

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

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⁵ Chantel R. Wetzel¹
⁶ Lee Cronin-Fine²

⁷ ¹Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and
⁸ Atmospheric Administration, National Marine Fisheries Service, 2725 Montlake Boulevard East,
⁹ Seattle, Washington 98112

¹⁰ ³University of Washington, School of Aquatic and Fishery Sciences

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⁸⁹ **Executive Summary**

⁹⁰ **Stock**

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

¹⁰⁰ **Landings**

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

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

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

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

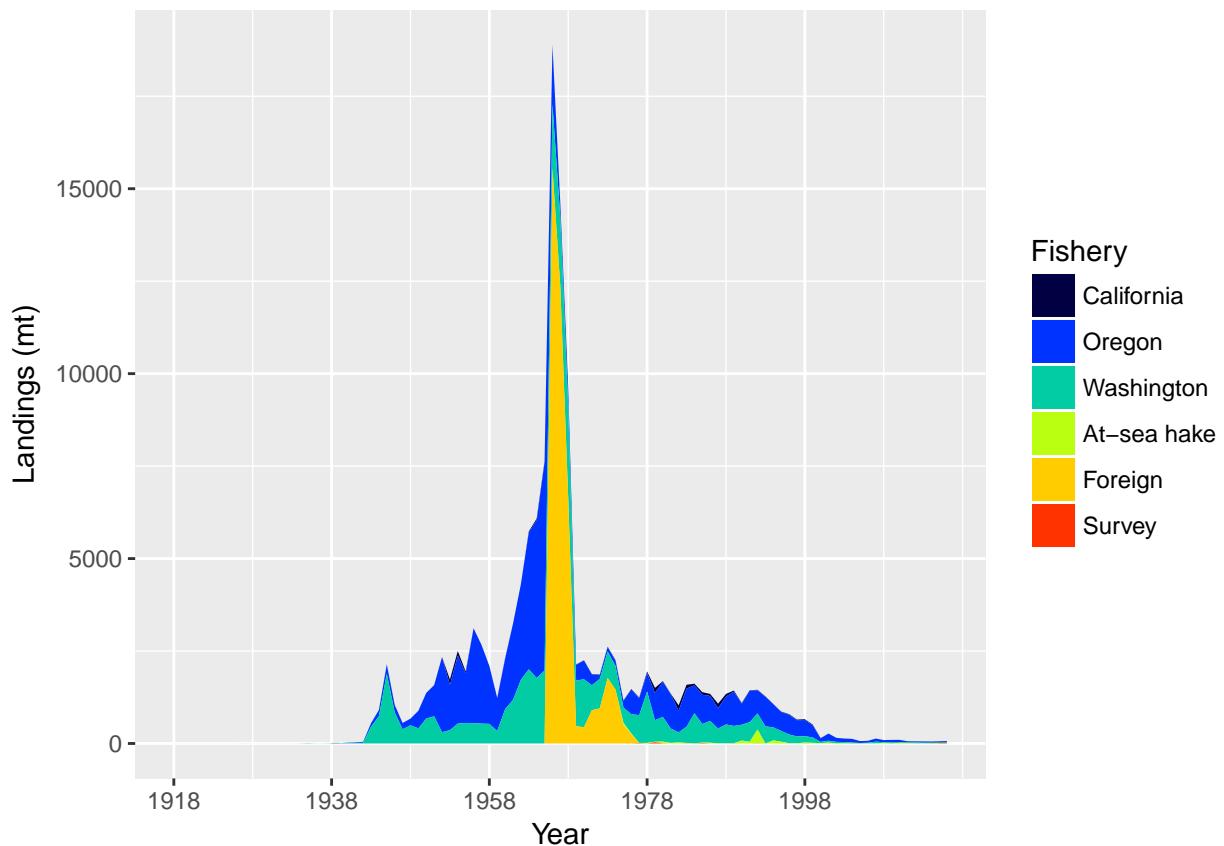


Figure a: Landings of Pacific ocean perch for California, Oregon, Washington, the Foreign fishery (1966-1976), At-sea hake fishery, and fishery-independent surveys.

¹¹⁸ **Data and Assessment**

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

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

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

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

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

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

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

¹⁶⁹ Stock Biomass

¹⁷⁰ The predicted spawning biomass from the base model generally showed a slight decline
¹⁷¹ over the time-series until 1966 when the foreign fleet began. A short, but sharp decline
¹⁷² occurred, followed by a period of the stock biomass stabilizing or with a minimal decline
¹⁷³ until the late 1990s. The stock showed increases in stock size following the year 2000 due to
¹⁷⁴ a combination of strong recruitment and low catches. The 2017 estimated spawning biomass
¹⁷⁵ relative to unfished equilibrium spawning biomass is above the target of 40% of unfished
¹⁷⁶ spawning biomass at 74.9% (~95% asymptotic interval: $\pm 53.2\%-96.7\%$). Approximate
¹⁷⁷ confidence intervals based on the asymptotic variance estimates show that the uncertainty in
¹⁷⁸ the estimated spawning biomass is high.

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

Year	Spawning Output (million eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	3238.00	1381 - 5096	0.49	0.333 - 0.639
2009	3370.00	1442 - 5298	0.51	0.347 - 0.664
2010	3459.00	1483 - 5435	0.52	0.357 - 0.681
2011	3518.00	1511 - 5526	0.53	0.364 - 0.692
2012	3561.00	1534 - 5588	0.53	0.369 - 0.700
2013	3597.00	1556 - 5639	0.54	0.374 - 0.706
2014	3732.00	1627 - 5838	0.56	0.390 - 0.730
2015	4107.00	1814 - 6400	0.62	0.433 - 0.799
2016	4586.00	2047 - 7125	0.69	0.487 - 0.889
2017	4993.00	2244 - 7742	0.75	0.532 - 0.967

Spawning output with ~95% asymptotic intervals

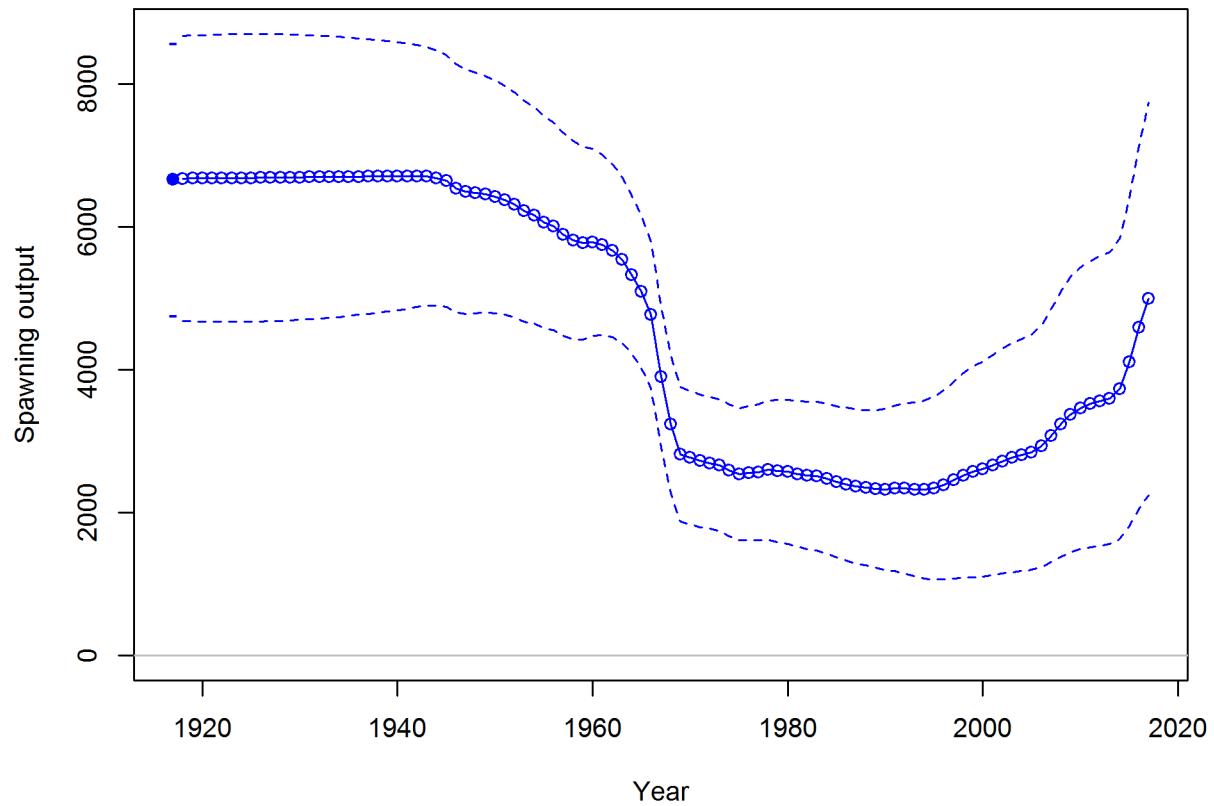


Figure b: Time-series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model.

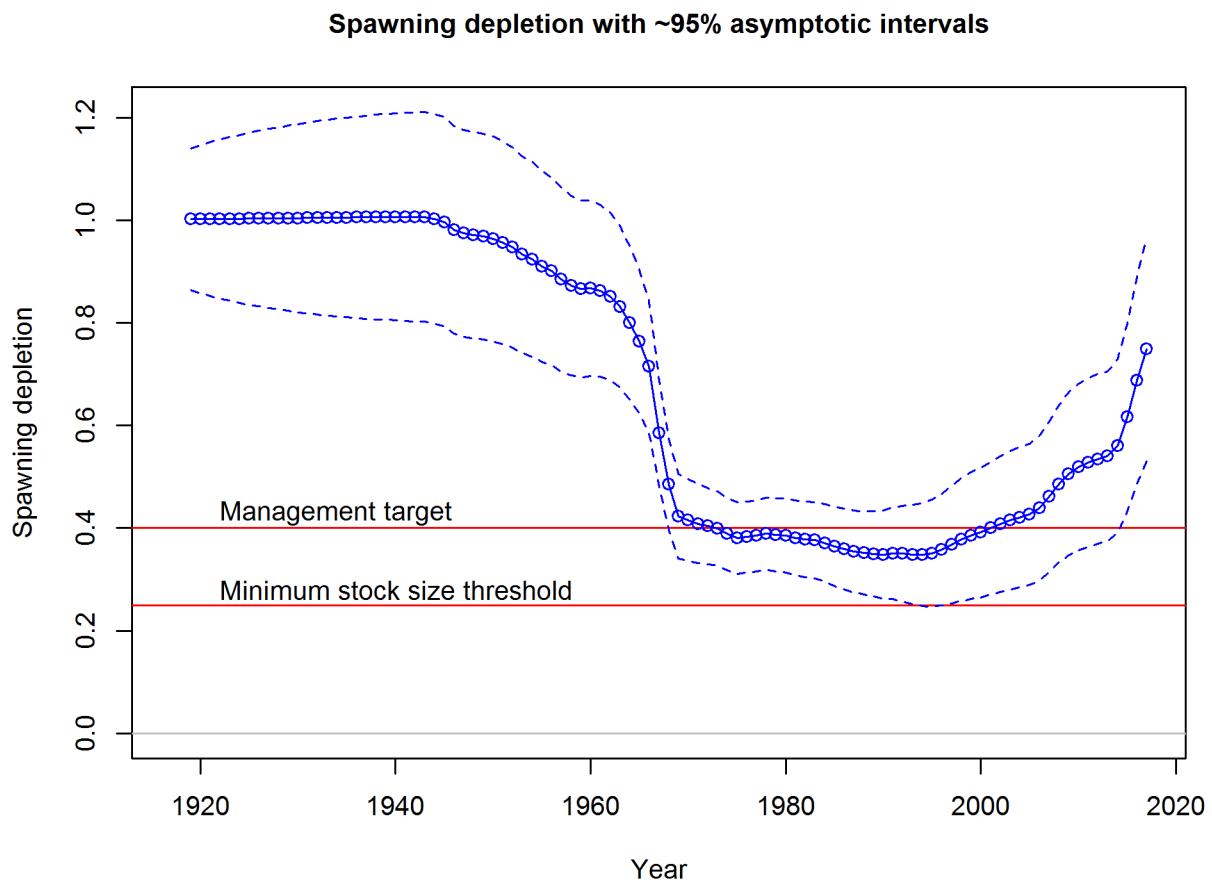


Figure c: Estimated relative spawning biomass (depletion) with approximate 95% asymptotic confidence intervals (dashed lines) for the base assessment model.

¹⁷⁹ **Recruitment**

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

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

Year	Estimated Recruitment	~ 95% confidence interval	Estimated Devs.	~ 95% confidence interval
2008	127759.00	72715 - 224471	2.80	2.494 - 3.100
2009	4660.00	2017 - 10766	-0.53	-1.282 - 0.221
2010	8123.00	3956 - 16682	0.01	-0.572 - 0.602
2011	15970.00	8052 - 31673	0.68	0.145 - 1.224
2012	2255.00	936 - 5432	-1.28	-2.098 - -0.458
2013	34343.00	16175 - 72918	1.36	0.715 - 1.996
2014	5333.00	1813 - 15690	-0.61	-1.701 - 0.489
2015	10094.00	2827 - 36044	-0.00	-1.372 - 1.366
2016	10508.00	2941 - 37542	0.00	-1.372 - 1.372
2017	10795.00	3025 - 38526	0.00	-1.372 - 1.372

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

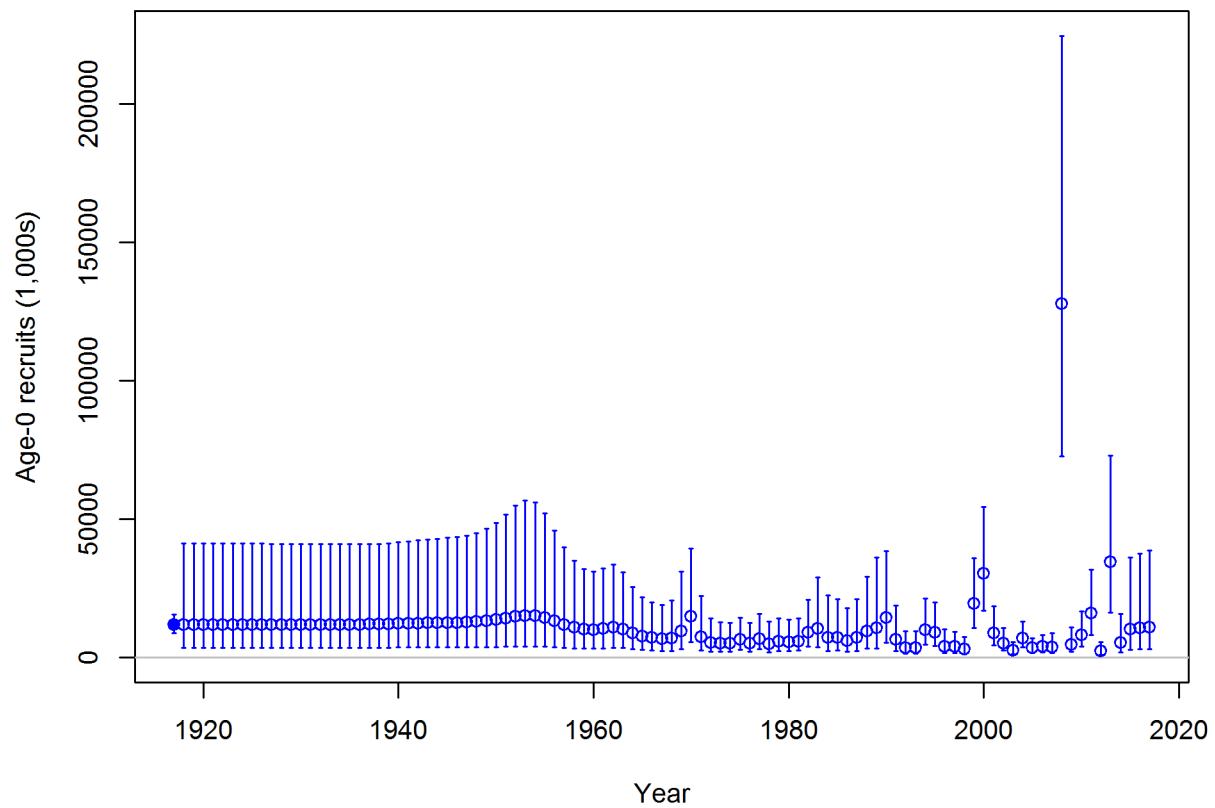


Figure d: Time-series of estimated Pacific ocean perch recruitments for the base model with 95% confidence or credibility intervals.

¹⁸⁷ **Exploitation status**

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

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

Year	$(1-SPR)/(1-SPR_{50\%})$	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.103	0.046 - 0.160	0.002	0.001 - 0.003
2008	0.085	0.036 - 0.134	0.002	0.001 - 0.003
2009	0.113	0.046 - 0.180	0.003	0.001 - 0.004
2010	0.107	0.044 - 0.170	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	0.013 - 0.044	0.001	0.000 - 0.001

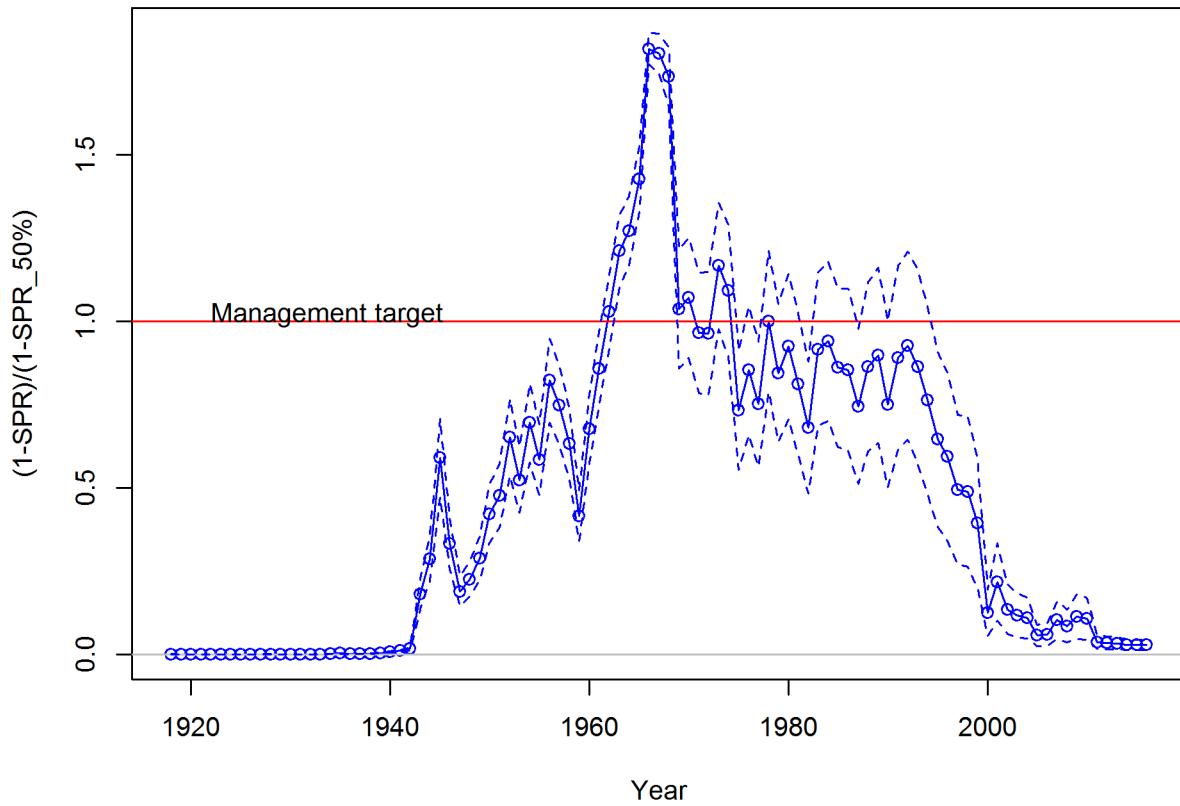


Figure e: Estimated spawning potential ratio $(1-SPR)/(1-SPR_{50\%})$ for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess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

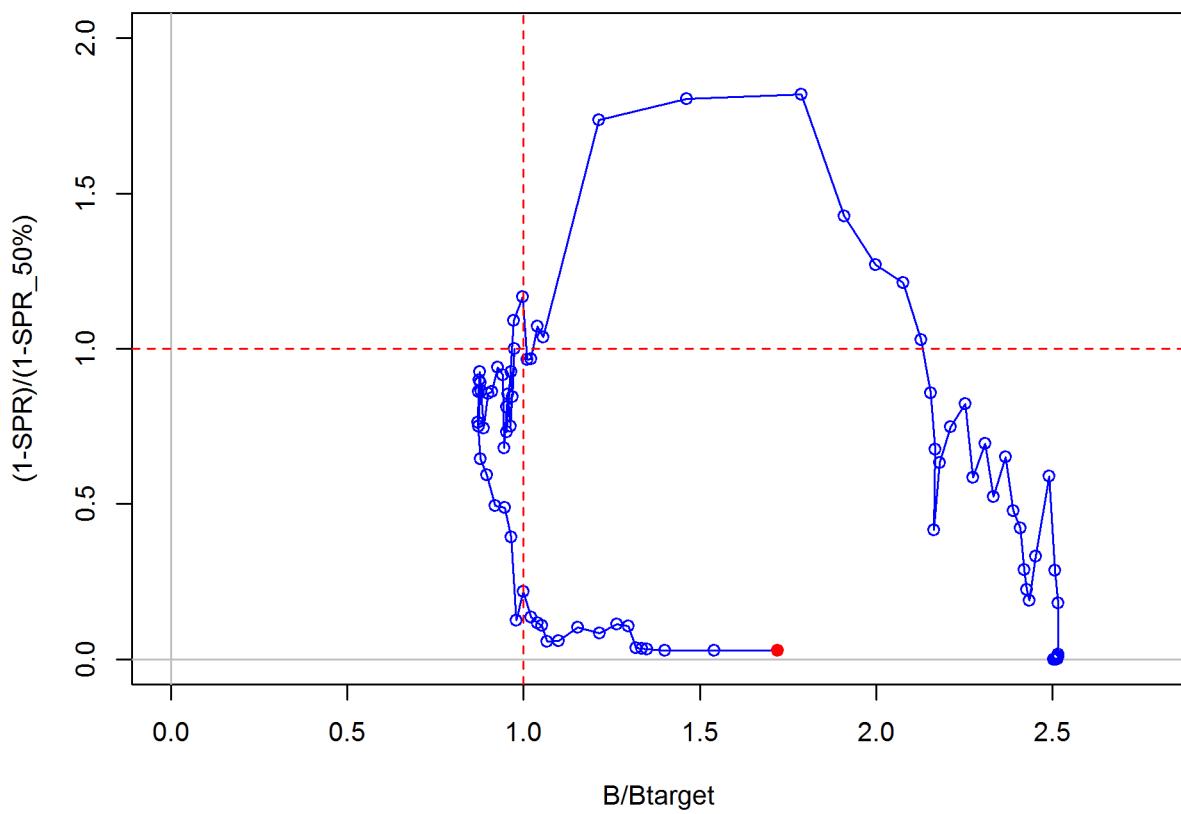


Figure f: Phase plot of estimated relative $(1-SPR)/(1-SPR_{50\%})$ vs. relative spawning biomass for the base case model. Relative biomass is the annual spawning biomass divided by the unfished spawning biomass.

195 **Ecosystem Considerations**

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

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

222 This stock assessment estimates that Pacific ocean perch are above the biomass target. Due
223 to reduced landing and 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 74.9% (~95%
225 asymptotic interval: $\pm 53.2\%-96.7\%$), corresponding to an unfished spawning output of 4993
226 million eggs (~95% asymptotic interval: 2244-7742 million eggs). Unfished age 3+ biomass
227 was estimated to be 140351 mt in the base model. The target spawning output based on the
228 biomass target ($SB_{40\%}$) is 2665.7 million eggs, which gives a catch of 1754 mt. Equilibrium
229 yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 1770.4 mt.

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

Quantity	Estimate	95% Confidence Interval
Unfished spawning output (million eggs)	6664.1	4756.8 - 8571.5
Unfished age 3+ biomass (mt)	140351	100391.1 - 180310.9
Unfished recruitment (R_0 , thousands)	11698.3	8822.7 - 15511.2
Spawning output(2017 million eggs)	4993.2	2244.3 - 7742
Relative biomass (depletion) (2017)	0.749	0.532 - 0.967
Reference points based on SB_{40%}		
Proxy spawning output ($B_{40\%}$)	2665.7	1902.7 - 3428.6
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)	1754	1256 - 2251.9
Reference points based on SPR proxy for MSY		
Spawning output	2221.4	1585.6 - 2857.1
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.034	0.033 - 0.034
Yield with SPR_{proxy} at SB_{SPR} (mt)	1770.4	1268.2 - 2272.5
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	2328.1	1657.7 - 2998.4
SPR_{MSY}	0.512	0.51 - 0.514
Exploitation rate at MSY	0.032	0.032 - 0.033
MSY (mt)	1772.4	1269.5 - 2275.2

230 Management Performance

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

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

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

²³⁷ **Unresolved Problems And Major Uncertainties**

²³⁸ TBD after STAR panel

²³⁹ **Decision Table**

²⁴⁰ TBD after STAR panel

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

Year	OFL	ACL	Spawning Output (million eggs)	Relative Biomass
2017	4245	281	4993	0.749
2018	4491	281	5300	0.795
2019	4656	4454	5551	0.833
2020	4607	4408	5596	0.840
2021	4524	4328	5611	0.842
2022	4418	4228	5579	0.837
2023	4300	4114	5512	0.827
2024	4175	3995	5423	0.814
2025	4053	3878	5322	0.799
2026	3938	3768	5214	0.782
2027	3831	3666	5103	0.766
2028	3732	3571	4990	0.749

Table h: Summary of 10-year projections beginning in 2019 for alternate states of nature based on an axis of uncertainty for the base model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. An entry of “-” indicates that the stock is driven to very low abundance under the particular scenario.

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

²⁴¹ **Research and Data Needs**

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

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

Table i: Base model results summary.

Quantity	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
OFL (mt)	911	1,160	1,173	1,026	1,007	844	838	842	850	964
ACL (mt)	150	189	200	180	183	150	153	158	164	281
Landings (mt)	92	94	97	60	57	55	54	58	65	65
Total Est. Catch (mt)	133	190	181	61	58	57	55	59	65	65
(1-SFR)(1-SFR _{50%})	0.085	0.113	0.107	0.037	0.035	0.033	0.029	0.028	0.028	0.028
Exploitation rate	0.002	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Age 3+ biomass (mt)	74081.1	74772.5	75005.2	87916.0	94368.4	10897.0	107696.0	112680.0	119811.0	124369.0
Spawning Output	3238	3370	3459	3518	3561	3597	3732	4107	4586	4933
95% CI	1381 - 5096	1442 - 5298	1483 - 5435	1511 - 5526	1534 - 5588	1556 - 5639	1627 - 5838	1814 - 6400	2047 - 7125	2244 - 7742
Relative Biomass	0.486	0.506	0.519	0.528	0.534	0.540	0.560	0.616	0.688	0.749
95% CI	0.333 - 0.639	0.347 - 0.664	0.357 - 0.681	0.364 - 0.692	0.369 - 0.700	0.374 - 0.706	0.390 - 0.730	0.433 - 0.79	0.487 - 0.889	0.532 - 0.967
Recruits	127759	4660	8123	15970	2255	34343	5333	10094	10508	10795
95% CI	72715 - 224471	2017 - 10766	3956 - 16682	8052 - 31673	936 - 5432	16175 - 72918	1813 - 15690	2827 - 36044	2941 - 37542	3025 - 38526

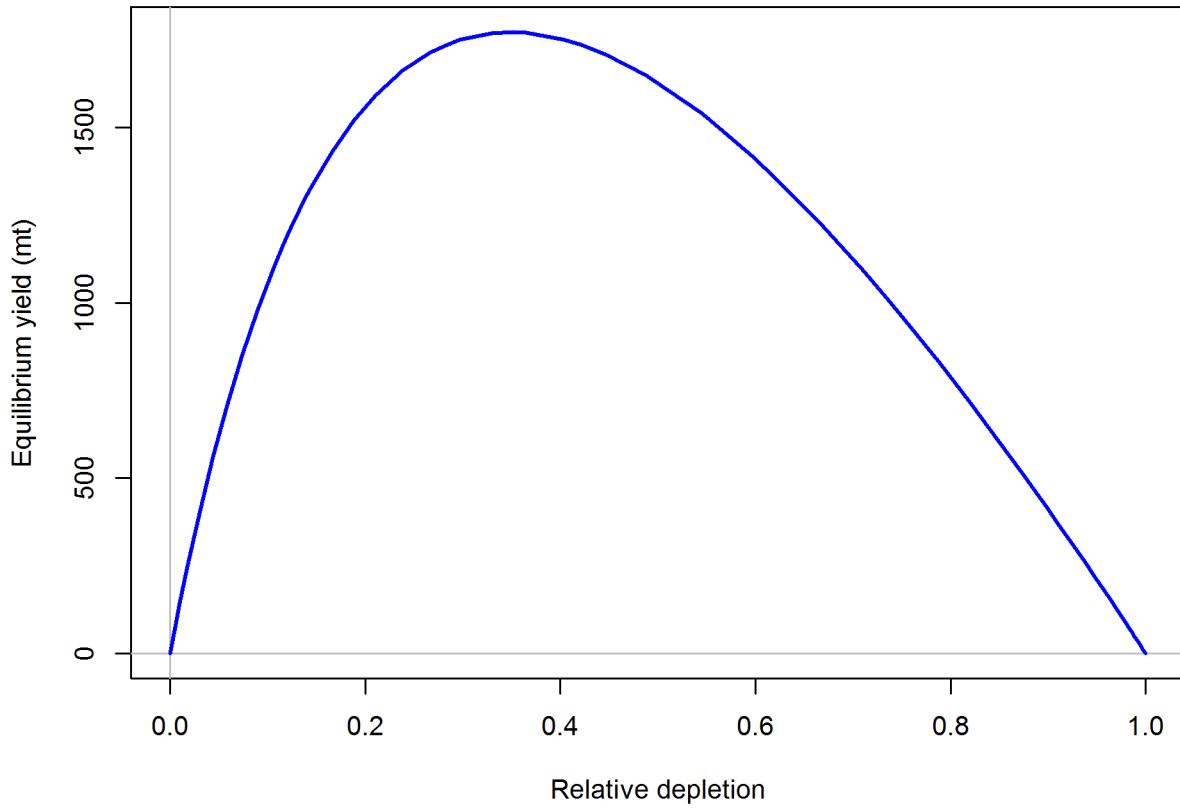


Figure g: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.50.

259 **1 Introduction**

260 **1.1 Basic Information**

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

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

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

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

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

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

327 1.2 Summary of Management History

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

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

³⁴³ 1.3 Fisheries off Canada and Alaska

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

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

³⁵⁶ 2 Data

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

³⁵⁹ 2.1 Fishery-Independent Data:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

⁴⁴² 2.1.4 Triennial Survey

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

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

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

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

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

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

488 2.1.5 Pacific ocean perch Survey

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

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

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

503 2.2 Fishery-Dependent Data

504 2.2.1 Commercial Fishery Landings

505 Washington

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

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

513 **Oregon**

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

523 **California**

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

530 **At-Sea Hake Fishery**

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

542 **Foreign Catches**

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

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

549 **2.2.2 Discards**

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

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

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

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

582 **2.2.4 Fishery Length And Age Data**

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

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

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

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

599 **2.2.5 Length and Age Data not Included in the Base Model**

600 Research length and ages were provided from Washington state. However, the information
601 regarding the nature of the research cruise and collection methods have been lost to time.
602 The data set includes lengths age ages that range from 1967-1972 and 1979. The distribution
603 of lengths across years collected were consistent with primarily only larger Pacific ocean perch,
604 35-40 cm, being selected. All age data were based upon surface reads which unfortunately are
605 highly biased at relatively young ages. Due to the lack of information regarding the collection
606 of these data, they were not selected to be apart of the base model but a sensitivity was
607 conducted which evaluated the impact of these data.

608 Oregon special project data were provided by the state. These data represent samples made
609 at either the dock or at processing plants from fishery landings. Length data was collected
610 primarily from 1970-1986, with limited samples from more recent years. Age data were
611 primarily available from 1981-1984. These data were collected for special projects and may
612 not have been sampled randomly from the fishery landings. Due to these concerns, these
613 data were not included in the base model but were included in a model sensitivity.

614 **2.3 Biological Data**

615 **2.3.1 Natural Mortality**

616 Historic Pacific ocean perch ages determined using scales and surface reading methods of
617 otoliths, resulted in estimates of natural mortality (M) between 0.10 and 0.20yr^{-1} with a
618 longevity less than 30 years (Gunderson 1977). Based on break-and-burn method of age
619 determination using otoliths, the maximum age of Pacific ocean perch was revised to be 90
620 years (Chilton and Beamish 1982). The updated understanding concerning Pacific ocean perch
621 longevity reduced the estimate of natural mortality based on Hoenig's (1983) relationship to
622 0.059yr^{-1} . The previous assessment applied a prior distribution on natural mortality based
623 upon multiple life history correlates (including Hoenig's method, Gunderson gonadosomatic
624 index (1997), and McCoy and Gillooly's (2008) theoretical relationship) developed separately
625 for female and male Pacific ocean perch.

626 Hamel (2015) developed a method for combining meta-analytic approaches relating the M
627 rate to other life-history parameters such as longevity, size, growth rate and reproductive
628 effort, to provide a prior on M . In that same issue of ICESJMS, Then et al. (2015), provided
629 an updated data set of estimates of M and related life history parameters across a large
630 number of fish species, from which to develop an M estimator for fish species in general.
631 They concluded by recommending M estimates be based on maximum age alone, based on
632 an updated Hoenig non-linear least squares (nls) estimator $M = 4.899A_{\max}^{-0.916}$. The approach
633 of basing M priors on maximum age alone was one that was already being used for West
634 Coast rockfish assessments. However, in fitting the alternative model forms relating M to
635 A_{\max} , Then et al. (2015) did not consistently apply their transformation. In particular,
636 in real space, one would expect substantial heteroscedasticity in both the observation and
637 process error associated with the observed relationship of M to A_{\max} . Therefore, it would be
638 reasonable to fit all models under a log transformation. This was not done. Re-evaluating
639 the data used in Then et al. (2015) by fitting the one-parameter A_{\max} model under a log-log
640 transformation (such that the slope is forced to be -1 in the transformed space (Hamel 2015)),
641 the point estimate for M is:

642
$$M = \frac{5.4}{A_{\max}}$$

643 The above is also the median of the prior. The prior is defined as a lognormal with mean
644 $\ln(\frac{5.4}{A_{\max}})$ and SE = 0.438. Using a maximum age of 100 the point estimate and median of the
645 prior is 0.054. The maximum age was selected based on available age data from all West Coast
646 data sources. The oldest aged rockfish was 120 years, captured by the commercial fishery
647 in 2007. However, age data are subject to ageing error which could impact this estimate of
648 longevity. The selection of 100 years was based on the range of other ages available with had
649 multiple observations of fish between 90 and 102 years of age.

650 **2.3.2 Sex Ratio, Maturation, and Fecundity**

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

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

669 **2.3.3 Length-Weight Relationship**

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

674 **2.3.4 Growth (Length-at-Age)**

675 The length-at-age was estimated for male and female Pacific ocean perch using data collected
676 from both fishery-dependent and -independent data sources that were collected from 1981-
677 2016. Figure 30 shows the lengths and ages for all years and all data as well as predicted
678 von Bertalanffy fits to the data. Females grow larger than males and sex specific growth
679 parameters were estimated at the following values:

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

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

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

684 **2.3.5 Ageing Precision And Bias**

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

695 **2.4 History Of Modeling Approaches Used For This Stock**

696 **2.4.1 Previous Assessments**

697 The status of Pacific ocean perch off British Columbia, Washington, and Oregon have been
698 periodically assessed since the intensive exploitation that occurred in the 1960s. Concerns
699 regarding Pacific ocean perch status off the coast the US west coast were raised in the late
700 1970s (Gunderson 1978, 1981) and in 1981 the PFMC adopted a 20-year plan to rebuild the
701 stock.

702 The 1992 assessment determined that Pacific ocean perch remained at low levels relative
703 to the population size in 1960 (Ianelli et al. 1992) and recommended additional harvest
704 restrictions to allow for stock rebuilding. The 1998 assessment (Ianelli and Zimmermann
705 1998) estimated that the stock was 13% of the unfished level, leading the National Marine
706 Fishery Service (NMFS) to declare the stock overfished in 1999. A formal rebuilding plan was
707 implemented in 2001. The rebuilding plan reduced the SPR harvest rate used to determine
708 catches to 0.864 (in contrast to the default harvest rate of 0.50). The last full assessment of
709 Pacific ocean perch was conducted in 2011 (Hamel and Ono 2011) which concluded that the
710 stock was still well below the target biomass of 40% SB_0 estimating the relative stock status
711 at 19.1%.

712 **2.4.2 Previous Assessment Recommendations**

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

⁷¹⁶ *STAT response: The STAT team agrees that this should be an ongoing area of research and*
⁷¹⁷ *collaboration between the US and Canada. This assessment presents a sensitivity where the*
⁷¹⁸ *inclusion of Canadian data are included within the model.*

⁷¹⁹ Recommendation: The benefits of adopting the complex model used this year should be
⁷²⁰ evaluated relative to simpler assumptions and models. While the transition from the simpler
⁷²¹ old model to Stock Synthesis was shown to be similar for the historical period, the depletion
⁷²² estimates in the most recent years were different enough to warrant further investigation.

⁷²³ *STAT response: This assessment was performed in Stock Synthesis, an integrated model,*
⁷²⁴ *which can be modified to either simple or complex structural forms based upon the available*
⁷²⁵ *data and the processes being modeled. There were not addtional explorations of alternative*
⁷²⁶ *modeling platforms.*

⁷²⁷ Recommendation: Discard estimates from observer programs should be presented, reviewed
⁷²⁸ (similar to the catch reconstructions), and be made available to the assessment process.

⁷²⁹ *STAT response: This assessment uses discard rates and discard lengths collected by the*
⁷³⁰ *WCGOP from 2003-2015.*

⁷³¹ Recommendation: The ability to allow different “plus groups” for specific data types should
⁷³² be evaluated (and implemented in Stock Synthesis). For example, this would provide the
⁷³³ ability to use the biased surface-aged data in an appropriate way.

⁷³⁴ *STAT response: The STAT team agrees that this should be explored, but additional research*
⁷³⁵ *needs to completed which evaluates the amount of bias and imprecision in surface-read ages.*
⁷³⁶ *Evaluating available surface-read ages within the PacFIN database fish of lengths between*
⁷³⁷ *23-44 cm can be aged at 10 years old. This large range of lengths at the same age indicates*
⁷³⁸ *considerable bias in ages for fish surface-read younger aged fish.*

⁷³⁹ Recommendation: Historical catch reconstruction estimates should be formally reviewed
⁷⁴⁰ prior to being used in assessments and should be coordinated so that interactions between
⁷⁴¹ stocks are appropriately treated. The relative reliability of the catch estimates over time
⁷⁴² could provide an axis of uncertainty in future assessments.

⁷⁴³ *STAT response: California and Oregon have undergone extensive work to create historical*
⁷⁴⁴ *catch reconstructions. This is the first assessment for Pacific ocean perch which includes a*
⁷⁴⁵ *Washington historical catch reconstruction. The data used in this assessment represent Wash-*
⁷⁴⁶ *ington state's current best estimate for historical catches. Both California and Washington*
⁷⁴⁷ *are conducting research to estimate uncertainty surround historical catches which could be*
⁷⁴⁸ *used to progegate uncertainty within the assessment.*

749 **3 Assessment**

750 **3.1 General Model Specifications and Assumptions**

751 Stock Synthesis version 3.30.03.05 was used to estimate the parameters in the model. R4SS,
752 revision 1.27.0, along with R version 3.3.2 were used to investigate and plot model fits. A
753 summary of the data sources used in the model (details discussed above) is shown in Figure
754 2.

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

757 **3.1.1 Changes Between the 2011 Assessment Model and Current Model**

758 The current model for Pacific ocean perch has many made many similar assumptions to the
759 2011 assessment but differs in some key ways. This assessment disaggregated the fleets into
760 a trawl/other gear, At-sea hake, historical foreign fleet, and research fleets. The previous
761 assessment implemented a single fleet where removal from all sources were aggregated together.
762 The separating of fleets applied in this assessment allowed for differing assumptions regarding
763 current and historical discarding practices. Although there are no compositional data
764 available from the foreign fleet, it is assumed that very little to no discarding of fish occurred.
765 Additionally, the At-sea hake fishery removals represent both discarded and retained fish
766 and hence an additional discard rate would not be appropriate. Similar logic was applied in
767 regard to survey removals.

768 The historical landings used in the model differs from those used in 2011. The assessment
769 includes the first state provided historical reconstruction landings for Washington. The
770 historical reconstruction has removals starting in 1916 and have larger removals in the 1940s
771 relative to those used in 2011 (Figure 32). Given the increase in historical removals prior to
772 1940, the 2011 model starting year, the starting year for modeling the stock was revised to
773 1918, the first year Pacific ocean perch landings exceeded 1 mt. Explorations were conducted
774 relative to the model starting year and no differences were found between the 1918 start
775 year compared to starting the model in 1892, the first record of Pacific ocean perch landings
776 between California, Oregon, and Washington landings data.

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

782 All fishery-independent indices have been re-evaluated for this assessment using a spatial-
783 temporal delta generalized linear mixed model (VAST delta-GLMM) which is updated

784 approach from that used 2011 which did not incorporate spatial effects. An additional update
785 to the treatment of survey data was the decision to use the Triennial survey as a single
786 time-series ranging from 1980-2004. The previous assessment opted to split this survey into
787 an early and a late index of abundance based upon the change in southern sampling and a
788 shift in survey timing. Northern California is considered to be the southern end of Pacific
789 ocean perch West Coast distribution with rare encounters in central or southern California
790 waters. The biological data from the Triennial survey showed no discernible ontogenetic shifts
791 in Pacific ocean perch during the early or late period of summer samples. Based upon these
792 investigations, the Triennial survey was retained as a single index of abundance.

793 Maturity and fecundity were updated for this assessment based upon new research. Fecundity
794 for Pacific ocean perch used in this assessment was base on a re-evaluation of the fecundity
795 of West Coast rockfish by Dick et al. (2017), updating the previous fecundity estimates used
796 in the 2011 assessment (Dick 2009) (Figure 27). Maturity in this assessment was based on
797 examination of 537 fish samples which were used to estimate functional maturity, an approach
798 that classifies rockfish maturity with developing oocytes as mature or immature based on
799 the proportion of vitellogenin in the cytoplasm and the measured frequency of atretic cells
800 (Melissa Head, personal communication, NWFSC, NOAA). The updated maturity curve
801 was based on maturity-at-length where the previous estimates used in 2011 were based on
802 maturity-at-age (Figure 26).

803 In this assessment, the beta prior developed from a meta-analysis of West Coast groundfish
804 was updated to the 2017 value (James Thorson, personal communication, NWFSC, NOAA)
805 in preliminary models, with steepness fixed at an alternative value in the final base model.
806 Additionally, the prior for natural mortality was updated based on analysis conducted by
807 Owen Hamel (personal communication, NWFSC, NOAA), where female and male natural
808 mortality fixed at the prior median.

809 3.1.2 Summary of Fleets and Areas

810 Pacific ocean perch are most frequently observed in Oregon and Washington waters in survey
811 and fishery observations. Multiple fisheries encounter Pacific ocean perch. Bottom trawl,
812 mid-water trawl, fixed gear, and the At-sea (mid-water) hake fisheries account for the majority
813 of the current Pacific ocean perch landings.

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

823 3.1.3 Other Specifications

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

831 Age data were available for the commercial and At-sea hake fishery, as well as the Triennial,
832 the Pacific ocean perch, the NWFSC slope, and the NWFSC shelf-slope surveys. The ages
833 from the NWFSC shelf-slope survey and were entered into the model as conditional age-at-
834 length. The assessment used length-frequencies collected by the fishery fleet, the At-sea hake
835 fishery, the Triennial, Pacific ocean perch, AFSC slope, NWFSC slope, and the NWFSC
836 shelf-slope surveys.

837 The specification of when to estimate recruitment deviations is an assumption that likely
838 affects model uncertainty. It was decided to estimate recruitment deviations from 1900-2014
839 to appropriately quantify uncertainty. The earliest length-composition data occur in 1966
840 and the earliest age data were in 1981. The most informed years for estimating recruitment
841 deviations were from about the mid-1970s to about 2011. The period from 1900-1974 was fit
842 using an early series with little or no bias adjustment, the main period of recruitment deviates
843 occurred from 1975-2014 with an upward and downward ramping of bias adjustment (Figure
844 9), and 2015 onward was fit using forecast recruitment deviates with little bias adjustment.
845 Methot and Taylor (2011) summarize the reasoning behind varying levels of bias adjustment
846 based on the information available to estimate the deviates. The standard deviation of
847 recruitment variability was assumed to be 0.70.

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

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

858 The following distributions were assumed for data fitting. Survey indices were lognormal,
859 total discards were lognormal.

860 **3.1.4 Modeling Software**

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

866 **3.1.5 Priors**

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

872 The prior for steepness (h) assumes a beta distribution with parameters based on an update
873 of the Thorson-Dorn rockfish prior (commonly used in past West Coast rockfish assessments)
874 conducted by James Thorson (personal communication, NWFSC, NOAA) which was reviewed
875 and endorsed by the Science and Statistical Committee in 2017. The prior is a beta distribution
876 with $\mu=0.72$ and $\sigma=0.15$. However, fixing steepness within the model resulted in what was
877 determined to be unrealistic relative biomass levels ($\sim 97\%SB_0$), and it was decided to fix
878 steepness at 0.50. The previous assessment estimated and fixed steepness equal to 0.40. The
879 current data does not contain information regarding steepness and 0.50 was selected as an
880 intermediate value between the prior and the previous assessment value. The steepness value
881 of 0.50 was contained within the estimated uncertainty envelope from the assessment model
882 when either the prior value of 0.72 or 0.40 values were assumed.

883 **3.1.6 Data Weighting**

884 The base model was weighted such that the various data sources were mostly consistent with
885 each other in terms of the relationship between input and effective sample sizes. Length and
886 age-at-length compositions from the NWFSC shelf-slope survey were fit along with length
887 and marginal age compositions from the fishery and other survey fleets. Length data started
888 with a sample size determined from the equation listed in Sections 2.1.1 (survey data) and
889 2.2.4 (fishery data). Age-at-length data assumed that each age was a random sample within
890 the length bin and started with a sample size equal to the number of fish in that length
891 bin. However, the 2016 NWFSC shelf-slope age-at-length data was variable compared to
892 previous years for both males and females with observed fish being generally larger at age.
893 Model exploration determined that the model was more sensitive than would be reasonably
894 expected to the inclusion of this data year. Due to the increased variability within this data

895 year and the model's sensitivity, the effective sample size for this year was reduced to 50% of
896 the number of fish within each length-age bin.

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

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

908 3.1.7 Estimated And Fixed Parameters

909 There were 164 estimated parameters in the base model. These included one parameter for
910 R_0 , 8 parameters for growth, 2 parameters for extra variability on the Triennial and NWFSC
911 shelf-slope survey indices, 24 parameters for selectivity, retention, and time blocking of the
912 fleets and the surveys, 117 recruitment deviations, and 12 forecast recruitment deviations
913 (Table 23).

914 Fixed parameters in the model were as follows. Steepness was fixed at 0.50. A sensitivity
915 analysis and a likelihood profile were done for steepness. Natural mortality was fixed at
916 0.054 for females and males, which is the median of the prior. The standard deviation of
917 recruitment deviates was fixed at 0.70. Maturity-at-length was fixed as described in Section
918 2.3.2. Length-weight parameters were fixed at estimates using all length-weight observations
919 (Figure 29).

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

925 3.2 Model Selection and Evaluation

926 The base assessment model for Pacific ocean perch was developed to balance parsimony and
927 realism, and the goal was to estimate a biomass trajectory for the population of Pacific

928 ocean perch off the west coast of the US. The model contains many assumptions to achieve
929 parsimony and uses many different sources of data to estimate reality. A series of investigative
930 model runs were done to achieve the final base model.

931 **3.2.1 Key Assumptions and Structural Choices**

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

938 Structurally, the model assumed that the landings from each fleet were representative of
939 the coastwide population, instead of specific areas, and fishing mortality prior to 1918 was
940 negligible. It also assumed that discards were low prior to 1992.

941 **3.2.2 Alternate Models Considered**

942 The exploration of models began by bridging from the 2011 assessment to Stock Synthesis
943 version 3.30.03.05, which produced no discernible difference. The updated landings data and
944 discard rates added to the 2011 assessment produced insignificant differences in the relative
945 scale of the population although the updated historical removals resulted in an increase in
946 the estimate of unfished biomass. Updating the survey indices produced small differences in
947 the relative scale of the population. Adding age and length data each resulted in less of a
948 population decline from the 1970s to pre-2000, resulting in an increase in the estimated 2017
949 final stock status. However, the addition of new data resulted in an early pattern within
950 recruitment, indicating that the assumptions within the previous model may not represent
951 the best fit to the current data.

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

958 Natural mortality was also investigated and a new prior was developed assuming a maximum
959 age of 100 years for females and males. The previous assessment estimated male natural
960 mortality as an offset from female natural mortality with the final values being estimated
961 and then fixed within the 2011 assessment. This assessment attempted to estimate natural
962 mortality for both sexes using the 2017 updated prior, but there was little to no information

963 on natural mortality within the data and hence opted to fix the value for females within the
964 base model. Upon additional exploration, the model estimated very little difference in male
965 natural mortality relative to females (< 0.002) and in the interest of selecting the model that
966 fit the data with the fewest parameters required, males were fixed equal to the female natural
967 mortality in the base model.

968 Finally, multiple models were investigated where steepness was either estimated, fixed at the
969 prior, or at an alternate value. The assessment in 2011 determined that there was sufficient
970 information concerning steepness where the parameter was estimated and then fixed at the
971 estimated value of 0.40. Based upon likelihood profiles performed on the current model, there
972 was no longer support for a steepness value of 0.40. The likelihood profile was flat across
973 various levels of steepness with a very small improvement in likelihood (<0.50 log likelihood
974 units) at the lowest steepness values. Estimating steepness starting at the median of the
975 “type C” prior, the meta-analysis prior evaluated omitting information from Pacific ocean
976 perch, of 0.76 resulted in very little if any movement from the median value due to the flat
977 likelihood surface across values for this parameter with the final relative stock status for 2017
978 being estimated to > 100% of unfished biomass. Fixing steepness at the median of the prior
979 of 0.72 resulted in relative stock status estimates for 2017 at 98.6% of unfished biomass. It
980 was determined that the resulting stock status estimates when steepness was fixed at the
981 meta-analysis prior were overly optimistic and unrealistic given the biology and historical
982 exploitation of Pacific ocean perch.

983 3.2.3 Convergence

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

992 3.3 Response To The Current STAR Panel Requests

993 TBD after the STAR panel.

994 3.4 Base Model Results

995 The base model parameter estimates along with approximate asymptotic standard errors
996 are shown in Table 23 and the likelihood components are shown in Table 24. Estimates of

⁹⁹⁷ derived reference points and approximate 95% asymptotic confidence intervals are shown in
⁹⁹⁸ Table 25. Time-series of estimated stock size over time are shown in Table 26.

⁹⁹⁹ 3.4.1 Parameter Estimates

¹⁰⁰⁰ The estimates of maximum length and the von Bertanlaffy growth coefficient, k , were less
¹⁰⁰¹ than the external estimates for males and females (Figure 30), but were well within the
¹⁰⁰² 95% confidence interval given the estimated uncertainty (Table 23 and Figure 34). Female
¹⁰⁰³ and male Pacific ocean perch grow quickly at younger ages, reaching near maximum length
¹⁰⁰⁴ by age 20, with female Pacific ocean perch reaching larger maximum lengths.

¹⁰⁰⁵ Selectivity curves were estimated for the fishery and survey fleets. The estimated selectivity
¹⁰⁰⁶ for all fleets within the model are shown in Figure 35. The fishery selectivity was estimated
¹⁰⁰⁷ dome shaped, reaching maximum selectivity for fish between 35 and 40 cm. The At-sea hake
¹⁰⁰⁸ fishery was estimated to have little selectivity for smaller Pacific ocean perch reaching full
¹⁰⁰⁹ selectivity at the largest sizes. The foreign fleet for which only catch data are available was
¹⁰¹⁰ assumed to be identical to the main fishery, although a sensitivity was performed (not shown)
¹⁰¹¹ that mirrored the foreign selectivity to that of the Pacific ocean perch survey selectivity
¹⁰¹² resulting in a negligible difference in stock status. Survey selectivities, excluding the Triennial
¹⁰¹³ survey, were estimated asymptotic during model explorations with the final selectivity fixed
¹⁰¹⁴ asymptotic in the final base model. The Triennial survey selectivity peaked at lengths between
¹⁰¹⁵ 25 and 30 cm and declined before reaching a constant selectivity for larger Pacific ocean
¹⁰¹⁶ perch.

¹⁰¹⁷ Retention curves were estimated for the fishery fleet only and were allowed to vary based
¹⁰¹⁸ upon discard data within the model over time (Figure 36). Historical retention was estimated
¹⁰¹⁹ high and declined over time due to management restriction on landings of Pacific ocean perch
¹⁰²⁰ with the lowest retention occurring in 2009 and 2010 prior to the implementation of ITQs.
¹⁰²¹ Post-2011 retention was estimated to be nearly 100% for the fishery fleet.

¹⁰²² Additional survey variability (process error added directly to each year's input variability)
¹⁰²³ for the Triennial and the NWFSC shelf-slope surveys were estimated within the model. The
¹⁰²⁴ estimated added variance for the Triennial survey was high at 0.39. The model estimated
¹⁰²⁵ a small added variance for the NWFSC shelf-slope survey of 0.027. Preliminary models
¹⁰²⁶ explored estimating added variance for each of the other indices, but resulted in no added
¹⁰²⁷ variance being estimated and hence were not estimated in the base model.

¹⁰²⁸ Estimates of recruitment suggest that the Pacific ocean perch population is characterized
¹⁰²⁹ by variable recruitment with occasional strong recruitments and periods of low recruitment
¹⁰³⁰ (Figures 37 and 38). There is little information regarding recruitment prior to 1970 and the
¹⁰³¹ uncertainty in those estimates is expressed in the model. The four lowest recruitments (in
¹⁰³² ascending order) occurred in 2012, 2003, 1998, and 2005. There are very large, but uncertain,
¹⁰³³ estimates of recruitment in 2008, 2013, 2000, and 1999. The 2008 recruitment event is

1034 estimated to be larger by an order of magnitude than any other recruitment estimated in
1035 the model. The uncertainty interval in number of recruits is large based on the uncertainty
1036 surrounding the spawning output in that year. However, the log recruitment deviation
1037 estimated uncertainty is low.

1038 3.4.2 Fits to the Data

1039 There are numerous types of data for which the fits are discussed: fishery CPUE index, survey
1040 abundance indices, discard data (biomass and length compositions), length composition data
1041 for the fisheries and surveys, marginal age compositions for the fisheries and surveys, and
1042 conditional age-at-length observations for the NWFSC shelf-slope survey

1043 The fits the fishery CPUE and five survey indices are shown in Figure 39. Extra standard
1044 error was estimated for the Triennial and NWFSC shelf-slope surveys. The fishery CPUE
1045 and Pacific ocean perch survey index were fit well by the model. The first two years of the
1046 Triennial survey index, 1980 and 1983, were much higher than the later years and were poorly
1047 fit by the model. Both the AFSC and NWFSC slope survey indices were generally flat and fit
1048 well by the model. The recent NWFSC shelf-slope survey showed a variable trend over the
1049 time period with the 2016 data point being the highest estimate of the series and given the
1050 uncertainty around each data point (input and model estimated added variance) the model
1051 fit the model fit fell within the uncertainty interval for all years.

1052 Fits to the total observed discard amounts required time blocks (Figure 40). Fits to the
1053 trawl discards from the Pikitch data in 1985-1987 were quite good. Discard rate change
1054 modeled over the 1992-2001 was based on management restrictions which were assumed to
1055 have increased discarding practices in the fishery fleet. The next required time block was
1056 based on the WCGOP data from 2002-2007 and were fit well by the model. Discarding
1057 increased prior to the implementation to ITQs requiring blocks for 2008 and the 2009-2010
1058 periods. The model fit the very low post-ITQ discard rates based on the WCGOP data well.
1059 The total estimated discard amount over time is shown in Figure 41.

