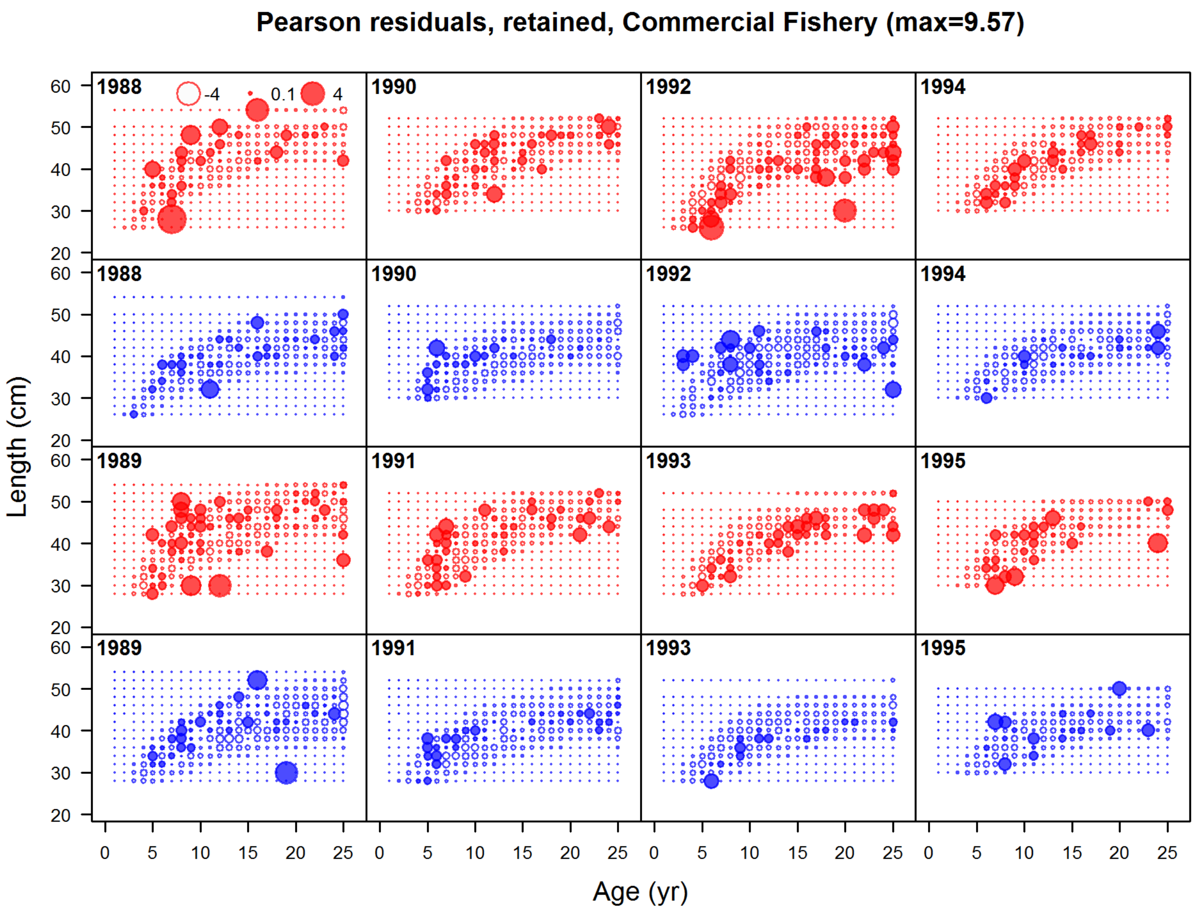


Figure 97: **Southern model** Pearson residuals, retained, Commercial Fishery (max=9.57) (plot 1 of 3)



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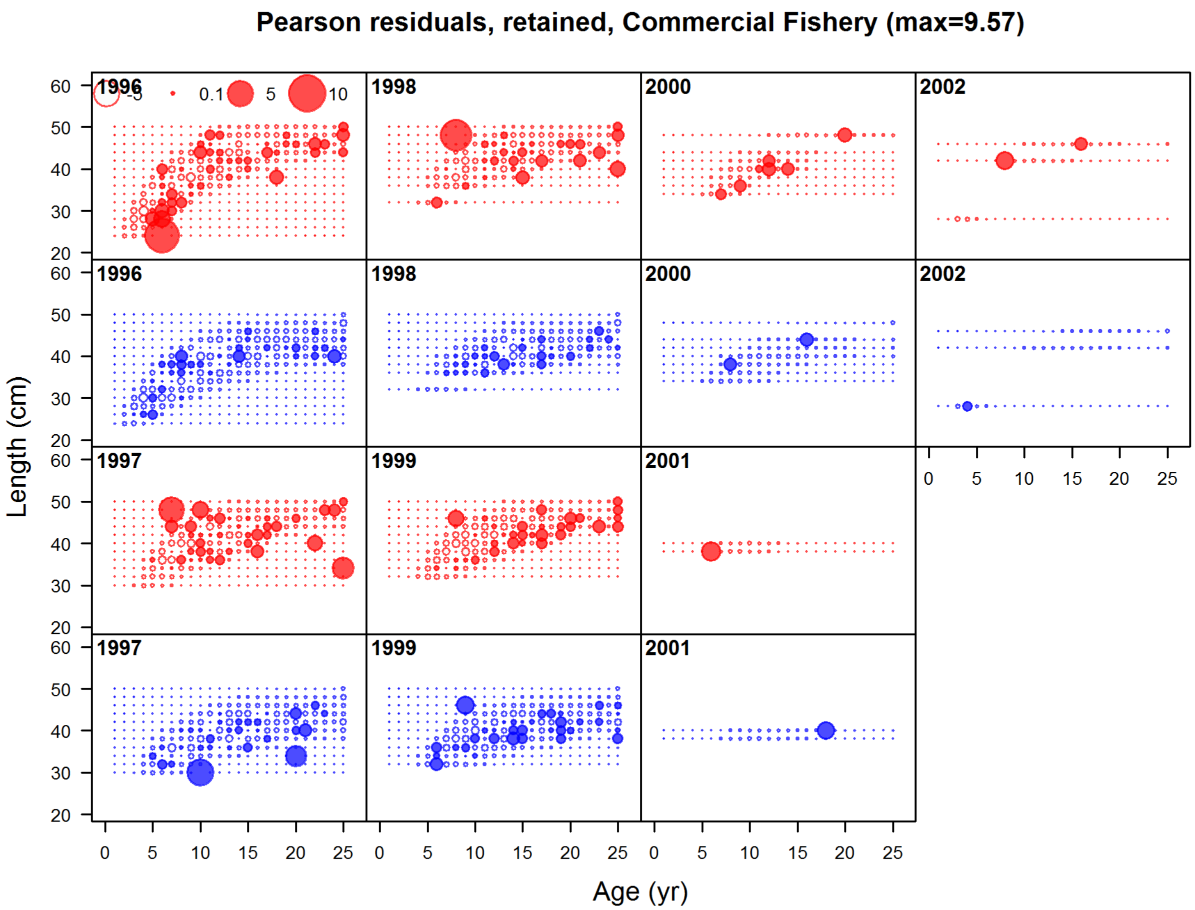
1605 Figure continued from previous page



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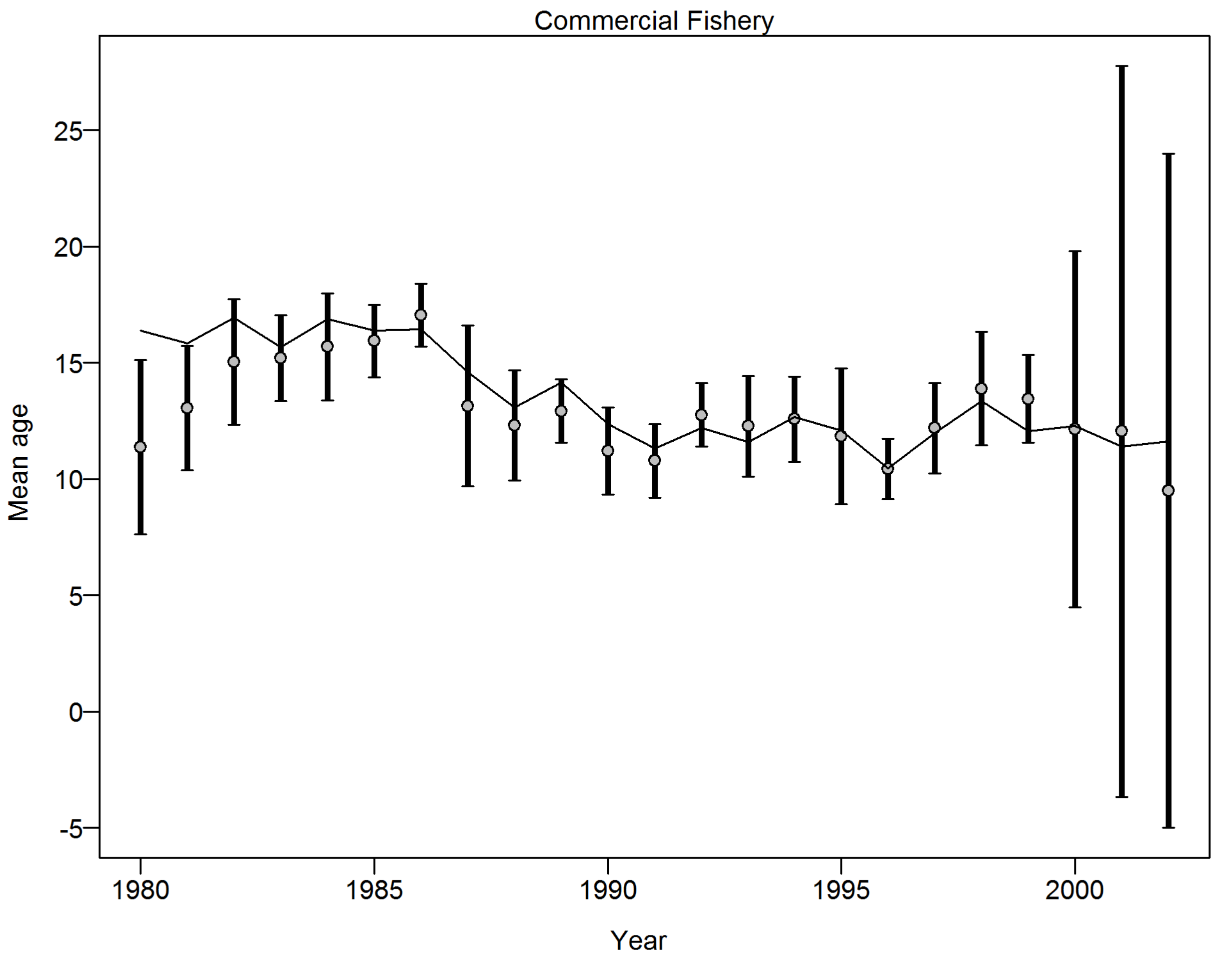


Figure 98: **Southern model** Mean age from conditional data (aggregated across length bins) for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for conditional age_at_length data from Commercial Fishery: 0.9966 (0.6565_2.1446) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

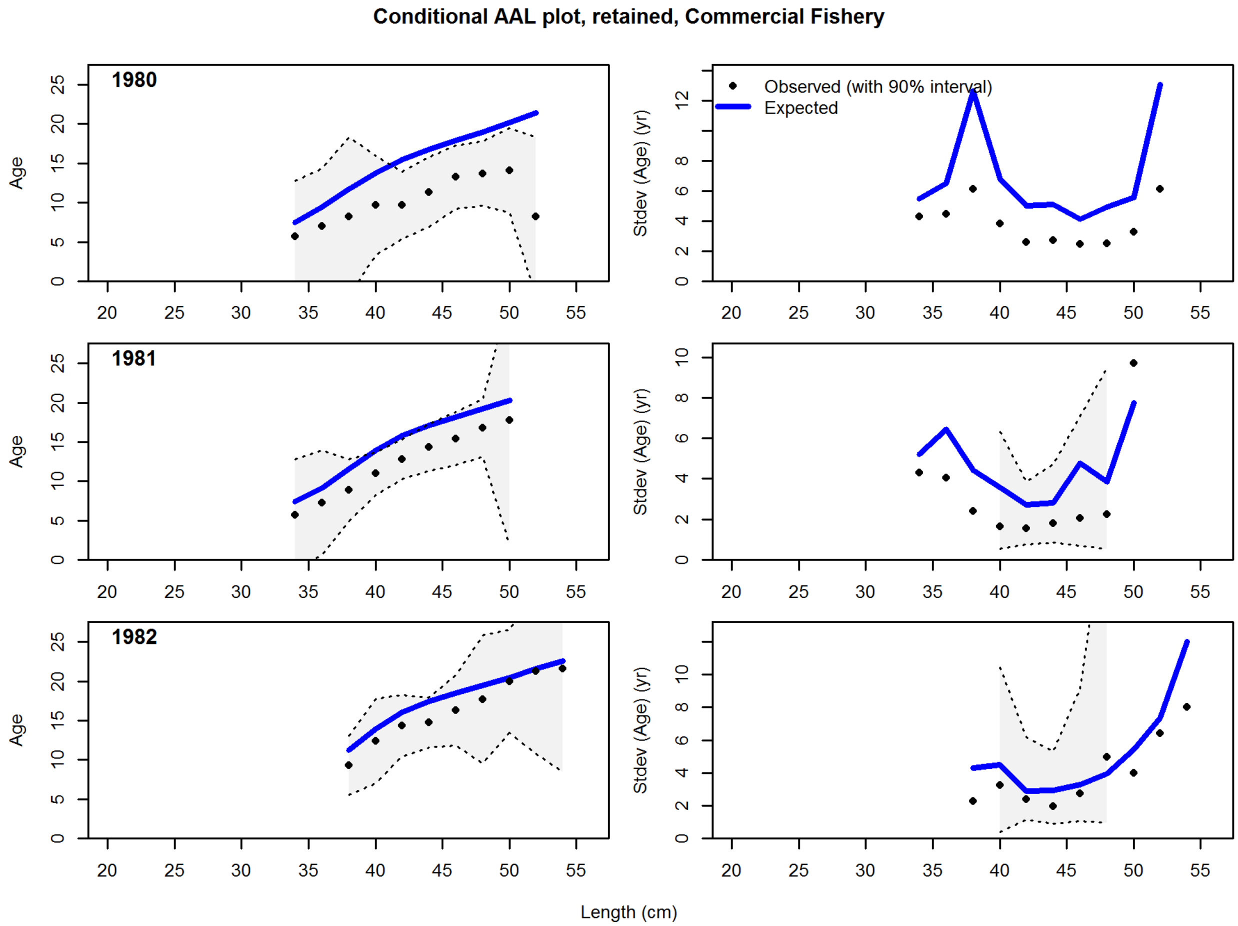
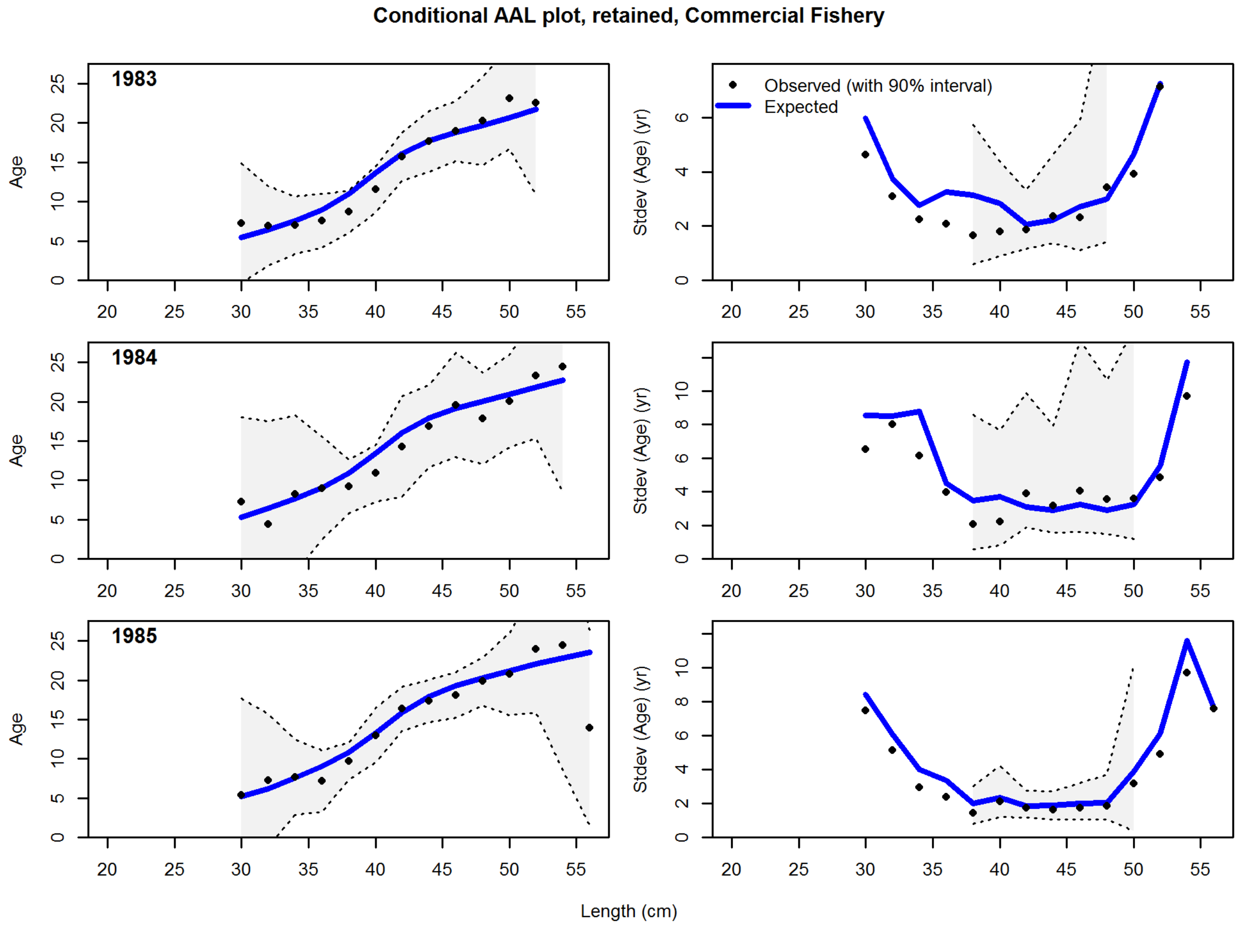


Figure 99: **Southern model** Conditional AAL plot, retained, Commercial Fishery (plot 1 of 8) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution.



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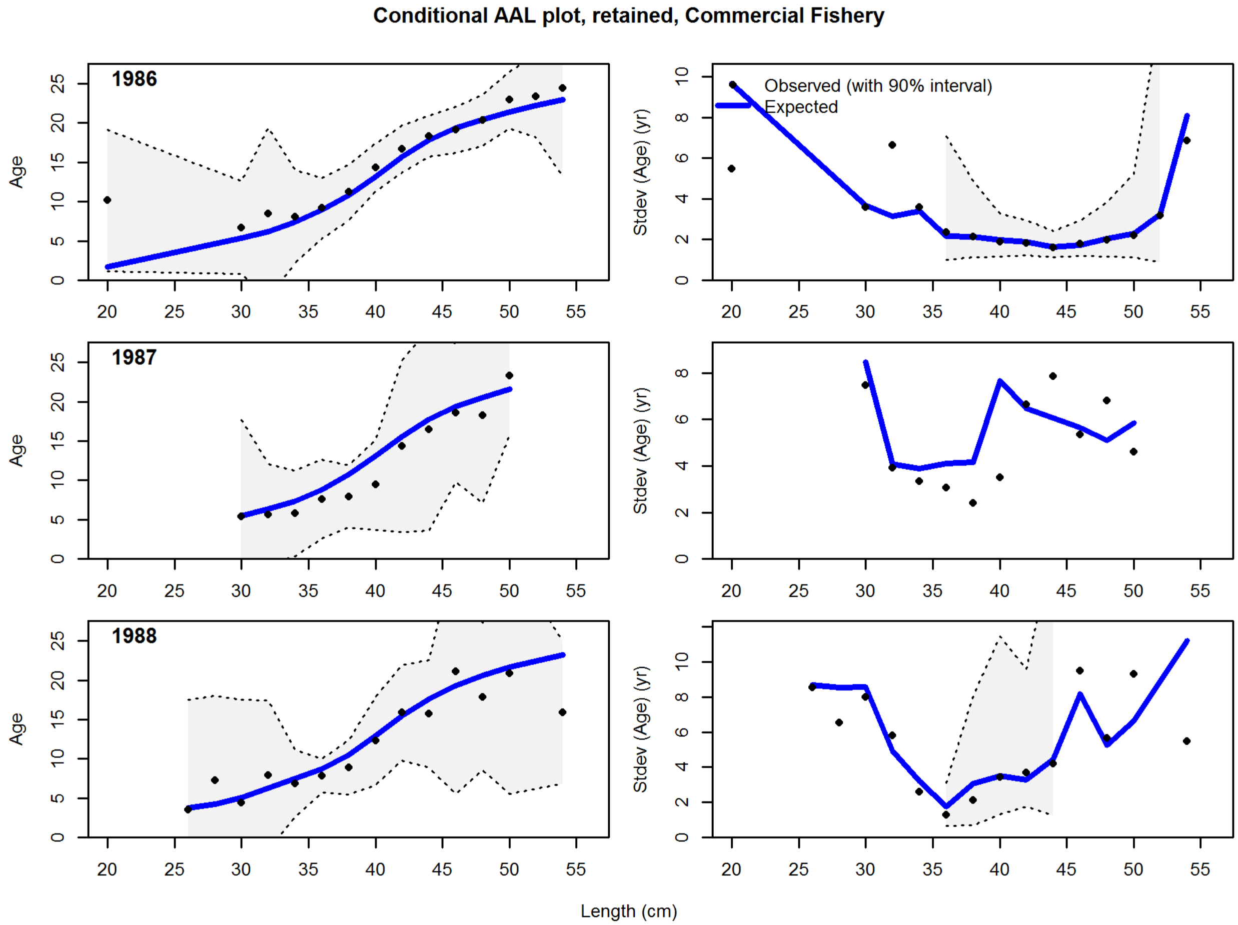

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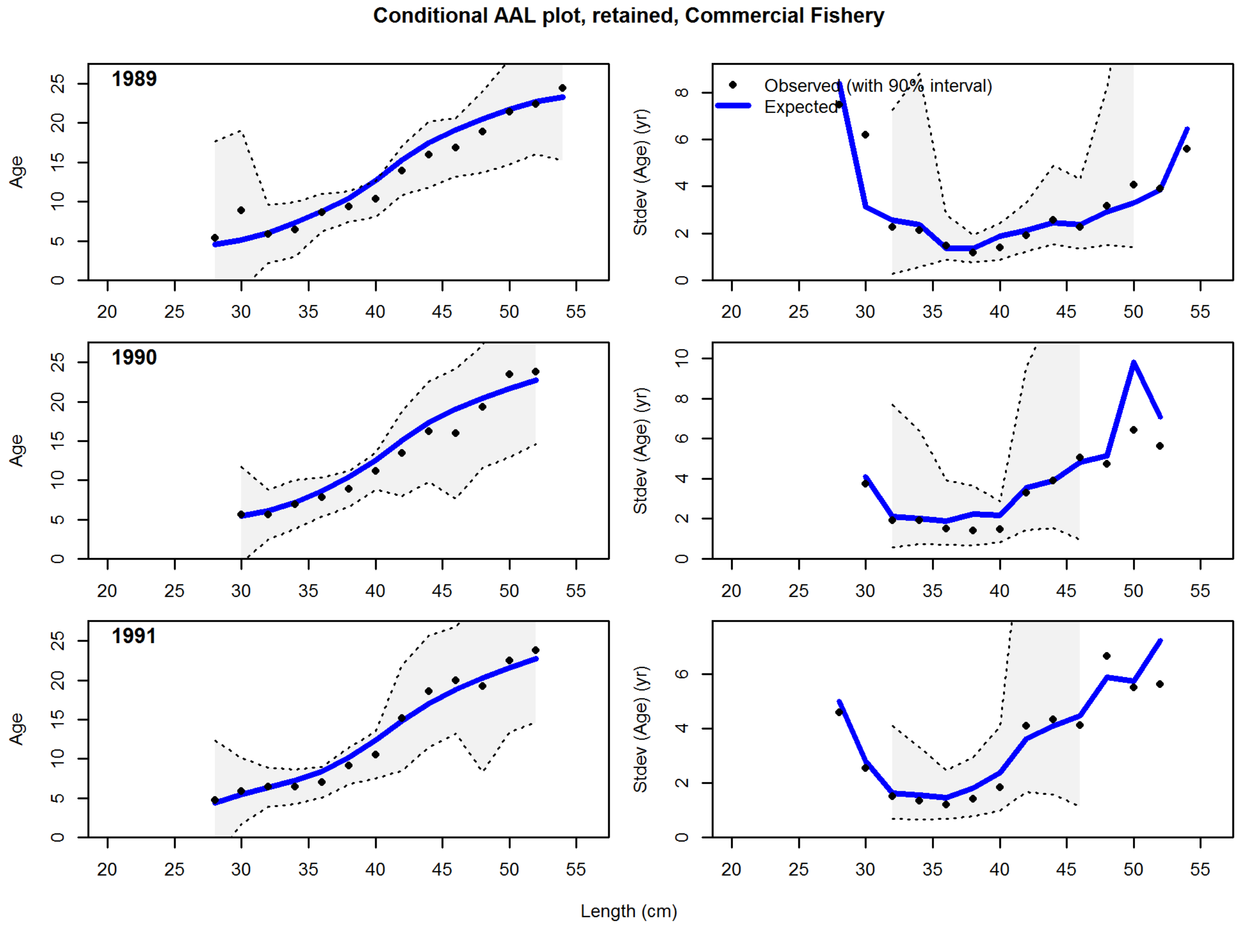
1611 Figure continued from previous page



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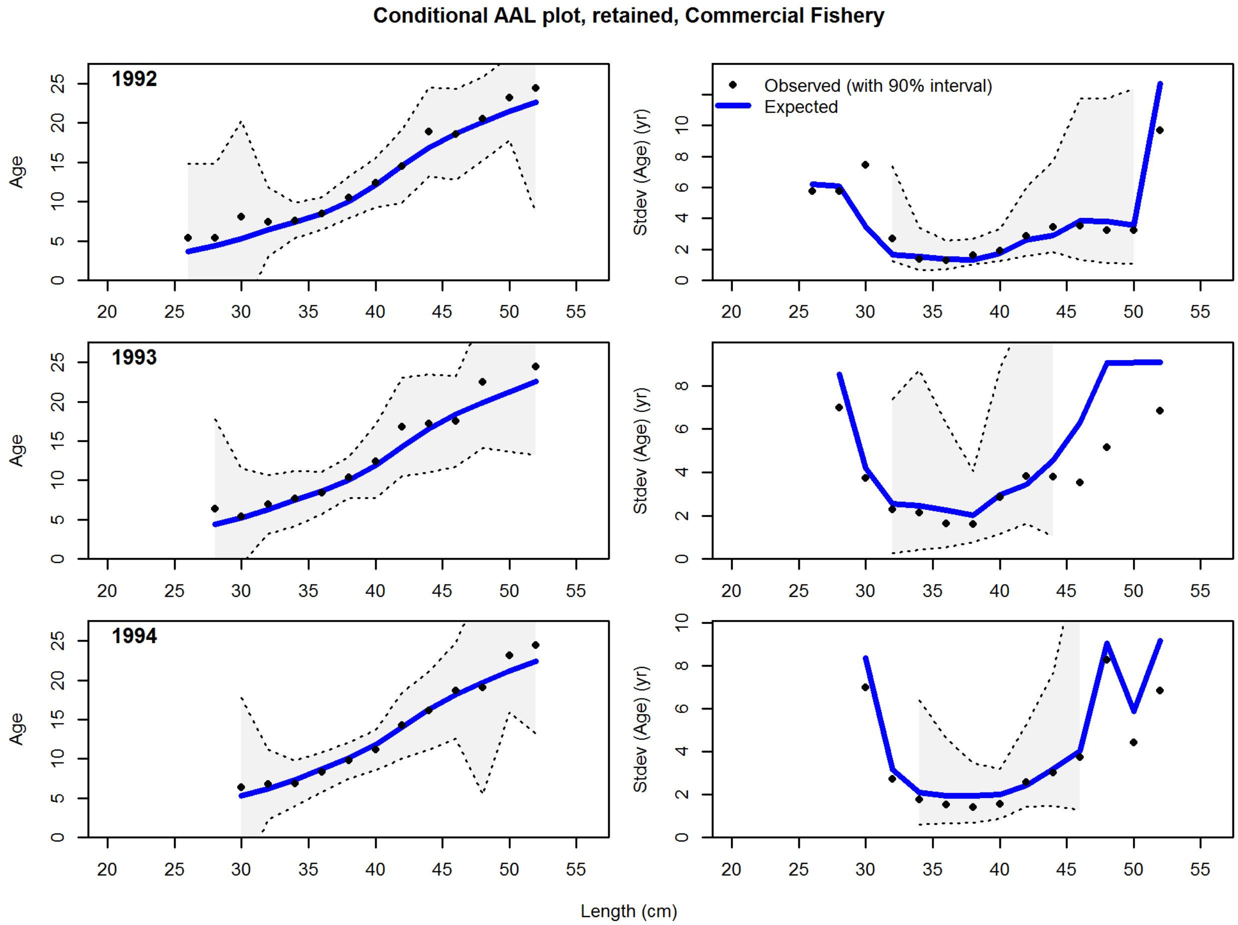
1613 Figure continued from previous page



