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

Andi Stephens[1]
Ian G. Taylor[2]

[1]Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2032 S.E. OSU Drive Newport, Oregon 97365

[2]Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112

DRAFT SAFE

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

Contents

Executive Summary

executive-summary

Stock

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 Southern Shelf Complex. This assessment analyzes 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.

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). A data-moderate assessment conducted in 2013 (Cope et al. 2013) was the first to analyze the southern stock, determining its contribution to the overfishing limit (OFL) for the Southern Shelf Complex.

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, much of the groundfish catch landed in northern Oregon is caught in Washington waters.

This assessment addresses 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. n.d.) that found distinct stocks north and south of Cape Mendocino but did not find stock differences within the northern area.

Catches

catches

Catches from the Northern stock 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 length-compositions.

Catches from the Southern stock were divided into two categories: commercial and recreational catch, both of which were entered as metric tons.

Include: trends and current levels-include table for last ten years and graph with long term data

Catch figures: (Figures a-b)
Catch tables: (Tables a-b)

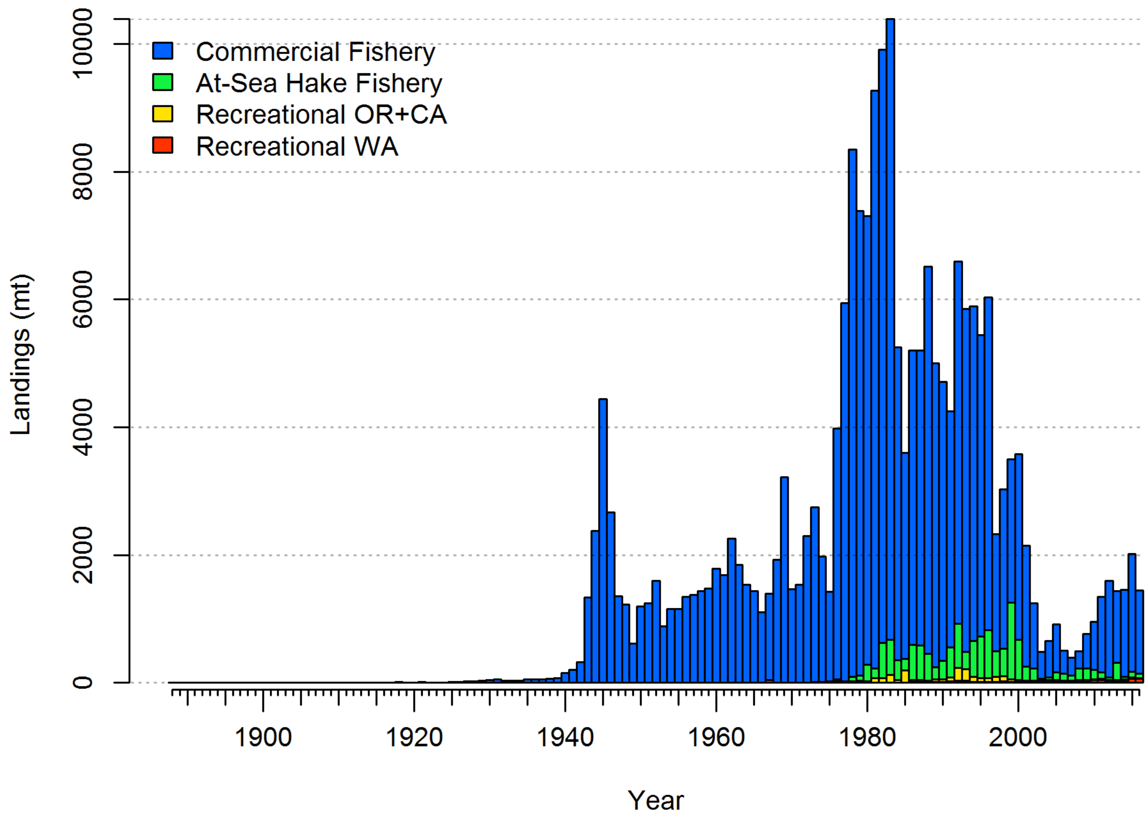


Figure a: Estimated catch history of Yellowtail Rockfish in the Northern model. Recreational catches in Washington are model estimates of total weigth converted from input catch in numbers using model estimates of growth and selectivity. fig:r4ss_catch_N

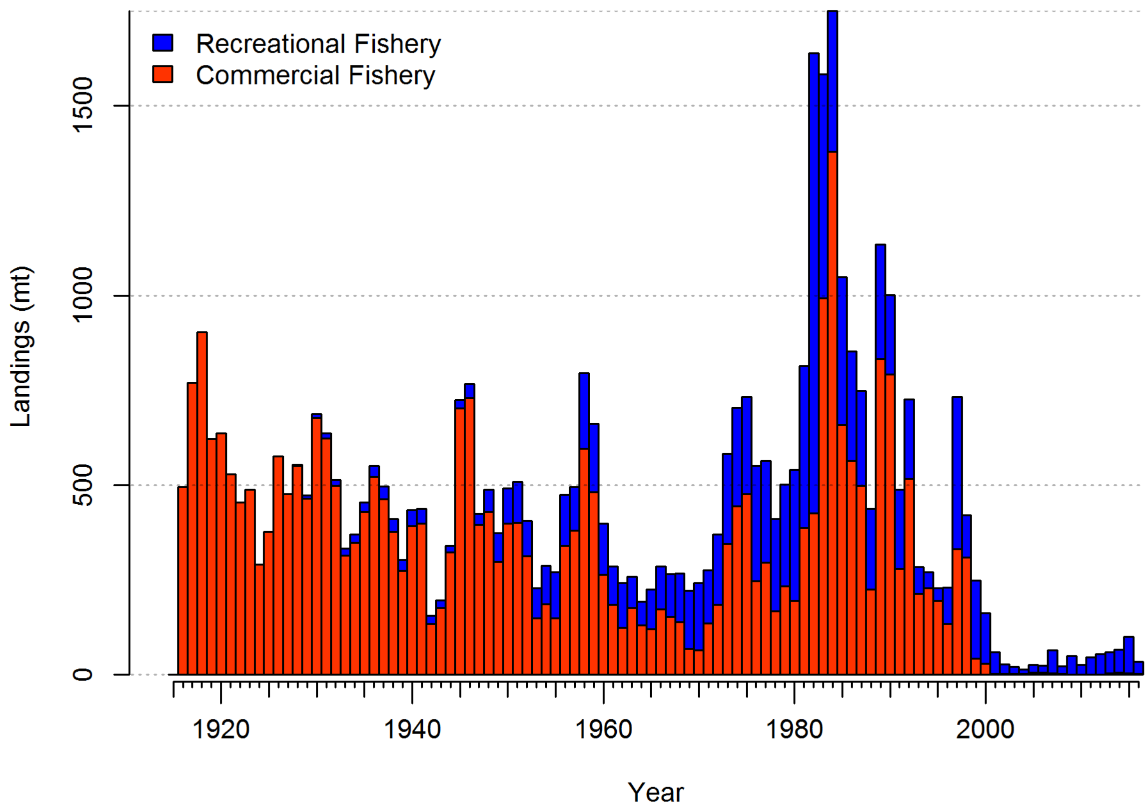


Figure b: Estimated catch history of Yellowtail Rockfish in the Southern model. fig:r4ss_catch_S

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

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

data-and-assessment

Include: date of last assessment, type of assessment model, data available, new information, and information lacking.

Yellowtail Rockfish was assessed north of Cape Mendocino in 2005 in a fully integrated age-based assessment. A 2013 data-moderate assessment was the first to address the southern stock (Cope et al. 2013).

This assessment uses Stock Synthesis version 3.3. The Northern model begins in 1889, with the assumption that the stock was at an unfished equilibrium that year? The Southern model begins in 1916, with the assumption that the stock was at an unfished equilibrium that year?

Map of assessment region: (Figure c).

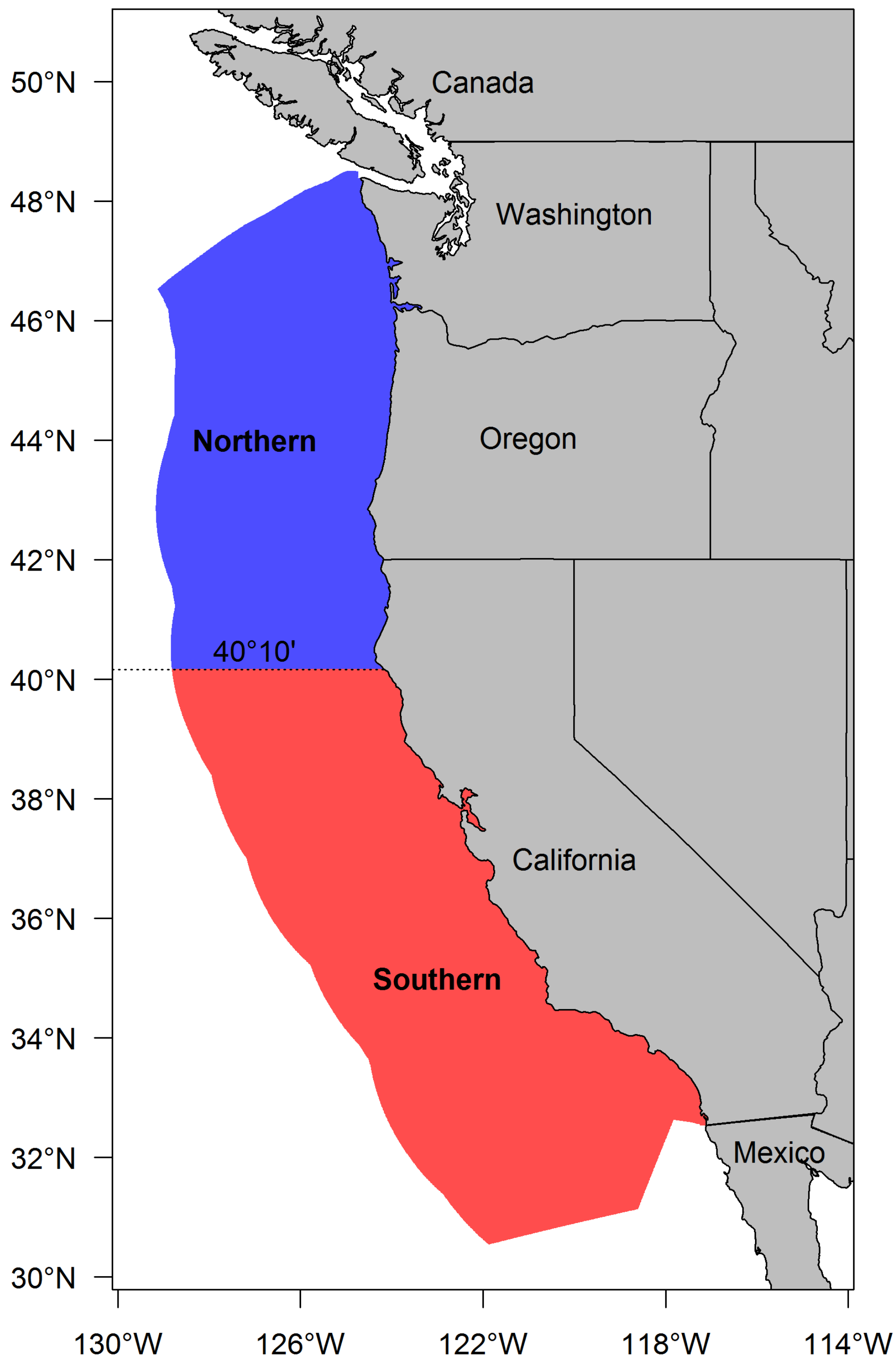


Figure c: Map depicting the boundaries for the base-case model. fig:assess_region_map_Ex

Stock Biomass

`stock-biomass`

Include: trends and current levels relative to virgin or historic levels, description of uncertainty-include table for last 10 years and graph with long term estimates.

Spawning output Figure: Figure d
Spawning output Table(s): Table c
Relative depletion Figure: Figure e

Example text (remove Models 2 and 3 if not needed - if using, remove the # in-line comments!!!) The estimated relative depletion level (spawning output relative to unfished spawning output) of the the base-case model in 2016 is 56.7% (~95% asymptotic interval: ± 45.4%-68.1%) (Figure e).

The estimated relative depletion level of model 2 in 2016 is 98% (~95% asymptotic interval: ± 75.5%-120%) (Figure e).

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

`tab:SpawningDeplete_mod1`

Year	Spawning Output (trillion eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	7.886	(5.79-9.98)	0.547	(0.415-0.678)
2009	8.289	(6.13-10.45)	0.575	(0.442-0.707)
2010	8.556	(6.34-10.77)	0.593	(0.461-0.726)
2011	8.652	(6.41-10.9)	0.600	(0.469-0.731)
2012	8.682	(6.42-10.94)	0.602	(0.474-0.73)
2013	8.591	(6.34-10.85)	0.596	(0.472-0.719)
2014	8.479	(6.23-10.73)	0.588	(0.468-0.708)
2015	8.374	(6.13-10.62)	0.580	(0.464-0.697)
2016	8.215	(5.96-10.48)	0.569	(0.455-0.684)
2017	8.186	(5.9-10.47)	0.567	(0.454-0.681)

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

tab:SpawningDeplete_mod2

Year	Spawning Output (trillion eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	3.934	(0-10.7)	0.678	(0.529-0.828)
2009	3.927	(0-10.65)	0.677	(0.531-0.823)
2010	3.953	(0-10.7)	0.681	(0.537-0.826)
2011	4.010	(0-10.84)	0.691	(0.546-0.837)
2012	4.088	(0-11.03)	0.705	(0.557-0.852)
2013	4.217	(0-11.36)	0.727	(0.574-0.88)
2014	4.384	(0-11.79)	0.756	(0.598-0.913)
2015	4.660	(0-12.52)	0.803	(0.633-0.974)
2016	5.083	(0-13.64)	0.876	(0.685-1.068)
2017	5.685	(0-15.25)	0.980	(0.755-1.205)

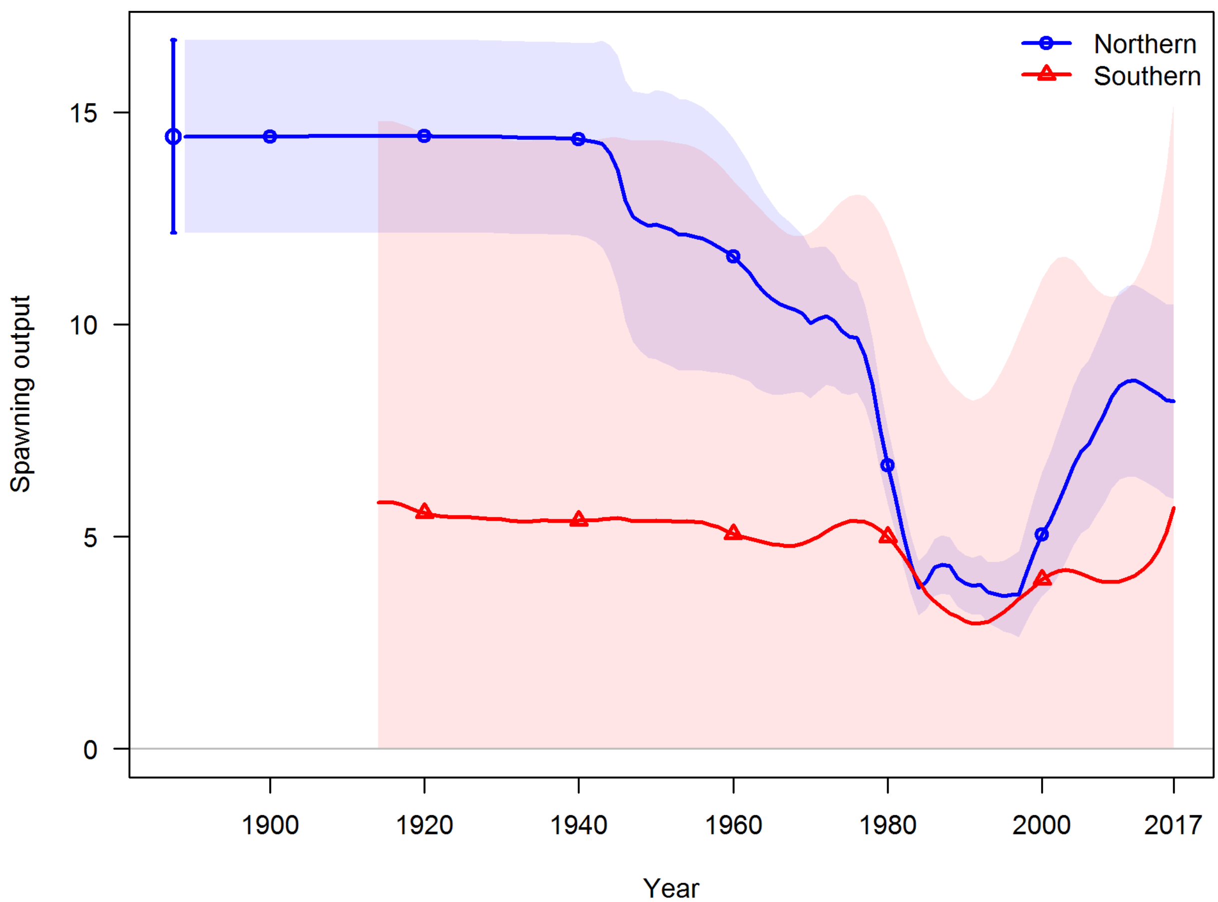


Figure d: Time series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model. fig:Spawnbio_all

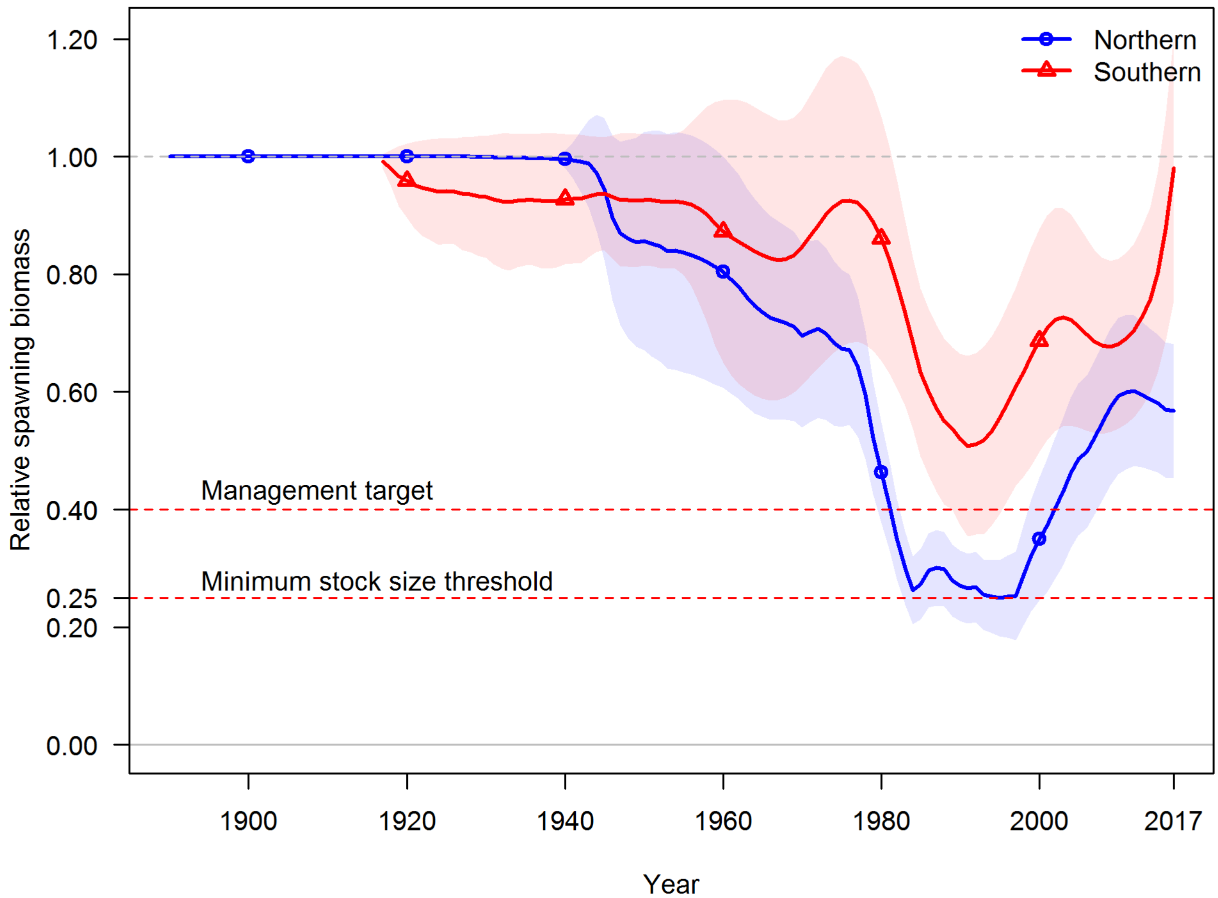


Figure e: Estimated relative depletion with approximate 95% asymptotic confidnce intervals (dashed lines) for the base case assessment model. fig:RelDeplete_all

Recruitment

recruitment

Include: trends and current levels relative to virgin or historic levels-include table for last 10 years and graph with long term estimates.

Recruitment Figure: (Figure f)
Recruitment Tables: (Tables e and f)

Table e: Recent recruitment for the Northern model.

tab:Recruit_mod1

Year	Estimated Recruitment (millions)	~ 95% confidence interval
2008	41.17	(25.53 - 66.41)
2009	12.42	(6.11 - 25.24)
2010	26.22	(14.25 - 48.26)
2011	17.76	(8.17 - 38.58)
2012	18.73	(7.45 - 47.06)
2013	30.71	(10.59 - 89.07)
2014	28.43	(9.78 - 82.61)
2015	28.52	(10.06 - 80.85)
2016	28.31	(10 - 80.14)
2017	28.29	(9.99 - 80.09)

Table f: Recent recruitment for the Southern model.

tab:Recruit_mod2

Year	Estimated Recruitment (millions)	~ 95% confidence interval
2008	234.32	(48.85 - 1124.05)
2009	66.93	(8.28 - 541.34)
2010	170.66	(28.63 - 1017.09)
2011	81.72	(11.33 - 589.32)
2012	59.53	(8.75 - 404.76)
2013	62.96	(10.56 - 375.27)
2014	46.19	(7.64 - 279.12)
2015	37.77	(6.4 - 222.96)
2016	35.70	(5.83 - 218.81)
2017	36.73	(6 - 225)

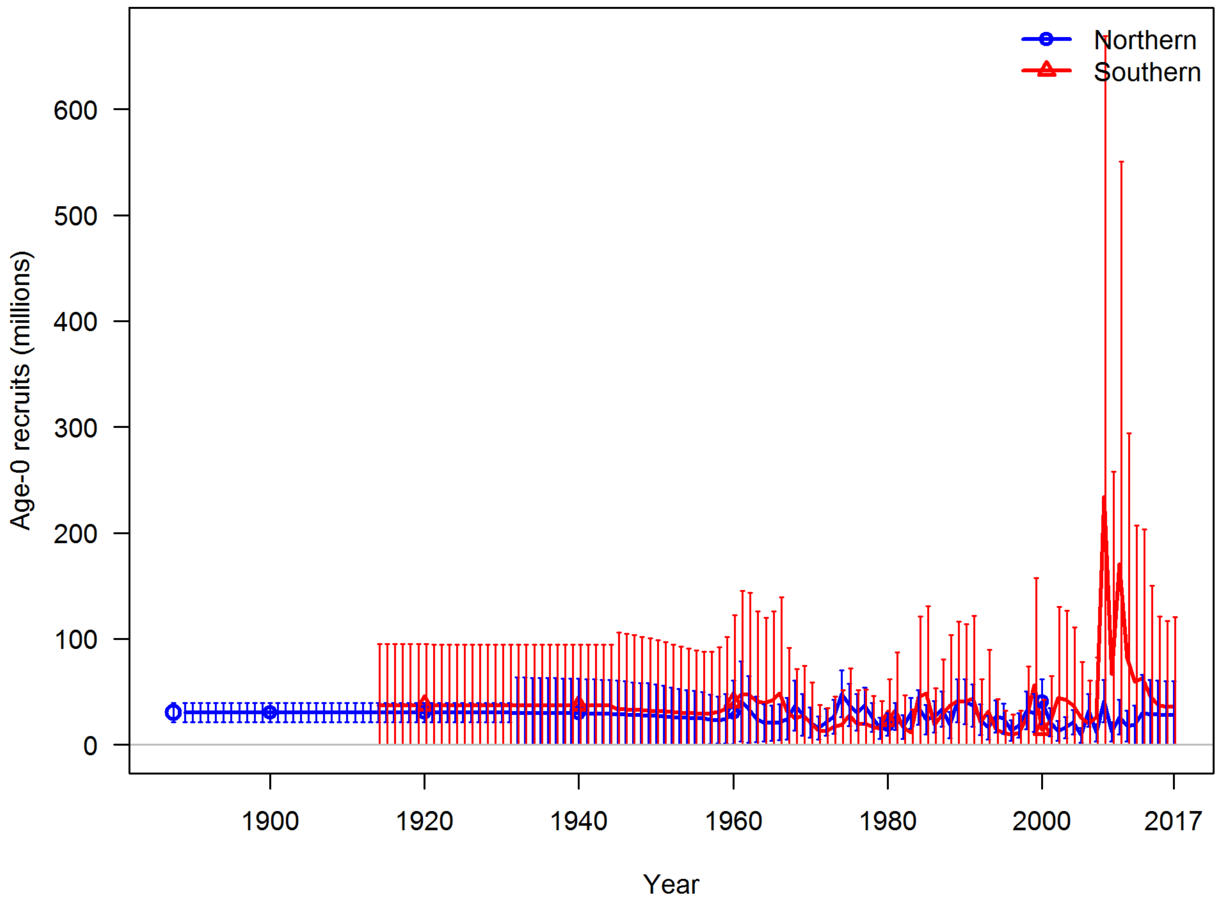


Figure f: Time series of estimated Yellowtail Rockfish recruitments for the base-case model with 95% confidence or credibility intervals. fig:Recruits_all

Exploitation status

exploitation-status

Include: exploitation rates (i.e., total catch divided by exploitable biomass, or the annual SPR harvest rate) include a table with the last 10 years of data and a graph showing the trend in fishing mortality relative to the target (y-axis) plotted against the trend in biomass relative to the target (x-axis).

Exploitation Tables: Tables g and h Exploitation Figure: Figure g).

A summary of Yellowtail Rockfish exploitation histories for 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 F divided by F_{SPR}.

tab:SPR_Exploit_mod1

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.30	(0.11-0.49)	0.01	(0-0.02)
2008	0.19	(0.13-0.25)	0.01	(0-0.01)
2009	0.35	(0.22-0.48)	0.01	(0.01-0.02)
2010	0.47	(0.24-0.7)	0.02	(0.01-0.03)
2011	0.41	(0.3-0.52)	0.02	(0.01-0.02)
2012	0.47	(0.35-0.59)	0.02	(0.01-0.02)
2013	0.44	(0.33-0.56)	0.02	(0.01-0.02)
2014	0.45	(0.33-0.57)	0.02	(0.01-0.02)
2015	0.59	(0.44-0.73)	0.02	(0.02-0.03)
2016	0.46	(0.34-0.57)	0.02	(0.01-0.02)

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 F divided by F_{SPR}.

`tab:SPR_Exploit_mod2`

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.02	(0-0.06)	0.00	(0-0)
2008	0.01	(0-0.02)	0.00	(0-0)
2009	0.02	(0-0.05)	0.00	(0-0)
2010	0.01	(0-0.02)	0.00	(0-0)
2011	0.01	(0-0.04)	0.00	(0-0)
2012	0.01	(0-0.04)	0.00	(0-0)
2013	0.01	(0-0.04)	0.00	(0-0)
2014	0.01	(0-0.04)	0.00	(0-0)
2015	0.02	(0-0.05)	0.00	(0-0)
2016	0.01	(0-0.02)	0.00	(0-0)

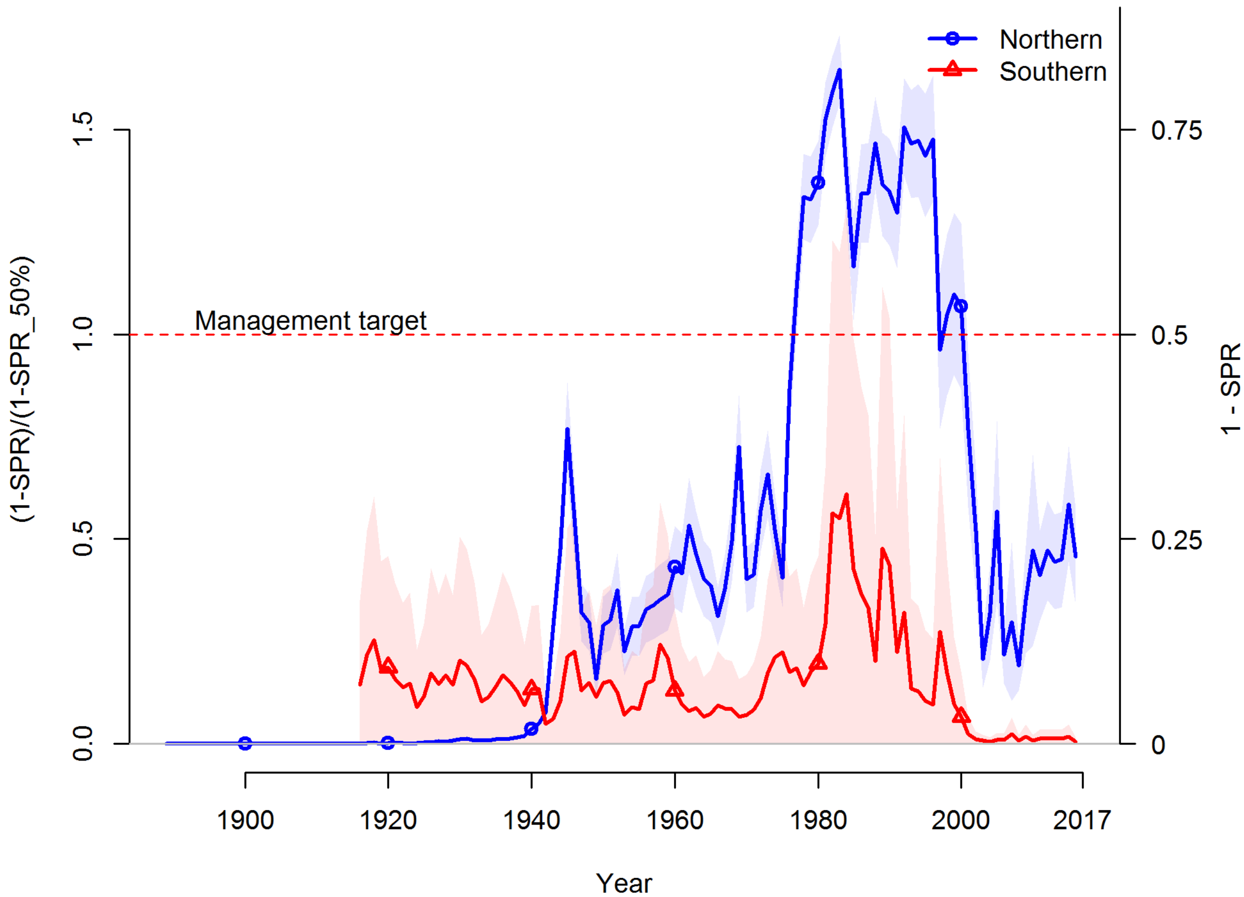


Figure g: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

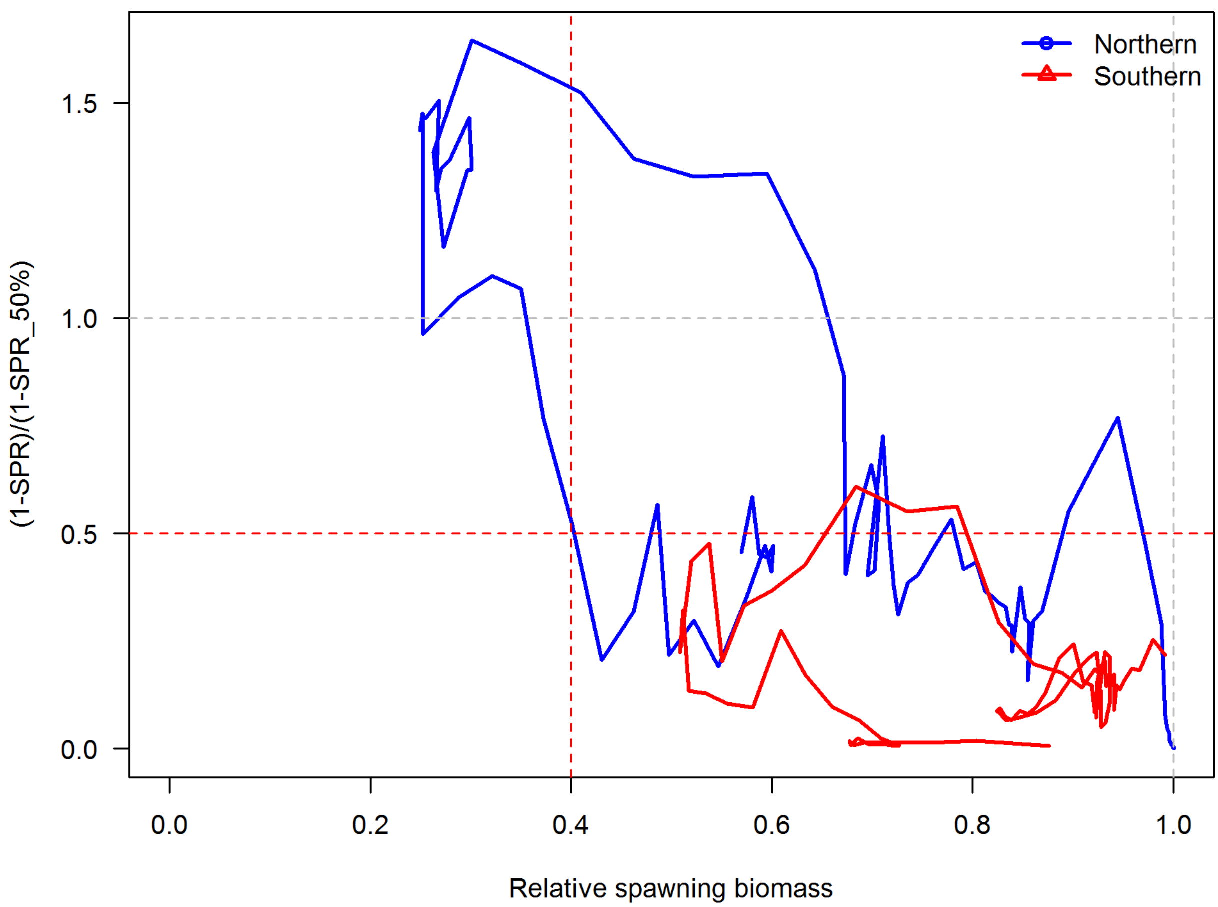


Figure h: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the unfished spawning biomass. fig:Phase_all

Ecosystem Considerations

ecosystem-considerations

In this assessment, ecosystem considerations were.....

Reference Points

reference-points

Include: management targets and definition of overfishing, including the harvest rate that brings the stock to equilibrium at $B_{40\%}$ (the B_{MSY} proxy) and the equilibrium stock size that results from fishing at the default harvest rate (the F_{MSY} proxy). Include a summary table that compares estimated reference points for SSB, SPR, Exploitation Rate and Yield based on SSBproxy for MSY, SPRproxy for MSY, and estimated MSY values

Write intro paragraph....and remove text for Models 2 and 3 if not needed

This stock assessment estimates that Yellowtail Rockfish in the Northern model are above the biomass target, but above the minimum stock size threshold. Add sentence about spawning output trend. The estimated relative depletion level for Model 1 in 2016 is 56.7% (~95% asymptotic interval: ± 45.4%-68.1%, corresponding to an unfished spawning output of 8.18588 trillion eggs (~95% asymptotic interval: 5.9-10.47 trillion eggs) of spawning output in the base model (Table i). Unfished age 4+ biomass was estimated to be 132.7 mt in the base case model. The target spawning output based on the biomass target ($SB_{40\%}$) is 5.8 trillion eggs, which gives a catch of 4116.9 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 3882.8 mt.

This stock assessment estimates that Yellowtail Rockfish in the Southern model are above the biomass target, but above the minimum stock size threshold. Add sentence about spawning output trend. The estimated relative depletion level for Model 2 in 2016 is 98% (~95% asymptotic interval: ± 75.5%-120%), corresponding to an unfished spawning output of 5.68452 trillion eggs (~95% asymptotic interval:) of spawning output in the base model (Table j). Unfished age 4+ biomass was estimated to be 117.6 mt in the base case model. The target spawning output based on the biomass target ($SB_{40\%}$) is 2.3 trillion eggs, which gives a catch of mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 3136.4 mt.

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

tab:Ref_pts_mod1

Quantity	**Estimate**	**95% Confidence Interval**
Unfished spawning output (trillion eggs)	14.4	(12.2-16.7)
Unfished age 4+ biomass (1000 mt)	132.7	(113.8-151.7)
Unfished recruitment (R0, millions)	30.3	(21.2-39.5)
Spawning output(2016 trillion eggs)	8.2	(6-10.5)
Relative Spawning Biomass (depletion)2016)	0.5694	(0.4547-0.6842)
Reference points based on $\mathbf{SB_{40\%}}$		
Proxy spawning output ($B_{40\%}$)	5.8	(4.9-6.7)
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.4589	(0.4589-0.4589)
Exploitation rate resulting in $B_{40\%}$	0.0545	(0.0521-0.0568)
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	4116.9	(3434-4799.7)
Reference points based on SPR proxy for MSY		
Spawning output	6.4	(5.4-7.4)
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.0483	(0.0462-0.0504)
Yield with SPR_{proxy} at SB_{SPR} (mt)	3882.8	(3242-4523.6)
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	3.4	(2.8-3.9)
SPR_{MSY}	0.3094	(0.3046-0.3142)
Exploitation rate at MSY	0.0833	(0.0793-0.0872)
MSY (mt)	4596.2	(3816-5376.4)

Table j: Summary of reference points and management quantities for the base case Southern model.

tab:Ref_pts_mod2

Quantity	Estimate	95% Confidence Interval
Unfished spawning output (trillion eggs)	5.8	(-3.1787-14.8)
Unfished age 4+ biomass (1000 mt)	117.6	(-63.5774-298.8)
Unfished recruitment (R0, millions)	37.3	(-20.3528-95)
Spawning output(2016 trillion eggs)	5.1	(-3.4779-13.6)
Relative Spawning Biomass (depletion)2016)	0.8763	(0.6849-1.1)
Reference points based on $\mathbf{SB_{40\%}}$		
Proxy spawning output ($B_{40\%}$)	2.3	(-1.2714-5.9)
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.4589	(0.4589-0.4589)
Exploitation rate resulting in $B_{40\%}$	0.0579	(0.0564-0.0595)
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	3314	(-1804.9955-8432.9)
Reference points based on SPR proxy for MSY		
Spawning output	2.6	(-1.4163-6.6)
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.0511	(0.0497-0.0524)
Yield with SPR_{proxy} at SB_{SPR} (mt)	3136.4	(-1707.975-7980.7)
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	1.4	(-0.7714-3.6)
SPR_{MSY}	0.3172	(0.3138-0.3206)
Exploitation rate at MSY	0.0891	(0.0869-0.0913)
MSY (mt)	3649	(-1988.6596-9286.7)

Management Performance

management-performance

Include: catches in comparison to OFL, ABC and OY/ACL values for the most recent 10 years (when available), overfishing levels, actual catch and discard. Include OFL(encountered), OFL(retained) and OFL(dead) if different due to discard and discard mortality.

Management performance table: Table k

Table k: Recent trend in total catch and commercial landings (mt) relative to the management guidelines. Estimated total catch reflect the commercial landings plus the model estimated discarded biomass.

tab:mnmgt_perform

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Estimated total catch (mt)
2007	-	-	-	-
2008	-	-	-	-
2009	-	-	-	-
2010	-	-	-	-
2011	-	-	-	-
2012	-	-	-	-
2013	-	-	-	-
2014	-	-	-	-
2015	-	-	-	-
2016	-	-	-	-
2017	-	-	-	-
2018	-	-	-	-

Unresolved Problems And Major Uncertainties

unresolved-problems-and-major-uncertainties

TBD after STAR panel

Decision Table(s) (groundfish only)

decision-tables-groundfish-only

Include: projected yields (OFL, ABC and ACL), spawning biomass, and stock depletion levels for each year. Not required in draft assessments undergoing review.

OFL projection table: Table l

Decision table(s) Table m and Table n

`Yield curve: Figure \ref{fig:Yield_all}`

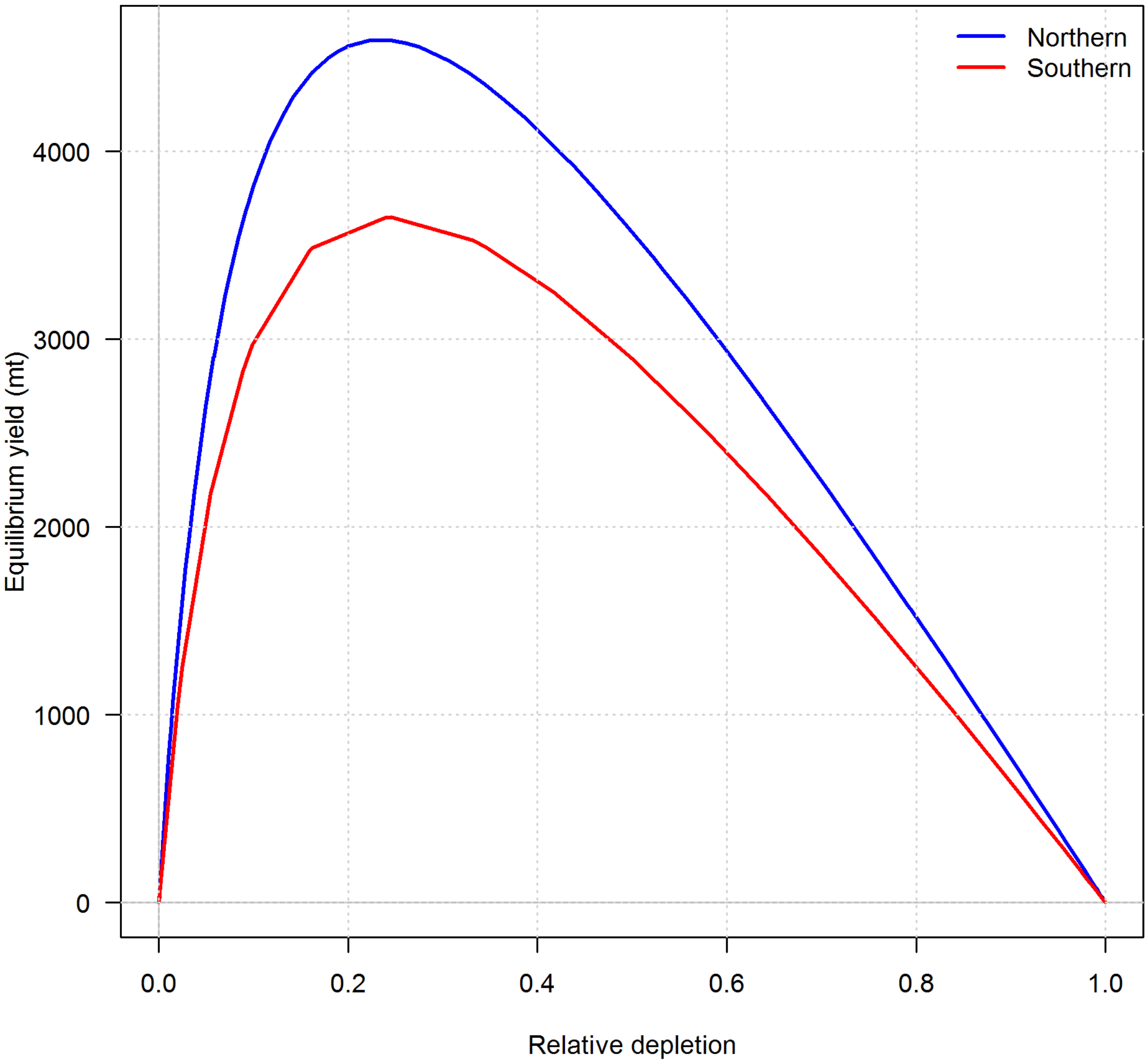


Figure i: Equilibrium yield curve for the base case models. fig:Yield_all

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

tab:OFL_projection

Year	Model 1	Model 2	Total
2017	4442.62	8532.88	12975.50
2018	4253.88	8218.96	12472.84
2019	4091.96	7829.98	11921.94
2020	3963.19	7411.41	11374.60
2021	3875.23	6992.17	10867.40
2022	3829.28	6588.47	10417.75
2023	3818.58	6210.08	10028.66
2024	3831.98	5862.74	9694.72
2025	3858.22	5549.17	9407.39
2026	3888.53	5269.82	9158.35
2027	3917.23	5023.55	8940.78
2028	3941.29	4808.12	8749.41

Table m: Summary of 10-year projections beginning in 2018 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. An entry of "–" indicates that the stock is driven to very low abundance under the particular scenario.

tab:Decision_table_mod1

			States of nature					
			Low M 0.05		Base M 0.07		High M 0.09	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
40-10 Rule, Low M	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
40-10 Rule	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
40-10 Rule, High M	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
Average Catch	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-

Table n: Summary of 10-year projections beginning in 2018 for alternate states of nature based on an axis of uncertainty for the Southern model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. An entry of "–" indicates that the stock is driven to very low abundance under the particular scenario.

tab:Decision_table_mod2

			States of nature					
			Low M 0.05		Base M 0.07		High M 0.09	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
40-10 Rule, Low M	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
40-10 Rule	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
40-10 Rule, High M	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Average Catch	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-

Table o: Yellowtail Rockfish base case results summary.

tab:base_summary

Model Region	Quantity	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	Landings (mt)										
	Total Est. Catch (mt)										
	OFL (mt)										
	ACL (mt)										
Model 1	(1-SPR)(1-$SPR_{50\%}$)	0.19	0.35	0.47	0.41	0.47	0.44	0.45	0.59	0.46	
Base Case	Exploitation rate	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
	Age 4+ biomass (mt)	84.43	84.93	83.80	84.55	82.56	84.38	83.12	83.43	82.79	81.56
	Spawning Output	7.9	8.3	8.6	8.7	8.7	8.6	8.5	8.4	8.2	8.2
	95% CI	(5.79-9.98)	(6.13-10.45)	(6.34-10.77)	(6.41-10.9)	(6.42-10.94)	(6.34-10.85)	(6.23-10.73)	(6.13-10.62)	(5.96-10.48)	(5.9-10.47)
	Depletion	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	95% CI	(0.415-0.678)	(0.442-0.707)	(0.461-0.726)	(0.469-0.731)	(0.474-0.73)	(0.472-0.719)	(0.468-0.708)	(0.464-0.697)	(0.455-0.684)	(0.454-0.681)
	Recruits	41.17	12.42	26.22	17.76	18.73	30.71	28.43	28.52	28.31	28.29
	95% CI	(25.53 - 66.41)	(6.11 - 25.24)	(14.25 - 48.26)	(8.17 - 38.58)	(7.45 - 47.06)	(10.59 - 89.07)	(9.78 - 82.61)	(10.06 - 80.85)	(10 - 80.14)	(9.99 - 80.09)
Model 2	(1-SPR)(1-$SPR_{50\%}$)	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	
Base Case	Exploitation rate	0	0	0	0	0	0	0	0	0	
	Age 4+ biomass (mt)	76.70	79.02	79.53	78.85	78.88	112.66	122.55	148.50	160.74	167.87
	Spawning Output	4	4	4	4	4	4	4	5	5	6
	95% CI	(0-10.7)	(0-10.65)	(0-10.7)	(0-10.84)	(0-11.03)	(0-11.36)	(0-11.79)	(0-12.52)	(0-13.64)	(0-15.25)
	Depletion	0.68	0.68	0.68	0.69	0.70	0.73	0.76	0.80	0.88	0.98
	95% CI	(0.529-0.828)	(0.531-0.823)	(0.537-0.826)	(0.546-0.837)	(0.557-0.852)	(0.574-0.88)	(0.598-0.913)	(0.633-0.974)	(0.685-1.068)	(0.755-1.205)
	Recruits	234.32	66.93	170.66	81.72	59.53	62.96	46.19	37.77	35.70	36.73
	95% CI	(48.85 - 1124.05)	(8.28 - 541.34)	(28.63 - 1017.09)	(11.33 - 589.32)	(8.75 - 404.76)	(10.56 - 375.27)	(7.64 - 279.12)	(6.4 - 222.96)	(5.83 - 218.81)	(6 - 225)

Research And Data Needs

research-and-data-needs

Include: identify information gaps that seriously impede the stock assessment.

We recommend the following research be conducted before the next assessment:

1. List item No. 1 in the list
2. List item No. 2 in the list, etc.

Rebuilding Projections

rebuilding-projections

Include: reference to the principal results from rebuilding analysis if the stock is overfished. This section should be included in the Final/SAFE version assessment document but is not required for draft assessments undergoing review. See Rebuilding Analysis terms of reference for detailed information on rebuilding analysis requirements.

1 Introduction

introduction

1.1 Basic Information

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).

Once thought to comprise a single stock, a recent genetic study indicates that there are in fact two sub-species, with a genetic cline at Cape Mendocino, California, roughly 40°10′ North Latitude (Hess et al. n.d.). 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 the first attempt to do so.

Yellowtail rockfish are colloquially known as "greenies", although *flavidus* is Latin for "yellow" (Love 2011). We have summarized yellowtail rockfish life history, fisheries, assessment and management here, but in-depth, extensive background information on yellowtail and other managed species is available at (Council 2016).

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

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 can 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). Yellowtail 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 2.3 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).

1.3 Fishery and Management History

fishery-and-management-history

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).

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 canary rockfish catch, 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 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 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-moderate analysis (Cope et al. 2013).

1.4 Assessment History

assessment-history

Early studies of yellowtail 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 53shows the timeseries of age 4+ biomass for Yellowtail Rockfish across past assessments.

The yellowtail 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.

Include: Management performance tables comparing Overfishing Limit (OFL), Annual Catch Limit (ACL), Harvest Guideline (HG) [CPS only], landings, and catch (i.e., landings plus discard) for each area and year.

Management performance table: (Table k)

A summary of these values as well as other base case summary results can be found in Table o.

1.5 Fisheries off Canada, Alaska, and/or Mexico

fisheries-off-canada-alaska-andor-mexico

The 2015 Stock Assessment conducted by the Department of Fisheries and Oceans (DFO) found the stock to be at 0.49B0, in the "healthy" range.

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

data

Data used in the Northern and Southern yellowtail rockfish assessments are summarized in Figures 6 and 58.

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.

2.1 Northern Model Data

northern-model-data

Summary of the data sources in the Northern model.

tab:Data_sources

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

2.1.1 Commercial Fishery Landings

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.

2.1.2 Sport Fishery Removals

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.

2.1.3 Estimated Discards

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.

2.1.4 Abundance Indices

abundance-indices

Commercial Logbook CPUE

The commercial logbook (fish-ticket) data in PacFIN was used to generate an index 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 modeled with a modified Stephens-MacCall approach (Stephens and MacCall 2004). This approach uses the species composition of the catch 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 from the index that could not encounter yellowtail.

Usually, the Stephens-MacCall approach is a simple binomial model for presence-absence of the predictive species and the target, however a generalized linear mixed-effects approach – modeling the species as binomial and adding random effects for the interaction of year and vessel, for haul duration, and for month improved the model fit.

The hauls identified with a reasonable probability of encountering yellowtail were then modeled in a delta-lognormal glm to produce an annual index of abundance, bootstrapped 500 times to evaluate uncertainty.

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 et al. YYYY) 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.

2.1.5 Fishery-Independent Data

`fishery-independent-data`

Northwest Fisheries Science Center (NWFSC) shelf-slope survey

This survey, referred to as the **NWFSCcombo Survey**, has been conducted annually starting in 2003. 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). 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.

Both lognormal and gamma distributions were explored for the positive tows and produced similar results with the lognormal model showing better patterns in Q-Q plot. 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. A design-based index extrapolated from swept area densities without any geostatistical standardization shows a more dramatic increase from 2015 to 2016.

Length and age compositions were also developed from this survey.

Alaska Fisheries Science Center (AFSC) Triennial shelf survey

The **Triennial Survey** was conducted by the AFSC every third year between 1977 and 2001, (and was conducted in 2004 by the NWFSC using the same protocols). The 1977 survey had incomplete coverage and is not believe to be comparable to the later years. 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.

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. The index shows a gradual decline from 1980 to 1992 followed by high variability in the final 4 points spanning 1995-2004.

2.1.6 Biological Samples

`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.

tab:Length_sources

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

Age structure data were available from the following sources:

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

tab:Age_sources

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

2.2 Southern Model Data

southern-model-data

Summary of the data source in the Southern model.

tab:Data_sources

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
SmallResearch		Y	Y	Y		Study

2.2.1 Commercial Fishery Landings

commercial-fishery-landings-1

California Commercial Landings
The California Commercial Fishery Database (**CalCOM**) provided landings in California south of 40° 10'N for 1969-2016.

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.

2.2.2 Sport Fishery Removals

sport-fishery-removals-1

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.

Small Research Study A small number of fish were collected from the recreational fishery by the SWFSC and are included in the data for 1978-1984.

2.2.3 Estimated Discards

estimated-discards-1

No discard data were available for the Southern model.

2.2.4 Abundance Indices

abundance-indices-1

MRFSS Index

An index of abundance was developed from trip-aggregated MRFSS data for the years 1980-1989, 1992-2003.

California Onboard Survey

An Onboard recreational survey conducted by provided data for an index of abundance provided by the SWFSC for 1987-2016.

Research Study Index An index of abundance for the small juvenile fish research study was provided by the SWFSC for 2001-2016.

2.2.5 Fishery-Independent Data

fishery-independent-data-1

Hook and Line Survey

The NWFSC Hook and Line survey provided data for an index in the Southern California Bight from 2004-2016.

2.2.6 Biological Samples

biological-samples-1

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.

tab:Length_sources

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

Age structure data were available from the following sources:

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

tab:Age_sources

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

2.3 Biological Parameters Common to Both Models

bio-params
biological-parameters-common-to-both-models

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.).

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 $\beta = 3.0672$.

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).

Natural Mortality Natural Mortality priors were provided by Owen Hamel (pers. comm.). See Section 3.2.5 for further discussion.

Sex ratios

The largest fish seen in the data are females, however the oldest are males. The sex ratio falls off differently in each model, as can be seen in Figs(x,y).

2.3.1 Environmental Or Ecosystem Data Included In The Assessment

`environmental-or-ecosystem-data-included-in-the-assessment`

No environmental index is present in either model.

3 Assessment

assessment

3.1 History Of Modeling Approaches Used For This Stock

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. n.d.). 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.

3.1.1 Previous Assessment Recommendations

previous-assessment-recommendations

Many of the recommendations of the previous STAR panel are not relevant to this assessment, as they related to data deficiencies at that time that have since been resolved. The 2004 STAR particularly recommended a focus on abundance indices, which they noted might require further survey information.

This assessment provides four indices for the Northern model, and three for the Southern model. All indices are newly developed for this analysis.

3.2 Model Description

model-description

3.2.1 Transition To The Current Stock Assessment

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. n.d.). 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.

3.2.2 Definition of Fleets and Areas

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 Appendix **??**.

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). These catches are recorded and biological sampling takes place but the fish are processed at sea (typically into fish meal) and are not included in the PacFIN database, so this fishery requires separate analysis. 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 for two reasons: first, the length composition of the Washington catches were different from those in the recreational landings in Oregon and northern California (MRFSS/RecFIN data). There are very large fish in this dataset, and fewer small ones. Second, the WA_Sport landings are not available by weight, so they are entered in the model as numbers, andStock 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. Details on the workup of the CPUE (in biomass/area towed) can be found in Appendix **??**.

The Northwest Fisheries Science Center's NWFSCcombo survey provides age- and length-compositions, as well as an index of abundance. Details on the workup of the CPUE (in biomass/area towed) can be found in Appendix **??**.

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: Fish per angler-hour is the basis for the Washington_Sport and Pikitch 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 fish per tow.

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 in Appendix **??**.

California Onbord 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.

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: A separate index, length comps and a single year of ages reflect a small study of juvenile fish conducted by the SWFSC.

3.2.3 Modeling Software

`modeling-software`

The STAT team used Stock Synthesis 3 (Methot 2015), which is the Pacific Fishery Management Council's preferred modeling platform for assessments.

3.2.4 Data Weighting

`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 uses either the Francis method (Francis 2011) or the Ianelli-McAllister harmonic mean method (McAllister and Ianelli 1997). The Francis method was used for all fleets, except for the age data from the Southern model's Hook and Line survey, which is a single year of data to which we applied the Ianelli-McAllister method.

3.2.5 Priors priors

priors

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 lna(5.4/Amax) and SE = 0.4384343.

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. In the Northern model, both the female value and the male offset could be estimated without priors so the priors were not used. 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 (commonly used in past West Coast rockfish assessments) conducted by James Thorson (personal communication, NWFSC, NOAA) 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

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 https://DEVORE

3.2.7 Estimated And Fixed Parameters

estimated-and-fixed-parameters

A full list of all estimated and fixed parameters is provided in Tables.... Estimated and fixed parameters tables currently read in from .csv file, EXAMPLE: Table **??**

Growth 5 parameters for female growth are estimated in each model: 3 von Bertalanffy parameters and 2 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. Natural Mortality is fixed in the Southern model at the values provided by the Hamel (2015) analysis described above.

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.

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 19xx to 2013. For the Southern model recruitment deviations are estimated from 19xx to 2013. list range of years for each model with some comment as to how this range was chosen.

A parameter for extra standard deviation was added to the index based on bycatch in the at-sea hake fishery, because this index was not well fit by any of the models considered.

3.3 Model Selection and Evaluation

model-selection-and-evaluation

3.3.1 Key Assumptions and Structural Choices

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

alternate-models-considered

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.

These approaches resulted in model fits to data that were obviously poor, and so they were rejected

3.3.3 Convergence

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 Northern model report jittering when it's been done.

3.4 Response To The Current STAR Panel Requests

`response-to-the-current-star-panel-requests`

Request No. 1: Add after STAR panel.

Rationale: Add after STAR panel.

STAT Response: Add after STAR panel.

Request No. 2: Add after STAR panel.

Rationale: Add after STAR panel.

STAT Response: Add after STAR panel.

Request No. 3: Add after STAR panel.

Rationale: Add after STAR panel.

STAT Response: Add after STAR panel.

Request No. 4: Example of a request that may have a list:

- **Item No. 1**
- **Item No. 2**
- **Item No. 3, etc.**

Rationale: Add after STAR panel.

STAT Response: Continue requests as needed.

3.5 Life History Results for both models

life-history-results-for-both-models

Maturity in the model was estimated outside the model at the Northwest Fisheries Science Center by Melissa Head, and is shown in Figure 3.

Figure 4 shows the results of the analysis of the Weight-Length relationship estimated and used as fixed input for both models.

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

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{fig:ssb.N}. 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 48 shows the total biomass following a similar pattern; the ending value is 86070 metric tonnes.

The relative spawning output (Figure 49) 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 57% (see Table **??**).

Figures 50 and 51 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 Methot et al. (2011)) which is slightly lower than what has been assumed or estimated for other rockfish in the California Current. The stock-recruit curve, Figure 52 shows a shallow relationship between stock size and recruitment.}

3.6.1 Selectivities, Indices and Discards

selectivities-indices-and-discards

Selectivities in the Northern model (Figure 9) shows 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 **??**) 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

lengths

Bubble plots for the lengths in the fishery (Figure 17) 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. That the WA_Sport fishery catches larger fish is represented in the large bubbles at the top of the panel. Had we examined that fishery earlier in the process of putting the model together, we might have settled on a larger maximum size bin, however that fishery remains the smallest portion of the catches.

Commercial length comps are very well fit (Figures **??** and **??**). Commercial discards are noiser and not well fit (Figure **??**). The panel describing the combined fits and data weighting for the commercial fishery is duplicted, need to remove redundant figure.

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 (Figure **??**). Figure **??** shows that the fits in the early period have twice (at last) the uncertainty of the later period.

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 **??** and **??**).

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

The Triennial lengths Figures **??** and 30 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 fit that may represent a good recruitment several years earlier Figures **??** and **??**.

Figure 33 shows the relative fits among the data sources, aggregated across time. The timeseries of presence-absence residuals indicated by filled- and open-bubbles Figure 34 and Figure 35 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

ages

The NWFSCcombo survey provided the only source of 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 **??** are quite good from about 1979 on, even fitting the tail where the ages beyond 55 are lumped. The weightings panel Figure **??** 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 **??** and Figure **??**.