1060 Fits to the length data are shown based on the proportions of lengths observed by year and
1061 the Pearson residuals-at-length for all fleets. Detailed fits to the length data by year and
1062 fleet are provided in Appendix 10. Aggregate fits by fleet are shown in Figure 42. There
1063 are a few things that stand out when examining the aggregated length composition data.
1064 First, the sexed discard lengths appear to be poorly fit by the model but this is related to
1065 small sample sizes. The NWFS slope survey lengths were under estimated by the model, but
1066 these data are over only two years. Finally, both the Triennial and the NWFSC shelf-slope
1067 surveys select both young and old fish in contrast to the other data sources where typically
1068 only larger fish were observed.

1069 Discard lengths from the Pikitch data (1986) and the WCGOP were fit well by the model
1070 and show no obvious pattern in the residuals (Figure 43). The residuals to the fishery lengths

1071 clearly showed the growth differential between males and females where the majority of
1072 residuals at larger sizes were from female fish (Figure 44). The fishery showed large positive
1073 residuals for smaller fish for 2013-2016 which are attributed to the strong 2008 year class
1074 moving through the fishery. The At-sea hake fishery did not show an obvious pattern in
1075 residuals but clearly showed the selectivity of larger fish (Figure 45). The residuals for each
1076 of the surveys are shown in Figures 46, 47, 48, 49, and 50. The Pearson residuals from
1077 the NWFSC shelf-slope survey clearly showed the strong year classes moving through the
1078 population.

1079 The model was weighted according to the Francis weights which adjust the weight given to a
1080 data set based on the fit to the mean lengths by year. The mean lengths from the fishery
1081 were consistent across the sampled period, showing only a decline in the mean length in
1082 2013-2015 likely due to the large 2008 cohort (Figure 51). The At-sea hake fishery showed
1083 an increase in the mean length of fish observed to 2009 and then fluctuated at larger mean
1084 lengths thereafter (Figure 52). The mean lengths were consistent across the two sample years
1085 of the Pacific ocean perch survey (Figure 53). However, the model expected a decline in
1086 mean length over the period. The Triennial survey had a decreasing and then increasing
1087 trend in the mean lengths over the sample period (Figure 54). The trend in the mean lengths
1088 observed by the AFSC slope survey was generally flat excluding the samples from 1997 which
1089 were smaller fish (Figure 55). The NWFSC slope length data from 2001 and 2002 were highly
1090 variable with differing mean lengths between the years which were not fit well by the model
1091 (Figure 56). The mean length for the NWFSC shelf-slope survey declined in 2012 and 2016
1092 due to a large observation of young small fish by the survey (Figure 57).

1093 Age data were fitted to as marginal age compositions for the main fishery fleet, the At-sea
1094 hake fleet, the Pacific ocean perch survey, the Triennial survey, and the NWFSC slope survey.
1095 The NWFSC shelf-slope ages were treated as conditional age-at-length data in order to
1096 facilitate the estimation of growth within the model. The aggregated fits to the marginal age
1097 data are shown in Figure 58. The aggregated age data was fit well for the fishery fleet which
1098 had the largest sample of ages. The At-sea hake fleet and the surveys had significantly lower
1099 sample sizes which resulted in spiky patterns in the aggregated data. However, the model
1100 generally captured the trend of the data. Detailed fits to the age data by year and fleet are
1101 provided in Appendix 11.

1102 The Pearson residuals for the main fishery fleet are show in Figure 59. There are diagonal
1103 patterns in the residuals across years which likely are cohorts moving through the fishery.
1104 The At-sea hake fishery only had age data for four non-consecutive years, combined with
1105 the tendency of this fleet to select older fish, prevented general conclusions regarding fits
1106 to the data over time and cohort strength over time (Figure 60). The Pacific ocean perch
1107 survey only had one year of age data (the 1979 were all surface reads) but both sexes had a
1108 larger observed number of older fish relative to the model estimate (Figure 61). The Triennial
1109 age data which ranged from 1989-2004 did not show a clear pattern in residuals (Figure 62).
1110 However, the final year of the survey, 2004, did have an increase in positive residuals for
1111 female fish compared to earlier years. The Pearson residuals for the two years of age data
1112 from NWFSC slope survey are shown in Figure 63. The residual pattern differs between the

1113 years and by sex with positive residuals of male fish across ages in the 2001 data.

1114 The observed and expected conditional age-at-length fits are shown in Figures 64, 65, 66,
1115 67, and 68 for the NWFSC shelf-slope survey observations. The fits generally match the
1116 observations. Some outliers are apparent with large residuals. The 2016 data varies from
1117 previous years where larger fish across all ages have higher observations compared to the
1118 model expectation.

1119 The age data were also weighted according to Francis weighting which adjust the weight
1120 given to a data set based on the fit to the mean age by year. The mean ages from the fishery
1121 appear to have declined in recent years which could be due to incoming cohorts (Figure 69).
1122 The At-sea hake fishery mean age are similar for 2006 and 2007 but both 2003 and 2014 have
1123 lower average age in the samples (Figure 70). The mean age for the Triennial survey varied
1124 across the sampling period but the distribution of sampled ages were highly variable across
1125 the years (Figure 71). The NWFSC slope had a decline in the mean age between the two
1126 data years (Figure 72). The mean age for the NWFSC shelf-slope survey generally showed a
1127 declining trend over the time-series excluding 2012 and 2016 which sampled older fish relative
1128 to the surrounding years (Figure 73).

1129 3.4.3 Population Trajectory

1130 The predicted spawning output (in millions of eggs) is given in Table 26 and plotted in Figure
1131 74. The predicted spawning output from the base model generally showed a slight decline
1132 over the time-series until when the foreign fleet began. A short, but sharp decline occurred
1133 during the period of the foreign fishery in the late 1960s. The stock continued to decline
1134 minimally until 2000 when a combination of strong recruitment and low catches resulted in
1135 an increase in biomass at the end of the time-series. The recent increase is even faster for
1136 total biomass (Figure 75) because not all fish from the 2008 recruitment are mature (Figure
1137 26). The 2017 spawning biomass relative to unfished equilibrium spawning biomass is above
1138 the target of 40% of unfished spawning biomass (74.9%), with a low of 34.8% in 1994 (Figure
1139 76). Approximate confidence intervals based on the asymptotic variance estimates show that
1140 the uncertainty in the estimated spawning biomass is high, especially in the early years. The
1141 standard deviation of the log of the spawning biomass in 2017 is 0.28.

1142 Recruitment deviations were estimated for the entire time-series that was modeled (Figure
1143 37 and discussed in Section 3.4.1) and provide a more realistic portrayal of uncertainty.
1144 Recruitment predictions from the mid-1970s and early 1980s were mostly below average,
1145 with the 1999, 2000, 2008, and 2013 cohorts being the strongest over the modeled period.
1146 Many other stock assessments of rockfish along the west coast of the US have estimated a
1147 large recruitment event in 1999 (e.g., greenstriped rockfish (Hicks et al. 2009), chilipepper
1148 rockfish (Field 2007), darkblotched rockfish (Gertseva et al. 2015)). The 2008 year classes
1149 was estimated as the strongest year class measured to date for Pacific ocean perch. This
1150 year has been estimated to have very strong year classes for other West Coast stocks (e.g.

1151 darkblotched rockfish (Gertseva et al. 2015), widow rockfish (Hicks and Wetzel 2015)). It
1152 may be worthwhile to investigate the periods of strong and weak year classes further to see if
1153 it is an artifact of the data, a consistent autocorrelation, or a result of the environment.

1154 The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 77 with
1155 estimated recruitments also shown. The stock is predicted to have never fallen to low enough
1156 levels that the steepness is obvious. However, the lowest levels of predicted spawning biomass
1157 showed some of the smallest recruitments and very few above average recruitments. Steepness
1158 was not estimated in this model, but sensitivities to alternative values of steepness are
1159 discussed below.

1160 3.4.4 Uncertainty and Sensitivity Analyses

1161 A number of sensitivity analyses were conducted, including:

- 1162 1. Data weighting according to the harmonic mean.
- 1163 2. Fixed steepness at the prior value of 0.72.
- 1164 3. Estimate natural mortality for female and male Pacific ocean perch.
- 1165 4. Maturity relationship used in the previous assessment.
- 1166 5. Fecundity relationship used in the previous assessment.
- 1167 6. Split the Triennial survey into two time-series, early (1980-1992) and late (1995-2004).
- 1168 7. Remove the historical commercial CPUE index.
- 1169 8. Inclusion of available Canadian fishery and survey data (does not constitute all data
1170 used in Canadian assessments). This sensitivity includes Canadian fishery landings
1171 (1997-2016 with landings ranging from 260-400 mt by year) and survey removals (2004,
1172 2006, 2008, 2010, 2012, 2014, 2016), no fishery or survey index of abundance, but with
1173 length and age composition from both the fishery and survey.
- 1174 9. Inclusion of historical Washington research lengths.
- 1175 10. Inclusion of Oregon special projects length and age data which are sampled at the
1176 dockside or processing facilities.

1177 Likelihood values and estimates of key parameters from each sensitivity are available in
1178 Tables 27 and 28. Plots of the estimated time-series of spawning output and relative biomass
1179 are shown in Figures 78, 79, 80, and 81.

1180 The sensitivities which explored steepness or natural mortality had the largest change in
1181 estimated stock status relative to the base model. Fixing steepness at the prior value resulted
1182 in the stock being near unfished spawning biomass output. When natural mortality was
1183 estimated the estimated values were higher relative to the median of the prior used in base
1184 model, resulting in the relative biomass to be 93%.

1185 Including additional data from either Canada, Washington research lengths, and or Oregon
1186 special projects data resulted in estimated lower stock status relative to the base model.
1187 However, the status was still well above the management target.

1188 Weighting the data according to the harmonic means resulted in the largest decrease in the
1189 estimated stock status relative to the base model with the stock being estimated at 68% of
1190 unfished biomass.

1191 The sensitivities that explored the removal of the CPUE index, the 2011 maturity, or fecundity
1192 relationship had little impact relative to the base model results.

1193 3.4.5 Retrospective Analysis

1194 A 5-year retrospective analysis was conducted by running the model using data only through
1195 2011, 2012, 2013, 2014, and 2015, progressively (Figure 82 and 83). The initial scale of the
1196 spawning population was basically unchanged for all of these retrospectives. The estimation
1197 of the 2008 recruitment deviation decreased as more data was removed. Overall, no alarming
1198 trends were present in the retrospective analysis.

1199 3.4.6 Likelihood Profiles

1200 Likelihood profiles were conducted for R_0 , steepness, and over natural mortality values
1201 separately. These likelihood profiles were conducted by fixing the parameter at specific values
1202 and estimated the remaining parameters based on the fixed parameter value.

1203 For steepness, the negative log-likelihood was essentially flat between values of 0.30 - 0.80
1204 (Figure 84). Likelihood components by data source show that the fishery length and age data
1205 supports a low steepness value, but the NWFSC shelf-slope age data supports a higher value
1206 for steepness. The Triennial survey index indicates a low value of steepness while the other
1207 surveys do not provide information concerning steepness. The relative biomass for Pacific
1208 ocean perch has a wide range across different assumed values of steepness (Figure 85).

1209 The negative log-likelihood was minimized at a natural mortality value of 0.06, but the 95%
1210 confidence interval extends over the majority of natural mortality values. The age and length
1211 data likelihood contribution was minimized at natural morality values ranging from 0.055-0.06

1212 (Figure 86). The relative biomass for Pacific ocean perch widely varied across alternative
1213 values of natural mortality (Figure 87).

1214 In regards to values of R_0 , the negative log-likelihood was minimized at approximately $\log(R_0)$
1215 of 9.30 (Figure 88). The fishery and survey composition data was in opposition regarding
1216 values of R_0 where the fishery length and age data indicated lower values of R_0 while the
1217 survey ages from the Pacific ocean perch and the NWFSC shelf-slope surveys indicated a
1218 higher value.

1219 3.4.7 Reference Points

1220 Reference points were calculated using the estimated selectivities and catch distribution
1221 among fleets in the most recent year of the model (2016). Sustainable total yields (landings
1222 plus discards) were 1770.4 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95%
1223 confidence interval of 1268.2 - 2272.5 mt based on estimates of uncertainty. The spawning
1224 output equivalent to 40% of the unfished spawning output ($SB_{40\%}$) was 2665.7 millions of
1225 eggs. The recent catches (landings plus discards) have been below the point estimate of
1226 potential long-term yields calculated using an $SPR_{50\%}$ reference point and the population
1227 has been increasing over the last 15 years.

1228 The predicted spawning biomass from the base model generally showed a sharp decline during
1229 the 1960s, steep increase above unfished equilibrium levels, followed by less of a decline
1230 until 2001 (Figure 74). Since 2001, the spawning biomass has been increasing due to small
1231 catches, and recently, above average recruitment. The 2017 spawning biomass relative to
1232 unfished equilibrium spawning biomass is above the target of 40% of unfished spawning
1233 biomass (Figure 76). The fishing intensity, $(1 - SPR)/(1 - SPR_{50\%})$, exceeded the current
1234 estimates of the harvest rate limit ($SPR_{50\%}$) throughout the 1960s as seen in Figure 89.
1235 Recent exploitation rates on Pacific ocean perch were predicted to be much less than target
1236 levels. In recent years, the stock has experienced exploitation rates that have been below the
1237 target level while the biomass level has remained above the target level.

1238 Table 25 shows the full suite of estimated reference points for the base model and Figure 90
1239 shows the equilibrium curve based on a steepness value fixed at 0.50.

1240 4 Harvest Projections and Decision Tables

1241 A twelve year projection of the base model with catches equal to the estimated ACL for years
1242 2019-2028 and a catch allocation equal to the percentages for each fleet over the period of
1243 2014-2016 predicts an increase in the spawning output due to large 2008 cohort, with a slight
1244 downturn beginning in 2023 (Table 29).

1245 Add additional projection post STAR based upon the decision table: Table 30

1246 5 Regional Management Considerations

1247 The distribution of Pacific ocean perch occur primarily in the US west coast waters of
1248 Washington, Oregon, and northern California and is currently managed to a species level
1249 with harvest limits set for the stock north of the $40^{\circ}10'$ latitude. The population within this
1250 area is treated as a single stock due to the lack of biological and genetic data indicating the
1251 presence of multiple stocks. Analysis conducted within this assessment did not find support
1252 for regional management within the area that Pacific ocean perch occur.

1253 6 Research Needs

1254 There are many areas of research that could be improved to benefit the understanding and
1255 assessment of Pacific ocean perch. Below, are issues that are considered of the importance.

- 1256 1. **Natural mortality:** Uncertainty in natural mortality translates into uncertain estimates
1257 of status and sustainable fishing levels for Pacific ocean perch. The collection
1258 of additional age data, re-reading of older age samples, reading old age samples that
1259 are unread, and improved understanding of the life-history of Pacific ocean perch may
1260 reduce that uncertainty.
- 1261 2. **Steepness:** The amount of stock resilience, steepness, dictates the rate at which a
1262 stock can rebuild from low stock sizes. Improved understanding regarding the steepness
1263 of US west coast Pacific ocean perch will reduce our uncertainty regarding current stock
1264 status.
- 1265 3. **Basin-wide understanding of stock structure, biology, connectivity, and distribution:** This is a stock assessment for Pacific ocean perch off of the west coast of the
1266 US and does not consider data from British Columbia or Alaska. Further investigating
1267 and comparing the data and predictions from British Columbia and Alaska to determine
1268 if there are similarities with the US west Coast observations would help to define the
1269 connectivity between Pacific ocean perch north and south of the U.S.-Canada border.
1270

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1278 Patrick Mirrick (ODFW), and Ted Calavan (ODFW) provided Oregon composition data,
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1281 data. John Field (SWFSC) provided historical catch information and Don Pearson (SWFSC)
1282 compiled the extensive management changes for Pacific ocean perch which were critical in
1283 understanding and modeling fishery behavior. John Wallace provided multiple last minute
1284 PacFIN extractions and analyzed historical discard rates for use in the assessment.

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1291 through the many discussions within the Population Ecology team in the FRAM division at
1292 the NWFSC.

₁₂₉₃ 8 Tables

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

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

Year	California	Oregon	Washington	At-Sea Hake	Foreign	Research
1932	0.3	0.1	0.4	0.0	0	0.0
1933	0.6	0.1	0.5	0.0	0	0.0
1934	0.4	0.0	2.3	0.0	0	0.0
1935	0.4	0.1	7.7	0.0	0	0.0
1936	0.2	0.2	1.6	0.0	0	0.0
1937	0.5	0.4	2.0	0.0	0	0.0
1938	0.6	0.1	5.1	0.0	0	0.0
1939	0.9	0.4	8.7	0.0	0	0.0
1940	0.9	9.1	12.2	0.0	0	0.0
1941	1.3	14.0	13.6	0.0	0	0.0
1942	0.4	26.6	18.6	0.0	0	0.0
1943	1.0	94.3	453.6	0.0	0	0.0
1944	2.8	164.5	739.3	0.0	0	0.0
1945	6.7	247.1	1887.1	0.0	0	0.0
1946	7.3	193.2	845.9	0.0	0	0.0
1947	2.6	167.2	385.3	0.0	0	0.0
1948	3.9	177.8	491.1	0.0	0	0.0
1949	2.0	472.9	409.5	0.0	0	0.0
1950	1.5	690.1	675.7	0.0	0	0.0
1951	4.3	840.1	735.1	0.0	0	0.0
1952	2.9	2030.5	305.6	0.0	0	0.0
1953	145.6	1223.5	361.6	0.0	0	0.0
1954	123.2	1837.5	538.8	0.0	0	0.0
1955	48.8	1346.4	555.6	0.0	0	0.0
1956	3.8	2563.8	548.2	0.0	0	0.0
1957	1.6	2128.1	538.5	0.0	0	0.0
1958	2.9	1564.9	530.4	0.0	0	0.0
1959	1.5	892.6	337.0	0.0	0	0.0
1960	19.6	1358.8	928.1	0.0	0	0.0
1961	1.1	2061.9	1179.8	0.0	0	0.0
1962	0.6	2584.9	1725.2	0.0	0	0.0
1963	32.5	3693.9	2006.0	0.0	0	0.0
1964	46.1	4261.6	1770.7	0.0	0	0.0
1965	34.9	5627.8	1972.1	0.0	0	0.0
1966	5.2	1591.2	1725.5	0.0	15561	0.0
1967	17.8	354.7	1861.0	0.0	12357	0.0
1968	21.9	466.4	2501.2	0.0	6639	0.0
1969	8.4	422.3	1236.0	0.0	469	0.0
1970	8.7	507.4	1293.3	0.0	441	0.0
1971	12.2	290.4	673.6	0.0	902	0.0
1972	11.4	105.3	796.5	0.0	950	0.0
1973	11.9	121.2	713.1	0.0	1773	0.0
1974	15.7	136.7	641.8	0.0	1457	0.0
1975	11.4	181.3	413.9	62.3	496	0.0
1976	17.1	663.7	521.133	31.9	239	0.0

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

Table 2: West Coast history of regulations.

Date	Area	Regulation
11/10/1983	Columbia	Closed Columbia area to Pacific ocean perch fishing until the end of the year, as 950 mt OY for this species has been reached;
11/10/1983	Vancouver	retained 5,000-pound trip limit or 10% of total trip weight on landings of Pacific ocean perch in the Vancouver area.
1/1/1984	ALL	Continued 5,000-pound trip limit or 10% of total trip weight on Pacific ocean perch as specified in FMP. Fishery to close when area OYs are reached (see action effective November 10, 1983 above).
8/1/1984	Vancouver	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	
	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	0.35
2012	-	-	-	-	-	-	-	-	9289	0.35
2013	-	-	-	-	-	-	-	-	8093	0.35
2014	-	-	-	-	-	-	-	-	4914	0.35
2015	-	-	-	-	-	-	-	-	5752	0.32
2016	-	-	-	-	-	-	-	-	11770	0.37

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Year	Tows	Fish	Sample Size
1985	29	1635	70

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 23: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
NatM_p_1.Fem.GP_1	0.054	-5	(0.02, 0.1)	OK	0.14	Log_Norm (-2.92, 0.44)
L_at_Amin_Fem.GP_1	20.7686	3	(15, 25)	OK	0.15	None
L_at_Amax_Fem.GP_1	41.6117	2	(35, 45)	OK	0.00	None
VonBert_K.Fem.GP_1	0.167283	3	(0.1, 0.4)	OK	0.06	None
SD_young_Fem.GP_1	1.34834	5	(0.03, 5)	OK	0.12	None
SD_old.Fem.GP_1	2.56021	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	20.7686	-2	(6, 68)	None	None	
L_at_Amax_Mal.GP_1	38.9163	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	1.34834	-5	(0, 742.07)	None	None	
SD_old.Mal.GP_1	2.283	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)	9.3672	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	0.00388544	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_17	0.0040848	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_16	0.00429136	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_15	0.00450479	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_14	0.00472451	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_13	0.0049499	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_12	0.00517993	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_11	0.00541357	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_10	0.00564907	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_9	0.00588464	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_8	0.00611646	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_7	0.00634191	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_6	0.00656373	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_5	0.00678881	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_4	0.00702092	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_3	0.00726012	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_2	0.00750606	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_1	0.00775873	3	(-6, 6)	act	0.70	dev (NA, NA)
LnQ_base_Fishery(1)	-12.3155	-1	(-15, 15)	None	None	None
LnQ_base_POP(4)	-0.134547	-1	(-15, 15)	None	None	None
LnQ_base_Triennial(5)	-1.8261	-1	(-15, 15)	None	None	None
Q_extraSD_Triennial(5)	0.390496	2	(0, 0.5)	OK	0.15	None
LnQ_base_AFSCSlope(6)	-2.49914	-1	(-15, 15)	None	None	None
LnQ_base_NWEFSCSlope(7)	-2.86217	-1	(-15, 15)	None	None	None
LnQ_base_NWFSCCombo(8)	-2.61938	-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)	0.027175	2	(0, 0.5) (20, 45)	OK	0.07	None
SizeSel_P1_Fishery(1)	37.9661	1	(20, 45)	OK	0.17	None
SizeSel_P2_Fishery(1)	-5	-2	(-6, 4)	None		
SizeSel_P3_Fishery(1)	3.70558	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)	0.47798	2	(-5, 9)	OK	0.30	None
Retain_P1_Fishery(1)	28.2716	1	(15, 45)	OK	0.34	None
Retain_P2_Fishery(1)	1.07118	1	(0.1, 10)	OK	0.13	None
Retain_P3_Fishery(1)	6.83751	1	(-10, 10)	OK	1.23	None
Retain_P4_Fishery(1)	0	-3	(0, 0)	None		
SizeSel_P1_ASHOP(2)	49.4949	1	(20, 49.5)	HI	0.16	None
SizeSel_P2_ASHOP(2)	-5	-2	(-6, 4)	None		
SizeSel_P3_ASHOP(2)	5.08226	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)	24.37	1	(20, 70)	OK	2.21	None
SizeSel_P2_POP(4)	10.9478	3	(0.001, 50)	OK	3.98	None
SizeSel_P1_Triennial(5)	27.5713	1	(20, 45)	OK	5.04	None
SizeSel_P2_Triennial(5)	-5	-2	(-6, 4)	None		
SizeSel_P3_Triennial(5)	5.5	-3	(-1, 9)	None		
SizeSel_P4_Triennial(5)	3.32415	3	(-1, 9)	OK	2.26	None
SizeSel_P5_Triennial(5)	-5	-4	(-5, 9)	None		
SizeSel_P6_Triennial(5)	-0.803296	2	(-5, 9)	OK	0.63	None
SizeSel_P1_AFSCSlope(6)	21.6639	1	(20, 45)	OK	6.23	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)
SizeSel.P2_AFSCSlope(6)	-5	-2	(-6, 4)	OK	6.35	None
SizeSel.P3_AFSCSlope(6)	1.21491	3	(-1, 9)	OK	6.35	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)	35.9361	1	(20, 45)	OK	2.21	None
SizeSel.P2_NWFSCSlope(7)	-5	-2	(-6, 4)	None	None	None
SizeSel.P3_NWFSCSlope(7)	1.76915	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)	21.5036	1	(18, 49.5)	OK	3.62	None
SizeSel.P2_NWFFSCCombo(8)	-5	-2	(-6, 4)	None	None	None
SizeSel.P3_NWFFSCCombo(8)	3.00277	3	(-1, 9)	OK	1.91	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	3.99168	4	(-10, 10)	OK	0.10	None
Retain_P3_Fishery(1)_BLK1repl_1992	2.30707	4	(-10, 10)	OK	0.37	None
Retain_P3_Fishery(1)_BLK1repl_2002	1.71687	4	(-10, 10)	OK	0.12	None
Retain_P3_Fishery(1)_BLK1repl_2008	0.607918	4	(-10, 10)	OK	0.28	None
Retain_P3_Fishery(1)_BLK1repl_2009	-0.0154006	4	(-10, 10)	OK	0.24	None

Table 24: Likelihood components from the base model

Likelihood Component	Value
Total	1772.52
Survey	0
Discard	-25.61
Length-frequency data	-33.39
Age-frequency data	146.4
Recruitment	1671.52
Forecast Recruitment	12.58
Parameter Priors	0

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

Quantity	Estimate	95% Confidence Interval
Unfished spawning output (million eggs)	6664.1	4756.8 - 8571.5
Unfished age 3+ biomass (mt)	140351	100391.1 - 180310.9
Unfished recruitment (R_0 , thousands)	11698.3	8822.7 - 15511.2
Spawning output(2017 million eggs)	4993.2	2244.3 - 7742
Depletion (2017)	0.749	0.532 - 0.967
Reference points based on $SB_{40\%}$		
Proxy spawning output ($B_{40\%}$)	2665.7	1902.7 - 3428.6
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)	1754	1256 - 2251.9
Reference points based on SPR proxy for MSY		
Spawning output	2221.4	1585.6 - 2857.1
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.034	0.033 - 0.034
Yield with SPR_{proxy} at SB_{SPR} (mt)	1770.4	1268.2 - 2272.5
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	2328.1	1657.7 - 2998.4
SPR_{MSY}	0.512	0.51 - 0.514
Exploitation rate at MSY	0.032	0.032 - 0.033
MSY (mt)	1772.4	1269.5 - 2275.2

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	140674	6675	139946	1.00	11797	0	0	0
1919	140702	6676	139973	1.00	11801	1	0	0
1920	140731	6677	140002	1.00	11805	0	0	0
1921	140761	6678	140032	1.00	11808	0	0	0
1922	140791	6680	140062	1.00	11812	0	0	0
1923	140823	6681	140093	1.00	11816	0	0	0
1924	140855	6682	140125	1.00	11820	0	0	0
1925	140887	6684	140157	1.00	11824	1	0	0
1926	140920	6685	140190	1.00	11827	1	0	0
1927	140953	6687	140223	1.00	11830	1	0	0
1928	140987	6688	140256	1.00	11834	1	0	0
1929	141021	6690	140290	1.00	11836	1	0	0
1930	141056	6691	140324	1.00	11839	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	141091	6693	140359	1.00	11841	1	0	0
1932	141126	6695	140395	1.00	11843	1	0	0
1933	141163	6696	140431	1.00	11846	1	0	0
1934	141198	6698	140467	1.00	11849	1	0	0
1935	141233	6699	140501	1.00	11854	3	0	0
1936	141261	6701	140529	1.00	11863	8	0	0
1937	141297	6702	140564	1.00	11878	2	0	0
1938	141332	6704	140599	1.00	11900	3	0	0
1939	141365	6706	140631	1.00	11933	6	0	0
1940	141397	6707	140661	1.00	12152	10	0.005	0
1941	141422	6708	140681	1.00	12207	23	0.005	0
1942	141452	6708	140701	1.00	12272	30	0.01	0
1943	141485	6708	140730	1.00	12343	47	0.09	0
1944	141025	6683	140265	1.00	12406	562	0.145	0.004
1945	140238	6640	139474	0.99	12467	929	0.295	0.007
1946	138239	6538	137472	0.98	12510	2194	0.165	0.016
1947	137450	6493	136679	0.97	12617	1072	0.095	0.008
1948	137227	6473	136452	0.97	12806	569	0.115	0.004
1949	136937	6451	136154	0.97	13104	690	0.145	0.005
1950	136491	6421	135694	0.96	13539	906	0.21	0.007
1951	135627	6370	134809	0.95	14100	1401	0.24	0.01
1952	134655	6311	133808	0.95	14693	1619	0.325	0.012
1953	133041	6218	132160	0.93	15048	2398	0.26	0.018
1954	132231	6158	131318	0.92	14943	1775	0.35	0.014
1955	130811	6065	129885	0.91	14236	2564	0.29	0.02
1956	130134	6004	129226	0.90	13045	2001	0.41	0.015
1957	128386	5893	127530	0.88	11791	3198	0.375	0.025
1958	127174	5813	126392	0.87	10747	2739	0.315	0.022
1959	126530	5771	125821	0.86	10074	2154	0.21	0.017
1960	126672	5781	126020	0.87	9908	1264	0.34	0.01
1961	125537	5747	124917	0.86	10309	2367	0.43	0.019
1962	123274	5670	122654	0.85	10835	3326	0.515	0.027
1963	119787	5538	119144	0.83	10188	4420	0.605	0.037
1964	114773	5328	114119	0.80	8656	5876	0.635	0.051
1965	109382	5091	108781	0.76	7608	6231	0.715	0.057
1966	102358	4767	101843	0.71	7086	7827	0.91	0.077
1967	84188	3898	83731	0.58	6645	18969	0.905	0.227
1968	70554	3234	70125	0.48	6926	14651	0.87	0.209

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	62026	2815	61606	0.42	9437	9713	0.52	0.158
1970	61150	2768	60668	0.41	14746	2183	0.535	0.036
1971	60256	2721	59606	0.41	7366	2300	0.485	0.039
1972	59963	2693	59179	0.40	5185	1905	0.48	0.032
1973	59854	2661	59435	0.40	5077	1888	0.585	0.032
1974	58881	2591	58563	0.39	5097	2643	0.545	0.045
1975	58156	2538	57839	0.38	6378	2275	0.365	0.039
1976	58391	2550	58058	0.38	5083	1183	0.425	0.02
1977	58154	2565	57777	0.38	6707	1507	0.375	0.026
1978	58038	2596	57703	0.39	4912	1263	0.5	0.022
1979	57055	2580	56669	0.39	5630	1998	0.42	0.035
1980	56484	2570	56169	0.39	5547	1507	0.465	0.027
1981	55591	2539	55244	0.38	5850	1723	0.405	0.031
1982	54998	2518	54643	0.38	8890	1380	0.34	0.025
1983	54728	2509	54313	0.38	10420	1057	0.46	0.019
1984	53976	2471	53410	0.37	7216	1624	0.47	0.03
1985	53383	2429	52792	0.36	7196	1658	0.43	0.031
1986	53199	2395	52757	0.36	5866	1412	0.425	0.027
1987	53107	2362	52682	0.35	7073	1375	0.37	0.026
1988	53334	2346	52946	0.35	9489	1107	0.43	0.021
1989	53321	2329	52842	0.35	10642	1379	0.45	0.026
1990	53345	2322	52732	0.35	14203	1469	0.375	0.028
1991	53929	2337	53233	0.35	6423	1123	0.445	0.021
1992	54372	2335	53630	0.35	3475	1478	0.465	0.028
1993	54866	2323	54517	0.35	3486	1567	0.43	0.029
1994	55322	2321	55091	0.35	9874	1418	0.38	0.026
1995	55841	2340	55523	0.35	9043	1180	0.325	0.021
1996	56493	2386	55910	0.36	3884	952	0.295	0.017
1997	57219	2452	56745	0.37	3816	879	0.245	0.015
1998	57953	2522	57716	0.38	2924	715	0.245	0.012
1999	58441	2570	58179	0.39	19458	721	0.195	0.012
2000	59037	2609	58560	0.39	30181	562	0.06	0.01
2001	60338	2666	59014	0.40	8825	160	0.11	0.003
2002	62302	2720	60795	0.41	5106	293	0.07	0.005
2003	64925	2770	64447	0.41	2549	179	0.06	0.003
2004	67392	2806	67107	0.42	6853	155	0.055	0.002
2005	69635	2843	69416	0.43	3323	147	0.03	0.002
2006	71610	2928	71243	0.44	3814	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	73235	3076	73022	0.46	3643	85	0.05	0.001
2008	74624	3238	74081	0.49	127759	157	0.045	0.002
2009	76715	3370	74773	0.50	4660	133	0.055	0.002
2010	80899	3459	75005	0.52	8123	190	0.055	0.003
2011	88280	3518	87916	0.53	15970	181	0.02	0.002
2012	94964	3561	94368	0.53	2255	61	0.015	0.001
2013	101740	3597	100897	0.54	34343	58	0.015	0.001
2014	108287	3732	107696	0.56	5333	57	0.015	0.001
2015	114340	4107	112680	0.62	10094	55	0.015	0
2016	120219	4586	119811	0.69	10508	59	0.015	0
2017	125001	4993	124369	0.75	10795	65	0.055	0.001
2018	128840	5300	128185	0.79	10991	-	-	-
2019	131938	5551	131267	0.83	11140	-	-	-
2020	130228	5596	129547	0.84	11165	-	-	-
2021	128028	5611	127340	0.84	11174	-	-	-
2022	125508	5579	124819	0.84	11156	-	-	-
2023	122801	5512	122112	0.83	11117	-	-	-
2024	120013	5423	119325	0.81	11066	-	-	-
2025	117222	5322	116537	0.80	11005	-	-	-
2026	114481	5214	113799	0.78	10938	-	-	-
2027	111824	5103	111146	0.76	10867	-	-	-
2028	109271	4990	108597	0.75	10793	-	-	-

Table 27: Sensitivity of the base model

Label	Base	Harmonic weights	Steepness at prior	Estimate M	Old Maturity	Old Fecundity
Total Likelihood	1772.52	2573.89	1772.41	1772.04	1772.52	1761.96
Survey Likelihood	-25.61	-26.07	-25.09	-25.76	-25.61	-25.50
Discard Likelihood	-33.39	-21.88	-33.45	-33.47	-33.40	-34.07
Length Likelihood	146.40	880.26	146.74	146.40	146.40	135.99
Age Likelihood	1671.52	1720.85	1671.17	1671.51	1671.54	1671.90
Recruitment Likelihood	12.58	19.71	12.90	12.39	12.58	12.62
Forecast Recruitment Likelihood	0.00	0.00	0.00	0.00	0.00	0.00
Parameter Priors Likelihood	1.00	1.00	0.13	0.95	1.00	1.00
Parameter Deviation Likelihood	0.00	0.00	0.00	0.00	0.00	0.00
log(R0)	9.37	9.27	9.42	9.74	9.37	9.37
SB Virgin	6664.15	6152.53	7009.14	7898.65	6534.89	7770.18
SB 2017	4993.17	4106.91	6786.50	7312.32	5010.70	6130.12
Depletion 2017	0.75	0.67	0.97	0.93	0.77	0.79
Total Yield	1770.36	1621.31	2489.17	2328.86	1764.90	1793.42
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	20.77	20.77	20.77	20.77	20.77	20.78
Length at Amax - Female	41.61	41.67	41.62	41.62	41.61	41.60
Von Bert. k - Female	0.17	0.17	0.17	0.17	0.17	0.17
SD young - Female	1.35	1.37	1.35	1.35	1.35	1.34
SD old - Female	2.56	2.80	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	20.77	20.77	20.77	20.77	20.77	20.78
Length at Amax - Male	38.92	38.95	38.93	38.91	38.92	38.90
Von Bert. k - Male	0.20	0.20	0.20	0.20	0.20	0.20
SD young - Male	1.35	1.37	1.35	1.35	1.35	1.34
SD old - Male	2.28	2.52	2.28	2.28	2.28	2.28

Table 28: Sensitivity of the base model

Label	Base	Split Triennial	Remove CPUE	Canadian Data	WA Research Lengths	OR Special Projects
Total Likelihood	1772.52	1770.77	1785.20	1875.50	1794.10	1839.46
Survey Likelihood	-25.61	-27.99	-12.81	-25.97	-26.14	-26.07
Discard Likelihood	-33.39	-33.39	-33.38	-32.40	-33.34	-33.56
Length Likelihood	146.40	146.19	146.32	194.09	166.75	177.11
Age Likelihood	1671.52	1672.26	1671.62	1725.50	1672.67	1705.77
Recruitment Likelihood	12.58	12.68	12.44	13.25	13.14	15.19
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)	9.37	9.40	9.36	9.37	9.33	9.28
SB Virgin	6664.15	6913.79	6630.90	6736.61	6381.32	6129.38
SB 2017	4993.17	5371.02	4947.65	4689.48	4616.63	4345.79
Depletion 2017	0.75	0.78	0.75	0.70	0.72	0.71
Total Yield	1770.36	1836.01	1761.71	1785.43	1709.54	1628.83
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	20.77	20.77	20.77	20.74	20.75	20.78
Length at Amax - Female	41.61	41.62	41.61	41.70	41.54	41.61
Von Bert. k - Female	0.17	0.17	0.17	0.17	0.17	0.17
SD young - Female	1.35	1.35	1.35	1.36	1.35	1.34
SD old - Female	2.56	2.56	2.56	2.54	2.56	2.57
Natural Mortality - Male	0.05	0.05	0.05	0.05	0.05	0.05
Length at Amin - Male	20.77	20.77	20.77	20.74	20.75	20.78
Length at Amax - Male	38.92	38.92	38.91	38.97	38.89	38.96
Von Bert. k - Male	0.20	0.20	0.20	0.20	0.20	0.20
SD young - Male	1.35	1.35	1.35	1.36	1.35	1.34
SD old - Male	2.28	2.28	2.28	2.28	2.29	2.31

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

Year	OFL (mt)	ACL (mt)	Age 3+ biomass (mt)	Spawning Output	Depletion
2017	4245	281	124369	4993	0.75
2018	4491	281	128185	5300	0.80
2019	4656	4454	131267	5551	0.83
2020	4607	4408	129547	5596	0.84
2021	4524	4328	127340	5611	0.84
2022	4418	4228	124819	5579	0.84
2023	4300	4114	122112	5512	0.83
2024	4175	3995	119325	5423	0.81
2025	4053	3878	116537	5322	0.80
2026	3938	3768	113799	5214	0.78
2027	3831	3666	111146	5103	0.77
2028	3732	3571	108597	4990	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	
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	-	-	-	-	-	-	

₁₂₉₄ 9 Figures

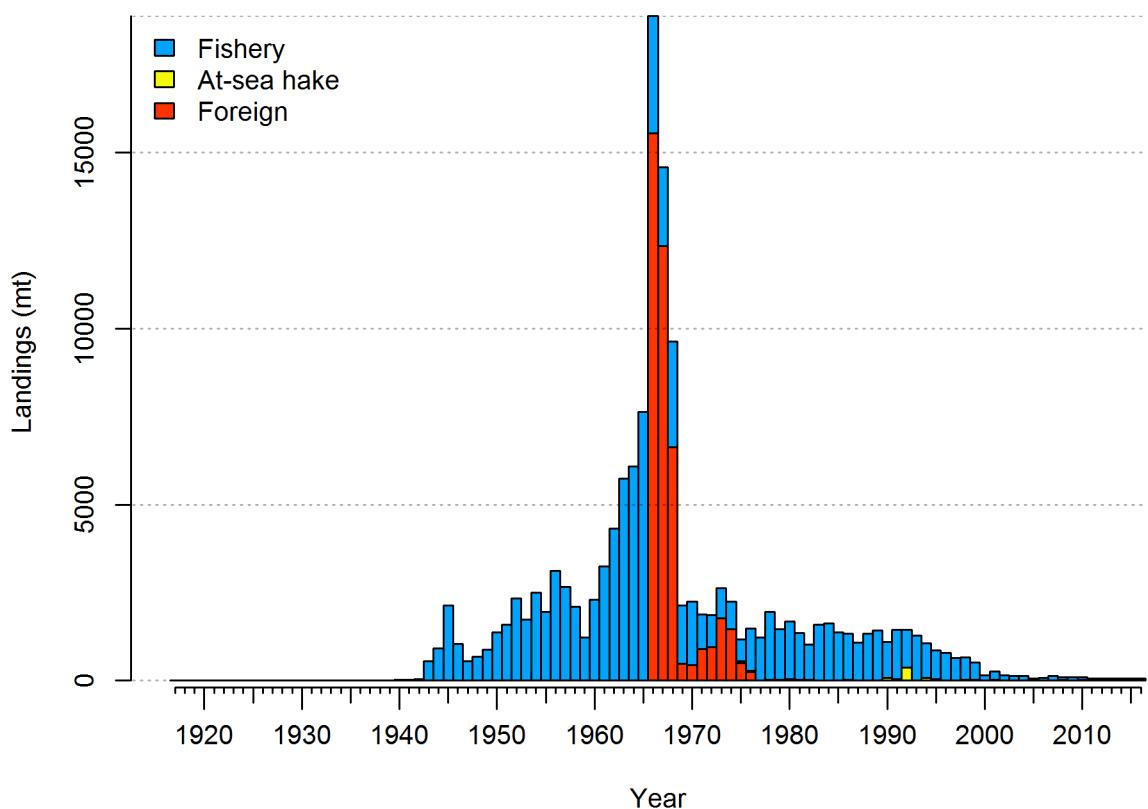


Figure 1: Total catches Pacific ocean perch through 2016.

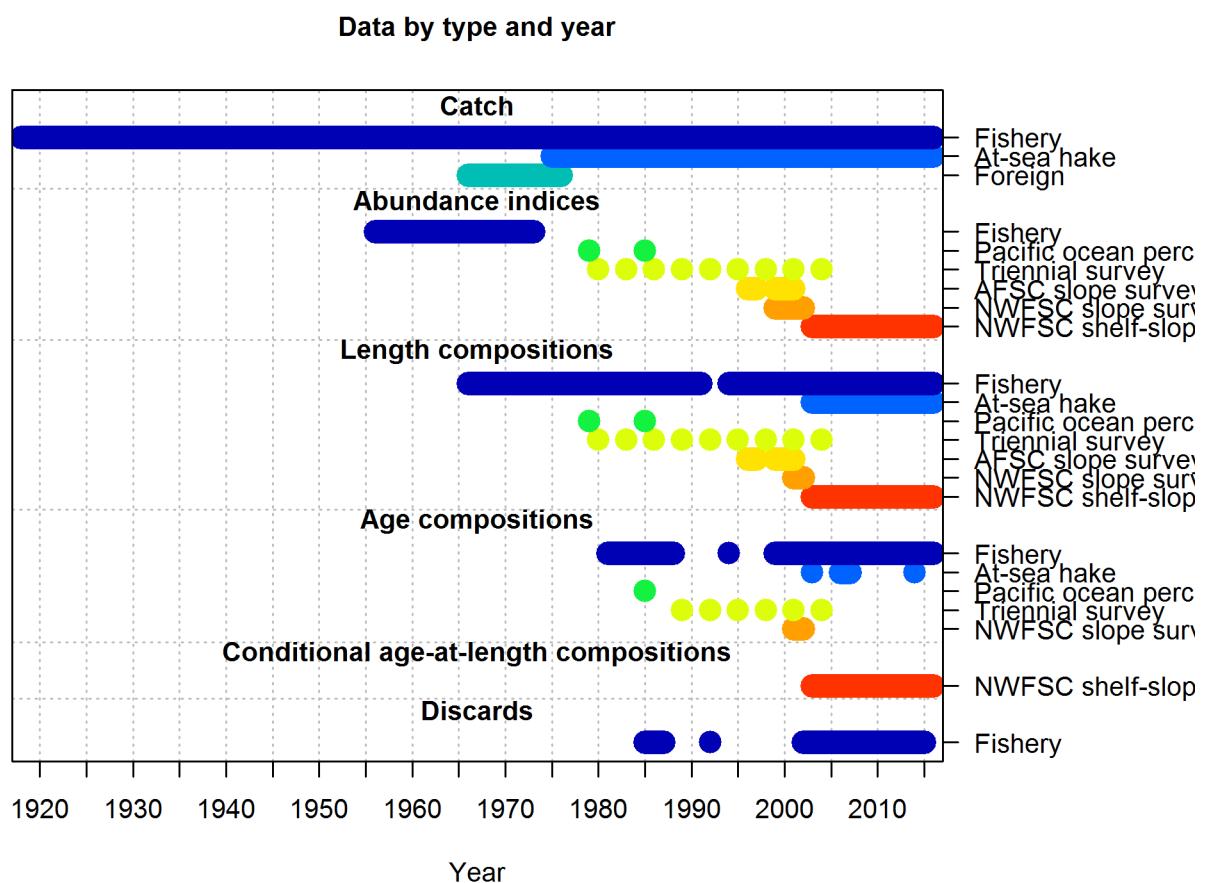


Figure 2: Summary of data sources used in the base model.

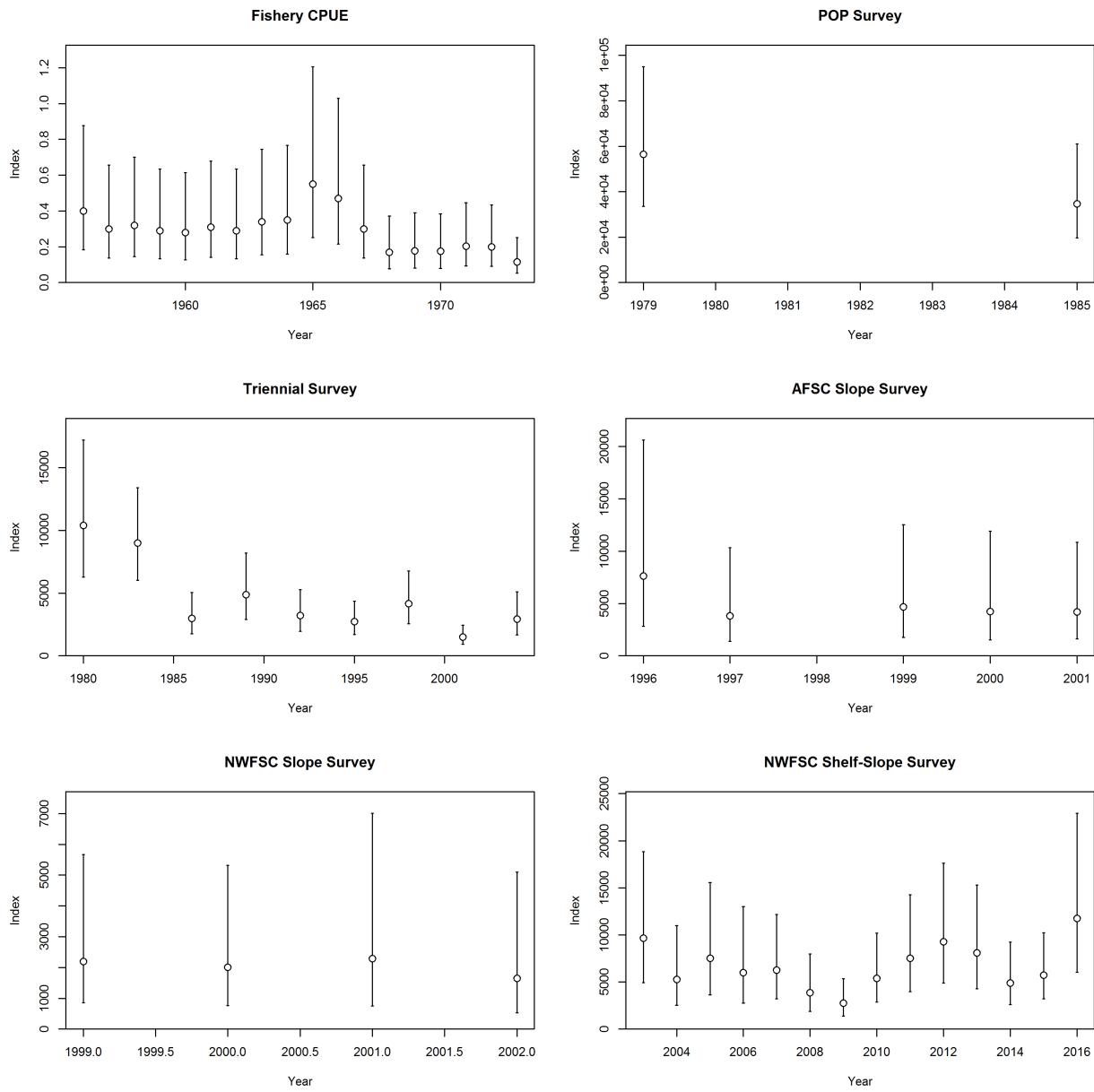


Figure 3: Fishery-dependent and fishery-independent indices for Pacific ocean perch.

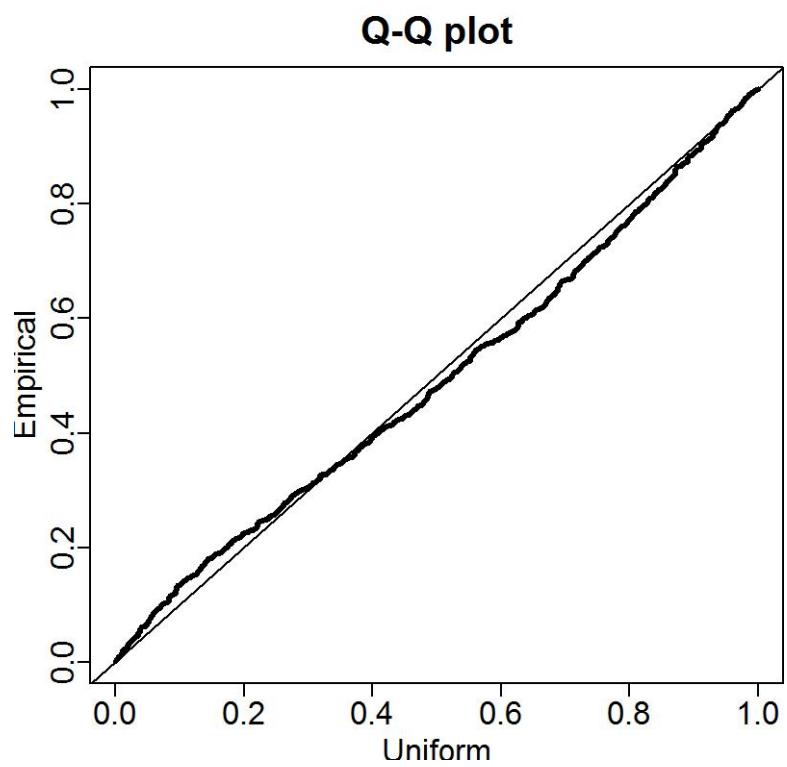


Figure 4: Q-Q plots for the VAST lognormal distribution for the NWFSC shelf-slope survey.

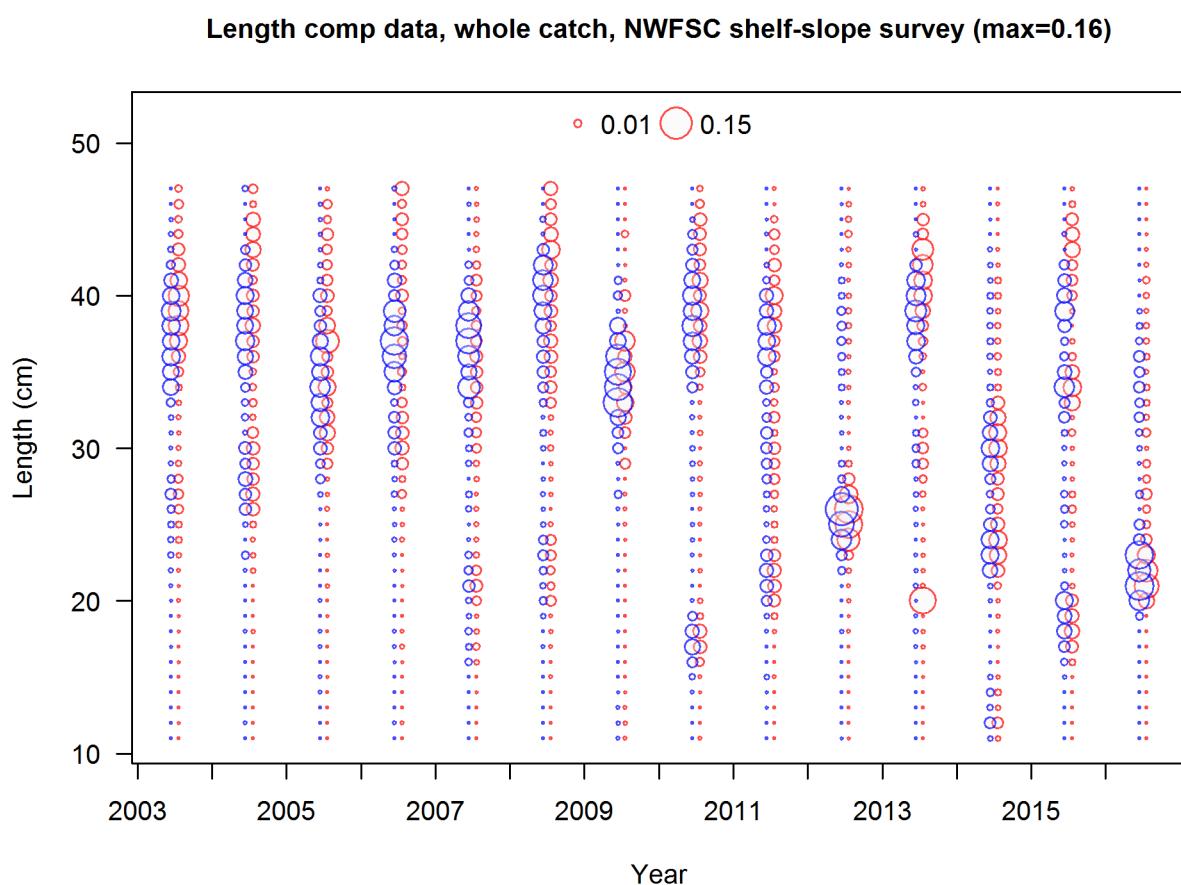


Figure 5: NWFSC shelf-slope survey length frequency distributions for Pacific ocean perch.

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

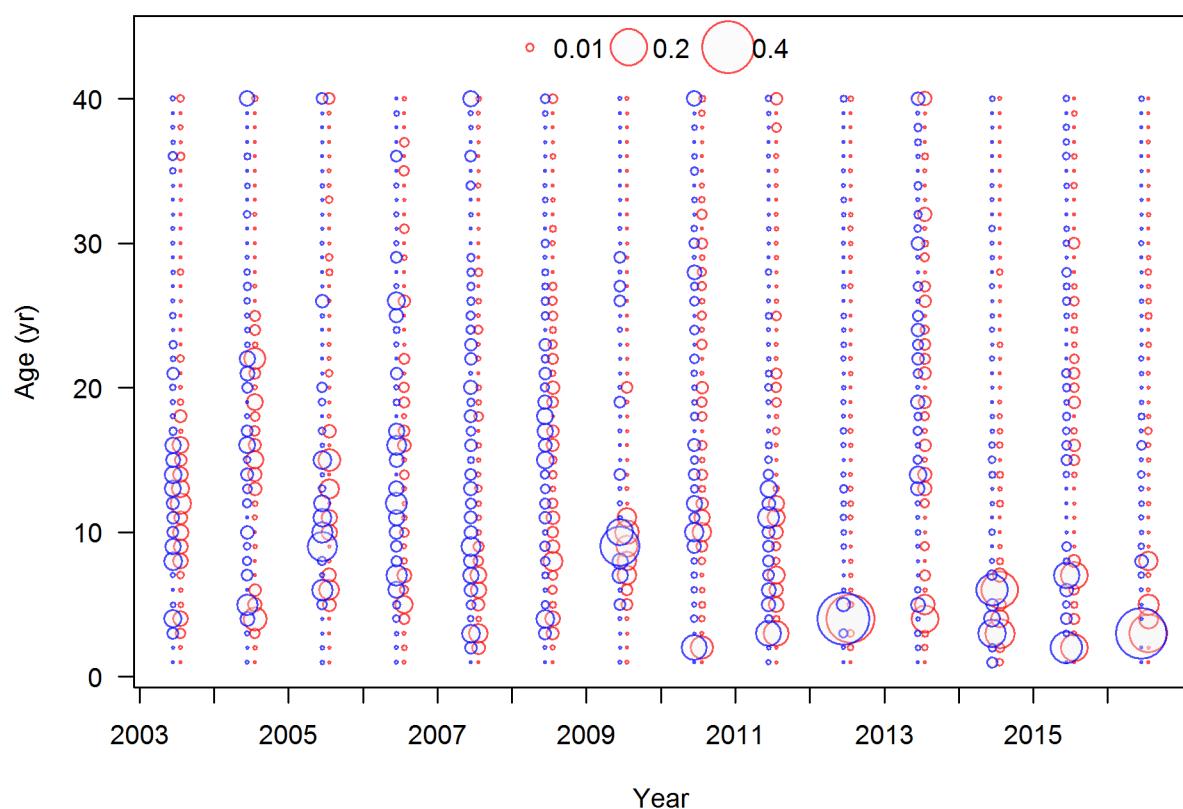


Figure 6: NWFSC shelf-slope survey age frequency distributions for Pacific ocean perch.

