

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



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<sup>16</sup> or policy.

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

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126 **References**

<sup>127</sup> **Executive Summary**

executive-summary

<sup>128</sup> **Stock**

stock

<sup>129</sup> This assessment reports the status of the Yellowtail Rockfish (*Sebastodes flavidus*) resource in  
<sup>130</sup> U.S. waters off the coast of California, Oregon, and Washington using data through 2016.

<sup>131</sup> The Pacific Fishery Management Council (PFMC) manages the U.S. fishery as two stocks  
<sup>132</sup> separated at Cape Mendocino, California (40° 10'N). The northern stock has long been  
<sup>133</sup> assessed on its own; the southern stock is managed as part of the Southern Shelf Complex.  
<sup>134</sup> This assessment analyzes each stock independently, with the southern stock extending  
<sup>135</sup> southward to the U.S./Mexico border and the northern stock extending northward to the  
<sup>136</sup> U.S./Canada border.

<sup>137</sup> The most recent fully integrated assessment (Wallace and Lai [2005](#)), following the pattern of  
<sup>138</sup> prior assessments, included only the Northern stock which it divided into three assessment  
<sup>139</sup> areas with divisions at Cape Elizabeth (47° 20'N) and Cape Falcon (45° 46'N). A data-  
<sup>140</sup> moderate assessment conducted in 2013 (Cope et al. [2013](#)) was the first to analyze the  
<sup>141</sup> southern stock, determining its contribution to the overfishing limit (OFL) for the Southern  
<sup>142</sup> Shelf Complex.

<sup>143</sup> Since the 2005 assessment, reconstruction of historical catch by Washington and Oregon  
<sup>144</sup> makes any border but the state line (roughly 46° N) incompatible with the data from those  
<sup>145</sup> states. Additionally, much of the groundfish catch landed in northern Oregon is caught in  
<sup>146</sup> Washington waters.

<sup>147</sup> This assessment addresses the stock in two areas consistent with the management border  
<sup>148</sup> at Cape Mendocino. This is consistent, as well, with a recent genetic analysis (Hess et al.  
<sup>149</sup> n.d.) that found distinct stocks north and south of Cape Mendocino but did not find stock  
<sup>150</sup> differences within the northern area.

<sup>151</sup> **Catches**

catches

<sup>152</sup> Catches from the Northern stock were divided into four categories: commercial catch, bycatch  
<sup>153</sup> in the at-sea hake fishery, recreational catch in Oregon and California (north of 40° 10'N),  
<sup>154</sup> and recreational catch in Washington. The first three of these fleets were entered in metric  
<sup>155</sup> tons, but the recreational catch from Washington was entered in the model as numbers of fish  
<sup>156</sup> with the average weight calculated internally in the model from the weight-length relationship  
<sup>157</sup> and the length-compositions.

<sup>158</sup> Catches from the Southern stock were divided into two categories: commercial and recreational  
<sup>159</sup> catch, both of which were entered as metric tons.

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

162 Catch figures: (Figures a-b)

163 Catch tables: (Tables a-b)

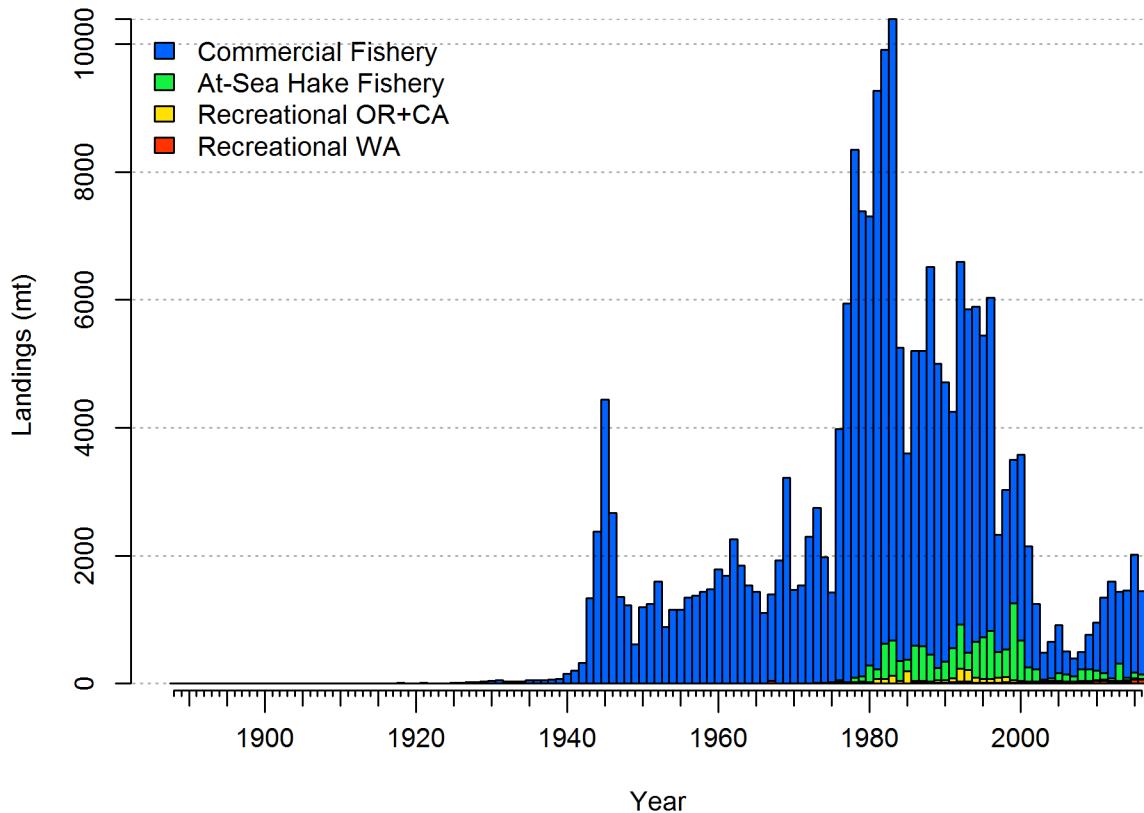


Figure a: Estimated catch history of Yellowtail Rockfish in the Northern model. Recreational catches in Washington are model estimates of total weight converted from input catch in numbers using model estimates of growth and selectivity.  
fig:r4ss\_catch\_N

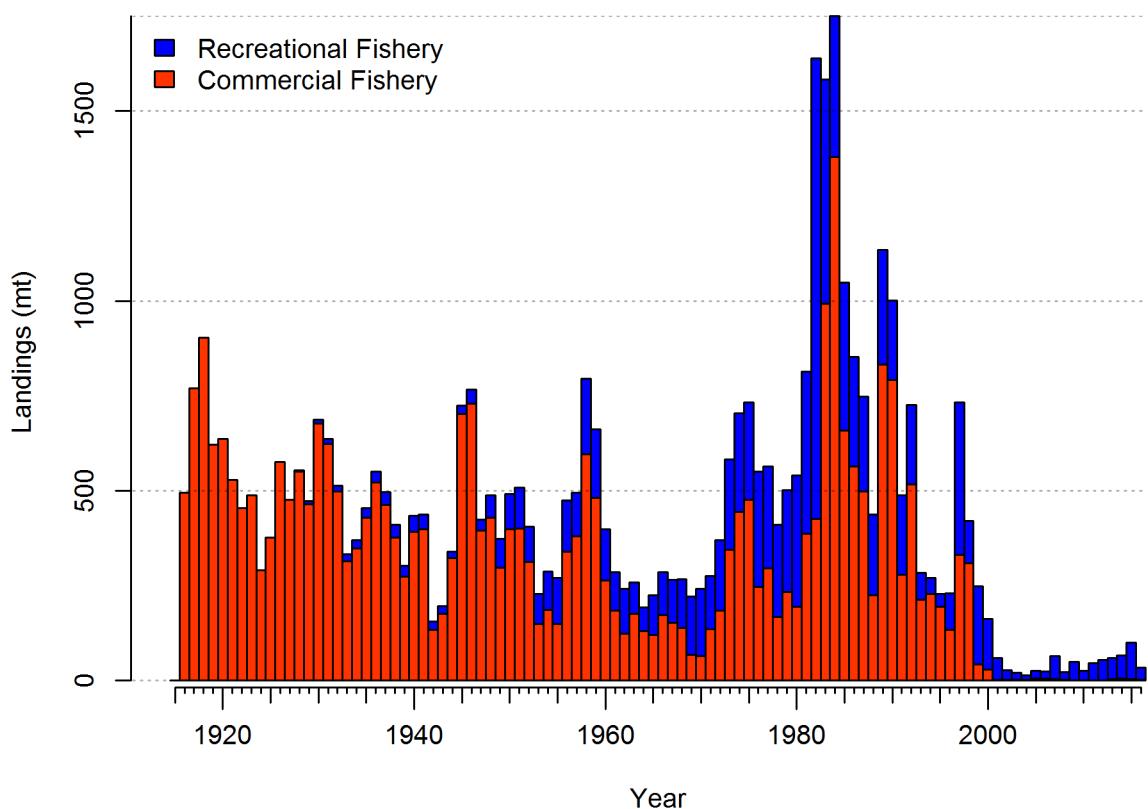


Figure b: Estimated catch history of Yellowtail Rockfish in the Southern model. [fig:r4ss\\_catch\\_S](#)

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

`tab:Exec_catch_N`

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

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

`tab:Exec_catch_S`

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

## 164 Data and Assessment

`data-and-assessment`

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

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

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

173 Map of assessment region: (Figure c).

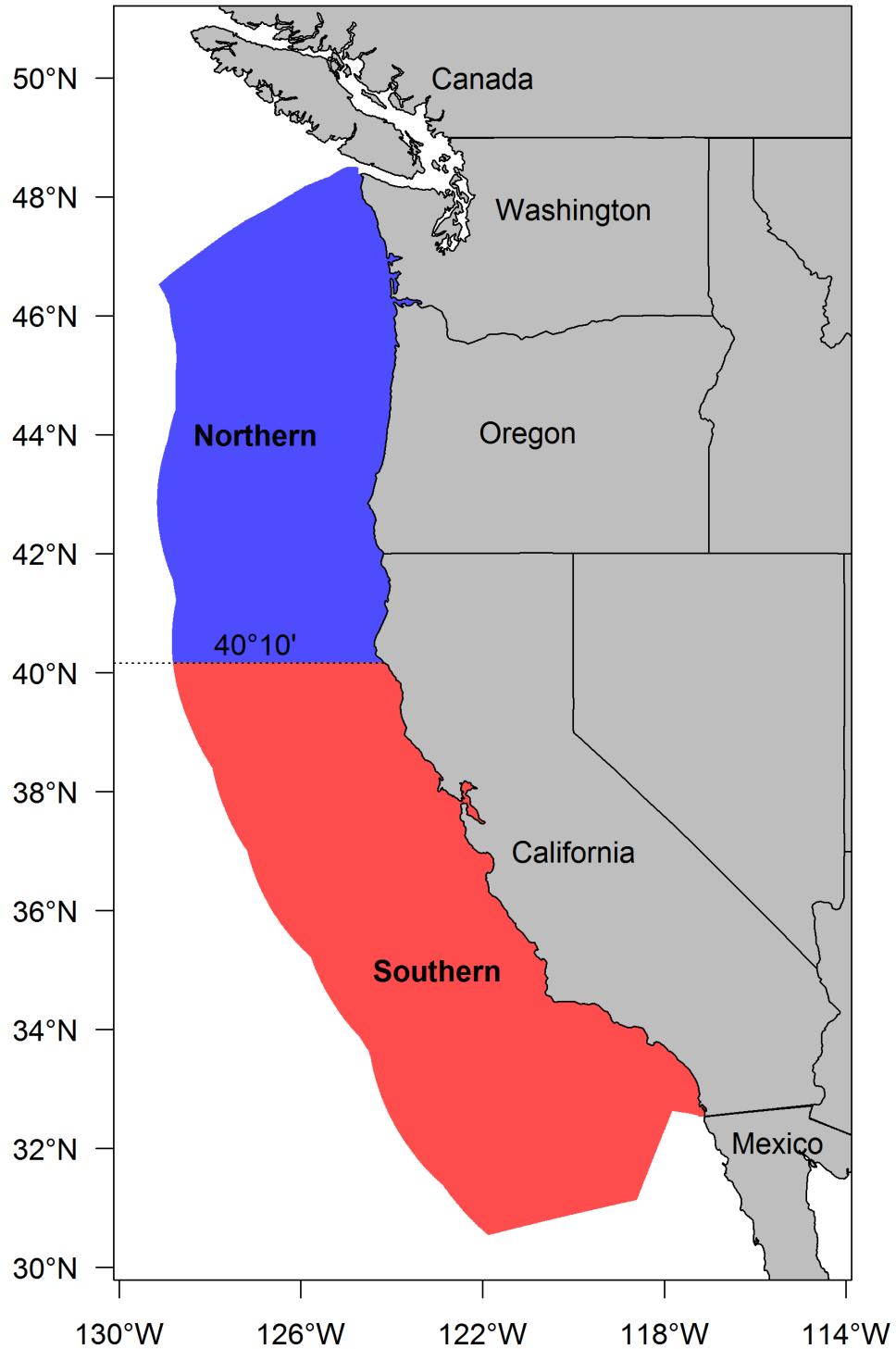


Figure c: Map depicting the boundaries for the base-case model. fig:assess\_region\_map\_Ex

<sup>174</sup> **Stock Biomass**

stock-biomass

<sup>175</sup> **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.**

<sup>177</sup> Spawning output Figure: Figure [d](#)

<sup>178</sup> Spawning output Table(s): Table [c](#)

<sup>179</sup> Relative depletion Figure: Figure [e](#)

<sup>180</sup> Example text (remove Models 2 and 3 if not needed - if using, remove the # in-line comments!!!)

<sup>181</sup> The estimated relative depletion level (spawning output relative to unfished spawning output)

<sup>182</sup> of the the base-case model in 2016 is 56.7% (~95% asymptotic interval: ± 45.4%-68.1%)

<sup>183</sup> (Figure [e](#)).

<sup>184</sup> The estimated relative depletion level of model 2 in 2016 is 98% (~95% asymptotic interval:

<sup>185</sup> ± 75.5%-120%) (Figure [e](#)).

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

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)

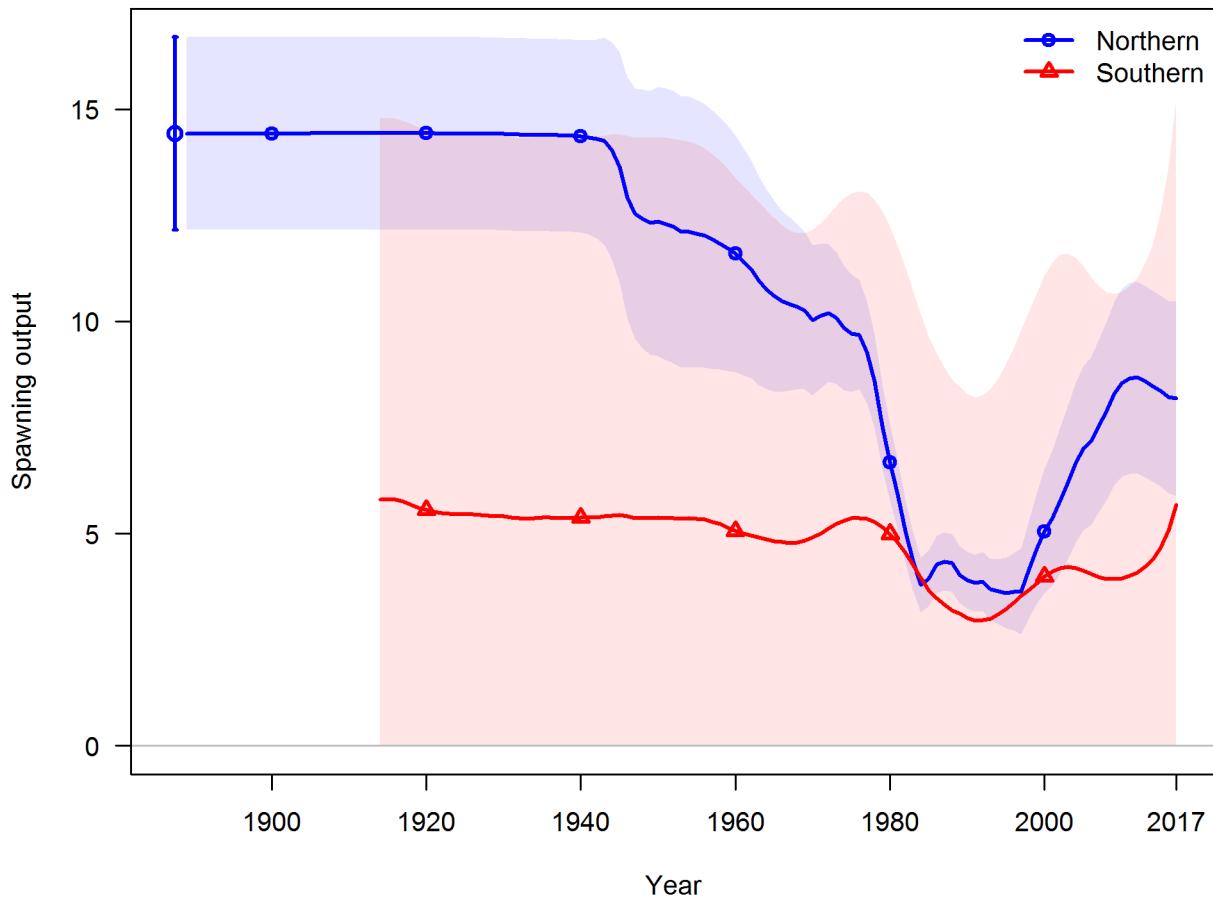


Figure d: Time series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model. [fig:Spawnbio\\_all](#)

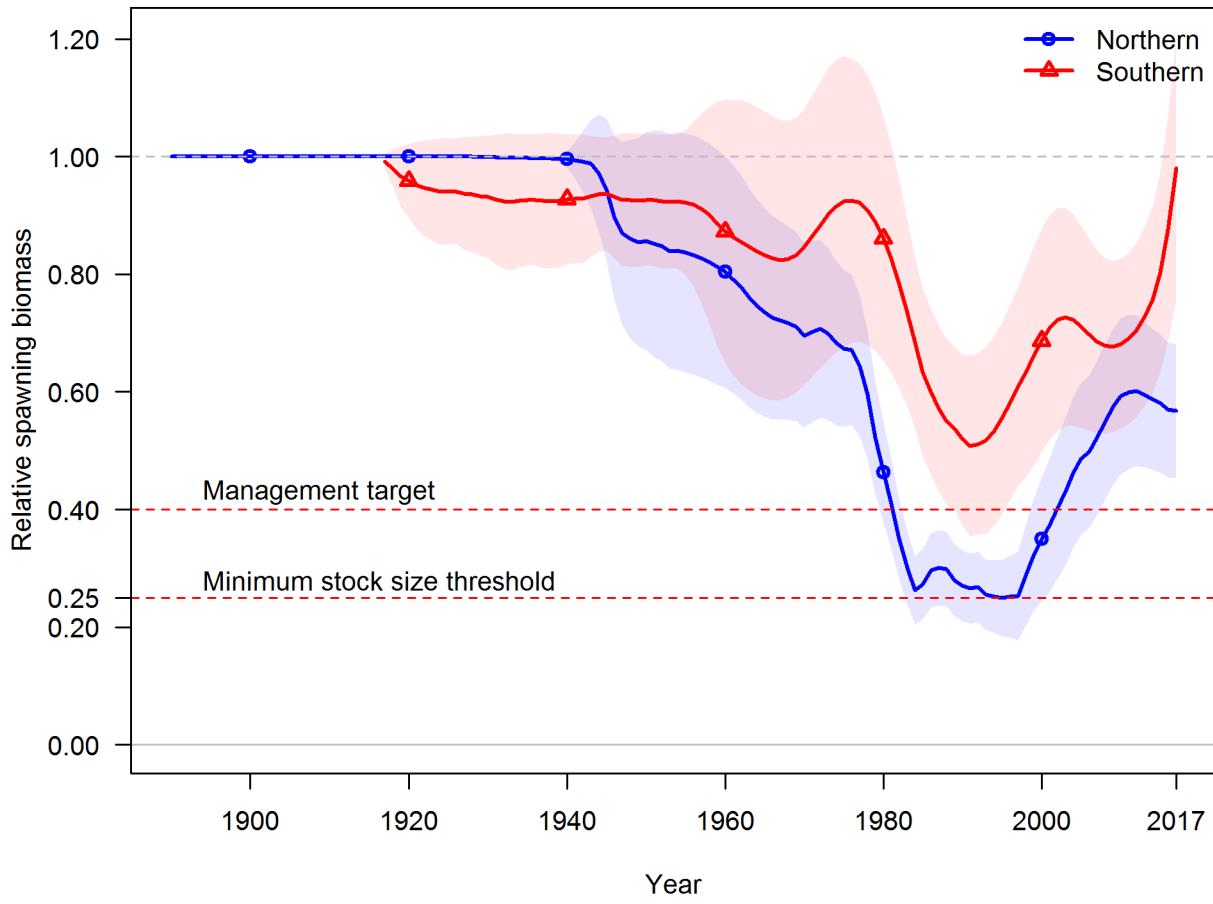


Figure e: Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. [fig:RelDeplete\\_all](#)

<sup>186</sup> **Recruitment**

recruitment

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

<sup>189</sup> Recruitment Figure: (Figure f)

<sup>190</sup> Recruitment Tables: (Tables e and f)

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)	

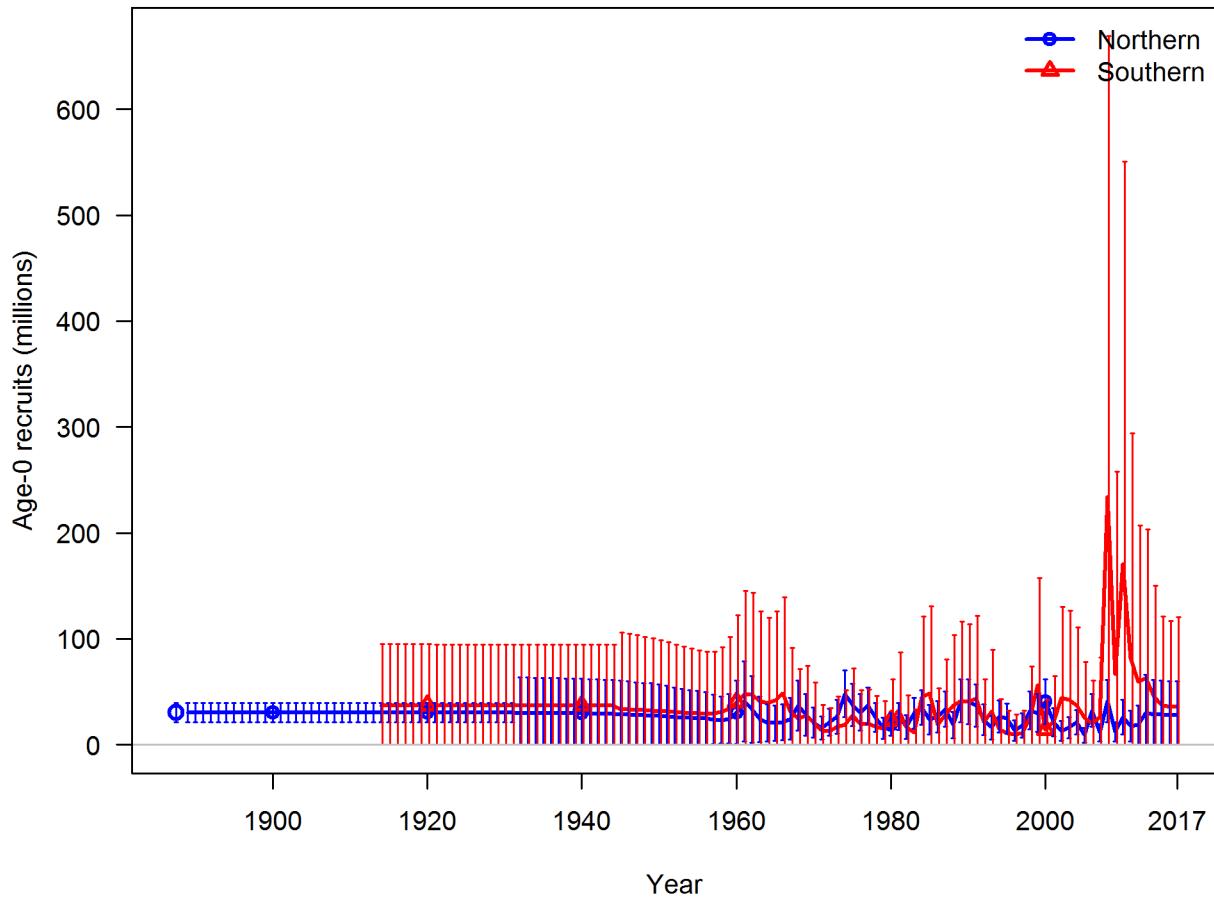


Figure f: Time series of estimated Yellowtail Rockfish recruitments for the base-case model with 95% confidence or credibility intervals. | [fig:Recruits\\_all](#)

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: Tables [g](#) and [h](#) 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	<b>tab:SPR_Exploit_mod2</b>
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)	

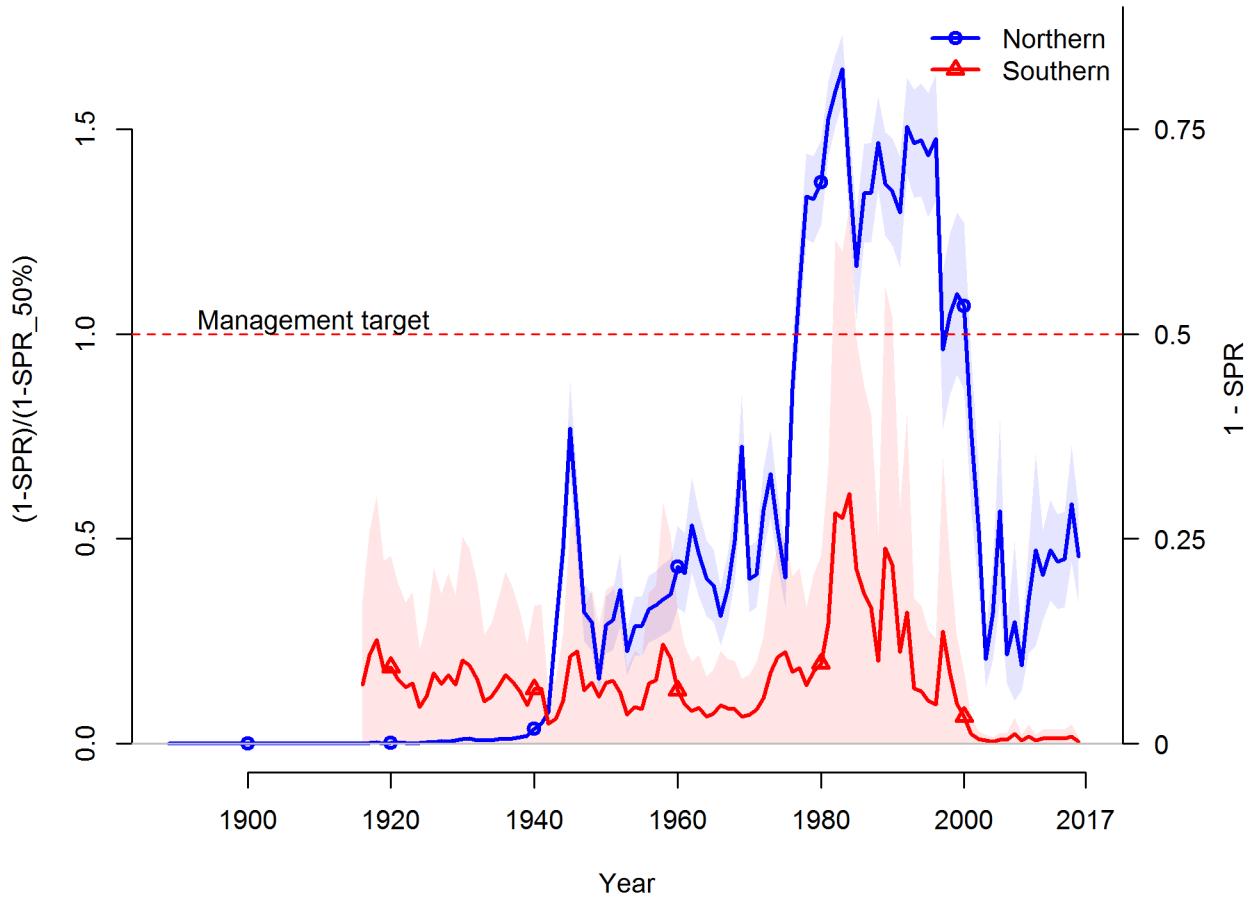


Figure g: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

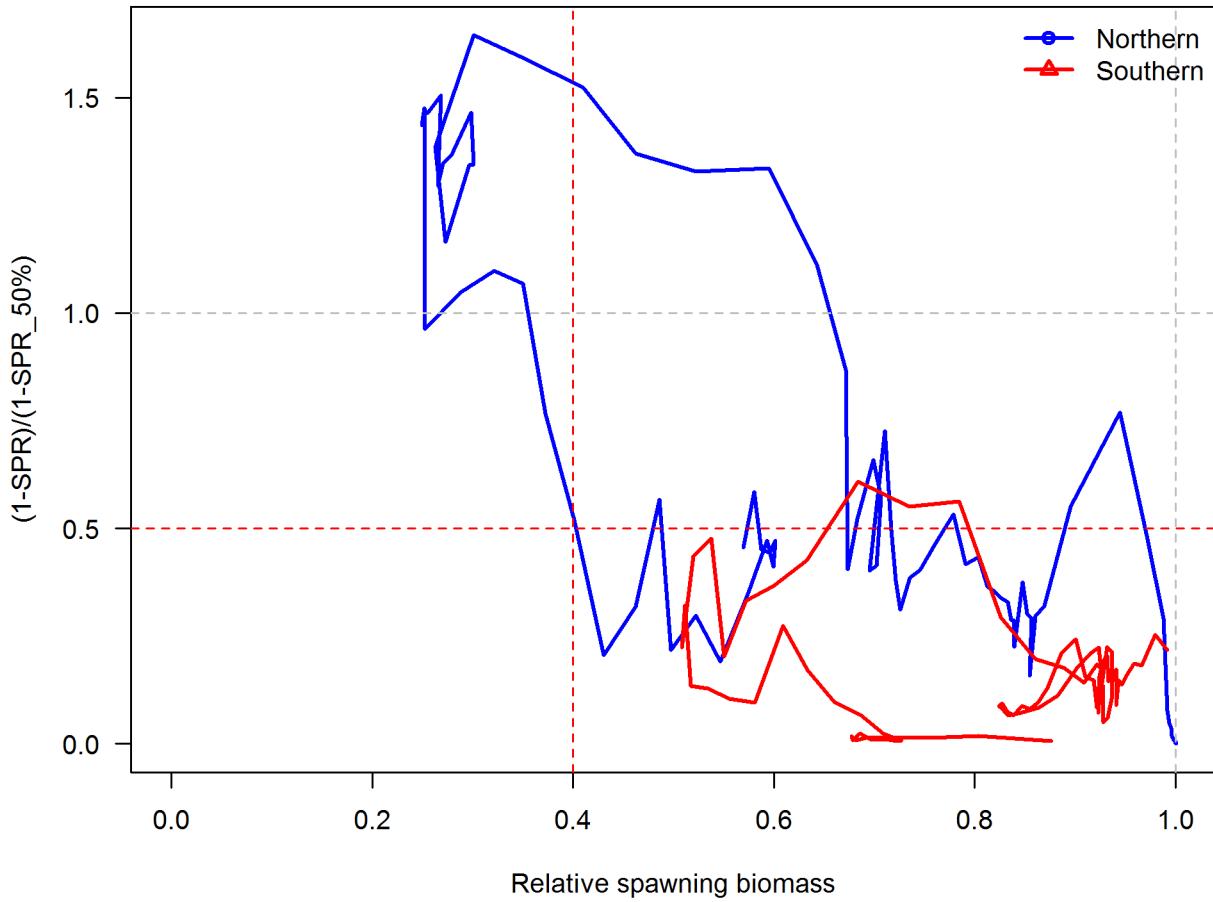


Figure h: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the unfished spawning biomass. | [fig:Phase\\_all](#)

<sup>199</sup> **Ecosystem Considerations**

ecosystem-considerations

<sup>200</sup> In this assessment, ecosystem considerations were. . . .

<sup>201</sup> **Reference Points**

reference-points

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

<sup>207</sup> Write intro paragraph....and remove text for Models 2 and 3 if not needed

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

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

<sup>226</sup> **Management Performance**

management-performance

<sup>227</sup> **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.

<sup>230</sup> 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)
<b>2007</b>	-	-	-	-
<b>2008</b>	-	-	-	-
<b>2009</b>	-	-	-	-
<b>2010</b>	-	-	-	-
<b>2011</b>	-	-	-	-
<b>2012</b>	-	-	-	-
<b>2013</b>	-	-	-	-
<b>2014</b>	-	-	-	-
<b>2015</b>	-	-	-	-
<b>2016</b>	-	-	-	-
<b>2017</b>	-	-	-	-
<b>2018</b>	-	-	-	-

<sup>231</sup> **Unresolved Problems And Major Uncertainties**

unresolved-problems-and-major-uncertainties

<sup>232</sup> TBD after STAR panel

<sup>233</sup> **Decision Table(s) (groundfish only)**

decision-tables-groundfish-only

<sup>234</sup> **Include:** projected yields (OFL, ABC and ACL), spawning biomass, and stock depletion levels for each year. Not required in draft assessments undergoing review.

<sup>236</sup> OFL projection table: Table [l](#)

<sup>237</sup> Decision table(s) Table [m](#) and Table [n](#)

<sup>238</sup> Yield curve: Figure \ref{fig:Yield\_all}

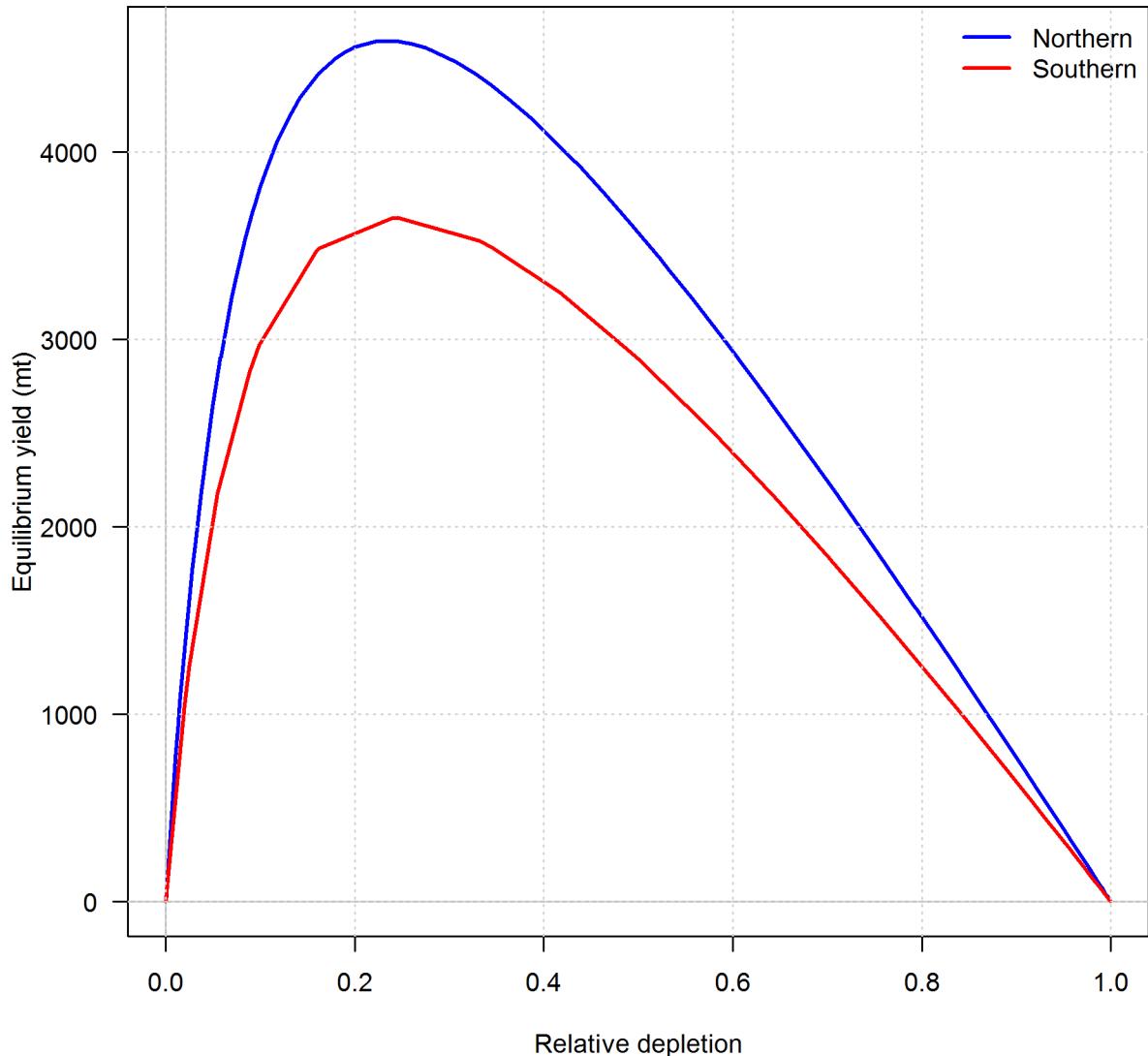


Figure i: Equilibrium yield curve for the base case models.<sup>fig:Yield\_all</sup>

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)														
<b>Model 1 (1-SPR)(1-SPR<sub>50%</sub>)</b>																						
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)
<b>Model 2 (1-SPR)(1-SPR<sub>50%</sub>)</b>																						
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	148.50	
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)	(0-12.52)	
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	0.76	
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)	(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	35.70	
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)	(5.83 - 218.81)

<sup>239</sup> **Research And Data Needs**

research-and-data-needs

<sup>240</sup> Include: identify information gaps that seriously impede the stock assessment.

<sup>241</sup> We recommend the following research be conducted before the next assessment:

<sup>242</sup> 1. List item No. 1 in the list

<sup>243</sup> 2. List item No. 2 in the list, etc.

<sup>244</sup> **Rebuilding Projections**

rebuilding-projections

<sup>245</sup> Include: reference to the principal results from rebuilding analysis if the stock is overfished.

<sup>246</sup> This section should be included in the Final/SAFE version assessment document but is not

<sup>247</sup> required for draft assessments undergoing review. See Rebuilding Analysis terms of reference

<sup>248</sup> for detailed information on rebuilding analysis requirements.

<sup>249</sup> **1 Introduction**

introduction

<sup>250</sup> **1.1 Basic Information**

basic-information

<sup>251</sup> Yellowtail rockfish, *Sebastodes flavidus*, occur off the West Coast of the United States from  
<sup>252</sup> Baja California to the Aleutian Islands. Yellowtail is a major commercial species, captured  
<sup>253</sup> mostly in trawls from Central California to British Columbia (Love 2011). Because it is an  
<sup>254</sup> aggregating, midwater species it is usually caught in the commercial midwater trawl fishery.  
<sup>255</sup> In California there is a large recreational fishery as well. The center of yellowtail rockfish  
<sup>256</sup> abundance is from southern Oregon through British Columbia (Fraidenburg 1980).

<sup>257</sup> Once thought to comprise a single stock, a recent genetic study indicates that there are in  
<sup>258</sup> fact two sub-species, with a genetic cline at Cape Mendocino, California, roughly 40°10'  
<sup>259</sup> North Latitude (Hess et al. n.d.). The species has never had a full length and age integrated  
<sup>260</sup> assessment south of Cape Mendocino, mainly due to a lack of fishery-independent data; this  
<sup>261</sup> assessment represents the first attempt to do so.

<sup>262</sup> Yellowtail rockfish are colloquially known as “greenies”, although *flavidus* is Latin for “yellow”  
<sup>263</sup> (Love 2011). We have summarized yellowtail rockfish life history, fisheries, assessment and  
<sup>264</sup> management here, but in-depth, extensive background information on yellowtail and other  
<sup>265</sup> managed species is available at (Council 2016).

<sup>266</sup> A map showing the scope of the assessment and depicting boundaries for fisheries or data  
<sup>267</sup> collection strata is provided in Figure 2.

<sup>268</sup> **1.2 Life History**

life-history

<sup>269</sup> Rockfish are in general long-lived and slow-growing, however yellowtail rockfish have a high  
<sup>270</sup> growth rate relative to other rockfish species, reaching a maximum size of about 55 cm in  
<sup>271</sup> approximately 15 years (Tagart 1991). Yellowtail can live at least 64 years (Love 2011),  
<sup>272</sup> however no fish that old occur in data available for this assessment (For the Northern model,  
<sup>273</sup> the 95th percentile of age is 35 years for females and 45 years for males and for the Southern  
<sup>274</sup> model, 30 and 40 years respectively for females and males). Yellowtail rockfish are among  
<sup>275</sup> those that are fertilized internally and release live young. Spawning aggregations occur in  
<sup>276</sup> the fall, and parturition in the winter and spring (January-May) (Eldridge et al. 1991).  
<sup>277</sup> Young-of-the-year recruit to nearshore waters from April through August, migrating to deeper  
<sup>278</sup> water in the fall. Preferred habitat is the midwater over reefs and boulder fields.

<sup>279</sup> Yellowtail rockfish are extremely motile, and make rapid and frequent ascents and descents of  
<sup>280</sup> 40 meters; they also exhibit strong homing tendencies (Love 2011). They are able to quickly  
<sup>281</sup> release gas from their swim bladders, perhaps making them less susceptible to barotrauma  
<sup>282</sup> than similar species (Eldridge et al. 1991).

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

286 Literature values for von Bertallanfy parameters are  $L_\infty = 52.2, k = 0.17, t_0 = -0.75$   
287 for females,  $L_\infty = 47.6, k = 0.19, t_0 = -1.69$  for males. Length-Weight parameters are  
288  $W = 0.0287L^{2.822}$  for females,  $W = 0.0359L^{2.745}$  for males (Love 2011). See Section 2.3 for  
289 a discussion of the new analysis of the weight-length relationship. Fecundity is represented  
290 in the models as:  $1.1185^{-11}W^{4.59}$ . This is a rescaling of the values provided in (Dick et al.  
291 2017).

### 292 1.3 Fishery and Management History

fishery-and-management-history

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

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

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

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

<sup>319</sup> improved status of constraining stocks, the industry is developing strategies to better attain  
<sup>320</sup> allocations of yellowtail and widow rockfish.

<sup>321</sup> Yellowtail rockfish are currently managed with stock-specific harvest specifications north of  
<sup>322</sup> 40°10' N. latitude, and as part of the Southern Shelf Rockfish complex south of 40°10' N.  
<sup>323</sup> latitude. The Over Fishing Limit (OFL) contribution of yellowtail rockfish to the Southern  
<sup>324</sup> Shelf Rockfish complex is based on a data-moderate analysis (Cope et al. 2013).

## <sup>325</sup> 1.4 Assessment History

`assessment-history`

<sup>326</sup> Early studies of yellowtail stocks on the U.S. West Coast north of 40°10' N. latitude (Cape  
<sup>327</sup> Mendocino, northern California) began in the 1980s with observational surveys. Statistical  
<sup>328</sup> assessments of yellowtail rockfish were conducted in 1982 (Tagart 1982), 1988 (Tagart 1988),  
<sup>329</sup> 1996 (Tagart et al. 1997), and 1997 (Tagart et al. 1997) to determine harvest specifications  
<sup>330</sup> for the stock. These early assessments employed a variety of statistical methods, for example,  
<sup>331</sup> the 1997 assessment used cohort analysis and dynamic pool modeling. Figure 54 shows the  
<sup>332</sup> timeseries of age 4+ biomass for Yellowtail Rockfish across past assessments.

<sup>333</sup> The yellowtail assessment in 2000 (Tagart et al. 2000) was the first that estimated stock  
<sup>334</sup> status, with an estimated depletion of 60.5 percent at the start of 2000. Lai et al. (Lai et al.  
<sup>335</sup> 2003) updated the 2000 assessment and estimated that stock depletion was 46 percent at the  
<sup>336</sup> start of 2003. A second assessment update was prepared in 2005 (Wallace and Lai 2005) with  
<sup>337</sup> an estimated depletion of 55 percent at the start of 2005. The 2000 assessment and updates  
<sup>338</sup> were age-structured assessments conducted using AD Model Builder as the software platform  
<sup>339</sup> for nonlinear optimization (Fournier et al. 2012).

<sup>340</sup> A data-moderate assessment of yellowtail rockfish south of 40°10' N. latitude was conducted  
<sup>341</sup> in 2013 (Cope et al. 2013). This assessment estimated depletion at the start of 2013 at 67  
<sup>342</sup> percent, and estimated the spawning biomass at 50,043 mt. This was a large biomass increase  
<sup>343</sup> relative to previous estimates and may be attributed to the low removals over the previous  
<sup>344</sup> decade.

<sup>345</sup> **Include:** Management performance tables comparing Overfishing Limit (OFL), Annual Catch  
<sup>346</sup> Limit (ACL), Harvest Guideline (HG) [CPS only], landings, and catch (i.e., landings plus  
<sup>347</sup> discard) for each area and year.

<sup>348</sup> Management performance table: (Table k)

<sup>349</sup> A summary of these values as well as other base case summary results can be found in Table  
<sup>350</sup> O.

<sup>351</sup> **1.5 Fisheries off Canada, Alaska, and/or Mexico**  
<sup>fisheries-off-canada-alaska-andor-mexico</sup>

<sup>352</sup> The 2015 Stock Assessment conducted by the Department of Fisheries and Oceans (DFO)  
<sup>353</sup> found the stock to be at 0.49B0, in the “healthy” range.

<sup>354</sup> The Alaska Fisheries Science Center assesses yellowtail rockfish as one of 25 species in the  
<sup>355</sup> “Other Rockfish” complex in the Gulf of Alaska. The 2015 full assessment of this complex  
<sup>356</sup> found no evidence of overfishing, which is confirmed in the 2016 SAFE document(Center  
<sup>357</sup> 2016).

<sup>358</sup> Limited catches of yellowtail are reported as far south as Baja California(Love 2011).

<sup>359</sup> **2 Data**

data

<sup>360</sup> Data used in the Northern and Southern yellowtail rockfish assessments are summarized in  
<sup>361</sup> Figures 6 and 59.

<sup>362</sup> Data sources for the two models are largely distinct. Northern fisheries and surveys had very  
<sup>363</sup> sparse data (if any) for the south and vice-versa. Among the 12 data sources referenced  
<sup>364</sup> below, only 2 data sources are common to both models. These are the MRFSS/RecFIN  
<sup>365</sup> recreational dockside survey, which focuses on California and Oregon, and the CalCOM  
<sup>366</sup> California commercial dataset, which contributed data from the northern-most California  
<sup>367</sup> counties (Eureka and Del Norte) to the Northern model. The CalCOM data account for less  
<sup>368</sup> than five percent of the commercial landings in the Northern model, and less than 1% of the  
<sup>369</sup> biological samples.

<sup>370</sup> Commercial landings are not differentiated in either model. For the Northern model, this is  
<sup>371</sup> due to the very small portion (1.15 %) of the landings that are attributed to non-trawl gear.  
<sup>372</sup> For the Southern model, this is due to the paucity of data.

<sup>373</sup> A description of each model's data sources follows.

<sup>374</sup> **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

<sup>375</sup> **2.1.1 Commercial Fishery Landings**

*commercial-fishery-landings*

<sup>376</sup> **Washington and Oregon Landings** The bulk of the commercial landings for Washington  
<sup>377</sup> and Oregon came from the Pacific Fisheries Information Network (**PacFIN**)  
<sup>378</sup> database.

<sup>379</sup> **Washington Catch Information**

<sup>380</sup> The Washington Department of Fisheries and Wildlife (**WDFW**) provided historical yellow-  
<sup>381</sup> tail catch for 1889–1980. Landings for 1981-2016 came from the PacFIN database. WDFW  
<sup>382</sup> also provided catches for the period 1981 – 2016 to include the re-distribution of the un-  
<sup>383</sup> speciated “URCK” landings in PacFIN; this information is currently not available from  
<sup>384</sup> PacFIN.

<sup>385</sup> **Oregon Catch Information**

<sup>386</sup> The Oregon Department of Fisheries and Wildlife (**ODFW**) provided historical yellowtail  
<sup>387</sup> catch from 1892-1985. ODFW also provided estimates of yellowtail rockfish in the in the  
<sup>388</sup> un-speciated PacFIN “URCK” and “POP1” catch categories for recent years, and those  
<sup>389</sup> estimates were combined with PacFIN landings for 1986-2016.

<sup>390</sup> **Northern California Catch**

<sup>391</sup> The California Commercial Fishery Database (**CalCOM**) provided landings for the Northern  
<sup>392</sup> model for the two counties north of 40°10' (Eureka and Del Norte) for 1969-2016.

<sup>393</sup> **Hake Bycatch**

<sup>394</sup> The Alaska Fisheries Science Center (**AFSC**) provided data for yellowtail bycatch in the  
<sup>395</sup> hake fishery from 1976-2016.

<sup>396</sup> **2.1.2 Sport Fishery Removals**

*sport-fishery-removals*

<sup>397</sup> **Washington Sport Catch**

<sup>398</sup> WDFW provided recreational catches for 1967 and 1975-2016.

<sup>399</sup> **Oregon Sport Catch**

<sup>400</sup> ODFW provided recreational catch data for 1979-2016.

<sup>401</sup> **MRFSS and RecFIN** Data from Northern California came from the Marine Recreational  
<sup>402</sup> Fisheries Statistical Survey (**MRFSS**) and from the Recreational Fisheries Information  
<sup>403</sup> Network (**RecFIN**). These are dockside surveys focused on California and Oregon. MRFSS  
<sup>404</sup> was conducted from 1980-1989 and 1993-2003, RecFIN from 2004 to the present.

405 **2.1.3 Estimated Discards**

estimated-discards

406 **Commercial Discards**

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

411 **Pikitch Study**

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

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

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

422 **2.1.4 Abundance Indices**

abundance-indices

423 **Commercial Logbook CPUE**

424 The commercial logbook (fish-ticket) data in PacFIN was used to generate an index for the  
425 years 1987-1998, a period in which management of the fishery was stable, i.e., regulations  
426 weren “t changing fishery practices.

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

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

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

438 **Hake Bycatch Index**

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

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

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

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

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

472 **2.1.5 Fishery-Independent Data**

fishery-independent-data

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

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

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

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

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

## 492 **Alaska Fisheries Science Center (AFSC) Triennial shelf survey**

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

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

### 507 **2.1.6 Biological Samples**

biological-samples

#### 508 **Length And Age Compositions**

509 Length composition data were compiled from PacFIN for Oregon and Washington for the

<sup>510</sup> Northern model and combined with raw (unexpanded) length data from CalCOM for the  
<sup>511</sup> two California counties north of 40° 10'N (Eureka and Del Norte counties).

<sup>512</sup> 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

<sup>513</sup> 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

514 **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

515 **2.2.1 Commercial Fishery Landings**

commercial-fishery-landings-1

516 **California Commercial Landings**

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

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

521 **2.2.2 Sport Fishery Removals**

sport-fishery-removals-1

522 **MRFSS Estimates and RecFIN**

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

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

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

531 **2.2.3 Estimated Discards**

estimated-discards-1

532 No discard data were available for the Southern model.

533 **2.2.4 Abundance Indices**

abundance-indices-1

534 **MRFSS Index**

535 An index of abundance was developed from trip-aggregated MRFSS data for the years  
536 1980-1989, 1992-2003.

537 **California Onboard Survey**

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

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

542 **2.2.5 Fishery-Independent Data**

fishery-independent-data-1

543 **Hook and Line Survey**

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

546 **2.2.6 Biological Samples**

biological-samples-1

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

549 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

550 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

551 **2.3 Biological Parameters Common to Both Models** <sup>bio-params</sup>  
biological-parameters-common-to-both-models

552 **Aging Precision And Bias**

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

560 **Weight-Length**

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

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

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

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

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

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

582 141 samples collected in 2016. These include 96 from the NWFSC Combo survey, 25 from  
583 mid-water catches in the NWFSC acoustic/trawl survey, 13 from the Hook and Line survey,

<sup>584</sup> and 7 from Oregon Department of Fish and Wildlife. The sample sizes were not adequate to  
<sup>585</sup> estimate differences in maturity by area. Length at 50% maturity was estimated at 42.49cm  
<sup>586</sup> (Figure 3) which was consistent with the range 37-45cm cited in the previous assessment  
<sup>587</sup> (Wallace and Lai 2005).

<sup>588</sup> **Natural Mortality** Natural Mortality priors were provided by Owen Hamel (pers. comm.).  
<sup>589</sup> See Section 3.2.5 for further discussion.

<sup>590</sup> **Sex ratios**

<sup>591</sup> The largest fish seen in the data are females, however the oldest are males. The sex ratio  
<sup>592</sup> falls off differently in each model, as can be seen in Figs(x,y).

<sup>593</sup> **2.3.1 Environmental Or Ecosystem Data Included In The Assessment**  
environmental-or-ecosystem-data-included-in-the-assessment

<sup>594</sup> No environmental index is present in either model.

595 **3 Assessment**

assessment

596 **3.1 History Of Modeling Approaches Used For This Stock**

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

597 Yellowtail rockfish was previously modeled as an age-structured, 3-area stock north of 40°10' in 1999 (Tagart et al. 2000) using a model written in ADMB (Fournier et al. 2012); an update 598 of this assessment was last conducted in 2004 (Wallace and Lai 2005). That assessment 599 divided the stock into 3 INPFC areas based on the suggestion that there might be biological 600 differences in the stock, however recent genetic studies don't support that (Hess et al. n.d.). 601 The INPFC area boundaries are not coincident with state boundaries; this is a concern in that 602 recent reconstructions of historical catch are state-by-state along the West Coast. Because 603 we cannot produce data that conform to the areas previously assessed, we have made no 604 effort to reproduce the previous model.

605 A data-moderate approach was used to evaluate stock status in 2013 (Cope et al. 2013). 606 The data-moderate model used only indices of abundance and made simplifying assumptions 607 about selectivity and growth since no length or age data were included in the model. This 608 approach is also incompatible with the current model, and we have made no attempt to 609 reproduce it, either.

611 **3.1.1 Previous Assessment Recommendations**

previous-assessment-recommendations

612 Many of the recommendations of the previous STAR panel are not relevant to this assessment, 613 as they related to data deficiencies at that time that have since been resolved. The 2004 614 STAR particularly recommended a focus on abundance indices, which they noted might 615 require further survey information.

616 This assessment provides four indices for the Northern model, and three for the Southern 617 model. All indices are newly developed for this analysis.

618 **3.2 Model Description**

model-description

619 **3.2.1 Transition To The Current Stock Assessment**

transition-to-the-current-stock-assessment

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

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

633 **3.2.2 Definition of Fleets and Areas**

definition-of-fleets-and-areas

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

637 **Northern Model**

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

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

649 The PacFIN logbook (fish ticket) index developed for the commercial fishery is in fish/tow.  
650 Further information about how the data for the index was worked up is in Appendix ??.

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

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

661 *Washington-Sport*: The Washington data (WA\_Sport) provides catches, lengths and ages,  
662 and was treated as a separate fleet for two reasons: first, the length composition of the  
663 Washington catches were different from those in the recreational landings in Oregon and  
664 northern California (MRFSS/RecFIN data). There are very large fish in this dataset, and  
665 fewer small ones. Second, the WA\_Sport landings are not available by weight, so they are  
666 entered in the model as numbers, and Stock Synthesis internally converts them to weight using  
667 the combination of estimated selectivity for this fleet (informed by the length compositions),  
668 estimated growth, and the weight-length relationship. Sex was available for the biological data,  
669 however many lengthened fish were not sexed, so the lengths for this fleet are undifferentiated  
670 by sex, although the ages are.

671 *Research*: The Alaska Fisheries Science Center's Triennial Trawl survey, provides age- and  
672 length-compositions, and an index of abundance. This survey was conducted every third year  
673 from 1977-2004. Details on the workup of the CPUE (in biomass/area towed) can be found  
674 in Appendix ??.

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

678 *Conditional Age-at-Length*: Only the NWFSCCombo ages were used as conditional age-at-  
679 length in the model. All other aged fleets (Commercial, Washington\_Sport, and Triennial)  
680 are present in the model as marginal ages due to the amount of noise in the age data for  
681 those fleets.

682 *Indices*: Fish per angler-hour is the basis for the Washington\_Sport and Pikitch indices. The  
683 NWFSCCombo and Triennial surveys provide indices based on biomass per area-towed. The  
684 logbook survey for the commercial fleet is in units of fish per tow.

## 685 Southern Model

- 686    *Commercial*: The commercial fleet consists primarily of hook and line and trawl gear. Hook  
687 and line gear account for 78% of the landings by weight in the recent period (1978-2016).  
688 Commercial data were sexed, although there are many unsexed lengths. To preserve the large  
689 numbers of lengths, the length data are entered in the model as undifferentiated, however  
690 the ages are sexed and provide the sole conditional age-at-length timeseries in the Southern  
691 Model.
- 692    *Recreational*: The recreational fleet includes data from sport fishery off the California coast  
693 south of Cape Mendocino. The recreational lengths are unsexed. The index is in fish per  
694 angler\_hour. Further information about how the index was worked up is in Appendix ??.
- 695    *California Onboard Recreational Survey*: Research derived-data include observations from  
696 the California Onboard recreational survey. The length-compositions from this survey are  
697 undifferentiated by sex. The index is in fish per angler\_hour.
- 698    *NWFSC Hook-and-Line Survey*: The data from this survey are used in the model as an  
699 index of fish per angler\_hour, a single year of marginal age data by sex, and sexed length  
700 compositions.
- 701    *Small Fish Study*: A separate index, length comps and a single year of ages reflect a small  
702 study of juvenile fish conducted by the SWFSC.

### 703    3.2.3    Modeling Software

modeling-software

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

### 706    3.2.4    Data Weighting

data-weighting

- 707    Commercial and survey length composition and marginal age composition data are weighted  
708    according to the method of Ian Stewart (pers.comm):
- 709    Sample Size =  $0.138 * \text{Nfish} + \text{Ntows}$  if  $\text{Nfish}/\text{Ntows} < 44$ , and  $\text{Ntows} * 7.06$  otherwise.
- 710    Age-at-Length samples are unwieghted; that is, each fish is assumed to represent an indepen-  
711    dent sample.
- 712    Recreational trips (the analogue of tows in the commercial fishery) are difficult to define in  
713    most cases. Since much of the recreational data are from the dockside interview MRFSS  
714    program, which didn't anticipate the need to delineate samples as belonging to particular  
715    trips, we chose to use all recreational data "as-is", with the initial weights entered as number  
716    of fish.

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

### 721 3.2.5 Priors <sup>priors</sup>

722 Hamel (2015) developed a method for combining meta-analytic approaches to relating the  
723 natural mortality rate M to other life-history parameters such as longevity, size, growth rate  
724 and reproductive effort, to provide a prior on M. In that same issue of ICESJMS, Then et al.  
725 (2015), provided an updated data set of estimates of M and related life history parameters  
726 across a large number of fish species, from which to develop an M estimator for fish species  
727 in general. They concluded by recommending M estimates be based on maximum age alone,  
728 based on an updated Hoenig non-linear least squares estimator  $M = 4.899A_{max}^{-0.916}$ .

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

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

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

740 Natural mortality priors for these models were based on examination of the 99% quantile of  
741 the observed ages from early in the time-series, before the full impact of fishing would have  
742 taken place. For the Northern model, these quantiles were approximately 35 years for females  
743 and 45 years for males, resulting in median M values of 0.15 and 0.12 for females and males.  
744 For the Southern model, the 99% quantile of the early age observations were approximately  
745 30 and 40 years for females and males, resulting in median M prior values of 0.18 and 0.135,  
746 respectively. In both models, M for males was represented as an offset from females. In the  
747 Northern model, both the female value and the male offset could be estimated without priors  
748 so the priors were not used. For the southern model, M was fixed at the median prior values  
749 for the two sexes.

750 The prior for steepness ( $h$ ) assumes a beta distribution with parameters based on an update  
751 of the Thorson-Dorn rockfish prior (commonly used in past West Coast rockfish assessments)  
752 conducted by James Thorson (personal communication, NWFSC, NOAA) which was reviewed

<sup>753</sup> and endorsed by the Scientific and Statistical Committee in 2017. The prior is a beta  
<sup>754</sup> distribution with  $\mu=0.718$  and  $\sigma=0.158$ .

