

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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⁹⁰ **Executive Summary**

⁹¹ **Stock**

⁹² This assessment reports the status of the Pacific ocean perch rockfish (*Sebastodes alutus*) off
⁹³ the US west coast from Northern California to the Canadian border using data through 2016.
⁹⁴ Pacific ocean perch are most abundant in the Gulf of Alaska and have been observed off
⁹⁵ of Japan, in the Bering Sea, and south to Baja California, though they are sparse south
⁹⁶ of Oregon and rare in southern California. Although neither catches nor other data from
⁹⁷ north of the US-Canada border were included in this assessment, the connectivity of these
⁹⁸ populations and the contribution to the biomass possibly through adult migration and/or
⁹⁹ larval dispersion is not certain. To date, no significant genetic differences have been found in
¹⁰⁰ the range covered by this assessment.

¹⁰¹ **Landings**

¹⁰² Harvest of Pacific ocean perch first exceeded 1 mt off the US west coast in 1918. Catches
¹⁰³ ramped up in the 1940s with large removals in Washington waters. During the 1950s the
¹⁰⁴ removals primary occurred in Oregon waters with catches from Washington declining following
¹⁰⁵ the 1940s. The largest removals, occurring between 1966-1968, were largely a result of harvest
¹⁰⁶ by foreign vessels. The fishery proceeded with more moderate removals ranging between
¹⁰⁷ 1165 to 2619 metric tons (mt) per year between 1969 and 1980. Removals generally declined
¹⁰⁸ from 1981 to 1994 to between 1031 and 1616 mt per year. Pacific ocean perch was declared
¹⁰⁹ overfished in 1999, resulting in large reductions in harvest in years since the declaration.
¹¹⁰ Since 2000, annual landings of Pacific ocean perch have ranged between 54-267 mt, with
¹¹¹ landings in 2016 totaling 65 mt.

¹¹² Pacific ocean perch are a desirable market species and discarding has historically been low.
¹¹³ However, management restrictions (e.g. trip limits) resulted in increased discarding starting
¹¹⁴ in the early 1990s. During the 2000s discarding increased for Pacific ocean perch due to
¹¹⁵ harvest restrictions imposed to allow rebuilding, with estimated discard rates from the fishery
¹¹⁶ peaking in 2009 and 2010 to approximately 50%, prior to implementation of catch shares in
¹¹⁷ 2011. Since 2011, discarding of Pacific ocean perch has been estimated to be less than 3.5%.

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

| 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 |

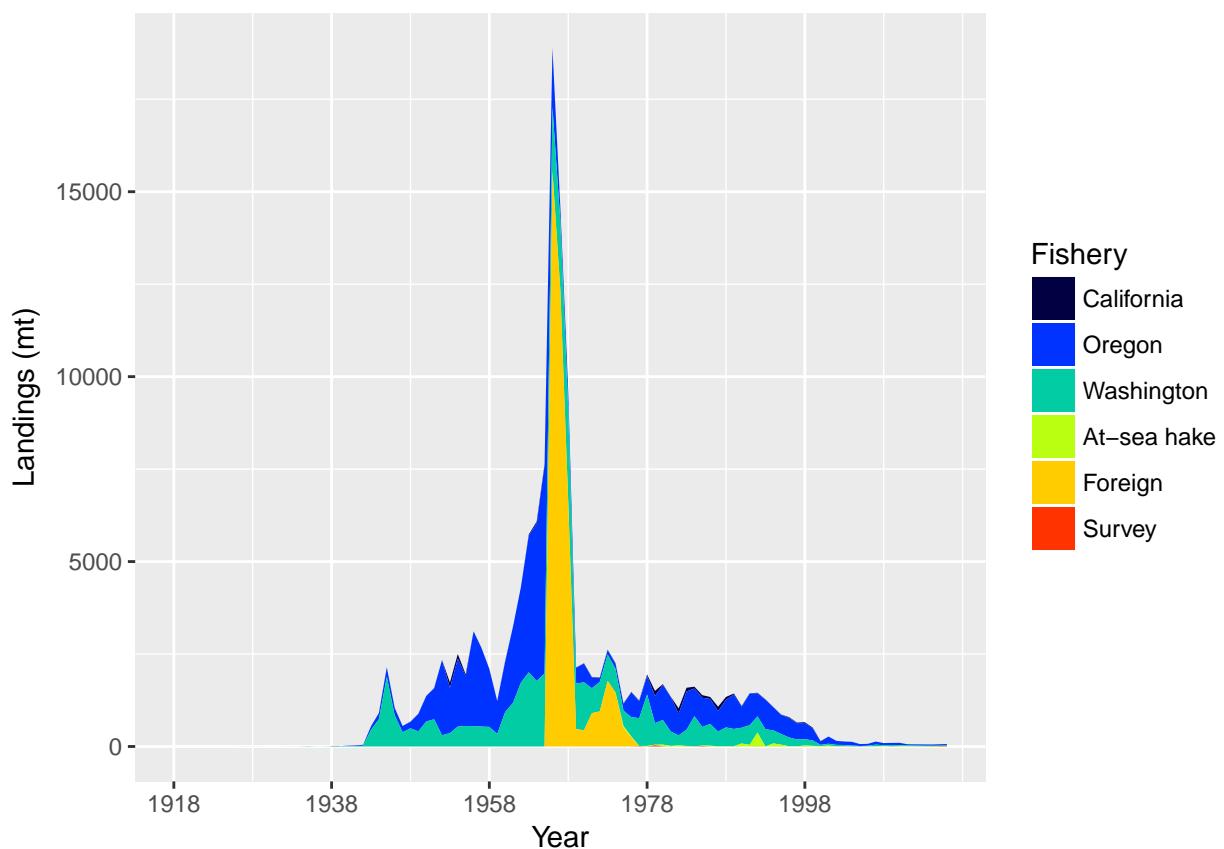


Figure a: Landings of Pacific ocean perch for California, Oregon, Washington, the foreign fishery (1966-1976), At-sea hake fishery, and fishery-independent surveys.

¹¹⁸ Data and Assessment

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

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

¹³³ The definition of fishing fleets have changed from those in the 2011 assessment. Three fishing
¹³⁴ fleets were specified within the model: 1) a combined bottom trawl, mid-water trawl and
¹³⁵ fixed gear fleet where only a small fraction of Pacific ocean perch were captured 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 on discarding data and known management restrictions. However, very little if
¹³⁹ 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-effort and
¹⁴³ 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; information on natural
¹⁴⁶ mortality and the steepness of the Beverton-Holt stock-recruitment relationship; and estimates
¹⁴⁷ of ageing error. Recruitment at “equilibrium spawning output”, length-based selectivity of
¹⁴⁸ the fisheries and surveys, retention of the fishery, catchability of the surveys, growth, the
¹⁴⁹ time-series of biomass, age and size structure, and current and projected future stock status
¹⁵⁰ are outputs of the model. Natural mortality and steepness were fixed in the final model.
¹⁵¹ This was done due to relatively flat likelihood surfaces, such that fixing parameters and then
¹⁵² varying them in sensitivity analyses was deemed the best way to characterize uncertainty.

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

¹⁶⁷ A base model was selected which best captures the central tendency for those sources of
¹⁶⁸ uncertainty considered in the model.

¹⁶⁹ Stock Biomass

¹⁷⁰ The predicted spawning output from the base model generally showed a slight decline prior
¹⁷¹ to 1966 when fishing by the foreign fleet commenced. A short, but sharp decline occurred
¹⁷² between 1966 and 1970, followed by a period of the spawning output stabilizing or with a
¹⁷³ minimal decline until the late 1990s. The stock showed increases in stock size following the
¹⁷⁴ year 2000 due to a combination of strong recruitment and low catches. The 2017 estimated
¹⁷⁵ spawning output relative to unfished equilibrium spawning output is above the target of
¹⁷⁶ 40% of unfished spawning output at 74.9% (~95% asymptotic interval: $\pm 53.2\%-96.7\%$).
¹⁷⁷ Approximate confidence intervals based on the asymptotic variance estimates show that the
¹⁷⁸ uncertainty in the estimated spawning output is high.

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

| 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

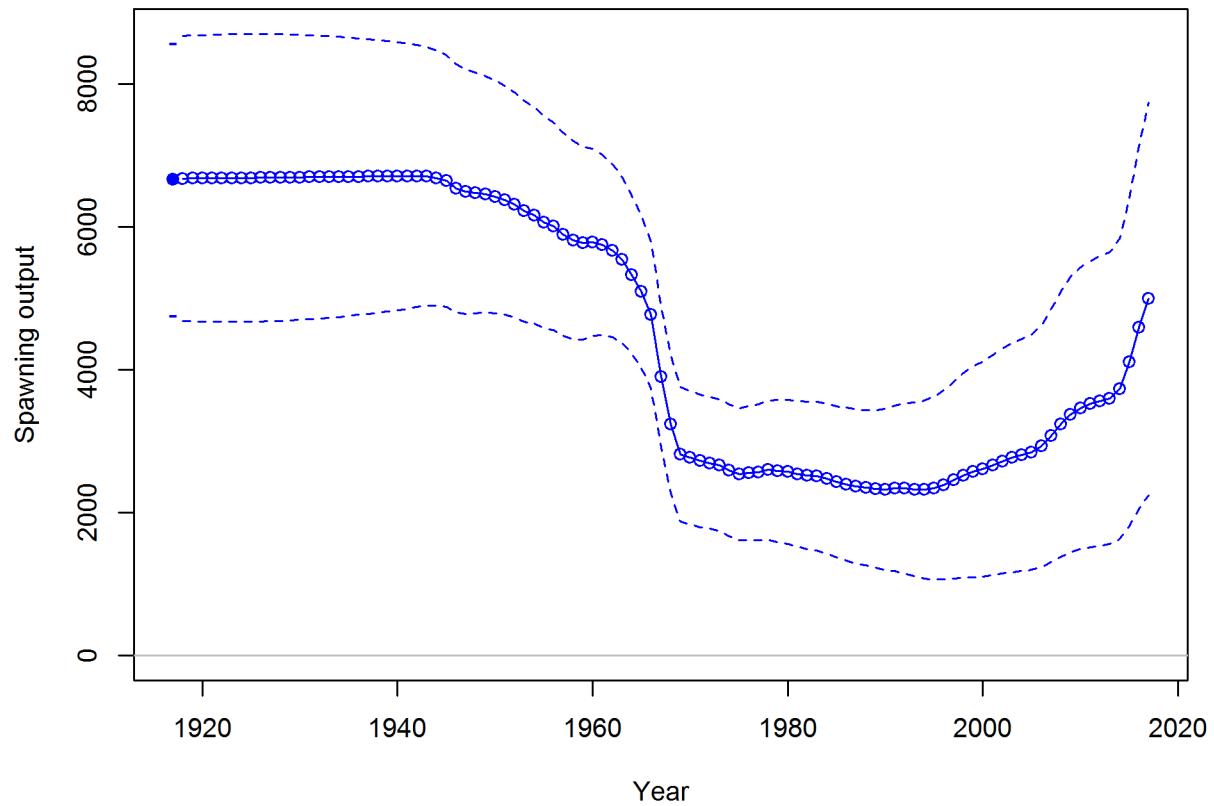


Figure b: Time-series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model.

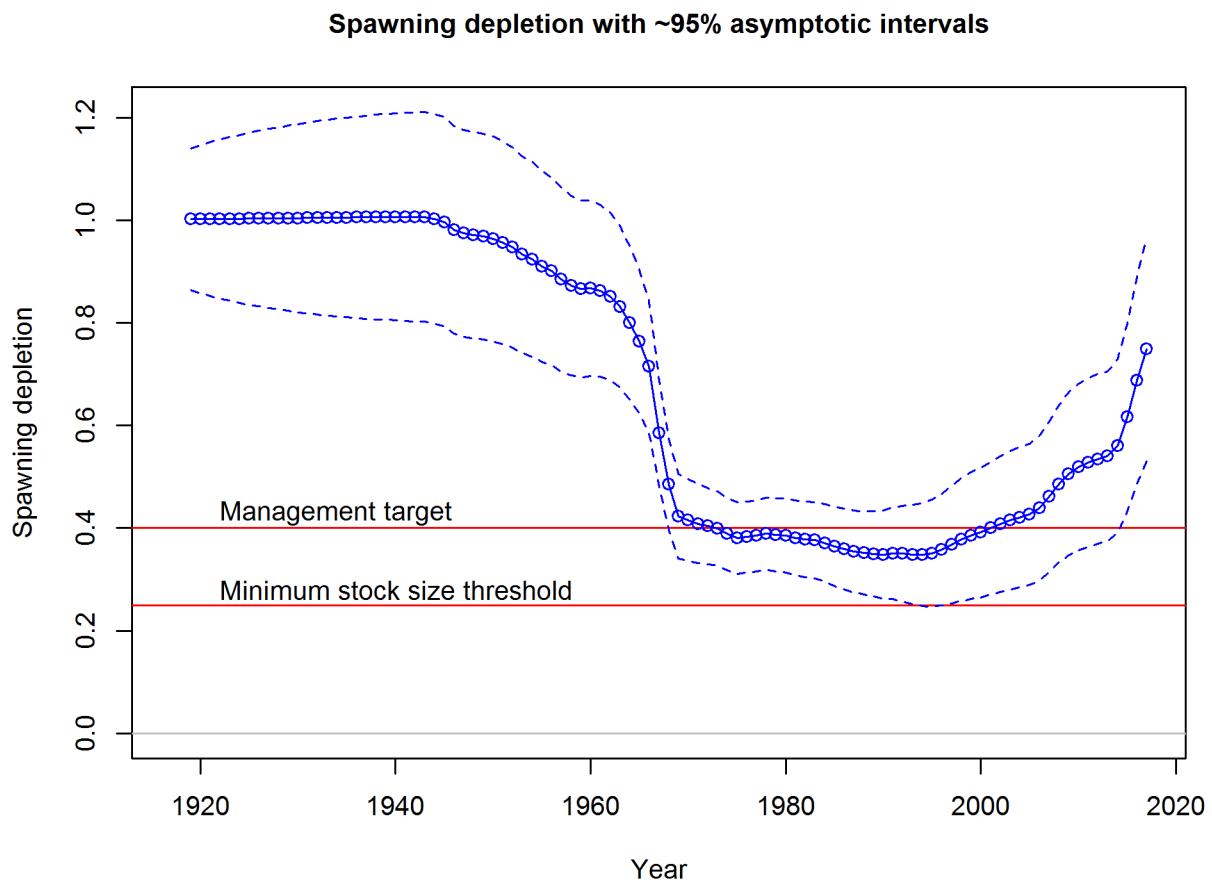


Figure c: Estimated relative spawning output (depletion) with approximate 95% asymptotic confidence intervals (dashed lines) for the base assessment model.

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. Additionally, there is early evidence of a strong recruitment in 2013. The four lowest
¹⁸⁵ recruitments estimated within the model (in ascending order) occurred in 2012, 2003, 1998,
¹⁸⁶ 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 Recruitment 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

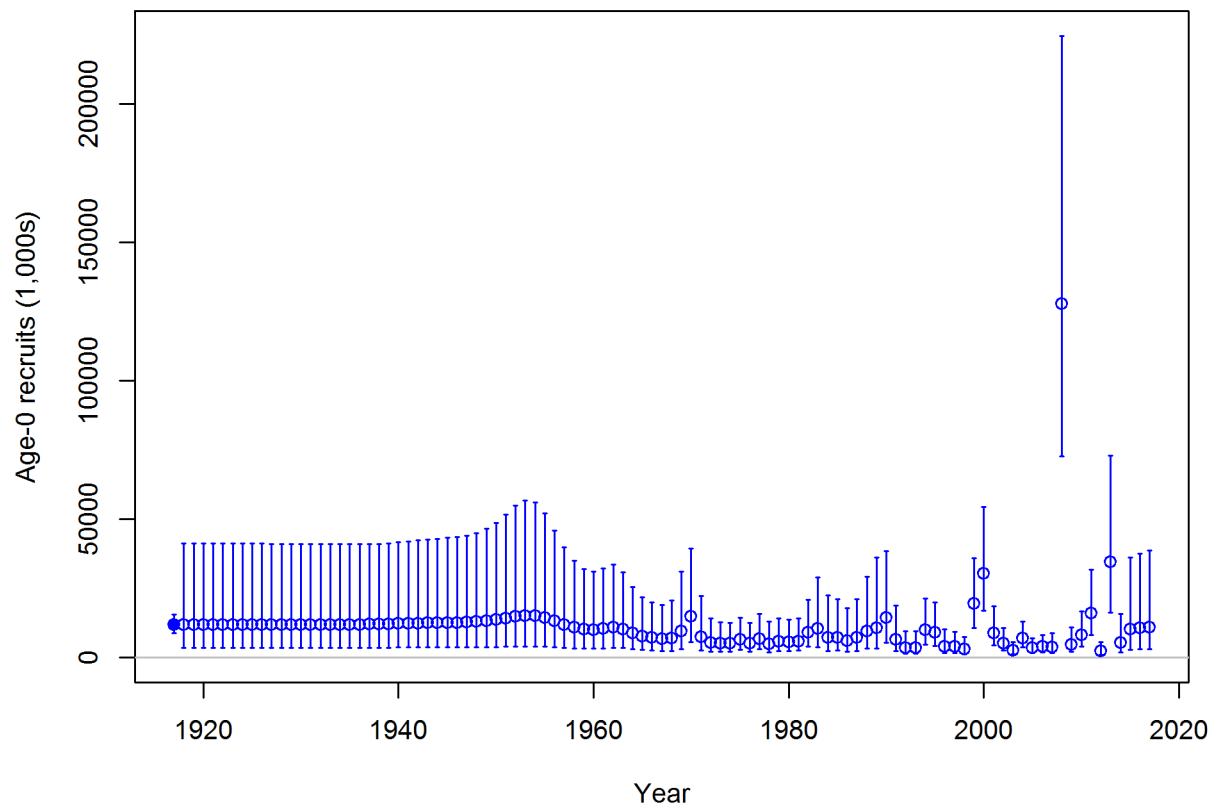


Figure d: Time-series of estimated Pacific ocean perch recruitments for the base model with 95% confidence or credibility intervals.

¹⁸⁷ **Exploitation status**

¹⁸⁸ The spawning output 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 depletion 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 output 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 |

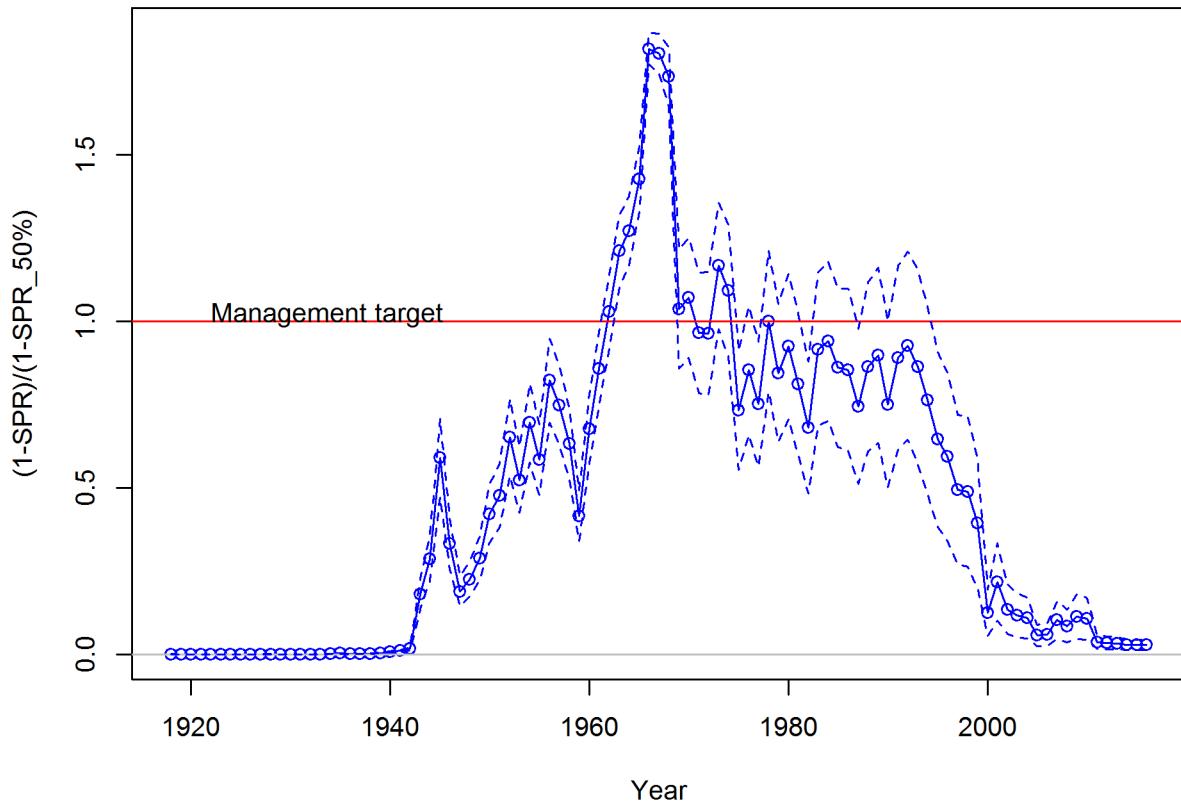


Figure e: Estimated spawning potential ratio $(1-\text{SPR})/(1-\text{SPR}_{50\%})$ for the base model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests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

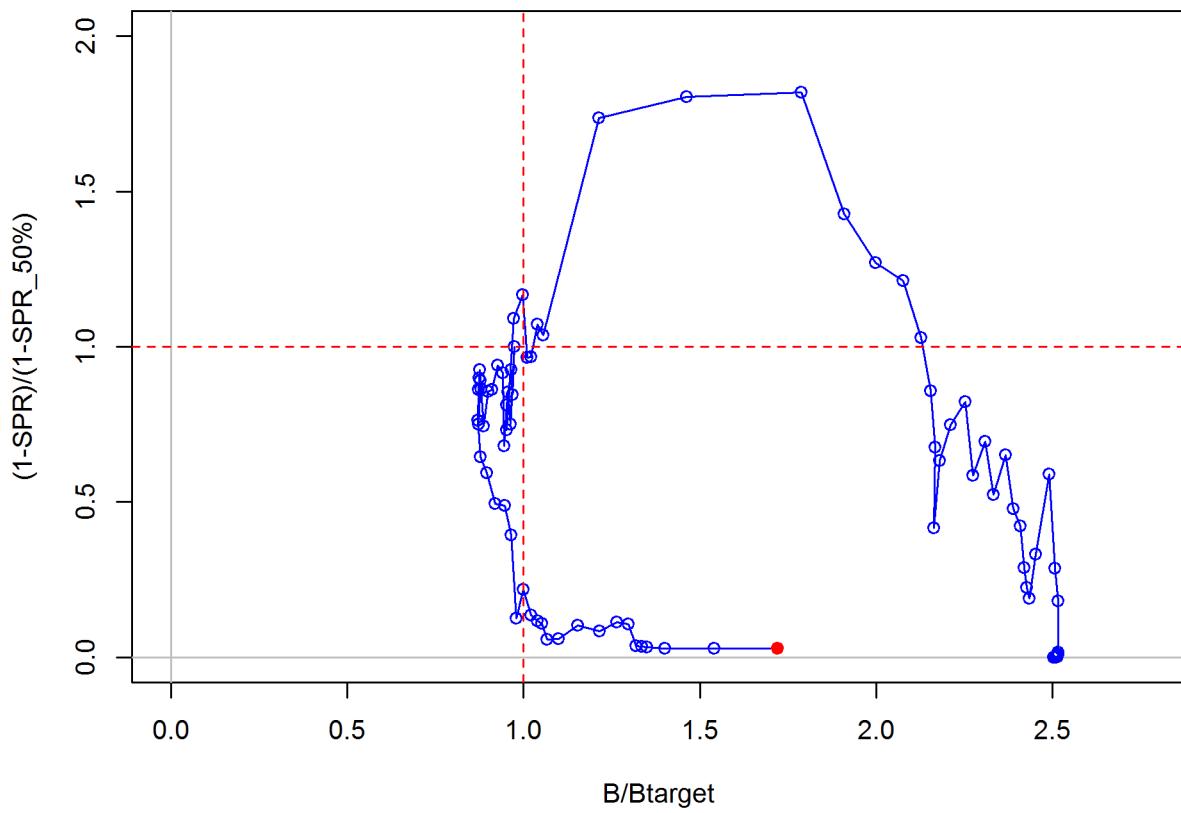


Figure f: Phase plot of estimated relative $(1-\text{SPR})/(1-\text{SPR}_{50\%})$ vs. relative spawning output (depletion) for the base case model.

¹⁹⁵ **Ecosystem Considerations**

¹⁹⁶ Rockfish are an important component of the California Current ecosystem along the US west
¹⁹⁷ coast, with 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 above average recruitment deviations 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 management target.
²²³ Due to reduced landing and the large 2008 year-class, an increasing trend in spawning biomass
²²⁴ was estimated in the base model. The estimated depletion in 2017 is 74.9% (~95% asymptotic
²²⁵ interval: ± 53.2%-96.7%), corresponding to an unfished spawning output of 4993 million eggs
²²⁶ (~95% asymptotic interval: 2244-7742 million eggs). Unfished age 3+ biomass was estimated
²²⁷ to be 140351 mt in the base model. The target spawning output based on the biomass target
²²⁸ ($SB_{40\%}$) is 2665.7 million eggs, with an equilibrium catch of 1754 mt. Equilibrium yield at
²²⁹ the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 1770.4 mt. Estimated MSY catch
²³⁰ is at a 1772.4 spawning output of 2328.1 million eggs (34.9% depletion)

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 |

231 Management Performance

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

Table f: Recent trend in total catch and landings (mt) relative to the management guidelines. Estimated total catch reflect the 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 |

²³⁹ Unresolved Problems And Major Uncertainties

²⁴⁰ TBD after STAR panel

²⁴¹ Decision Table

²⁴² TBD after STAR panel

Table g: Projections of potential OFL (mt) and ACL (mt) and the estimated spawning output and relative depletion. 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 Depletion |
|------|------|------|-----------------------------------|--------------------|
| 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 | - | - | - | - | - | - | - |

²⁴³ **Research and Data Needs**

²⁴⁴ There are many areas of research that could be improved to benefit the understanding and
²⁴⁵ assessment of Pacific ocean perch. Below, are issues that are considered of the importance.

- ²⁴⁶ 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.
- ²⁵¹ 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.
- ²⁵⁵ 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 Depletion | 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 |

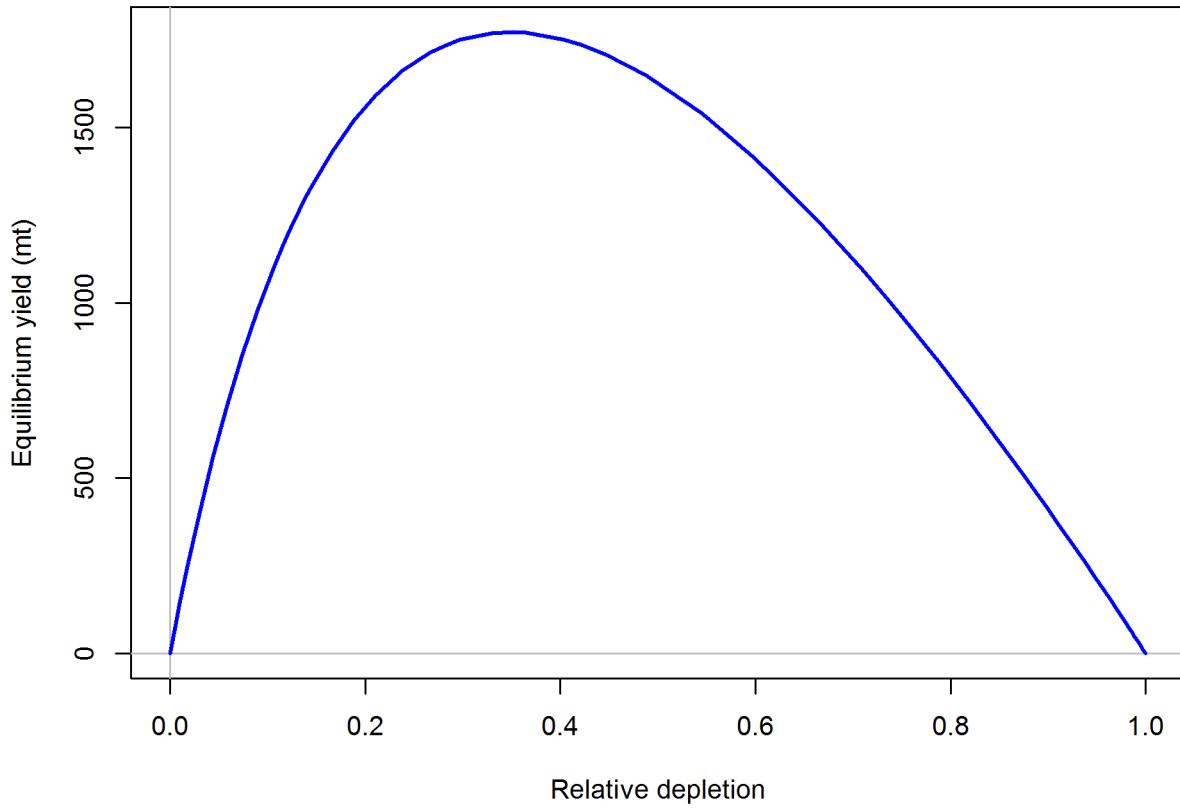


Figure g: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.50.

261 **1 Introduction**

262 **1.1 Distribution and Stock Structure**

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

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

279 **1.2 Historical and Current Fishery**

280 Prior to 1966, the Pacific ocean perch resource off of the northern portion of the US west
281 coast was harvested almost entirely by Canadian and US vessels. Harvest was negligible
282 prior to 1940, reached 1367 mt in 1950, 3243 mt in 1961 and 7635 mt in 1965. Catches
283 increased dramatically after 1965, with the introduction of large distant-water fishing fleets
284 from the Soviet Union and Japan. Both nations employed large factory stern trawlers as their
285 primary method for harvesting Pacific ocean perch. Peak removals are estimated at 18883
286 mt in 1966 and 14591 mt in 1967. These numbers are based upon a re-analysis of the foreign
287 catch data (Rogers [2003](#)), which focused on deriving a more realistic species composition for
288 catches previously identified only as Pacific ocean perch. Catches declined rapidly following
289 these peak years, and Pacific ocean perch stocks were considered to be severely depleted
290 throughout the Oregon-Vancouver Island region by 1969 (Gunderson [1977](#), Gunderson et al.
291 [1977](#)). Landed harvest averaged 1377 mt over the period 1977-94. Landings have continued
292 to decline since 1994, primarily due to more restrictive management (Table 1 and Figure 1).

293 **1.3 Summary of Management History and Performance**

294 Prior to 1977, Pacific ocean perch in the northeast Pacific were managed by the Canadian
295 Government in its waters and by the individual states in waters off of the US. With imple-
296 mentation of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1977,
297 US territorial waters were extended to 200 miles from shore, and primary responsibility for
298 management of the groundfish stocks off Washington, Oregon and California shifted from the
299 states to the Pacific Fishery Management Council (PFMC) and the National Marine Fisheries
300 Service (NMFS). At that time, however, a Fishery Management Plan for the West Coast
301 groundfish stocks had not yet been approved. In the interim, the state agencies worked with
302 the PFMC to address conservation issues. In 1981, the PFMC adopted a management strategy
303 to rebuild the depleted Pacific ocean perch stocks to levels that would produce Maximum
304 Sustainable Yield (MSY) within 20 years. On the basis of cohort analysis (Gunderson 1978),
305 the PFMC set Acceptable Biological Catch (ABC) levels at 600 mt for the US portion of
306 the Vancouver INPFC area and 950 mt for the Columbia International North Pacific Fishery
307 Commission (INPFC) area. To implement this strategy, the states of Oregon and Washington
308 each established landing limits for Pacific ocean perch. Trawl trip limits of various forms
309 remained in effect through 2016 (Table 2).

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

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

325 **1.4 Fisheries off Canada and Alaska**

326 Pacific ocean perch can be found in waters off the US west coast and northward through
327 Alaskan waters. In contrast the Pacific ocean perch stock off the US west coast, each assessed
328 portion of the stock in Canada and Alaskan waters have historically been estimated to be
329 above management targets. The subset of the stock off the US west coast represents the tail
330 of the species distribution with little to no Pacific ocean perch being encountered south of

³³¹ northern California. The most recent updated assessments for the Bering Sea and the Gulf
³³² of Alaska stocks determined that neither stock is in an overfished state and recommended
³³³ acceptable biological catches of 43,723 mt and 23,918 mt, respectively, for 2017.

³³⁴ In Canadian waters Pacific ocean perch has the largest single-species quota, accounting for
³³⁵ approximately 25% of all rockfish landings by weight in the bottom trawl fleet. The Canadian
³³⁶ Pacific ocean perch stock is broken into three separate areas that are individually assessed.
³³⁷ The status of the stock within each area are above Canadian management targets.

³³⁸ 2 Data

³³⁹ Data used in the Pacific ocean perch assessment are summarized in Figure 2. A description
³⁴⁰ of each data source is provided below.

³⁴¹ 2.1 Fishery-Independent Data

³⁴² Research surveys have been used to provide fishery-independent information about the
³⁴³ abundance, distribution, and biological characteristics of Pacific ocean perch s???. A coast-
³⁴⁴ wide survey was conducted in 1977 (Gunderson and Sample 1980) and repeated every three
³⁴⁵ years through 2004 (referred to as the ‘Triennial shelf survey’). The National Marine Fisheries
³⁴⁶ Service (NMFS) coordinated a cooperative research survey of the Pacific ocean perch stocks
³⁴⁷ off Washington and Oregon with the Washington Department of Fisheries (WDFW) and
³⁴⁸ the Oregon Department of Fish and Wildlife (ODFW) in March-May 1979 (Wilkins and
³⁴⁹ Golden 1983). This survey was repeated in 1985 (referred to as the Pacific ocean perch
³⁵⁰ survey). Two slope surveys have been conducted off the West Coast in recent years, one
³⁵¹ using the research vessel Miller Freeman, which ended in 2001 (referred to as the ‘AFSC
³⁵² slope survey’), and another ongoing cooperative survey using commercial fishing vessels which
³⁵³ began in 1998 as a DTS (Dover sole, thornyhead and sablefish) survey and was expanded to
³⁵⁴ other groundfish in 1999 (referred to as the ‘NWFSC slope survey’). In 2003, this survey
³⁵⁵ was expanded spatially to include the shelf. This last survey, conducted by the NWFSC,
³⁵⁶ continues to cover depths from 30-700 fathoms (55-1280 meters) on an annual basis (referred
³⁵⁷ to as the ‘NWFSC shelf-slope survey’).

³⁵⁸ Age estimates for Pacific ocean perch prior to the 1980s were made via surface ageing of
³⁵⁹ otoliths, which misses the very tight annuli at the edge of the otolith once the fish reaches
³⁶⁰ near maximum size. Ages are highly biased by age 14, and maximum age was estimated to be
³⁶¹ in the 20s, which lead to an overestimate of the natural mortality rate and the productivity
³⁶² of the stock. Using break and burn methods, Pacific ocean perch have been aged to over 100
³⁶³ years. Otoliths from fishery-independent and dependent sources that were only surface age
³⁶⁴ reads were excluded from this assessment due to the bias associated with these age reads.

365 **2.1.1 Northwest Fisheries Science Center (NWFSC) shelf-slope survey**

366 The NWFSC shelf-slope survey is based on a random-grid design; covering the coastal waters
367 from a depth of 55 m to 1,280 m (Bradburn et al. 2011). This design uses four chartered
368 industry vessels in most years, assigned to a roughly equal number of randomly selected
369 grid cells. The survey, which has been conducted from late-May to early-October each year,
370 is divided into two 2-vessel passes of the coast, which are executed from north to south.
371 This design therefore incorporates both vessel-to-vessel differences in catchability as well as
372 variance associated with selecting a relatively small number (approximately 700) of cells from
373 a very large population of possible cells (greater than 11,000) distributed from the Mexican
374 to the Canadian border.

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

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

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

403 The input sample sizes for length and marginal age composition data for all fishery-independent
404 surveys were calculated according to Stewart and Hamel (2014) which determined that the

405 approximate realized sample size for shelf/slope rockfish species was 2.43^*N_{tow} . The effective
406 sample size of conditional-age-at-length data was set at the number of fish at each length by
407 sex and by year.

408 2.1.2 Northwest Fisheries Science Center (NWFSC) slope survey

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

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

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

426 2.1.3 Alaska Fisheries Science Center (AFSC) slope survey

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

436 An index of abundance was estimated based on the data using the VAST delta-GLMM model.
437 The estimated index of abundance is shown in Table 4. The lognormal distribution with
438 random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot

⁴³⁹ does not show any departures from the assumed distribution (Figure 10). The trend in the
⁴⁴⁰ indices was generally flat over time.

⁴⁴¹ Length compositions were available for each year the survey was conducted. No age data were
⁴⁴² available from this survey. The expanded length frequencies from this survey were generally
⁴⁴³ of larger fish (> 30 cm), for 1997 where the highest frequency of fish were between 20 and
⁴⁴⁴ 30 cm for both females and males (Figure 11).

⁴⁴⁵ The input sample sizes for length and marginal age composition data were calculated according
⁴⁴⁶ to Stewart and Hamel (2014) described in Section 2.1.1.

⁴⁴⁷ 2.1.4 Triennial Shelf Survey

⁴⁴⁸ The Triennial shelf survey was first conducted by the AFSC in 1977 and spanned the time-
⁴⁴⁹ frame from 1977-2004. The survey's design and sampling methods are most recently described
⁴⁵⁰ in (Weinberg et al. 2002). Its basic design was a series of equally-spaced transects from
⁴⁵¹ which searches for tows in a specific depth range were initiated. The survey design has
⁴⁵² changed slightly over the period of time. In general, all of the surveys were conducted in the
⁴⁵³ mid-summer through early fall: the 1977 survey was conducted from early July through late
⁴⁵⁴ September; the surveys from 1980 through 1989 ran from mid-July to late September; the
⁴⁵⁵ 1992 survey spanned from mid-July through early October; the 1995 survey was conducted
⁴⁵⁶ from early June to late August; the 1998 survey ran from early June through early August;
⁴⁵⁷ and the 2001 and 2004 surveys were conducted in May-July.

⁴⁵⁸ Haul depths ranged from 91-457 m during the 1977 survey with no hauls shallower than 91 m.
⁴⁵⁹ The surveys in 1980, 1983, and 1986 covered the West Coast south to 36.8° N latitude and a
⁴⁶⁰ depth range of 55-366 meters. The surveys in 1989 and 1992 covered the same depth range
⁴⁶¹ but extended the southern range to 34.5° N (near Point Conception). From 1995 through
⁴⁶² 2004, the surveys covered the depth range 55-500 meters and surveyed south to 34.5° N. In
⁴⁶³ the final year of the Triennial series, 2004, the NWFSC's Fishery Resource and Monitoring
⁴⁶⁴ division (FRAM) conducted the survey and followed very similar protocols as the AFSC.

⁴⁶⁵ Given the different depths surveyed during 1977 and the number of water hauls, the data from
⁴⁶⁶ that year were not included in this assessment. Water hauls (Zimmermann et al. 2003) and
⁴⁶⁷ tows located in Canadian waters across all years were also excluded from the analysis of this
⁴⁶⁸ survey. The data was examined for varying distribution of length and/or ages of fish based
⁴⁶⁹ upon the shift in survey timing and little evidence was found of ontogenetic shifts in Pacific
⁴⁷⁰ ocean perch during the summer months. Pacific ocean perch are rarely encountered south
⁴⁷¹ of 40° N where the change in southern range of the survey would have no impact on data
⁴⁷² collected regarding Pacific ocean perch. Given these factors the Triennial shelf survey was
⁴⁷³ analyzed as a single time-series using data from sampling depths of 55 - 350 m, a departure
⁴⁷⁴ from how the previous assessment which split the time-series into an early (1980-1992)
⁴⁷⁵ and a late period (1995-2004).

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

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

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

494 2.1.5 Pacific ocean perch Survey

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

502 Length and age compositions were expanded based on the stratification. The survey had 125
503 and 126 Pacific ocean perch tows (Table 12) and ages were only available in 1985 due to
504 surface reads for the 1979 data (Table 13). The length frequencies for both years are highest
505 between the 30-45 cm range (Figure 16) with ages in 1985 having a large number of fish age
506 40 and greater (Figure 17).

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

509 **2.2 Fishery-Dependent Data**

510 **2.2.1 Commercial Fishery Landings**

511 **Washington**

512 Historical commercial fishery landings of Pacific ocean perch in Washington for the years
513 1908-2016 were obtained from Theresa Tsou (WDFW) and Phillip Weyland (WDFW). This
514 assessment is the first Pacific ocean perch assessment to include a state provide historical
515 catch reconstruction and, hence, the historical catches for Washington differ from those
516 used in the 2011 assessment. WDFW also provided catches for 1981-2016 period to include
517 re-distribution of the “URCK” landings in the PacFIN database. These data are currently
518 not available from PacFIN.