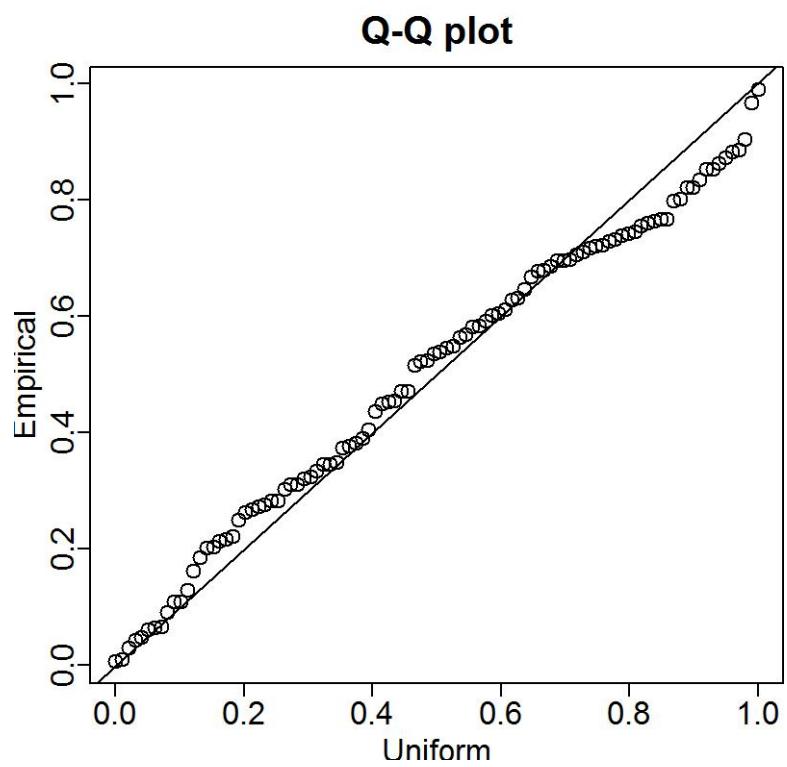


Figure 7: Q-Q plots for the VAST lognormal distribution for the NWFSC slope survey.

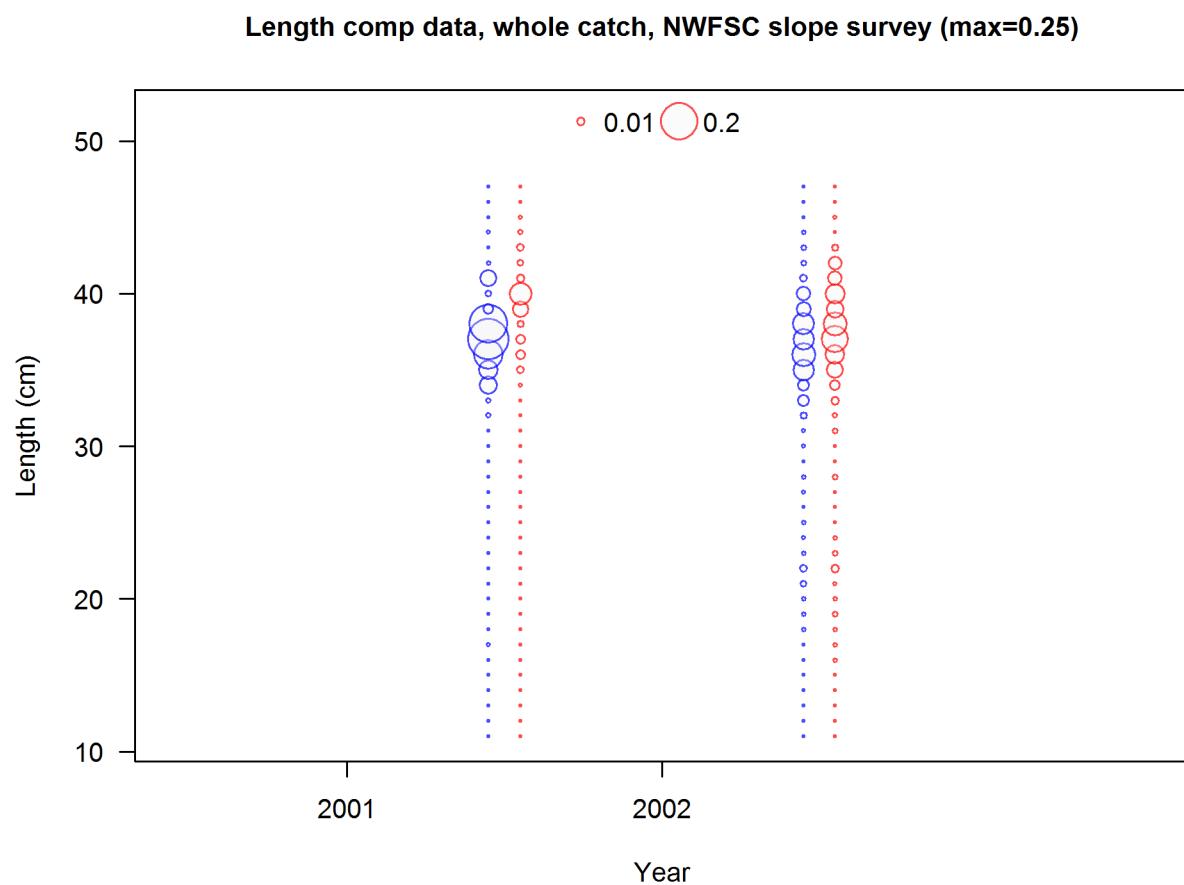


Figure 8: NWFSC slope survey length frequency distributions for Pacific ocean perch.

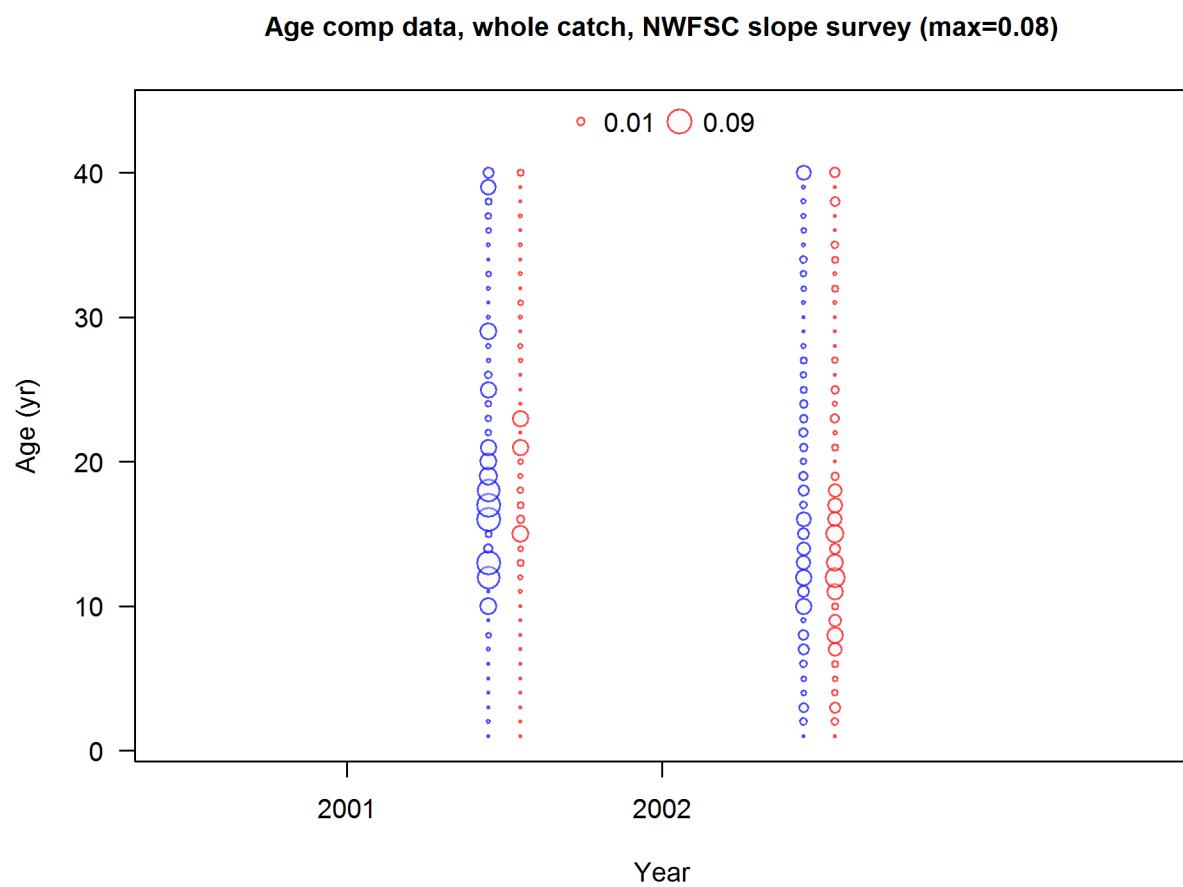


Figure 9: NWFSC slope survey age frequency distributions for Pacific ocean perch.

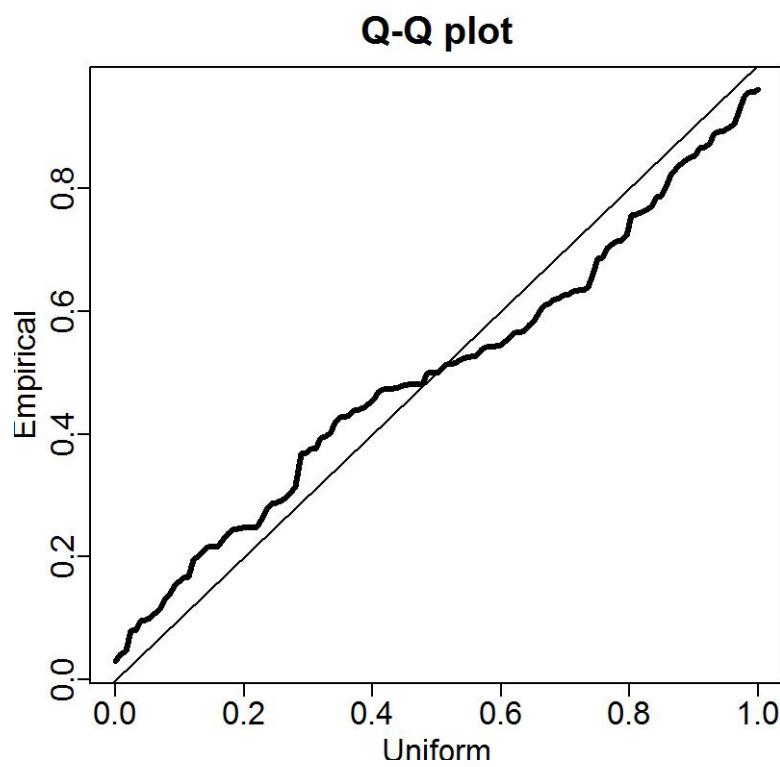


Figure 10: Q-Q plots for the VAST lognormal distribution for the AFSC slope survey.

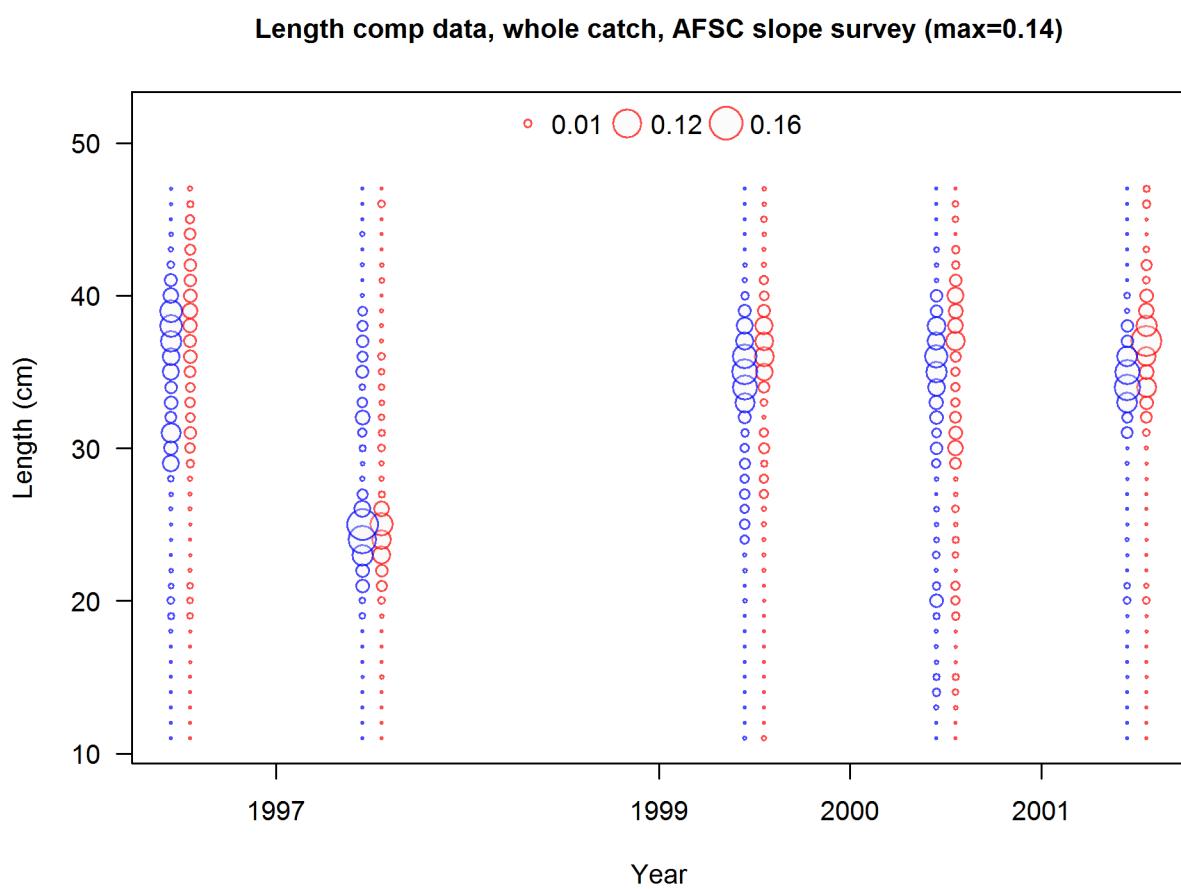


Figure 11: AFSC slope survey length frequency distributions for Pacific ocean perch.

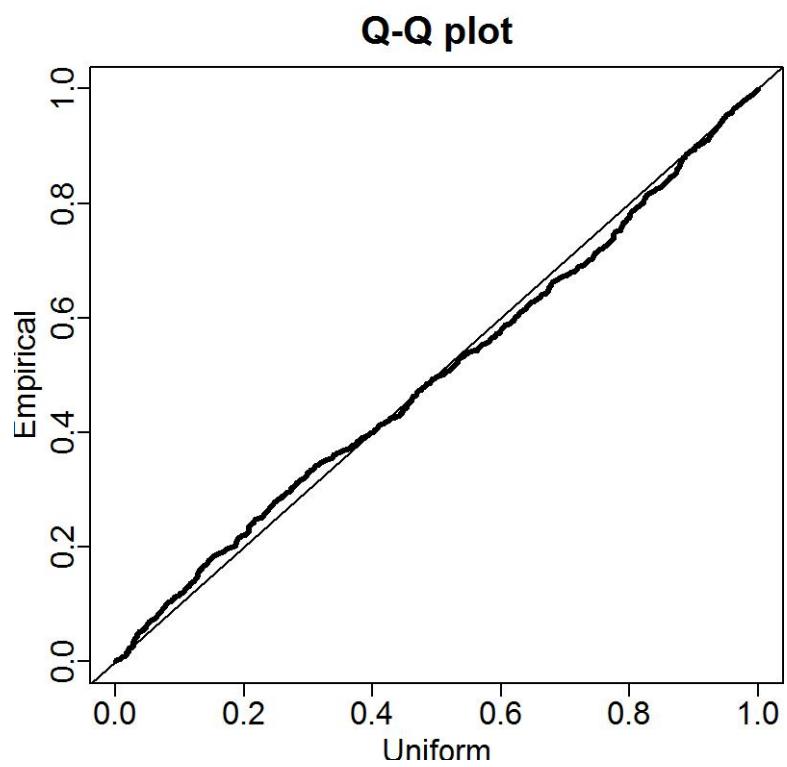


Figure 12: Q-Q plots for the VAST lognormal distribution for the Triennial survey.

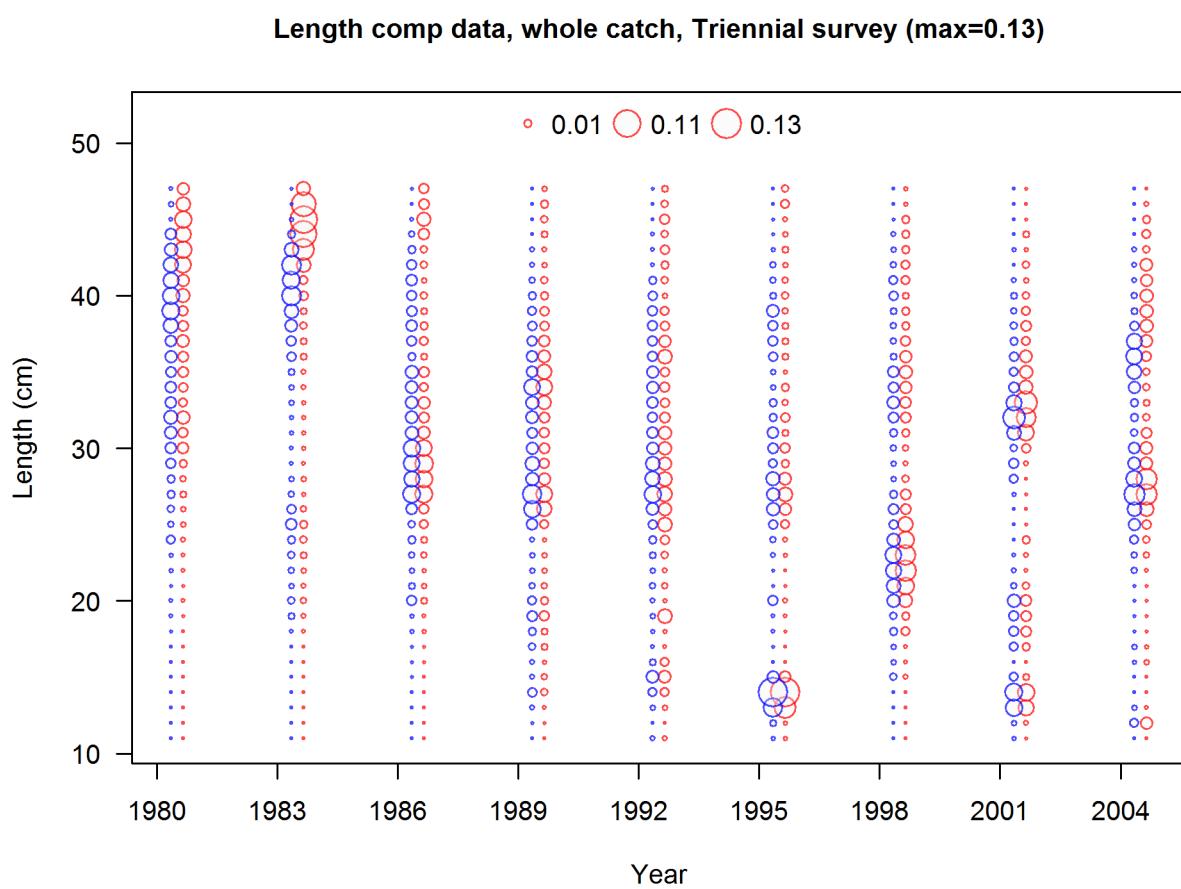


Figure 13: Triennial survey length frequency distributions for Pacific ocean perch.

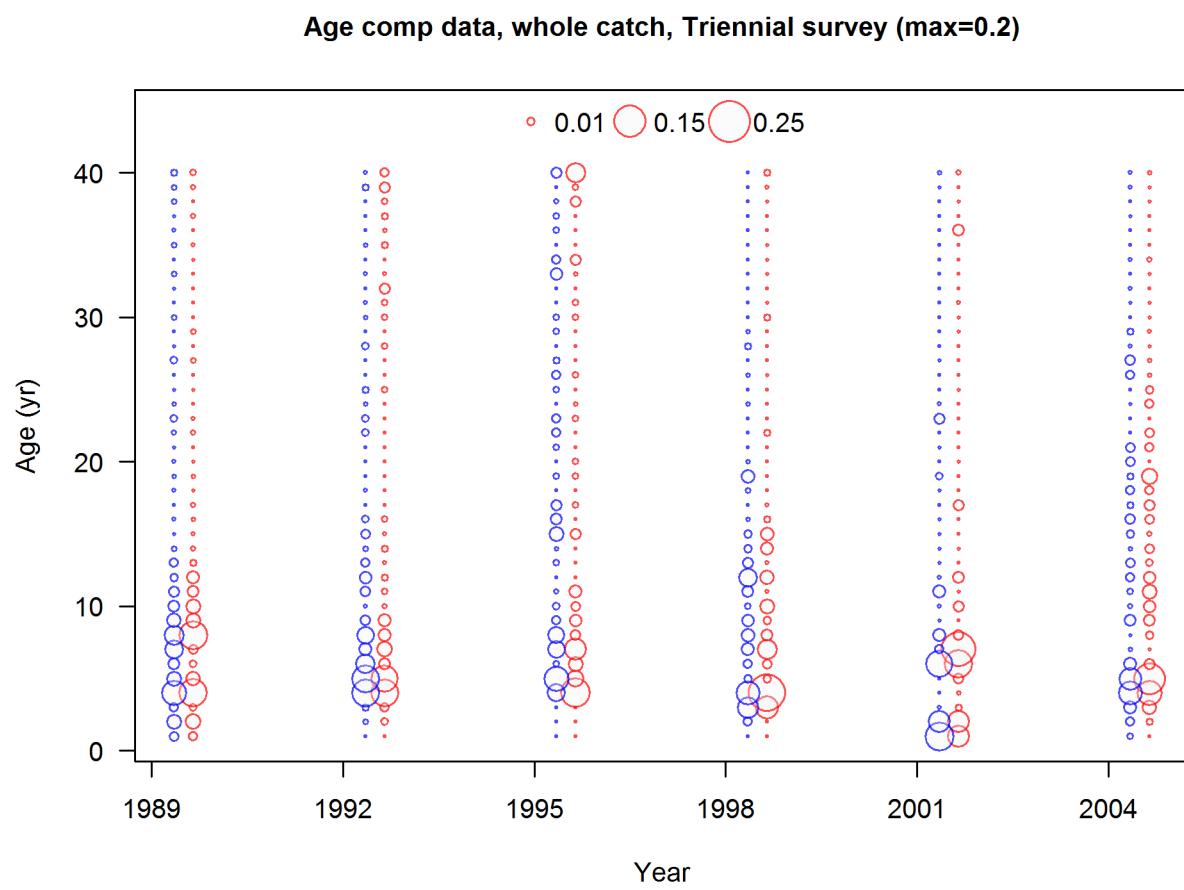


Figure 14: Triennial survey age frequency distributions for Pacific ocean perch.

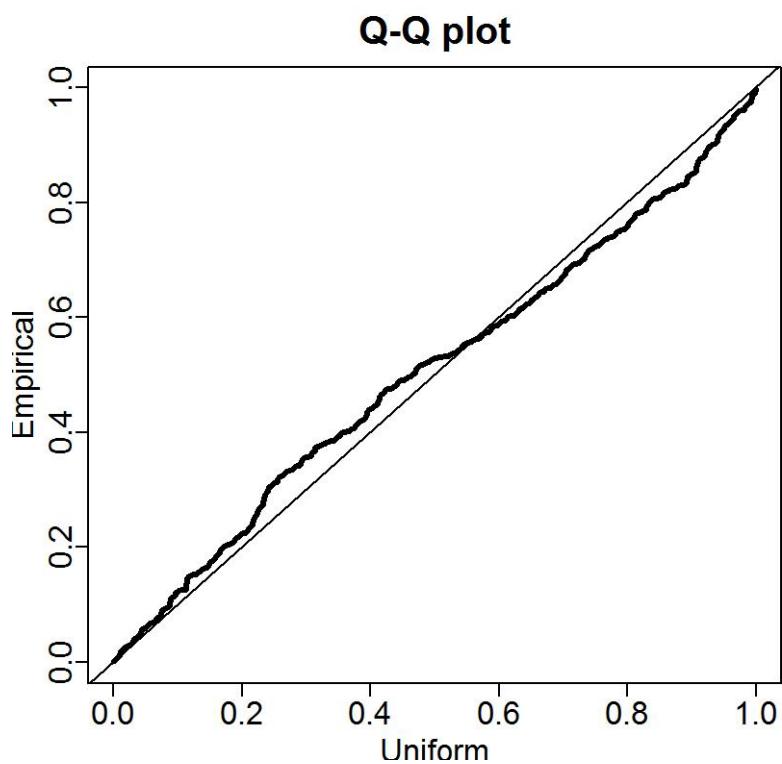


Figure 15: Q-Q plots for the VAST lognormal distribution for the Pacific ocean perch survey.

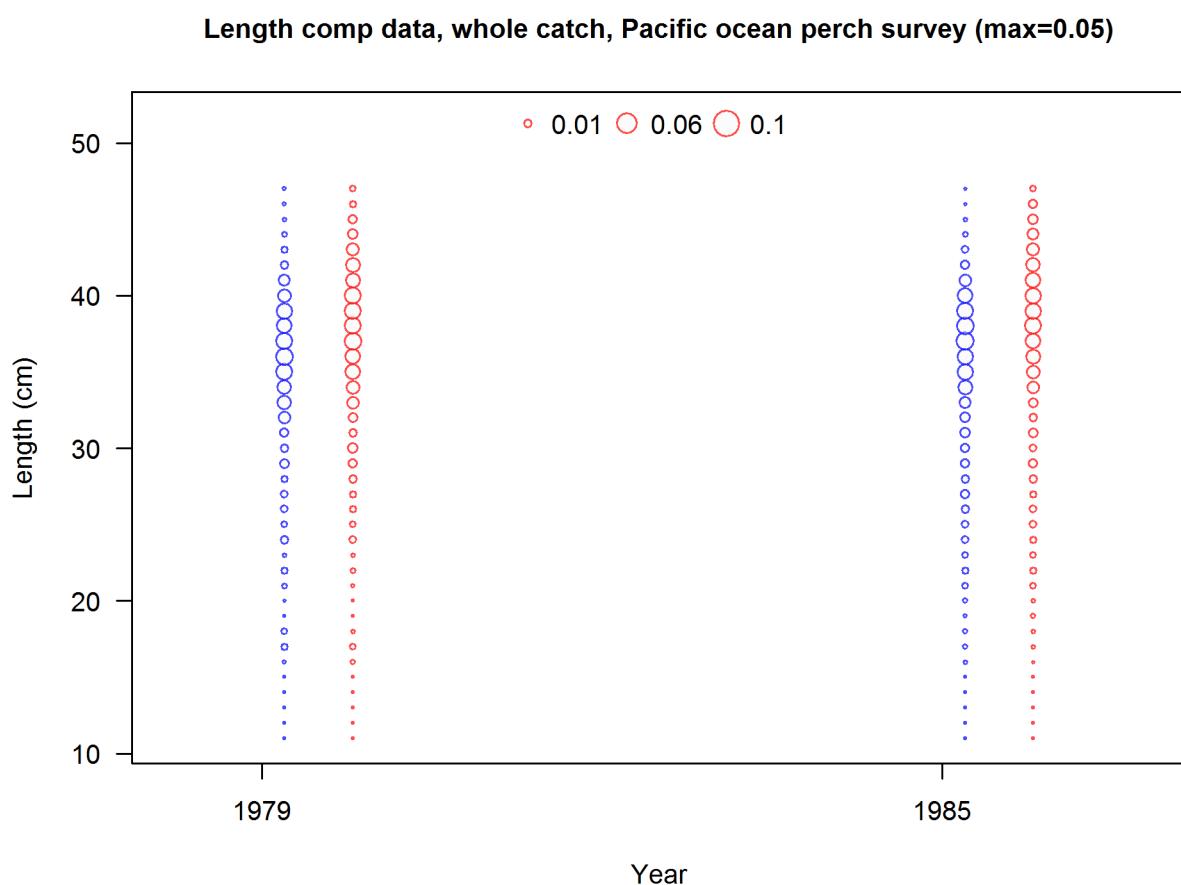


Figure 16: Pacific ocean perch survey length frequency distributions for Pacific ocean perch.

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

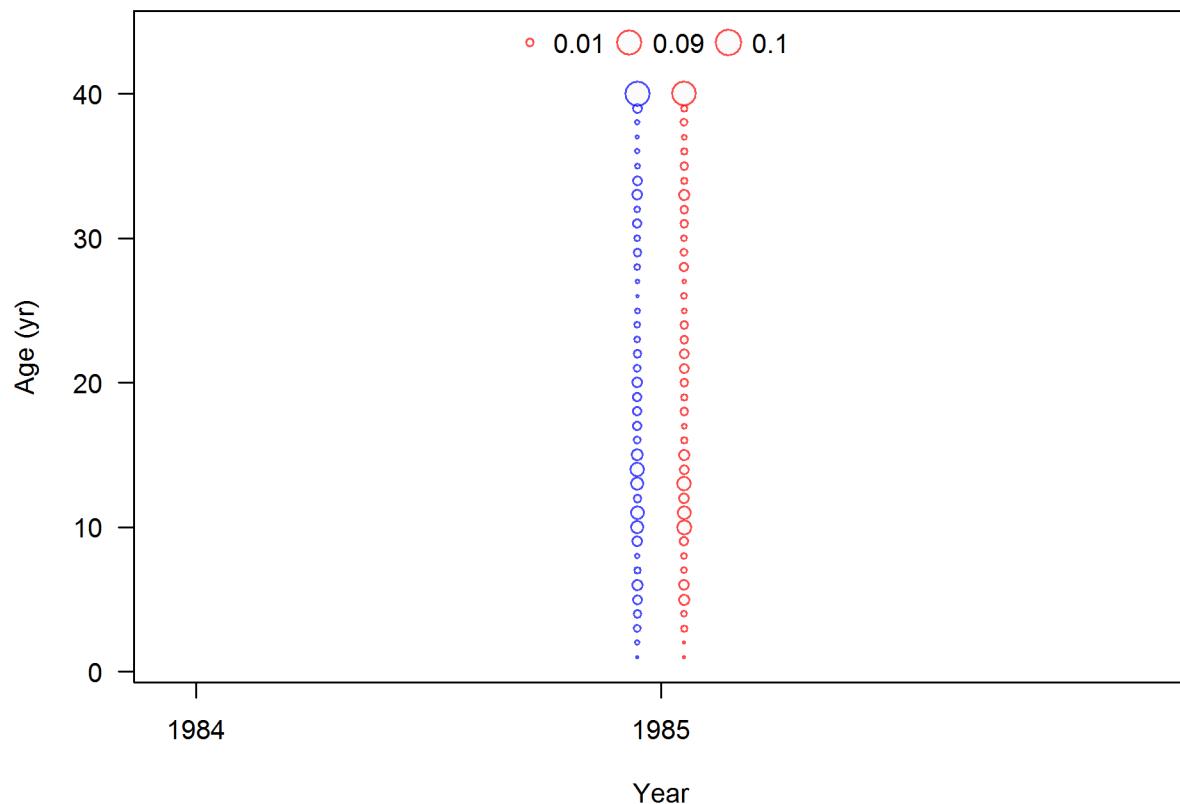


Figure 17: Pacific ocean perch survey age frequency distributions for Pacific ocean perch.

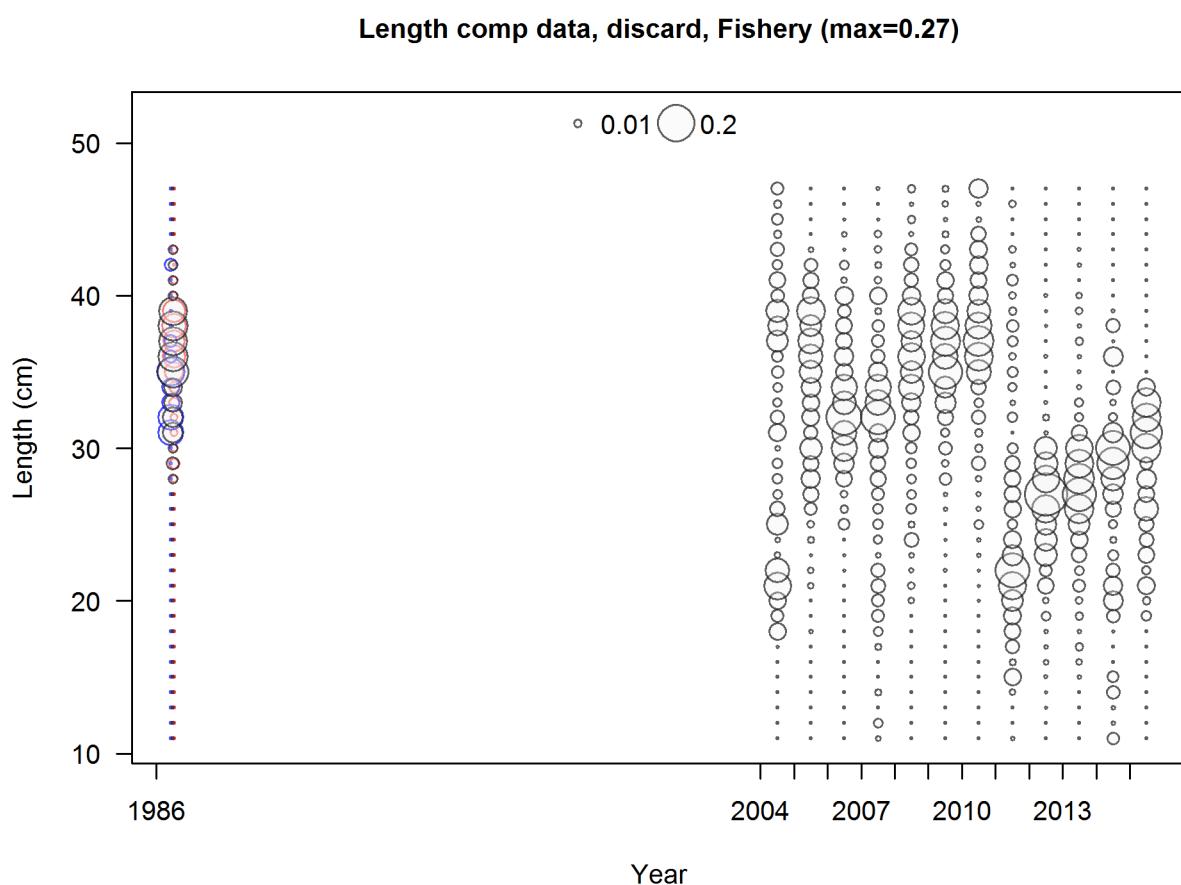


Figure 18: Discard length frequency distributions from WCGOP for Pacific ocean perch.

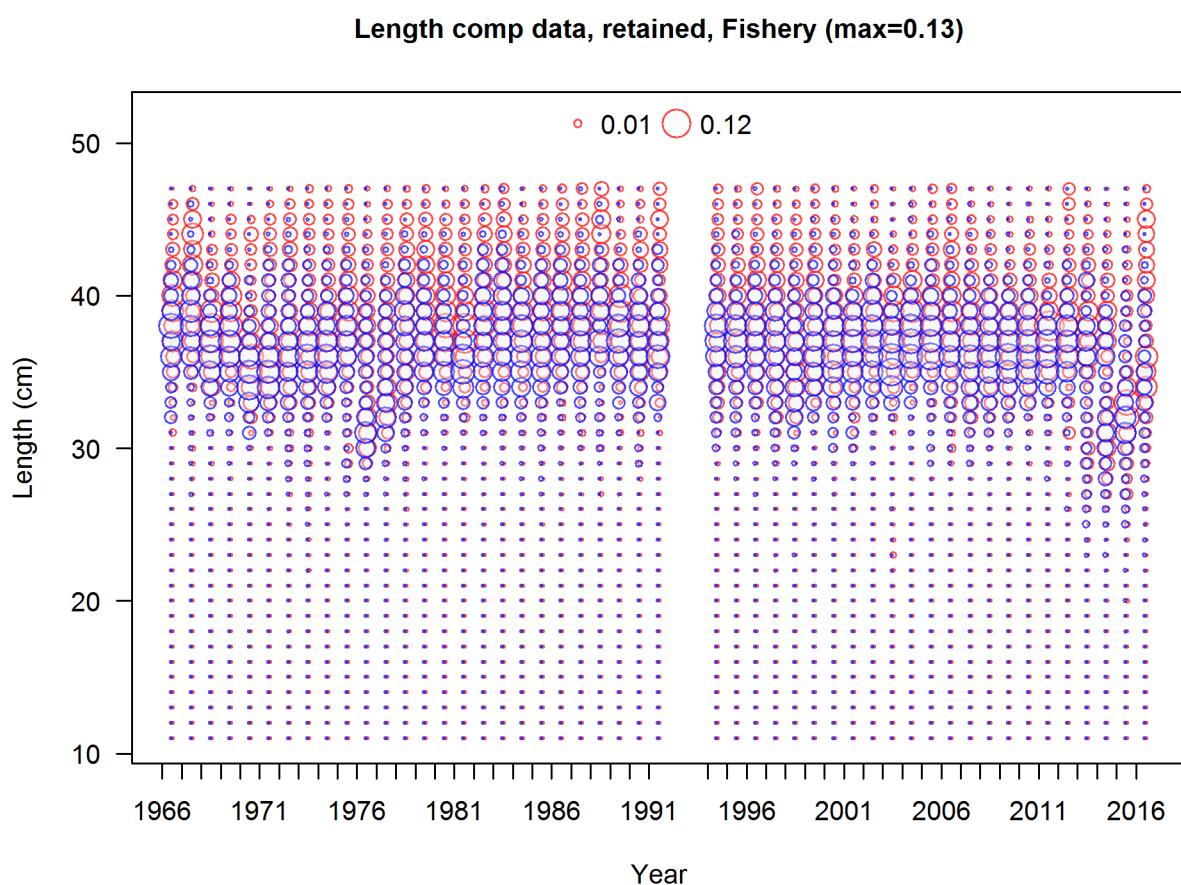


Figure 19: Commercial fishery length frequency distributions for Pacific ocean perch.

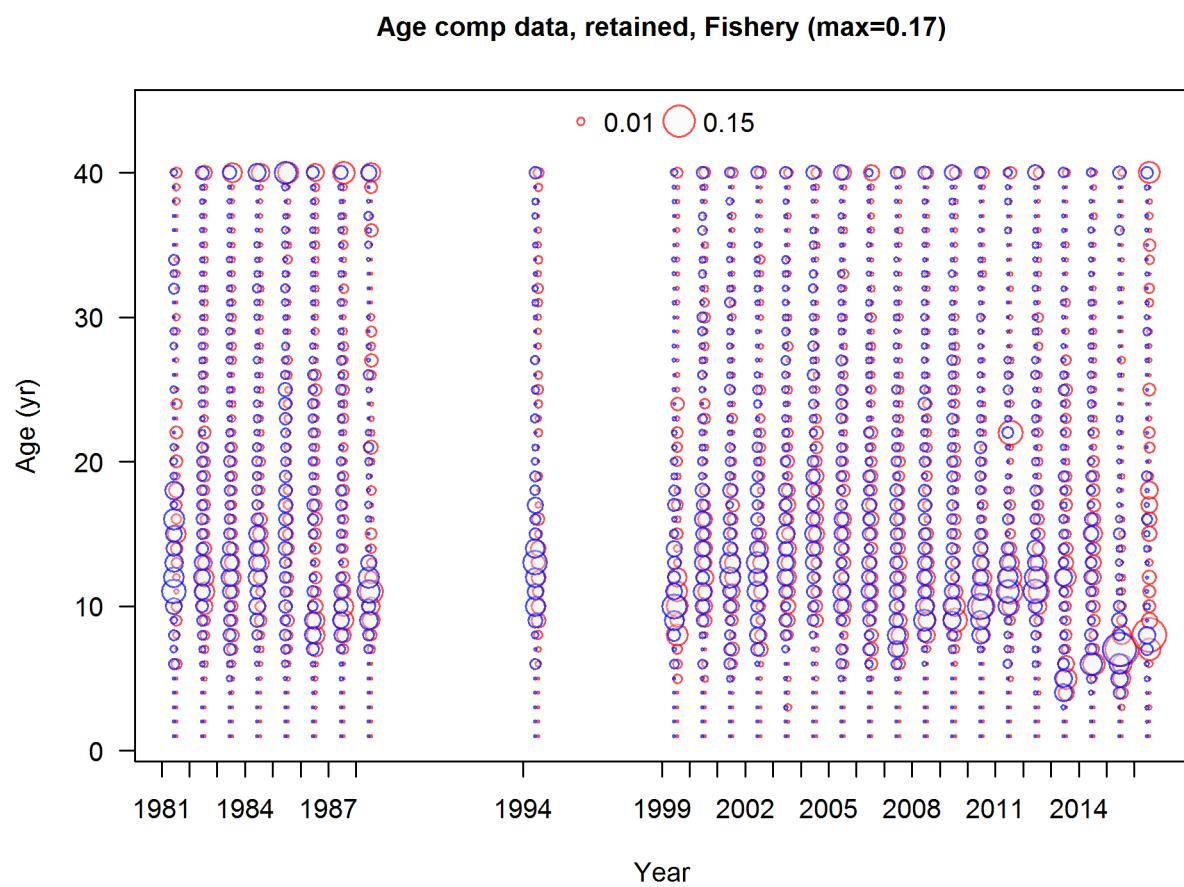


Figure 20: Commercial fishery age frequency distributions for Pacific ocean perch.

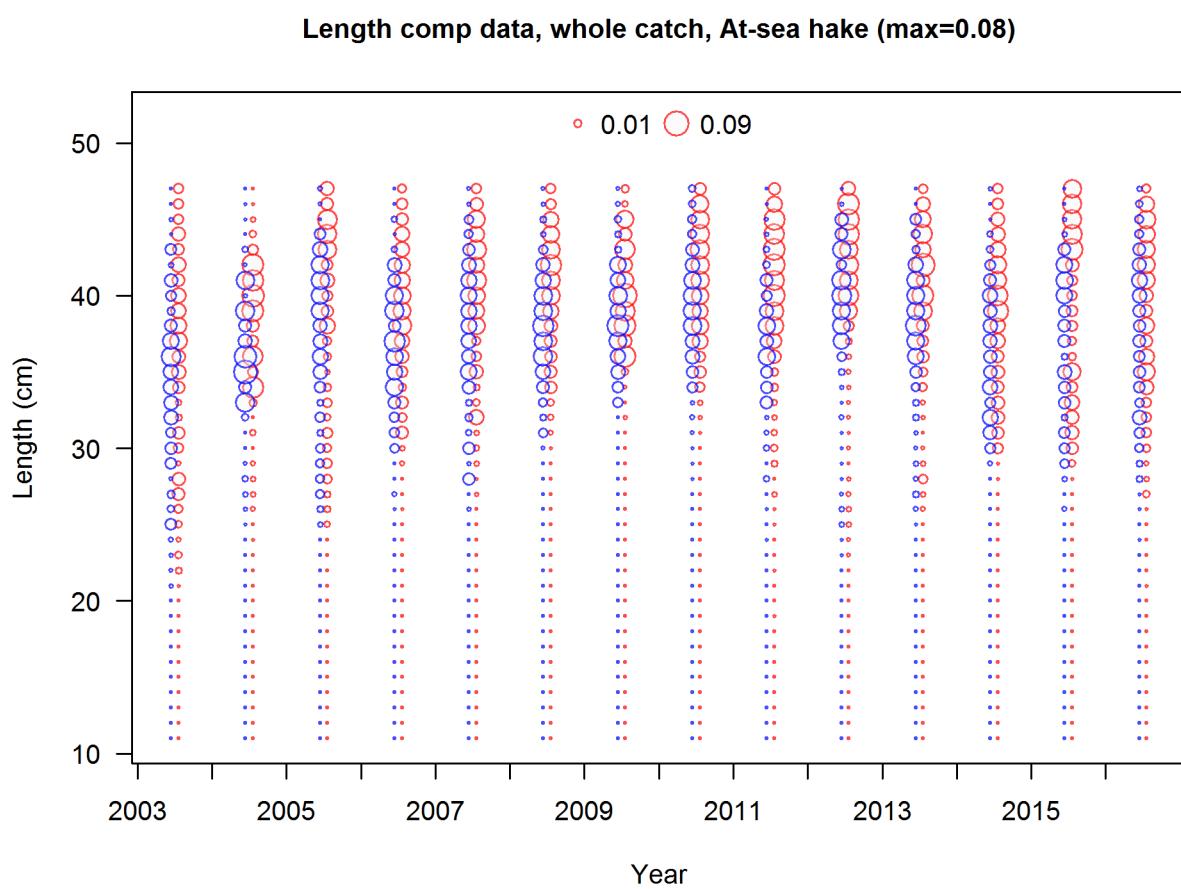


Figure 21: At-sea hake fishery length frequency distributions for Pacific ocean perch.

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

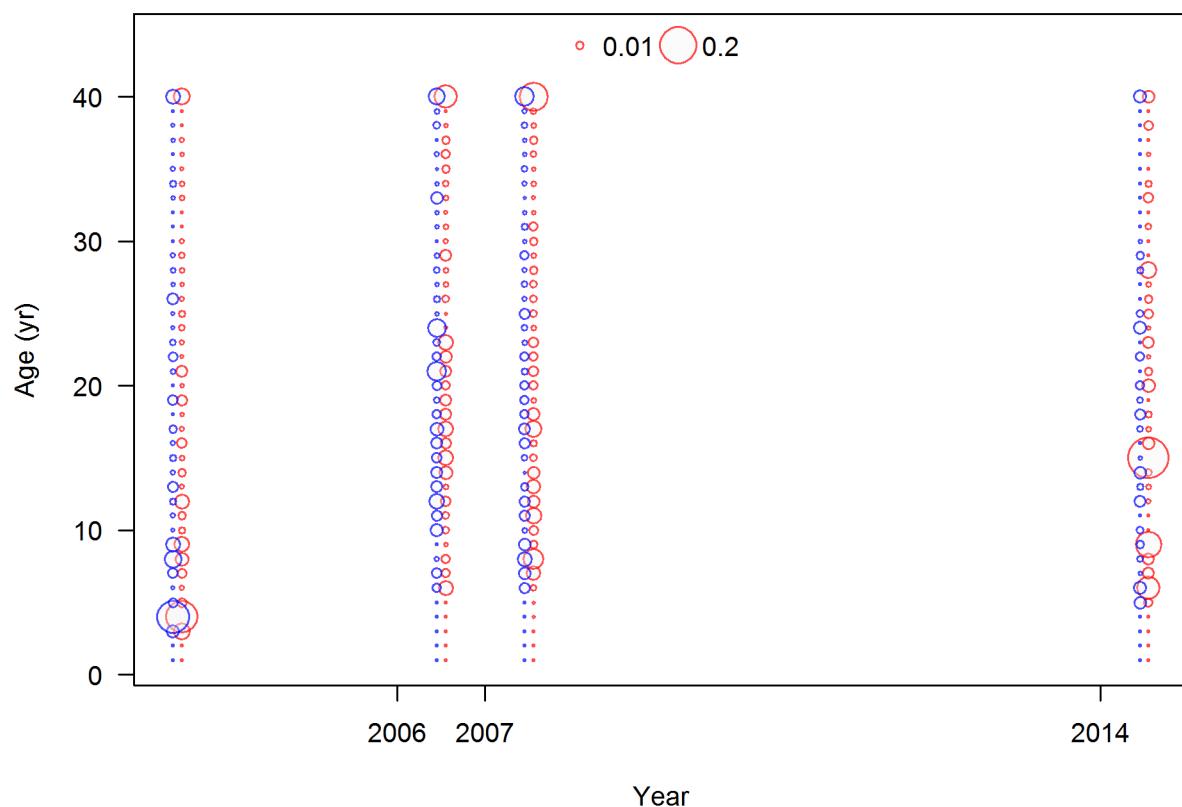


Figure 22: At-sea hake fishery age frequency distributions for Pacific ocean perch.

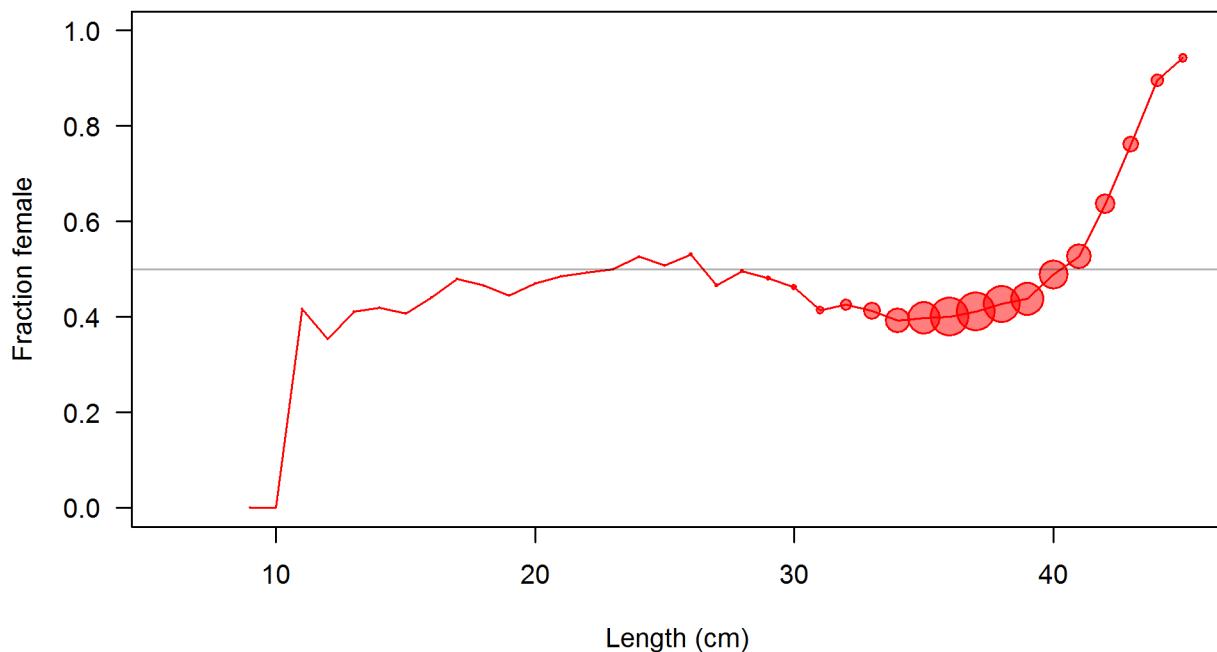


Figure 23: The estimated sex ratio of Pacific ocean perch at length from all biological data sources.

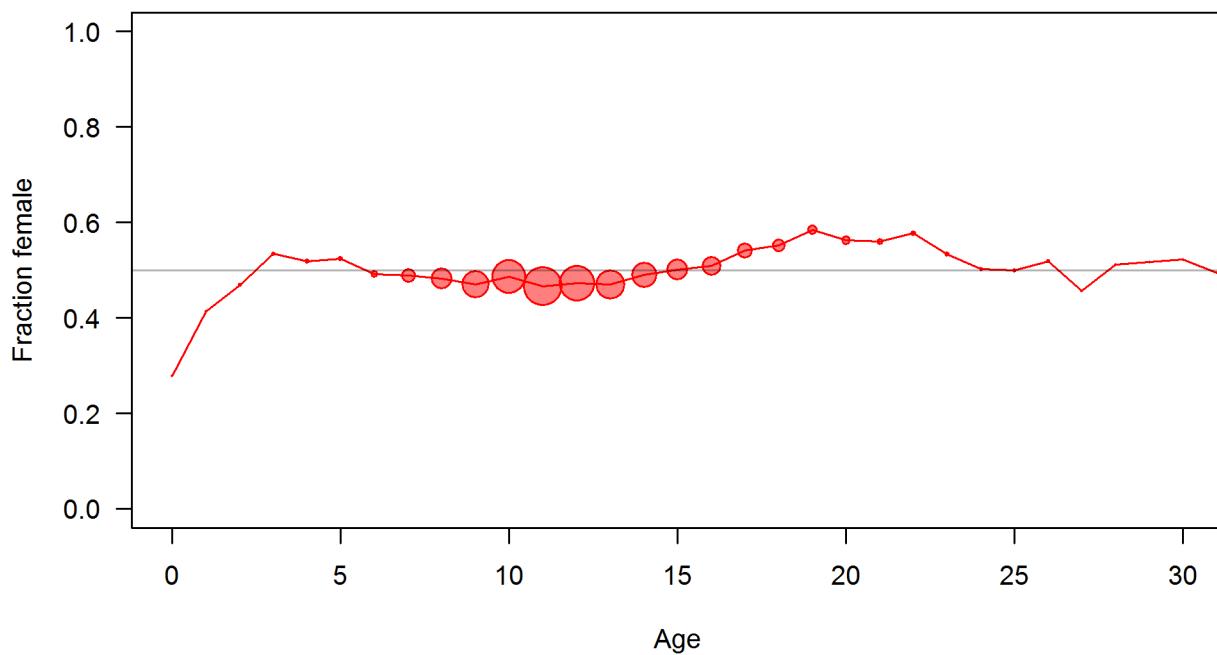


Figure 24: The estimated sex ratio of Pacific ocean perch at age from all biological data sources.