### <sup>755</sup> 3.2.6 General Model Specifications

general-model-specifications

<sup>756</sup> Fecundity is represented in the models as:  $1.1185^{-11}W^{4.59}$ . This is a rescaling of the values  
<sup>757</sup> provided in (Dick et al. 2017).

<sup>758</sup> Model data, control, starter, and forecast files can be found at <https://DEVORE>

### <sup>759</sup> 3.2.7 Estimated And Fixed Parameters

estimated-and-fixed-parameters

<sup>760</sup> A full list of all estimated and fixed parameters is provided in Tables.... Estimated and fixed  
<sup>761</sup> parameters tables currently read in from .csv file, EXAMPLE: Table 3

<sup>762</sup> **Growth** 5 parameters for female growth are estimated in each model: 3 von Bertalanffy  
<sup>763</sup> parameters and 2 parameters for CV as a function of length at age related to variability in  
<sup>764</sup> length at age for small and large fish.

<sup>765</sup> Three parameters are estimated for male growth in each model as offset from female growth.  
<sup>766</sup> The size for small fish and CV for small fish were assumed equal to females.

<sup>767</sup> **Natural Mortality** Natural mortality is estimated in the Northern model with an offset for  
<sup>768</sup> males from females. Natural Mortality is fixed in the Southern model at the values provided  
<sup>769</sup> by the Hamel (2015) analysis described above.

<sup>770</sup> **Selectivity** Selectivity for all fleets was initially estimated as a 4-parameter double normal,  
<sup>771</sup> which allows selectivity to be dome shaped, with parameters controlling the position of the  
<sup>772</sup> peak selectivity, the width of the peak, and the ascending and descending slopes.

<sup>773</sup> For all fleets where the estimated patterns were asymptotic, we fixed the parameters related  
<sup>774</sup> to the dome, leaving only the position of the peak and the ascending slope as estimated  
<sup>775</sup> parameters. For a few fleets, the position of the peak hit the upper bound, and was fixed at  
<sup>776</sup> 55cm.

<sup>777</sup> **Retention** Retention for commercial fishery in Northern model is a logistic function of size,  
<sup>778</sup> with three parameters estimated: length at 50% retention, the slope of the curve, and the  
<sup>779</sup> asymptotic retention fraction. The asymptote was allowed to be time-varying, with one  
<sup>780</sup> value applied for the early years through 2001. From 2002 through 2011 we applied annual  
<sup>781</sup> time-blocks for these years when the WCGOP program observed high discards. The final  
<sup>782</sup> block runs from 2012 forward, reflecting the current period in which the implementation of  
<sup>783</sup> the IFQ program has led to low discard rates.

<sup>784</sup> **Other Estimated Parameters** Log(R0) is the equilibrium recruitment, which is estimated  
<sup>785</sup> in each model.

<sup>786</sup> Recruitment deviations for the Northern model are estimated from 19xx to 2013. For the  
<sup>787</sup> Southern model recruitment deviations are estimated from 19xx to 2013. list range of years  
for each model with some comment as to how this range was chosen.

<sup>789</sup> A parameter for extra standard deviation was added to the index based on bycatch in the  
<sup>790</sup> at-sea hake fishery, because this index was not well fit by any of the models considered.

791 **3.3 Model Selection and Evaluation**

model-selection-and-evaluation

792 **3.3.1 Key Assumptions and Structural Choices**

key-assumptions-and-structural-choices

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

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

801 **3.3.2 Alternate Models Considered**

alternate-models-considered

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

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

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

808 **3.3.3 Convergence**

convergence

809 Convergence testing through use of dispersed starting values often requires extreme values  
810 to explore new areas of the multivariate likelihood surface. Stock Synthesis provides a  
811 jitter option that generates random starting values from a normal distribution logically  
812 transformed into each parameter's range (Methot 2015). We used this function to find  
813 parameter values for convergence in the Southern model. The Northern model report jittering  
814 when it's been done.

815 **3.4 Response To The Current STAR Panel Requests**  
response-to-the-current-star-panel-requests

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

817

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

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

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

821

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

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

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

825

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

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

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

829

- 830     • **Item No. 1**
- 831     • **Item No. 2**
- 832     • **Item No. 3, etc.**

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

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

835 **3.5 Life History Results for both models**

life-history-results-for-both-models

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

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

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

843 **3.6 Northern Model Base Case Results**

northern-model-base-case-results

844 The data used in the Northern model by fishery is shown in Figure 6. Estimated catches are  
845 shown in Figure 7; estimated discards are in Figure 8. These show the large catches in the  
846 1980s and 90s are being predicted by the model. The large discards in latter years match the  
847 data well for those years.

848 The timeseries of estimated spawning output in trillions of eggs is shown in Figure 48. The  
849 model is estimating two periods of decline, one beginning in the forties and a steeper decline  
850 in the 1970s and 1980s, followed by an increase since 2000 to pre-1980 levels. There is a  
851 decrease in the final years of the timeseries coincident with increased uncertainty.

852 Figure 49 shows the total biomass following a similar pattern; the ending value is 86070  
853 metric tonnes.

854 The relative spawning output (Figure 50) went below the 40% target in the early 1980s,  
855 and may have been below the minimum stock size limit of 25% in the late 1990s, but has  
856 rebounded since to 57% (see Table 5).

857 Figures 51 and 52 address recruitments estimated by the model. The first of these shows  
858 the age-0 recruits, and the second the recruitment deviations. There are no strong patterns  
859 in recruitment and the variability of the recruitment deviations was tuned to be 0.546 (based  
860 on the method of Methot & Taylor Methot et al. (2011)) which is slightly lower than what  
861 has been assumed or estimated for other rockfish in the California Current. The stock-recruit  
862 curve, Figure 53 shows a shallow relationship between stock size and recruitment.}

863 **3.6.1 Selectivities, Indices and Discards**

selectivities-indices-and-discards

864 Selectivities in the Northern model (Figure 9) shows the difference between the recreational  
865 fisheries and the commercial fishery and survey sampling. All of the fish are fully selected by  
866 50 cm, but the recreational fish are fully selected at 30 cm.

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

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

872 Fits to the indices for the northern model (Figure 16) demonstrate the utility of the NWFSC-  
873 combo survey. Although the model misses the uptick at the end of the timeseries, it is the only  
874 recent index and is well-fit by the model. The other indices are noisier. Most of the indices  
875 are fairly flat, indicating little change in abundance during each time-period. Although the  
876 fit to the Triennial index is poor, the data nicely reflects the changes in management during  
877 its tenure: the CPUE was falling during the 1980s and 1990s, then rising after stringent  
878 restrictions began in 2000.

### 879 3.6.2 Lengths

lengths

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

887 Commercial length comps are very well fit (Figures 19 and 20). Commercial discards are  
888 noiser and not well fit (Figure 21) although the fit to the mean length (which is lower than  
889 for the retained fish), is reasonable (Figure 20).

890 Lengths in the early period of the Hake Bycatch fishery are noisy (doubtless due to small  
891 sample sizes). By 1992, the model is able to fit the data well (Figures 23 and 24).

892 The recreation OR+N.CA timeseries of lengths demonstrates the difference between the  
893 MRFSS sampling and RecFIN sampling. The fits in the early period are good, those in the  
894 later period are noisy and model uncertainty is high (Figures 25 and 26).

895 The WA\_Sport length fits might have been improved with a better choice of maximum size  
896 bin for the model (Figures 27 and 28), however the data are noisy throughout the size range  
897 represented.

898 The Triennial lengths Figures 29 and 30 are fit well in some years and not in others. The  
899 data is not noisy, however the intermittency of data collection may mean that the model is  
900 unable to capture interannual variation as well as for an annual timeseries.

901 NWFSCcombo lengths are not well fit, particularly in 2013, where the data show a large  
902 number of small fish that may represent a good recruitment several years earlier Figures 31  
903 and 32.

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

908 **3.6.3 Ages**

ages

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

911 The fits to the marginal commercial Figure 36 are quite good from about 1979 on, even fitting  
912 the tail where the ages beyond 55 are lumped. The weightings panel Figure 37 shows the  
913 same thing: fits are good after about 1979, and the decrease in mean age in the population  
914 corresponds with high catches in the 1980s and 1990s, with mean age increasing after 2000  
915 as catches were curtailed.

916 The Washington Sport ages are noisy, and the fit is poor throughout the timeseries, see  
917 Figure 38 and Figure 39.

918 The Triennial ages are noisy but are fit surprisingly well 40; 41. That the model misses the  
919 influx of young fish in 1986 may be due to the timing of the survey; three-year surveys may  
920 not provide enough data for the model to fit recruitment events.

921 Aggregated age comps for the Commercial, Washington Sport and Triennial fleets are shown  
922 in Figure 42, for comparison. Aggregated fits for the Commercial and Triennial fleets are  
923 very satisfying.

924 The implied marginal age comps for the NWFSCcombo survey (Figure 43) are the conditional-  
925 age-at-length compositions for the survey aggregated over length. This figure is included for  
926 informational purposes only; the marginal “ghost” comps are not included in the likelihood  
927 calculations. It is interesting that the model fits these implied marginal ages less well than  
928 the conditional ages at length. This is likely due to a combination of factors: the implied  
929 marginal ages are not included in the likelihood, and when anomalous patterns appear, such as  
930 the numerous age-5 fish in 2013, as long as their ages are as expected given their lengths, the  
931 conditional-age-at-length data will be well fit. The implied marginal ages are also expanded  
932 to account for the size of the sampled catch relative to the total catch while the conditional  
933 data are not.

934 Pearson residuals for the marginal age comps, are shown in the bubble plots in Figure  
935 44. The filled bubbles represent estimates greater than observations, and the open bubbles

936 observations greater than estimates. The large filled bubbles at age 25 in a few years suggest  
937 that we might have chosen a slightly older age as the compilation age.

938 The residuals for the conditional age-at-length from the NWFSCcombo survey show that  
939 growth appears to be reasonably estimated with no strong patterns suggesting consistently  
940 older or younger fish than expected in any year (Figure 45). However, the mean age aggregated  
941 across length bins shows more variability in the observations than expected by the model  
942 (Figure 46). This may represent young fish recruiting to the fishery, which would happen  
943 approximately 5 years after a biological recruitment event. The conditional age-at-length  
944 fits are also shown in Figure 46. These plots explain the reason this survey was chosen  
945 to represent conditional age-at-length; the model was able to fit these data much better  
946 than other datasets, and improved fit, lower likelihood values and increased parsimony all  
947 contributed to a better model.

## 948 3.7 Northern Model Parameters

northern-model-parameters

949 For the Base model, the parameter estimates are given in Table 3. Status for all of the  
950 estimated parameters is good, with the exception of the 6th parameter for the selectivity in  
951 the Washington Sport fishery.

### 952 3.7.1 Northern Model Uncertainty and Sensitivity Analyses

section

953 Table 4

### 954 3.7.2 Northern Model Retrospective Analysis

northern-model-retrospective-analysis

### 955 3.7.3 Northern Model Likelihood Profiles

northern-model-likelihood-profiles

956 We profiled the change in negative log likelihood for the data sources and model total  
957 likelihood for critical parameters in the model: **R0**, the log of equilibrium recruitment; female  
958 natural mortality, **MF**; male natural mortality, **MM**; and steepness, **h**, the parameter that  
959 reflects how quickly the stock-recruit relationship allows the stock to rebound from depleted  
960 stock size.

961 The likelihood profile over a range of values (from 9 to 11) R0 are shown in Figure 55. This  
962 plot shows the tension between the index data and the other data sources. The indices are  
963 better fit with a smaller value of R0, near 9.6, while all other data sources are better fit at  
964 larger values. The overall likelihood in the model is lowest at 10.3 in this figure. The discards

965 show very little change (are insensitive) over this range of R0, while the recruitments, ages  
966 and lengths are all minimized at values larger than 10.5.

967 The likelihood profile over female natural mortality, MF, is over a range from 0.1 to 0.24  
968 (Figure 56). In this figure, the indices are fit best when MF is 0.1, the ages and lengths are  
969 fit nearer 0.18, and the recruitments and total log likelihoods are minimized at 0.15.

970 Figure 57 shows the likelihood profile for male natural mortality, MM, over a range of negative  
971 values that are the offset from female mortality (FM). The index data are again at odds  
972 with the other data sources; all but the indices are minimized at a value of -0.15. Male  
973 natural mortality is represented as an offset from that for females based on the equation  
974  $MM = MF * \exp(offset)$ , such that an offset of 0 results in equal mortality for males and  
975 females, and an offset of -0.3 results in a male natural mortality which is about 74% of the  
976 female mortality ( $\exp(-0.3) = 0.7408$ ).

977 The profile over values of steepness, h, from 0.5 to 0.9, Figure 58, shows the index data for  
978 once in the majority as all data sources except the lengths support 0.9 as minimizing the  
979 likelihood, while the lengths support a value closer to 0.5. The scale of this plot differs from  
980 the others; it is roughly a tenth of the scale of the R0 plot, meaning that the choice of h  
981 within this range has far less impact on likelihood in the model than choices for the other  
982 profiled parameters. This suggests the stock is not depleted; the choice of steepness would  
983 have a much greater impact on a depleted stock.

#### 984 3.7.4 Northern Model Reference Points

northern-model-reference-points

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

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

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

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

## 990 3.8 Southern Model Base Case Results southern-model-base-case-results

991 Data used in the Southern model is shown in Figure 59.

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

995 Estimated catches are shown in Figure 60.

996 The estimated spawning biomass in Figure 86 shows the size of the uncertainty in this model.  
997 Total biomass (Figure 87) shows a sharp upward trend in recent years, the decade with only  
998 one year of age data from the Hook-and-Line Survey. Spawning depletion has sinuous curves  
999 and was likely never as low as the 40% target, even in the 1980s-1990s (Figure 88).

1000 Recruitments have been constant, except 2008 and 2010, when the model sees extra large  
1001 recruitments with extra large recruitment deviations (Figures 89 and 90). The spawner-recruit  
1002 curve, Figure 91 is a line.

### 1003 3.8.1 Southern Model Selectivities, Indices and Discards southern-model-selectivities-indices-and-discards

1004 Selectivity by fleet is shown in Figure 61. Selectivities for all but the recreational Onboard  
1005 fishery are modeled as asymptotic; both recreational fleets (MRFSS/RecFIN and Onboard)  
1006 are fully selected at 30cm; the remaining fleets show full selectivity at 45-50 cm.

1007 Index fits leave something to be desired. All are more-or-less flat, with all of the three current  
1008 indices, the Onboard, the Juvenile study and the Hook-and-Line survey all missing a downturn  
1009 at the end of the timeseries. During model tuning, we tried introducing a time-blocked index  
1010 for the two periods of the Onboard survey, however it didn't improve the fit to the index  
1011 significantly, and increased the (negative log) likelihood of the model.

1012 There was little information to inform the Southern Model of discard behavior, except in  
1013 the Onboard survey, where it was represented by extremely small numbers. We included  
1014 these discards in the retained fishery, since attempts to include it as a type-1 "retained plus  
1015 discards" fishery prevented the model from converging.

### 1016 3.8.2 Southern Model Lengths

southern-model-lengths

1017 Lengths in the Southern model were entered as unsexed, except for the Hook-and-Line fishery.  
1018 There were sexes for the Commercial lengths, however there were also large numbers of

1019 unsexed lengths, and we chose to model the lengths as unsexed, to include as much of the  
1020 data as possible. This was true of the Small-Fish study, as well.

1021 Bubble plots of the lengths by year in each fishery are in Figure 63. The plot for the  
1022 recreational fishery clearly shows the transition from the MRFSS sampling program to  
1023 RecFIN in 2003/2004, as well as suggesting the existence of larger fish in the 1980s. The  
1024 Commercial fishery data has been sparse in recent years, however the fish taken in the  
1025 Commercial catch are consistently larger than those in the recreational fishery, no doubt  
1026 reflecting trawling in deeper waters. The Onboard survey lengths reflect two eras of sampling,  
1027 again with larger fish in the earlier period. The panel for the Hook-and-Line survey shows  
1028 that the females landed are always larger than the males, in agreement with the model  
1029 estimates of growth: Figure 5.

1030 The fits to the lengths in the Recreational fishery Figure 64 show variable fits through the  
1031 years, with the noisy and sparse data in 2004 heralding the transition between MRFSS  
1032 sampling and RecFIN. Overall, the timeseries is fit fairly well: Figure ??

1033 The Commercial length comps are fit well through 2005, when data becomes sparse and noisy  
1034 Figure 66; and Figure 67.

1035 Fits for the Onboard Survey lengths are good in the early survey, and poor for the later  
1036 period 68; 69. Attempting to apply a time-block to this data resulted in poor convergence.

1037 The Hook-and-Line Survey lengths are noisy (Figure 70), but the fits are acceptable, and  
1038 follow the trend of the data better than those for the other datasets: Figure 71.

1039 The small fish survey lengths are not fit badly 72; 73, and it is perhaps a shame that there  
1040 are so few years to this timeseries.

1041 The aggregate fits to the length comps for all five datasets is shown in Figure 74, and Pearson  
1042 residuals for the lengths in Figure 75. Filled bubbles represent under-estimation of the data,  
1043 open bubbles represent overestimation.

### 1044 3.8.3 Southern Model Ages

southern-model-ages

1045 There are few marginal ages in the model. Bubble plots for the Southern model ages (Figure  
1046 76) show the small sample from the Juvenile Fish Study and the single year of ages from the  
1047 Hook-and-Line Survey. The samples are too small to show any inter-annual variation, and  
1048 are noisy within-year.

1049 Figure ?? shows the fit to the Recreational Fishery samples, which is poor in all four years.  
1050 The mean age in this data is shown in Figure ??, at 10 years.

1051 The Hook-and-Line Survey age “fit” is shown in Figure 79. The Francis tuning method could  
1052 not be applied in this case as it depends on the fit to multiple years of data.

1053 The aggregated fits for the marginal, and I *do* mean *marginal* ages are shown in Figure 80.  
1054 They speak for themselves.

1055 The implied marginal age distribution from the commercial conditional-age-at-length com-  
1056 positions is shown in Figure ???. This figure is included for informational purposes only; as  
1057 it does not contribute to the model likelihood calculations. The fits here are quite good  
1058 1981-1999, however the last three years of data are very sparse and not well fit.

1059 Pearson residuals for the Small Fish Juvenile Study and the Hook-and-Line Survey are shown  
1060 in Figure 82. Bubble size indicates the amount of disappointment in the fits. The filled  
1061 bubbles indicate underestimates by the model; the open bubbles indicate overestimates.

1062 The good news age-data comes from the commercial fleet, as was foreshadowed by the implied  
1063 marginal ages. Figure ?? shows the interannual fits to the mean age in the commercial age-  
1064 at-length data. Except for 1981, 1982 and 1989, the model is able to fit the data reasonably  
1065 well, detecting the downward trend in the late 1980s and into the mid-1990s.

1066 The annual plots of age-at-length fits (Figure 85) show good fits in all years except 2001-2002.

#### 1067 3.8.4 Southern Model Uncertainty and Sensitivity Analyses southern-model-uncertainty-and-sensitivity-analyses

#### 1068 3.8.5 Southern Model Retrospective Analysis southern-model-retrospective-analysis

#### 1069 3.8.6 Southern Model Likelihood Profiles southern-model-likelihood-profiles

1070 We profiled the change in negative log likelihood for the data sources and model total  
1071 likelihood for critical parameters fixed in the model: **R0**, the log of equilibrium recruitment;  
1072 female natural mortality, **MF**; male natural mortality, **MM**; and steepness, **h** the parameter  
1073 that reflects how quickly the stock-recruit relationship allows the stock to rebound from  
1074 depleted stock size.

1075 The likelihood profile for **R0** is shown in Figure 92. R0 was profiled over values from 8.5  
1076 -11. The figure shows that the age data and indices are minimized when R0 is 11; the length  
1077 data are minimized around 8.5, and the recruitments at 9.8 (or so). The overall likelihood is  
1078 minimized near 10.5.

1079 The female natural mortality (FM) profile, 93 ranges from 0.1 to 0.24. The age and length  
1080 data sources are at odds over FM; the ages and recruitments are minimized when FM is  
1081 the low end of the range, and the lengths and indices when it is highest. Changes to the

1082 recruitment likelihood is minimal over the whole range. The overall likelihood is minimized  
1083 near 0.22.

1084 Male natural mortality (MM) is profiled over a range from -0.4 to 0. Male natural mortality is  
1085 represented as an offset from that for females based on the equation  $MM = MF * \exp(offset)$ ,  
1086 such that an offset of 0 results in equal mortality for males and females, and an offset  
1087 of -0.3 results in a male natural mortality which is about 74% of the female mortality  
1088 ( $\exp(-0.3) = 0.7408$ ). All roads lead to Rome in this figure (Figure 94); since all data sources  
1089 and the overall likelihood are minimized at zero. Likelihoods for recruitments and indices are  
1090 flat over the range of MM; the other data sources show changes of 20 (lengths) and 80 (ages)  
1091 likelihood values.

1092 The steepness profile (Figure 95) is the most colorful, as the lines bounce around and change  
1093 direction, however the likelihood scale is from 0 to 0.7, meaning that none of the values in  
1094 this range (0.5 - 0.9) would have much impact on likelihood in the model. This supports the  
1095 conclusion that the stock is abundant. For a depleted stock, steepness would have a very  
1096 large impact on the likelihood.

1097 **3.8.7 Southern Model Reference Points**

southern-model-reference-points

1098 **3.9 Comparison of the Northern and Southern Model Results.**

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

1099 No text yet

<sub>1100</sub> **4 Harvest Projections and Decision Tables**

harvest-projections-and-decision-tables

<sub>1101</sub> Table [k](#)

<sub>1102</sub> \*\* Northern Model Projections and Decision Table (groundfish only)\*\* (Table [6](#)

<sub>1103</sub> Table [m](#)

<sub>1104</sub> \*\* Southern Model Projections and Decision Table (groundfish only)\*\*

1105 **5 Regional Management Considerations**

regional-management-considerations

1106 Management of the yellowtail rockfish northern stock has always been delineated by the  
1107  $40^{\circ} 10'$  line and the Canadian border. That the stock's genetic cline was found at Cape  
1108 Mendocino is a happy accident that reinforces  $40^{\circ} 10'$  as the appropriate management line.

1109 This assessment was not designed to test that choice. Given that the data for commercial  
1110 and recreational fisheries is collected by the individual states (WA, OR, CA), it might have  
1111 been interesting to investigate a management line at the California/Oregon border, had the  
1112 STAT team the time and managers the interest in investigating a change.

<sub>1113</sub> **6 Research Needs**

research-needs

- <sub>1114</sub> 1. A longer timeseries of the juvenile rockfish CPUE in the south.
- <sub>1115</sub> 2. A commercial index in the north. This is by far the largest segment of the fishery, and  
<sub>1116</sub> the introduction of trawl rationalization program should mean that an index can be  
<sub>1117</sub> developed for the current fishery when the next assessment is performed.
- <sub>1118</sub> 3. More recent ages for the southern model. The commercial age timeseries currently  
<sub>1119</sub> stops in 2002.

<sub>1120</sub> **7 Acknowledgments**

**acknowledgments**

- <sub>1121</sub> The authors thank the following individuals for their contributions to this assessment:
- <sub>1122</sub> Washington Department of Fish and Wildlife staff: Theresa Tsou and Phillip Weyland
- <sub>1123</sub> Oregon Department of Fish and Wildlife staff: Alison Whitman and Troy Buell
- <sub>1124</sub> California Department of Fish and Wildlife staff: John Budrick
- <sub>1125</sub> Southwest Fisheries Science Center staff: Melissa Monk, E.J. Dick, and Don Pearson
- <sub>1126</sub> Northwest Fisheries Science Center staff: Jim Hastie, Chantel Wetzel, Beth Horness, Melissa
- <sub>1127</sub> Head, John Wallace, Vanessa Tuttle, James Thorson and Owen Hamel
- <sub>1128</sub> RecFIN staff: Rob Ames
- <sub>1129</sub> John DeVore, Pacific Fisheries Management Council staff
- <sub>1130</sub> John Field, STAR panel Chair, SWFSC
- <sub>1131</sub> CIE Reviewers: Panagiota Apostolaki and Kevin Stokes
- <sub>1132</sub> John Budrick, CDFW
- <sub>1133</sub> Jessi Doerpinghaus, WDFW and Pacific Fishery Management Council / Groundfish Manage-
- <sub>1134</sub> ment Team
- <sub>1135</sub> Dan Waldeck, Pacific Fishery Management Council / Groundfish Advisory Panel

<sub>1136</sub> **8 Tables**

tables

<sub>1137</sub> **8.1 Northern Model Tables**

northern-model-tables

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

Region	ID	Fleet	Years	Name	Fishery ind.	Filtering	Method	Endorsed
WA	1	4	1981- 2014	Dockside CPUE	No	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

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**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

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**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

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**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-model1-params

**Table 5. Time-series of population estimates from the Northern model base-case.**

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output (depletion)	Age-0 recruits	Total catch (mt)	Relative exploitation	SPR
1889	132737	14.43	0.00	30370	0	0.00	1.00
1890	132737	14.43	1.00	30370	0	0.00	1.00
1891	132736	14.43	1.00	30370	0	0.00	1.00
1892	132718	14.43	1.00	30370	2	0.00	1.00
1893	132721	14.43	1.00	30370	2	0.00	1.00
1894	132721	14.43	1.00	30369	2	0.00	1.00
1895	132734	14.43	1.00	30369	1	0.00	1.00
1896	132737	14.43	1.00	30369	0	0.00	1.00
1897	132737	14.43	1.00	30369	0	0.00	1.00
1898	132738	14.43	1.00	30370	0	0.00	1.00
1899	132738	14.43	1.00	30370	0	0.00	1.00
1900	132737	14.43	1.00	30370	0	0.00	1.00
1901	132737	14.43	1.00	30370	0	0.00	1.00
1902	132736	14.43	1.00	30370	0	0.00	1.00
1903	132736	14.43	1.00	30370	0	0.00	1.00
1904	132733	14.43	1.00	30370	1	0.00	1.00
1905	132735	14.43	1.00	30370	0	0.00	1.00
1906	132734	14.43	1.00	30370	1	0.00	1.00
1907	132734	14.43	1.00	30371	1	0.00	1.00
1908	132732	14.43	1.00	30371	1	0.00	1.00
1909	132733	14.43	1.00	30371	1	0.00	1.00
1910	132733	14.43	1.00	30371	1	0.00	1.00
1911	132732	14.43	1.00	30371	1	0.00	1.00
1912	132732	14.43	1.00	30371	1	0.00	1.00
1913	132731	14.43	1.00	30371	1	0.00	1.00
1914	132731	14.43	1.00	30371	1	0.00	1.00
1915	132730	14.43	1.00	30371	1	0.00	1.00
1916	132708	14.43	1.00	30371	4	0.00	1.00
1917	132687	14.43	1.00	30371	6	0.00	1.00
1918	132609	14.43	1.00	30371	16	0.00	1.00
1919	132698	14.43	1.00	30370	5	0.00	1.00
1920	132691	14.43	1.00	30370	6	0.00	1.00
1921	132676	14.43	1.00	30370	8	0.00	1.00
1922	132690	14.43	1.00	30370	6	0.00	1.00
1923	132711	14.43	1.00	30370	3	0.00	1.00

**Table 5. Time-series of population estimates from the Northern model base-case.**

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output (depletion)	Age-0 recruits	Total catch (mt)	Relative exploitation	SPR
1924	132686	14.43	1.00	30370	6	0.00	1.00
1925	132616	14.43	1.00	30370	15	0.00	1.00
1926	132608	14.43	1.00	30370	16	0.00	1.00
1927	132515	14.43	1.00	30369	27	0.00	1.00
1928	132533	14.42	1.00	30369	25	0.00	1.00
1929	132465	14.42	1.00	30368	33	0.00	1.00
1930	132351	14.42	1.00	30367	47	0.00	0.99
1931	132286	14.41	1.00	30366	55	0.00	0.99
1932	132435	14.40	1.00	30061	37	0.00	1.00
1933	132457	14.40	1.00	30027	34	0.00	1.00
1934	132466	14.40	1.00	29987	33	0.00	1.00
1935	132305	14.39	1.00	29940	52	0.00	0.99
1936	132302	14.39	1.00	29883	53	0.00	0.99
1937	132256	14.38	1.00	29818	58	0.00	0.99
1938	132156	14.38	1.00	29744	70	0.00	0.99
1939	132069	14.37	1.00	29663	81	0.00	0.99
1940	131440	14.36	1.00	29575	158	0.00	0.98
1941	131008	14.34	0.99	29475	211	0.00	0.98
1942	129977	14.31	0.99	29362	340	0.00	0.96
1943	122219	14.25	0.99	29235	1402	0.01	0.86
1944	115294	14.02	0.97	29062	2485	0.02	0.76
1945	103942	13.63	0.94	28845	4645	0.04	0.62
1946	112462	12.92	0.90	28486	2792	0.02	0.72
1947	121077	12.54	0.87	28163	1415	0.01	0.84
1948	121990	12.41	0.86	27914	1281	0.01	0.85
1949	127016	12.33	0.85	27672	642	0.01	0.92
1950	122199	12.35	0.86	27382	1250	0.01	0.85
1951	121754	12.29	0.85	26905	1304	0.01	0.85
1952	119033	12.23	0.85	26274	1671	0.01	0.81
1953	124574	12.11	0.84	25652	927	0.01	0.89
1954	122350	12.11	0.84	25310	1208	0.01	0.86
1955	122297	12.07	0.84	25204	1210	0.01	0.86
1956	120757	12.02	0.83	24833	1406	0.01	0.84
1957	120421	11.93	0.83	23943	1440	0.01	0.83
1958	119898	11.83	0.82	23271	1497	0.01	0.82

**Table 5. Time-series of population estimates from the Northern model base-case.**

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output (depletion)	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1959	119435	11.72	0.81	24479	1544	0.01	0.82
1960	116905	11.59	0.80	30504	1873	0.02	0.78
1961	117518	11.41	0.79	41184	1759	0.02	0.79
1962	113117	11.24	0.78	33497	2357	0.02	0.73
1963	115737	10.96	0.76	24157	1933	0.02	0.77
1964	117977	10.76	0.75	20819	1605	0.02	0.80
1965	118648	10.61	0.74	20494	1500	0.01	0.81
1966	121432	10.47	0.73	21247	1154	0.01	0.84
1967	118830	10.41	0.72	24468	1453	0.01	0.81
1968	114510	10.34	0.72	36865	2019	0.02	0.75
1969	105639	10.25	0.71	28418	3368	0.03	0.64
1970	118067	10.03	0.70	20856	1535	0.02	0.80
1971	117615	10.13	0.70	15939	1603	0.02	0.79
1972	111639	10.20	0.71	21380	2406	0.02	0.71
1973	108258	10.09	0.70	26645	2872	0.03	0.67
1974	113481	9.85	0.68	48211	2063	0.02	0.74
1975	117893	9.72	0.67	37738	1488	0.02	0.80
1976	99984	9.69	0.67	30536	4160	0.04	0.57
1977	89749	9.28	0.64	36828	6213	0.07	0.44
1978	79613	8.58	0.60	25805	8728	0.10	0.33
1979	79943	7.53	0.52	15833	7720	0.09	0.34
1980	78034	6.68	0.46	19076	7631	0.09	0.31
1981	70079	5.92	0.41	26632	9692	0.12	0.24
1982	66437	5.06	0.35	16864	10338	0.13	0.20
1983	63156	4.35	0.30	29732	10841	0.15	0.18
1984	77361	3.79	0.26	35338	5476	0.08	0.31
1985	87119	3.94	0.27	23862	3751	0.06	0.42
1986	79641	4.28	0.30	26514	5411	0.08	0.33
1987	79511	4.34	0.30	33745	5418	0.08	0.33
1988	73356	4.31	0.30	18702	6800	0.10	0.27
1989	78190	4.02	0.28	41556	5227	0.08	0.32
1990	79214	3.90	0.27	40789	4916	0.08	0.33
1991	81752	3.83	0.27	37070	4418	0.07	0.35
1992	71063	3.87	0.27	23923	6856	0.11	0.25
1993	73002	3.68	0.26	16312	6103	0.09	0.27

**Table 5. Time-series of population estimates from the Northern model base-case.**

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output (depletion)	Age-0 recruits	Total catch (mt)	Relative exploitation	SPR
1994	73046	3.64	0.25	26729	6140	0.09	0.26
1995	75058	3.60	0.25	24756	5657	0.08	0.28
1996	73008	3.63	0.25	13530	6275	0.09	0.26
1997	96571	3.65	0.25	18297	2412	0.03	0.52
1998	92920	4.15	0.29	32535	3142	0.04	0.48
1999	91643	4.64	0.32	29955	3599	0.05	0.45
2000	92286	5.05	0.35	40705	3716	0.05	0.47
2001	104324	5.38	0.37	21247	2235	0.03	0.62
2002	113918	5.79	0.40	13150	1356	0.02	0.74
2003	125270	6.21	0.43	16293	491	0.01	0.90
2004	121125	6.67	0.46	21226	839	0.01	0.84
2005	111843	7.01	0.49	8998	1751	0.02	0.72
2006	125004	7.18	0.50	32422	565	0.01	0.89
2007	121973	7.54	0.52	11625	850	0.01	0.85
2008	126048	7.89	0.55	41174	519	0.01	0.90
2009	120080	8.29	0.57	12417	1095	0.01	0.82
2010	115508	8.56	0.59	26224	1598	0.02	0.76
2011	117687	8.65	0.60	17759	1348	0.02	0.79
2012	115366	8.68	0.60	18728	1593	0.02	0.76
2013	116760	8.59	0.60	30713	1432	0.02	0.78
2014	116163	8.48	0.59	28431	1459	0.02	0.77
2015	111011	8.37	0.58	28515	2016	0.02	0.71
2016	115907	8.22	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 output, and depletion for the base case model.**

Yr	OFL contribution (mt)	ACL landings (mt)	Age 4+ biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output (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

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**Table 7. Summary of the biomass/abundance time series used in the stock assessment.**

Region	ID	Fleet	Years	Name	Fishery ind.	Filtering	Method	Endorsed	tab:Index_summary
CA	1	1	1981- 2003	Dockside CPUE	No	trip, area, Stephens- MacCall	delta-GLM (bin- lognormal)	SSC	
CA	3	3	1987- 2006	Onboard CPUE	No		Polygon	SSC	
CA	4	4	2004- 2016	Hook- and- Line	Yes (?)	-	-	-	
CA	5	5	2001- 2016	Juvenile CPUE	Yes	-	-	-	

**Table 8. 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 9. List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
1	NatM_p_1_Fem_GP_1	0.180	-2	(0.02, 0.25)	OK	0.916	None
2	L_at_Amin_Fem_GP_1	18.178	3	(1, 25)	OK	0.916	None
3	L_at_Amax_Fem_GP_1	49.548	2	(35, 70)	OK	0.340	None
4	VonBert_K_Fem_GP_1	0.112	3	(0.1, 0.4)	OK	0.006	None
5	CV_young_Fem_GP_1	0.078	5	(0.03, 0.16)	OK	0.013	None
6	CV_old_Fem_GP_1	0.057	5	(0.03, 0.16)	OK	0.005	None
7	Wtlen_1_Fem	0.000	-50	(0, 3)	None	None	None
8	Wtlen_2_Fem	3.067	-50	(2, 4)	None	None	None
9	Mat50%_Fem	42.490	-50	(30, 56)	None	None	None
10	Mat_slope_Fem	-0.401	-50	(-2, 1)	None	None	None
11	Eggs_scalar_Fem	0.000	-50	(0, 6)	None	None	None
12	Eggs_exp_len_Fem	4.590	-50	(2, 7)	None	None	None
13	NatM_p_1_Mal_GP_1	-0.288	-2	(-3, 3)	Normal (0, 99)	None	None
14	L_at_Amin_Mal_GP_1	0.000	-2	(-1, 1)	None	None	None
15	L_at_Amax_Mal_GP_1	-0.124	2	(-1, 1)	OK	0.015	None
16	VonBert_K_Mal_GP_1	0.142	3	(-1, 1)	OK	0.063	None
17	CV_young_Mal_GP_1	0.000	-5	(-1, 1)	None	None	None
18	CV_old_Mal_GP_1	0.337	5	(-1, 1)	OK	0.163	None
19	Wtlen_1_Mal	0.000	-50	(0, 3)	None	None	None
20	Wtlen_2_Mal	3.067	-50	(2, 4)	None	None	None
24	CohortGrowDev	1.000	-50	(0, 2)	None	None	None
25	FracFemale_GP_1	0.500	-99	(0.001, 0.999)	None	None	None
26	SR_LN(R0)	10.527	1	(5, 20)	OK	0.789	None
27	SR_BH_stEEP	0.718	-6	(0.2, 1)	None	None	None
28	SR_sigmaR	0.850	-6	(0.5, 1.2)	None	None	None
29	SR_regime	0.000	-50	(-5, 5)	None	None	None

Continued on next page

Table 9. List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD)).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
30	SR.autocorr	0.000	-50	(0, 2)			None
129	LnQ.base_OnboardSurvey(3)	-13.315	-1	(-30, 15)			None
130	LnQ.base_HookAndLineSurvey(4)	-13.181	-1	(-30, 15)			None
131	LnQ.base_RecStudy(5)	-9.231	-1	(-30, 15)			None
138	SizeSel_P1_CommercialCatch(2)	55.000	-1	(20, 55)			None
139	SizeSel_P2_CommercialCatch(2)	20.000	-4	(-20, 20)			None
140	SizeSel_P3_CommercialCatch(2)	5.276	3	(-5, 20)	OK	0.056	None
141	SizeSel_P4_CommercialCatch(2)	20.000	-4	(-5, 20)			None
142	SizeSel_P5_CommercialCatch(2)	-999.000	-99	(-999, 25)			None
143	SizeSel_P6_CommercialCatch(2)	-999.000	-99	(-999, 25)			None
144	SizeSel_P1_OnboardSurvey(3)	30.066	1	(20, 55)	OK	1.324	None
145	SizeSel_P2_OnboardSurvey(3)	-20.000	-4	(-20, 7)			None
146	SizeSel_P3_OnboardSurvey(3)	3.490	3	(-5, 20)	OK	0.381	None
147	SizeSel_P4_OnboardSurvey(3)	7.586	4	(-5, 20)	OK	1.962	None
148	SizeSel_P5_OnboardSurvey(3)	-999.000	-99	(-999, 25)			None
149	SizeSel_P6_OnboardSurvey(3)	-999.000	-99	(-999, 25)			None
150	SizeSel_P1_HookAndLineSurvey(4)	49.031	1	(20, 55)	OK	3.651	None
151	SizeSel_P2_HookAndLineSurvey(4)	20.000	-4	(-20, 20)			None
152	SizeSel_P3_HookAndLineSurvey(4)	5.178	3	(-5, 20)	OK	0.279	None
153	SizeSel_P4_HookAndLineSurvey(4)	20.000	-4	(-5, 20)			None
154	SizeSel_P5_HookAndLineSurvey(4)	-999.000	-99	(-999, 25)			None
155	SizeSel_P6_HookAndLineSurvey(4)	-999.000	-99	(-999, 25)			None
156	SizeSel_P1_RecStudy(5)	49.449	1	(20, 55)	OK	2.552	None
157	SizeSel_P2_RecStudy(5)	20.000	-4	(-20, 20)			None
158	SizeSel_P3_RecStudy(5)	5.379	3	(-5, 20)	OK	0.195	None
159	SizeSel_P4_RecStudy(5)	20.000	-4	(-5, 20)			None
160	SizeSel_P5_RecStudy(5)	-999.000	-99	(-999, 25)			None

Continued on next page

Table 9. List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD)).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
161	SizeSelP6_RecStudy(5)	-999.000	-99	(-999, 25)	None		

tab:Model2-params

**Table 11. Time-series of population estimates from the Southern model base-case.**

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output (depletion)	Age-0 recruits	Total catch (mt)	Relative exploitation	SPR
1916	114120	5.80	0.00	37363	494	0.00	0.93
1917	112299	5.75	0.99	37334	769	0.00	0.89
1918	111403	5.68	0.98	37290	904	0.01	0.87
1919	113174	5.60	0.97	37240	622	0.01	0.91
1920	113059	5.56	0.96	37210	636	0.01	0.91
1921	113769	5.52	0.95	37182	528	0.01	0.92
1922	114269	5.49	0.95	37164	454	0.00	0.93
1923	114018	5.47	0.94	37152	489	0.00	0.93
1924	115423	5.46	0.94	37141	290	0.00	0.95
1925	114798	5.46	0.94	37143	377	0.00	0.94
1926	113404	5.46	0.94	37141	576	0.01	0.91
1927	114085	5.44	0.94	37127	476	0.00	0.93
1928	113531	5.43	0.94	37120	554	0.01	0.92
1929	114082	5.41	0.93	37110	472	0.00	0.93
1930	112594	5.40	0.93	37106	687	0.01	0.90
1931	112914	5.38	0.93	37088	636	0.01	0.90
1932	113747	5.36	0.92	37074	513	0.01	0.92
1933	115028	5.35	0.92	37070	333	0.00	0.95
1934	114755	5.37	0.93	37079	370	0.00	0.94
1935	114145	5.37	0.93	37084	454	0.00	0.93
1936	113457	5.37	0.93	37084	551	0.01	0.92
1937	113823	5.36	0.92	37078	496	0.00	0.92
1938	114438	5.36	0.92	37076	410	0.00	0.94
1939	115226	5.37	0.93	37079	303	0.00	0.95
1940	114246	5.38	0.93	37089	434	0.00	0.93
1941	114228	5.38	0.93	37090	438	0.00	0.93
1942	116353	5.38	0.93	37091	155	0.00	0.98
1943	116050	5.41	0.93	37109	196	0.00	0.97
1944	115013	5.43	0.94	37123	339	0.00	0.95
1945	112321	5.43	0.94	33637	724	0.01	0.89
1946	111978	5.40	0.93	33335	767	0.01	0.89
1947	114342	5.37	0.93	33017	424	0.00	0.93
1948	113815	5.37	0.93	32682	488	0.00	0.93
1949	114585	5.37	0.93	32307	373	0.00	0.94
1950	113686	5.37	0.93	31890	492	0.00	0.93

**Table 11. Time-series of population estimates from the Southern model base-case.**

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output (depletion)	Age-0 recruits	Total catch (mt)	Relative exploitation	SPR
1951	113515	5.37	0.93	31441	509	0.01	0.92
1952	114270	5.36	0.92	30963	406	0.00	0.94
1953	115609	5.35	0.92	30483	228	0.00	0.96
1954	115104	5.36	0.92	30038	286	0.00	0.96
1955	115155	5.35	0.92	29652	270	0.00	0.96
1956	113572	5.33	0.92	29448	475	0.00	0.93
1957	113439	5.28	0.91	29677	495	0.01	0.92
1958	111005	5.22	0.90	30903	794	0.01	0.88
1959	111908	5.14	0.89	34089	662	0.01	0.90
1960	113961	5.06	0.87	40373	398	0.00	0.93
1961	114923	5.01	0.86	47766	285	0.00	0.95
1962	115216	4.96	0.85	47160	241	0.00	0.96
1963	115190	4.91	0.85	41604	258	0.00	0.96
1964	115783	4.87	0.84	39680	193	0.00	0.97
1965	115447	4.83	0.83	41815	224	0.00	0.96
1966	114955	4.80	0.83	48585	285	0.00	0.95
1967	115143	4.78	0.82	31271	265	0.00	0.96
1968	115142	4.79	0.83	24970	267	0.00	0.96
1969	115493	4.83	0.83	27187	221	0.00	0.97
1970	115303	4.91	0.85	21644	242	0.00	0.96
1971	115120	5.01	0.86	13645	276	0.00	0.96
1972	114295	5.12	0.88	12610	370	0.00	0.94
1973	112588	5.23	0.90	17200	582	0.01	0.91
1974	111597	5.31	0.92	19160	703	0.01	0.89
1975	111257	5.36	0.92	27748	733	0.01	0.89
1976	112204	5.37	0.93	19352	550	0.01	0.91
1977	112070	5.35	0.92	19851	564	0.01	0.91
1978	113170	5.27	0.91	17270	411	0.01	0.93
1979	112215	5.16	0.89	15052	501	0.01	0.91
1980	111350	4.99	0.86	22885	540	0.01	0.90
1981	108565	4.79	0.83	32588	813	0.01	0.85
1982	98586	4.55	0.78	16810	1638	0.02	0.72
1983	101229	4.26	0.73	11800	1583	0.02	0.72
1984	100528	3.97	0.68	45024	1750	0.03	0.70
1985	105173	3.67	0.63	48288	1049	0.02	0.79

**Table 11. Time-series of population estimates from the Southern model base-case.**

Yr	Total biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output (depletion)	Age-0 recruits	Total catch (mt)	Relative exploitation	SPR
1986	107125	3.48	0.60	18699	853	0.01	0.82
1987	108191	3.32	0.57	28898	748	0.01	0.83
1988	111602	3.19	0.55	37021	437	0.01	0.90
1989	104337	3.12	0.54	41438	1134	0.02	0.76
1990	105803	3.01	0.52	40548	1001	0.02	0.78
1991	111178	2.95	0.51	43645	488	0.01	0.89
1992	108788	2.97	0.51	21121	726	0.01	0.84
1993	114029	3.00	0.52	31647	284	0.00	0.93
1994	114329	3.10	0.53	14631	271	0.00	0.94
1995	114924	3.22	0.56	10902	227	0.00	0.95
1996	114877	3.37	0.58	9806	230	0.00	0.95
1997	109313	3.53	0.61	10978	733	0.01	0.86
1998	112958	3.67	0.63	25527	421	0.01	0.91
1999	114339	3.83	0.66	56443	248	0.00	0.95
2000	115390	3.99	0.69	14211	162	0.00	0.97
2001	116746	4.11	0.71	21999	59	0.00	0.99
2002	117205	4.19	0.72	44511	27	0.00	0.99
2003	117307	4.22	0.73	42434	20	0.00	1.00
2004	117395	4.19	0.72	36848	14	0.00	1.00
2005	117257	4.12	0.71	25730	25	0.00	0.99
2006	117284	4.04	0.70	20145	24	0.00	1.00
2007	116755	3.98	0.69	26284	64	0.00	0.99
2008	117307	3.93	0.68	234325	22	0.00	1.00
2009	116967	3.93	0.68	66935	49	0.00	0.99
2010	117300	3.95	0.68	170658	25	0.00	1.00
2011	117129	4.01	0.69	81723	46	0.00	0.99
2012	117131	4.09	0.70	59526	54	0.00	0.99
2013	117139	4.22	0.73	62964	60	0.00	0.99
2014	117145	4.38	0.76	46187	65	0.00	0.99
2015	116965	4.66	0.80	37772	99	0.00	0.99
2016	117389	5.08	0.88	35705			

tab:Timeseries\_mod2

**Table 10. 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_model2
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 12. Projection of potential OFL, spawning output, and depletion for the base case model.**

Yr	OFL contribution (mt)	ACL landings (mt)	Age 4+ biomass (mt)	Spawning output (trillions of eggs)	Relative spawning output (depletion)
2017	8532.88	8157.43	173802.00	5.68	0.98
2018	8218.96	7857.32	167681.00	6.13	1.06
2019	7829.98	7485.46	159255.00	6.58	1.14
2020	7411.41	7085.31	150010.00	6.97	1.20
2021	6992.17	6684.51	140892.00	7.22	1.25
2022	6588.47	6298.58	132229.00	7.31	1.26
2023	6210.08	5936.83	124166.00	7.23	1.25
2024	5862.74	5604.78	116824.00	7.01	1.21
2025	5549.17	5305.00	110252.00	6.69	1.15
2026	5269.82	5037.95	104446.00	6.32	1.09
2027	5023.55	4802.52	99367.80	5.92	1.02
2028	4808.12	4596.56	94958.40	5.53	0.95

<sub>1139</sub> 9 Figures

figures

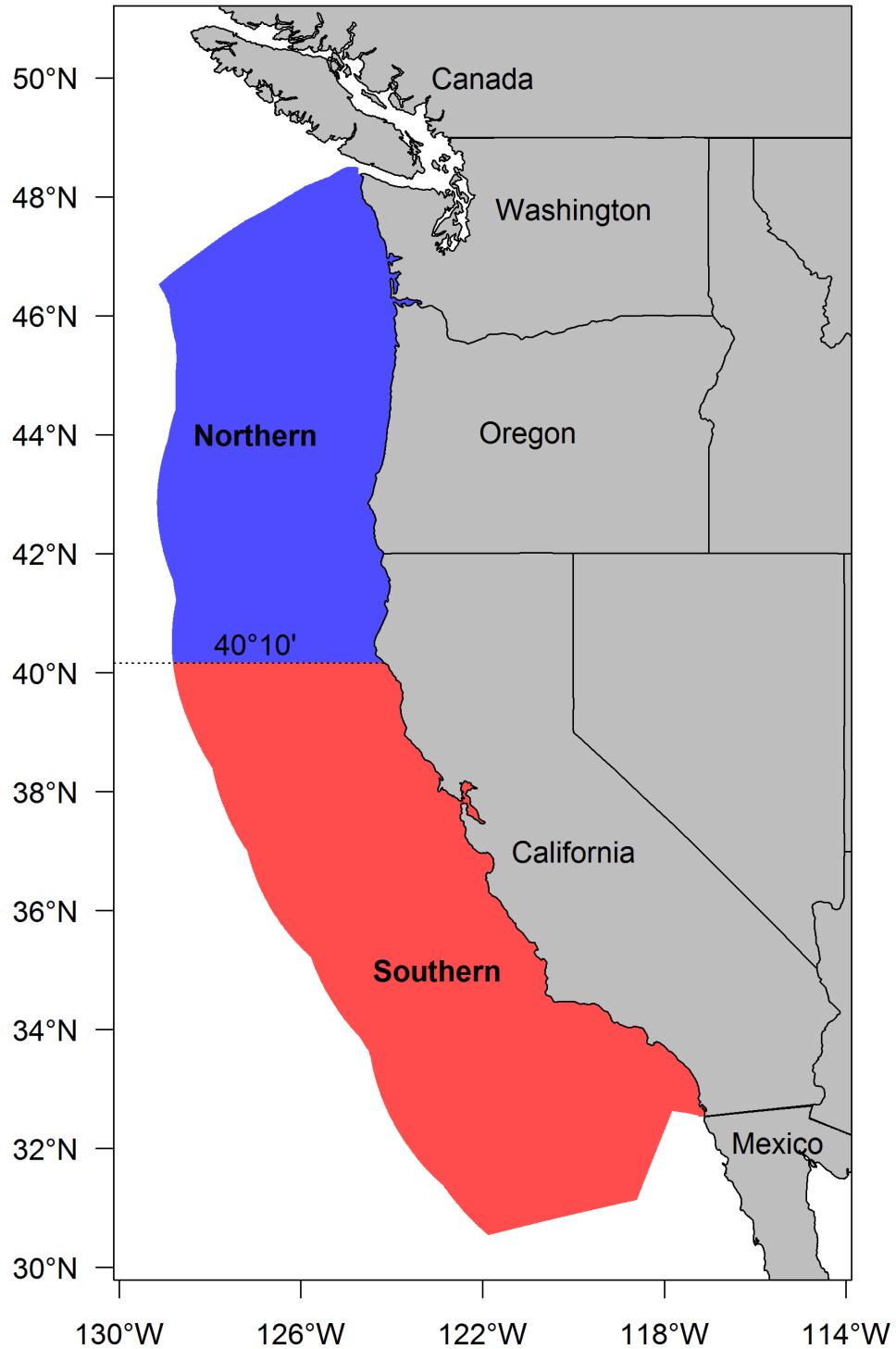


Figure 1: Map depicting the boundaries for the base-case model. fig:assess\_region\_map

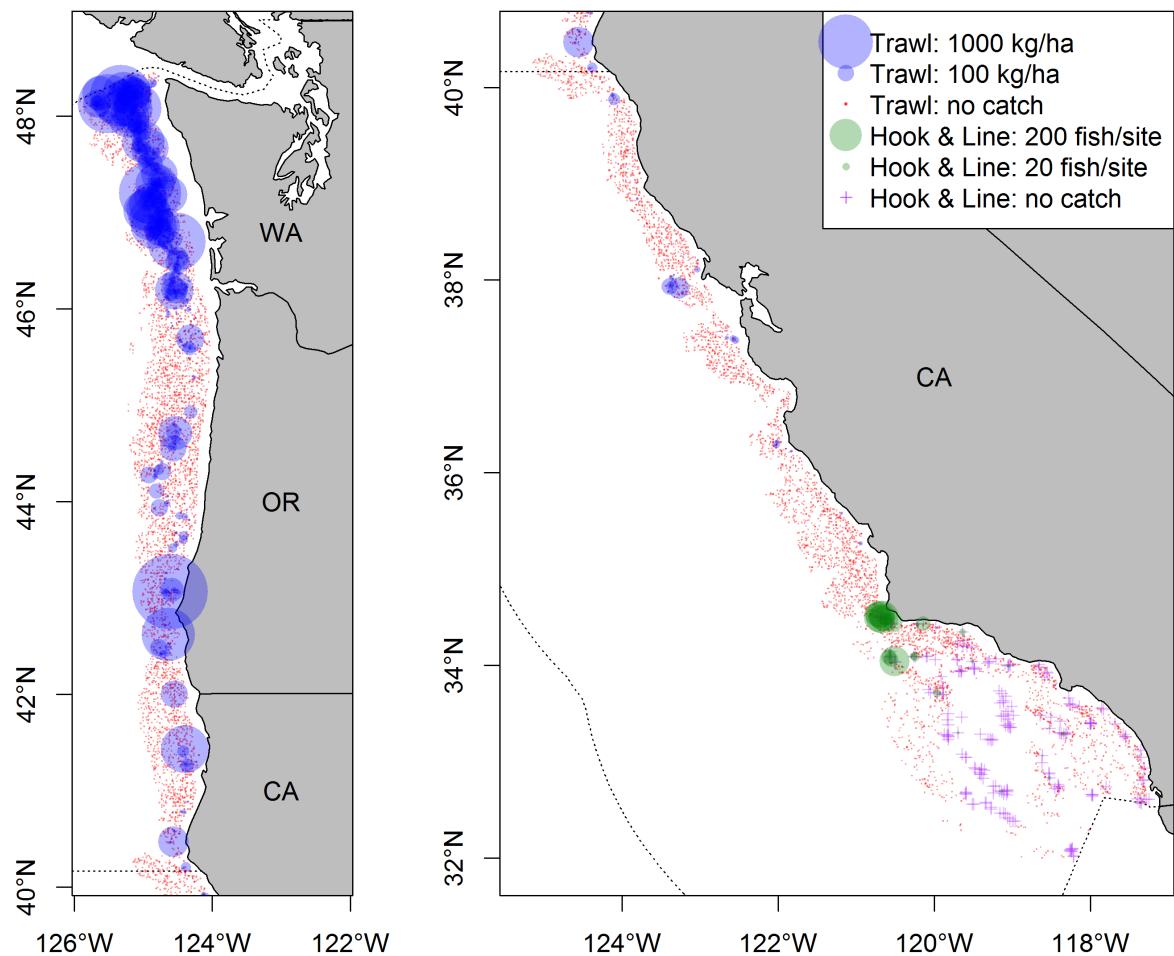


Figure 2: Map showing observations of Yellowtail Rockfish in the NWFSCcombo trawl survey and Hook & Line survey. [fig:assess\\_region\\_map](#)

1140 9.1 Life history (maturity, fecundity, and growth) for both models  
life-history-maturity-fecundity-and-growth-for-both-models

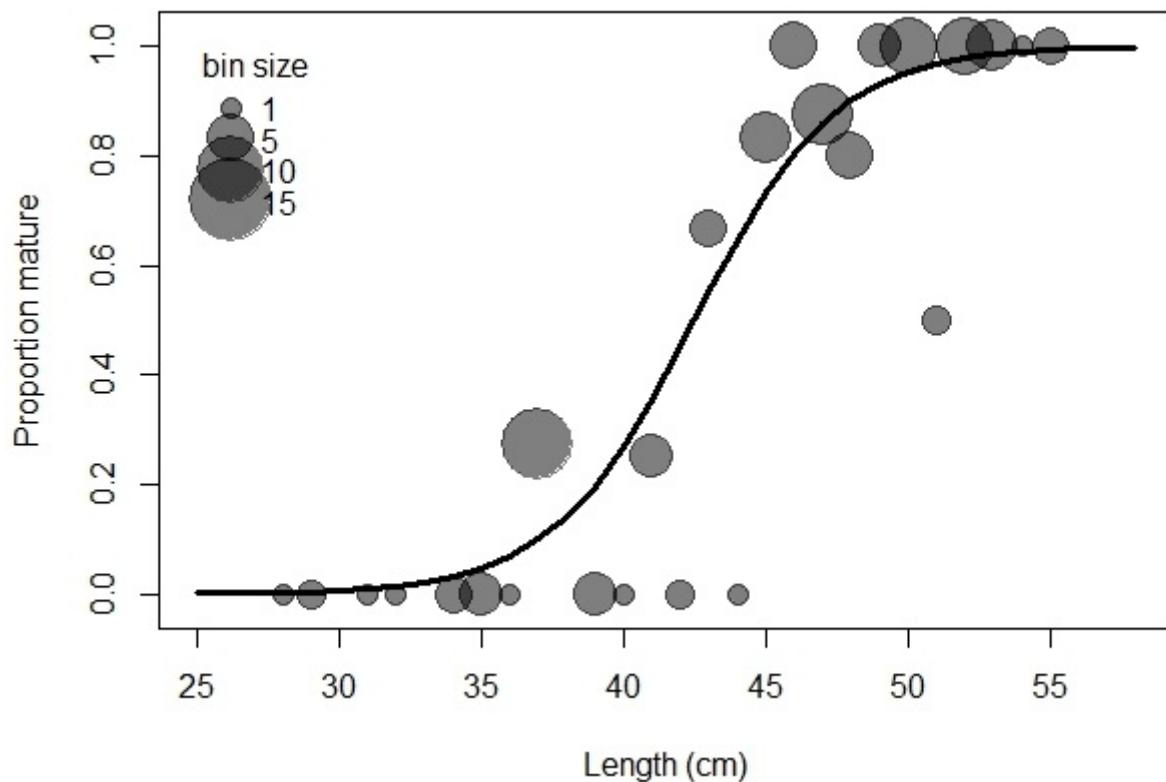


Figure 3: Estimated maturity relationship for Yellowtail Rockfish used in both models. Gray points indicate average observed functional maturity within each length bin with point size proportional to the number of samples.  
fig:maturity

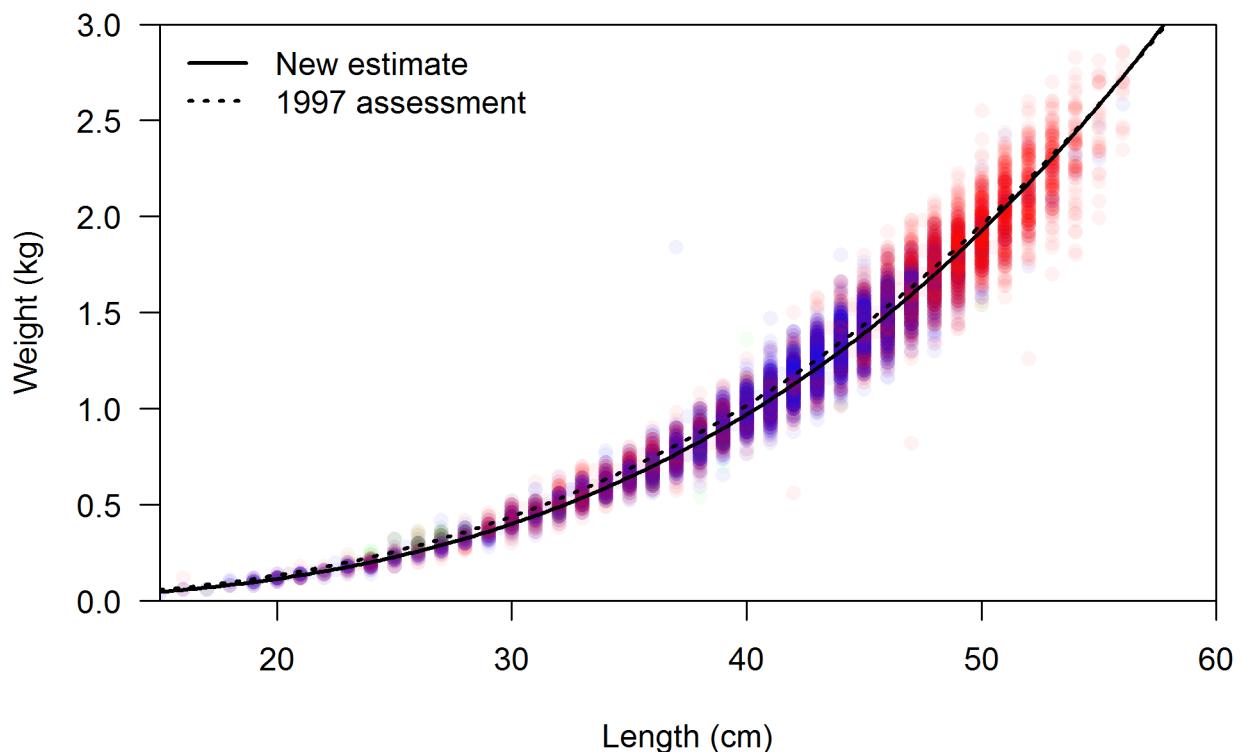


Figure 4: Estimated weight-length relationship for Yellowtail Rockfish used in both models. Colored points show observed values (red for females, blue for males, and green for unsexed). The black line indicates the estimated relationship  $W = 0.000011843L^{3.0672}$ .  
fig:weight-length