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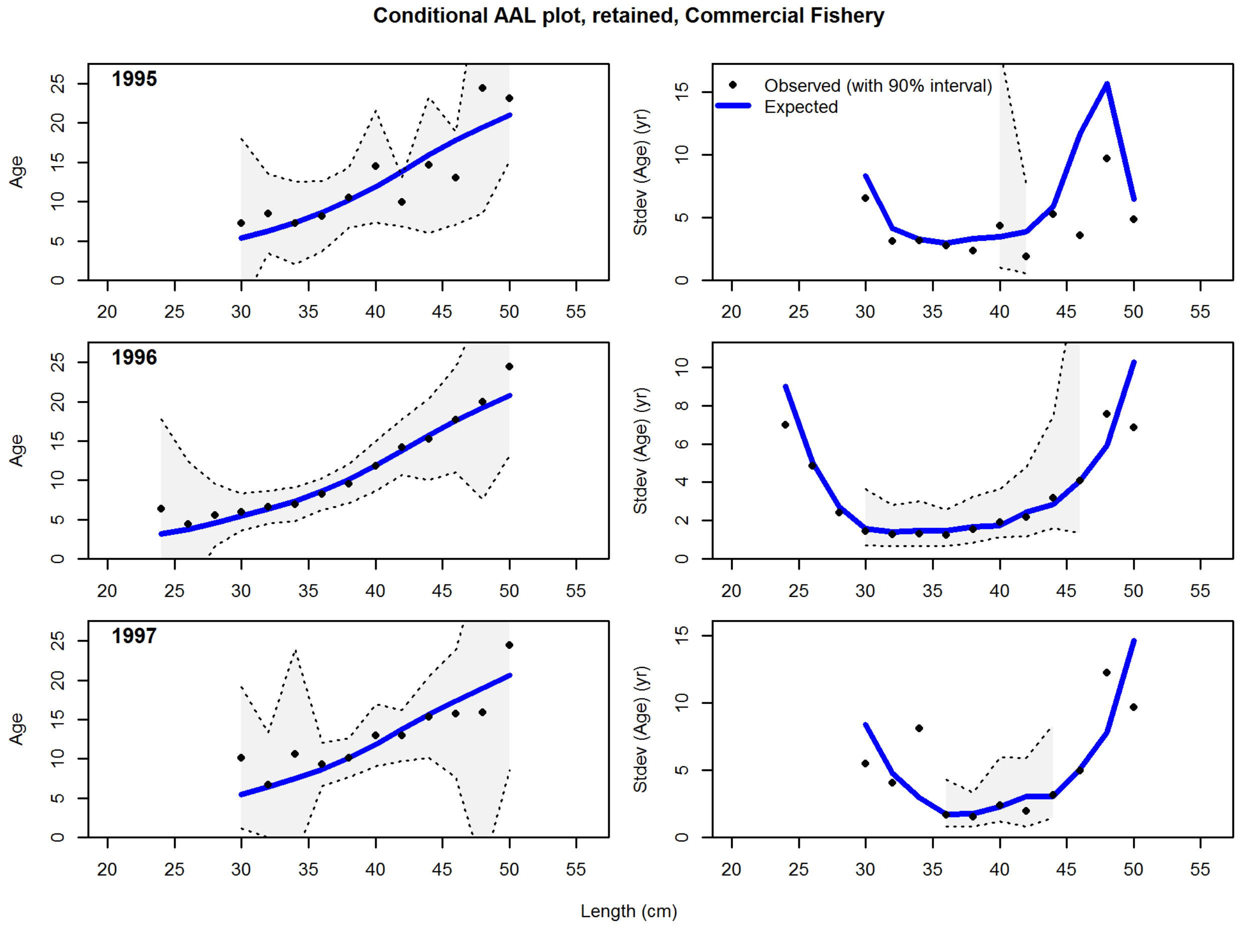
1615 Figure continued from previous page



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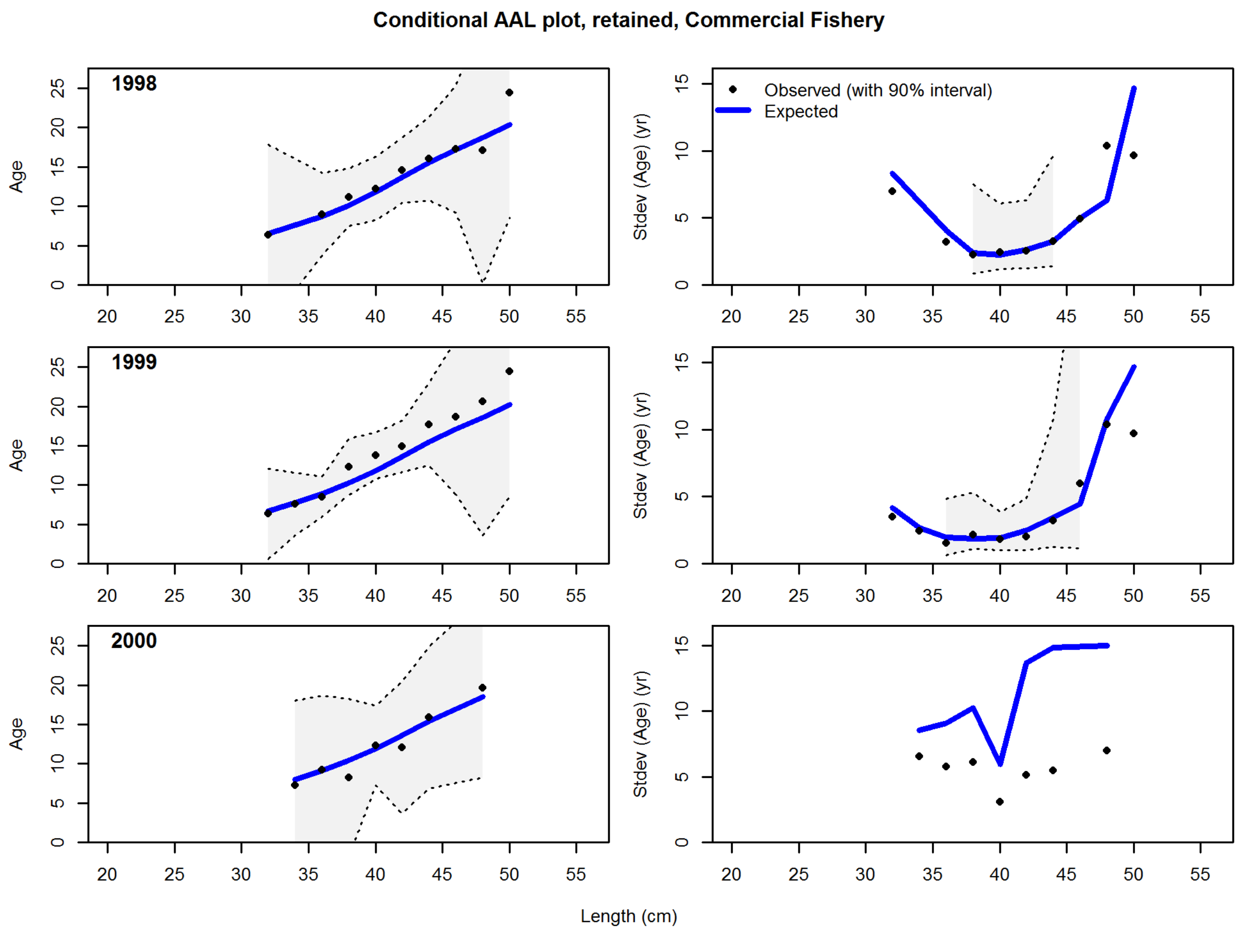
1617 Figure continued from previous page



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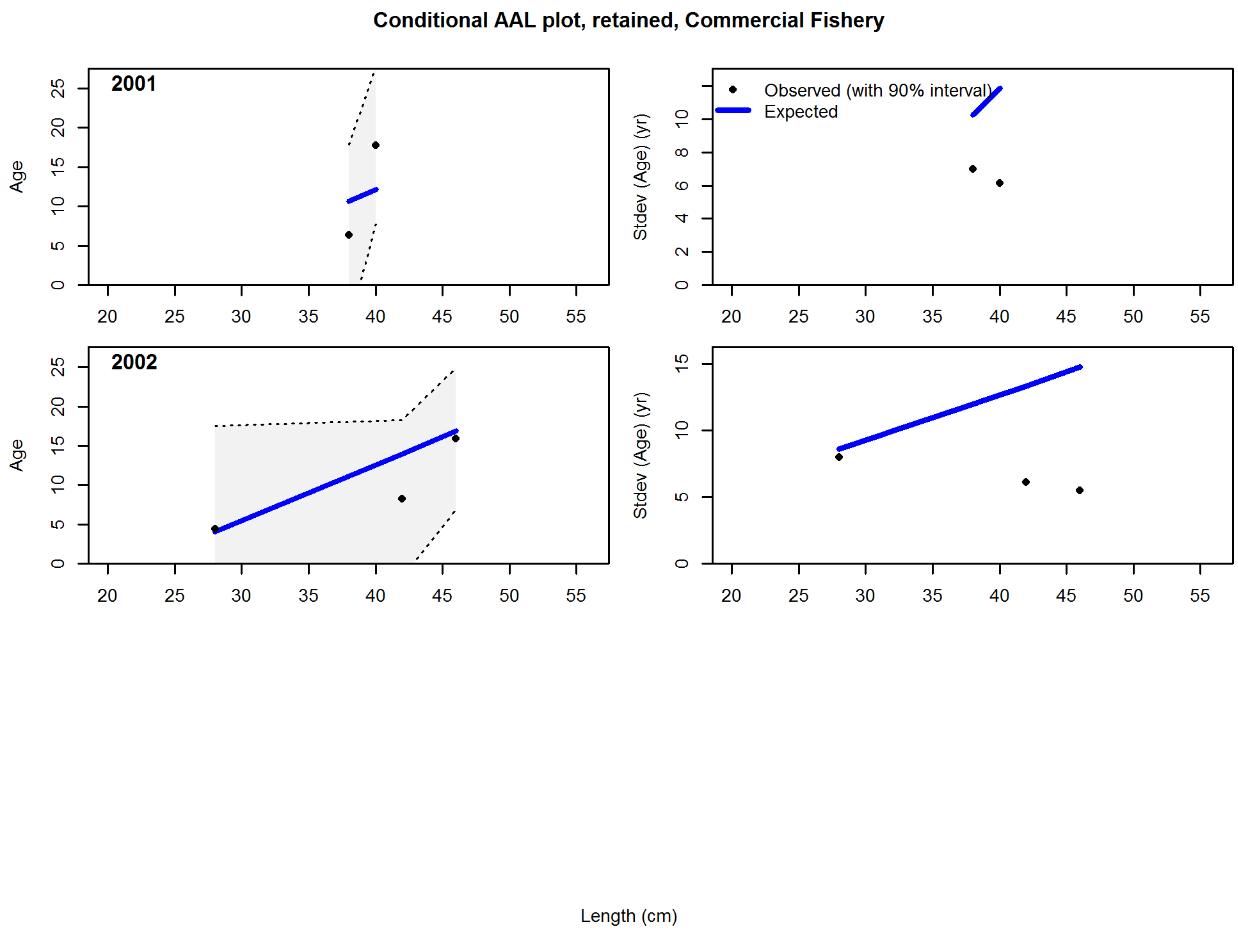
1619 Figure continued from previous page



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9.5 Model results for Southern model

9.5.1 Base model results for Southern model

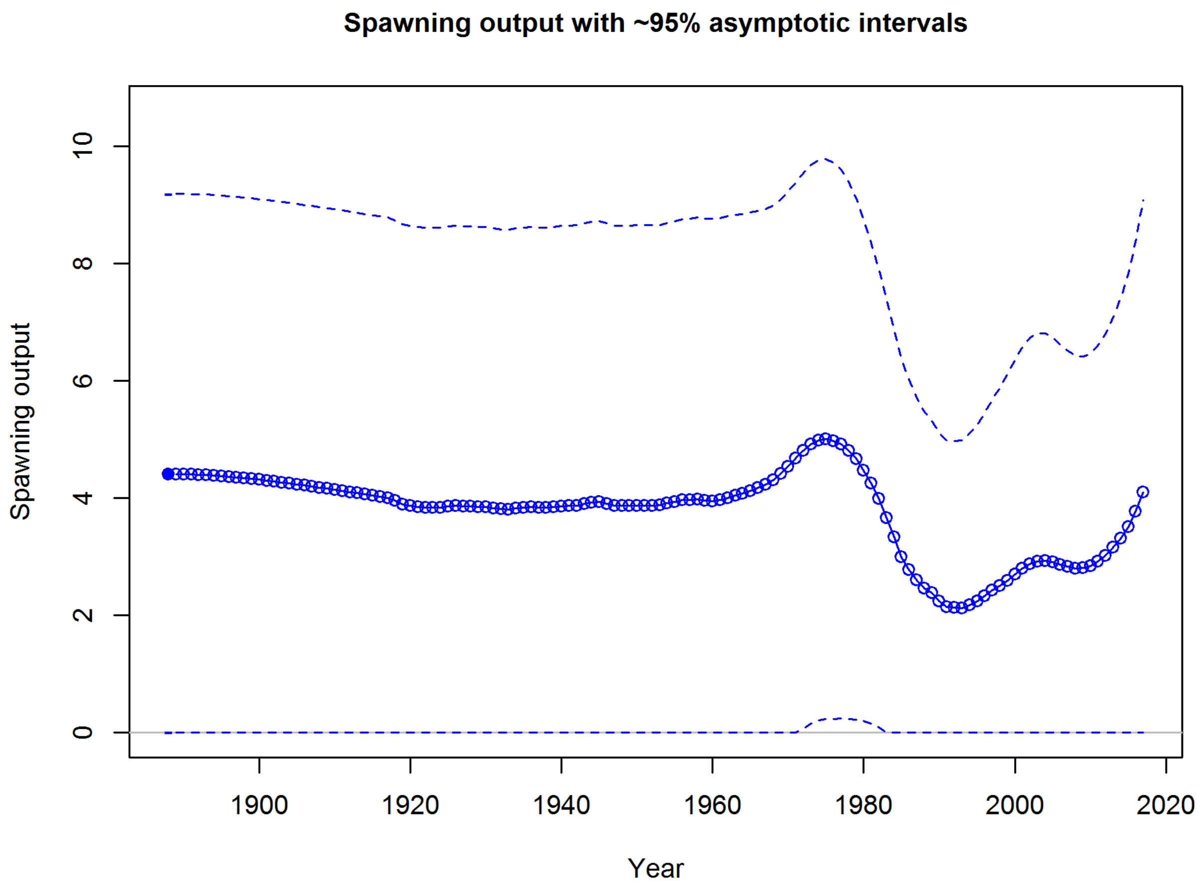

Figure 100: Estimated time-series of spawning output for Southern model.

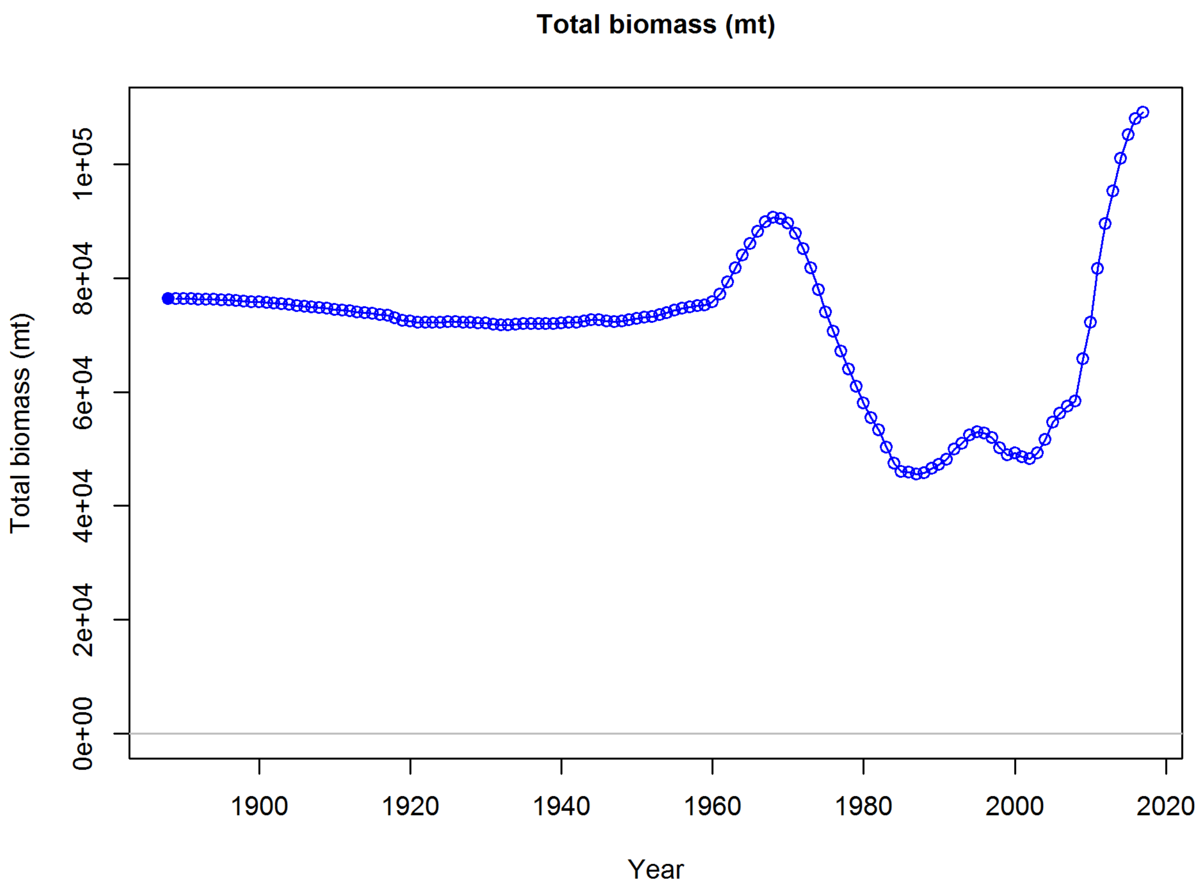

Figure 101: Estimated time-series of total biomass for Southern model.

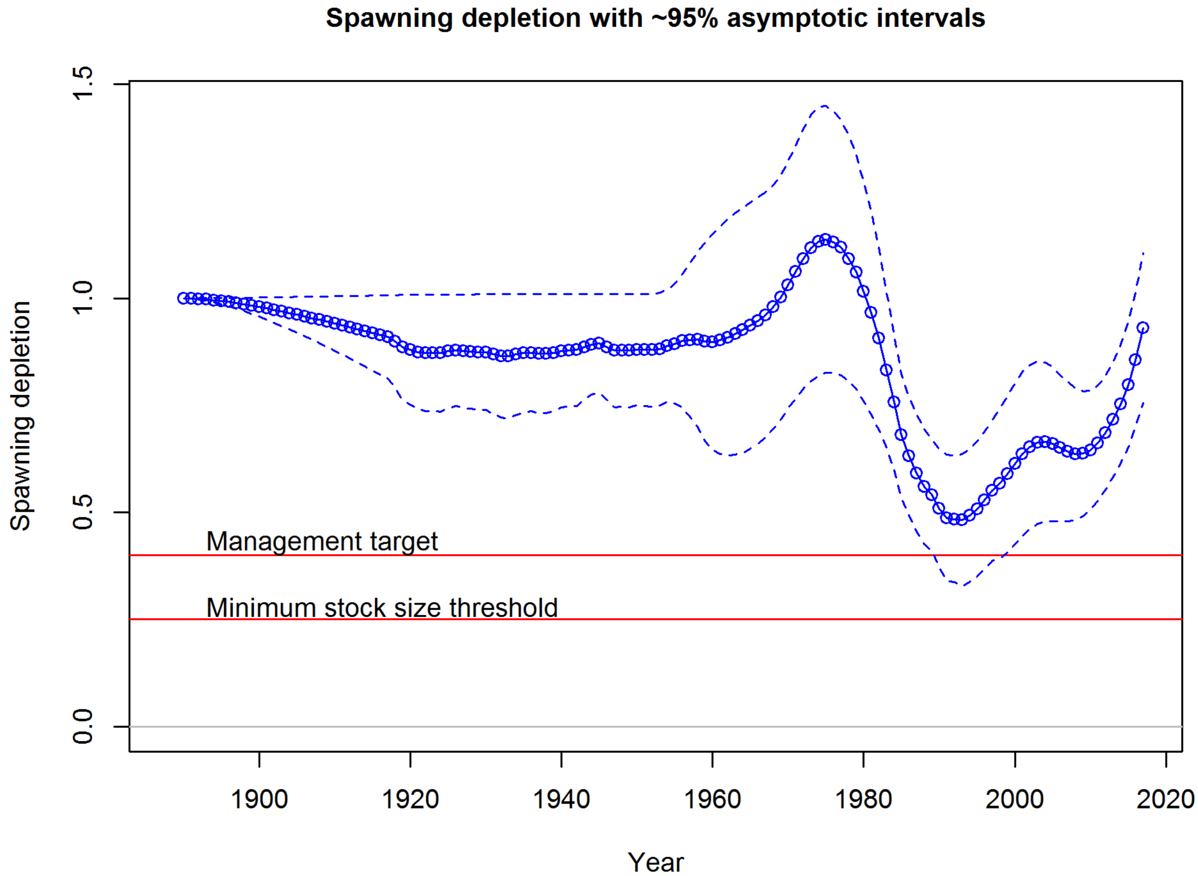

Figure 102: Estimated time-series of relative biomass for Southern model.

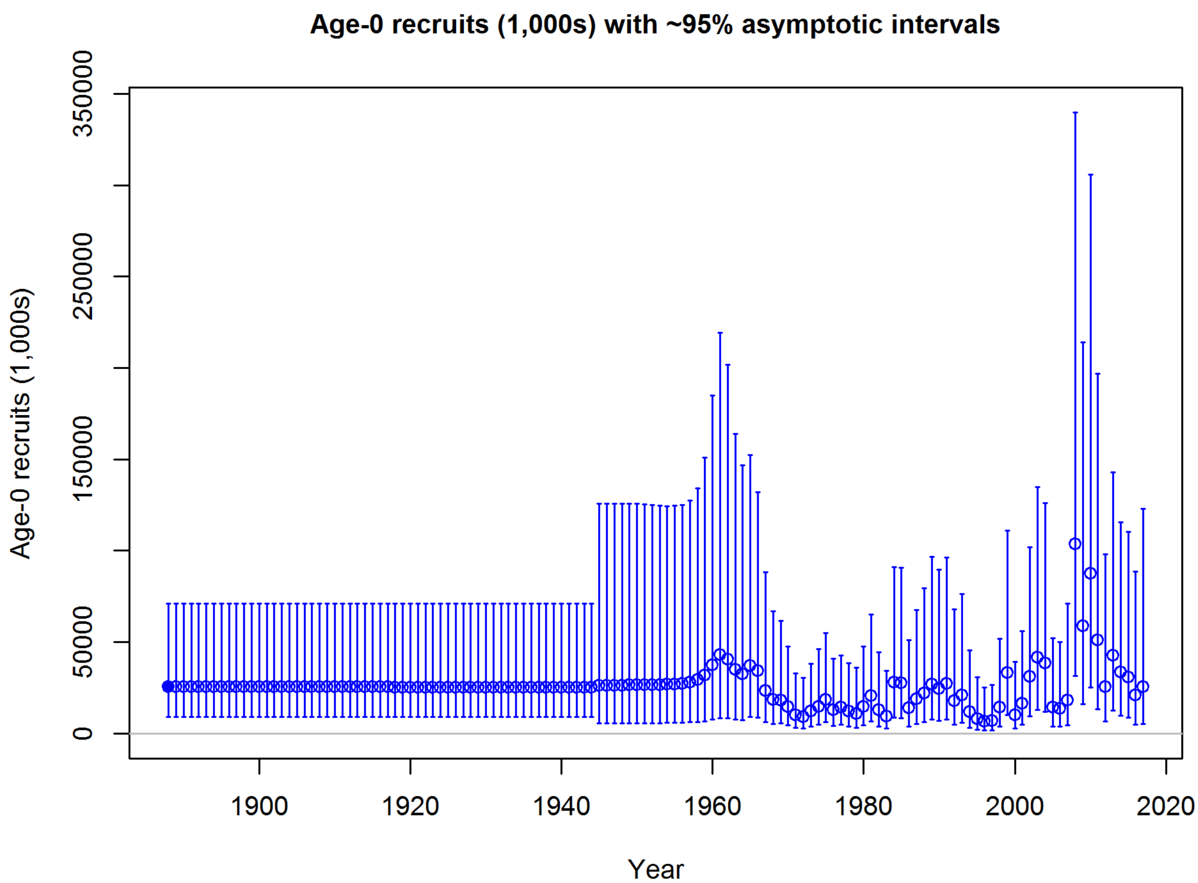

Figure 103: Estimated time-series of recruitment for the Southern model.

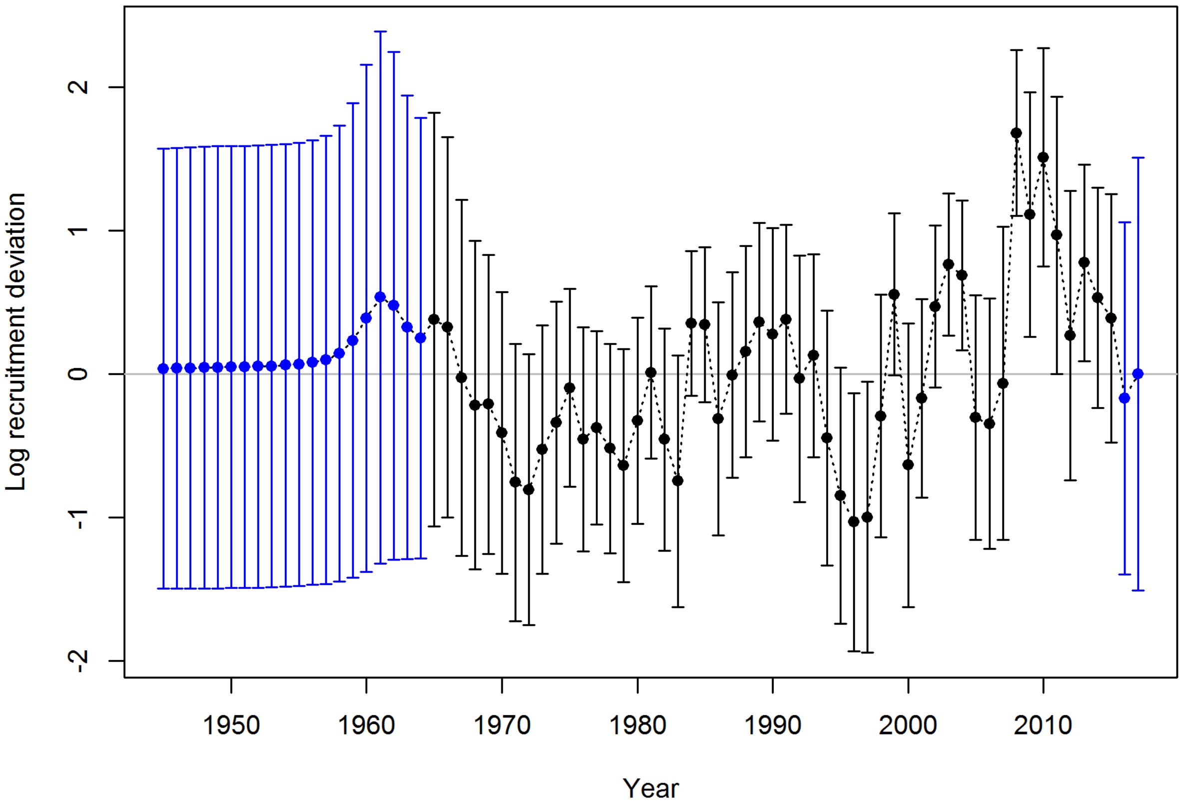

Figure 104: Estimated time-series of recruitment deviations for the Southern model.