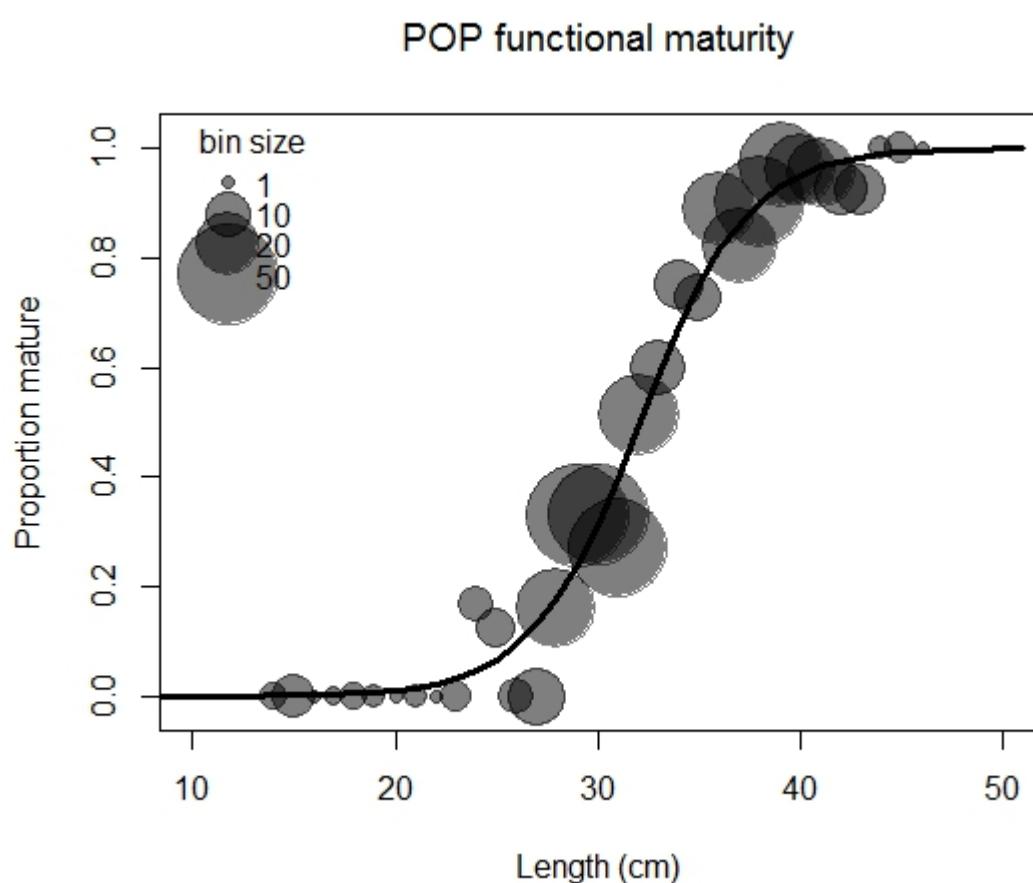
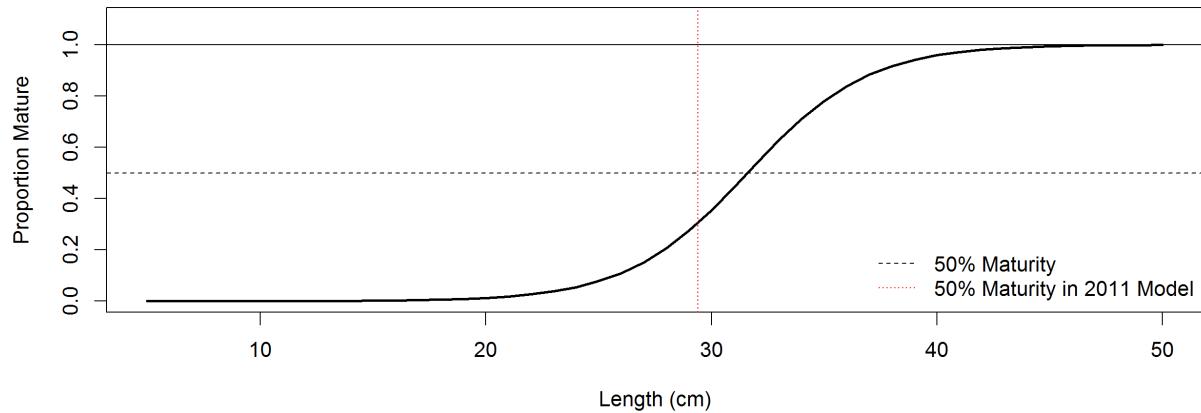


Figure 25: The estimated functional maturity of Pacific ocean perch at length.

Functional Maturity by Length (2017 Assessment)



Maturity by Age (2011 Assessment)

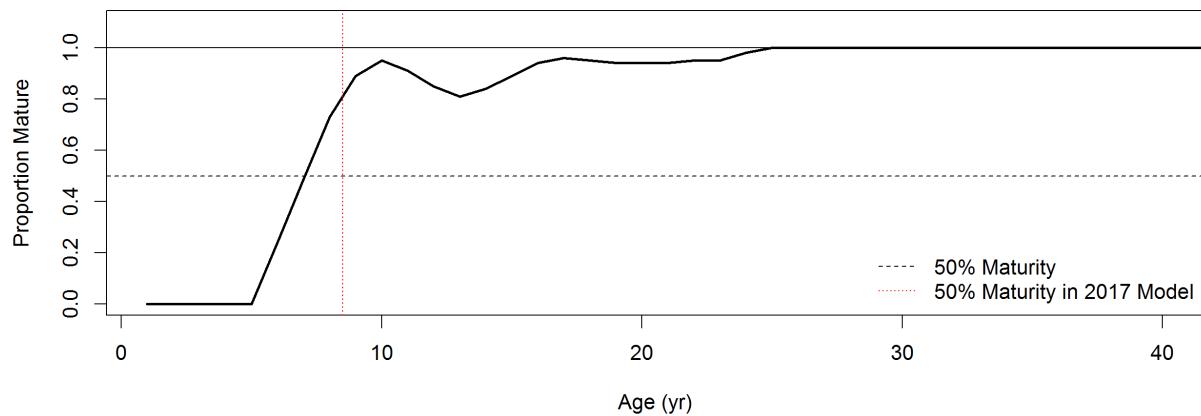


Figure 26: Comparison between estimated maturity-at-length used in this assessment and maturity-at-age applied in the 2011 assessment of Pacific ocean perch.

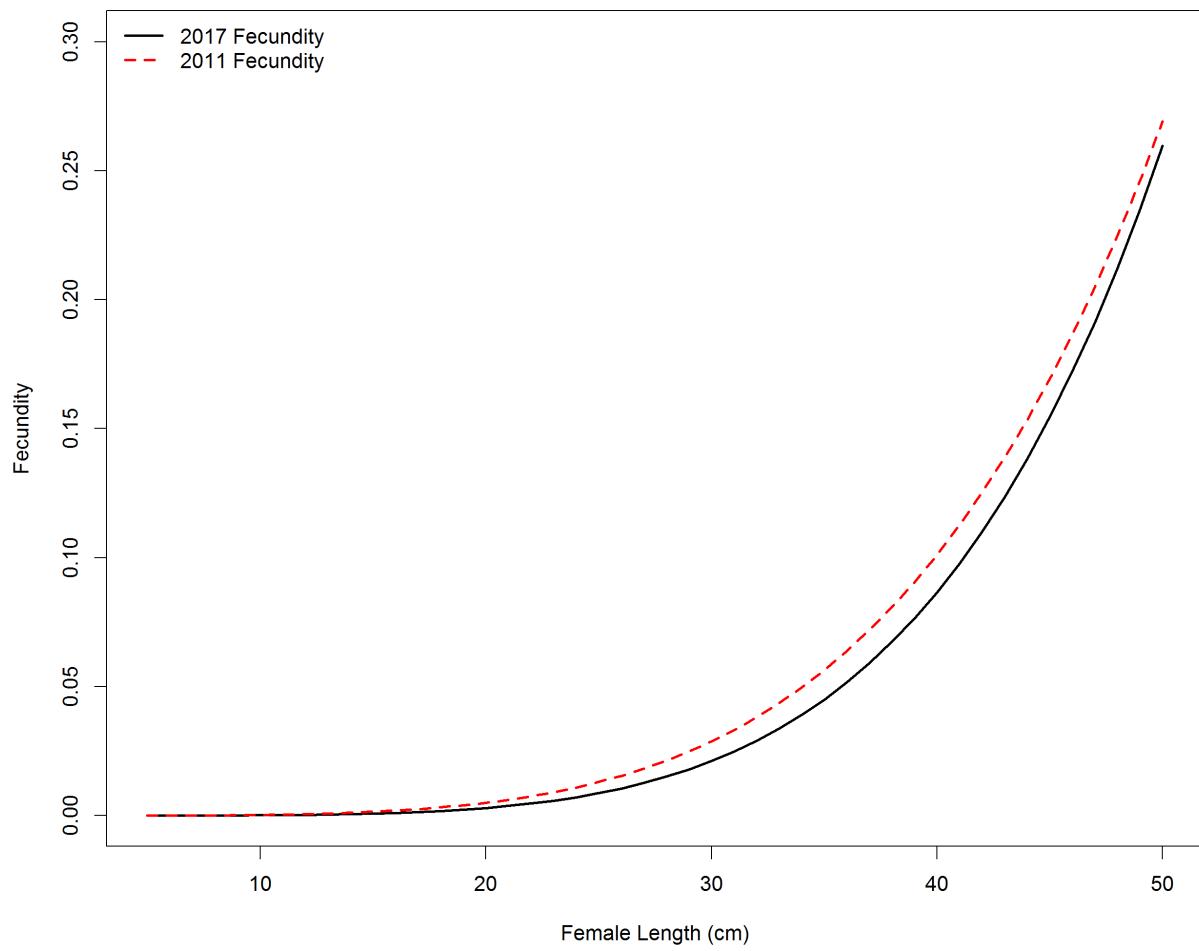


Figure 27: Fecundity at length of Pacific ocean perch in the base model and a comparison of the fecundity in the 2011 assessment.

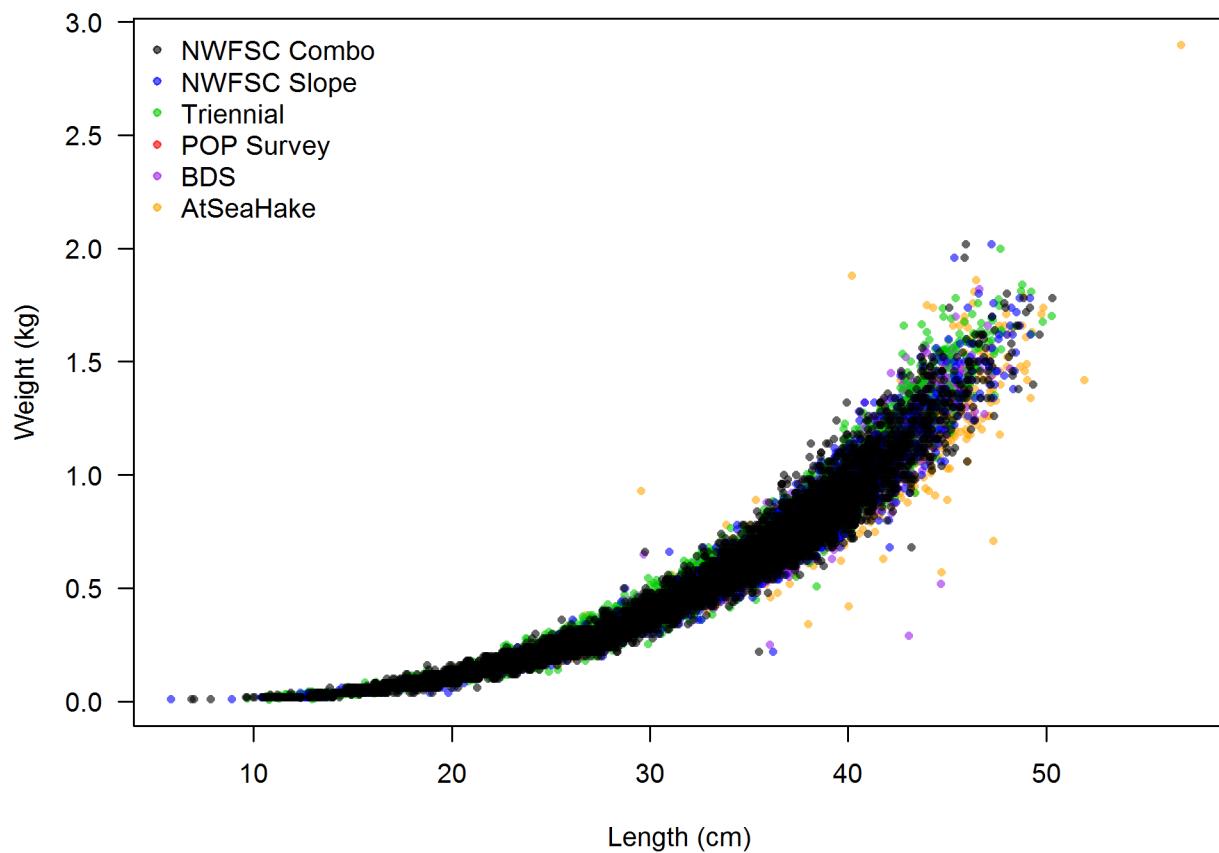


Figure 28: Weight-at-length for Pacific ocean perch from all data sources.

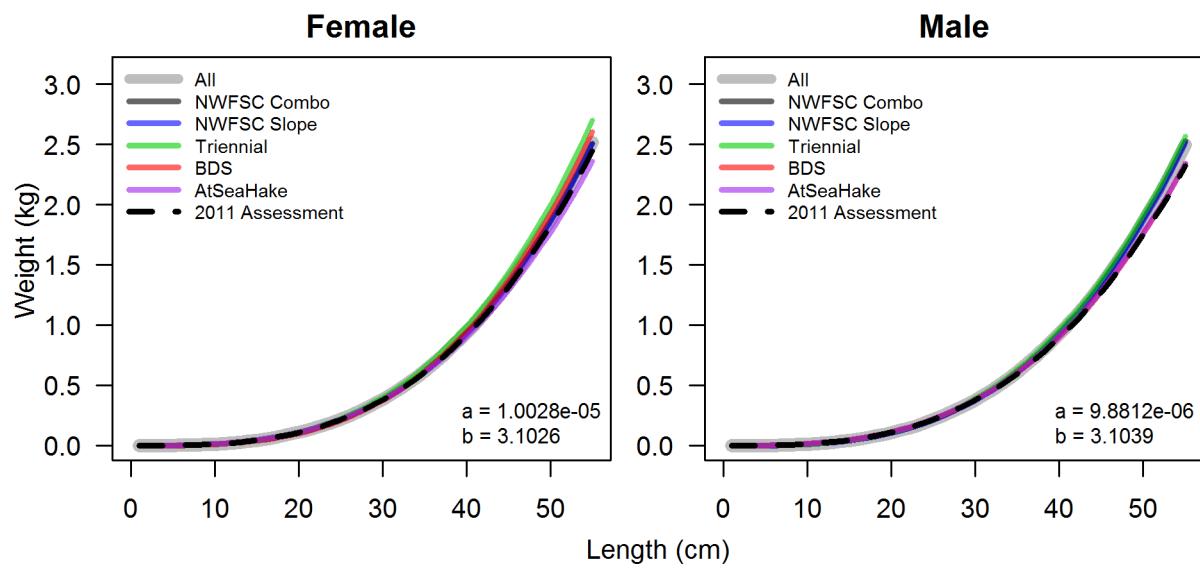


Figure 29: Estimated weight-at-length for Pacific ocean perch from all data sources.

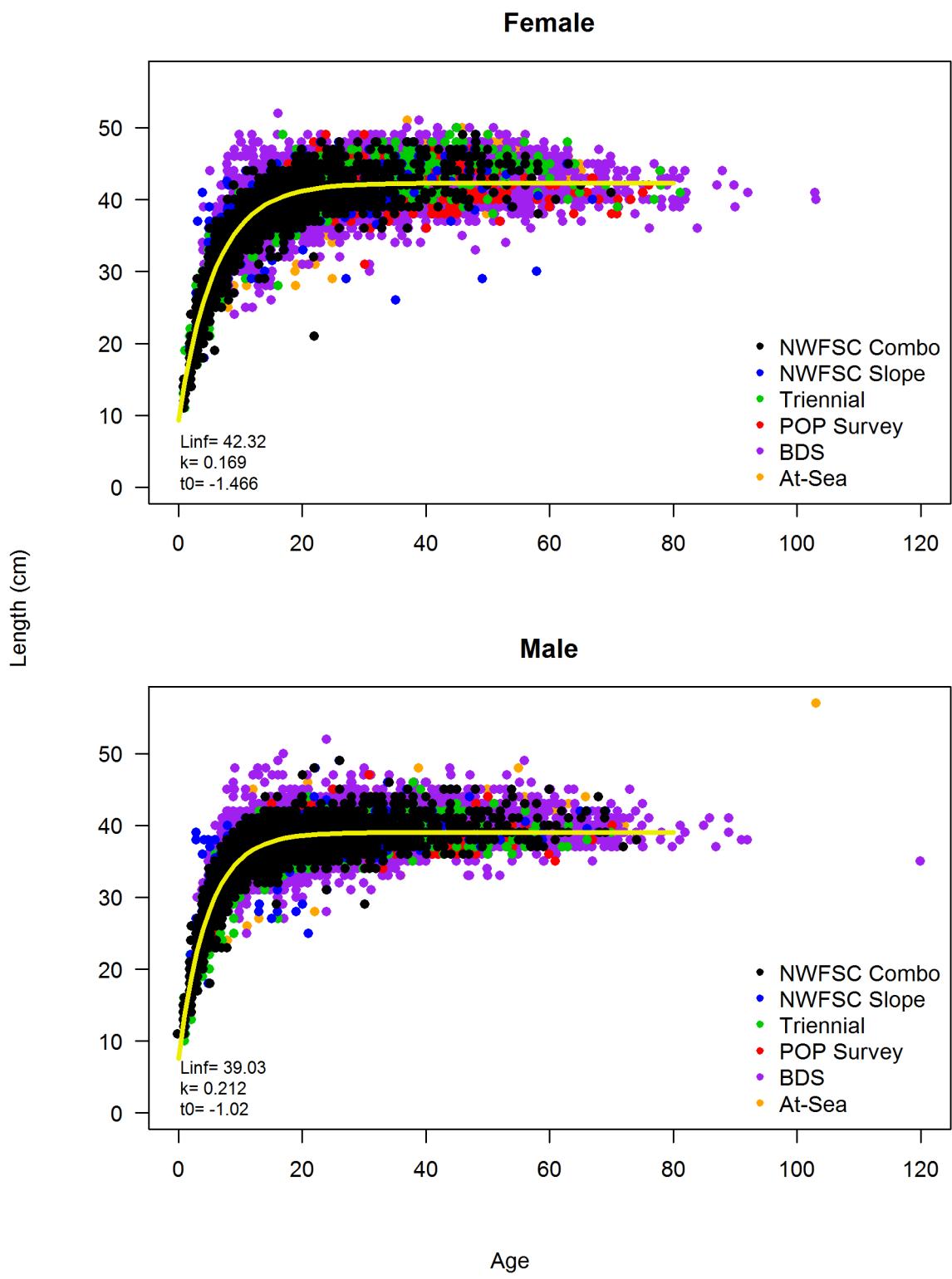


Figure 30: Estimated length-at-age for Pacific ocean perch from all data sources.

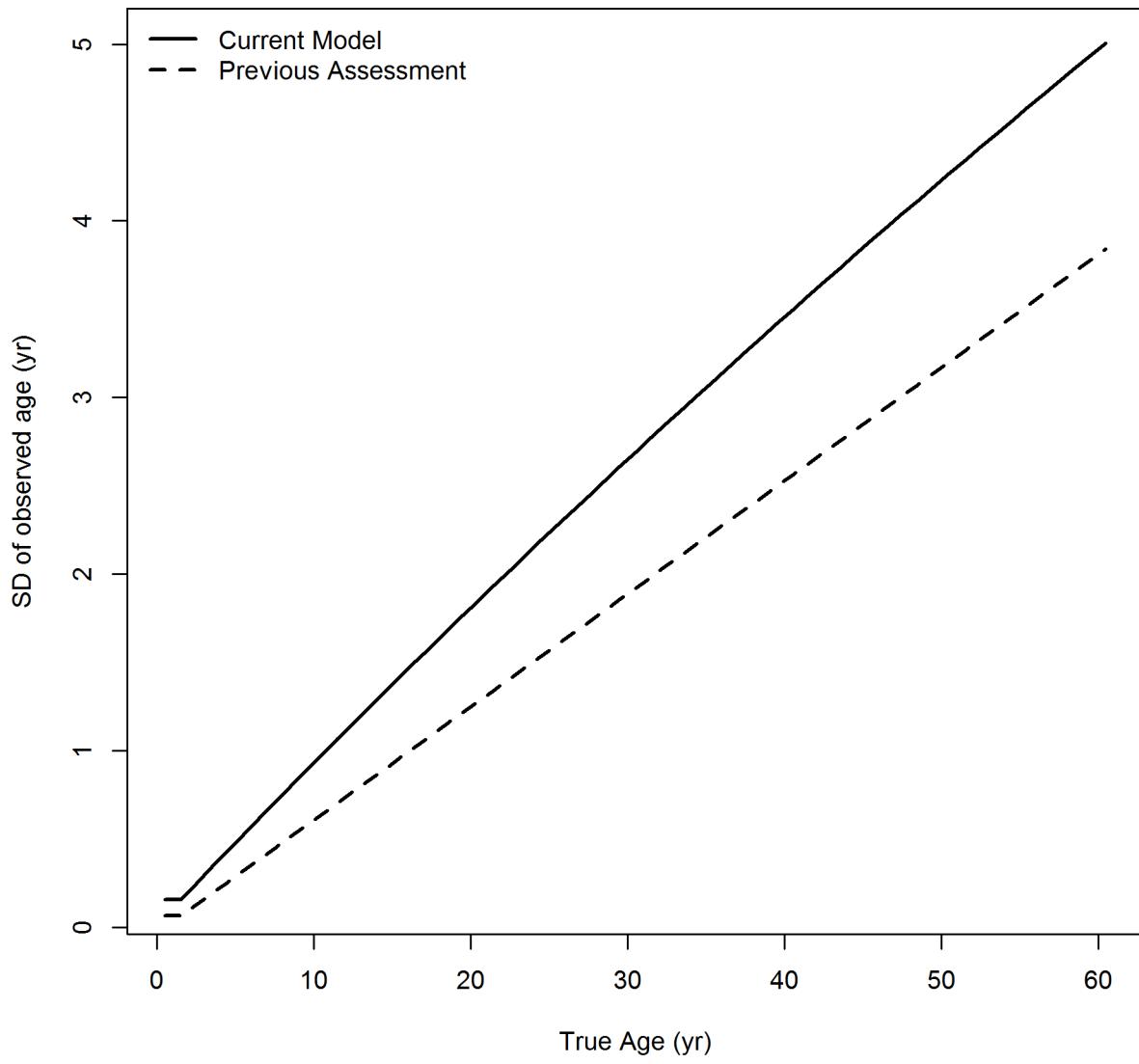


Figure 31: The estimated ageing error used in this assessment compared to the ageing error assumed in the previous assessment for Pacific ocean perch.

1295 *Recruitment bias ramp applied in the base model.*

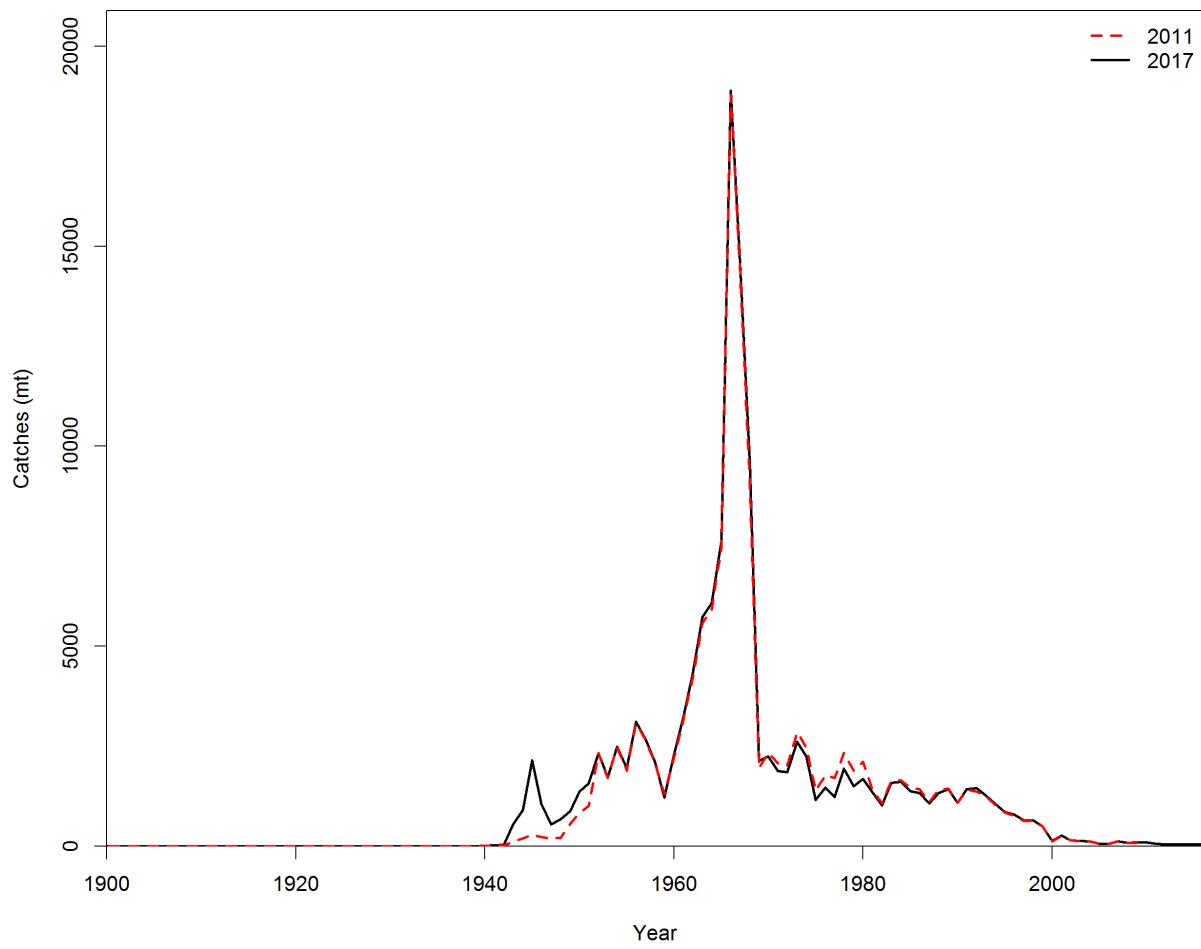


Figure 32: Comparison of the catches assumed by this assessment and the previous assessment for Pacific ocean perch.

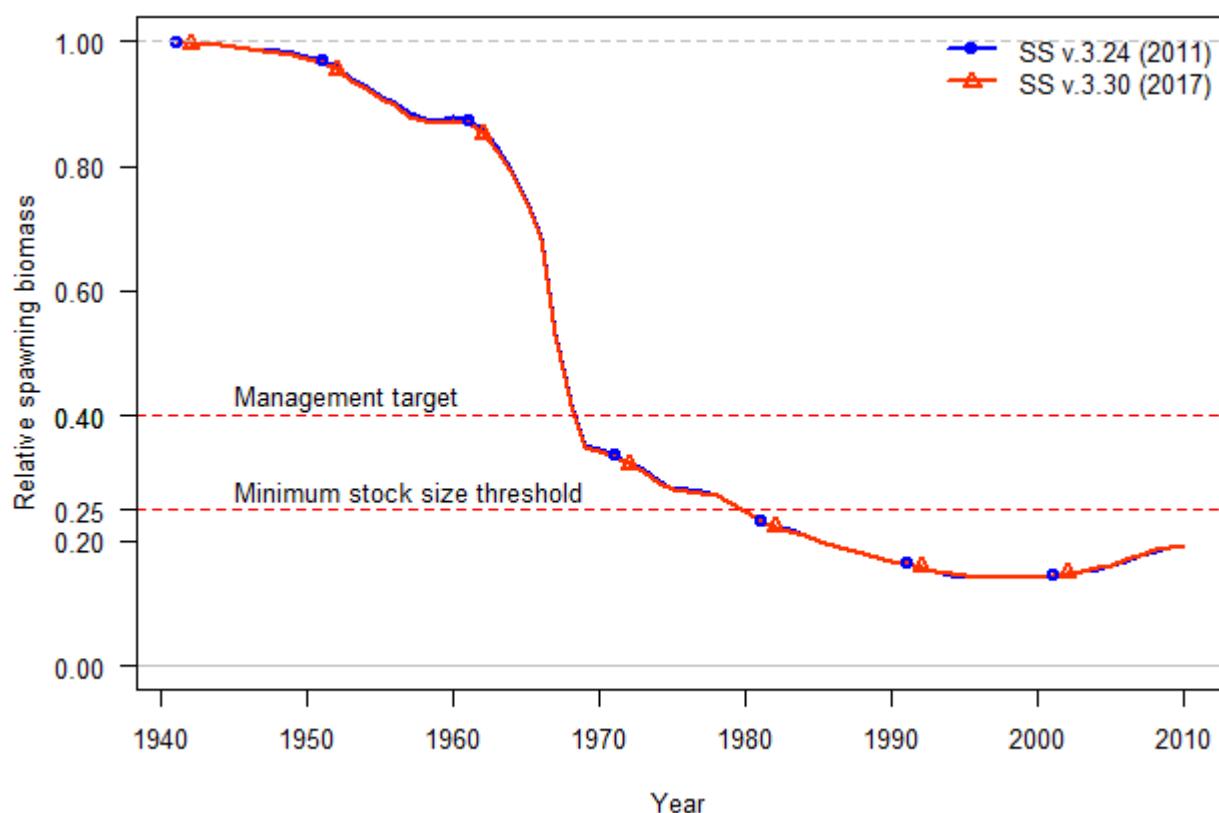
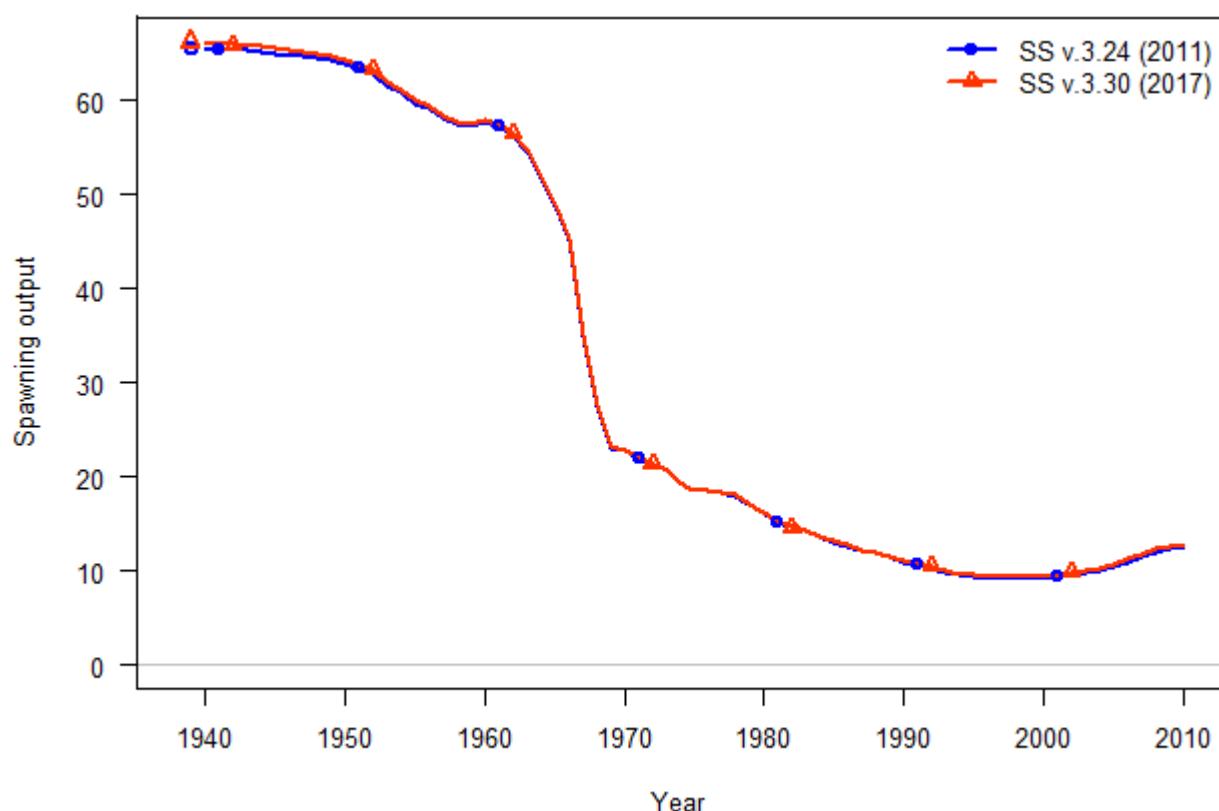


Figure 33: Comparison of estimates from Stock Synthesis version 3.30 and 3.24 for Pacific ocean perch.
98

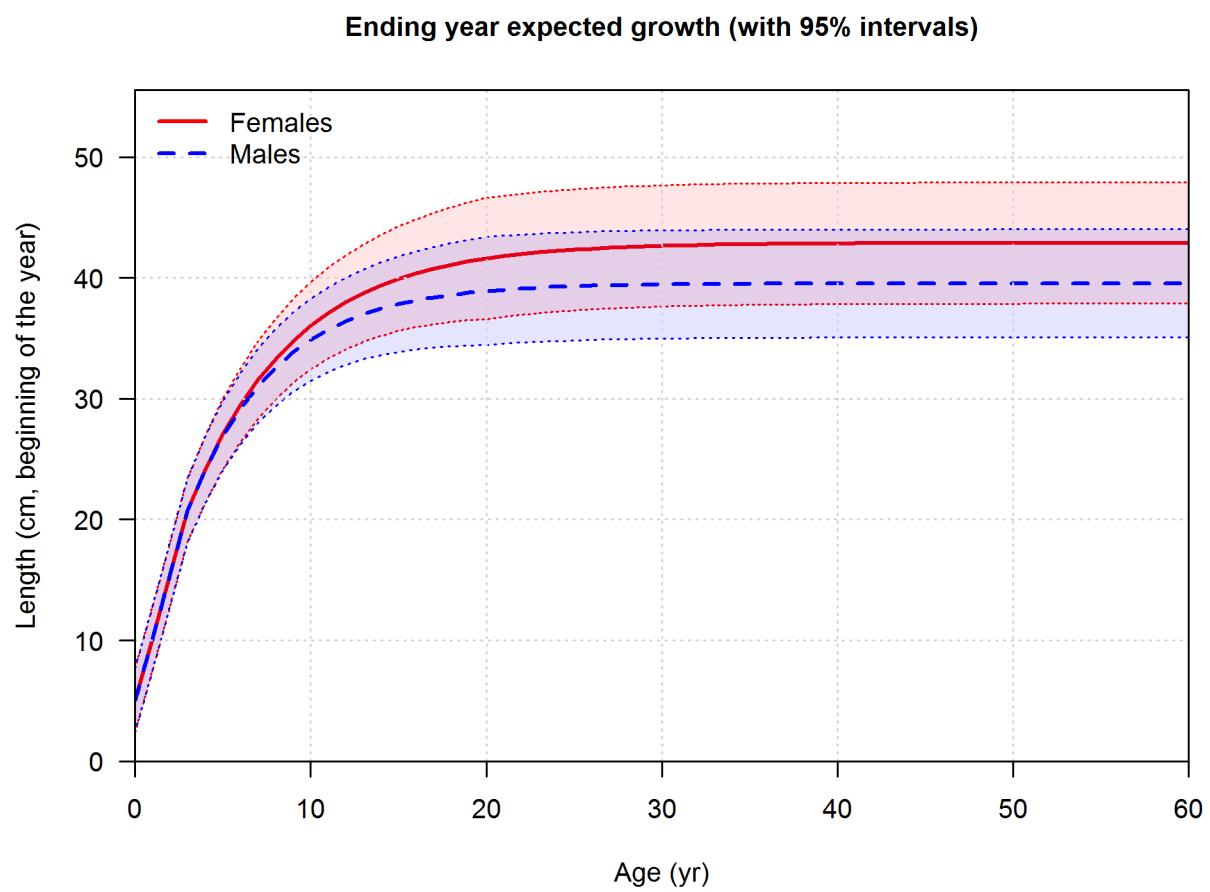


Figure 34: Estimated length-at-age for male and female for Pacific ocean perch with estimated CV.

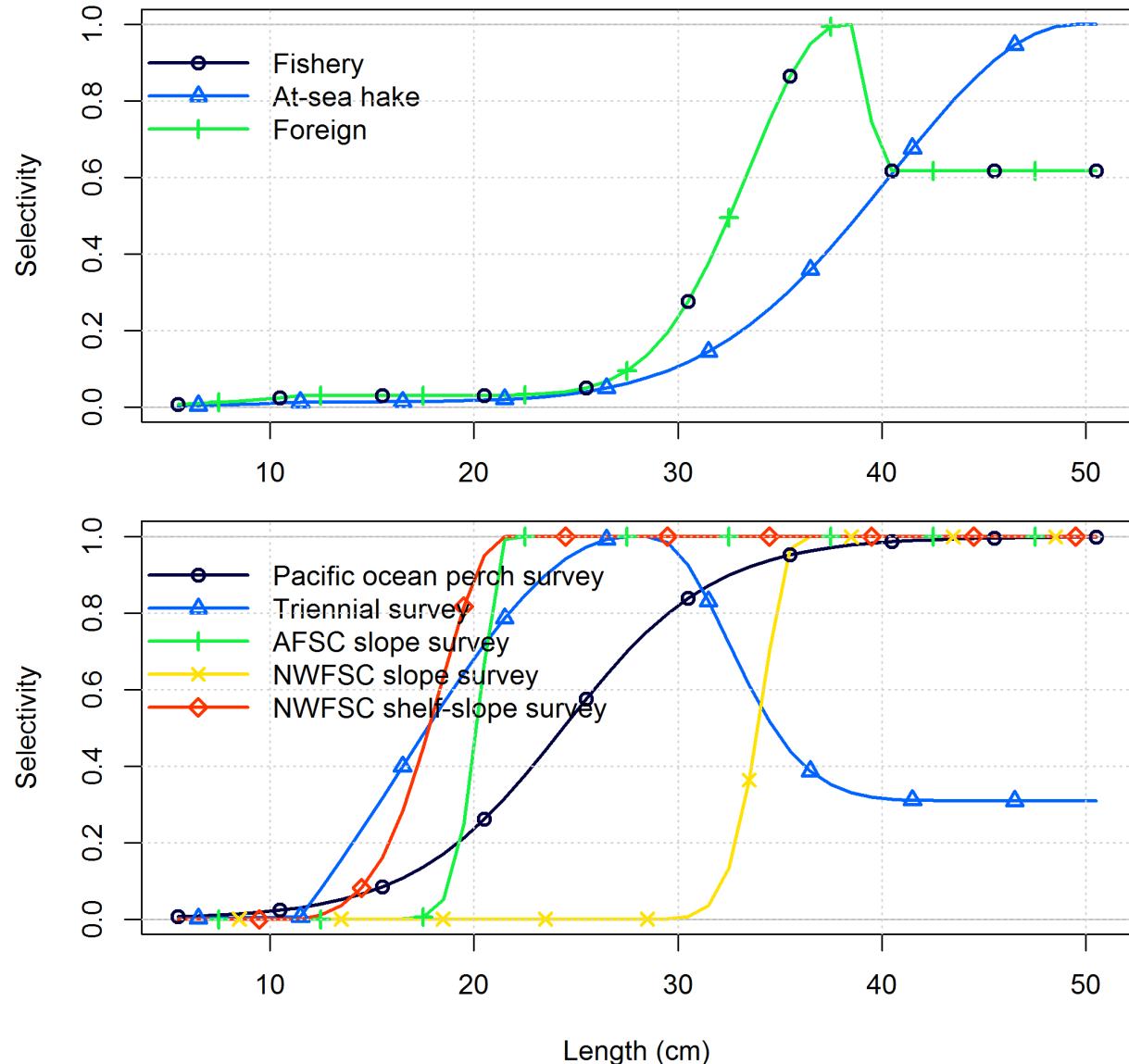


Figure 35: Estimated selectivity by length by each fishery and survey for Pacific ocean perch.

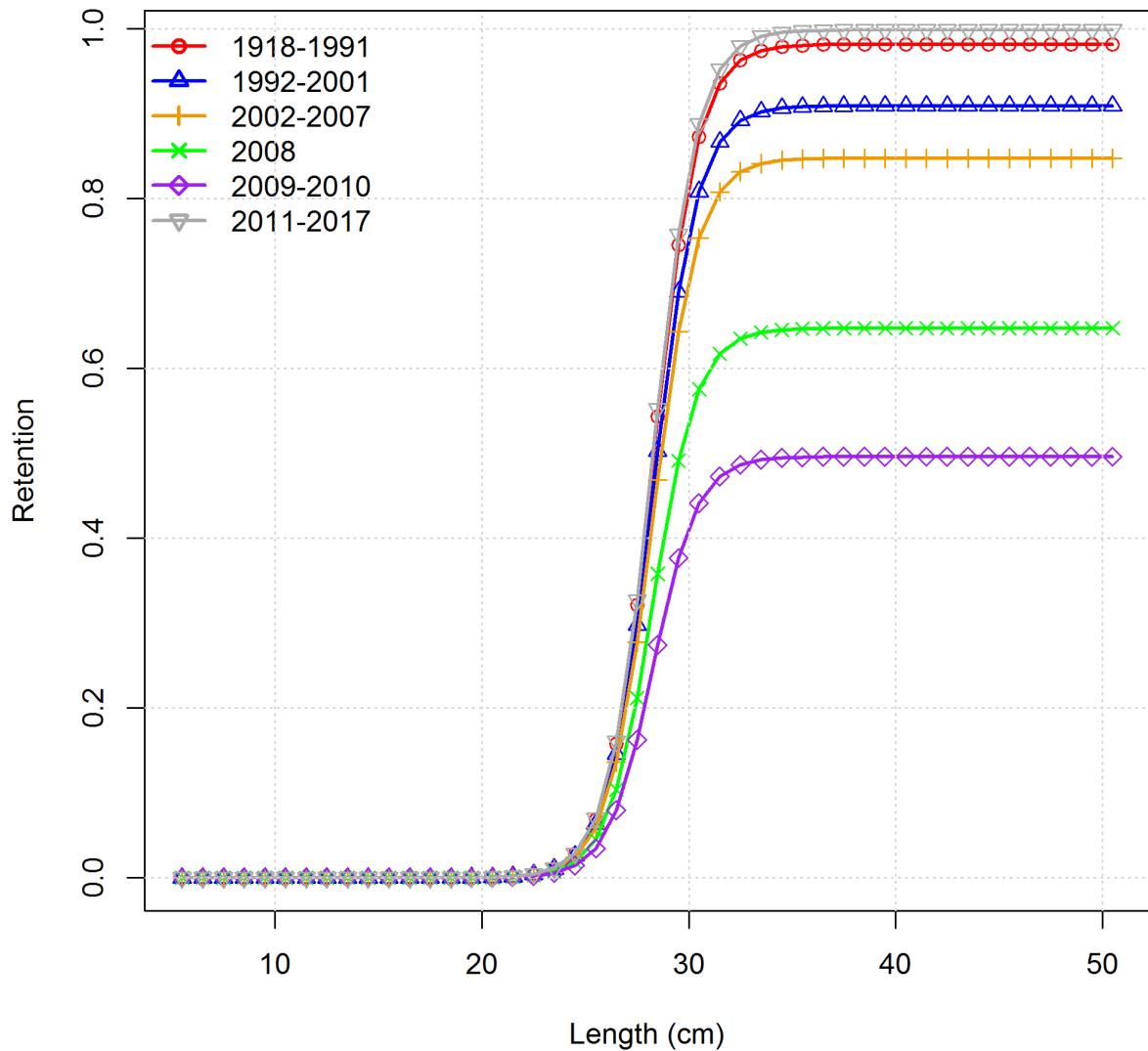


Figure 36: Estimated retention by length by the fishery fleet for Pacific ocean perch.

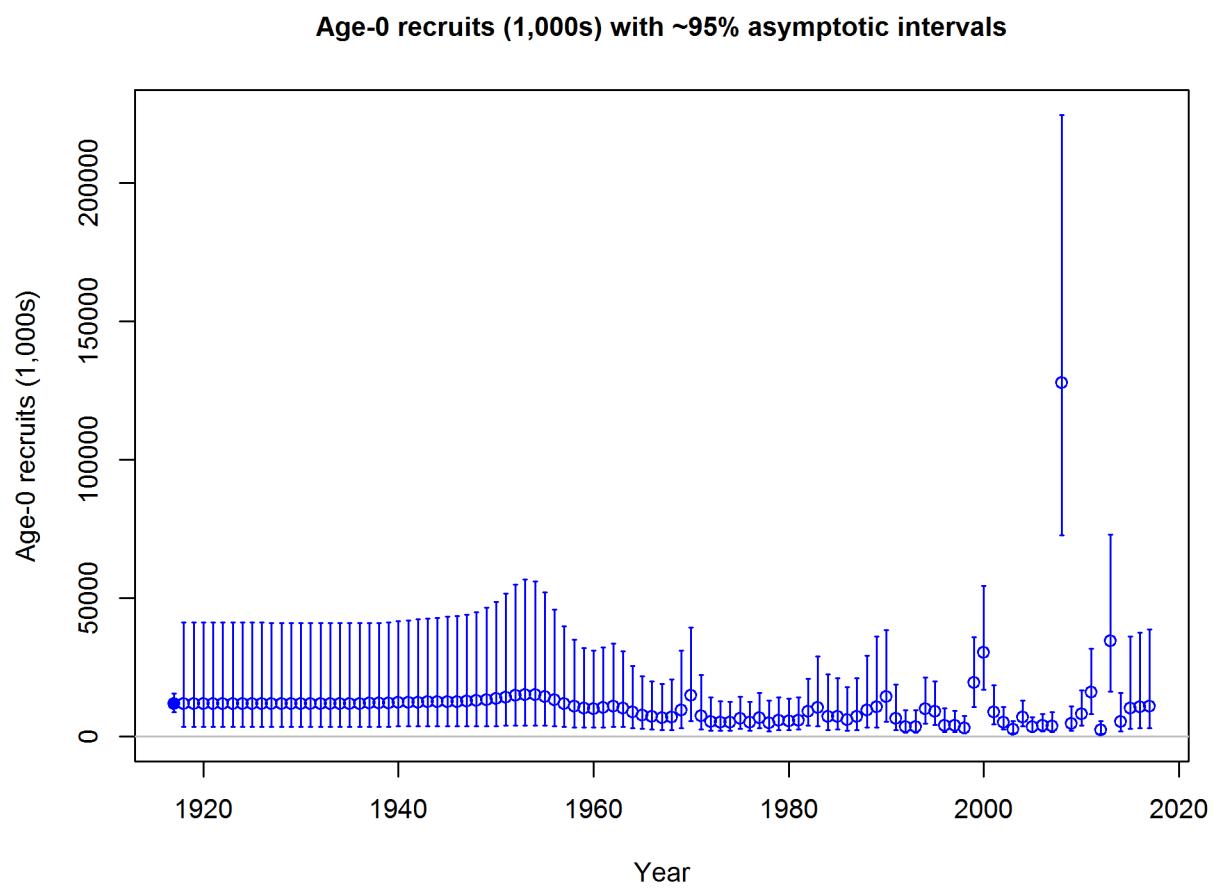


Figure 37: Estimated time-series of recruitment for Pacific ocean perch.

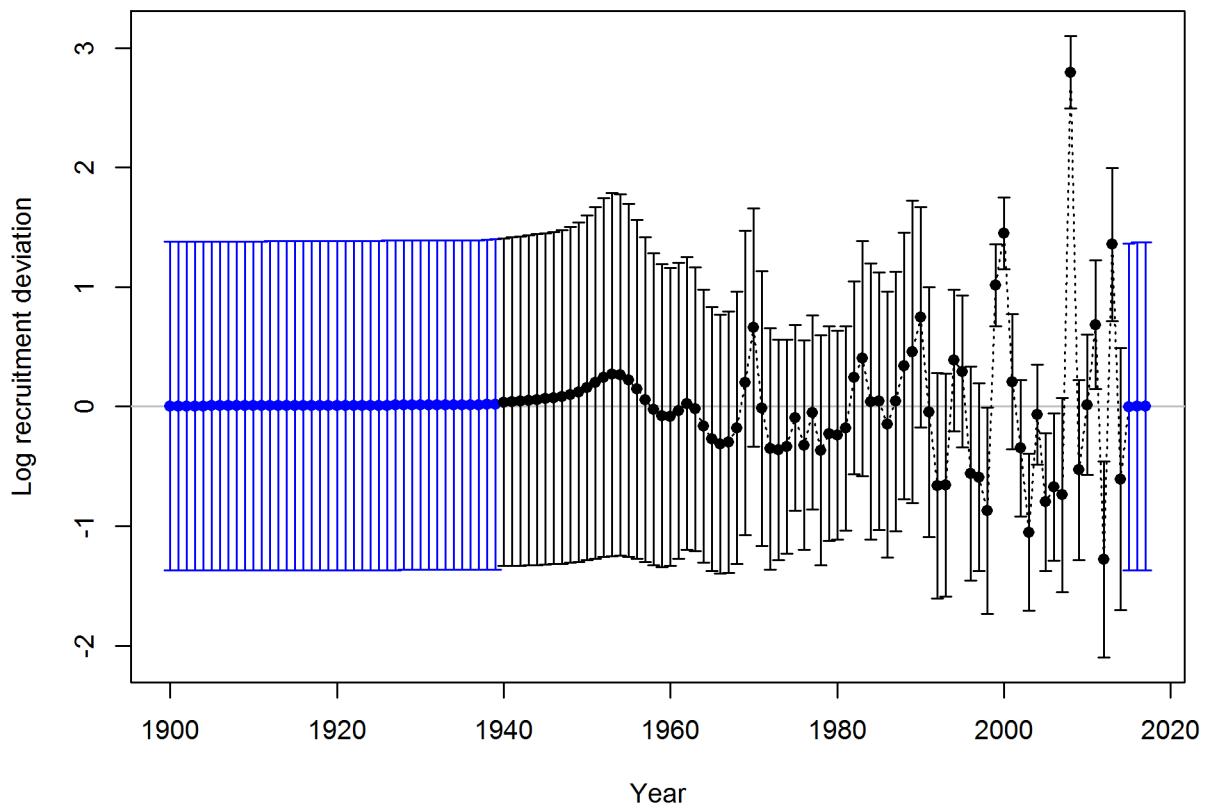


Figure 38: Estimated time-series of recruitment deviations for Pacific ocean perch.

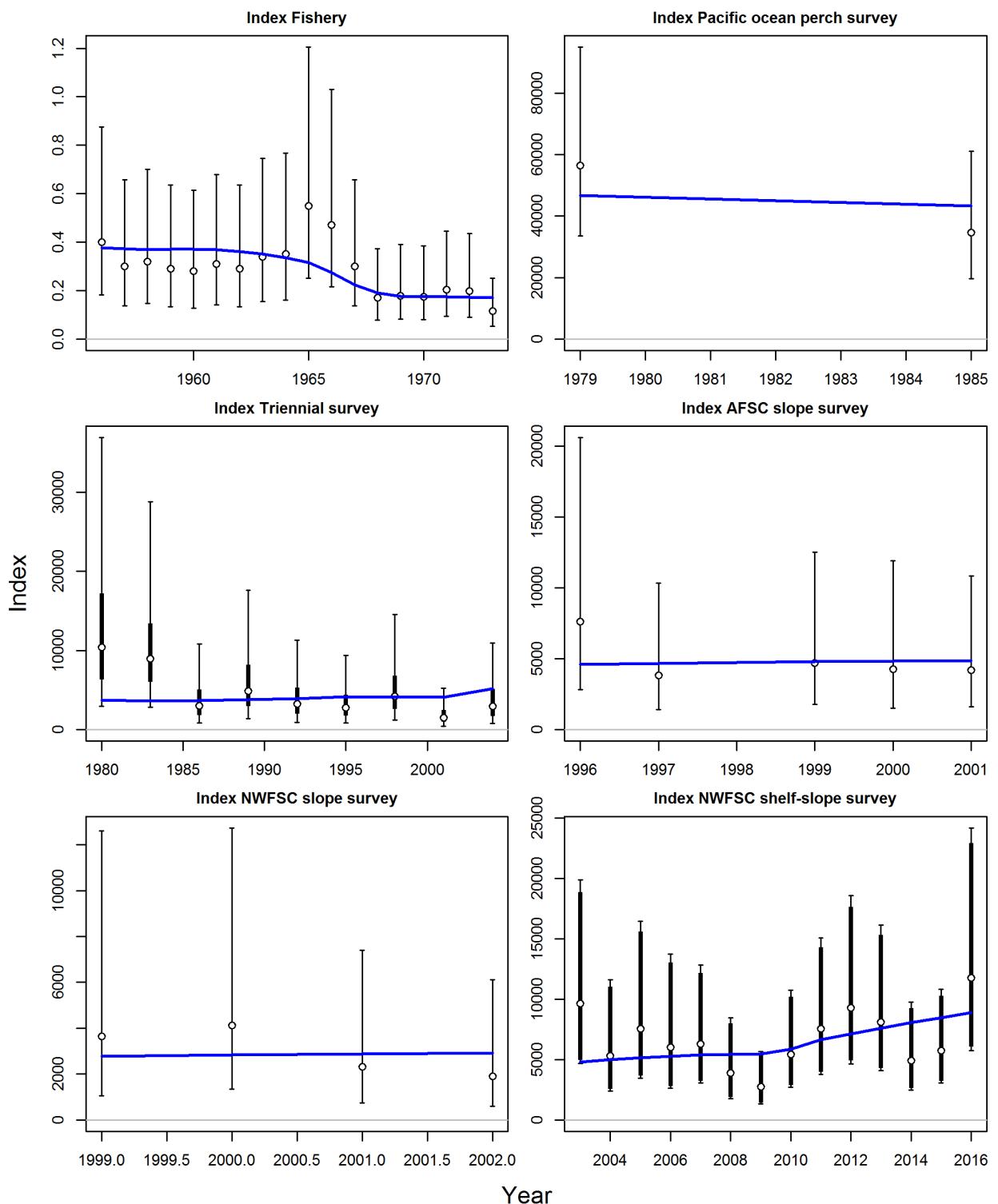


Figure 39: Estimated fits to the CPUE and survey indices for Pacific ocean perch.

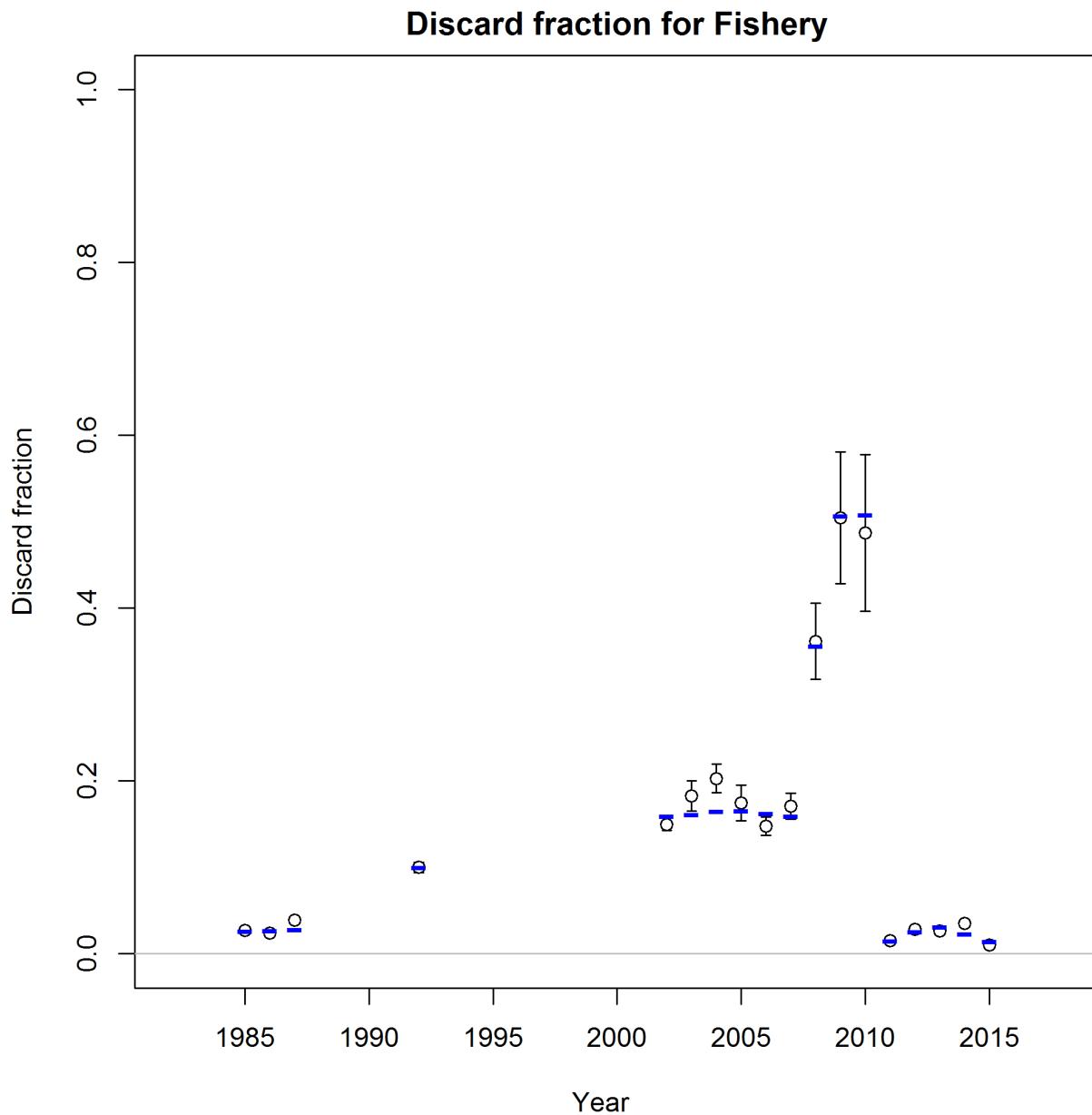


Figure 40: Estimated fits to the discard rates for Pacific ocean perch.