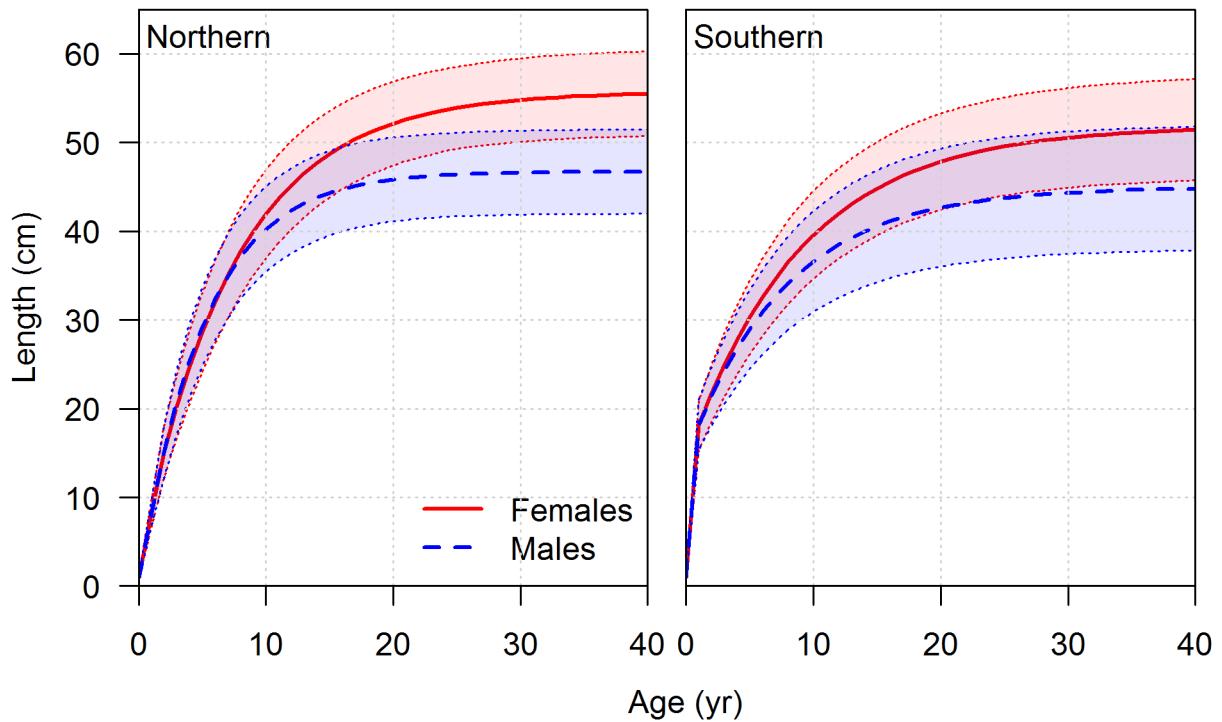


Figure 5: Estimated length-at-age for female and male Yellowtail Rockfish in each model. Shaded areas indicate 95% intervals for distribution of lengths at each age. Values represent beginning-of-year growth. fig:growth

1141 9.2 Data and model fits for the Northern model  
[data-and-model-fits-for-the-northern-model](#)

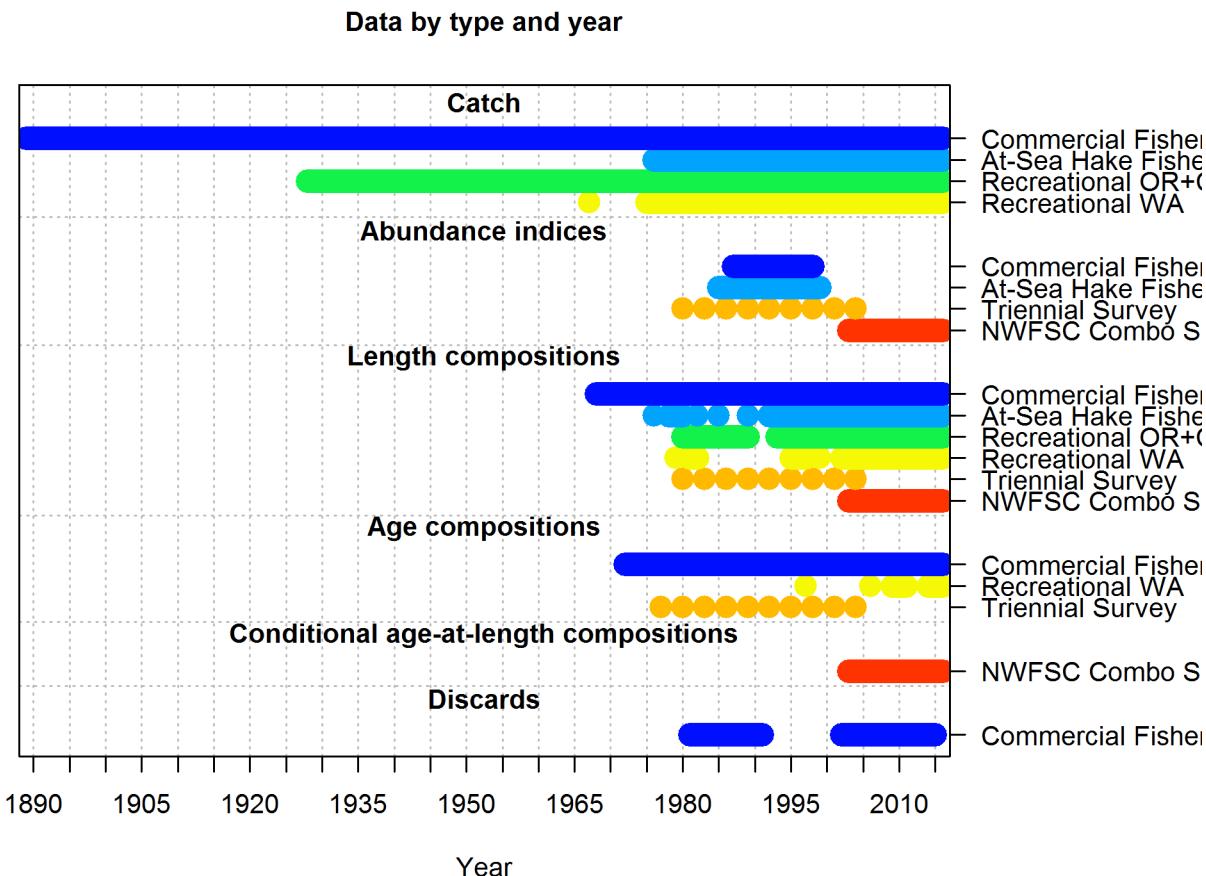


Figure 6: Summary of data sources used in the Northern model. [fig:data\\_plot.N](#)

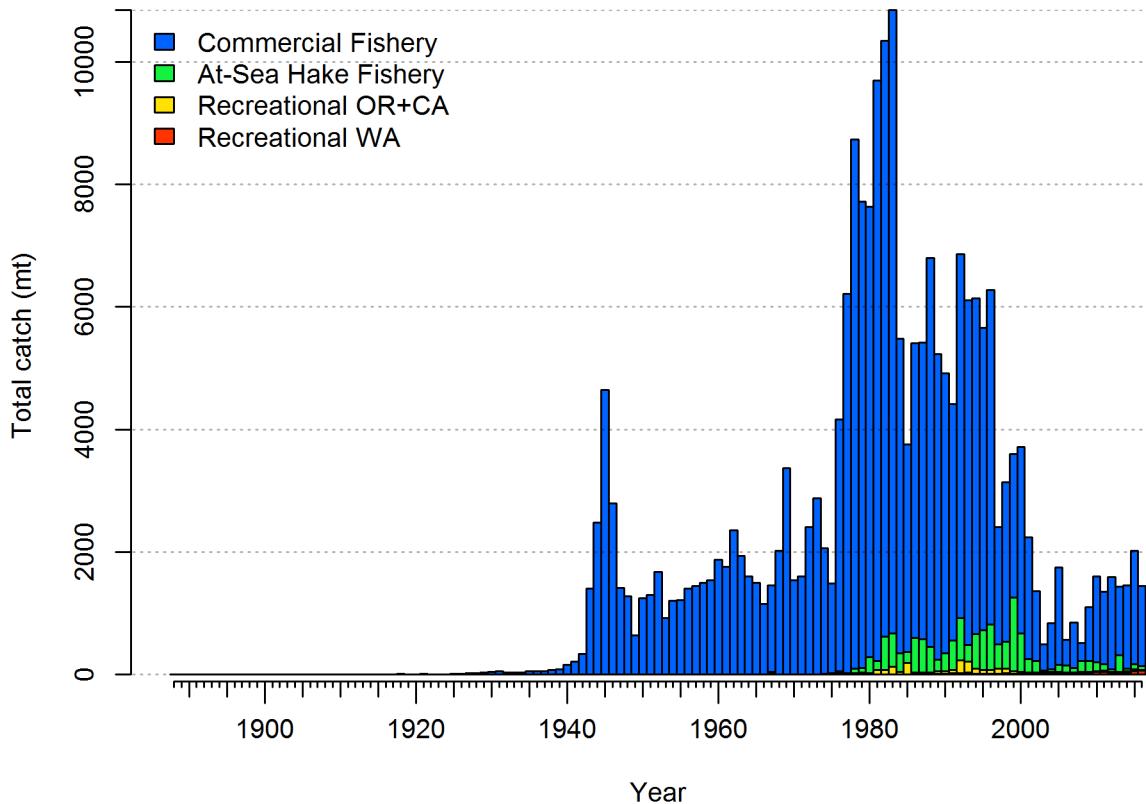


Figure 7: Estimated catch history of Yellowtail Rockfish in the Northern model. Recreational catches in Washington are model estimates of total weight converted from input catch in numbers using model estimates of growth and selectivity. Catches for the Commercial Fishery include estimated discards.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

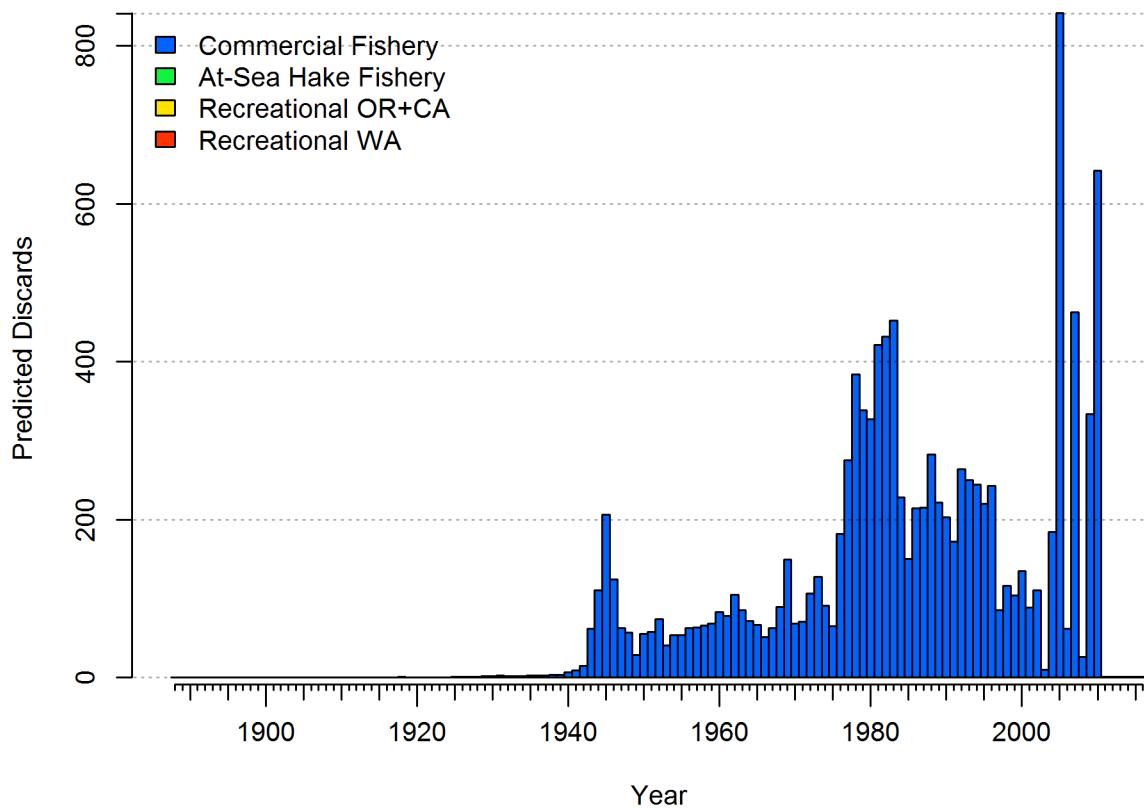


Figure 8: Estimated discards in the Commercial Fishery in the Northern model. Estimates are influenced by the data for landings, discard ratios, and discard length combines and depend on the estimated parameters controlling selectivity and retention.<sup>fig:r4ss\_discard\_N</sup>

1142 9.2.1 Selectivity, retention, and discards for Northern model  
[selectivity-retention-and-discards-for-northern-model](#)

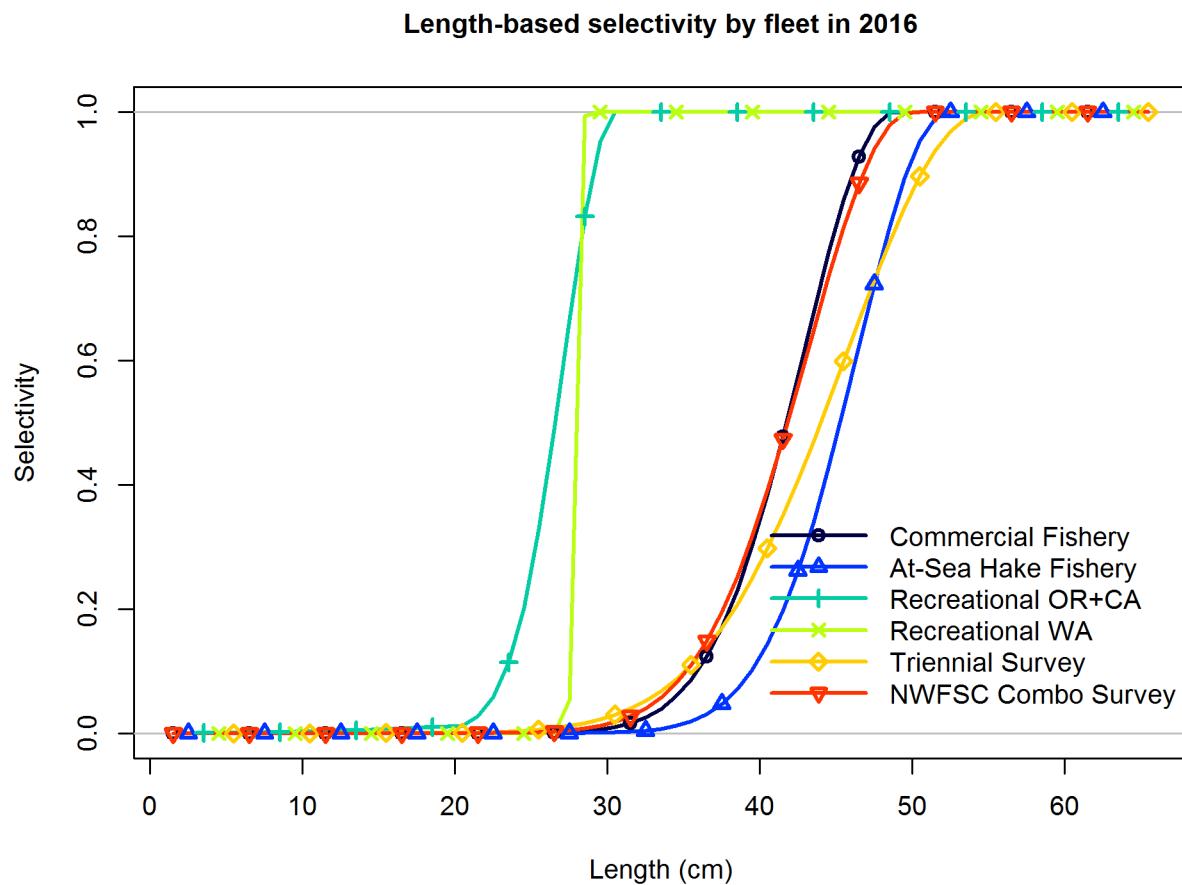


Figure 9: Estimated selectivity by length by each fishery and survey in the Northern model. [fig:selex.N](#)

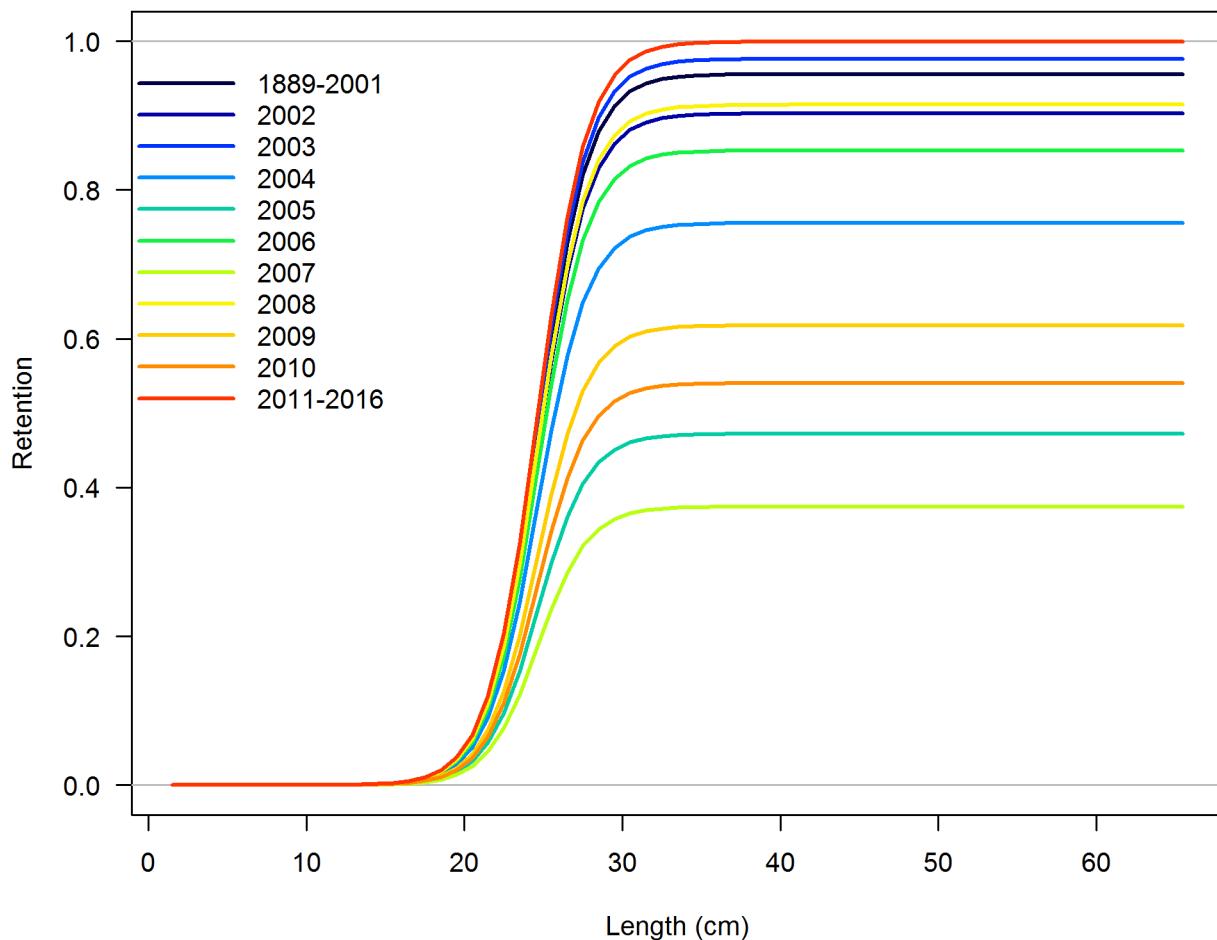


Figure 10: Estimated retention by length by the Commercial Fishery in the Northern model. `fig:retention`

### Discard fraction for Commercial Fishery

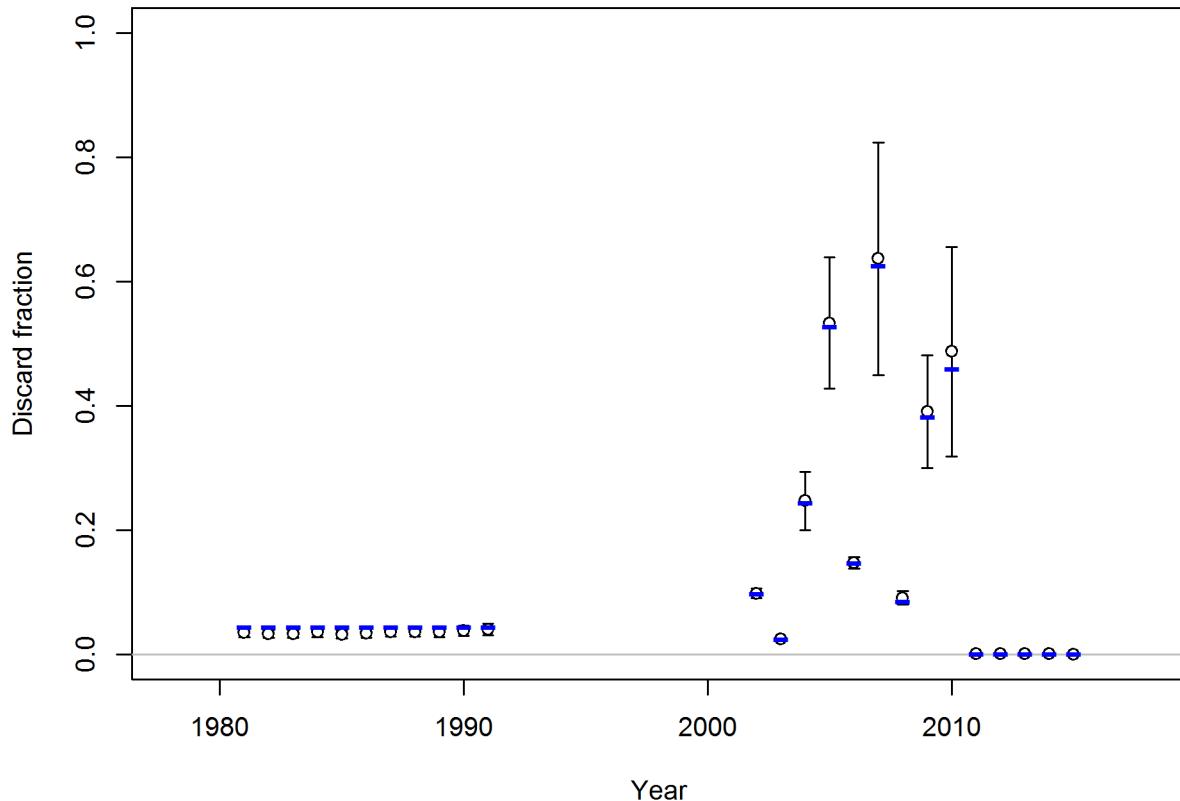


Figure 11: Fit to discard fractions for the commercial fishery in the Northern model.<sup>fig:r4ss\_discard</sup>

<sub>1143</sub> 9.2.2 At-Sea Hake Bycatch Index

at-sea-hake-bycatch-index

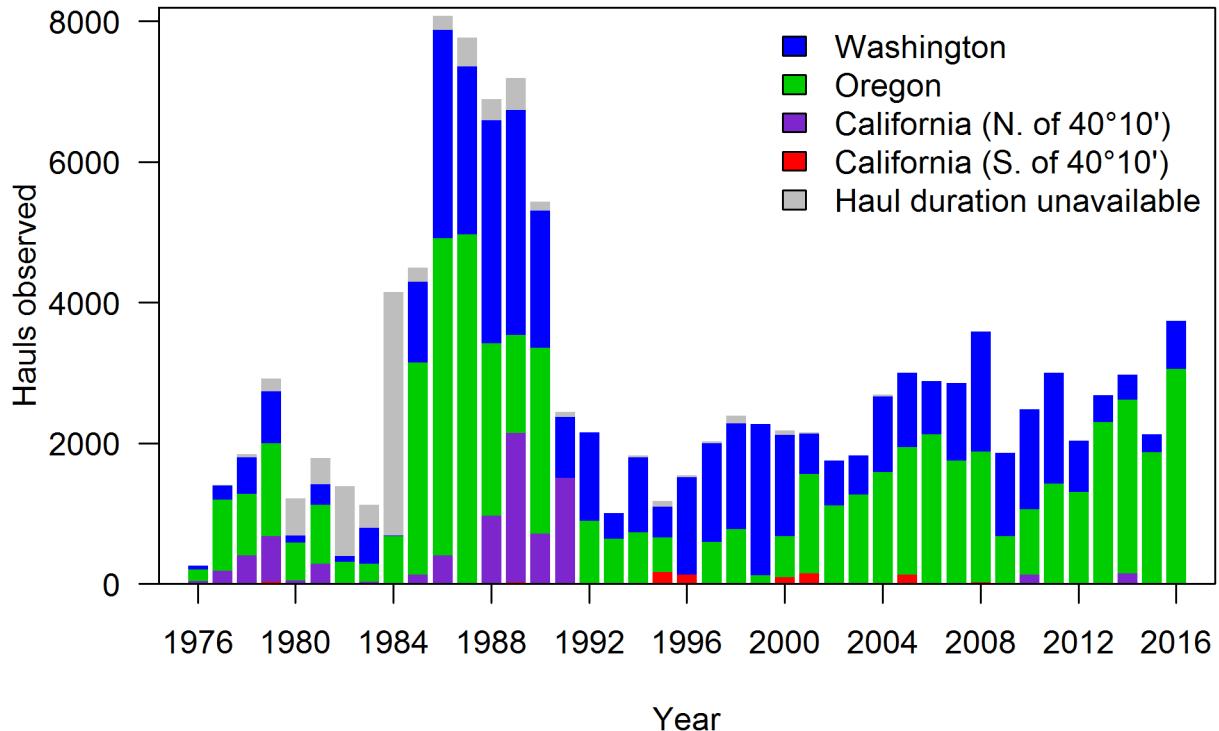


Figure 12: Number of observed hauls from the at-sea hake fishery classified by location relative to Washington, Oregon, and California (north and south of 40°10'). Grey bars indicate observed tows with no haul duration available which were excluded from the CPUE analysis.  
fig:ASHOP\_X1

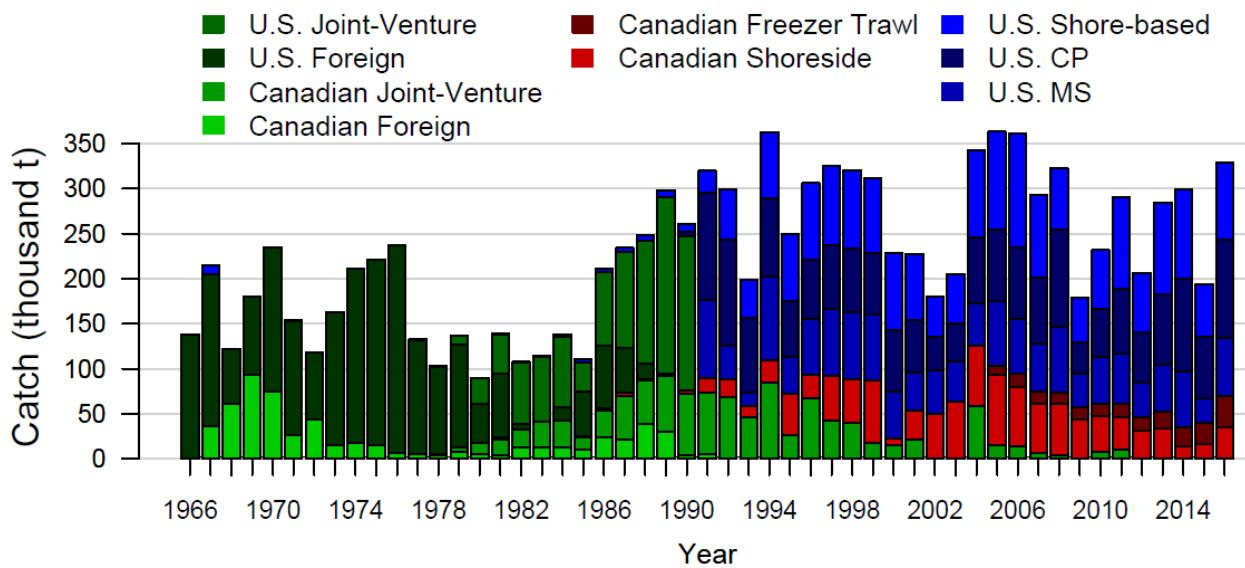


Figure 13: Catch history for Pacific Hake by sector. Data used in the CPUE analysis are from the “U.S. Joint-Venture” and “U.S. Foreign sectors” through 1990 and from the <sup>fig:ASHOP\_X2</sup> Catcher-Processor (“U.S. CP”) and Mothership (“U.S. MS”) sectors from 1990 onward.

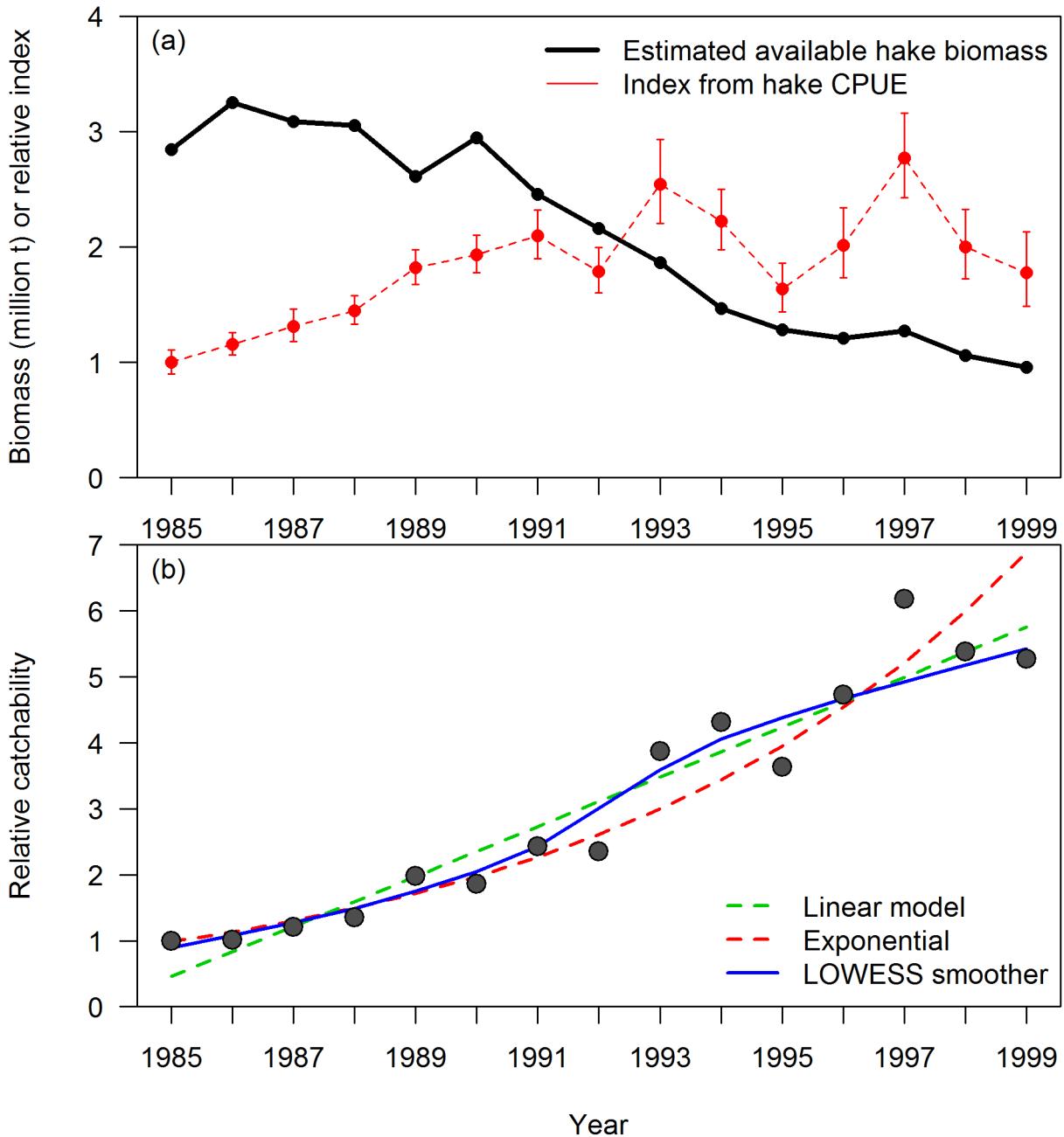


Figure 14: Geostatistical index for Pacific Hake developed using VAST compared to the estimated available hake biomass.  
fig:ASHOP\_X3

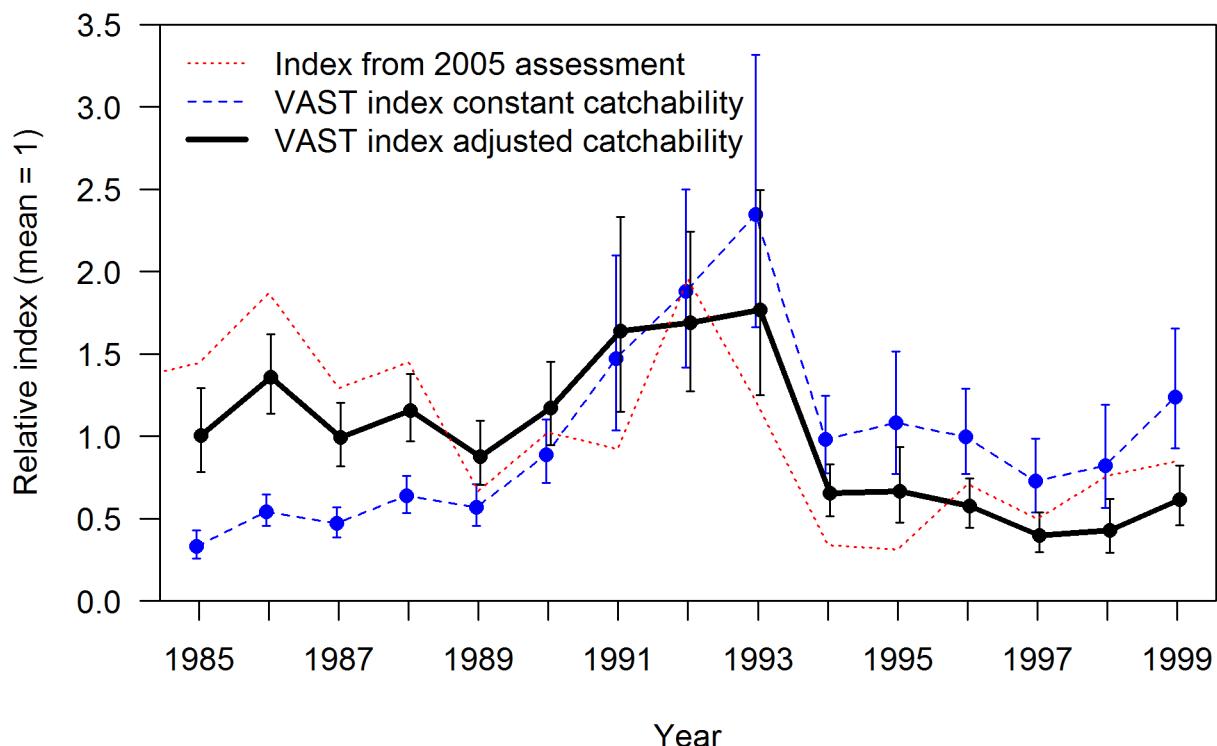


Figure 15: Index from the geostatistical model VAST with constant catchability and adjusted for the estimated increase in catchability (previous figure). These are compared to the index from the most recent yellowtail assessment (Wallace and Lai, 2005).  
fig:ASHP\_X4

1144 9.2.3 Fits to indices of abundance for Northern model  
fits-to-indices-of-abundance-for-northern-model

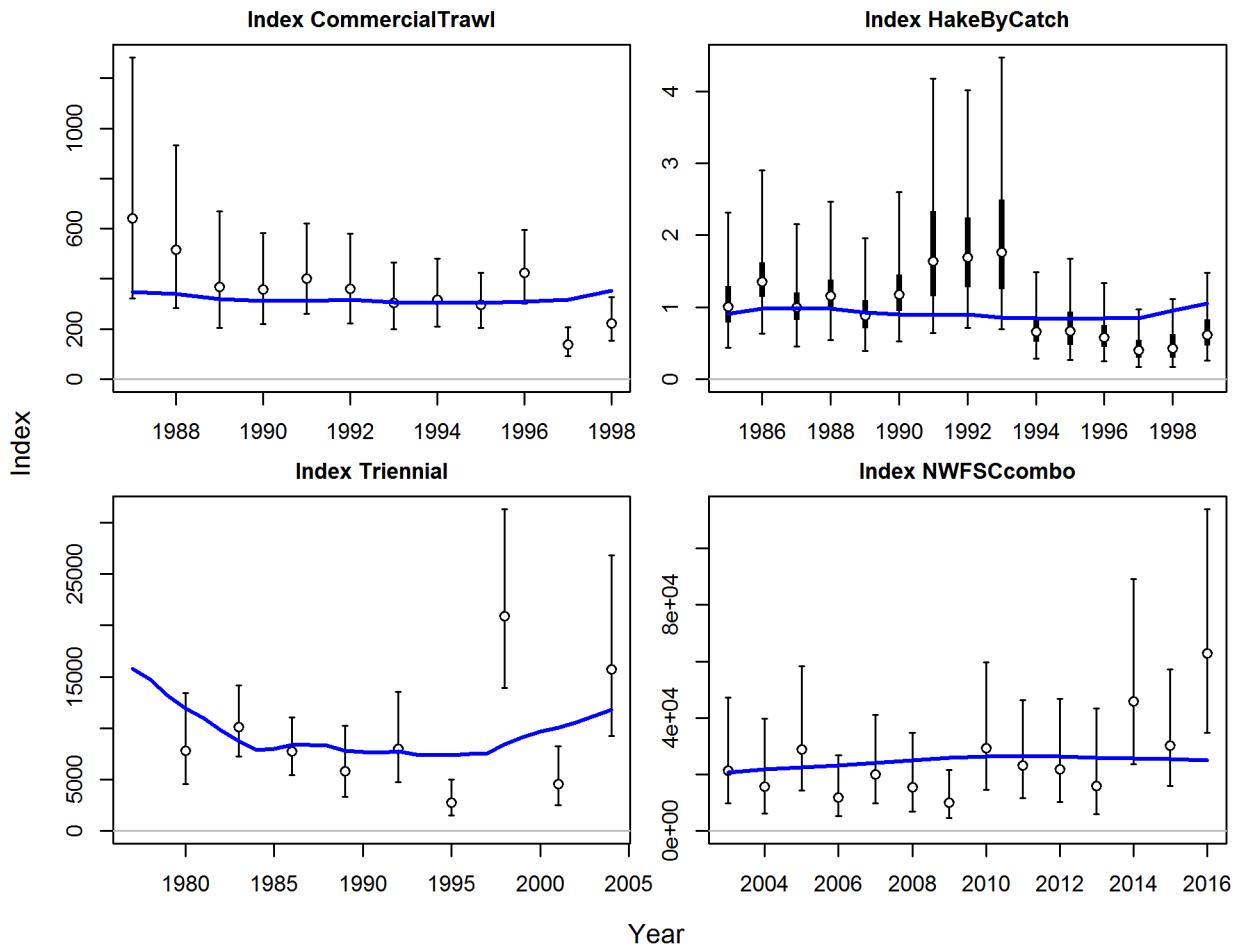


Figure 16: Estimated fits to the CPUE and survey indices for the Northern model. fig:index\_fits1

<sup>1145</sup> **9.2.4 Length compositions for Northern model**  
[length-compositions-for-northern-model](#)

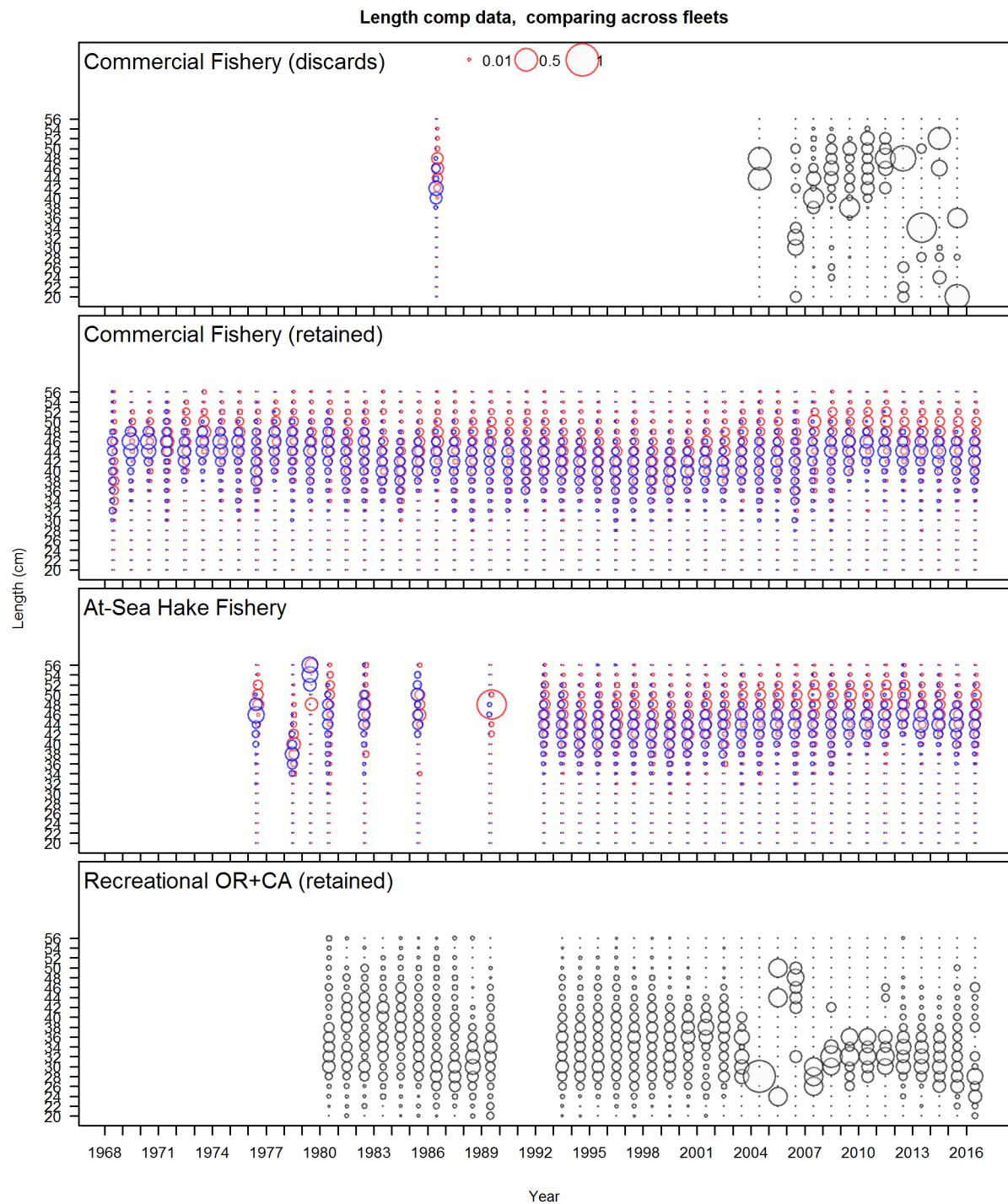


Figure 17: Length compositions for all fleets in the Northern model (figure 1 of 2). Bubble size is proportional to proportions within each year. Bubble colors indicate unsexed fish (gray), females (red), and males (blue).  
fig:comp\_length\_bubble\_mod1\_page1

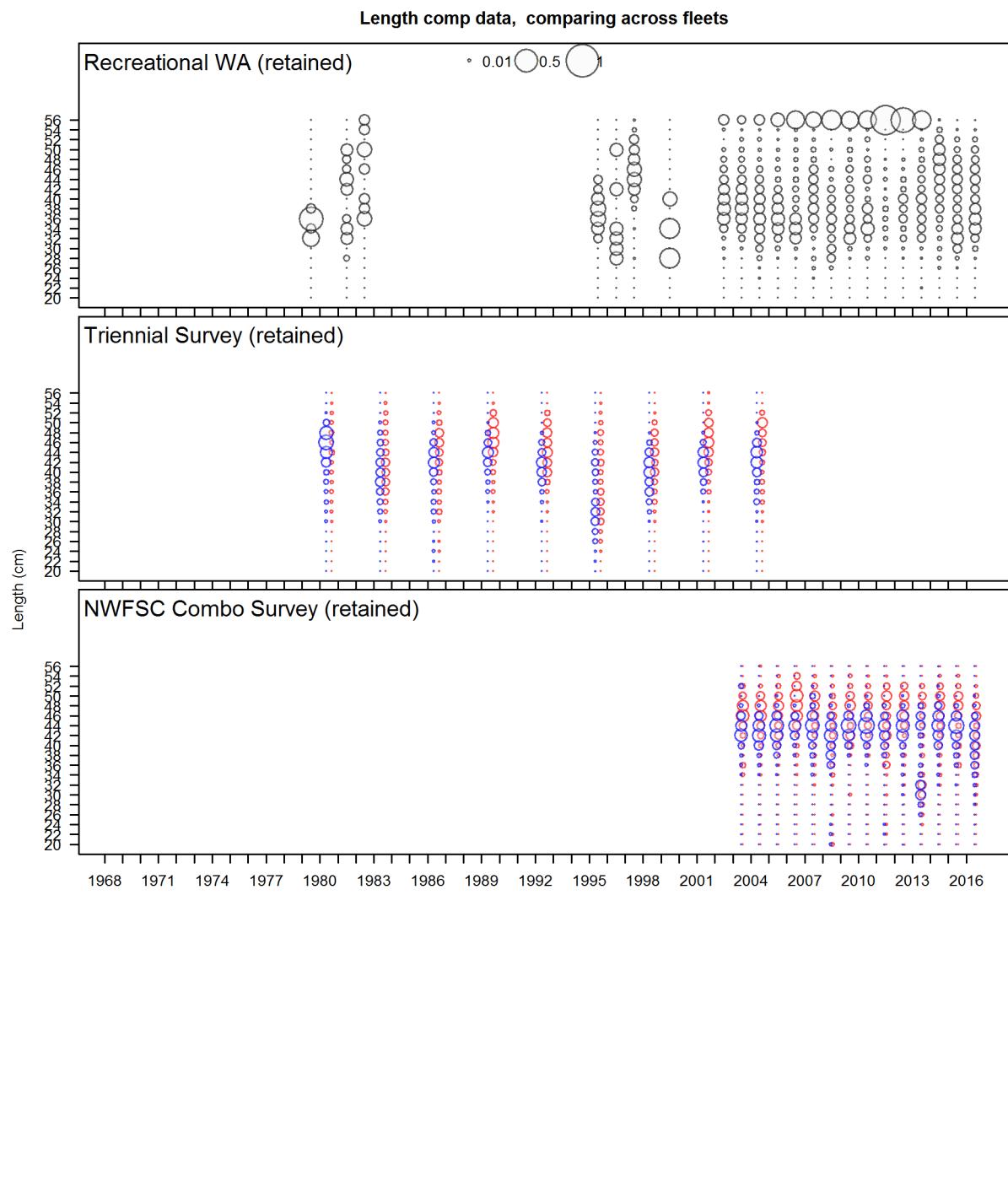


Figure 18: Length compositions for all fleets in the Northern model (figure 2 of 2). `fig:comp_length`

### Length comps, retained, Commercial Fishery

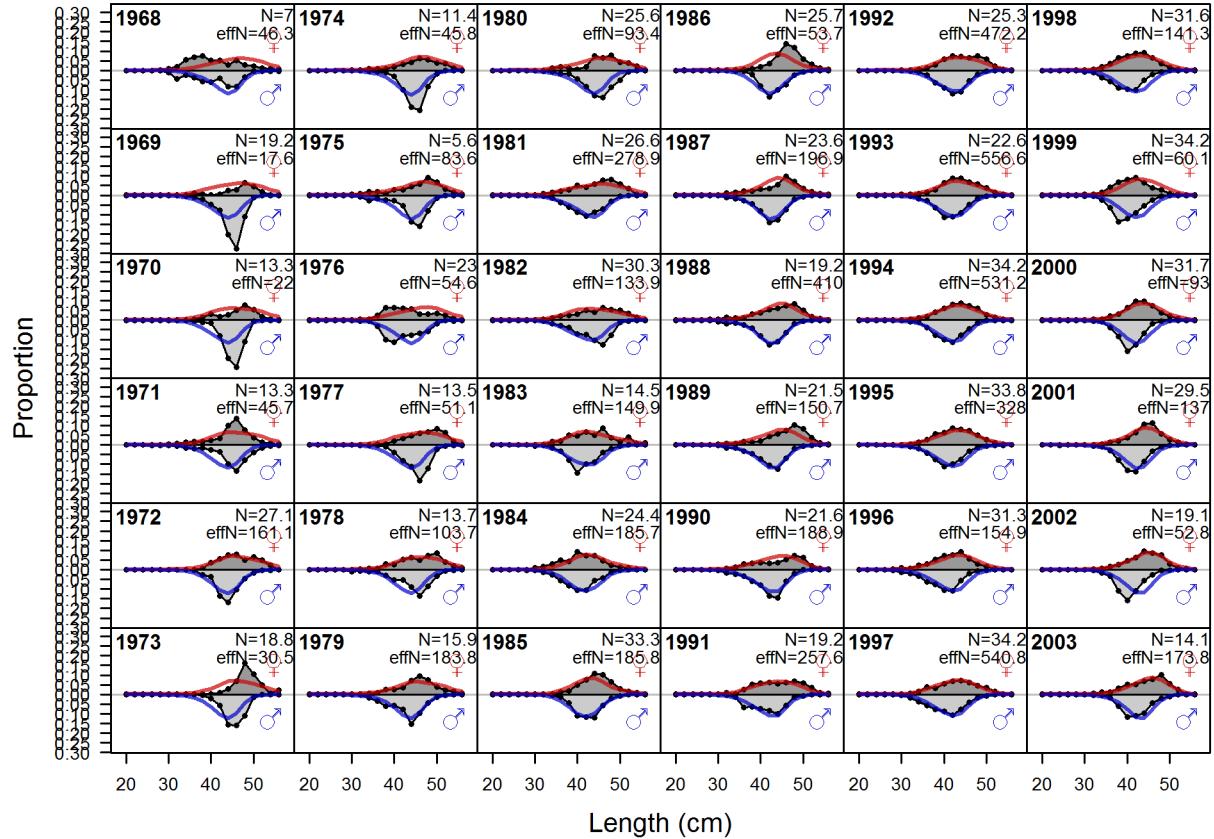
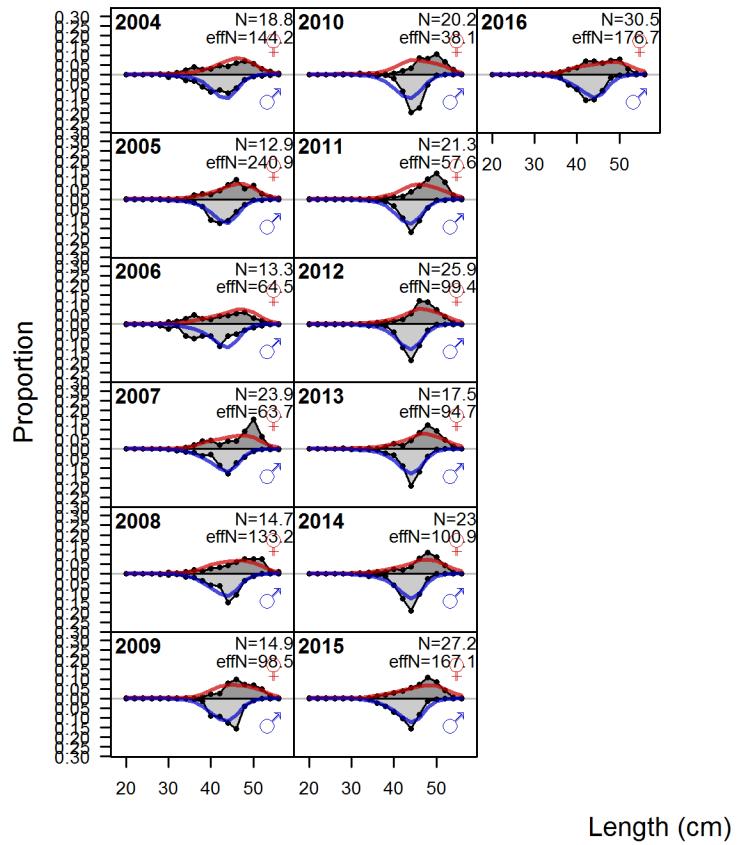


Figure 19: **Northern model** Length comps, retained, Commercial Fishery (plot 1 of 2) `fig:mod1_1_com`

### Length comps, retained, Commercial Fishery



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Figure continued from previous page

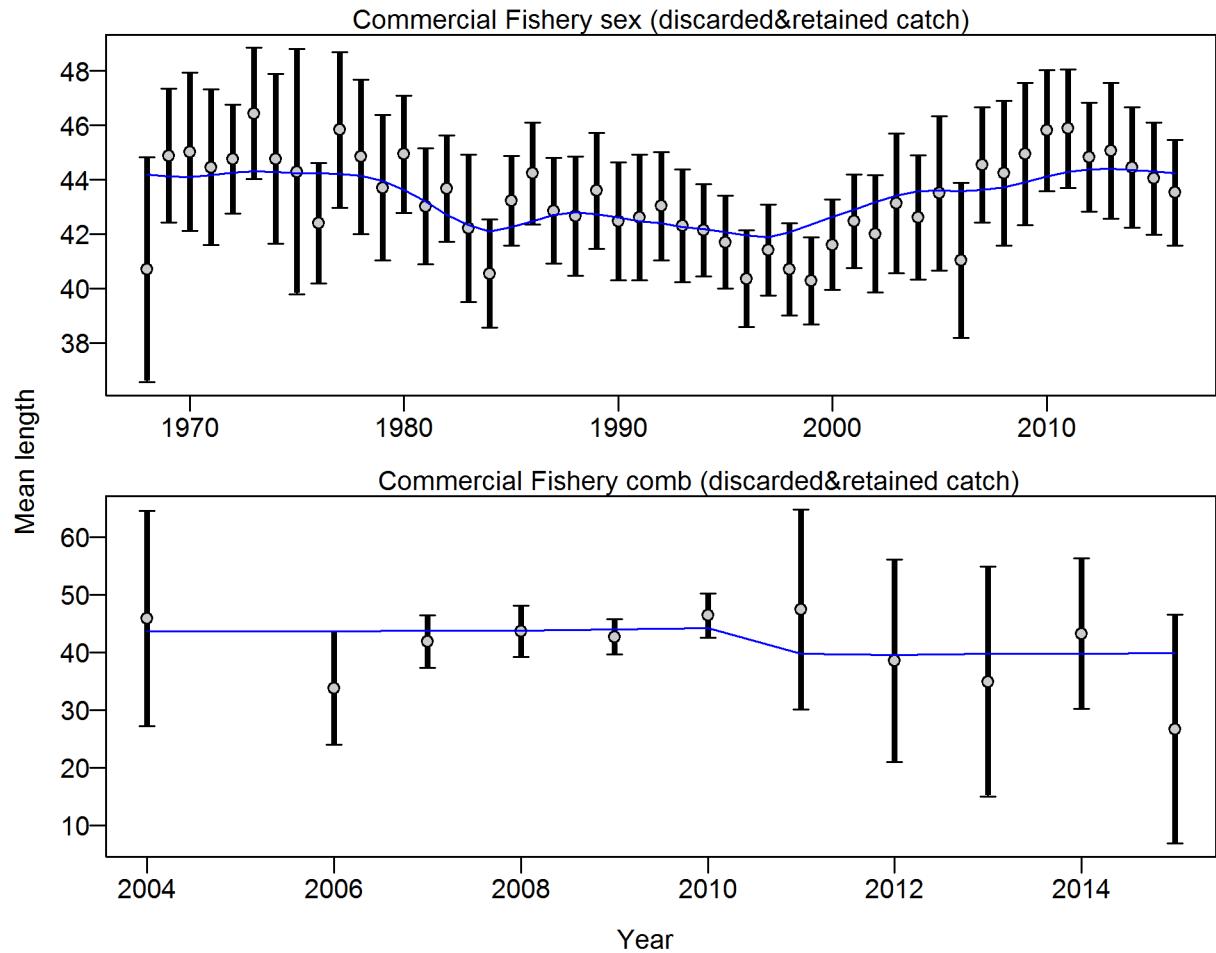


Figure 20: **Northern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

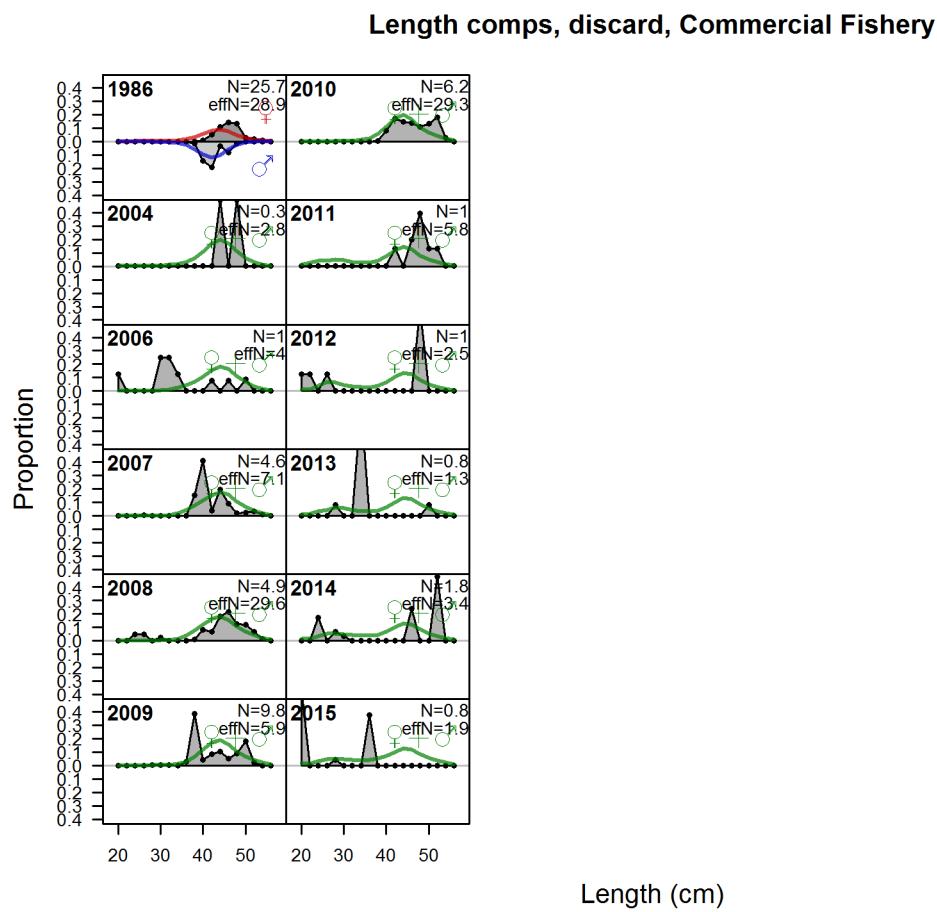


Figure 21: Northern model Length comps, discard, Commercial Fishery fig:mod1\_6\_comp\_lenf