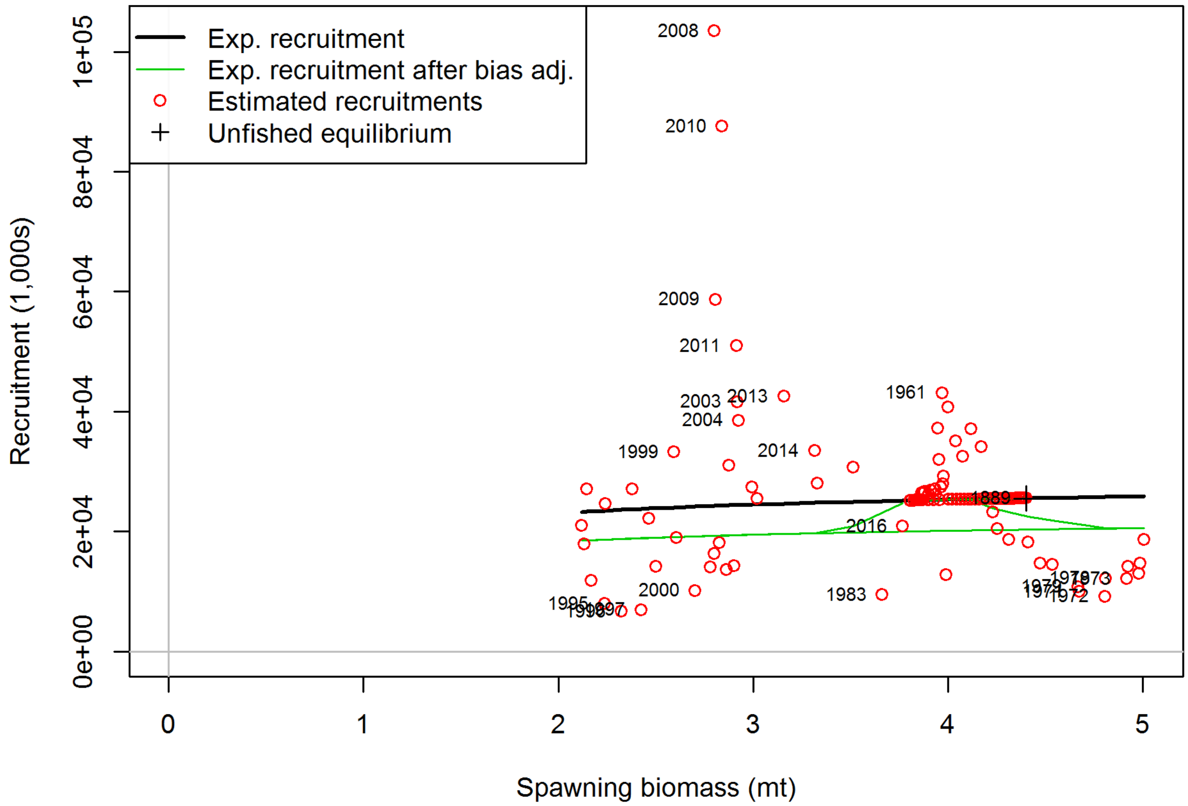

Figure 105: Estimated recruitment (red circles) for the Southern model relative to the stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution

1624 ### 9.5.2 Sensitivity analyses for Southern model

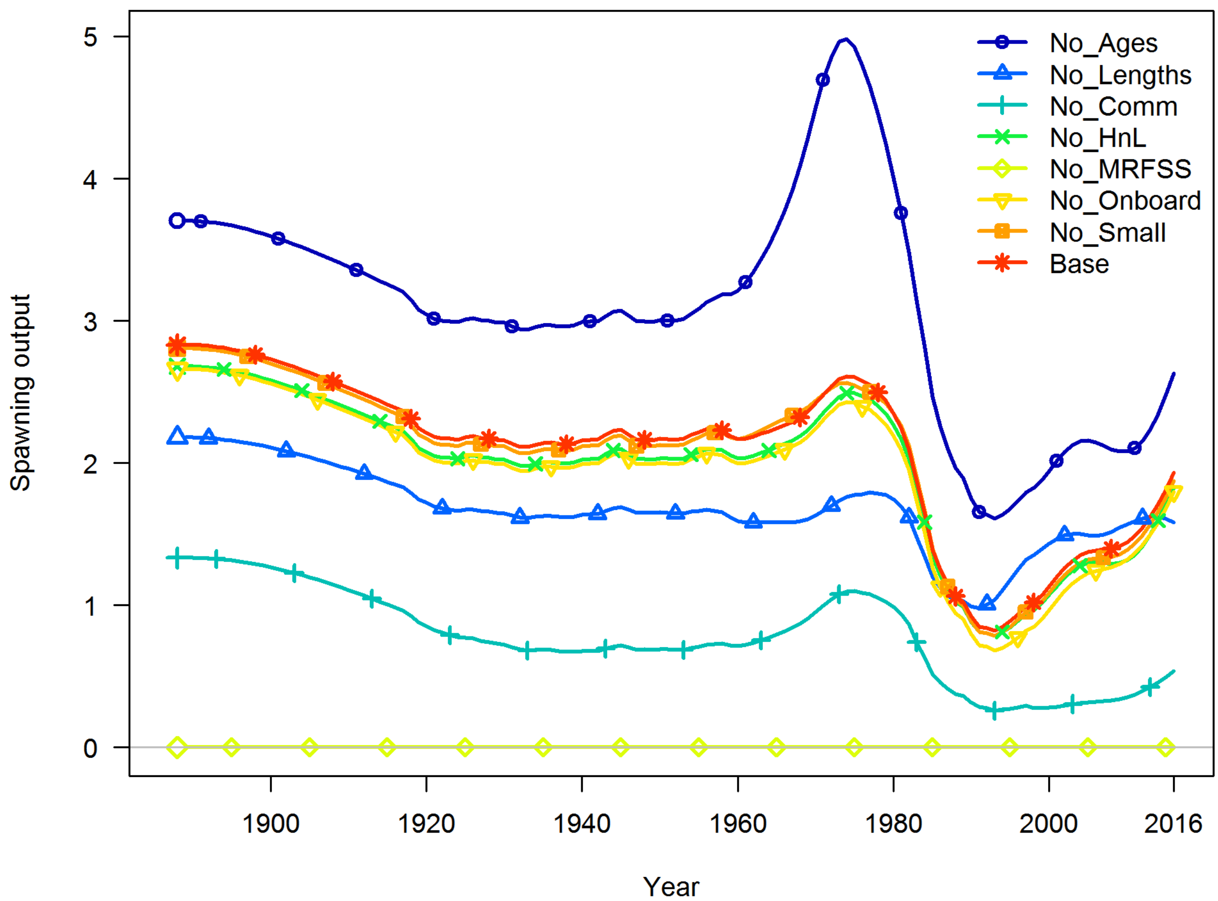

Figure 106: Time series of spawning output (in trillions of eggs) estimated in the subset of sensitivity analyses for the Southern model related to removing biological data from the model. The yellow line at 0 associated with removing the MRFSS data represents a model that did not converge.

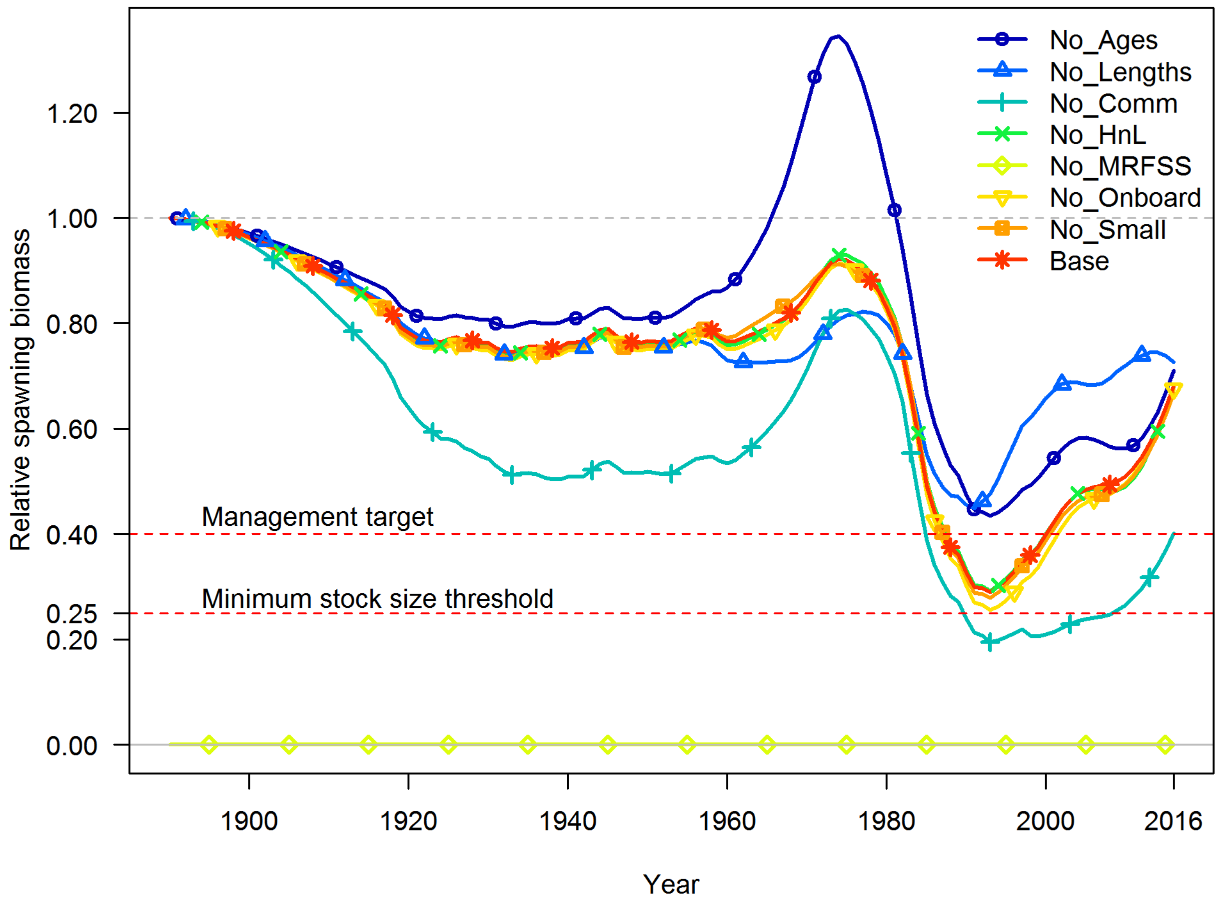

Figure 107: Time series of relative spawning output estimated in the subset of sensitivity analyses for the Southern model related to removing biological data from the model. The yellow line at 0 associated with removing the MRFSS represents a model that did not converge.

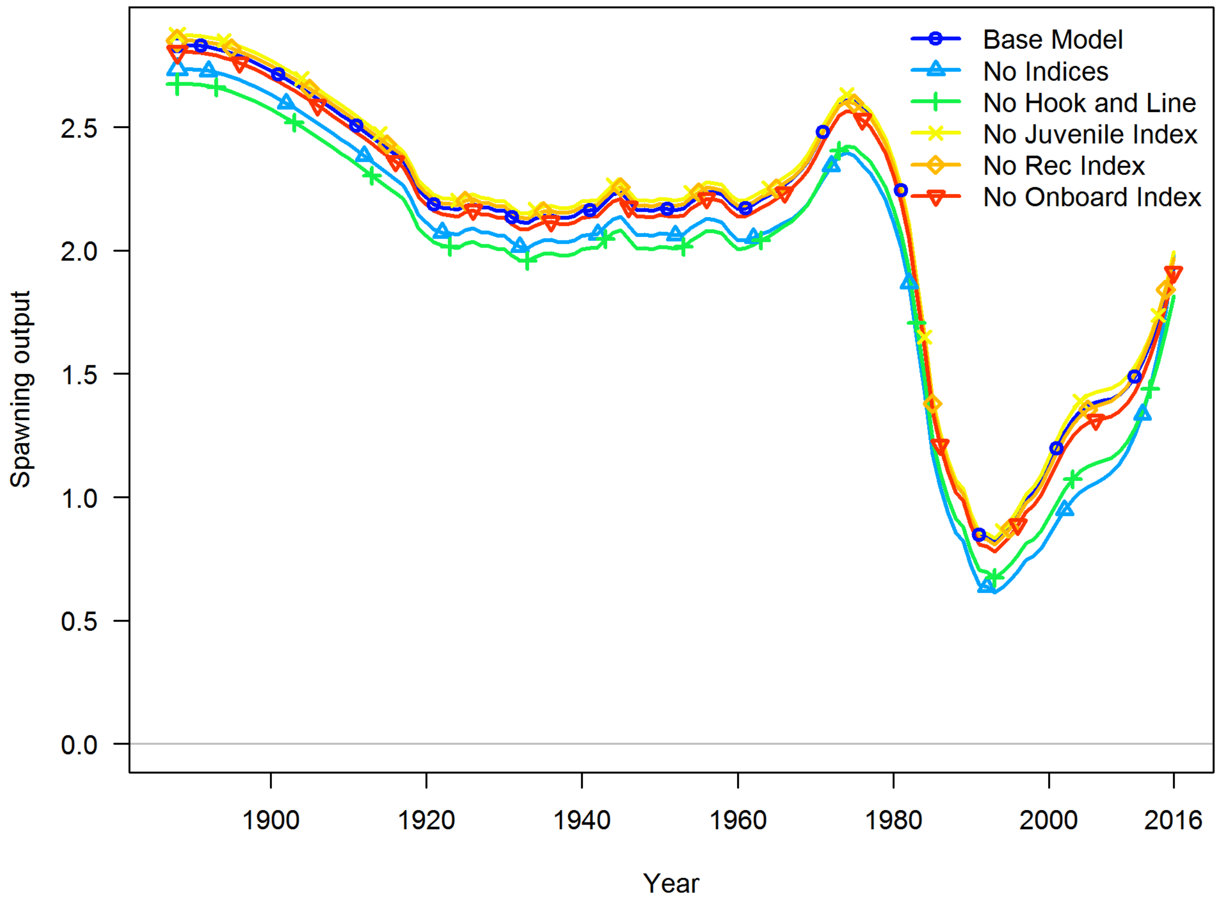

Figure 108: Time series of spawning output (in trillions of eggs) estimated in the subset of sensitivity analyses for the Southern model related to removing indices of abundance from the model.

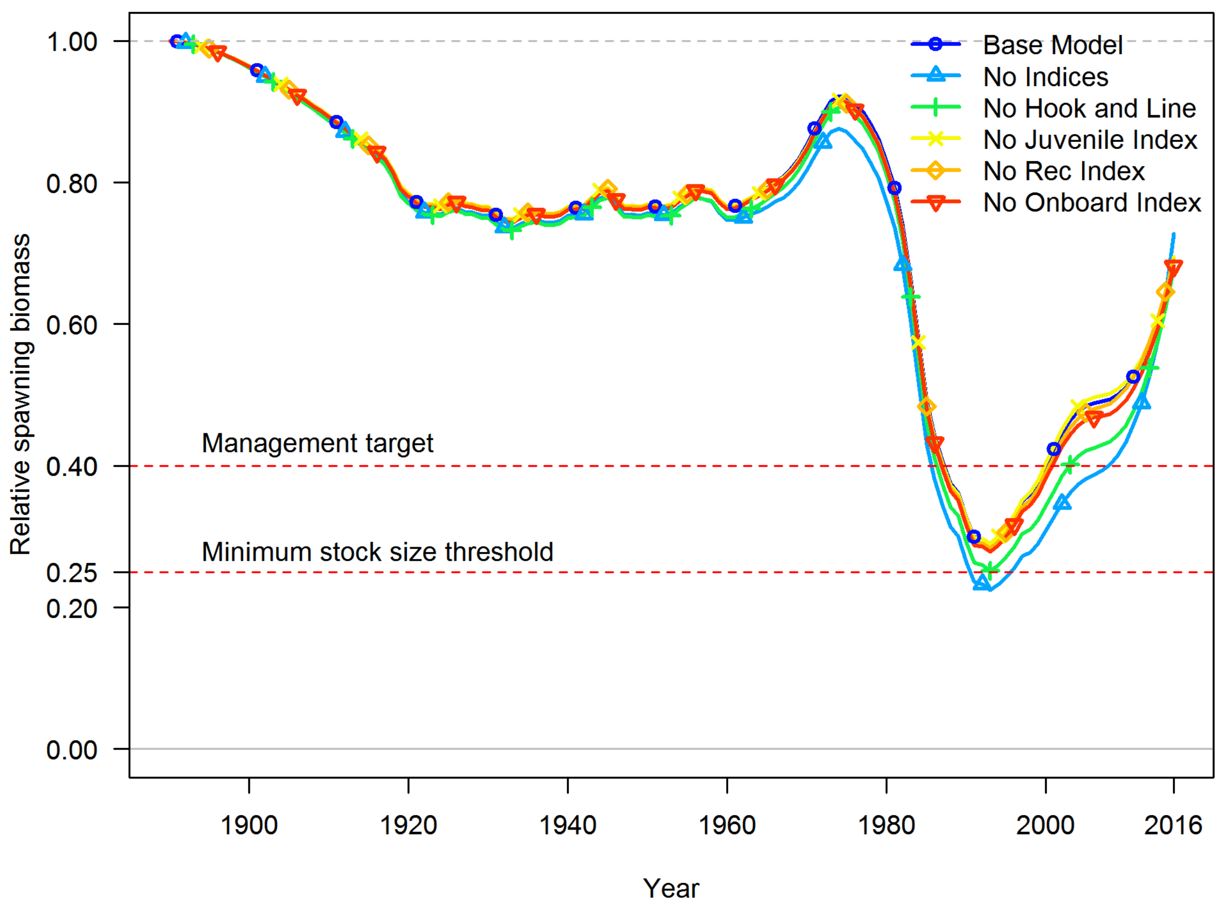

Figure 109: Time series of relative spawning output estimated in the subset of sensitivity analyses for the Southern model related to removing indices of abundance from the model.

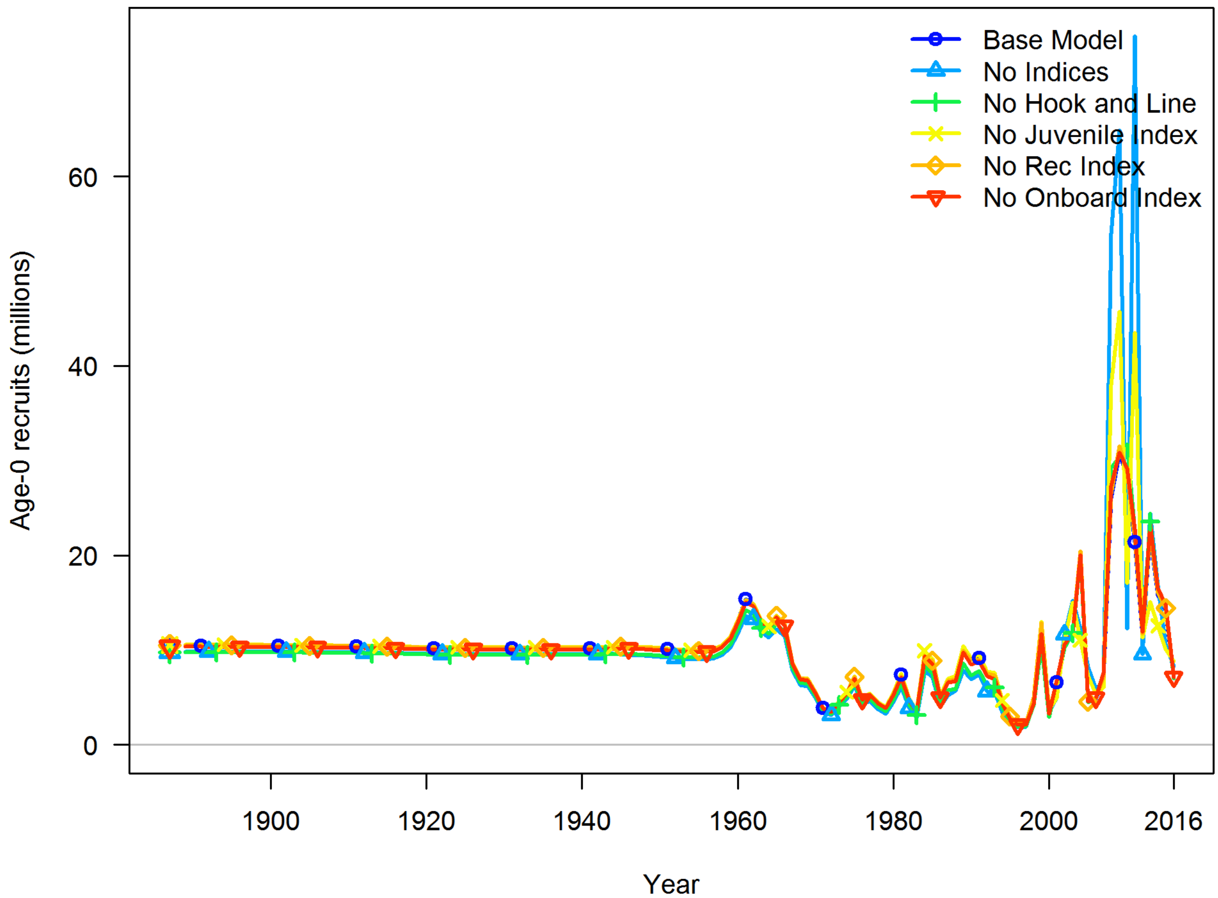

Figure 110: Time series of recruitment estimated in the subset of sensitivity analyses for the Southern model related to removing indices of abundance from the model.

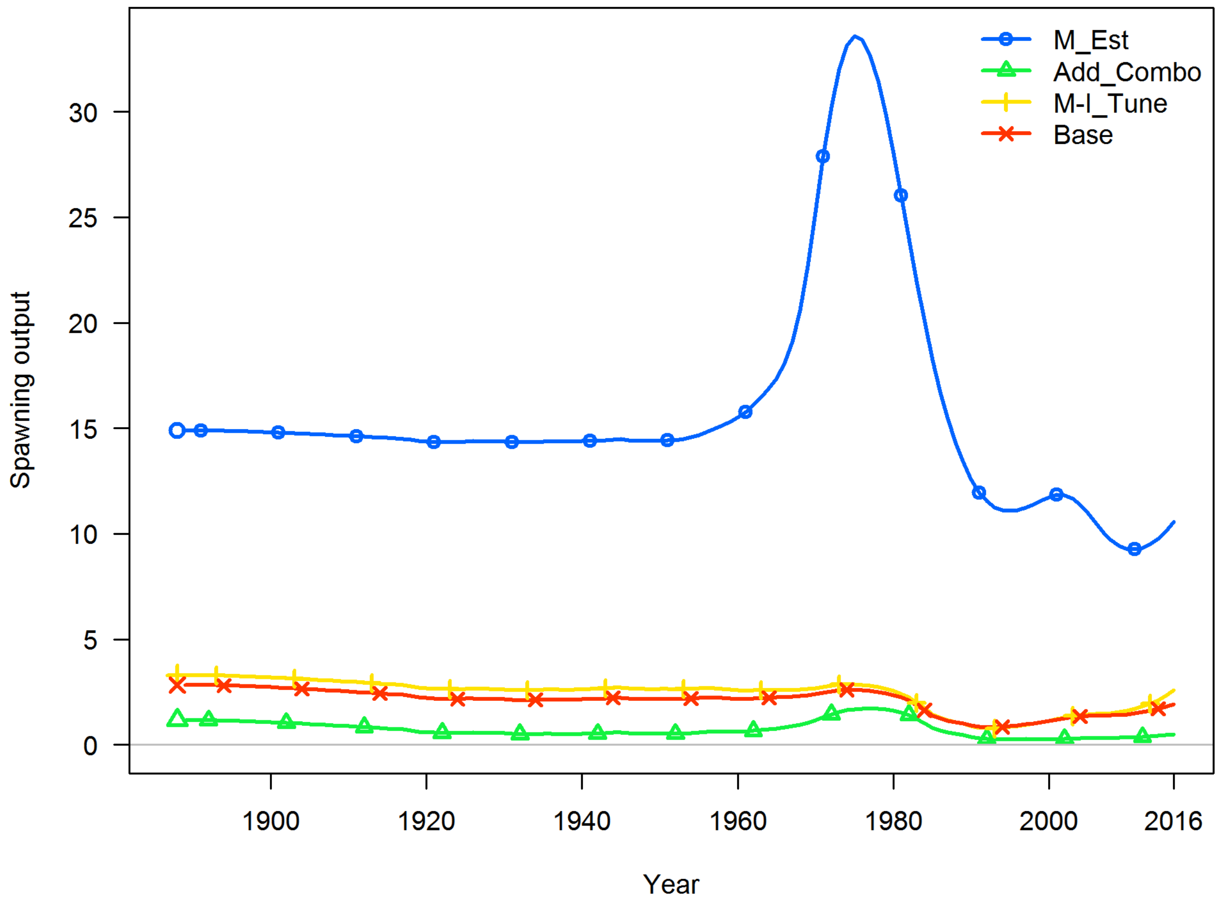

Figure 111: Time series of spawning output (in trillions of eggs) estimated in the additional sensitivity analyses for the Southern model not representend in the three figures above.

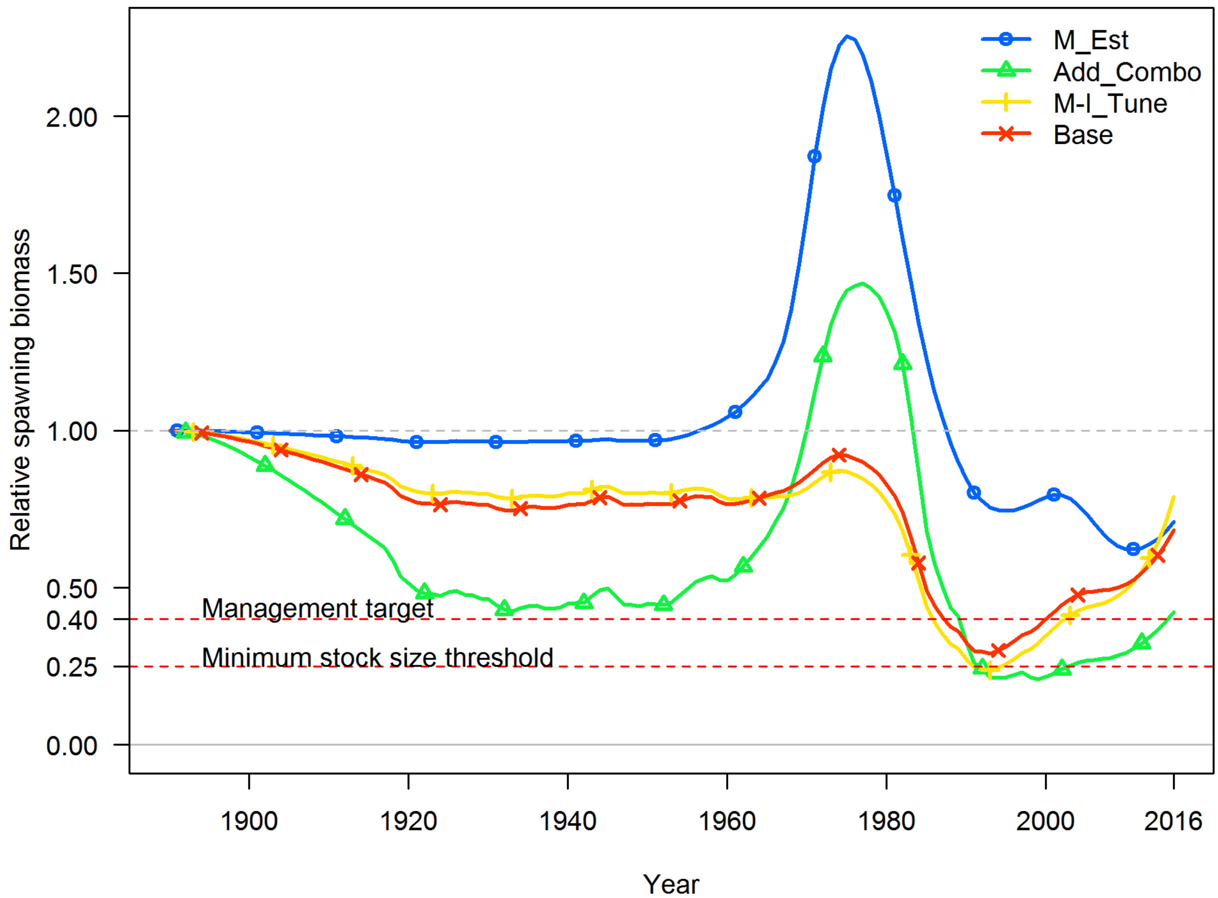

Figure 112: Time series of relative spawning output estimated in the additional sensitivity analyses for the Southern model not representend in the three figures above.

9.5.3 Likelihood profiles for Southern model

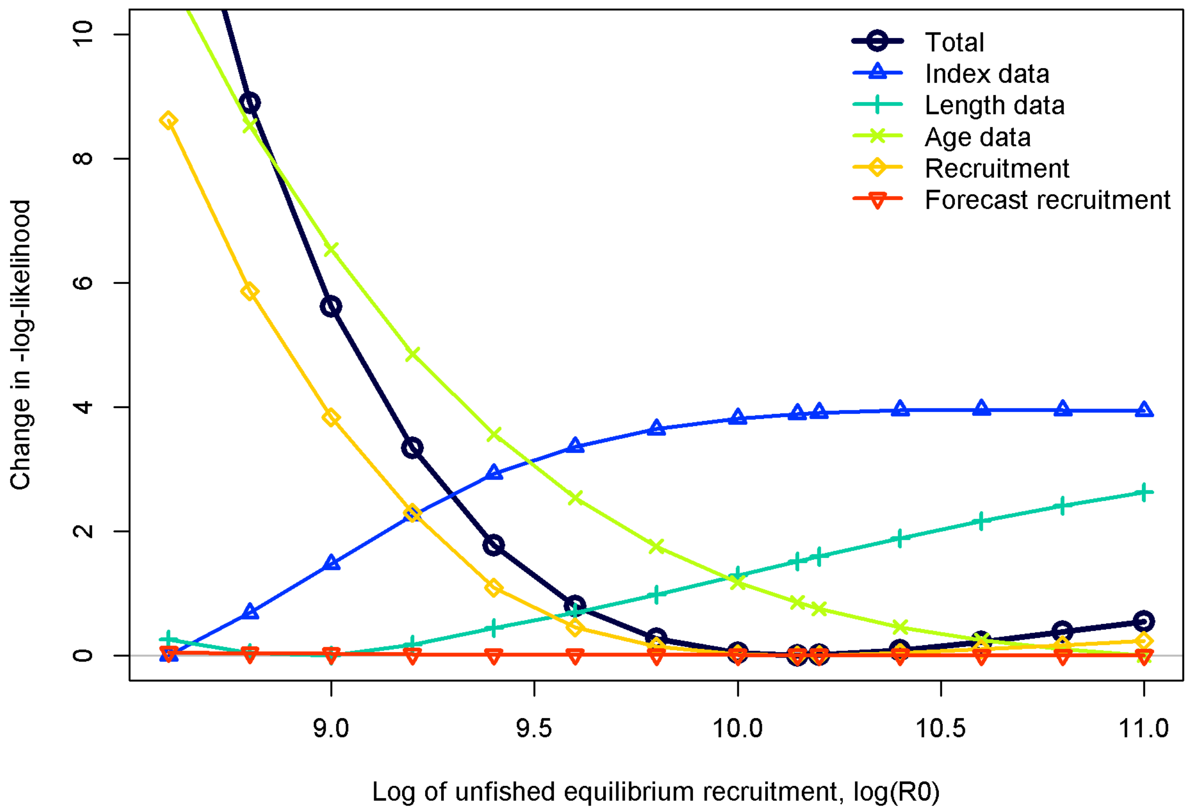

Figure 113: Likelihood profile over the log of equilibrium recruitment (R_0) for the Southern model.

