

<sup>1</sup> Status of Pacific ocean perch (*Sebastodes alutus*) along the US west coast in 2017

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DRAFT SAFE

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# Status of Pacific ocean perch (*Sebastodes alutus*) along the US west coast in 2017

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## <sup>89</sup> Executive Summary

### <sup>90</sup> Stock

<sup>91</sup> This assessment reports the status of the Pacific ocean perch rockfish (*Sebastodes alutus*) off  
<sup>92</sup> the US west coast from Northern California to the Canadian Border using data through  
<sup>93</sup> 2017. Pacific ocean perch are most abundant in the Gulf of Alaska and have been observed off of  
<sup>94</sup> Japan, in the Bering Sea, and south to Baja California, although they are sparse south of  
<sup>95</sup> Oregon and rare in southern California. Although catches north of the US-Canada border  
<sup>96</sup> were not included in this assessment, it is not certain the connectivity of these populations  
<sup>97</sup> with contribution to the biomass possibly through adult migration and/or larval dispersion.  
<sup>98</sup> To date, no significant genetic differences have been found in the range covered by this  
<sup>99</sup> assessment.

### <sup>100</sup> Landings

<sup>101</sup> The first year that harvest of Pacific ocean perch exceeded 1 mt off the US west coast  
<sup>102</sup> first occurred in 1918. Catches ramped up in the 1940s with large removals in Washington  
<sup>103</sup> waters. During the 1950s the removals primarily occurred in Oregon waters with catches from  
<sup>104</sup> Washington declining following the 1940s. The largest removals occurring between 1966-1968  
<sup>105</sup> were largely a result of harvest by foreign vessels. The fishery proceeded with more moderate  
<sup>106</sup> removals ranging between 1165 to 2619 metric tons (mt) per year between 1969 and 1980.  
<sup>107</sup> Removals generally declined from 1981 to 1994 to between 1031 and 1616 mt per year. Pacific  
<sup>108</sup> ocean perch was declared overfished in 1999, resulting in large reductions in harvest in recent  
<sup>109</sup> years since the declaration. Since 2000, landings of Pacific ocean perch have ranged between  
<sup>110</sup> 54-267 mt, with landings in 2016 totaling 65 mt.

<sup>111</sup> Pacific ocean perch are a desirable market species and discarding has historically been low.  
<sup>112</sup> However, management restrictions (e.g. trip limits) have resulted in increased discarding since  
<sup>113</sup> the early 1990s. During the 2000s discarding increased for Pacific ocean perch due to harvest  
<sup>114</sup> restrictions imposed to allow rebuilding, with estimated discard rates from the bottom trawl  
<sup>115</sup> fishery peaking in 2009 and 2010 to discard rates of 50.4%, prior to implementation of catch  
<sup>116</sup> shares in 2011. Since 2011, discarding of Pacific ocean perch has been estimated to be less  
<sup>117</sup> than 3.5% based on observer data.

Table a: Landings (mt) for the past 10 years for Pacific ocean perch by fleet.

Year	California	Oregon	Washington	At-sea hake	Survey	Total Landings
2007	0.15	83.65	45.12	4.05	0.58	133.55
2008	0.39	58.64	16.61	15.93	0.80	92.36
2009	0.92	58.74	33.22	1.56	2.72	97.17
2010	0.14	58.00	22.29	16.87	1.68	98.98
2011	0.12	30.26	19.66	9.17	1.94	61.14
2012	0.18	30.41	21.79	4.52	1.62	58.51
2013	0.08	34.86	14.83	5.41	1.71	56.89
2014	0.18	33.91	15.82	3.92	0.57	54.40
2015	0.12	38.05	11.41	8.71	1.59	59.88
2016	0.23	40.81	13.12	10.30	3.10	67.56

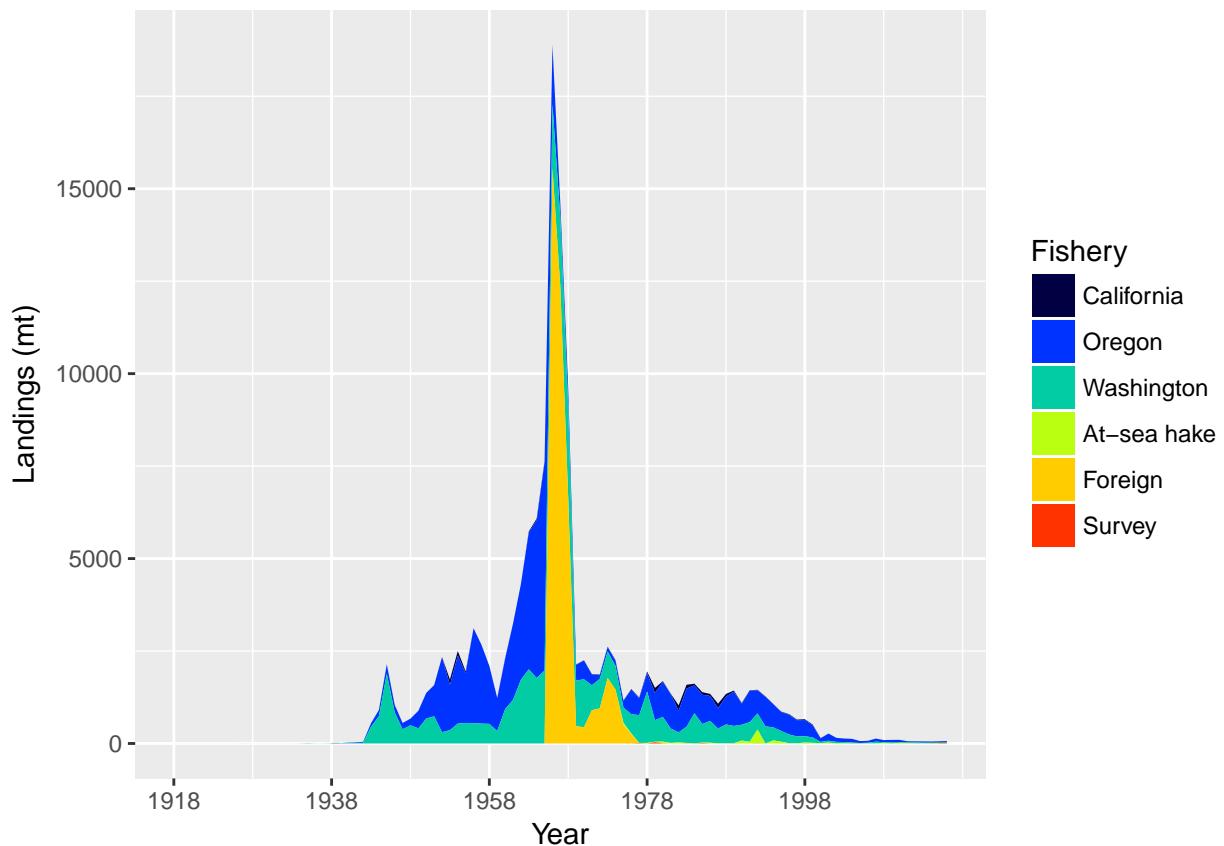


Figure a: Landings of Pacific ocean perch for California, Oregon, Washington, the Foreign fishery (1966-1976), At-sea hake fishery, and fishery-independent surveys.

<sup>118</sup> **Data and Assessment**

<sup>119</sup> This a new full assessment for Pacific ocean perch which was last assessed in 2011. In  
<sup>120</sup> this assessment, aspects of the model including landings, data, and modelling assumptions  
<sup>121</sup> were re-evaluated as much as possible. The assessment was conducted using the length-  
<sup>122</sup> and age-structured modeling software Stock Synthesis (version 3.30.03.05). The coastwide  
<sup>123</sup> population was modeled to allow separate growth and mortality parameters for each sex (a  
<sup>124</sup> two-sex model) from 1918 to 2017, and forecasted beyond 2017.

<sup>125</sup> All of the sources of data for Pacific ocean perch have been re-evaluated for 2017, excluding  
<sup>126</sup> the historical fishery catch-per-unit time series. Changes of varying degrees have occurred  
<sup>127</sup> in the data from those used in previous assessments. These current data represent the best  
<sup>128</sup> available scientific information. The landings history has been updated and extended back to  
<sup>129</sup> 1918. Harvest was negligible prior to that year. Survey data from the Alaska and Northwest  
<sup>130</sup> Fisheries Science Centers have been used to construct indices of abundance analyzed using a  
<sup>131</sup> spatio-temporal delta-model. Length, marginal age or conditional age-at-length compositions  
<sup>132</sup> were also created for each fishery-independent data source.

<sup>133</sup> The definition of fishing fleets have been changed from those in the 2011 assessment. Three  
<sup>134</sup> fishing fleets were specified within the model: 1) a combined bottom trawl, mid-water trawl  
<sup>135</sup> and fixed gear fleet where only a small fraction of Pacific ocean perch occurring by fixed gear  
<sup>136</sup> (termed the fishery fleet), 2) the historical foreign fleet, and 3) the At-sea hake fishery. The  
<sup>137</sup> fleet grouping were based on discarding practices. The fishery fleet estimated a retention  
<sup>138</sup> curve based upon discarding data and known management restrictions. However, very little  
<sup>139</sup> if any discarding is assumed to have occurred by the foreign fleet and the catch reported by  
<sup>140</sup> the At-sea hake fishery accounts for both discarded and landed fish and hence, no additional  
<sup>141</sup> mortality was estimated for each of these fleets.

<sup>142</sup> The assessment uses landings data and discard-fraction estimates; catch-per-unit-of-effort  
<sup>143</sup> and survey indices; length or age composition data for each year and fishery or survey (with  
<sup>144</sup> conditional age-at-length compositional data for the NWFSC shelf-slope survey); information  
<sup>145</sup> on weight-at-length, maturity-at-length, and fecundity-at-length; priors on natural mortality  
<sup>146</sup> and the steepness of the Beverton-Holt stock-recruitment relationship; and estimates of  
<sup>147</sup> ageing error. Recruitment at “equilibrium biomass”, length-based selectivity of the fishery  
<sup>148</sup> and surveys, retention of the fishery, catchability of the surveys, growth, the time-series of  
<sup>149</sup> biomass, age and size structure, and current and projected future stock status are outputs of  
<sup>150</sup> the model. Natural mortality and steepness were fixed in the final model. This was done due  
<sup>151</sup> to relatively flat likelihood surfaces, such that fixing parameters and then varying them was  
<sup>152</sup> deemed the best way to characterize uncertainty.

<sup>153</sup> Although there are many types of data available for Pacific ocean perch since the 1980s, which  
<sup>154</sup> were used in this assessment, there is little information about steepness and natural mortality.  
<sup>155</sup> Estimates of steepness are uncertain partly because of variable recruitment. Uncertainty in  
<sup>156</sup> natural mortality is common in many fish stock assessments even when length and age data  
<sup>157</sup> are available.

<sup>158</sup> A number of sources of uncertainty are explicitly included in this assessment. This assessment  
<sup>159</sup> includes gender differences in growth, a non-linear relationship between individual spawner  
<sup>160</sup> biomass and effective spawning output, and an updated relationship between length and  
<sup>161</sup> maturity, based upon non-published information (Melissa Head, personal communication,  
<sup>162</sup> NOAA, NWFSC). As is always the case, overall uncertainty is greater than that predicted by  
<sup>163</sup> a single model specification. Among other sources of uncertainty that are not included in  
<sup>164</sup> the current model are the degree of connectivity between the stocks of Pacific ocean perch  
<sup>165</sup> off of Vancouver Island, British Columbia and those in US waters, and the effect of climatic  
<sup>166</sup> variables on recruitment, growth and survival of Pacific ocean perch.

<sup>167</sup> A reference case was selected which adequately captures the central tendency for those sources  
<sup>168</sup> of uncertainty considered in the model.

## <sup>169</sup> Stock Biomass

<sup>170</sup> The predicted spawning biomass from the base model generally showed a slight decline  
<sup>171</sup> over the time-series until 1966 when the foreign fleet began. A short, but sharp decline  
<sup>172</sup> occurred, followed by a period of the stock biomass stabilizing or with a minimal decline  
<sup>173</sup> until the late 1990s. The stock showed increases in stock size following the year 2000 due to  
<sup>174</sup> a combination of strong recruitment and low catches. The 2017 estimated spawning biomass  
<sup>175</sup> relative to unfished equilibrium spawning biomass is above the target of 40% of unfished  
<sup>176</sup> spawning biomass at 76.1% (~95% asymptotic interval:  $\pm 53.8\%-98.4\%$ ). Approximate  
<sup>177</sup> confidence intervals based on the asymptotic variance estimates show that the uncertainty in  
<sup>178</sup> the estimated spawning biomass is high.

Table b: Recent trend in estimated spawning output (million eggs) and relative spawning output.

Year	Spawning Output (million eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	3211.00	1362 - 5060	0.48	0.330 - 0.638
2009	3346.00	1425 - 5267	0.50	0.345 - 0.664
2010	3438.00	1467 - 5408	0.52	0.355 - 0.681
2011	3500.00	1496 - 5504	0.53	0.362 - 0.693
2012	3545.00	1521 - 5570	0.53	0.368 - 0.701
2013	3584.00	1544 - 5625	0.54	0.373 - 0.708
2014	3727.00	1618 - 5835	0.56	0.390 - 0.733
2015	4118.00	1812 - 6425	0.62	0.435 - 0.807
2016	4620.00	2054 - 7186	0.70	0.491 - 0.902
2017	5047.00	2259 - 7835	0.76	0.538 - 0.984

### Spawning output with ~95% asymptotic intervals

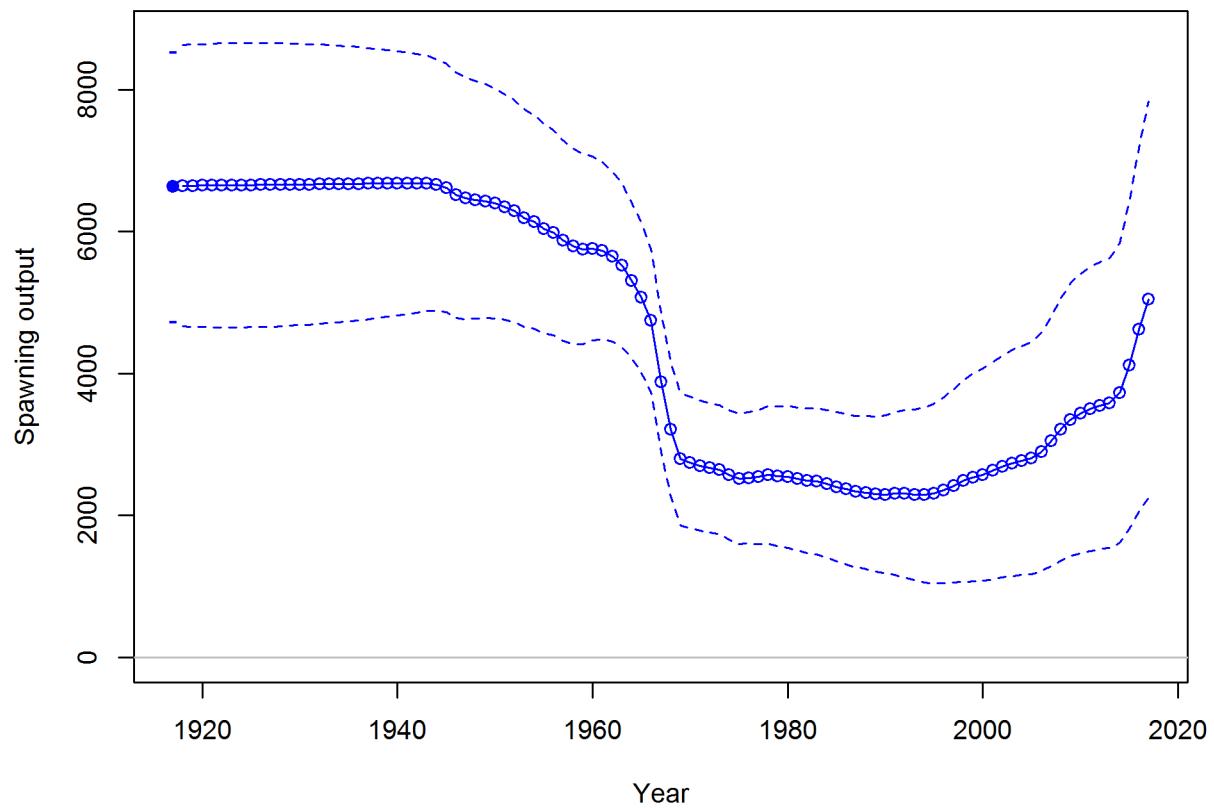


Figure b: Time-series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model.

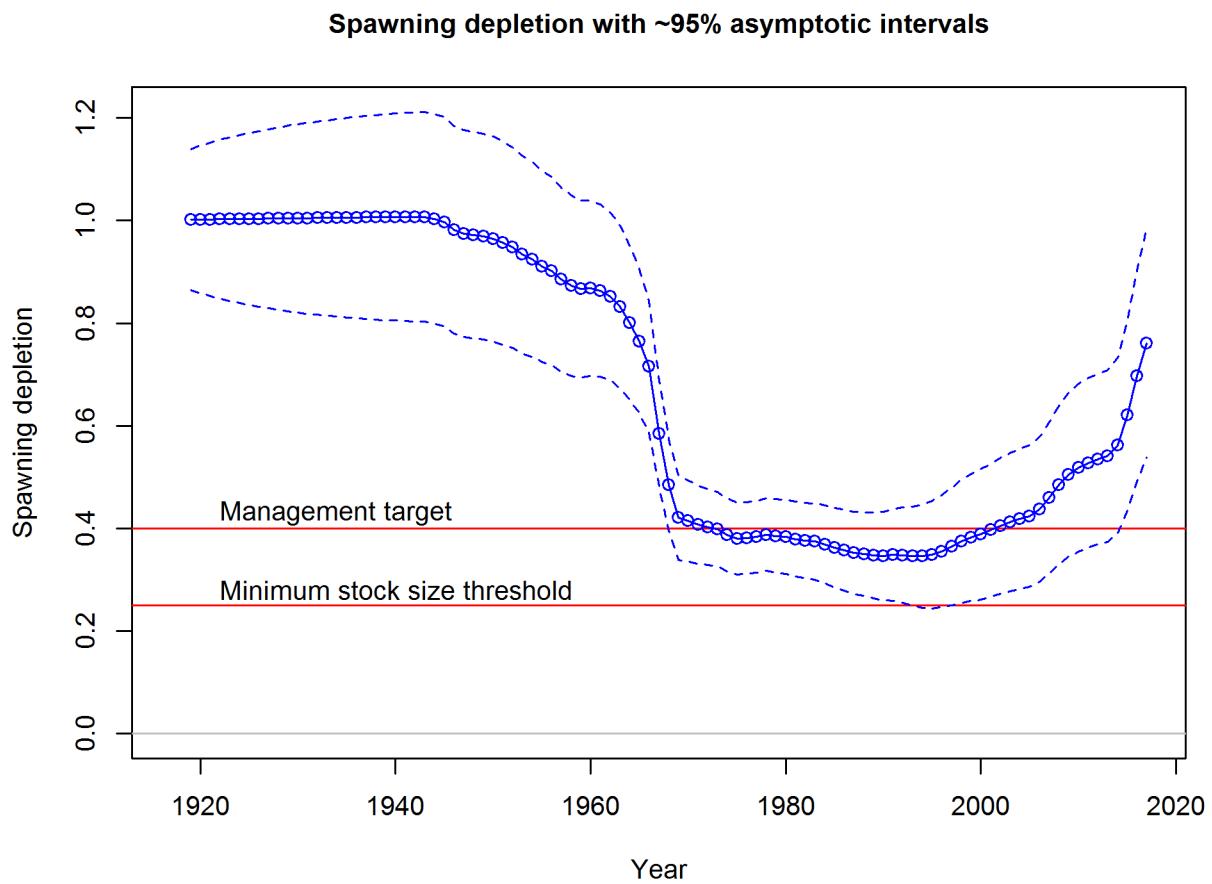


Figure c: Estimated relative spawning biomass (depletion) with approximate 95% asymptotic confidence intervals (dashed lines) for the base assessment model.

<sup>179</sup> **Recruitment**

<sup>180</sup> Recruitment deviations were estimated for the entire time-series modeled. There is little  
<sup>181</sup> information regarding recruitment prior to 1965, and the uncertainty in these estimates is  
<sup>182</sup> expressed in the model. Historically, there are estimates of large recruitments in 1999 and  
<sup>183</sup> 2000. In recent years, a recruitment of unprecedented size is estimated to have occurred in  
<sup>184</sup> 2008 but is highly uncertain. Additionally, there is early evidence of a strong recruitment in  
<sup>185</sup> 2013. The four lowest recruitments estimated within the model (in ascending order) occurred  
<sup>186</sup> in 2012, 2003, 1998, and 2005.

Table c: Recent estimated trend in recruitment and estimated recruitment deviations determined from the base model

Year	Estimated Recruitment	~ 95% confidence interval	Estimated Devs.	~ 95% confidence interval
2008	133246.00	75744 - 234402	2.84	2.542 - 3.145
2009	4814.00	2070 - 11196	-0.49	-1.254 - 0.267
2010	8279.00	4007 - 17102	0.04	-0.558 - 0.633
2011	16107.00	8067 - 32159	0.70	0.146 - 1.246
2012	2113.00	870 - 5132	-1.34	-2.173 - -0.507
2013	29278.00	13512 - 63442	1.20	0.525 - 1.872
2014	5078.00	1728 - 14918	-0.65	-1.748 - 0.441
2015	10096.00	2827 - 36059	-0.00	-1.372 - 1.367
2016	10520.00	2945 - 37581	0.00	-1.372 - 1.372
2017	10816.00	3031 - 38596	0.00	-1.372 - 1.372

**Age-0 recruits (1,000s) with ~95% asymptotic intervals**

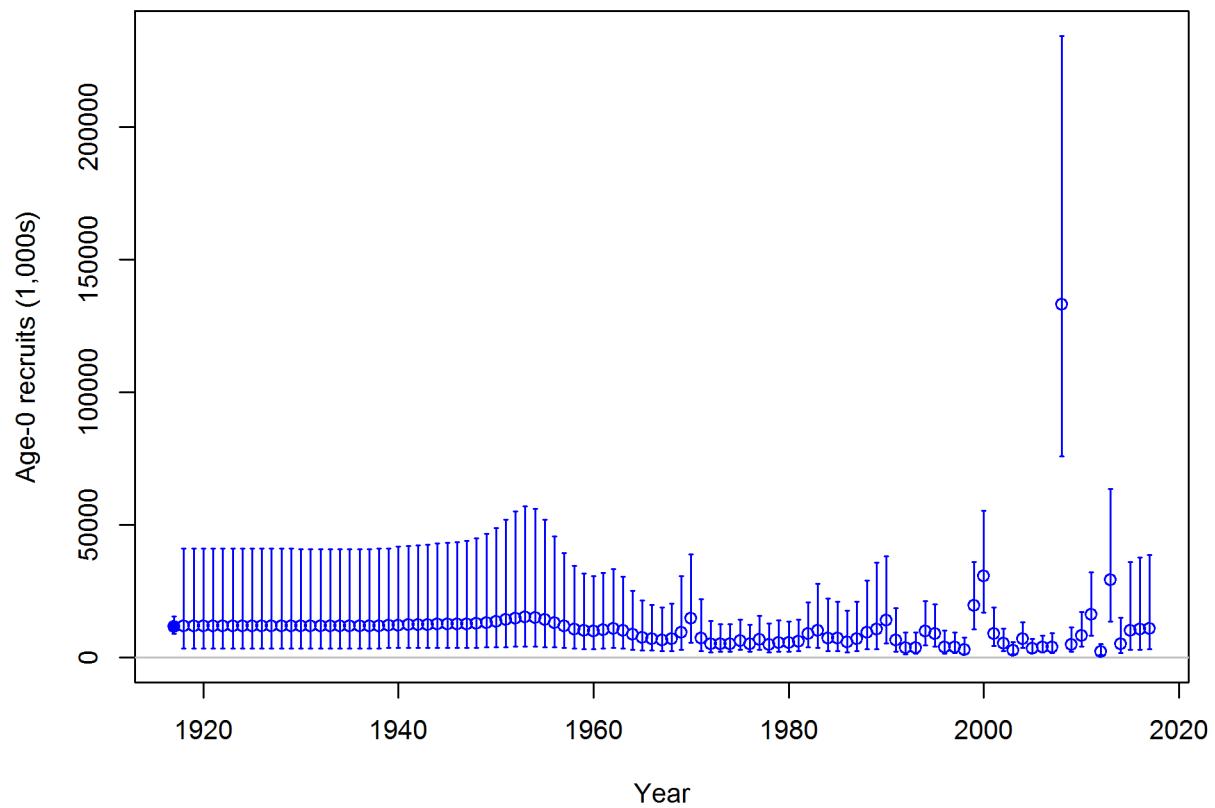


Figure d: Time-series of estimated Pacific ocean perch recruitments for the base model with 95% confidence or credibility intervals.

<sup>187</sup> **Exploitation status**

<sup>188</sup> The spawning biomass of Pacific ocean perch reached a low in 1994. Landings for Pacific  
<sup>189</sup> ocean perch decreased significantly in 2000 compared to previous years. The estimated  
<sup>190</sup> relative biomass was possibly below the overfished level in the early 2000s, but has likely  
<sup>191</sup> remained above that level otherwise, and currently is significantly greater than the 40%  
<sup>192</sup> unfished spawning biomass target. Throughout the late 1960s and 1970s the exploitation  
<sup>193</sup> rate and  $(1-SPR)/(1-SPR_{50\%})$  were mostly above target levels. Recent exploitation rates on  
<sup>194</sup> Pacific ocean perch were predicted to be significantly below target levels.

Table d: Recent trend in spawning potential ratio (1-SPR)(1-SPR50) and summary exploitation rate for Pacific ocean perch.

Year	$(1-SPR)/(1-SPR_{50\%})$	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.104	0.046 - 0.162	0.002	0.001 - 0.003
2008	0.086	0.036 - 0.135	0.002	0.001 - 0.003
2009	0.113	0.046 - 0.181	0.003	0.001 - 0.004
2010	0.107	0.044 - 0.171	0.002	0.001 - 0.004
2011	0.037	0.016 - 0.058	0.001	0.000 - 0.001
2012	0.035	0.015 - 0.054	0.001	0.000 - 0.001
2013	0.033	0.014 - 0.051	0.001	0.000 - 0.001
2014	0.029	0.013 - 0.045	0.001	0.000 - 0.001
2015	0.028	0.013 - 0.044	0.001	0.000 - 0.001
2016	0.028	0.012 - 0.043	0.001	0.000 - 0.001

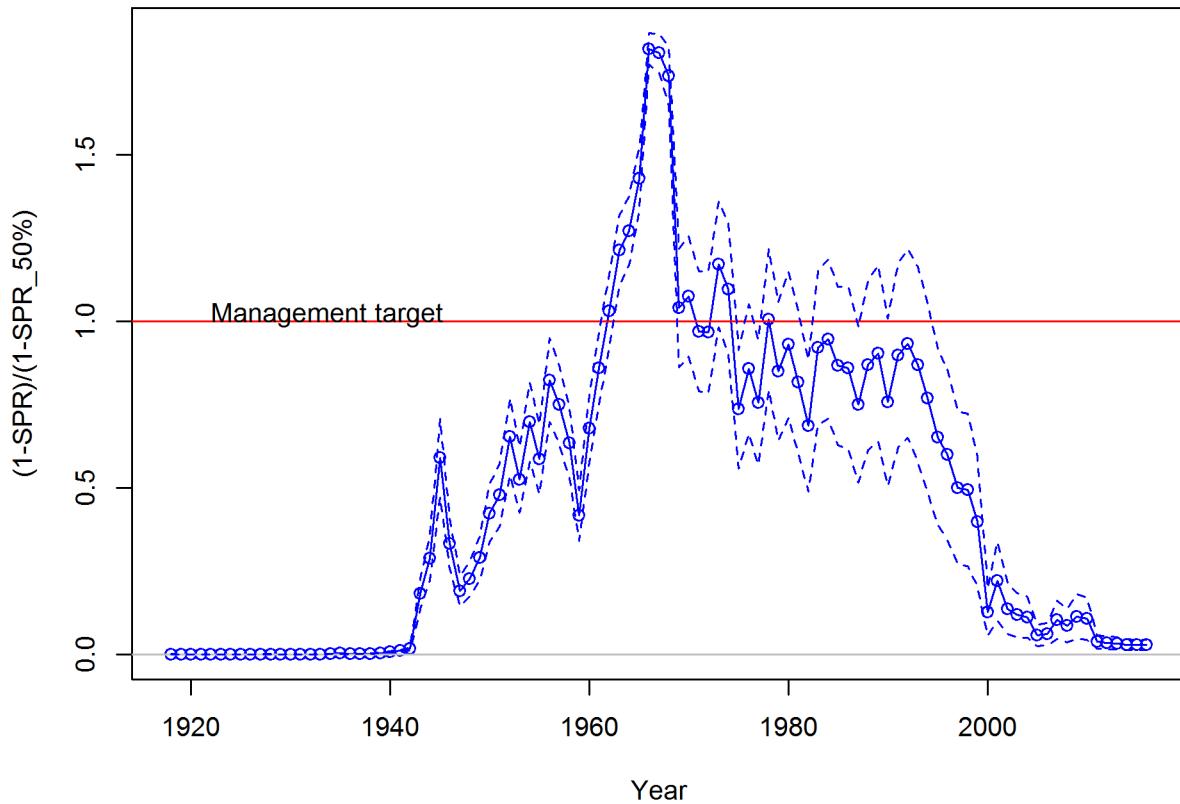


Figure e: Estimated spawning potential ratio  $(1-SPR)/(1-SPR_{50\%})$  for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR50% harvest rate. The last year in the time series is 2016.

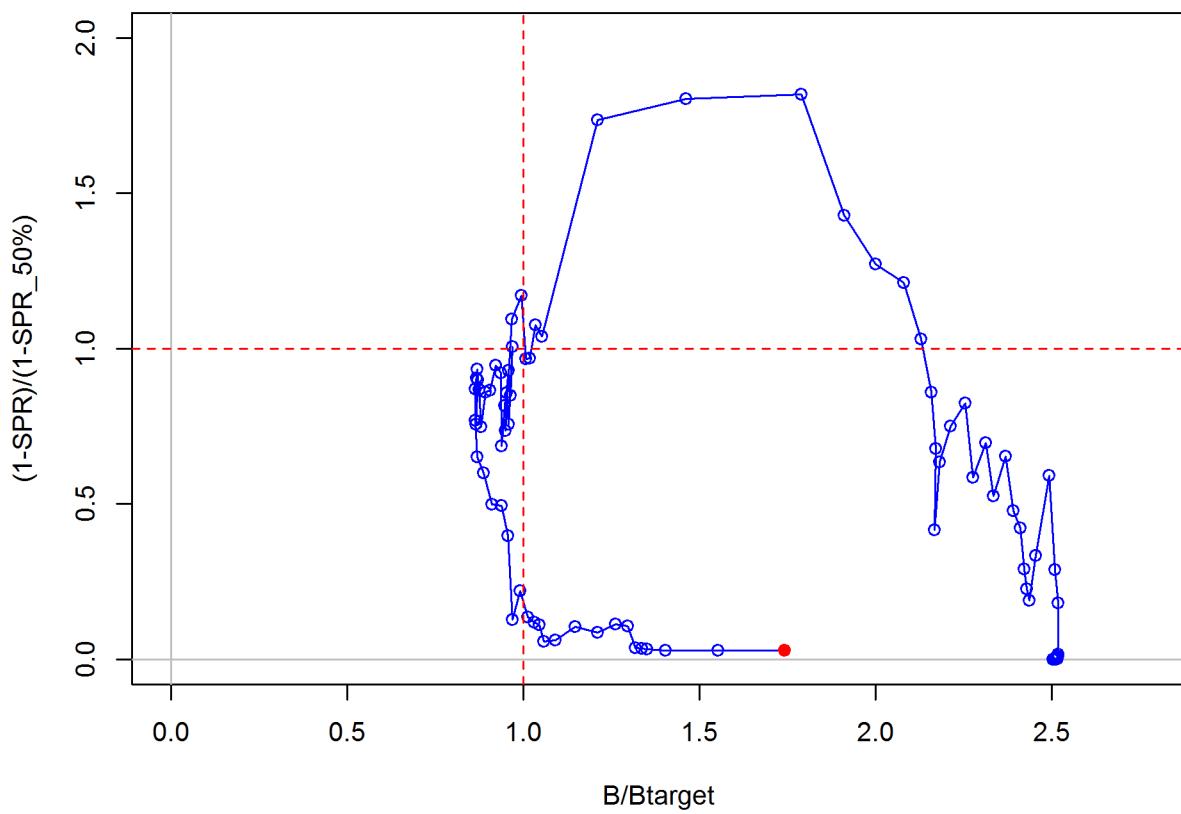


Figure f: Phase plot of estimated relative  $(1-SPR)/(1-SPR_{50\%})$  vs. relative spawning biomass for the base case model. Relative biomass is the annual spawning biomass divided by the unfished spawning biomass.

<sup>195</sup> **Ecosystem Considerations**

<sup>196</sup> Rockfish are an important component of the California Current ecosystem along the US west  
<sup>197</sup> coast, with its more than sixty five species filling various niches in both soft and hard bottom  
<sup>198</sup> habitats from the nearshore to the continental slope, as well as near bottom and pelagic  
<sup>199</sup> zones. Pacific ocean perch are generally considered to be semi-demersal but, there can at  
<sup>200</sup> times, be a significant pelagic component to their distribution.

<sup>201</sup> Recruitment is one mechanism by which the ecosystem may directly impact the population  
<sup>202</sup> dynamics of Pacific ocean perch. The 1999 cohort for many species of rockfish was large -  
<sup>203</sup> sometimes significantly so. Long-term averages suggesting that environmental conditions  
<sup>204</sup> may influence the spawning success and survival of larvae and juvenile rockfish. Pacific ocean  
<sup>205</sup> perch showed an above average recruitment deviation in 1999 and 2000. The specific pathways  
<sup>206</sup> through which environmental conditions exert influence on Pacific ocean perch dynamics  
<sup>207</sup> are unclear; however, changes in water temperature and currents, distribution of prey and  
<sup>208</sup> predators, and the amount and timing of upwelling are all possible linkages. Changes in the  
<sup>209</sup> environment may also result in changes in length-at-maturity, fecundity, growth, and survival  
<sup>210</sup> which can affect the status of the stock and its susceptibility to fishing. Unfortunately, there  
<sup>211</sup> are few data available for Pacific ocean perch that provide insights into these effects.

<sup>212</sup> Fishing has effects on both the age structure of a population, as well as the habitat with  
<sup>213</sup> which the target species is associated. Fishing often targets larger, older fish, and years of  
<sup>214</sup> fishing mortality results in a truncated age-structure when compared to unfished conditions.  
<sup>215</sup> Rockfish are often associated with habitats containing living structure such as sponges and  
<sup>216</sup> corals, and fishing may alter that habitat to a less desirable state. This assessment provides  
<sup>217</sup> a look at the effects of fishing on age structure, and recent studies on essential fish habitat  
<sup>218</sup> are beginning to characterize important locations for rockfish throughout their life history;  
<sup>219</sup> however there is little current information available to evaluate the specific effects of fishing  
<sup>220</sup> on the ecosystem issues specific to Pacific ocean perch.

<sup>221</sup> **Reference Points**

<sup>222</sup> This stock assessment estimates that Pacific ocean perch are above the biomass target. Due  
<sup>223</sup> to reduced landing and the large 2008 year-class, an increasing trend in spawning biomass  
<sup>224</sup> was estimated in the base model. The estimated relative biomass level in 2017 is 76.1% (~95%  
<sup>225</sup> asymptotic interval: ± 53.8%-98.4%), corresponding to an unfished spawning output of 5047  
<sup>226</sup> million eggs (~95% asymptotic interval: 2259-7835 million eggs). Unfished age 3+ biomass  
<sup>227</sup> was estimated to be 139810 mt in the base model. The target spawning output based on the  
<sup>228</sup> biomass target ( $SB_{40\%}$ ) is 2653.2 million eggs, which gives a catch of 1748.2 mt. Equilibrium  
<sup>229</sup> yield at the proxy  $F_{MSY}$  harvest rate corresponding to  $SPR_{50\%}$  is 1764.8 mt.

Table e: Summary of reference points and management quantities for the base case.

Quantity	Estimate	95% Confidence Interval
Unfished spawning output (million eggs)	6633.1	4736.7 - 8529.5
Unfished age 3+ biomass (mt)	139810	100052.5 - 179567.5
Unfished recruitment ( $R_0$ , thousands)	11665.7	8801.4 - 15462.1
Spawning output(2017 million eggs)	5047.2	2259.2 - 7835.1
Relative biomass (depletion) (2017)	0.761	0.538 - 0.984
<b>Reference points based on SB<sub>40%</sub></b>		
Proxy spawning output ( $B_{40\%}$ )	2653.2	1894.7 - 3411.8
SPR resulting in $B_{40\%}$ ( $SPR_{B40\%}$ )	0.55	0.55 - 0.55
Exploitation rate resulting in $B_{40\%}$	0.028	0.028 - 0.029
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	1748.2	1252.4 - 2244
<b>Reference points based on SPR proxy for MSY</b>		
Spawning output	2211	1578.9 - 2843.2
$SPR_{proxy}$	0.5	
Exploitation rate corresponding to $SPR_{proxy}$	0.034	0.033 - 0.034
Yield with $SPR_{proxy}$ at $SB_{SPR}$ (mt)	1764.8	1264.8 - 2264.8
<b>Reference points based on estimated MSY values</b>		
Spawning output at MSY ( $SB_{MSY}$ )	2315.7	1649.6 - 2981.8
$SPR_{MSY}$	0.512	0.51 - 0.514
Exploitation rate at MSY	0.032	0.032 - 0.033
$MSY$ (mt)	1766.7	1266.1 - 2267.4

## 230 Management Performance

231 Exploitation rates on Pacific ocean perch exceeded MSY proxy target harvest rates during  
 232 the 1960s and 1970s, resulting in sharp declines in the spawning output. Exploitation rates  
 233 subsequently declined to rates at or below the management target in the 1980s. Management  
 234 restrictions imposed in the 1990s further reduced exploitation rates. An overfished declaration  
 235 for Pacific ocean perch resulted in very low exploitation rates since 2001 with the ACLs being  
 236 set far below the OFL and ABC values.

Table f: 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)	Total landings (mt)	Estimated total catch (mt)
2007	900		150	133	157
2008	911		150	92	133
2009	1,160		189	94	190
2010	1,173		200	97	181
2011	1,026	981	180	60	61
2012	1,007	962	183	57	58
2013	844	807	150	55	57
2014	838	801	153	54	55
2015	842	805	158	58	59
2016	850	813	164	65	65

<sup>237</sup> **Unresolved Problems And Major Uncertainties**

<sup>238</sup> TBD after STAR panel

<sup>239</sup> **Decision Table**

<sup>240</sup> TBD after STAR panel

Table g: Projections of potential OFL (mt) and ACL (mt) and the estimated spawning output and relative biomass. The ACL values for 2017 and 2018 are set at the harvest limits currently set by management.

Year	OFL	ACL	Spawning Output (million eggs)	Relative Biomass
2017	4306	281	5047	0.761
2018	4559	281	5369	0.809
2019	4719	4515	5625	0.848
2020	4654	4453	5657	0.853
2021	4552	4356	5654	0.852
2022	4431	4240	5606	0.845
2023	4302	4116	5528	0.833
2024	4172	3992	5431	0.819
2025	4048	3873	5324	0.803
2026	3932	3762	5211	0.786
2027	3826	3660	5096	0.768
2028	3727	3566	4981	0.751

Table h: Summary of 10-year projections beginning in 2019 for alternate states of nature based on an axis of uncertainty for the base 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.

	Year	Catch	States of nature					
			Low State of Nature		Base State of Nature		High State of Nature	
			Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
Catch Option 1	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Catch Option 2	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Catch Option 3	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Average Catch	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-

<sup>241</sup> **Research and Data Needs**

<sup>242</sup> There are many areas of research that could be improved to benefit the understanding and  
<sup>243</sup> assessment of Pacific ocean perch. Below, are issues that are considered of the importance.

- <sup>244</sup> 1. **Natural mortality:** Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for Pacific ocean perch. The collection of additional age data, re-reading of older age samples, reading old age samples that are unread, and improved understanding of the life-history of Pacific ocean perch may reduce that uncertainty.
- <sup>249</sup> 2. **Steepness:** The amount of stock resilience, steepness, dictates the rate at which a stock can rebuild from low stock sizes. Improved understating regarding the steepness of US west coast Pacific ocean perch will reduce our uncertainty regarding current stock status.
- <sup>253</sup> 3. **Basin-wide understanding of stock structure, biology, connectivity, and distribution:** This is a stock assessment for Pacific ocean perch off of the west coast of the US and does not consider data from British Columbia or Alaska. Further investigating and comparing the data and predictions from British Columbia and Alaska to determine if there are similarities with the US west coast observations would help to define the connectivity between Pacific ocean perch north and south of the US-Canada border.

Table i: Base model results summary.

Quantity	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
OFL (mt)	911	1,160	1,173	1,026	1,007	844	838	842	850	964
ACL (mt)	150	189	200	180	183	150	153	158	164	281
Landings (mt)	92	94	97	60	57	55	54	58	65	65
Total Est. Catch (mt)	133	190	181	61	58	57	55	59	65	65
(1-SFR)(1-SFR <sub>50%</sub> )	0.086	0.113	0.107	0.037	0.035	0.033	0.029	0.028	0.028	0.028
Exploitation rate	0.002	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Age 3+ biomass (mt)	73810.2	74590.2	74832.0	88388.8	95169.1	102021.0	109119.0	114333.0	121131.0	125534.0
Spawning Output	3211	3346	3438	3500	3545	3584	3727	4118	4620	5047
95% CI	1362 - 5060	1425 - 5267	1467 - 5408	1496 - 5504	1521 - 5570	1544 - 5625	1618 - 5835	1812 - 6425	2054 - 7186	2259 - 7835
Relative Biomass	0.484	0.504	0.518	0.528	0.534	0.540	0.562	0.621	0.697	0.761
95% CI	0.330 - 0.638	0.345 - 0.664	0.355 - 0.681	0.362 - 0.693	0.368 - 0.701	0.373 - 0.708	0.390 - 0.733	0.435 - 0.807	0.491 - 0.902	0.558 - 0.984
Recruits	133246	4814	8279	16107	2113	29278	5078	10096	10520	10816
95% CI	75744 - 234402	2070 - 11196	4007 - 17102	8067 - 32159	870 - 5132	13512 - 63442	1728 - 14918	2827 - 36059	2945 - 37581	3031 - 38596

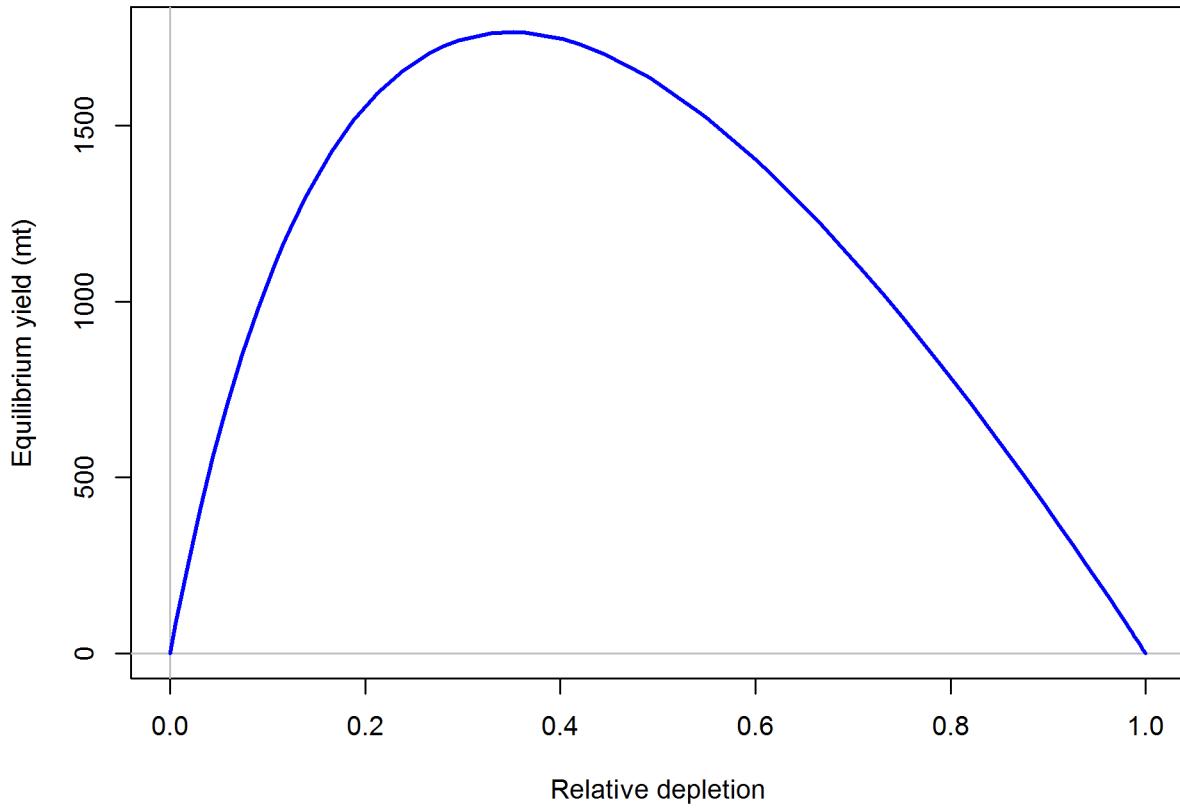


Figure g: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.50.

259 **1 Introduction**

260 **1.1 Basic Information**

261 Pacific ocean perch (*Sebastes alutus*) are most abundant in the Gulf of Alaska, and have been  
262 observed off of Japan, in the Bering Sea, and south to Baja California, although they are  
263 sparse south of Oregon and rare in southern California. While genetic studies have found  
264 three populations of Pacific ocean perch off of British Columbia related to unique geography  
265 and oceanic conditions (Seeb and Gunderson 1988, Withler et al. 2001) with, notably, a  
266 separate stock off of Vancouver Island, no significant genetic differences have been found  
267 in the range covered by this assessment. Pacific ocean perch show dimorphic growth, with  
268 females reaching a slightly large size than males. Males and females are equally abundant on  
269 rearing grounds at age 1.5.

270 The Pacific ocean perch population has been modeled as a single stock off of the US west  
271 coast (essentially northern California to the Canadian border, since Pacific ocean perch are  
272 seen extremely rarely in central and southern California). Good recruitments show up in  
273 size-composition data throughout all portions of this area, which supports the single stock  
274 hypothesis. This assessment includes landings and catch data for Pacific ocean perch from  
275 the states of Washington, Oregon and California, along with records from foreign fisheries,  
276 the At-sea hake fleet, and fishery-independent surveys.

277 Prior to 1966, the Pacific ocean perch resource off of the northern portion of the US west  
278 coast was harvested almost entirely by Canadian and US vessels. Harvest was negligible  
279 prior to 1940, reached 1367 mt in 1950, 3243 mt in 1961 and 7635 mt in 1965. Catches  
280 increased dramatically after 1965, with the introduction of large distant-water fishing fleets  
281 from the Soviet Union and Japan. Both nations employed large factory stern trawlers as their  
282 primary method for harvesting Pacific ocean perch. Peak removals are estimated at 18883  
283 mt in 1966 and 14591 mt in 1967. These numbers are based upon a re-analysis of the foreign  
284 catch data (Rogers 2003), which focused on deriving a more realistic species composition for  
285 catches previously identified only as Pacific ocean perch. Catches declined rapidly following  
286 these peak years, and Pacific ocean perch stocks were considered to be severely depleted  
287 throughout the Oregon-Vancouver Island region by 1969 (Gunderson 1977, Gunderson et al.  
288 1977). Landed harvest averaged 1377 mt over the period 1977-94. Landings have continued  
289 to decline since 1994, primarily due to more restrictive management (Table 1 and Figure 1).

290 Prior to 1977, Pacific ocean perch in the northeast Pacific were managed by the Canadian  
291 Government in its waters and by the individual states in waters off of the US. With imple-  
292 mentation of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1977,  
293 US territorial waters were extended to 200 miles from shore, and primary responsibility for  
294 management of the groundfish stocks off Washington, Oregon and California shifted from the  
295 states to the Pacific Fishery Management Council (PFMC) and the National Marine Fisheries  
296 Service (NMFS). At that time, however, a Fishery Management Plan for the West Coast

297 groundfish stocks had not yet been approved. In the interim, the state agencies worked with  
298 the PFMC to address conservation issues. In 1981, the PFMC adopted a management strategy  
299 to rebuild the depleted Pacific ocean perch stocks to levels that would produce Maximum  
300 Sustainable Yield (MSY) within 20 years. On the basis of cohort analysis (Gunderson 1978),  
301 the PFMC set Acceptable Biological Catch (ABC) levels at 600 mt for the US portion of  
302 the Vancouver INPFC area and 950 mt for the Columbia International North Pacific Fishery  
303 Commission (INPFC) area. To implement this strategy, the states of Oregon and Washington  
304 each established landing limits for Pacific ocean perch. Trawl trip limits of various forms  
305 remained in effect through 2016 (Table 2).

306 Age estimates for Pacific ocean perch prior to the 1980s were made via surface ageing of  
307 otoliths, which misses the very tight annuli at the edge of the otolith once the fish reaches  
308 near maximum size. Ages are highly biased by around age 10-12, and maximum age was  
309 estimated to be in the 20s, which lead to an overestimate of the natural mortality rate and  
310 the productivity of the stock. Using break and burn methods, Pacific ocean perch have been  
311 aged to over 100 years. Research surveys have been used to provide fishery-independent  
312 information about the abundance, distribution, and biological characteristics of Pacific ocean  
313 perch. A coast-wide survey of the rockfish resource was conducted in 1977 (Gunderson and  
314 Sample 1980) and was repeated every three years through 2004 (referred to as the ‘Triennial  
315 survey’). The National Marine Fisheries Service (NMFS) coordinated a cooperative research  
316 survey of the Pacific ocean perch stocks off Washington and Oregon with the Washington  
317 Department of Fisheries (WDFW) and the Oregon Department of Fish and Wildlife (ODFW)  
318 in March-May 1979 (Wilkins and Golden 1983). This survey was repeated in 1985 (referred to  
319 as the Pacific ocean perch survey). Two slope surveys have been conducted off the West Coast  
320 in recent years, one using the research vessel Miller Freeman, which ended in 2001 (referred  
321 to as the ‘AFSC slope survey’), and another ongoing cooperative survey using commercial  
322 fishing vessels which began in 1998 as a DTS (Dover sole, thornyhead and sablefish) survey  
323 and was expanded to other groundfish in 1999 (referred to as the ‘NWFSC slope survey’). In  
324 2003, this survey was expanded spatially to include the shelf. This last survey, conducted by  
325 the NWFSC, continues to cover depths from 30-700 fathoms (55-1280 meters) on an annual  
326 basis (referred to as the ‘NWFSC shelf-slope survey’).

## 327 1.2 Summary of Management History

328 The landings of Pacific ocean perch have been historically governed by harvest guidelines and  
329 trip limits, while recently management has imposed total catch harvest limits in the form  
330 of overfishing limits (OFLs), acceptable biological catches (ABCs), and annual catch limits  
331 (ACLs). A trawl rationalization program, consisting of an individual fishing quota (IFQ)  
332 catch shares system was implemented in 2011 for the limited entry trawl fleet targeting non-  
333 whiting groundfish, including Pacific ocean perch, and the trawl fleet targeting and delivering  
334 whiting to shore-based processors. The limited entry at-sea trawl sectors (motherships and  
335 catch-processors) that target whiting and process at-sea are managed in a system of harvest  
336 cooperatives.

<sup>337</sup> Limits on Pacific ocean perch were first established in 1983 (Table 2). These were implemented  
<sup>338</sup> as area closures, trip limits, and cumulative landing limits. In 1999, Pacific ocean perch  
<sup>339</sup> was declared overfished with the assessment estimating the spawning output below the  
<sup>340</sup> management limit (25% of virgin biomass). In reaction to the overfished declaration, harvest  
<sup>341</sup> limits were reduced relative to previous years and a rebuilding plan was implemented in 2001  
<sup>342</sup> with recent ACLs being set well below the estimated OFLs (Table 3).

### <sup>343</sup> 1.3 Fisheries off Canada and Alaska

<sup>344</sup> Pacific ocean perch can be found in waters off the US west coast and northward through  
<sup>345</sup> Alaskan waters. In contrast the Pacific ocean perch stock off the US west coast, each assessed  
<sup>346</sup> portion of the stock in Canada and Alaskan waters have historically been estimated to be  
<sup>347</sup> above management targets. The subset of the stock off the US west coast represents the tail  
<sup>348</sup> of the species distribution with little to no Pacific ocean perch being encountered south of  
<sup>349</sup> northern California. The most recent updated assessments for the Bering Sea and the Gulf  
<sup>350</sup> of Alaska stocks determined that neither stock are in an overfished state and recommended  
<sup>351</sup> and acceptable biological catch of 43,723 mt and 23,918 mt, respectively, for 2017.

<sup>352</sup> In Canadian waters Pacific ocean perch has the largest single-species quota, accounting for  
<sup>353</sup> approximately 25% of all rockfish landings by weight in the bottom trawl fleet. The Canadian  
<sup>354</sup> Pacific ocean perch stock is broken into three separate areas that are individually assessed.  
<sup>355</sup> The status of the stock within each area are above Canadian management targets.

## <sup>356</sup> 2 Data

<sup>357</sup> Data used in the Pacific ocean perch assessment are summarized in Figure 2. A description  
<sup>358</sup> of each data source is provided below.

### <sup>359</sup> 2.1 Fishery-Independent Data:

#### <sup>360</sup> 2.1.1 Northwest Fisheries Science Center (NWFSC) shelf-slope survey

<sup>361</sup> The NWFSC shelf-slope survey is based on a random-grid design; covering the coastal waters  
<sup>362</sup> from a depth of 55 m to 1,280 m (Bradburn et al. 2011). This design uses four chartered  
<sup>363</sup> industry vessels in most years, assigned to a roughly equal number of randomly selected  
<sup>364</sup> grid cells. The survey, which has been conducted from late-May to early-October each year,  
<sup>365</sup> is divided into two 2-vessel passes of the coast, which are executed from north to south.  
<sup>366</sup> This design therefore incorporates both vessel-to-vessel differences in catchability as well as

367 variance associated with selecting a relatively small number (approximately 700) of cells from  
368 a very large population of possible cells (greater than 11,000) distributed from the Mexican  
369 to the Canadian border.

370 The data from the NWFSC shelf-slope survey was analyzed using a spatio-temporal delta-  
371 model (Thorson et al. 2015), implemented as an R package VAST (Thorson and Barnett  
372 2017) and publicly available online (<https://github.com/James-Thorson/VAST>). Spatial  
373 and spatio-temporal variation is specifically included in both encounter probability and  
374 positive catch rates, a logit-link for encounter probability, and a log-link for positive catch  
375 rates. Vessel-year effects were included for each unique combination of vessel and year  
376 in the database, to account for the random selection of commercial vessels used during  
377 sampling (Helser et al. 2004, Thorson and Ward 2014). Spatial variation was approximated  
378 using 1000 knots, and use the bias-correction algorithm (Thorson and Kristensen 2016) in  
379 Template Model Builder (Kristensen et al. 2016). Further details regarding model structure  
380 are available in the user manual ([https://github.com/James-Thorson/VAST/blob/master/examples/VAST\\_user\\_manual.pdf](https://github.com/James-Thorson/VAST/blob/master/examples/VAST_user_manual.pdf)).

382 The smallest Pacific ocean perch tend to occur in the shallower depths (< 200 m) with only  
383 larger individuals occurring at depths deeper than 300 m. Data collected by the NWFSC shelf-  
384 slope survey between depths of 55 - 549 m and north of 42° and south of 49° were stratified  
385 to generate an index of abundance from 2003-2016. The estimated index of abundance is  
386 shown in Table 4. The lognormal distribution with random strata-year and vessel effects  
387 had the lowest AIC and was chosen as the final model. The Q-Q plot does not show any  
388 departures from the assumed distribution (Figure 4). The indices for the NWFSC shelf-slope  
389 survey show a tentative decline in the population between 2003 and 2009, with an increasing  
390 trend in biomass between the 2009 and 2016 median point estimates.

391 Length compositions were expanded based upon the stratification and the age data was used  
392 as conditional age-at-length data. The number of tows with length data ranged from 33  
393 in 2006 to 69 in 2015 (Table 5) where ages were collected for Pacific ocean perch in nearly  
394 every tow (Table 6). The expanded length frequencies from this survey show an increase in  
395 small fish starting in 2010 (Figure 5). The age frequencies provide clear evidence of large  
396 year-classes moving through the population from the 1999, 2000, and 2008 recruitment; with  
397 early indications of a large 2013 recruitment (Figure 6).

398 The effective sample sizes for length and marginal age composition data for all fishery-  
399 independent surveys were calculated according to Stewart and Hamel (2014) which determined  
400 that the approximate realized sample size for shelf/slope rockfish species was  $2.43 * N_{\text{tow}}$ . The  
401 effective sample size of conditional-age-at-length data was set at the number of fish at each  
402 length by sex and by year.

403 **2.1.2 Northwest Fisheries Science Center (NWFSC) slope survey**

404 The NWFSC slope survey covered waters throughout the summer from 183 m to 1280 m north  
405 of  $34^{\circ}30' S$ , which is near Point Conception between 1999 and 2002. Tows conducted between  
406 the depths of 183 and 549 m were used to create an index of abundance using a bayesian  
407 delta-GLMM and the VAST delta-GLMM models. The estimated index of abundance is  
408 show in Table 4. Based on the diagnostics the bayesian delta-GLMM, which does not account  
409 for spatial effects, gamma distribution with year-vessel random effects was selected as the  
410 final model. The Q-Q plot does show a minimal departure from the assumed distribution  
411 (Figure 7), but was determined to be acceptable based on the alternative model distributions.  
412 The trend of abundance across the four surveys years was generally flat with high estimated  
413 annual variance. Sensitivities were done evaluating the use of this index within the base  
414 model.

415 Length and age compositions were available for 2001 and 2002 and were expanded based upon  
416 the survey stratification (Tables 7 and 8). The expanded length frequencies from this survey  
417 shows that primarily only large fish were captured both years (Figure 8). The majority of  
418 fish observed by this survey were aged at greater than 10 years (Figure 9).

419 The effective sample sizes for length and marginal age composition data were calculated  
420 according to Stewart and Hamel (2014) described in Section 2.1.1.

421 **2.1.3 Alaska Fisheries Science Center (AFSC) slope survey**

422 The AFSC slope survey operated during autumn (October-November) aboard the R/V Miller  
423 Freeman. Partial survey coverage of the US west coast occurred during 1988-96 and complete  
424 coverage (north of  $34^{\circ}30' S$ ) during 1997, 1999, 2000, and 2001. Only the four years of  
425 consistent and complete surveys plus 1996, which surveyed north of  $43^{\circ} N$  latitude to the  
426 US-Canada border, were used in this assessment. The number of tows with length data  
427 ranged from 19 in 2000 to 48 in 1996 (Table 9). Because a large number of positive tows  
428 occurred in 1996, it was decided to include that year, which surveyed from  $43^{\circ} N$  latitude to  
429 the US-Canada border. Therefore, only tows from  $43^{\circ} N$  latitude to the US-Canada border  
430 were used.

431 An index of abundance was estimated based on the data using the VAST delta-GLMM model.  
432 The estimated index of abundance is shown in Table 4. The lognormal distribution with  
433 random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot  
434 does not show any departures from the assumed distribution (Figure 10). The trend in the  
435 indices was generally flat over time.

436 Length compositions were available for each year the survey was conducted. No age data were  
437 available from this survey. The expanded length frequencies from this survey were generally

<sup>438</sup> of larger fish ( $> 30$  cm), except for 1997 where the highest frequency of fish were between 20  
<sup>439</sup> and 30 cm for both females and males (Figure 11).

<sup>440</sup> The effective sample sizes for length and marginal age composition data were calculated  
<sup>441</sup> according to Stewart and Hamel (2014) described in Section 2.1.1.

#### <sup>442</sup> 2.1.4 Triennial Bottom Trawl Survey

<sup>443</sup> The Triennial survey was first conducted by the AFSC in 1977 and spanned the time-frame  
<sup>444</sup> from 1977-2004. The survey's design and sampling methods are most recently described  
<sup>445</sup> in (Weinberg et al. 2002). Its basic design was a series of equally-spaced transects from  
<sup>446</sup> which searches for tows in a specific depth range were initiated. The survey design has  
<sup>447</sup> changed slightly over the period of time. In general, all of the surveys were conducted in the  
<sup>448</sup> mid-summer through early fall: the 1977 survey was conducted from early July through late  
<sup>449</sup> September; the surveys from 1980 through 1989 ran from mid-July to late September; the  
<sup>450</sup> 1992 survey spanned from mid-July through early October; the 1995 survey was conducted  
<sup>451</sup> from early June to late August; the 1998 survey ran from early June through early August;  
<sup>452</sup> and the 2001 and 2004 surveys were conducted in May-July.

<sup>453</sup> Haul depths ranged from 91-457 m during the 1977 survey with no hauls shallower than 91 m.  
<sup>454</sup> The surveys in 1980, 1983, and 1986 covered the West Coast south to  $36.8^\circ$  N latitude and a  
<sup>455</sup> depth range of 55-366 meters. The surveys in 1989 and 1992 covered the same depth range  
<sup>456</sup> but extended the southern range to  $34.5^\circ$  N (near Point Conception). From 1995 through  
<sup>457</sup> 2004, the surveys covered the depth range 55-500 meters and surveyed south to  $34.5^\circ$  N. In  
<sup>458</sup> the final year of the Triennial series, 2004, the NWFSC's Fishery Resource and Monitoring  
<sup>459</sup> division (FRAM) conducted the survey and followed very similar protocols as the AFSC.

<sup>460</sup> Given the different depths surveyed during 1977, the data from that year were not included  
<sup>461</sup> in this assessment. Water hauls (Zimmermann et al. 2003) and tows located in Canadian  
<sup>462</sup> waters were also excluded from the analysis of this survey. The data was examined for varying  
<sup>463</sup> distribution of length and/or ages of fish based upon the shift in survey timing and little  
<sup>464</sup> evidence was found of ontogenetic shifts in Pacific ocean perch during the summer months.  
<sup>465</sup> Pacific ocean perch are rarely encountered south of  $40^\circ$  where the change in southern range  
<sup>466</sup> of the survey would have no impact on data collected regarding Pacific ocean perch. Given  
<sup>467</sup> these factors the Triennial survey was analyzed as a single time-series, a departure from how  
<sup>468</sup> the previous assessment which split the time-series into an early (1980-1992) and a late  
<sup>469</sup> period (1995-2004).

<sup>470</sup> An index of abundance was estimated based on the data using the VAST delta-GLMM model.  
<sup>471</sup> The estimated index of abundance is shown in Table 4. The lognormal distribution with  
<sup>472</sup> random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot  
<sup>473</sup> does not show any departures from the assumed distribution (Figure 12). The index shows a  
<sup>474</sup> decline in abundance in the early years of the time-series and abundance remaining flat for  
<sup>475</sup> the latter years.

476 Length and age compositions were expanded based upon the stratification. The number of  
477 tows with length data ranged from 17 in 1986 to 81 in 1998 (Table 10). Ages were read using  
478 surface reading methods until 1989 when the break-and-burn method replaced surface reads  
479 as the best method to age Pacific ocean perch. Unfortunately, surface reading of Pacific ocean  
480 perch otoliths results in significant underestimates of age. Due to this, these otoliths were  
481 excluded from analysis. The available ages from the Triennial survey and the number of tows  
482 where otoliths were collected are shown in Table 11. The expanded length frequencies from  
483 this survey show an increase in small fish starting in 1995 (Figure 13). The age frequencies  
484 provide clear evidence of large year-classes moving through the population from the 1999  
485 and 2000 recruitment (Figure 14).

486 The effective sample sizes for length and marginal age composition data were calculated  
487 according to Stewart and Hamel (2014) described in Section 2.1.1.

#### 488 2.1.5 Pacific ocean perch Survey

489 A survey designed to sample Pacific ocean perch was conducted in 1979 and again in 1985  
490 (for a detailed description see (Ianelli et al. 1992)). An index of abundance was estimated  
491 based on the data using the VAST delta-GLMM model. The estimated index of abundance  
492 is shown in Table 4. The lognormal distribution with random strata-year had the lowest AIC  
493 and was chosen as the final model. The Q-Q plot does not show any departures from the  
494 assumed distribution (Figure 15). The index shows a clear decline in abundance between the  
495 two survey years.

496 Length and age compositions were expanded based on the stratification. The survey had 125  
497 and 126 Pacific ocean perch tows (Table 12) and ages were only available in 1985 due to  
498 surface reads for the 1979 data (Table 13). The length frequencies for both years are highest  
499 between the 30-45 cm range (Figure 16) with ages in 1985 having a large number of fish age  
500 40 and greater (Figure 17).

501 The effective sample sizes for length and marginal age composition data were calculated  
502 according to Stewart and Hamel (2014) described in Section 2.1.1.

## 503 2.2 Fishery-Dependent Data

### 504 2.2.1 Commercial Fishery Landings

#### 505 Washington

506 Historical commercial fishery landings of Pacific ocean perch from Washington for the years  
507 1908-2016 were obtained from Theresa Tsou (WDFW) and Phillip Weyland (WDFW). This

508 assessment is the first Pacific ocean perch assessment to include a state provide historical  
509 catch reconstruction and hence, the historical catches for Washington differ from those used  
510 in the 2011 assessment. Due to recent corrections to the landings of Pacific ocean perch based  
511 upon market categories (1981-2016) were obtained directly from Washington state rather  
512 than from Pacific Fisheries Information Network (PacFIN).

## 513 **Oregon**

514 Historical commercial fishery landings of Pacific ocean perch from Oregon for the years  
515 1892-1986 were obtained from Alison Dauble (ODFW). A description of the methods can be  
516 found in Karnowski et al. (2014). Recent landings (1987-2016) were obtained from PacFIN  
517 retrieval dated May 2, 2017, Pacific States Marine Fisheries Commission, Portland, Oregon;  
518 www.psmfc.org. The catch data in from the POP and POP2 categories contained within  
519 PacFIN for Pacific ocean perch were used for this assessment. Additional catches from  
520 1987-1999 for Pacific ocean perch under the UROCK category not yet available in PacFIN  
521 were received directly from the state and combined with the catch data available for that  
522 period within PacFIN (Patrick Mirrick, personal communication, ODFW).

## 523 **California**

524 Historical commercial fishery landings of Pacific ocean perch were obtained directly from  
525 John Field at the SWFSC due to database issues for the historical period for the California  
526 Cooperative Groundfish Survey, also known as CALCOM (128.114.3.187) for the years 1916-  
527 1980. A description of the historical reconstruction methods can be found in (Ralston et al.  
528 2010). Recent landings (1981-2016) were obtained from PacFIN retrieval dated May 2, 2017,  
529 Pacific States Marine Fisheries Commission, Portland, Oregon; www.psmfc.org.

## 530 **At-Sea Hake Fishery**

531 Catches of Pacific ocean perch are monitored aboard the vessel by observers in the At-Sea  
532 hake Observer program (ASHOP) and were available for the years of 1975-2016. Observers  
533 use a spatial sample design, based on weight, to randomly choose a portion of the haul to  
534 sample for species composition. For the last decade, this is typically 30-50% of the total  
535 weight. The total weight of the sample is determined by all catch passing over a flow scale.  
536 All species other than hake are removed and weighed by species on a motion compensated  
537 flatbed scale. Observers record the weights of all non-hake species. Non-hake species total  
538 weights are expanded in the database by using the proportion of the haul sampled to the  
539 total weight of the haul. The catches of non-hake species in unsampled hauls is determined  
540 using bycatch rates determined from sampled hauls. Since 2001, more than 97% of the hauls  
541 have been observed and sampled.