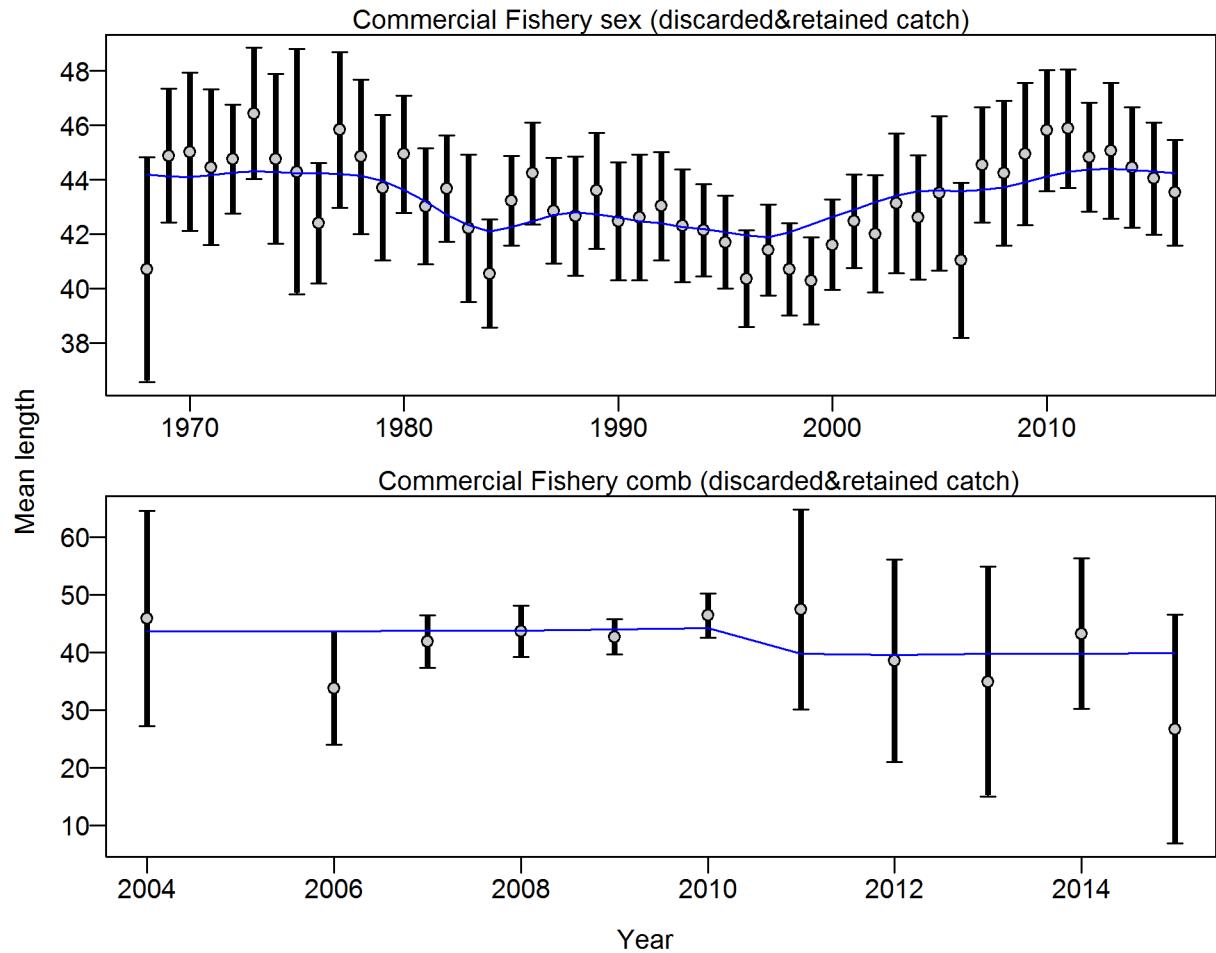


Figure 22: **Northern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

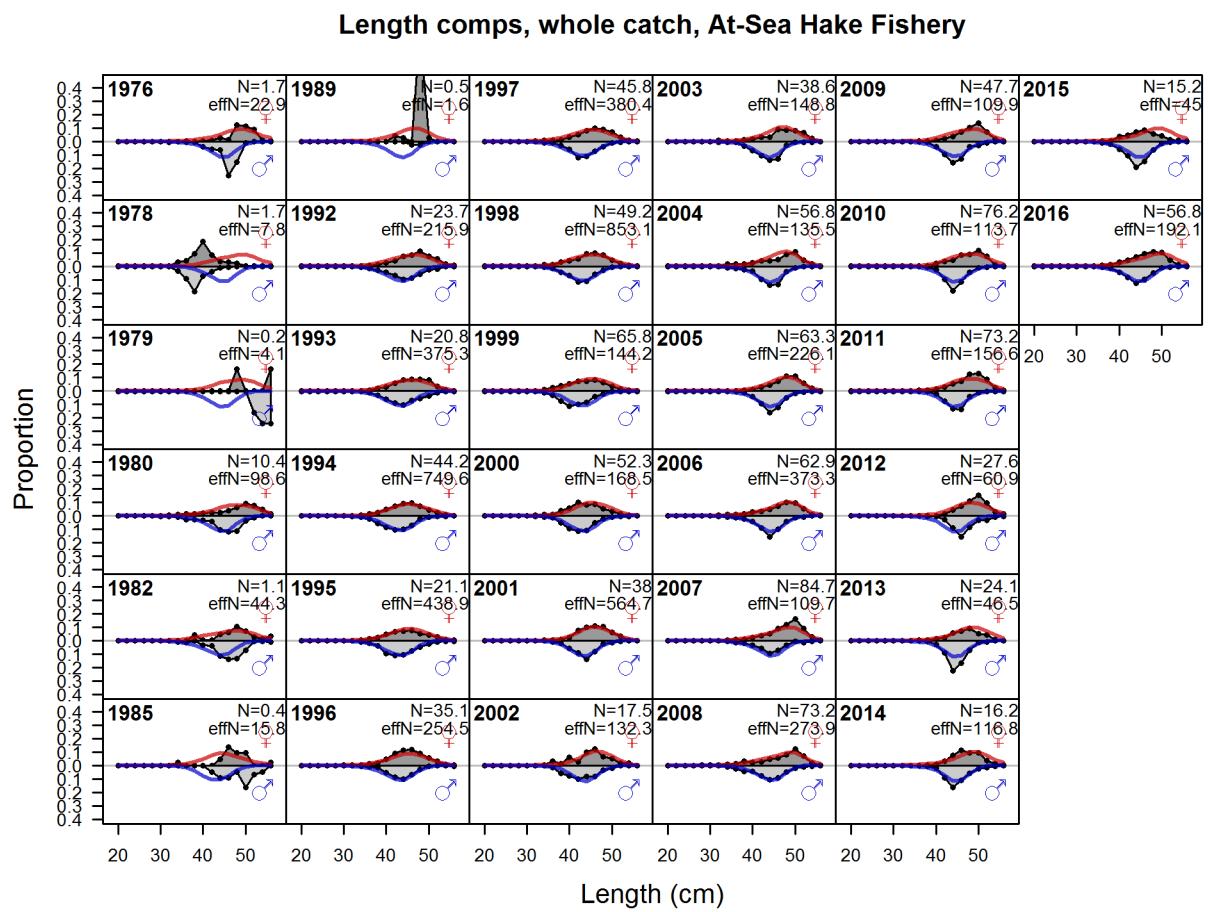


Figure 23: Northern model Length comps, whole catch, At-Sea Hake Fishery fig:mod1\_10\_comp\_1

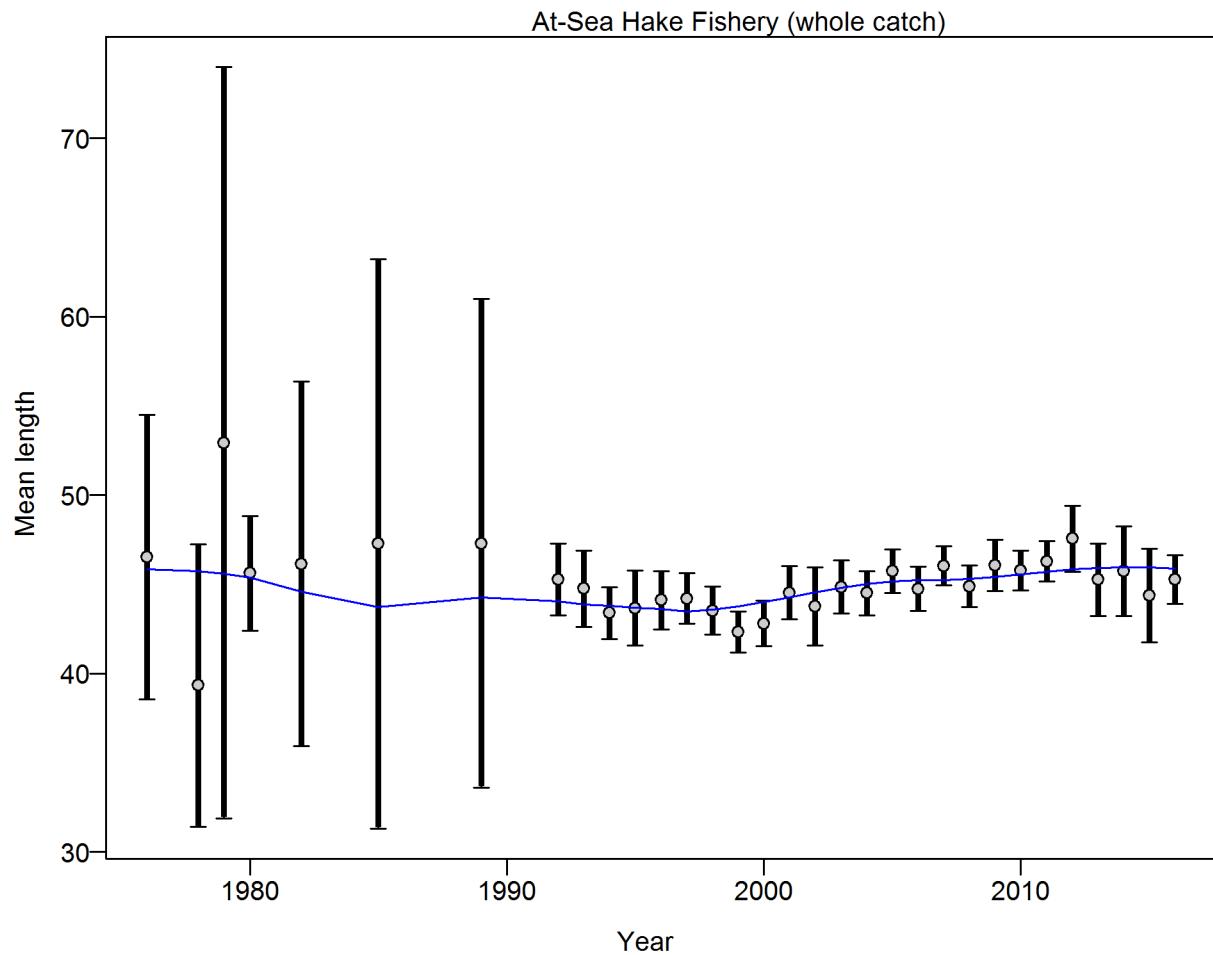


Figure 24: **Northern model** Mean length for At-Sea Hake Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

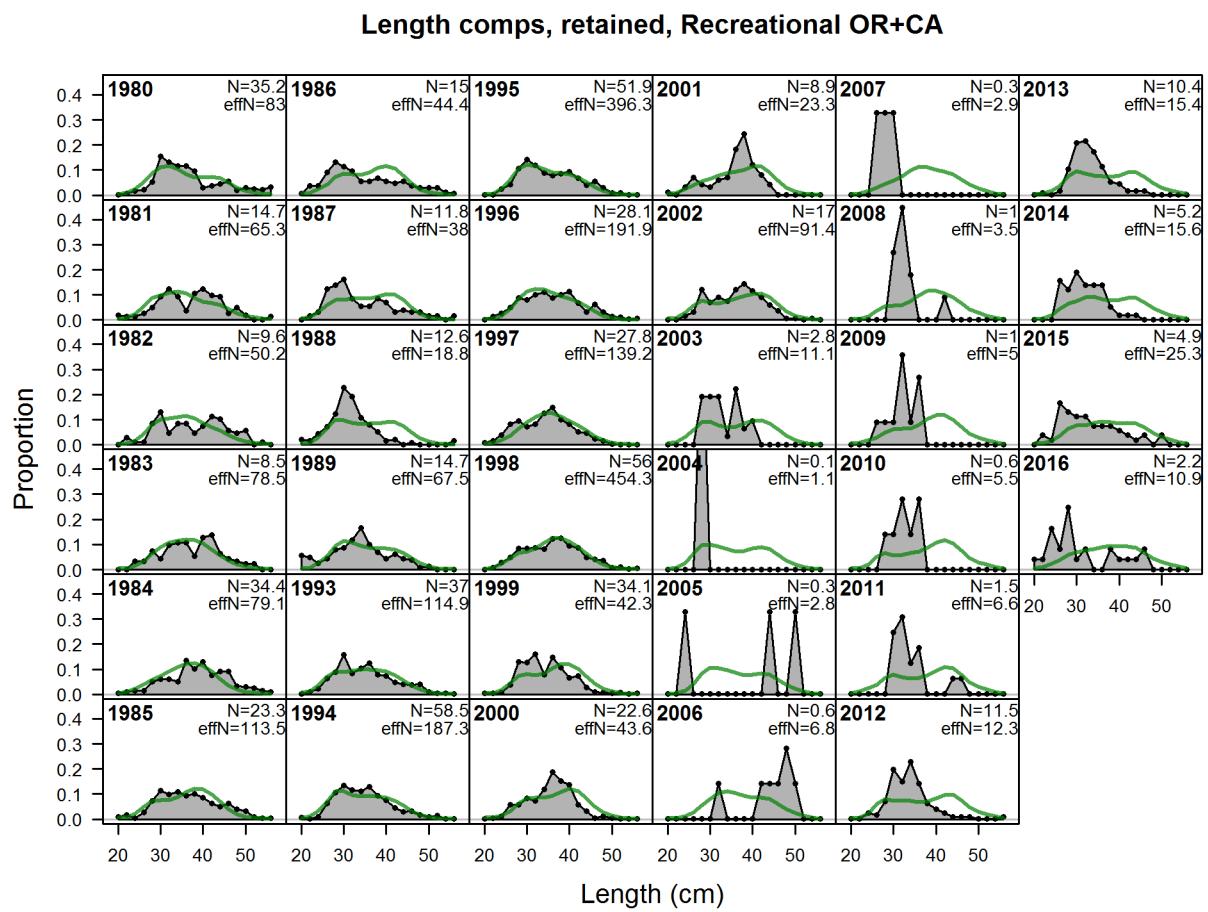


Figure 25: Northern model Length comps, retained, Recreational OR+CA fig:mod1\_14\_comp\_le

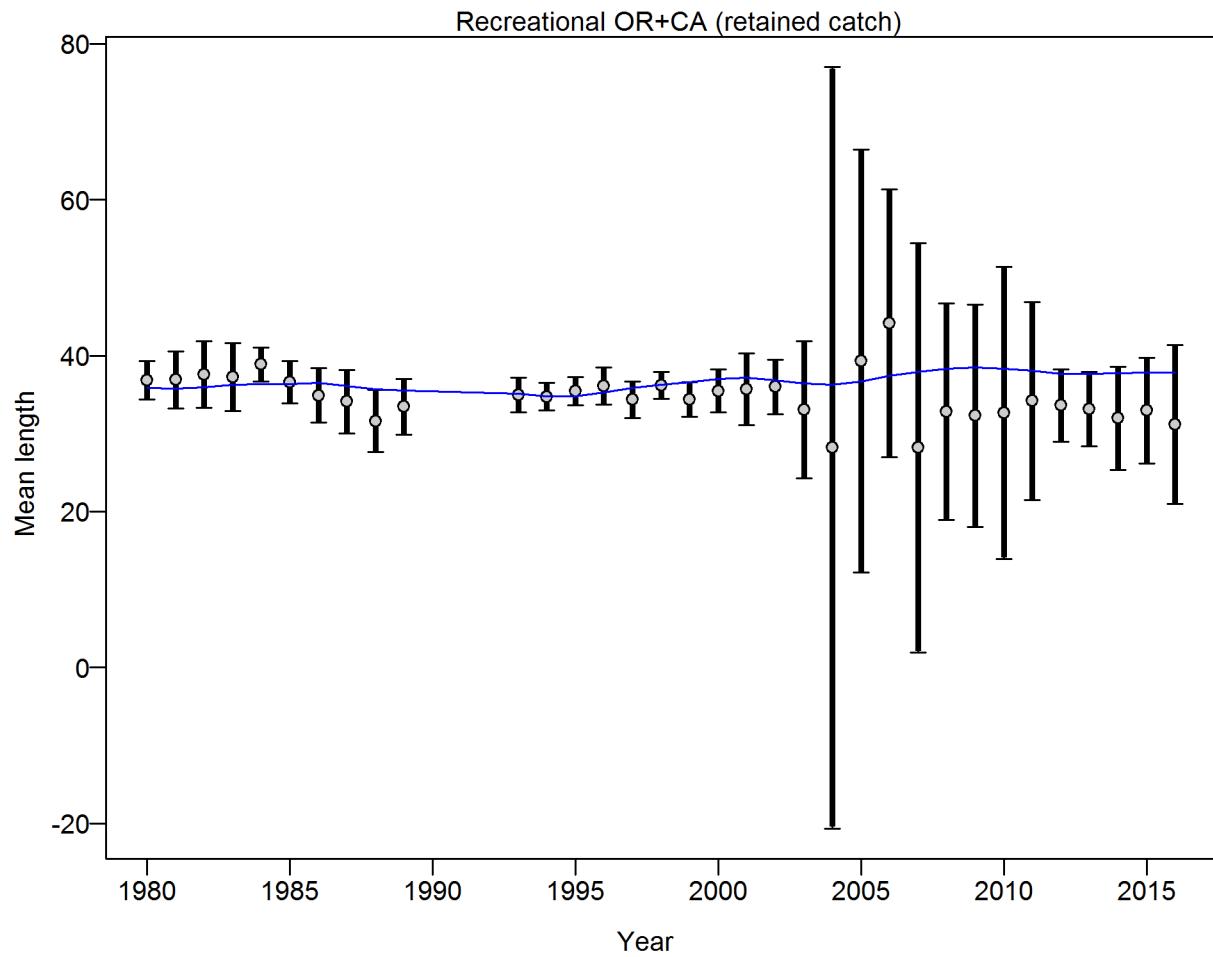


Figure 26: **Northern model** Mean length for Recreational OR+CA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

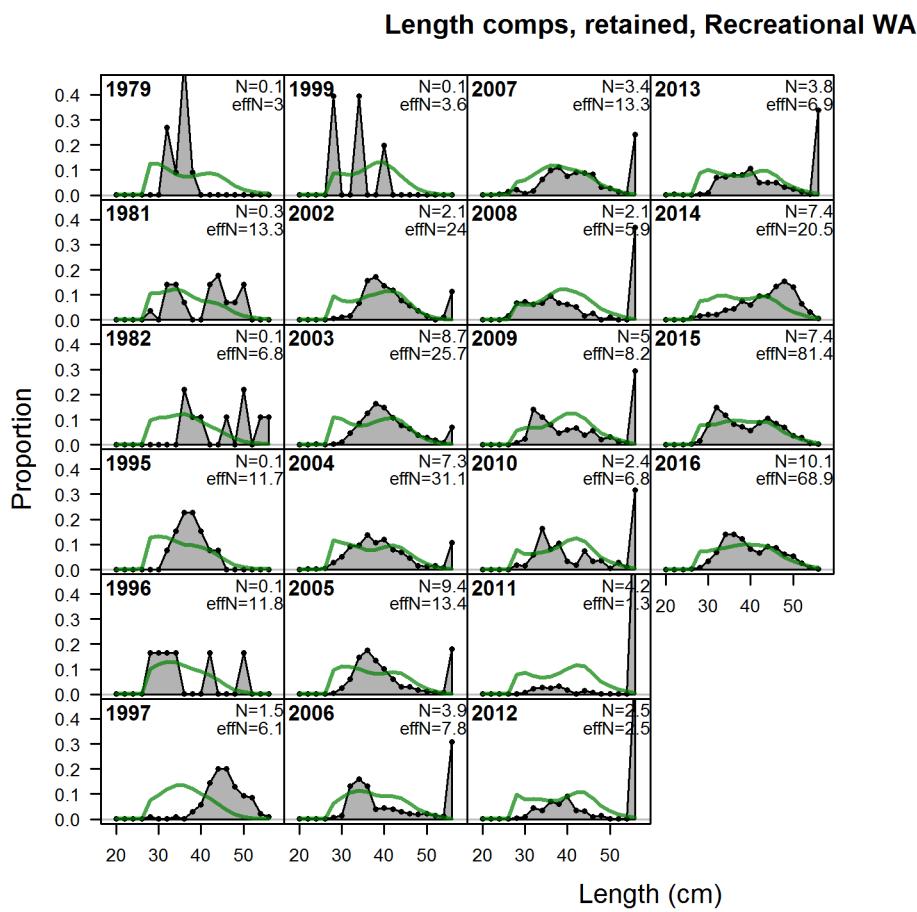


Figure 27: Northern model Length comps, retained, Recreational WA fig:mod1\_18\_comp\_lenf

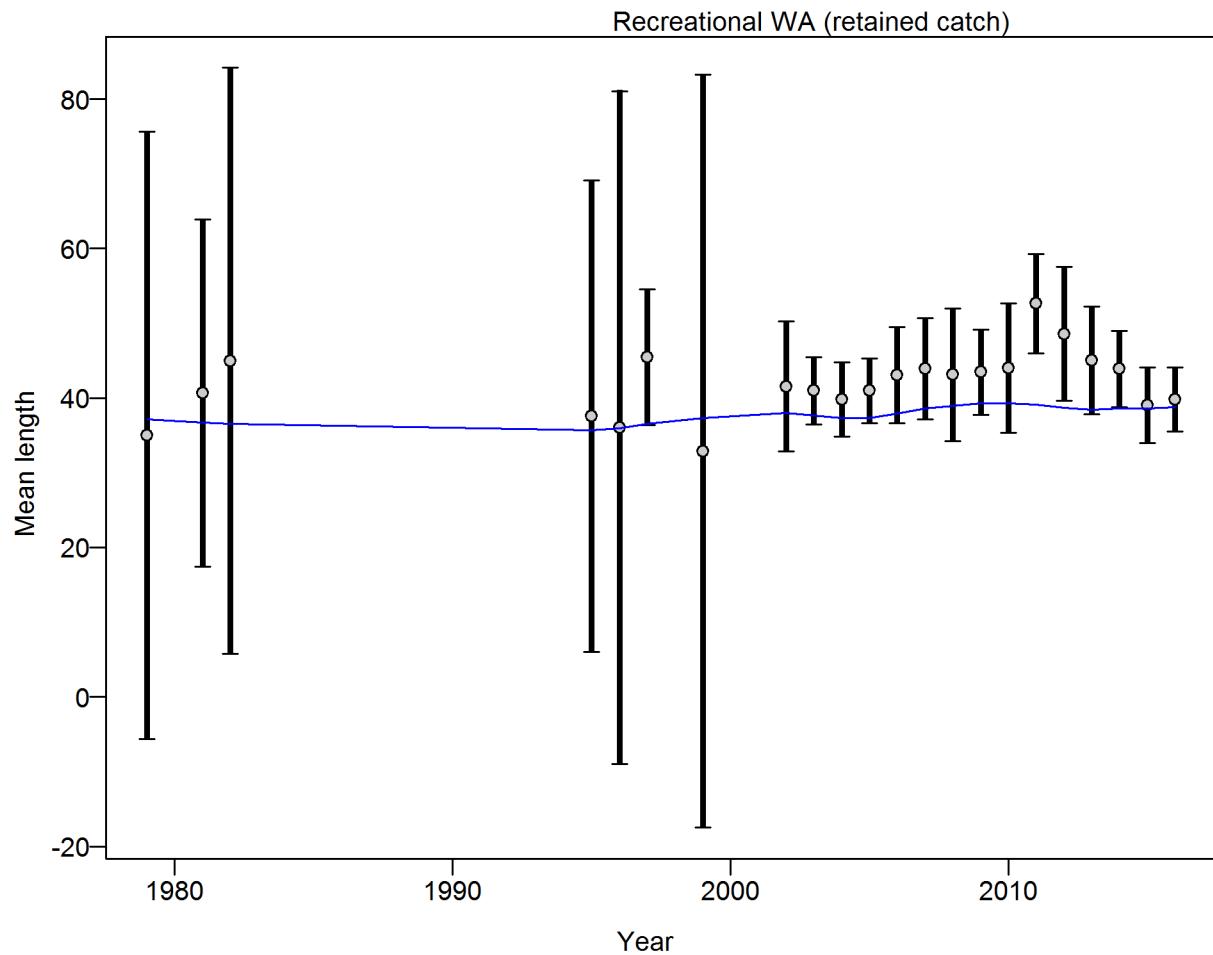


Figure 28: **Northern model** Mean length for Recreational WA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len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

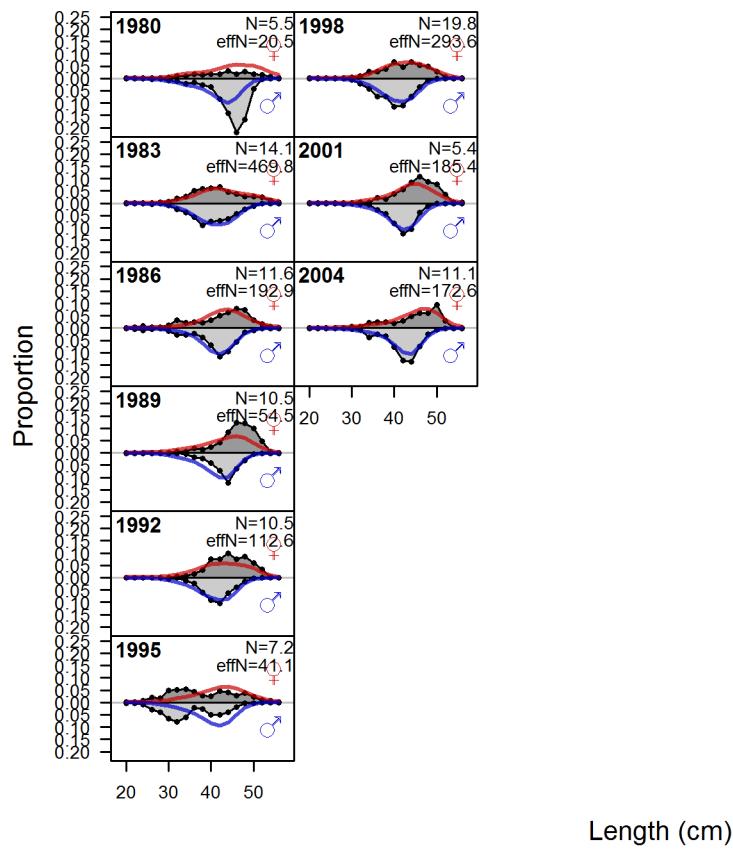


Figure 29: **Northern model** Length comps, retained, Triennial Survey fig:mod1\_22\_comp\_lenf

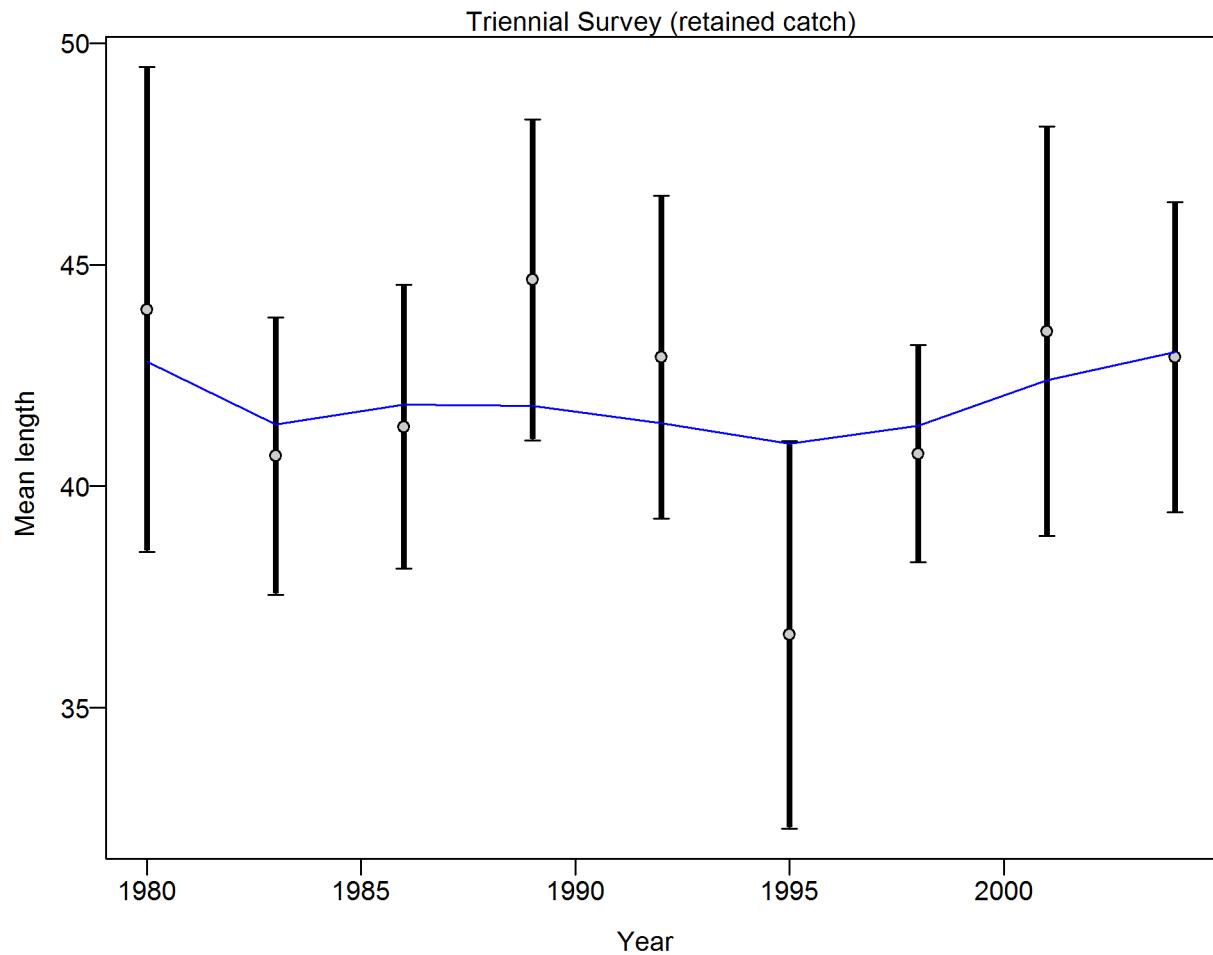


Figure 30: **Northern model** Mean length for Triennial Survey with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for len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

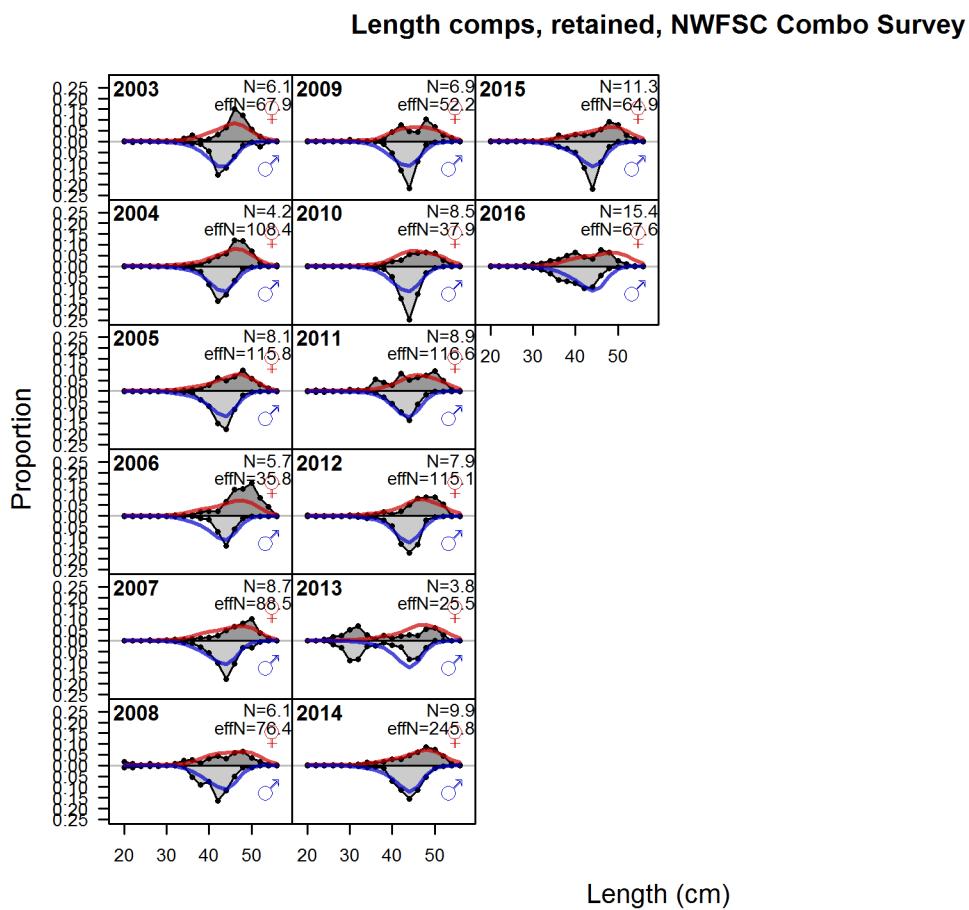


Figure 31: Northern model Length comps, retained, NWFSC Combo Survey | [fig:mod1\\_26\\_comp\\_1](#)

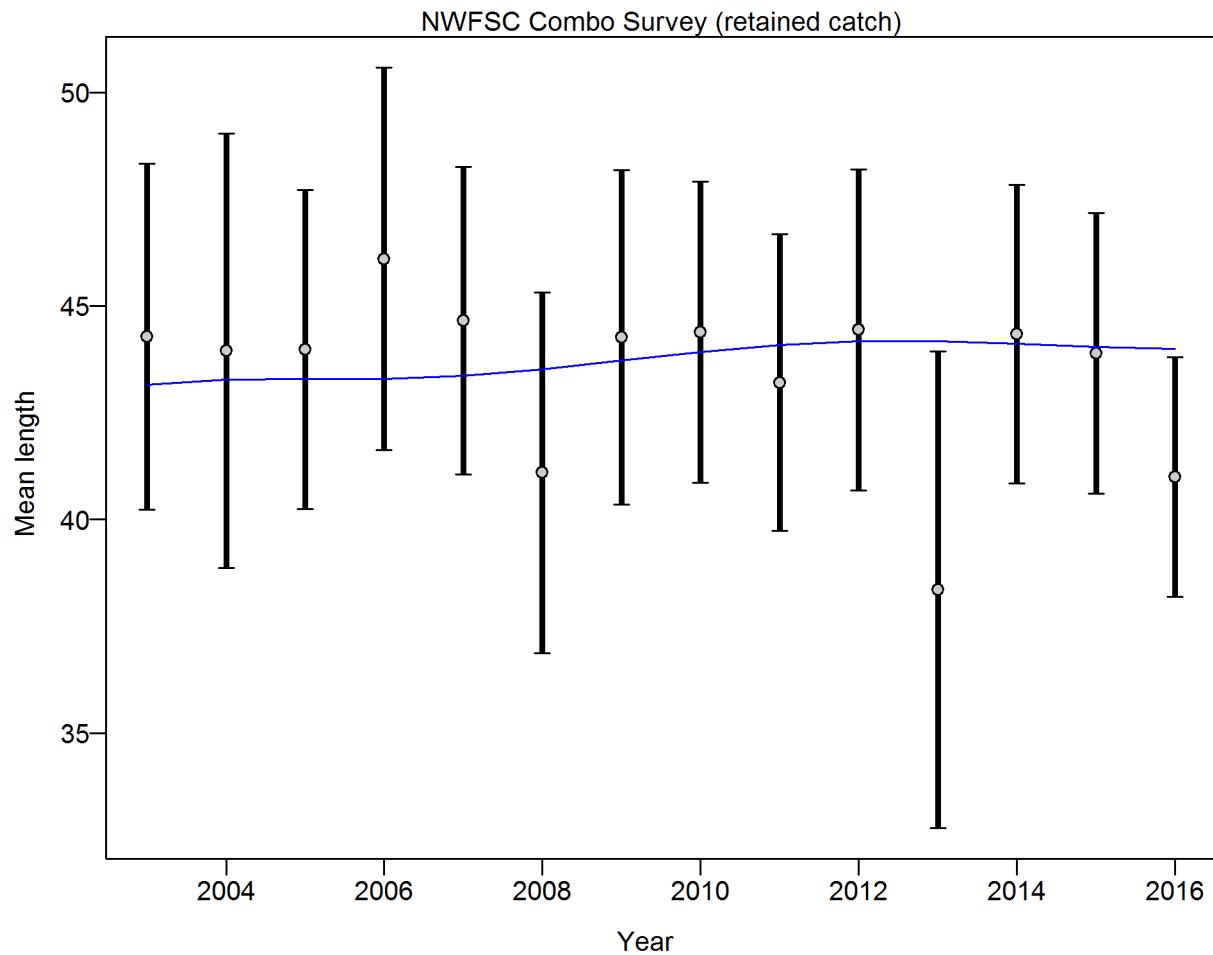


Figure 32: **Northern model** Mean length for NWFSC Combo Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for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

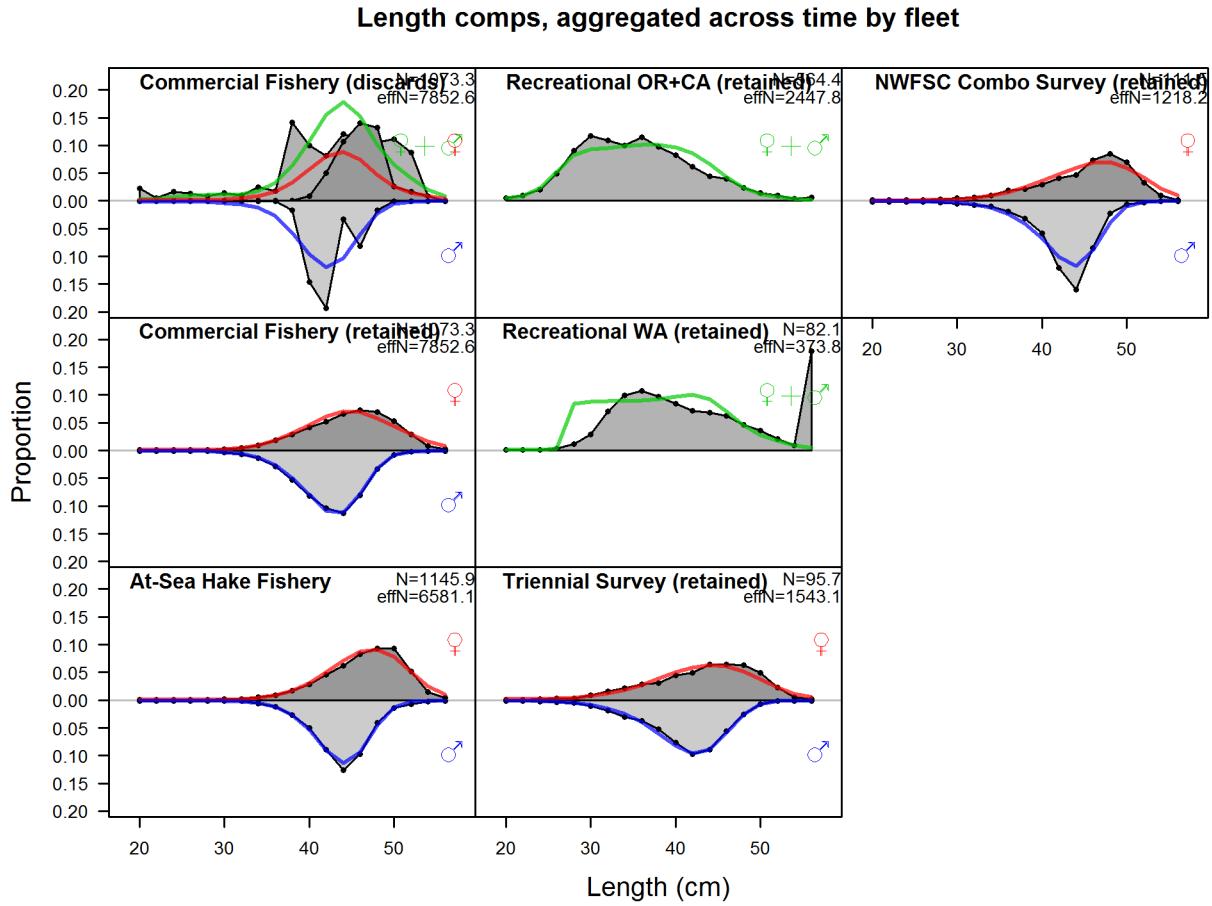


Figure 33: **Northern model** Length comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch.

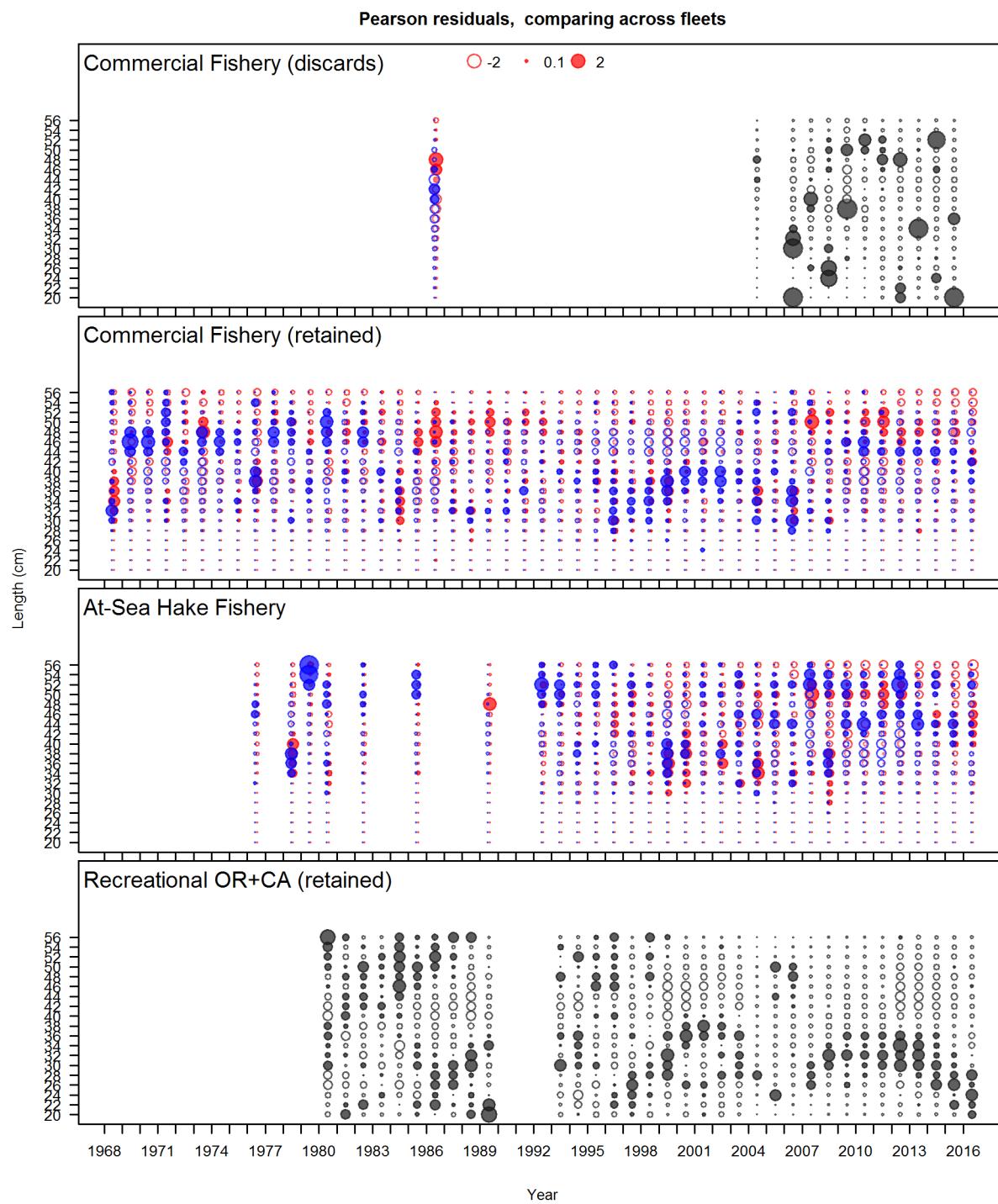


Figure 34: Length composition Pearson residuals for all fleets in the Northern model (Figure 1 of 2). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble colors indicate unsexed fish (gray), females (red), and males (blue).  
fig:comp\_Pearson\_length\_mod1\_page1

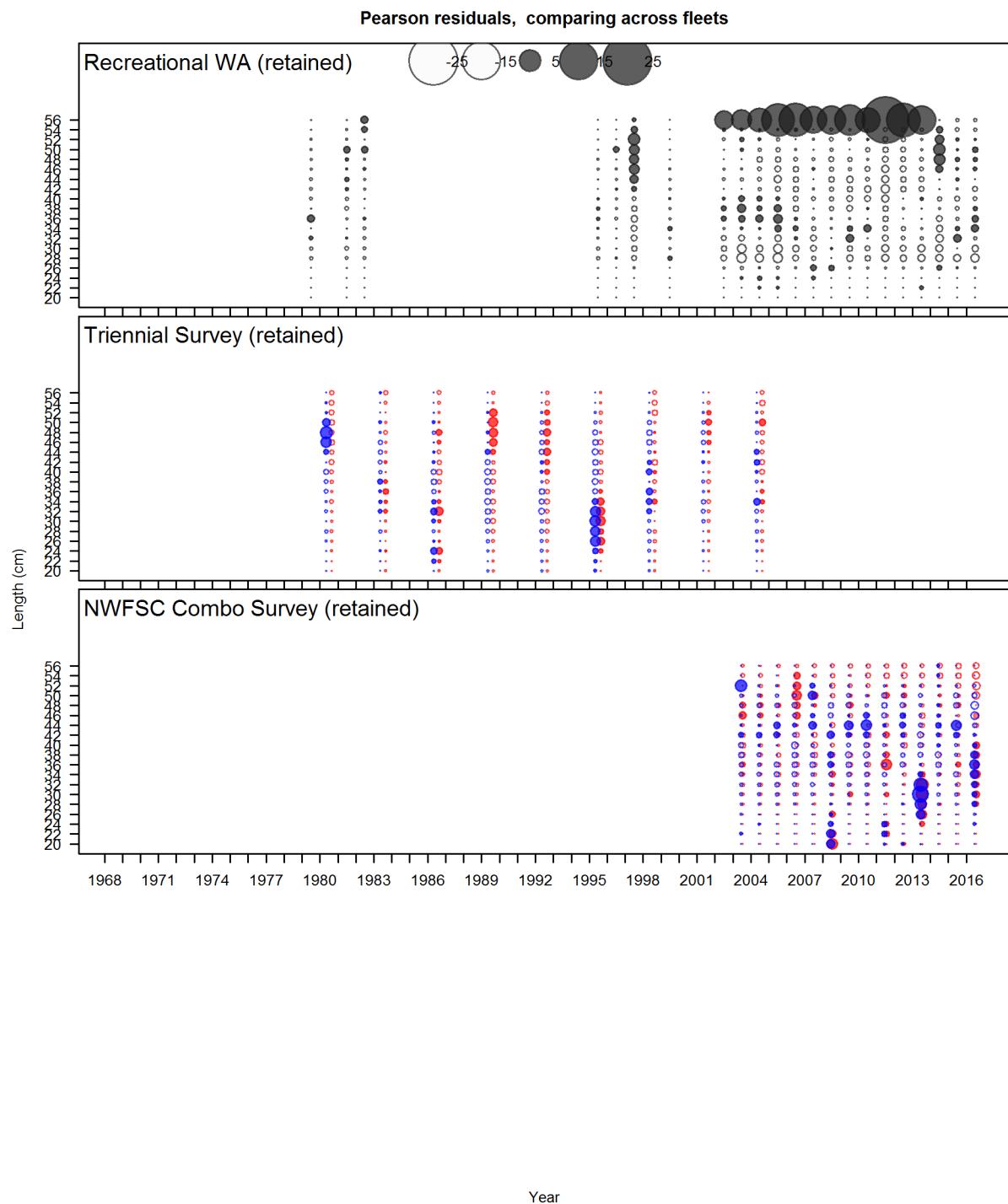


Figure 35: Length composition Pearson residuals for all fleets in the Northern model (Figure 2 of 2).  
[fig:comp\\_Pearson\\_length\\_mod1\\_page2](#)

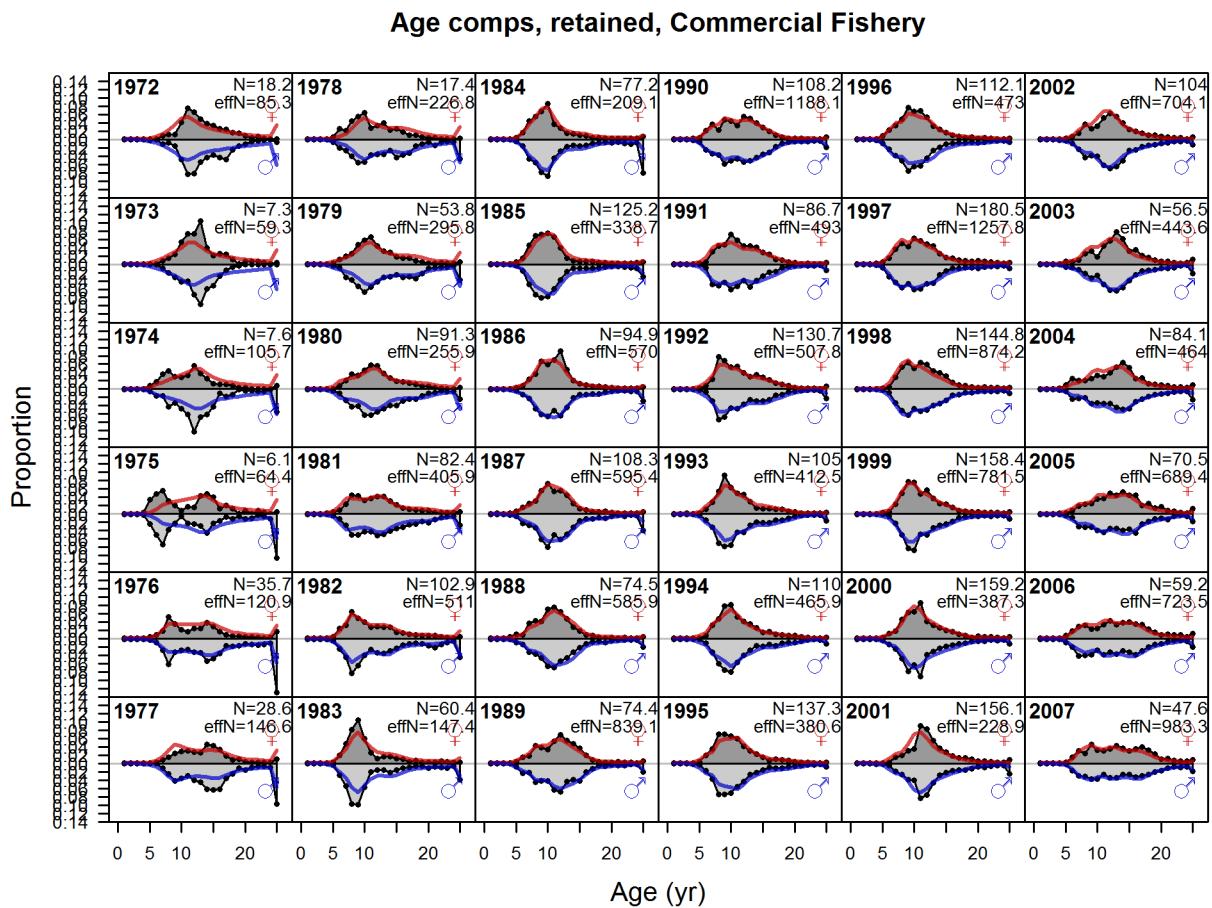
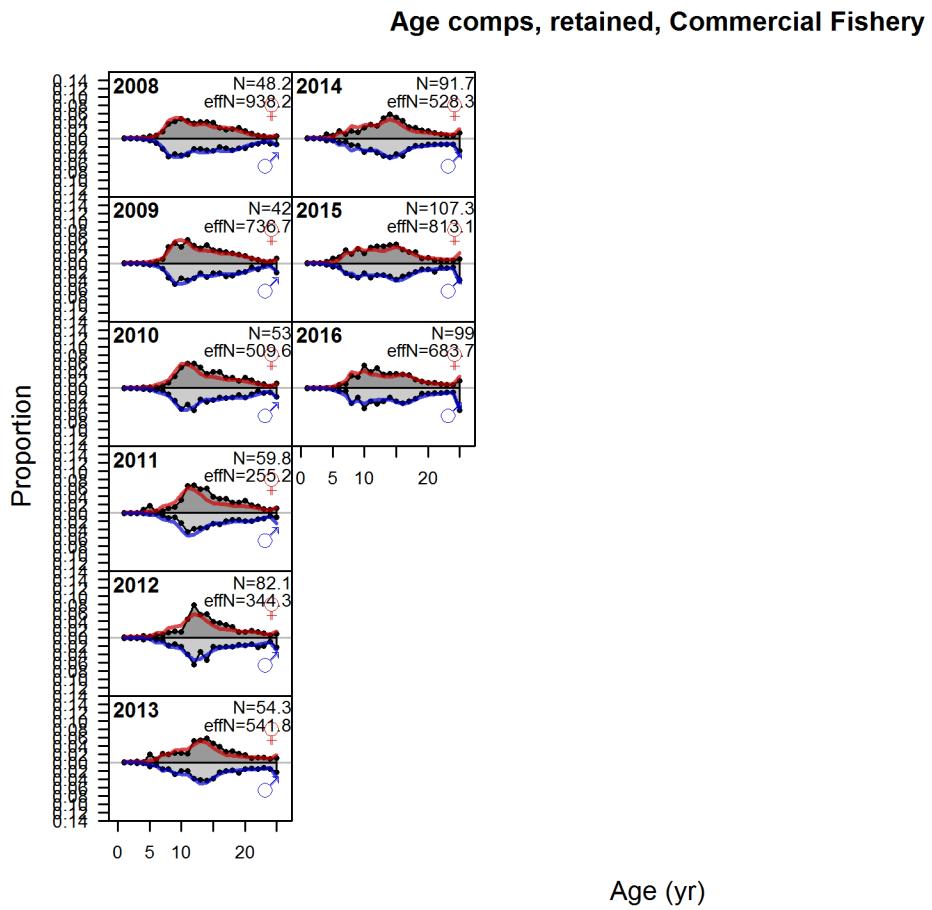


Figure 36: **Northern model** Age comps, retained, Commercial Fishery (plot 1 of 2) fig:mod1\_1\_comp

1148 9.2.5 Fits to age compositions for Northern model  
fits-to-age-compositions-for-northern-model



1149

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Figure continued from previous page

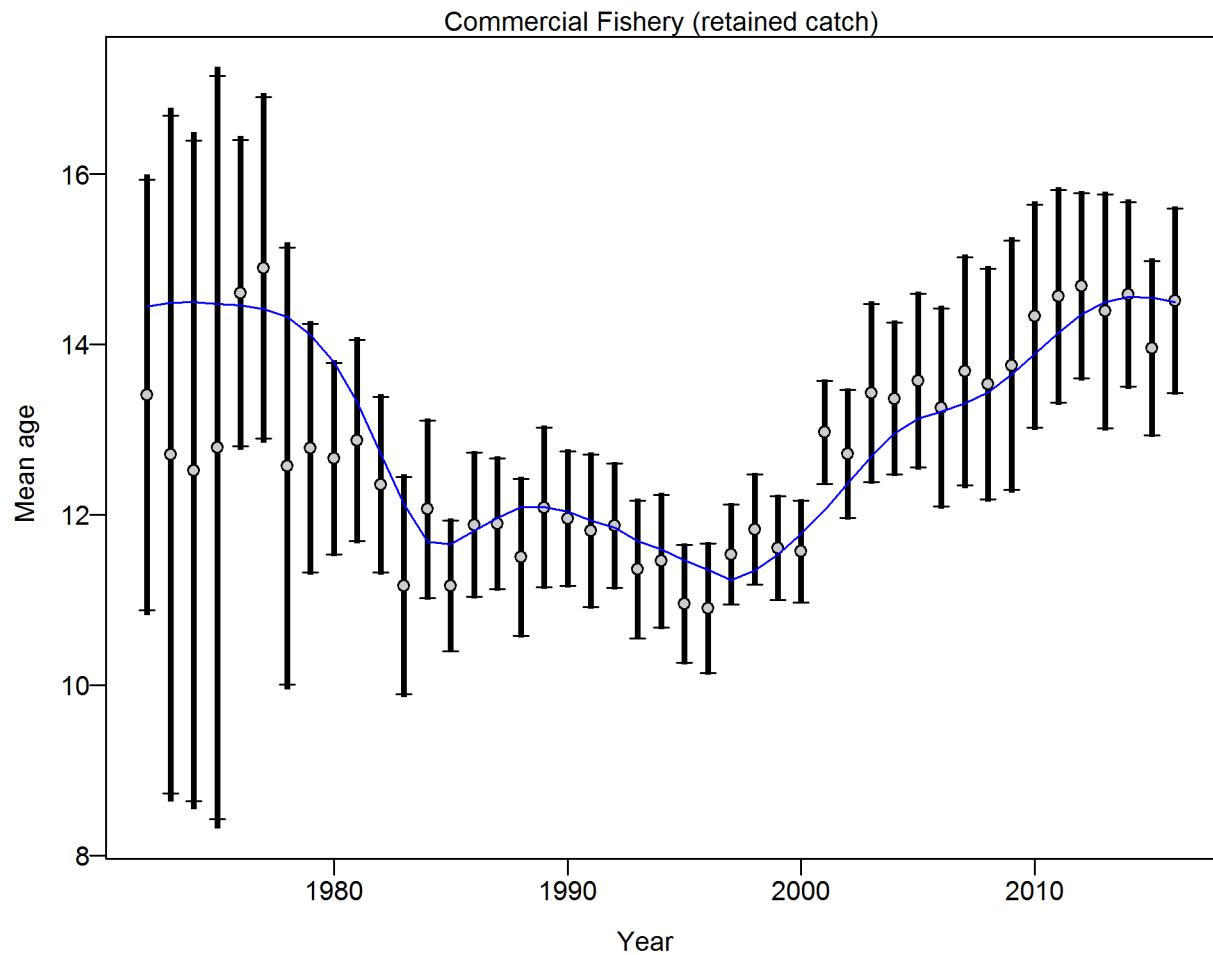


Figure 37: **Northern model** Mean age for Commercial Fishery with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age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