519 **Oregon**

520 Historical commercial fishery landings of Pacific ocean perch in Oregon for the years 1892-
521 1986 were obtained from Alison Whitman (ODFW). A description of the methods can be
522 found in Karnowski et al. (2014). Recent landings (1987-2016) were obtained from PacFIN
523 (retrieval dated May 2, 2017, Pacific States Marine Fisheries Commission, Portland, Oregon;
524 www.psmfc.org). The catch data from the POP and POP2 categories contained within
525 PacFIN for Pacific ocean perch were used for this assessment. Additional catches from
526 1987-1999 for Pacific ocean perch under the UROCK category not yet available in PacFIN
527 were received directly from the state and combined with the landings data available for that
528 period within PacFIN (Patrick Mirrick, personal communication, ODFW).

529 **California**

530 Historical commercial fishery landings of Pacific ocean perch were obtained directly from John
531 Field at the SWFSC due to database issues for the historical period for the California Coop-
532 erative Groundfish Survey data system, also known as CALCOM Database (128.114.3.187)
533 for the years 1916-1980. A description of the historical reconstruction methods can be
534 found in (Ralston et al. 2010). Recent landings (1981-2016) were obtained from PacFIN
535 (retrieval dated May 2, 2017, Pacific States Marine Fisheries Commission, Portland, Oregon;
536 www.psmfc.org).

537 **At-Sea Hake Fishery**

538 Catches of Pacific ocean perch are monitored aboard the vessel by observers in the at-sea
539 hake Observer program (ASHOP) and were available for the years of 1975-2016. Observers
540 use a spatial sample design, based on weight, to randomly choose a portion of the haul to
541 sample for species composition. For the last decade, this is typically 30-50% of the total
542 weight. The total weight of the sample is determined by all catch passing over a flow scale.
543 All species other than hake are removed and weighed by species on a motion compensated

544 flatbed scale. Observers record the weights of all non-hake species. Non-hake species total
545 weights are expanded in the database by using the proportion of the haul sampled to the
546 total weight of the haul. The catches of non-hake species in unsampled hauls is determined
547 using bycatch rates determined from sampled hauls. Since 2001, more than 97% of the hauls
548 have been observed and sampled.

549 Foreign Catches

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

556 2.2.2 Discards

557 Data on discards of Pacific ocean perch are available from two different data sources. The
558 earliest source is referred to as the Pikitch data and comes from a study organized by Ellen
559 Pikitch that collected trawl discards from 1985-1987 (Pikitch et al. 1988). The northern and
560 southern boundaries of the study were 48°42' N latitude and 42°60' N. latitude respectively,
561 which is primarily within the Columbia INPFC area (Pikitch et al. 1988, Rogers and Pikitch
562 1992). Participation in the study was voluntary and included vessels using bottom, midwater,
563 and shrimp trawl gears. Observers of normal fishing operations on commercial vessels collected
564 the data, estimated the total weight of the catch by tow and recorded the weight of species
565 retained and discarded in the sample. Results of the Pikitch data were obtained from John
566 Wallace (personal communication, NWFSC, NOAA) in the form of ratios of discard weight to
567 retained weight of Pacific ocean perch and sex-specific length frequencies. Discard estimates
568 are shown in Table 14.

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

582 **2.2.3 Historical Commercial Catch-per-unit effort**

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

589 **2.2.4 Fishery Length And Age Data**

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

600
$$\text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}} \text{ if } N_{\text{fish}}/N_{\text{trips}} < 44$$

601
$$\text{Input effN} = 7.06 * N_{\text{trips}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \geq 44$$

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

606 **2.2.5 Length and Age Data Not Included in the Base Model**

607 Research length and ages were provided by WDFW. However, the information regarding the
608 nature of the research cruise and collection methods has been lost to time. The data set
609 includes lengths and ages that were collected between 1967-1972 and in 1979. The distribution
610 of lengths across years collected were consistent with primarily only larger Pacific ocean perch,
611 35-40 cm, being selected. All age data were based upon surface reads which unfortunately are
612 highly biased at relatively young ages for Pacific ocean perch. Due to the lack of information
613 regarding the collection of these data, they were not selected to be apart of the base model
614 but a sensitivity was conducted which evaluated the impact of these data.

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

621 2.3 Biological Data

622 2.3.1 Natural Mortality

623 Historic Pacific ocean perch ages determined using scales and surface reading methods of
624 otoliths, resulted in estimates of natural mortality (M) between 0.10 and 0.20yr^{-1} with a
625 longevity less than 30 years (Gunderson 1977). Based on break-and-burn method of age
626 determination using otoliths, the maximum age of Pacific ocean perch was revised to be 90
627 years (Chilton and Beamish 1982). The updated understanding concerning Pacific ocean perch
628 longevity reduced the estimate of natural mortality based on Hoenig's (1983) relationship to
629 0.059yr^{-1} . The previous assessment applied a prior distribution on natural mortality based
630 upon multiple life history correlates (including Hoenig's method, Gunderson gonadosomatic
631 index (1997), and McCoy and Gillooly's (2008) theoretical relationship) developed separately
632 for female and male Pacific ocean perch.

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

$$649 M = \frac{5.4}{A_{\max}}$$

650 The above is also the median of the prior. The prior is defined as a lognormal with mean
651 $\ln(\frac{5.4}{A_{\max}})$ and $\text{SE} = 0.438$. Using a maximum age of 100 the point estimate and median of the

652 prior is 0.054. The maximum age was selected based on available age data from all West Coast
653 data sources. The oldest aged rockfish was 120 years, captured by the commercial fishery
654 in 2007. However, age data are subject to ageing error which could impact this estimate of
655 longevity. The selection of 100 years was based on the range of other ages available with had
656 multiple observations of fish between 90 and 102 years of age.

657 2.3.2 Sex Ratio, Maturation, and Fecundity

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

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

676 2.3.3 Length-Weight Relationship

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

681 2.3.4 Growth (Length-at-Age)

682 The length-at-age was estimated for male and female Pacific ocean perch using data collected
683 from both fishery-dependent and -independent data sources that were collected from 1981-
684 2016. Figure 30 shows the lengths and ages for all years and all data as well as predicted

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

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

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

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

691 2.3.5 Ageing Precision And Bias

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

702 2.4 History Of Modeling Approaches Used For This Stock

703 2.4.1 Previous Assessments

704 The status of Pacific ocean perch off British Columbia, Washington, and Oregon have been
705 periodically assessed since the intensive exploitation that occurred in the 1960s. Concerns
706 regarding Pacific ocean perch status off the coast the US west coast were raised in the late
707 1970s (Gunderson 1978, 1981) and in 1981 the PFMC adopted a 20-year plan to rebuild the
708 stock.

709 The 1992 assessment determined that Pacific ocean perch remained at low levels relative
710 to the population size in 1960 (Ianelli et al. 1992) and recommended additional harvest
711 restrictions to allow for stock rebuilding. The 1998 assessment (Ianelli and Zimmermann
712 1998) estimated that the stock was 13% of the unfished level, leading the National Marine
713 Fishery Service (NMFS) to declare the stock overfished in 1999. A formal rebuilding plan was
714 implemented in 2001. The rebuilding plan reduced the SPR harvest rate used to determine
715 catches to 0.864 (in contrast to the default harvest rate of 0.50). The last full assessment of
716 Pacific ocean perch was conducted in 2011 (Hamel and Ono 2011) which concluded that the

⁷¹⁷ stock was still well below the target biomass of 40% SB_0 estimating the relative stock status
⁷¹⁸ at 19.1%.

⁷¹⁹ 2.4.2 Previous Assessment Recommendations

⁷²⁰ Recommendation: Considering trans-boundary stock effects should be pursued. In particular
⁷²¹ the consequences of having spawning contributions from external stock components should
⁷²² be evaluated relative to the steepness estimates obtained in the present assessment.

⁷²³ *STAT response: The STAT team agrees that this should be an ongoing area of research and*
⁷²⁴ *collaboration between the US and Canada. This assessment presents a sensitivity where the*
⁷²⁵ *inclusion of Canadian data are included within the model.*

⁷²⁶ Recommendation: The benefits of adopting the complex model used this year should be
⁷²⁷ evaluated relative to simpler assumptions and models. While the transition from the simpler
⁷²⁸ old model to Stock Synthesis was shown to be similar for the historical period, the depletion
⁷²⁹ estimates in the most recent years were different enough to warrant further investigation.

⁷³⁰ *STAT response: This assessment was performed in Stock Synthesis, an integrated model,*
⁷³¹ *which can be modified to either simple or complex structural forms based upon the available*
⁷³² *data and the processes being modeled. There were not additional explorations of alternative*
⁷³³ *modeling platforms.*

⁷³⁴ Recommendation: Discard estimates from observer programs should be presented, reviewed
⁷³⁵ (similar to the catch reconstructions), and be made available to the assessment process.

⁷³⁶ *STAT response: This assessment uses discard rates and discard lengths collected by the*
⁷³⁷ *WCGOP from 2003-2015.*

⁷³⁸ Recommendation: The ability to allow different “plus groups” for specific data types should
⁷³⁹ be evaluated (and implemented in Stock Synthesis). For example, this would provide the
⁷⁴⁰ ability to use the biased surface-aged data in an appropriate way.

⁷⁴¹ *STAT response: The STAT team agrees that this should be explored, but additional research*
⁷⁴² *needs to completed which evaluates the amount of bias and imprecision in surface-read ages.*
⁷⁴³ *Evaluating available surface-read ages within the PacFIN database fish of lengths between*
⁷⁴⁴ *23-44 cm can be aged at 10 years old. This large range of lengths at the same age indicates*
⁷⁴⁵ *considerable bias in ages for fish surface-read younger aged fish.*

⁷⁴⁶ Recommendation: Historical catch reconstruction estimates should be formally reviewed
⁷⁴⁷ prior to being used in assessments and should be coordinated so that interactions between
⁷⁴⁸ stocks are appropriately treated. The relative reliability of the catch estimates over time
⁷⁴⁹ could provide an axis of uncertainty in future assessments.

750 *STAT response: California and Oregon have undergone extensive work to create historical*
751 *catch reconstructions. This is the first assessment for Pacific ocean perch which includes*
752 *a Washington historical catch reconstruction. The data used in this assessment represent*
753 *Washington state's current best estimate for historical catches. An historical catch reconstruc-*
754 *tion meeting was held in November of 2016 were states discussed methods and approaches*
755 *to improve historical catch estimates. Additionally, both California and Washington are*
756 *conducting research to estimate uncertainty surround historical catches which could be used to*
757 *propagate uncertainty within the assessment.*

758 **3 Assessment**

759 **3.1 General Model Specifications and Assumptions**

760 Stock Synthesis version 3.30.03.05 was used to estimate the parameters in the model. R4SS,
761 revision 1.27.0, along with R version 3.3.2 were used to investigate and plot model fits. A
762 summary of the data sources used in the model (details discussed above) is shown in Figure
763 2.

764 **3.1.1 Changes Between the 2011 Assessment Model and Current Model**

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

775 The historical landings used in the model differ from those used in 2011. This assessment
776 includes the first state provided historical reconstruction landings for Washington. The
777 historical reconstruction has removals starting in 1908 and has larger removals in the 1940s
778 relative to those used in the 2011 assessment (Figure 33). The starting year for modeling
779 the stock was revised to 1918, the first year Pacific ocean perch landings exceeded 1 mt,
780 rather than 1940 as modeled in the previous assessment, given the new information regarding
781 historical removals prior to 1940. Explorations were conducted relative to the model starting
782 year and no differences were found between the 1918 start year compared to starting the

783 model in 1892 which was the first year there is record landings of Pacific ocean perch between
784 California, Oregon, and Washington.

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

790 All fishery-independent indices have been re-evaluated for this assessment using a spatial-
791 temporal delta generalized linear mixed model (VAST delta-GLMM) which is an updated
792 approach from that used in 2011, which did not incorporate spatial effects. An additional
793 update to the treatment of survey data was the decision to use the Triennial shelf survey
794 as a single time-series ranging from 1980-2004. The previous assessment opted to split this
795 survey into an early (1980-1992) and a late (1995-2004) index of abundance based upon the
796 change in southern sampling and a shift in survey timing. Northern California is considered
797 to be the southern end of Pacific ocean perch West Coast distribution with rare encounters
798 in central or southern California waters. The biological data from the Triennial shelf survey
799 showed no discernible ontogenetic shifts in Pacific ocean perch during the early or late period
800 of summer samples. Based upon these investigations, the Triennial shelf survey was retained
801 as a single index of abundance in this assessment.

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

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

818 3.1.2 Summary of Fleets and Areas

819 Pacific ocean perch are most frequently observed in Oregon and Washington waters in survey
820 and fishery observations. Multiple fisheries encounter Pacific ocean perch. Bottom trawl,

821 mid-water trawl, fixed gear, and the at-sea (mid-water) hake fisheries account for the majority
822 of the current Pacific ocean perch landings.

823 The majority of removals of Pacific ocean perch are attributable to trawl gears with fixed gear
824 accounting for a small fraction of the catches available within PacFIN. Trawl and fixed gears
825 were combined into a coast-wide fleet. For the period from 1918 to the early 1990s, prior
826 to the introduction of trip limits for rockfish, limited discarding of Pacific ocean perch was
827 assumed. Observations of Pacific ocean perch in the Pikitch et al. (1988) data (1986-1987)
828 allowed for a formal analysis of discard rates which were applied to the historical period of
829 the fishery. Foreign trawl catches (1966-1976) were modeled as a single fleet. The at-sea hake
830 fishery operates as a mid-water fishery targeting Pacific whiting but encounters Pacific ocean
831 perch as a bycatch species. This fleet was also modeled as a single fleet.

832 3.1.3 Other Specifications

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

840 Age data for the commercial and at-sea hake fisheries, as well as the Triennial shelf survey,
841 the Pacific ocean perch, the NWFSC slope, and the NWFSC shelf-slope surveys were used in
842 this assessment. The ages from the NWFSC shelf-slope survey were entered into the model
843 as conditional age-at-length. The assessment used length-frequencies collected by the fishery
844 fleet, the at-sea hake fishery, the Triennial shelf, Pacific ocean perch, AFSC slope, NWFSC
845 slope, and the NWFSC shelf-slope surveys.

846 The specification of when to estimate recruitment deviations is an assumption that likely affects
847 model uncertainty. Recruitment deviations were estimated from 1900-2014 to appropriately
848 quantify uncertainty. The earliest length-composition data occur in 1966 and the earliest
849 age data were in 1981. The most informed years for estimating recruitment deviations were
850 from about the mid-1970s to 2013. The period from 1900-1974 was fit using an early series
851 with little or no bias adjustment, the main period of recruitment deviates occurred from
852 1975-2014 with an upward and downward ramping of bias adjustment (Figure 32), and 2015
853 onward was fit using forecast recruitment deviates with no bias adjustment. Methot and
854 Taylor (2011) summarize the reasoning behind varying levels of bias adjustment based on
855 the information available to estimate the deviates. The standard deviation of recruitment
856 variability was assumed to be 0.70.

857 The recommended selectivity in Stock Synthesis is the double normal parameterization and
858 was used in this assessment for the all fleets, except the Pacific ocean perch survey which was

assumed logistic based on the length composition data. Changes in retention curves were estimated for the commercial fishery fleet.

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

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

3.1.4 Modeling Software and Model Bridging

The STAT team used Stock Synthesis version 3.30.03.05 by Dr. Richard Methot at the NWFSC (Methot and Wetzel 2013). This most recent version was used, since it included improvements and corrections to older versions. The previous assessment of Pacific ocean perch also used Stock Synthesis but a earlier version, 3.24, model bridging was performed between both versions of Stock Synthesis and are shown in Figure 34.

3.1.5 Priors

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

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

892 **3.1.6 Data Weighting**

893 Length and age-at-length compositions from the NWFSC shelf-slope survey were fit along
894 with length and marginal age compositions from the fishery and other survey fleets. Length
895 data started with a sample size determined from the equation listed in Sections 2.1.1 (survey
896 data) and 2.2.4 (fishery data). Age-at-length data assumed that each age was a random
897 sample within the length bin and started with a sample size equal to the number of fish in
898 that length bin. However, the 2016 NWFSC shelf-slope age-at-length data were variable
899 compared to previous years for both males and females with observed fish being generally
900 larger at age. Model exploration determined that the model was more sensitive than would
901 be reasonably expected to the inclusion of this data year. Due to the increased variability
902 within this data year and the model's sensitivity, the input sample size for this year was
903 reduced to 50% of the number of fish within each length-age bin.

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

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

916 **3.1.7 Estimated And Fixed Parameters**

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

922 Fixed parameters in the model were as follows. Steepness was fixed at 0.50. A sensitivity
923 analysis and a likelihood profile were done for steepness. Natural mortality was fixed at
924 0.054 for females and males, which is the median of the prior. The standard deviation of
925 recruitment deviates was fixed at 0.70. Maturity-at-length was fixed as described in Section
926 2.3.2. Length-weight parameters were fixed at estimates using all length-weight observations
927 (Figure 29).

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

933 3.2 Model Selection and Evaluation

934 The base assessment model for Pacific ocean perch was developed to balance parsimony and
935 realism, and the goal was to estimate a spawning output trajectory for the population of
936 Pacific ocean perch off the west coast of the US. The model contains many assumptions to
937 achieve parsimony and uses many different sources of data to estimate reality. A series of
938 investigative model runs were done to achieve the final base model.

939 3.2.1 Key Assumptions and Structural Choices

940 The key assumptions in the model were that the assessed population is a single stock with
941 biological parameters characterizing the entire coast, natural mortality and maturity-at-length
942 has remained constant over the period modeled, weight-at-length has remained constant over
943 the period modeled, the standard deviation in recruitment deviation is 0.70, and steepness is
944 0.50. These are simplifying assumptions that unfortunately cannot be verified or disproved.
945 Sensitivity analyses were conducted for most of these assumptions to determine their effect
946 on the results.

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

950 3.2.2 Alternate Models Considered

951 The exploration of models began by bridging from the 2011 assessment to Stock Synthesis
952 version 3.30.03.05, which produced no discernible difference (Figure 34). The updated landings
953 data and discard rates added to the 2011 assessment produced insignificant differences in
954 the relative scale of the population although the updated historical removals resulted in an
955 increase in the estimate of unfished spawning output. Updating the survey indices produced
956 small differences in the relative scale of the population. Adding age and length data each
957 resulted in less of a population decline from the 1970s to pre-2000, resulting in an increase in
958 the estimated 2017 final stock status. However, the addition of new data resulted in an early
959 pattern within recruitment, indicating that the assumptions within the previous model may
960 not represent the best fit to the current data.

961 This assessment estimated discards in the model, so time was spent investigating time blocks
962 for changes in selectivity and retention to match the discard data as best as possible. Using
963 major changes in management and observed changes in landings, a set of blocks for retention
964 were determined for the fishery fleet. In the spirit of parsimony, as few blocks as possible
965 were used, blocks were only for time periods with data or when we felt they were justified by
966 changes in management.

967 Natural mortality was also investigated and a new prior was developed assuming a maximum
968 age of 100 years for females and males. The previous assessment estimated male natural
969 mortality as an offset from a fixed female natural mortality. This assessment attempted to
970 estimate natural mortality for both sexes using the 2017 updated prior, but there was little
971 to no information on natural mortality within the data and hence opted to fix the value
972 for females within the base model. Upon additional exploration, the model estimated very
973 little difference in male natural mortality relative to females (< 0.002) and in the interest of
974 selecting the model that fit the data with the fewest parameters required, males were fixed
975 equal to the female natural mortality in the base model.

976 Finally, multiple models were investigated where steepness was either estimated, fixed at the
977 prior, or at an alternate value. The assessment in 2011 determined that there was sufficient
978 information concerning steepness where the parameter was estimated and then fixed at the
979 estimated value of 0.40. Based upon likelihood profiles performed on the current model, there
980 was no longer support for a steepness value of 0.40. The likelihood profile was flat across
981 various levels of steepness with a very small improvement in likelihood (<0.50 log likelihood
982 units) at the lowest steepness values. Estimating steepness starting at the median of the
983 “type C” prior, the meta-analysis prior evaluated omitting information from Pacific ocean
984 perch, of 0.76 resulted in very little if any movement from the median value due to the flat
985 likelihood surface across values for this parameter with the final relative stock status for 2017
986 being estimated to > 100% of unfished spawning output. Fixing steepness at the median
987 of the prior of 0.72 resulted in relative stock status estimates for 2017 at 96.8% of unfished
988 spawning output. It was determined that the resulting stock status estimate when steepness
989 was fixed at the meta-analysis prior were overly optimistic and unrealistic given the biology
990 and historical exploitation of Pacific ocean perch.

991 3.2.3 Convergence

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

1000 **3.3 Response To The Current STAR Panel Requests**

1001 TBD after the STAR panel.

1002 **3.4 Base Model Results**

1003 The base model parameter estimates along with approximate asymptotic standard errors
1004 are shown in Table 23 and the likelihood components are shown in Table 24. Estimates of
1005 derived reference points and approximate 95% asymptotic confidence intervals are shown in
1006 Table 25. Time-series of estimated stock size over time are shown in Table 26.

1007 **3.4.1 Parameter Estimates**

1008 The estimates of maximum length and the von Bertalanffy growth coefficient, k , were less
1009 than the the external estimates for males and females (Figure 30), but were well within the
1010 95% confidence interval given the estimated uncertainty (Table 23 and Figure 35). Female
1011 and male Pacific ocean perch grow quickly at younger ages, reaching near maximum length
1012 by age 20, with female Pacific ocean perch reaching larger maximum lengths.

1013 Selectivity curves were estimated for the fishery and survey fleets. The estimated selectivities
1014 for all fleets within the model are shown in Figure 36. The fishery selectivity was estimated
1015 dome shaped, reaching maximum selectivity for fish between 35 and 40 cm. The at-sea hake
1016 fishery was estimated to have little selectivity for smaller Pacific ocean perch reaching full
1017 selectivity at the largest sizes. The foreign fleet for which only catch data are available was
1018 assumed to be identical to the main fishery, although a sensitivity was performed (not shown)
1019 that mirrored the foreign selectivity to that of the Pacific ocean perch survey selectivity
1020 resulting in a negligible difference in stock status. Survey selectivities, excluding the Triennial
1021 shelf survey, were estimated asymptotic during model explorations with the final selectivity
1022 fixed asymptotic in the final base model. The Triennial shelf survey selectivity peaked at
1023 lengths between 25 and 30 cm and declined before reaching a constant selectivity for larger
1024 Pacific ocean perch.

1025 Retention curves were estimated for the fishery fleet only and were allowed to vary based
1026 upon discard data within the model over time (Figure 37). Historical retention was estimated
1027 high and declined over time due to management restriction on landings of Pacific ocean perch
1028 with the lowest retention occurring in 2009 and 2010 prior to the implementation of ITQs.
1029 Post-2011 retention was estimated to be nearly 100% for the fishery fleet.

1030 Additional survey variability (process error added directly to each year's input variability)
1031 for the Triennial shelf and the NWFSC shelf-slope surveys were estimated within the model.
1032 The estimated added variance for the Triennial shelf survey was high at 0.39. The model

1033 estimated a small added variance for the NWFSC shelf-slope survey of 0.027. Preliminary
1034 models explored estimating added variance for each of the other indices, but resulted in no
1035 added variance being estimated and hence were not estimated in the base model.

1036 Estimates of recruitment suggest that the Pacific ocean perch population is characterized
1037 by variable recruitment with occasional strong recruitments and periods of low recruitment
1038 (Figures 38 and 39). There is little information regarding recruitment prior to 1970 and
1039 the uncertainty in those estimates is expressed in the model. The four lowest recruitments
1040 (in ascending order) occurred in 2012, 2003, 1998, and 2005. There are very large, but
1041 uncertain, estimates of recruitment in 2008, 2013, 2000, and 1999. The 2008 recruitment
1042 event is estimated to be larger by an order of magnitude compared to other recruitments
1043 estimated in the model. The uncertainty interval in number of recruits is large based on the
1044 uncertainty surrounding the spawning output in that year. However, the log recruitment
1045 deviation estimated uncertainty is low.

1046 3.4.2 Fits to the Data

1047 There are numerous types of data for which the fits are discussed: fishery CPUE index, survey
1048 abundance indices, discard data (biomass and length compositions), length composition data
1049 for the fisheries and surveys, marginal age compositions for the fisheries and surveys, and
1050 conditional age-at-length observations for the NWFSC shelf-slope survey

1051 The fits to the fishery CPUE and five survey indices are shown in Figure 40. Extra standard
1052 error was estimated for the Triennial shelf and NWFSC shelf-slope surveys. The fishery
1053 CPUE and Pacific ocean perch survey index were fit well by the model. The first two years
1054 of the Triennial shelf survey index, 1980 and 1983, were much higher than the later years
1055 and were poorly fit by the model. Both the AFSC and NWFSC slope survey indices were
1056 generally flat and fit well by the model. The recent NWFSC shelf-slope survey showed a
1057 variable trend over the time period with the 2016 data point being the highest estimate of
1058 the series and given the uncertainty around each data point (input and model estimated
1059 added variance) the model fit fell within the uncertainty interval for all years.

1060 Fits to the total observed discard amounts required time blocks (Figure 41). Fits to the trawl
1061 discards from the Pikitch data in 1985-1987 were quite good. The change in the discard rate
1062 modeled over the 1992-2001 was based on management restrictions which were assumed to
1063 have increased discarding practices in the fishery fleet. The next required time block was
1064 based on the WCGOP data from 2002-2007 and were fit well by the model. Discarding
1065 increased prior to the implementation to ITQs requiring blocks for 2008 and the 2009-2010
1066 periods. The model fit the very low post-ITQ discard rates based on the WCGOP data well.
1067 The total estimated discard amount over time is shown in Figure 42.

1068 Fits to the length data are shown based on the proportions of lengths observed by year and
1069 the Pearson residuals-at-length for all fleets. Detailed fits to the length data by year and

1070 fleet are provided in Appendix 10. Aggregate fits by fleet are shown in Figure 43. There are
1071 a few things that stand out when examining the aggregated length composition data. First,
1072 the sexed discard lengths appear to be poorly fit by the model but this is related to small
1073 sample sizes. The NWFS slope survey lengths were under estimated by the model, but these
1074 data are over only two years. Finally, both the Triennial shelf and the NWFSC shelf-slope
1075 surveys select both young and old fish in contrast to the other data sources where typically
1076 only larger fish were observed.

1077 Discard lengths from WCGOP were fit well by the model and show no obvious pattern in
1078 the residuals (Figure 44). The residuals to the fishery lengths clearly showed the growth
1079 differential between males and females where the majority of residuals at larger sizes were
1080 from female fish (Figure 45). The fishery showed large positive residuals for smaller fish for
1081 2013-2016 which were attributed to the strong 2008 year class moving through the fishery.
1082 The at-sea hake fishery did not show an obvious pattern in residuals but clearly showed
1083 the selectivity of larger fish (Figure 46). The residuals for each of the surveys are shown in
1084 Figures 47, 48, 49, 50, and 51. The Pearson residuals from the NWFSC shelf-slope survey
1085 clearly showed the strong year classes moving through the population.

1086 The model was weighted according to the Francis weights which adjust the weight given to a
1087 data set based on the fit to the mean lengths by year. The mean lengths from the fishery
1088 were consistent across the sampled period, showing only a decline in the mean length in
1089 2013-2015 likely due to the large 2008 cohort (Figure 52). The at-sea hake fishery showed
1090 an increase in the mean length of fish observed to 2009 and then fluctuated at larger mean
1091 lengths thereafter (Figure 53). The mean lengths were consistent across the two sample years
1092 of the Pacific ocean perch survey (Figure 54). However, the model expected a decline in
1093 mean length over the period. The Triennial shelf survey had a decreasing and then increasing
1094 trend in the mean lengths over the sample period (Figure 55). The trend in the mean lengths
1095 observed by the AFSC slope survey was generally flat excluding the samples from 1997 which
1096 were smaller fish (Figure 56). The NWFSC slope length data from 2001 and 2002 were highly
1097 variable with differing mean lengths between the years which were not fit well by the model
1098 (Figure 57). The mean length for the NWFSC shelf-slope survey declined in 2012 and 2016
1099 due to a large observation of young small fish by the survey (Figure 58).

1100 Age data were fitted to as marginal age compositions for the main fishery fleet, the at-sea
1101 hake fleet, the Pacific ocean perch survey, the Triennial shelf survey, and the NWFSC slope
1102 survey. The NWFSC shelf-slope ages were treated as conditional age-at-length data in order
1103 to facilitate the estimation of growth within the model. The aggregated fits to the marginal
1104 age data are shown in Figure 59. The aggregated age data was fit well for the fishery fleet
1105 which had the largest sample of ages. The at-sea hake fleet and the surveys had significantly
1106 lower sample sizes which resulted in spiky patterns in the aggregated data. However, the
1107 model generally captured the trend of the data. Detailed fits to the age data by year and
1108 fleet are provided in Appendix 11.

1109 The Pearson residuals for the main fishery fleet are show in Figure 60. There are diagonal
1110 patterns in the residuals across years which likely are cohorts moving through the fishery.

1111 The at-sea hake fishery only had age data for four non-consecutive years, combined with the
1112 tendency of this fleet to select older fish, prevented general conclusions regarding fits to the
1113 data and cohort strength over time (Figure 61). The Pacific ocean perch survey only had
1114 one year of age data (the 1979 were all surface reads) but both sexes had a larger observed
1115 number of older fish relative to the model estimates (Figure 62). The Triennial shelf survey
1116 age data which ranged from 1989-2004 did not show a clear pattern in residuals (Figure 63).
1117 However, the final year of the survey, 2004, did have an increase in positive residuals for
1118 female fish compared to earlier years. The Pearson residuals for the two years of age data
1119 from NWFSC slope survey are shown in Figure 64. The residual pattern differs between the
1120 years and by sex with positive residuals of male fish across ages in the 2001 data.

1121 The observed and expected conditional age-at-length fits are shown in Figures 65, 66, 67,
1122 68, and 69 for the NWFSC shelf-slope survey observations. The fits generally match the
1123 observations. Some outliers are apparent with large residuals. The 2016 data varies from
1124 previous years where larger fish across all ages have higher observations compared to the
1125 model expectation.

1126 The age data were also weighted according to Francis weighting which adjust the weight
1127 given to a data set based on the fit to the mean age by year. The mean ages from the fishery
1128 appear to have declined in recent years which could be due to incoming cohorts (Figure 70).
1129 The at-sea hake fishery mean age are similar for 2006 and 2007 but both 2003 and 2014 have
1130 lower average age in the samples (Figure 71). The mean age for the Triennial shelf survey
1131 varied across the sampling period but the distribution of sampled ages were highly variable
1132 across the years (Figure 72). The NWFSC slope had a decline in the mean age between
1133 the two data years (Figure 73). The mean age for the NWFSC shelf-slope survey generally
1134 showed a declining trend over the time-series excluding 2012 and 2016 which sampled older
1135 fish relative to the other years (Figure 74).

1136 3.4.3 Population Trajectory

1137 The predicted spawning output (in millions of eggs) is given in Table 26 and plotted in Figure
1138 75. The predicted spawning output from the base model generally showed a slight decline over
1139 the time-series until when the foreign fleet began. A short, but sharp decline occurred during
1140 the period of the foreign fishery in the late 1960s. The stock continued to decline minimally
1141 until 1994 (34.8%) when a combination of strong recruitment and low catches resulted in
1142 an increase in spawning output at the end of the time-series. The recent increase is even
1143 faster for total biomass (Figure 76) because not all fish from the 2008 recruitment are mature
1144 (Figure 26). The 2017 spawning output relative to unfished equilibrium spawning output
1145 is above the target of 40% of unfished spawning output (74.9%) (Figure 77). Approximate
1146 confidence intervals based on the asymptotic variance estimates show that the uncertainty in
1147 the estimated spawning output is high, especially in the early years. The standard deviation
1148 of the log of the spawning output in 2017 is 0.28.

1149 Recruitment deviations were estimated for the entire time-series that was modeled (Figure
1150 38 and discussed in Section 3.4.1) and provide a more realistic portrayal of uncertainty.
1151 Recruitment predictions from the mid-1970s and early 1980s were mostly below average,
1152 with the 1999, 2000, 2008, and 2013 cohorts being the strongest over the modeled period.
1153 Many other stock assessments of rockfish along the west coast of the US have estimated a
1154 large recruitment event in 1999 (e.g., greenstriped rockfish (Hicks et al. 2009), chilipepper
1155 rockfish (Field 2007), darkblotched rockfish (Gertseva et al. 2015)). The 2008 year classes
1156 was estimated as the strongest year class measured to date for Pacific ocean perch. This
1157 year has been estimated to have very strong year classes for other West Coast stocks (e.g.
1158 darkblotched rockfish (Gertseva et al. 2015), widow rockfish (Hicks and Wetzel 2015)). It
1159 may be worthwhile to investigate the periods of strong and weak year classes further to see if
1160 it is an artifact of the data, a consistent autocorrelation, or a result of the environment.

1161 The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 78 with
1162 estimated recruitments also shown. The stock is predicted to have never fallen to low enough
1163 levels that the steepness is obvious. However, the lowest levels of predicted spawning output
1164 showed some of the smallest recruitments and very few above average recruitments. Steepness
1165 was not estimated in this model, but sensitivities to an alternative value of steepness is
1166 discussed below.

1167 3.4.4 Uncertainty and Sensitivity Analyses

1168 A number of sensitivity analyses were conducted, including:

- 1169 1. Data weighting according to the harmonic mean.
- 1170 2. Fixed steepness at the prior value of 0.72.
- 1171 3. Estimate natural mortality for female and male Pacific ocean perch.
- 1172 4. Maturity relationship used in the previous assessment.
- 1173 5. Fecundity relationship used in the previous assessment.
- 1174 6. Split the Triennial shelf survey into two time-series, early (1980-1992) and late (1995-
1175 2004).
- 1176 7. Remove the historical commercial CPUE index.
- 1177 8. Inclusion of available Canadian fishery and survey data (does not constitute all data
1178 used in Canadian assessments). This sensitivity includes Canadian fishery landings
1179 (1997-2016 with landings ranging from 260-400 mt by year) and survey removals (2004,
1180 2006, 2008, 2010, 2012, 2014, 2016), no fishery or survey index of abundance, but with
1181 length and age composition from both the fishery and survey.

- 1182 9. Inclusion of historical Washington research lengths.
- 1183 10. Inclusion of Oregon special projects length and age data which are sampled at the
1184 dockside or processing facilities.
- 1185 Likelihood values and estimates of key parameters from each sensitivity are available in Tables
1186 27 and 28. Plots of the estimated time-series of spawning output and relative depletion are
1187 shown in Figures 79, 80, 81, and 82.
- 1188 The sensitivities which explored steepness or natural mortality had the largest change in
1189 estimated stock status relative to the base model. Fixing steepness at the prior value resulted
1190 in the stock being near unfished spawning output. When natural mortality was estimated the
1191 estimated values were higher relative to the median of the prior used in base model, resulting
1192 in the relative depletion to be 93%.
- 1193 Including additional data from either Canada, Washington research lengths, and or Oregon
1194 special projects data resulted in estimated lower stock status relative to the base model.
1195 However, the status was still well above the management target.
- 1196 Weighting the data according to the harmonic means resulted in the largest decrease in the
1197 estimated stock status relative to the base model with the stock being estimated at 68% of
1198 unfished spawning output.
- 1199 The sensitivities that explored the removal of the CPUE index, the 2011 maturity, or fecundity
1200 relationship had little impact relative to the base model results.

1201 **3.4.5 Retrospective Analysis**

1202 A 5-year retrospective analysis was conducted by running the model using data only through
1203 2011, 2012, 2013, 2014, and 2015, progressively (Figure 83 and 84). The initial scale of the
1204 spawning population was basically unchanged for all of these retrospectives. The estimation
1205 of the 2008 recruitment deviation decreased as more data was removed. Overall, no alarming
1206 trends were present in the retrospective analysis.

1207 **3.4.6 Likelihood Profiles**

1208 Likelihood profiles were conducted for R_0 , steepness, and over natural mortality values
1209 separately. These likelihood profiles were conducted by fixing the parameter at specific values
1210 and estimated the remaining parameters based on the fixed parameter value.

1211 For steepness, the negative log-likelihood was essentially flat between values of 0.30 - 0.80
1212 (Figure 85). Likelihood components by data source show that the fishery length and age data

1213 supports a low steepness value, but the NWFSC shelf-slope age data supports a higher value
1214 for steepness. The Triennial shelf survey index indicates a low value of steepness while the
1215 other surveys do not provide information concerning steepness. The relative depletion for
1216 Pacific ocean perch has a wide range across different assumed values of steepness (Figure 86).

1217 The negative log-likelihood was minimized at a natural mortality value of 0.06, but the 95%
1218 confidence interval extends over the majority of natural mortality values. The age and length
1219 data likelihood contribution was minimized at natural morality values ranging from 0.055-0.06
1220 (Figure 87). The relative depletion for Pacific ocean perch widely varied across alternative
1221 values of natural mortality (Figure 88).

1222 In regards to values of R_0 , the negative log-likelihood was minimized at approximately $\log(R_0)$
1223 of 9.30 (Figure 89). The fishery and survey composition data was in opposition regarding
1224 values of R_0 where the fishery length and age data indicated lower values of R_0 while the
1225 survey ages from the Pacific ocean perch and the NWFSC shelf-slope surveys indicated a
1226 higher value.

1227 3.4.7 Reference Points

1228 Reference points were calculated using the estimated selectivities and catch distribution
1229 among fleets in the most recent year of the model (2016). Sustainable total yields (landings
1230 plus discards) were 1770.4 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95%
1231 confidence interval of 1268.2 - 2272.5 mt based on estimates of uncertainty. The spawning
1232 output equivalent to 40% of the unfished spawning output ($SB_{40\%}$) was 2665.7 millions of
1233 eggs. The recent catches (landings plus discards) have been below the point estimate of
1234 potential long-term yields calculated using an $SPR_{50\%}$ reference point and the population
1235 has been increasing over the last 15 years.

1236 The predicted spawning output from the base model generally showed a sharp decline during
1237 the 1960s followed by less of a decline until 1994 (Figure 75). Since 2001, the spawning output
1238 has been rapidly increasing due to small catches, and recently, above average recruitment. The
1239 2017 spawning output relative to unfished equilibrium spawning output is above the target of
1240 40% of unfished spawning output (Figure 77). The fishing intensity, $(1 - SPR)/(1 - SPR_{50\%})$,
1241 exceeded the current estimates of the harvest rate limit ($SPR_{50\%}$) throughout the 1960s as
1242 seen in Figure 90. Recent exploitation rates on Pacific ocean perch were predicted to be
1243 much less than target levels. In recent years, the stock has experienced exploitation rates
1244 that have been below the target level while the spawning output level has remained above
1245 the target level.

1246 Table 25 shows the full suite of estimated reference points for the base model and Figure 91
1247 shows the equilibrium curve based on a steepness value fixed at 0.50.

¹²⁴⁸ 4 Harvest Projections and Decision Tables

¹²⁴⁹ A twelve year projection of the base model with catches equal to the estimated ACL for years
¹²⁵⁰ 2019-2028 and a catch allocation equal to the percentages for each fleet over the period of
¹²⁵¹ 2014-2016 predicts an increase in the spawning output due to large 2008 cohort, with a slight
¹²⁵² downturn beginning in 2023 (Table 29).

¹²⁵³ Add additional projection post STAR based upon the decision table: Table 30

¹²⁵⁴ 5 Regional Management Considerations

¹²⁵⁵ The distribution of Pacific ocean perch occur primarily in the US west coast waters of
¹²⁵⁶ Washington, Oregon, and northern California and he is currently managed to a species level
¹²⁵⁷ with harvest limits set for the stock north of the 40°10' latitude. The population within this
¹²⁵⁸ area is treated as a single stock due to the lack of biological and genetic data indicating the
¹²⁵⁹ presence of multiple stocks. Analysis conducted within this assessment did not find support
¹²⁶⁰ for regional management within the area that Pacific ocean perch occur.

¹²⁶¹ 6 Research Needs

¹²⁶² There are many areas of research that could be improved to benefit the understanding and
¹²⁶³ assessment of Pacific ocean perch. Below, are issues that are considered of the importance.

- ¹²⁶⁴ 1. **Natural mortality:** Uncertainty in natural mortality translates into uncertain estimates
¹²⁶⁵ of status and sustainable fishing levels for Pacific ocean perch. The collection
¹²⁶⁶ of additional age data, re-reading of older age samples, reading old age samples that
¹²⁶⁷ are unread, and improved understanding of the life-history of Pacific ocean perch may
¹²⁶⁸ reduce that uncertainty.
- ¹²⁶⁹ 2. **Steepness:** The amount of stock resilience, steepness, dictates the rate at which a
¹²⁷⁰ stock can rebuild from low stock sizes. Improved understanding regarding the steepness
¹²⁷¹ of US west coast Pacific ocean perch will reduce our uncertainty regarding current stock
¹²⁷² status.
- ¹²⁷³ 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
¹²⁷⁴ US and does not consider data from British Columbia or Alaska. Further investigating
¹²⁷⁵ and comparing the data and predictions from British Columbia and Alaska to determine
¹²⁷⁶ if there are similarities with the US west Coast observations would help to define the
¹²⁷⁷ connectivity between Pacific ocean perch north and south of the U.S.-Canada border.