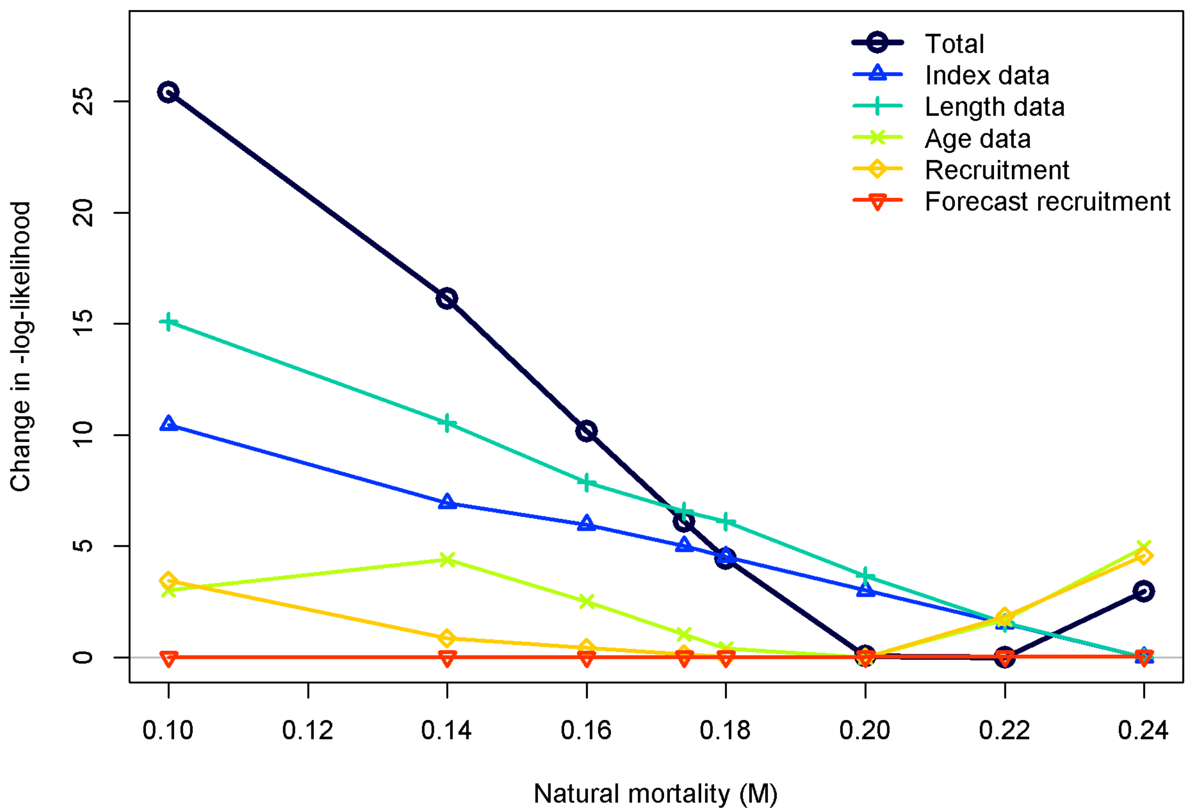

Figure 114: Likelihood profile over female natural mortality for the Southern model.

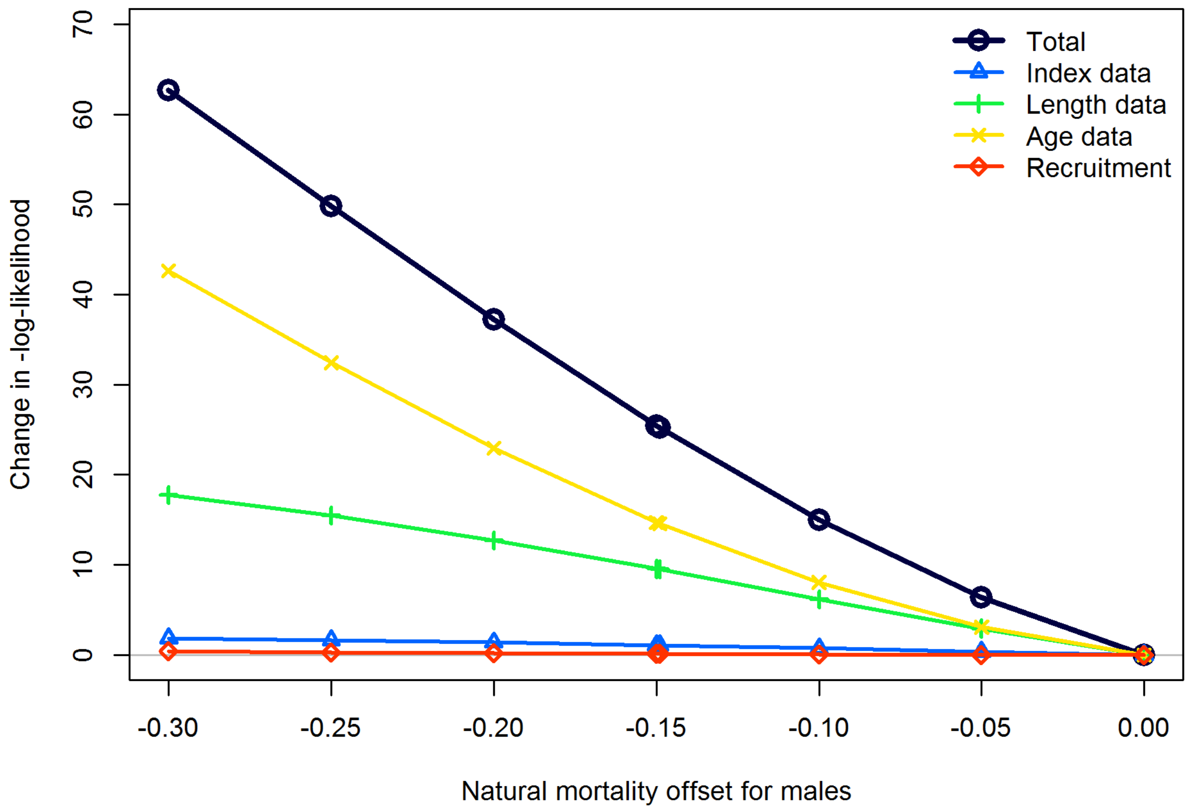

Figure 115: Likelihood profile over the male offset for natural mortality for the Southern model. Negative values are associated with natural mortality being lower for males than females.

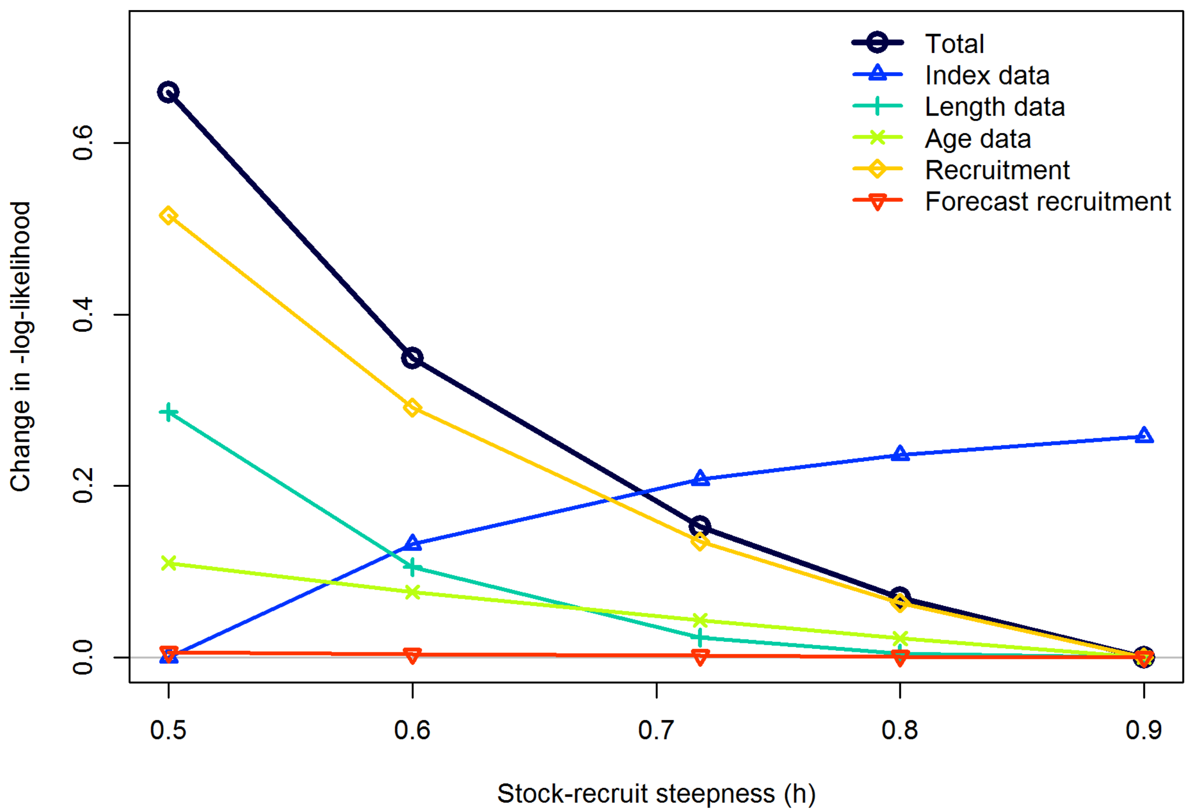

Figure 116: Likelihood profile over stock-recruit steepness (h) for the Southern model.

1626 ### 9.5.4 Retrospective analysis for Southern model

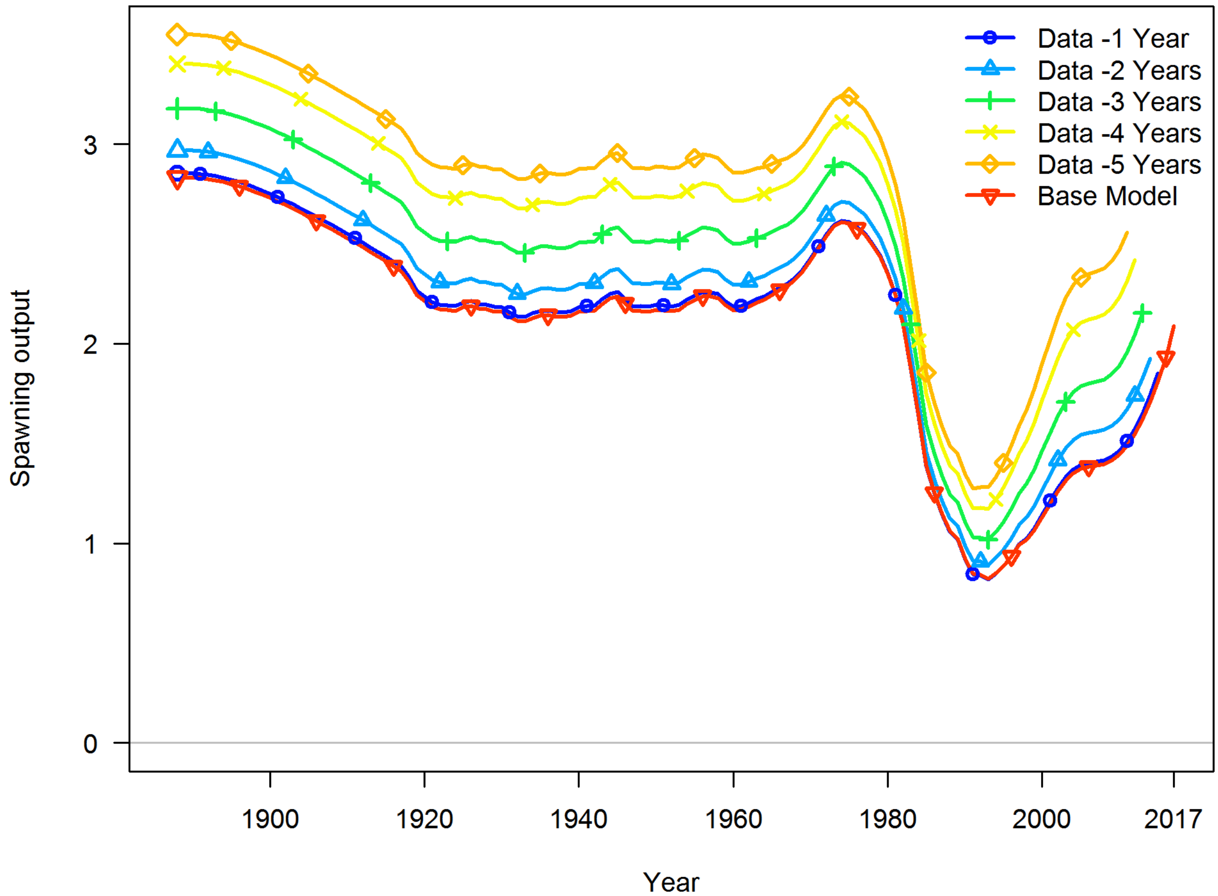

Figure 117: Retrospective analysis of spawning output for the Southern model.

1627 ### 9.5.5 Forecasts for Southern model

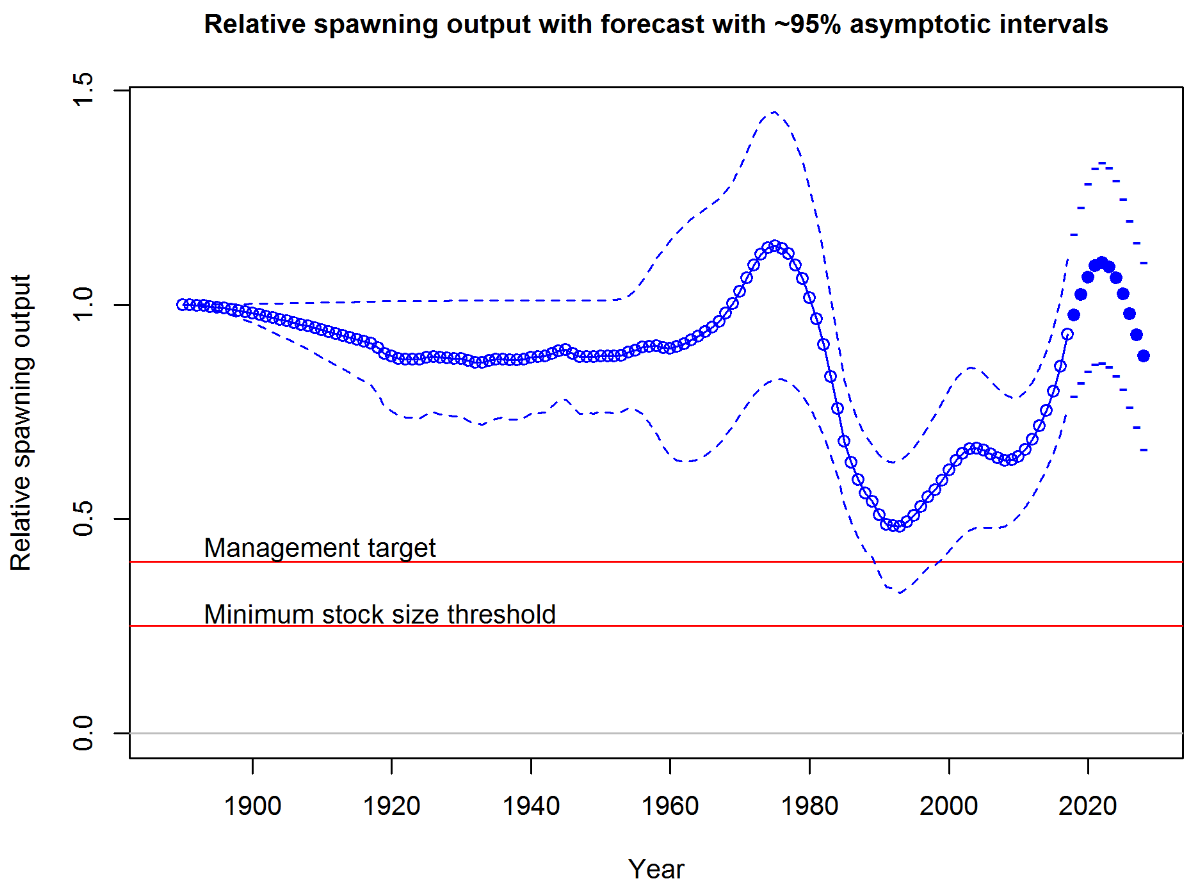

Figure 118: Forecast of relative spawning output for the Southern model. Filled circles for the years 2017 indicate forecast years.

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1781 # Appendix A. Regulations history

1782 ## Regulations history for Yellowtail Rockfish (page 1 of 20)

1783

Regulation date	Location	Regulation
1/1/1983	Vancouver Columbia	Established a 40,000 pound coastwide trip limit on Sebastes complex, to be adjusted as necessary in midseason so that annual catch in the Vancouver and Columbia areas falls about halfway between the 1982 catch and 1983 aggregate ABC (about 14,000 mt).
6/28/1983	Vancouver Columbia	retained 40,000-pound trip limit on Sebastes complex; trip frequency in Vancouver and Columbia areas set at one per week; when 18,500 mt quota is achieved, fishery closes (Vancouver and Columbia areas ABC = 9,500 mt). Harvest guidelines for the Vancouver and Columbia areas Sebastes complex shall not be permitted to exceed 130\% of the respective summed ABCs in 1984 for Vancouver and Columbia.
9/10/1983	4300 South	Continued 40,000-pound trip limit on Sebastes complex south of 43N latitude; no limit on number of trips.
9/10/1983	Vancouver Columbia	Established a 3,000-pound trip limit on Sebastes complex in Vancouver and Columbia areas, with stipulation that if 18,500 mt quota is reached, fishery closes.
9/10/1983	Vancouver Columbia	Removed once per week trip frequency limit on sebastes complex in Vancouver and Columbia.
1/1/1984	4300 South	Continued 40,000-pound trip limit on Sebastes complex south of 4300 (changed to 4250 on February, 12, 1984); no limit on trip frequency.
1/1/1984	Vancouver Columbia	Established 30,000-pound trip limit on Sebastes complex from Vancouver and Columbia areas; 1 trip per week north of 4300 N latitude (changed to Cape Blanco, 4250, on February 12,1984).
2/12/1984	Vancouver Columbia	Southern boundary of Vancouver and Columbia areas shifted south, from 4300 N latitude to 4250 N latitude for management of Sebastes complex; application of Sebastes complex regulations clarified.
5/6/1984	ALL	Specified that fishing for groundfish on a Sebastes complex trip may occur on only one side of Cape Blanco (4250), which allows southern caught fish to be landed north of Cape Blanco using the southern trip limit of 40,000 pounds with appropriate declaration of intent.
5/6/1984	Vancouver Columbia	Reduced Vancouver and Columbia areas Sebastes complex from 30,000 pounds once per week to 15,000 pounds once per week, with option to land 30,000 pounds once every 2 weeks with appropriate advance declaration of intent.
8/1/1984	ALL	Vessel operators on combined groundfish/Sebastes complex trips allowed to fish on both sides of a line at 4250 N latitude (Cape Blanco), but landings of Sebastes complex in excess of 3,000 pounds controlled by the trip limit/trip frequency in effect north of the line (Vancouver and Columbia areas). Appropriate advance declaration of intent required.
8/1/1984	Vancouver Columbia	Reduced Sebastes complex trip limit in Vancouver and Columbia areas to 7,500 pounds once each week or 15,000 pounds once every two weeks with appropriate advance declaration of intent. Recommended that when the 10,100 mt harvest guideline is reached, a 3,000 pounds trip limit will be imposed.
1/10/1985	ALL	If fishers fish on both sides of the Cape Blanco line during a trip, the northern limit on Sebastes complex applies.
1/10/1985	ALL	Landings of Sebastes complex and widow rockfish smaller than 3,000 pounds unrestricted.
1/10/1985	Cape Blanco North	For Sebastes complex north of Cape Blanco (4250 N latitude), established a 30,000-pound weekly trip limit of which no more than 10,000 pounds may be yellowtail rockfish (or 60,000 pounds once every two weeks of which no more than 20,000 pounds may be yellowtail rockfish with appropriate declaration to state in which fish are landed).
1/10/1985	Cape Blanco South	For Sebastes complex south of Cape Blanco, established a 40,000-pound trip limit without a trip frequency.

Regulation date	Location	Regulation
4/28/1985	ALL	Added a third option to land 7,500 pounds twice each week of which no more than 3,000 pounds in each landing may be yellowtail rockfish; landings declaration applies.
4/28/1985	Cape Blanco North	For the Sebastes complex north of Cape Blanco (4250 N latitude), reduced the trip limit to 15,000 pounds once per week of which no more than 5,000 pounds may be yellowtail rockfish (or 30,000 pounds once every two weeks of which no more than 10,000 pounds may be yellowtail rockfish).
9/1/1985	ALL	Changed the management boundary line separating northern and southern trip limits for the Sebastes complex from Cape Blanco (4250 N latitude) northward 30 miles to the north jetty at Coos Bay (4322 N latitude).
10/6/1985	Vancouver Columbia	Increased the Vancouver and Columbia areas Sebastes complex trip limit to 20,000 pounds once per week except that no more than 5,000 pounds may be yellowtail rockfish (or one landing once every 2 weeks of 40,000 pounds of which no more than 10,000 pounds may be yellowtail rockfish, or 2 landings per week of 10,000 pounds each of which no more than 3,000 pounds per landing may be yellowtail rockfish; landings declaration apply).
1/1/1986	ALL	For Sebastes complex north of Coos Bay, established 25,000-pound weekly trip limit of which no more than 10,000 pounds may be yellowtail rockfish (or 50,000 pounds biweekly of which no more than 20,000 pounds may be yellowtail rockfish, or 12,500 pounds twice per week of which no more than 5,000 pounds may be yellowtail rockfish; biweekly and twice weekly landings require appropriate declaration to state in which fish are landed). For Sebastes complex south of Coos Bay, established 40,000-pound trip limit; no trip frequency. Landings of less than 3,000 pounds of Sebastes complex and widow rockfish unrestricted. Fishers fishing the Sebastes complex on both sides of the Coos Bay line during a trip must conform with the northern (more restrictive) trip limit.
1785 8/31/1986	Coos Bay North	For Sebastes complex north of Coos Bay, Oregon, increased trip limits as follows: weekly =30,000 pounds of which no more than 12,500 pounds may be yellowtail rockfish; biweekly = 60,000 pounds of which no more than 25,000 pounds may be yellowtail rockfish and twice weekly = 15,000 pounds of which no more than 6,500 pounds may be yellowtail rockfish.
1/1/1987	Coos Bay North	For Sebastes complex north of Coos Bay, established 25,000-pound weekly trip limit of which no more than 10,000 pounds may be yellowtail rockfish (or 50,000 pounds biweekly of which no more than 20,000 pounds may be yellowtail rockfish, or 12,500 pounds twice per week of which no more than 5,000 pounds may be yellowtail rockfish; biweekly and twice weekly landings require appropriate declaration to state in which fish are landed); no restriction on landings less than 3,000 pounds.
1/1/1987	Coos Bay South	For Sebastes complex south of Coos Bay, established 40,000-pound trip limit; no trip frequency limit.
5/3/1987	ALL	Changed the definition of fishing week from Sunday through Saturday to Wednesday through Tuesday for Sebastes complex and widow rockfish.
7/22/1987	Coos Bay North	Reduced the weekly trip limit for yellowtail rockfish caught north of Coos Bay to 7,500 pounds (or 15,000 pounds biweekly, or 3,750 pounds twice weekly).
1/1/1988	ALL	For Sebastes complex north of Coos Bay, established a 25,000-pound weekly trip limit of which no more than 10,000 pounds may be yellowtail rockfish (or 50,000 pounds biweekly of which no more than 20,000 pounds may be yellowtail rockfish, or 12,500 pounds twice per week, of which no more than 5,000 pounds may be yellowtail rockfish; biweekly and twice weekly landings require appropriate declaration to state in which fish are landed). No restriction on landings less than 3,000 pounds. For Sebastes complex south of Coos Bay, established a 40,000-pound trip limit; no trip frequency restriction.
10/5/1988	Coos Bay North	reduced the weekly trip limit for yellowtail rockfish north of Coos Bay from 10,000 to 7,500 pounds (biweekly and twice weekly options to remain in effect).

Regulations history for Yellowtail Rockfish (page 3 of 20)

Regulation date	Location	Regulation
1/1/1989	Coos Bay North	For Sebastes complex north of Coos Bay, established a 25,000 pounds weekly trip limit of which no more than 7,500 pounds may be yellowtail rockfish (or 50,000 pounds biweekly of which no more than 15,000 pounds may be yellowtail rockfish, or 12,500 pounds twice per week, of which no more than 3,750 pounds may be yellowtail rockfish; biweekly and twice weekly landings require appropriate declaration to state in which fish are landed). No restriction on landings less than 3,000 pounds.
1/1/1989	Coos Bay South	For Sebastes complex south of Coos Bay, established a 40,000-pound trip limit; no trip frequency restriction.
7/26/1989	ALL	Reduced the trip limit for yellowtail rockfish to 3,000 pounds or 20\% of the Sebastes complex, whichever is greater.
1/1/1990	Coos Bay North	For Sebastes complex north of Coos Bay, established the weekly trip limit at 25,000 pounds of which no more than 7,500 pounds may be yellowtail rockfish (or 50,000 pounds biweekly of which no more than 15,000 pounds may be yellowtail rockfish, or 12,500 pounds twice per week of which no more than 3,750 pounds may be yellowtail rockfish; biweekly and twice weekly landings require appropriate declaration to state in which fish are landed). No restriction on landings less than 3,000 pounds.
1/1/1990	Coos Bay South	For Sebastes complex south of Coos Bay, established the trip limit at 40,000 pound; no trip frequency restriction.
7/25/1990	ALL	Reduced the weekly trip limit for yellowtail rockfish caught with any gear north of Coos Bay to 3,000 pounds or 20\% of the Sebastes complex, whichever is greater. Biweekly and twice weekly landing options remain in effect.
1/1/1991	Coos Bay North	For Sebastes complex north of Coos Bay, the weekly trip limit remains at 25,000 pounds of which no more than 5,000 pounds may be yellowtail rockfish (or 50,000 pounds biweekly of which no more than 10,000 pounds may be yellowtail rockfish, or 12,500 pounds twice per week of which no more than 3,000 pounds may be yellowtail rockfish; biweekly and twice weekly landings require appropriate declaration to state in which fish are landed). No restriction on landings less than 3,000 pounds.
1/1/1991	Coos Bay South	For Sebastes complex south of Coos Bay, the trip limit established at 25,000 pounds, including no more than 5,000 pounds of bocaccio; no trip frequency restriction; harvest guideline for bocaccio set at 1,100 mt (ABC = 800 mt).
4/24/1991	Coos Bay North	Reduced the trip limit for yellowtail rockfish north of Coos Bay from 5,000 pounds per week to 5,000 pounds once per 2 weeks.
1/1/1992	4030 South	For the Sebastes complex, established a cumulative landing limit per specified 2 week period of 50,000 pounds. Within this 50,000 pounds, no more than no more than 10,000 pounds cumulative may be bocaccio landed south of Cape Mendocino, California (4030 latitude). All landings count toward the 50,000-pound limit.
1/1/1992	All cape lookout	For the Sebastes complex, established a cumulative landing limit per specified 2 week period of 50,000 pounds. Within this 50,000 pounds, no more than 8,000 pounds cumulative may be yellowtail rockfish landed north of Cape Lookout. All landings count toward the 50,000-pound limit.
7/29/1992	Coos Bay North	Reduced the cumulative 2-week landing limit of yellowtail rockfish north of the north jetty of Coos Bay, Oregon from 8,000 pounds to 6,000 pounds. If a vessel fishes north of the boundary during the 2-week period, the northern limit applies.

Regulations history for Yellowtail Rockfish (page 4 of 20)

Regulation date	Location	Regulation
1/1/1993	4030 South	For Sebastes complex established a cumulative landing limit per specified 2-week period of 50,000 pounds. Within this 50,000 pounds, no more than 10,000 pounds cumulative may be bocaccio caught south of Cape Mendocino, California (4030 latitude). All landings count toward the cumulative limits. If a vessel fishes in the more restrictive area at any time during the 2-week period, the more restrictive limit applies for that vessel.
1/1/1993	Coos Bay North	For Sebastes complex north of Coos Bay, established a cumulative landing limit per specified 2-week period of 50,000 pounds. Within this 50,000 pounds, no more than 8,000 pounds cumulative may be yellowtail rockfish caught north of Coos Bay All landings count toward the cumulative limits. If a vessel fishes in the more restrictive area at any time during the 2-week period, the more restrictive limit applies for that vessel.
4/21/1993	Coos Bay North	Reduced the 2-week cumulative trip limit for yellowtail rockfish caught north of Coos Bay, Oregon (4321.34 latitude) from 8,000 to 6,000 pounds (no change to the Sebastes complex limit).
1/1/1994	4030 South	For Sebastes complex, bocaccio and yellowtail, cumulative limit of 80,000 pounds per calendar month, no more than 30,000 pounds may be bocaccio caught south of Cape Mendocino, California (4030 latitude).
1/1/1994	Cape lookout North	For Sebastes complex, bocaccio and yellowtail, cumulative limit of 80,000 pounds per calendar month, of which no more than 14,000 pounds may be yellowtail rockfish caught north of Cape Lookout, Oregon (4520.15 latitude), no more than 30,000 pounds may be yellowtail rockfish caught south of Cape Lookout
9/1/1994	4030 South	Increased the cumulative trip limit for the Sebastes complex caught south of Cape Mendocino, California (4030 latitude) in the limited entry groundfish fishery from 80,000 pounds to 100,000 pounds per calendar month.
1/1/1995	4030 South	For Sebastes complex, cumulative limit of 100,000 pounds per month south of Cape Mendocino.
1/1/1995	4030 South	For bocaccio, the cumulative limit is 30,000 pounds per month south of Cape Mendocino, and no limit north of Cape Mendocino (other than the limit on the Sebastes complex).
1/1/1995	Cape lookout North	Sebastes Complex cumulative limit of 35,000 pounds per calendar month north of Cape Lookout, Oregon (4520.15 latitude), no more than 14,000 pounds may be yellowtail rockfish caught north of Cape Lookout, Oregon
5/1/1995	Cape lookout North	The yellowtail rockfish cumulative monthly limit increased from 14,000 pounds to 18,000 pounds north of Cape Lookout, Oregon
5/1/1995	Cape lookout South	For Sebastes complex, bocaccio and yellowtail, cumulative limit of 80,000 pounds per calendar month, no more than 30,000 pounds may be yellowtail rockfish caught south of Cape Lookout.
8/1/1995	ALL	Increased the monthly cumulative trip limit for canary rockfish from 6,000 pounds (2,722 kg) to 9,000 pounds (4,082 kg). The Sebastes complex limit was not increased.