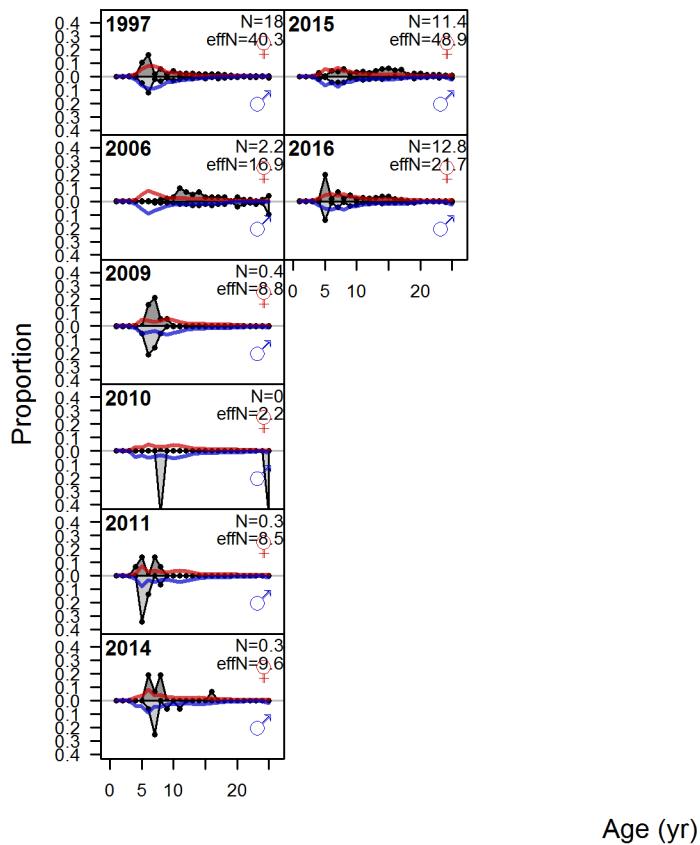


Figure 38: Northern model Age comps, retained, Recreational WA fig:mod1\_6\_comp\_agefit

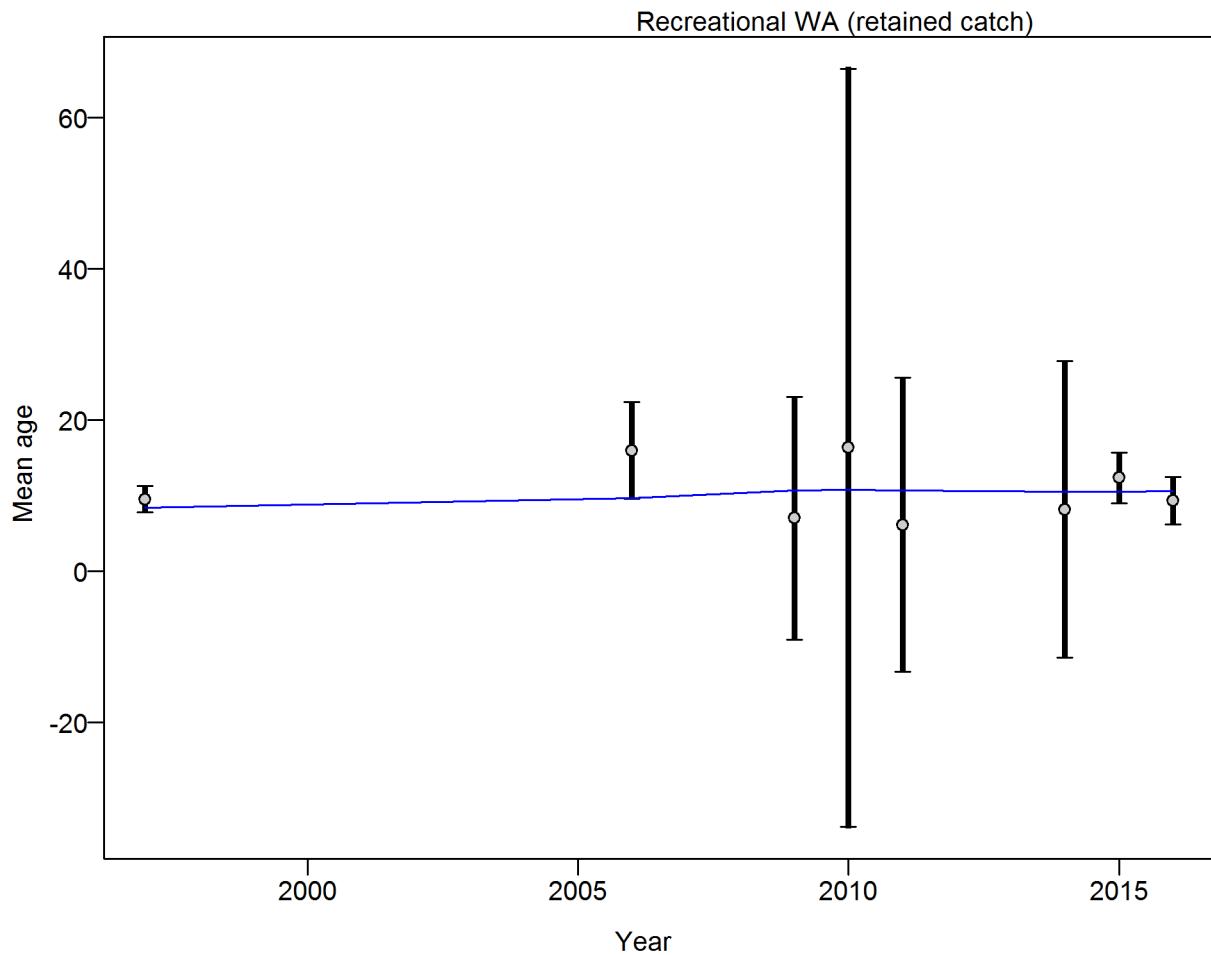


Figure 39: **Northern model** Mean age for Recreational WA with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data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

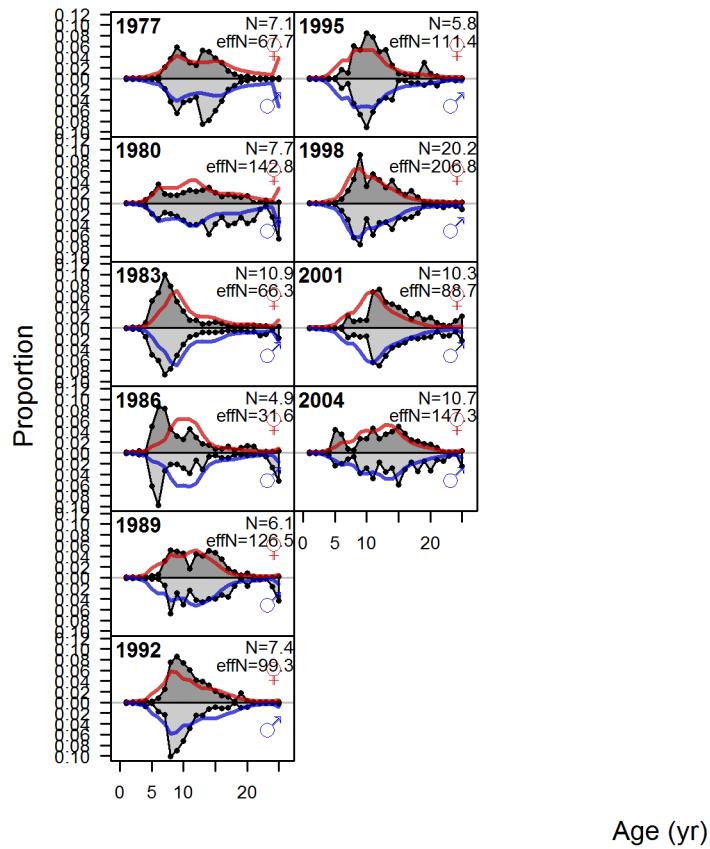


Figure 40: **Northern model** Age comps, retained, Triennial Survey `fig:mod1_10_comp_agefit`

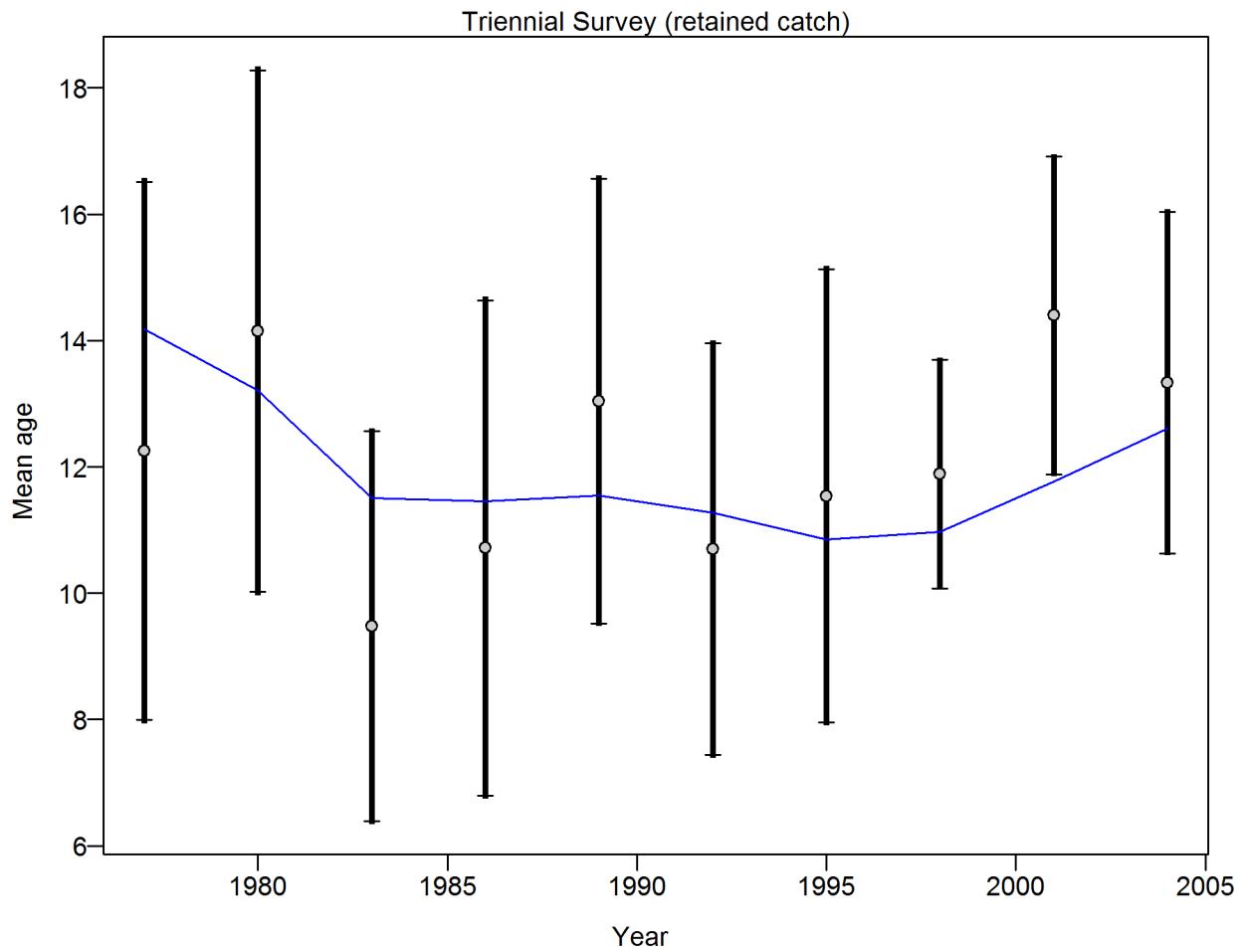


Figure 41: **Northern model** Mean age for Triennial Survey with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age data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

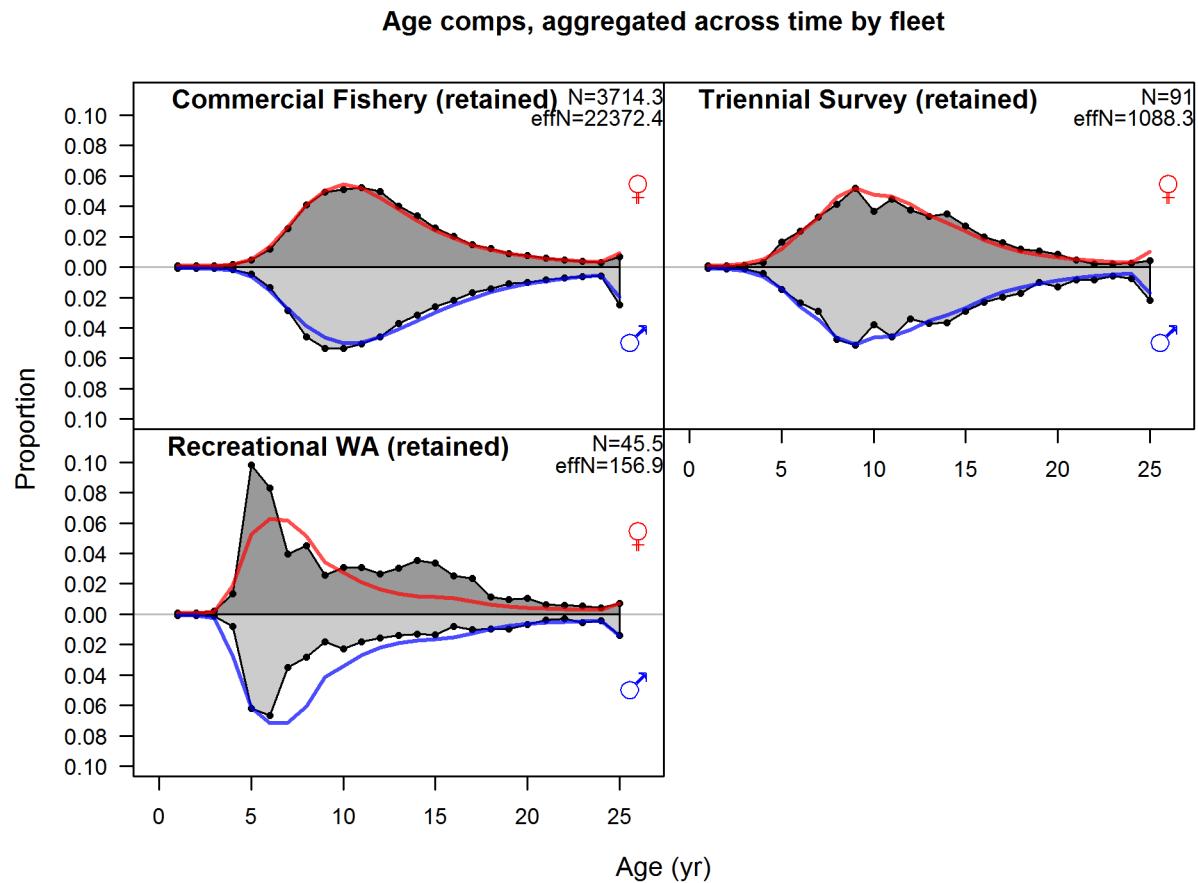


Figure 42: **Northern model** Age comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. [fig:mod1\\_14\\_comp\\_agefit\\_\\_aggregated\\_across\\_time](#)

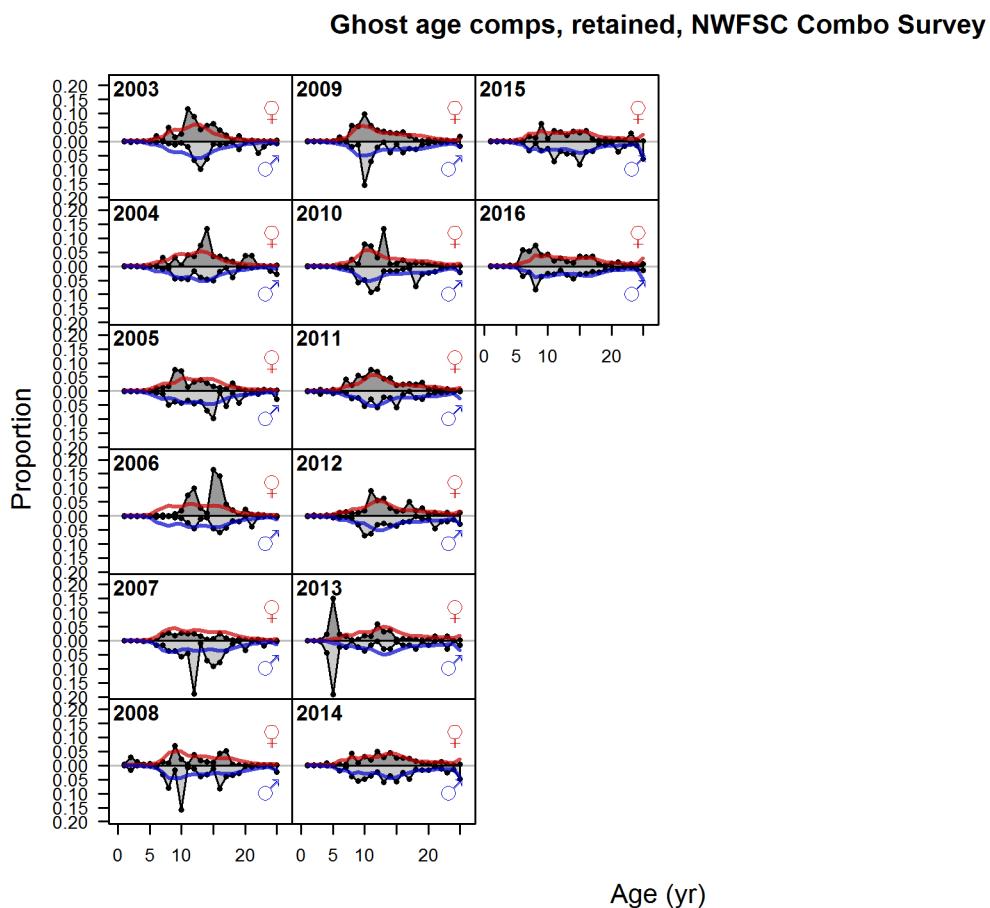


Figure 43: **Northern model** Ghost age comps, retained, NWFSC Combo Survey | [fig:mod1\\_16\\_comp](#)

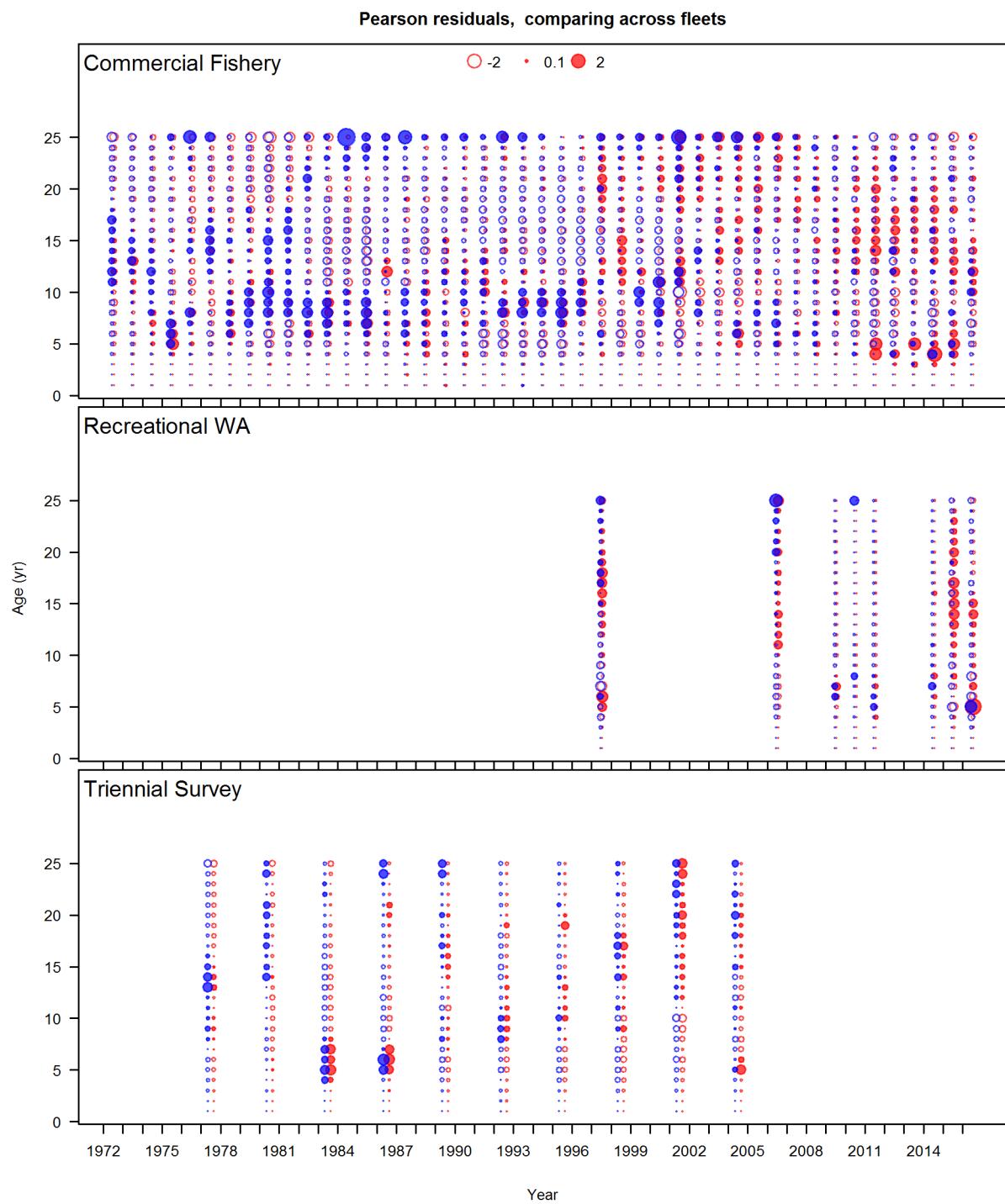


Figure 44: Age composition Pearson residuals for all fleets in the Northern model. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble colors indicate unsexed fish (gray), females (red), and males (blue).  
*fig:comp\_Pearson\_age\_mod1*

1151 9.2.6 Fits to conditional-age-at-length compositions for Northern model  
fits-to-conditional-age-at-length-compositions-for-northern-model

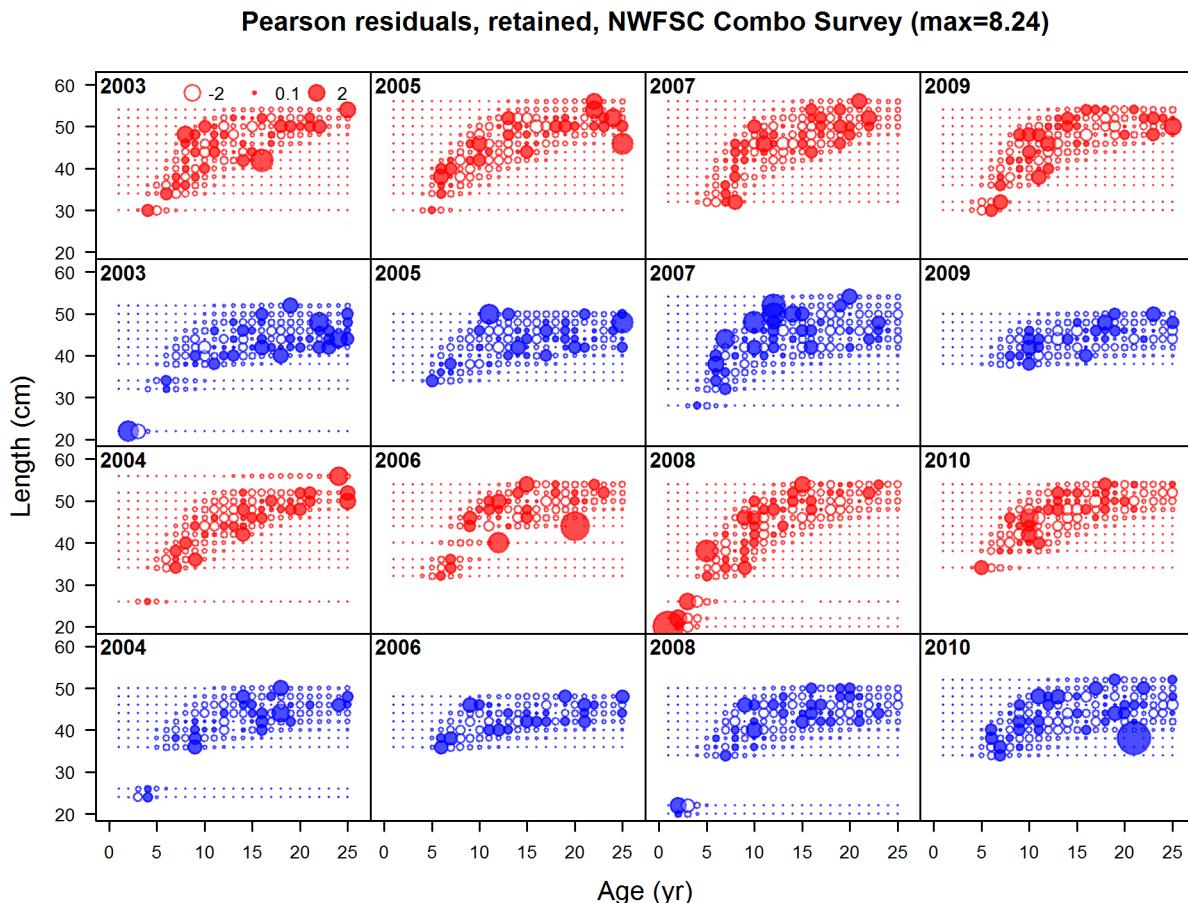
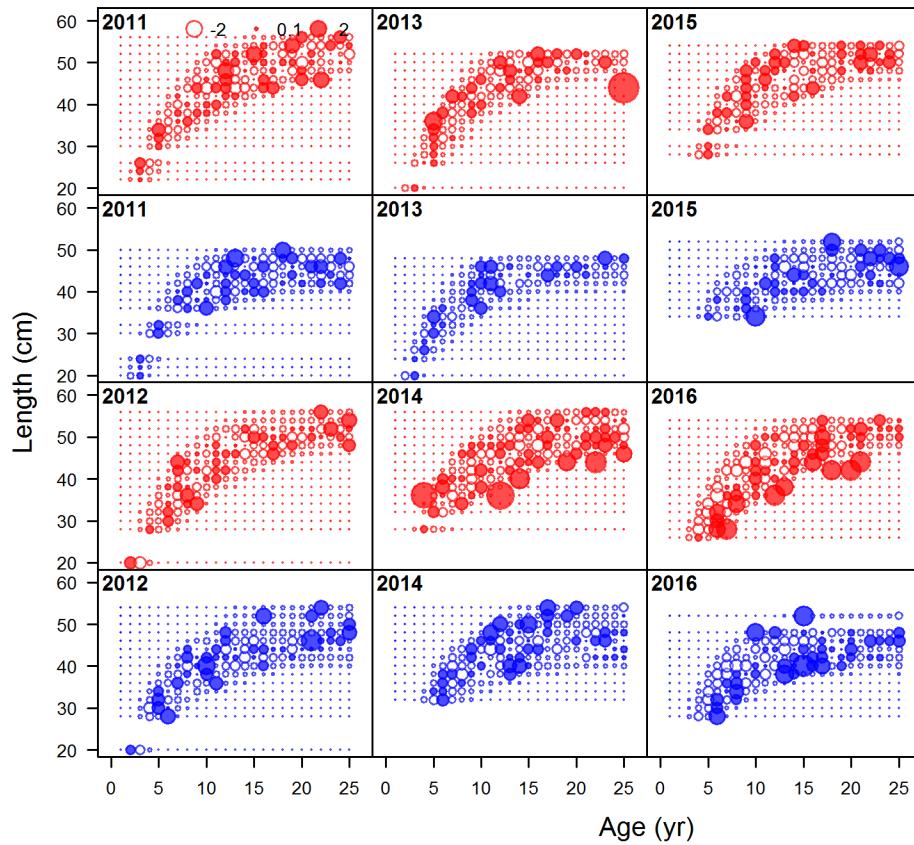


Figure 45: Northern model Pearson residuals, retained, NWFSC Combo Survey (max=8.24)  
fig:mod1\_1\_comp\_condAALfit\_residsf1t6mkt2\_page1  
(plot 1 of 2)

Pearson residuals, retained, NWFSC Combo Survey (max=8.24)



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Figure continued from previous page

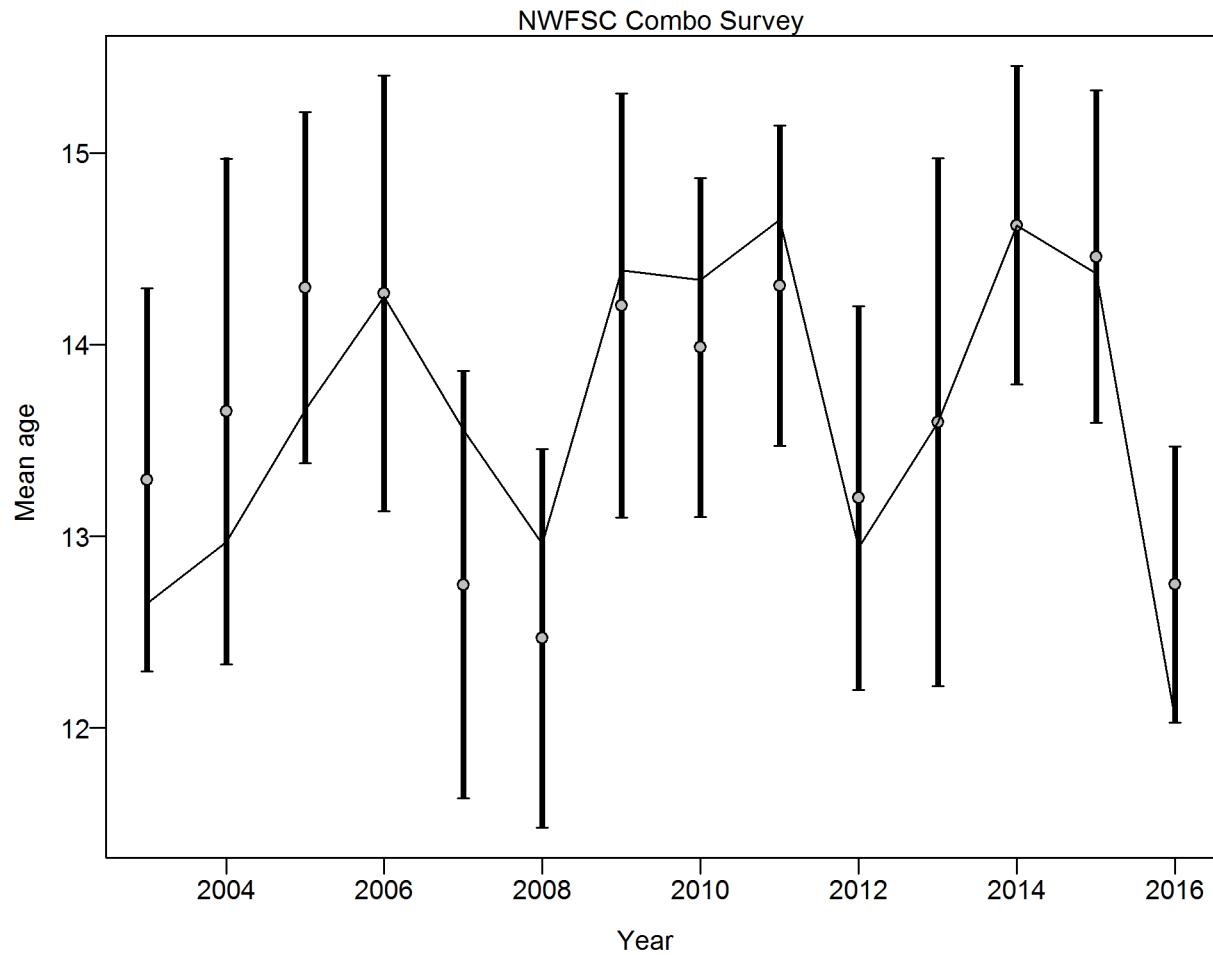


Figure 46: **Northern model** Mean age from conditional data (aggregated across length bins) for NWFSC Combo Survey with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based 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](#)

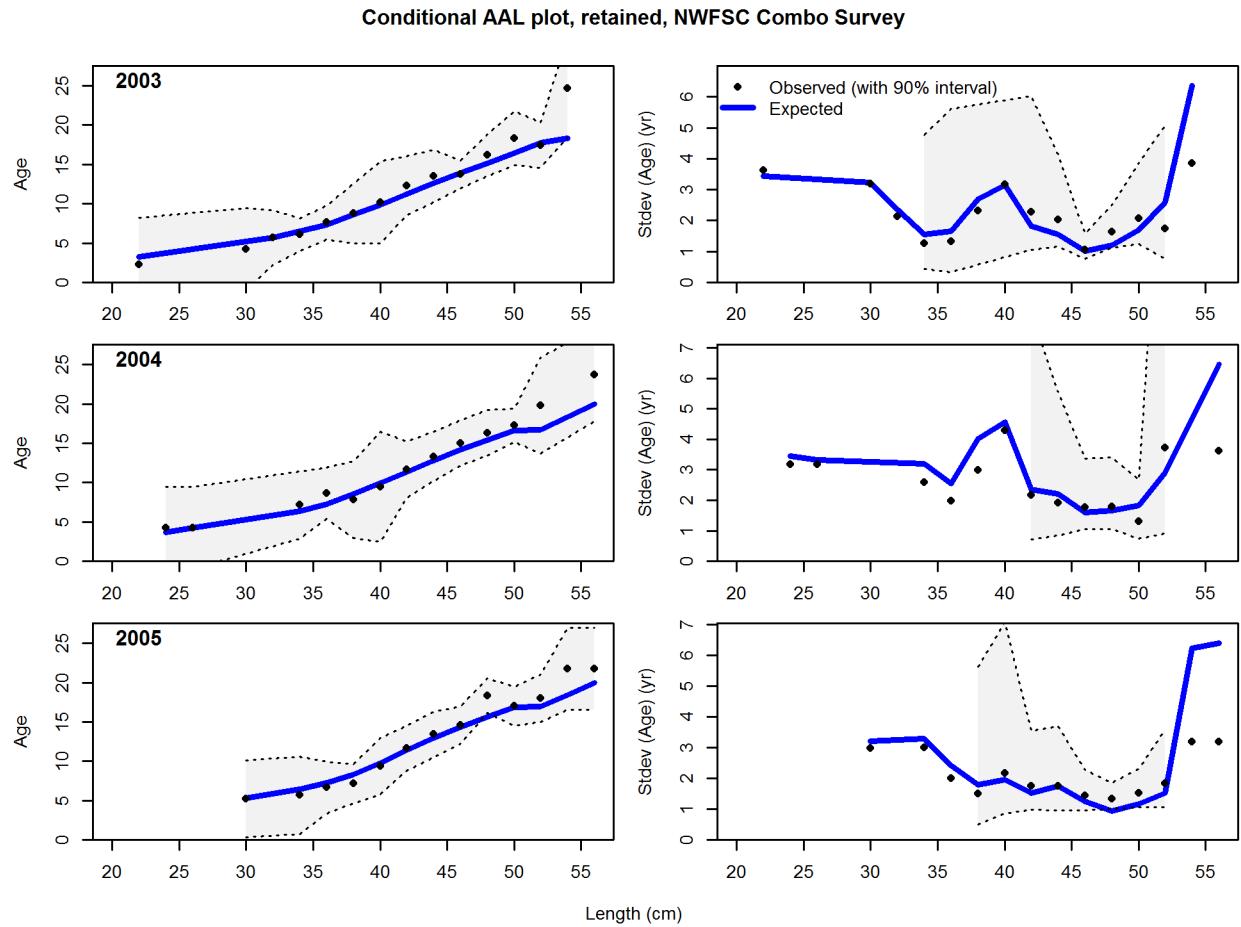
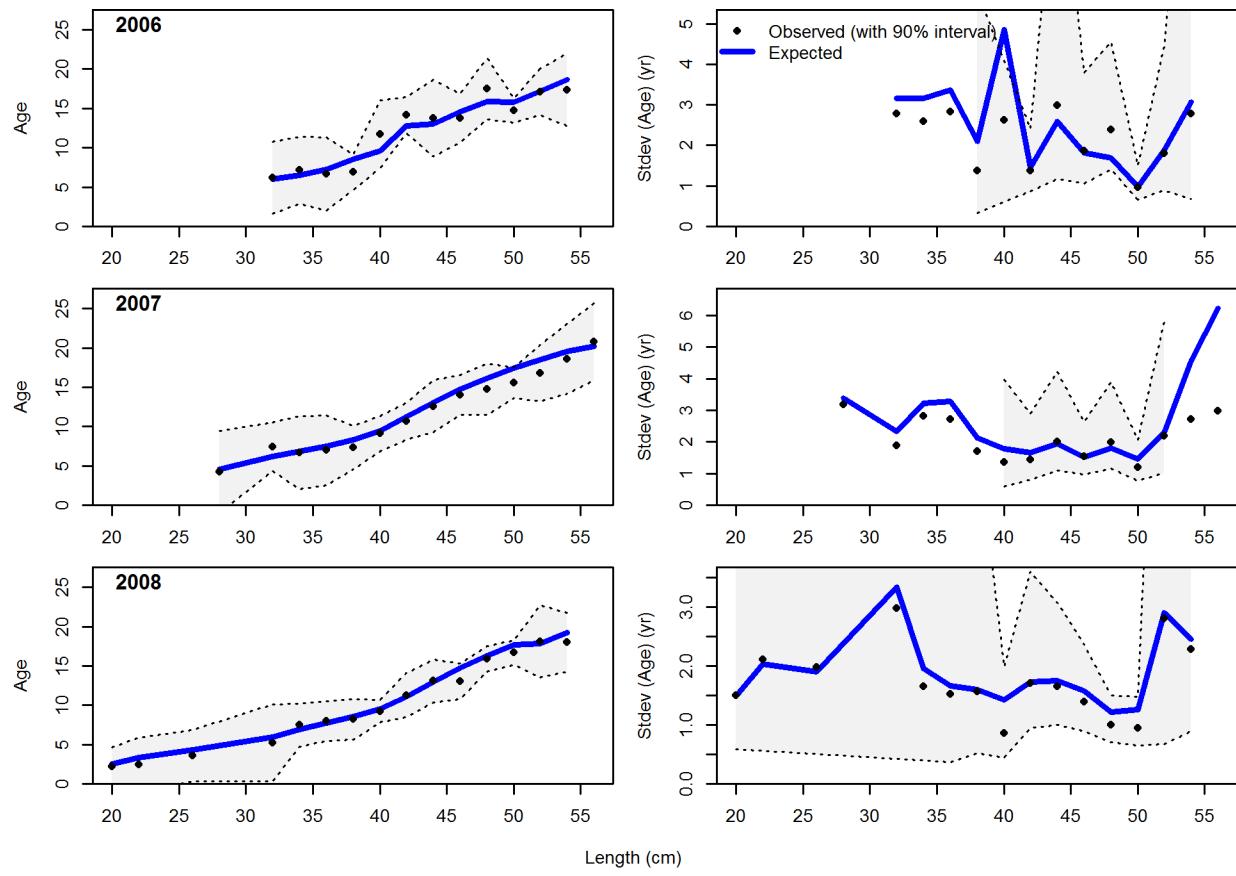


Figure 47: **Northern model** Conditional AAL plot, retained, NWFSC Combo Survey (plot 1 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size\_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE 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

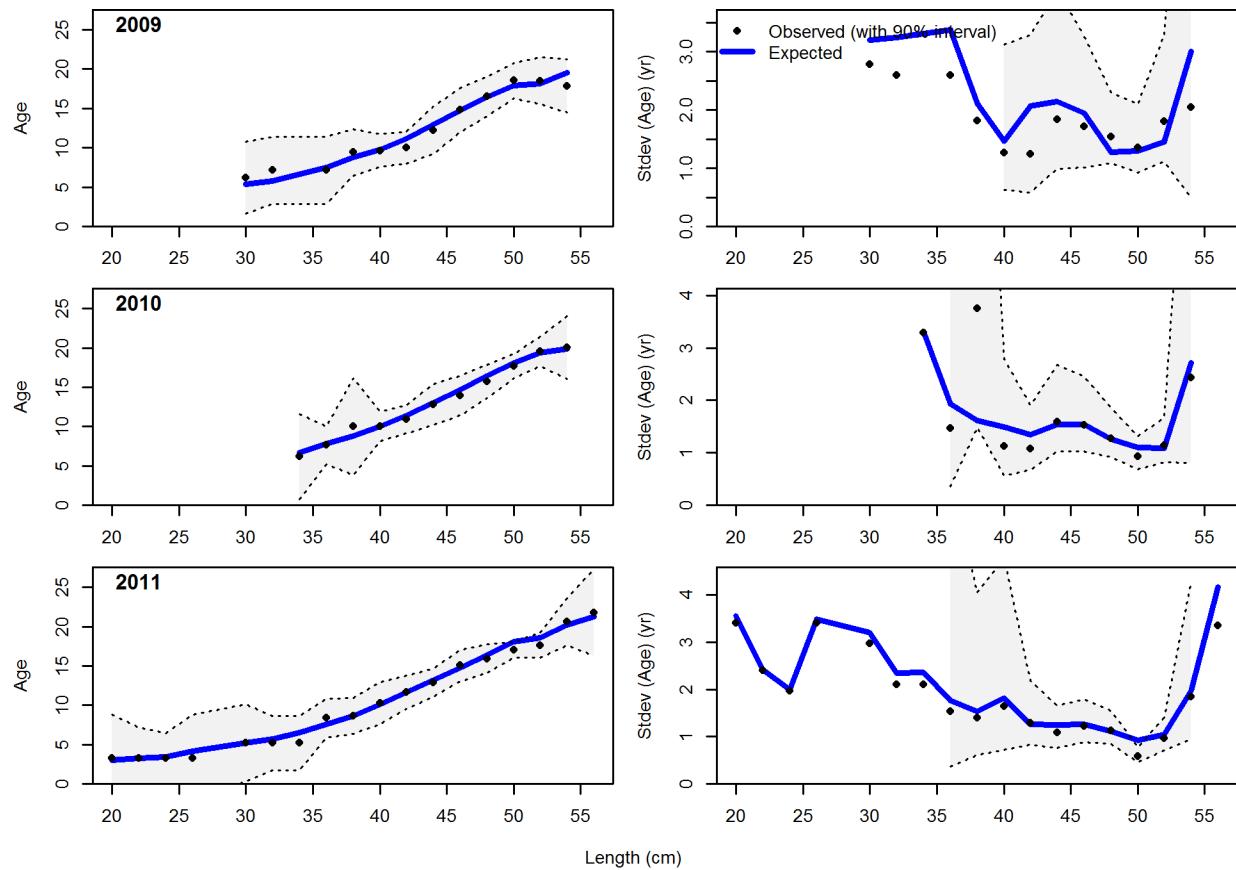


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Figure continued from previous page

Conditional AAL plot, retained, NWFSC Combo Survey

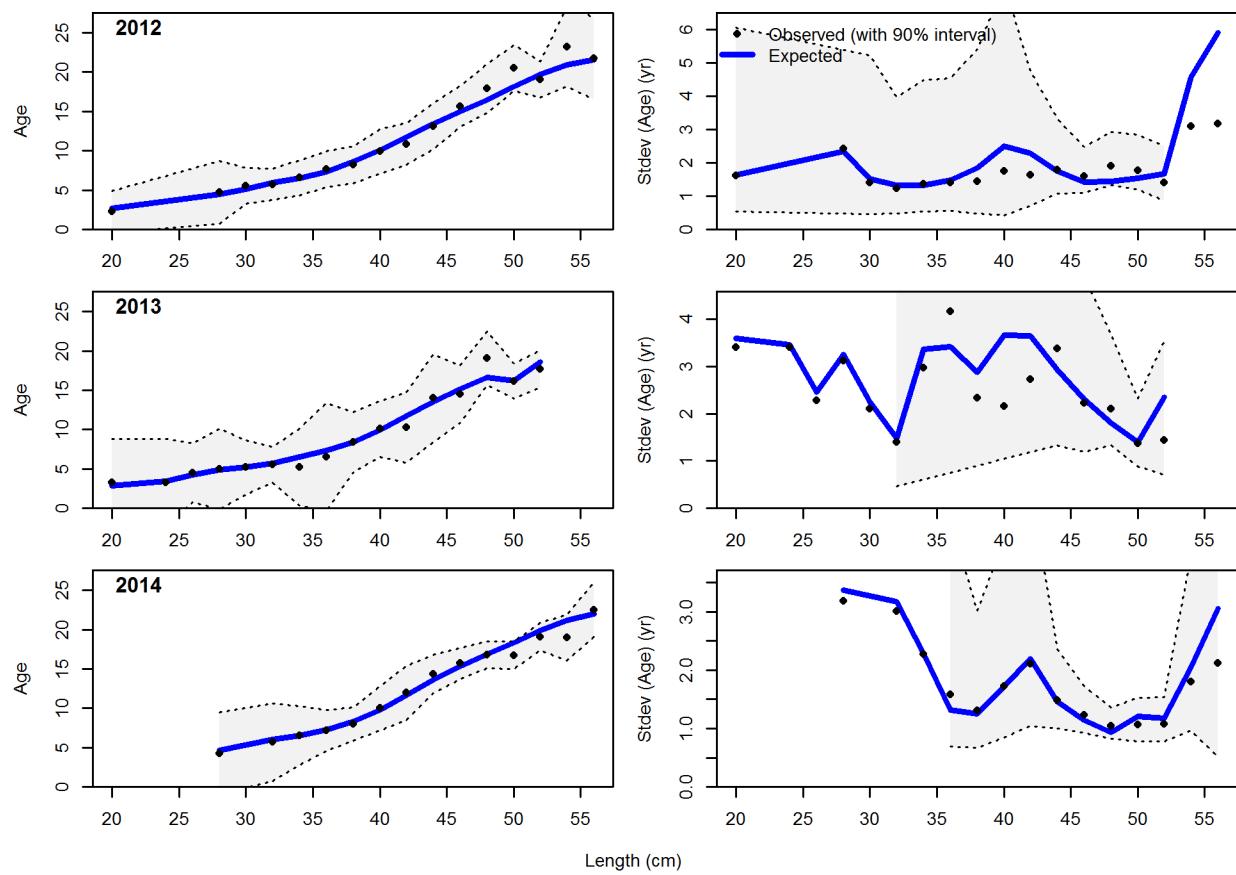


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Figure continued from previous page

Conditional AAL plot, retained, NWFSC Combo Survey

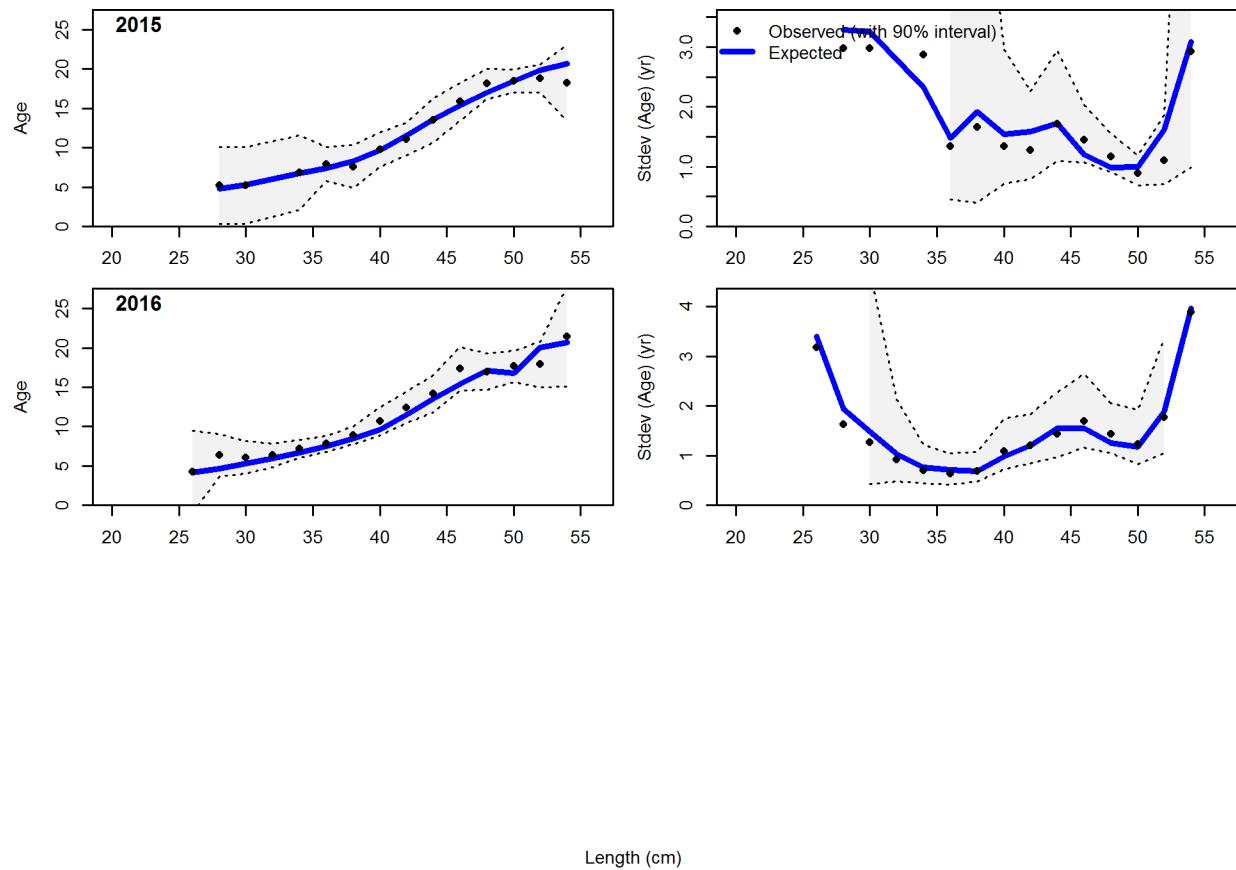


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Figure continued from previous page

Conditional AAL plot, retained, NWFSC Combo Survey



1160

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Figure continued from previous page

<sub>1162</sub> **9.3 Model results for Northern model** [model-results-for-northern-model](#)

<sub>1163</sub> **9.3.1 Base model results for Northern model** [base-model-results-for-northern-model](#)

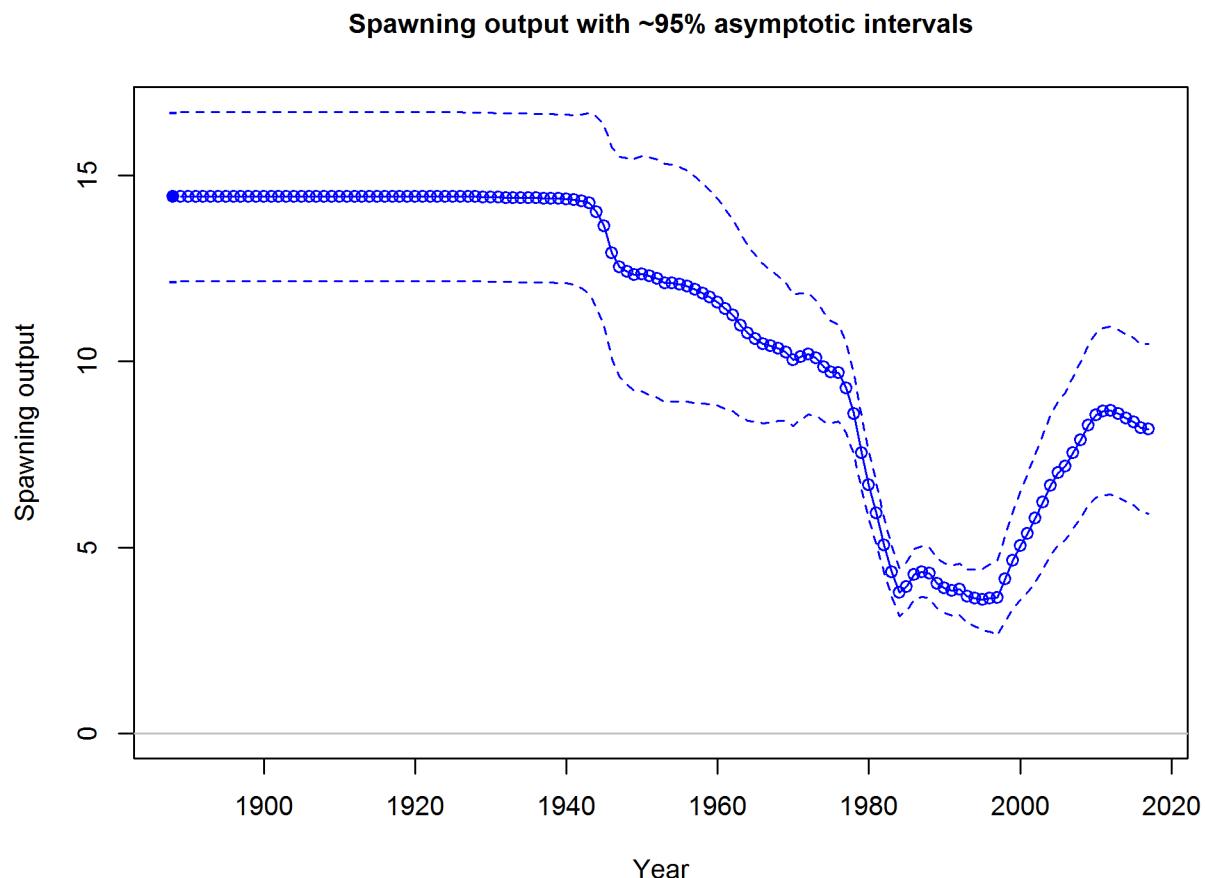


Figure 48: Estimated time-series of spawning output for Northern model. [fig:ssb.N](#)

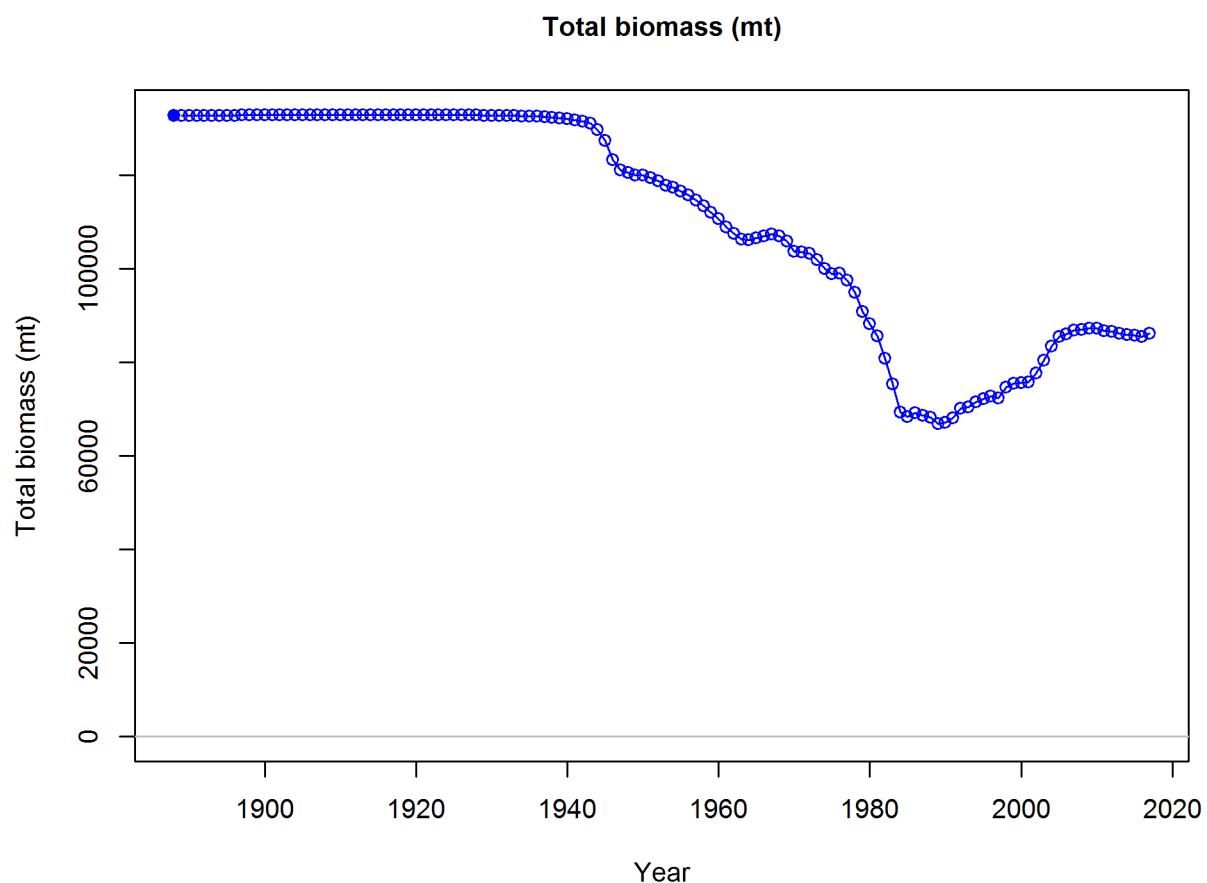


Figure 49: Estimated time-series of total biomass for Northern model. `fig:total_bio.N`

### Spawning depletion with ~95% asymptotic intervals

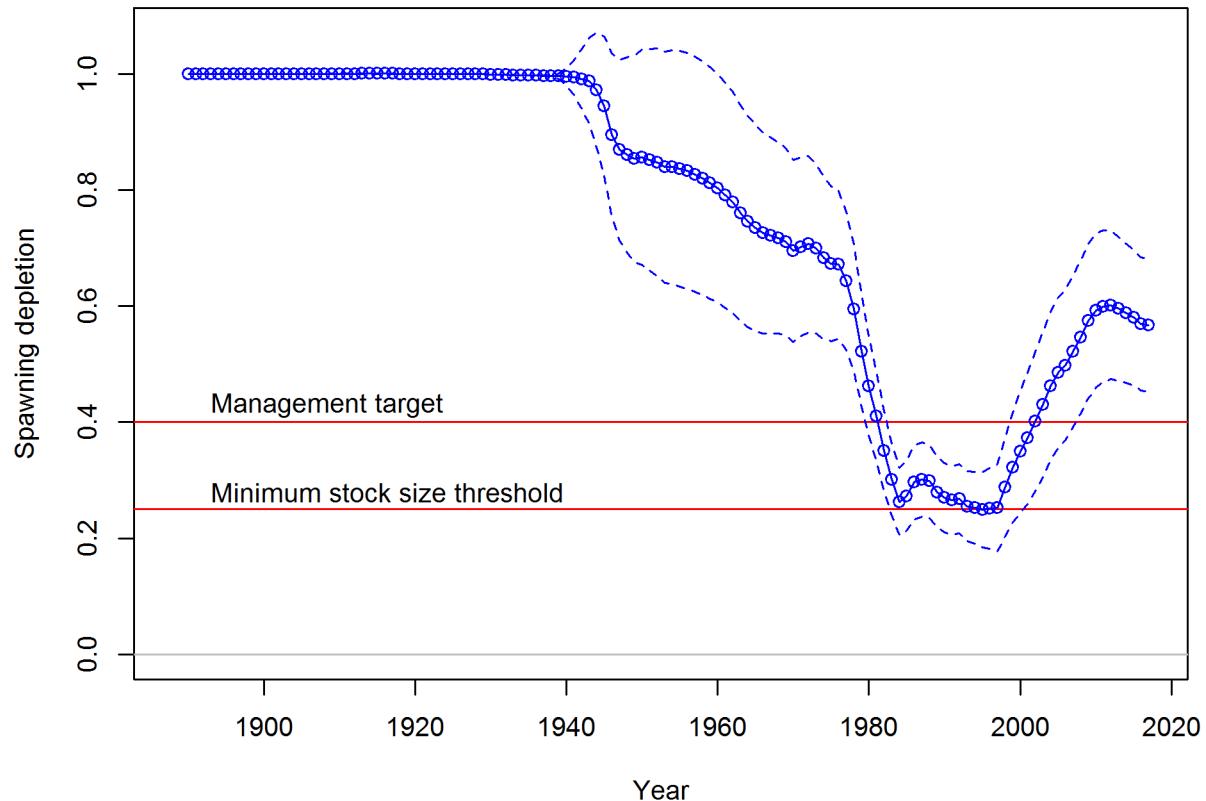


Figure 50: Estimated time-series of relative biomass for Northern model. [fig:dep1.N](#)

