

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

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⁸⁷ Executive Summary

executive-summary

⁸⁸ Stock

stock

⁸⁹ This assessment reports the status of the Pacific ocean perch (*Sebastes alutus*) species off
⁹⁰ rockfish off the U.S. West Coast from Northern California to the Canadian Border using data
⁹¹ through 2017. Pacific ocean perch are most abundant in the Gulf of Alaska and have observed
⁹² off of Japan, in the Bering Sea, and south to Baja California, although they are sparse south
⁹³ of Oregon and rare in southern California. Although catches north of the US-Canada border
⁹⁴ were not included in this assessment, it is not certain the connectivity of these populations
⁹⁵ with contribution to the biomass possibly through adult migration and/or larval dispersion.
⁹⁶ Composition data indicate that good recruitment years coincide in Oregon and Washington.
⁹⁷ To date, no significant genetic differences have been found in the range covered by this
⁹⁸ assessment.

⁹⁹ Landings

landings

¹⁰⁰ The first year that harvest of Pacific ocean perch exceeded 1 mt off the US West Coast
¹⁰¹ first occurred in 1929. Catches ramped up in the 1940s with large removals in Washington
¹⁰² waters. During the 1950s the removals primary occurred in Oregon waters with catches from
¹⁰³ Washington declining following the 1940s. The largest removals in 1966-1968 were largely a
¹⁰⁴ result of harvest by foreign vessels. The fishery proceed with more moderate removals ranging
¹⁰⁵ between 1,200 to 2,600 metric tons per year between 1969 to 1980. Removals generally
¹⁰⁶ declined from 1981 to 1994 to between 1,000 and 1,700 metric tons per year. Pacific ocean
¹⁰⁷ perch was declared overfished in 1999 resulting in large reduction in harvest in recent years
¹⁰⁸ since the declaration. Since 2000, catches of Pacific ocean perch have ranged between 269 -
¹⁰⁹ 60 mt, with catches in 2016 totaling 67 mt.

¹¹⁰ Pacific ocean perch are a desirable market species and discarding has historically been low.
¹¹¹ However, management restrictions (e.g. trip limits) have resulted in increased discarding since
¹¹² the early 1990s. During the 2000s discarding increased for Pacific ocean perch due to harvest
¹¹³ restrictions imposed to allow rebuilding, with estimated discard rates from the bottom trawl
¹¹⁴ fishery peaking in 2009 and 2010, prior to implementation of catch shares in 2011. Since 2011,
¹¹⁵ discarding of Pacific ocean perch has been estimated to be less than 4% given observer data.

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

Year	California	Oregon	Washington	At-sea Hake	Research	Total Landings	tab:Exec_catch
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	

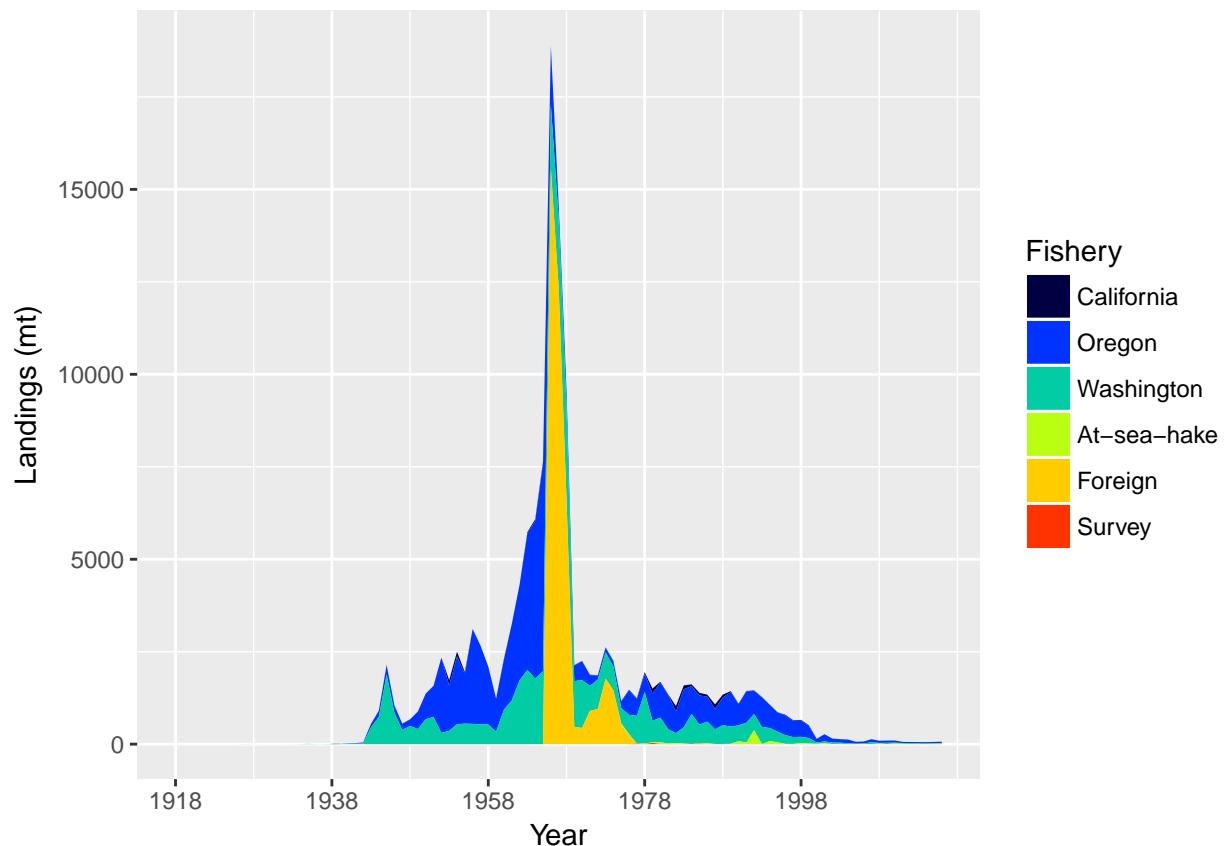


Figure a: Landings of Pacific ocean perch for California, Oregon, Washington, the Foreign fishery (1966-1976), At-Sea Hake fishery, and fishery independent surveys. fig:Exec_catch1

116 Data and Assessment

data-and-assessment

117 This a new full assessment for Pacific ocean perch which was last assessed in 2011. In this
118 assessment, all aspects of the model including catches, data, and modelling assumptions
119 were re-evaluated as much as possible. The assessment was conducted using the length-
120 and age-structured modeling software Stock Synthesis (version 3.30.30.05). The coastwide
121 population was modeled assuming separate growth and mortality parameters for each sex (a
122 two-sex model) from 1918 to 2017, and forecasted beyond 2017.

123 All of the sources of data for Pacific ocean perch have been re-evaluated for 2017, excluding
124 the historical fishery catch-per-unit time series. Changes of varying degrees have occurred
125 in the data from those used in previous assessments. These current data represent the
126 best available scientific information. The landings history has been updated and extended
127 back to 1918, harvest was negligible before that year. Survey data from the Alaska and
128 Northwest Fisheries Science Centers have been used to construct series of indices using a
129 spatial temporal delta GLMM model as well as length, age and conditional age-at length
130 compositions consistent with the stratifications used for constructing the indices.

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

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

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

156 A number of sources of uncertainty are explicitly included in this assessment. For example,
157 allowance is made for uncertainty in survey catchability coefficients. Furthermore, this
158 assessment includes gender differences in growth, a non-linear relationship between individual
159 spawner biomass and effective spawning output, and an updated relationship between length
160 and maturity, based upon non-published information (M. Head, personal communication).
161 As is always the case, overall uncertainty is greater than that predicted by a single model
162 specification. Among other sources of uncertainty that are not included in the current model
163 are the degree of connectivity between the stocks of Pacific ocean perch off of Vancouver
164 Island, British Columbia and those in PFMC waters, and the effect of climatic variables on
165 recruitment, growth and survival of Pacific ocean perch.

166 A reference case was selected which adequately captures the central tendency for those sources
167 of uncertainty considered in the model.

168 Stock Biomass

stock-biomass

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

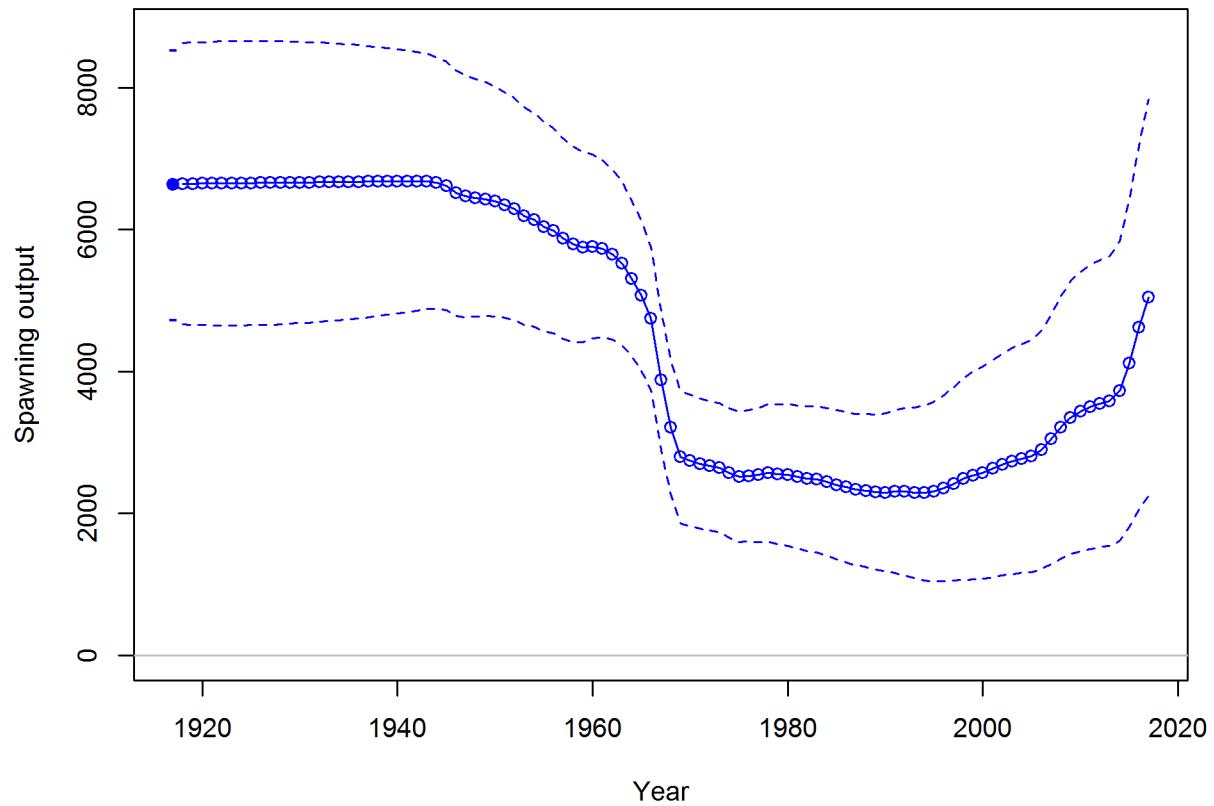


Figure b: Time series of spawning output trajectory (circles and line; median; light broken lines: 95% credibility intervals) for the base case assessment model. | [fig:Spawnbio_all](#)

Spawning depletion with ~95% asymptotic intervals

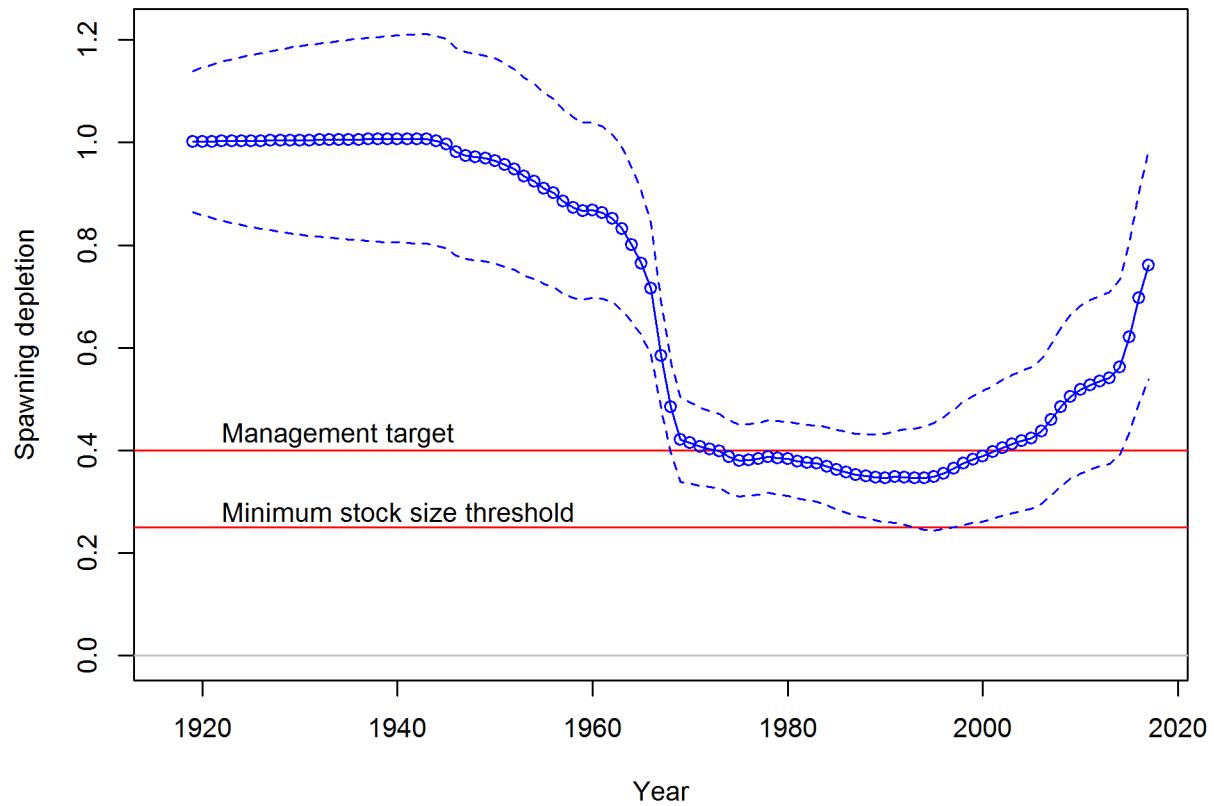


Figure c: Estimated relative spawning biomass (depletion) with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. [fig:RelDeplete_all](#)

¹⁷⁸ **Recruitment**

recruitment

¹⁷⁹ Recruitment deviations were estimated for the entire time-series modeled. There is little
¹⁸⁰ information regarding recruitment prior to 1965, and the uncertainty in these estimates is
¹⁸¹ expressed in the model. Historically, there are estimates of large recruitments in 1999 and
¹⁸² 2000. In recent years, a recruitment of unprecedented size is estimated to have occurred in
¹⁸³ 2008 but is highly uncertain. Additionally, there is early evidence of a strong recruitment in
¹⁸⁴ 2013. The four lowest recruitments (in ascending order) occurred in 2012, 2003, 1998, and
¹⁸⁵ 2005.

Table c: Recent estimated trend in recruitment with approximate 95% confidence intervals determined from the base model

Year	Estimated Recruitment	~ 95% confidence interval	Estimated Recruitment 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

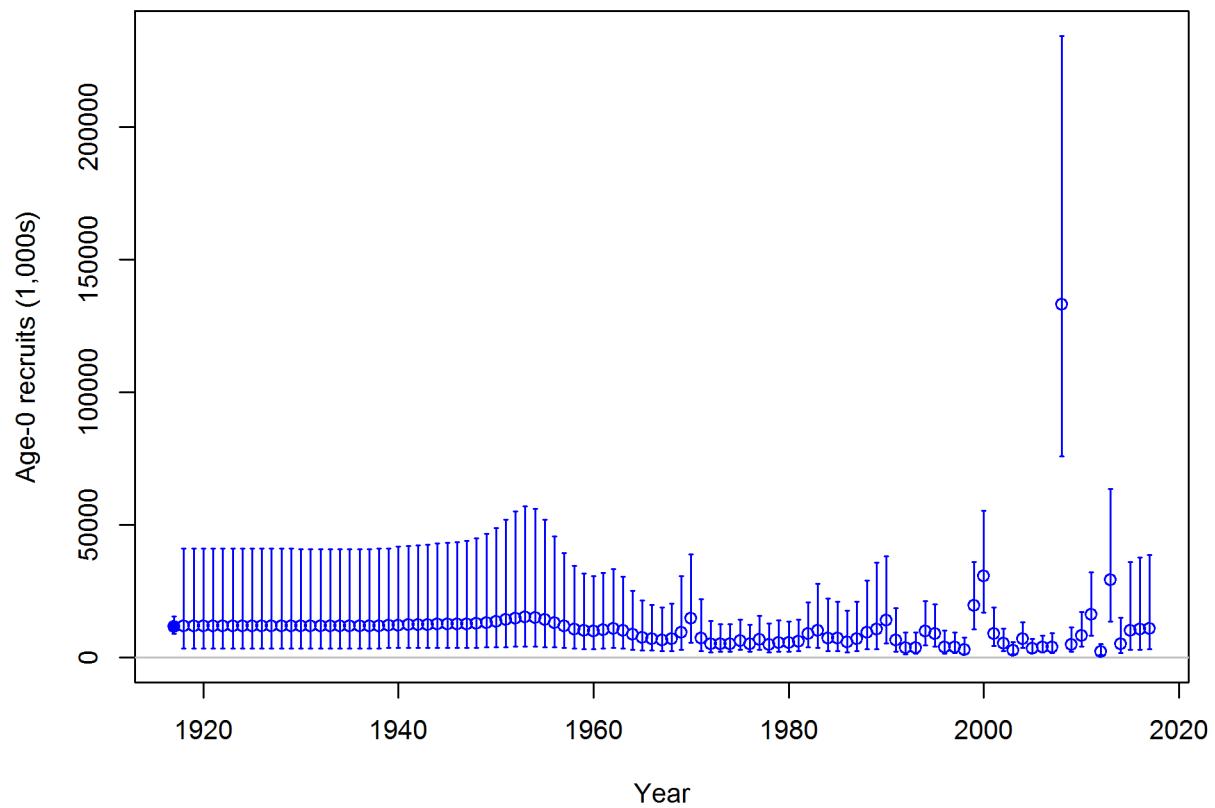


Figure d: Time series of estimated Pacific ocean perch recruitments for the base-case model with 95% confidence or credibility intervals. | [fig:Recruits_all](#)

¹⁸⁶ **Exploitation status**

exploitation-status

¹⁸⁷ The spawning biomass of Pacific ocean perch reached a low in 1994. Catches for Pacific
¹⁸⁸ ocean perch decreased significantly in 2000 compared to previous years. The estimated
¹⁸⁹ relative biomass was possibly below the overfished level in the early 2000s, but has likely
¹⁹⁰ remained above that level otherwise, and currently is significantly greater than the 40%
¹⁹¹ unfished spawning biomass target. Throughout the late 1960s and 1970s the exploitation
¹⁹² rate and $(1-SPR)/(1-SPR_{50\%})$ were mostly above target levels. Recent exploitation rates on
¹⁹³ Pacific ocean perch were predicted to be significantly below target levels.

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

Year	(1-SPR)	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval	tab:SPR_Exploit_mod1
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	

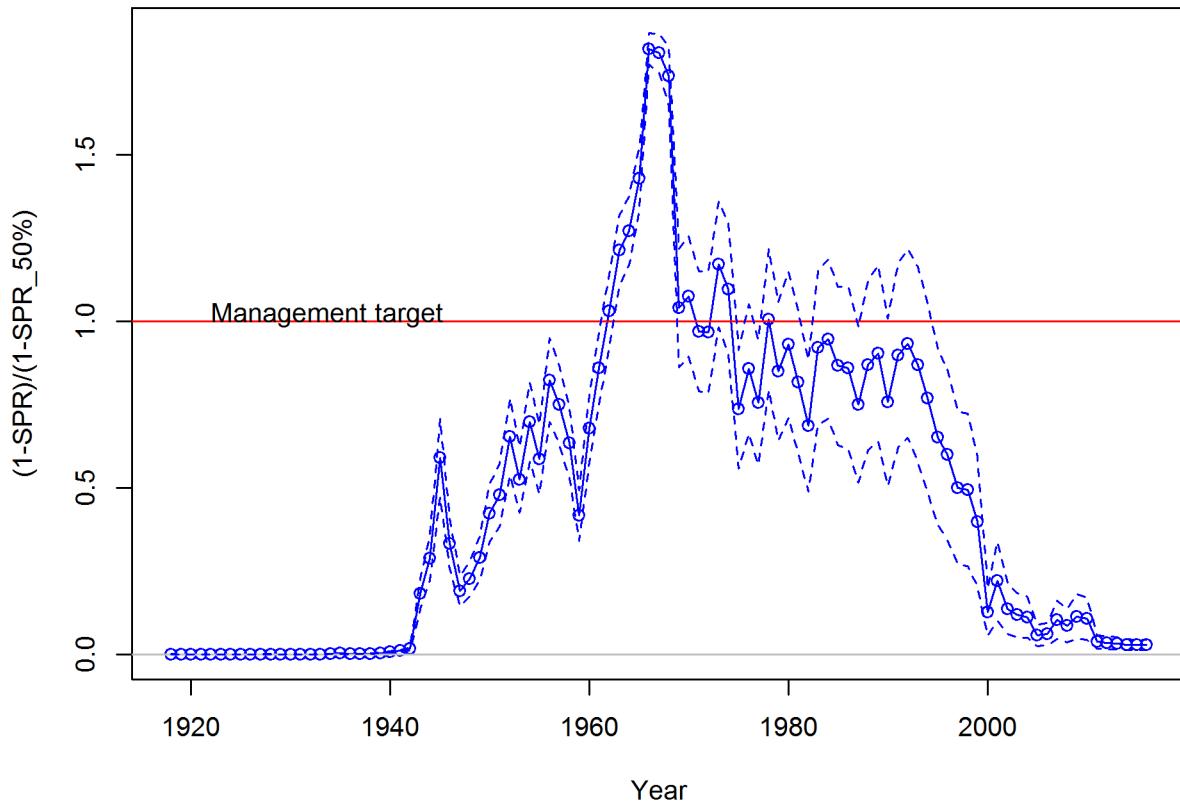


Figure e: Estimated spawning potential ratio $(1-SPR)/(1-SPR_{50\%})$ for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess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

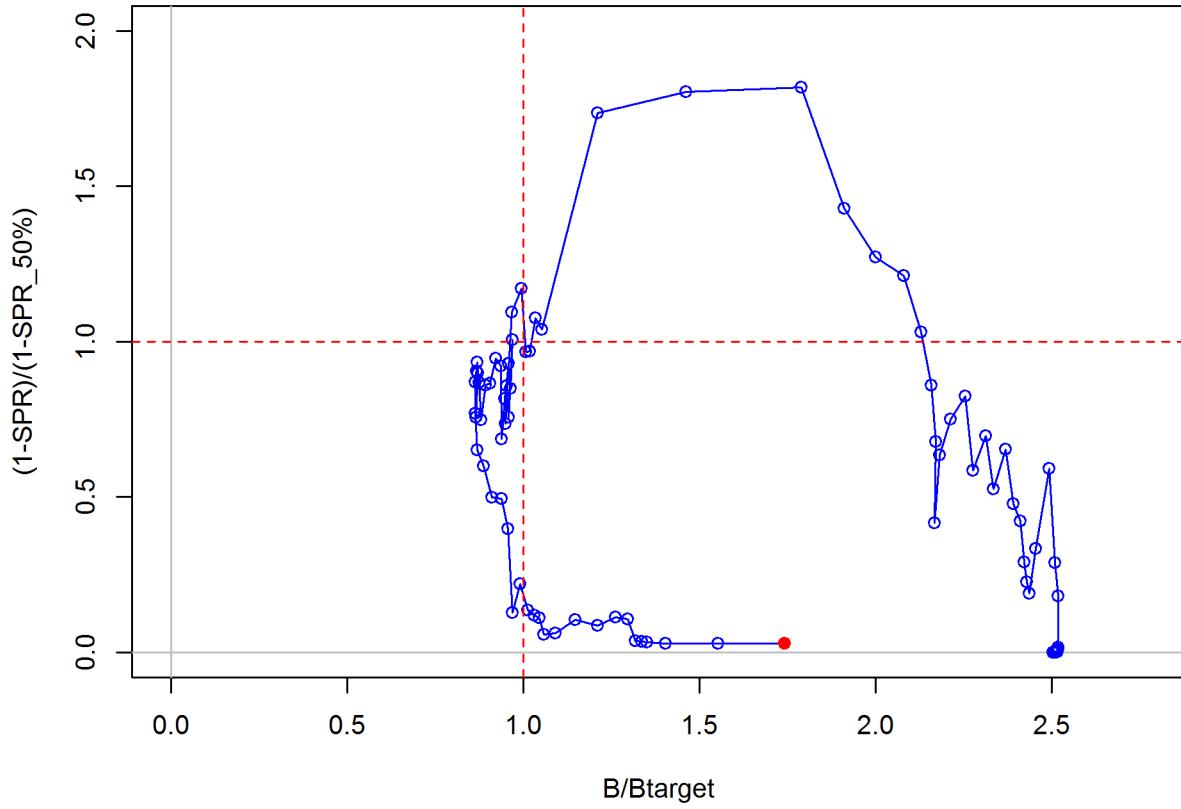


Figure f: Phase plot of estimated relative $(1-SPR)/(1-SPR_{50\%})$ vs. relative spawning biomass for the base case model. Relative biomass is the annual spawning biomass divided by the unfished spawning biomass. | [fig:Phase_all](#)

¹⁹⁴ **Ecosystem Considerations**

ecosystem-considerations

¹⁹⁵ Rockfish are an important component of the California Current ecosystem along the US west
¹⁹⁶ coast, with its more than sixty five species filling various niches in both soft and hard bottom
¹⁹⁷ habitats from the nearshore to the continental slope, as well as near bottom and pelagic
¹⁹⁸ zones. Pacific ocean perch are generally considered to be semi-demersal but, there can at
¹⁹⁹ times, be a significant pelagic component to their distribution.

²⁰⁰ Recruitment is one mechanism by which the ecosystem may directly impact the population
²⁰¹ dynamics of Pacific ocean perch. The 1999 cohort for many species of rockfish was large -
²⁰² sometimes significantly so - from these species' long-term averages suggesting that environ-
²⁰³ mental conditions may influence the spawning success and survival of larvae and juvenile
²⁰⁴ rockfish. Pacific ocean perch showed an above average recruitment deviation in 1999 and
²⁰⁵ 2000, but absolute recruitment was not as large as other years. The specific pathways through
²⁰⁶ which environmental conditions exert influence on Pacific ocean perch dynamics are unclear;
²⁰⁷ however, changes in water temperature and currents, distribution of prey and predators, and
²⁰⁸ the amount and timing of upwelling are all possible linkages. Changes in the environment
²⁰⁹ may also result in changes in age-at-maturity, fecundity, growth, and survival which can affect
²¹⁰ how the status of the stock and its susceptibility to fishing are determined. Unfortunately,
²¹¹ there are few data available for Pacific ocean perch that provide insights into these effects.

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

²²¹ **Reference Points**

reference-points

²²² This stock assessment estimates that Pacific ocean perch in the base model are above the
²²³ biomass target. Due to the large 2008 year-class, an increasing trend in spawning biomass
²²⁴ was estimated in the base model. The estimated relative biomass level in 2017 is 76.1%
²²⁵ (~95% asymptotic interval: ± 53.8%-98.4%), corresponding to an unfished spawning output
²²⁶ of 5047 million eggs (~95% asymptotic interval: 2259-7835 million eggs) of spawning output
²²⁷ in the base model. Unfished age 3+ biomass was estimated to be 139810 mt in the base case
²²⁸ model. The target spawning output based on the biomass target ($SB_{40\%}$) is 2653.2 million
²²⁹ eggs, which gives a catch of 1748.2 mt. Equilibrium yield at the proxy F_{MSY} harvest rate
²³⁰ 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	tab:Ref_pts_mod1
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	
Reference points based on $SB_{40\%}$			
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	
Reference points based on SPR proxy for MSY			
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	
Reference points based on estimated MSY values			
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	

231 Management Performance

management-performance

232 Exploitation rates on Pacific ocean perch exceeded MSY proxy target harvest rates during
 233 the 1960s and 1970s and spawning biomass is predicted to have fallen below the proxy
 234 management target of 40%. Exploitation rates subsequently declined to rates at or below
 235 the management target in the 1980s. Management restrictions imposed in the 1990s further
 236 reduced exploitation rates. An overfished declaration for Pacific ocean perch resulted in very
 237 low exploitation rates since 2001 with the ACLs being 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)	<small>tab:mnmgt_perform</small> 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

238 **Unresolved Problems And Major Uncertainties**
unresolved-problems-and-major-uncertainties

239 TBD after STAR panel

240 **Decision Table**

decision-table

241 TBD after STAR panel

Table g: Projections of potential OFL (mt) and ACL (mt) and the estimated spawning output and relative biomass.

Year	OFL	ACL	Spawning Output (million eggs)	<small>tab:OFL_projection</small> 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.

		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
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	-	-	-	-	-	-

242 Research and Data Needs

research-and-data-needs

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

- 245 1. **Natural mortality:** Uncertainty in natural mortality translates into uncertain esti-
246 mates of status and sustainable fishing levels for Pacific ocean perch. The collection
247 of additional age data, re-reading of older age samples, reading old age samples that
248 are unread, and improved understanding of the life-history of Pacific ocean perch may
249 reduce that uncertainty.
- 250 2. **Steepness:** The amount of stock resilience, steepness, dictates the rate at which a
251 stock can rebuild from low stock sizes. Improved understanding regarding the steepness
252 of US west coast Pacific ocean perch will reduce our uncertainty regarding current stock
253 status.
- 254 3. **Basin-wide understanding of stock structure, biology, connectivity, and dis-
255 tribution:** This is a stock assessment for Pacific ocean perch off of the west coast of the
256 US and does not consider data from British Columbia or Alaska. Further investigating
257 and comparing the data and predictions from British Columbia and Alaska to determine
258 if there are similarities with the US west Ccast observations would help to define the
259 connectivity between Pacific ocean perch north and south of the U.S.-Canada border.

Table i: Base model results summary.

Quantity	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Landings (mt)	911	1,160	1,173	1,026	1,007	844	838	842	850	964
Total Est. Catch (mt)	150	189	200	180	183	150	153	158	164	281
OFL (mt)	92	94	97	60	57	55	54	58	65	65
ACL (mt)	133	190	181	61	58	57	55	59	65	65
(1-SPR)(1-SPR _{50%})	0.09	0.11	0.11	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Exploitation rate	0	0	0	0	0	0	0	0	0	0
Age 3+ biomass (mt)	73810.2	74550.2	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
Depletion	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

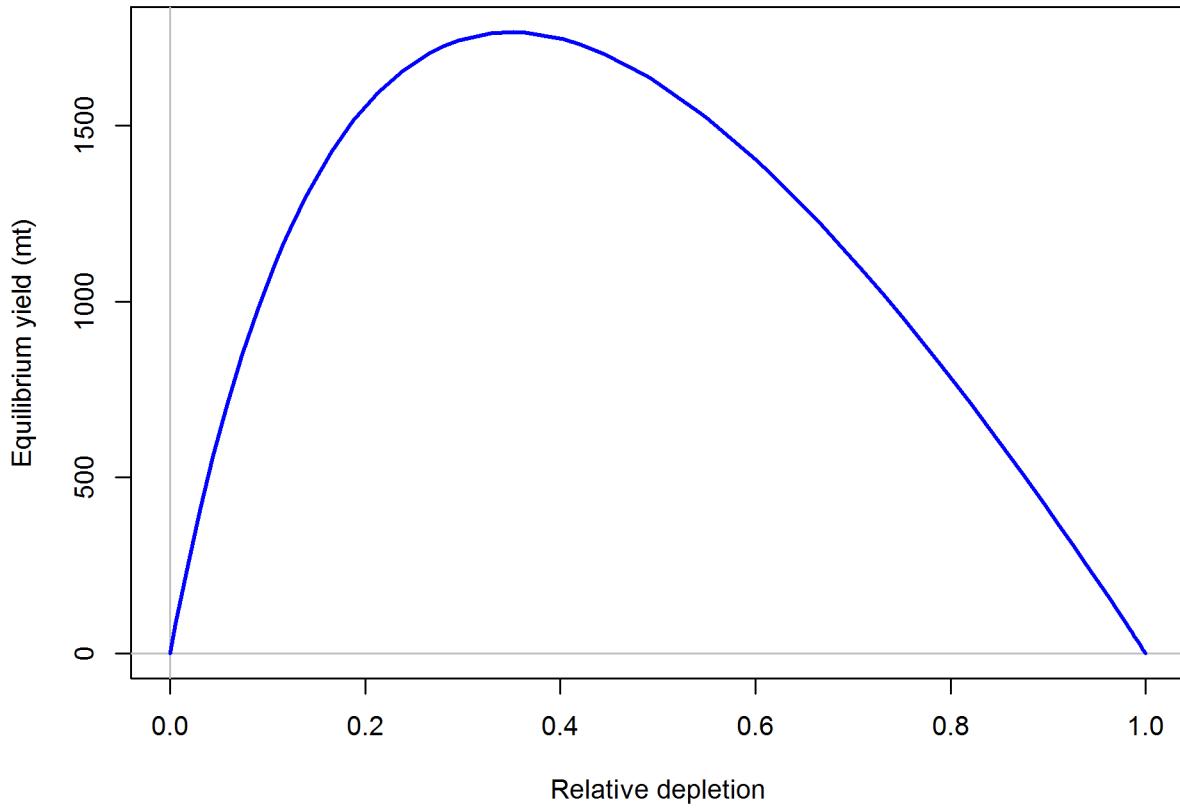


Figure g: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.50. [fig:Yield_all](#)

260 **1 Introduction**

introduction

261 **1.1 Basic Information**

basic-information

262 Pacific ocean perch (*Sebastodes alutus*) are most abundant in the Gulf of Alaska, and have been
263 observed off of Japan, in the Bering Sea, and south to Baja California, although they are
264 sparse south of Oregon and rare in southern California. While genetic studies have found
265 three populations of Pacific ocean perch off of British Columbia (Seeb and Gunderson 1988,
266 Withler et al. 2001) with, notably, a separate stock off of Vancouver Island, no significant
267 genetic differences have been found in the range covered by this assessment. Pacific ocean
268 perch show dimorphic growth, with females reaching a slightly large size than males. Males
269 and females are equally abundant on 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 United States vessels. Harvest was
279 negligible prior to 1940, reached 1,300 mt in 1950, 3,200 mt in 1961 and exceeded 7,600 mt in
280 1965. Catches increased dramatically after 1965, with the introduction of large distant-water
281 fishing fleets from the Soviet Union and Japan. Both nations employed large factory stern
282 trawlers as their primary method for harvesting Pacific ocean perch. Peak removals by all
283 foreign nations combined are estimated at over 15,000 mt in 1966 and remained over 12,000 mt
284 in 1967. These numbers are based upon a re-analysis of the foreign catch data (Rogers 2003),
285 which focused on deriving a more realistic species composition for catches previously identified
286 only as Pacific ocean perch. Catches declined rapidly following these peak years, and Pacific
287 ocean perch stocks were considered to be severely depleted throughout the Oregon-Vancouver
288 Island region by 1969 (Gunderson 1977, Gunderson et al. 1977). Landed harvest averaged
289 1,350 mt over the period 1977-94. Landings have continued to decline since 1994, primarily
290 due to more restrictive management (Table 1 and Figure 1).

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

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

307 Age estimates for Pacific ocean perch prior to the 1980s were made via surface ageing of
308 otoliths, which misses the very tight annuli at the edge of the otolith once the fish reaches near
309 maximum size. Ages are biased by around age 10-12, and maximum age was estimated to be
310 in the 20s, which lead to an overestimate of the natural mortality rate and the productivity
311 of the stock. Using break and burn methods, Pacific ocean perch have been aged to over
312 100 years, and we now know that the underlying assumptions of the early models were
313 overly optimistic about productivity. Research surveys have been used to provide fishery-
314 independent information about the abundance, distribution, and biological characteristics
315 of Pacific ocean perch. A coast-wide survey of the rockfish resource was conducted in 1977
316 (Gunderson and Sample 1980) and was repeated every three years through 2004 (referred to
317 as the ‘Triennial Survey’). The National Marine Fisheries Service (NMFS) coordinated a
318 cooperative research survey of the Pacific ocean perch stocks off Washington and Oregon
319 with the Washington Department of Fisheries (WDFW) and the Oregon Department of
320 Fish and Wildlife (ODFW) in March-May 1979 (Wilkins and Golden 1983). This survey
321 was repeated in 1985 (referred to as the Pacific ocean perch Survey). Two slope surveys
322 have been conducted off the West Coast in recent years, one using the research vessel Miller
323 Freeman, which ended in 2001 (referred to as the ‘AFSC Slope Survey’), and another ongoing
324 cooperative survey using commercial fishing vessels which began in 1998 as a DTS (Dover sole,
325 thornyhead and sablefish) survey, was expanded to other groundfish in 1999 (referred to as
326 the ‘NWFSC Slope Survey’). In 2003, this survey was expanded spatially to include the shelf.
327 This last survey, conducted by the NWFSC, continues to cover depths from 30-700 fathoms
328 (55-1280 meters) on an annual basis (referred to as the ‘NWFSC Shelf-Slope Survey’).

329 1.2 Summary of Management History

summary-of-management-history

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

³³⁷ (motherships and catch-processors) that target whiting and process at sea are managed in a
³³⁸ system of harvest cooperatives.

³³⁹ Limits on Pacific ocean perch were first established in 1983 (Table 3). These were implemented
³⁴⁰ as area closures, trip limits, and cumulative landing limits. In 1999, Pacific ocean perch
³⁴¹ was declared overfished with the assessment estimating the spawning output below the
³⁴² management limit (25% of virgin biomass). In reaction to the overfished declaration, harvest
³⁴³ limits were reduced relative to previous years and a rebuilding plan was implemented in 2001.

³⁴⁴ 1.3 Fisheries off Canada and Alaska

`fisheries-off-canada-and-alaska`

³⁴⁵ Pacific ocean perch can be found in waters off the US west coast and northward through
³⁴⁶ Alaskan waters. In contrast the Pacific ocean perch stock off the US west coast, each
³⁴⁷ assessed portion of the stock in Canada and Alaskan waters are estimated to be above
³⁴⁸ management targets. The subset of the stock off the US west coast represents the tail of the
³⁴⁹ species distribution with little to no Pacific ocean perch being encountered south of northern
³⁵⁰ California. Pacific ocean perch are harvested both in Canada and Alaska. The most recent
³⁵¹ updated assessments for the Bering Sea and the Gulf of Alaska stocks determined that neither
³⁵² stock are in an overfished state and recommended and acceptable biological catch of 43,723
³⁵³ mt and 23,918 mt, respectively, for 2017.

³⁵⁴ In Canadian waters Pacific ocean perch has the largest single-species quota, accounting for
³⁵⁵ approximately 25% of all rockfish landings by weight in the bottom trawl fleet. The Canadian
³⁵⁶ Pacific ocean perch stock is broken into three separate areas that are individually assessed.
³⁵⁷ The status of the stock within each area are above Canadian management targets.

³⁵⁸ 2 Data

`data`

³⁵⁹ Data used in the Pacific ocean perch assessment are summarized in Figure 2. A description
³⁶⁰ of each data source is provided below.

³⁶¹ 2.1 Fishery-Independent Data:

`fishery-independent-data`

³⁶² 2.1.1 Northwest Fisheries Science Center (NWFSC) shelf-slope survey

`northwest-fisheries-science-center-nwfsc-shelf-slope-survey`

³⁶³ The NWFSC shelf-slope survey is based on a random-grid design; covering the coastal waters
³⁶⁴ from a depth of 55 m to 1,280 m (Bradburn et al. 2011). This design uses four chartered
³⁶⁵ industry vessels in most years, assigned to a roughly equal number of randomly selected

grid cells. The survey, which has been conducted from late-May to early-October each year, is divided into two 2-vessel passes of the coast, which are executed from north to south. This design therefore incorporates both vessel-to-vessel differences in catchability as well as variance associated with selecting a relatively small number (approximately 700) of cells from a very large population of possible cells (greater than 11,000) distributed from the Mexican to the Canadian border.

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

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

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

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

405 **2.1.2 Northwest Fisheries Science Center (NWFSC) slope survey**
northwest-fisheries-science-center-nwfsc-slope-survey

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

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 **2.1.3 Alaska Fisheries Science Center (AFSC) slope survey**
alaska-fisheries-science-center-afsc-slope-survey

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

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

434 Length compositions were available for each year the survey was conducted. No age data were
435 available from this survey. The expanded length frequencies from this survey were generally
436 of larger fish (> 30 cm), except for 1997 where the highest frequency of fish were between 20
437 and 30 cm for both females and males (Figure 11).

438 **2.1.4 Triennial Bottom Trawl Survey**

triennial-bottom-trawl-survey

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

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

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

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

472 Length and age compositions were expanded based upon the stratification. The number of
473 tows with length data ranged from 17 in 1986 to 81 in 1998 10. Ages were read using surface
474 reading methods until 1989 when the break-and-burn method replaced surface reads as the
475 best method to age Pacific ocean perch. Unfortunately, surface reading of Pacific ocean
476 perch otoliths results in significant underestimates of age. Due to this, these otolith were

477 excluded from analysis. The available ages from the Triennial survey and the number of tows
478 where otoliths were collected are shown in Table 11. The expanded length frequencies from
479 this survey show an increase in small fish starting in 1995 (Figure 13). The age frequencies
480 provide clear evidence of large year-classes moving through the population from the 1999
481 and 2000 recruitment (Figure 14).

482 2.1.5 Pacific ocean perch Survey

pacific-ocean-perch-survey

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

490 Length and age compositions were expanded based on the stratification. The survey had 125
491 and 126 Pacific ocean perch tows (Table 12) and ages were only available in 1985 due to
492 surface reads for the 1979 data (Table 13). The length frequencies for both years are highest
493 between the 30-45 cm range (Figure 16) with ages in 1985 having a large number of fish age
494 40 and greater (Figure 17).

495 2.2 Fishery-Dependent Data

fishery-dependent-data

496 2.2.1 Commercial Fishery Landings

commercial-fishery-landings

497 Washington

498 Historical commercial fishery landings of Pacific ocean perch from Washington for the years
499 1918-2016 were obtained from Theresa Tsou (WDFW) and Phillip Weyland (WDFW). This
500 assessment is the first Pacific ocean perch assessment to include a state provide historical
501 catch reconstruction and hence, the historical catches for Washington vary markedly from
502 those used in the 2011 assessment. Due to Recent landings (1981-2016) were obtained directly
503 from Washington state rather than from PacFIN (Pacific Fisheries Information Network
504 (PacFIN) due to identified missing catches not available within PacFIN for Pacific ocean
505 perch.

506 Oregon

507 Historical commercial fishery landings of Pacific ocean perch from Oregon for the years
508 1892-1986 were obtained from Alison Dauble (ODFW). A description of the methods can be

509 found in Karnowski et al. (2014). Recent landings (1987-2016) were obtained from PacFIN
510 retrieval dated May 2, 2017}, Pacific States Marine Fisheries Commission, Portland, Oregon;
511 www.psmfc.org). The catch data in from the POP and POP2 categories contained within
512 PacFIN for Pacific ocean perch were used for this assessment. Additional catches from
513 1987-1999 for Pacific ocean perch under the UROCK category not yet available in PacFIN
514 were received directly from the state and combined with the catch data available for that
515 period within PacFIN.

516 California

517 Historical commercial fishery landings of Pacific ocean perch were obtained directly from
518 John Field at the SWFSC due to database issues for the historical period for the California
519 Cooperative Groundfish Survey, also known as CALCOM (128.114.3.187) for the years 1916-
520 1980. A description of the methods can be found in (Ralston et al. 2010). Recent landings
521 (1981-2016) were obtained from PacFIN (Pacific Fisheries Information Network (PacFIN)
522 retrieval dated May 2, 2017, Pacific States Marine Fisheries Commission, Portland, Oregon;
523 www.psmfc.org).

524 At-Sea Hake Fishery

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

536 Foreign Catches

537 From the 1960s through the early 1970s, foreign trawling enterprises harvested considerable
538 amounts of rockfish off Washington and Oregon, and along with the domestic trawling fleet,
539 landed large quantities of Pacific ocean perch. Foreign catches of individual species were
540 estimated by Rogers (2003) and attributed to INPFC areas for the years of 1966-1976 for
541 Pacific ocean perch. The foreign catches were combined across areas for a coastwide removal
542 total.

543 2.2.2 Discards

discards

544 Data on discards of Pacific ocean perch are available from two different data sources. The
545 earliest source is called the Pikitch data and comes from a study organized by Ellen Pikitch

546 that collected trawl discards from 1985-1987 (Pikitch et al. 1988). The northern and southern
547 boundaries of the study were 48°42' N latitude and 42°60' N. latitude respectively, which is
548 primarily within the Columbia INPFC area (Pikitch et al. 1988 , Rogers and Pikitch 1992).
549 Participation in the study was voluntary and included vessels using bottom, midwater, and
550 shrimp trawl gears. Observers of normal fishing operations on commercial vessels collected
551 the data, estimated the total weight of the catch by tow and recorded the weight of species
552 retained and discarded in the sample. Results of the Pikitch data were obtained from John
553 Wallace (pers comm, NWFSC, NOAA) in the form of ratios of discard weight to retained
554 weight of Pacific ocean perch and sex-specific length frequencies. Discard estimates are shown
555 in Table 14.

556 The second source is from the West Coast Groundfish Observer Program (WCGOP). This
557 program is part of the NWFSC and has been recording discard observations since 2003. Table
558 14 shows the discard ratios (discarded/(discarded + retained)) of Pacific ocean perch from
559 the WCGOP. Since 2011, when the trawl rationalization program was implemented, observer
560 coverage rates increased to nearly 100% for all the limited entry trawl vessels in the program
561 and discard rates declined compared to pre-2011 rates. Discard rates were obtained for both
562 the catch-share and the non-catch share sector for Pacific ocean perch. A single discard rate
563 was calculated by weighting discard rates based on the commercial landings by each sector.
564 Coeffienct of variations were calculated by bootstrapping vessels within ports because the
565 observer program randomly chooses vessels within porats to be observed in the non-catch
566 shares sectors. Discard length composition for the trawl fleet varied by year, with larger fish
567 being discarded prior to 2011 (Figure 18).

568 2.2.3 Historical Commercial Catch-per-unit effort

historical-commercial-catch-per-unit-effort

569 Data on catch-per-unit-effort (CPUE) in mt/hr from the domestic fishery were combined for
570 the INPFC Vancouver and Columbia areas (Table 15, from Gunderson (1977)). Although
571 these data reflect catch rates for the US fleet, the highest catch rates coincided with the
572 beginning of removals by the foreign fleet. This suggest that, barring unaccounted changes in
573 fishing efficiency during this period, the level of abundance was high at that time. A CV of
574 0.40 was used in this assessment to be consistent with the CV observed in the survey data.

575 2.2.4 Fishery Length And Age Data

fishery-length-and-age-data

576 Biological data from commercial fisheries that caught Pacific ocean perch were extracted
577 from PacFIN (PFSMFC) on May 4, 2017. Lengths taken during port sampling in Oregon and
578 Washington were used to calculate length and age compositions. There were no biological
579 data for Pacific ocean perch available within PacFIN. The overwhelming majority of these
580 data were collected from the mid-water and bottom trawl gear, but additional biological data
581 were collected from non-trawl gear which was grouped together with trawl gear data. Tables

582 16 and 17 show the number of trips and fish sampled, along with the calculated sample sizes.
583 Length and age data were acquired at the trip level, and then aggregated to the state level.
584 The sample sizes were calculated via the Stewart Method (Ian Stewart, pers comm, IPHC)
585 which for commercial fishery data is:

586 $\text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}}$ if $N_{\text{fish}}/N_{\text{trips}}$ is < 44

587 $\text{Input effN} = 7.06 * N_{\text{trips}}$ if $N_{\text{fish}}/N_{\text{trips}}$ is ≥ 44

588 2.3 Biological Data

biological-data

589 2.3.1 Natural mortality

natural-mortality

590 Historic Pacific ocean perch ages determined using scales and surface reading methods of
591 otoliths, resulted in estimates of natural mortality (M) of between 0.10 and 0.20 yr^{-1} with
592 a longevity less than 30 years(Gunderson 1977). Based on break-and-burn method of age
593 determination using otoliths, the maximum age of Pacific ocean perch was revised to be 90
594 years (Chilton and Beamish 1982). The updated understanding concerning Pacific ocean perch
595 longevity reduced the estimate of natural mortality based on Hoenig's (1983) relationship to
596 0.059 yr^{-1} . The previous assessment applied a prior distribution on natural mortality based
597 upon multiple life history correlates (including Hoenig's method, Gunderson gonadosomatic
598 index (1997), and McCoy and Gillooly's (2008) theoretical relationship) developed separately
599 for female and male Pacific ocean perch.

600 Hamel (2015) developed a method for combining meta-analytic approaches to relating the
601 natural mortality rate M to other life-history parameters such as longevity, size, growth rate
602 and reproductive effort, to provide a prior on M . In that same issue of ICESJMS, Then et al.
603 (2015), provided an updated data set of estimates of M and related life history parameters
604 across a large number of fish species, from which to develop an M estimator for fish species
605 in general. They concluded by recommending M estimates be based on maximum age alone,
606 based on an updated Hoenig non-linear least squares (nls) estimator $M=4.899A_{\text{max}}^{-.916}$.
607 The approach of basing M priors on maximum age alone was one that was already being used
608 for West Coast rockfish assessments. However, in fitting the alternative model forms relating
609 M to A_{max} , Then et al. (2015) did not consistently apply their transformation. In particular,
610 in real space, one would expect substantial heteroscedasticity in both the observation and
611 process error associated with the observed relationship of M to A_{max} . Therefore, it would
612 be reasonable to fit all models under a log transformation. This was not done. Reevaluating
613 the data used in Then et al. (2015) by fitting the one-parameter A_{max} model under a log-log
614 transformation (such that the slope is forced to be -1 in the transformed space (Hamel 2015)),
615 the point estimate for M is:

616
$$M = \frac{5.4}{A_{\text{max}}}$$

617 The above is also the median of the prior. The prior is defined as a lognormal with mean
618 $\ln(\frac{5.4}{A_{\max}})$ and SE = 0.4384343. Using a maximum age of 100 the point estimate and median
619 of the prior is 0.054. The maximum age was selected based on available age data from all
620 West Coast data sources. The oldest aged rockfish was 120 years, captured by the commercial
621 fishery in 2007. However, age data are subject to ageing error which could impact this
622 estimate of longevity. The selection of 100 years was based on the range of other ages
623 available with had multiple observations of fish between 90 and 102 years of age.

