

¹ Status of Yellowtail Rockfish (*Sebastes*
² *flavidus*) Along the U.S. Pacific Coast in 2017



³ Jean DeMarignac (SIMoN / MBNMS), Public Domain

⁴ Andi Stephens¹
⁵ Ian G. Taylor²

⁶ ¹Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and
⁷ Atmospheric Administration, National Marine Fisheries Service, 2032 S.E. OSU Drive Newport,
⁸ Oregon 97365

⁹ ²Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and
¹⁰ Atmospheric Administration, National Marine Fisheries Service, 2725 Montlake Boulevard East,
¹¹ Seattle, Washington 98112

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18 *flavidus*) Along the U.S. Pacific Coast in 2017

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¹²⁵ **Executive Summary**

executive-summary

¹²⁶ **Stock**

stock

¹²⁷ This assessment reports the status of the Yellowtail Rockfish (*Sebastodes flavidus*) resource in
¹²⁸ U.S. waters off the coast of California, Oregon, and Washington using data through 2016.

¹²⁹ The Pacific Fishery Management Council (PFMC) manages the U.S. fishery as two stocks
¹³⁰ separated at Cape Mendocino, California ($40^{\circ} 10'N$). The northern stock has long been
¹³¹ assessed on its own; the southern stock is treated as part of the Southern Shelf Complex. This
¹³² assessment analyzes each stock independently, with the southern stock extending southward
¹³³ to the U.S./Mexico border and the northern stock extending northward to the U.S./Canada
¹³⁴ border.

¹³⁵ The most recent fully integrated assessment (Wallace and Lai [2005](#)), following the pattern of
¹³⁶ prior assessments, included only the Northern stock which it divided into three assessment
¹³⁷ areas with divisions at Cape Elizabeth ($47^{\circ} 20'N$) and Cape Falcon ($45^{\circ} 46'N$). A data-
¹³⁸ moderate assessment conducted in 2013 (Cope et al. [2013](#)) was the first to analyze the
¹³⁹ southern stock, determining its contribution to the overfishing limit (OFL) for the Southern
¹⁴⁰ Shelf Complex.

¹⁴¹ Since the 2005 assessment, reconstruction of historical catch by Washington and Oregon
¹⁴² makes any border but the state line (roughly 46° N) incompatible with the data from those
¹⁴³ states. Additionally, much of the groundfish catch landed in northern Oregon is caught in
¹⁴⁴ Washington waters.

¹⁴⁵ This assessment addresses the stock in two areas consistent with the management border
¹⁴⁶ at Cape Mendocino. This is consistent, as well, with a recent genetic analysis (Hess et al.
¹⁴⁷ n.d.) that found distinct stocks north and south of Cape Mendocino but did not find stock
¹⁴⁸ differences within the northern area.

¹⁴⁹ **Catches**

catches

¹⁵⁰ Catches from the Northern stock were divided into four categories: commercial catch, bycatch
¹⁵¹ in the at-sea hake fishery, recreational catch in Oregon and California (north of $40^{\circ} 10'N$),
¹⁵² and recreational catch in Washington. The first three of these fleets were entered in metric
¹⁵³ tons, but the recreational catch from Washington was entered in the model as numbers of fish
¹⁵⁴ with the average weight calculated internally in the model from the weight-length relationship
¹⁵⁵ and the length-compositions.

¹⁵⁶ Catches from the Southern stock were divided into two categories: commercial and recreational
¹⁵⁷ catch, both of which were entered as metric tons.

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

160 Catch figures: (Figures a-b)

161 Catch tables: (Tables a-b)

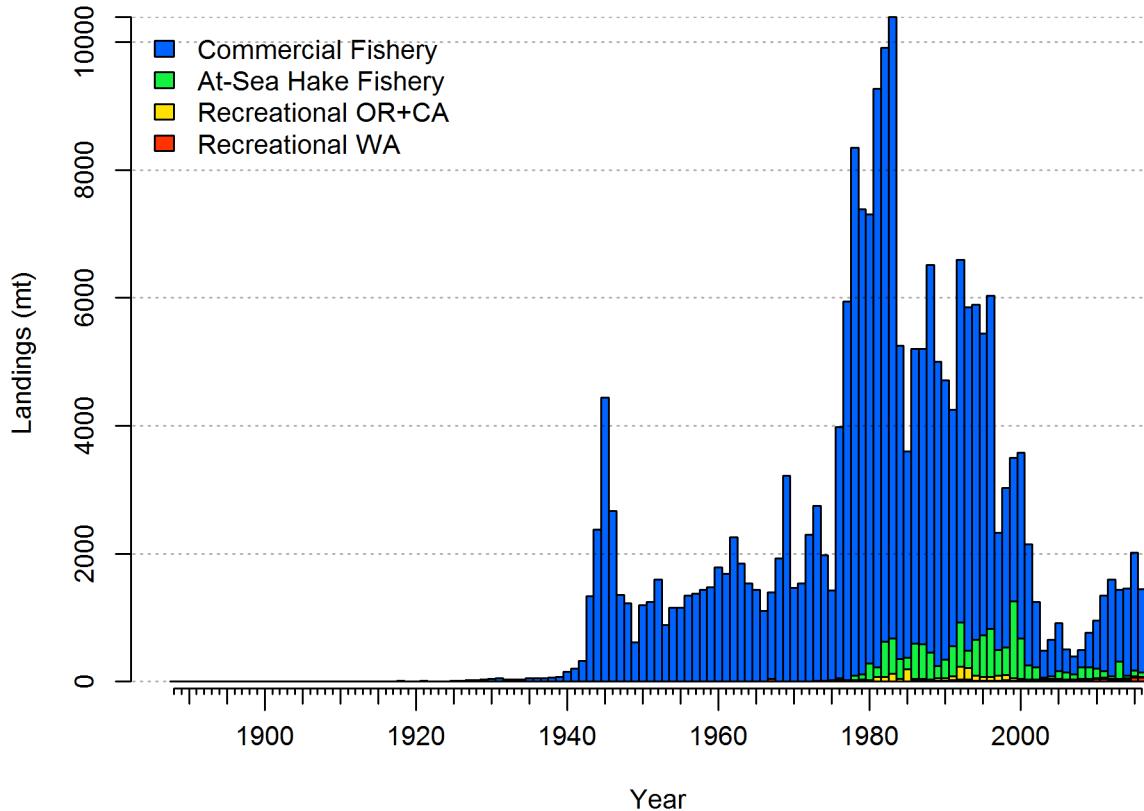


Figure a: Estimated catch history of Yellowtail Rockfish in the Northern model. Recreational catches in Washington are model estimates of total weight converted from input catch in numbers using model estimates of growth and selectivity.
fig:r4ss_catch_N

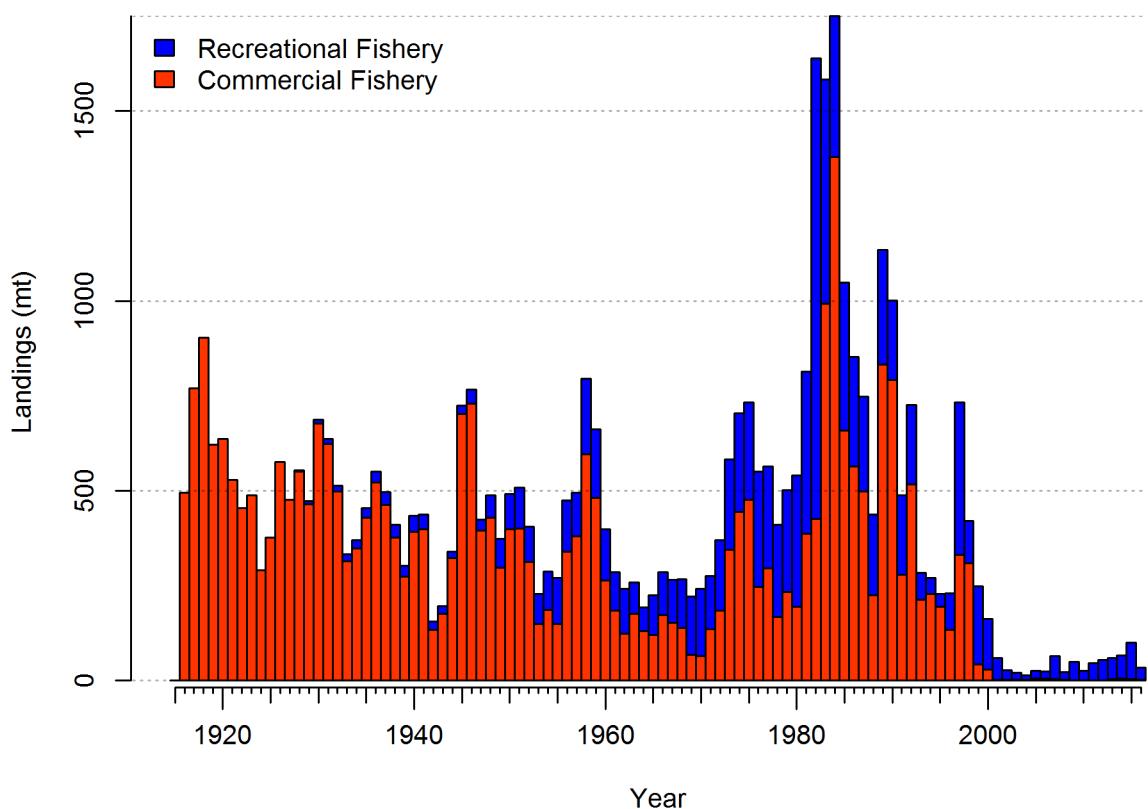


Figure b: Estimated catch history of Yellowtail Rockfish in the Southern model. [fig:r4ss_catch_S](#)

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

tab:Exec_catch_N

Year	Commercial (t)	At-sea hake bycatch (t)	Recreational OR+CA (t)	Recreational WA (1000s)
2007	-	-	-	-
2008	-	-	-	-
2009	-	-	-	-
2010	-	-	-	-
2011	-	-	-	-
2012	-	-	-	-
2013	-	-	-	-
2014	-	-	-	-
2015	-	-	-	-
2016	-	-	-	-

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

tab:Exec_catch_S

Year	Recreational (t)	Commercial (t)
2007	-	-
2008	-	-
2009	-	-
2010	-	-
2011	-	-
2012	-	-
2013	-	-
2014	-	-
2015	-	-
2016	-	-

162 Data and Assessment

data-and-assessment

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

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

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

171 Map of assessment region: (Figure c).

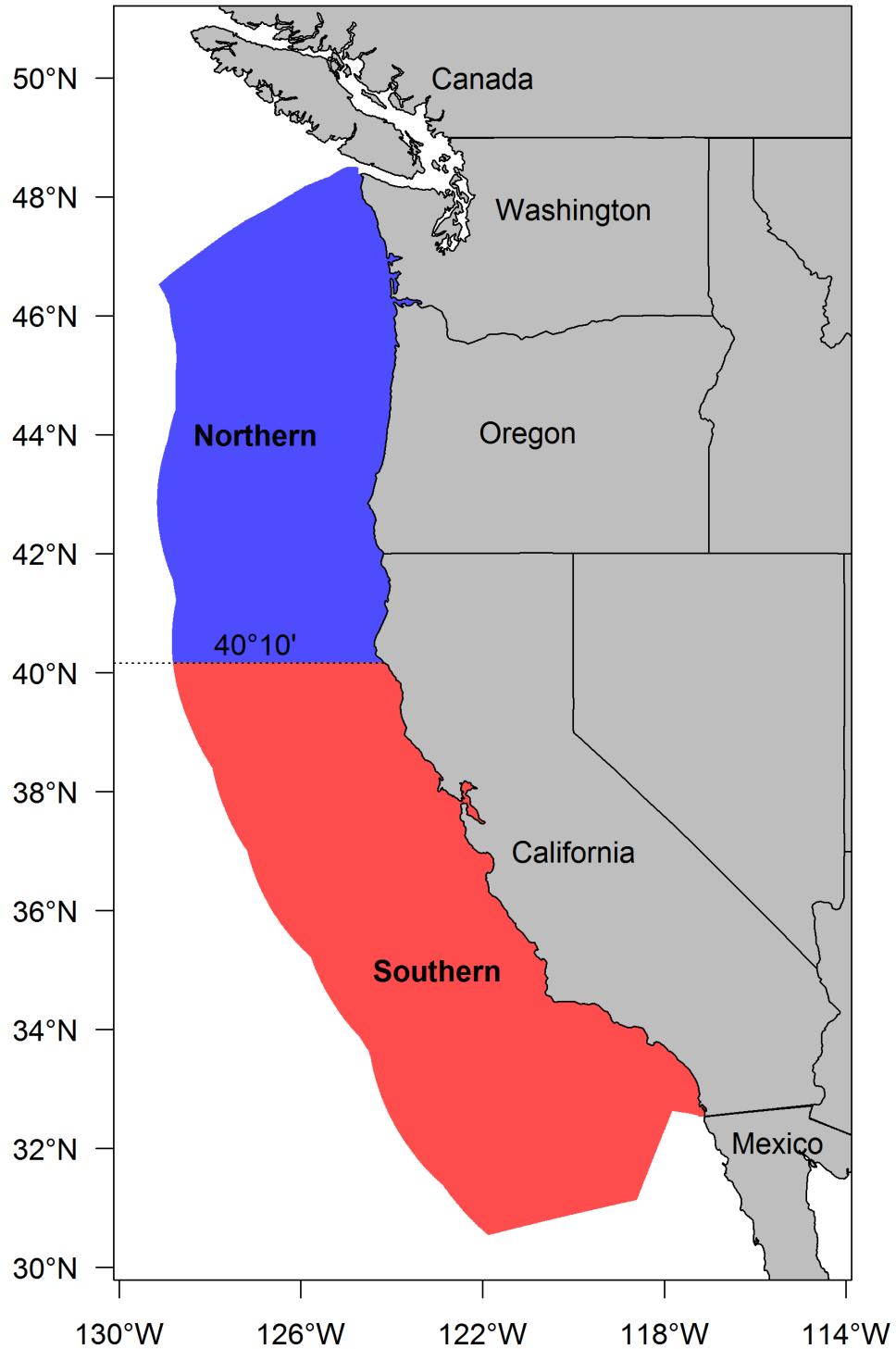


Figure c: Map depicting the boundaries for the base-case model. fig:assess_region_map_Ex

172 Stock Biomass

stock-biomass

173 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.

175 Spawning output Figure: Figure [d](#)

176 Spawning output Table(s): Table [c](#)

177 Relative depletion Figure: Figure [e](#)

178 Example text (remove Models 2 and 3 if not needed - if using, remove the # in-line comments!!!)

179 The estimated relative depletion level (spawning output relative to unfished spawning output)

180 of the the base-case model in 2016 is 56.7% (~95% asymptotic interval: ± 45.4%-68.1%)

181 (Figure [e](#)).

182 The estimated relative depletion level of model 2 in 2016 is 98% (~95% asymptotic interval:

183 ± 75.5%-120%) (Figure [e](#)).

184 The estimated relative depletion level of model 3 in 2016 is (~95% asymptotic interval: ±)
185 (Figure [e](#)).

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

Year	Spawning Output (trillion eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	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.

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)

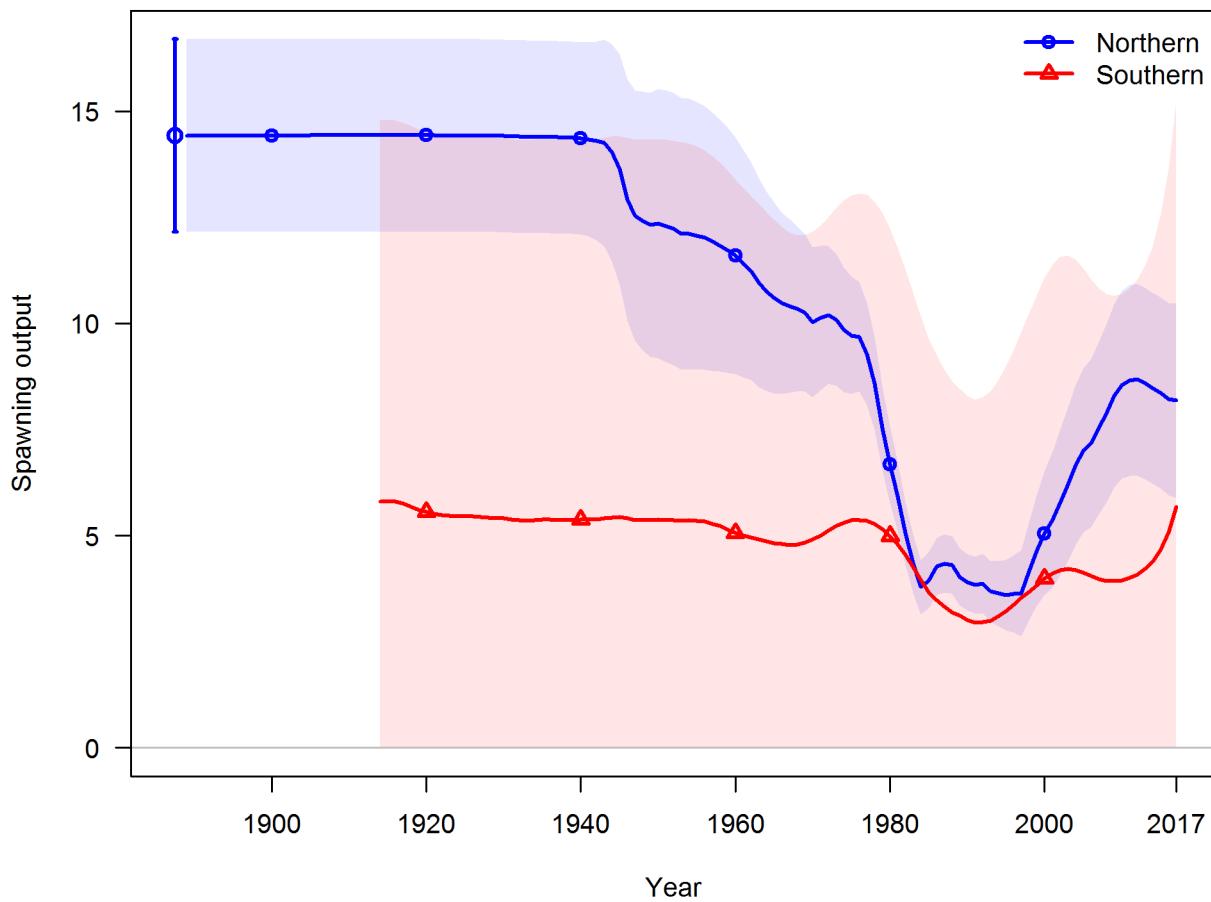


Figure d: Time series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model. [fig:Spawnbio_all](#)

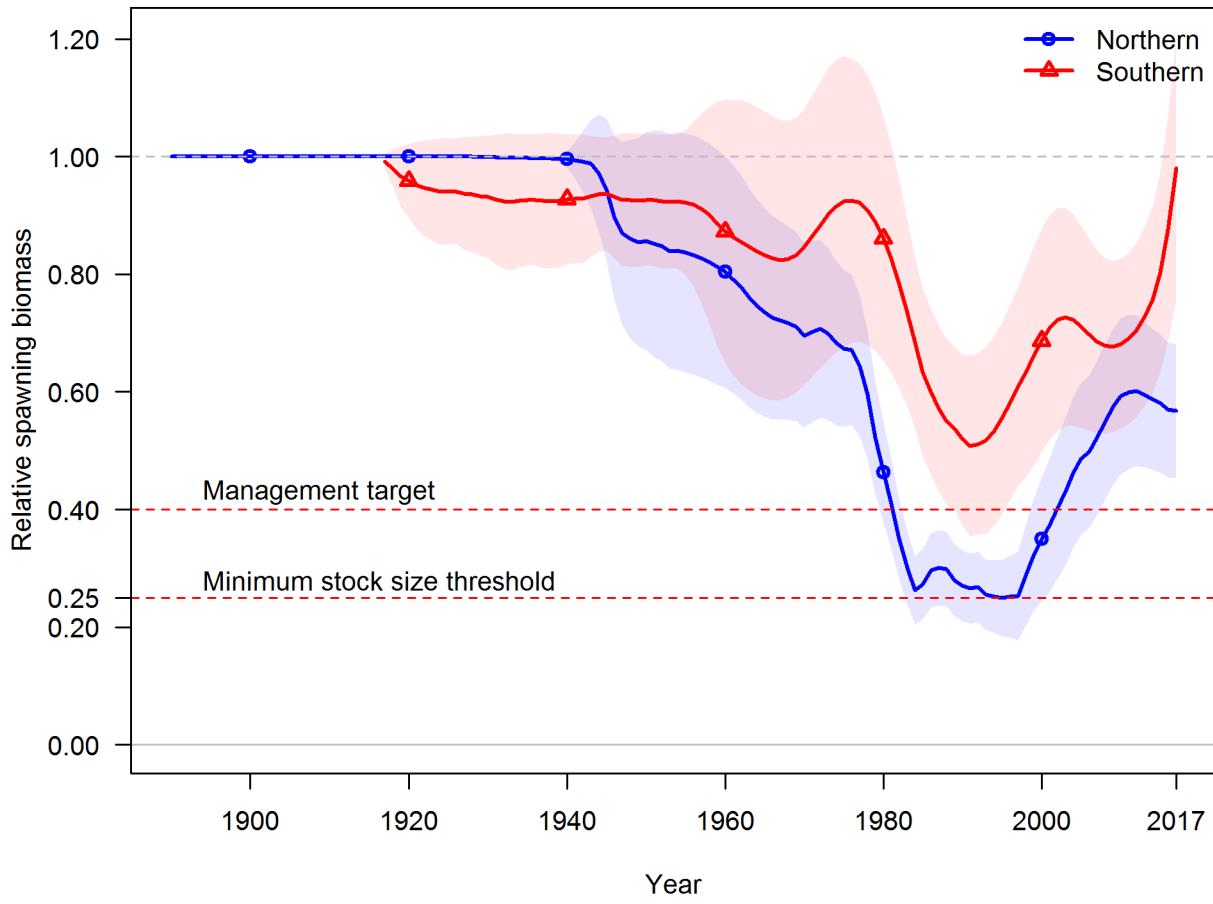


Figure e: Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. [fig:RelDeplete_all](#)

¹⁸⁶ **Recruitment**

recruitment

¹⁸⁷ Include: trends and current levels relative to virgin or historic levels-include table for last 10 years and graph with long term estimates.

¹⁸⁹ Recruitment Figure: (Figure f)

¹⁹⁰ Recruitment Tables: (Tables e, f and ??)

Table e: Recent recruitment for the Northern model.

Year	Estimated Recruitment (millions)	~ 95% confidence interval	tab:Recruit_mod1
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.

Year	Estimated Recruitment (millions)	~ 95% confidence interval	tab:Recruit_mod2
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)	

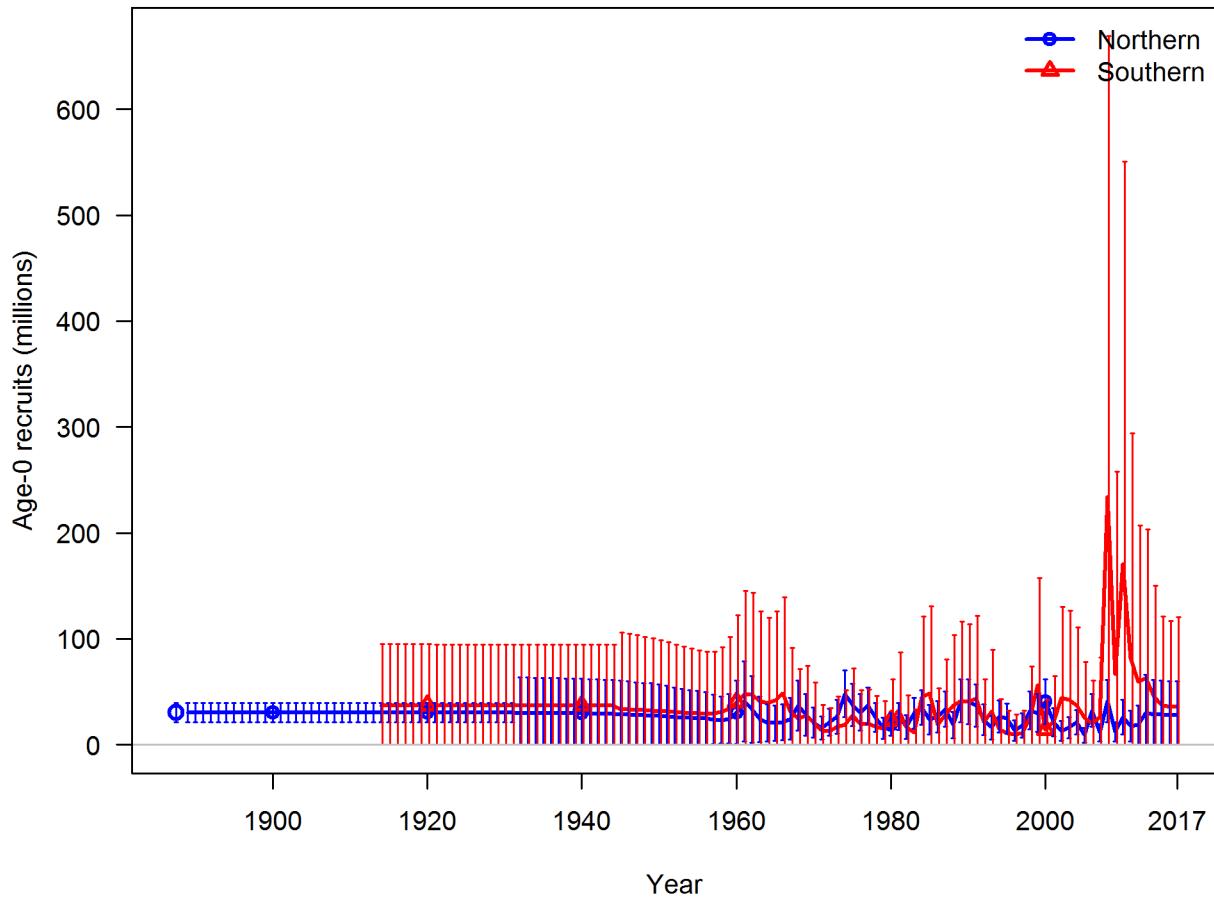


Figure f: Time series of estimated Yellowtail Rockfish recruitments for the base-case model with 95% confidence or credibility intervals. | [fig:Recruits_all](#)

191 **Exploitation status**

exploitation-status

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

196 Exploitation Tables: Table [g](#), Table [h](#), Table ?? Exploitation Figure: Figure [g](#)).

197 A summary of Yellowtail Rockfish exploitation histories for base model is provided as Figure
198 [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} .

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} .

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval	tab:SPR_Exploit_mod2
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)	

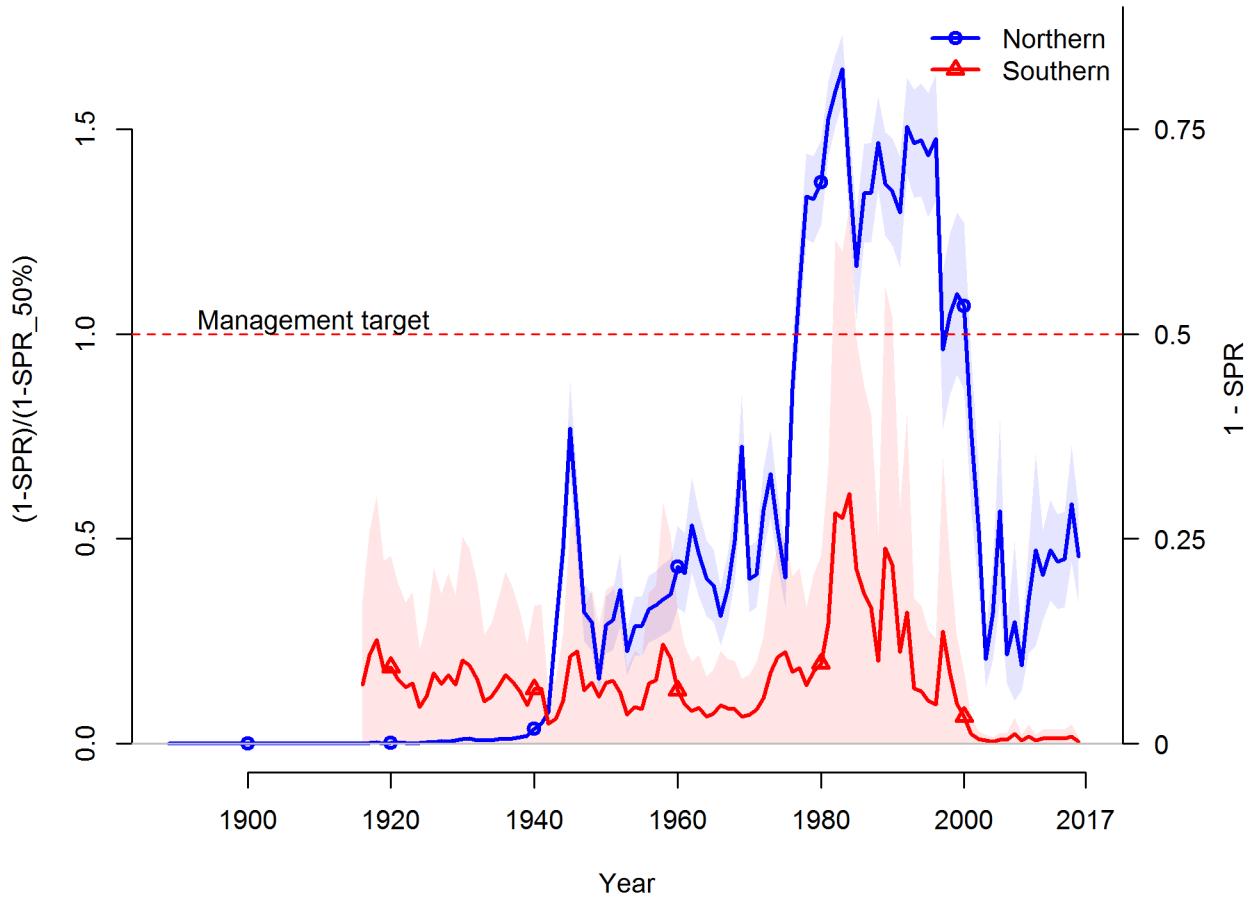


Figure g: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

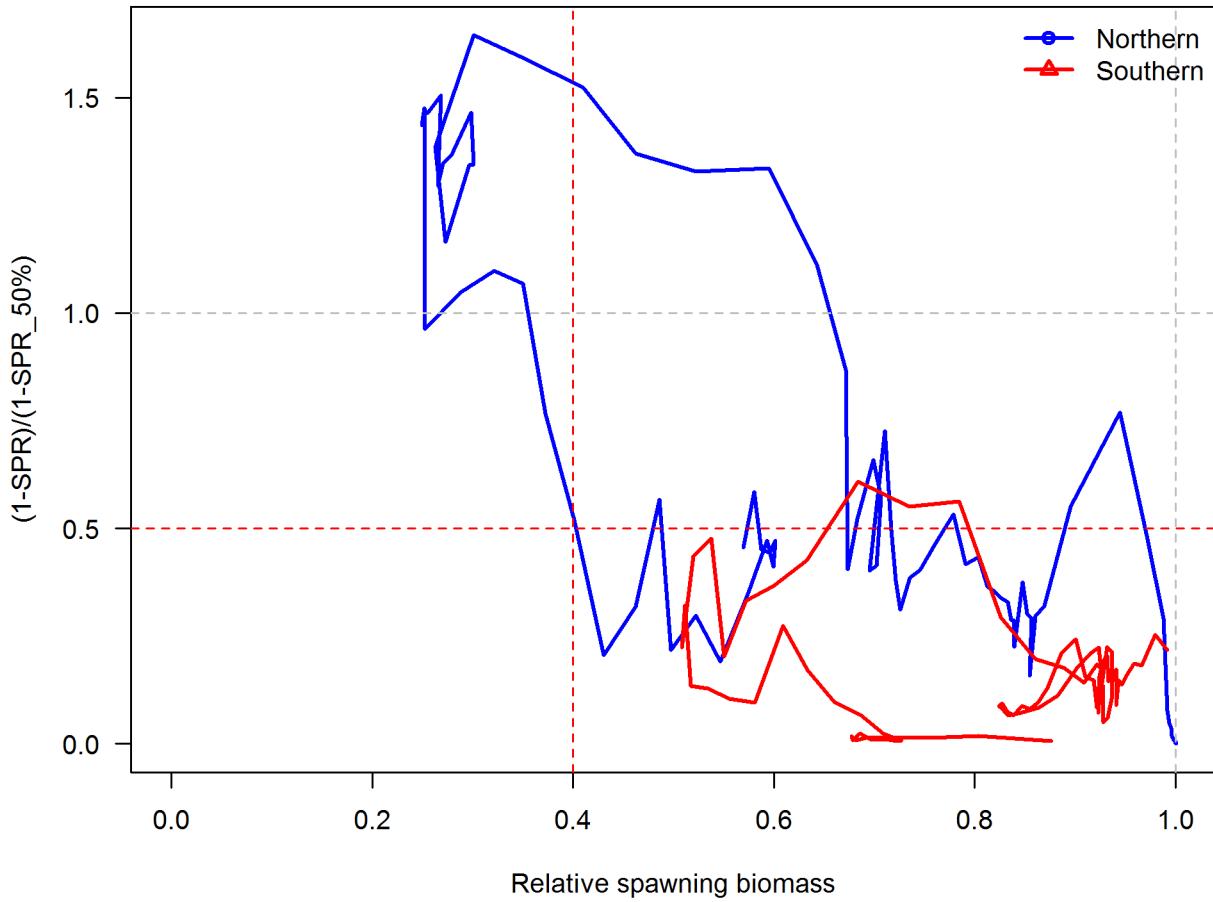


Figure h: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the unfished spawning biomass. | [fig:Phase_all](#)

199 **Ecosystem Considerations**

ecosystem-considerations

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

201 **Reference Points**

reference-points

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

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

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

217 This stock assessment estimates that Yellowtail Rockfish in the Southern model are above
218 the biomass target, but above the minimum stock size threshold. Add sentence about
219 spawning output trend. The estimated relative depletion level for Model 2 in 2016 is 98%
220 (~95% asymptotic interval: $\pm 75.5\%-120\%$), corresponding to an unfished spawning output
221 of 5.68452 trillion eggs (~95% asymptotic interval:) of spawning output in the base model
222 (Table j). Unfished age 4+ biomass was estimated to be 117.6 mt in the base case model. The
223 target spawning output based on the biomass target ($SB_{40\%}$) is 2.3 trillion eggs, which gives
224 a catch of mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$
225 is 3136.4 mt.

226 This stock assessment estimates that Yellowtail Rockfish in the are

227 the biomass target, but
228 the minimum stock size threshold. Add sentence about spawning output trend. The estimated
229 relative depletion level or Model 3 in 2016 is (~95% asymptotic interval: \pm), corresponding
230 to an unfished spawning output of (~95% asymptotic interval:) of spawning output in the
231 base model (Table ??). Unfished age 4+ biomass was estimated to be mt in the base case
232 model. The target spawning output based on the biomass target ($SB_{40\%}$) is , which gives a
233 catch of mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is
234 mt.

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

Quantity	Estimate	<small>tab:Ref_pts_mod1</small> 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 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.

Quantity	Estimate	<small>tab:Ref_pts_mod2</small>	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 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)

²³⁵ **Management Performance**

management-performance

²³⁶ **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.

²³⁹ 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.

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	-	-	-	-

²⁴⁰ **Unresolved Problems And Major Uncertainties**

unresolved-problems-and-major-uncertainties

²⁴¹ TBD after STAR panel

²⁴² **Decision Table(s) (groundfish only)**

decision-tables-groundfish-only

²⁴³ **Include:** projected yields (OFL, ABC and ACL), spawning biomass, and stock depletion levels for each year. Not required in draft assessments undergoing review.

²⁴⁵ OFL projection table: Table [l](#)

²⁴⁶ Decision table(s) Table [m](#), Table [n](#), Table ??

²⁴⁷ Yield curve: Figure \ref{fig:Yield_all}

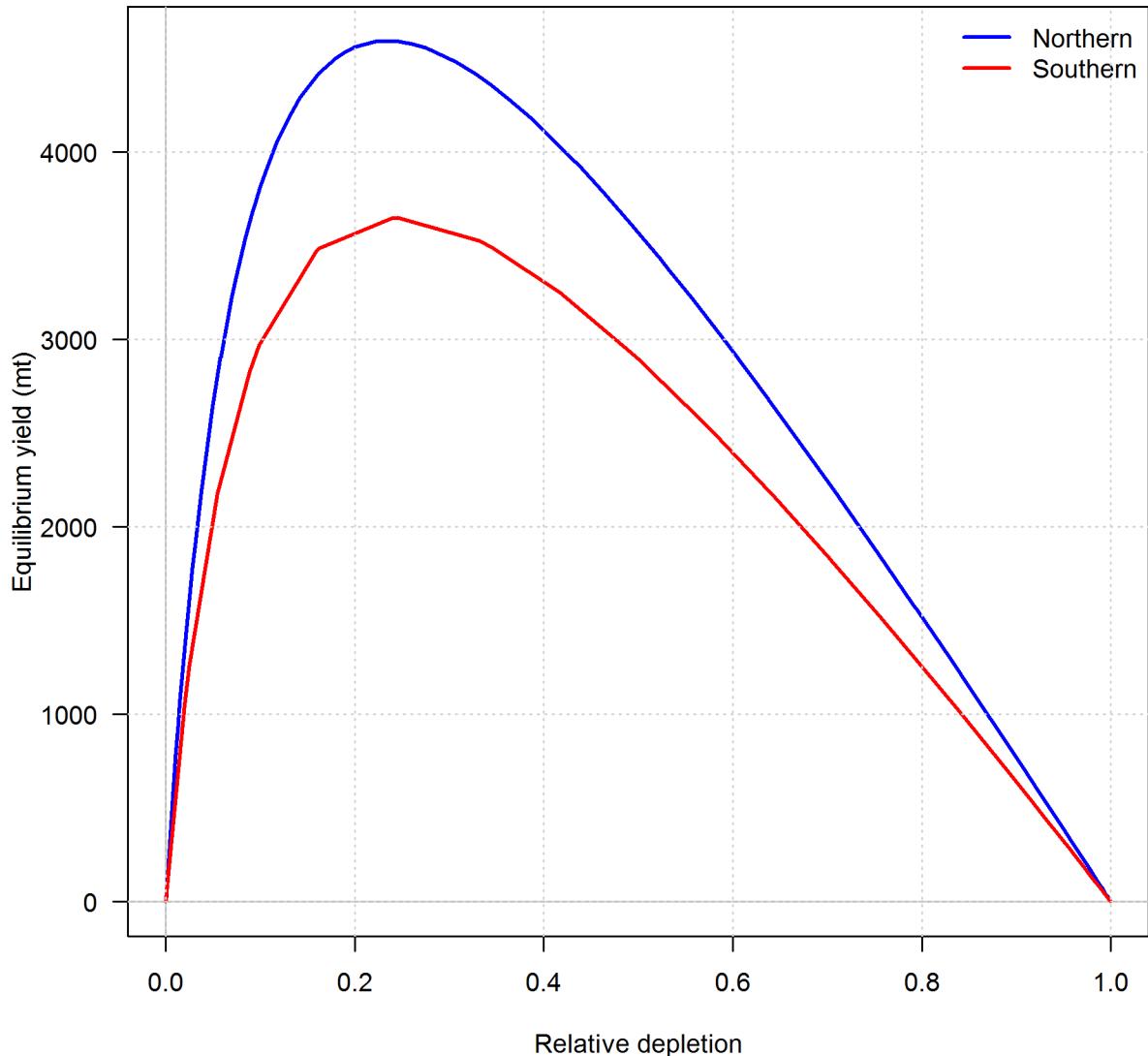


Figure i: Equilibrium yield curve for the base case models.^{fig:Yield_all}

Table 1: 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

	Year	Catch	Low M 0.05		Base M 0.07		High M 0.09	
			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 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.

		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
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.

Model Region	Quantity	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		
		Total Est.	Catch (mt)	Landings (mt)		OFL (mt)		OCL (mt)														
Model 1 (1-SPR)(1-SPR_{50%})																						
Base Case	Exploitation rate	0.19	0.35	0.47	0.41	0.47	0.44	0.45	0.44	0.47	0.44	0.45	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	
Age 4+ biomass (mt)	84.43	84.93	83.80	84.55	82.56	84.38	83.12	83.43	82.79	83.12	83.43	82.79	82.79	82.79	82.79	82.79	82.79	82.79	82.79	82.79	81.56	
Spawning Output	7.9	8.3	8.6	8.7	8.7	8.6	8.5	8.4	8.5	8.6	8.5	8.4	8.2	8.2	8.2	8.2	8.2	8.2	8.2	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)	(6.23-10.73)	(6.13-10.62)	(5.96-10.48)	(5.96-10.48)	(5.96-10.48)	(5.96-10.48)	(5.96-10.48)	(5.96-10.48)	(5.96-10.48)	(5.96-10.48)	(5.96-10.48)	(5.96-10.48)	
Depletion	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	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)	(0.464-0.697)	(0.468-0.708)	(0.464-0.697)	(0.464-0.697)	(0.455-0.684)	(0.455-0.684)	(0.454-0.684)	(0.454-0.684)	(0.454-0.684)	(0.454-0.684)	(0.454-0.684)	(0.454-0.684)	(0.454-0.684)	(0.454-0.684)
Recruits	41.17	12.42	26.22	17.76	18.73	30.71	28.43	28.52	28.52	28.43	28.52	28.52	28.31	28.31	28.31	28.31	28.31	28.31	28.31	28.31	28.31	
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)	(10.06 - 80.85)	(9.78 - 82.61)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)	(10.06 - 80.85)
Model 2 (1-SPR)(1-SPR_{50%})																						
Base Case	Exploitation rate	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Age 4+ biomass (mt)	76.70	79.02	79.53	78.85	78.88	112.66	122.55	148.50	160.74	148.50	148.50	148.50	148.50	148.50	148.50	148.50	148.50	148.50	148.50	148.50	167.87	
Spawning Output	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
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)	(0-12.52)	(0-12.52)	(0-12.52)	(0-12.52)	(0-12.52)	(0-12.52)	(0-12.52)	(0-12.52)	(0-12.52)	(0-12.52)	(0-12.52)	6	
Depletion	0.68	0.68	0.68	0.69	0.70	0.73	0.76	0.80	0.88	0.73	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	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)	(0.598-0.913)	(0.598-0.913)	(0.633-0.974)	(0.685-1.068)	(0.685-1.068)	(0.685-1.068)	(0.685-1.068)	(0.685-1.068)	(0.685-1.068)	(0.685-1.068)	(0.685-1.068)	(0.685-1.068)	
Recruits	234.32	66.93	170.66	81.72	59.53	62.96	46.19	37.77	35.70	46.19	37.77	35.70	35.70	35.70	35.70	35.70	35.70	35.70	35.70	35.70	36.73	
95% CI	(48.85 - 1124.05)	(8.28 - 541.34)	(11.33 - 1017.09)	(8.75 - 589.32)	(8.75 - 404.76)	(10.56 - 375.27)	(7.64 - 279.12)	(6.4 - 222.96)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	(5.83 - 218.81)	

²⁴⁸ **Research And Data Needs**

research-and-data-needs

²⁴⁹ Include: identify information gaps that seriously impede the stock assessment.

²⁵⁰ We recommend the following research be conducted before the next assessment:

²⁵¹ 1. List item No. 1 in the list

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

²⁵³ **Rebuilding Projections**

rebuilding-projections

²⁵⁴ Include: reference to the principal results from rebuilding analysis if the stock is overfished.

²⁵⁵ This section should be included in the Final/SAFE version assessment document but is not

²⁵⁶ required for draft assessments undergoing review. See Rebuilding Analysis terms of reference

²⁵⁷ for detailed information on rebuilding analysis requirements.

258 **1 Introduction**

introduction

259 **1.1 Basic Information**

basic-information

260 Yellowtail rockfish, *Sebastodes flavidus*, occur off the West Coast of the United States from
261 Baja California to the Aleutian Islands. Yellowtail is a major commercial species, captured
262 mostly in trawls from Central California to British Columbia (Love 2011). Because it is
263 an aggregating, midwater species it is usually caught between 60 and 120 fathoms in the
264 commercial midwater trawl fishery. In California there is a large recreational fishery as
265 well. The center of yellowtail rockfish abundance is from southern Oregon through British
266 Columbia (Fraidenburg 1980).

267 Once thought to comprise a single stock, a recent genetic study has shown that there are
268 in fact two sub-species, with a genetic cline at Cape Mendocino, California, roughly 40°10'
269 North Latitude (Hess et al. n.d.). The species has never had a full length and age integrated
270 assessment south of Cape Mendocino, mainly due to a lack of fishery-independent data; this
271 assessment represents the first attempt to do so.

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

276 **1.2 Map**

map

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

279 **1.3 Life History**

life-history

280 Rockfish are in general long-lived and slow-growing, however yellowtail rockfish have a
281 high growth rate relative to other rockfish species, reaching a maximum size of about 55
282 cm in approximately 15 years (Tagart 1991). Yellowtail can live at least 64 years (Love
283 2011). Yellowtail rockfish are among those that are fertilized internally and release live
284 young. Spawning aggregations occur in the fall, and parturition in the winter and spring
285 (January-May) (Eldridge et al. 1991). Young-of-the-year recruit to nearshore waters from
286 April through August, migrating to deeper water in the fall. Preferred habitat is the midwater
287 over reefs and boulder fields.

288 Yellowtail rockfish are extremely motile, and make rapid and frequent ascents and descents of
289 40 meters; they also exhibit strong homing tendencies (Love 2011). They are able to quickly
290 release gas from their swim bladders, perhaps making them less susceptible to barotrauma
291 than similar species (Eldridge et al. 1991).

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

295 1.4 Fishery and Management History

fishery-and-management-history

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

301 Until late 2002, yellowtail rockfish were harvested as part of a directed mid-water trawl
302 fishery, with fairly high landings in the 1980s and 1990s. Yellowtail commonly co-occur
303 with canary, widow rockfish and several other rockfishes (Tagart 1988); (Rogers and Pikitch
304 1992). Association with these and other rockfish species has substantially altered fishing
305 opportunity for yellowtail rockfish since canary rockfish stocks were declared overfished by
306 National Marine Fisheries service in 2000. In order to achieve the necessary reduction in
307 the canary rockfish catch, stringent management measures were adopted, limiting harvest of
308 yellowtail rockfish as well as other co-occurring species.

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

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

³²⁴ Yellowtail rockfish are currently managed with stock-specific harvest specifications north of
³²⁵ 40°10' N. latitude, and as part of the Southern Shelf Rockfish complex south of 40°10' N.
³²⁶ latitude. The Over Fishing Limit (OFL) contribution of yellowtail rockfish to the Southern
³²⁷ Shelf Rockfish complex is based on a data-moderate analysis (Cope et al. 2013).

³²⁸ 1.5 Assessment History

`assessment-history`

³²⁹ Early studies of yellowtail stocks on the U.S. West Coast north of 40°10' N. latitude (Cape
³³⁰ Mendocino, northern California) began in the 1980s with observational surveys. Statistical
³³¹ assessments of yellowtail rockfish were conducted in 1982 (Tagart 1982), 1988 (Tagart 1988),
³³² 1996 (Tagart et al. 1997), and 1997 (Tagart et al. 1997) to determine harvest specifications
³³³ for the stock. These early assessments employed a variety of statistical methods, for example,
³³⁴ the 1997 assessment used cohort analysis and dynamic pool modeling.

³³⁵ The yellowtail assessment in 2000 (Tagart et al. 2000) was the first that estimated stock
³³⁶ status, with an estimated depletion of 60.5 percent at the start of 2000. Lai et al. (Lai et al.
³³⁷ 2003) updated the 2000 assessment and estimated that stock depletion was 46 percent at the
³³⁸ start of 2003. A second assessment update was prepared in 2005 (Wallace and Lai 2005) with
³³⁹ an estimated depletion of 55 percent at the start of 2005. The 2000 assessment and updates
³⁴⁰ were age-structured assessments conducted using AD Model Builder as the software platform
³⁴¹ for nonlinear optimization (Fournier et al. 2012).

³⁴² A data-moderate assessment of yellowtail rockfish south of 40°10' N. latitude was conducted
³⁴³ in 2013 (Cope et al. 2013). This assessment estimated depletion at the start of 2013 at 67
³⁴⁴ percent, and estimated the spawning biomass at 50,043 mt. This was a large biomass increase
³⁴⁵ relative to previous estimates and may be attributed to the low removals over the previous
³⁴⁶ decade.

³⁴⁷ \hl{Include: Management performance tables comparing Overfishing Limit (OFL), Annual
³⁴⁸ Catch Limit (ACL), Harvest Guideline (HG) [CPS only], landings, and catch (i.e., landings
³⁴⁹ plus discard) for each area and year. Management performance table: (Table k)
³⁵⁰ A summary of these values as well as other base case summary results can be found in Table
³⁵¹ o.

³⁵² 1.6 Fisheries off Canada, Alaska, and/or Mexico

`fisheries-off-canada-alaska-and-or-mexico`

³⁵³ The 2015 Stock Assessment conducted by the Department of Fisheries and Oceans (DFO)
³⁵⁴ found the stock to be at 0.49B0, in the “healthy” range.

³⁵⁵ The Alaska Fisheries Science Center assesses yellowtail rockfish as one of 25 species in the
³⁵⁶ “Other Rockfish” complex in the Gulf of Alaska. The 2015 full assessment of this complex

³⁵⁷ found no evidence of overfishing, which is confirmed in the 2016 SAFE document(Center
³⁵⁸ 2016).

³⁵⁹ Limited catches yellowtail are reported as far south as Baja California(Love 2011).

360 **2 Data**

data

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

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

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

374 A description of each model's data sources follows.

375 **2.1 Northern Model Data**

northern-model-data

Summary of the data sources in the Northern model.

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

³⁷⁶ **2.1.1 Commercial Fishery Landings**

commercial-fishery-landings

³⁷⁷ **Washington and Oregon Landings** The bulk of the commercial landings for Washington
³⁷⁸ and Oregon came from the Pacific Fisheries Information Network (**PacFIN**)
³⁷⁹ database.

³⁸⁰ **Washington Catch Information**

³⁸¹ The Washington Department of Fisheries and Wildlife (**WDFW**) provided historical yellow-
³⁸² tail catch for 1889–1980. Landings for 1981-2016 came from the PacFIN database. WDFW
³⁸³ also provided catches for the period 1981 – 2016 to include the re-distribution of the un-
³⁸⁴ speciated “URCK” landings in PacFIN; this information is currently not available from
³⁸⁵ PacFIN.

³⁸⁶ **Oregon Catch Information**

³⁸⁷ The Oregon Department of Fisheries and Wildlife (**ODFW**) provided historical yellowtail
³⁸⁸ catch from 1892-1985. ODFW also provided estimates of yellowtail rockfish in the in the
³⁸⁹ un-speciated PacFIN “URCK” and “POP1” catch categories for recent years, and those
³⁹⁰ estimates were combined with PacFIN landings for 1986-2016.

³⁹¹ **Northern California Catch**

³⁹² The California Commercial Fishery Database (**CalCOM**) provided landings for the Northern
³⁹³ model for the two counties north of 40°10' (Eureka and Del Norte) for 1969-2016.

³⁹⁴ **Hake Bycatch**

³⁹⁵ The Alaska Fisheries Science Center (**AFSC**) provided data for yellowtail bycatch in the
³⁹⁶ hake fishery from 1976-2016.

³⁹⁷ **2.1.2 Sport Fishery Removals**

sport-fishery-removals

³⁹⁸ **Washington Sport Catch**

³⁹⁹ WDFW provided recreational catches for 1967 and 1975-2016.

⁴⁰⁰ **Oregon Sport Catch**

⁴⁰¹ ODFW provided recreational catch data for 1979-2016.

⁴⁰² **MRFSS and RecFIN** Data from Northern California came from the Marine Recreational
⁴⁰³ Fisheries Statistical Survey (**MRFSS**) and from the Recreational Fisheries Information
⁴⁰⁴ Network (**RecFIN**). These are dockside surveys focused on California and Oregon. MRFSS
⁴⁰⁵ was conducted from 1980-1989 and 1993-2003, RecFIN from 2004 to the present.

406 **2.1.3 Estimated Discards**

estimated-discards

407 **Commercial Discards**

408 The West Coast Groundfish Observing Program (**WCGOP**) is an onboard observer program
409 that has extensively surveyed fishing practices since 2002, with nearly 100% observer coverage
410 in the trawl sector in recent years. WCGOP provided discard ratios for yellowtail rockfish
411 from 2002 to 2015.

412 **Pikitch Study**

413 The Pikitch study was conducted between 1985 and 1987 (Pikitch et al. [1988](#)). The northern
414 and southern boundaries of the study were 48°42' N latitude and 42°60' N. latitude respectively,
415 which is primarily within the Columbia INPFC area (Pikitch et al. [1988](#), Rogers and Pikitch
416 [1992](#)).

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

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

423 **2.1.4 Abundance Indices**

abundance-indices

424 **Commercial Logbook CPUE**

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

428 The data were modeled with a modified Stephens-MacCall approach (Stephens and MacCall
429 [2004](#)). This approach uses the species composition of the catch to evaluate the per-haul
430 probability of encountering a particular species; in this case, yellowtail rockfish. The intent
431 of the analysis is to eliminate all hauls from the index that could not encounter yellowtail.

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

436 The hauls identified with a reasonable probability of encountering yellowtail were then
437 modeled in a delta-lognormal glm to produce an annual index of abundance, bootstrapped
438 500 times to evaluate uncertainty.

439 **Hake Bycatch Index**

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

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

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

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

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

473 **2.1.5 Fishery-Independent Data**

fishery-independent-data

474 **Northwest Fisheries Science Center (NWFSC) shelf-slope survey**

475 This survey, referred to as the **NWFSCcombo Survey**, has been conducted annually
476 starting in 2003. It uses a random-grid design covering the coastal waters from a depth
477 of 55 m to 1,280 m from late-May to early-October (add reference: Bradburn 2011). Four
478 chartered industry vessels are used each year (with the exception of 2013 when the U.S.
479 federal government shutdown curtailed the survey).

480 The data from the NWFSCcombo survey was analyzed using a spatio-temporal delta-model
481 (add reference: Thorson2015), implemented as an R package VAST (add reference: Thor-
482 son2017) and publicly available online (<https://github.com/James-Thorson/VAST>). Spatial
483 and spatio-temporal variation is specifically included in both encounter probability and
484 positive catch rates, a logit-link for encounter probability, and a log-link for positive catch
485 rates. Vessel-year effects were included for each unique combination of vessel and year in the
486 database.