## 542 **Foreign Catches**

543 From the 1960s through the early 1970s, foreign trawling enterprises harvested considerable  
544 amounts of rockfish off Washington and Oregon, and along with the domestic trawling fleet,

545 landed large quantities of Pacific ocean perch. Foreign catches of individual species were  
546 estimated by Rogers (2003) and attributed to INPFC areas for the years of 1966-1976 for  
547 Pacific ocean perch. The foreign catches were combined across areas for a coastwide removal  
548 total.

549 **2.2.2 Discards**

550 Data on discards of Pacific ocean perch are available from two different data sources. The  
551 earliest source is referred to as the Pikitch data and comes from a study organized by Ellen  
552 Pikitch that collected trawl discards from 1985-1987 (Pikitch et al. 1988). The northern and  
553 southern boundaries of the study were 48°42' N latitude and 42°60' N. latitude respectively,  
554 which is primarily within the Columbia INPFC area (Pikitch et al. 1988, Rogers and Pikitch  
555 1992). Participation in the study was voluntary and included vessels using bottom, midwater,  
556 and shrimp trawl gears. Observers of normal fishing operations on commercial vessels collected  
557 the data, estimated the total weight of the catch by tow and recorded the weight of species  
558 retained and discarded in the sample. Results of the Pikitch data were obtained from John  
559 Wallace (personal communication, NWFSC, NOAA) in the form of ratios of discard weight to  
560 retained weight of Pacific ocean perch and sex-specific length frequencies. Discard estimates  
561 are shown in Table 14.

562 The second source is from the West Coast Groundfish Observer Program (WCGOP). This  
563 program is part of the NWFSC and has been recording discard observations since 2003. Table  
564 14 shows the discard ratios (discarded/(discarded + retained)) of Pacific ocean perch from  
565 WCGOP. Since 2011, when the trawl rationalization program was implemented, observer  
566 coverage rates increased to nearly 100% for all the limited entry trawl vessels in the program  
567 and discard rates declined compared to pre-2011 rates. Discard rates were obtained for both  
568 the catch-share and the non-catch share sector for Pacific ocean perch. A single discard rate  
569 was calculated by weighting discard rates based on the commercial landings by each sector.  
570 Coefficient of variations were calculated for the non-catch shares sector and pre-catch share  
571 years by bootstrapping vessels within ports because the observer program randomly chooses  
572 vessels within ports to be observed. Post-ITQ all catch share boats have 100% observer  
573 coverage and discarding is assumed known. Discard length composition for the trawl fleet  
574 varied by year, with larger fish being discarded prior to 2011 (Figure 18).

575 **2.2.3 Historical Commercial Catch-per-unit effort**

576 Data on catch-per-unit-effort (CPUE) in mt/hr from the domestic fishery were combined for  
577 the INPFC Vancouver and Columbia areas (Table 15, from Gunderson (1977)). Although  
578 these data reflect catch rates for the US fleet, the highest catch rates coincided with the  
579 beginning of removals by the foreign fleet. This suggest that, barring unaccounted changes in  
580 fishing efficiency during this period, the level of abundance was high at that time. A CV of  
581 0.40 was used in this assessment to be consistent with the CV observed in the survey data.

582 **2.2.4 Fishery Length And Age Data**

583 Biological data from commercial fisheries that caught Pacific ocean perch were extracted from  
584 PacFIN on May 4, 2017. Lengths taken during port sampling in Oregon and Washington  
585 were used to calculate length and age compositions. There were no biological data from  
586 California for Pacific ocean perch available within PacFIN. The overwhelming majority of  
587 these data were collected from the mid-water and bottom trawl gear, but additional biological  
588 data were collected from non-trawl gear which was grouped together with trawl gear data.  
589 Tables 16 and 17 show the number of trips and fish sampled, along with the calculated  
590 sample sizes. Length and age data were acquired at the trip level, and then aggregated to the  
591 state level. The sample sizes were calculated via the Stewart Method (Ian Stewart, personal  
592 communication, IPHC):

593  $\text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is } < 44$

594  $\text{Input effN} = 7.06 * N_{\text{trips}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is } \geq 44$

595 The fishery fleet observed Pacific ocean perch that were generally greater than 30 cm across  
596 all years of available data (Figure 19). The fishery fleet age data has clear trends of a large  
597 cohort moving through the population (Figure 20). Lengths and ages were also available for  
598 the At-sea hake fishery and are shown in Figures 21 and 22.

599 **2.3 Biological Data**

600 **2.3.1 Natural Mortality**

601 Historic Pacific ocean perch ages determined using scales and surface reading methods of  
602 otoliths, resulted in estimates of natural mortality ( $M$ ) of between 0.10 and  $0.20\text{yr}^{-1}$  with  
603 a longevity less than 30 years (Gunderson 1977). Based on break-and-burn method of age  
604 determination using otoliths, the maximum age of Pacific ocean perch was revised to be 90  
605 years (Chilton and Beamish 1982). The updated understanding concerning Pacific ocean perch  
606 longevity reduced the estimate of natural mortality based on Hoenig's (1983) relationship to  
607  $0.059\text{yr}^{-1}$ . The previous assessment applied a prior distribution on natural mortality based  
608 upon multiple life history correlates (including Hoenig's method, Gunderson gonadosomatic  
609 index (1997), and McCoy and Gillooly's (2008) theoretical relationship) developed separately  
610 for female and male Pacific ocean perch.

611 Hamel (2015) developed a method for combining meta-analytic approaches relating the  
612 natural mortality rate  $M$  to other life-history parameters such as longevity, size, growth rate  
613 and reproductive effort, to provide a prior on  $M$ . In that same issue of ICESJMS, Then et al.  
614 (2015), provided an updated data set of estimates of  $M$  and related life history parameters  
615 across a large number of fish species, from which to develop an  $M$  estimator for fish species

616 in general. They concluded by recommending  $M$  estimates be based on maximum age alone,  
 617 based on an updated Hoenig non-linear least squares (nls) estimator  $M = 4.899A_{max}^{(} - .916\text{)}.$   
 618 The approach of basing  $M$  priors on maximum age alone was one that was already being used  
 619 for West Coast rockfish assessments. However, in fitting the alternative model forms relating  
 620  $M$  to  $A_{max}$ , Then et al. (2015) did not consistently apply their transformation. In particular,  
 621 in real space, one would expect substantial heteroscedasticity in both the observation and  
 622 process error associated with the observed relationship of  $M$  to  $A_{max}$ . Therefore, it would be  
 623 reasonable to fit all models under a log transformation. This was not done. Re-evaluating  
 624 the data used in Then et al. (2015) by fitting the one-parameter  $A_{max}$  model under a log-log  
 625 transformation (such that the slope is forced to be -1 in the transformed space (Hamel 2015)),  
 626 the point estimate for  $M$  is:

$$M = \frac{5.4}{A_{max}}$$

628 The above is also the median of the prior. The prior is defined as a lognormal with mean  
 629  $\ln(\frac{5.4}{A_{max}})$  and SE = 0.438. Using a maximum age of 100 the point estimate and median of the  
 630 prior is 0.054. The maximum age was selected based on available age data from all West Coast  
 631 data sources. The oldest aged rockfish was 120 years, captured by the commercial fishery  
 632 in 2007. However, age data are subject to ageing error which could impact this estimate of  
 633 longevity. The selection of 100 years was based on the range of other ages available with had  
 634 multiple observations of fish between 90 and 102 years of age.

### 635 2.3.2 Sex Ratio, Maturation, and Fecundity

636 Examining all biological data sources, the sex ratio of young fish are within 5% of 1:1 by  
 637 length until larger sizes which are dominated by females who reach a larger maximum size  
 638 relative to males (Figure 23), with the sex ratio being approximately equal across ages (Figure  
 639 24), and hence this assessment the sex ratio at birth was assumed to be 1:1. This assessment  
 640 assumed a logistic maturity-at-length curve based on analysis of 537 fish maturity samples  
 641 collected from the NWFSC shelf-slope survey. This is revised from the previous assessment  
 642 which assumed maturity-at-age based on the work of Hannah and Parker (2007). Additionally,  
 643 the new maturity-at-length curve is based on the estimate of functional maturity, an approach  
 644 that classifies rockfish maturity with developing oocytes as mature or immature based on  
 645 the proportion of vitellogenin in the cytoplasm and the measured frequency of atretic cells  
 646 (Melissa Head, personal communication, NWFSC, NOAA). The 50% size-at-maturity was  
 647 estimated at 32.1 cm with maturity asymptoting to 1.0 for larger fish (Figure 25). Comparison  
 648 between the maturity-at-age used in the previous assessment and the updated functional  
 649 maturity-at-length is shown in Figure 26.

650 The fecundity-at-age has also been updated from the previous assessment based on new  
 651 research. Dick (2017) estimated new fecundity relationships for select West Coast stocks  
 652 where fecundity for Pacific ocean perch was estimated equal to  $8.66e-10L^{4.98}$  in millions of  
 653 eggs. Spawning output at length is shown in Figure 27.

654 **2.3.3 Length-Weight Relationship**

655 The length-weight relationship for Pacific ocean perch was estimated outside the model using  
656 all biological data available from fishery-dependent and -independent data sources where the  
657 female weight-at-length in grams was estimated at  $1.044e-05L^{3.09}$  and males at  $1.05e-05L^{3.08}$   
658 where  $L$  is length in cm (Figures 28 and 29).

659 **2.3.4 Growth (Length-at-Age)**

660 The length-at-age was estimated for male and female Pacific ocean perch using data collected  
661 from both fishery-dependent and -independent data sources that were collected from 1981-  
662 2016. Figure 30 shows the lengths and ages for all years and all data as well as predicted  
663 von Bertalanffy fits to the data. Females grow larger than males and sex specific growth  
664 parameters were estimated at the following values:

665  $\text{Females } L_{\infty} = 42.32; k = 0.169; t_0 = -1.466$

666  $\text{Males } L_{\infty} = 39.03; k = 0.212; t_0 = -1.02$

667 These values were used as starting parameter values within the model prior to estimating  
668 each parameter for male and female Pacific ocean perch.

669 **2.3.5 Ageing Precision And Bias**

670 Uncertainty surrounding the ageing error process for Pacific ocean perch was incorporated by  
671 estimating ageing error by age. Age-composition data used in the model were from break-  
672 and-burn otolith reads aged by the Cooperative Ageing Project (CAP) in Newport, Oregon.  
673 Break-and-burn double reads of more than 1500 otoliths were provided by the CAP lab. An  
674 ageing error estimate was made based on these double reads using a computational tool  
675 specifically developed for estimating ageing error (Punt et al. 2008), and using release 1.0.0  
676 of the R package nwfscAgeingError (Thorson et al. 2012) for input and output diagnostics,  
677 publicly available at: <https://github.com/nwfsc-assess/nwfscAgeingError>. A non-linear  
678 standard error was estimated by age where there is more variability in the age of older fish  
679 (Table 20 and Figure 31).

680 **2.4 History Of Modeling Approaches Used For This Stock**

681 **2.4.1 Previous Assessments**

682 The status of Pacific ocean perch off British Columbia, Washington, and Oregon have been  
683 periodically assessed since the intensive exploitation that occurred in the 1960s. Concerns

684 regarding Pacific ocean perch status off the coast the US west coast were raised in the late  
685 1970s (Gunderson 1978, 1981) and in 1981 the PFMC adopted a 20-year plan to rebuild the  
686 stock.

687 The 1992 assessment determined that Pacific ocean perch remained at low levels relative  
688 to the population size in 1960 (Ianelli et al. 1992) and recommended additional harvest  
689 restrictions to allow for stock rebuilding. The 1998 assessment (Ianelli and Zimmermann  
690 1998) estimated that the stock was 13% of the unfished level, leading the National Marine  
691 Fishery Service (NMFS) to declare the stock overfished in 1999. A formal rebuilding plan was  
692 implemented in 2001. The rebuilding plan reduced the SPR harvest rate used to determine  
693 catches to 0.864 (in contrast to the default harvest rate of 0.50). The last full assessment of  
694 Pacific ocean perch was conducted in 2011 (Hamel and Ono 2011) which concluded that the  
695 stock was still well below the target biomass of  $40\%SB_0$  estimating the relative stock status  
696 at 19.1%.

#### 697 2.4.2 Previous Assessment Recommendations

698 Recommendation: Considering trans-boundary stock effects should be pursued. In particular  
699 the consequences of having spawning contributions from external stock components should  
700 be evaluated relative to the steepness estimates obtained in the present assessment.

701 *STAT response: The STAT team agrees that this should be an ongoing area of research and*  
702 *collaboration between the US and Canada. This assessment presents a sensitivity where the*  
703 *inclusion of Canadian data are included within the model.*

704 Recommendation: The benefits of adopting the complex model used this year should be  
705 evaluated relative to simpler assumptions and models. While the transition from the simpler  
706 old model to Stock Synthesis was shown to be similar for the historical period, the depletion  
707 estimates in the most recent years were different enough to warrant further investigation.

708 *STAT response: This assessment was performed in Stock Synthesis, an integrated model,*  
709 *which can be modified to either simple or complex structural forms based upon the available*  
710 *data and the processes being modeled. There were not addtional explorations of alternative*  
711 *modeling platforms.*

712 Recommendation: Discard estimates from observer programs should be presented, reviewed  
713 (similar to the catch reconstructions), and be made available to the assessment process.

714 *STAT response: This assessment uses discard rates and discard lengths collected by the*  
715 *WCGOP from 2003-2015.*

716 Recommendation: The ability to allow different “plus groups” for specific data types should  
717 be evaluated (and implemented in Stock Synthesis). For example, this would provide the  
718 ability to use the biased surface-aged data in an appropriate way.

<sup>719</sup> *STAT response: Additional research needs to completed which evaluates the amount of bias and*  
<sup>720</sup> *imprecision in surface-read ages. Evaluating available surface-read ages within the PacFIN*  
<sup>721</sup> *database fish of lengths between 23-44 cm can be aged at 10 years old. This large range of*  
<sup>722</sup> *lengths at the same age indicates considerable bias in ages for fish surface-read younger aged*  
<sup>723</sup> *fish.*

<sup>724</sup> Recommendation: Historical catch reconstruction estimates should be formally reviewed  
<sup>725</sup> prior to being used in assessments and should be coordinated so that interactions between  
<sup>726</sup> stocks are appropriately treated. The relative reliability of the catch estimates over time  
<sup>727</sup> could provide an axis of uncertainty in future assessments.

<sup>728</sup> *STAT response: California and Oregon have undergone extensive work to create historical*  
<sup>729</sup> *catch reconstructions. This is the first assessment for Pacific ocean perch which includes a*  
<sup>730</sup> *Washington historical catch reconstruction. The data used in this assessment represent Wash-*  
<sup>731</sup> *ington state's current best estimate for historical catches. Both California and Washington*  
<sup>732</sup> *are conducting research to estimate uncertainty surround historical catches which could be*  
<sup>733</sup> *used to propegate uncertainty within the assessment.*

## <sup>734</sup> 3 Assessment

### <sup>735</sup> 3.1 General Model Specifications and Assumptions

<sup>736</sup> Stock Synthesis version 3.30.03.05 was used to estimate the parameters in the model. R4SS,  
<sup>737</sup> revision 1.27.0, along with R version 3.3.2 were used to investigate and plot model fits. A  
<sup>738</sup> summary of the data sources used in the model (details discussed above) is shown in Figure  
<sup>739</sup> 2.

<sup>740</sup> Stock Synthesis has many options when setting up a model and the assessment model for  
<sup>741</sup> Pacific ocean perch was set up in the following manner.

#### <sup>742</sup> 3.1.1 Changes Between the 2011 Assessment Model and Current Model

<sup>743</sup> The current model for Pacific ocean perch has many made many similar assumptions to the  
<sup>744</sup> 2011 assessment but differs in some key ways. This assessment disaggregated the fleets into  
<sup>745</sup> a trawl/other gear, At-sea hake, historical foreign fleet, and research fleets. The previous  
<sup>746</sup> assessment implemented a single fleet where removal from all sources were aggregated together.  
<sup>747</sup> The separating of fleets applied in this assessment allowed for differing assumptions regarding  
<sup>748</sup> current and historical discarding practices. Although there are no compositional data available  
<sup>749</sup> from the foreign fleet, it is assumed that very little discarding to no discarding of fish occurred.  
<sup>750</sup> Additionally, the At-sea hake fishery removals are represent both discarded and retained fish

751 and hence an additional discard rate would not be appropriate. Similar logic was applied in  
752 regard to survey removals.

753 The historical landings used in the model differs from those used in 2011. The assessment  
754 includes the first state provided historical reconstruction landings for Washington state. The  
755 historical reconstruction has removals starting in 1916 and have larger removals in the 1940s  
756 relative to those used in 2011 (Figure 32). Given the increase in historical removals prior to  
757 1940, the 2011 model starting year, the starting year for modeling the stock was revised to  
758 1918, the first year Pacific ocean perch landings exceeded 1 mt. Explorations were conducted  
759 relative to the model starting year and no differences were found between the 1918 start  
760 year compared to starting the model in 1892, the first record of Pacific ocean perch landings  
761 between California, Oregon, and Washington catch data.

762 Selectivity in this model is assumed to be length-based and is modeled using double-normal  
763 for all fleets, except the Pacific ocean perch survey which retained the previous assessment  
764 assumption of logistic selectivity. The previous assessment mirrored selectivity among the  
765 Pacific ocean perch and both slope surveys (AFSC and NWFSC). This assessment allows for  
766 survey specific selectivity.

767 All fishery-independent indices have been reevaluated for this assessment using a spatial-  
768 temporal delta generalized linear mixed model (VAST delta-GLMM) which is updated  
769 approach from that used 2011 which did not incorporate spatial effects. An additional update  
770 to the treatment of survey data was the decision to use the Triennial survey as a single  
771 time-series ranging from 1980-2004. The previous assessment opted to split this survey into  
772 an early and a late index of abundance based upon the change in southern sampling and a  
773 shift in survey timing. Northern California is considered to be the southern end of Pacific  
774 ocean perch West Coast distribution with rare encounters in central or southern California  
775 waters. The biological data from the Triennial survey showed no discernible ontogenetic shifts  
776 in Pacific ocean perch during the early or late period of summer samples. Based upon these  
777 investigations, the Triennial survey was retained as a single index of abundance.

778 Maturity and fecundity were updated for this assessment based upon new research. Fecundity  
779 for Pacific ocean perch used in this assessment was base on a reevaluation of the fecundity of  
780 West Coast rockfish by Dick et al. (2017), updating the previous fecundity estimates used  
781 in the 2011 assessment (Dick 2009) (Figure 27). Maturity in this assessment was based on  
782 examination of 537 fish samples which were used to estimate functional maturity, an approach  
783 that classifies rockfish maturity with developing oocytes as mature or immature based on  
784 the proportion of vitellogenin in the cytoplasm and the measured frequency of atretic cells  
785 (Melissa Head, personal communication, NWFSC, NOAA). The updated maturity curve  
786 was based on maturity-at-length where the previous estimates used in 2011 were based on  
787 maturity-at-age (Figure 26).

788 In this assessment, the beta prior developed from a meta-analysis of West Coast groundfish  
789 was updated to the 2017 value (James Thorson, personal communication, NWFSC, NOAA)  
790 in preliminary models, with steepness fixed at an alternative value in the final base model.

791 Additionally, the prior for natural mortality was updated based on analysis conducted by  
792 Owen Hamel (personal communication, NWFSC, NOAA), where female and male natural  
793 mortality fixed at the prior median.

### 794 3.1.2 Summary of Fleets and Areas

795 Pacific ocean perch are most frequently observed in Oregon and Washington waters in survey  
796 and fishery observations. Multiple fisheries encounter Pacific ocean perch. Trawl, fixed gear,  
797 and the At-sea (mid-water) hake fisheries account for the majority of the current Pacific  
798 ocean perch landings.

799 The majority of removals of Pacific ocean perch were observed by the trawl gears with fixed  
800 gear accounting for a small fraction of the catches available within PacFIN. Trawl and fixed  
801 gears were combined into a coast-wide fleet. For the period from 1918 to the early 1990s, prior  
802 to the introduction of trip limits for rockfish, limited discarding of Pacific ocean perch was  
803 assumed. Observations of Pacific ocean perch in the Pikitch et al. (1988) data (1986-1987)  
804 allowed for a formal analysis of discard rates which were applied to the historical period of  
805 the fishery. Foreign trawl catches (1966-1976) were modeled as a single fleet. The At-sea  
806 hake fishery operates as a mid-water fishery targeting Pacific whiting but encounters Pacific  
807 ocean perch as a bycatch species. This fleet was also modeled as a single fleet.

### 808 3.1.3 Other Specifications

809 The specifications of the assessment are listed in Table 21. The model is a two-sex, age-  
810 structured model starting in 1918 with an accumulated age group at 60 years. Growth was  
811 estimated and natural mortality was fixed at the median of the prior. The lengths in the  
812 population were tracked by 1 cm intervals and the length data were binned into 1 cm intervals.  
813 A curvilinear ageing imprecision relationship was estimated and used to model ageing error.  
814 Fecundity-at-length was fixed at the values from Dick et al. (2017) for Pacific ocean perch  
815 and spawning output was defined in millions of eggs.

816 Age data were available for the commercial and At-sea hake fishery, as well as the Triennial,  
817 the Pacific ocean perch, the NWFSC slope, and the NWFSC shelf-slope surveys. The ages  
818 from the NWFSC shelf-slope survey and were entered into the model as conditional age-at-  
819 length. The assessment used length-frequencies collected by the fishery fleet, the At-sea hake  
820 fishery, the Triennial, Pacific ocean perch, AFSC slope, NWFSC slope, and the NWFSC  
821 shelf-slope surveys.

822 The specification of when to estimate recruitment deviations is an assumption that likely  
823 affects model uncertainty. It was decided to estimate recruitment deviations from 1900-2014  
824 to appropriately quantify uncertainty. The earliest length-composition data occur in 1966  
825 and the earliest age data were in 1981. The most informed years for estimating recruitment

826 deviations were from about the mid-1970s to about 2011. The period from 1900-1974 was fit  
827 using an early series with little or no bias adjustment, the main period of recruitment deviates  
828 occurred from 1975-2014 with an upward and downward ramping of bias adjustment, and  
829 2015 onward was fit using forecast recruitment deviates with little bias adjustment. Methot  
830 and Taylor (2011) summarize the reasoning behind varying levels of bias adjustment based  
831 on the information available to estimate the deviates. The standard deviation of recruitment  
832 variability was assumed to be 0.70.

833 The recommended selectivity type in Stock Synthesis is the double normal and was used in  
834 this assessment for the all fleets, except the Pacific ocean perch survey which was assumed  
835 logistic based on the length composition data. Changes in retention curves were estimated  
836 for the commercial fishery fleet.

837 Time blocks for the fishery fleet are provided in Table 21. Fishery retention has changed over  
838 the modeled period due to management changes. The time block on the retention curves  
839 for the fishery were set from 1918-1991, 1992-2001, 2002-2007, 2008, 2009-2010, 2011-2016  
840 based on available discarding data and changes in trip limits that likely resulted in changes  
841 to discarding patterns of Pacific ocean perch. No discarding was assumed in the At-sea hake  
842 and the foreign fisheries.

843 The following distributions were assumed for data fitting. Survey indices were lognormal,  
844 total discards were lognormal.

#### 845 3.1.4 Modeling Software

846 The STAT team used Stock Synthesis version 3.30.03.05 by Dr. Richard Methot at the  
847 NWFSC (Methot and Wetzel 2013). This most recent version was used, since it included  
848 improvements and corrections to older versions. The previous assessment of Pacific ocean  
849 perch also used Stock Synthesis but a earlier version, 3.24, model bridging was performed  
850 between both versions of Stock Synthesis and are shown in Figure 33.

#### 851 3.1.5 Priors

852 A prior distribution was developed for natural mortality ( $M$ ) from an analysis based on an  
853 assumed maximum age of 100 years. The analysis was performed by Owen Hamel (personal  
854 communications, NWFSC, NOAA) and used data from Then et al. (2015) to provide a  
855 lognormal distribution for natural mortality. The median of the lognormal prior is 0.054 and  
856 has a standard error of 0.438.

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

and endorsed by the Science and Statistical Committee in 2017. The prior is a beta distribution with  $\mu=0.72$  and  $\sigma=0.15$ . However, fixing steepness within the model resulted in what was determined to be unrealistic relative biomass levels ( $> 1$ ), and it was decided to fix steepness at 0.50. The previous assessment estimated and fixed steepness equal to 0.40. The current data does not contain information regarding steepness and 0.50 was selected as an intermediate value between the prior and the previous assessment value. The steepness value of 0.50 was contained within the estimated uncertainty envelope from the assessment model when either the prior value of 0.72 or 0.40 values were assumed.

### 3.1.6 Data Weighting

The base case was weighted such that the various data sources were mostly consistent with each other in terms of the relationship between input and effective sample sizes. Length and age-at-length compositions from the NWFSC shelf-slope survey were fit along with length and marginal age compositions from the fishery and other survey fleets. Length data started with a sample size determined from the equation listed in Sections 2.1.1 (survey data) and 2.2.4 (fishery data). Age-at-length data assumed that each age was a random sample within the length bin and started with a sample size equal to the number of fish in that length bin. However, the 2016 NWFSC shelf-slope age-at-length data was variable compared to previous years for both males and females relative to all other years with observed fish being larger at age. Model exploration determined that the model was more sensitive than would be reasonably expected to the inclusion of this data year. Due to the increased variability within this data year and the mode's sensitivity, the effective sample size for this year was reduced to 50% of the number of fish within each length-age bin.

One extra variability parameter was estimated and added to the input variance for the Triennial and the NWFSC shelf-slope survey indices. Estimating additional variance for the CPUE and other surveys were explored and determined to not be required. Vessels present in the WCGOP data were bootstrapped to provide uncertainty of the total discards (Table 14).

The base case assessment model was weighted using the “Francis method”, which was based on equation TA1.8 in Francis (2011). This formulation looks at the mean length or age and the variance of the mean to determine if across years, the variability is explained by the model. If the variability around the mean does not encompass the model predictions, then that data source should be down-weighted. This method does account for correlation in the data (i.e., the multinomial distribution) as opposed to the McAllister and Ianelli (1997) method of looking at the difference between individual observations and predictions.

### 3.1.7 Estimated And Fixed Parameters

There were 164 estimated parameters in the base case model. These included one parameter for  $R_0$ , 8 parameters for growth, 2 parameters for extra variability on the Triennial and NWFSC

896 shelf-slope surveys indices, 24 parameters for selectivity, retention, and time blocking of the  
897 fleets and the surveys, 117 recruitment deviations, and 12 forecast recruitment deviations  
898 (Table 23).

899 Fixed parameters in the model were as follows. Steepness was fixed at 0.50. A sensitivity  
900 analysis and a likelihood profile were done for steepness. Natural mortality was fixed at  
901 0.054 for females and males, which is the median of the prior. The standard deviation of  
902 recruitment deviates was fixed at 0.70. Maturity-at-length was fixed as described in Section  
903 2.3.2. Length-weight parameters were fixed at estimates using all length-weight observations  
904 (Figure 29).

905 Dome-shaped selectivity was explored for all fleets within the model. Older Pacific ocean  
906 perch are often found in deeper waters and may move into areas that limit their availability  
907 to fishing gear, especially trawl gear. Domed shape selectivity was determined to provide  
908 the best fit to the data for the fishery fleet and the Triennial survey. The final base model  
909 assumed asymptotic selectivity for the At-sea hake fishery, and all other surveys.

## 910 3.2 Model Selection and Evaluation

911 The base case assessment model for Pacific ocean perch was developed to balance parsimony  
912 and realism, and the goal was to estimate a biomass trajectory for the population of Pacific  
913 ocean perch on the west coast of the US. The model contains many assumptions to achieve  
914 parsimony and uses many different sources of data to estimate reality. A series of investigative  
915 model runs were done to achieve the final base case model.

### 916 3.2.1 Key Assumptions and Structural Choices

917 The key assumptions in the model were that the assessed population is a single stock with  
918 biological parameters characterizing the entire coast, maturity at age has remained constant  
919 over the period modeled, weight-at-length has remained constant over the period modeled,  
920 the standard deviation in recruitment deviation is 0.70, and steepness is 0.50. These are  
921 simplifying assumptions that unfortunately cannot be verified or disproved. Sensitivity  
922 analyses were conducted for most of these assumptions to determine their effect on the  
923 results.

924 Structurally, the model assumed that the catches from each fleet were representative of  
925 the coastwide population, instead of specific areas, and fishing mortality prior to 1918 was  
926 negligible. It also assumed that discards were low prior to 1992 and after 2010.

927 **3.2.2 Alternate Models Considered**

928 The exploration of models began by bridging from the 2011 assessment to Stock Synthesis  
929 version 3.30.03.05, which produced no discernible difference. The updated catch series with  
930 discards added per the 2011 assessment produced insignificant differences in the relative scale  
931 of the population although the updated historical removals resulted in an increase in the  
932 estimate of unfished biomass. Updating the survey indices produced small differences in  
933 the relative scale of the population. Adding age and length data each resulted in less of a  
934 population decline from the 1970s to pre-2000, resulting in an increase in the estimated 2017  
935 final stock status. However, the addition of new data resulted in an early pattern within  
936 recruitment, indicating that the assumptions within the previous model may not represent  
937 the best fit to the current data.

938 This assessment estimated discards in the model, so time was spent investigating time blocks  
939 for changes in selectivity and retention to match the discard data as best as possible. Using  
940 major changes in management and observed changes in landings, a set of blocks for retention  
941 was found for the fishery fleet. In the spirit of parsimony, as few blocks as possible were used,  
942 allowed blocks only for time periods with data, and added new blocks when we felt they were  
943 justified by changes in management and they improved the fit to the data.

944 Natural mortality was also investigated and a new prior was developed assuming a maximum  
945 age of 100 years for females and males. The previous assessment estimated male natural  
946 mortality as an offset from female natural mortality which was fixed at the median of the  
947 2011 prior (0.05). This assessment attempted to estimate natural mortality for both sexes  
948 using the 2017 updated prior, but there was little to no information on natural mortality  
949 within the data and hence opted to fix the value for females within the base model. Upon  
950 additional exploration, the model estimated very little difference in male natural mortality  
951 relative to females (< 0.002) and in the interest of selecting the model that fit the data with  
952 the fewest parameters required, males were fixed equal to the female natural mortality.

953 Finally, multiple models were investigated where steepness was either estimated, fixed at the  
954 prior, or at an alternate value. The assessment in 2011 determined that there was sufficient  
955 information concerning steepness where the parameter was estimated and then fixed at  
956 0.40. Based upon likelihood profiles performed on the current model, there was no longer  
957 support for a steepness value of 0.40. The likelihood profile was flat across various levels of  
958 steepness with a very small improvement in likelihood (<0.50 log likelihood units) at the  
959 lowest steepness values. Estimating steepness starting at the median of the “type C” prior,  
960 the meta-analysis prior evaluated omitting information from Pacific ocean perch, of 0.76  
961 resulted in very little if any movement from the median value due to the flat likelihood surface  
962 across values for this parameter with final relative stock status for 2017 being estimated to >  
963 100% of unfished biomass. Fixing steepness at the median of the prior of 0.72 resulted in  
964 relative stock status estimates for 2017 at 98.6% of unfished biomass. It was determined that  
965 the resulting stock status estimates when steepness was fixed at the meta-analysis prior were  
966 overly optimistic and unrealistic given the biology and historical exploitation of Pacific ocean  
967 perch.

968 **3.2.3 Convergence**

969 Proper convergence was determined by starting the minimization process from dispersed  
970 values of the maximum likelihood estimates to determine if the model found a better minimum.  
971 This was repeated 100 times and a better minimum was not found (Table 22). The model  
972 did not experience convergence issues when provided reasonable starting values. Through  
973 the jittering done as explained above and likelihood profiles, we are confident that the base  
974 case as presented represents the best fit to the data given the assumptions made. There were  
975 no difficulties in inverting the Hessian to obtain estimates of variability, although much of  
976 the early model investigation was done without attempting to estimate a Hessian.

977 **3.3 Response To The Current STAR Panel Requests**

978 TBD after the STAR panel.

979 **3.4 Base Model Results**

980 The base model parameter estimates along with approximate asymptotic standard errors  
981 are shown in Table 23 and the likelihood components are shown in Table 24. Estimates of  
982 derived reference points and approximate 95% asymptotic confidence intervals are shown in  
983 Table 25. Time-series of estimated stock size over time are shown in Table 26.

984 **3.4.1 Parameter Estimates**

985 The estimates of maximum length and the von Bertanlaffy growth coefficient,  $k$ , were less  
986 than the the external estimates for males and females (Figure 30), but were well within the  
987 95% confidence interval given the estimated uncertainty (Table 23 and Figure 34). Female  
988 and male Pacific ocean perch grow quickly at younger ages, reaching near maximum length  
989 by age 20, with female Pacific ocean perch reaching larger maximum lengths.

990 Selectivity curves were estimated for commercial and survey fleets. The estimated selectivity  
991 for all fleets within the model are shown in Figure 35. The fishery selectivity was estimated  
992 dome shaped, reaching maximum selectivity for fish between 35 and 40 cm. The At-sea  
993 hake fishery was estimated to have little selectivity for smaller Pacific ocean perch and only  
994 reaching full selectivity at the largest sizes. Survey selectivities, excluding the Triennial  
995 survey, were estimated asymptotic during model explorations with the final selectivity fixed  
996 asymptotic in the final base model. The Triennial survey selectivity peaked at lengths between  
997 25 and 30 cm and declined before reaching a constant selectivity for larger Pacific ocean  
998 perch. The foreign fleet for which only catch data are available was assumed to be identical

<sup>999</sup> to the main fishery, although a sensitivity was performed (not shown) that mirrored the  
<sup>1000</sup> foreign selectivity to that of the Pacific ocean perch survey selectivity resulting in a negligible  
<sup>1001</sup> difference in stock status.

<sup>1002</sup> Retention curves were estimated for the fishery fleet only and were allowed to vary based  
<sup>1003</sup> upon discard data within the model over time (Figure 36). Historical retention was estimated  
<sup>1004</sup> high and declined over time due to management restriction on landings of Pacific ocean perch  
<sup>1005</sup> with the lowest retention occurring in 2009 and 2010 prior to the implementation of ITQs.  
<sup>1006</sup> Post-2011 retention was estimated to be nearly 100% for the fishery fleet.

<sup>1007</sup> Additional survey variability (process error added directly to each year's input variability)  
<sup>1008</sup> for the Triennial and the NWFSC shelf-slope surveys were estimated within the model. The  
<sup>1009</sup> estimated added variance for the Triennial survey was high at 0.39. The model estimated a  
<sup>1010</sup> small added variance for the NWFSC shelf-slope survey of 0.03. Preliminary models explored  
<sup>1011</sup> estimating added variance for each of the other indices, but resulted in no added variance  
<sup>1012</sup> being estimated and hence were not estimated in the base model.

<sup>1013</sup> Estimates of recruitment suggest that the Pacific ocean perch population is characterized  
<sup>1014</sup> by variable recruitment with occasional strong recruitments and periods of low recruitment  
<sup>1015</sup> (Figures 37 and 38). There is little information regarding recruitment prior to 1970 and the  
<sup>1016</sup> uncertainty in those estimates is expressed in the model. The four lowest recruitments (in  
<sup>1017</sup> ascending order) occurred in 2012, 2003, 1998, and 2005. There are very large, but uncertain,  
<sup>1018</sup> estimates of recruitment in 2008, 2013, 2000, and 1999. The 2008 recruitment event is  
<sup>1019</sup> estimated to be larger by an order of magnitude than any other recruitment estimated in  
<sup>1020</sup> the model. The uncertainty interval in number of recruits is large based on the uncertainty  
<sup>1021</sup> surrounding the spawning output in that year. However, the log recruitment deviation  
<sup>1022</sup> estimated uncertainty is low.

### <sup>1023</sup> 3.4.2 Fits to the Data

<sup>1024</sup> There are numerous types of data for which the fits are discussed: fishery CPUE index, survey  
<sup>1025</sup> abundance indices, discard data (biomass and length compositions), length composition data  
<sup>1026</sup> for the fisheries and surveys, marginal age compositions for the fisheries and surveys, and  
<sup>1027</sup> conditional age-at-length observations for the NWFSC shelf-slope survey

<sup>1028</sup> The fits the fishery CPUE and five survey indices are shown in Figure 39. Extra standard  
<sup>1029</sup> error was estimated for the Triennial and NWFSC shelf-slope surveys. The fishery CPUE  
<sup>1030</sup> and Pacific ocean perch survey index were fit well by the model. The first two years of the  
<sup>1031</sup> Triennial survey index, 1980 and 1983, were much higher than the later years and were poorly  
<sup>1032</sup> fit by the model. Both the AFSC and NWFSC slope survey indices were generally flat and  
<sup>1033</sup> fit well by the model. The recent NWFSC shelf-slope survey showed a variable trend over  
<sup>1034</sup> the time period with the 2016 data point being the highest estimate of the series and given  
<sup>1035</sup> the uncertainty around each data point the model fit the model fit fell with the uncertainty  
<sup>1036</sup> interval for all years.

1037 Fits to the total observed discard amounts required time blocks (Figure 40). Fits to the trawl  
1038 discards from the Pikitch data in 1985-1987 were quite good. Discard rate change modeled  
1039 over the 1992 - 2001 was based on management restrictions which were assumed to have  
1040 increased discarding practices in the fishery fleet. The next required time block was based on  
1041 the WCGOP data from 2002-2007 and were fit well by the model. Discarding increased prior  
1042 to the implementation to ITQs requiring blocks for 2008 and the 2009-2010 periods. The  
1043 model fit the very low post-ITQ discard rates based on the WCGOP data well. The total  
1044 estimated discard amount over time is shown in Figure 41.

1045 Fits to the length data are shown based on the proportions of lengths observed by year and  
1046 the Pearson residuals-at-length for all fleets. Detailed fits to the length data by year and  
1047 fleet are provided in Appendix 10. Aggregate fits by fleet are shown in Figure 42. There  
1048 are a few things that stand out when examining the aggregated length composition data.  
1049 First, the sexed discard lengths appear to be poorly fit by the model but this is related to  
1050 small sample sizes. The NWFS slope survey lengths were under estimated by the model, but  
1051 these data are over only two years. Finally, both the Triennial and the NWFSC shelf-slope  
1052 surveys select both young and old fish in contrast to the other data sources where typically  
1053 only larger fish were observed.

1054 Discard lengths from the Pikitch data (1986) and the WCGOP were fit well by the model  
1055 and show no obvious pattern in the residuals (Figure 43). The residuals to the fishery lengths  
1056 clearly showed the growth differential between males and females where the majority of  
1057 residuals at larger sizes were from female fish (Figure 44). The fishery showed large positive  
1058 residuals for smaller fish for 2013-2016 which are attributed to the strong 2008 year class  
1059 moving through the fishery. The At-sea hake fishery did not show an obvious pattern in  
1060 residuals but clearly showed the selectivity of the fishery for larger fish (Figure 45). The  
1061 residuals for each of the surveys are shown in Figures 46, 47, 48, 49, and 50. The Pearson  
1062 residuals from the NWFSC shelf-slope survey clearly showed the strong year classes moving  
1063 through the population.

1064 The model was weighted according to the Francis weights which adjust the weight given to a  
1065 data set based on the fit to the mean lengths by year. The mean lengths and the estimated  
1066 model fits are shown in Figures 51, 52, 53, 54, 55, 56, and 57. The mean lengths from the  
1067 fishery were consistent across the sampled period (Figure 69), showing only a decline in the  
1068 mean length in 2013-2015 likely due to the large 2008 cohort. The At-sea hake fishery showed  
1069 an increase in the mean length of fish observed to 2009 and then fluctuated at larger mean  
1070 lengths (Figure 70). The Triennial survey had a decreasing and then increasing trend in the  
1071 mean lengths over the sample period (Figure 54). The trend in the mean lengths observed  
1072 by the AFSC slope survey was generally flat excluding the samples from 1997 which were  
1073 smaller fish (Figure 55). The NWFSC slope length data from 2001 and 2002 were highly  
1074 variable with differing mean lengths between the years which were not fit well by the model  
1075 (Figure 56). The mean length for the NWFSC shelf-slope survey declined in 2012 and 2016  
1076 due to a large observation of young small fish by the survey (Figure 57).

1077 Age data were fitted to as marginal age compositions for the main fishery fleet, the At-sea

1078 hake fleet, the Pacific ocean perch survey, the Triennial survey, and the NWFSC slope survey.  
1079 The NWFSC shelf-slope ages were treated as conditional age-at-length data in order to  
1080 facilitate the estimation of growth within the model. The aggregated fits to the marginal age  
1081 data are shown in Figure 58. The aggregated age data was fit well for the fishery fleet which  
1082 had the largest sample of ages. The At-sea hake fleet and the surveys had significantly lower  
1083 sample sizes which resulted in spiky patterns in the aggregated data. However, the model  
1084 generally captured the trend of the data. Detailed fits to the age data by year and fleet are  
1085 provided in Appendix 11.

1086 The Pearson residuals for the main fishery fleet are show in Figure 59. There are diagonal  
1087 patterns in the residuals across year which likely are cohorts moving through the fishery.  
1088 The At-sea hake fishery only had age data for four non-consecutive years, combined with  
1089 the tendency of this fleet to select older fish, prevented general conclusions regarding fits  
1090 to the data over time and cohort strength over time (Figure 60). The Pacific ocean perch  
1091 survey only had one year of age data (the 1979 were all surface reads) but both sexes had a  
1092 larger observed number of older fish relative to the model estimate (Figure 61). The Triennial  
1093 age data which ranged from 1989-2004 did not show a clear pattern in residuals (Figure 62).  
1094 However, the final year of the survey, 2004, did have an increase in positive residuals for  
1095 female fish compared to earlier years. The Pearson residuals for the two years of age data  
1096 from NWFSC slope survey are shown in Figure 63. The residual pattern differs between the  
1097 years and by sex with positive residuals of male fish across ages in the 2001 data.

1098 The observed and expected age-at-length are shown in Figures 64, 65, 66, 67, and 67 for the  
1099 NWFSC shelf-slope survey observations. The fits generally match the observations. Some  
1100 outliers are apparent with large residuals. The 2016 data varies from previous years where  
1101 larger fish across all ages have higher observations compared to the model expectation.

1102 The age data were also weighted according the Francis weighting which adjust the weight  
1103 given to a data set based on the fit to the mean lengths by year. The mean age and the  
1104 estimated model fits are shown in Figures 69, 70, 71, 72, and 73. The mean ages from the  
1105 fishery appear to have declined in recent years which could be due to incoming cohorts (Figure  
1106 69). The At-sea hake fishery mean age are similar for 2006 and 2007 but both 2003 and 2014  
1107 have lower average age in the samples (Figure 70). The mean age for the Triennial survey  
1108 varied across the sampling period but the distribution of sampled ages were highly variable  
1109 across the years (Figure 71). The NWFSC slope had a decline in the mean age between  
1110 the two data years (Figure 72). The mean age for the NWFSC shelf-slope survey generally  
1111 showed a declining trend over the time-series excluding 2012 and 2016 which sampled older  
1112 fish relative to the surrounding years (Figure 73).

### 1113 3.4.3 Population Trajectory

1114 The predicted spawning output (in millions of eggs) is given in Table 26 and plotted in  
1115 Figure 74. The predicted spawning output from the base model generally showed a slight

1116 decline over the time-series until when the foreign fleet began. A short, but sharp decline  
1117 occurred during the period of the foreign fishery in the late 1960s. The stock continued  
1118 to decline minimally until 2000 when a combination of strong recruitment and low catches  
1119 resulted in an increase at the end of the time-series. The recent increase is even faster for  
1120 total biomass (Figure 75) because not all fish from the 2008 recruitment are mature (Figure  
1121 26). The 2017 spawning biomass relative to unfished equilibrium spawning biomass is above  
1122 the target of 40% of unfished spawning biomass (76.1%), with a low of 34.5% in 1994 (Figure  
1123 76). Approximate confidence intervals based on the asymptotic variance estimates show that  
1124 the uncertainty in the estimated spawning biomass is high, especially in the early years. The  
1125 standard deviation of the log of the spawning biomass in 2017 is 0.28.

1126 Recruitment deviations were estimated for the entire time series that was modeled (Figure  
1127 37 and discussed in Section 3.4.1) and provide a more realistic portrayal of uncertainty.  
1128 Recruitment predictions from the mid-1970s and early 1980s were mostly below average,  
1129 with the 1999, 2000, 2008, and 2013 cohorts being the strongest over the modeled period.  
1130 Many other stock assessments of rockfish along the west coast of the US have estimated a  
1131 large recruitment event in 1999 (e.g., greenstriped rockfish (Hicks et al. 2009) chilipepper  
1132 rockfish (Field 2007), darkblotched rockfish (Gertseva et al. 2015)). The 2008 year classes  
1133 was estimated as the strongest year class. This year has been estimated to have very strong  
1134 year classes for other West Coast stocks (e.g. darkblotched rockfish (Gertseva et al. 2015),  
1135 widow rockfish (Hicks and Wetzel 2015)). It may be worthwhile to investigate the periods  
1136 of strong and weak year classes further to see if it is an artifact of the data, a consistent  
1137 autocorrelation, or a result of the environment.

1138 The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 77 with  
1139 estimated recruitments also shown. The stock is predicted to have never fallen to low enough  
1140 levels that the steepness is obvious. However, the lowest levels of predicted spawning biomass  
1141 showed some of the smallest recruitments and very few above average recruitments. Steepness  
1142 was not estimated in this model, but sensitivities to alternative values of steepness are  
1143 discussed below.

#### 1144 3.4.4 Uncertainty and Sensitivity Analyses

1145 A number of sensitivity analyses were conducted, including:

- 1146 1. Data weighting according to the harmonic mean.
- 1147 2. Fixed steepness at the prior value of 0.72.
- 1148 3. Estimate natural mortality for female and male Pacific ocean perch.
- 1149 4. Maturity relationship used in the previous assessment.
- 1150 5. Fecundity relationship used in the previous assessment.

- 1151     6. Split the Triennial survey into two time-series, early (1980-1992) and late (1995-2004).  
1152     7. Remove the historical commercial CPUE index.  
1153     8. Inclusion of available Canadian fishery and survey data (does not constitute all data  
1154        used in Canadian assessments).  
1155     9. Inclusion of historical Washington research lengths.  
1156     10. Inclusion of Oregon special projects length and age data which are sampled at the  
1157        dockside or processing facilities.
- 1158 Likelihood values and estimates of key parameters from each sensitivity are available in  
1159 Tables 27 and 28. Plots of the estimated time-series of spawning output and relative biomass  
1160 are shown in Figures 78, 79, 80, and 81.
- 1161 The sensitivities which explored steepness or natural mortality had the largest change in  
1162 estimated stock status relative to the base model. Fixing steepness at the prior value resulted  
1163 in the stock being near unfished spawning biomass output. When natural mortality was  
1164 estimated the estimated values were higher relative to the median of the prior used in base  
1165 model, resulting in the relative biomass to be > 93%.
- 1166 Including additional data from either Canada, Washington research lengths, and or Oregon  
1167 special projects data resulted in estimated lower stock status relative to the base model.  
1168 However, the status was still well above the management target.
- 1169 Weighting the data according to the harmonic means resulted in the largest decrease in the  
1170 estimated stock status relative to the base model with the stock being estimated at 68% of  
1171 unfished biomass.
- 1172 The sensitivities that explored the removal of the CPUE index, the 2011 maturity, or fecundity  
1173 relationship had little impact relative to the base model results.

### 1174     **3.4.5 Retrospective Analysis**

1175 A 5-year retrospective analysis was conducted by running the model using data only through  
1176 2011, 2012, 2013, 2014, and 2015, progressively (Figure 82 and 83). The initial scale of the  
1177 spawning population was basically unchanged for all of these retrospectives. The estimation  
1178 of the 2008 recruitment deviation decreased as more data was removed. Overall, no alarming  
1179 trends were present in the retrospective analysis.

1180 **3.4.6 Likelihood Profiles**

1181 Likelihood profiles were conducted for  $R_0$ , steepness, and over natural mortality values  
1182 separately. These likelihood profiles were conducted by fixing the parameter at specific values  
1183 and estimated the remaining parameters based on the fixed parameter value.

1184 For steepness, the negative log-likelihood was essentially flat between values of 0.30 - 0.80  
1185 (Figure 84). Likelihood components by data source show that the fishery length and age data  
1186 supports a low steepness value, but the NWFSC shelf-slope age data supports a higher value  
1187 for steepness. The Triennial survey index indicates a low value of steepness while the other  
1188 surveys do not provide information concerning steepness. The relative biomass for Pacific  
1189 ocean perch has a wide range across different assumed values of steepness (Figure 85).

1190 The negative log-likelihood was minimized at a natural mortality value of 0.06, but the 95%  
1191 confidence interval extends over the majority of natural mortality values. The age and length  
1192 data likelihood contribution was minimized at natural morality values ranging from 0.055-0.06  
1193 (Figure 86). The relative biomass for Pacific ocean perch widely varied across alternative  
1194 values of natural mortality (Figure 87).

1195 In regards to values of  $R_0$ , the negative log-likelihood was minimized at approximately  $\log(R_0)$   
1196 of 9.30 (Figure 88). The fishery and survey composition data was in opposition regarding  
1197 values of  $R_0$  where the fishery length and age data indicated lower values of  $R_0$  while the  
1198 survey ages from the Pacific ocean perch and the NWFSC shelf-slope surveys indicated a  
1199 higher value.

1200 **3.4.7 Reference Points**

1201 Reference points were calculated using the estimated selectivities and catch distribution  
1202 among fleets in the most recent year of the model (2016). Sustainable total yields (landings  
1203 plus discards) were 1764.8 mt when using an  $SPR_{50\%}$  reference harvest rate and with a 95%  
1204 confidence interval of 1264.8 - 2264.8 mt based on estimates of uncertainty. The spawning  
1205 output equivalent to 40% of the unfished spawning output ( $SB_{40\%}$ ) was 2653.2 millions of  
1206 eggs. The recent catches (landings plus discards) have been below the point estimate of  
1207 potential long-term yields calculated using an  $SPR_{50\%}$  reference point and the population  
1208 has been increasing over the last decade.

1209 The predicted spawning biomass from the base model generally showed a sharp decline during  
1210 the 1960s, steep increase above unfished equilibrium levels, followed by less of a decline  
1211 until 2001 (Figure 74). Since 2001, the spawning biomass has been increasing due to small  
1212 catches, and recently, above average recruitment. The 2017 spawning biomass relative to  
1213 unfished equilibrium spawning biomass is above the target of 40% of unfished spawning  
1214 biomass (Figure 76). The fishing intensity,  $(1 - SPR)/(1 - SPR_{50\%})$ , exceeded the current  
1215 estimates of the harvest rate limit ( $SPR_{50\%}$ ) throughout the 1960s as seen in Figure 89.

1216 Recent exploitation rates on Pacific ocean perch were predicted to be much less than target  
1217 levels. In recent years, the stock has experienced exploitation rates that have been below the  
1218 target level while the biomass level has remained above the target level.

1219 Table 25 shows the full suite of estimated reference points for the base model and Figure 90  
1220 shows the equilibrium curve based on a steepness value fixed at 0.50.

## 1221 4 Harvest Projections and Decision Tables

1222 A twelve year projection of the base model with catches equal to the estimated ACL for years  
1223 2019-2028 and a catch allocation equal to the percentages for each fleet over the period of  
1224 2014-2016 predicts an increase in the spawning output due to large 2008 cohort, with a slight  
1225 downturn beginning in 2023 (Table 29).

1226 Add additional projection post STAR based upon the decision table.

1227 Table 30

## 1228 5 Regional Management Considerations

1229 The distribution of Pacific ocean perch occur primarily in the US west coast waters of  
1230 Washington, Oregon, and northern California and he is currently managed to a species level  
1231 with harvest limits set for the stock north of the 40°10' latitude. The population within this  
1232 area is treated as a single stock due to the lack of biological and genetic data indicating the  
1233 presence of multiple stocks. Analysis conducted within this assessment did not find support  
1234 for regional management within the area that Pacific ocean perch occur.

## 1235 6 Research Needs

1236 There are many areas of research that could be improved to benefit the understanding and  
1237 assessment of Pacific ocean perch. Below, are issues that are considered of the importance.

- 1238 1. **Natural mortality:** Uncertainty in natural mortality translates into uncertain esti-  
1239 mates of status and sustainable fishing levels for Pacific ocean perch. The collection  
1240 of additional age data, re-reading of older age samples, reading old age samples that  
1241 are unread, and improved understanding of the life-history of Pacific ocean perch may  
1242 reduce that uncertainty.

- 1243    2. **Steepness:** The amount of stock resilience, steepness, dictates the rate at which a  
1244    stock can rebuild from low stock sizes. Improved understanding regarding the steepness  
1245    of US west coast Pacific ocean perch will reduce our uncertainty regarding current stock  
1246    status.
- 1247    3. **Basin-wide understanding of stock structure, biology, connectivity, and dis-**  
1248    **distribution:** This is a stock assessment for Pacific ocean perch off of the west coast of the  
1249    US and does not consider data from British Columbia or Alaska. Further investigating  
1250    and comparing the data and predictions from British Columbia and Alaska to determine  
1251    if there are similarities with the US west Ccast observations would help to define the  
1252    connectivity between Pacific ocean perch north and south of the U.S.-Canada border.

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1273    through the many discussions within the Population Ecology team in the FRAM division at  
1274    the NWFSC.

<sub>1275</sub> 8 Tables

Table 1: Landings for each state (all gears combined), the At-sea hake fishery, the foreign fleet, and surveys.

Year	California	Oregon	Washington	At-Sea Hake	Foreign	Research
1892	0.0	0.1	0.0	0.0	0	0.0
1893	0.0	0.1	0.0	0.0	0	0.0
1894	0.0	0.1	0.0	0.0	0	0.0
1895	0.0	0.0	0.0	0.0	0	0.0
1896	0.0	0.0	0.0	0.0	0	0.0
1897	0.0	0.0	0.0	0.0	0	0.0
1898	0.0	0.0	0.0	0.0	0	0.0
1899	0.0	0.0	0.0	0.0	0	0.0
1900	0.0	0.0	0.0	0.0	0	0.0
1901	0.0	0.0	0.0	0.0	0	0.0
1902	0.0	0.0	0.0	0.0	0	0.0
1903	0.0	0.0	0.0	0.0	0	0.0
1904	0.0	0.0	0.0	0.0	0	0.0
1905	0.0	0.0	0.0	0.0	0	0.0
1906	0.0	0.0	0.0	0.0	0	0.0
1907	0.0	0.0	0.0	0.0	0	0.0
1908	0.0	0.0	0.1	0.0	0	0.0
1909	0.0	0.0	0.1	0.0	0	0.0
1910	0.0	0.0	0.1	0.0	0	0.0
1911	0.0	0.0	0.1	0.0	0	0.0
1912	0.0	0.0	0.0	0.0	0	0.0
1913	0.0	0.0	0.0	0.0	0	0.0
1914	0.0	0.0	0.0	0.0	0	0.0
1915	0.0	0.0	0.0	0.0	0	0.0
1916	0.0	0.0	0.4	0.0	0	0.0
1917	0.1	0.0	0.8	0.0	0	0.0
1918	0.1	0.0	1.1	0.0	0	0.0
1919	0.0	0.0	0.4	0.0	0	0.0
1920	0.0	0.0	0.3	0.0	0	0.0
1921	0.0	0.0	0.3	0.0	0	0.0
1922	0.0	0.0	0.1	0.0	0	0.0
1923	0.0	0.0	0.2	0.0	0	0.0
1924	0.1	0.0	0.5	0.0	0	0.0
1925	0.1	0.0	0.6	0.0	0	0.0
1926	0.1	0.0	1.0	0.0	0	0.0
1927	0.1	0.0	1.4	0.0	0	0.0
1928	0.1	0.1	1.2	0.0	0	0.0
1929	0.3	0.1	0.7	0.0	0	0.0
1930	0.2	0.1	0.9	0.0	0	0.0
1931	0.4	0.1	0.4	0.0	0	0.0

Year	California	Oregon	Washington	At-Sea Hake	Foreign	Research
1932	0.3	0.1	0.4	0.0	0	0.0
1933	0.6	0.1	0.5	0.0	0	0.0
1934	0.4	0.0	2.3	0.0	0	0.0
1935	0.4	0.1	7.7	0.0	0	0.0
1936	0.2	0.2	1.6	0.0	0	0.0
1937	0.5	0.4	2.0	0.0	0	0.0
1938	0.6	0.1	5.1	0.0	0	0.0
1939	0.9	0.4	8.7	0.0	0	0.0
1940	0.9	9.1	12.2	0.0	0	0.0
1941	1.3	14.0	13.6	0.0	0	0.0
1942	0.4	26.6	18.6	0.0	0	0.0
1943	1.0	94.3	453.6	0.0	0	0.0
1944	2.8	164.5	739.3	0.0	0	0.0
1945	6.7	247.1	1887.1	0.0	0	0.0
1946	7.3	193.2	845.9	0.0	0	0.0
1947	2.6	167.2	385.3	0.0	0	0.0
1948	3.9	177.8	491.1	0.0	0	0.0
1949	2.0	472.9	409.5	0.0	0	0.0
1950	1.5	690.1	675.7	0.0	0	0.0
1951	4.3	840.1	735.1	0.0	0	0.0
1952	2.9	2030.5	305.6	0.0	0	0.0
1953	145.6	1223.5	361.6	0.0	0	0.0
1954	123.2	1837.5	538.8	0.0	0	0.0
1955	48.8	1346.4	555.6	0.0	0	0.0
1956	3.8	2563.8	548.2	0.0	0	0.0
1957	1.6	2128.1	538.5	0.0	0	0.0
1958	2.9	1564.9	530.4	0.0	0	0.0
1959	1.5	892.6	337.0	0.0	0	0.0
1960	19.6	1358.8	928.1	0.0	0	0.0
1961	1.1	2061.9	1179.8	0.0	0	0.0
1962	0.6	2584.9	1725.2	0.0	0	0.0
1963	32.5	3693.9	2006.0	0.0	0	0.0
1964	46.1	4261.6	1770.7	0.0	0	0.0
1965	34.9	5627.8	1972.1	0.0	0	0.0
1966	5.2	1591.2	1725.5	0.0	15561	0.0
1967	17.8	354.7	1861.0	0.0	12357	0.0
1968	21.9	466.4	2501.2	0.0	6639	0.0
1969	8.4	422.3	1236.0	0.0	469	0.0
1970	8.7	507.4	1293.3	0.0	441	0.0
1971	12.2	290.4	673.6	0.0	902	0.0
1972	11.4	105.3	796.5	0.0	950	0.0
1973	11.9	121.2	713.1	0.0	1773	0.0
1974	15.7	136.7	641.8	0.0	1457	0.0
1975	11.4	181.3	413.9	62.3	496	0.0
1976	17.1	663.7	521.132	31.9	239	0.0

Year	California	Oregon	Washington	At-Sea Hake	Foreign	Research
1977	16.7	457.1	752.0	3.8	0	11.9
1978	42.5	498.7	1391.5	15.4	0	0.0
1979	136.7	735.9	581.4	15.1	0	34.5
1980	19.2	948.6	666.2	47.0	0	4.6
1981	10.8	929.7	390.3	15.4	0	0.0
1982	145.9	584.0	273.0	28.3	0	0.0
1983	102.0	1032.7	437.7	10.9	0	4.4
1984	47.6	750.4	815.7	2.3	0	0.9
1985	70.9	789.5	503.2	11.4	0	13.6
1986	52.8	676.5	588.9	19.8	0	1.4
1987	120.9	550.0	399.4	5.4	0	0.0
1988	75.4	749.8	509.8	4.5	0	0.5
1989	29.5	927.8	466.2	4.3	0	4.2
1990	18.3	567.8	427.2	80.9	0	0.0
1991	8.4	853.2	530.1	46.1	0	0.0
1992	15.3	623.4	435.2	373.3	0	4.9
1993	11.0	797.8	464.7	0.9	0	0.2
1994	6.7	626.4	352.0	83.8	0	0.0
1995	9.2	515.0	289.8	46.6	0	2.8
1996	18.4	531.1	236.7	6.3	0	1.2
1997	15.8	439.1	184.9	6.4	0	0.1
1998	21.6	436.7	172.4	22.3	0	3.8
1999	19.8	326.8	145.8	16.5	0	1.4
2000	6.8	95.1	33.0	10.1	0	0.6
2001	0.5	193.4	51.8	21.0	0	2.8
2002	0.8	107.0	39.5	3.9	0	0.3
2003	0.2	94.6	30.2	6.3	0	3.6
2004	2.1	97.7	22.3	1.1	0	2.5
2005	0.1	51.2	10.4	1.7	0	1.8
2006	0.2	52.2	15.8	3.1	0	1.2
2007	0.2	83.7	45.1	4.0	0	0.6
2008	0.4	58.6	16.6	15.9	0	0.8
2009	0.9	58.7	33.2	1.6	0	2.7
2010	0.1	58.0	22.3	16.9	0	1.7
2011	0.1	30.3	19.7	9.2	0	1.9
2012	0.2	30.4	21.8	4.5	0	1.6
2013	0.1	34.9	14.8	5.4	0	1.7
2014	0.2	33.9	15.8	3.9	0	0.6
2015	0.1	38.1	11.4	8.7	0	1.6
2016	0.2	40.8	13.1	10.3	0	3.1

Table 2: West Coast history of regulations.

Date	Area	Regulation
11/10/1983	Columbia	Closed Columbia area to Pacific ocean perch fishing until the end of the year, as 950 mt OY for this species has been reached;
11/10/1983	Vancouver	retained 5,000-pound trip limit or 10% of total trip weight on landings of Pacific ocean perch in the Vancouver area.
1/1/1984	ALL	Continued 5,000-pound trip limit or 10% of total trip weight on Pacific ocean perch as specified in FMP. Fishery to close when area OYs are reached (see action effective November 10, 1983 above).
8/1/1984	Vancouver Columbia	Reduced trip limit for Pacific ocean perch in the Vancouver and Columbia areas to 20% by weight of all fish on board, not to exceed 5,000 pounds per vessel per trip.
8/16/1984	Columbia	Commercial fishing for Pacific ocean perch in the Columbia area closed for remainder of the year.
1/10/1985	Vancouver Columbia	Established Vancouver and Columbia areas Pacific ocean perch trip limit of 20% by weight of all fish on board (no 5,000-pound limit as specified in last half of 1984).
4/28/1985	Vancouver Columbia	Reduced the Vancouver and Columbia areas Pacific ocean perch trip limit to 5,000 pounds or 20% by weight of all fish on board, whichever is less.
4/28/1985	ALL	Landings of Pacific ocean perch less than 1,000 pounds will be unrestricted. The fishery for this species will close when the OY in each area is reached.
6/10/1985	ALL	Landings of Pacific ocean perch up to 1,000 pounds per trip will be unrestricted regardless of the percentage of these fish on board.
1/1/1986	Cape Blanco North	Established the Pacific ocean perch trip limit north of Cape Blanco (4250) at 20% (by weight) of all fish on board or 10,000 pounds whichever is less; landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 600 mt; Columbia area OY = 950 mt.
1/1/1986	ALL	landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 600 mt; Columbia area OY = 950 mt.
12/1/1986	Vancouver	OY quota for Pacific ocean perch reached in the Vancouver area; fishery closed until January 1, 1987.
1/1/1987	ALL	Established coastwide Pacific ocean perch limit at 20% of all legal fish on board or 5,000 pounds whichever is less (in round weight); landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 500 mt; Columbia area OY = 800 mt.
1/1/1988	ALL	Established the coastwide Pacific ocean perch trip limit at 20% (by weight) of all fish on board or 5,000 pounds, whichever is less; landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board;
1/1/1989	ALL	Established the coastwide Pacific ocean perch trip limit at 20% (by weight) of all fish on board or 5,000 pounds whichever is less;
1/1/1989	ALL	landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board (Vancouver area OY = 500 mt; Columbia area OY = 800 mt).
7/26/1989	ALL	Reduced the coastwide trip limit for Pacific ocean perch to 2,000 pounds or 20% of all fish on board, whichever is less, with no trip frequency restriction.
12/13/1989	Columbia	Closed the Pacific ocean perch fishery in the Columbia area because 1,040 mt OY reached.
1/1/1990	ALL	Established the coastwide Pacific ocean perch trip limit at 20% (by weight) of all fish on board or 3,000 pounds whichever is less; landings of Pacific ocean perch be unrestricted if less than 1,000 pounds regardless of percentage on board. (Vancouver area OY = 500 mt; Columbia area OY = 1,040 mt).
1/1/1991	ALL	Established the coastwide Pacific ocean perch trip limit at 20% (by weight) of all groundfish on board or 3,000 pounds whichever is less; landings of Pacific ocean perch be unrestricted if less than 1,000 pounds regardless of percentage on board (harvest guideline for combined Vancouver and Columbia areas = 1,000 mt).
1/1/1992	ALL	For Pacific ocean perch, established the coastwide trip limit at 20% (by weight) of all groundfish on board or 3,000 pounds whichever is less; landings of Pacific ocean perch be unrestricted if less than 1,000 pounds regardless of percentage on board (harvest guideline for combined Vancouver and Columbia areas = 1,550 mt).