1790 Regulations history for Yellowtail Rockfish (page 5 of 20)

Regulation date	Location	Regulation
1/1/1996	ALL	Sebastes complex and bocaccio 200,000 pounds per 2-months south of Cape Mendocino. For bocaccio, the cumulative limit is 60,000 pounds per 2-months south of Cape Mendocino, and no limit north of Cape Mendocino (other than the limit on the Sebastes complex).
1/1/1996	ALL	for fishing in areas with different trip limits for the same species: Trip limits for a species or species complex may differ in different geographic areas along the coast. The following crossover provisions apply to all vessels (limited entry and open access) operating in different geographical areas with different cumulative or per trip limits for the same species, except for species with daily-trip-limits (nontrawl sablefish, open access thornyhead), black rockfish off Washington State, or those otherwise exempted by a State declaration procedure (yellowtail rockfish and the Sebastes complex off Washington and Oregon).
1/1/1996	Cape lookout North	Sebastes complex and yellowtail cumulative limit of 70,000 pounds per specified 2-month period north of Cape Lookout, Oregon (4520.15 latitude), . Within the cumulative 2-month limits for the Sebastes complex, no more than 32,000 pounds may be yellowtail rockfish caught north of Cape Lookout, Oregon
9/1/1996	Cape lookout North	Reduced the cumulative 2-month limits for yellowtail rockfish north of Cape Lookout from 32,000 pounds to 20,000 pounds
11/1/1996	4030 North	All Sebastes limits north of Cape Mendocino will be one-month cumulative limits to maintain the continuity of the Cape Lookout declaration option. The cumulative trip limit for the Sebastes complex taken and retained north of Cape Lookout is 35,000 pounds per month, of which no more than 6,000 pounds may be yellowtail rockfish and no more than 9,000 pounds may be canary rockfish.
1791 11/1/1996	Cape lookout North	Reduced the cumulative limit for yellowtail rockfish north of Cape Lookout, Oregon (4520.15 latitude) to 6,000 pounds per month effective November 1 in an effort to keep landings within 10\% of the harvest guideline.
1/1/1997	4030 North	Sebastes Complex limited entry fishery cumulative limit of 30,000 pounds per specified 2-month period north of Cape Mendocino, California (4030 latitude), no more than 6,000 pounds may be yellowtail rockfish
1/1/1997	ALL	for open access (non-groundfish) trawls in 1997, in addition to the limits for any groundfish species or complex in the limited entry fishery: Pink Shrimp cumulative trip limit of 500 pounds (multiplied by the number of days of the trip) of groundfish species for any vessel engaged in fishing for pink shrimp. In addition, not more than 300 pounds per trip may be sablefish and not more than one landing per day may include sablefish. Vessels using shrimp gear may not exceed half the limited entry two-month cumulative limits in a month, and are limited to 3,000 pounds of yellowtail rockfish and 6,000 pounds of sablefish per month.
5/1/1997	4030 South	Sebastes Complex (Including Yellowtail Rockfish and Bocaccio) reduced the two-month cumulative limit on bocaccio to 10,000 pounds south of Cape Mendocino.
10/1/1997	4030 North	Sebastes Complex (Including Yellowtail Rockfish and Bocaccio) changed from two-month limits to one-month limits for Sebastes. Increase Sebastes one month limits to 20,000 pounds north of Cape Mendocino no more than 5,000 pounds of which may be yellowtail rockfish north of Cape Mendocino
10/1/1997	4030 South	changed from two-month limits to one-month limits for Sebastes complex 75,000 pounds south of Cape Mendocino, no more than 5,000 pounds of which may be bocaccio south of Cape Mendocino, and no more than 10,000 pounds of which may be canary rockfish coastwide
10/1/1997	ALL	Sebastes complex coastwide no more than 10,000 pounds of which may be canary rockfish

Regulations history for Yellowtail Rockfish (page 6 of 20)

Regulation date	Location	Regulation
1/1/1998	4030 North	Sebastes Complex (Including yellowtail, canary and bocaccio rockfish): limited entry fishery Cumulative limit of 40,000 pounds per specified two-month period north of Cape Mendocino, California (4030 latitude), Within the cumulative two-month limits for the Sebastes complex, no more than 11,000 pounds may be yellowtail rockfish caught north of Cape Mendocino
1/1/1998	4030 South	Sebastes Complex (Including yellowtail, canary and bocaccio rockfish): limited entry fishery Cumulative limit of 150,000 pounds per two-months south of Cape Mendocino. For bocaccio, the cumulative limit is 2,000 pounds per two-months south of Cape Mendocino, and no limit north
5/1/1998	4030 North	Sebastes Complex: Limited Entry: increased cumulative limit for yellowtail to 13,000 pounds per specified two-month period north of Cape Mendocino.
7/1/1998	4030 South	Limited Entry Sebastes Complex: south of Cape Mendocino, decreased the 2-month cumulative limit to 40,000 pounds.
7/1/1998	ALL	Open Access Rockfish: removed overall rockfish monthly limit and replaced it with limits for component rockfish species: for Sebastes complex, monthly cumulative limit is 33,000 pounds, for widow rockfish, monthly cumulative trip limit is 3,000 pounds, for Pacific Ocean Perch, monthly cumulative trip limit is 4,000 pounds.
10/1/1998	4030 South	Sebastes complex South of Cape Mendocino: Limited Entry: decreased monthly limit to 15,000 pounds.
1/1/1999	4030 North	for the limited entry fishery Sebastes Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio):North of Cape Mendocino, California (4030 latitude), Phase 1: 24,000 pounds per period, for this period, the Sebastes complex limit north of Cape Mendocino equals the sum of the yellowtail and canary rockfish limits, a vessel may not exceed the overall Sebastes limit, regardless of the amount of yellowtail and/or canary rockfish landed within that limit; Phase 2: 25,000pounds per period; Phase 3: 10,000 pounds per period
1/1/1999	4030 North	for the limited entry fishery Sebastes Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio):Yellowtail Rockfish: north of Cape Mendocino, Phase 1: 15,000 pounds per period; Phase 2: 13,000 pounds per period; Phase 3: 5,000 pounds per period.
1/1/1999	4030 North	for open access gear: Sebastes complex: north of Cape Mendocino, 3,600 pounds per month.
1/1/1999	4030 South	for the limited entry fishery Sebastes Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio):South of Cape Mendocino, California, Phase1: 13,000 pounds per period; Phase 2: 6,500 pounds per period; Phase 3: 5,000pounds per period.
1/1/1999	4030 South	for the limited entry fishery Sebastes Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio):Bocaccio: south of Cape Mendocino, Phase 1: 750 pounds per month; Phase 2: 750 pounds per month; Phase 3: 750 pounds per month
1/1/1999	4030 South	for open access gear: Sebastes complex: south of Cape Mendocino, 2,000 pounds per month.
1/1/1999	ALL	for the limited entry fishery Sebastes Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio):Canary Rockfish: coastwide, Phase 1: 9,000 pounds per period; Phase 2: 9,000 pounds per period; Phase 3: 3,000 pounds per period
1/1/1999	ALL	for open access gear: Yellowtail Rockfish: 2,600 pounds per month.

Regulations history for Yellowtail Rockfish (page 7 of 20)

Regulation date	Location	Regulation
4/1/1999	4030 North	For 'A' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, increased overall monthly limit from 3,600 pounds to 12,000 pounds;
4/1/1999	4030 North	For 'A' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, Yellowtail Rockfish, increased cumulative limit from 2,600 pounds to 6,500 pounds per month;
4/1/1999	4030 North	For 'A' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, Canary Rockfish, increased cumulative limit from 1,000 pounds to 2,000 pounds per month;
4/1/1999	4030 North	For 'A' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, Combined Black Rockfish and Blue Rockfish cumulative limit is 3,500 pounds per month;
4/1/1999	4030 North	For 'A' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, No more than 2,000 pounds per month may be species other than yellowtail, canary, black, and blue rockfish.
4/1/1999	4030 South	For 'A' Platoon Vessels: Limited Entry Canary Rockfish: south of Cape Mendocino, decreased 2-month cumulative limit from 9,000 pounds to 6,500 pounds. Landings of canary rockfish south of Cape Mendocino are limited by and count against the overall Sebastes complex 2-month cumulative limit south of Cape Mendocino, which is 6,500 pounds.
4/1/1999	ALL	For 'A' Platoon Vessels: Limited Entry and Open Access Sebastes complex: north and south of Cape Mendocino, if a vessel takes and retains, possesses, or lands any splitnose or chilipepper rockfish south of Cape Mendocino, then the more restrictive Sebastes complex cumulative trip limit applies throughout the same cumulative limit period, no matter where the Sebastes complex is taken and retained, possessed, or landed.
4/16/1999	4030 North	For 'B' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, increased overall monthly limit from 3,600 pounds to 12,000 pounds;
4/16/1999	4030 North	For 'B' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, Canary Rockfish, increased cumulative limit from 1,000 pounds to 2,000 pounds per month;
4/16/1999	4030 North	For 'B' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, Yellowtail Rockfish, increased cumulative limit from 2,600 pounds to 6,500 pounds per month;
4/16/1999	4030 North	For 'B' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, Combined Black Rockfish and Blue Rockfish cumulative limit is 3,500 pounds per month;
4/16/1999	4030 North	For 'B' Platoon Vessels: Open Access Sebastes complex: north of Cape Mendocino, No more than 2,000 pounds per month may be species other than yellowtail, canary, black, and blue rockfish.
4/16/1999	4030 South	For 'B' Platoon Vessels: Limited Entry and Open Access Sebastes complex: north and south of Cape Mendocino, if a vessel takes and retains, possesses, or lands any splitnose or chilipepper rockfish south of Cape Mendocino, then the more restrictive Sebastes complex cumulative trip limit applies throughout the same cumulative limit period, no matter where the Sebastes complex is taken and retained, possessed, or landed.
4/16/1999	4030 South	For 'B' Platoon Vessels: Limited Entry Canary Rockfish: south of Cape Mendocino, decreased 2-month cumulative limit from 9,000 pounds to 6,500 pounds. Landings of canary rockfish south of Cape Mendocino are limited by and count against the overall Sebastes complex 2-month cumulative limit south of Cape Mendocino, which is 6,500 pounds.

1796 Regulations history for Yellowtail Rockfish (page 8 of 20)

	Regulation date	Location	Regulation
	6/1/1999	4030 North	Limited Entry, Platoon 'A': Sebastes complex: north of Cape Mendocino, 2 month cumulative trip limit for the periods June 1 through July 31 and August 1 through September 30 increased from 25,000 pounds to 30,000 pounds, within which: (1) yellowtail rockfish north of Cape Mendocino, 2-month cumulative trip limit increased from 13,000 pounds to 16,000 pounds, and (2) canary rockfish north of Cape Mendocino, 2-month cumulative trip limit increased from 9,000 pounds to 14,000 pounds.
	6/1/1999	4030 North	Limited Entry, Platoon 'B': Sebastes complex: north of Cape Mendocino, 2 month cumulative trip limit for the periods June 1 through July 31 and August 1 through September 30 increased from 25,000 pounds to 30,000 pounds, within which: (1) yellowtail rockfish north of Cape Mendocino, 2-month cumulative trip limit increased from 13,000 pounds to 16,000 pounds, and (2) canary rockfish north of Cape Mendocino, 2-month cumulative trip limit increased from 9,000 pounds to 14,000 pounds.
	6/1/1999	4030 South	Limited Entry, Platoon 'A': Sebastes complex: south of Cape Mendocino, limited entry 2 month cumulative trip limit for the periods June 1 through July 31 and August 1 through September 30 decreased from 6,500 pounds to 3,500 pounds, within which: (1) Bocaccio monthly trip limit of 750 pounds decreased and changed to a 2-month cumulative trip limit of 1,000 pounds with a 500 pounds per trip limit, and (2) canary rockfish 2-month cumulative trip limit decreased to 3,500 pounds.
1797	6/1/1999	4030 South	Limited Entry, Platoon 'B': Sebastes complex: south of Cape Mendocino, limited entry 2 month cumulative trip limit for the periods June 1 through July 31 and August 1 through September 30 decreased from 6,500 pounds to 3,500 pounds, within which: (1) Bocaccio monthly trip limit of 750 pounds decreased and changed to a 2-month cumulative trip limit of 1,000 pounds with a 500 pounds per trip limit, and (2) canary rockfish 2-month cumulative trip limit decreased to 3,500 pounds.
	8/1/1999	4030 North	Sebastes complex, Limited Entry, Platoon 'A': north of Cape Mendocino, 2 month cumulative trip limit for the period August 1 through September 30 increased from 30,000 pounds to 35,000 pounds, within which: (1) yellowtail rockfish, north of Cape Mendocino, 2-month cumulative trip limit increased from 16,000 pounds to 20,000 pounds; (2) canary rockfish, north of Cape Mendocino, 2-month cumulative trip limit remains at 14,000 pounds; and (3) added 2-month cumulative trip limit of 10,000pounds for rockfish other than yellowtail rockfish and canary rockfish north of Cape Mendocino.
	8/16/1999	4030 North	Sebastes complex, Limited Entry, Platoon 'B': north of Cape Mendocino, 2 month cumulative trip limit for the period August 16 through October 15 increased from 30,000 pounds to 35,000 pounds, within which: (1) yellowtail rockfish, north of Cape Mendocino, 2-month cumulative trip limit increased from 16,000 pounds to 20,000 pounds; (2) canary rockfish, north of Cape Mendocino, 2-month cumulative trip limit remains at 14,000 pounds; and (3) added 2-month cumulative trip limit of 10,000pounds for rockfish other than yellowtail rockfish and canary rockfish north of Cape Mendocino.

Regulations history for Yellowtail Rockfish (page 9 of 20)

Regulation date	Location	Regulation
10/1/1999	4030 North	Limited Entry Sebastes Complex, 'A' platoon: decreased 1-month cumulative trip limits from 10,000 pounds (north of Cape Mendocino)
10/1/1999	4030 North	Yellowtail Rockfish Limited Entry, 'A' platoon: north of Cape Mendocino, 1-month cumulative trip limit of 300 pounds.
10/1/1999	4030 South	Limited Entry Sebastes Complex, 'A' platoon: decreased 1-month cumulative trip limits from 5,000 pounds (south of Cape Mendocino) to a coastwide limit of 500 pounds per month.
10/1/1999	ALL	Limited Entry, 'A' platoon: The 1-month cumulative trip limits for canary rockfish, coastwide; Bocaccio, south of Cape Mendocino; and other species in the Sebastes complex, which count together towards the overall Sebastes complex limit, may not exceed the 500-pound cumulative monthly limit.
10/16/1999	4030 North	Limited Entry Sebastes Complex, 'B' platoon: decreased 1-month cumulative trip limits from 10,000 pounds (north of Cape Mendocino)
10/16/1999	4030 North	Yellowtail Rockfish Limited Entry, 'B' platoon: north of Cape Mendocino, 1-month cumulative trip limit of 300 pounds.
10/16/1999	4030 South	Limited Entry Sebastes Complex, 'B' platoon: decreased 1-month cumulative trip limits from 5,000 pounds (south of Cape Mendocino) to a coastwide limit of 500 pounds per month.
10/16/1999	ALL	Limited Entry, 'B' platoon: The 1-month cumulative trip limits for canary rockfish, coastwide; Bocaccio, south of Cape Mendocino; and other species in the Sebastes complex, which count together towards the overall Sebastes complex limit, may not exceed the 500-pound cumulative monthly limit.
1/1/2000	4010 North	Limited entry trawl, midwater trawl only, yellowtail rockfish, 10000 per 2 months
1/1/2000	4010 North	Limited entry trawl, small footrope only, yellowtail rockfish, 1500 lbs per month
1/1/2000	4010 North	Yellowtail rockfish, limited entry fixed gear, 1500 lbs per month
1/1/2000	ALL	Yellowtail rockfish, Open Access gear except exempted trawl, 100 lbs per month
5/1/2000	4010 North	Limited entry trawl, midwater trawl only, yellowtail rockfish, 30000 lbs per 2 months
5/1/2000	4010 North	Limited entry trawl, small footrope only, yellowtail rockfish, 1500 lbs per month
11/1/2000	4010 North	Limited entry trawl, midwater trawl only, yellowtail rockfish, 10000 per 2 months

1800 ## Regulations history for Yellowtail Rockfish (page 10 of 20)

Regulation date	Location	Regulation
1/1/2001	4010 North	Yellowtail rockfish, open access, 100 lbs per month
1/1/2001	4010 North	Yellowtail rockfish, limited entry fixed gear, 1500 lbs per month
1/1/2001	4010 North	Yellowtail rockfish, limited entry trawl, midwater trawl only, 30000 lbs per 2 months
1/1/2001	4010 North	Yellowtail rockfish, limited entry trawl, small footrope only, without flatfish - 1500 lbs per month, as flatfish bycatch - 33\% by weight of all flatfish (except arrowtooth flounder) not to exceed 2500 lbs per trip and 20000 lbs per 2 months
5/1/2001	4010 North	Yellowtail rockfish, limited entry trawl, midwater trawl only, 15000 lbs per 2 months
5/1/2001	4010 North	Yellowtail rockfish, limited entry trawl, small footrope only, small footrope only, without flatfish - 1500 lbs per month, as flatfish bycatch - 33\% by weight of all flatfish (except arrowtooth flounder) not to exceed 7500 lbs per trip and 15000 lbs per 2 months
10/1/2001	4010 North	Yellowtail rockfish, limited entry trawl, midwater trawl only,
10/1/2001	4010 North	Yellowtail rockfish, limited entry trawl, small footrope only, without flatfish - 1500 lbs per month, as flatfish bycatch - 33\% by weight of all flatfish (except arrowtooth flounder) not to exceed 2500 lbs per trip and 30000 lbs per 2 months
1/1/2002	3427 South	shelf rockfish south including minor shelf rockfish, widow rockfish and yellowtail rockfish, open access, closed
1/1/2002	3427 South	Shelf rockfish south including minor shelf rockfish, widow rockfish and yellowtail rockfish, limited entry fixed gear, closed
1801 1/1/2002	4010 North	shelf rockfish north including minor shelf rockfish, widow rockfish and yellowtail rockfish, open access, 200 lbs per month
1/1/2002	4010 North	Shelf rockfish north including minor shelf rockfish, widow rockfish and yellowtail rockfish, limited entry fixed gear, 200 lbs per month
1/1/2002	4010 North	Yellowtail rockfish, limited entry midwater trawl, closed
1/1/2002	4010 North	Yellowtail rockfish, limited entry small footrope trawl, without flatfish 1000 lbs per month, as flatfish bycatch - 33\% (by weight) of all flatfish except arrowtooth, plus 10\% (by weight) of arrowtooth flounder, not to exceed 30000 lbs per 2 months
3/1/2002	3427 South	shelf rockfish south including minor shelf rockfish, widow rockfish and yellowtail rockfish, open access, 500 lbs per month
3/1/2002	3427 South	Shelf rockfish south including minor shelf rockfish, widow rockfish and yellowtail rockfish, limited entry fixed gear, 1000 lbs per month
5/1/2002	4010 North	Yellowtail rockfish, limited entry midwater trawl,during primary whiting season, trips of at least 10000 lbs of whiting: combined widow and yellowtail limit of 500 lbs per trip with a cumulative yellowtail limit of 2000 lbs per month
5/1/2002	ALL	widow rockfish, limited entry midwater trawl, during primary whiting season, trips of at least 10000 lbs of whiting: combined widow and yellowtail limit of 500 lbs per trip with a cumulative widow limit of 1500 lbs per month
11/1/2002	3427 South	shelf rockfish south including minor shelf rockfish, widow rockfish and yellowtail rockfish, open access, closed
11/1/2002	3427 South	Shelf rockfish south including minor shelf rockfish, widow rockfish and yellowtail rockfish, limited entry fixed gear, closed
11/1/2002	4010 North	Yellowtail rockfish, limited entry midwater trawl, closed

Regulations history for Yellowtail Rockfish (page 11 of 20)

Regulation date	Location	Regulation
1/1/2003	4010 North	minor shelf rockfish north including widow, yellowtail, bocaccio and chilipepper, open access gears, 200 lbs per month
1/1/2003	4010 North	minor shelf rockfish north including widow, yellowtail, bocaccio and chilipepper, limited entry fixed gear, 200 lbs per month
1/1/2003	4010 North	yellowtail rockfish with midwater trawl within the RCA, Limited entry trawl gear, small footrope or midwater trawl only, closed
1/1/2003	4010 North	yellowtail rockfish with small footrope, Limited entry trawl gear, in landings without flatfish - 1000 lbs per month, as flatfish bycatch - per trip limit is 33\% (by weight) of all flatfish (except arrowtooth flounder) plus 10\% (by weight) of arrowtooth flounder. Total yellowtail landings no to exceed 10000 lbs per 2 months with no more than 1000 lbs landed without flatfish
1/1/2003	4010 South	minor shelf rockfish south including widow, chilipepper, and yellowtail, open access gear, 100 lbs per 2 months
1/1/2003	4010 South	minor shelf rockfish south including widow, yellowtail, and chilipepper rockfish, limited entry fixed gear, 100 lbs per 2 months
1/1/2003	4010 South	minor shelf rockfish south including widow, chilipepper, and yellowtail rockfish, limited entry trawl, small footrope or midwater trawl only, 300 lbs per month
3/1/2003	4010 South	minor shelf rockfish south including widow, chilipepper, and yellowtail, open access gear, closed
3/1/2003	4010 South	minor shelf rockfish south including widow, yellowtail, and chilipepper rockfish, limited entry fixed gear, closed
5/1/2003	4010 North	widow rockfish with midwater trawl within the RCA, Limited entry trawl gear, during whiting primary season, in trips with at least 10000 lbs of whiting, combined widow and yellowtail rockfish limit of 500 lbs per trip with no more than 1500 lbs of widow rockfish per month
5/1/2003	4010 North	yellowtail rockfish with midwater trawl within the RCA, Limited entry trawl gear, small footrope or midwater trawl only, during whiting primary season, in trips with at least 10000 lbs of whiting, combined widow and yellowtail rockfish limit of 500 lbs per trip with no more than 2000 lbs of yellowtail rockfish per month
5/1/2003	4010 South	minor shelf rockfish south including widow, chilipepper, and yellowtail, open access gear, 200 lbs per 2 months
5/1/2003	4010 South	minor shelf rockfish south including widow, yellowtail, and chilipepper rockfish, limited entry fixed gear, 200 lbs per 2 months
7/1/2003	4010 South	minor shelf rockfish south including widow, chilipepper, and yellowtail, open access gear, 250 lbs per 2 months
7/1/2003	4010 South	minor shelf rockfish south including widow, yellowtail, and chilipepper rockfish, limited entry fixed gear, 250 lbs per 2 months
9/1/2003	4010 South	minor shelf rockfish south including widow, chilipepper, and yellowtail, open access gear, 200 lbs per 2 months
9/1/2003	4010 South	minor shelf rockfish south including widow, yellowtail, and chilipepper rockfish, limited entry fixed gear, 200 lbs per 2 months
11/1/2003	4010 North	yellowtail rockfish with midwater trawl within the RCA, Limited entry trawl gear, small footrope or midwater trawl only, closed
11/1/2003	4010 South	minor shelf rockfish south including widow, chilipepper, and yellowtail, open access gear, 100 lbs per 2 months
11/1/2003	4010 South	minor shelf rockfish south including widow, yellowtail, and chilipepper rockfish, limited entry fixed gear, 100 lbs per 2 months

1804 Regulations history for Yellowtail Rockfish (page 12 of 20)

	Regulation date	Location	Regulation
	1/1/2004	3427 South	minor shelf rockfish south including widow rockfish, chilipepper rockfish, and yellowtail rockfish, open access gear, closed
	1/1/2004	3427 South	minor shelf rockfish south including widow rockfish, and yellowtail rockfish, limited entry fixed gear, closed
	1/1/2004	4010 North	minor shelf rockfish north including widow rockfish, yellowtail rockfish, bocaccio, and chilipepper rockfish, open access gear, 200 lbs per month
	1/1/2004	4010 North	salmon troll, 1 lb of yellowtail for every 2 lbs of salmon landed up to 200 lbs per month: other restrictions apply - refer to Federal Register
	1/1/2004	4010 North	minor shelf rockfish north including widow, bocaccio, chilipepper and yellowtail rockfish, limited entry fixed gear, 200 lbs per month
	1/1/2004	4010 North	widow rockfish, midwater trawl, limited entry trawl, before the primary whiting season: closed, during the primary whiting season: in trips of at least 10000 lbs of whiting: combined widow and yellowtail limit of 500 lbs per trip with a cumulative monthly limit of 1500 lbs of widow; after the primary whiting season: closed
	1/1/2004	4010 North	yellowtail rockfish, large footrope, limited entry trawl, closed
	1/1/2004	4010 North	yellowtail rockfish. Midwater trawl, limited entry trawl, before the primary whiting season: closed, during the primary whiting season: in trips of at least 10000 lbs of whiting: combined widow and yellowtail limit of 500 lbs per trip with a cumulative monthly limit of 2000 lbs of widow; after the primary whiting season: closed
1805	1/1/2004	4010 North	yellowtail rockfish, small footrope, limited entry trawl, in landings without flatfish: 1000 lbs per month, as flatfish bycatch, per trip limit is the sum of 33\% (by weight) of all flatfish except arrowtooth flounder plus 10\% by weight of arrowtooth flounder. Total yellowtail landings not to exceed 10000 lbs per 2 months, no more than 1000 lbs per month may be landed without flatfish
	1/1/2004	4010 South	minor shelf rockfish south including yellowtail rockfish, limited entry trawl, large footrope or midwater trawl, 300 lbs per month
	1/1/2004	4010 South	minor shelf rockfish south including yellowtail rockfish, limited entry trawl, small footrope, 300 lbs per month
	3/1/2004	3427 South	minor shelf rockfish south including widow rockfish, chilipepper rockfish, and yellowtail rockfish, open access gear, 500 lbs per 2 months
	3/1/2004	3427 South	minor shelf rockfish south including widow rockfish, and yellowtail rockfish, limited entry fixed gear, 2000 lbs per 2 months
	7/1/2004	4010 South	minor shelf rockfish south including yellowtail rockfish, limited entry trawl, small footrope, 1000 lbs per month, no more than 200 lbs per month of which may be minor shelf rockfish or widow rockfish
	7/1/2004	4010 South	chilipepper rockfish, limited entry trawl, small footrope, 1000 lbs per month, no more than 200 lbs per month of which may be minor shelf south rockfish or widow rockfish
	7/1/2004	4010 South	widow rockfish, limited entry trawl, small footrope, 1000 lbs per month, no more than 200 lbs per month of which may be minor shelf south rockfish or widow rockfish
	11/1/2004	4010 North	yellowtail rockfish, small footrope, limited entry trawl, closed
	11/1/2004	4010 South	minor shelf rockfish south including yellowtail rockfish, limited entry trawl, small footrope, 300 lbs per month

Regulations history for Yellowtail Rockfish (page 13 of 20)

Regulation date	Location	Regulation
1/1/2005	3427 South	minor shelf rockfish south species including yellowtail, shortbelly, widow and chilipepper rockfish, open access gear, 500 lbs per 2 months
1/1/2005	3427 South	minor shelf south rockfish including yellowtail, shortbelly and widow rockfish, limited entry fixed gear, 300 lbs per 2 months
1/1/2005	4010 North	minor shelf rockfish north including shortbelly, widow, yellowtail, bocaccio, chilipepper and cowcod, open access gears, 200 lbs per month
1/1/2005	4010 North	Salmon troll, 1 lb of yellowtail for every 2 lbs of salmon landed with a cumulative monthly limit of 200 lbs per month. Additional regulations apply - refer to the Federal register.
1/1/2005	4010 North	minor shelf rockfish north including shortbelly, widow, bocaccio, chilipepper, cowcod, and yelloweye rockfish, limited entry trawl gear, midwater trawl for widow rockfish, before the primary whiting season - closed; during the primary whiting season in trips with at least 10000 lbs of whiting - combined widow rockfish and yellowtail rockfish 500 lbs per trip with a cumulative limit of 1500 lbs of widow rockfish per month. Midwater trawl permitted in the RCA. After the primary whiting season - closed
1/1/2005	4010 North	yellowtail rockfish, limited entry trawl gear, midwater trawl, before the primary whiting season - closed; during the primary whiting season in trips with at least 10000 lbs of whiting - combined widow rockfish and yellowtail rockfish 500 lbs per trip with a cumulative limit of 2000 lbs of yellowtail rockfish per month. Midwater trawl permitted in the RCA. After the primary whiting season - closed
1/1/2005	4010 North	yellowtail rockfish, limited entry trawl gear, large and small footrope, 300 lbs per 2 months
1/1/2005	4010 North	yellowtail rockfish, limited entry trawl gear, selective flatfish gear, 2000 lbs per 2 months
1/1/2005	4010 North	yellowtail rockfish, limited entry trawl gear, multiple bottom trawl gear, 300 lbs per 2 months
1/1/2005	4010 North	minor shelf rockfish north including shortbelly, widow, yellowtail, chilipepper, bocaccio, and cowcod, limited entry fixed gear, 200 lbs per month
1/1/2005	4010 South	minor shelf rockfish south including chilipepper, shortbelly, widow, yellowtail and yelloweye rockfish, limited entry trawl, large footrope or midwater trawl for minor shelf rockfish or shortbelly rockfish, 300 lbs per month
1/1/2005	4010 South	minor shelf rockfish south including chilipepper, shortbelly, widow, yellowtail and yelloweye rockfish, limited entry trawl, large footrope or midwater trawl for minor shelf rockfish or chilipepper rockfish, 2000 lbs per 2 months
1/1/2005	4010 South	minor shelf rockfish south including chilipepper, shortbelly, widow, yellowtail and yelloweye rockfish, limited entry trawl, large footrope or midwater trawl for widow rockfish and yelloweye rockfish, closed
1/1/2005	4010 South	minor shelf rockfish south including chilipepper, shortbelly, widow, yellowtail and yelloweye rockfish, limited entry trawl, small footrope trawl, 300 lbs per month
3/1/2005	3427 South	minor shelf rockfish south species including yellowtail, shortbelly, widow and chilipepper rockfish, open access gear, closed
3/1/2005	3427 South	minor shelf south rockfish including yellowtail, shortbelly and widow rockfish, limited entry fixed gear, closed
5/1/2005	3427 South	minor shelf rockfish south species including yellowtail, shortbelly, widow and chilipepper rockfish, open access gear, 500 lbs per 2 months
5/1/2005	3427 South	minor shelf south rockfish including yellowtail, shortbelly and widow rockfish, limited entry fixed gear, 2000 lbs per 2 months
5/1/2005	4010 South	minor shelf rockfish south including chilipepper, shortbelly, widow, yellowtail and yelloweye rockfish, limited entry trawl, large footrope or midwater trawl for minor shelf rockfish or chilipepper rockfish, 12000 lbs per 2 months