487 Both lognormal and gamma distributions were explored for the positive tows and produced
488 similar results with the lognormal model showing better patterns in Q-Q plot. The index
489 shows variability with an overall gradual increase from 2003 to 2013 with high estimates near
490 the end of the time series in 2014 and 2016. A design-based index extrapolated from swept
491 area densities without any geostatistical standardization shows a more dramatic increase
492 from 2015 to 2016.

493 Length and age compositions were also developed from this survey.

494 **Alaska Fisheries Science Center (AFSC) Triennial shelf survey**

495 The **Triennial Survey** was conducted by the AFSC every third year between 1977 and 2001,
496 (and was conducted in 2004 by the NWFSC using the same protocols). The 1977 survey
497 had incomplete coverage and is not believed to be comparable to the later years. The survey
498 design used equally-spaced transects from which searches for tows in a specific depth range
499 were initiated. The depth range and latitudinal range was not consistent across years, but
500 all years in the period 1980-2004 included the area from 40° 10'N north to the Canadian
501 border and a depth range that included 55-366 meters, which spans the range where the vast
502 majority of Yellowtail encountered in all trawl surveys. Therefore the index was based on
503 this depth range.

504 An index of abundance was estimated based on the VAST delta-GLMM model as described
505 for the NWFSCcombo Index above. In this case as well, Q-Q plots indicated slightly better
506 performance of the lognormal over gamma models for positive tows. The index shows a
507 gradual decline from 1980 to 1992 followed by high variability in the final 4 points spanning
508 1995-2004.

509 **2.1.6 Biological Samples**

biological-samples

510 **Length And Age Compositions**

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

514 Length compositions were provided from the following sources:

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

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

515 Age structure data were available from the following sources:

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

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

516 **2.2 Southern Model Data**

southern-model-data

Summary of the data source in the Southern model.

Source	Landings	Lengths	Ages	Indices	Discard	tab:Data_sources
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

517 **2.2.1 Commercial Fishery Landings**

commercial-fishery-landings-1

518 **California Commercial Landings**

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

521 **Historical Data** A reconstruction of the historical commercial fishery south of Cape Men-
522 docino was provided by the Southwest Fisheries Science Center (**SWFSC**) for 1916-1968.

523 **2.2.2 Sport Fishery Removals**

sport-fishery-removals-1

524 **MRFSS Estimates and RecFIN**

525 The California Department of Fish and Wildlife (**CDFW**) provided estimated yellowtail
526 removals for the Marine Recreational Fisheries Statistical Survey (**MRFSS**) from 1980-1989,
527 1993-2003. The Recreational FIsheries Information Network, (**RecFIN**) provided landings
528 for 2004-2016.

529 **Historical Data** A reconstruction of the historical recreational fishery south of Cape
530 Mendocino was provided by the Southwest Fisheries Science Center (**SWFSC**) for 1928-1980.

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

533 **2.2.3 Estimated Discards**

estimated-discards-1

534 No discard data were available for the Southern model.

535 **2.2.4 Abundance Indices**

abundance-indices-1

536 **MRFSS Index**

537 An index of abundance was developed from trip-aggregated MRFSS data for the years
538 1980-1989, 1992-2003.

539 **California Onboard Survey**

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

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

544 **2.2.5 Fishery-Independent Data**

fishery-independent-data-1

545 **Hook and Line Survey**

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

548 **2.2.6 Biological Samples**

biological-samples-1

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

551 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

552 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

553 **2.3 Biological Parameters Common to Both Models**

biological-parameters-common-to-both-models

554 **Aging Precision And Bias**

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

562 **Weight-Length**

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

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

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

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

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

583 **Maturity And Fecundity** Maturity was estimated from histological analysis of

584 141 samples collected in 2016. These include 96 from the NWFSC Combo survey, 25 from
585 mid-water catches in the NWFSC acoustic/trawl survey, 13 from the Hook and Line survey,

586 and 7 from Oregon Department of Fish and Wildlife. The sample sizes were not adequate to
587 estimate differences in maturity by area. Length at 50% maturity was estimated at 42.49cm
588 (Figure ??) which was consistent with the range 37-45cm cited in the previous assessment
589 (Wallace and Lai 2005).

590 **Natural Mortality**

591 Natural mortality estimates were provided by Owen Hamel (pers. comm.).

592 **Sex ratios**

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

595 **2.3.1 Environmental Or Ecosystem Data Included In The Assessment**
environmental-or-ecosystem-data-included-in-the-assessment

596 No environmental index is present in either model.

597 **3 Assessment**

assessment

598 **3.1 History Of Modeling Approaches Used For This Stock**

history-of-modeling-approaches-used-for-this-stock

599 Yellowtail rockfish was previously modeled as a age-structured, 3-area stock north of 40°10'
600 in 1999 (Tagart et al. 2000) using a model written in ADMB (Fournier et al. 2012); an update
601 of this assessment was last conducted in 2004 (Wallace and Lai 2005). That assessment
602 divided the stock into 3 INPFC areas which are not coincident with state boundaries; this is
603 a concern in that recent reconstructions of historical catch are state-by-state along the West
604 Coast. Because we cannot produce data that conform to the areas previously assessed, we
605 have made no effort to reproduce the previous model.

606 A data-moderate approach was used to evaluate stock status in 2013 (Cope et al. 2013).
607 This approach is not compatible with the current model, and we have made no attempt to
608 reproduce it.

609 **3.1.1 Previous Assessment Recommendations**

previous-assessment-recommendations

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

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

616 **3.2 Model Description**

model-description

617 **3.2.1 Transition To The Current Stock Assessment**

transition-to-the-current-stock-assessment

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

- 619 1. Transition to Stock Synthesis. *Rationale*: The Pacific Fishery Management Council's
620 preferred modeling platform for stock assessments is Stock Synthesis (Methot 2015),
621 developed since the last full assessment of yellowtail rockfish.
- 622 2. Addition of Southern model. *Rationale*: Hess, et al. determined that the West Coast
623 yellowtail stocks show a genetic cline occurring near Cape Mendocino, which is roughly
624 40°10' north latitude (Hess et al. n.d.). This divides the stock into two genetically
625 distinct substocks which we model independently.
- 626 3. Availability of recent data. *Rationale*: Ten years of data collection have occurred since
627 the last update assessment, and the data necessary for an assessment of the Southern
628 stock is now available.
- 629 4. Historical catch reconstructions. *Rationale*: Reconstruction of catch timeseries in
630 California, Washington and Oregon clarify stock history as far back as 1889.

631 **3.2.2 Definition of Fleets and Areas**

definition-of-fleets-and-areas

632 The Northern model comprises the area between Cape Mendocino, California, and the
633 Canadian border. The Southern model runs from Cape Mendocino to the Mexican border.

634 **Northern Model**

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

640 The data associated with the commercial fleet includes age- and length-composition data
641 from PacFIN and CalCOM, historical catch timeseries from CDFW, ODFW and WDFW,
642 and observations from the West Coast Groundfish Observing Program (**WCGOP**), which
643 documents discarding in the commercial fishery (providing discard lengths), as well as discard
644 rates calculated from WCGOP data. Sex was available for the comps in the retained catch,
645 which is by-sex in the model, but was not available for the discards, so they are undifferentiated
646 by sex.

647 The PacFIN logbook (fish ticket) index developed for the commercial fishery is in fish/tow.

648 *At-Sea Hake Fishery*: Yellowtail Rockfish are frequently caught in mid-water trawls associated
649 with the At-Sea Hake Fishery (consisting of the Catcher-Processor and Mothership sectors).
650 These catches are recorded and biological sampling takes place but the fish are processed at
651 sea (typically into fish meal) and are not included in the PacFIN database, so this fishery
652 requires separate analysis. The At-Sea Hake fishery provides catches, length compositions by
653 sex, and an index of abundance.

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

658 *Washington-Sport*: The Washington data (WA_Sport) provides catches, lengths and ages,
659 and was treated as a separate fleet for two reasons: first, the length composition of the
660 Washington catches were different from those in the recreational landings in Oregon and
661 northern California (MRFSS/RecFIN data). There are very large fish in this dataset, and
662 fewer small ones. Second, the WA_Sport landings are not available by weight, so they are
663 entered in the model as numbers, and Stock Synthesis internally converts them to weight,
664 using the percentages-at-length and the Weight-Length relationship. Sex was available for
665 the biological data, however many lengthed fish were not sexed, so the lengths for this fleet
666 are undifferentiated by sex, although the ages are.

667 *Research*: Research fleets (3). The Alaska Fisheries Science Center's **Triennial** Trawl survey,
668 and the Northwest Fisheries Science Center's **NWFSCcombo** survey each provide age- and
669 length-compositions, as well as an index of abundance.

670 The remaining research fleet is the **Pikitch study**, which provides discard length-compositions
671 and an index of abundance.

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

676 *Indices*: Fish per angler-hour is the basis for the Washington_Sport and Pikitch indices. The
677 NWFSCcombo and Triennial surveys provide indices based on fish per area-towed. The
678 logbook survey for the commercial fleet is in units of fish per tow.

679 Southern Model

680 *Commercial*: The commercial fleet consists primarily of hook and line and trawl gear. Hook
681 and line gear account for 78% of the landings by weight in the recent period (1978-2016).
682 Commercial data were sexed, although there are many unsexed lengths. To preserve the large

683 numbers of lengths, the length data are entered in the model as undifferentiated, however
684 the ages are sexed and provide the sole conditional age-at-length timeseries in the Southern
685 Model.

686 *Recreational*: The recreational fleet includes data from sport fishery off the California coast
687 south of Cape Mendocino. The recreational lengths are unsexed. The index is in fish per
688 angler_hour.

689 *California Onboard Recreational Survey*: Research derived-data include observations from
690 the California Onboard recreational survey. The length-compositions from this survey are
691 undifferentiated by sex. The index is in fish per angler_hour.

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

695 *Small Fish Study*: A separate index, length comps and a single year of ages reflect a small
696 study of juvenile fish conducted by the SWFSC.

697 3.2.3 Modeling Software

modeling-software

698 The STAT team used Stock Synthesis 3 ([Methot 2015](#)), which is the Pacific Fishery Manage-
699 ment Council's preferred modeling platform for assessments.

700 3.2.4 Data Weighting

data-weighting

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

703 Sample Size = $0.138 * \text{Nfish} + \text{Ntows}$ if $\text{Nfish}/\text{Ntows} < 44$, and $\text{Ntows} * 7.06$ otherwise.

704 Age-at-Length samples are unwieghted; that is, each fish is assumed to represent an indepen-
705 dent sample.

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

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

715 **3.2.5 Priors**

priors

716 Natural Mortality (M) priors were provided by Owen Hamel (Hamel 2015). Natural mortality
717 priors were based on examination of the 99% quantile of the observed ages from early in the
718 time-series, before the full impact of fishing would have taken place. For the Northern model,
719 these quantiles were approximately 35 years for females and 45 years for males, resulting in
720 median M values of 0.15 and 0.12 for females and males. For the Southern model, the 99%
721 quantile of the early age observations were approximately 30 and 40 years for females and
722 males, resulting in median M prior values of 0.18 and 0.135, respectively. In both models, M
723 for males was represented as an offset from females. In the Northern model, both the female
724 value and the male offset could be estimated without priors so the priors were not used. For
725 the southern model, M was fixed at the median prior values for the two sexes.

726 The prior for steepness (h, 0.718) was provided by James Thorson and used as a fixed
727 parameter in both models. <TOADS: Citation>

728 **3.2.6 General Model Specifications**

general-model-specifications

729 Citation for posterior predictive fecundity relationship from Dick (2009)

730 Model data, control, starter, and forecast files can be found at <https://DEVORE> .

731 **3.2.7 Estimated And Fixed Parameters**

estimated-and-fixed-parameters

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

⁷³⁴ **3.3 Model Selection and Evaluation**

model-selection-and-evaluation

⁷³⁵ **3.3.1 Key Assumptions and Structural Choices**

key-assumptions-and-structural-choices

⁷³⁶ Selectivity in both models is asymptotic, with the exception of the OR-CA MRFSS recreational
⁷³⁷ fleet in the Northern model, and the Onboard recreational fleet in the Southern model.

⁷³⁸ **3.3.2 Alternate Models Considered**

alternate-models-considered

⁷³⁹ Time-blocked selectivity and retention were investigated in the Northern model, as were
⁷⁴⁰ domed selectivities.

⁷⁴¹ We also explored time-blocks on selectivity in the Southern model, and domed selectivity for
⁷⁴² the MRFSS/RecFIN data.

⁷⁴³ These approaches resulted in model fits to data that were obviously poor, and so they were
⁷⁴⁴ rejected

⁷⁴⁵ **3.3.3 Convergence**

convergence

⁷⁴⁶ Convergence testing through use of dispersed starting values often requires extreme values
⁷⁴⁷ to explore new areas of the multivariate likelihood surface. Stock Synthesis provides a
⁷⁴⁸ jitter option that generates random starting values from a normal distribution logically
⁷⁴⁹ transformed into each parameter's range (Methot 2015). We used this function to find
⁷⁵⁰ parameter values for convergence in the Southern model. The Northern model did not require
⁷⁵¹ jittering.

752 **3.4 Response To The Current STAR Panel Requests**
response-to-the-current-star-panel-requests

753 **Request No. 1: Add after STAR panel.**

754

755 **Rationale:** Add after STAR panel.

756 **STAT Response:** Add after STAR panel.

757 **Request No. 2: Add after STAR panel.**

758

759 **Rationale:** Add after STAR panel.

760 **STAT Response:** Add after STAR panel.

761 **Request No. 3: Add after STAR panel.**

762

763 **Rationale:** Add after STAR panel.

764 **STAT Response:** Add after STAR panel.

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

766

- 767 • **Item No. 1**
- 768 • **Item No. 2**
- 769 • **Item No. 3, etc.**

770 **Rationale:** Add after STAR panel.

771 **STAT Response:** Continue requests as needed.

772 **3.5 Life History Results for both models**

life-history-results-for-both-models

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

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

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

780 **3.6 Northern Model Base Case Results**

northern-model-base-case-results

781 The data used in the Northern model by fishery is shown in Figure 58. Estimated catches
782 are shown in Figure 7; estimated discards are in Figure 8. These show the large catches in
783 the 1980s and 90s are being predicted by the model. The large discards in latter years match
784 the data well for those years.

785 **3.6.1 Selectivities, Indices and Discards**

selectivities-indices-and-discards

786 Selectivities in the Northern model (Figure ??) shows the difference between the recreational
787 fisheries and the commercial fishery and survey sampling. All of the fish are fully selected by
788 50 cm, but the recreational fish are fully selected at 30 cm.

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

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

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

801 **3.6.2 Lengths**

lengths

802 Bubble plots for the lengths in the fishery (Figure 17) show the constancy of the commercial
803 fleet, and the differences in growth between males and females; the females are larger, the
804 males smaller. The recreational fleet is represented by two different sampling regimes, and
805 the changeover in the mid-2000s is clear in that panel. That the WA_Sport fishery catches
806 larger fish is represented in the large bubbles at the top of the panel. Had we examined that
807 fishery earlier in the process of putting the model together, we might have settled on a larger
808 maximum size bin, however that fishery remains the smallest portion of the catches.

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

812 Lengths in the early period of the Hake Bycatch fishery are noisy (doubtless due to small
813 sample sizes). By 1992, the model is able to fit the data well (Figure ??). Figure ?? shows
814 that the fits in the early period have twice (at last) the uncertainty of the later period.

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

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

821 The Trinnial lengths Figures ?? and 30 are fit well in some years and not in others. The data
822 is not noisy, however the intermittency of data collection may mean that the model is unable
823 to capture interannual variation as well as for an annual timeseries.

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

827 Figure 33 shows the relative fits among the data sources, aggregated across time. The
828 timeseries of presence-absence residuals indicated by filled- and open-bubbles Figure 34 and
829 Figure 35 demonstrates the relative disappointment in model fits; the smaller the bubble, the
830 better the match between the data and the model expectation.

831 **3.6.3 Ages**

ages

832 The NWFSCcombo survey provided the only source of conditional age-at-length data for the
833 Northern model; ages for other fleets were treated as marginal ages.

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

839 The Washington Sport ages are noisy, and the fit is poor throughout the timeseries, see
840 Figure ?? and Figure ??.

841 The Triennial ages are noisy but are fit surprisingly well ??; 41. That the model misses the
842 influx of young fish in 1986 may be due to the timing of the survey; three-year surveys may
843 not provide enough data for the model to fit recruitment events.

844 Aggregated age comps for the Commercial, Washington Sport and Triennial fleets are shown
845 in Figure 42, for comparison. Aggregated fits for the Commercial and Triennial fleets are
846 very satisfying.

847 The Ghost age comps Figure ?? for the NWFSCcombo survey are the marginal age comps
848 for the survey aggregated over length. This figure is included for informational purposes only;
849 the marginal “ghost” comps are not included in the likelihood calculations. It is interesting
850 that the model fits this aggregated data poorly, but the disaggregated data well. This may
851 be due to the fact that for marginal ages, the data are weighted interannually with number
852 of tows or trips, but this ghost fleet is unweighted.

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

857 The fits to the length-aggregate NWFSCcombo data show more variation in mean age in
858 the population in latter years than might be expected in years with relatively low landings
859 Figure ???. These may represent young fish recruiting to the fishery, which would happen
860 approximately 5 years after a biological recruitment event. The conditional age-at-length fits
861 are shown in Figure 46. These plots explain the reason this survey was chosen to represent
862 conditional age-at-length; the model was able to fit these data much better than other
863 datasets, and improved fit, lower likelihood values and increased parsimony all contributed
864 to a better model.

865 3.7 Northern Model Parameters

northern-model-parameters

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

869 **3.7.1 Northern Model Uncertainty and Sensitivity Analyses**

section

870 Table 4

871 **3.7.2 Northern Model Retrospective Analysis**

northern-model-retrospective-analysis

872 **3.7.3 Northern Model Likelihood Profiles**

northern-model-likelihood-profiles

873 **3.7.4 Northern Model Reference Points**

northern-model-reference-points

874 Intro sentence or two....(Table 5).

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

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

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

879 **3.8 Southern Model Base Case Results** southern-model-base-case-results

880 Data used in the Southern model is shown in Figure 58.
881 One thing to point out is that although the scale of the biomass in the model is somewhat
882 sensitive to various data sources, the depletion is not. In tuning the model we were surprised
883 to note that depletion always stayed above 80%.

884 **3.8.1 Southern Model Selectivities, Indices and Discards** southern-model-selectivities-indices-and-discards

885 Selectivity by fleet is shown in Figure 60. Selectivities for all but the recreational Onboard
886 fishery are modeled as asymptotic; both recreational fleets (MRFSS/RecFIN and Onboard)
887 are fully selected at 30cm; the remaining fleets show full selectivity at 45-50 cm.

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

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

897 **3.8.2 Southern Model Lengths** southern-model-lengths

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

902 Bubble plots of the lengths by year in each fishery are in Figure 62. The plot for the
903 recreational fishery clearly shows the transition from the MRFSS sampling program to
904 RecFIN in 2003/2004, as well as suggesting the existence of larger fish in the 1980s. The
905 Commercial fishery data has been sparse in recent years, however the fish taken in the
906 Commercial catch are consistently larger than those in the recreational fishery, no doubt
907 reflecting trawling in deeper waters. The Onboard survey lengths reflect two eras of sampling,
908 again with larger fish in the earlier period. The panel for the Hook-and-Line survey shows
909 that the females landed are always larger than the males, in agreement with the model
910 estimates of growth: Figure 5.

- 911 The fits to the lengths in the Recreational fishery Figure ?? show variable fits through the
912 years, with the noisy and sparse data in 2004 heralding the transition between MRFSS
913 sampling and RecFIN. Overall, the timeseries is fit fairly well: Figure ??
- 914 The Commercial length comps are fit well through 2005, when data becomes sparse and noisy
915 Figure ??; and Figure ??.
- 916 Fits for the Onboard Survey lengths are good in the early survey, and poor for the later
917 period ??; ?. Attempting to apply a time-block to this data resulted in poor convergence.
- 918 The Hook-and-Line Survey lengths are noisy (Figure ??), but the fits are acceptable, and
919 follow the trend of the data better than those for the other datasets: Figure ??.
- 920 The small fish survey lengths are not fit badly ??; ??, and it is perhaps a shame that there
921 are so few years to this timeseries.
- 922 The aggregate fits to the length comps for all five datasets is shown in Figure 73, and Pearson
923 residuals for the lengths in Figure 74. Filled bubbles represent under-estimation of the data,
924 open bubbles represent overestimation.

925 **3.8.3 Southern Model Ages**

southern-model-ages

926 **3.8.4 Southern Model Uncertainty and Sensitivity Analyses**

southern-model-uncertainty-and-sensitivity-analyses

927 **3.8.5 Southern Model Retrospective Analysis**

southern-model-retrospective-analysis

928 **3.8.6 Southern Model Likelihood Profiles**

southern-model-likelihood-profiles

929 **3.8.7 Southern Model Reference Points**

southern-model-reference-points

930 **4 Harvest Projections and Decision Tables**

harvest-projections-and-decision-tables

931 Table [k](#)

932 ** Northern Model Projections and Decision Table (groundfish only)** (Table [6](#)

933 Table [m](#)

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

935 **5 Regional Management Considerations**

936 regional-management-considerations

936 Management of the yellowtail rockfish northern stock has always been delineated by the
937 40° 10' line and the Canadian border. That the stock's genetic cline was found at Cape
938 Mendocino is a happy accident that reinforces 40° 10' as the appropriate management line.

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

943 **6 Research Needs**

research-needs

- 944 1. A longer timeseries of the juvenile rockfish CPUE in the south.
- 945 2. A commercial index in the north. This is by far the largest segment of the fishery, and
946 the introduction of trawl rationalization program should mean that an index can be
947 developed for the current fishery when the next assessment is performed.
- 948 3. More recent ages for the southern model. The commercial age timeseries currently
949 stops in 2002.

950 **7 Acknowledgments**

acknowledgments

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- 964 ment Team
- 965 Dan Waldeck, Pacific Fishery Management Council / Groundfish Advisory Panel

966 **8 Tables**

tables

Table 1. Summary of the biomass/abundance time series used in the stock assessment.

Region	ID	Fleet	Years	Name	Fishery	Filtering	Method	Endorsed
WA	1	4	1981- 2014	Dockside CPUE	No ind.	trip, area, month, Stephens- MacCall	delta-GLM (bin- gamma)	SSC
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-

Table 2. Results from 100 jitters from each of the three models.

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

tab:jitter

Table 3. 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) (1, 25)	OK	0.009	None
2	Lat_Amin_Fem_GP_1	15.094	3	(1, 25)	OK	0.556	None
3	Lat_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	Lat_Amin_Mal_GP_1	0.000	-2	(-1, 1)			None
15	Lat_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)	OK	0.070	None
18	CV_old_Mal_GP_1	0.168	5	(-1, 1)			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 3. 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_NWFSCombo(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 3. 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)	OK	2.392	None
169	SizeSel_P3_RecWA(4)	-1.427	6	(-5, 20)	OK		None
170	SizeSel_P4_RecWA(4)	70.000	-4	(-5, 70)	OK		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)	OK		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)	OK		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)	OK		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)	OK		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)_BLK1repL2002	2.228	6	(-10, 20)	OK	0.457	None
186	Retain_P3_CommercialTrawl(1)_BLK1repL2003	3.708	6	(-10, 20)	OK	0.756	None
187	Retain_P3_CommercialTrawl(1)_BLK1repL2004	1.129	6	(-10, 20)	OK	0.522	None
188	Retain_P3_CommercialTrawl(1)_BLK1repL2005	-0.112	6	(-10, 20)	OK	0.400	None
189	Retain_P3_CommercialTrawl(1)_BLK1repL2006	1.760	6	(-10, 20)	OK	0.260	None
190	Retain_P3_CommercialTrawl(1)_BLK1repL2007	-0.514	6	(-10, 20)	OK	0.623	None
191	Retain_P3_CommercialTrawl(1)_BLK1repL2008	2.370	6	(-10, 20)	OK	0.815	None
192	Retain_P3_CommercialTrawl(1)_BLK1repL2009	0.481	6	(-10, 20)	OK	0.495	None

Continued on next page

Table 3. 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)_BLK1rep1.2010	0.161	6	(-10, 20)	OK	0.677	None
194	Retain.P3_CommercialTrawl(1)_BLK1rep1.2011	7.316	6	(-10, 20)	OK	0.661	None

tab-model-params

Table 5. 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 ex- ploitation 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 5. 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 ex- ploitation 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 5. 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 ex- ploitation 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 5. 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 ex- ploitation 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 4. Sensitivity of the base model to dropping or down-weighting data sources and alternative assumptions about growth.

Label	Base (Francis weights)	Harmonic mean weights)	Drop index	Drop ages	Down- weight lengths	Free size Age0	Free CV	External Amin growth	tab:Sensitivity_model1
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_SPRtgthousand_mt	-	-	-	-	-	-	-	-	-
Fstd_SPRtgthousand_mt	-	-	-	-	-	-	-	-	-
TotYield_SPRtgthousand_mt	-	-	-	-	-	-	-	-	-
SSB_MSY_thousand_mt	-	-	-	-	-	-	-	-	-
SPR_MSY	-	-	-	-	-	-	-	-	-
Fstd_MSY	-	-	-	-	-	-	-	-	-
TotYield_MSY_thousand_mt	-	-	-	-	-	-	-	-	-
RecrYield_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 6. Projection of potential OFL, spawning biomass, and depletion for the base case model.

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

₉₆₇ 9 Figures

figures

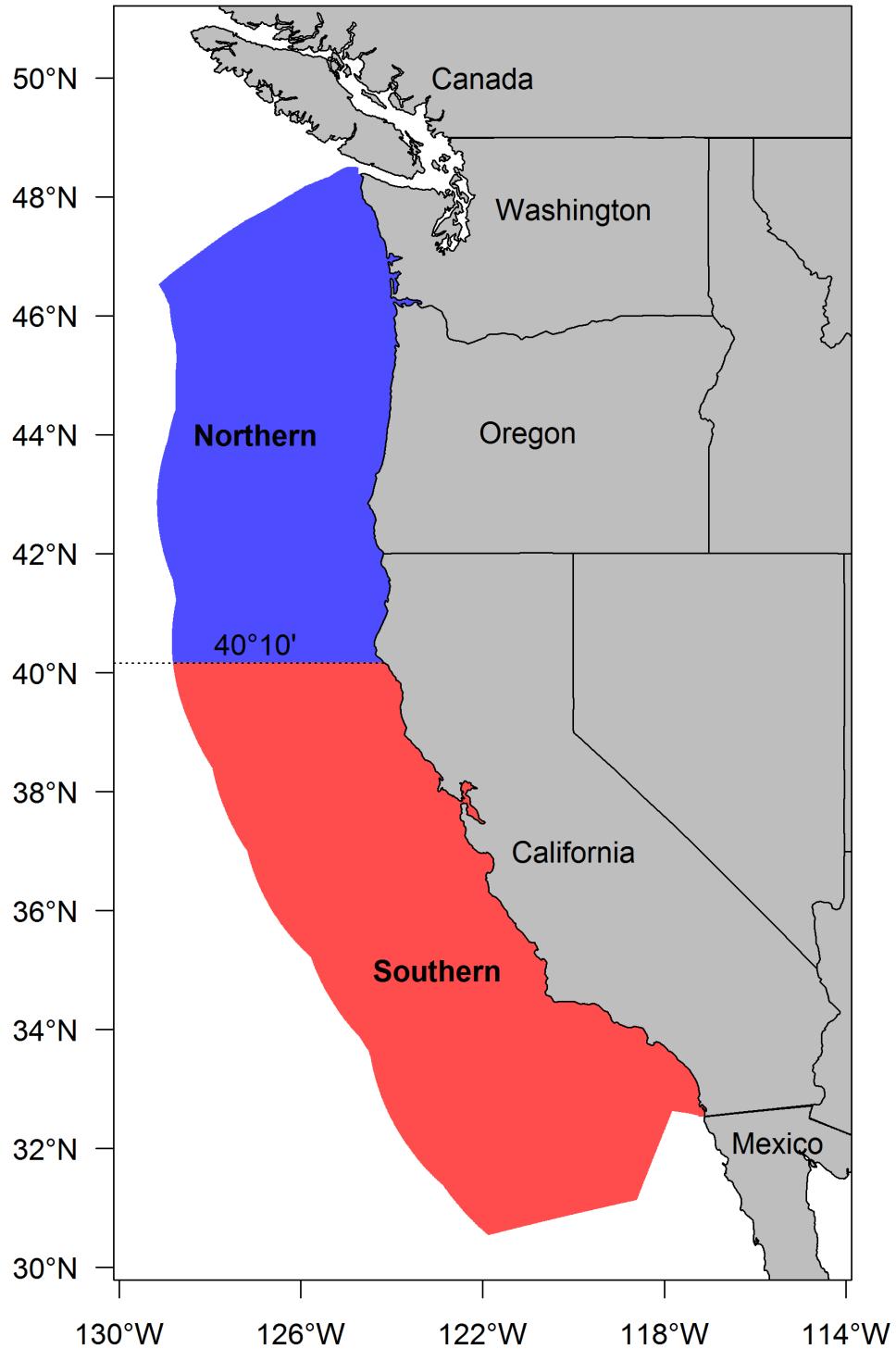


Figure 1: Map depicting the boundaries for the base-case model. fig:assess_region_map

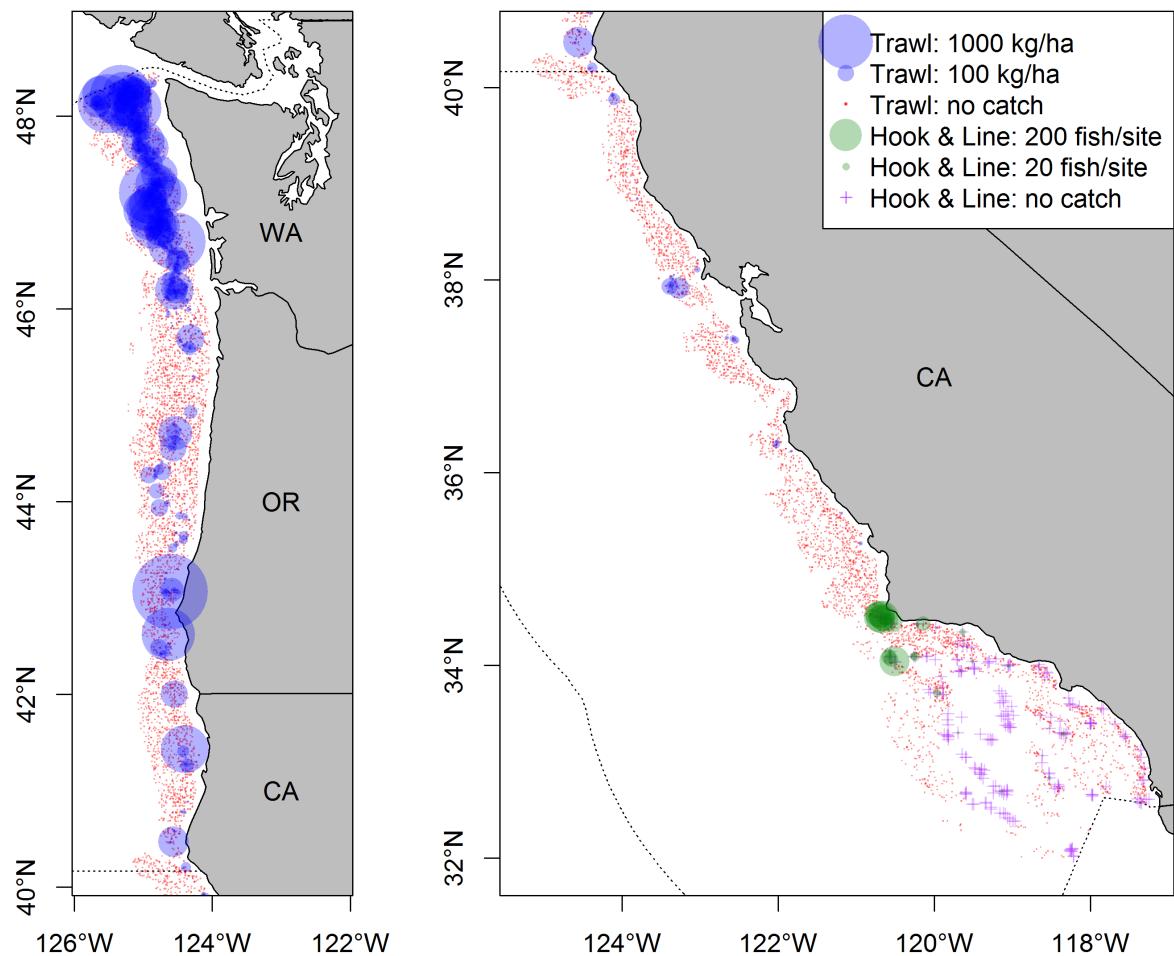


Figure 2: Map showing observations of Yellowtail Rockfish in the NWFSCcombo trawl survey and Hook & Line survey. [fig:assess_region_map](#)

968 9.1 Life history (maturity, fecundity, and growth) for both models
life-history-maturity-fecundity-and-growth-for-both-models

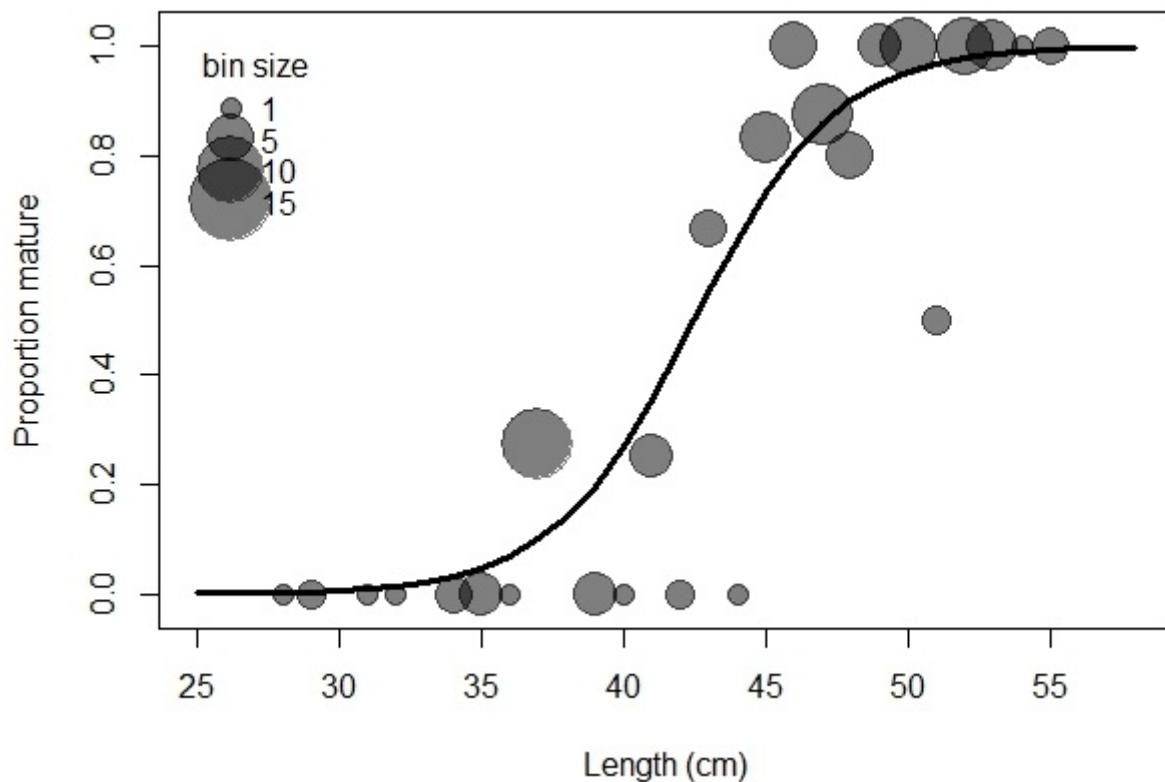


Figure 3: Estimated maturity relationship for Yellowtail Rockfish used in both models. Gray points indicate average observed functional maturity within each length bin with point size proportional to the number of samples.
fig:maturity

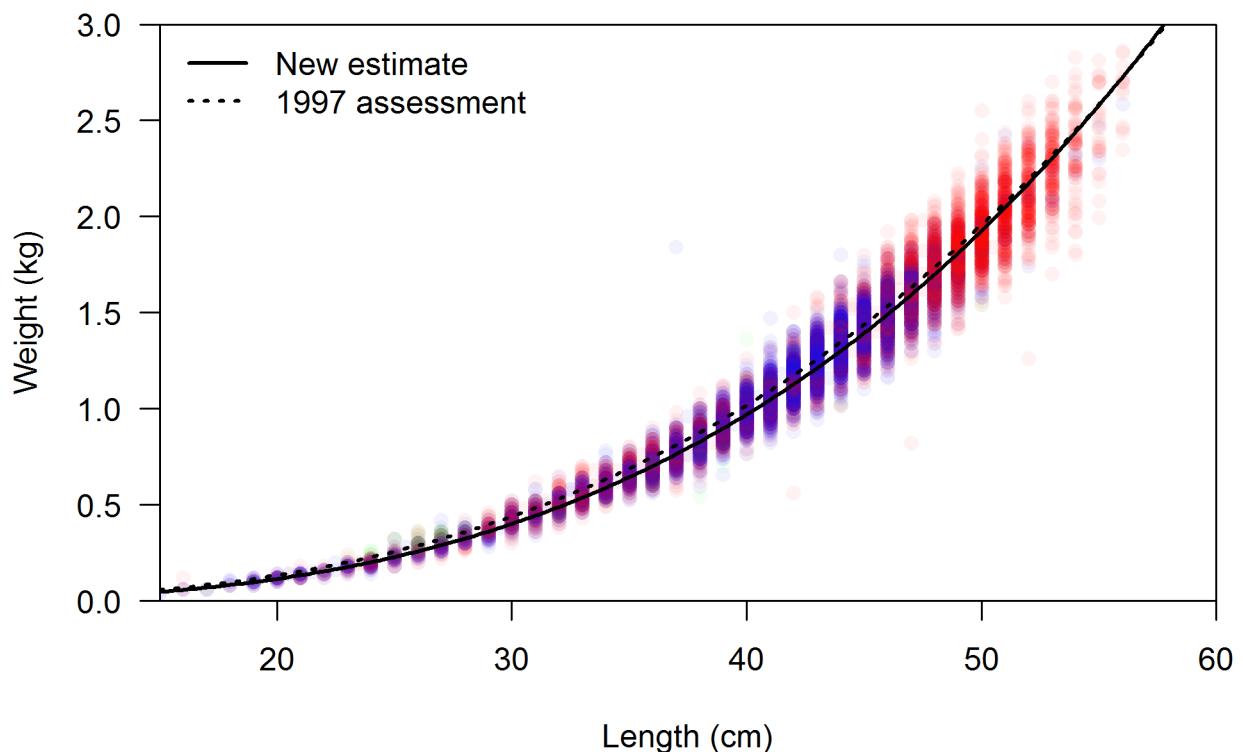


Figure 4: Estimated weight-length relationship for Yellowtail Rockfish used in both models. Colored points show observed values (red for females, blue for males, and green for unsexed). The black line indicates the estimated relationship $W = 0.000011843L^{3.0672}$.
fig:weight-length

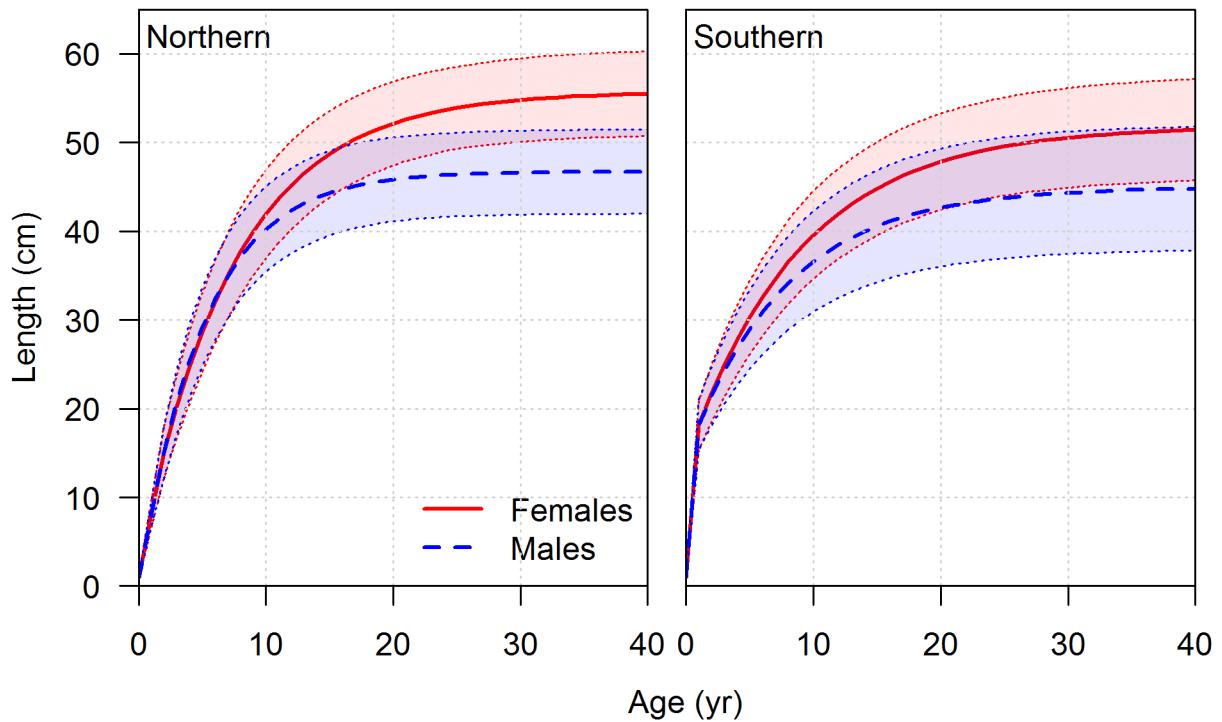


Figure 5: Estimated length-at-age for female and male Yellowtail Rockfish in each model. Shaded areas indicate 95% intervals for distribution of lengths at each age. Values represent beginning-of-year growth. fig:growth

969 9.2 Data and model fits for the Northern model
data-and-model-fits-for-the-northern-model

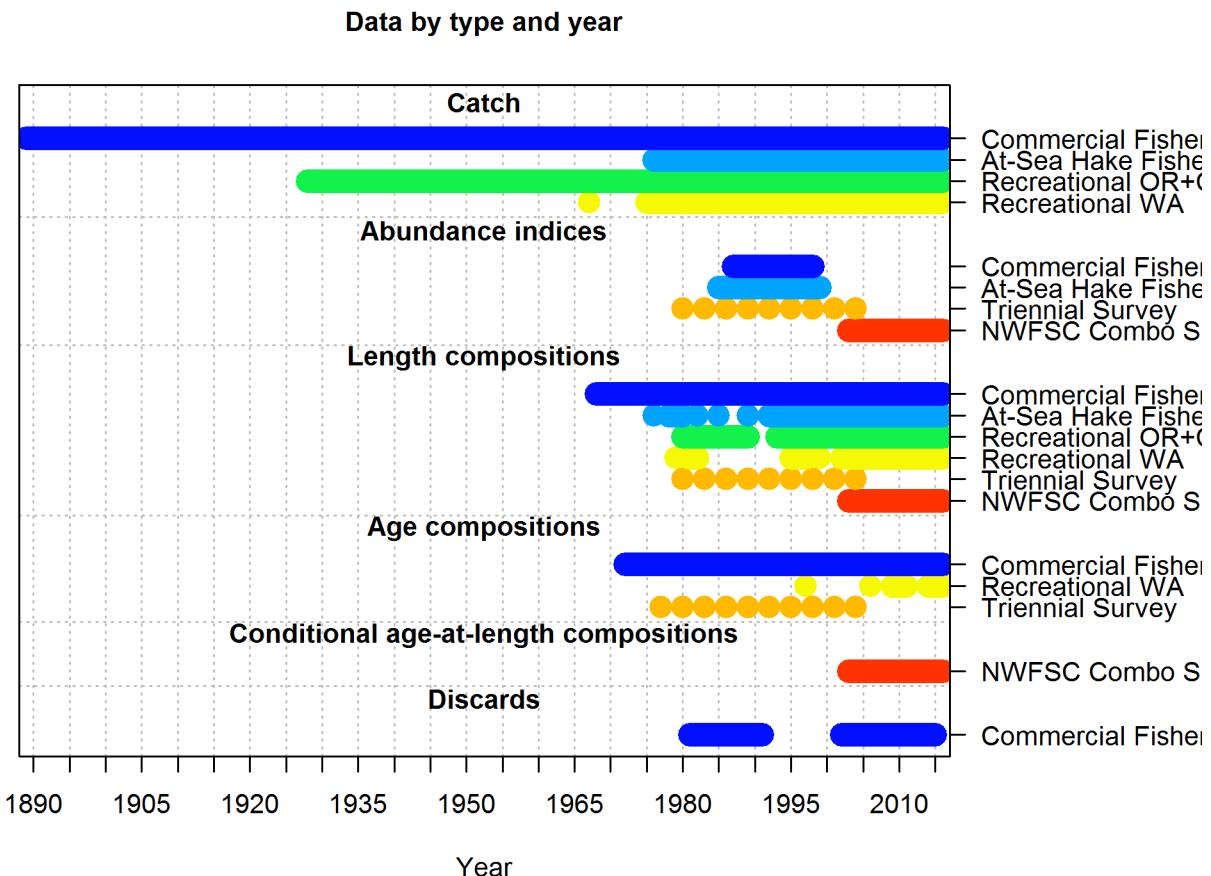


Figure 6: Summary of data sources used in the Northern model. fig:data_plot

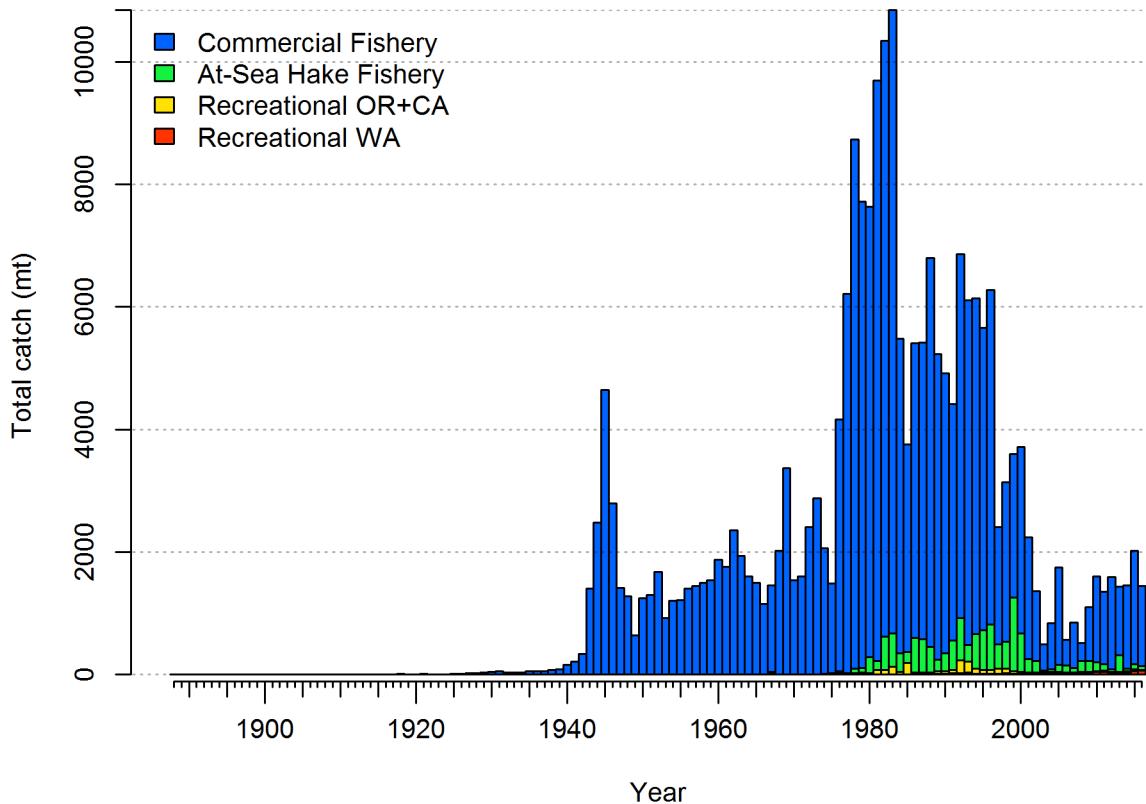


Figure 7: Estimated catch history of Yellowtail Rockfish in the Northern model. Recreational catches in Washington are model estimates of total weight converted from input catch in numbers using model estimates of growth and selectivity. Catches for the Commercial Fishery include estimated discards.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

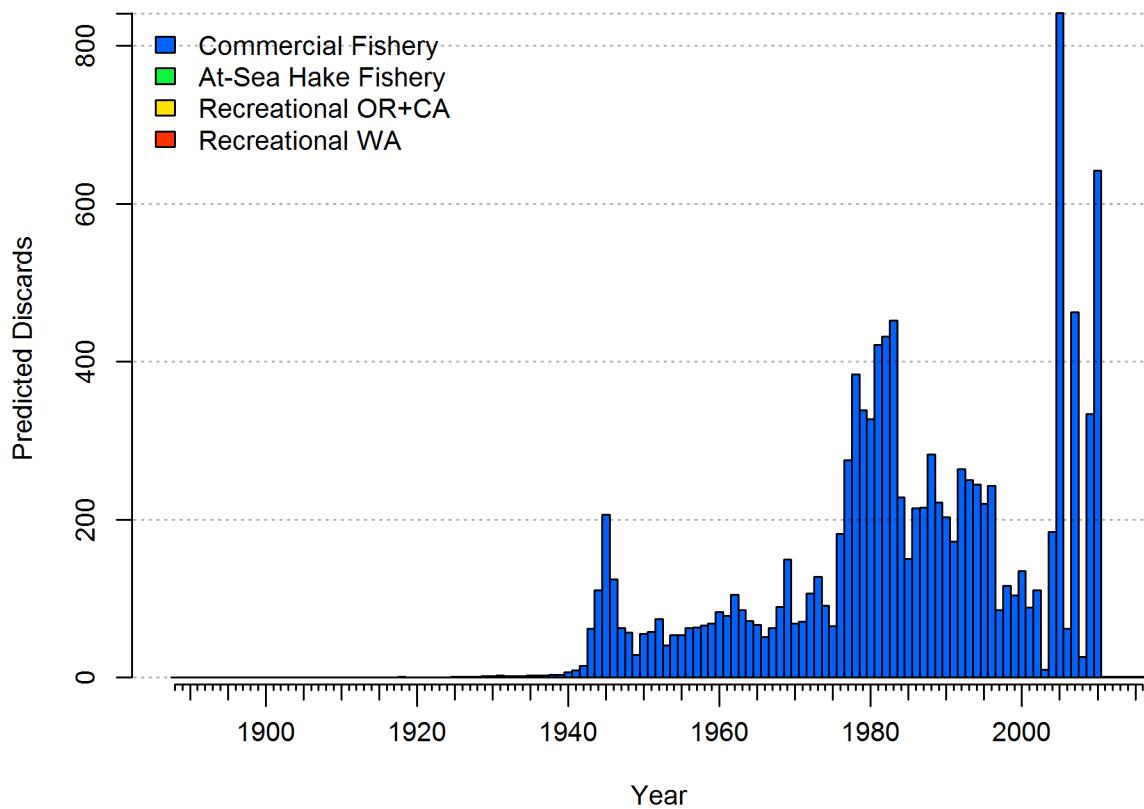


Figure 8: Estimated discards in the Commercial Fishery in the Northern model. Estimates are influenced by the data for landings, discard ratios, and discard length combines and depend on the estimated parameters controlling selectivity and retention.^{fig:r4ss_discard_N}

970 9.2.1 Selectivity, retention, and discards for Northern model
selectivity-retention-and-discards-for-northern-model

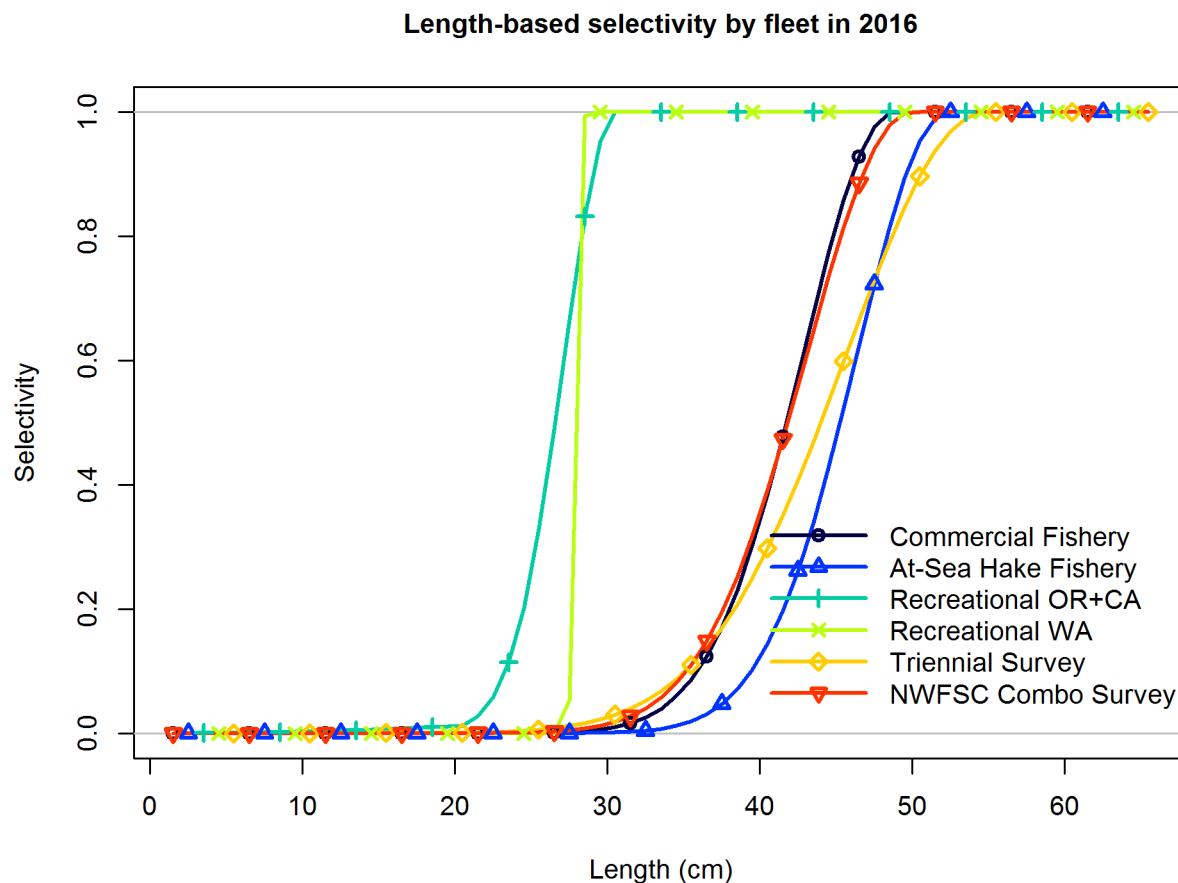


Figure 9: Estimated selectivity by length by each fishery and survey in the Northern model. fig:selex