Date	Area	Regulation
1/1/1993	Cape Mendocino Coos Bay	For Pacific ocean perch, continued the coastwide trip limit at 20% (by weight) of all groundfish on board or 3,000 pounds whichever is less; landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board (harvest guideline for combined Vancouver and Columbia areas = 1,550 mt).
1/1/1994	ALL	Pacific Ocean Perch trip limit of 3,000 pounds or 20% of all fish on board, whichever is less, in landings of Pacific ocean perch above 1,000 pounds.
1/1/1995	ALL	For Pacific Ocean Perch, established a cumulative trip limit of 6,000 pounds per month
1/1/1996	ALL	Pacific Ocean Perch cumulative trip limit of 10,000 pounds per two-month period.
7/1/1996	4030 North	Reduced the cumulative 2-month limit for Pacific ocean perch to 8,000 pounds, and established the cumulative 2-month limit for Dover sole north of Cape Mendocino at 38,000 pounds
1/1/1997	ALL	Pacific Ocean Perch limited entry fishery cumulative trip limit of 8,000 pounds per two-month period
1/1/1998	ALL	Pacific Ocean Perch: limited entry fishery Cumulative trip limit of 8,000 pounds per two-month period.
7/1/1998	ALL	Open Access Rockfish: removed overall rockfish monthly limit and replaced it with limits for component rockfish species: for <i>Sebastodes</i> complex, monthly cumulative limit is 33,000 pounds, for widow rockfish, monthly cumulative trip limit is 3,000 pounds, for Pacific Ocean Perch, monthly cumulative trip limit is 4,000 pounds.
1/1/1999	ALL	for the limited entry fishery A new three phase cumulative limit period system is introduced for 1999. Phase 1 is a single cumulative limit period that is 3months long, from January 1 - March 31. Phase 2 has 3 separate 2 month cumulative limit periods of April 1 - May 31, June 1 - July 31, and August 1 - September 30. Phase 3 has 3 separate 1 month cumulative limit periods of October 1-31, November 1-30, and December 1-31. For all species except Pacific ocean perch and Bocaccio, there will be no monthly limit within the cumulative landings limit periods. An option to apply cumulative trip limits lagged by 2 weeks (from the 16th to the 15th) was made available to limited entry trawl vessels when their permits were renewed for 1999. Vessels that are authorized to operate in this "B" platoon may take and retain, but may not land, groundfish during January 1-15, 1999.
1/1/1999	ALL	for the limited entry fishery Pacific Ocean Perch: cumulative limit, Phase 1: 4,000 pounds per month; Phase 2: 4,000 pounds per month; Phase 3: 4,000 pounds per month.
1/1/1999	ALL	for open access gear: Pacific Ocean Perch: coastwide, 100 pounds per month.
1/1/2000	ALL	Limited entry trawl, Pacific Ocean Perch, 500 lbs per month
1/1/2000	ALL	Pacific Ocean Perch, Open Access gear except exempted trawl, 100 lbs per month
1/1/2000	ALL	Pacific Ocean Perch, limited entry fixed gear, 500 lbs per month
5/1/2000	ALL	Limited entry trawl, Pacific Ocean Perch, 2500 lbs per 2 months
5/1/2000	ALL	Pacific Ocean Perch, limited entry fixed gear, 2500 lbs per month
11/1/2000	ALL	Limited entry trawl, Pacific Ocean Perch, 500 lbs per month
11/1/2000	ALL	Pacific Ocean Perch, limited entry fixed gear, 500 lbs per month
1/1/2001	3600 North	Pacific Ocean Perch, open access, 100 lbs per month
1/1/2001	4010 North	Pacific Ocean Perch, limited entry trawl, 1500 lbs per month
1/1/2001	ALL	Pacific Ocean Perch, limited entry fixed gear, 1500 lbs per month
5/1/2001	4010 North	Pacific Ocean Perch, limited entry trawl, 2500 lbs per month
5/1/2001	ALL	Pacific Ocean Perch, limited entry fixed gear, 2500 lbs per month
10/1/2001	4010 North	Pacific Ocean Perch, limited entry trawl, 1500 lbs per month
11/1/2001	ALL	Pacific Ocean Perch, limited entry fixed gear, 1500 lbs per month
1/1/2002	4010 North	Pacific Ocean Perch, open access, 100 lbs per month
1/1/2002	4010 North	Pacific Ocean Perch, limited entry fixed gear, 2000 lbs per month
1/1/2002	4010 North	Pacific Ocean Perch, limited entry trawl, 2000 lbs per month
4/1/2002	4010 North	Pacific Ocean Perch, limited entry fixed gear, 4000 lbs per month
5/1/2002	4010 North	Pacific Ocean Perch, limited entry trawl, 4000 lbs per month
11/1/2002	4010 North	Pacific Ocean Perch, limited entry fixed gear, 2000 lbs per month
11/1/2002	4010 North	Pacific Ocean Perch, limited entry trawl, 2000 lbs per month
1/1/2003	3800 South	minor slope rockfish south including pacific ocean perch, open access gear, 10000 lbs per 2 months

Date	Area	Regulation
1/1/2003	3800 South	Minor slope rockfish south including Pacific ocean perch, limited entry fixed gear, 30000 lbs per 2 months
1/1/2003	3800 South	Minor slope rockfish south including Pacific ocean perch , limited entry trawl, 30000 lbs per 2 months
1/1/2003	3800 4010	minor slope rockfish south including pacific ocean perch, open access gear, per trip no more than 25% (by weight) of sablefish landed
1/1/2003	3800 4010	Minor slope rockfish south including Pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2003	3800 4010	Minor slope rockfish south including Pacific ocean perch , limited entry trawl, 1800 lbs per 2 months
1/1/2003	4010 North	pacific ocean perch, open access gears, 100 lbs per month
1/1/2003	4010 North	pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2003	4010 North	Pacific Ocean Perch, Limited entry trawl gear, 3000 lbs per 2 months
3/1/2003	3800 4010	Minor slope rockfish south including Pacific ocean perch, limited entry fixed gear, no more than 25% of the weight of sablefish landed per trip
11/1/2003	3800 4010	Minor slope rockfish south including Pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2004	3800 South	Minor slope rockfish south including Pacific ocean perch, open access gear, 10000 lbs per 2 months
1/1/2004	3800 South	minor slope rockfish south inclding pacific ocean perch, limited entry fixed gear, 40000 lbs per 2 months
1/1/2004	3800 South	minor slope rockfish south including pacific ocean perch, limited entry trawl, 40000 lbs per 2 months
1/1/2004	3800 4010	Minor slope rockfish south including Pacific ocean perch, open access gear, per trip no more than 25% of the weight of sablefish landed
1/1/2004	3800 4010	minor slope rockfish south including pacific ocean perch, limited entry fixed gear, 7000 lbs per 2 months
1/1/2004	3800 4010	minor slope rockfish south including pacific ocean perch, limited entry trawl, 7000 lbs per 2 months
1/1/2004	4010 North	pacific ocean perch, open access gear, 100 lbs per month
1/1/2004	4010 North	pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2004	4010 North	pacific ocean perch, limited entry trawl, 3000 lbs per 2 months
5/1/2004	3800 South	minor slope rockfish south inclding pacific ocean perch, limited entry fixed gear, 50000 lbs per 2 months
5/1/2004	3800 South	minor slope rockfish south including pacific ocean perch, limited entry trawl, 50000 lbs per 2 months
5/1/2004	3800 4010	minor slope rockfish south including pacific ocean perch, limited entry fixed gear, 50000 lbs per 2 months
5/1/2004	3800 4010	minor slope rockfish south including pacific ocean perch, limited entry trawl, 50000 lbs per 2 months
11/1/2004	3800 South	minor slope rockfish south inclding pacific ocean perch, limited entry fixed gear, 50000 lbs per 2 months
11/1/2004	3800 South	minor slope rockfish south including pacific ocean perch, limited entry trawl, 50000 lbs per 2 months
11/1/2004	3800 4010	minor slope rockfish south including pacific ocean perch, limited entry fixed gear, 10000 lbs per 2 months
11/1/2004	3800 4010	minor slope rockfish south including pacific ocean perch, limited entry trawl, 10000 lbs per 2 months
1/1/2005	3800 South	minor slope rockfish south including darkblotched and pacific ocean perch, open access gear, 10000 lbs per 2 months
1/1/2005	3800 South	minor slope rockfish south including darkblotched rockfish and pacific ocean perch, limited entry trawl, closed
1/1/2005	3800 4010	minor slope rockfish south including darkblotched and pacific ocean perch, open access gear, per trip no more than 25% of weight of sablefish onboard
1/1/2005	3800 4010	minor slope rockfish south including darkblotched rockfish and pacific ocean perch, limited entry trawl, 4000 lbs per 2 months
1/1/2005	4010 North	pacific ocean perch, open access gears, 100 lbs per month
1/1/2005	4010 North	pacific ocean perch, limited entry trawl gear, 3000 lbs per 2 months
1/1/2005	4010 North	pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2005	4010 South	minor slope rockfish south including darkblotched and pacific ocean perch, limited entry fixed gear, 40000 lbs per 2 months
5/1/2005	3800 4010	minor slope rockfish south including darkblotched rockfish and pacific ocean perch, limited entry trawl, 8000 lbs per 2 months

Date	Area	Regulation
1/1/2008	3800 4010	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, limited entry trawl, 15000 lbs per 2 months
1/1/2008	4010 North	pacific ocean perch, limited entry trawl, 1500 lbs per 2 months
1/1/2009	4010 North	pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2009	4010 South	minor slope rockfish south including pacific ocean perch and darkblotched, limited entry fixed gear, 40000 lbs per 2 months
1/1/2009	3800 South	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, open access gear, 10000 lbs per 2 months
1/1/2009	3800 4010	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, open access gear, per trip no more than 25% (by weight) of sablefish landed
1/1/2009	4010 North	pacific ocean perch, open access gears, 100 lbs per month
1/1/2009	3800 South	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, limited entry trawl, 55000 lbs per 2 months
1/1/2009	3800 4010	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, limited entry trawl, 15000 lbs per 2 months
1/1/2009	4010 North	pacific ocean perch, limited entry trawl, 1500 lbs per 2 months
7/1/2009	3800 4010	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, limited entry trawl, 10000 lbs per 2 months
11/1/2009	3800 4010	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, limited entry trawl, 15000 lbs per 2 months
1/1/2010	4010 North	pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2010	4010 South	minor slope rockfish south including pacific ocean perch and darkblotched, limited entry fixed gear, 40000 lbs per 2 months
1/1/2010	3800 South	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, open access gear, 10000 lbs per 2 months
1/1/2010	3800 4010	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, open access gear, per trip no more than 25% (by weight) of sablefish landed
1/1/2010	4010 North	pacific ocean perch, open access gears, 100 lbs per month
1/1/2010	3800 South	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, limited entry trawl, 55000 lbs per 2 months
1/1/2010	3800 4010	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, limited entry trawl, 15000 lbs per 2 months
1/1/2010	4010 North	pacific ocean perch, limited entry trawl, 1500 lbs per 2 months
1/1/2011	4010 North	pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2011	4010 South	minor slope rockfish south including pacific ocean perch and darkblotched, limited entry fixed gear, 40000 lbs per 2 months
1/1/2011	3800 South	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, open access gear, 10000 lbs per 2 months
1/1/2011	3800 4010	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, open access gear, per trip no more than 25% (by weight) of sablefish landed
1/1/2011	4010 North	pacific ocean perch, open access gears, 100 lbs per month
1/1/2011	ALL	Pacific Ocean Perch managed in part by IFQ
1/1/2012	4010 North	pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2012	4010 South	minor slope rockfish south including pacific ocean perch and darkblotched, limited entry fixed gear, 40000 lbs per 2 months
1/1/2012	3800 South	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, open access gear, 10000 lbs per 2 months
1/1/2012	3800 4010	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, open access gear, per trip no more than 25% (by weight) of sablefish landed
1/1/2012	4010 North	pacific ocean perch, open access gears, 100 lbs per month
1/1/2013	4010 North	pacific ocean perch, open access gears, 100 lbs per month
1/1/2013	4010 North	pacific ocean perch, limited entry fixed gear, 1800 lbs per 2 months
1/1/2013	4010 South	minor slope rockfish south including pacific ocean perch and darkblotched, limited entry fixed gear, 40000 lbs per 2 months no more than 1375 lbs may be blackgill
1/1/2013	4010 South	minor slope rockfish south including pacific ocean perch and darkblotched rockfish, open access gear, 10000 lbs per 2 months no more than 475 lbs of which may be blackgill rockfish
1/1/2014	4010 North	non-trawl, limited entry, pacific ocean perch, 1800 lbs per 2 months
1/1/2014	4010 South	non-trawl, limited entry, minor slope rockfish and darkblotched rockfish and pacific ocean perch, 40000 lbs per 2 months of which no more than 1375 lbs may be blackgill rockfish

Date	Area	Regulation
1/1/2014	4010 North	non-trawl, open access, pacific ocean perch, 100 lbs per month
1/1/2014	4010 South	non-trawl, open access, minor slope rockfish including darkblotched rockfish and pacific ocean perch, 10000 lbs per 2 months of which no more than 475 lbs may be blackgill rockfish
1/1/2015	4010 North	non-trawl, limited entry, pacific ocean perch, 1800 lbs per 2 months
1/1/2015	4010 South	non-trawl, limited entry, minor slope rockfish and darkblotched rockfish and pacific ocean perch, 40000 lbs per 2 months of which no more than 1375 lbs may be blackgill rockfish
1/1/2015	4010 North	non-trawl, open access, pacific ocean perch, 100 lbs per month
1/1/2015	4010 South	non-trawl, open access, minor slope rockfish including darkblotched rockfish and pacific ocean perch, 10000 lbs per 2 months of which no more than 475 lbs may be blackgill rockfish
7/1/2015	4010 South	non-trawl, limited entry, minor slope rockfish and darkblotched rockfish and pacific ocean perch, 40000 lbs per 2 months of which no more than 1600 lbs may be blackgill rockfish
7/1/2015	4010 South	non-trawl, open access, minor slope rockfish including darkblotched rockfish and pacific ocean perch, 10000 lbs per 2 months of which no more than 550 lbs may be blackgill rockfish
1/1/2016	4010 North	non-trawl, limited entry, pacific ocean perch, 1800 lbs per 2 months
1/1/2016	4010 North	non-trawl, open access, pacific ocean perch, 100 lbs per month
1/1/2016	4010 South	non-trawl, open access, minor slope rockfish including darkblotched rockfish and pacific ocean perch, 10000 lbs per 2 months of which no more than 475 lbs may be blackgill rockfish
7/1/2016	4010 South	non-trawl, open access, minor slope rockfish including darkblotched rockfish and pacific ocean perch, 10000 lbs per 2 months of which no more than 550 lbs may be blackgill rockfish

Table 3: Recent trend in estimated total catch relative to management guidelines.

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Total landings (mt)	Estimated total catch (mt)
2007	900		150	133	157
2008	911		150	92	133
2009	1,160		189	94	190
2010	1,173		200	97	181
2011	1,026	981	180	60	61
2012	1,007	962	183	57	58
2013	844	807	150	55	57
2014	838	801	153	54	55
2015	842	805	158	58	59
2016	850	813	164	65	65

Table 4: Summary of the fishery-independant biomass/abundance time-series used in the stock assessment. The standard error includes the input annual standard error and model estimated added variance.

Year	POP		Triennial		AFSC Slope		NWFSC Slope		NWFSC Shelf-Slope	
	Obs	SE	Obs	SE	Obs	SE	Obs	SE	Obs	SE
1979	56461	0.27	-	-	-	-	-	-	-	-
1980	-	-	10384	0.65	-	-	-	-	-	-
1983	-	-	8974	0.59	-	-	-	-	-	-
1985	34645	0.29	-	-	-	-	-	-	-	-
1986	-	-	2977	0.66	-	-	-	-	-	-
1989	-	-	4873	0.66	-	-	-	-	-	-
1992	-	-	3207	0.64	-	-	-	-	-	-
1995	-	-	2724	0.63	-	-	-	-	-	-
1996	-	-	-	-	7621	0.51	-	-	-	-
1997	-	-	-	-	3807	0.51	-	-	-	-
1998	-	-	4163	0.64	-	-	-	-	-	-
1999	-	-	-	-	4694	0.50	3643	0.63	-	-
2000	-	-	-	-	4243	0.53	4120	0.58	-	-
2001	-	-	1494	0.64	4187	0.49	2325	0.59	-	-
2002	-	-	-	-	-	-	1903	0.60	-	-
2003	-	-	-	-	-	-	-	-	9646	0.37
2004	-	-	2922	0.67	-	-	-	-	5284	0.40
2005	-	-	-	-	-	-	-	-	7528	0.40
2006	-	-	-	-	-	-	-	-	6010	0.42
2007	-	-	-	-	-	-	-	-	6268	0.37
2008	-	-	-	-	-	-	-	-	3867	0.40
2009	-	-	-	-	-	-	-	-	2745	0.37
2010	-	-	-	-	-	-	-	-	5404	0.35
2011	-	-	-	-	-	-	-	-	7533	0.36
2012	-	-	-	-	-	-	-	-	9289	0.36
2013	-	-	-	-	-	-	-	-	8093	0.35
2014	-	-	-	-	-	-	-	-	4914	0.35
2015	-	-	-	-	-	-	-	-	5752	0.32
2016	-	-	-	-	-	-	-	-	11770	0.37

Table 5: Summary of NWFSC shelf-slope survey length samples used in the stock assessment.

Year	Tows	Fish	Sample Size
2003	46	80	111
2004	34	56	82
2005	38	81	92
2006	33	73	80
2007	50	74	121
2008	39	75	94
2009	46	61	111
2010	53	73	128
2011	53	72	128
2012	50	79	121
2013	45	76	109
2014	52	77	126
2015	69	67	167
2016	50	58	121

Table 6: Summary of NWFSC shelf-slope survey age samples used in the stock assessment.

Year	Tows	Fish	Sample Size
2003	45	265	109
2004	34	149	82
2005	38	192	92
2006	33	170	80
2007	50	228	121
2008	39	218	94
2009	45	190	109
2010	53	292	128
2011	53	258	128
2012	49	217	119
2013	44	308	106
2014	52	195	126
2015	68	182	165
2016	44	281	106

Table 7: Summary of NWFSC slope survey length samples used in the stock assessment.

Year	Tows	Fish	Sample Size
2001	18	27	43
2002	24	54	58

Table 8: Summary of NWFSC slope survey age samples used in the stock assessment.

Year	Tows	Fish	Sample Size
2001	17	125	41
2002	24	216	58

Table 9: Summary of AFSC slope survey length samples used in the stock assessment.

Year	Tows	Fish	Sample Size
1996	48	1396	116
1997	21	347	51
1999	21	562	51
2000	19	353	46
2001	23	390	55

Table 10: Summary of Triennial survey length samples used in the stock assessment.

Year	Tows	Fish	Sample Size
1980	18	1315	43
1983	40	2820	97
1986	17	877	41
1989	42	1851	102
1992	33	1182	80
1995	71	1136	172
1998	81	1482	196
2001	74	669	179
2004	63	1240	153

Table 11: Summary of Triennial survey age samples used in the stock assessment.

Year	Tows	Fish	Sample Size
1989	15	577	36
1992	10	373	24
1995	12	275	29
1998	28	352	68
2001	43	342	104
2004	57	416	138

Table 12: Summary of Pacific ocean perch survey length samples used in the stock assessment.

Year	Tows	Fish	Sample Size
1979	125	2375	303
1985	126	2558	306

Table 13: Summary of Pacific ocean perch survey age samples used in the stock assessment.

Year	Tows	Fish	Sample Size
1985	29	1635	70

Table 14: Summary of discard rates used in the model by each data source.

Year	Source	Discard	Standard Error
1985	Pikitch	0.027	0.068
1986	Pikitch	0.024	0.063
1987	Pikitch	0.039	0.083
1992	Management Restrictions	0.100	0.300
2002	WCGOP	0.150	0.164
2003	WCGOP	0.183	0.268
2004	WCGOP	0.203	0.206
2005	WCGOP	0.175	0.346
2006	WCGOP	0.148	0.243
2007	WCGOP	0.171	0.261
2008	WCGOP	0.362	0.172
2009	WCGOP	0.504	0.153
2010	WCGOP	0.487	0.195
2011	WCGOP	0.015	0.053
2012	WCGOP	0.028	0.054
2013	WCGOP	0.027	0.054
2014	WCGOP	0.035	0.050
2015	WCGOP	0.010	0.053

Table 15: Summary of the commercial catch-per-unit effort time-series used in the stock assessment.

Year	Obs	SE
1956	0.40	0.40
1957	0.30	0.40
1958	0.32	0.40
1959	0.29	0.40
1960	0.28	0.40
1961	0.31	0.40
1962	0.29	0.40
1963	0.34	0.40
1964	0.35	0.40
1965	0.55	0.40
1966	0.47	0.40
1967	0.30	0.40
1968	0.17	0.40
1969	0.18	0.40
1970	0.17	0.40
1971	0.20	0.40
1972	0.20	0.40
1973	0.11	0.40

Table 16: Summary of commercial fishery length samples used in the stock assessment.

Year	Trips	Fish	Sample Size
1966	1	238	7
1967	5	1020	35
1968	3	912	21
1969	4	1213	28
1970	13	1830	92
1971	22	4698	155
1972	23	4561	162
1973	17	4134	120
1974	20	4806	141
1975	19	3637	134
1976	21	3677	148
1977	32	4846	226
1978	52	7715	367
1979	34	3414	240
1980	55	5425	388
1981	40	3921	282
1982	48	4824	339
1983	39	3944	275
1984	31	3102	219
1985	45	4508	318
1986	40	4002	282
1987	43	3053	304
1988	9	601	64
1989	16	798	113
1990	12	599	85
1991	8	216	38
1994	43	2608	304
1995	49	3161	346
1996	64	3085	452
1997	76	3570	537
1998	56	3450	395
1999	58	2812	409
2000	49	2004	326
2001	59	1696	293
2002	50	1666	280

Year	Trips	Fish	Sample Size
2003	67	1661	296
2004	53	1202	219
2005	51	1277	227
2006	59	1486	264
2007	81	2248	391
2008	101	3058	523
2009	107	3207	550
2010	134	2872	530
2011	100	1943	368
2012	97	1873	355
2013	117	2167	416
2014	140	2850	533
2015	110	2504	456
2016	131	2158	429

Table 17: Summary of commercial fishery age samples used in the stock assessment.

Year	Trips	Fish	Sample Size
1981	20	1901	141
1982	40	2776	282
1983	33	3317	233
1984	27	2625	191
1985	21	2096	148
1986	17	1693	120
1987	24	1193	169
1988	4	199	28
1994	8	238	41
1999	18	863	127
2000	14	677	99
2001	40	1349	226
2002	38	1414	233
2003	40	1309	221
2004	30	854	148
2005	37	1018	177
2006	49	1258	223
2007	63	1825	315
2008	44	1129	200
2009	75	1548	289
2010	54	1264	228
2011	85	1230	255
2012	7	331	49
2013	10	265	47
2014	91	587	172
2015	78	513	149
2016	21	254	56

Table 18: Summary of At-sea hake fishery length samples used in the stock assessment.

Year	Trips	Fish	Sample Size
2003	153	805	263
2004	128	329	172
2005	221	734	321
2006	210	751	312
2007	319	1119	470
2008	26	2491	162
2009	12	366	63
2010	22	1794	155
2011	36	1748	226
2012	26	881	148
2013	26	834	140
2014	31	532	103
2015	23	925	150
2016	35	1947	240

Table 19: Summary of At-sea hake fishery age samples used in the stock assessment.

Year	Trips	Fish	Sample Size
2003	142	378	194
2006	198	410	255
2007	297	620	383
2014	22	101	36

Table 20: Estimated ageing error from the CAPS lab used in the assessment model

True Age (yr)	SD of Observed Age (yr)	True Age (yr)	SD of Observed Age (yr)
0.5	0.156	31.5	2.772
1.5	0.156	32.5	2.854
2.5	0.249	33.5	2.935
3.5	0.341	34.5	3.016
4.5	0.433	35.5	3.097
5.5	0.524	36.5	3.177
6.5	0.615	37.5	3.257
7.5	0.706	38.5	3.337
8.5	0.796	39.5	3.416
9.5	0.886	40.5	3.495
10.5	0.976	41.5	3.574
11.5	1.065	42.5	3.652
12.5	1.154	43.5	3.73
13.5	1.242	44.5	3.808
14.5	1.33	45.5	3.885
15.5	1.418	46.5	3.962
16.5	1.505	47.5	4.039
17.5	1.592	48.5	4.115
18.5	1.679	49.5	4.191
19.5	1.765	50.5	4.267
20.5	1.851	51.5	4.342
21.5	1.937	52.5	4.417
22.5	2.022	53.5	4.492
23.5	2.107	54.5	4.566
24.5	2.191	55.5	4.641
25.5	2.275	56.5	4.714
26.5	2.359	57.5	4.788
27.5	2.442	58.5	4.861
28.5	2.525	59.5	4.934
29.5	2.608	60.5	5.007
30.5	2.69		

Table 21: Specifications of the base model for Pacific ocean perch.

Model Specification	Base Model
Starting year	1918
<u>Population characteristics</u>	
Maximum age	60
Gender	2
Population lengths	5-50 cm by 1 cm bins
Summary biomass (mt)	Age 3+
<u>Data characteristics</u>	
Data lengths	11-47 cm by 1 cm bins
Data ages	1-40
Minimun age for growth calculations	3
Maximum age for growth calculations	20
First mature age	0
Starting year of estimated recruitment	1940
<u>Fishery characteristics</u>	
Fishery timing	mid-year
Fishing mortality method	discrete
Maximum F	0.9
Catchability	Analytical estimate
Fishery selectivity	Double Normal
At-Sea Hake selectivity	Double Normal
POP survey selectivity	Logistic
Triennial survey	Double Normal
AFSC slope survey	Double Normal
NWFSC slope survey	Double Normal
NWFSC shelf/slope survey	Double Normal
<u>Fishery time blocks</u>	
Fishery selectivity	none
Fishery retention	1918-1991, 1992-2001, 2002-2007, 2008, 2009-2010, 2011-2016

Table 22: Results from 100 jitters from the base model.

Status	Base.Model
Returned to base case	33
Found local minimum	45
Found better solution	0
Error in likelihood	22
Total	100

Table 23: 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).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
NatM_p_1.Fem.GP_1	0.054	-5	(0.02, 0.1)			Log_Norm (-2.92, 0.44)
L_at_Amin_Fem_GP_1	20.7848	3	(15, 25)	OK	0.14	None
L_at_Amax_Fem_GP_1	41.5953	2	(35, 45)	OK	0.15	None
VonBert_K_Fem_GP_1	0.167029	3	(0.1, 0.4)	OK	0.00	None
SD_young_Fem_GP_1	1.34323	5	(0.03, 5)	OK	0.06	None
SD_old_Fem_GP_1	2.5618	5	(0.03, 5)	OK	0.12	None
Wtlen_1.Fem	1.044e-05	-99	(0, 3)			None
Wtlen_2.Fem	3.088	-99	(2, 4)			None
Mat50%_Fem	32.1	-99	(20, 40)			None
Mat_slope_Fem	-1	-99	(-2, 4)			None
Eggs_scalar_Fem	8.66e-10	-99	(0, 6)			None
Eggs_exp_len_Fem	4.9767	-99	(-3, 5)			None
NatM_p_1.Mal.GP_1	0.054	-5	(0, 0.3)			Normal (0.05, 0.1)
L_at_Amin_Mal_GP_1	20.7848	-2	(6, 68)			None
L_at_Amax_Mal_GP_1	38.8999	2	(13, 122)	OK	0.00	None
VonBert_K_Mal_GP_1	0.199	3	(0.04, 1.09)	OK	0.03	None
SD_young_Mal_GP_1	1.34323	-5	(0, 742.07)			None
SD_old_Mal_GP_1	2.287	5	(0, 742.07)	OK	0.06	None
Wtlen_1.Mal	1.05e-05	-99	(0, 3)			None
Wtlen_2.Mal	3.083	-99	(2, 4)			None
CohortGrowDev	1	-99	(0, 2)			None
FracFemale_GP_1	0.5	-99	(0.01, 0.99)			None
SR_LN(R0)	9.36441	1	(5, 20)	OK	0.14	None
SR_BH_stEEP	0.5	-2	(0.2, 1)			Full_Beta (0.72, 0.15)
SR_sigmaR	0.7	-6	(0.5, 1.2)			None
SR_regime	0	-99	(-5, 5)			None

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Table 23: 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).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SR_autocorr	0	-99	(0, 2)	act	0.70	dev (NA, NA)
Early_InitAge_18	0.00423169	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_17	0.00444885	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_16	0.00467384	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_15	0.00490632	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_14	0.00514567	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_13	0.00539119	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_12	0.00564178	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_11	0.0058963	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_10	0.00615286	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_9	0.00640947	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_8	0.0066662	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_7	0.00690763	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_6	0.00714936	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_5	0.00739472	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_4	0.0076478	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_3	0.00790868	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_2	0.00817704	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_1	0.00845291	3	(-6, 6)	act	0.70	dev (NA, NA)
LnQ_base_Fishery(1)	-12.313	-1	(-15, 15)	None	None	None
LnQ_base_POP(4)	-0.122911	-1	(-15, 15)	None	None	None
LnQ_base_Triennial(5)	-1.82534	-1	(-15, 15)	OK	0.15	None
Q_extraSD_Triennial(5)	0.390454	2	(0, 0.5)	OK	0.15	None
LnQ_base_AFSCSlope(6)	-2.48805	-1	(-15, 15)	None	None	None
LnQ_base_NWEFSCSlope(7)	-2.84895	-1	(-15, 15)	None	None	None
LnQ_base_NWFSCCombo(8)	-2.62228	-1	(-15, 15)	None	None	None

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Table 23: 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).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Q_extraSD_NWFSCcombo(8)	0.029722	2	(0, 0.5) (20, 45)	OK	0.07	None
SizeSel_P1_Fishery(1)	37.9626	1	(20, 45)	OK	0.18	None
SizeSel_P2_Fishery(1)	-5	-2	(-6, 4)	None		
SizeSel_P3_Fishery(1)	3.67946	3	(-1, 9)	OK	0.13	None
SizeSel_P4_Fishery(1)	-1.65	-3	(-9, 9)	None		
SizeSel_P5_Fishery(1)	-3.5	-4	(-5, 9)	None		
SizeSel_P6_Fishery(1)	0.496266	2	(-5, 9)	OK	0.31	None
Retain_P1_Fishery(1)	28.2834	1	(15, 45)	OK	0.34	None
Retain_P2_Fishery(1)	1.07725	1	(0.1, 10)	OK	0.13	None
Retain_P3_Fishery(1)	6.97035	1	(-10, 10)	OK	1.36	None
Retain_P4_Fishery(1)	0	-3	(0, 0)	None		
SizeSel_P1_ASHOP(2)	49.495	1	(20, 49.5)	HI	0.16	None
SizeSel_P2_ASHOP(2)	-5	-2	(-6, 4)	None		
SizeSel_P3_ASHOP(2)	5.06196	3	(-1, 9)	OK	0.18	None
SizeSel_P4_ASHOP(2)	1	-3	(-1, 9)	None		
SizeSel_P5_ASHOP(2)	-4.35	-4	(-9, 9)	None		
SizeSel_P6_ASHOP(2)	999	-2	(-5, 999)	None		
SizeSel_P1_POP(4)	24.4703	1	(20, 70)	OK	2.24	None
SizeSel_P2_POP(4)	11.1655	3	(0.001, 50)	OK	4.04	None
SizeSel_P1_Triennial(5)	27.6389	1	(20, 45)	OK	5.03	None
SizeSel_P2_Triennial(5)	-5	-2	(-6, 4)	None		
SizeSel_P3_Triennial(5)	5.5	-3	(-1, 9)	None		
SizeSel_P4_Triennial(5)	3.297	3	(-1, 9)	OK	2.29	None
SizeSel_P5_Triennial(5)	-5	-4	(-5, 9)	None		
SizeSel_P6_Triennial(5)	-0.782413	2	(-5, 9)	OK	0.64	None
SizeSel_P1_AFSCSlope(6)	21.7007	1	(20, 45)	OK	6.45	None

Continued on next page

Table 23: 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).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SizeSel.P2_AFSCSlope(6)	-5	-2	(-6, 4)	OK	6.47	None
SizeSel.P3_AFSCSlope(6)	1.23847	3	(-1, 9)	OK	6.47	None
SizeSel.P4_AFSCSlope(6)	1	-3	(-1, 9)	None	None	None
SizeSel.P5_AFSCSlope(6)	-9	-4	(-9, 9)	None	None	None
SizeSel.P6_AFSCSlope(6)	999	-2	(-5, 999)	None	None	None
SizeSel.P1_NWFSCSlope(7)	35.9583	1	(20, 45)	OK	2.22	None
SizeSel.P2_NWFSCSlope(7)	-5	-2	(-6, 4)	None	None	None
SizeSel.P3_NWFSCSlope(7)	1.77694	3	(-1, 9)	OK	1.85	None
SizeSel.P4_NWFSCSlope(7)	1	-3	(-1, 9)	None	None	None
SizeSel.P5_NWFSCSlope(7)	-9	-4	(-9, 9)	None	None	None
SizeSel.P6_NWFSCSlope(7)	999	-2	(-5, 999)	None	None	None
SizeSel.P1_NWFFSCCombo(8)	21.3537	1	(18, 49.5)	OK	5.84	None
SizeSel.P2_NWFFSCCombo(8)	-5	-2	(-6, 4)	None	None	None
SizeSel.P3_NWFFSCCombo(8)	2.86381	3	(-1, 9)	OK	3.06	None
SizeSel.P4_NWFFSCCombo(8)	1	-3	(-1, 9)	None	None	None
SizeSel.P5_NWFFSCCombo(8)	-9	-4	(-9, 9)	None	None	None
SizeSel.P6_NWFFSCCombo(8)	999	-2	(-5, 999)	None	None	None
Retain_P3_Fishery(1)_BLK1repl_1918	3.98279	4	(-10, 10)	OK	0.09	None
Retain_P3_Fishery(1)_BLK1repl_1992	2.30477	4	(-10, 10)	OK	0.37	None
Retain_P3_Fishery(1)_BLK1repl_2002	1.71753	4	(-10, 10)	OK	0.12	None
Retain_P3_Fishery(1)_BLK1repl_2008	0.608476	4	(-10, 10)	OK	0.28	None
Retain_P3_Fishery(1)_BLK1repl_2009	-0.0174503	4	(-10, 10)	OK	0.24	None

Table 24: Likelihood components from the base model

Likelihood Component	Value
Total	1726.16
Survey	0
Discard	-25.51
Length-frequency data	-34.22
Age-frequency data	135.74
Recruitment	1636.59
Forecast Recruitment	12.54
Parameter Priors	0

Table 25: Summary of reference points and management quantities for the base case.

Quantity	Estimate	95% Confidence Interval
Unfished spawning output (million eggs)	6633.1	4736.7 - 8529.5
Unfished age 3+ biomass (mt)	139810	100052.5 - 179567.5
Unfished recruitment ( $R_0$ , thousands)	11665.7	8801.4 - 15462.1
Spawning output(2017 million eggs)	5047.2	2259.2 - 7835.1
Depletion (2017)	0.761	0.538 - 0.984
<b>Reference points based on <math>SB_{40\%}</math></b>		
Proxy spawning output ( $B_{40\%}$ )	2653.2	1894.7 - 3411.8
SPR resulting in $B_{40\%}$ ( $SPR_{B40\%}$ )	0.55	0.55 - 0.55
Exploitation rate resulting in $B_{40\%}$	0.028	0.028 - 0.029
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	1748.2	1252.4 - 2244
<b>Reference points based on SPR proxy for MSY</b>		
Spawning output	2211	1578.9 - 2843.2
$SPR_{proxy}$	0.5	
Exploitation rate corresponding to $SPR_{proxy}$	0.034	0.033 - 0.034
Yield with $SPR_{proxy}$ at $SB_{SPR}$ (mt)	1764.8	1264.8 - 2264.8
<b>Reference points based on estimated MSY values</b>		
Spawning output at $MSY$ ( $SB_{MSY}$ )	2315.7	1649.6 - 2981.8
$SPR_{MSY}$	0.512	0.51 - 0.514
Exploitation rate at $MSY$	0.032	0.032 - 0.033
$MSY$ (mt)	1766.7	1266.1 - 2267.4

Table 26: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exp. rate
1918	140160	6644	139432	1.00	11773	0	0	0
1919	140191	6646	139462	1.00	11777	1	0	0
1920	140222	6647	139494	1.00	11781	0	0	0
1921	140255	6648	139526	1.00	11785	0	0	0
1922	140288	6650	139559	1.00	11790	0	0	0
1923	140322	6651	139593	1.00	11794	0	0	0
1924	140357	6653	139627	1.00	11798	0	0	0
1925	140392	6654	139662	1.00	11802	1	0	0
1926	140428	6656	139698	1.00	11806	1	0	0
1927	140464	6658	139734	1.00	11810	1	0	0
1928	140500	6659	139770	1.00	11813	1	0	0
1929	140538	6661	139807	1.00	11817	1	0	0
1930	140576	6663	139844	1.00	11820	1	0	0

Table 26: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 re-cruits	Estimated total catch (mt)	1-SPR	Exp. rate
1931	140614	6664	139883	1.00	11822	1	0	0
1932	140653	6666	139922	1.00	11825	1	0	0
1933	140693	6668	139961	1.00	11828	1	0	0
1934	140732	6670	140000	1.00	11832	1	0	0
1935	140770	6671	140038	1.00	11837	3	0	0
1936	140802	6673	140070	1.00	11847	8	0	0
1937	140842	6675	140109	1.00	11862	2	0	0
1938	140881	6677	140147	1.00	11886	3	0	0
1939	140918	6678	140183	1.01	11919	6	0	0
1940	140954	6680	140217	1.01	12146	10	0.005	0
1941	140983	6681	140242	1.01	12203	23	0.005	0
1942	141018	6681	140265	1.01	12269	30	0.01	0
1943	141056	6681	140300	1.01	12341	47	0.09	0
1944	140602	6656	139842	1.00	12405	562	0.145	0.004
1945	139822	6614	139058	1.00	12466	929	0.295	0.007
1946	137832	6512	137064	0.98	12511	2194	0.165	0.016
1947	137052	6466	136280	0.97	12620	1072	0.095	0.008
1948	136839	6448	136062	0.97	12813	569	0.115	0.004
1949	136558	6426	135773	0.97	13116	690	0.145	0.005
1950	136122	6396	135323	0.96	13560	906	0.21	0.007
1951	135270	6345	134450	0.95	14128	1401	0.24	0.01
1952	134310	6287	133460	0.95	14724	1619	0.325	0.012
1953	132711	6194	131826	0.93	15069	2398	0.26	0.018
1954	131916	6135	131000	0.92	14941	1775	0.35	0.014
1955	130512	6042	129584	0.91	14203	2564	0.295	0.02
1956	129852	5981	128942	0.90	12989	2002	0.41	0.016
1957	128117	5871	127262	0.88	11722	3198	0.375	0.025
1958	126915	5791	126135	0.87	10675	2739	0.315	0.022
1959	126275	5750	125569	0.87	10004	2154	0.21	0.017
1960	126415	5761	125766	0.87	9845	1264	0.34	0.01
1961	125275	5728	124657	0.86	10252	2367	0.43	0.019
1962	123003	5651	122386	0.85	10774	3327	0.515	0.027
1963	119505	5519	118864	0.83	10117	4420	0.605	0.037
1964	114480	5309	113829	0.80	8593	5877	0.635	0.052
1965	109077	5071	108480	0.76	7553	6231	0.715	0.057
1966	102042	4747	101530	0.71	7030	7828	0.91	0.077
1967	83867	3877	83412	0.58	6588	18969	0.9	0.227
1968	70229	3212	69803	0.48	6869	14651	0.87	0.21

Table 26: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exp. rate
1969	61697	2793	61280	0.42	9376	9712	0.52	0.158
1970	60813	2747	60334	0.41	14602	2183	0.535	0.036
1971	59909	2700	59263	0.41	7299	2300	0.485	0.039
1972	59604	2671	58826	0.40	5143	1905	0.485	0.032
1973	59479	2639	59064	0.40	5037	1888	0.585	0.032
1974	58489	2568	58173	0.39	5064	2643	0.545	0.045
1975	57748	2516	57433	0.38	6344	2275	0.37	0.04
1976	57966	2527	57636	0.38	5048	1183	0.43	0.021
1977	57717	2541	57341	0.38	6659	1507	0.38	0.026
1978	57590	2572	57256	0.39	4884	1263	0.505	0.022
1979	56599	2555	56214	0.38	5599	1998	0.425	0.036
1980	56021	2544	55707	0.38	5514	1507	0.465	0.027
1981	55123	2513	54778	0.38	5878	1723	0.41	0.031
1982	54527	2491	54173	0.37	8884	1380	0.345	0.025
1983	54257	2482	53841	0.37	10035	1057	0.46	0.02
1984	53504	2444	52943	0.37	7130	1624	0.47	0.031
1985	52905	2402	52332	0.36	7183	1658	0.435	0.032
1986	52705	2368	52266	0.36	5839	1412	0.43	0.027
1987	52596	2335	52171	0.35	7017	1375	0.375	0.026
1988	52807	2320	52421	0.35	9406	1107	0.435	0.021
1989	52778	2302	52302	0.35	10569	1379	0.45	0.026
1990	52787	2295	52177	0.35	14046	1469	0.38	0.028
1991	53355	2308	52663	0.35	6385	1123	0.45	0.021
1992	53782	2305	53046	0.35	3456	1478	0.465	0.028
1993	54258	2292	53911	0.34	3469	1567	0.435	0.029
1994	54699	2290	54469	0.34	9862	1418	0.385	0.026
1995	55205	2308	54888	0.35	9012	1180	0.325	0.022
1996	55849	2354	55266	0.35	3880	952	0.3	0.017
1997	56573	2418	56100	0.36	3814	879	0.25	0.016
1998	57307	2487	57070	0.37	2935	716	0.245	0.013
1999	57798	2535	57535	0.38	19539	721	0.2	0.013
2000	58403	2574	57923	0.39	30595	562	0.065	0.01
2001	59724	2630	58388	0.40	8937	160	0.11	0.003
2002	61725	2685	60195	0.40	5185	293	0.07	0.005
2003	64401	2736	63916	0.41	2597	179	0.06	0.003
2004	66917	2772	66628	0.42	6944	155	0.055	0.002
2005	69212	2810	68989	0.42	3345	147	0.03	0.002
2006	71239	2896	70867	0.44	3865	76	0.03	0.001

Table 26: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exp. rate
2007	72918	3046	72703	0.46	3723	85	0.05	0.001
2008	74370	3211	73810	0.48	133246	157	0.045	0.002
2009	76575	3346	74550	0.50	4814	133	0.055	0.002
2010	80990	3438	74832	0.52	8279	190	0.055	0.003
2011	88763	3500	88389	0.53	16107	181	0.02	0.002
2012	95774	3545	95169	0.53	2113	61	0.015	0.001
2013	102857	3584	102021	0.54	29279	58	0.015	0.001
2014	109633	3727	109119	0.56	5078	57	0.015	0.001
2015	115762	4118	114333	0.62	10096	55	0.015	0
2016	121528	4620	121131	0.70	10520	59	0.015	0
2017	126167	5047	125534	0.76	10816	65	0.055	0.001
2018	129828	5369	129171	0.81	11017	-	-	-
2019	132735	5625	132062	0.85	11166	-	-	-
2020	130783	5657	130099	0.85	11184	-	-	-
2021	128376	5654	127685	0.85	11182	-	-	-
2022	125691	5606	124999	0.84	11155	-	-	-
2023	122860	5528	122169	0.83	11110	-	-	-
2024	119983	5431	119294	0.82	11054	-	-	-
2025	117128	5324	116442	0.80	10990	-	-	-
2026	114343	5211	113661	0.78	10921	-	-	-
2027	111655	5096	110977	0.77	10848	-	-	-
2028	109081	4981	108407	0.75	10772	-	-	-

Table 27: Sensitivity of the base model

Label	Base weights	Harmonic at prior M	Steepness Estimate	Old Maturity	Old Fecundity
Total Likelihood	1726.16	2432.50	1726.05	1725.66	1726.17
Survey Likelihood	-25.51	-25.88	-24.99	-25.68	-25.52
Discard Likelihood	-34.22	-27.17	-34.28	-34.29	-34.22
Length Likelihood	135.74	748.49	136.05	135.75	135.75
Age Likelihood	1636.59	1717.85	1636.26	1636.59	1636.58
Recruitment Likelihood	12.54	18.20	12.87	12.34	12.54
Forecast Recruitment Likelihood	0.00	0.00	0.00	0.00	0.00
Parameter Priors Likelihood	1.00	1.00	0.13	0.94	1.00
Parameter Deviation Likelihood	0.00	0.00	0.00	0.00	0.00
log(R0)	9.36	9.27	9.41	9.74	9.37
SB Virgin	6633.08	6136.91	6979.48	7885.80	6505.70
SB 2017	5047.16	4199.96	6883.61	7436.66	5070.80
Depletion 2017	0.76	0.68	0.99	0.94	0.78
Total Yield	1764.80	1605.33	2482.46	2329.27	1759.53
Steepness	0.50	0.50	0.72	0.50	0.50
Natural Mortality - Female	0.05	0.05	0.05	0.06	0.05
Length at Amin - Female	20.78	20.87	20.79	20.78	20.78
Length at Amax - Female	41.60	41.72	41.61	41.61	41.60
Von Bert. k - Female	0.17	0.17	0.17	0.17	0.17
SD young - Female	1.34	1.35	1.34	1.34	1.34
SD old - Female	2.56	2.76	2.56	2.56	2.56
Natural Mortality - Male	0.05	0.05	0.05	0.06	0.05
Length at Amin - Male	20.78	20.87	20.79	20.78	20.78
Length at Amax - Male	38.90	38.91	38.91	38.90	38.90
Von Bert. k - Male	0.20	0.20	0.20	0.20	0.20
SD young - Male	1.34	1.35	1.34	1.34	1.34
SD old - Male	2.29	2.60	2.29	2.29	2.29

Table 28: Sensitivity of the base model

Label	Base	Split Trien- nial	CPUE	Remove Data	Canadian search Lengths	VWA Re- search Lengths	OR Special Projects
Total Likelihood	1726.16	1724.43	1738.84	1829.64	1747.71	1793.59	
Survey Likelihood	-25.51	-27.89	-12.72	-25.91	-26.03	-26.02	
Discard Likelihood	-34.22	-34.22	-34.21	-33.26	-34.17	-34.27	
Length Likelihood	135.74	135.54	135.66	184.34	156.08	166.78	
Age Likelihood	1636.59	1637.33	1636.69	1690.33	1637.74	1671.26	
Recruitment Likelihood	12.54	12.65	12.40	13.13	13.08	14.81	
Forecast Recruitment Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	
Parameter Priors Likelihood	1.00	1.00	1.00	1.00	1.00	1.00	
Parameter Deviation Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	
log(R0)	9.36	9.40	9.36	9.36	9.33	9.28	
SB Virgin	6633.08	6884.08	6594.29	6700.11	6356.26	6128.38	
SB 2017	5047.16	5434.58	4992.37	4716.26	4673.44	4392.80	
Depletion 2017	0.76	0.79	0.76	0.70	0.74	0.72	
Total Yield	1764.80	1830.92	1754.69	1777.27	1705.62	1626.60	
Steepness	0.50	0.50	0.50	0.50	0.50	0.50	
Natural Mortality - Female	0.05	0.05	0.05	0.05	0.05	0.05	
Length at Amin - Female	20.78	20.78	20.78	20.75	20.77	20.80	
Length at Amax - Female	41.60	41.60	41.59	41.68	41.52	41.62	
Von Bert. k - Female	0.17	0.17	0.17	0.17	0.17	0.17	
SD young - Female	1.34	1.34	1.34	1.35	1.34	1.33	
SD old - Female	2.56	2.56	2.56	2.54	2.56	2.58	
Natural Mortality - Male	0.05	0.05	0.05	0.05	0.05	0.05	
Length at Amin - Male	20.78	20.78	20.78	20.75	20.77	20.80	
Length at Amax - Male	38.90	38.91	38.90	38.96	38.87	38.93	
Von Bert. k - Male	0.20	0.20	0.20	0.20	0.20	0.20	
SD young - Male	1.34	1.34	1.34	1.35	1.34	1.33	
SD old - Male	2.29	2.29	2.29	2.28	2.30	2.35	

Table 29: Projection of potential OFL, spawning biomass, and depletion for the base case model.

Year	OFL (mt)	ACL (mt)	Age 3+ biomass (mt)	Spawning Output	Depletion
2017	4306	281	125534	5047	0.76
2018	4559	281	129171	5369	0.81
2019	4719	4515	132062	5625	0.85
2020	4654	4453	130099	5657	0.85
2021	4552	4356	127685	5654	0.85
2022	4431	4240	124999	5606	0.85
2023	4302	4116	122169	5528	0.83
2024	4172	3992	119294	5431	0.82
2025	4048	3873	116442	5324	0.80
2026	3932	3762	113661	5211	0.79
2027	3826	3660	110977	5096	0.77
2028	3727	3566	108407	4981	0.75

Table 30: Summary of 10-year projections beginning in 2019 for alternate states of nature based on an axis of uncertainty for the base 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 State of Nature			Base State of Nature		High State of Nature	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
Catch Option 1	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Catch Option 2	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Catch Option 3	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Average Catch	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-

<sub>1276</sub> 9 Figures

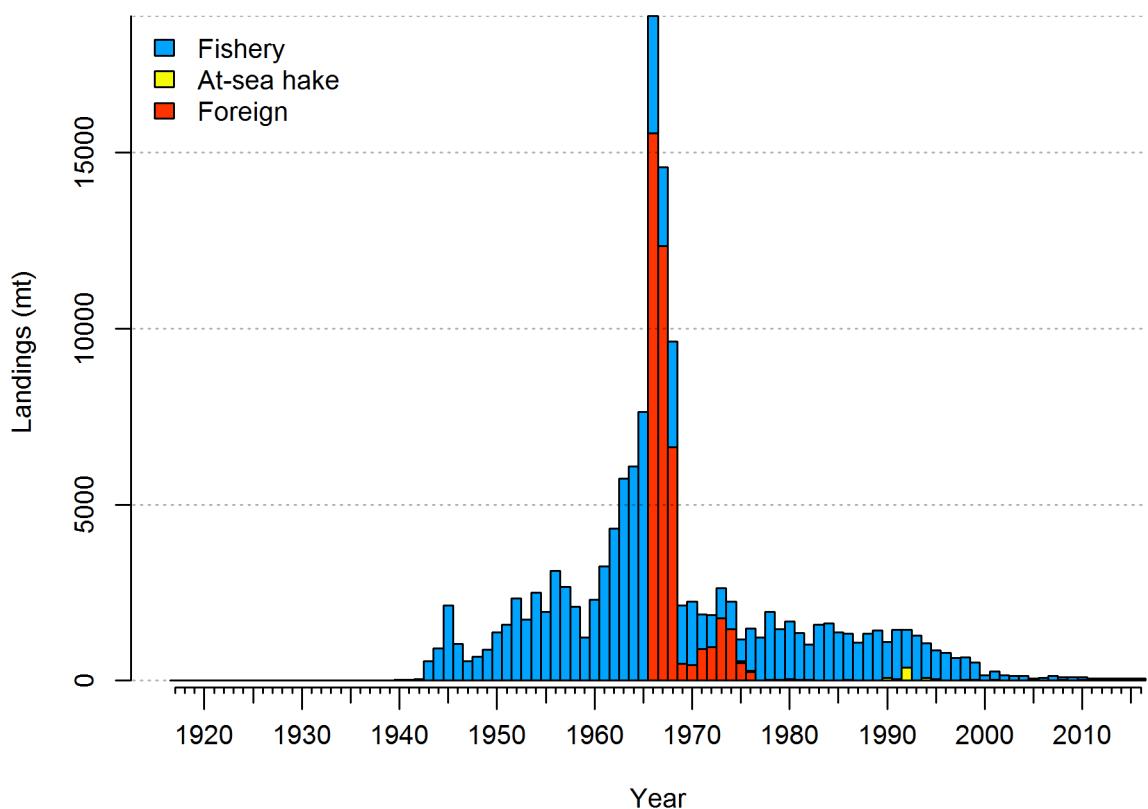


Figure 1: Total catches Pacific ocean perch through 2016.

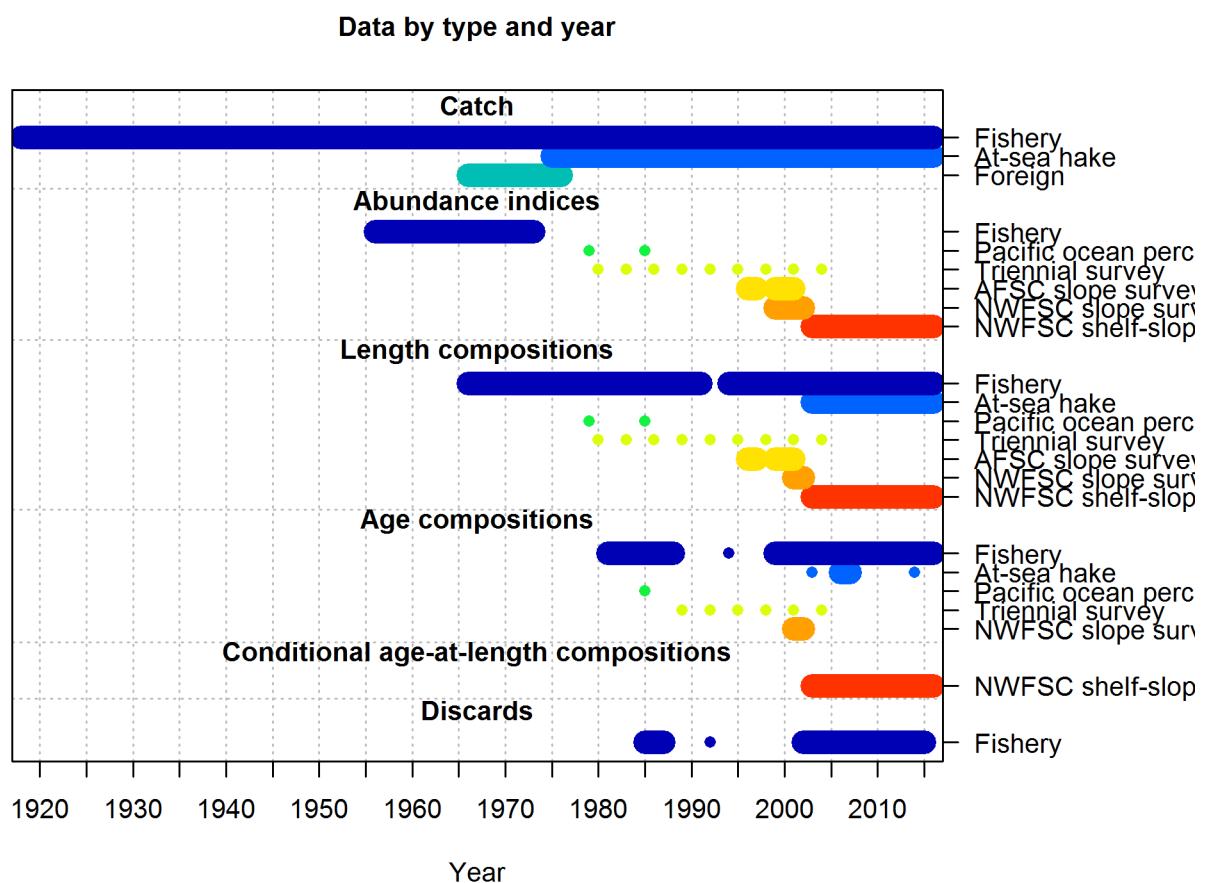


Figure 2: Summary of data sources used in the base model.

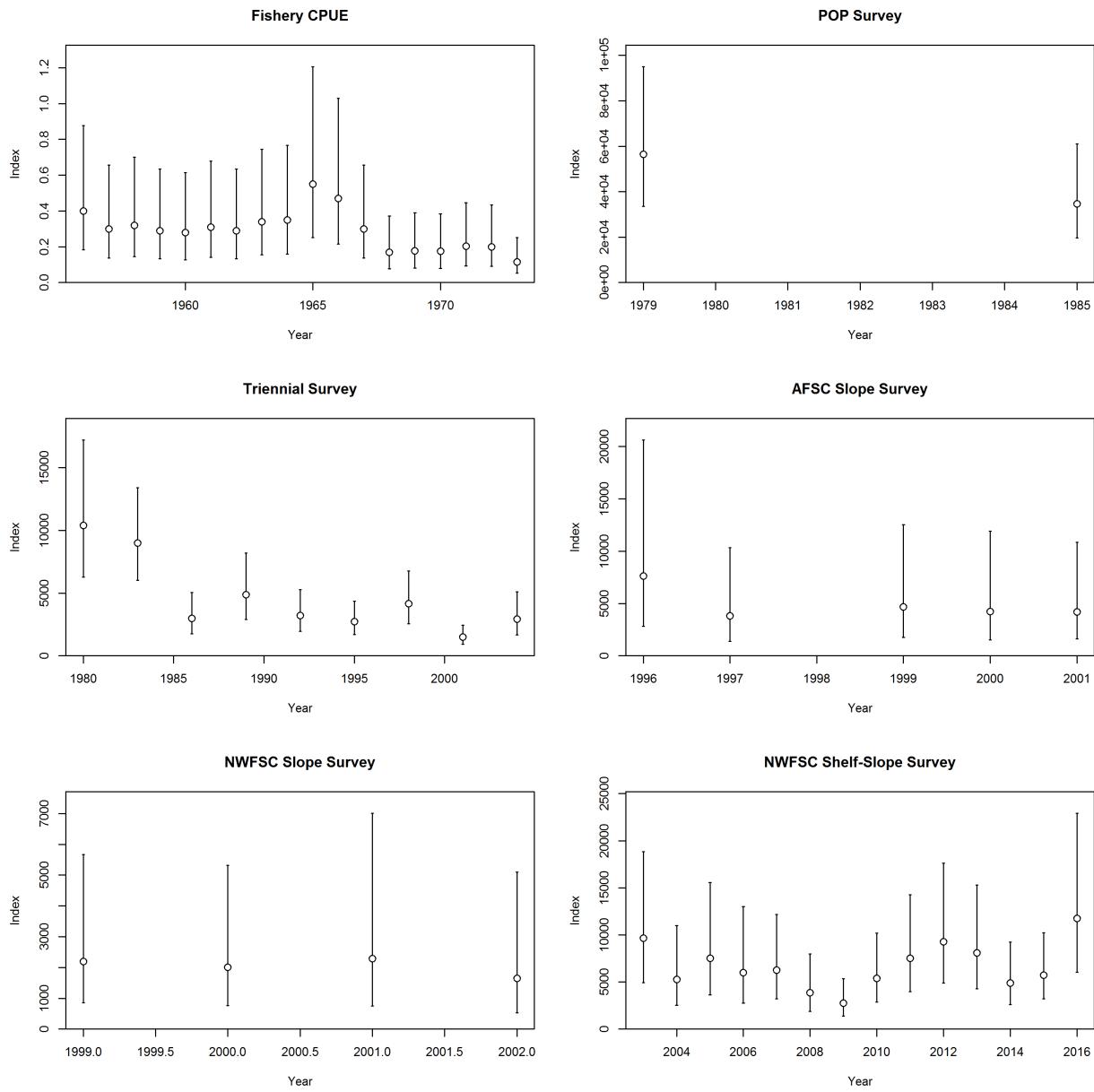


Figure 3: Fishery-dependent and fishery-independent indices for Pacific ocean perch.

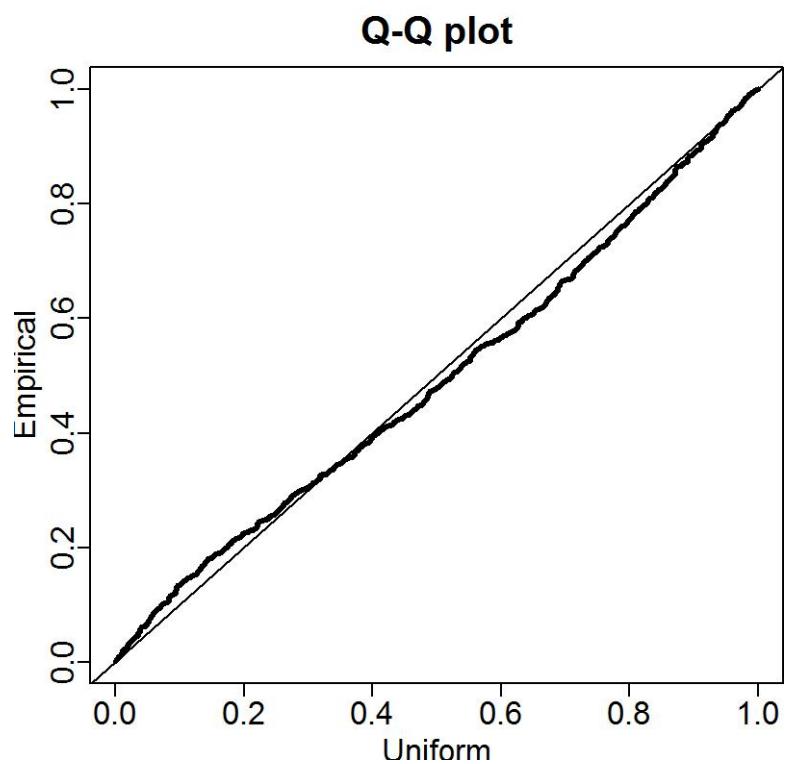


Figure 4: Q-Q plots for the VAST lognormal distribution for the NWFSC shelf-slope survey.

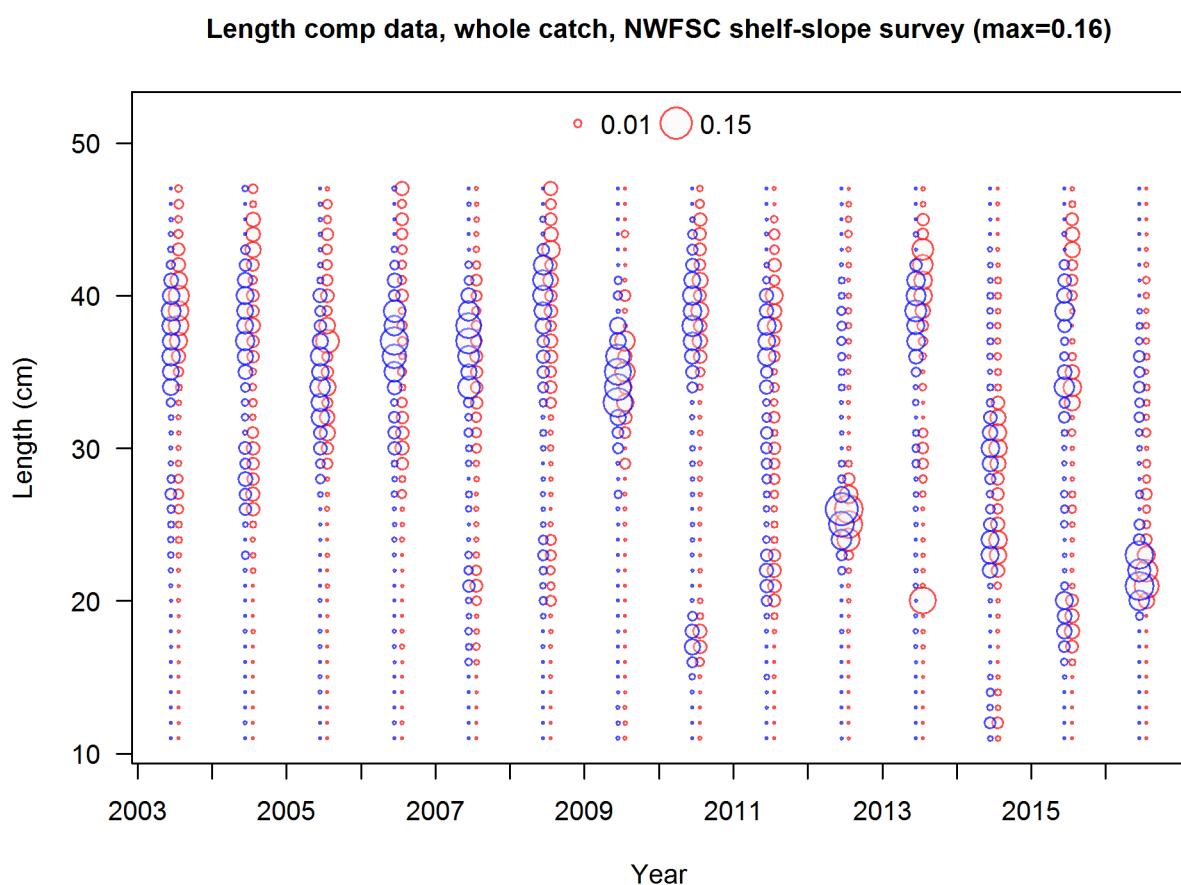


Figure 5: NWFSC shelf-slope survey length frequency distributions for Pacific ocean perch.

**Ghost age comp data, whole catch, NWFSC shelf-slope survey (max=0.4)**

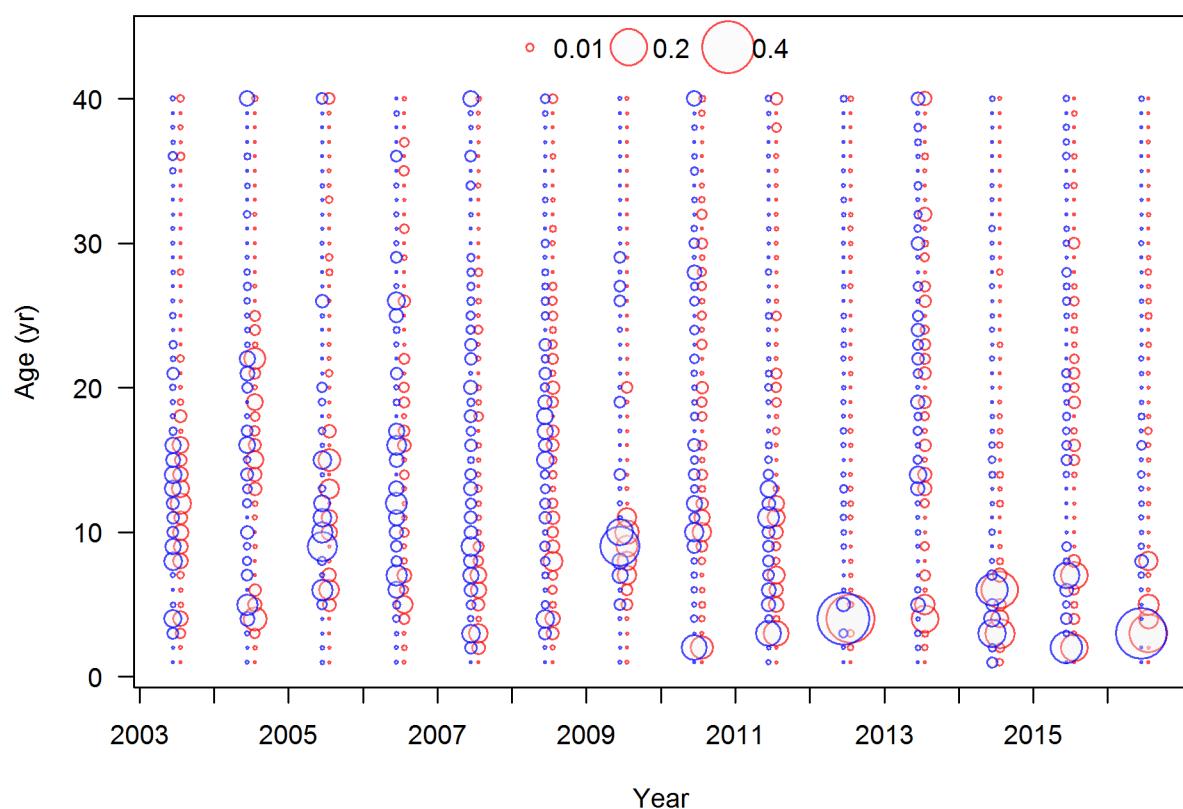


Figure 6: NWFSC shelf-slope survey age frequency distributions for Pacific ocean perch.

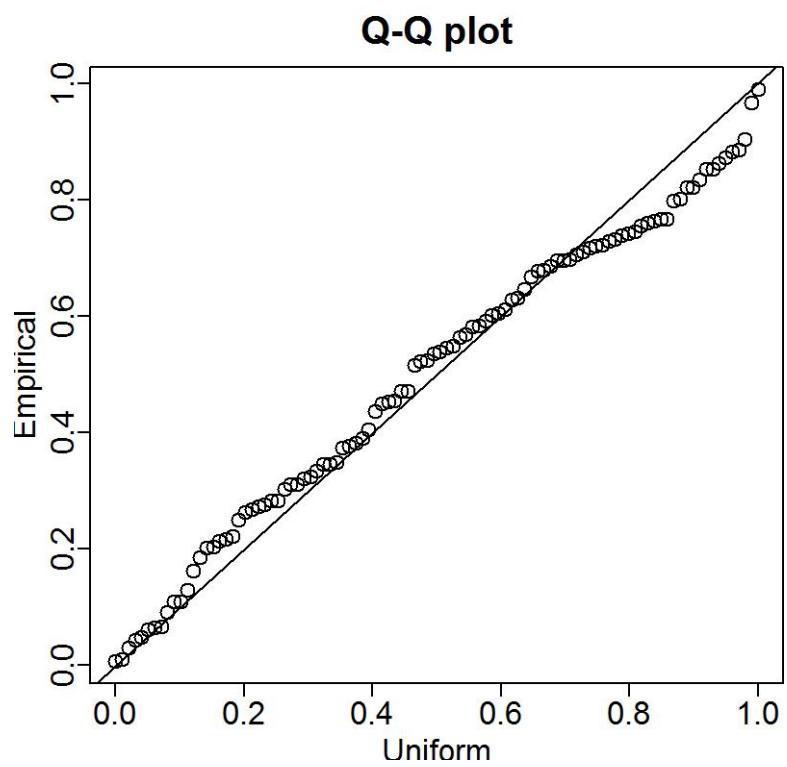


Figure 7: Q-Q plots for the VAST lognormal distribution for the NWFSC slope survey.