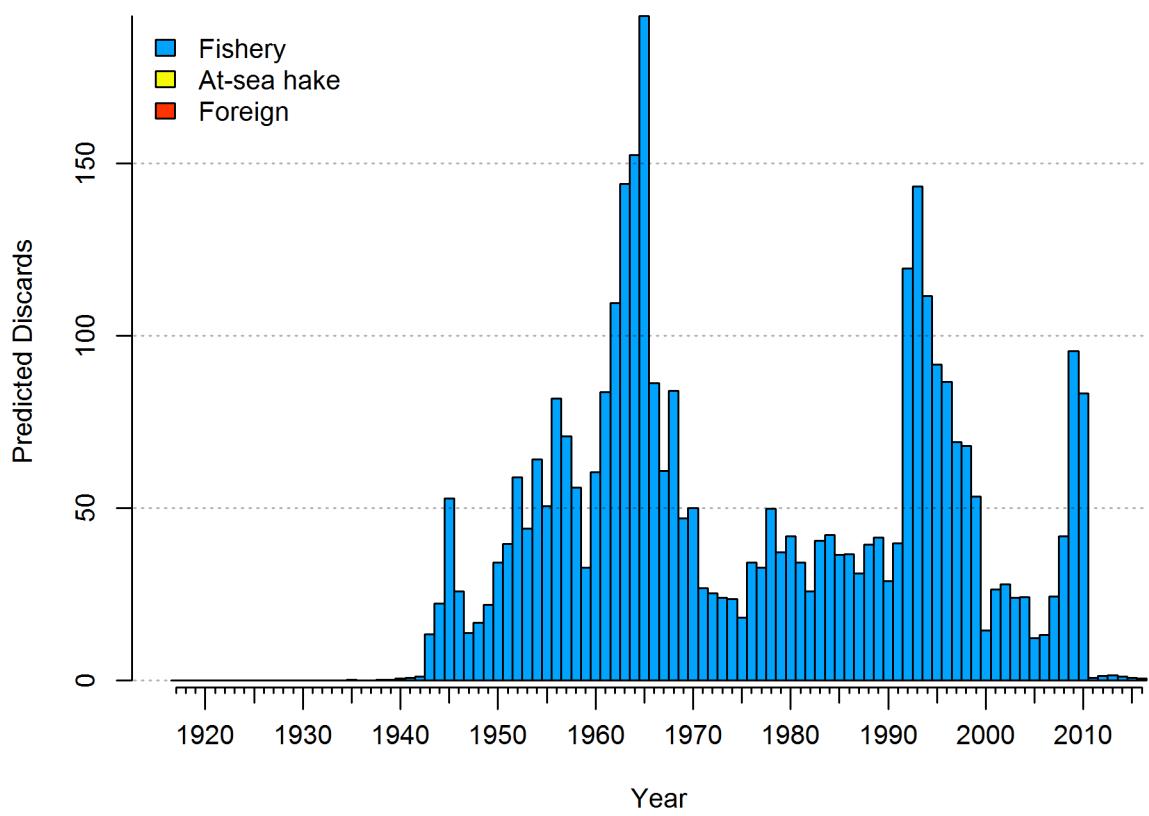


Figure 41: Estimated total discards for Pacific ocean perch.

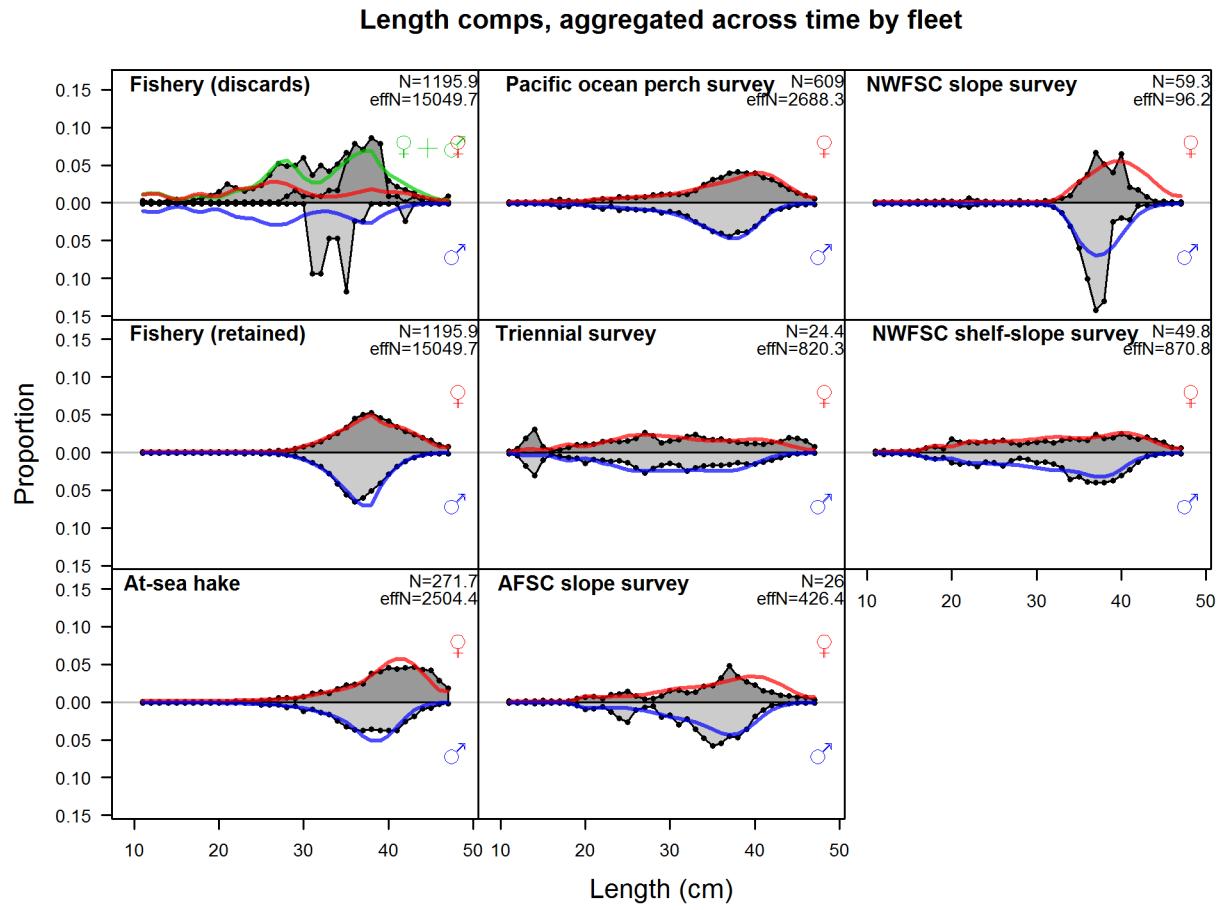


Figure 42: Length compositions aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate retained or discarded samples for each fleet. Panels without this designation represent the whole catch.

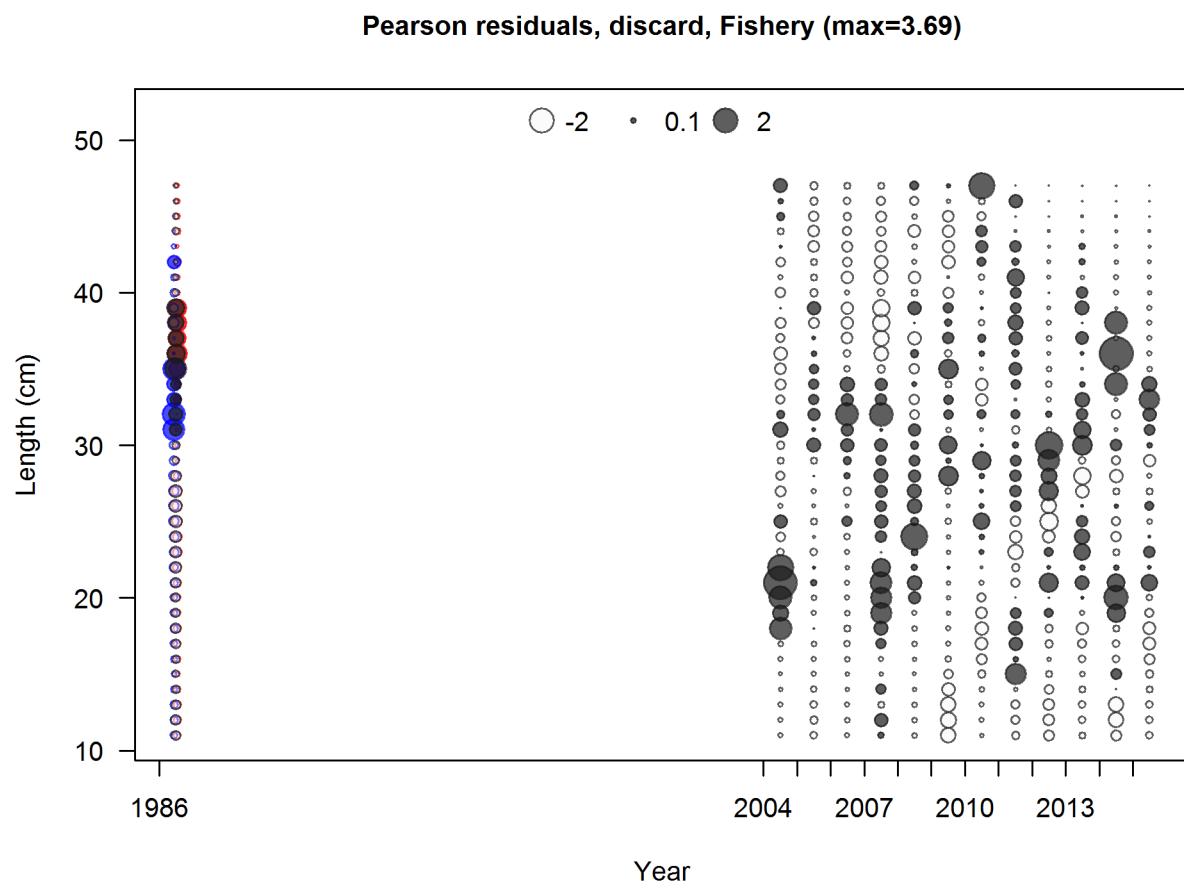


Figure 43: Pearson residuals, discard, Fishery (max=3.69)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

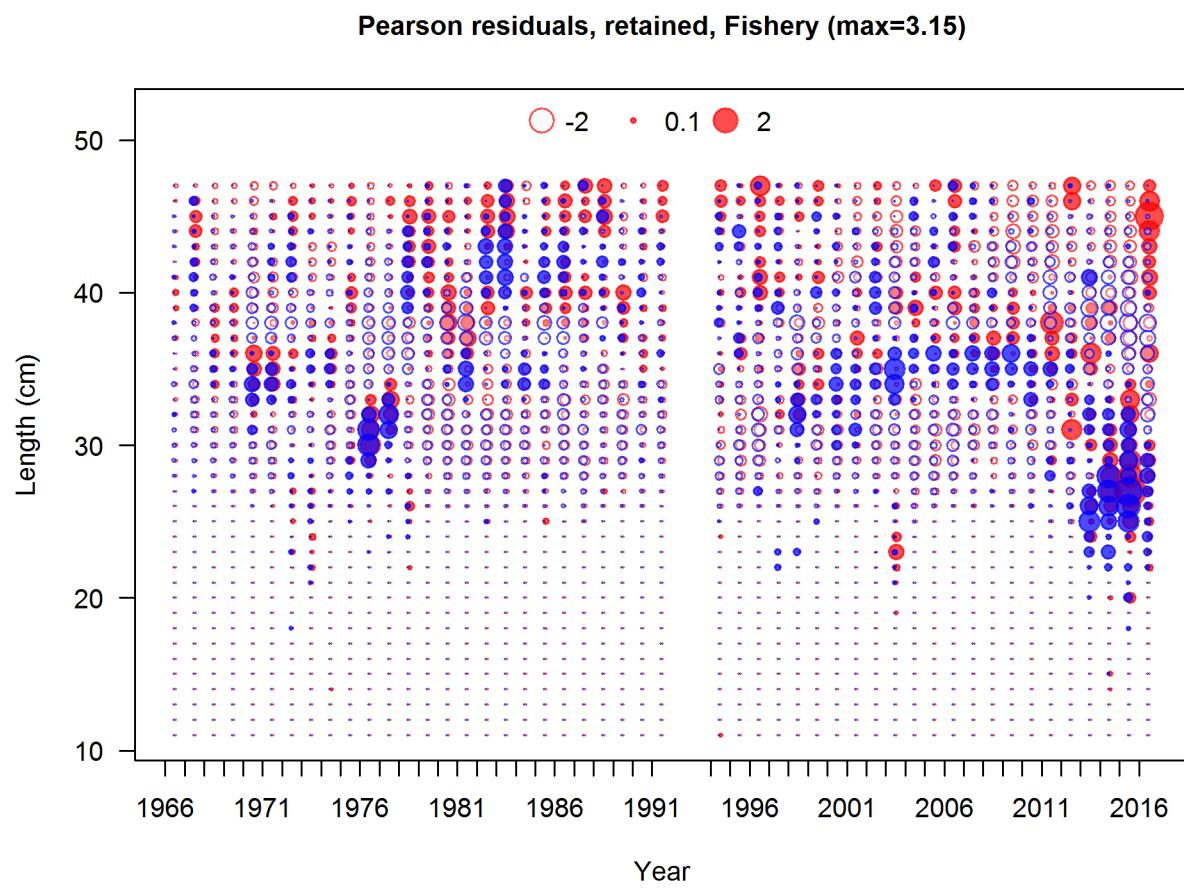


Figure 44: Pearson residuals, retained, Fishery (max=3.15) (plot 4 of 4)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

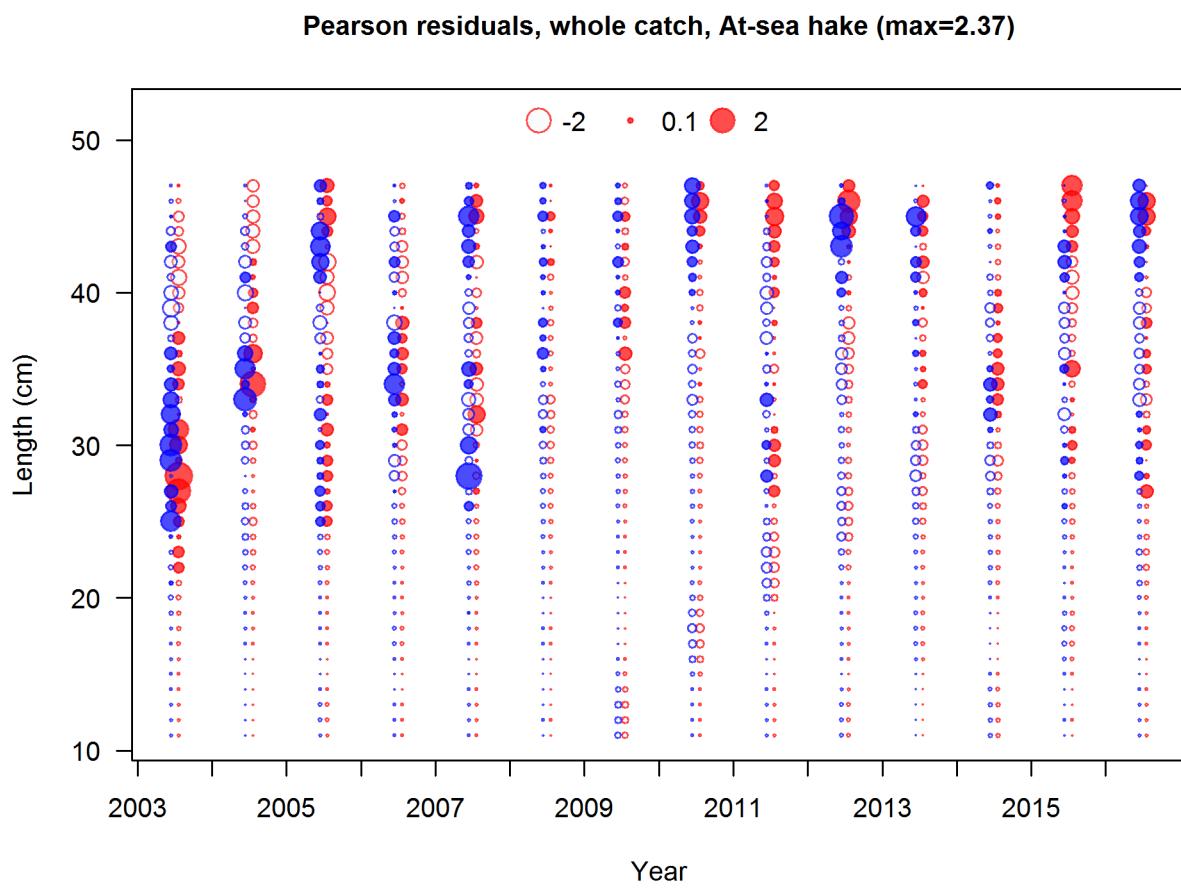


Figure 45: Pearson residuals, whole catch, At_sea hake (max=2.37)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

Pearson residuals, whole catch, Pacific ocean perch survey (max=1.76)

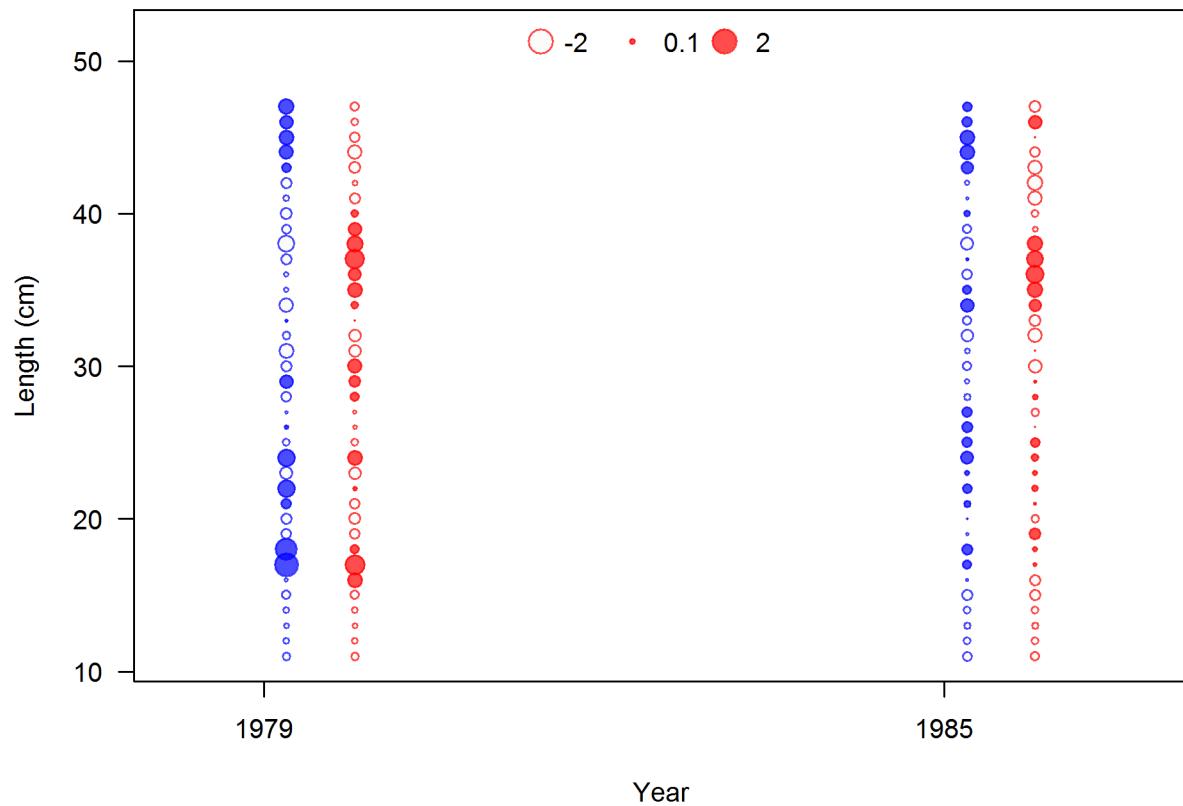


Figure 46: Pearson residuals, whole catch, Pacific ocean perch survey (max=1.76)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

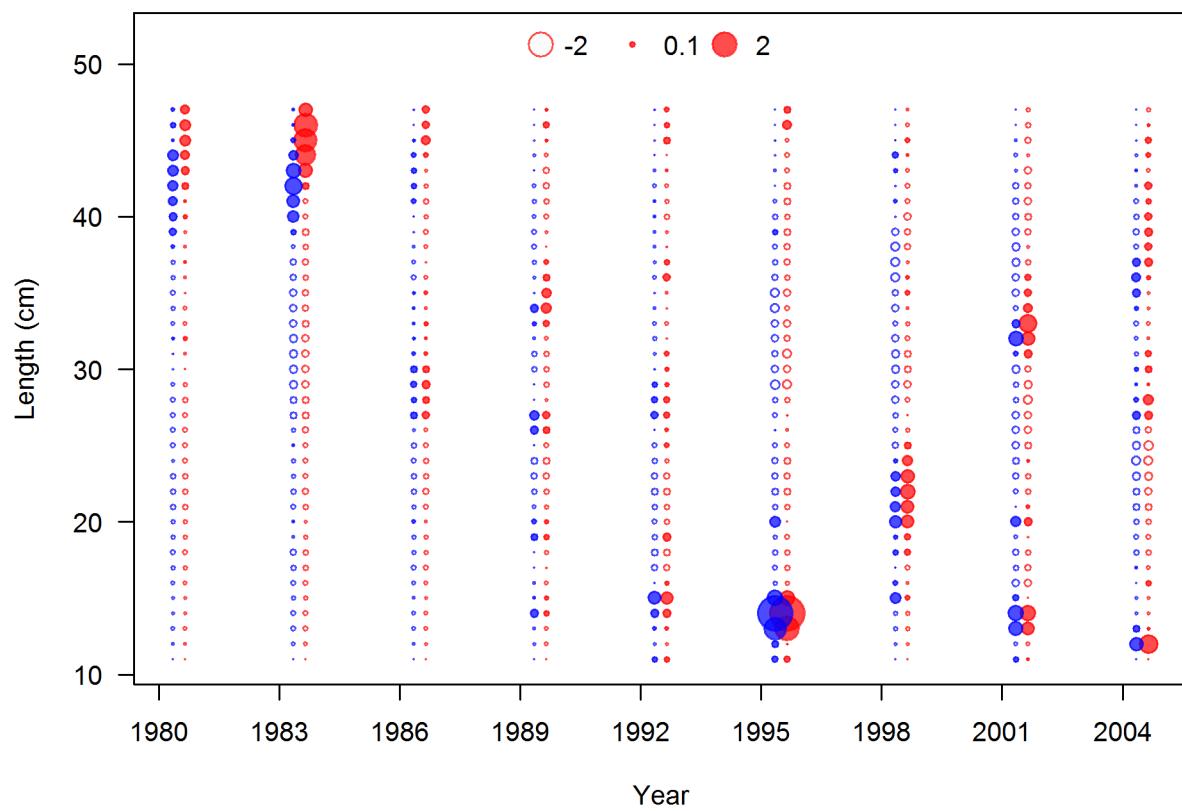


Figure 47: Pearson residuals, whole catch, Triennial survey (max=4.01)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

Pearson residuals, whole catch, AFSC slope survey (max=2.95)

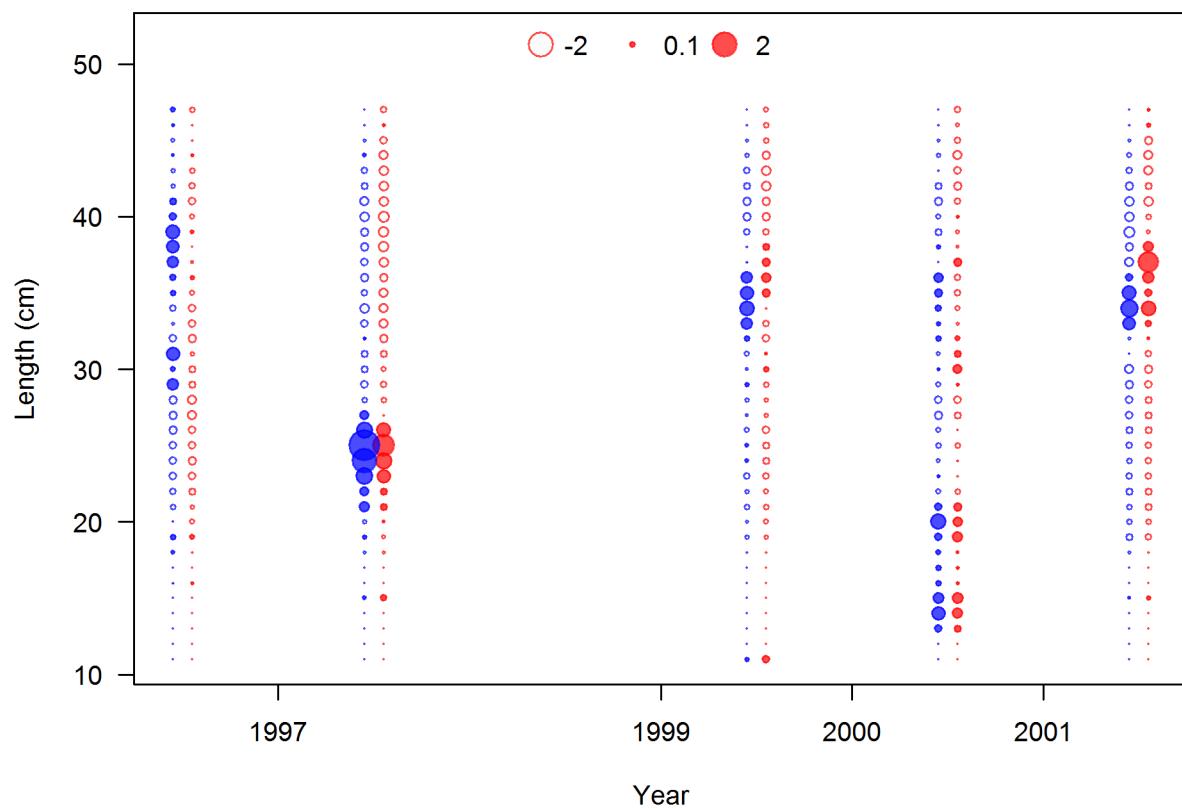


Figure 48: Pearson residuals, whole catch, AFSC slope survey (max=2.95)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

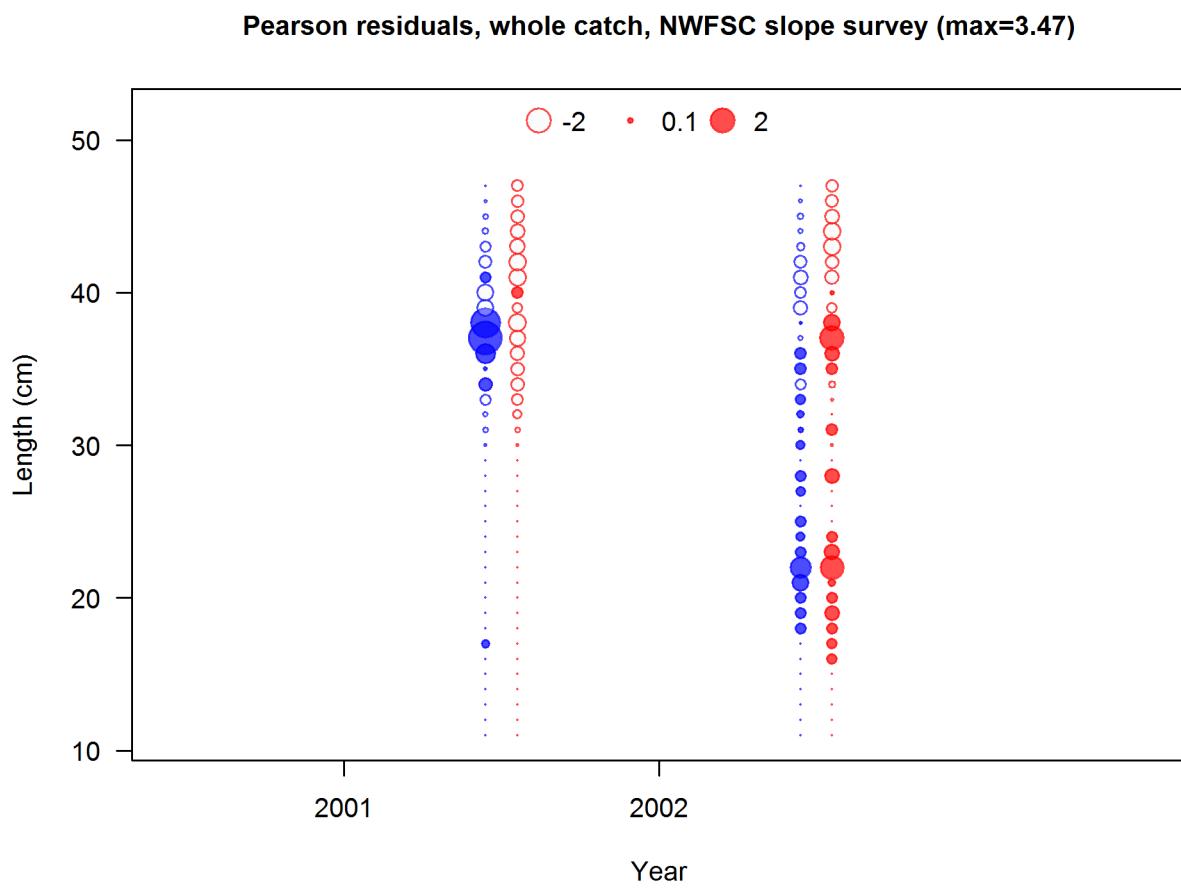


Figure 49: Pearson residuals, whole catch, NWFSC slope survey (max=3.47)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

Pearson residuals, whole catch, NWFSC shelf-slope survey (max=2.82)

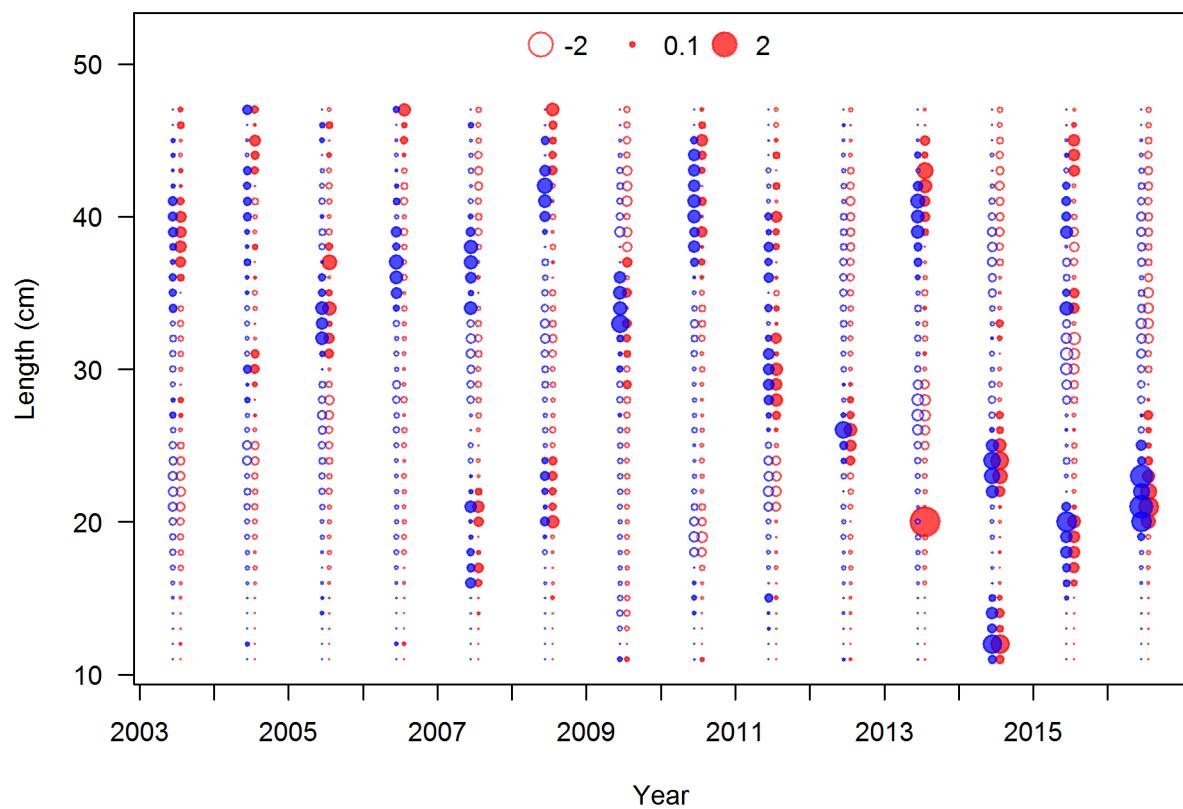


Figure 50: Pearson residuals, whole catch, NWFSC shelf_slope survey (max=2.82)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

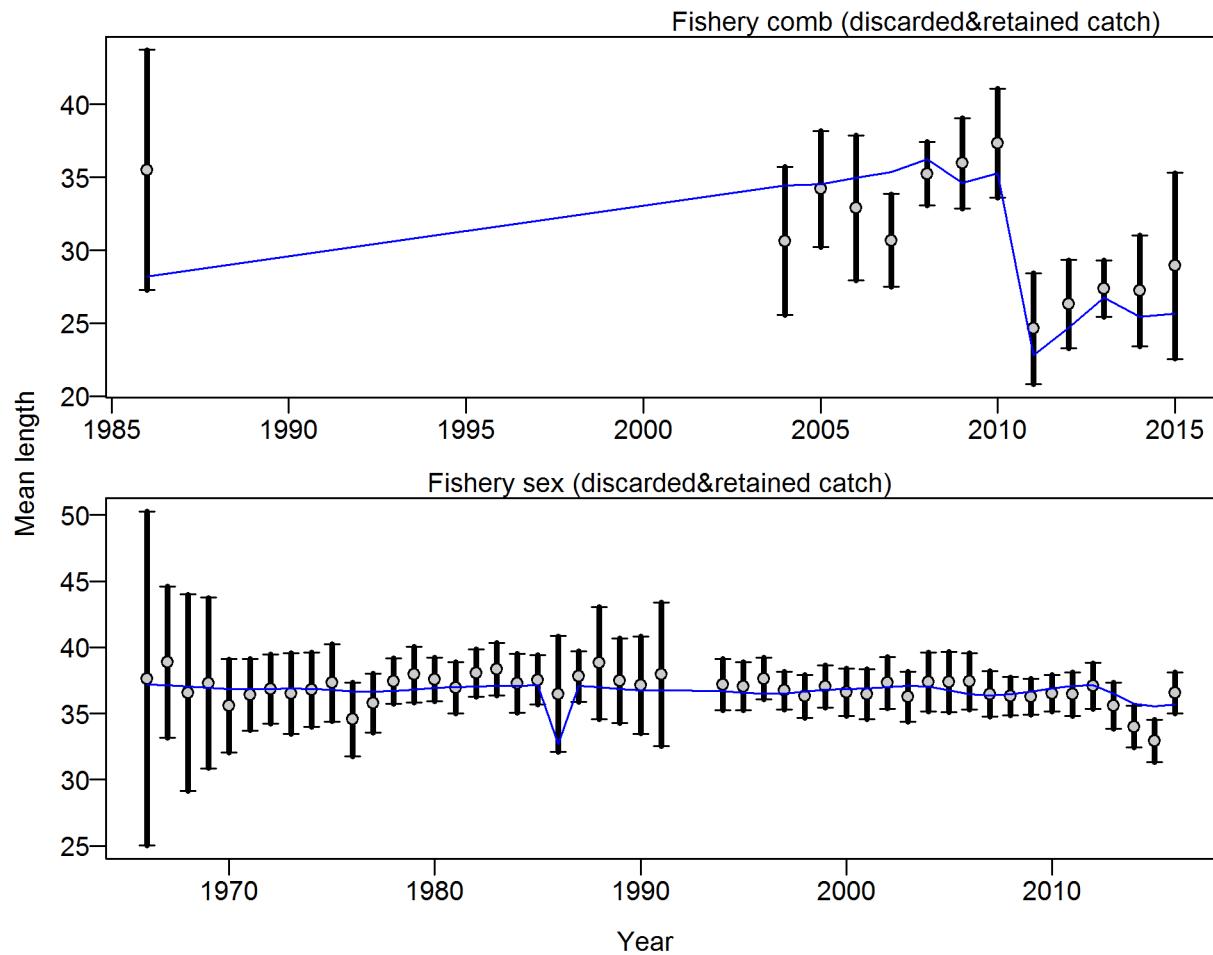


Figure 51: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.9967 (0.6541_1.8326) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

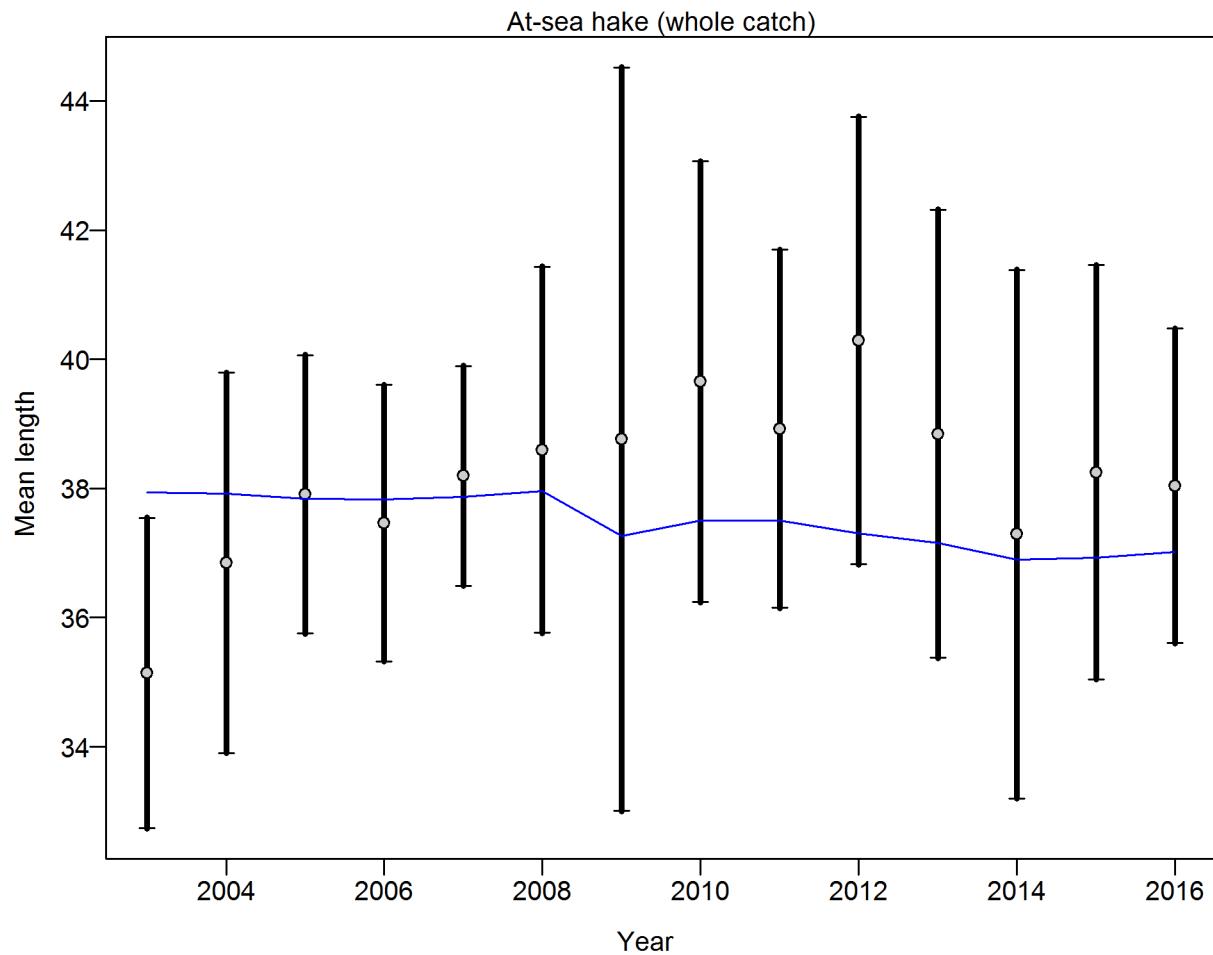


Figure 52: Francis data weighting method TA1.8: At_sea hake Suggested sample size adjustment (with 95% interval) for len data from At_sea hake: 1.0038 (0.529_5.1808) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

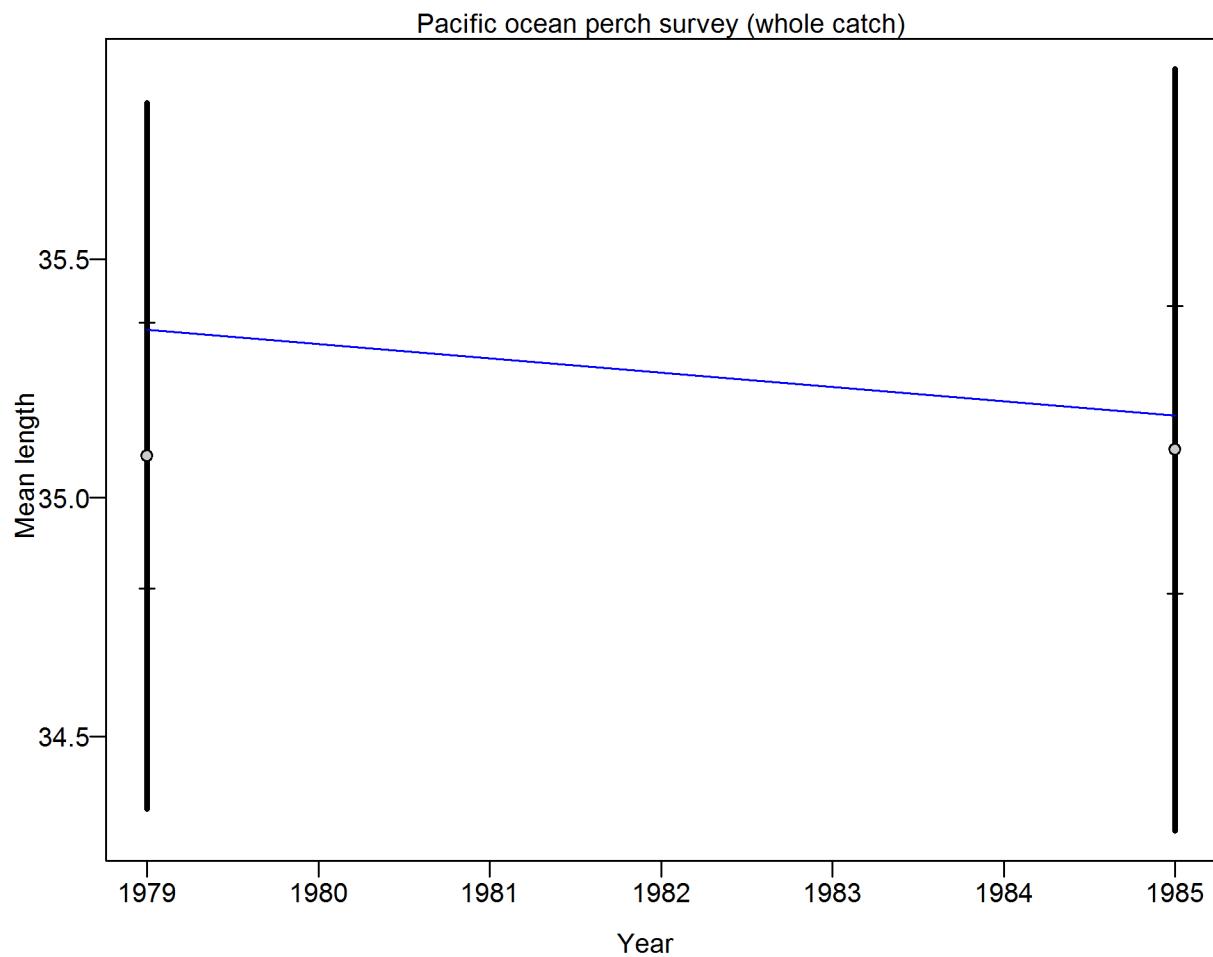


Figure 53: Francis data weighting method TA1.8: Pacific ocean perch survey Suggested sample size adjustment (with 95% interval) for len data from Pacific ocean perch survey: 7.0231 (7.0231_Inf) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124–1138.

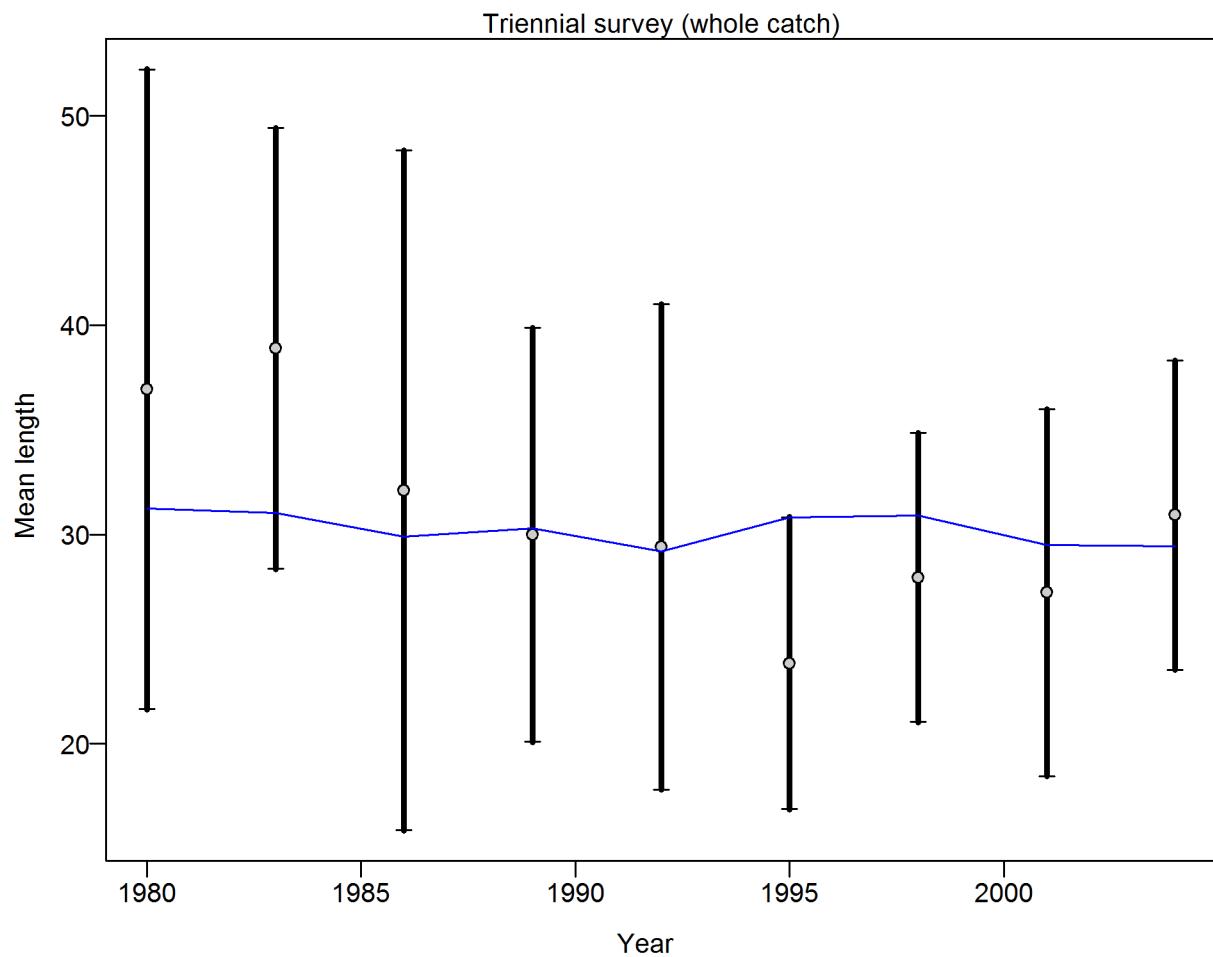


Figure 54: Francis data weighting method TA1.8: Triennial survey Suggested sample size adjustment (with 95% interval) for len data from Triennial survey: 1.002 (0.5287_5.3592)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Can. J. Fish. Aquat. Sci.* 68: 1124_1138.

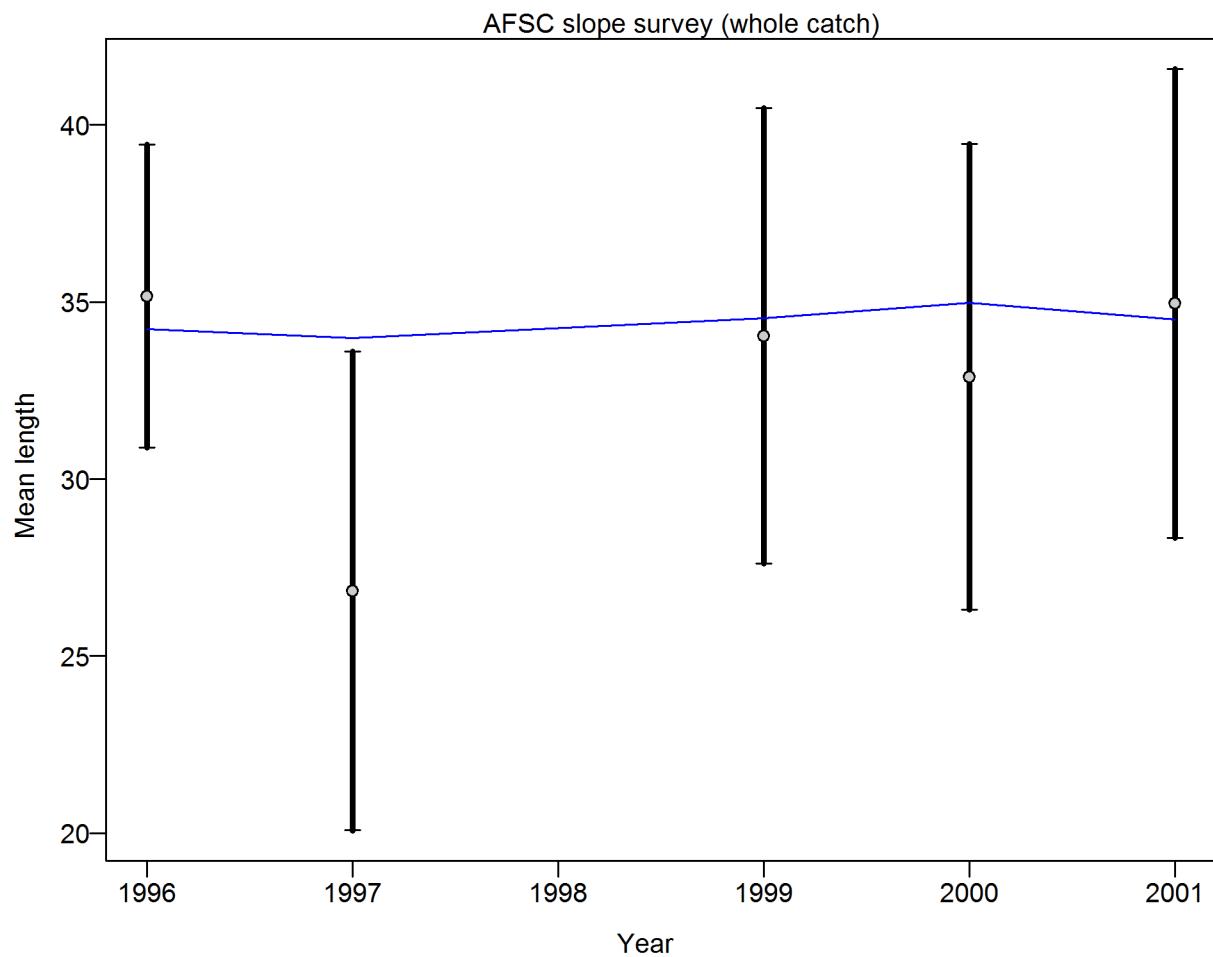


Figure 55: Francis data weighting method TA1.8: AFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from AFSC slope survey: 1.0006 (0.5848_21.9944)
 For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

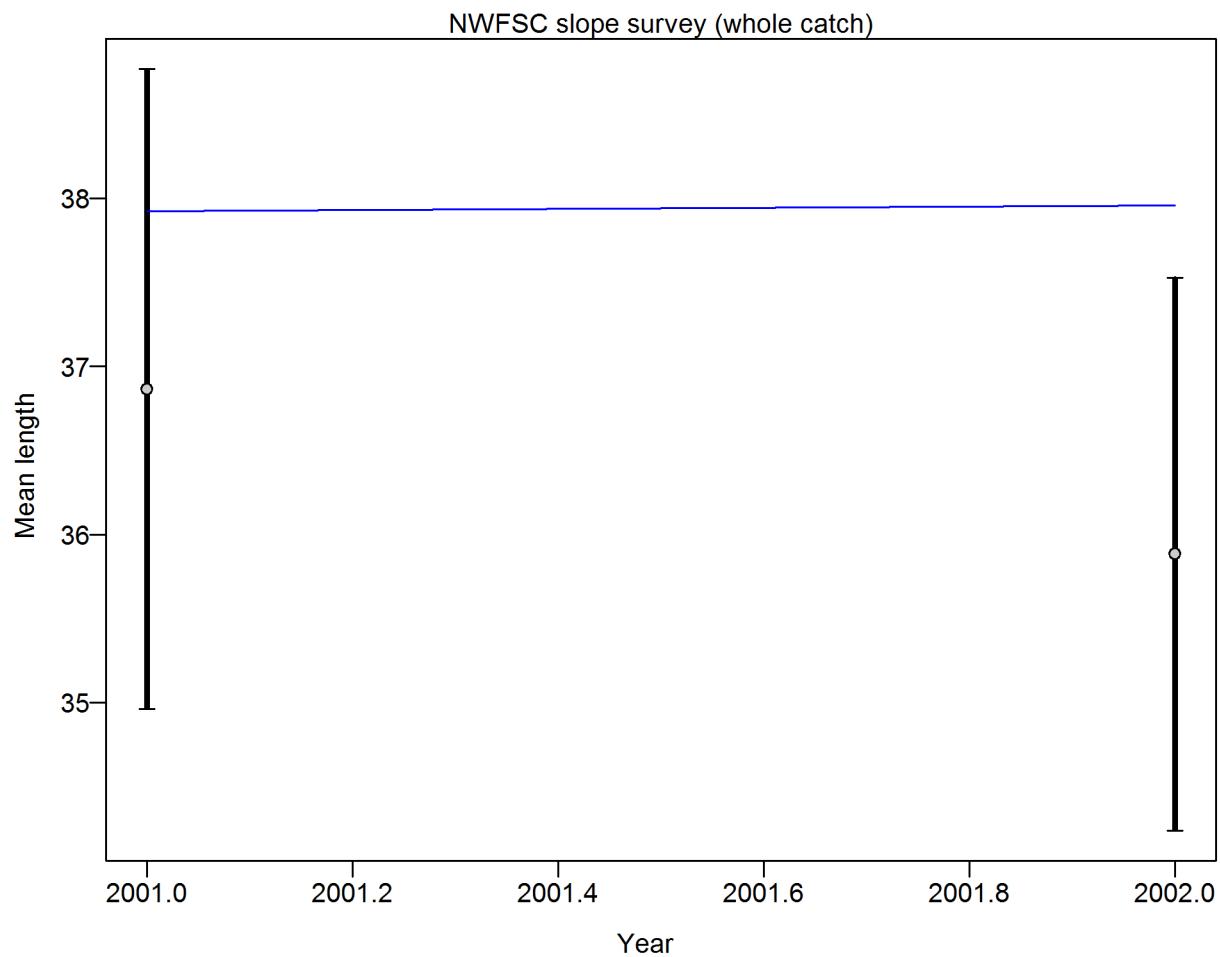


Figure 56: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC slope survey: 0.9902 (0.9902_Inf)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138.