624 **2.3.2 Sex ratio, maturation, and fecundity**

sex-ratio-maturation-and-fecundity

625 Examining all biological data sources, the sex ratio of young fish are within 5% of 1:1 by either
626 length or age (Figures 23 and 24), and hence this assessment the sex ratio at birth was assumed
627 to be 1:1. This assessment assumed a logistic maturity-at-length curve based on analysis
628 of 537 fish maturity samples collected from the NWFSC shelf-slope survey. This is revised
629 from the previous assessment which assumed maturity-at-age based on the work of Hannah
630 and Parker (Hannah and Parker 2007). Additionally, the new maturity-at-length curve is
631 based on the estimate of functional maturity an approach that classifies rockfish maturity
632 with developing oocytes as mature or immature based on the proportion of vitellogenin in
633 the cytoplasm and the measured frequency of atretic cells (M. Head, pers comm, NWFSC,
634 NOAA). The 50% size-at-maturity was estimated at 32.1 cm with maturity asymptoting to
635 one for larger fish (Figure 25). Comparison between the maturity-at-age used in the previous
636 assessment and the updated functional maturity-at-length is shown in Figure 26.

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

641 **2.3.3 Length-weight relationship**

length-weight-relationship

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

646 **2.3.4 Growth (length-at-age)**

growth-length-at-age

647 The length-at-age was estimated for male and female Pacific ocean perch using data collected
648 from both fishery-dependent and -independent data sources that were collected from 1981-
649 2016. Figure 30 shows the lengths and ages for all years and all data as well as predicted

650 von Bertalanffy fits to the data. Females grow larger than males and sex specific growth
651 parameters were estimated at the following values:

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

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

654 2.3.5 Ageing Precision And Bias

ageing-precision-and-bias

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

665 2.4 History Of Modeling Approaches Used For This Stock

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

666 2.4.1 Previous Assessments

previous-assessments

667 The status of Pacific ocean perch off British Columbia, Washington, and Oregon have been
668 periodically assessed since the intensive exploitation that occurred in the 1960s. Concerns
669 regarding Pacific ocean perch status off the coast of the US west coast were raised in the late
670 1970s (Gunderson 1978, Gunderson (1981)) and in 1981 the PFMC adopted a 20-year plan
671 to rebuild the stock.

672 The 1992 assessment determined that Pacific ocean perch remained at low levels relative
673 to the population size in 1960 (Ianelli et al. 1992) and recommended additional harvest
674 restrictions to allow for stock rebuilding. The 1998 assessment (Ianelli and Zimmermann
675 1998) estimated that the stock was 13% of the unfished level, leading the National Marine
676 Fishery Service (NMFS) to declare the stock overfished in 1999. The formal rebuilding
677 plan was implemented in 2001. The rebuilding plan reduced the SPR harvest rate used to
678 determine catches to 0.864, relative to the PFMC rockfish default harvest (SPR = 0.50).
679 The last full assessment of Pacific ocean perch was conducted in 2011 (Hamel and Ono 2011)
680 which concluded that the stock was still well below the target biomass of $0.40SB_0$ estimating
681 the relative stock status at 19.1%.

682 **2.4.2 Previous Assessment Recommendations**
previous-assessment-recommendations

683 Recommendation: Considering trans-boundary stock effects should be pursued. In particular
684 the consequences of having spawning contributions from external stock components should
685 be evaluated relative to the steepness estimates obtained in the present assessment (see
686 more complete discussion of this recommendation under the Unresolved Problems and Major
687 Uncertainties section, above).

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

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

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

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

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

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

706 *STAT response: Additional research needs to completed which evaluates the amount of bias
707 and imprecision in surface-read ages. Evaluating avaiable surface-read ages within the PacFIN
708 database fish of lengths between 23-44 cm can be aged at 10 years old. This large range of
709 lengths at the same age indicates considerable bias in ages for fish surface-read younger aged
710 fish.*

711 Recommendation: Historical catch reconstruction estimates should be formally reviewed prior
712 to being used in assessments and should be coordinated so that interactions between stocks
713 are appropriately treated. The relative reliability of the catch estimates over time could
714 provide an axis of uncertainty in future assessments.

715 *STAT response: California and Oregon have ungone extensive work to create historical catch
716 reconstructions. This is the first assessment for Pacific ocean perch which includes a Wash-
717 ington historical catch reconstruction. The data used in this assessment represent Washington*

718 state's current best estimate for historical catches. Both California and Washington are
719 conducting research to estimate uncertainty surround historical catches which could be used to
720 propegate uncertainty within the assessment.

721 3 Assessment

assessment

722 3.1 General Model Specifications and Assumptions

general-model-specifications-and-assumptions

723 Stock Synthesis v3.30.03.05 was used to estimate the parameters in the model. R4SS, revision
724 1.27.0, along with R version 3.3.2 were used to investigate and plot model fits. A summary
725 of the data sources used in the model (details discussed above) is shown in Figure 2.

726 Stock Synthesis has many options when setting up a model and the assessment model for
727 Pacific ocean perch was set up in the following manner.

728 3.1.1 Changes between the 2011 assessment model and current model

changes-between-the-2011-assessment-model-and-current-model

729 The current model for Pacific ocean perch has many made many similar assumptions to the
730 2011 assessment but differs in some key ways. This assessment disaggrated the fleets into
731 a trawl/other gear, at-sea hake, historical foreign fleet, and research fleets. The previous
732 assessment implemented a single fleet where removal from all sources were aggregated together.
733 The seperating of fleets applied in this assessment allowed for differing assumptions regarding
734 current and historical discarding practices. Although there are no compositional data available
735 from the foreign fleet, it is assumed that very little discarding to no discarding of fish occured.
736 Additionally, the at-sea hake fishery removals are represent both discarded and retained fish
737 and hence an additional discard rate would not be appropriate. Similar logic was applied in
738 regard to survey and research removals.

739 The historical landing used in the model differs from those used in 2011. The assessment
740 includes the first state provided historical reconstruction landings for Washington state.
741 The historical reconstruction provided Pacific ocean perch landing within Washington state
742 starting in 1916 and have larger removals in the 1940s relative to those used in 2011 32.
743 Given the increase in historical removals prior to 1940, the 2011 model starting year, the
744 starting year for modeling the stock was revised to 1918, the first year Pacific ocean perch
745 landings exceeded 1 mt, for this assessment. Explorations were conducted relative to the
746 model starting year and no differences were found between the 1918 start year compared to
747 starting the model in 1892, the first record of Pacific ocean perch landings between California,
748 Oregon, and Washington catch data.

749 Selectivity in this model is assumed to be length-based and is modeled using double-normal
750 for all fleets, except the Pacific ocean perch survey which retained the previous assessment

751 assumption of logistic selectivity. The previous assessment mirrored selectivity among the
752 Pacific ocean perch and both slope surveys (AFSC and NWFSC). This assessment allow for
753 survey specific estimated double-normal selectivity.

754 All fishery-independent indices have been reevaluated for this assessment using a spatial-
755 temporal delta generalized linear mixed model (VAST delta-GLMM) which is updated from
756 2011 which used a bayesian delta-GLMM which did not incorporate spatial effects. An
757 additional update to the treatment of survey data was the decision to use the Triennial
758 survey as a single time series ranging from 1980-2004. The previous assessment opted to
759 split this survey into early and a late index of abundance based upon the change in southern
760 sampling and a shift in survey timing. Northern California is considered to be the southern
761 end of Pacific ocean perch West Coast distribution with rare encounters in central or southern
762 California waters. The biological data from the Triennial survey showed no discernable
763 ontogenetic shifts in Pacific ocean perch during the early or late period of summer samples.
764 Based upon these investigations, the Triennial survey was retained as a single index of
765 abundance.

766 Maturity and fecundity were updated for this assessment based upon new research. Fecundity
767 for Pacific ocean perch used in this assessment was base on reevaluation of the fecundity of
768 West Coast rockfish by Dick et al. (2017) updating the previous fecundity estimates used
769 in the 2011 assessment (Dick 2009) (Figure 27). Maturity in this assessment was based
770 on examination of 537 fish samples which were used to estimate functional maturity, an
771 approach that classifies rockfish maturity with developing oocytes as mature or immature
772 based on the proportion of vitellogenin in the cytoplasm and the measured frequency of atretic
773 cells (M. Head, pers comm, NWFSC, NOAA). The updated maturity curve was based on
774 maturity-at-length where the previous estimates used in 2011 were based on maturity-at-age
775 (Figure 26).

776 In this assessment, the beta prior developed from a meta-analysis of West Coast groundfish
777 was updated to the 2017 value (J. Thorson, pers comm, NWFSC, NOAA) in preliminary
778 models, with steepness fixed in the final base model. Additionally, the prior for natural
779 mortality was updated base on analysis conducted by Owen Hamel (pers comm, NWFSC,
780 NOAA), where female natural mortality was fixed at the prior median with males estimated
781 as an offset from the female value.

782 3.1.2 Summary of Fleets and Areas

summary-of-fleets-and-areas

783 Pacific ocean perch are most frequently observed in Oregon and Washington waters, however,
784 they are observed along the entire US West Coast in survey and fishery observations. Multiple
785 fisheries encounter Pacific ocean perch. Trawl, fixed gear, and the at-sea (mid-water) hake
786 fisheries account for the majority of the Pacific ocean perch landings both historically and
787 currently.

788 The majority of removals of Pacific ocean perch were observed by eht bottom trawl fishery
789 with fixed gear accounting for a small fraction of the catches avaiable within PacFIN. Trawl
790 and fixed gears were combined into a coast-wide fleet. For the period from 1918 to the early
791 1990s, prior to the introduction of trip limits for rockfish, limited discarding of Pacific ocean
792 perch was assumed. Observations of Pacific ocean perch in the Pikitch et al. (1988) data
793 (1986-1987) allowed for a formal analysis of discard rates which were applied to the historical
794 period of the fishery. Foreign trawl catches (1966-1976) was modeled as a single fleet. The
795 at-sea fishery operates as a mid-water fishery targeting Pacific whiting but encounters Pacific
796 ocean perch as a bycatch species. This fleet was also modeled as a single fleet.

797 3.1.3 Other Specifications

other-specifications

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

805 The Triennial survey was kept as a single series. Assessment of other groundfish have split
806 this survey into an early and a late series, based mostly on the shift to deeper depths and
807 the timing of the survey, by estimating different catchability parameters and selectivity
808 parameters for each period. Age data were available for the commercial and at-sea hake
809 fishery, as well as the Triennial, the Pacific ocean perch, the NWFSC slope, and the NWFSC
810 shelf-slope survies. The ages from the NWFSC shelf-slope survey and were entered into the
811 model as conditional age-at-length. Length-frequencies were calculated for the Triennial,
812 Pacific ocean perch, AFSC slope, NWFSC slope, and the NWFSC shelf-slope surveys within
813 each stratum, and then combined across strata using the biomass in each stratum as the
814 weighting factor. This reduced the influence of a few fish observed in a large area.

815 The specification of when to estimate recruitment deviations is an assumption that likely
816 affects model uncertainty. It was decided to estimate recruitment deviations from 1900-2014
817 to appropriately quantify uncertainty. The earliest length-composition data occur in 1966
818 and the earliest age data were in 1981. The most informed years for estimating recruitment
819 deviations were from about the mid-1970s to about 2011. The period from 1900-1974 was fit
820 using an early series with little or no bias adjustment, the main period of recruitment deviates
821 occurred from 1975-2014 with an upward and downward ramping of bias adjustment, and
822 2015 onward was fit using forecast recruitment deviates with little bias adjustment. Methot
823 and Taylor (2011) summarize the reasoning behind varying levels of bias adjustment based
824 on the information available to estimate the deviates. Recruitment deviation was assumed to
825 be 0.70.

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

830 Time blocks for the bottom trawl, midwater trawl, and hook-and-line fishery are provided
831 in Table 21. Fishery selectivity retention has changed over the modeled period due to
832 management changes. The time block on the retention curves for the trawl fishery were
833 set from 1918-1991, 1992-2001, 2002-2007, 2008, 2009-2010, 2011-2016 based on available
834 discarding data and changes in trip limits that likely resulted in changes to discarding patterns
835 of Pacific ocean perch. No discarding was assumed in the at-sea hake and the foreign fisheries.

836 The following distributions were assumed for data fitting. Survey indices were lognormal,
837 total discards were lognormal.

838 3.1.4 Modeling Software

modeling-software

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

844 3.1.5 Priors

priors

845 A prior distribution was developed for the natural mortality parameter from an analysis
846 of a maximum age of 100 years. The analysis was performed by Owen Hamel (pers comm,
847 NWFSC, NOAA) and used data from Then et al. (2015) to provide a lognormal distribution
848 for natural mortality. The median of the lognormal prior is 0.054 and has a standard error of
849 0.4384343.

850 The prior for steepness (h) assumes a beta distribution with parameters based on an update of
851 the Dorn rockfish prior (commonly used in past West Coast rockfish assessments) conducted
852 by J. Thorson (pers comm, NWFSC, NOAA) which was reviewed and endorsed by the SSC
853 in 2017. The prior is a beta distribution with $\mu=0.72$ and $\sigma=0.15$. However, fixing steepness
854 within the model resulted in unrealistic relative biomass levels (> 1), it was also decided to
855 fix steepness at 0.50. The previous assessment estimated and fixed steepness equal to 0.40.
856 The current data does not contain information regarding steepness and 0.50 was selected as
857 an intermediate value between the prior and the previous assessment value. The steepness
858 value of 0.50 was contained within the estimated uncertainty envelope from the assessment
859 model when either the prior value of 0.72 or 0.40 values were assumed.

860 **3.1.6 Data Weighting**

data-weighting

861 The base case was weighted such that the various data sources were mostly consistent with
862 each other in terms of the relationship between input and effective sample sizes. Length and
863 age-at-length compositions from the NWFSC shelf-slope survey were fit along with length
864 and marginal age compositions from the fishery fleets. Length data started with a sample size
865 determined from the equation listed in Section 2.2.4 and 2.1.1. Age-at-length data assumed
866 that each age was a random sample within the length bin and started with a sample size equal
867 to the number of fish in that length bin. However, the 2016 NWFSC shelf-slope age-at-length
868 data was variable compared to previous years for both males and females relative to all other
869 years with observed fish being smaller at age. Due to the increased variability within this
870 data year, the effective sample size for this year was reduced to 50% of the number of fish
871 within each length-age bin.

872 One extra variability parameter that was added to the input variance was estimated for the
873 Triennial and the NWFSC shelf-slope survey indices. Vessels present in the WCGOP data
874 were bootstrapped to provide uncertainty of the total discards (Table 14).

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

882 **3.1.7 Estimated And Fixed Parameters**

estimated-and-fixed-parameters

883 There were 164 estimated parameters in the base case model. These included one parameter for
884 R_0 , 8 parameters for growth, 2 parameters for extra variability on the Triennial and NWFSC
885 shelf-slope surveys indices, 24 parameters for selectivity, retention, and time blocking of the
886 fleets and the surveys, 117 recruitment deviations, and 12 forecast recruitment deviations
887 (Table 23).

888 Fixed parameters in the model were as follows. Steepness was fixed at 0.50. A sensitivity
889 analysis and a likelihood profile were done for steepness. Natural mortality was fixed at
890 0.054 for females and males, which is the median of the prior. The standard deviation of
891 recruitment deviates was fixed at 0.70. Maturity at age was fixed as described in Section
892 2.3.2. Length-weight parameters were fixed at estimates using all length-weight observations
893 (Figure 29).

894 Dome-shaped selectivity was explored for both the fishery and the surveys. Older Pacific
895 ocean perch are often found in deeper waters and may move into areas that limit their

896 availability to fishing gear, especially trawl gear. Domed shape selectivity was assumed for the
897 fishery fleet and the Triennial survey. The final base model assumed asymptotic selectivity
898 for the at-sea hake fishery, and all other surveys.

899 **3.2 Model Selection and Evaluation**

model-selection-and-evaluation

900 The base case assessment model for Pacific ocean perch was developed to balance parsimony
901 and realism, and the goal was to estimate a biomass trajectory for the population of Pacific
902 ocean perch on the west coast of the United States. The model contains many assumptions
903 to achieve parsimony and uses many different sources of data to estimate reality. A series of
904 investigative model runs were done to achieve the final base case model.

905 **3.2.1 Key Assumptions and Structural Choices**

key-assumptions-and-structural-choices

906 The key assumptions in the model were that the assessed population is a single stock with
907 biological parameters characterizing the entire coast, maturity at age has remained constant
908 over the period modeled, weight-at-length has remained constant over the period modeled,
909 the standard deviation in recruitment deviation is 0.70, and steepness is 0.50. These are
910 simplifying assumptions that unfortunately cannot be verified or disproven. Sensitivity
911 analyses were conducted for most of these assumptions to determine their effect on the
912 results.

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

916 **3.2.2 Alternate Models Considered**

alternate-models-considered

917 The exploration of models began by bridging from the 2011 assessment to SS version 3.24U,
918 which produced no discernable difference. The updated catch series with discards added per
919 the 2011 assessment produced insignificant differences in the relative scale of the population
920 although the updated historical removals resulted in an increase in the estimate of unfished
921 biomass. Updating the survey indices produced small differences in the relative scale of the
922 population. Adding age and length data each resulted in less of a population decline from
923 the 1970s to pre-2000, resulting in an increase in the estimated final stock status as of 2017.
924 However, the addition of new data resulted in an early pattern within recruitment, indicating
925 that the assumptions within the previous model may not represent the best fit to the current
926 data.

927 This assessment estimated discards in the model, so time was spent investigating time blocks
928 for changes in selectivity and retention to match the limited discard data as best as possible.
929 Using major changes in management and observed changes in landings, a set of blocks for
930 retention was found for the bottom trawl fleets. In the spirit of parsimony, we used as few
931 blocks as possible, allowed blocks only for time periods with data, and added new blocks
932 when we felt they were justified by changes in management and they improved the fit to the
933 data.

934 Natural mortality was also investigated and a new prior was developed assuming a maximum
935 age of 100 years for females and males. The previous assessment estimated male natural
936 mortality as an offset from female natural mortality which was fixed at the median of the
937 2011 prior. This assessment attempted to estimate natural mortality for both sexes using the
938 2017 updated prior, but there was little to no information on natural mortality within the
939 data and hence opted to fix the value for females. Upon additional exploration, the model
940 estimated very little difference in male natural mortality relative to females (< 0.002) and
941 in the interest of selecting the model that fit the data with the fewest parameters required,
942 males were fixed equal to the female natural mortality.

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

958 3.2.3 Convergence

convergence

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

967 **3.3 Response To The Current STAR Panel Requests**
response-to-the-current-star-panel-requests

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

969

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

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

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

973

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

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

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

977

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

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

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

981

- 982 • **Item No. 1**
- 983 • **Item No. 2**
- 984 • **Item No. 3, etc.**

985 **3.4 Base Model Results**

base-model-results

986 The base model parameter estimates along with approximate asymptotic standard errors
987 are shown in Table 23 and the likelihood components are shown in Table 24. Time-series of
988 estimated stock size over time are shown in Table 26. Estimates of key derived parameters
989 and approximate 95% asymptotic confidence intervals are shown in Table 25.

990 **3.4.1 Parameter Estimates**

parameter-estimates

991 The estimates of maximum length and the von Bertanlaffy growth coefficient, k , were less
992 than the external estimates for males and females (Figure 30, but were well within the
993 95% confidence interval given the estimated uncertainty (Table 23 and Figure 34). Female
994 and male Pacific ocean perch grow quickly at younger ages, reaching near maximum length
995 by age 20 with female Pacific ocean perch having a larger maximum length.

996 Selectivity curves were estimated for commercial and survey fleets. The estimated selectivity
997 for all fleets within the model are shown in Figure 35. The fishery selectivity was estimated
998 dome shaped, reaching maximum selectivity for fish between 35 and 40 cm. The At-Sea
999 Hake fishery was estimated to have little selectivity for smaller Pacific ocean perch and only
1000 reaching full selectivity at the largest sizes. Survey selectivities, excluding the Triennial
1001 survey, were estimated asymptotic during model explorations with the final selectivity fixed
1002 asymptotic in the final base model. The Triennial survey selectivity peaked at lengths between
1003 25 and 30 cm and declined before reaching a constant selectivity for larger Pacific ocean
1004 perch. The foreign fleet for which only catch data are available was assumed to be identical
1005 to the main fishery, although a sensitivity was performed (not shown) that mirrored the
1006 foreign selectivity to that of the Pacific ocean perch survey selectivity resulting in only a
1007 small difference in stock status.

1008 Retention curves were estimated for the fishery fleet only and were allowed to vary based
1009 upon discard data within the model over time (Figure 36). Historical retention was estimated
1010 high and declined over time due to management restriction on catch of Pacific ocean perch
1011 with the lowest retention occurring in 2009 and 2010 prior to the implementation of ITQs.
1012 Post-2011 retention was estimated to be nearly 100% for the fishery fleet.

1013 Additional survey variability (process error added directly to each year's input variability)
1014 for the Triennial and the NWFSC shelf-slope surveys were estimated within the model. The
1015 estimated added variance for the Triennial survey was high at 0.39. The model estimated a
1016 small added variance for the NWFSC shelf-slope survey of 0.03. Preliminary models explored
1017 estimating added variance for each of the other indices, but resulted in no added variance
1018 being estimated and hence were not estimated in the base model.

1019 Estimates of recruitment suggest that the Pacific ocean perch population is characterized
1020 by variable recruitment with occasional strong recruitments and periods of low recruitment
1021 (Figures 37 and 38). There is little information regarding recruitment prior to 1970 and the
1022 uncertainty in those estimates is expressed in the model. The four lowest recruitments (in
1023 ascending order) occurred in 2012, 2003, 1998, and 2005. There are very large, but uncertain,
1024 estimates of recruitment in 2008, 2013, 2000, and 1999. The 2008 recruitment event is
1025 estimated to be larger by an order of magnitude than any other recruitment estimated in
1026 the model. The uncertainty interval in number of recruits is large for this year based on the
1027 uncertainty surrounding the spawning output in that year. However, the log recruitment
1028 deviation estimated uncertainty is low.

1029 3.4.2 Fits to the Data

fits-to-the-data

1030 There are numerous types of data for which the fits are discussed: survey abundance indices,
1031 discard data (biomass and length compositions), length composition data for the fisheries and
1032 surveys, marginal age compositions for the fisheries and surveys, and conditional age-at-length
1033 observations for the NWFSC shelf-slope survey

1034 The fits the fishery CPUE and five survey indices are shown in Figure 40. Extra standard
1035 error was estimated for the Triennial and NWFSC shelf-slope surveys. The fishery CPUE
1036 and Pacific ocean perch survey index were fit well by the model. The first two years of the
1037 Triennial survey index, 1980 and 1983, were much higher than the later years and were poorly
1038 fit by the model. Both the AFSC and NWFSC slope survey indices were generally flat and
1039 fit well by the model. The recent NWFSC shelf-slope survey showed a variable trend over
1040 the time period with the 2016 data point being the highest estimate of the series.

1041 Fits to the total observed discard amounts required time blocks (Figure 39). Fits to the trawl
1042 discards from the Pikitch data in 1985-1987 were quite good. Discard rate change modeled
1043 over the 1992 - 2001 was based on management restrictions which were assumed to have
1044 increased discarding practices in the fishery fleet. The next required time block was based on
1045 the WCGOP data from 2002-2007 and were fit well by the model. Discarding increased prior
1046 to the implementation to ITQs requiring blocks for 2008 and the 2009-2010 periods. The
1047 model fit the very low post-ITQ discard rates based on the WCGOP data well.

1048 Fits to the length data are shown based on the proportions of lengths observed by year and
1049 the Pearson residuals-at-length for all fleets. Aggregate fits by fleet are shown in Figure 57.
1050 There are a few things that stand out when examining the aggregated length composition
1051 data. First, the sexed discard lengths appear to be poorly fit by the model but this is
1052 related to small sample sizes. The NWFS slope survey lengths were under estimated by the
1053 model, but these data are over only two years. Finally, both the Triennial and the NWFSC
1054 shelf-slope surveys select both young and old fish in contrast to the other data sources where
1055 larger fish were observed.

1056 Discard lengths from the Pikitch data (1986) and the WCGOP were fit well by the model
1057 and show no obvious pattern in the residuals (Figure 42). The residuals to the fishery lengths
1058 clearly showed the growth differential between males and females where the majority of
1059 residuals at larger sizes were from female fish (Figure 43). The fishery showed large positive
1060 residuals for smaller fish for 2013-2016 which are attributed to the strong 2008 year class
1061 moving through the fishery. The At-sea hake fishery did not show an obvious pattern in
1062 residuals but clearly showed the selectivity of the fishery for larger fish (44). The residuals
1063 for each of the surveys are shown in Figures 45, 46, 47, 48, and 49. The Pearson residuals
1064 from the NWFSC shelf-slope survey clearly showed the strong year classes moving through
1065 the population.

1066 The model was weighted according the Francis weighting which adjust the weight given to a
1067 data set based on the fit to the mean lengths by year. The mean lengths and the estimated
1068 model fits are shown in Figures 50, 51, 52, 53, 54, ??, and 56. The mean lengths from the
1069 fishery were consistent across the sampled period (Figure 70), showing only a decline in the
1070 mean length in 2013-2015 likely due to the large 2008 cohort. The At-sea hake fishery showed
1071 an increase in the mean length of fish observed to 2009 and then fluctuated at larger lengths
1072 (Figure 71). The mean length for the NWFSC shelf-slope survey declined in 2012 and 2016
1073 due to a large observation of young small fish by the survey (Figure 74).

1074 AGE DATA FITS

1075 COND AGE DATA FITS

1076 MEAN AGE DATA FITS

1077 3.4.3 Population trajectory

population-trajectory

1078 The predicted spawning output (in millions of eggs) is given in Table 26 and plotted in Figure
1079 75. The predicted spawning output from the base model generally showed a slight decline
1080 over the time series until when the foreign fleet began. A short, but sharp decline occurred
1081 during the period of the foreign fishery in the late 1960s. The stock continued to decline until
1082 2000 when a combination of strong recruitment and low catches resulted in an increase at
1083 the end of the time series. The recent increase is even faster for total biomass (Figure ??)
1084 because not all fish from the 2008 recruitment are mature (Figure 26). The 2017 spawning
1085 biomass relative to unfished equilibrium spawning biomass is above the target of 40% of
1086 unfished spawning biomass (76.1%), with a low of 34.5% in 1994 (Figure 77). Approximate
1087 confidence intervals based on the asymptotic variance estimates show that the uncertainty in
1088 the estimated spawning biomass is high, especially in the early years. The standard deviation
1089 of the log of the spawning biomass in 2017 is 0.18.

1090 Recruitment deviations were estimated for the entire time series that was modeled (Figure
1091 37 and discussed in Section 3.4.1) and provide a more realistic portrayal of uncertainty.
1092 Recruitment predictions from the mid-1970s and early 1980s were mostly below average,
1093 with the 1999, 2000, 2008, and 2013 cohorts being the strongest over the modeled period.
1094 Many other stock assessments of rockfish along the west coast of the US have estimated a
1095 large recruitment event in 1999 (e.g., greenstriped rockfish (Hicks et al. (2009)) chilipepper
1096 rockfish (Field 2007), darkblotched rockfish (Gertseva et al. 2015)). The 2008 year classes
1097 was estimated as the strongest year class. This year has been estimated to have very strong
1098 year classes for other West Coast stocks (e.g. darkblotched rockfish (Gertseva et al. 2015)),
1099 widow rockfish (Hicks and Wetzel 2015)). It may be worthwhile to investigate the periods
1100 of strong and weak year classes further to see if it is an artifact of the data, a consistent
1101 autocorrelation, or a result of the environment.

1102 The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 78 with
1103 estimated recruitments also shown. The stock is predicted to have never fallen to low enough
1104 levels that the steepness is obvious. However, the lowest levels of predicted spawning biomass
1105 showed some of the smallest recruitments and very few above average recruitments. Steepness
1106 was not estimated in this model, but sensitivities to alternative values of steepness are
1107 discussed below.

1108 3.4.4 Uncertainty and Sensitivity Analyses

uncertainty-and-sensitivity-analyses

1109 A number of sensitivity analyses were conducted, including:

- 1110 1. Data weighting according to the harmonic mean.
- 1111 2. Fixed steepness at the prior value of 0.72.
- 1112 3. Estimate natural mortality for female and male Pacific ocean perch.
- 1113 4. Maturity relationship used in the previous assessment.
- 1114 5. Fecundity relationship used in the previous assessment.
- 1115 6. Split the Triennial survey into two time-series, early (1980-1995) and late (1998-2004).
- 1116 7. Remove the historical commercial CPUE index.
- 1117 8. Inclusion of available Canadian fishery and survey data (does not constitute all data
1118 used in Canadian assessments).
- 1119 9. Inclusion of historical Washington research lengths.
- 1120 10. Inclusion of Oregon special projects length and age data which are sampled at the
1121 dockside of processing facilities.

1122 Likelihood values and estimates of key parameters from each sensitivity are available in Tables
1123 27 and 28. Plots of the estimated time-series of spawning output and relative biomass are
1124 shown in Figures 79, 80, 81, and 82.

1125 The sensitivities which explored steepness or natural mortality had the largest change in
1126 estimated stock status relative to the base model. Fixing steepness at the prior value resulted
1127 in the stock being near unfished spawning biomass output. When natural mortality was
1128 estimated the estimated values were higher relative to the median of the prior used in base
1129 model, resulting in the relative biomass to be > 93%.

1130 Including additional data from either Canada, Washington research lengths, and or Oregon
1131 special projects data resulted in estimated lower stock status relative to the base model.
1132 However, the status was still well above the management target.

1133 Weighting the data according to the harmonic means resulted in the largest decrease in the
1134 estimated stock status relative to the base model with the stock being estimated at 68% of
1135 unfished biomass.

1136 3.4.5 Retrospective Analysis

retrospective-analysis

1137 A 5-year retrospective analysis was conducted by running the model using data only through
1138 2011, 2012, 2013, 2014, and 2015, progressively (Figure 83 and 84). The initial scale of the
1139 spawning population was basically unchanged for all of these retrospectives. The estimation

1140 of the 2008 recruitment deviation decreased as more data was removed. Overall, no alarming
1141 trends were present in the retrospective analysis.

1142 A look at past assessments shows that the prediction of spawning biomass has generally
1143 increased with each assessment (Figure 78). This assessment (2015) predicts the largest
1144 spawning biomass. All assessments show similar trends.

1145 3.4.6 Likelihood Profiles

likelihood-profiles

1146 Likelihood profiles were conducted for R_0 , steepness, and over natural mortality values
1147 separately. These likelihood profiles were conducted by fixing the parameter at specific values
1148 and estimated the remaining parameters based on the fixed parameter value.

1149 For steepness, the negative log-likelihood was minimized at a steepness of 0.30, but the 95%
1150 confidence interval extends over the entire range of possible steepness values (excluding 0.20)
1151 (Figure 85). Likelihood components by data source show that the fishery length and age data
1152 supports a low steepness value, but the NWFSC shelf-slope age data supports a higher value
1153 for steepness. The Triennial survey index indicates a low value of steepness while the other
1154 surveys do not provide information concerning steepness. The relative biomass for Pacific
1155 ocean perch has a wide range across different assumed values of steepness (Figure 86).

1156 The negative log-likelihood was minimized at a natural mortality value of 0.06, but the 95%
1157 confidence interval extends over the majority of natural moratility values. The age and
1158 length data likelihood contribution was minimized at natural morality values ranging from
1159 0.055-0.06 (Figure 87). The relative biomass for Pacific ocean perch widely varied across
1160 alternative values of natural mortality (Figure 88).

1161 In regards to values of R_0 , the negative log-likehood was minimized at approximately $\log(R_0)$
1162 of 9.30 (Figure 89). The fishery and survey composition data was in opposition regarding
1163 values of R_0 where the fishery legnth and age data indicated lower values or R_0 while the
1164 survey ages from the Pacific ocean perch and the NWFSC shelf-slope surveys indicated a
1165 higher value.

1166 3.4.7 Reference Points

reference-points-1

1167 Reference points were calculated using the estimated selectivities and catch distribution
1168 among fleets in the most recent year of the model (2016). Sustainable total yields (landings
1169 plus discards) were 1764.8 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95%
1170 confidence interval of 'r 1264.8 - 2264.8 mt based on estimates of uncertainty. The spawning
1171 output equivalent to 40% of the unfished spawning output ($SB_{40\%}$) was 2653.2 millions of
1172 eggs. The recent catches (landings plus discards) have been below the point estimate of

1173 potential long-term yields calculated using an $SPR_{50\%}$ reference point and the population
1174 has been increasing over the last decade.

1175 The predicted spawning biomass from the base model generally showed a sharp decline during
1176 the 1960s, steep increase above unfished equilibrium levels, followed by less of a decline until
1177 2001 (Figure 75). Since 2001, the spawning biomass has been increasing due to small catches,
1178 and recently, above average recruitment. The 2017 spawning biomass relative to unfished
1179 equilibrium spawning biomass is above the target of 40% of unfished spawning biomass
1180 (Figure 77). The fishing intensity (relative 1-SPR) exceeded the current estimates of the
1181 harvest rate limit ($SPR_{50\%}$) throughout the 1960s as seen in Figure 90. Recent exploitation
1182 rates on Pacific ocean perch were predicted to be much less than target levels. In recent years,
1183 the stock has experienced exploitation rates that have been below the target level while the
1184 biomass level has remained above the target level.

1185 Table 25 shows the full suite of estimated reference points for the base model and Figure 91
1186 shows the equilibrium curve based on a steepness value fixed at 0.50.

1187 4 Harvest Projections and Decision Tables

harvest-projections-and-decision-tables

1188 A twelve year projection of the base model with catches equal to the estimated ACL for years
1189 2019-2028 and a catch allocation equal to the percentages for each fleet over the period of
1190 2014-2016 predicts an increase in the spawning output due to large 2008 cohort, with a slight
1191 downturn beginning in 2023 (Table 29).

1192 Add additional projection post STAR based upon the decision table.

1193 Table 30

1194 5 Regional Management Considerations

regional-management-considerations

1195 6 Research Needs

research-needs

1196 There are many areas of research that could be improved to benefit the understanding and
1197 assessment of Pacific ocean perch. Below, are issues that are considered of the importance.

1198 1. **Natural mortality:** Uncertainty in natural mortality translates into uncertain esti-
1199 mated status and sustainable fishing levels for Pacific ocean perch. The collection

1200 of additional age data, re-reading of older age samples, reading old age samples that
1201 are unread, and improved understanding of the life-history of Pacific ocean perch may
1202 reduce that uncertainty.

1203 **2. Steepness:** The amount of stock resilience, steepness, dictates the rate at which a
1204 stock can rebuild from low stock sizes. Improved understandting regarding the steepness
1205 of US west coast Pacific ocean perch will reduce our uncertainty regarding current stock
1206 status.

1207 **3. Basin-wide understanding of stock structure, biology, connectivity, and dis-**
1208 **distribution:** This is a stock assessment for Pacific ocean perch off of the west coast of the
1209 US and does not consider data from British Columbia or Alaska. Further investigating
1210 and comparing the data and predictions from British Columbia and Alaska to determine
1211 if there are similarities with the US west Ccast observations would help to define the
1212 connectivity between Pacific ocean perch north and south of the U.S.-Canada border.

1213 7 Acknowledgments

acknowledgments

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1220 Patrick Mirrick (ODFW), and Ted Calavan (ODFW) provided Oregon composition data,
1221 historical catches, corrected PacFIN catches, and quickly uploaded age data that were critical
1222 to this assessment. We appreciate Vanessa Tuttle's patience and responsiveness to providing
1223 data. Don Pearson (NOAA) provided historical catch information and compiled the extensive
1224 management changes for Pacific ocean perch which were critical in understanding and
1225 modeling fishery behavior. John Wallace provided multiple last minute PacFIN extractions
1226 and analyzed historical discard rates for use in the assessment.

1227 We are very grateful to Patrick McDonald and the team of agers at CAP for their hard
1228 work reading numerous otoliths and availability to answer questions when needed. Beth
1229 Harness was always eager to help, quick to supply survey extractions, and answered numerous
1230 questions we had. Jason Jannot and Kayleigh Sommers assisted with data from the WCGOP
1231 and entertained our many questions. We would like to acknowledge our survey team and
1232 their dedication to improving the assessments we do. The assessment was greatly improved
1233 through the many discussions within the Population Ecology team in the FRAM division at
1234 the NWFSC.

1235 **8 Tables**

tables

Table 1: Landings for each state (all gears combined), the At-Sea Hake fishery, the Foreign fleet, and research.

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	521.131	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
2017	0.0	13.0	0.0	0.0	0	0.0

Table 2: West Coast history of regulations.

tab:Regs

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	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	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	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	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;
1/1/1986	North	landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 600 mt;
1/1/1986	ALL	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		tab:Index_Summary
	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	tab:NWslope_Ages
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	tab:AFSC_Lengths
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	tab:TriennialLengths
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	tab:Triennial_Ages
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	tab:POP_Lengths
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	tab:POP_Ages
1985	29	1635	70	

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

Year	Source	Discard	Standard Error	tab:Discard
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	tab:CPUE_Summary
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.

tab:Comm_Lengths

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.

`tab:Comm_Ages`

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	tab:ASHOP_Lengths
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	tab:ASHOP_Ages
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

tab:Age_Error

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	<code>tab:Model_setup</code>
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.

`tab:jitter`

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)	OK	0.14	Log_Norm (-2.92, 0.44)
L_at_Amin_Fem_GP_1	20.7848	3	(15, 25)	OK	0.15	None
L_at_Amax_Fem_GP_1	41.5953	2	(35, 45)	OK	0.00	None
VonBert_K_Fem_GP_1	0.167029	3	(0.1, 0.4)	OK	0.06	None
SD_young_Fem_GP_1	1.34323	5	(0.03, 5)	OK	0.12	None
SD_old_Fem_GP_1	2.5618	5	(0.03, 5)	OK	None	
Wtlen_1.Fem	1.044e-05	-99	(0, 3)	None	None	
Wtlen_2.Fem	3.088	-99	(2, 4)	None	None	
Mat50%_Fem	32.1	-99	(20, 40)	None	None	
Mat_slope_Fem	-1	-99	(-2, 4)	None	None	
Eggs_scalar_Fem	8.66e-10	-99	(0, 6)	None	None	
Eggs_exp_len_Fem	4.9767	-99	(-3, 5)	None	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	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	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	None	
Wtlen_2.Mal	3.083	-99	(2, 4)	None	None	
CohortGrowDev	1	-99	(0, 2)	None	None	
FracFemale_GP_1	0.5	-99	(0.01, 0.99)	None	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	None	
SR_regime	0	-99	(-5, 5)	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)
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

=tab:meete1_params

Table 24: Likelihood components from the base model

`tab:like`

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	<small>tab:Ref_pts</small>
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	
Reference points based on $SB_{40\%}$			
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	
Reference points based on SPR proxy for MSY			
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	
Reference points based on estimated MSY values			
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	-	-	-

tab:Timeseries_mod1

Table 27: Sensitivity of the base model

Label	Base	Harmonic weights at prior	Steepness M	Estimate	Old Maturity	NA	tab:Sensitivity1
Total Likelihood	1726.16	2432.50	1726.05	1725.66	1726.17	1726.18	
Survey Likelihood	-25.51	-25.88	-24.99	-25.68	-25.52	-25.49	
Discard Likelihood	-34.22	-27.17	-34.28	-34.29	-34.22	-34.22	
Length Likelihood	135.74	748.49	136.05	135.75	135.74	135.75	
Age Likelihood	1636.59	1717.85	1636.26	1636.59	1636.62	1636.58	
Recruitment Likelihood	12.54	18.20	12.87	12.34	12.54	12.54	
Forecast Recruitment Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	
Parameter Priors Likelihood	1.00	1.00	0.13	0.94	1.00	1.00	
Parameter Deviation Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	
log(R0)	9.36	9.27	9.41	9.74	9.36	9.37	
SB Virgin	6633.08	6136.91	6979.48	7885.80	6505.70	7745.48	
SB 2017	5047.16	4199.96	6883.61	7436.66	5070.80	6103.65	
Depletion 2017	0.76	0.68	0.99	0.94	0.78	0.79	
Total Yield	1764.80	1605.33	2482.46	2329.27	1759.53	1788.51	
Steepness	0.50	0.50	0.72	0.50	0.50	0.50	
Natural Mortality - Female	0.05	0.05	0.05	0.06	0.05	0.05	
Length at Amin - Female	20.78	20.87	20.79	20.78	20.78	20.78	
Length at Amax - Female	41.60	41.72	41.61	41.61	41.60	41.60	
Von Bert. k - Female	0.17	0.17	0.17	0.17	0.17	0.17	
SD young - Female	1.34	1.35	1.34	1.34	1.34	1.34	
SD old - Female	2.56	2.76	2.56	2.56	2.56	2.56	
Natural Mortality - Male	0.05	0.05	0.05	0.06	0.05	0.05	
Length at Amin - Male	20.78	20.87	20.79	20.78	20.78	20.78	
Length at Amax - Male	38.90	38.91	38.91	38.90	38.90	38.90	
Von Bert. k - Male	0.20	0.20	0.20	0.20	0.20	0.20	
SD young - Male	1.34	1.35	1.34	1.34	1.34	1.34	
SD old - Male	2.29	2.60	2.29	2.29	2.29	2.29	

Table 28: Sensitivity of the base model

tab:Sensitivity2

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	tab:Forecast_mod1
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	-	-	-	-	-	-	-

₁₂₃₆ 9 Figures

figures

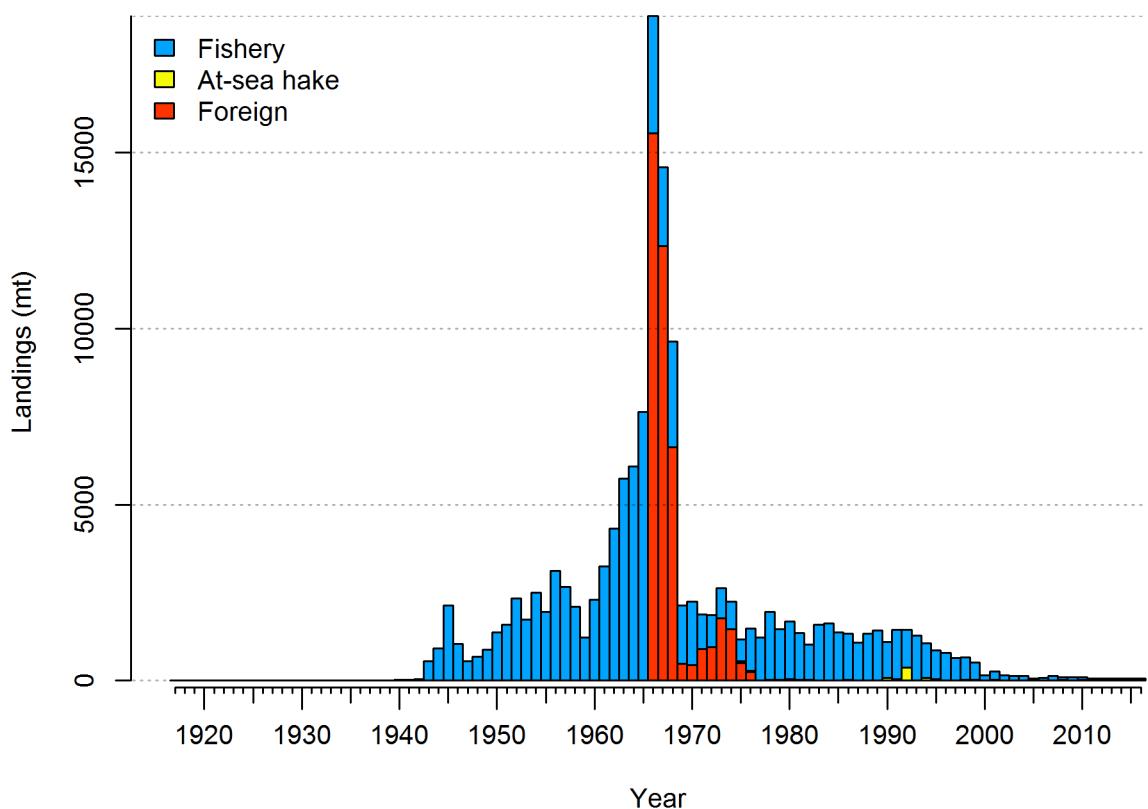


Figure 1: Total catches Pacific ocean perch through 2016. fig:Catch

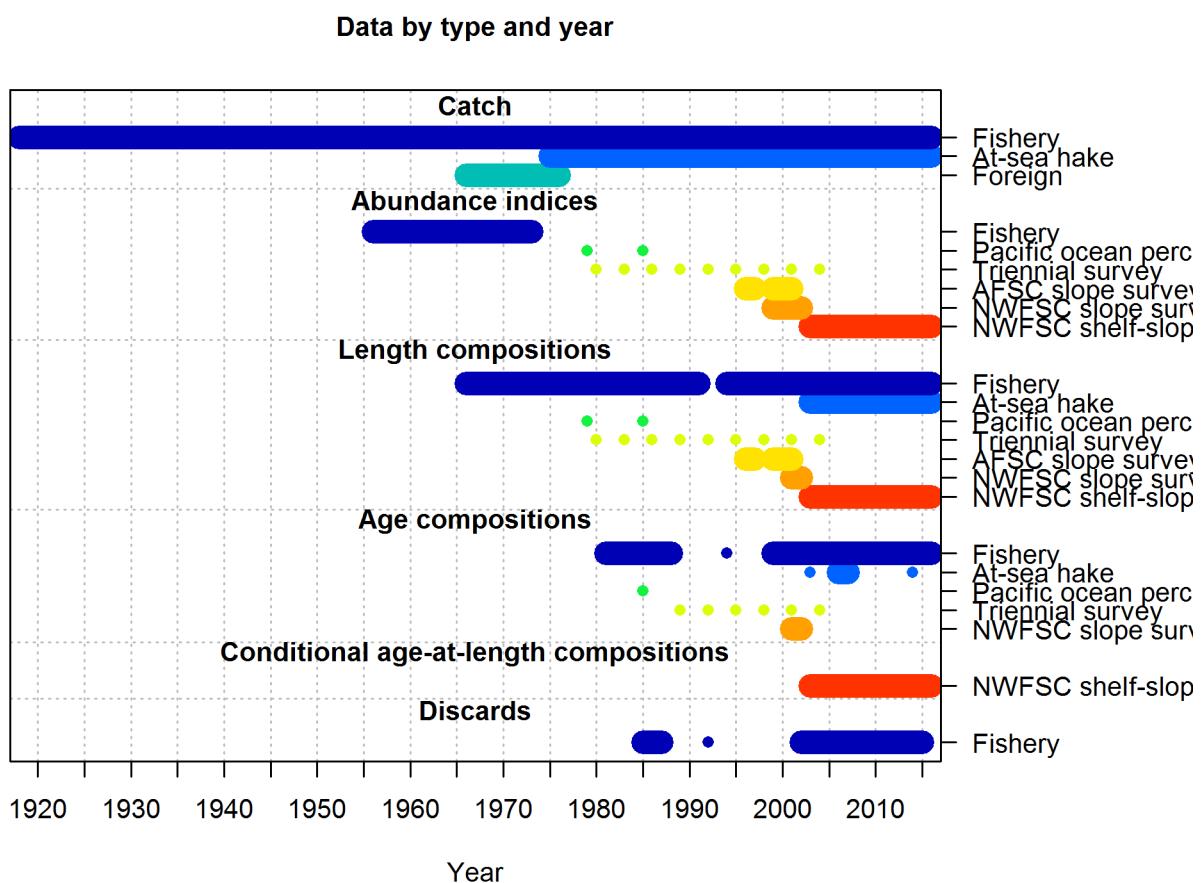


Figure 2: Summary of data sources used in the base model. fig:data_plot

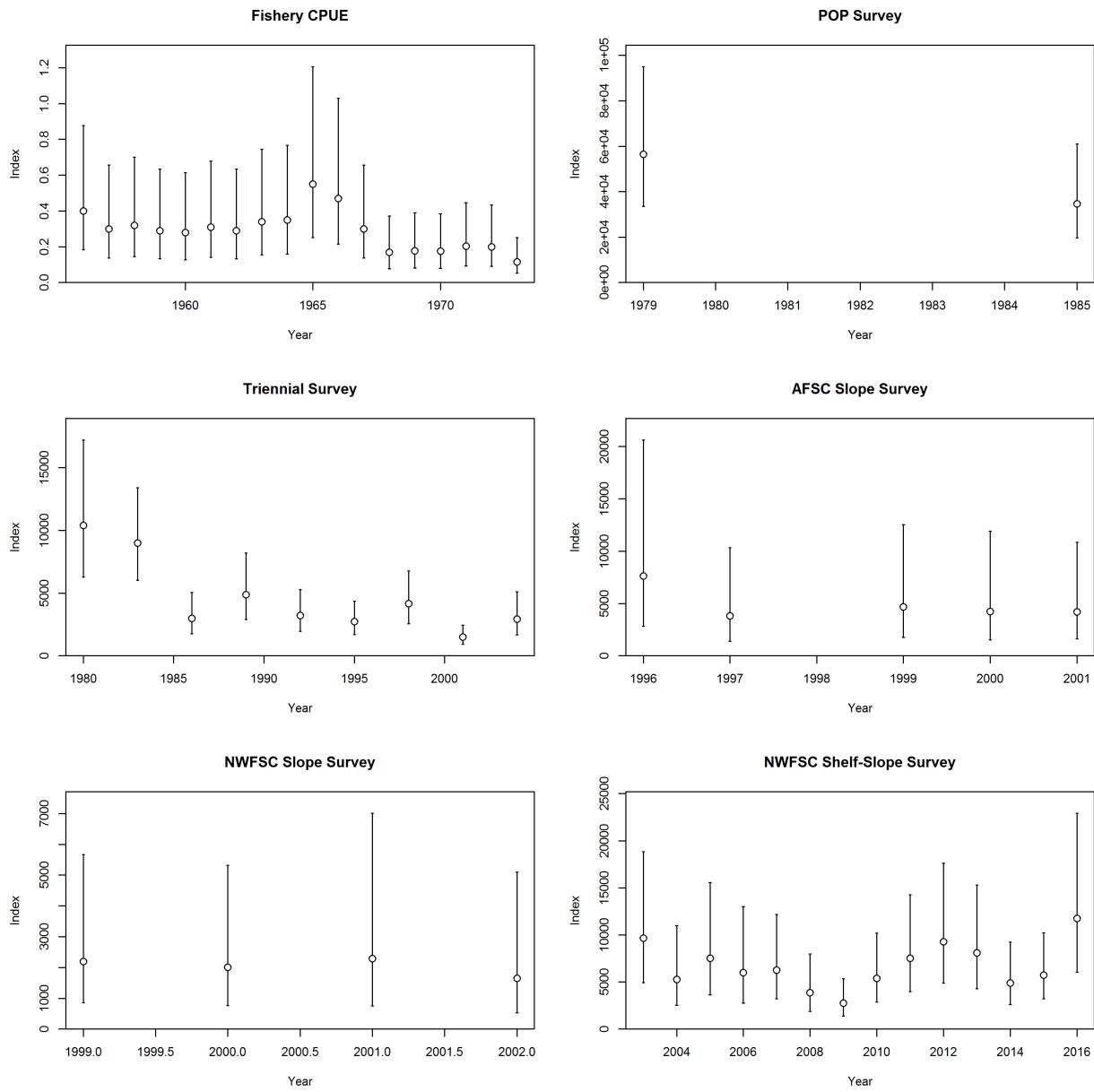


Figure 3: Fishery-dependent and fishery-independent indices for Pacific ocean perch. fig:indices