The Triennial ages are noisy but are fit surprisingly well **??**; 41. 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 42, for comparison. Agreggated fits for the Commercial and Triennial fleets are very satisfying.

The Ghost age comps Figure **??** for the NWFSCcombo survey are the marginal age comps 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. It is interesting that the model fits this aggregated data poorly, but the disaggregated data well. This may be due to the fact that for marginal ages, the data are weighted interannually with number of tows or trips, but this ghost fleet is unweighted.

Pearson residuals for the marginal age comps, are shown in the bubble plots in Figure **??**. 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 fits to the length-aggregate NWFSCcombo data show more variation in mean age in the population in latter years than might be expected in years with relatively low landings Figure **??**. These 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 shown in Figure 46. 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.

3.7 Northern Model Parameters

`northern-model-parameters`

For the Base model, the parameter fits are given in Table **??**. Status for all of the estimated parameters is good, with the exception of the 6th parameter for the selectivity in the Washington Sport fishery.

3.7.1 Northern Model Uncertainty and Sensitivity Analyses

`section`

Table 7

3.7.2 Northern Model Retrospective Analysis

`northern-model-retrospective-analysis`

3.7.3 Northern Model Likelihood Profiles

`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: **R0**, 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) R0 are shown in Figure 54. This plot shows the tension between the index data and the other data sources. The indices are better fit with a smaller value of R0, near 9.6, while all other data sources are better fit at larger values. The overall likelihood in the model is lowest at 10.3 in this figure. The discards show very little change (are insensitive) over this range of R0, while the recruitments, ages and lengths are all minimized at values larger than 10.5.

The likelihood profile over female natural mortality, MF, is over a range from 0.1 to 0.24 (Figure 55). 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 56 shows the likelihood profile for male natural mortality, MM, over a range of negative values that are the offset from female mortality (FM). The index data are again at odds with the other data sources; all but the indices are minimized at a value of -0.15. Male natural mortality is represented as an offset from that for females based on the equation $MM = MF * exp(offset)$, 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 profile over values of steepness, h, from 0.5 to 0.9, Figure 57, 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; it is roughly a tenth of the scale of the R0 plot, meaning 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.

3.7.4 Northern Model Reference Points

`northern-model-reference-points`

Intro sentence or two....(Table 8).

Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is

Knit kept whining about missing ref pts table, wouldn't work, took out ref.

shows the full suite of estimated reference points for the northern area model and Figure i shows the equilibrium yield curve.

3.8 Southern Model Base Case Results

southern-model-base-case-results

Data used in the Southern model is shown in Figure 58.

One thing to point out is that although the scale of the biomass in the model is somewhat sensitive to various data sources, the depletion is not. In tuning the model we were suprised to note that depletion always stayed above 80%.

Estimated catches are shown in Figure 59.

The estimated spawning biomass in Figure 85 shows the size of the uncertainty in this model. Total biomass (Figure 86) shows a sharp upward trend in recent years, the decade with only one year of age data from the Hook-and-Line Survey. Spawning depletion has sinuous curves and was likely never as low as the 40% target, even in the 1980s-1990s (Figure 87.

Recruitments have been constant, except 2008 and 2010, when the model sees extra large recruitments with extra large recruitment deviations (Figures 88 and 89). The spawner-recruit curve, Figure 90 is a line.

3.8.1 Southern Model Selectivities, Indices and Discards

southern-model-selectivities-indices-and-discards

Selectivity by fleet is shown in Figure 60. 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 45-50 cm.

Index fits leave something to be desired. All are more-or-less flat, with all of the three current indices, the Onboard, the Juvenile study and the Hook-and-Line survey all missing a downturn at the end of the timeseries. During model tuning, we tried introducing a time-blocked index for the two periods of the Onboard survey, however it didn't improve the fit to the index significantly, and increased the (negative log) likelihood of the model.

There was little information to inform the Southern 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.

3.8.2 Southern Model Lengths

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 62. 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 63 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 is fit fairly well: Figure **??**

The Commercial length comps are fit well through 2005, when data becomes sparse and noisy Figure 65; and Figure 66.

Fits for the Onboard Survey lengths are good in the early survey, and poor for the later period 67; 68. Attempting to apply a time-block to this data resulted in poor convergence.

The Hook-and-Line Survey lengths are noisy (Figure 69), but the fits are acceptable, and follow the trend of the data better than those for the other datasets: Figure 70.

The small fish survey lengths are not fit badly 71; 72, 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 73, and Pearson residuals for the lengths in Figure 74. Filled bubbles represent under-estimation of the data, open bubbles represent overestimation.

3.8.3 Southern Model Ages

`southern-model-ages`

There are few marginal ages in the model. Bubble plots for the Southern model ages (Figure **??**) show the small sample from the Juvenile 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 **??** shows the fit to the Juvenile Fish samples, which is poor in all four years. The mean age in this data is shown in Figure **??**, at 10 years.

The Hook-and-Line Survey age "fit" is shown in Figure ??. Mean age could not be calculated for the single year of data, as it is a inter-annual mean.

The aggregated fits for the marginal, and I *do* mean *marginal* ages are shown in Figure 80. They speak for themselves.

The ghost fleet commercial comps aggregated as a marginal timeseries is shown in Figure ??. This figure is included for informational purposes only; ghosts do 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 Juvenile Study and the Hook-and-Line Survey are shown in Figure 82. 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 ghost fleet. Figure **??** 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 84) show good fits in all years except 2001-2002 ("the sparse years, when we had to eat Gefilte-miltz").

3.8.4 Southern Model Uncertainty and Sensitivity Analyses

`southern-model-uncertainty-and-sensitivity-analyses`

3.8.5 Southern Model Retrospective Analysis

`southern-model-retrospective-analysis`

3.8.6 Southern Model Likelihood Profiles

`southern-model-likelihood-profiles`

We profiled the change in negative log likelihood for the data sources and model total likelihood for critical parameters fixed in the model: **R0**, 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 **R0** is shown in Figure 91. R0 was profiled over values from 8.5 -11. The figure shows that the age data and indices are minimized when R0 is 11; the length data are minimized around 8.5, and the recruitments at 9.8 (or so). The overall likelihood is minimized near 10.5.

The female natural mortality (FM) profile, 92 ranges from 0.1 to 0.24. The age and length data sources are at odds over FM; the ages and recruitments are minimized when FM is the low end of the range, and the lengths and indices when it is highest. Changes to the recruitment likelihood is minimal over the whole range. The overall likelihood is minimized near 0.22.

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 $MM = MF * exp(offset)$, 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 93); 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 20 (lengths) and 80 (ages) likelihood values.

The steepness profile (Figure 94is the most colorful, as the lines bounce around and change direction, however the likelihood scale is from 0 to 0.7, meaning that none of the values in this range (0.5 - 0.9) would have much impact on likelihood in the model. This supports the conclusion that the stock is abundant. For a depleted stock, steepness would have a very large impact on the likelihood.

3.8.7 Southern Model Reference Points

southern-model-reference-points

3.9 Comparison of the Northern and Southern Model Results.

comparison-of-the-northern-and-southern-model-results.

No text yet

4 Harvest Projections and Decision Tables

harvest-projections-and-decision-tables

Table k

** Northern Model Projections and Decision Table (groundfish only)** (Table 9

Table m

** Southern Model Projections and Decision Table (groundfish only)**

5 Regional Management Considerations

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 Needs

research-needs

1. A longer timeseries of the juvenile rockfish CPUE in the south.

2. A commercial index in the north. This is by far the largest segment of the fishery, and the introduction of trawl rationalization program should mean that an index can be developed for the current fishery when the next assessment is performed.

3. More recent ages for the southern model. The commercial age timeseries currently stops in 2002.

7 Acknowledgments

`acknowledgments`

The authors thank the following individuals for their contributions to this assessment:

Washington Department of Fish and Wildlife staff: Theresa Tsou and Phillip Weyland

Oregon Department of Fish and Wildlife staff: Alison Whitman and Troy Buell

California Department of Fish and Wildlife staff: John Budrick

Southwest Fisheries Science Center staff: Melissa Monk, E.J. Dick, and Don Pearson

Northwest Fisheries Science Center staff: Jim Hastie, Chantel Wetzel, Beth Horness, Melissa Head, John Wallace, Vanessa Tuttle, James Thorson and Owen Hamel

RecFIN staff: Rob Ames

John DeVore, Pacific Fisheries Management Council staff

John Field, STAR panel Chair, SWFSC

CIE Reviewers: Panagiota Apostolaki and Kevin Stokes

John Budrick, CDFW

Jessi Doerpinghaus, WDFW and Pacific Fishery Management Council / Groundfish Management Team

Dan Waldeck, Pacific Fishery Management Council / Groundfish Advisory Panel

8 Tables

tables

8.1 Northern Model Tables

northern-model-tables

Table 1. Catch timeseries for the Northern model.

Year	Commercial Trawl	Hake Bycatch	Rec CA and OR	Rec WA
1889	0.130	0.000	0.000	0
1890	0.140	0.000	0.000	0
1891	0.250	0.000	0.000	0
1892	2.371	0.000	0.000	0
1893	2.081	0.000	0.000	0
1894	2.081	0.000	0.000	0
1895	0.565	0.000	0.000	0
1896	0.129	0.000	0.000	0
1897	0.131	0.000	0.000	0
1898	0.074	0.000	0.000	0
1899	0.126	0.000	0.000	0
1900	0.177	0.000	0.000	0
1901	0.228	0.000	0.000	0
1902	0.280	0.000	0.000	0
1903	0.331	0.000	0.000	0
1904	0.663	0.000	0.000	0
1905	0.434	0.000	0.000	0
1906	0.485	0.000	0.000	0
1907	0.537	0.000	0.000	0
1908	0.738	0.000	0.000	0
1909	0.640	0.000	0.000	0
1910	0.691	0.000	0.000	0
1911	0.742	0.000	0.000	0
1912	0.794	0.000	0.000	0
1913	0.845	0.000	0.000	0
1914	0.896	0.000	0.000	0
1915	1.048	0.000	0.000	0
1916	3.490	0.000	0.000	0
1917	5.917	0.000	0.000	0
1918	14.960	0.000	0.000	0
1919	4.695	0.000	0.000	0
1920	5.478	0.000	0.000	0
1921	7.192	0.000	0.000	0
1922	5.582	0.000	0.000	0
1923	3.139	0.000	0.000	0
1924	6.019	0.000	0.000	0

Continued on next page

Table 1. Catch timeseries for the Northern model.

Year	Commercial Trawl	Hake Bycatch	Rec CA and OR	Rec WA
1925	14.165	0.000	0.000	0
1926	15.039	0.000	0.000	0
1927	25.832	0.000	0.000	0
1928	23.610	0.000	0.130	0
1929	31.277	0.000	0.260	0
1930	44.509	0.000	0.300	0
1931	51.825	0.000	0.400	0
1932	34.422	0.000	0.500	0
1933	31.818	0.000	0.600	0
1934	30.575	0.000	0.690	0
1935	49.166	0.000	0.790	0
1936	49.321	0.000	0.890	0
1937	54.513	0.000	1.060	0
1938	66.117	0.000	1.040	0
1939	76.285	0.000	0.910	0
1940	149.448	0.000	1.310	0
1941	200.358	0.000	1.210	0
1942	323.924	0.000	0.640	0
1943	1338.800	0.000	0.620	0
1944	2374.280	0.000	0.510	0
1945	4438.180	0.000	0.670	0
1946	2666.850	0.000	1.160	0
1947	1351.190	0.000	0.920	0
1948	1222.360	0.000	1.840	0
1949	611.332	0.000	2.380	0
1950	1191.600	0.000	2.900	0
1951	1242.680	0.000	3.330	0
1952	1593.940	0.000	2.910	0
1953	883.619	0.000	2.480	0
1954	1151.700	0.000	3.100	0
1955	1152.670	0.000	3.720	0
1956	1339.530	0.000	4.160	0
1957	1372.880	0.000	3.560	0
1958	1424.560	0.000	6.120	0
1959	1470.120	0.000	5.570	0
1960	1785.550	0.000	4.140	0
1961	1678.250	0.000	3.110	0
1962	2248.650	0.000	3.640	0
1963	1844.920	0.000	2.530	0
1964	1532.230	0.000	1.940	0
1965	1430.030	0.000	3.200	0

Continued on next page

Table 1. Catch timeseries for the Northern model.

Year	Commercial Trawl	Hake Bycatch	Rec CA and OR	Rec WA
1966	1099.010	0.000	3.490	0
1967	1348.270	0.000	3.510	38
1968	1925.580	0.000	3.940	0
1969	3214.310	0.000	4.770	0
1970	1461.690	0.000	5.490	0
1971	1527.220	0.000	4.330	0
1972	2293.800	0.000	5.760	0
1973	2737.720	0.000	7.370	0
1974	1964.060	0.000	8.020	0
1975	1402.010	0.000	7.960	12
1976	3921.900	29.490	9.390	16
1977	5913.880	7.440	8.300	8
1978	8248.320	75.450	7.540	13
1979	7270.420	82.020	25.160	4
1980	7022.470	255.350	24.030	3
1981	9045.710	152.570	69.130	4
1982	9283.520	551.200	69.510	2
1983	9714.850	548.330	123.260	3
1984	4896.430	312.010	37.400	3
1985	3231.210	174.160	190.480	5
1986	4599.790	560.140	29.140	9
1987	4623.250	541.400	23.880	16
1988	6062.340	423.420	17.810	16
1989	4764.720	184.630	41.680	16
1990	4367.370	295.110	37.700	14
1991	3690.010	478.090	52.430	30
1992	5669.320	694.750	200.810	32
1993	5366.200	273.360	177.910	42
1994	5239.450	560.410	80.730	18
1995	4713.170	646.750	65.190	15
1996	5209.460	746.210	60.240	20
1997	1836.280	396.320	76.600	20
1998	2490.160	438.090	70.610	30
1999	2240.970	1198.560	45.350	11
2000	2905.630	635.300	27.360	13
2001	1898.940	213.370	26.110	9
2002	1024.690	189.920	27.280	4
2003	413.739	36.600	20.080	11
2004	568.282	47.560	18.770	22
2005	752.053	112.180	26.870	20
2006	357.589	108.710	23.360	14

Continued on next page

Table 1. Catch timeseries for the Northern model.

Year	Commercial Trawl	Hake Bycatch	Rec CA and OR	Rec WA
2007	276.397	78.710	17.780	15
2008	275.982	174.990	23.860	18
2009	538.738	176.160	16.850	28
2010	753.629	150.090	11.570	38
2011	1181.320	101.170	18.430	43
2012	1508.610	43.000	20.060	19
2013	1117.140	269.040	20.170	24
2014	1366.500	41.960	15.850	33
2015	1840.850	86.390	29.130	56
2016	1308.440	62.320	13.970	60

tab:Northern_catch

Table 2. Commercial discard timeseries for the Northern model.

tab:Northern_discard

Year	Discard
1981	0.0349
1982	0.0327
1983	0.0325
1984	0.0354
1985	0.0319
1986	0.0333
1987	0.0361
1988	0.0363
1989	0.0358
1990	0.0376
1991	0.0399
2002	0.0981
2003	0.0241
2004	0.2469
2005	0.5334
2006	0.1473
2007	0.6366
2008	0.0907
2009	0.3906
2010	0.4872
2011	0.0010
2012	0.0010
2013	0.0010
2014	0.0010
2015	0.0002

Table 3. Summary of the biomass/abundance time series used in the stock assessment.

tab:Index_summary

Years	Name	Fishery ind.	Method	Endorsed
1987-1998	Commercial Logbook	No	delta-GLM (bin-lognormal)	
1985-1999	Hake Bycatch	No	VAST	SSC
1977-2004	Triennial	Yes	VAST	SSC
2003-2016	NWFSCcombo	Yes	VAST	SSC

Table 4. CPUE timeseries for the Northern model.

tab:Northern_CPUE

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 5. Results from 100 jitters from each of the three models.

tab:jitter

Status	Model.1	Model.2	Model.3
Returned to base case	-	-	-
Found local minimum	-	-	-
Found better solution	-	-	-
Error in likelihood	-	-	-
Total	100	100	100

Table 6. List of parameters used in the 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	0.149	2	(0.02, 0.25)	OK	0.009	None
2	L_at_Amin_Fem_GP_1	15.094	3	(1, 25)	OK	0.556	None
3	L_at_Amax_Fem_GP_1	53.899	2	(35, 70)	OK	0.238	None
4	VonBert_K_Fem_GP_1	0.135	3	(0.1, 0.4)	OK	0.004	None
5	CV_young_Fem_GP_1	0.098	5	(0.03, 0.16)	OK	0.010	None
6	CV_old_Fem_GP_1	0.044	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	-0.142	2	(-3, 3)	OK	0.016	None
14	L_at_Amin_Mal_GP_1	0.000	-2	(-1, 1)			None
15	L_at_Amax_Mal_GP_1	-0.150	2	(-1, 1)	OK	0.005	None
16	VonBert_K_Mal_GP_1	0.381	3	(-1, 1)	OK	0.027	None
17	CV_young_Mal_GP_1	0.000	-5	(-1, 1)			None
18	CV_old_Mal_GP_1	0.168	5	(-1, 1)	OK	0.070	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)	10.320	1	(5, 20)	OK	0.154	None
27	SR_BH_steep	0.718	-6	(0.2, 1)			None
28	SR_sigmaR	0.546	-6	(0.5, 1.2)			None
29	SR_regime	0.000	-50	(-5, 5)			None

Continued on next page

Table 6. List of parameters used in the 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
140	LnQ_base_CommercialTrawl(1)	-4.443	-1	(-30, 15)			None
141	LnQ_base_HakeByCatch(2)	-9.851	-1	(-30, 15)			None
142	Q_extraSD_HakeByCatch(2)	0.297	1	(0, 0.5)	OK	0.086	None
143	LnQ_base_Triennial(5)	-1.004	-1	(-30, 15)			None
144	LnQ_base_NWFSCcombo(6)	-0.616	-1	(-30, 15)			None
145	SizeSel_P1_CommercialTrawl(1)	48.832	1	(20, 55)	OK	0.701	None
146	SizeSel_P2_CommercialTrawl(1)	70.000	-4	(-20, 70)			None
147	SizeSel_P3_CommercialTrawl(1)	4.286	3	(-5, 20)	OK	0.092	None
148	SizeSel_P4_CommercialTrawl(1)	70.000	-4	(-5, 70)			None
149	SizeSel_P5_CommercialTrawl(1)	-999.000	-99	(-999, 25)			None
150	SizeSel_P6_CommercialTrawl(1)	-999.000	-99	(-999, 25)			None
151	Retain_P1_CommercialTrawl(1)	24.650	3	(20, 55)	OK	3.300	None
152	Retain_P2_CommercialTrawl(1)	1.582	3	(0.1, 40)	OK	0.708	None
153	Retain_P3_CommercialTrawl(1)	3.071	3	(-10, 20)	OK	0.708	None
154	Retain_P4_CommercialTrawl(1)	0.000	-4	(-3, 3)			None
155	SizeSel_P1_HakeByCatch(2)	52.344	1	(20, 55)	OK	0.859	None
156	SizeSel_P2_HakeByCatch(2)	70.000	-4	(-20, 70)			None
157	SizeSel_P3_HakeByCatch(2)	4.281	3	(-5, 20)	OK	0.111	None
158	SizeSel_P4_HakeByCatch(2)	70.000	-4	(-5, 70)			None
159	SizeSel_P5_HakeByCatch(2)	-999.000	-99	(-999, 25)			None
160	SizeSel_P6_HakeByCatch(2)	-999.000	-99	(-999, 25)			None
161	SizeSel_P1_RecORandCA(3)	30.553	1	(20, 55)	OK	0.698	None
162	SizeSel_P2_RecORandCA(3)	4.047	4	(-20, 7)	OK	9229.460	None
163	SizeSel_P3_RecORandCA(3)	3.132	3	(-5, 20)	OK	0.230	None
164	SizeSel_P4_RecORandCA(3)	9.475	4	(-5, 20)	OK	17038.000	None
165	SizeSel_P5_RecORandCA(3)	-999.000	-99	(-999, 25)			None

Continued on next page

Table 6. List of parameters used in the 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)
166	SizeSel_P6_RecORandCA(3)	-999.000	-99	(-999, 25)			None
167	SizeSel_P1_RecWA(4)	28.338	6	(20, 55)	OK	0.919	None
168	SizeSel_P2_RecWA(4)	70.000	-4	(-20, 70)			None
169	SizeSel_P3_RecWA(4)	-1.427	6	(-5, 20)	OK	2.392	None
170	SizeSel_P4_RecWA(4)	70.000	-4	(-5, 70)			None
171	SizeSel_P5_RecWA(4)	-999.000	-99	(-999, 25)			None
172	SizeSel_P6_RecWA(4)	-999.000	-99	(-999, 25)			None
173	SizeSel_P1_Triennial(5)	54.793	1	(20, 55)	HI	4.207	None
174	SizeSel_P2_Triennial(5)	70.000	-4	(-20, 70)			None
175	SizeSel_P3_Triennial(5)	5.127	3	(-5, 20)	OK	0.316	None
176	SizeSel_P4_Triennial(5)	70.000	-4	(-5, 70)			None
177	SizeSel_P5_Triennial(5)	-999.000	-99	(-999, 25)			None
178	SizeSel_P6_Triennial(5)	-999.000	-99	(-999, 25)			None
179	SizeSel_P1_NWFSCcombo(6)	49.892	1	(20, 55)	OK	2.853	None
180	SizeSel_P2_NWFSCcombo(6)	70.000	-4	(-20, 70)			None
181	SizeSel_P3_NWFSCcombo(6)	4.544	3	(-5, 20)	OK	0.419	None
182	SizeSel_P4_NWFSCcombo(6)	70.000	-4	(-5, 70)			None
183	SizeSel_P5_NWFSCcombo(6)	-999.000	-99	(-999, 25)			None
184	SizeSel_P6_NWFSCcombo(6)	-999.000	-99	(-999, 25)			None
185	Retain_P3_CommercialTrawl(1)_BLK1repl_2002	2.228	6	(-10, 20)	OK	0.457	None
186	Retain_P3_CommercialTrawl(1)_BLK1repl_2003	3.708	6	(-10, 20)	OK	0.756	None
187	Retain_P3_CommercialTrawl(1)_BLK1repl_2004	1.129	6	(-10, 20)	OK	0.522	None
188	Retain_P3_CommercialTrawl(1)_BLK1repl_2005	-0.112	6	(-10, 20)	OK	0.400	None
189	Retain_P3_CommercialTrawl(1)_BLK1repl_2006	1.760	6	(-10, 20)	OK	0.260	None
190	Retain_P3_CommercialTrawl(1)_BLK1repl_2007	-0.514	6	(-10, 20)	OK	0.623	None
191	Retain_P3_CommercialTrawl(1)_BLK1repl_2008	2.370	6	(-10, 20)	OK	0.815	None
192	Retain_P3_CommercialTrawl(1)_BLK1repl_2009	0.481	6	(-10, 20)	OK	0.495	None

Continued on next page

Table 6. List of parameters used in the 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)
193	Retain_P3_CommercialTrawl(1)_BLK1repl_2010	0.161	6	(-10, 20)	OK	0.677	None
194	Retain_P3_CommercialTrawl(1)_BLK1repl_2011	7.316	6	(-10, 20)	OK	0.661	None

tab:model_params

Table 8. Time-series of population estimates from the base-case model.

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1889	132737	14	0.00	30370	0	0.00	1.00
1890	132737	14	1.00	30370	0	0.00	1.00
1891	132736	14	1.00	30370	0	0.00	1.00
1892	132718	14	1.00	30370	2	0.00	1.00
1893	132721	14	1.00	30370	2	0.00	1.00
1894	132721	14	1.00	30369	2	0.00	1.00
1895	132734	14	1.00	30369	1	0.00	1.00
1896	132737	14	1.00	30369	0	0.00	1.00
1897	132737	14	1.00	30369	0	0.00	1.00
1898	132738	14	1.00	30370	0	0.00	1.00
1899	132738	14	1.00	30370	0	0.00	1.00
1900	132737	14	1.00	30370	0	0.00	1.00
1901	132737	14	1.00	30370	0	0.00	1.00
1902	132736	14	1.00	30370	0	0.00	1.00
1903	132736	14	1.00	30370	0	0.00	1.00
1904	132733	14	1.00	30370	1	0.00	1.00
1905	132735	14	1.00	30370	0	0.00	1.00
1906	132734	14	1.00	30370	1	0.00	1.00
1907	132734	14	1.00	30371	1	0.00	1.00
1908	132732	14	1.00	30371	1	0.00	1.00
1909	132733	14	1.00	30371	1	0.00	1.00
1910	132733	14	1.00	30371	1	0.00	1.00
1911	132732	14	1.00	30371	1	0.00	1.00
1912	132732	14	1.00	30371	1	0.00	1.00
1913	132731	14	1.00	30371	1	0.00	1.00
1914	132731	14	1.00	30371	1	0.00	1.00
1915	132730	14	1.00	30371	1	0.00	1.00
1916	132708	14	1.00	30371	4	0.00	1.00
1917	132687	14	1.00	30371	6	0.00	1.00
1918	132609	14	1.00	30371	16	0.00	1.00
1919	132698	14	1.00	30370	5	0.00	1.00
1920	132691	14	1.00	30370	6	0.00	1.00
1921	132676	14	1.00	30370	8	0.00	1.00
1922	132690	14	1.00	30370	6	0.00	1.00
1923	132711	14	1.00	30370	3	0.00	1.00
1924	132686	14	1.00	30370	6	0.00	1.00
1925	132616	14	1.00	30370	15	0.00	1.00
1926	132608	14	1.00	30370	16	0.00	1.00
1927	132515	14	1.00	30369	27	0.00	1.00
1928	132533	14	1.00	30369	25	0.00	1.00

Table 8. Time-series of population estimates from the base-case model.

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1929	132465	14	1.00	30368	33	0.00	1.00
1930	132351	14	1.00	30367	47	0.00	0.99
1931	132286	14	1.00	30366	55	0.00	0.99
1932	132435	14	1.00	30061	37	0.00	1.00
1933	132457	14	1.00	30027	34	0.00	1.00
1934	132466	14	1.00	29987	33	0.00	1.00
1935	132305	14	1.00	29940	52	0.00	0.99
1936	132302	14	1.00	29883	53	0.00	0.99
1937	132256	14	1.00	29818	58	0.00	0.99
1938	132156	14	1.00	29744	70	0.00	0.99
1939	132069	14	1.00	29663	81	0.00	0.99
1940	131440	14	1.00	29575	158	0.00	0.98
1941	131008	14	0.99	29475	211	0.00	0.98
1942	129977	14	0.99	29362	340	0.00	0.96
1943	122219	14	0.99	29235	1402	0.01	0.86
1944	115294	14	0.97	29062	2485	0.02	0.76
1945	103942	14	0.94	28845	4645	0.04	0.62
1946	112462	13	0.90	28486	2792	0.02	0.72
1947	121077	13	0.87	28163	1415	0.01	0.84
1948	121990	12	0.86	27914	1281	0.01	0.85
1949	127016	12	0.85	27672	642	0.01	0.92
1950	122199	12	0.86	27382	1250	0.01	0.85
1951	121754	12	0.85	26905	1304	0.01	0.85
1952	119033	12	0.85	26274	1671	0.01	0.81
1953	124574	12	0.84	25652	927	0.01	0.89
1954	122350	12	0.84	25310	1208	0.01	0.86
1955	122297	12	0.84	25204	1210	0.01	0.86
1956	120757	12	0.83	24833	1406	0.01	0.84
1957	120421	12	0.83	23943	1440	0.01	0.83
1958	119898	12	0.82	23271	1497	0.01	0.82
1959	119435	12	0.81	24479	1544	0.01	0.82
1960	116905	12	0.80	30504	1873	0.02	0.78
1961	117518	11	0.79	41184	1759	0.02	0.79
1962	113117	11	0.78	33497	2357	0.02	0.73
1963	115737	11	0.76	24157	1933	0.02	0.77
1964	117977	11	0.75	20819	1605	0.02	0.80
1965	118648	11	0.74	20494	1500	0.01	0.81
1966	121432	10	0.73	21247	1154	0.01	0.84
1967	118830	10	0.72	24468	1453	0.01	0.81
1968	114510	10	0.72	36865	2019	0.02	0.75

Table 8. Time-series of population estimates from the base-case model.

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1969	105639	10	0.71	28418	3368	0.03	0.64
1970	118067	10	0.70	20856	1535	0.02	0.80
1971	117615	10	0.70	15939	1603	0.02	0.79
1972	111639	10	0.71	21380	2406	0.02	0.71
1973	108258	10	0.70	26645	2872	0.03	0.67
1974	113481	10	0.68	48211	2063	0.02	0.74
1975	117893	10	0.67	37738	1488	0.02	0.80
1976	99984	10	0.67	30536	4160	0.04	0.57
1977	89749	9	0.64	36828	6213	0.07	0.44
1978	79613	9	0.60	25805	8728	0.10	0.33
1979	79943	8	0.52	15833	7720	0.09	0.34
1980	78034	7	0.46	19076	7631	0.09	0.31
1981	70079	6	0.41	26632	9692	0.12	0.24
1982	66437	5	0.35	16864	10338	0.13	0.20
1983	63156	4	0.30	29732	10841	0.15	0.18
1984	77361	4	0.26	35338	5476	0.08	0.31
1985	87119	4	0.27	23862	3751	0.06	0.42
1986	79641	4	0.30	26514	5411	0.08	0.33
1987	79511	4	0.30	33745	5418	0.08	0.33
1988	73356	4	0.30	18702	6800	0.10	0.27
1989	78190	4	0.28	41556	5227	0.08	0.32
1990	79214	4	0.27	40789	4916	0.08	0.33
1991	81752	4	0.27	37070	4418	0.07	0.35
1992	71063	4	0.27	23923	6856	0.11	0.25
1993	73002	4	0.26	16312	6103	0.09	0.27
1994	73046	4	0.25	26729	6140	0.09	0.26
1995	75058	4	0.25	24756	5657	0.08	0.28
1996	73008	4	0.25	13530	6275	0.09	0.26
1997	96571	4	0.25	18297	2412	0.03	0.52
1998	92920	4	0.29	32535	3142	0.04	0.48
1999	91643	5	0.32	29955	3599	0.05	0.45
2000	92286	5	0.35	40705	3716	0.05	0.47
2001	104324	5	0.37	21247	2235	0.03	0.62
2002	113918	6	0.40	13150	1356	0.02	0.74
2003	125270	6	0.43	16293	491	0.01	0.90
2004	121125	7	0.46	21226	839	0.01	0.84
2005	111843	7	0.49	8998	1751	0.02	0.72
2006	125004	7	0.50	32422	565	0.01	0.89
2007	121973	8	0.52	11625	850	0.01	0.85
2008	126048	8	0.55	41174	519	0.01	0.90

Table 8. Time-series of population estimates from the base-case model.

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
2009	120080	8	0.57	12417	1095	0.01	0.82
2010	115508	9	0.59	26224	1598	0.02	0.76
2011	117687	9	0.60	17759	1348	0.02	0.79
2012	115366	9	0.60	18728	1593	0.02	0.76
2013	116760	9	0.60	30713	1432	0.02	0.78
2014	116163	8	0.59	28431	1459	0.02	0.77
2015	111011	8	0.58	28515	2016	0.02	0.71
2016	115907	8	0.57	28306			

tab:Timeseries_mod1

Table 7. Sensitivity of the base model to dropping or down-weighting data sources and alternative assumptions about growth.

tab:Sensitivity_model1

Label	Base (Francis weights)	Harmonic mean weights	Drop index	Drop ages	Down-weight lengths	Free size Age0	Free CV Amin	External growth
TOTAL_like	-	-	-	-	-	-	-	-
Catch_like	-	-	-	-	-	-	-	-
Equil_catch_like	-	-	-	-	-	-	-	-
Survey_like	-	-	-	-	-	-	-	-
Length_comp_like	-	-	-	-	-	-	-	-
Age_comp_like	-	-	-	-	-	-	-	-
Parm_priors_like	-	-	-	-	-	-	-	-
SSB_Unfished_thousand_mt	-	-	-	-	-	-	-	-
TotBio_Unfished	-	-	-	-	-	-	-	-
SmryBio_Unfished	-	-	-	-	-	-	-	-
Recr_Unfished_billions	-	-	-	-	-	-	-	-
SSB_Btgt_thousand_mt	-	-	-	-	-	-	-	-
SPR_Btgt	-	-	-	-	-	-	-	-
Fstd_Btgt	-	-	-	-	-	-	-	-
TotYield_Btgt_thousand_mt	-	-	-	-	-	-	-	-
SSB_SPRtgt_thousand_mt	-	-	-	-	-	-	-	-
Fstd_SPRtgt	-	-	-	-	-	-	-	-
TotYield_SPRtgt_thousand_mt	-	-	-	-	-	-	-	-
SSB_MSY_thousand_mt	-	-	-	-	-	-	-	-
SPR_MSY	-	-	-	-	-	-	-	-
Fstd_MSY	-	-	-	-	-	-	-	-
TotYield_MSY_thousand_mt	-	-	-	-	-	-	-	-
RetYield_MSY	-	-	-	-	-	-	-	-
Bratio_2015	-	-	-	-	-	-	-	-
F_2015	-	-	-	-	-	-	-	-
SPRratio_2015	-	-	-	-	-	-	-	-
Recr_2015	-	-	-	-	-	-	-	-
Recr_Virgin_billions	-	-	-	-	-	-	-	-
L_at_Amin_Fem_GP_1	-	-	-	-	-	-	-	-
L_at_Amax_Fem_GP_1	-	-	-	-	-	-	-	-
VonBert_K_Fem_GP_1	-	-	-	-	-	-	-	-
CV_young_Fem_GP_1	-	-	-	-	-	-	-	-
CV_old_Fem_GP_1	-	-	-	-	-	-	-	-

Table 9. Projection of potential OFL, spawning biomass, and depletion for the base case model.

tab:Forecast_mod1

Yr	OFL contriubtion (mt)	ACL landings (mt)	Age 5+ biomass (mt)	Spawning Biomass (mt)	Depletion
2017	4442.62	4076.59	82391.70	8.19	0.57
2018	4253.88	3903.56	80797.70	7.75	0.54
2019	4091.96	3755.17	79889.10	7.37	0.51
2020	3963.19	3637.19	79504.40	7.04	0.49
2021	3875.23	3556.62	79528.60	6.77	0.47
2022	3829.28	3514.55	79802.60	6.57	0.46
2023	3818.58	3504.82	80202.90	6.46	0.45
2024	3831.98	3517.13	80631.90	6.42	0.45
2025	3858.22	3541.16	81023.90	6.43	0.45
2026	3888.53	3568.89	81344.10	6.46	0.45
2027	3917.23	3595.16	81582.70	6.50	0.45
2028	3941.29	3617.17	81745.60	6.54	0.45

8.2 Southern Model Tables

southern-model-tables

Table 10. Catch timeseries for the Southern model.

Year	Commercial Catch	Recreational Catch
1915	0.000	0.000
1916	494.400	0.000
1917	769.480	0.000
1918	903.620	0.000
1919	622.040	0.000
1920	635.630	0.000
1921	527.620	0.000
1922	453.790	0.000
1923	488.660	0.000
1924	290.080	0.000
1925	377.100	0.000
1926	576.240	0.000
1927	476.440	0.000
1928	549.670	4.190
1929	463.810	8.370
1930	677.450	9.630
1931	623.520	12.830
1932	497.450	16.040
1933	313.830	19.250
1934	347.640	22.460
1935	428.730	25.670
1936	522.050	28.870
1937	461.910	34.240
1938	376.050	33.670
1939	273.430	29.440
1940	392.070	42.370
1941	398.890	39.160
1942	134.130	20.800
1943	176.170	19.890
1944	322.540	16.330
1945	702.370	21.780
1946	729.070	37.480
1947	394.470	29.770
1948	428.470	59.430
1949	296.470	76.980
1950	398.040	93.850
1951	400.920	107.790
1952	311.840	93.940
1953	148.040	80.160

Continued on next page

Table 10. Catch timeseries for the Southern model.

Year	Commercial Catch	Recreational Catch
1954	186.270	100.210
1955	149.650	120.260
1956	340.270	134.480
1957	379.930	115.200
1958	596.510	197.870
1959	481.690	180.070
1960	264.020	133.910
1961	184.710	100.600
1962	123.540	117.740
1963	175.860	81.880
1964	130.810	62.610
1965	120.530	103.550
1966	171.950	112.870
1967	151.960	113.490
1968	139.450	127.260
1969	67.206	154.180
1970	64.961	177.460
1971	135.863	139.940
1972	183.984	186.280
1973	344.077	238.410
1974	444.105	259.330
1975	475.854	257.440
1976	245.911	303.660
1977	295.579	268.240
1978	167.066	243.640
1979	233.641	267.270
1980	193.560	346.000
1981	386.441	427.000
1982	425.479	1213.000
1983	992.887	590.000
1984	1378.600	371.000
1985	658.530	390.000
1986	564.622	288.000
1987	498.568	249.000
1988	224.076	213.000
1989	831.536	302.000
1990	792.226	208.600
1991	279.010	208.600
1992	516.909	208.600
1993	212.892	71.000
1994	228.906	42.000

Continued on next page

Table 10. Catch timeseries for the Southern model.

Year	Commercial Catch	Recreational Catch
1995	194.465	33.000
1996	133.622	96.000
1997	331.053	402.000
1998	309.193	112.000
1999	42.873	205.000
2000	28.195	134.000
2001	2.825	56.000
2002	2.396	25.000
2003	1.213	19.000
2004	1.212	13.000
2005	4.985	20.230
2006	5.083	18.760
2007	4.335	59.761
2008	2.412	19.997
2009	1.080	48.230
2010	0.925	24.121
2011	0.708	45.222
2012	0.844	52.834
2013	4.419	55.477
2014	5.309	60.112
2015	3.455	95.814
2016	1.787	31.857

tab:Southern_catch

Table 11. Summary of the biomass/abundance time series used in the stock assessment.

tab:Index_summary_S

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		
2001-2016	Juvenile CPUE	Yes		

Table 12. CPUE timeseries for the Southern model.

tab:Southern_CPUE

Year	Hook and Line	SE	Recreational	SE	Onboard	SE	Juvenile Survey	SE
1980					0.17	0.64		
1981					0.14	0.67		
1982					0.34	0.62		
1983					0.33	0.64		
1984					0.34	0.60		
1985					0.38	0.58		
1986					0.37	0.60		
1987			0.85	1.30	0.12	0.72		
1988			1.02	2.27	0.13	0.67		
1989			1.31	3.43	0.31	0.68		
1990			1.22	1.44				
1991			0.94	1.22				
1992			1.04	1.54				
1993			0.69	1.15	0.50	0.92		
1994			0.74	1.26	0.43	0.78		
1995			0.93	1.45	0.47	0.67		
1996			0.80	1.61	0.28	0.61		
1997			0.98	1.71	1.18	0.60		
1998			0.83	1.91	0.72	0.64		
1999			0.13	0.62	0.32	0.62		
2000			0.10	0.47	0.20	0.76		
2001			0.08	0.34	0.09	0.69	2.72	0.40
2002			0.07	0.59	0.11	0.71	3.66	0.32
2003			0.06	0.33	0.08	0.72	4.55	0.30
2004	0.11	0.36	0.11	0.50			12.87	0.29
2005	0.14	0.32	0.14	0.51			1.54	0.75
2006	0.12	0.34	0.28	0.93			1.22	0.83
2007	0.17	0.32	0.37	1.00			1.35	0.80
2008	0.07	0.39	0.09	0.39			4.65	0.28
2009	0.09	0.40	0.13	0.52			4.98	0.30
2010	0.06	0.45	0.13	0.58			3.90	0.44
2011	0.05	0.42	0.31	1.20			2.99	0.47
2012	0.07	0.40	0.19	0.74			2.71	0.69
2013	0.09	0.42	0.28	1.13			8.96	0.30
2014	0.06	0.40	0.26	0.99			5.96	0.32
2015	0.09	0.37	0.24	0.86			5.03	0.39
2016	0.05	0.43	0.13	0.58			1.75	0.82

Table 13. Results from 100 jitters from each of the three models.

tab:jitter

Status	Model.1	Model.2	Model.3
Returned to base case	-	-	-
Found local minimum	-	-	-
Found better solution	-	-	-
Error in likelihood	-	-	-
Total	100	100	100

Table 14. List of parameters used in the 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	0.180	-2	(0.02, 0.25)			None
2	L_at_Amin_Fem_GP_1	18.178	3	(1, 25)	OK	0.916	None
3	L_at_Amax_Fem_GP_1	49.548	2	(35, 70)	OK	0.340	None
4	VonBert_K_Fem_GP_1	0.112	3	(0.1, 0.4)	OK	0.006	None
5	CV_young_Fem_GP_1	0.078	5	(0.03, 0.16)	OK	0.013	None
6	CV_old_Fem_GP_1	0.057	5	(0.03, 0.16)	OK	0.005	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	-0.288	-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	-0.124	2	(-1, 1)	OK	0.015	None
16	VonBert_K_Mal_GP_1	0.142	3	(-1, 1)	OK	0.063	None
17	CV_young_Mal_GP_1	0.000	-5	(-1, 1)			None
18	CV_old_Mal_GP_1	0.337	5	(-1, 1)	OK	0.163	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)	10.527	1	(5, 20)	OK	0.789	None
27	SR_BH_steep	0.718	-6	(0.2, 1)			None
28	SR_sigmaR	0.850	-6	(0.5, 1.2)			None
29	SR_regime	0.000	-50	(-5, 5)			None

Continued on next page

Table 14. List of parameters used in the 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(3)	-13.315	-1	(-30, 15)			None
130	LnQ_base_HookAndLineSurvey(4)	-13.181	-1	(-30, 15)			None
131	LnQ_base_RecStudy(5)	-9.231	-1	(-30, 15)			None
138	SizeSel_P1_CommercialCatch(2)	55.000	-1	(20, 55)			None
139	SizeSel_P2_CommercialCatch(2)	20.000	-4	(-20, 20)			None
140	SizeSel_P3_CommercialCatch(2)	5.276	3	(-5, 20)	OK	0.056	None
141	SizeSel_P4_CommercialCatch(2)	20.000	-4	(-5, 20)			None
142	SizeSel_P5_CommercialCatch(2)	-999.000	-99	(-999, 25)			None
143	SizeSel_P6_CommercialCatch(2)	-999.000	-99	(-999, 25)			None
144	SizeSel_P1_OnboardSurvey(3)	30.066	1	(20, 55)	OK	1.324	None
145	SizeSel_P2_OnboardSurvey(3)	-20.000	-4	(-20, 7)			None
146	SizeSel_P3_OnboardSurvey(3)	3.490	3	(-5, 20)	OK	0.381	None
147	SizeSel_P4_OnboardSurvey(3)	7.586	4	(-5, 20)	OK	1.962	None
148	SizeSel_P5_OnboardSurvey(3)	-999.000	-99	(-999, 25)			None
149	SizeSel_P6_OnboardSurvey(3)	-999.000	-99	(-999, 25)			None
150	SizeSel_P1_HookAndLineSurvey(4)	49.031	1	(20, 55)	OK	3.651	None
151	SizeSel_P2_HookAndLineSurvey(4)	20.000	-4	(-20, 20)			None
152	SizeSel_P3_HookAndLineSurvey(4)	5.178	3	(-5, 20)	OK	0.279	None
153	SizeSel_P4_HookAndLineSurvey(4)	20.000	-4	(-5, 20)			None
154	SizeSel_P5_HookAndLineSurvey(4)	-999.000	-99	(-999, 25)			None
155	SizeSel_P6_HookAndLineSurvey(4)	-999.000	-99	(-999, 25)			None
156	SizeSel_P1_RecStudy(5)	49.449	1	(20, 55)	OK	2.552	None
157	SizeSel_P2_RecStudy(5)	20.000	-4	(-20, 20)			None
158	SizeSel_P3_RecStudy(5)	5.379	3	(-5, 20)	OK	0.195	None
159	SizeSel_P4_RecStudy(5)	20.000	-4	(-5, 20)			None
160	SizeSel_P5_RecStudy(5)	-999.000	-99	(-999, 25)			None

Continued on next page

Table 14. List of parameters used in the 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)
161	SizeSel_P6_RecStudy(5)	-999.000	-99	(-999, 25)			None

tab:model_params

Table 16. **Time-series of population estimates from the base-case model.**

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1916	114120	6	0.00	37363	494	0.00	0.93
1917	112299	6	0.99	37334	769	0.00	0.89
1918	111403	6	0.98	37290	904	0.01	0.87
1919	113174	6	0.97	37240	622	0.01	0.91
1920	113059	6	0.96	37210	636	0.01	0.91
1921	113769	6	0.95	37182	528	0.01	0.92
1922	114269	5	0.95	37164	454	0.00	0.93
1923	114018	5	0.94	37152	489	0.00	0.93
1924	115423	5	0.94	37141	290	0.00	0.95
1925	114798	5	0.94	37143	377	0.00	0.94
1926	113404	5	0.94	37141	576	0.01	0.91
1927	114085	5	0.94	37127	476	0.00	0.93
1928	113531	5	0.94	37120	554	0.01	0.92
1929	114082	5	0.93	37110	472	0.00	0.93
1930	112594	5	0.93	37106	687	0.01	0.90
1931	112914	5	0.93	37088	636	0.01	0.90
1932	113747	5	0.92	37074	513	0.01	0.92
1933	115028	5	0.92	37070	333	0.00	0.95
1934	114755	5	0.93	37079	370	0.00	0.94
1935	114145	5	0.93	37084	454	0.00	0.93
1936	113457	5	0.93	37084	551	0.01	0.92
1937	113823	5	0.92	37078	496	0.00	0.92
1938	114438	5	0.92	37076	410	0.00	0.94
1939	115226	5	0.93	37079	303	0.00	0.95
1940	114246	5	0.93	37089	434	0.00	0.93
1941	114228	5	0.93	37090	438	0.00	0.93
1942	116353	5	0.93	37091	155	0.00	0.98
1943	116050	5	0.93	37109	196	0.00	0.97
1944	115013	5	0.94	37123	339	0.00	0.95
1945	112321	5	0.94	33637	724	0.01	0.89
1946	111978	5	0.93	33335	767	0.01	0.89
1947	114342	5	0.93	33017	424	0.00	0.93
1948	113815	5	0.93	32682	488	0.00	0.93
1949	114585	5	0.93	32307	373	0.00	0.94
1950	113686	5	0.93	31890	492	0.00	0.93
1951	113515	5	0.93	31441	509	0.01	0.92
1952	114270	5	0.92	30963	406	0.00	0.94
1953	115609	5	0.92	30483	228	0.00	0.96
1954	115104	5	0.92	30038	286	0.00	0.96
1955	115155	5	0.92	29652	270	0.00	0.96

Table 16. Time-series of population estimates from the base-case model.

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1956	113572	5	0.92	29448	475	0.00	0.93
1957	113439	5	0.91	29677	495	0.01	0.92
1958	111005	5	0.90	30903	794	0.01	0.88
1959	111908	5	0.89	34089	662	0.01	0.90
1960	113961	5	0.87	40373	398	0.00	0.93
1961	114923	5	0.86	47766	285	0.00	0.95
1962	115216	5	0.85	47160	241	0.00	0.96
1963	115190	5	0.85	41604	258	0.00	0.96
1964	115783	5	0.84	39680	193	0.00	0.97
1965	115447	5	0.83	41815	224	0.00	0.96
1966	114955	5	0.83	48585	285	0.00	0.95
1967	115143	5	0.82	31271	265	0.00	0.96
1968	115142	5	0.83	24970	267	0.00	0.96
1969	115493	5	0.83	27187	221	0.00	0.97
1970	115303	5	0.85	21644	242	0.00	0.96
1971	115120	5	0.86	13645	276	0.00	0.96
1972	114295	5	0.88	12610	370	0.00	0.94
1973	112588	5	0.90	17200	582	0.01	0.91
1974	111597	5	0.92	19160	703	0.01	0.89
1975	111257	5	0.92	27748	733	0.01	0.89
1976	112204	5	0.93	19352	550	0.01	0.91
1977	112070	5	0.92	19851	564	0.01	0.91
1978	113170	5	0.91	17270	411	0.01	0.93
1979	112215	5	0.89	15052	501	0.01	0.91
1980	111350	5	0.86	22885	540	0.01	0.90
1981	108565	5	0.83	32588	813	0.01	0.85
1982	98586	5	0.78	16810	1638	0.02	0.72
1983	101229	4	0.73	11800	1583	0.02	0.72
1984	100528	4	0.68	45024	1750	0.03	0.70
1985	105173	4	0.63	48288	1049	0.02	0.79
1986	107125	3	0.60	18699	853	0.01	0.82
1987	108191	3	0.57	28898	748	0.01	0.83
1988	111602	3	0.55	37021	437	0.01	0.90
1989	104337	3	0.54	41438	1134	0.02	0.76
1990	105803	3	0.52	40548	1001	0.02	0.78
1991	111178	3	0.51	43645	488	0.01	0.89
1992	108788	3	0.51	21121	726	0.01	0.84
1993	114029	3	0.52	31647	284	0.00	0.93
1994	114329	3	0.53	14631	271	0.00	0.94
1995	114924	3	0.56	10902	227	0.00	0.95

Table 16. **Time-series of population estimates from the base-case model.**

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1996	114877	3	0.58	9806	230	0.00	0.95
1997	109313	4	0.61	10978	733	0.01	0.86
1998	112958	4	0.63	25527	421	0.01	0.91
1999	114339	4	0.66	56443	248	0.00	0.95
2000	115390	4	0.69	14211	162	0.00	0.97
2001	116746	4	0.71	21999	59	0.00	0.99
2002	117205	4	0.72	44511	27	0.00	0.99
2003	117307	4	0.73	42434	20	0.00	1.00
2004	117395	4	0.72	36848	14	0.00	1.00
2005	117257	4	0.71	25730	25	0.00	0.99
2006	117284	4	0.70	20145	24	0.00	1.00
2007	116755	4	0.69	26284	64	0.00	0.99
2008	117307	4	0.68	234325	22	0.00	1.00
2009	116967	4	0.68	66935	49	0.00	0.99
2010	117300	4	0.68	170658	25	0.00	1.00
2011	117129	4	0.69	81723	46	0.00	0.99
2012	117131	4	0.70	59526	54	0.00	0.99
2013	117139	4	0.73	62964	60	0.00	0.99
2014	117145	4	0.76	46187	65	0.00	0.99
2015	116965	5	0.80	37772	99	0.00	0.99
2016	117389	5	0.88	35705			

tab:Timeseries_mod2

Table 15. Sensitivity of the base model to dropping or down-weighting data sources and alternative assumptions about growth.

tab:Sensitivity_model2

Label	Base (Francis weights)	Harmonic mean weights	Drop index	Drop ages	Down-weight lengths	Free size Age0	Free CV Amin	External growth
TOTAL_like	-	-	-	-	-	-	-	-
Catch_like	-	-	-	-	-	-	-	-
Equil_catch_like	-	-	-	-	-	-	-	-
Survey_like	-	-	-	-	-	-	-	-
Length_comp_like	-	-	-	-	-	-	-	-
Age_comp_like	-	-	-	-	-	-	-	-
Parm_priors_like	-	-	-	-	-	-	-	-
SSB_Unfished_thousand_mt	-	-	-	-	-	-	-	-
TotBio_Unfished	-	-	-	-	-	-	-	-
SmryBio_Unfished	-	-	-	-	-	-	-	-
Recr_Unfished_billions	-	-	-	-	-	-	-	-
SSB_Btgt_thousand_mt	-	-	-	-	-	-	-	-
SPR_Btgt	-	-	-	-	-	-	-	-
Fstd_Btgt	-	-	-	-	-	-	-	-
TotYield_Btgt_thousand_mt	-	-	-	-	-	-	-	-
SSB_SPRtgt_thousand_mt	-	-	-	-	-	-	-	-
Fstd_SPRtgt	-	-	-	-	-	-	-	-
TotYield_SPRtgt_thousand_mt	-	-	-	-	-	-	-	-
SSB_MSY_thousand_mt	-	-	-	-	-	-	-	-
SPR_MSY	-	-	-	-	-	-	-	-
Fstd_MSY	-	-	-	-	-	-	-	-
TotYield_MSY_thousand_mt	-	-	-	-	-	-	-	-
RetYield_MSY	-	-	-	-	-	-	-	-
Bratio_2015	-	-	-	-	-	-	-	-
F_2015	-	-	-	-	-	-	-	-
SPRratio_2015	-	-	-	-	-	-	-	-
Recr_2015	-	-	-	-	-	-	-	-
Recr_Virgin_billions	-	-	-	-	-	-	-	-
L_at_Amin_Fem_GP_1	-	-	-	-	-	-	-	-
L_at_Amax_Fem_GP_1	-	-	-	-	-	-	-	-
VonBert_K_Fem_GP_1	-	-	-	-	-	-	-	-
CV_young_Fem_GP_1	-	-	-	-	-	-	-	-
CV_old_Fem_GP_1	-	-	-	-	-	-	-	-

Table 17. Projection of potential OFL, spawning biomass, and depletion for the base case model.

tab:Forecast_mod2

Yr	OFL contriubtion (mt)	ACL landings (mt)	Age 5+ biomass (mt)	Spawning Biomass (mt)	Depletion
2017	8532.88	8157.43	173802.00	5.68	0.98
2018	8218.96	7857.32	167681.00	6.13	1.06
2019	7829.98	7485.46	159255.00	6.58	1.14
2020	7411.41	7085.31	150010.00	6.97	1.20
2021	6992.17	6684.51	140892.00	7.22	1.25
2022	6588.47	6298.58	132229.00	7.31	1.26
2023	6210.08	5936.83	124166.00	7.23	1.25
2024	5862.74	5604.78	116824.00	7.01	1.21
2025	5549.17	5305.00	110252.00	6.69	1.15
2026	5269.82	5037.95	104446.00	6.32	1.09
2027	5023.55	4802.52	99367.80	5.92	1.02
2028	4808.12	4596.56	94958.40	5.53	0.95

9 Figures

figures

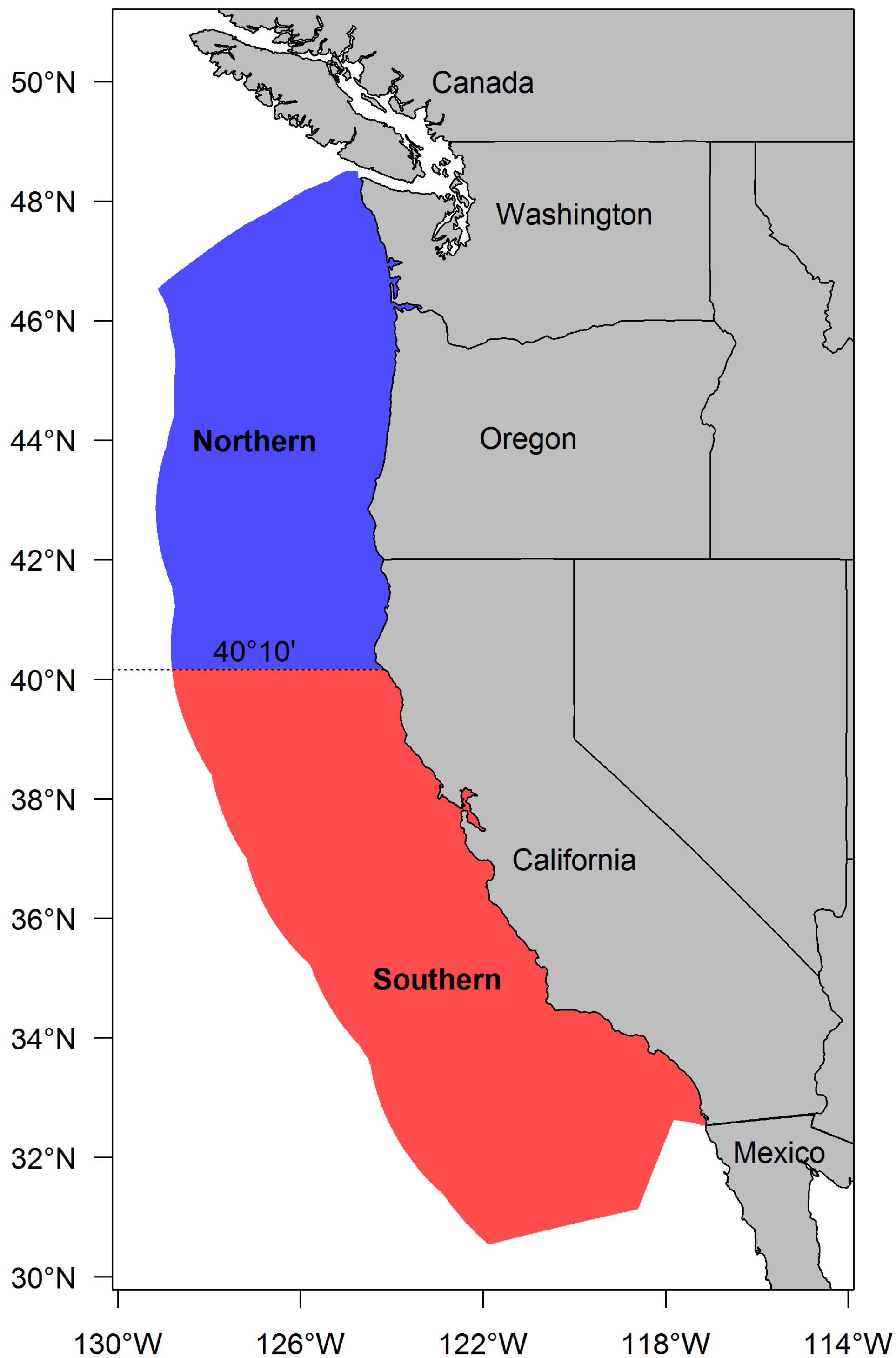


Figure 1: Map depicting the boundaries for the base-case model. fig:assess_region_map

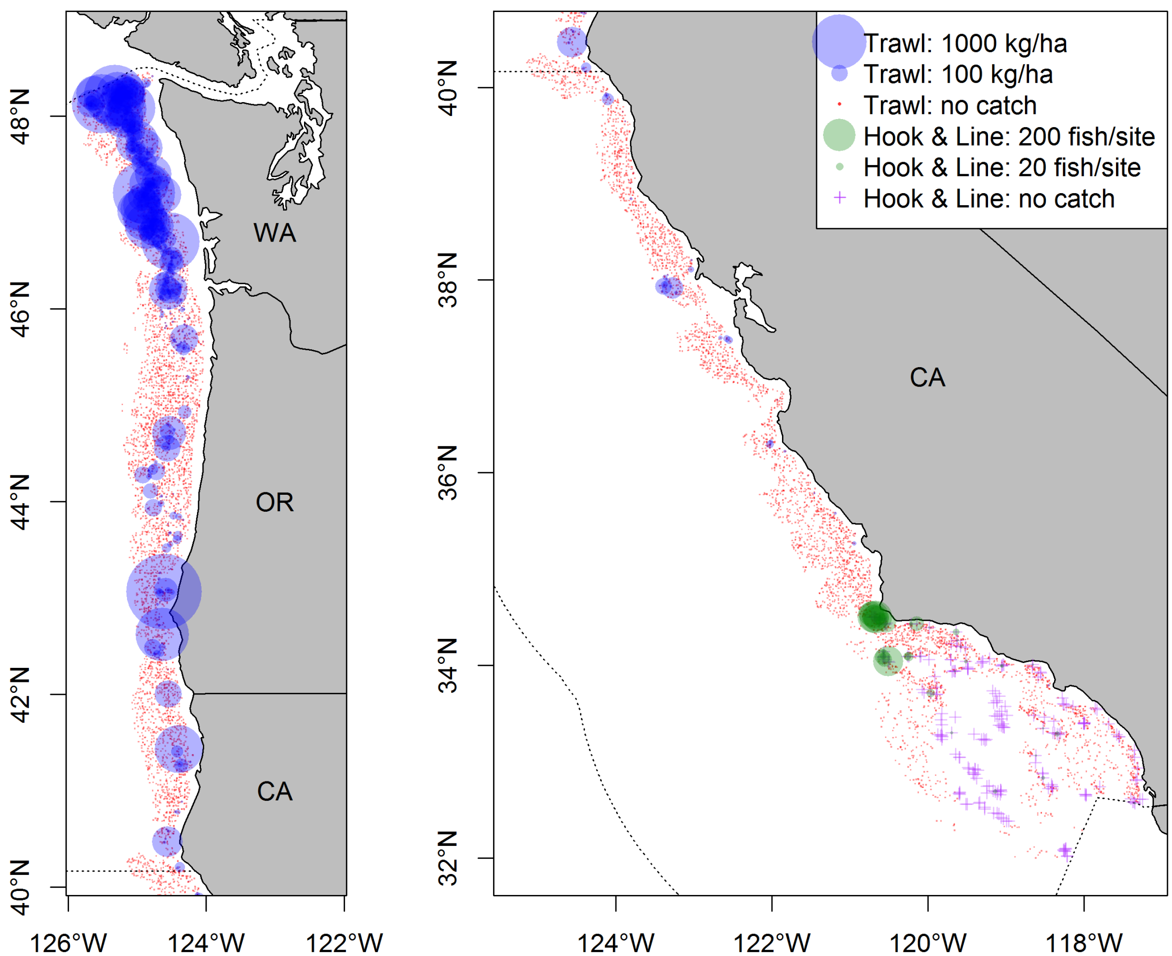


Figure 2: Map showing observations of Yellowtail Rockfish in the NWFSCcombo trawl survey and Hook & Line survey. fig:assess_region_map