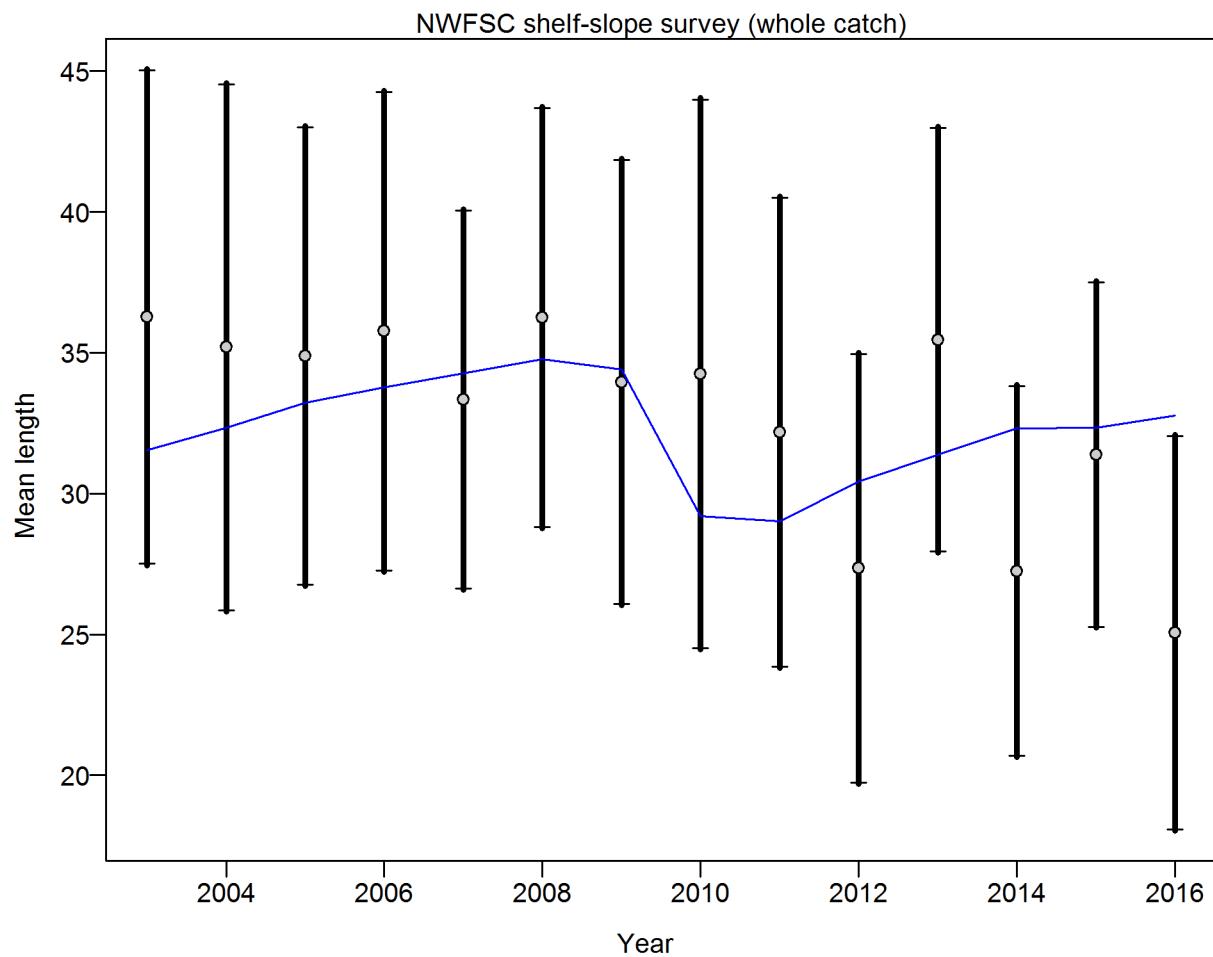


Figure 57: Francis data weighting method TA1.8: NWFSC shelf_slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC shelf_slope survey: 1.0116 (0.6092_3.8943) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

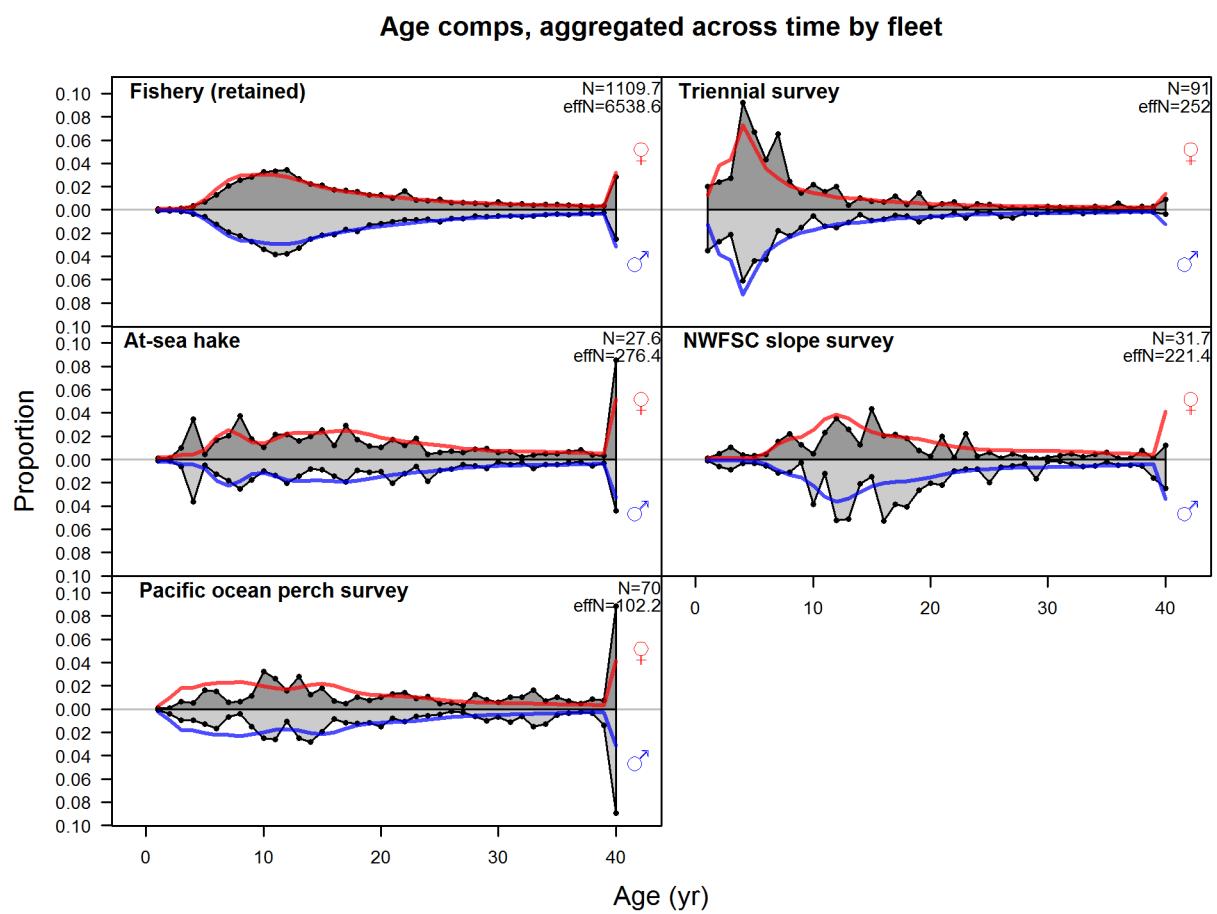


Figure 58: Age compositions aggregated across time by fleet.

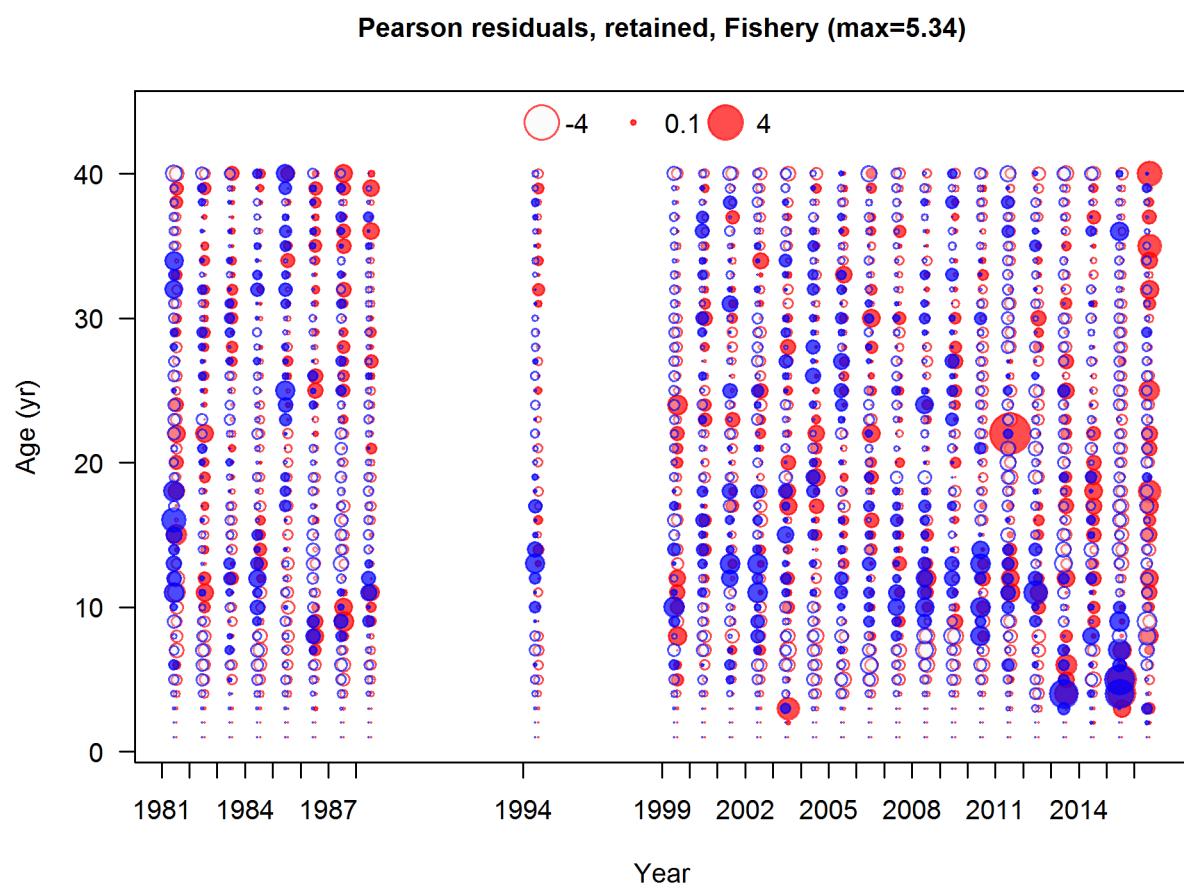


Figure 59: Pearson residuals, retained, Fishery (max=5.34) (plot 2 of 2)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

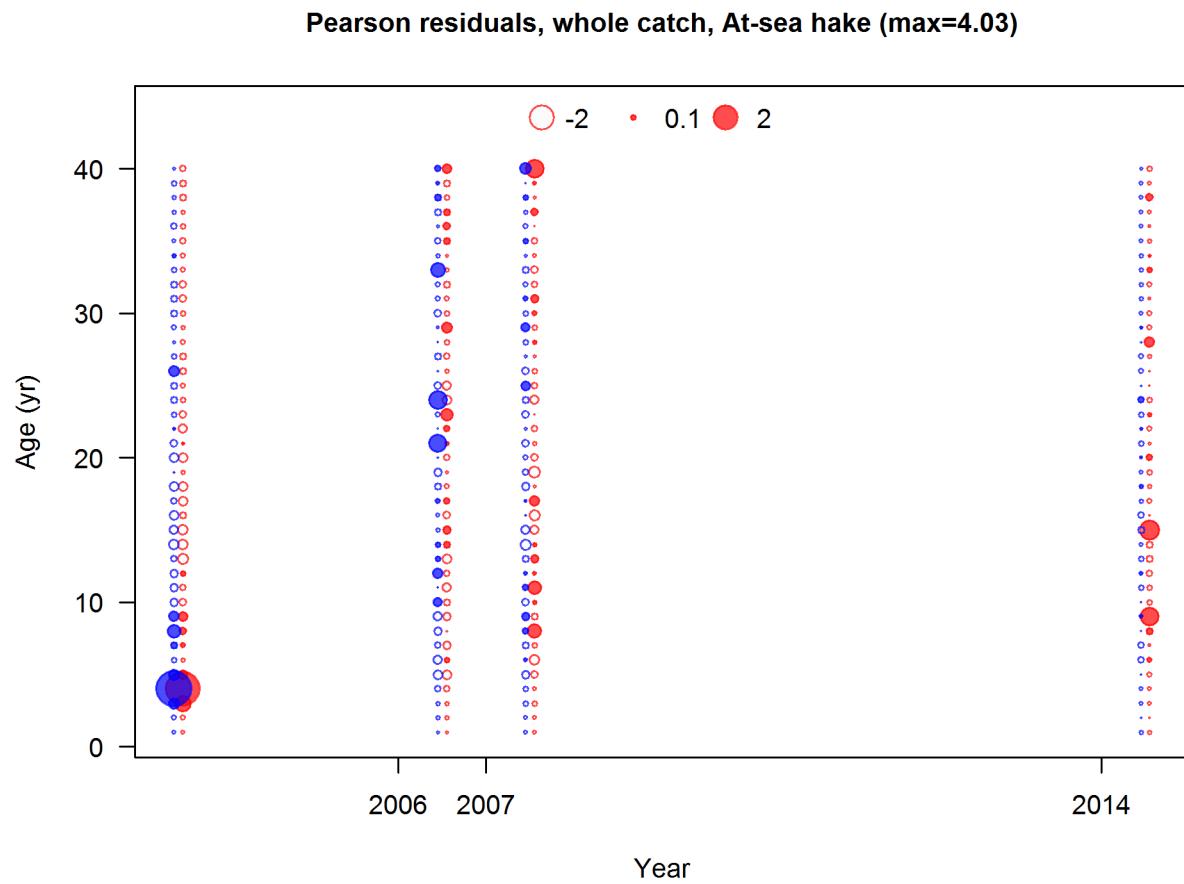


Figure 60: Pearson residuals, whole catch, At_sea hake (max=4.03)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

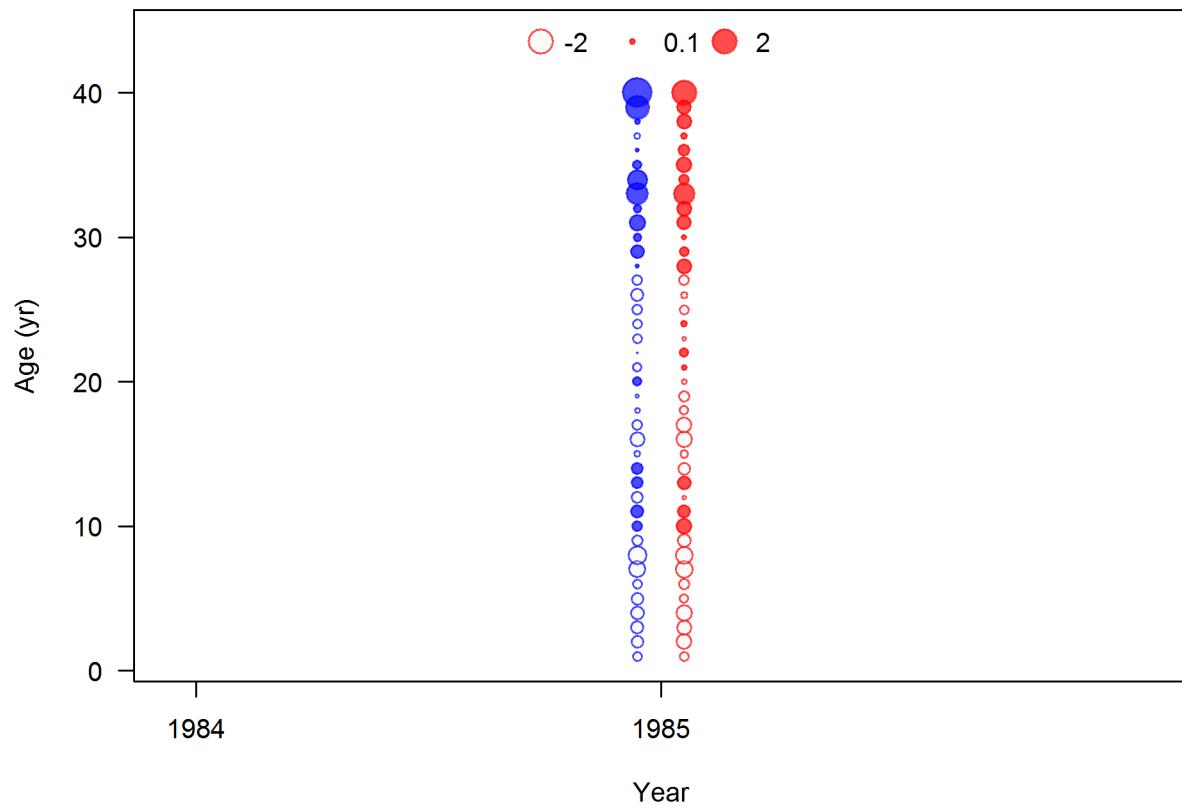


Figure 61: Pearson residuals, whole catch, Pacific ocean perch survey (max=2.76)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

Pearson residuals, whole catch, Triennial survey (max=3.76)

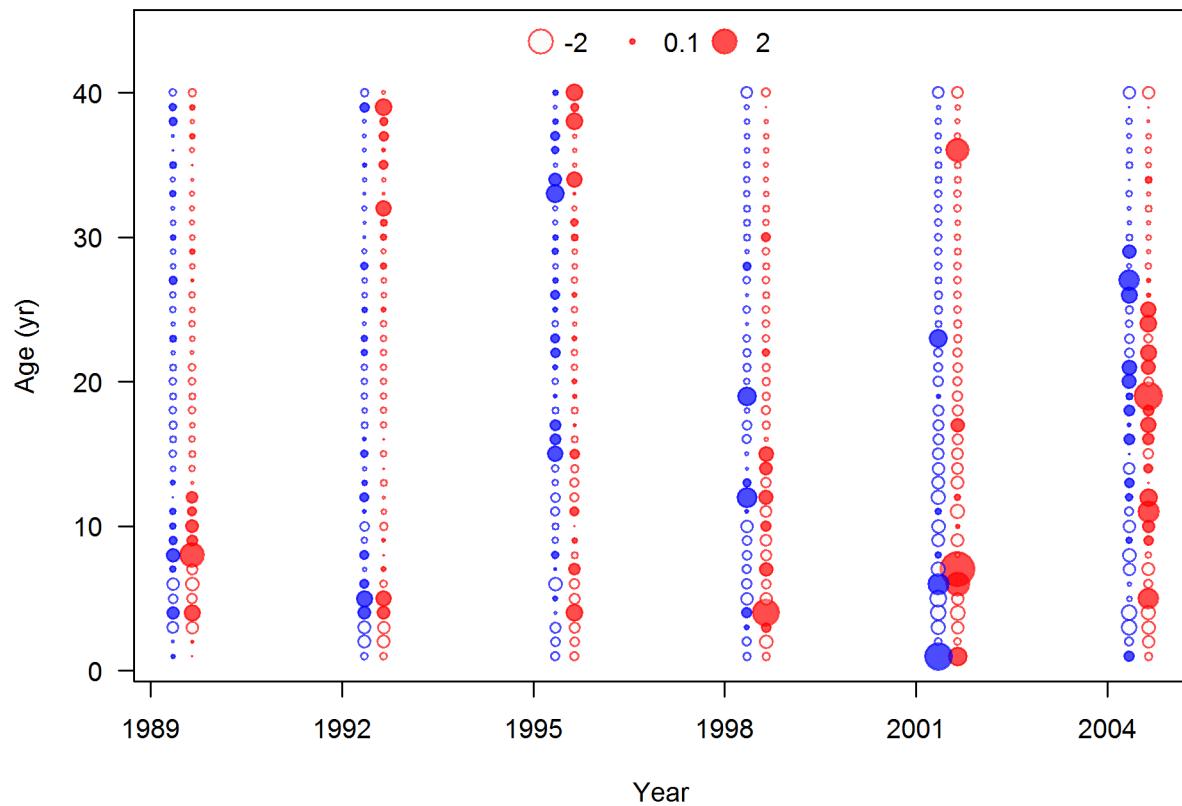


Figure 62: Pearson residuals, whole catch, Triennial survey (max=3.76)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

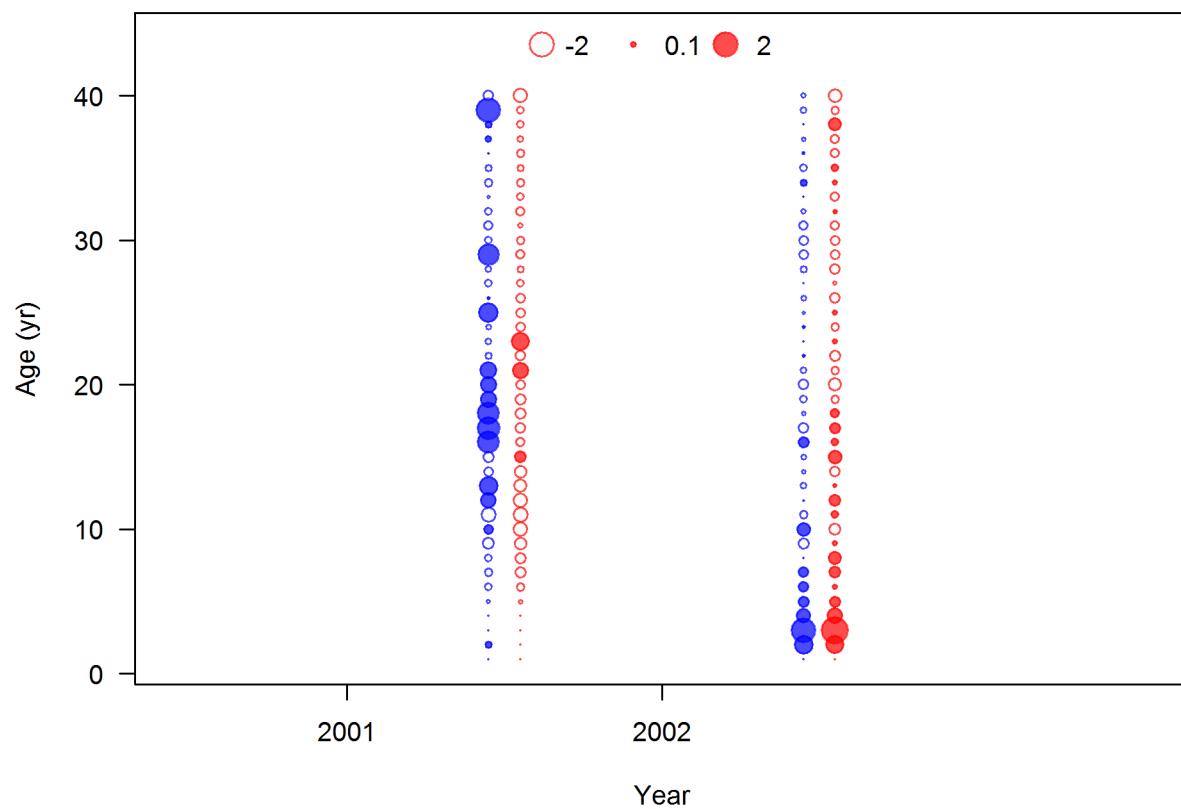


Figure 63: Pearson residuals, whole catch, NWFSC slope survey (max=2.34)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

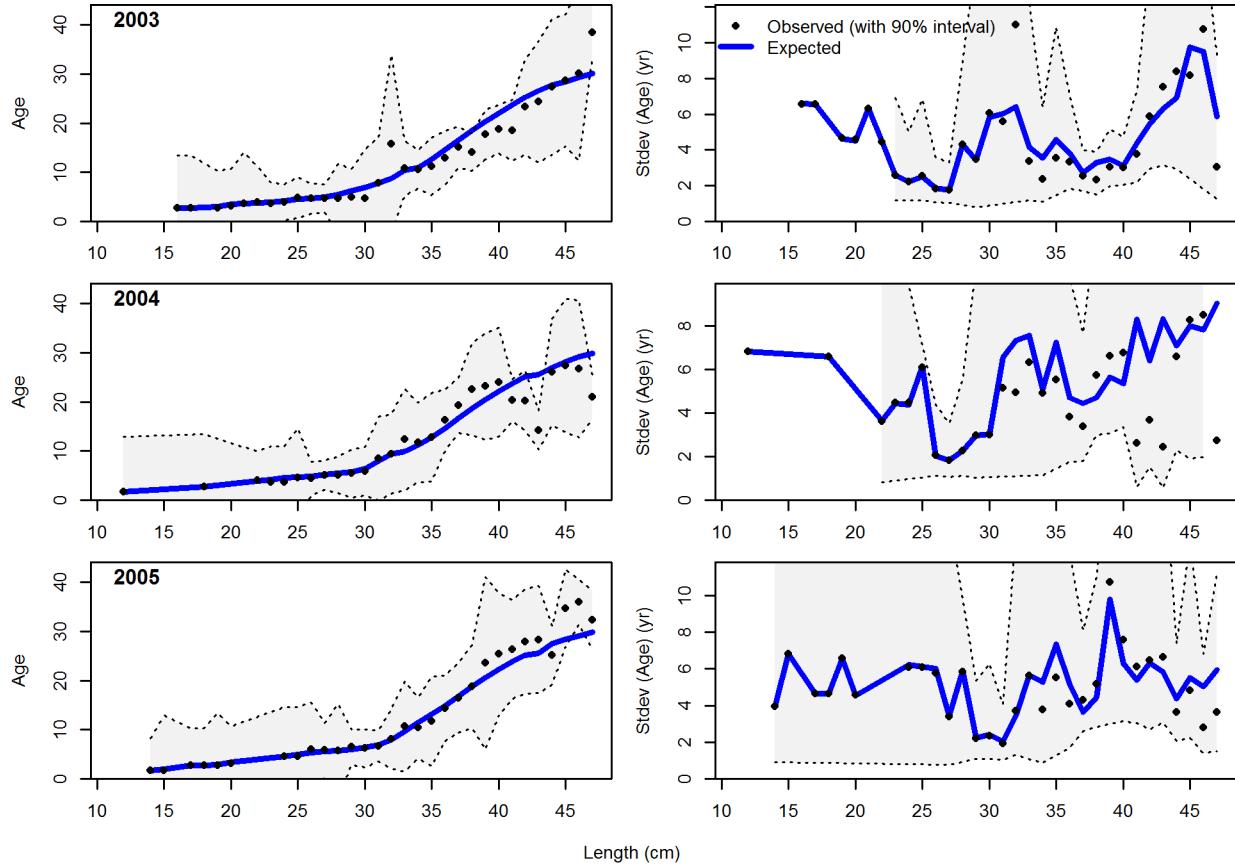


Figure 64: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 1 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

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

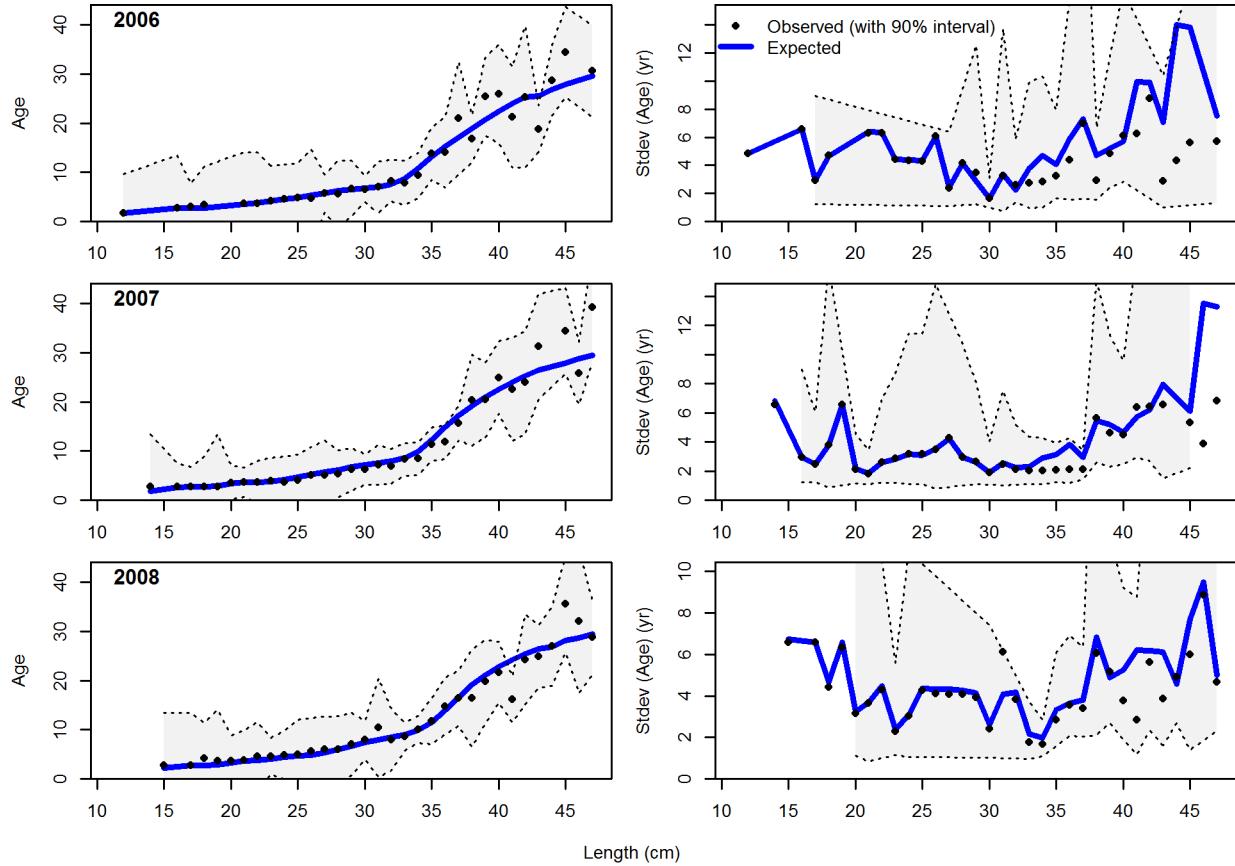


Figure 65: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 2 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

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

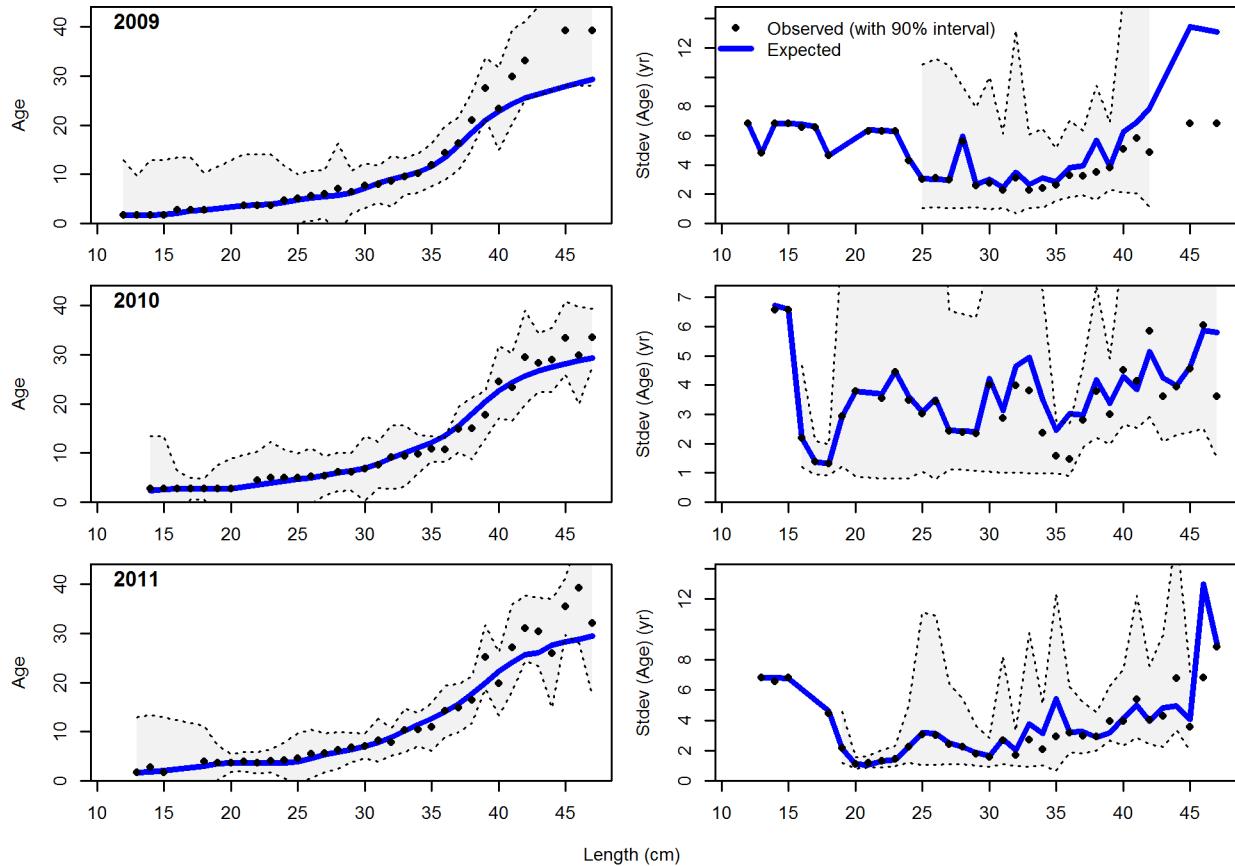


Figure 66: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 3 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

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

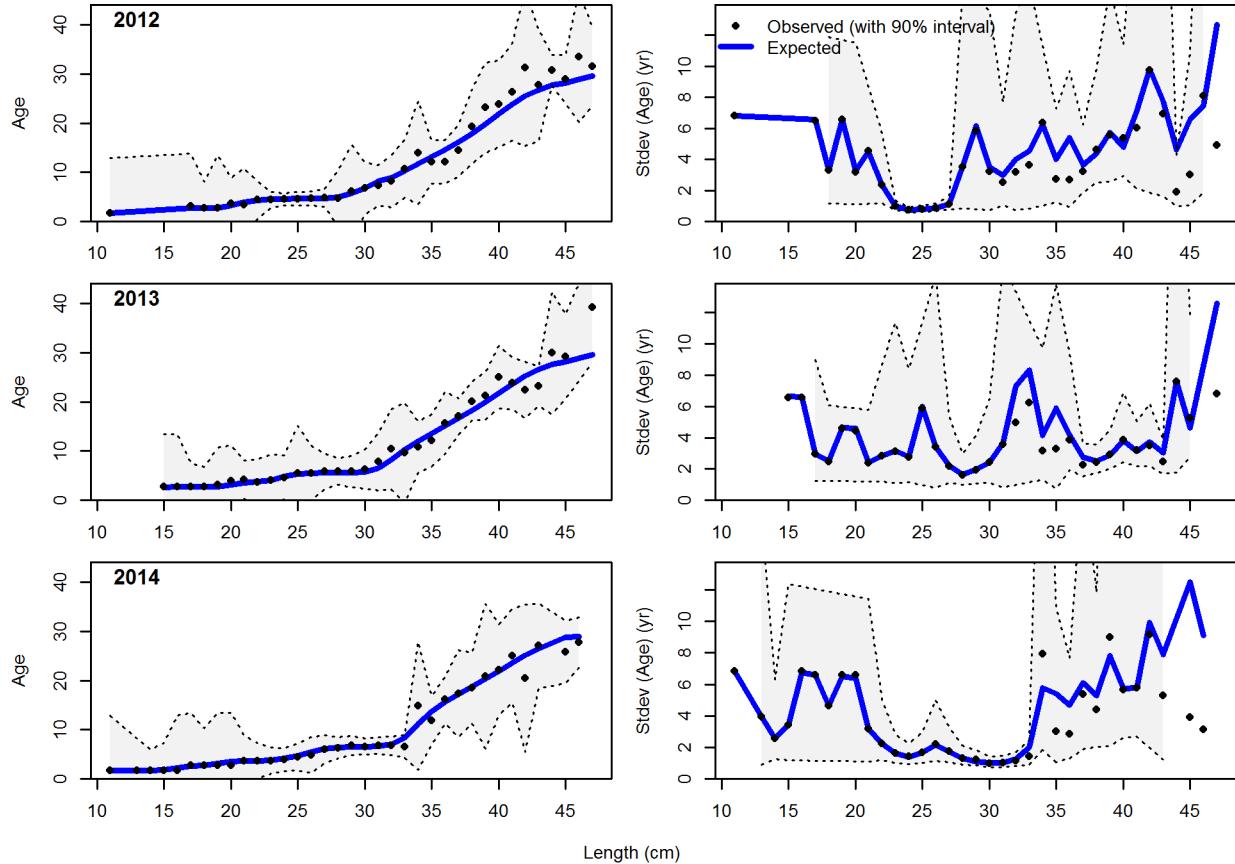


Figure 67: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 4 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

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

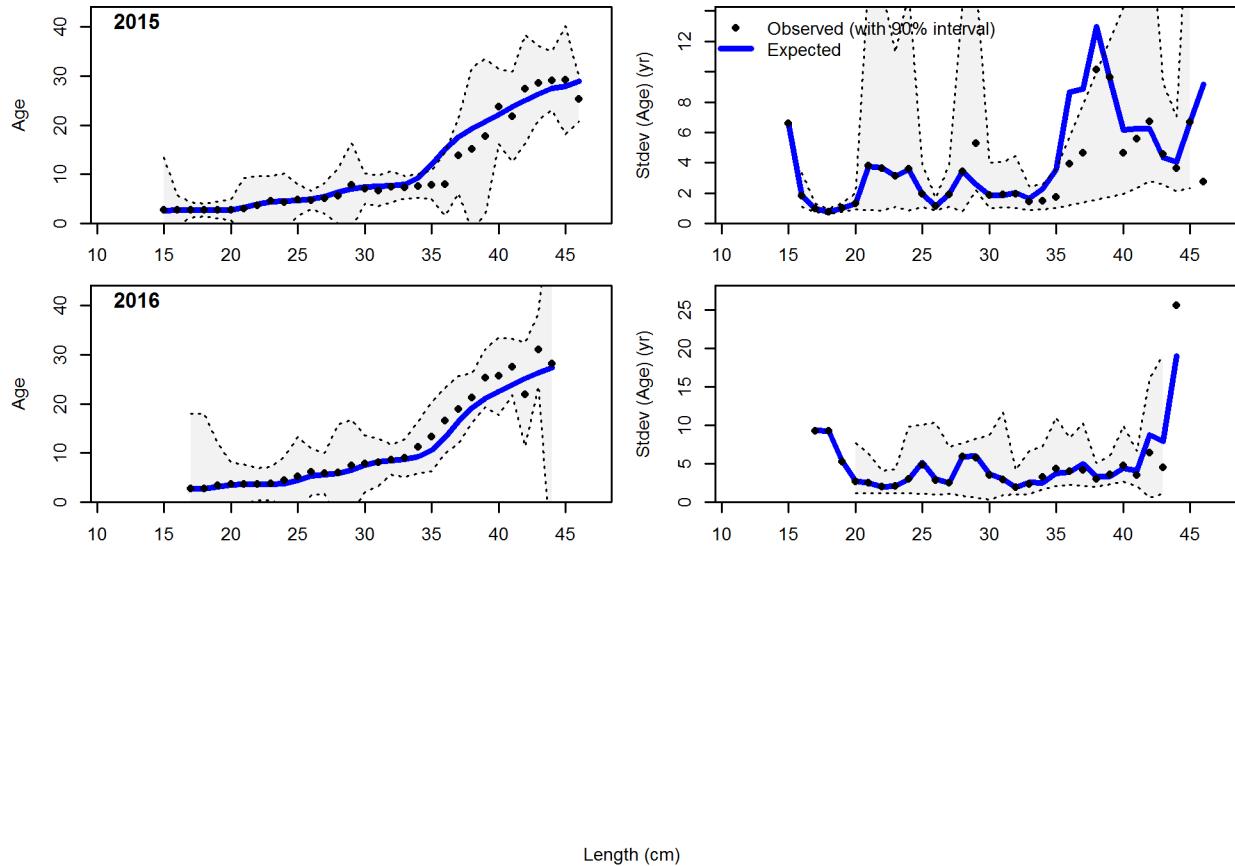


Figure 68: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 5 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

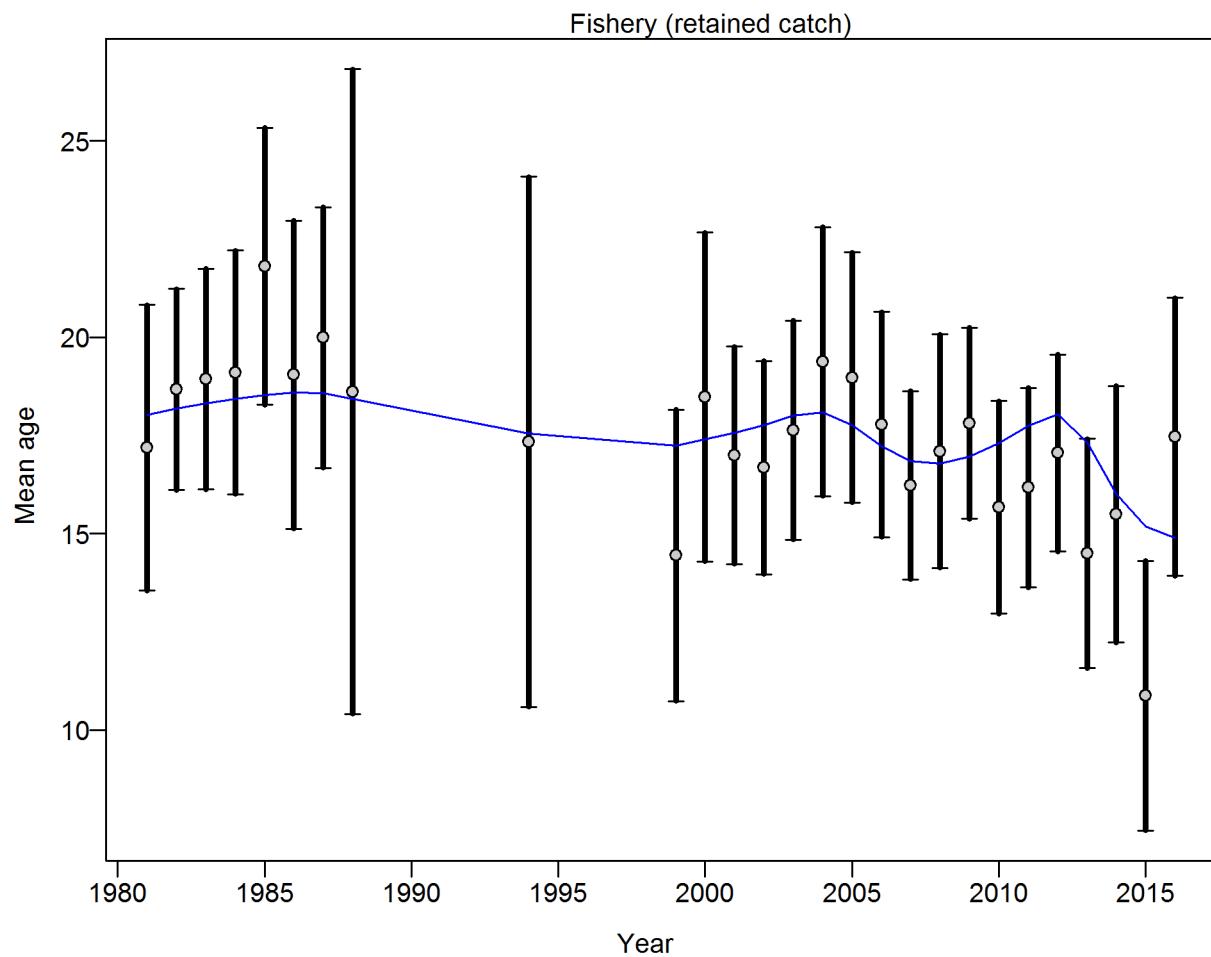


Figure 69: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for age data from Fishery: 0.9951 (0.6625_2.0165) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

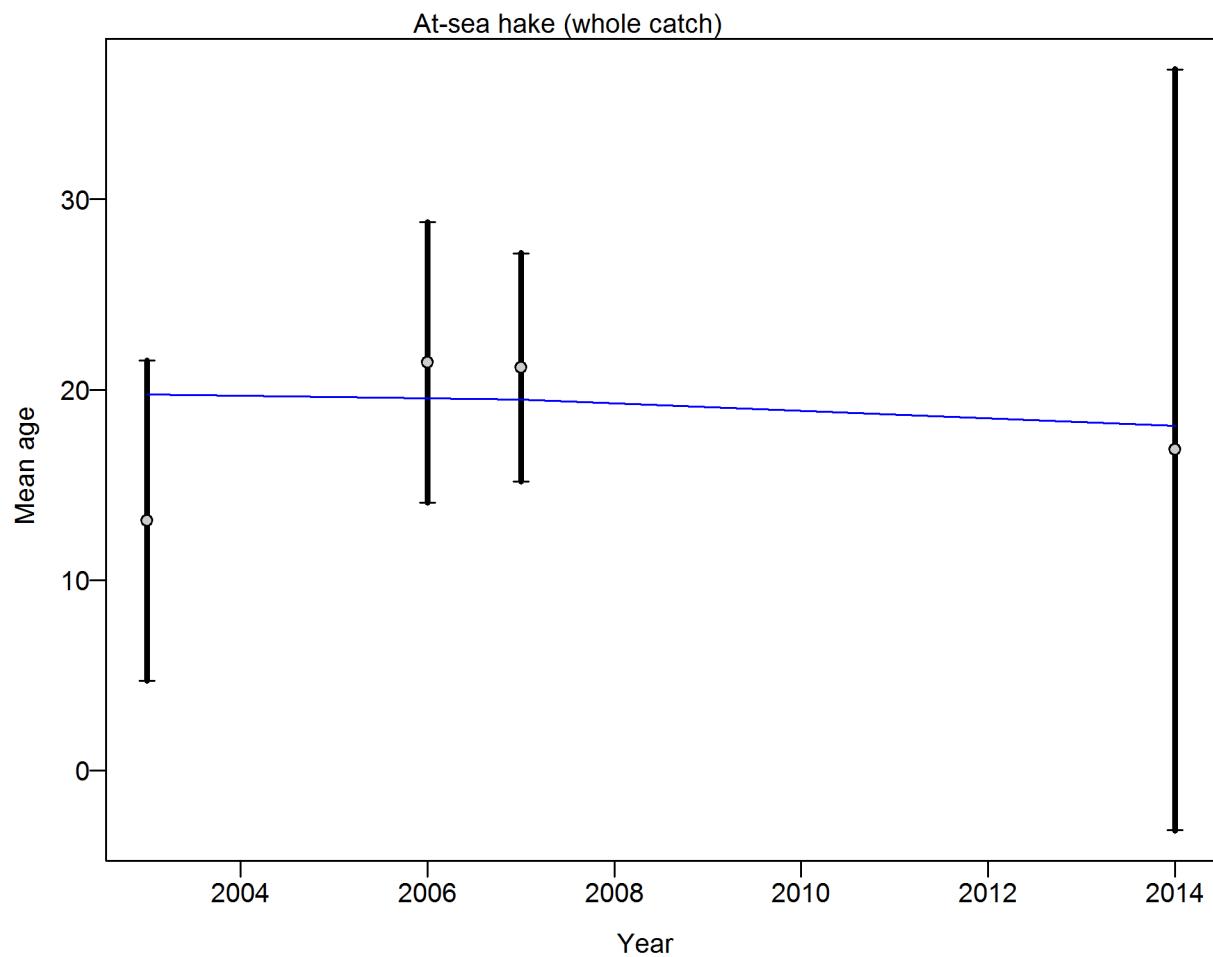


Figure 70: Francis data weighting method TA1.8: At_sea hake Suggested sample size adjustment (with 95% interval) for age data from At_sea hake: 1.0023 (0.6686_1573.0001)
 For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Can. J. Fish. Aquat. Sci.* 68: 1124_1138.

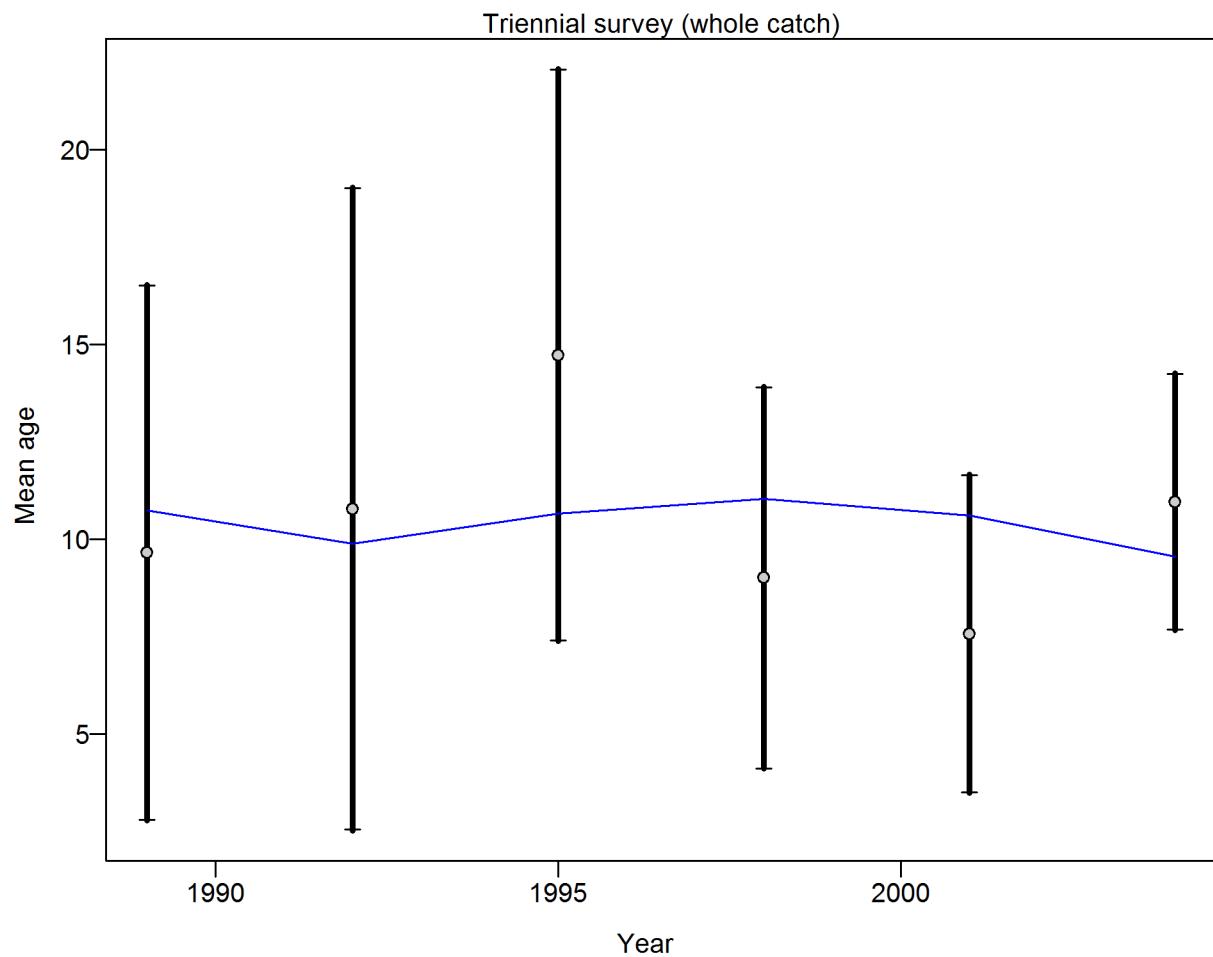


Figure 71: Francis data weighting method TA1.8: Triennial survey Suggested sample size adjustment (with 95% interval) for age data from Triennial survey: 1.0053 (0.6419_5.9131)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Can. J. Fish. Aquat. Sci.* 68: 1124_1138.

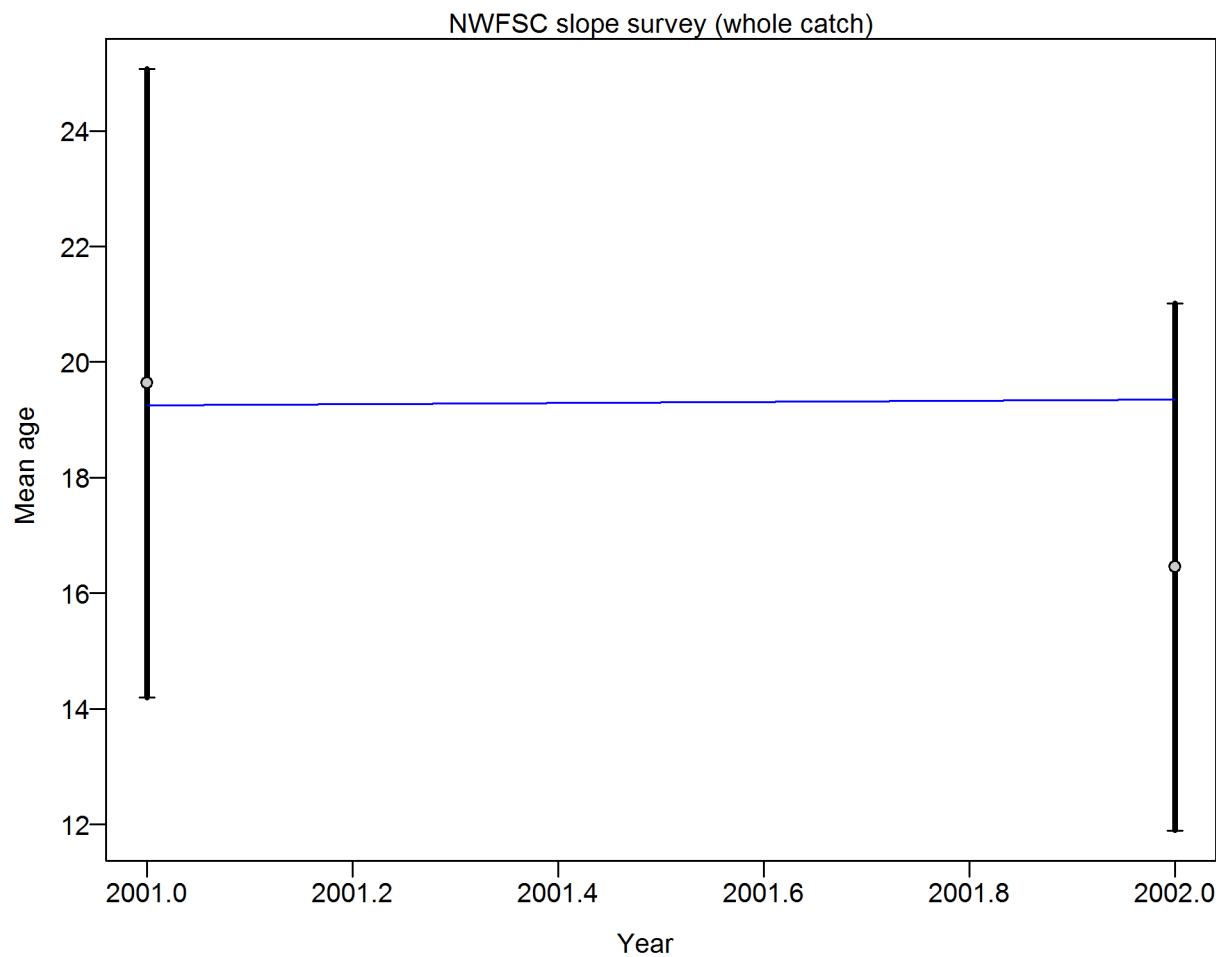


Figure 72: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for age data from NWFSC slope survey: 0.9992 (0.9992_Inf)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138.