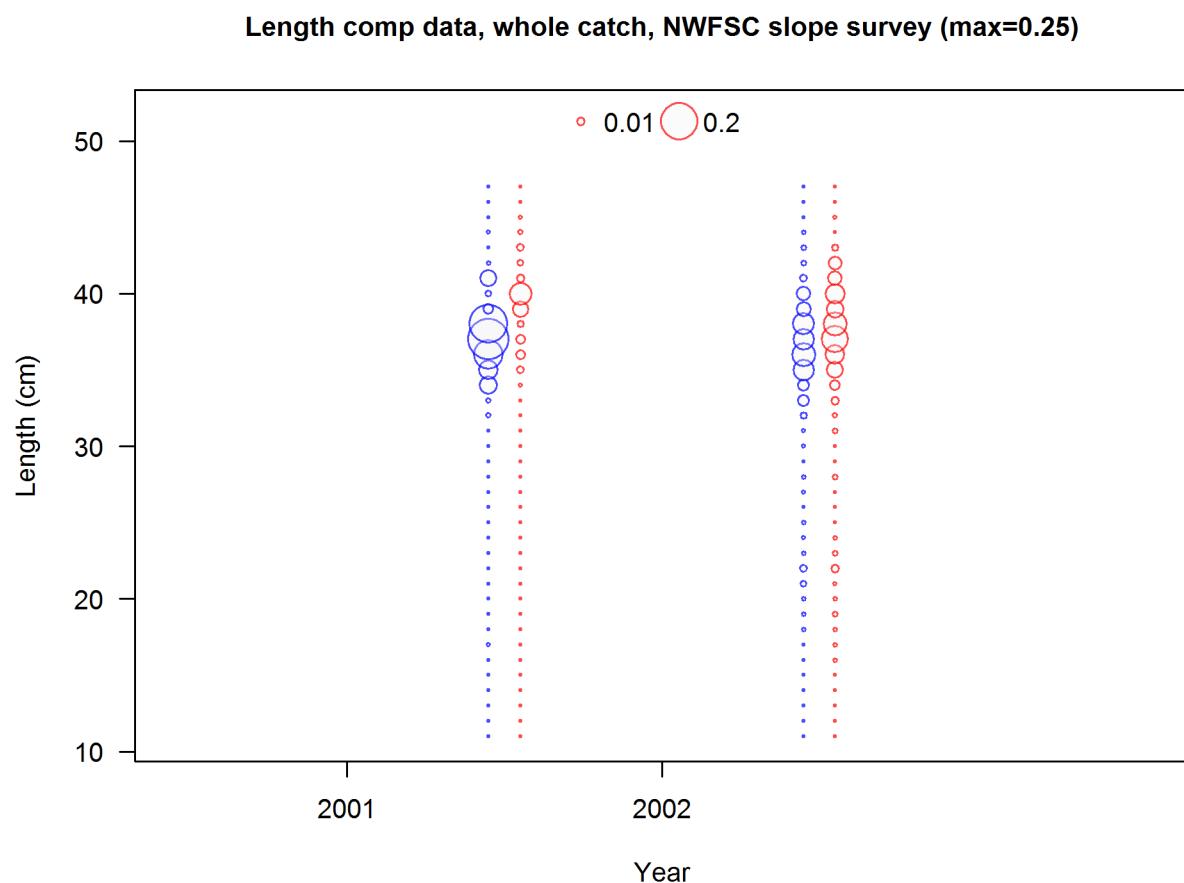


Figure 8: NWFSC slope survey length frequency distributions for Pacific ocean perch.

**Age comp data, whole catch, NWFSC slope survey (max=0.08)**

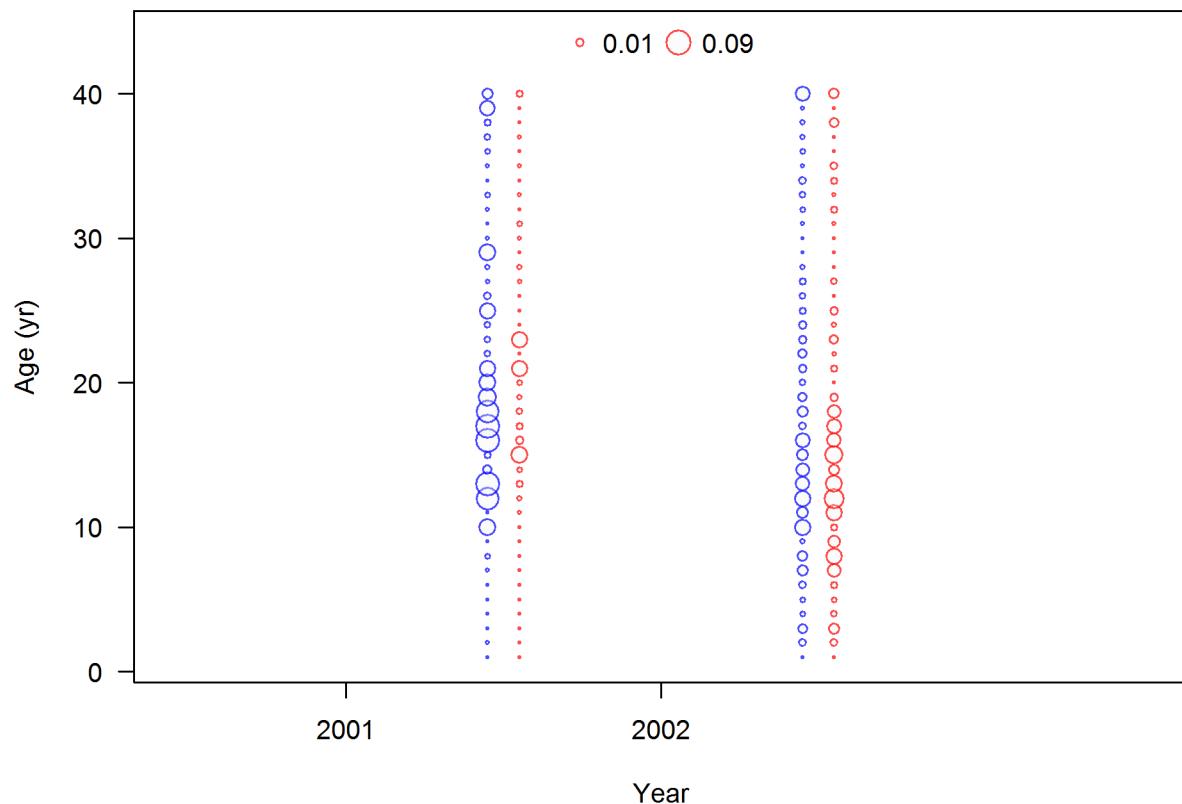


Figure 9: NWFSC slope survey age frequency distributions for Pacific ocean perch.

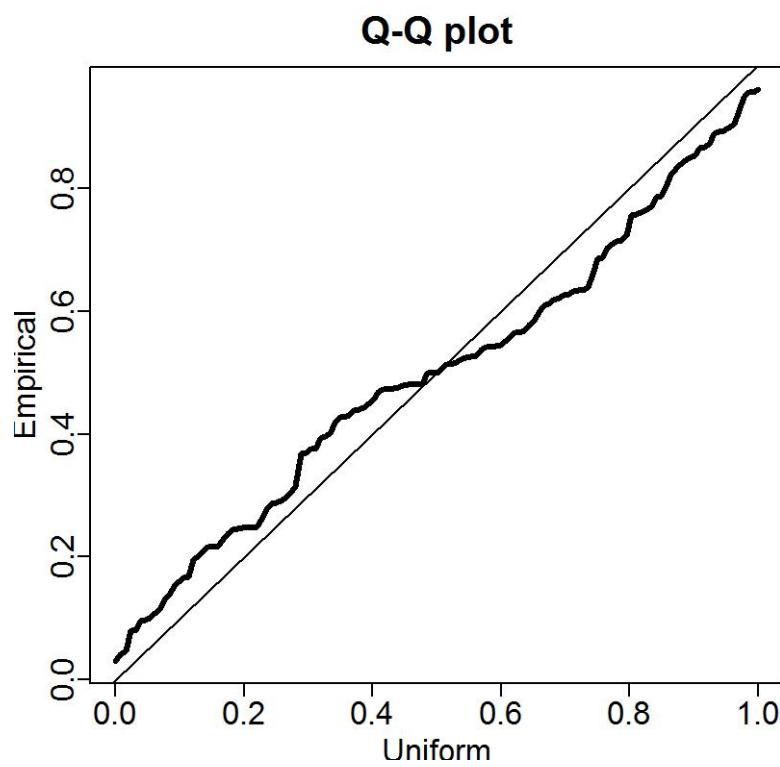


Figure 10: Q-Q plots for the VAST lognormal distribution for the AFSC slope survey.

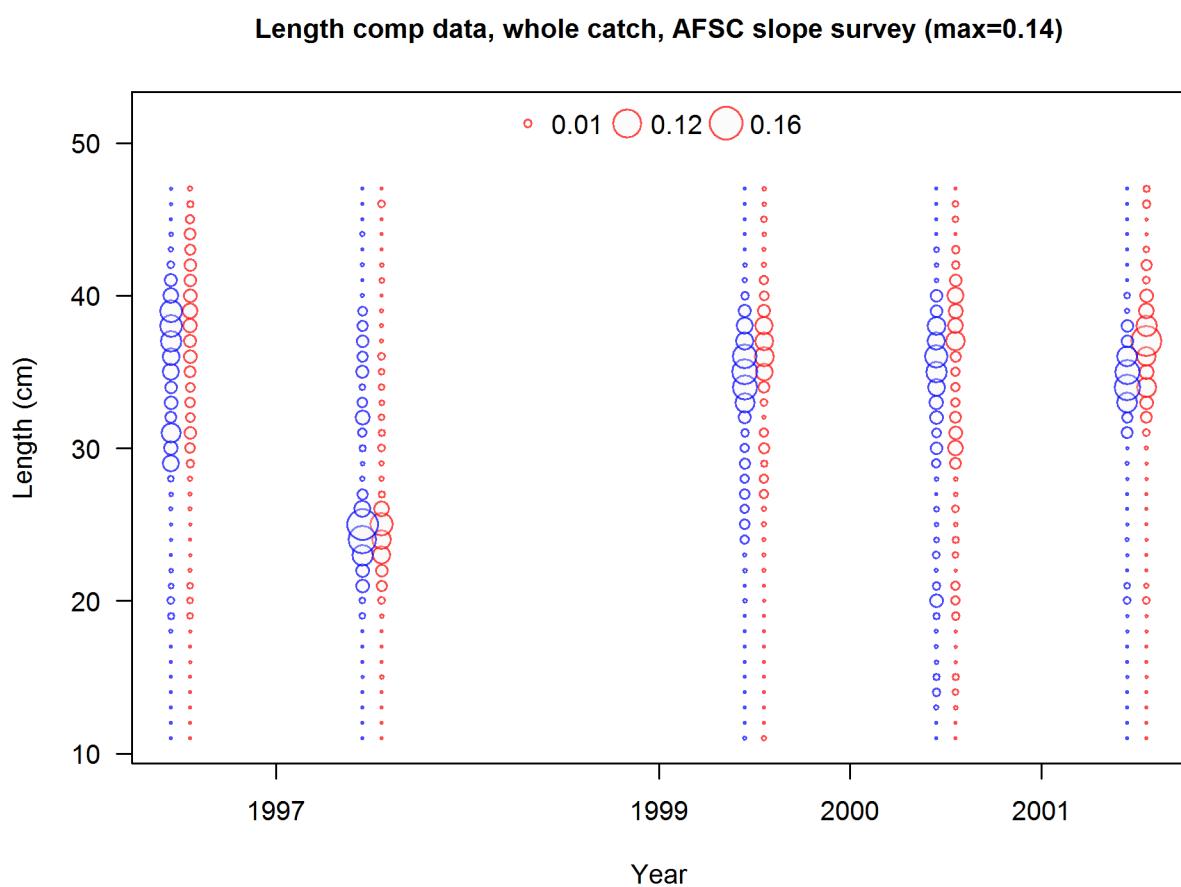


Figure 11: AFSC slope survey length frequency distributions for Pacific ocean perch.

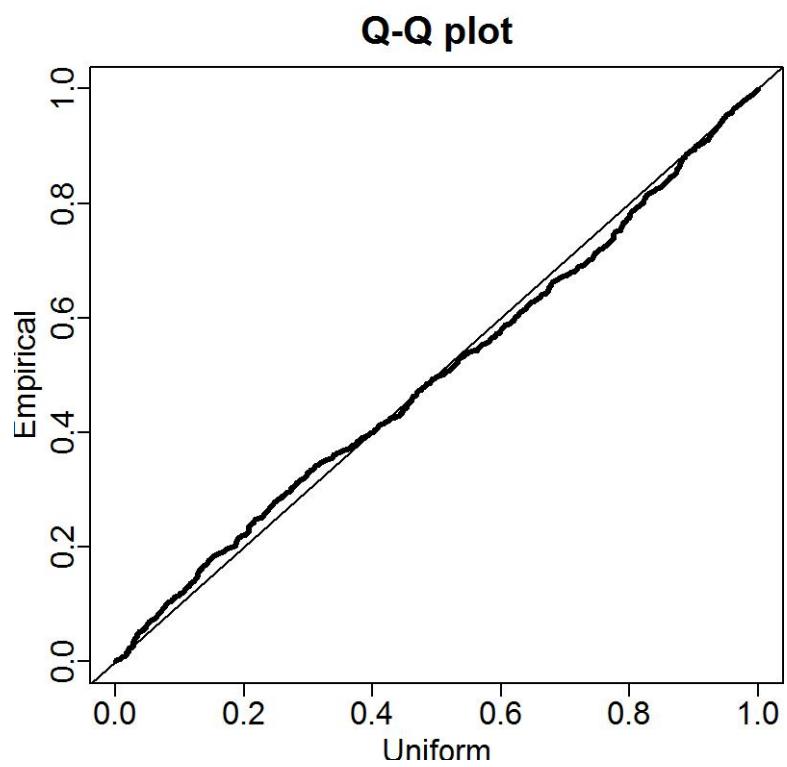


Figure 12: Q-Q plots for the VAST lognormal distribution for the Triennial survey.

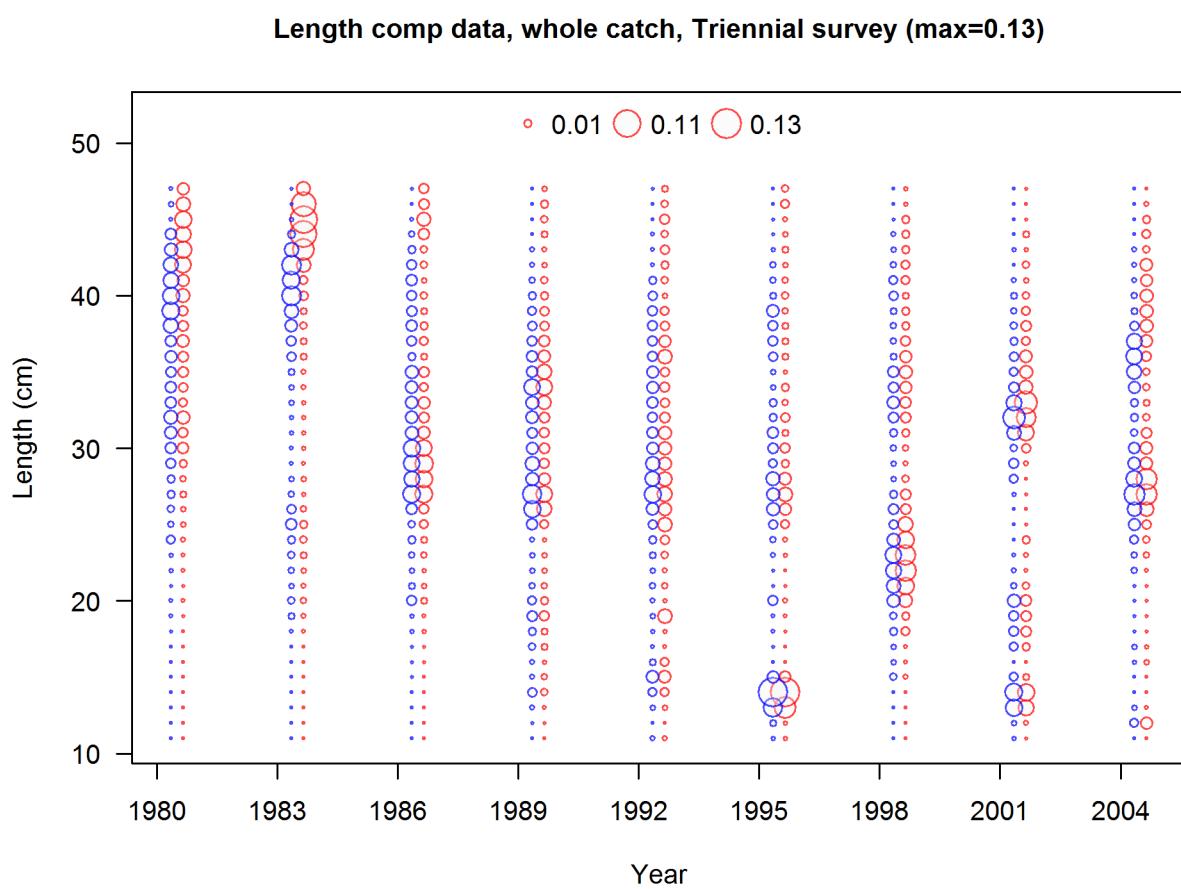


Figure 13: Triennial survey length frequency distributions for Pacific ocean perch.

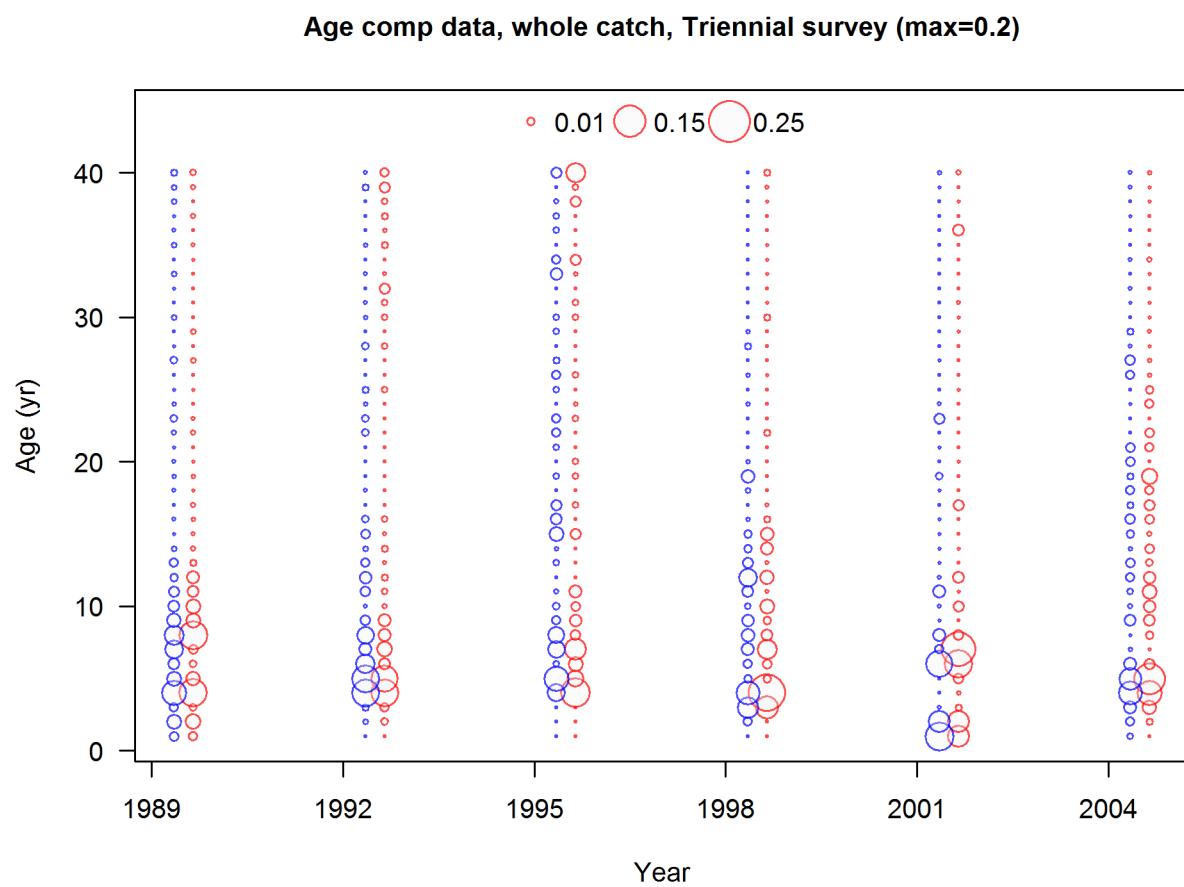


Figure 14: Triennial survey age frequency distributions for Pacific ocean perch.

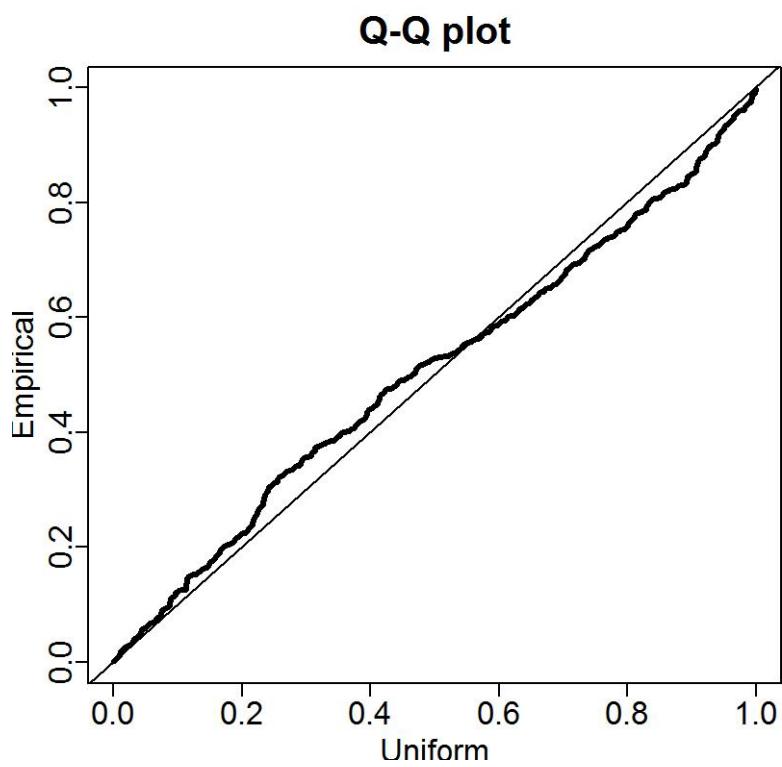


Figure 15: Q-Q plots for the VAST lognormal distribution for the Pacific ocean perch survey.

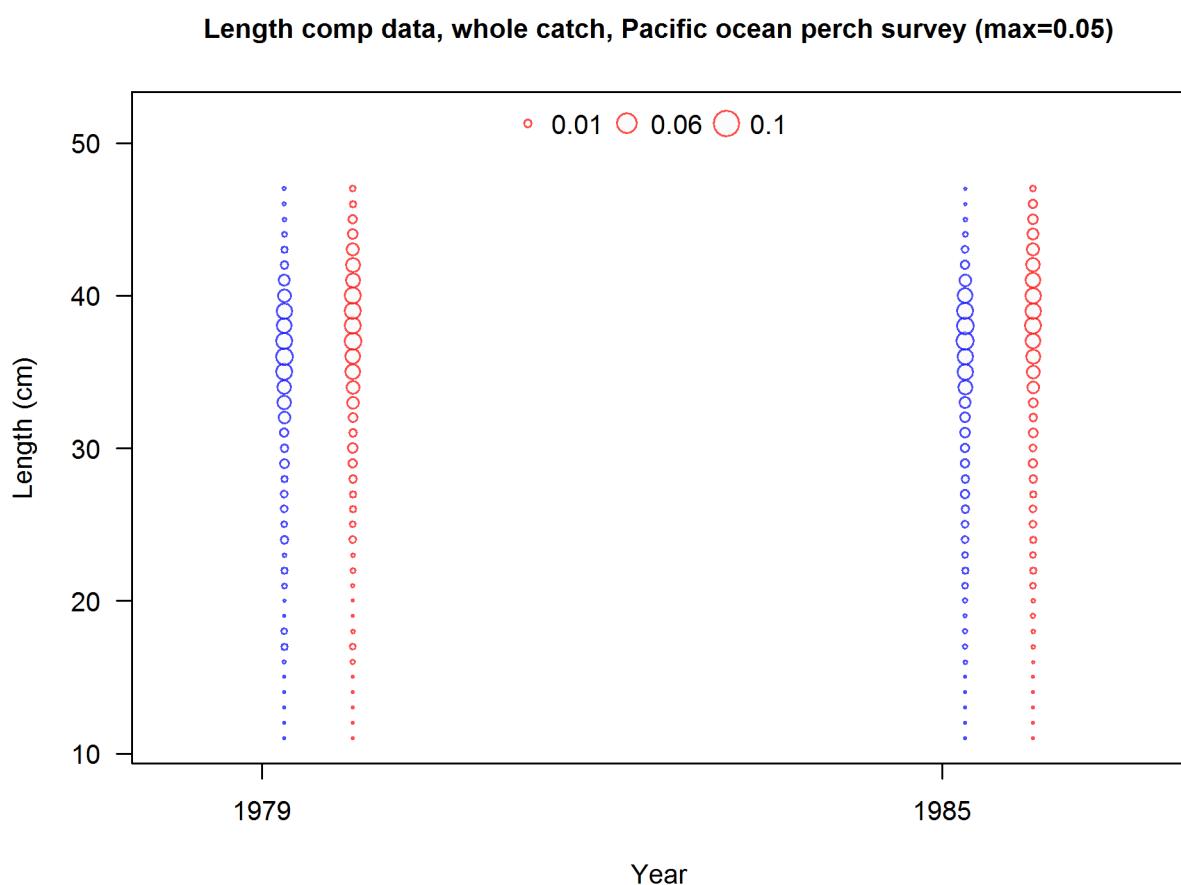


Figure 16: Pacific ocean perch survey length frequency distributions for Pacific ocean perch.

**Age comp data, whole catch, Pacific ocean perch survey (max=0.09)**

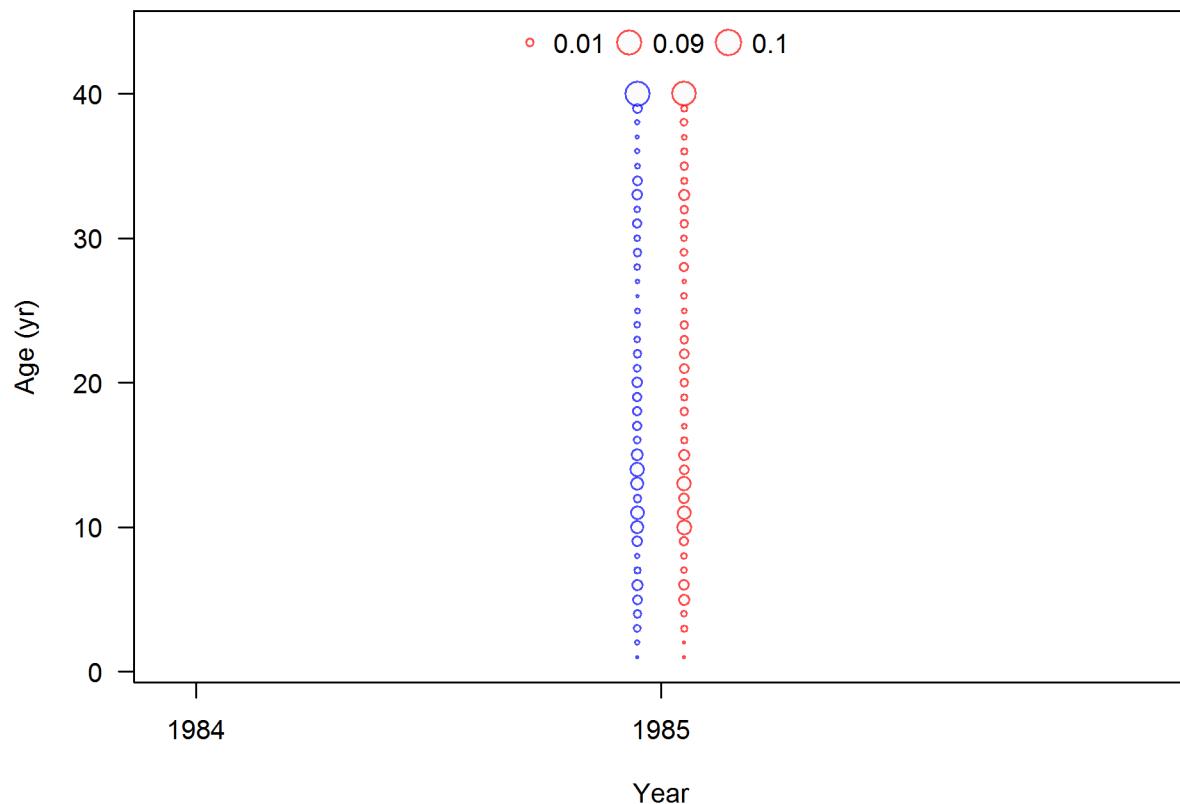


Figure 17: Pacific ocean perch survey age frequency distributions for Pacific ocean perch.

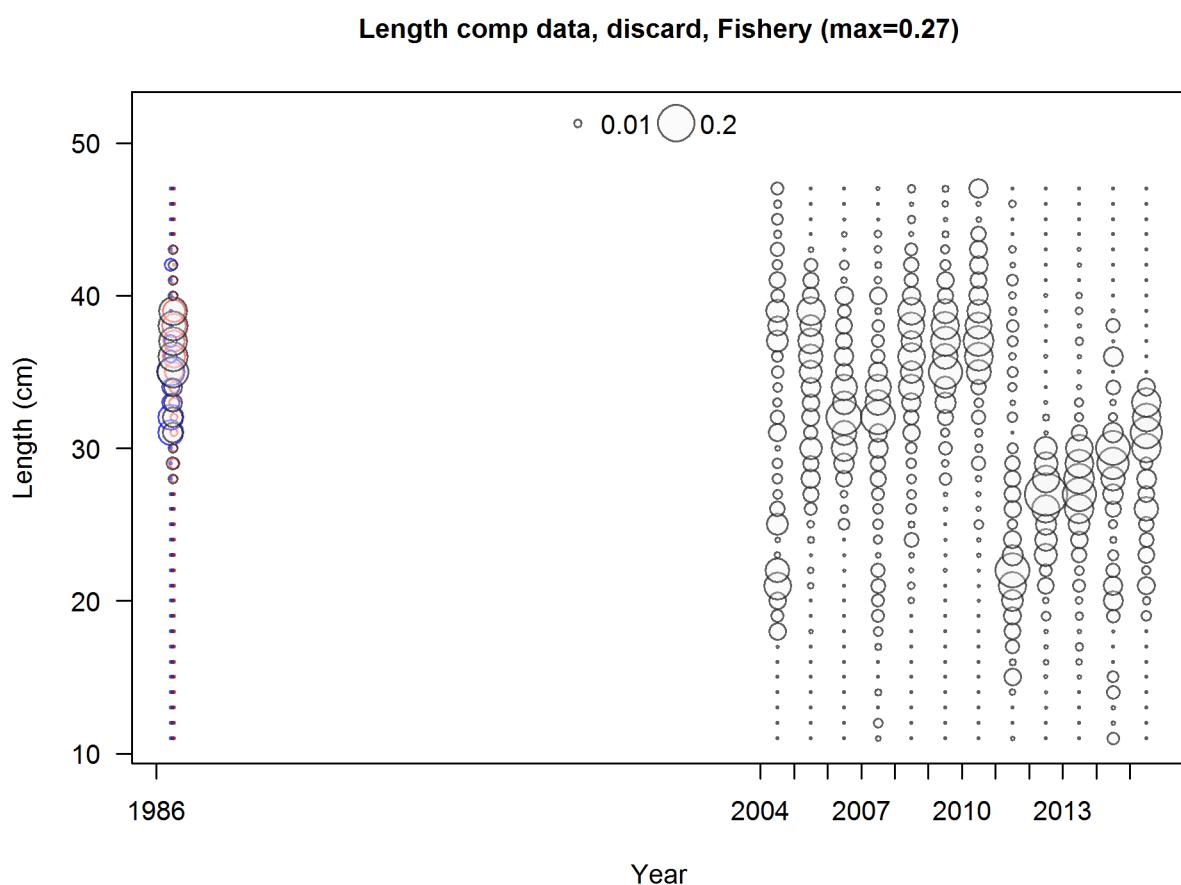


Figure 18: Discard length frequency distributions from WCGOP for Pacific ocean perch.

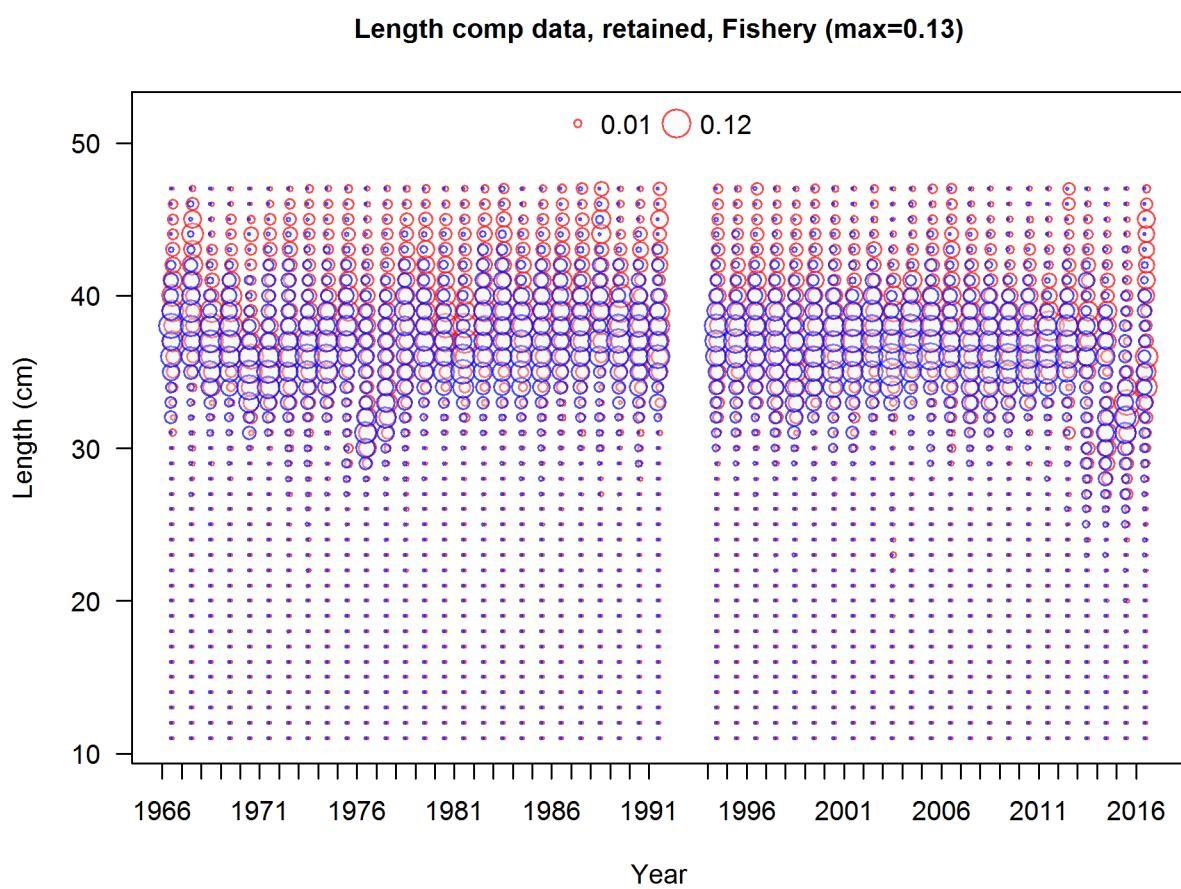


Figure 19: Commercial fishery length frequency distributions for Pacific ocean perch.

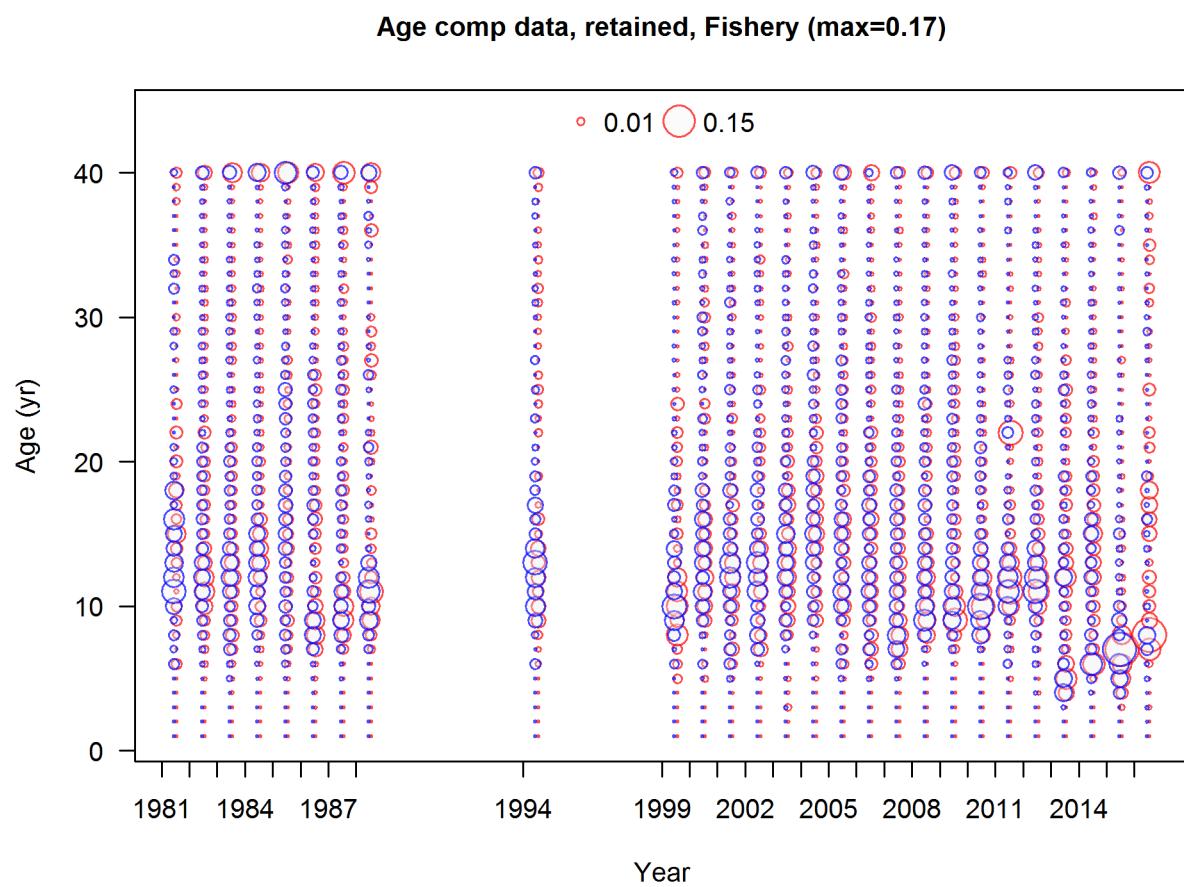


Figure 20: Commercial fishery age frequency distributions for Pacific ocean perch.

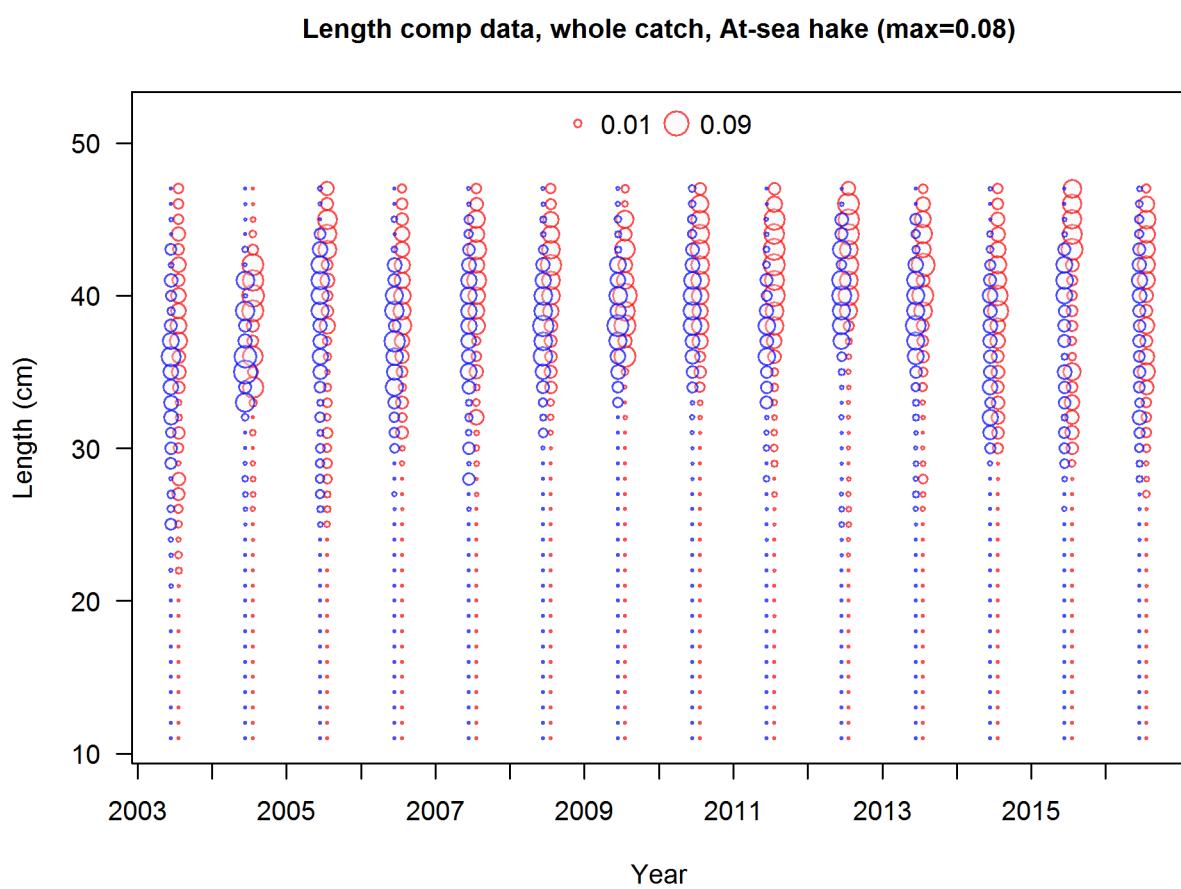


Figure 21: At-sea hake fishery length frequency distributions for Pacific ocean perch.

**Age comp data, whole catch, At-sea hake (max=0.24)**

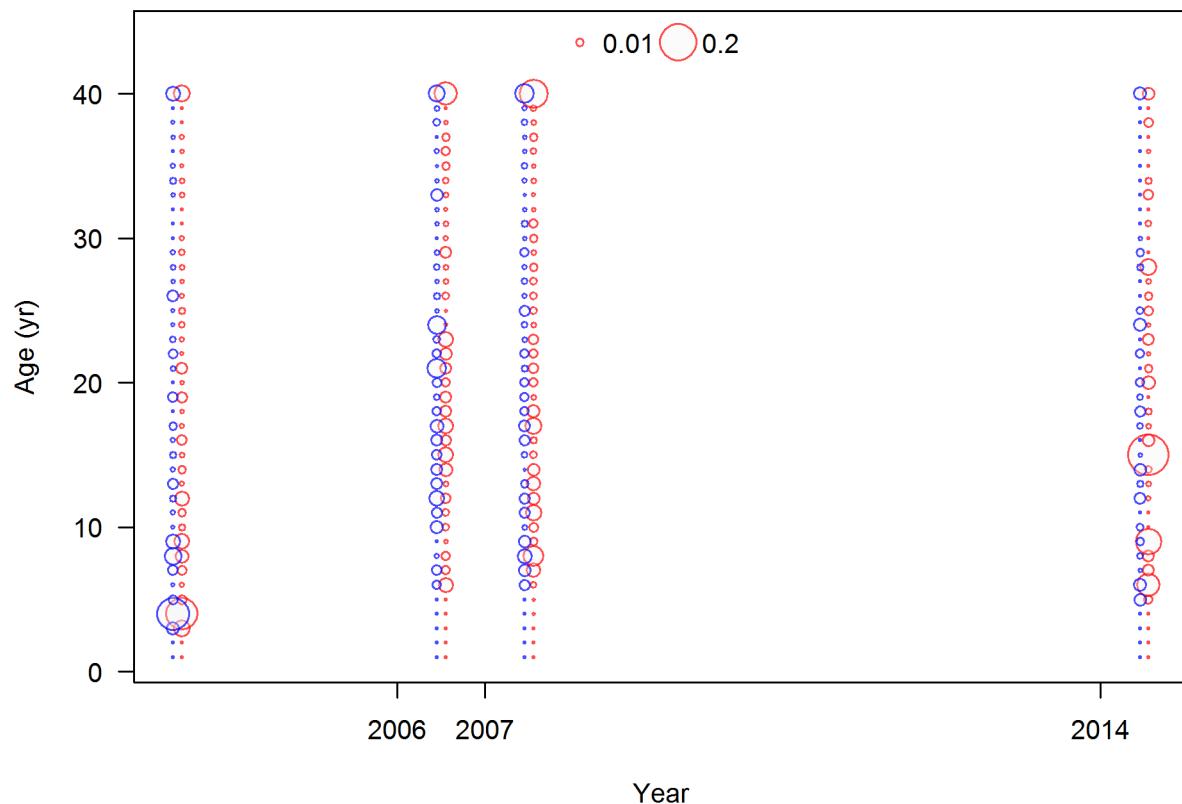


Figure 22: At-sea hake fishery age frequency distributions for Pacific ocean perch.

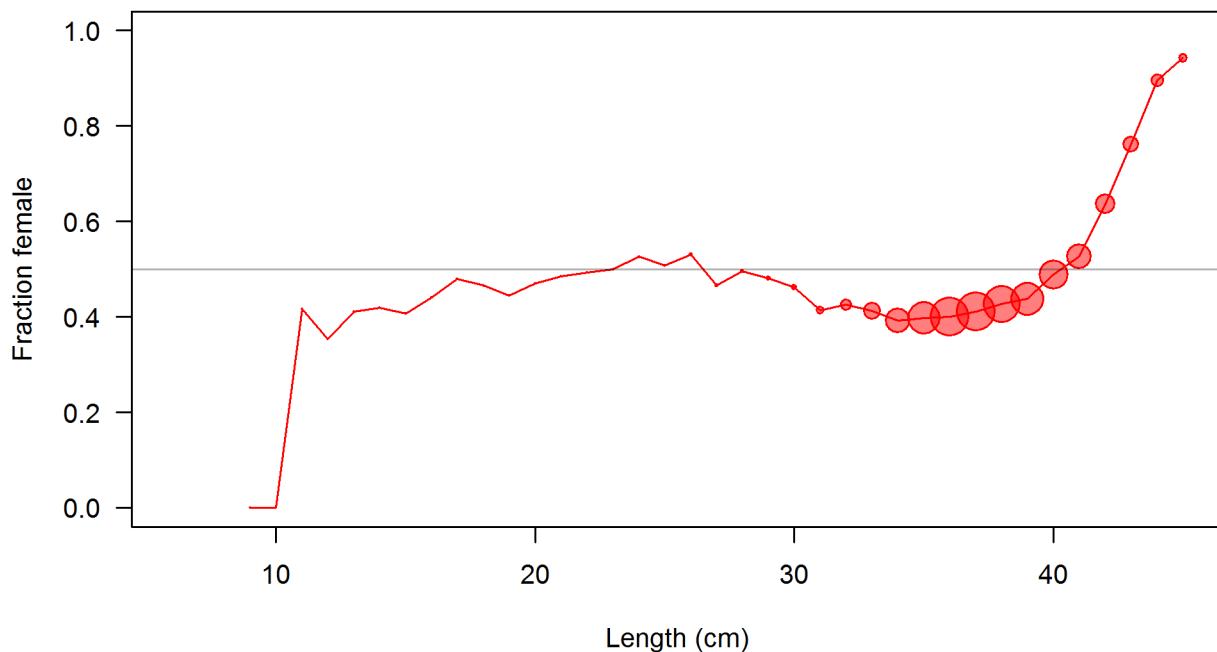


Figure 23: The estimated sex ratio of Pacific ocean perch at length from all biological data sources.

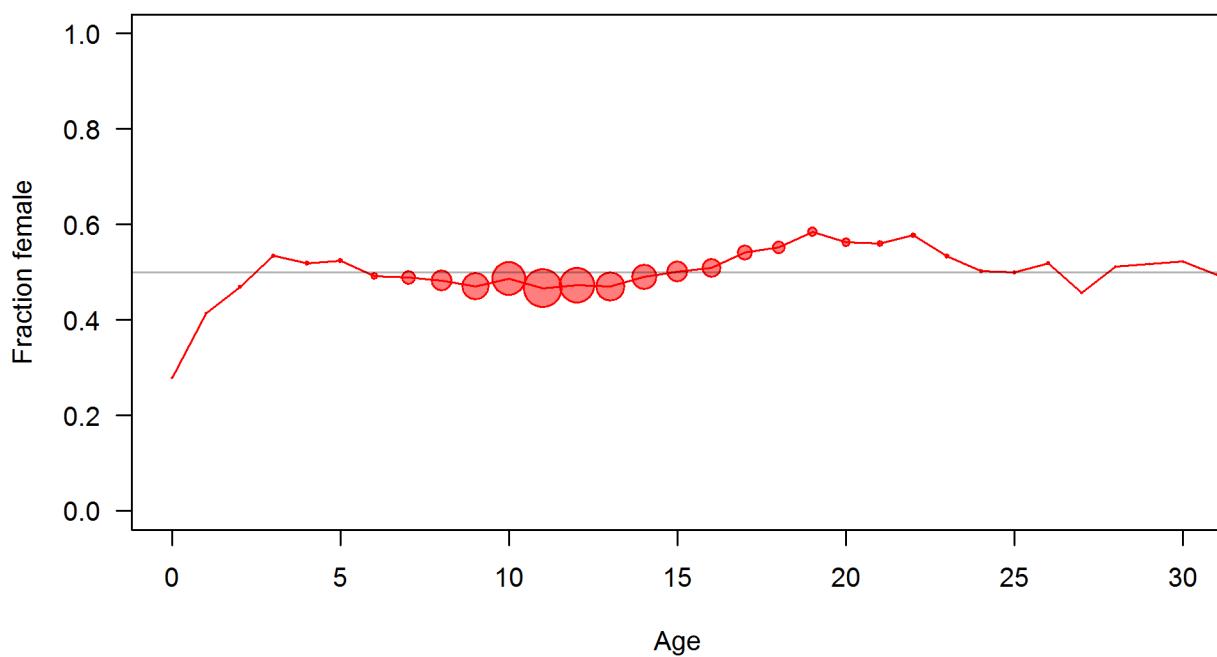


Figure 24: The estimated sex ratio of Pacific ocean perch at age from all biological data sources.

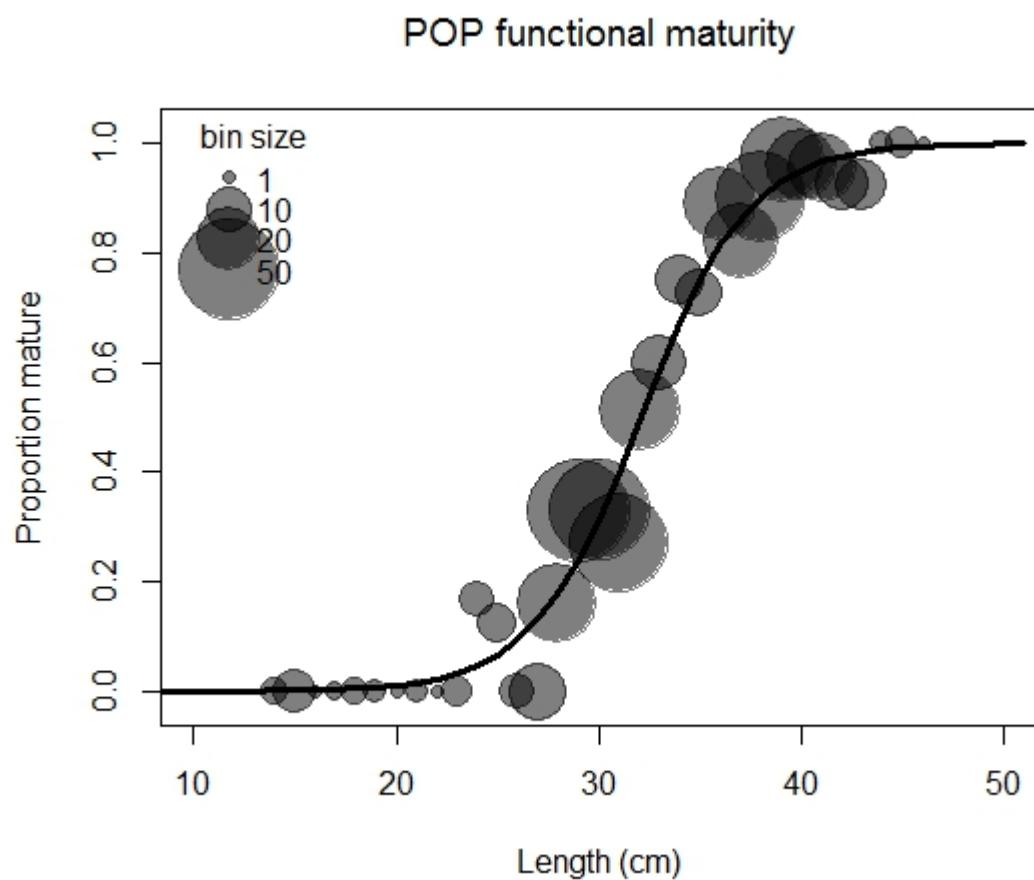
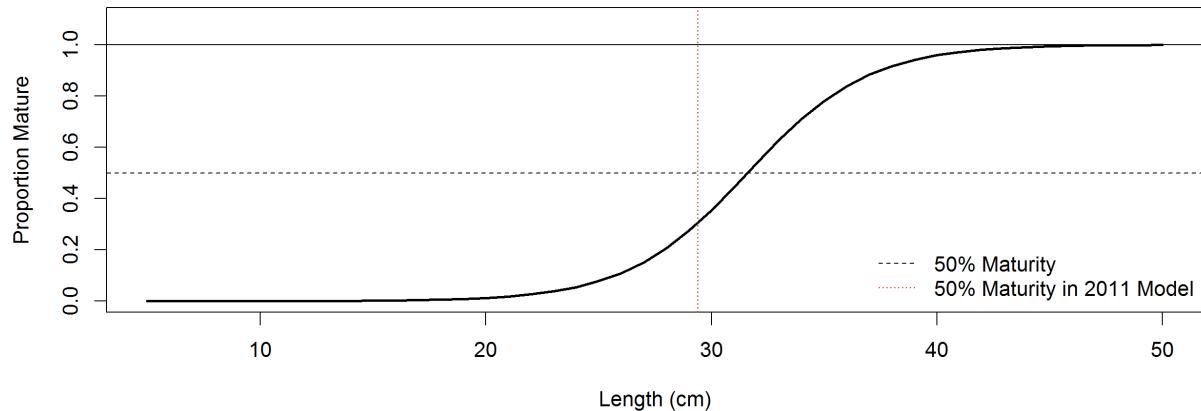


Figure 25: The estimated functional maturity of Pacific ocean perch at length.

**Functional Maturity by Length (2017 Assessment)**



**Maturity by Age (2011 Assessment)**

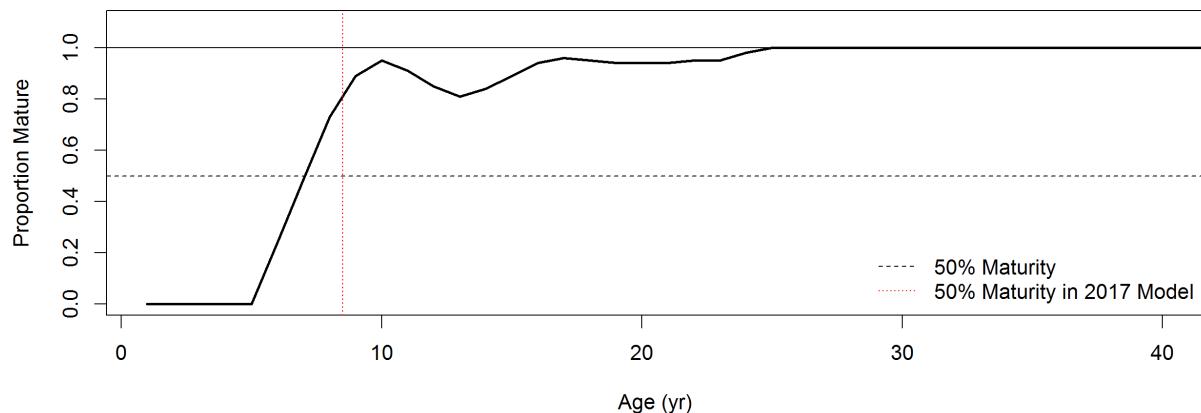


Figure 26: Comparison between estimated maturity-at-length used in this assessment and maturity-at-age applied in the 2011 assessment of Pacific ocean perch.

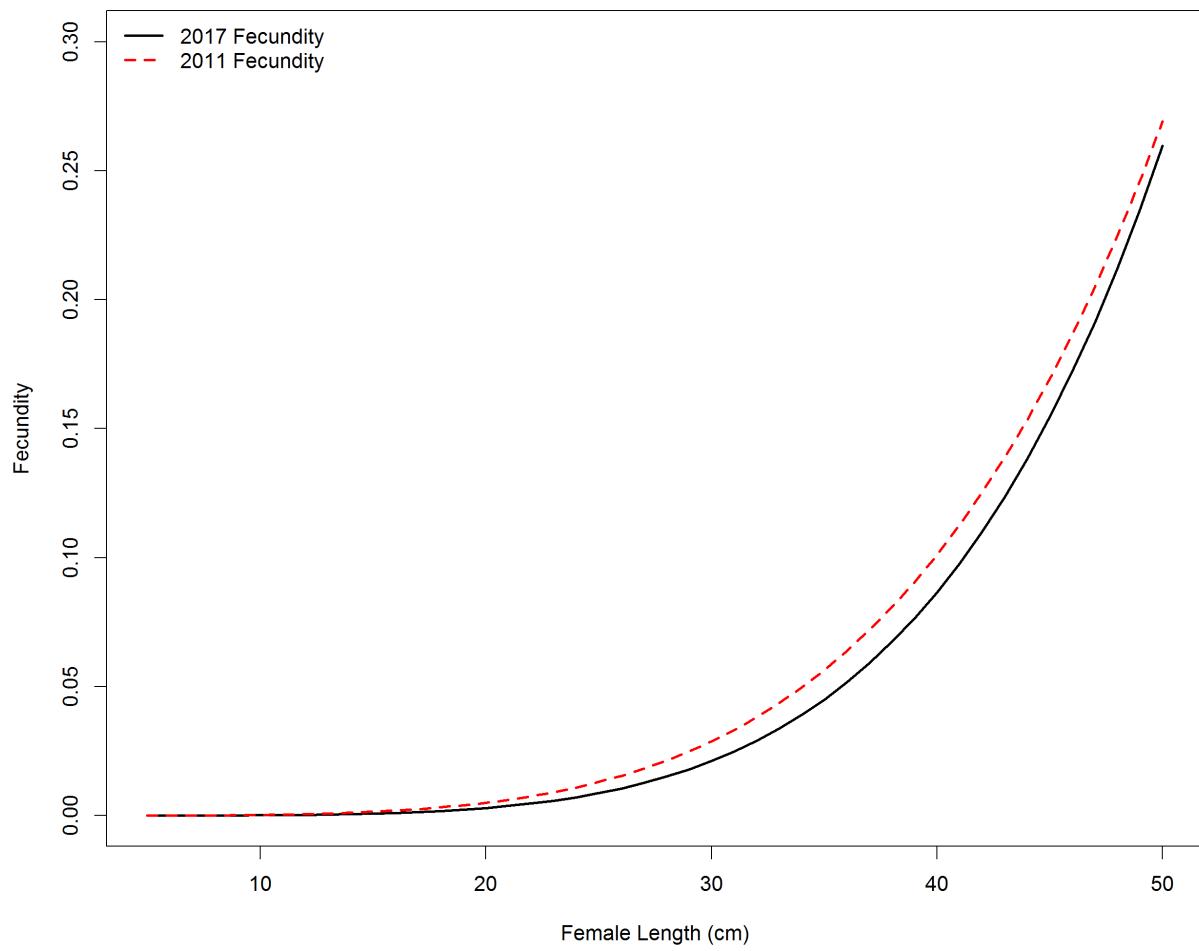


Figure 27: Fecundity at length of Pacific ocean perch in the base model and a comparison of the fecundity in the 2011 assessment.

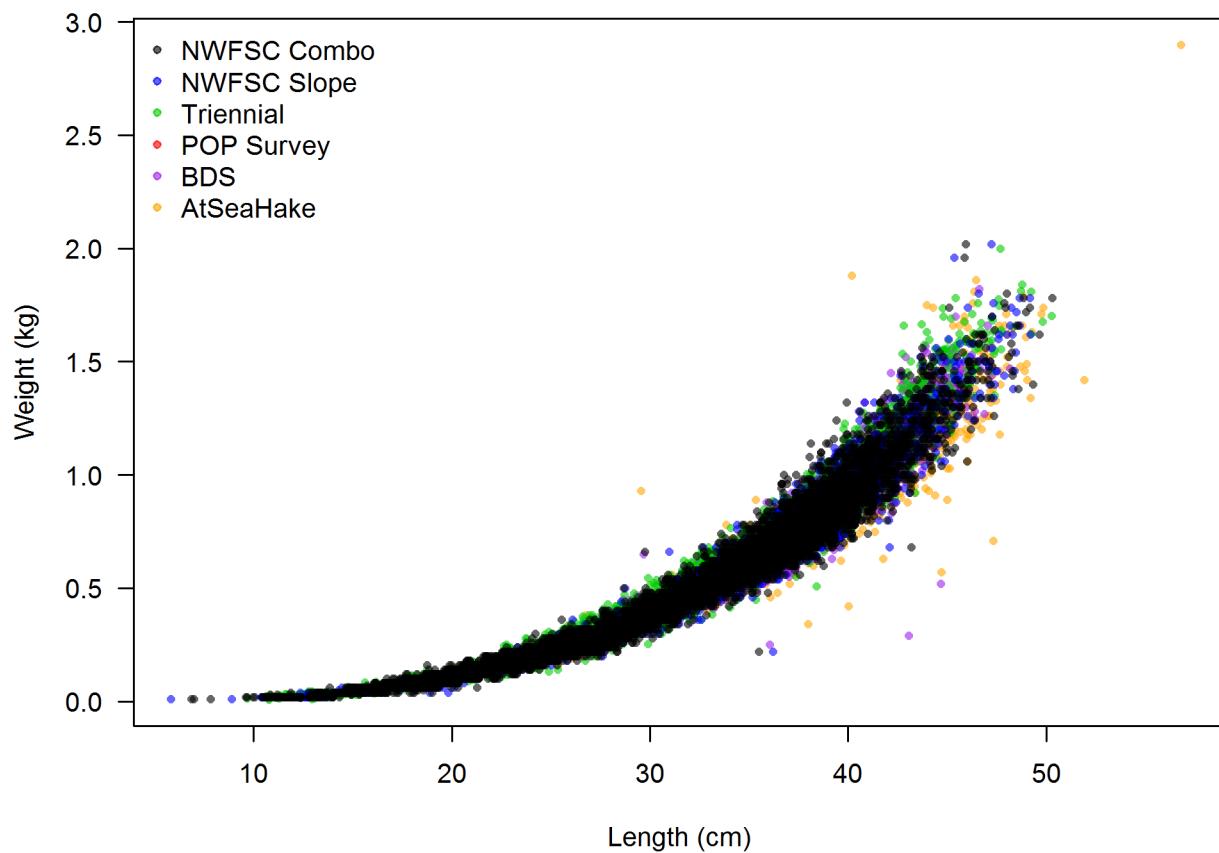


Figure 28: Weight-at-length for Pacific ocean perch from all data sources.

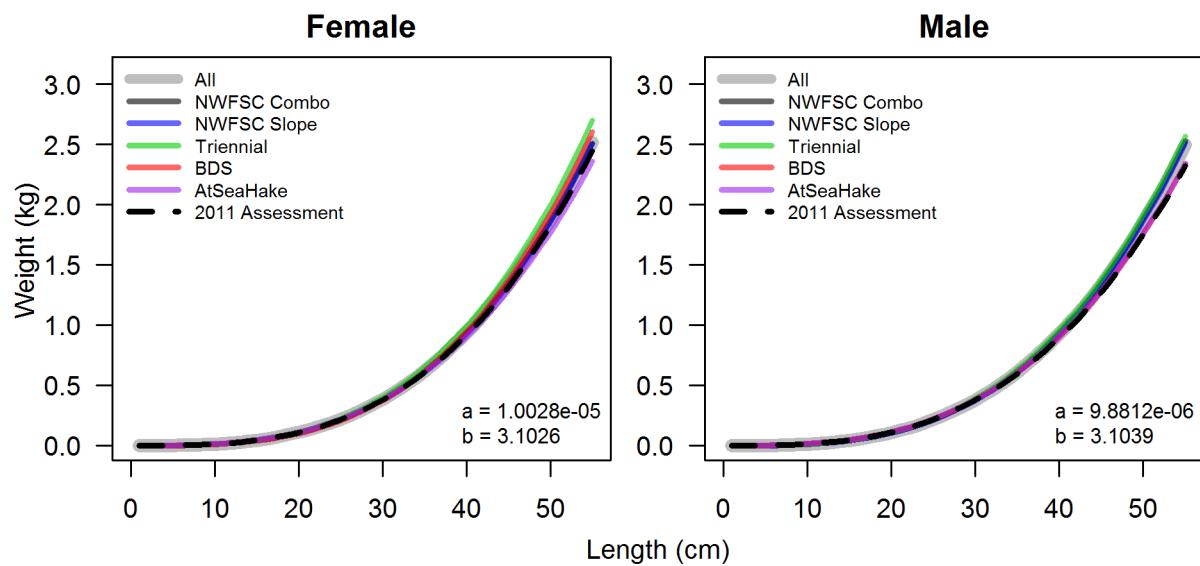


Figure 29: Estimated weight-at-length for Pacific ocean perch from all data sources.