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1290 compiled the extensive management changes for Pacific ocean perch which were critical in
1291 understanding and modeling fishery behavior. John Wallace provided multiple last minute
1292 PacFIN extractions and analyzed historical discard rates for use in the assessment.

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1299 through the many discussions within the Population Ecology team in the FRAM division at
1300 the NWFSC.

₁₃₀₁ 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 Columbia | Reduced trip limit for Pacific ocean perch in the Vancouver and Columbia areas to 20% by weight of all fish on board, not to exceed 5,000 pounds per vessel per trip. |
| 8/16/1984 | Columbia | Commercial fishing for Pacific ocean perch in the Columbia area closed for remainder of the year. |
| 1/10/1985 | Vancouver Columbia | Established Vancouver and Columbia areas Pacific ocean perch trip limit of 20% by weight of all fish on board (no 5,000-pound limit as specified in last half of 1984). |
| 4/28/1985 | Vancouver Columbia | Reduced the Vancouver and Columbia areas Pacific ocean perch trip limit to 5,000 pounds or 20% by weight of all fish on board, whichever is less. |
| 4/28/1985 | ALL | Landings of Pacific ocean perch less than 1,000 pounds will be unrestricted. The fishery for this species will close when the OY in each area is reached. |
| 6/10/1985 | ALL | Landings of Pacific ocean perch up to 1,000 pounds per trip will be unrestricted regardless of the percentage of these fish on board. |
| 1/1/1986 | Cape Blanco North | Established the Pacific ocean perch trip limit north of Cape Blanco (4250) at 20% (by weight) of all fish on board or 10,000 pounds whichever is less; landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 600 mt; Columbia area OY = 950 mt. |
| 1/1/1986 | ALL | landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 600 mt; Columbia area OY = 950 mt. |
| 12/1/1986 | Vancouver | OY quota for Pacific ocean perch reached in the Vancouver area; fishery closed until January 1, 1987. |
| 1/1/1987 | ALL | Established coastwide Pacific ocean perch limit at 20% of all legal fish on board or 5,000 pounds whichever is less (in round weight); landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 500 mt; Columbia area OY = 800 mt. |
| 1/1/1988 | ALL | Established the coastwide Pacific ocean perch trip limit at 20% (by weight) of all fish on board or 5,000 pounds, whichever is less; landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board; |
| 1/1/1989 | ALL | Established the coastwide Pacific ocean perch trip limit at 20% (by weight) of all fish on board or 5,000 pounds whichever is less; |
| 1/1/1989 | ALL | landings of Pacific ocean perch unrestricted if less than 1,000 pounds regardless of percentage on board (Vancouver area OY = 500 mt; Columbia area OY = 800 mt). |
| 7/26/1989 | ALL | Reduced the coastwide trip limit for Pacific ocean perch to 2,000 pounds or 20% of all fish on board, whichever is less, with no trip frequency restriction. |
| 12/13/1989 | Columbia | Closed the Pacific ocean perch fishery in the Columbia area because 1,040 mt OY reached. |
| 1/1/1990 | ALL | Established the coastwide Pacific ocean perch trip limit at 20% (by weight) of all fish on board or 3,000 pounds whichever is less; landings of Pacific ocean perch be unrestricted if less than 1,000 pounds regardless of percentage on board. (Vancouver area OY = 500 mt; Columbia area OY = 1,040 mt). |
| 1/1/1991 | ALL | Established the coastwide Pacific ocean perch trip limit at 20% (by weight) of all groundfish on board or 3,000 pounds whichever is less; landings of Pacific ocean perch be unrestricted if less than 1,000 pounds regardless of percentage on board (harvest guideline for combined Vancouver and Columbia areas = 1,000 mt). |
| 1/1/1992 | ALL | For Pacific ocean perch, established the coastwide trip limit at 20% (by weight) of all groundfish on board or 3,000 pounds whichever is less; landings of Pacific ocean perch be unrestricted if less than 1,000 pounds regardless of percentage on board (harvest guideline for combined Vancouver and Columbia areas = 1,550 mt). |

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

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

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

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

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

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

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

| Year | POP | | Triennial | | AFSC Slope | | NWFSC Slope | | NWFSC Shelf-Slope | |
|------|-------|------|-----------|------|------------|------|-------------|------|-------------------|------|
| | Obs | SE | Obs | SE | Obs | SE | Obs | SE | Obs | SE |
| 1979 | 56461 | 0.27 | - | - | - | - | - | - | - | - |
| 1980 | - | - | 10384 | 0.65 | - | - | - | - | - | - |
| 1983 | - | - | 8974 | 0.59 | - | - | - | - | - | - |
| 1985 | 34645 | 0.29 | - | - | - | - | - | - | - | - |
| 1986 | - | - | 2977 | 0.66 | - | - | - | - | - | - |
| 1989 | - | - | 4873 | 0.66 | - | - | - | - | - | - |
| 1992 | - | - | 3207 | 0.64 | - | - | - | - | - | - |
| 1995 | - | - | 2724 | 0.63 | - | - | - | - | - | - |
| 1996 | - | - | - | - | 7621 | 0.51 | - | - | - | - |
| 1997 | - | - | - | - | 3807 | 0.51 | - | - | - | - |
| 1998 | - | - | 4163 | 0.64 | - | - | - | - | - | - |
| 1999 | - | - | - | - | 4694 | 0.50 | 3643 | 0.63 | - | - |
| 2000 | - | - | - | - | 4243 | 0.53 | 4120 | 0.58 | - | - |
| 2001 | - | - | 1494 | 0.64 | 4187 | 0.49 | 2325 | 0.59 | - | - |
| 2002 | - | - | - | - | - | - | 1903 | 0.60 | - | - |
| 2003 | - | - | - | - | - | - | - | - | 9646 | 0.37 |
| 2004 | - | - | 2922 | 0.67 | - | - | - | - | 5284 | 0.40 |
| 2005 | - | - | - | - | - | - | - | - | 7528 | 0.40 |
| 2006 | - | - | - | - | - | - | - | - | 6010 | 0.42 |
| 2007 | - | - | - | - | - | - | - | - | 6268 | 0.37 |
| 2008 | - | - | - | - | - | - | - | - | 3867 | 0.40 |
| 2009 | - | - | - | - | - | - | - | - | 2745 | 0.37 |
| 2010 | - | - | - | - | - | - | - | - | 5404 | 0.35 |
| 2011 | - | - | - | - | - | - | - | - | 7533 | 0.35 |
| 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 shelf 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 shelf 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 (continued on next page).

| 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 | |

Continued on next page

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

| Parameter | Value | Phase | Bounds | Status | SD | Prior (Exp.Val, SD) |
|-------------------------|------------|-------|-----------|--------|------|---------------------|
| 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 |

Continued on next page

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

| Parameter | Value | Phase | Bounds | Status | SD | Prior (Exp.Val, SD) |
|-------------------------|-----------|-------|----------------------|--------|------|---------------------|
| 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 |

Continued on next page

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

| Parameter | Value | Phase | Bounds | Status | SD | Prior (Exp.Val, SD) |
|------------------------------------|------------|-------|------------|--------|------|---------------------|
| SizeSel.P2_AFSCSlope(6) | -5 | -2 | (-6, 4) | OK | 6.35 | 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 | - | - | - | - | - | - | |

₁₃₀₂ 9 Figures

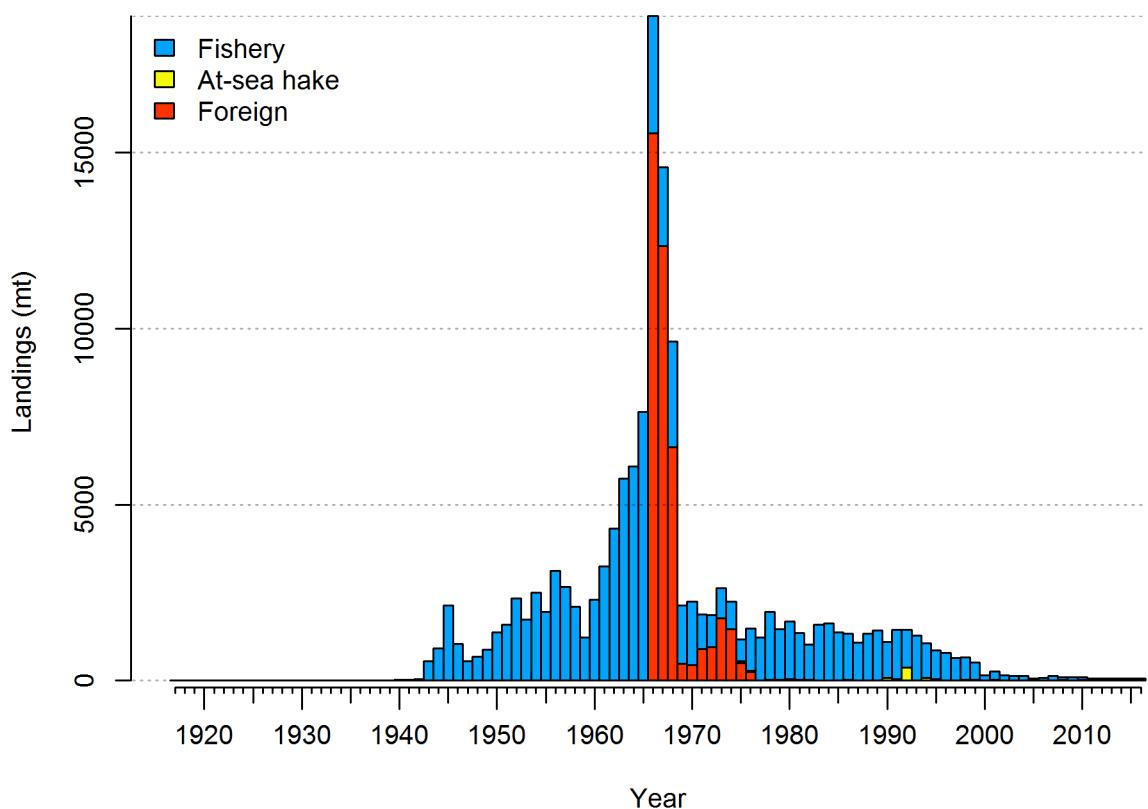


Figure 1: Total catches Pacific ocean perch through 2016.

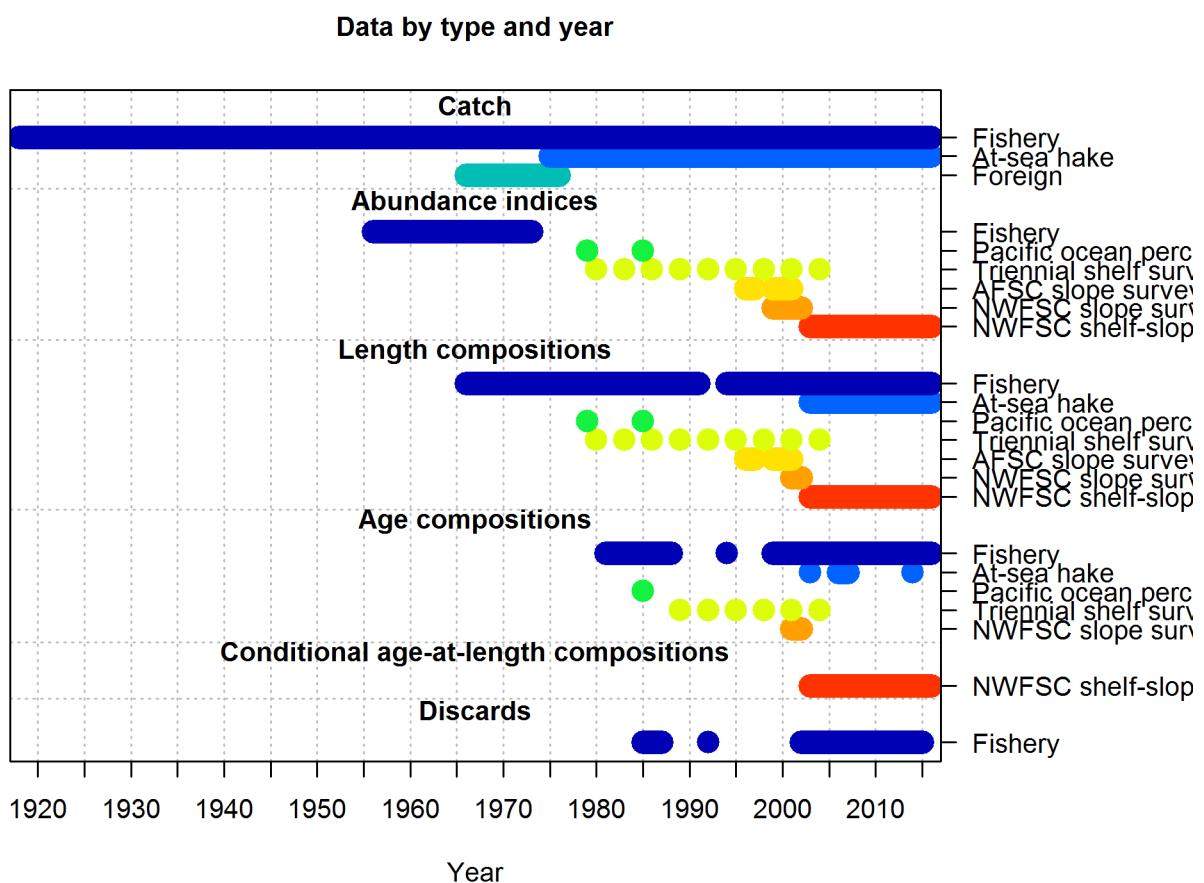


Figure 2: Summary of data sources used in the base model.

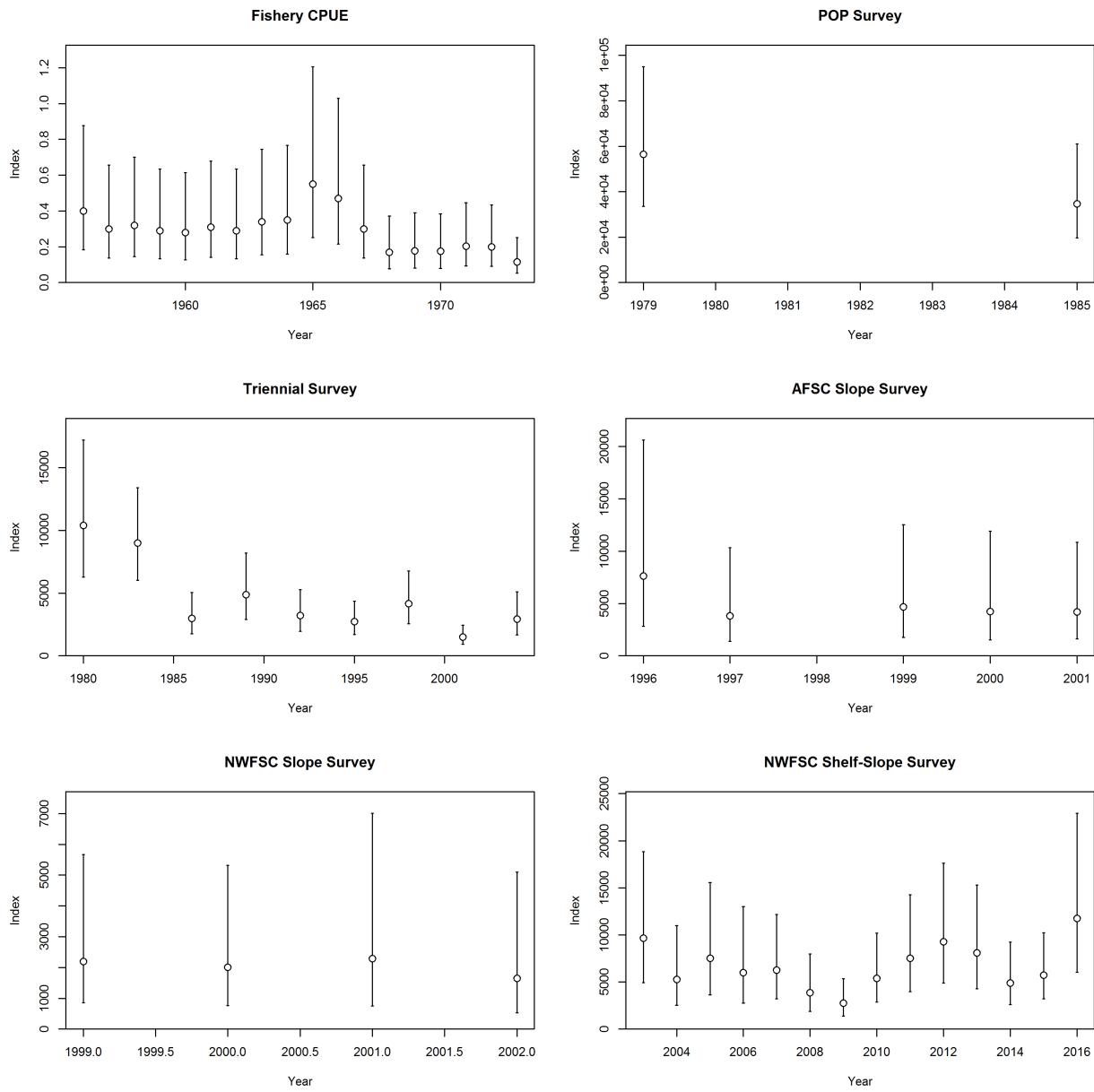


Figure 3: Fishery-dependent and fishery-independent indices for Pacific ocean perch.

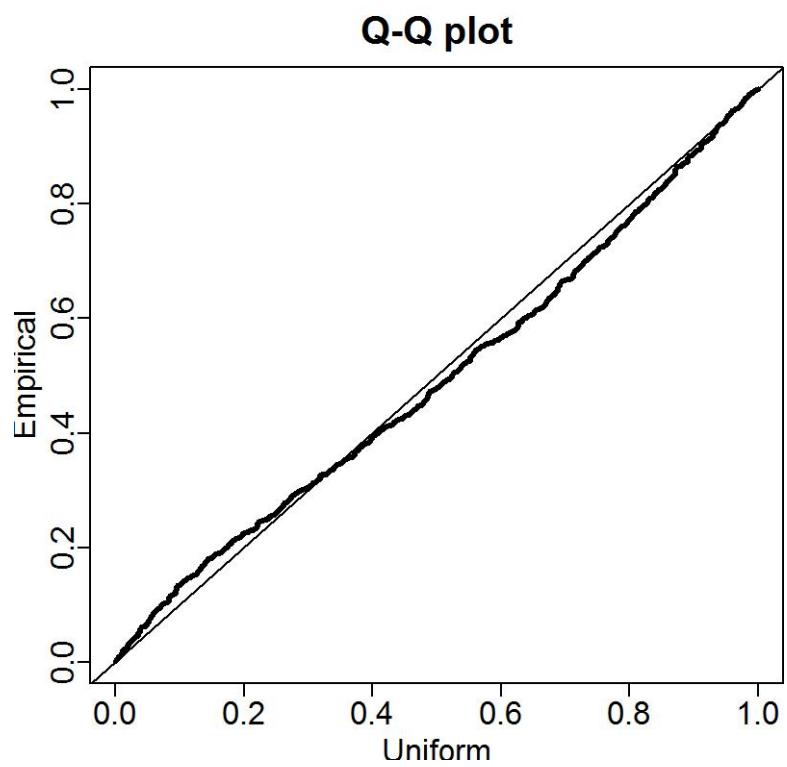


Figure 4: Q-Q plots for the VAST lognormal distribution for the NWFSC shelf-slope survey.

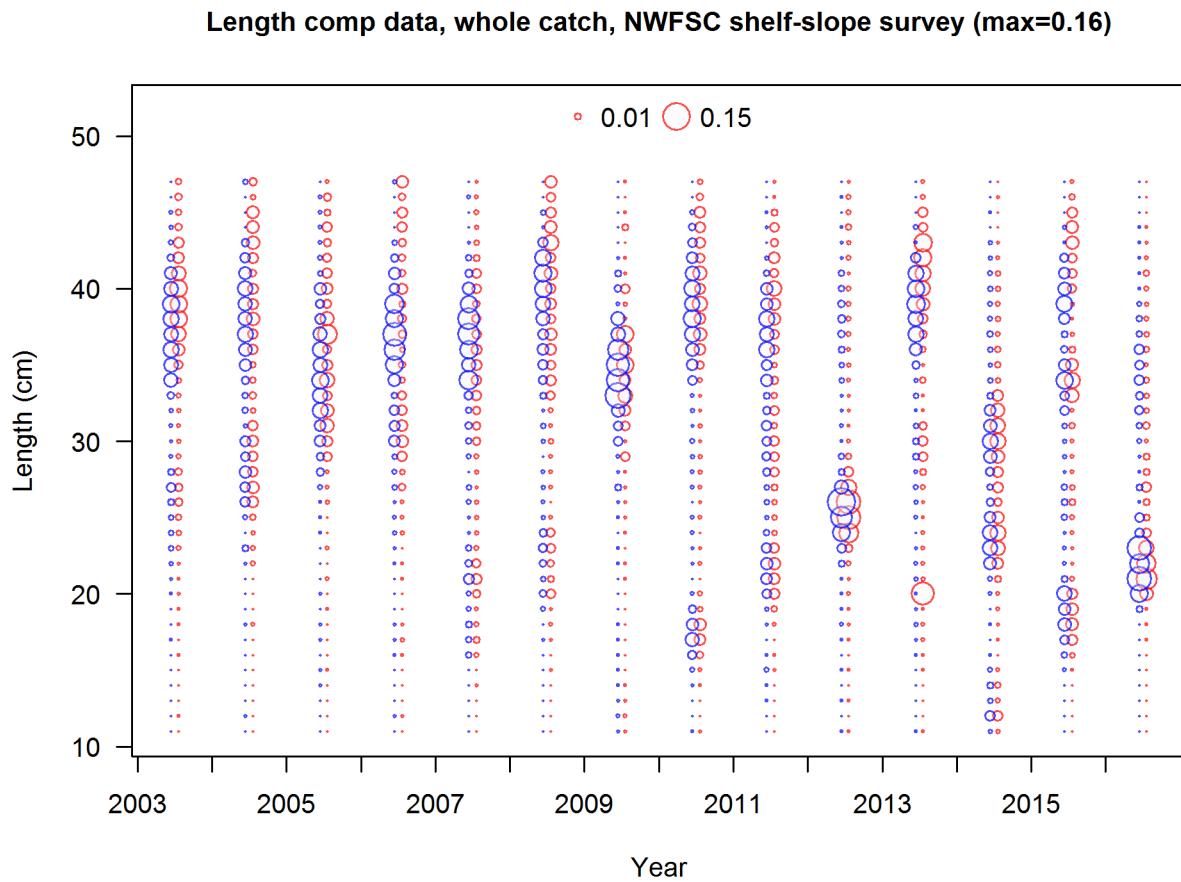


Figure 5: NWFSC shelf-slope survey length frequency distributions for Pacific ocean perch.

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

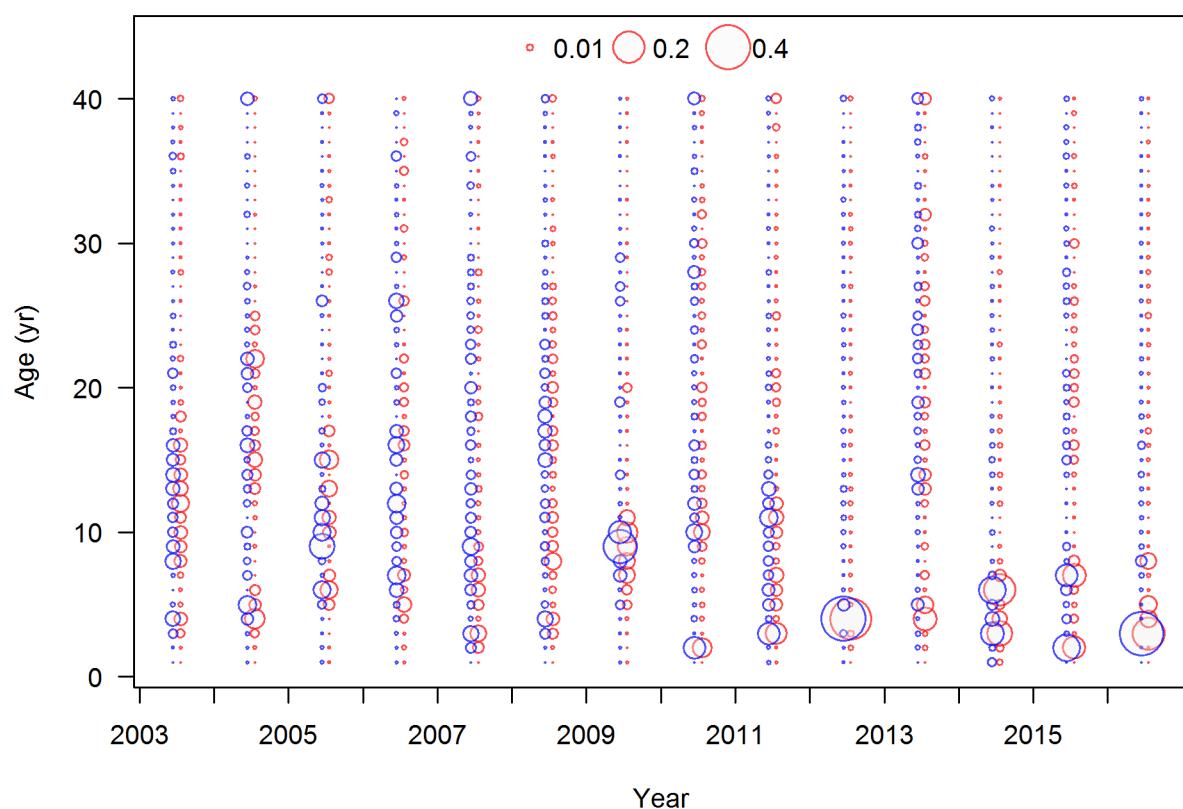


Figure 6: NWFSC shelf-slope survey age frequency distributions for Pacific ocean perch.

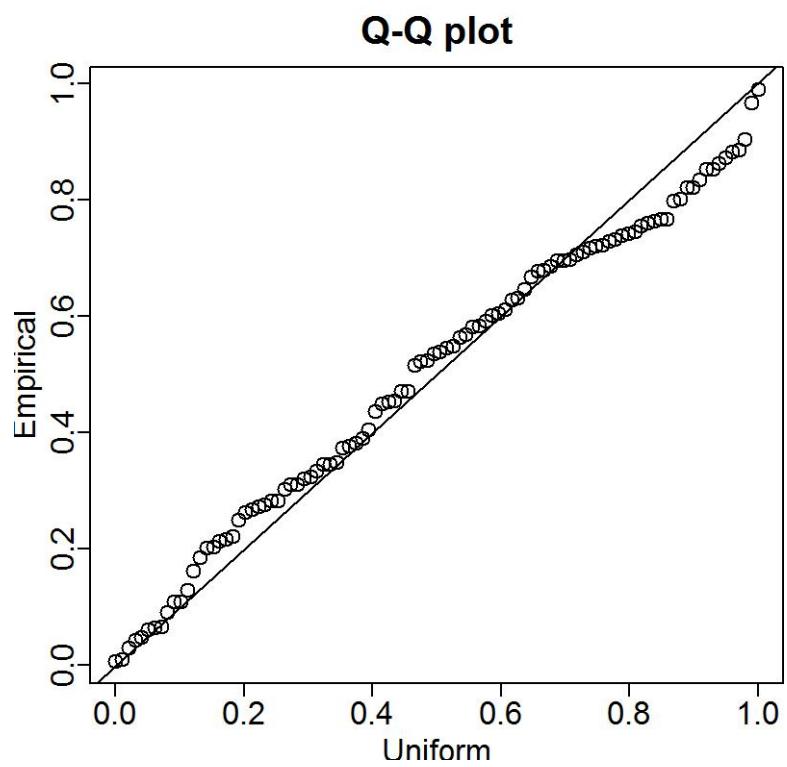


Figure 7: Q-Q plots for the VAST lognormal distribution for the NWFSC slope survey.

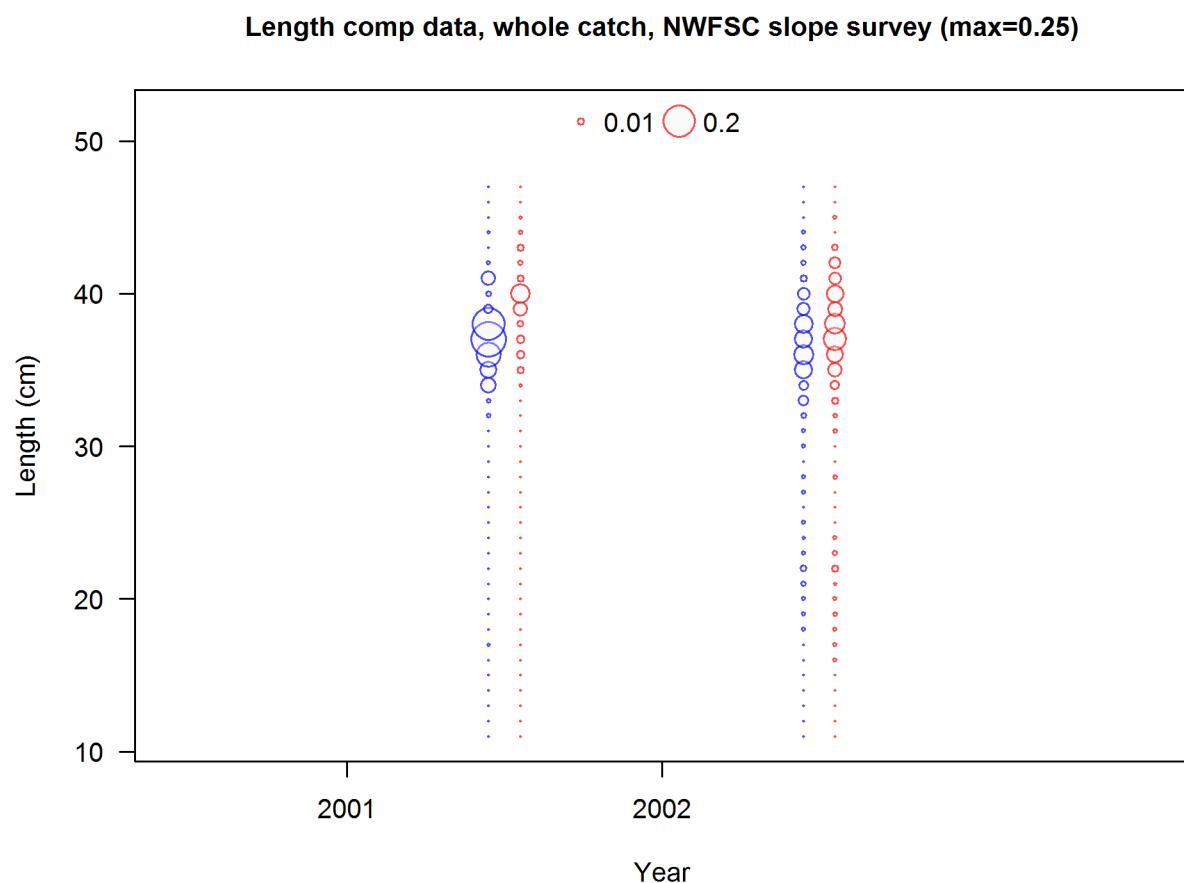


Figure 8: NWFSC slope survey length frequency distributions for Pacific ocean perch.

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

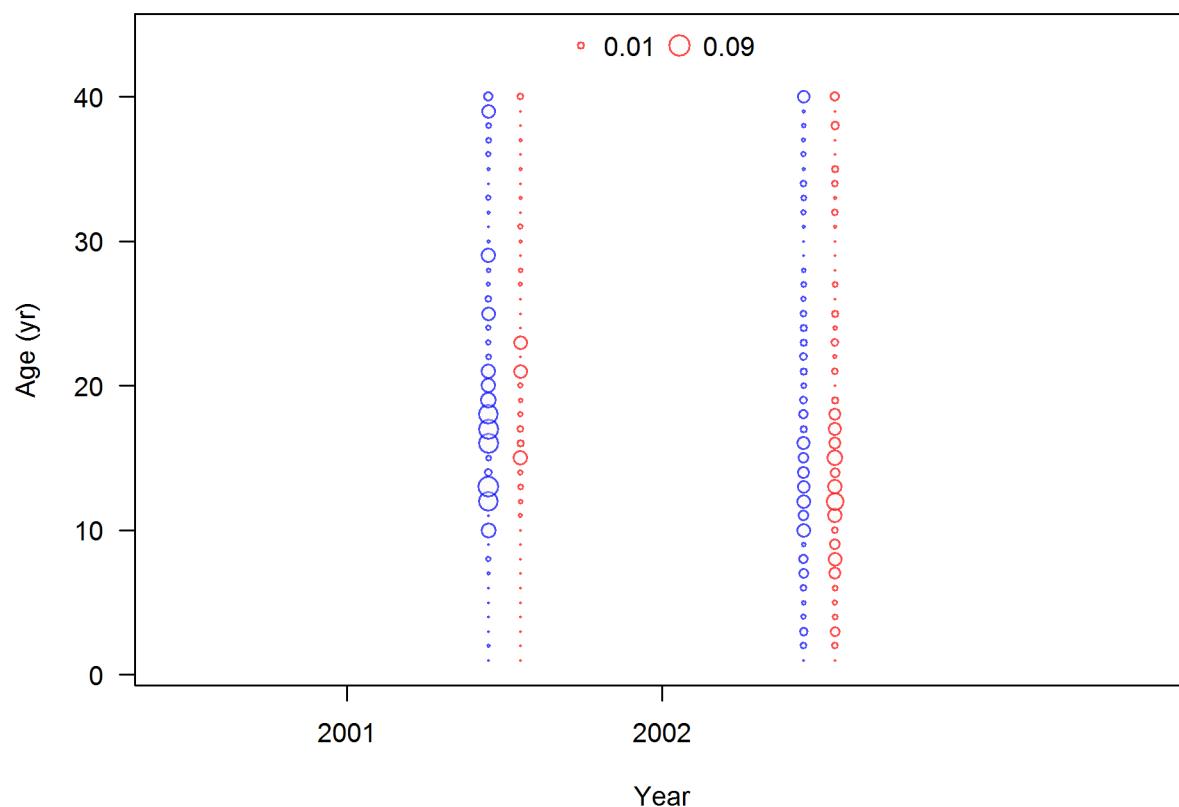


Figure 9: NWFSC slope survey age frequency distributions for Pacific ocean perch.

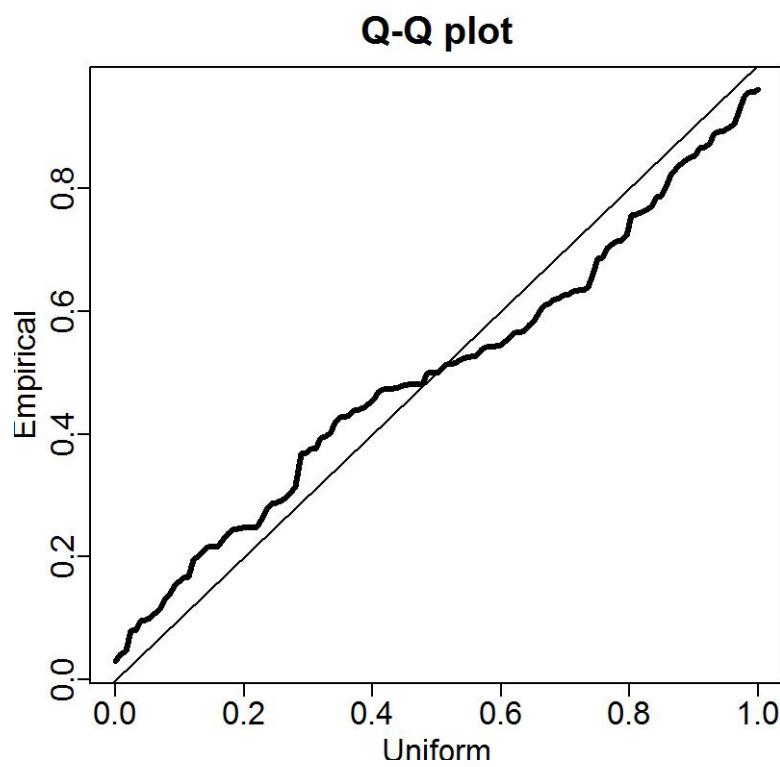


Figure 10: Q-Q plots for the VAST lognormal distribution for the AFSC slope survey.

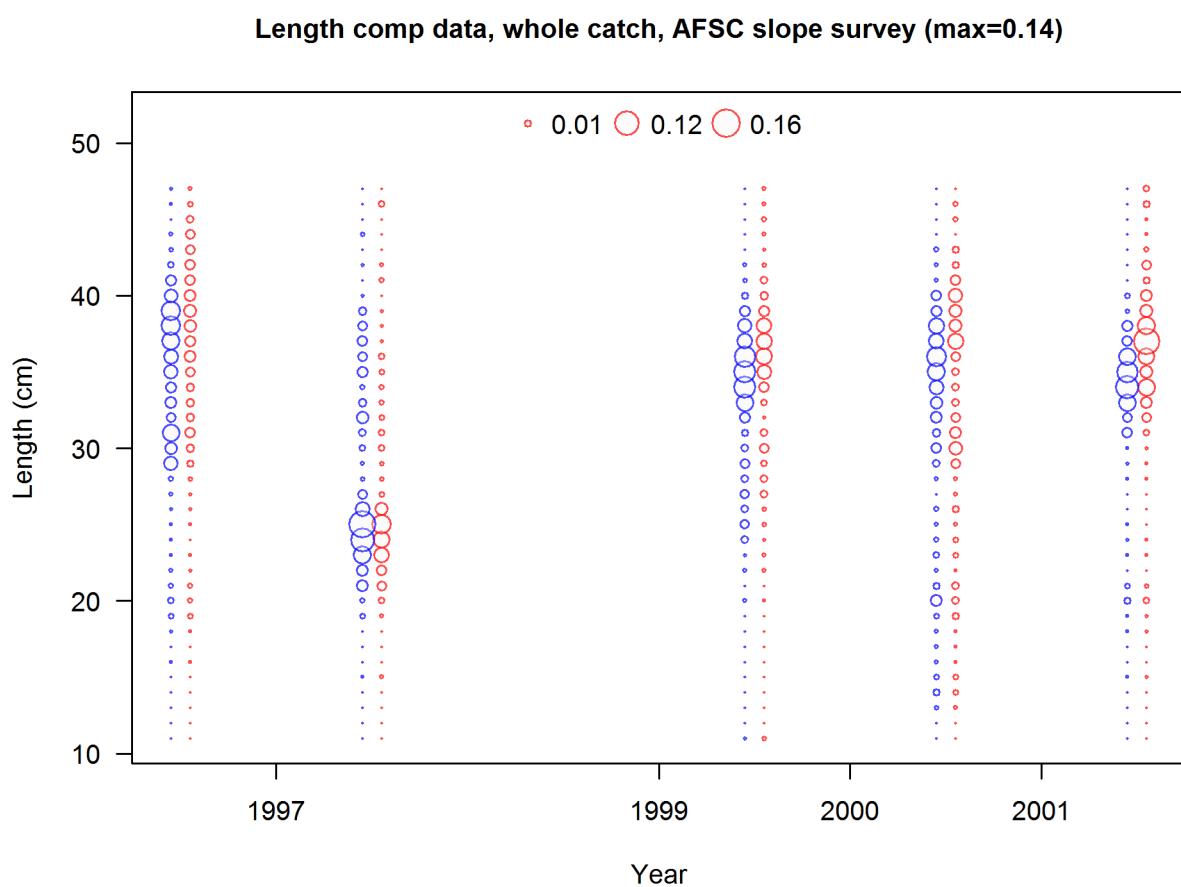


Figure 11: AFSC slope survey length frequency distributions for Pacific ocean perch.

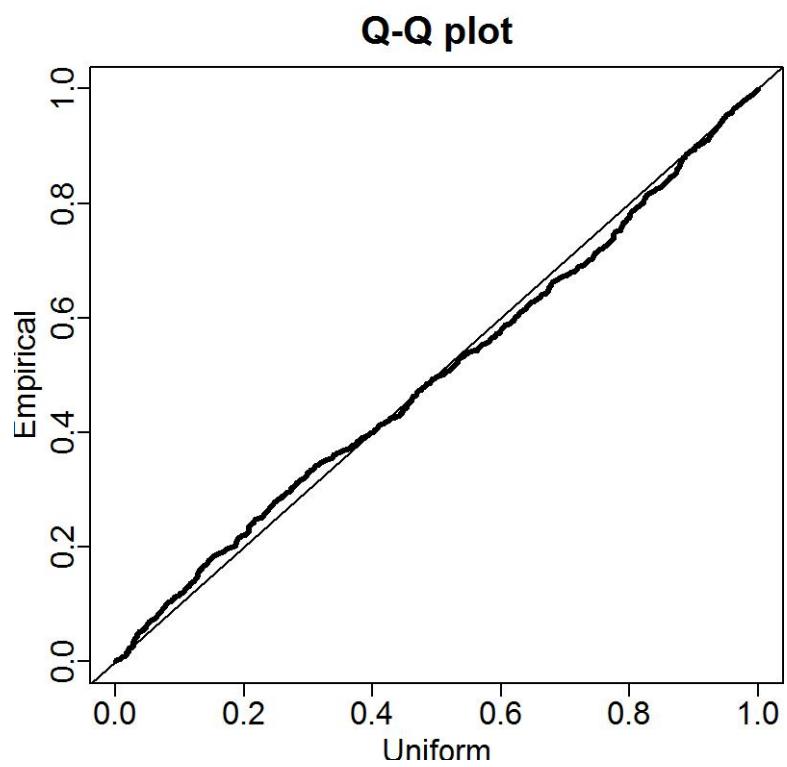


Figure 12: Q-Q plots for the VAST lognormal distribution for the Triennial shelf survey.