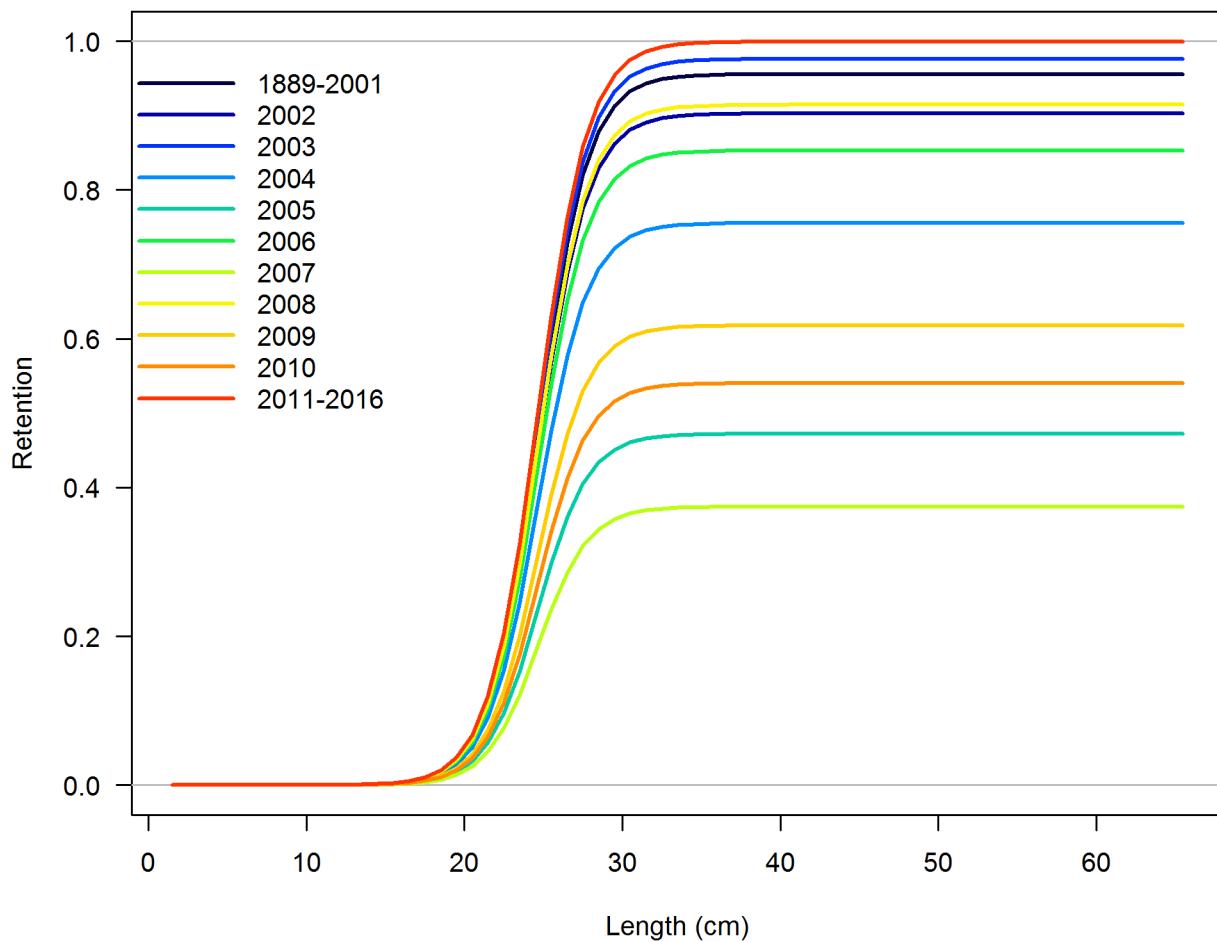


Figure 10: Estimated retention by length by the Commercial Fishery in the Northern model. `fig:retention`

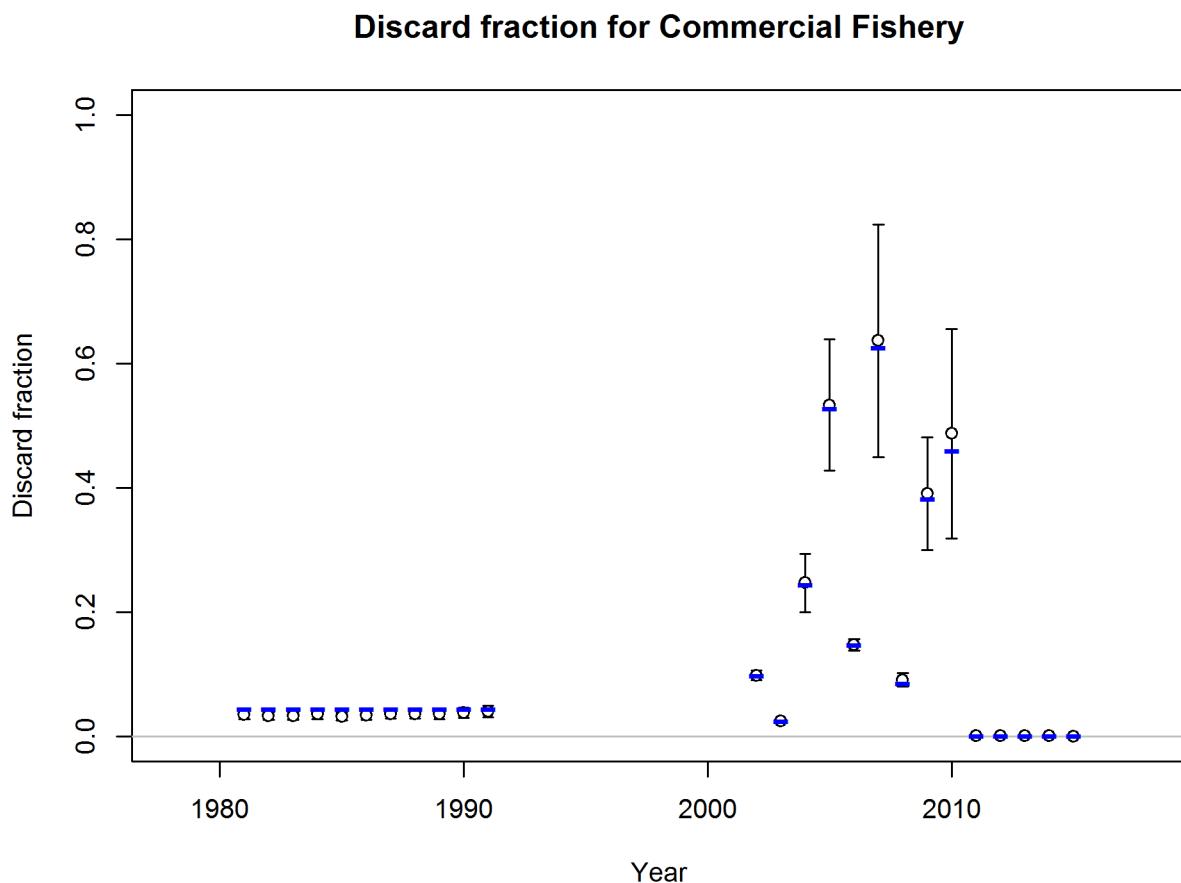


Figure 11: Fit to discard fractions for the commercial fishery in the Northern model.
fig:r4ss_discard

971 9.2.2 At-Sea Hake Bycatch Index

at-sea-hake-bycatch-index

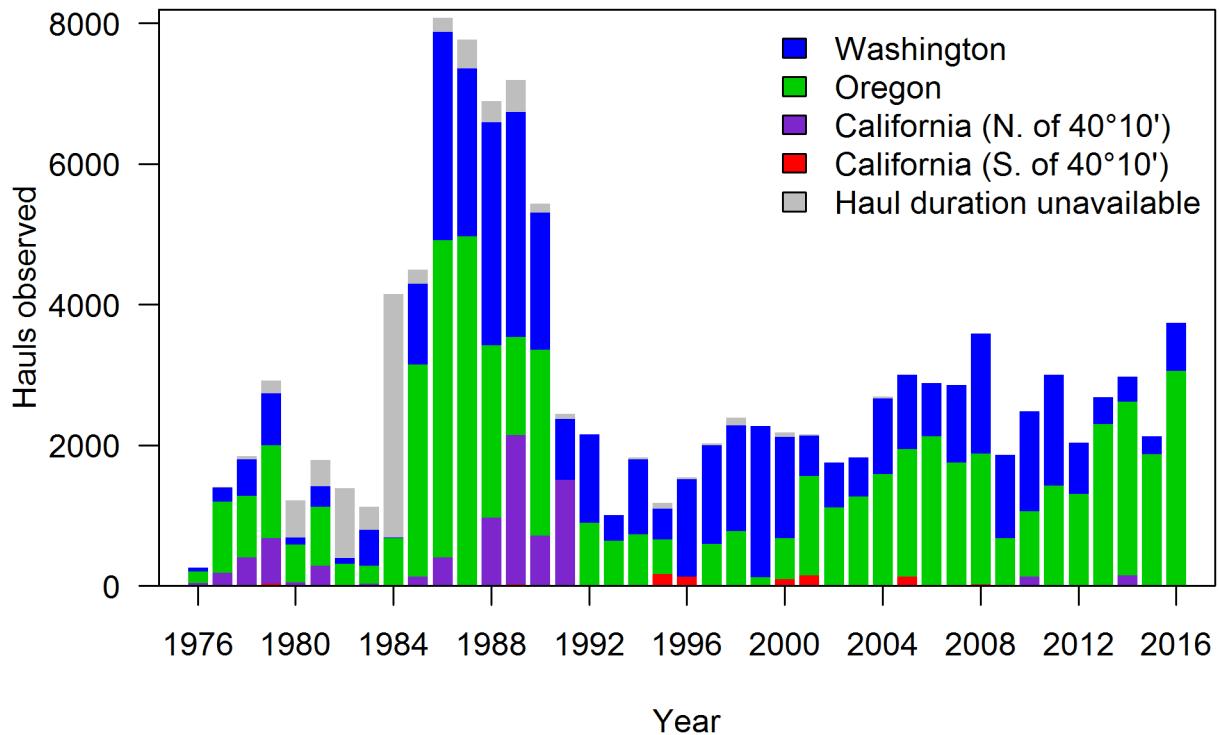


Figure 12: Number of observed hauls from the at-sea hake fishery classified by location relative to Washington, Oregon, and California (north and south of 40-10). Grey bars indicate observed tows with no haul duration available which were excluded from the CPUE analysis.
fig:ASHOP_X1

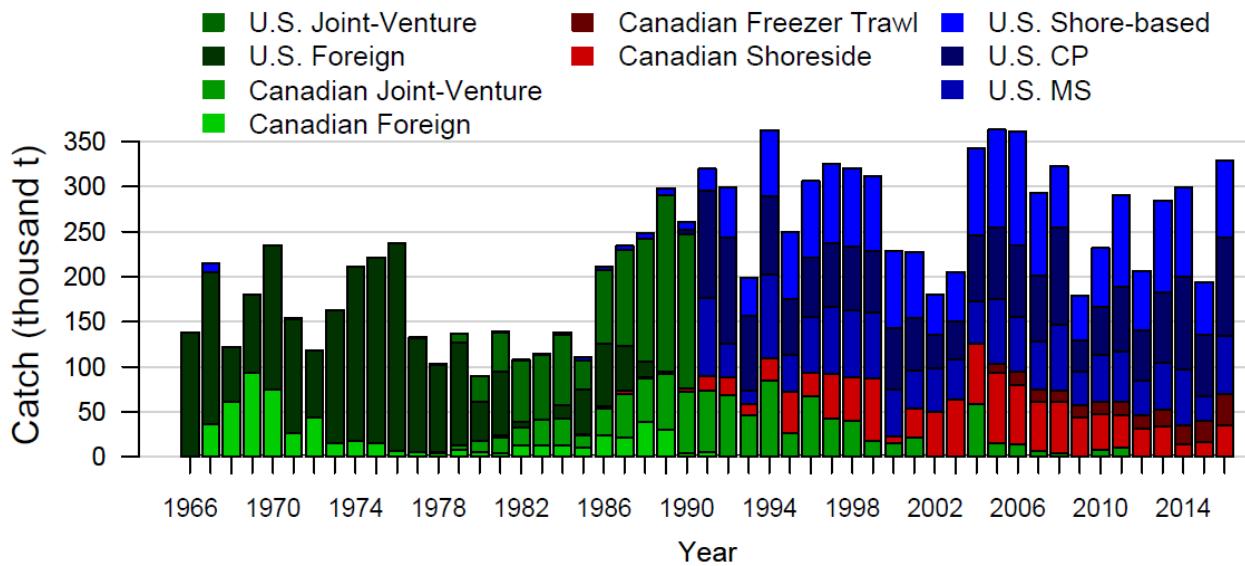


Figure 13: Catch history for Pacific Hake by sector. Data used in the CPUE analysis are from the “U.S. Joint-Venture” and “U.S. Foreign sectors” through 1990 and from the ^{fig:ASHOP_X2} Catcher-Processor (“U.S. CP”) and Mothership (“U.S. MS”) sectors from 1990 onward.

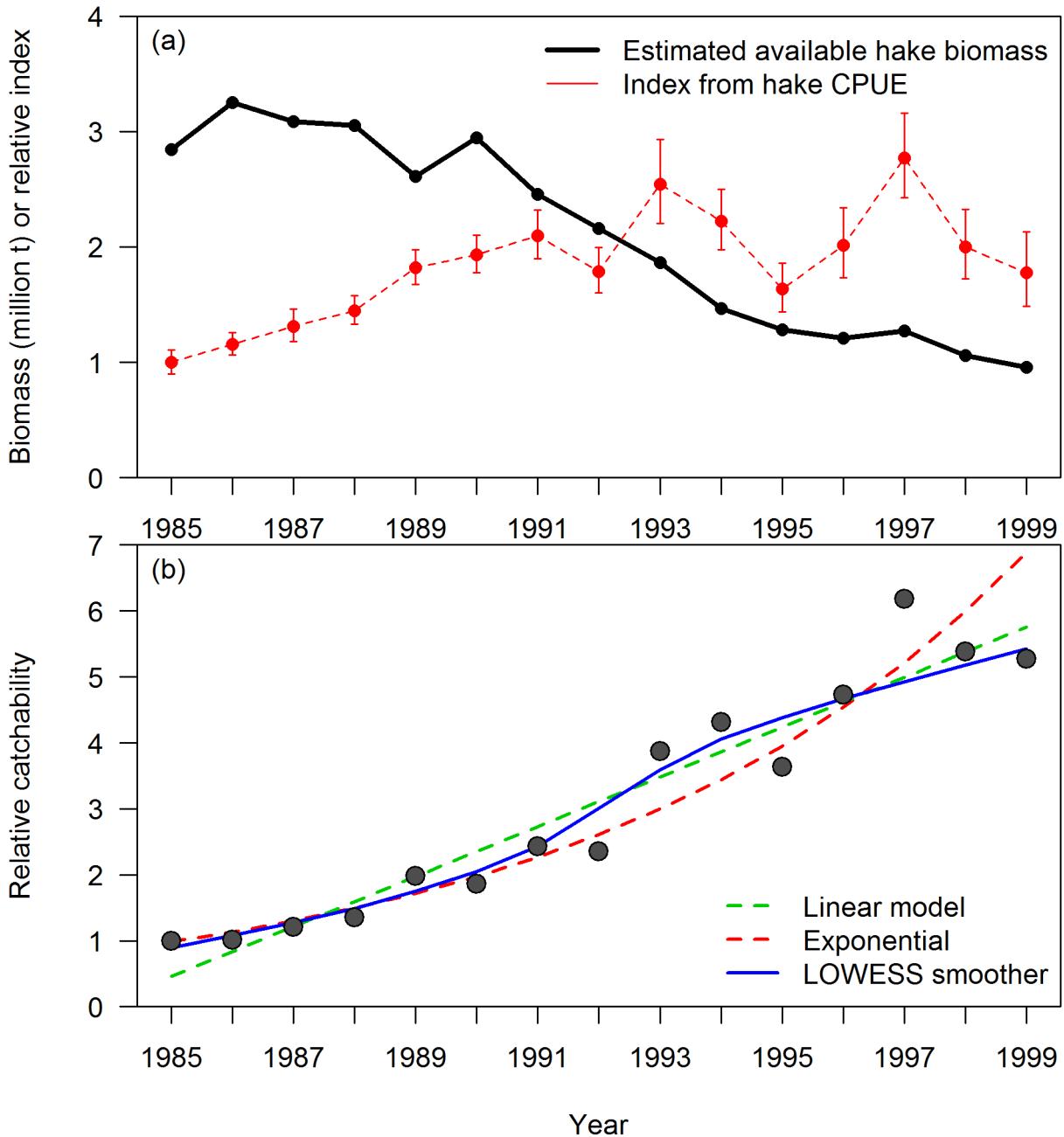


Figure 14: Geostatistical index for Pacific Hake developed using VAST compared to the estimated available hake biomass.
fig:ASHOP_X3

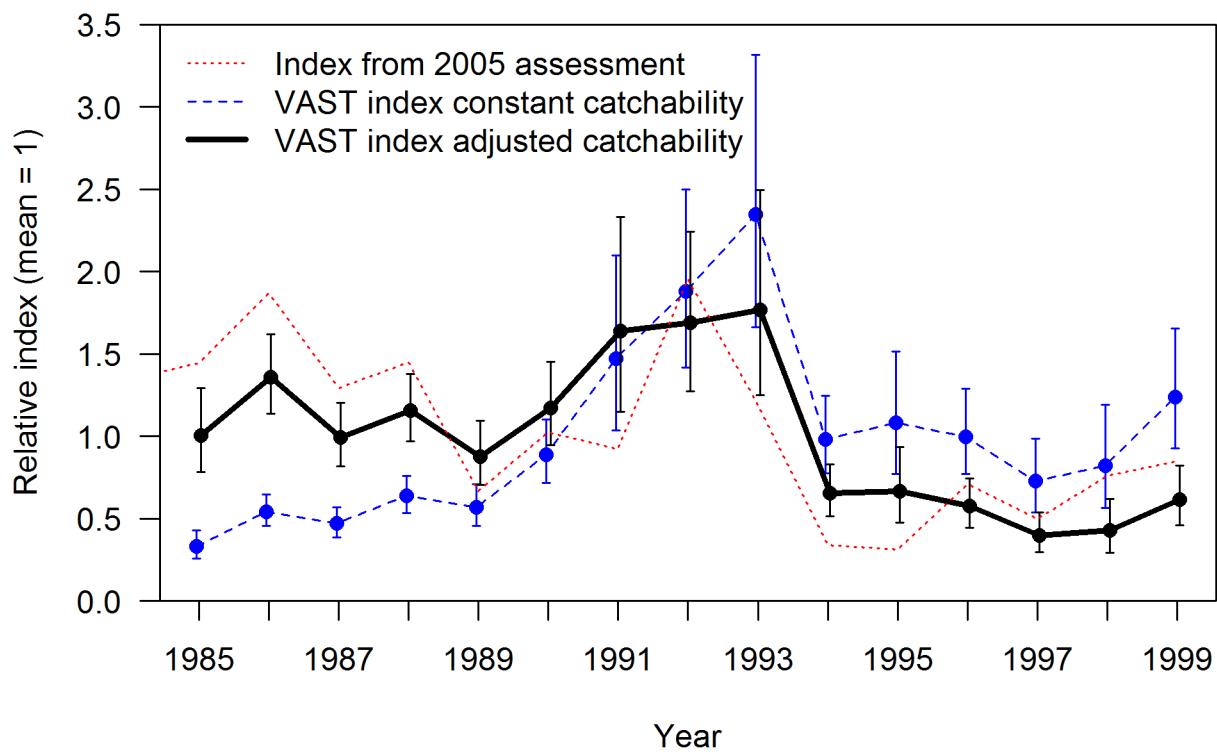


Figure 15: Index from the geostatistical model VAST with constant catchability and adjusted for the estimated increase in catchability (previous figure). These are compared to the index from the most recent yellowtail assessment (Wallace and Lai, 2005).
fig:ASHP_X4

972 9.2.3 Fits to indices of abundance for Northern model
[fits-to-indices-of-abundance-for-northern-model](#)

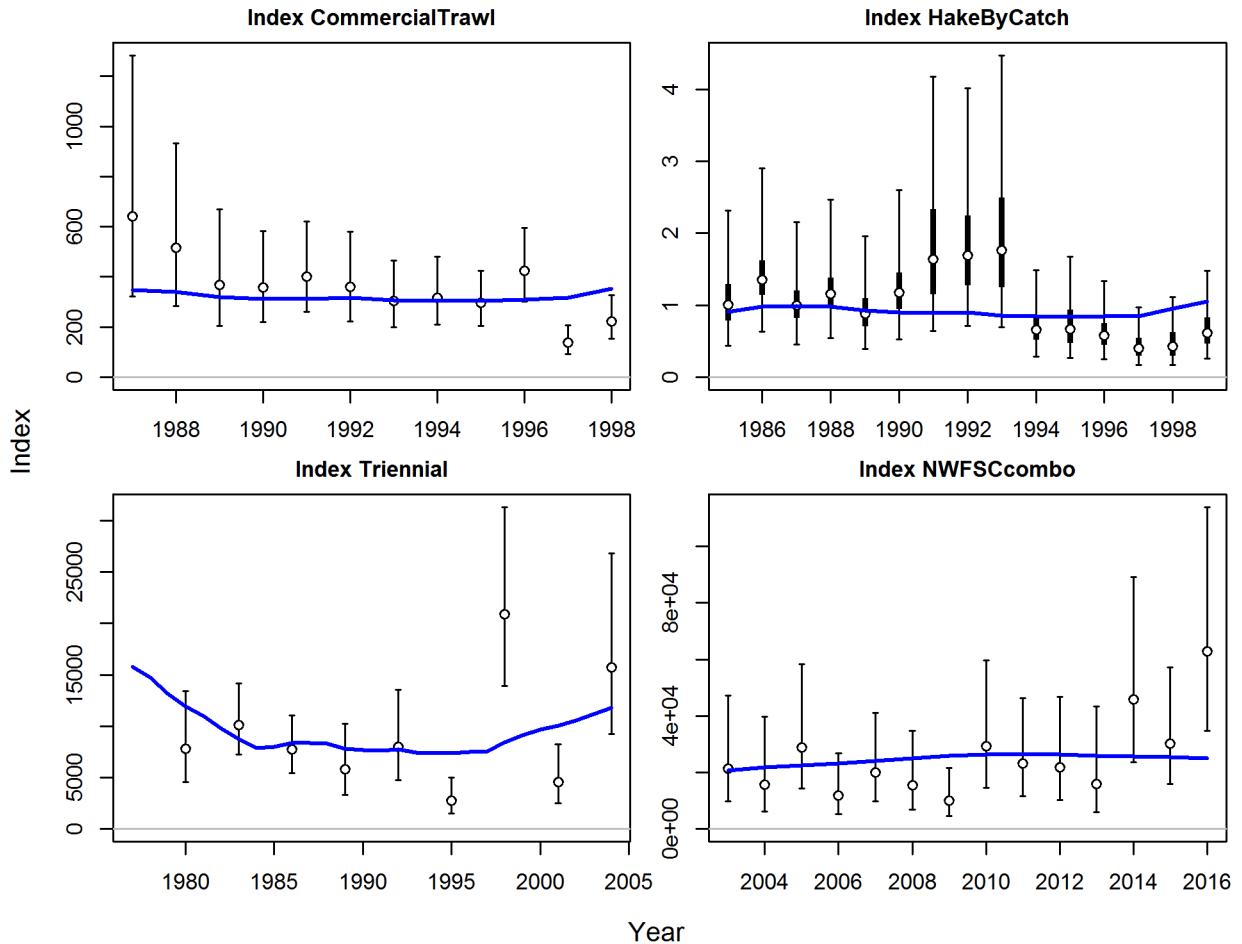


Figure 16: Estimated fits to the CPUE and survey indices for the Northern model. [fig:index_fits1](#)

₉₇₃ **9.2.4 Length compositions for Northern model**
[length-compositions-for-northern-model](#)

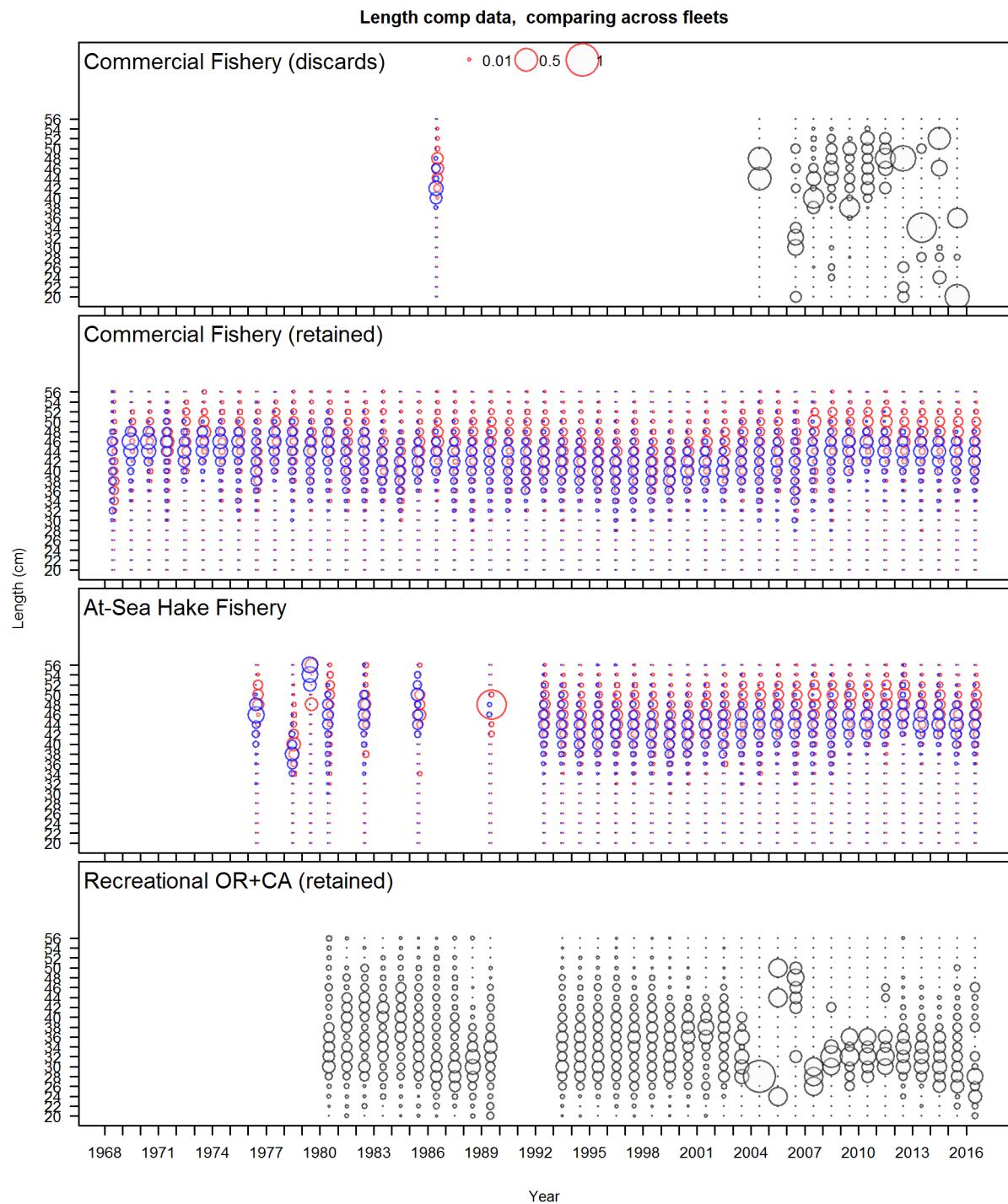


Figure 17: Length compositions for all fleets in the Northern model (figure 1 of 2). Bubble size is proportional to proportions within each year. Bubble colors indicate unsexed fish (gray), females (red), and males (blue).
fig:comp_length_bubble_mod1_page1

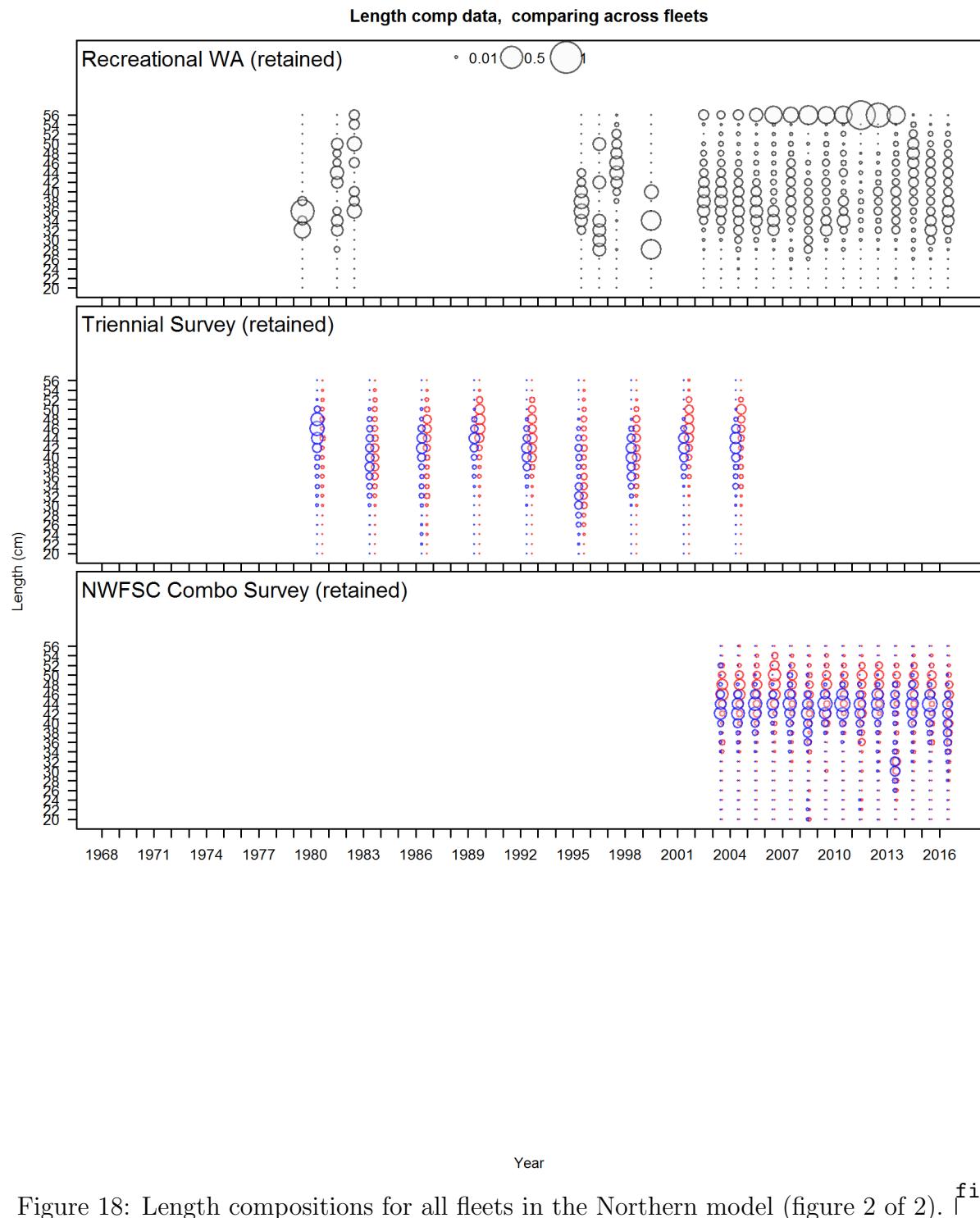


Figure 18: Length compositions for all fleets in the Northern model (figure 2 of 2). `fig:comp_length`

Length comps, retained, Commercial Fishery

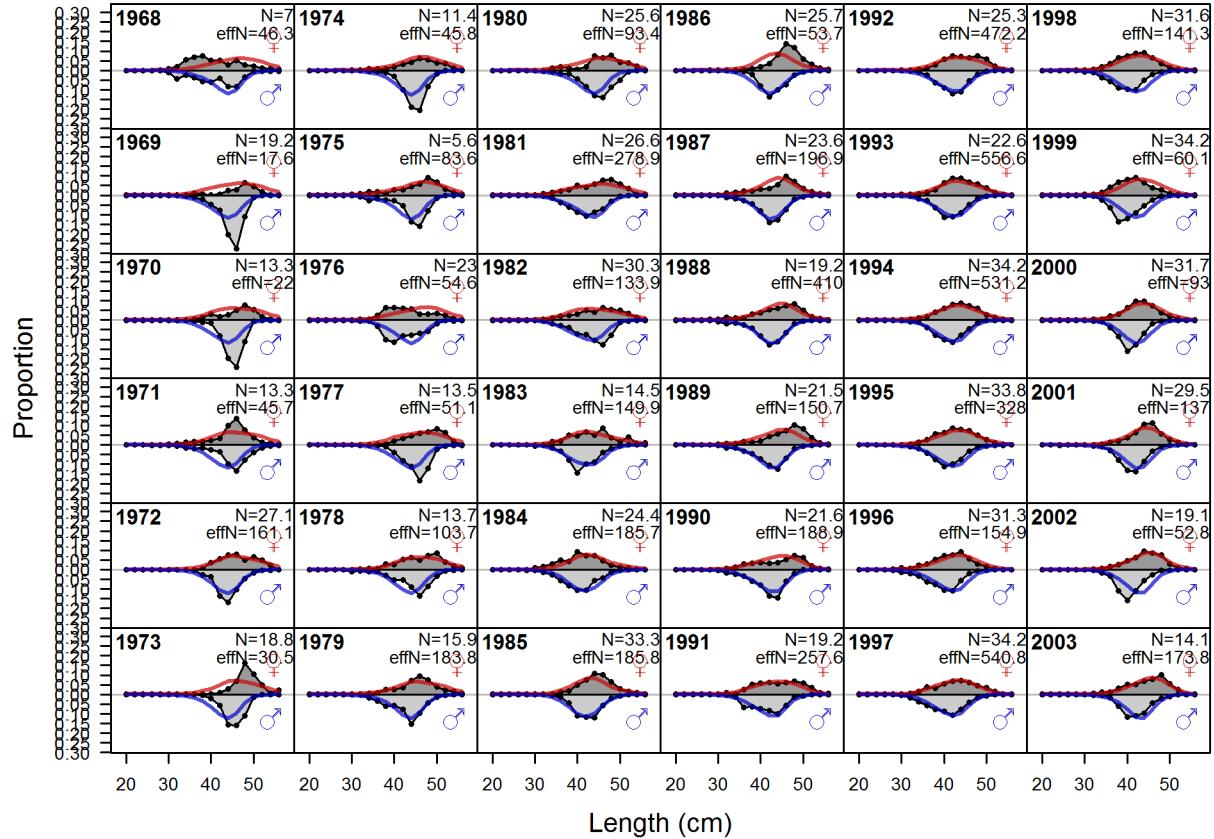
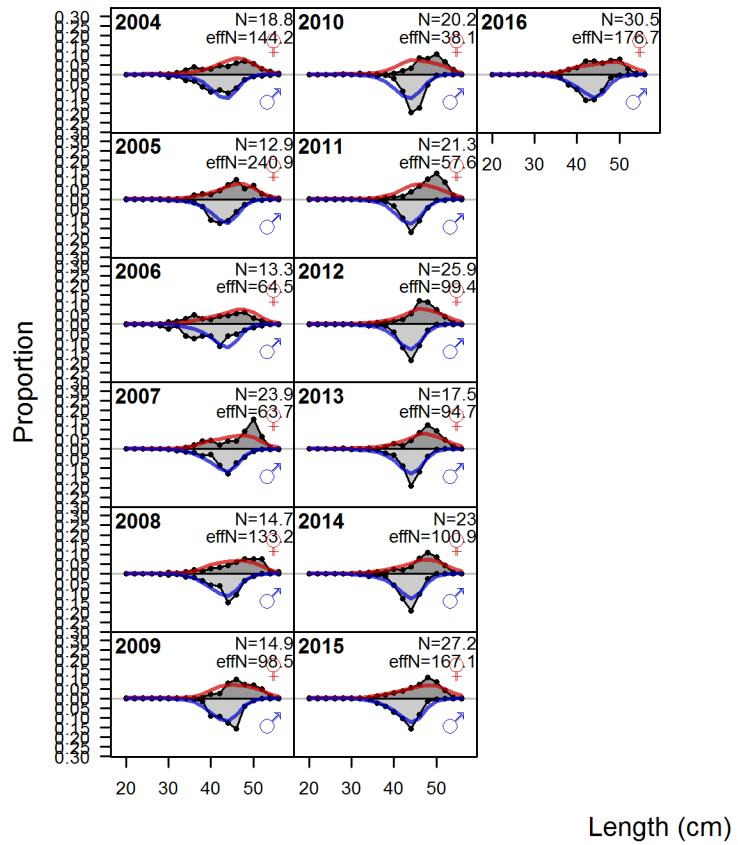


Figure 19: **Northern model** Length comps, retained, Commercial Fishery (plot 1 of 2) `fig:mod1_1_com`

Length comps, retained, Commercial Fishery



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Figure continued from previous page

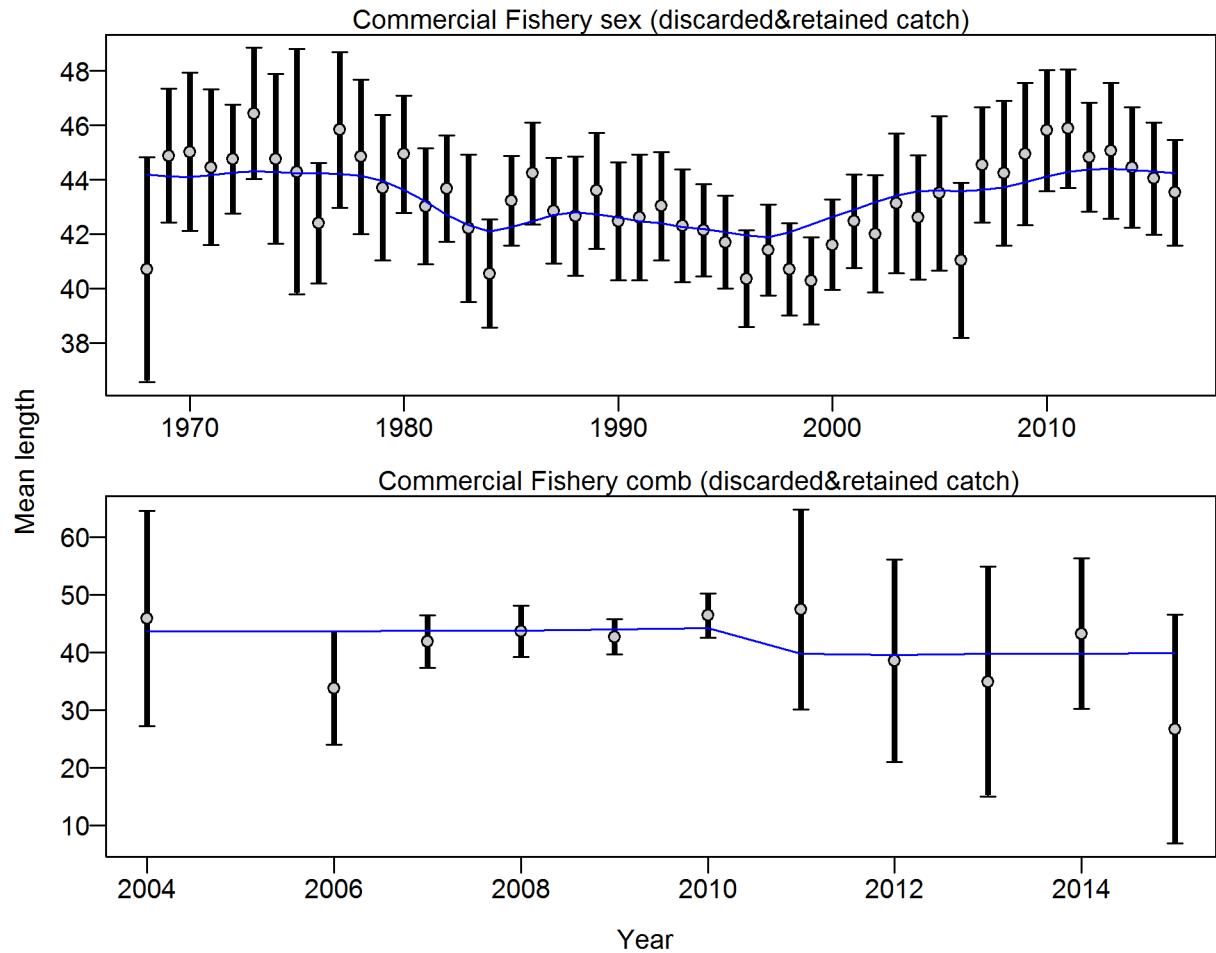


Figure 20: **Northern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

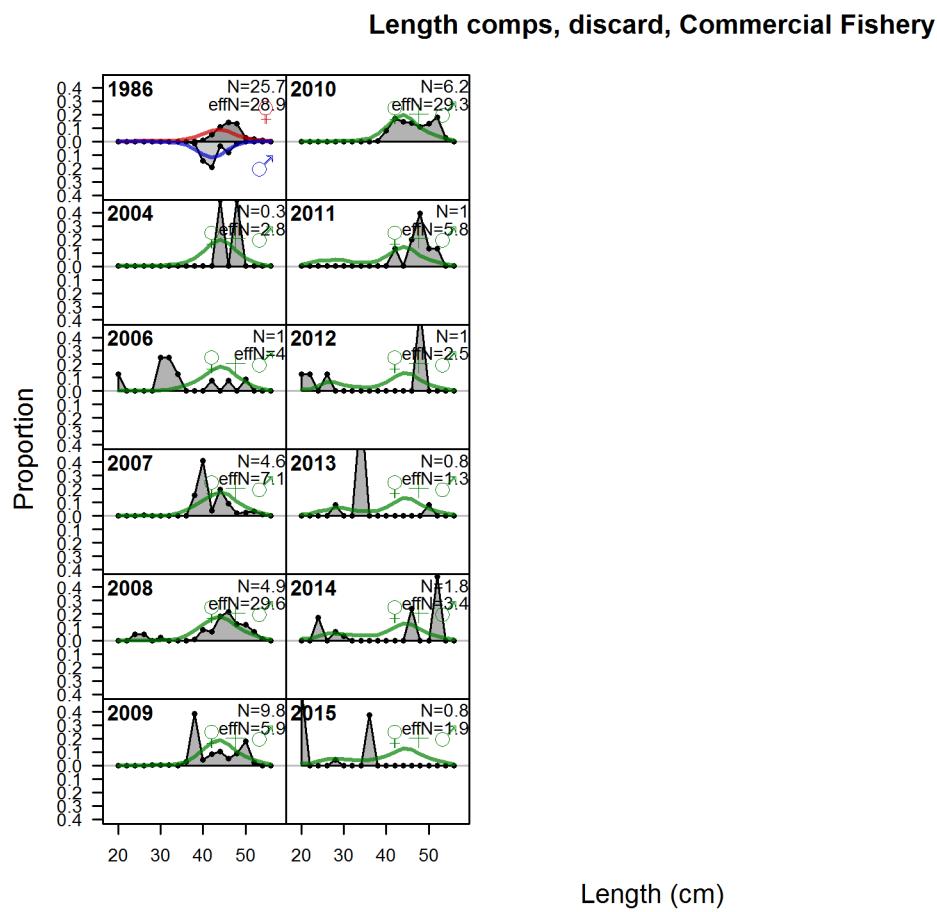


Figure 21: **Northern model** Length comps, discard, Commercial Fishery fig:mod1_6_comp_lenf

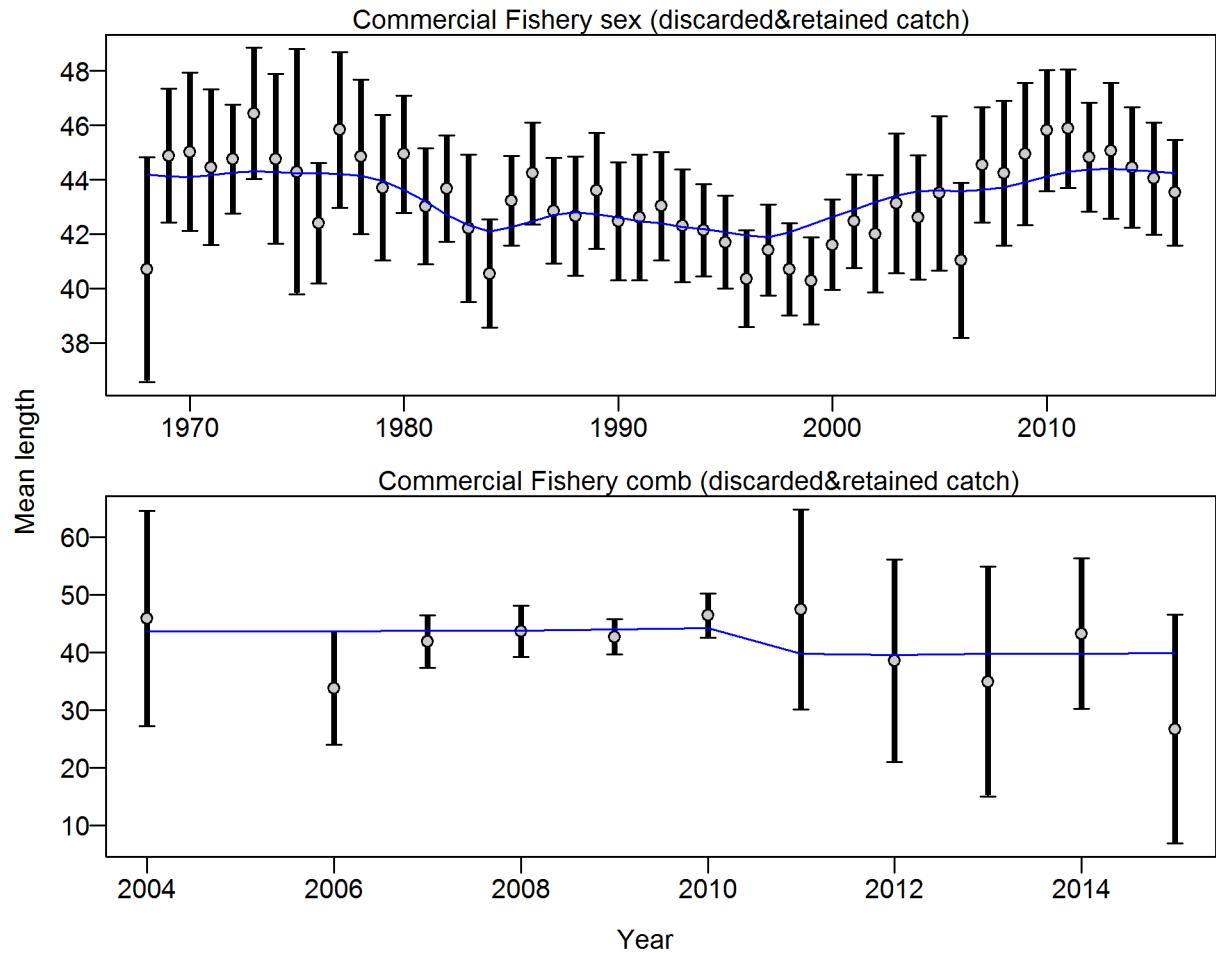


Figure 22: **Northern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

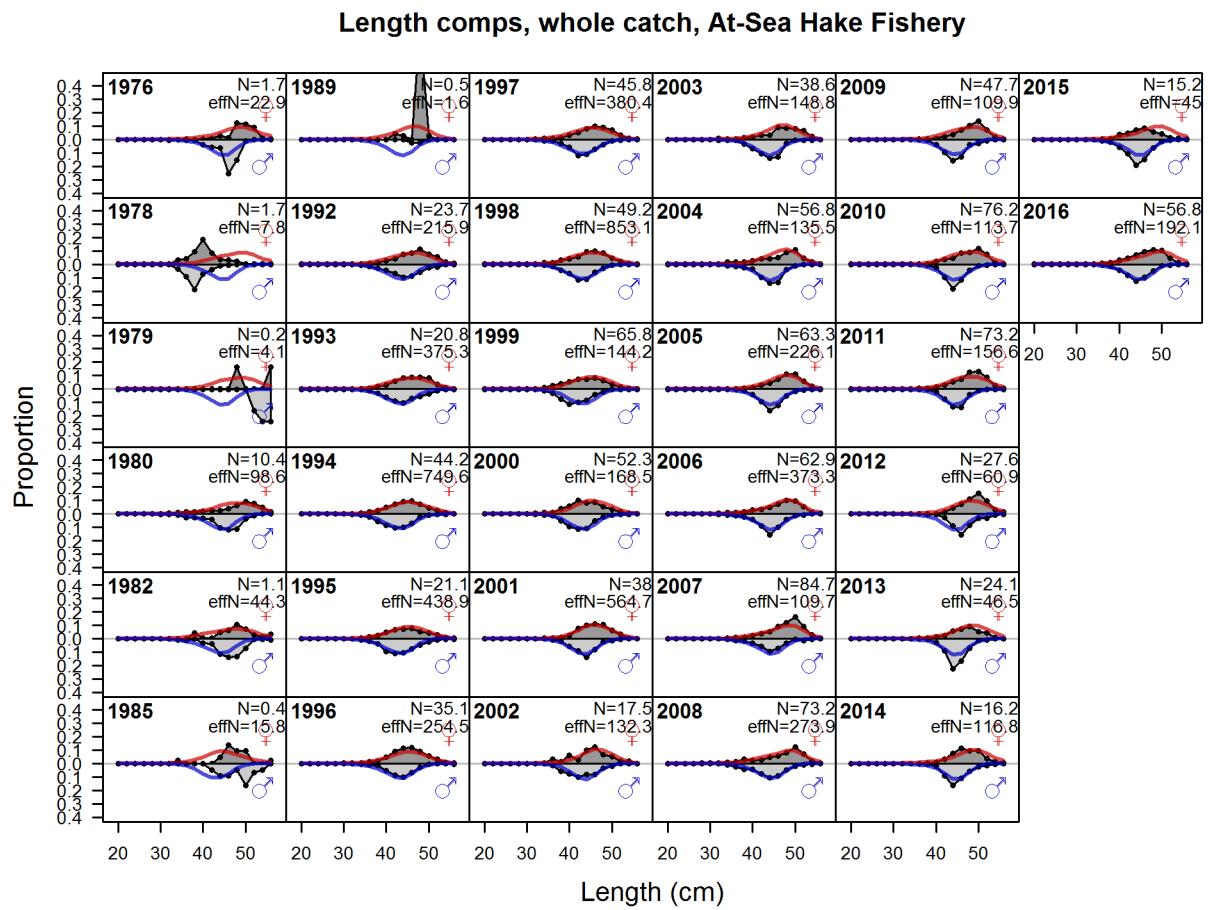


Figure 23: Northern model Length comps, whole catch, At-Sea Hake Fishery fig:mod1_10_comp_1

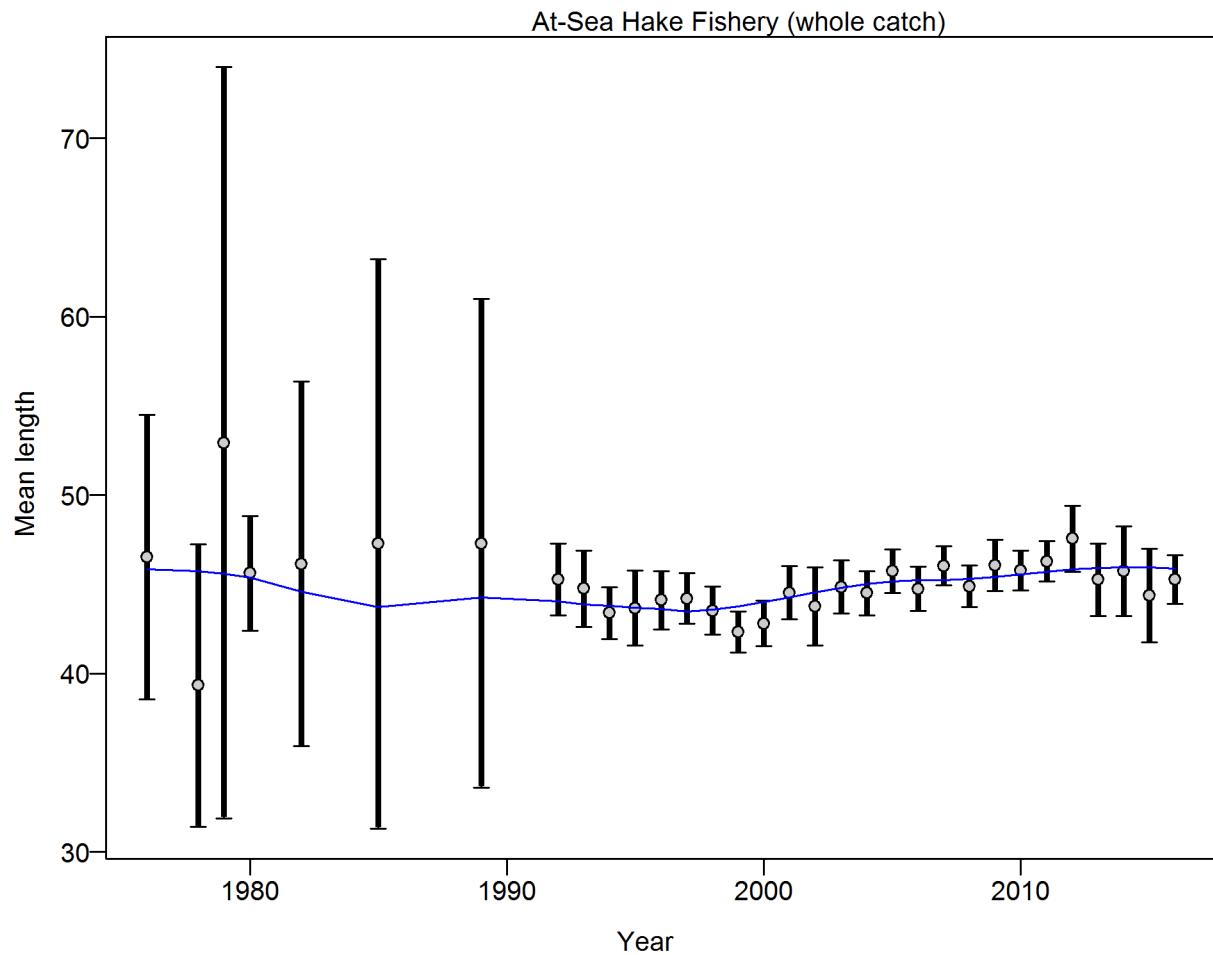


Figure 24: **Northern model** Mean length for At-Sea Hake Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for 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](#)