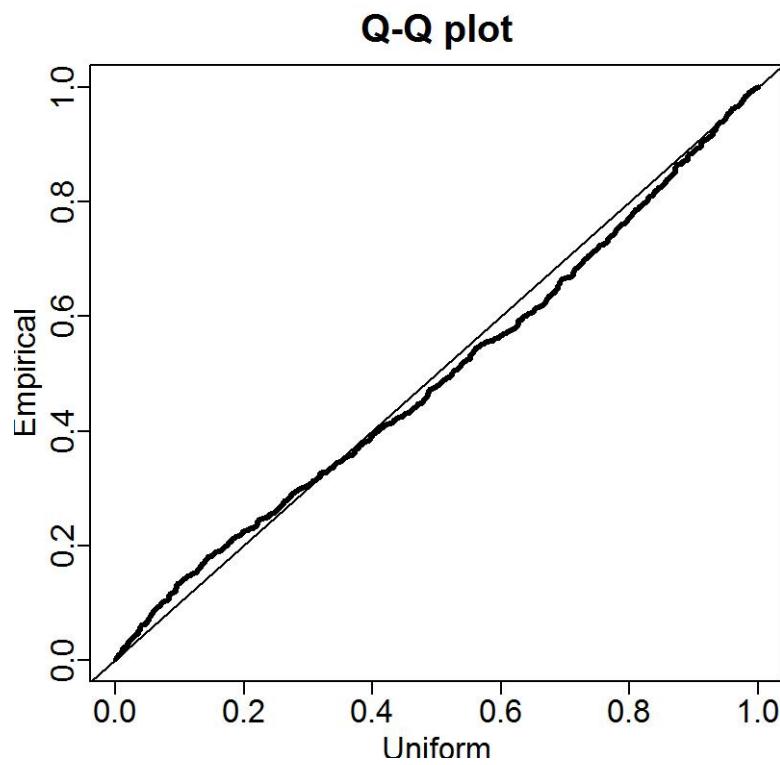


Figure 4: Q-Q plots for the VAST lognormal distribution for the NWFSC shelf-slope survey. fig:nw_qq

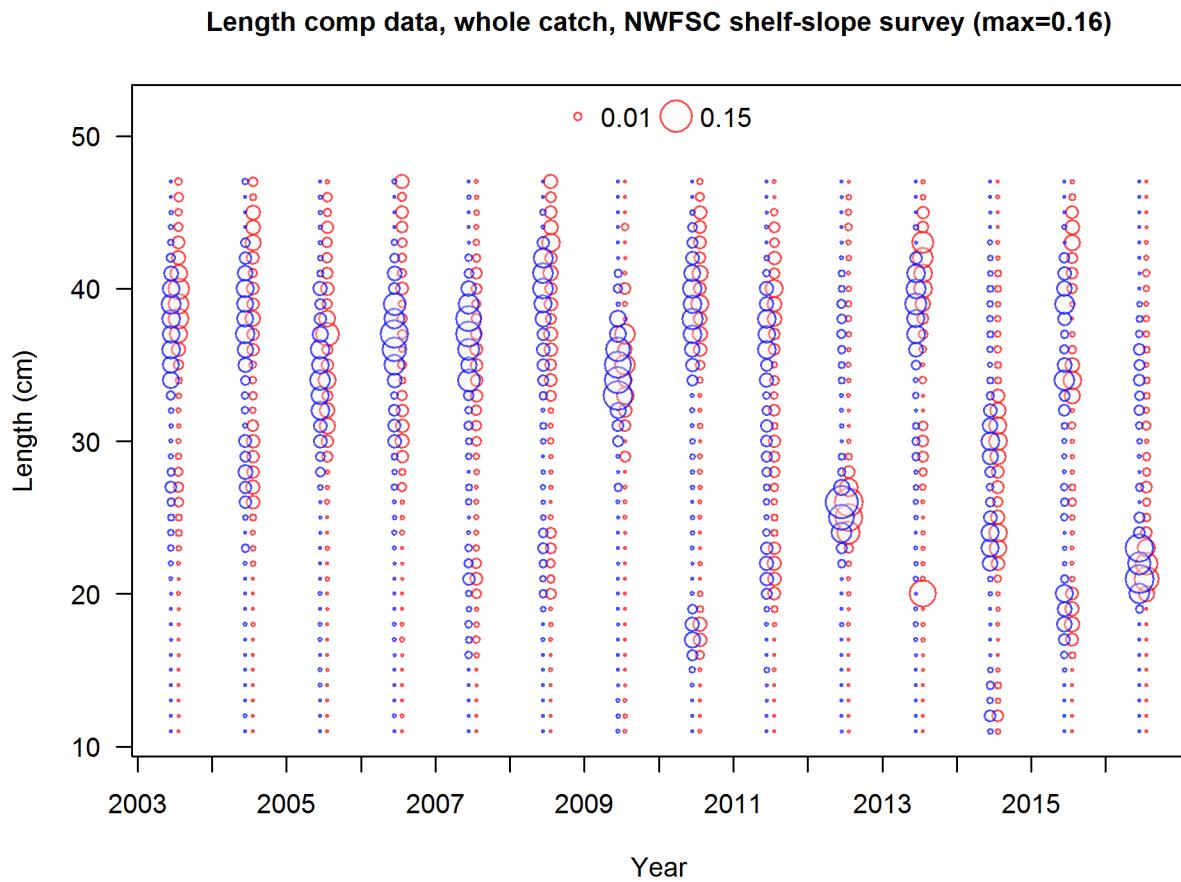


Figure 5: NWFSC shelf-slope survey length frequency distributions for Pacific ocean perch. fig:nw_Length

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

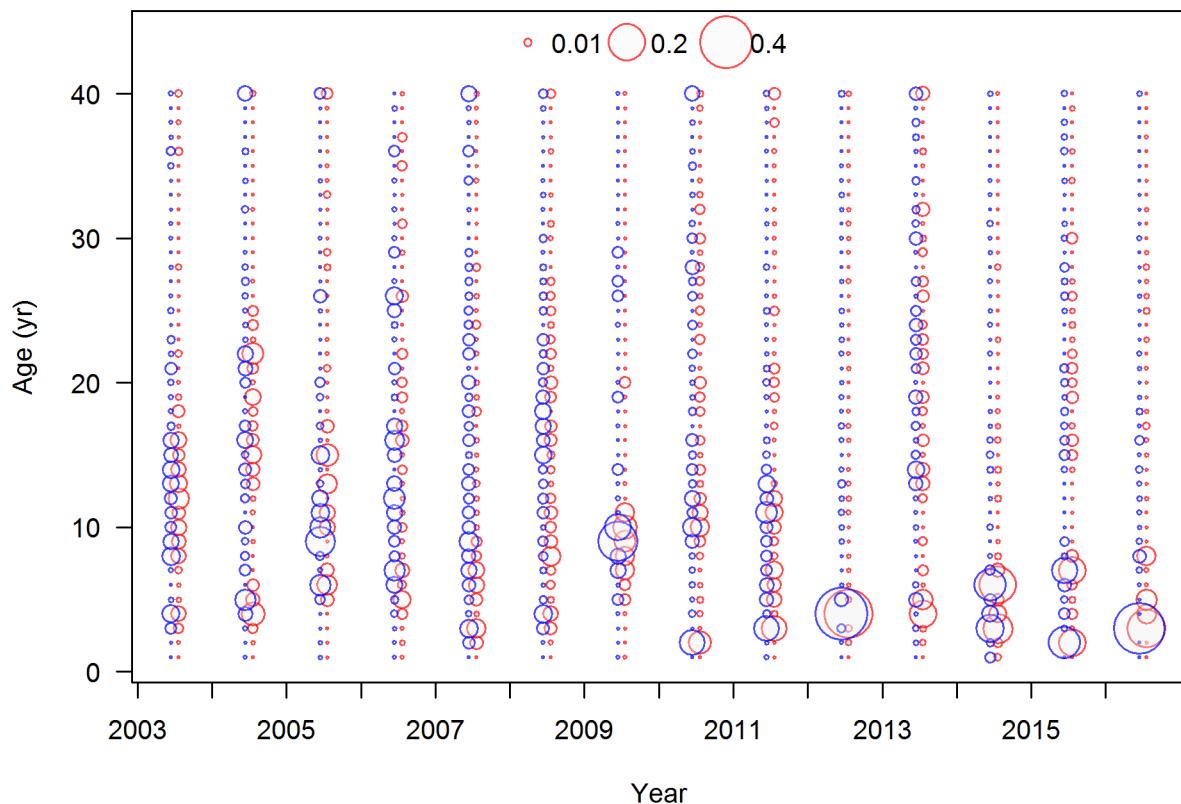


Figure 6: NWFSC shelf-slope survey age frequency distributions for Pacific ocean perch. fig:nw_Age

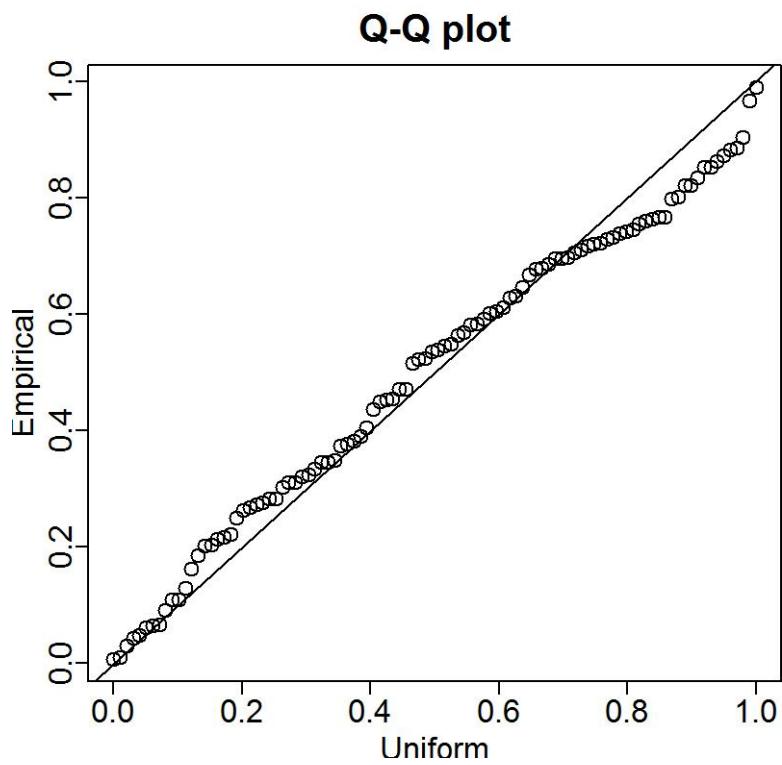


Figure 7: Q-Q plots for the VAST lognormal distribution for the NWFSC slope survey. `fig:nw_slope_q`

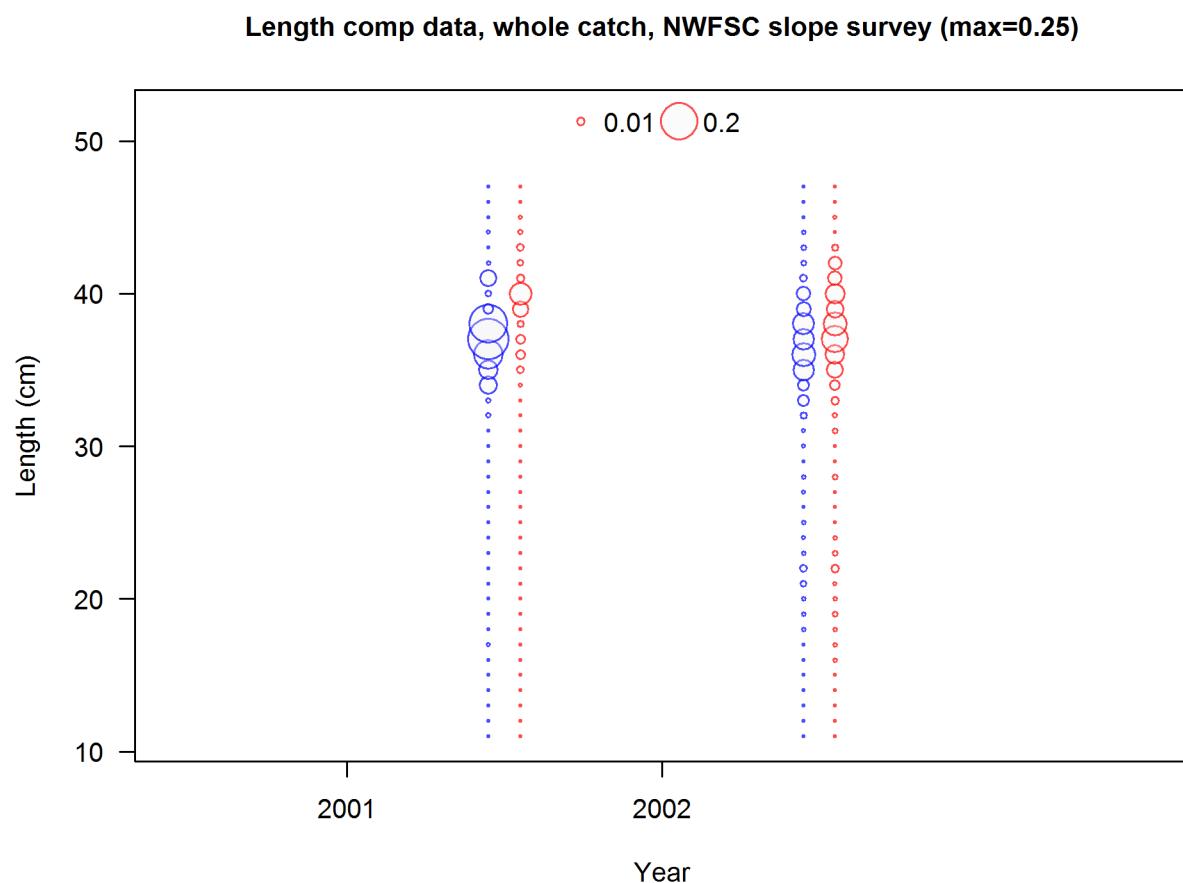


Figure 8: NWFSC slope survey length frequency distributions for Pacific ocean perch. fig:nw_slope_L

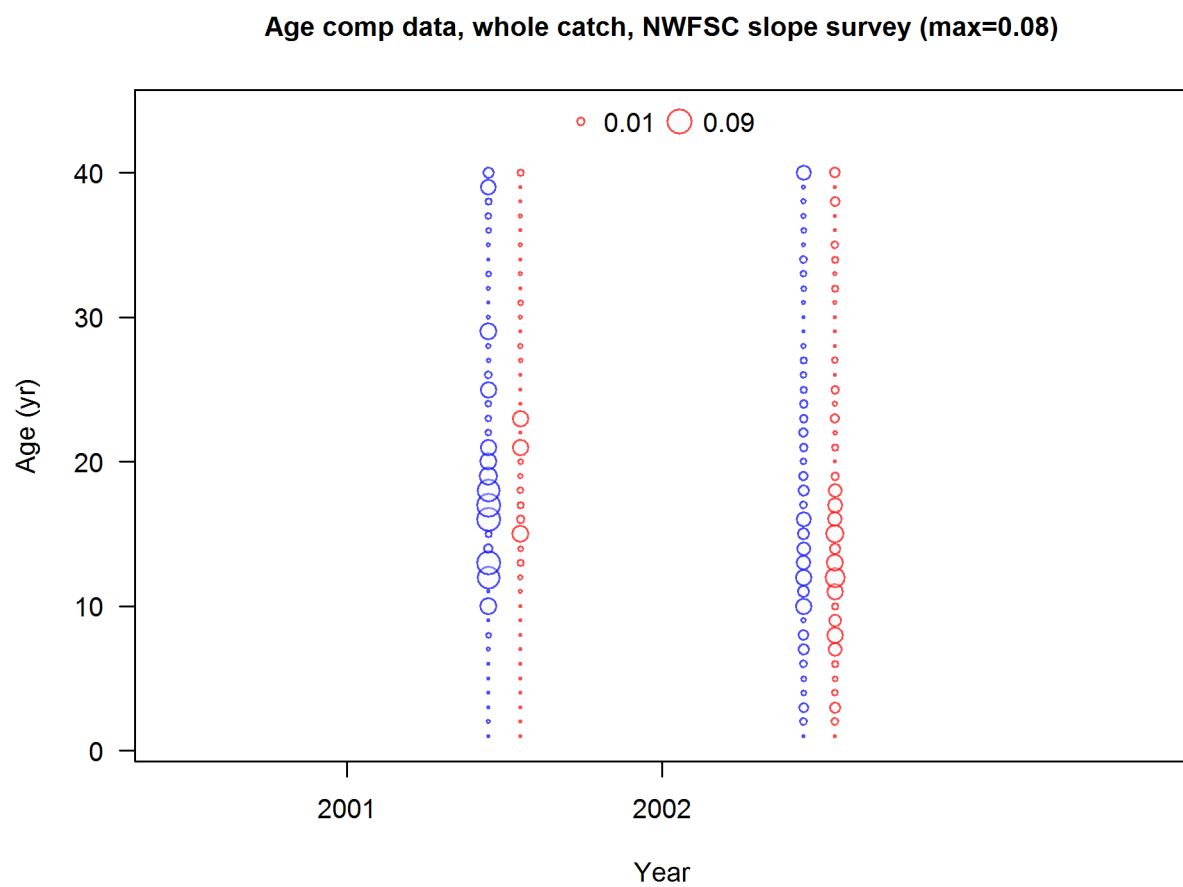


Figure 9: NWFSC slope survey age frequency distributions for Pacific ocean perch. `fig:nw_slope_Age`

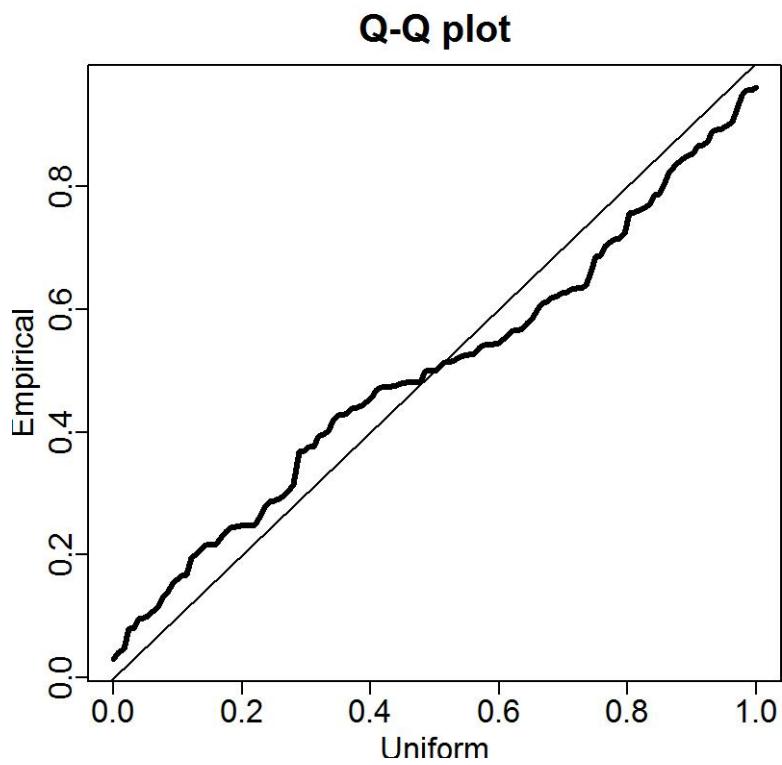


Figure 10: Q-Q plots for the VAST lognormal distribution for the AFSC slope survey. `fig:afsc_qq`

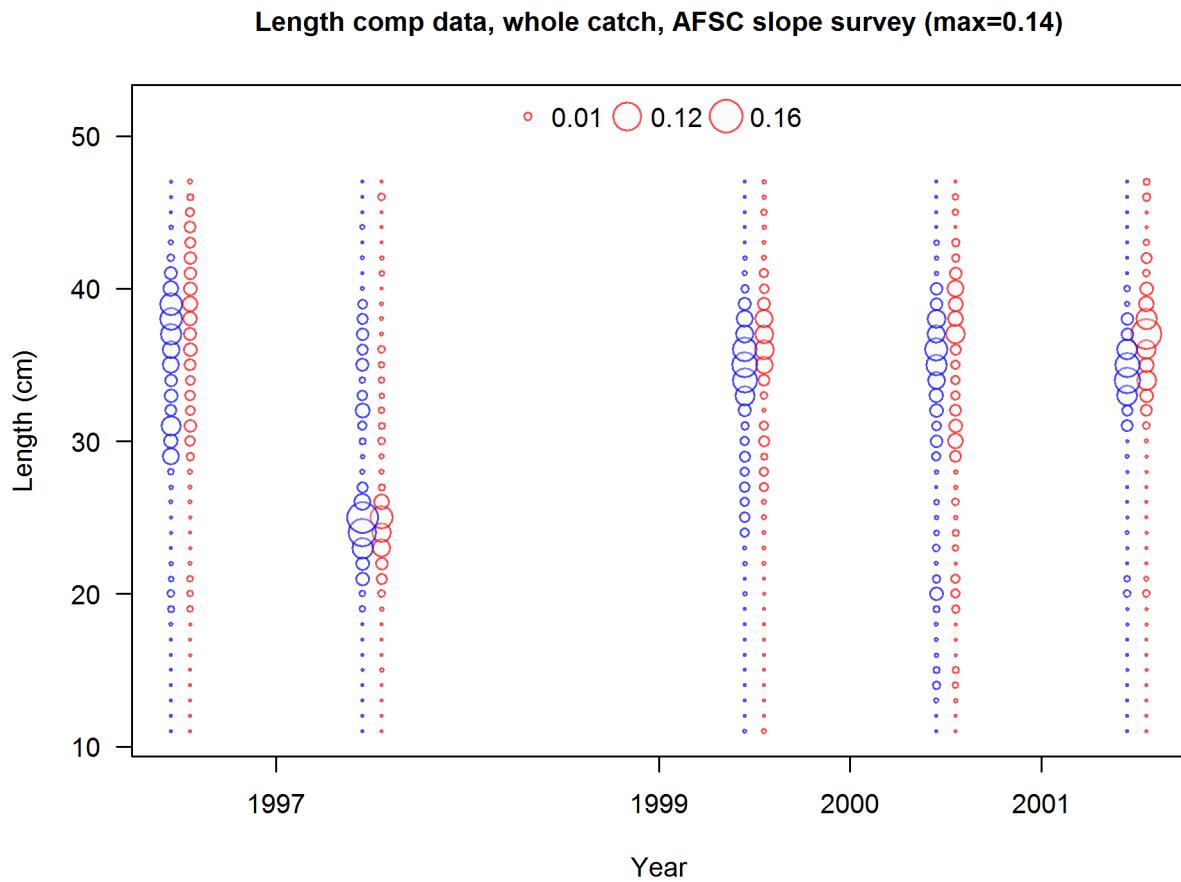


Figure 11: AFSC slope survey length frequency distributions for Pacific ocean perch. fig:afsc_Length

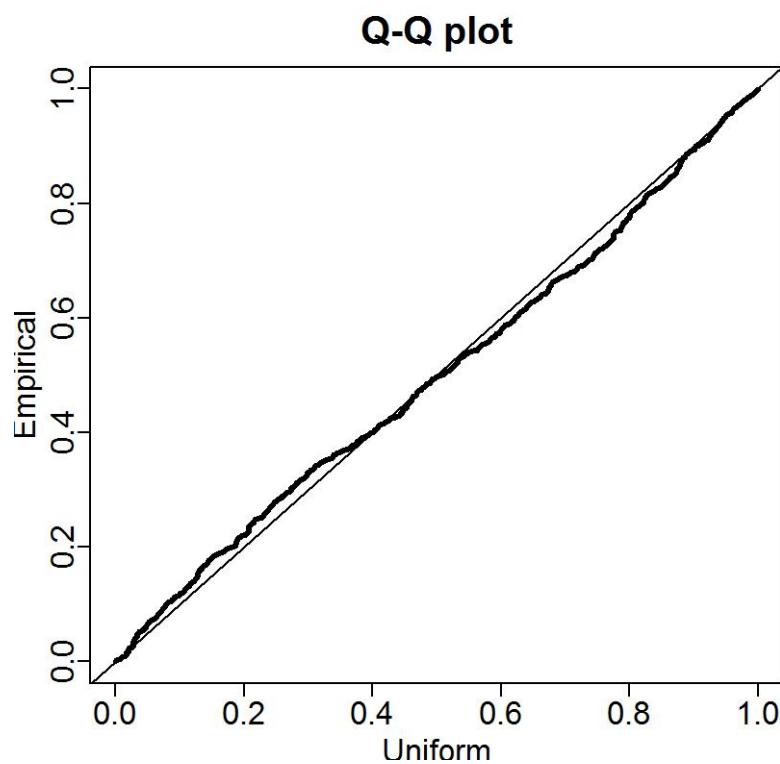


Figure 12: Q-Q plots for the VAST lognormal distribution for the Triennial survey. fig:tri_qq

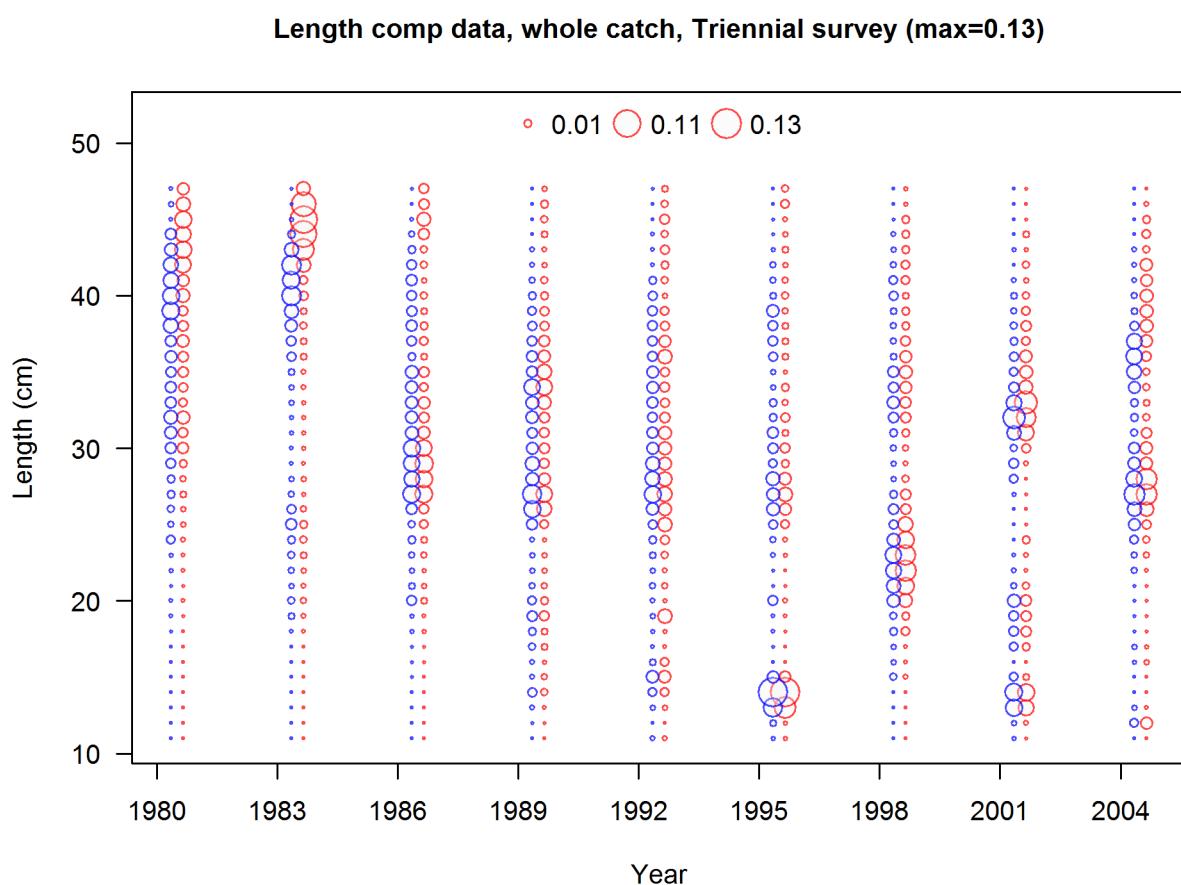


Figure 13: Triennial survey length frequency distributions for Pacific ocean perch. fig:Tri_Length

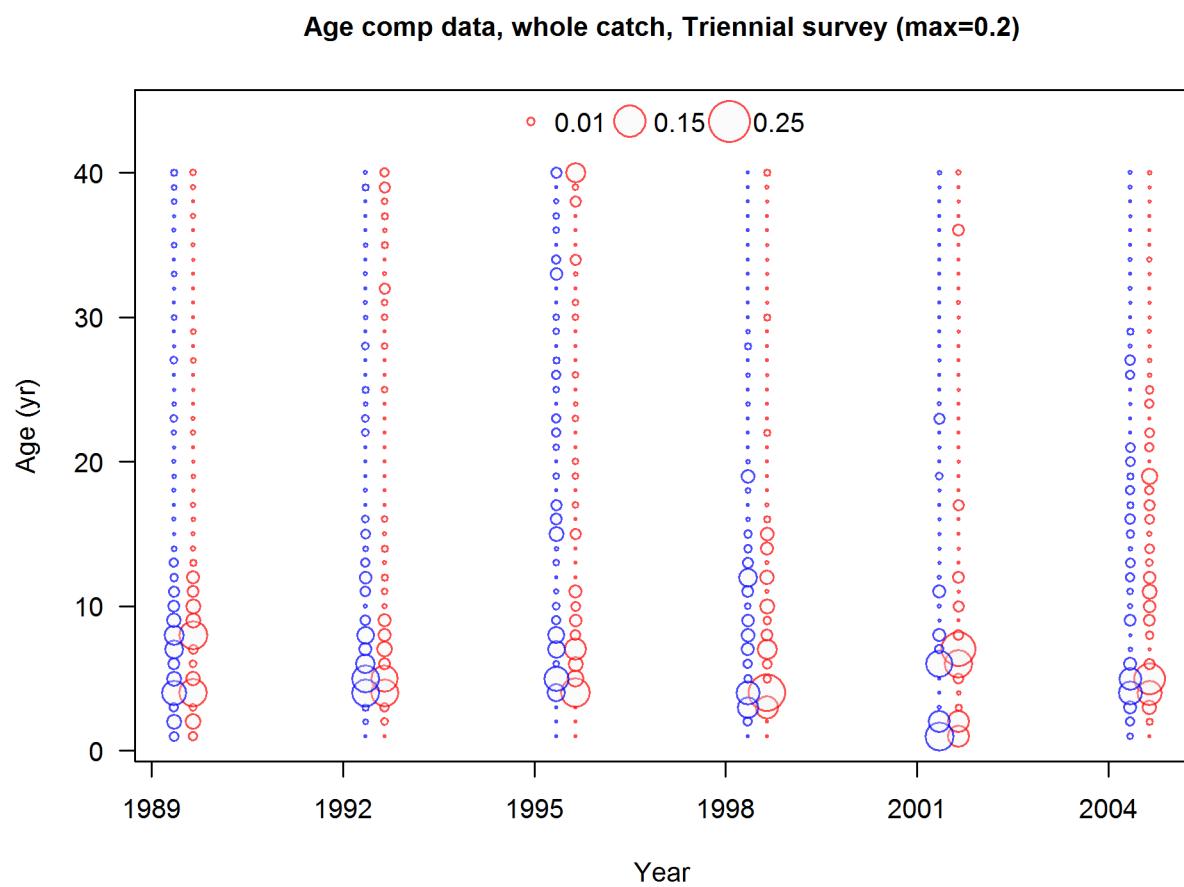


Figure 14: Triennial survey age frequency distributions for Pacific ocean perch. `fig:Tri_Age`

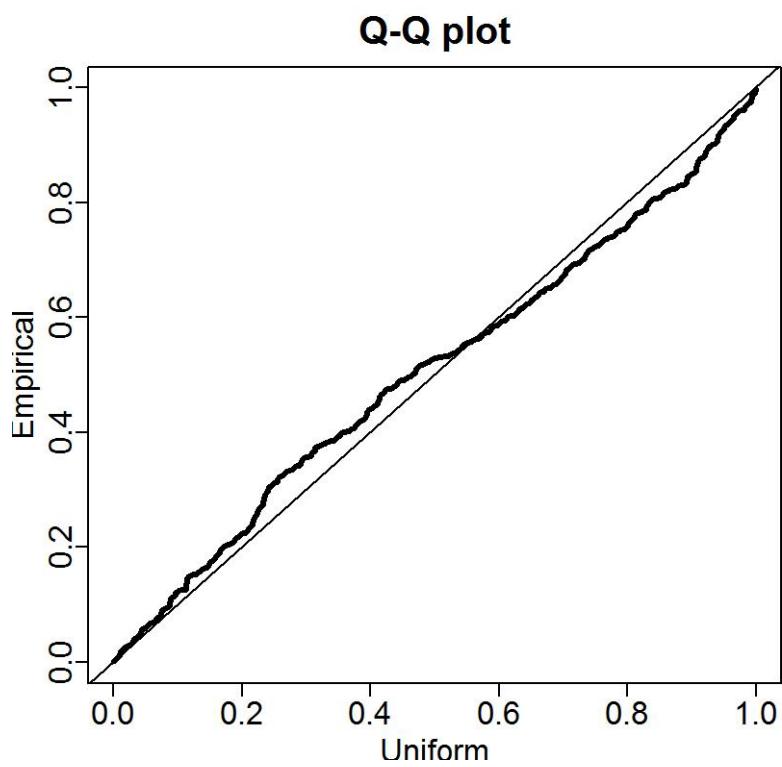


Figure 15: Q-Q plots for the VAST lognormal distribution for the Pacific ocean perch survey.
fig:pop_qq

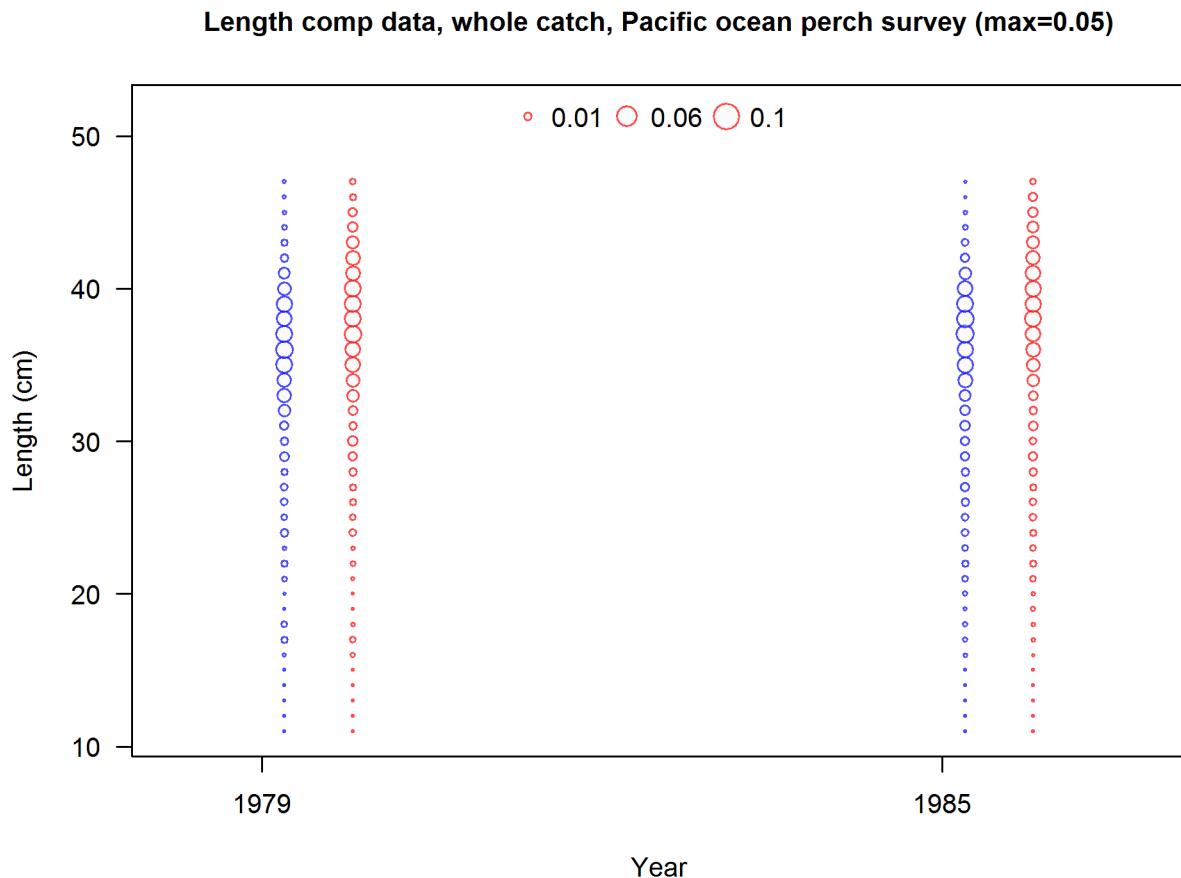


Figure 16: Pacific ocean perch survey length frequency distributions for Pacific ocean perch. fig:POP_Length

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

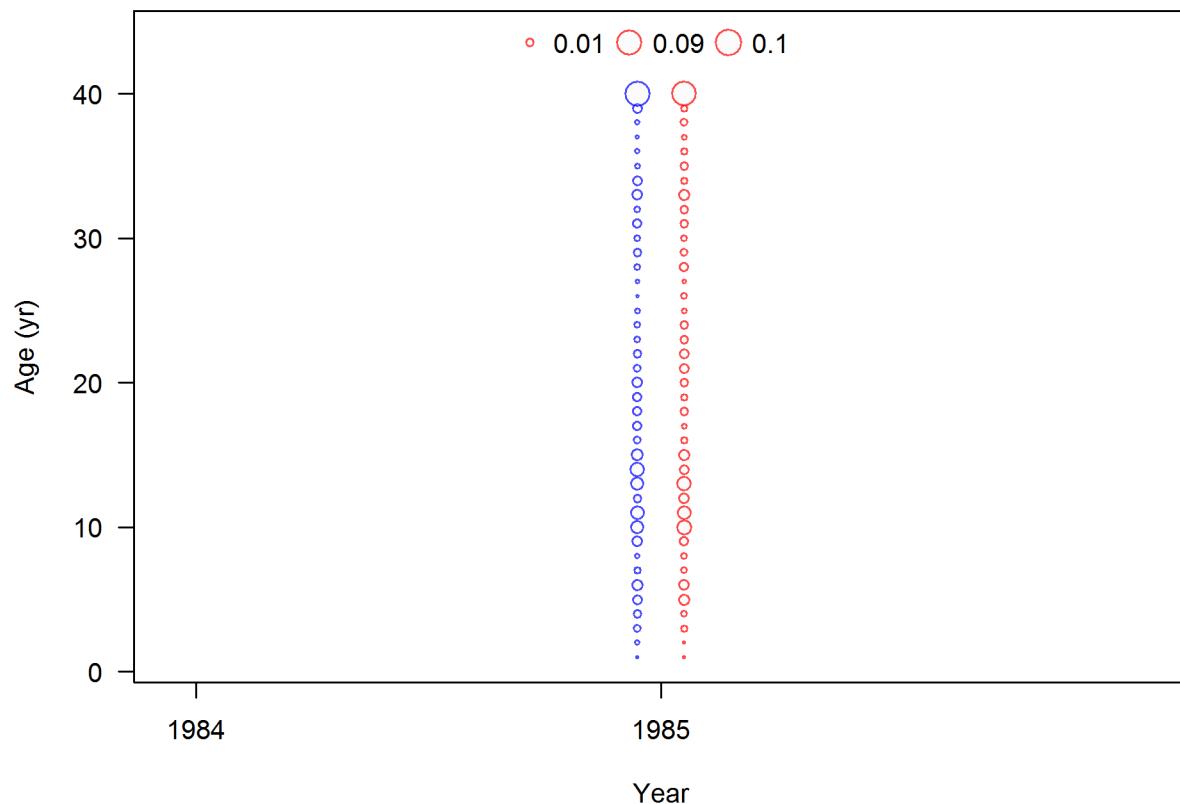


Figure 17: Pacific ocean perch survey age frequency distributions for Pacific ocean perch. fig:POP_Age

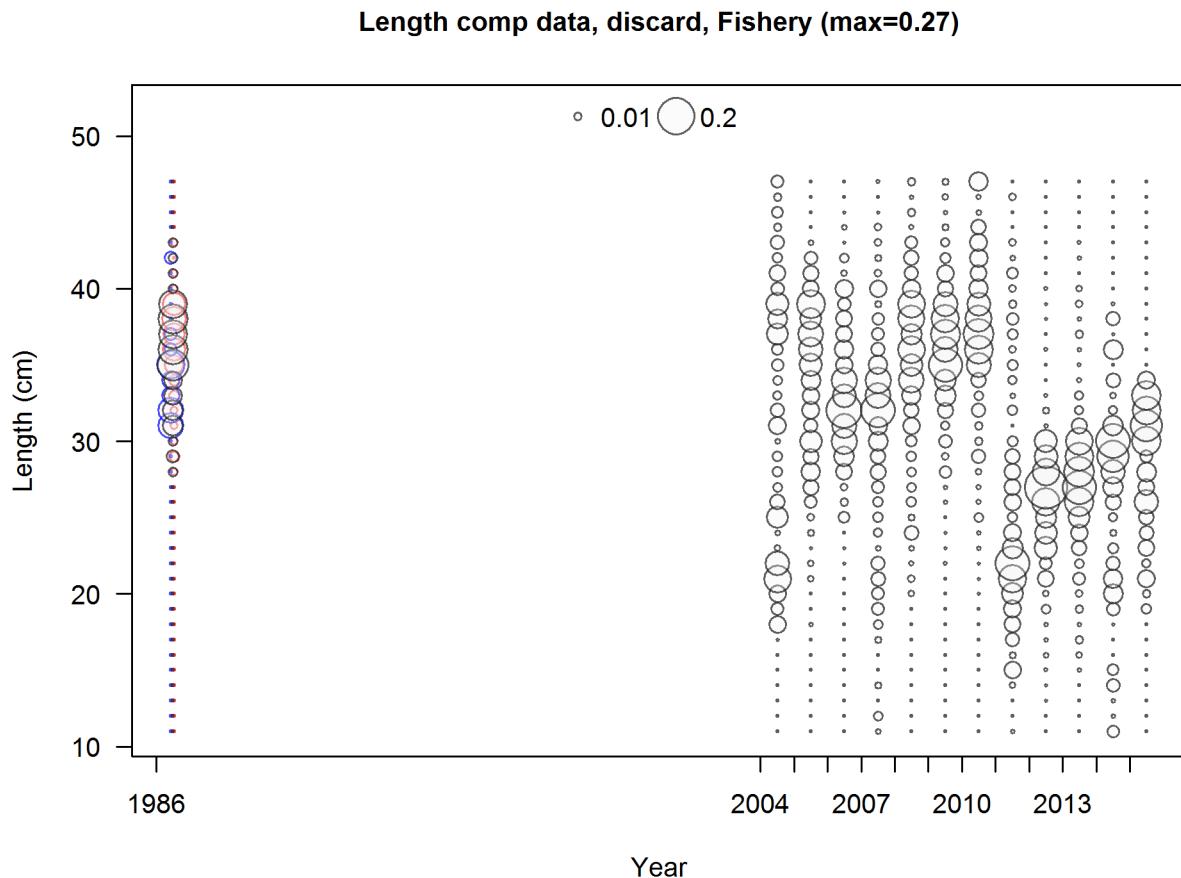


Figure 18: Discard length frequency distributions from WCGOP for Pacific ocean perch. fig:WCGOP_discard

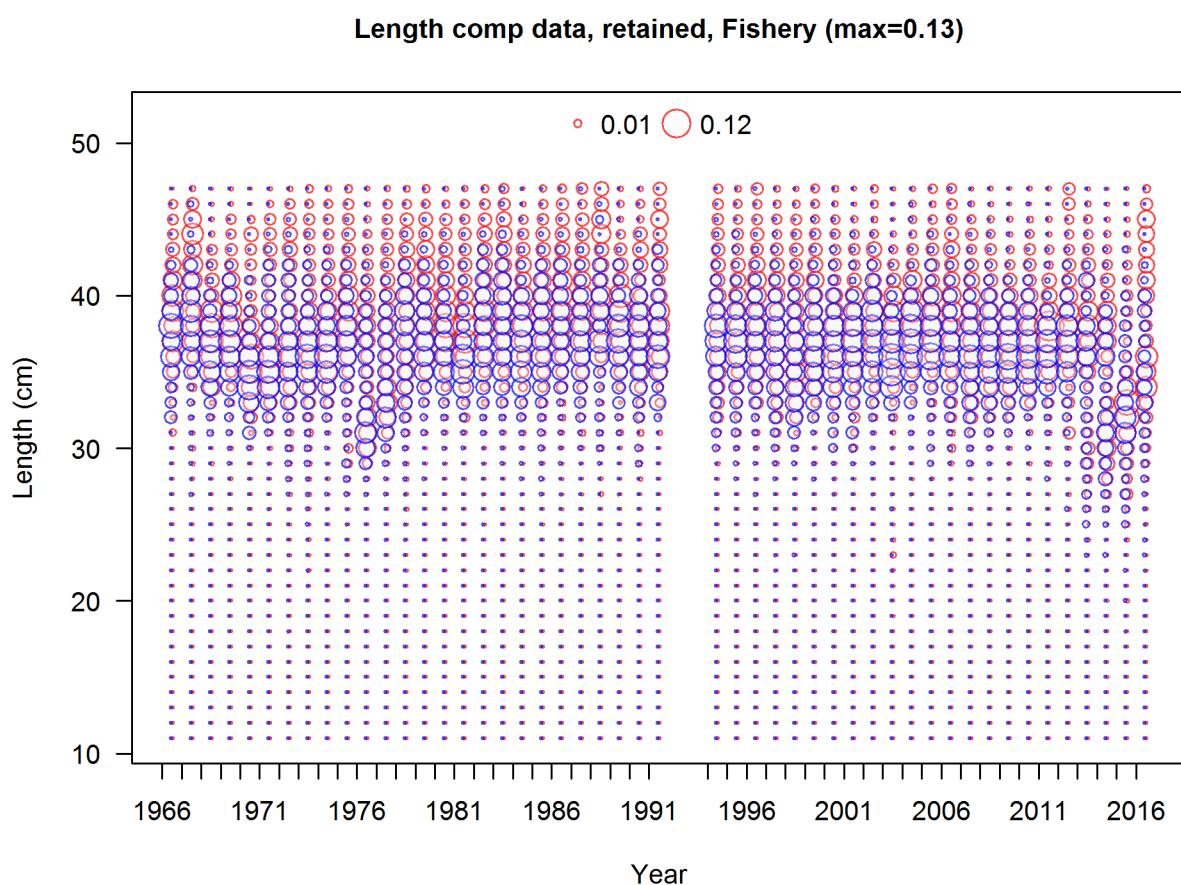


Figure 19: Commercial fishery length frequency distributions for Pacific ocean perch. `fig:Comm_Length`

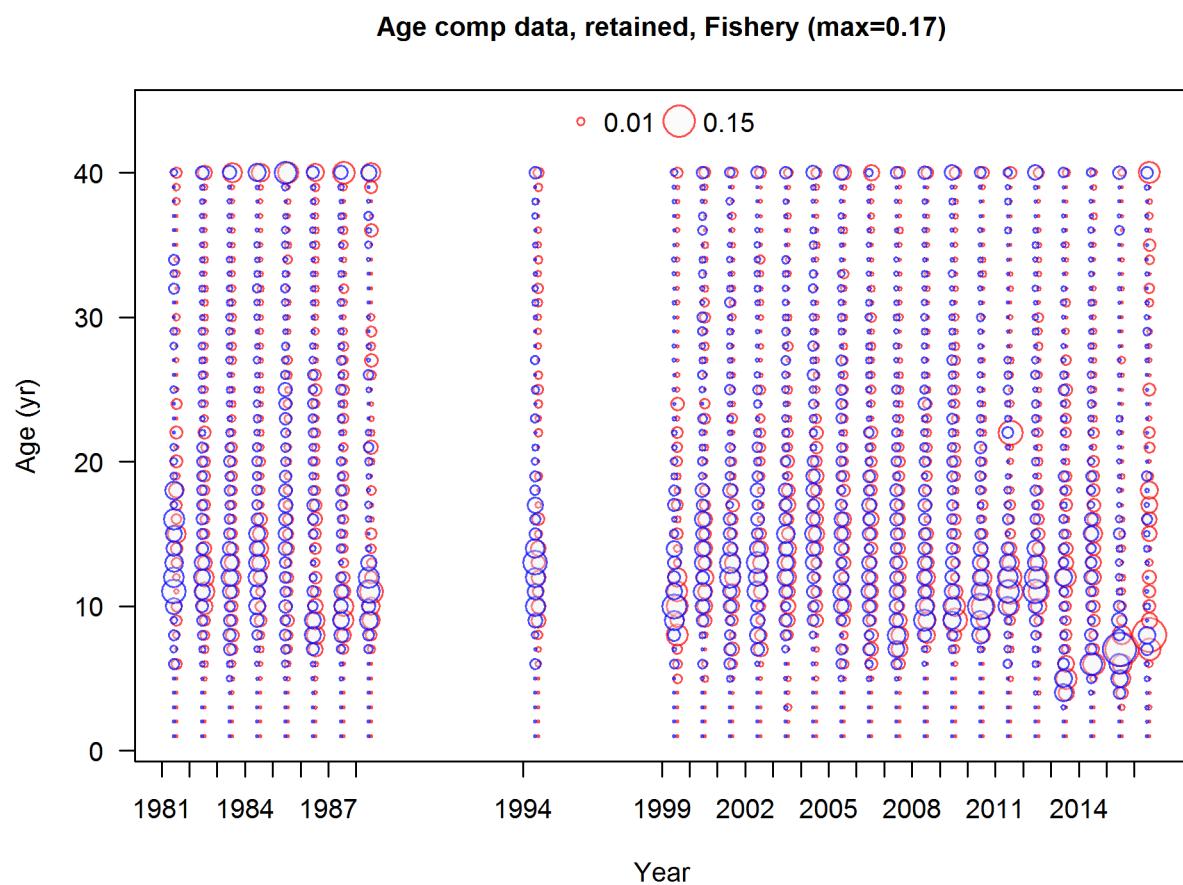


Figure 20: Commercial fishery age frequency distributions for Pacific ocean perch. `fig:Comm_Age`