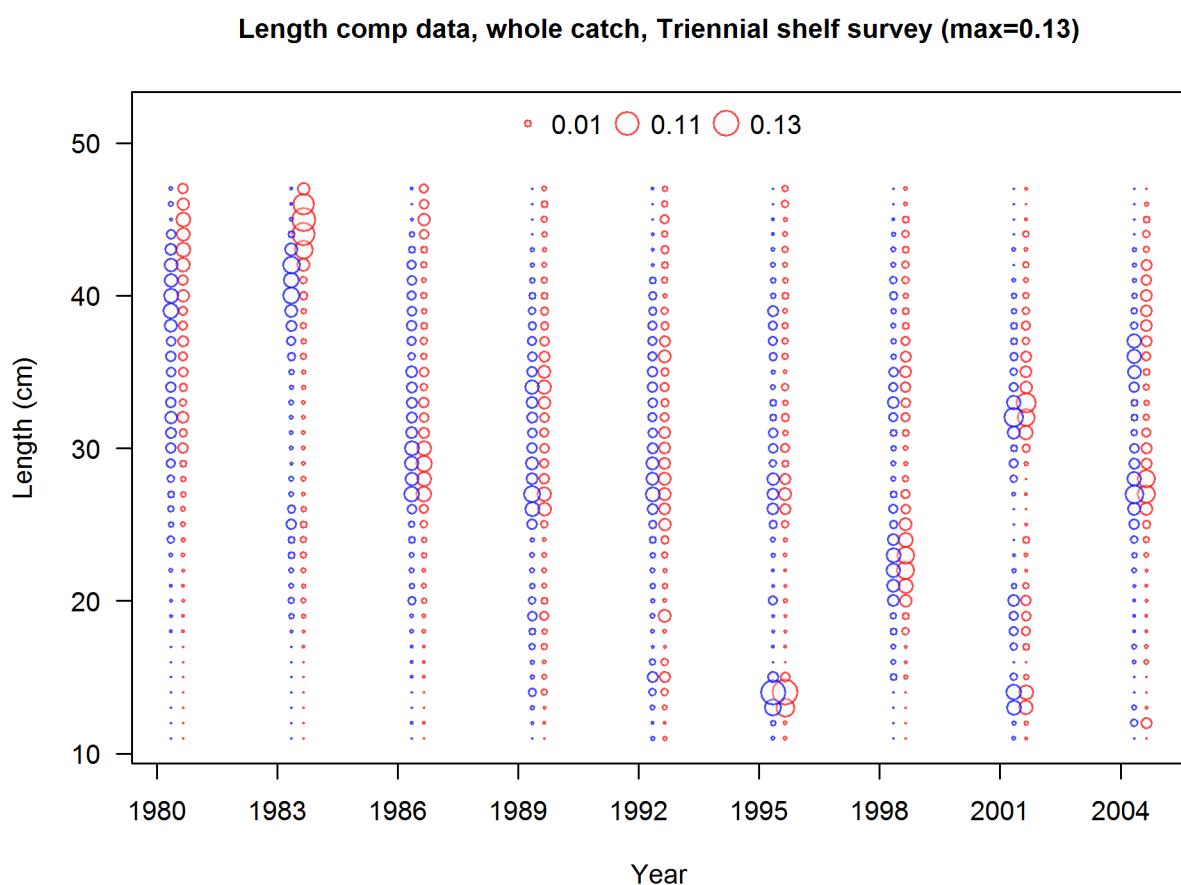


Figure 13: Triennial shelf survey length frequency distributions for Pacific ocean perch.

Age comp data, whole catch, Triennial shelf survey (max=0.2)

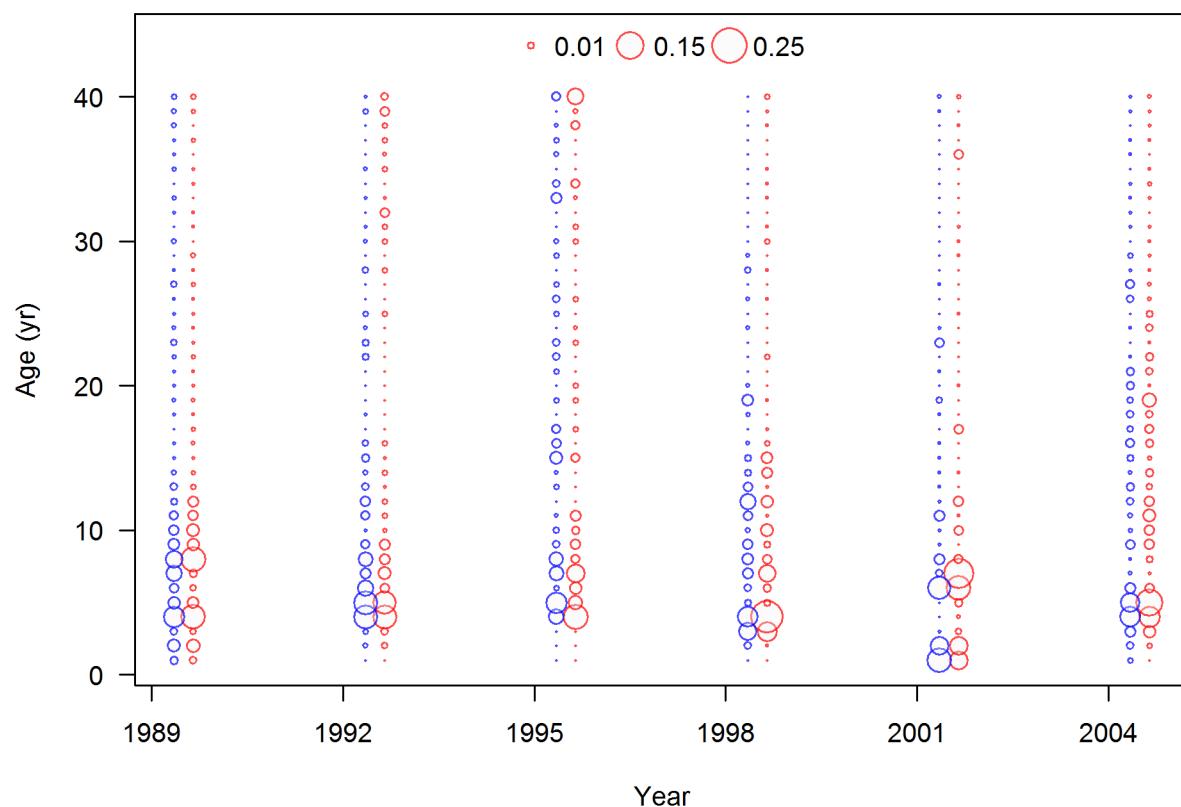


Figure 14: Triennial shelf survey age frequency distributions for Pacific ocean perch.

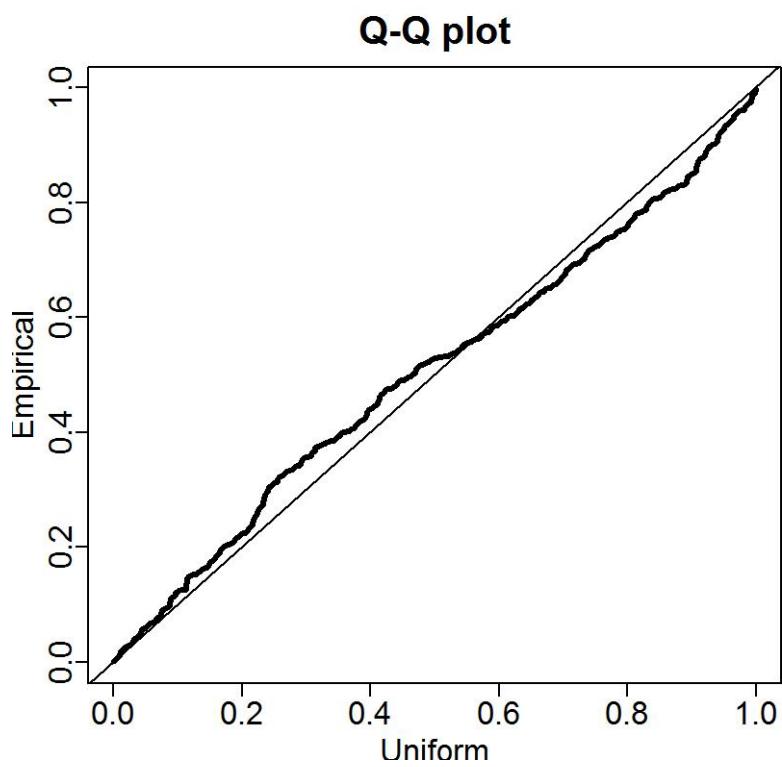


Figure 15: Q-Q plots for the VAST lognormal distribution for the Pacific ocean perch survey.

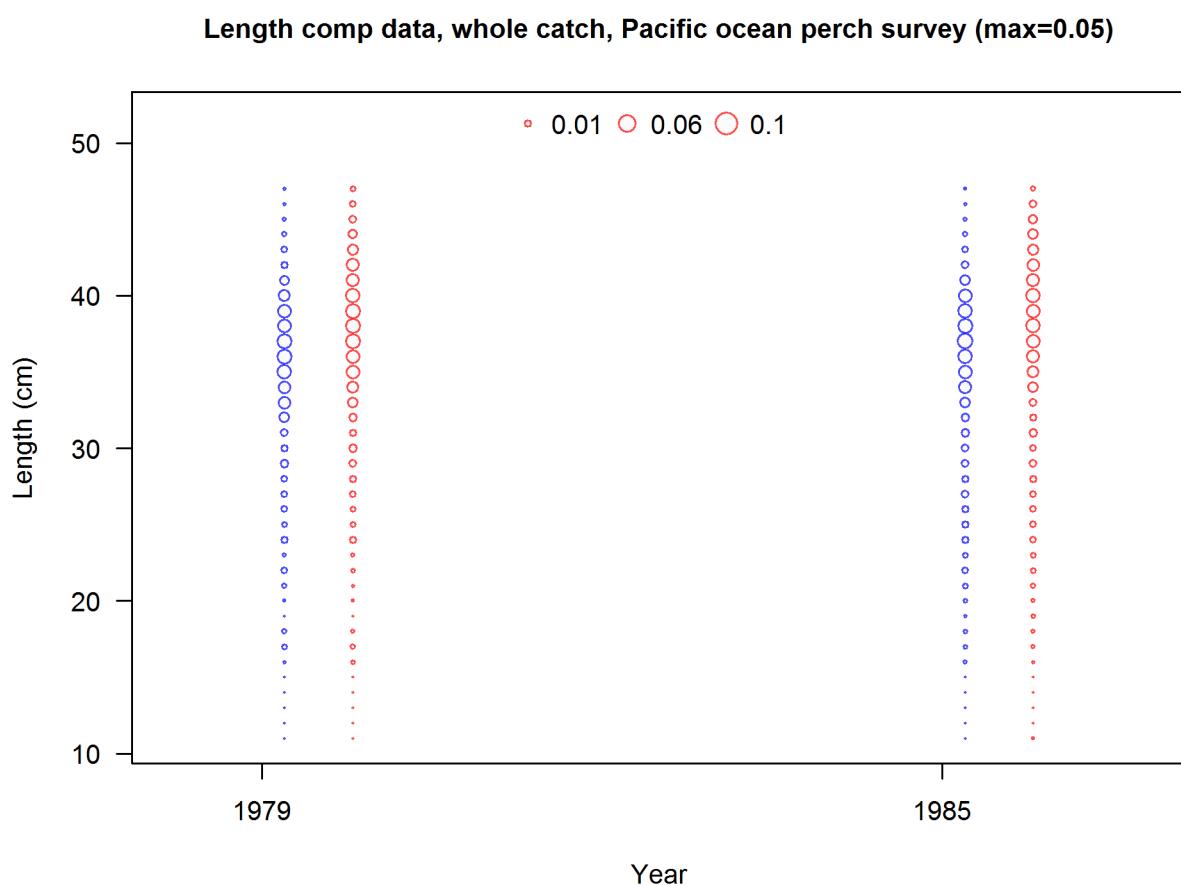


Figure 16: Pacific ocean perch survey length frequency distributions for Pacific ocean perch.

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

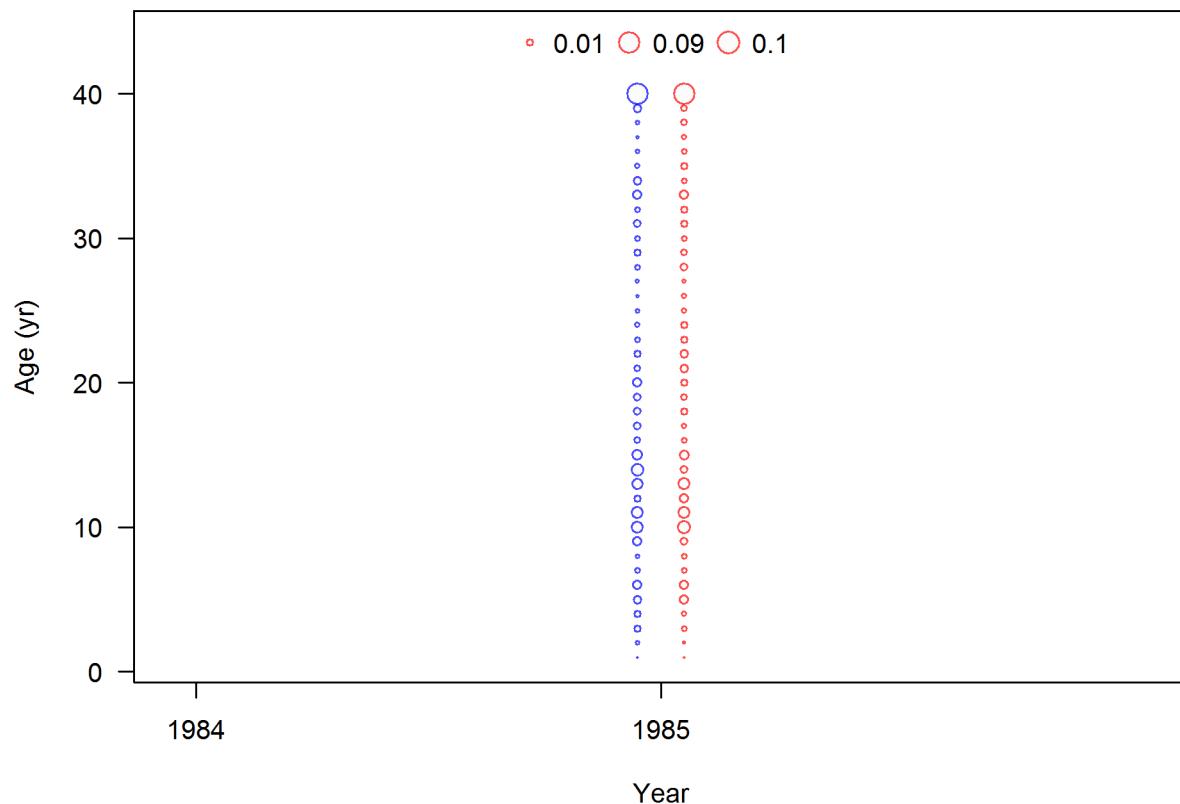


Figure 17: Pacific ocean perch survey age frequency distributions for Pacific ocean perch.

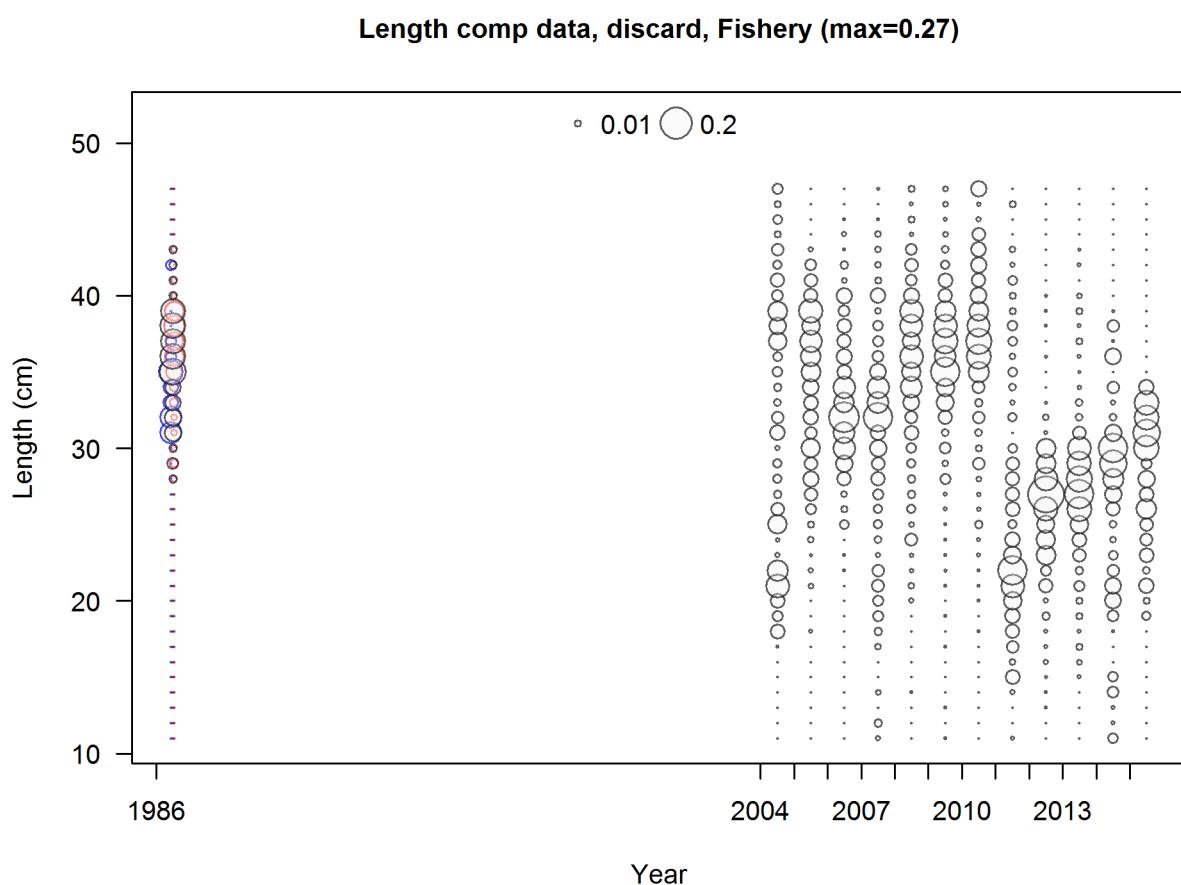


Figure 18: Discard length frequency distributions from WCGOP for Pacific ocean perch.

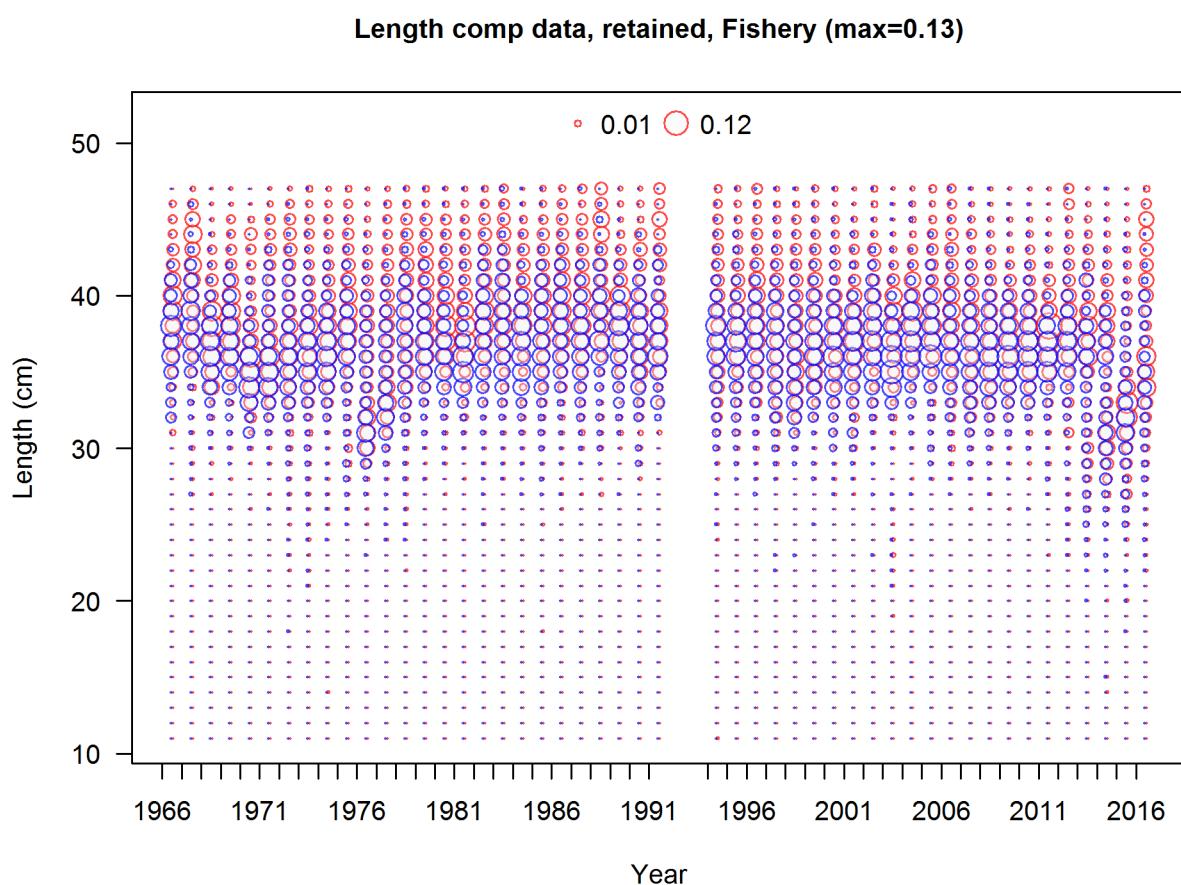


Figure 19: Commercial fishery length frequency distributions for Pacific ocean perch.

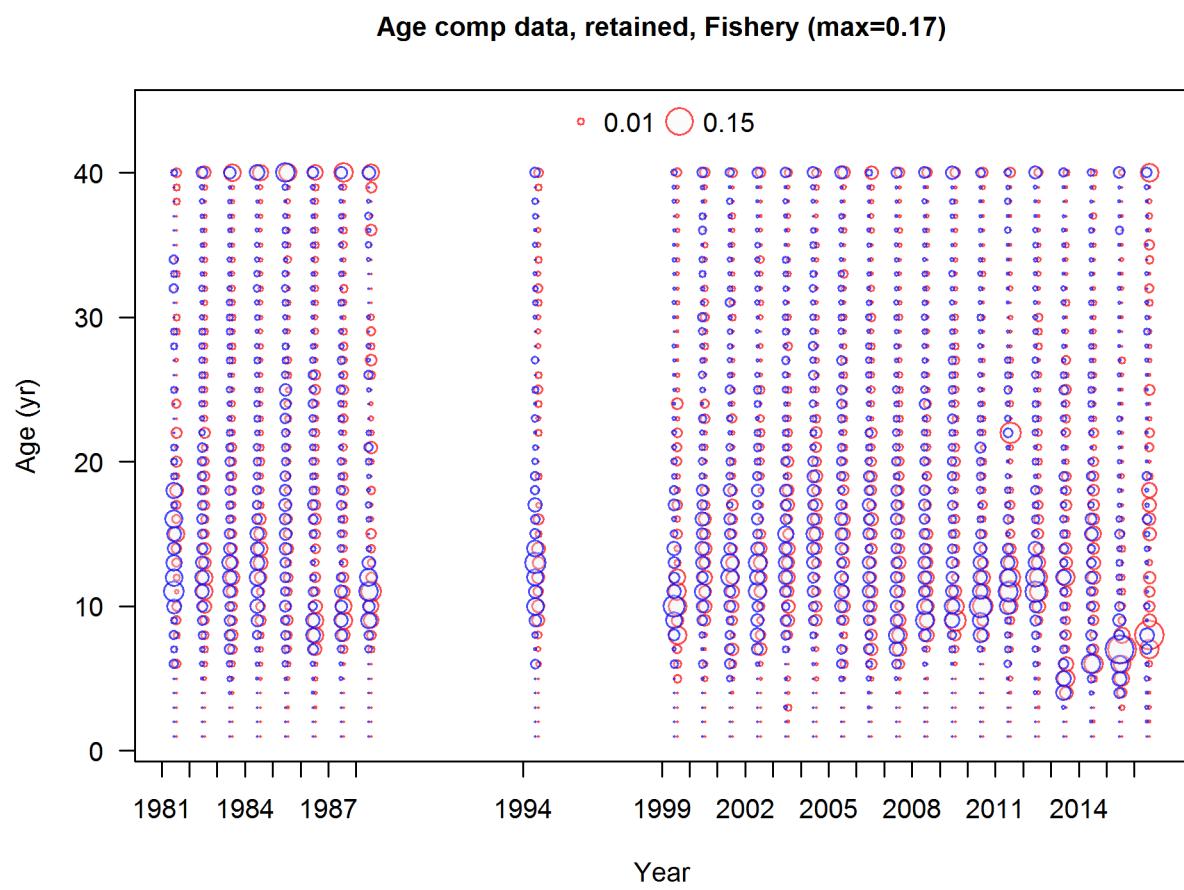


Figure 20: Commercial fishery age frequency distributions for Pacific ocean perch.

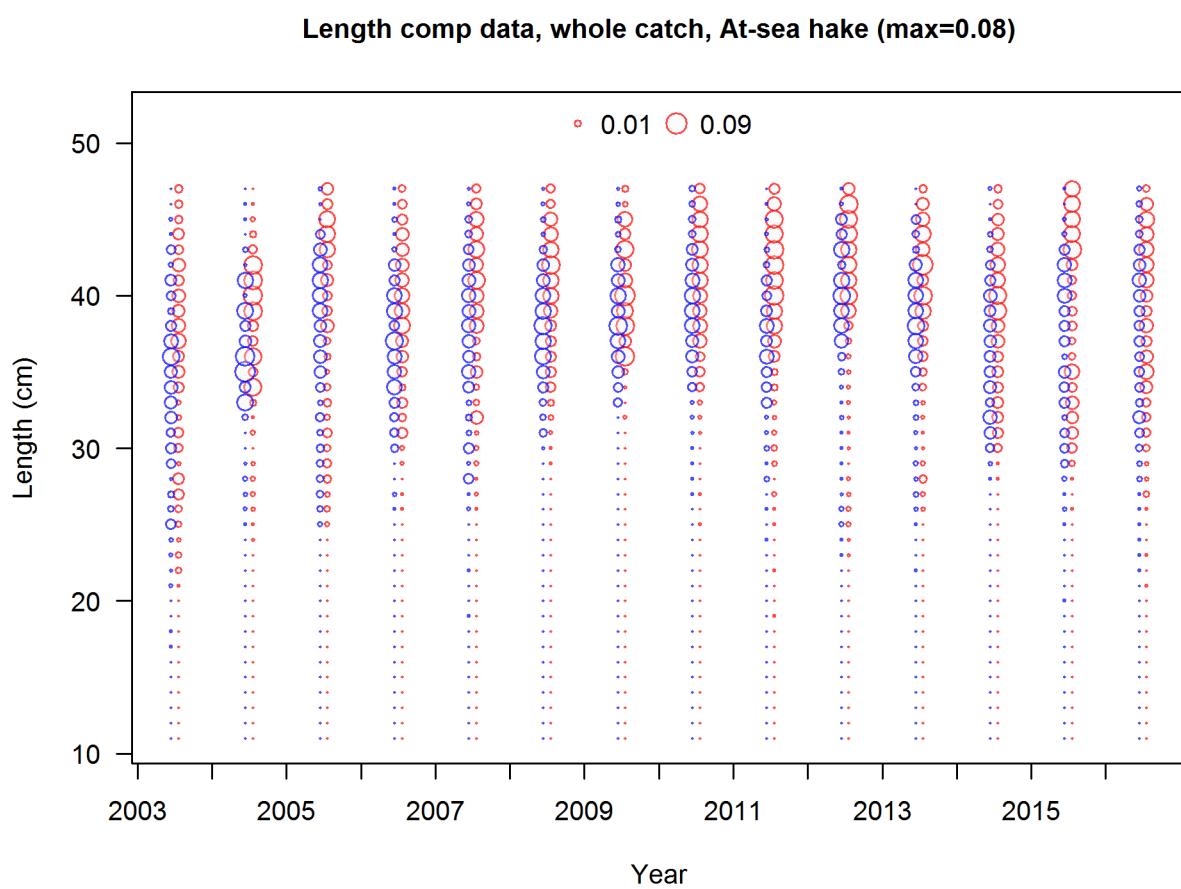


Figure 21: At-sea hake fishery length frequency distributions for Pacific ocean perch.

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

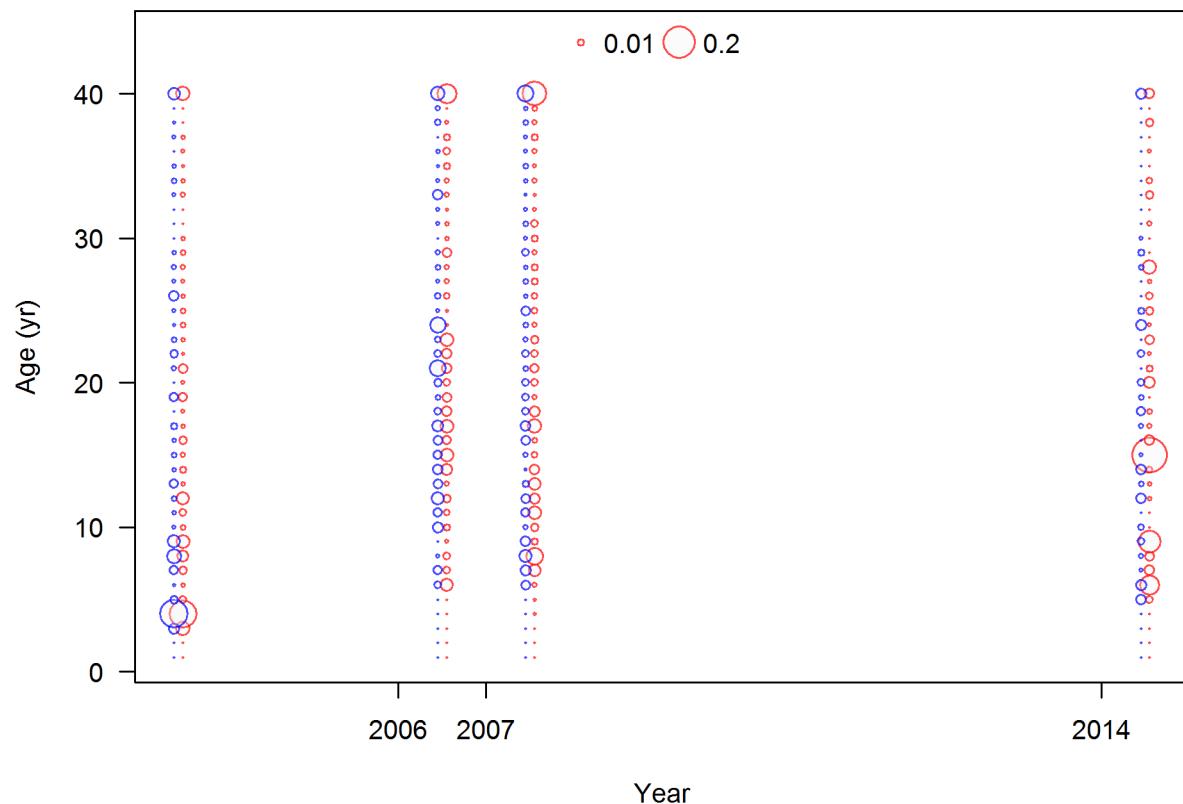


Figure 22: At-sea hake fishery age frequency distributions for Pacific ocean perch.

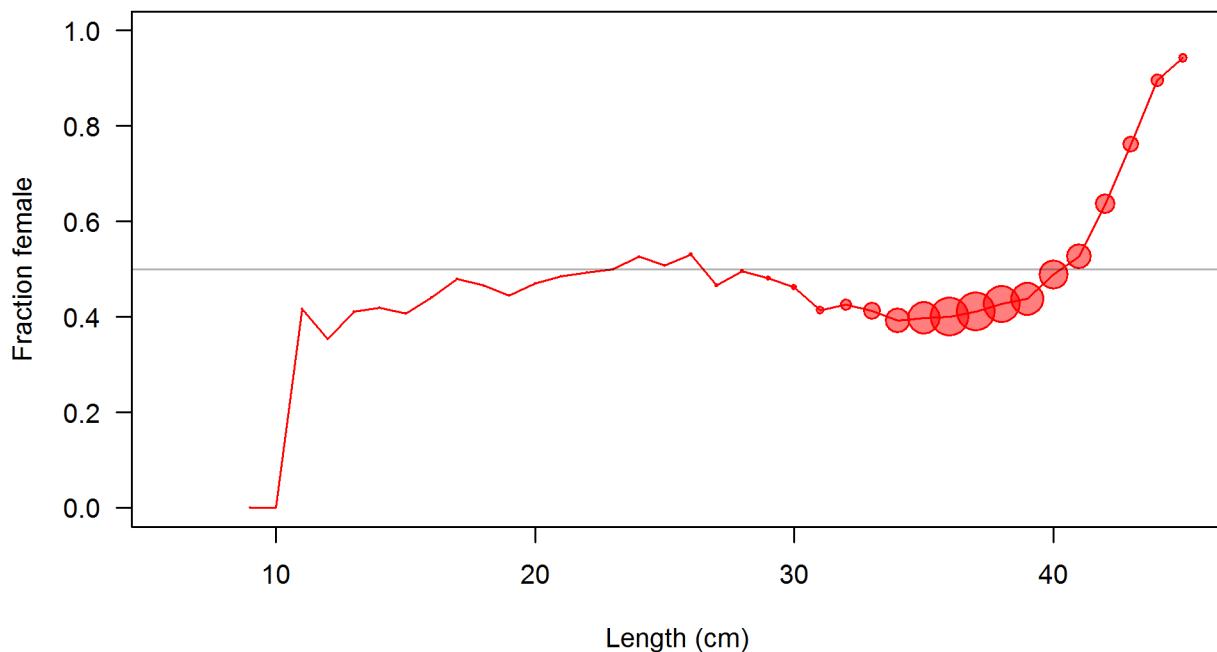


Figure 23: The estimated sex ratio of Pacific ocean perch at length from all biological data sources.

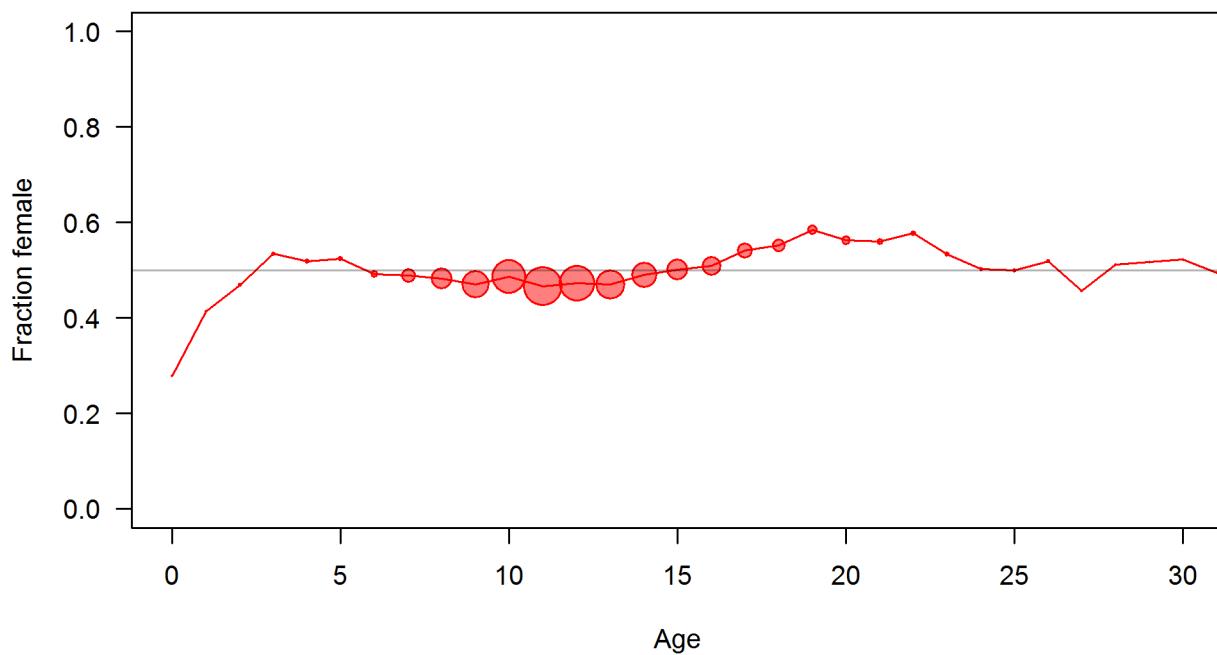


Figure 24: The estimated sex ratio of Pacific ocean perch at age from all biological data sources.

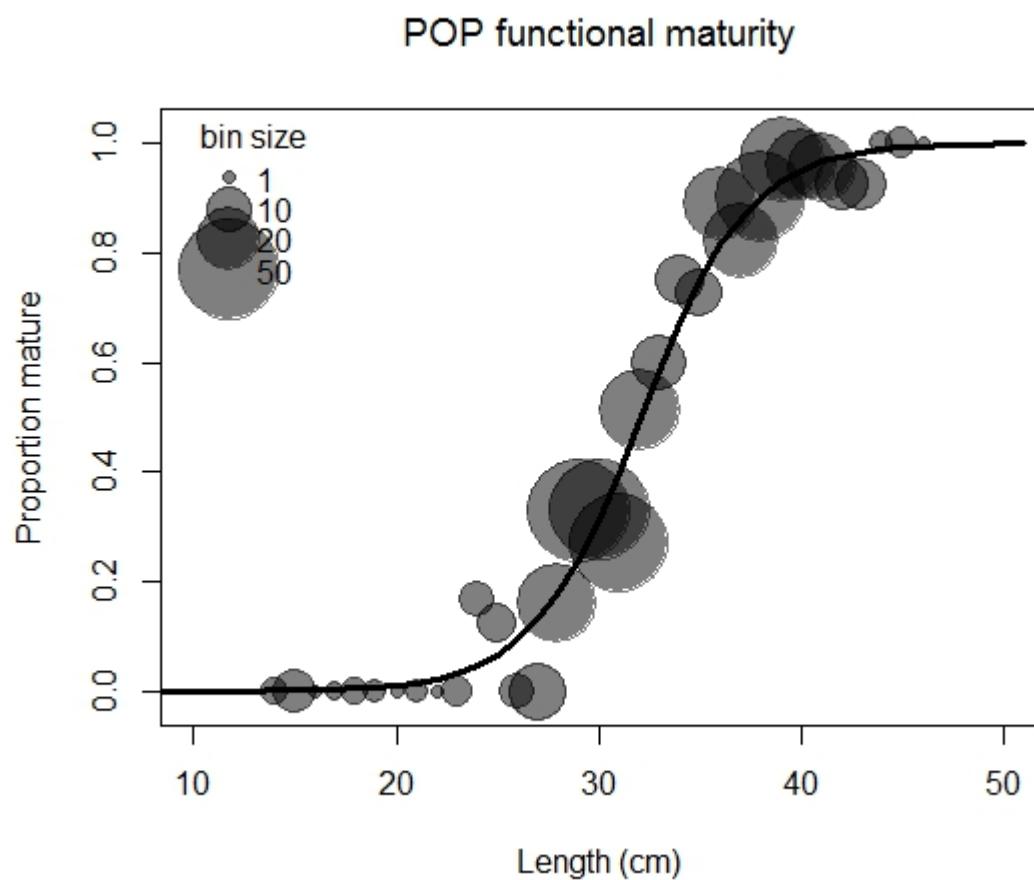
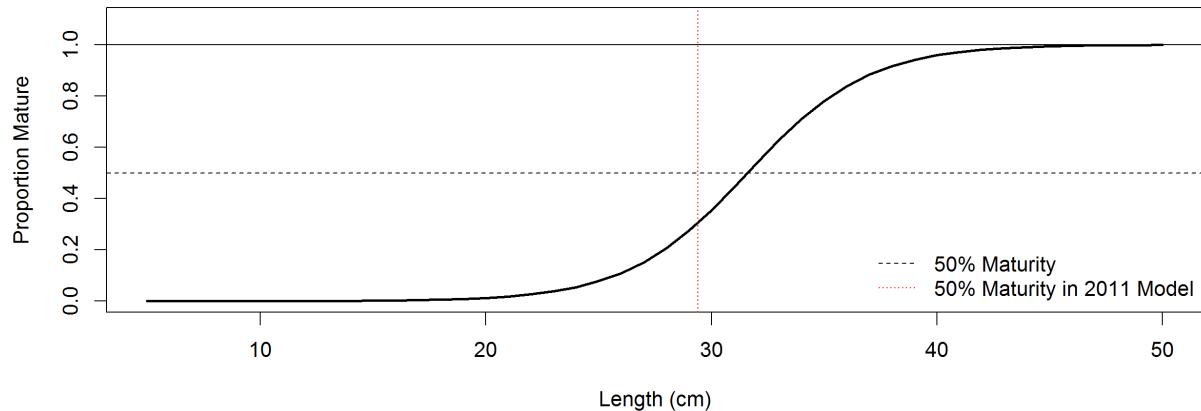


Figure 25: The estimated functional maturity of Pacific ocean perch at length.