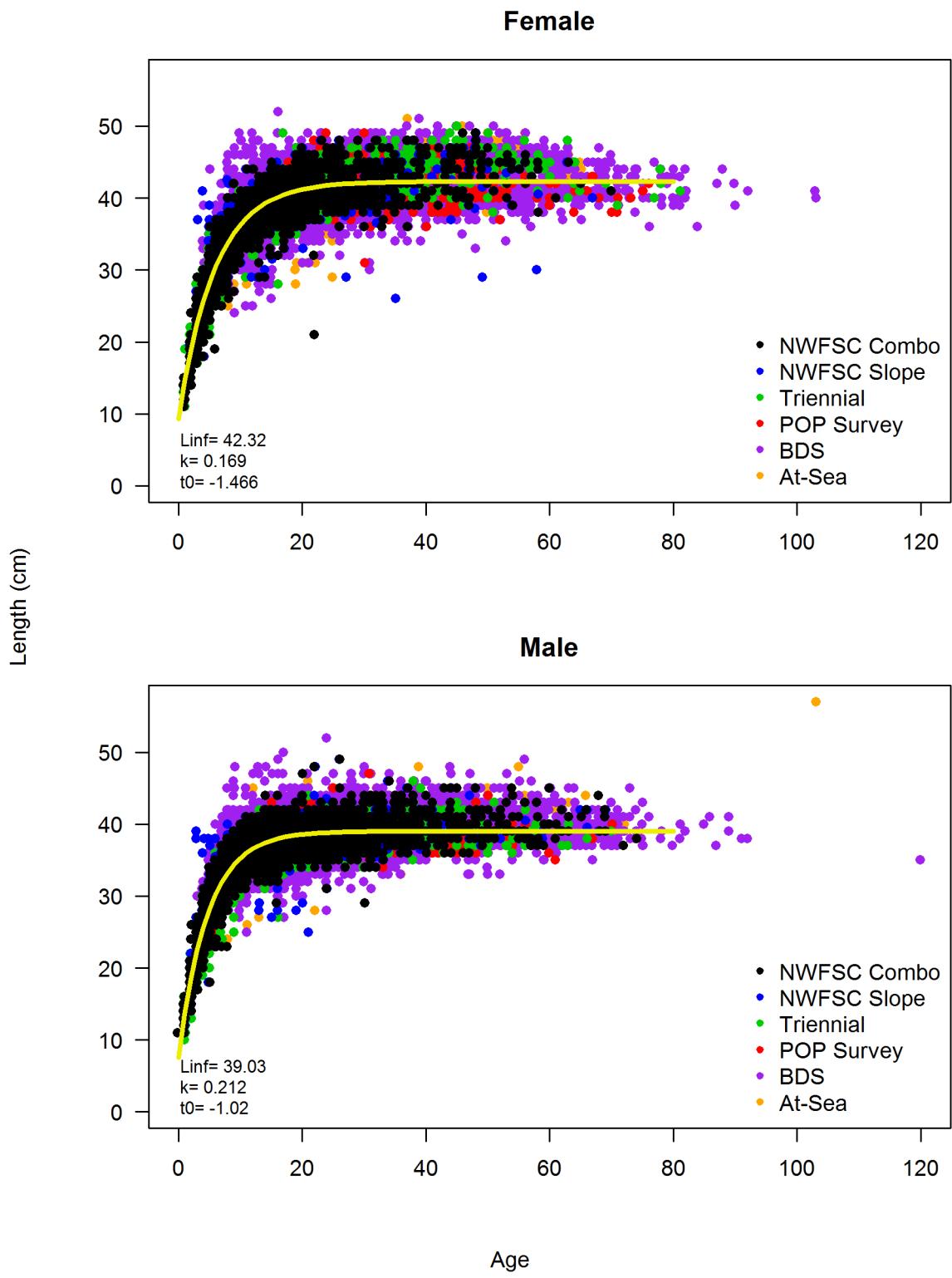


Figure 30: Estimated length-at-age for Pacific ocean perch from all data sources.

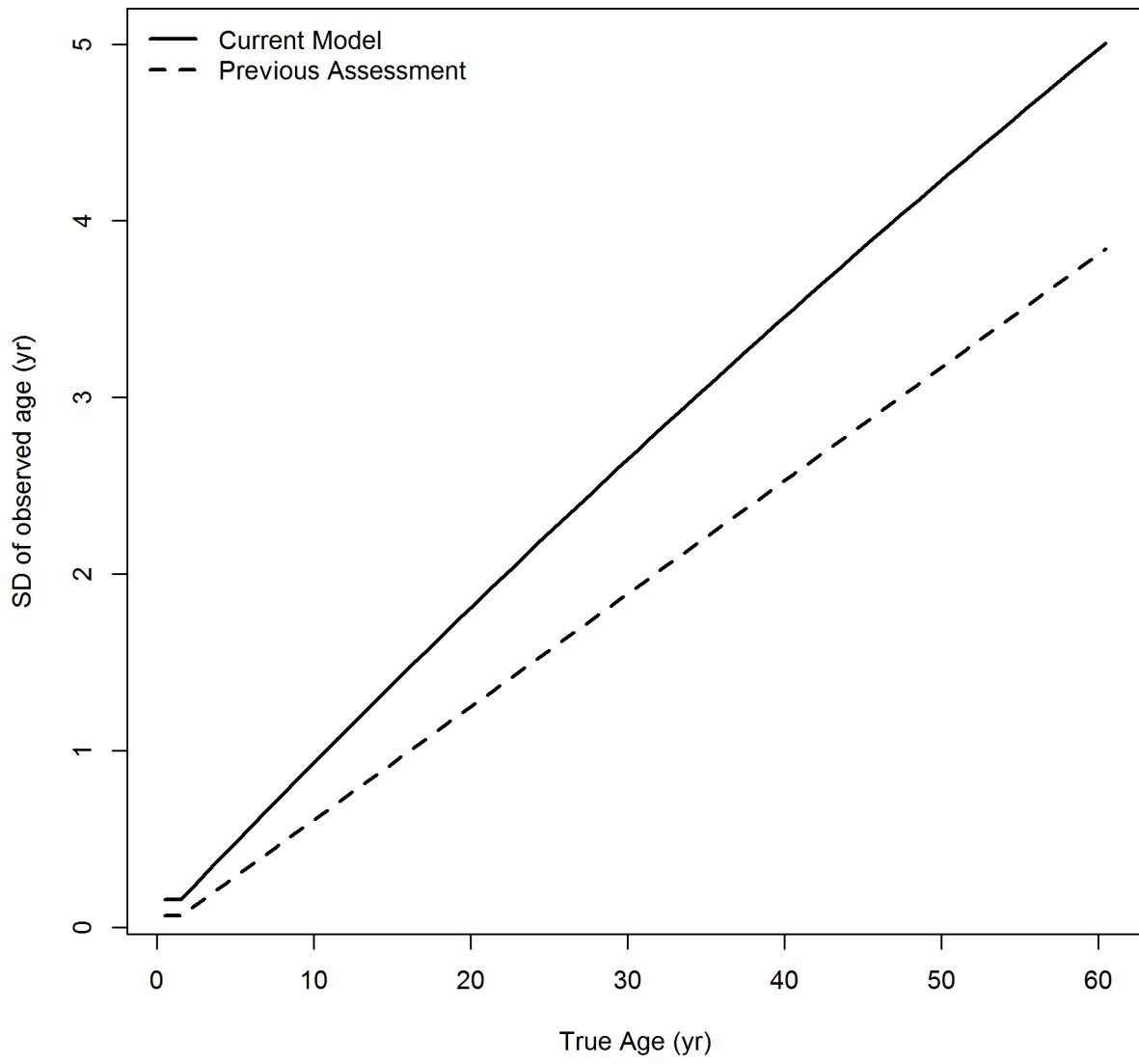


Figure 31: The estimated ageing error used in this assessment compared to the ageing error assumed in the previous assessment for Pacific ocean perch.

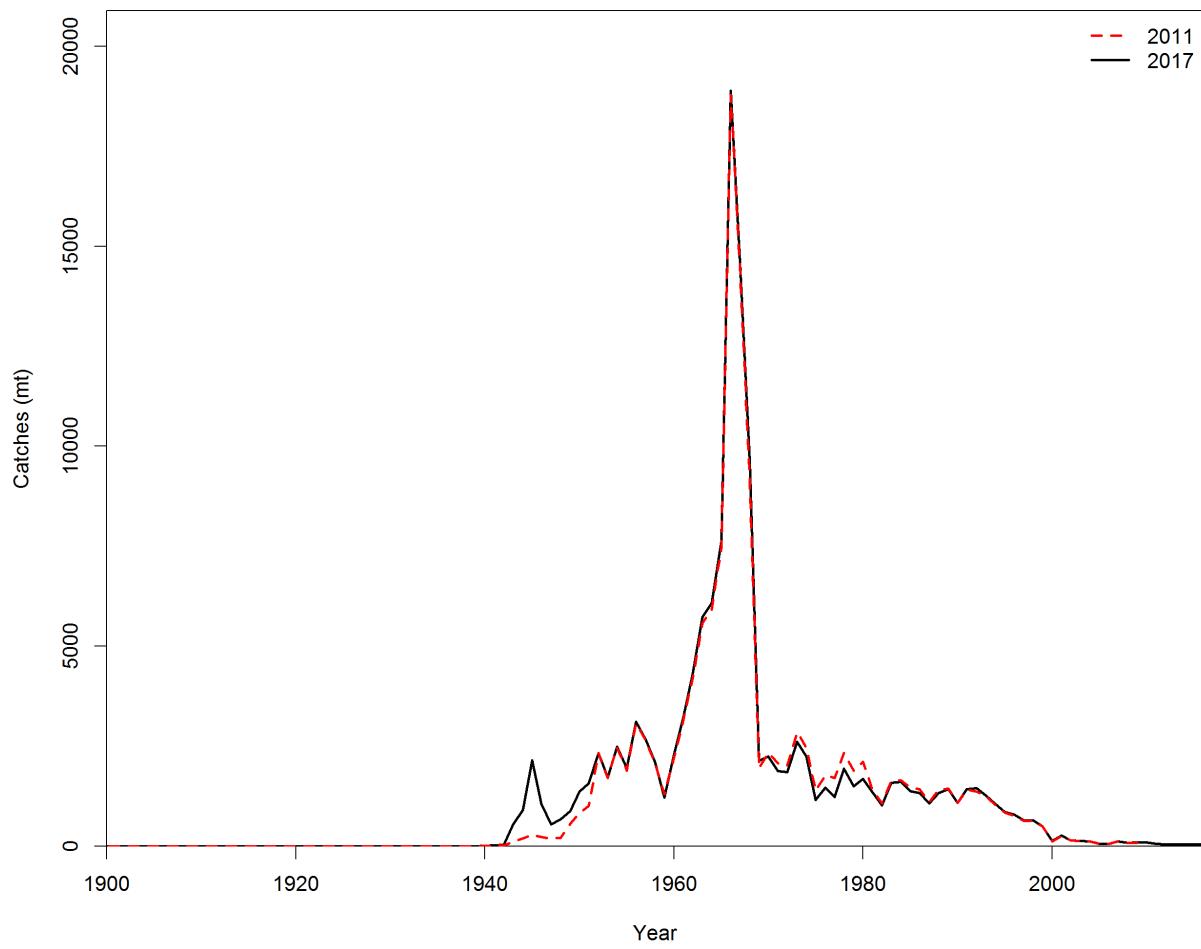


Figure 32: Comparison of the catches assumed by this assessment and the previous assessment for Pacific ocean perch.

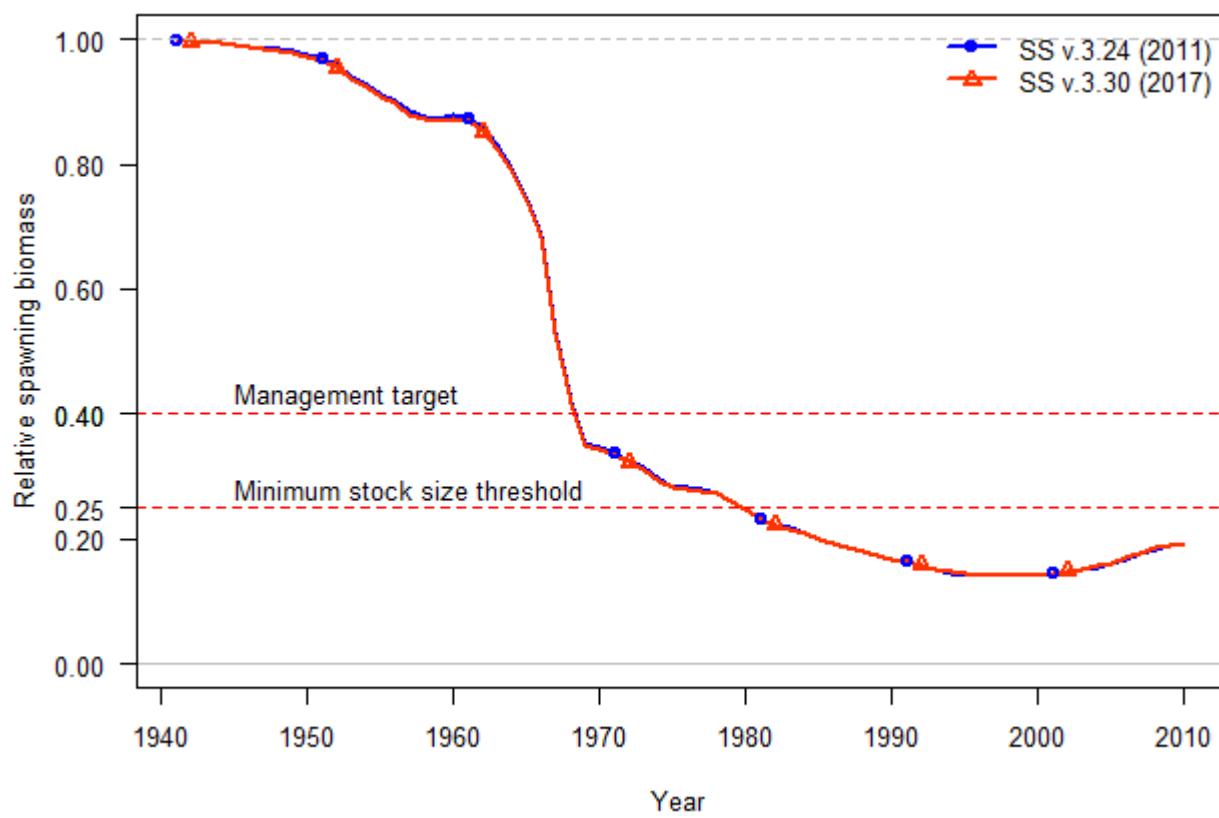
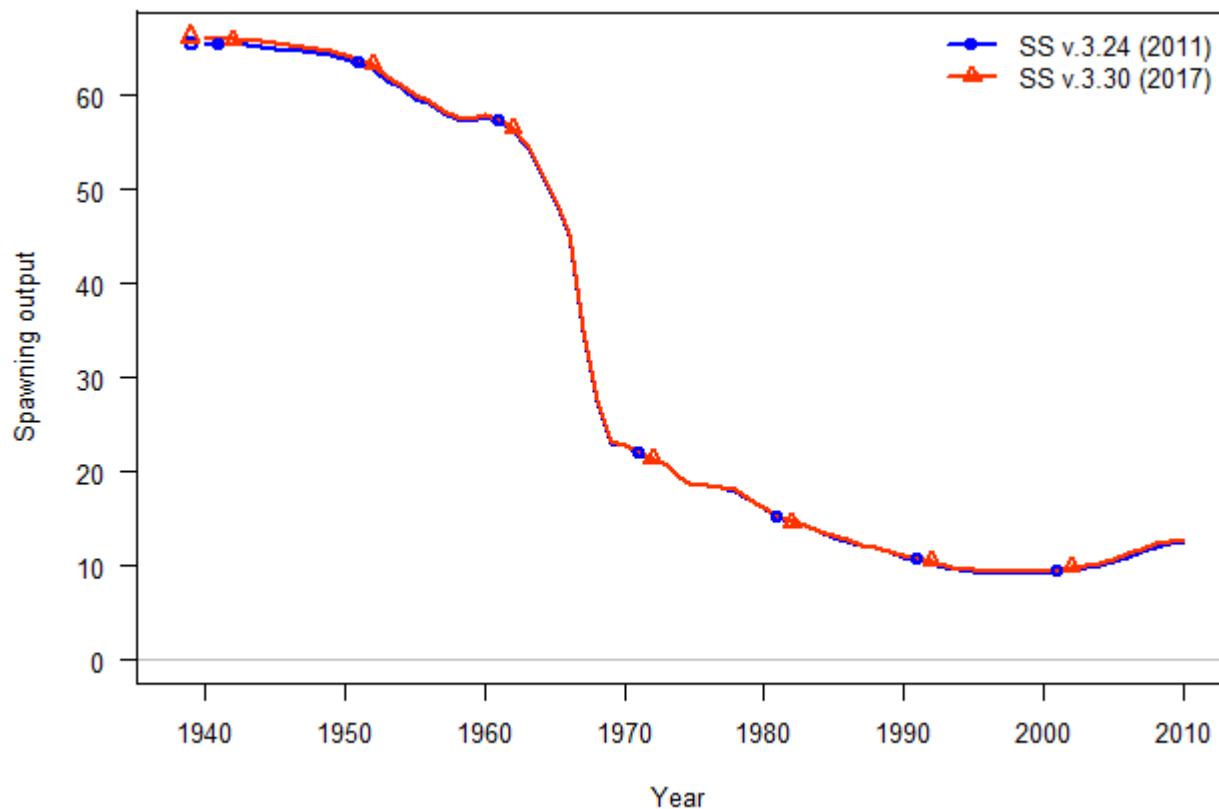


Figure 33: Comparison of estimates from Stock Synthesis version 3.30 and 3.24 for Pacific ocean perch.

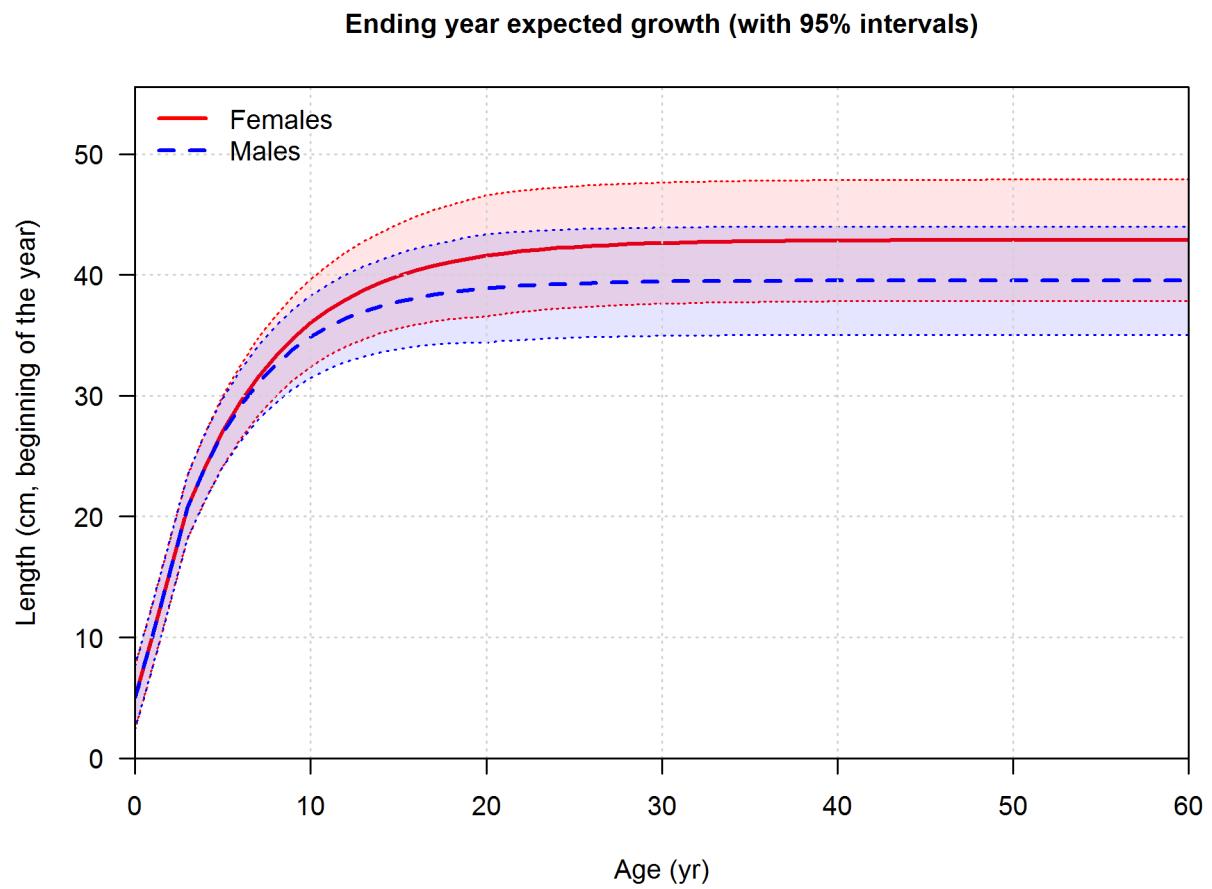


Figure 34: Estimated length-at-age for male and female for Pacific ocean perch with estimated CV.

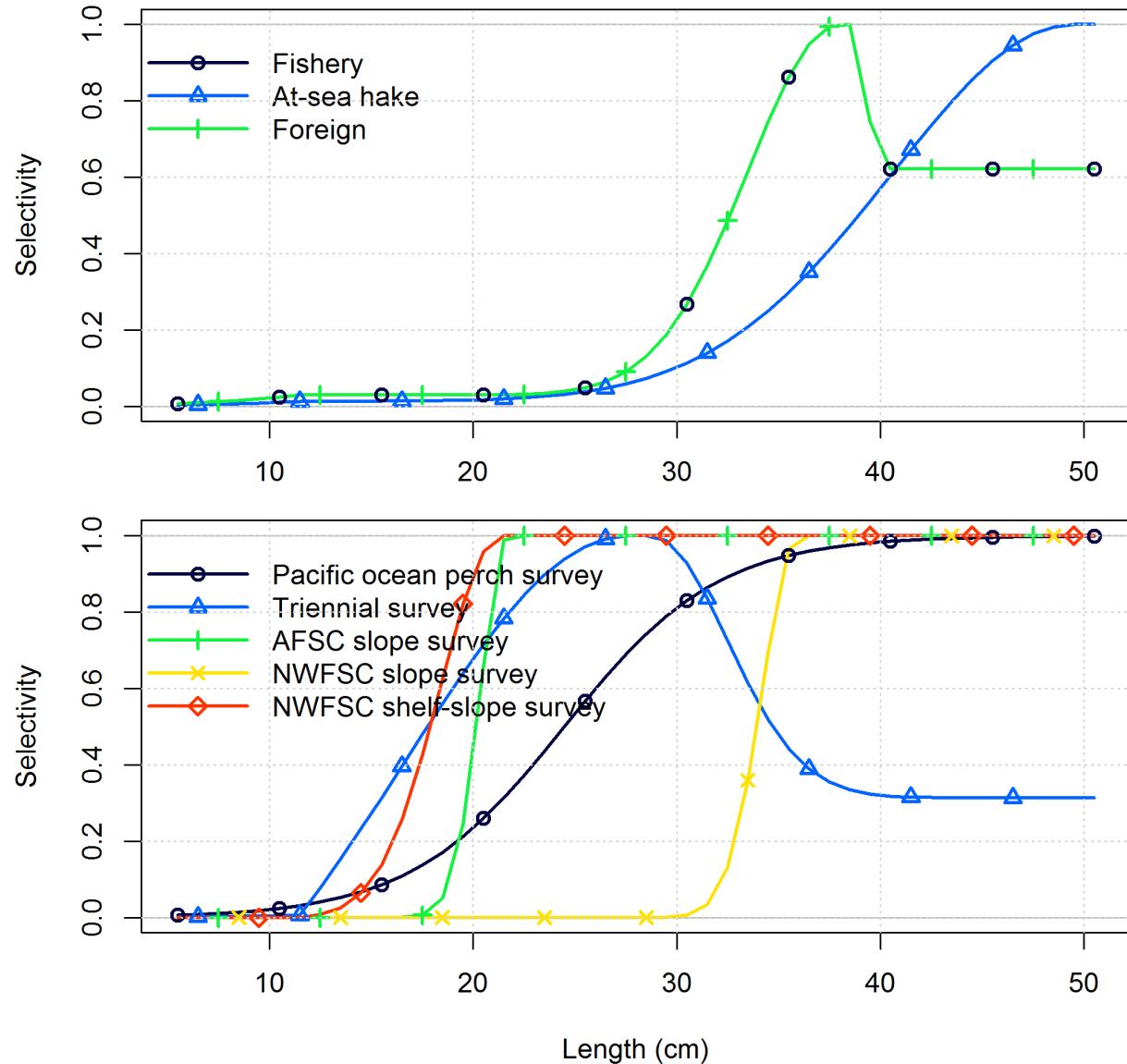


Figure 35: Estimated selectivity by length by each fishery and survey for Pacific ocean perch.

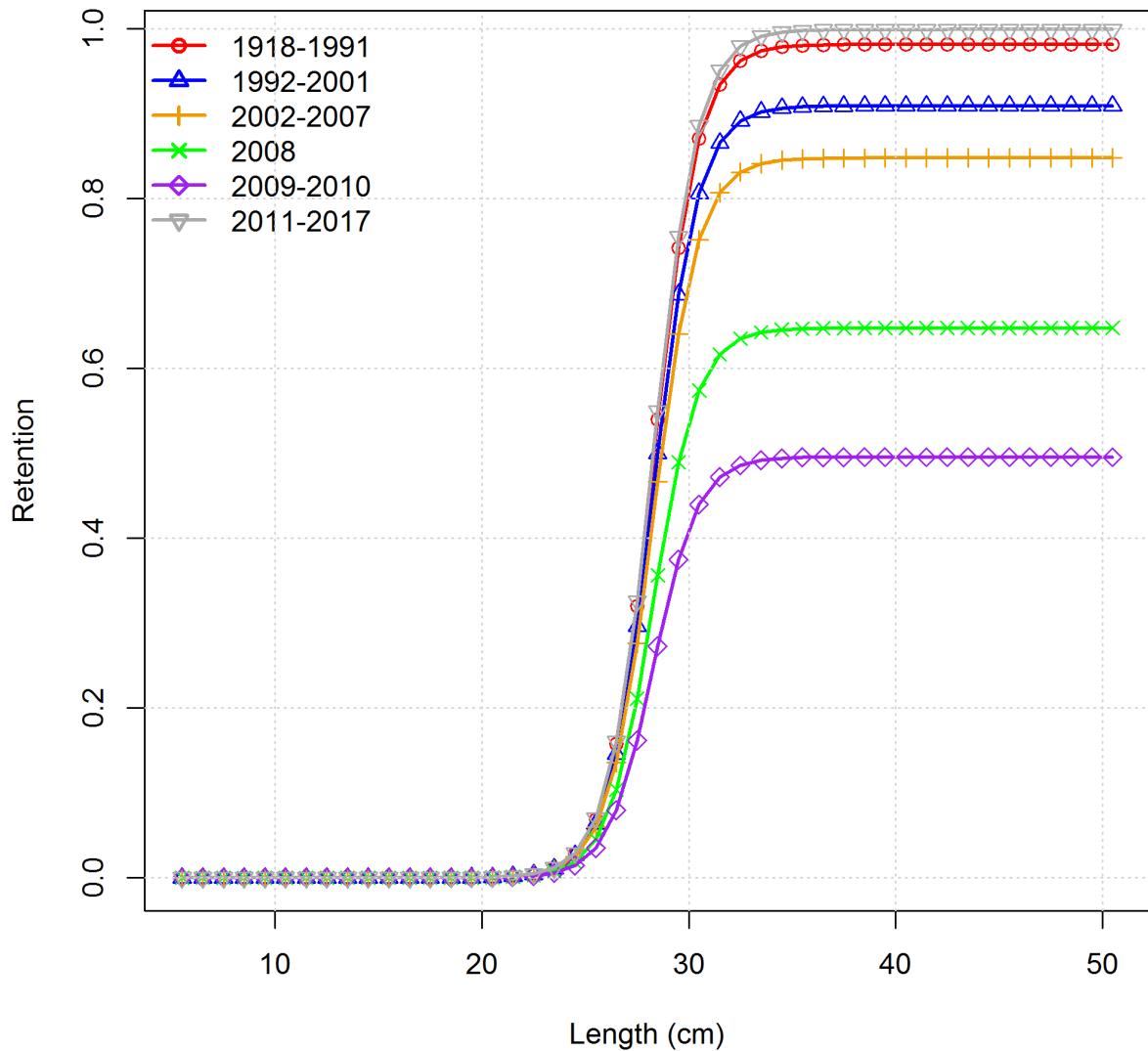


Figure 36: Estimated retention by length by the fishery fleet for Pacific ocean perch.

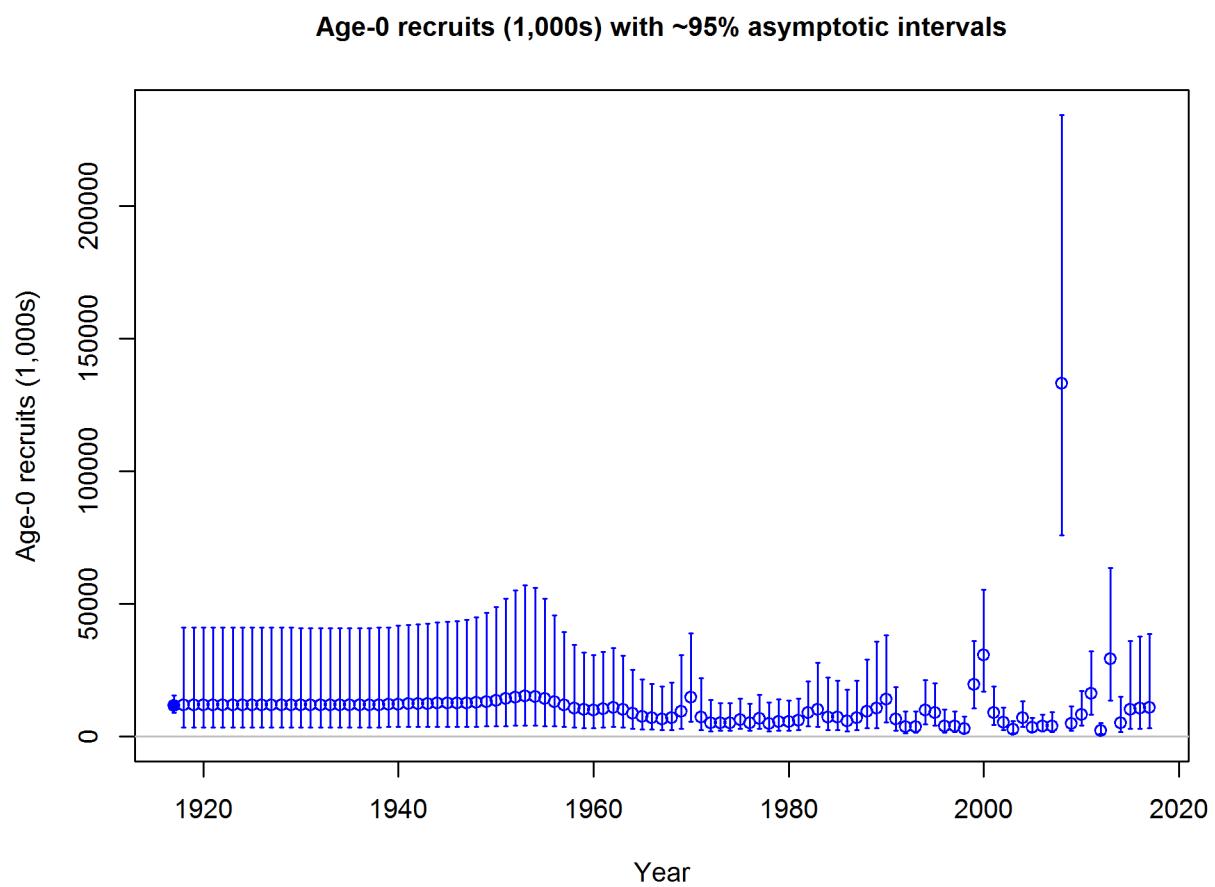


Figure 37: Estimated time-series of recruitment for Pacific ocean perch.

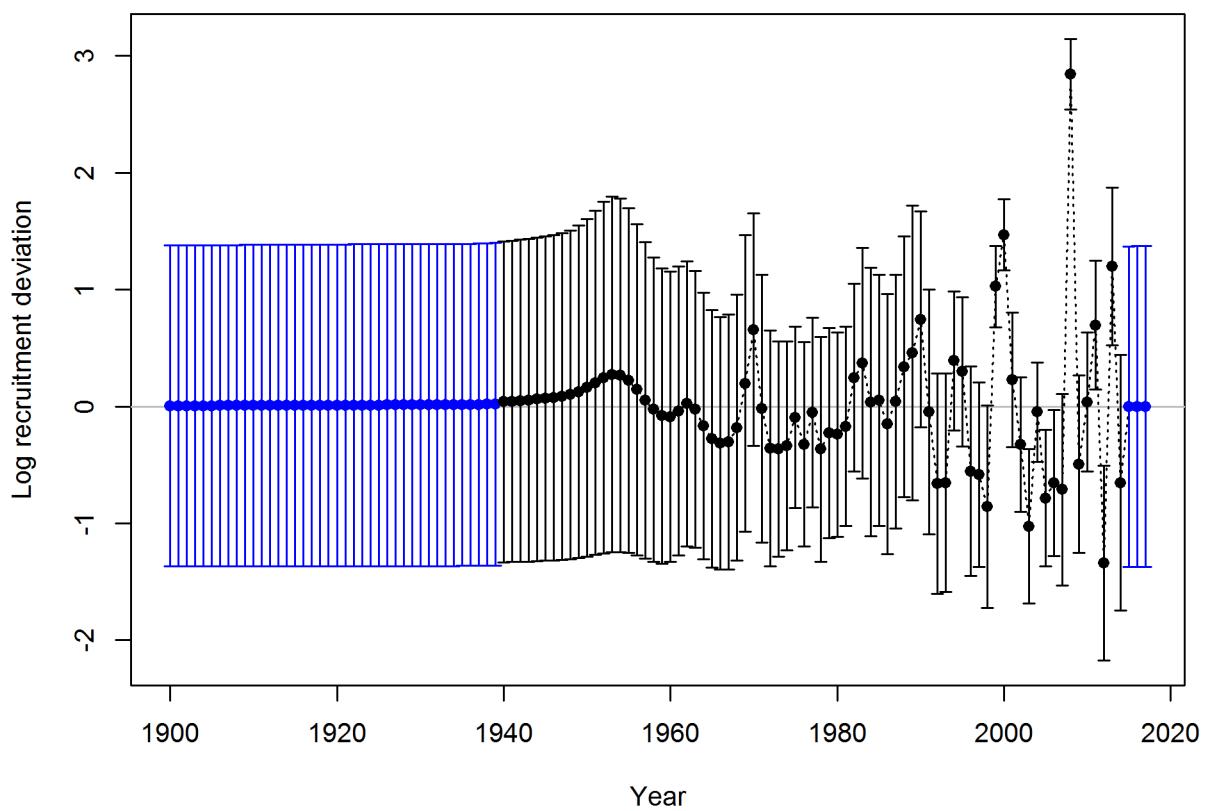


Figure 38: Estimated time-series of recruitment deviations for Pacific ocean perch.

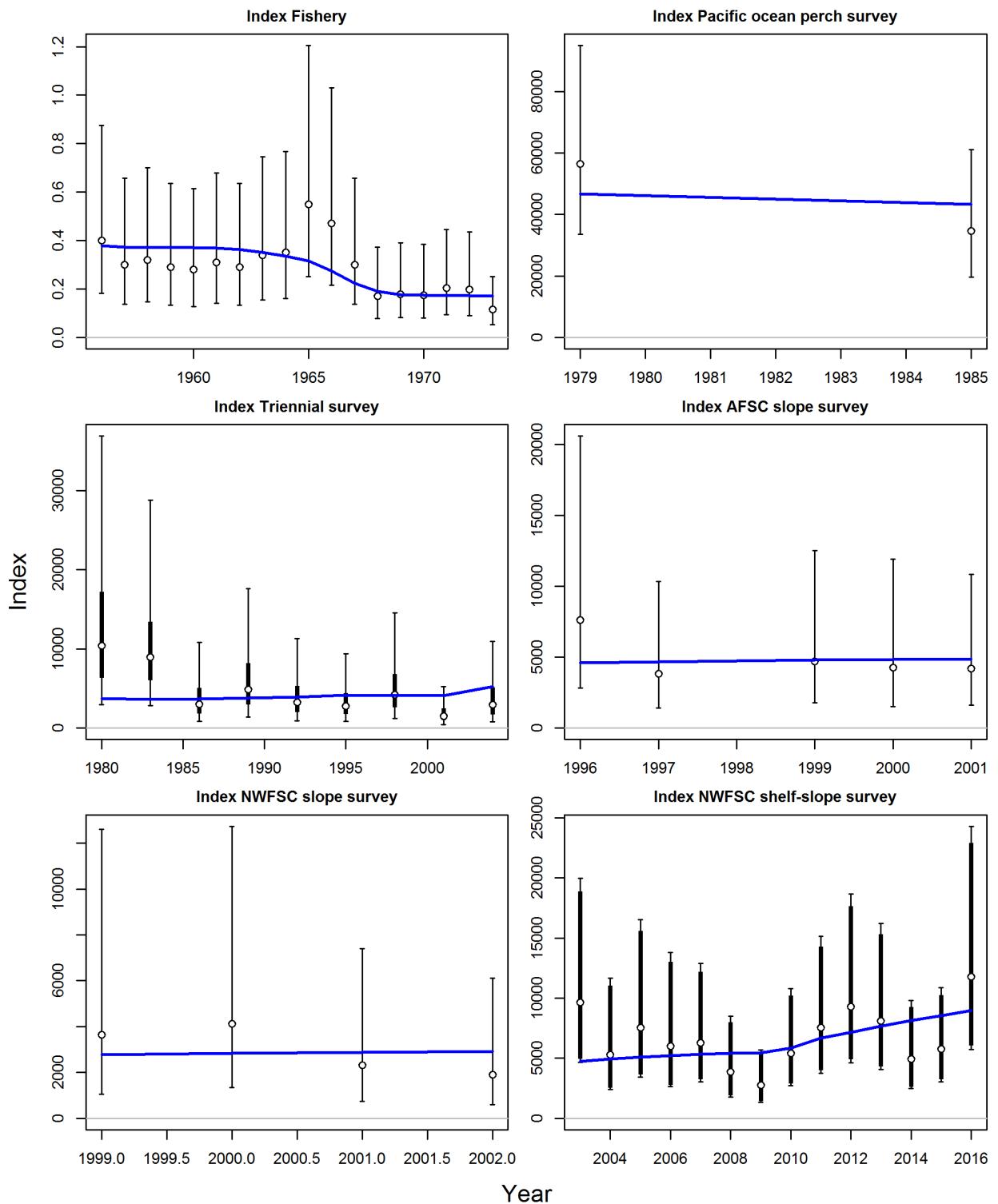


Figure 39: Estimated fits to the CPUE and survey indices for Pacific ocean perch.

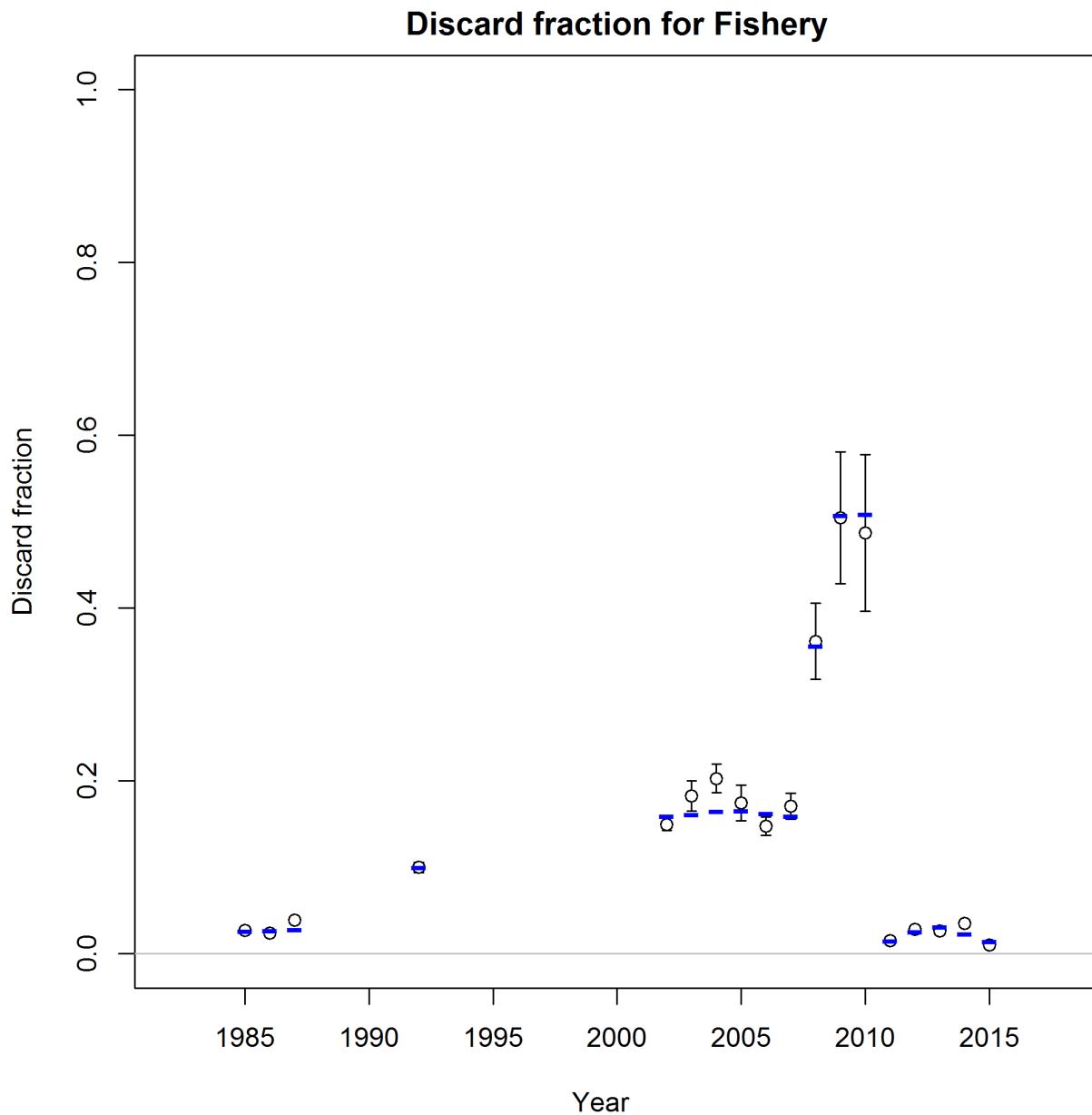


Figure 40: Estimated fits to the discard rates for Pacific ocean perch.

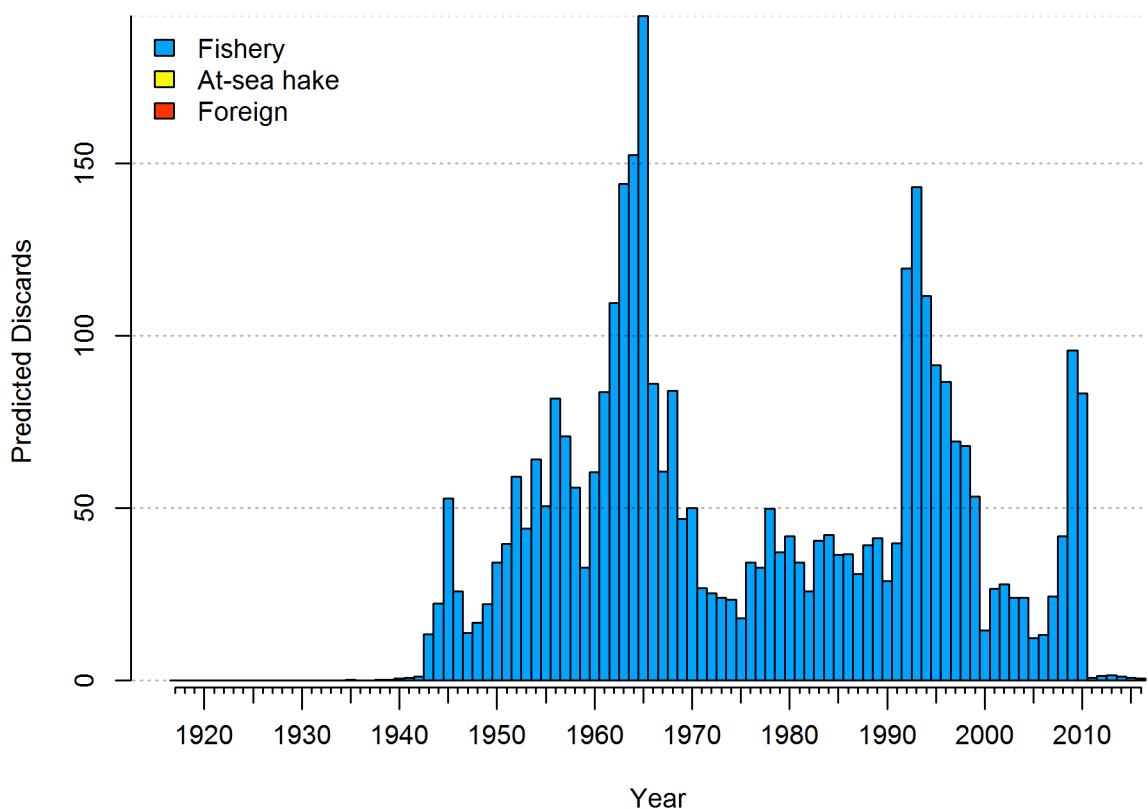


Figure 41: Estimated total discards for Pacific ocean perch.

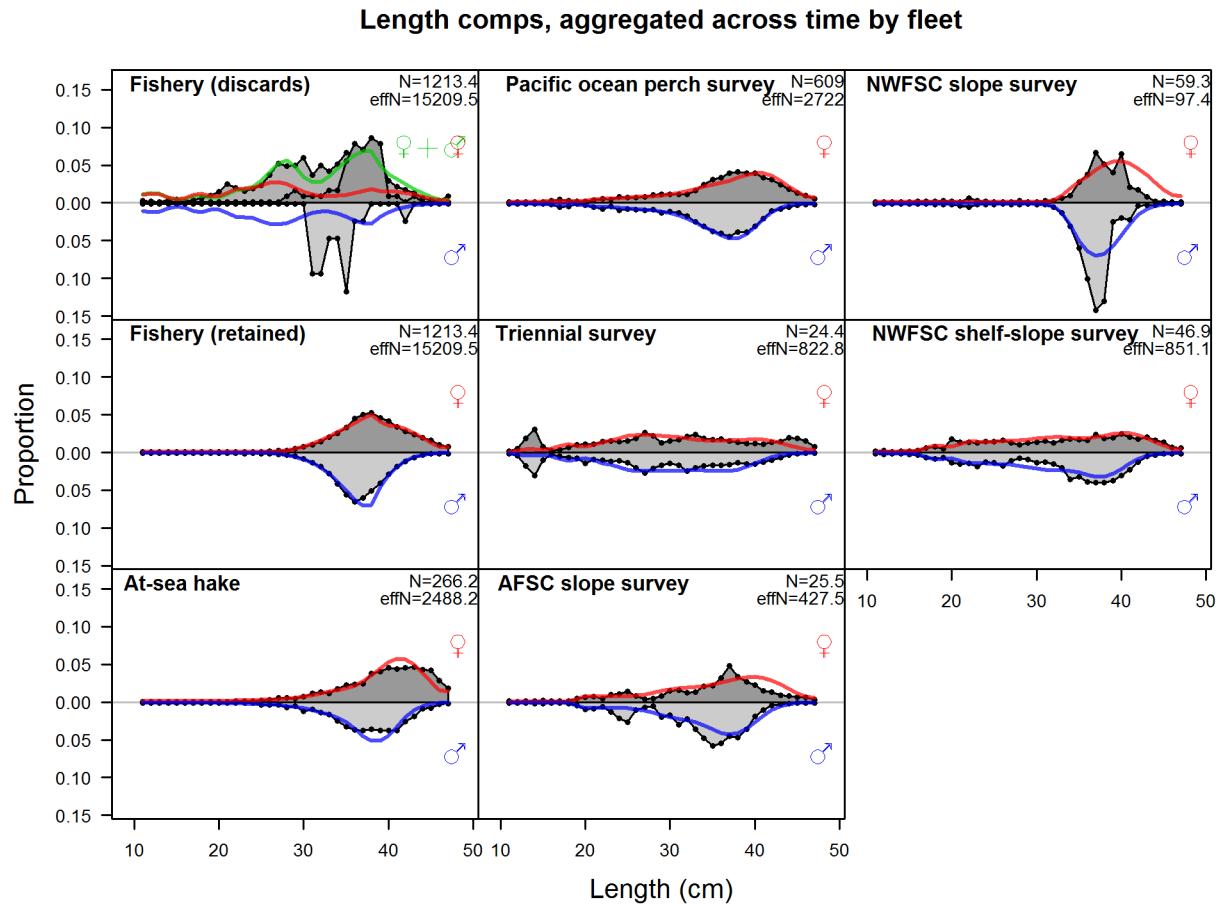


Figure 42: Length compositions aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate retained or discarded samples for each fleet. Panels without this designation represent the whole catch.

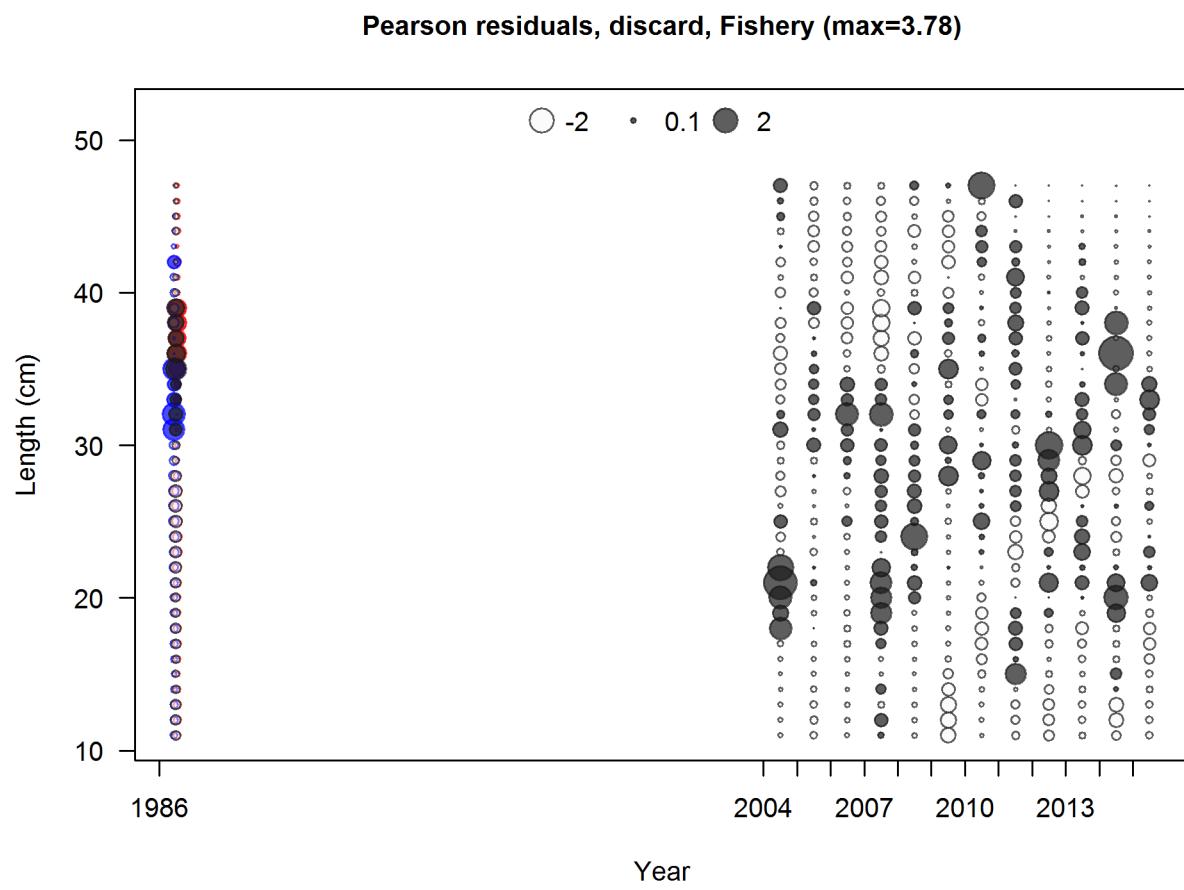


Figure 43: Pearson residuals, discard, Fishery (max=3.78)  
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

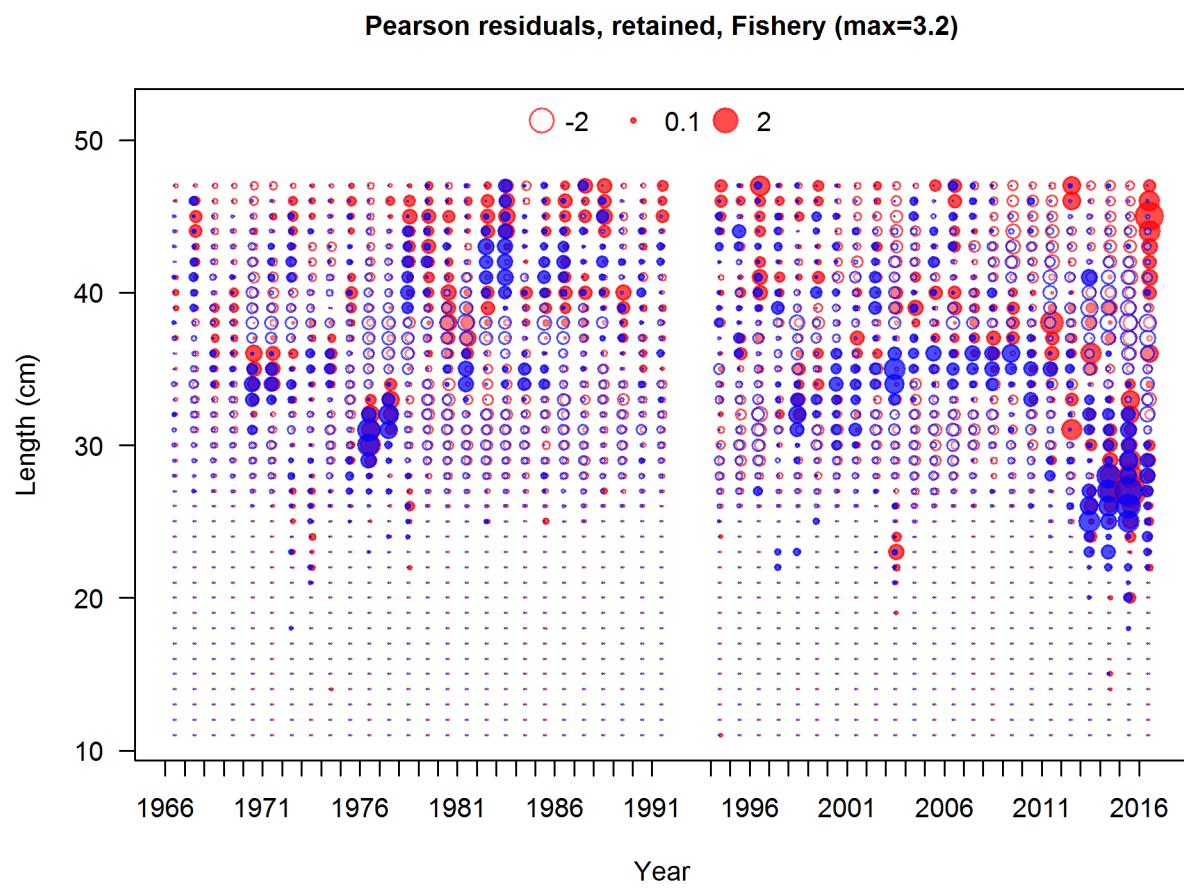


Figure 44: Pearson residuals, retained, Fishery (max=3.2) (plot 4 of 4)  
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

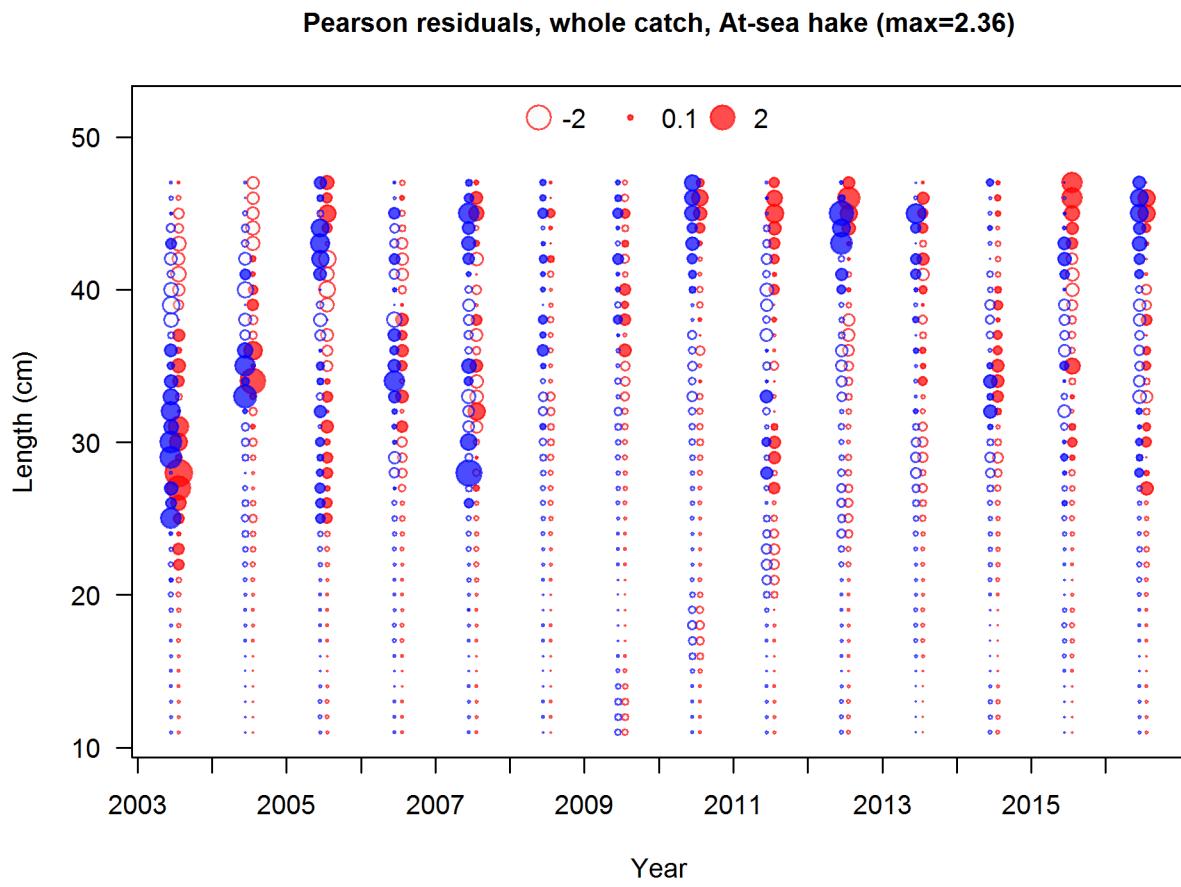


Figure 45: Pearson residuals, whole catch, At\_sea hake (max=2.36)  
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

**Pearson residuals, whole catch, Pacific ocean perch survey (max=1.74)**

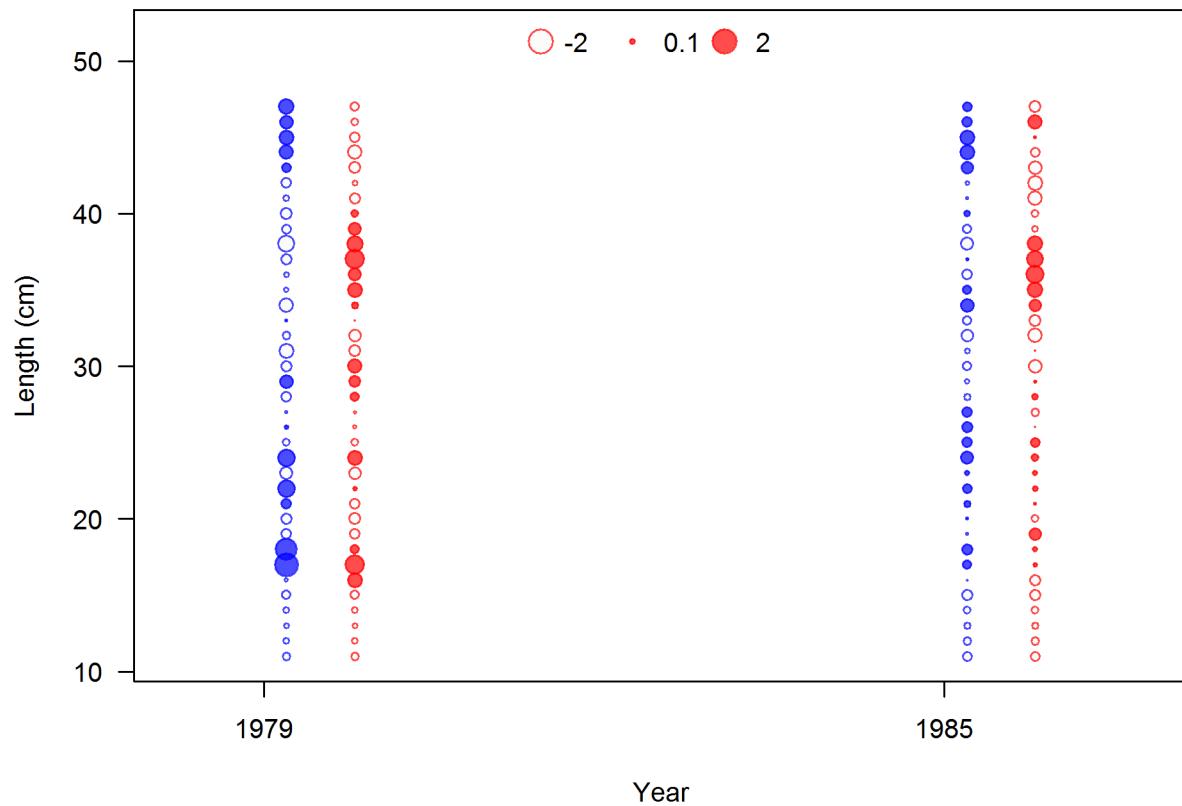


Figure 46: Pearson residuals, whole catch, Pacific ocean perch survey (max=1.74)  
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

**Pearson residuals, whole catch, Triennial survey (max=4.01)**

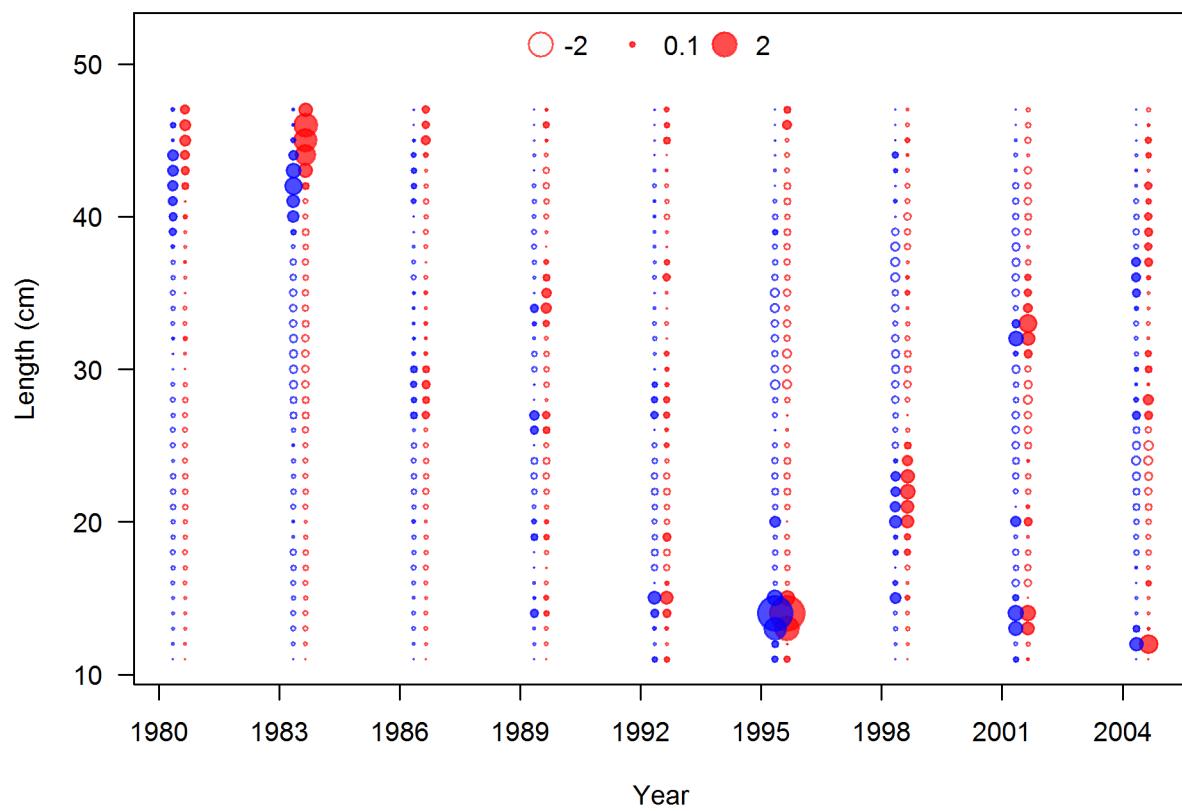


Figure 47: Pearson residuals, whole catch, Triennial survey (max=4.01)  
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

**Pearson residuals, whole catch, AFSC slope survey (max=2.91)**

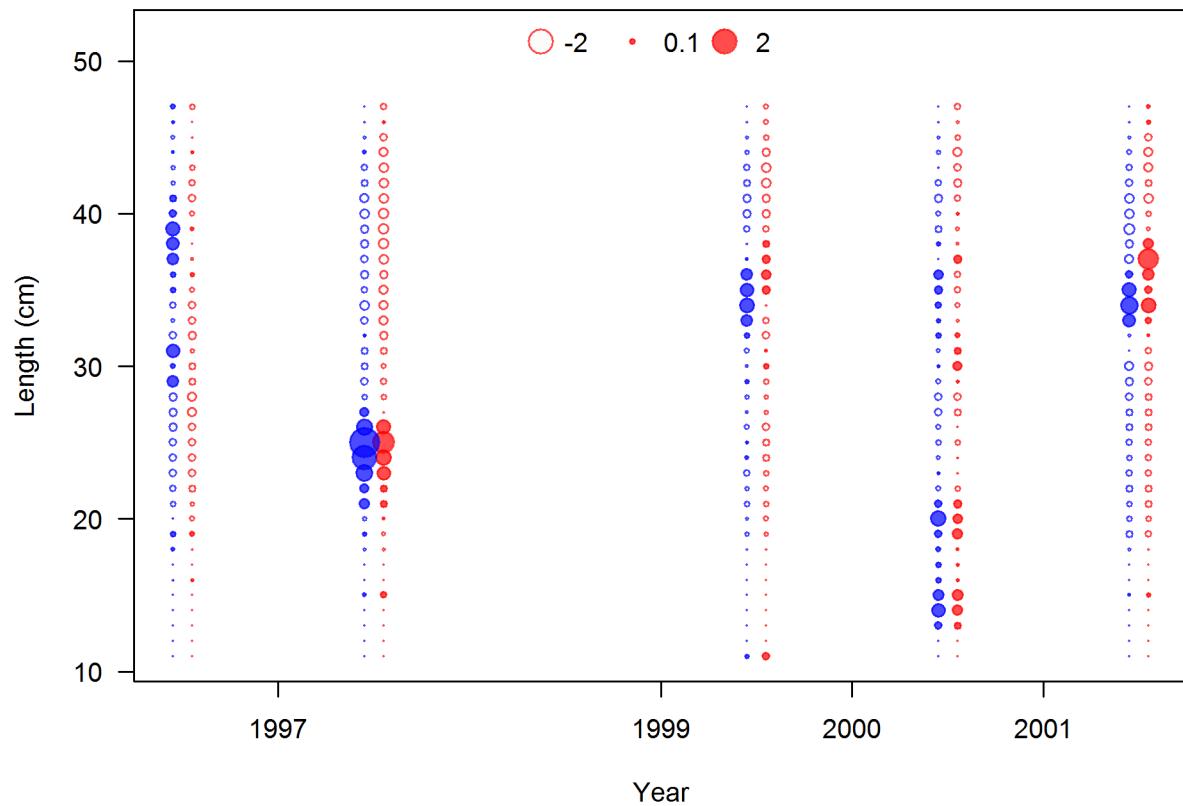


Figure 48: Pearson residuals, whole catch, AFSC slope survey (max=2.91)  
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