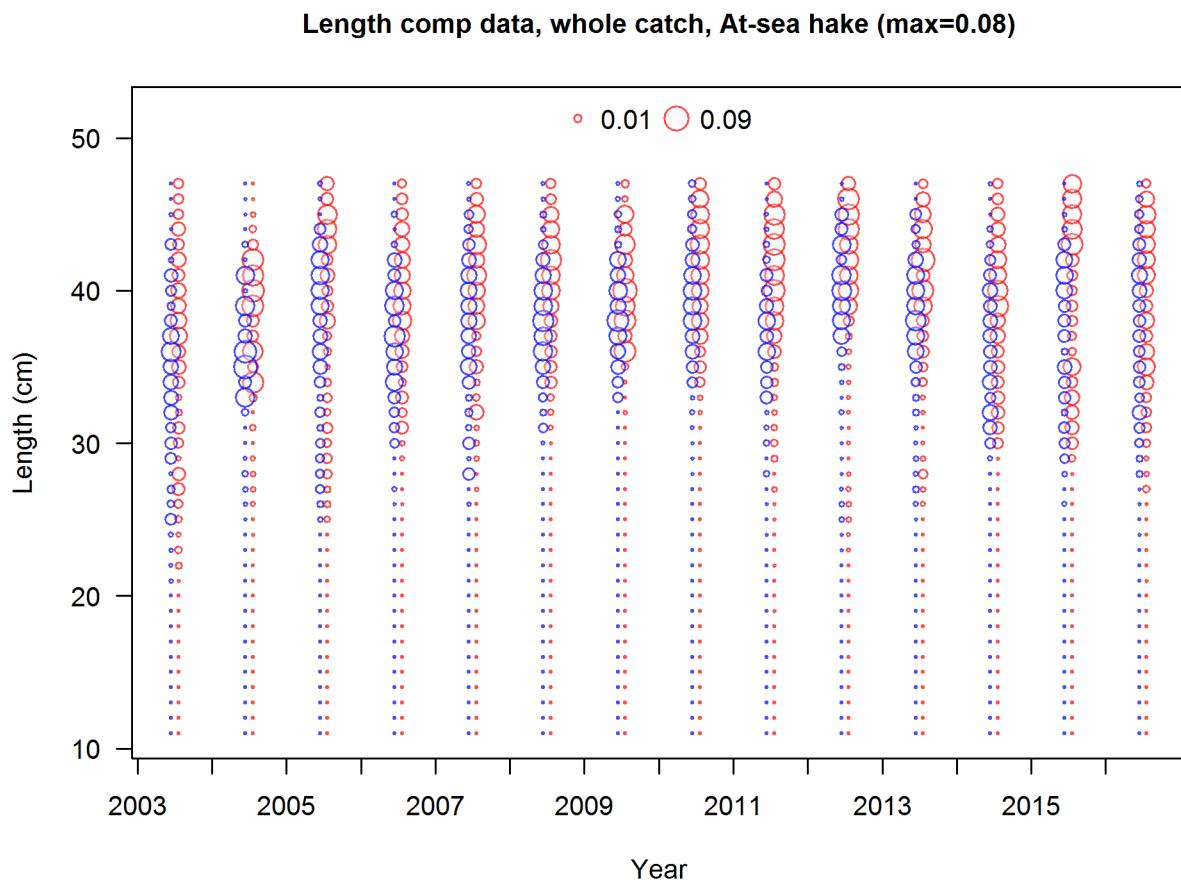


Figure 21: At-Sea hake fishery length frequency distributions for Pacific ocean perch. fig:ASHOP_Length

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

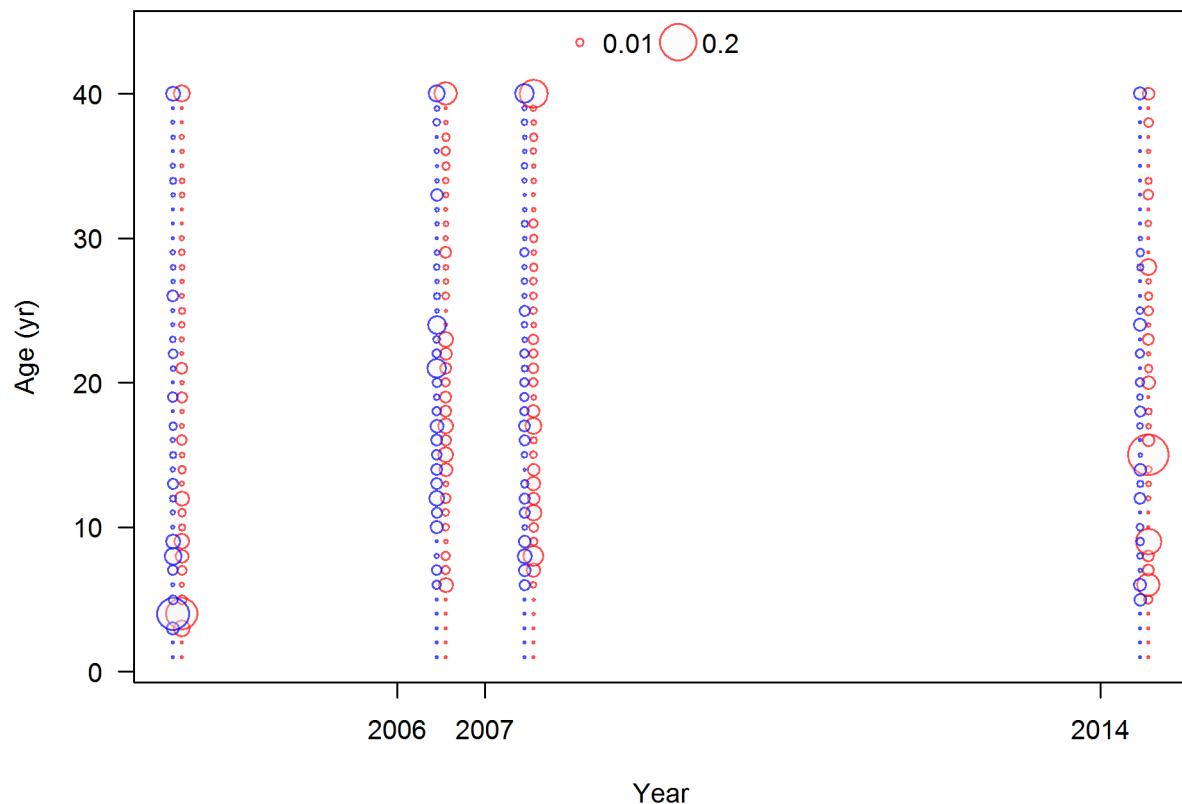


Figure 22: At-Sea hake fishery age frequency distributions for Pacific ocean perch. fig:ASHOP_Age

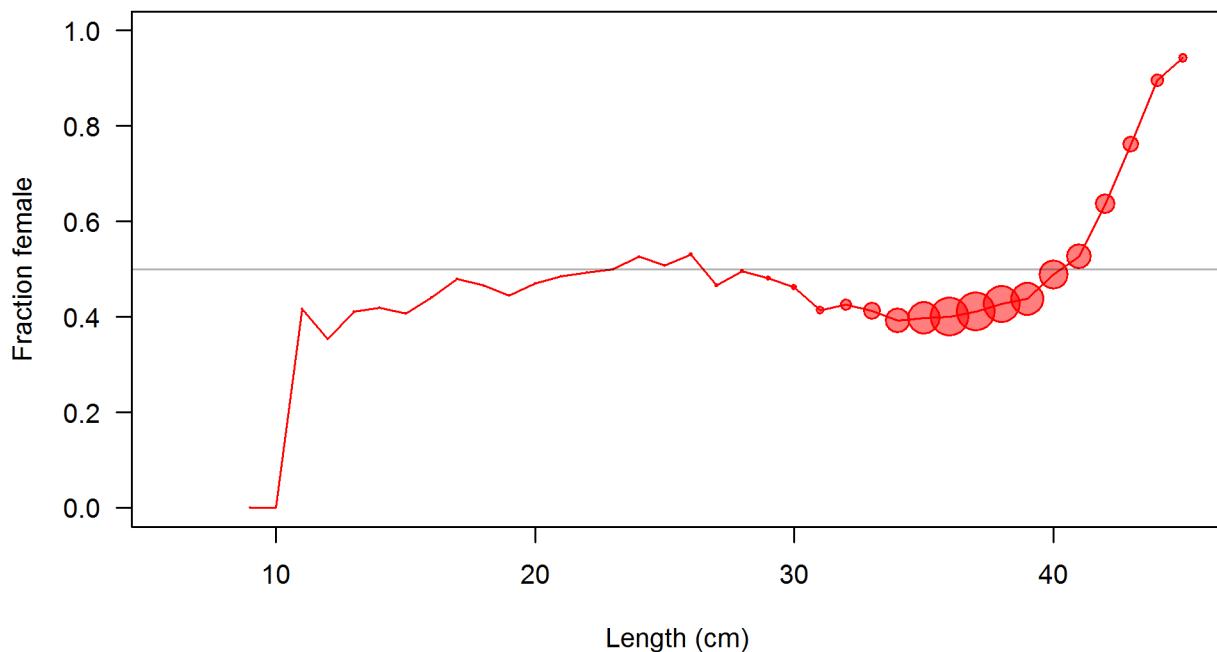


Figure 23: The estimated sex ratio of Pacific ocean perch at length from all biological data sources. | [fig:sexratio](#)

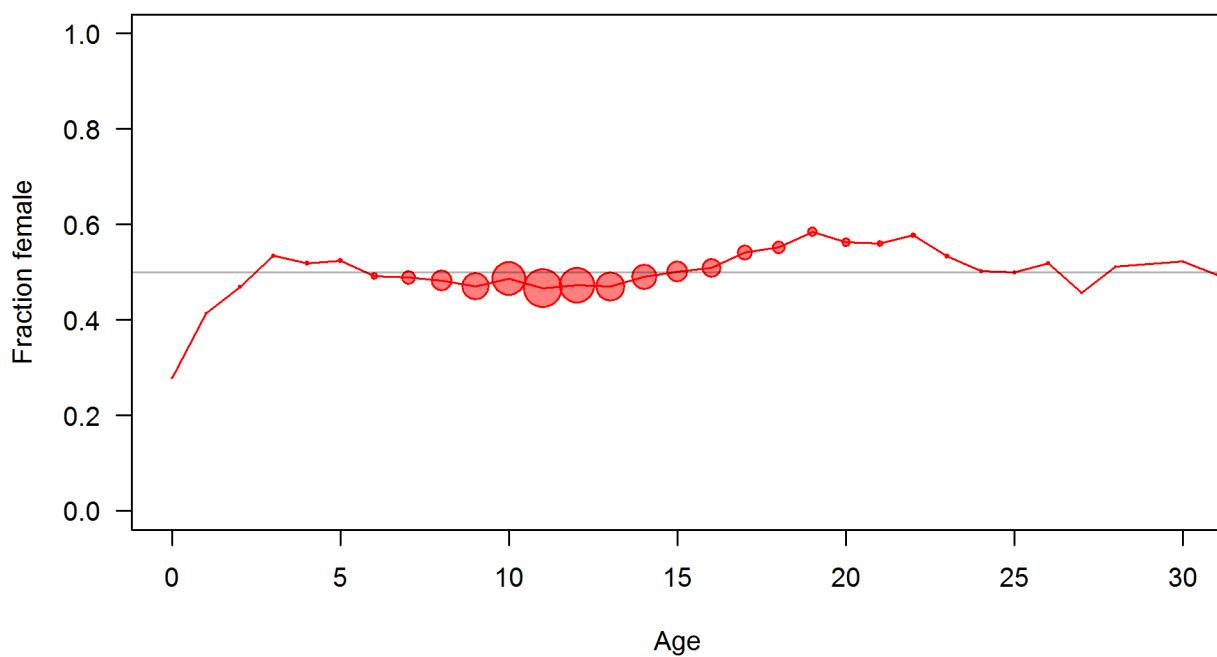


Figure 24: The estimated sex ratio of Pacific ocean perch at age from all biological data sources. | [fig:sexratio_Age](#)

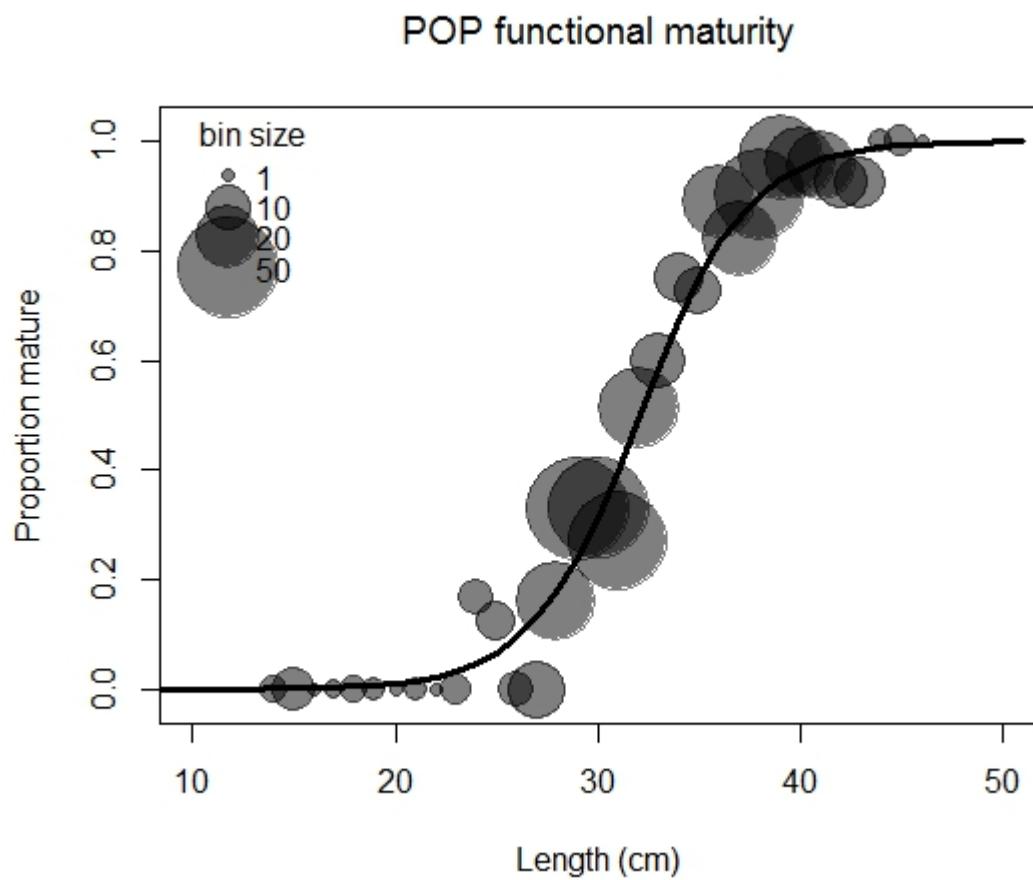


Figure 25: The estimated functional maturity of Pacific ocean perch at length. fig:mat

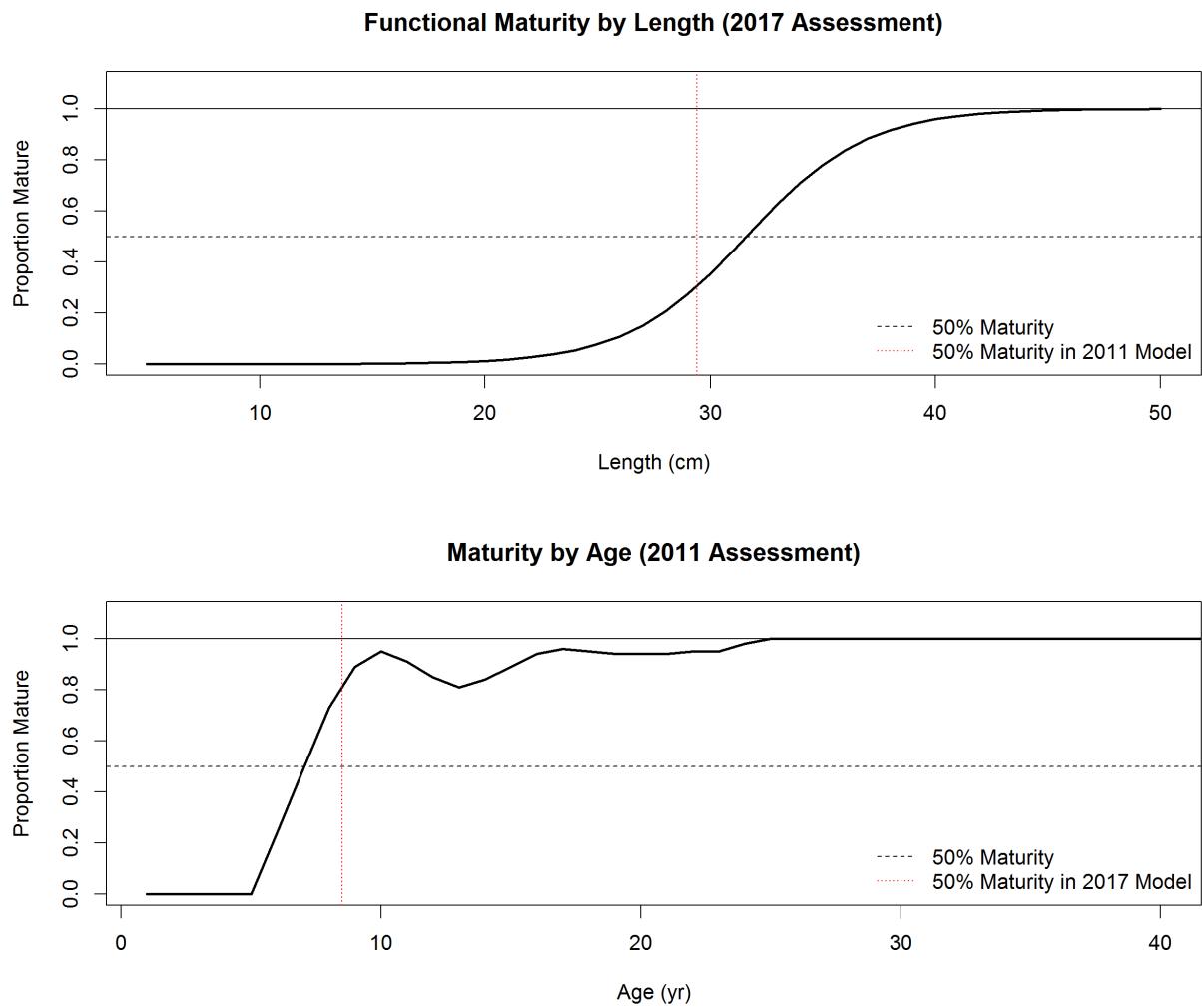


Figure 26: Comparison between estimated maturity-at-length used in this assessment and maturity-at-age applied in the 2011 assessment of Pacific ocean perch. `fig:mat_compare`

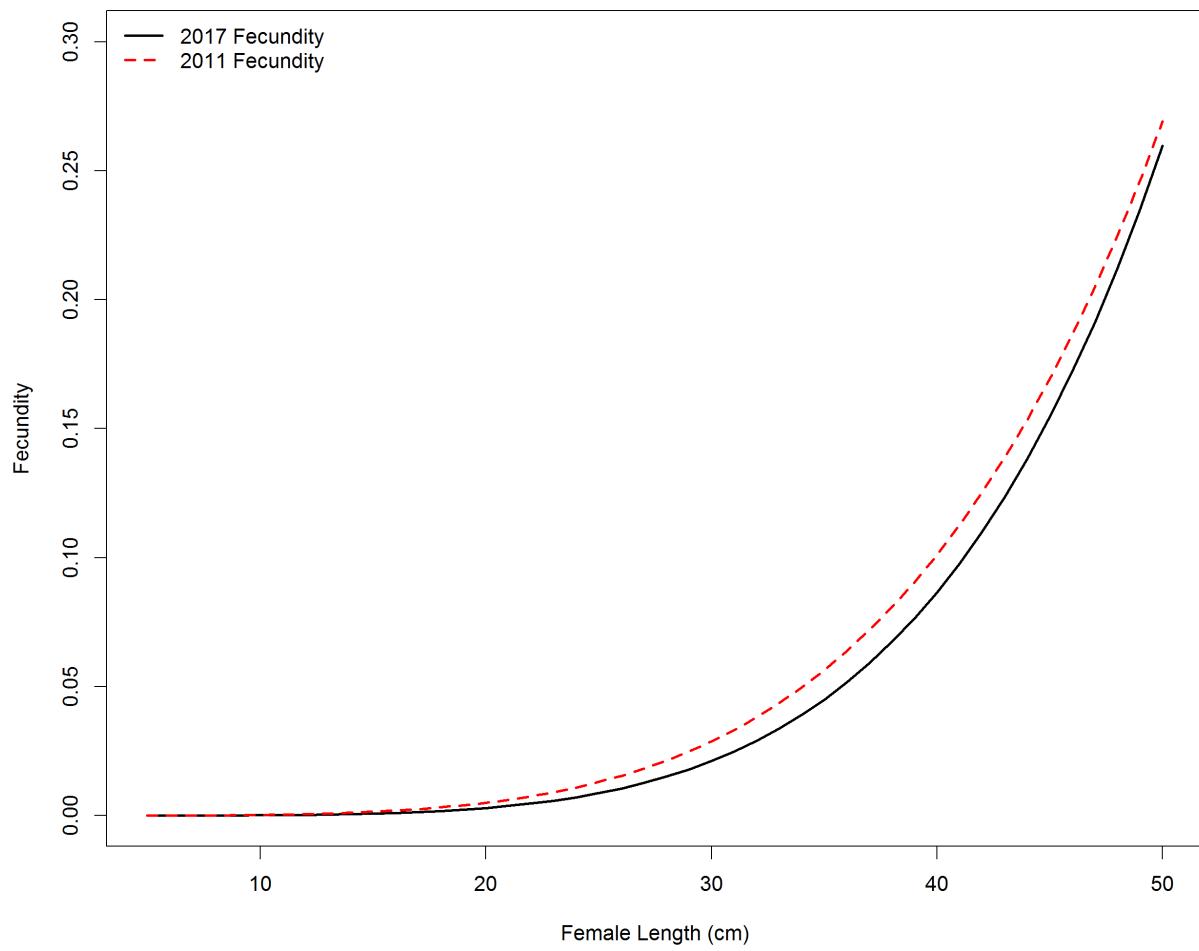


Figure 27: Fecundity at length of Pacific ocean perch in the base model and a comparison of the fecundity in the 2011 assessment. fig:fecundity

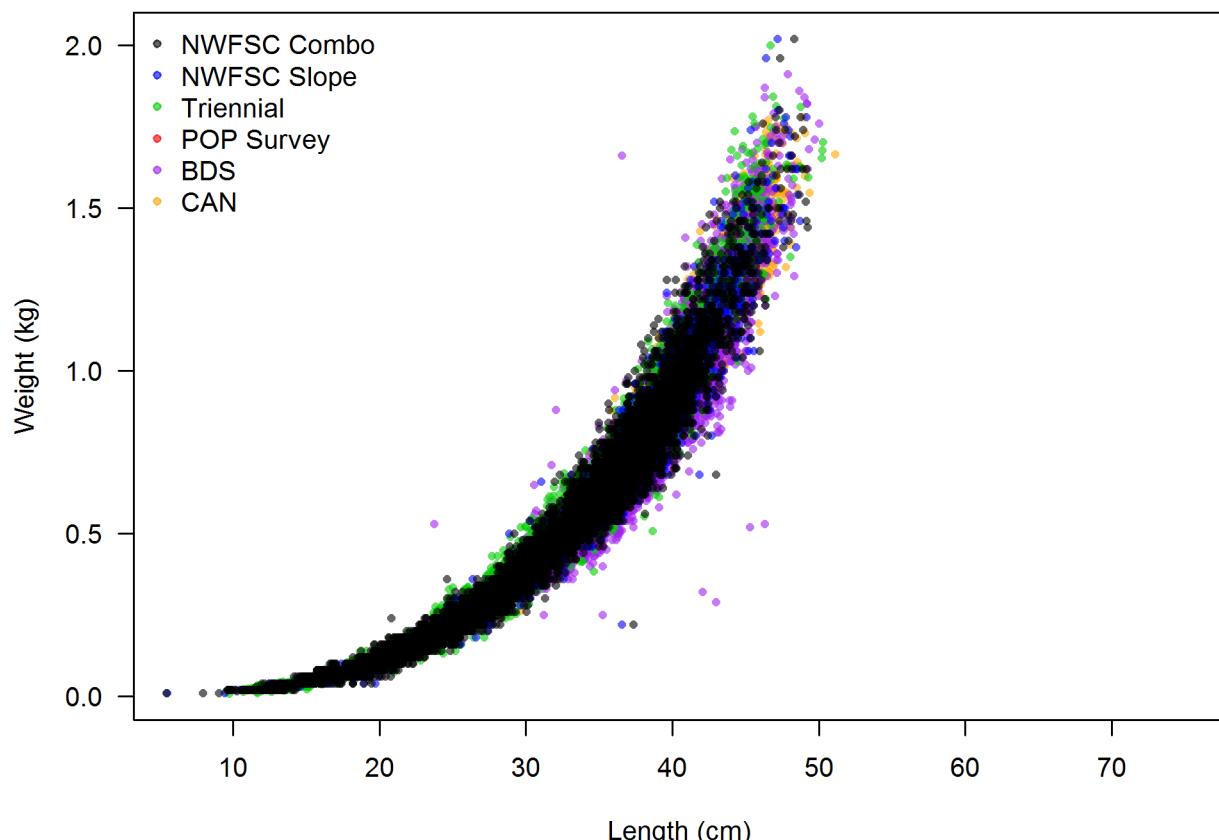


Figure 28: Weight-at-length for Pacific ocean perch from all data sources. `fig:Wt_len`

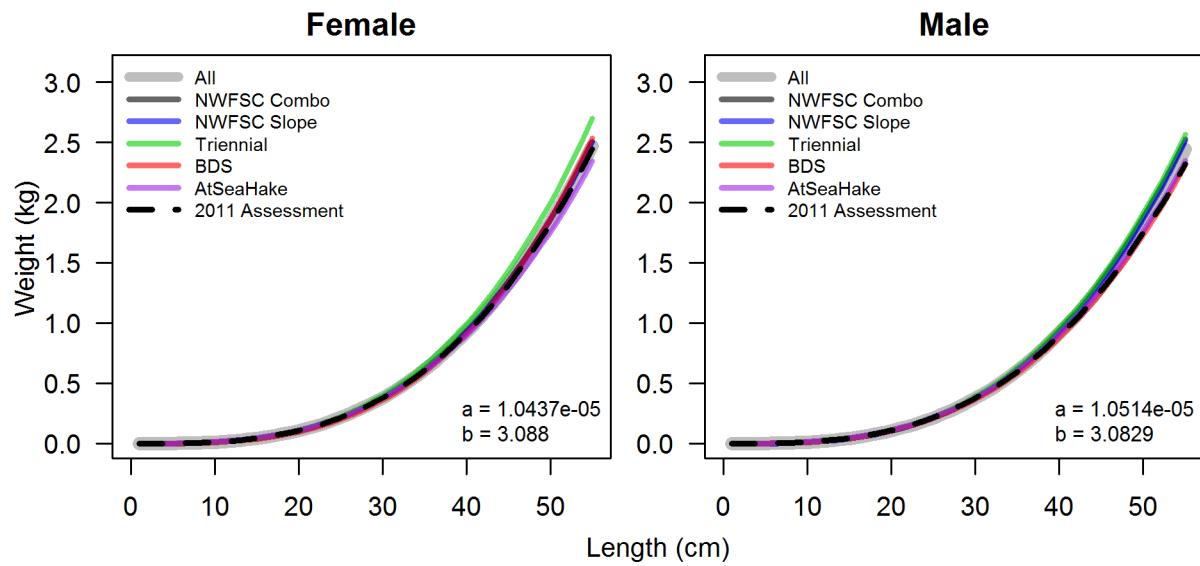


Figure 29: Estimated weight-at-length for Pacific ocean perch from all data sources. `fig:Wt_len_pred`

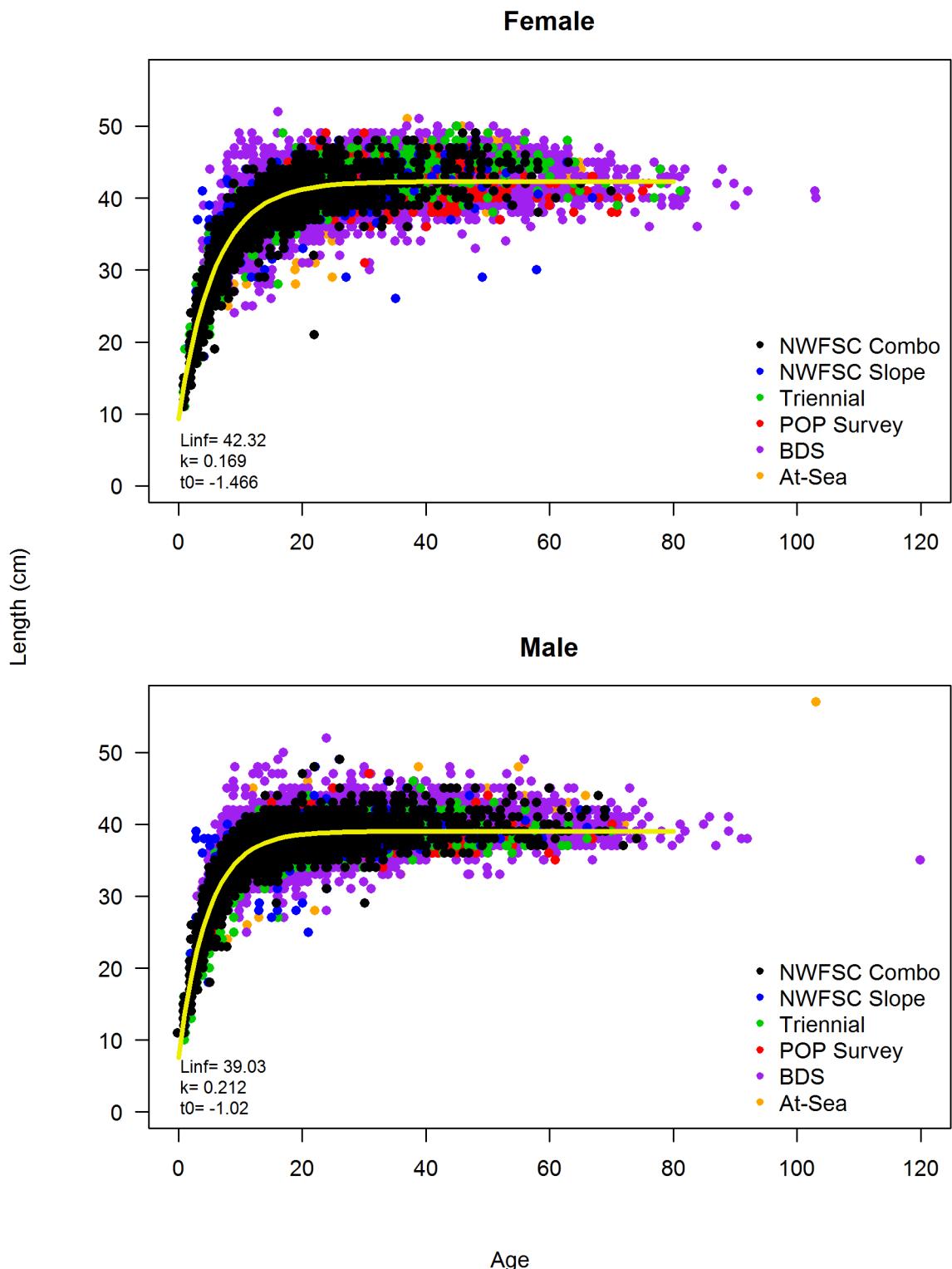


Figure 30: Estimated length-at-age for Pacific ocean perch from all data sources. fig:Len_Age

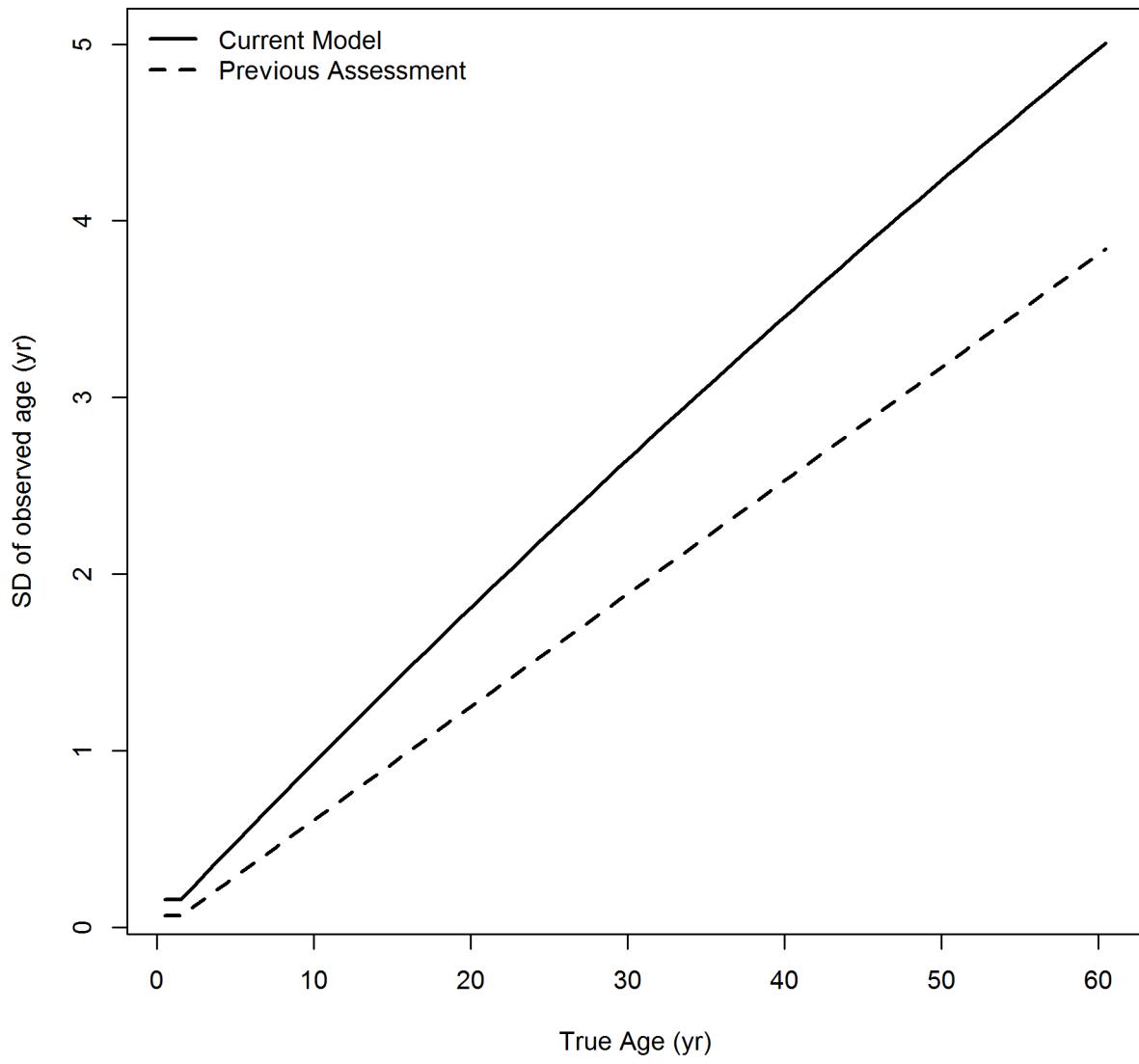


Figure 31: The estimated ageing error used in this assessment compared to the ageing error assumed in the previous assessment for Pacific ocean perch. [fig:Age_Error](#)

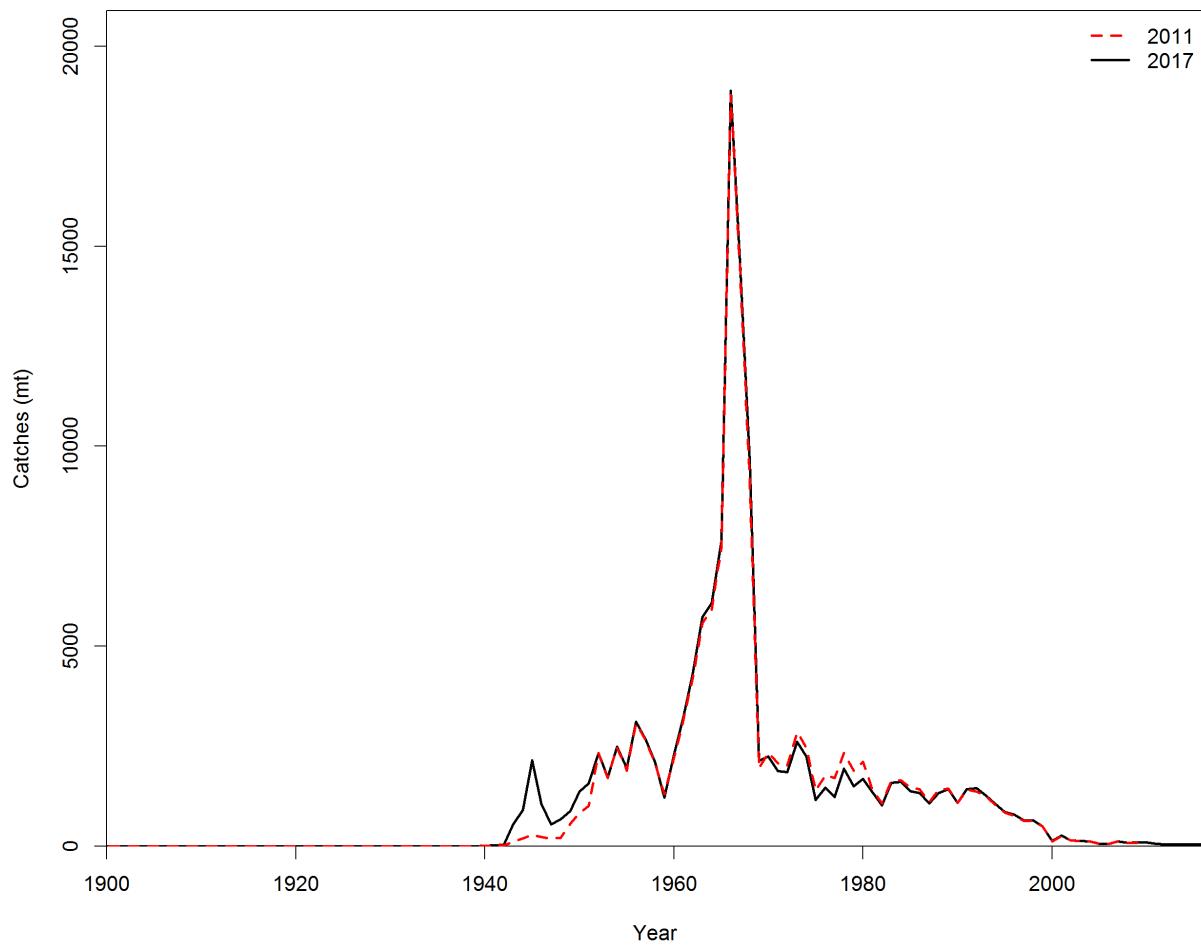


Figure 32: Comparison of the catches assumed by this assessment and the previous assessment for Pacific ocean perch. fig:Catch_Compare

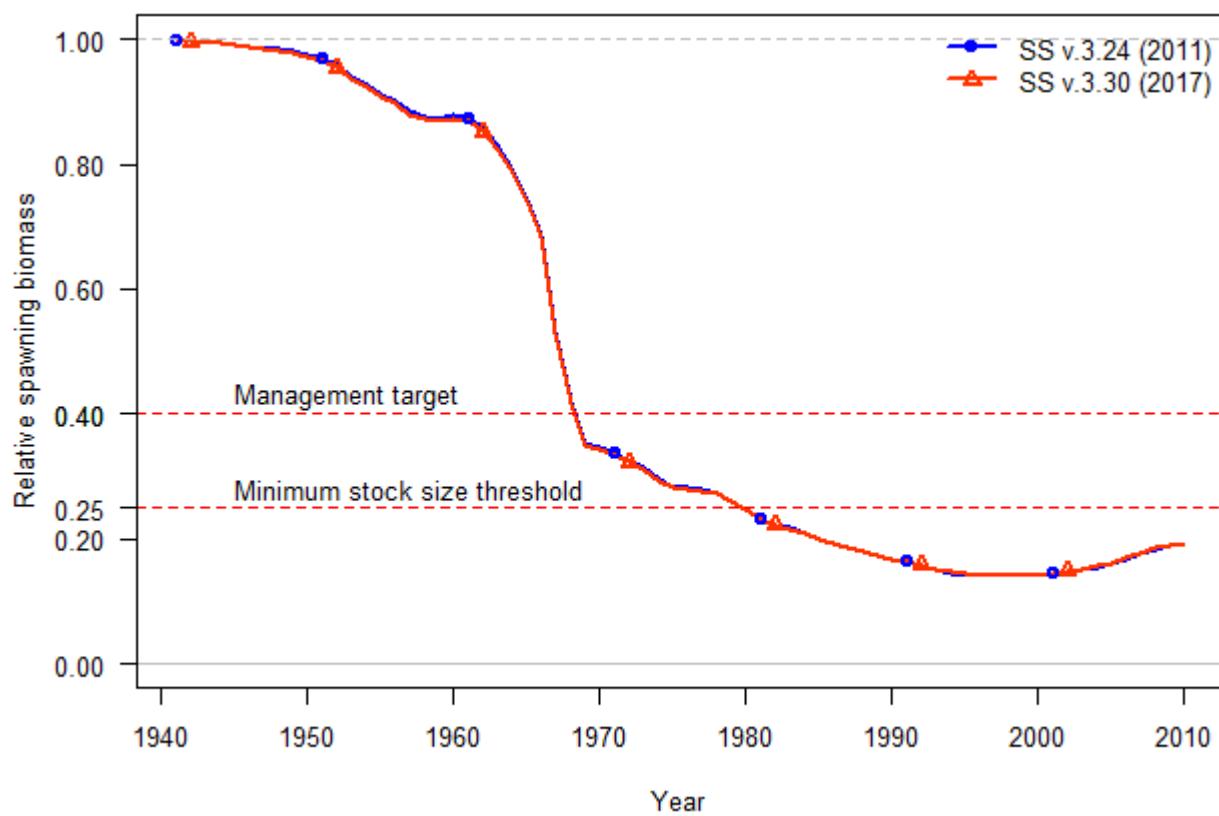
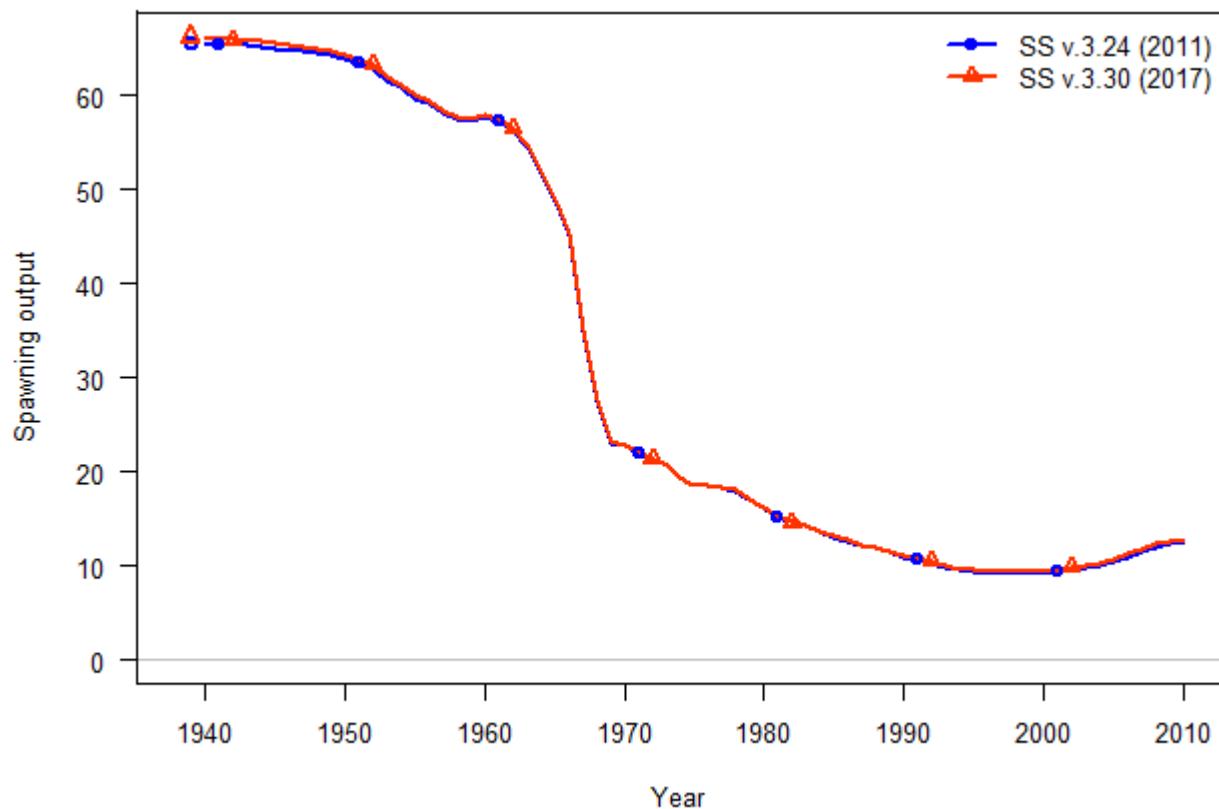


Figure 33: Comparison of estimates from Stock Synthesis version 3.30 and 3.24 for Pacific ocean perch.
 fig:bridge 95

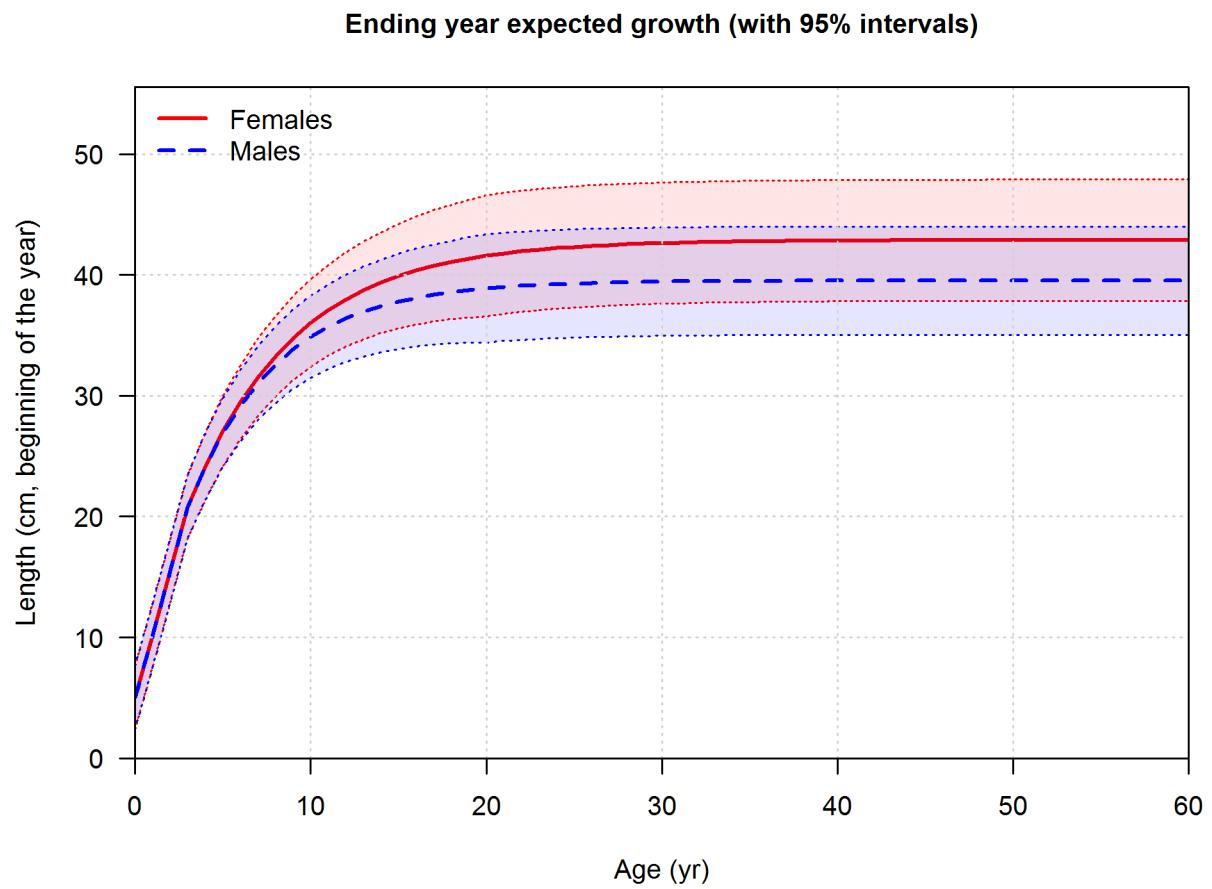


Figure 34: Estimated length-at-age for male and female for Pacific ocean perch with estimated CV. | [fig:sizeatage](#)