1136 9.1 Life history (maturity, fecundity, and growth) for both models

life-history-maturity-fecundity-and-growth-for-both-models

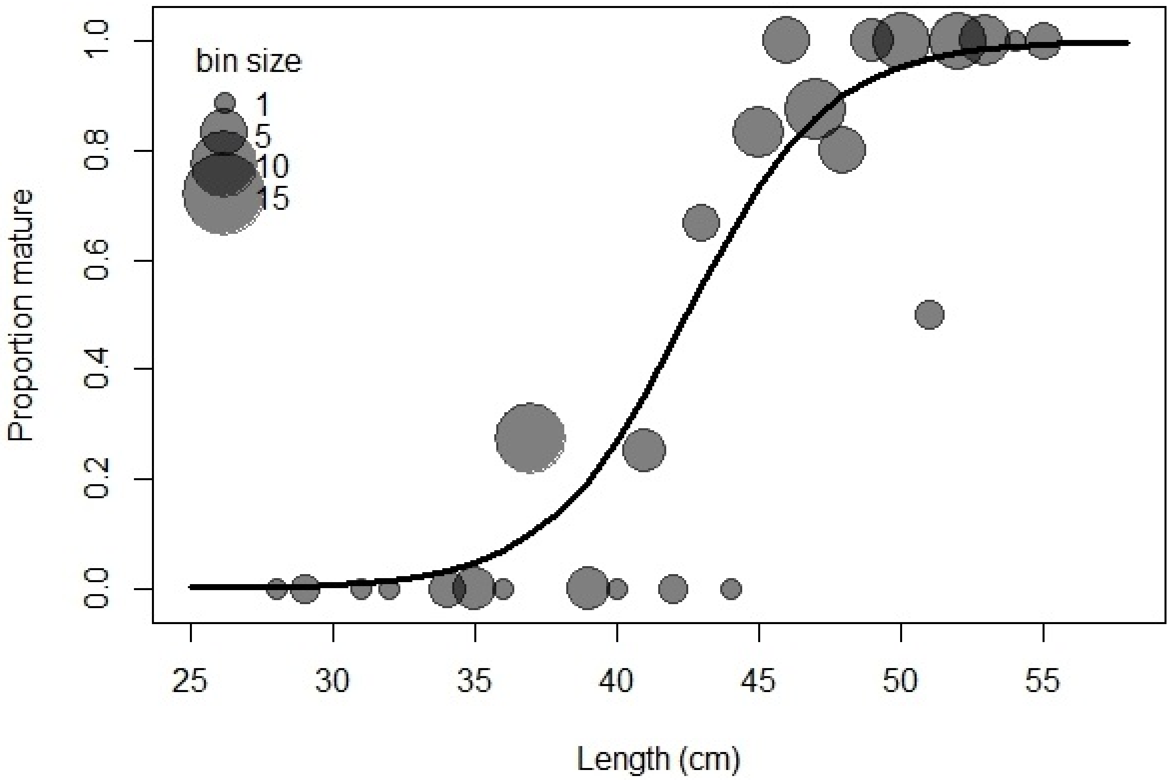


Figure 3: Estimated maturity relationship for Yellowtail Rockfish used in both models. Gray points indicate average observed functional maturity within each length bin with point size proportional to the number of samples. fig:maturity

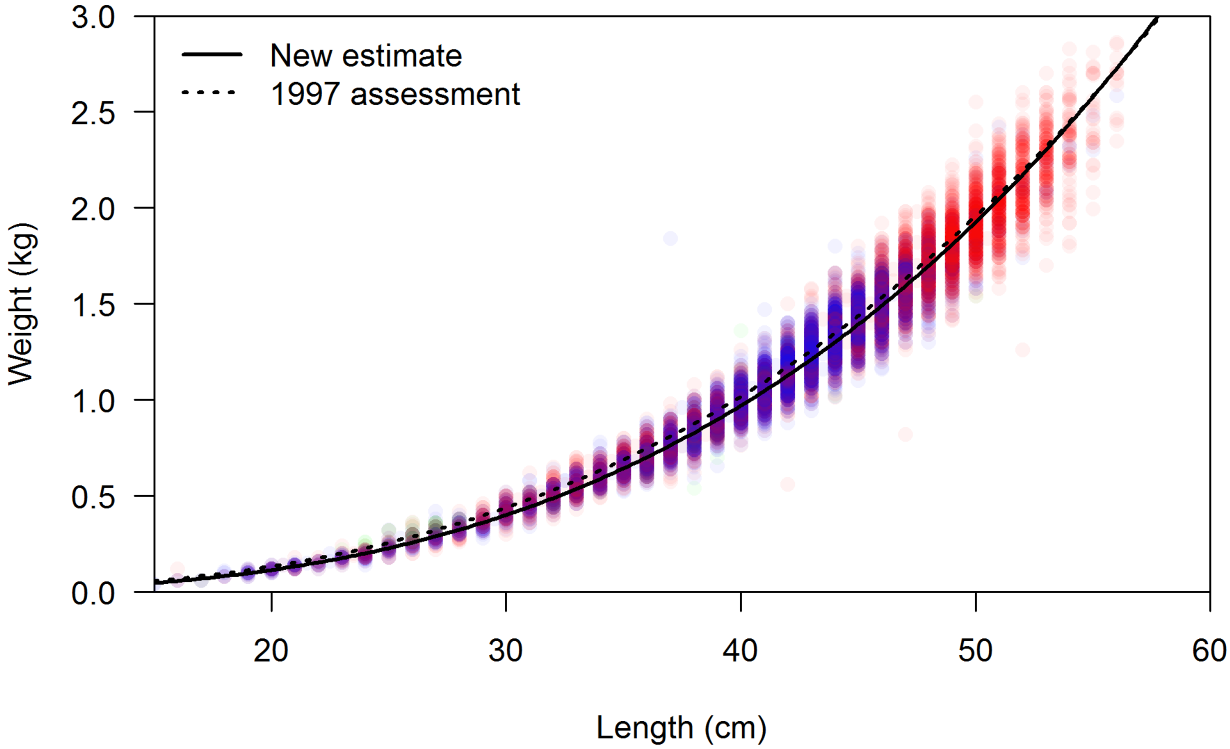


Figure 4: Estimated weight-length relationship for Yellowtail Rockfish used in both models. Colored points show observed values (red for females, blue for males, and green for unsexed). The black line indicates the estimated relationship $W = 0.000011843L^{3.0672}$. fig:weight-length

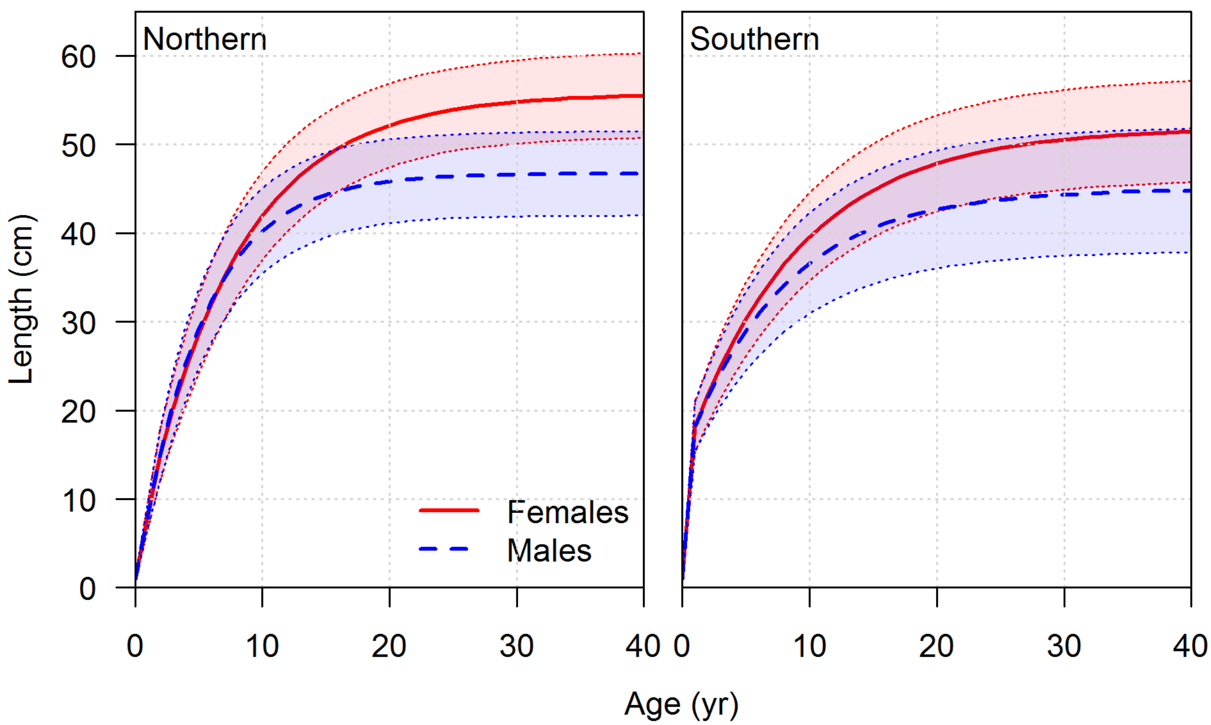


Figure 5: Estimated length-at-age for female and male Yellowtail Rockfish in each model. Shaded areas indicate 95% intervals for distribution of lengths at each age. Values represent beginning-of-year growth. fig:growth

9.2 Data and model fits for the Northern model

data-and-model-fits-for-the-northern-model

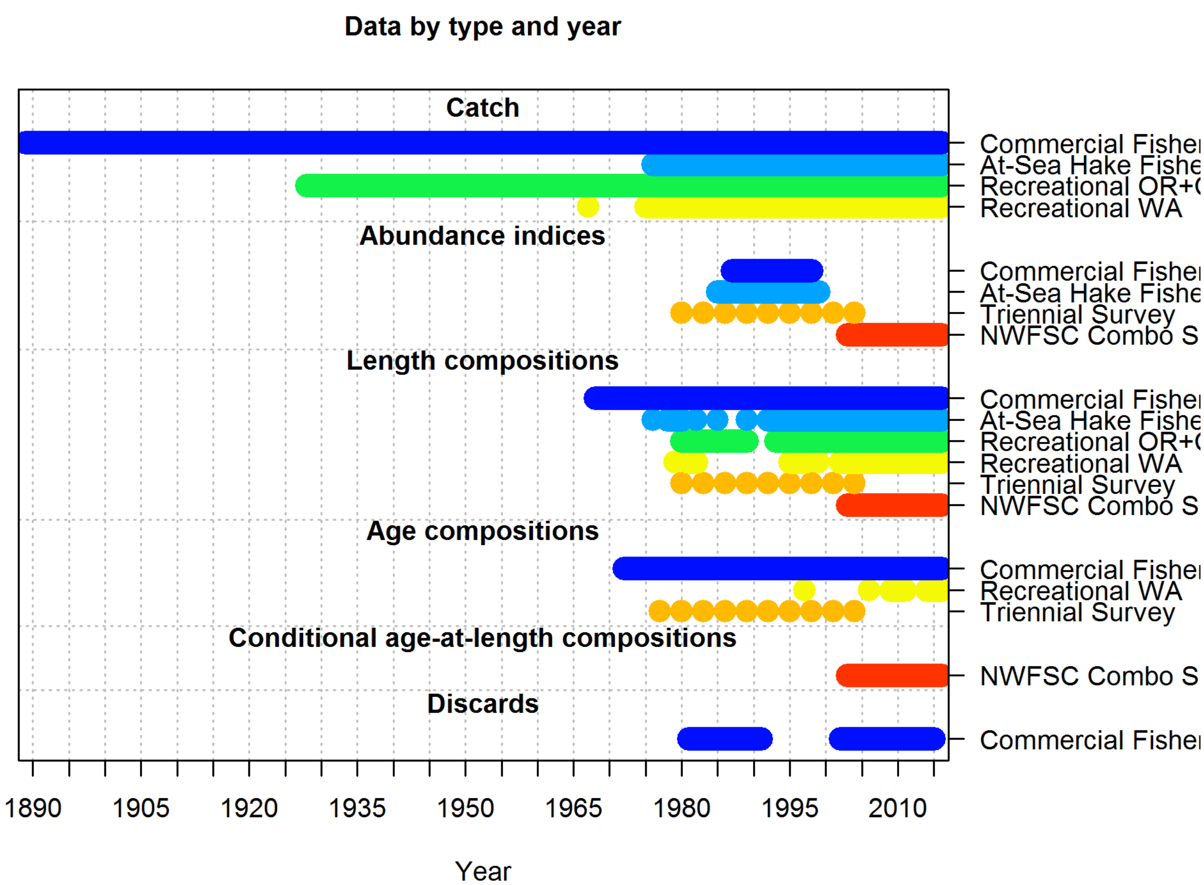


Figure 6: Summary of data sources used in the Northern model. fig:data_plot.N

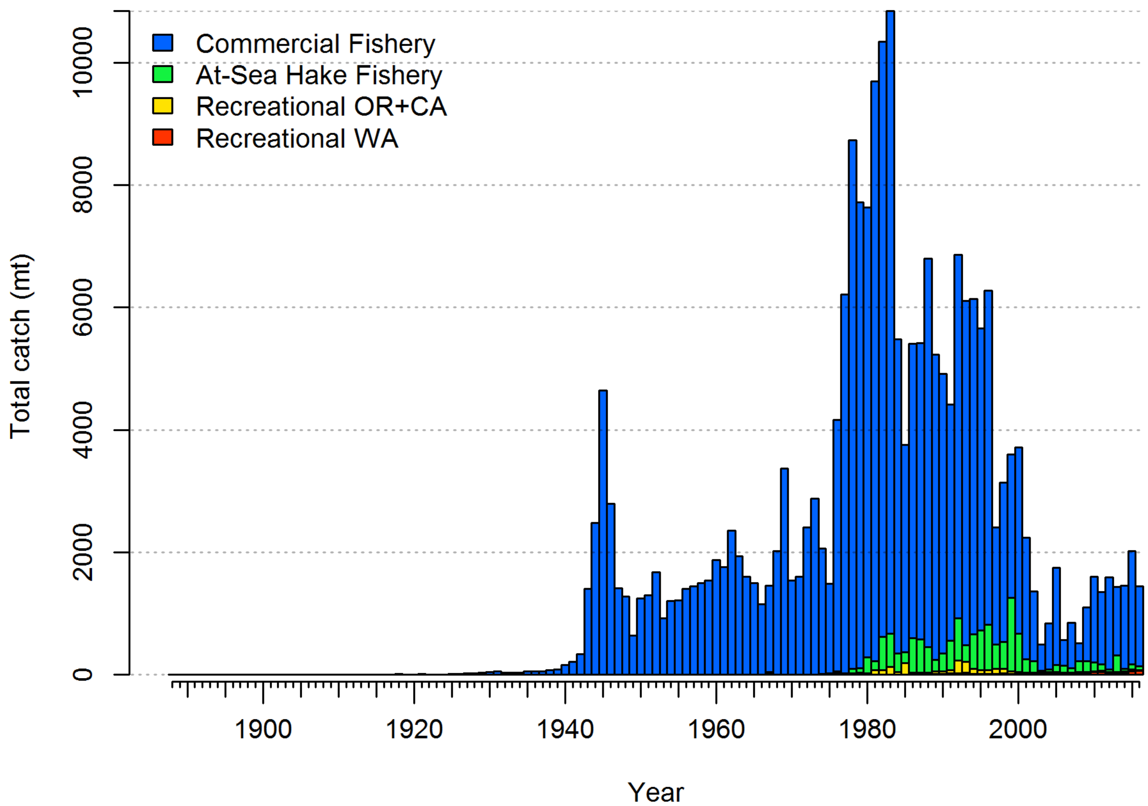


Figure 7: Estimated catch history of Yellowtail Rockfish in the Northern model. Recreational catches in Washington are model estimates of total weigth converted from input catch in numbers using model estimates of growth and selectivity. Catches for the Commercial Fishery include estimated discards. fig:r4ss_total_catch_N

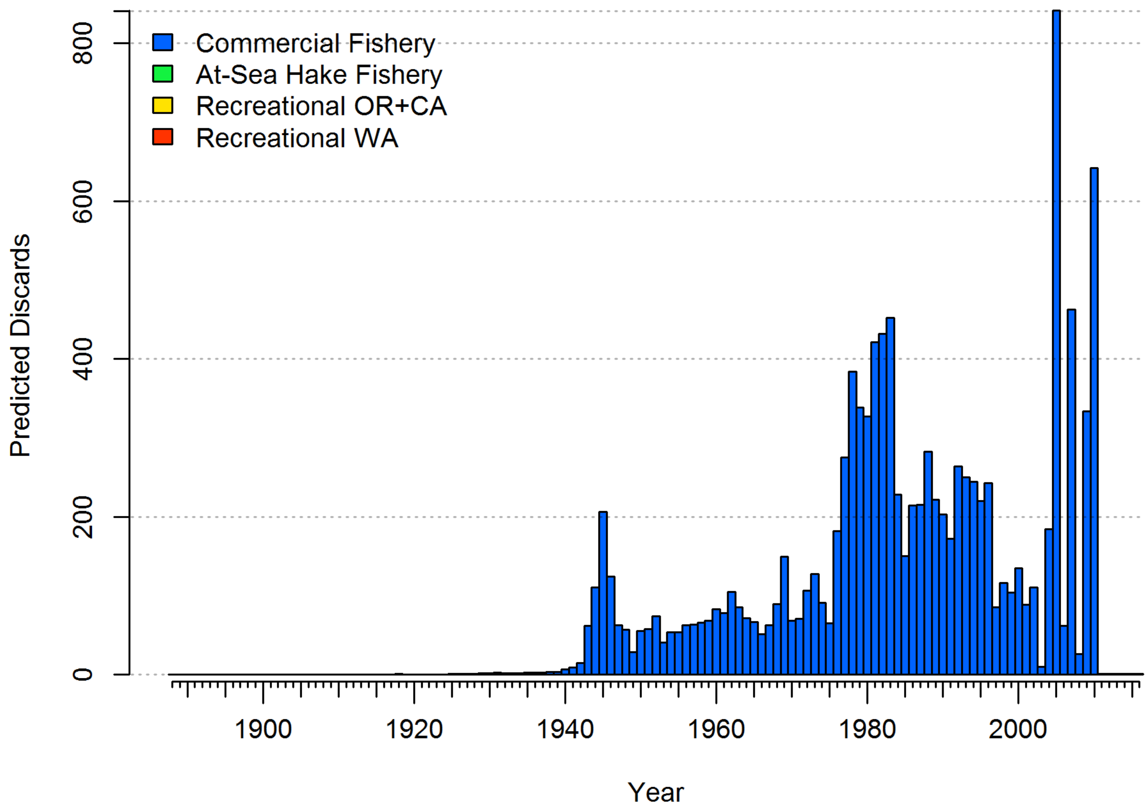


Figure 8: Estimated discards in the Commercial Fishery in the Northern model. Estimates are influenced by the data for landings, discard ratios, and discard length combines and depend on the estimated parameters controlling selectivity and retention. fig:r4ss_discard_N

1138 ### 9.2.1 Selectivity, retention, and discards for Northern model
selectivity-retention-and-discards-for-northern-model

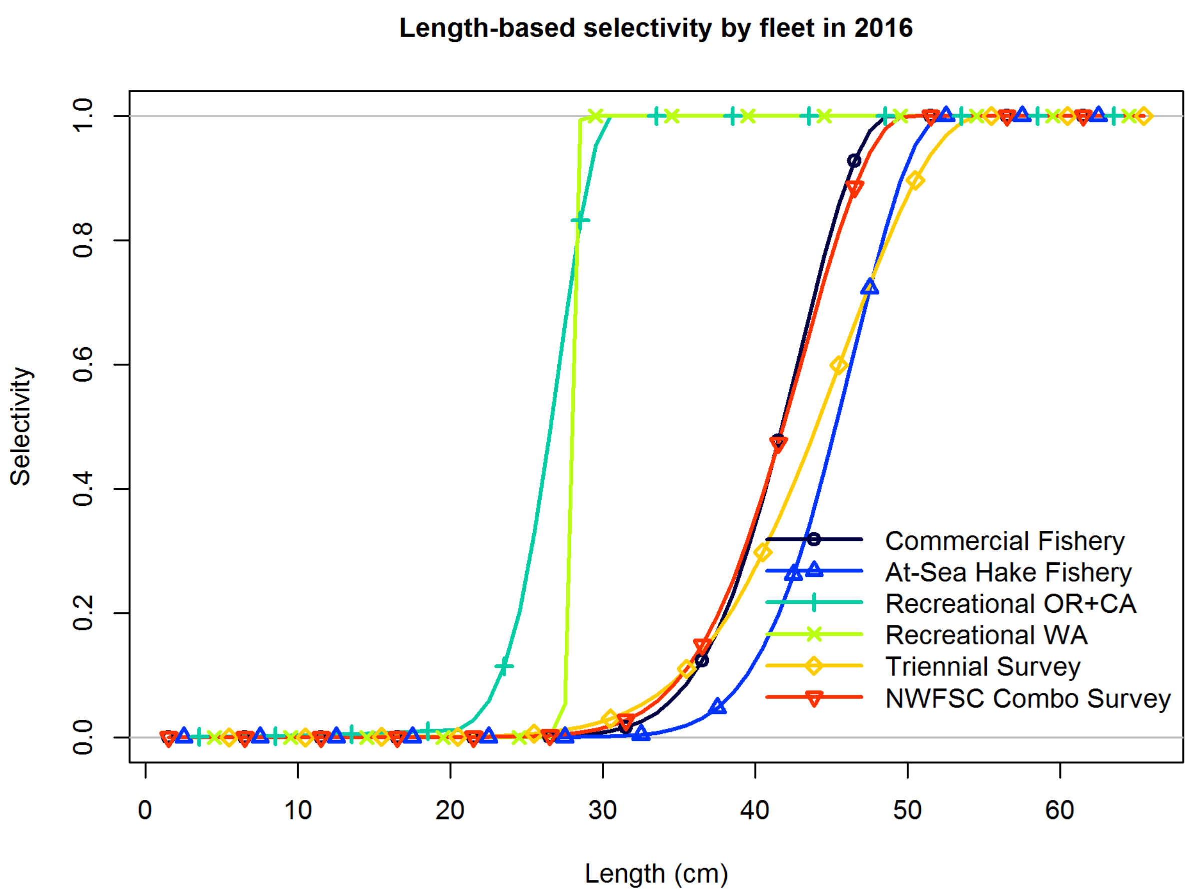


Figure 9: Estimated selectivity by length by each fishery and survey in the Northern model. fig:selex.N

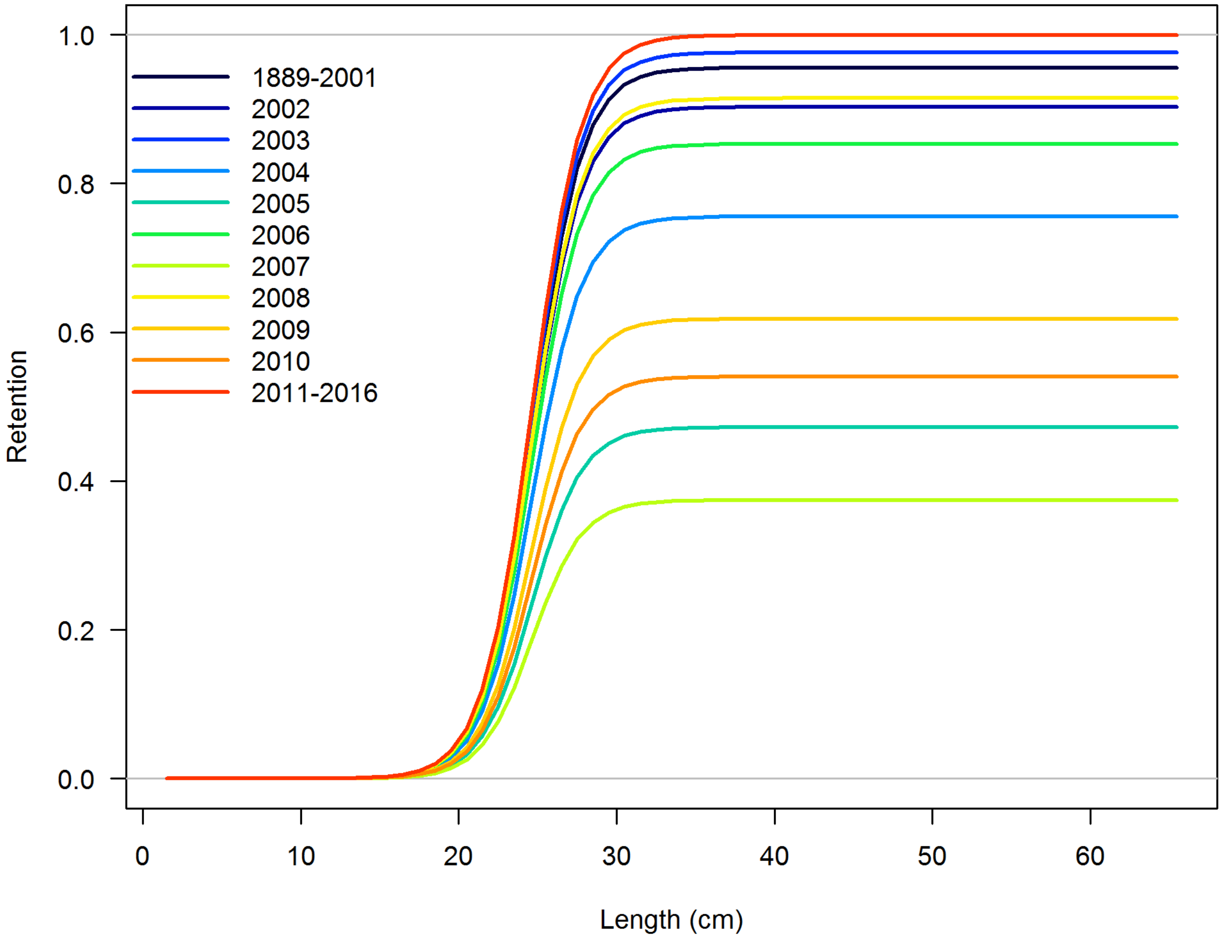


Figure 10: Estimated retention by length by the Commercial Fishery in the Northern model. fig:retention

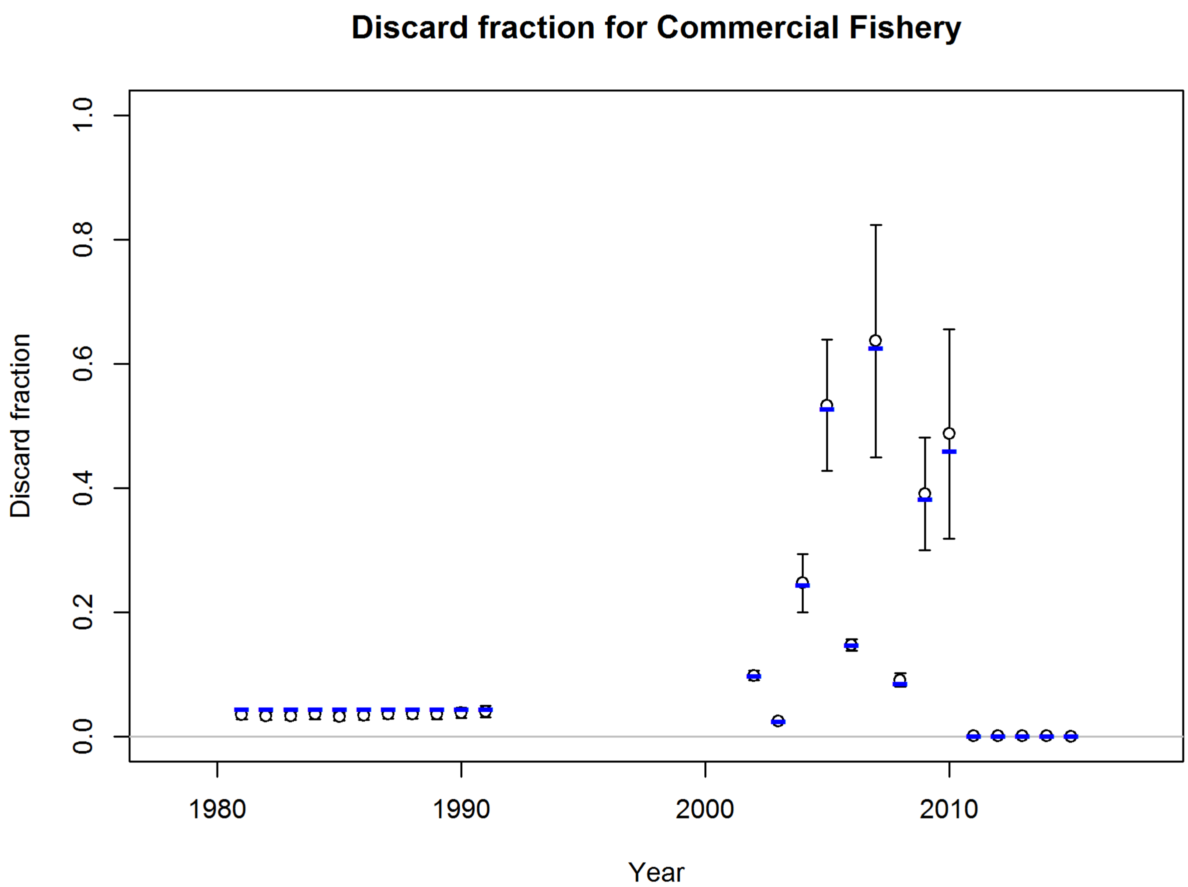


Figure 11: Fit to discard fractions for the commercial fishery in the Northern model. fig:r4ss_discarc

9.2.2 At-Sea Hake Bycatch Index

at-sea-hake-bycatch-index

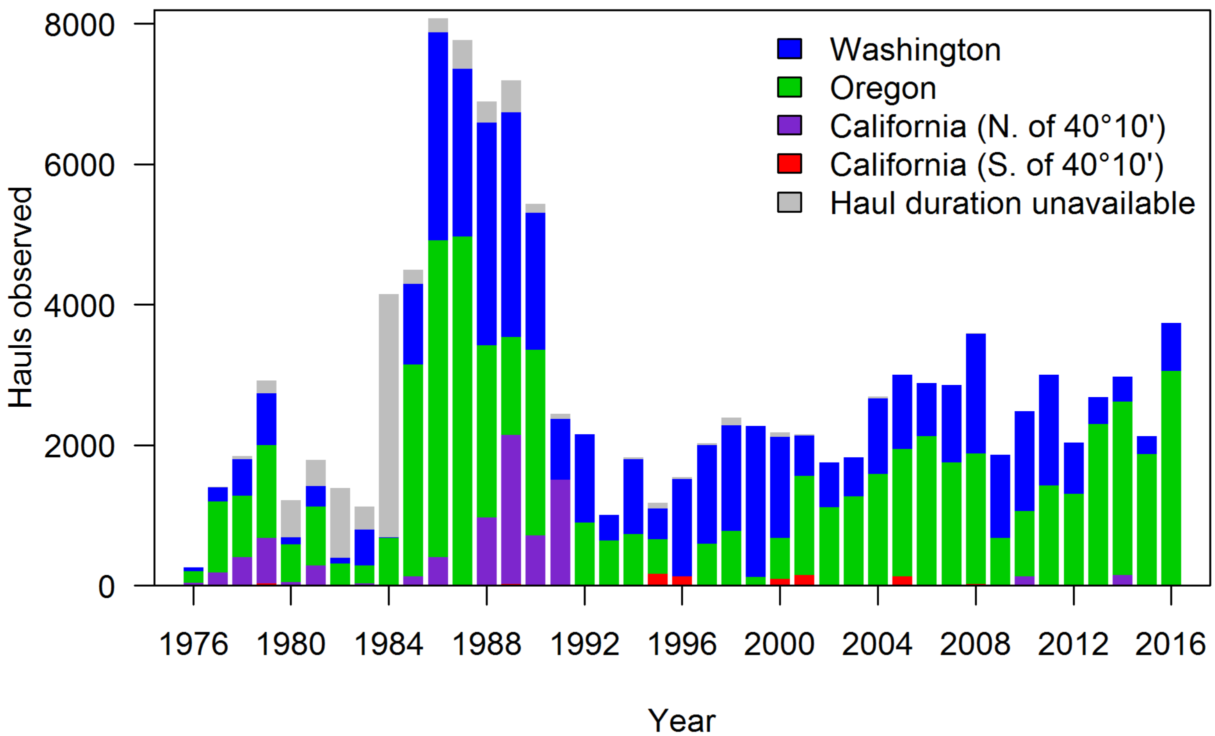


Figure 12: Number of observed hauls from the at-sea hake fishery classified by location relative to Washington, Oregon, and California (north and south of 40-10). Grey bars indicate observed tows with no haul duration available which were excluded from the CPUE analysis. fig:ASHOP_X1

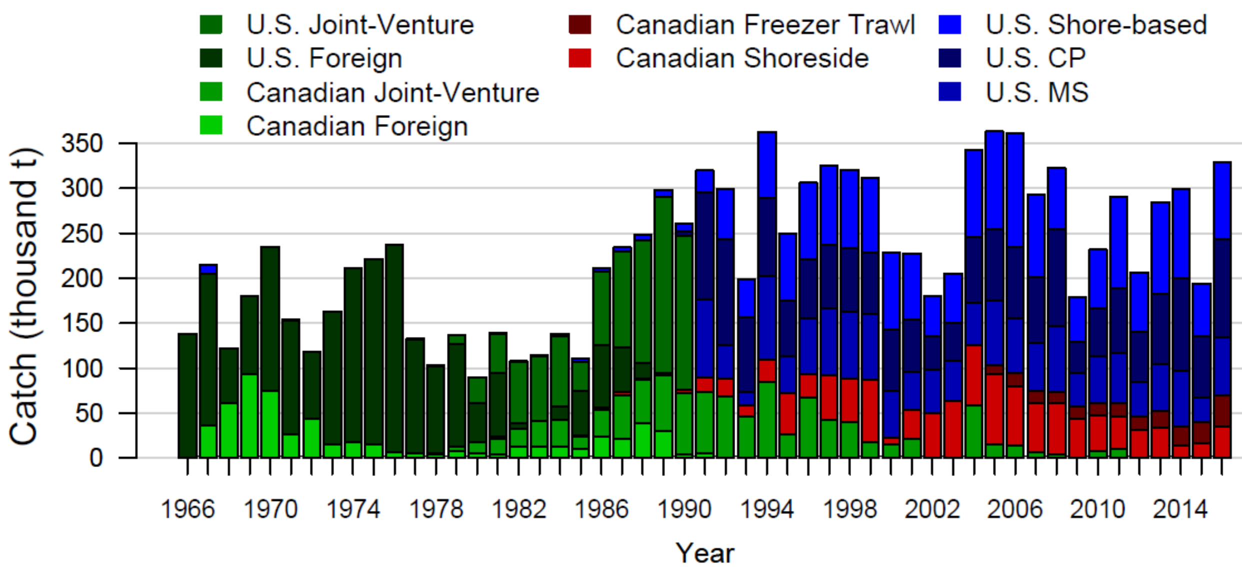


Figure 13: Catch history for Pacific Hake by sector. Data used in the CPUE analysis are from the "U.S. Joint-Venture" and "U.S. Foreign sectors" through 1990 and from the Catcher-Processor ("U.S. CP") and Mothership ("U.S. MS") sectors from 1990 onward. fig:ASHOP_X2

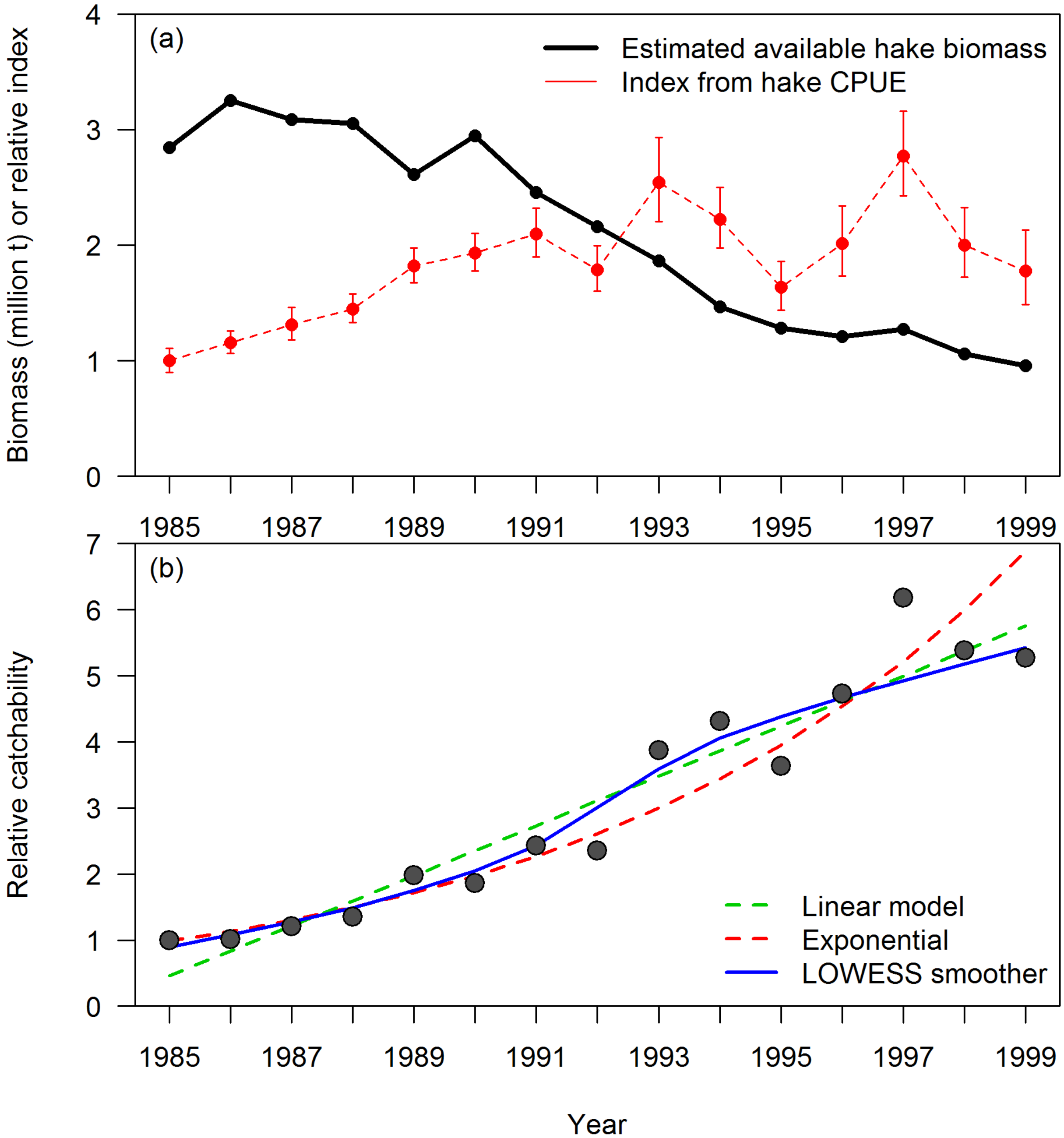


Figure 14: Geostatical index for Pacific Hake developed using VAST compared to the estimated avaialble hake biomass. fig:ASHOP_X3

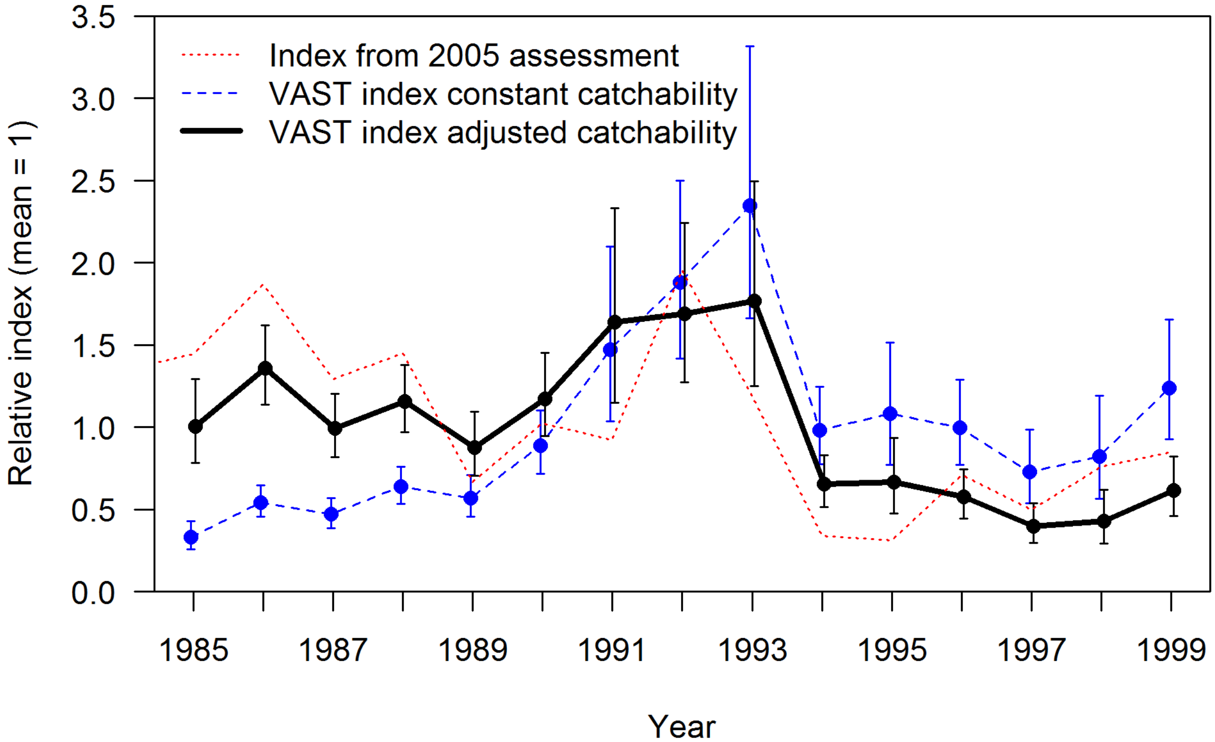


Figure 15: Index from the geostatistical model VAST with constant catchability and adjusted for the estimated increase in catchability (previous figure). These are compared to the index from the most recent yellowtail assessment (Wallace and Lai, 2005). fig:ASHOP_X4

1140 ### 9.2.3 Fits to indices of abundance for Northern model

fits-to-indices-of-abundance-for-northern-model

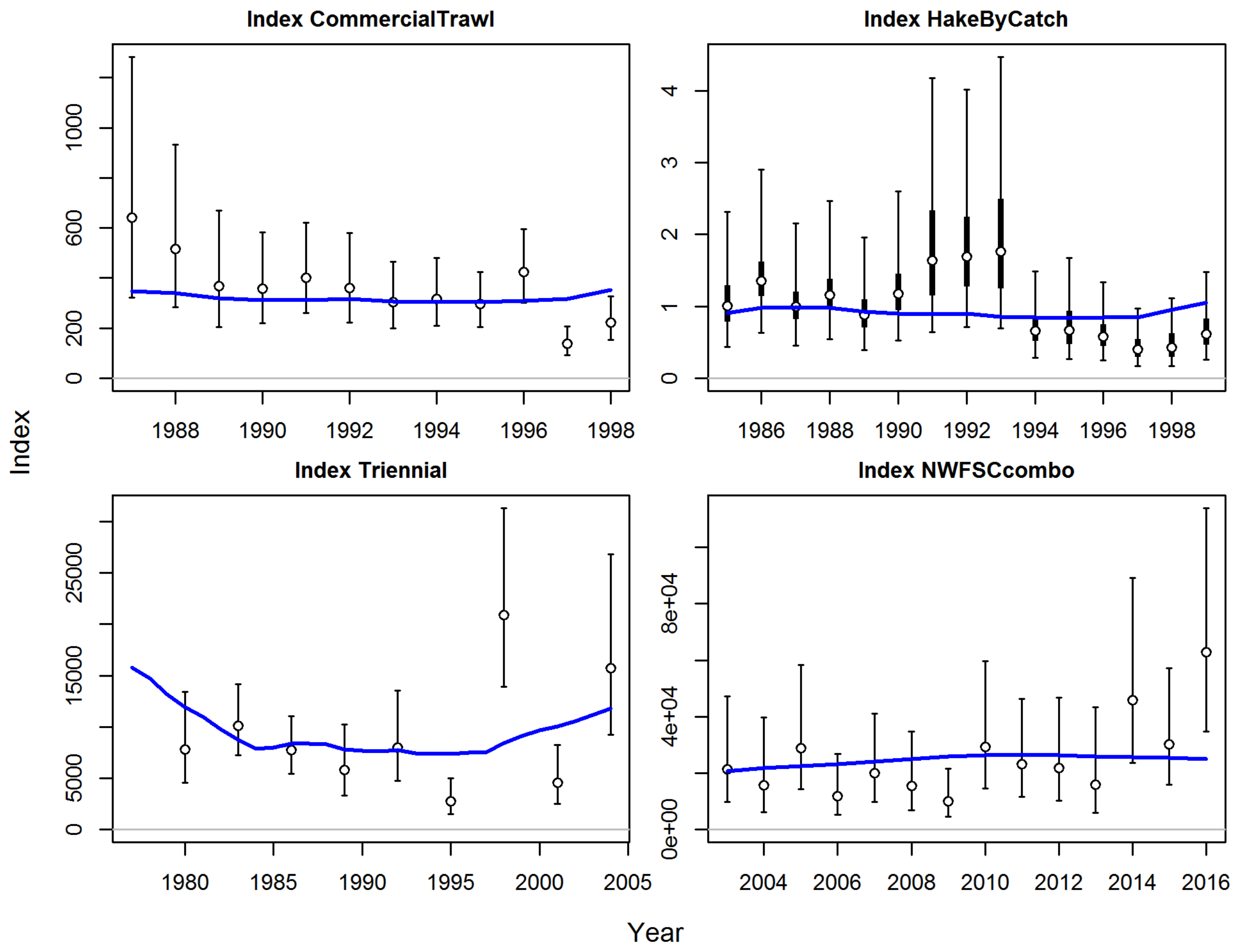


Figure 16: Estimated fits to the CPUE and survey indices for the Northern model. fig:index_fits1

9.2.4 Length compositions for Northern model

`length-compositions-for-northern-model`

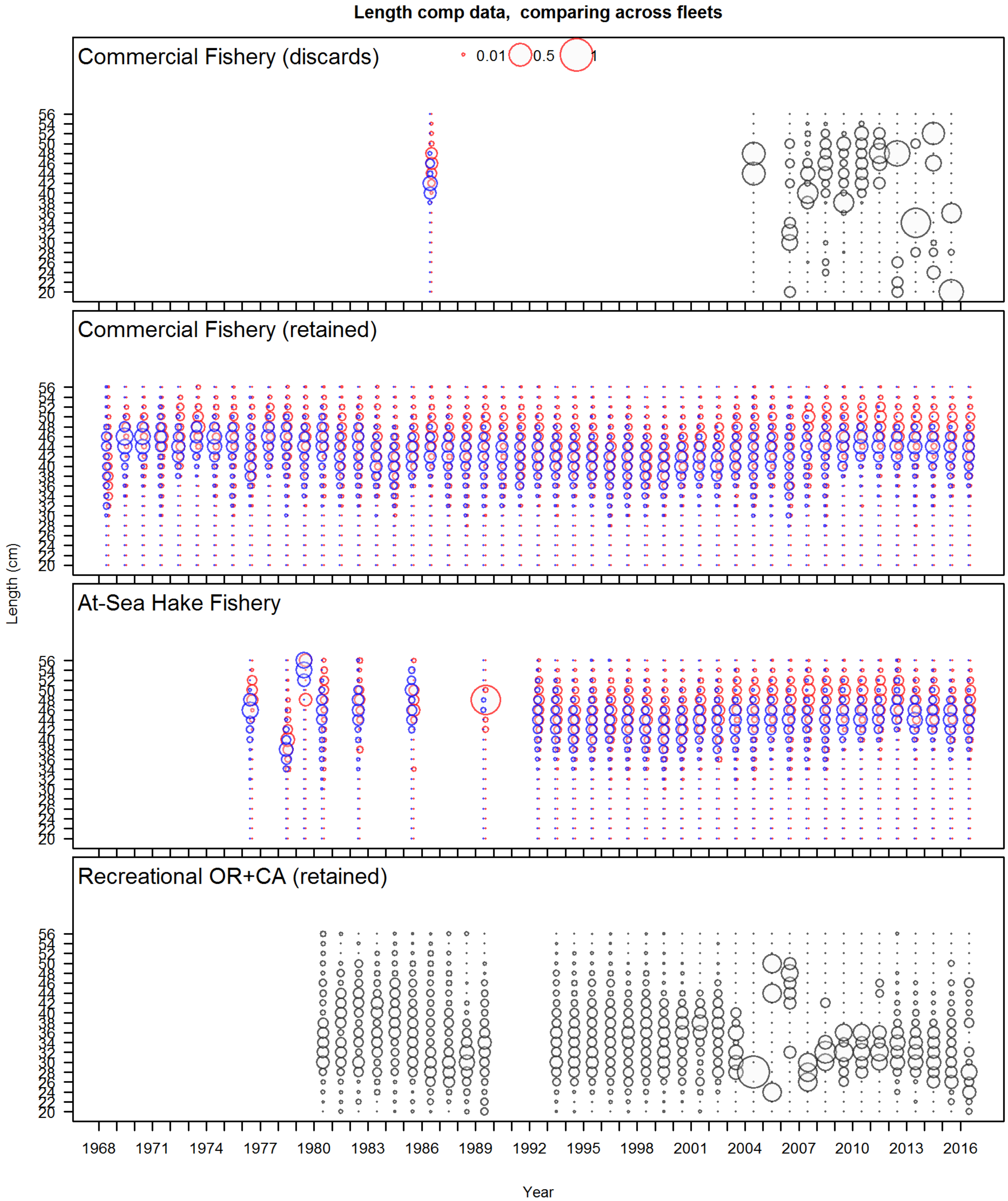


Figure 17: Length compositions for all fleets in the Northern model (figure 1 of 2). Bubble size is proportional to proportions within each year. Bubble colors indicate unsexed fish (gray), females (red), and males (blue). fig:comp_length_bubble_mod1_page1

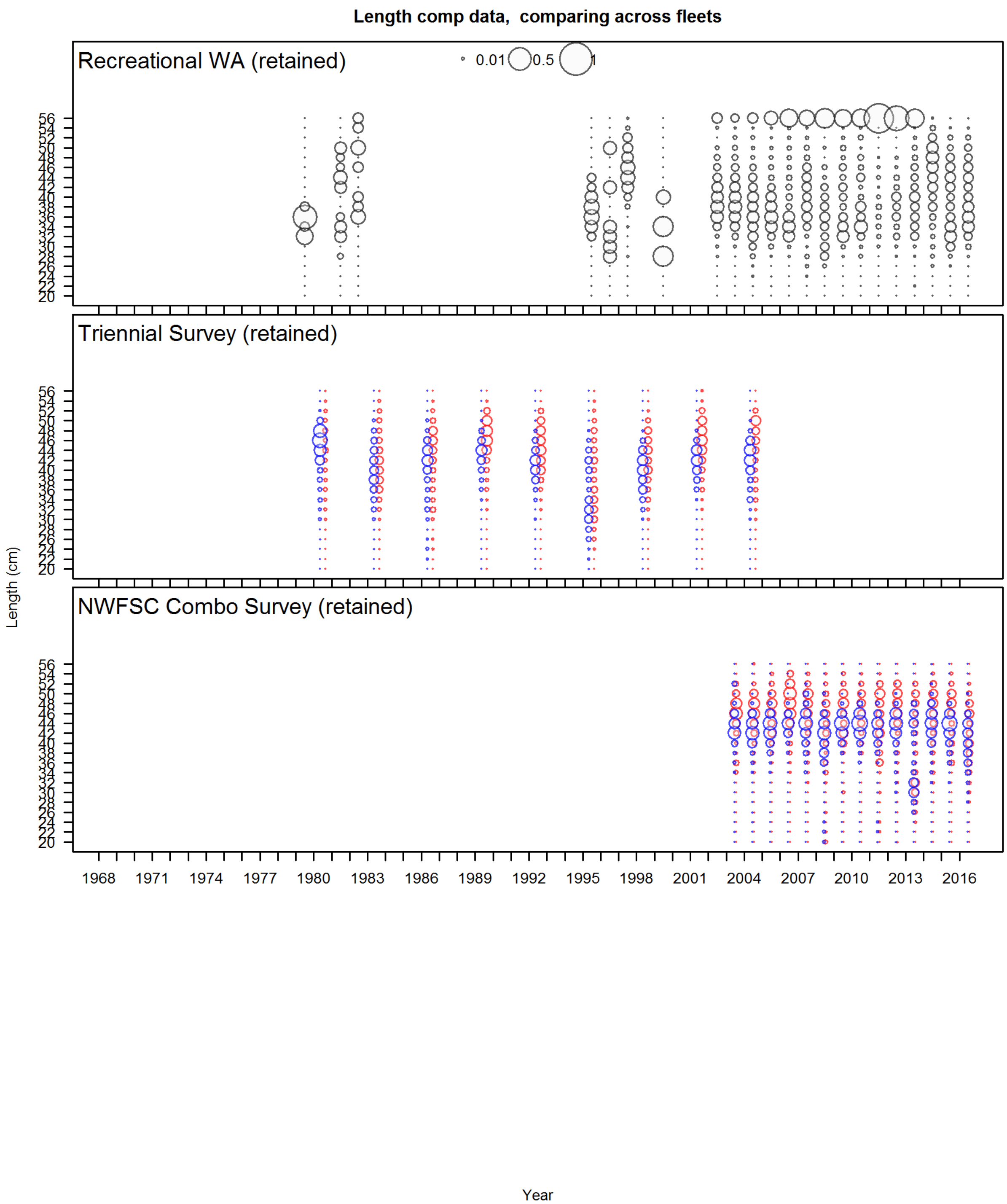


Figure 18: Length compositions for all fleets in the Northern model (figure 2 of 2). fig:comp_length_

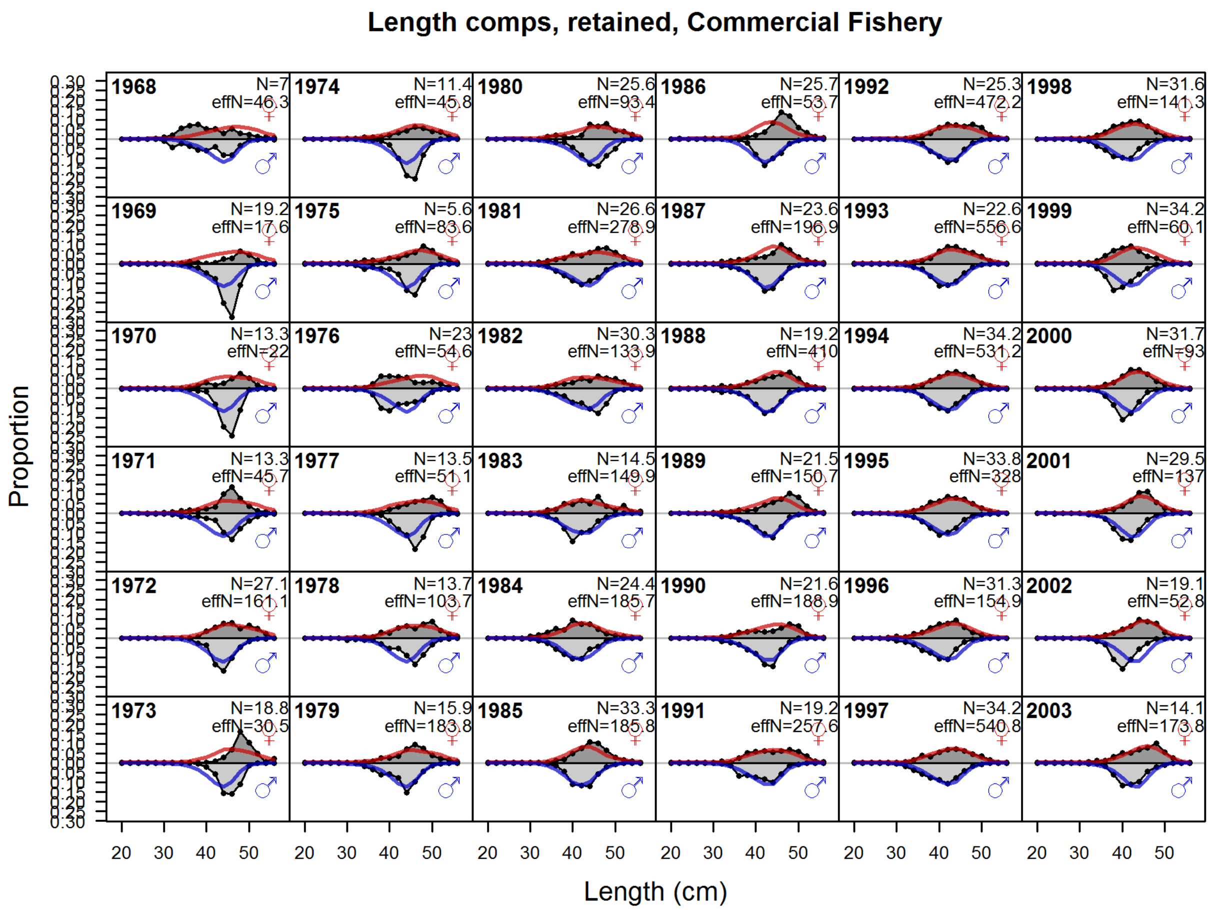
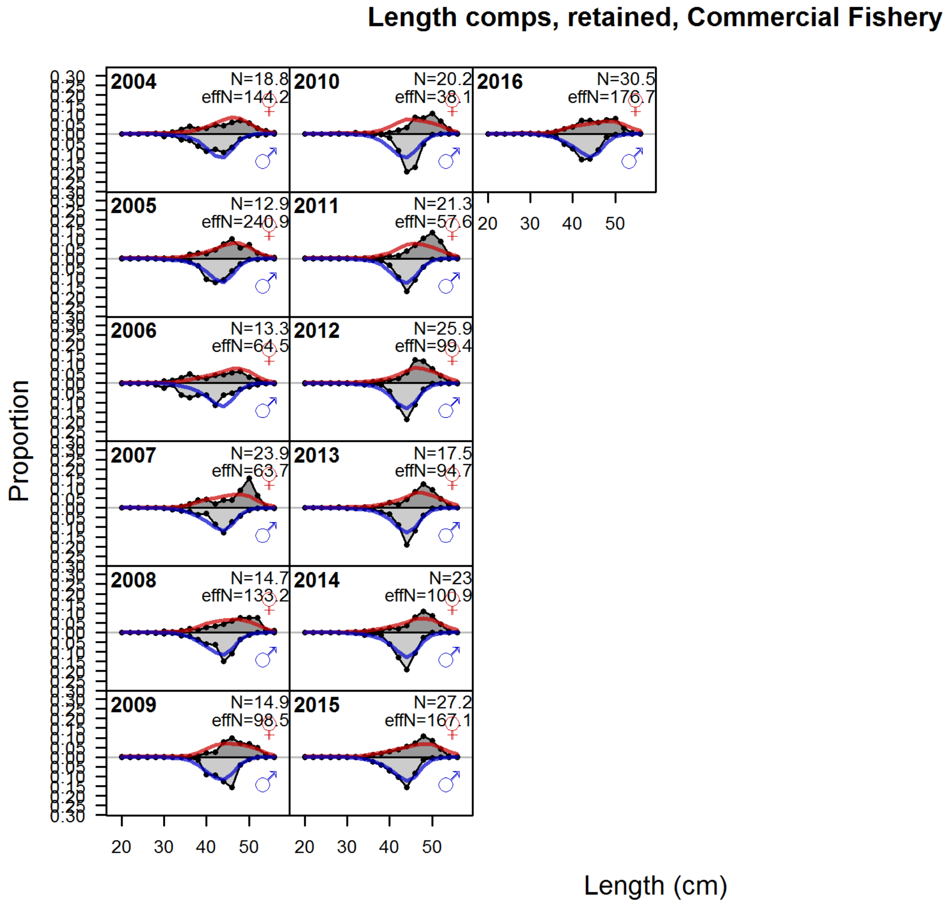


Figure 19: **Northern model** Length comps, retained, Commercial Fishery (plot 1 of 2) fig:mod1_1_com