**Pearson residuals, whole catch, NWFSC slope survey (max=3.46)**

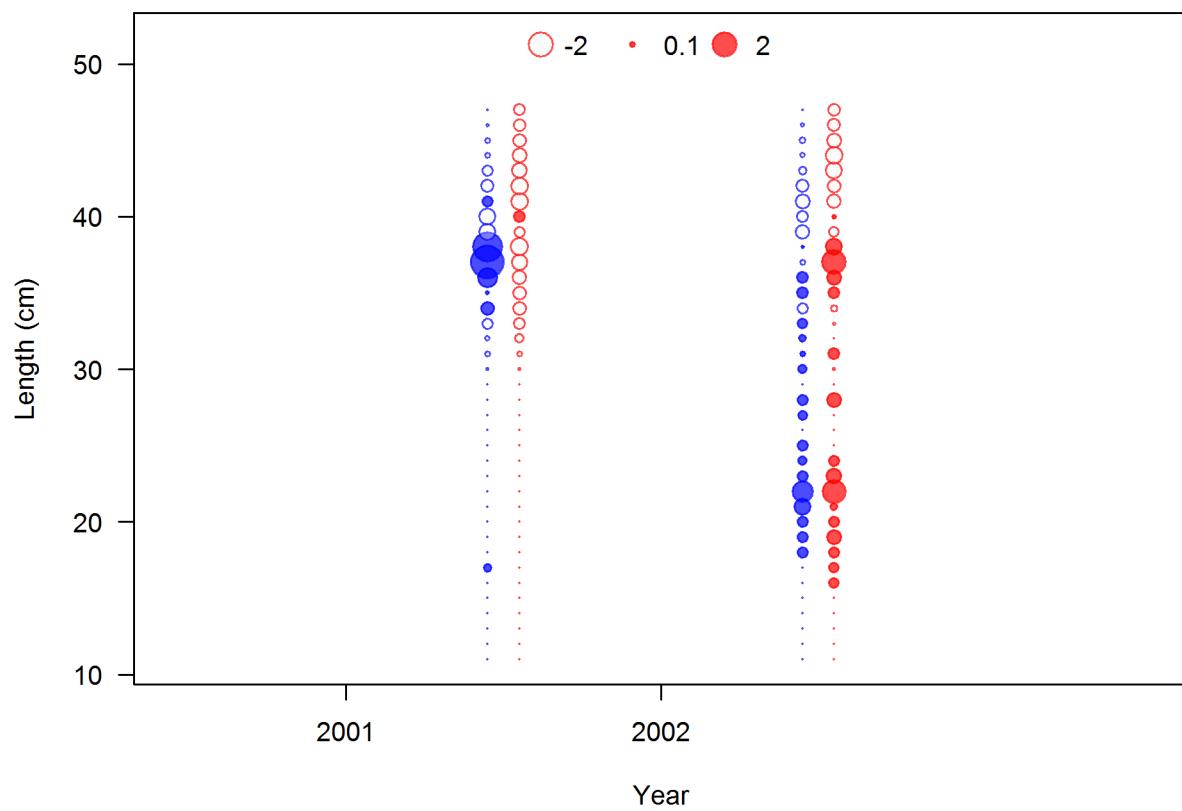


Figure 49: Pearson residuals, whole catch, NWFSC slope survey (max=3.46)  
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

Pearson residuals, whole catch, NWFSC shelf-slope survey (max=2.74)

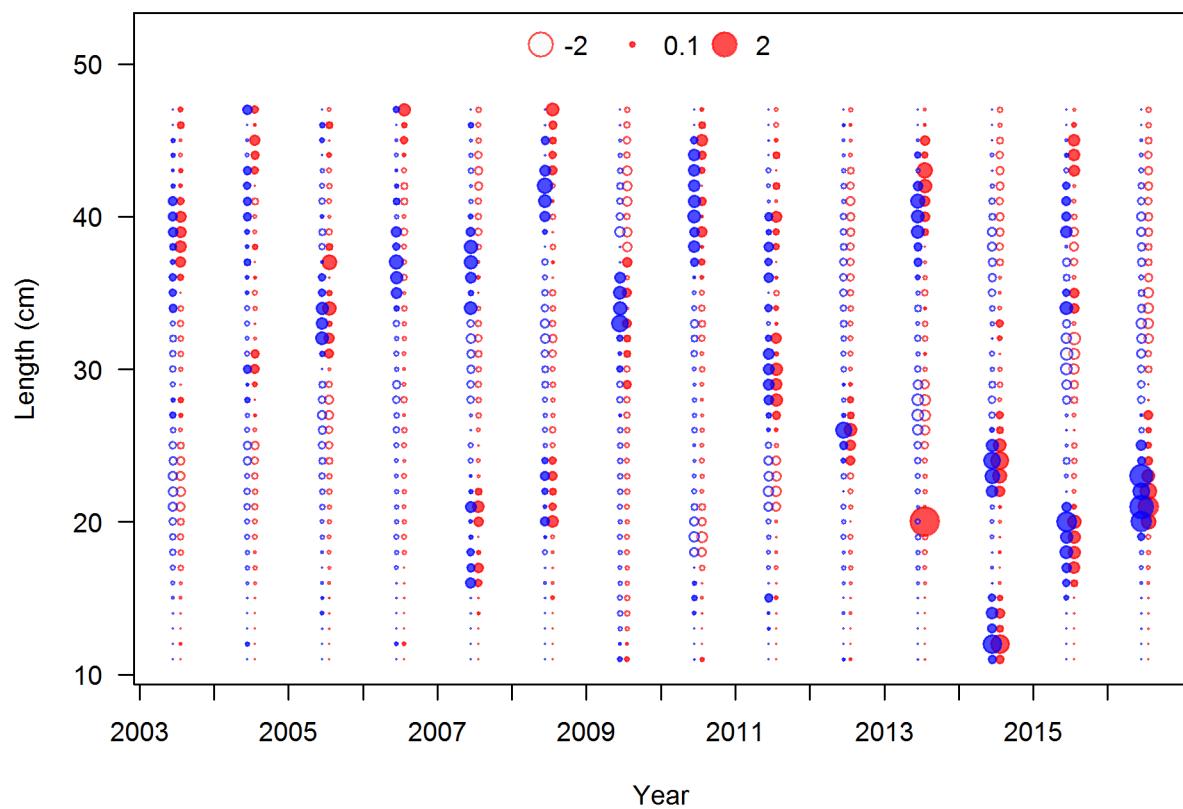


Figure 50: Pearson residuals, whole catch, NWFSC shelf\_slope survey (max=2.74)  
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

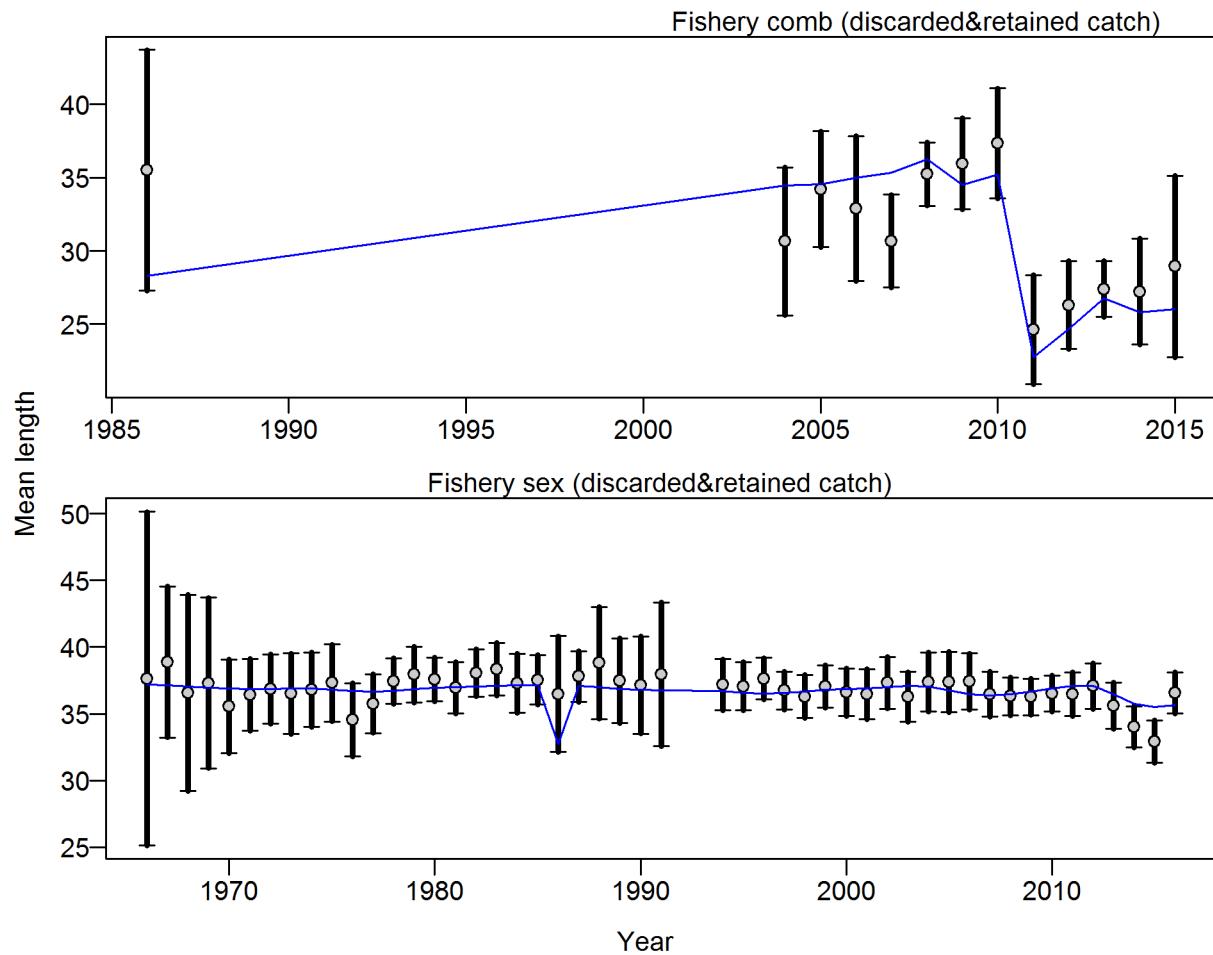


Figure 51: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.9951 (0.6685\_1.8165) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124\_1138.

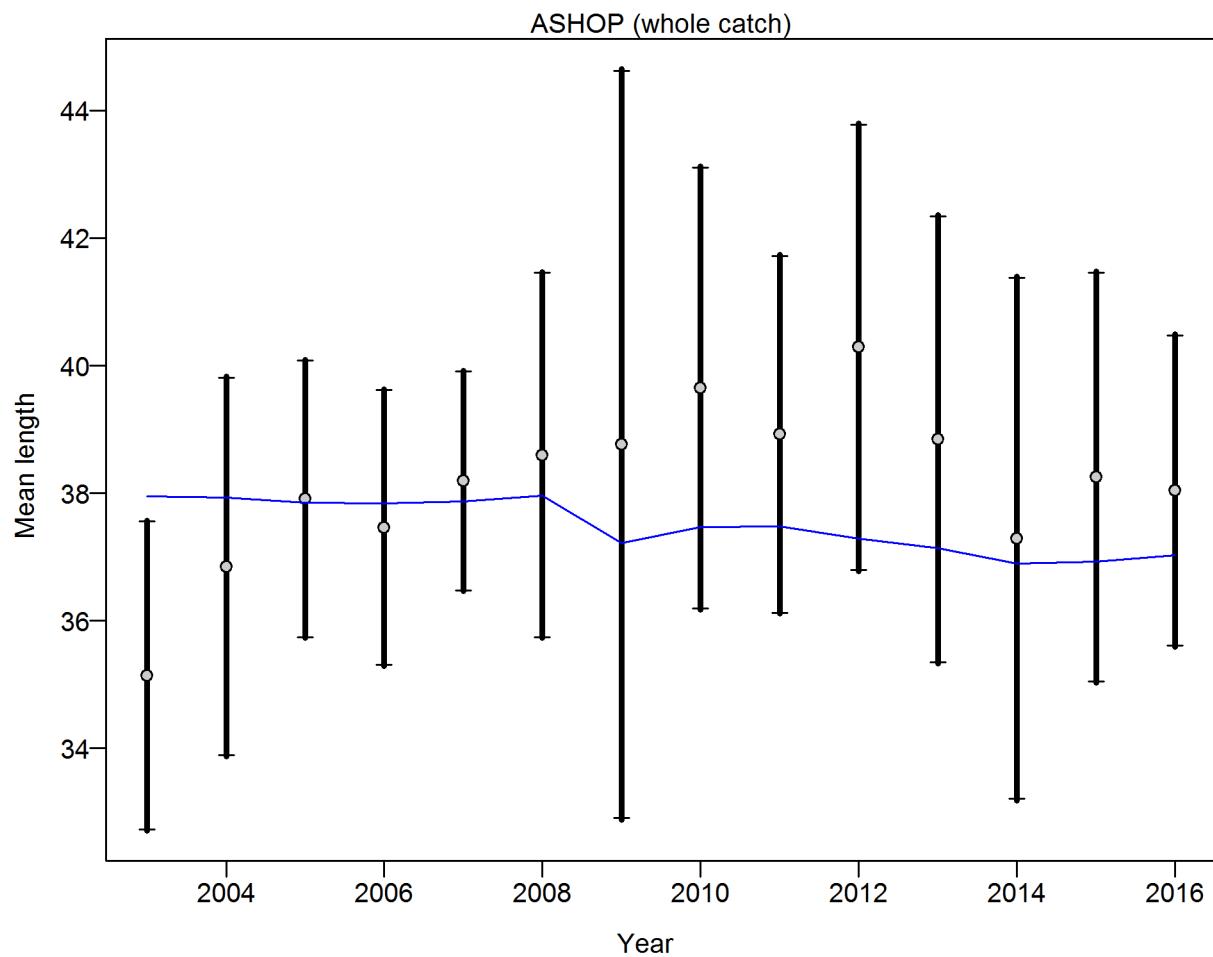


Figure 52: Francis data weighting method TA1.8: At\_sea hake Suggested sample size adjustment (with 95% interval) for len data from At\_sea hake: 1.0115 (0.5352\_4.8582) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124\_1138.

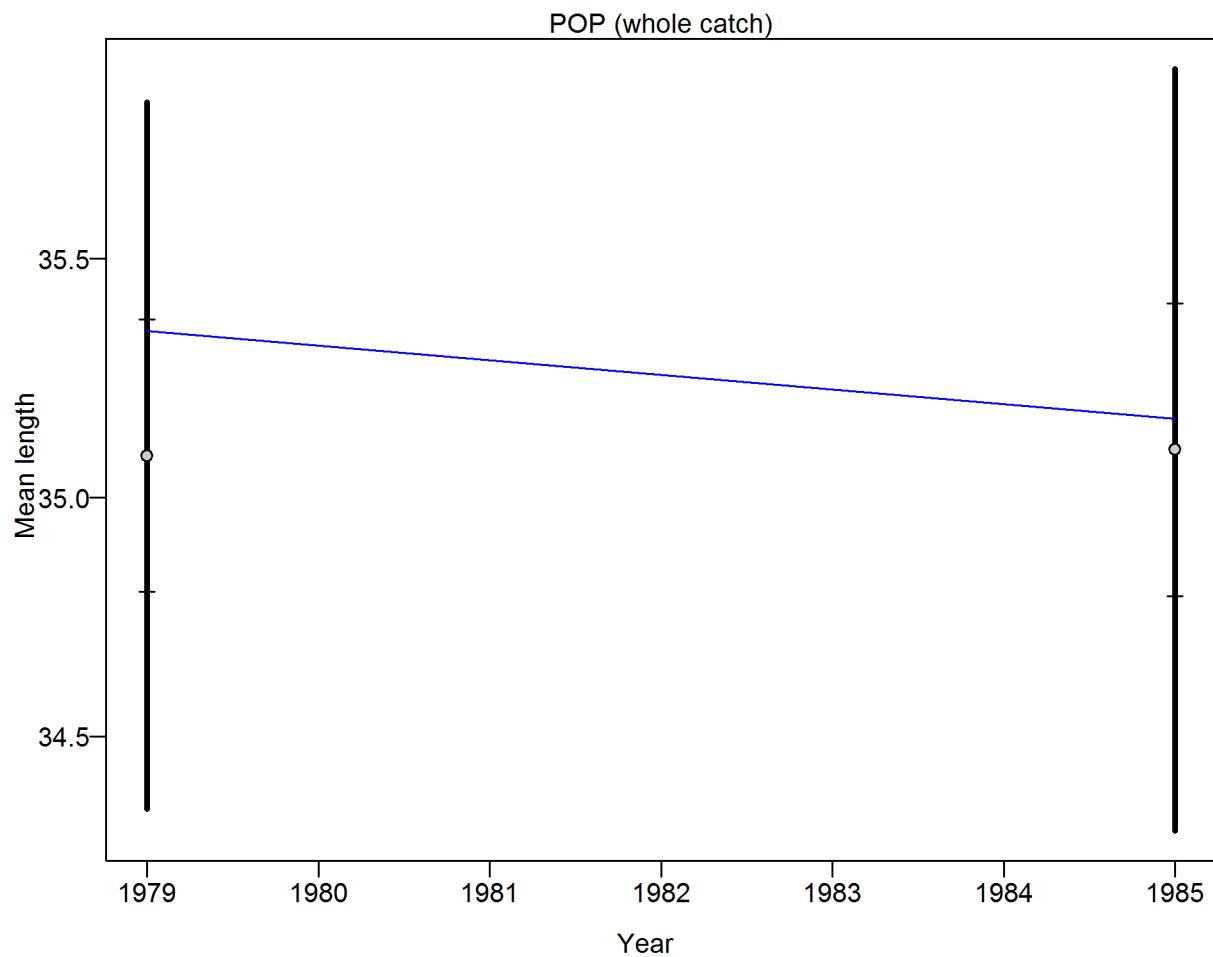


Figure 53: Francis data weighting method TA1.8: Pacific ocean perch survey Suggested sample size adjustment (with 95% interval) for len data from Pacific ocean perch survey: 6.7496 (6.7496\_Inf) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124–1138.

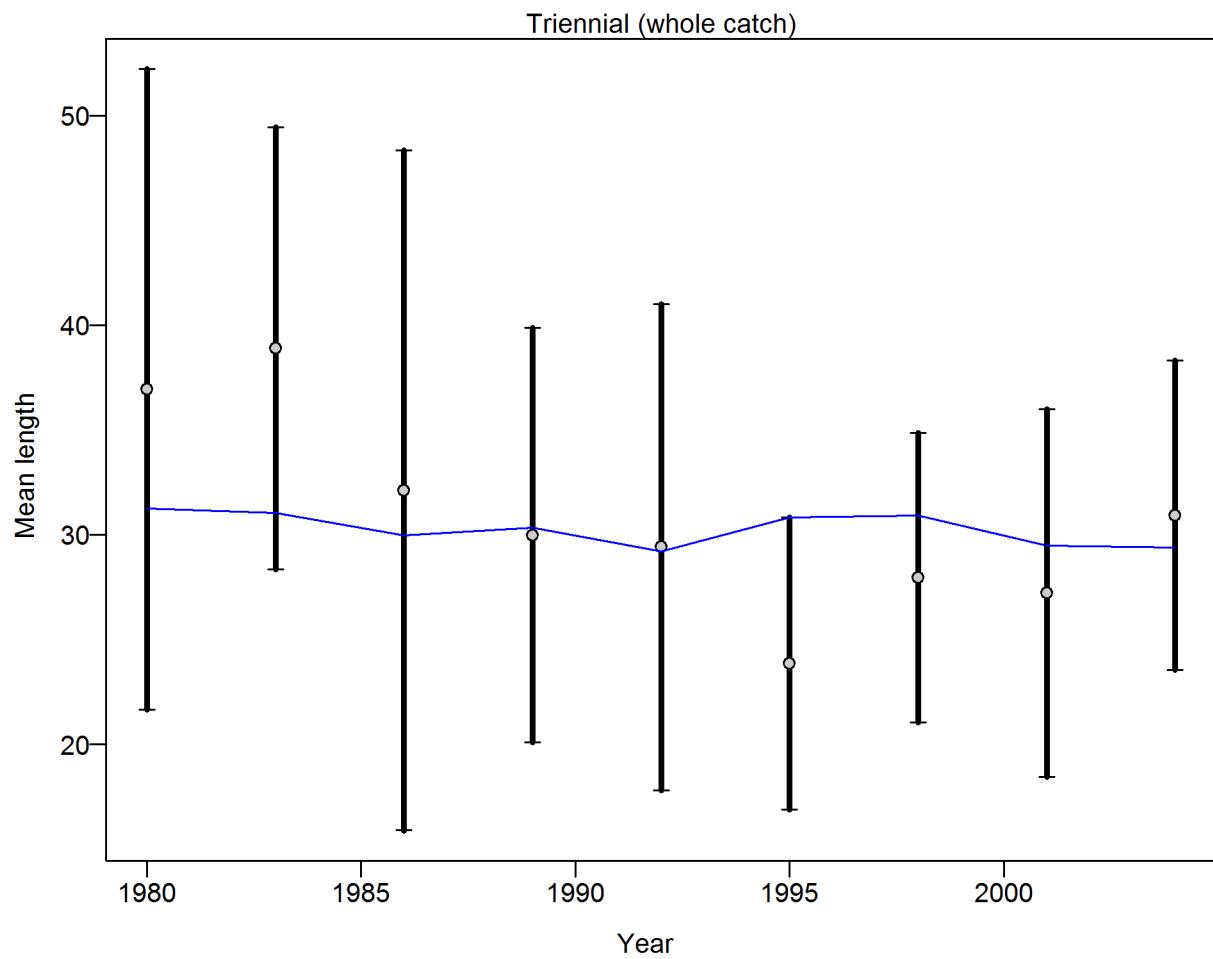


Figure 54: Francis data weighting method TA1.8: Triennial survey Suggested sample size adjustment (with 95% interval) for len data from Triennial survey: 1.0004 (0.5362\_5.786)  
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124\_1138.

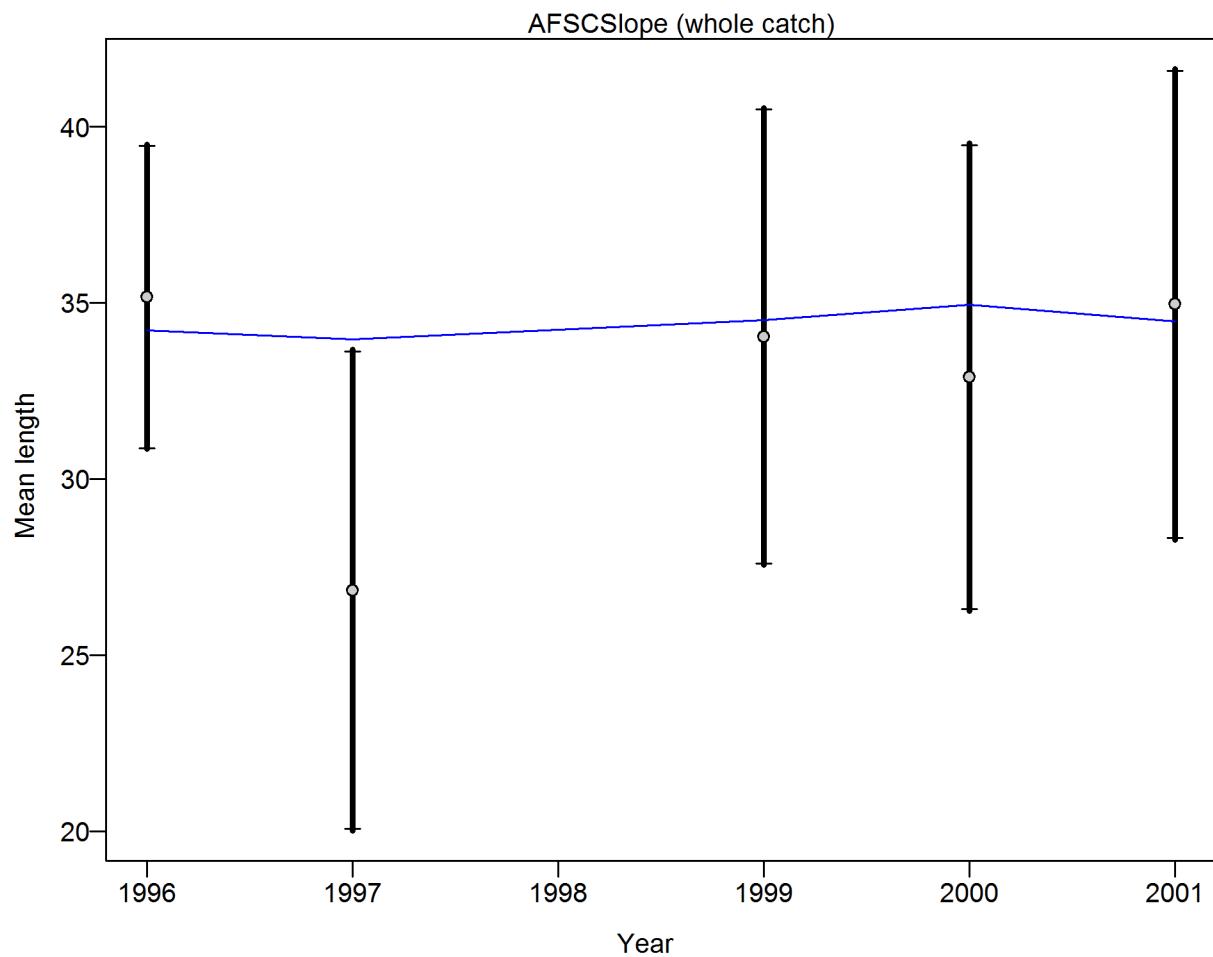


Figure 55: Francis data weighting method TA1.8: AFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from AFSC slope survey: 1.0151 (0.5859\_16.7225)  
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124\_1138.

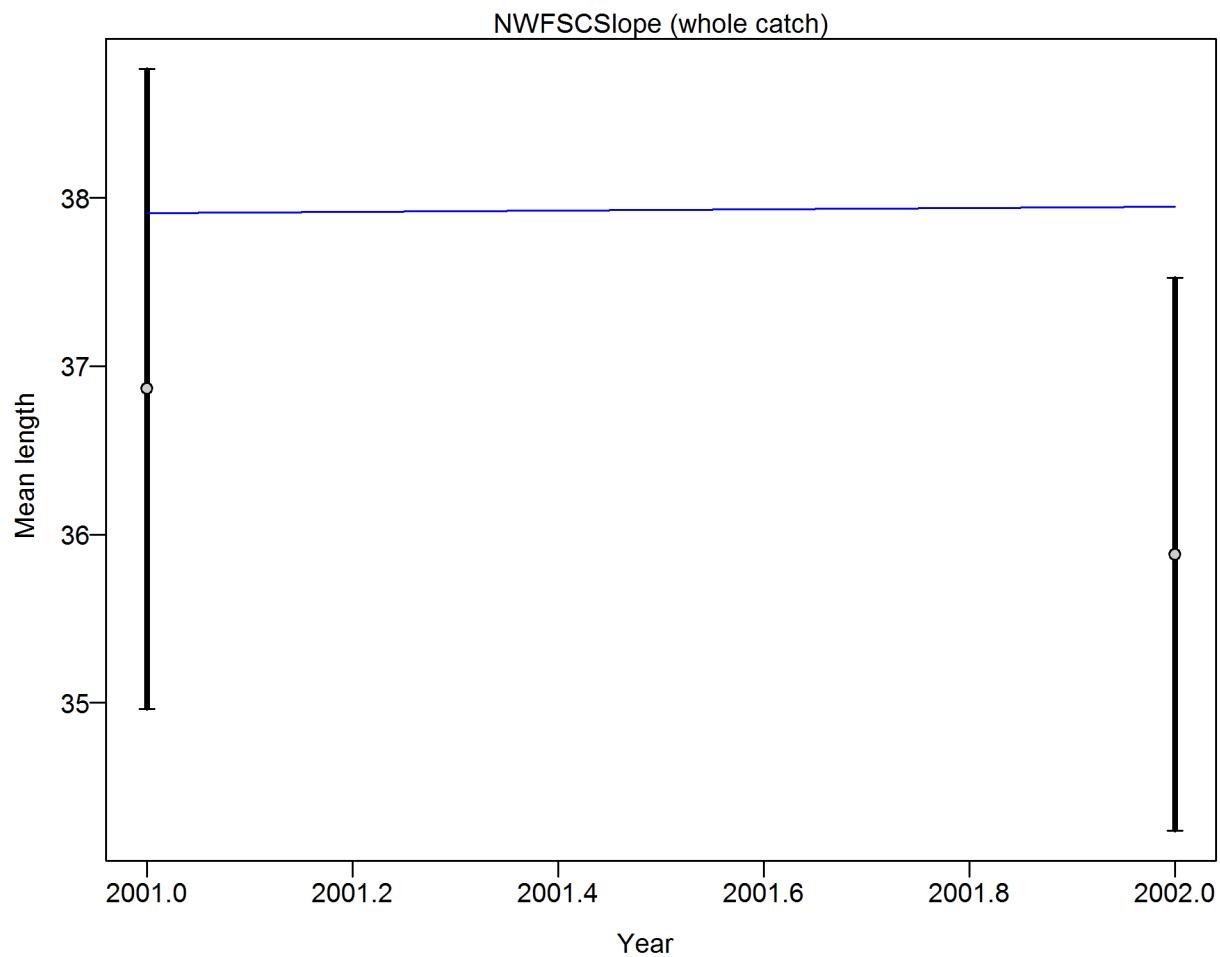


Figure 56: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC slope survey: 0.9922 (0.9922\_Inf)  
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138.

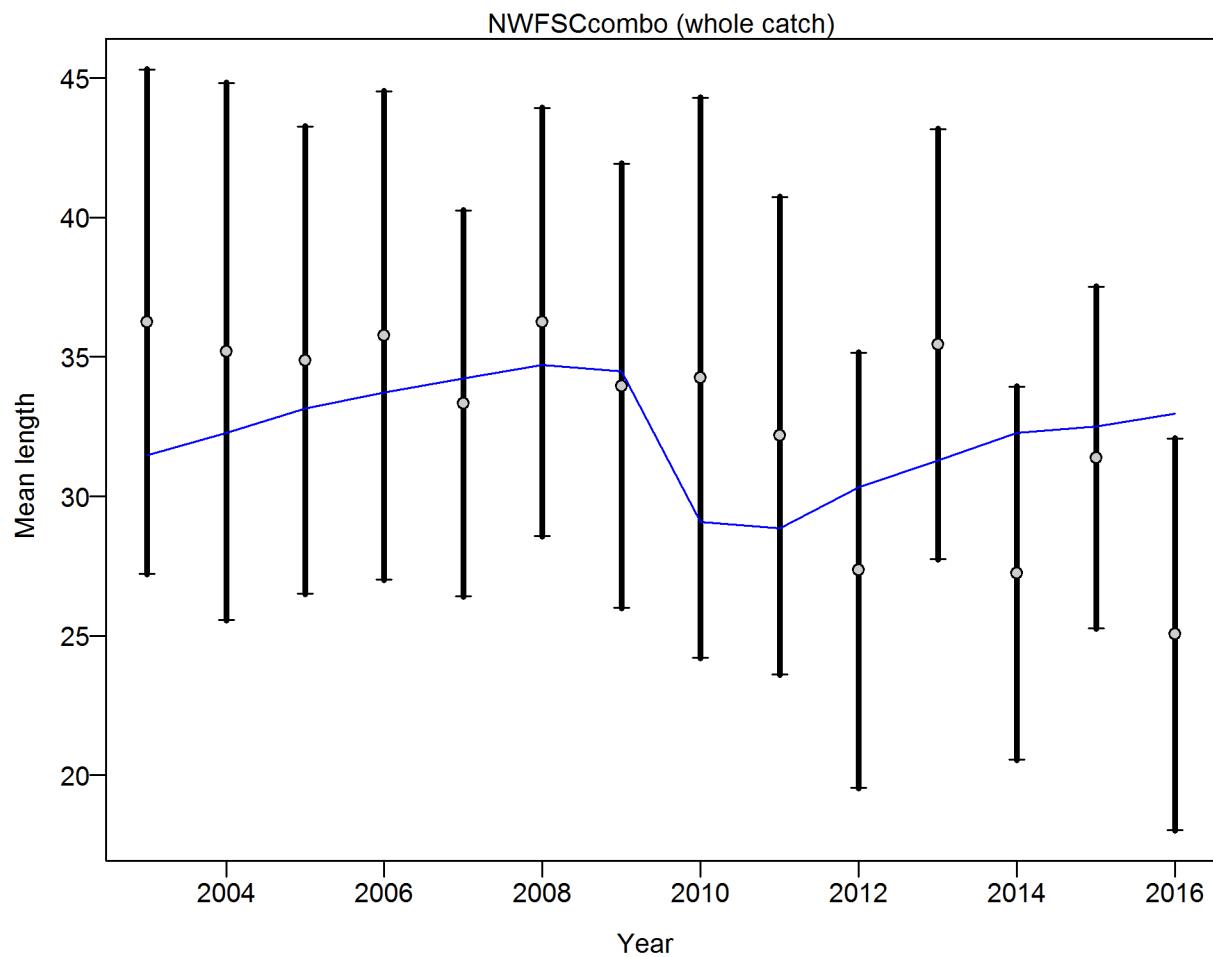


Figure 57: Francis data weighting method TA1.8: NWFSC shelf\_slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC shelf\_slope survey: 1.0055 (0.6199\_4.021) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124\_1138.

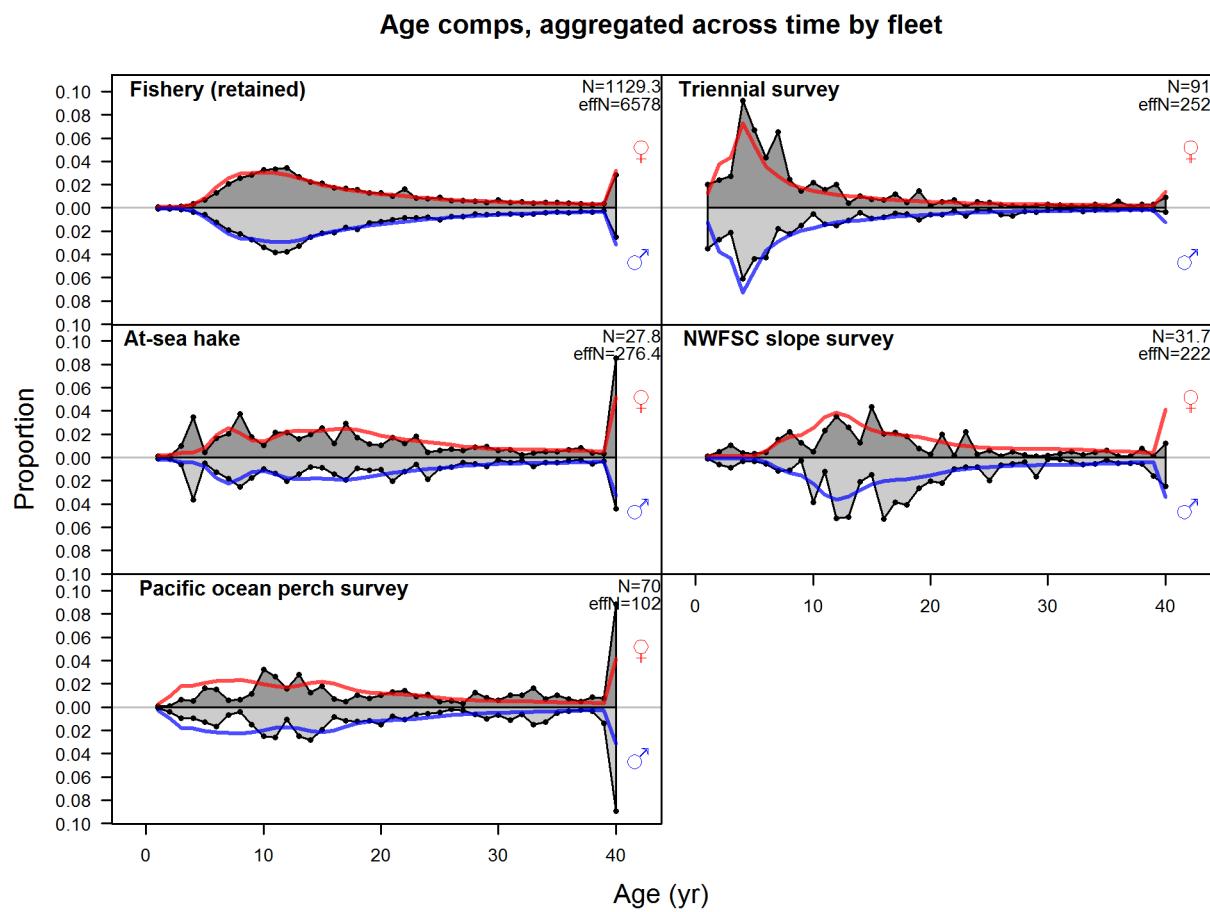


Figure 58: Age compositions aggregated across time by fleet.

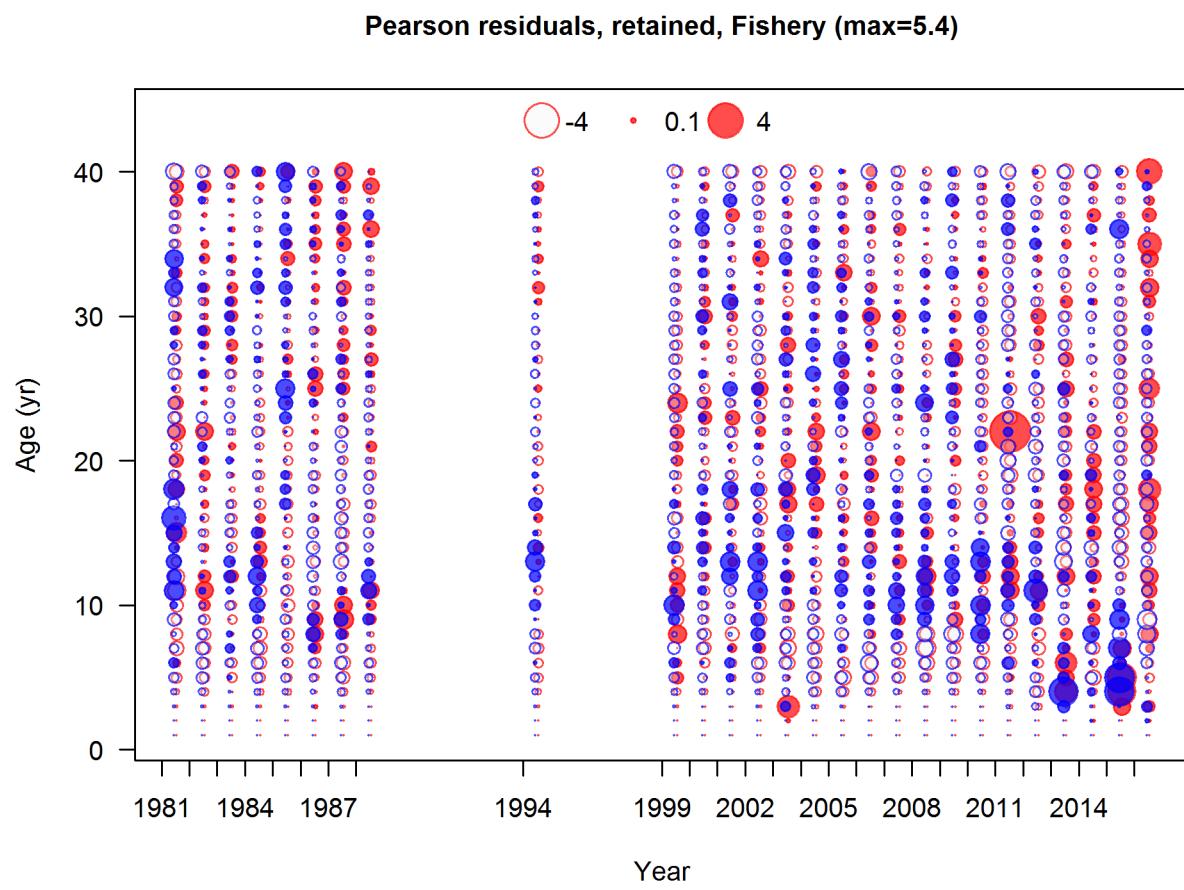


Figure 59: Pearson residuals, retained, Fishery (max=5.4) (plot 2 of 2)  
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

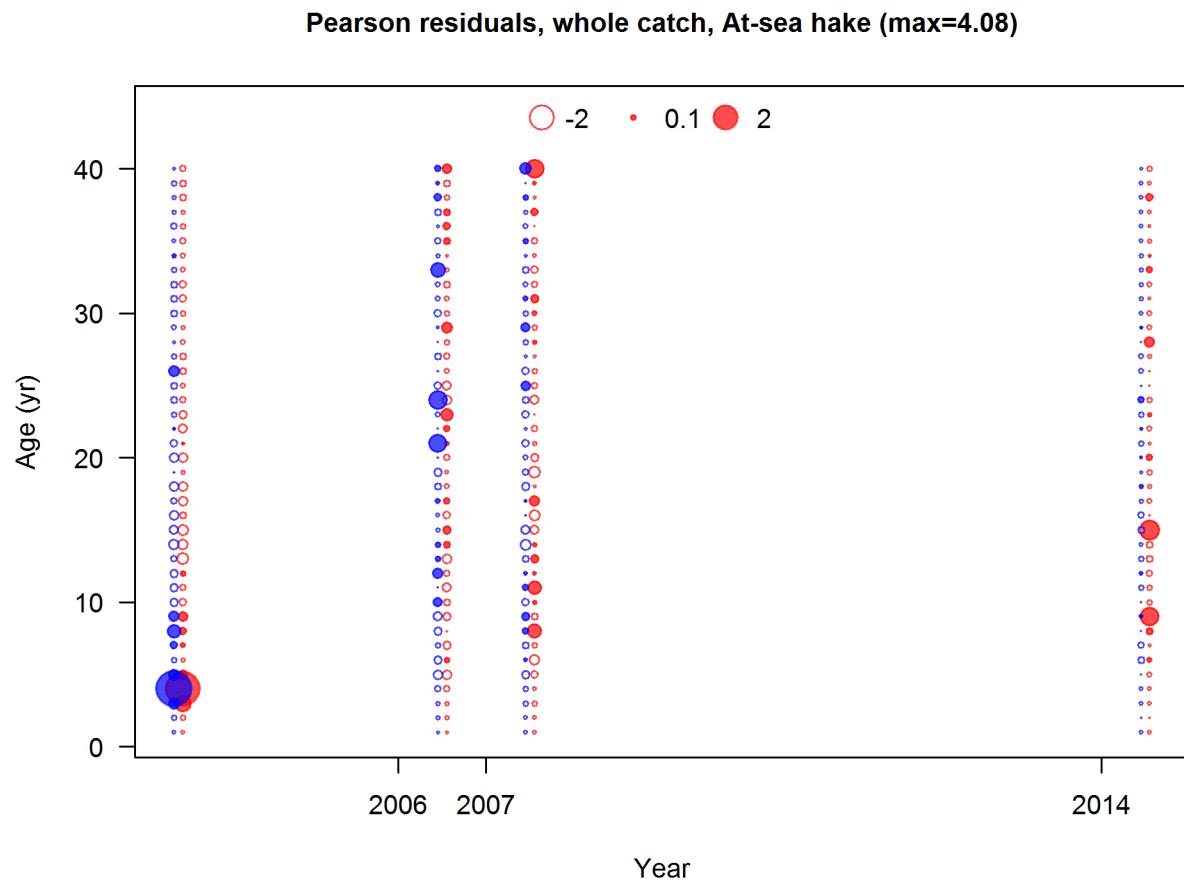


Figure 60: Pearson residuals, whole catch, At\_sea hake (max=4.08)  
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

**Pearson residuals, whole catch, Pacific ocean perch survey (max=2.76)**

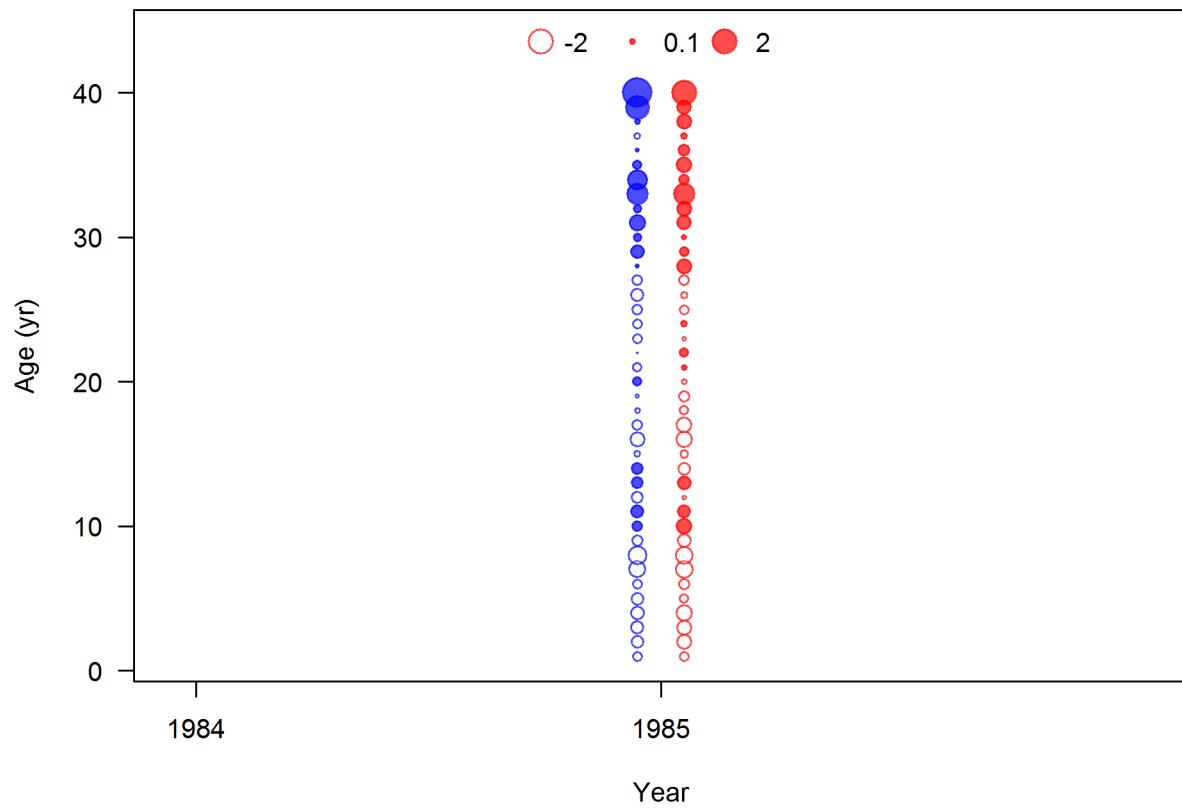


Figure 61: Pearson residuals, whole catch, Pacific ocean perch survey (max=2.76)  
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

**Pearson residuals, whole catch, Triennial survey (max=3.75)**

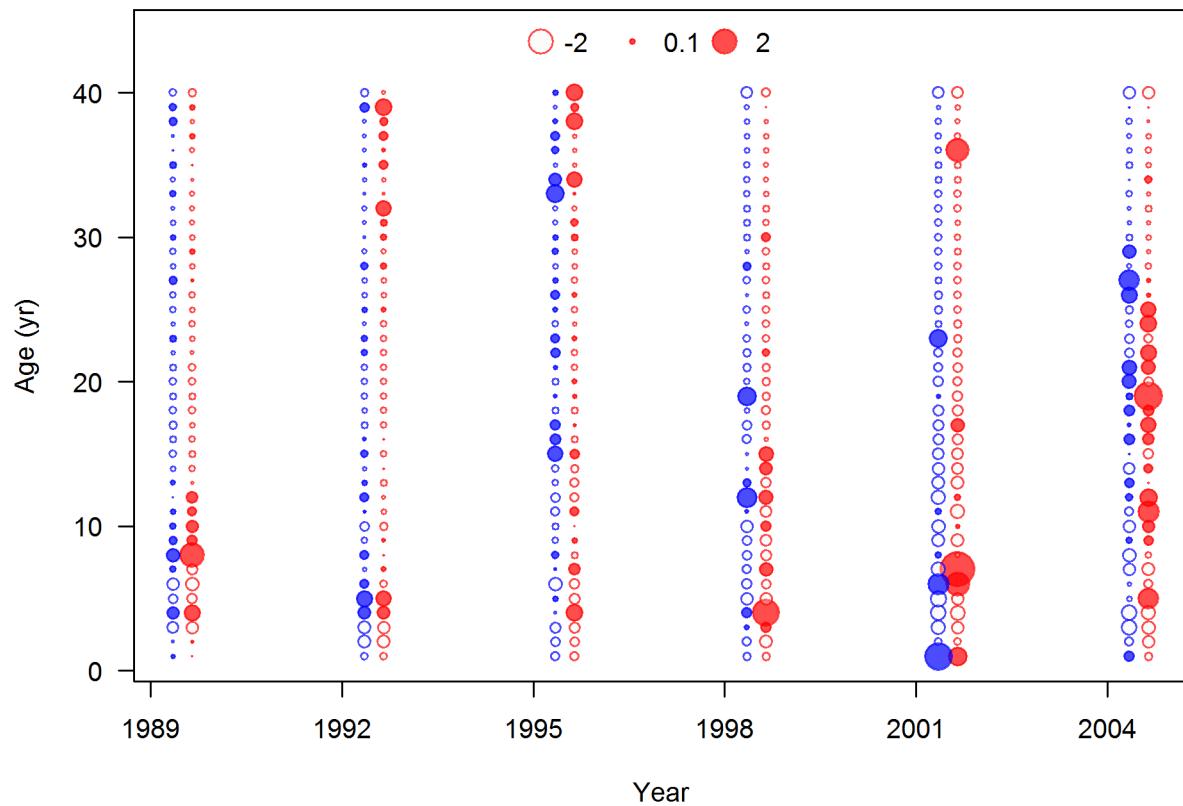


Figure 62: Pearson residuals, whole catch, Triennial survey (max=3.75)  
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

Pearson residuals, whole catch, NWFSC slope survey (max=2.34)

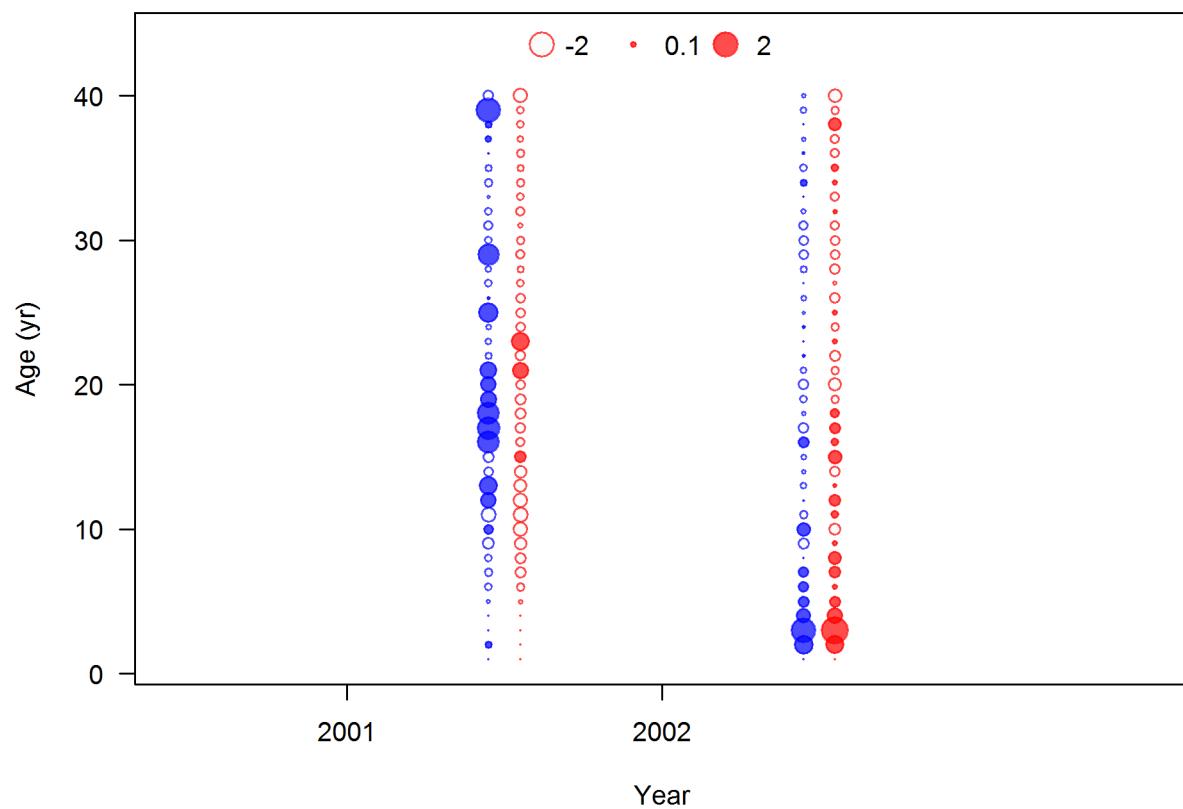


Figure 63: Pearson residuals, whole catch, NWFSC slope survey (max=2.34)  
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

Conditional AAL plot, whole catch, NWFSC shelf-slope survey

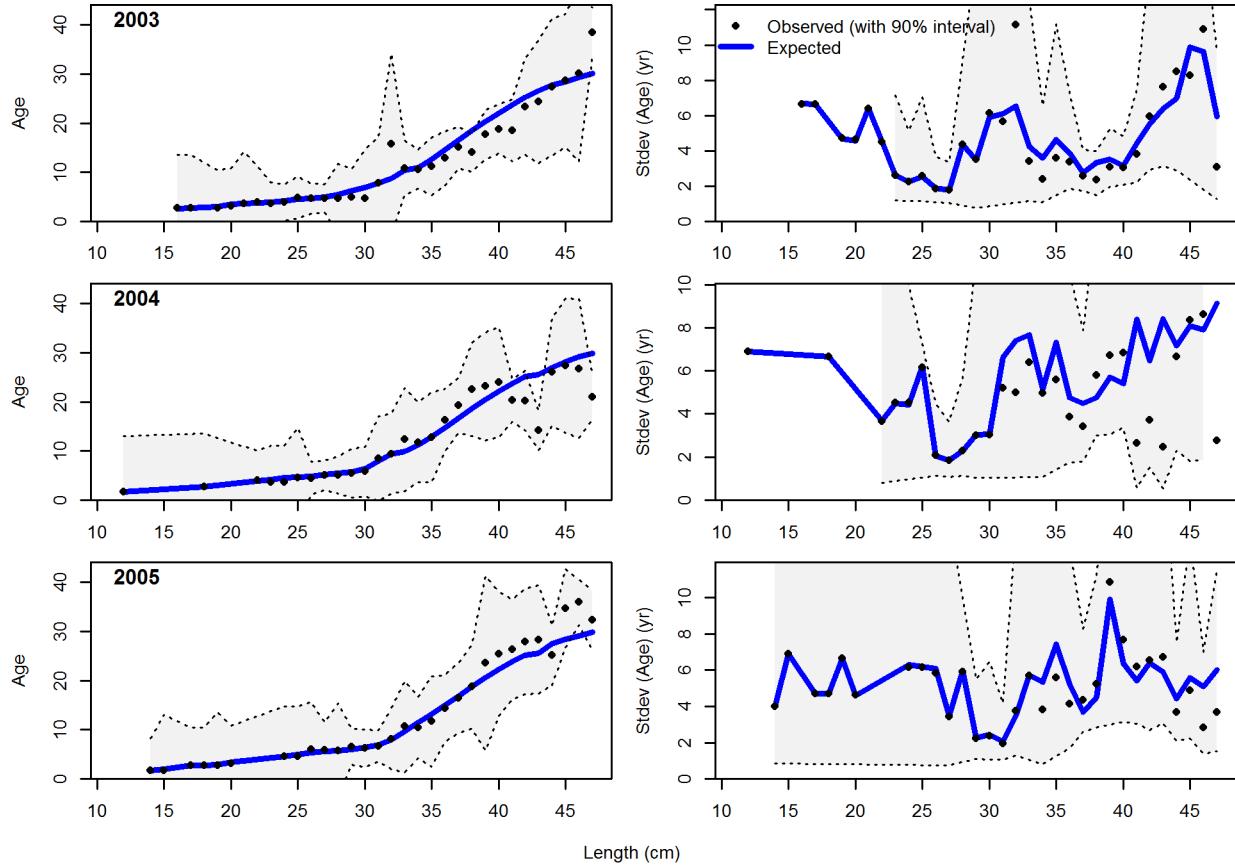


Figure 64: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 1 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size\_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution.

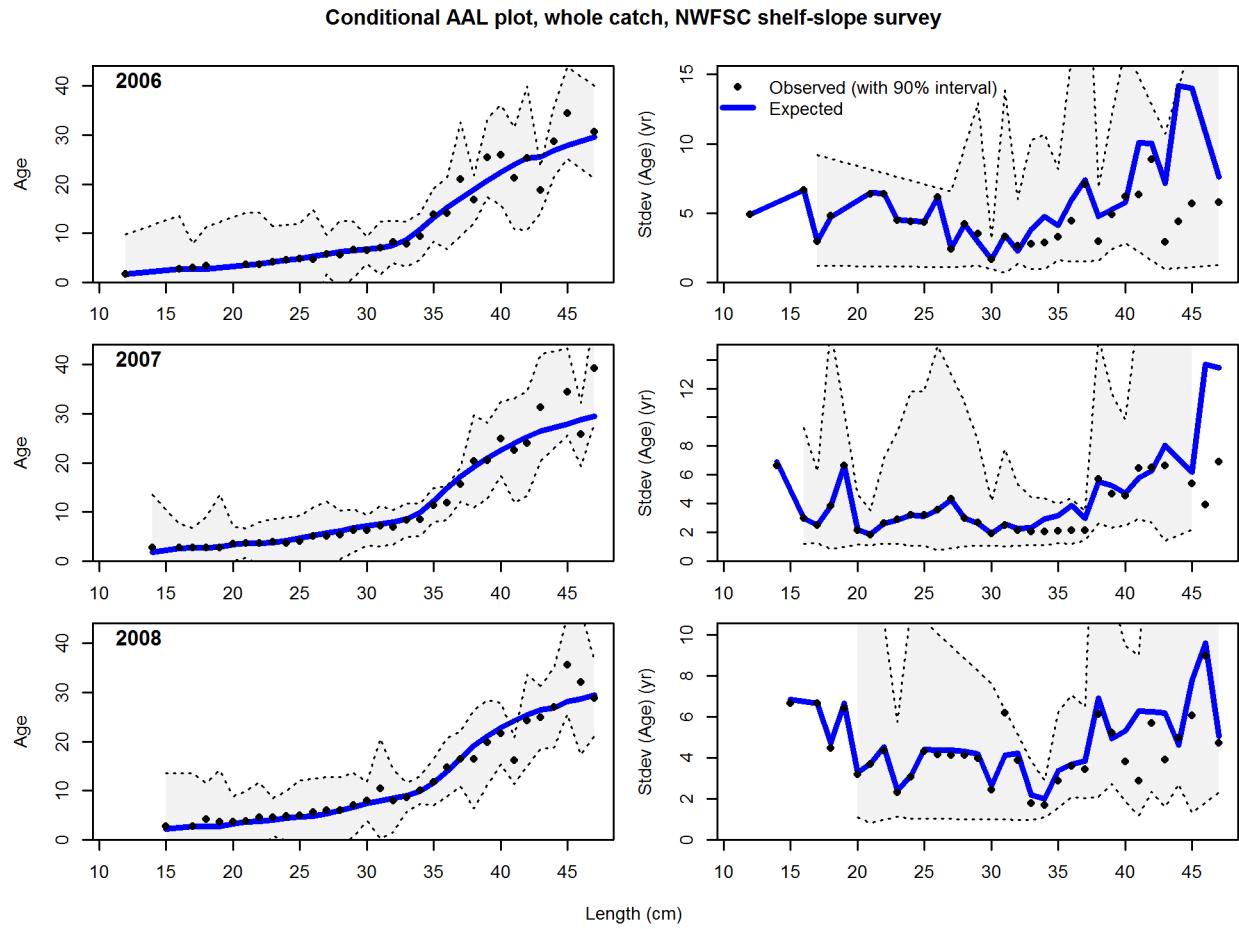


Figure 65: Conditional AAL plot, whole catch, NWFSC shelf\_slope survey (plot 2 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size\_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi\_square distribution.

Conditional AAL plot, whole catch, NWFSC shelf-slope survey

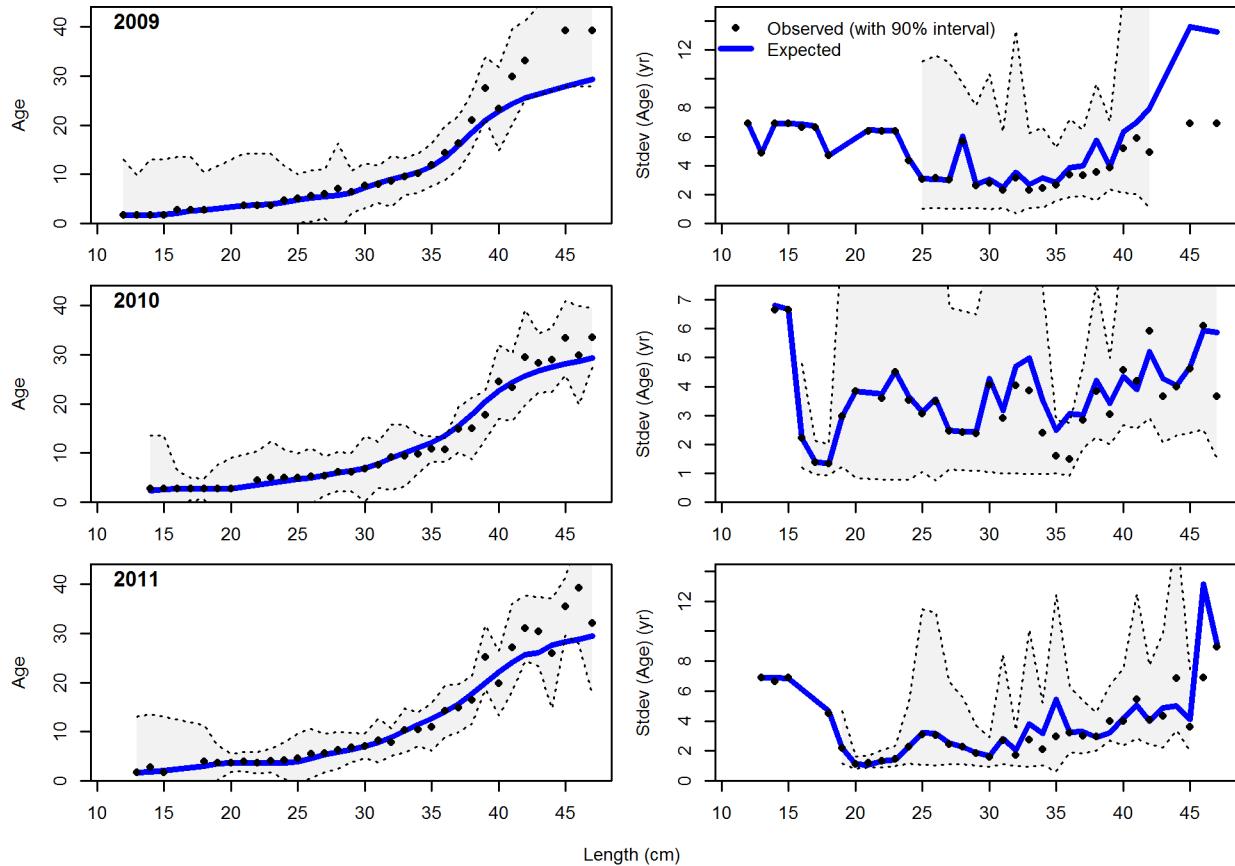


Figure 66: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 3 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size\_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution.

Conditional AAL plot, whole catch, NWFSC shelf-slope survey

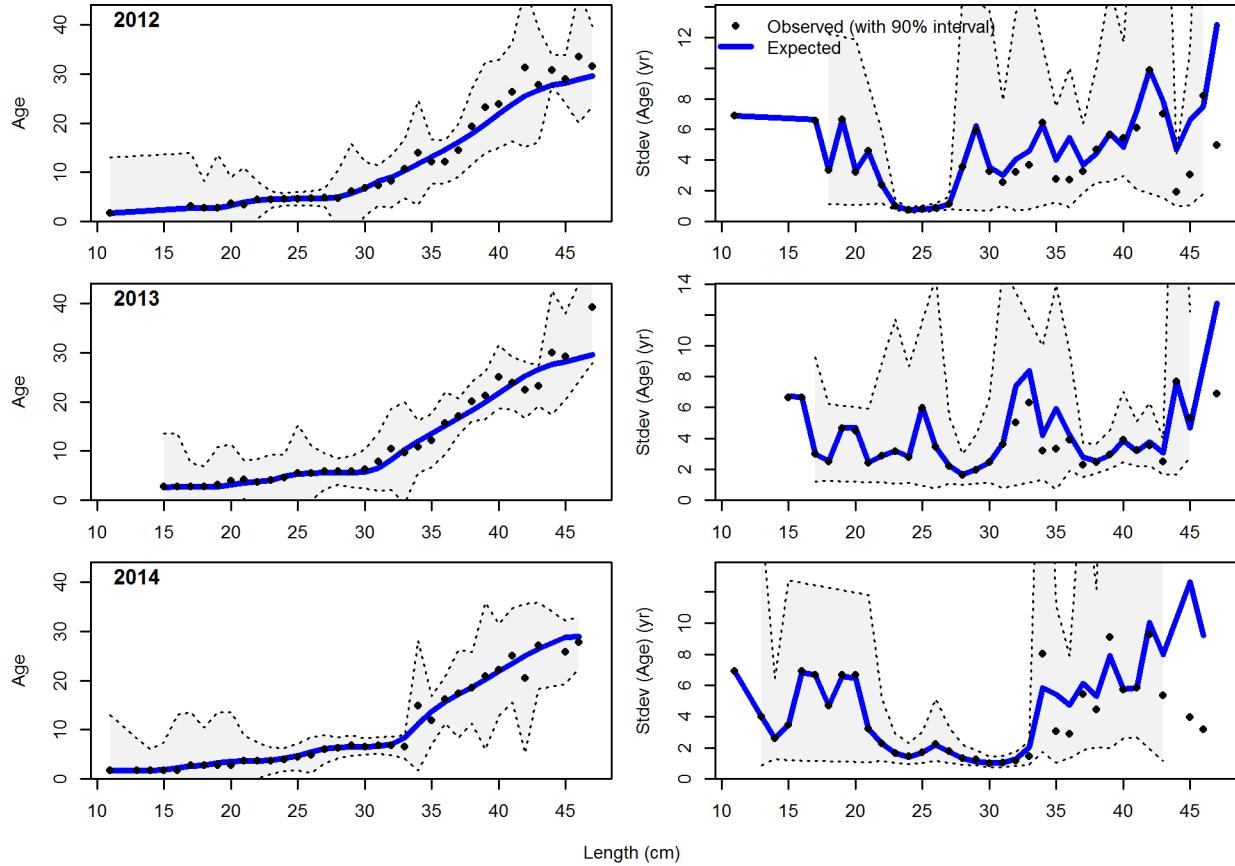


Figure 67: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 4 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size\_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution.