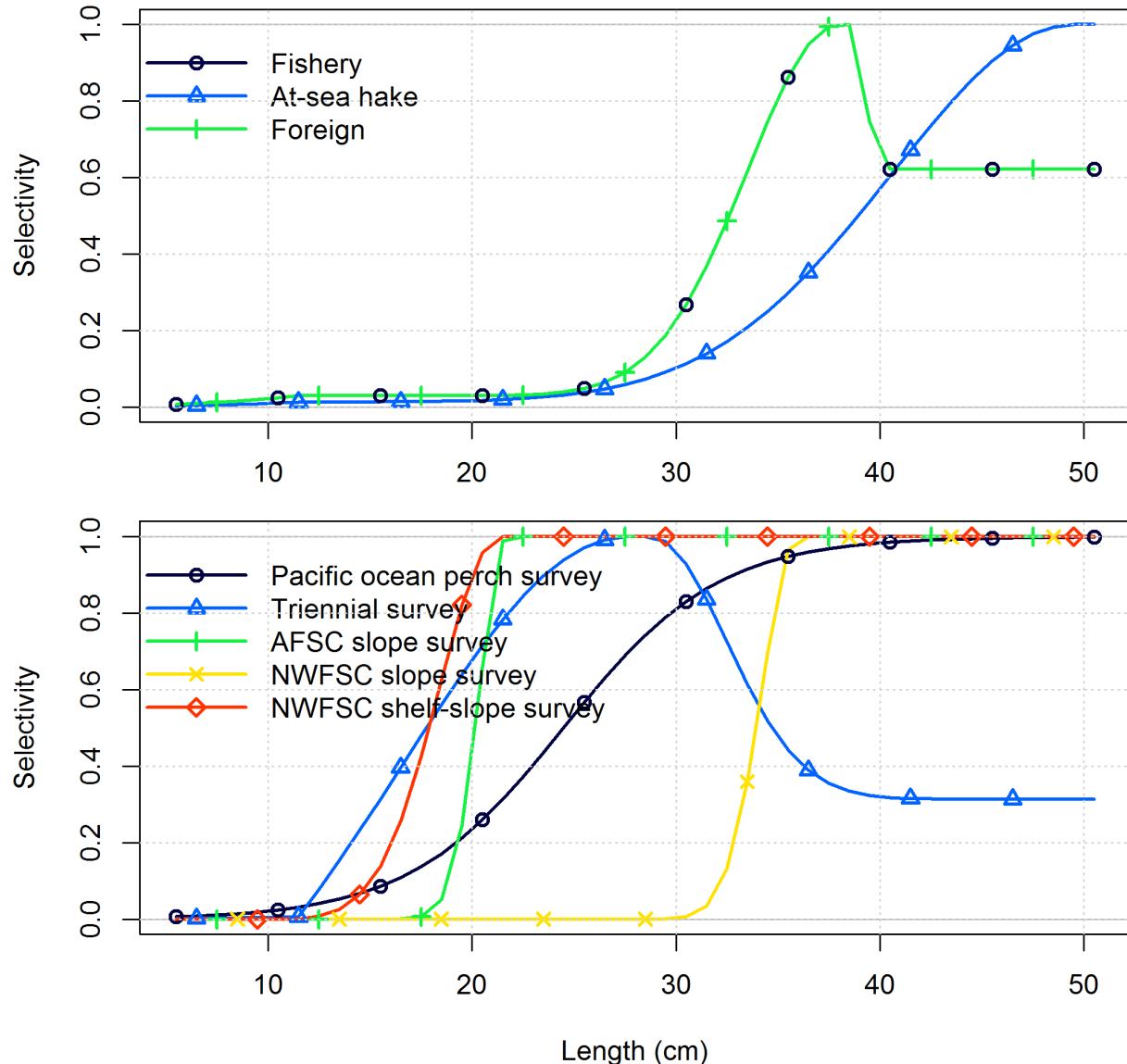


Figure 35: Estimated selectivity by length by each fishery and survey for Pacific ocean perch.
 fig:selex

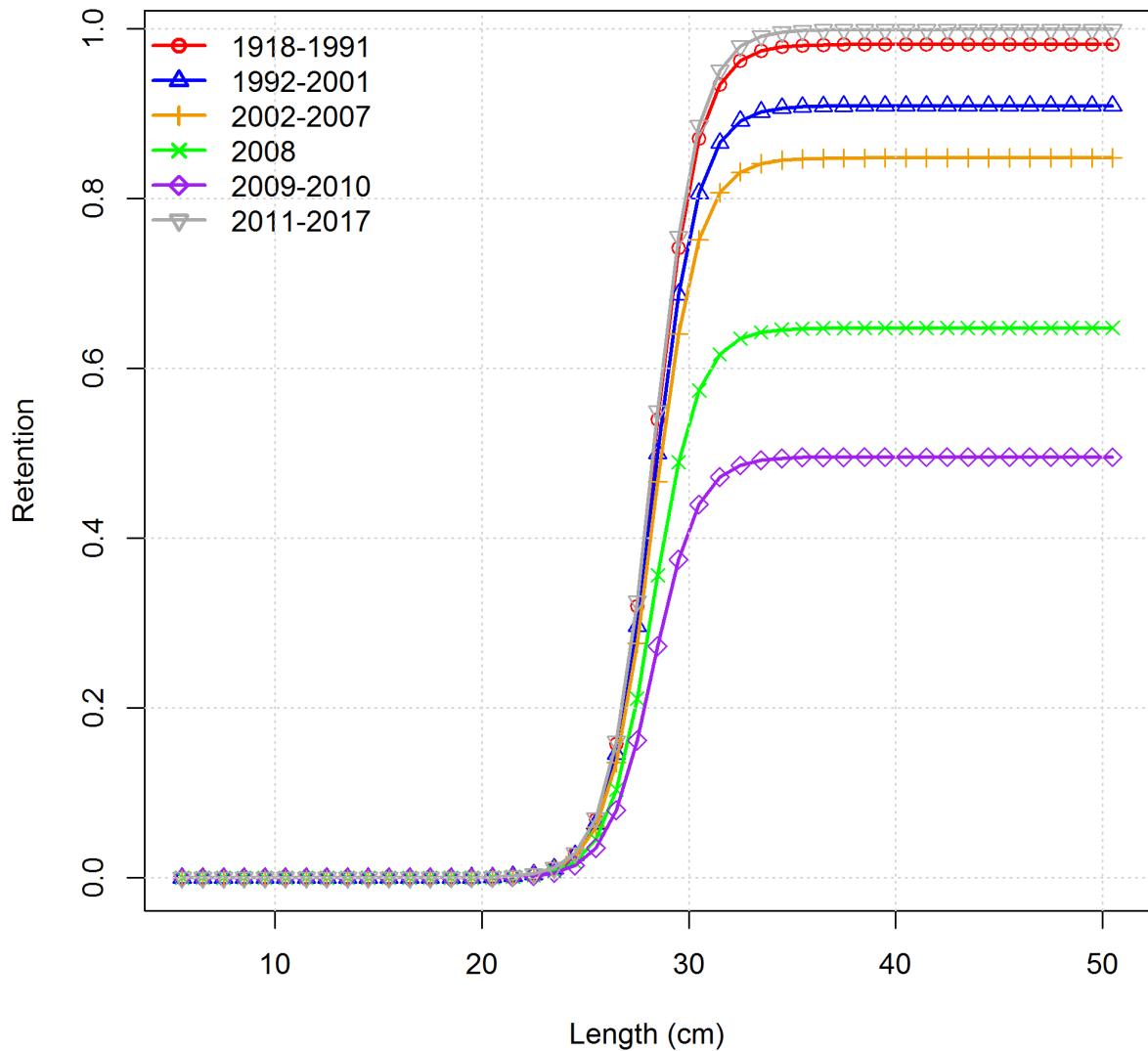


Figure 36: Estimated retention by length by the trawl fishery for Pacific ocean perch. `fig:retention`

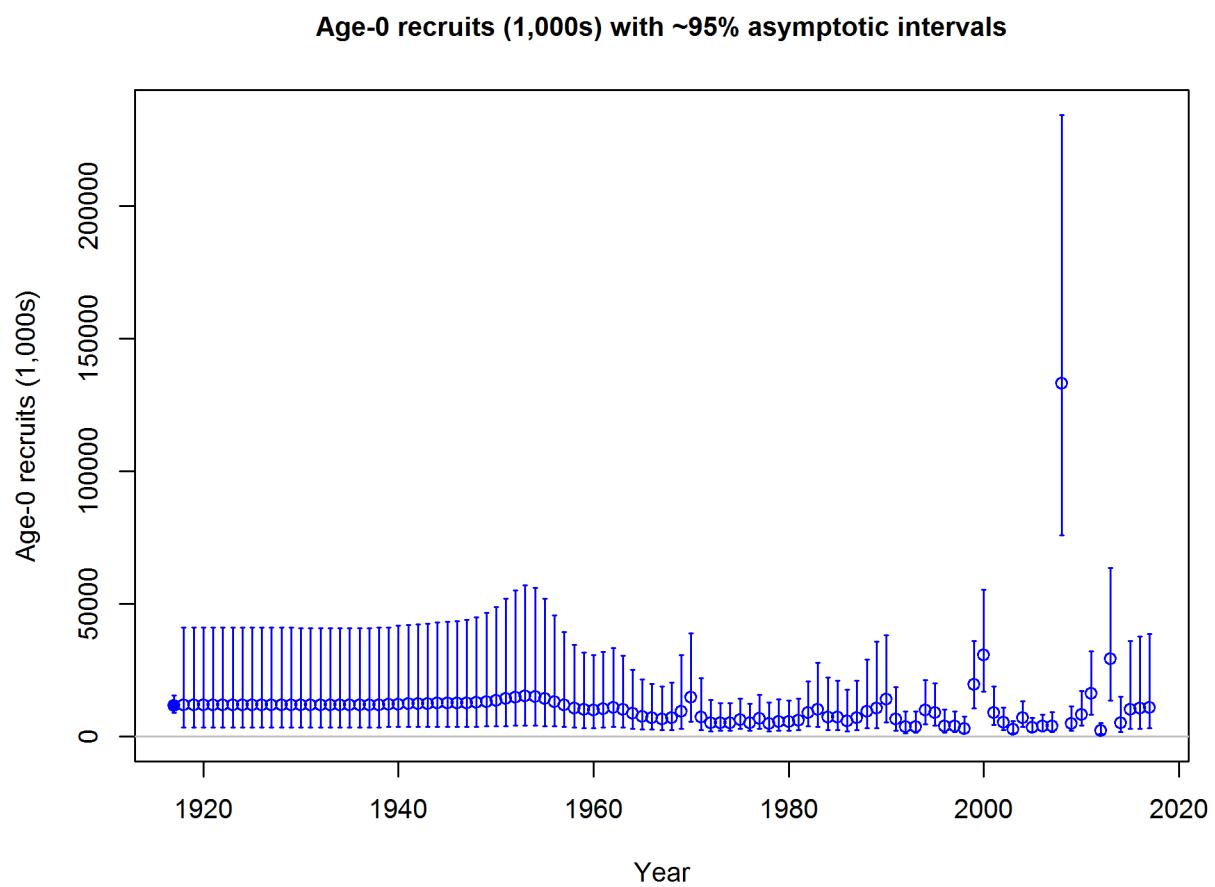


Figure 37: Estimated time-series of recruitment for Pacific ocean perch. fig:recruits

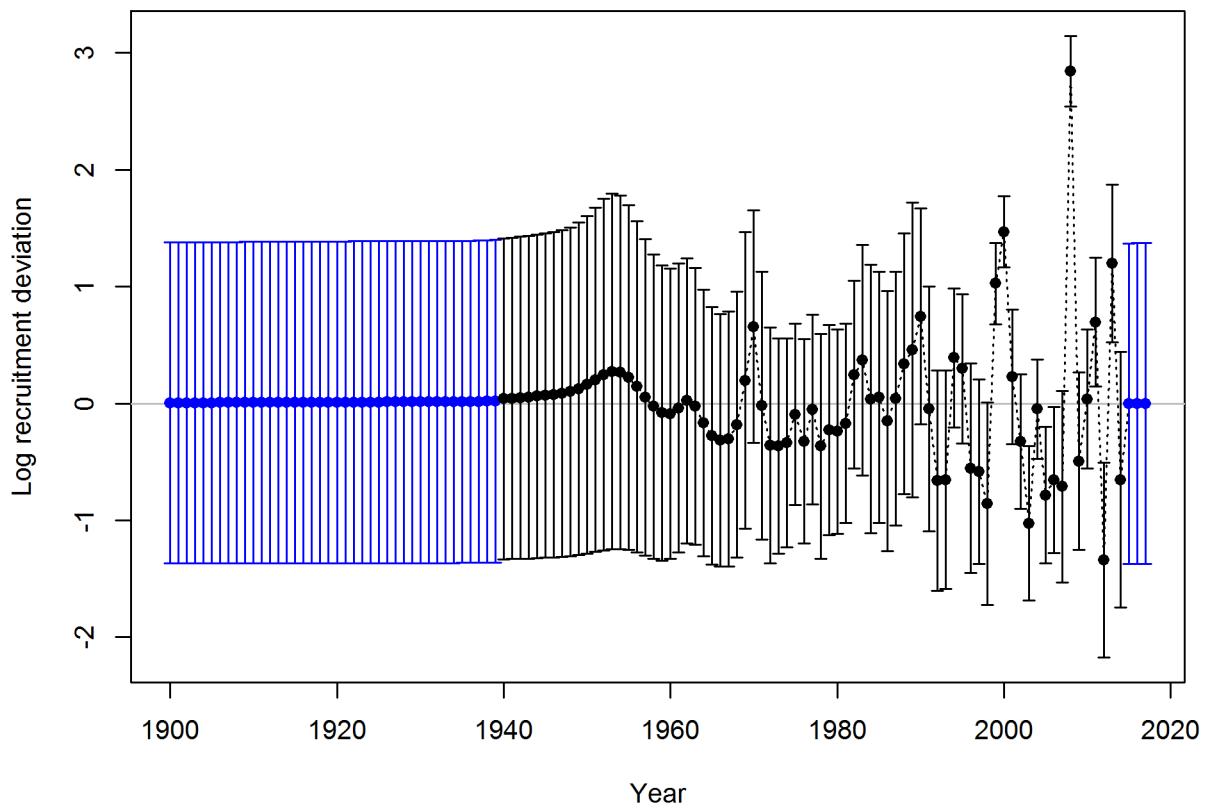


Figure 38: Estimated time-series of recruitment deviations for Pacific ocean perch. `fig:recdevs`

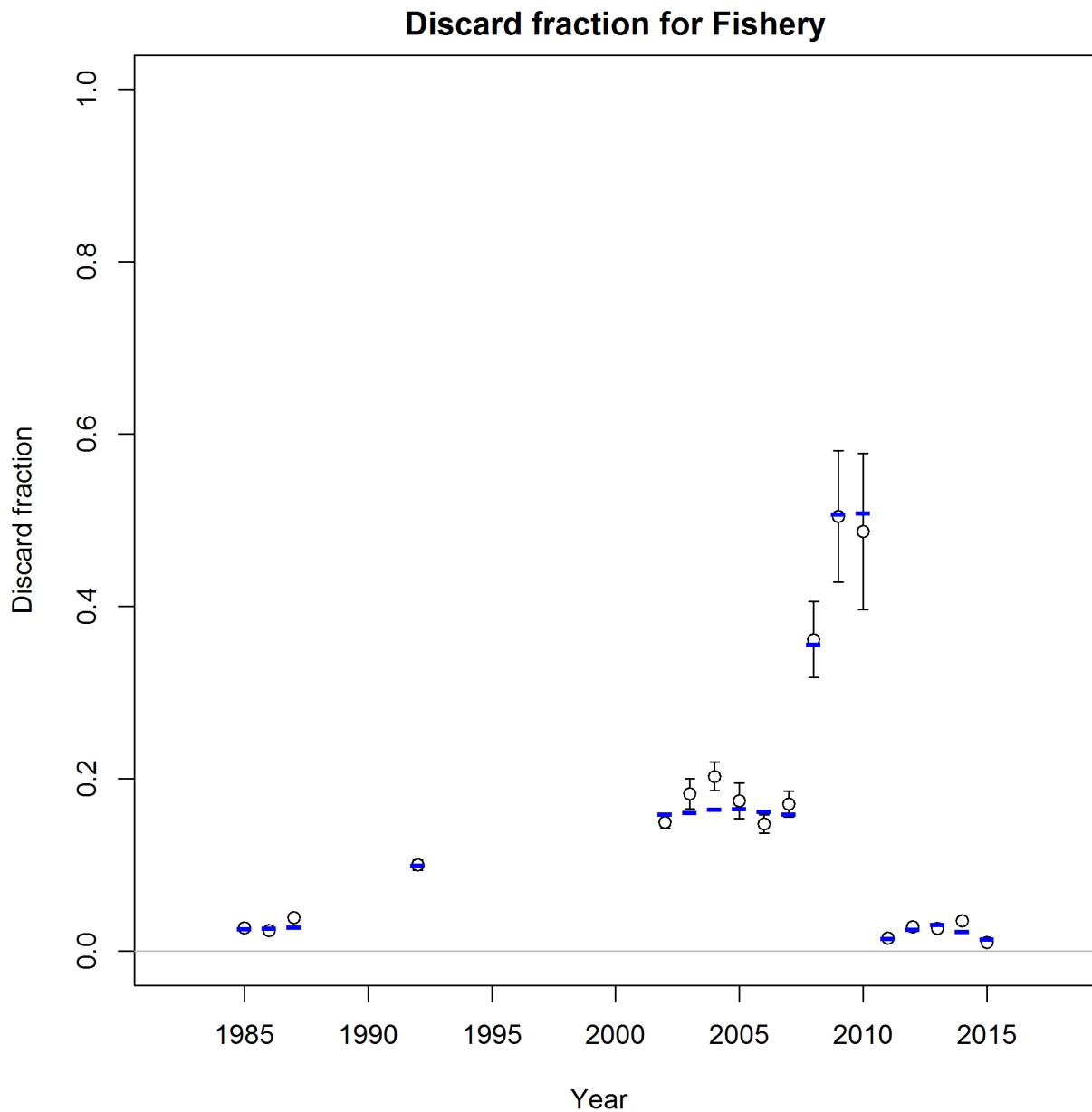


Figure 39: Estimated fits to the discard rates for Pacific ocean perch. `fig:discard_fits`

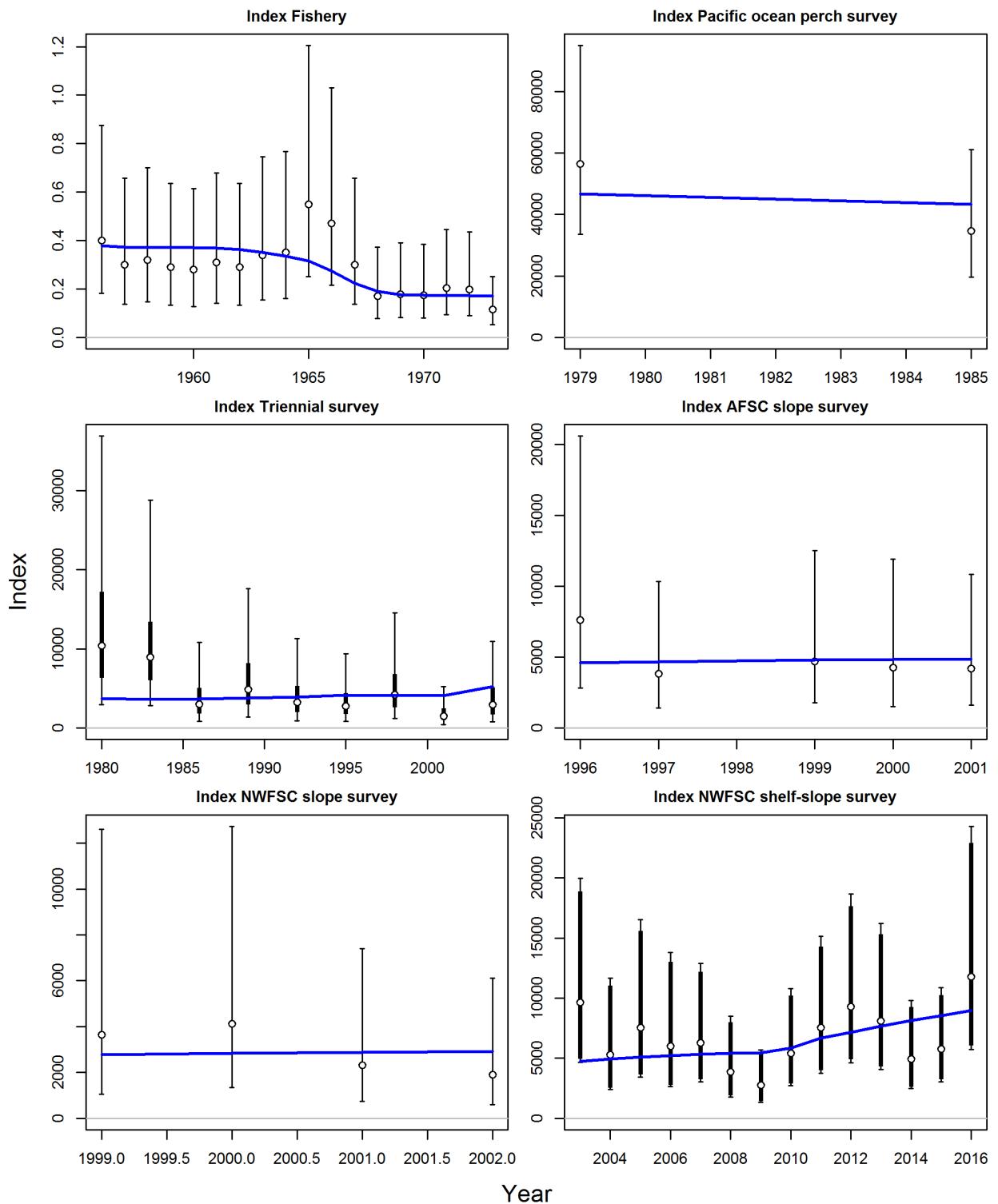


Figure 40: Estimated fits to the CPUE and survey indices for Pacific ocean perch. `fig:index_fits`

Length comps, aggregated across time by fleet

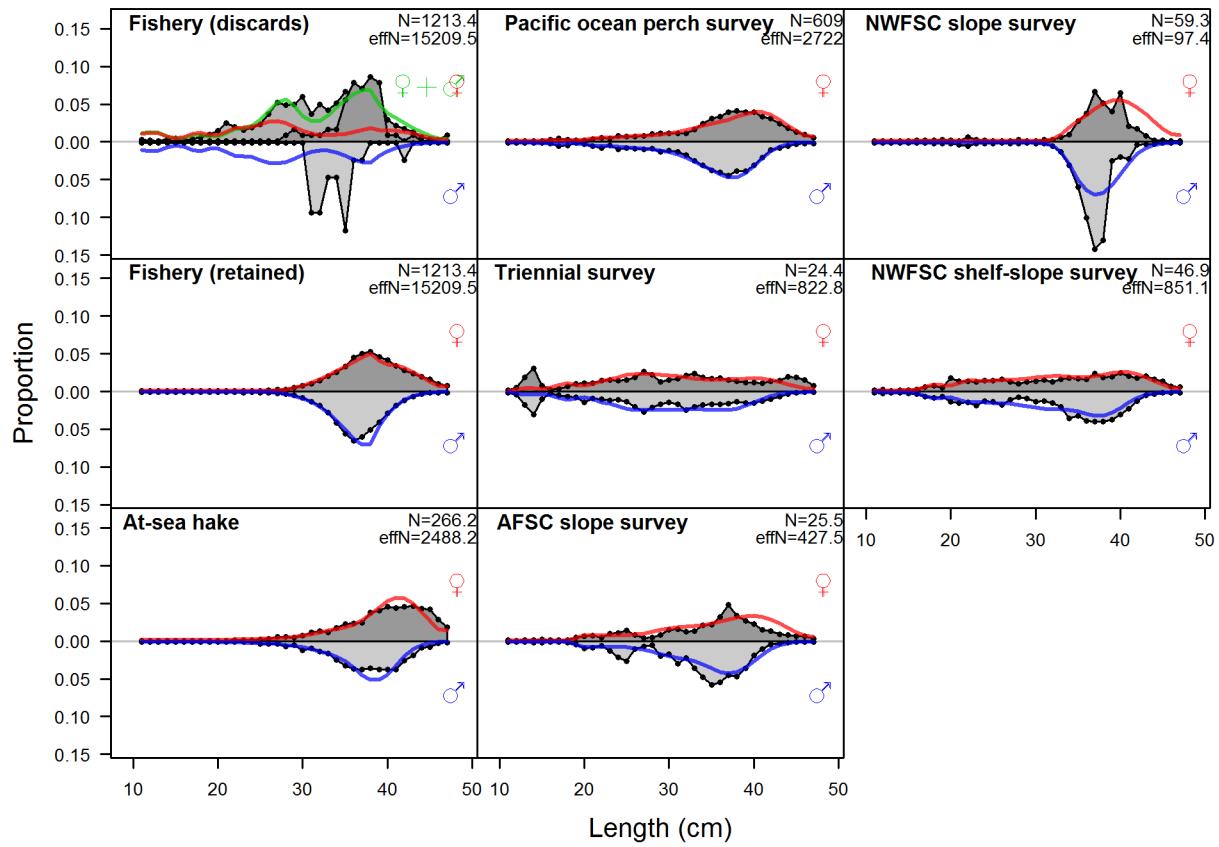


Figure 41: Length compositions aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate retained or discarded samples for each fleet. Panels without this designation represent the whole catch. | fig: length_agg

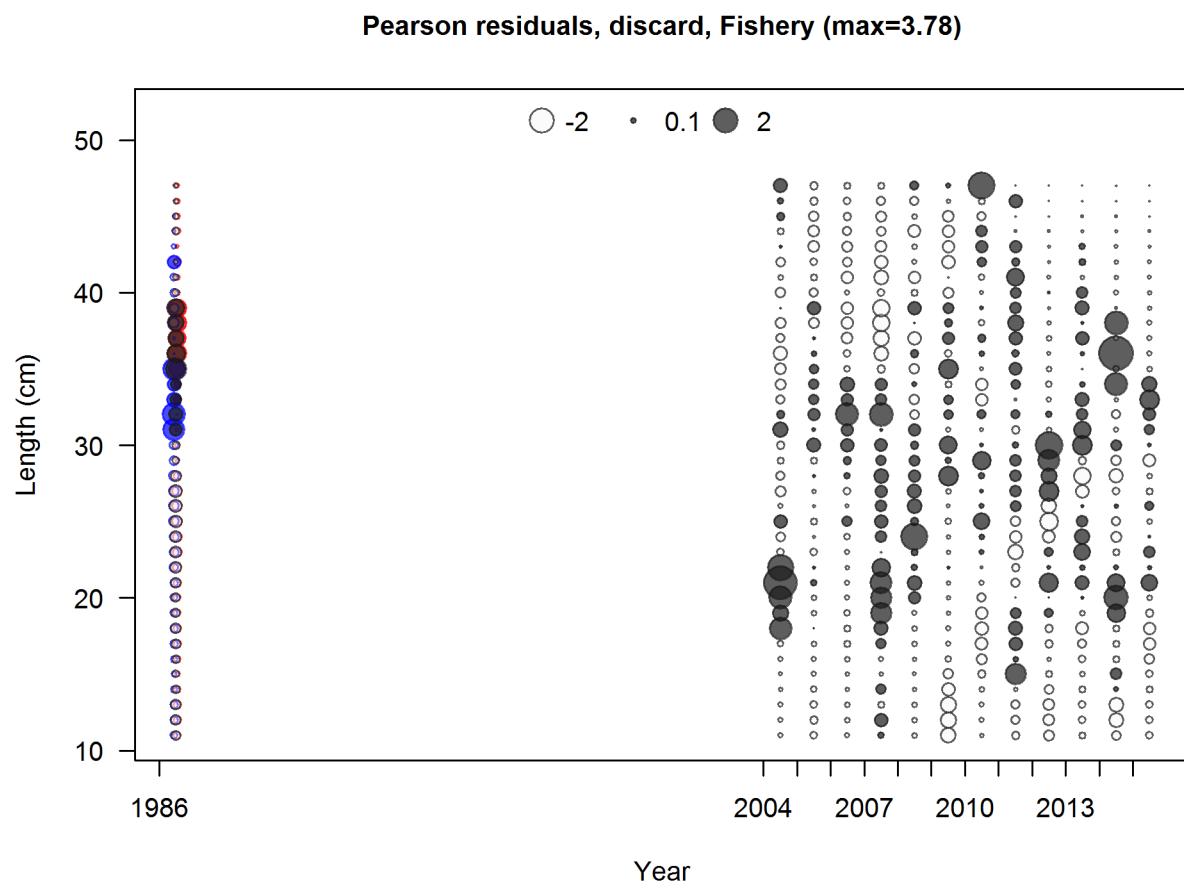


Figure 42: Pearson residuals, discard, Fishery (max=3.78)
 Closed bubbles are positive residuals ($\text{observed} > \text{expected}$) and open bubbles are negative residuals ($\text{observed} < \text{expected}$). [fig:discard_len_pearson](#)

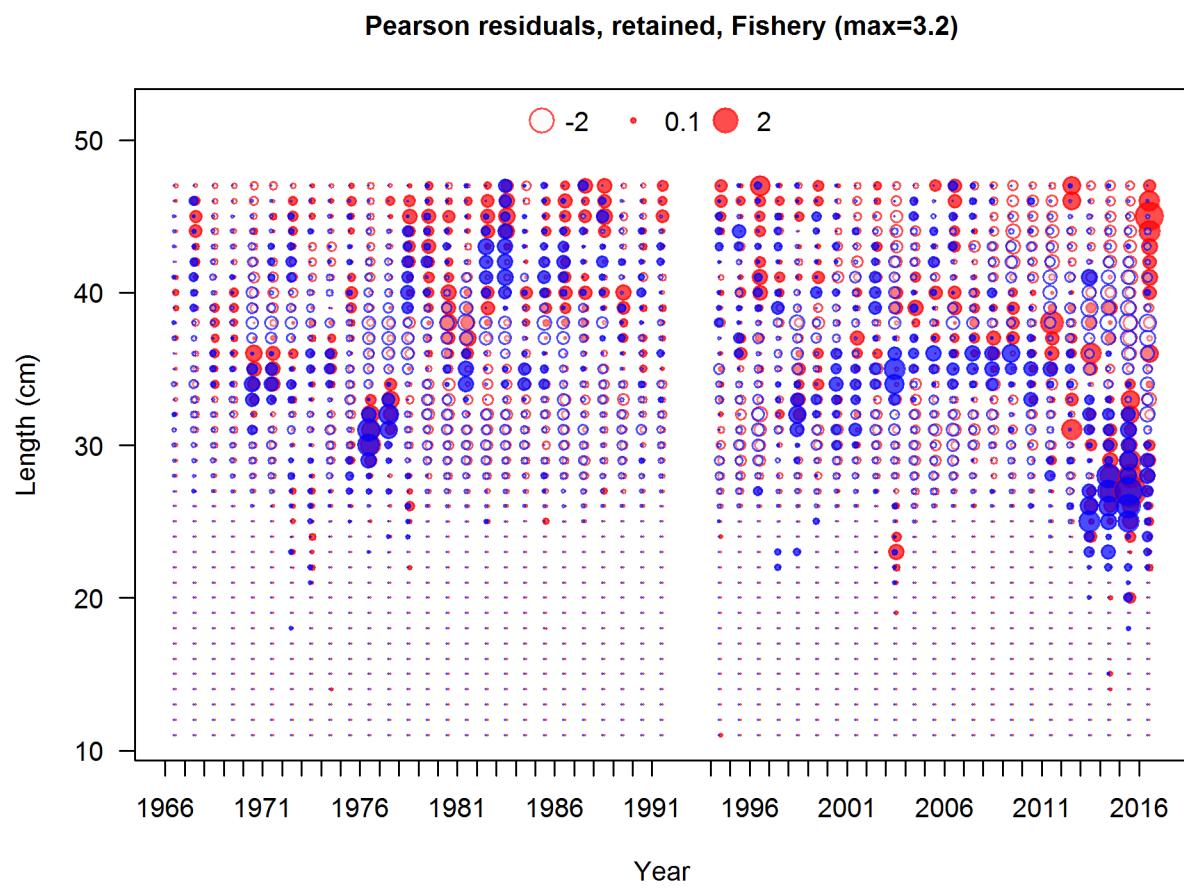


Figure 43: Pearson residuals, retained, Fishery (max=3.2) (plot 4 of 4)
 Closed bubbles are positive residuals ($\text{observed} > \text{expected}$) and open bubbles are negative residuals ($\text{observed} < \text{expected}$). [fig:fishery_len_pearson](#)

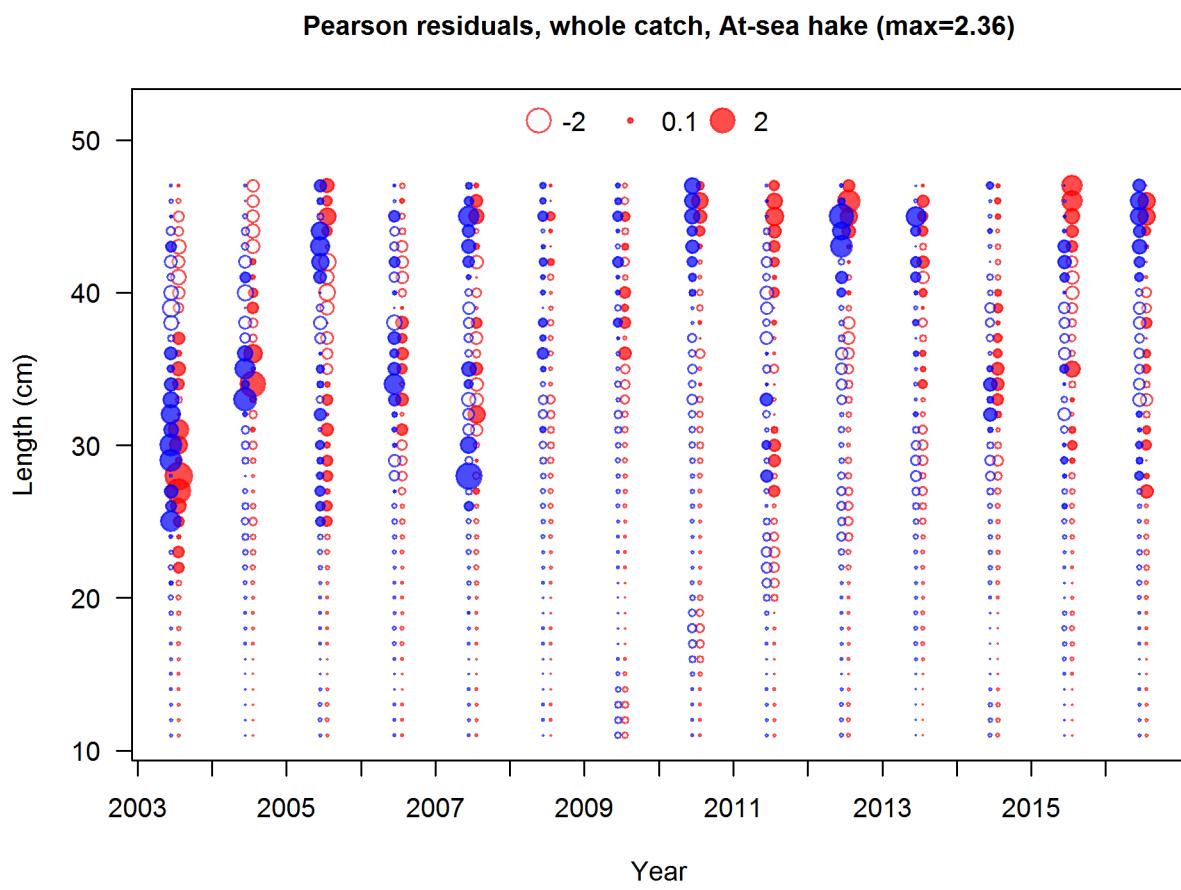


Figure 44: Pearson residuals, whole catch, At_sea hake (max=2.36)
 Closed bubbles are positive residuals ($\text{observed} > \text{expected}$) and open bubbles are negative residuals ($\text{observed} < \text{expected}$). [fig:ashop_ten_pearson](#)

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

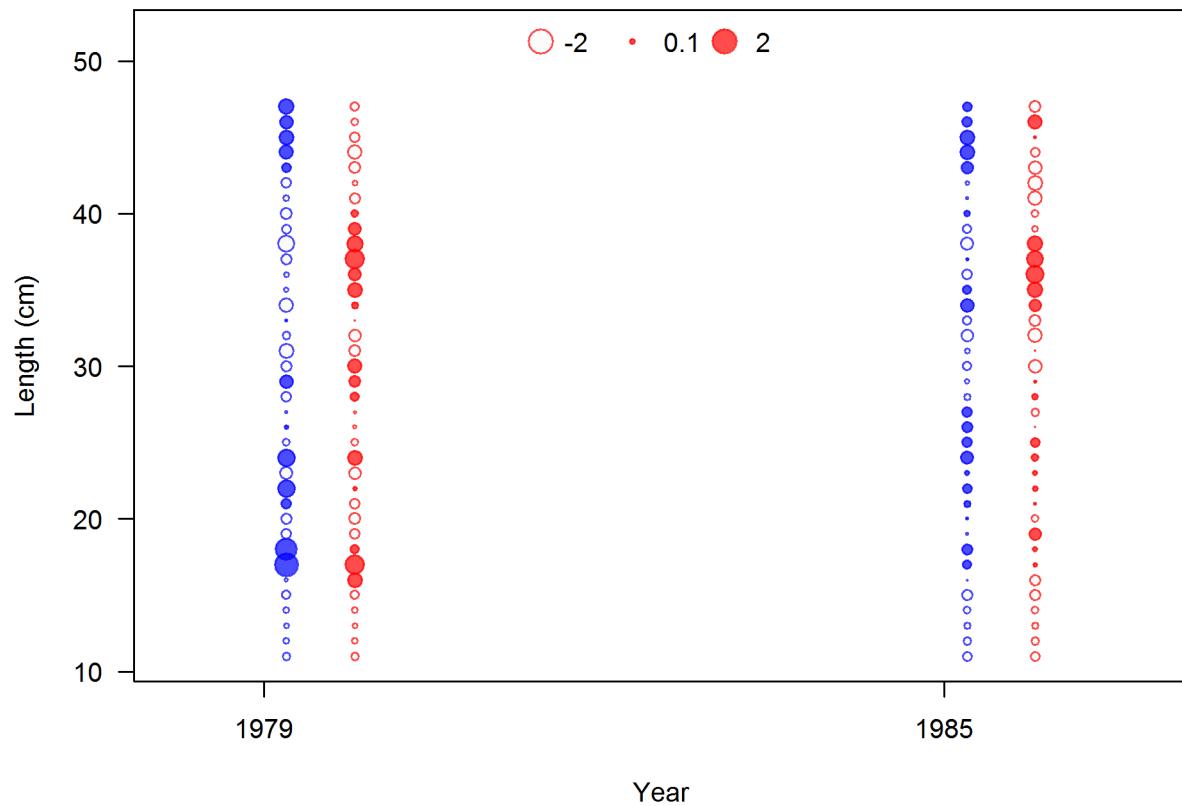


Figure 45: Pearson residuals, whole catch, Pacific ocean perch survey (max=1.74)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:pop_len_pearson](#)

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

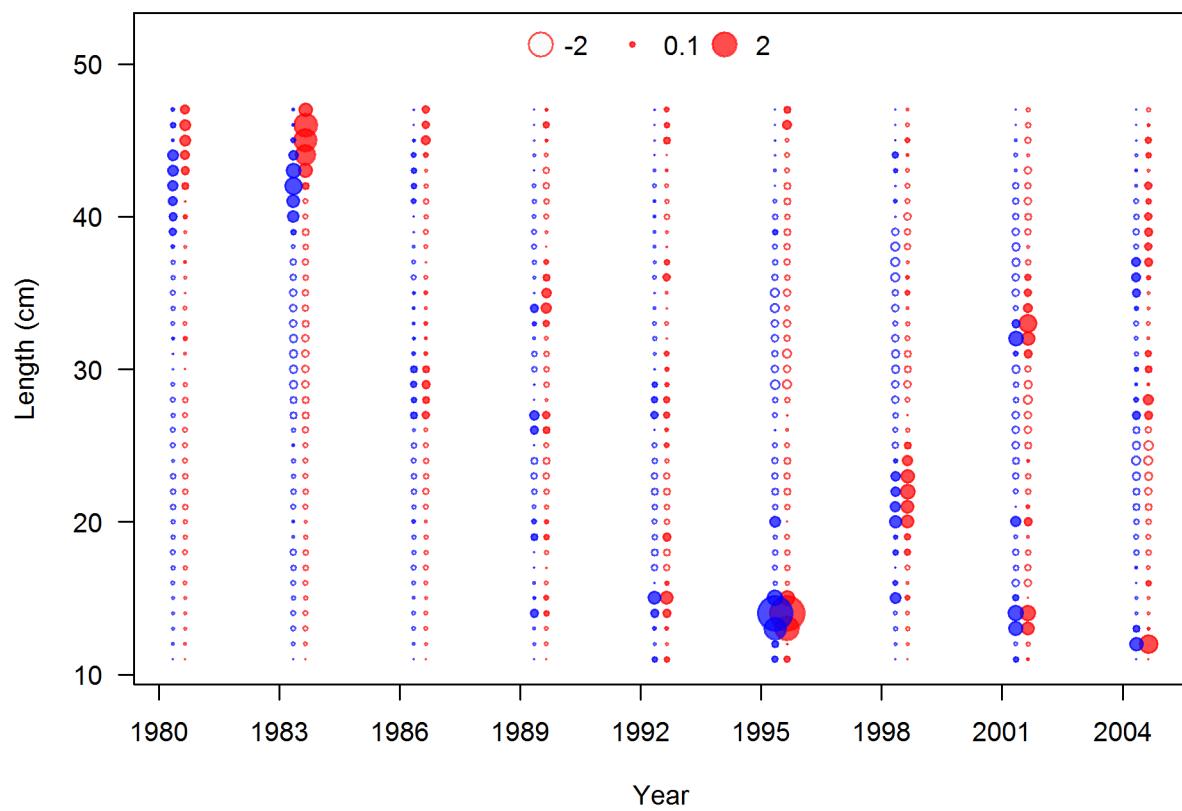


Figure 46: Pearson residuals, whole catch, Triennial survey (max=4.01)
Closed bubbles are positive residuals ($\text{observed} > \text{expected}$) and open bubbles are negative residuals ($\text{observed} < \text{expected}$). [fig:tri_len_pearson](#)

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

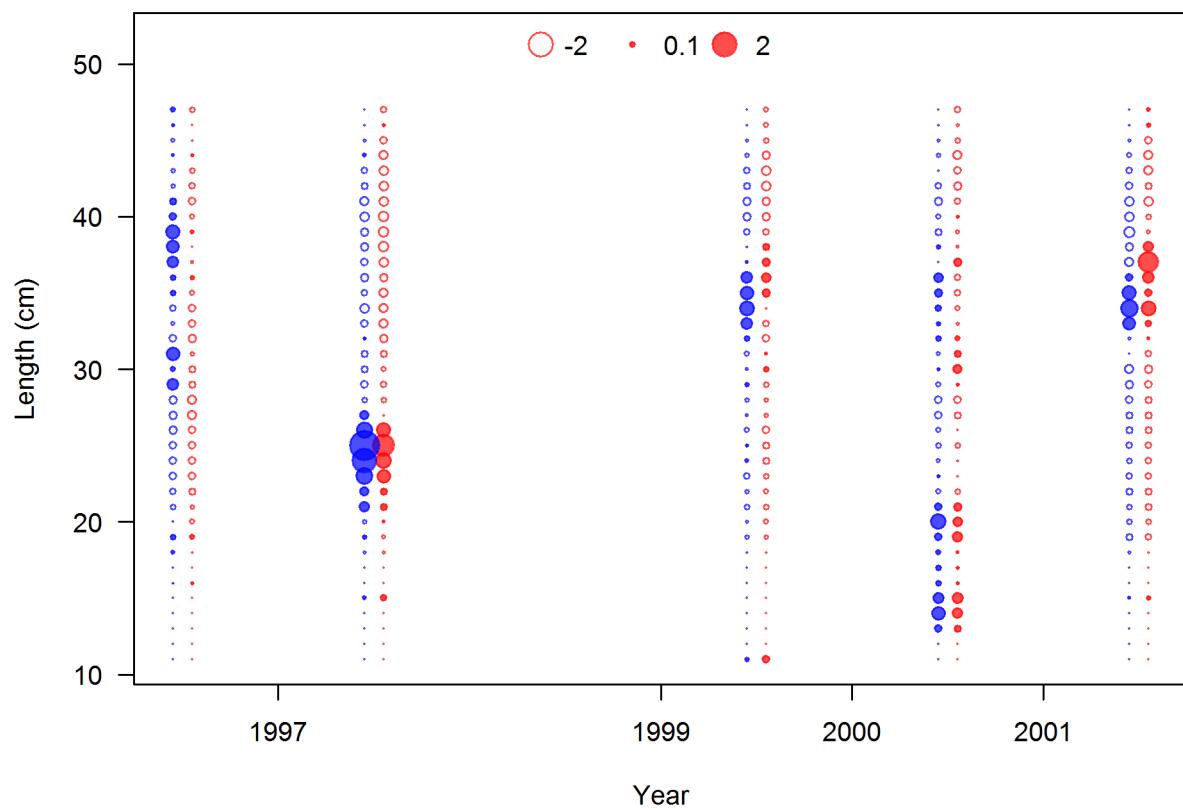


Figure 47: Pearson residuals, whole catch, AFSC slope survey (max=2.91)
Closed bubbles are positive residuals (observed $>$ expected) and open bubbles are negative residuals (observed $<$ expected). [fig_afsc_len_pearson](#)

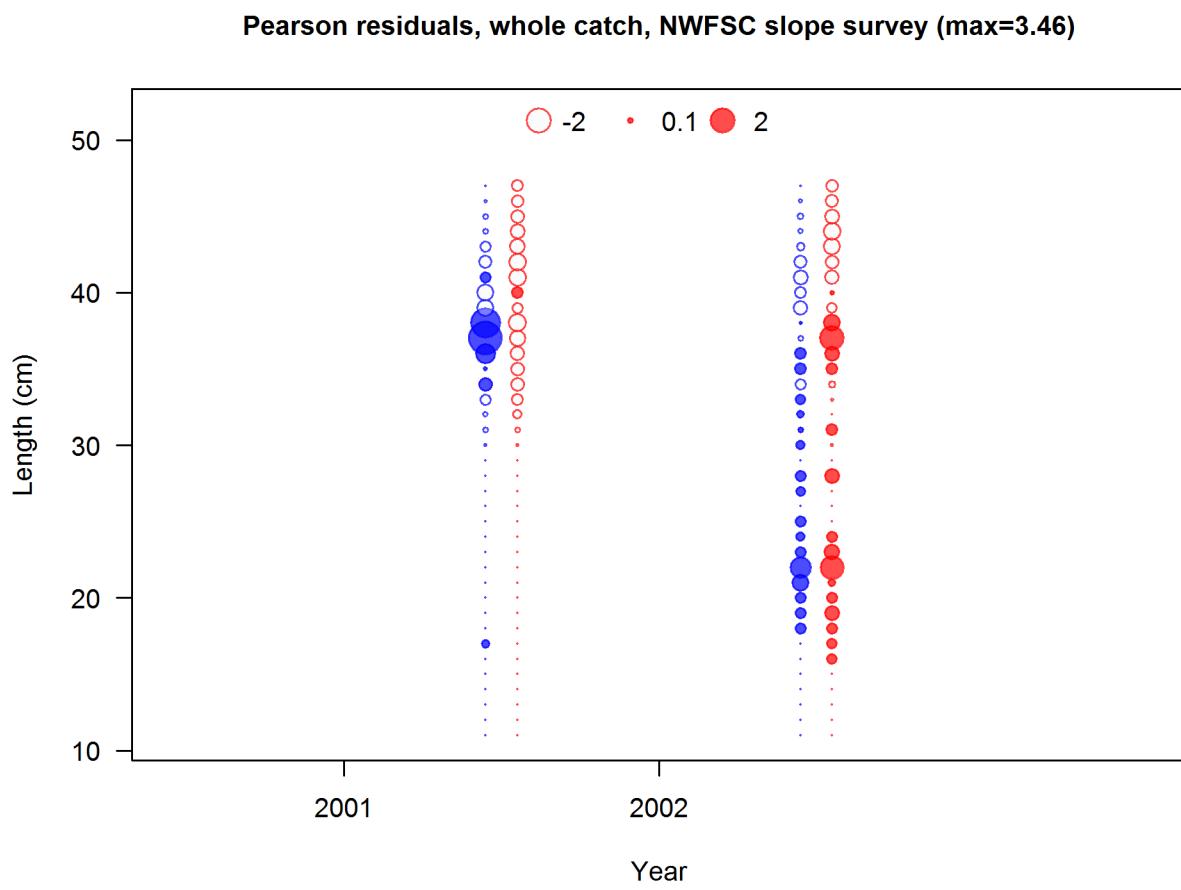


Figure 48: Pearson residuals, whole catch, NWFSC slope survey (max=3.46)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:nwfsc_ten_pearson](#)