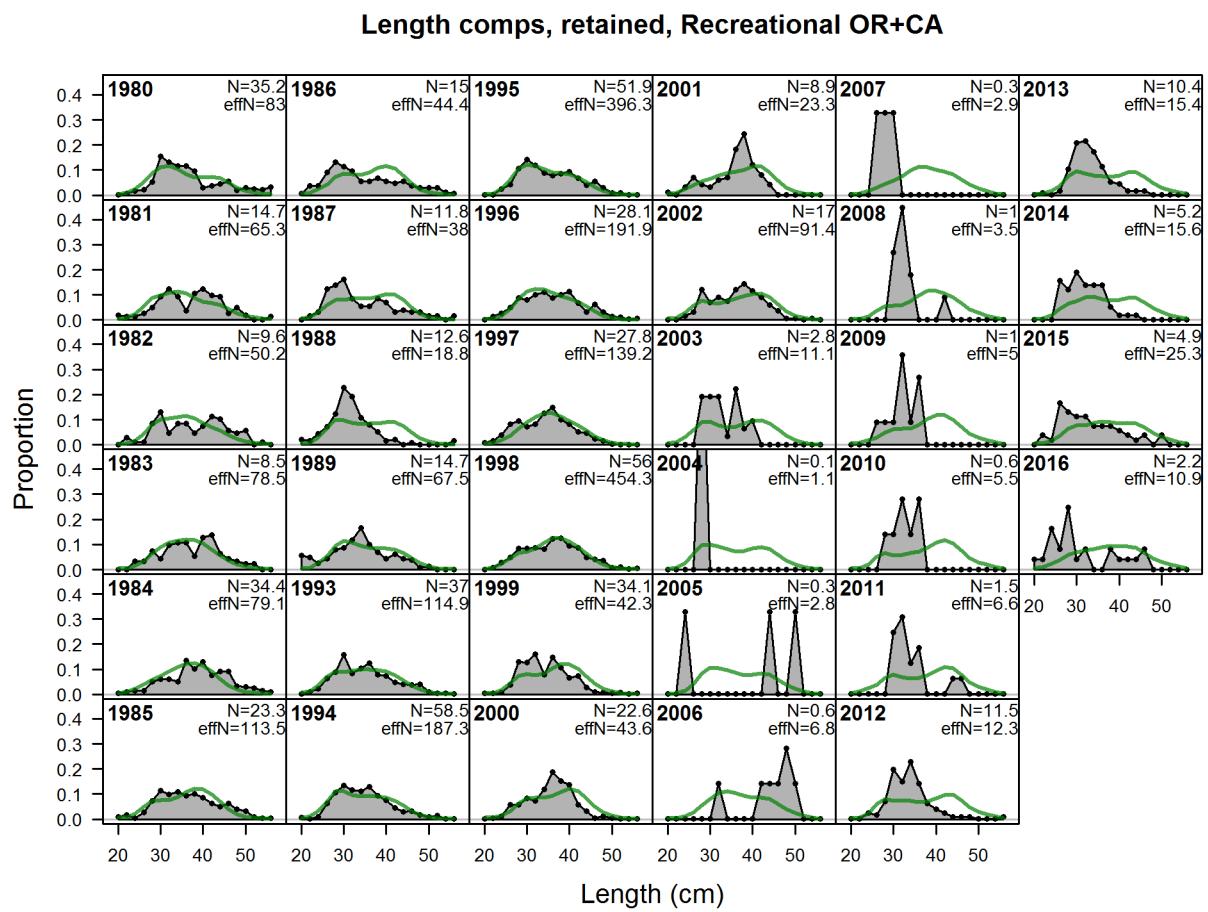


Figure 25: Northern model Length comps, retained, Recreational OR+CA fig:mod1_14_comp_le

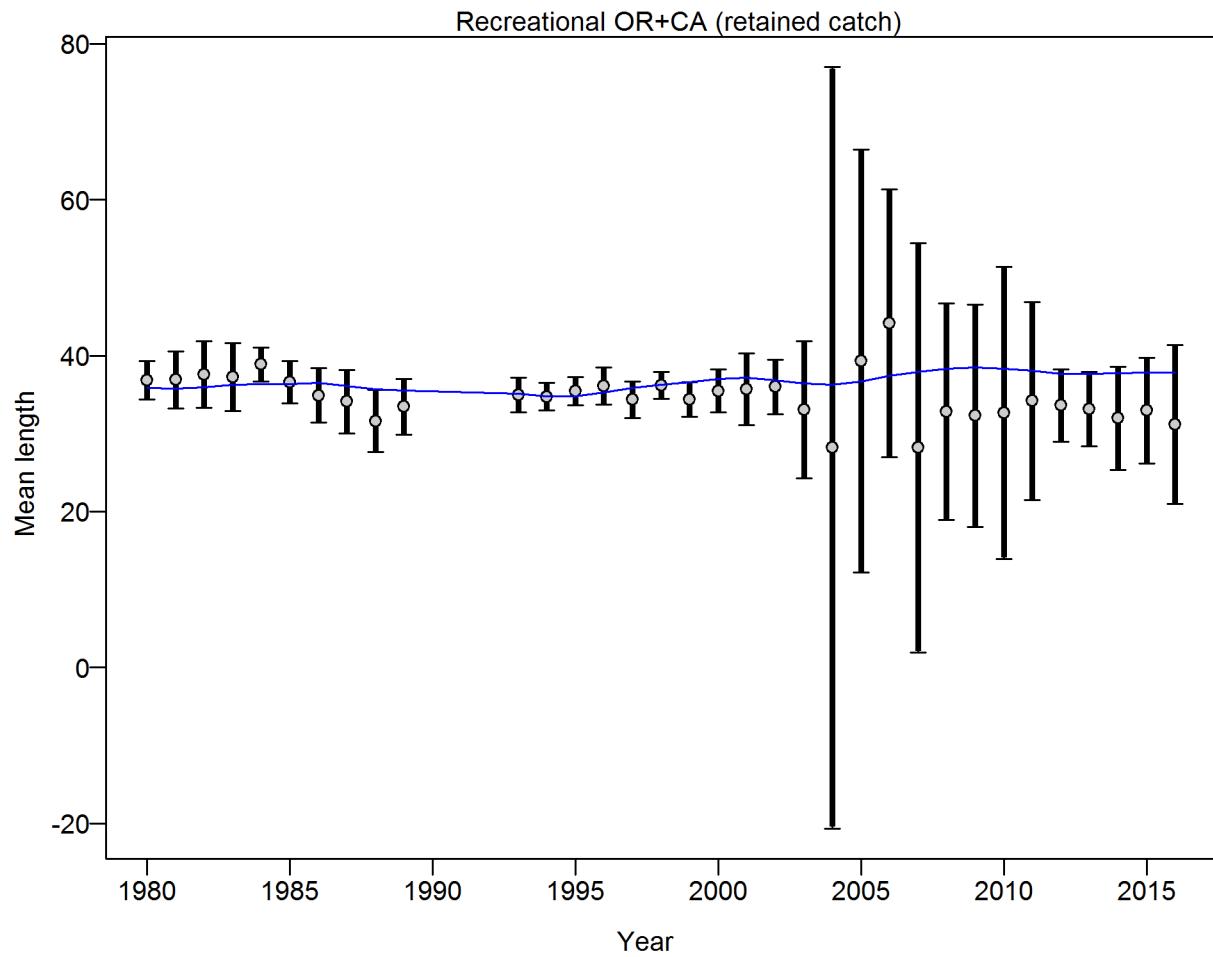


Figure 26: **Northern model** Mean length for Recreational OR+CA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

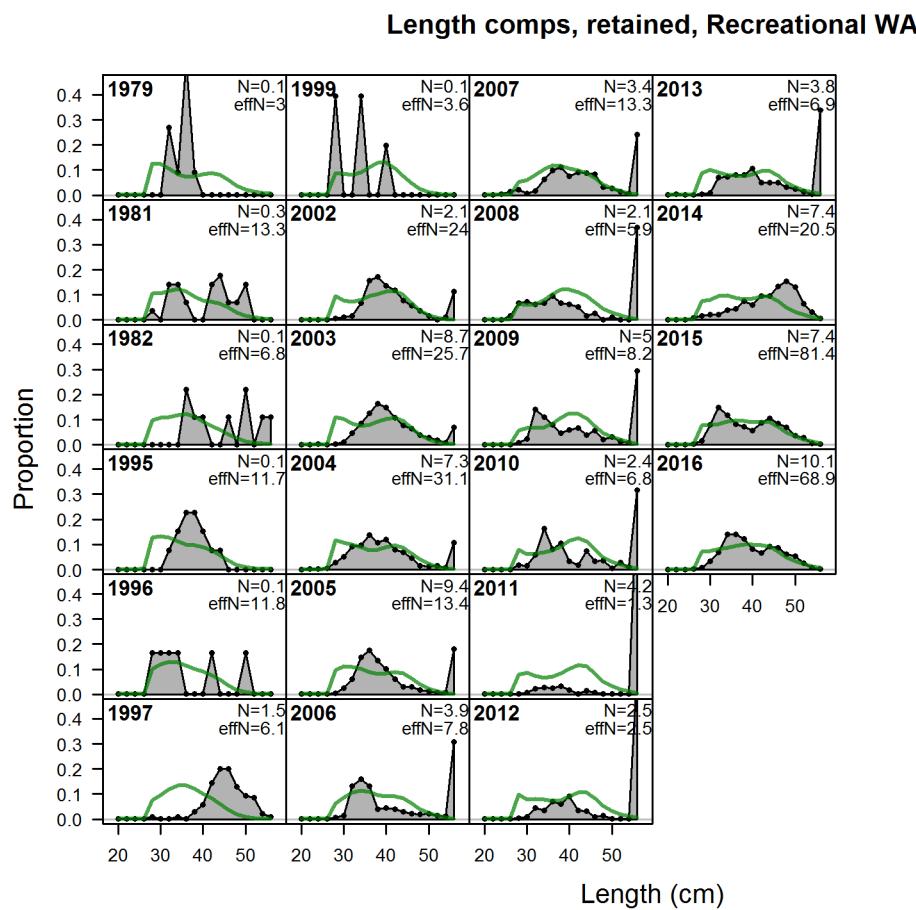


Figure 27: **Northern model** Length comps, retained, Recreational WA fig:mod1_18_comp_lenf

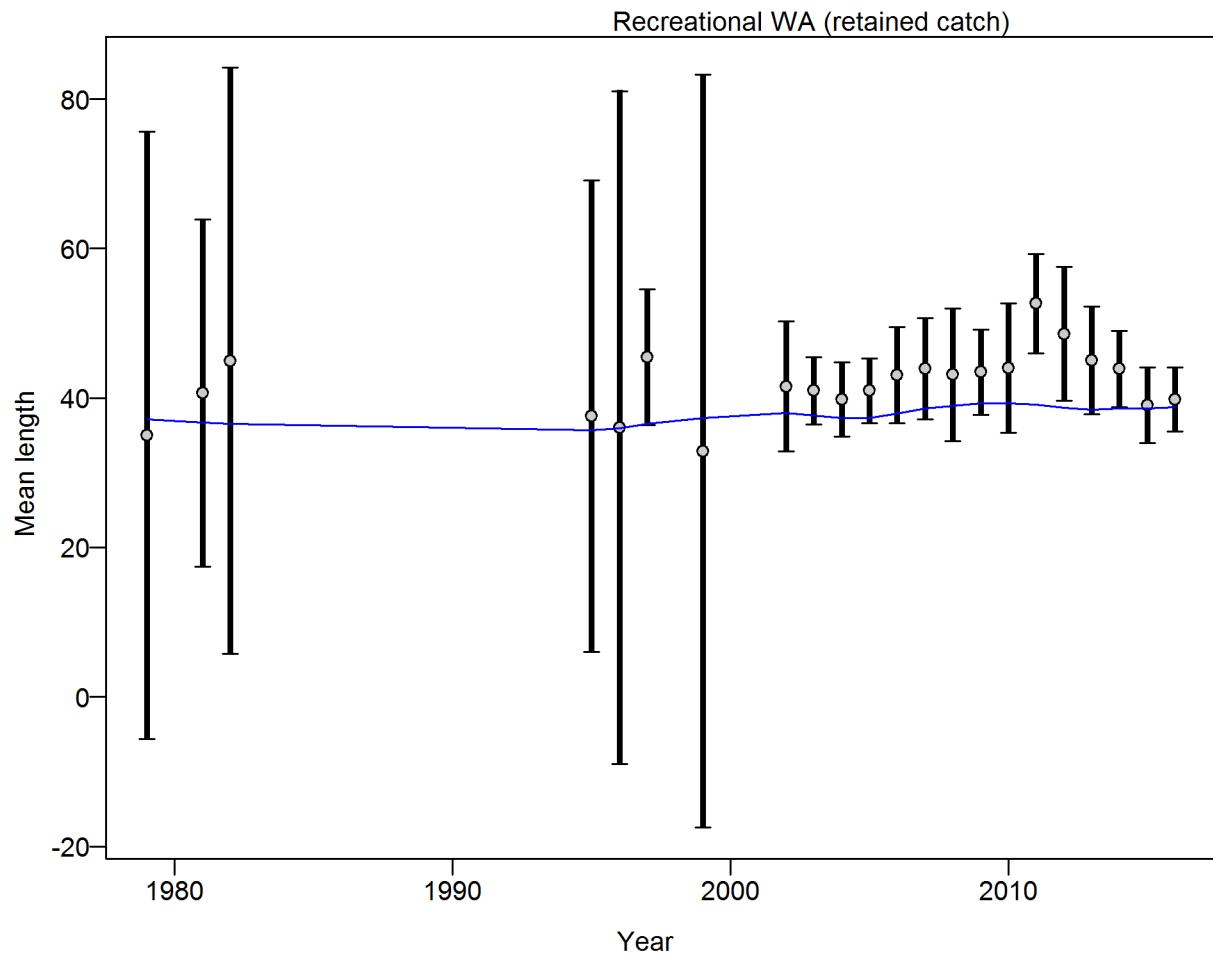


Figure 28: **Northern model** Mean length for Recreational WA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len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

Length comps, retained, Triennial Survey

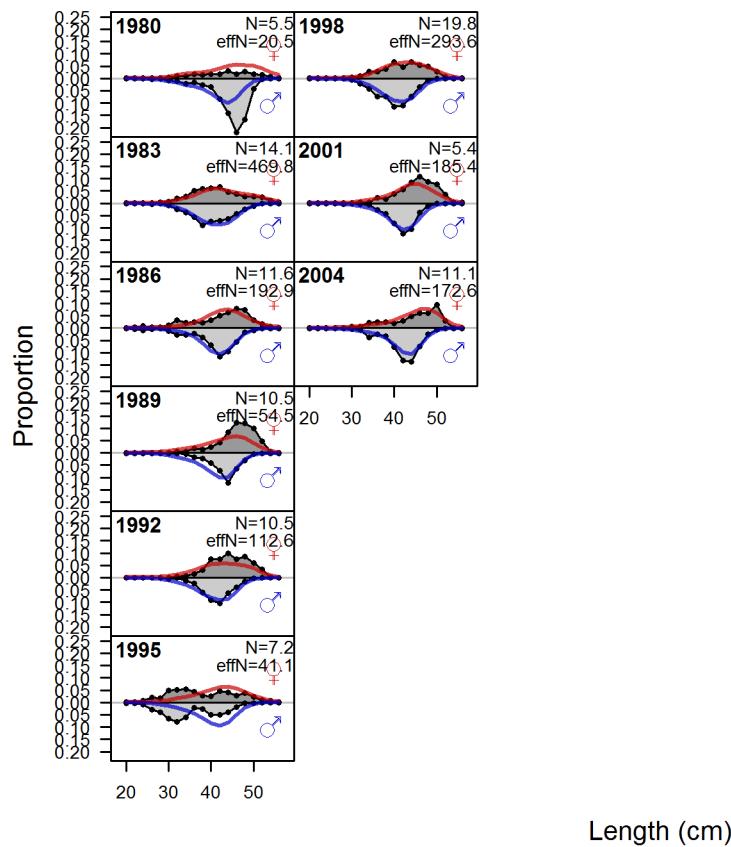


Figure 29: **Northern model** Length comps, retained, Triennial Survey fig:mod1_22_comp_lenf

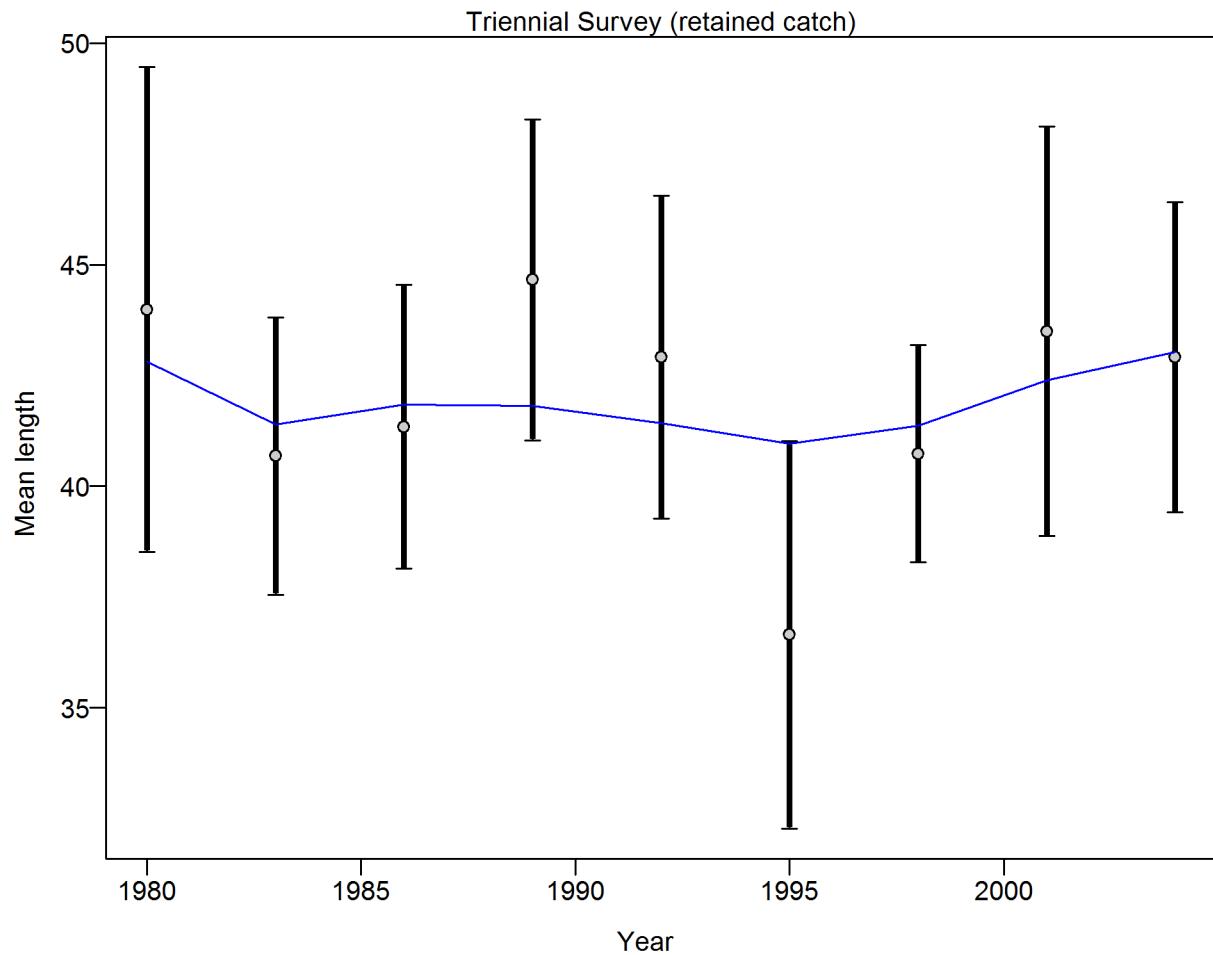


Figure 30: **Northern model** Mean length for Triennial Survey with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len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

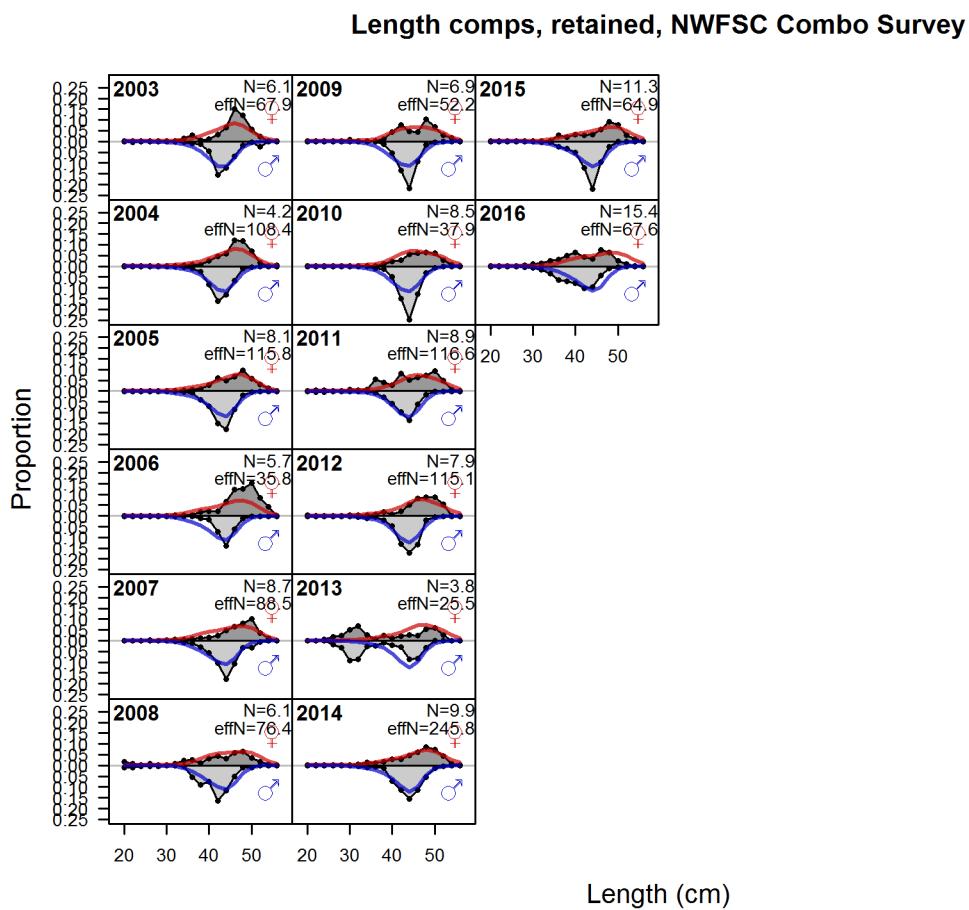


Figure 31: Northern model Length comps, retained, NWFSC Combo Survey | [fig:mod1_26_comp_1](#)

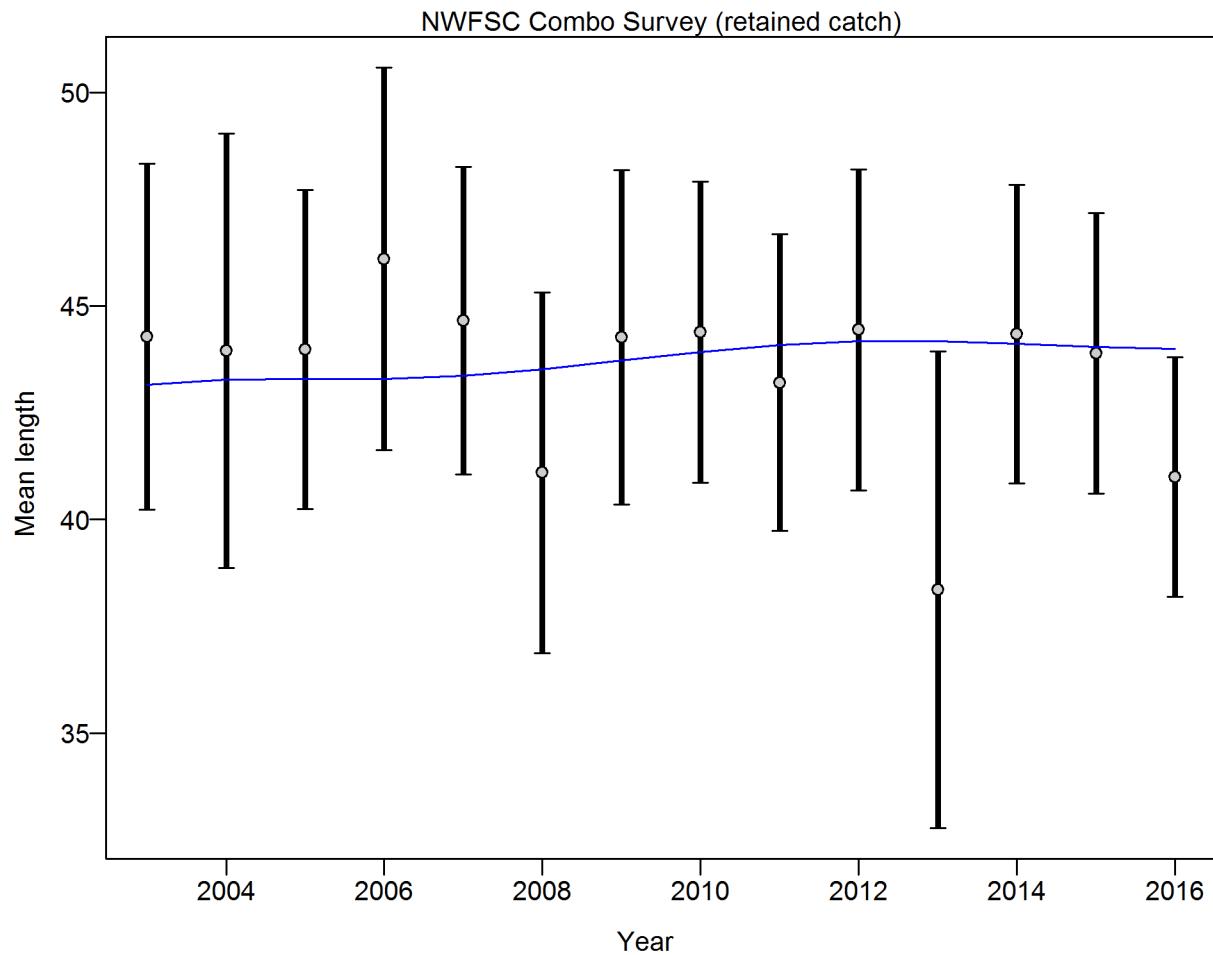


Figure 32: **Northern model** Mean length for NWFSC Combo Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

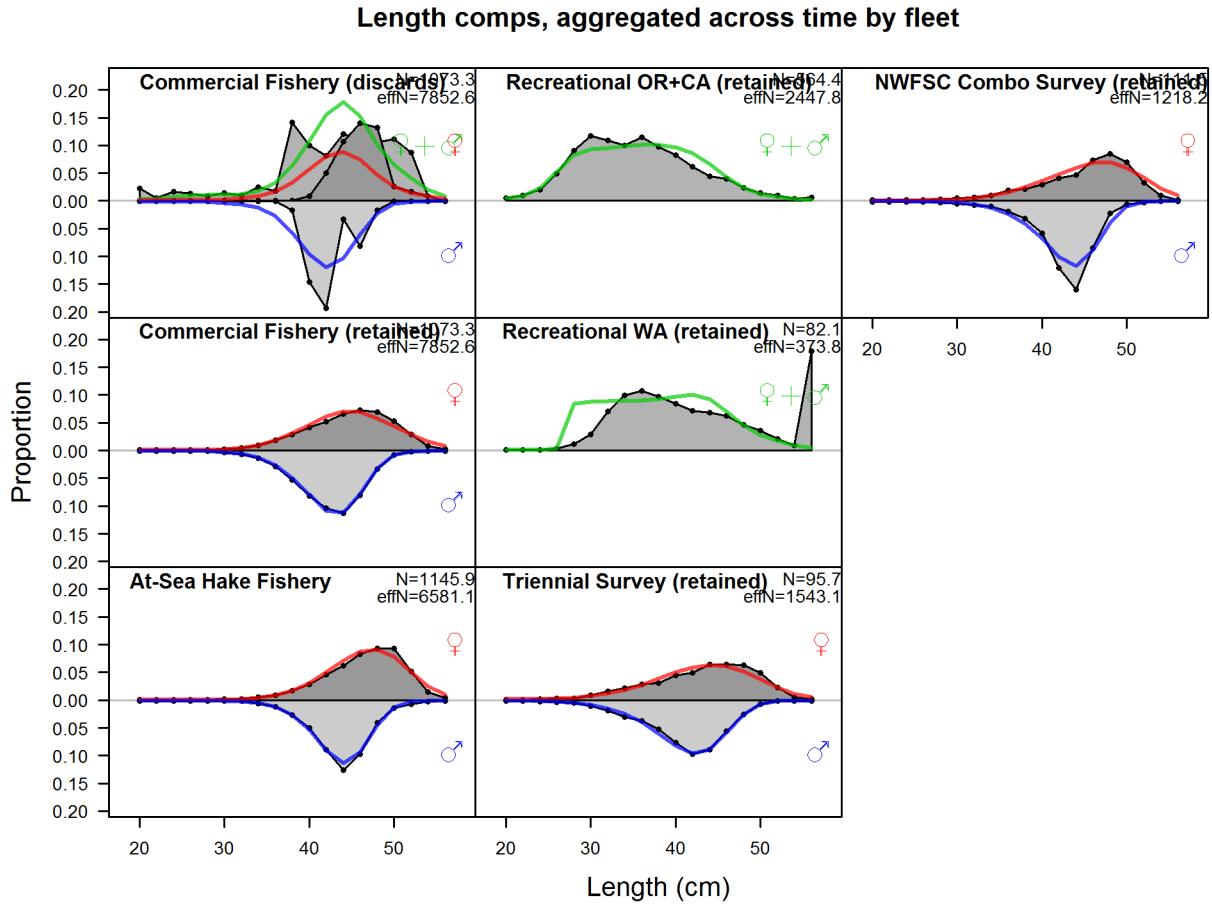


Figure 33: **Northern model** Length comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch.

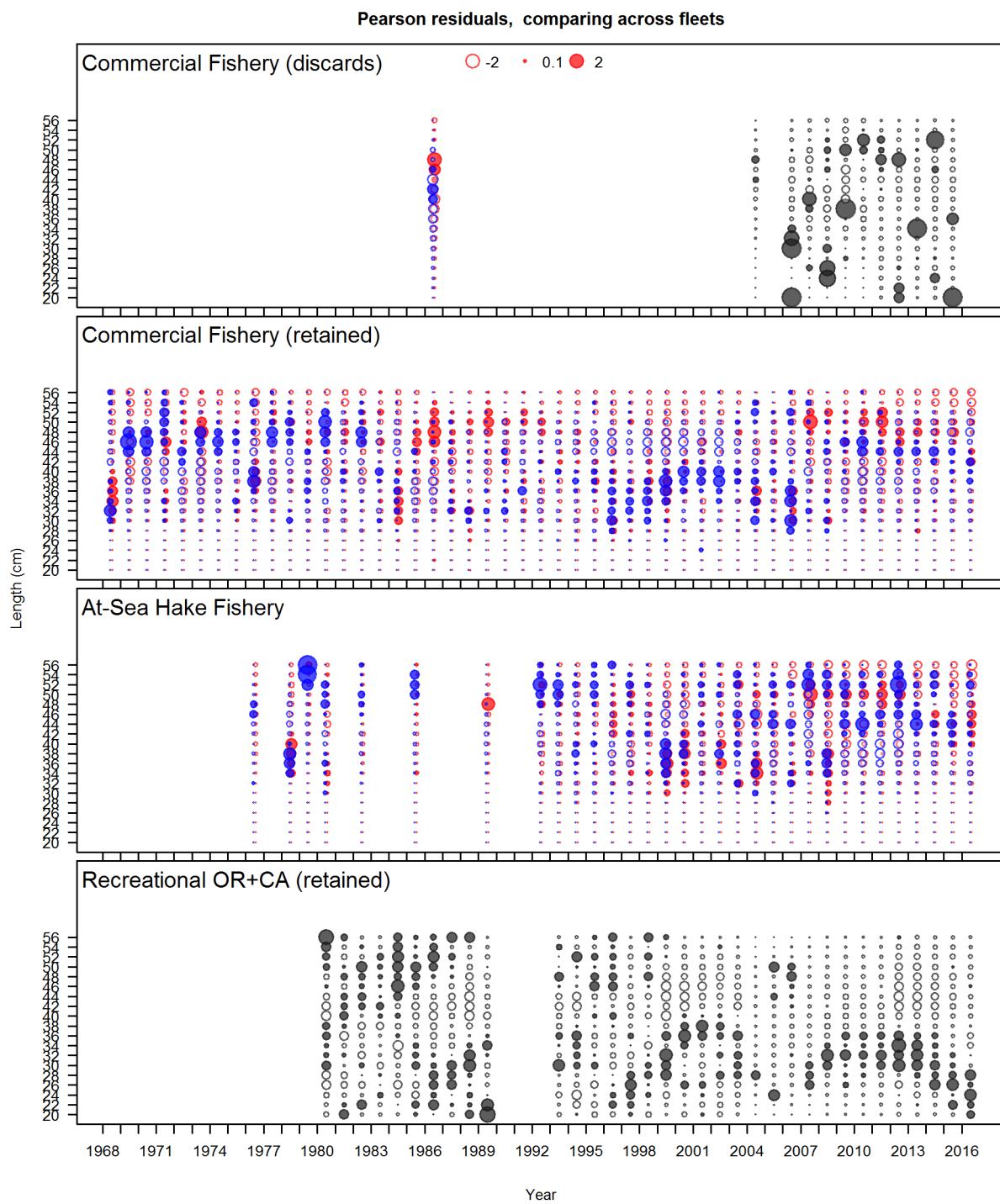


Figure 34: Length composition Pearson residuals for all fleets in the Northern model (Figure 1 of 2). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble colors indicate unsexed fish (gray), females (red), and males (blue).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

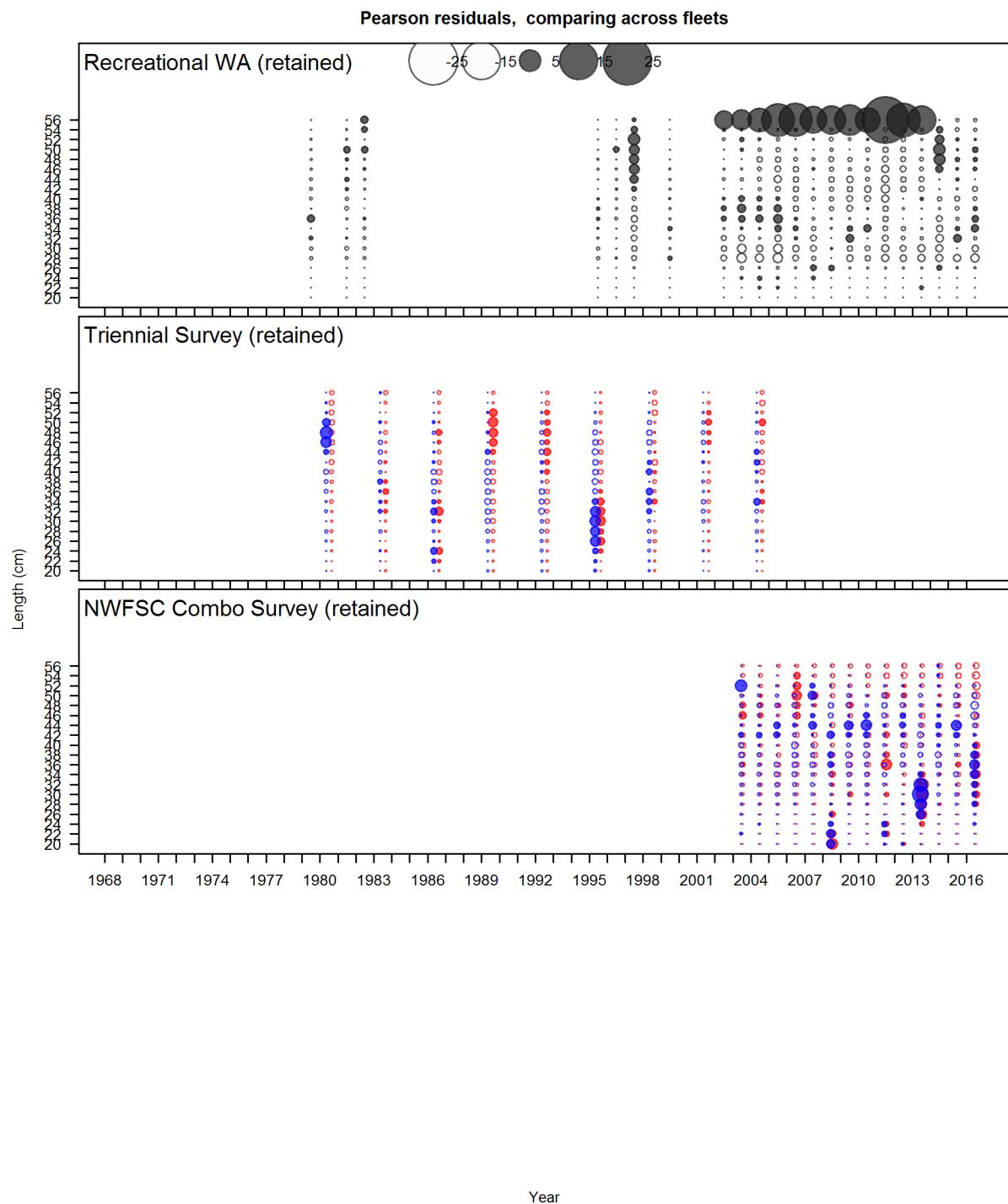


Figure 35: Length composition Pearson residuals for all fleets in the Northern model (Figure 2 of 2).
[fig:comp_Pearson_length_mod1_page2](#)

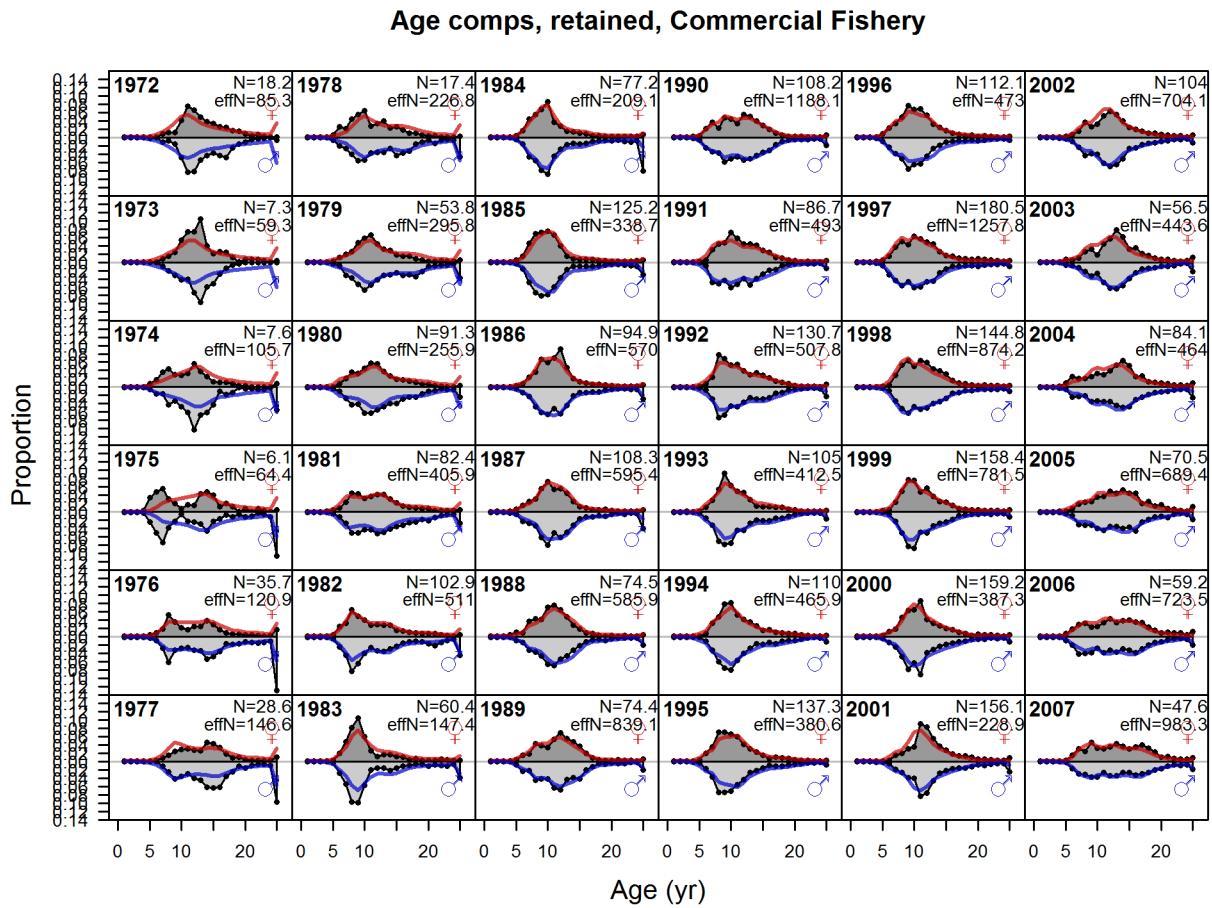
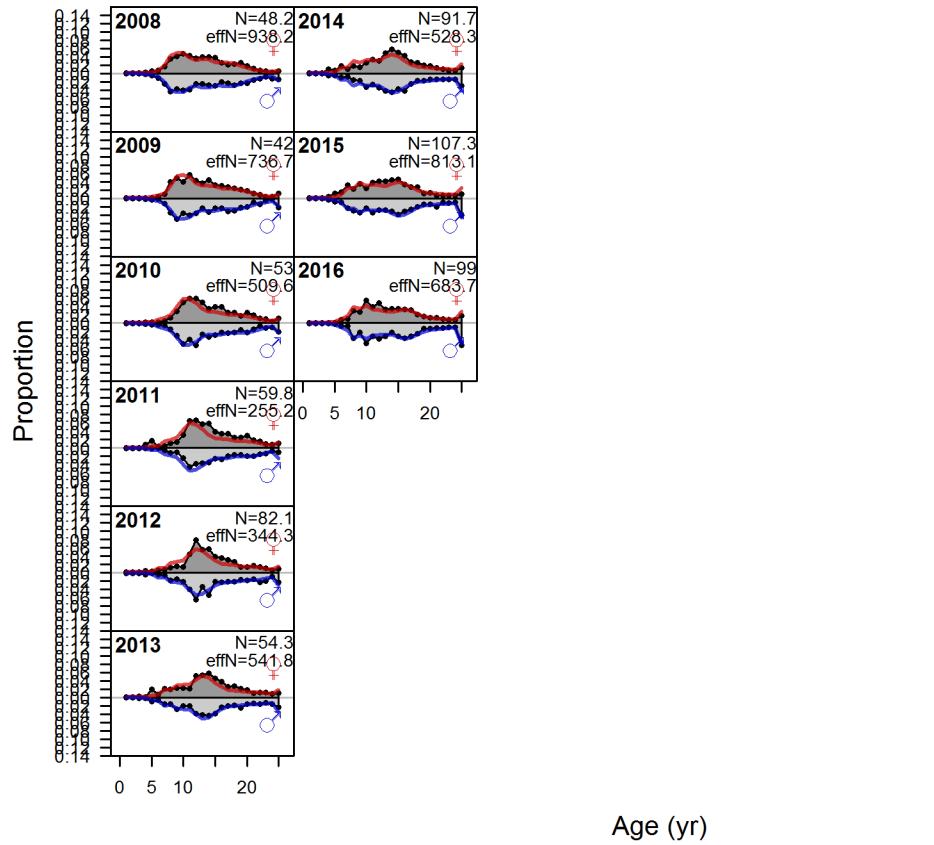


Figure 36: **Northern model** Age comps, retained, Commercial Fishery (plot 1 of 2) fig:mod1_1_comp

976 9.2.5 Fits to age compositions for Northern model

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

Age comps, retained, Commercial Fishery



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Figure continued from previous page

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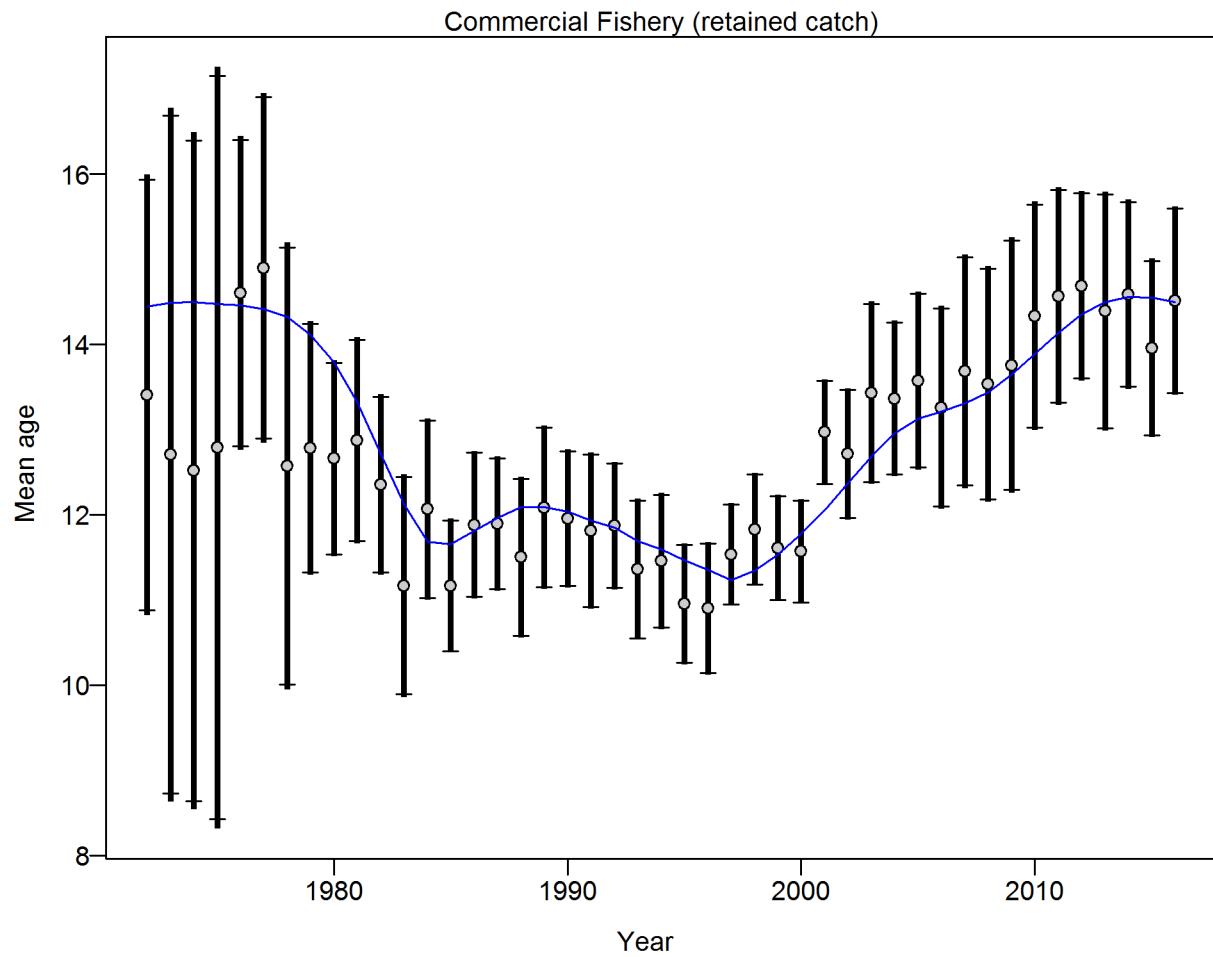


Figure 37: **Northern model** Mean age for Commercial Fishery with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age 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_agesfit_data_weighting_TA1.8_Comme](#)

Age comps, retained, Recreational WA

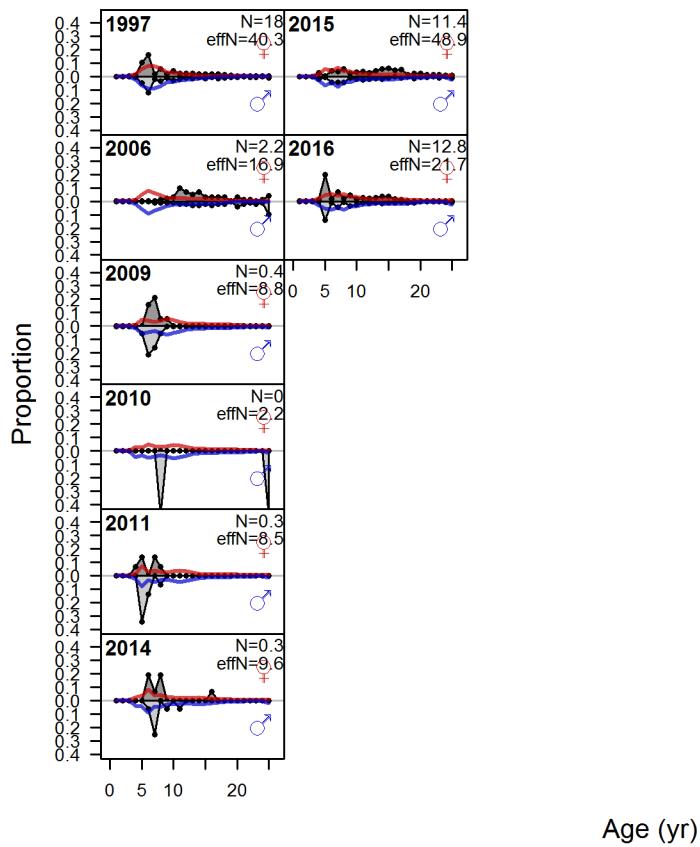


Figure 38: **Northern model** Age comps, retained, Recreational WA `fig:mod1_6_comp_agefit`

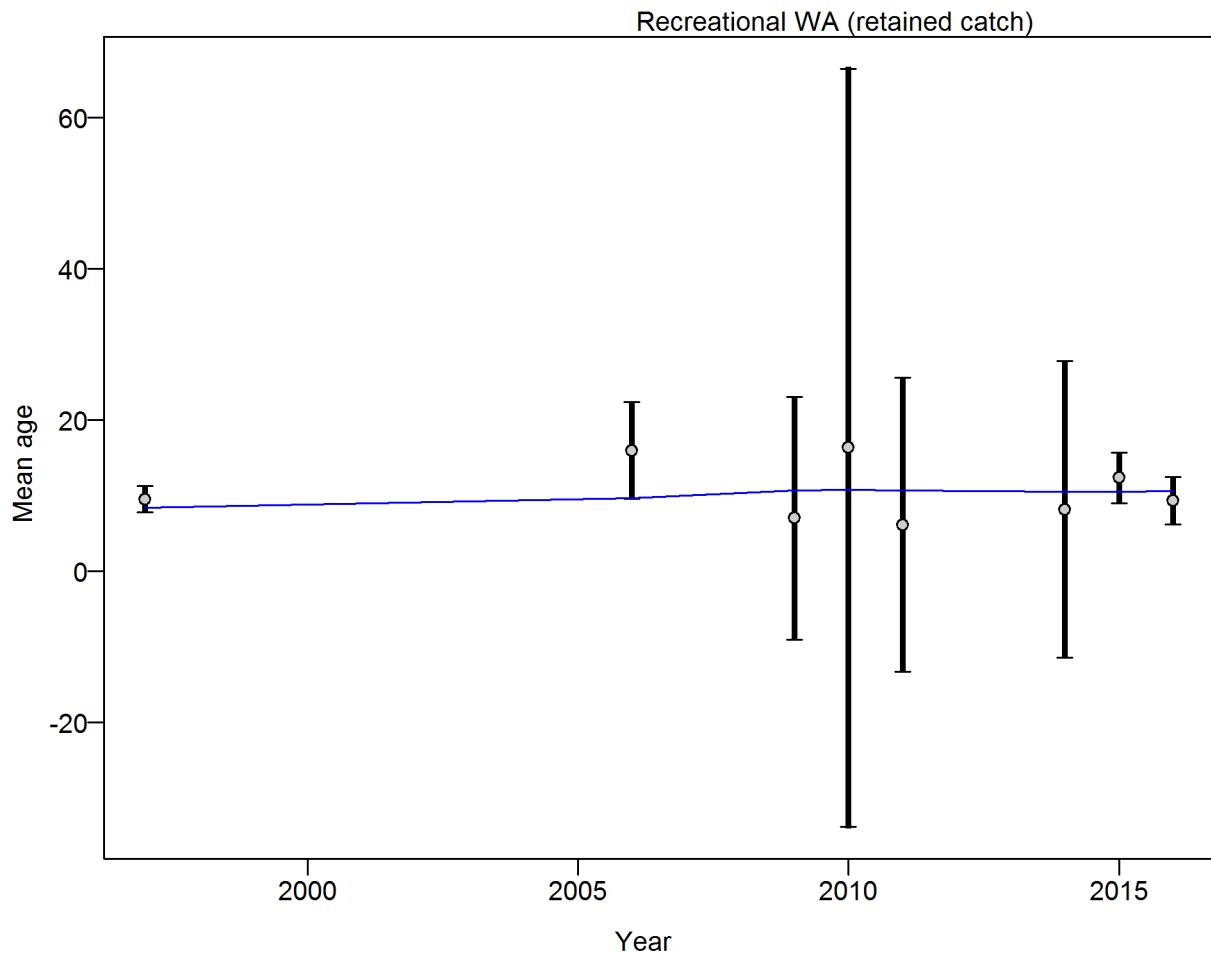


Figure 39: **Northern model** Mean age for Recreational WA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data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