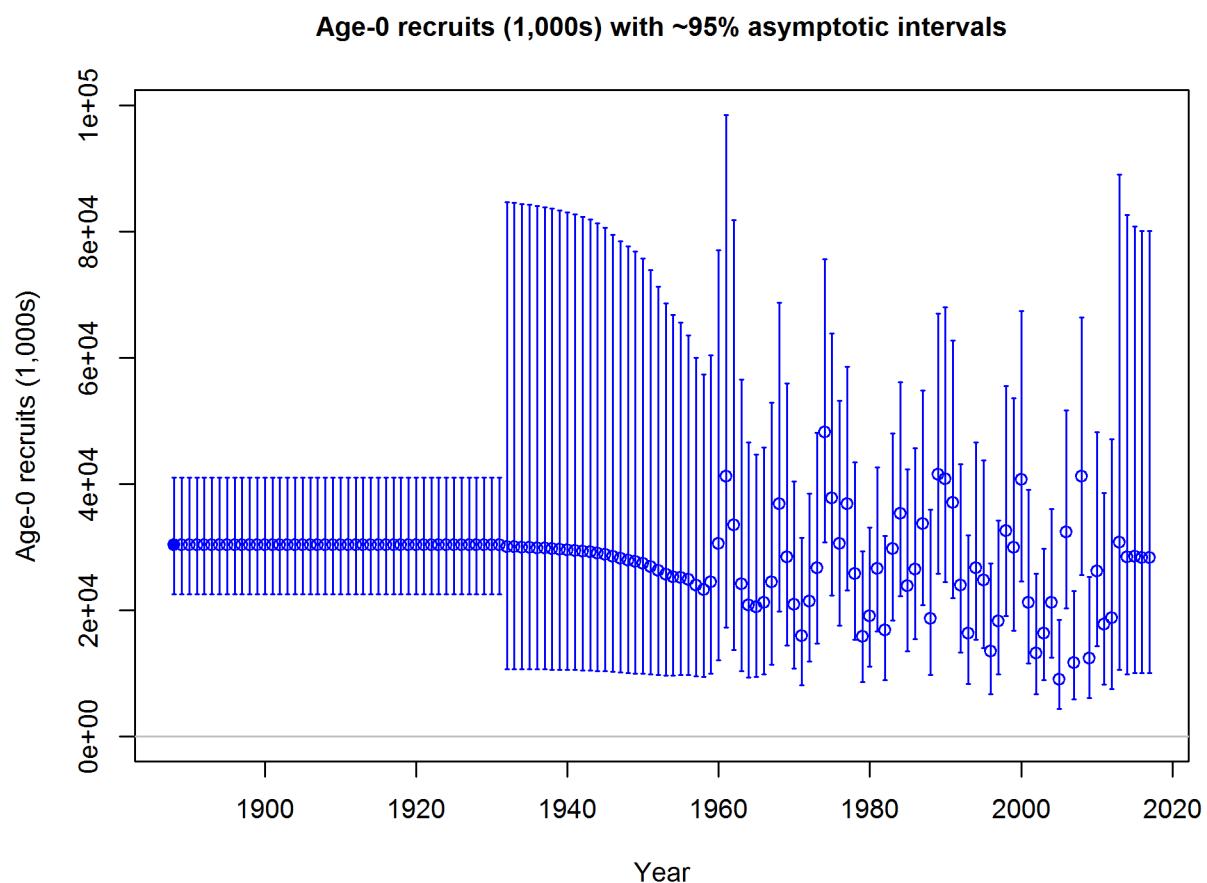


Figure 51: Estimated time-series of recruitment for the Northern model. fig:recruits1.N

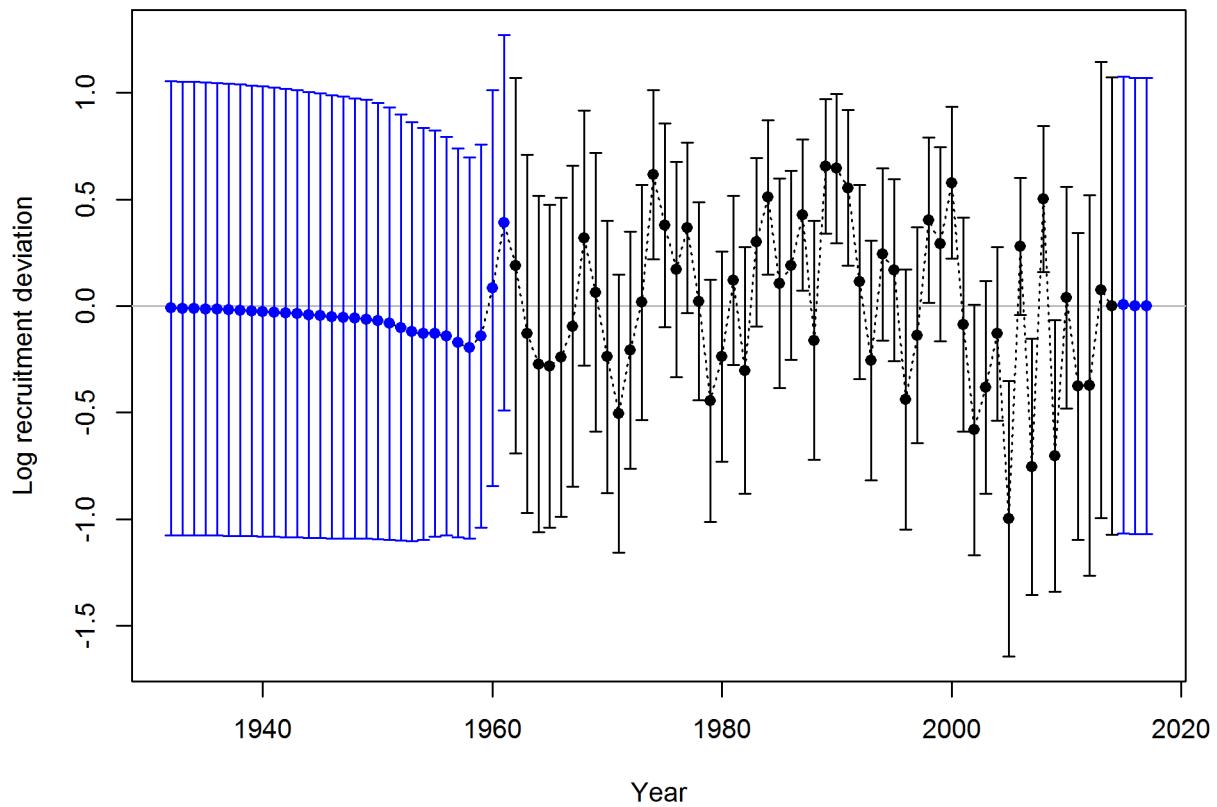


Figure 52: Estimated time-series of recruitment deviations for the Northern model. `fig:recdevs1.N`

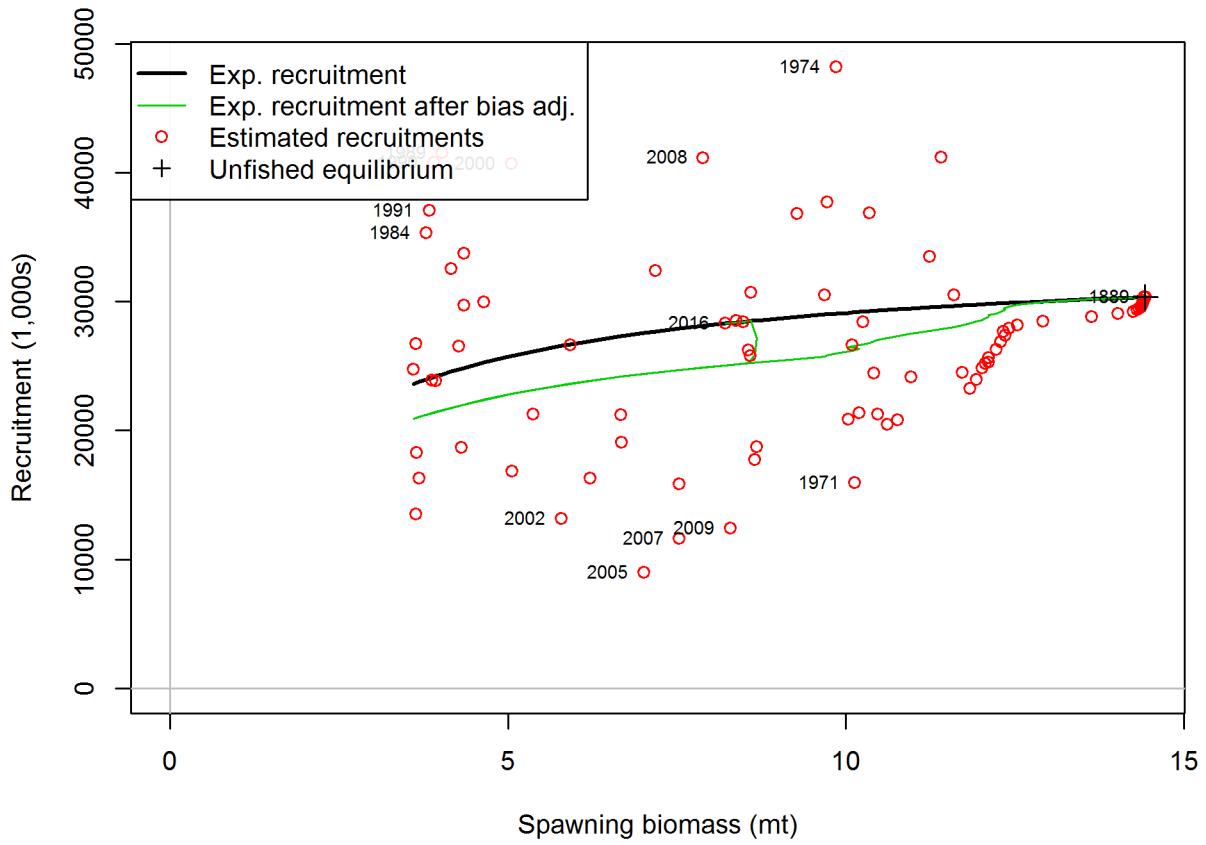


Figure 53: Estimated recruitment (red circles) for the Northern model relative to the stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution [fig:stock\\_recruit\\_curve.N](#)

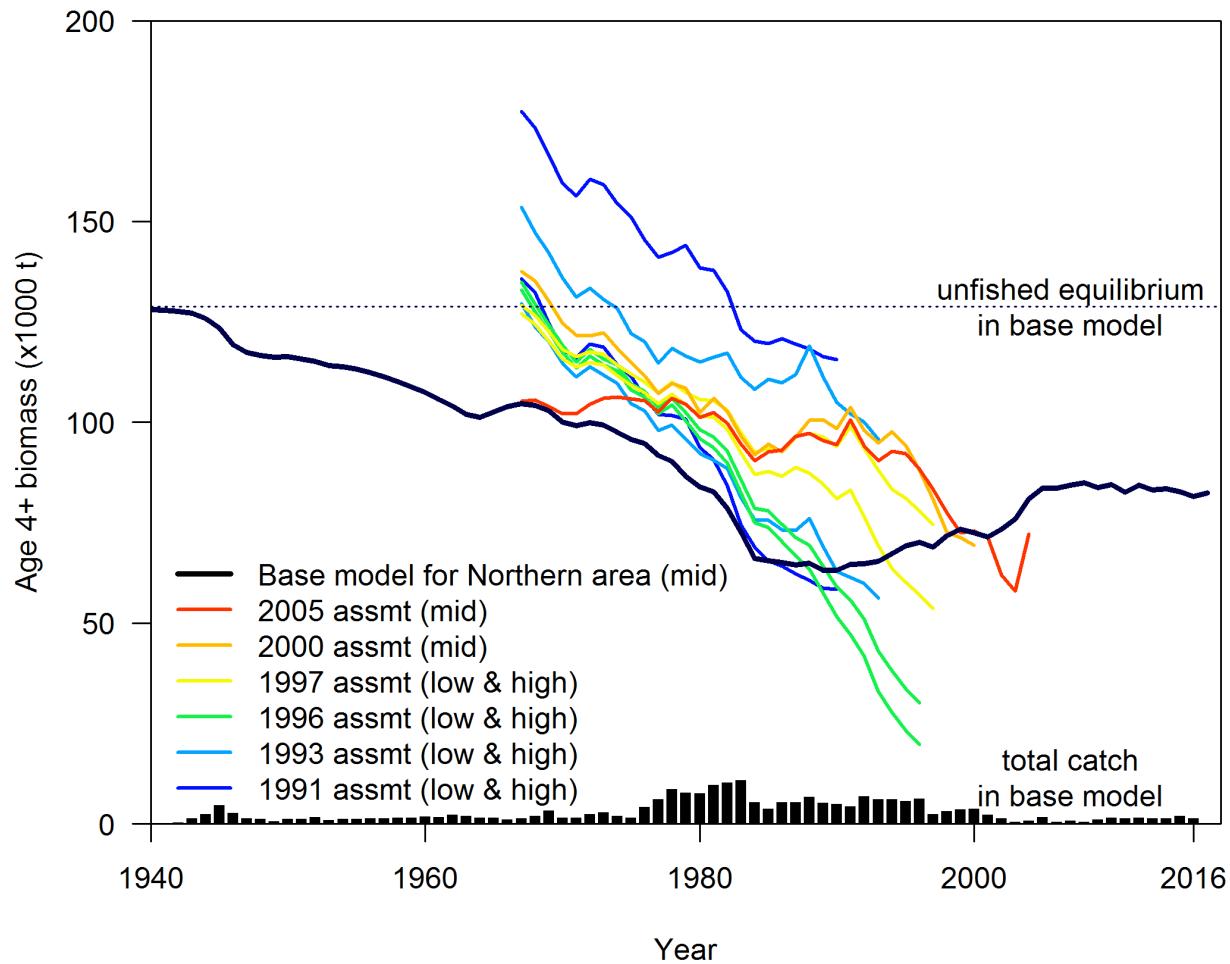


Figure 54: Comparison of time series of age 4+ biomass for Yellowtail Rockfish across past assessments. Previous assessments were focused only on the area north of  $40^{\circ}10'$ , but also included a small area within Canada. [fig:assessment\\_history](#)

<sub>1164</sub> 9.3.2 Sensitivity analyses for Northern model  
[sensitivity-analyses-for-northern-model](#)

<sub>1165</sub> to be added...

<sub>1166</sub> 9.3.3 Likelihood profiles for Northern model  
[likelihood-profiles-for-northern-model](#)

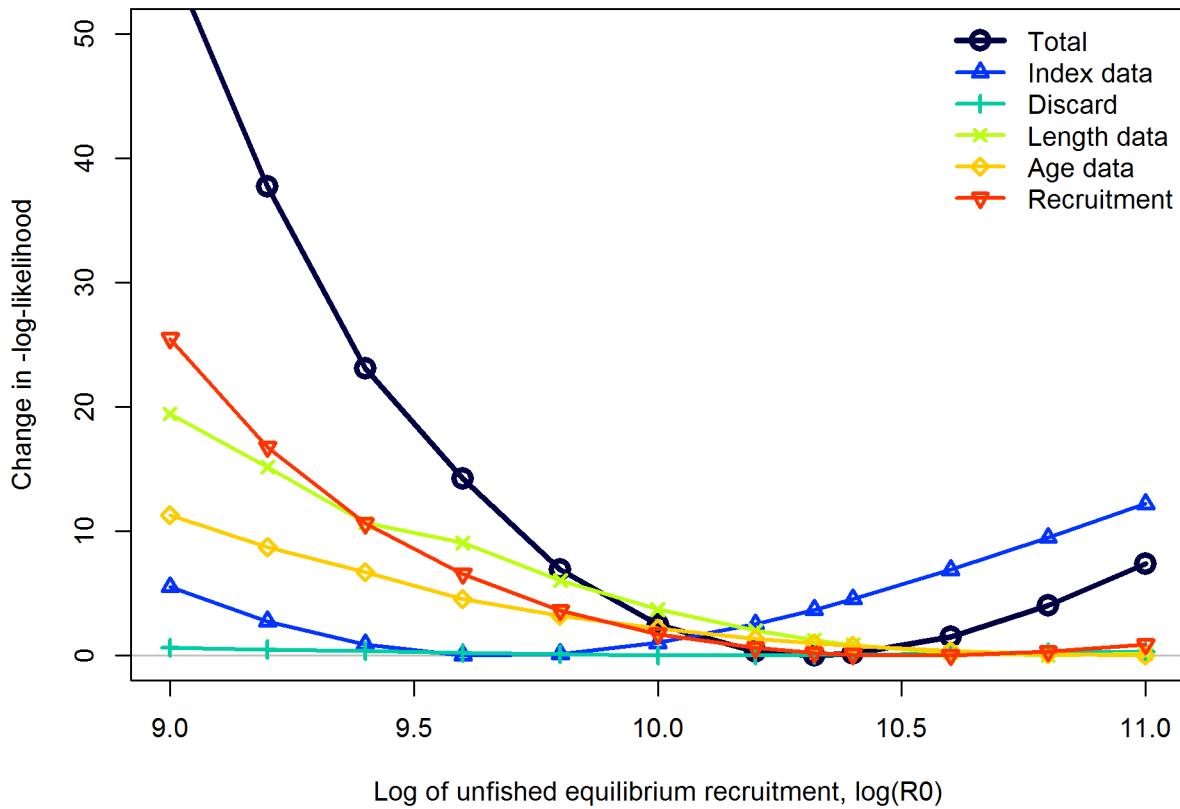


Figure 55: Likelihood profile over the log of equilibrium recruitment ( $R_0$ ) for the Northern model. [fig:profile\\_logR0.N](#)

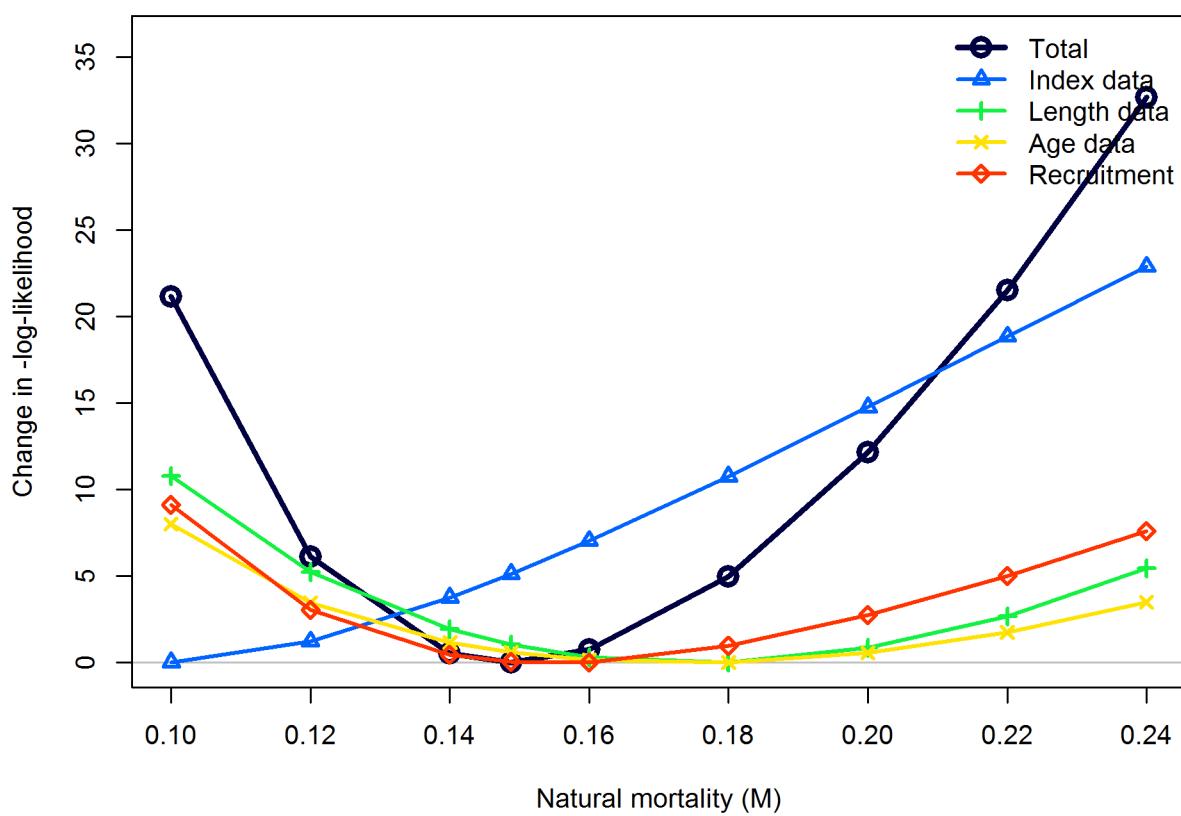


Figure 56: Likelihood profile over female natural mortality for the Northern model. `fig:profile_M.N`

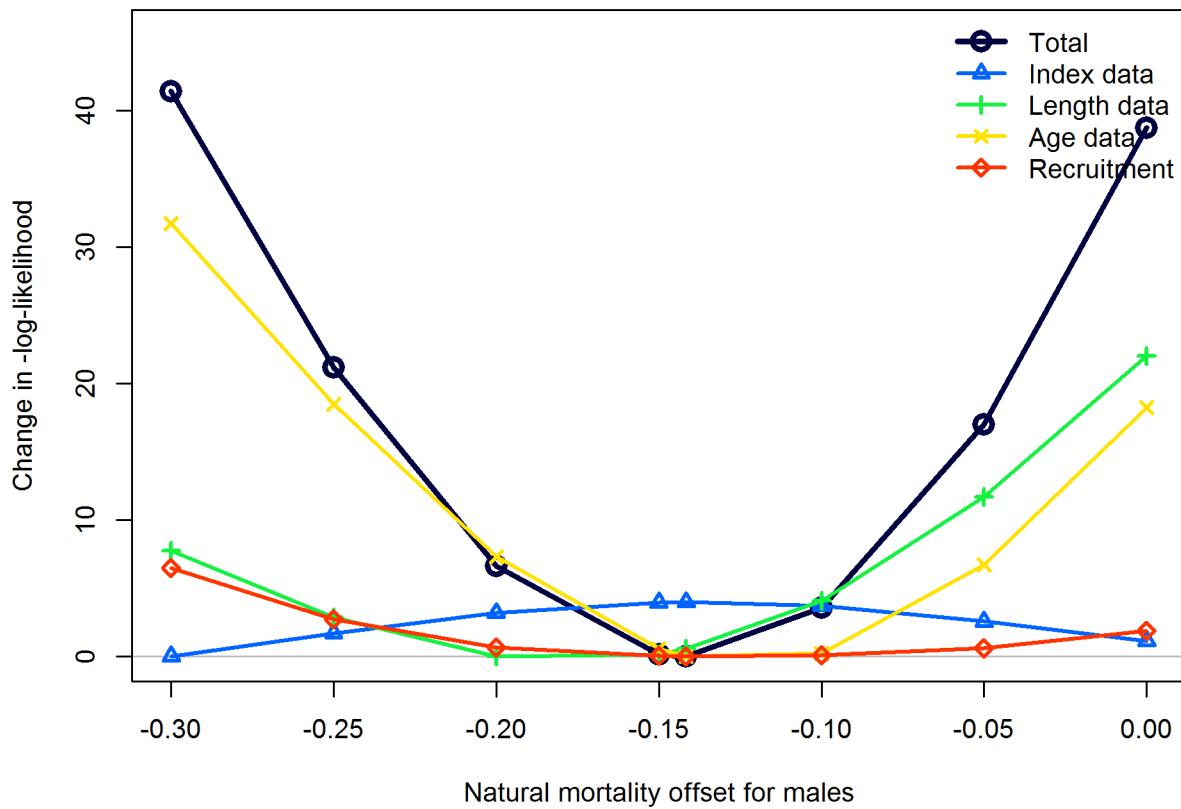


Figure 57: Likelihood profile over the male offset for natural mortality for the Northern model. Negative values are associated with natural mortality being lower for males than females.  
*fig:profile\_M2.N*

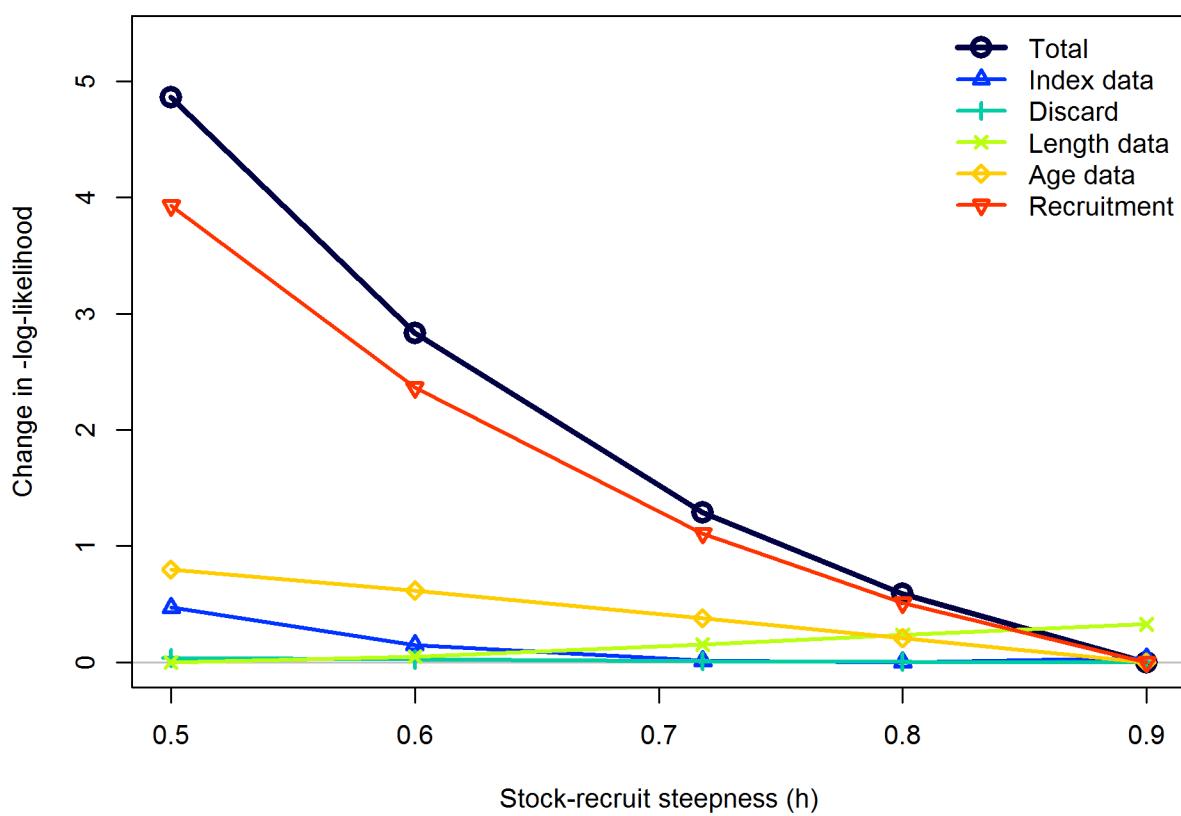


Figure 58: Likelihood profile over stock-recruit steepness ( $h$ ) for the Northern model. `fig:profile_h.N`

1167 **9.3.4 Retrospective analysis for Northern model**  
retrospective-analysis-for-northern-model

1168 Retrospective analysis of spawning output for the Northern model. fig:retro.N

1169 **9.3.5 Forecasts analysis for Northern model**  
forecasts-analysis-for-northern-model

1170 to be added...

1171 9.4 Data and model fits for Southern model  
[data-and-model-fits-for-southern-model](#)

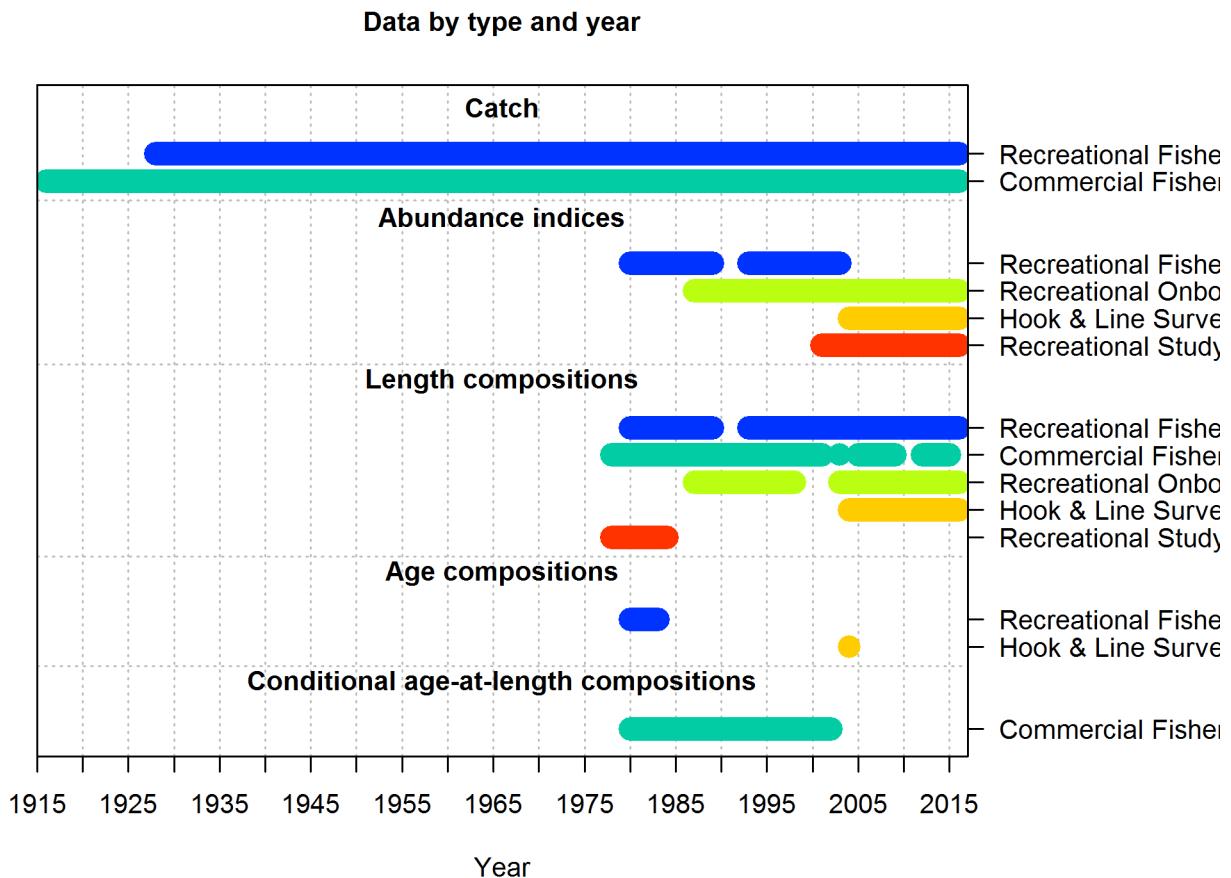


Figure 59: Summary of data sources used in the Southern model. [fig:data\\_plot.S](#)

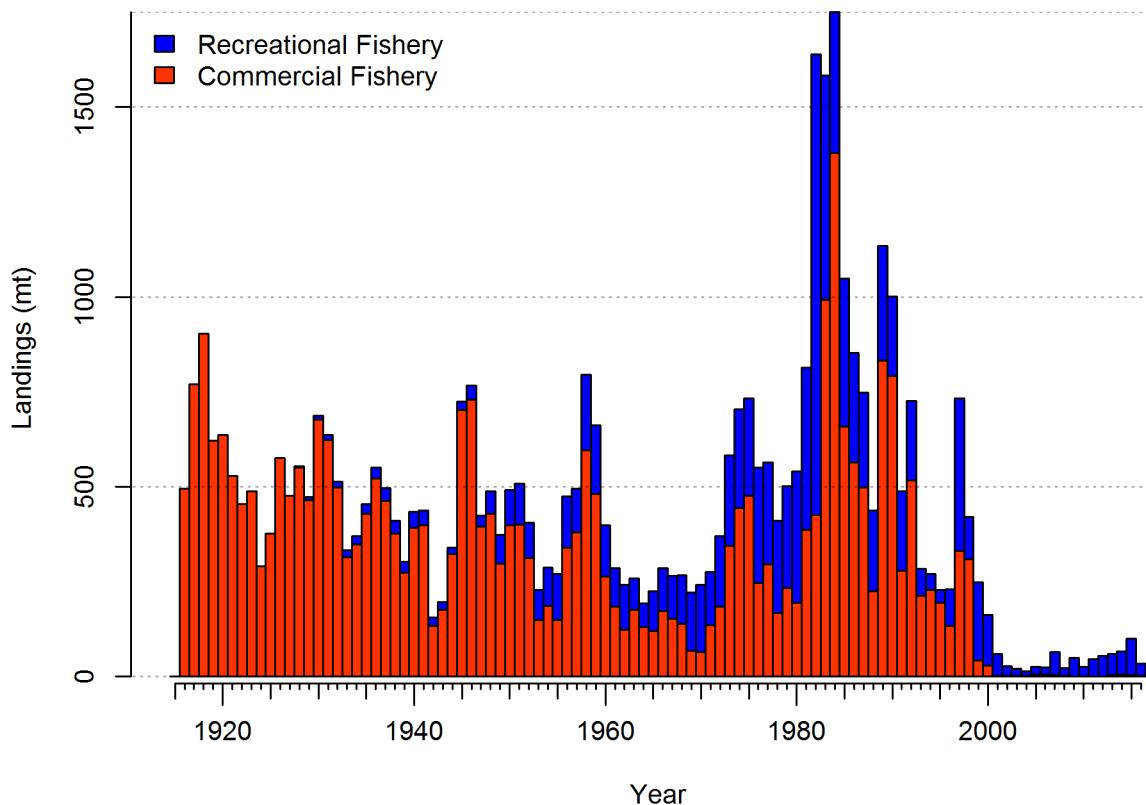


Figure 60: Estimated catch history of Yellowtail Rockfish in the Southern model. [fig:r4ss\\_catch2\\_S](#)

1172 9.4.1 Selectivity, retention, and discards for Southern model  
[selectivity-retention-and-discards-for-southern-model](#)

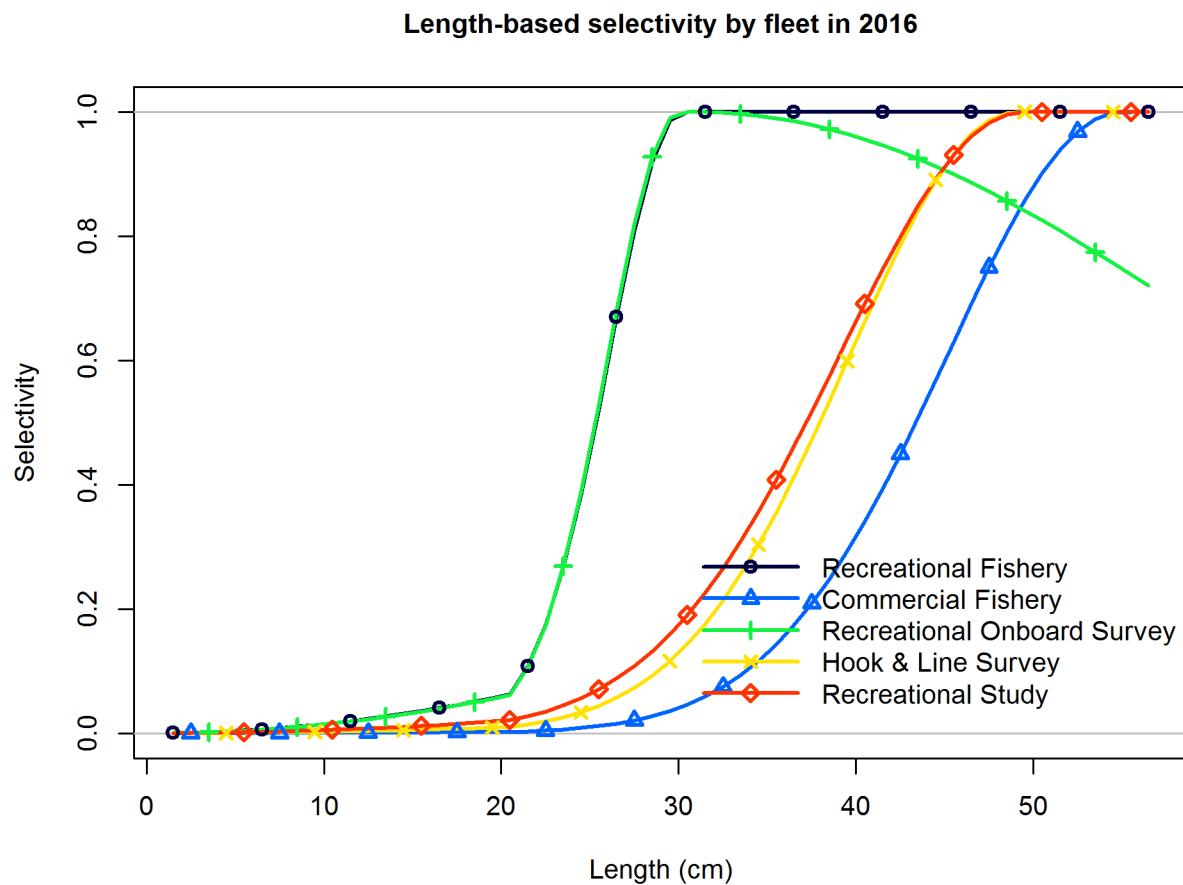


Figure 61: Estimated selectivity by length by each fishery and survey in the Southern model.  
[fig:selex.S](#)

1173 9.4.2 Fits to indices of abundance for Southern model  
fits-to-indices-of-abundance-for-southern-model

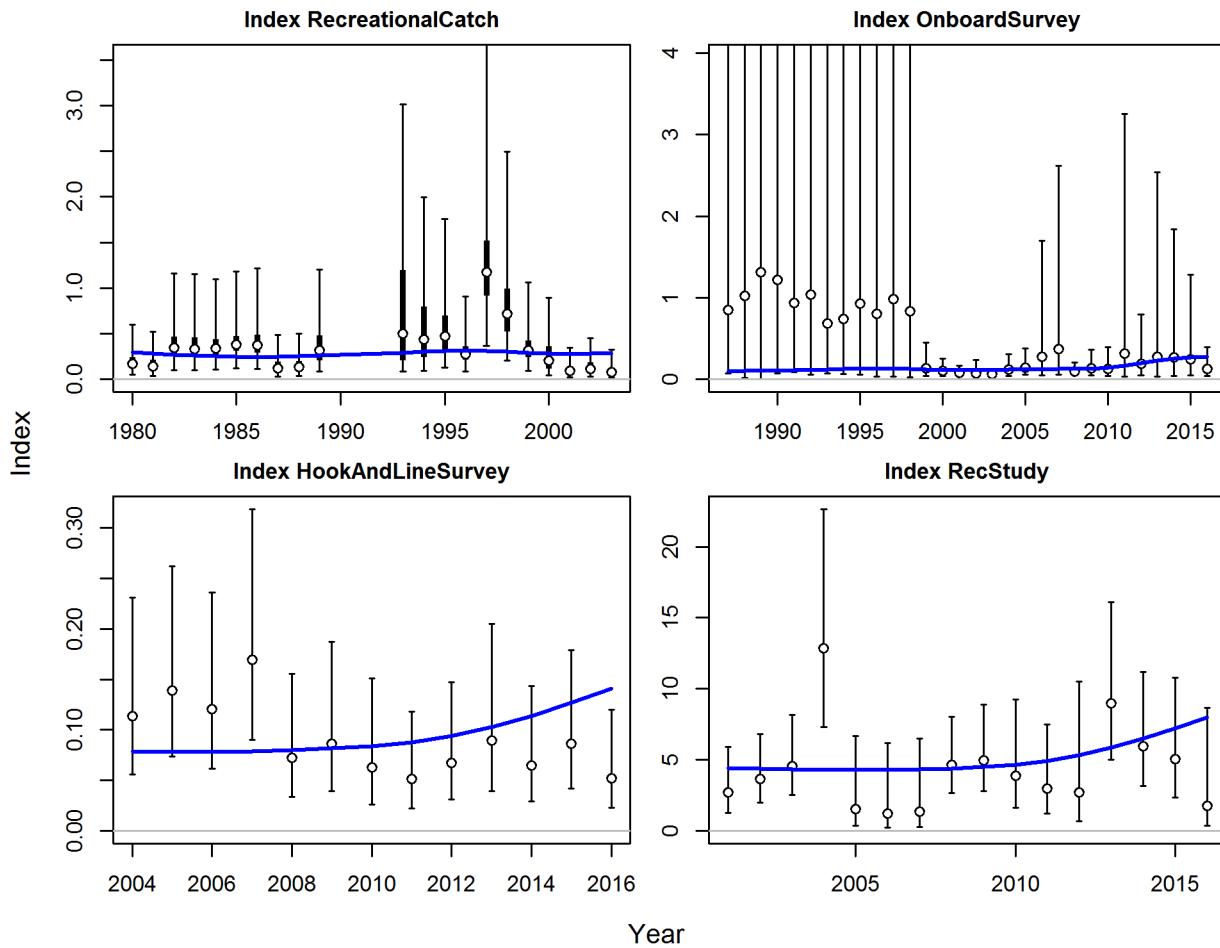


Figure 62: Estimated fits to the CPUE and survey indices for the Southern model. fig:index\_fits2

<sub>1174</sub> **9.4.3 Length compositions for Southern model**  
[length-compositions-for-southern-model](#)

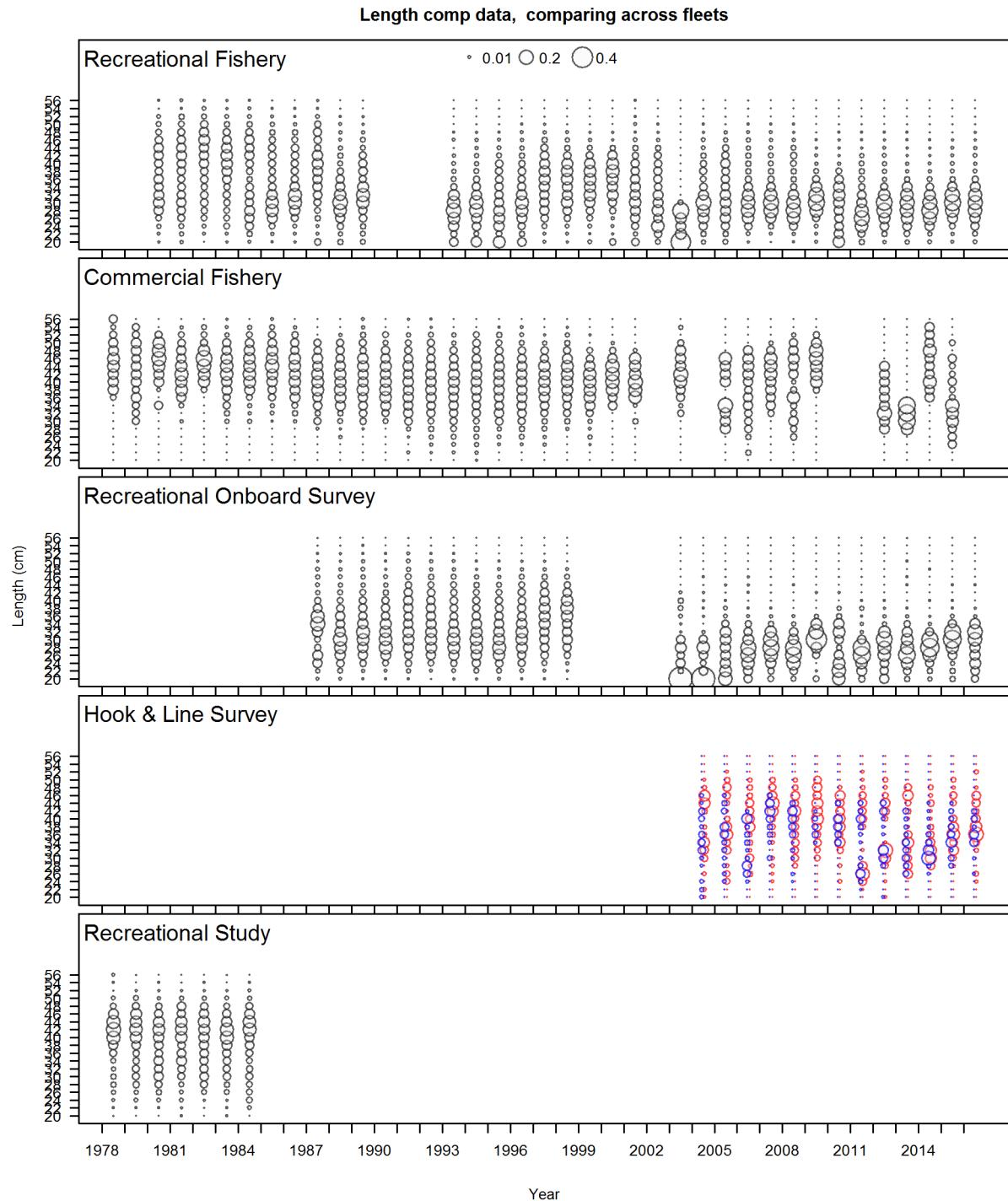


Figure 63: Length compositions for all fleets in the Southern model. Bubble size is proportional to proportions within each year. [fig:comp\\_length\\_bubble\\_mod2](#)

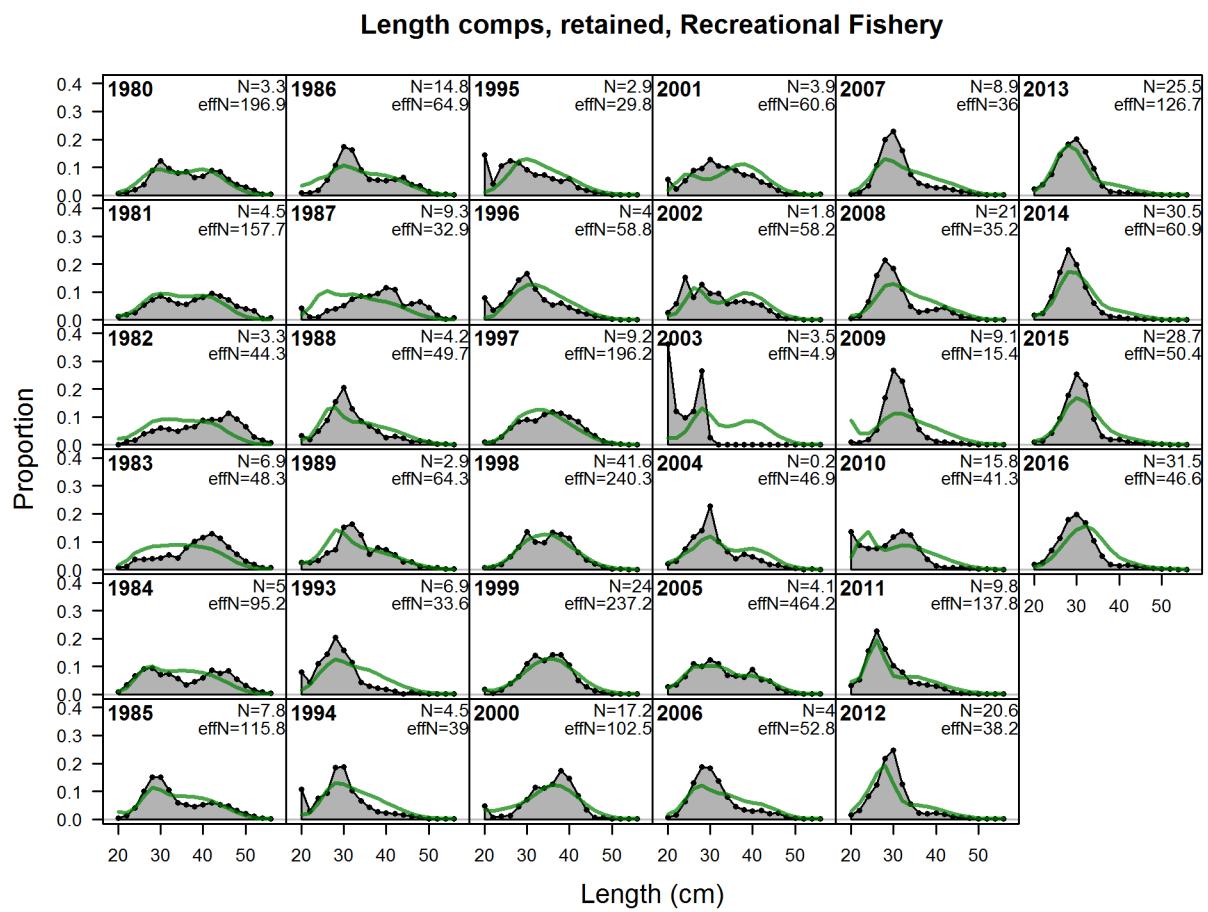


Figure 64: Southern model Length comps, retained, Recreational Fishery fig:mod2\_1\_comp\_len

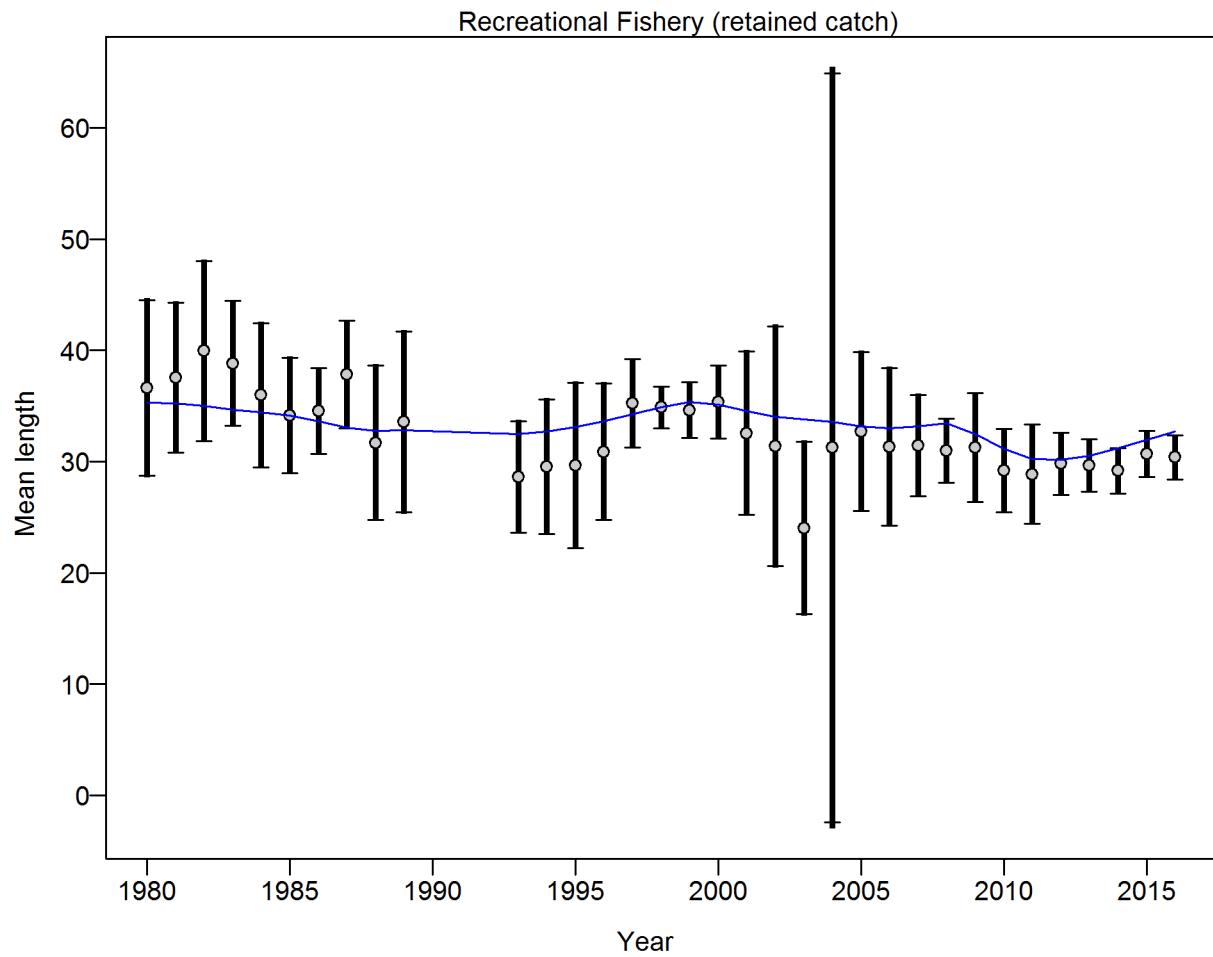


Figure 65: **Southern model** Mean length for Recreational Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for 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](#)

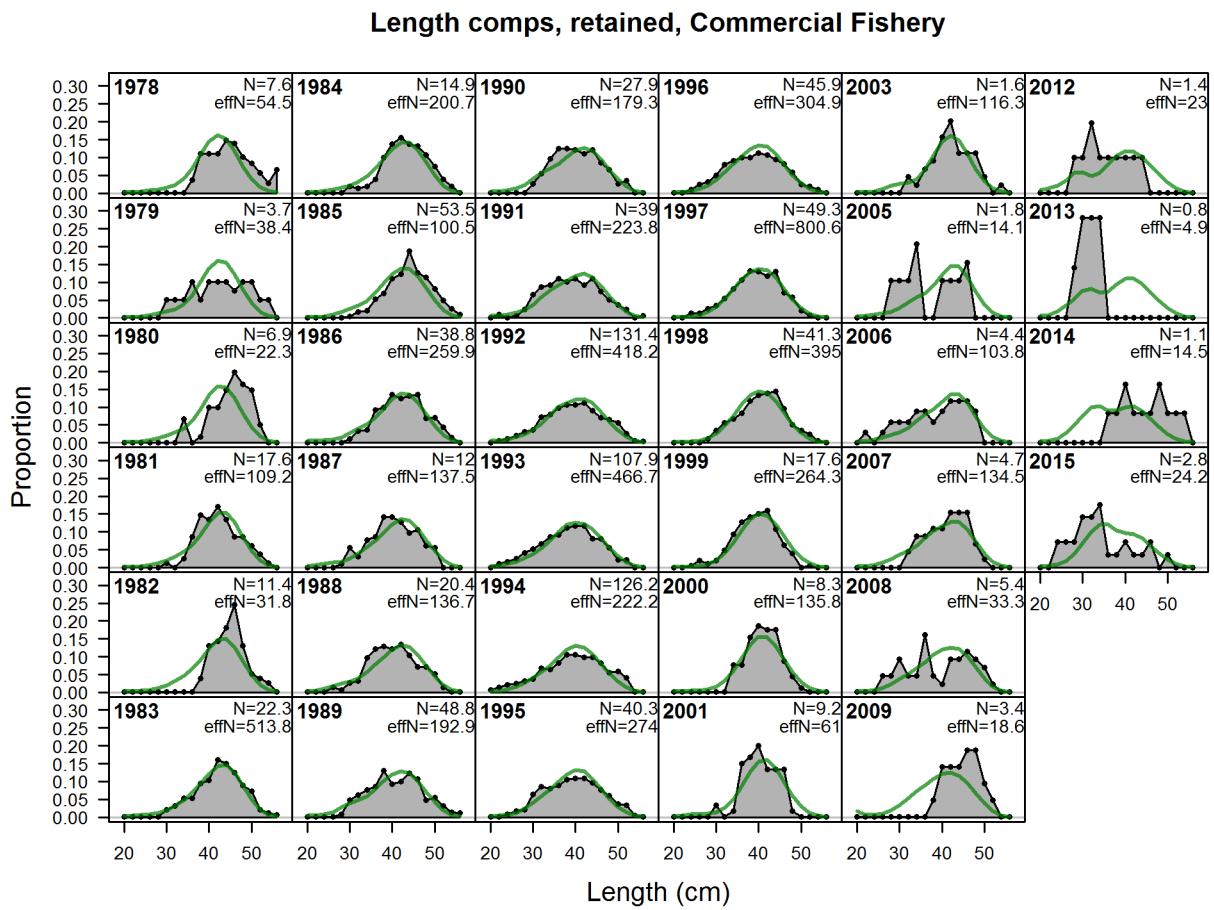


Figure 66: Southern model Length comps, retained, Commercial Fishery fig:mod2\_5\_comp\_leni

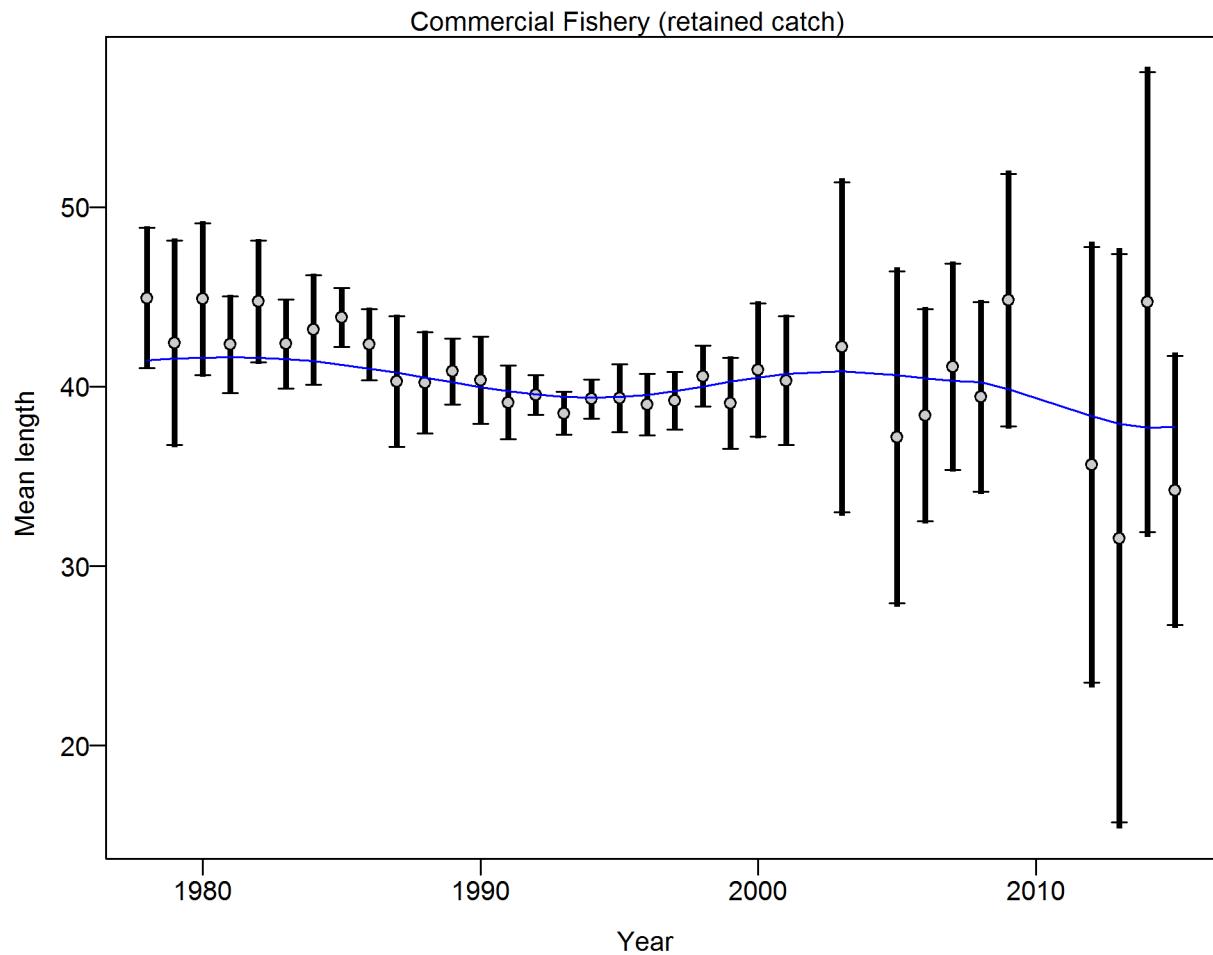


Figure 67: **Southern model** Mean length for Commercial Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for 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](#)