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

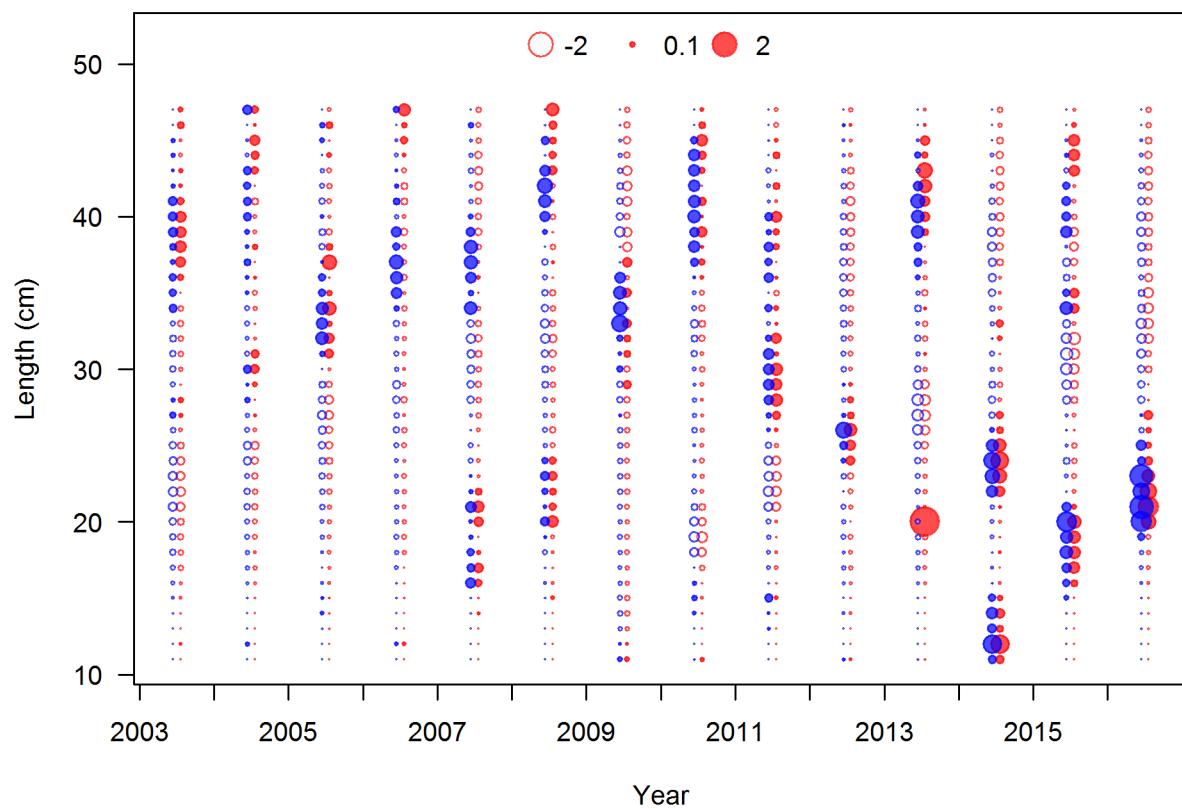


Figure 49: Pearson residuals, whole catch, NWFSC shelf_slope survey (max=2.74)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:nwfsc_combo_ten_pearson](#)

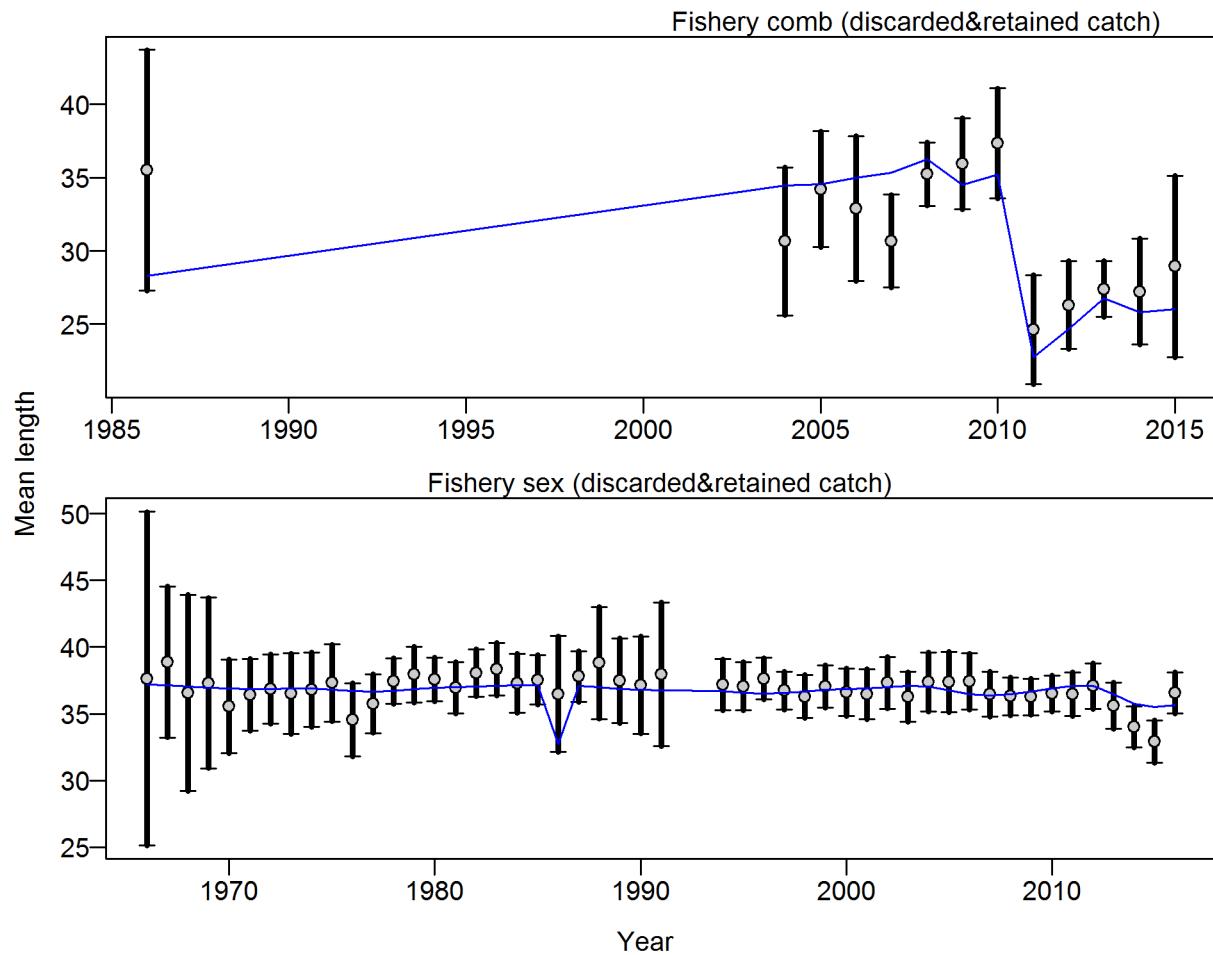


Figure 50: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.9951 (0.6685_1.8165) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:weighting_len_fishery](#)

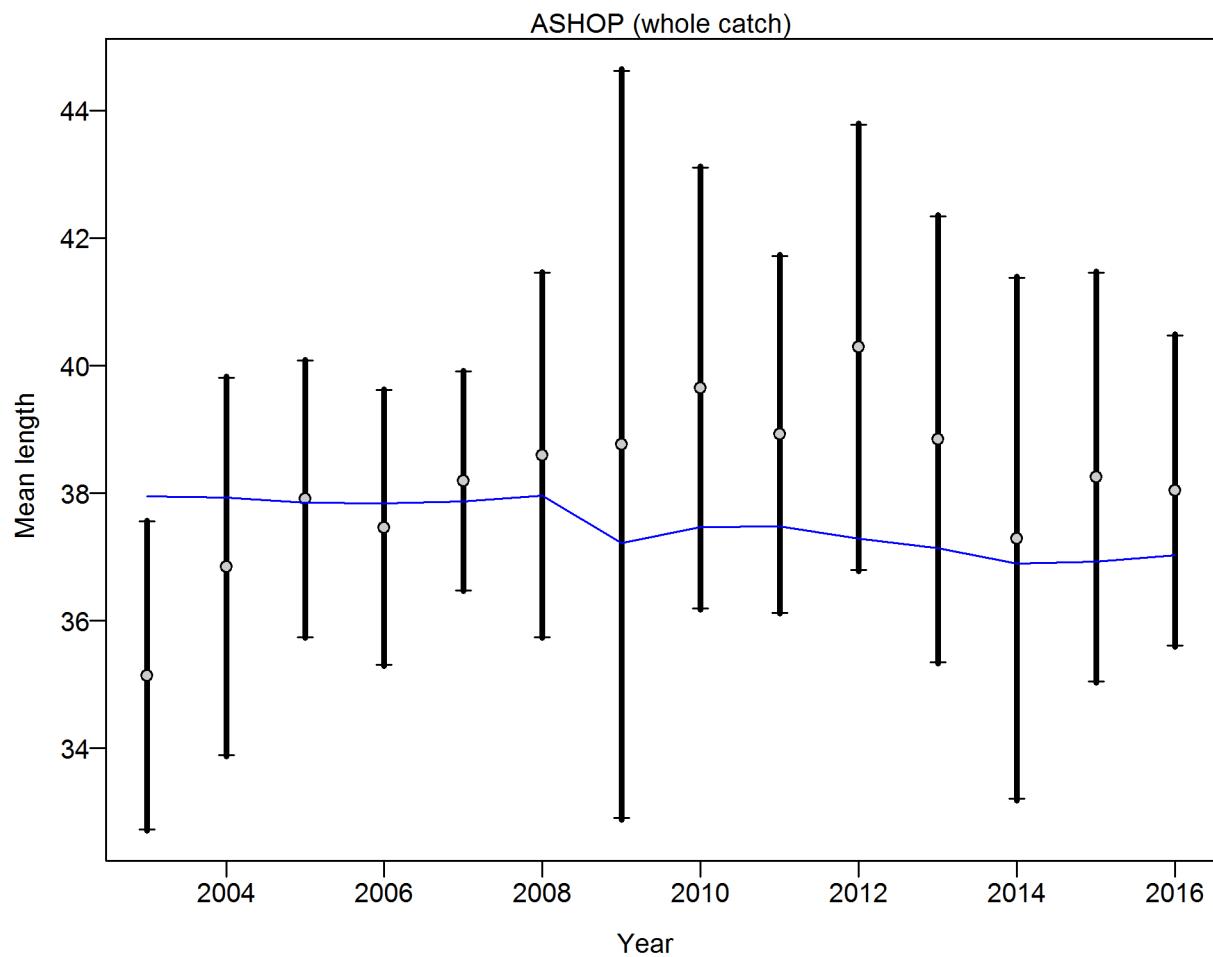


Figure 51: Francis data weighting method TA1.8: At_sea hake Suggested sample size adjustment (with 95% interval) for len data from At_sea hake: 1.0115 (0.5352_4.8582) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:weighting_len_ashop](#)

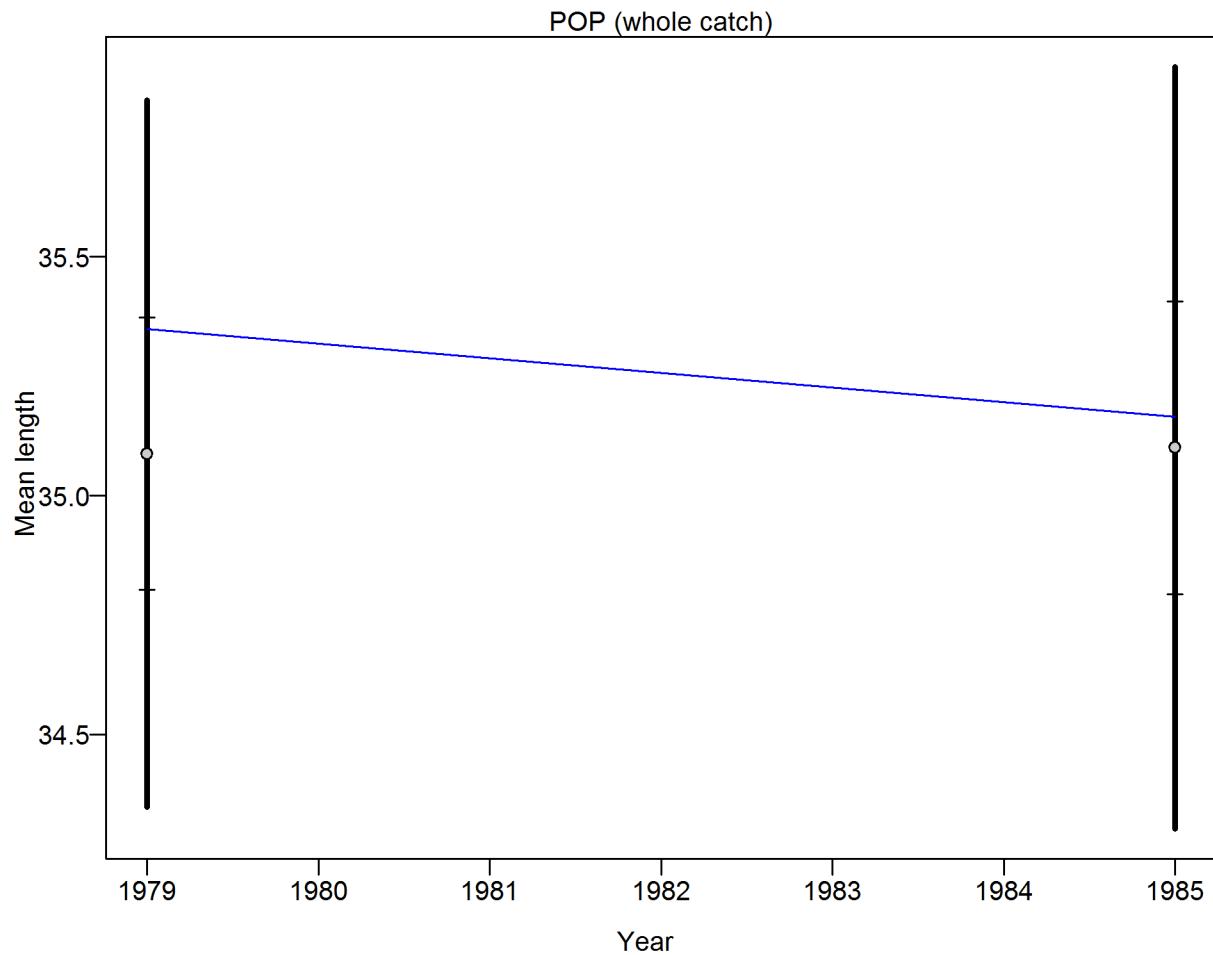


Figure 52: Francis data weighting method TA1.8: Pacific ocean perch survey Suggested sample size adjustment (with 95% interval) for len data from Pacific ocean perch survey: 6.7496 (6.7496_Inf) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124–1138. [fig:weighting_len_pop](#)

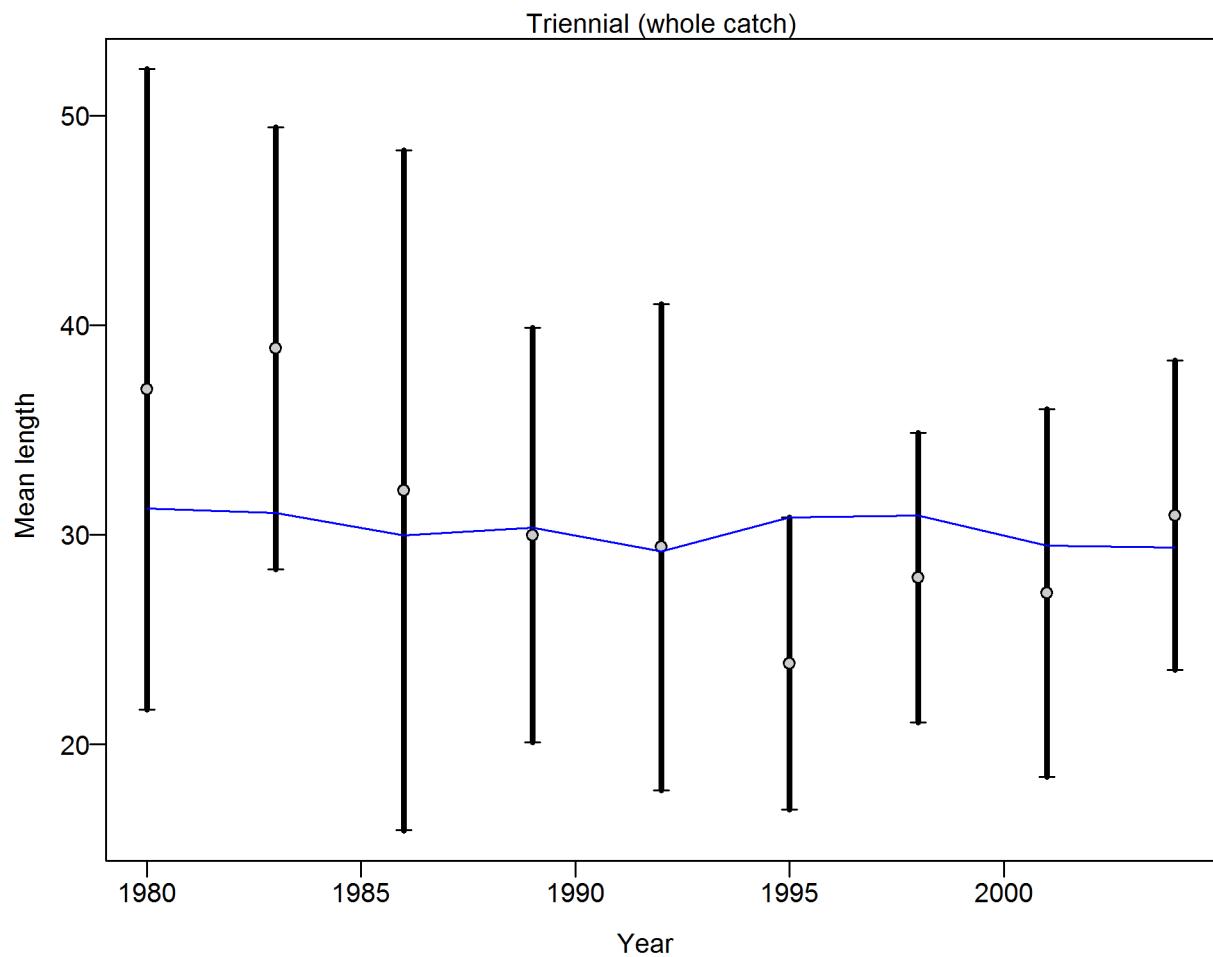


Figure 53: Francis data weighting method TA1.8: Triennial survey Suggested sample size adjustment (with 95% interval) for len data from Triennial survey: 1.0004 (0.5362-5.786)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. [fig:weighting_len_triennial](#)

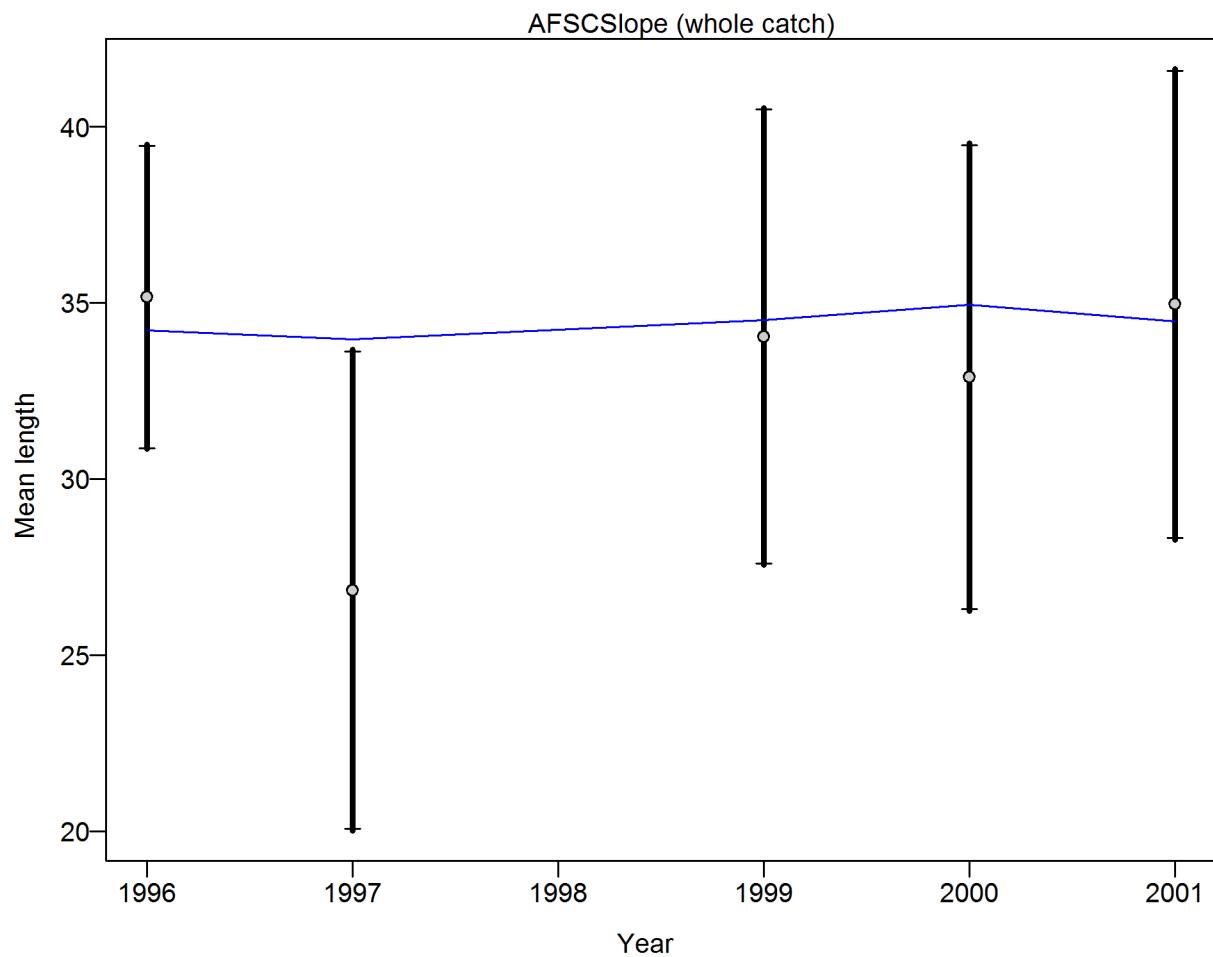


Figure 54: Francis data weighting method TA1.8: AFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from AFSC slope survey: 1.0151 (0.5859_16.7225)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:weighting_len_afsc](#)

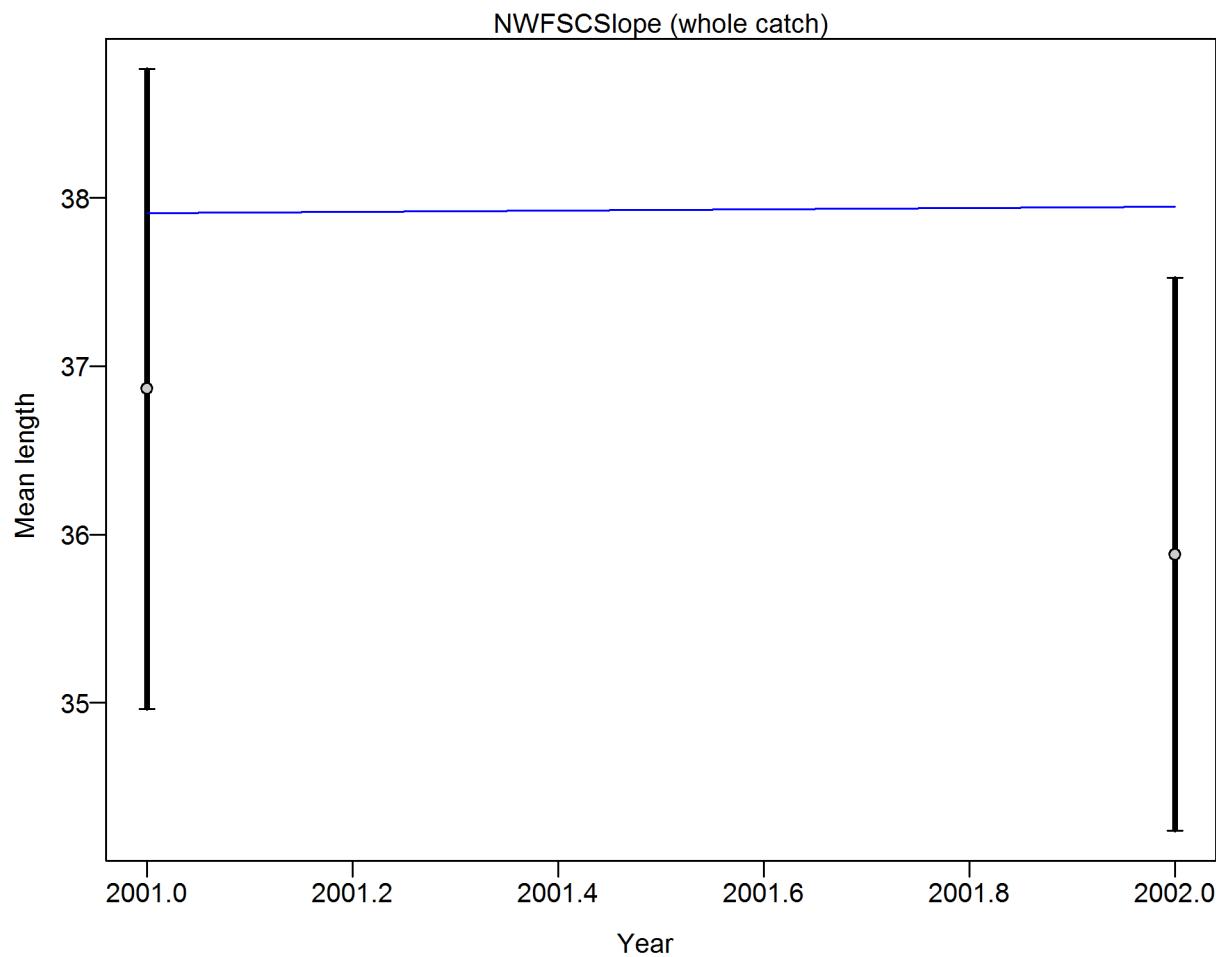


Figure 55: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC slope survey: 0.9922 (0.9922_Inf)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. [fig:weighting_len_nwfs](#)

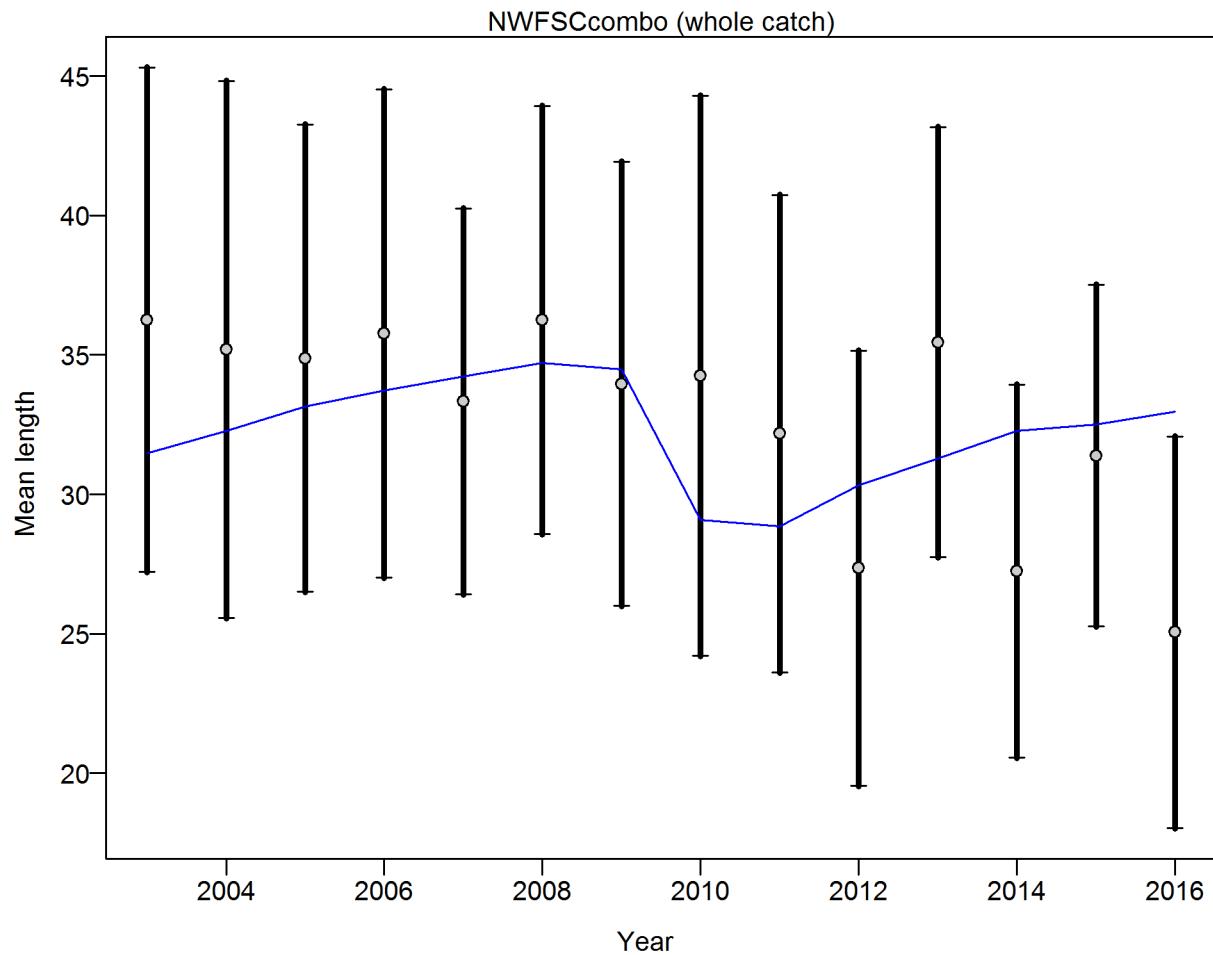


Figure 56: Francis data weighting method TA1.8: NWFSC shelf_slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC shelf_slope survey: 1.0055 (0.6199_4.021) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:weighting_len_nwfsccon](#)

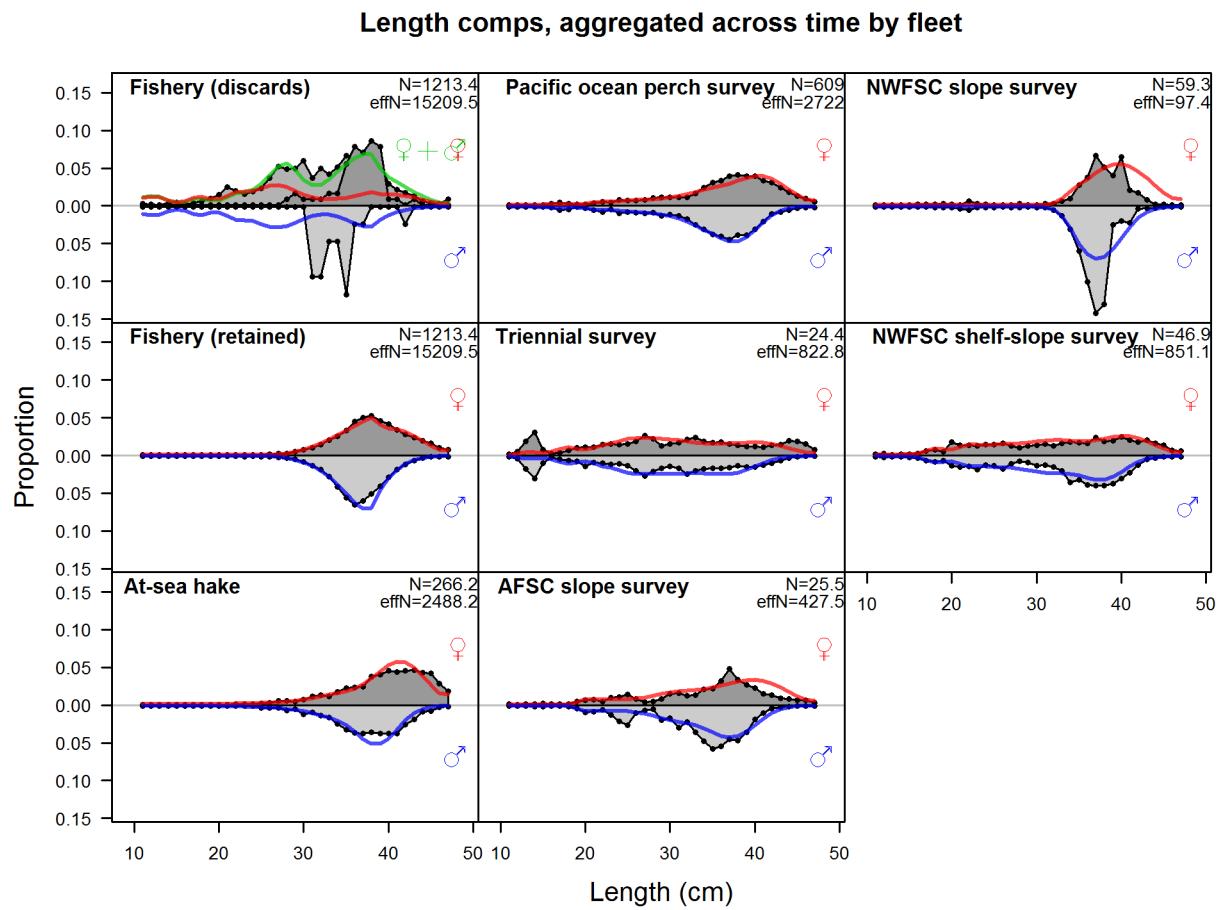


Figure 57: Age compositions aggregated across time by fleet. [fig:length_agg](#)

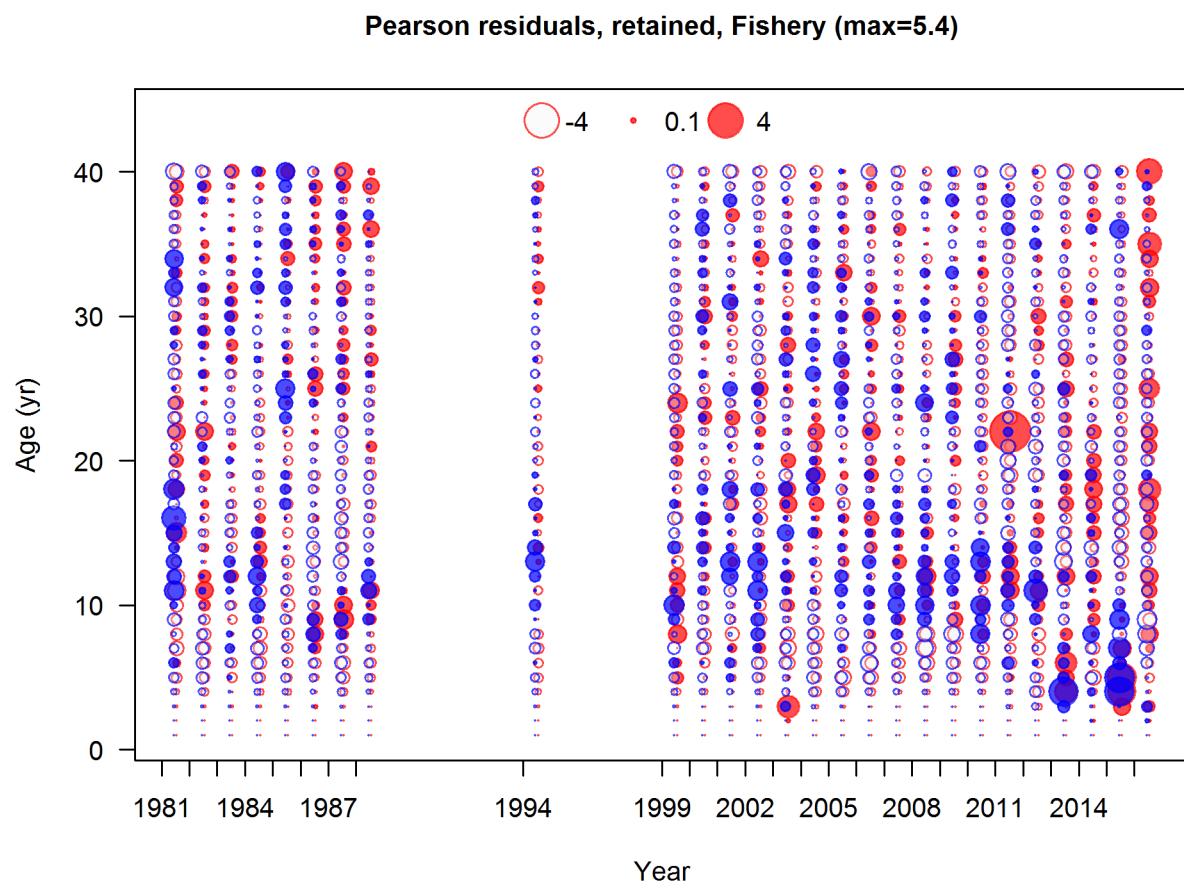


Figure 58: Pearson residuals, retained, Fishery (max=5.4) (plot 2 of 2)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:fishery_age_pearson](#)

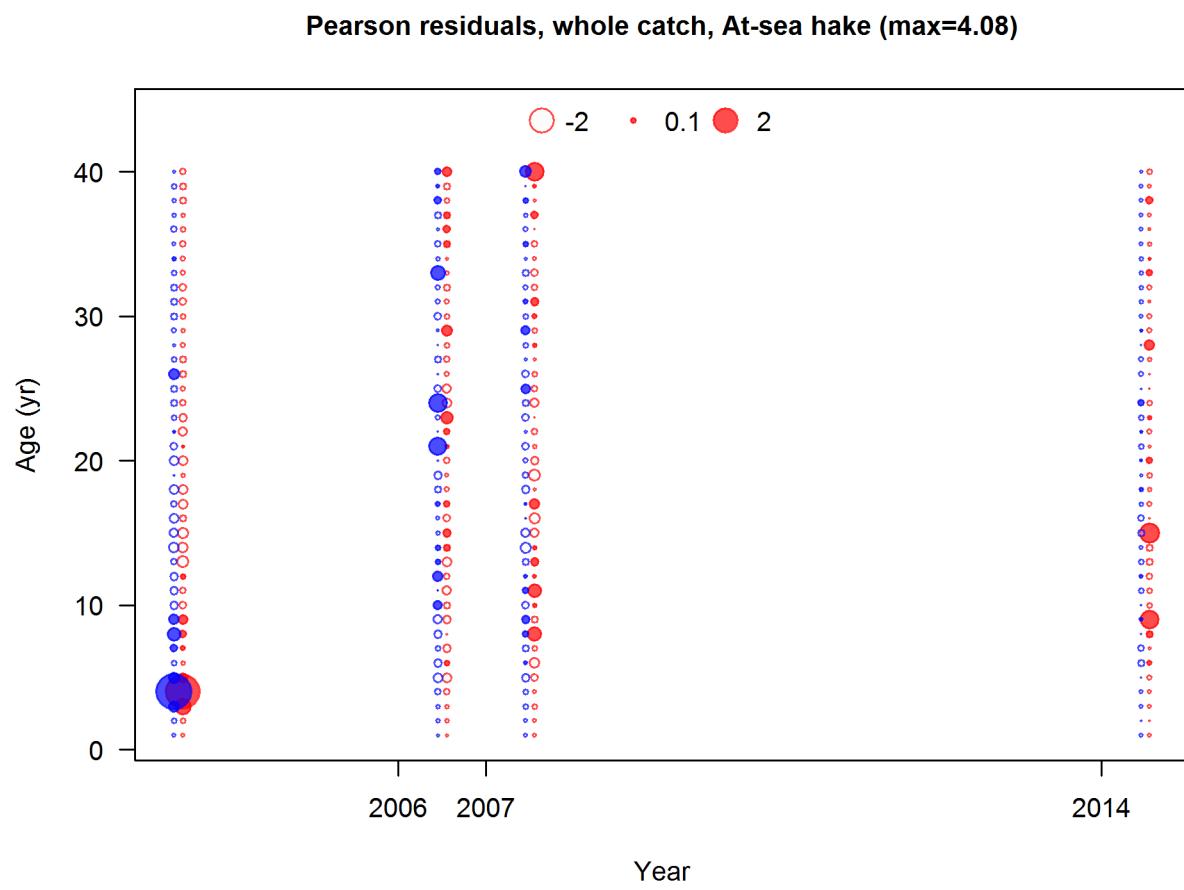


Figure 59: Pearson residuals, whole catch, At_sea hake (max=4.08)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:ashop_age_pearson](#)

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

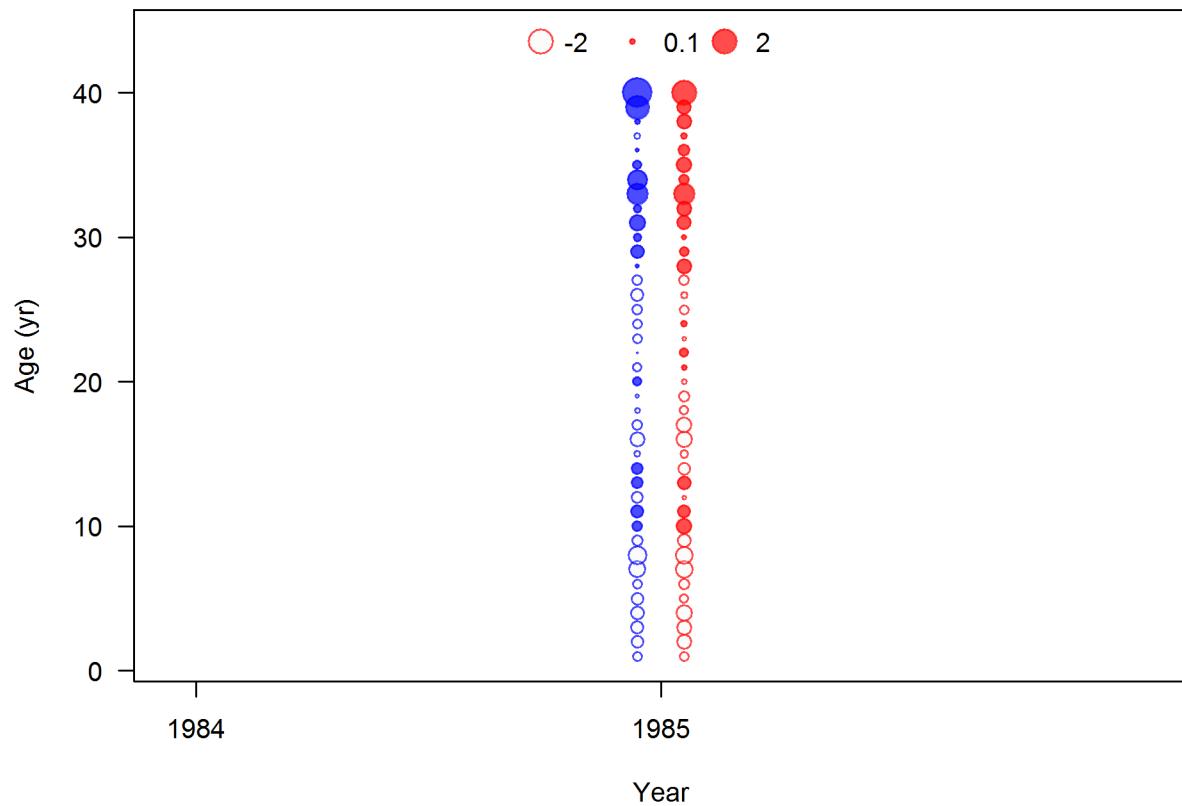


Figure 60: Pearson residuals, whole catch, Pacific ocean perch survey (max=2.76)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:pop_age_pearson](#)

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

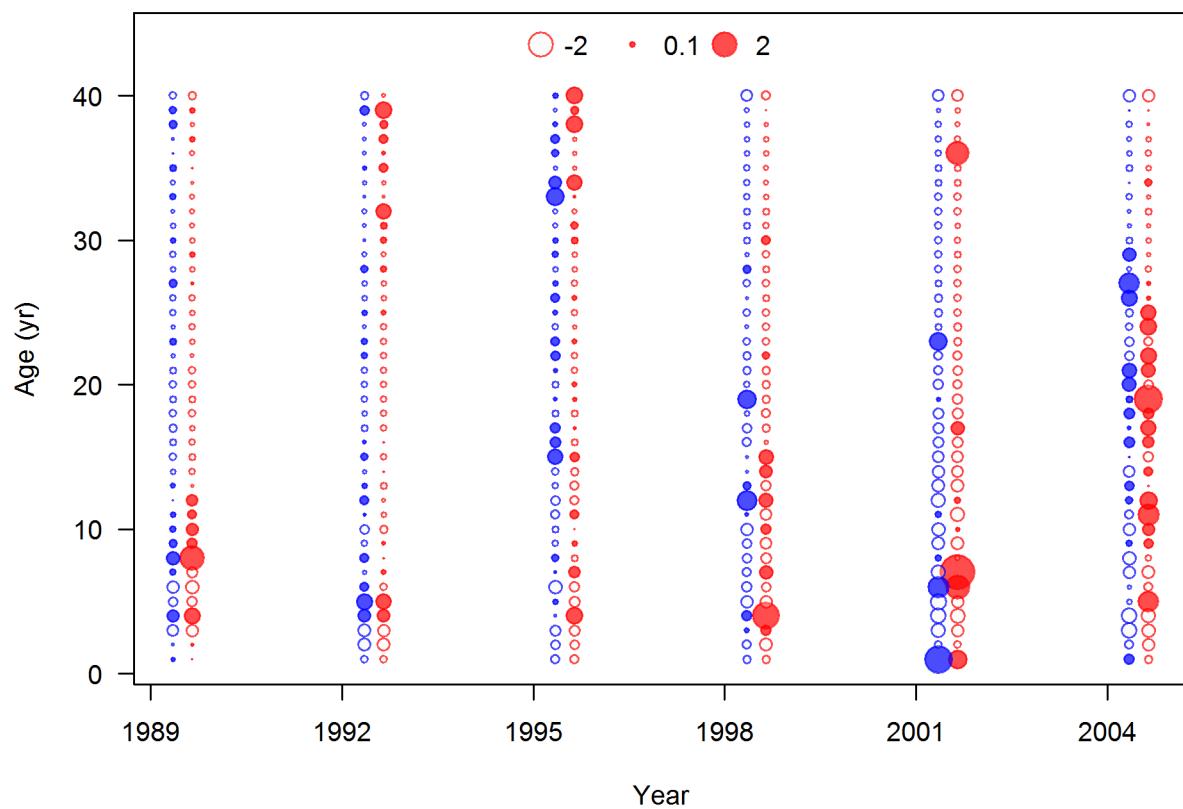


Figure 61: Pearson residuals, whole catch, Triennial survey (max=3.75)
Closed bubbles are positive residuals ($\text{observed} > \text{expected}$) and open bubbles are negative residuals ($\text{observed} < \text{expected}$). [fig:tri_age_pearson](#)

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

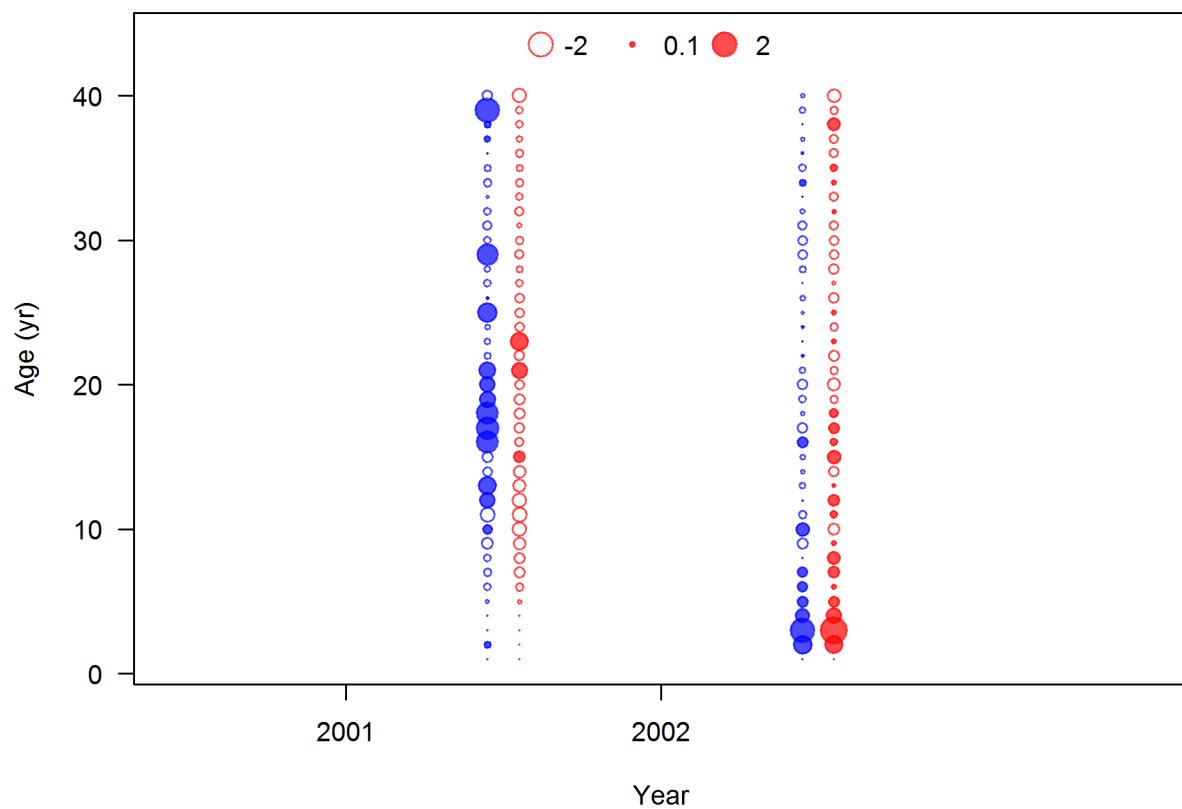


Figure 62: Pearson residuals, whole catch, NWFSC slope survey (max=2.34)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:nwfsc_pearson](#)

Pearson residuals, whole catch, NWFSC shelf-slope survey (max=18.49)