1142

1143 Figure continued from previous page

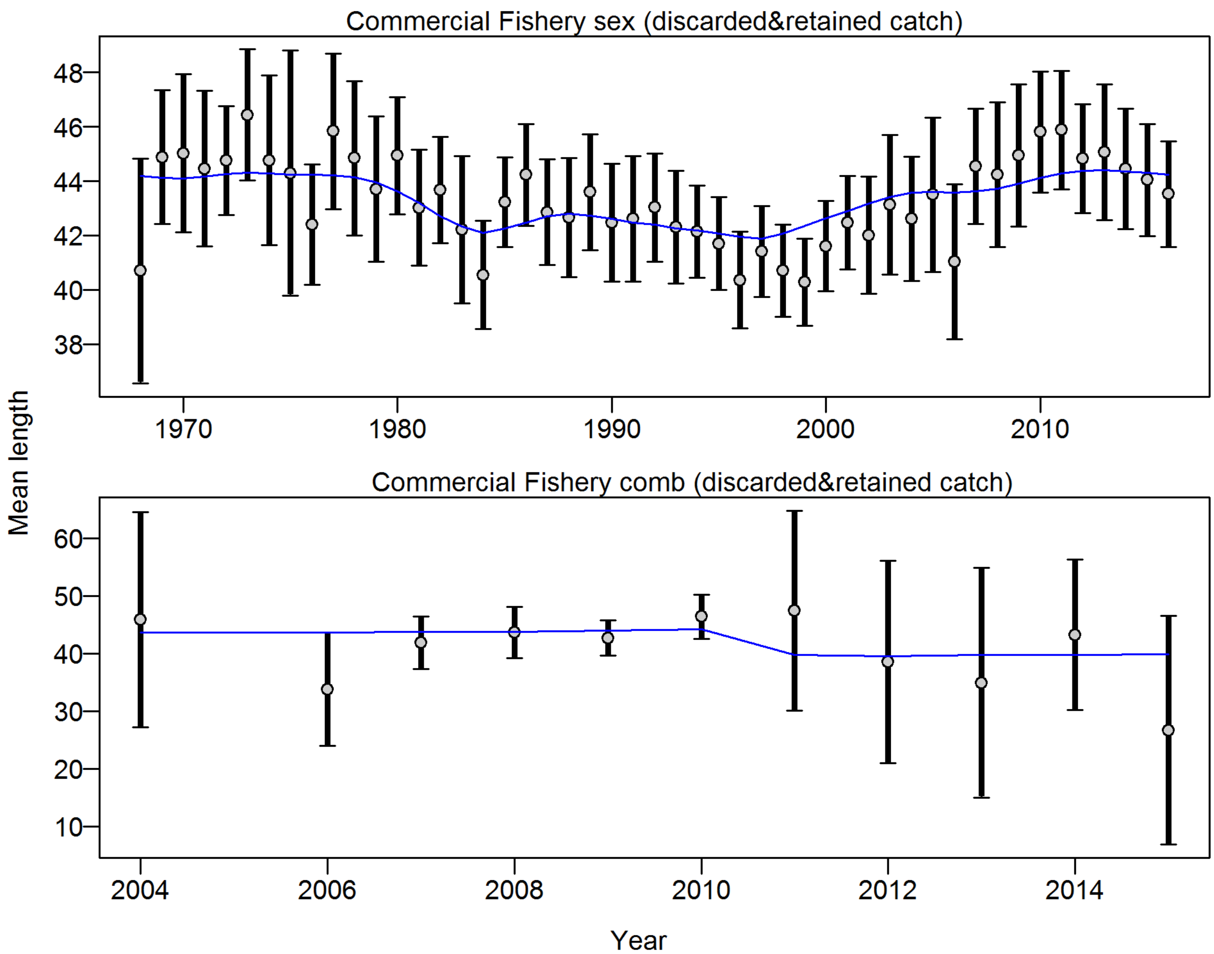


Figure 20: **Northern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Commercial Fishery: 0.9821 (0.7428_1.4551) 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. fig:mod1_5_comp_lenfit_data_weighting_T

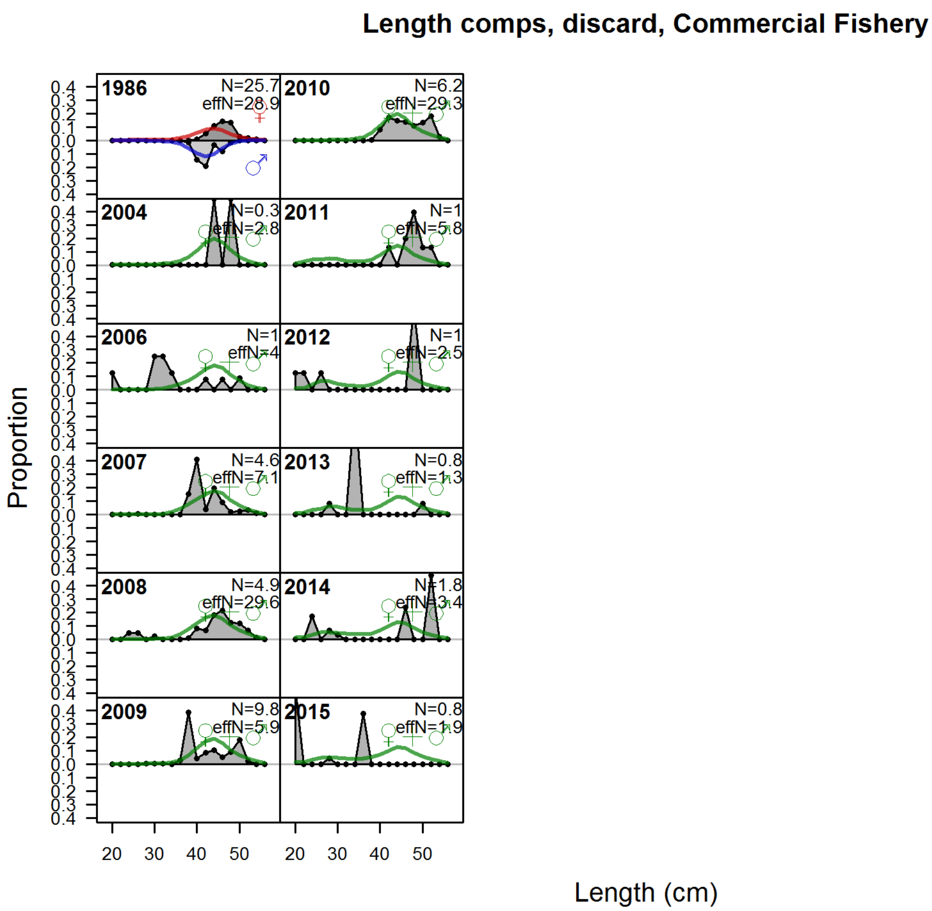


Figure 21: **Northern model** Length comps, discard, Commercial Fishery fig:mod1_6_comp_lenf

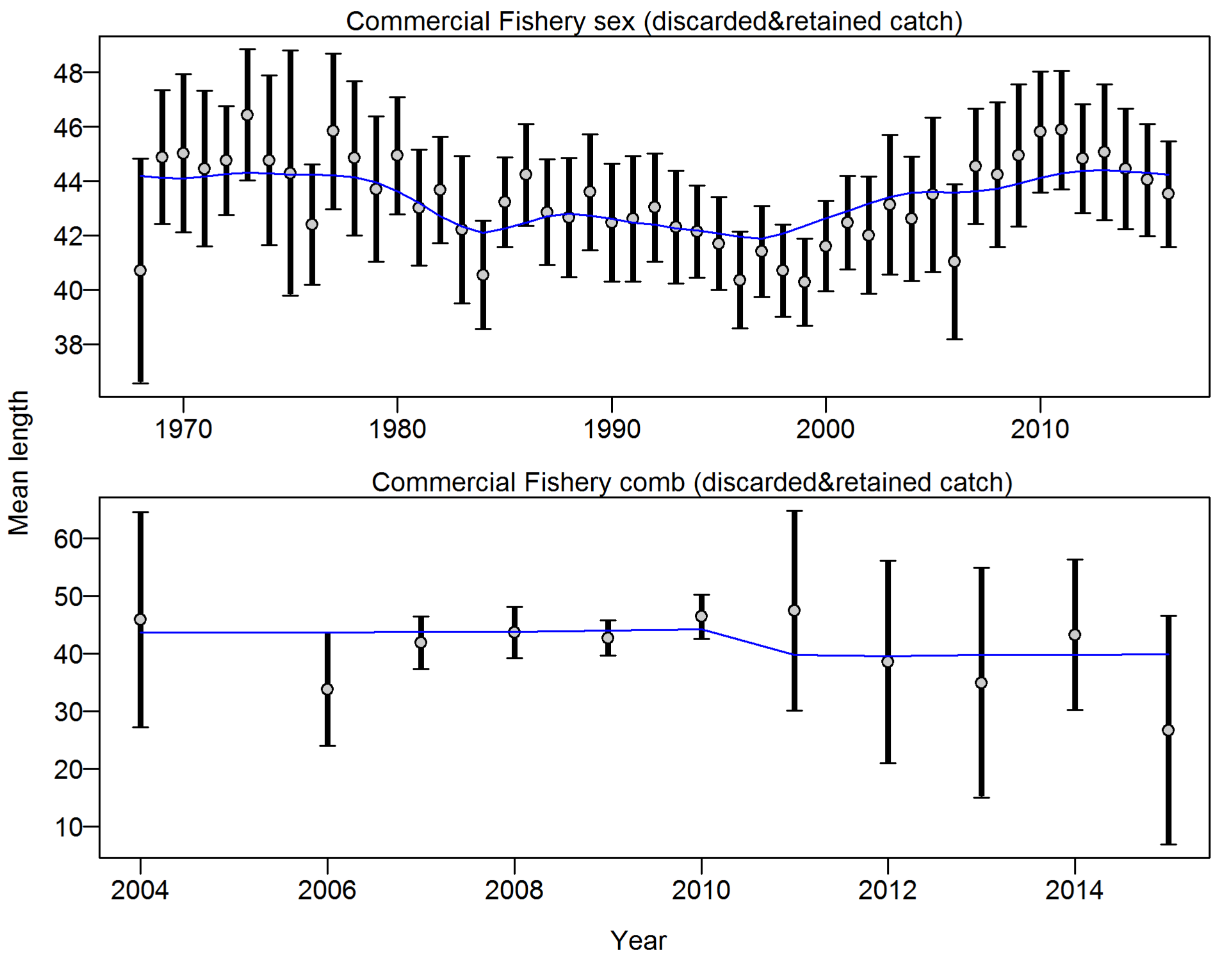


Figure 22: **Northern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Commercial Fishery: 0.9821 (0.7498_1.4377) 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. fig:mod1_9_comp_lenfit_data_weighting_T

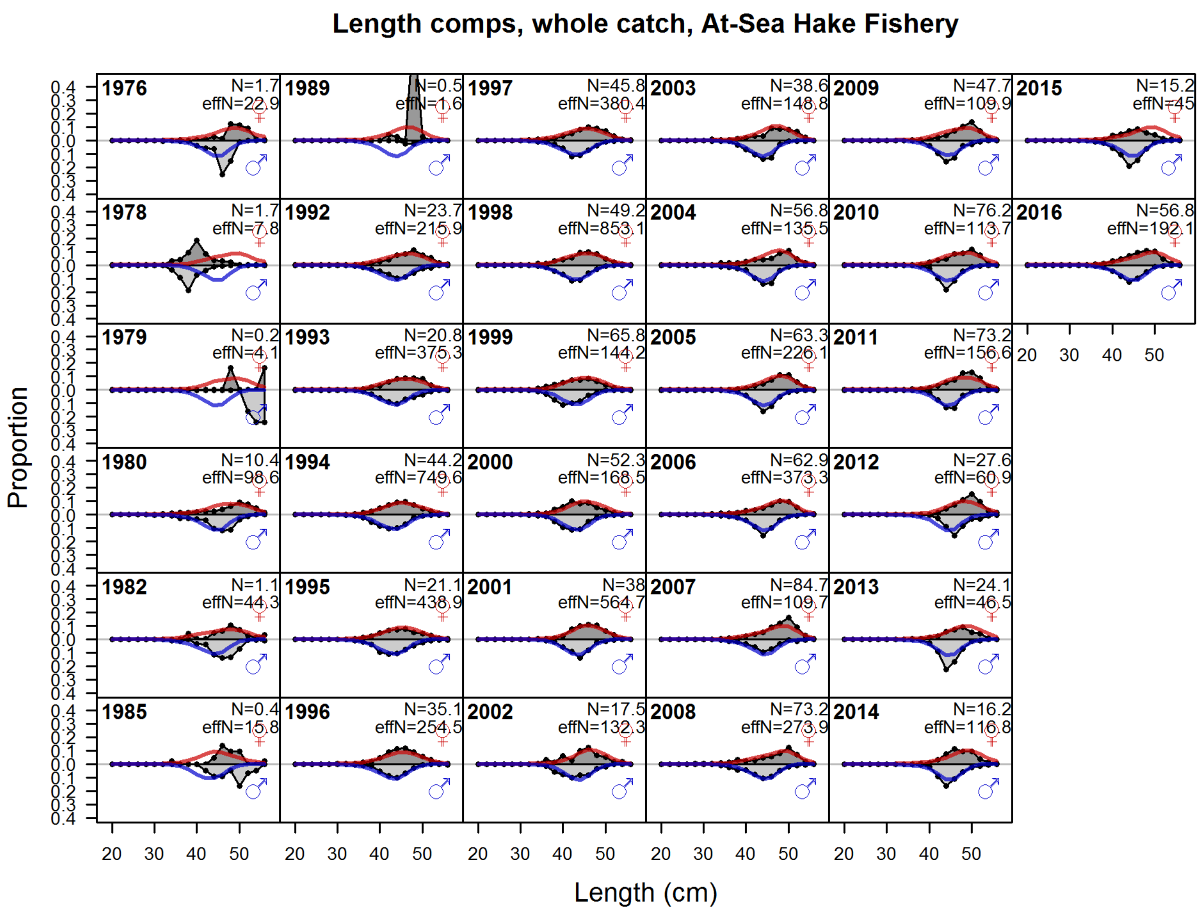


Figure 23: **Northern model** Length comps, whole catch, At_Sea Hake Fishery fig:mod1_10_comp_l

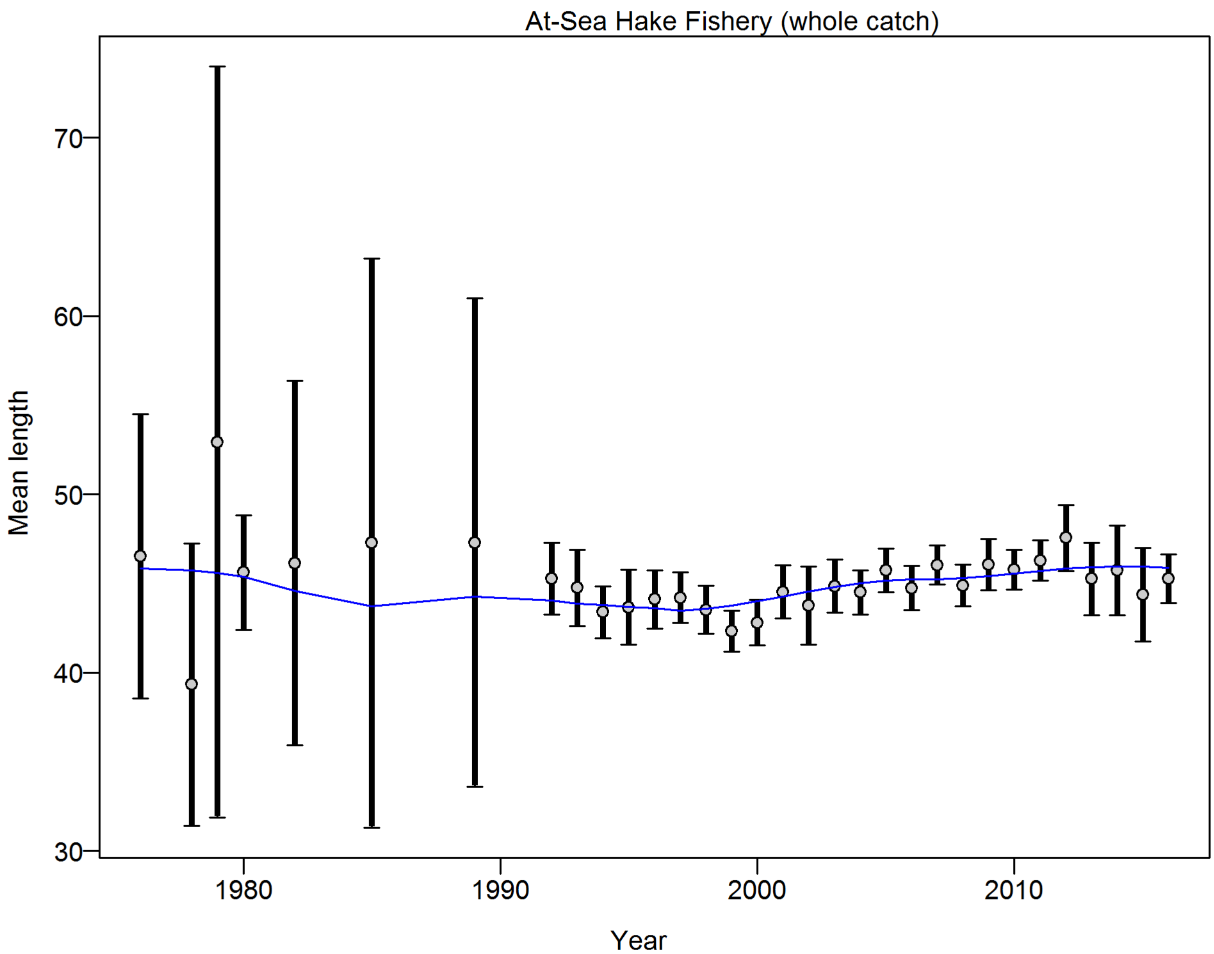


Figure 24: **Northern model** Mean length for At_Sea Hake Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from At_Sea Hake Fishery: 0.9923 (0.6694_1.8454) 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. fig:mod1_13_comp_lenfit_data_weighting_

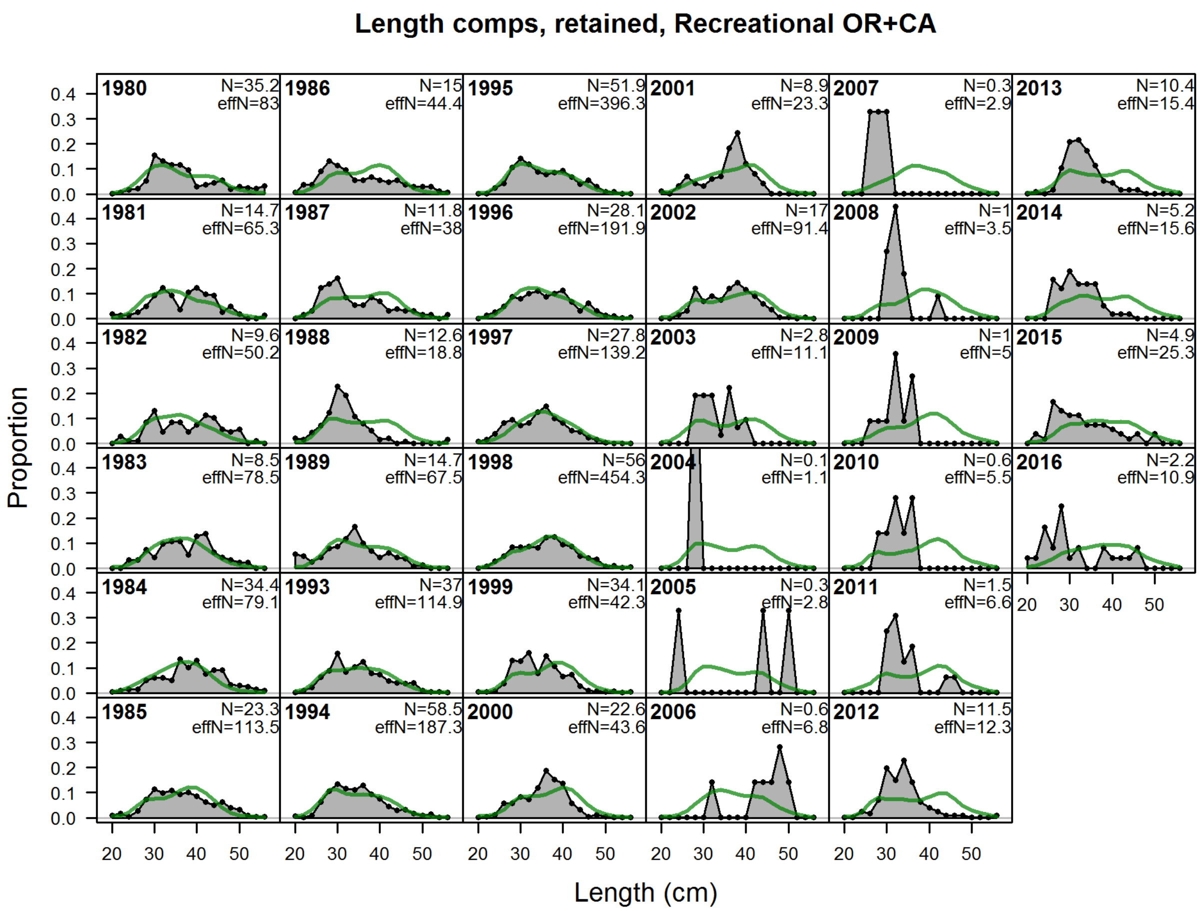


Figure 25: **Northern model** Length comps, retained, Recreational OR+CA fig:mod1_14_comp_le

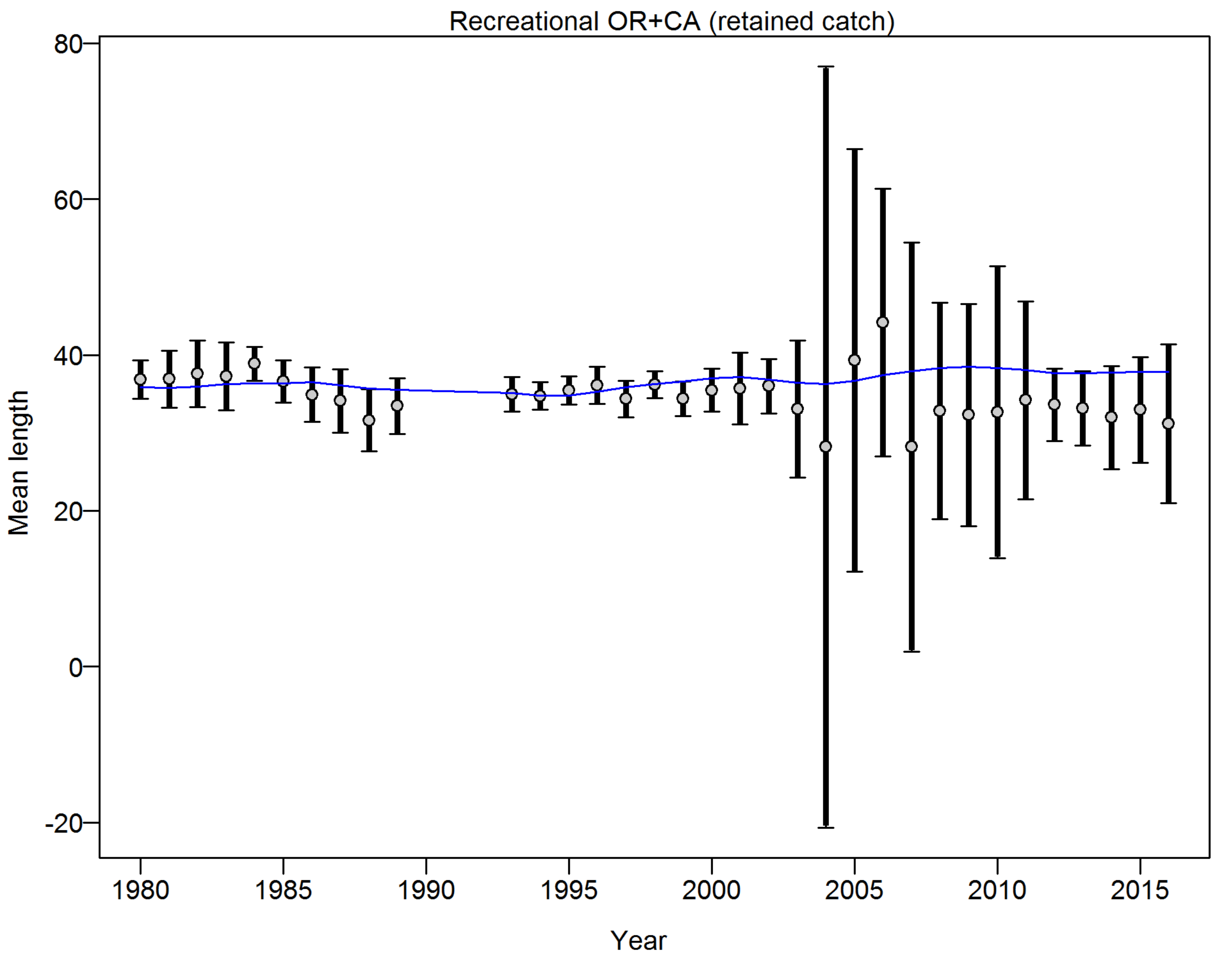


Figure 26: **Northern model** Mean length for Recreational OR+CA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Recreational OR+CA: 0.9909 (0.6731_1.7073) 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. fig:mod1_17_comp_lenfit_data_weighting_

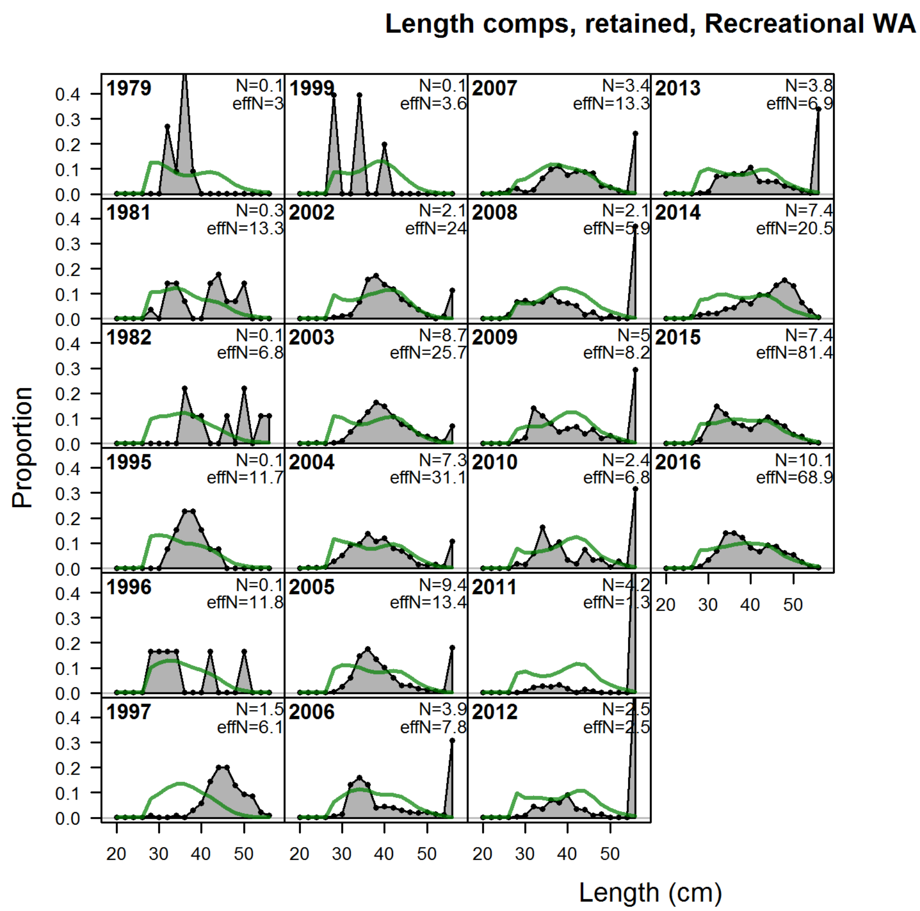


Figure 27: **Northern model** Length comps, retained, Recreational WA fig:mod1_18_comp_lenf

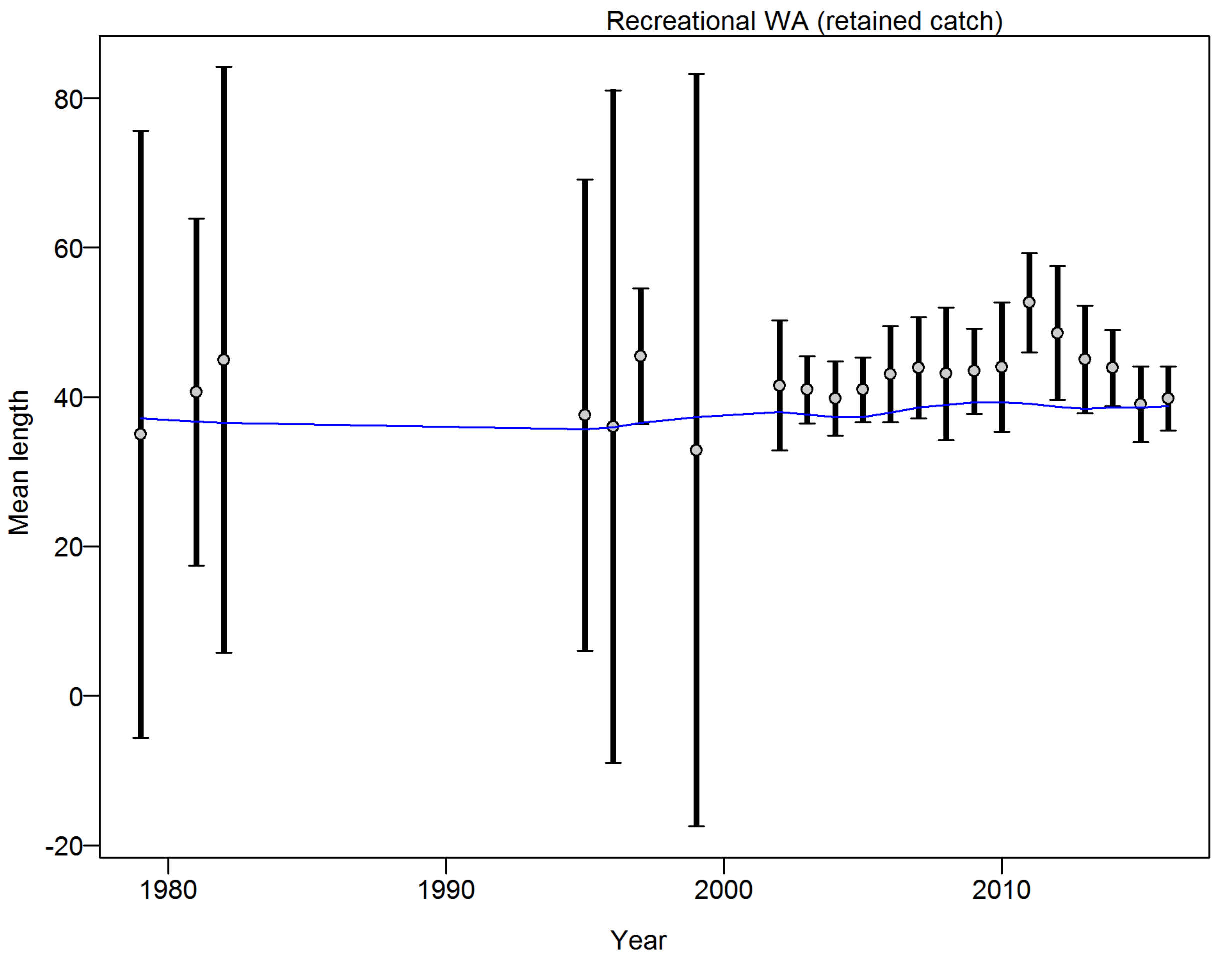


Figure 28: **Northern model** Mean length for Recreational WA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Recreational WA: 1.0056 (0.5535_2.3815) 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. `fig:mod1_21_comp_lenfit_data_weighting_TA1.8_Recreational`

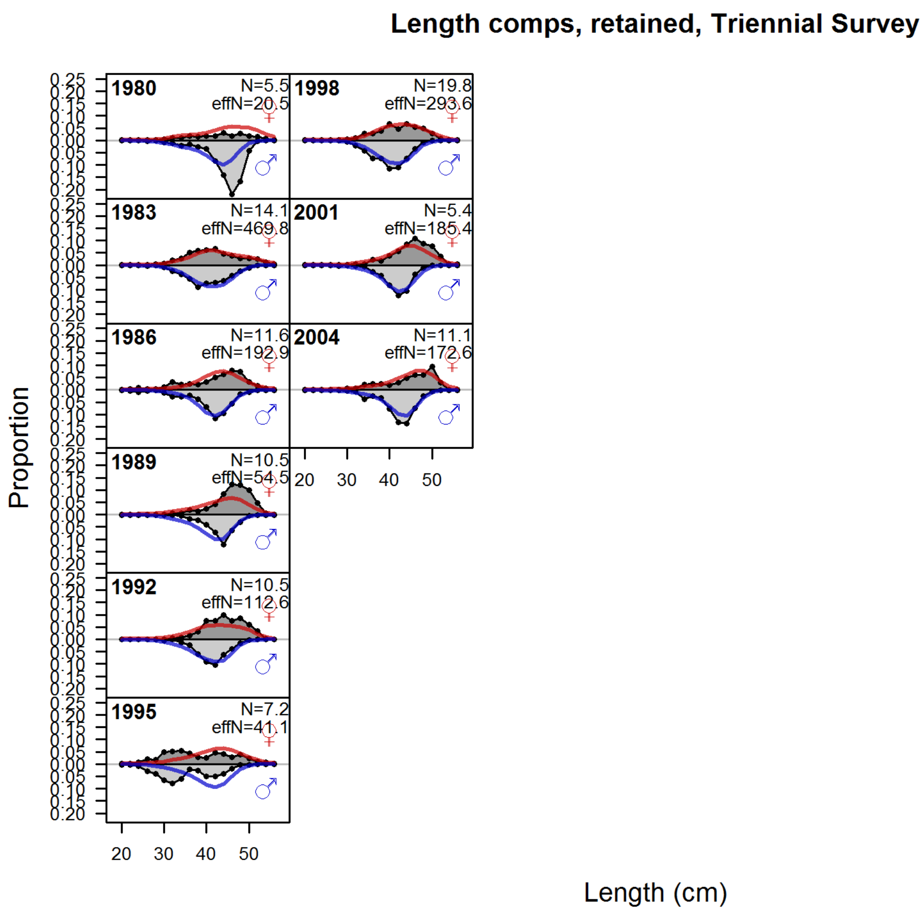


Figure 29: **Northern model** Length comps, retained, Triennial Survey fig:mod1_22_comp_lenf

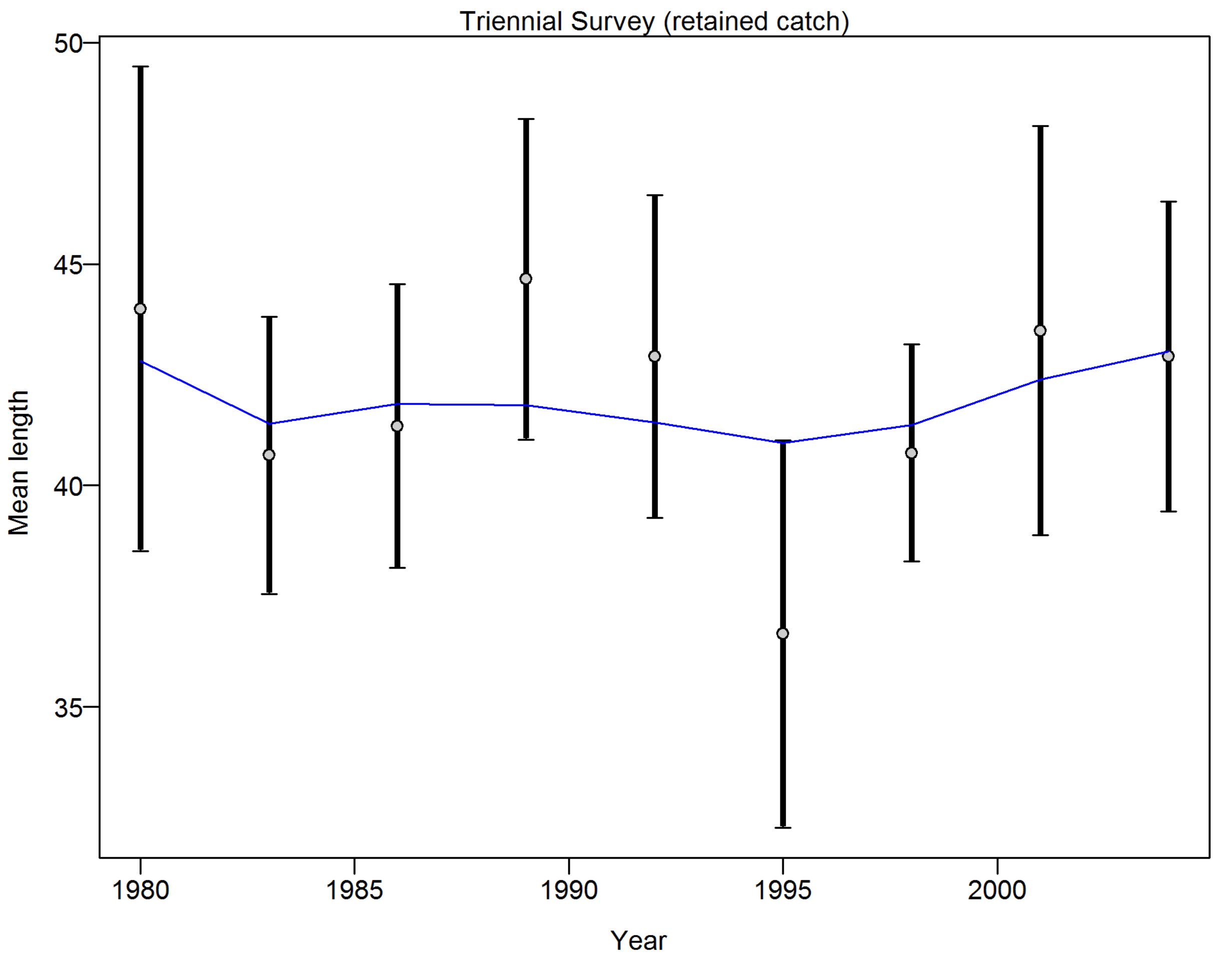


Figure 30: **Northern model** Mean length for Triennial Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Triennial Survey: 0.9901 (0.5251_5.0869) 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. fig:mod1_25_comp_lenfit_data_weighting_TA1.8_Triennial Su

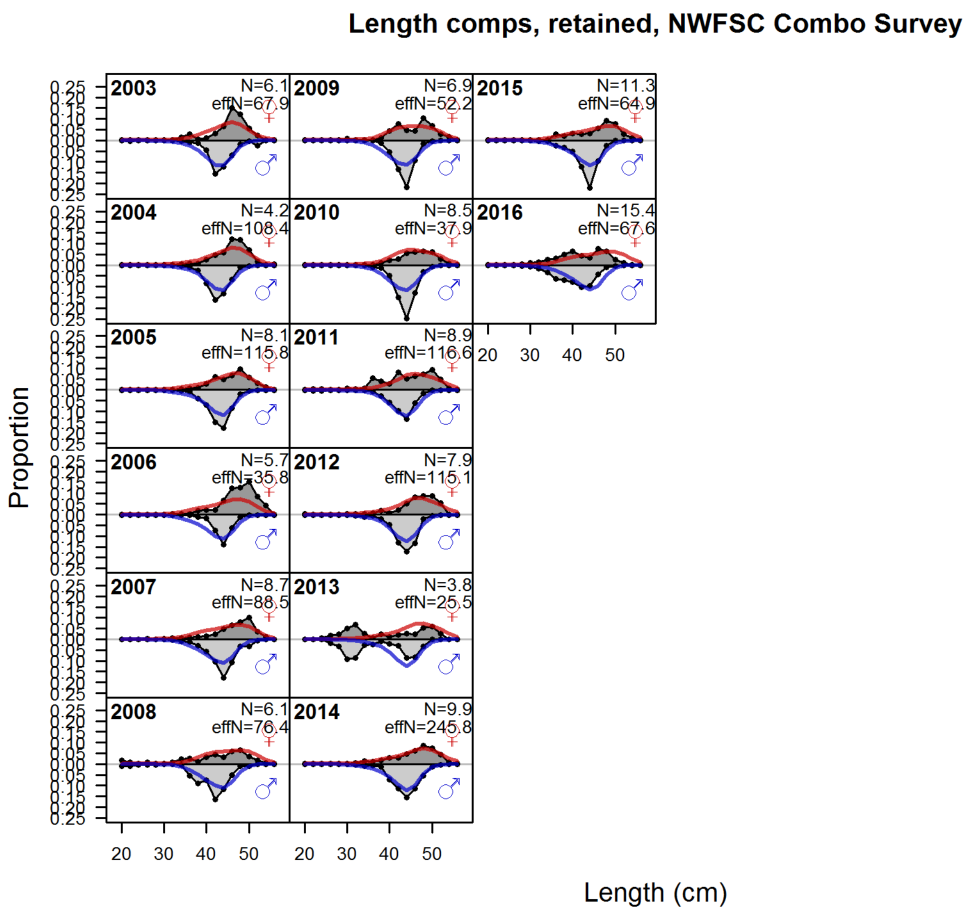


Figure 31: **Northern model** Length comps, retained, NWFSC Combo Survey fig:mod1_26_comp_l

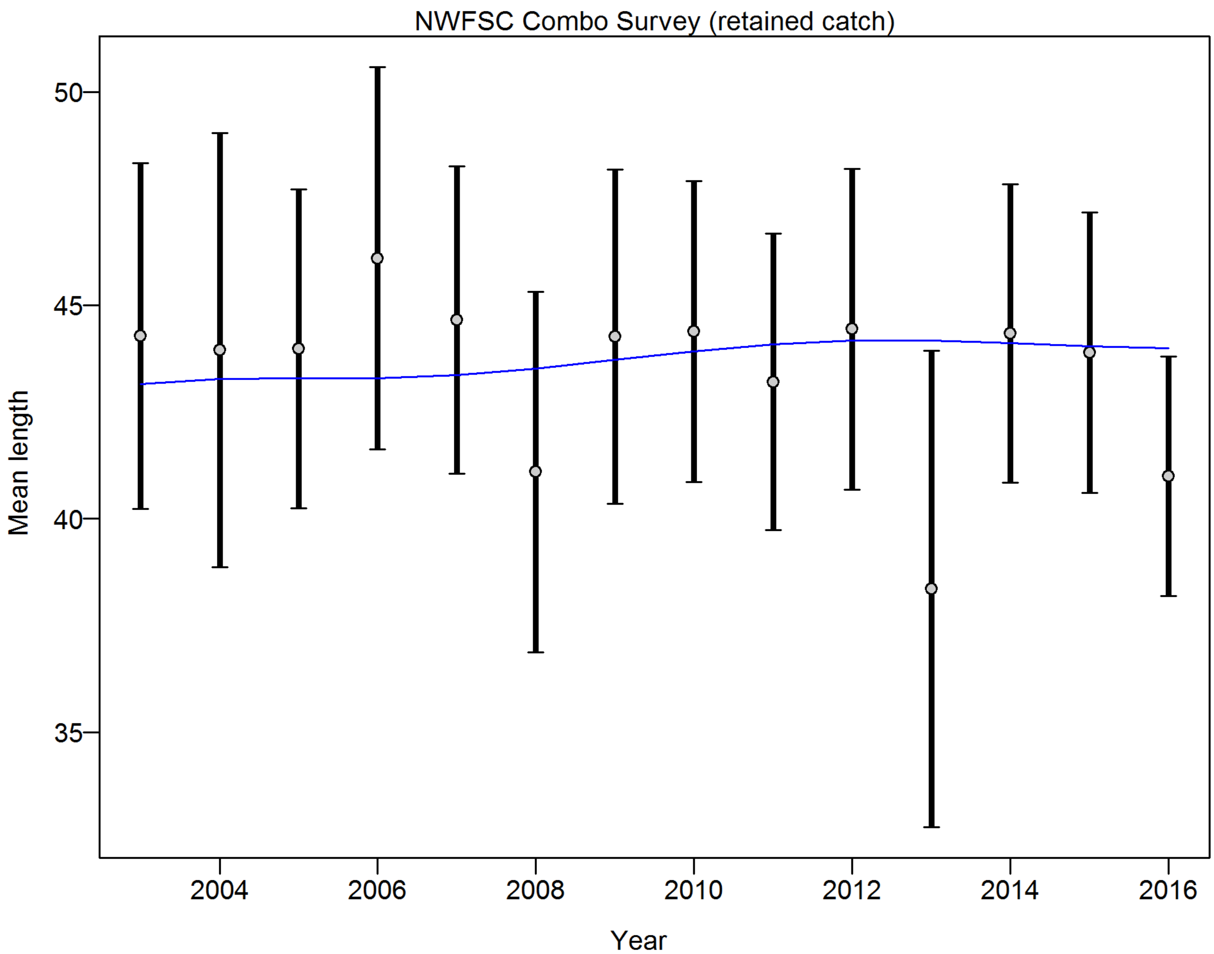


Figure 32: **Northern model** Mean length for NWFSC Combo Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from NWFSC Combo Survey: 1.0058 (0.6094_4.7808) 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. fig:mod1_29_comp_lenfit_da

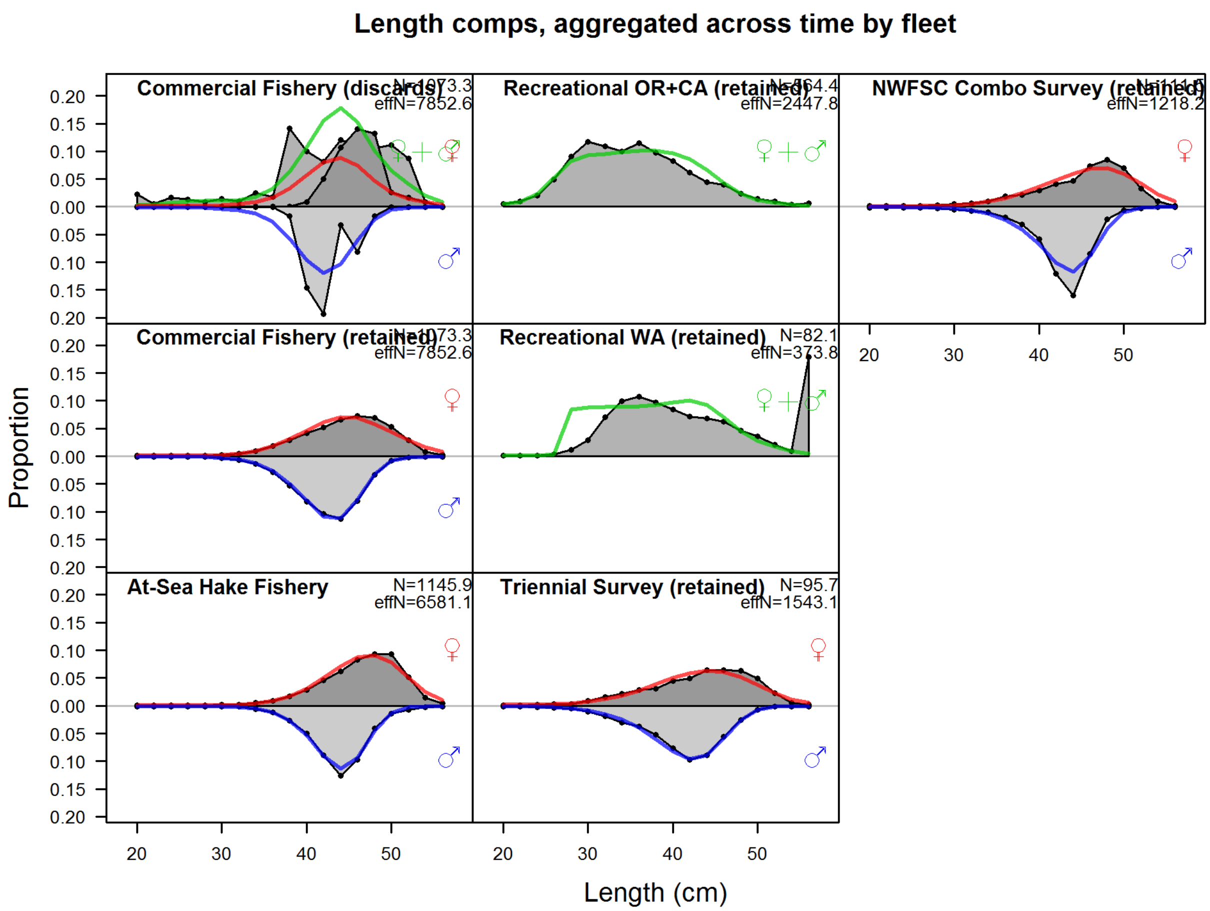


Figure 33: **Northern model** Length comps, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. fig:mod1_30_comp_lenfit__aggregated_across_time

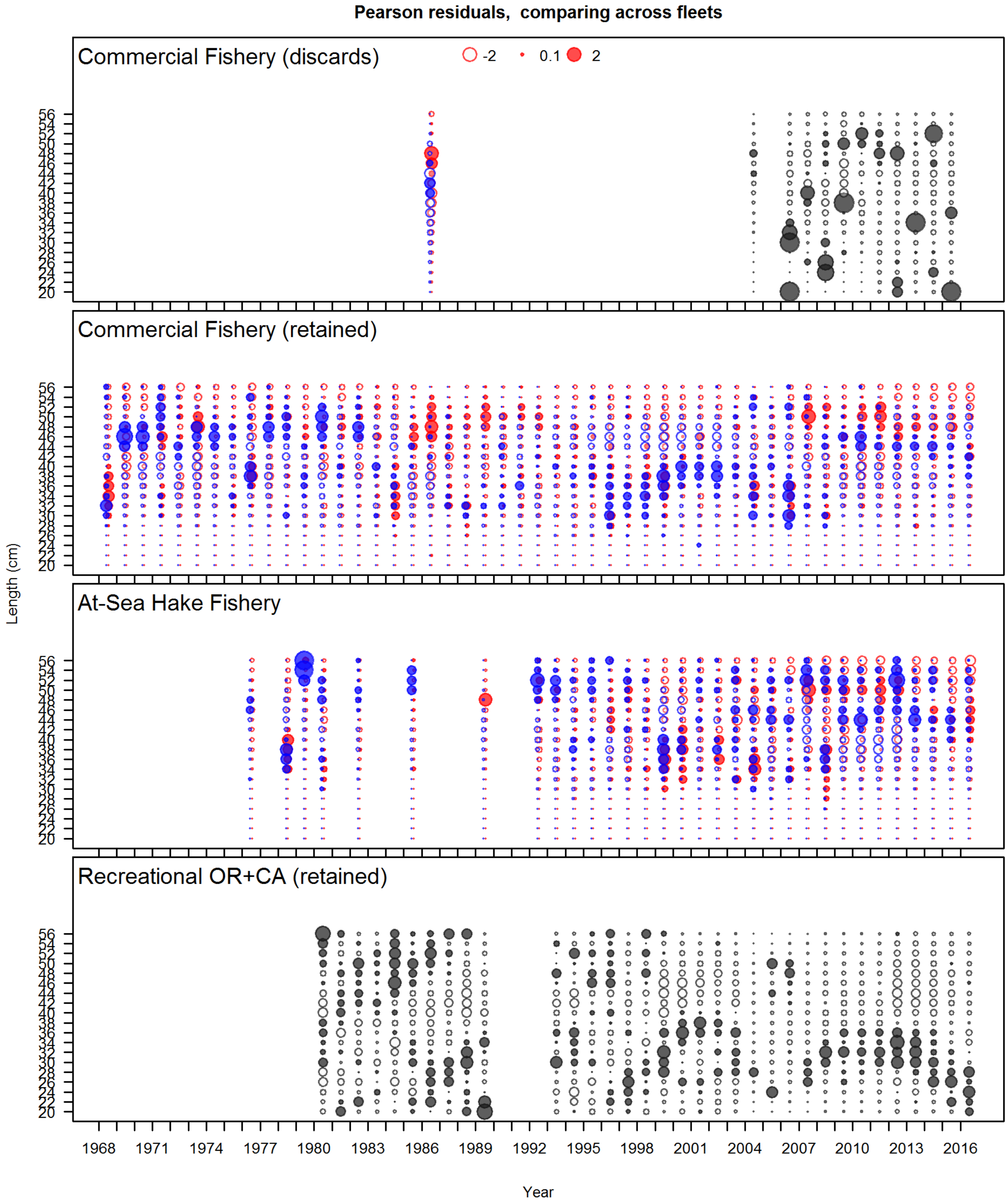


Figure 34: Length composition Pearson residuals for all fleets in the Northern model (Figure 1 of 2). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble colors indicate unsexed fish (gray), females (red), and males (blue). fig:comp_Pearson_length_mod1_page1

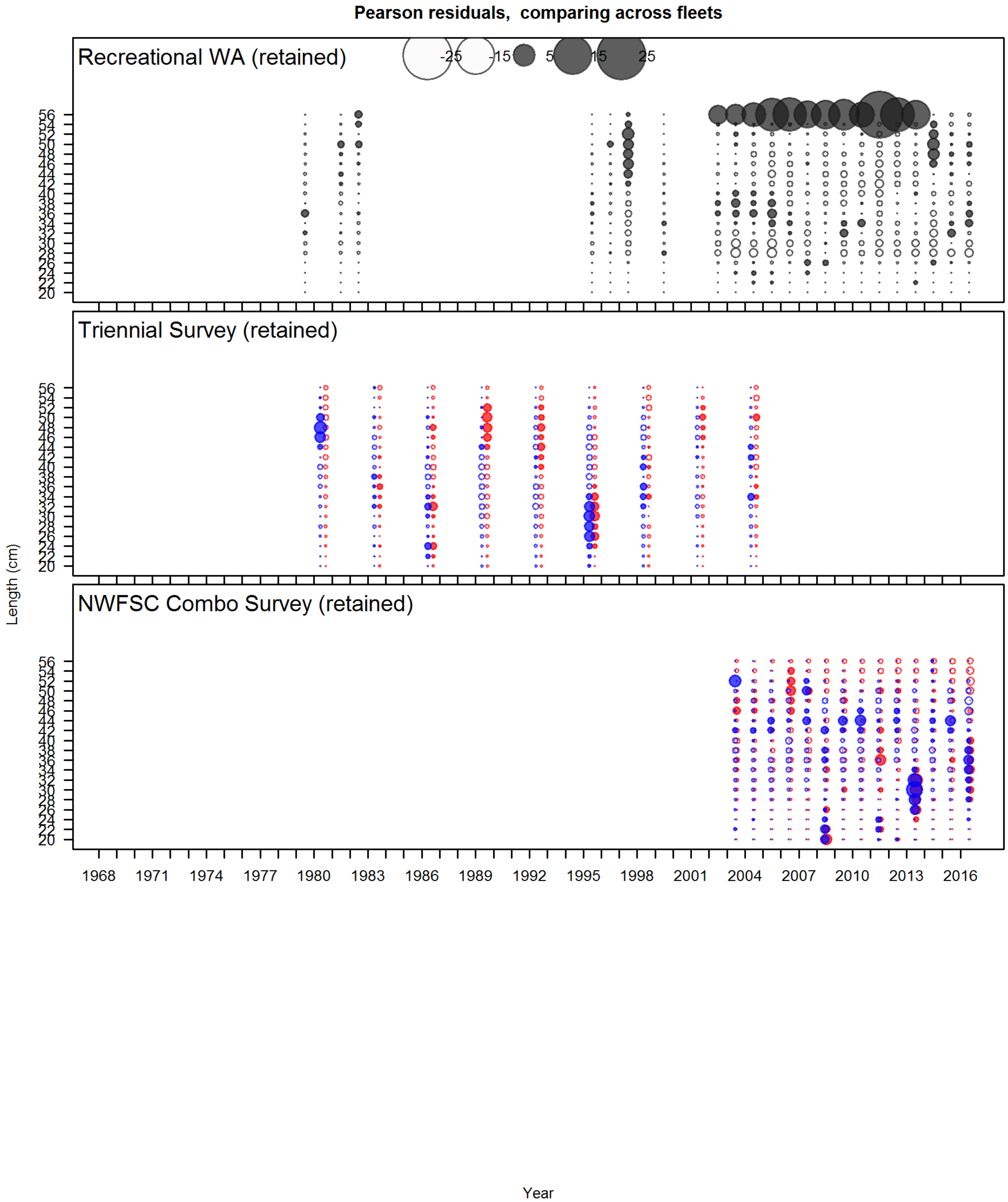


Figure 35: Length composition Pearson residuals for all fleets in the Northern model (Figure 2 of 2). fig:comp_Pearson_length_mod1_page2

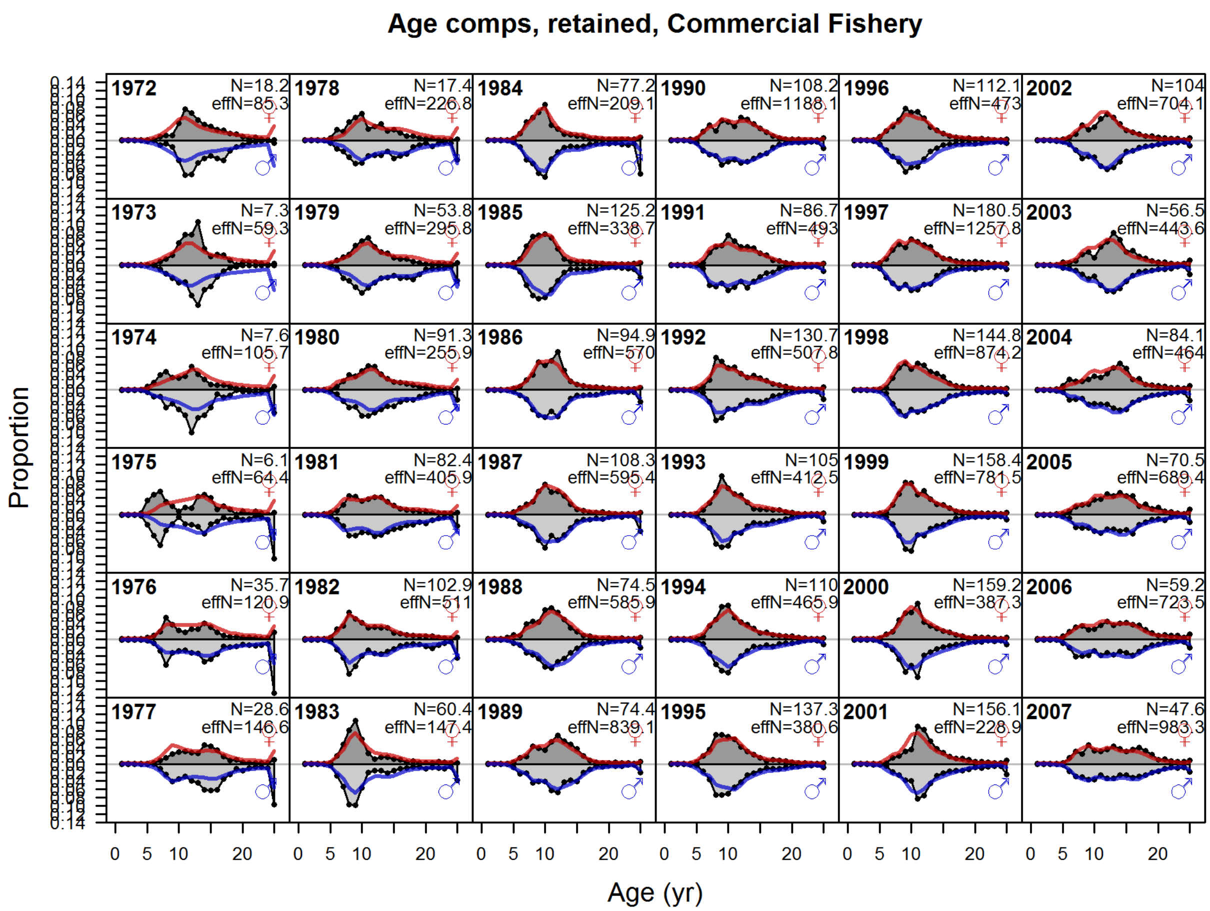
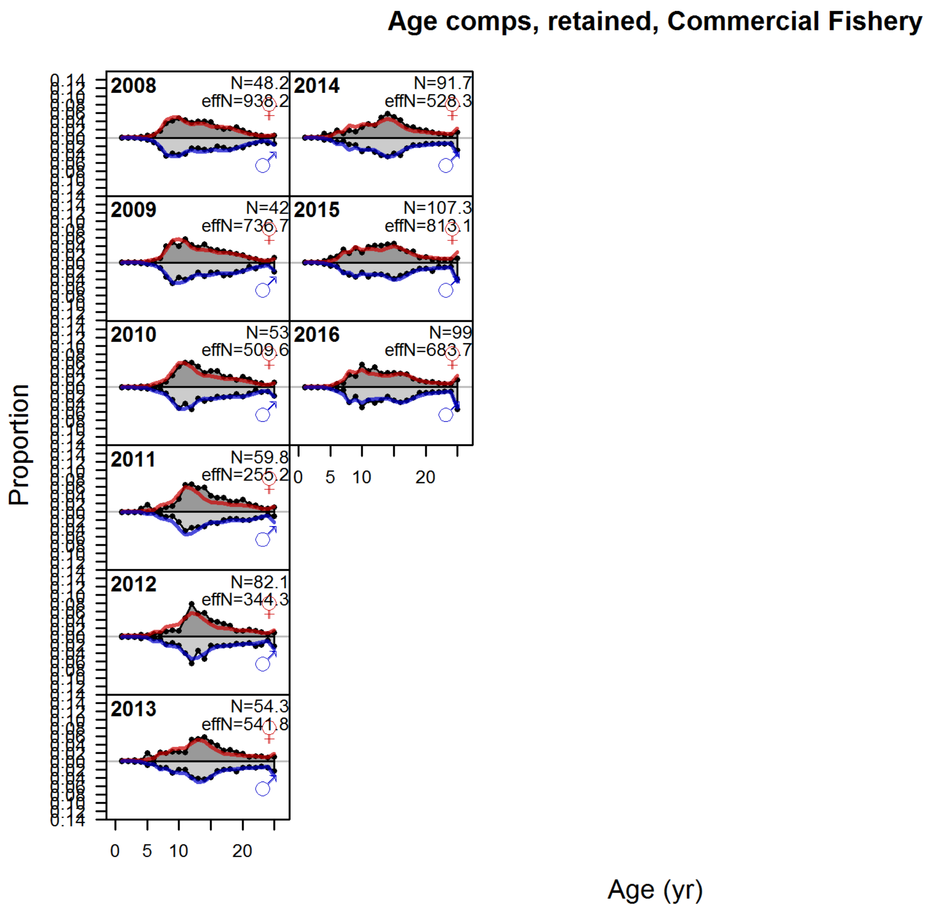