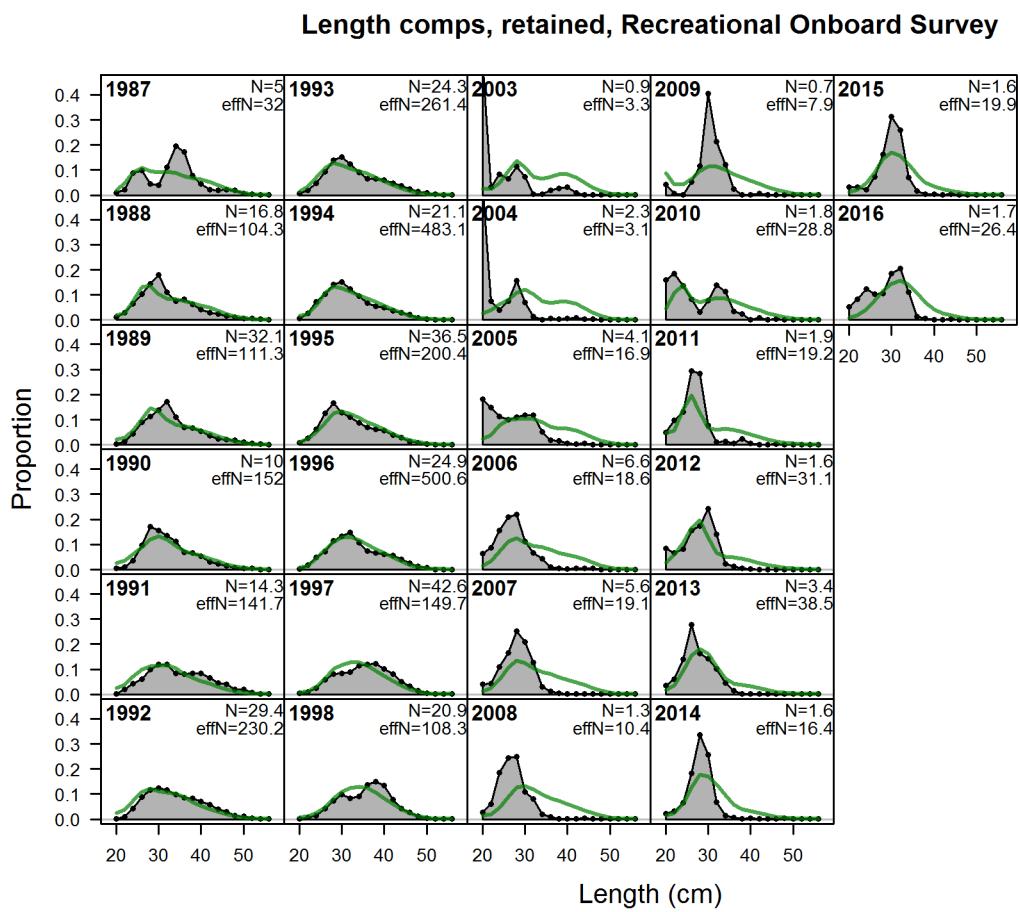


Figure 68: **Southern model** Length comps, retained, Recreational Onboard Survey | [fig:mod2\\_9\\_comp](#)

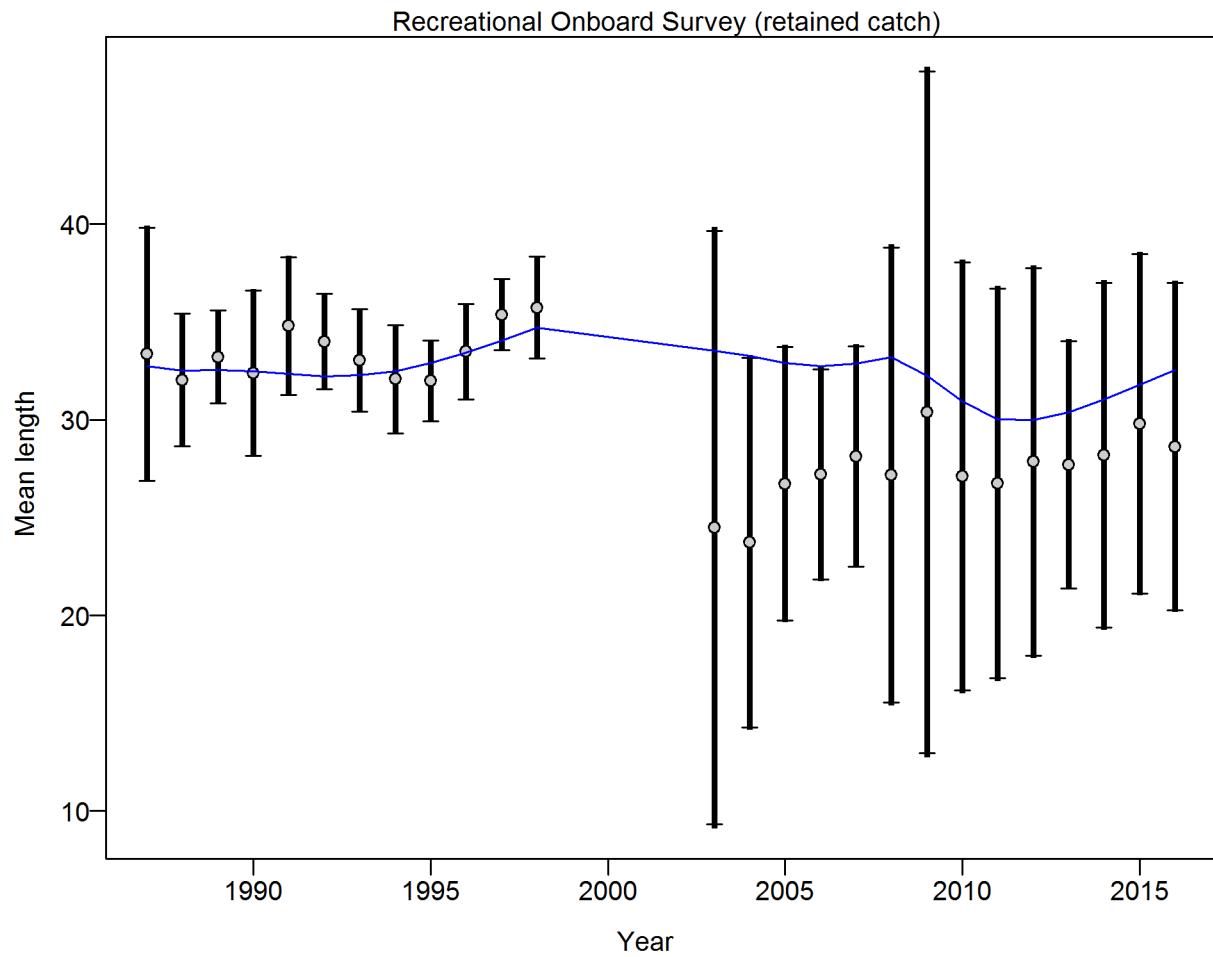


Figure 69: **Southern model** Mean length for Recreational Onboard Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) 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

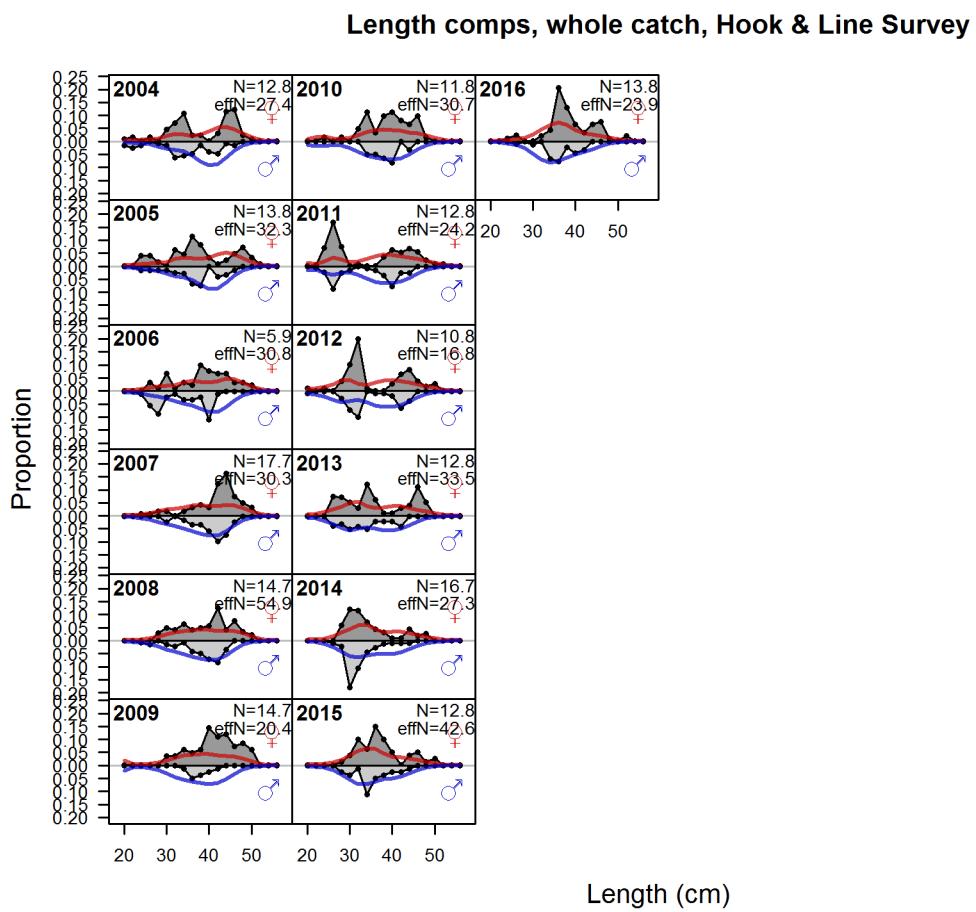


Figure 70: **Southern model** Length comps, whole catch, Hook & Line Survey | `fig:mod2_13_comp_1`

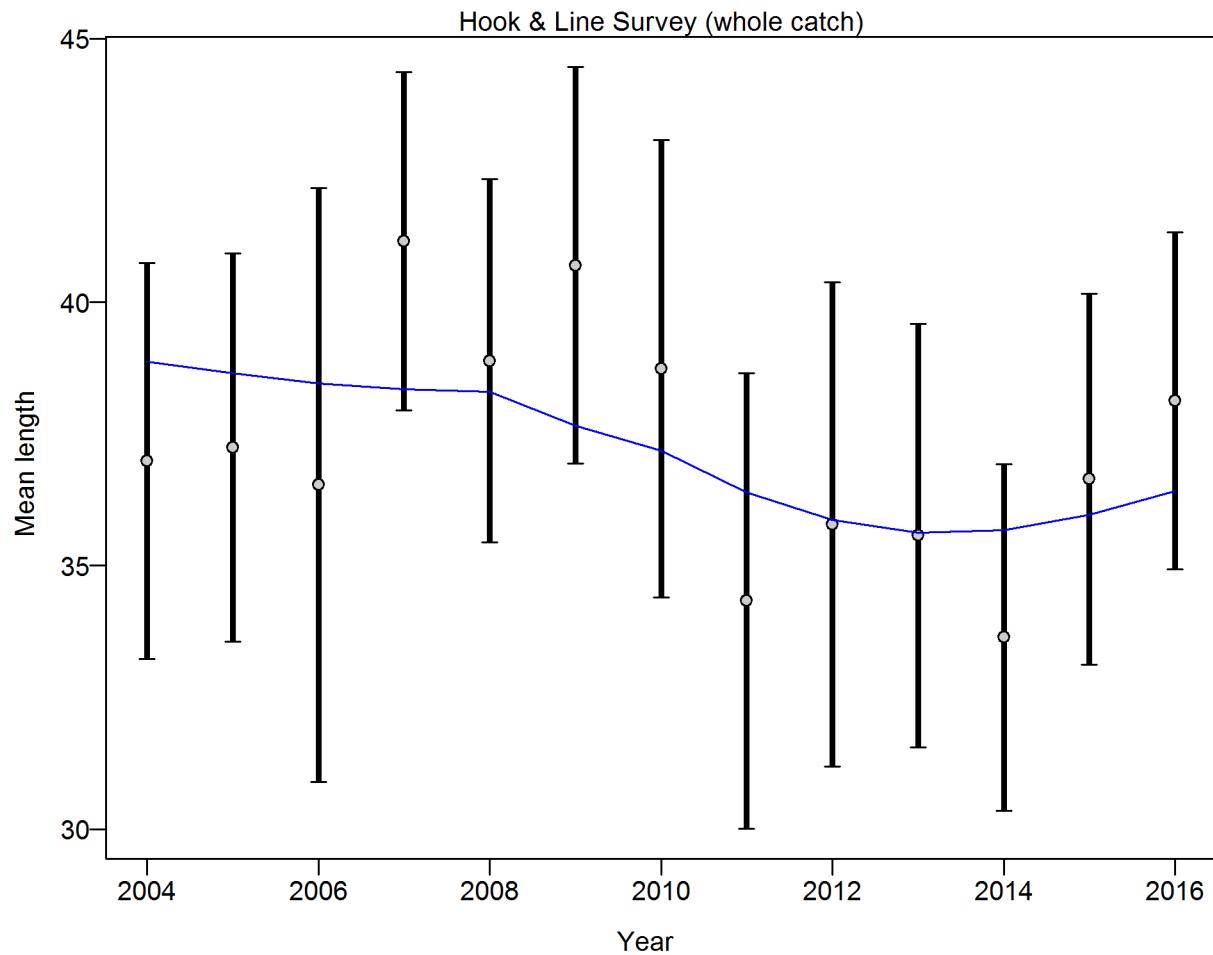


Figure 71: **Southern model** Mean length for Hook & Line Survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for 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](#)

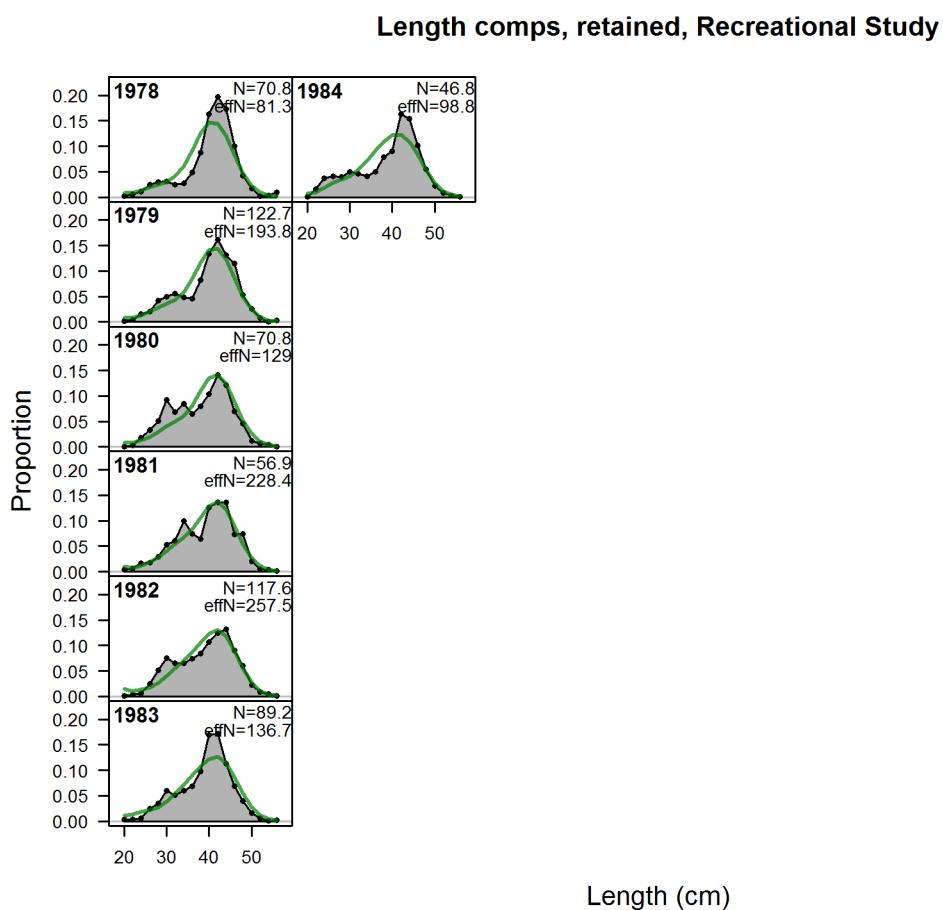


Figure 72: **Southern model** Length comps, retained, Recreational Study fig:mod2\_17\_comp\_len

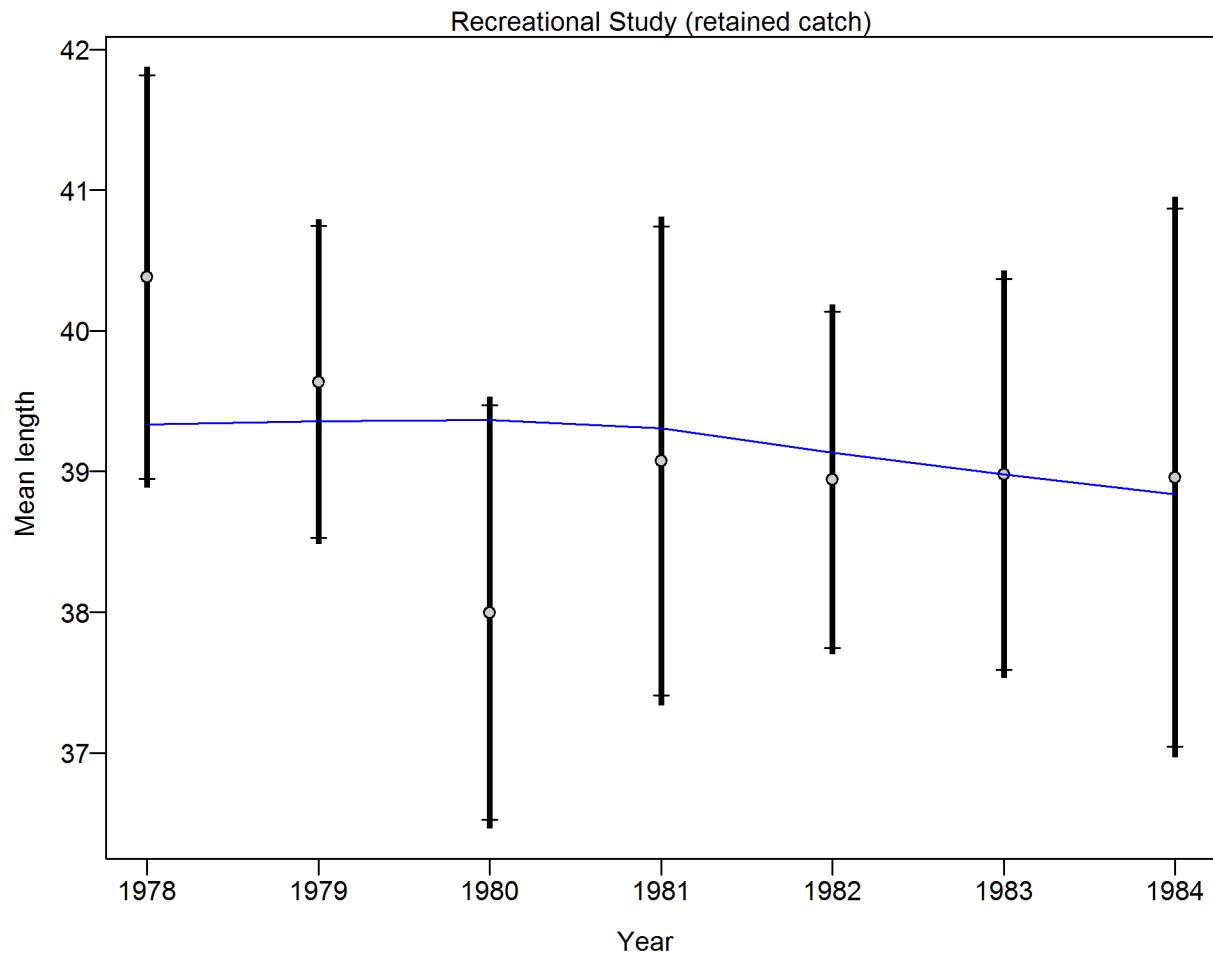


Figure 73: **Southern model** Mean length for Recreational Study with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for 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](#)

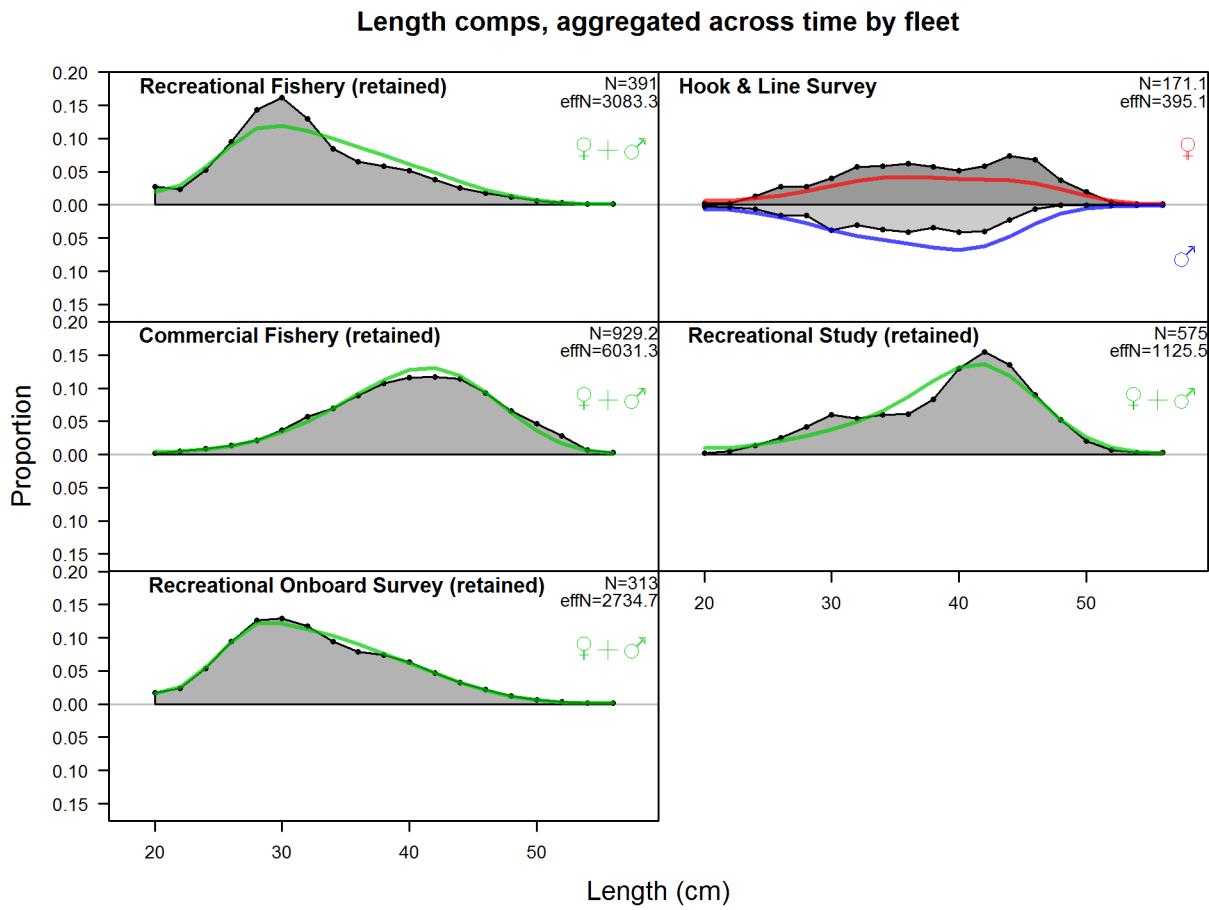


Figure 74: **Southern model** Length comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. [fig:mod2\\_21\\_comp\\_lenfit\\_\\_aggregated\\_across\\_time](#)

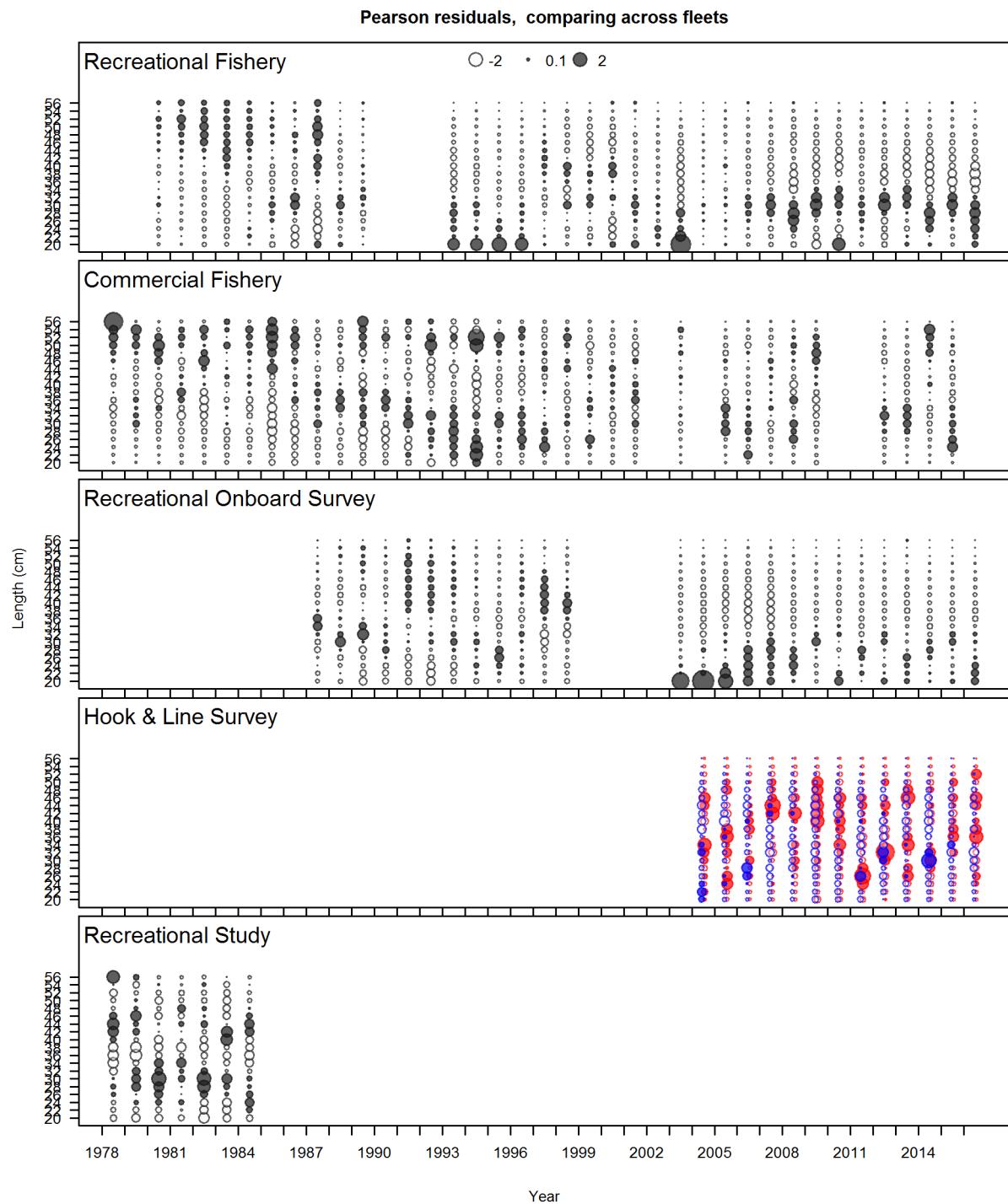


Figure 75: Length composition Pearson residuals for all fleets in the Southern model. Closed bubbles are positive residuals ( $\text{observed} > \text{expected}$ ) and open bubbles are negative residuals ( $\text{observed} < \text{expected}$ ). [fig:comp\\_Pearson\\_length\\_mod2](#)

1175 9.4.4 Age compositions for Southern model  
age-compositions-for-southern-model

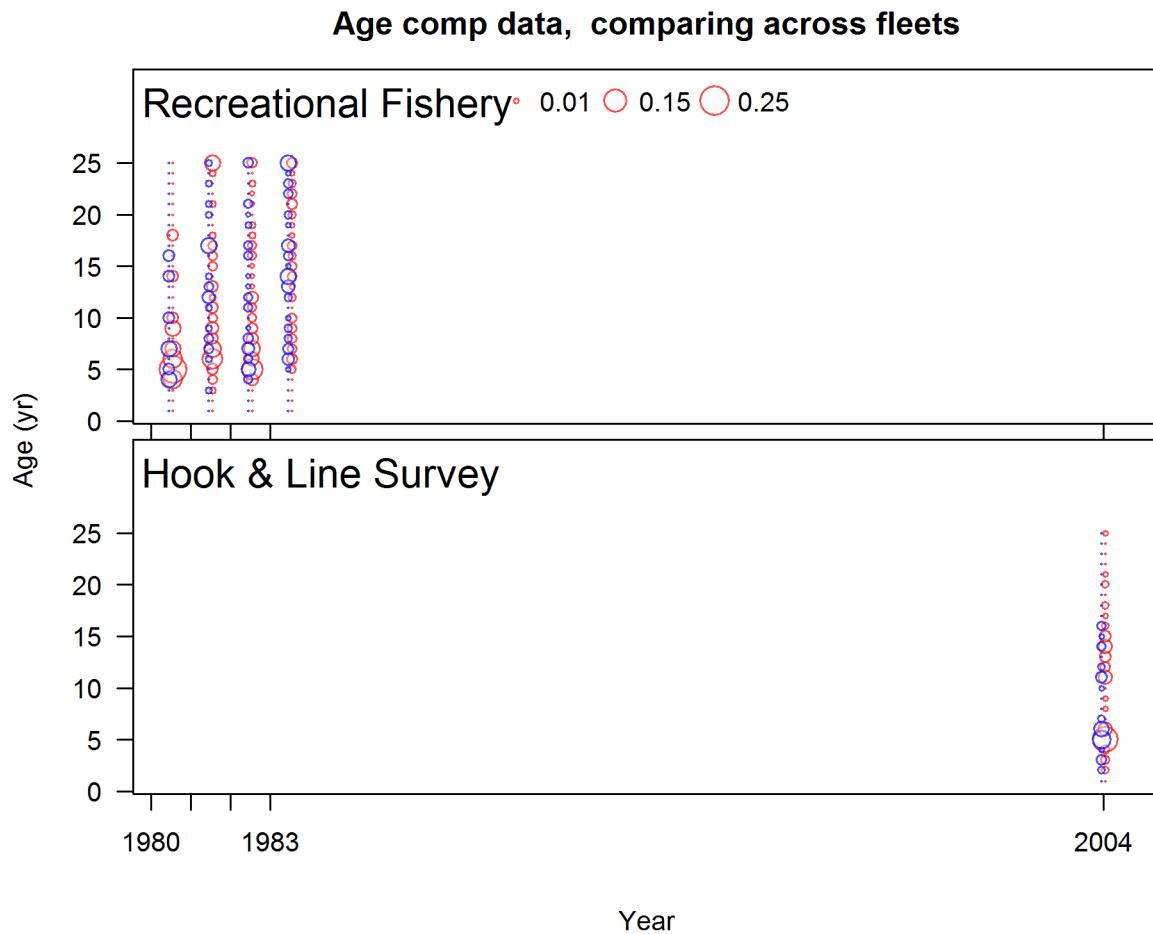


Figure 76: Age compositions for all fleets in the Southern model. Bubble size is proportional to proportions within each year. [fig:comp\\_age\\_bubble\\_mod2](#)

### Age comps, retained, Recreational Fishery

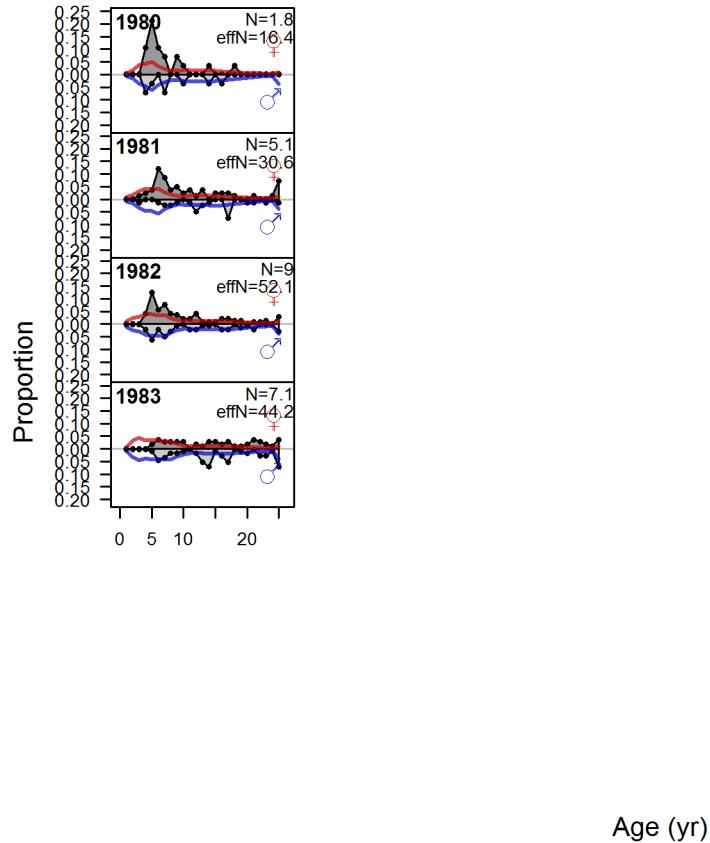


Figure 77: **Southern model** Age comps, retained, Recreational Fishery [fig:mod2\\_1\\_comp\\_agefi](#)

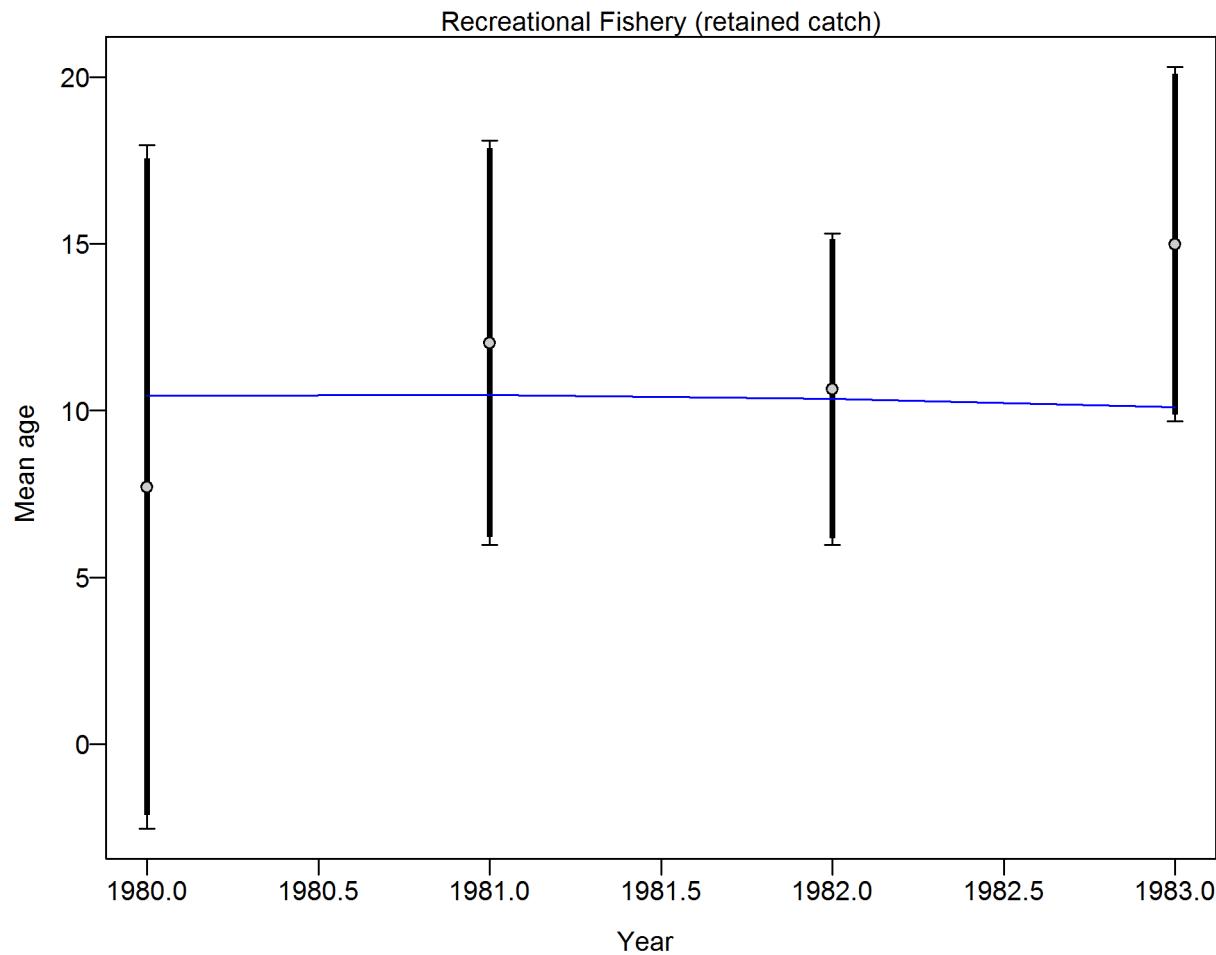
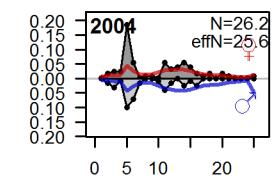


Figure 78: **Southern model** Mean age for Recreational Fishery with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for age 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](#)

**Age comps, whole catch, Hook & Line Survey**



Age (yr)

Figure 79: **Southern model** Age comps, whole catch, Hook & Line Survey `fig:mod2_5_comp_age`

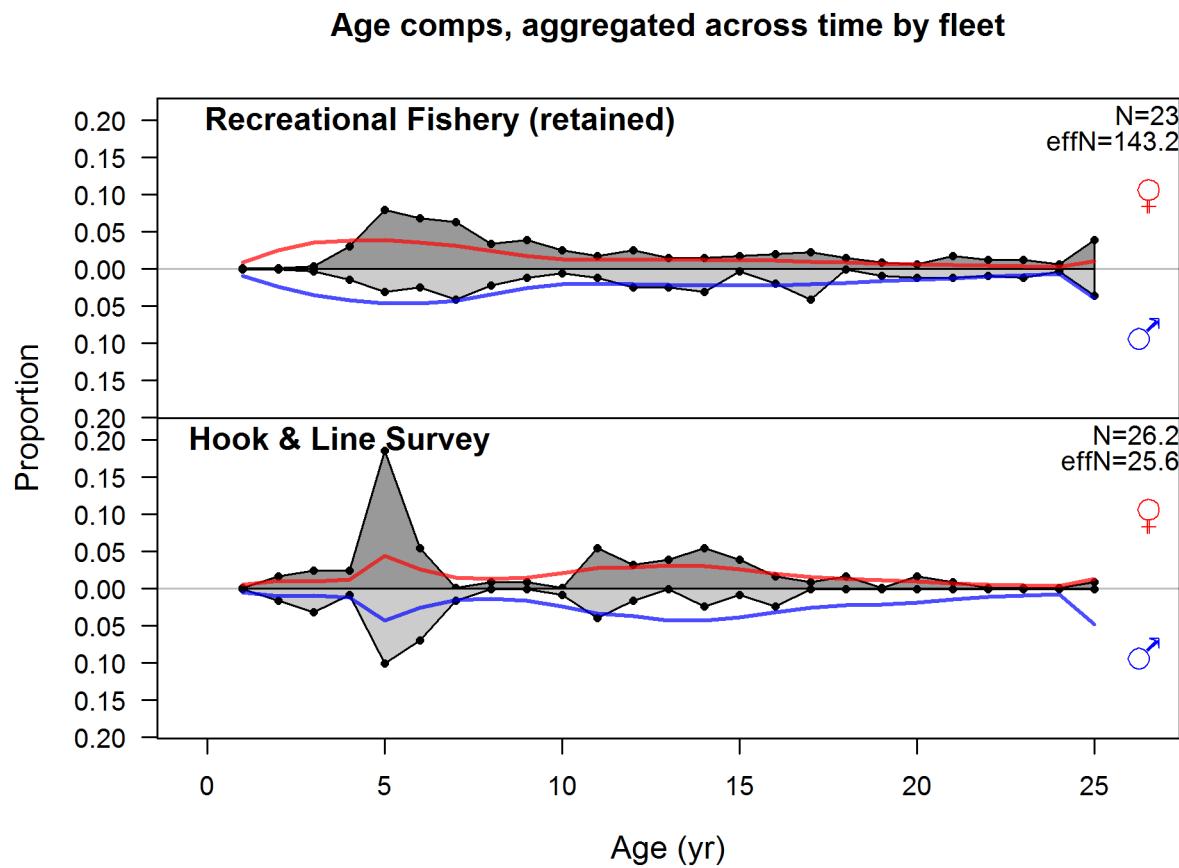


Figure 80: **Southern model** Age comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. [fig:mod2\\_9\\_comp\\_agerfit\\_\\_aggregated\\_across\\_time](#)

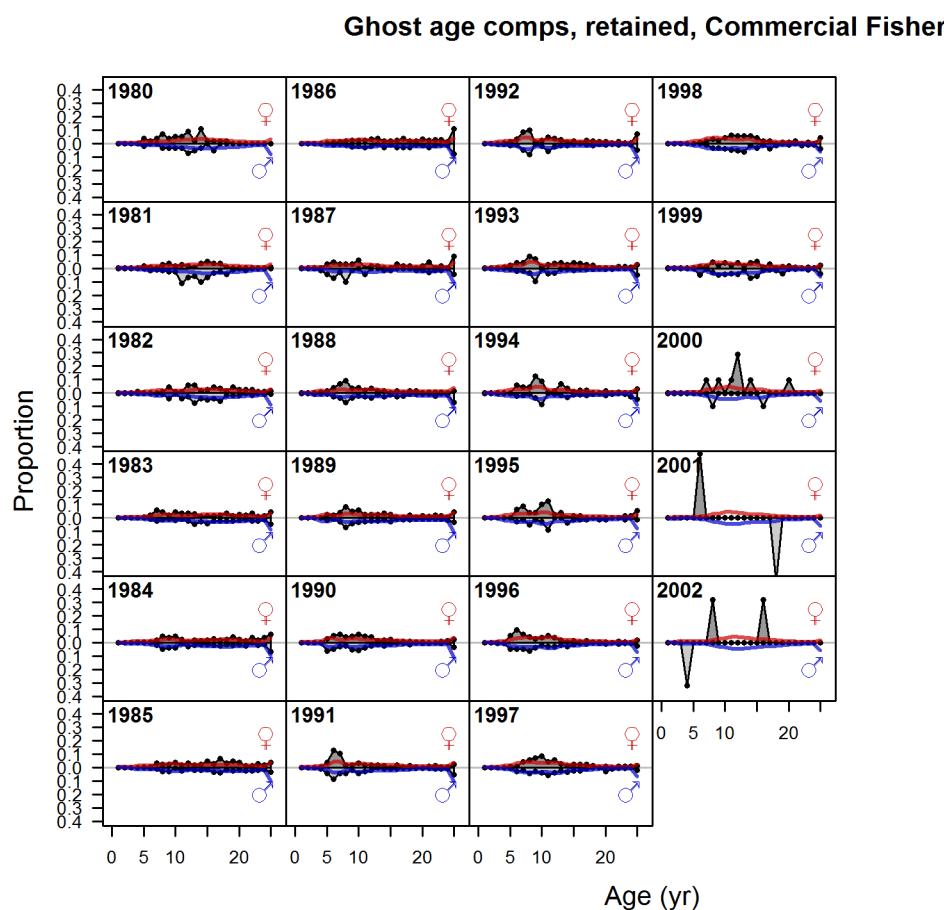


Figure 81: Southern model Ghost age comps, retained, Commercial Fishery fig:mod2\_11\_comp-g

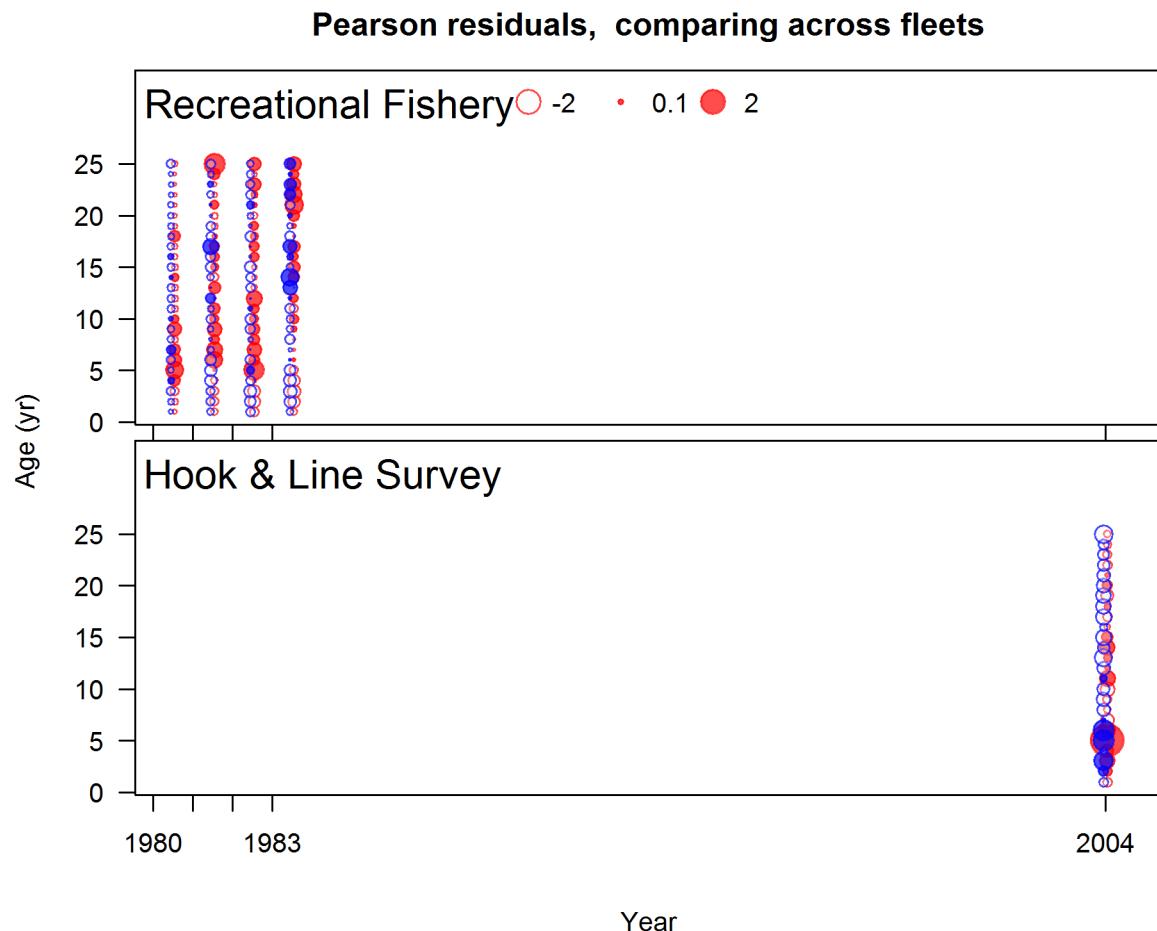


Figure 82: Age composition Pearson residuals for all fleets in the Southern model. Closed bubbles are positive residuals (observed  $>$  expected) and open bubbles are negative residuals (observed  $<$  expected). [fig:comp\\_Pearson\\_age\\_mod2](#)

1176 9.4.5 Fits to conditional-age-at-length compositions for Southern model  
fits-to-conditional-age-at-length-compositions-for-southern-model

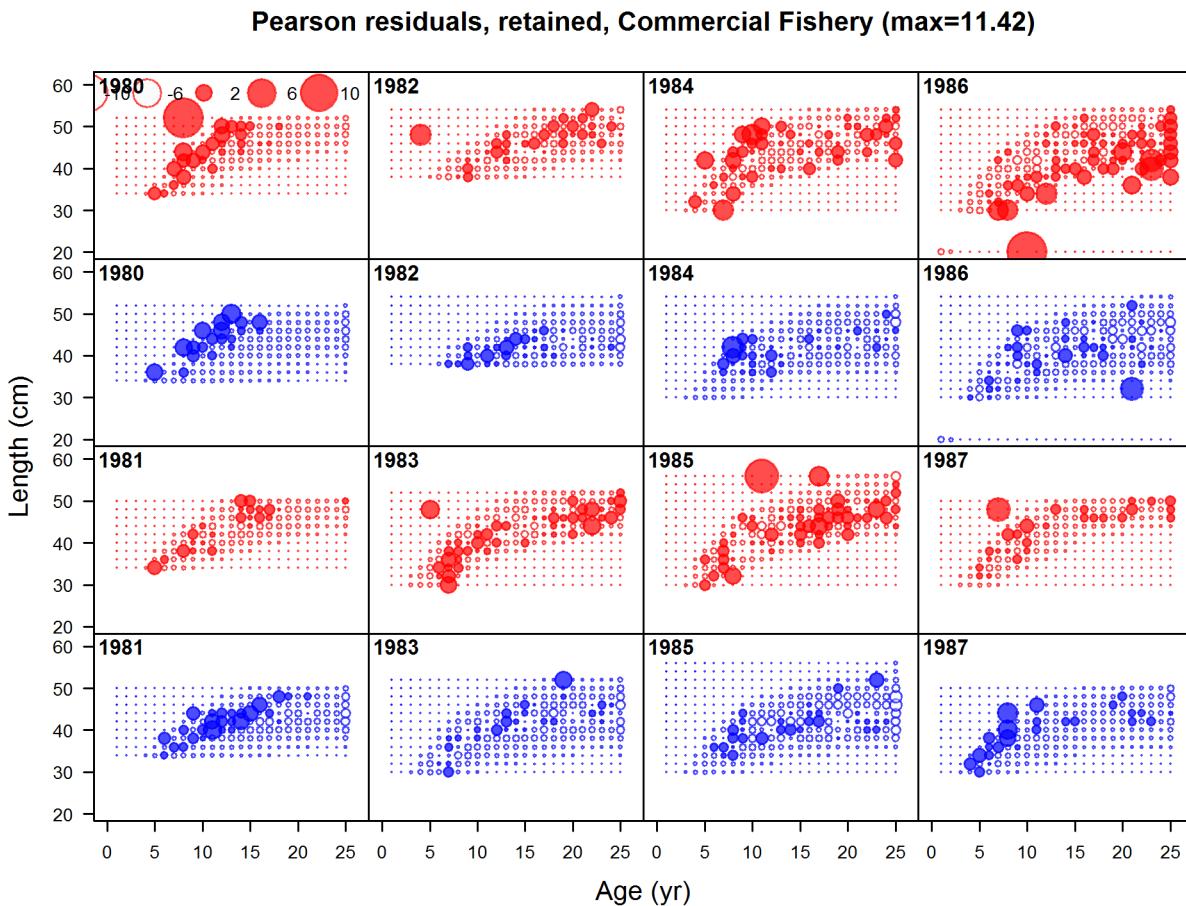
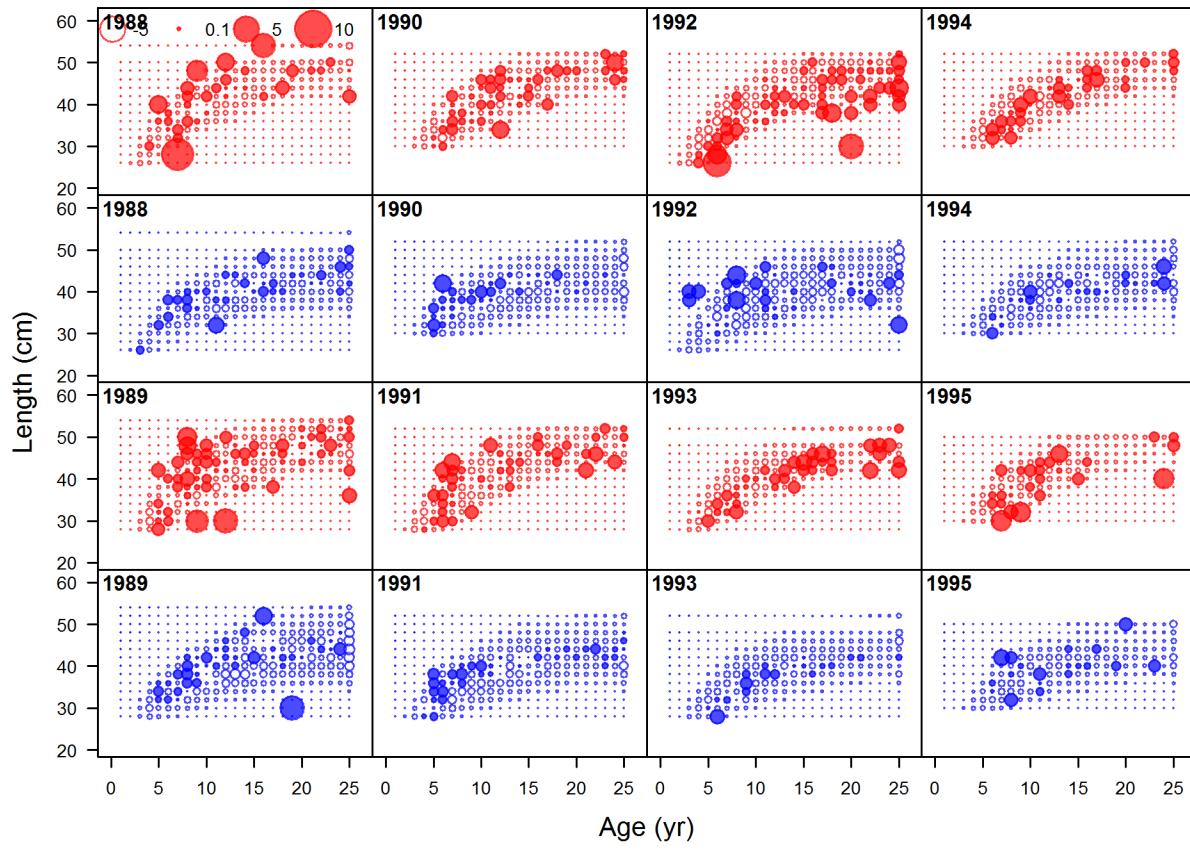


Figure 83: **Southern model** Pearson residuals, retained, Commercial Fishery (max=11.42)  
(plot 1 of 3) | fig:mod2\_1\_comp\_condAALfit\_residsfit2mkt2\_page1

Pearson residuals, retained, Commercial Fishery (max=11.42)

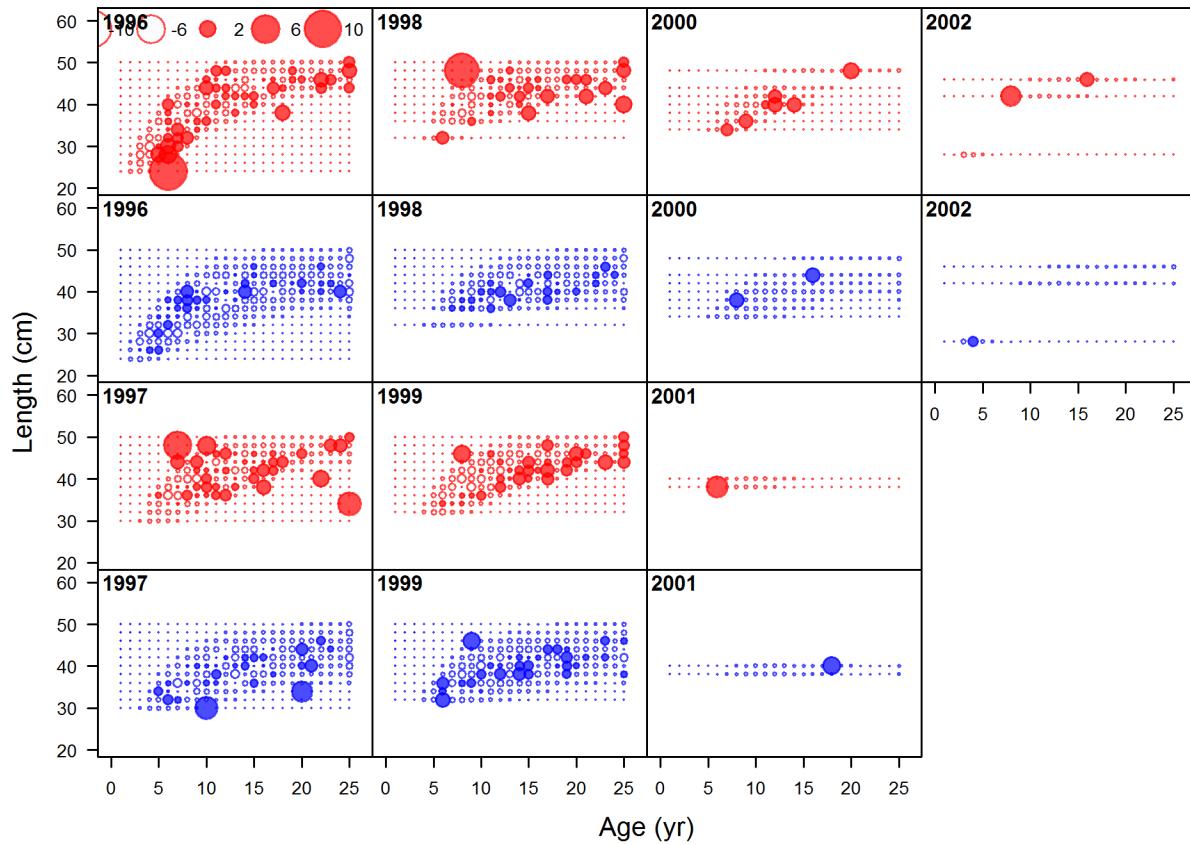


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**Pearson residuals, retained, Commercial Fishery (max=11.42)**



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Figure continued from previous page

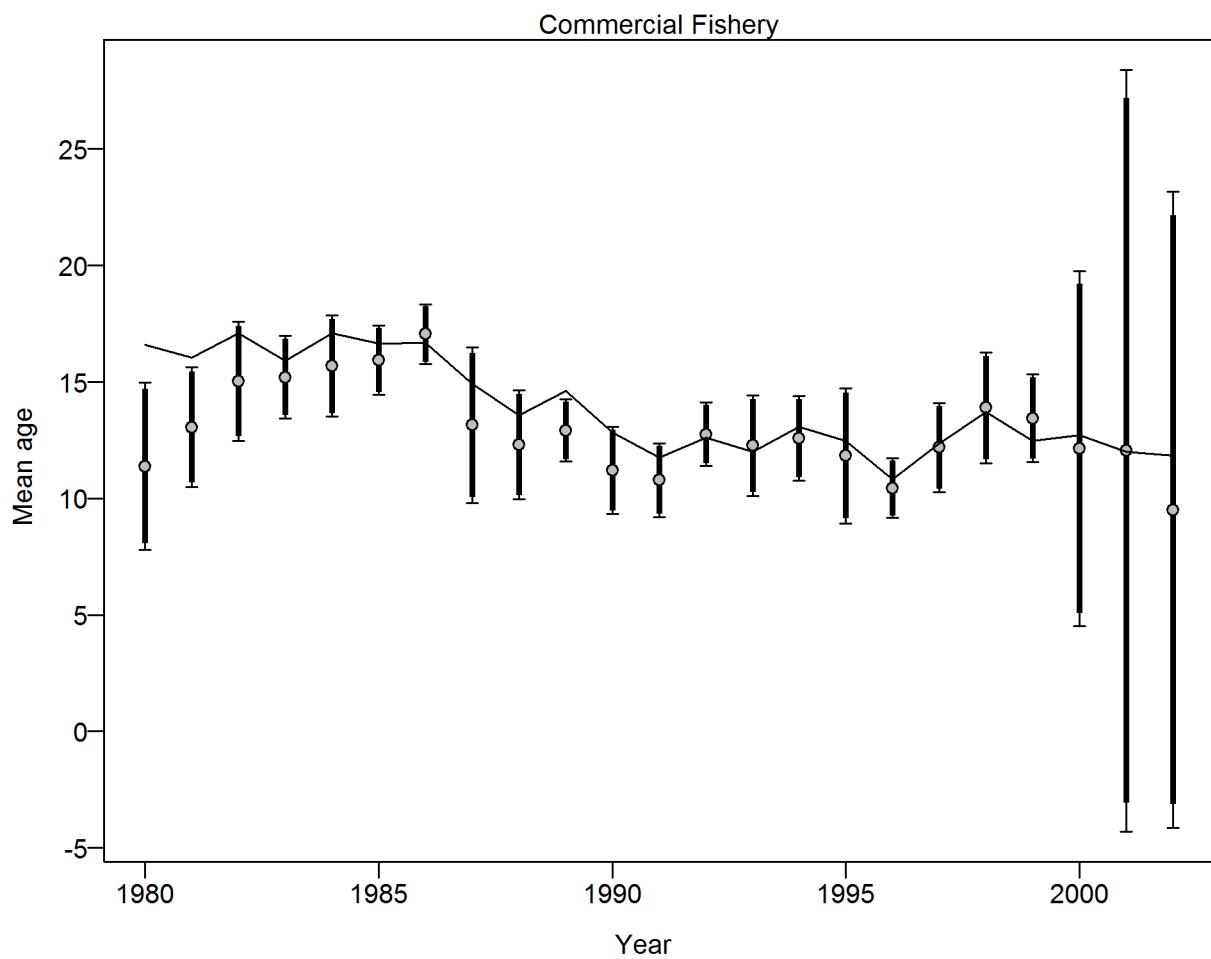


Figure 84: **Southern model** Mean age from conditional data (aggregated across length bins) for Commercial Fishery with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for 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](#)