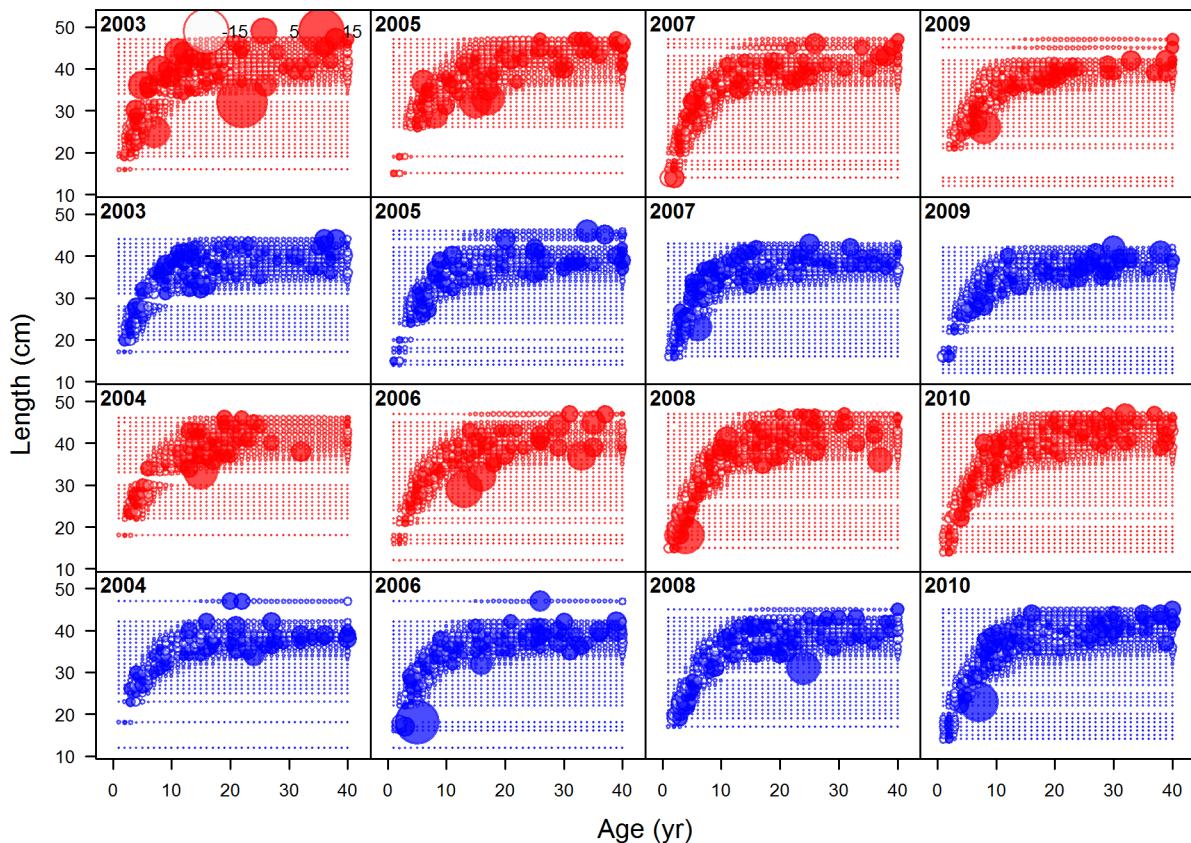


Figure 63: Pearson residuals, whole catch, NWFSC shelf_slope survey (max=18.49) (plot 1 of 2) | fig:nwsfc_combo_age_aal1

Pearson residuals, whole catch, NWFSC shelf-slope survey (max=18.49)

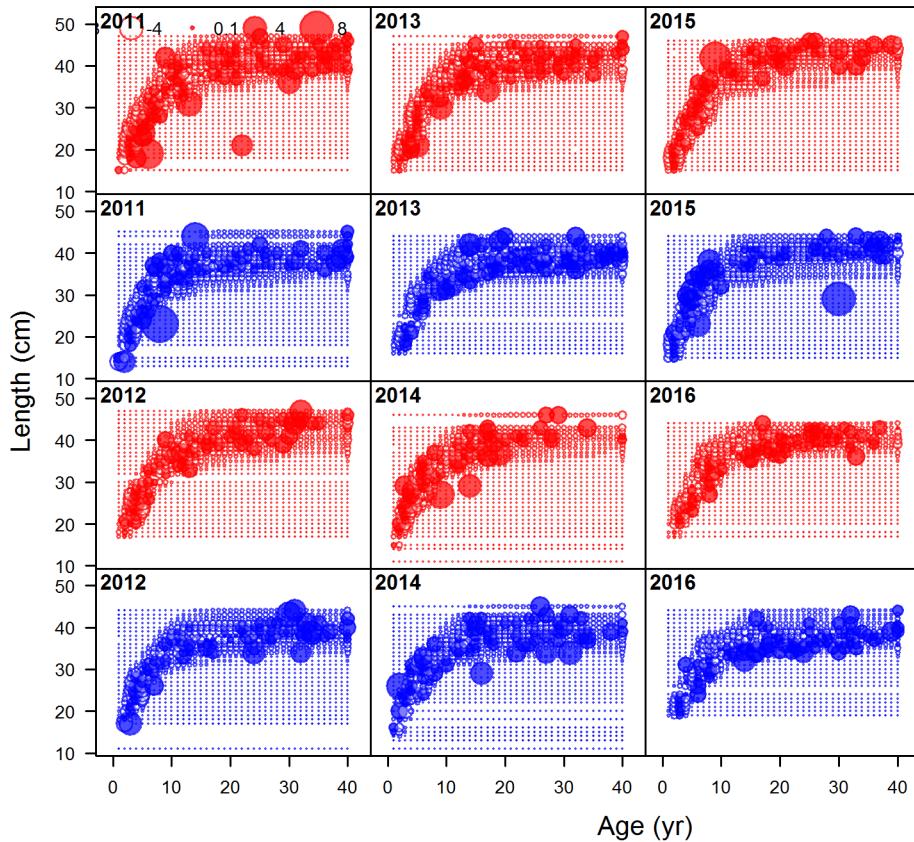


Figure 64: Pearson residuals, whole catch, NWFSC shelf_slope survey (max=18.49) (plot 1 of 2) (plot 2 of 2) [fig:nwsfc_combo_age_aa12](#)

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

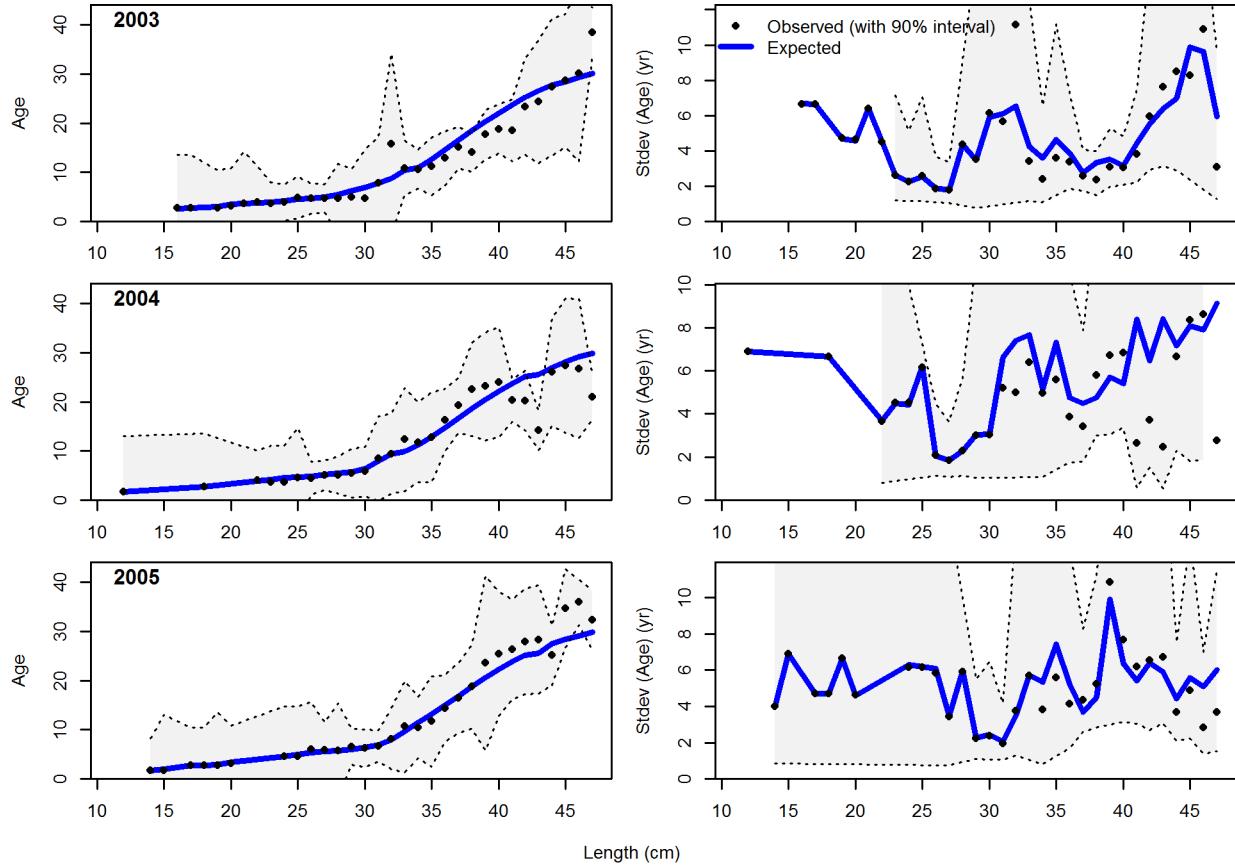


Figure 65: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 1 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution.

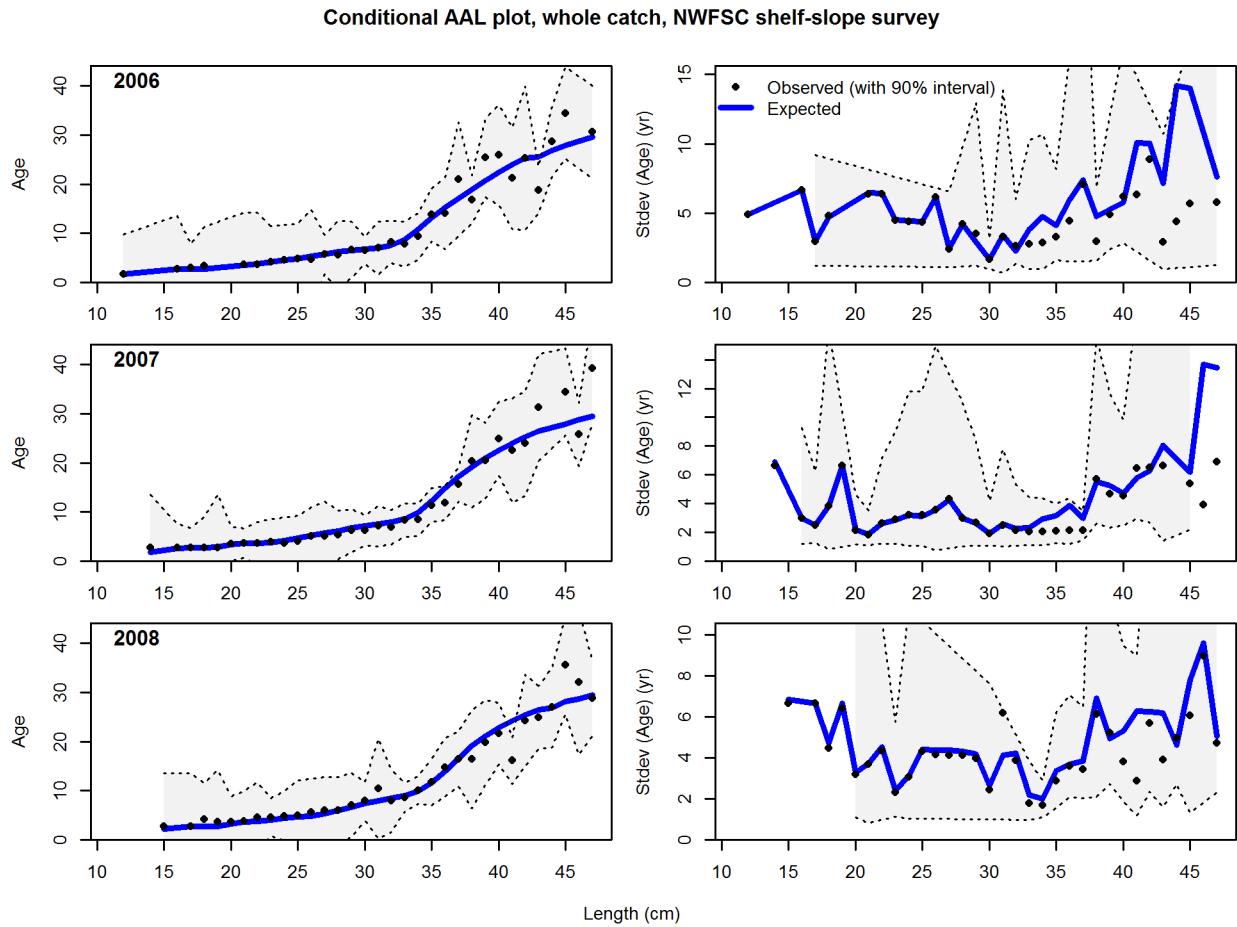


Figure 66: Conditional AAL plot, whole catch, NWFSC shelf_slope survey (plot 2 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution. | [fig:nwfsc_combo_andre_2](#)

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

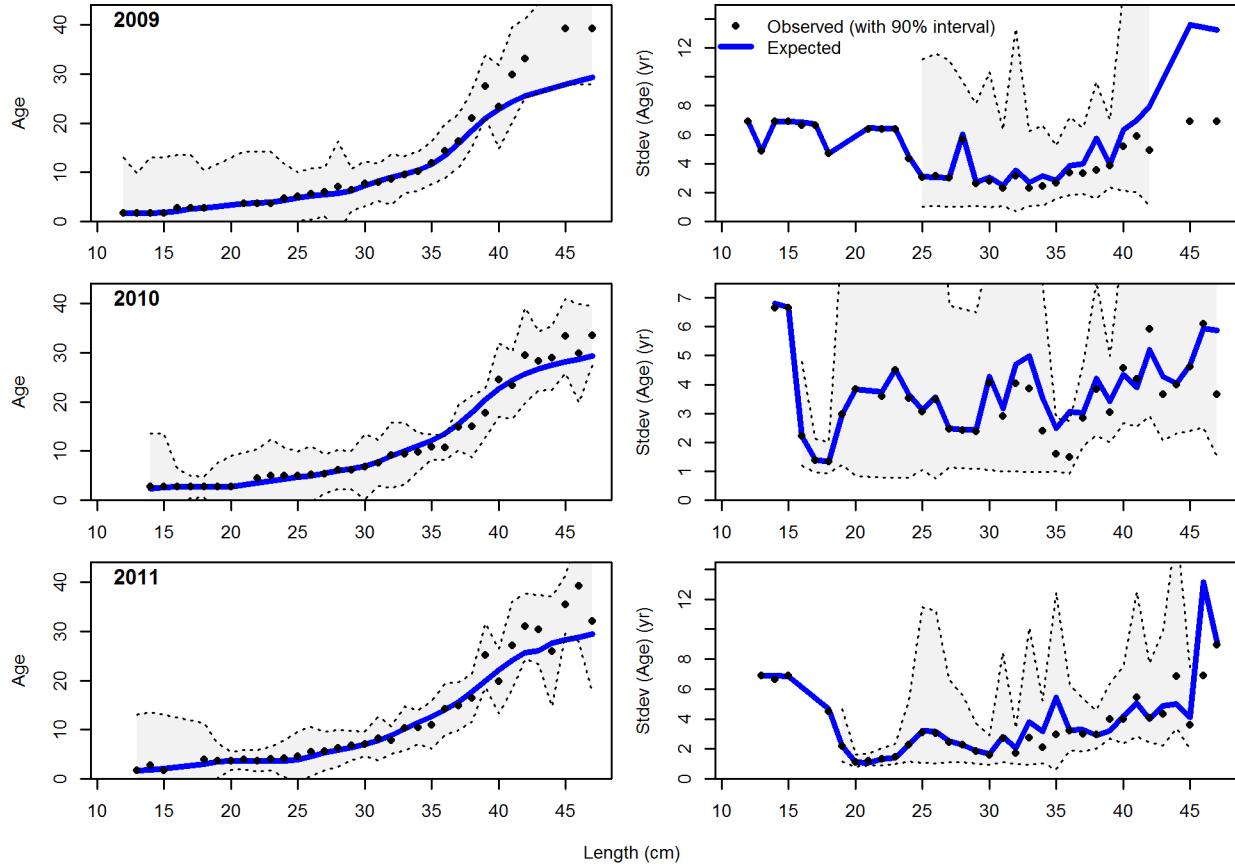


Figure 67: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 3 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution.

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

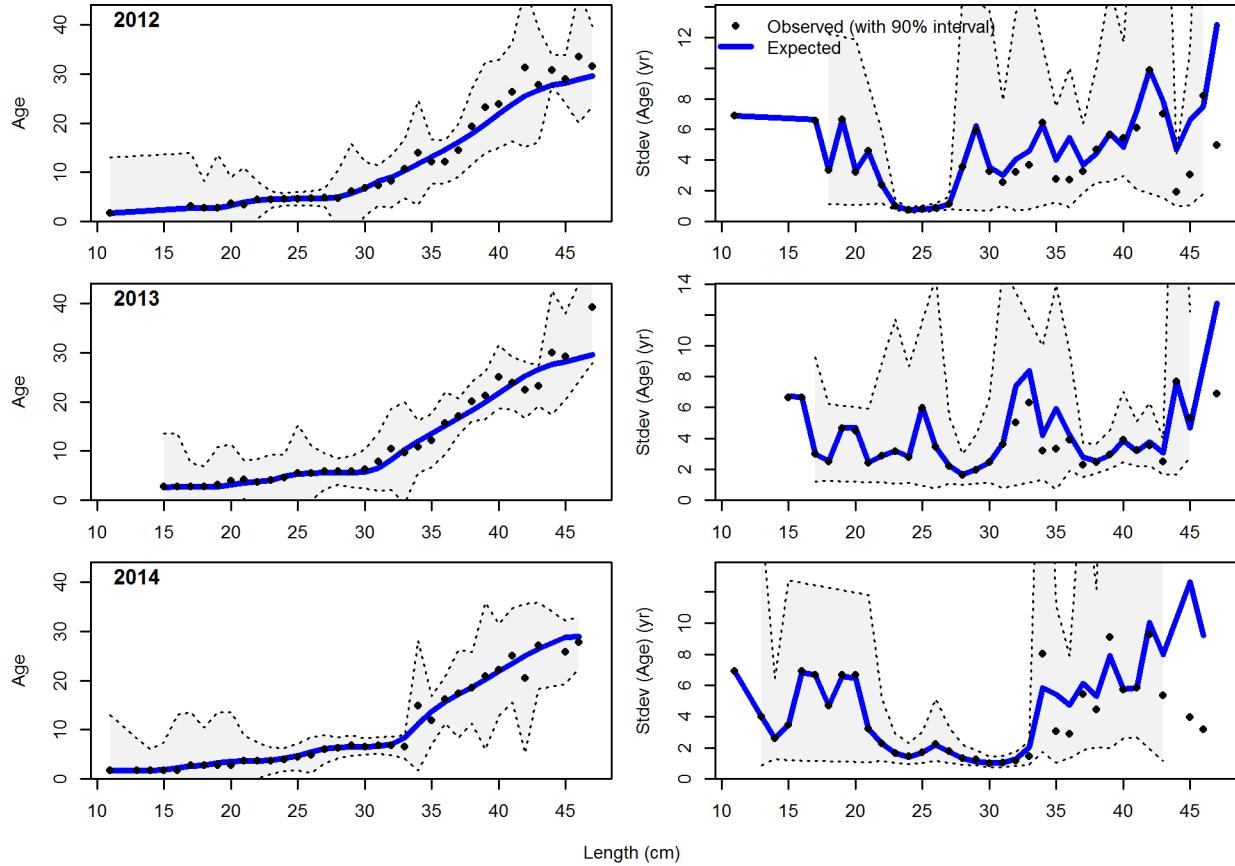


Figure 68: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 4 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution.

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

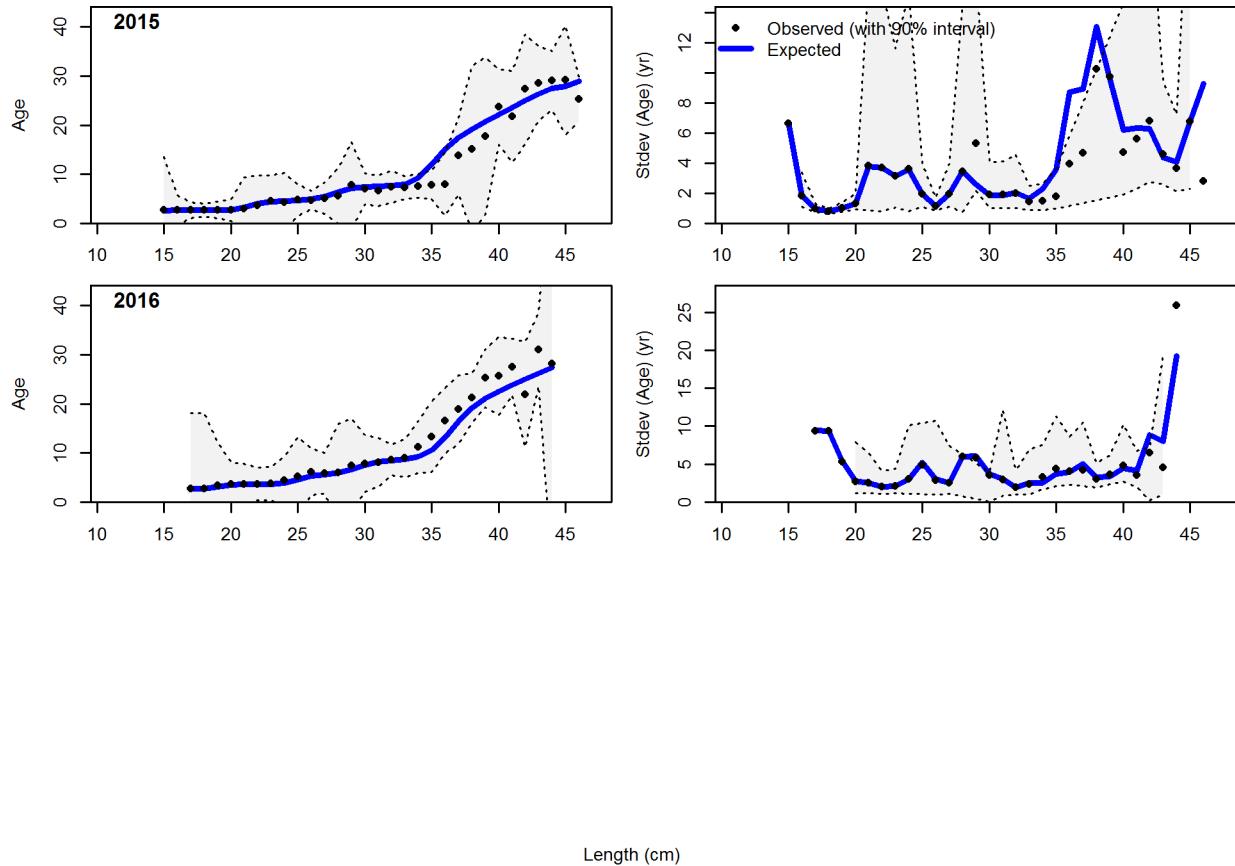


Figure 69: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 5 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution.

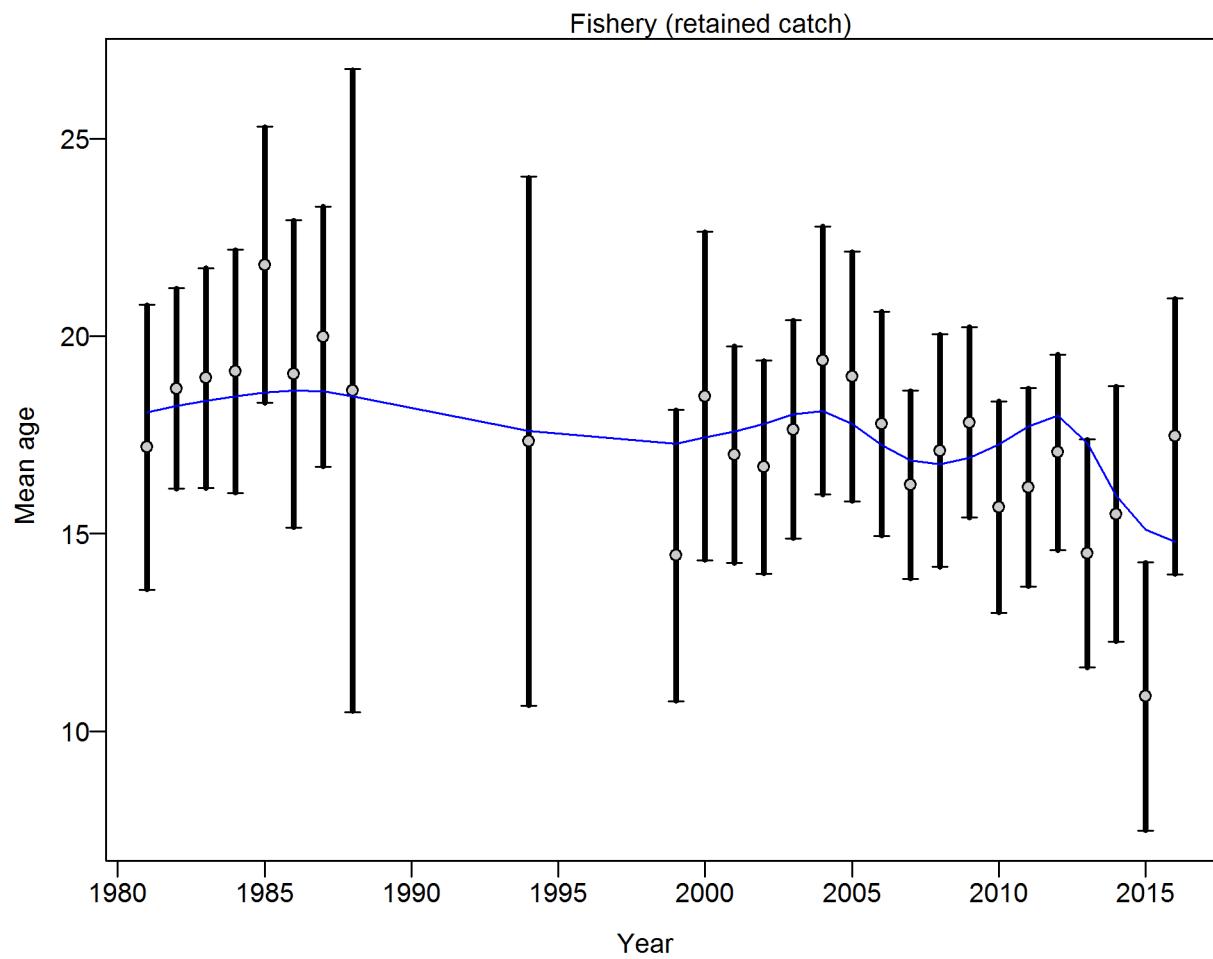


Figure 70: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for age data from Fishery: 0.9921 (0.6365_1.9959) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:weighting_fishery](#)

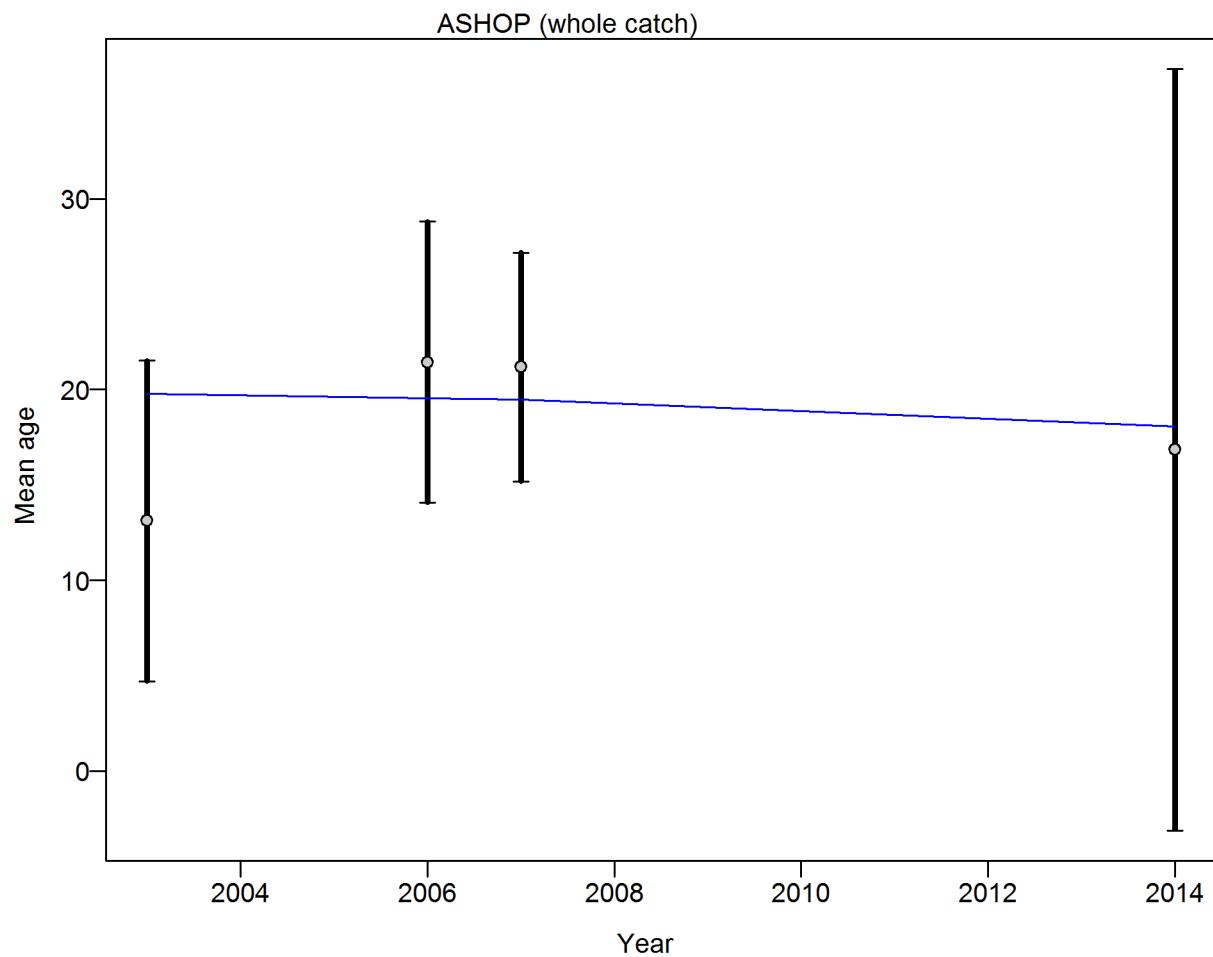


Figure 71: Francis data weighting method TA1.8: At_sea hake Suggested sample size adjustment (with 95% interval) for age data from At_sea hake: 0.9921 (0.6459_1420.3157)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:weighting_ashop](#)

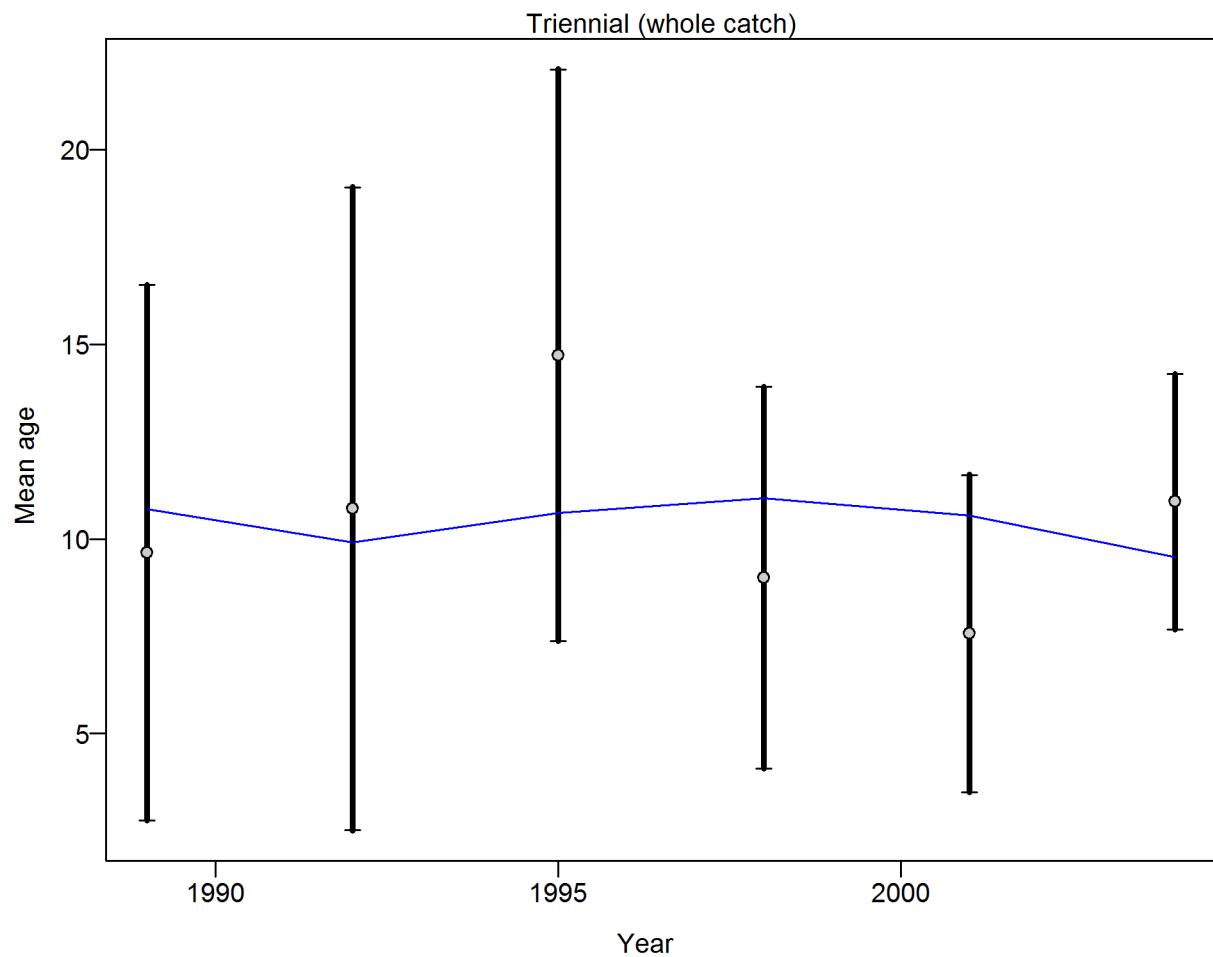


Figure 72: Francis data weighting method TA1.8: Triennial survey Suggested sample size adjustment (with 95% interval) for age data from Triennial survey: 1.0019 (0.6421_5.1354)
 For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:weighting_triennial](#)

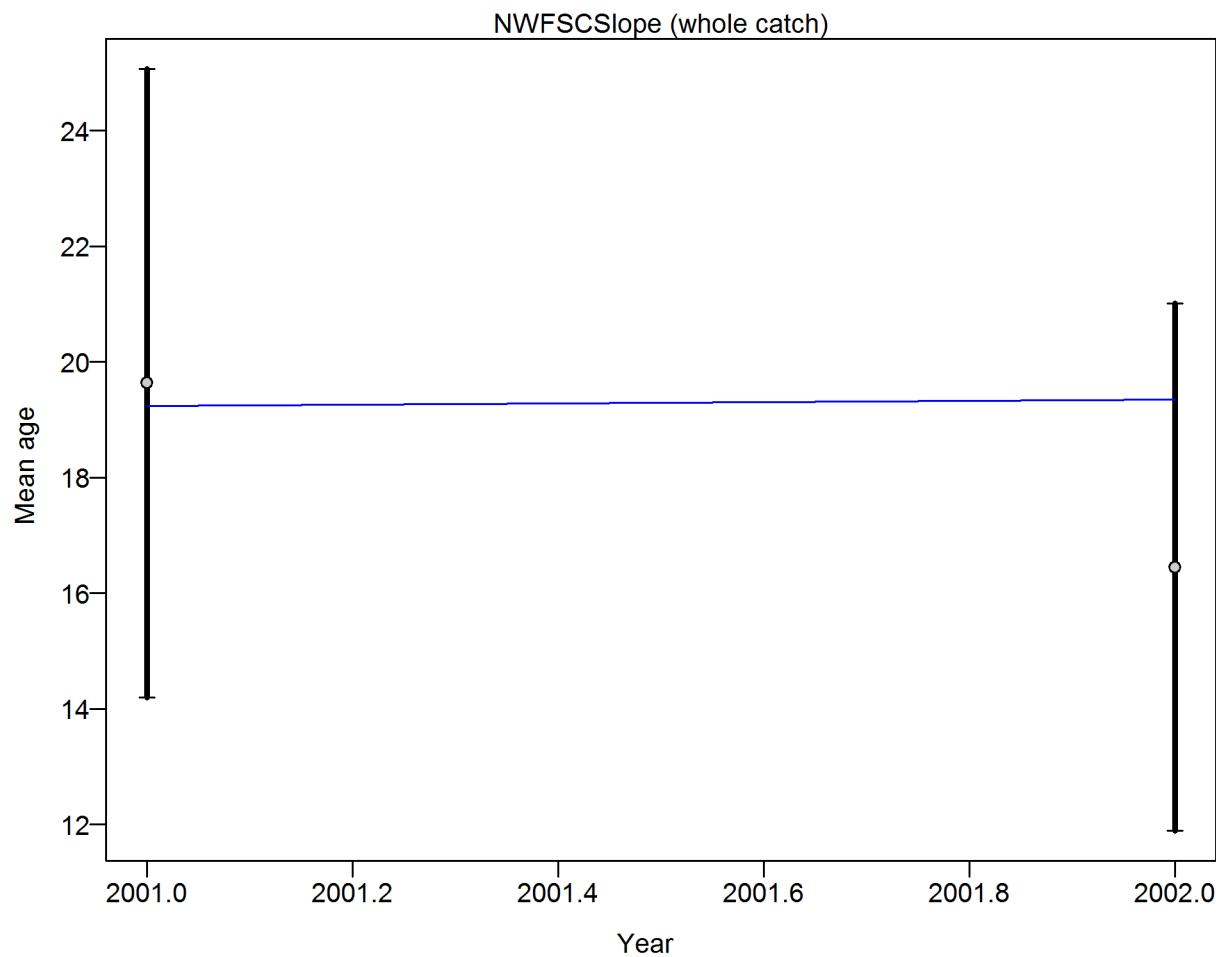


Figure 73: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for age data from NWFSC slope survey: 0.9998 (0.9998_Inf)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock
assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. [fig:weighting_nwfscslope](#)

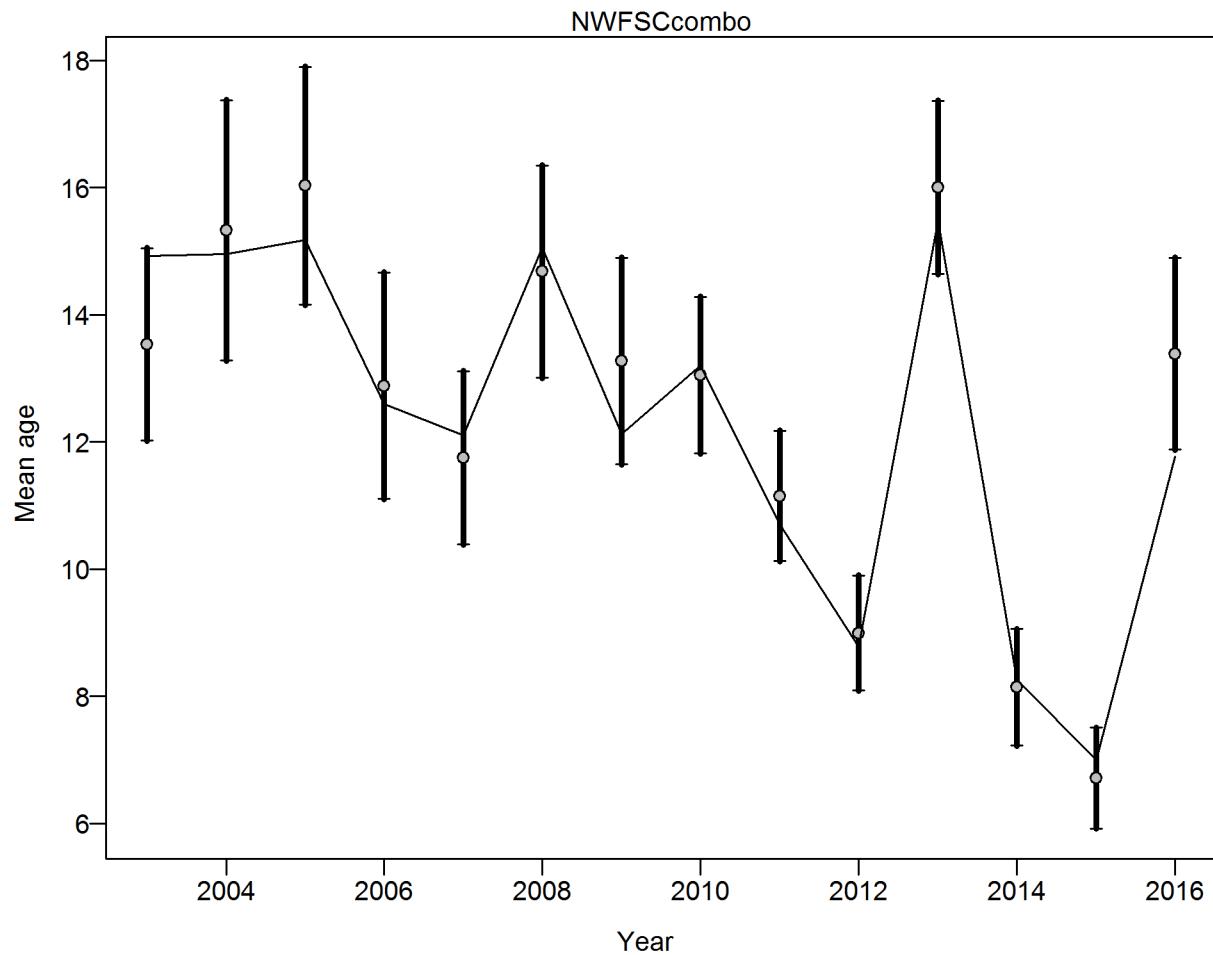


Figure 74: Francis data weighting method TA1.8 for conditional age [data:NWFSC](#) shelf_slope survey Suggested sample size adjustment (with 95% interval) for conditional age_at_length data from NWFSC shelf_slope survey: 1.0131 (0.5851_3.0487) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:weighting_nwfsccombo](#)

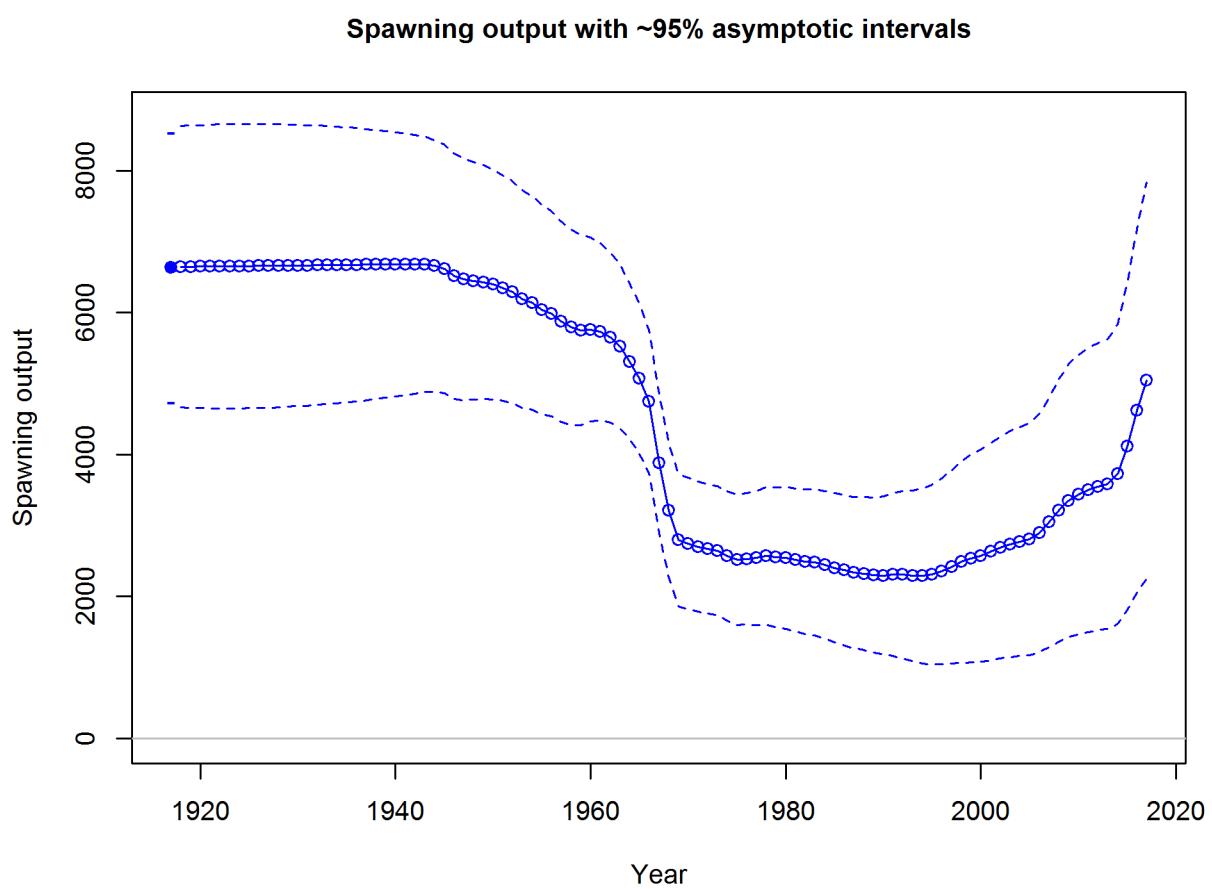


Figure 75: Estimated time-series of spawning output for Pacific ocean perch. fig:ssb

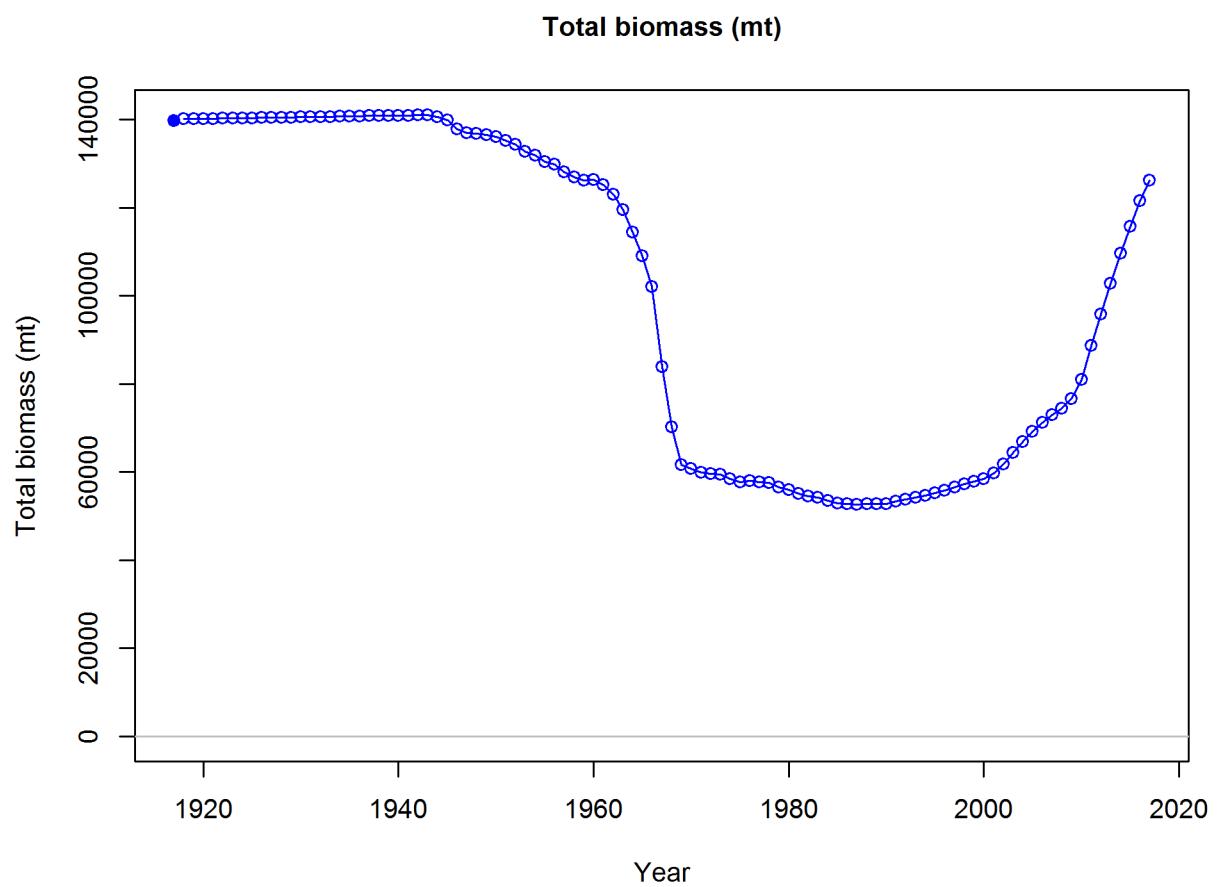


Figure 76: Estimated time-series of total biomass for Pacific ocean perch. $|^{\text{total_bio}}$