Figure 36: **Northern model** Age comps, retained, Commercial Fishery (plot 1 of 2) fig:mod1_1_comp

1144 ### 9.2.5 Fits to age compositions for Northern model

fits-to-age-compositions-for-northern-model



1145

1146 Figure continued from previous page

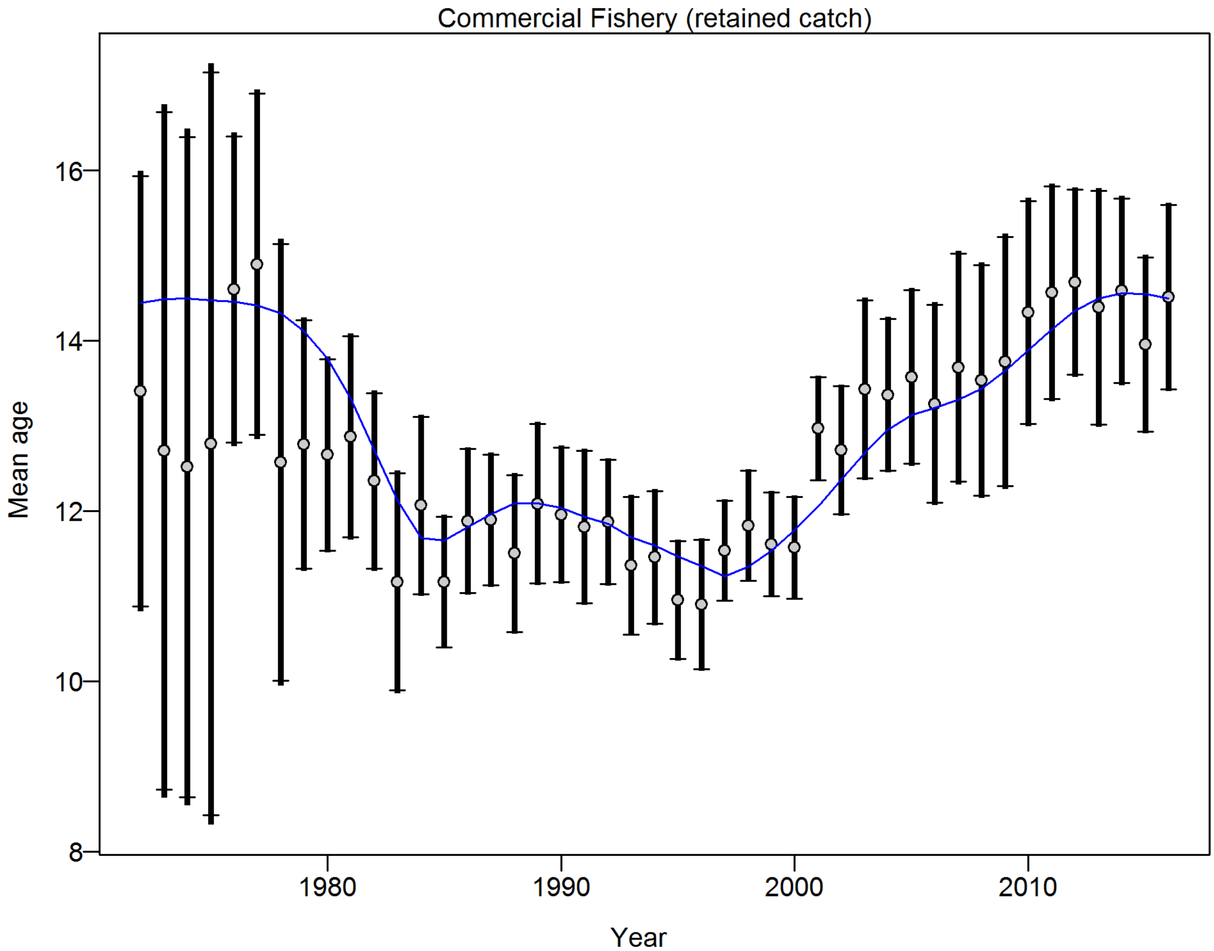


Figure 37: **Northern model** Mean age for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data from Commercial Fishery: 1.0493 (0.7095_1.7588) 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. fig:mod1_5_comp_agefit_data_weighting_TA1.8_Comme

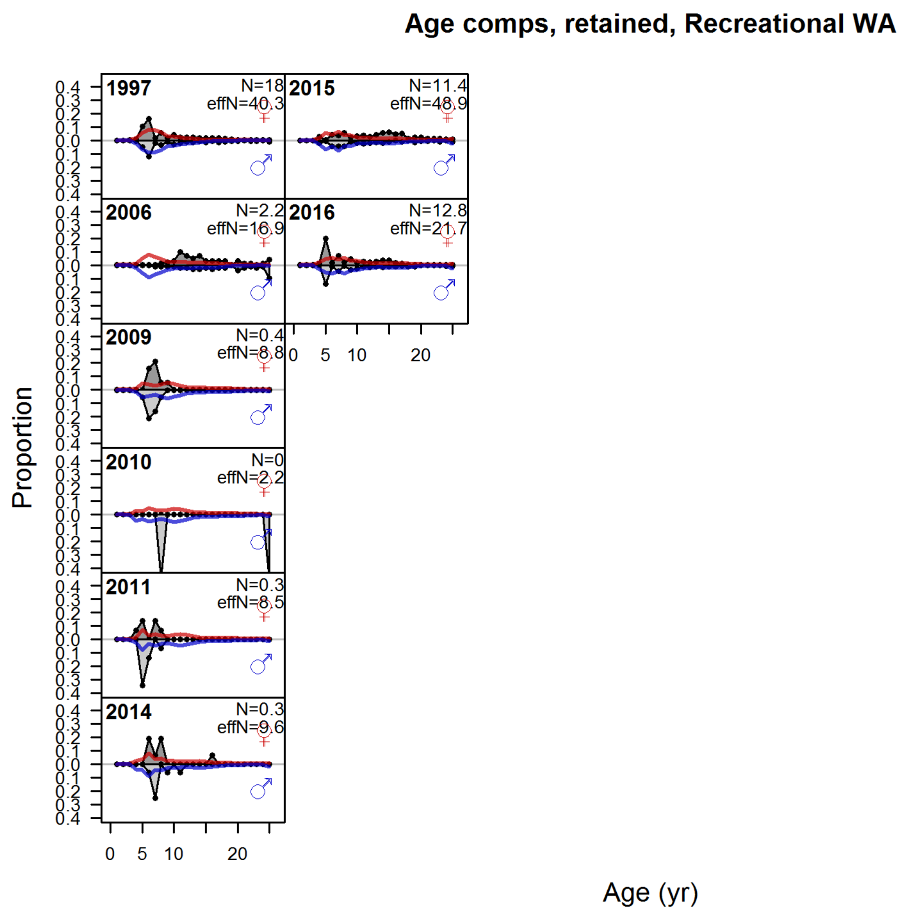


Figure 38: **Northern model** Age comps, retained, Recreational WA fig:mod1_6_comp_agefit

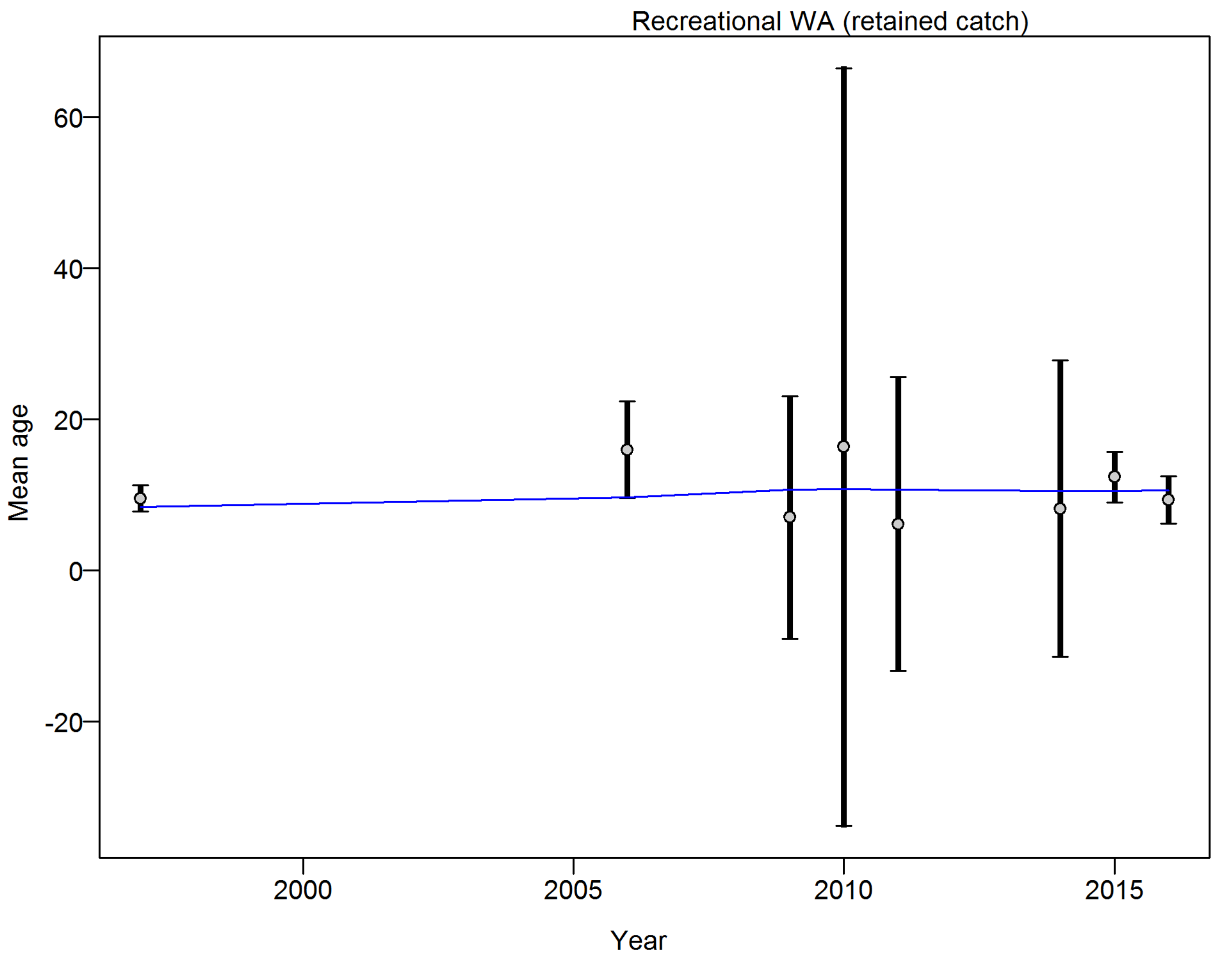


Figure 39: **Northern model** Mean age for Recreational WA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data from Recreational WA: 1.0094 (0.6602_3.0219) 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. fig:mod1_9_comp_agefit_data_weighting_TA1.8_Recreational

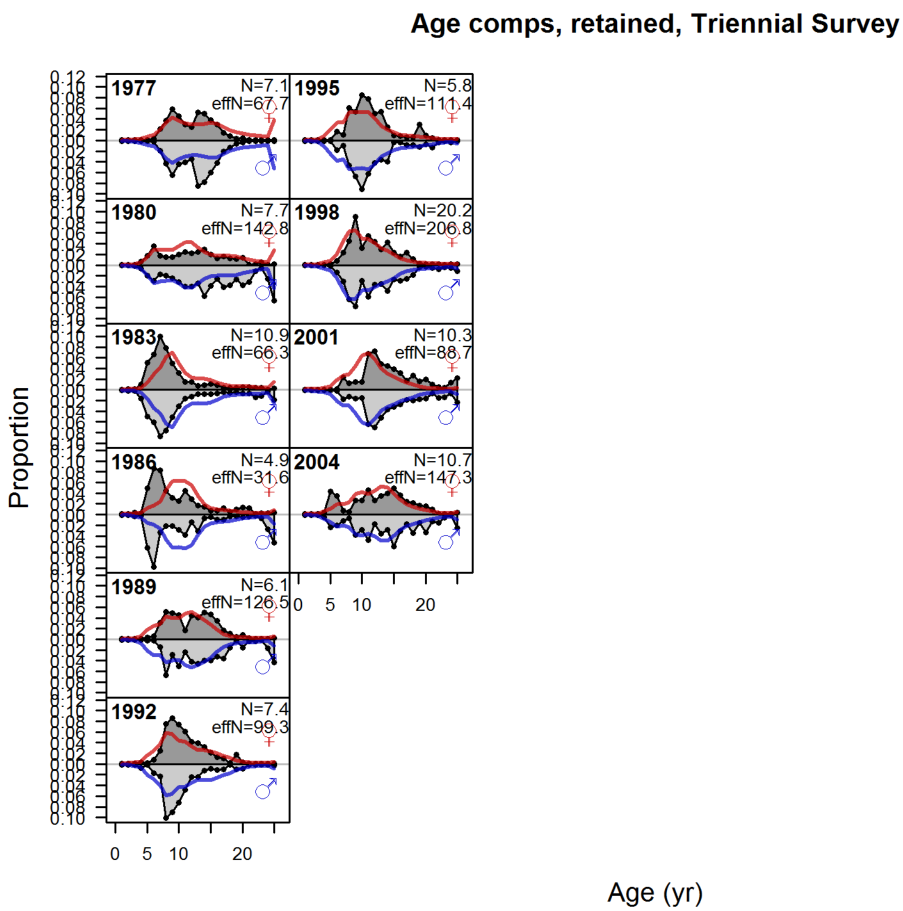


Figure 40: **Northern model** Age comps, retained, Triennial Survey fig:mod1_10_comp_agefit

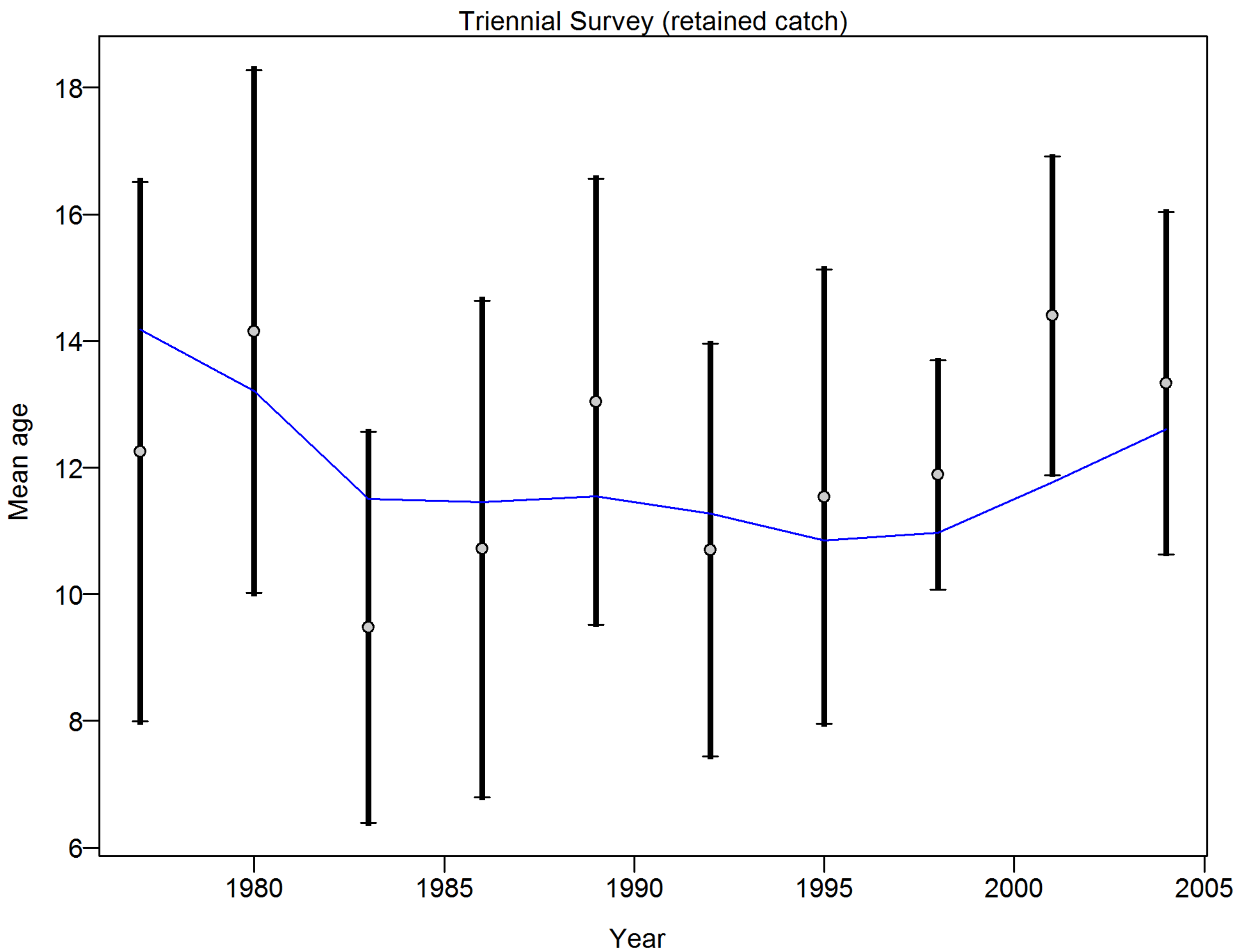


Figure 41: **Northern model** Mean age for Triennial Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data from Triennial Survey: 1.0287 (0.5938_3.3438) 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. fig:mod1_13_comp_agefit_data_weighting_TA1.8_Triennial Su

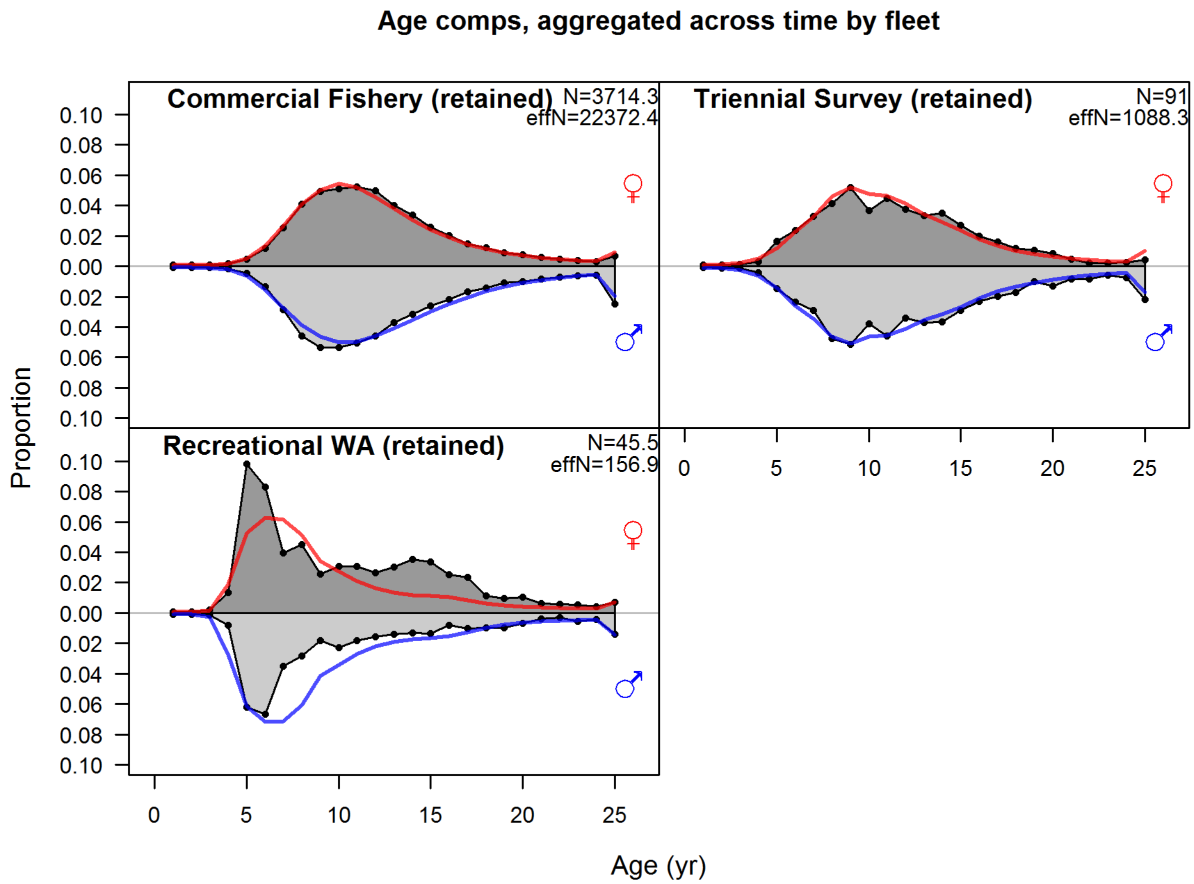


Figure 42: **Northern model** Age comps, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. fig:mod1_14_comp_agefit__aggregated_across_time

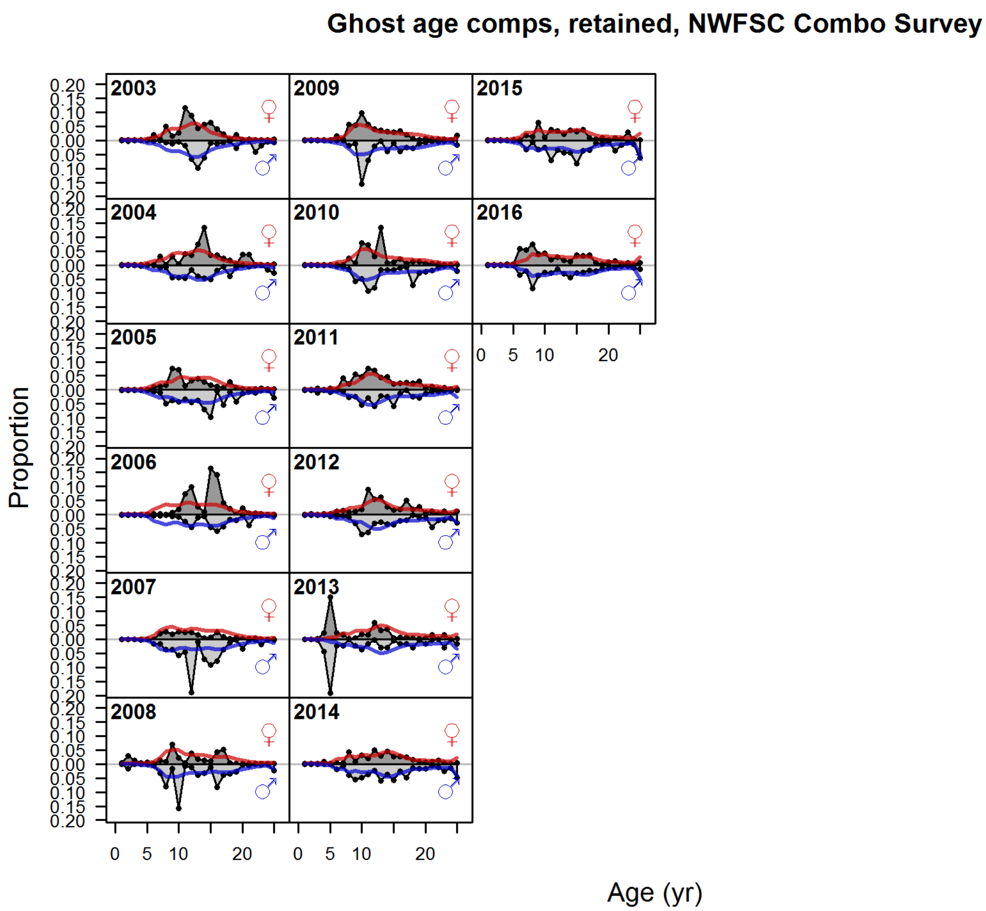


Figure 43: **Northern model** Ghost age comps, retained, NWFSC Combo Survey fig:mod1_16_comp_

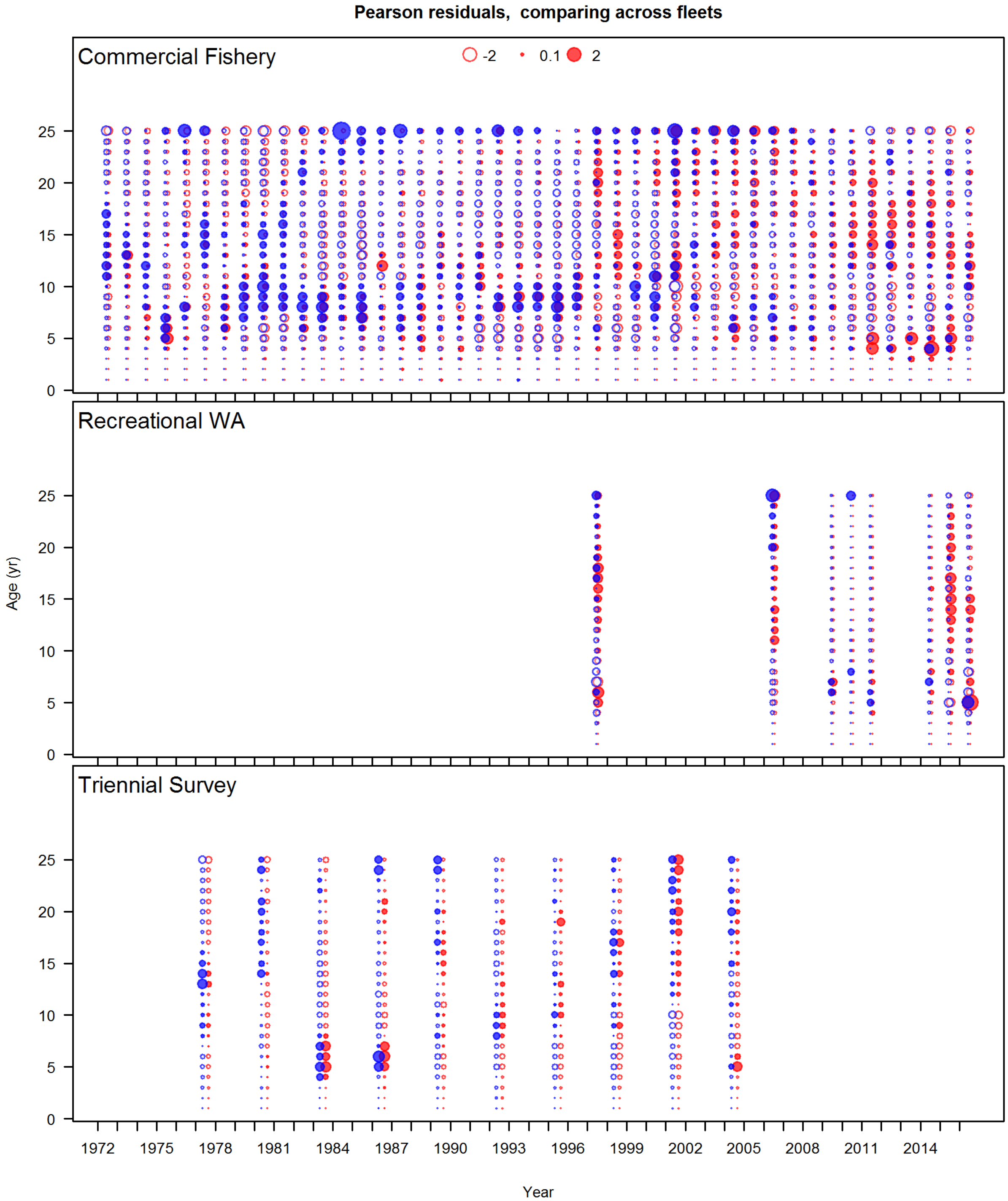


Figure 44: Age composition Pearson residuals for all fleets in the Northern model. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble colors indicate unsexed fish (gray), females (red), and males (blue). fig:comp_Pearson_age_mod1

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

fits-to-conditional-age-at-length-compositions-for-northern-model

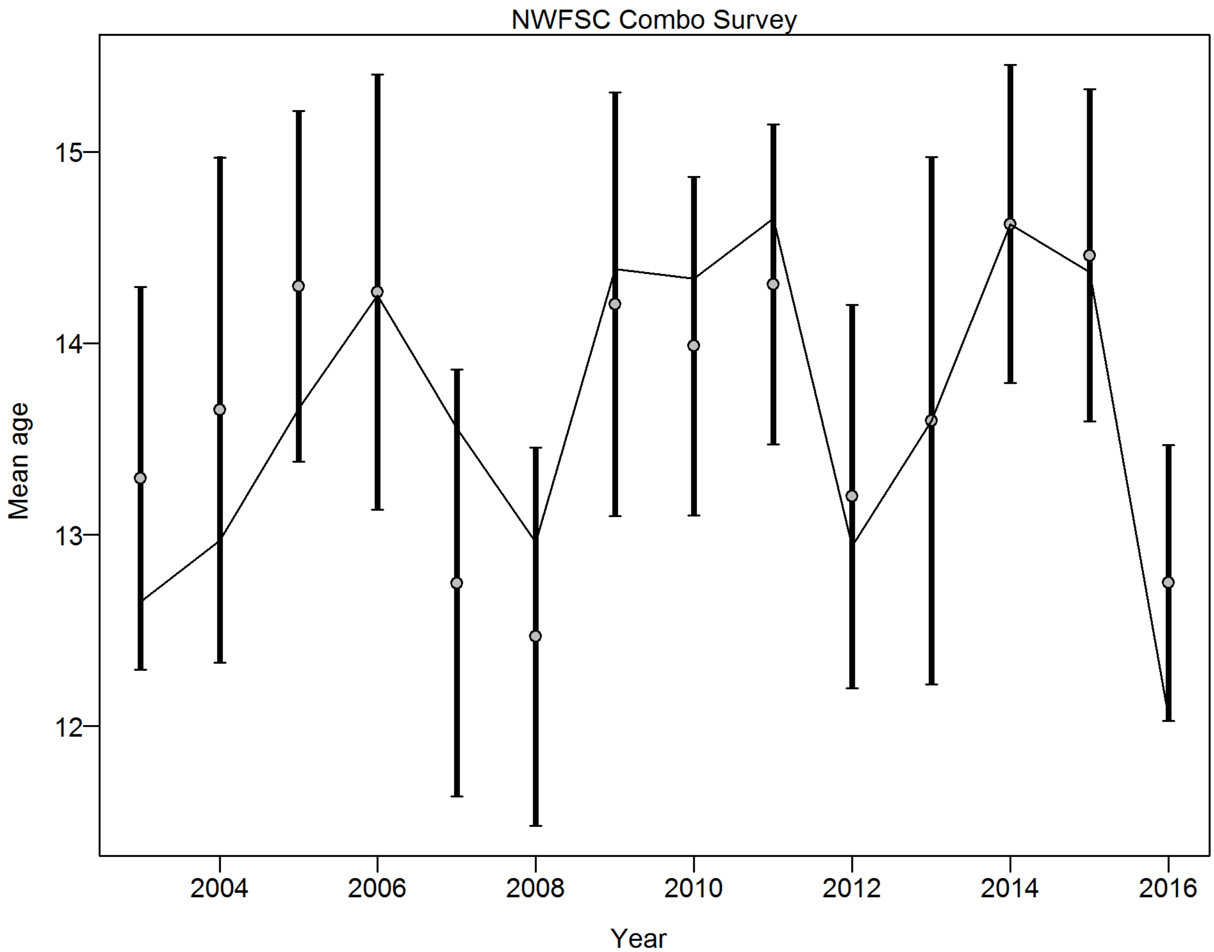


Figure 45: **Northern model** Mean age from conditional data (aggregated across length bins) for NWFSC Combo Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for conditional age_at_length data from NWFSC Combo Survey: 1.0073 (0.693_2.3446) 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. fig:mod1_3_comp_condAALfit_data_weighting_TA1.8_c

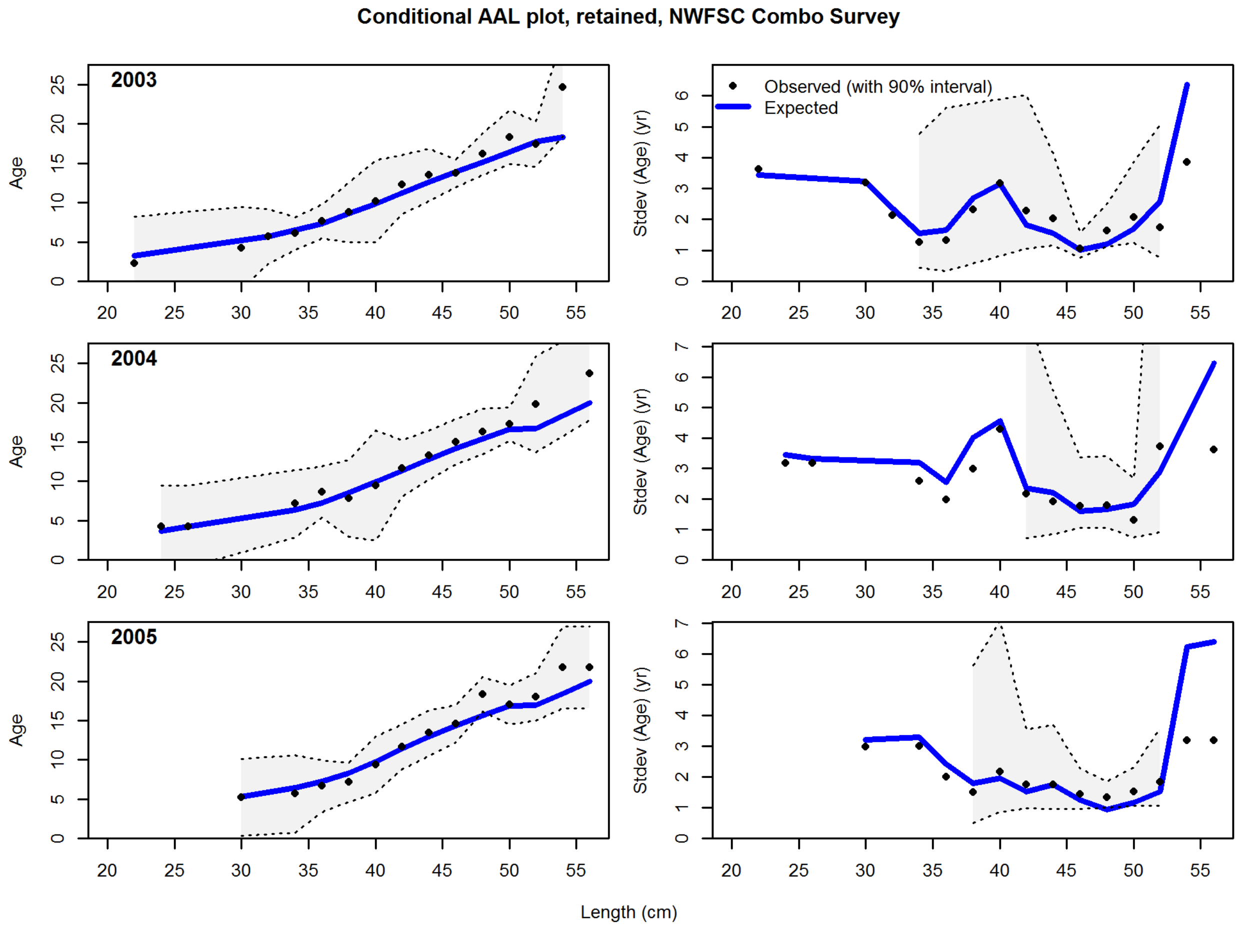
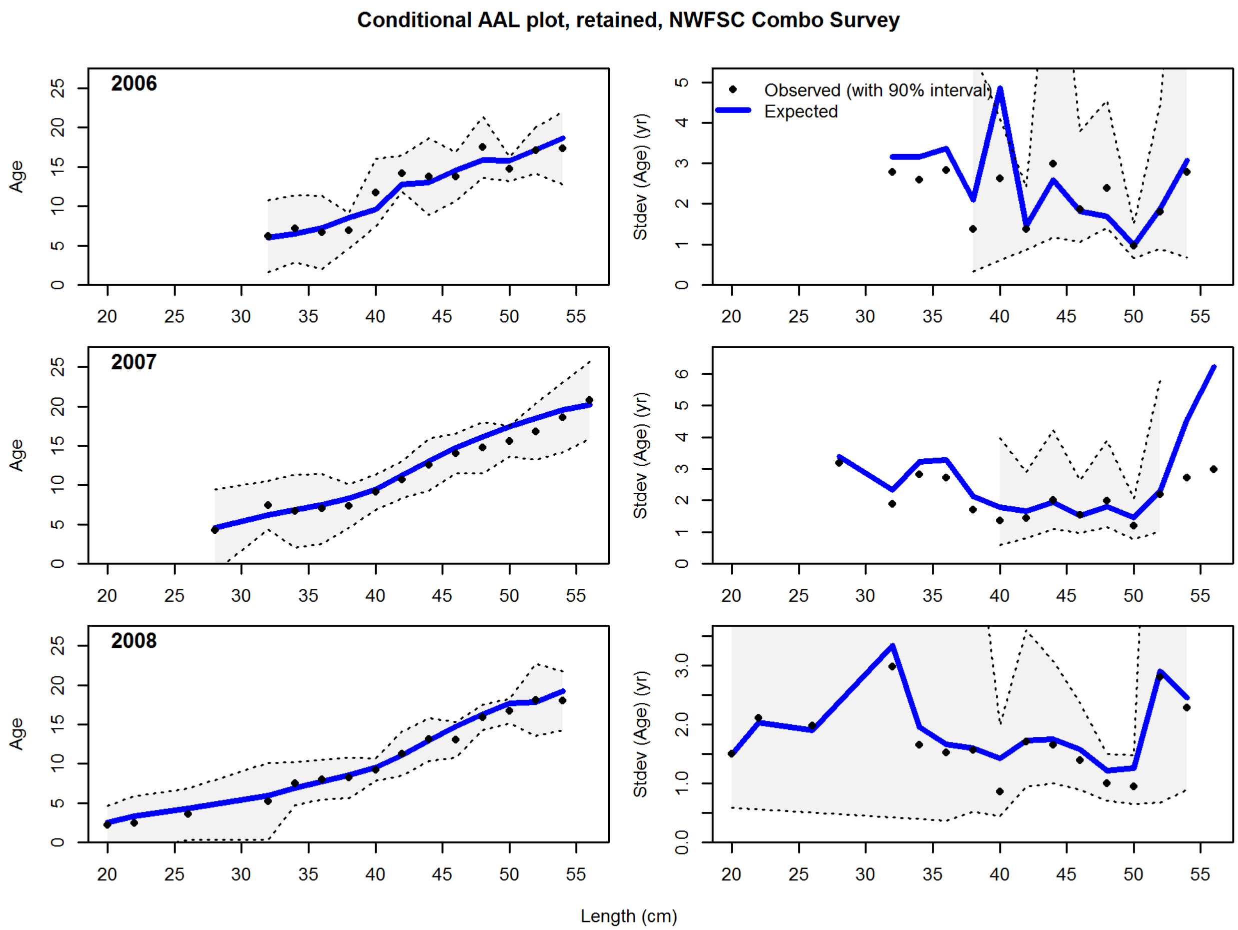


Figure 46: **Northern model** Conditional AAL plot, retained, NWFSC Combo Survey (plot 1 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution. fig:mod1_4_comp_condAALfit_Andre_plotsflt6mkt2_page1



1148

1149 Figure continued from previous page

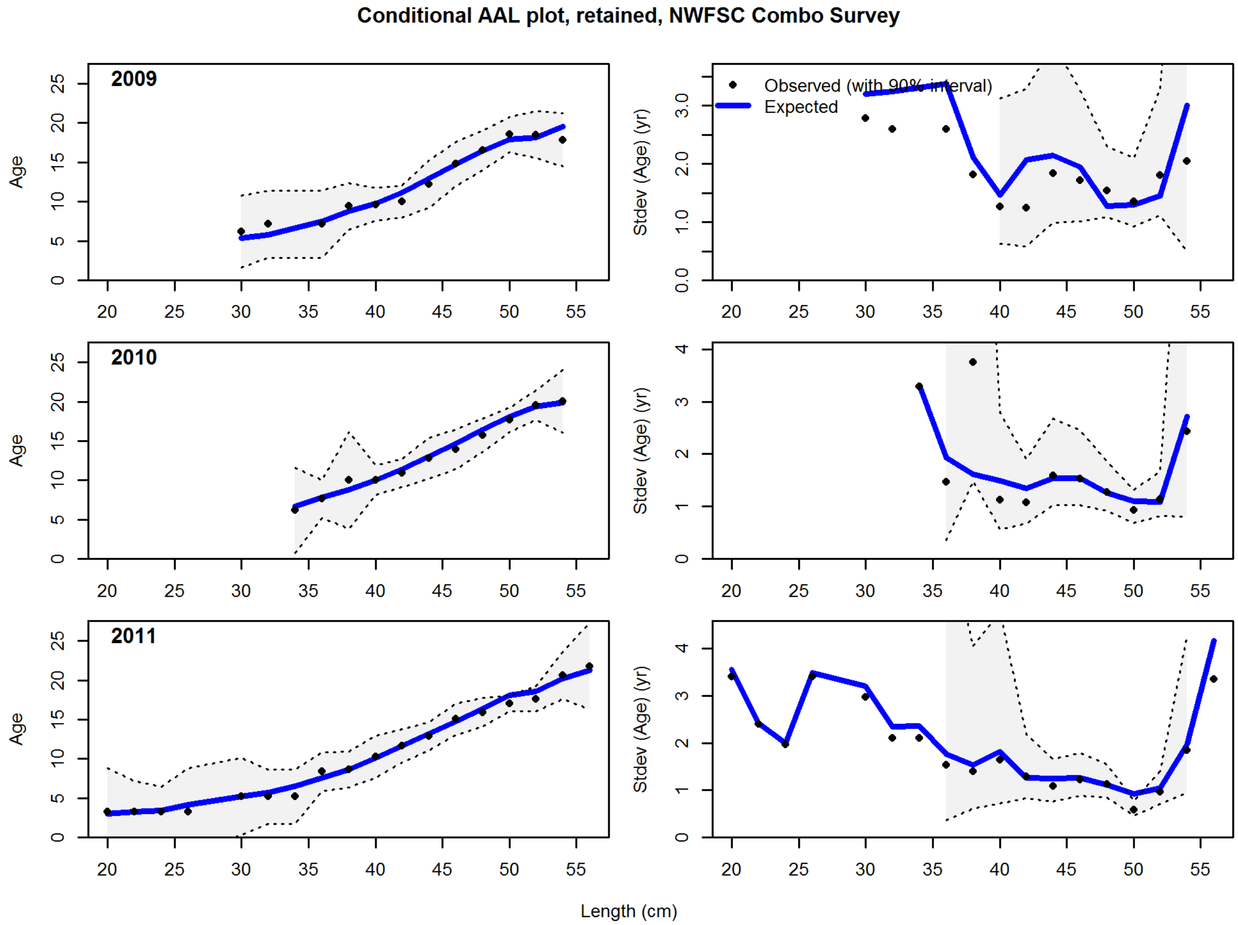
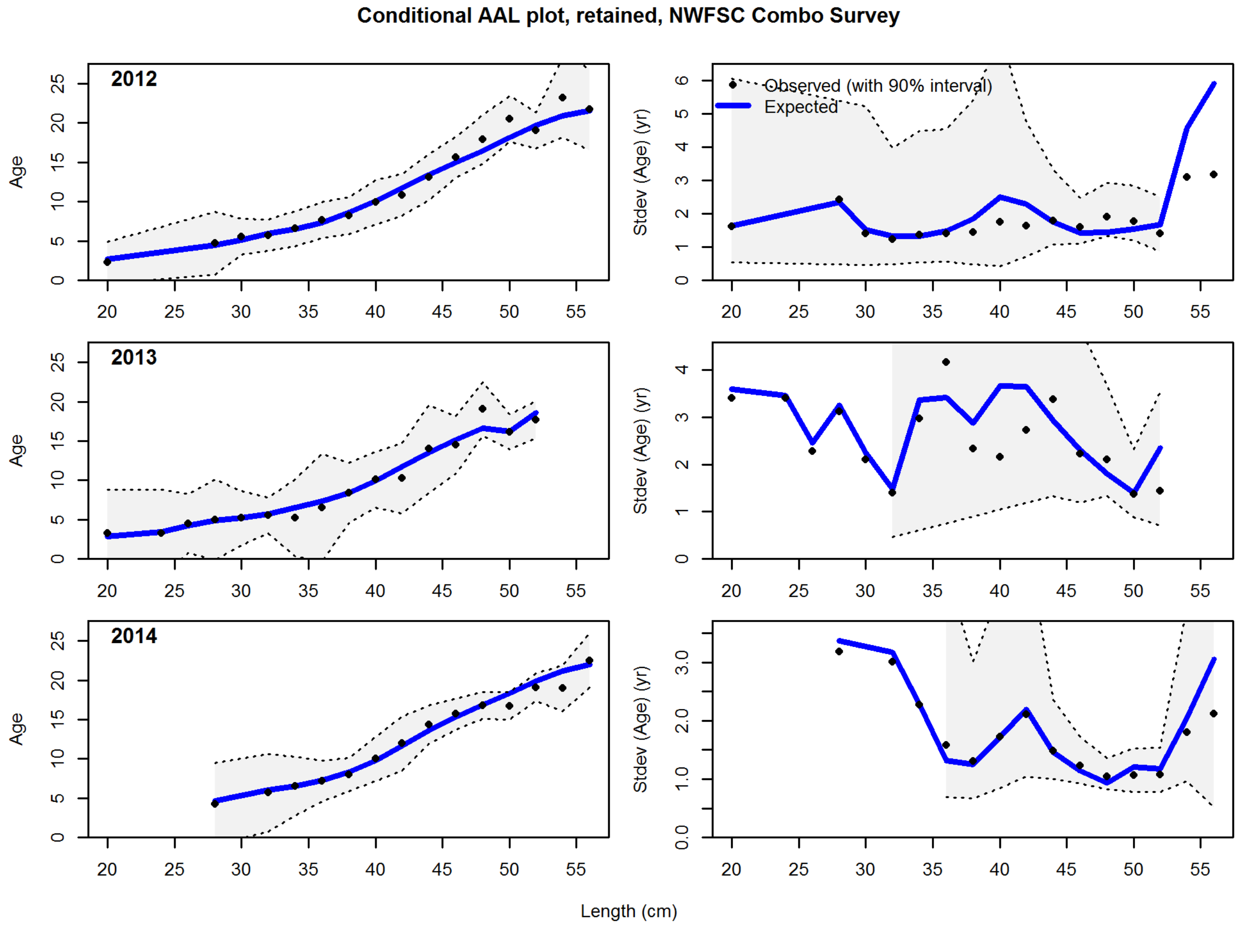


Figure continued from previous page



1152

1153 Figure continued from previous page

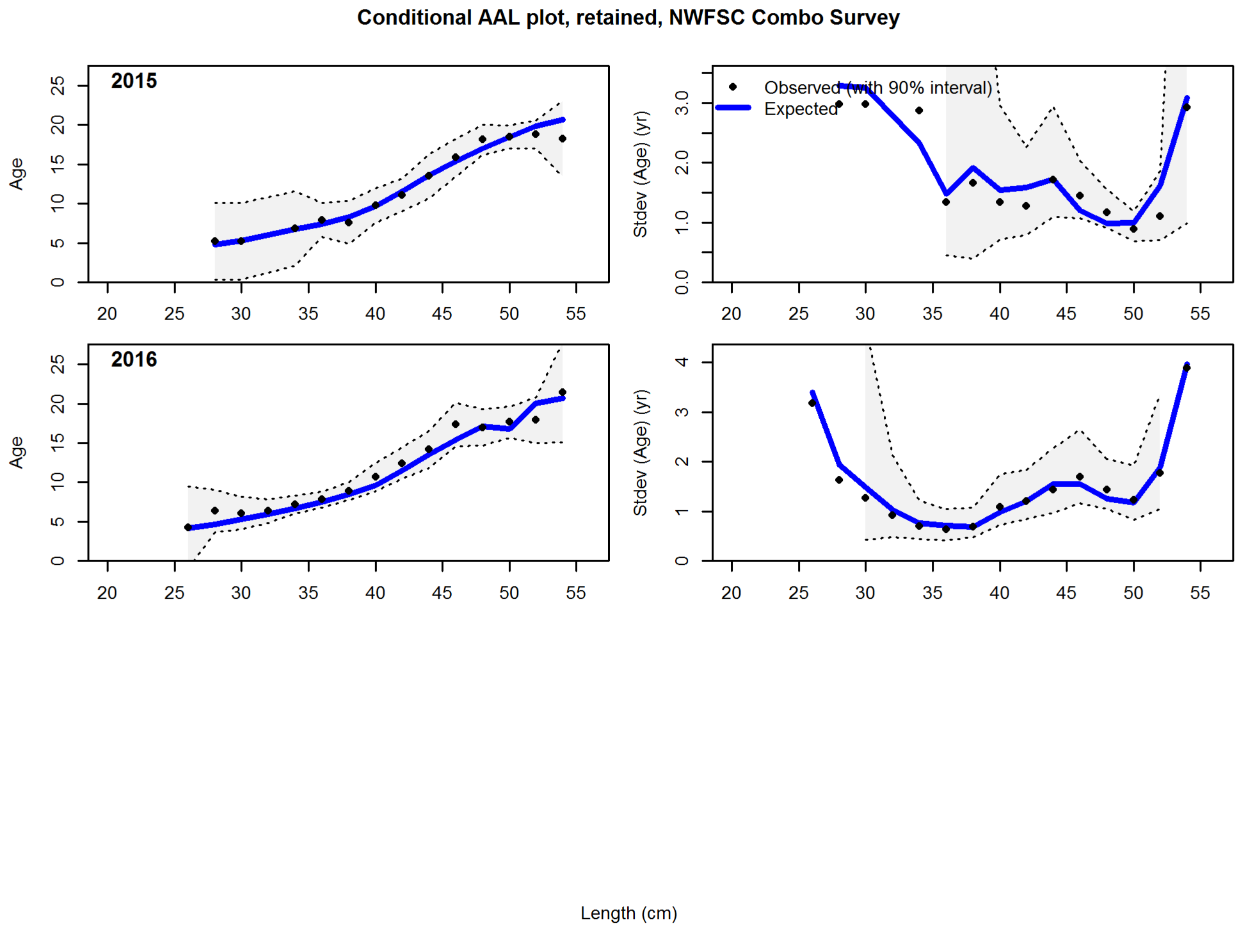


Figure continued from previous page

1156 ## 9.3 Model results for Northern model model-results-for-northern-model

1157 ### 9.3.1 Base model results for Northern model base-model-results-for-northern-model

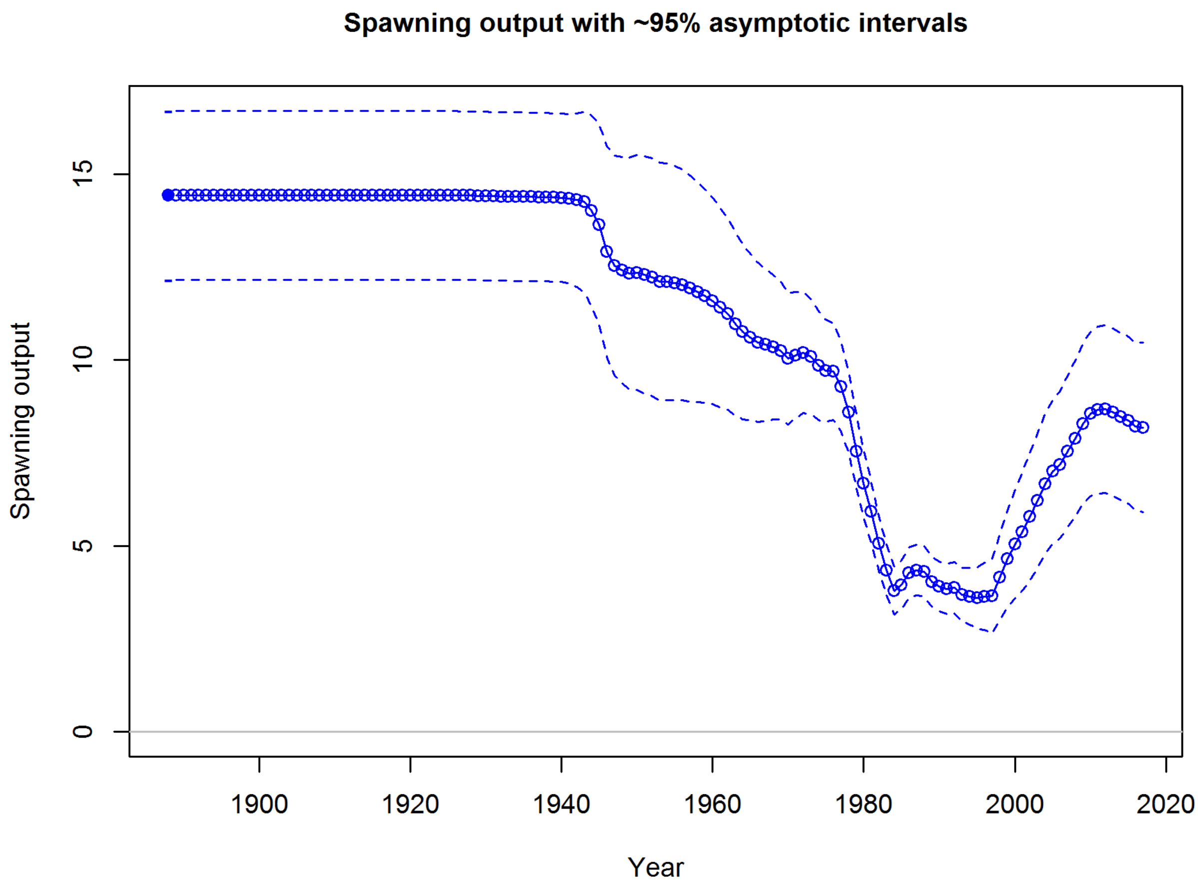


Figure 47: Estimated time-series of spawning output for Northern model. fig:ssb.N

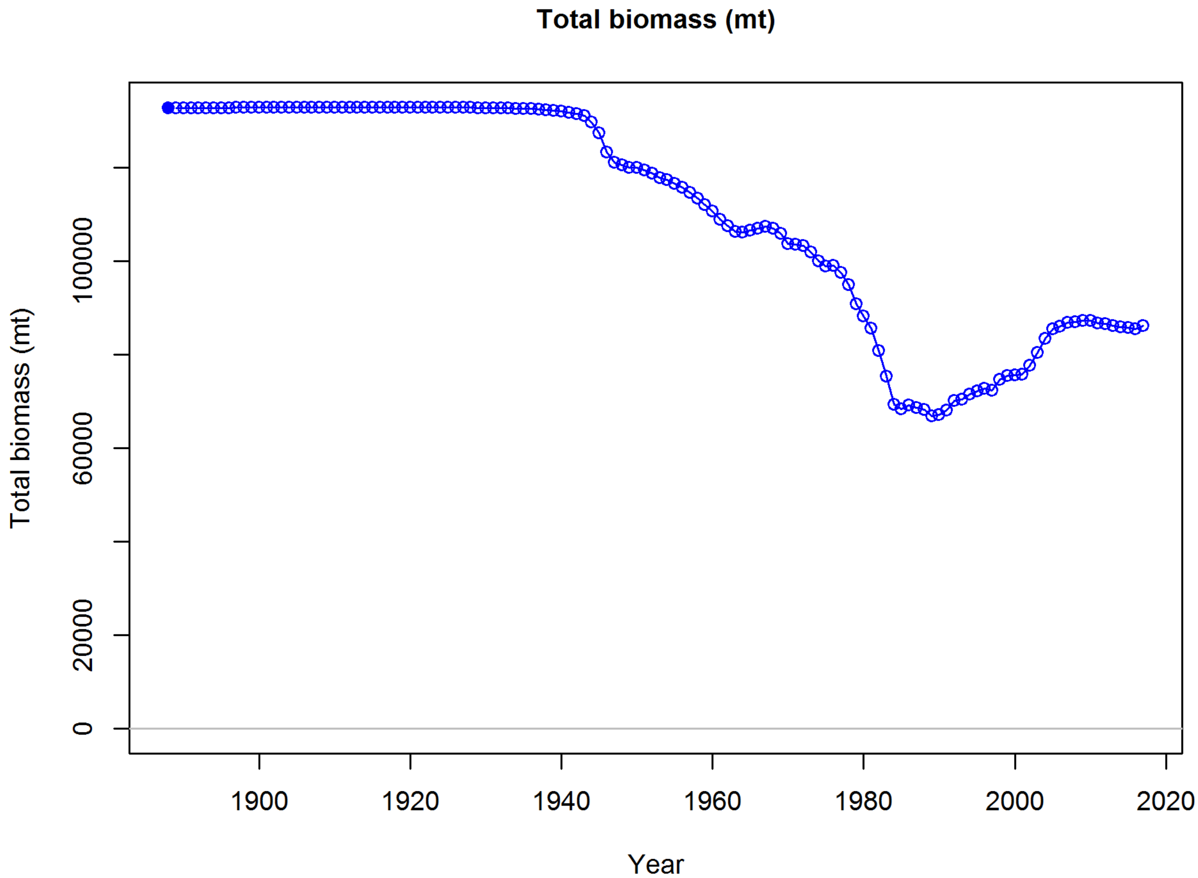


Figure 48: Estimated time-series of total biomass for Northern model. fig:total_bio.N