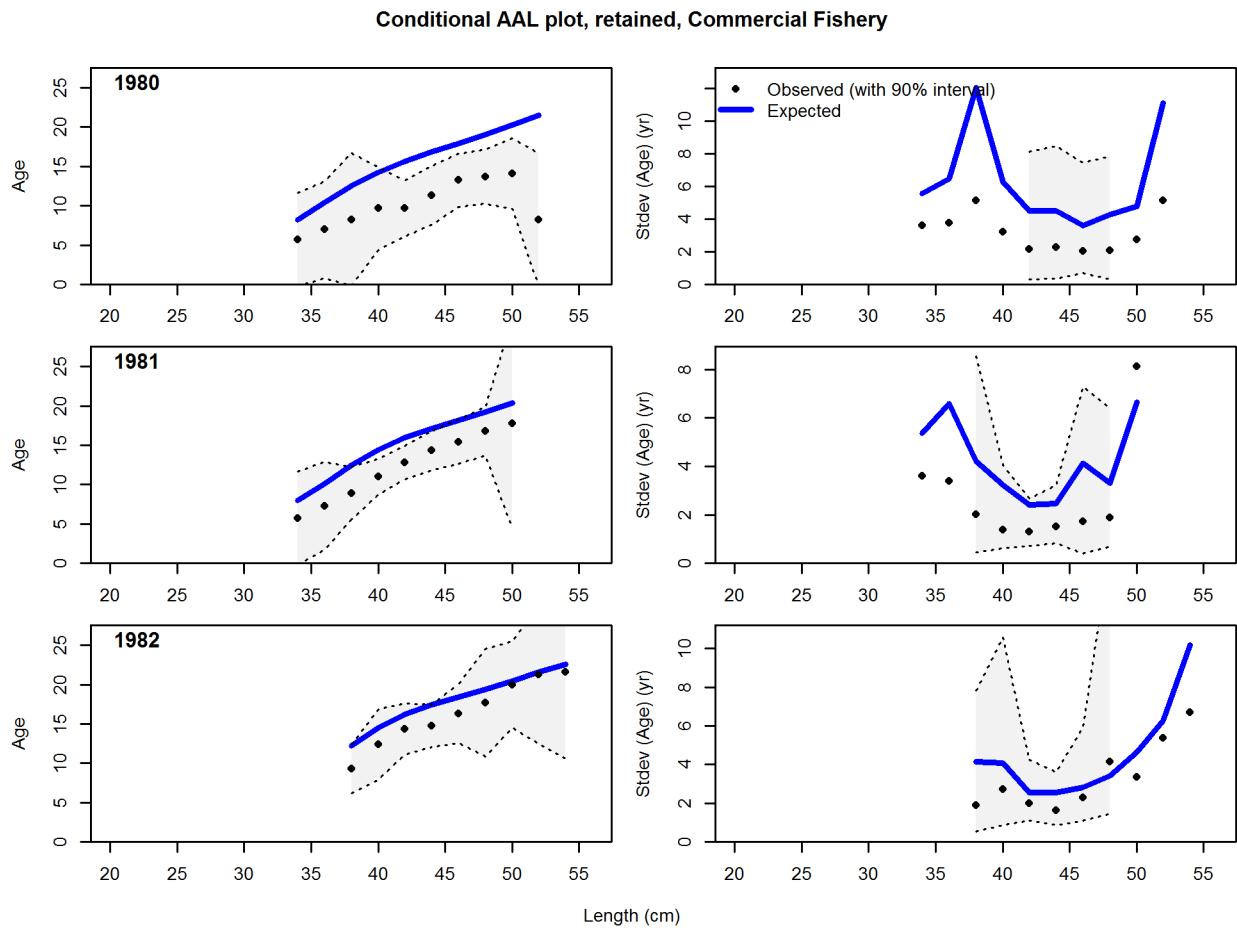
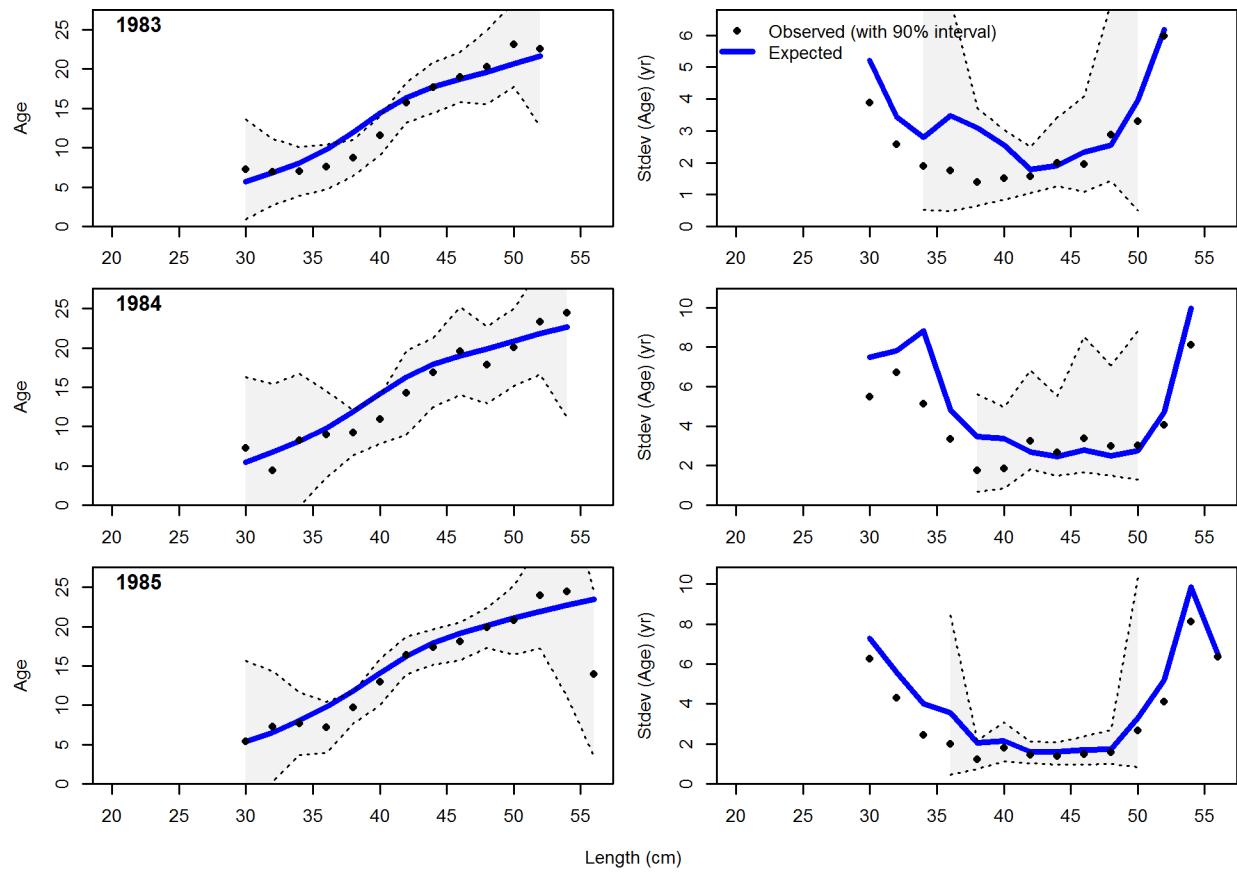


Figure 85: **Southern model** Conditional AAL plot, retained, Commercial Fishery (plot 1 of 8) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size\_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE 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**

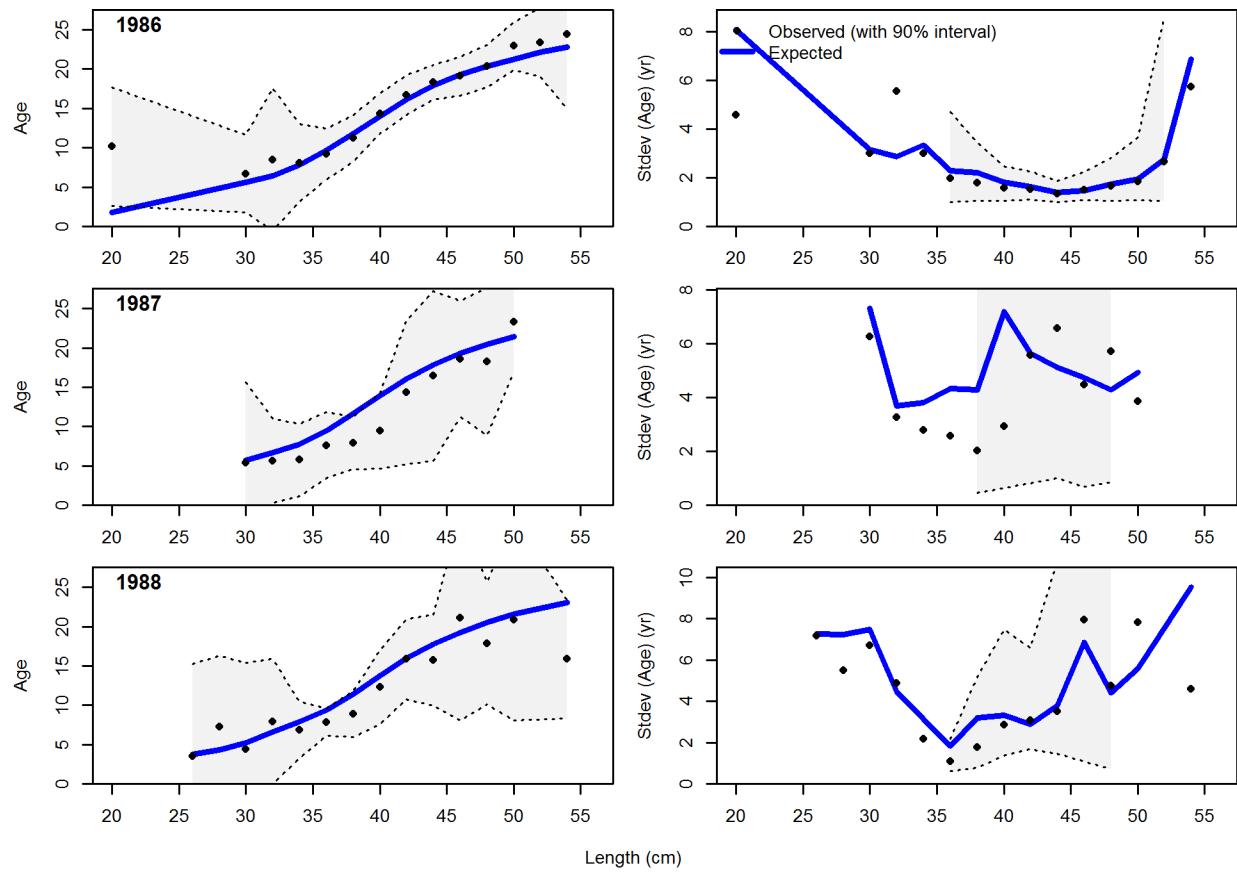


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Figure continued from previous page

**Conditional AAL plot, retained, Commercial Fishery**

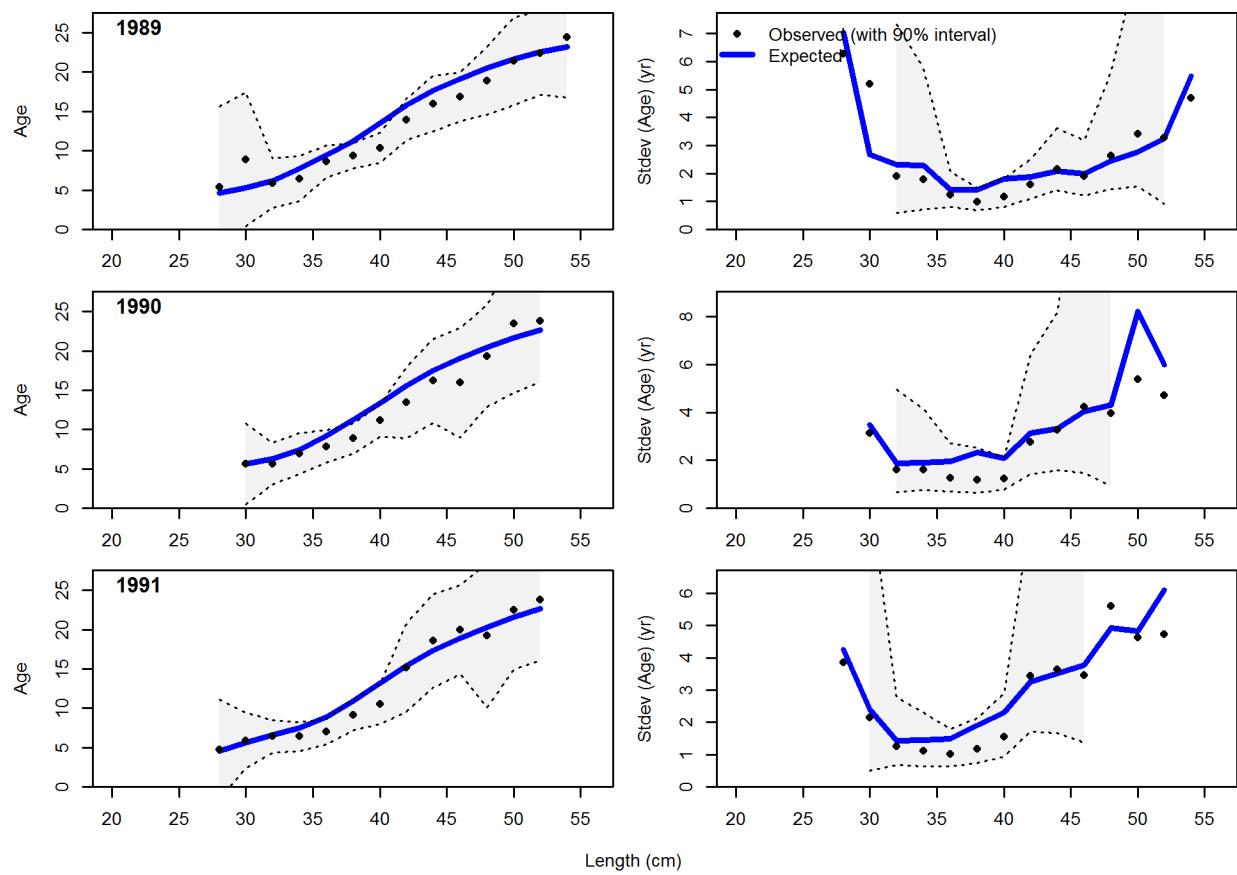


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**Conditional AAL plot, retained, Commercial Fishery**

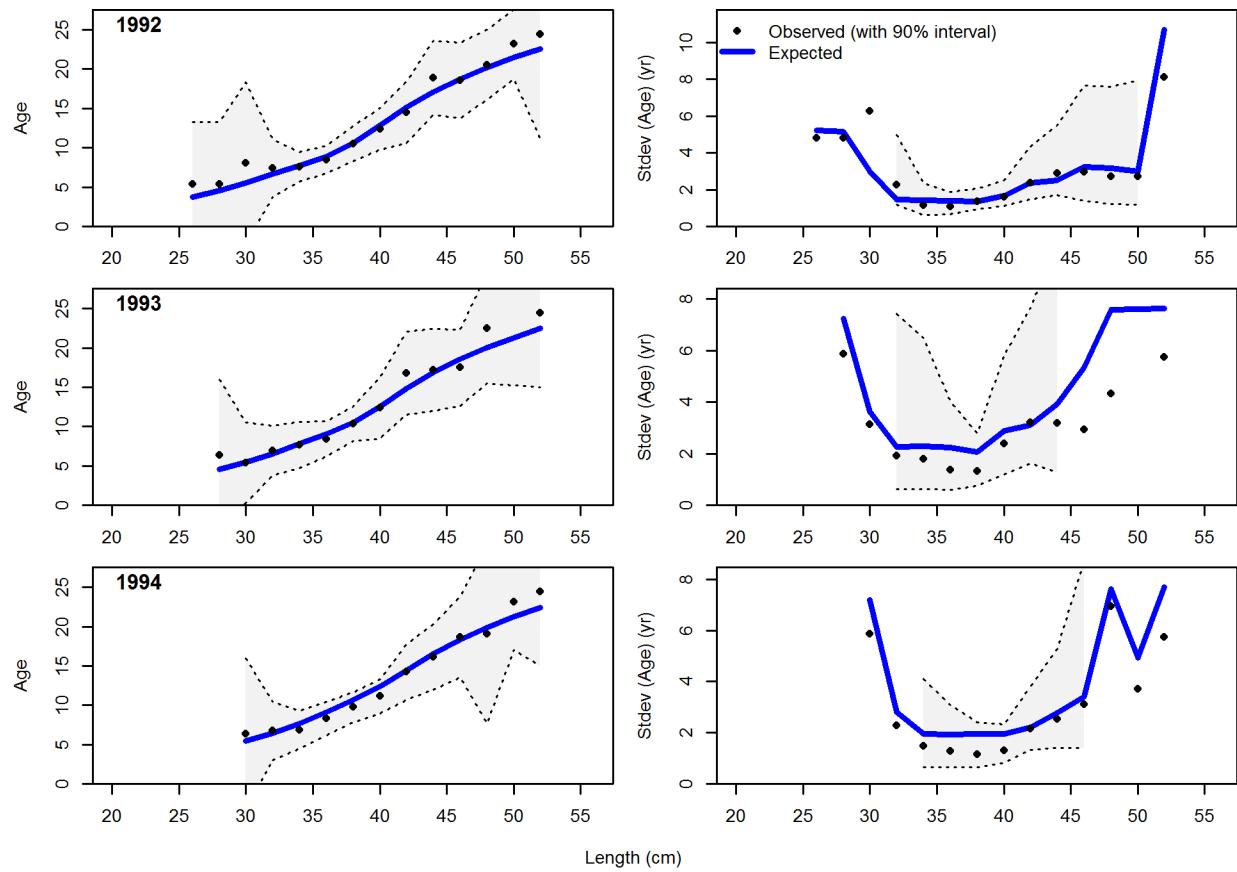


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**Conditional AAL plot, retained, Commercial Fishery**

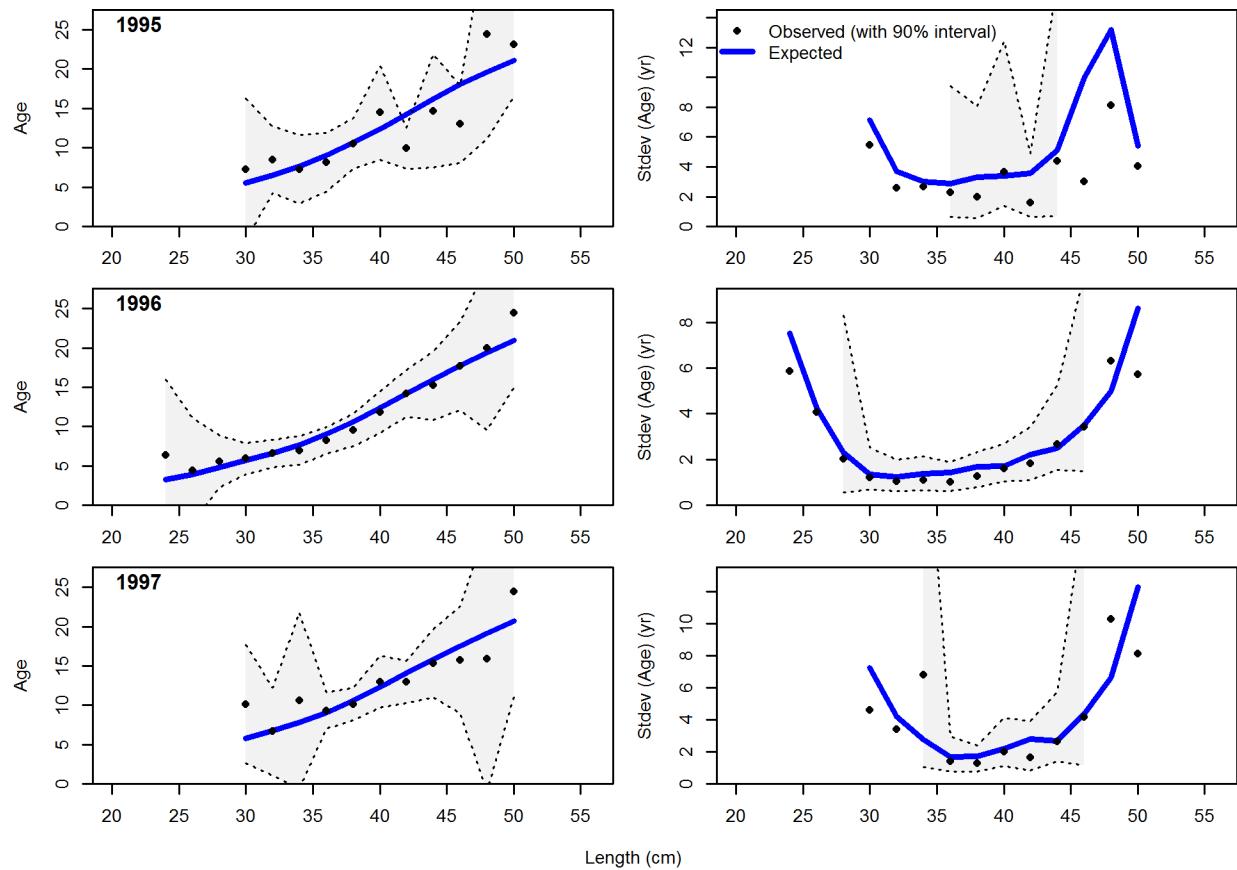


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Figure continued from previous page

**Conditional AAL plot, retained, Commercial Fishery**

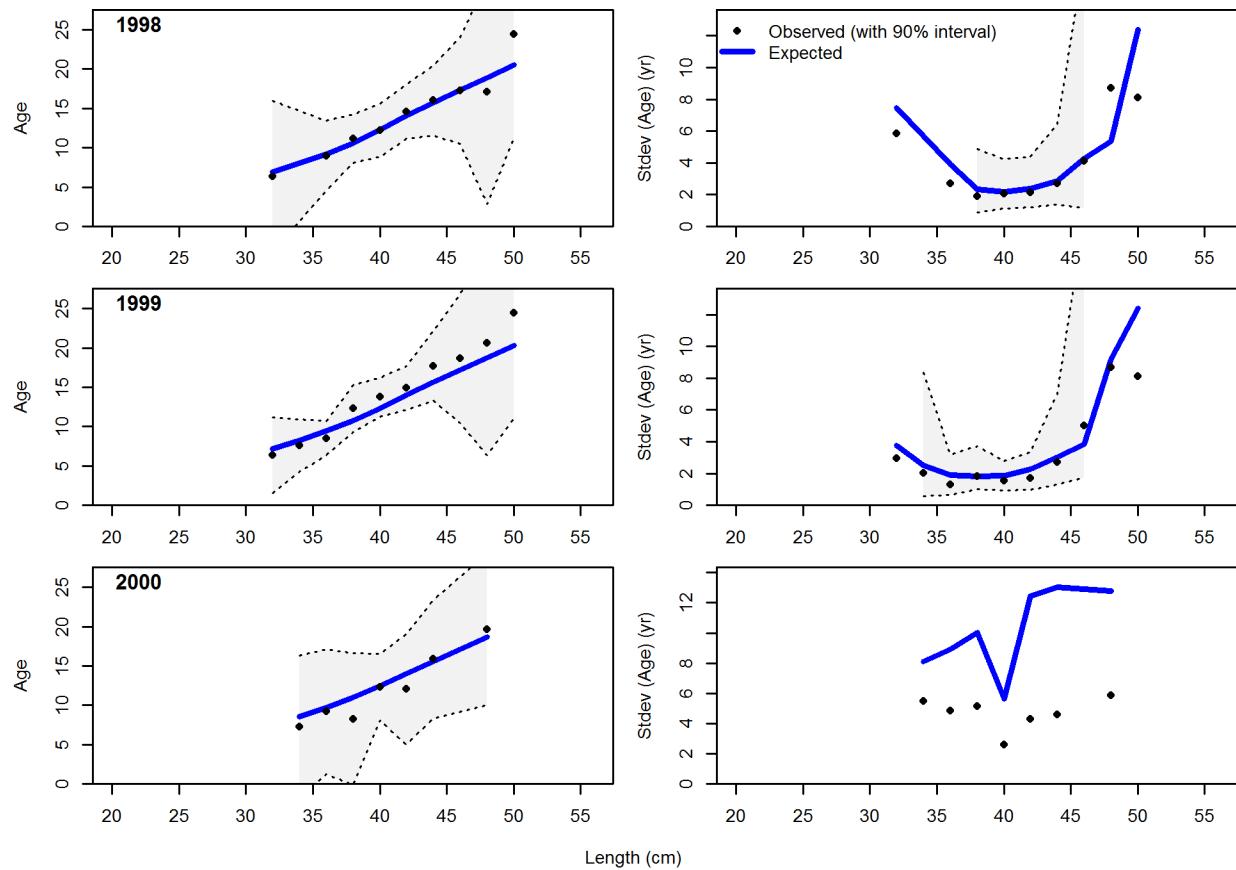


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**Conditional AAL plot, retained, Commercial Fishery**

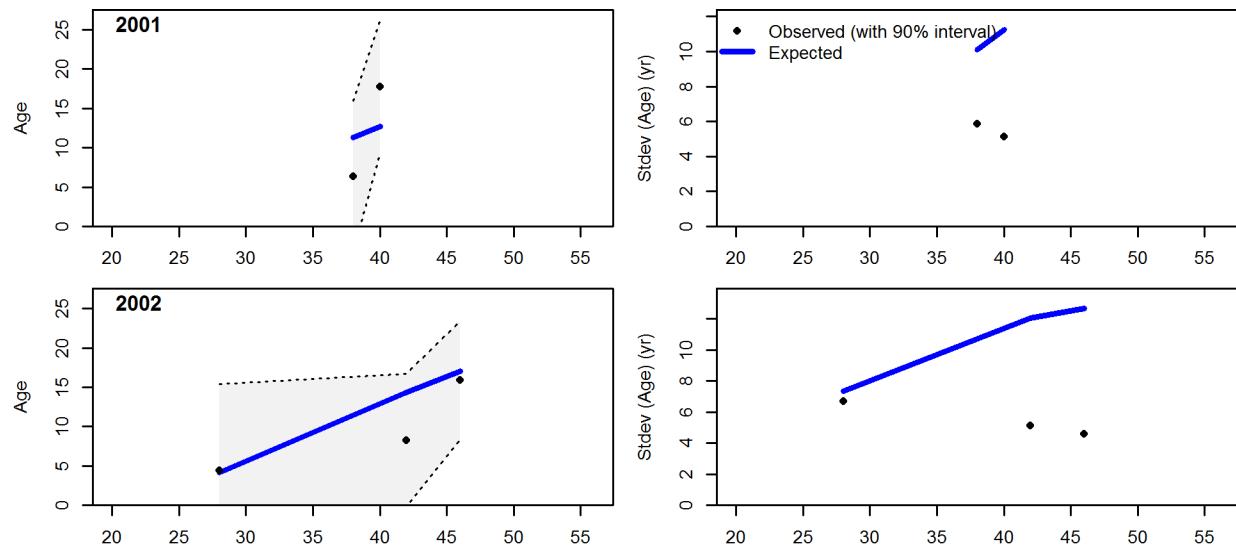


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**Conditional AAL plot, retained, Commercial Fishery**



Length (cm)

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Figure continued from previous page

1195 9.5 Model results for Southern model [model-results-for-southern-model](#)

1196 9.5.1 Base model results for Southern model [base-model-results-for-southern-model](#)

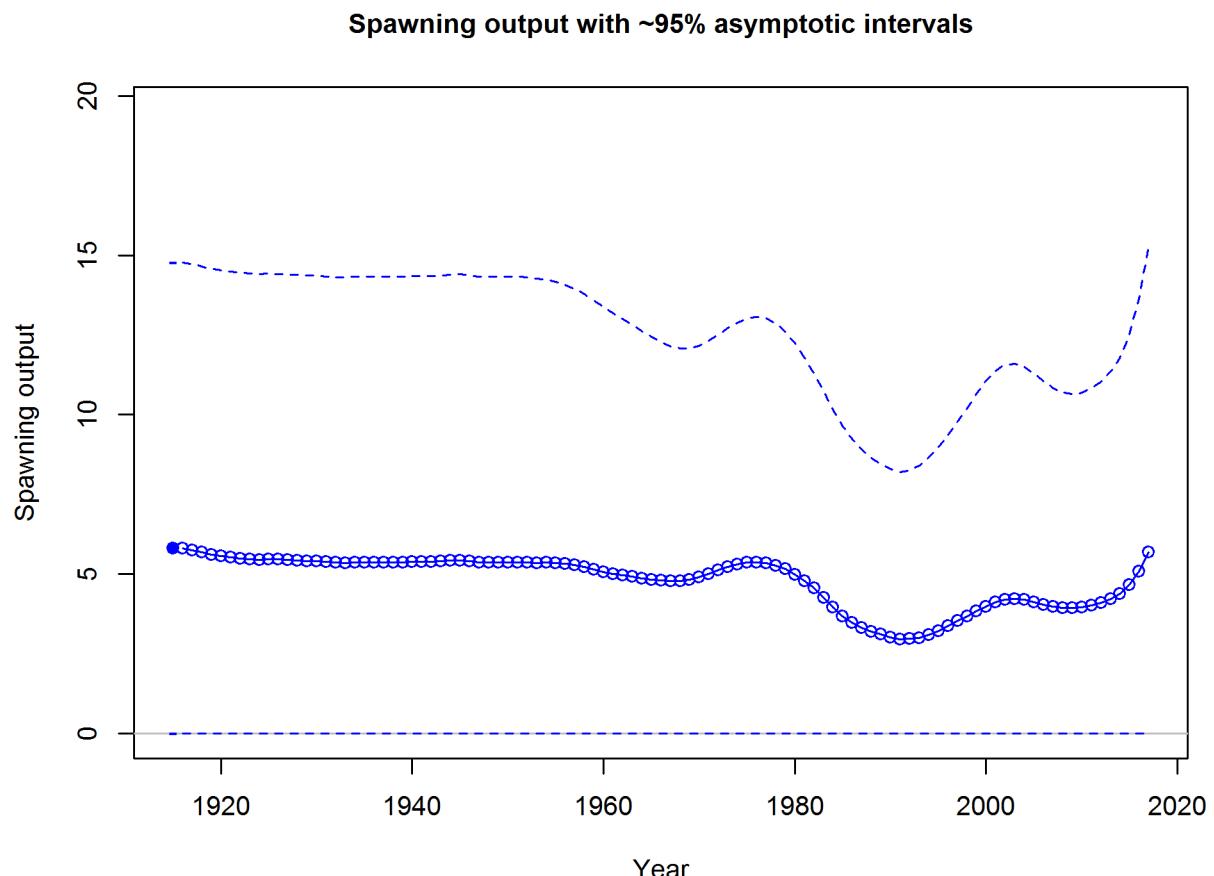


Figure 86: Estimated time-series of spawning output for Southern model. [fig:ssb.S](#)

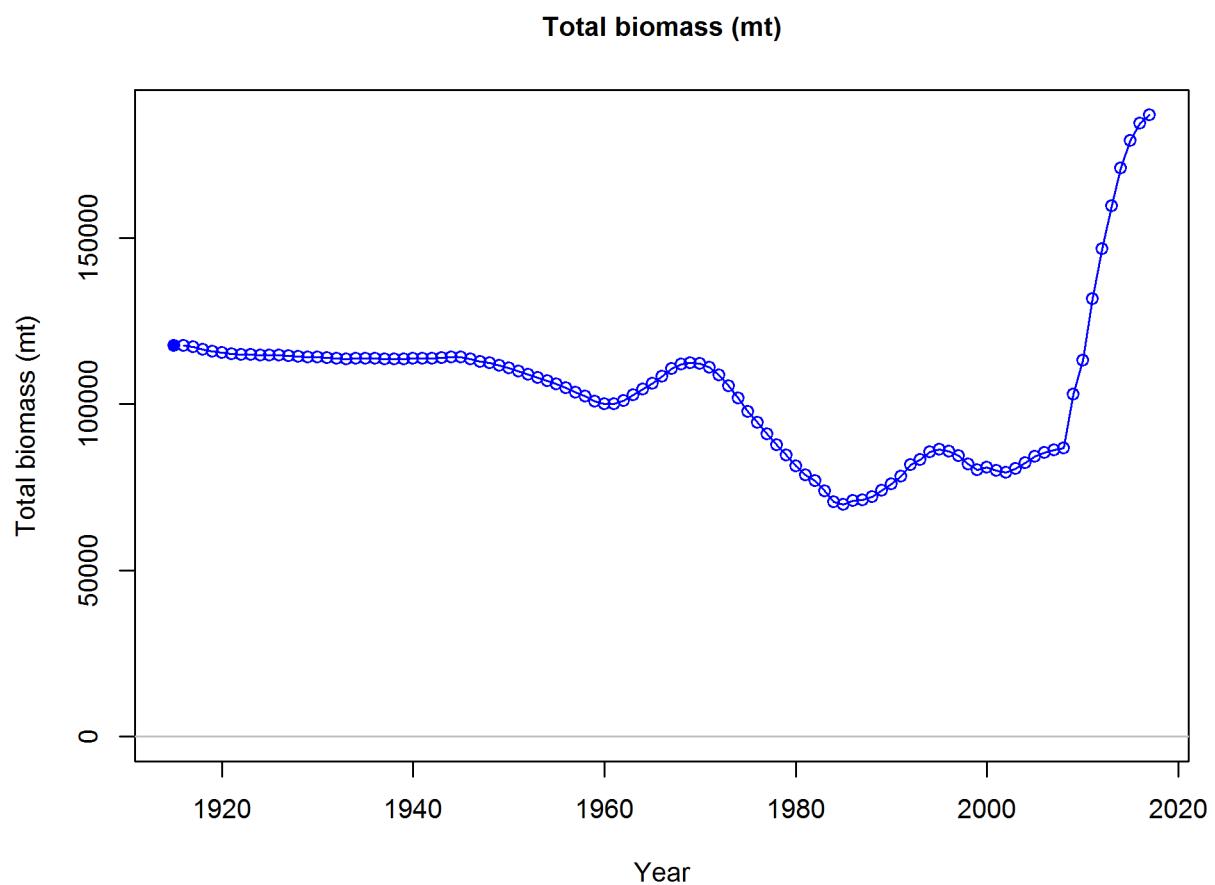


Figure 87: Estimated time-series of total biomass for Southern model. `fig:total_bio.S`

### Spawning depletion with ~95% asymptotic intervals

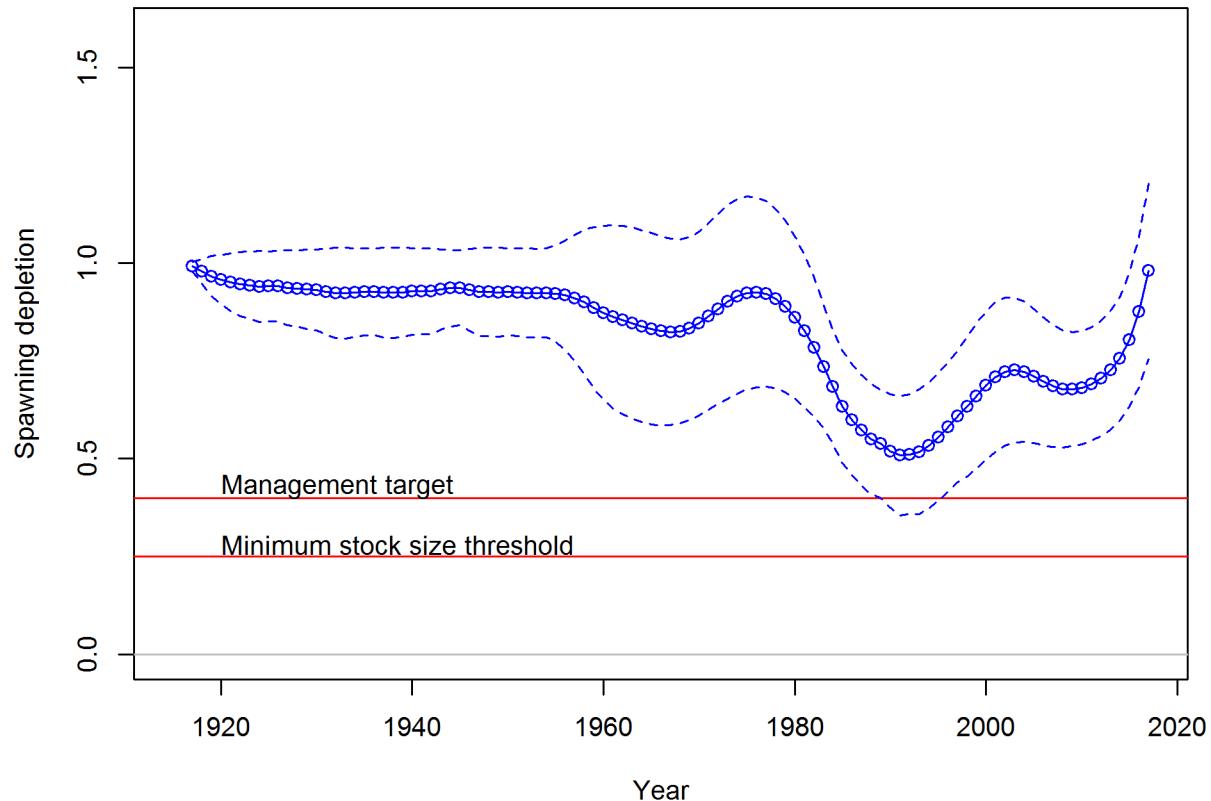


Figure 88: Estimated time-series of relative biomass for Southern model. [fig:depl.S](#)

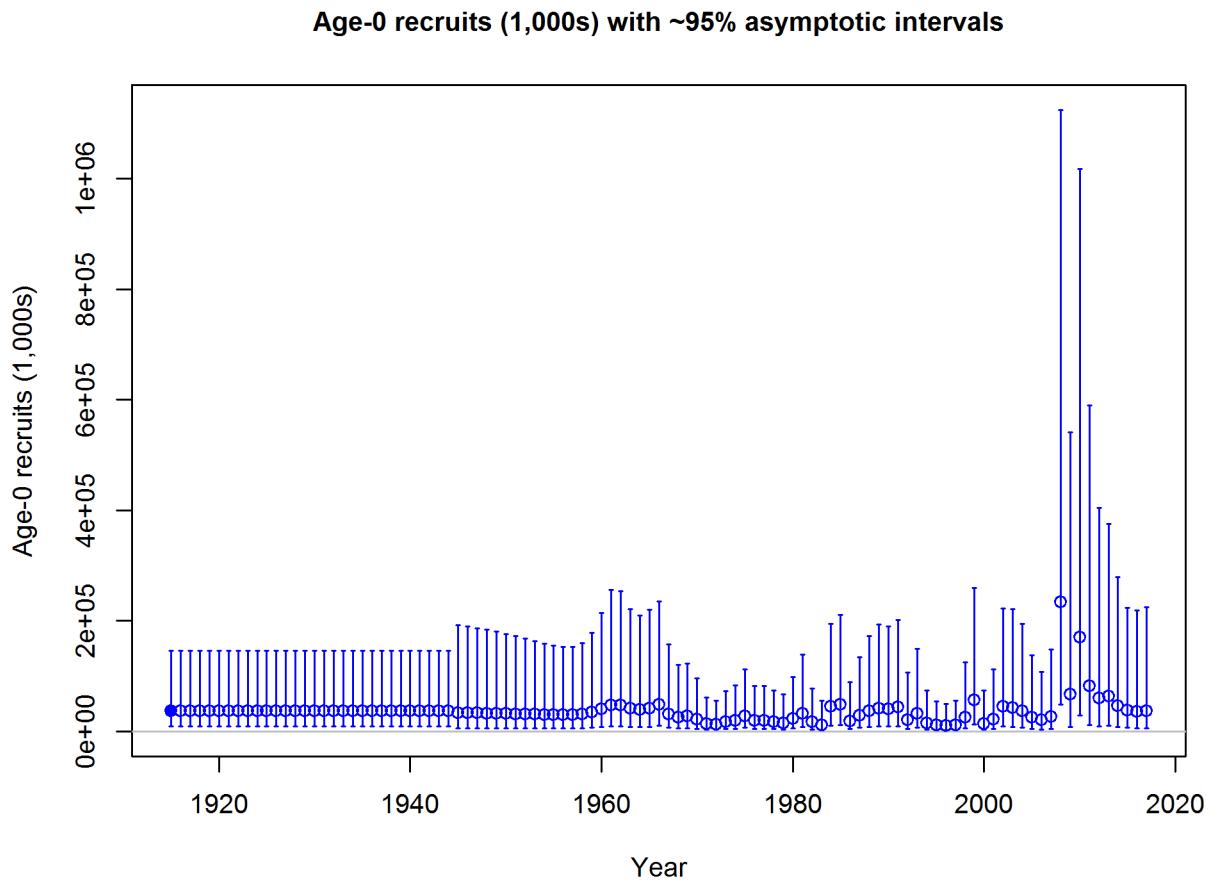


Figure 89: Estimated time-series of recruitment for the Southern model. fig:recruits1.S

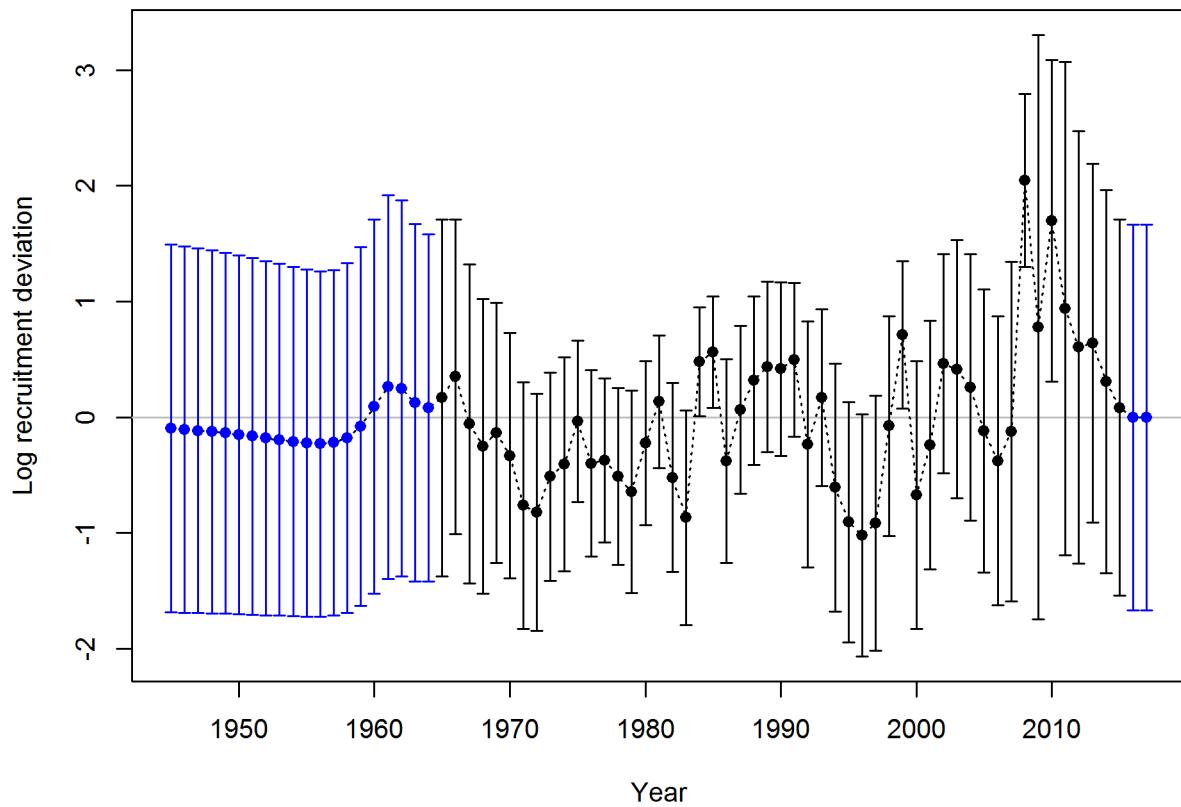


Figure 90: Estimated time-series of recruitment deviations for the Southern model. `fig:recdevs1.S`

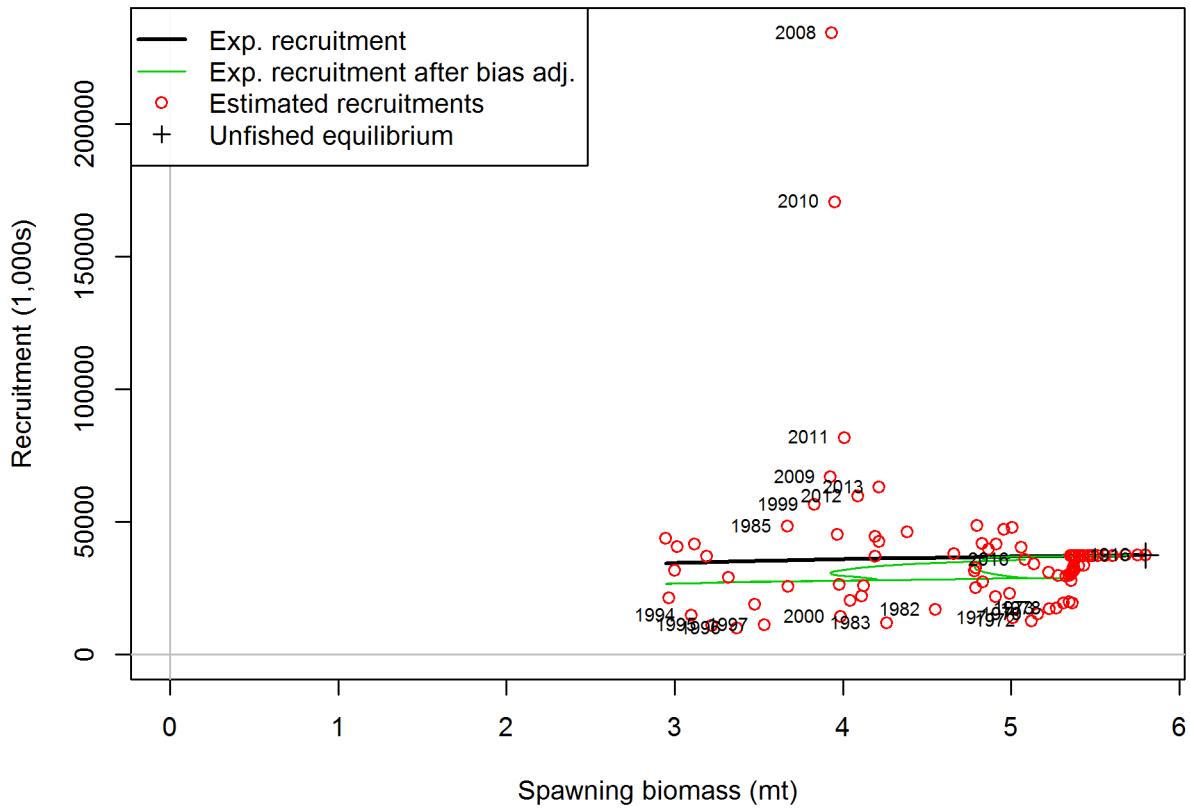


Figure 91: Estimated recruitment (red circles) for the Southern model relative to the stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution [fig:stock\\_recruit\\_curve.S](#)

1197 9.5.2 Sensitivity analyses for Southern model  
sensitivity-analyses-for-southern-model

1198 to be added...

1199 9.5.3 Likelihood profiles for Southern model  
likelihood-profiles-for-southern-model

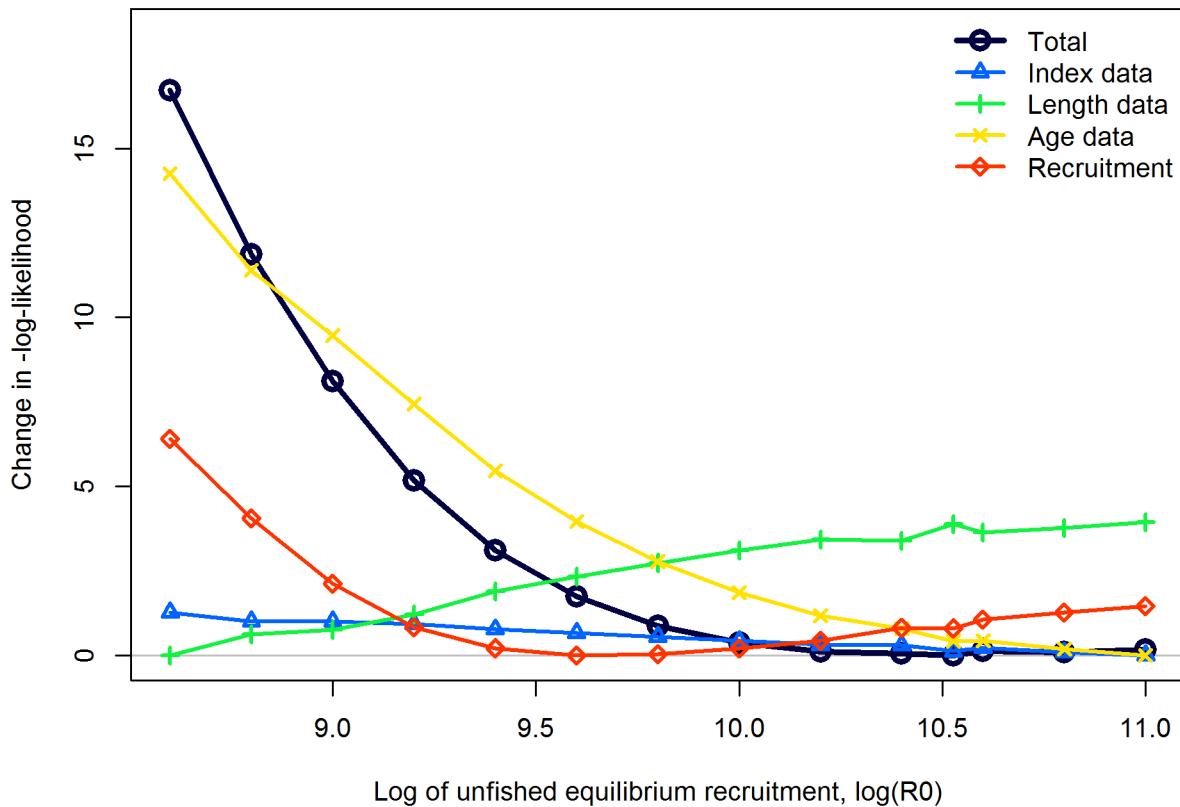


Figure 92: Likelihood profile over the log of equilibrium recruitment ( $R_0$ ) for the Southern model. | [fig:profile\\_logR0.S](#)

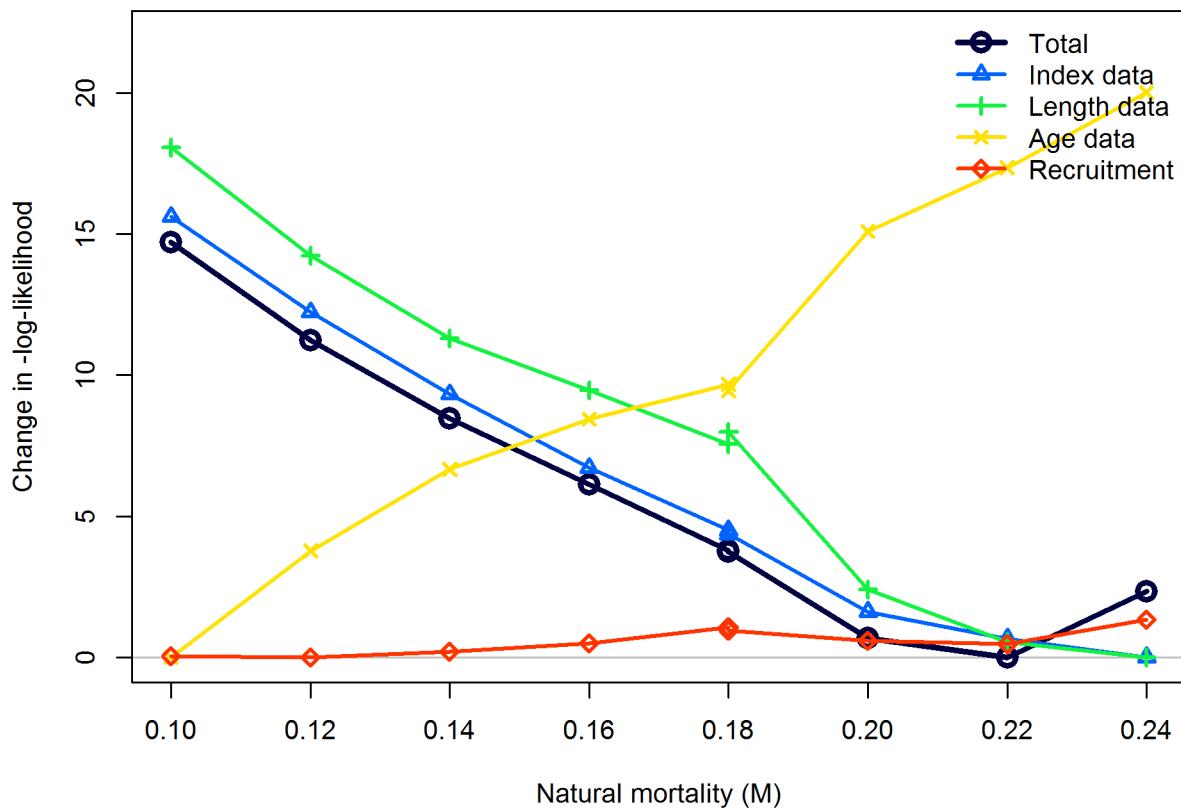


Figure 93: Likelihood profile over female natural mortality for the Southern model. `fig:profile_M.S`

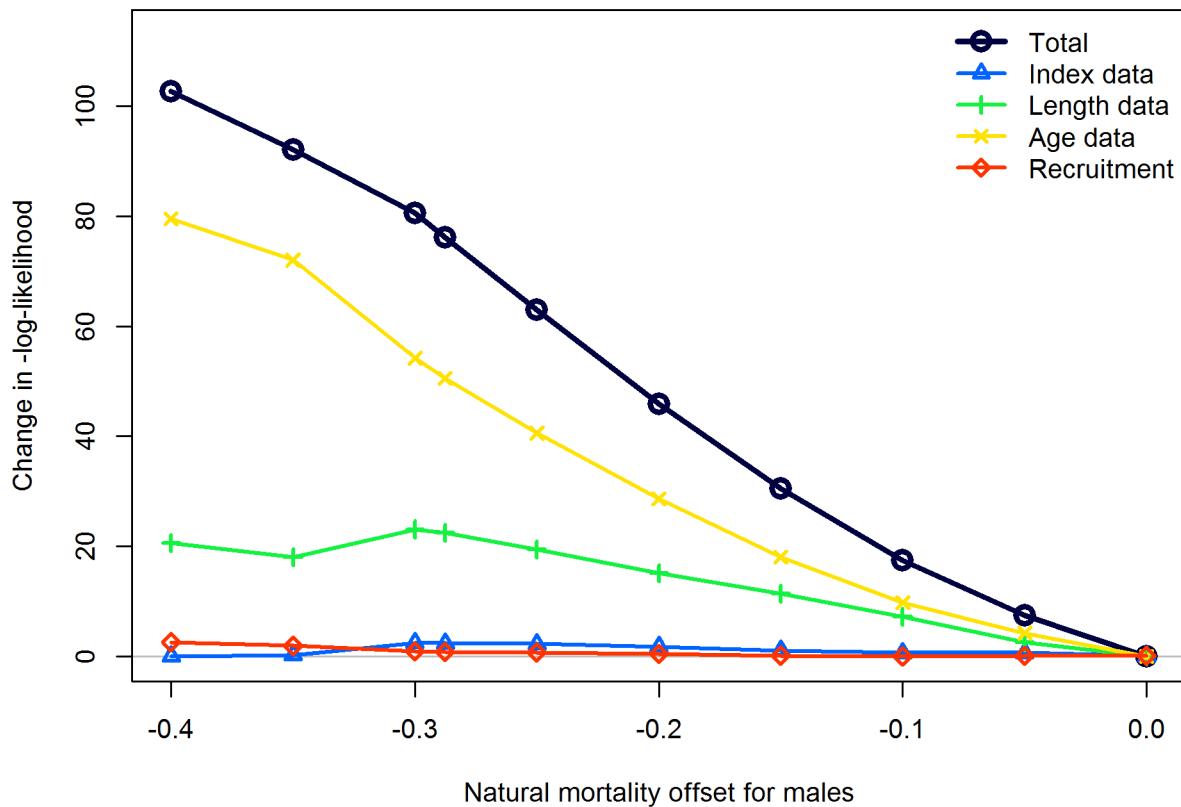


Figure 94: Likelihood profile over the male offset for natural mortality for the Southern model.  
Negative values are associated with natural mortality being lower for males than females. [fig:profile\\_M2](#)

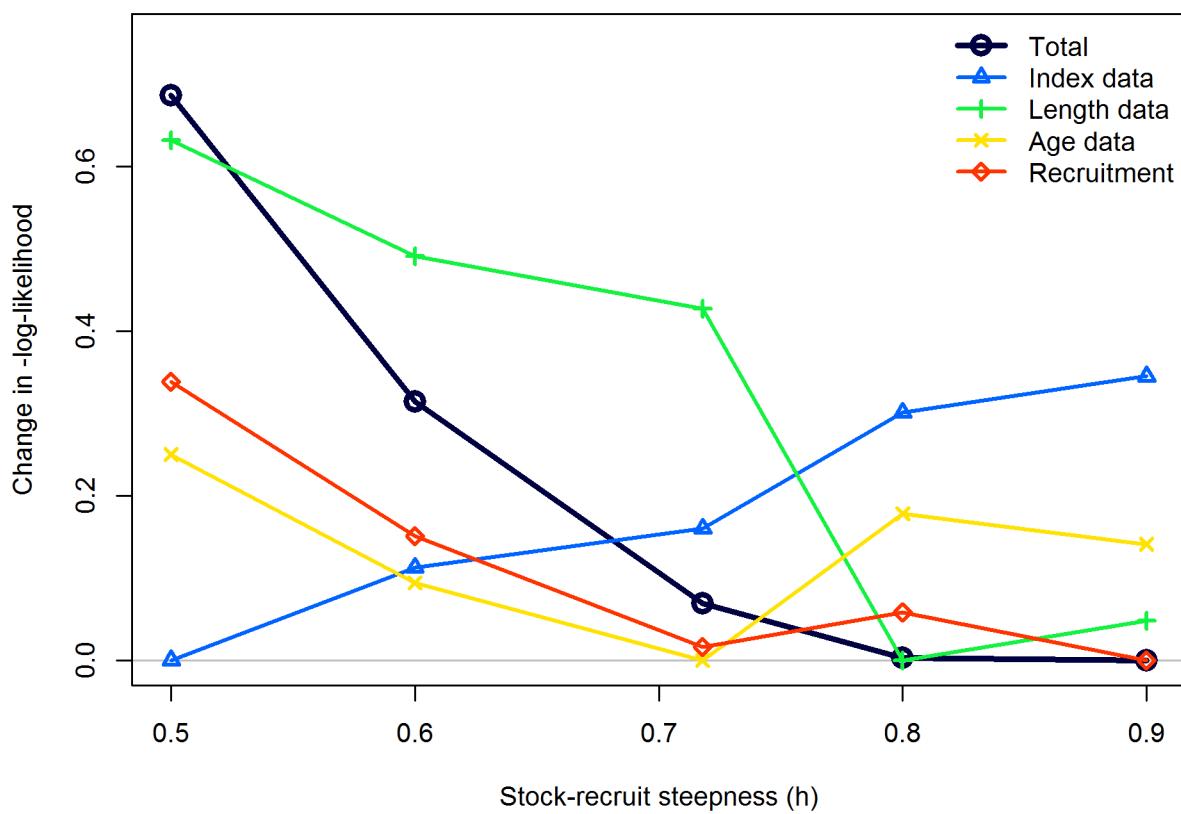


Figure 95: Likelihood profile over stock-recruit steepness ( $h$ ) for the Southern model. `fig:profile_h.S`

1200 **9.5.4 Retrospective analysis for Southern model**  
retrospective-analysis-for-southern-model

1201 Retrospective analysis of spawning output for the Southern model. [`fig:retro.S`](#)

1202 **9.5.5 Forecasts analysis for Southern model**  
forecasts-analysis-for-southern-model

1203 to be added...



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