Functional Maturity by Length (2017 Assessment)



Maturity by Age (2011 Assessment)

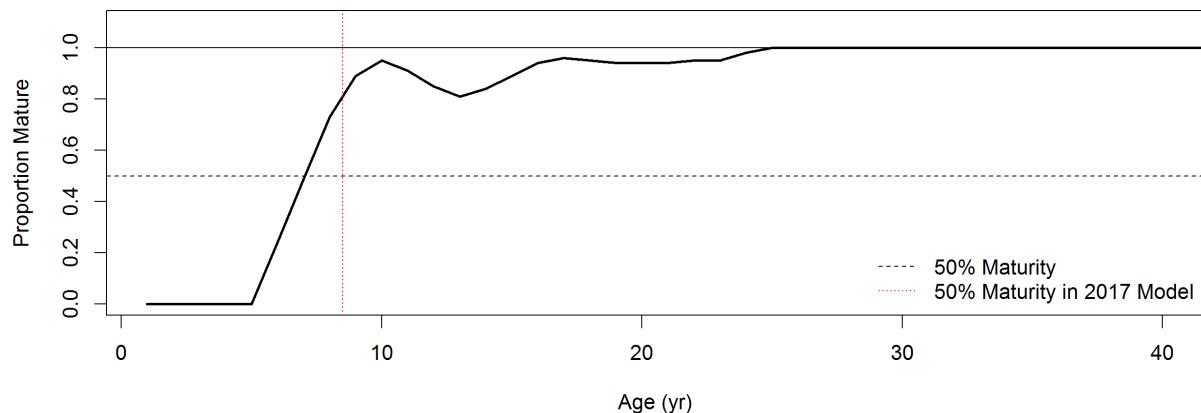


Figure 26: Comparison between estimated maturity-at-length used in this assessment and maturity-at-age applied in the 2011 assessment of Pacific ocean perch.

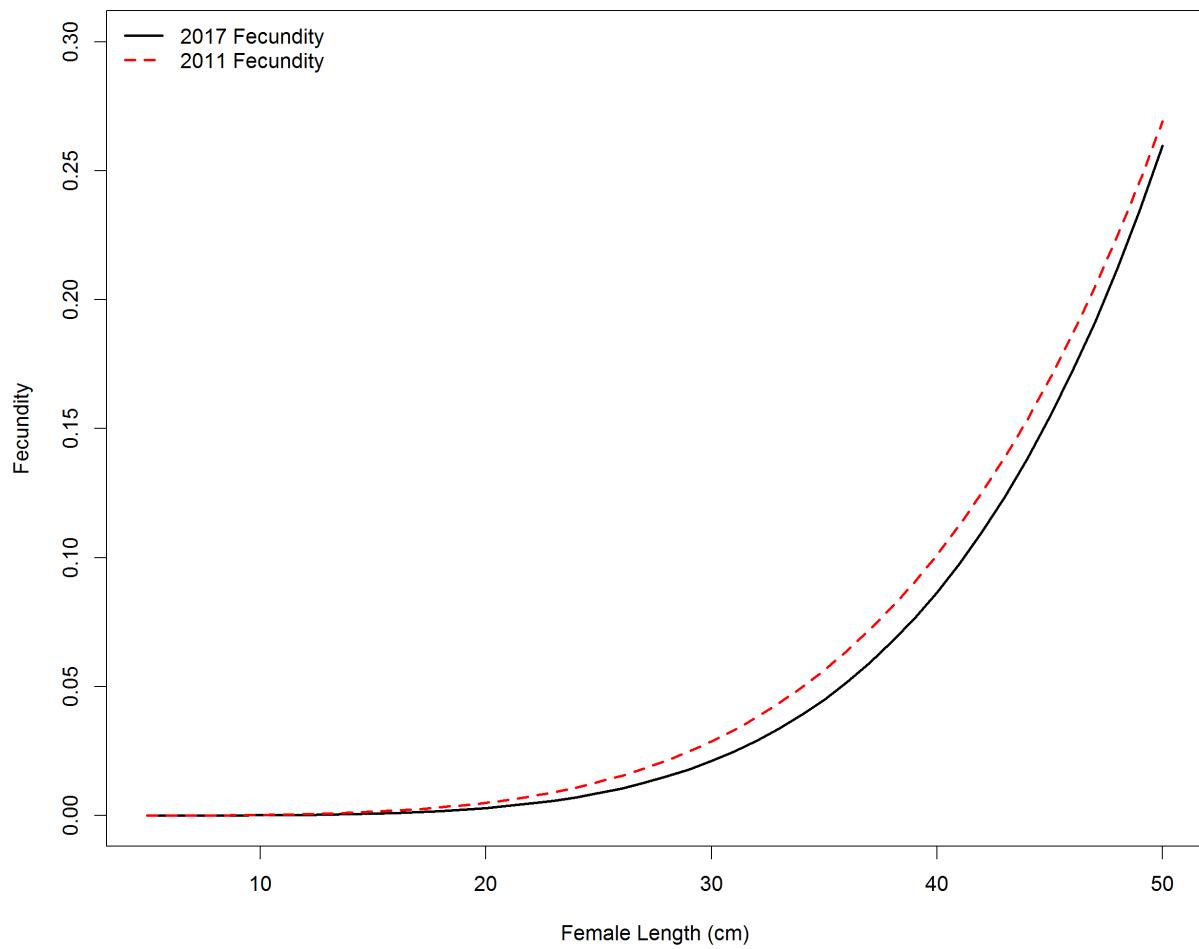


Figure 27: Fecundity at length of Pacific ocean perch in the base model and a comparison of the fecundity in the 2011 assessment.

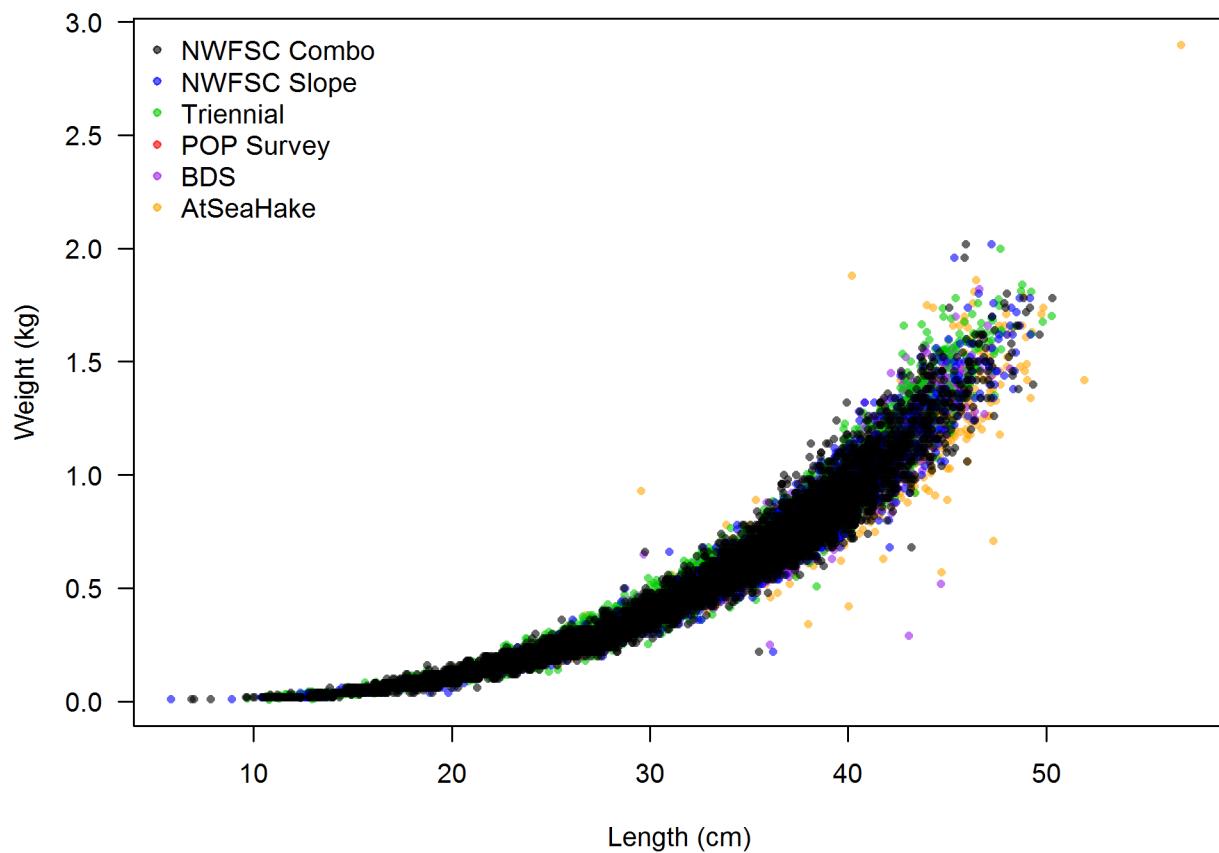


Figure 28: Weight-at-length for Pacific ocean perch from all data sources.

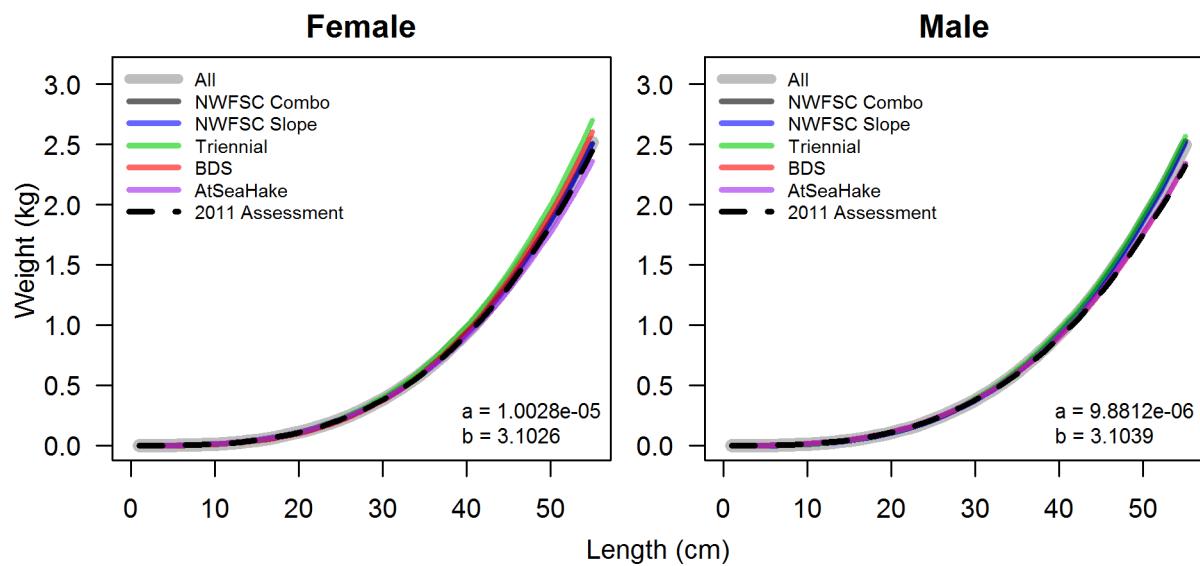


Figure 29: Estimated weight-at-length for Pacific ocean perch from all data sources.

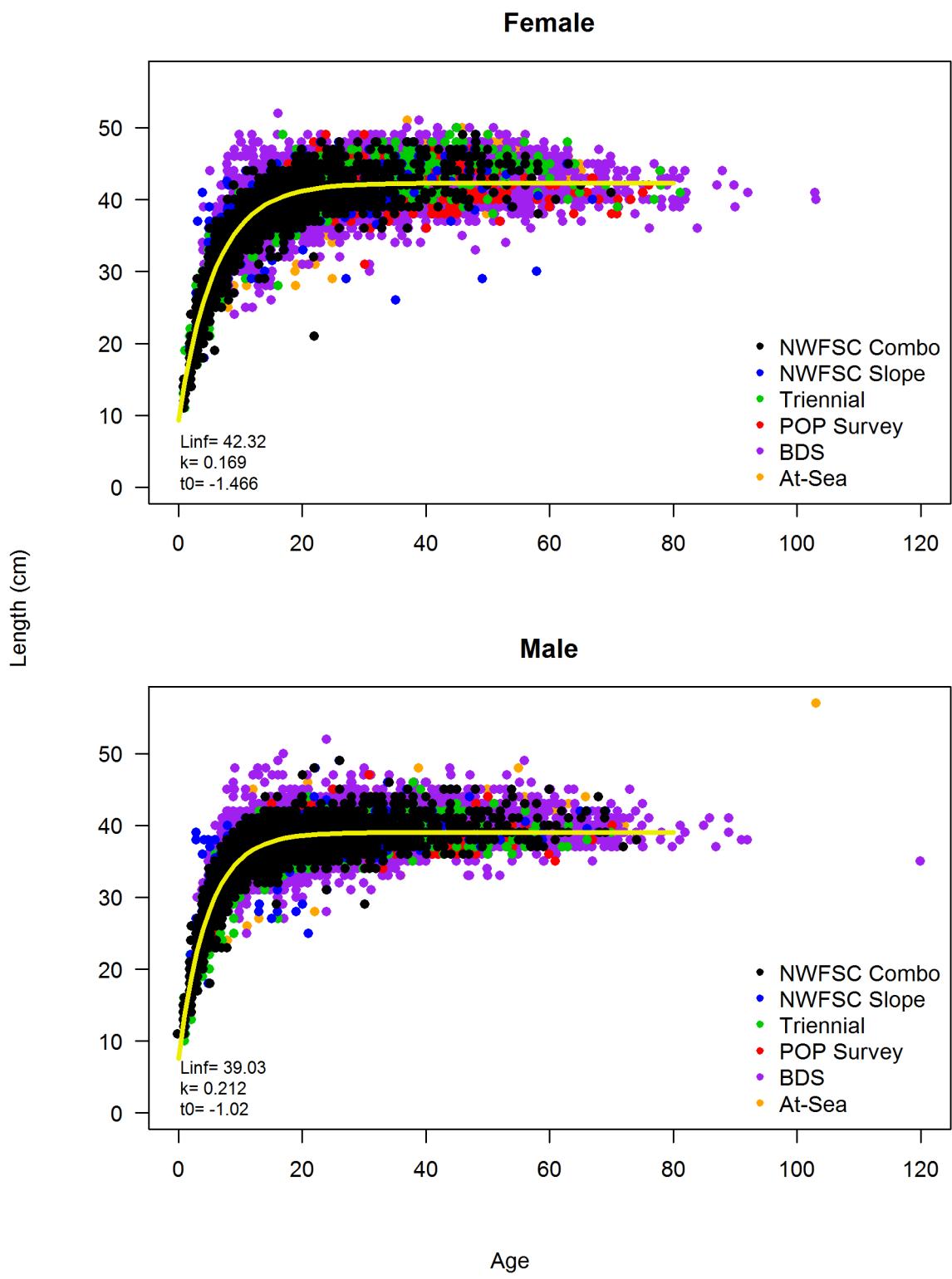


Figure 30: Estimated length-at-age for Pacific ocean perch from all data sources.

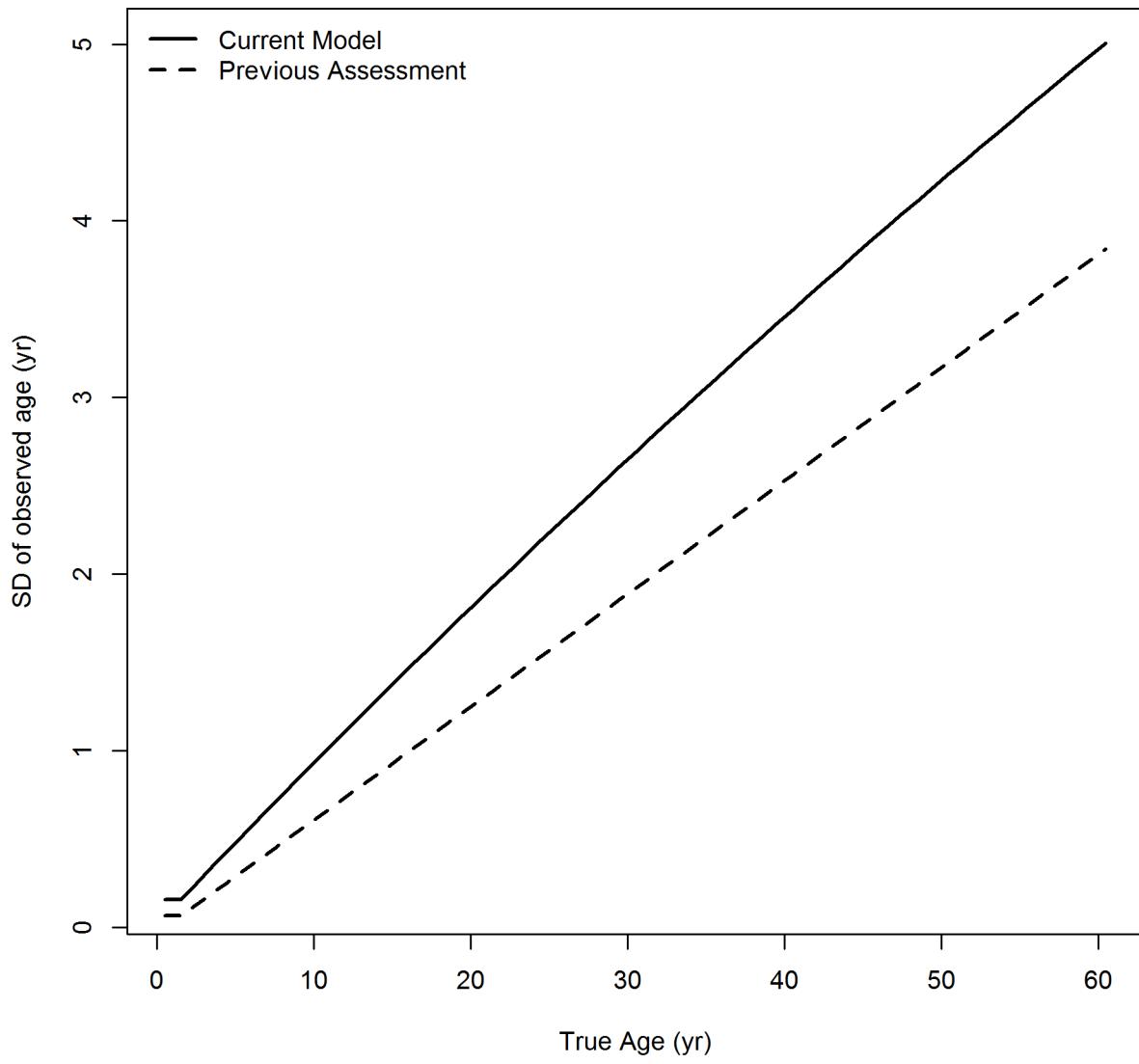


Figure 31: The estimated ageing error used in this assessment compared to the ageing error assumed in the previous assessment for Pacific ocean perch.

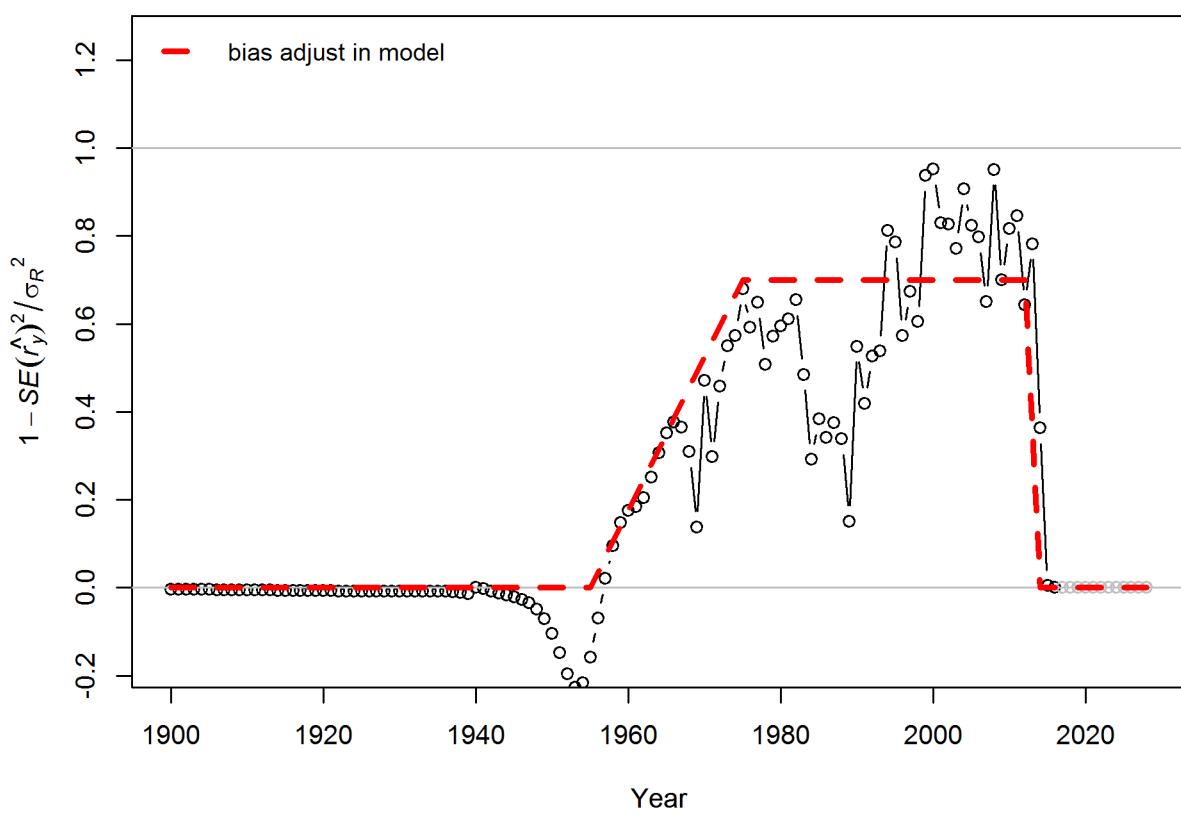


Figure 32: Recruitment bias ramp applied in the base model.

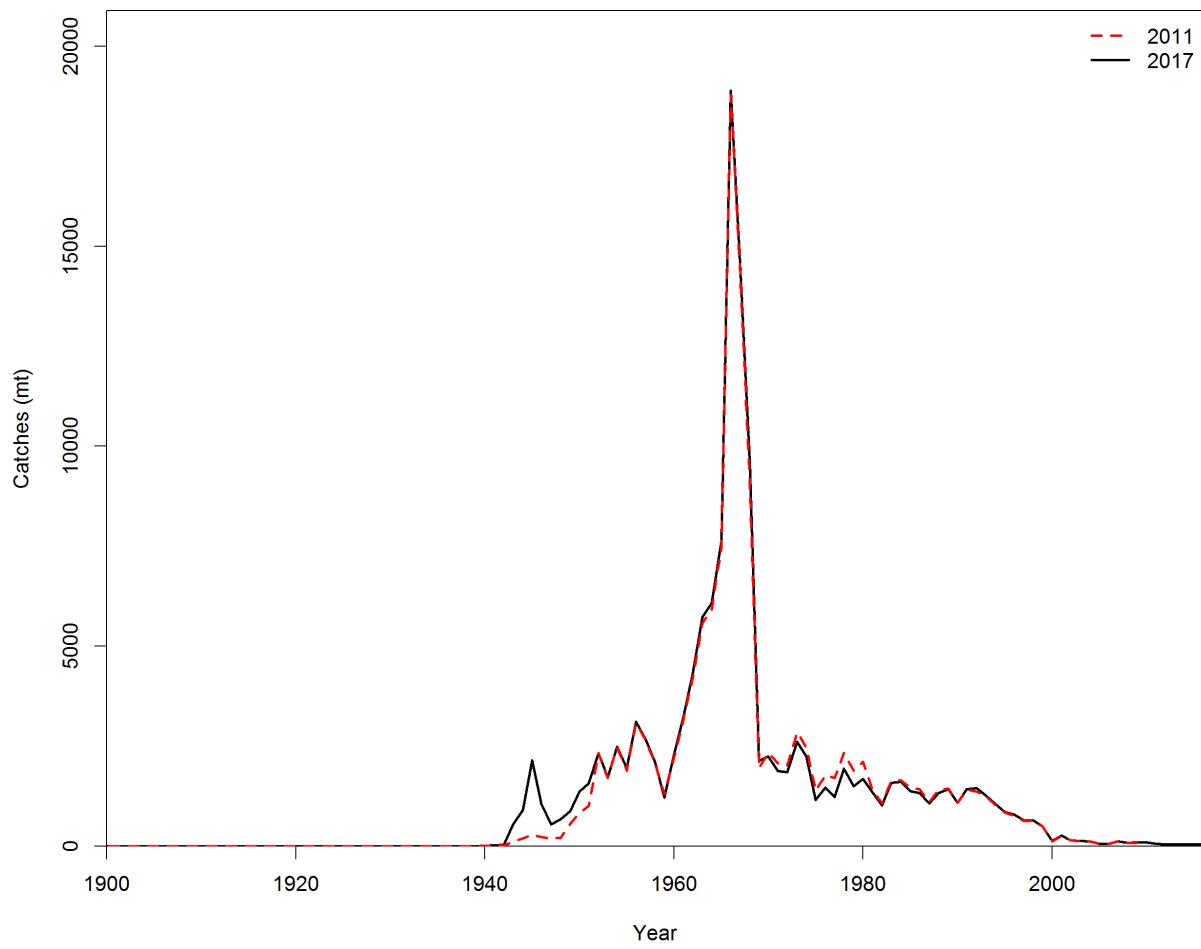


Figure 33: Comparison of the catches assumed by this assessment and the previous assessment for Pacific ocean perch.

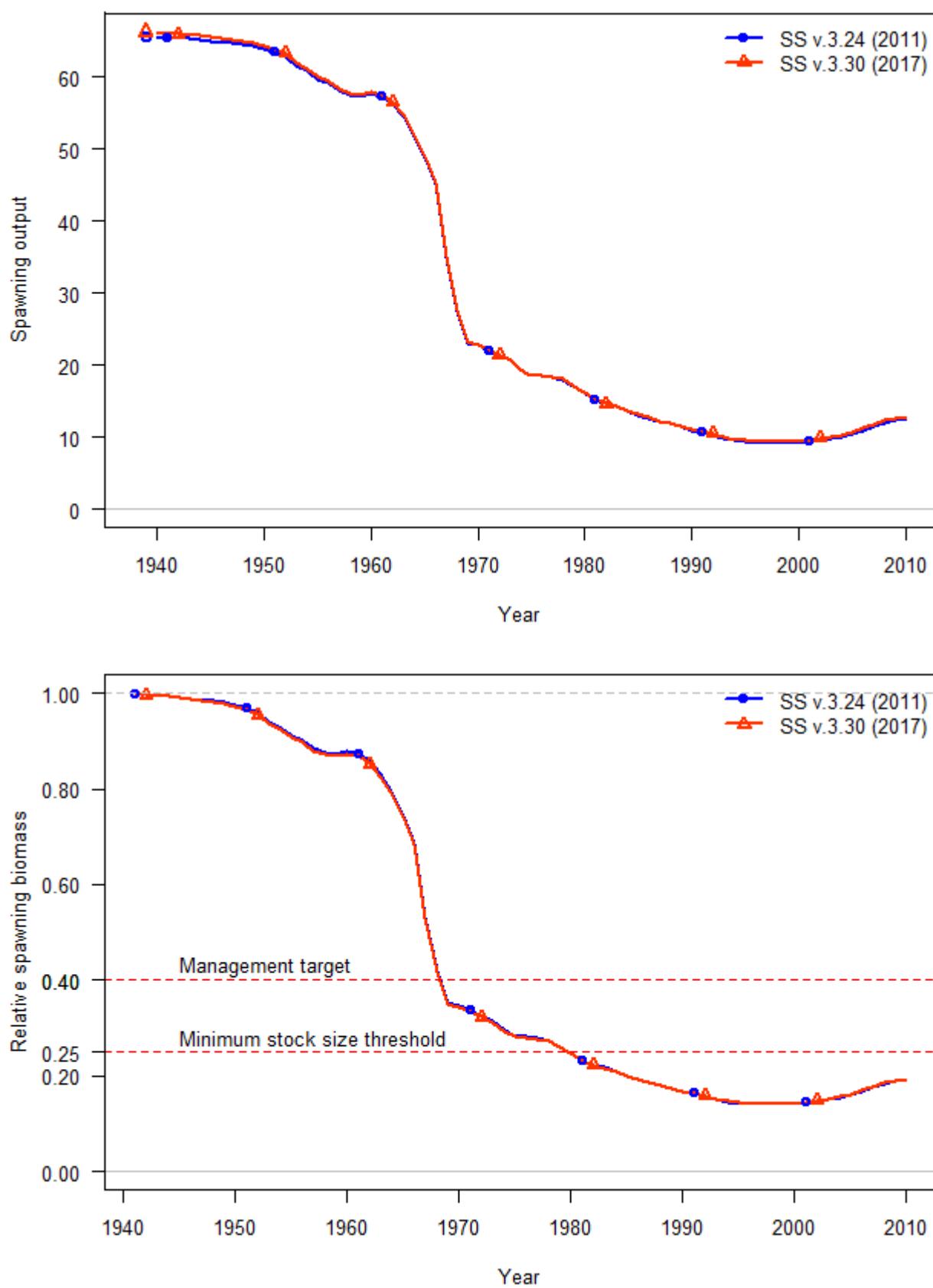


Figure 34: Comparison of model bridging estimates from Stock Synthesis version 3.30 and 3.24 for Pacific ocean perch for the 2011 assessment.
98

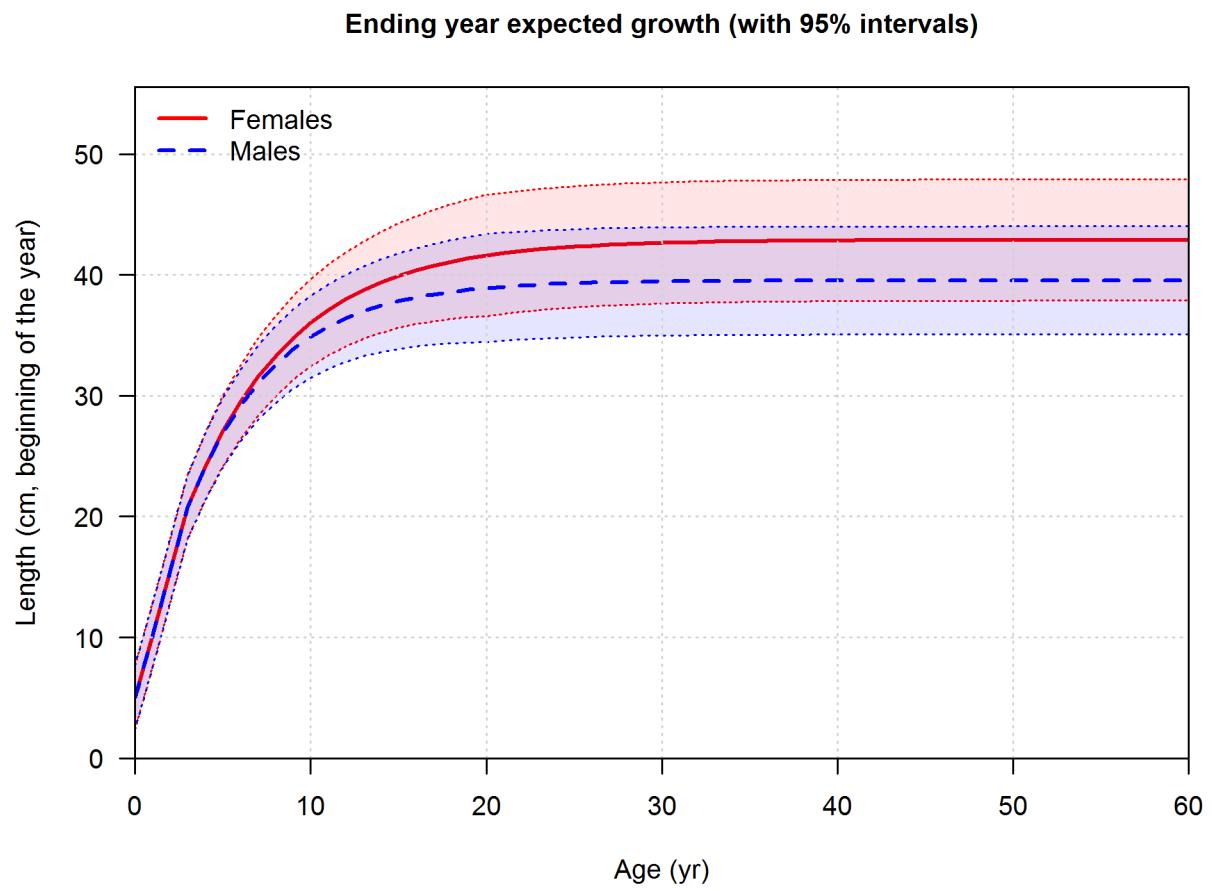


Figure 35: Estimated length-at-age for male and female for Pacific ocean perch with estimated CV.

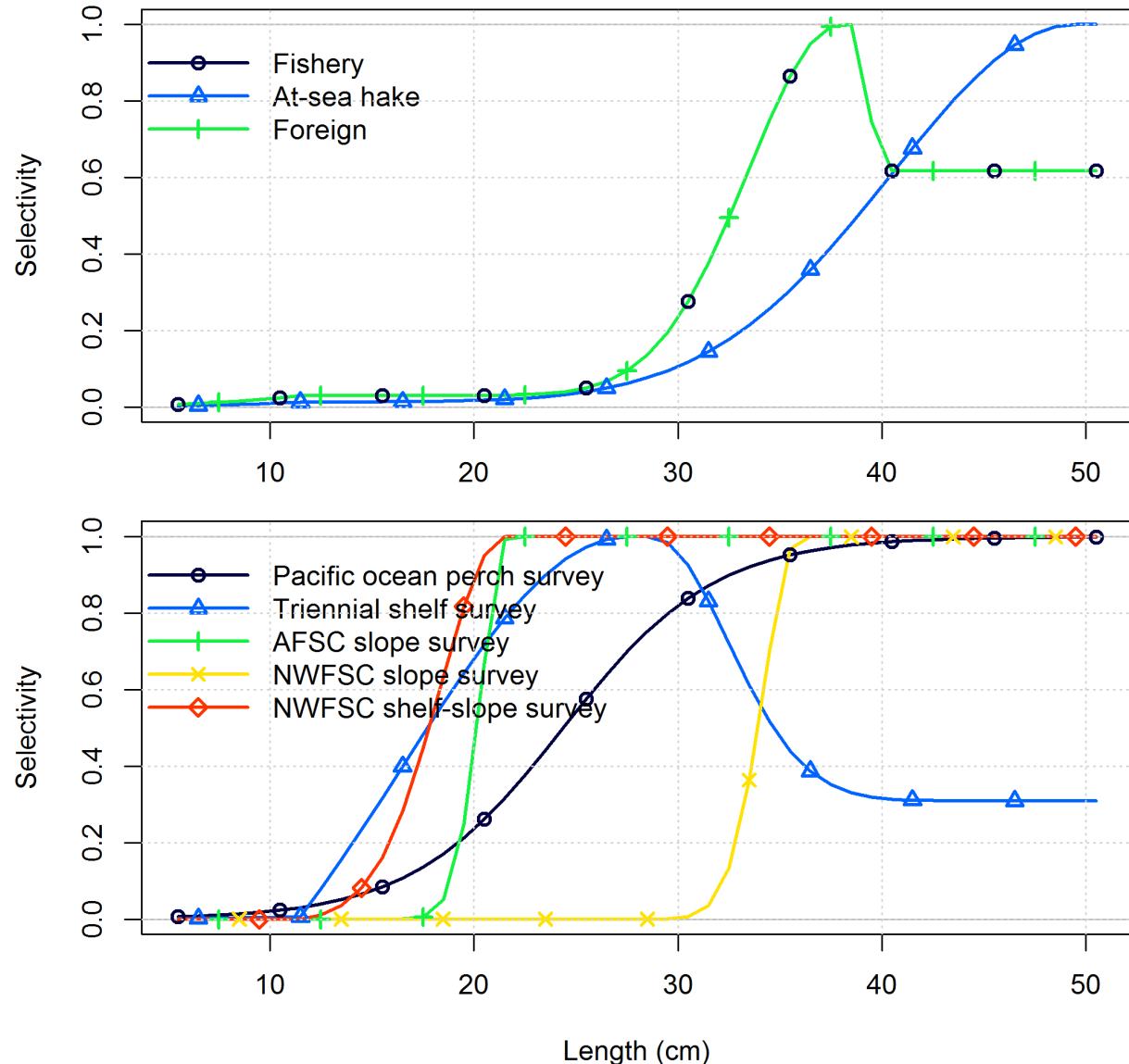


Figure 36: Estimated selectivity by length by each fishery and survey for Pacific ocean perch.

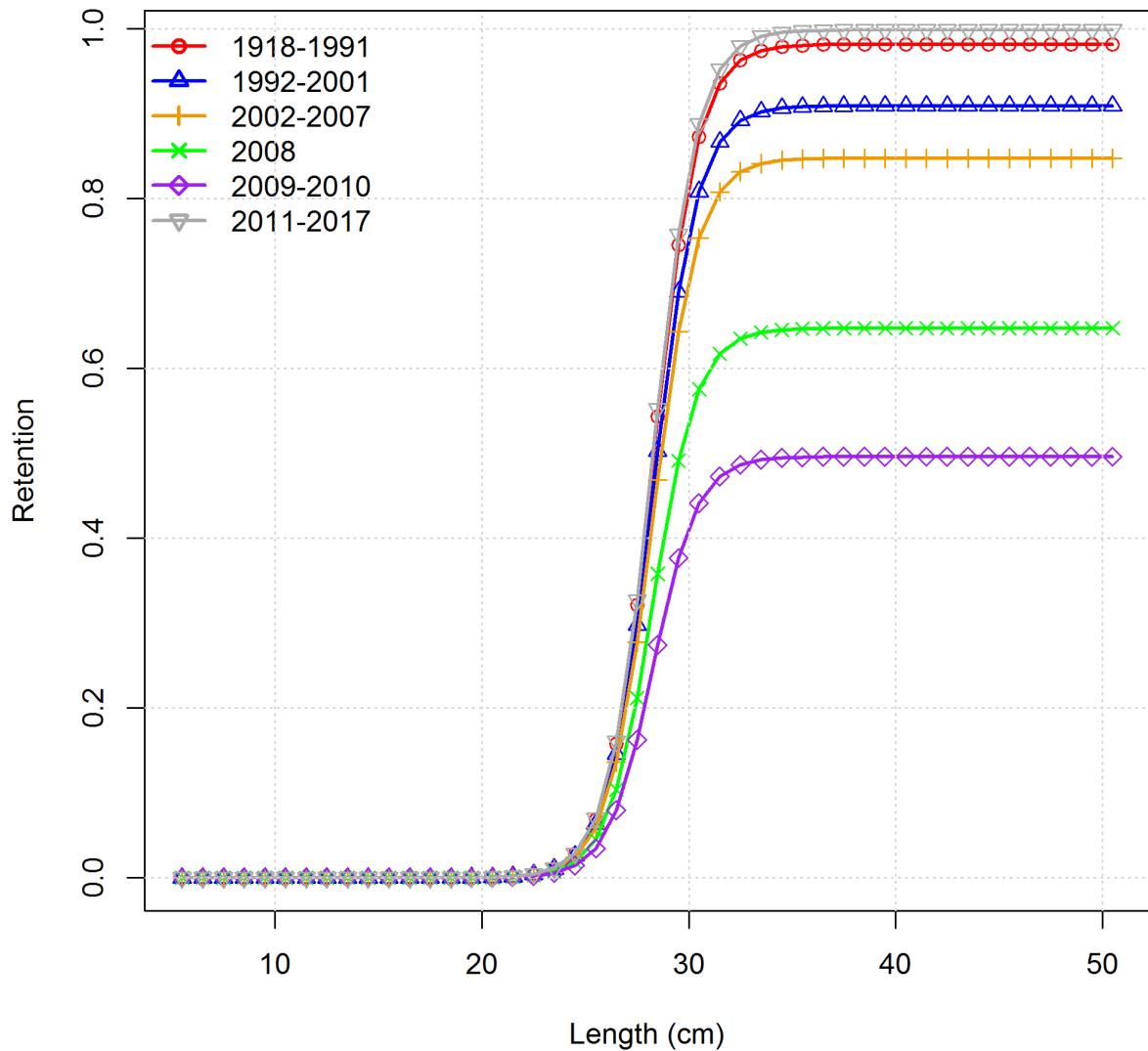


Figure 37: Estimated retention by length by the fishery fleet for Pacific ocean perch.