1808 Regulations history for Yellowtail Rockfish (page 14 of 20)

	Regulation date	Location	Regulation
	7/1/2005	3427 South	minor shelf rockfish south species including yellowtail, shortbelly, widow and chilipepper rockfish, open access gear, 750 lbs per 2 months
	7/1/2005	3427 South	minor shelf south rockfish including yellowtail, shortbelly and widow rockfish, limited entry fixed gear, 3000 lbs per months
	9/1/2005	4010 South	minor shelf rockfish south including chilipepper, shortbelly, widow, yellowtail and yelloweye rockfish, limited entry trawl, large footrope or midwater trawl for minor shelf rockfish or chilipepper rockfish, 8000 lbs per 2 months
	1/1/2006	3427 South	minor shelf rockfish south including chilipepper, shortbelly, widow, and yellowtail rockfish, open access gear, 750 lbs per 2 months
	1/1/2006	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish, limited entry fixed gear, 3000 lbs per 2 months
	1/1/2006	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow, and yellowtail rockfish, open access gear, 200 lbs per month
	1/1/2006	4010 North	salmon troll, open access gear, 1 lb of yellowtail for every 2 lbs of salmon with a cumulative limit of 200 lbs per month: Refer to Federal register for additional regulations
	1/1/2006	4010 North	minor shelf rockfish north including shortbelly, widow, yellowtail, bocaccio, chilipepper, and cowcod, limited entry fixed gear, 200 lbs per month
1809	1/1/2006	4010 North	midwater trawl for widow rockfish, limited entry trawl, before the primary whiting season - closed; during the primary whiting season in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip with a cumulative limit of 1500 lbs of widow per month, midwater trawl permitted in the RCA; after the primary whiting season - closed
	1/1/2006	4010 North	yellowtail rockfish, limited entry trawl, midwater trawl gear, before the primary whiting season - closed; during the primary whiting season in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip with a cumulative limit of 2000 lbs of yellowtail per month, midwater trawl permitted in the RCA; after the primary whiting season - closed
	1/1/2006	4010 North	yellowtail rockfish, limited entry trawl, large and small footrope gear, 150 lbs per month
	1/1/2006	4010 North	yellowtail rockfish, limited entry trawl, selective flatfish trawl gear, 1000 lbs per month
	1/1/2006	4010 North	yellowtail rockfish, limited entry trawl, multiple bottom trawl gear, 150 lbs per month
	1/1/2006	4010 South	minor shelf rockfish south including yellowtail, chilipepper, shortbelly, widow and yelloweye rockfish, limited entry trawl, small footrope, 300 lbs per month
	3/1/2006	4010 North	yellowtail rockfish, limited entry trawl, large and small footrope gear, 350 lbs per month
	3/1/2006	4010 North	yellowtail rockfish, limited entry trawl, selective flatfish trawl gear, 2000 lbs per 2 months
	3/1/2006	4010 North	yellowtail rockfish, limited entry trawl, multiple bottom trawl gear, 300 lbs per 2 months

1810 Regulations history for Yellowtail Rockfish (page 15 of 20)

Regulation date	Location	Regulation
1/1/2007	3427 South	minor shelf south rockfish including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, 3000 lbs per 2 months
1/1/2007	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
1/1/2007	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow, and yellowtail, limited entry fixed gear, 200 lbs per month
1/1/2007	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow and yellowtail, open access gears, 200 lbs per month
1/1/2007	4010 North	salmon troll, open access gear, 1 lb of yellowtail for every 2 lbs of salmon with a cumulative limit of 200 lbs per month: Refer to Federal register for additional regulations
1/1/2007	4010 North	yellowtail rockfish, limited entry trawl, midwater trawl, before the primary whiting season - closed; during the primary whiting season - in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip, cumulative 2000 lbs per month for yellowtail. Midwater trawl permitted in the RCA.
1811 1/1/2007	4010 North	yellowtail rockfish, limited entry trawl, large and small footrope gear, 300 lbs per 2 months
1/1/2007	4010 North	yellowtail rockfish, limited entry trawl, selective flatfish trawl, 2000 lbs per 2 months
1/1/2007	4010 North	yellowtail rockfish, limited entry trawl, multiple bottom trawl gear, 300 lbs per 2 months
1/1/2007	4010 South	minor shelf rockfish south including shortbelly and yellowtail, limited entry trawl, large footrope or midwater trawl, 300 lbs per month
1/1/2007	4010 South	minor shelf rockfish south including shortbelly, widow, yellowtail, and yelloweye, limited entry trawl, small footrope, 300 lbs per month
3/1/2007	3427 South	minor shelf south rockfish including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, closed
3/1/2007	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, closed
5/1/2007	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
11/1/2007	4010 North	widow rockfish, limited entry trawl, midwater trawl, before the primary whiting season - closed; during the primary whiting season - in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip, cumulative 1500 lbs per month for widow. Midwater trawl permitted in the RCA.

1812 Regulations history for Yellowtail Rockfish (page 16 of 20)

	Regulation date	Location	Regulation
	1/1/2008	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, 3000 lbs per 2 months
	1/1/2008	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
	1/1/2008	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow, and yellowtail, limited entry fixed gear, 200 lbs per month
	1/1/2008	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow and yellowtail, open access gears, 200 lbs per month
	1/1/2008	4010 North	salmon troll, open access gear, 1 lb of yellowtail for every 2 lbs of salmon with a cumulative limit of 200 lbs per month: Refer to Federal register for additional regulations
	1/1/2008	4010 North	widow rockfish, limited entry trawl, midwater trawl, before the primary whiting season - closed; during the primary whiting season - in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip, cumulative 1500 lbs per month for widow. Midwater trawl permitted in the RCA.
1813	1/1/2008	4010 North	yellowtail rockfish, limited entry trawl, midwater trawl, before the primary whiting season - closed; during the primary whiting season - in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip, cumulative 2000 lbs per month for yellowtail. Midwater trawl permitted in the RCA.
	1/1/2008	4010 North	yellowtail rockfish, limited entry trawl, large and small footrope gear, 300 lbs per 2 months
	1/1/2008	4010 North	yellowtail rockfish, limited entry trawl, selective flatfish trawl, 2000 lbs per 2 months
	1/1/2008	4010 North	yellowtail rockfish, limited entry trawl, multiple bottom trawl gear, 300 lbs per 2 months
	1/1/2008	4010 South	minor shelf rockfish south including shortbelly and yellowtail, limited entry trawl, large footrope or midwater trawl, 300 lbs per month
	1/1/2008	4010 South	minor shelf rockfish south including shortbelly, widow, yellowtail, and yelloweye, limited entry trawl, small footrope, 300 lbs per month
	3/1/2008	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, closed
	3/1/2008	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, closed
	5/1/2008	3427 South	minor shelf rockfish south including yellowtail, shortbelly, and widow rockfish,limited entry fixed gear, 3000 lbs per 2 months
	5/1/2008	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
	11/1/2008	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 1000 lbs per 2 months

Regulations history for Yellowtail Rockfish (page 17 of 20)

Regulation date	Location	Regulation
1/1/2009	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, 3000 lbs per 2 months
1/1/2009	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
1/1/2009	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow, and yellowtail, limited entry fixed gear, 200 lbs per month
1/1/2009	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow and yellowtail, open access gears, 200 lbs per month
1/1/2009	4010 North	salmon troll, open access gear, 1 lb of yellowtail for every 2 lbs of salmon with a cumulative limit of 200 lbs per month: Refer to Federal register for additional regulations
1/1/2009	4010 North	widow rockfish, limited entry trawl, midwater trawl, before the primary whiting season - closed; during the primary whiting season - in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip, cumulative 1500 lbs per month for widow. Midwater trawl permitted in the RCA.
1/1/2009	4010 North	yellowtail rockfish, limited entry trawl, midwater trawl, before the primary whiting season - closed; during the primary whiting season - in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip, cumulative 2000 lbs per month for yellowtail. Midwater trawl permitted in the RCA.
1/1/2009	4010 North	yellowtail rockfish, limited entry trawl, large and small footrope gear, 300 lbs per 2 months
1/1/2009	4010 North	yellowtail rockfish, limited entry trawl, selective flatfish trawl, 2000 lbs per 2 months
1/1/2009	4010 North	yellowtail rockfish, limited entry trawl, multiple bottom trawl gear, 300 lbs per 2 months
1/1/2009	4010 South	minor shelf rockfish south including shortbelly and yellowtail, limited entry trawl, large footrope or midwater trawl, 300 lbs per month
1/1/2009	4010 South	minor shelf rockfish south including shortbelly, widow, yellowtail, and yelloweye, limited entry trawl, small footrope, 300 lbs per month
3/1/2009	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, closed
3/1/2009	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, closed
5/1/2009	3427 South	minor shelf rockfish south including yellowtail, shortbelly, and widow rockfish,limited entry fixed gear, 3000 lbs per 2 months
5/1/2009	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months

Regulations history for Yellowtail Rockfish (page 18 of 20)

Regulation date	Location	Regulation
1/1/2010	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, 3000 lbs per 2 months
1/1/2010	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
1/1/2010	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow, and yellowtail, limited entry fixed gear, 200 lbs per month
1/1/2010	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow and yellowtail, open access gears, 200 lbs per month
1/1/2010	4010 North	salmon troll, open access gear, 1 lb of yellowtail for every 2 lbs of salmon with a cumulative limit of 200 lbs per month: Refer to Federal register for additional regulations
1/1/2010	4010 North	widow rockfish, limited entry trawl, midwater trawl, before the primary whiting season - closed; during the primary whiting season - in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip, cumulative 1500 lbs per month for widow. Midwater trawl permitted in the RCA.
1/1/2010	4010 North	yellowtail rockfish, limited entry trawl, midwater trawl, before the primary whiting season - closed; during the primary whiting season - in trips of at least 10000 lbs of whiting, combined widow and yellowtail limit of 500 lbs per trip, cumulative 2000 lbs per month for yellowtail. Midwater trawl permitted in the RCA.
1/1/2010	4010 North	yellowtail rockfish, limited entry trawl, large and small footrope gear, 300 lbs per 2 months
1/1/2010	4010 North	yellowtail rockfish, limited entry trawl, selective flatfish trawl, 2000 lbs per 2 months
1/1/2010	4010 North	yellowtail rockfish, limited entry trawl, multiple bottom trawl gear, 300 lbs per 2 months
1/1/2010	4010 South	minor shelf rockfish south including shortbelly and yellowtail, limited entry trawl, large footrope or midwater trawl, 300 lbs per month
1/1/2010	4010 South	minor shelf rockfish south including shortbelly, widow, yellowtail, and yelloweye, limited entry trawl, small footrope, 300 lbs per month
3/1/2010	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, closed
3/1/2010	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, closed
5/1/2010	3427 South	minor shelf rockfish south including yellowtail, shortbelly, and widow rockfish,limited entry fixed gear, 3000 lbs per 2 months
5/1/2010	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
1/1/2011	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, 3000 lbs per 2 months
1/1/2011	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
1/1/2011	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow, and yellowtail, limited entry fixed gear, 200 lbs per month
1/1/2011	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow and yellowtail, open access gears, 200 lbs per month
1/1/2011	4010 North	salmon troll, open access gear, 1 lb of yellowtail for every 2 lbs of salmon with a cumulative limit of 200 lbs per month: Refer to Federal register for additional regulations
1/1/2011	ALL	Yellowtail rockfish managed in part by IFQ

Regulations history for Yellowtail Rockfish (page 19 of 20)

Regulation date	Location	Regulation
3/1/2011	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish,limited entry fixed gear, closed
3/1/2011	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, closed
5/1/2011	3427 South	minor shelf rockfish south including yellowtail, shortbelly, and widow rockfish,limited entry fixed gear, 3000 lbs per 2 months
5/1/2011	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
7/1/2011	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 1000 lbs per 2 months
1/1/2012	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish, limited entry fixed gear, 3000 lbs per 2 months
1/1/2012	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
1/1/2012	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow and yellowtail, open access gears, 200 lbs per month
1/1/2012	4010 North	salmon troll, open access gear, 1 lb of yellowtail for every 2 lbs of salmon with a cumulative limit of 200 lbs per month: Refer to Federal register for additional regulations
1/1/2012	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow, and yellowtail, limited entry fixed gear, 200 lbs per month
3/1/2012	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish, limited entry fixed gear, closed
3/1/2012	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, closed
5/1/2012	3427 South	minor shelf rockfish south including yellowtail, shortbelly, and widow rockfish, limited entry fixed gear, 3000 lbs per 2 months
5/1/2012	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
7/1/2012	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 1000 lbs per 2 months
9/1/2012	3427 South	minor shelf rockfish south including yellowtail, shortbelly, and widow rockfish, limited entry fixed gear, 4000 lbs per 2 months
1/1/2013	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish, limited entry fixed gear, 3000 lbs per 2 months
1/1/2013	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
1/1/2013	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow and yellowtail, open access gears, 200 lbs per month
1/1/2013	4010 North	salmon troll, open access gear, 1 lb of yellowtail for every 2 lbs of salmon with a cumulative limit of 200 lbs per month: Refer to Federal register for additional regulations
1/1/2013	4010 North	minor shelf rockfish north including bocaccio, chilipepper, cowcod, shortbelly, widow, and yellowtail, limited entry fixed gear, 200 lbs per month
3/1/2013	3427 South	minor shelf rockfish south including yellowtail, shortbelly and widow rockfish, limited entry fixed gear, closed
3/1/2013	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, closed
5/1/2013	3427 South	minor shelf rockfish south including yellowtail, shortbelly, and widow rockfish, limited entry fixed gear, 3000 lbs per 2 months
5/1/2013	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 750 lbs per 2 months
7/1/2013	3427 South	minor shelf rockfish south including yellowtail, shortbelly, and widow rockfish, limited entry fixed gear, 4000 lbs per 2 months
7/1/2013	3427 South	minor shelf rockfish south including yellowtail, shortbelly, widow, and chilipepper, open access gear, 1000 lbs per 2 months

1820 Regulations history for Yellowtail Rockfish (page 20 of 20)

1821

Regulation date	Location	Regulation
1/1/2014	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, 3000 lbs per 2 months
1/1/2014	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, 750 lbs per 2 months
1/1/2014	4010 North	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, bocaccio, chilipepper, and cowcod, 200 lbs per month
1/1/2014	4010 North	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, bocaccio, chilipepper rockfish, and cowcod, 200 lbs per month
3/1/2014	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, closed
3/1/2014	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, closed
5/1/2014	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, 3000 lbs per 2 months
5/1/2014	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, 750 lbs per 2 months
7/1/2014	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, 4000 lbs per 2 months
7/1/2014	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, 1000 lbs per 2 months
1/1/2015	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, 4000 lbs per 2 months
1/1/2015	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, 1500 lbs per 2 months
1/1/2015	4010 North	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, bocaccio, chilipepper, and cowcod, 200 lbs per month
1/1/2015	4010 North	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, bocaccio, chilipepper rockfish, and cowcod, 200 lbs per month
3/1/2015	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, closed
3/1/2015	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, closed
5/1/2015	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, 4000 lbs per 2 months
5/1/2015	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, 1500 lbs per 2 months
1/1/2016	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, 4000 lbs per 2 months
1/1/2016	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, 1500 lbs per 2 months
1/1/2016	4010 North	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, bocaccio, chilipepper, and cowcod, 200 lbs per month
1/1/2016	4010 North	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, bocaccio, chilipepper rockfish, and cowcod, 200 lbs per month
3/1/2016	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, closed
3/1/2016	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, closed
5/1/2016	3427 South	non-trawl, limited entry, minor shelf rockfish including shortbelly, widow, and yellowtail rockfish, 4000 lbs per 2 months
5/1/2016	3427 South	non-trawl, open access, minor shelf rockfish including shortbelly, widow, yellowtail, and chilipepper, 1500 lbs per 2 months

Appendix B. Fishery-Dependent Indices withdrawn from the Northern Model

Commercial Logbook CPUE

The commercial logbook (fish-ticket) data in PacFIN was used to generate an index for the Northern model for the years 1987-1998, a period in which management of the fishery was stable, i.e., regulations weren't changing fishery practices.

The data were first filtered using a modified Stephens-MacCall approach (Stephens and MacCall 2004). This approach uses the species composition (presence-absence) of the catch in a binomial generalized linear model (glm) to evaluate the per-haul probability of encountering a particular species; in this case, Yellowtail Rockfish. The intent of the analysis is to eliminate all hauls with a very low probability of encountering Yellowtail Rockfish.

For this analysis, the species effects were combined with fishery variables in a mixed-effects glm (a glmm). The species were modeled as binomial, and random effects were added for haul duration, depth, port, state agency, and month, and the interaction of year and vessel. This approach reduced the number of hauls to be evaluated by 61%.

The hauls identified with a reasonable probability of encountering Yellowtail were then modeled in a delta-lognormal glm (Stefansson 1996) to produce an annual index of abundance, which was bootstrapped 500 times to evaluate uncertainty. See Figures 19 and 20 for Q-Q plots demonstrating that the lognormal glm fit the data better than the gamma.

MRFSS Index MRFSS data was used to generate an index of abundance for 1980-2003. The MRFSS data were aggregated as "trips" by staff at the SWFSC, and the Stephens-MacCall approach was used to filter the data to the set of fishing trips likely to have encountered yellowtail. This was followed by application of a delta-lognormal glm using variables month and AREA_X (indicating offshore/onshore fishing) to generate the index, which was then jackknifed to produce estimates of uncertainty. Q-Q plots for the MRFSS index are 21 and 22.

Hake Bycatch Index

The Hake bycatch data provided by the Alaska Fisheries Science Center (AFSC) was used to generate an index of abundance for 1985-1999.

Data on haul-by-haul catch of Yellowtail Rockfish and Pacific Hake for the period 1976-2016 were obtained from the At-Sea Hake Observer Program along associated information including the location of each tow and the duration. Previous Yellowtail assessments used an index of abundance for the years 1978-1999. The most recent assessment (Wallace and Lai, 2005) stated that the index was not updated to include years beyond 1999 because subsequent changes in fishery regulations and behavior have altered the statistical properties of these abundance indices. The ending year of 1999 was retained for this analysis. However, the years up to 1984 have relatively few tows with adequate information for CPUE analysis, and fishing effort off the coast of Washington where Yellowtail are most commonly encountered (Figure 12). Therefore, for this new analysis, 1985 was chosen as the starting year.

The hake fishery was evolving during the chosen 15 year period (1985-1999), which included a transition from foreign to domestic fleets fishing for Pacific Hake (Figure 13). The index from the at-sea hake fishery used in previous assessments standardized for changes in catchability by using a ratio estimator relating Yellowtail catch to hake catch and then scaling by an estimate of fishing effort for hake (Equation 1 in Wallace and Lai, 2005). However, that approach does not take into account differences in the spatial distribution of the at-sea hake fishery relative to the distributions of hake and yellowtail.

For this new analysis, changes in catchability were estimated by comparing an index based on a geostatistical analysis of the hake CPUE from VAST (Thorson and Barnett 2017) to the estimated available hake biomass from the most recent stock assessment (Berger et al. 2017). The relative catchability was then used to adjust an independent geostatistical index of Yellowtail CPUE (Figure 14). In order to capture the general trend in catchability, reducing the variability among years, linear, exponential, and locally smoothed (LOWESS) models were fit to the time series of individual estimates of hake index to available biomass (lower panel in Figure 14). Of these, the LOWESS model best captured the pattern of fastest change in the middle of the time series. The average rate of increase in the resulting estimated catchability time series is 13% per year.

VAST was then used to conduct a geostatistical standardization of the CPUE of Yellowtail caught as bycatch in the at-sea hake fishery. The resulting Yellowtail index after adjustment by the estimated changes in catchability is qualitatively more similar to the index used in previous assessments (Figure 15) than the index resulting from assuming constant catchability.

Appendix C. Pre-recuit Index

Appendix C. Coastwide Pre-Recruit Indices from SWFSC and NWFSC/PWCC Midwater trawl Surveys (2001-2016)

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Introduction

This document provides an update of coastwide pre-recruit indices of abundance developed for past stock assessment cycles (Ralston et al. 2015), using data collected during SWFSC, NWFSC and PWCC/NWFSC midwater trawl surveys for young-of-the-year (YOY) pelagic juvenile groundfish. Due to time constraints and complications related to the discovery of a problem in how past indices were developed, this document reports indices for only a handful of those species typically evaluated, with a focus on those being assessed for the 2017 assessment cycle (bocaccio, blue/deacon and yellowtail) and one relatively abundant species from which to evaluate the consequences of the computational issues in past indices (shortbelly rockfish). Some preliminary explorations of an alternative means of developing indices are also included for consideration in review panels of those assessments.

In recent stock assessment cycles, these indices have been developed with guidance from the 2006 Pre-Recruit Survey Workshop (Hastie and Ralston 2007), such that data collected by these different surveys using identical gear and methods could be pooled to develop "coastwide" indices of abundance for YOY *Sebastes* spp. (see Ralston et al. 2013, Ralston and Stewart 2013 and Sakuma et al. 2016 for reviews of data, methods, vessel comparison and select results). This was in recognition that the data collected over a longer time period (1983-present) from the "core" area of the SWFSC survey were likely to present a biased and/or imprecise representation of coastwide YOY abundance due to significant interannual shifts in the spatial distribution of pelagic juvenile YOY (Ralston and Stewart 2013). However, variable ship availability and survey effort make the development of truly "coastwide" indices for some years impossible.

Data Analysis

As in recent assessment cycles, we used only years with the most comprehensive coverage to evaluate the spatial scope appropriate for each individual stock for which an index might be developed. Figure 1 shows haul locations for the different surveys over time, for the SWFSC (1983-2016, fixed stations), NWFSC (2011, 2013-2016, fixed stations) and PWCC/NWFSC (no fixed stations) datasets. Table 1 shows the total number of hauls by 2° latitude bins (the reported latitude in the Table represents the "mean" latitude for that bin, such that latitude 46 includes hauls from 45°- 47° N) for all of the survey data when pooled together. As the years 2004-2009 and 2013-2016 included very comprehensive coastwide coverage (albeit with very little data north of 47°N), these years were used to develop "climatologies" of the spatial distribution of the catch, in order to evaluate where the majority of the catch by species took place, so that "coastwide" indices could be crafted for southerly and northerly distributed species. This time period included years of very high (2009, 2013-2016) as well as very low (but spatially variable, 2005- 2007) abundance, and thus should provide a reasonable characterization of the spatial distributions of most species.

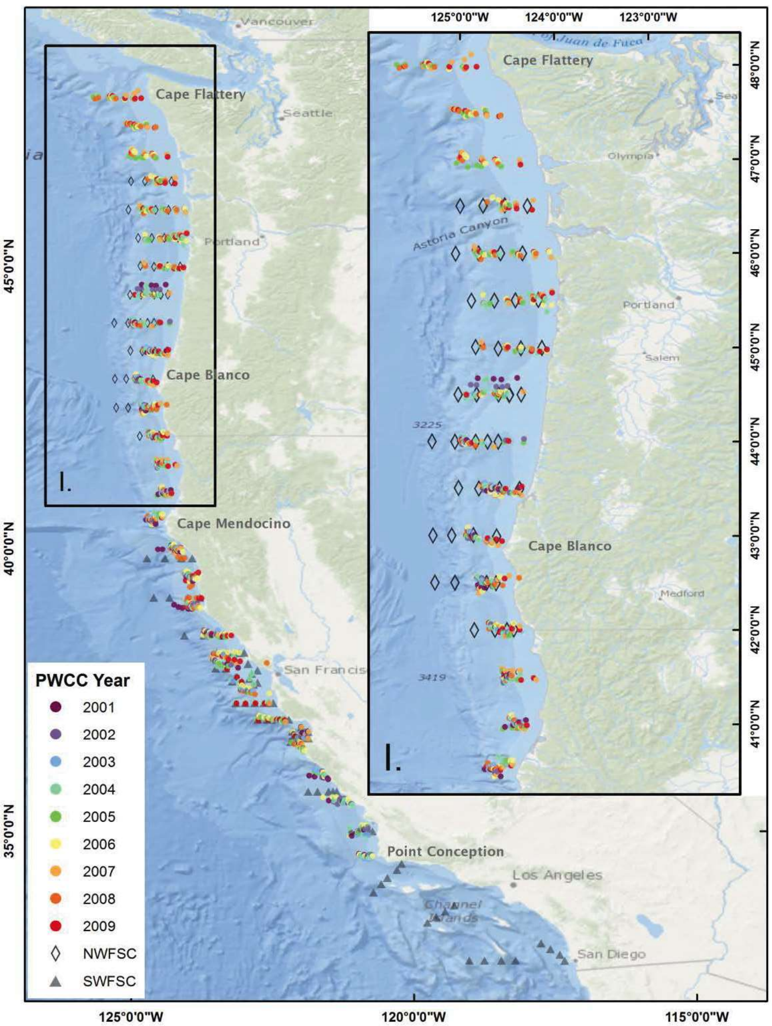

Figure 1: Station and haul locations for SWFSC, NWFSC and PWCC/NWFSC midwater trawl surveys.

Table 1: Number of hauls by year and latitude bin used to develop climatologies of spatial abundance (data prior to 2001 excluded).

only northern species
all species
only southern species

year	latbin 32	34	36	38	40	42	44	46	48	Total
2001		6	68	53	17	17	19			180
2002		6	63	52	19	21	17			178
2003		8	72	71	20	20	19			210
2004	8	27	76	74	28	20	25	20		278
2005	13	27	92	61	35	17	22	21	12	300
2006	14	24	83	86	40	21	20	22	13	323
2007	11	17	78	85	37	25	21	23	16	313
2008	13	20	43	43	37	21	22	18	15	232
2009	7	19	59	79	30	24	23	23	16	280
2010	6	15	44	52	16					133
2011			29	30	19	22	28	24	13	165
2012	3	13	51	27						94
2013	7	21	51	39	17	16	21	13		185
2014	5	13	54	57	16	15	18	9		187
2015	13	25	56	44	18	19	17	13		205
2016	12	26	56	35	6	9	20	12		176

The results of the exploration of catch rate climatologies indicated that some fairly rational generalizations could be made regarding the spatial survey extent that might represent "coastwide" coverage for the different species of rockfish. Specifically, for the "northern" species, widow rockfish (*S. entomelas*), yellowtail rockfish (*S. flavidus*), black rockfish (*S. melanops*), and canary rockfish (*S. pinniger*), the data from the years of the best truly coastwide coverage indicate that 99.7 to 100% of population abundance, as measured by spatial integration of average catch-per-unit-effort ($fish \cdot tow^{-1}$), has occurred within the 36 - 46° N latitudinal bins, representing the area between 35° and 47° N (Table 2). Thus, the best spatial coverage for these species are the years 2004-2009, 2011 and 2013-2016, as reflected by the indices developed for the 2015 assessment cycle (Ralston et al. 2015). By contrast, for blue/deacon rockfish (which have not historically been differentiated to the species level in this survey), catches were very uncommon north of 44 N, and consequently years in which the survey evaluated the region between 36 to 44 could be used for an index.

Similarly, for the "southern" species, chilipepper (*S. goodei*), squarespot rockfish (*S. hopkinsi*), shortbelly rockfish (*S. jordani*), bocaccio (*S. paucispinis*), and stripetail rockfish (*S. saxicola*), between 95 and 100% of the integrated abundance took place within or below the 40° latitude bin (e.g., latitudes 41° and south), although for bocaccio this range extended to the 42° N latitude bin with the addition of 2015-16 data. Thus, the indices developed for the 2017 assessment cycle were limited to those years that included the 32-34 latitude bins up through 42°N for bocaccio; namely 2004-2009, 2013-2016.

Prior to developing the Pre-Recruit index, the raw catch rate data were converted to standard age fish, due to substantial interannual variation in the size distribution of fish collected. To accomplish this, the length of each specimen of a species in a haul was converted to an estimated age using a linear regression of age $N = a + b\times SL$, where N is estimated age in days and SL is standard length (mm). Data used to fit all species-year regressions were generated by sub-sampling fish and counting daily otolith increments (see Woodbury and Ralston 1991). The contribution of each fish in a given haul was then age-adjusted according to:

$$N^*_{h,t} = N_{h,t} \exp[-M(100 - t_{hat}]$$

Where N^* is the number of fish in 100 day old equivalents, $N_{h,t}$, is the number of fish from haul h of estimated age t and M is the natural mortality rate of pelagic juvenile rockfish (0.04 day^{-1}; see Ralston and Howard 1995, Ralston et al. 2013). Standardized abundances were obtained by summing the number of 100 day old equivalent fishes within a haul. This effectively standardizes the contribution of all fish to a common age of 100 days, i.e., younger fish are downweighted and older fish are up-weighted. The number of age observations for each species is available in the 2015 documentation.

Following discussions during the 2006 Pre-Recruit Survey Workshop related to the strengths and weaknesses of alternative analytical approaches, indices distributed to stock assessment authors in recent assessment cycles (Ralston 2010, Sakuma and Ralston 2012) have been based on an ANOVA index, primarily because of its ability to best account for significant year x latitude interactions, and we continue this practice here. The specific form of the ANOVA mixed-effects model is:

$$\log(C_{i,j,k,l,m,n}+1) = Y_i \times L_j + Z_k + D_l + V_m + \varepsilon_{i,j,k,l,m,n}$$

with all independent variables treated as categorical. Specifically Y_i is a fixed year effect $\{Y_i \in 2001, 2002, \ldots, 2016\}$, L_j is a fixed latitudinal effect $\{L_j \in 32, 34, \ldots, 40\}$, Z_k is a fixed depth effect $\{Z_k \leq 160$ m or $Z > 160$ m$\}$, D_l is a fixed calendar date effect $\{D_l \in 120, 130, \ldots, 170\}$, V_m is a random vessel effect $[V_m \sim N(0,\sigma_v)]$, and $\varepsilon_{i,j,k,l,m,n}$ is normal error term $[\varepsilon \sim N(0,\sigma_\varepsilon)]$ for the n^{th} observation in a stratum. As in the case of the traditional ANOVA model, interactions between latitude and year were explicitly modeled.