Age comps, retained, Triennial Survey

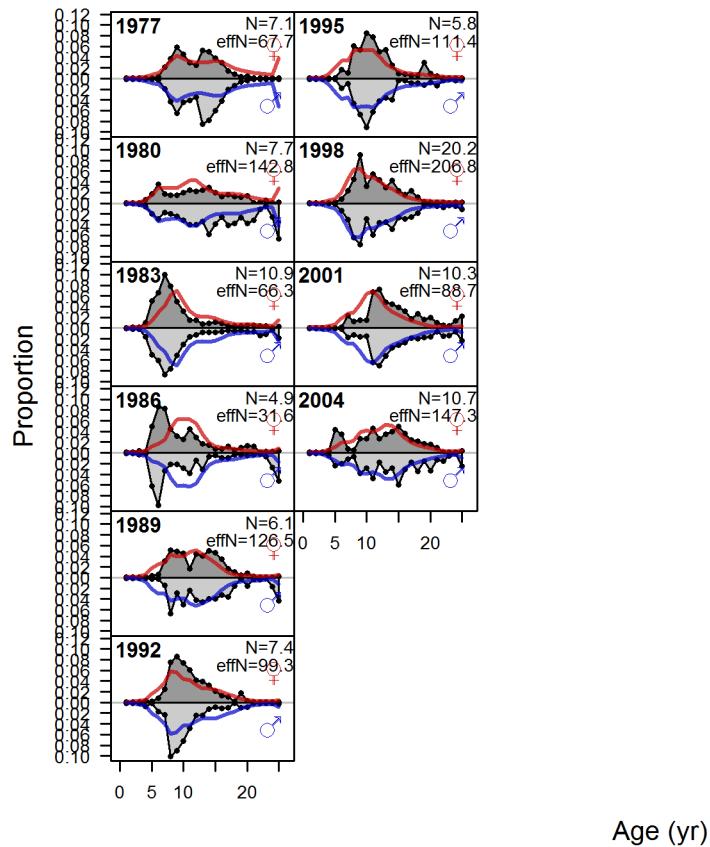


Figure 40: **Northern model** Age comps, retained, Triennial Survey fig:mod1_10_comp_agefit

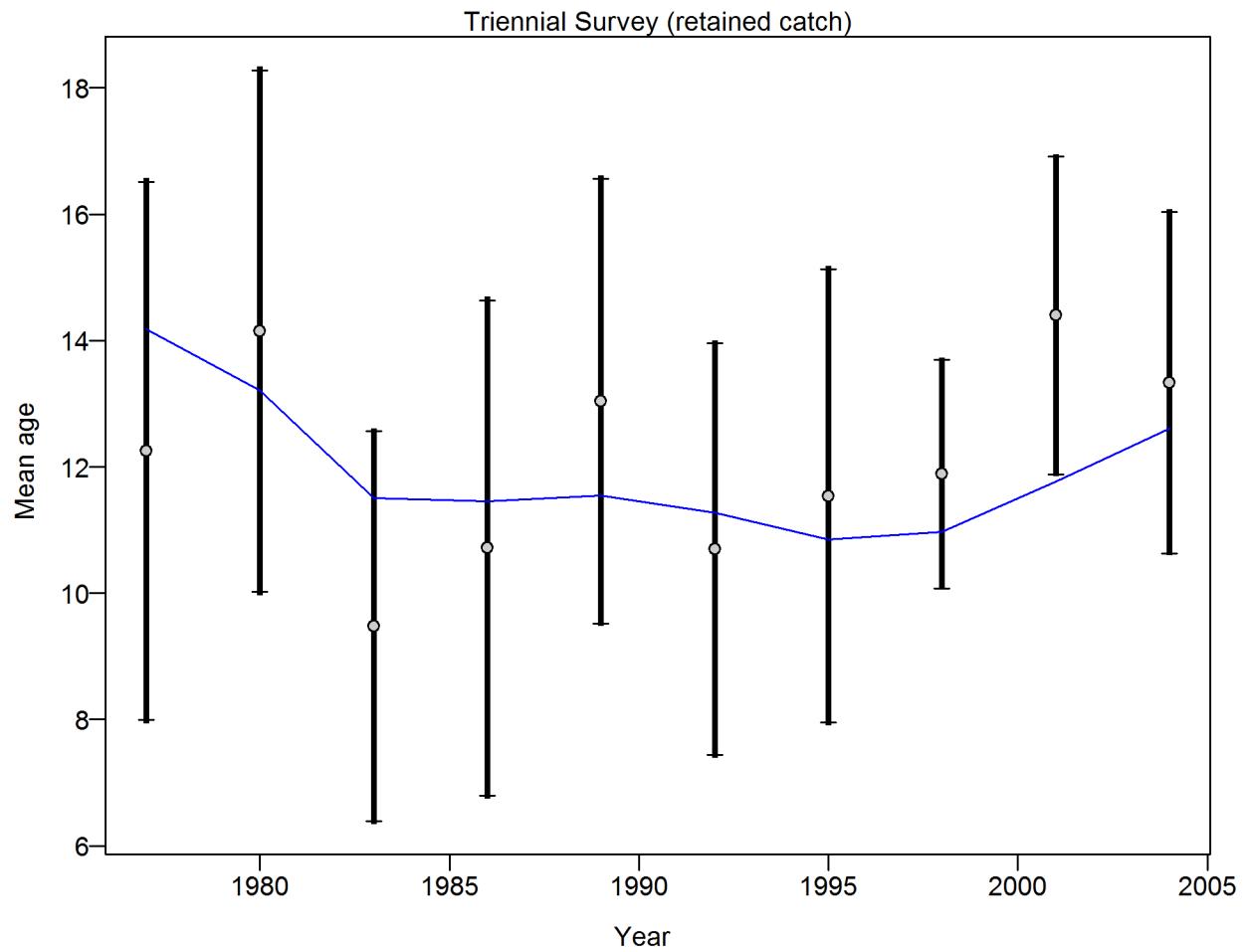


Figure 41: **Northern model** Mean age for Triennial Survey with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data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

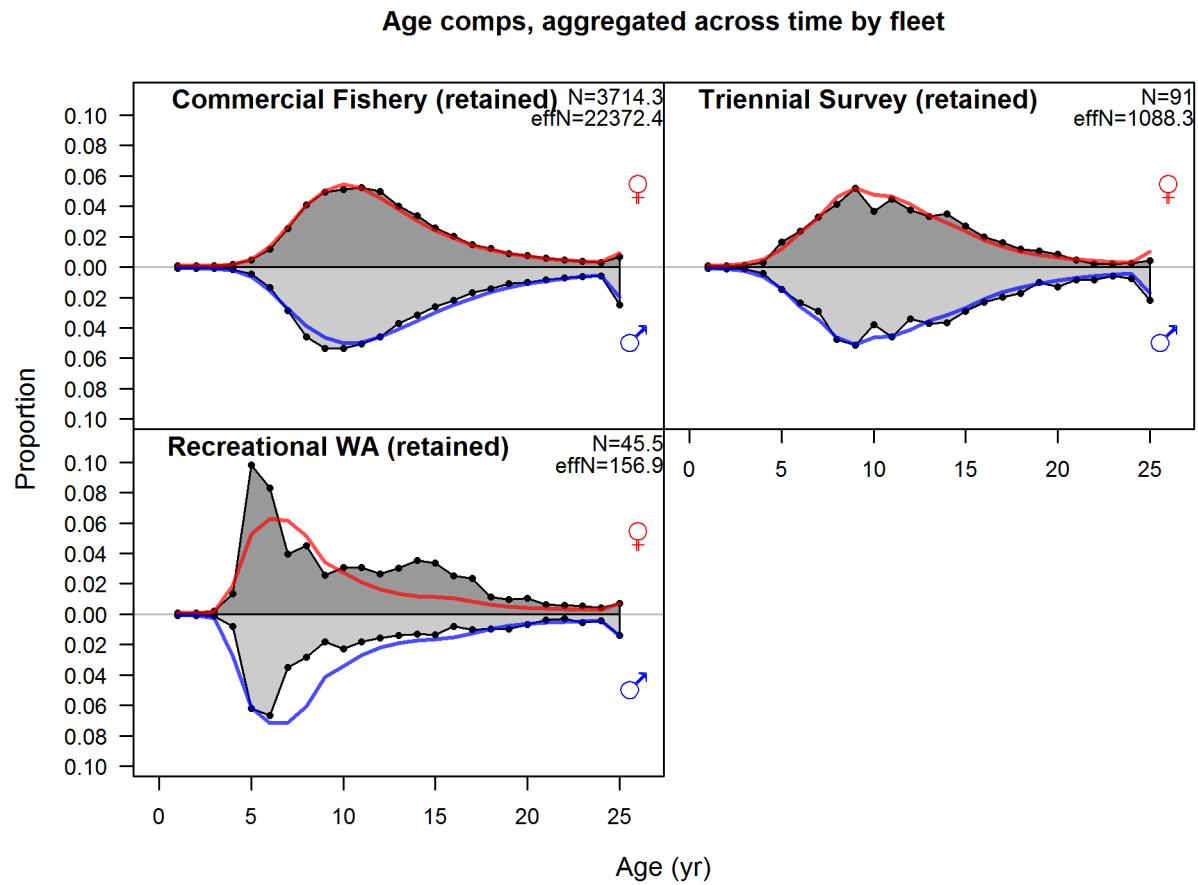


Figure 42: **Northern model** Age comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. [fig:mod1_14_comp_agefit__aggregated_across_time](#)

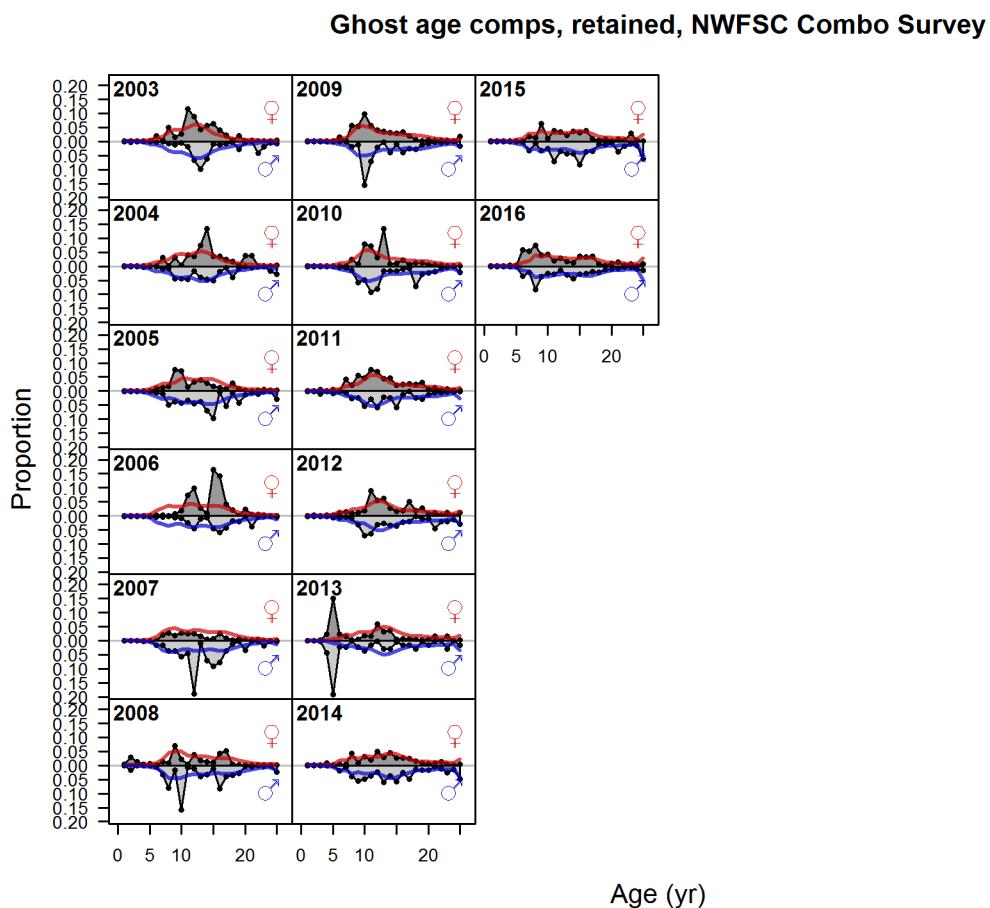


Figure 43: **Northern model** Ghost age comps, retained, NWFSC Combo Survey | [fig:mod1_16_comp](#)

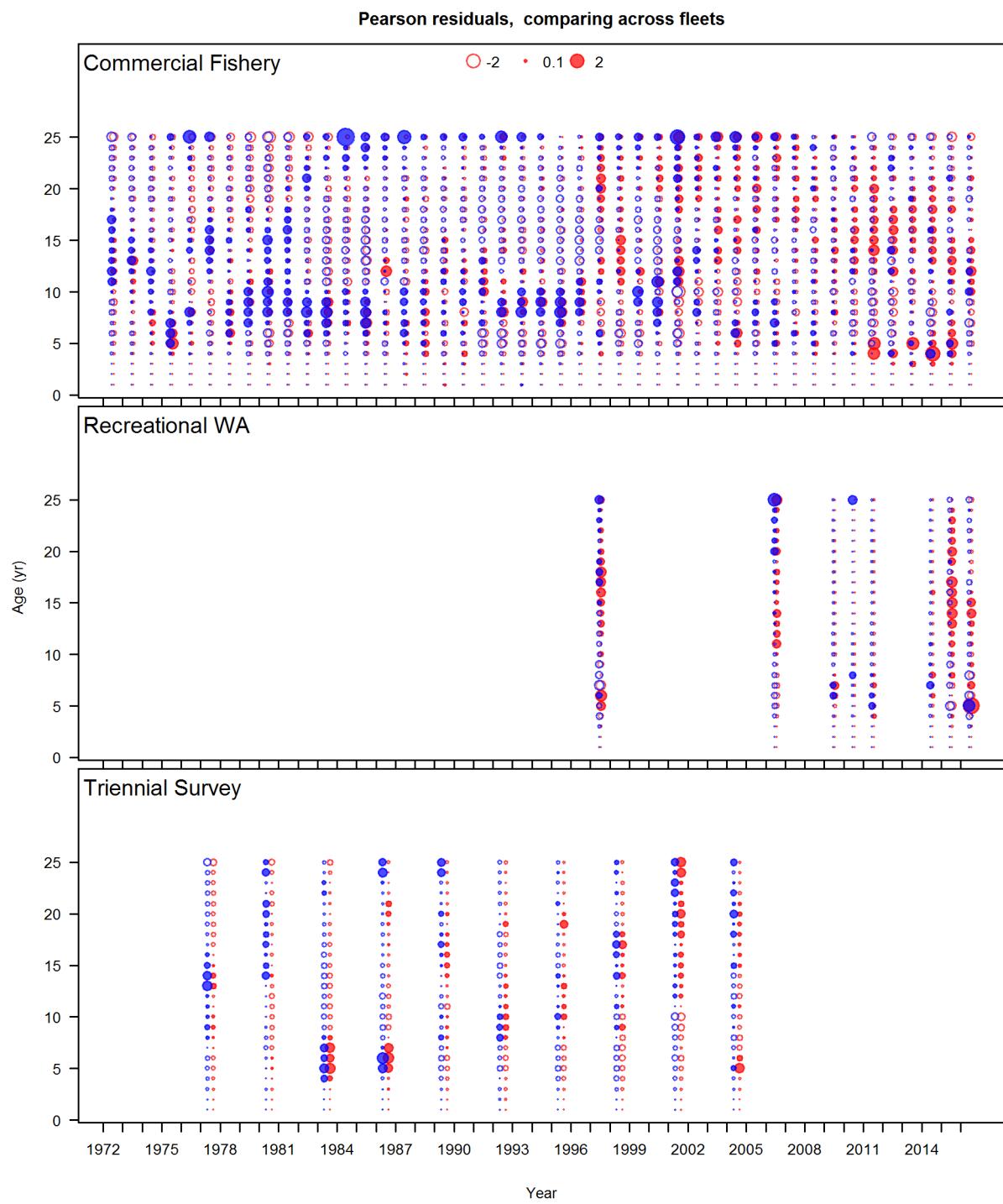


Figure 44: Age composition Pearson residuals for all fleets in the Northern model. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble colors indicate unsexed fish (gray), females (red), and males (blue).
fig:comp_Pearson_age_mod1

979 9.2.6 Fits to conditional-age-at-length compositions for Northern model
fits-to-conditional-age-at-length-compositions-for-northern-model

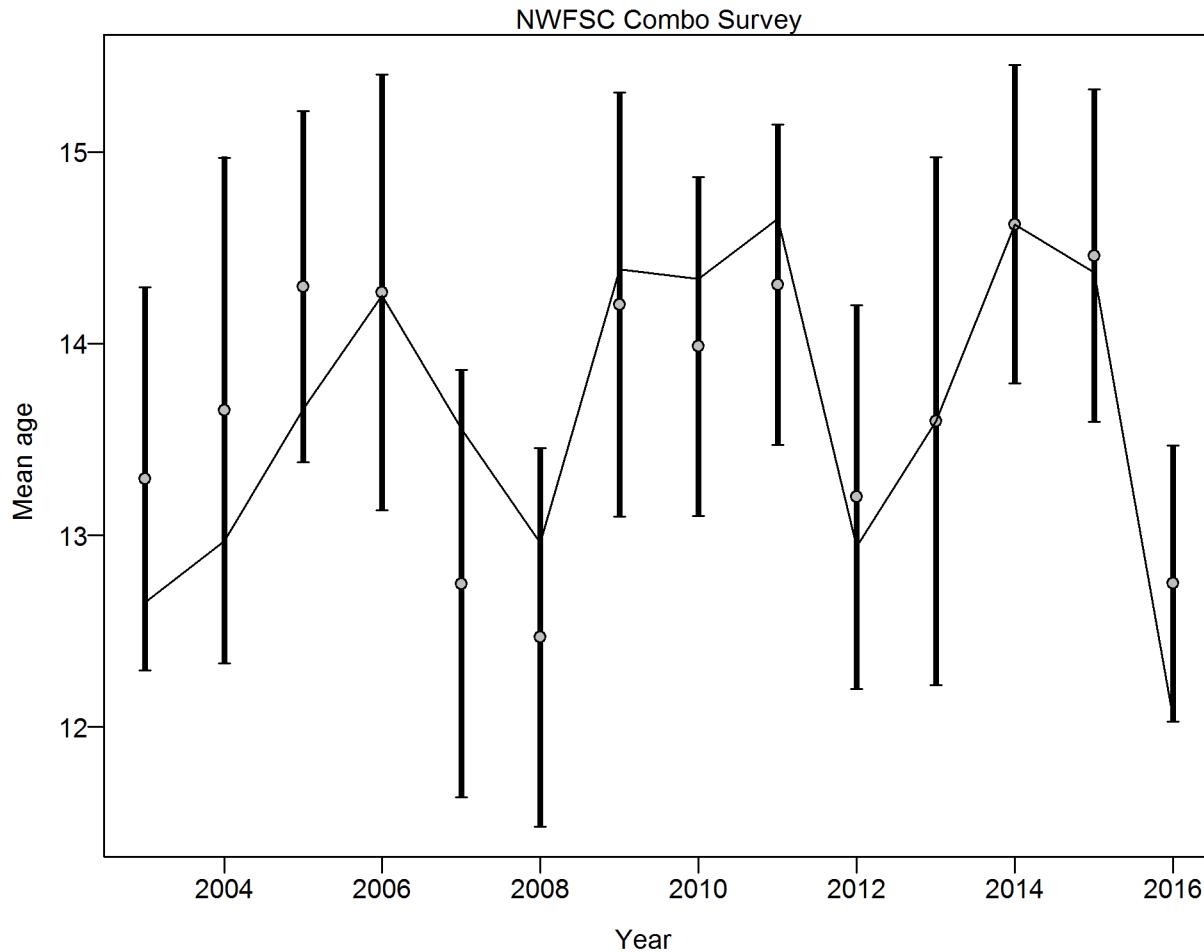


Figure 45: **Northern model** Mean age from conditional data (aggregated across length bins) for NWFSC Combo Survey with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based 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](#)

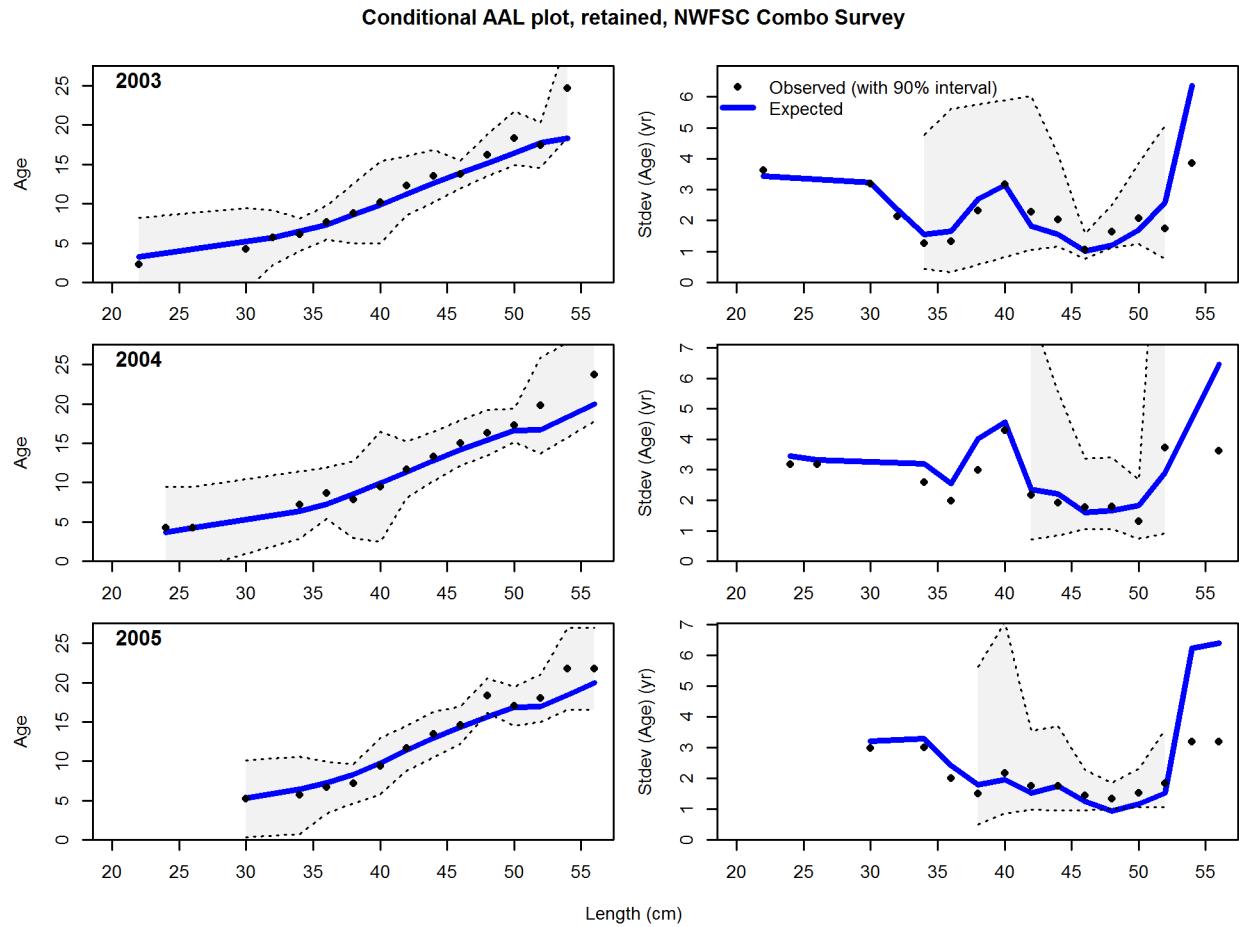
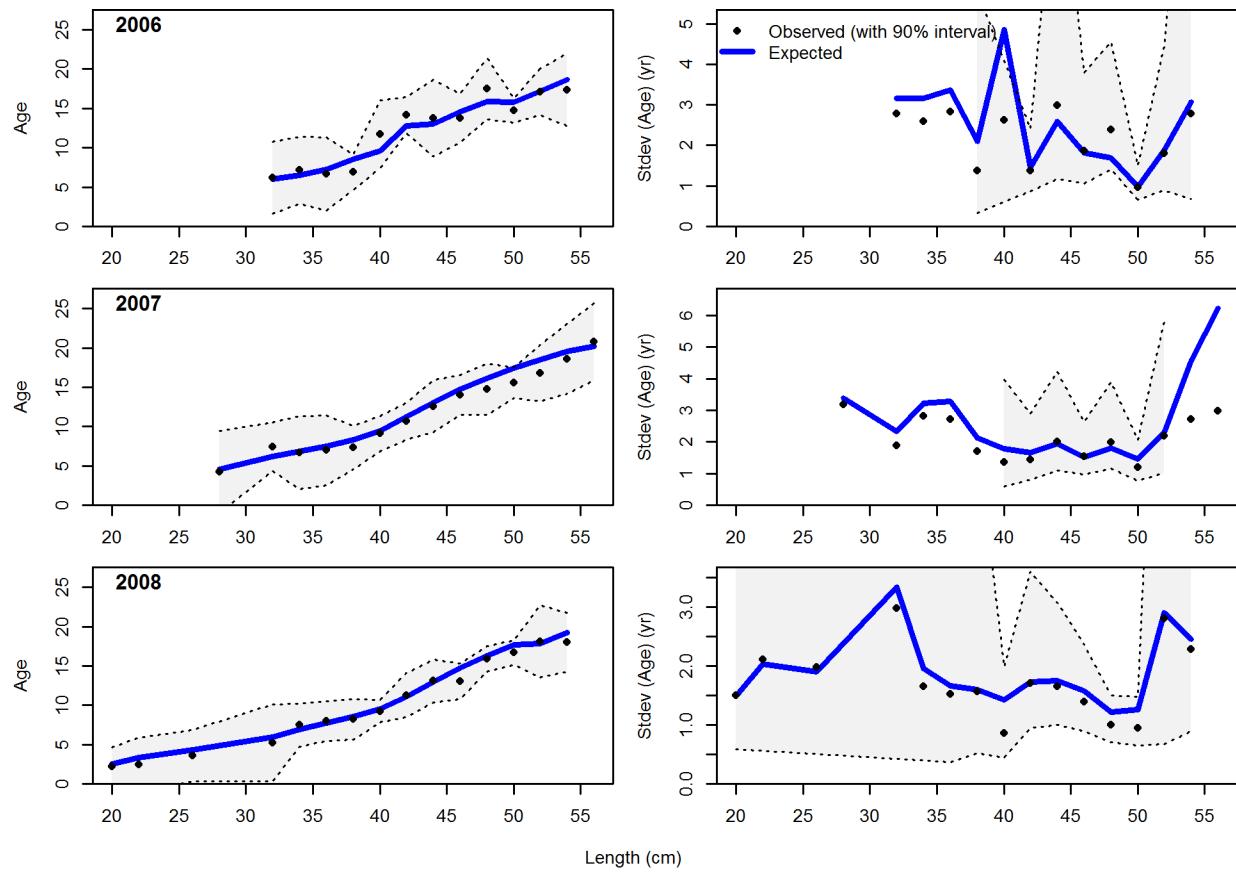


Figure 46: **Northern model** Conditional AAL plot, retained, NWFSC Combo Survey (plot 1 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution. | [fig:mod1_4_comp_condAALfitAndre_plotsfl6mkt2_page1](#)

Conditional AAL plot, retained, NWFSC Combo Survey

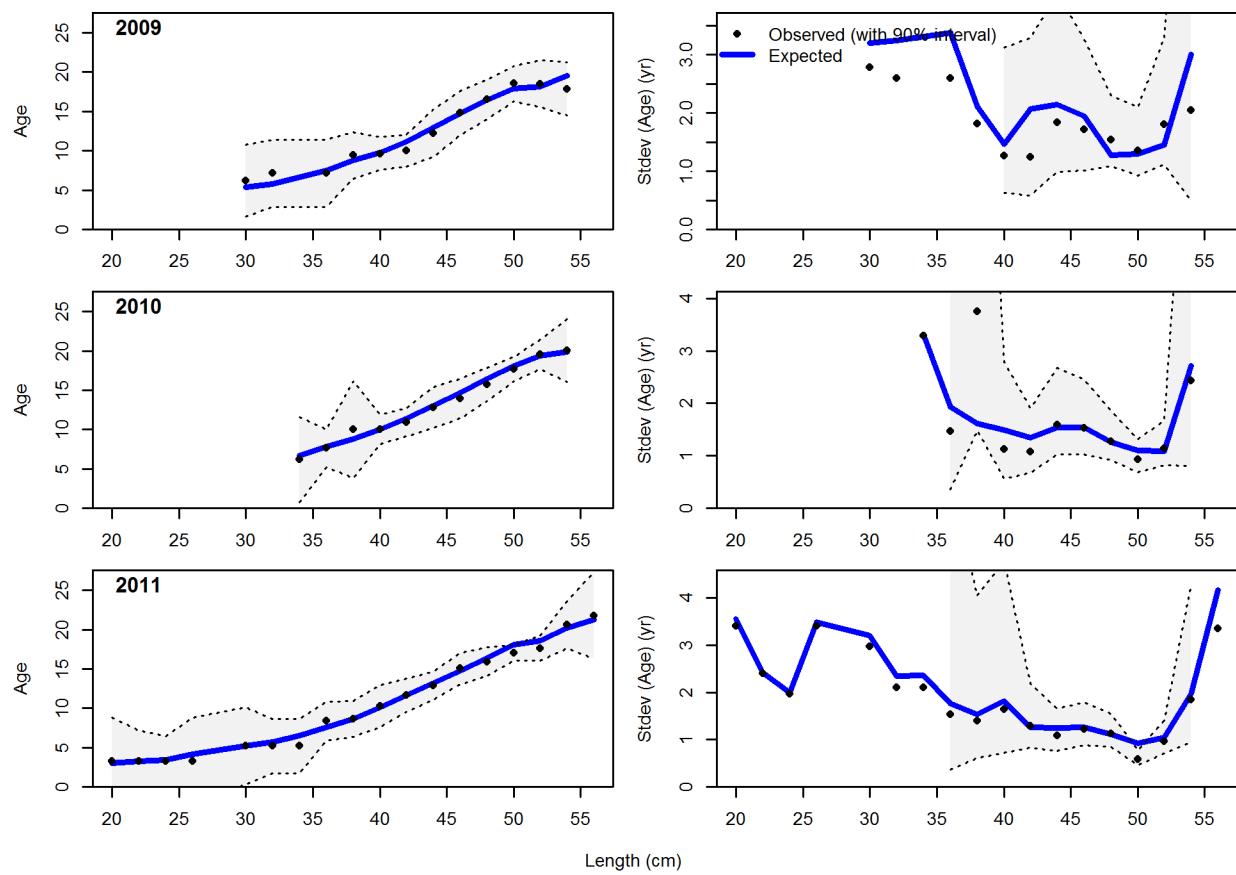


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Conditional AAL plot, retained, NWFSC Combo Survey

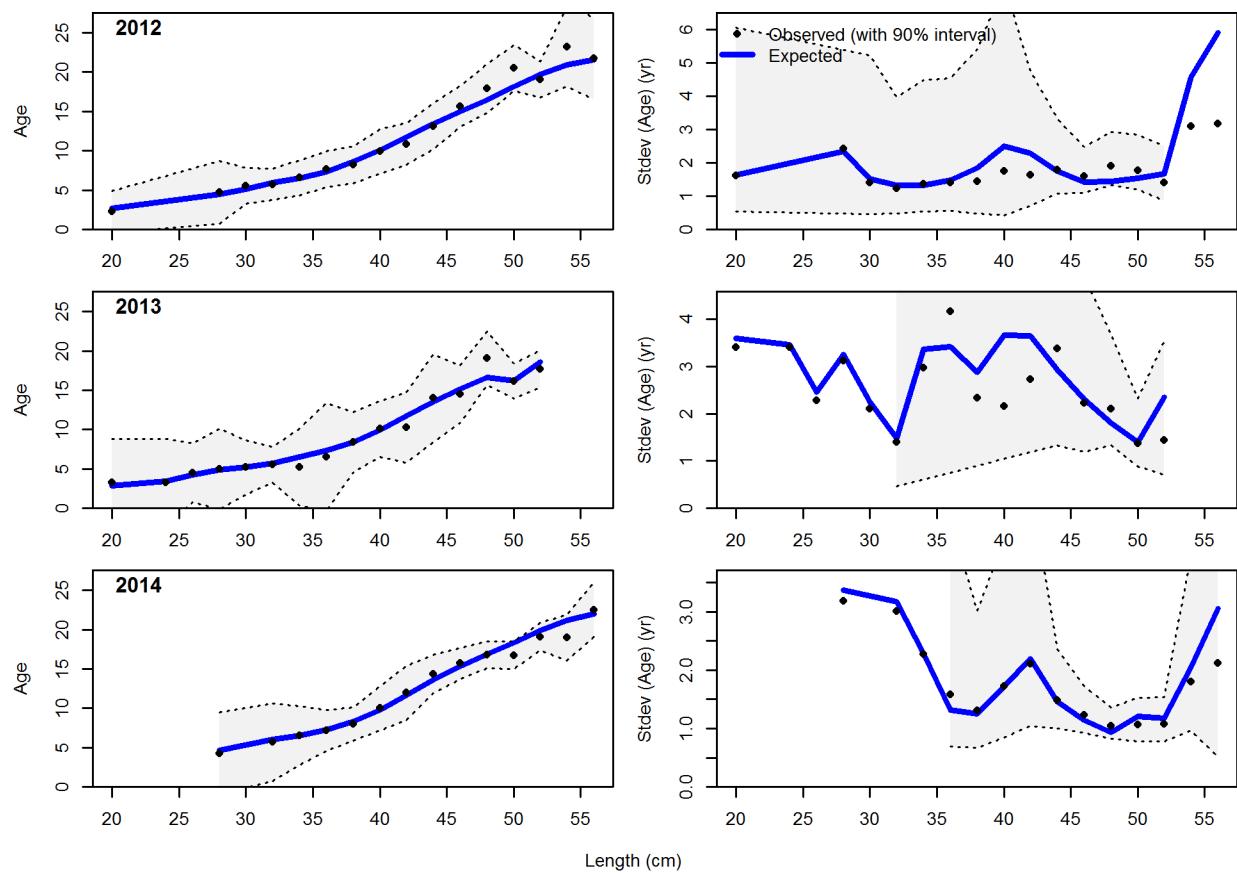


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Figure continued from previous page

Conditional AAL plot, retained, NWFSC Combo Survey

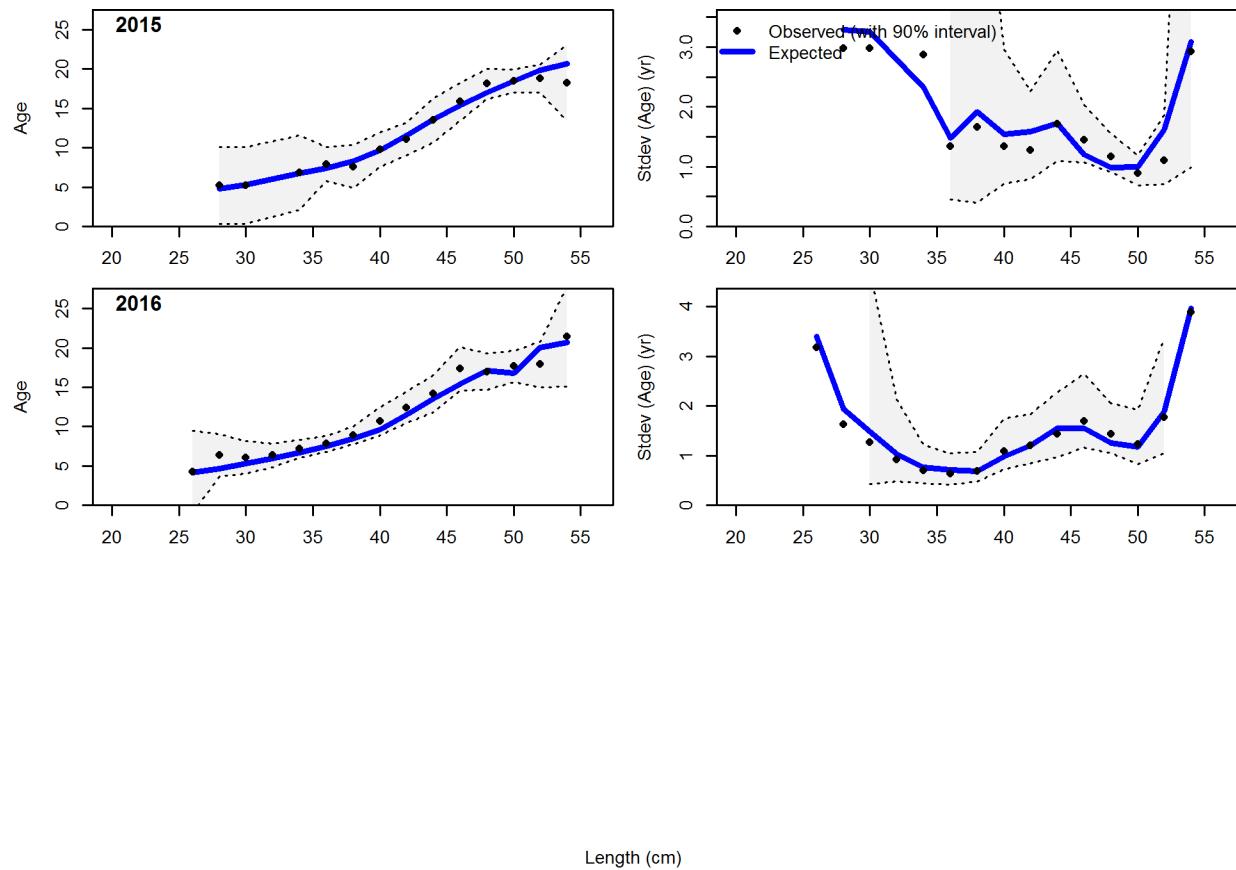


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Figure continued from previous page

Conditional AAL plot, retained, NWFSC Combo Survey



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Figure continued from previous page

988 9.3 Model results for Northern model [model-results-for-northern-model](#)

989 9.3.1 Base model results for Northern model [base-model-results-for-northern-model](#)

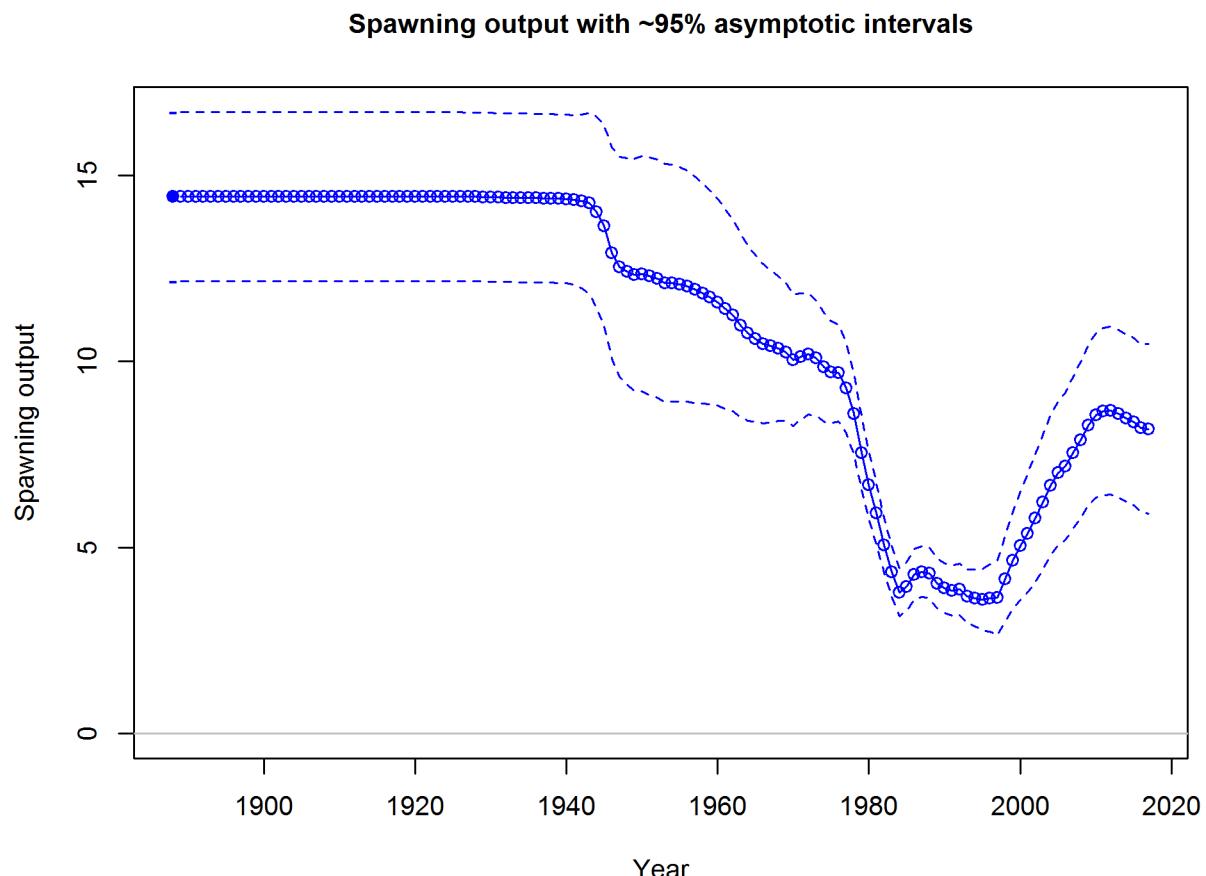


Figure 47: Estimated time-series of spawning output for Northern model. [fig:ssb](#)

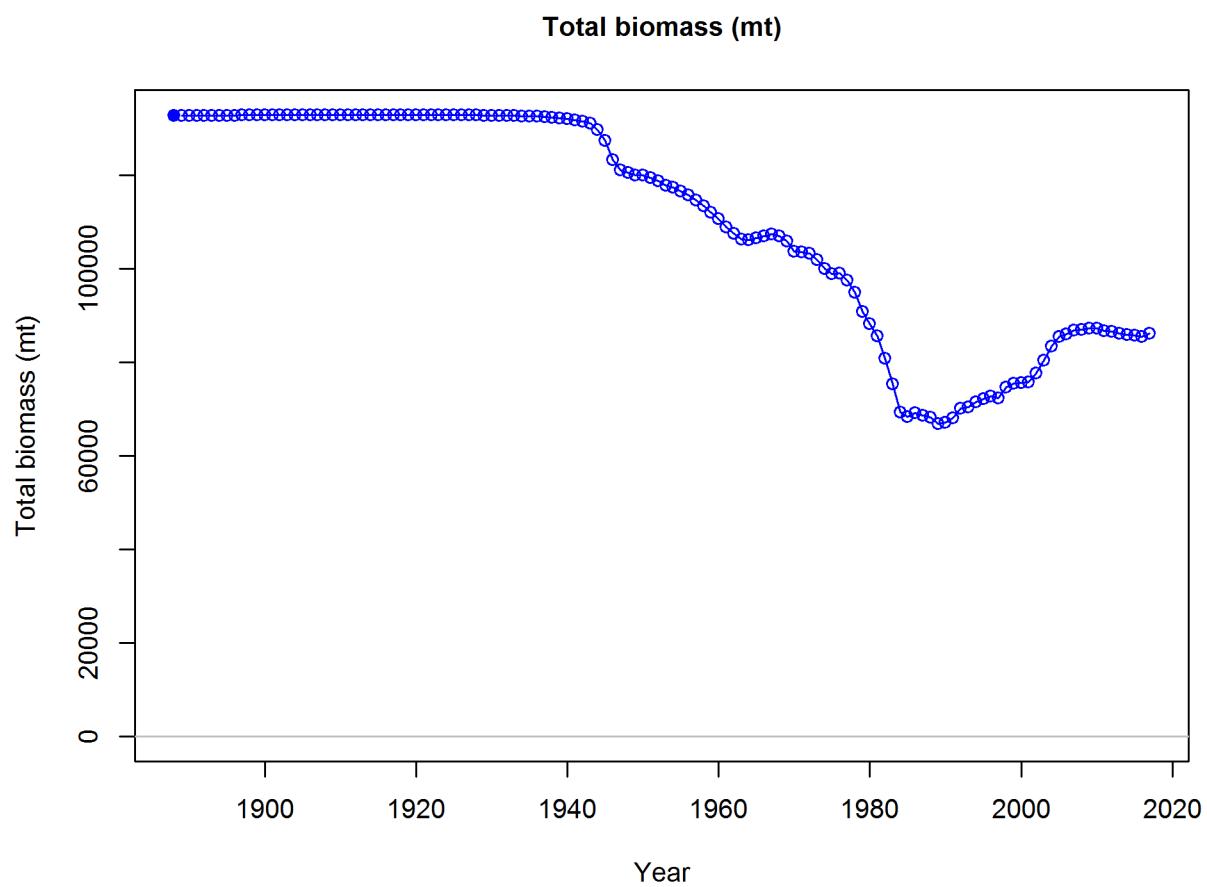


Figure 48: Estimated time-series of total biomass for Northern model. `fig:total_bio`

Spawning depletion with ~95% asymptotic intervals

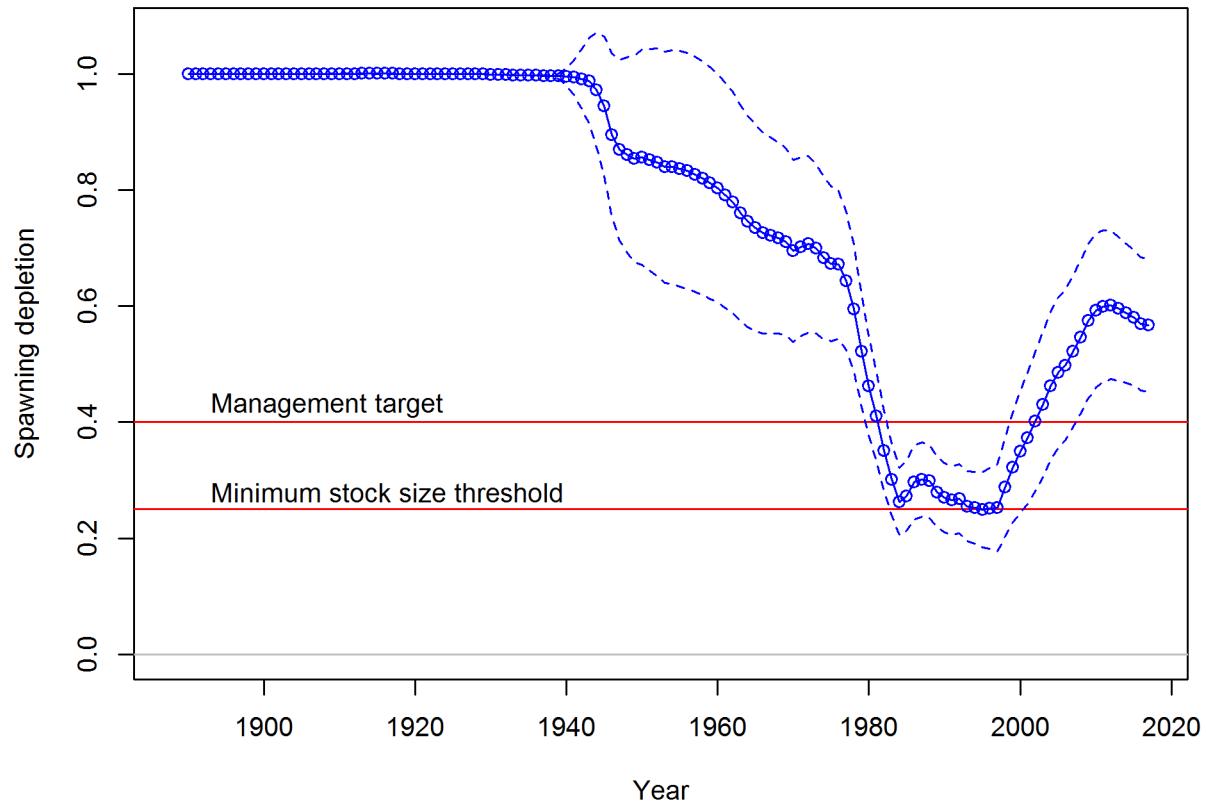


Figure 49: Estimated time-series of relative biomass for Northern model. ^{fig:dep1}

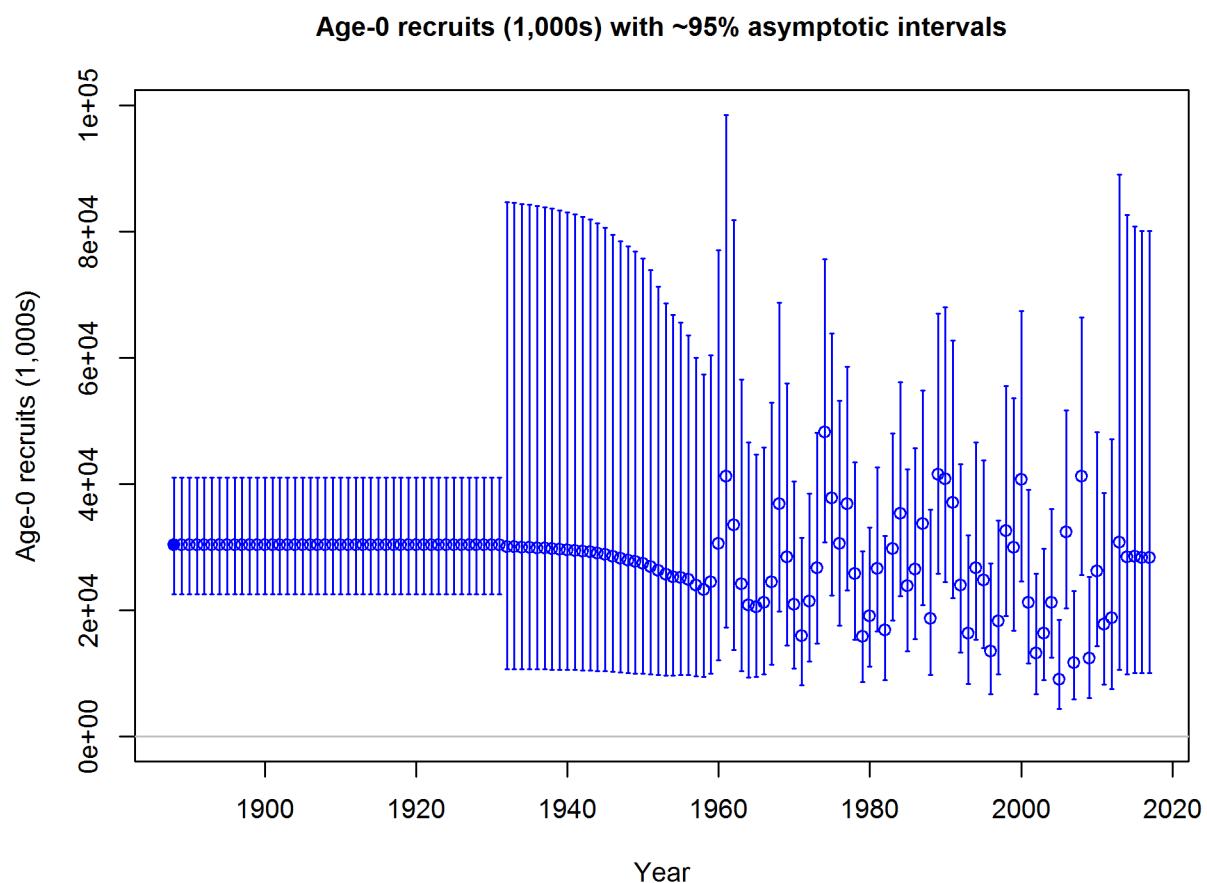


Figure 50: Estimated time-series of recruitment for the Northern model. fig:recruits1

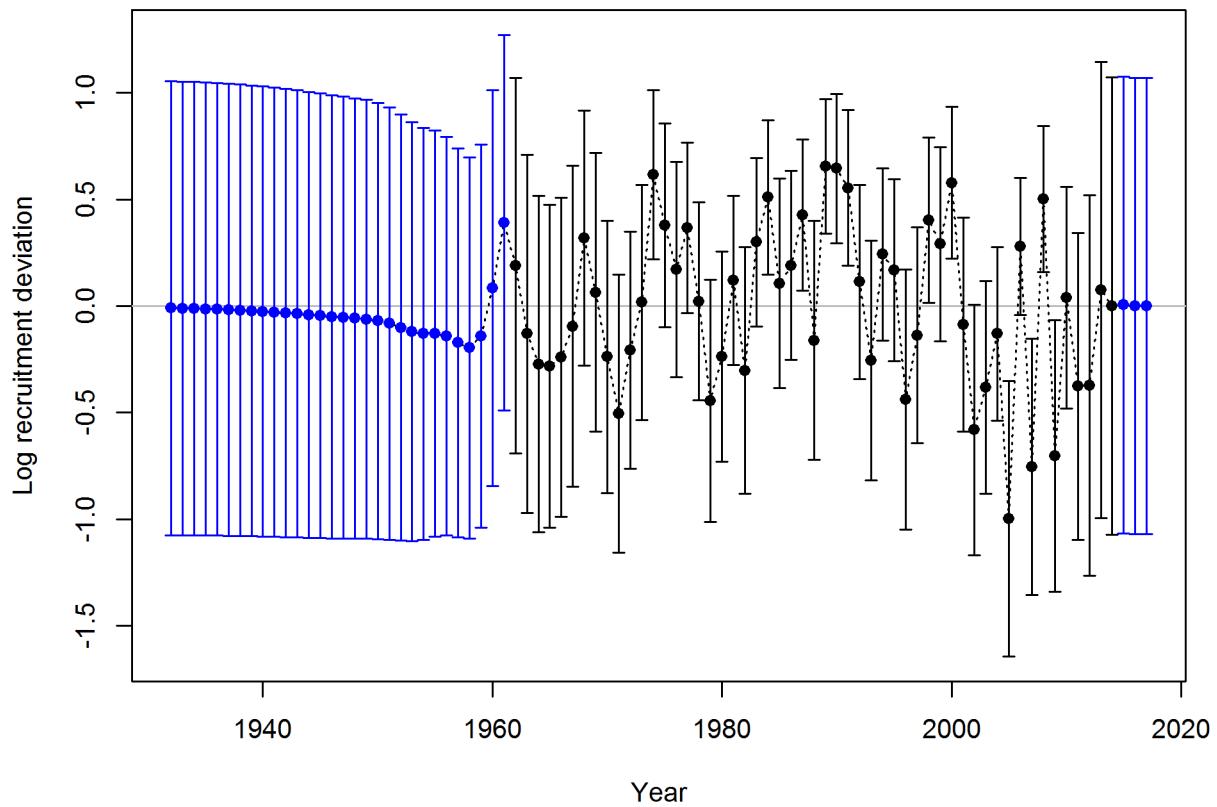


Figure 51: Estimated time-series of recruitment deviations for the Northern model. `fig:recdevs1`

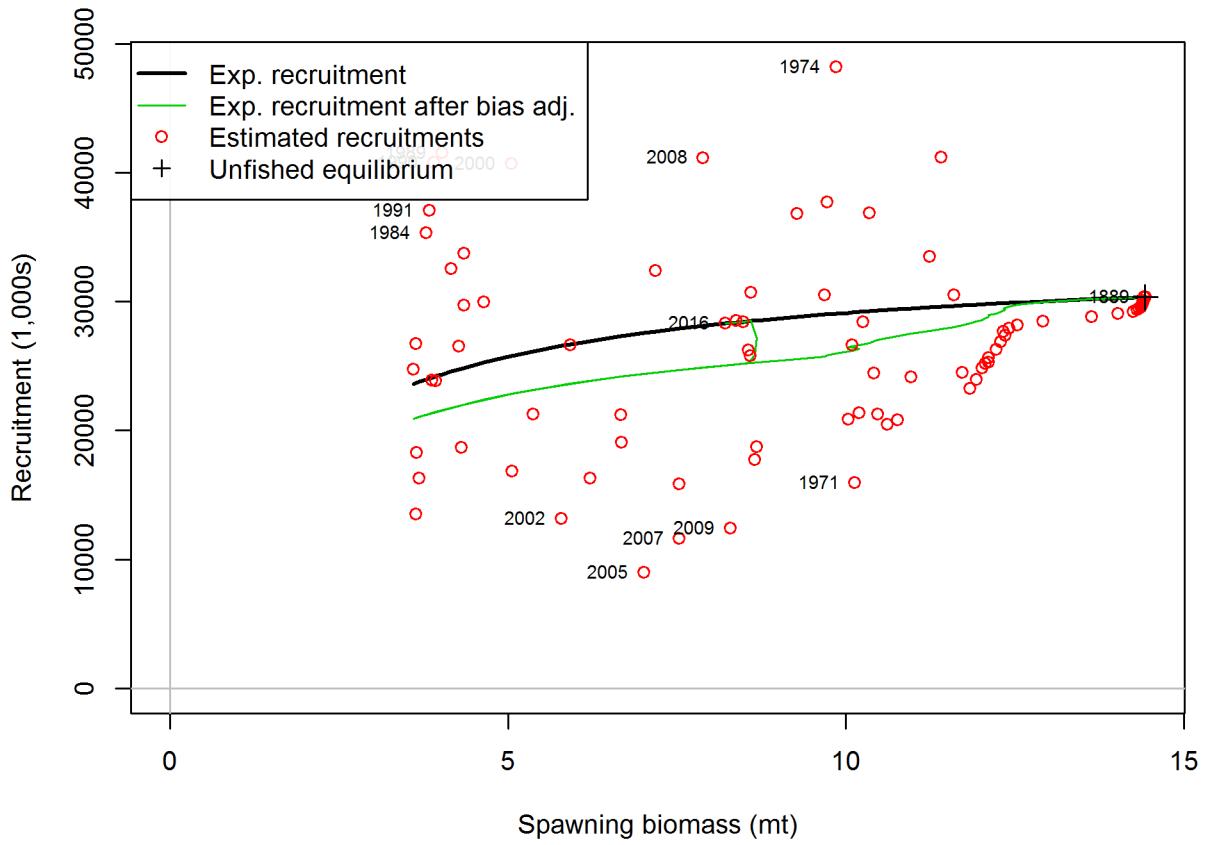


Figure 52: Estimated recruitment (red circles) for the Northern model relative to the stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution [fig:stock_recruit_curve](#)

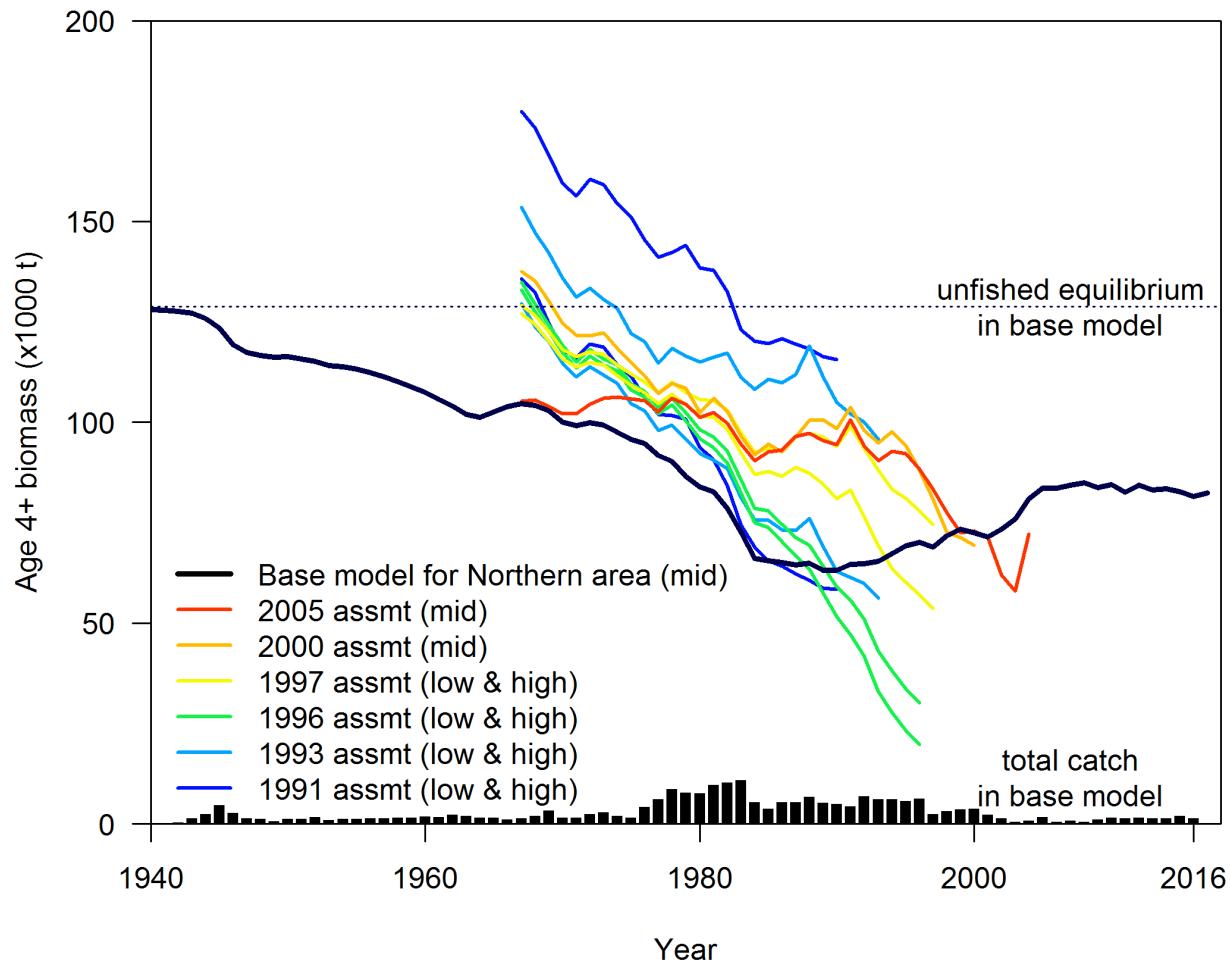


Figure 53: Comparison of time series of age 4+ biomass for Yellowtail Rockfish across past assessments. Previous assessments were focused only on the area north of $40^{\circ}10'$, but also included a small area within Canada. fig:assessment_history

990 9.3.2 Sensitivity analyses for Northern model

sensitivity-analyses-for-northern-model

991 to be added...