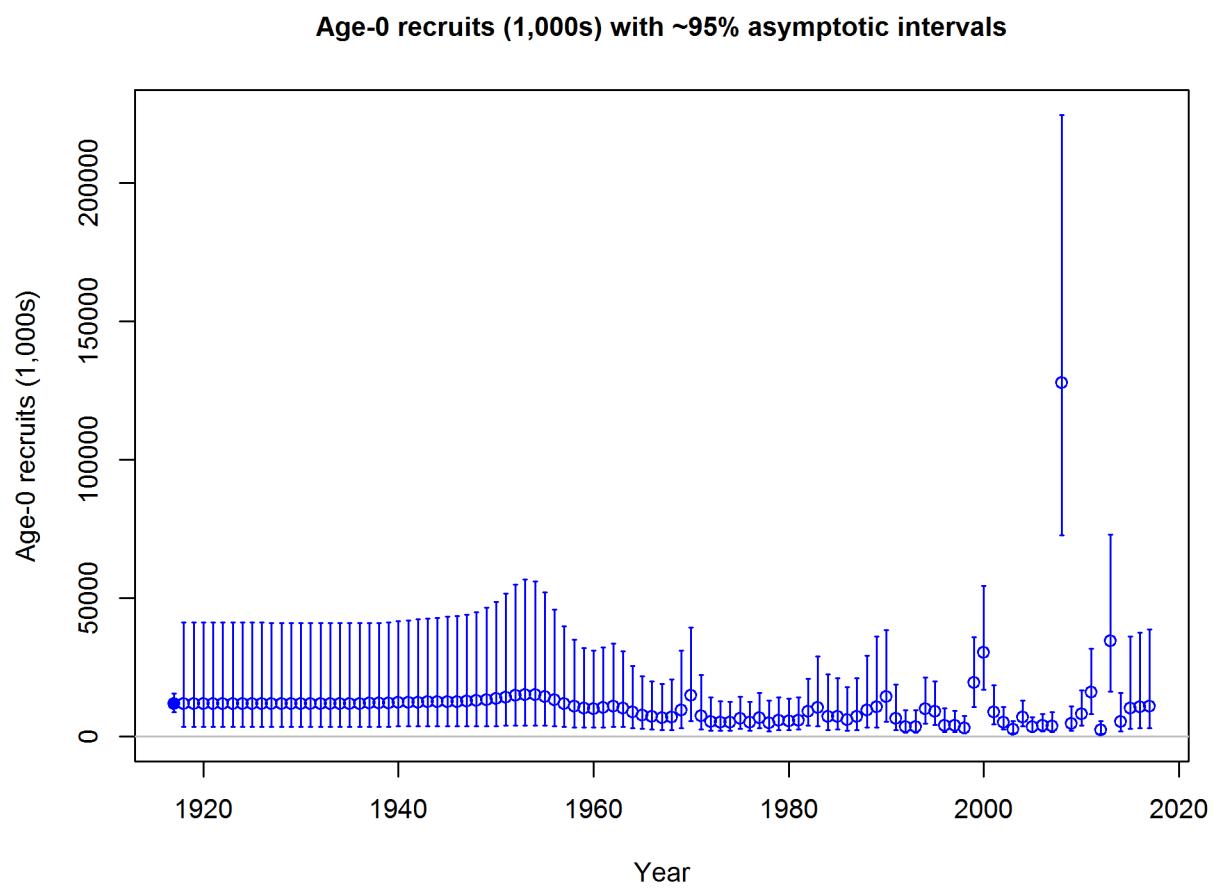


Figure 38: Estimated time-series of recruitment for Pacific ocean perch.

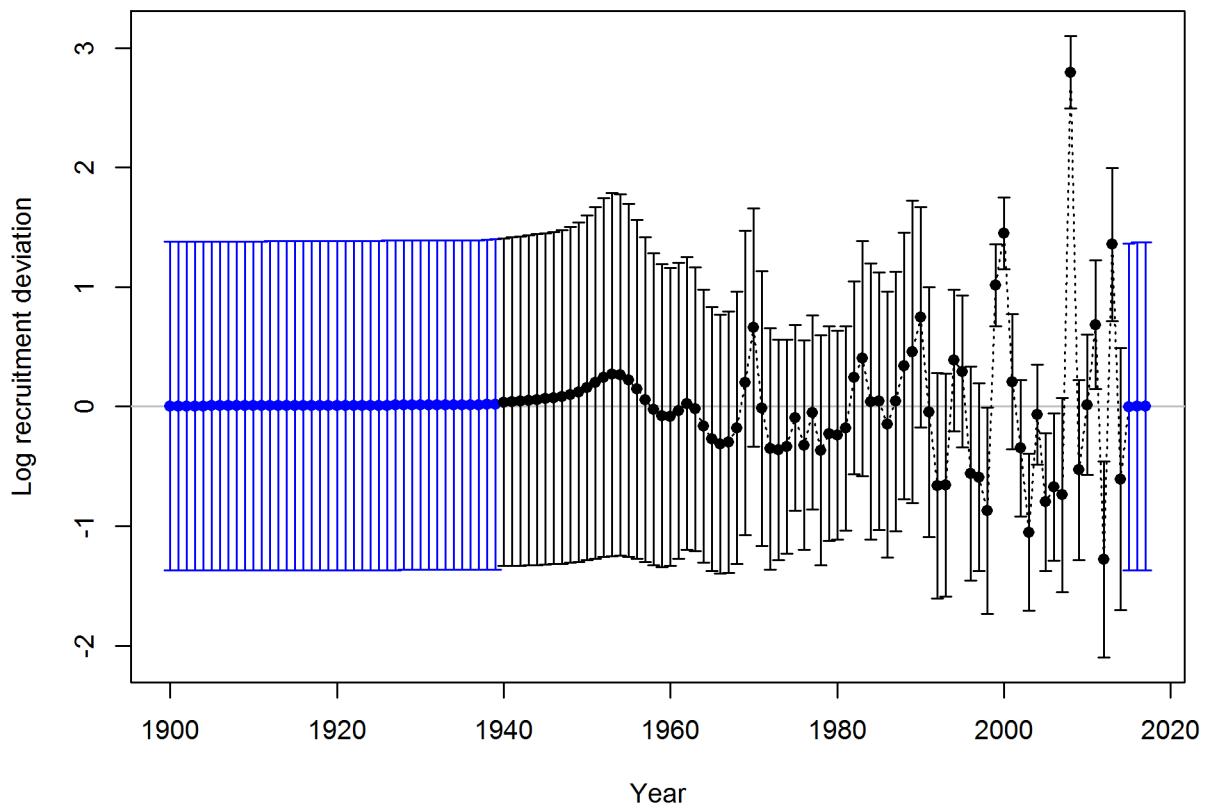


Figure 39: Estimated time-series of recruitment deviations for Pacific ocean perch.

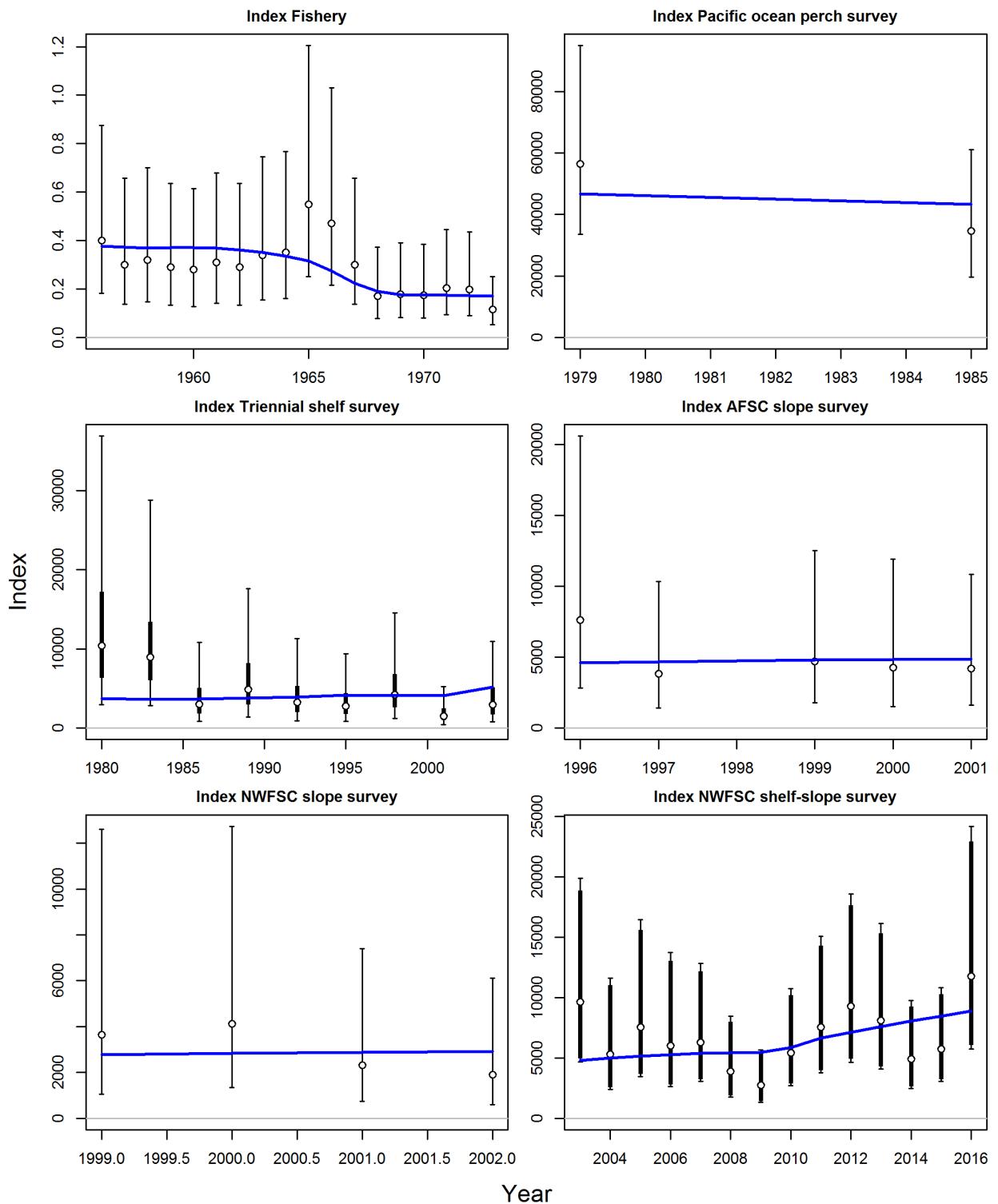


Figure 40: Estimated fits to the CPUE and survey indices for Pacific ocean perch.

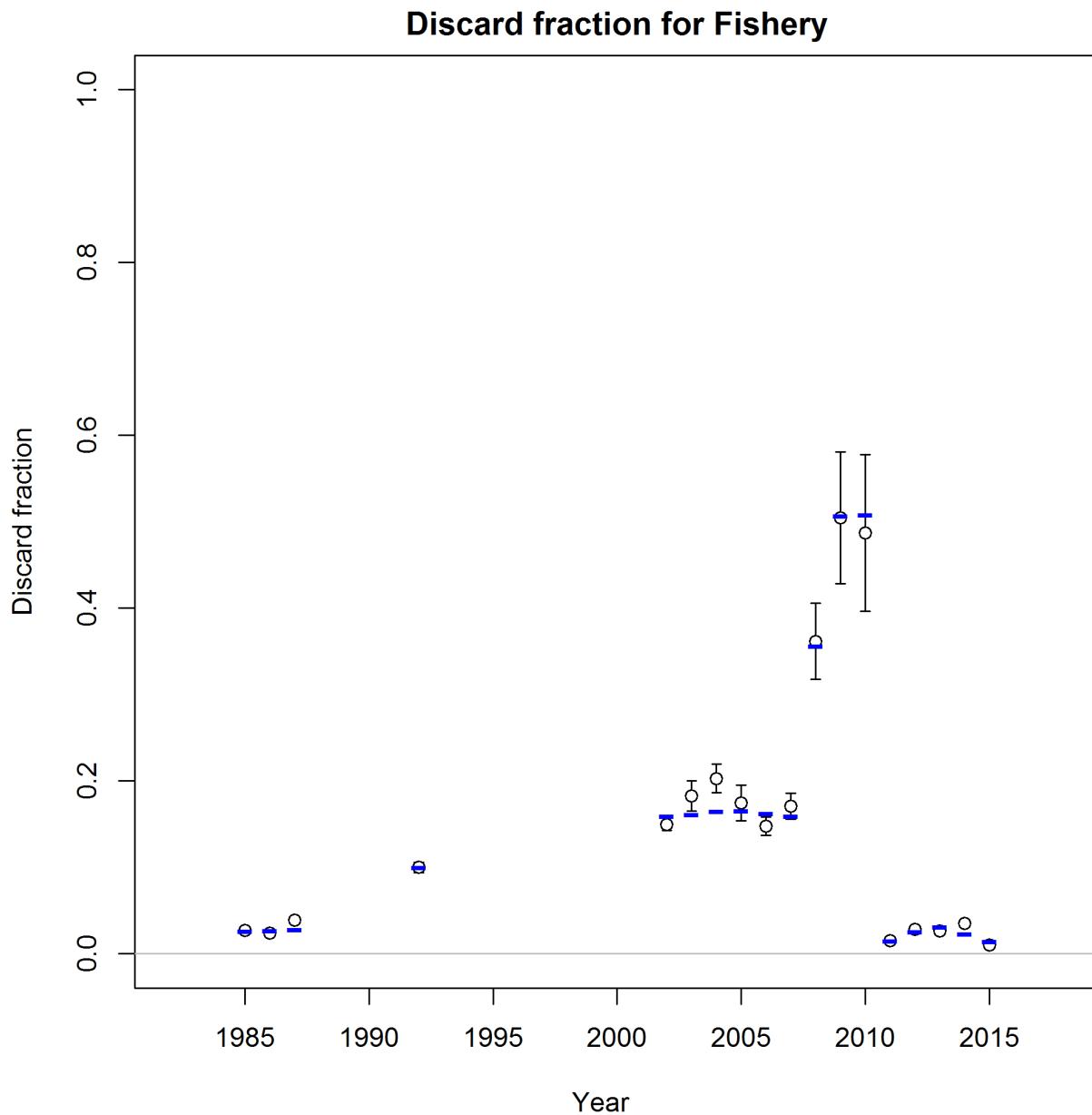


Figure 41: Estimated fits to the discard rates for Pacific ocean perch.

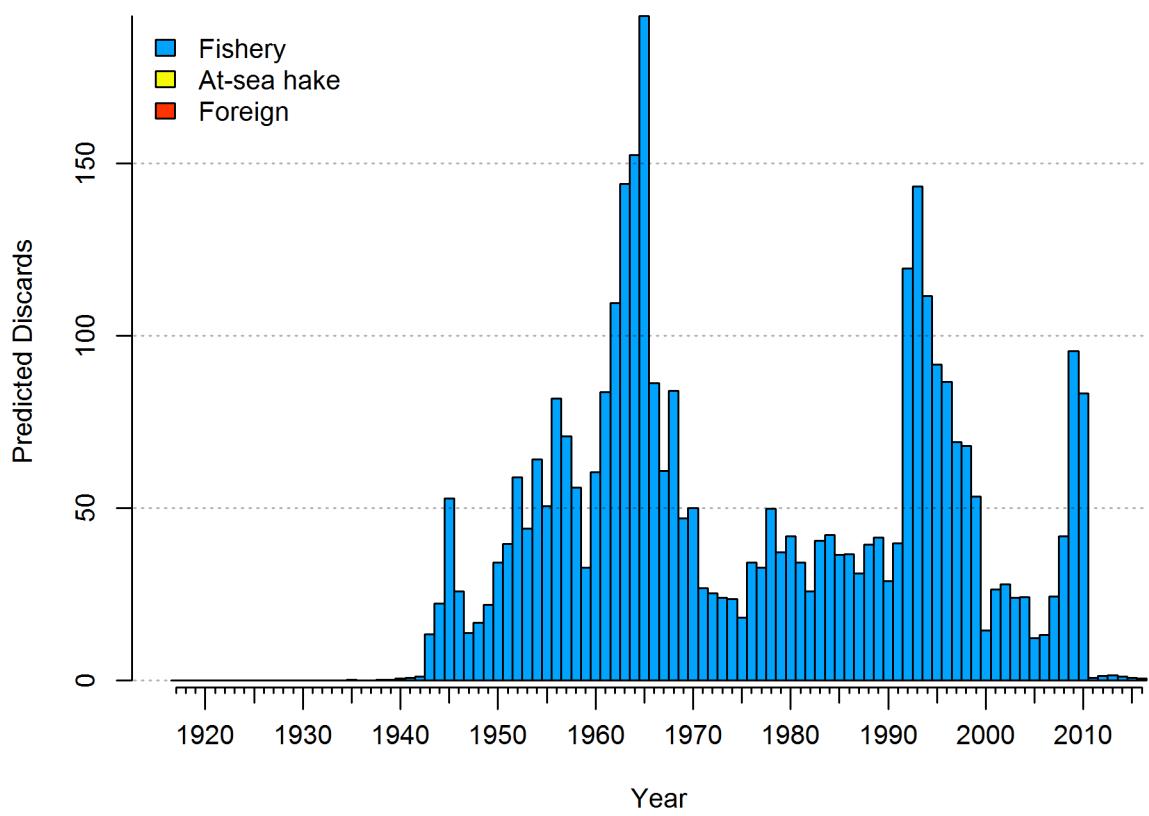


Figure 42: Estimated total discards for Pacific ocean perch.

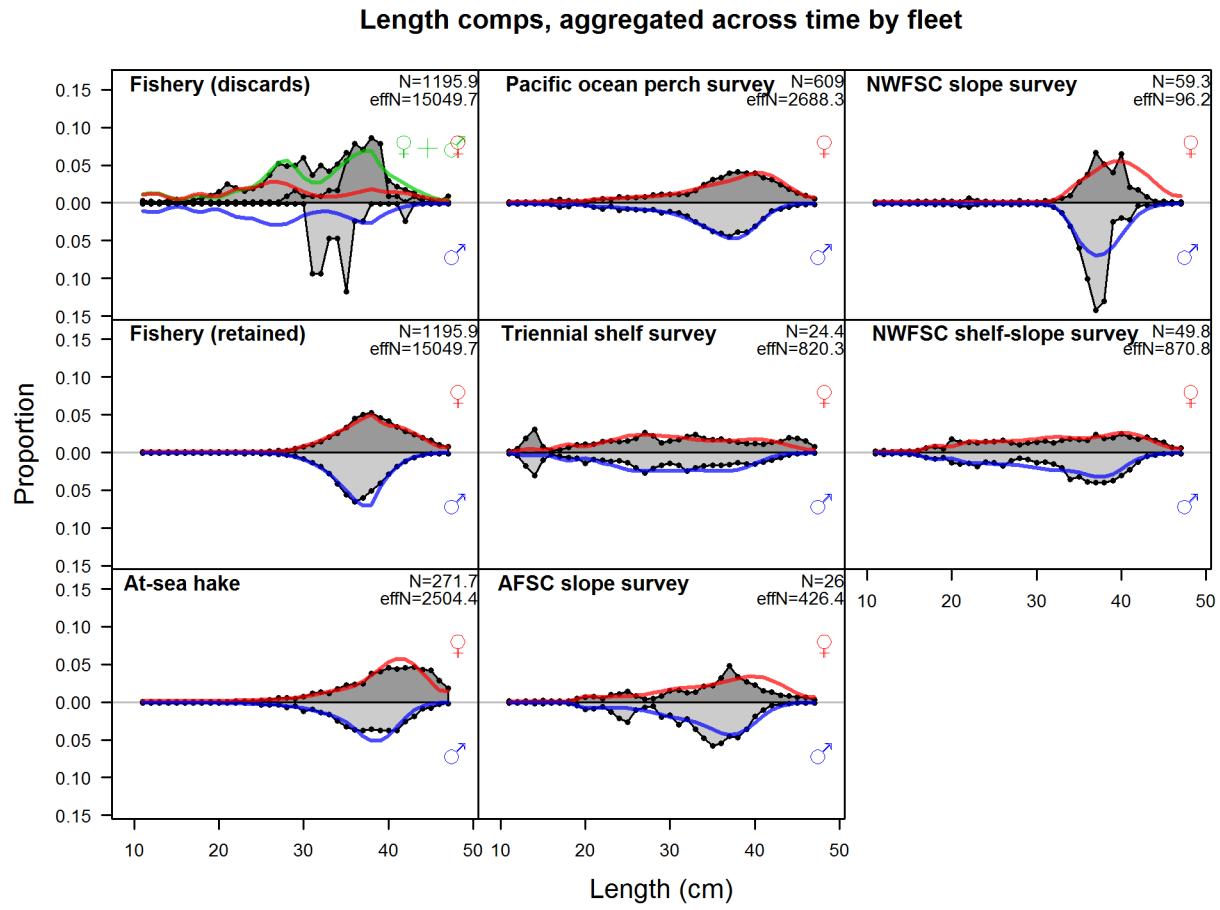


Figure 43: Length compositions aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate retained or discarded samples for each fleet. Panels without this designation represent the whole catch.

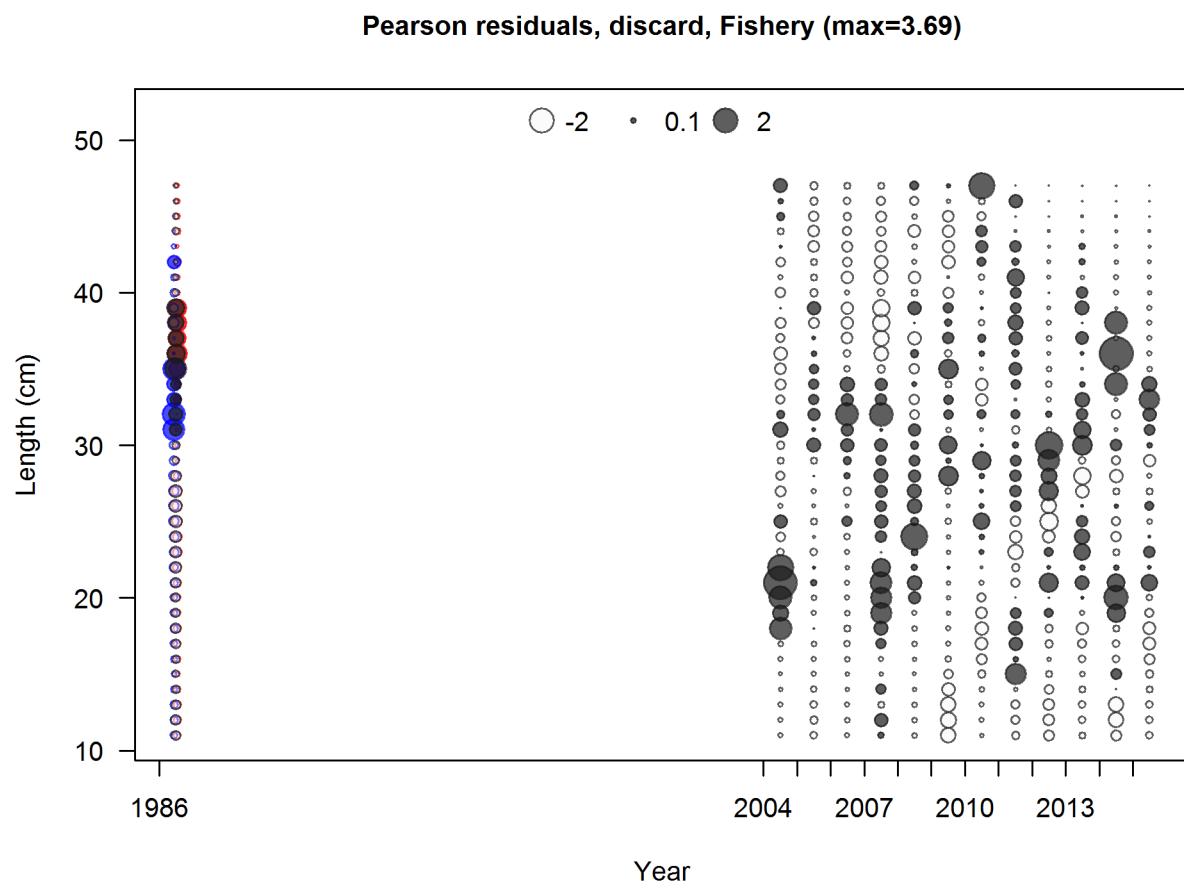


Figure 44: Pearson residuals, discard, Fishery (max=3.69)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

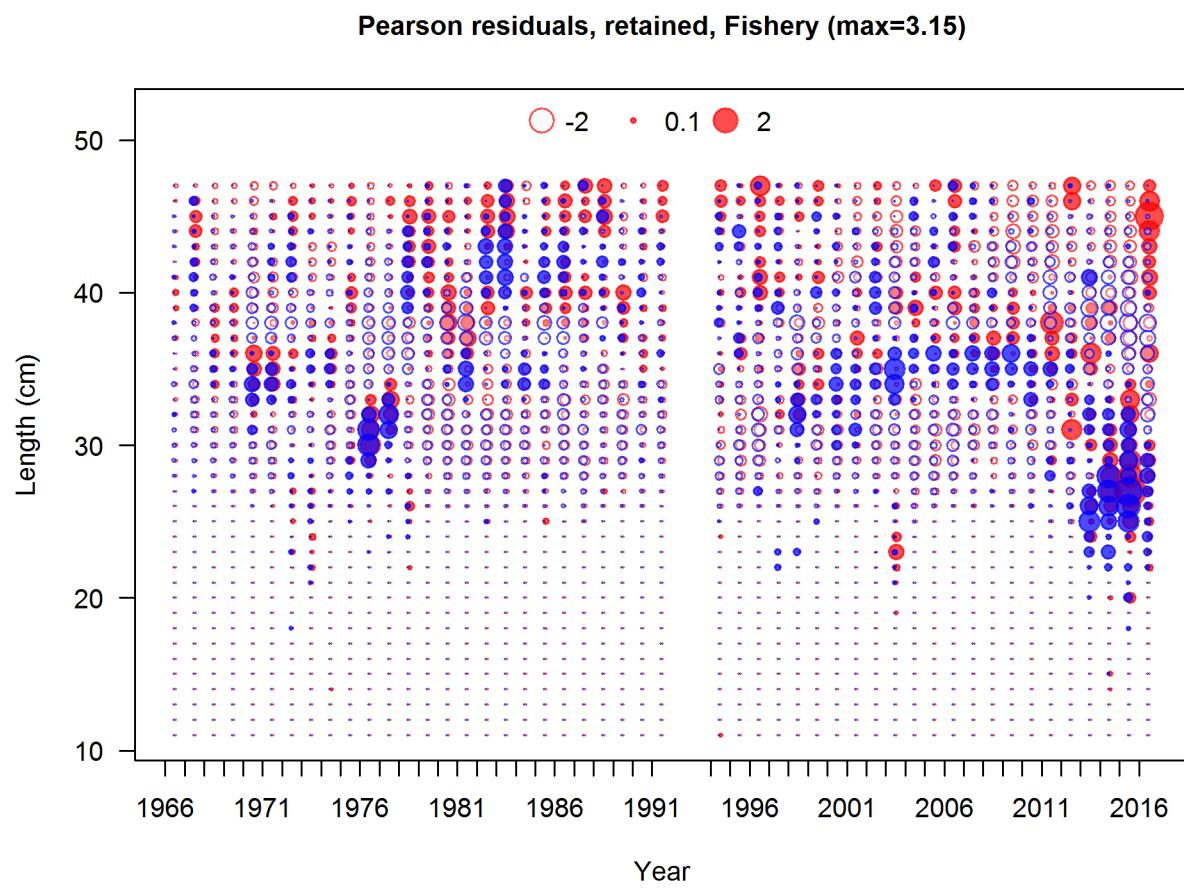


Figure 45: Pearson residuals, retained, Fishery (max=3.15) (plot 4 of 4)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

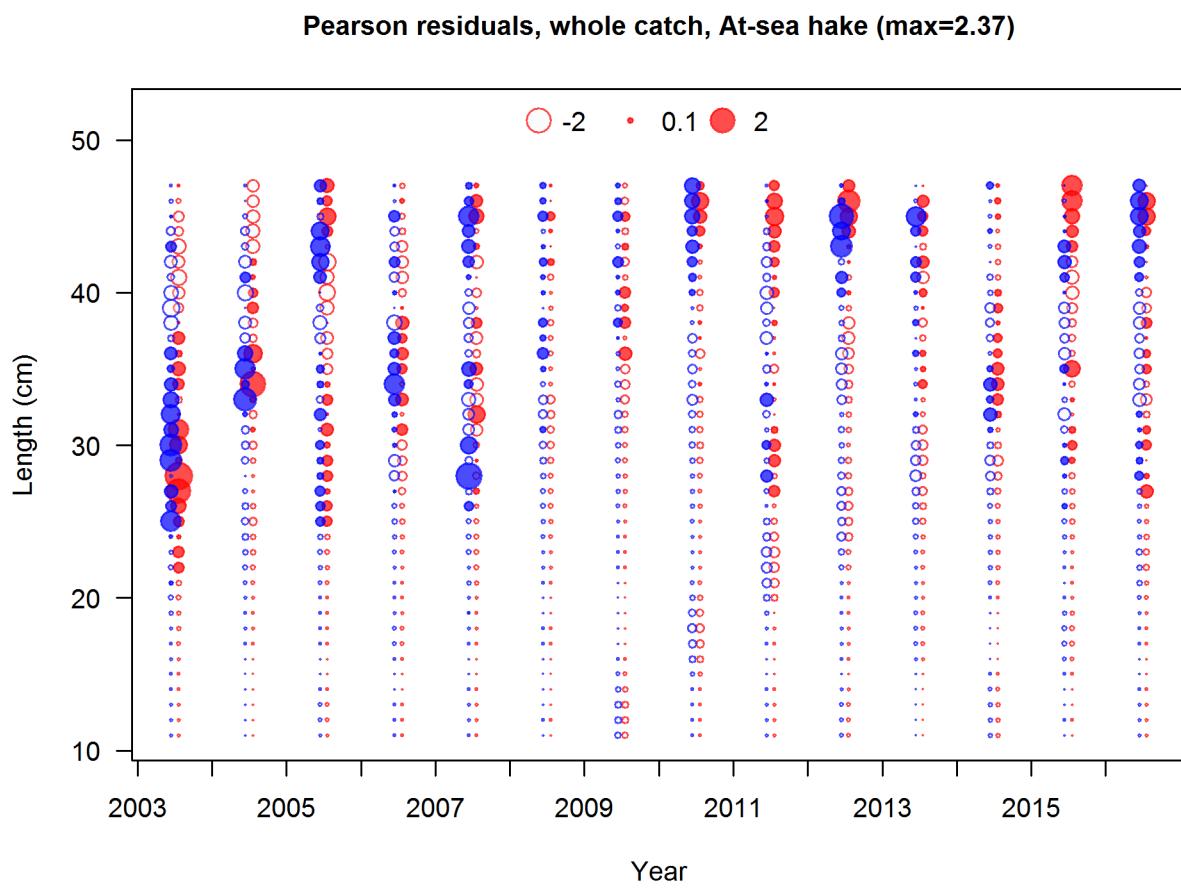


Figure 46: Pearson residuals, whole catch, At_sea hake (max=2.37)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

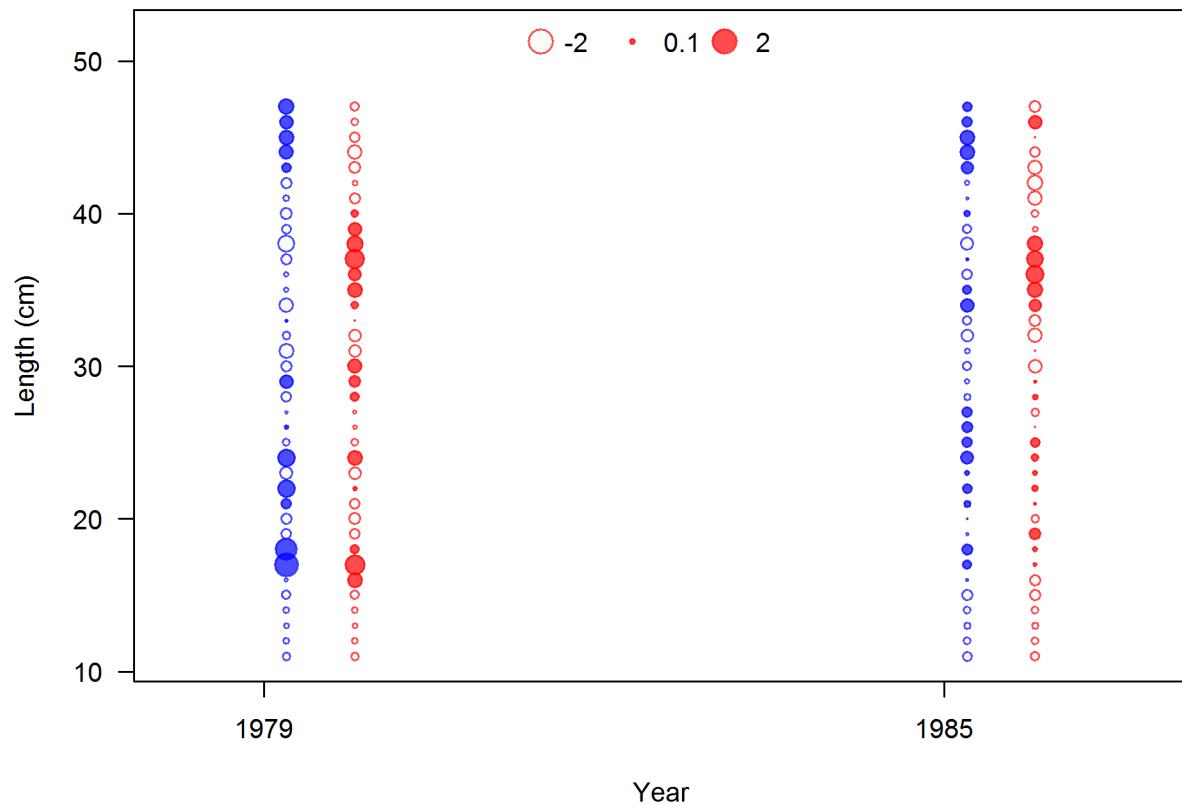


Figure 47: Pearson residuals, whole catch, Pacific ocean perch survey (max=1.76)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

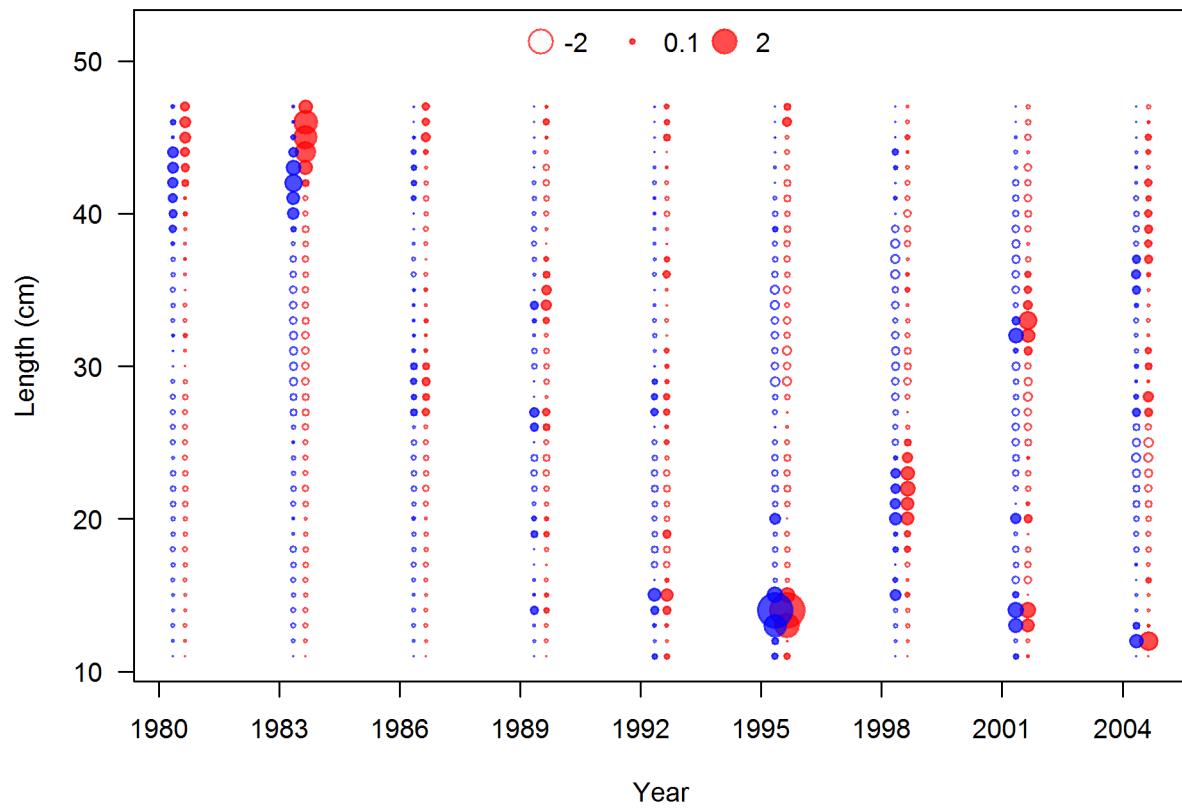


Figure 48: Pearson residuals, whole catch, Triennial shelf survey (max=4.01)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

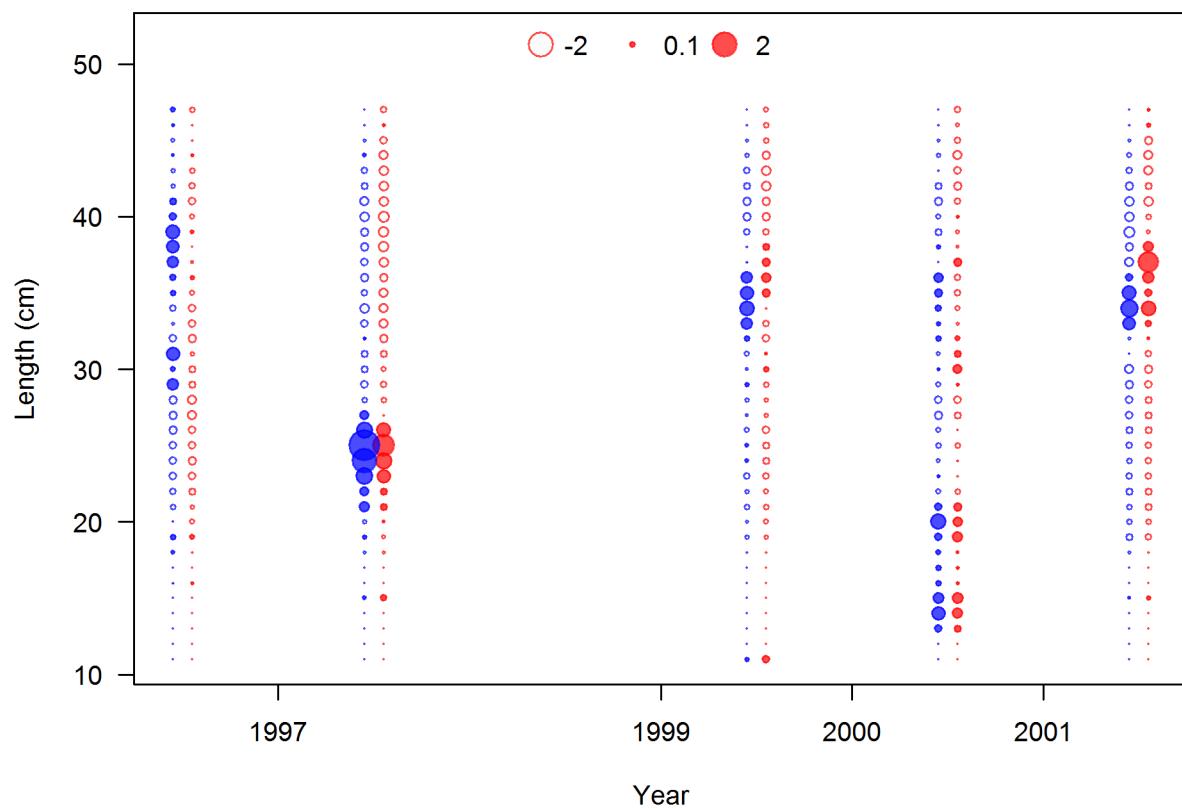


Figure 49: Pearson residuals, whole catch, AFSC slope survey (max=2.95)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

Pearson residuals, whole catch, NWFSC slope survey (max=3.47)