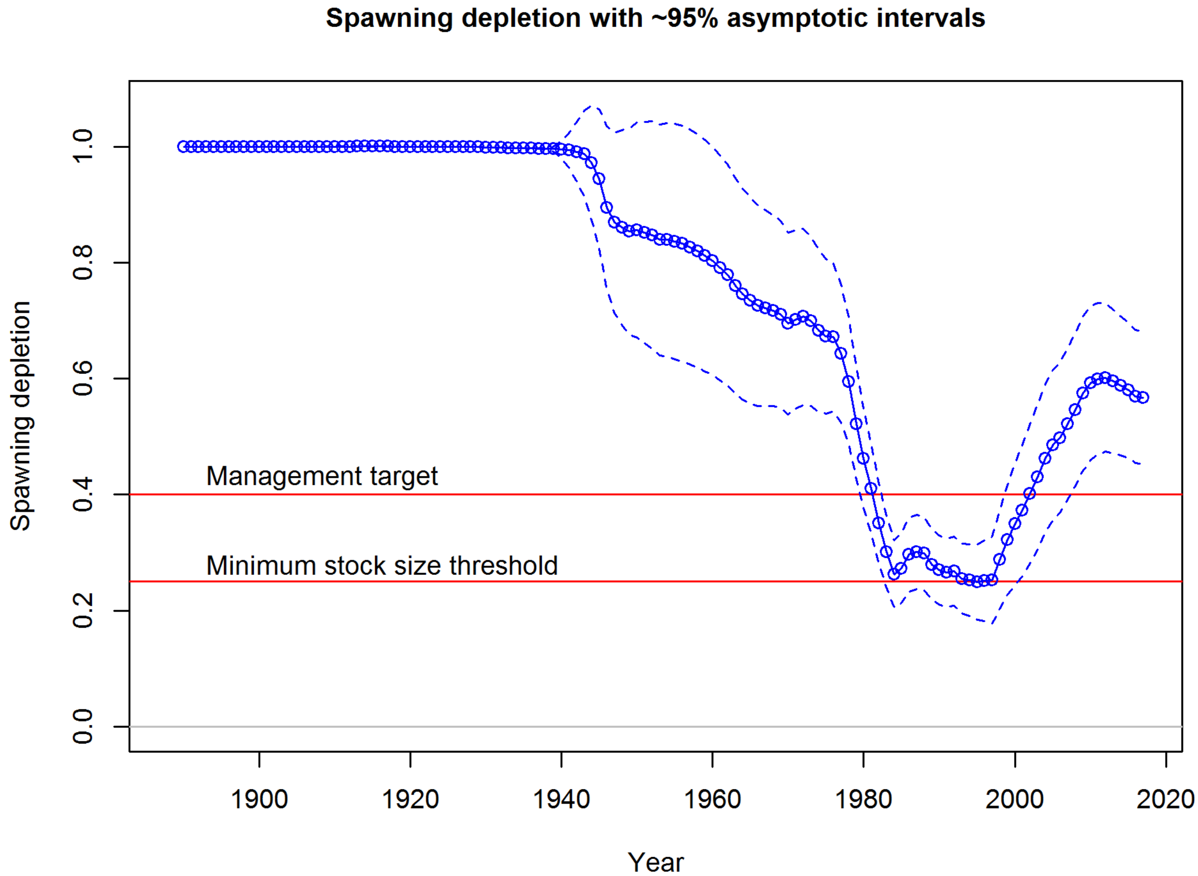


Figure 49: Estimated time-series of relative biomass for Northern model. fig:depl.N

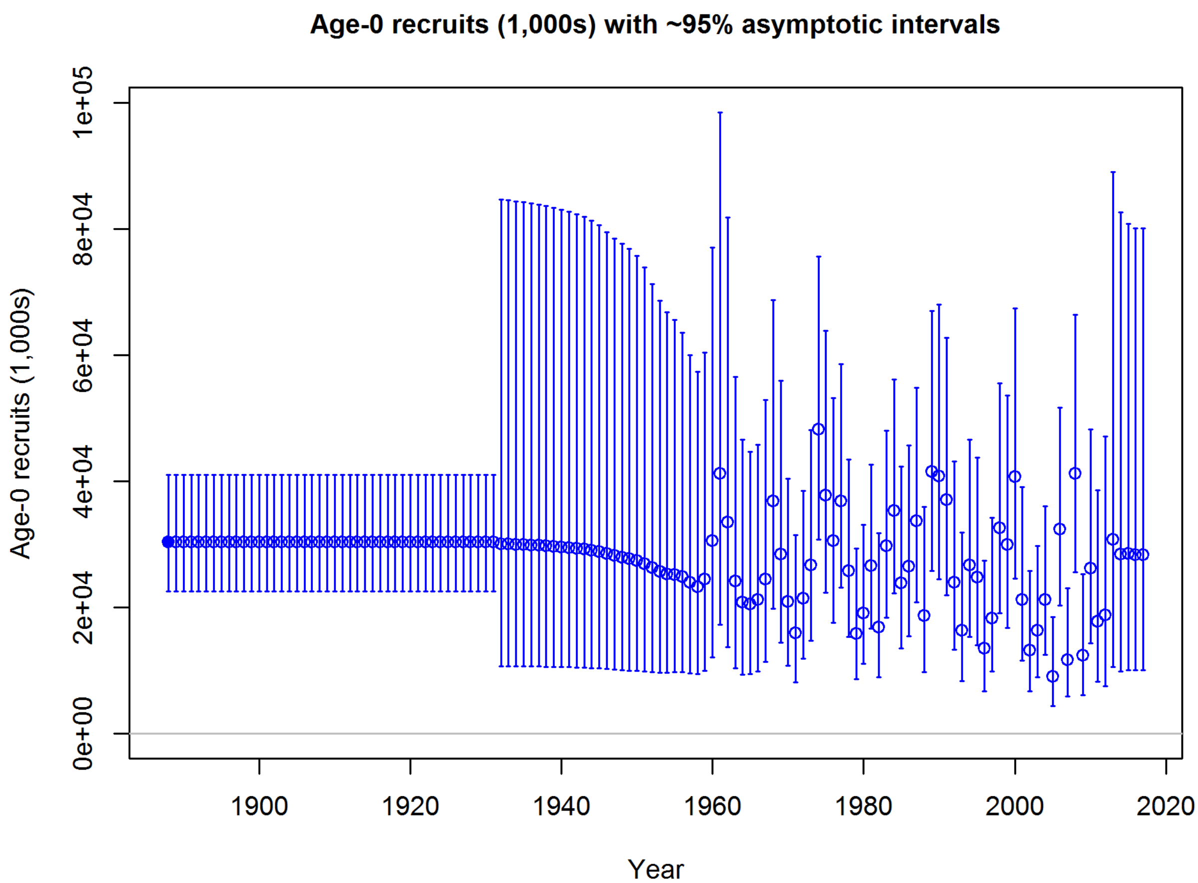


Figure 50: Estimated time-series of recruitment for the Northern model. fig:recruits1.N

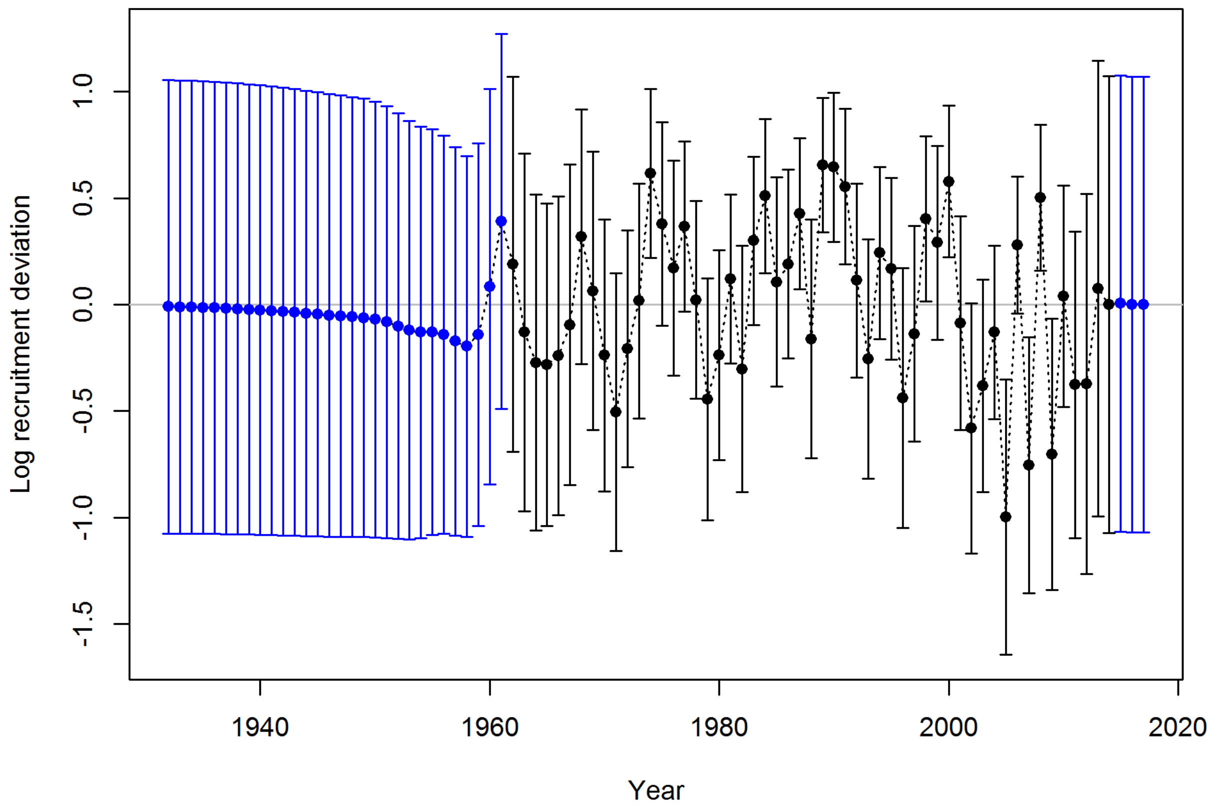


Figure 51: Estimated time-series of recruitment deviations for the Northern model. fig:recdevs1.N

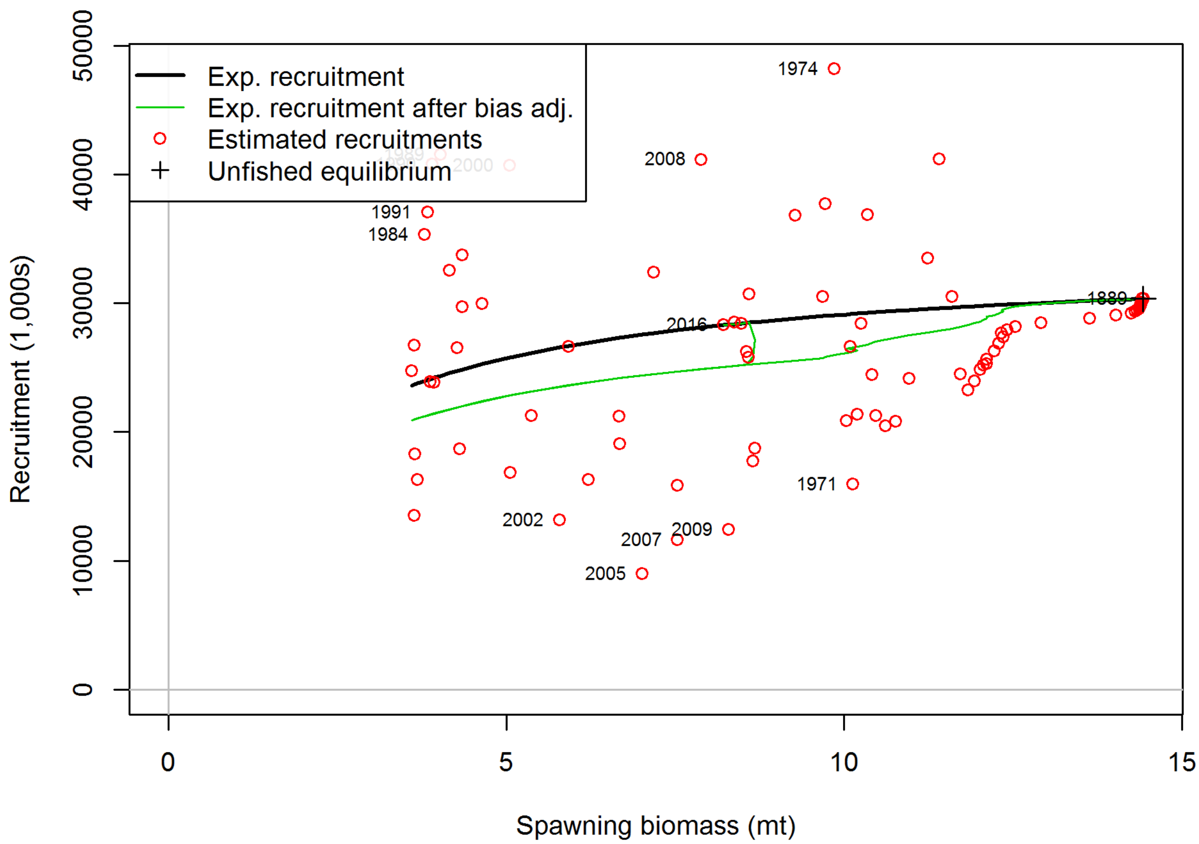


Figure 52: Estimated recruitment (red circles) for the Northern model relative to the stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution fig:stock_recruit_curve.N

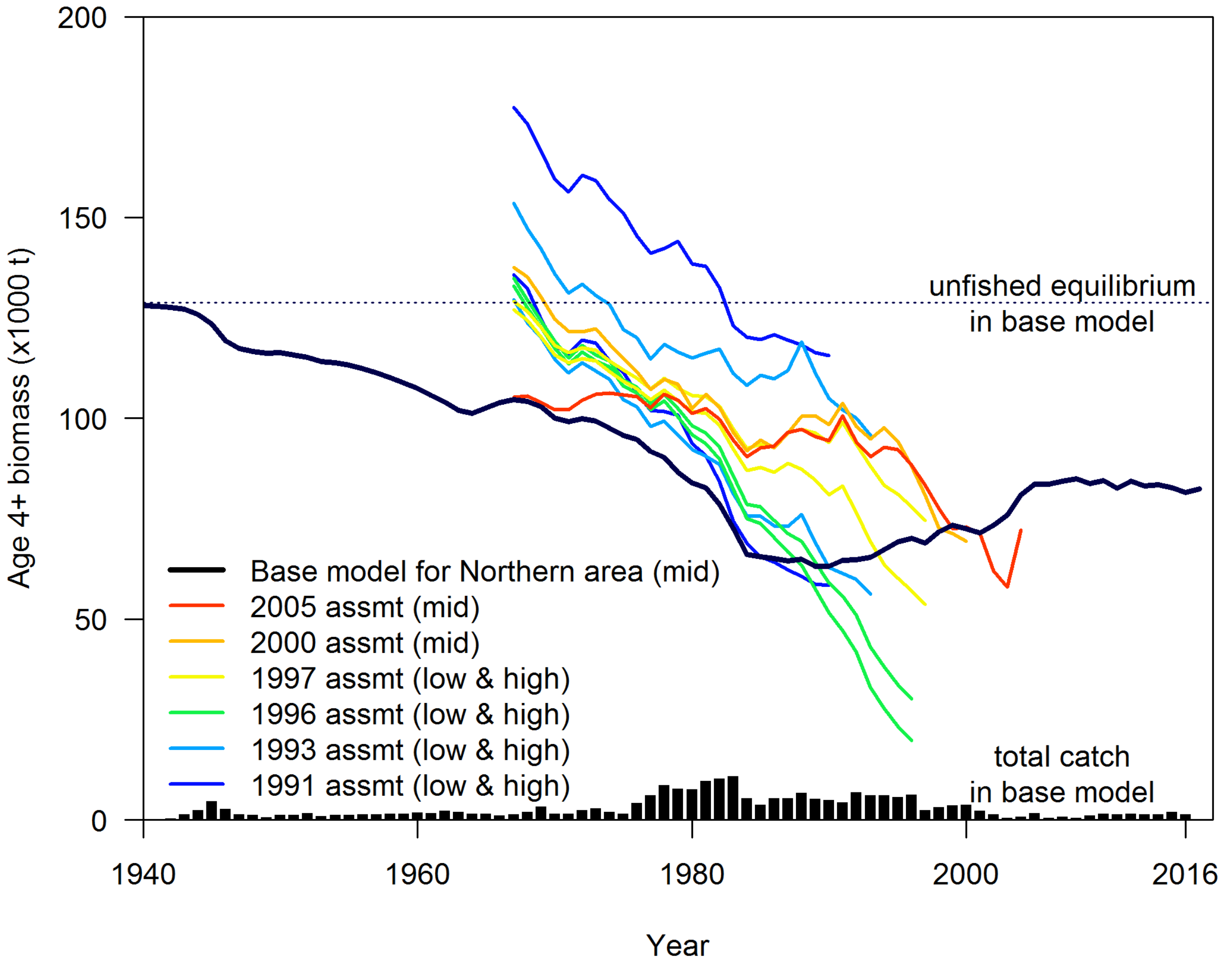


Figure 53: Comparison of time series of age 4+ biomass for Yellowtail Rockfish across past assessments. Previous assessments were focused only on the area north of 40°10′, but also included a small area within Canada. fig:assessment_history

9.3.2 Sensitivity analyses for Northern model

sensitivity-analyses-for-northern-model

to be added...

9.3.3 Likelihood profiles for Northern model

likelihood-profiles-for-northern-model

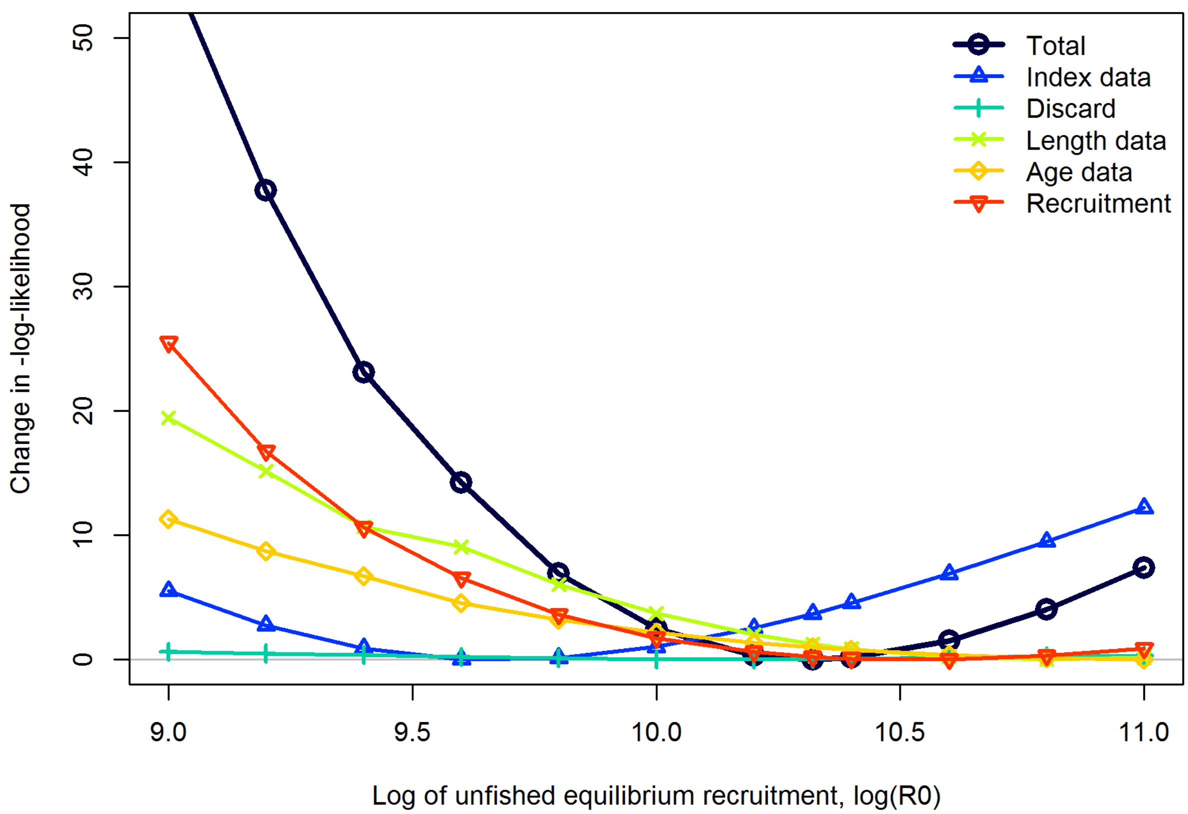


Figure 54: Likelihood profile over the log of equilibrium recruitment (R_0) for the Northern model. fig:profile_logR0.N

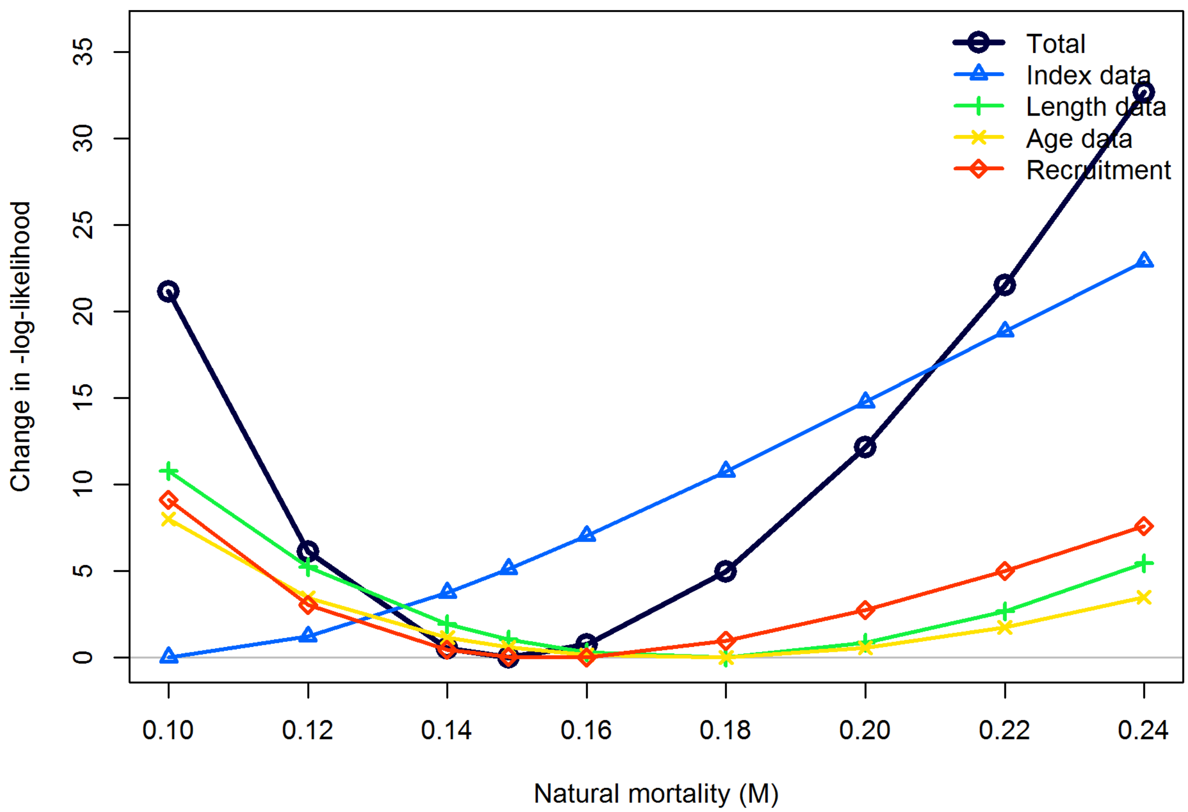


Figure 55: Likelihood profile over female natural mortality for the Northern model. fig:profile_M.N

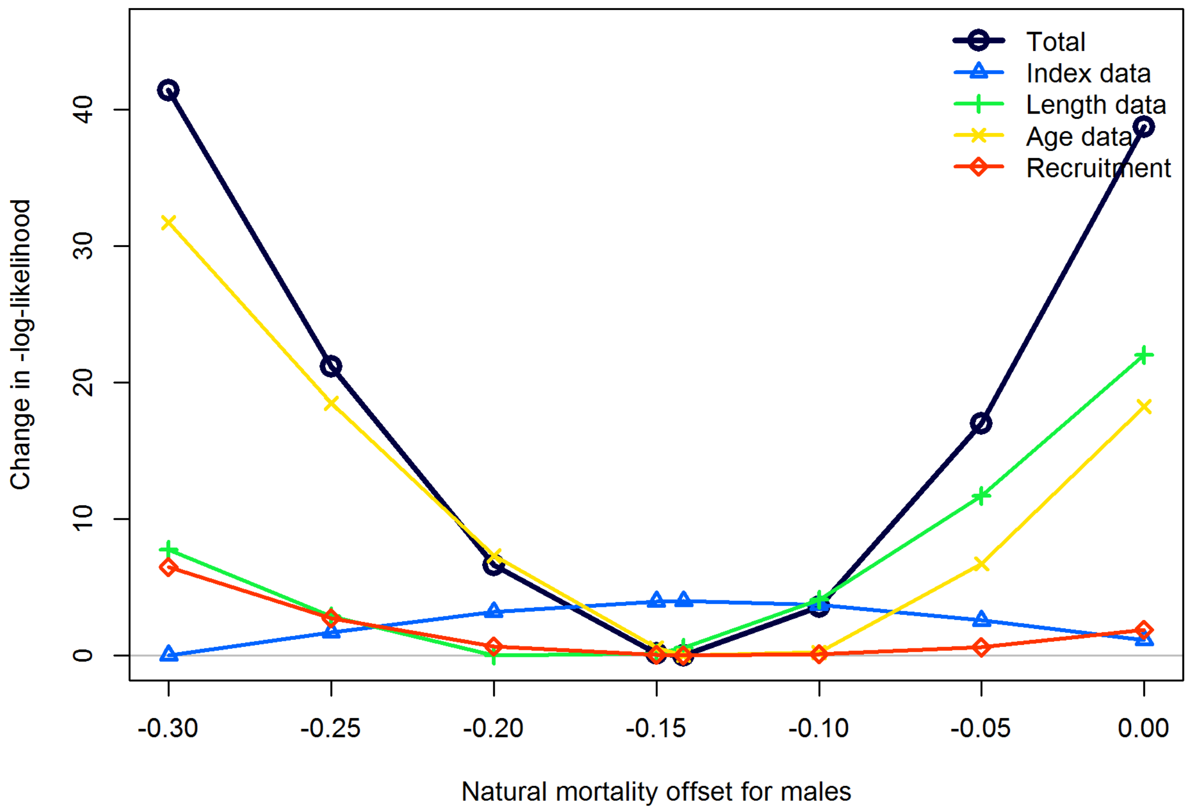


Figure 56: Likelihood profile over the male offset for natural mortality for the Northern model. Negative values are associated with natural mortality being lower for males than females. fig:profile_M2.N

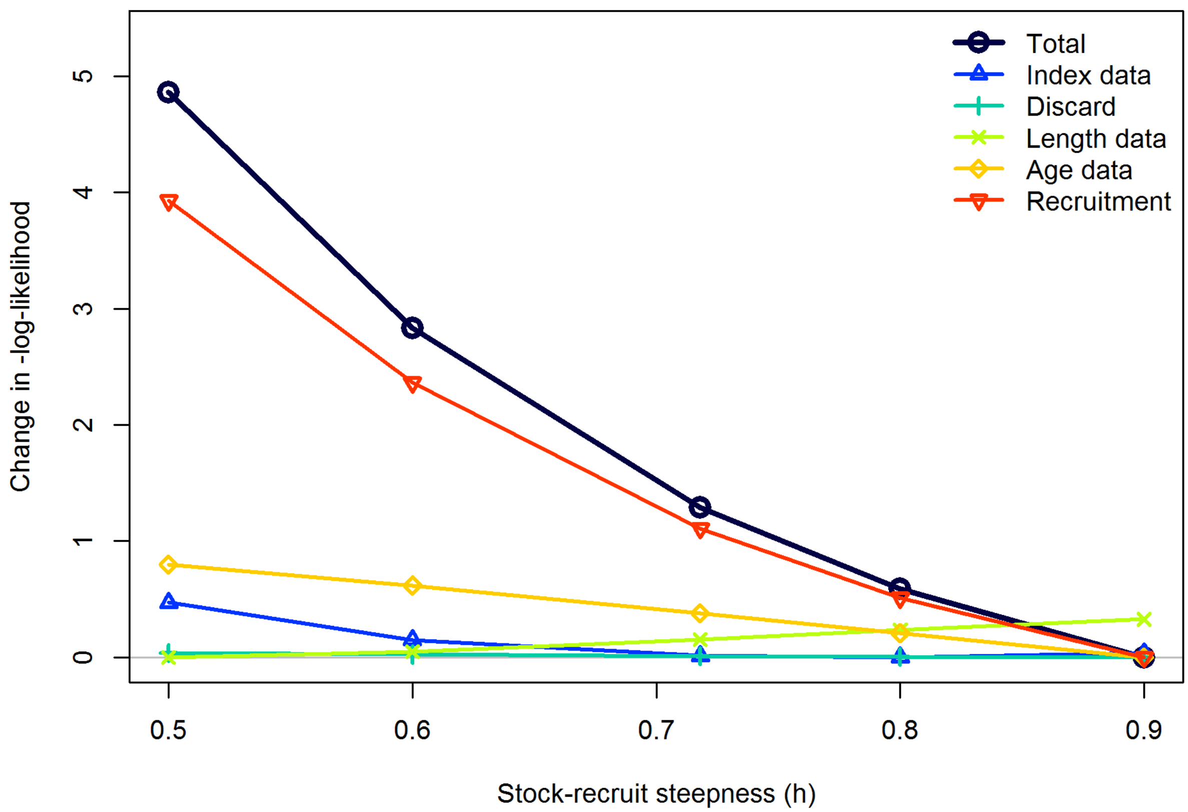


Figure 57: Likelihood profile over stock-recruit steepness (h) for the Northern model. fig:profile_h.N

9.3.4 Retrospective analysis for Northern model

retrospective-analysis-for-northern-model

Retrospective analysis of spawning output for the Northern model. fig:retro.N

9.3.5 Forecasts analysis for Northern model

forecasts-analysis-for-northern-model

to be added...

1165 ## 9.4 Data and model fits for Southern model

data-and-model-fits-for-southern-model

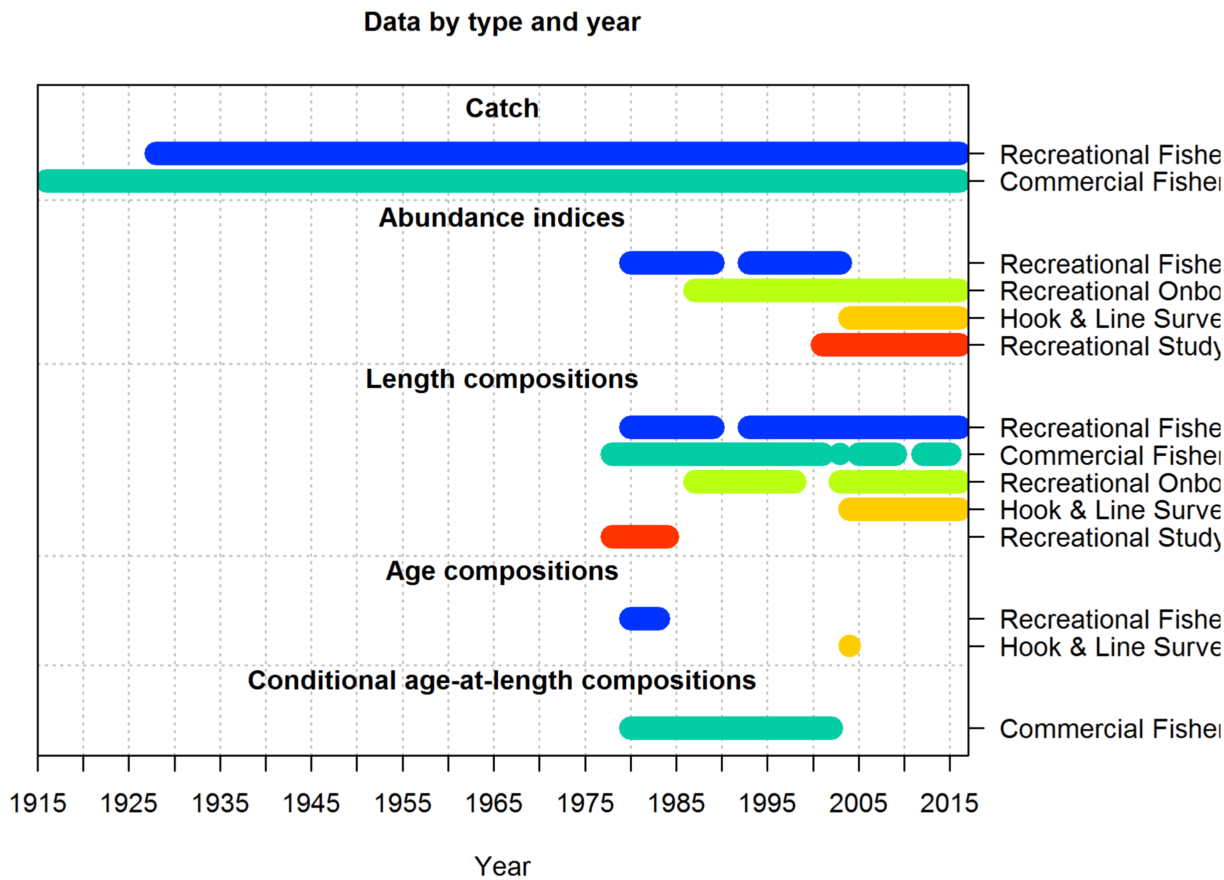


Figure 58: Summary of data sources used in the Southern model. fig:data_plot.S

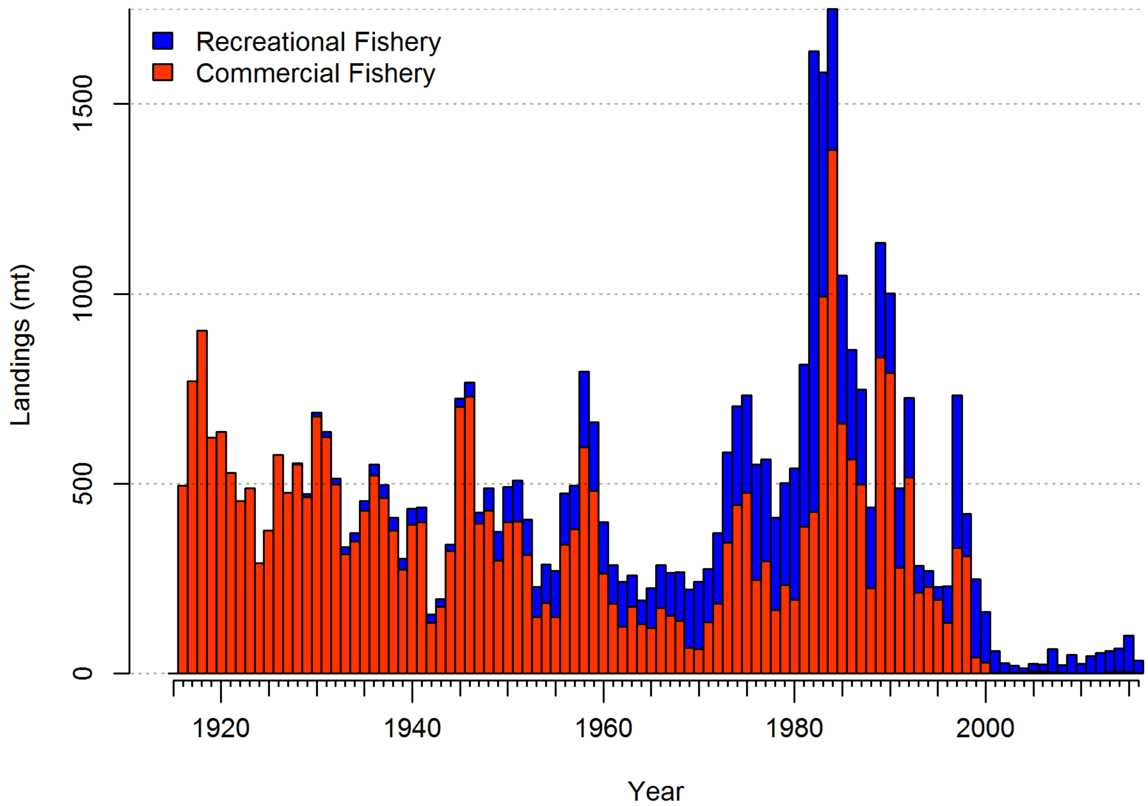


Figure 59: Estimated catch history of Yellowtail Rockfish in the Southern model. fig:r4ss_catch2_S

1166 ### 9.4.1 Selectivity, retention, and discards for Southern model

selectivity-retention-and-discards-for-southern-model

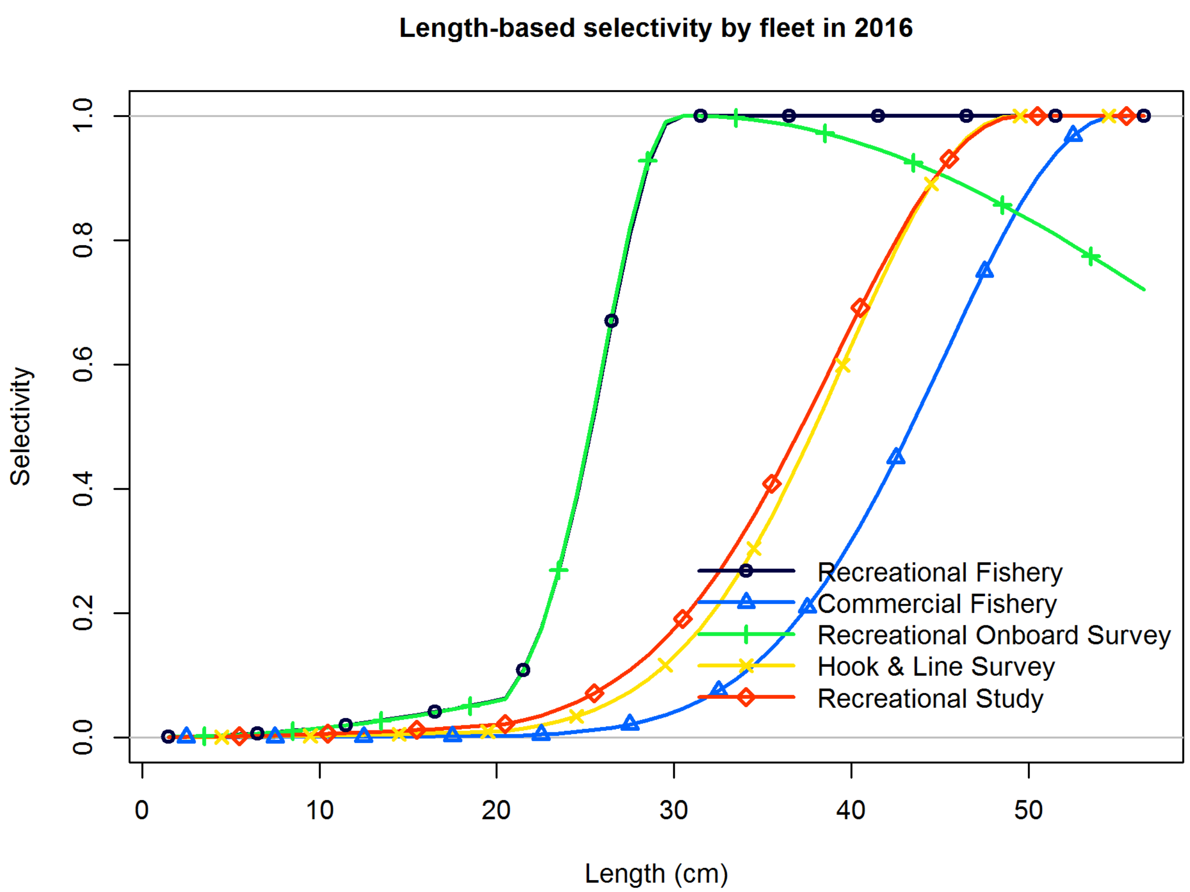


Figure 60: Estimated selectivity by length by each fishery and survey in the Southern model.
fig:selex.S

9.4.2 Fits to indices of abundance for Southern model

fits-to-indices-of-abundance-for-southern-model

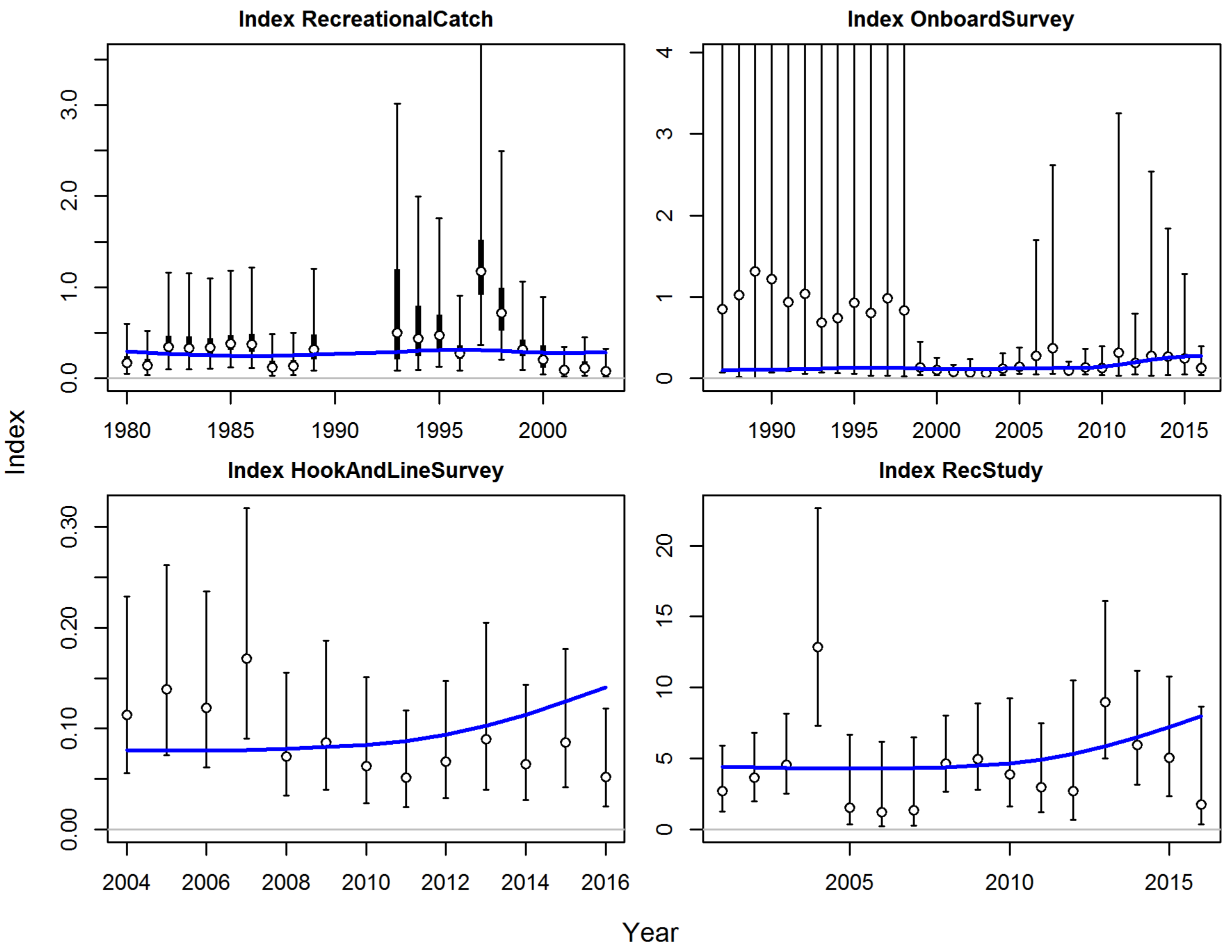


Figure 61: Estimated fits to the CPUE and survey indices for the Southern model. fig:index_fits2

9.4.3 Length compositions for Southern model

`length-compositions-for-southern-model`

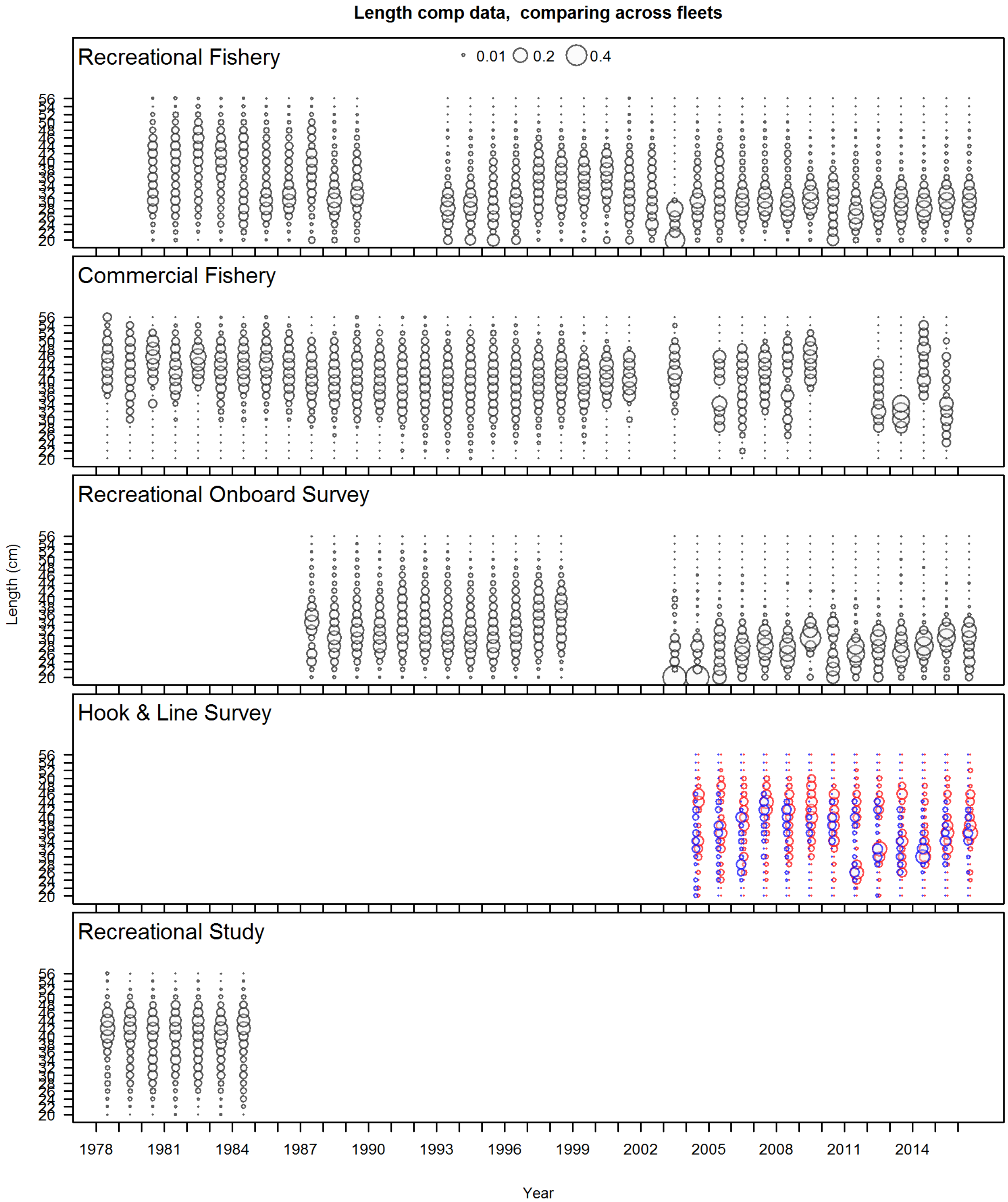


Figure 62: Length compositions for all fleets in the Southern model. Bubble size is proportional to proportions within each year. fig:comp_length_bubble_mod2

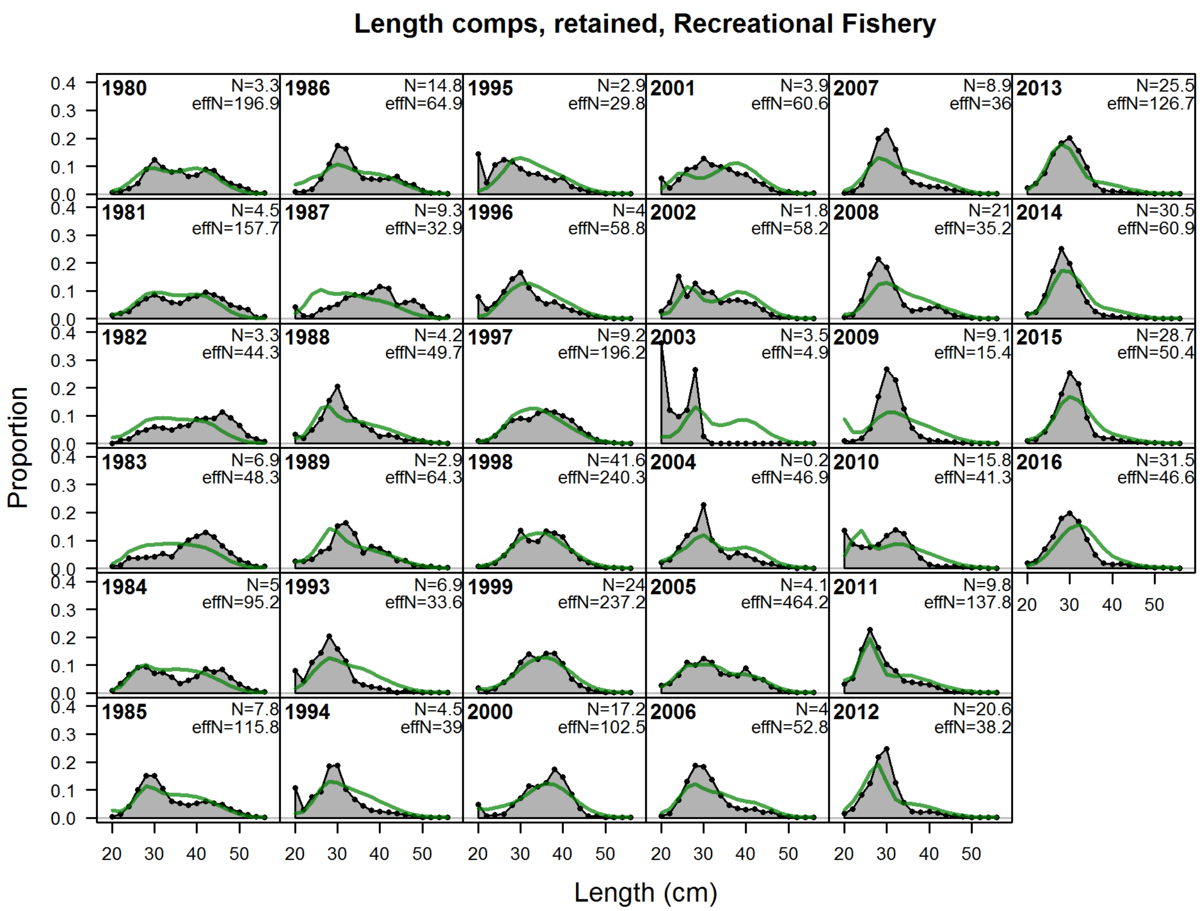


Figure 63: **Southern model** Length comps, retained, Recreational Fishery fig:mod2_1_comp_len

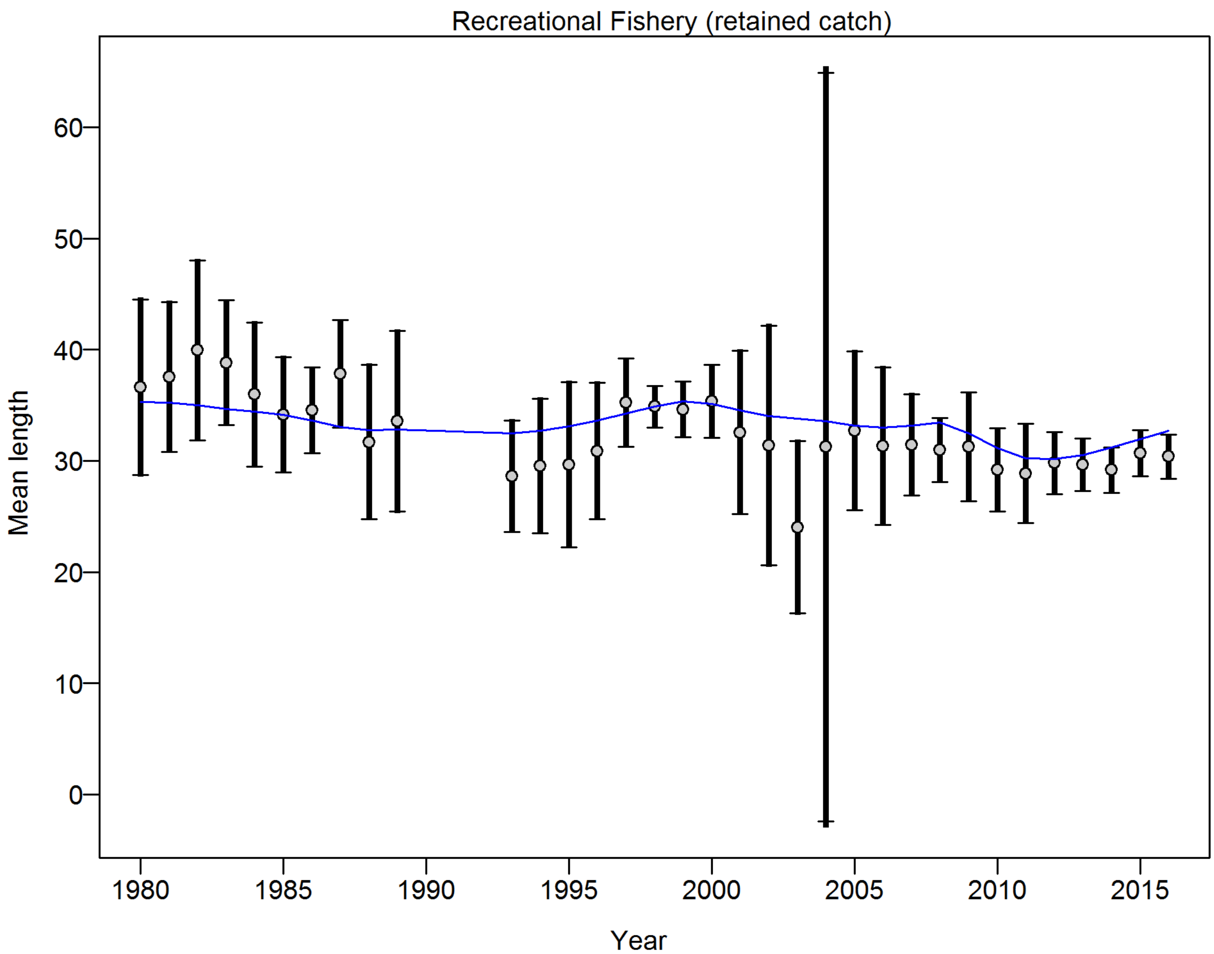


Figure 64: **Southern model** Mean length for Recreational Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Recreational Fishery: 1.0344 (0.6895_1.9004) 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. fig:mod2_4_comp_lenfit_data_weighting_T

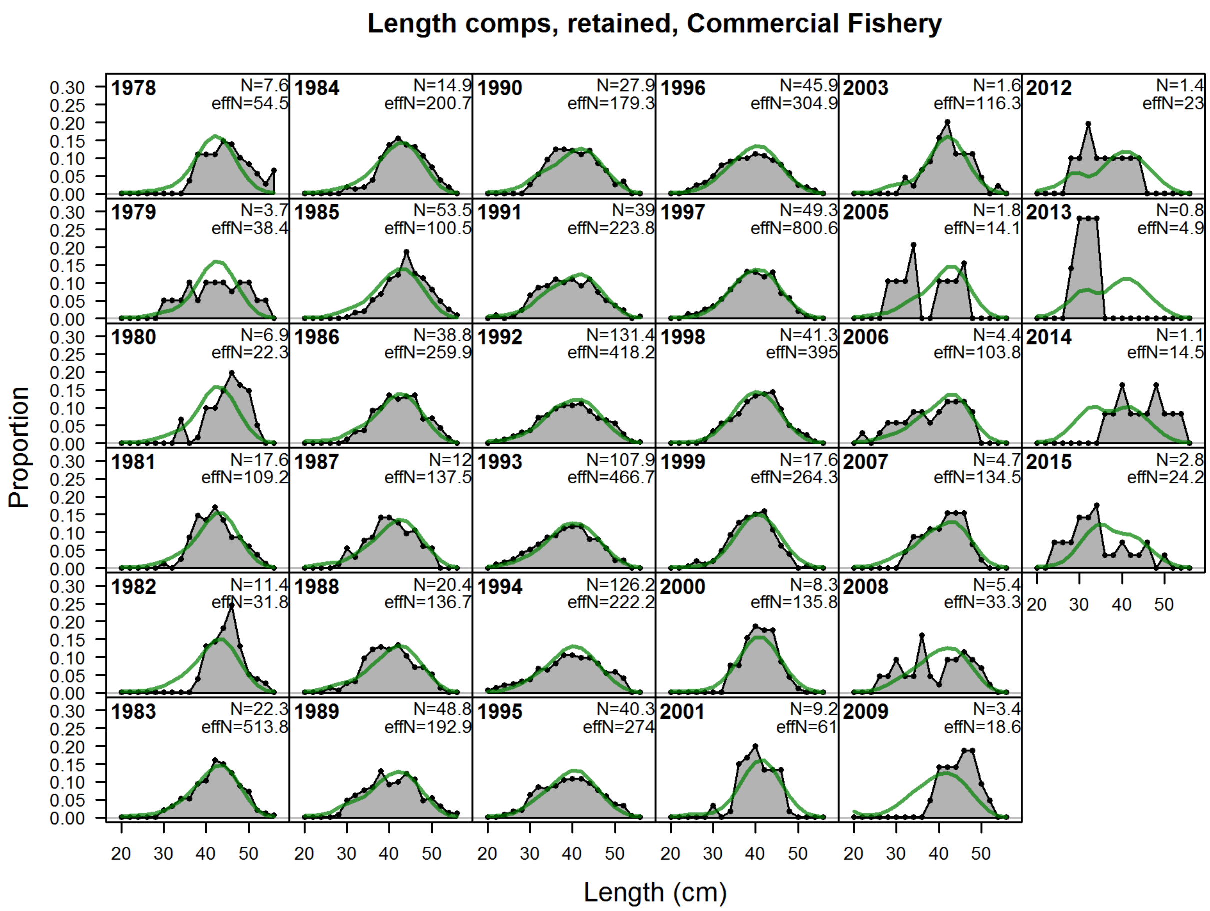


Figure 65: **Southern model** Length comps, retained, Commercial Fishery fig:mod2_5_comp_lent

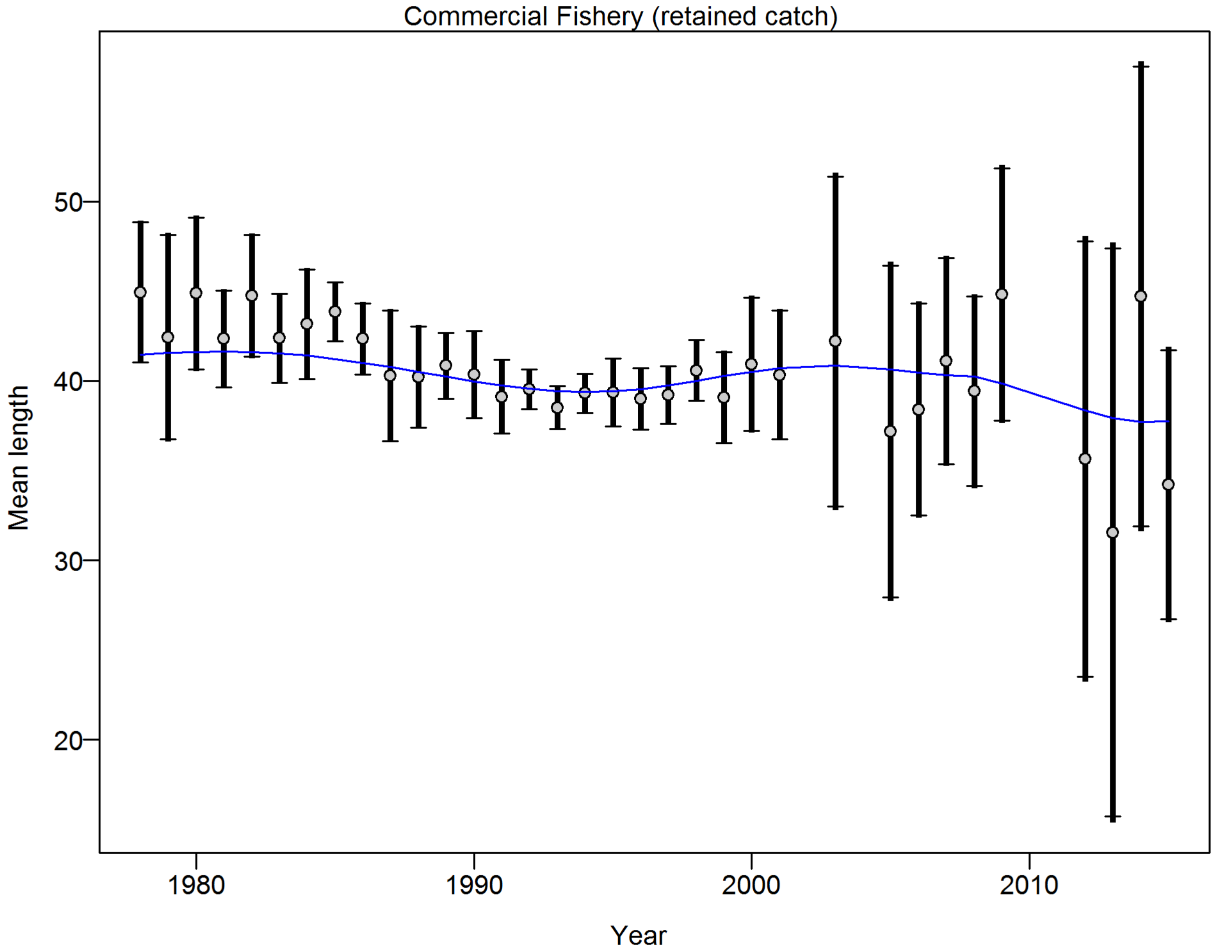


Figure 66: **Southern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Commercial Fishery: 1.0451 (0.7029_1.9625) 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. fig:mod2_8_comp_lenfit_data_weighting_T