992 9.3.3 Likelihood profiles for Northern model

likelihood-profiles-for-northern-model

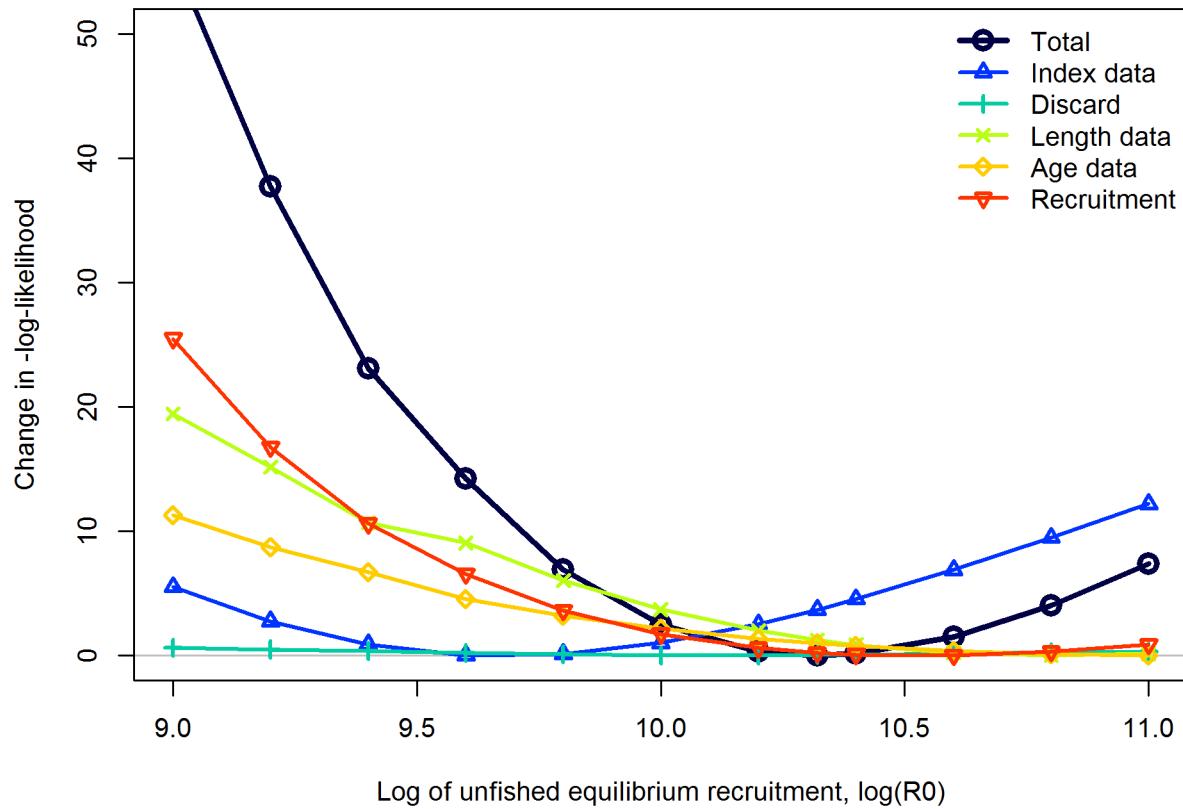


Figure 54: Likelihood profile over the log of equilibrium recruitment (R_0) for the Northern model. [fig:profile_logR0.N](#)

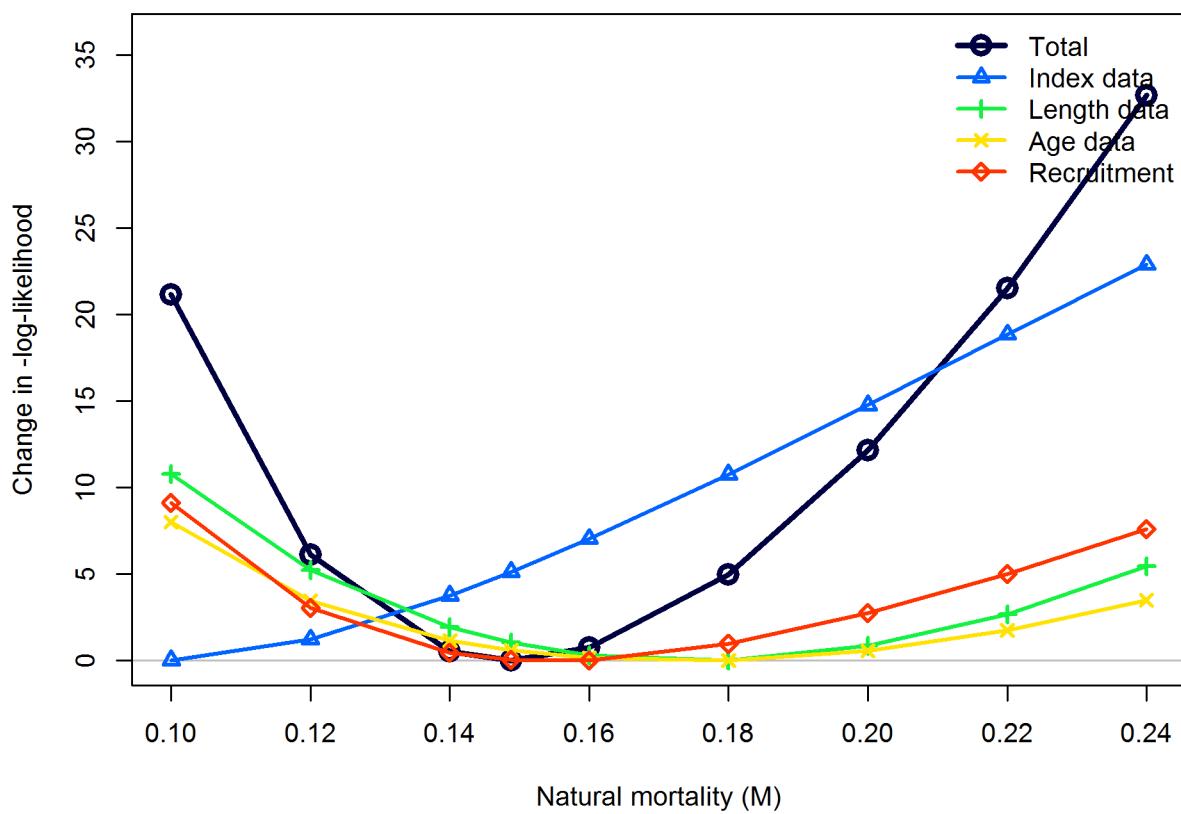


Figure 55: Likelihood profile over female natural mortality for the Northern model. `fig:profile_M.N`

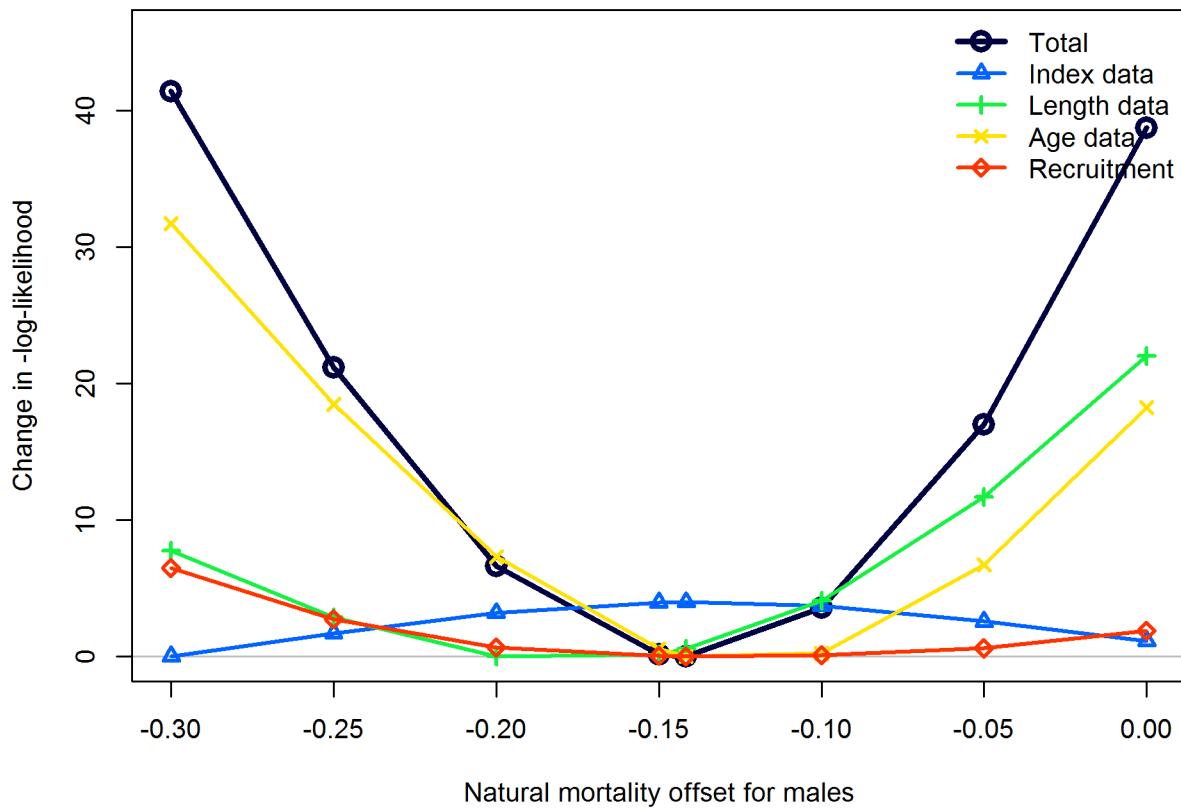


Figure 56: Likelihood profile over the male offset for natural mortality for the Northern model. Negative values are associated with natural mortality being lower for males than females.
fig:profile_M2.N

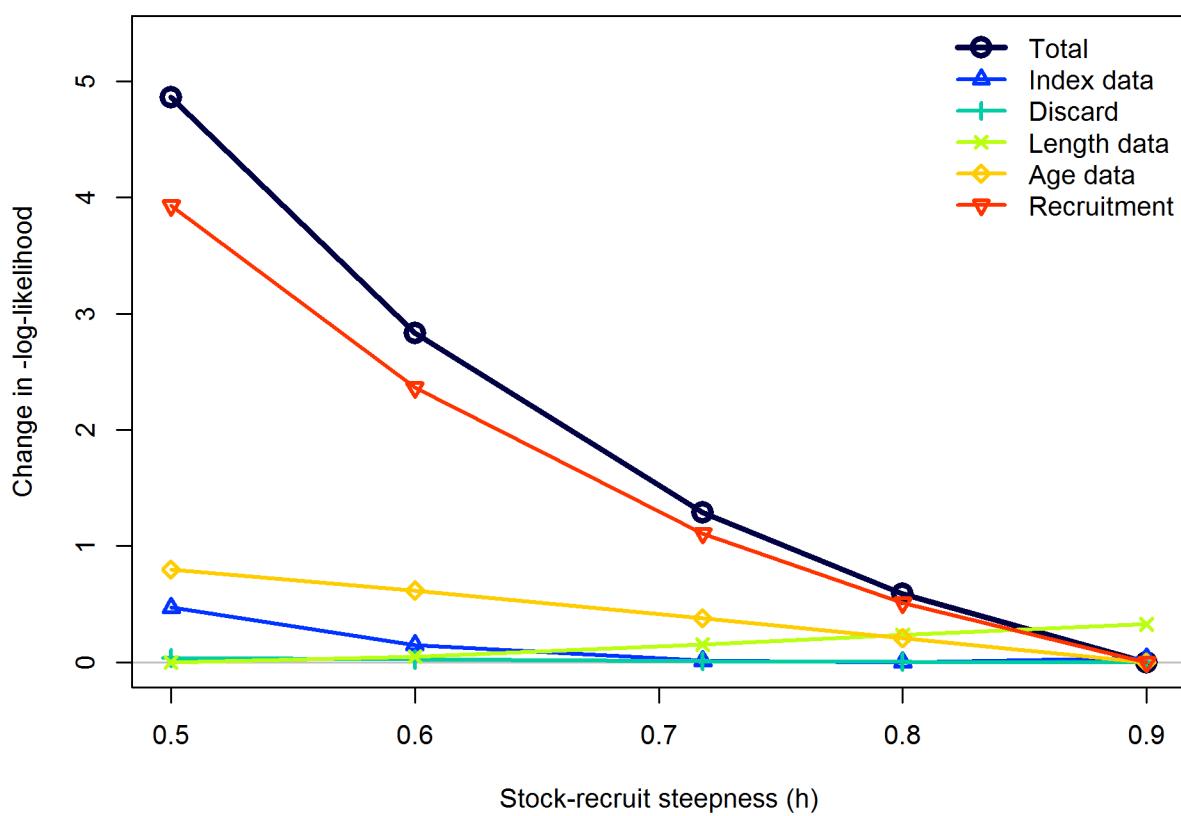


Figure 57: Likelihood profile over stock-recruit steepness (h) for the Northern model. `fig:profile_h.N`

993 **9.3.4 Retrospective analysis for Northern model**
retrospective-analysis-for-northern-model

994 to be added...

995 **9.3.5 Forecasts analysis for Northern model**
forecasts-analysis-for-northern-model

996 to be added...

997 9.4 Data and model fits for Southern model
data-and-model-fits-for-southern-model

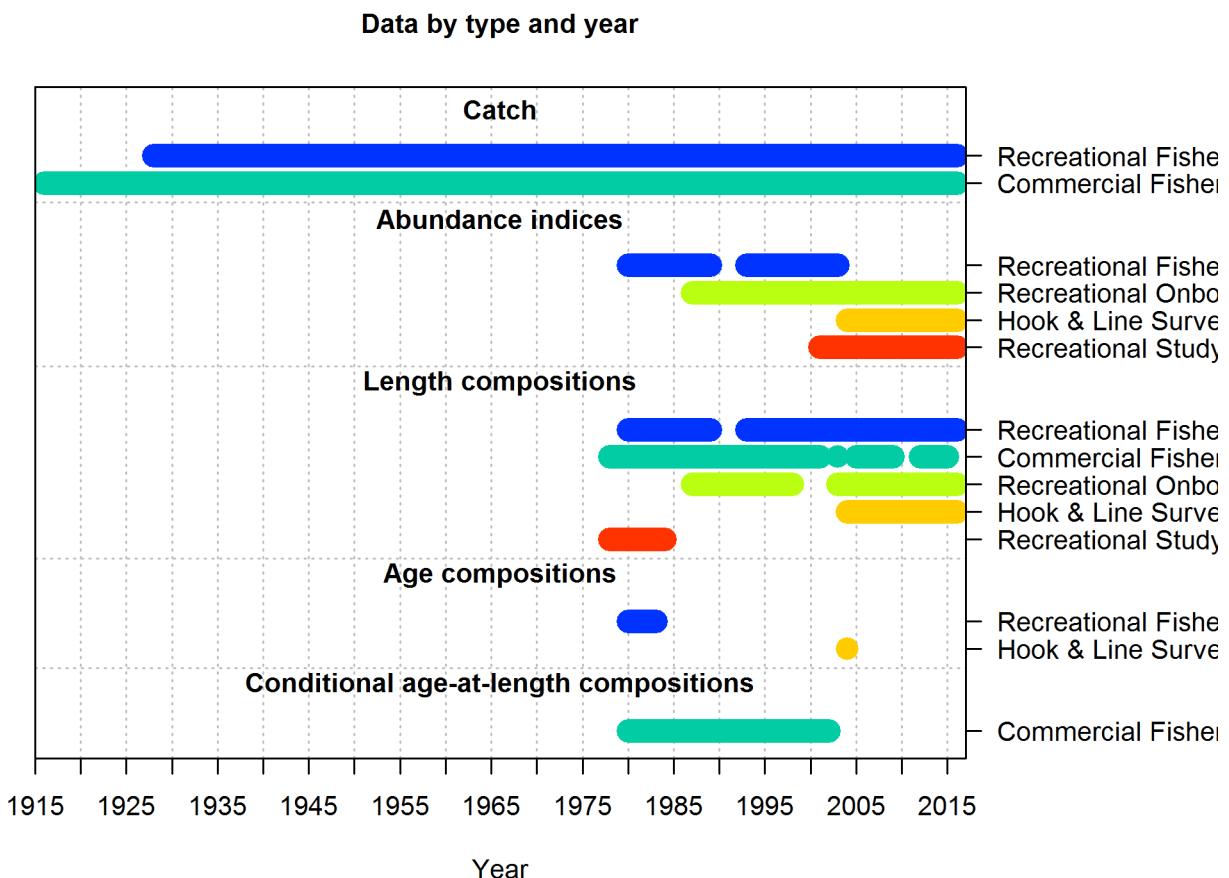


Figure 58: Summary of data sources used in the Southern model. fig:data_plot

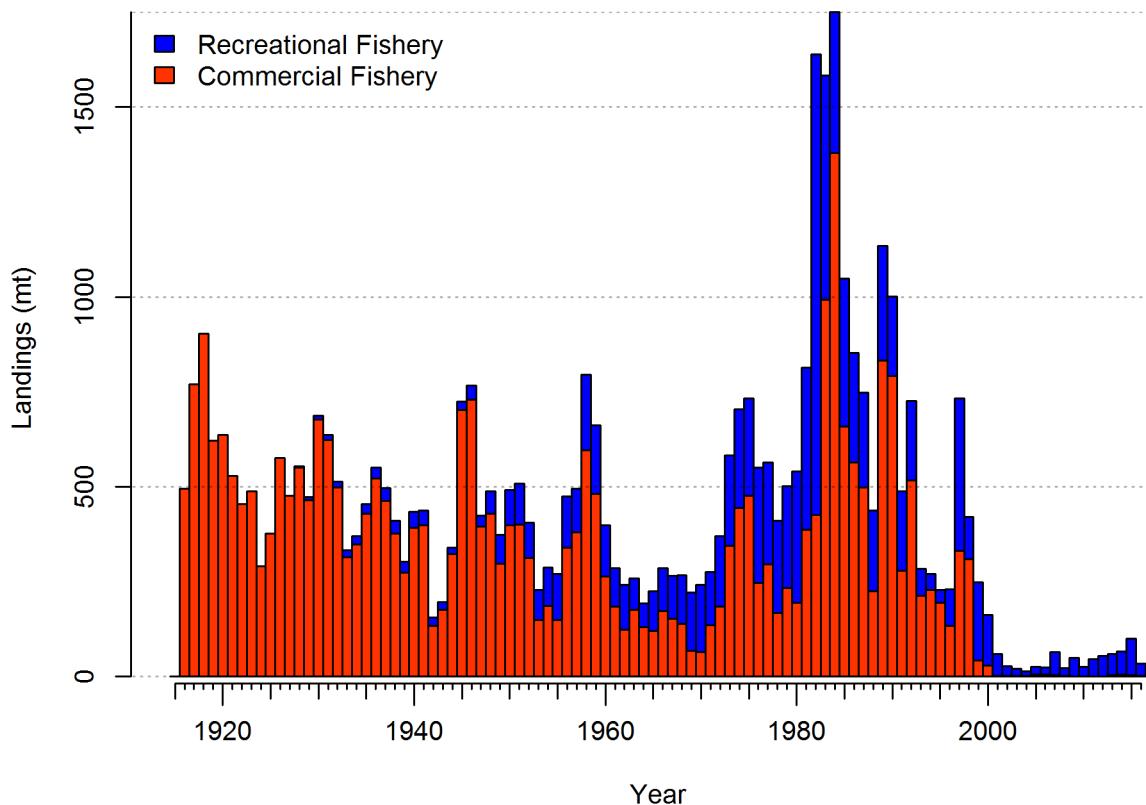


Figure 59: Estimated catch history of Yellowtail Rockfish in the Southern model. [fig:r4ss_catch2_S](#)

998 9.4.1 Selectivity, retention, and discards for Southern model
selectivity-retention-and-discards-for-southern-model

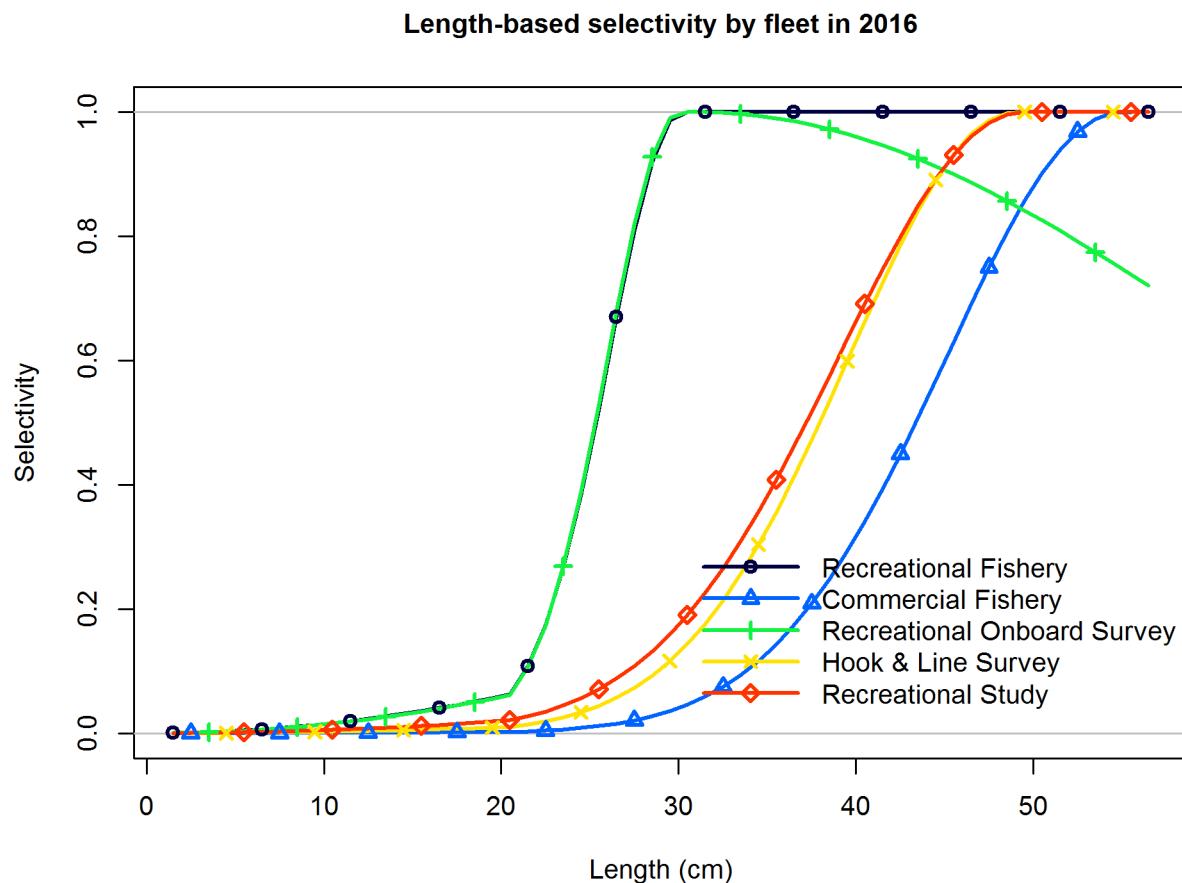


Figure 60: Estimated selectivity by length by each fishery and survey in the Southern model.
fig:selex

999 9.4.2 Fits to indices of abundance for Southern model
fits-to-indices-of-abundance-for-southern-model

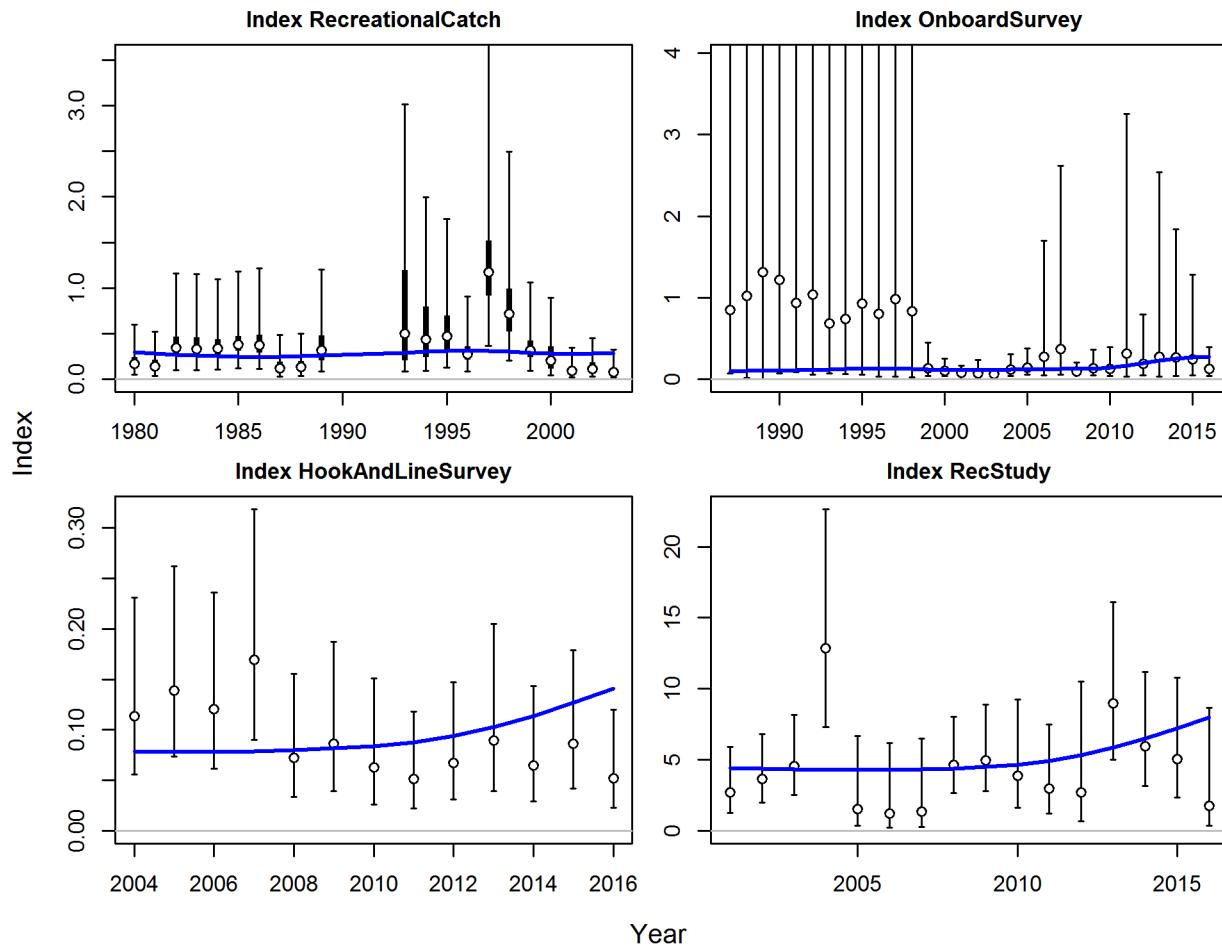


Figure 61: Estimated fits to the CPUE and survey indices for the Southern model. fig:index_fits2

1000 **9.4.3 Length compositions for Southern model**
[length-compositions-for-southern-model](#)

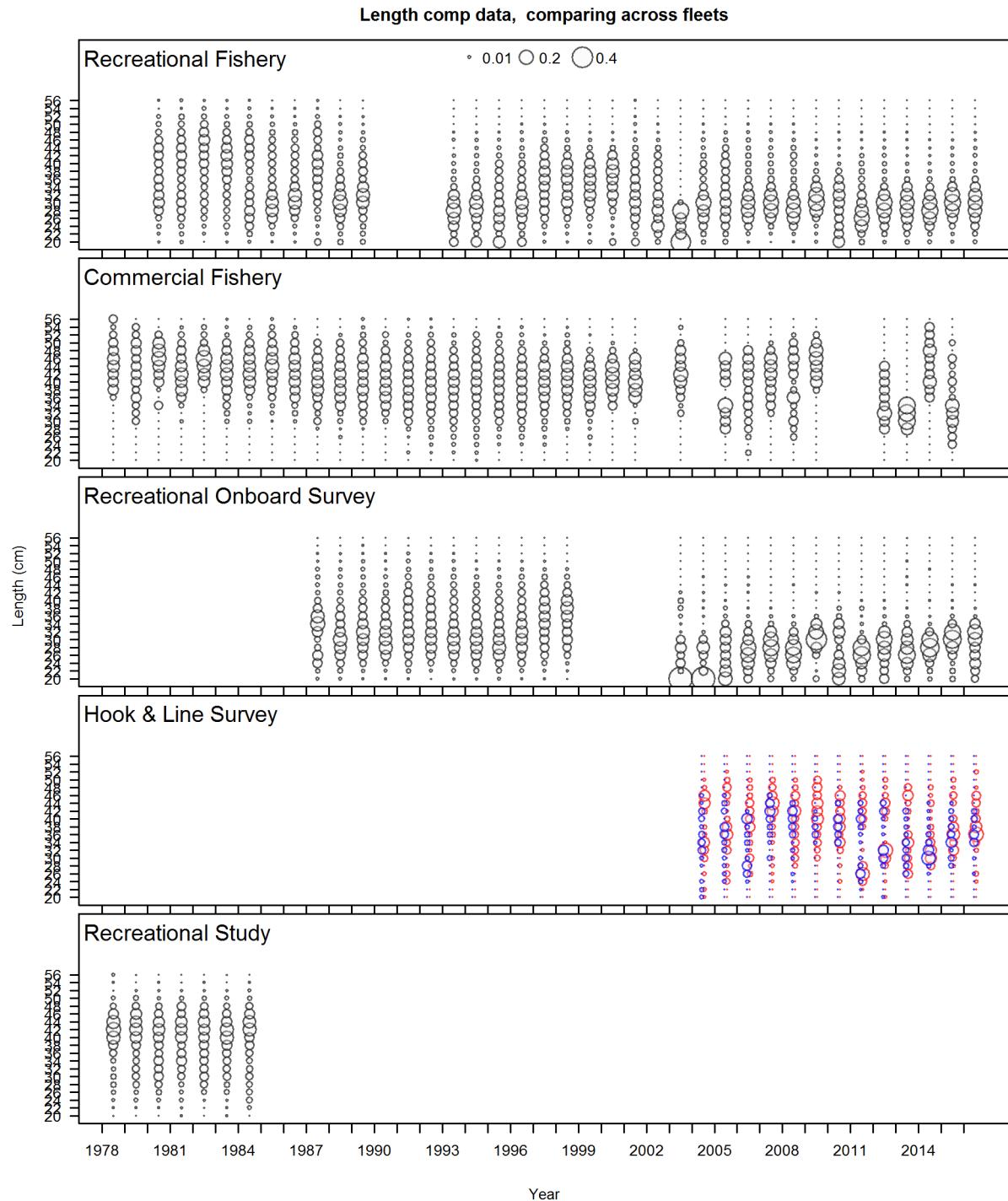


Figure 62: Length compositions for all fleets in the Southern model. Bubble size is proportional to proportions within each year. [fig:comp_length_bubble_mod2](#)

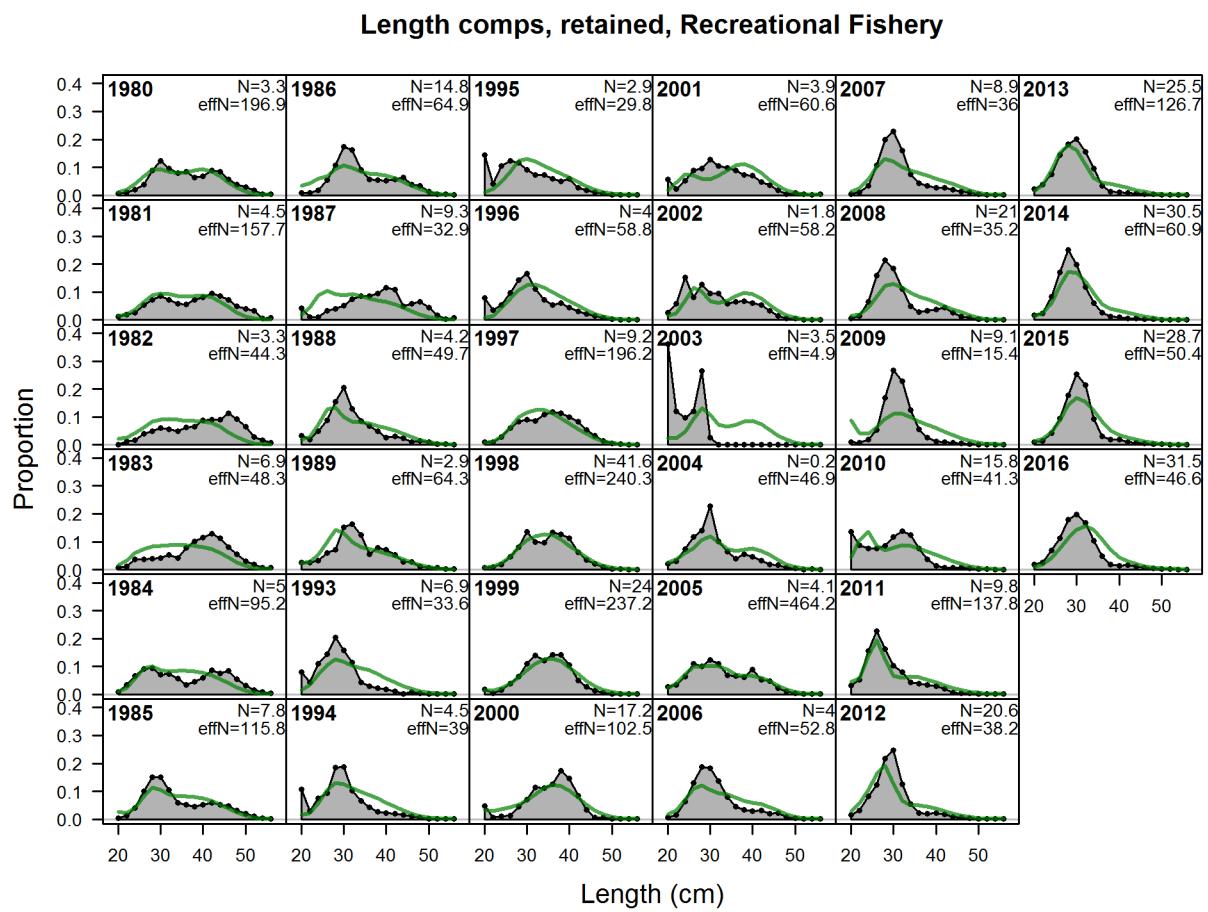


Figure 63: Southern model Length comps, retained, Recreational Fishery fig:mod2_1_comp_len

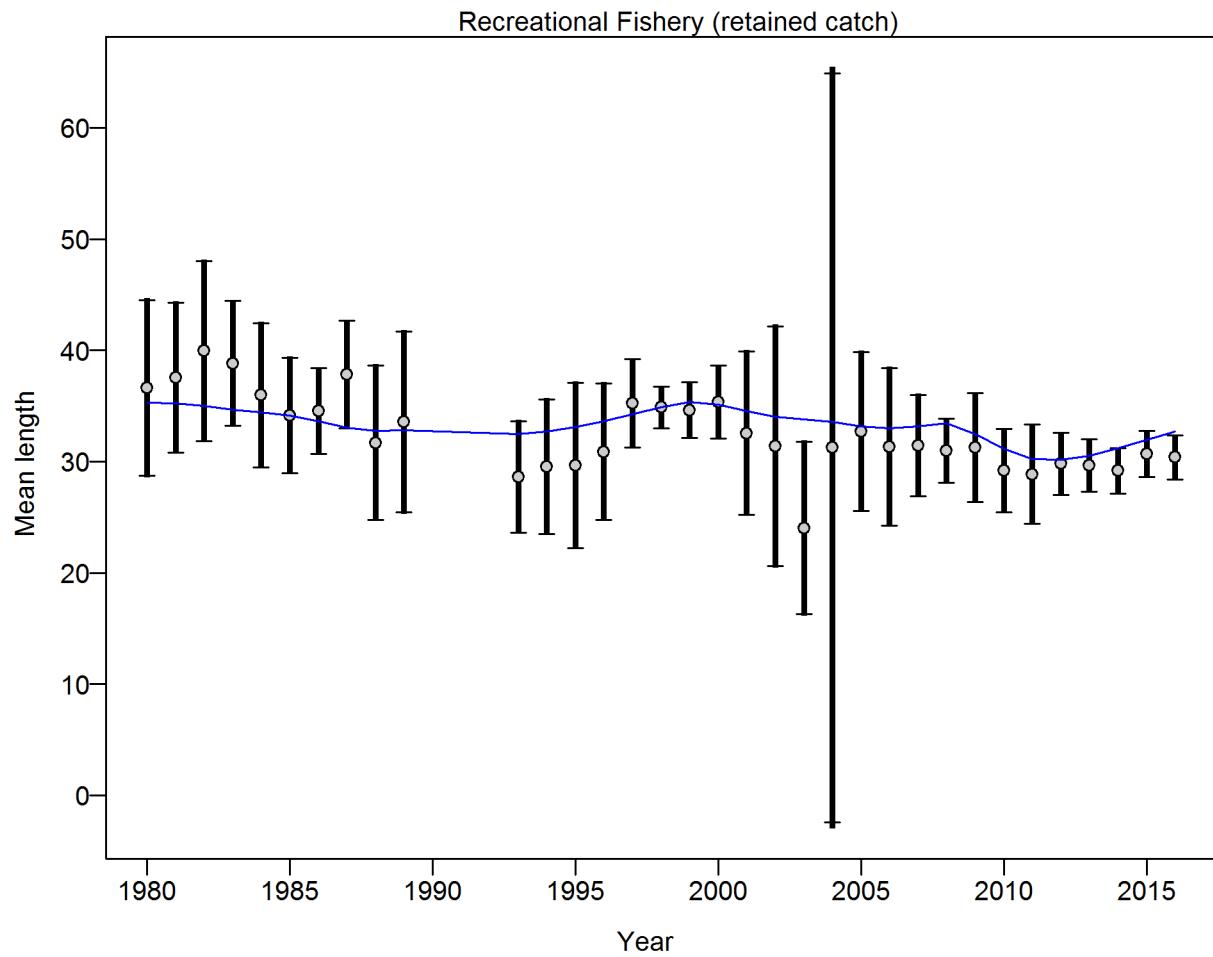


Figure 64: **Southern model** Mean length for Recreational Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

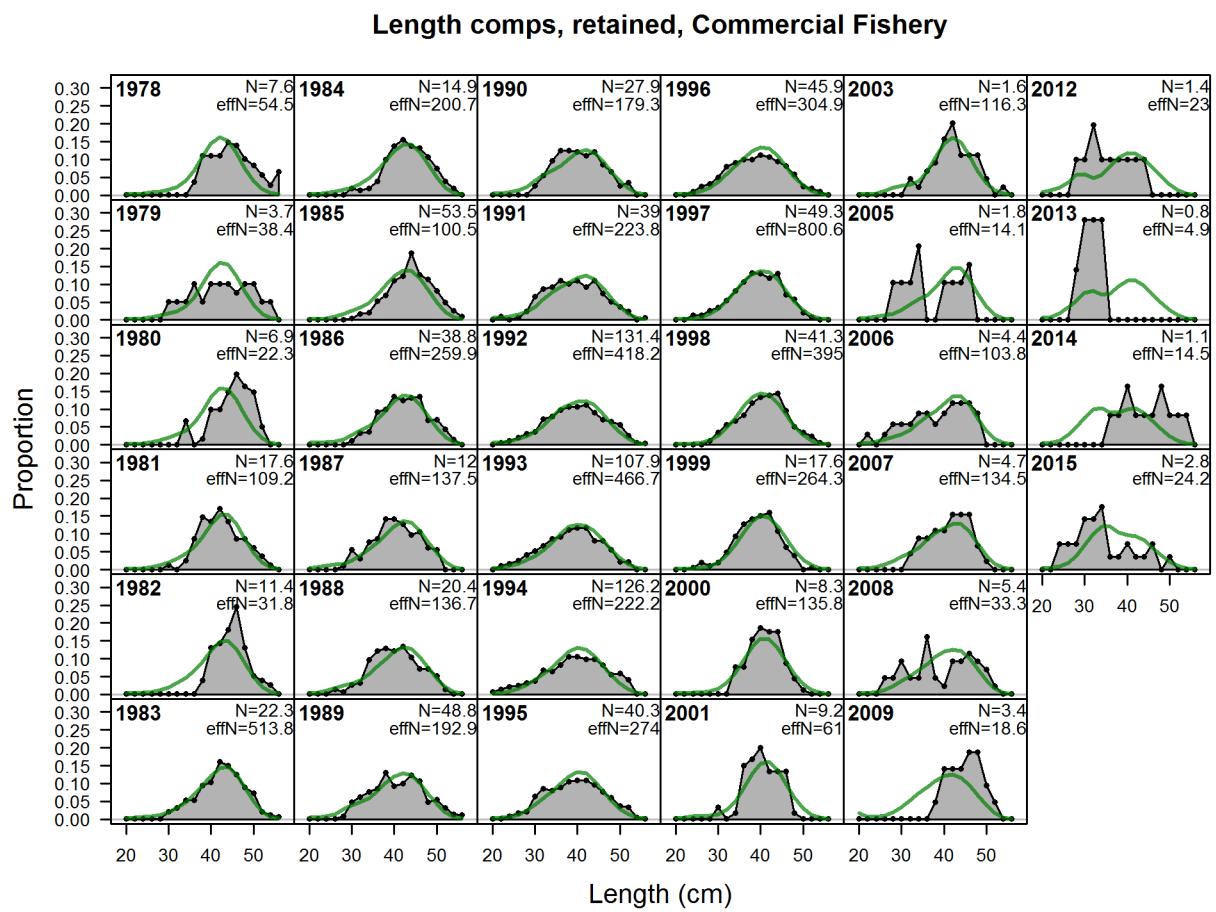


Figure 65: Southern model Length comps, retained, Commercial Fishery fig:mod2_5_comp_leni

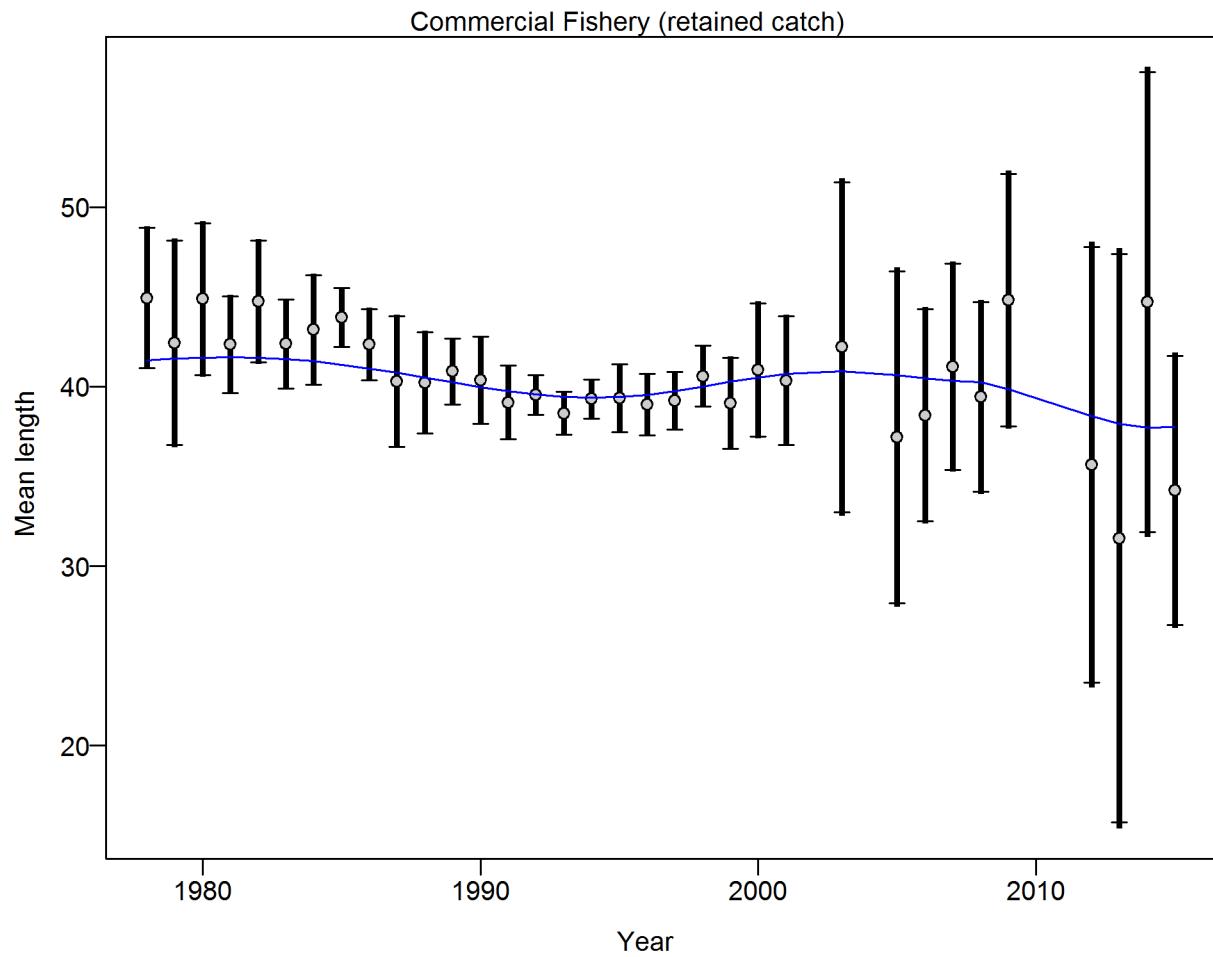


Figure 66: **Southern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

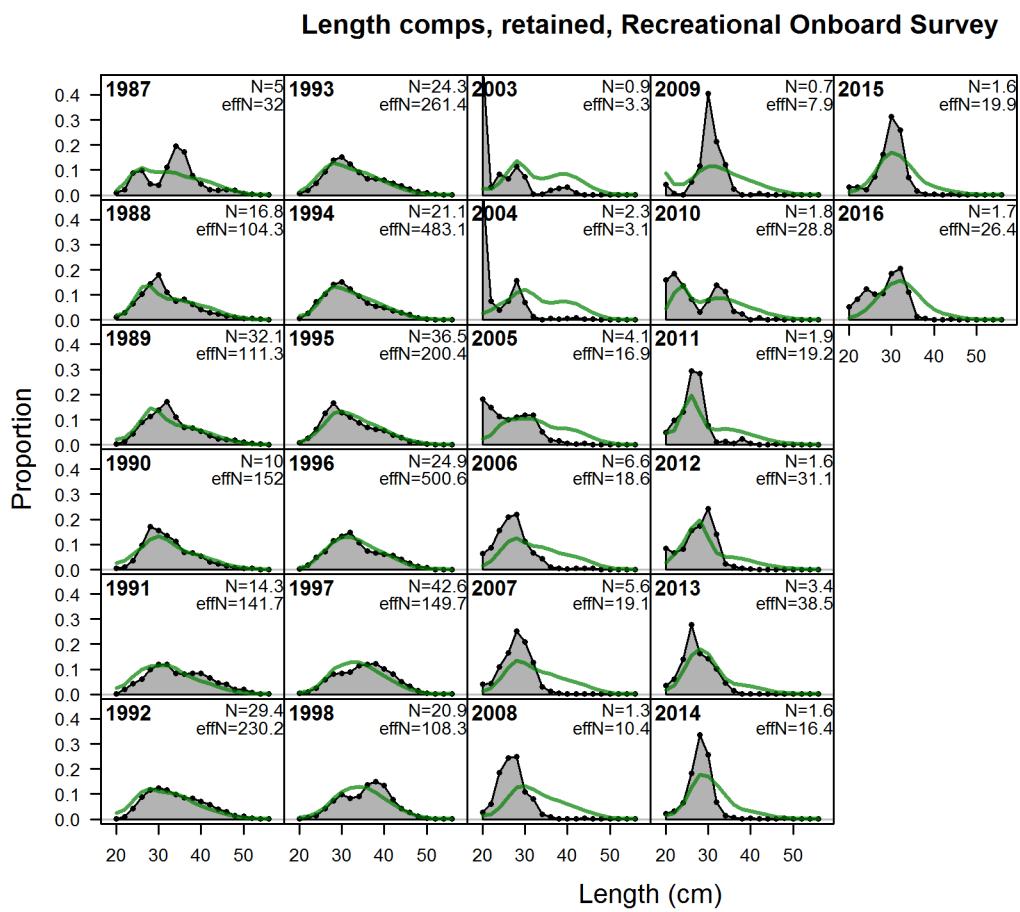


Figure 67: **Southern model** Length comps, retained, Recreational Onboard Survey | [fig:mod2_9_comp](#)