Prior to this year, the model was fit to the data using PROC MIXED (SAS Institute Inc. 2004) and the year:latitude parameter estimates were bias-corrected, integrated over latitude, and error estimates summarized in a manner directly analogous to the traditional ANOVA approach. This year the code for developing the indices was migrated from SAS to the R programming language to facilitate future rapid computation of indices. In doing so, a non-trivial issue was discovered related to how the indices were compiled from the year:latitude results. Specifically, the model as previously run summed across latitude parameters in log space, and then backtransformed the sum for each year estimate. However, upon greater consideration it was determined that the appropriate approach is to back-transform the latitude bin results and then sum across latitudes within each year, to produce the annual index in arithmetic space. The use of log(C+1) as a response variable also introduces minor complications with respect to back-transformation to obtain means on the arithmetic scale.

As a consequence of the conflicting time series produced by these two slightly different approaches, we also developed indices based on the well-established delta-GLM model (Lo et al. 1992, Stefánsson, 1996) for these four stocks (as done in earlier assessment cycles as well as Ralston et al. 2013). This model has the greatest potential, in our view, to provide a stopgap approach to developing a YOY index until a deeper modeling exploration can be conducted. The delta-GLM components (binomial and positive models) both contained categorical covariates as described for the ANOVA, above. The delta-GLM was fit using the "rstanarm" package in R to obtain Bayesian posterior distributions of the delta-GLM index. Finally, we also report the resulting indices developed when using the VAST software package (Thorson et al. 2015) on the same data.

Results

We report results of the four modeling approaches (past implementation of the ANOVA approach, "corrected" ANOVA approach, delta-GLM, and VAST) for bocaccio (update assessment) and blue/deacon and yellowtail rockfish (full assessments). We also report results for shortbelly rockfish as this species is the most frequently encountered rockfish in the surveys, has a broad spatial distribution, and thus should provide a better basis for understanding differences in modeling results among these species.

These results are shown in Figure 2, and Table 2 provides the numerical values and the associated CVs. Importantly, upon making the correction to the calculation of the ANOVA indices, the indices for several species appear unusually "flat," particularly for bocaccio but for other species as well, suggesting that even this corrected approach is far less than an ideal means of deriving these indices. Most likely it is the log(catch+1) transformation, which is used to address the issue of large numbers of zeros in the data, that is leading to poor performance of this modeling approach, which was masked by the increased variability in the indices when the summation was done inappropriately.

Relative to the corrected ANOVA, both the delta-GLM and VAST approaches show considerably greater variability in the indices, with high and low values typically ranging from one to several orders of magnitude among different years. Differences in interannual variability between indices derived from the ANOVA and delta-type models (delta-GLM and VAST) also depend on the number of zeros in the data. For example, the corrected ANOVA approach is extremely flat relative to the other two approaches for bocaccio, a species that is fairly rare in these surveys (present in 8.5% of hauls in the nominal range during the 2001-2016 period). However, the ANOVA begins to resemble both the Delta-GLM and the VAST indices for shortbelly rockfish, a species present in a far greater fraction of hauls (34% of hauls in the nominal range during the 2001-2016 period). This lends additional support for the concerns that the log(catch+1) transformation used in the ANOVA method is inappropriate for those species that are rarely encountered in the survey.

Despite these challenges, there are some clear indications in the data, as illustrated in all modeling approaches, of very strong recruitment for some stocks and years, particularly in 2013 for all of these stocks. Such signals were also evident in the 2015 chilipepper assessment update (Field et al. 2015) as well as the 2015 bocaccio assessment (He et al. 2015) and the pending update. Given the consistency of this strong year class with recent observations, the indices should provide some utility for full assessments of blue and yellowtail rockfish this assessment cycle.

Discussion

For bocaccio, the "corrected" ANOVA result is the most consistent with the intent of what had been done in prior assessments, despite the fact that it does not indicate recruitment variability of the magnitude expected from other sources of data (e.g., fishery and survey length frequency data). Consequently, the bocaccio assessment also includes sensitivity analyses that use both the same index (not extended in time) from the 2015 model (the nominally incorrect ANOVA) as well as the indices developed using the delta-GLM and VAST approaches. As none of these approaches suggest unusually strong recruitment since the 2013 year class, which is now largely informed by length composition and other data sources, we think this is a reasonable short-term fix for the purposes of an update.

For the full assessments being conducted in 2017 (blue/deacon, yellowtail rockfish), our current preference would be to use the delta-GLM results. However, the results presented here will need to be refined for the appropriate spatial strata associated with assessment boundaries, and will likely require some additional exploration and documentation. For example, the current VAST outputs include all years regardless of the spatial coverage of the survey, which is inconsistent with previous approaches and should be interpreted with caution (we may have revised in time). The VAST indices also do not include a within-year temporal effect (period effect) to account for the seasonality of sampling, which has varied in surveys throughout the years and has been demonstrated to be an important factor for many species. Consequently, both the delta-GLM and the VAST these results should be considered preliminary, and can be revised and considered in greater detail prior to the full STAR Panels for those two species.

Our intent is to return to alternative means of developing indices, including evaluation delta-GLM models (including the VAST geostatistical approach) as more robust approaches for developing YOY recruitment indices to support West Coast rockfish assessments. Ongoing analyses indicate that in fact there is likely to be considerably more coherence in YOY abundance trends than earlier envisioned, and that the 2005-2006 period was atypical with respect to strong differences in abundance between the historical core survey area and coastwide abundance trends.

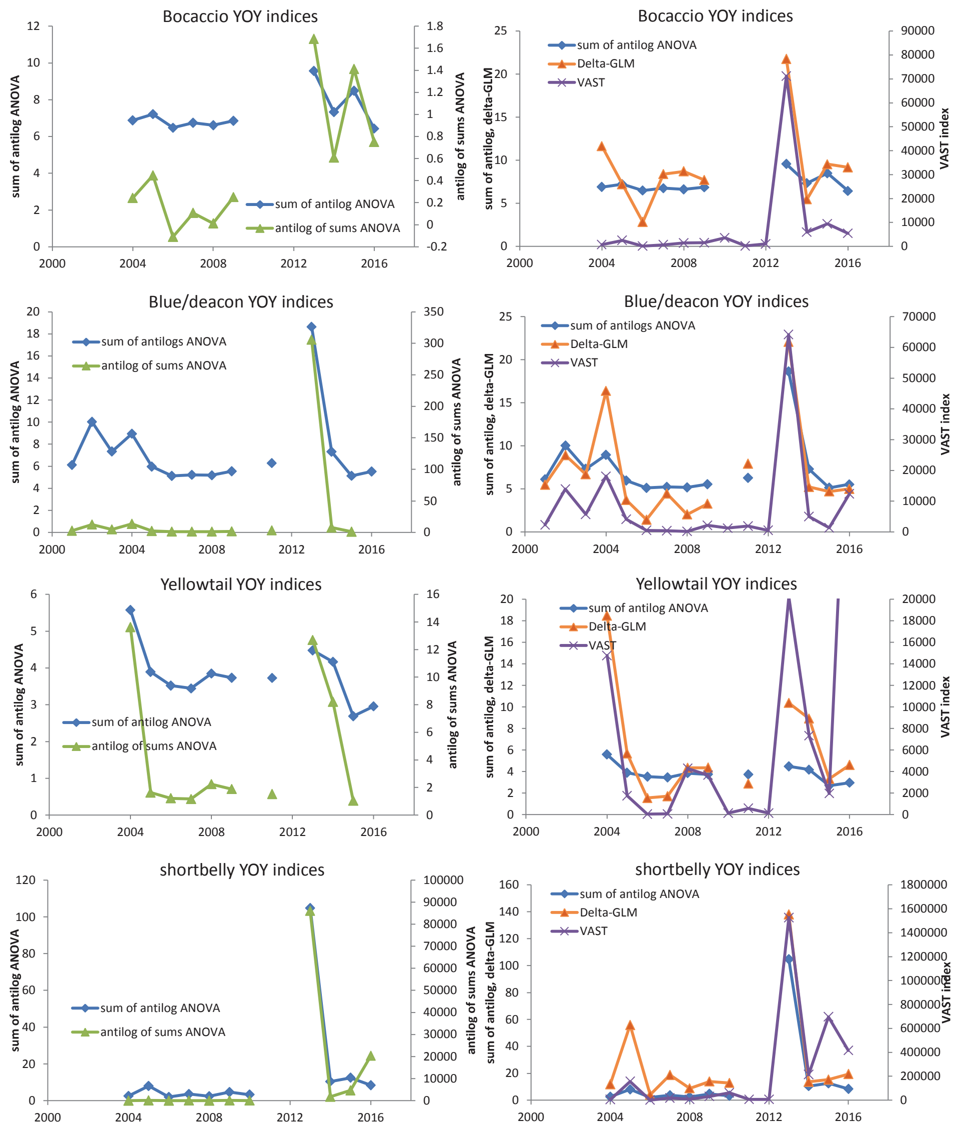

Figure 2: Comparisons of the two ANOVA based indices (using sum of the antilog values or the antilog of the sum of values for the year:latitude interaction model) for YOY rockfish (left panels) and of ANOVA, Delta-GLM and VAST indices for YOY rockfish indices (right panels).

Table 2: Index values and estimated coefficients of variation (CVs) from alternative approaches to developing YOY indices.

Bocaccio	sum antilog ANOVA		antilog sums ANOVA		Delta-GLM		VAST	
	Index	CV	Index	CV	Index	CV	Index	CV
2004	6.878	0.172	1.405	0.256	11.622	0.318	703	0.504
2005	7.216	0.171	1.724	0.237	7.193	0.318	2484	0.364
2006	6.471	0.17	0.987	0.228	2.831	0.46	97	0.75
2007	6.739	0.17	1.227	0.243	8.368	0.349	641	0.499
2008	6.613	0.17	1.115	0.246	8.705	0.355	1377	0.721
2009	6.852	0.171	1.414	0.286	7.692	0.413	1493	0.498
2010							3549	0.54
2011							184	0.791
2012							989	0.887
2013	9.556	0.166	5.94	0.299	21.754	0.378	71157	0.554
2014	7.327	0.169	2.023	0.321	5.458	0.367	5945	0.436
2015	8.481	0.166	4.521	0.251	9.523	0.302	9366	0.33
2016	6.43	0.174	2.333	0.555	9.169	0.438	5430	0.433

Blue/Deacon	sum antilog ANOVA		antilog sums ANOVA		Delta-GLM		VAST	
	Index	CV	Index	CV	Index	CV	Index	CV
2001	6.104	0.279	2.659	0.503	5.482	0.299	2288	0.436
2002	10.024	0.278	12.423	0.495	8.912	0.257	13937	0.289
2003	7.327	0.278	4.685	0.488	6.674	0.244	5729	0.387
2004	8.946	0.278	13.53	0.469	16.367	0.26	18113	0.291
2005	5.97	0.28	2.306	0.473	3.718	0.279	4132	0.311
2006	5.119	0.278	1.16	0.464	1.421	1.553	542	0.855
2007	5.218	0.277	1.274	0.461	4.456	0.375	420	0.52
2008	5.177	0.279	1.225	0.477	2.034	0.526	192	0.629
2009	5.534	0.275	1.683	0.466	3.278	0.314	2129	0.29
2010							1240	0.769
2011	6.283	0.281	3.102	0.5	7.909	0.42	1913	0.557
2012							542	0.855
2013	18.645	0.272	305.436	0.712	22.066	0.328	64142	0.203
2014	7.316	0.271	7.709	0.685	5.221	0.361	5002	0.352
2015	5.129	0.235	1.182	0.637	4.703	0.428	1340	0.54
2016	5.526	0.385	0	0	4.995	0.549	12412	0.475

Yellowtail	sum antilog ANOVA		antilog sums ANOVA		Delta-GLM		VAST	
	Index	CV	Index	CV	Index	CV	Index	CV
2004	5.575	0.314	13.624	0.33	18.472	0.316	14765	0.283
2005	3.892	0.314	1.62	0.333	5.669	0.328	1756	0.357
2006	3.518	0.313	1.214	0.327	1.531	0.72	45	1.078
2007	3.442	0.314	1.159	0.325	1.7	0.69	57	1.057
2008	3.846	0.314	2.239	0.335	4.341	0.324	4280	0.485
2009	3.732	0.31	1.884	0.328	4.354	0.315	3663	0.654
2010							129	0.993
2011	3.726	0.315	1.52	0.35	2.866	0.563	585	0.984
2012							129	0.993
2013	4.477	0.238	12.694	0.487	10.366	0.42	20243	0.474
2014	4.167	0.236	8.213	0.471	8.912	0.444	7323	0.359
2015	2.689	0.21	1.041	0.442	3.315	0.645	1957	0.577
2016	2.954	0.29	0	0	4.603	0.614	42874	0.432

Shortbelly	sum antilog ANOVA		antilog sums ANOVA		Delta-GLM		VAST	
	Index	CV	Index	CV	Index	CV	Index	CV
2004	2.602	0.827	10.099	0.67	11.849	0.666	6091	0.467
2005	8.011	0.854	106.005	0.592	55.807	0.528	157359	0.303
2006	2.04	0.812	3.018	0.578	4.066	0.863	1962	0.576
2007	3.625	0.837	17.624	0.64	18.742	0.62	18509	0.406
2008	2.416	0.81	6.573	0.636	8.838	0.739	7666	0.352
2009	4.676	0.825	79.865	0.826	13.902	0.61	32000	0.402
2010	3.323	0.9	27.044	0.853	12.817	0.931	62008	0.412
2011							7550	1.186
2012							7550	1.186
2013	104.757	1.662	85988.419	0.794	138.074	0.437	1526456	0.287
2014	10.426	1.667	1792.581	0.9	13.662	0.525	214435	0.388
2015	12.477	1.624	4677.989	0.68	15.331	0.45	697206	0.295
2016	8.375	0.468	20330.549	0.838	19.365	0.595	416177	0.366

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Appendix D. Responses to requests of the STAR Panel

10.1 Round 1 of Requests (Monday, July 10th)

Request 1 For the northern model, compare the geospatial GLMMs for the NWFSC Combo survey conducted in VAST to the delta-GLMM version of the VAST with the geo-spatial switches turned off and to the designed-based estimates. Include a table with the number of hauls, positives, and number of fish and/or length observations in the north and the south.

Rationale: This is strongly encouraged in the SSCs Accepted Practices guide. The data were too sparse to model a survey index independently in the southern region.

Response: The STAT provided a figure comparing the requested alternative indices. Figure 1 shows the trends and variance for the four indices. Pearson residuals for the non-spatial model are shown in Figure 2. Tables providing the number of hauls and positive hauls by area. Tables providing the numbers of length samples are provided in the main body of this document.

Request 2 For each model, provide the numbers of fish north and south of 4010 N lat. that were used for the ageing error matrix and show the results of the cross-reads.

Rationale: To see if there is greater uncertainty and/or bias from samples collected in only one area.

Response: There were an insufficient number of otoliths from each area for a comparison of cross-lab reads. Cross-reads between WDFW and NWFSC within-lab comparison for the northern area alone showed a minor deviation from the one to one line for the 121 samples compared (Figure 3).

There were 1085 otoliths from the northern area and only 88 fish from south (collected in the NWFSC Trawl survey) that were double read by the NWFSC in within-lab comparisons.

There were few deviations from the one to one line for within-lab double reads by the NWFSC in either area (Figure 3). The R-square values were 0.9198 and 0.9515 for northern or southern areas, respectively showing no discernable difference in the accuracy of reads between areas for the within-lab reads.

Request 3 Model the southern onboard recreational CPFV survey data for separate time periods pre- and post-1999 using a delta-GLMM modeling approach. Present the results of the delta-GLMM approach including the factors, CVs, and other diagnostics. Show the results of the Southern model with the new indices compared to the old indices as a sensitivity analysis.

Rationale: The indices were inappropriately input as averages rather than modeled results. The blocking after 1999 is supported by the CVs and the change in the sampling programs.

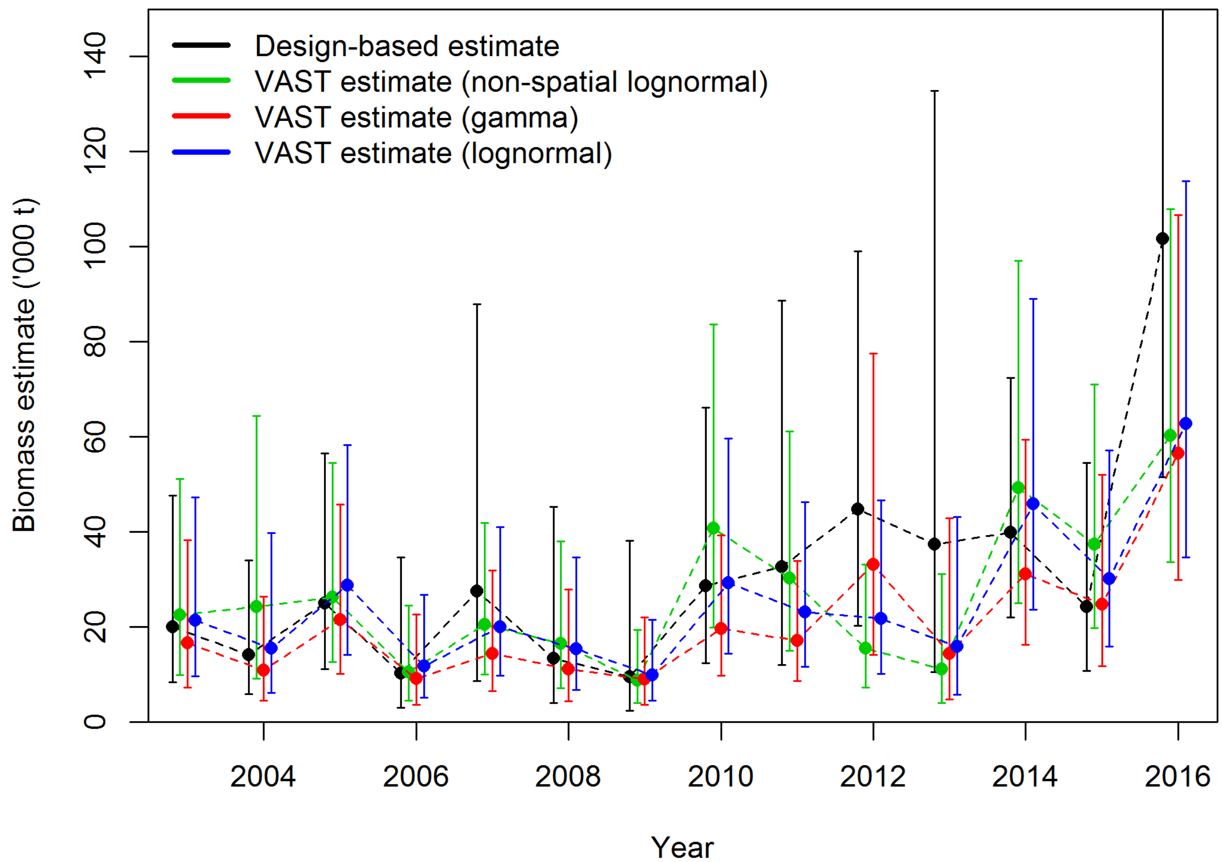

Figure 1: Comparison of trends in the geospatial GLMMs for the NWFSC Combo survey conducted in VAST to the delta-GLMM version of the VAST with the geo-spatial switches turned on and off as well as the results of the design-based delta-GLMMs.

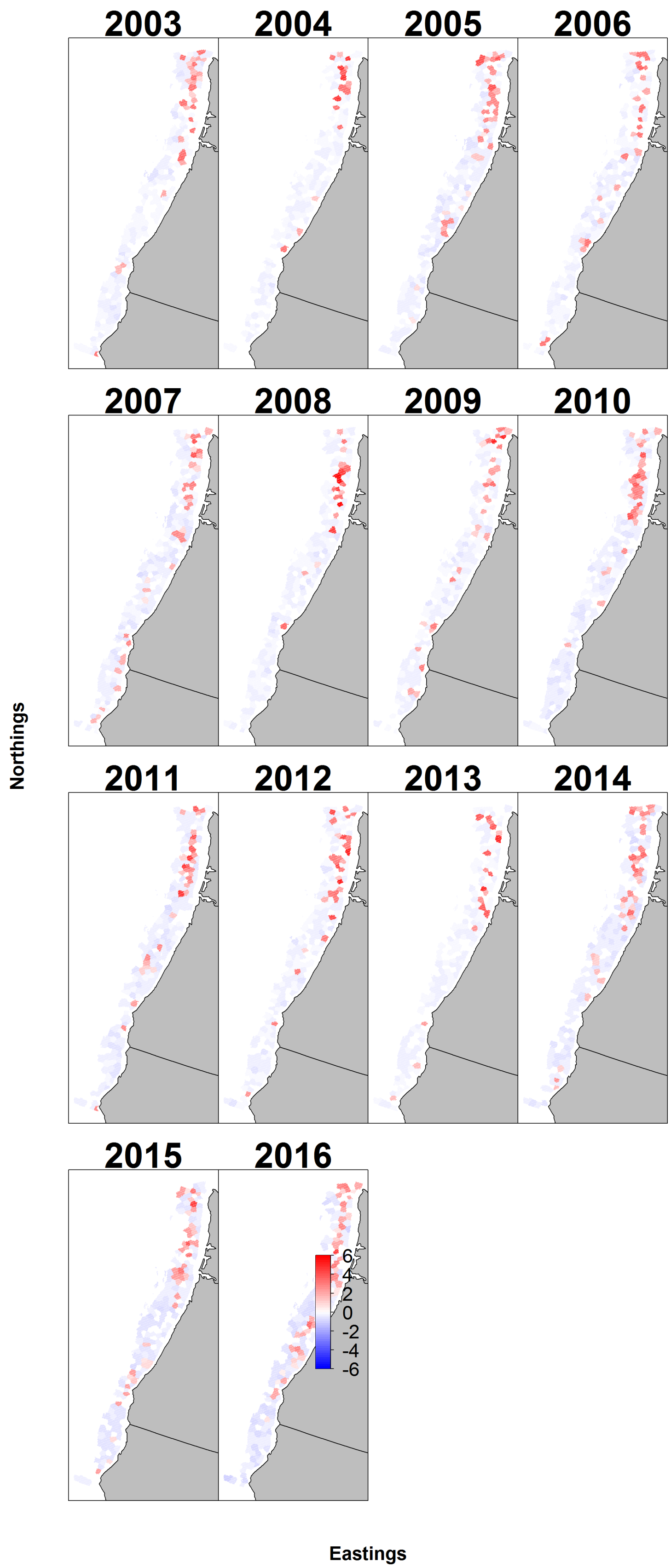

Figure 2: Pearson residuals for encounter probability in non-spatial model.

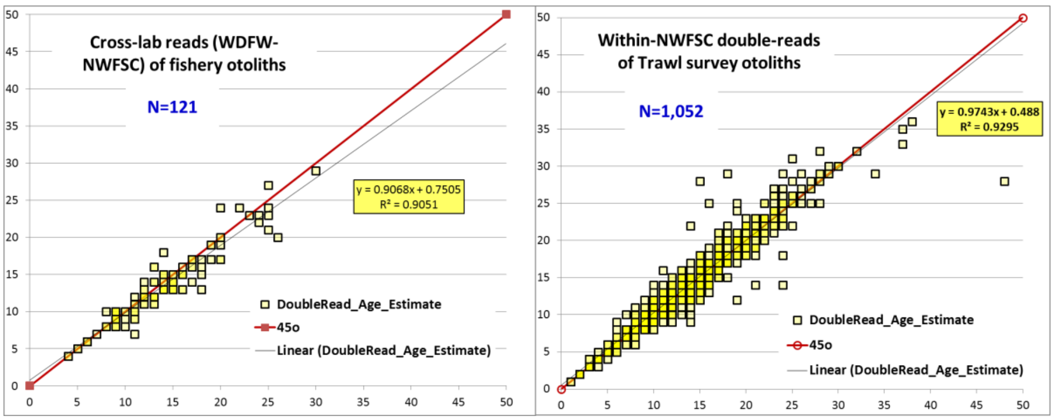

Figure 3: Comparison of yellowtail rockfish age determination double reads across aging laboratories (upper left) and within-lab (survey age structures) in each area.

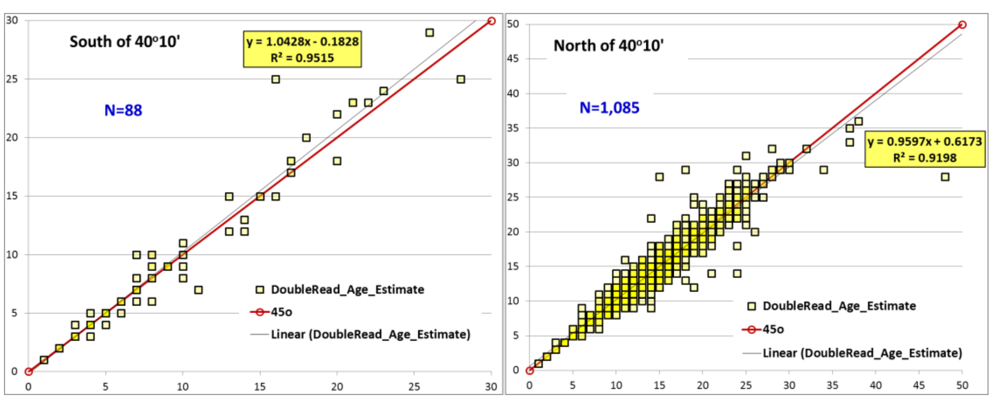

Figure 4

Response: Melissa Monk of the SWFSC provided two indices using the delta-GLMM method both with and without spatial information.

The early and late onboard surveys differ in that the early period (when only Central California was sampled) has asymptotic selectivity, while the later survey, which include the whole state, has domed shaped selectivity.

These indices were ultimately included in the final Southern model.

Request 4 If time allows, run the Southern model without the 1982 recreational catch spike (assume the average of 1981 and 1983).

Rationale: To understand the influence of this catch, which is suspiciously large.

Response: Changing 1982 recreational catch to the average of the 1981 and 1983 catch had little impact on model results. There was a 1.3% reduction in total removals from reducing this value.

Request 5 For the Northern model, provide a table of the species that occur in each state's trawl logbook program. Confirm the model is using nominal retained catch from the original logbook data.

Rationale: There may be different logbook reporting requirements by state that might influence construction of CPUE indices using these data.

Response: A table detailing the data that were used for the original analysis was provided to the panel. Discussions during day one were the impetus for a new analysis using 22 market categories that occurred in the dataset along the west coast. The nomina-only categories that were included in the analysis were those that occurred at least 50 times in each of the three areas (WA, OR and NCA).

Ultimately, the logbook index was withdrawn from the model due to the differences in the way the states speciated market categories during the late 1980s-1990s, which cannot be resolved within the time alloted for the panel.

Request 6 Recalculate the trawl logbook CPUE index to catch/tow hour rather than catch/tow.

Rationale: This is the appropriate metric for this index.

Response: An index based on the covariate species and using lbs per tow-hour as the response variable was provided. Estimates of uncertainty could not be produced for this index due to time and computational constraints. Figure 5 shows a comparison of the previous index (orange, with uncertainty) and the new index (blue, without).

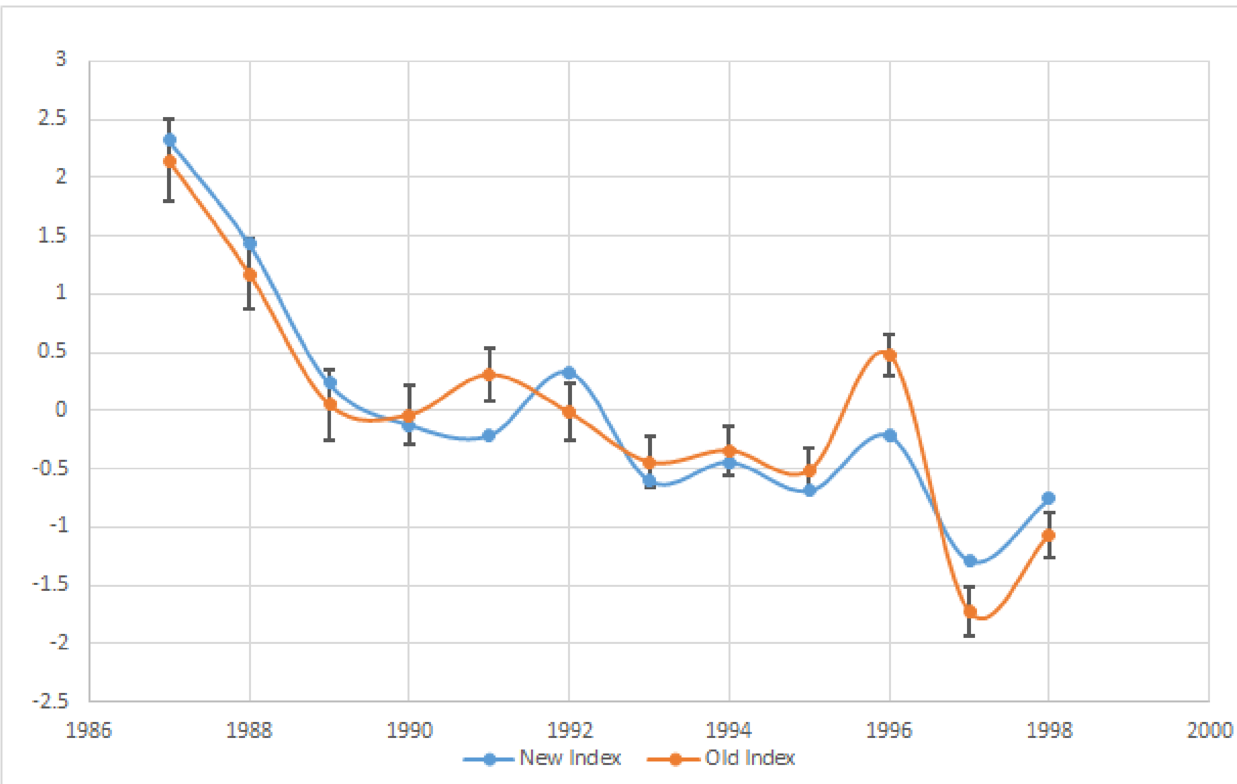

Figure 5: Original and revised trawl CPUE index upon standardizing data to catch per tow hour and refining the list of co-occurring species for the filtering model.