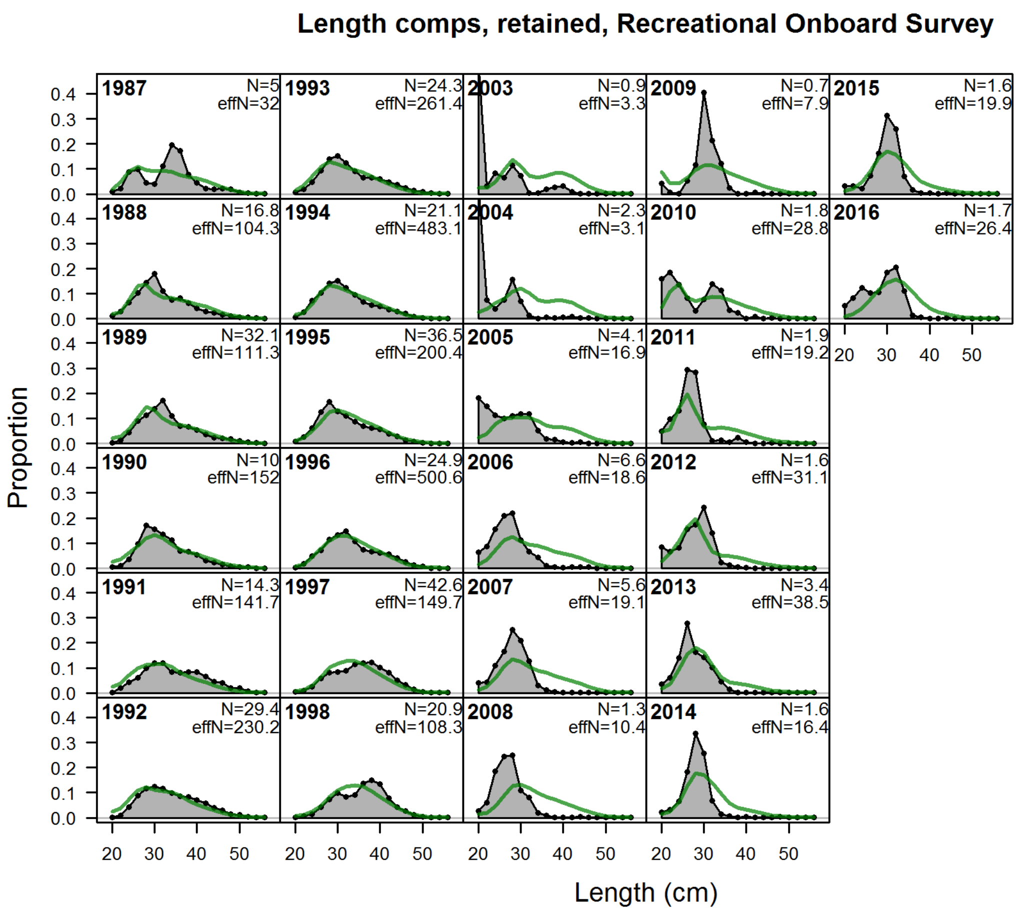


Figure 67: **Southern model** Length comps, retained, Recreational Onboard Survey fig:mod2_9_comp_

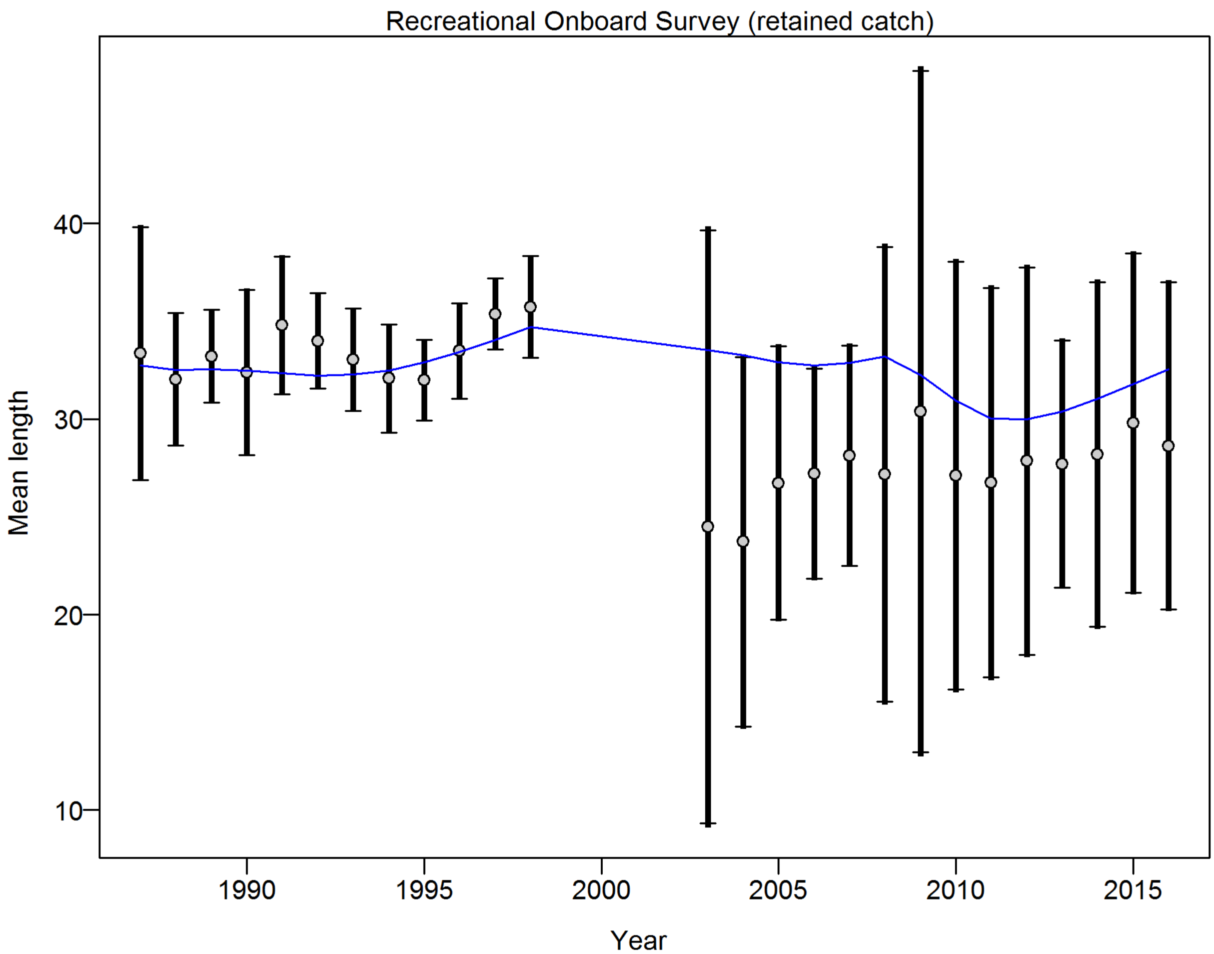


Figure 68: **Southern model** Mean length for Recreational Onboard Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Recreational Onboard Survey: 1.0273 (0.7124_1.8741) 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. fig:mod2_12_comp_

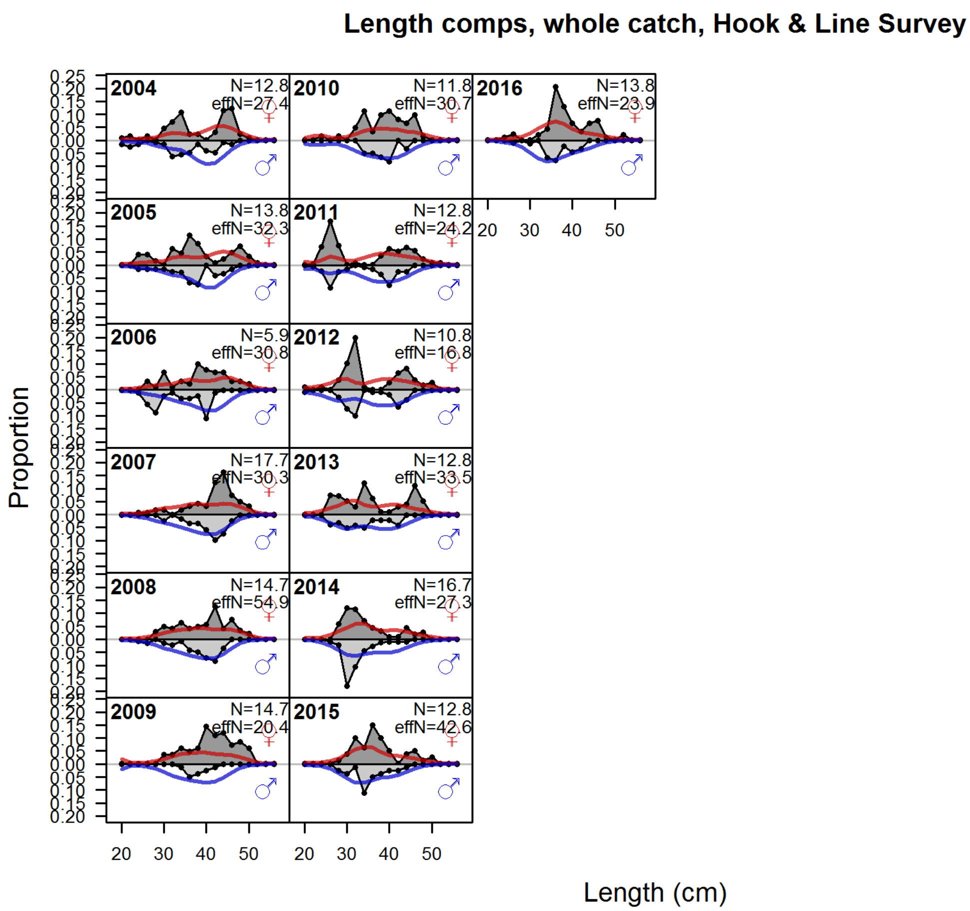


Figure 69: **Southern model** Length comps, whole catch, Hook & Line Survey fig:mod2_13_comp_l

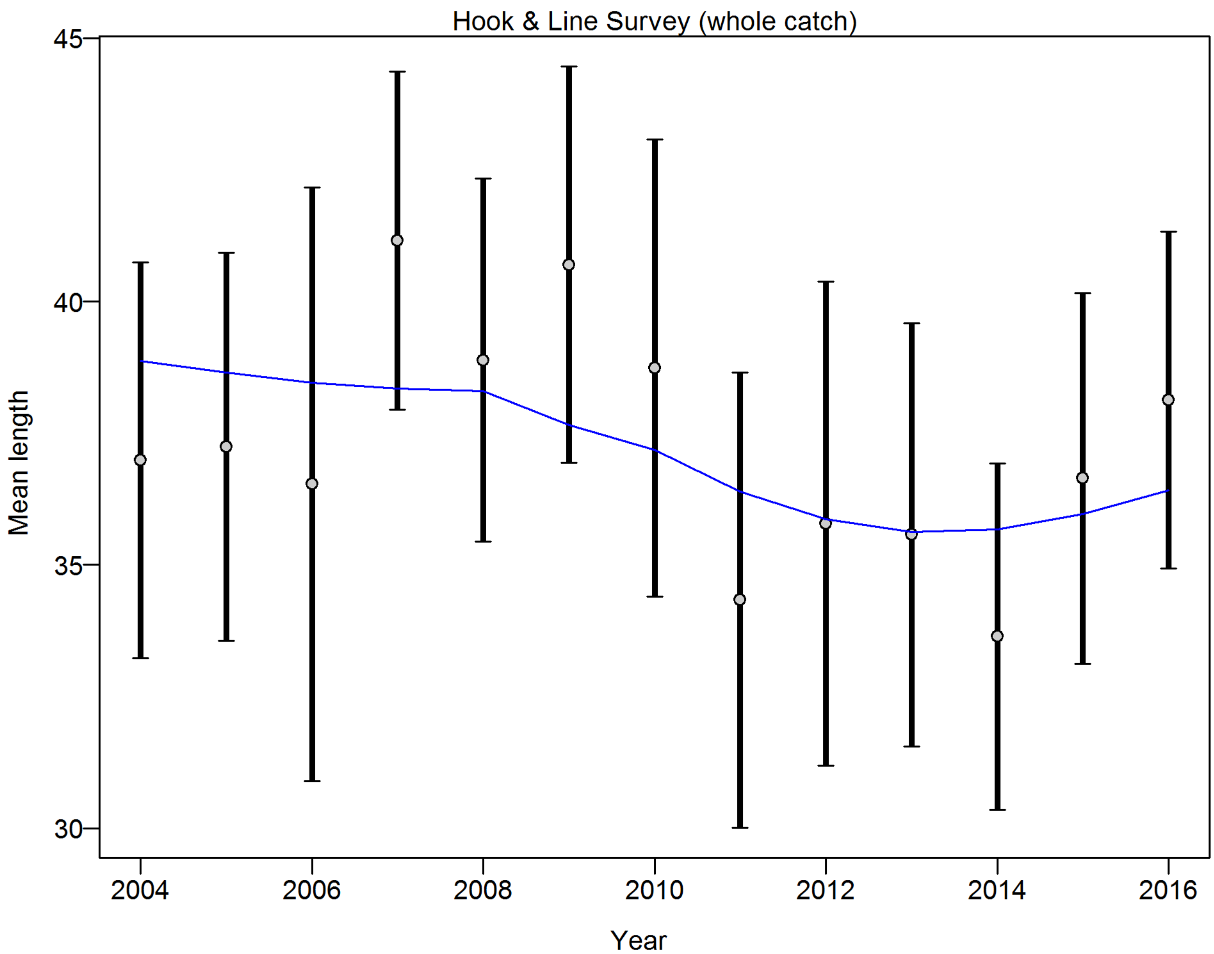


Figure 70: **Southern model** Mean length for Hook & Line Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Hook & Line Survey: 0.9978 (0.6843_2.3299) 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. fig:mod2_16_comp_lenfit_data_weighting_

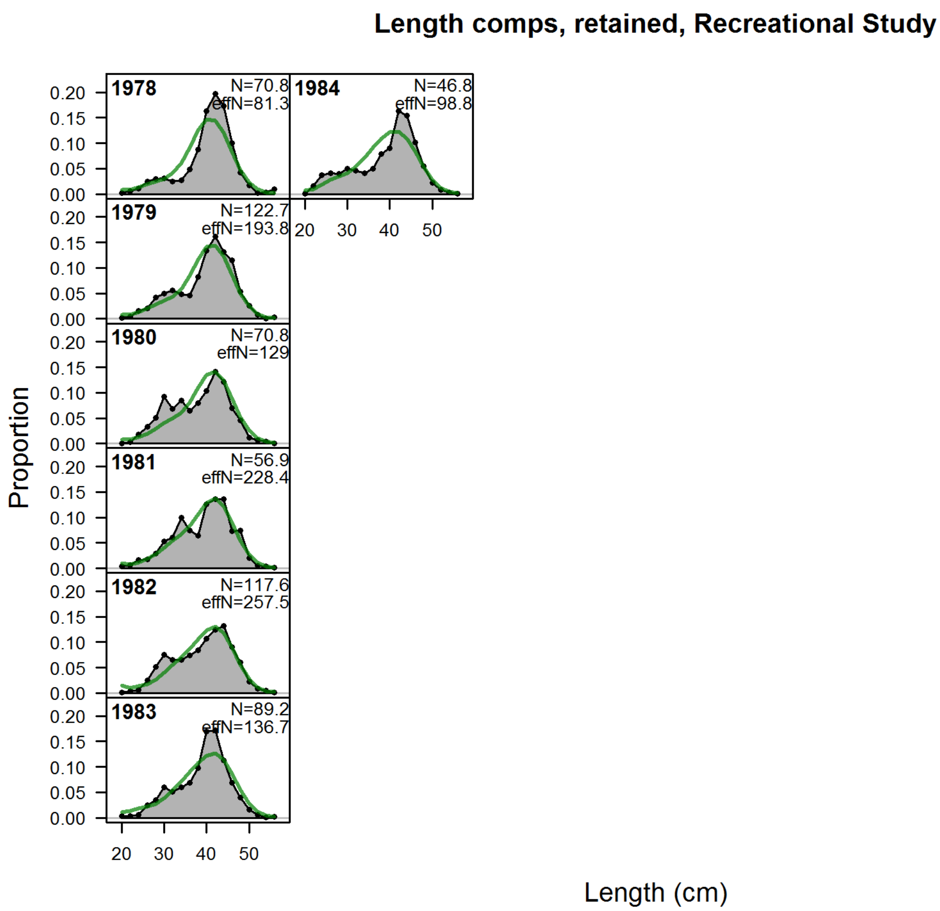


Figure 71: **Southern model** Length comps, retained, Recreational Study fig:mod2_17_comp_len

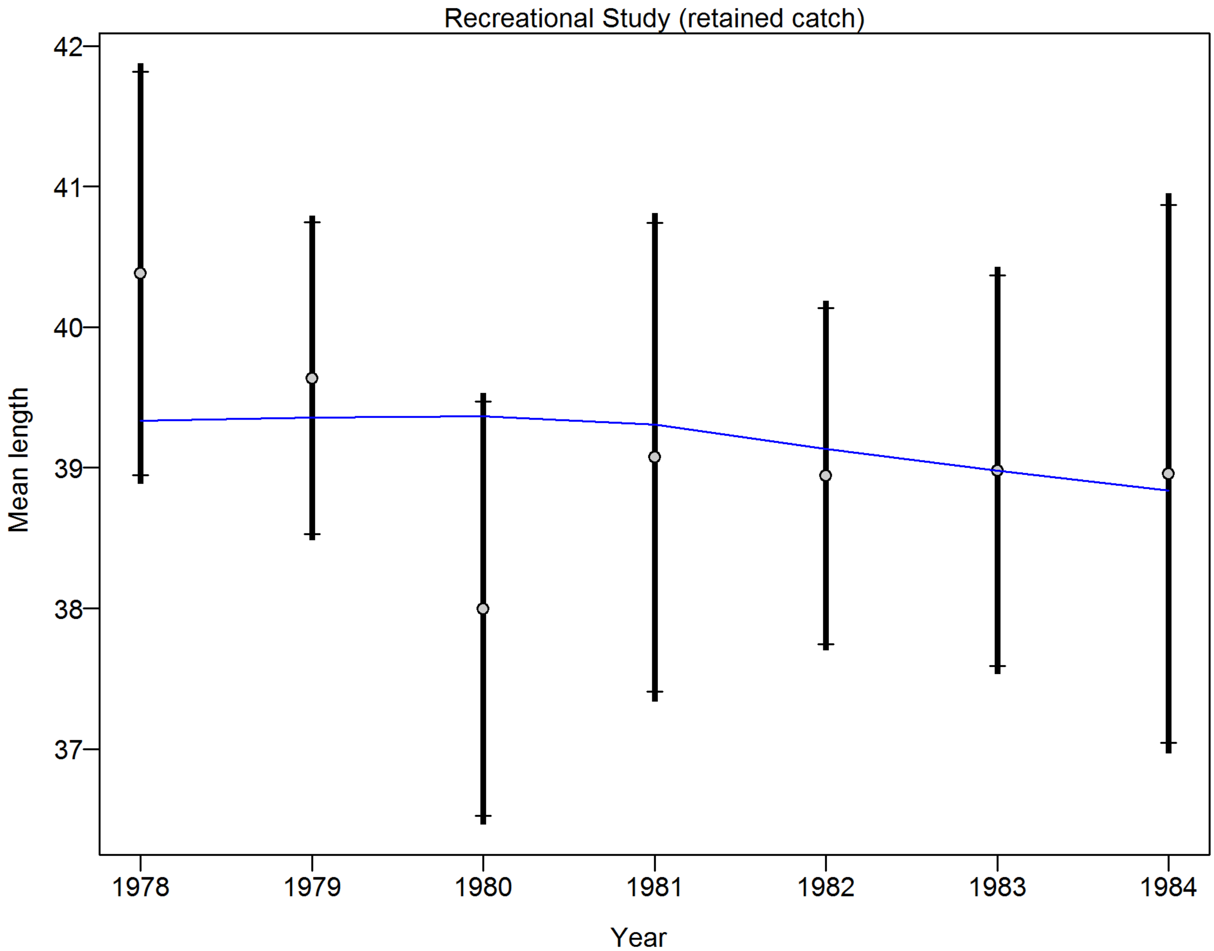


Figure 72: **Southern model** Mean length for Recreational Study with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len data from Recreational Study: 1.0852 (0.5552_14.1578) 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. fig:mod2_20_comp_lenfit_data_weighting_

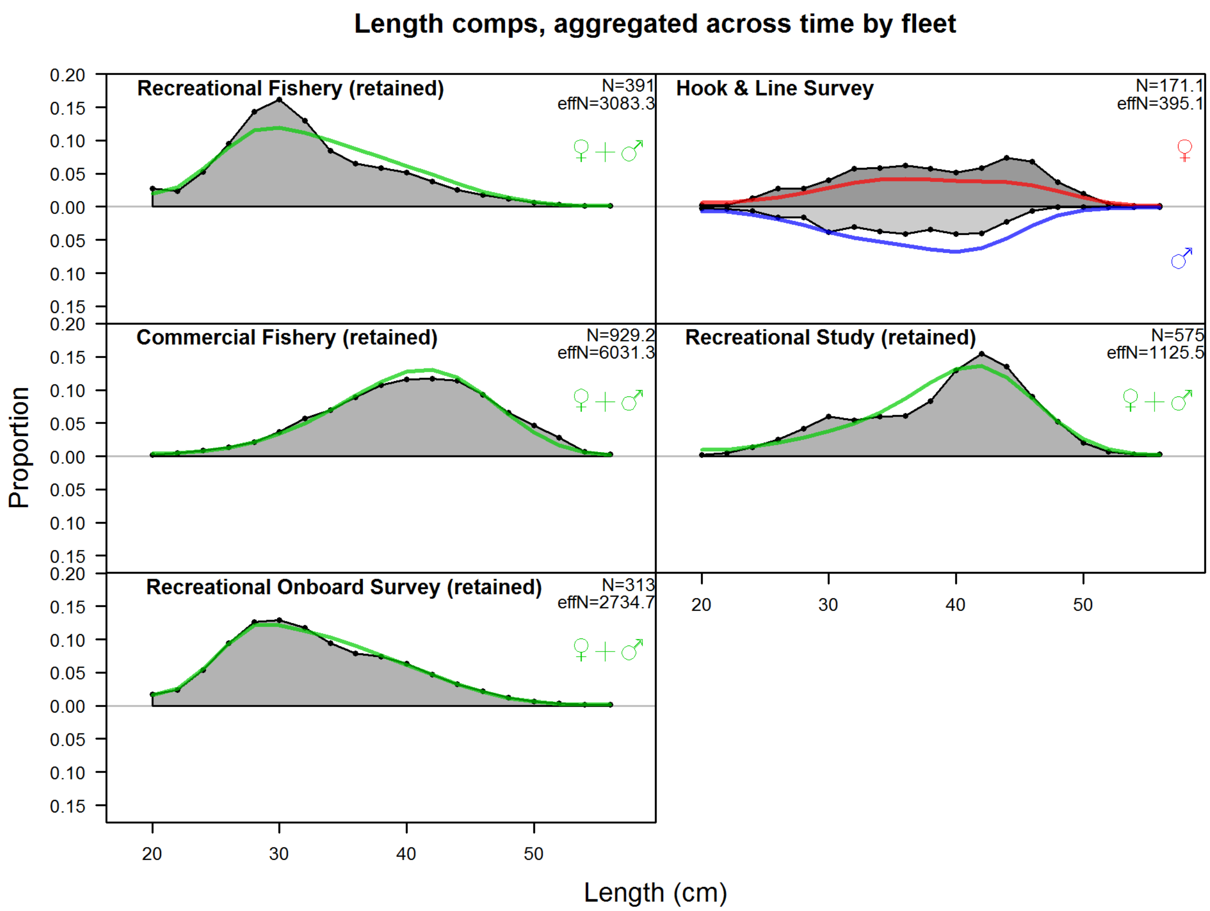


Figure 73: **Southern model** Length comps, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. fig:mod2_21_comp_lenfit__aggregated_across_time

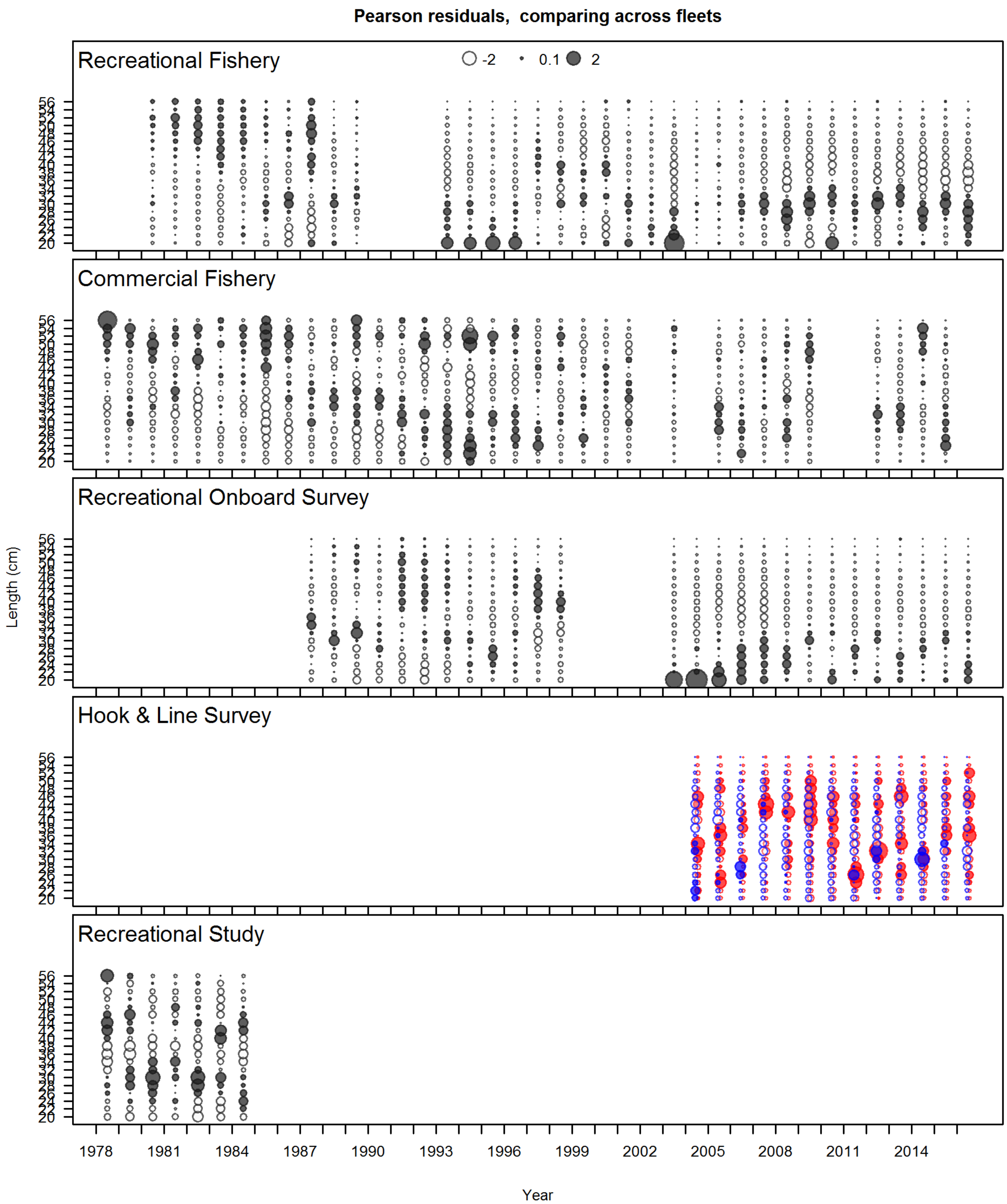


Figure 74: Length composition Pearson residuals for all fleets in the Southern model. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:comp_Pearson_length_mod2

1169 ### 9.4.4 Age compositions for Southern model

age-compositions-for-southern-model

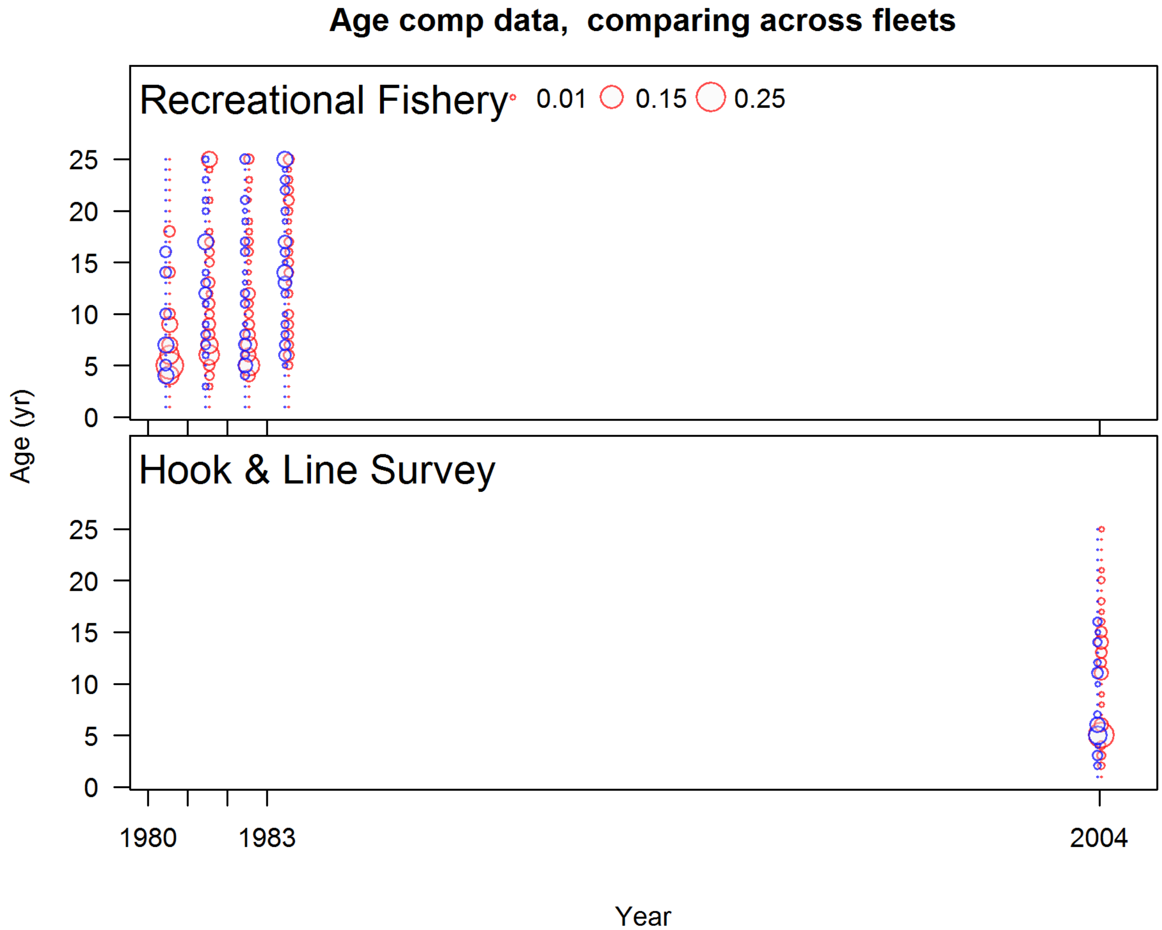


Figure 75: Age compositions for all fleets in the Southern model. Bubble size is proportional to proportions within each year. fig:comp_age_bubble_mod2

Age comps, retained, Recreational Fishery

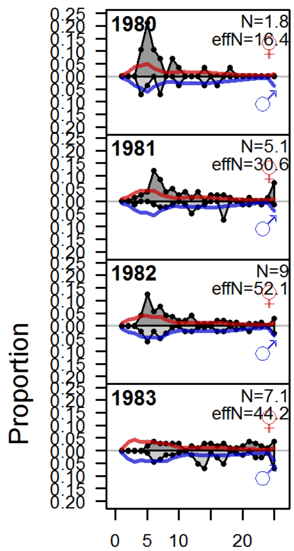


Figure 76: **Southern model** Age comps, retained, Recreational Fishery fig:mod2_1_comp_agefi

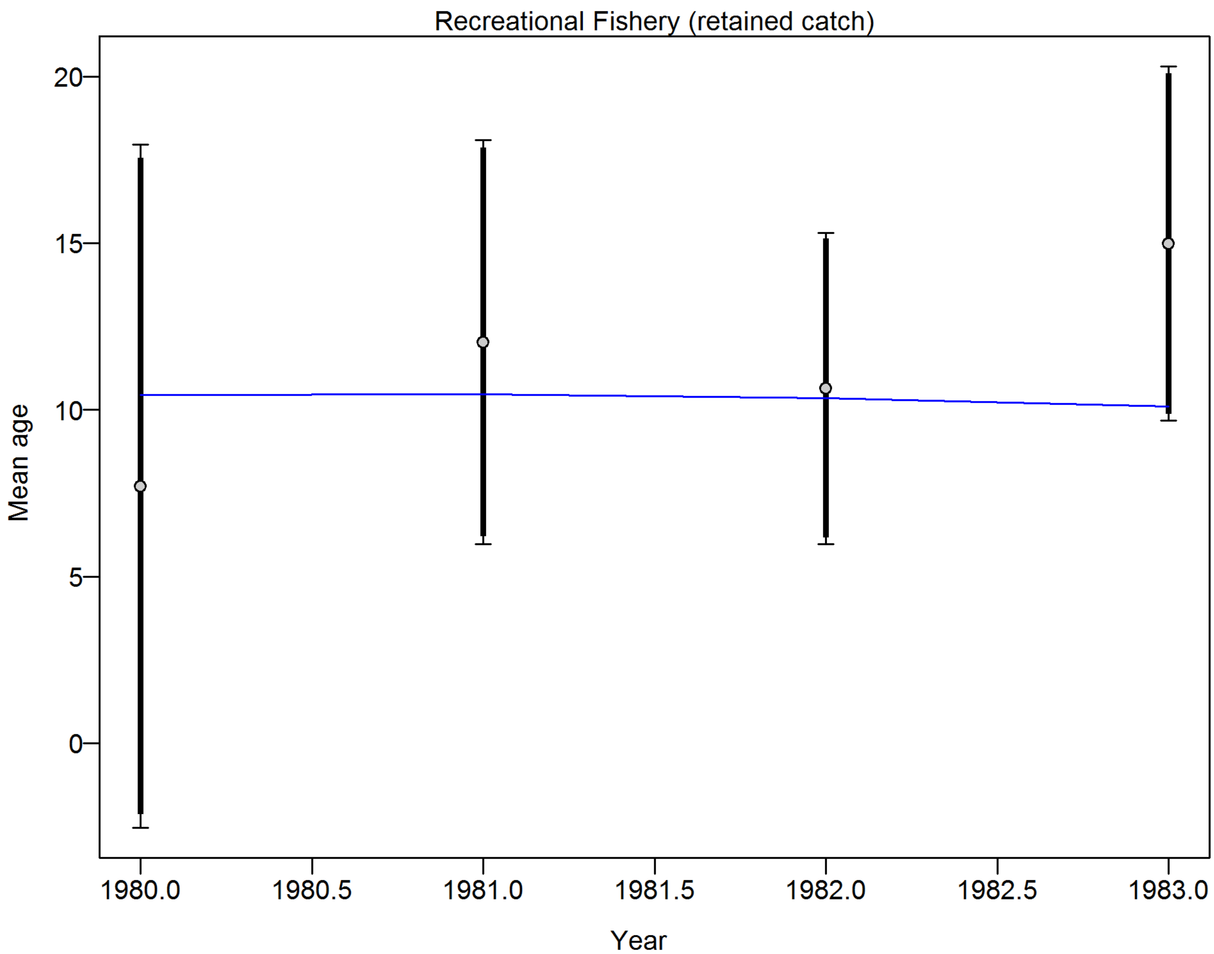


Figure 77: **Southern model** Mean age for Recreational Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data from Recreational Fishery: 0.925 (0.4929_24.4689) 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. fig:mod2_4_comp_agefit_data_weighting_TA1.8_Recre

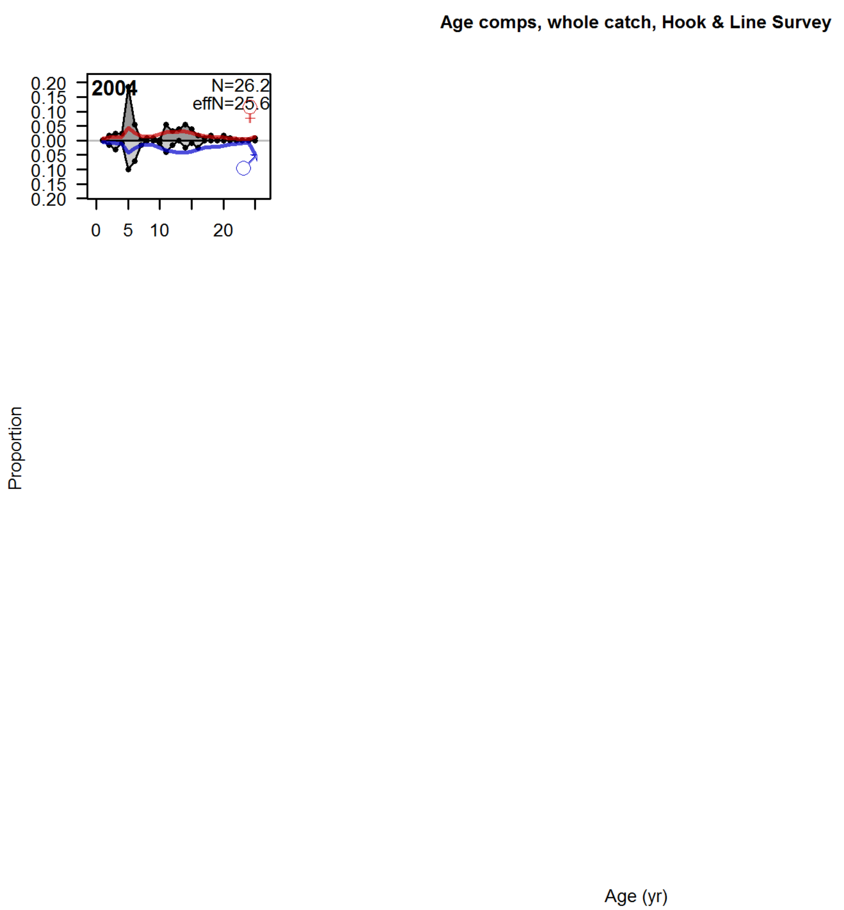


Figure 78: **Southern model** Age comps, whole catch, Hook & Line Survey fig:mod2_5_comp_age

Figure 79: **Southern model** Mean age for Hook & Line Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: too few points to calculate adjustments. 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. fig:mod2_8_comp_

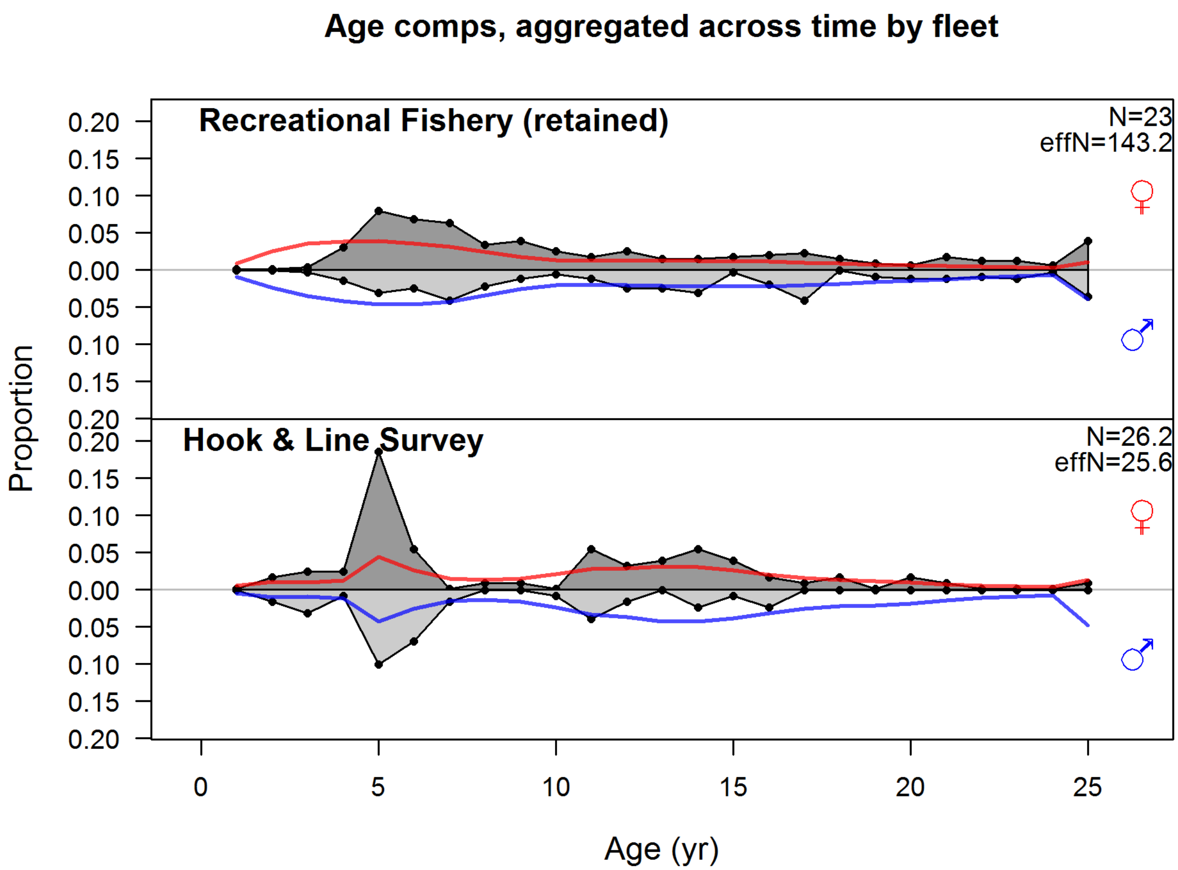


Figure 80: **Southern model** Age comps, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. fig:mod2_9_comp_agefit__aggregated_across_time

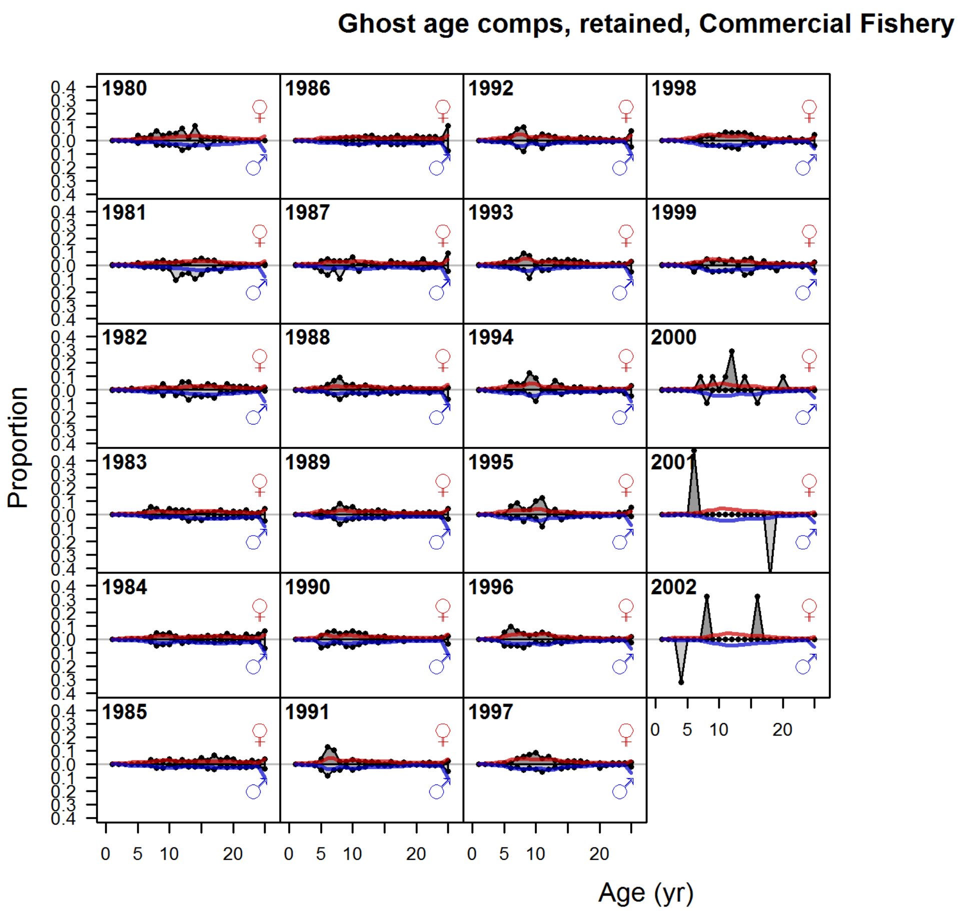


Figure 81: **Southern model** Ghost age comps, retained, Commercial Fishery fig:mod2_11_comp_g

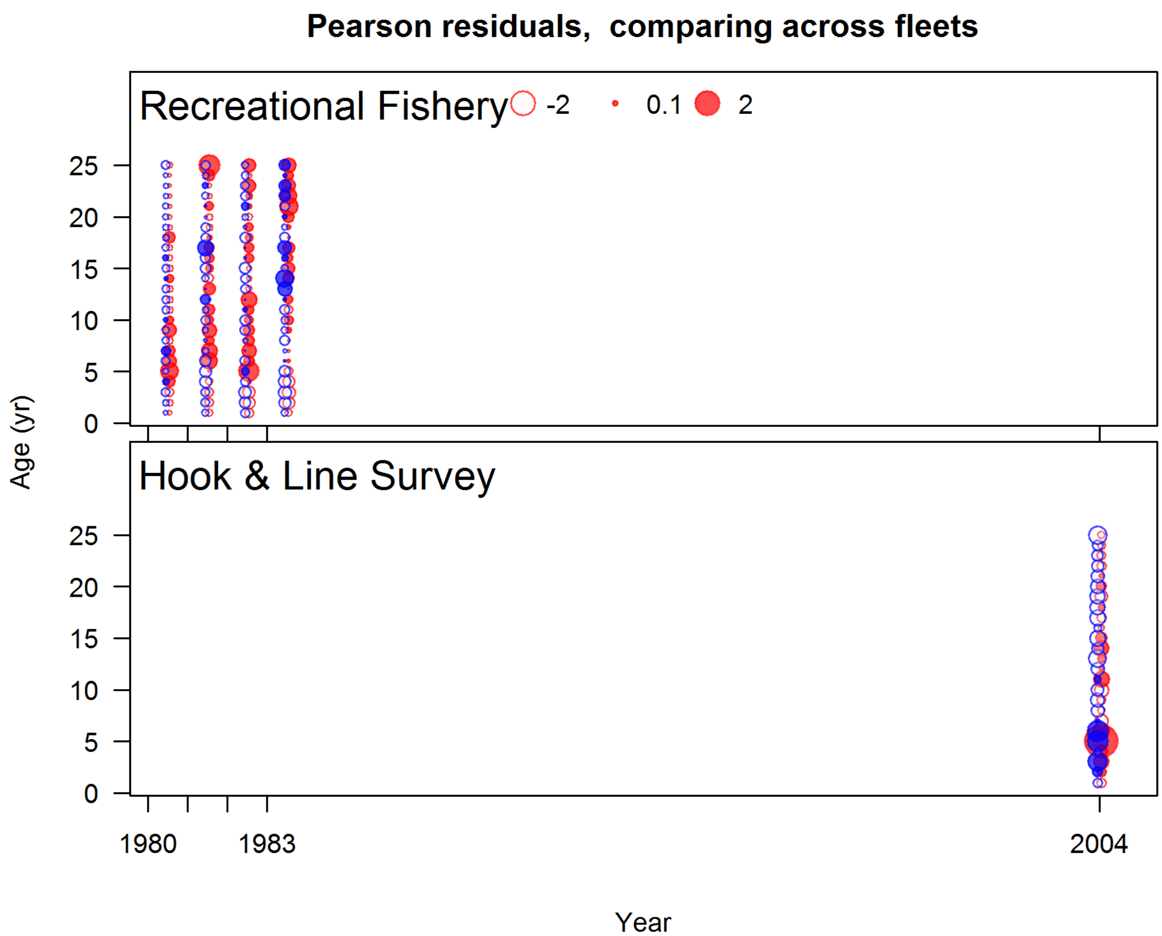


Figure 82: Age composition Pearson residuals for all fleets in the Southern model. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:comp_Pearson_age_mod2

1170 ### 9.4.5 Fits to conditional-age-at-length compositions for Southern model

fits-to-conditional-age-at-length-compositions-for-southern-model

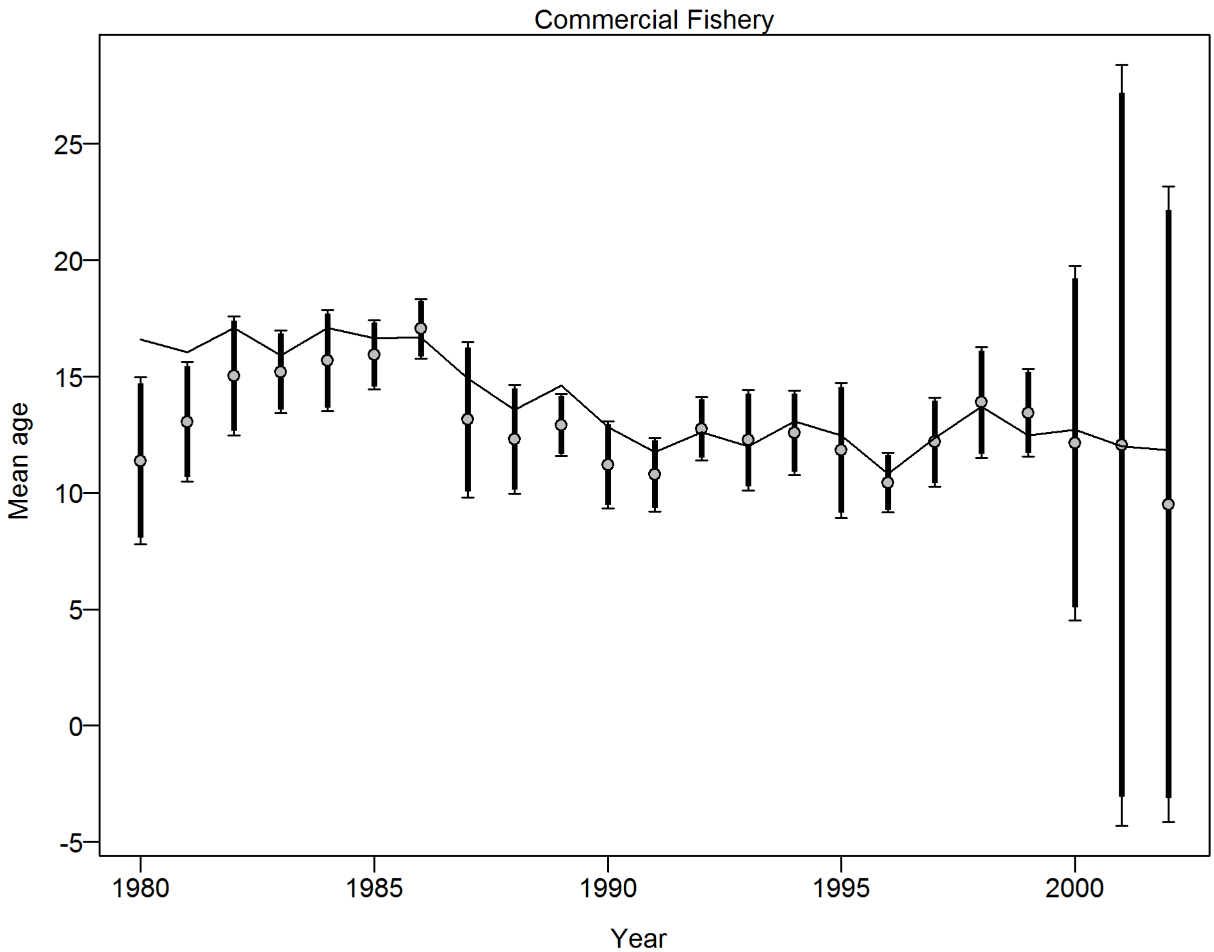


Figure 83: **Southern model** Mean age from conditional data (aggregated across length bins) for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for conditional age_at_length data from Commercial Fishery: 0.8567 (0.5727_1.8556) 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. fig:mod2_4_comp_condAALfit_data_weighting_TA1.8_condAgeCommerc

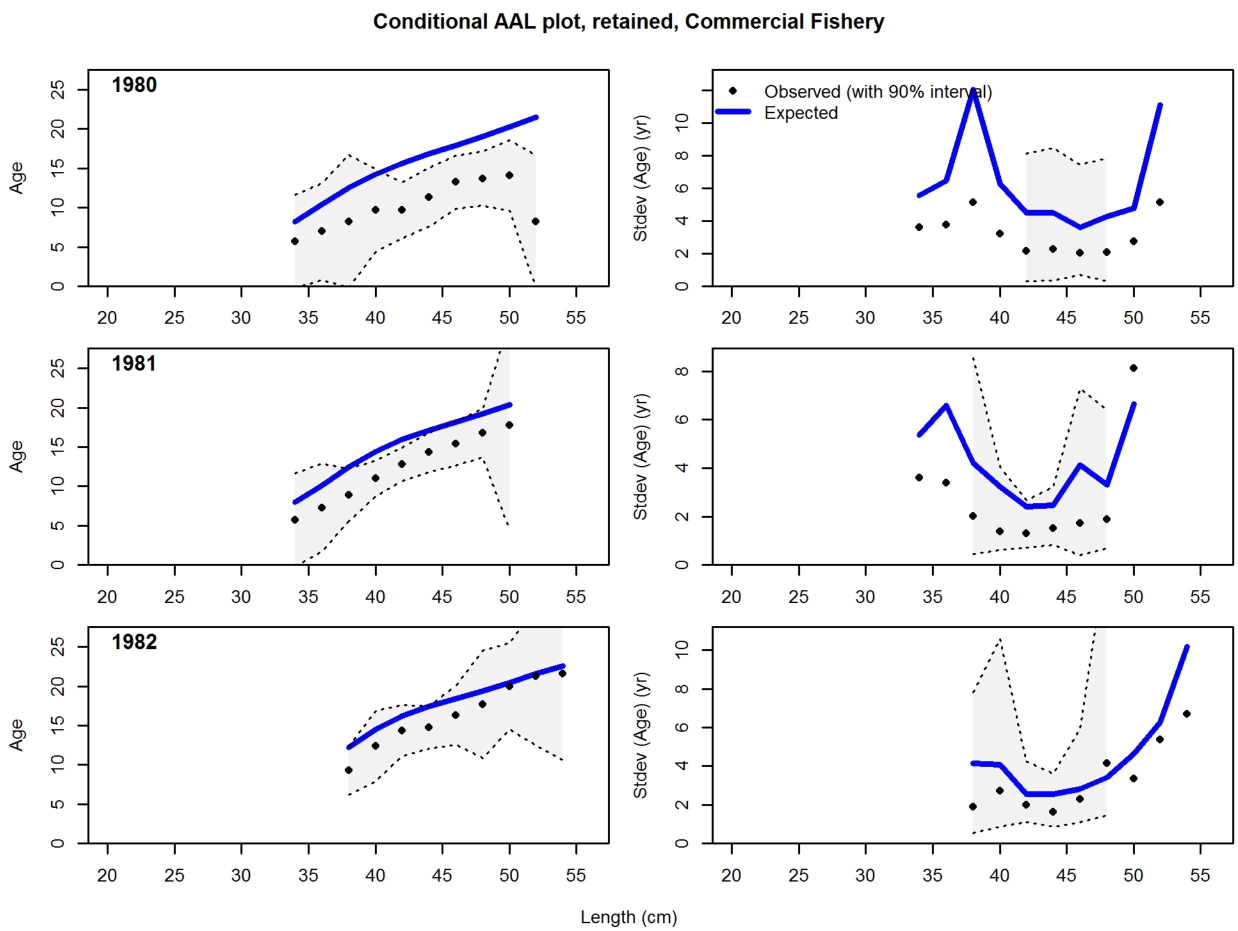
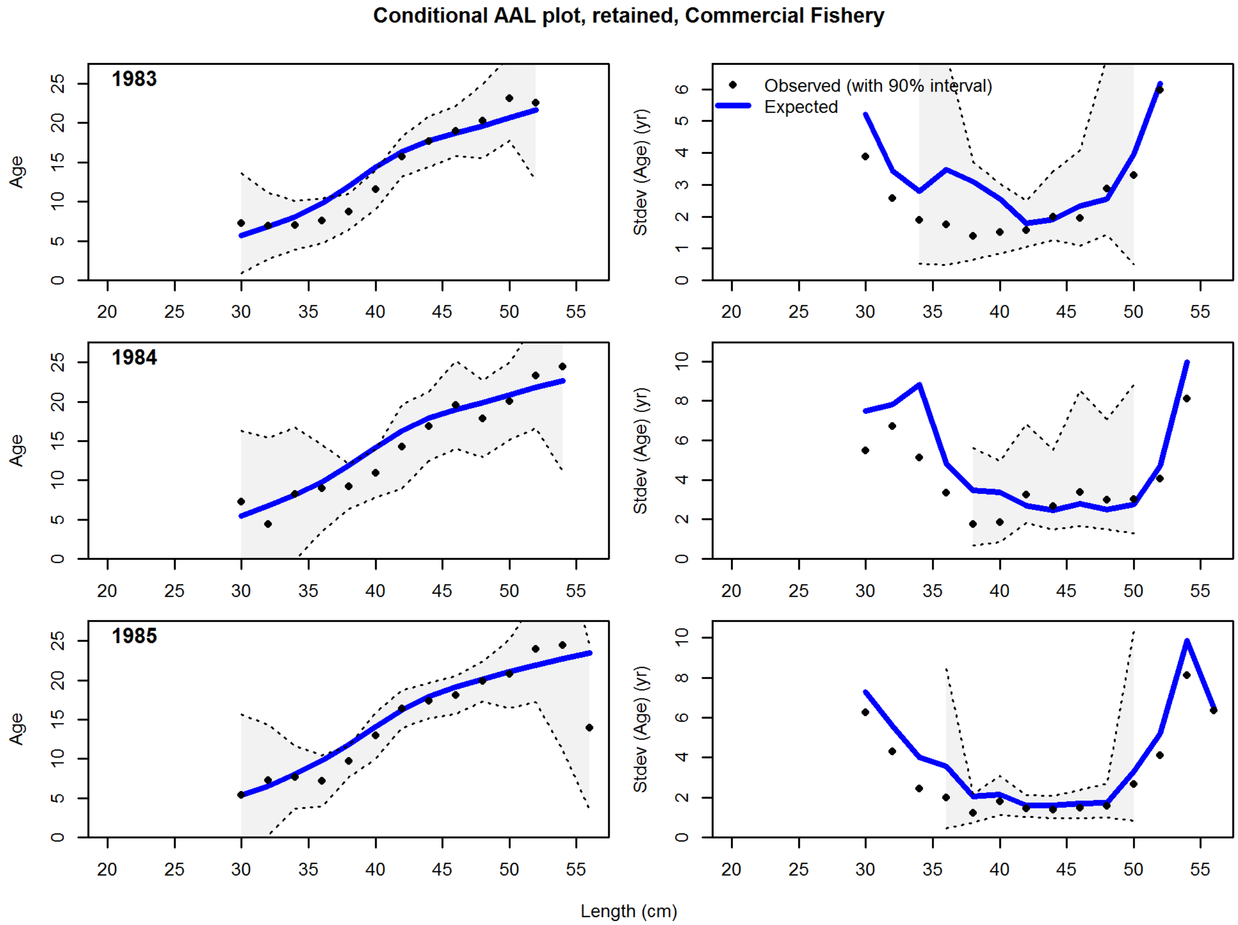
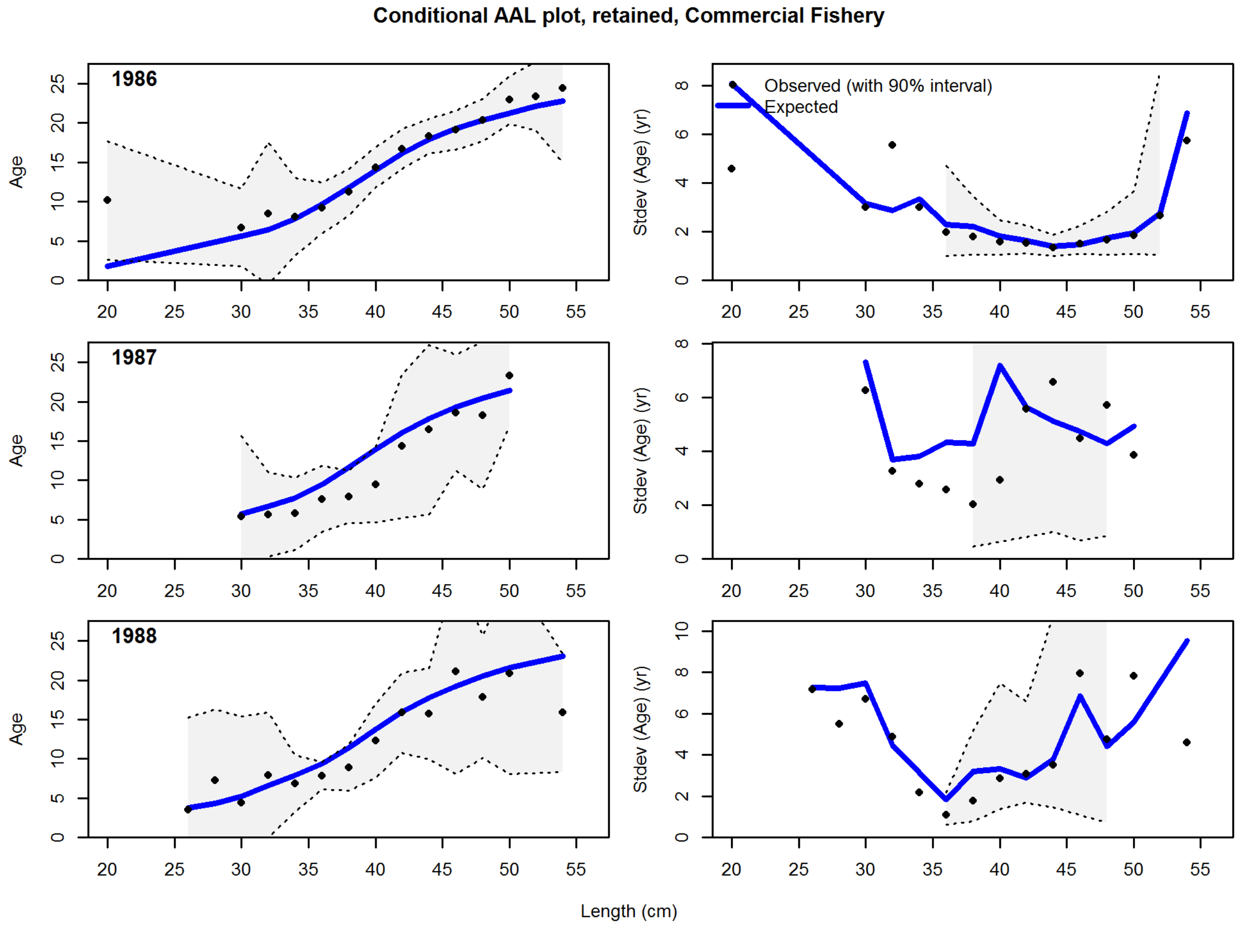