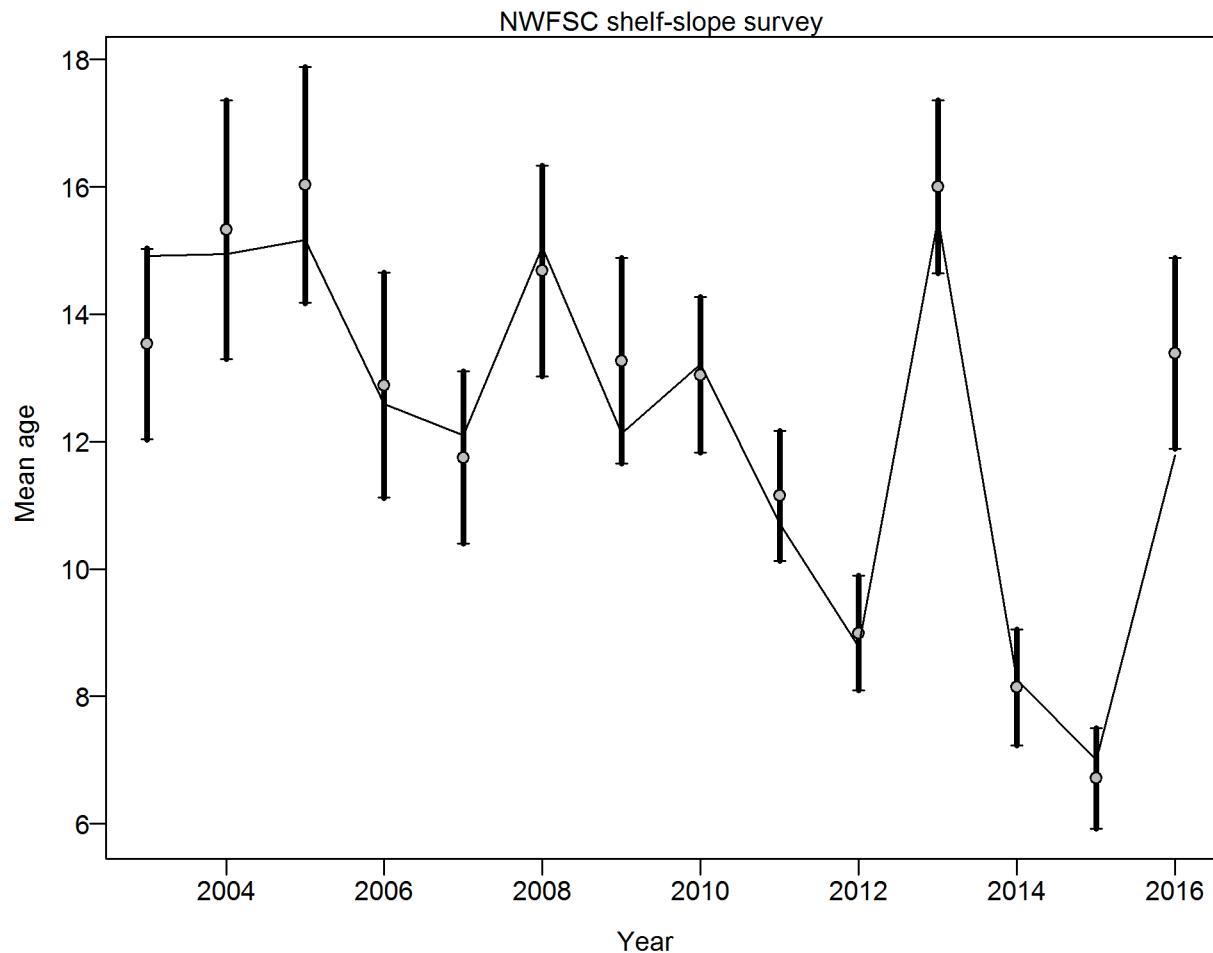


Figure 73: Francis data weighting method TA1.8 for conditional age [data:NWFSC](#) shelf_slope survey Suggested sample size adjustment (with 95% interval) for conditional age_at_length data from NWFSC shelf_slope survey: 1.0038 (0.5835_3.0273) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

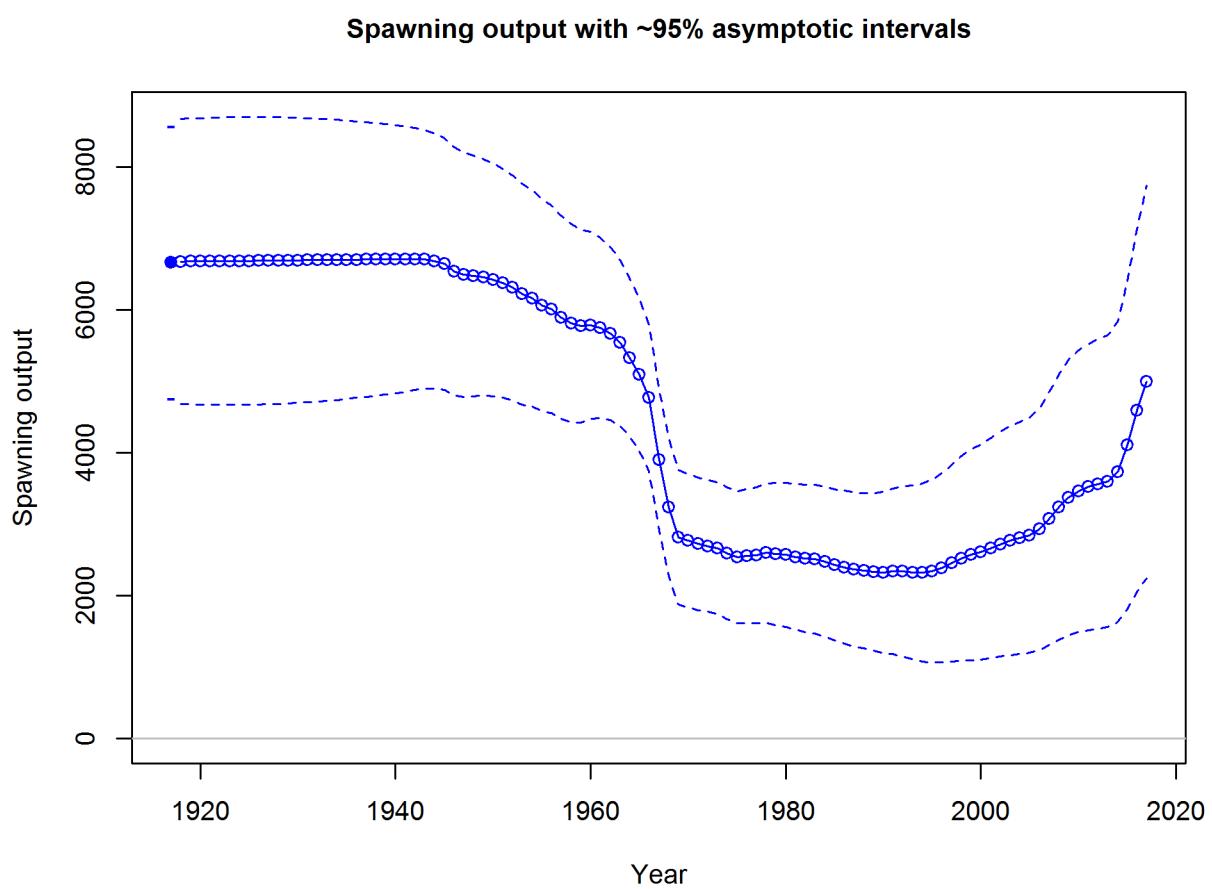


Figure 74: Estimated time-series of spawning output for Pacific ocean perch.

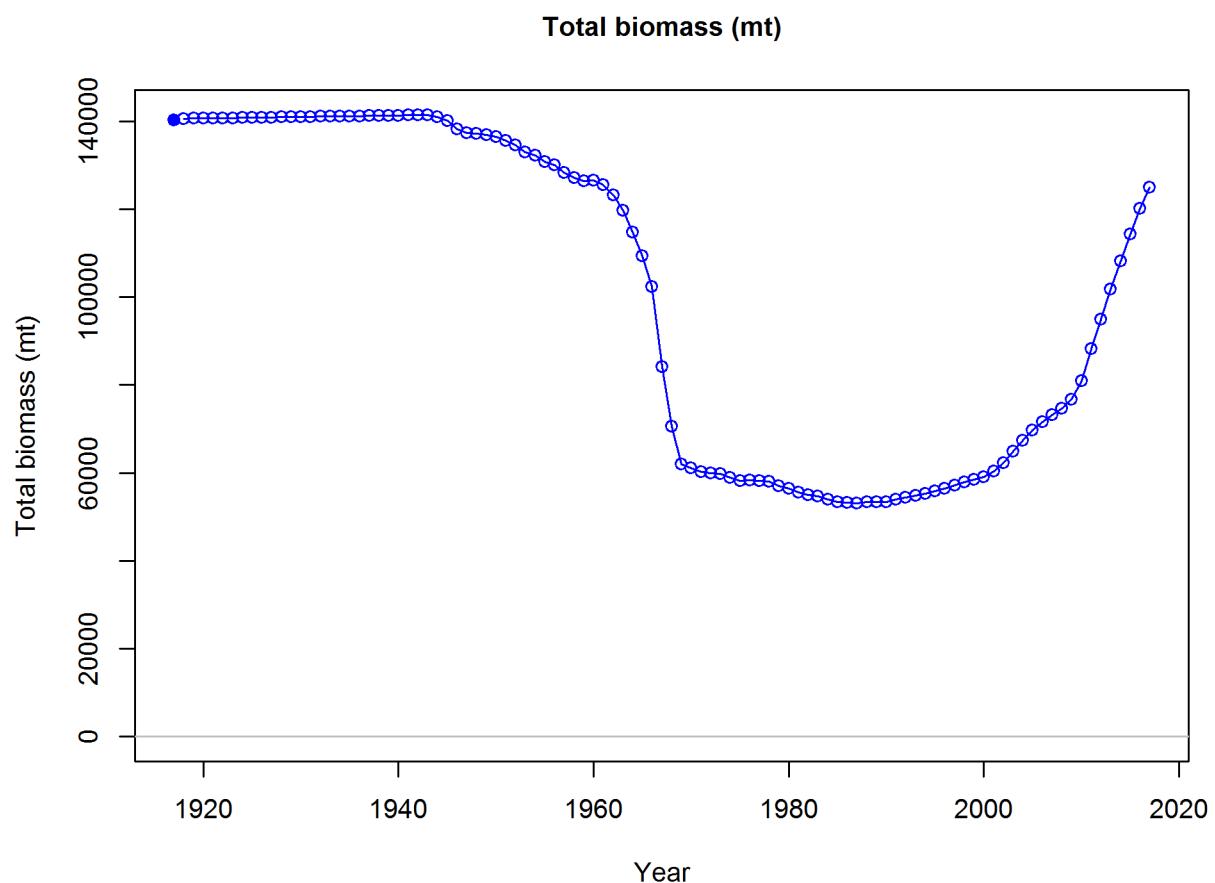


Figure 75: Estimated time-series of total biomass for Pacific ocean perch.

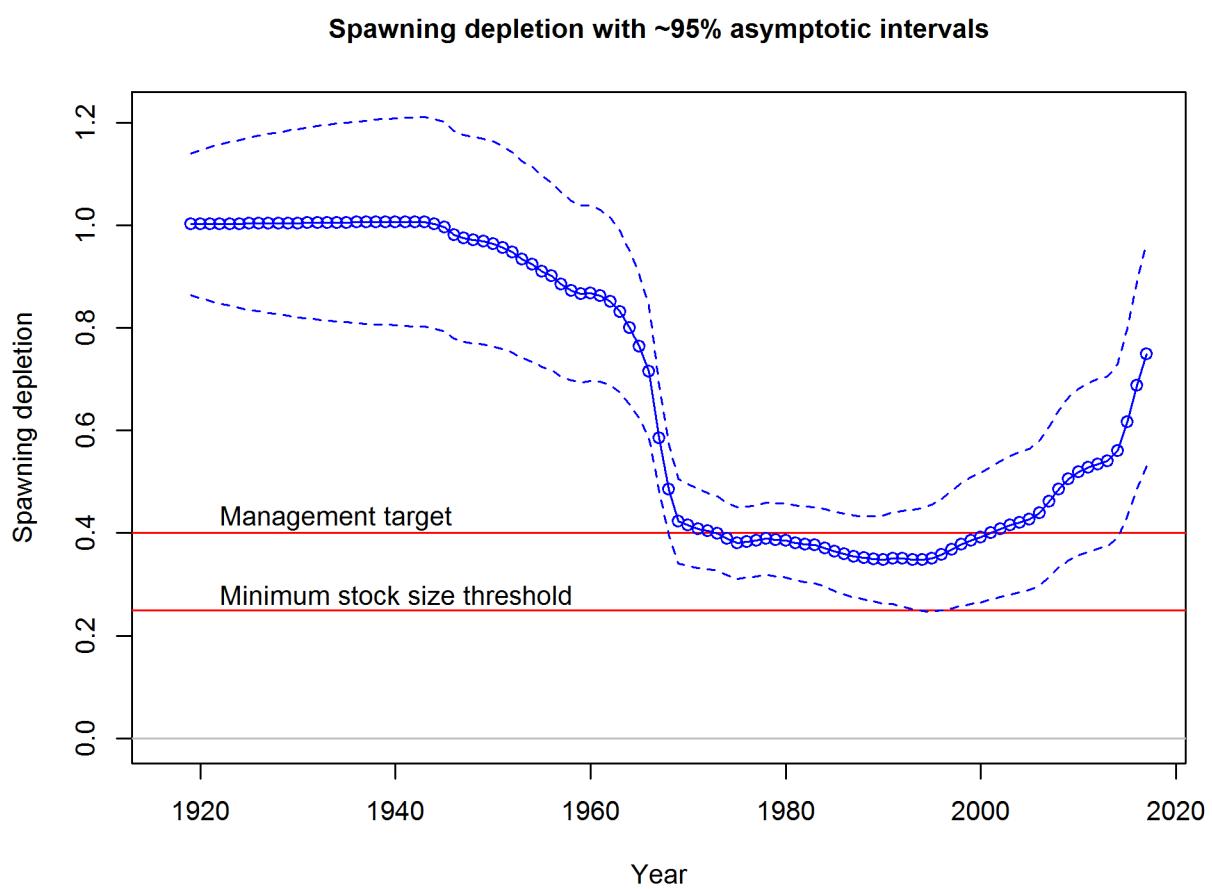


Figure 76: Estimated time-series of relative biomass for Pacific ocean perch.

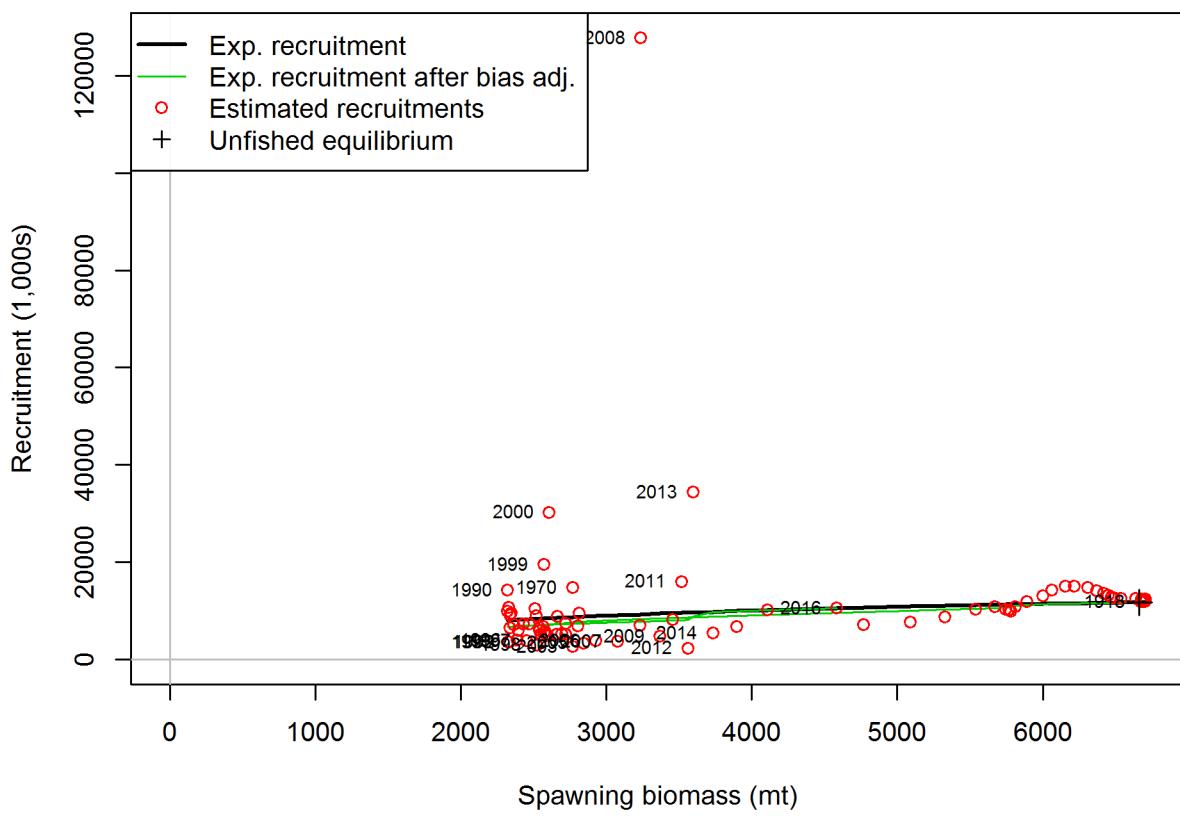


Figure 77: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution

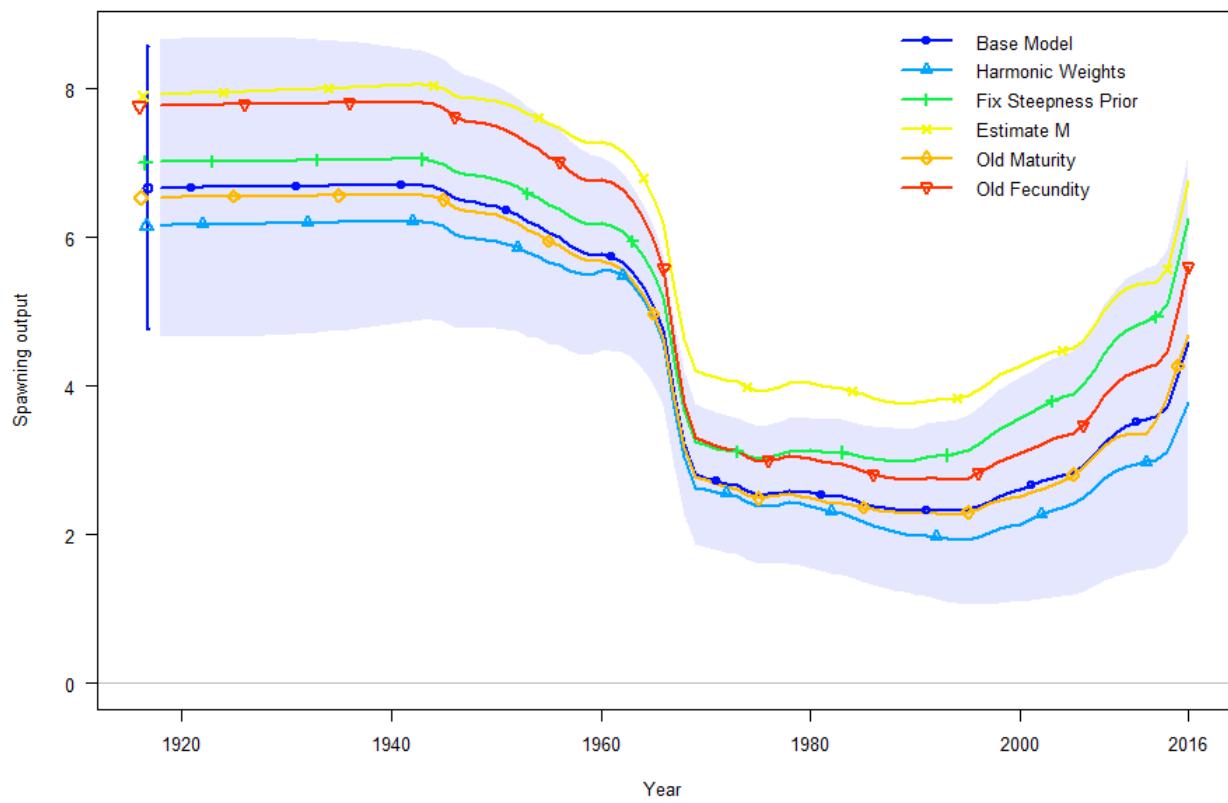


Figure 78: Time-series of spawning output for model sensitivities for Pacific ocean perch.

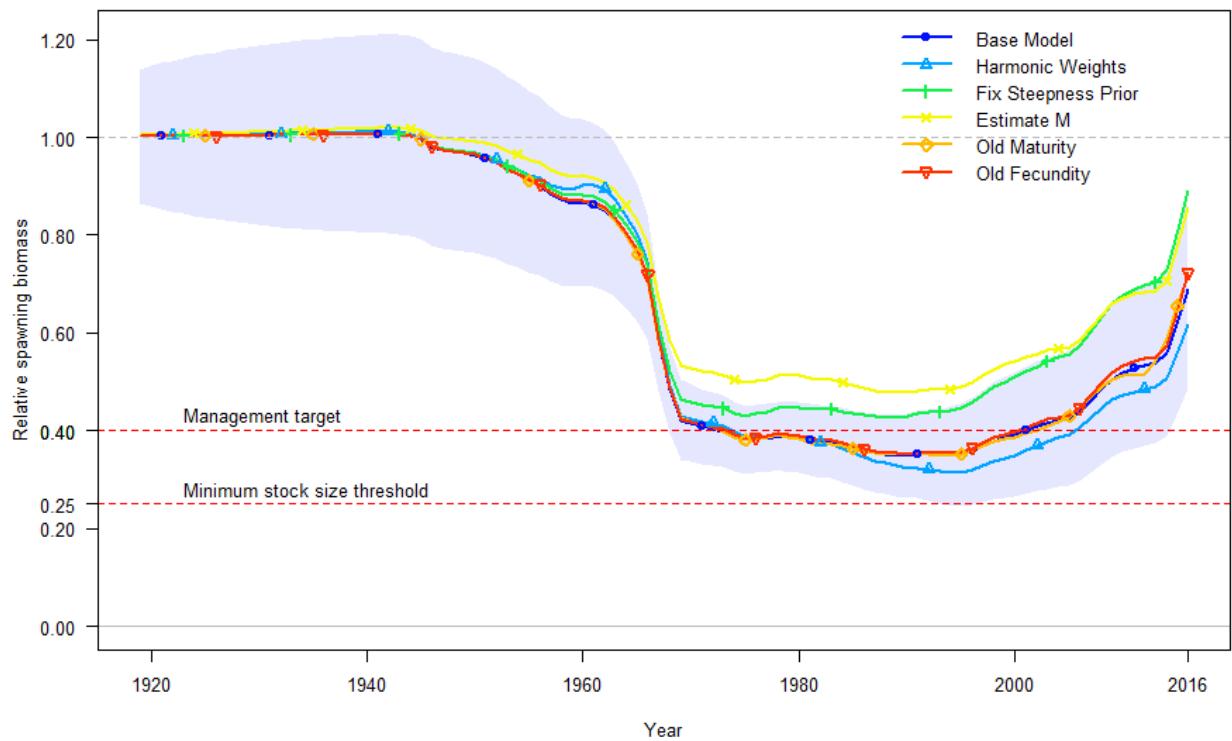


Figure 79: Time-series of relative biomass for model sensitivities for Pacific ocean perch.

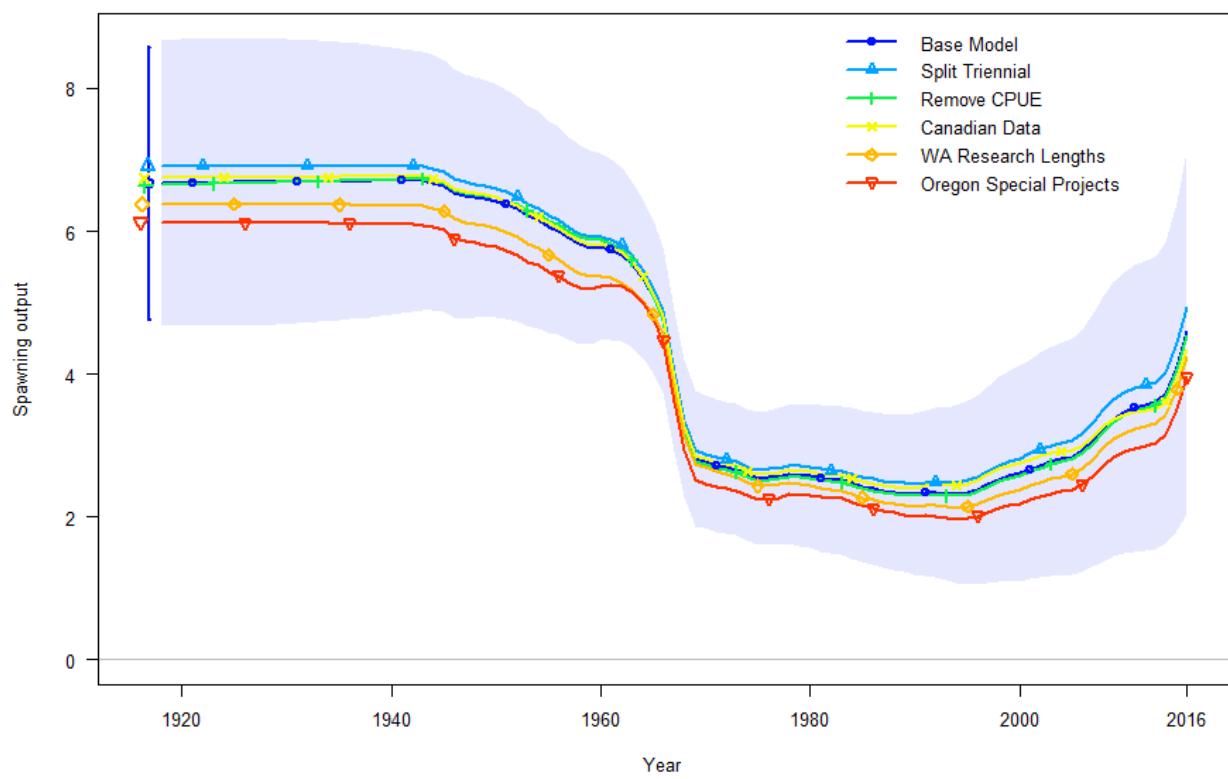


Figure 80: Time-series of spawning output for model sensitivities for Pacific ocean perch.

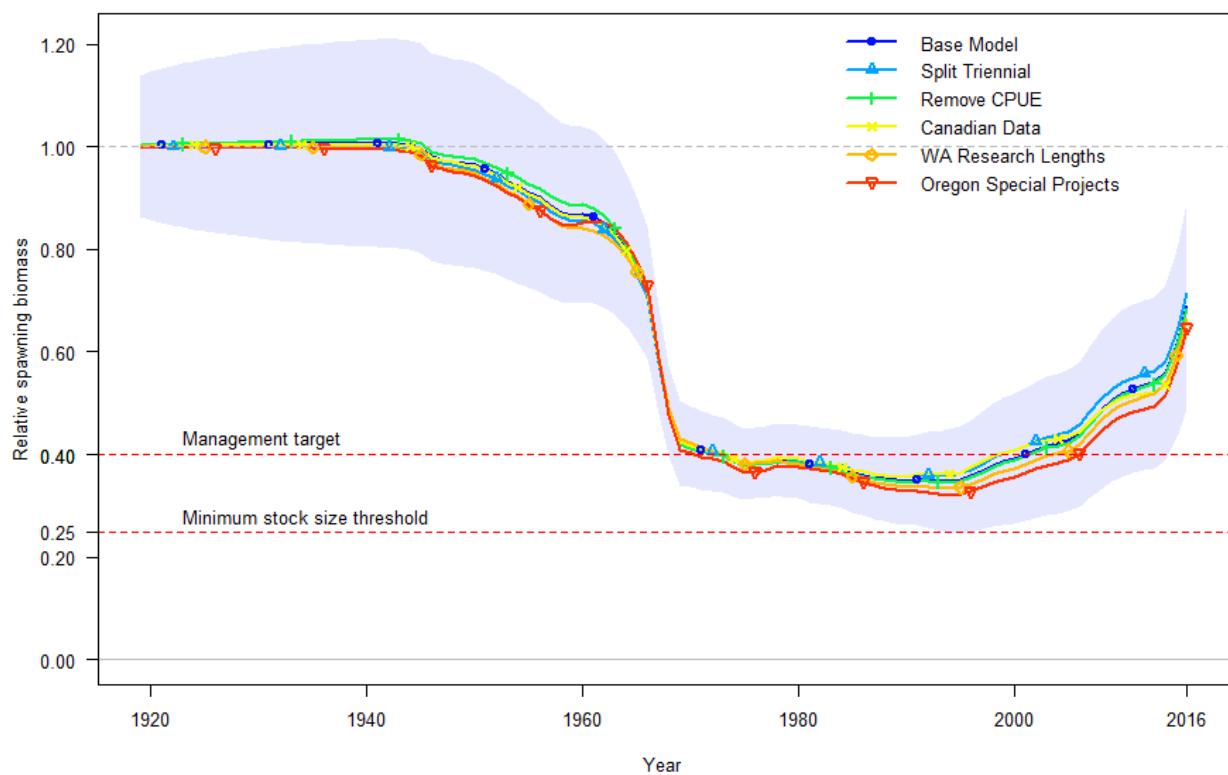


Figure 81: Time-series of relative biomass for model sensitivities for Pacific ocean perch.

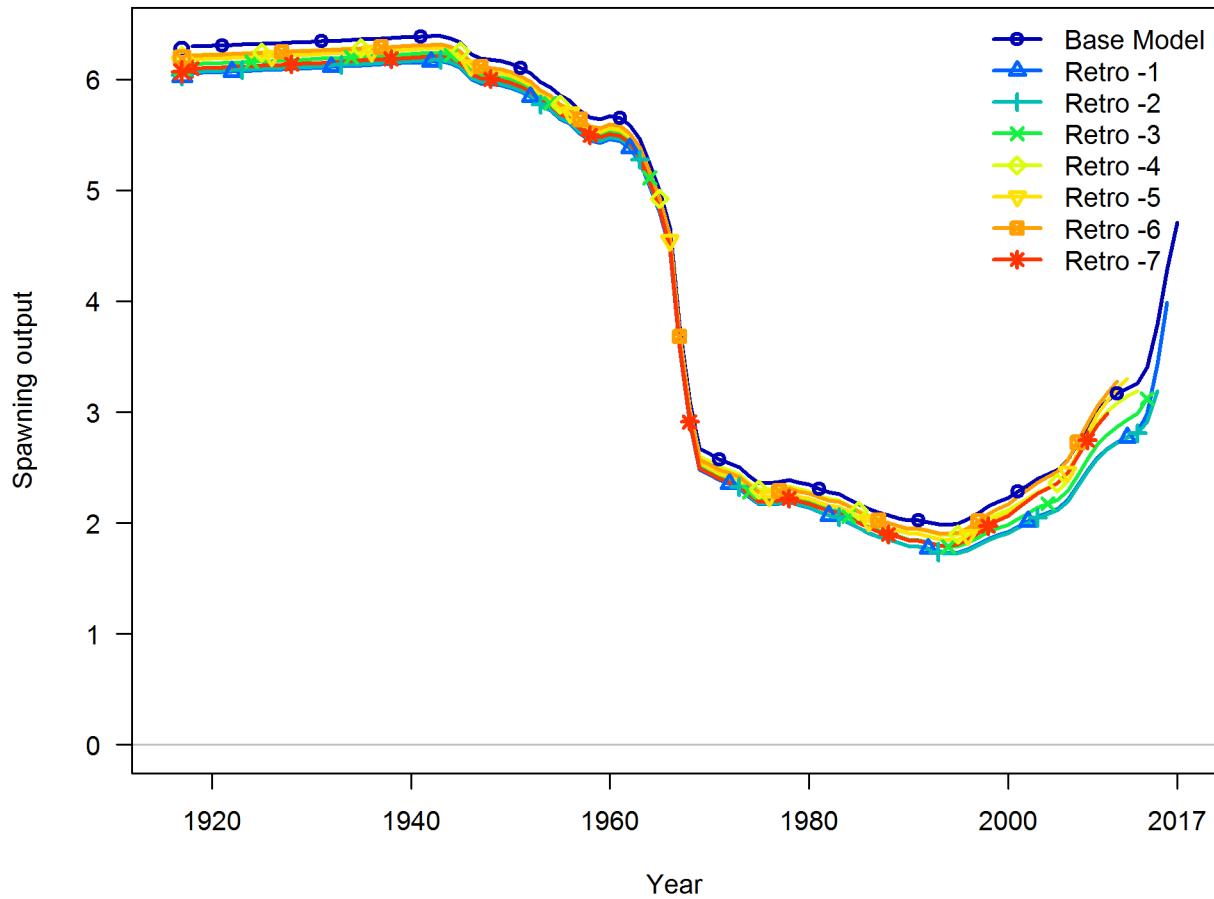


Figure 82: Retrospective pattern for spawning output.

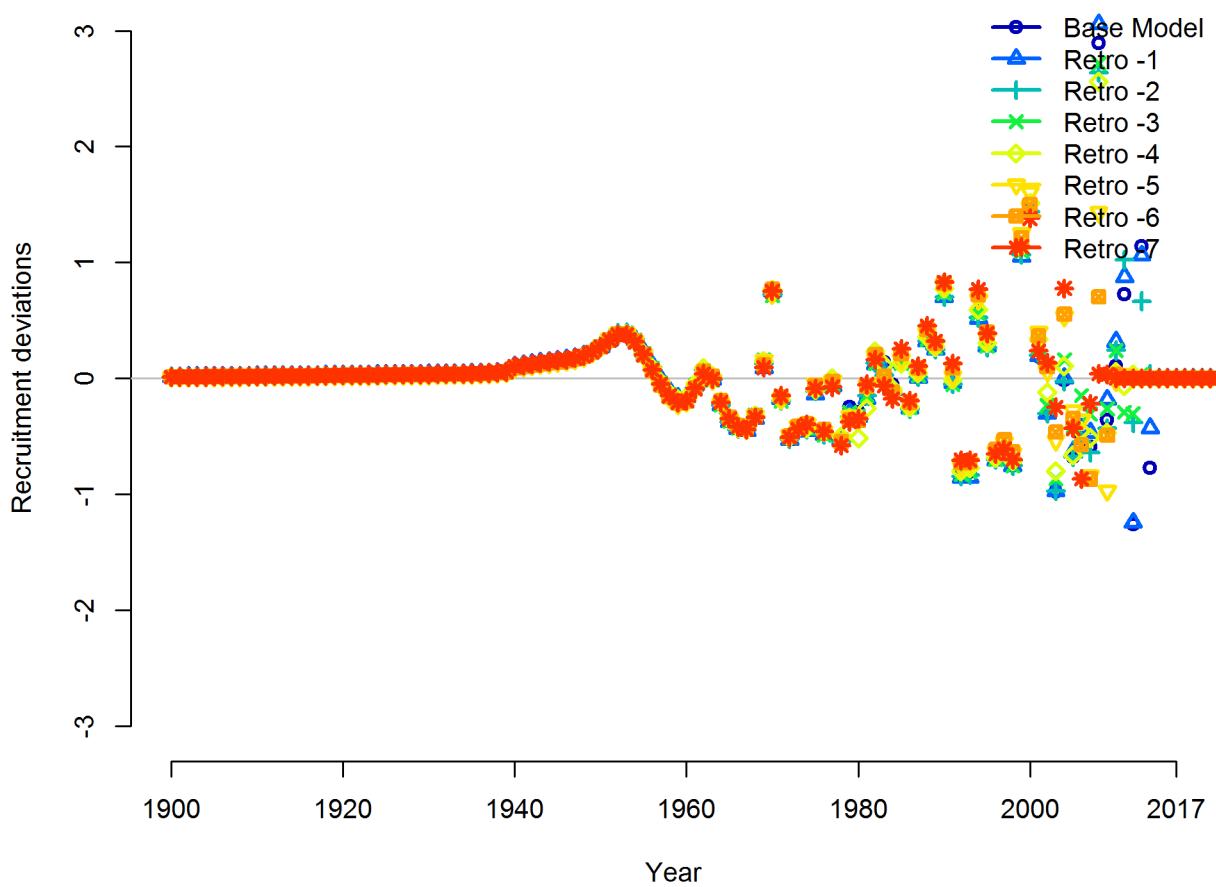


Figure 83: Retrospective pattern for estimated recruitment deviations.

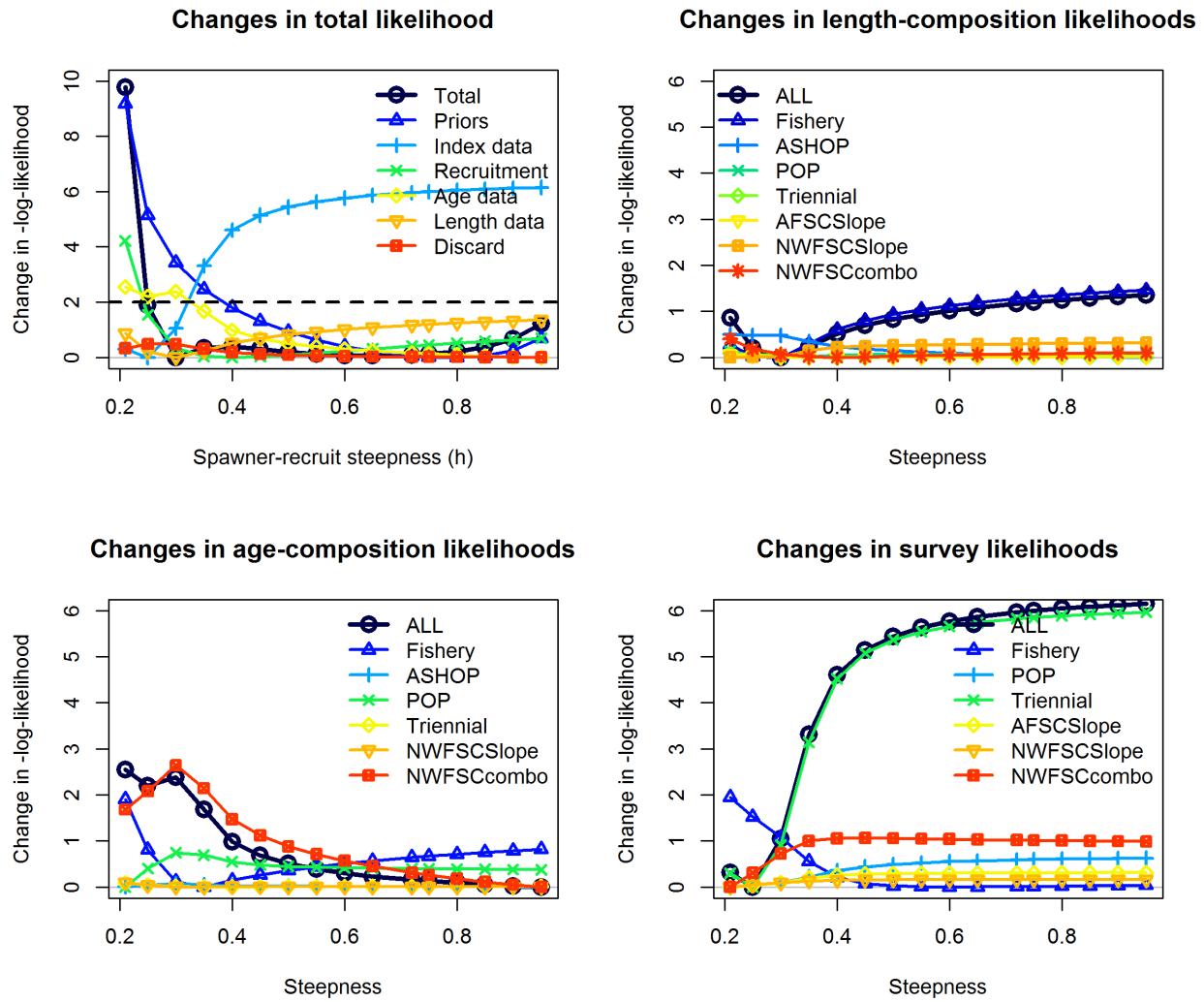


Figure 84: Likelihood profile across steepness values.

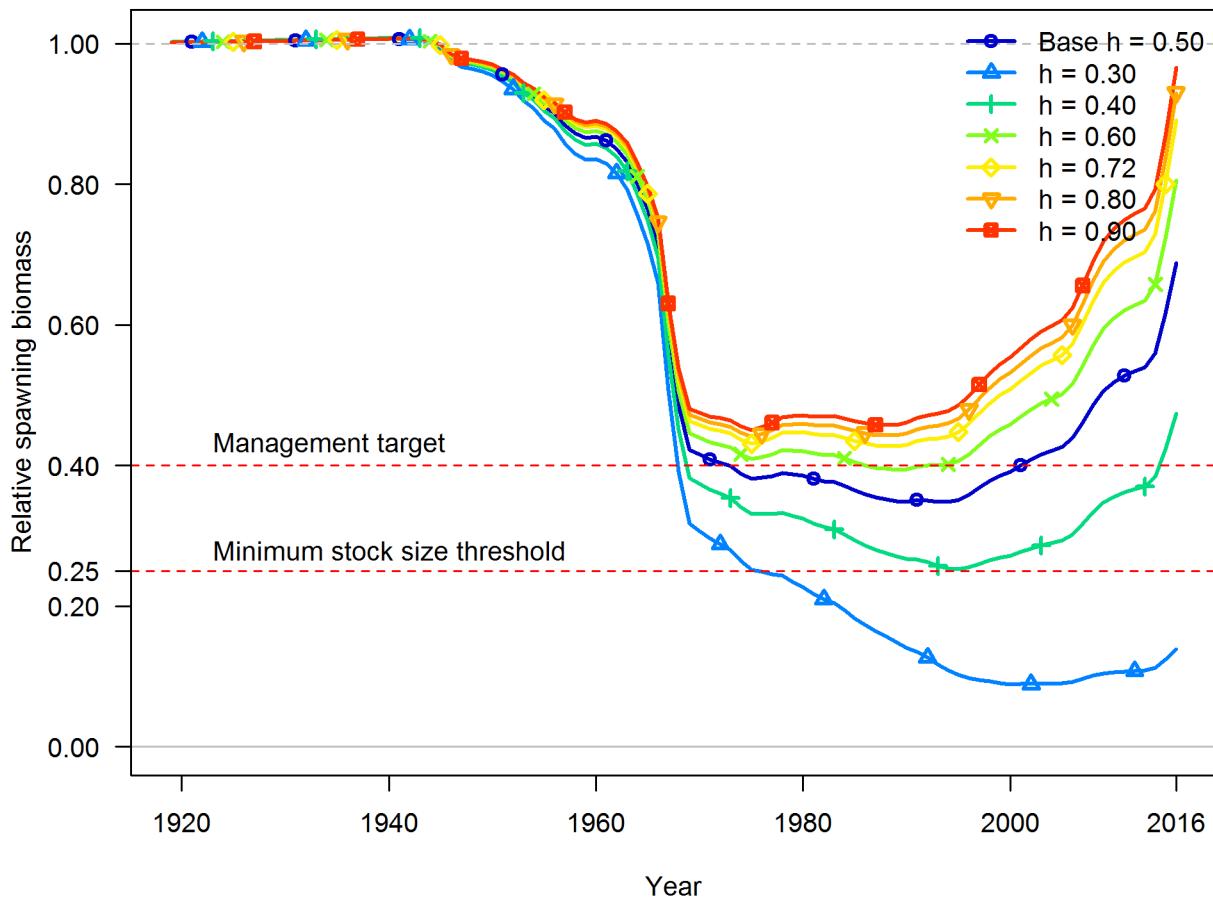


Figure 85: Trajectories of relative biomass across values of steepness.

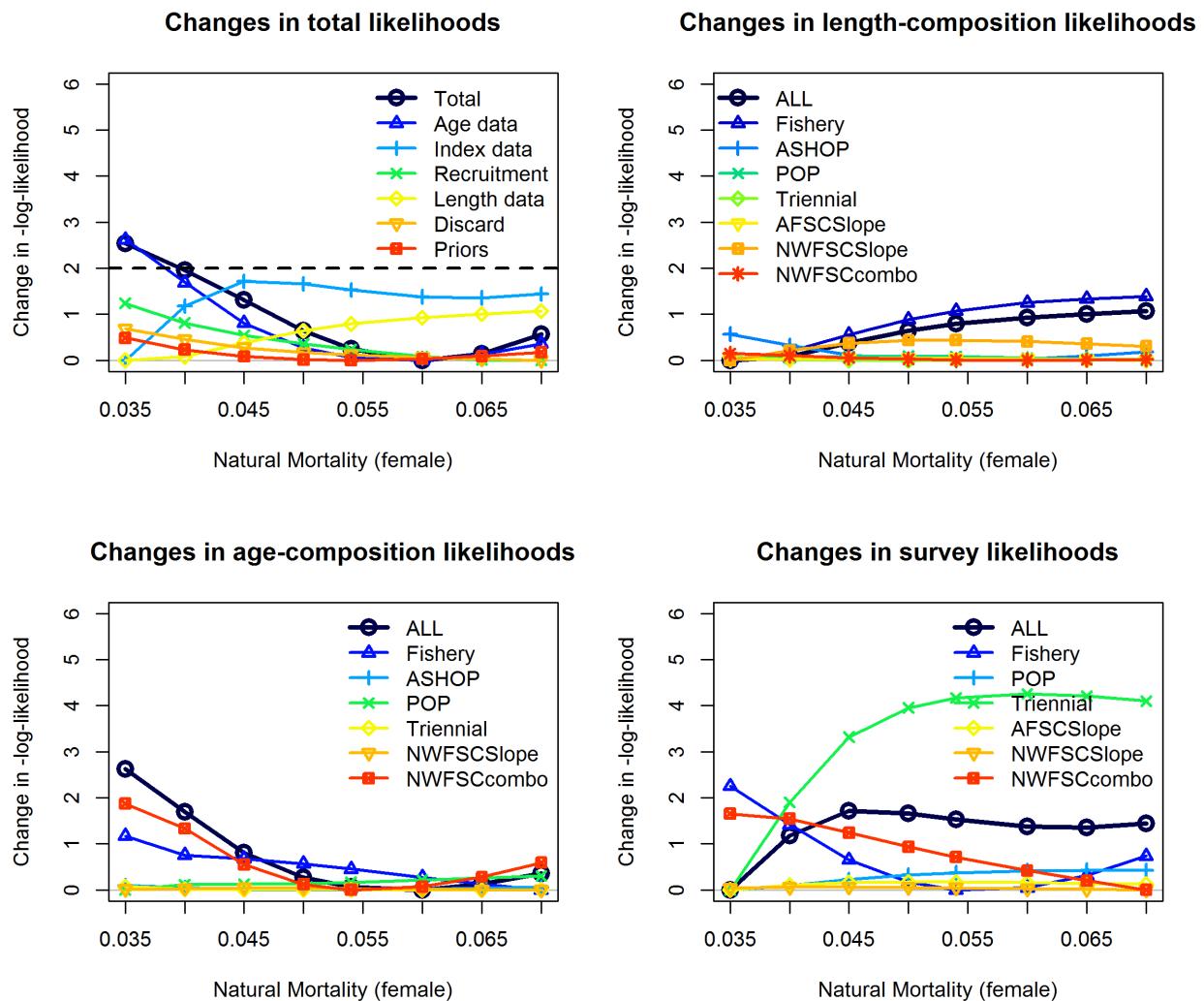


Figure 86: Likelihood profile across natural mortality values.

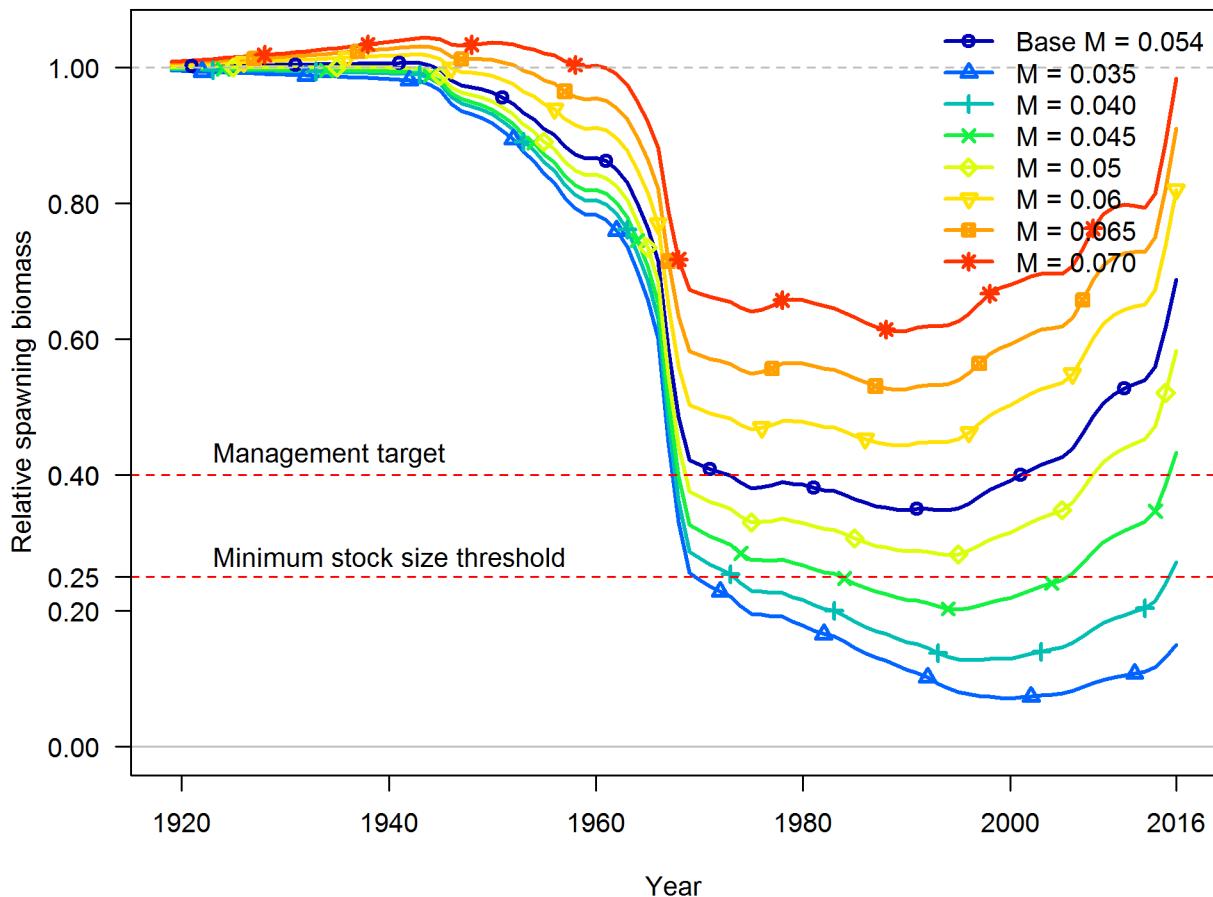


Figure 87: Trajectories of relative biomass across values of natural mortality.

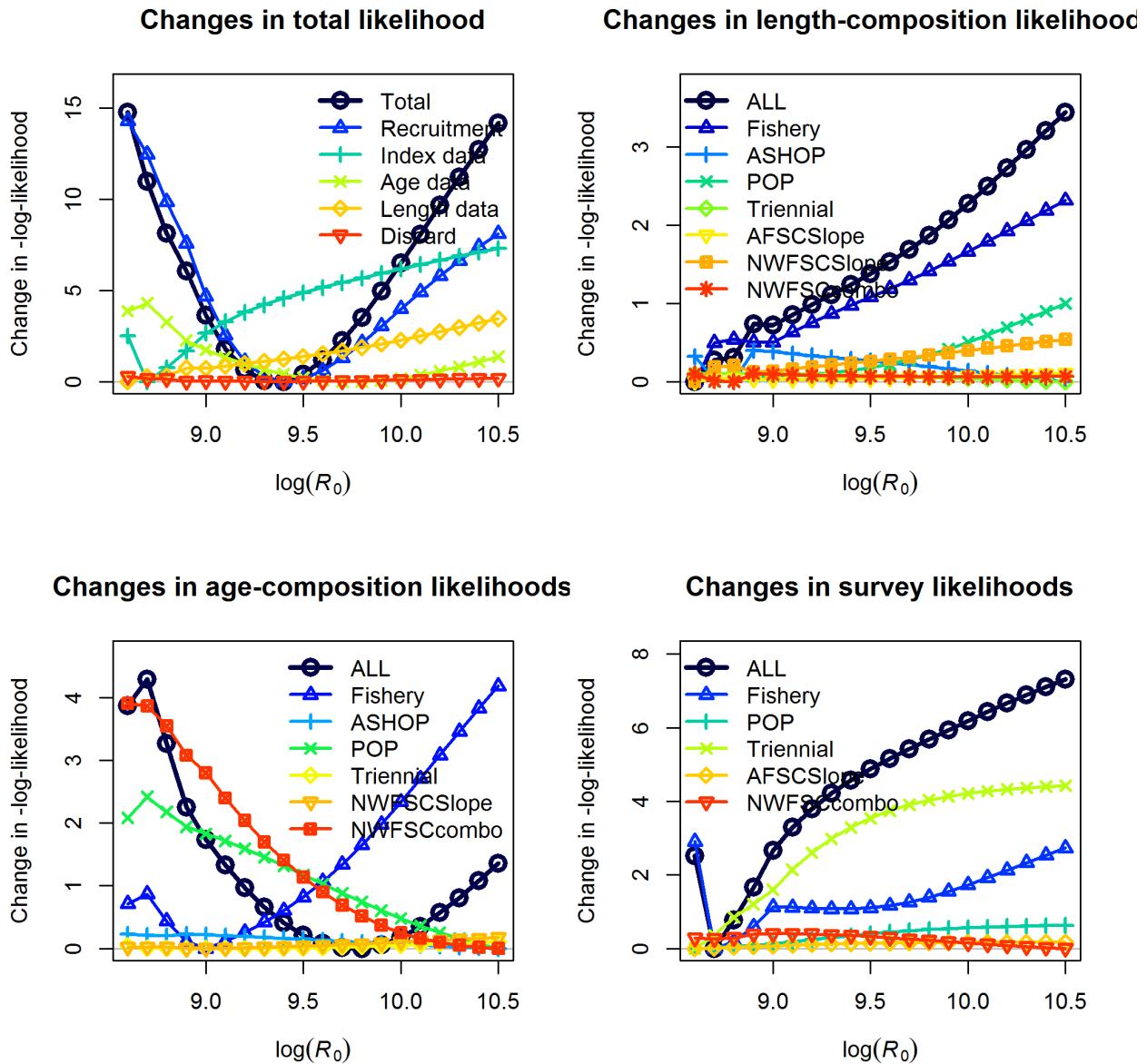


Figure 88: Likelihood profile across R_0 values.