Conditional AAL plot, whole catch, NWFSC shelf-slope survey

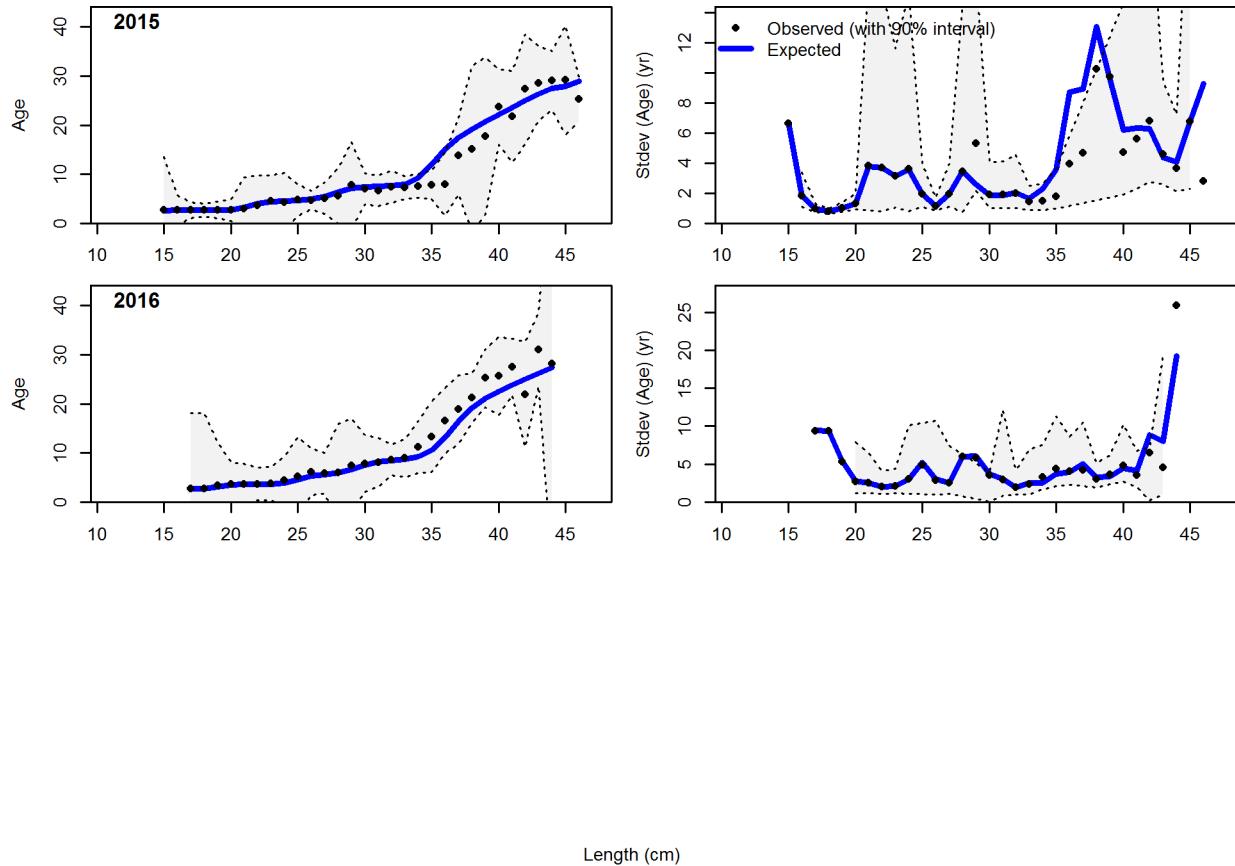


Figure 68: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 5 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size\_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution.

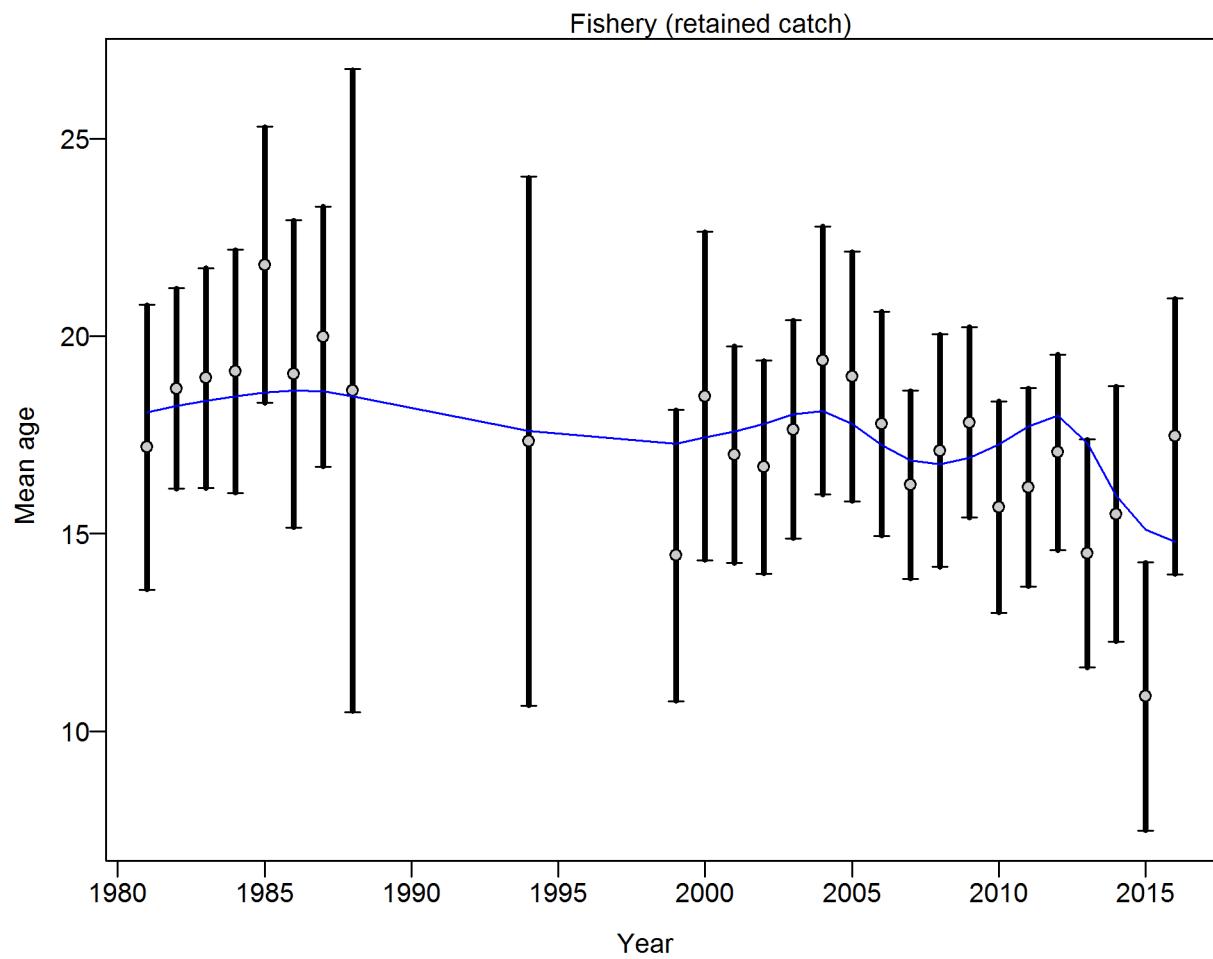


Figure 69: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for age data from Fishery: 0.9921 (0.6365\_1.9959) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124\_1138.

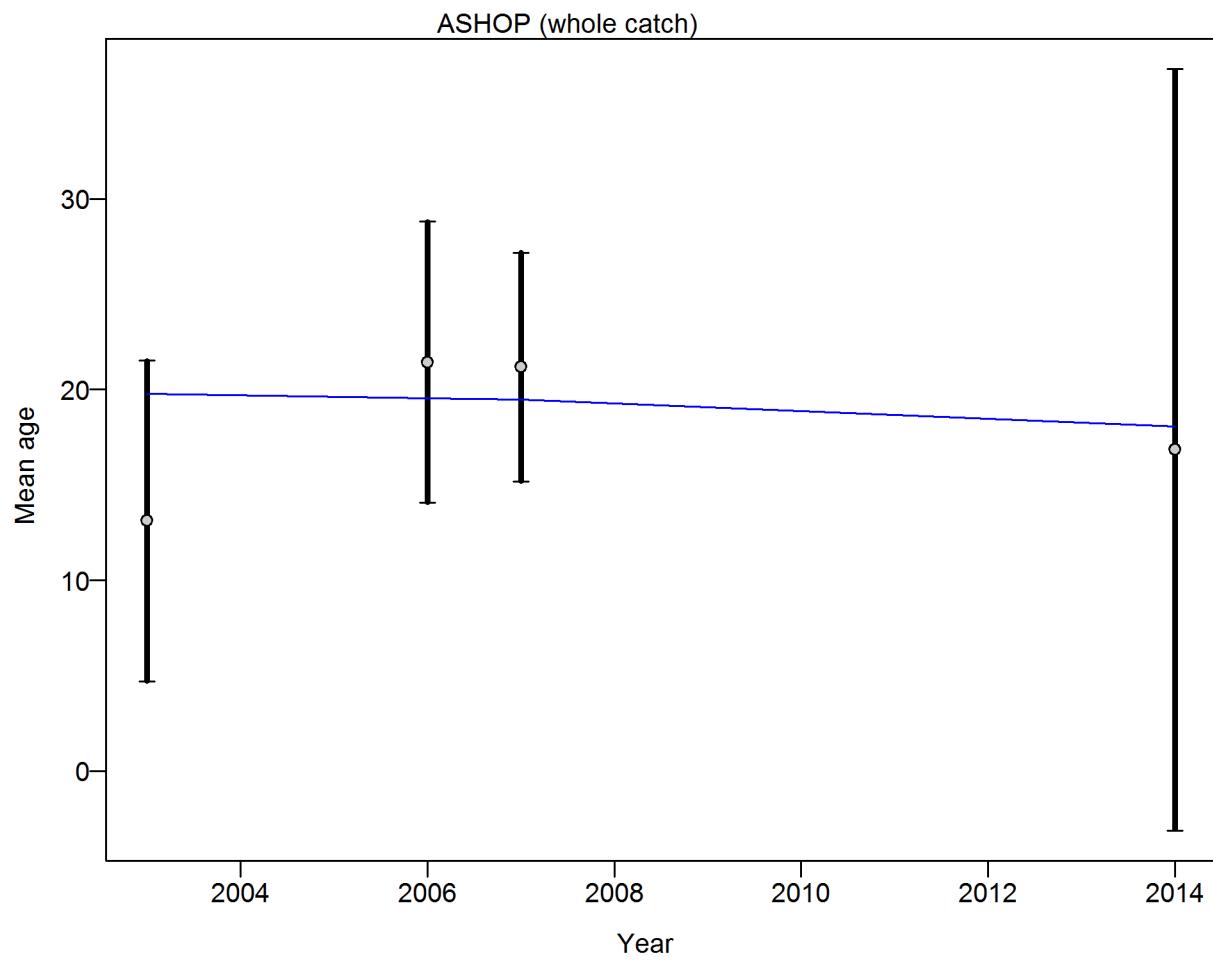


Figure 70: Francis data weighting method TA1.8: At\_sea hake Suggested sample size adjustment (with 95% interval) for age data from At\_sea hake: 0.9921 (0.6459\_1420.3157)  
 For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Can. J. Fish. Aquat. Sci.* 68: 1124\_1138.

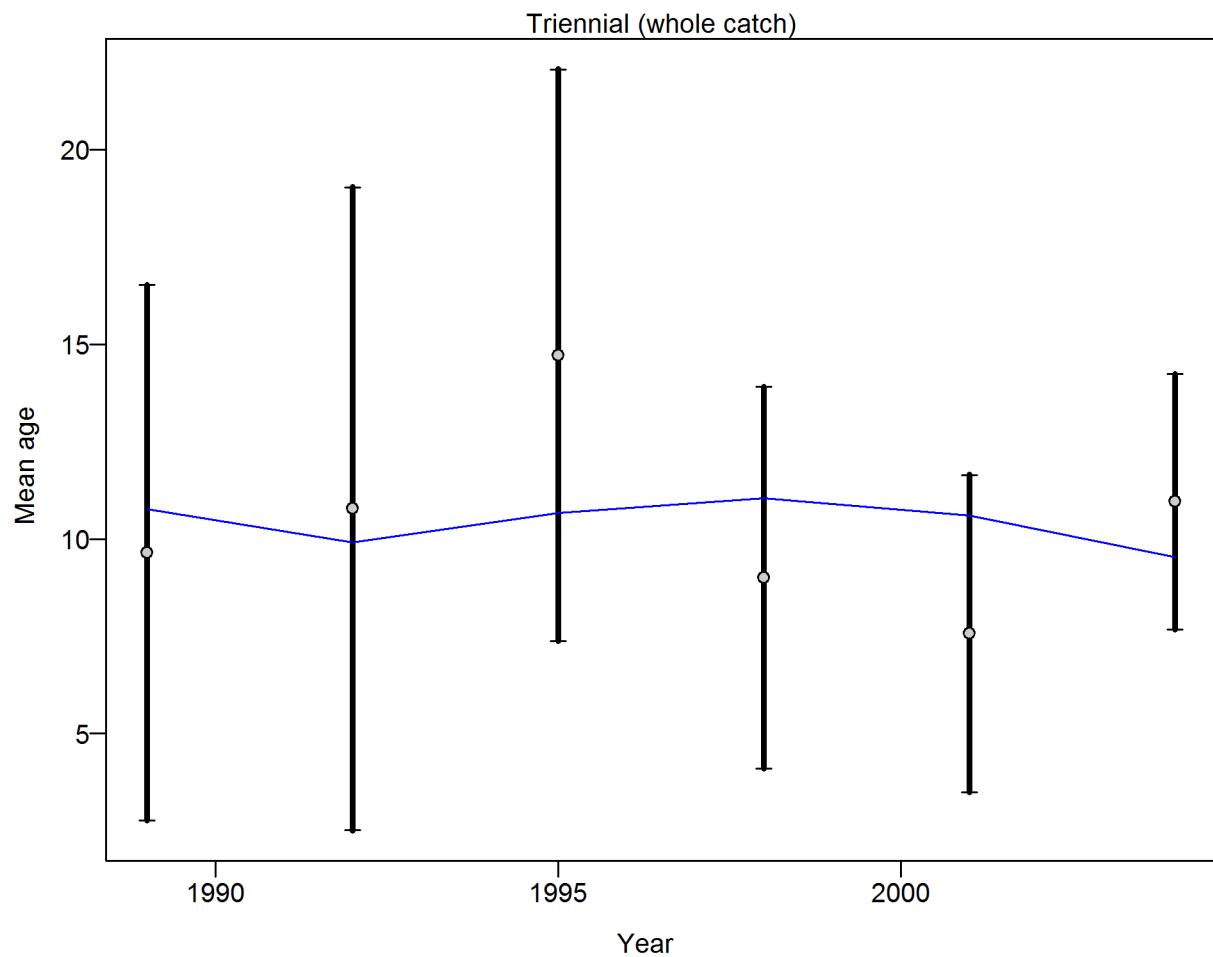


Figure 71: Francis data weighting method TA1.8: Triennial survey Suggested sample size adjustment (with 95% interval) for age data from Triennial survey: 1.0019 (0.6421\_5.1354)  
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124\_1138.

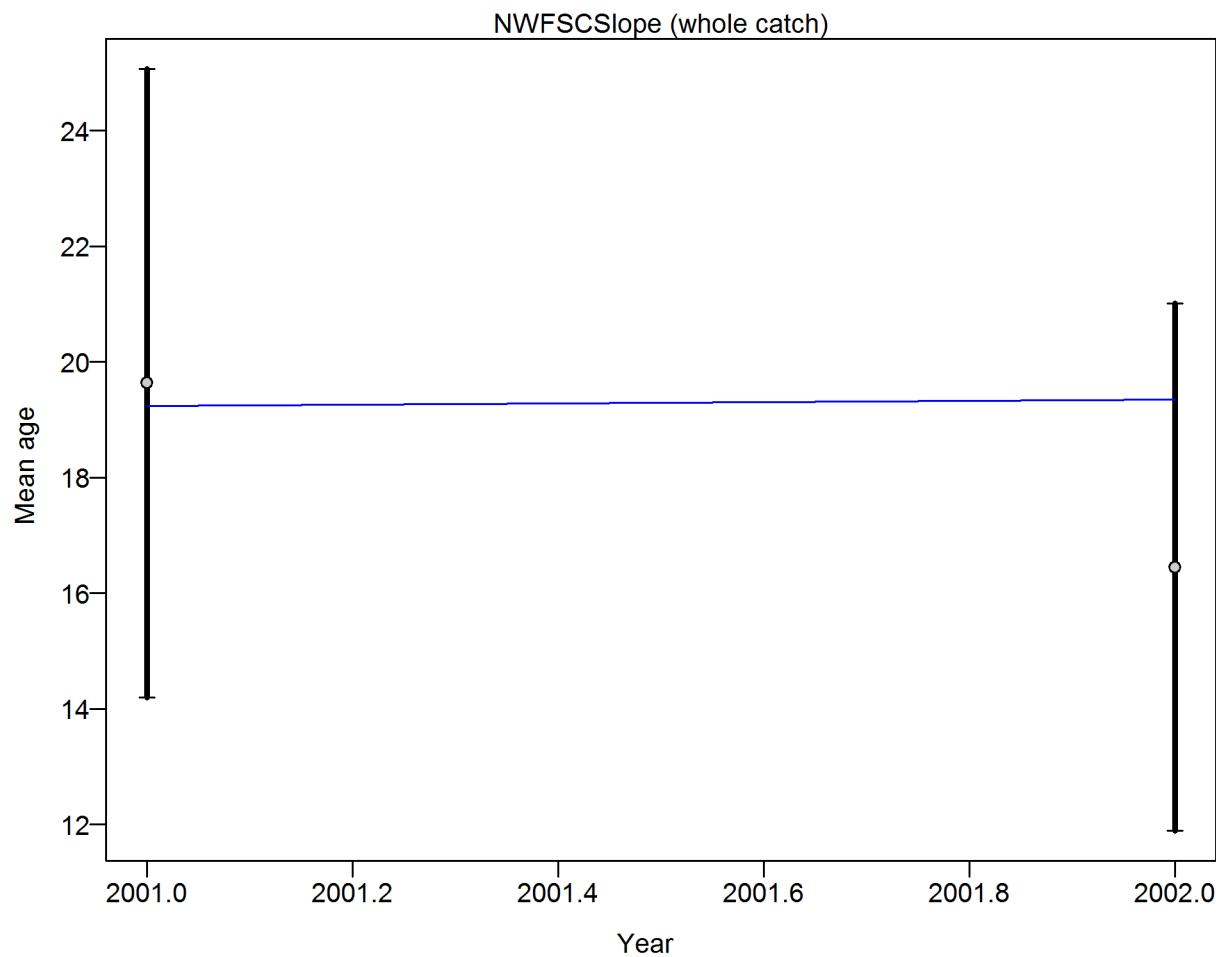


Figure 72: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for age data from NWFSC slope survey: 0.9998 (0.9998\_Inf)  
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138.

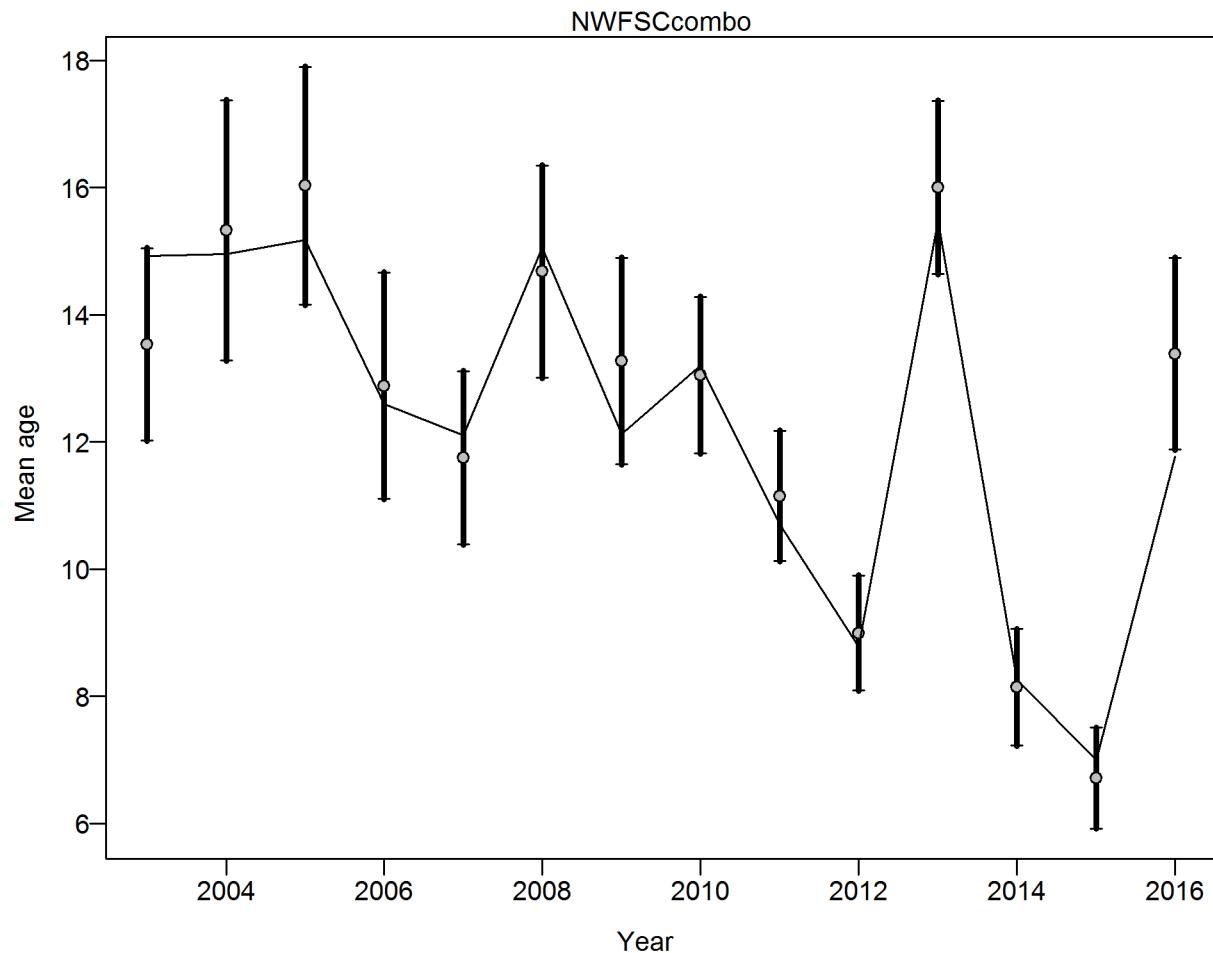


Figure 73: Francis data weighting method TA1.8 for conditional age [data:NWFSC](#) shelf\_slope survey Suggested sample size adjustment (with 95% interval) for conditional age\_at\_length data from NWFSC shelf\_slope survey: 1.0131 (0.5851\_3.0487) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124\_1138.

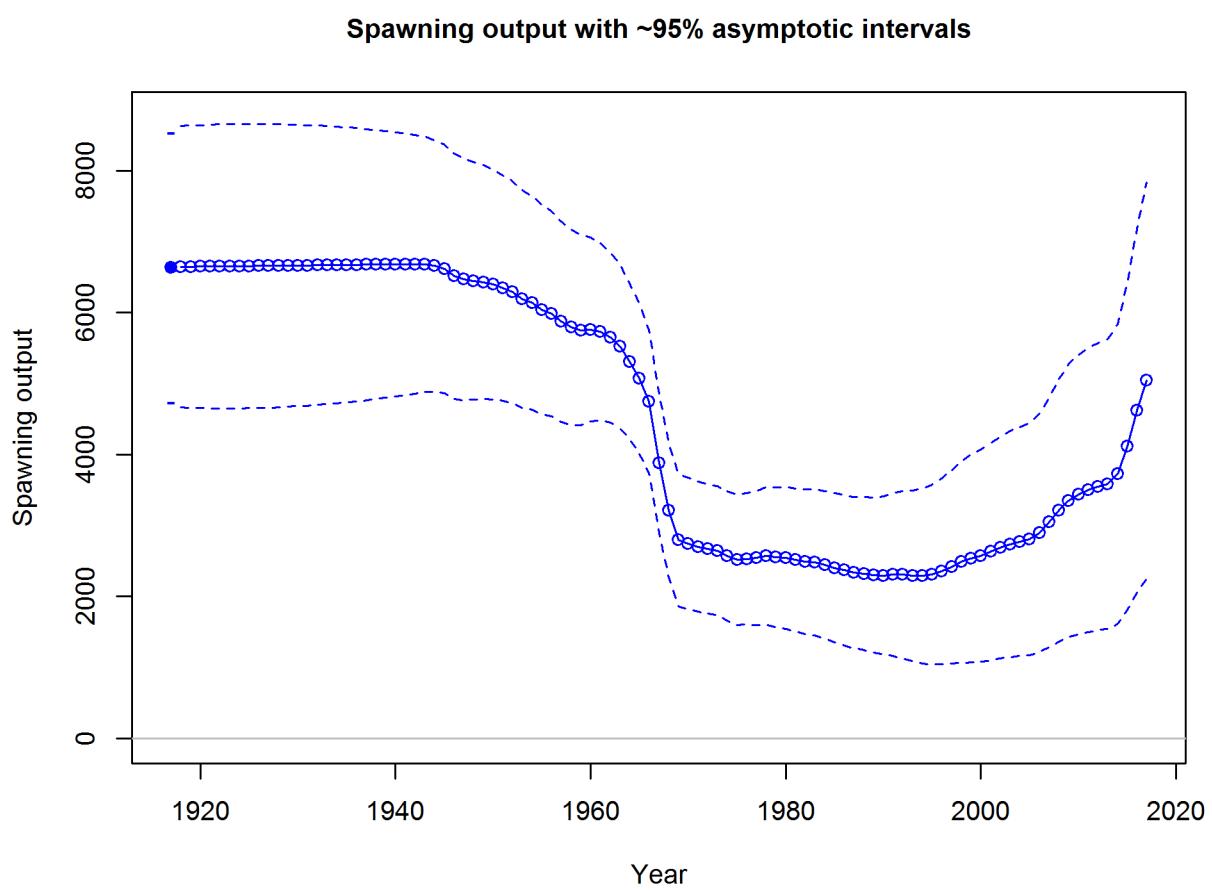


Figure 74: Estimated time-series of spawning output for Pacific ocean perch.

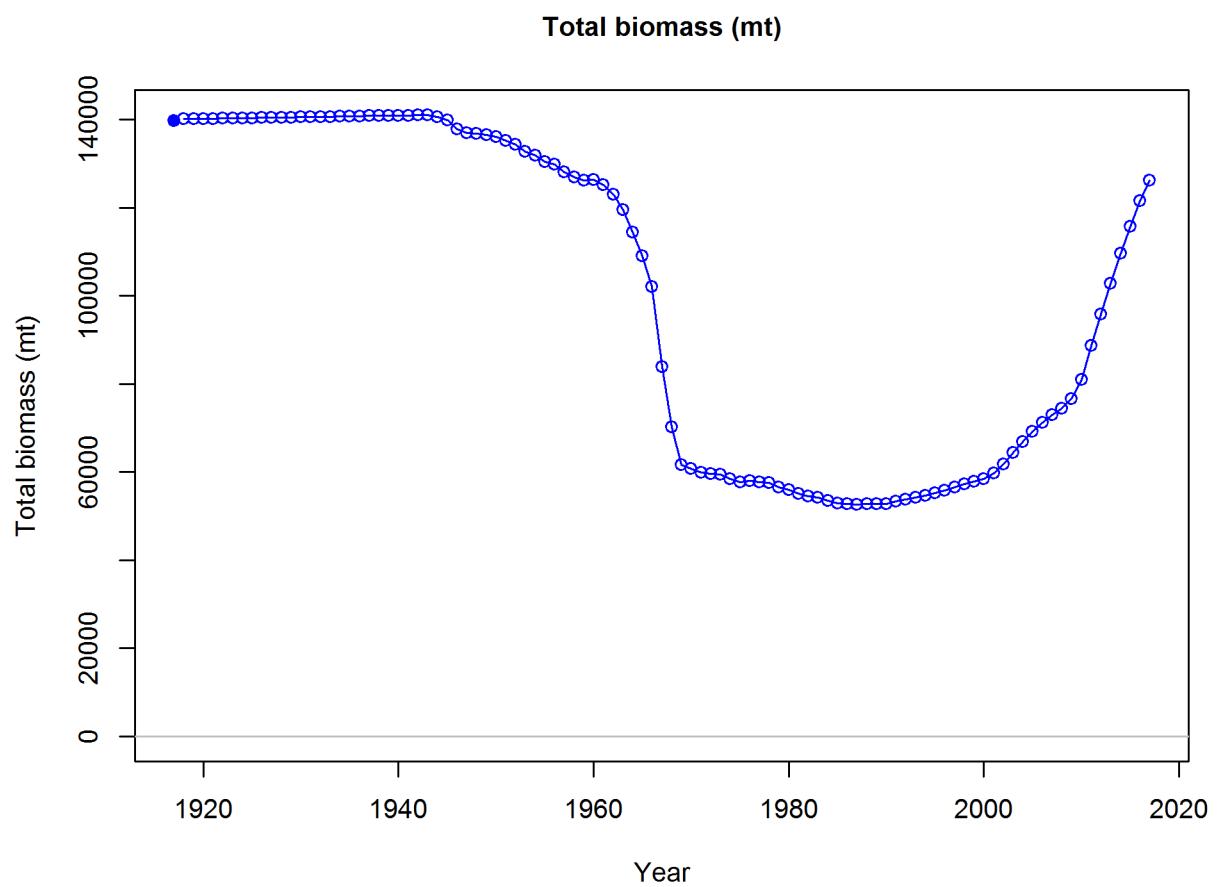


Figure 75: Estimated time-series of total biomass for Pacific ocean perch.

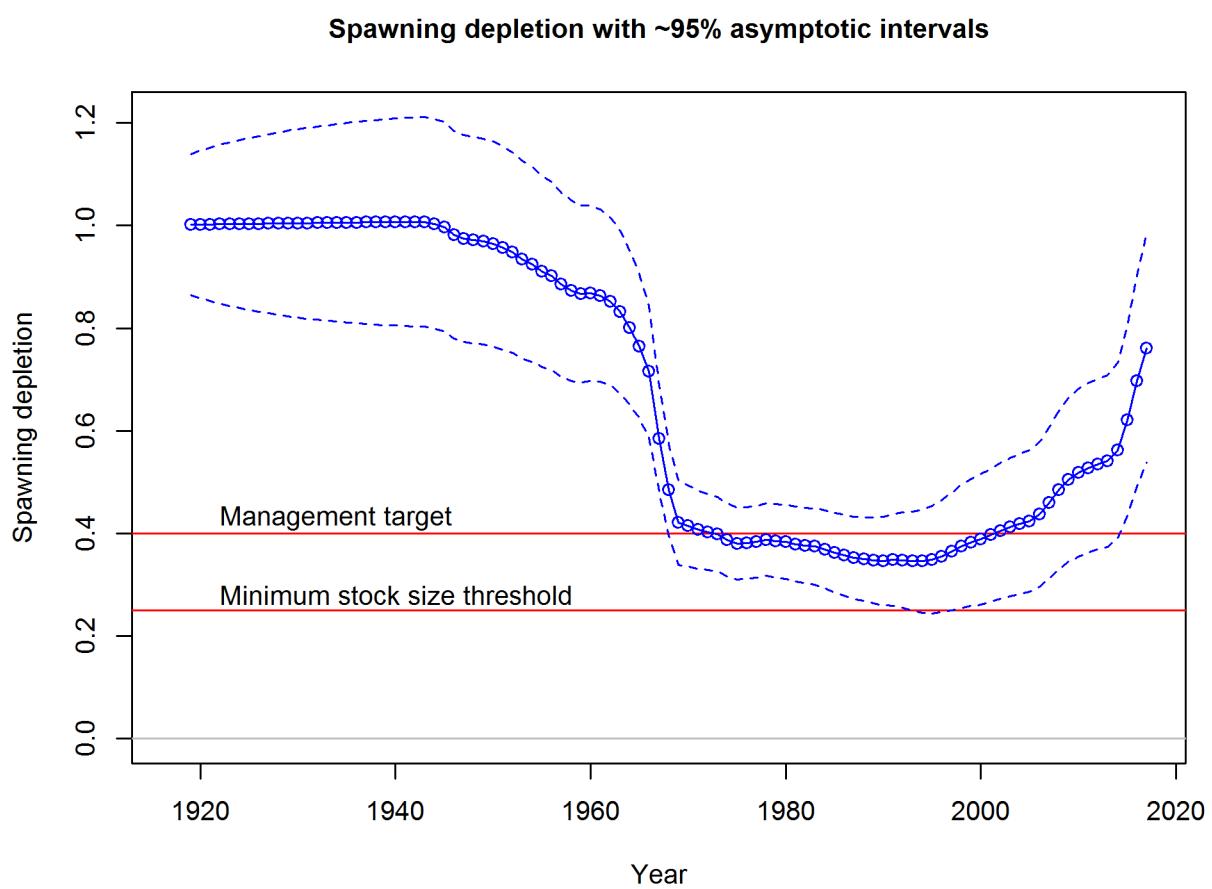


Figure 76: Estimated time-series of relative biomass for Pacific ocean perch.

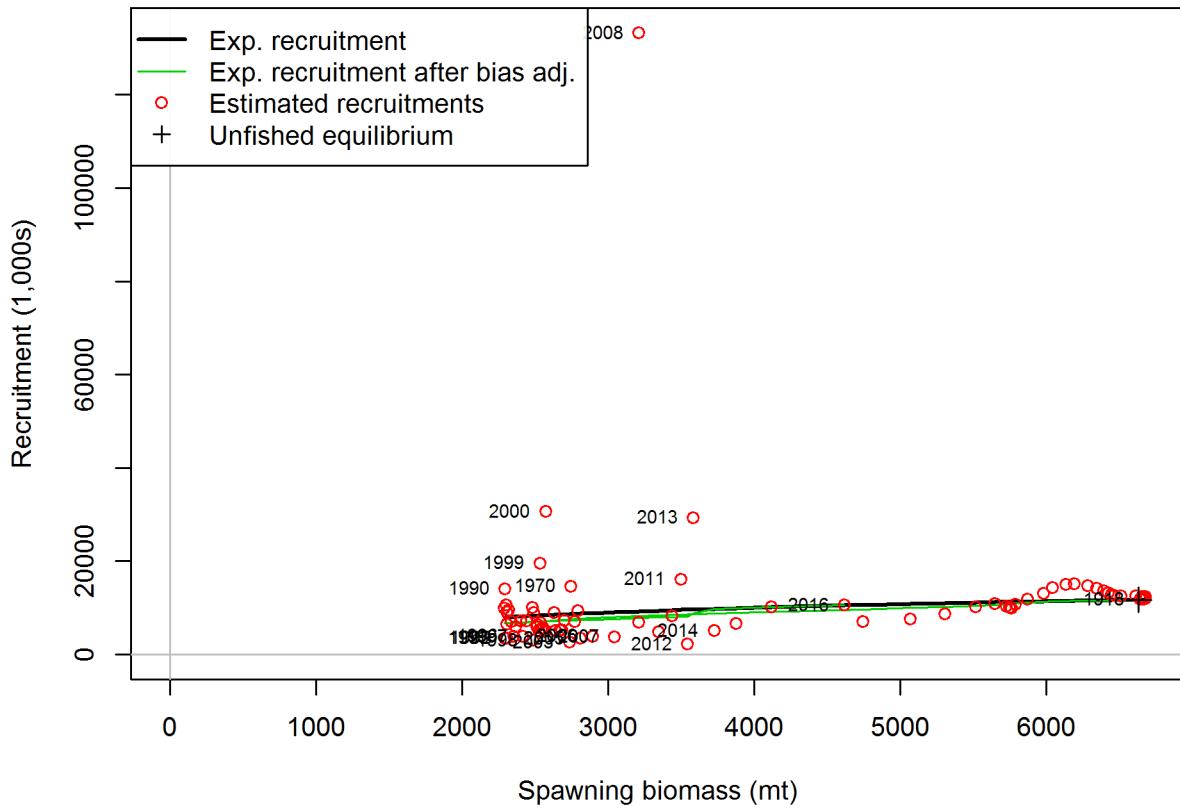


Figure 77: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution

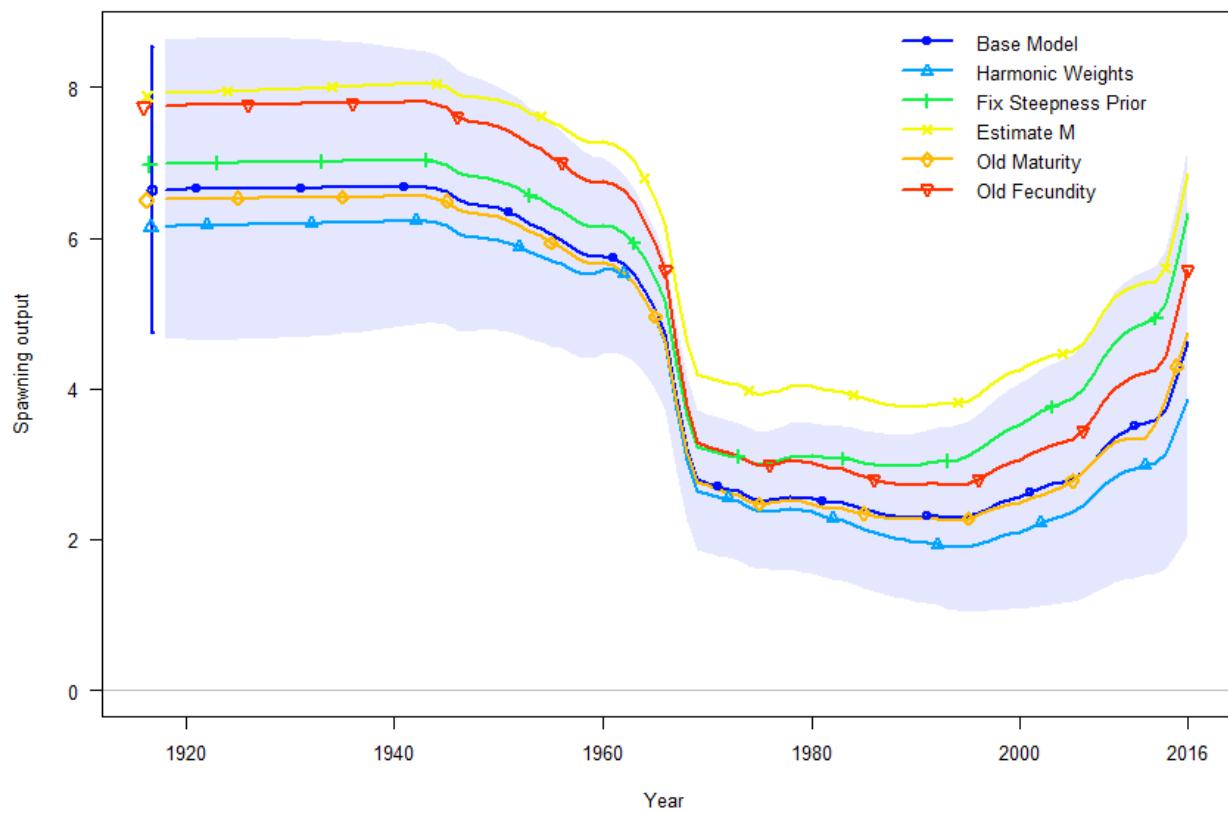


Figure 78: Time-series of spawning output for model sensitivities for Pacific ocean perch.

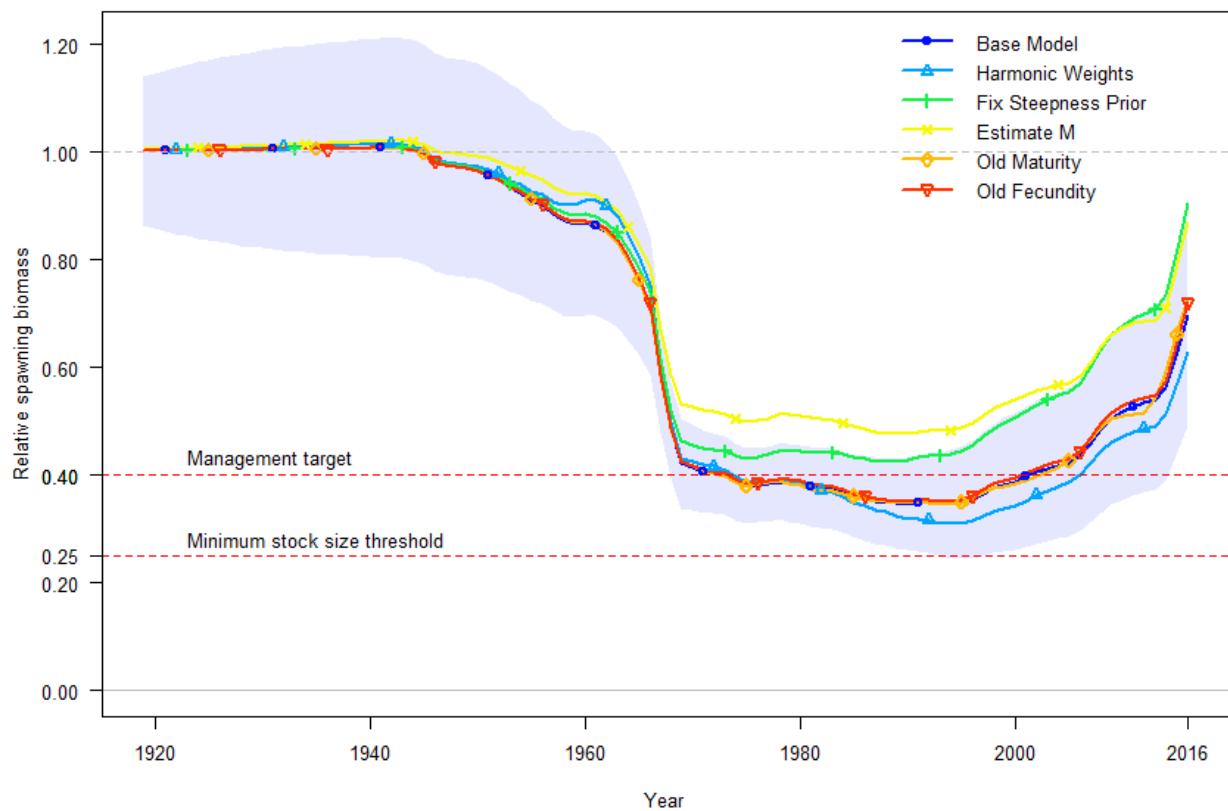


Figure 79: Time-series of relative biomass for model sensitivities for Pacific ocean perch.

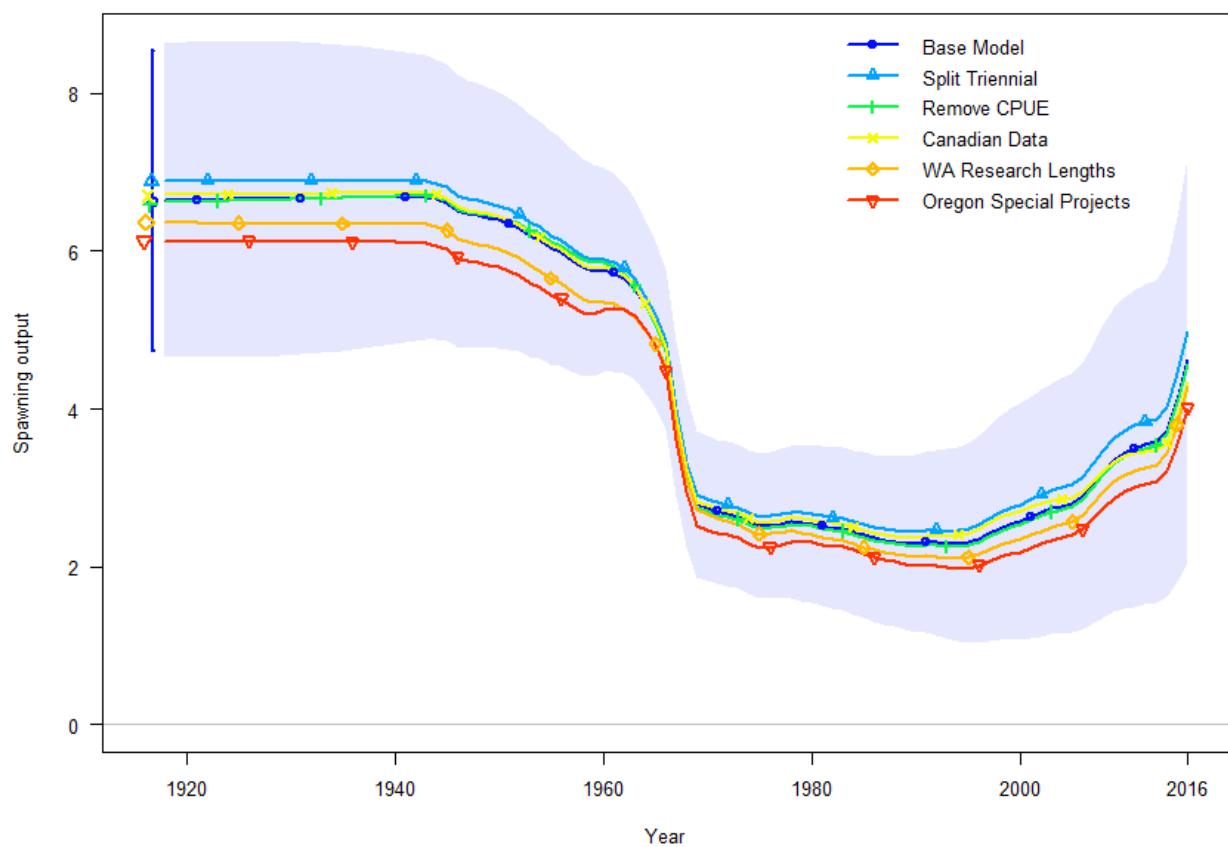


Figure 80: Time-series of spawning output for model sensitivities for Pacific ocean perch.

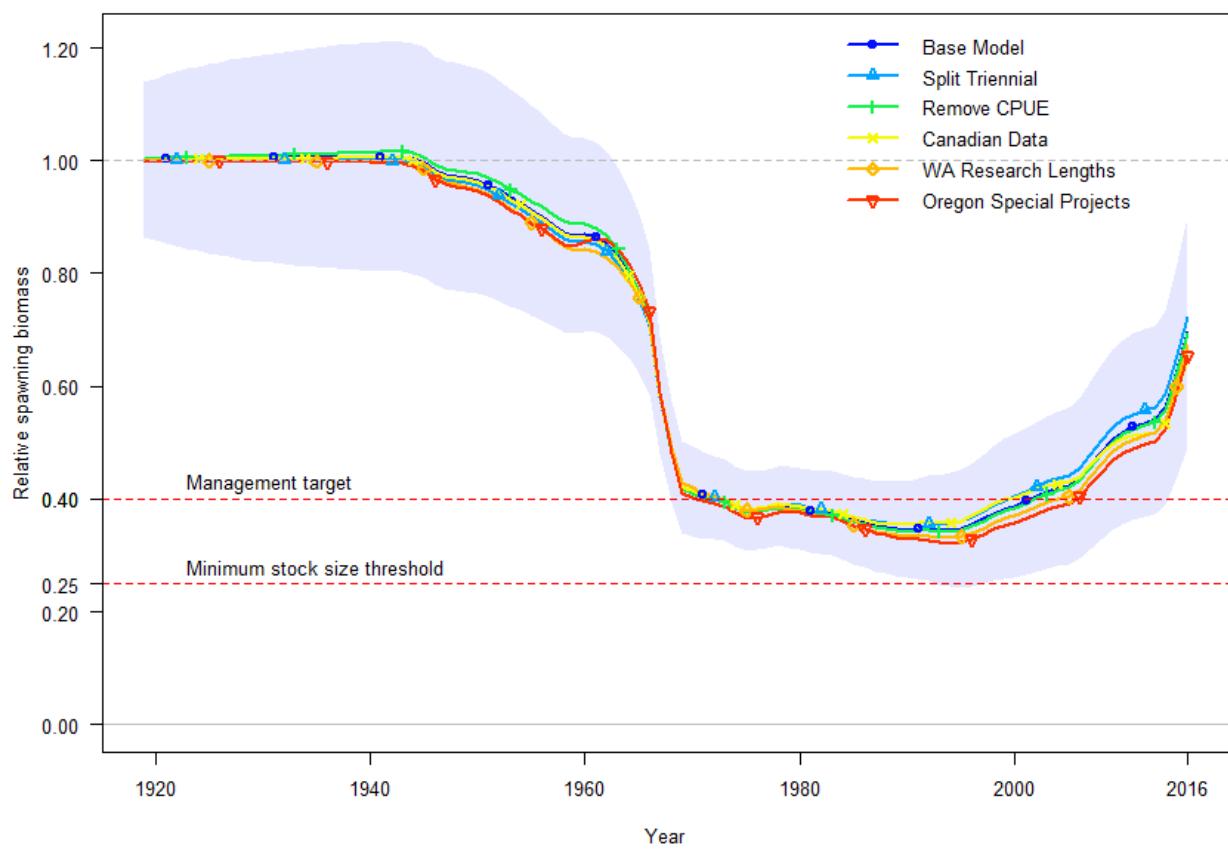


Figure 81: Time-series of relative biomass for model sensitivities for Pacific ocean perch.

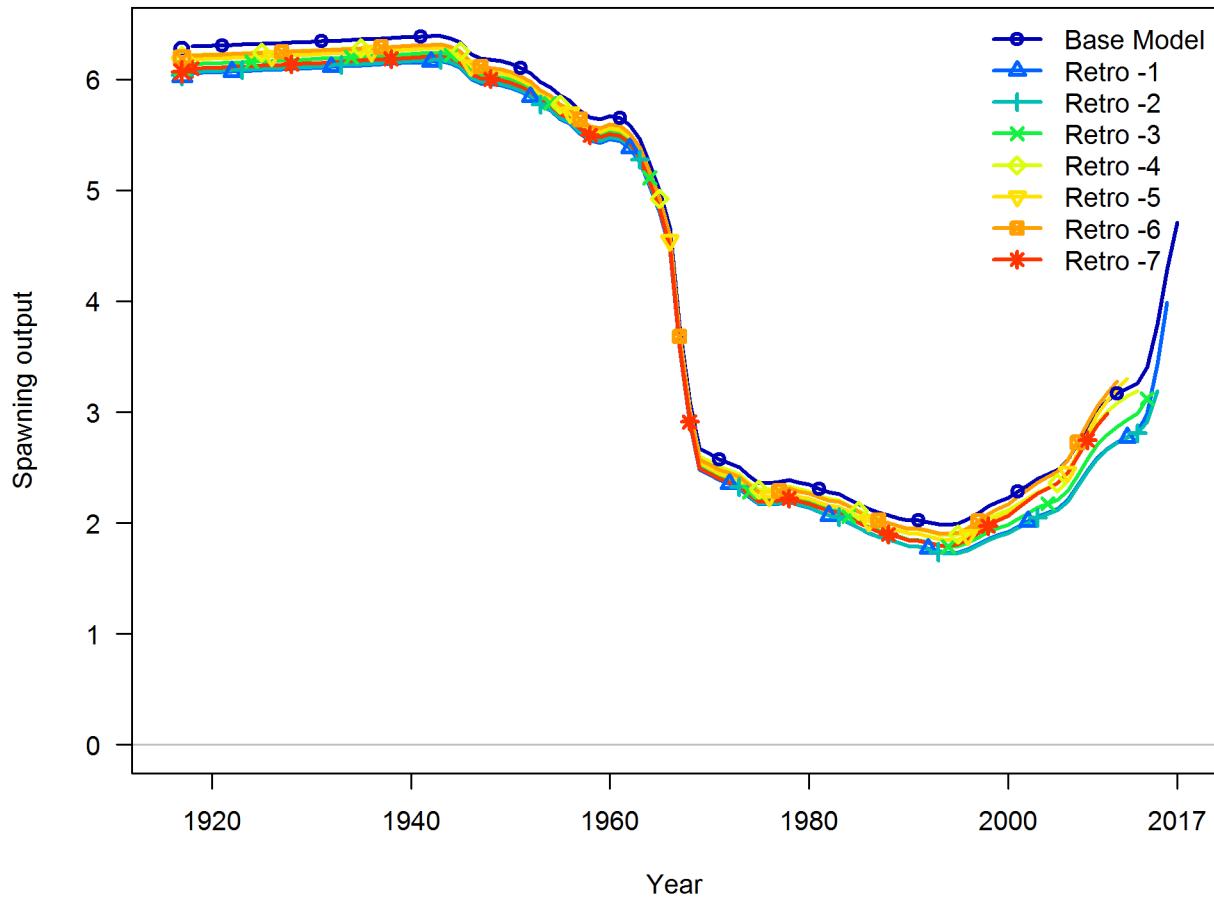


Figure 82: Retrospective pattern for spawning output.

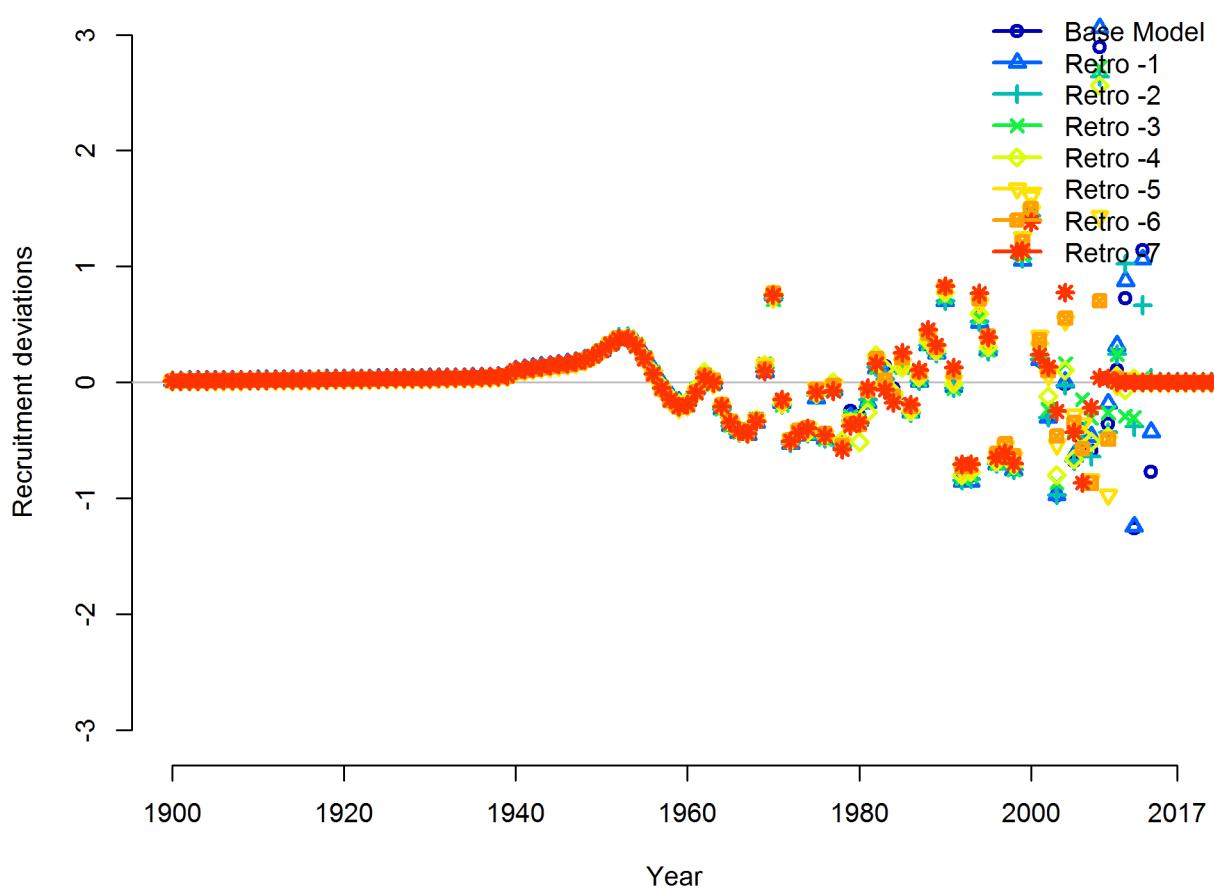


Figure 83: Retrospective pattern for estimated recruitment deviations.

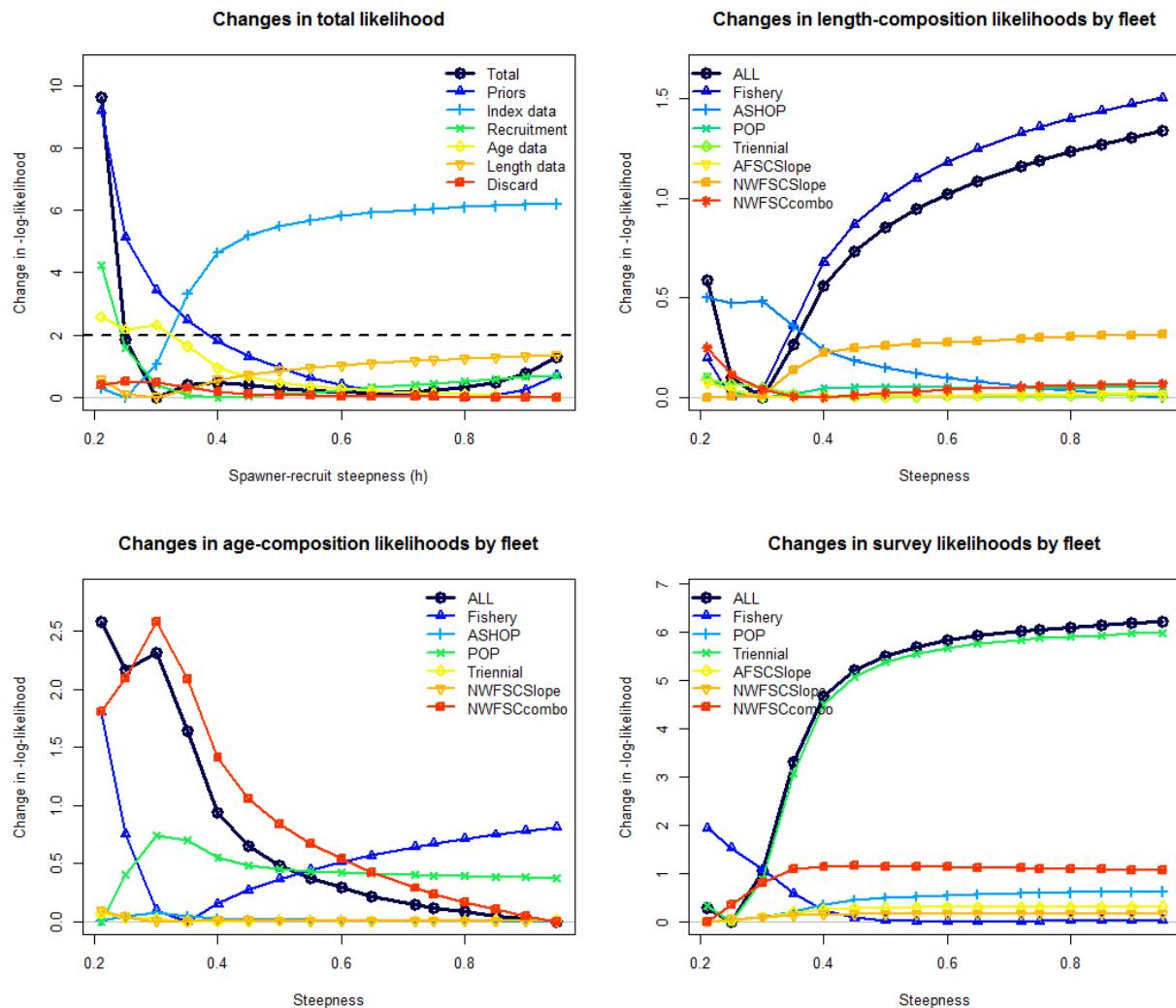


Figure 84: Likelihood profile across steepness values.

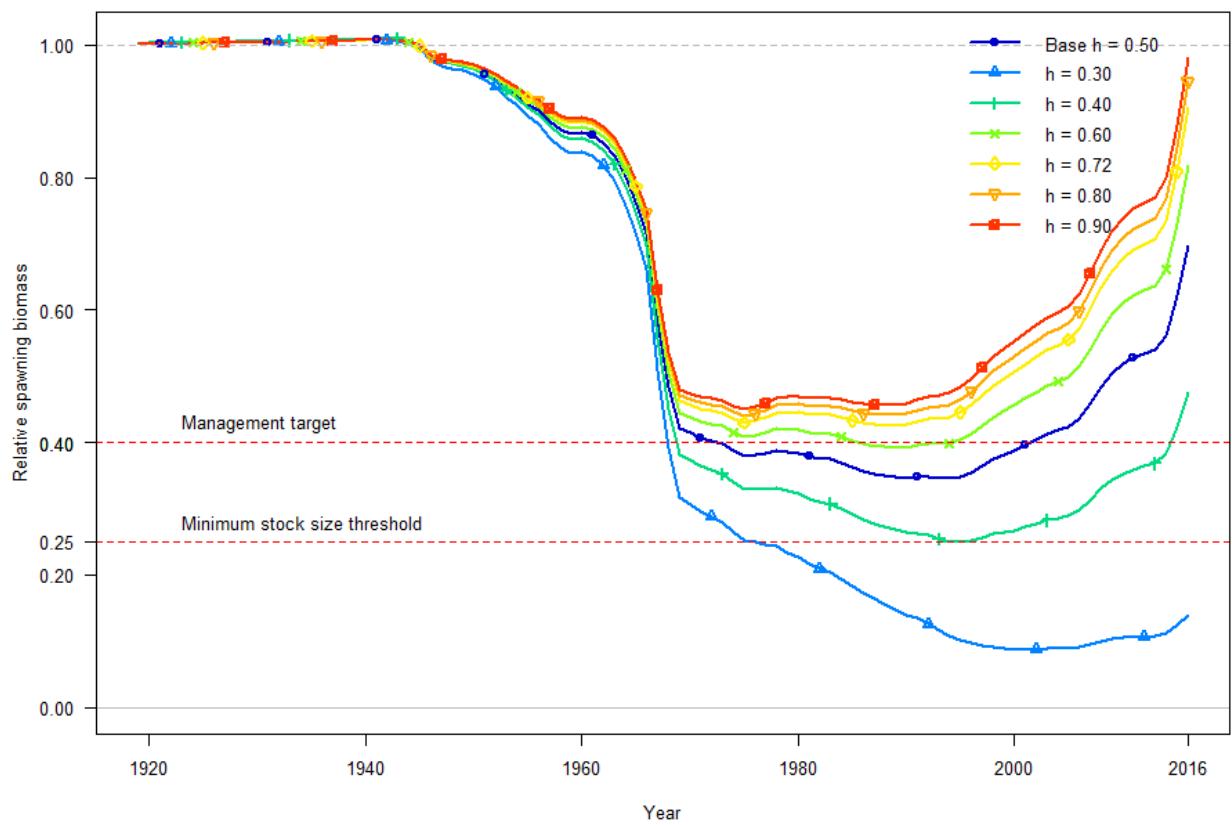


Figure 85: Trajectories of relative biomass across values of steepness.

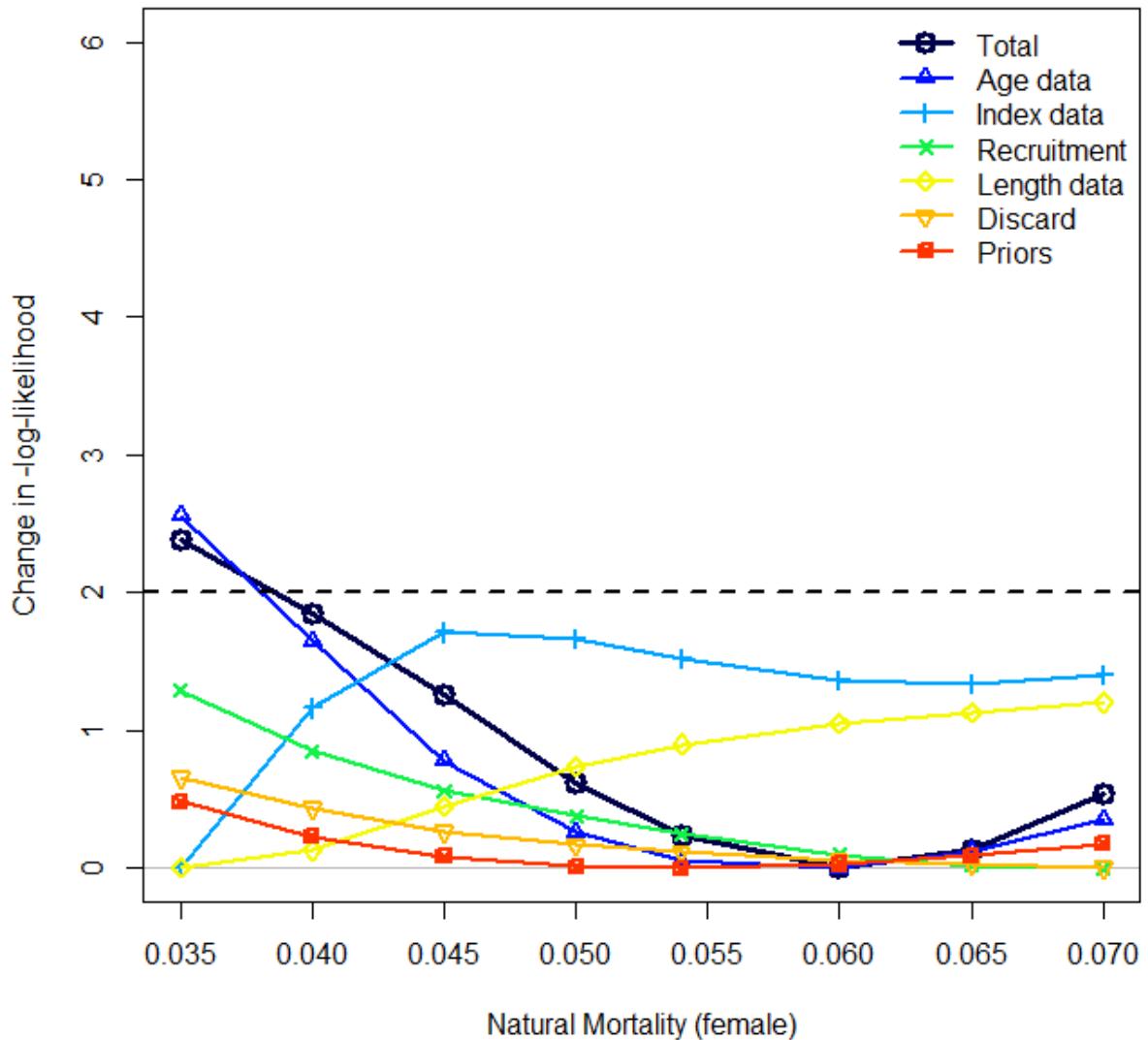


Figure 86: Likelihood profile across natural mortality values.