Information that came to light about the commercial data collection both in the trawl fishery and in the directed hake fishery during the course of the STAR panel eroded confidence in this index as well as confidence in the hake bycatch index. These indices were ultimately omitted from the Northern base model.

Request 7 Check the Washington composition data to determine the correct units in the length data. Double-check the number of ages from the WA recreational fishery.

Rationale: There was a suspicious spike in the time series that may have been due to the wrong units of measurement (cm vs. mm) in the length data. There is also suspicion the age comps used in the model are not consistent with WA records.

Response: Two issues were identified with respect to the Washington data. One was that the data were provided with varying units (some lengths in cm, others in mm).

The second issue concerned sample sizes for the age comps, for which there was a copy-and-paste error comitted in Excel, so that the column of sample-sizes was offset by one year in the data.

Both lengths and ages for the WA recreational fishery were re-processed. Old (above) and new (below) length compositions are shown in Figure 6. Data reprocessing removed the spikes at large sizes that were shown in the length composition.

These reworked data were used in the Northern base model.

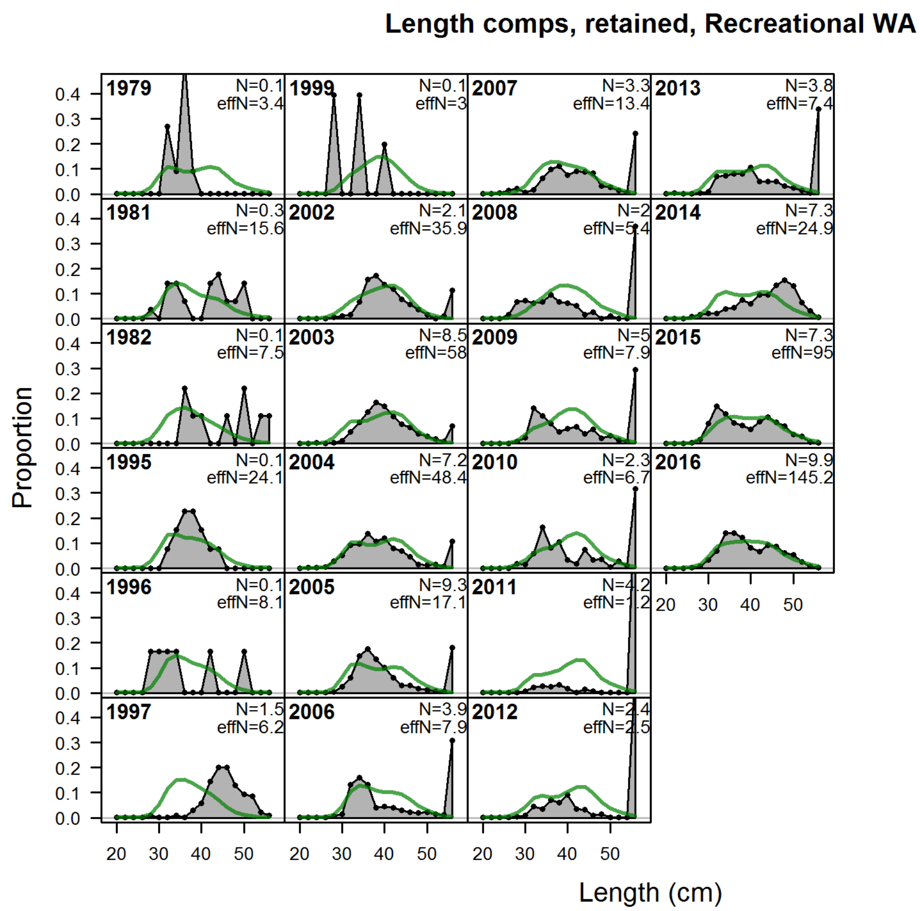

Figure 6: Draft (above) and final (below) model length compositions for the WA recreational fleet when correcting length units and effective starting sample sizes.

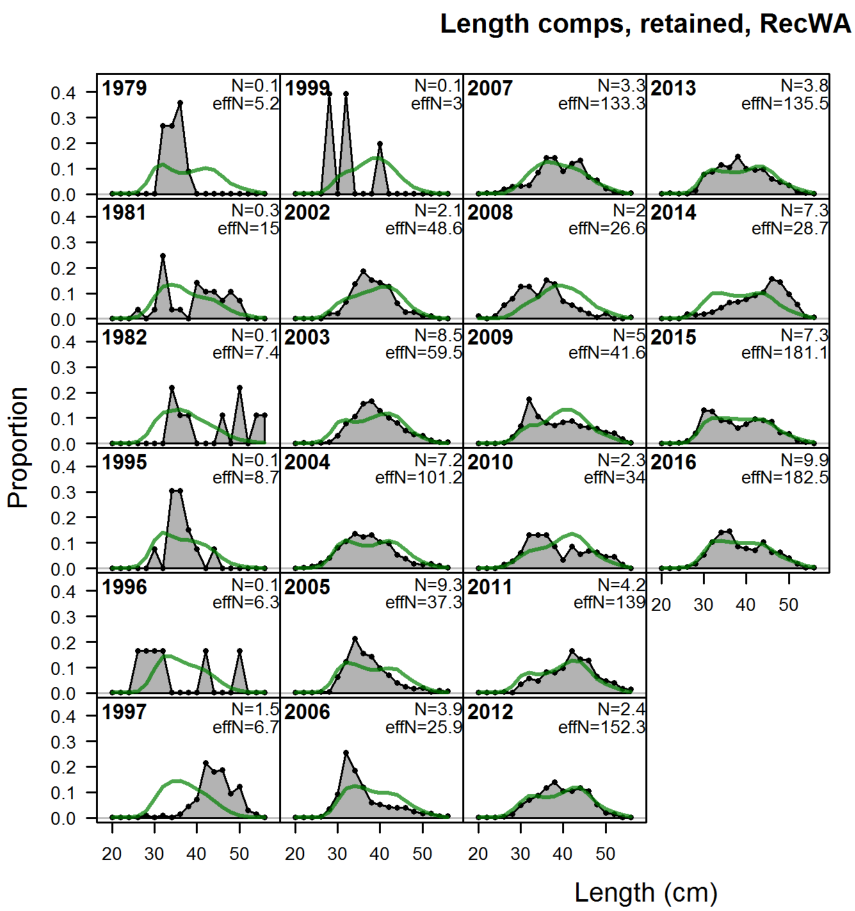

Figure 7: Figure continued from previous page

Request 8 Put a time block on the recreational selectivity pattern in the Northern model from 2003 onward.

Rationale: Implementation of depth restrictions forced fleets into shallower water affecting the size of fish caught. This was evidenced by a poor residual pattern.

Response: The model-estimated selectivity curves changed very little for the Oregon and Northern California recreational fisheries, however there was a noticeable change for Washington when the time block was added. The selectivity estimates are compared in Figure 8.

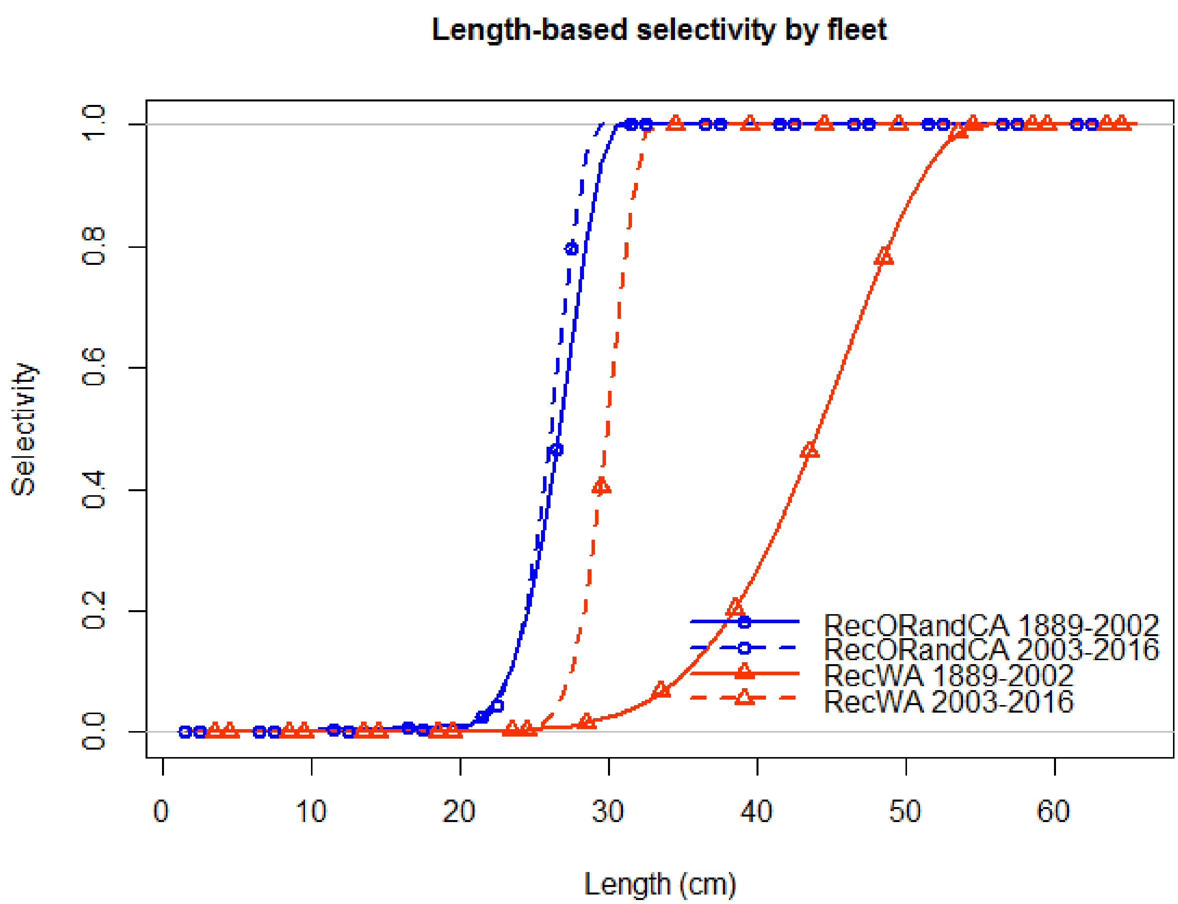

Figure 8: Estimated selectivity curves for northern model recreational fisheries when including a time block to account for regulatory changes.

The corrections to the length and age compositions for Washington data preceeded this change to selectivities. The selectivities were then allowed to be dome shaped, which resulted in better fits. Both the dome-shaped curve and the time block were incorporated into the base case model.

Request 9 If time allows, estimate the added variance parameter for all indices in each model.

Rationale: This is standard practice.

Response: Figure 9 shows the fits to the Northern model indices when additional variances for all indices are estimated.

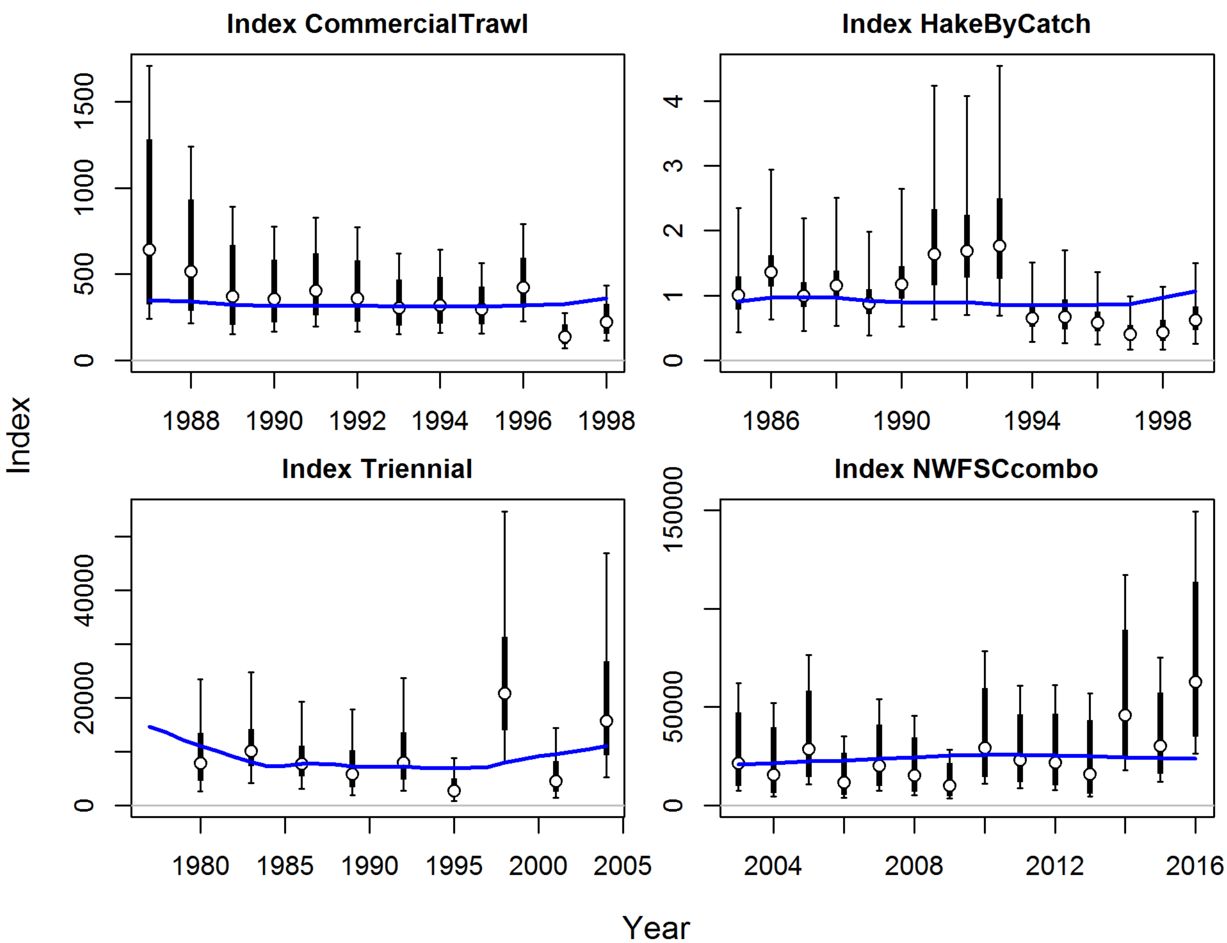

Figure 9: Fits to index data for the Northern Yellowtail model when added variance parameters are estimated. At this point in the review, all four indices were included in the model. For the final base model, the commercial trawl index and hake index were removed from the likelihood and the extra variance parameters no longer estimated.

This aspect of the analyses was not explored further but the additional variance was maintained in the model.

10.2 Round 2 of requests (Wednesday, July 12th)

Request 10 Re-tune the new base Northern model with the changes agreed on the 1st set of requests (i.e., corrected WA comp. data, extra variance added to indices, time block in 2003 for recreational catch, and allow dome-shaped selectivity for recreational catch in the recent time block).

Rationale: These changes corrected errors in the input data and improved model fits, and will be included in the new base model.

Response: The newly-tuned northern model was plotted with and without fishery CPUE indices, in comparison with the pre-STAR meeting model (Figure 10).

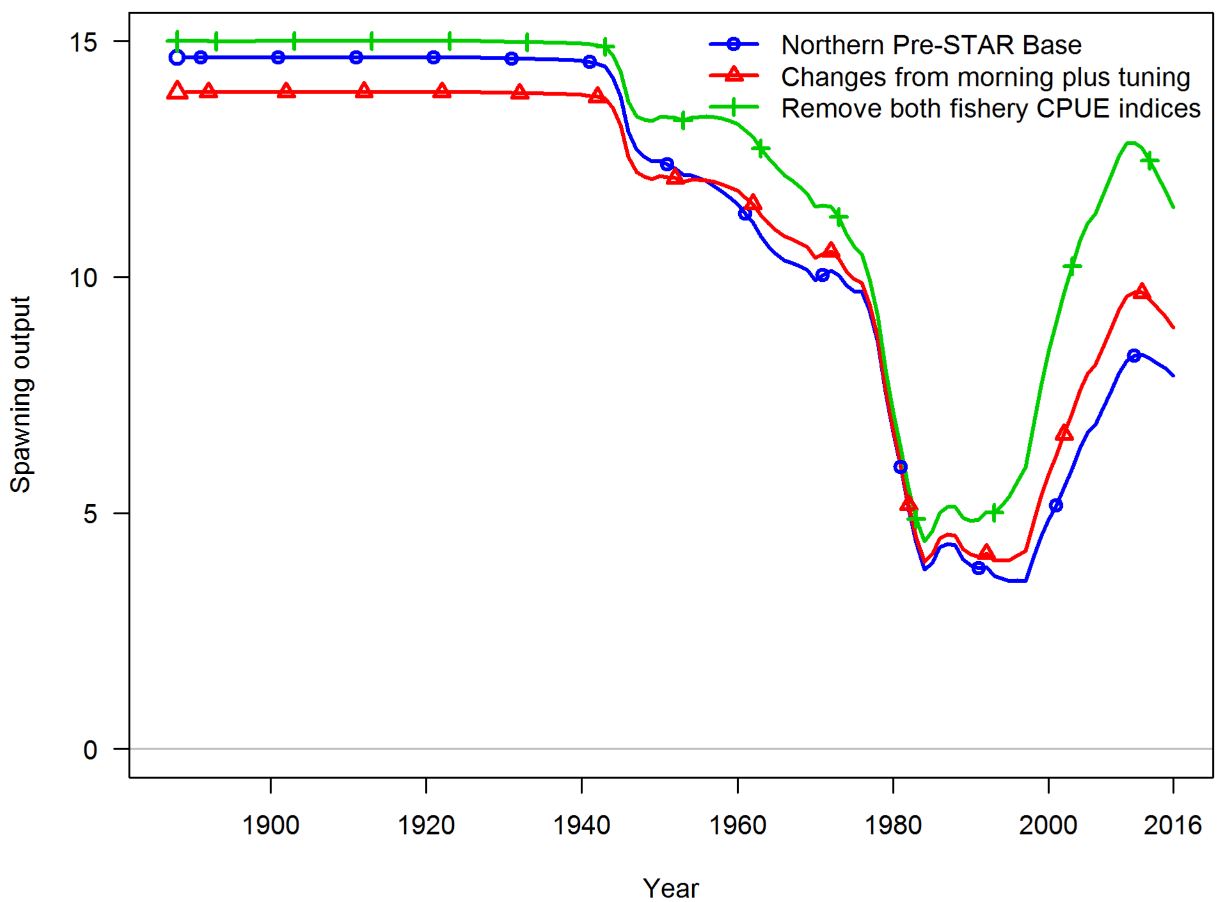

Figure 10: Changes in base model as a result of STAR and STAT recommendations.

The natural mortality estimated in northern models has increased due to the changed implemented. The posterior shown in Figure 11 is much narrower than the prior, supporting a much smaller range of plausible values for M. The M values associated with this series of models are shown in Table 1.

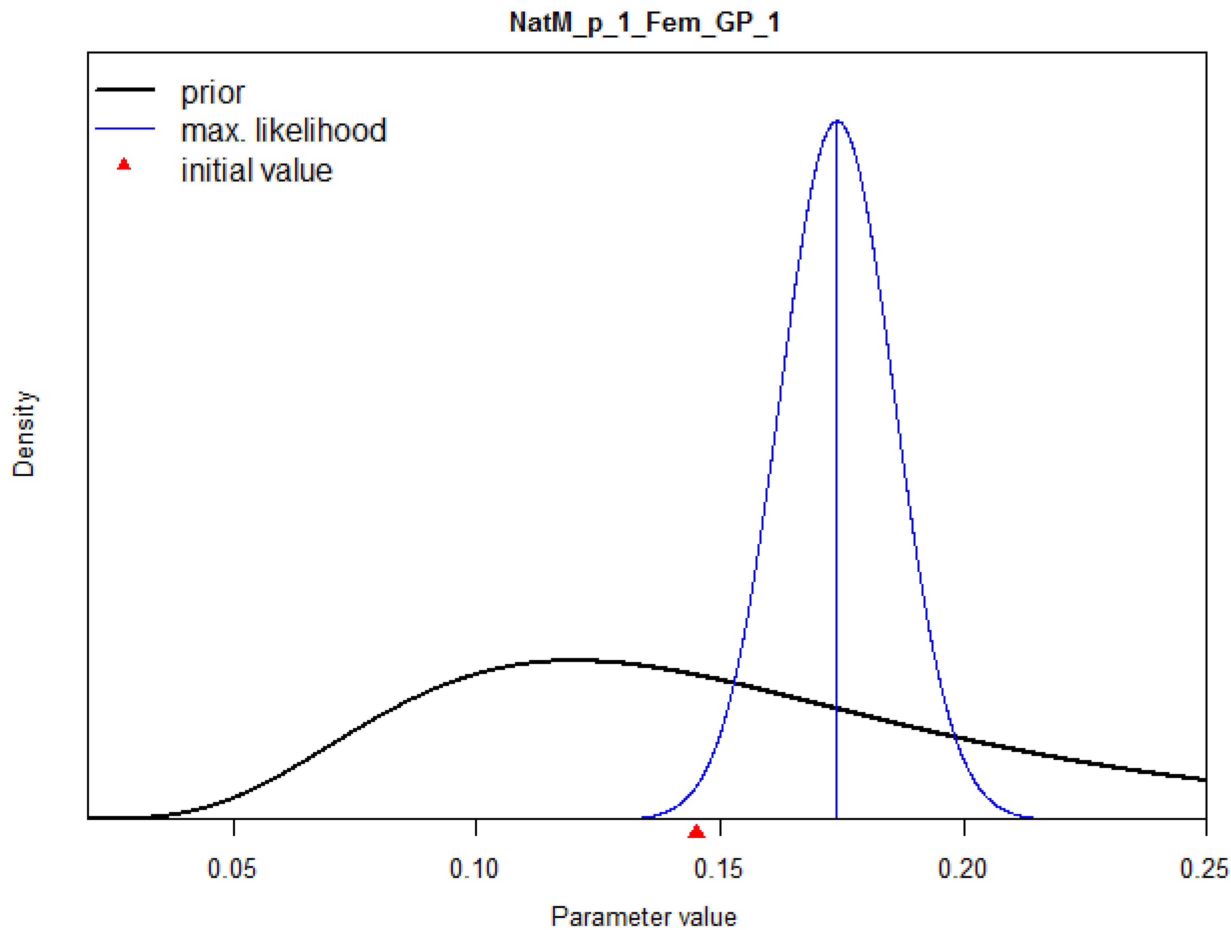

Figure 11: Comparison of prior distribution, model initial value, and posterior for natural mortality (females) as estimated from the Northern base model.

Table 1. Pre-STAR, intermediate, and Post-STAR model estimates of natural mortality for northern yellowtail.

Quantity	pre-STAR model	adjusted, tuned model	without cpue indices
M (females)	0.145	0.159	0.174
M (males)	0.138	0.138	0.150

Request 11 Use the preliminary new M estimate from the revised Northern model in the Southern model as revised after the first round of requests. Compare the existing Southern base and the new potential base using the new M estimate. Explore other M assumptions in the Southern model as deemed appropriate and as time allows.

Rationale: The changes to the northern base model will likely affect the estimate of M and consequently would change the assumed M in the southern model.

Response: The pre-STAR value for M of 0.14 was replaced by the value of 0.175 based on the value estimated in the proposed Northern base model. Results are shown in Figure 12.

Request 12 As time allows, provide the basis for and documentation of the use of the geospatial GLMMs for the Hake CPUE index in the Northern pre-STAR model that was conducted in VAST.

Rationale: This is needed to understand the basis for how this index is constructed and why there was no sensitivity to the non-spatial analysis.

Response: Upon greater discussion and evaluation, the STAT no longer felt this index should be included in the base model. The Panel did not request further work on this but noted that future assessments would benefit from further exploration of this index to ascertain its appropriateness and best type of analyses to apply.

Request 13 Jitter the new Northern base model.

Rationale: Final check for a global minimum

Response: The result of 100 jitter runs was shown to the panel and indicated that a global minimum had been attained.

Request 14 Decision table explorations for the Northern model:

Provide projections assuming a range of M values that the STAT considers to be an appropriate approximation of uncertainty for a decision table.

Provide projections assuming a range of R0 values based on the base model uncertainty estimates for R0, including the 87.5 and 12.5 percentiles and other explorations as appropriate, as a possible axis of uncertainty for a decision table.

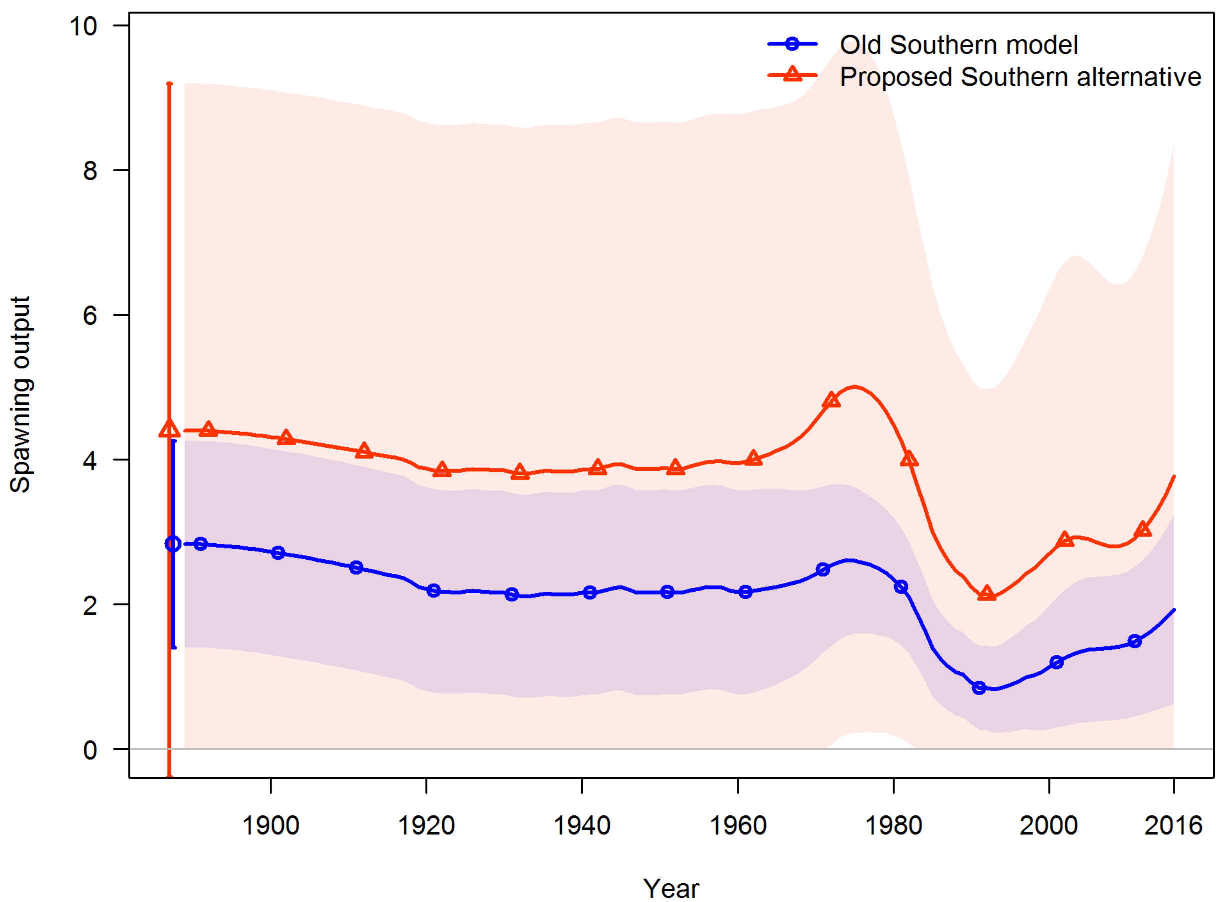

Figure 12: Spawning output and confidence intervals for the yellowtail rockfish southern assessment base model and the alternative model with a higher value of M.

Provide any additional projections that the STAT determines may be more appropriate for developing the axis of uncertainty for a decision table.

Rationale: To explore possible axis of uncertainty

Response: Likelihood profiles over R0 and M indicated a lower range of spawning output associated with the 12.5% and 87.5% cutoff (change in likelihood of 0.662) than the uncertainty in spawning output estimated for the base model.

Therefore, we used the 12.5% and 87.5% quantiles of a normal distribution representing 2017 spawning output, for which the base model had an MLE value of 11.28 (trillion eggs) with a standard deviation of 1.823.

This resulted in target 2017 spawning output values for the low and high states of nature of 9.17 and 13.38 (trillion eggs). R0 and M profiles using a fine step size (0.01 units of R0 or M) were used to find the best matching values of these two parameters for the low and high cases.

A further request was made during presentation of the results. It appeared that depletion could be very similar across the different scenarios. The range of depleteion covered was from 57% to about 82% of pre-exploited spawning output, but that was clearly smaller than the uncertainty envelope characterizing the base case results.

Therefore, we extended the range of values of M used to represent uncertainty by using the prior for M as the shape of the distribution but shifting the distribution so the mean was that estimated in the Northern base model, 0.174. The values that corresponded to the 12.5 and 87.5 percentiles of this distribution were 0.122 and 0.249.

Request 14 Provide projections based on the base model uncertainty estimates for M, including the 87.5 and 12.5 percentiles of the prior distribution centered around the base model estimate of M (low M = 0.122, base M = 0.174, high M = 0.249) as a possible axis of uncertainty for a decision table.

For catch stream alternatives, assume full attainment of 2017 and 2018 ACLs; i.e., 6,196 mt and 6,002 mt, respectively. Attribute fleet allocations based on the 2017 and 2018 sector allocations for 2017 and 2018; fleet allocations as per the assessment thereafter, such that the 2019-2028 catch streams are based on:

Default HCR: ACL = ABC (P* = 0.45) Constant catch of 4,000 mt (which was the approximate catch level when midwater targeting was occurring in the past; this is in line with the GMTs 2017-18 spex analysis) Constant catch of 2,000 mt (a marginal increase in recent-year average catch)

Rationale: To explore a possible axis of uncertainty for the decision table.

Response: The requested table is the decision table reported in the Executive Summary.