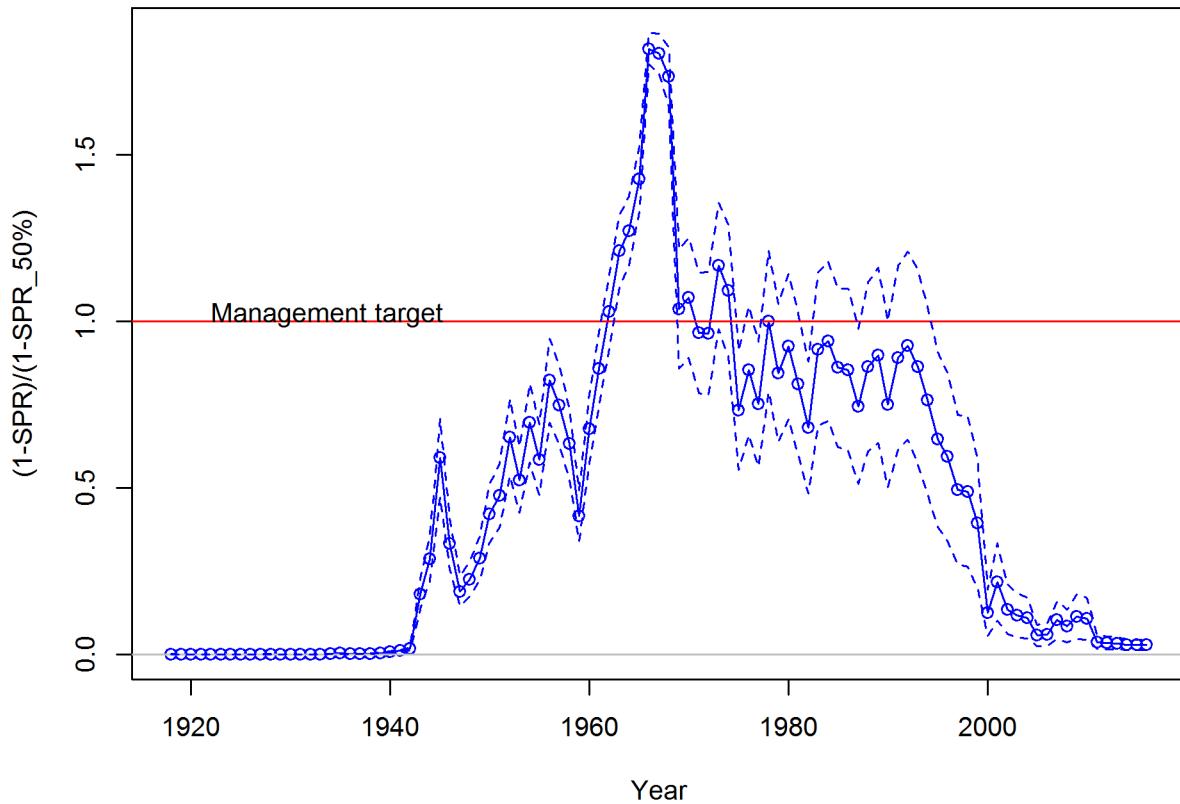


Figure 89: Estimated spawning potential ratio $(1-SPR)/(1-SPR_{50\%})$ for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess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

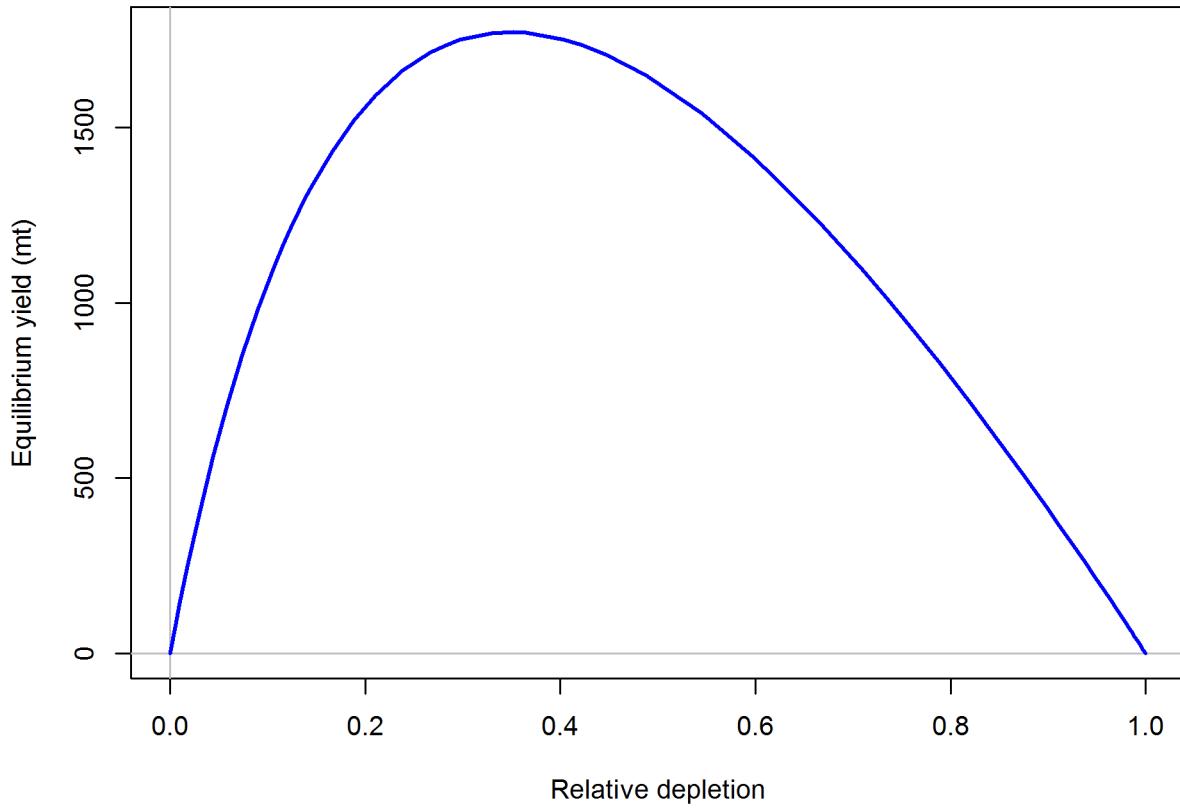


Figure 90: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.50.

₁₂₉₆ 10 Appendix A. Detailed Fit to Length Composition
₁₂₉₇ Data

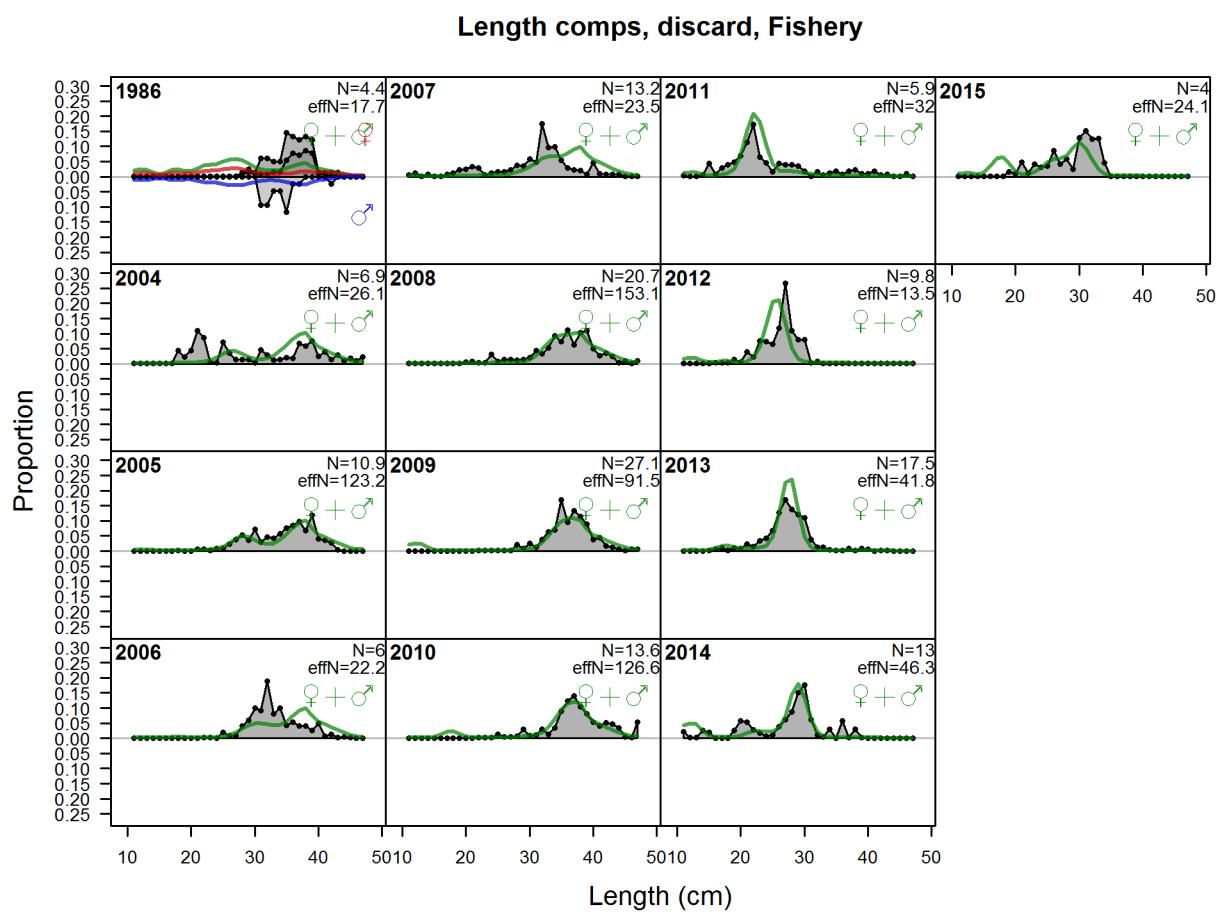


Figure 91: Length comps, discard, Fishery

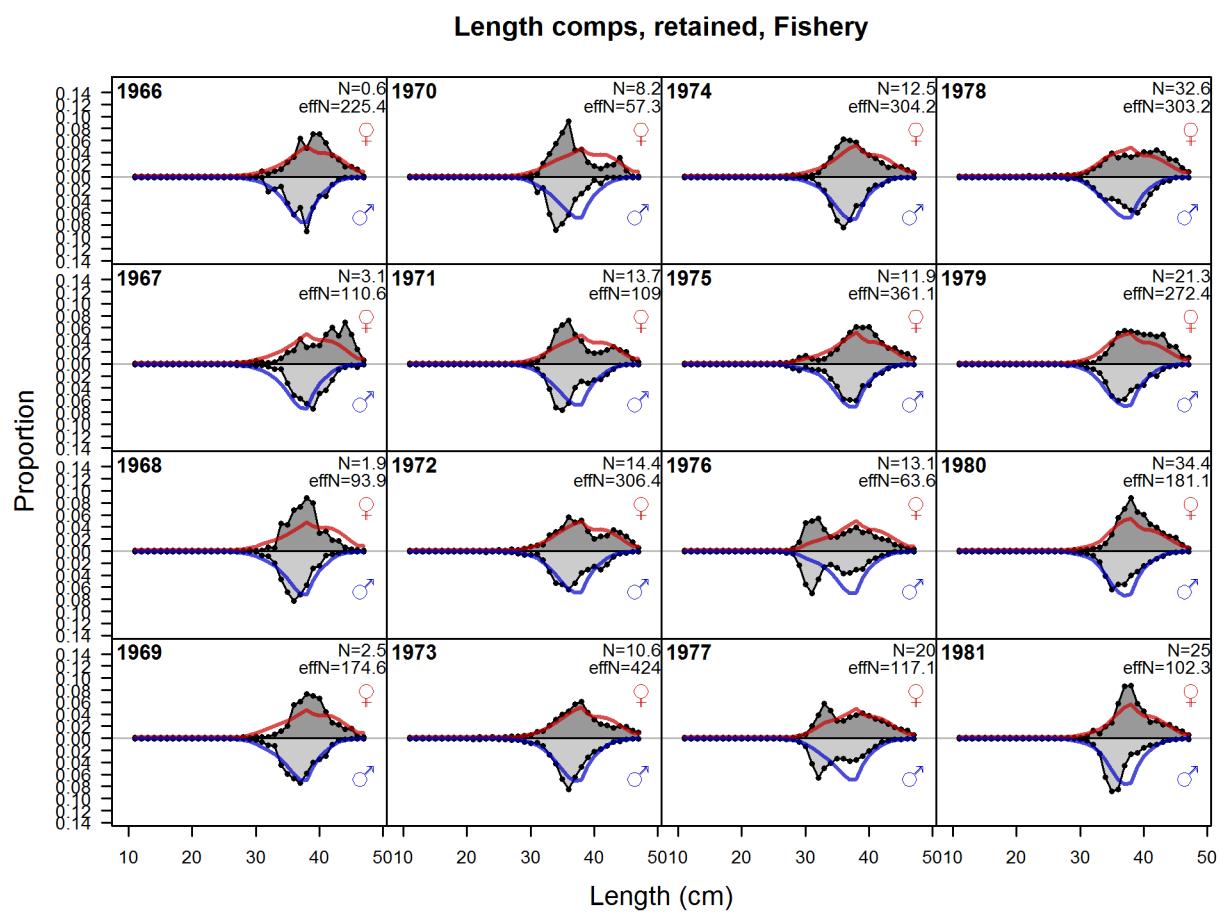


Figure 92: Length comps, retained, Fishery (plot 1 of 4)

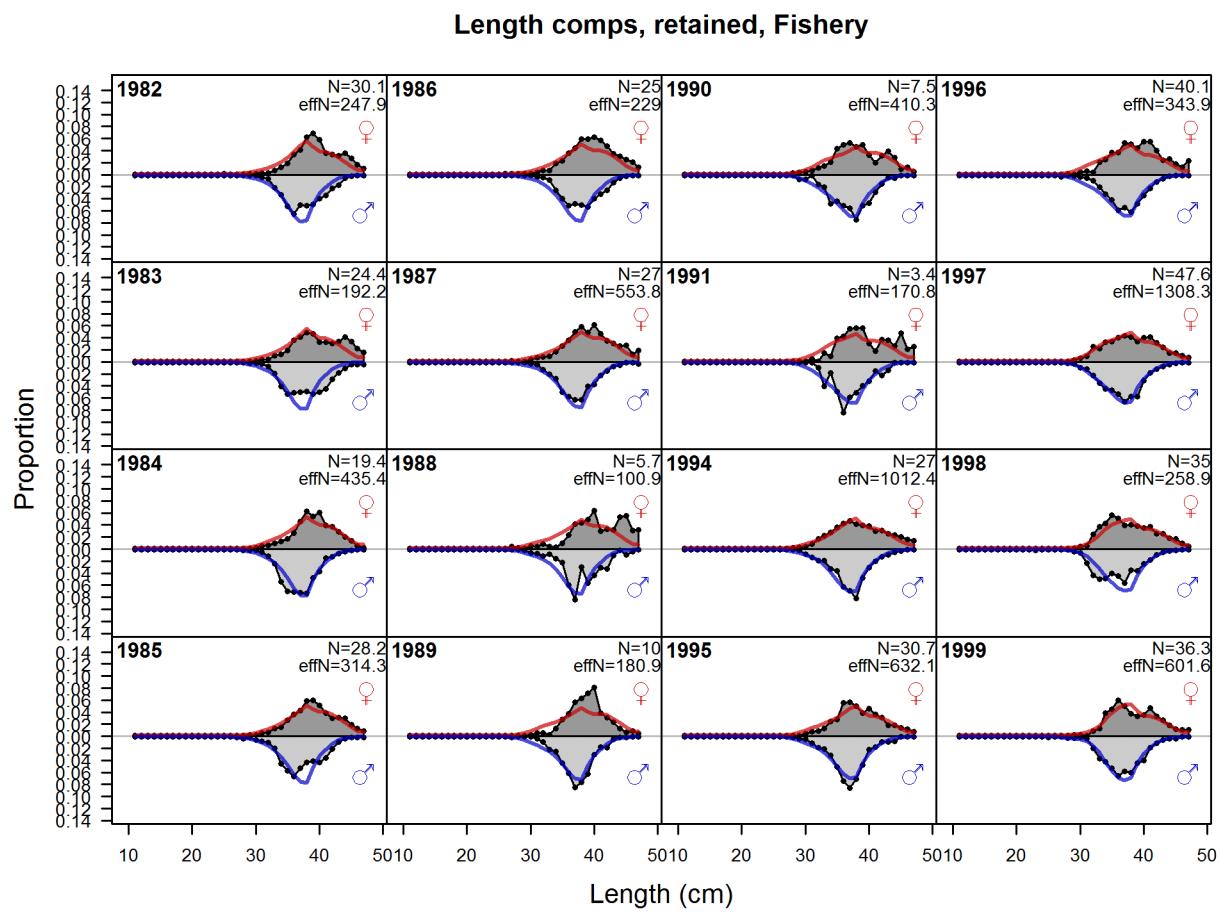


Figure 93: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4)

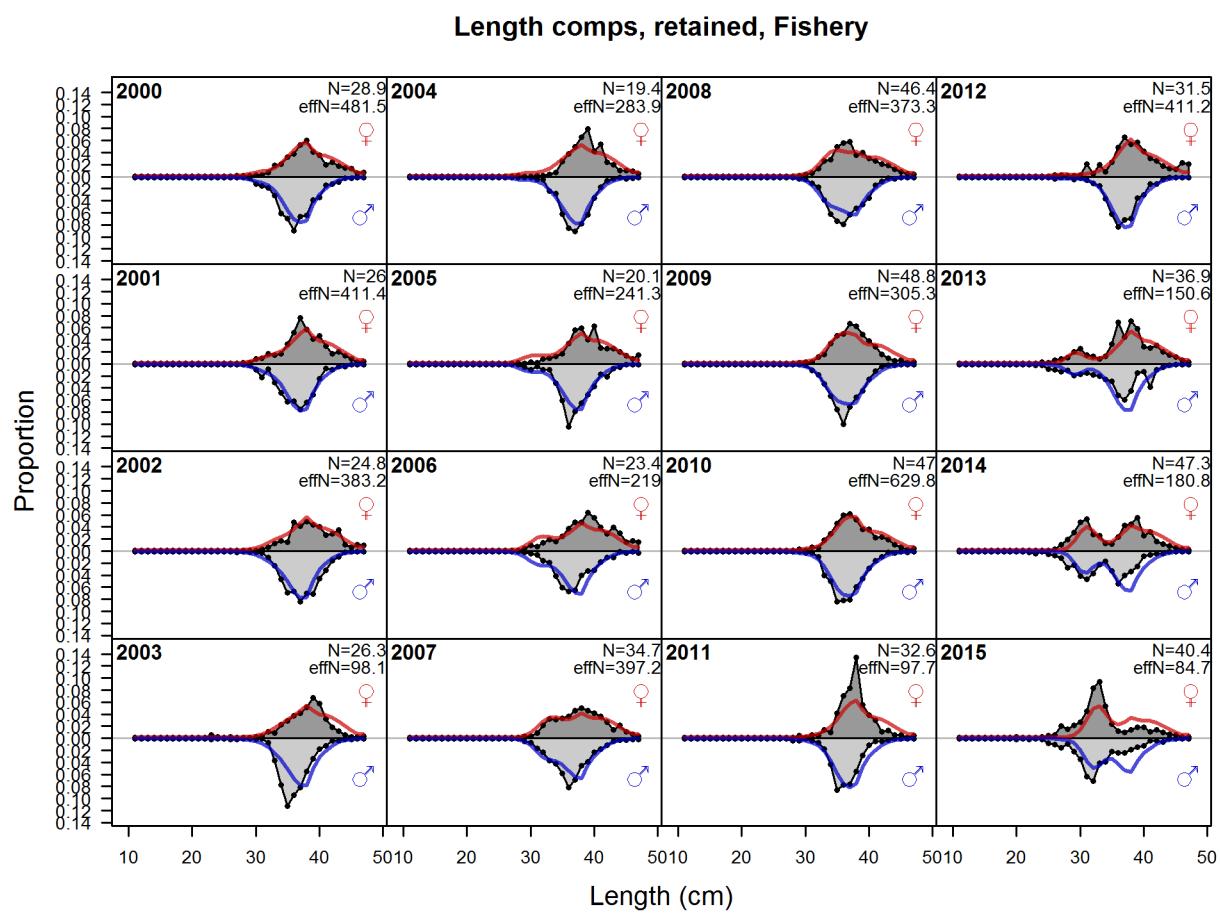


Figure 94: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4) (plot 3 of 4)

Proportion

Length comps, retained, Fishery

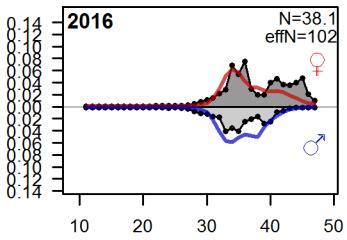


Figure 95: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4) (plot 3 of 4) (plot 4 of 4)

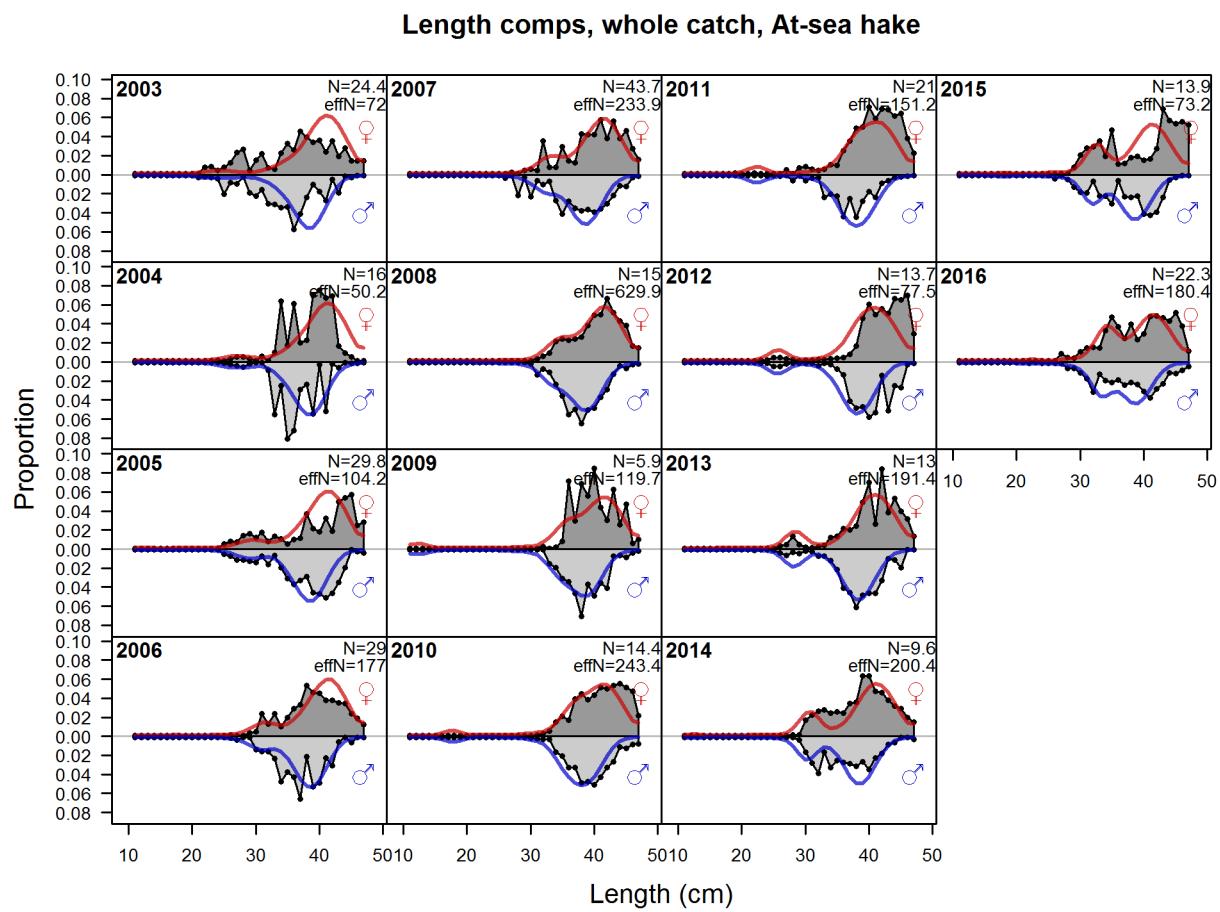


Figure 96: Length comps, whole catch, At_sea hake

Length comps, whole catch, Pacific ocean perch survey

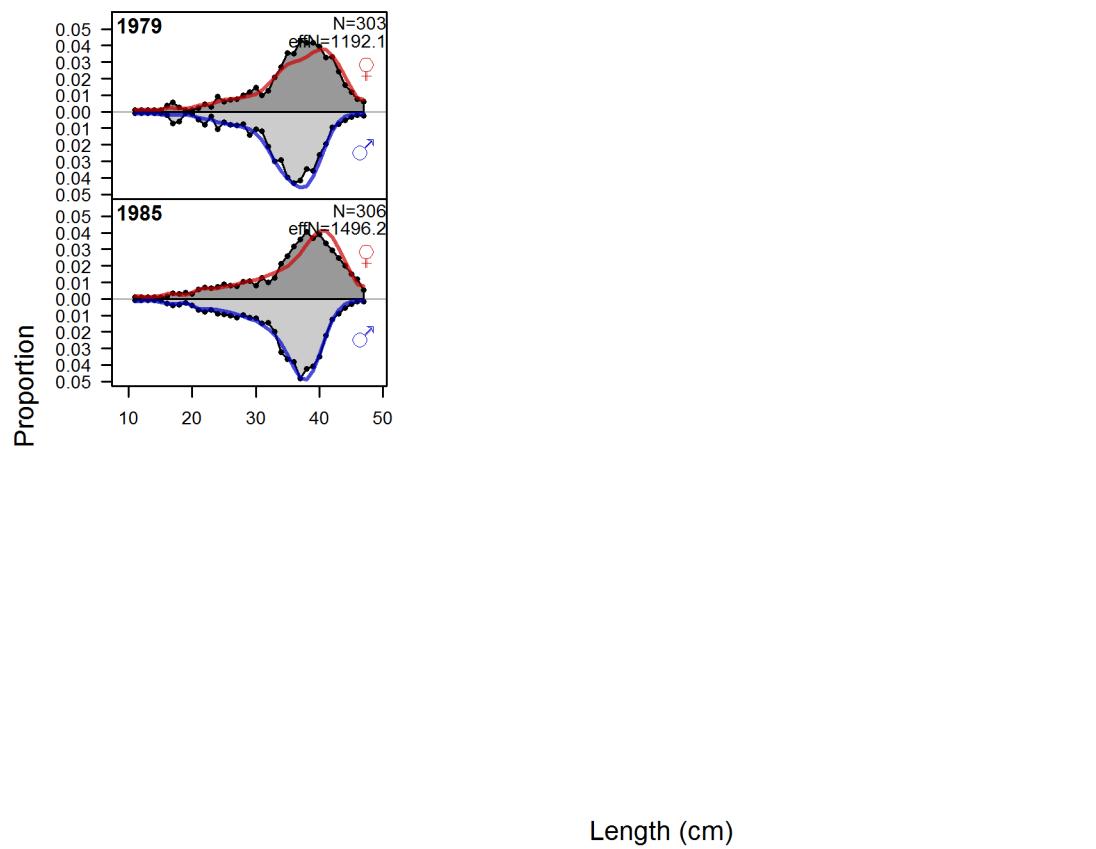


Figure 97: Length comps, whole catch, Pacific ocean perch survey

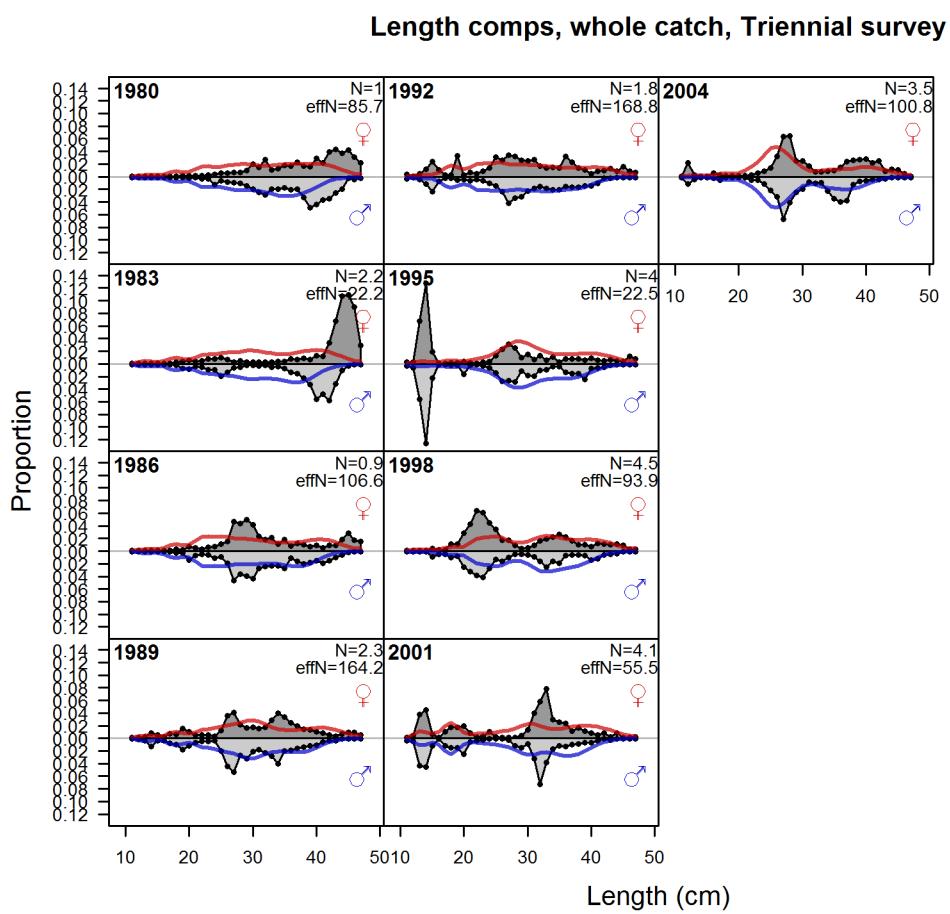


Figure 98: Length comps, whole catch, Triennial survey

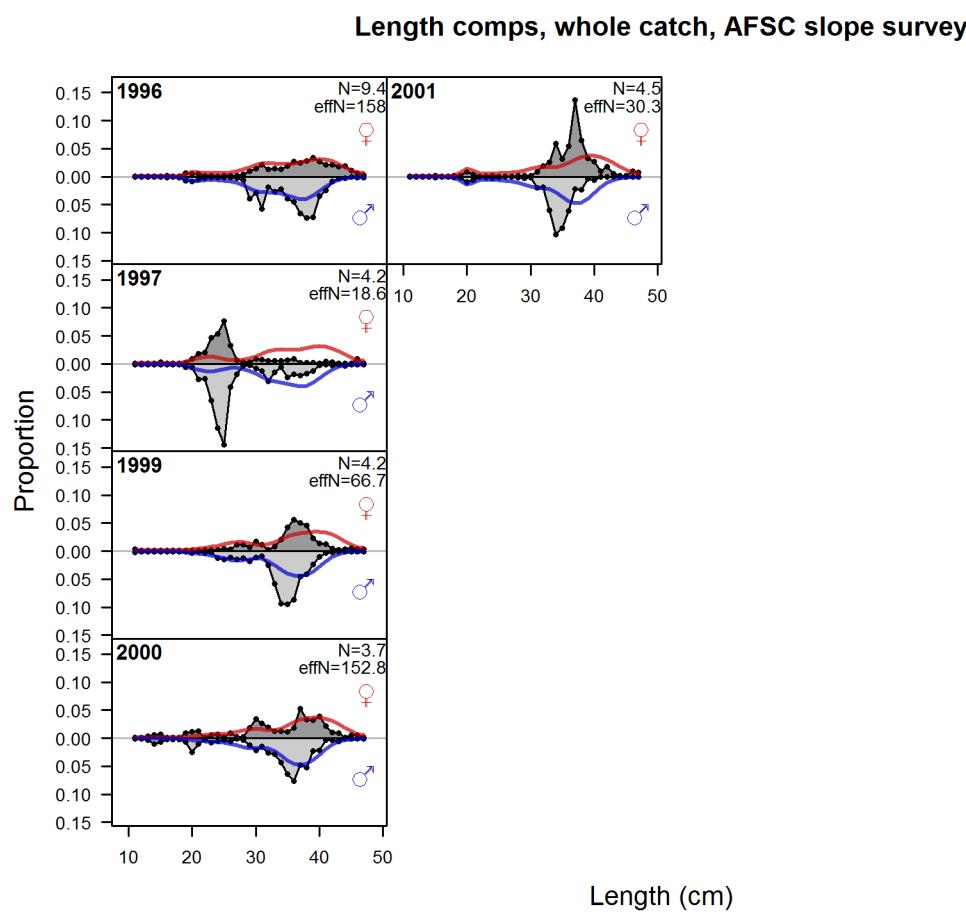


Figure 99: Length comps, whole catch, AFSC slope survey

Length comps, whole catch, NWFSC slope survey

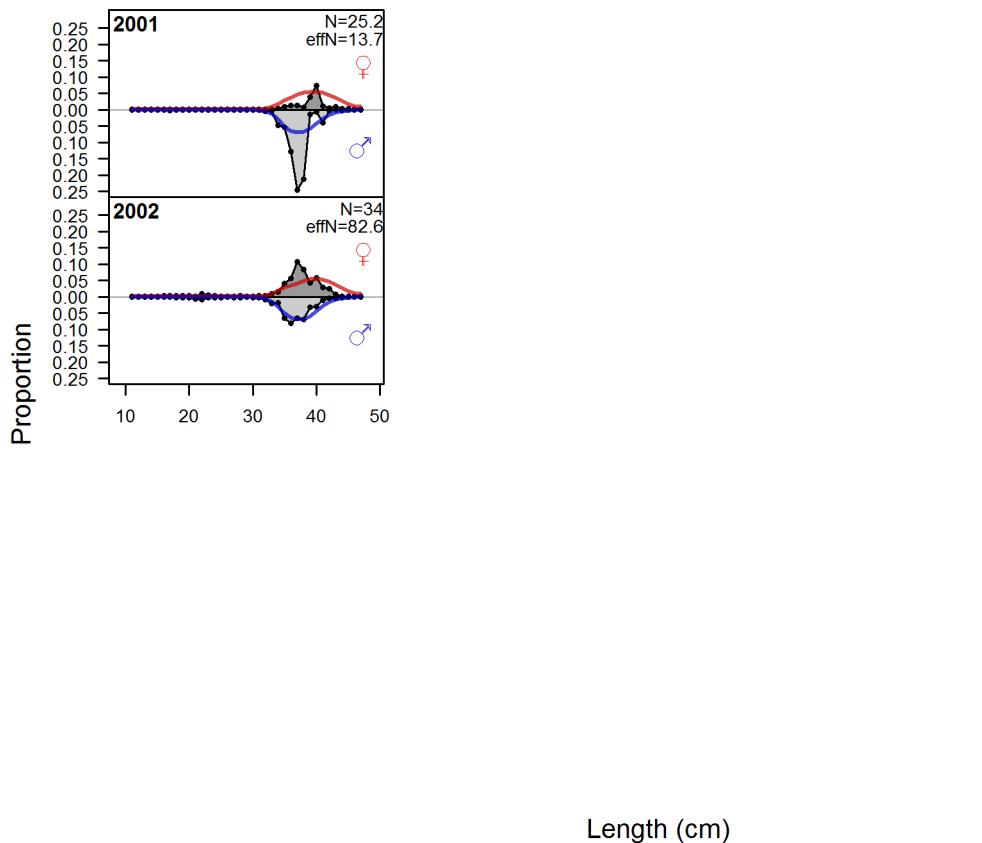


Figure 100: Length comps, whole catch, NWFSC slope survey

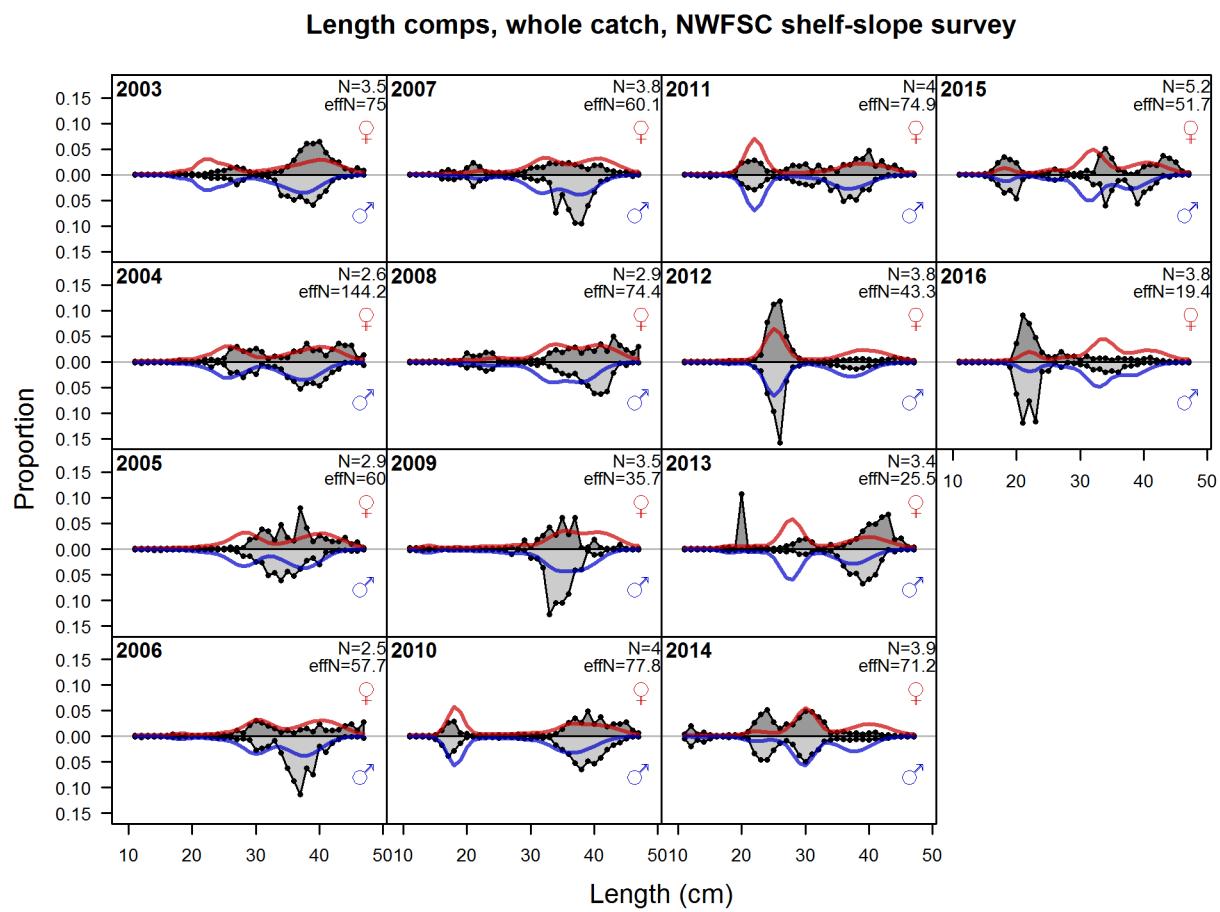


Figure 101: Length comps, whole catch, NWFSC shelf_slope survey

1298 **11 Appendix B. Detailed Fit to Age Composition Data**

1299 **12 References**

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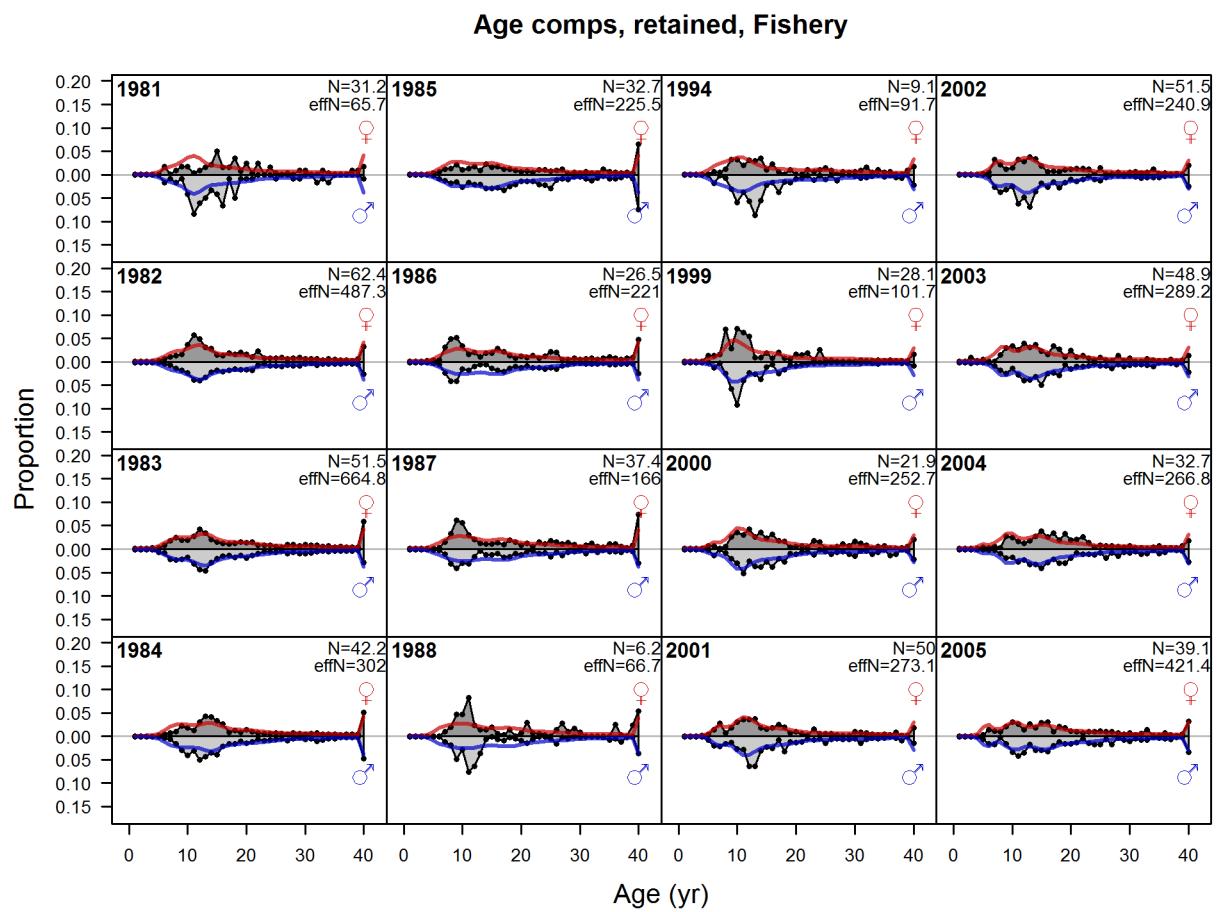


Figure 102: Age comps, retained, Fishery (plot 1 of 2)

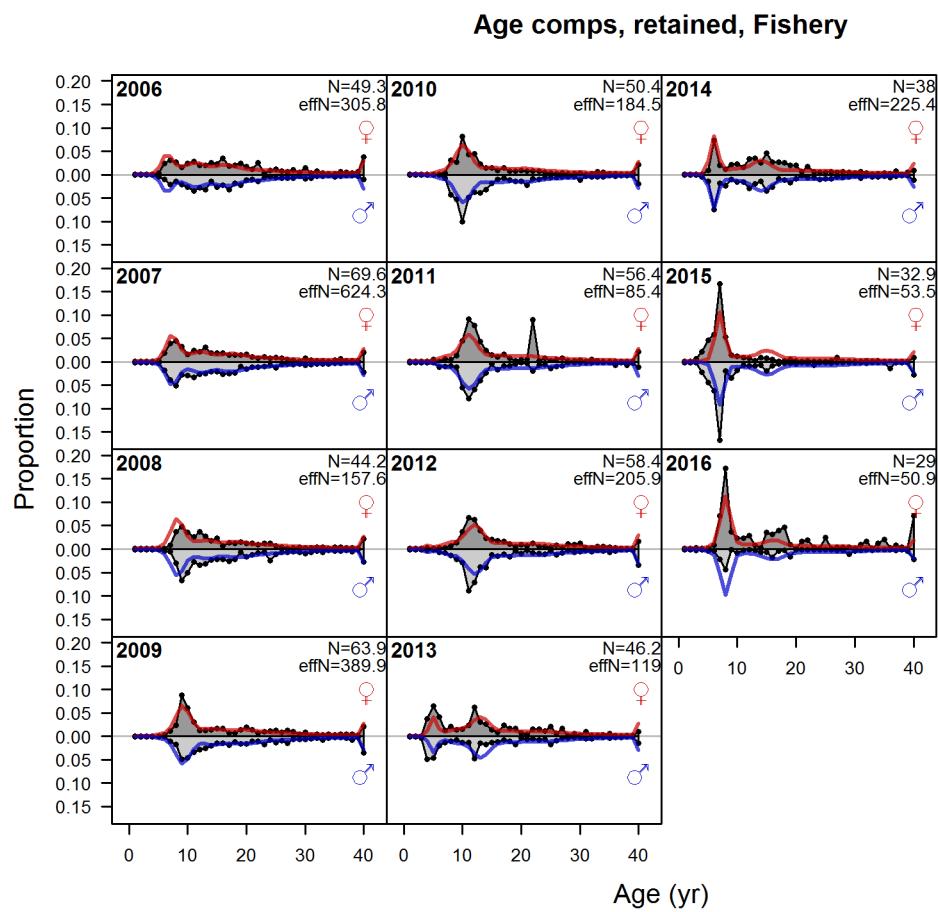


Figure 103: Age comps, retained, Fishery (plot 1 of 2) (plot 2 of 2)

Age comps, whole catch, At-sea hake

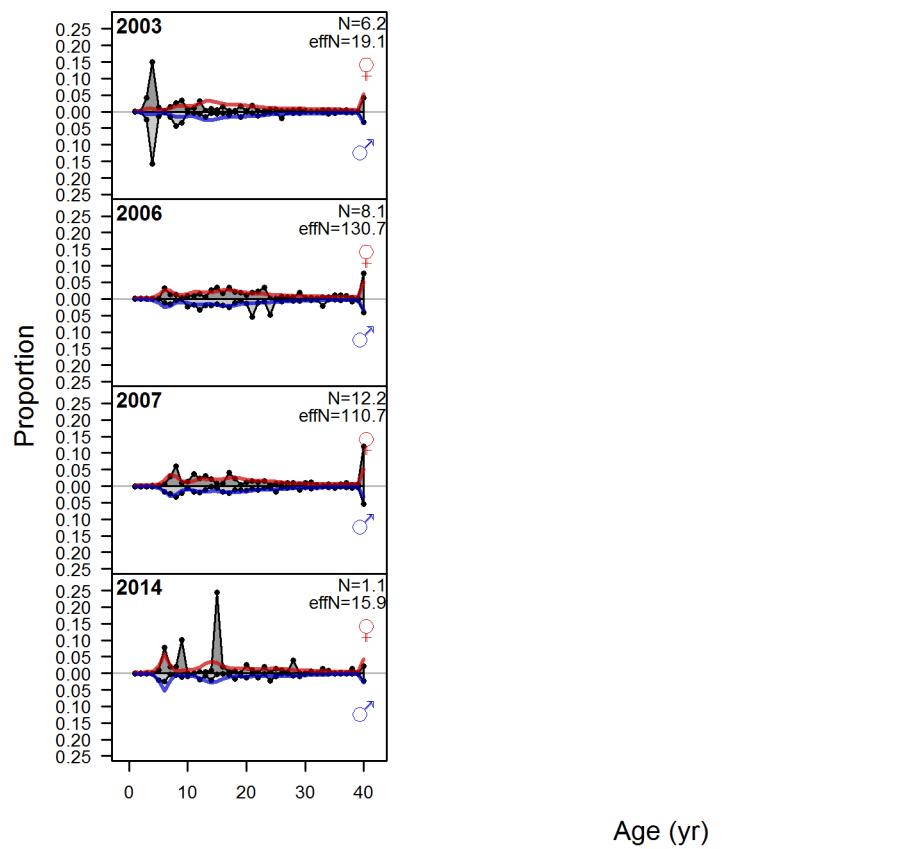
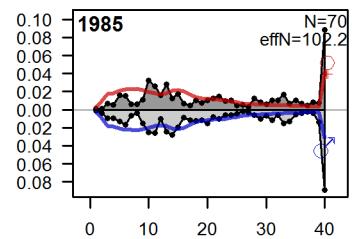


Figure 104: Age comps, whole catch, At_sea hake

Age comps, whole catch, Pacific ocean perch survey



Age (yr)

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

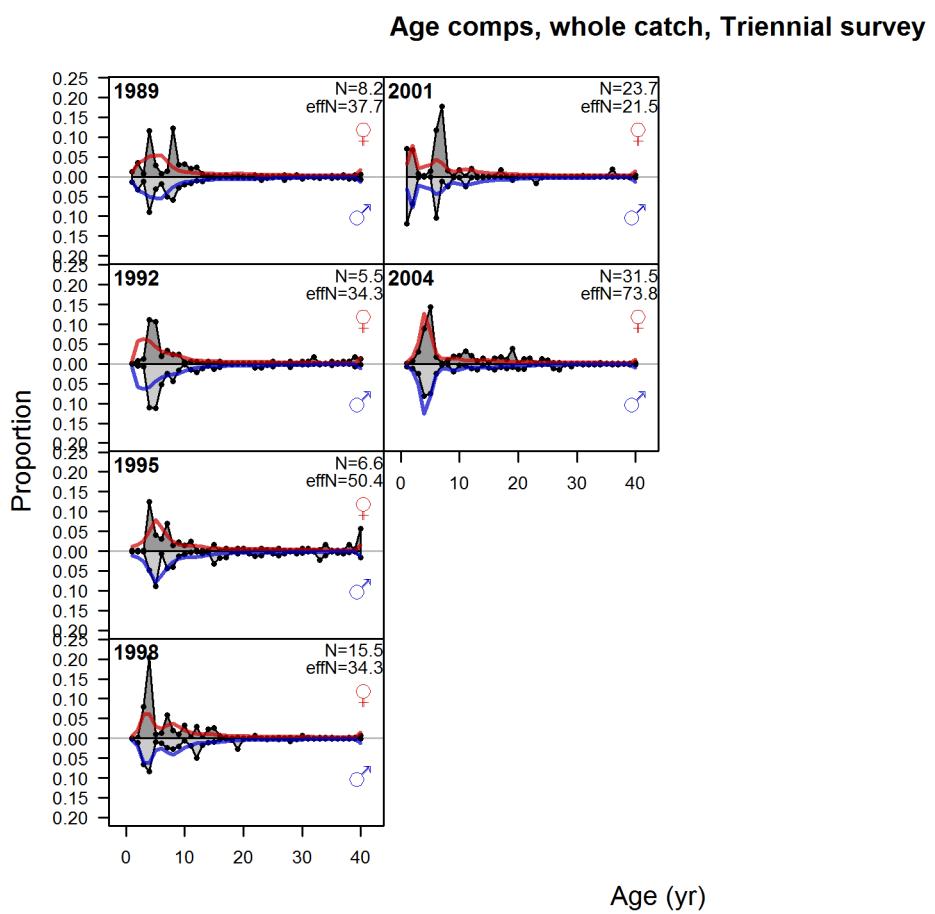


Figure 106: Age comps, whole catch, Triennial survey

Age comps, whole catch, NWFSC slope survey

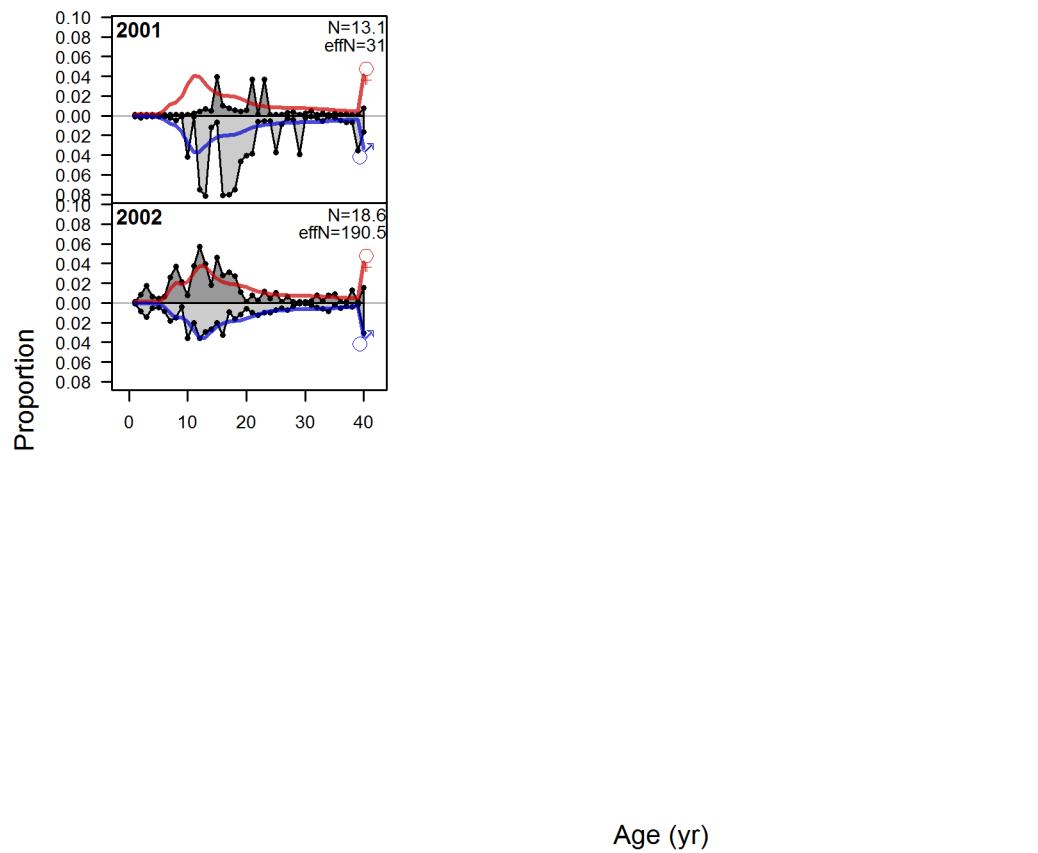


Figure 107: Age comps, whole catch, NWFSC slope survey

Ghost age comps, whole catch, NWFSC shelf-slope survey

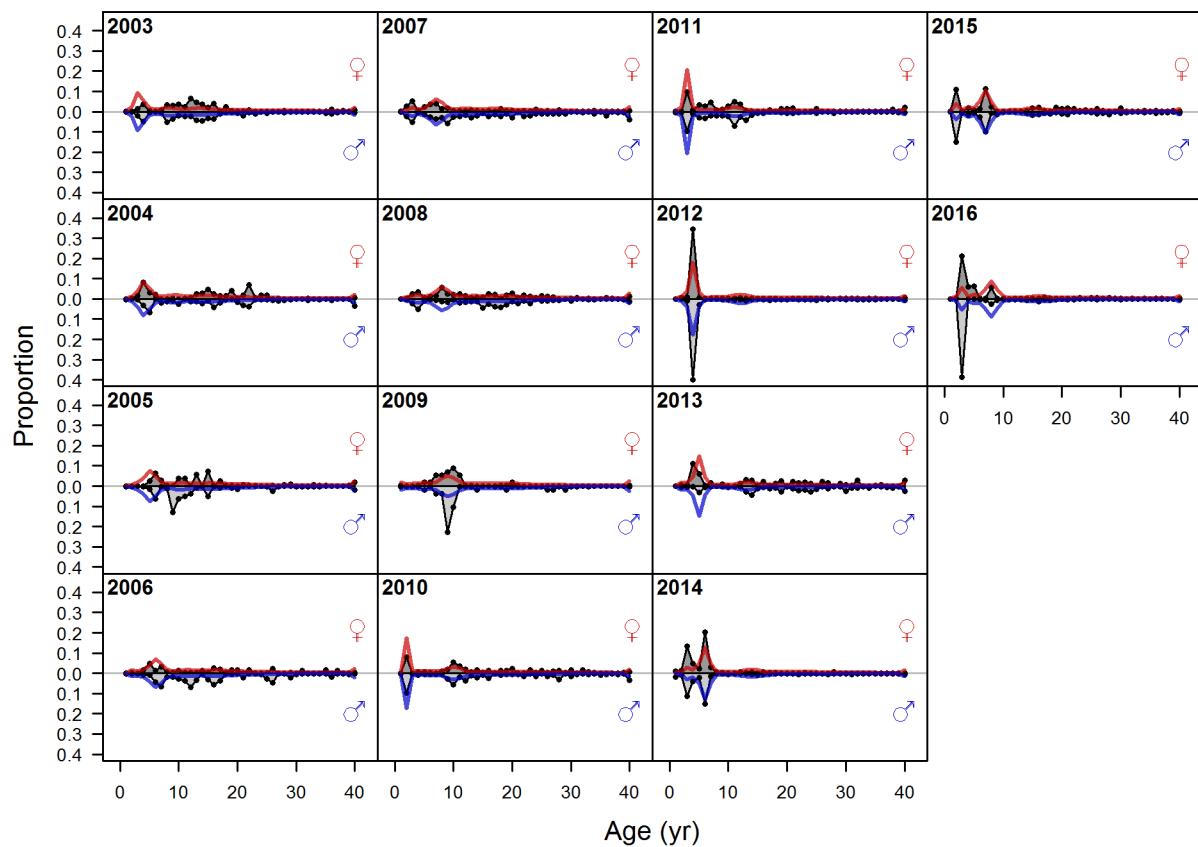


Figure 108: Ghost age comps, whole catch, NWFSC shelf_slope survey

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