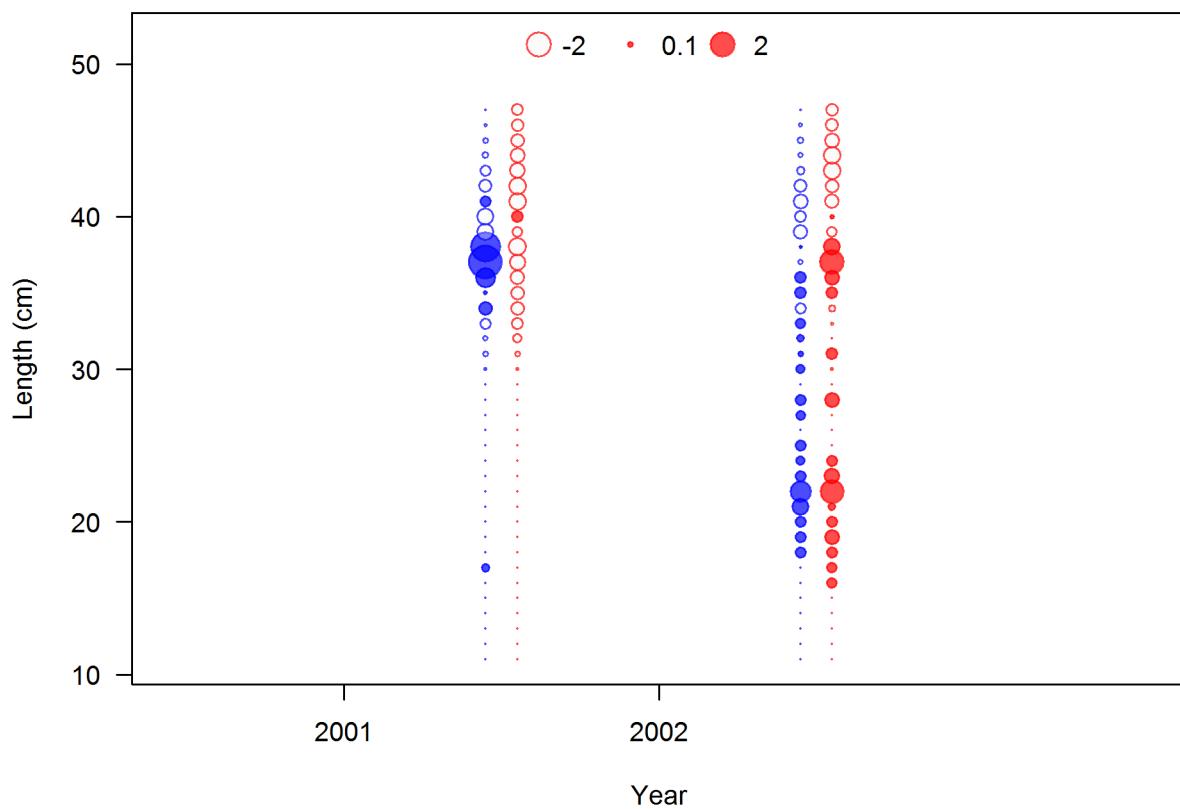


Figure 50: Pearson residuals, whole catch, NWFSC slope survey (max=3.47)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

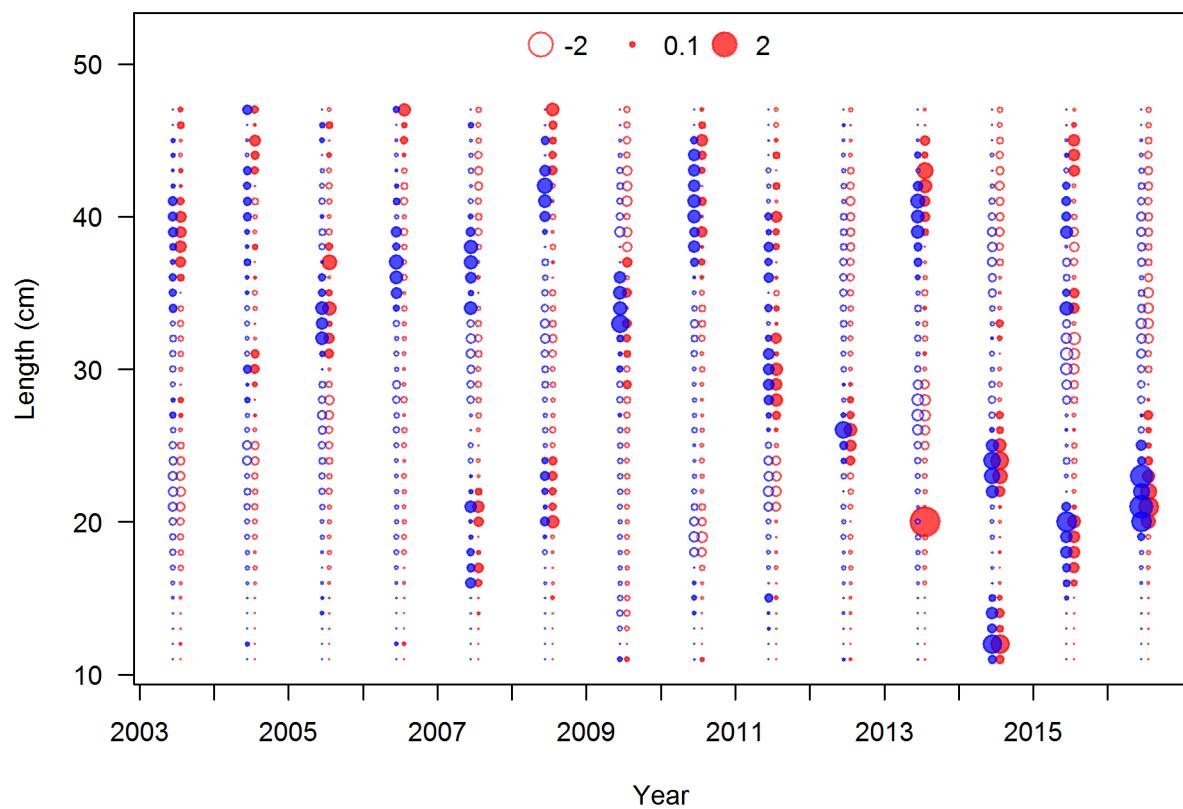


Figure 51: Pearson residuals, whole catch, NWFSC shelf_slope survey (max=2.82)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

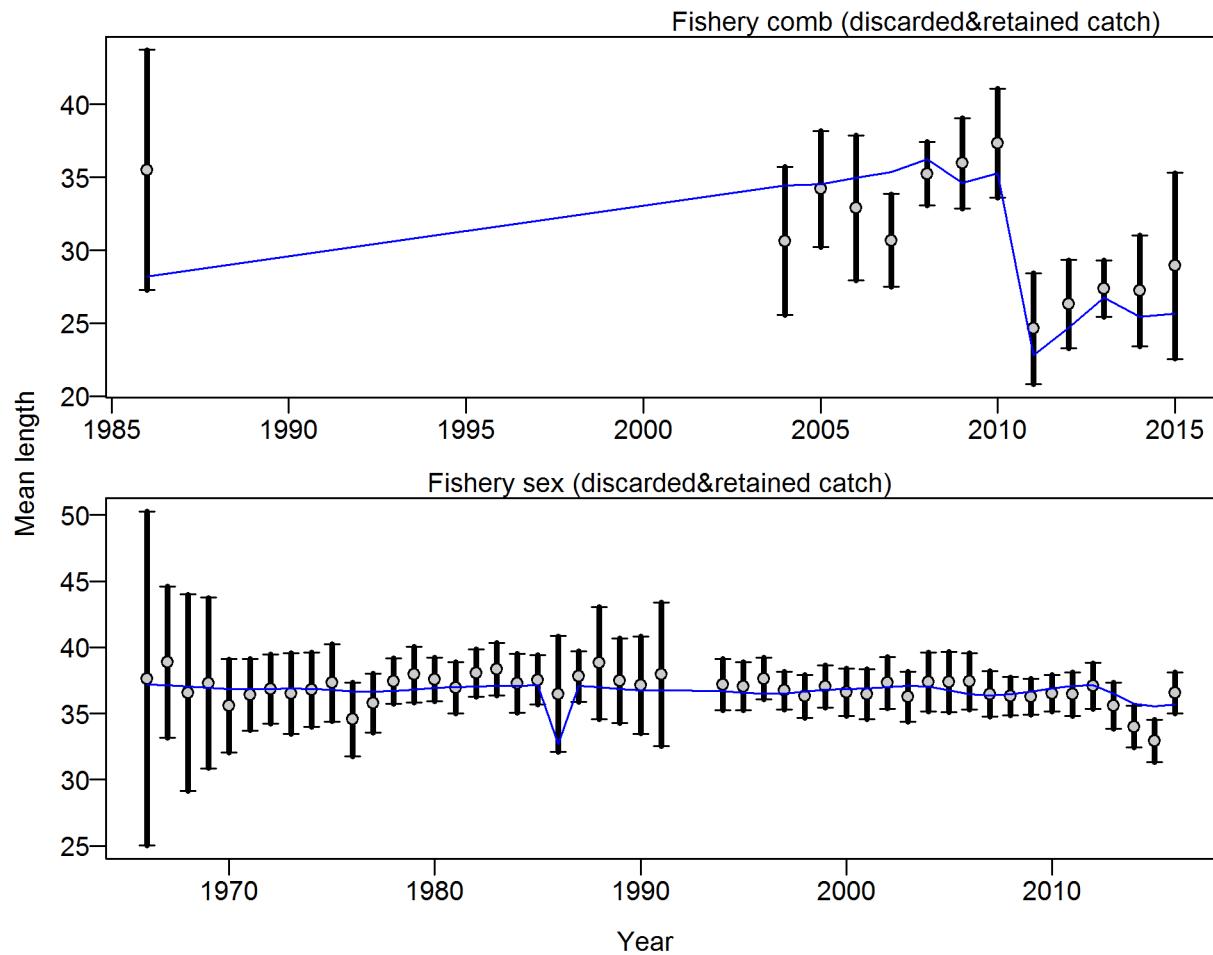


Figure 52: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.9967 (0.6542_1.8245) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

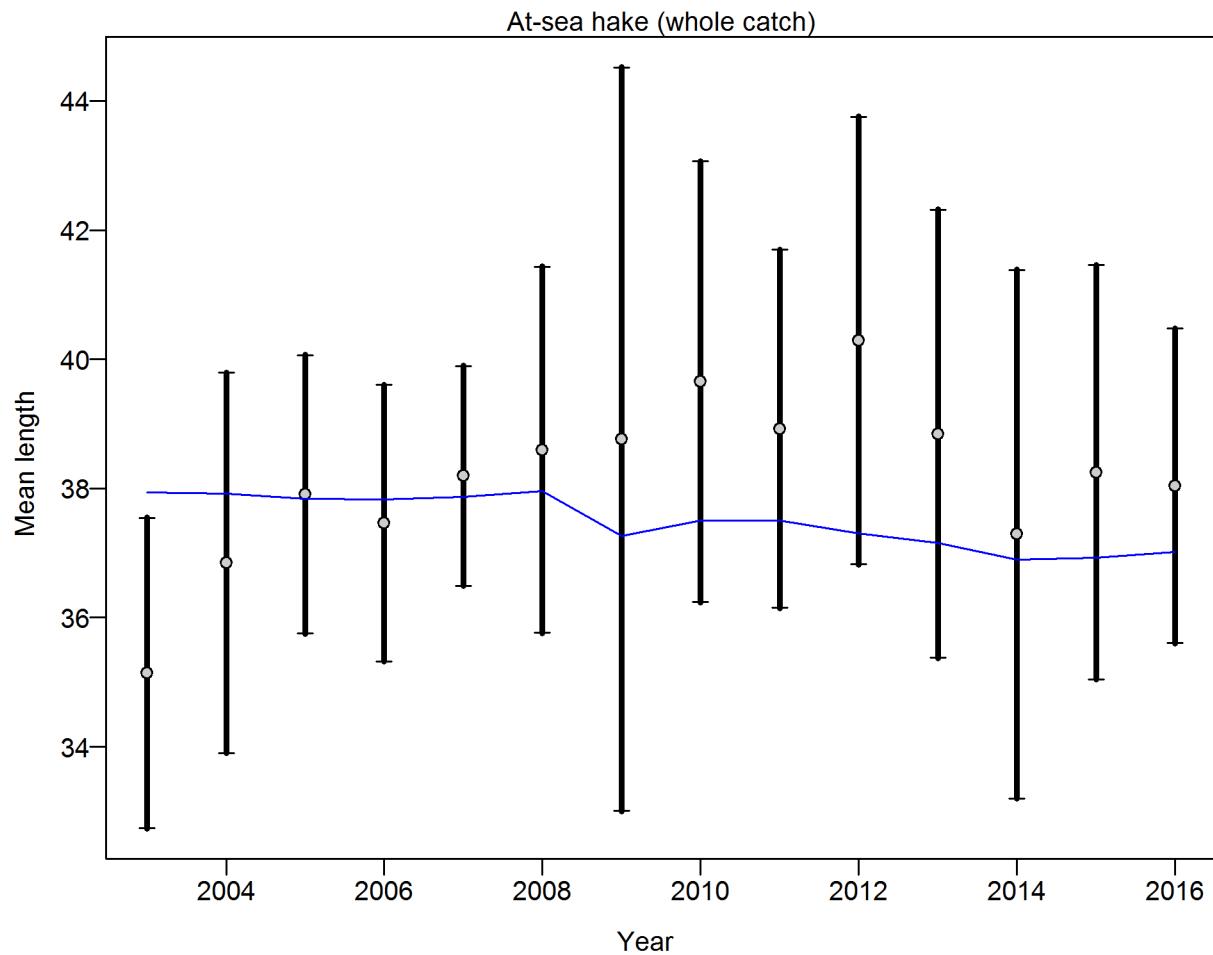


Figure 53: Francis data weighting method TA1.8: At_sea hake Suggested sample size adjustment (with 95% interval) for len data from At_sea hake: 1.0038 (0.512_5.0414) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

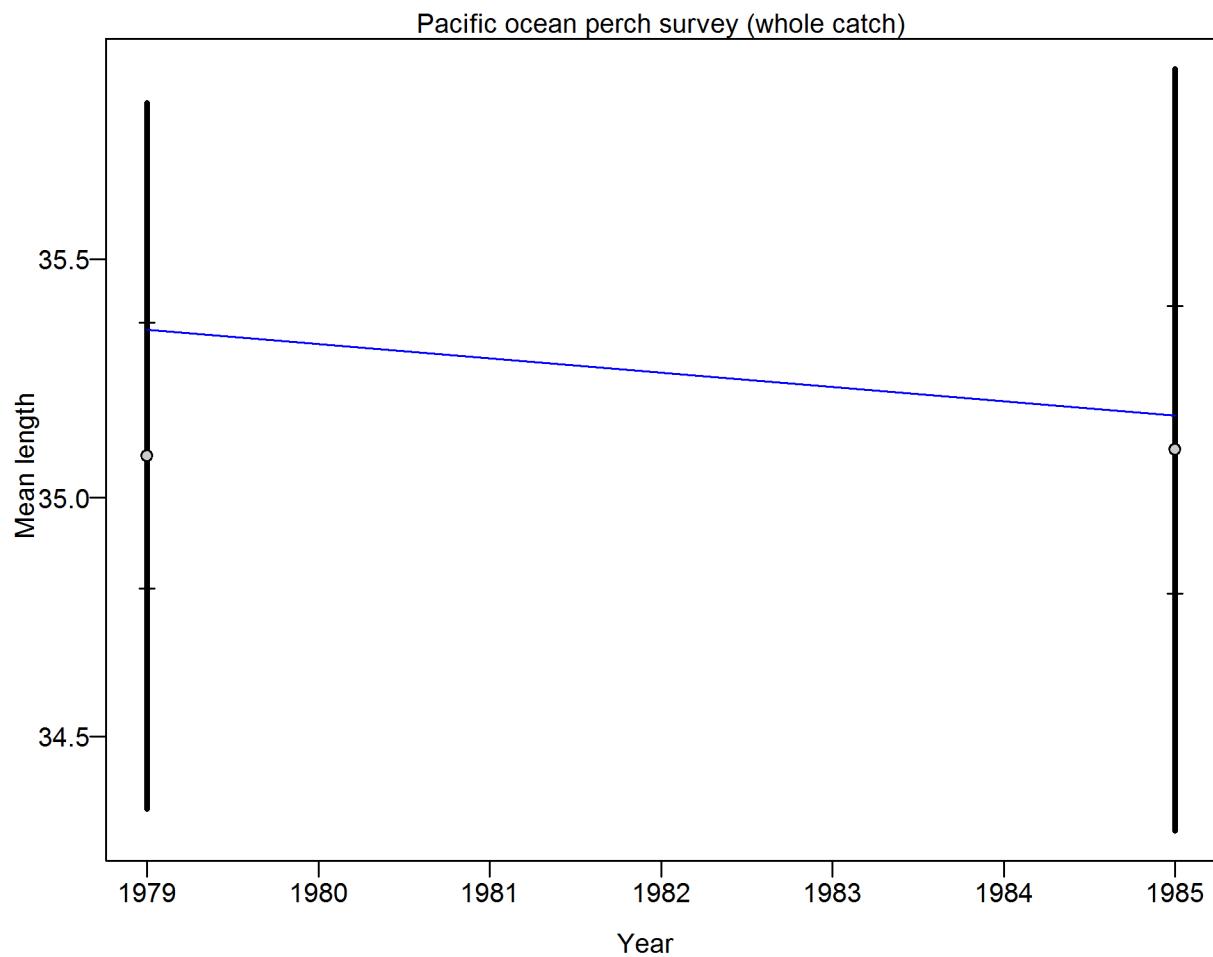


Figure 54: Francis data weighting method TA1.8: Pacific ocean perch survey Suggested sample size adjustment (with 95% interval) for len data from Pacific ocean perch survey: 7.0231 (7.0231_Inf) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124–1138.

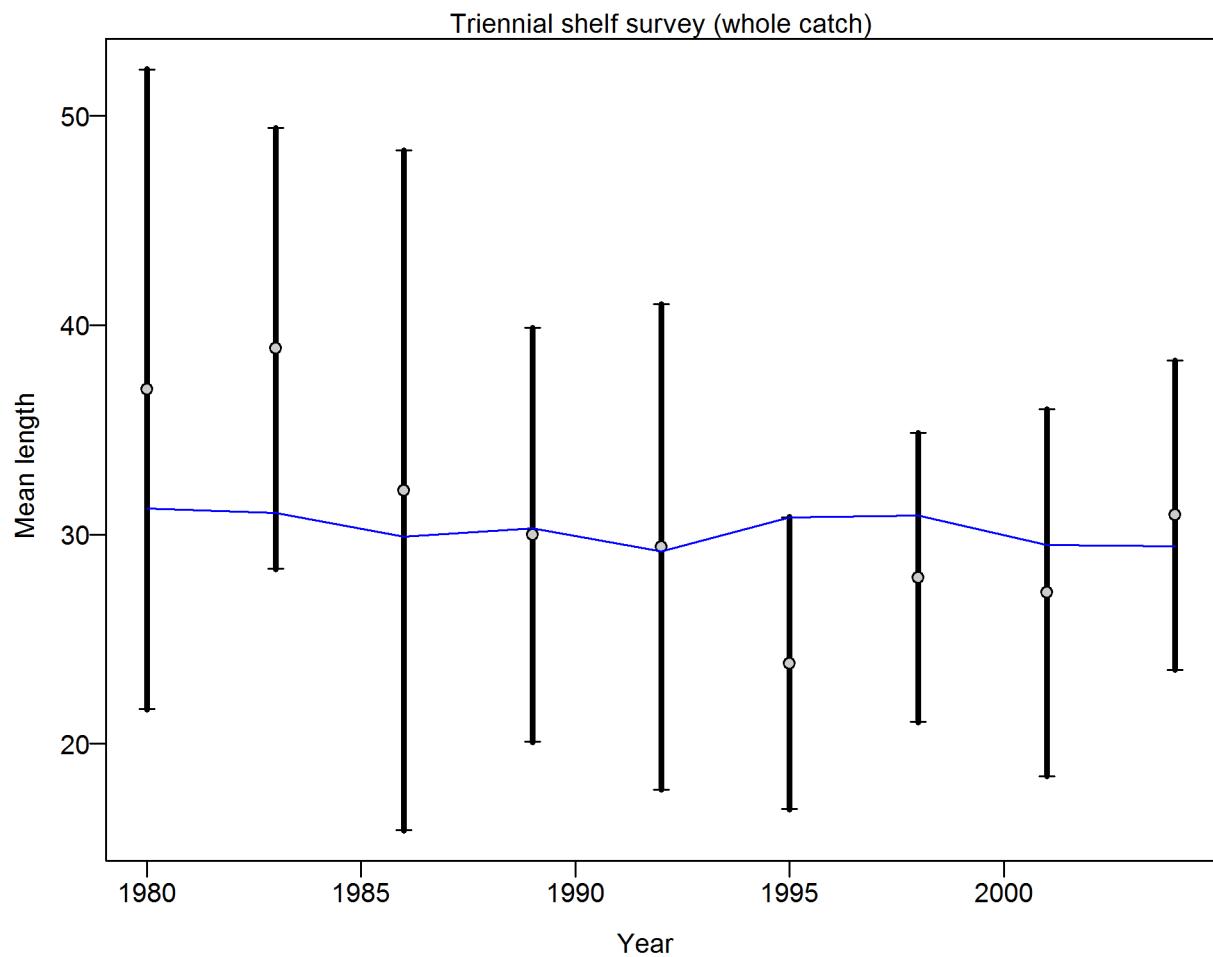


Figure 55: Francis data weighting method TA1.8: Triennial shelf survey Suggested sample size adjustment (with 95% interval) for len data from Triennial shelf survey: 1.002 (0.5492_5.6881)
 For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

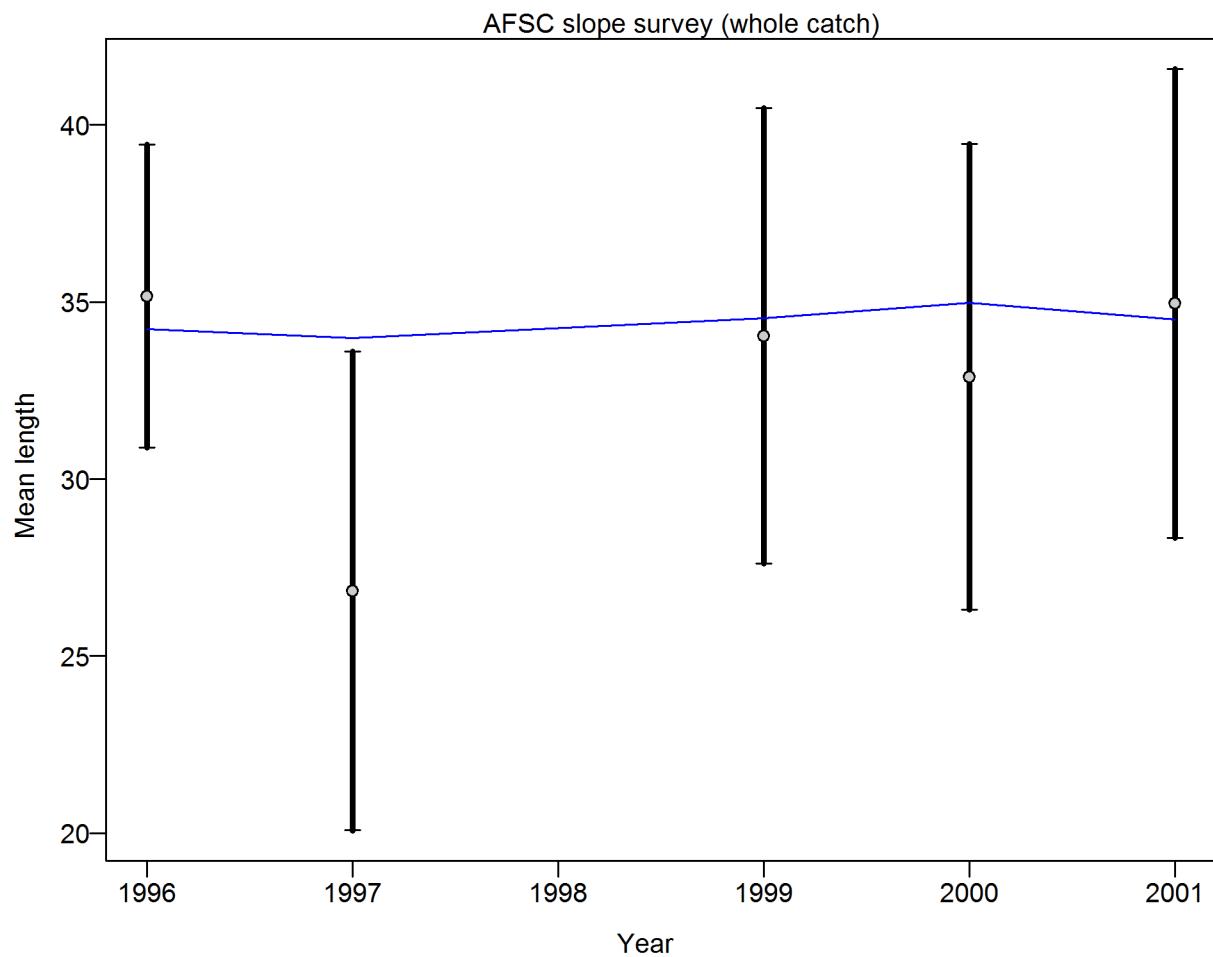


Figure 56: Francis data weighting method TA1.8: AFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from AFSC slope survey: 1.0006 (0.5777_23.4752)
 For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

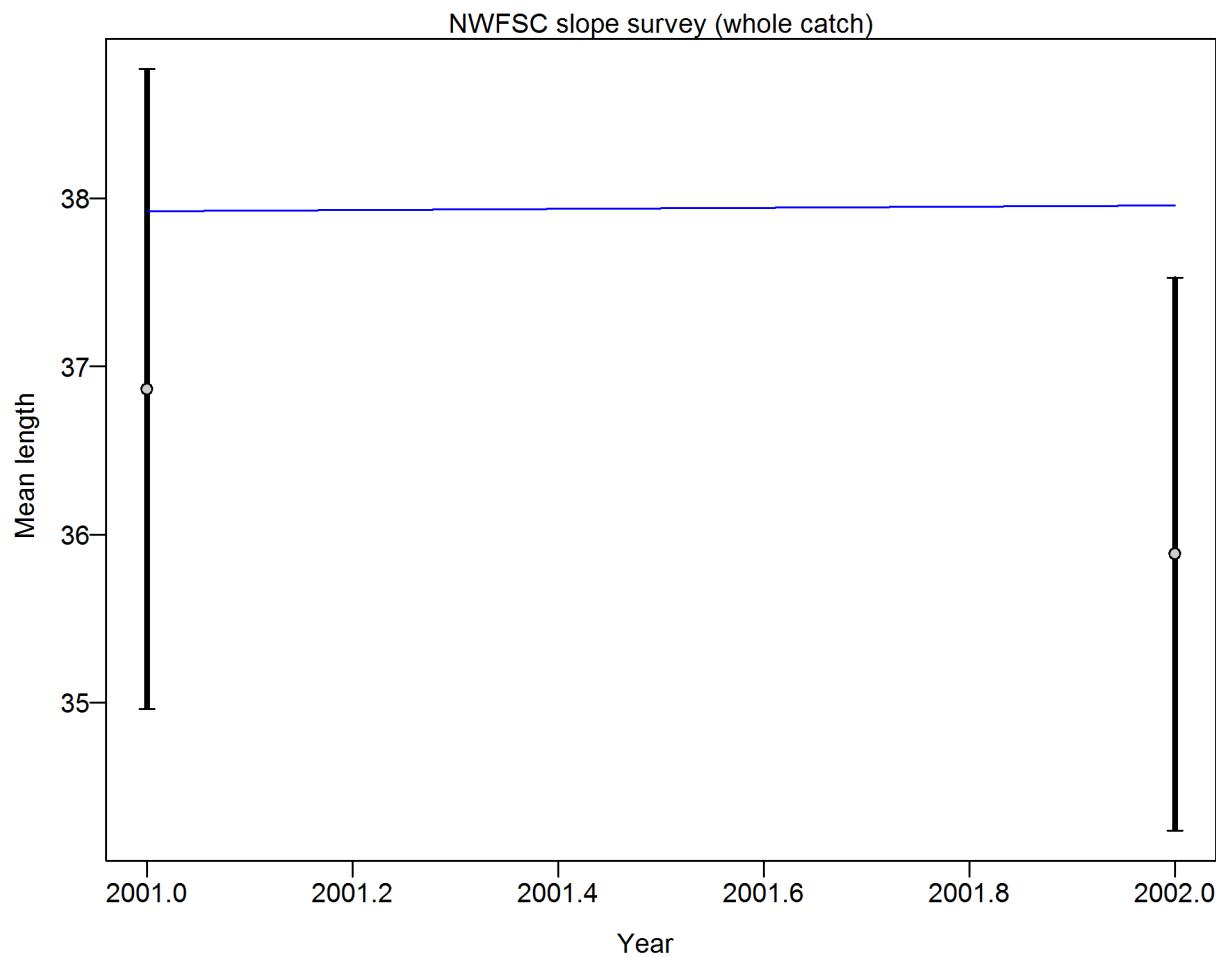


Figure 57: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC slope survey: 0.9902 (0.9902_Inf)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138.

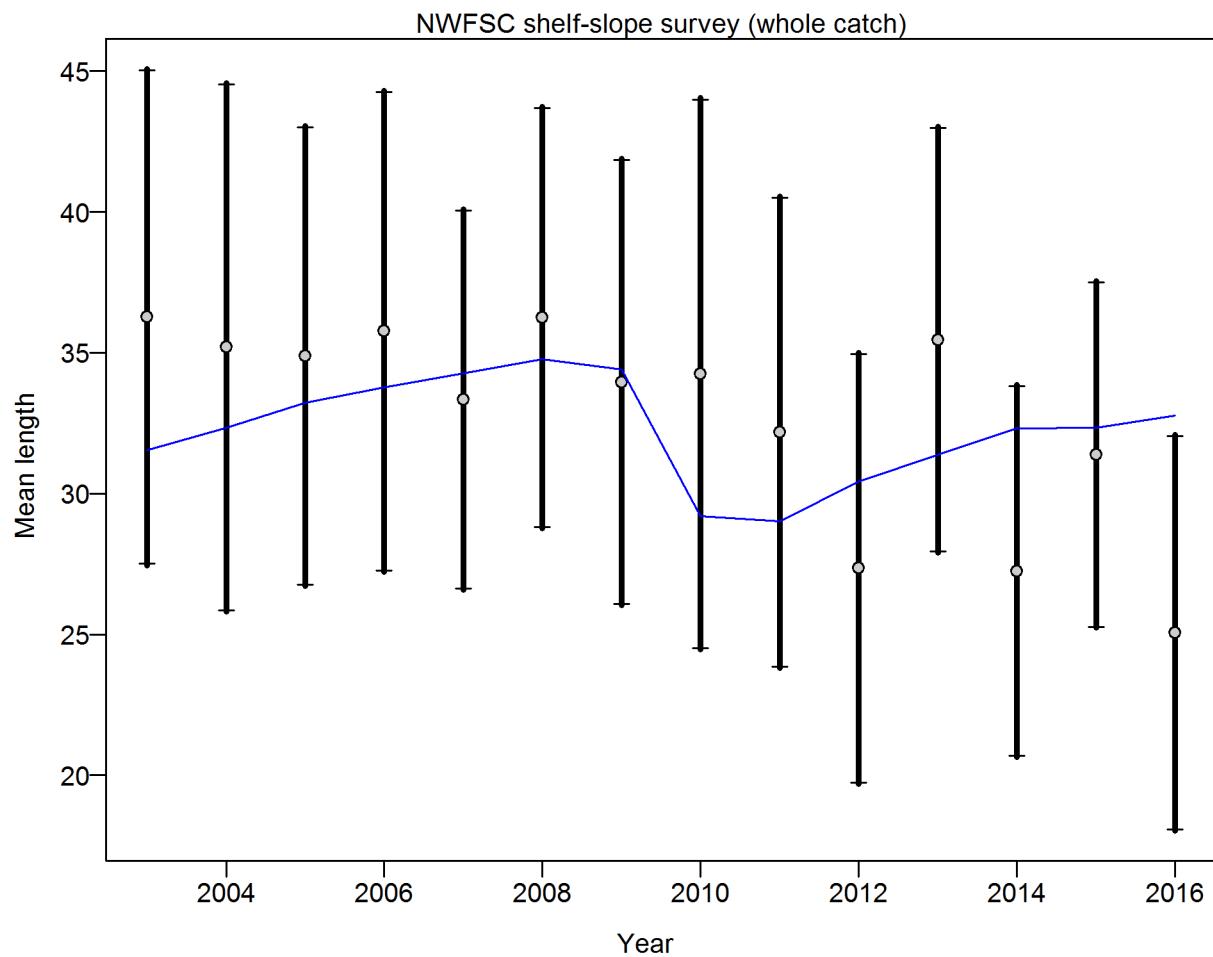


Figure 58: Francis data weighting method TA1.8: NWFSC shelf_slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC shelf_slope survey: 1.0116 (0.6135_3.7078) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

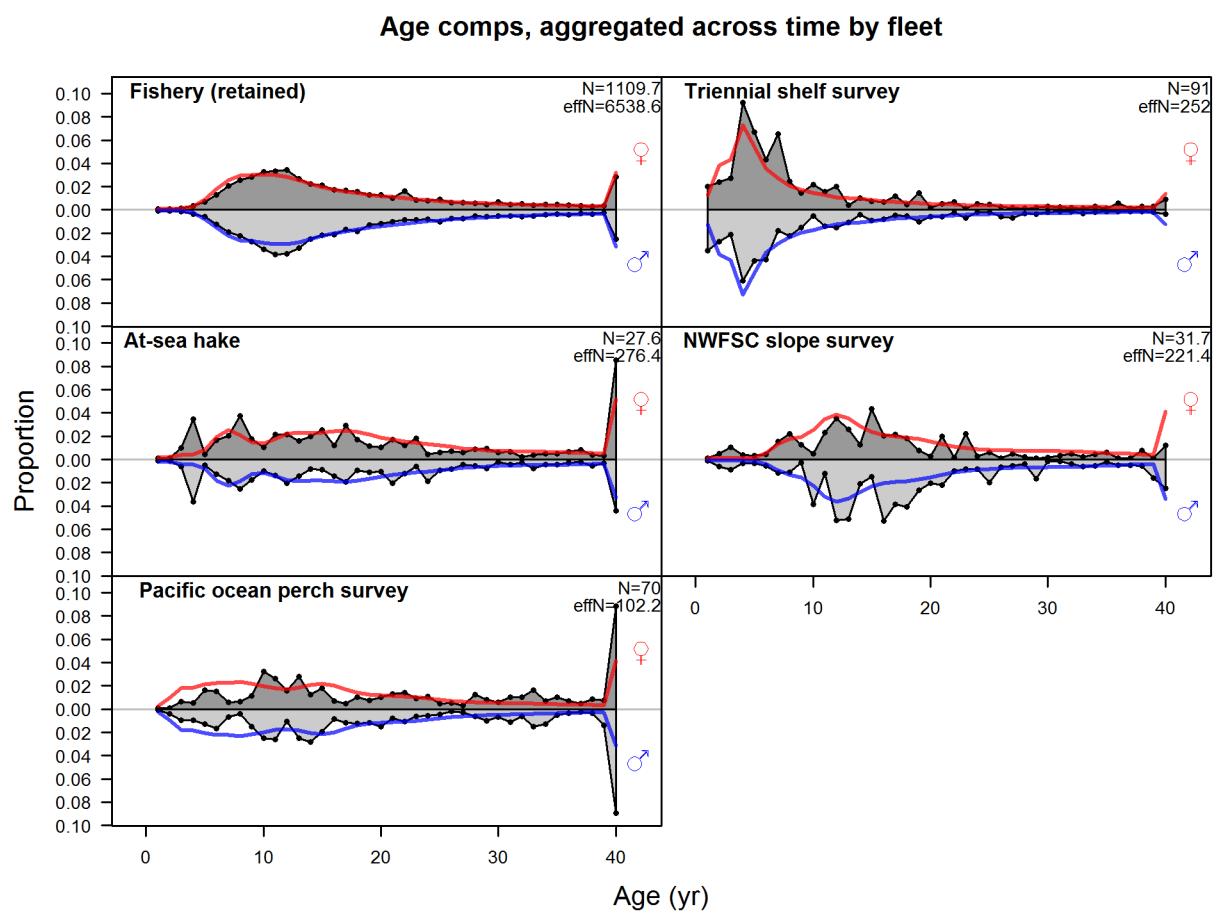


Figure 59: Age compositions aggregated across time by fleet.