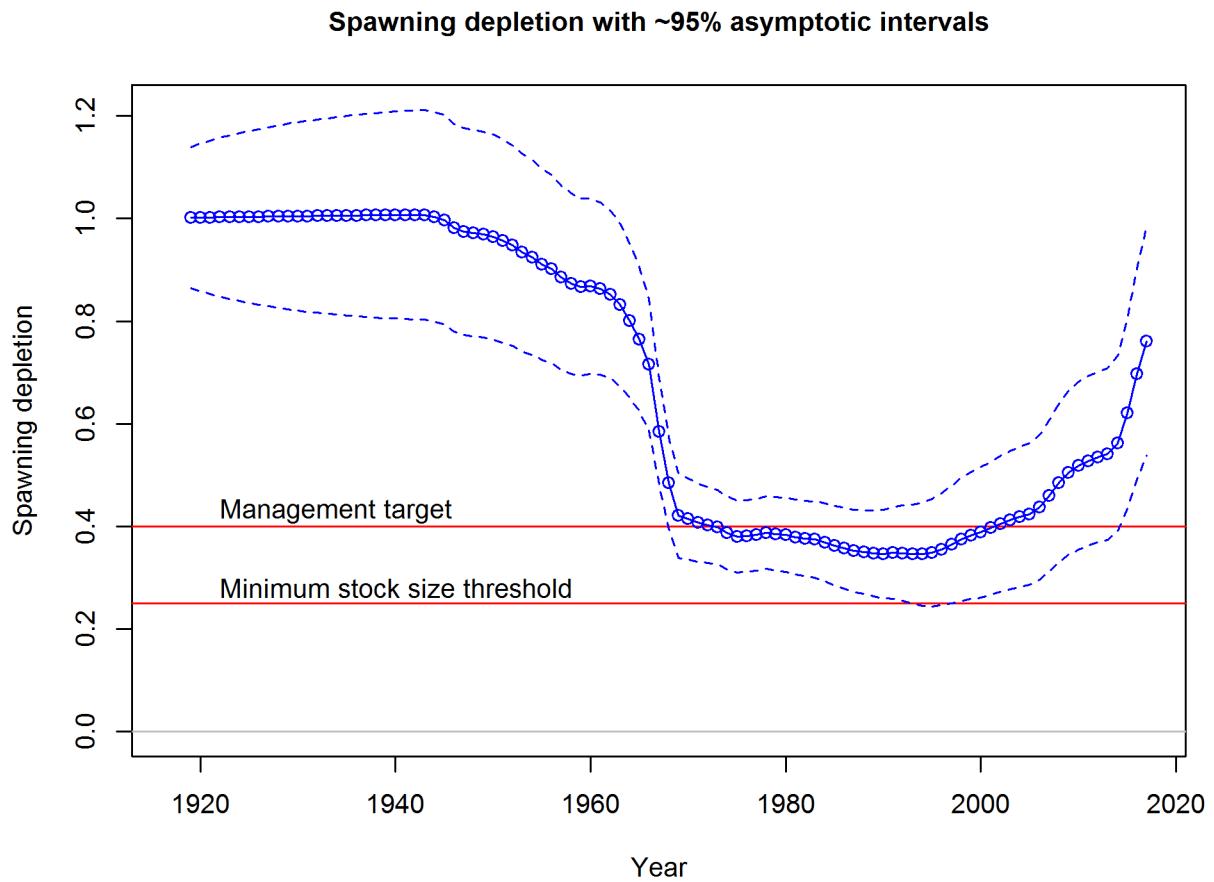


Figure 77: Estimated time-series of relative biomass for Pacific ocean perch. fig:dep1

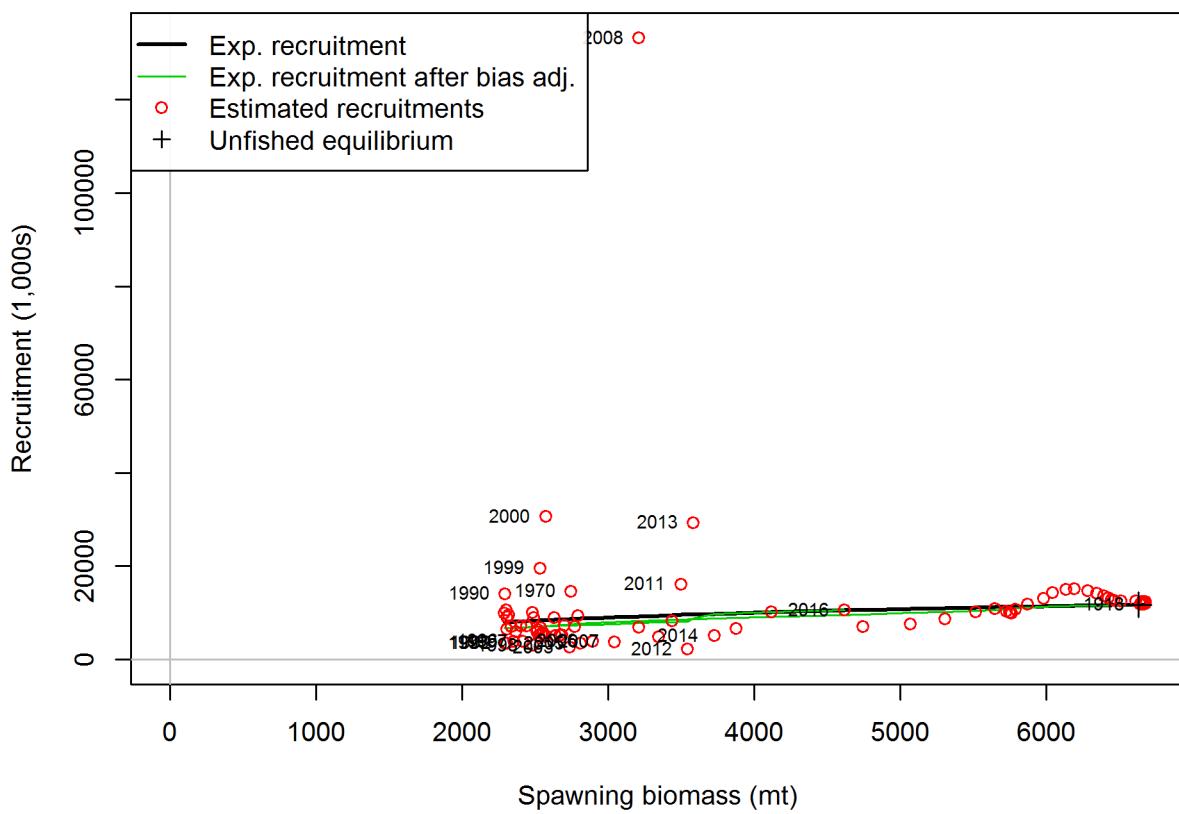


Figure 78: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution
 fig:stock_recruit_curve

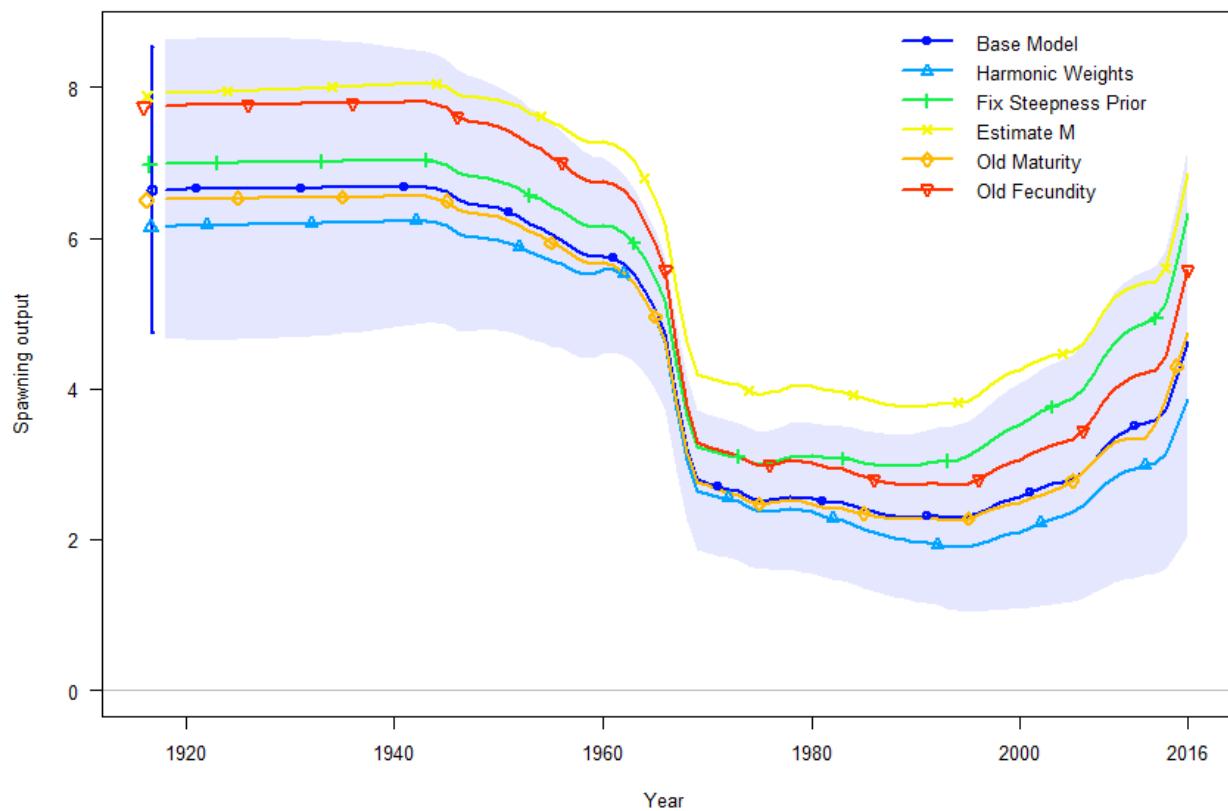


Figure 79: Time-series of spawning output for model sensitivities for Pacific ocean perch. fig:sensi_ssbb

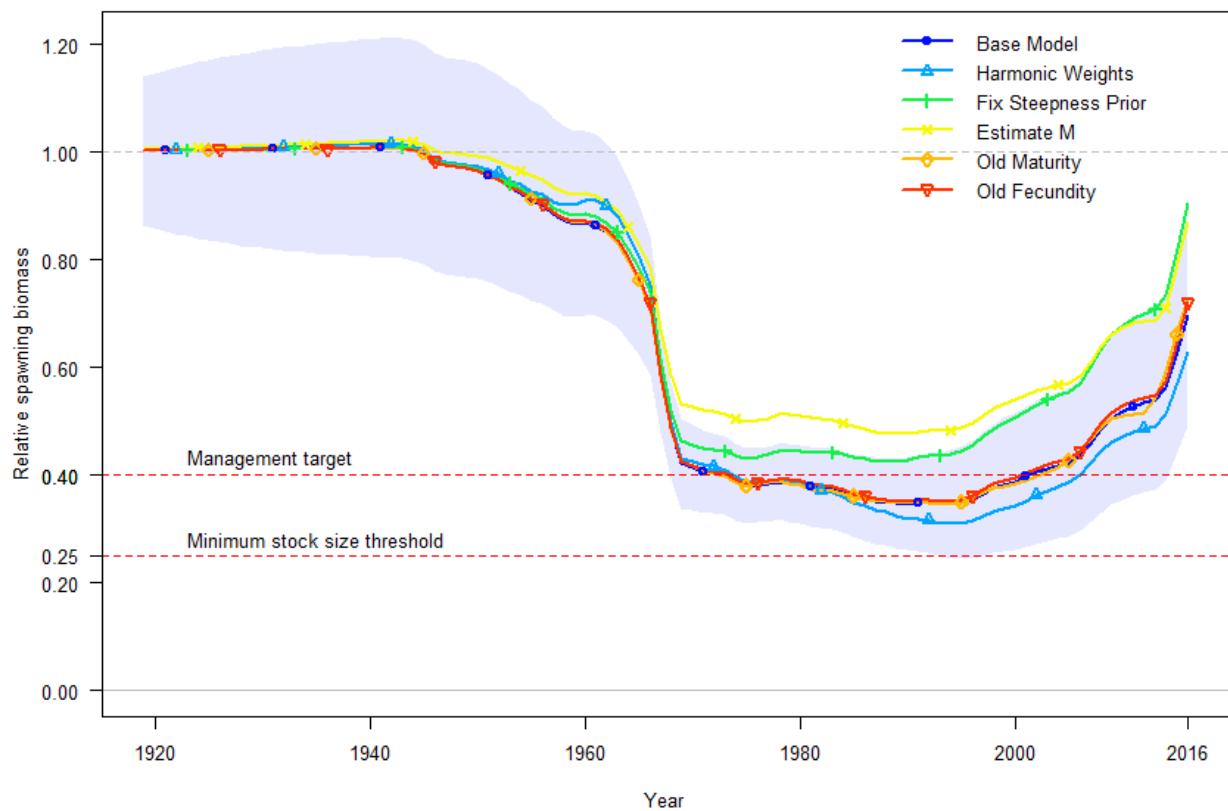


Figure 80: Time-series of relative biomass for model sensitivities for Pacific ocean perch. fig:sens1_dep

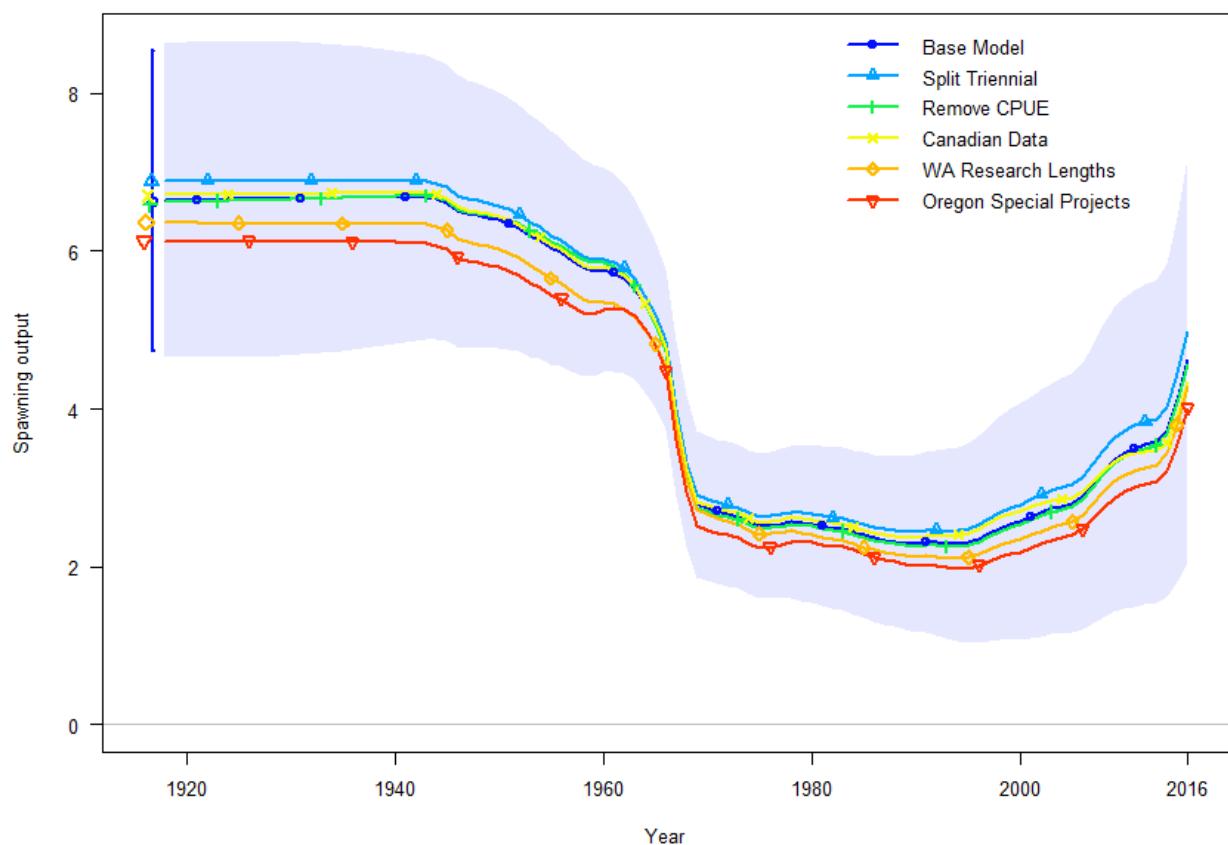


Figure 81: Time-series of spawning output for model sensitivities for Pacific ocean perch. fig:sens2_ssbb

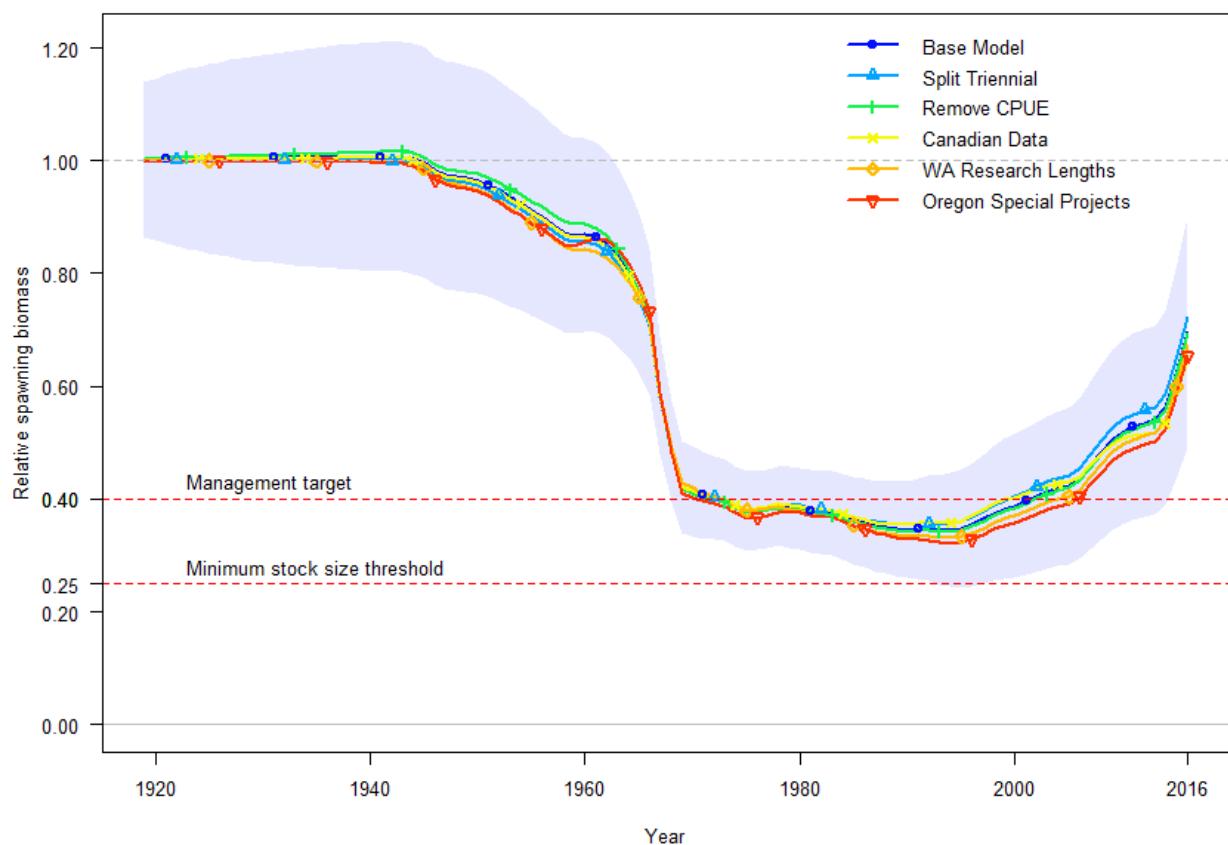


Figure 82: Time-series of relative biomass for model sensitivities for Pacific ocean perch. fig:sens2_dep

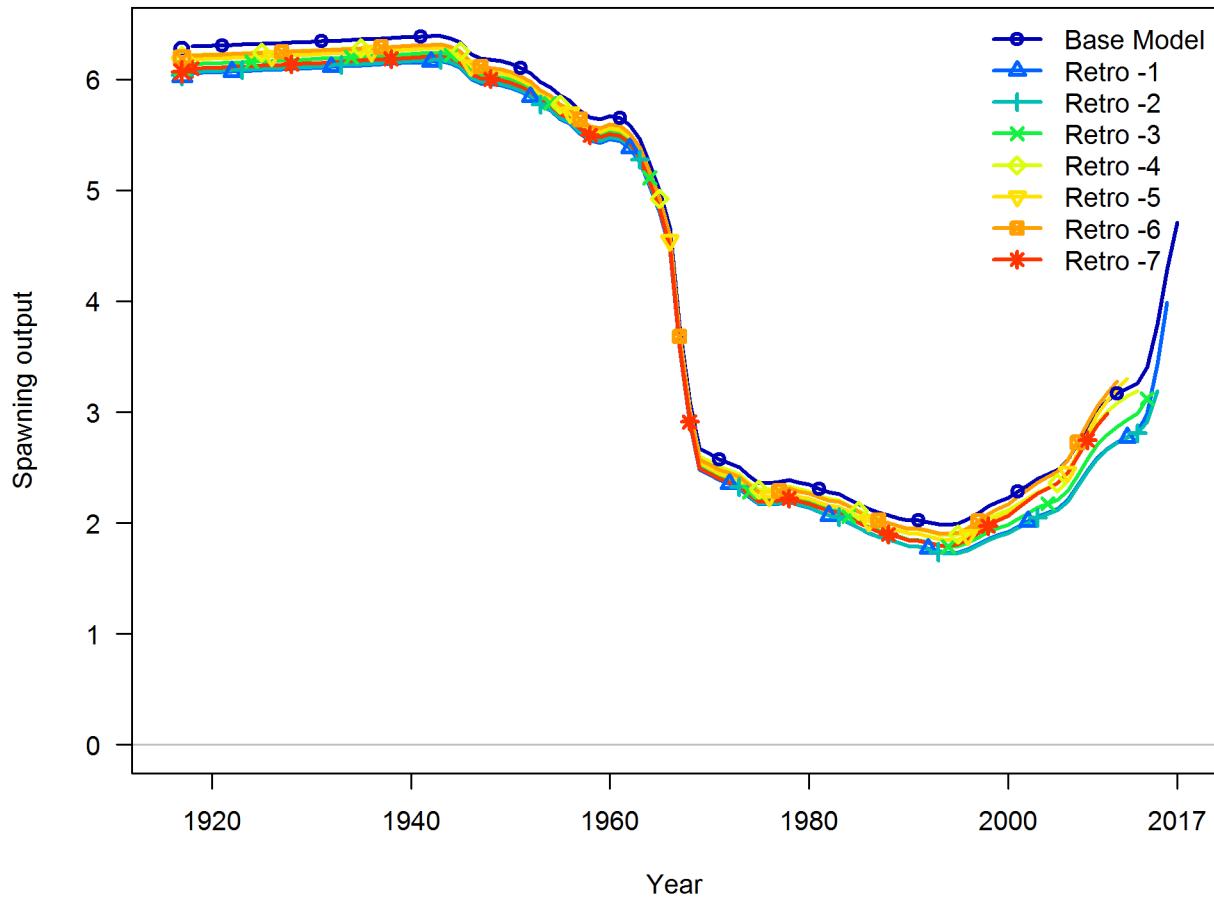


Figure 83: Retrospective pattern for spawning output. [fig:retro_sb](#)

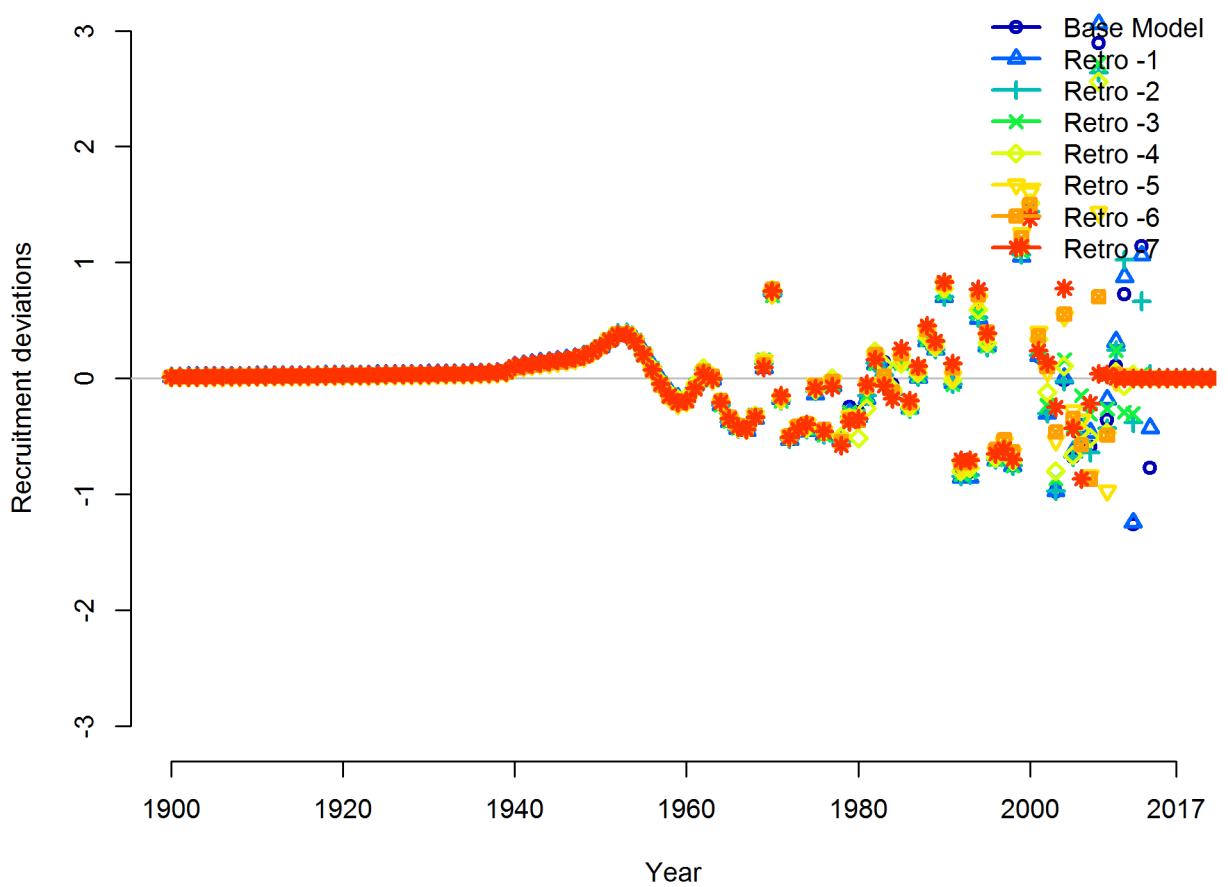


Figure 84: Retrospective pattern for estimated recruitment deviations. `fig:retro_recdev`

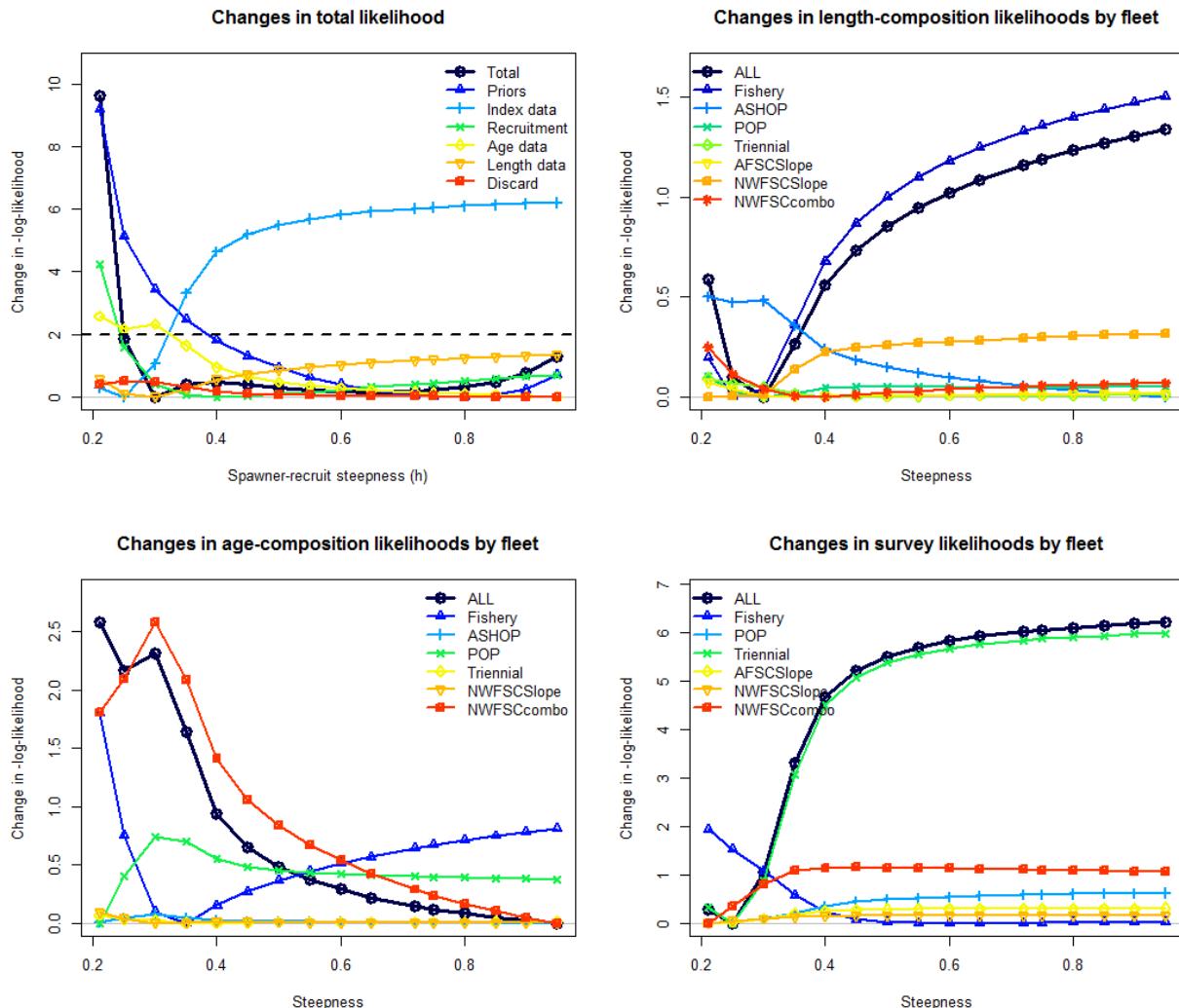


Figure 85: Likelihood profile across steepness values. fig:piner_h

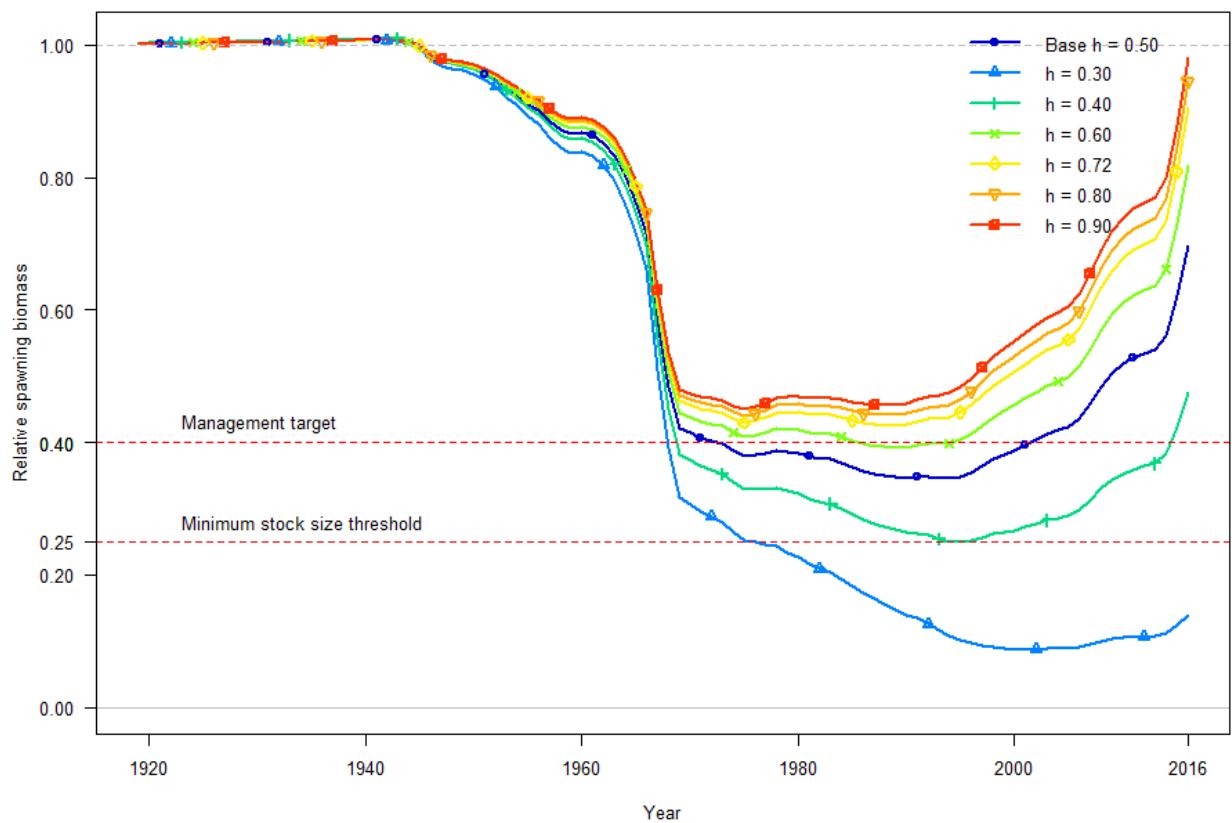


Figure 86: Trajectories of relative biomass across values of steepness. [fig:h_trajectory](#)

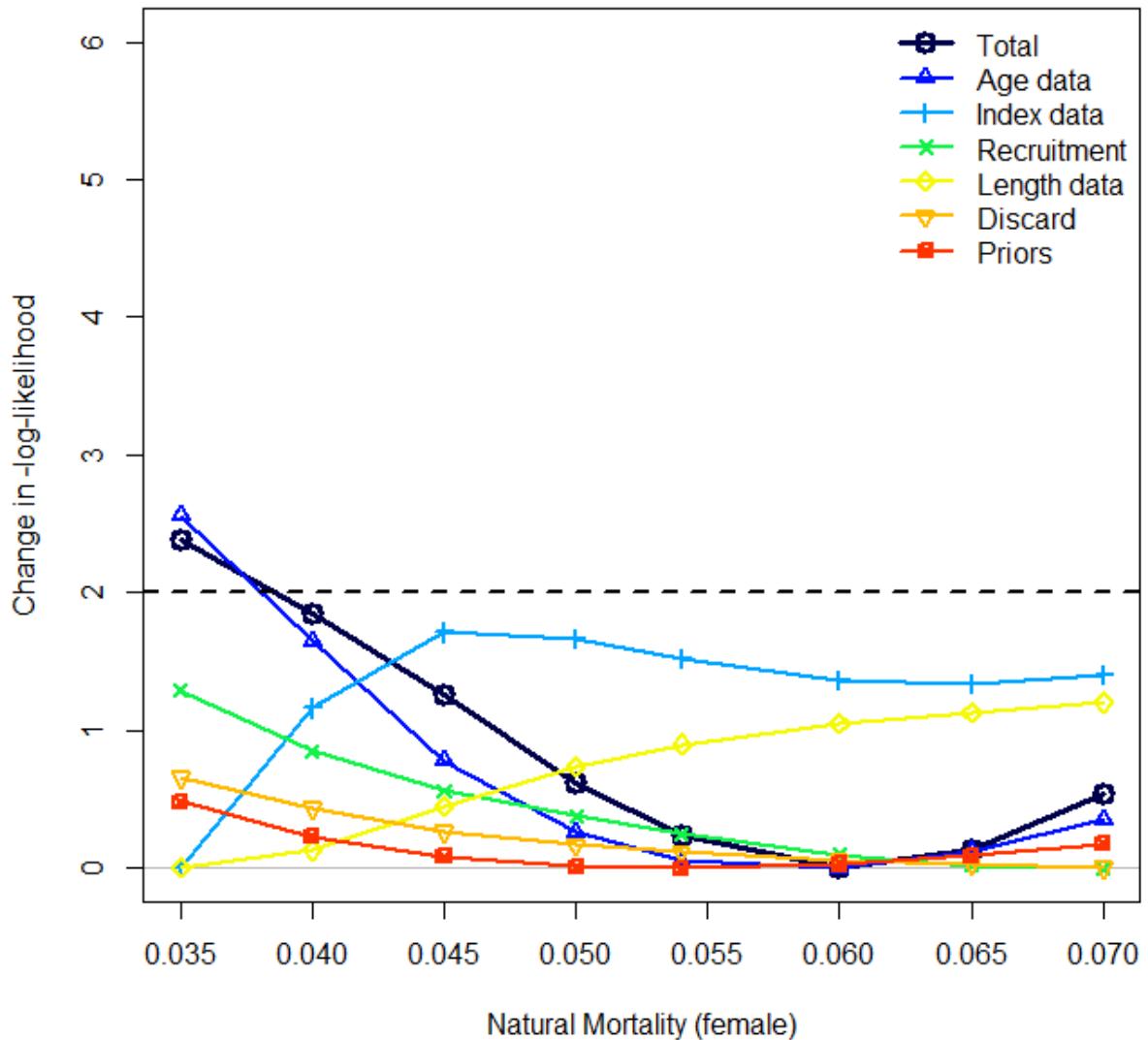


Figure 87: Likelihood profile across natural mortality values. `fig:m_like`

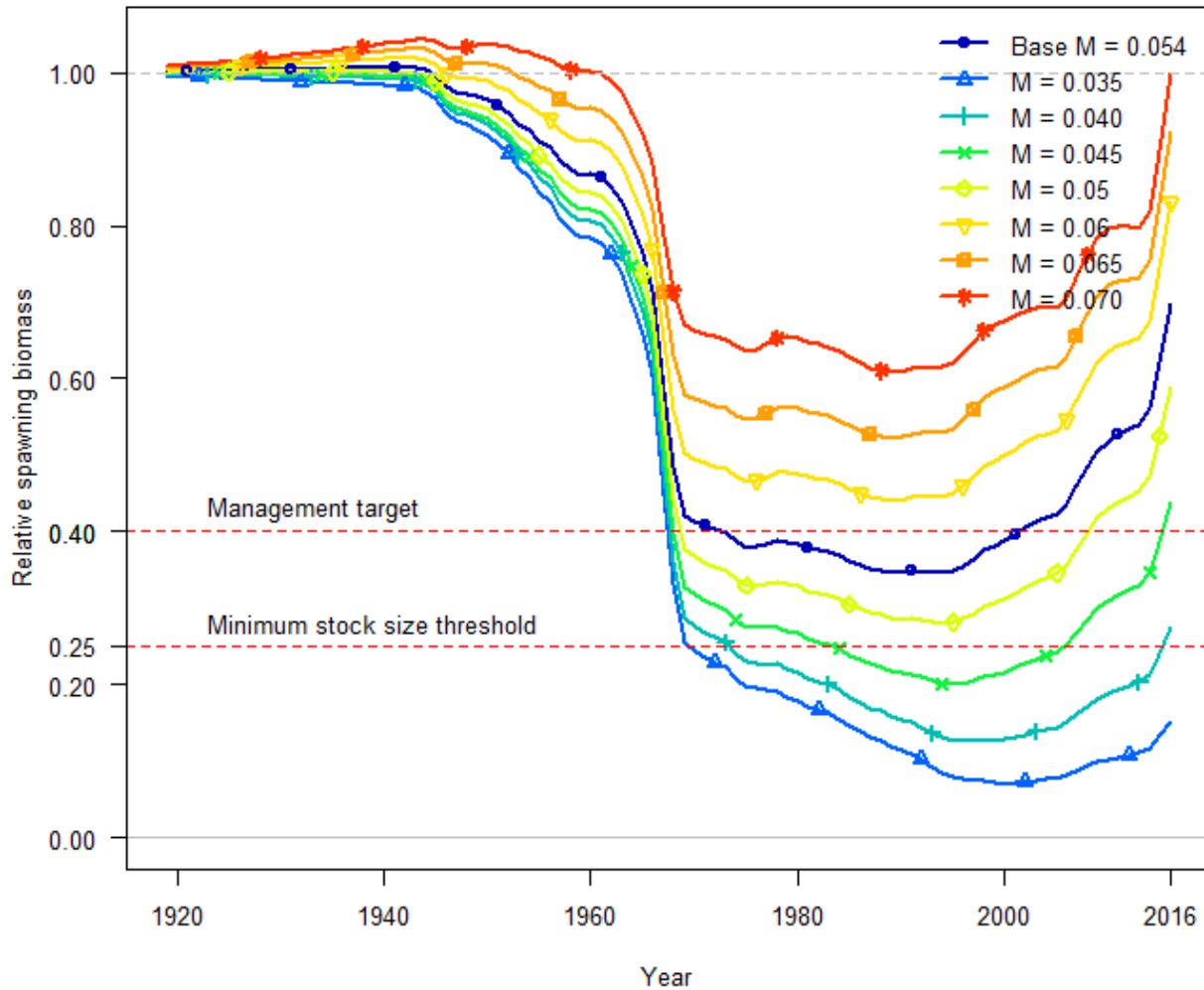


Figure 88: Trajectories of relative biomass across values of natural mortality. | [fig:m_trajectory](#)

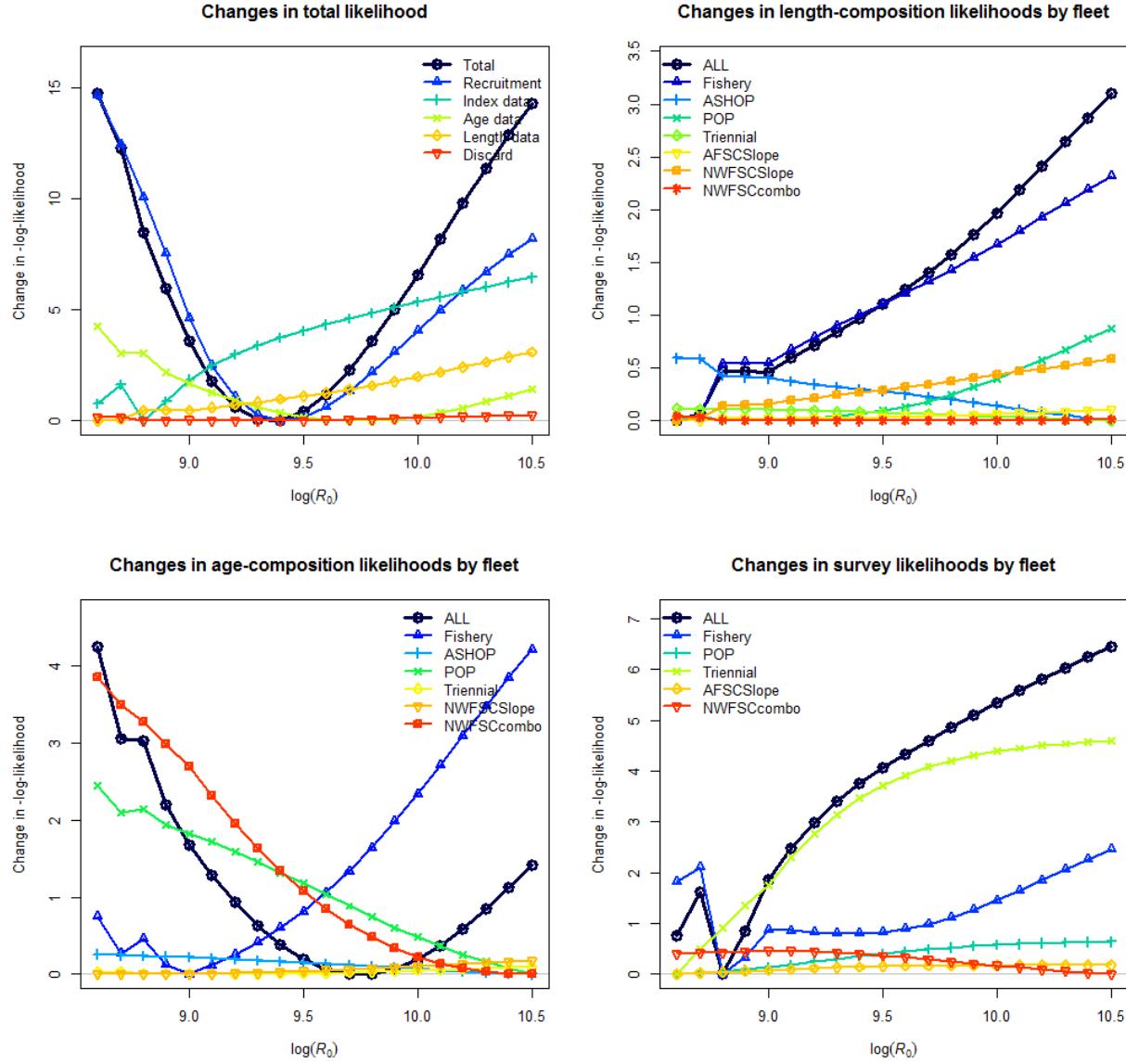


Figure 89: Likelihood profile across R_0 values. [fig:piner_R0](#)

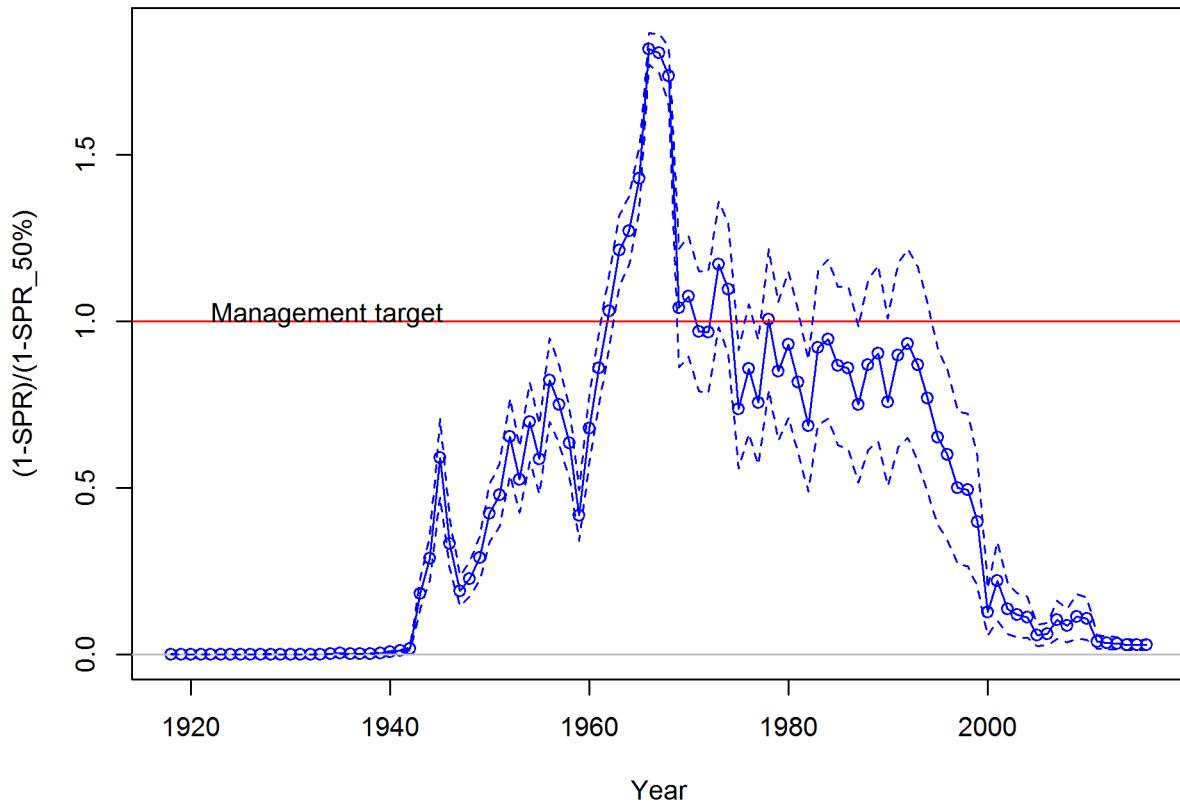


Figure 90: Estimated spawning potential ratio $(1-SPR)/(1-SPR_{50\%})$ for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR_{50%} harvest rate. The last year in the time series is 2016. | fig:SPR

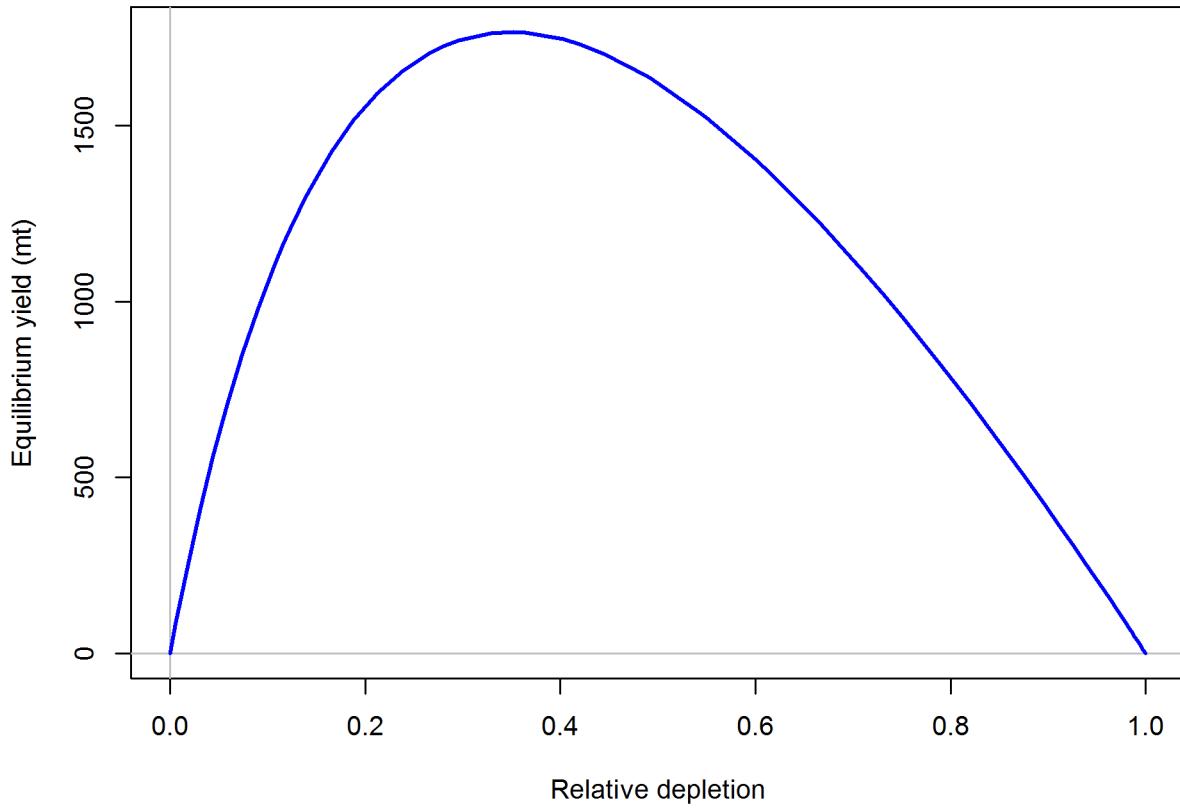


Figure 91: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.50. fig:yield

1237 10 References

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