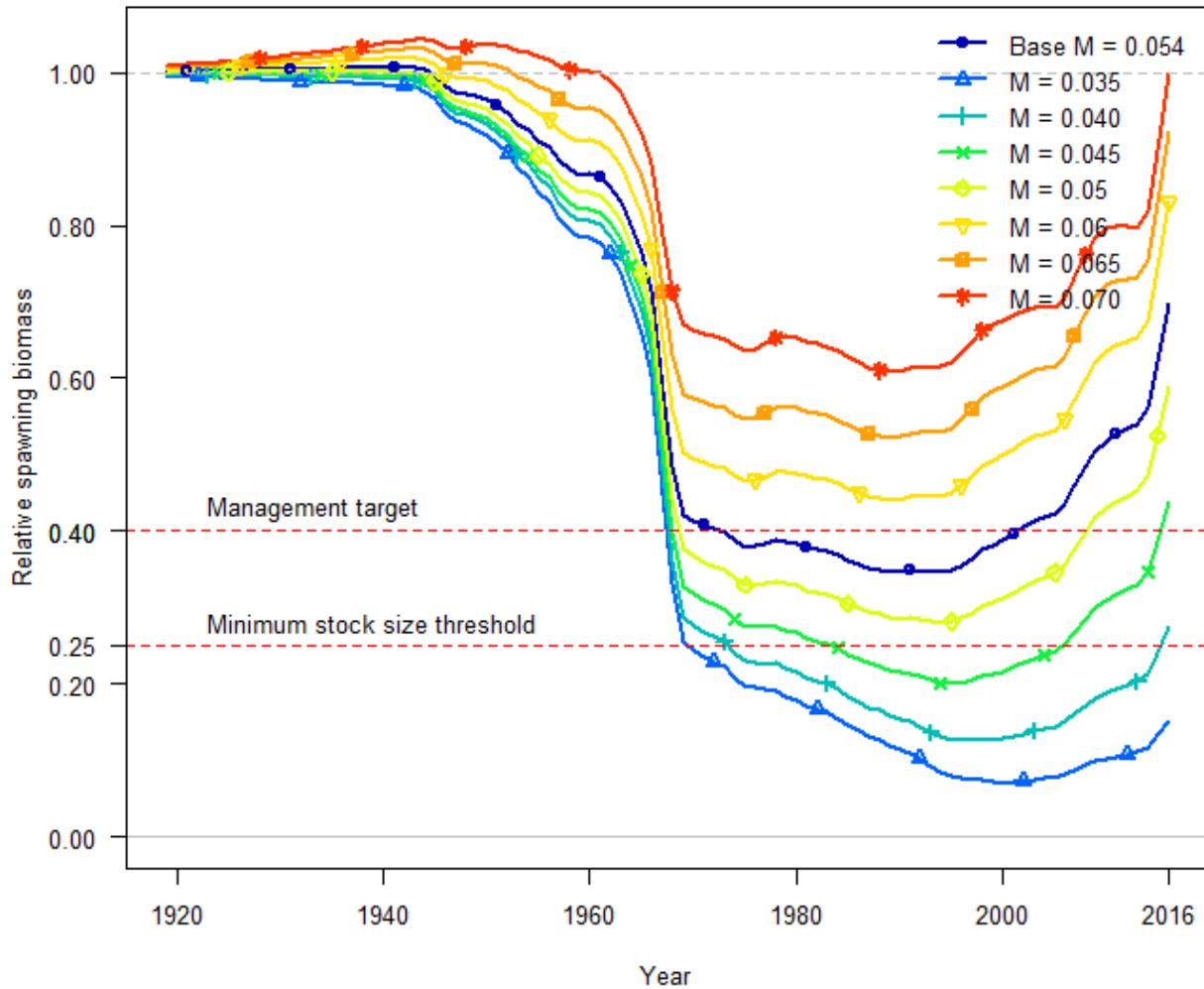


Figure 87: Trajectories of relative biomass across values of natural mortality.

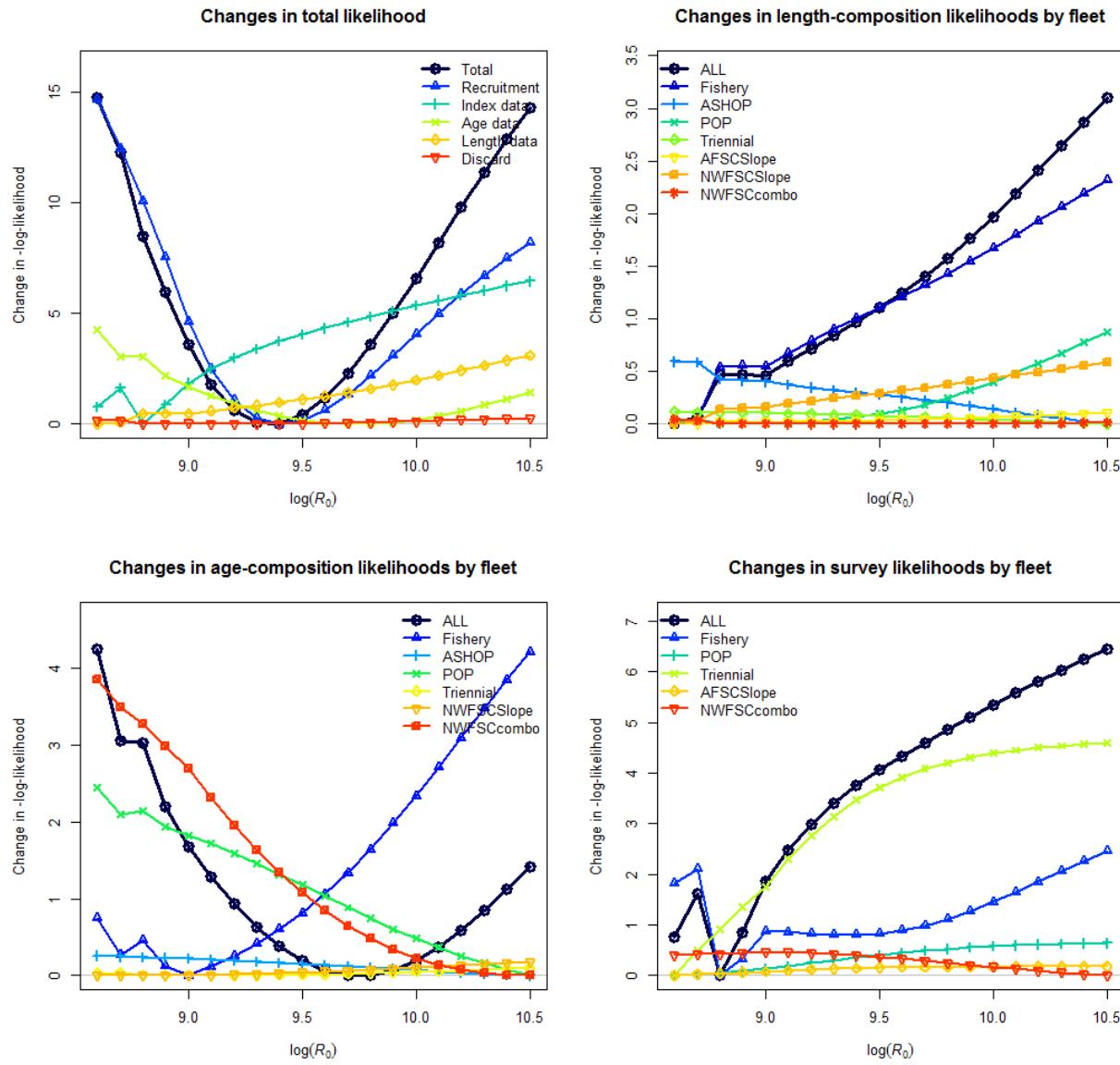


Figure 88: Likelihood profile across  $R_0$  values.

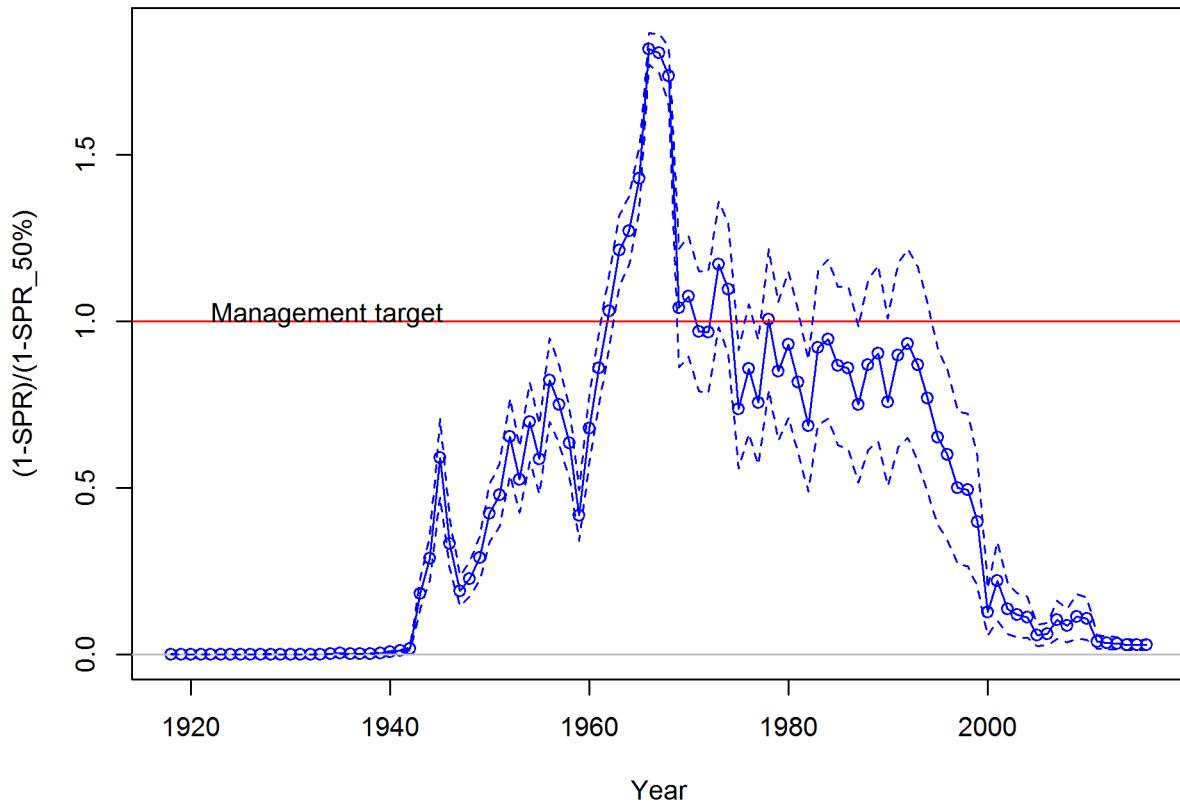


Figure 89: Estimated spawning potential ratio  $(1-SPR)/(1-SPR_{50\%})$  for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR50% harvest rate. The last year in the time series is 2016.

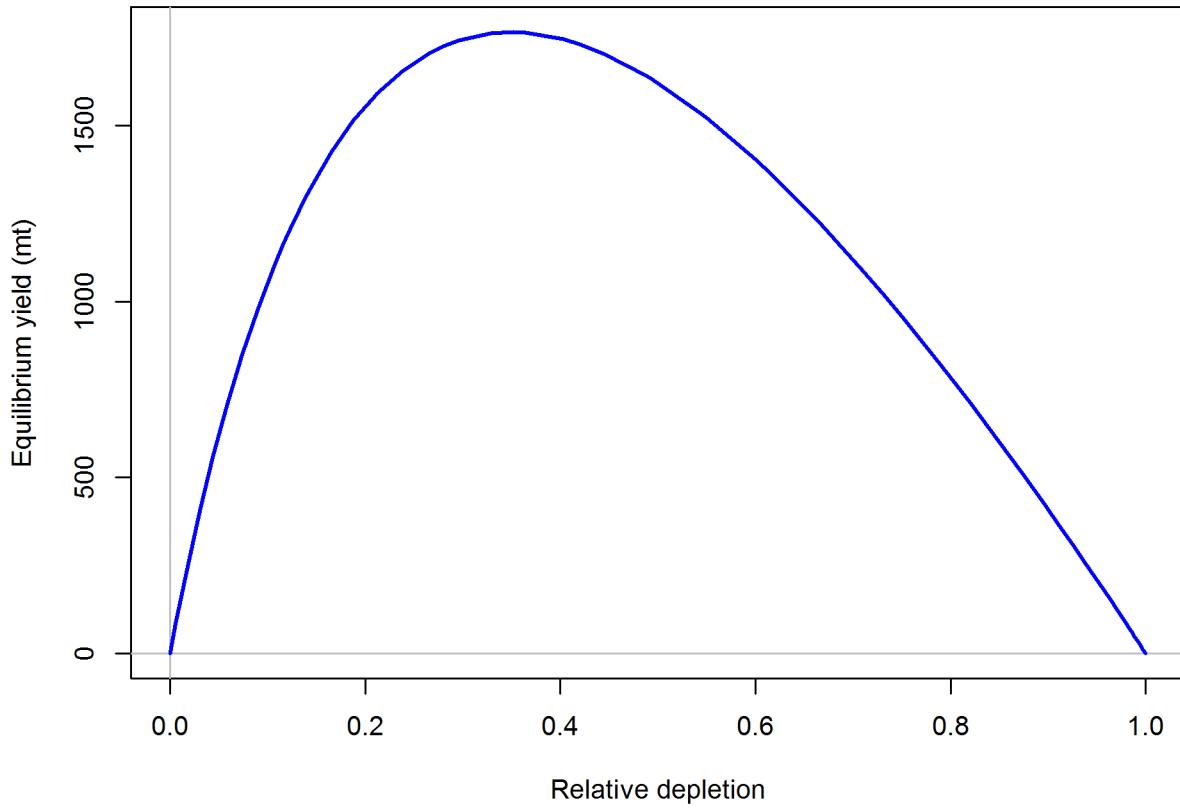


Figure 90: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.50.

<sub>1277</sub> 10 Appendix A. Detailed Fit to Length Composition  
<sub>1278</sub> Data

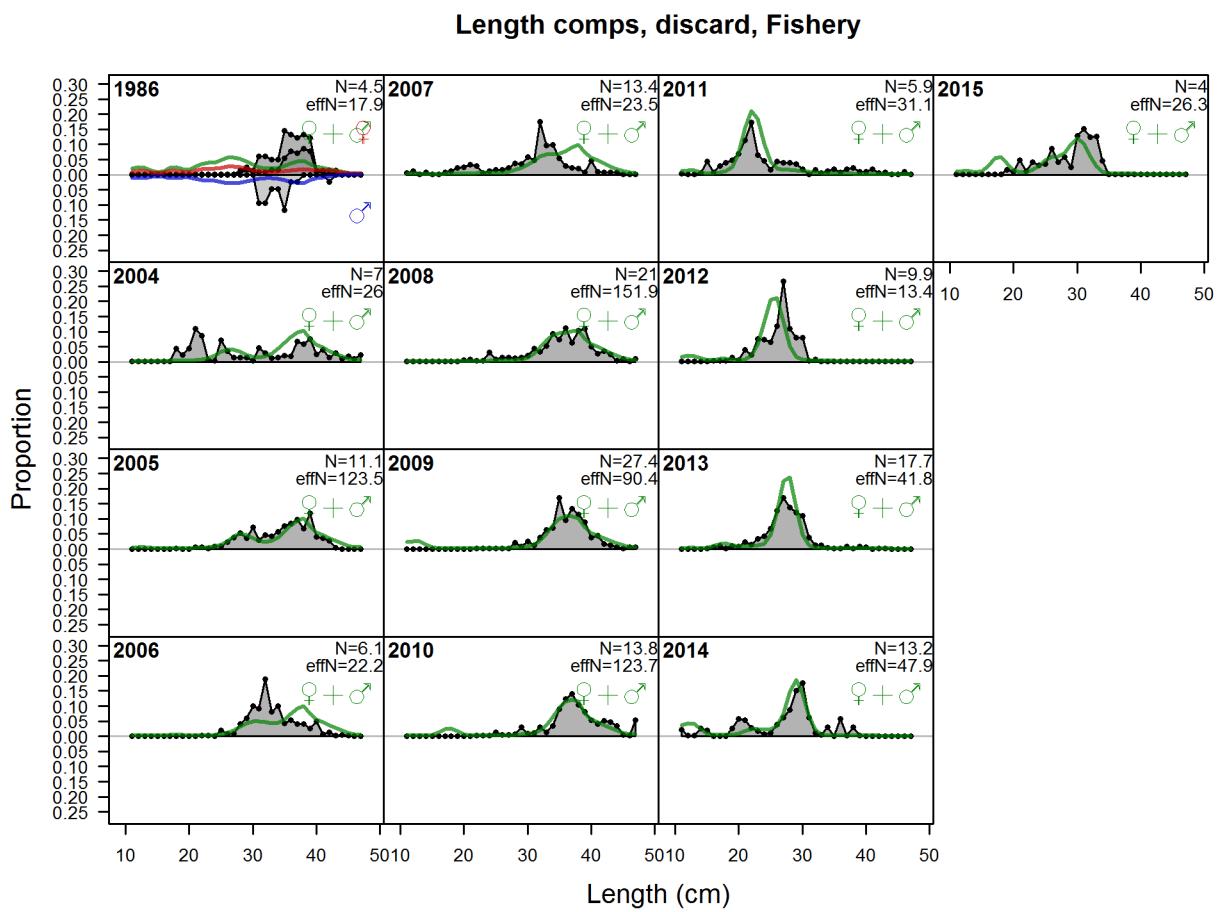


Figure 91: Length comps, discard, Fishery

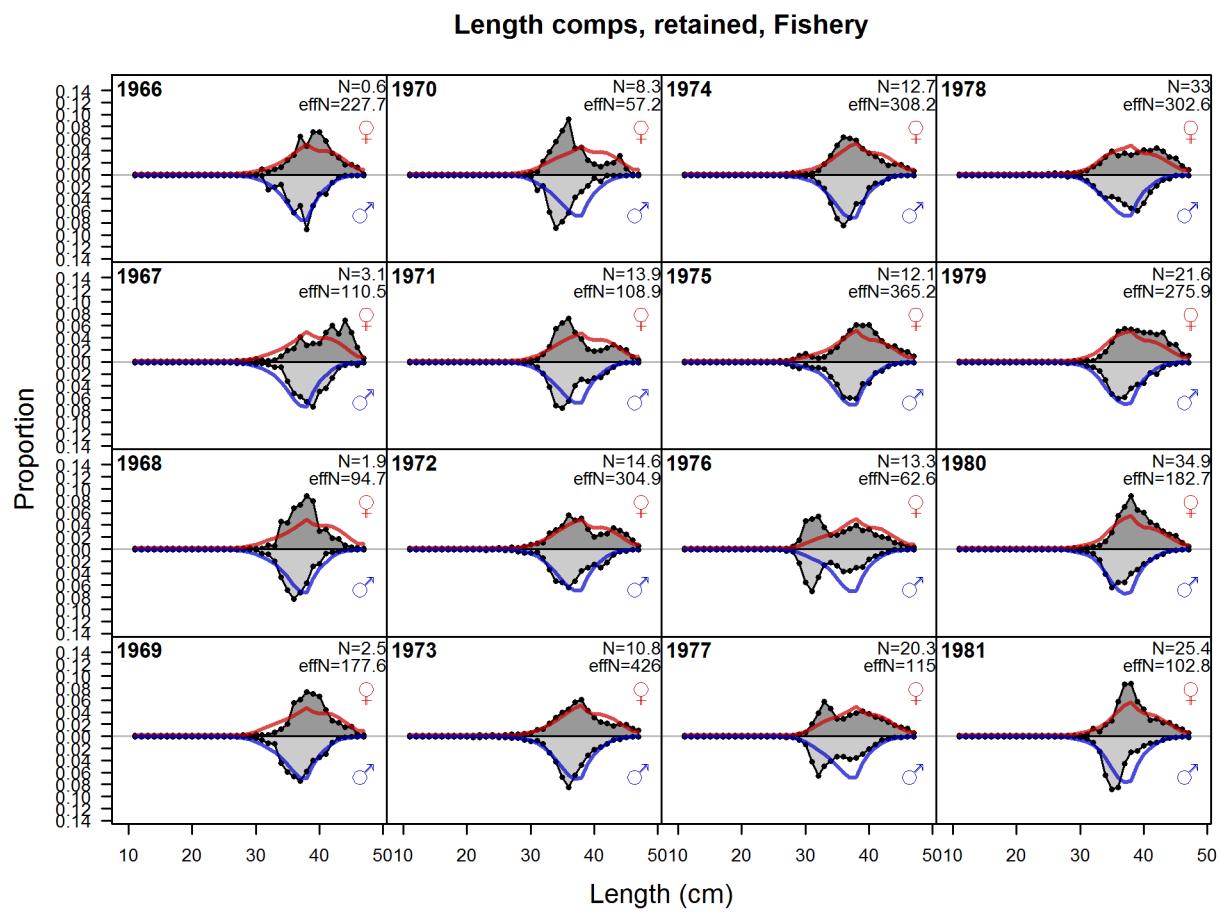


Figure 92: Length comps, retained, Fishery (plot 1 of 4)

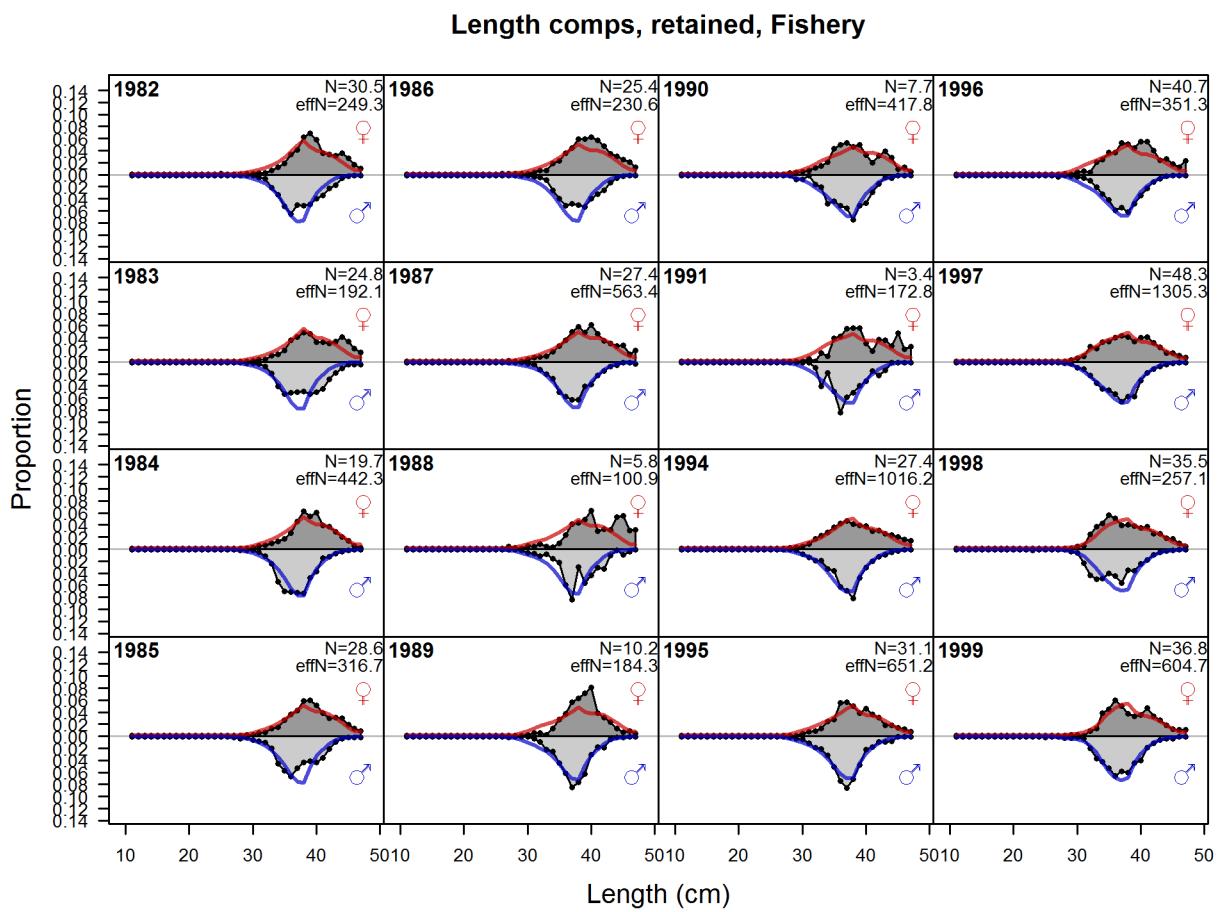


Figure 93: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4)

### Length comps, retained, Fishery

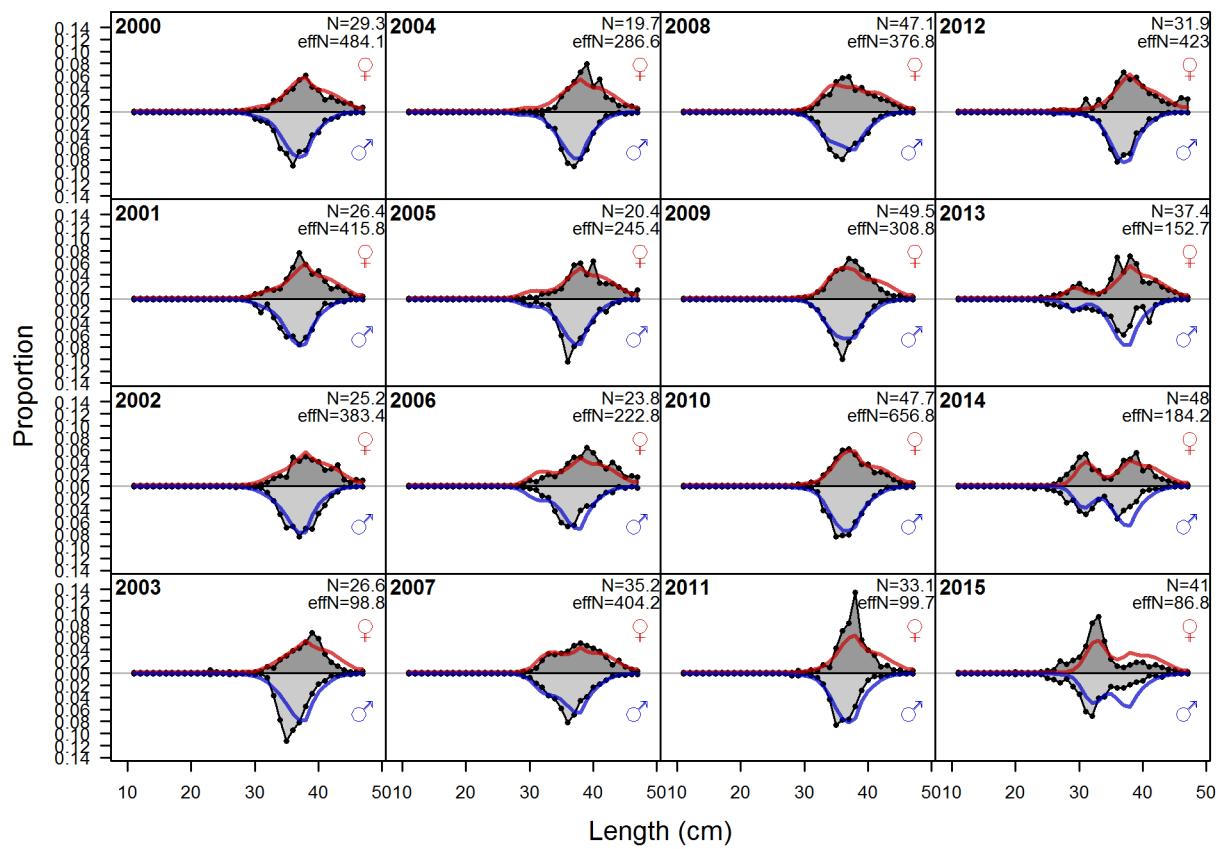


Figure 94: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4) (plot 3 of 4)

Proportion

### Length comps, retained, Fishery

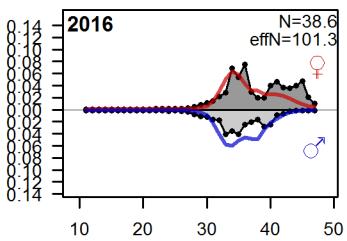


Figure 95: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4) (plot 3 of 4) (plot 4 of 4)

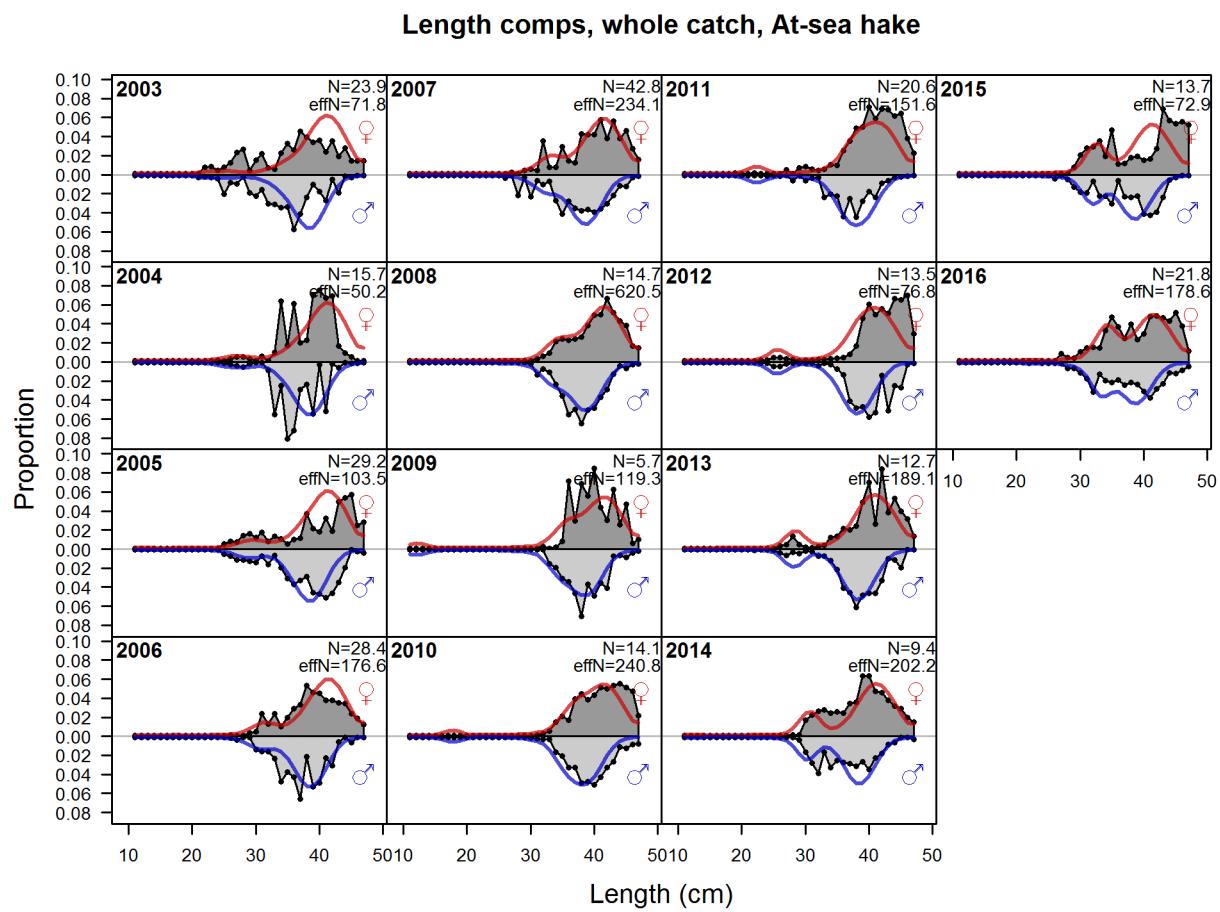


Figure 96: Length comps, whole catch, At\_sea hake

### Length comps, whole catch, Pacific ocean perch survey

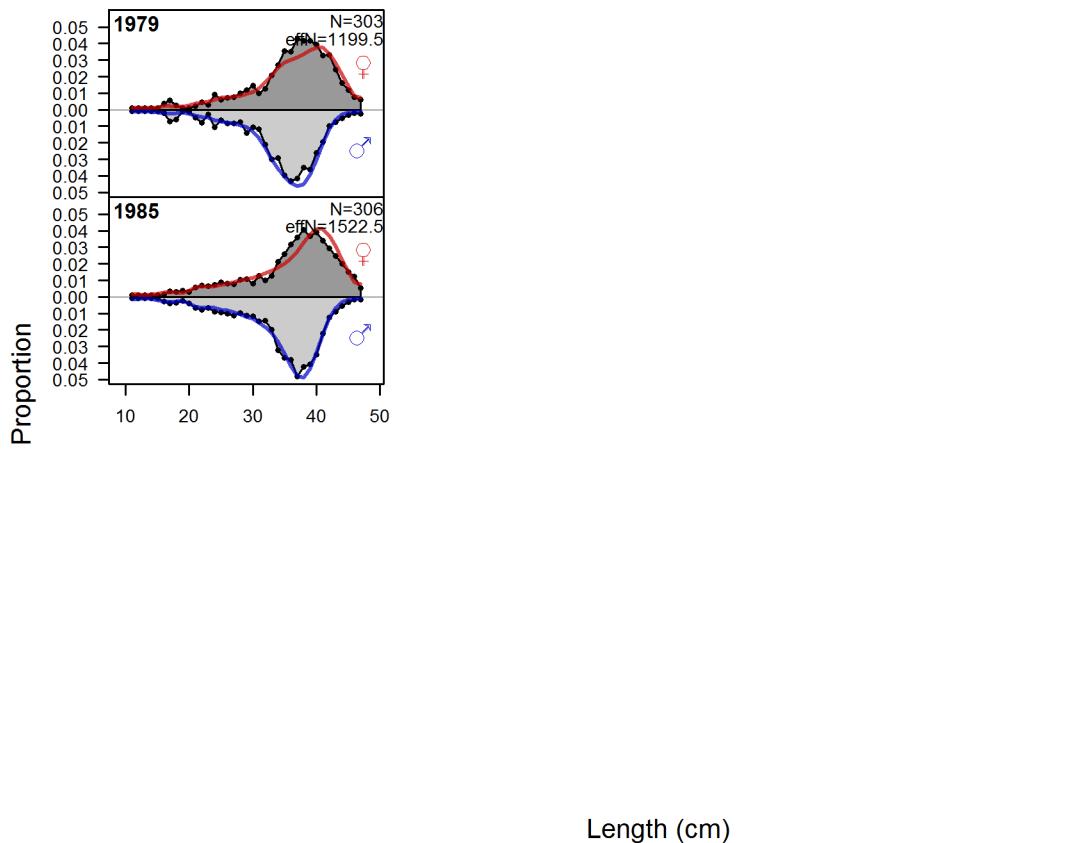


Figure 97: Length comps, whole catch, Pacific ocean perch survey

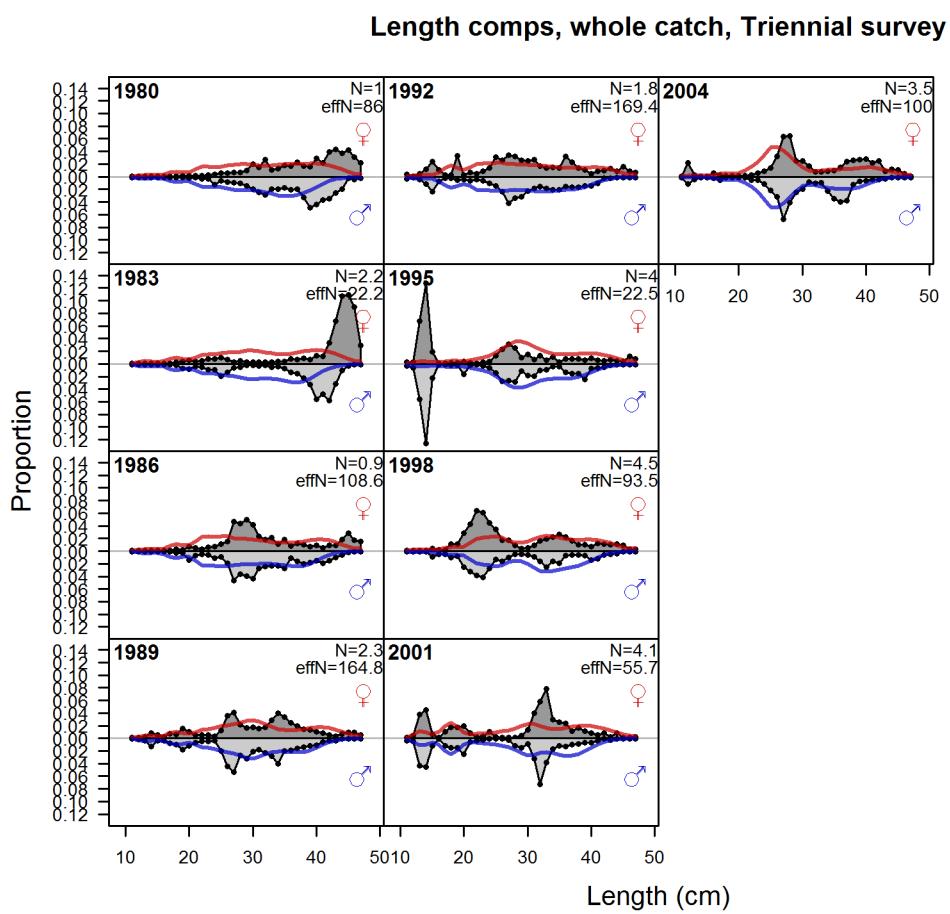


Figure 98: Length comps, whole catch, Triennial survey

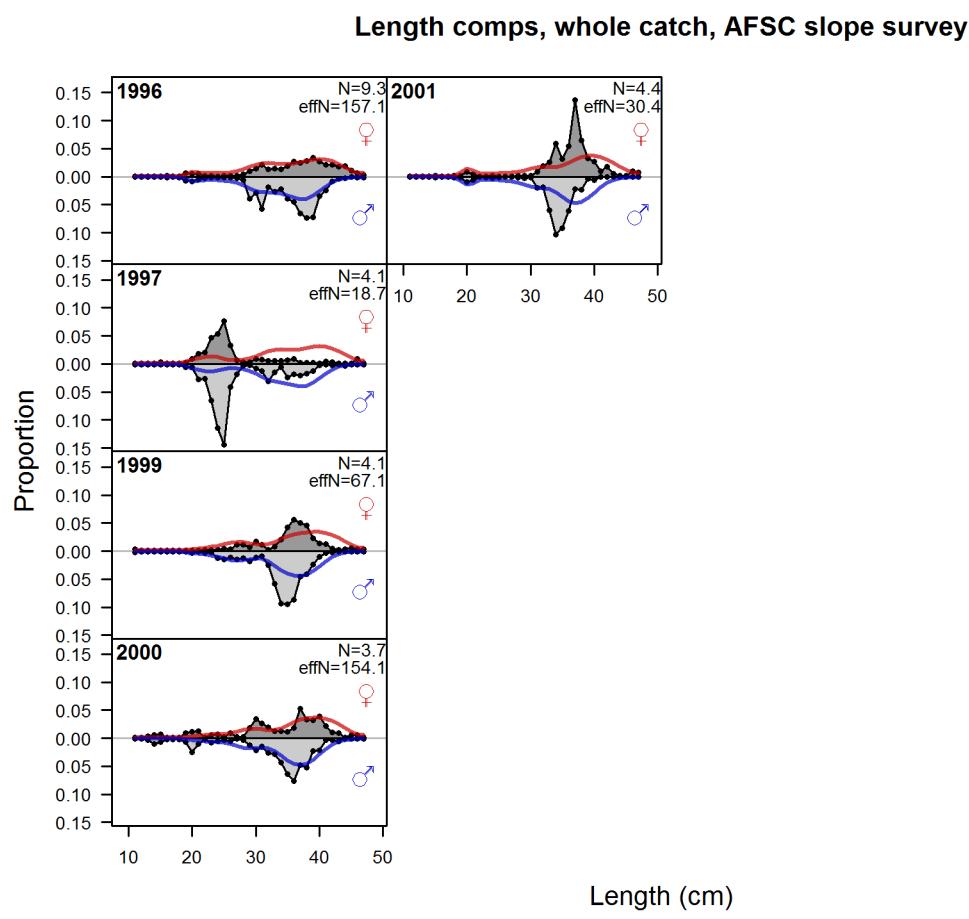


Figure 99: Length comps, whole catch, AFSC slope survey

### Length comps, whole catch, NWFSC slope survey

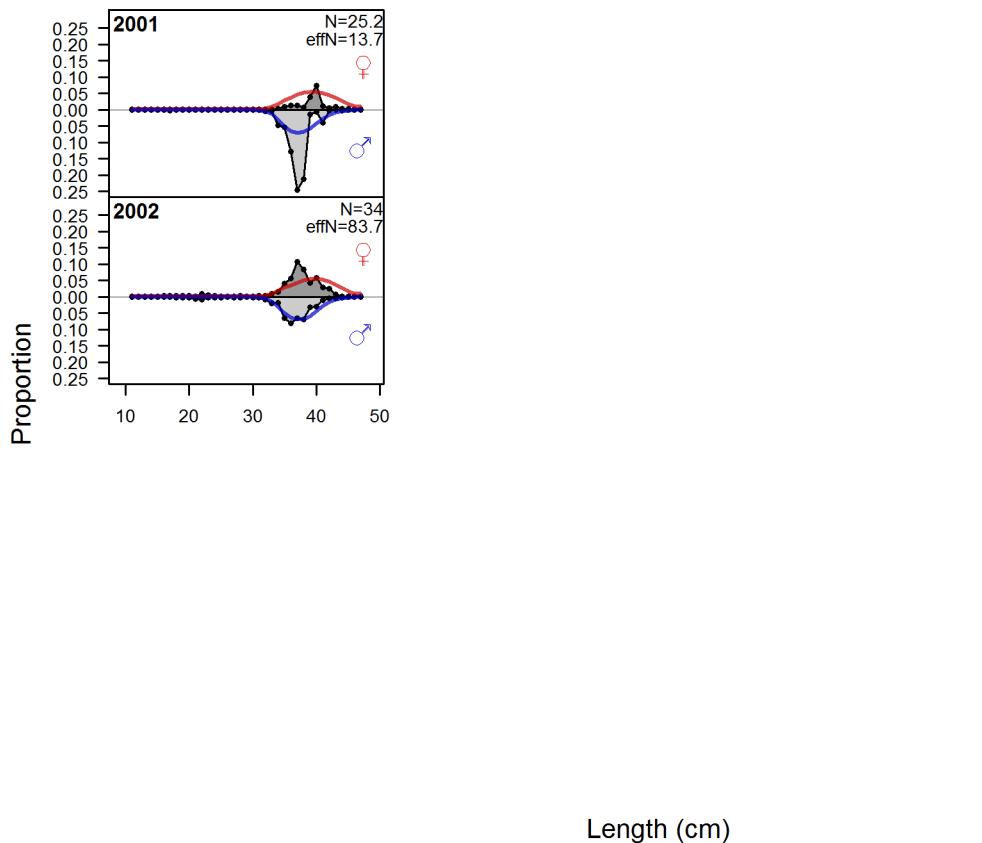


Figure 100: Length comps, whole catch, NWFSC slope survey

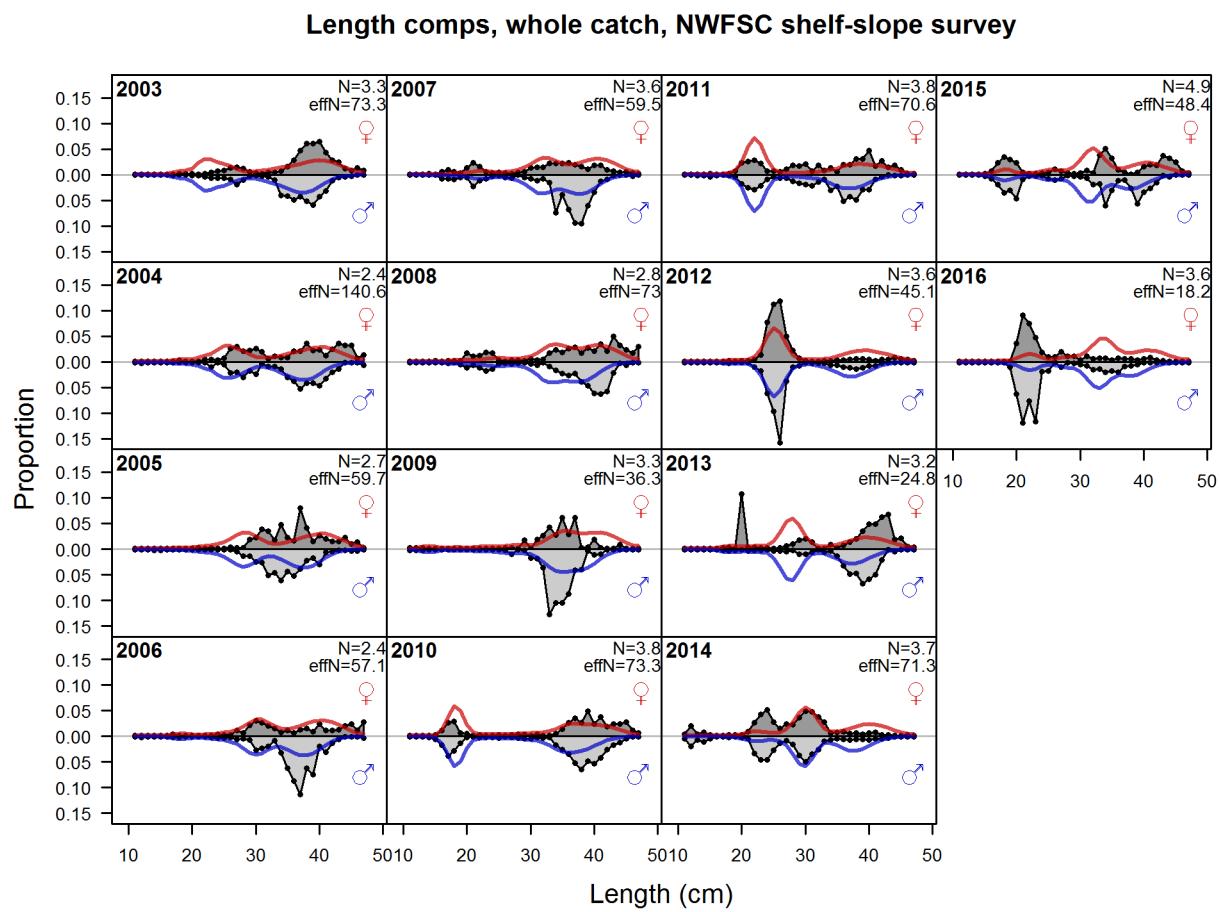


Figure 101: Length comps, whole catch, NWFSC shelf\_slope survey

<sup>1279</sup> 11 Appendix B. Detailed Fit to Age Composition Data

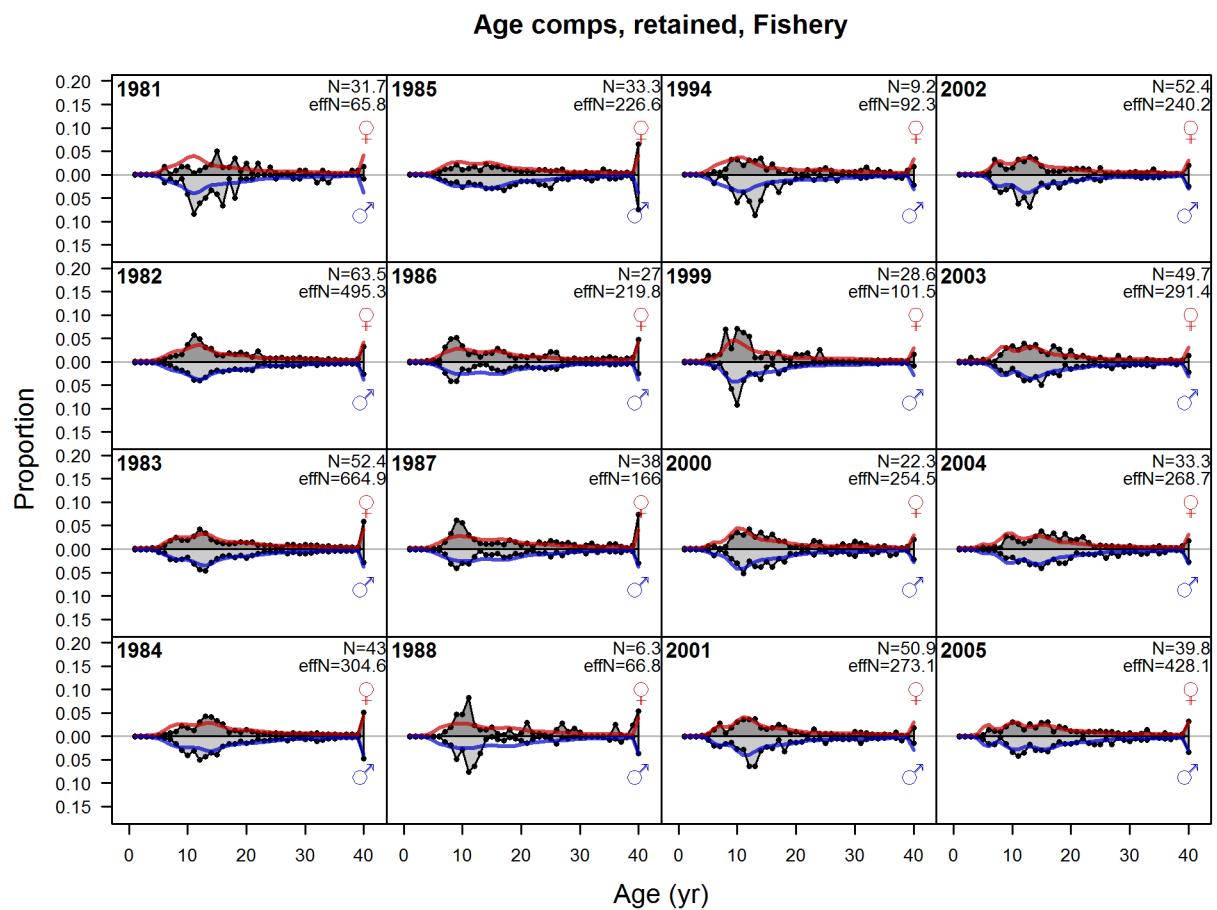


Figure 102: Age comps, retained, Fishery (plot 1 of 2)

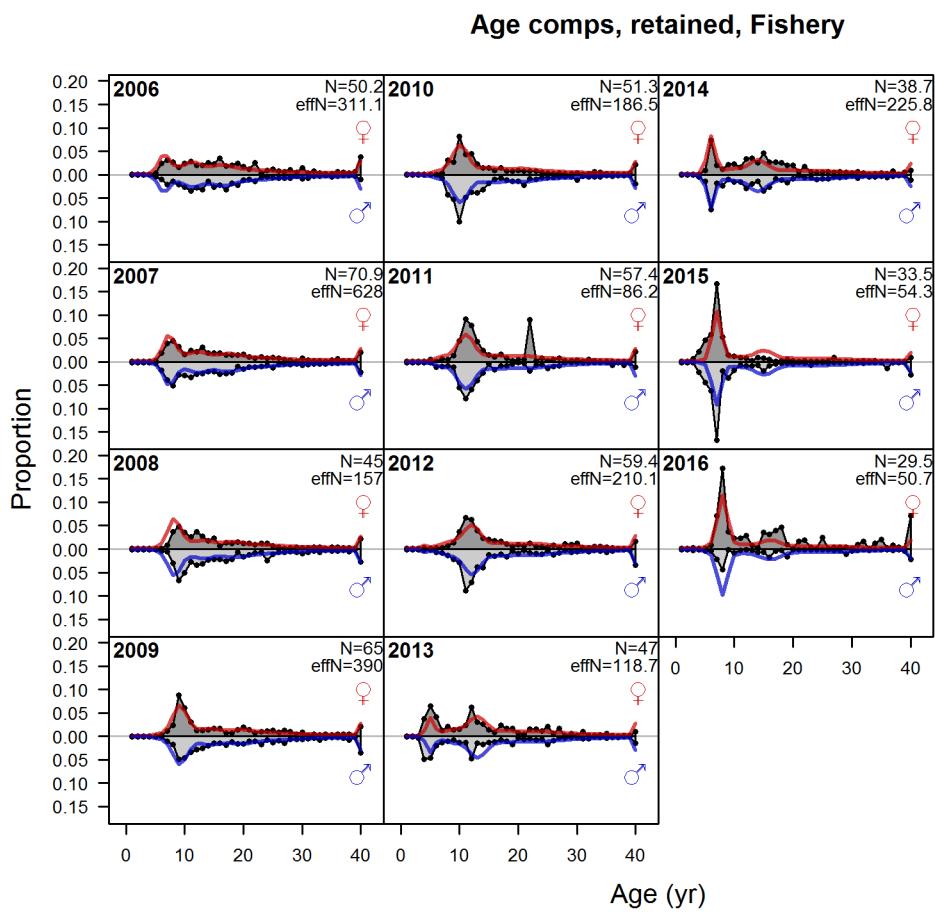


Figure 103: Age comps, retained, Fishery (plot 1 of 2) (plot 2 of 2)

### Age comps, whole catch, At-sea hake

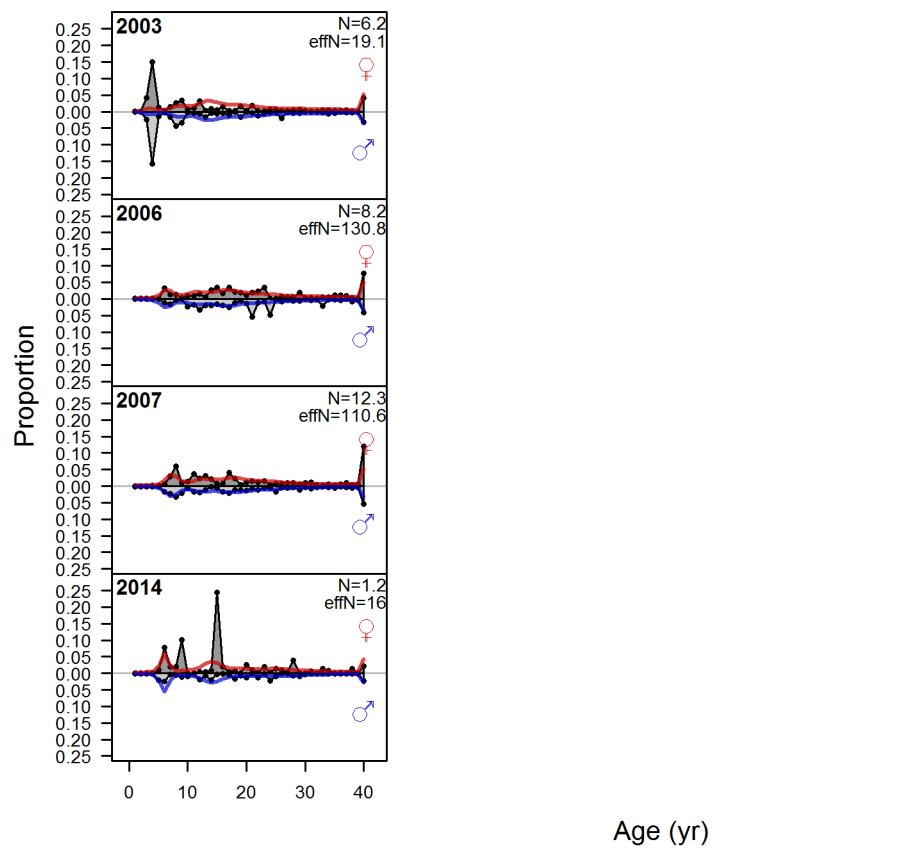


Figure 104: Age comps, whole catch, At\_sea hake

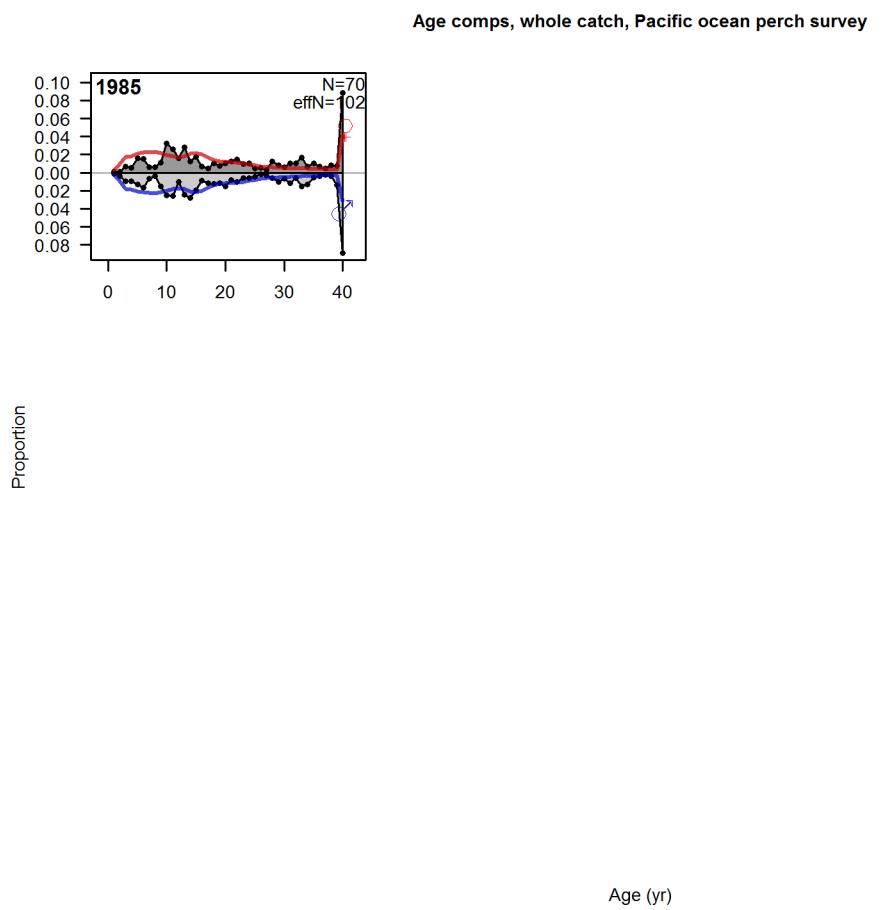


Figure 105: Age comps, whole catch, Pacific ocean perch survey

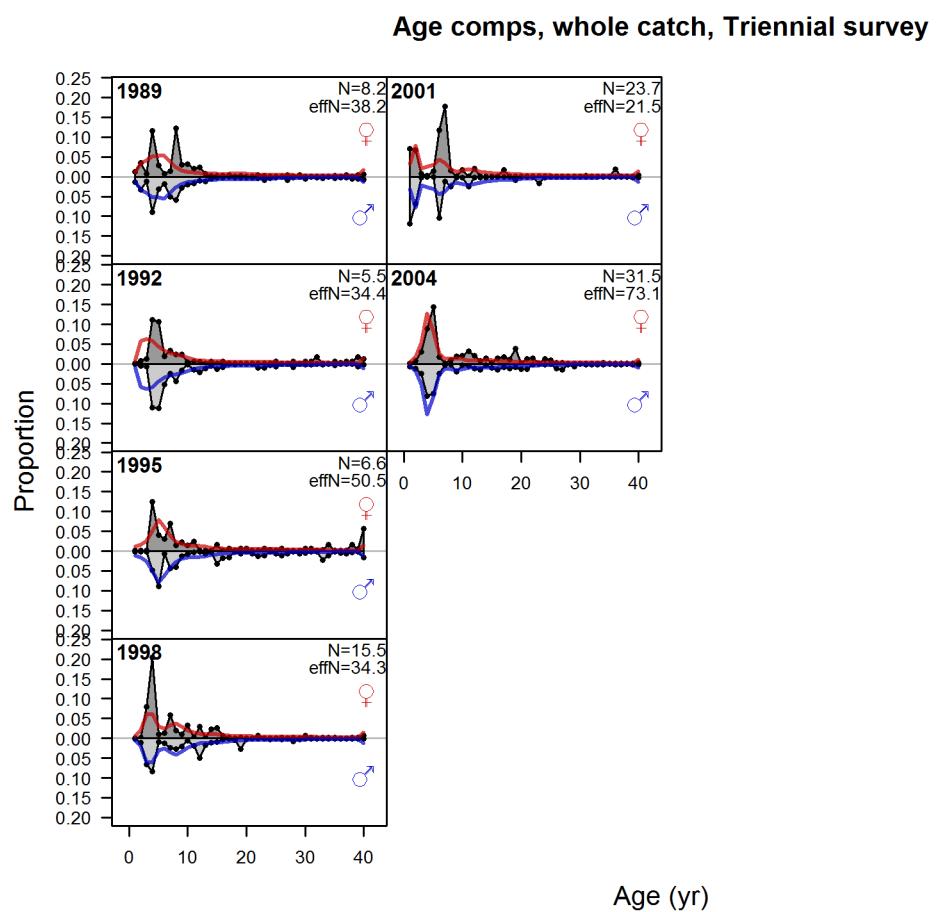


Figure 106: Age comps, whole catch, Triennial survey

### Age comps, whole catch, NWFSC slope survey

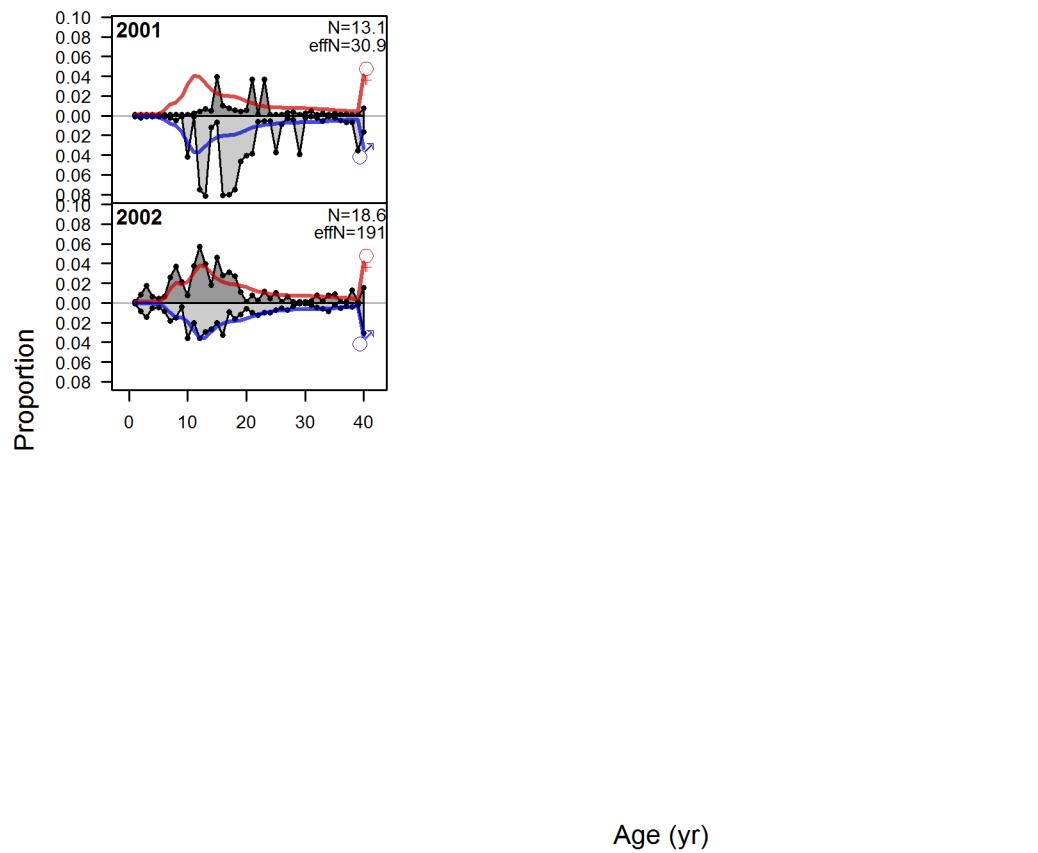


Figure 107: Age comps, whole catch, NWFSC slope survey

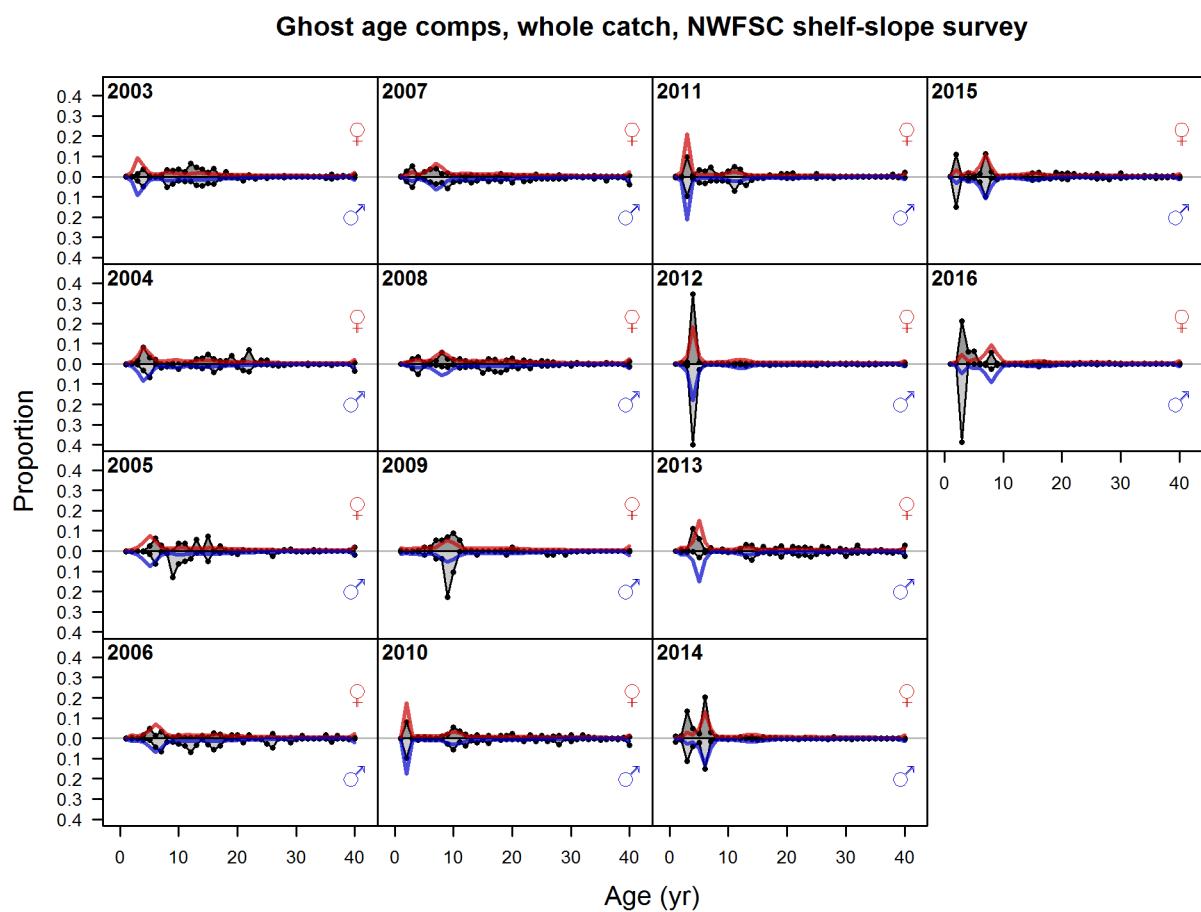


Figure 108: Ghost age comps, whole catch, NWFSC shelf\_slope survey

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