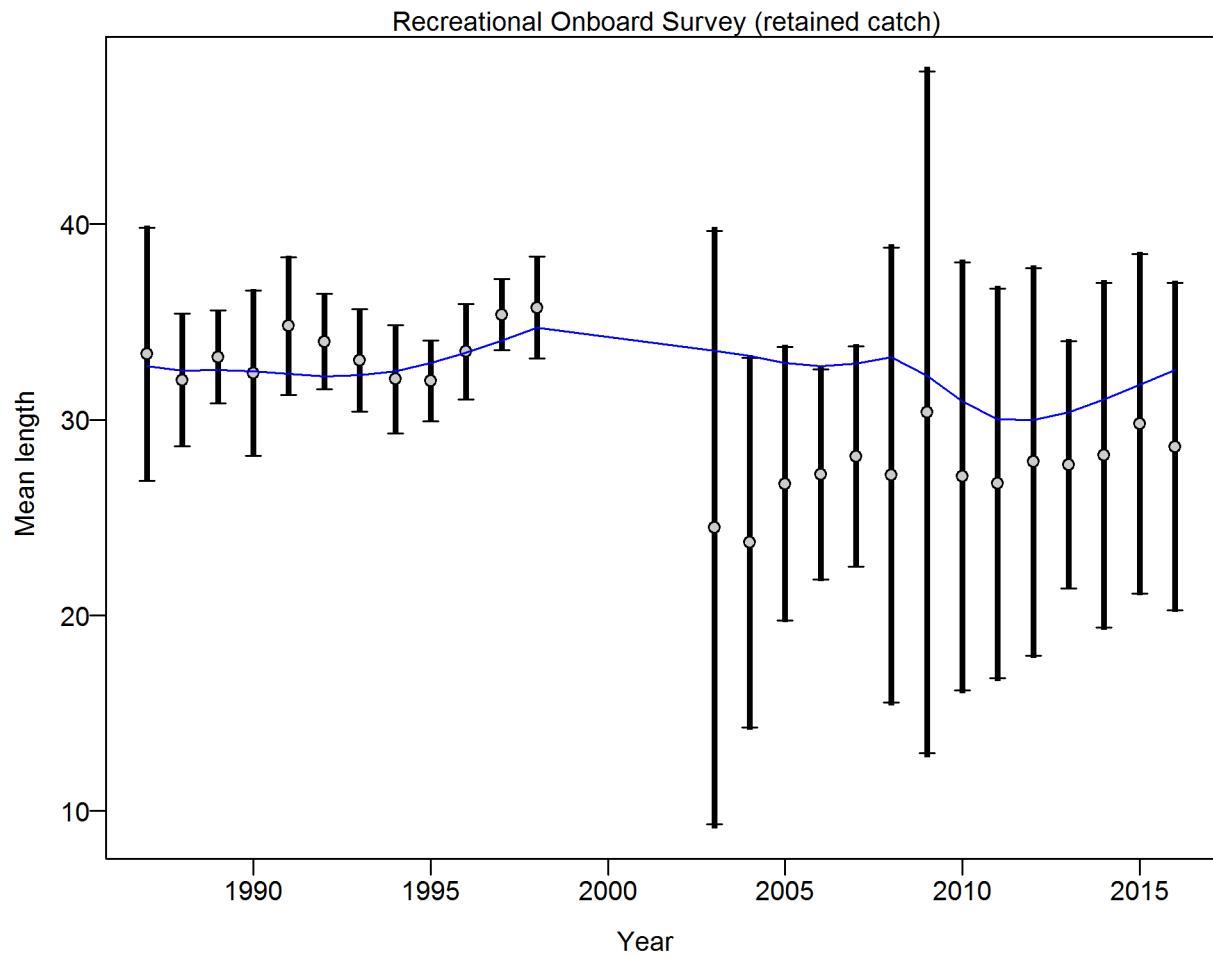


Figure 68: **Southern model** Mean length for Recreational Onboard Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval)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

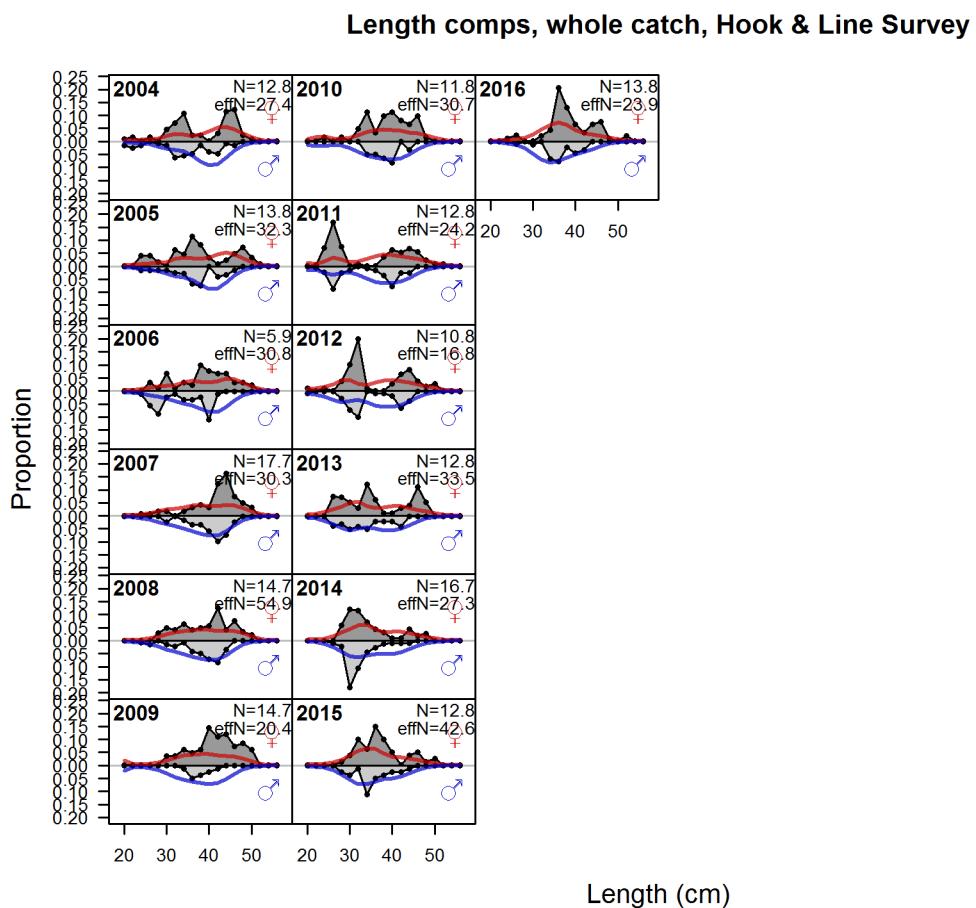


Figure 69: **Southern model** Length comps, whole catch, Hook & Line Survey | `fig:mod2_13_comp_1`

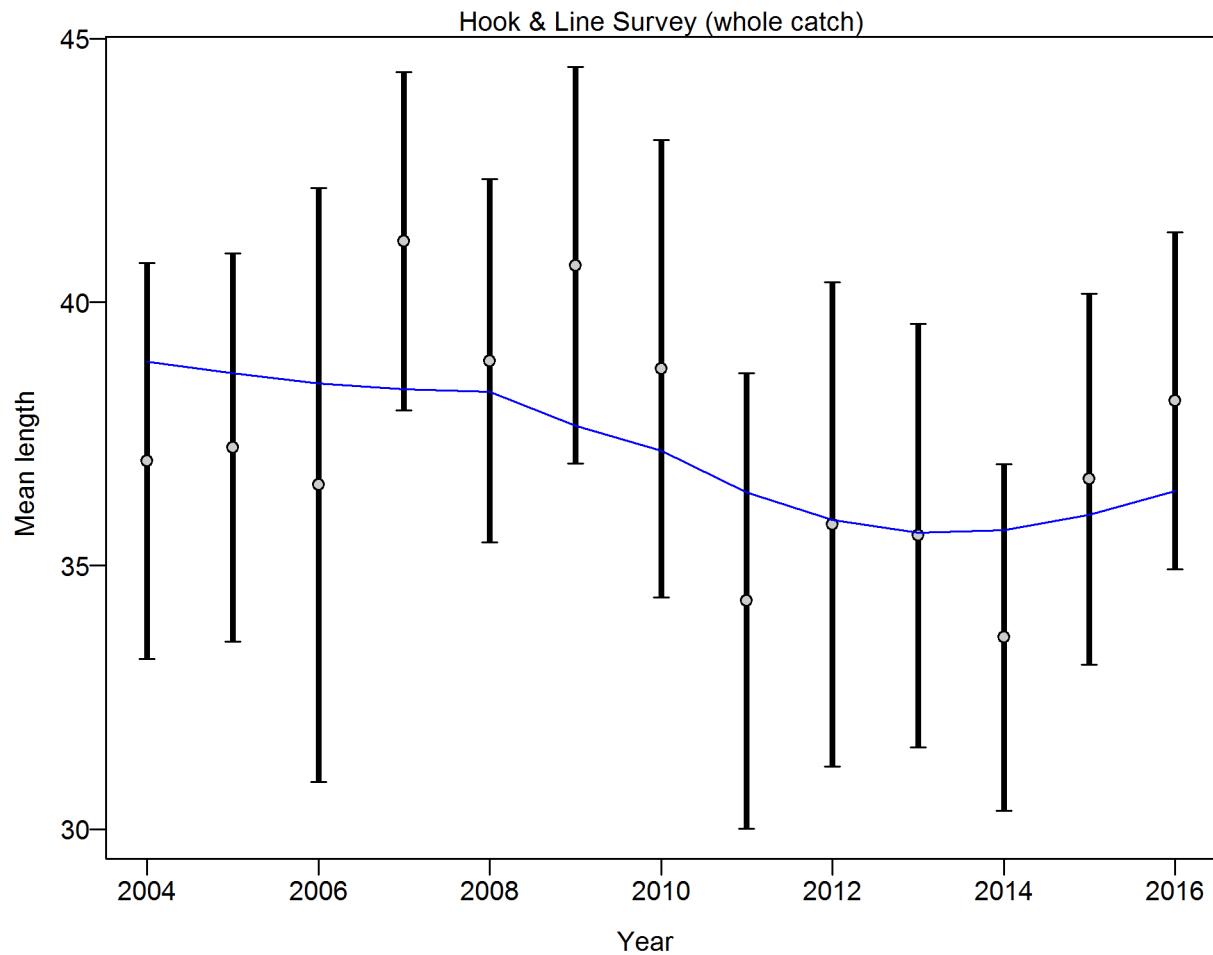


Figure 70: **Southern model** Mean length for Hook & Line Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

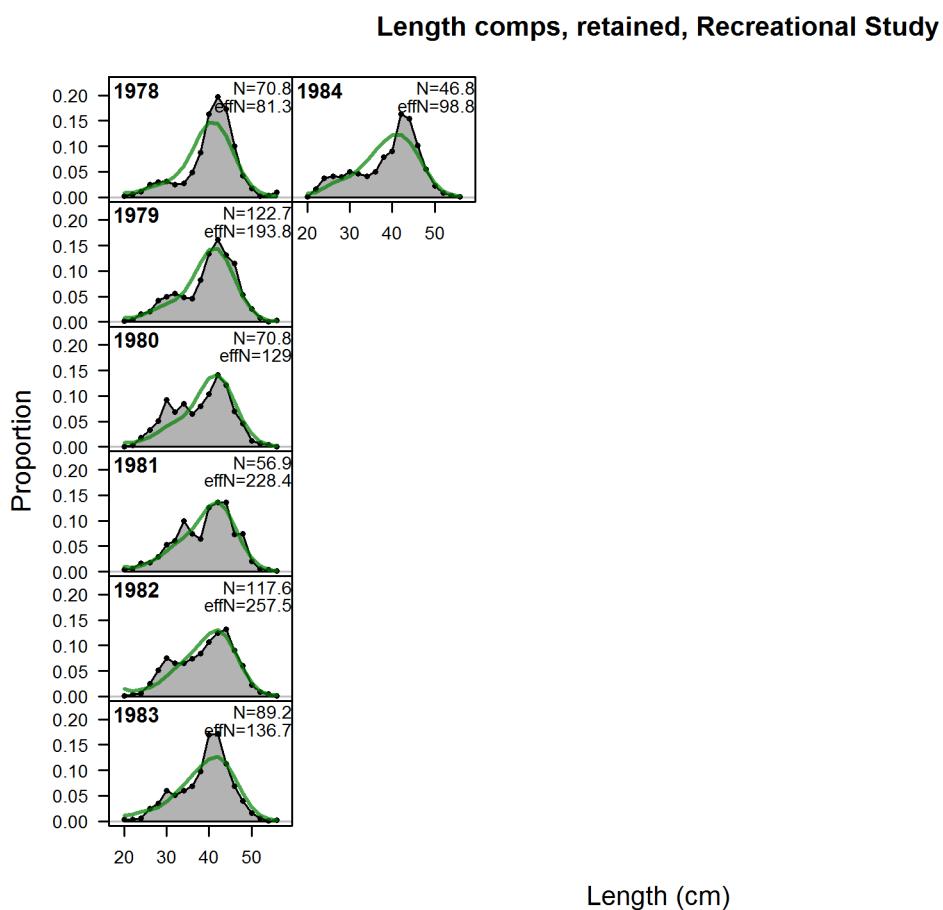


Figure 71: **Southern model** Length comps, retained, Recreational Study fig:mod2_17_comp_len

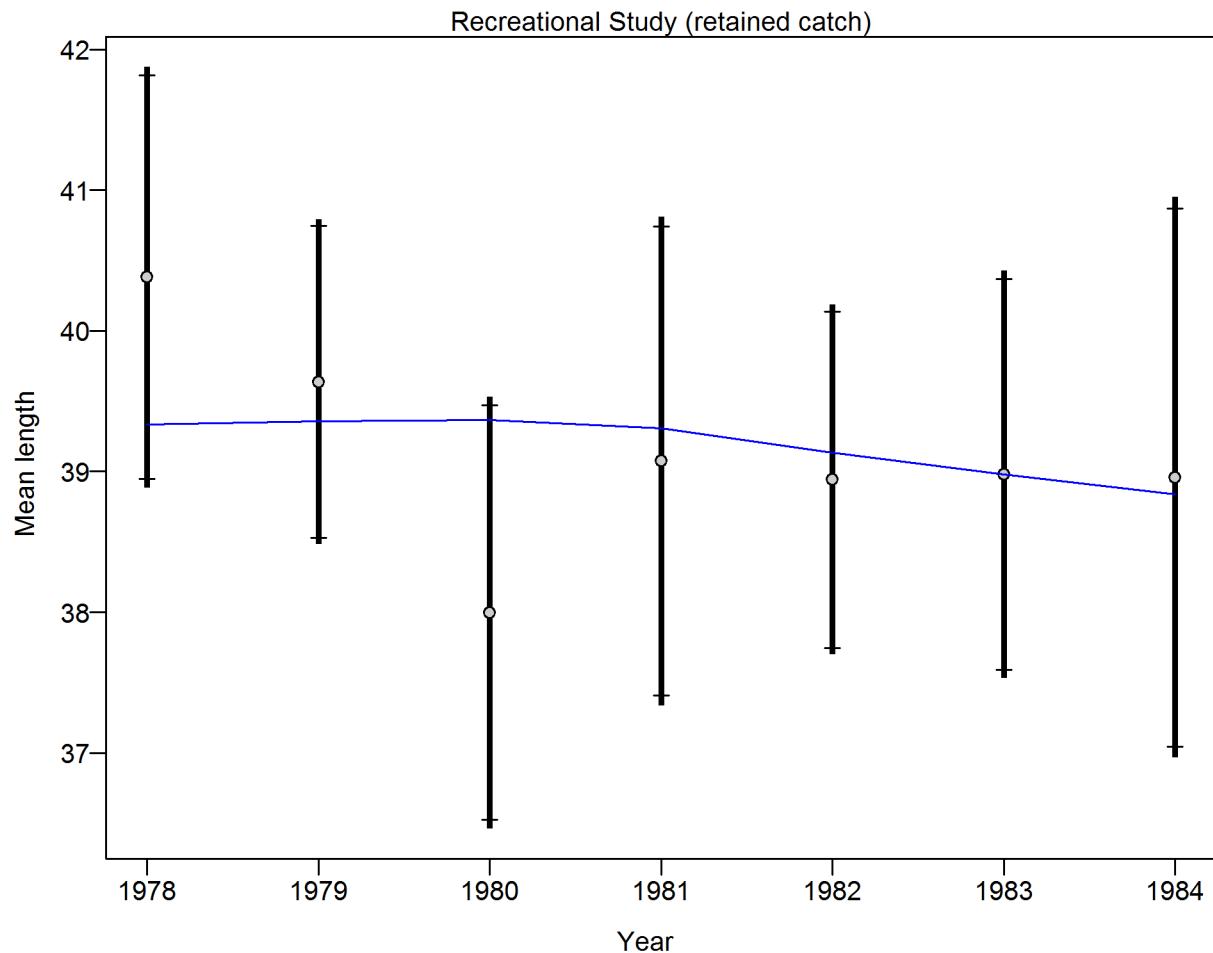


Figure 72: **Southern model** Mean length for Recreational Study with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

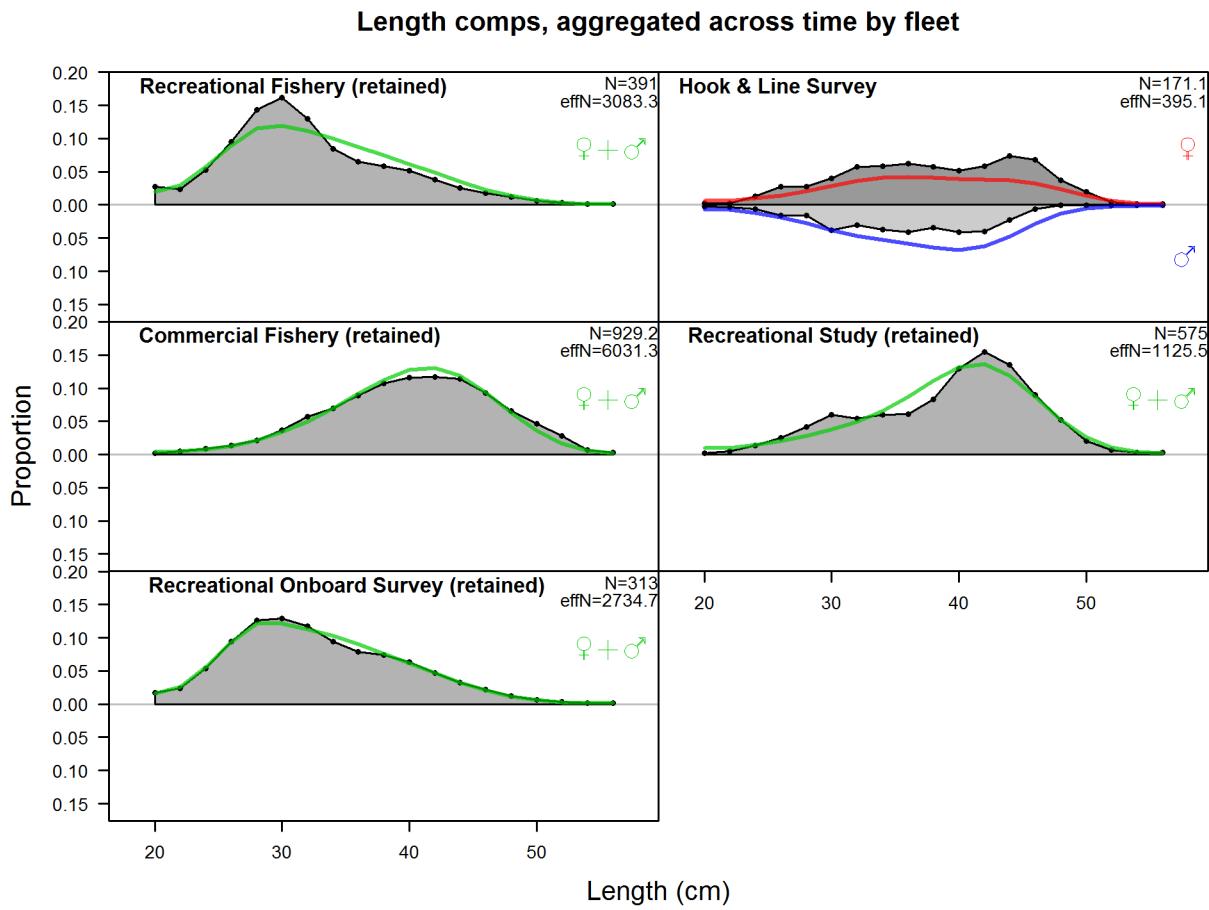


Figure 73: **Southern model** Length comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained samples for each fleet. Panels without this designation represent the whole catch. [fig:mod2_21_comp_lenfit__aggregated_across_time](#)

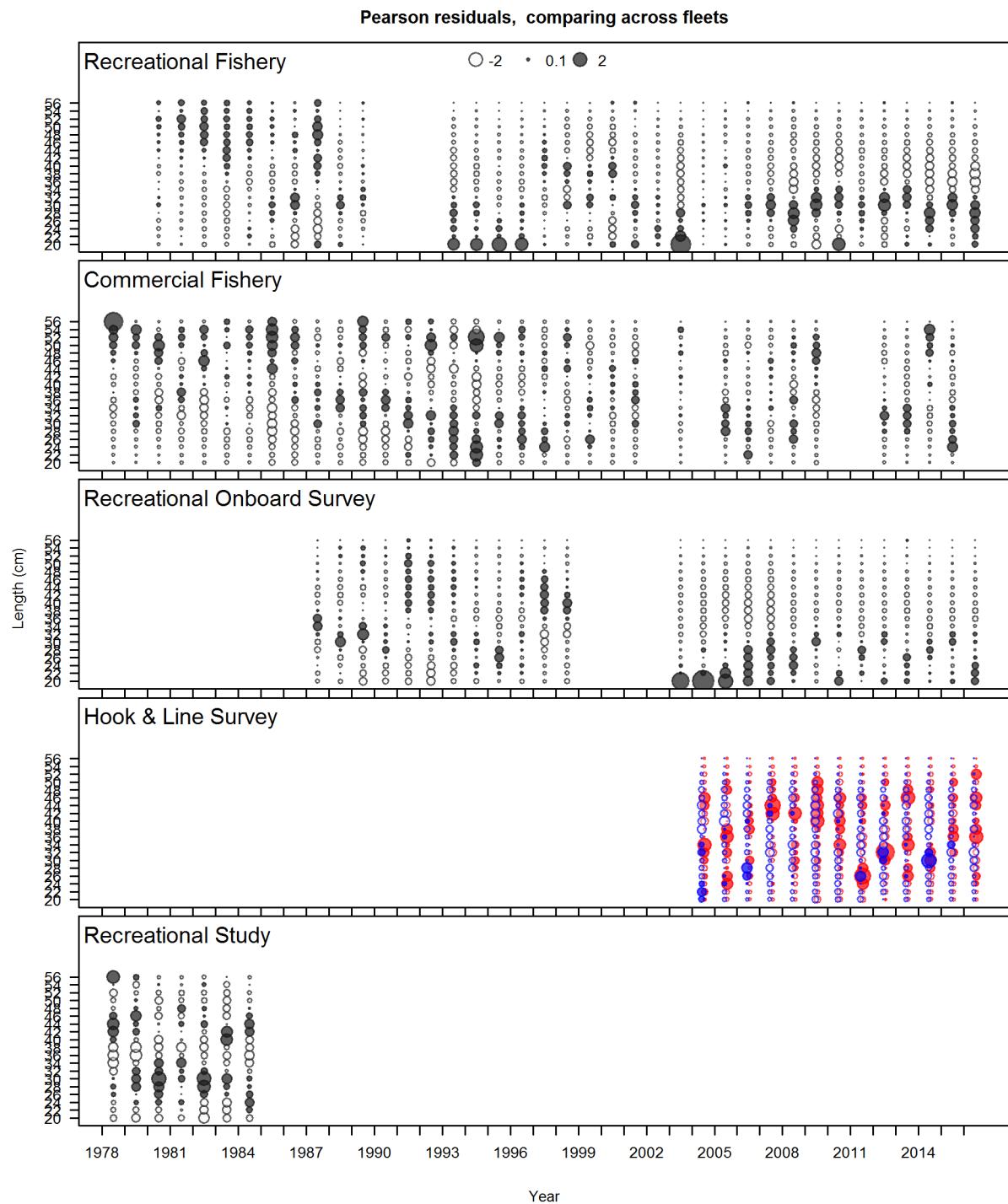


Figure 74: Length composition Pearson residuals for all fleets in the Southern model. Closed bubbles are positive residuals ($\text{observed} > \text{expected}$) and open bubbles are negative residuals ($\text{observed} < \text{expected}$). [fig:comp_Pearson_length_mod2](#)

1001 9.4.4 Age compositions for Southern model
age-compositions-for-southern-model

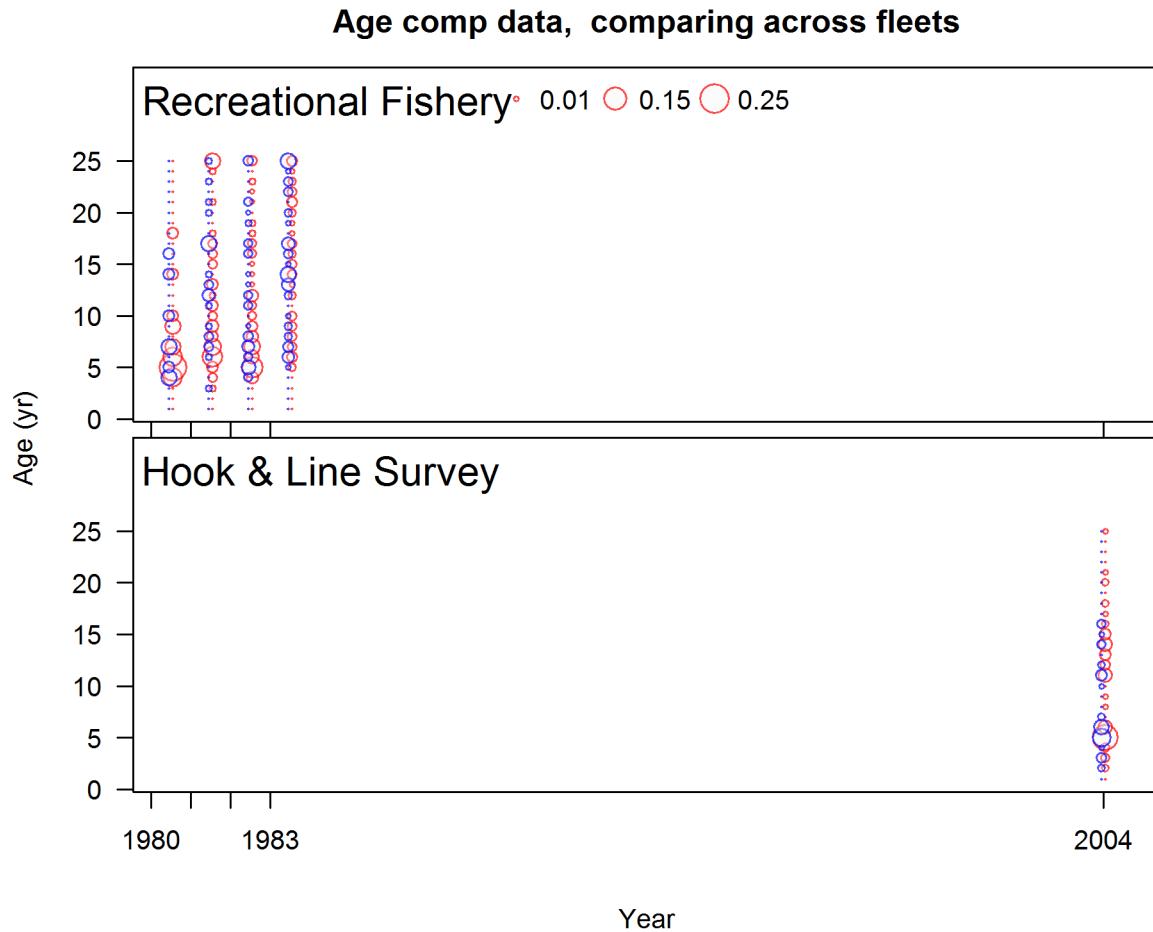


Figure 75: Age compositions for all fleets in the Southern model. Bubble size is proportional to proportions within each year. [fig:comp_age_bubble_mod2](#)

Age comps, retained, Recreational Fishery

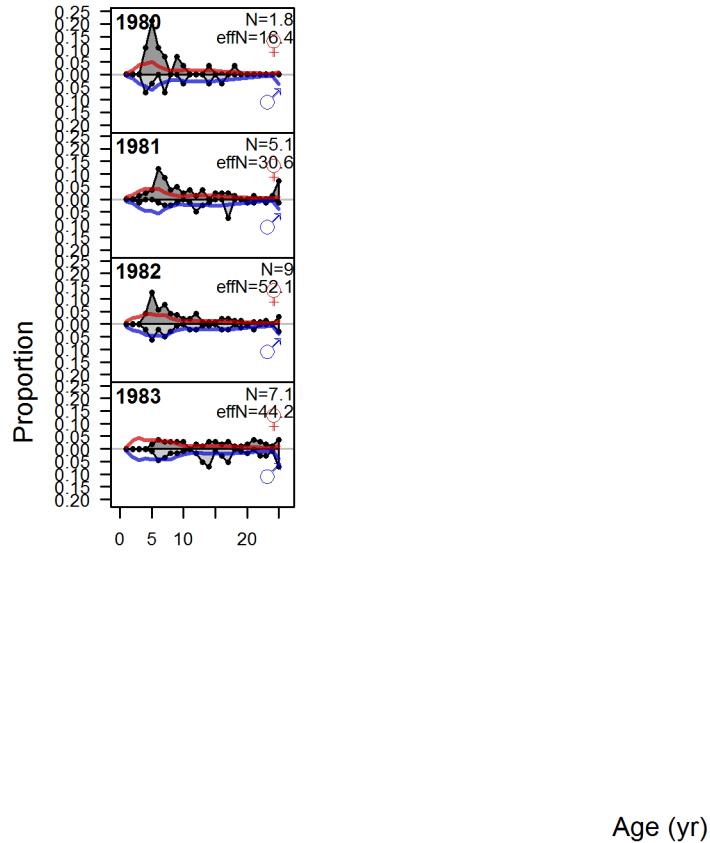


Figure 76: **Southern model** Age comps, retained, Recreational Fishery [fig:mod2_1_comp_agefi](#)

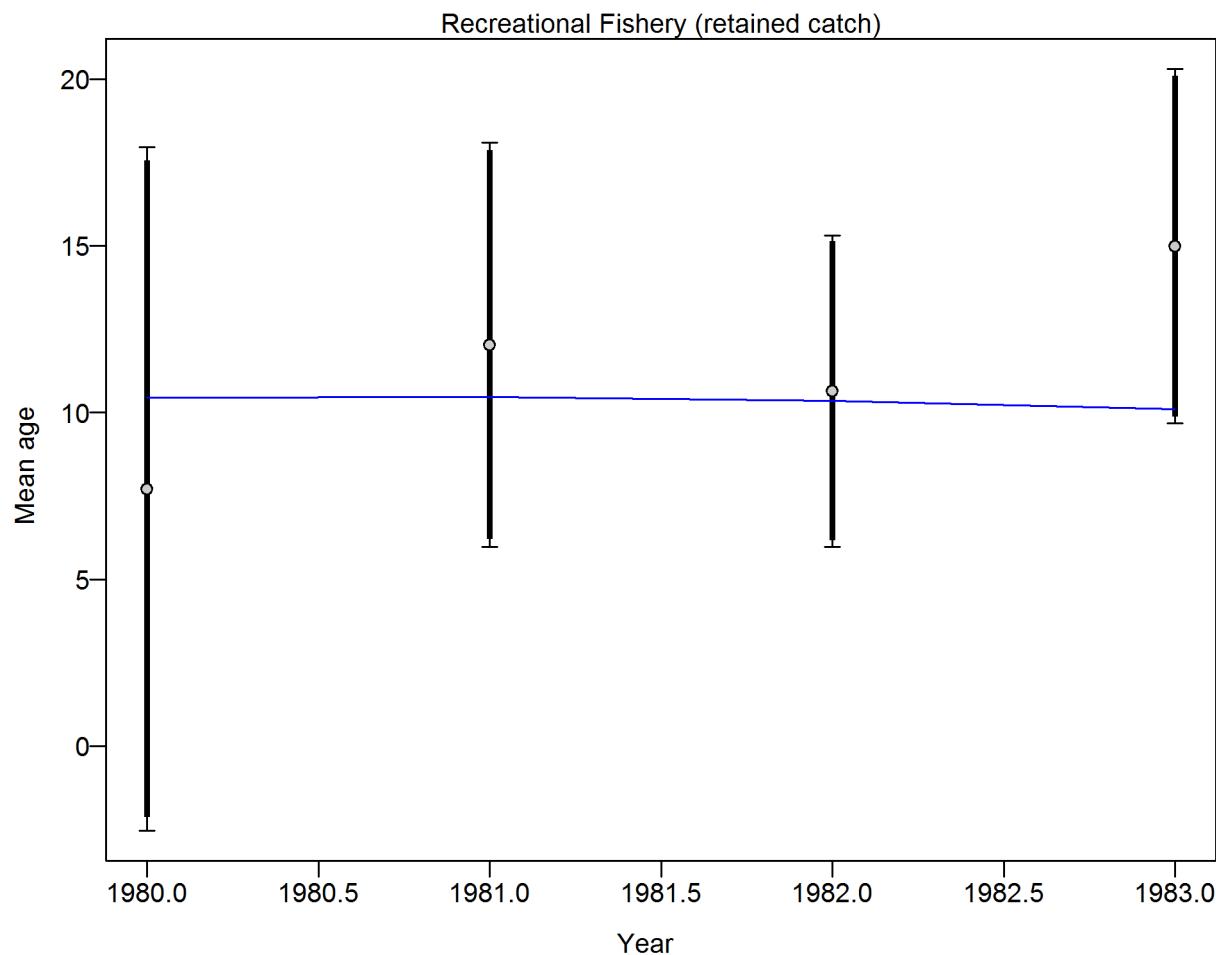
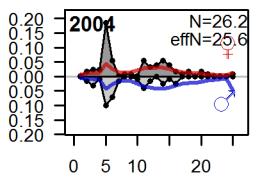


Figure 77: **Southern model** Mean age for Recreational Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age 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_agesfit_data_weighting_TA1.8_Recre](#)

Proportion

Age comps, whole catch, Hook & Line Survey



Age (yr)

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](#)

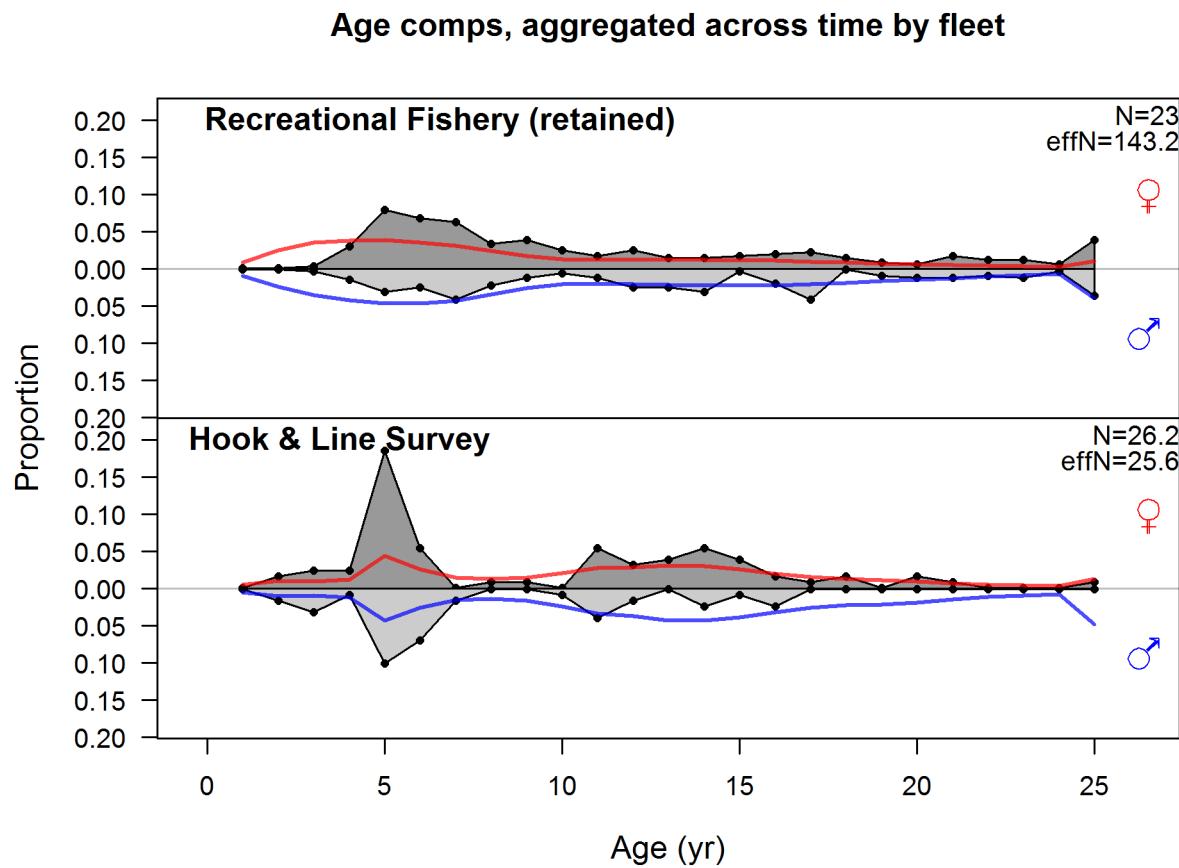


Figure 80: **Southern model** Age comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. [fig:mod2_9_comp_agerfit__aggregated_across_time](#)

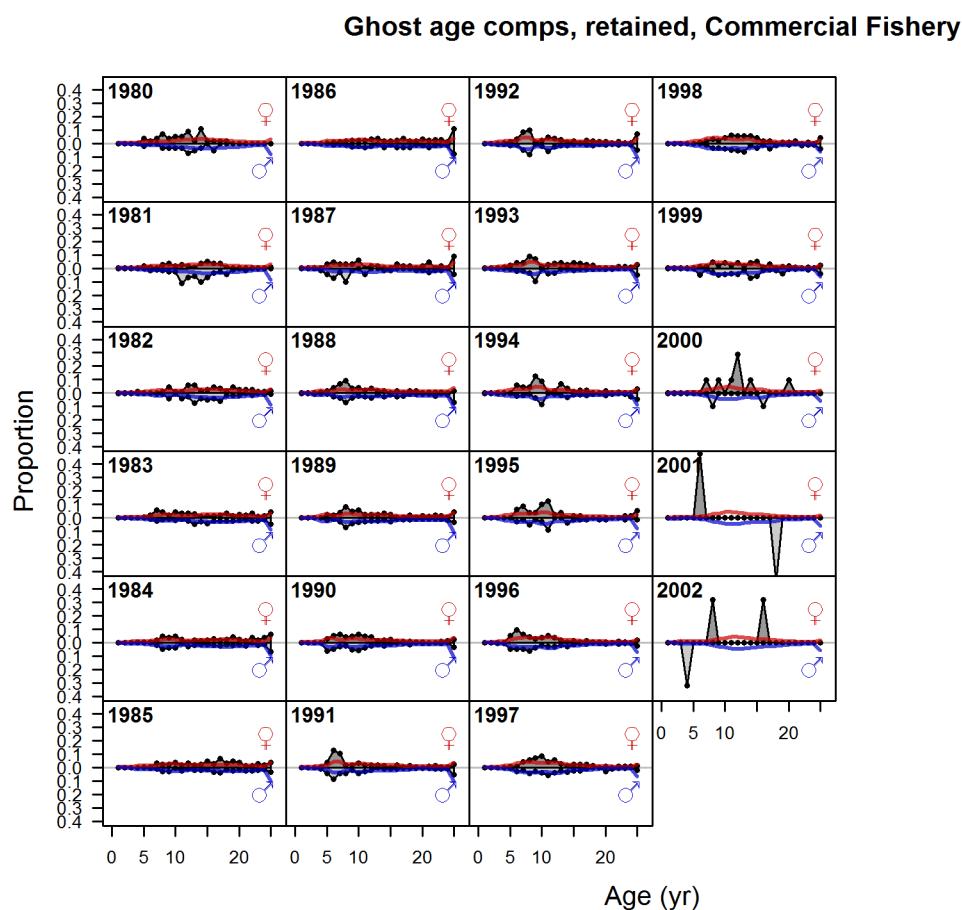


Figure 81: Southern model Ghost age comps, retained, Commercial Fishery fig:mod2_11_comp-g

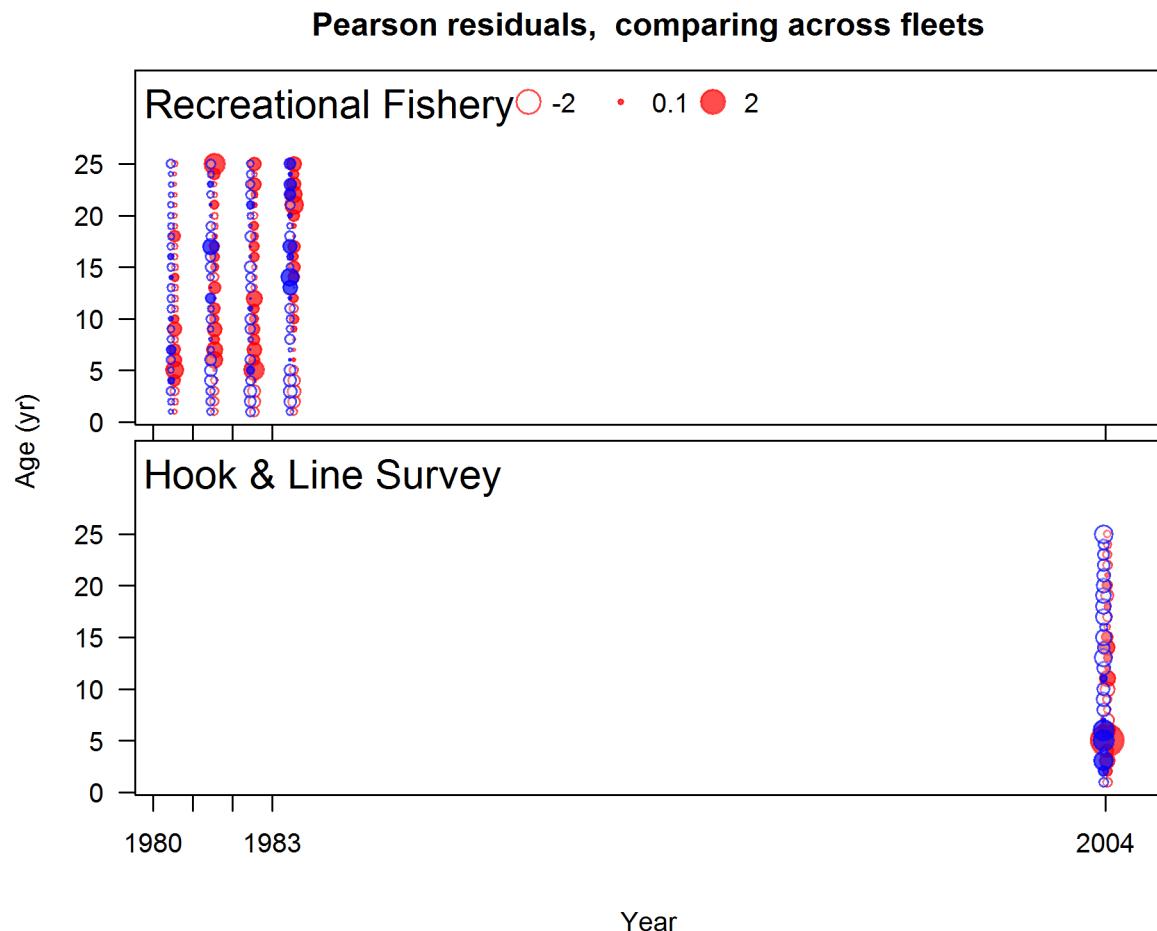


Figure 82: Age composition Pearson residuals for all fleets in the Southern model. Closed bubbles are positive residuals (observed $>$ expected) and open bubbles are negative residuals (observed $<$ expected). [fig:comp_Pearson_age_mod2](#)

1002 9.4.5 Fits to conditional-age-at-length compositions for Southern model
fits-to-conditional-age-at-length-compositions-for-southern-model

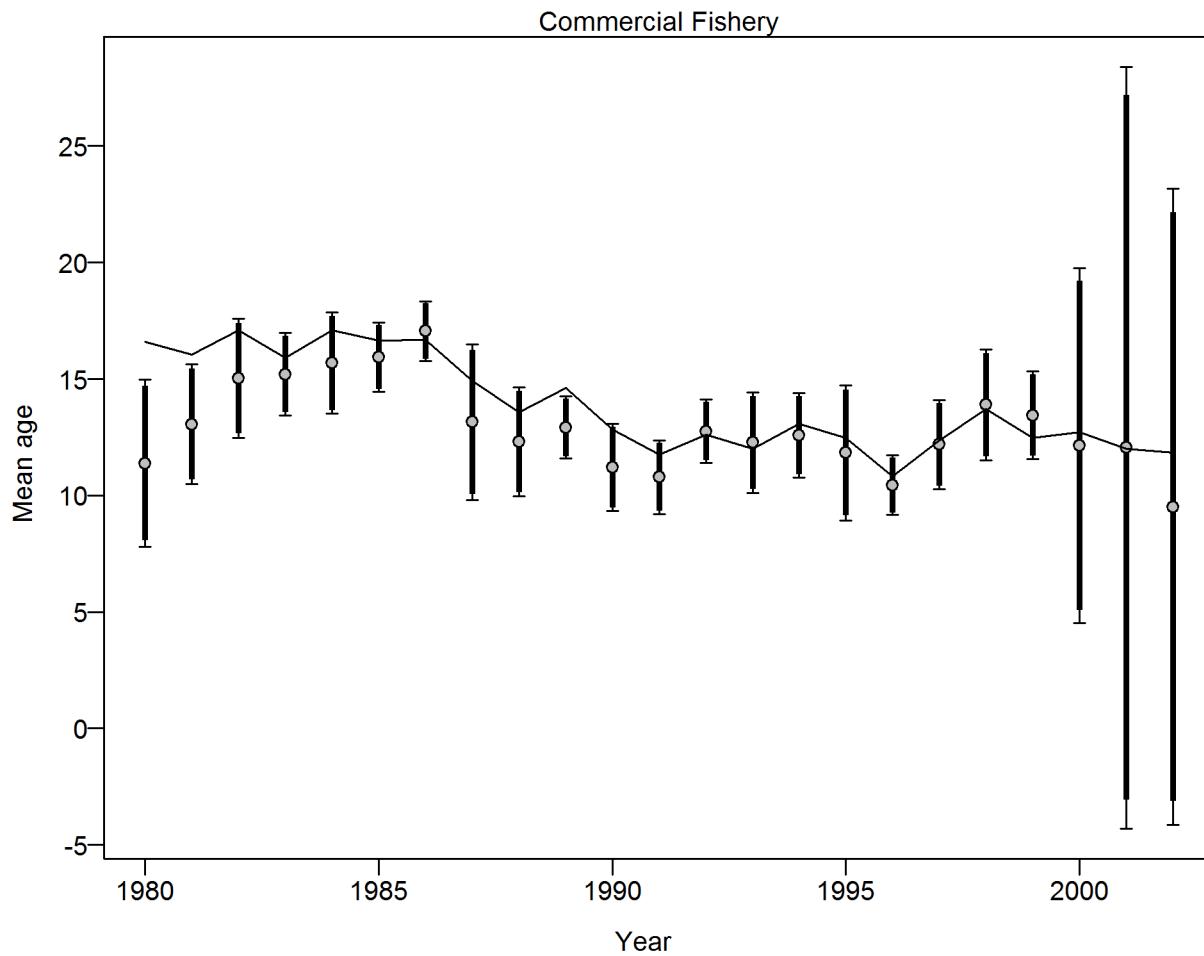


Figure 83: **Southern model** Mean age from conditional data (aggregated across length bins) for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based 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_condAgeCommercial

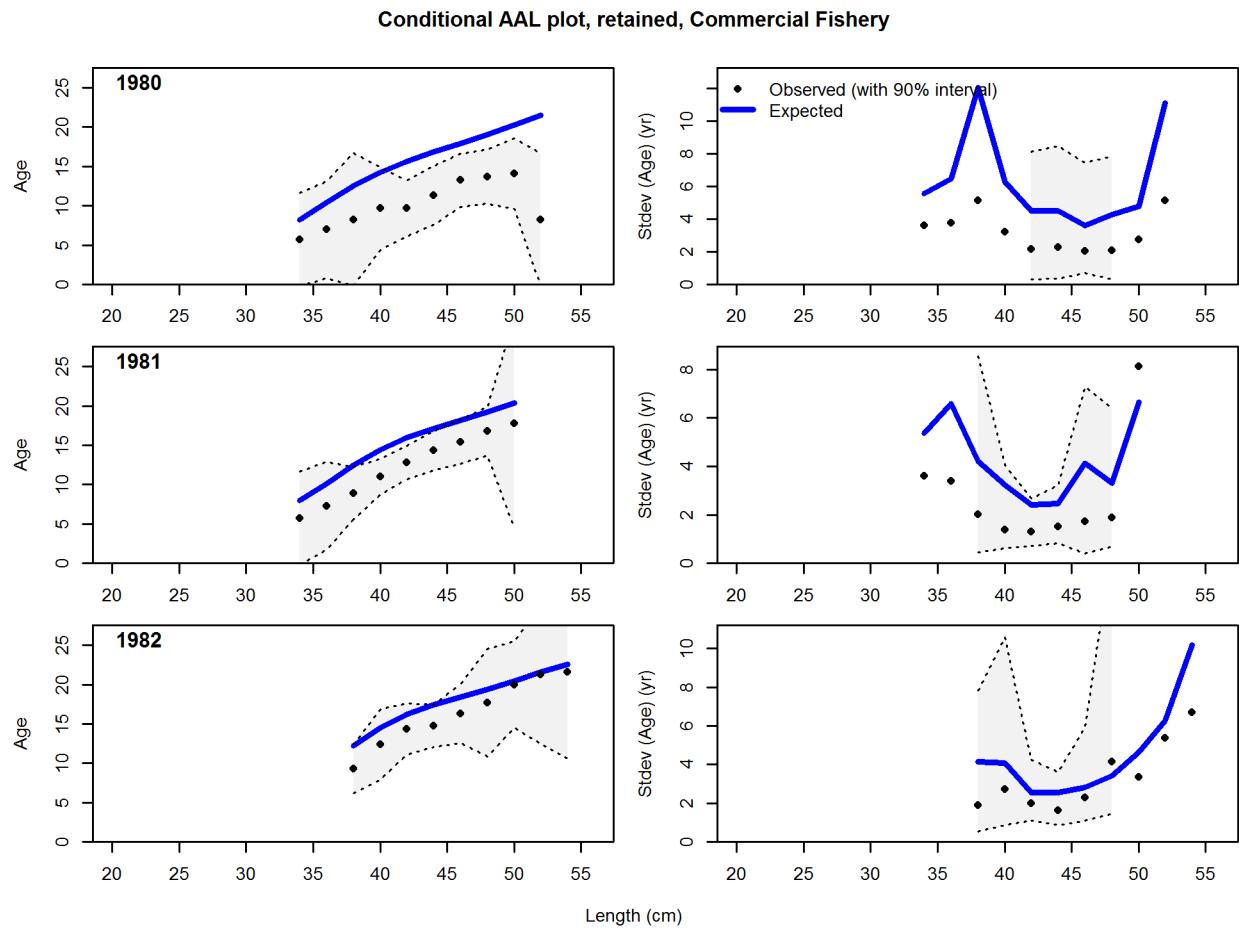
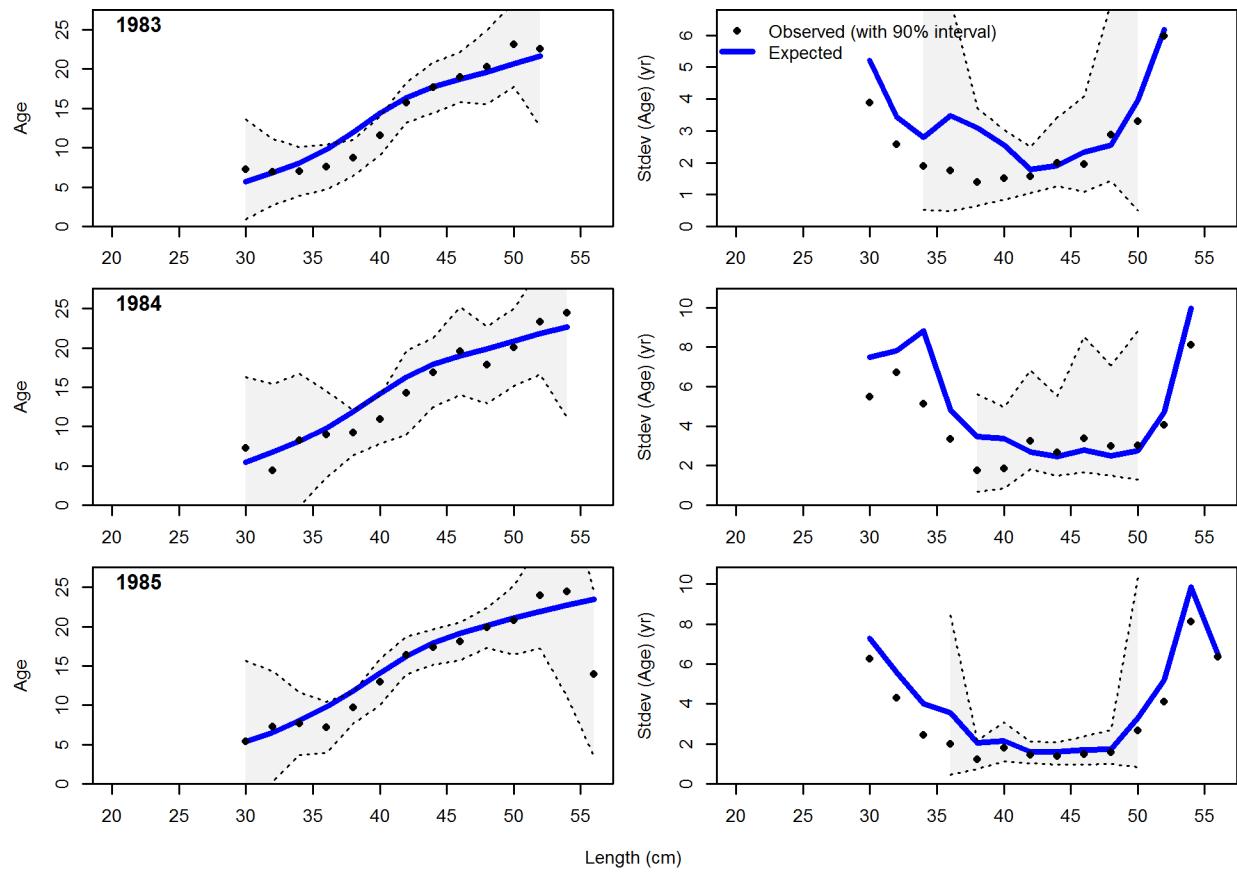