Figure 84: **Southern model** Conditional AAL plot, retained, Commercial Fishery (plot 1 of 8) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution. fig:mod2_5_comp_condAALfit_Andre_plotsflt2mkt2_page1



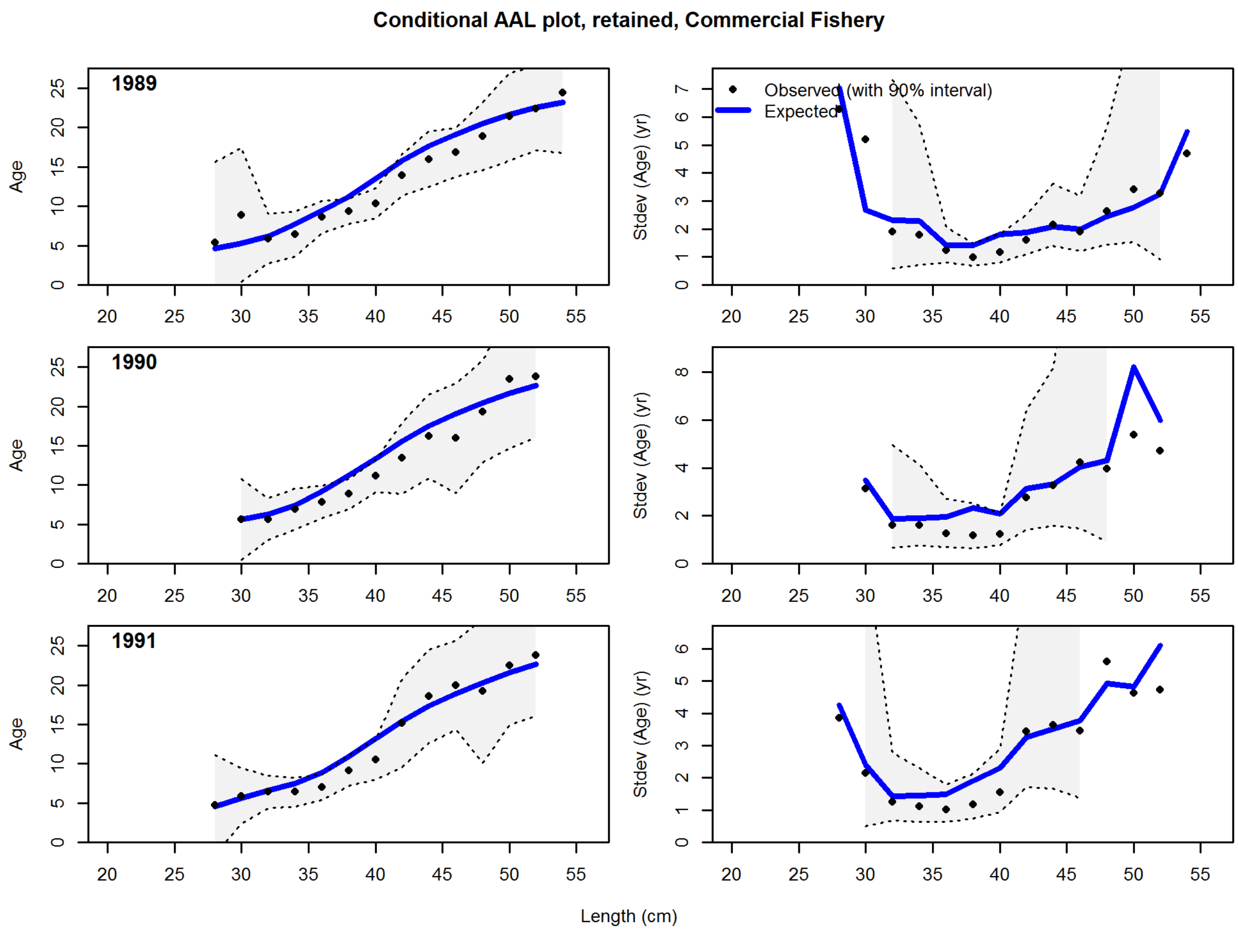
1171

1172 Figure continued from previous page



1173

1174 Figure continued from previous page



1175

1176 Figure continued from previous page

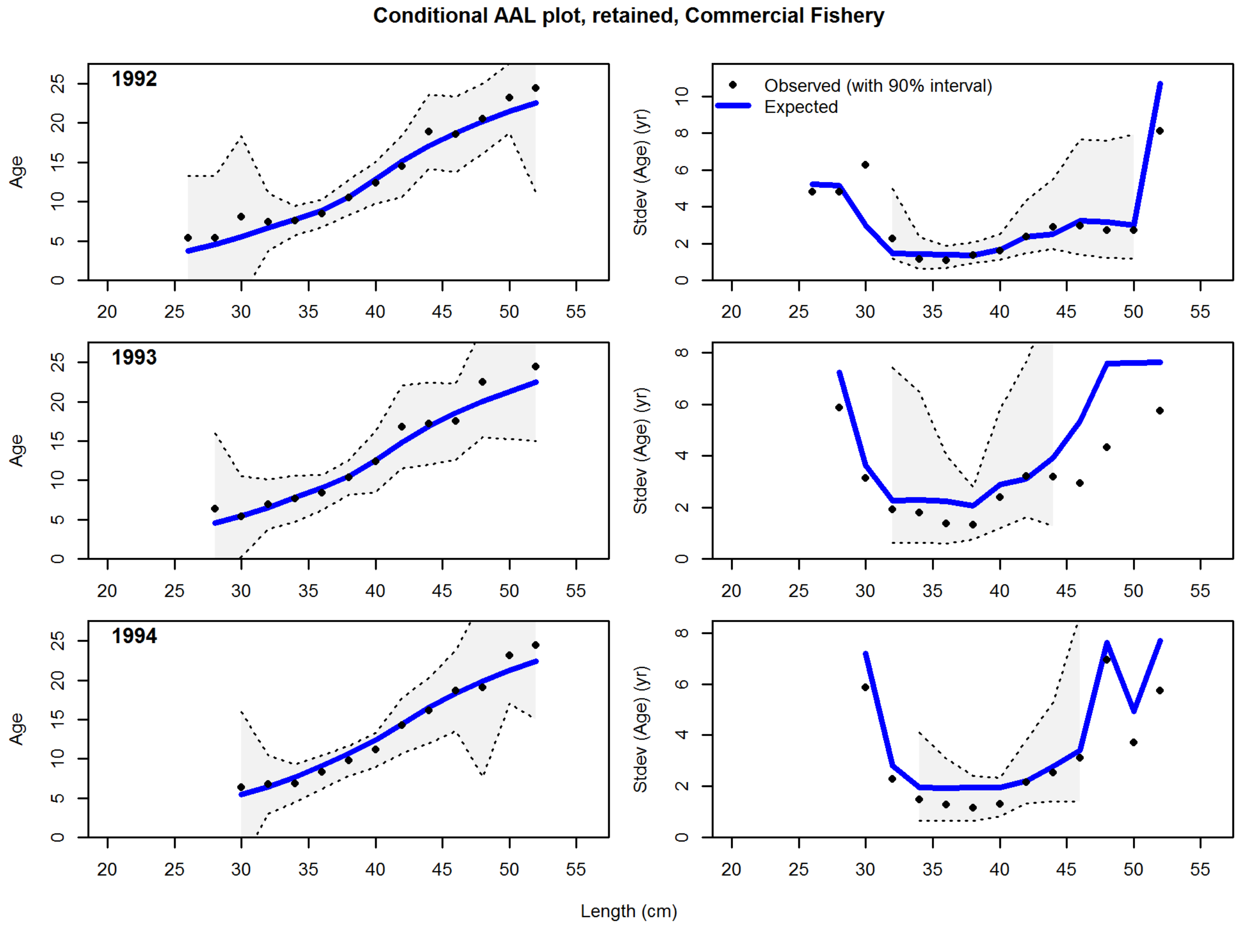
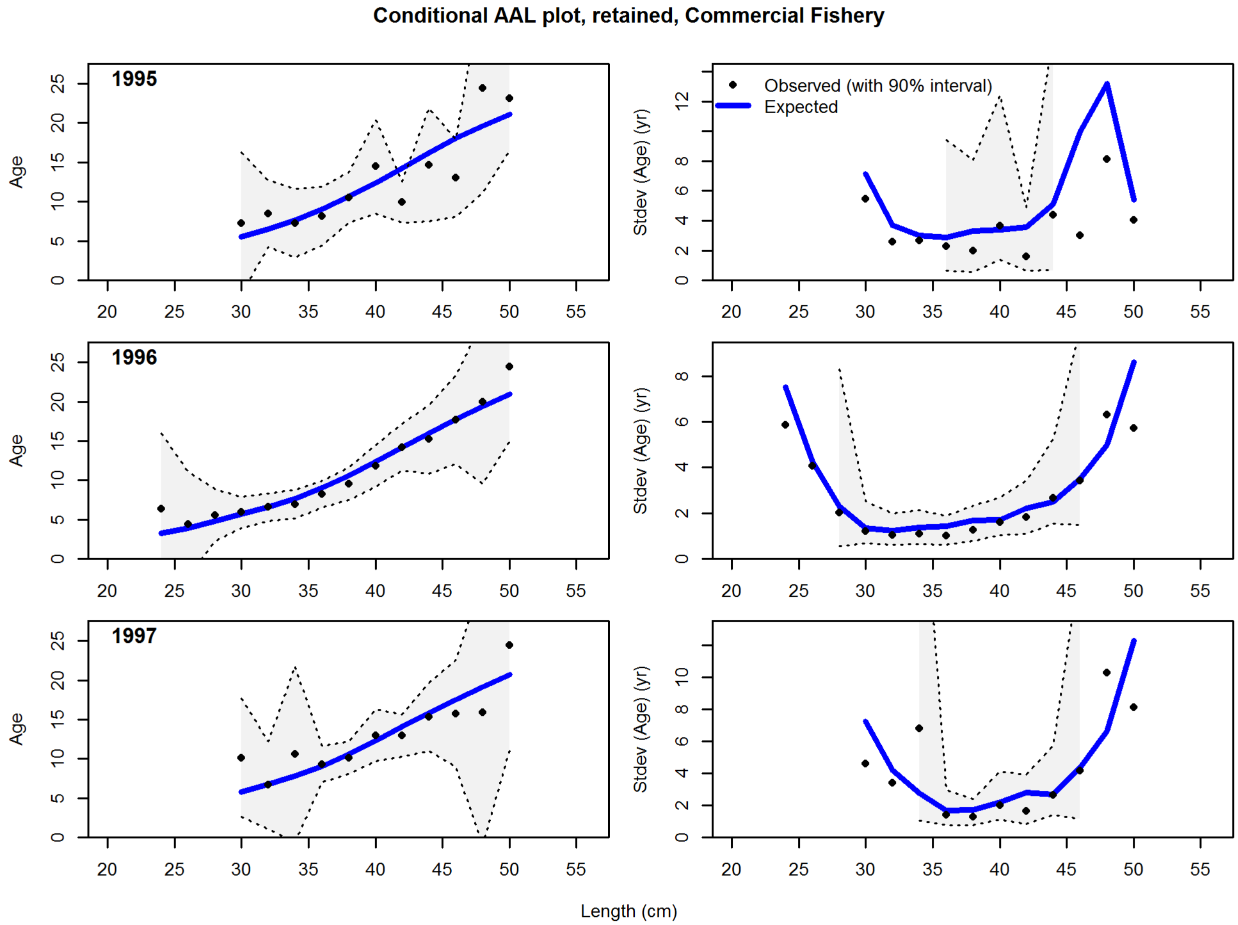


Figure continued from previous page



1179

1180 Figure continued from previous page

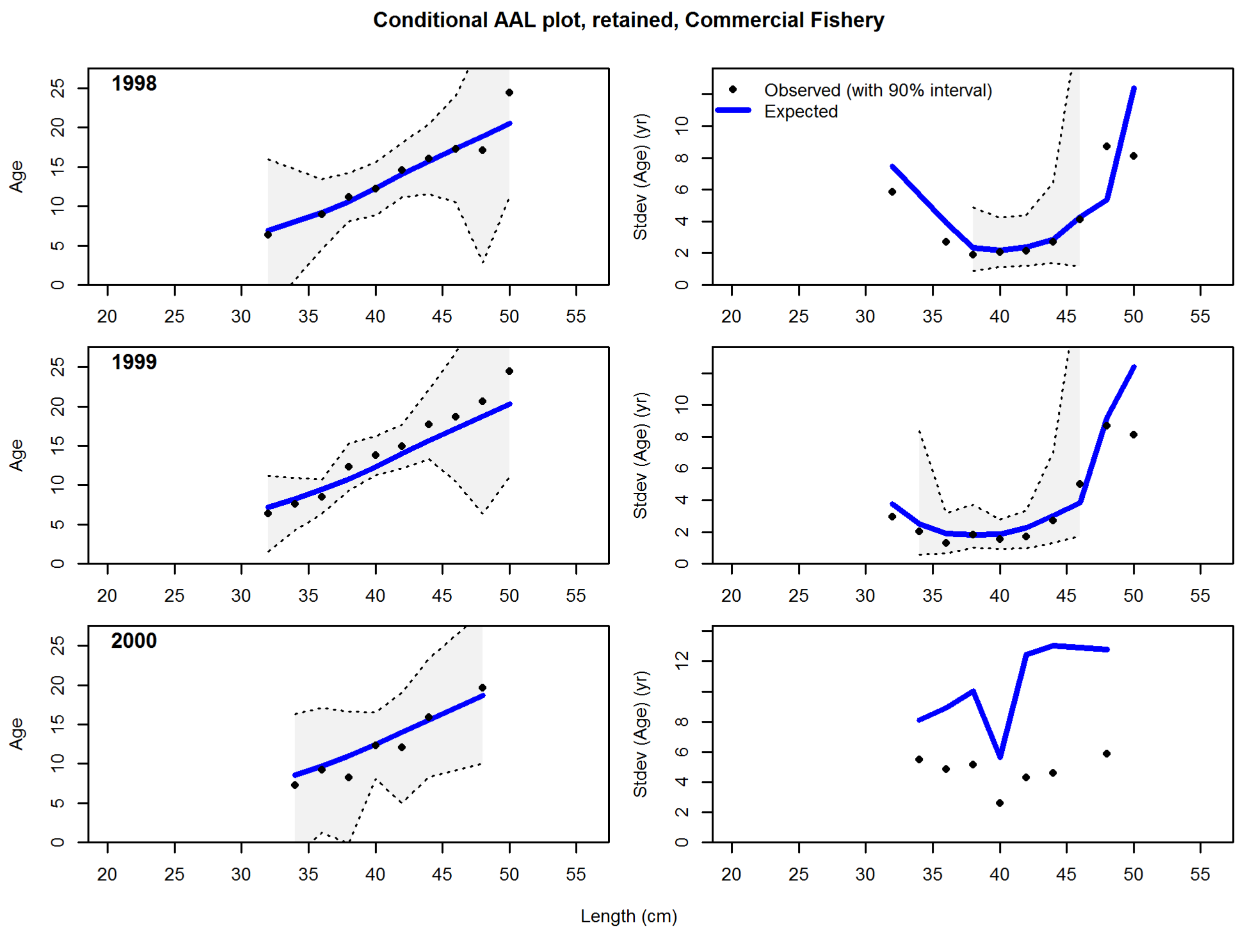


Figure continued from previous page

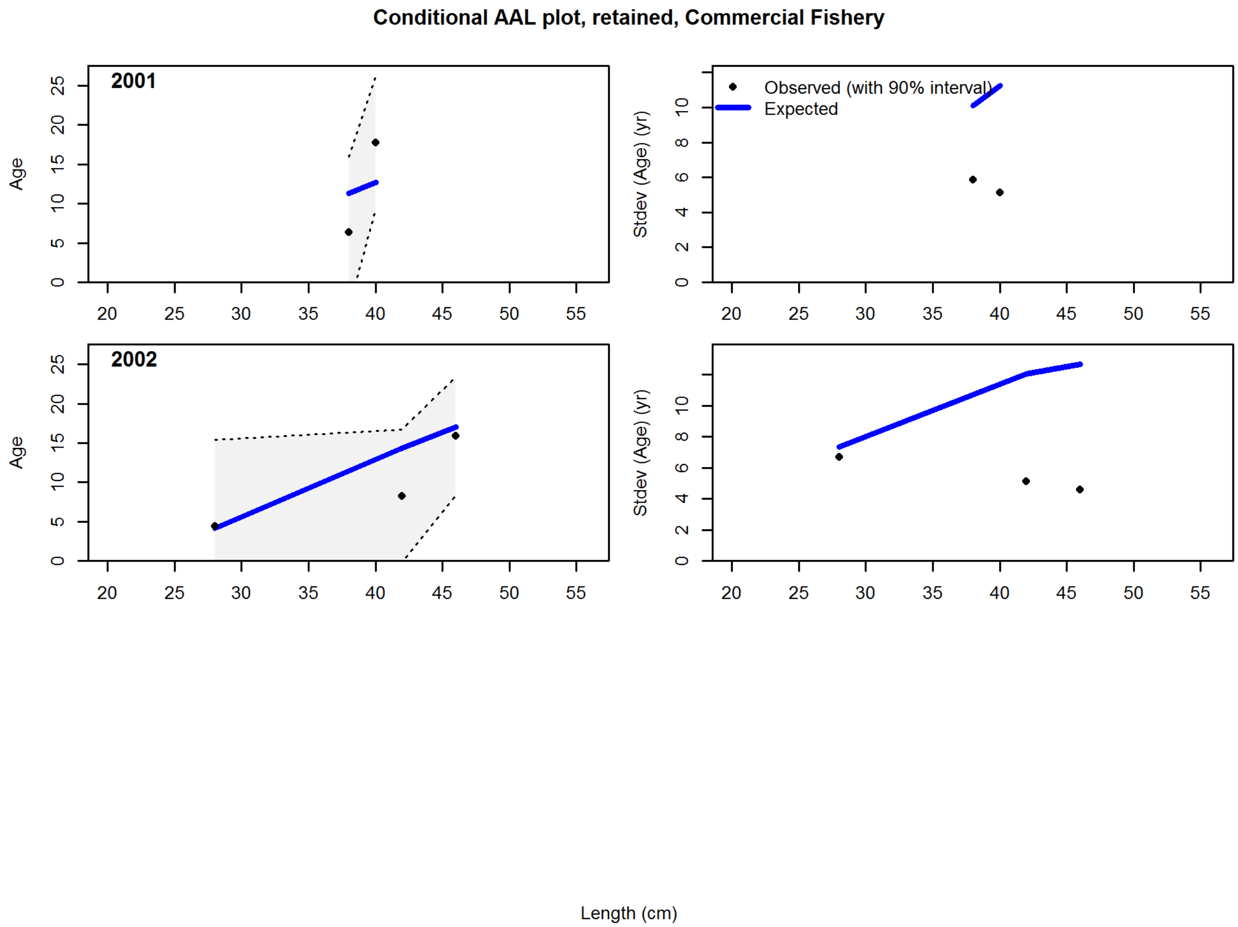


Figure continued from previous page

1185 9.5 Model results for Southern model

model-results-for-southern-model

1186 9.5.1 Base model results for Southern model

base-model-results-for-southern-model

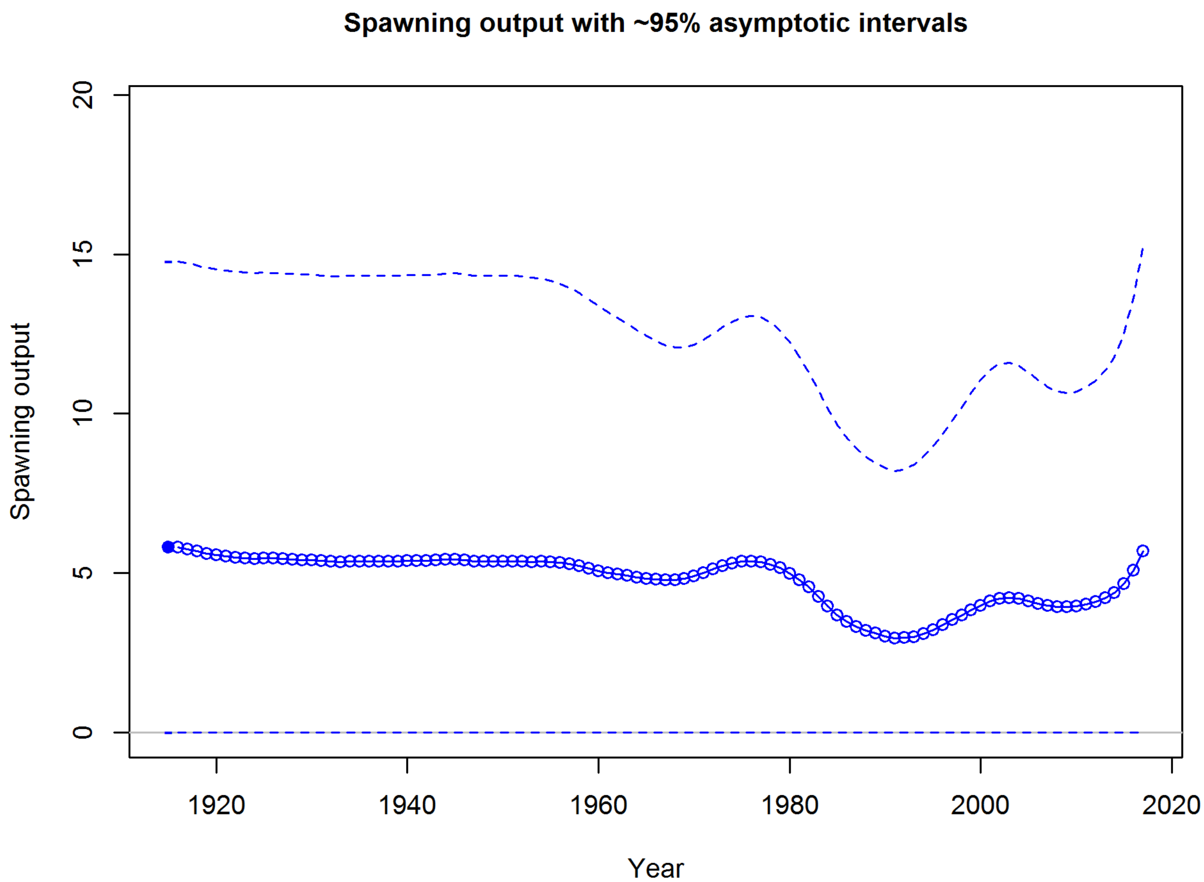


Figure 85: Estimated time-series of spawning output for Southern model. fig:ssb.S

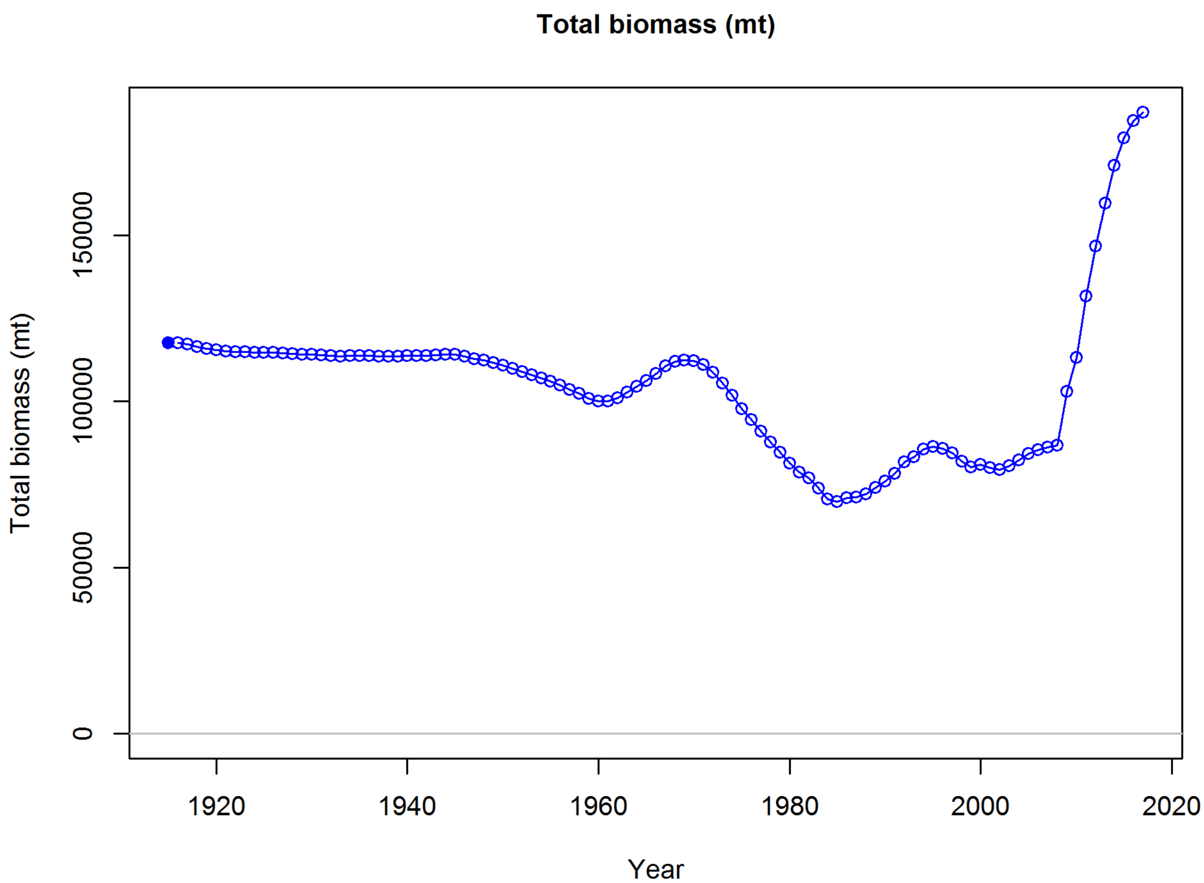


Figure 86: Estimated time-series of total biomass for Southern model. fig:total_bio.S

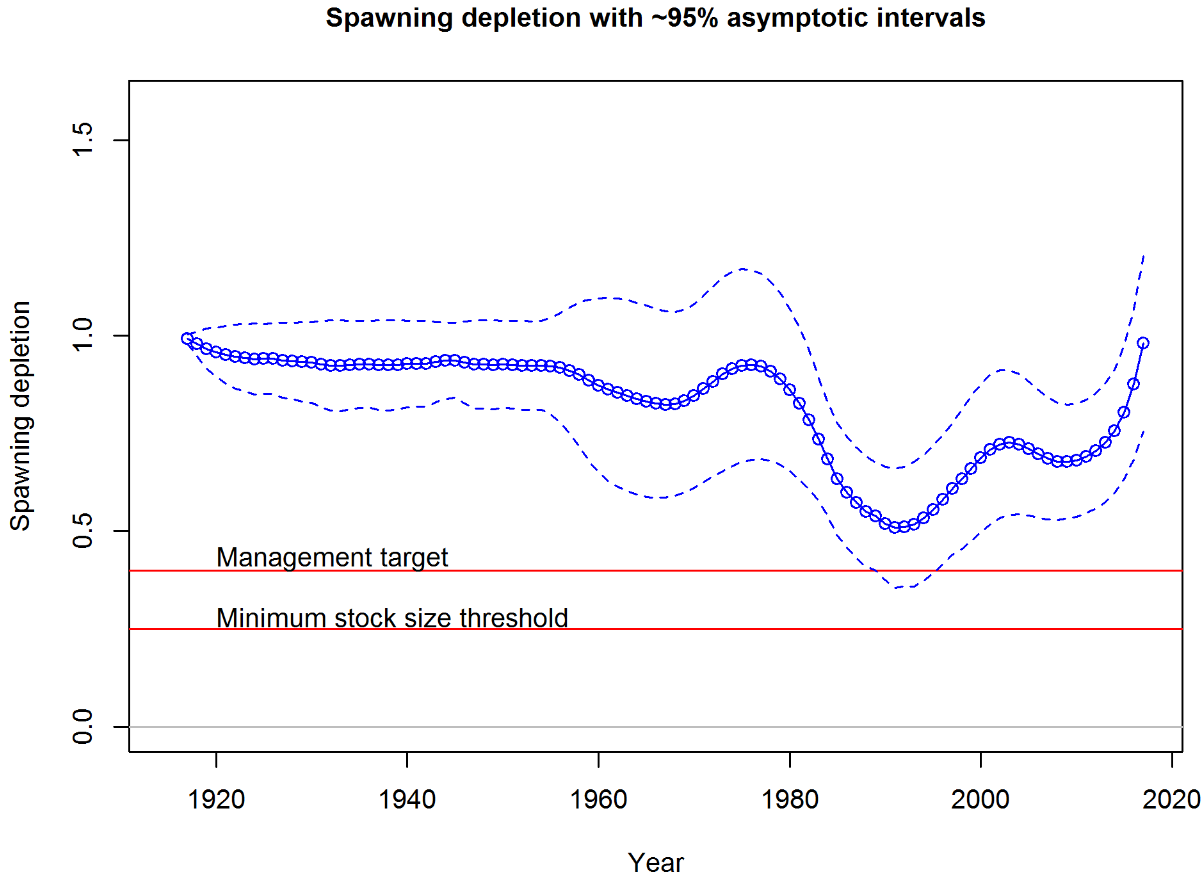


Figure 87: Estimated time-series of relative biomass for Southern model. fig:depl.S

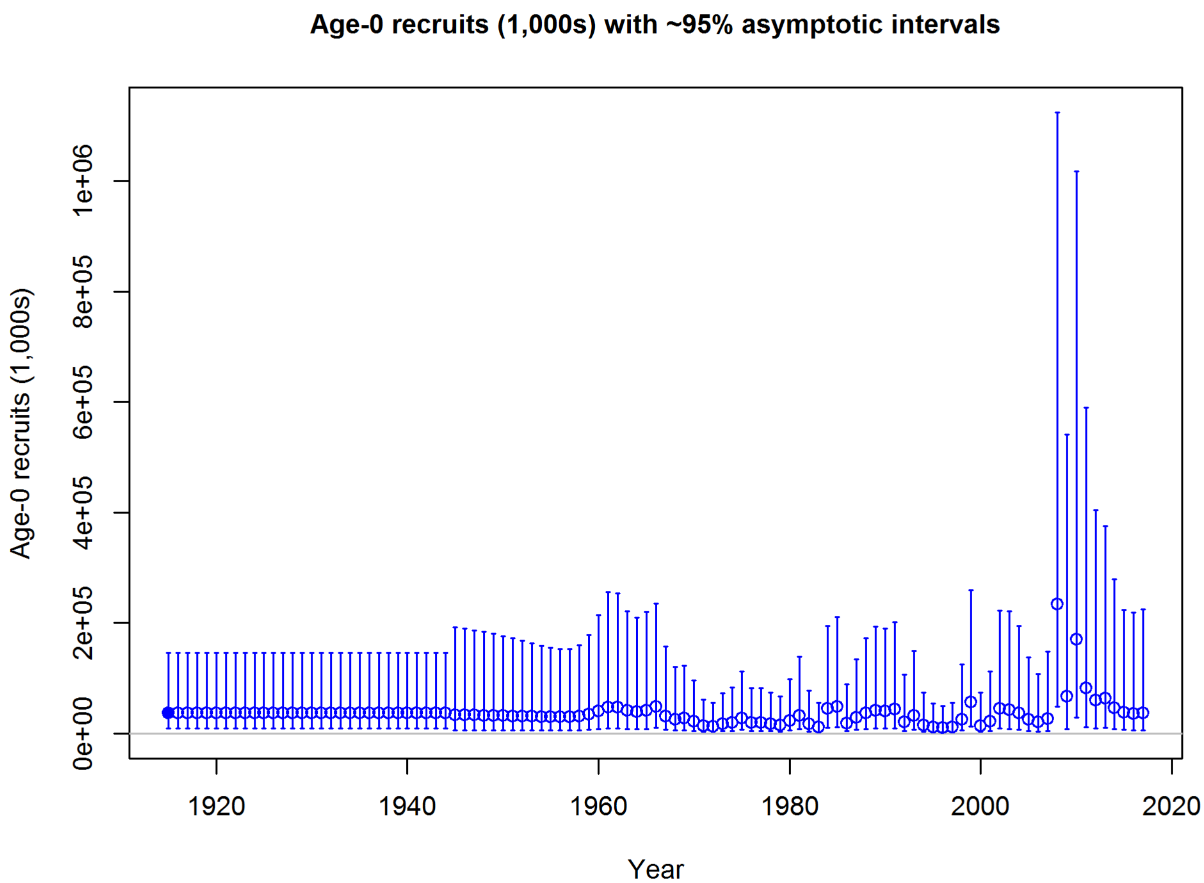


Figure 88: Estimated time-series of recruitment for the Southern model. fig:recruits1.S

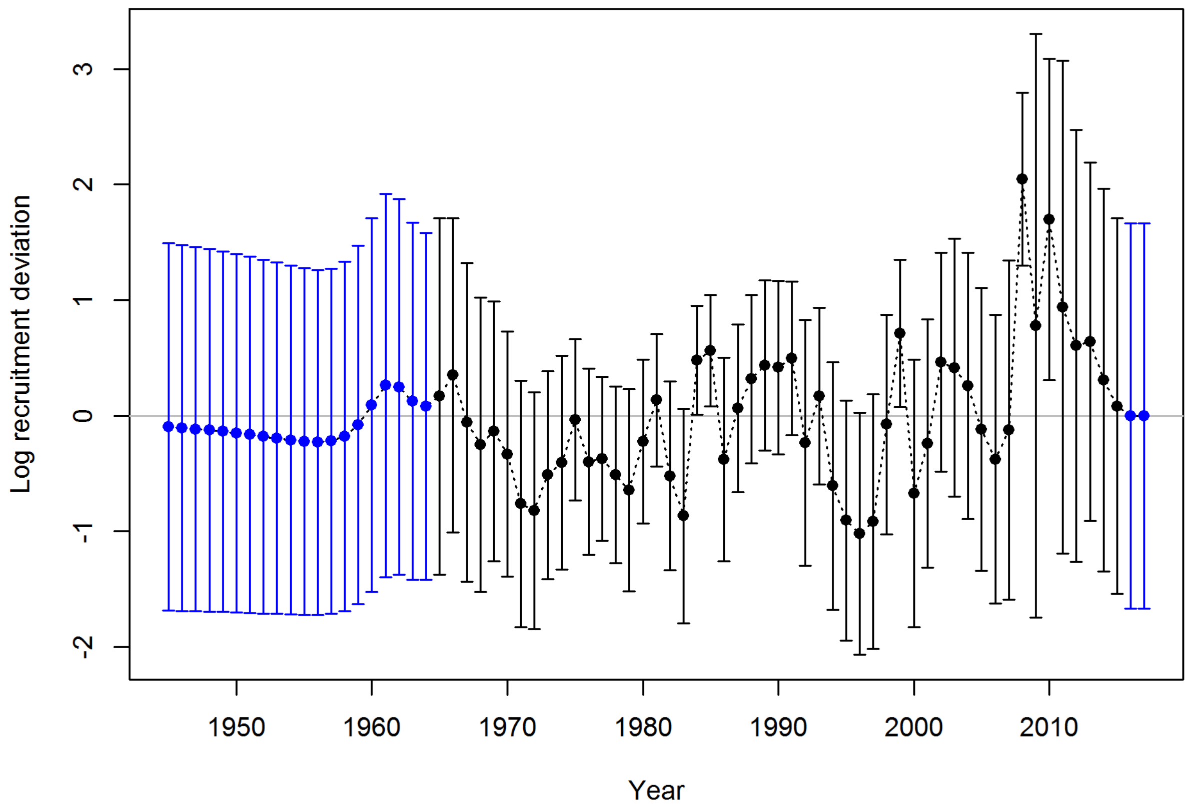


Figure 89: Estimated time-series of recruitment deviations for the Southern model. fig:recdevs1.S

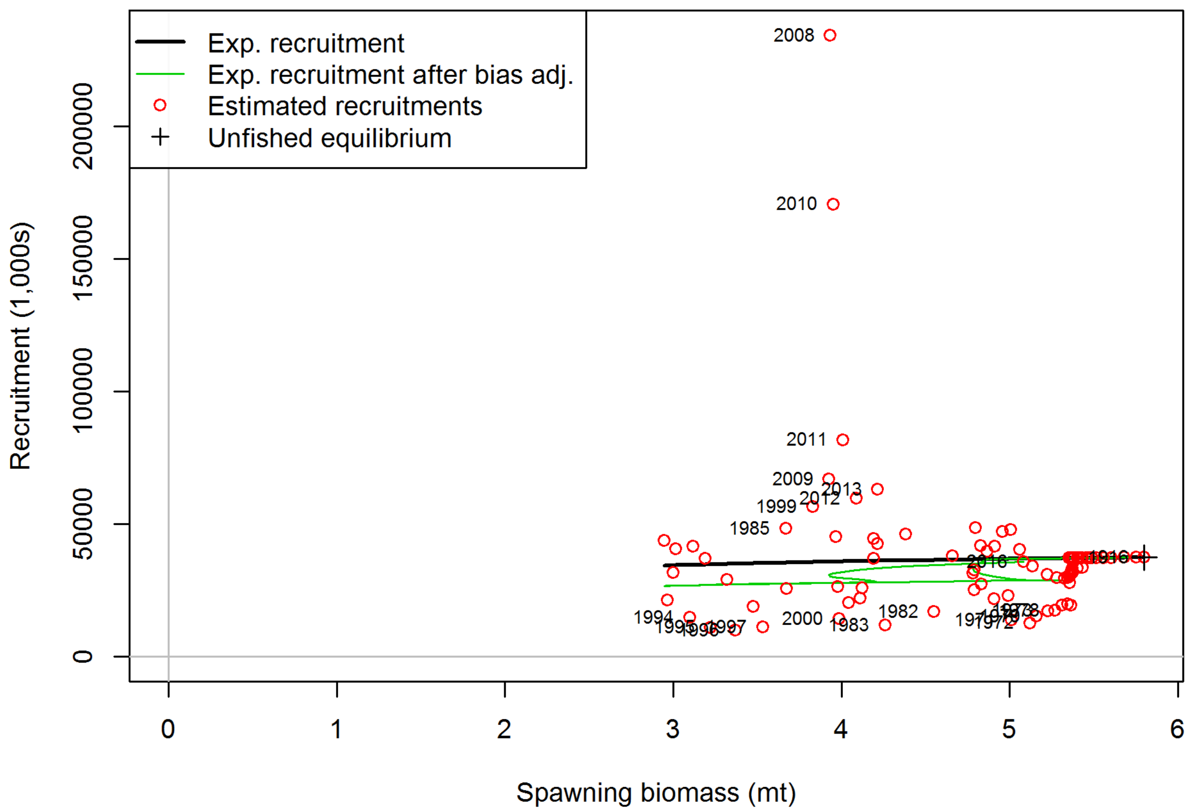


Figure 90: Estimated recruitment (red circles) for the Southern model relative to the stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution fig:stock_recruit_curve.S

9.5.2 Sensitivity analyses for Southern model

sensitivity-analyses-for-southern-model

to be added...

9.5.3 Likelihood profiles for Southern model

likelihood-profiles-for-southern-model

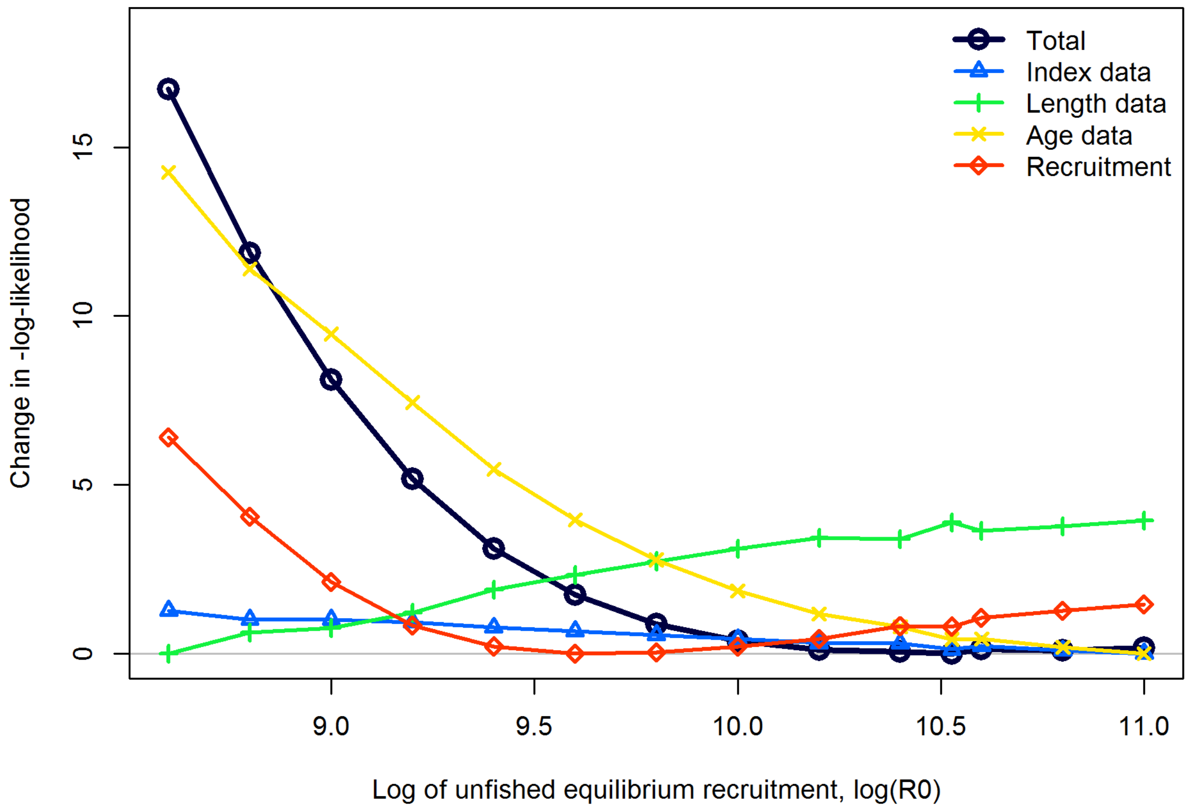


Figure 91: Likelihood profile over the log of equilibrium recruitment (R_0) for the Southern model. fig:profile_logR0.S

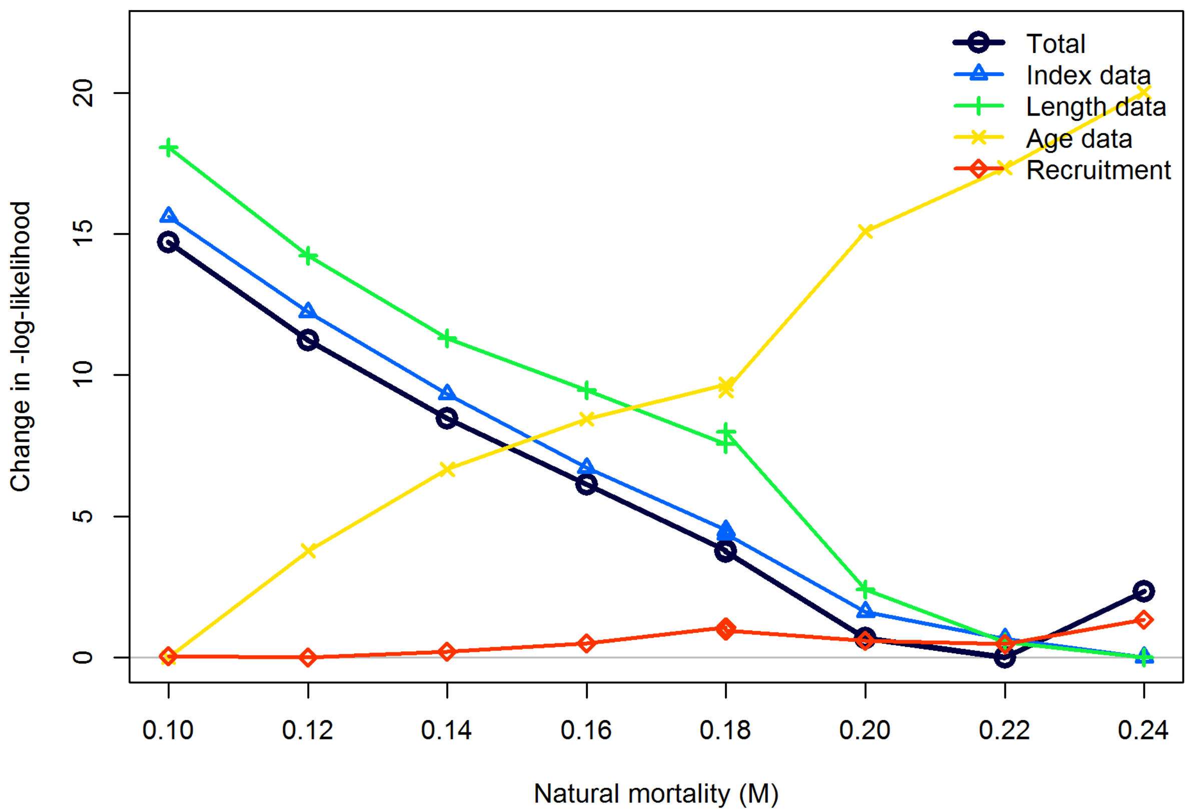


Figure 92: Likelihood profile over female natural mortality for the Southern model. fig:profile_M.S

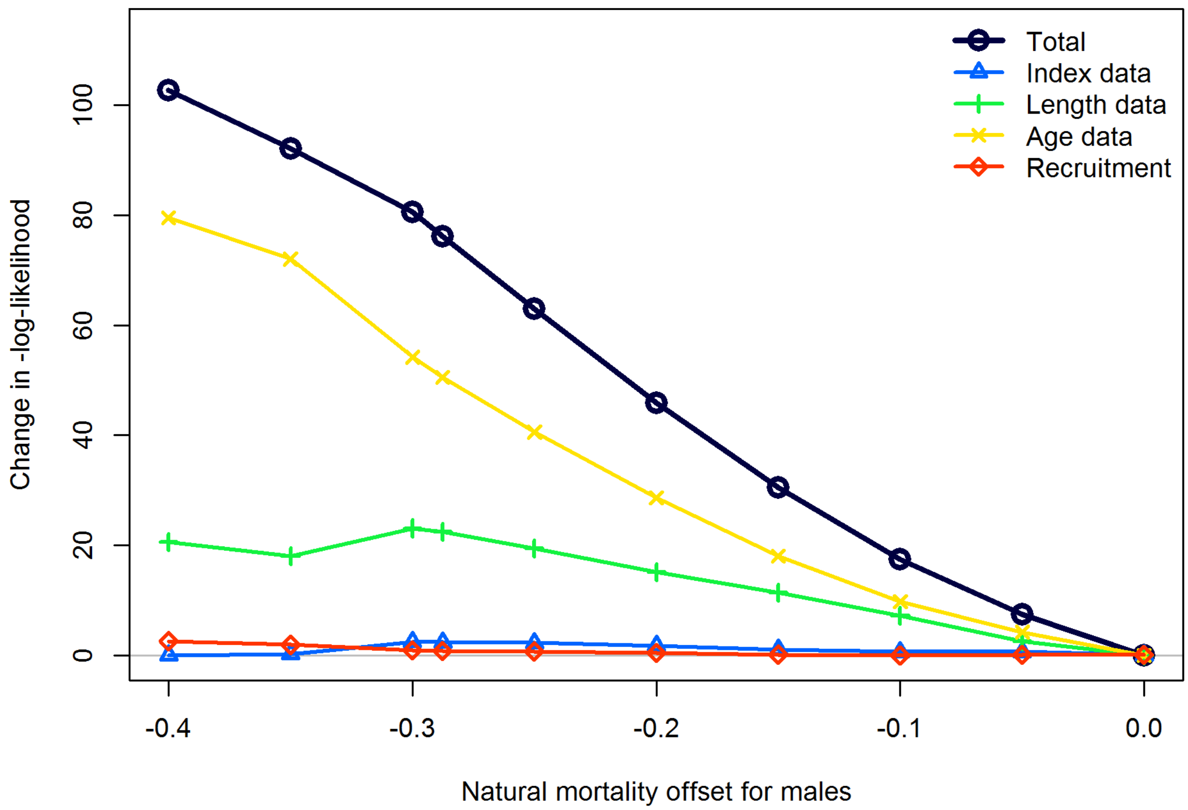


Figure 93: Likelihood profile over the male offset for natural mortality for the Southern model. Negative values are associated with natural mortality being lower for males than females. fig:profile_M2

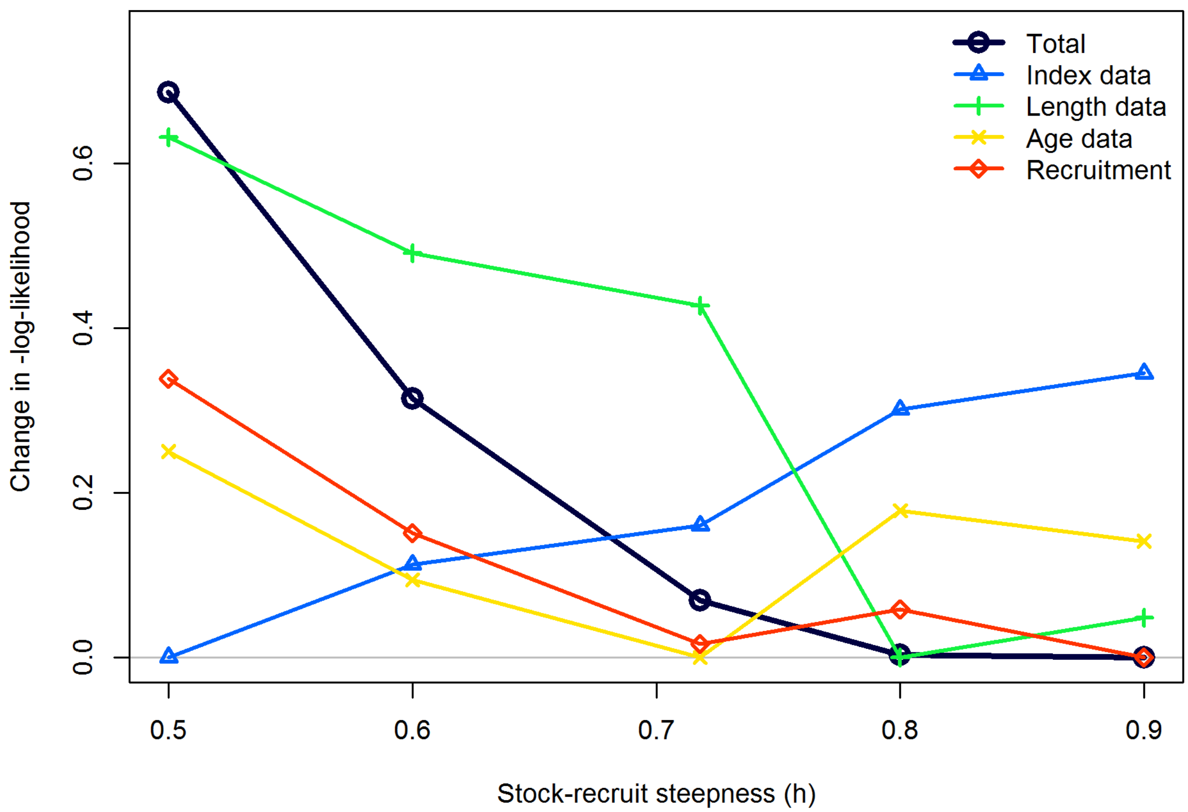


Figure 94: Likelihood profile over stock-recruit steepness (h) for the Southern model. fig:profile_h.S

9.5.4 Retrospective analysis for Southern model

retrospective-analysis-for-southern-model

Retrospective analysis of spawning output for the Southern model. fig:retro.S

9.5.5 Forecasts analysis for Southern model

forecasts-analysis-for-southern-model

to be added...

References

references

Alverson, D.L., Pruter, a T., and Ronholt, L.L. 1964. A Study of Demersal Fishes and Fisheries of the Northeastern Pacific Ocean. Institute of Fisheries, University of British Columbia.

Bradburn, M., Keller, A., and Horness, B. 2011. The 2003 to 2008 US West Coast bottom trawl surveys of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, length, and age composition. US Department of Commerce, National Oceanic; Atmospheric Administration, National Marine Fisheries Service.

Center, A.F.S. 2016. Assessment of the Other Rockfish stock complex in the Gulf of Alaska. Available from https://www.afsc.noaa.gov/REFM/Docs/2016/GOAorock.pdf [accessed 18 June 2017].

Cope, J., Dick, E., MacCall, A., Monk, M., Soper, B., and Wetzel, C. 2013. Data-moderate stock assessments for brown, china, copper, sharpchin, stripetail, and yellowtail rockfishes and english and rex soles in 2013. National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Council, P.F.M. 2016. STATUS OF THE PACIFIC COAST GROUNDFISH FISHERY. Available from http://www.pcouncil.org/wp-content/uploads/2017/02/SAFE_Dec2016_02_28_2017.pdf [accessed 18 June 2017].

Dick, E., Beyer, S., Mangel, M., and Ralston, S. 2017. A meta-analysis of fecundity in rockfishes (genus sebastes). Fisheries Research **187**: 73–85. Elsevier.

Eldridge, M.B., Whipple, J.A., Bowers, M.J., Jarvis, B.M., and Gold, J. 1991. Reproductive performance of yellowtail rockfish, sebastes flavidus. Environmental biology of fishes **30**(1): 91–102. Springer.

Fournier, D.A., Skaug, H.J., Ancheta, J., Ianelli, J., Magnusson, A., Maunder, M.N., Nielsen, A., and Sibert, J. 2012. AD model builder: Using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software **27**(2): 233–249. Taylor & Francis.

Fraidenburg, M. 1980. YELLOWTAIL rockfish, sebastes-flavidus, length and age composition off california, oregon, and washington in 1977. MARINE FISHERIES REVIEW **42**(3-4): 54–56. NATL MARINE FISHERIES SERVICE SCIENTIFIC PUBL OFFICE 7600 SAND POINT WAY NE BIN C15700, SEATTLE, WA 98115.

Francis, R. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciencies **68**: 1124–1138.

Hamel, O.S. 2015. A method for calculating a meta-analytical prior for the natural mortality rate using multiple life history correlates. ICES Journal of Marine Science: Journal du

Conseil **72**(1): 62–69. doi: 10.1093/icesjms/fsu131.

Harry, G., and Morgan, A. 1961. History of the trawl fishery, 1884-1961. Oregon Fish Commission Research Briefs **19**: 5–26.

Hess, J., Vetter, R., and Moran, P. (n.d.). A steep genetic cline in yellowtail rockfish, {Sebastes flavidus, suggests regional isolation across the cape mendocino faunal break. Canadian Journal of Fisheries and Aquatic Sciences: 89–104.

Lai, H., Tagart, J., Ianelli, J., and Wallace, F. 2003. Status of the yellowtail rockfish resource in 2003. Status of the Pacific Coast groundfish fishery through.

Love, M., Yoklavich, M., and Thorsteinson, L. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley, CA, USA.

Love, M.S. 2011. Certainly more than you want to know about the fishes of the pacific coast: A postmodern experience. Really Big Press.

Marks, C.I., Fields, R.T., Starr, R.M., Field, J.C., Miller, R.R., Beyer, S.G., Sogard, S.M., Miller, R.R., Beyer, S.G., Wilson-Vandenberg, D., and others. 2015. Changes in size composition and relative abundance of fishes in central california after a decade of spatial fishing closures. CALIFORNIA COOPERATIVE OCEANIC FISHERIES INVESTIGATIONS REPORTS **56**: 119–132. SCRIPPS INST OCEANOGRAPHY A-003, LA JOLLA, CA 92093 USA.

McAllister, M.K., and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and the sampling - importance resampling algorithm. Canadian Journal of Fisheries and Aquatic Sciences **54**(2): 284–300.

Methot, R.D. 2015. User manual for Stock Synthesis model version 3.24s. NOAA Fisheries, US Department of Commerce.

Methot, R.D., Taylor, I.G., and Chen, Y. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. Canadian Journal of Fisheries and Aquatic Sciences **68**(10): 1744–1760. doi: 10.1139/f2011-092.

Pikitch, E., Erickson, D., and Wallace, J. 1988. An evaluation of the effectiveness of trip limits as a management tool. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, US Department of Commerce.

Rogers, J., and Pikitch, E. 1992. Numerical definition of groundfish assemblages caught off the coasts of Oregon and Washington using commercial fishing strategies. Canadian Journal of Fisheries and and Aquatic Sciences **49**: 2648–2656.

Stephens, A., and MacCall, A. 2004. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. Fisheries Research **70**: 299–310.

Tagart, J. 1982. Status of the yellowtail rockfish (sebastes flavidus) fishery. State of Washington, Department of Fisheries.

Tagart, J. 1991. Population dynamics of yellowtail rockfish (sebastes flavidus) stocks in the northem california to southwest vancouver island region. Ph. D_ thesis, University of Wash-ington, Seattle.

Tagart, J., Ianelli, J., Hoffman, A., and Wallace, F. 1997. Status of the yellowtail rockfish resource in 1997. Pacific Fishery Management Council, Portland, OR.

Tagart, J., Wallace, F., and Ianelli, J.N. 2000. Status of the yellowtail rockfish resource in 2000. Pacific Fishery Management Council.

Tagart, J.V. 1988. Status of the yellowtail rockfish stocks in the international north pacific fishery commission vancouver and columbia areas. Department of Fish; Wildlife.

Then, A.Y., Hoenig, J.M., Hall, N.G., and Hewitt, D.A. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science **72**(1): 82–92. doi: 10.1093/icesjms/fsu136.

Thorson, J.T., and Barnett, L.A.K. 2017. Comparing estimates of abundance trends and distribution shifts using single- and multispecies models of fishes and biogenic habitat. ICES Journal of Marine Science: Journal du Conseil: fsw193. doi: 10.1093/icesjms/fsw193.

Thorson, J.T., Shelton, A.O., Ward, E.J., and Skaug, H.J. 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES Journal of Marine Science **72**(5): 1297–1310. doi: 10.1093/icesjms/fsu243.

Wallace, J., and Lai, H.-L. 2005. Status of the Yellowtail Rockfish in 2004. *In* Human Biology. Pacific Fisheries Management Council, Portland, OR.