Figure 84: **Southern model** Conditional AAL plot, retained, Commercial Fishery (plot 1 of 8) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution. | [fig:mod2_5_comp_condAALfitAndre_plotsf1t2mkt2_page1](#)

Conditional AAL plot, retained, Commercial Fishery

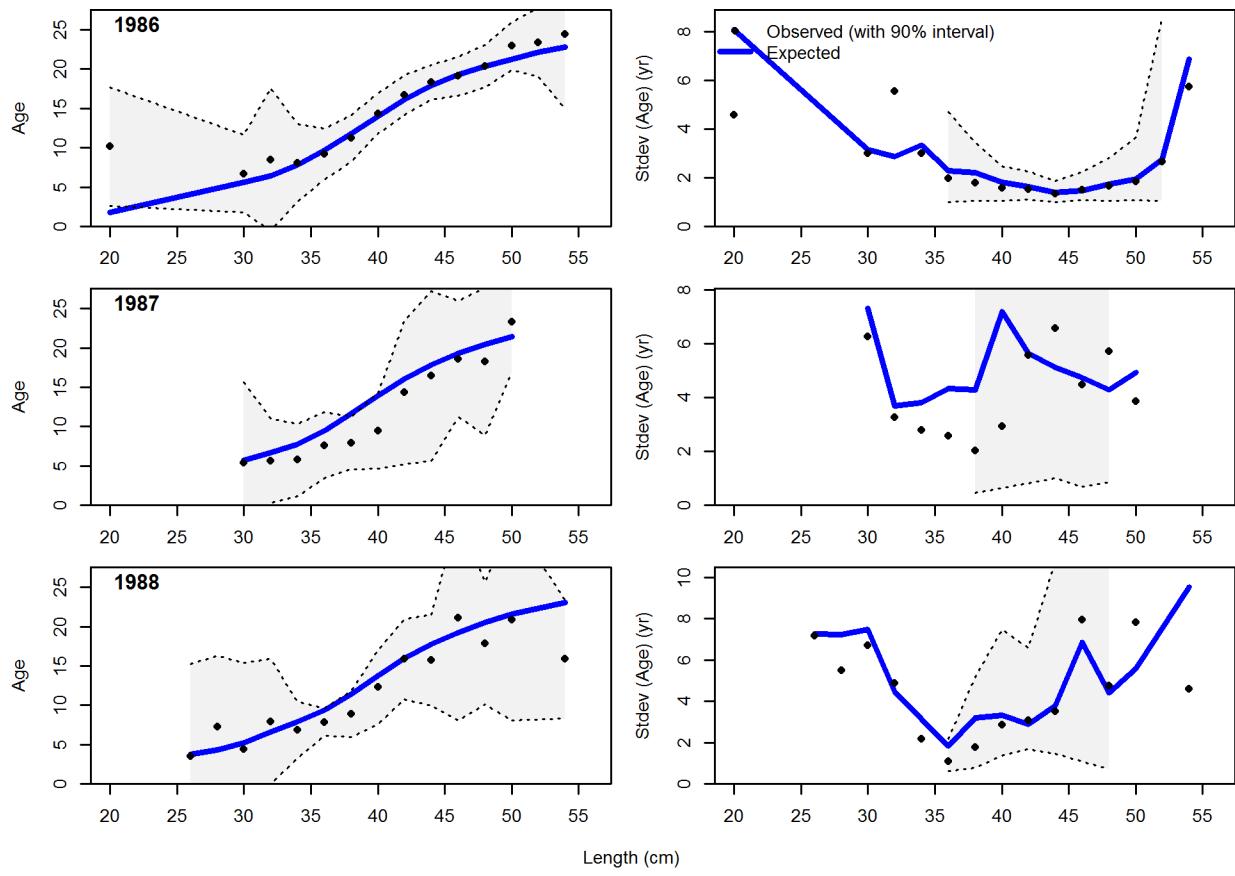


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Figure continued from previous page

Conditional AAL plot, retained, Commercial Fishery

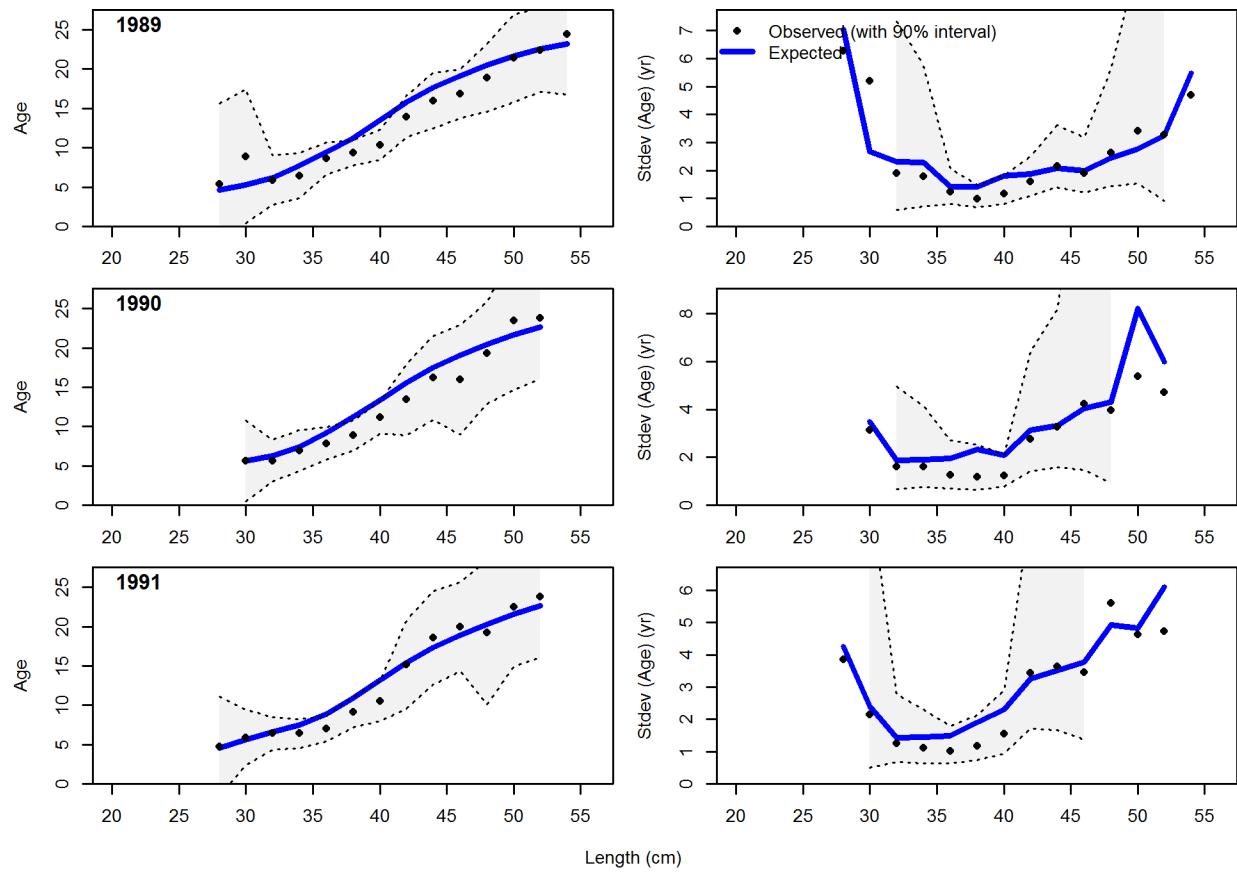


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Figure continued from previous page

Conditional AAL plot, retained, Commercial Fishery



1007

1008

Figure continued from previous page

Conditional AAL plot, retained, Commercial Fishery

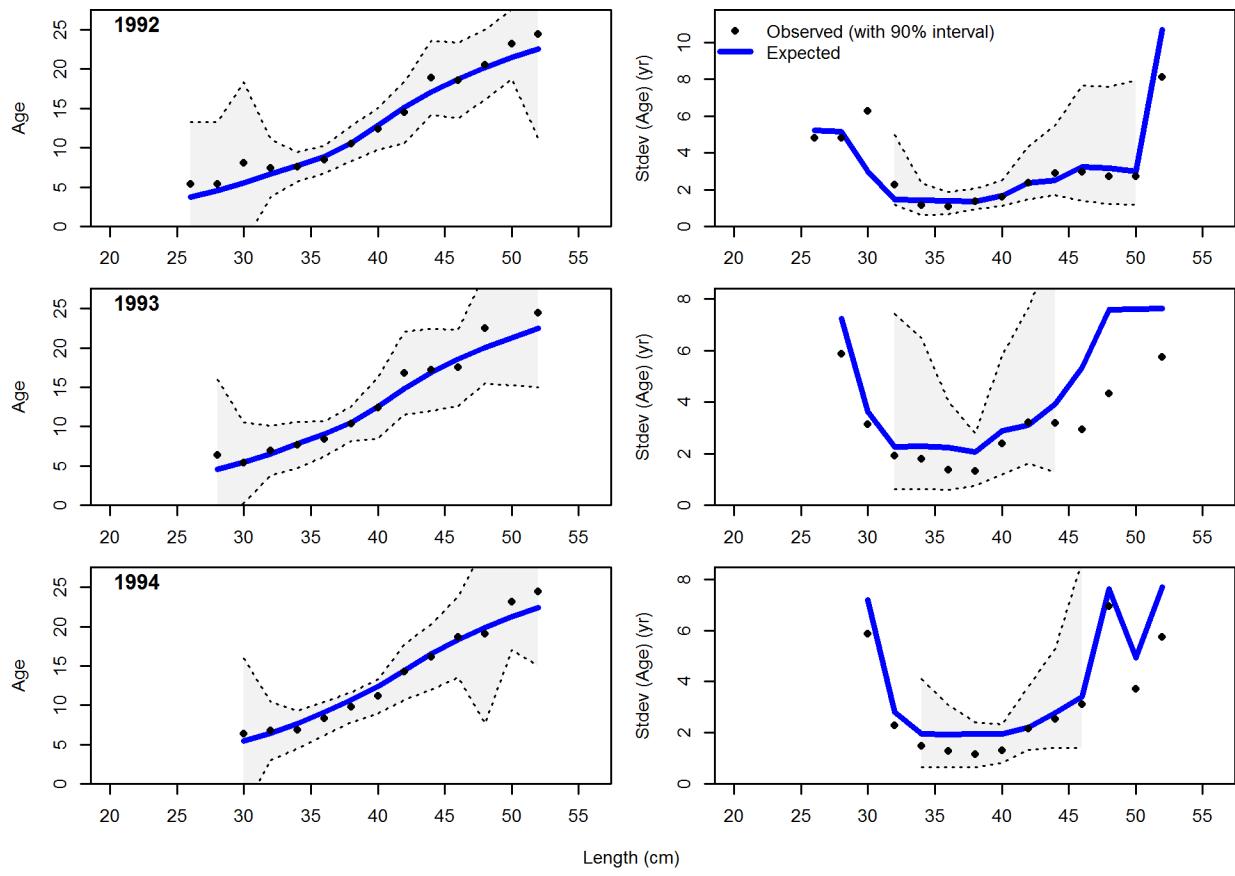
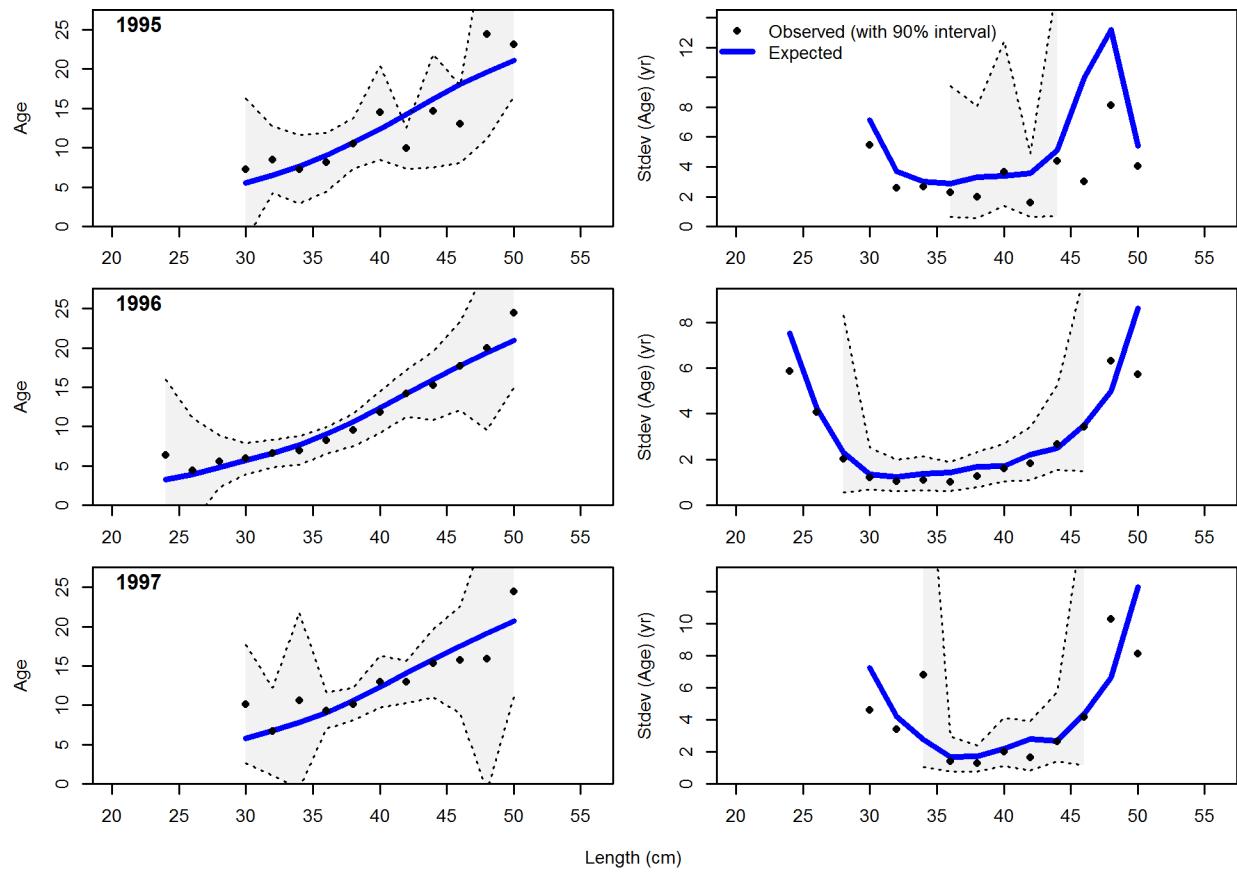


Figure continued from previous page

Conditional AAL plot, retained, Commercial Fishery

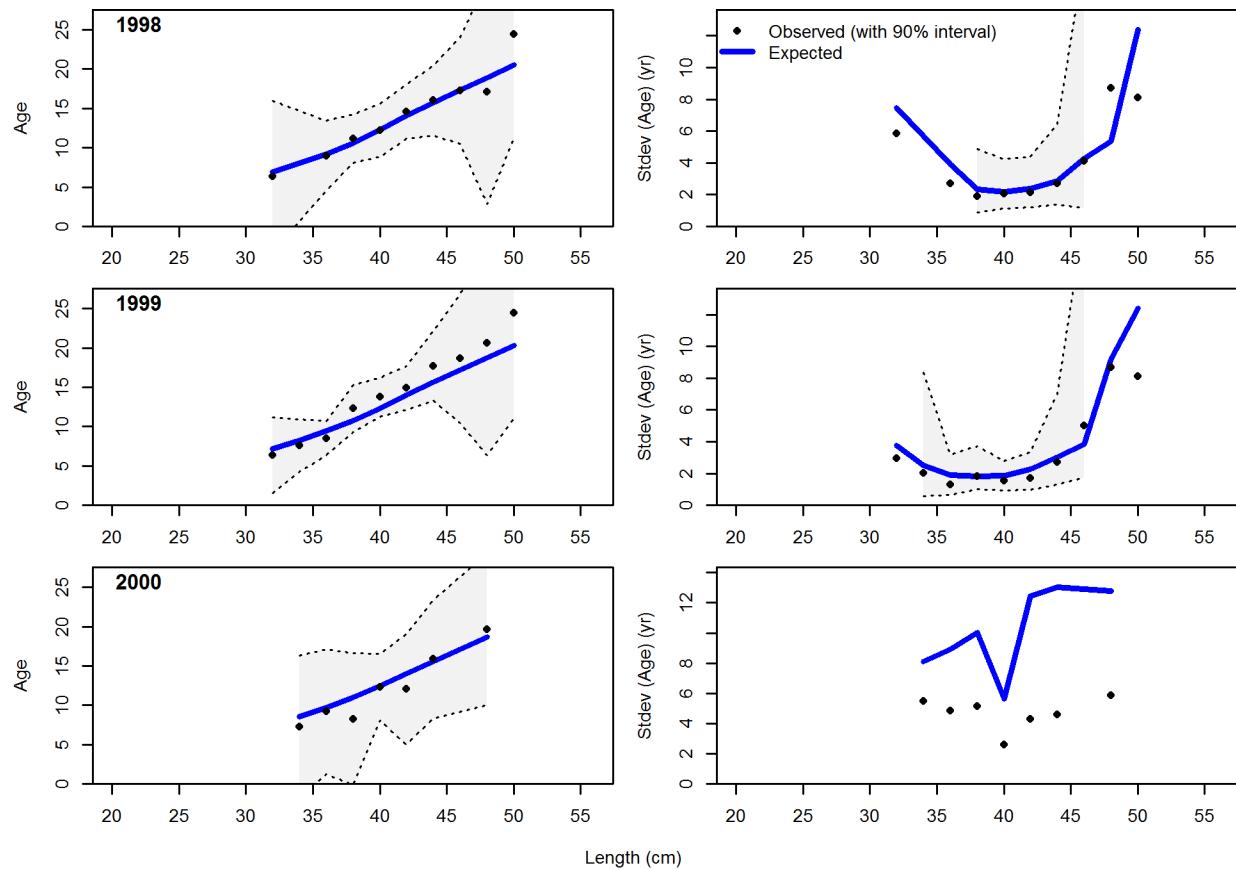


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Figure continued from previous page

Conditional AAL plot, retained, Commercial Fishery

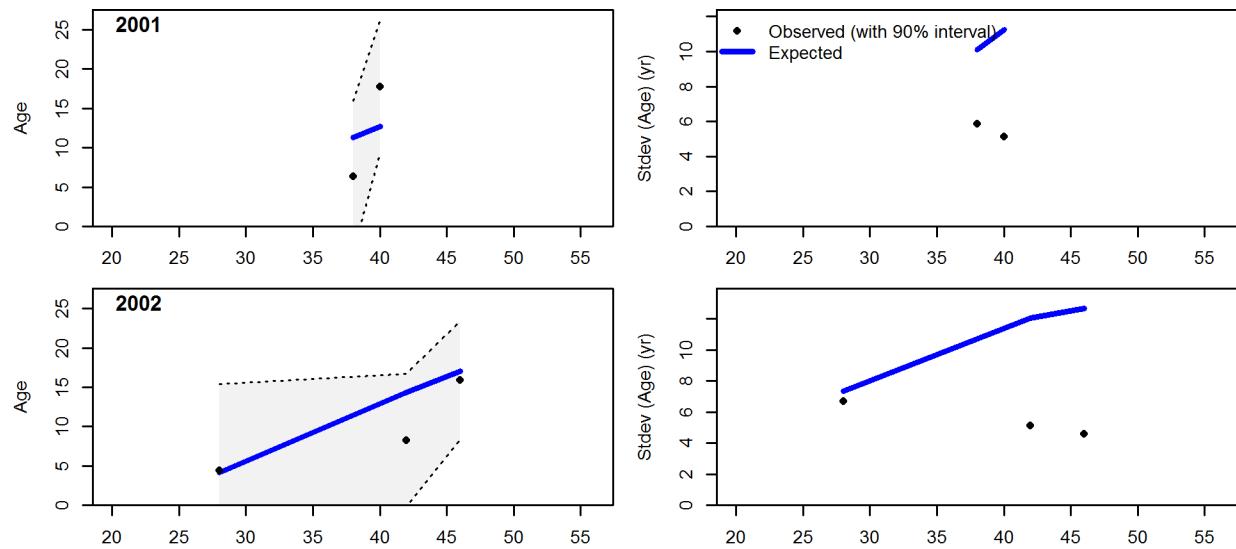


1013

1014

Figure continued from previous page

Conditional AAL plot, retained, Commercial Fishery



Length (cm)

1015

1016

Figure continued from previous page

1017 **9.5 Model results for Southern model** [model-results-for-southern-model](#)

1018 **9.5.1 Base model results for Southern model** [base-model-results-for-southern-model](#)

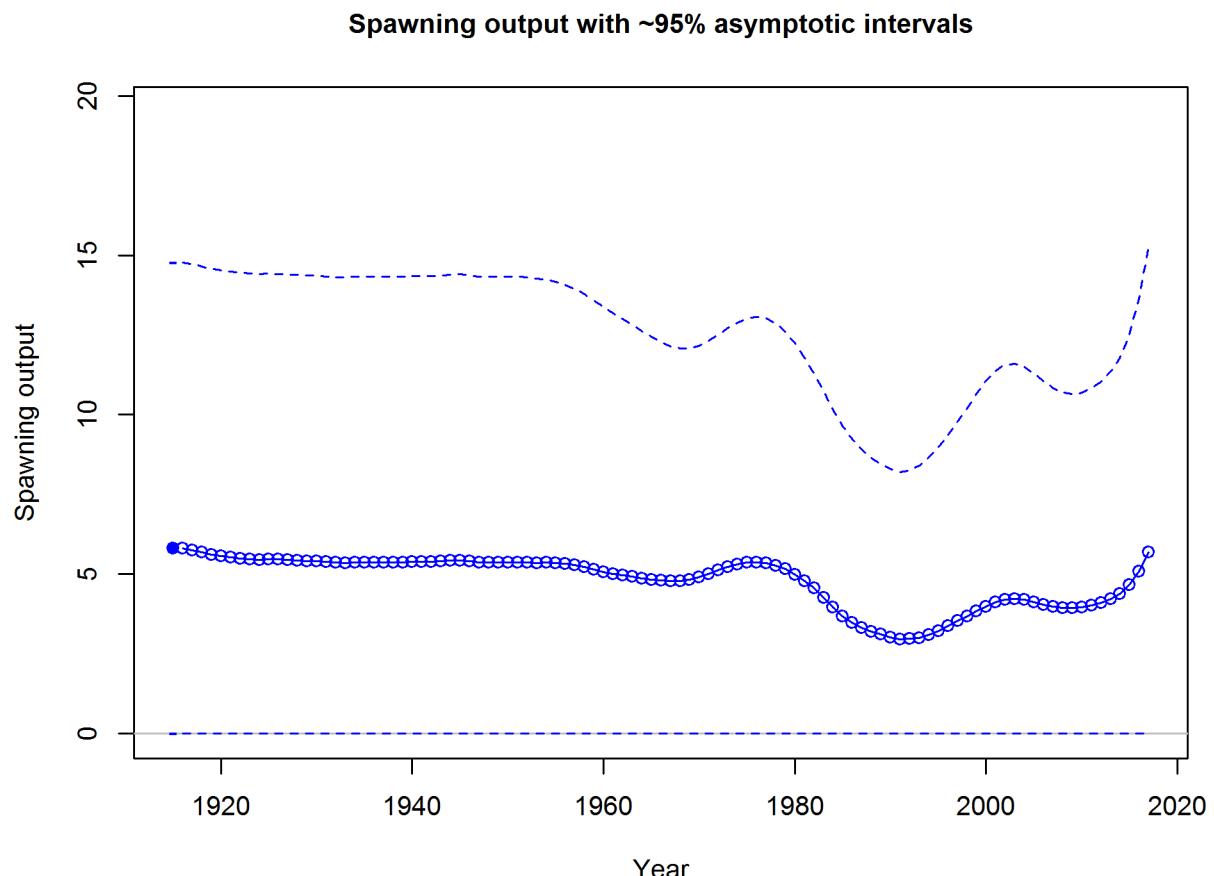


Figure 85: Estimated time-series of spawning output for Southern model. [fig:ssb](#)

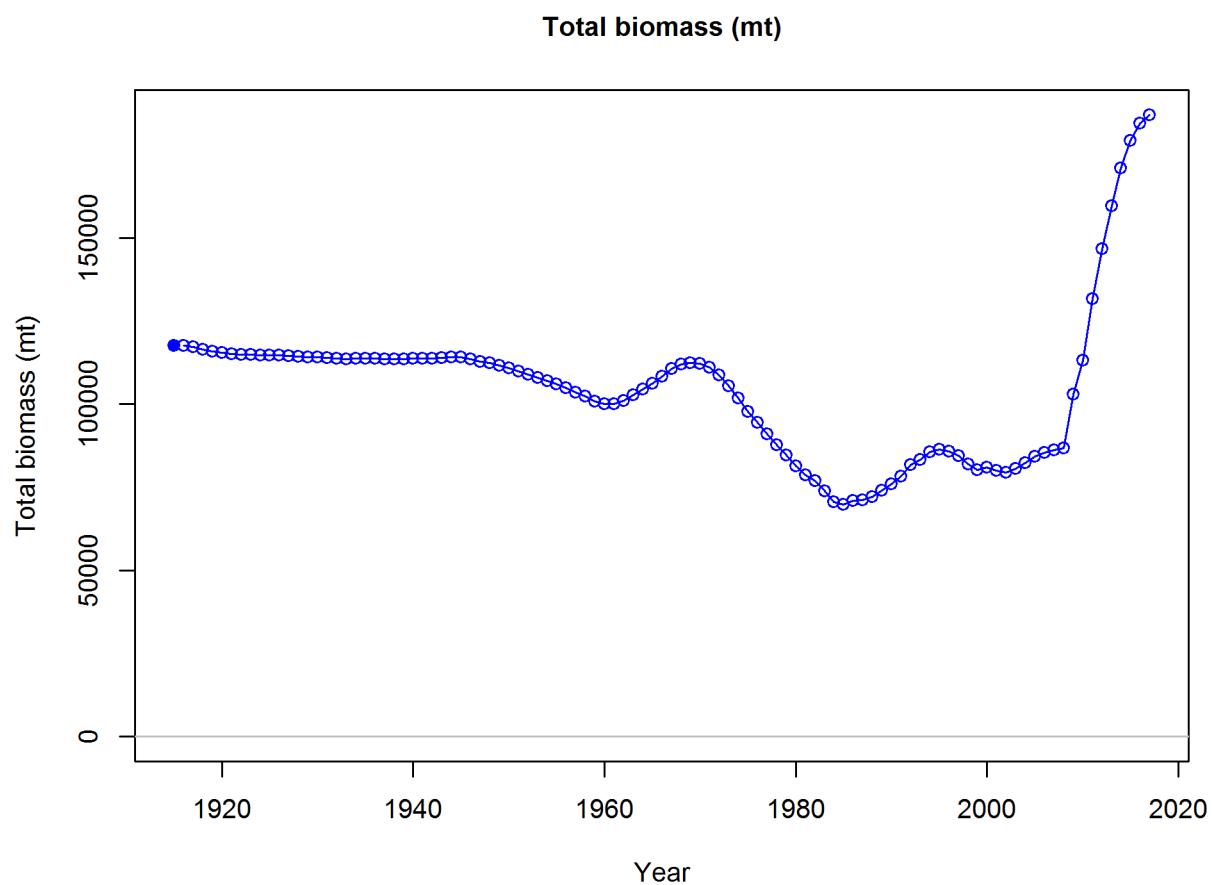


Figure 86: Estimated time-series of total biomass for Southern model. `fig:total_bio`

Spawning depletion with ~95% asymptotic intervals

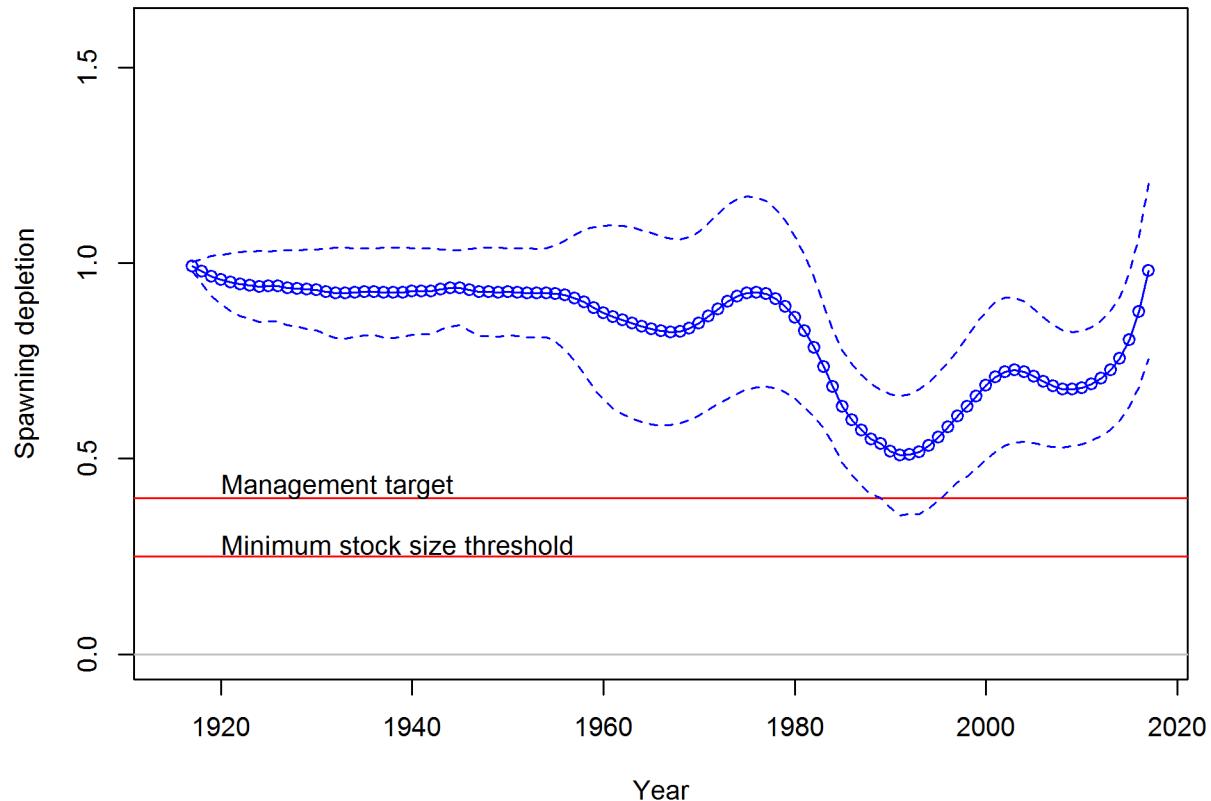


Figure 87: Estimated time-series of relative biomass for Southern model. ^{fig:dep1}

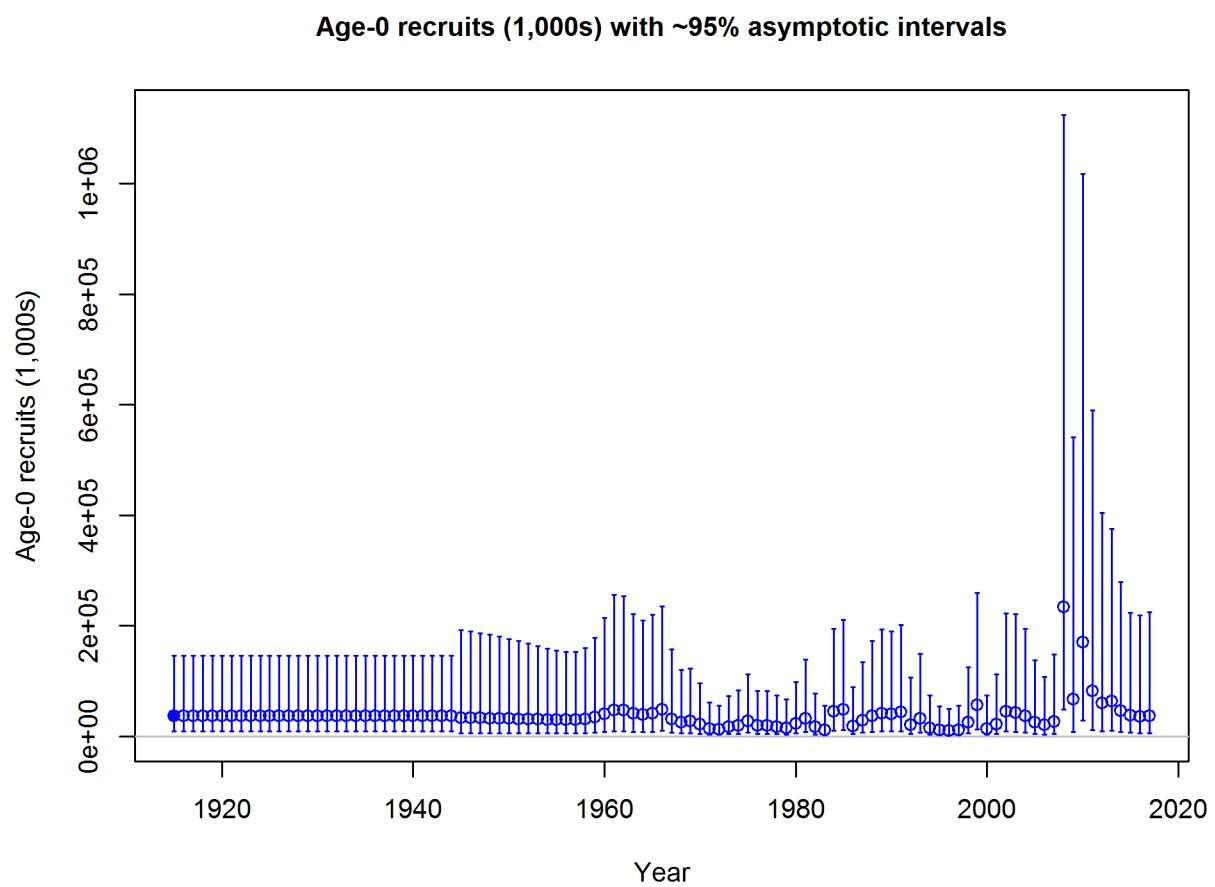


Figure 88: Estimated time-series of recruitment for the Southern model. fig:recruits1

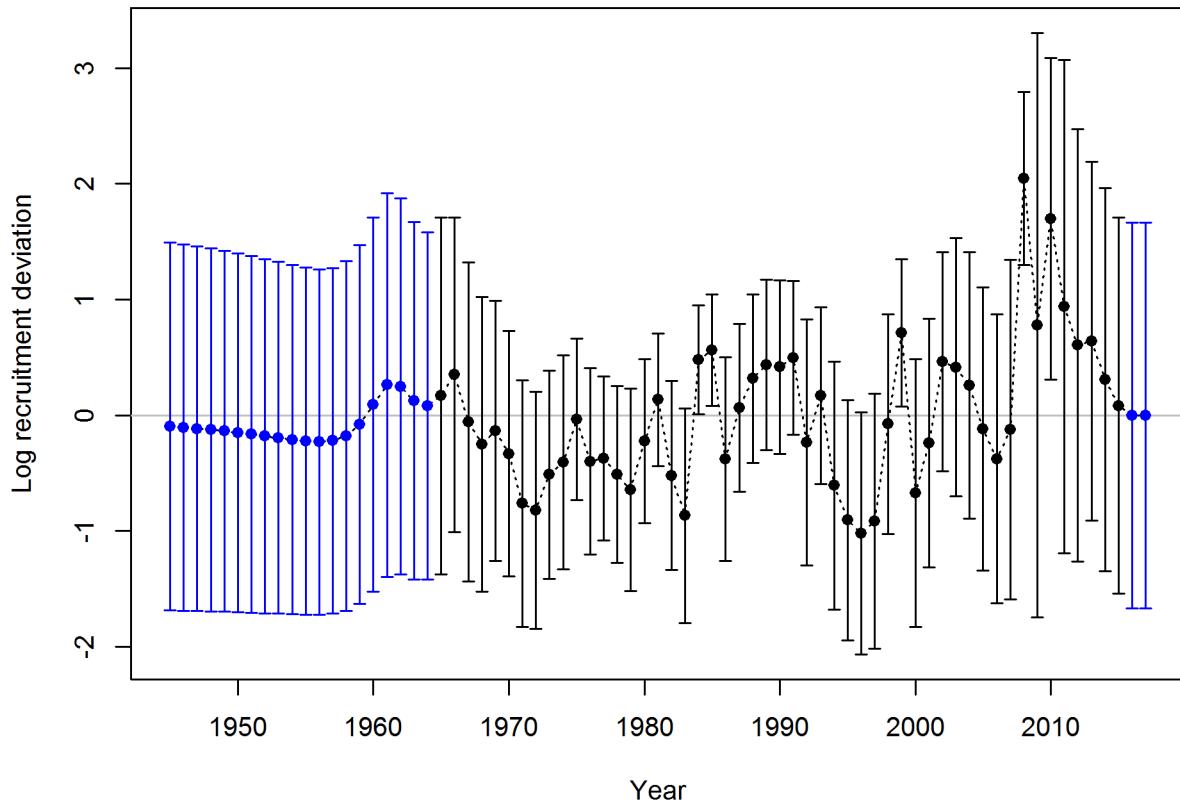


Figure 89: Estimated time-series of recruitment deviations for the Southern model. `fig:recdevs1`

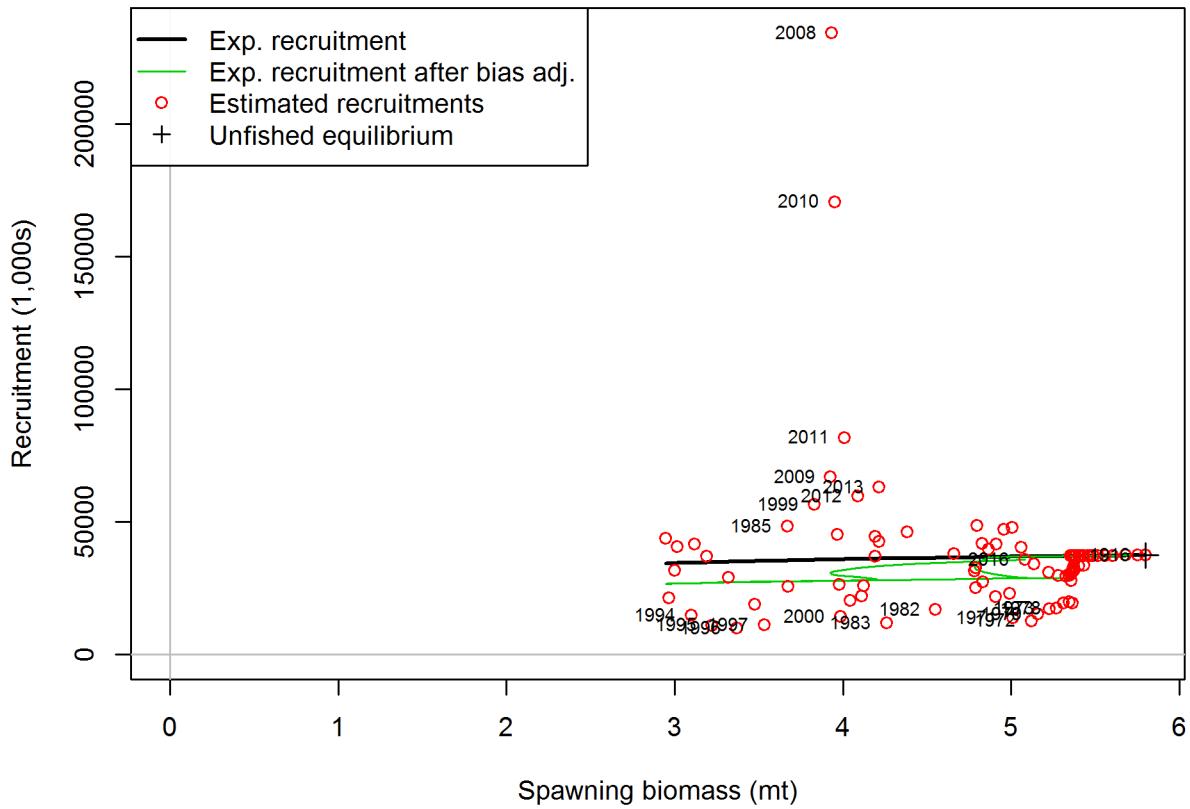


Figure 90: Estimated recruitment (red circles) for the Southern model relative to the stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution [fig:stock_recruit_curve](#)

1019 9.5.2 Sensitivity analyses for Southern model
sensitivity-analyses-for-southern-model

1020 to be added...

1021 9.5.3 Likelihood profiles for Southern model
likelihood-profiles-for-southern-model

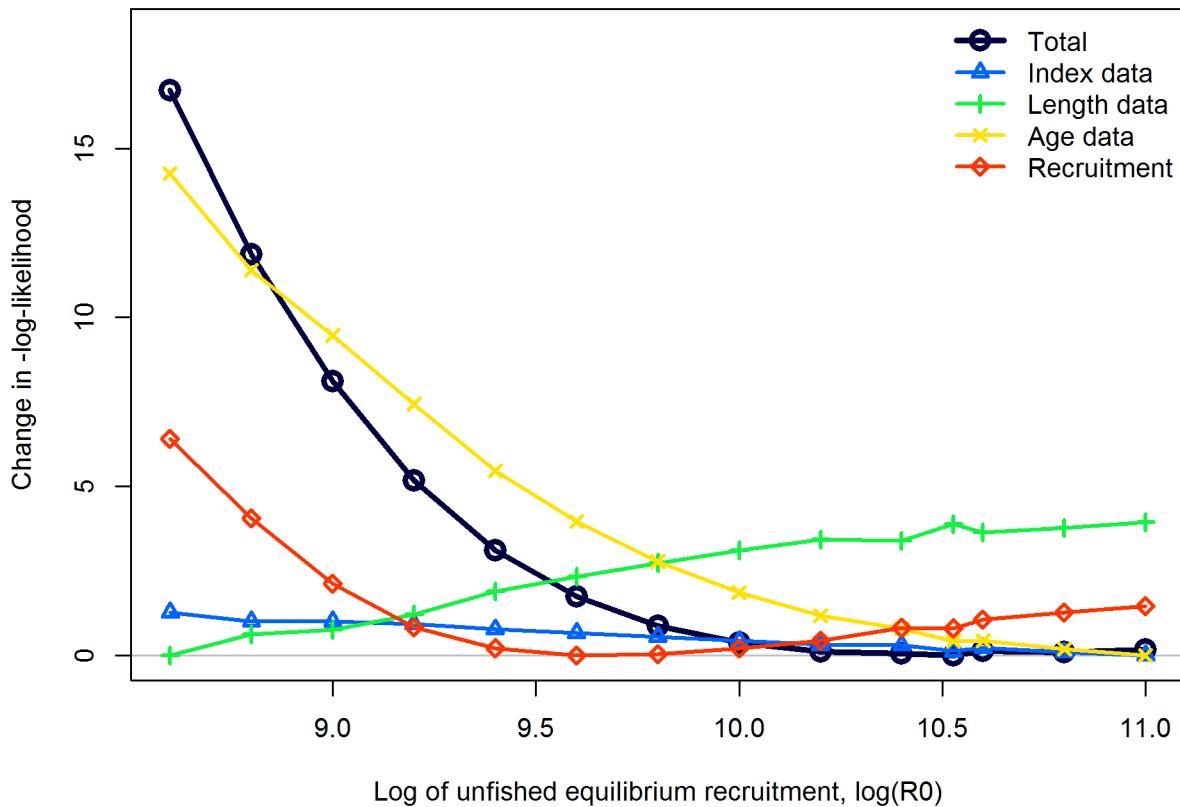


Figure 91: Likelihood profile over the log of equilibrium recruitment (R_0) for the Southern model. | [fig:profile_logR0.S](#)

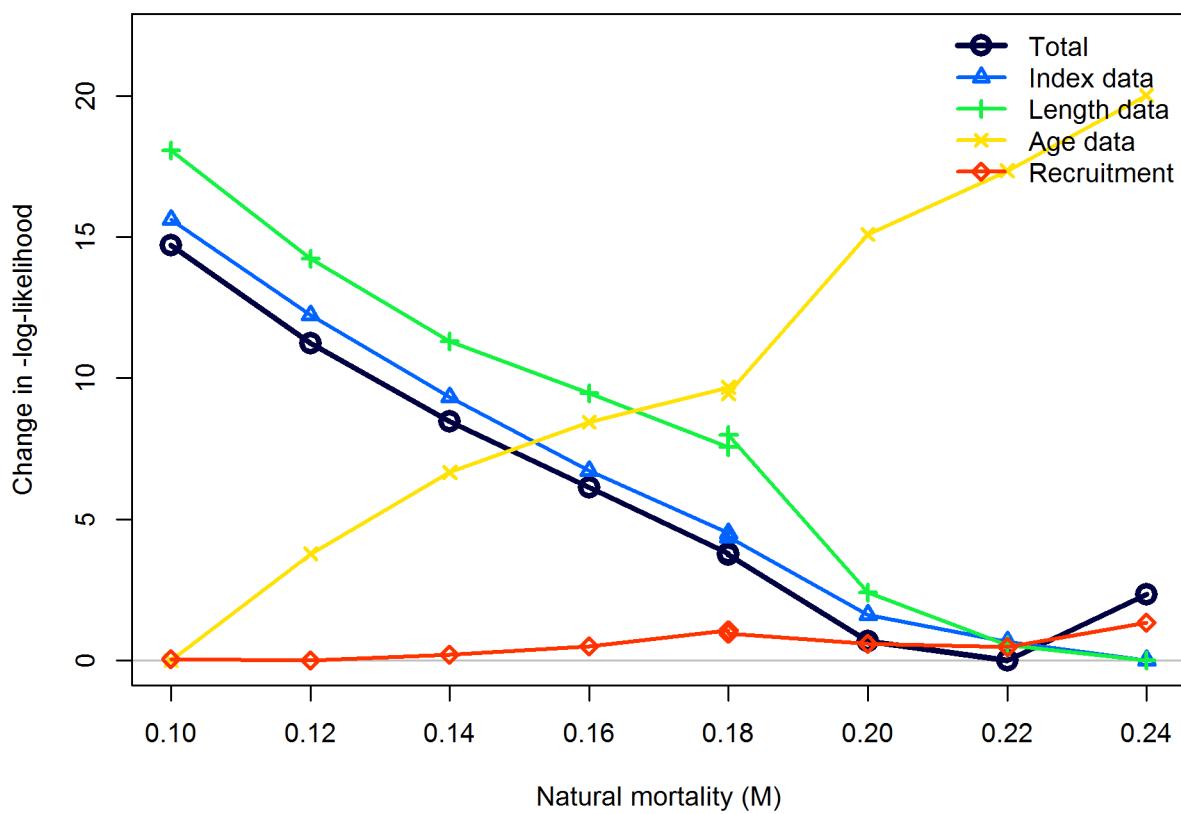


Figure 92: Likelihood profile over female natural mortality for the Southern model. `fig:profile_M.S`

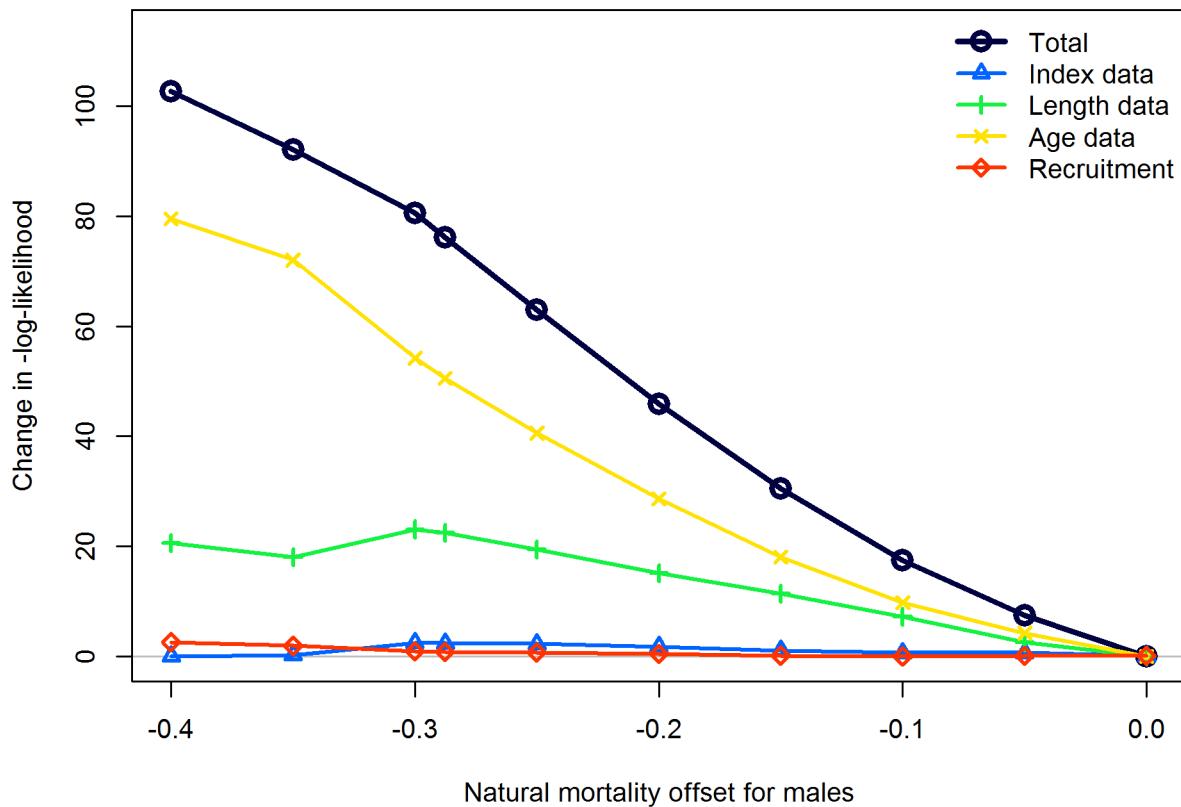


Figure 93: Likelihood profile over the male offset for natural mortality for the Southern model.
Negative values are associated with natural mortality being lower for males than females.
[fig:profile_M2](#)

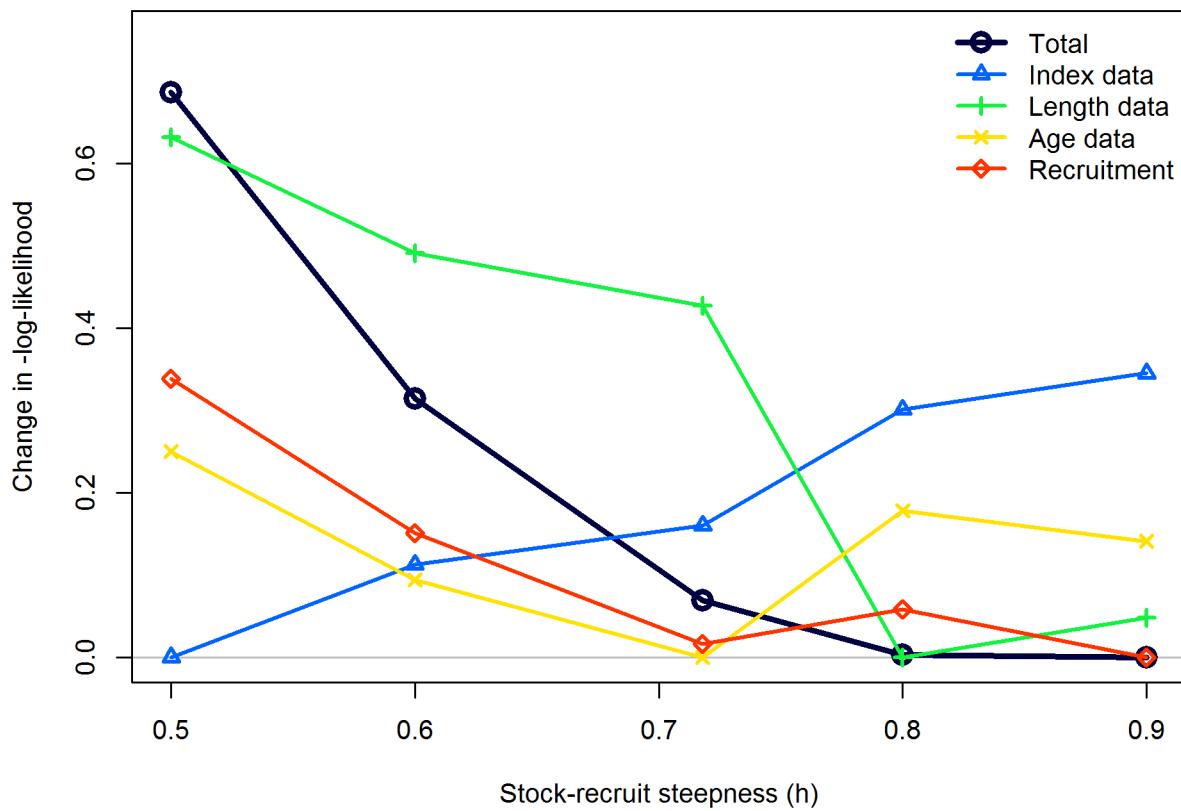


Figure 94: Likelihood profile over stock-recruit steepness (h) for the Southern model. `fig:profile_h.S`

1022 **9.5.4 Retrospective analysis for Southern model**
retrospective-analysis-for-southern-model

1023 to be added...

1024 **9.5.5 Forecasts analysis for Southern model**
forecasts-analysis-for-southern-model

1025 to be added...

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