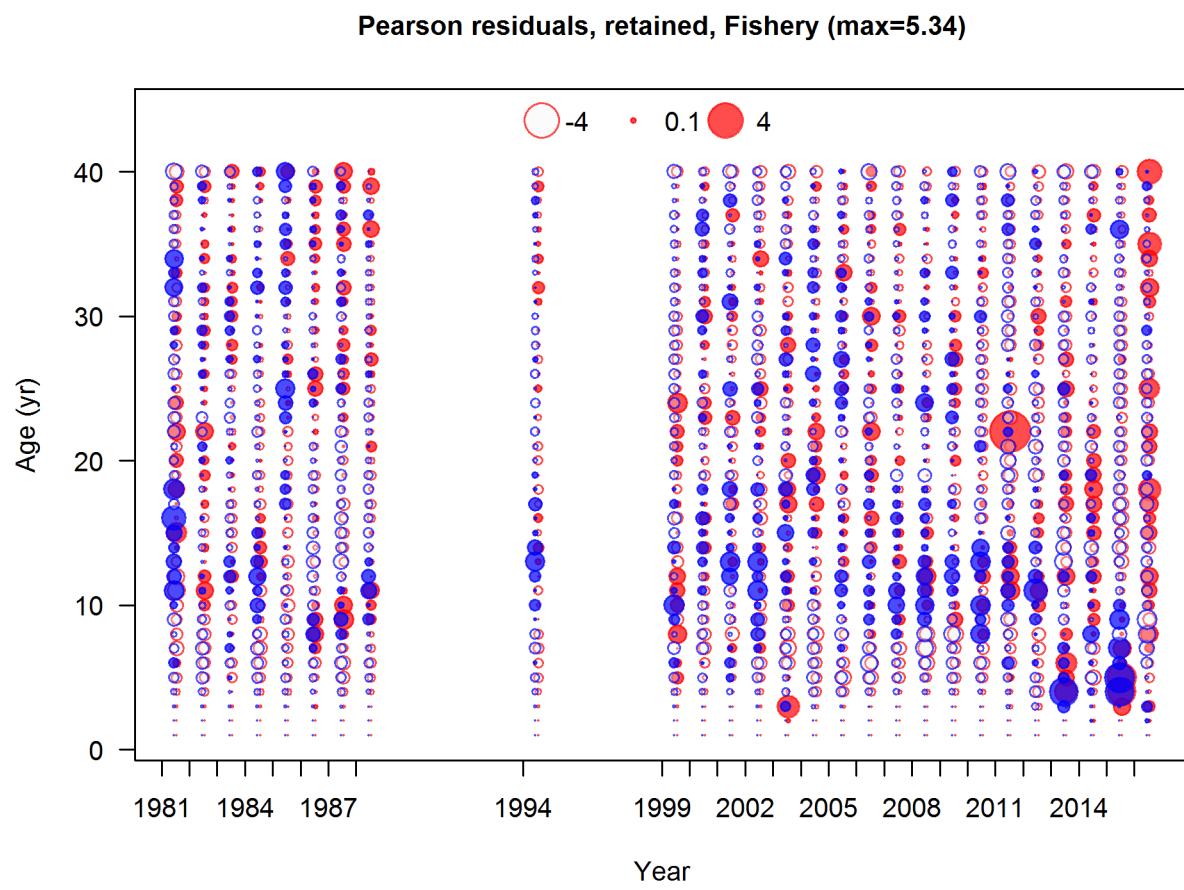


Figure 60: Pearson residuals, retained, Fishery (max=5.34) (plot 2 of 2)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

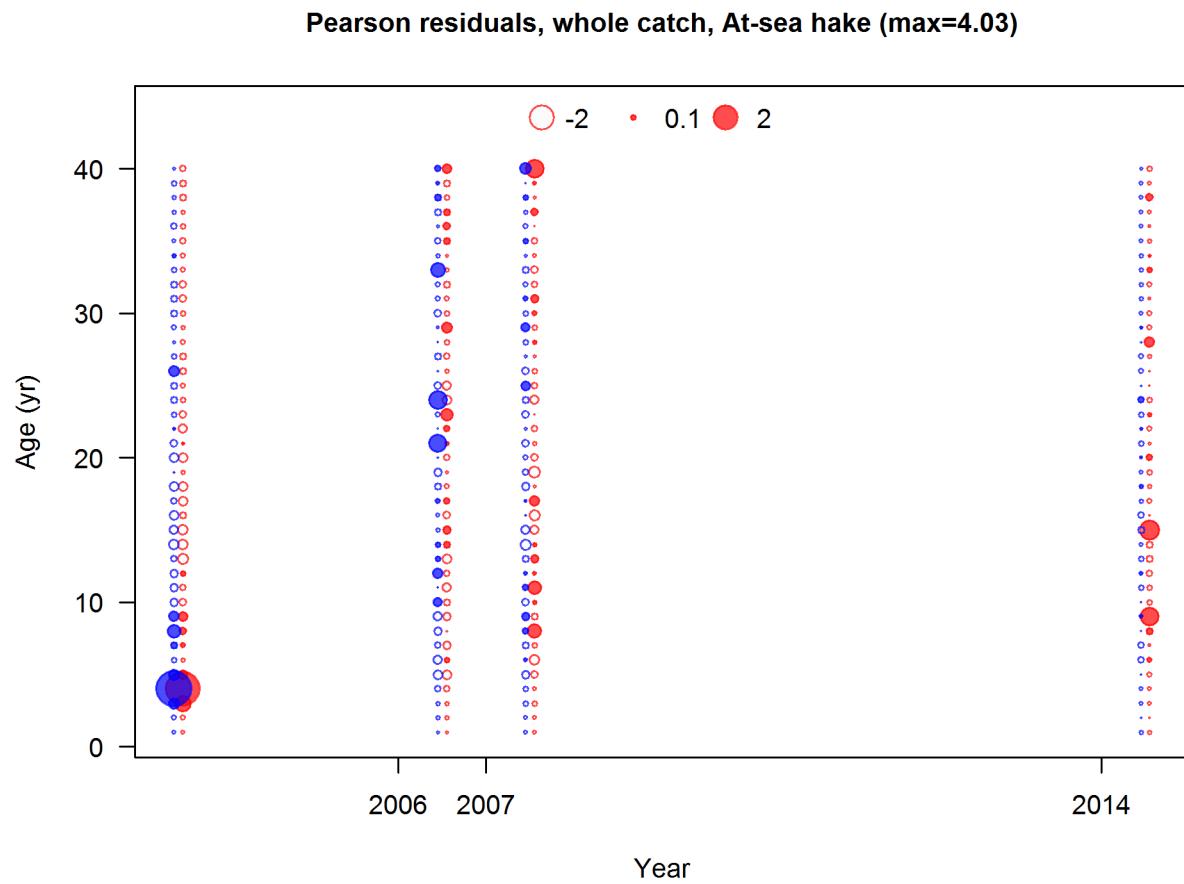


Figure 61: Pearson residuals, whole catch, At_sea hake (max=4.03)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

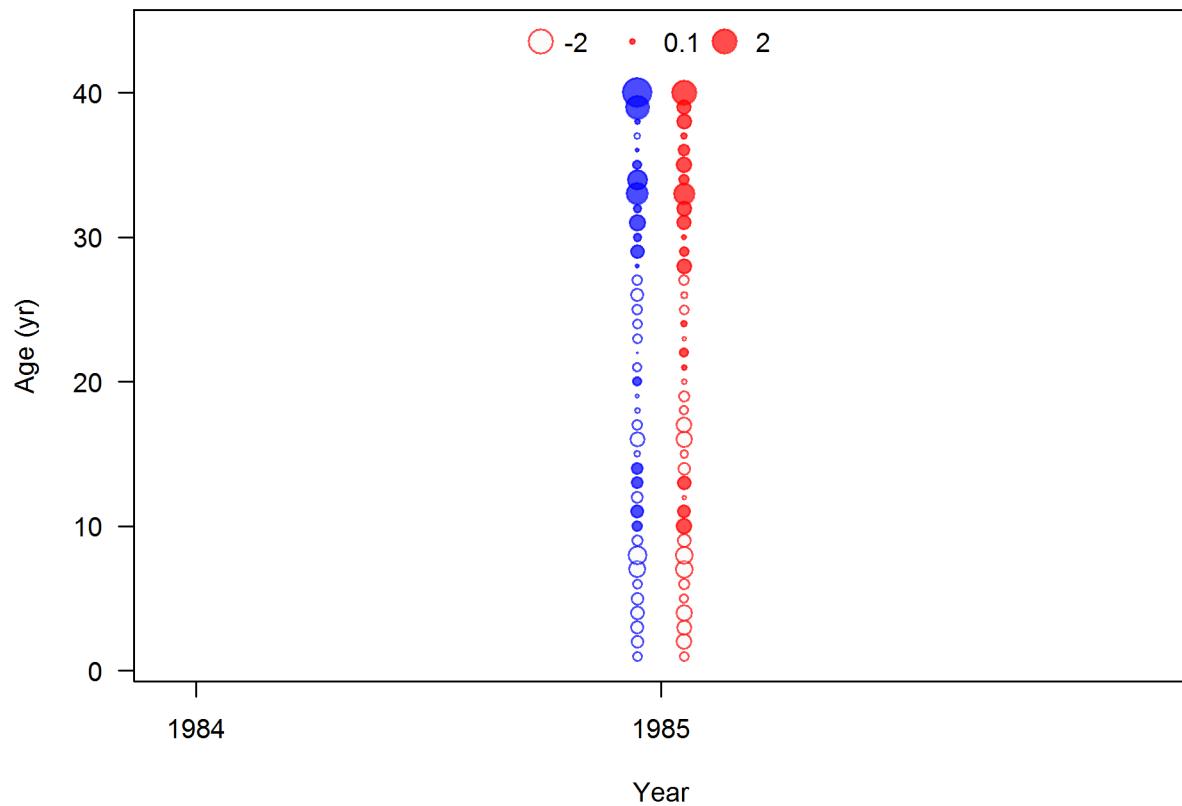


Figure 62: Pearson residuals, whole catch, Pacific ocean perch survey (max=2.76)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

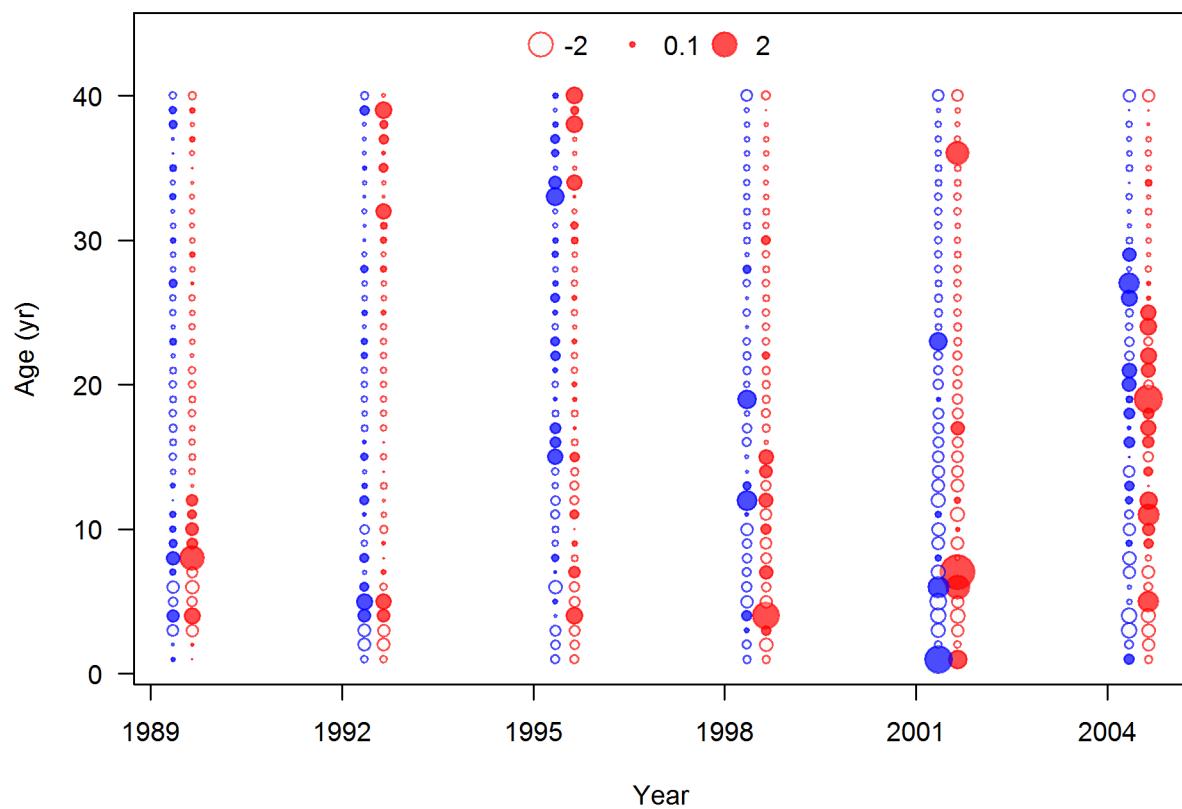


Figure 63: Pearson residuals, whole catch, Triennial shelf survey (max=3.76)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

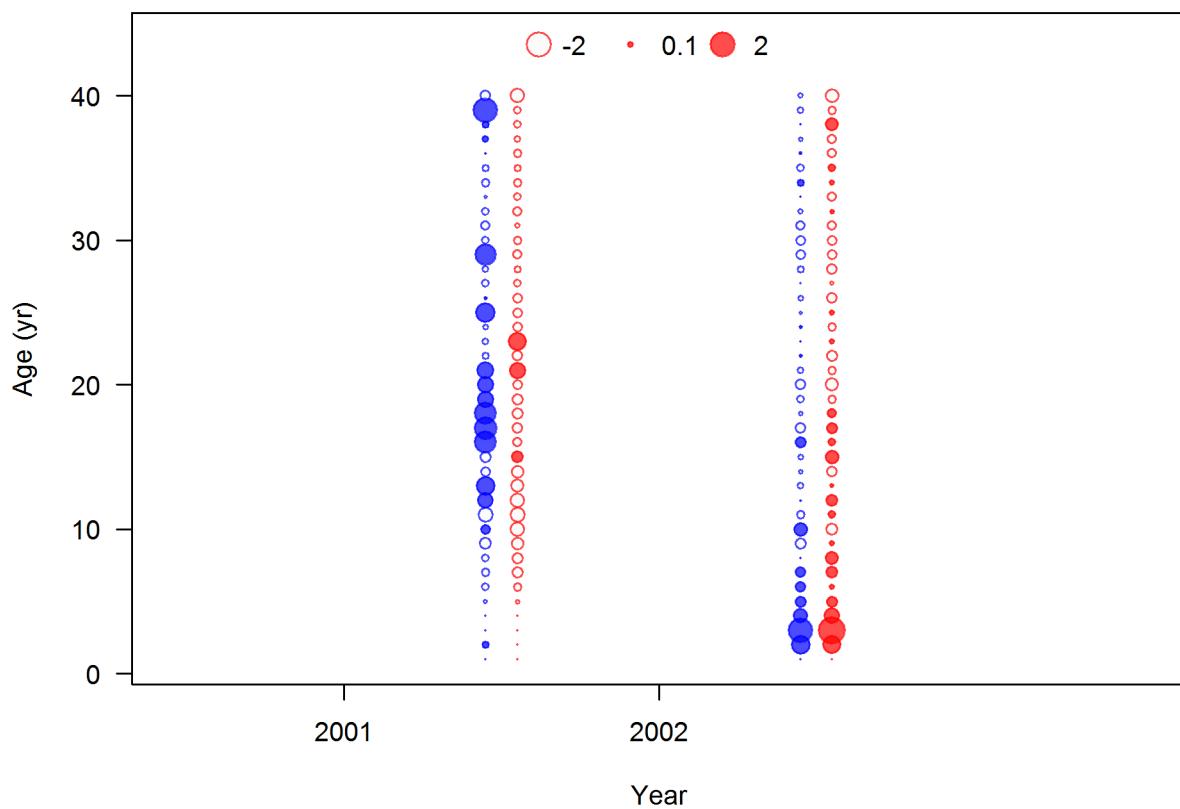


Figure 64: Pearson residuals, whole catch, NWFSC slope survey (max=2.34)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

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

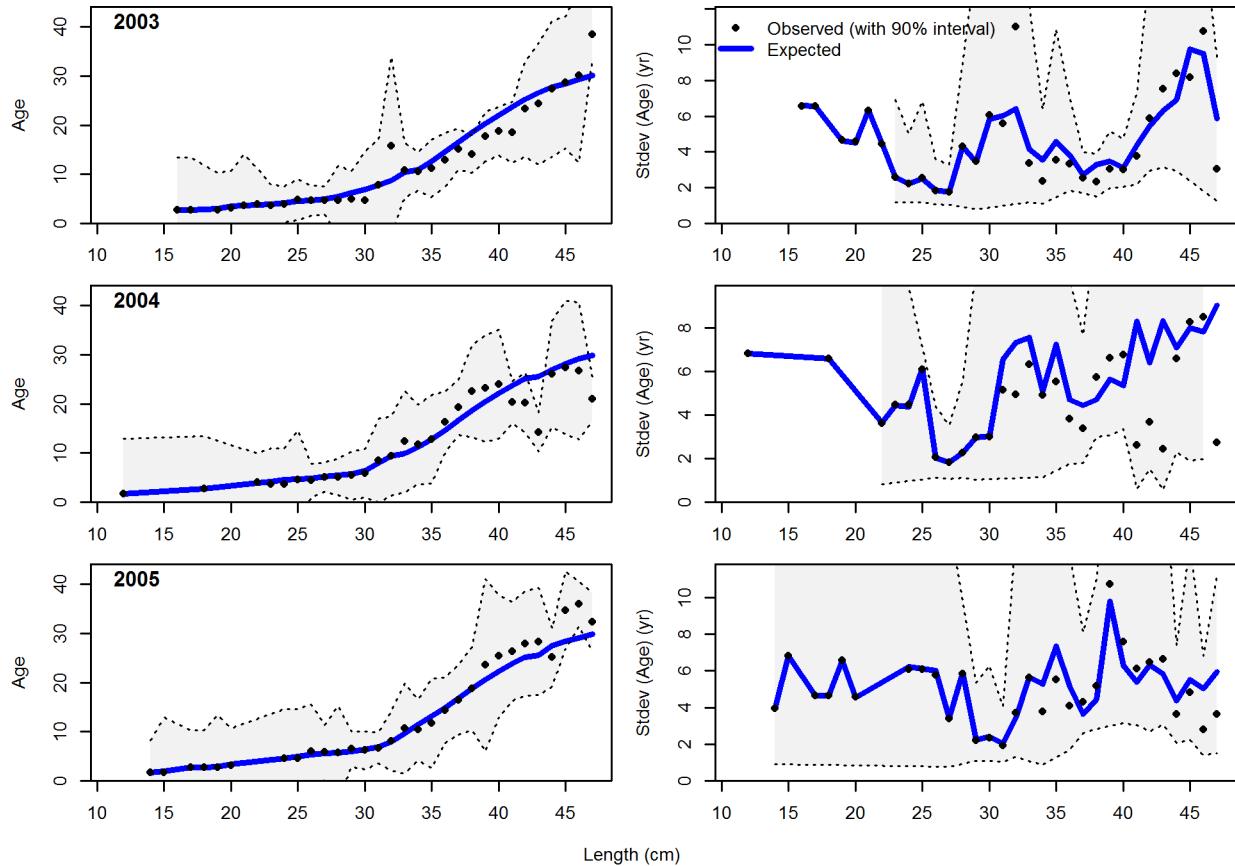


Figure 65: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 1 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

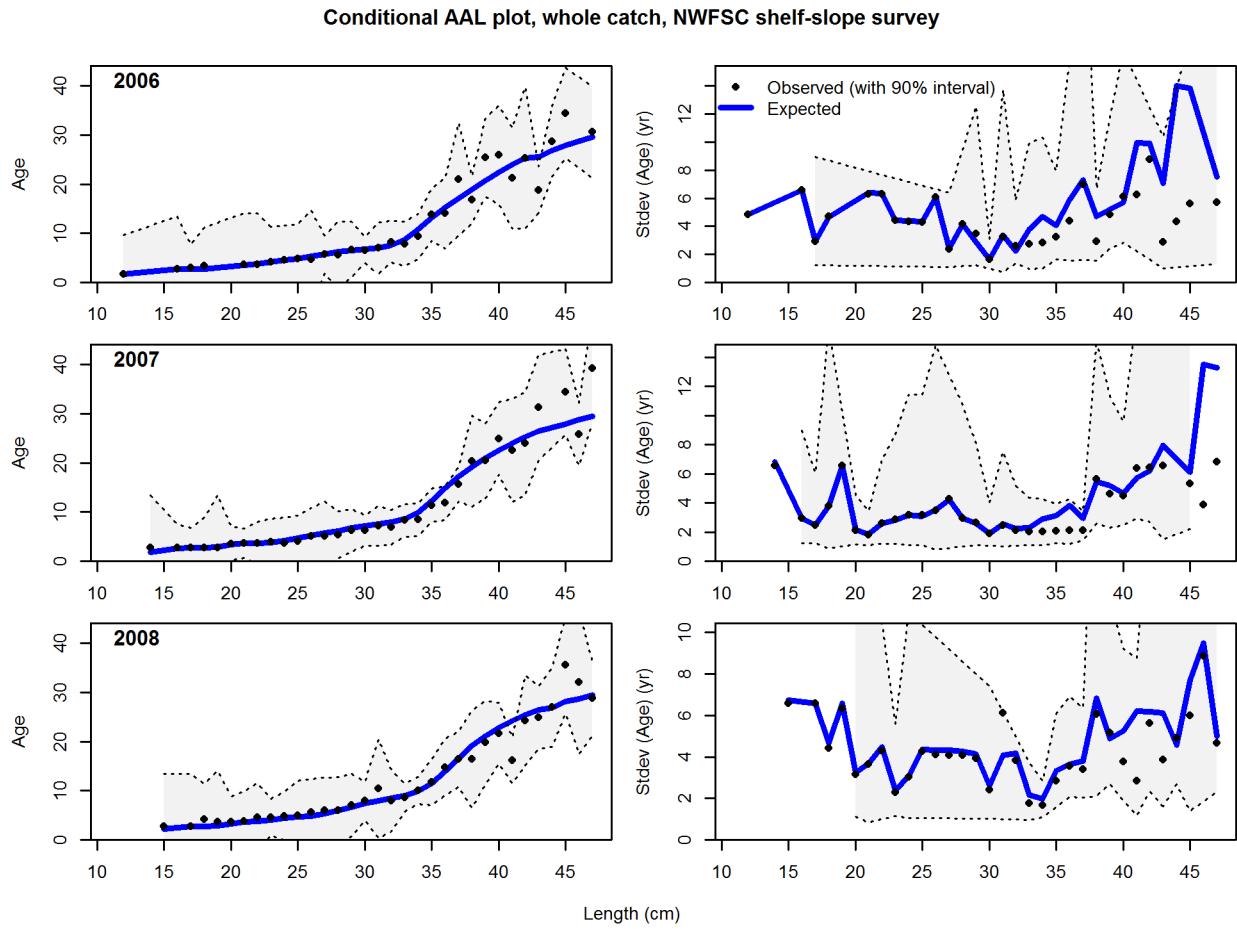


Figure 66: Conditional AAL plot, whole catch, NWFSC shelf_slope survey (plot 2 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

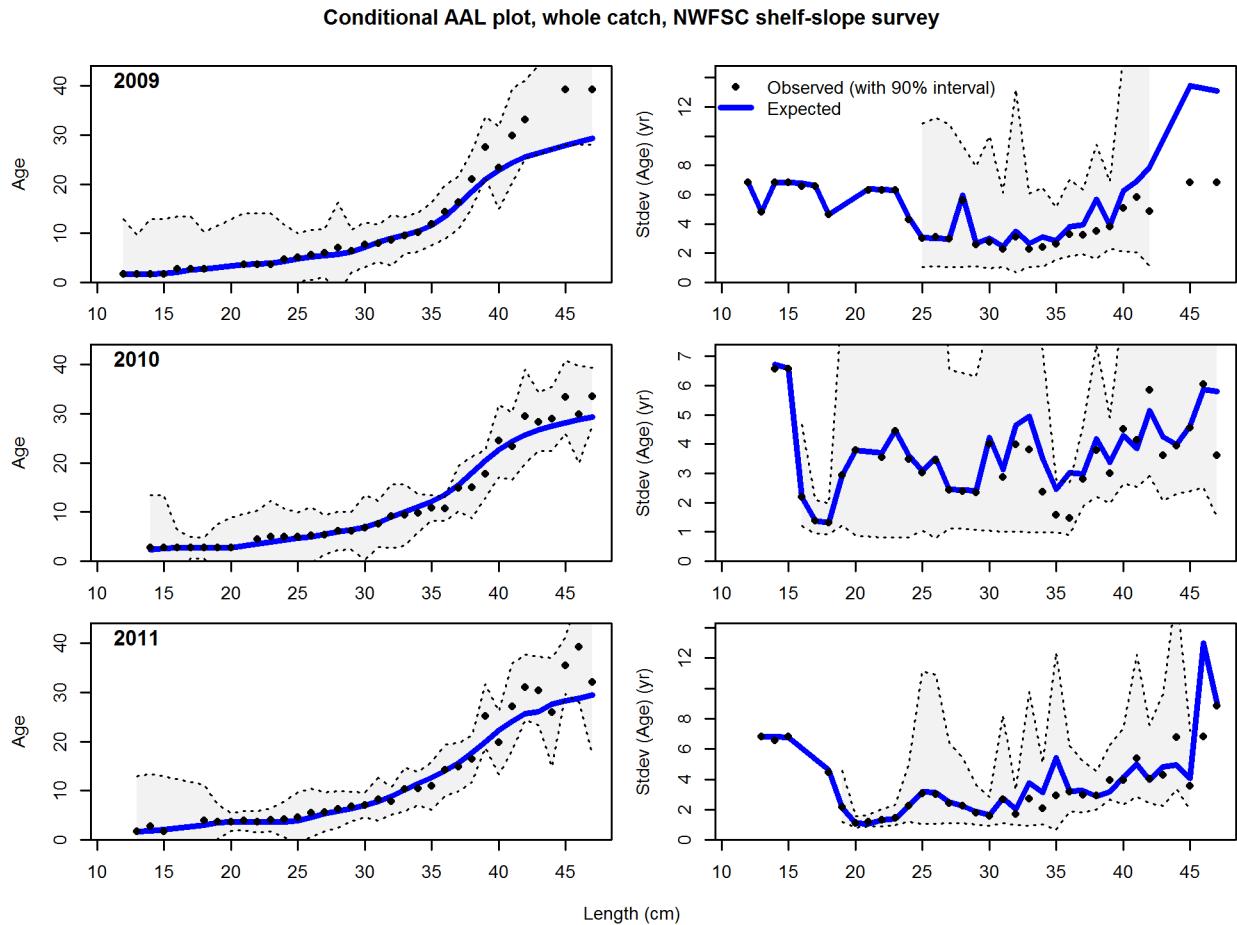


Figure 67: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 3 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

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

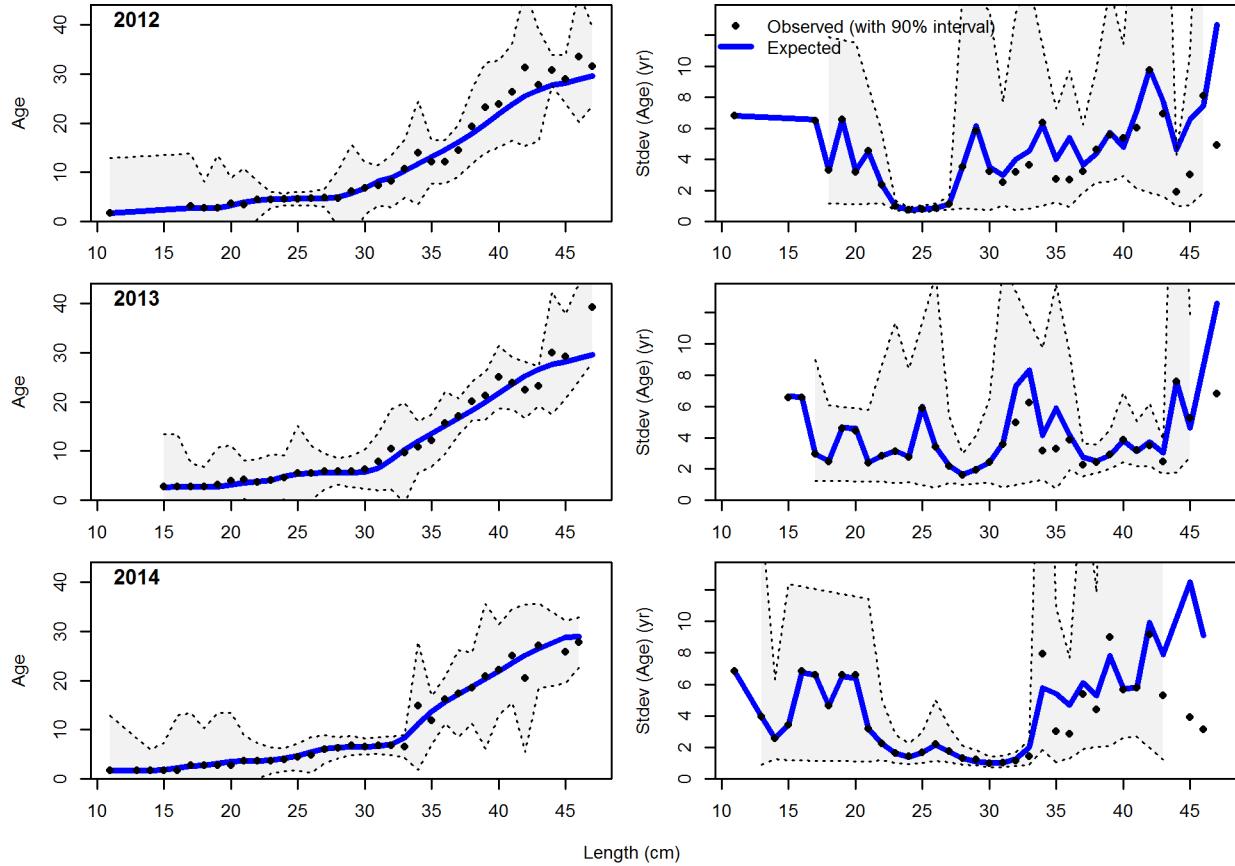


Figure 68: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 4 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

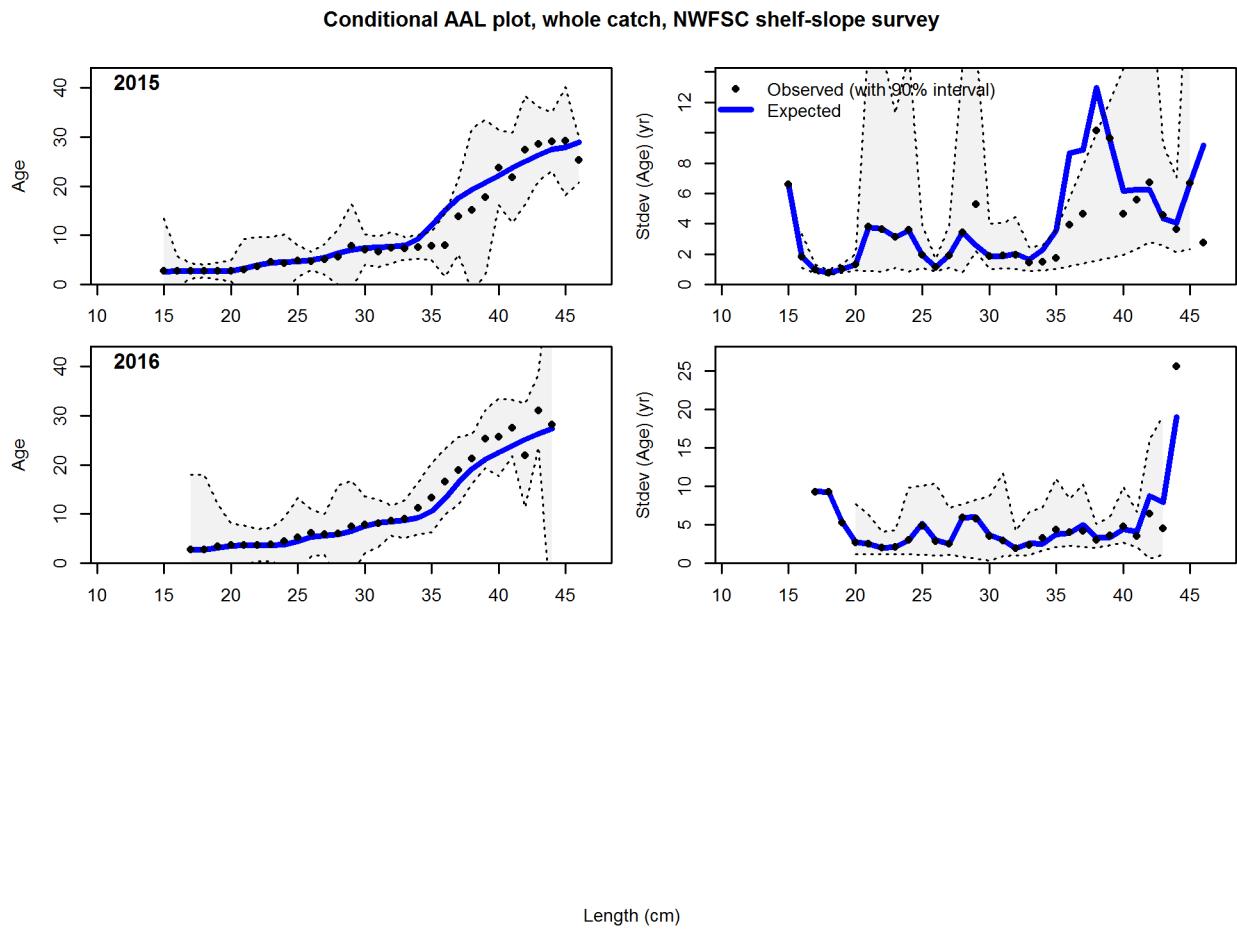


Figure 69: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 5 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL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

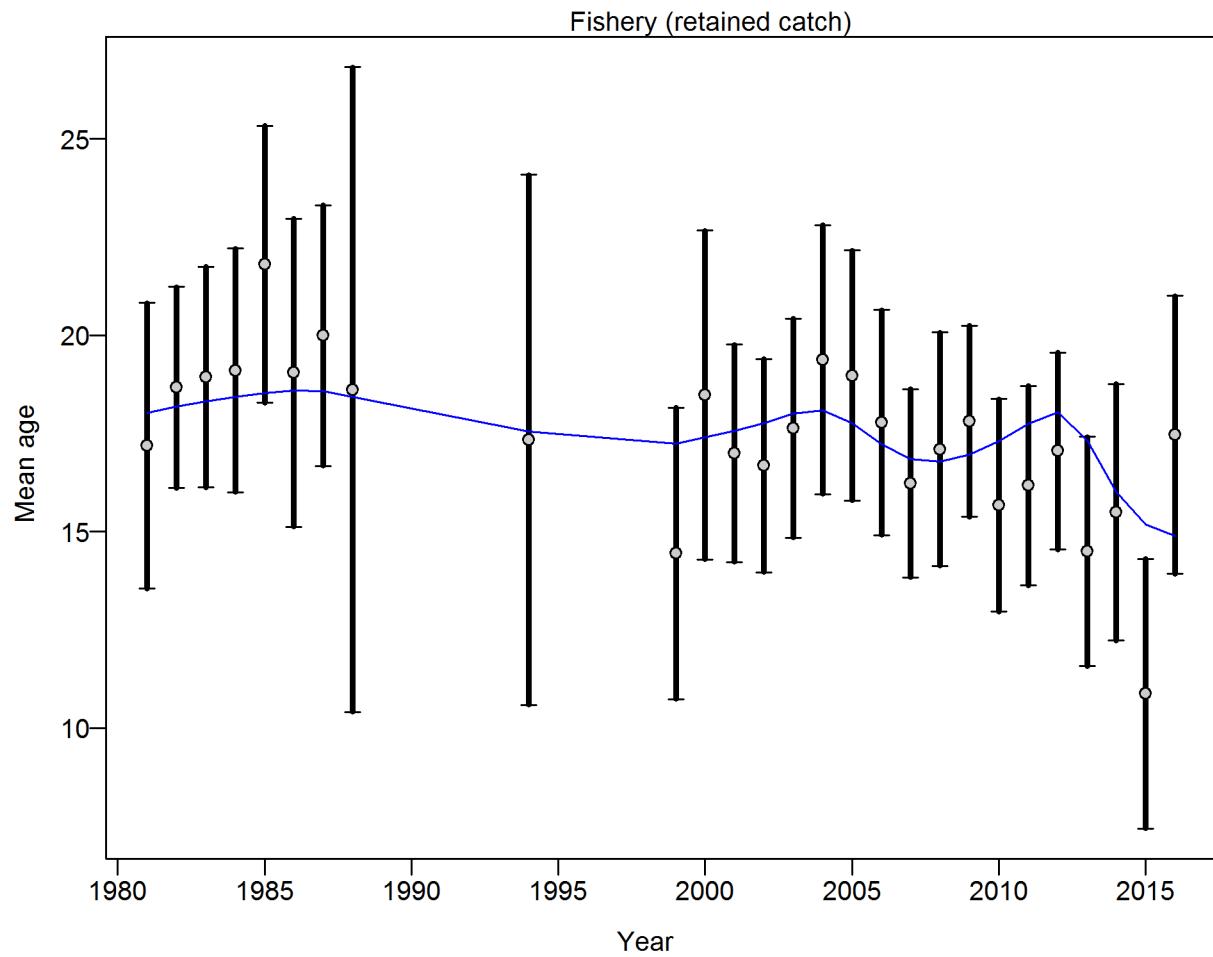


Figure 70: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for age data from Fishery: 0.9951 (0.6578_2.0211) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

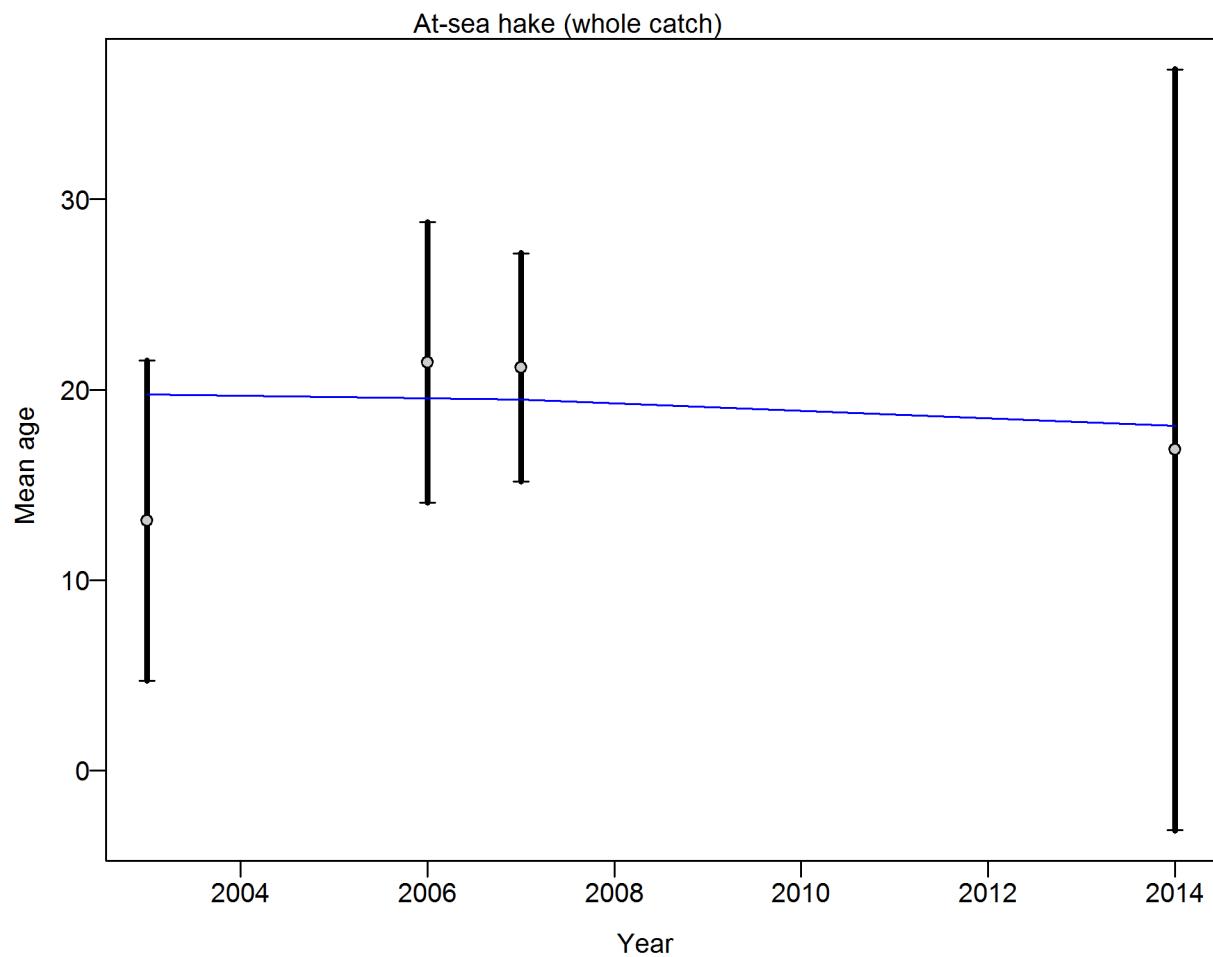


Figure 71: Francis data weighting method TA1.8: At_sea hake Suggested sample size adjustment (with 95% interval) for age data from At_sea hake: 1.0023 (0.6686_1573.0001)
 For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Can. J. Fish. Aquat. Sci.* 68: 1124_1138.

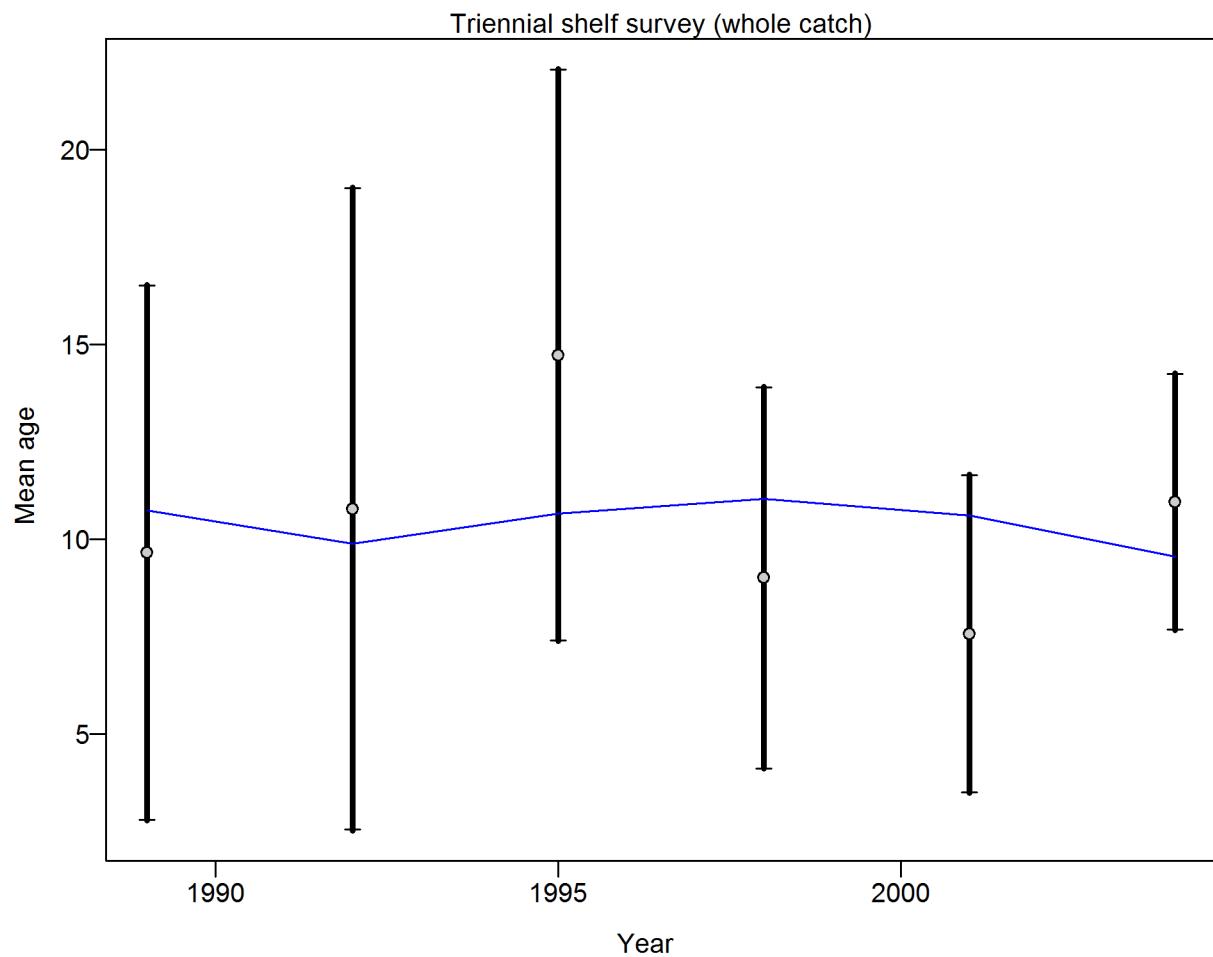


Figure 72: Francis data weighting method TA1.8: Triennial shelf survey Suggested sample size adjustment (with 95% interval) for age data from Triennial shelf survey: 1.0053 (0.6147–5.2192)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Can. J. Fish. Aquat. Sci.* 68: 1124–1138.

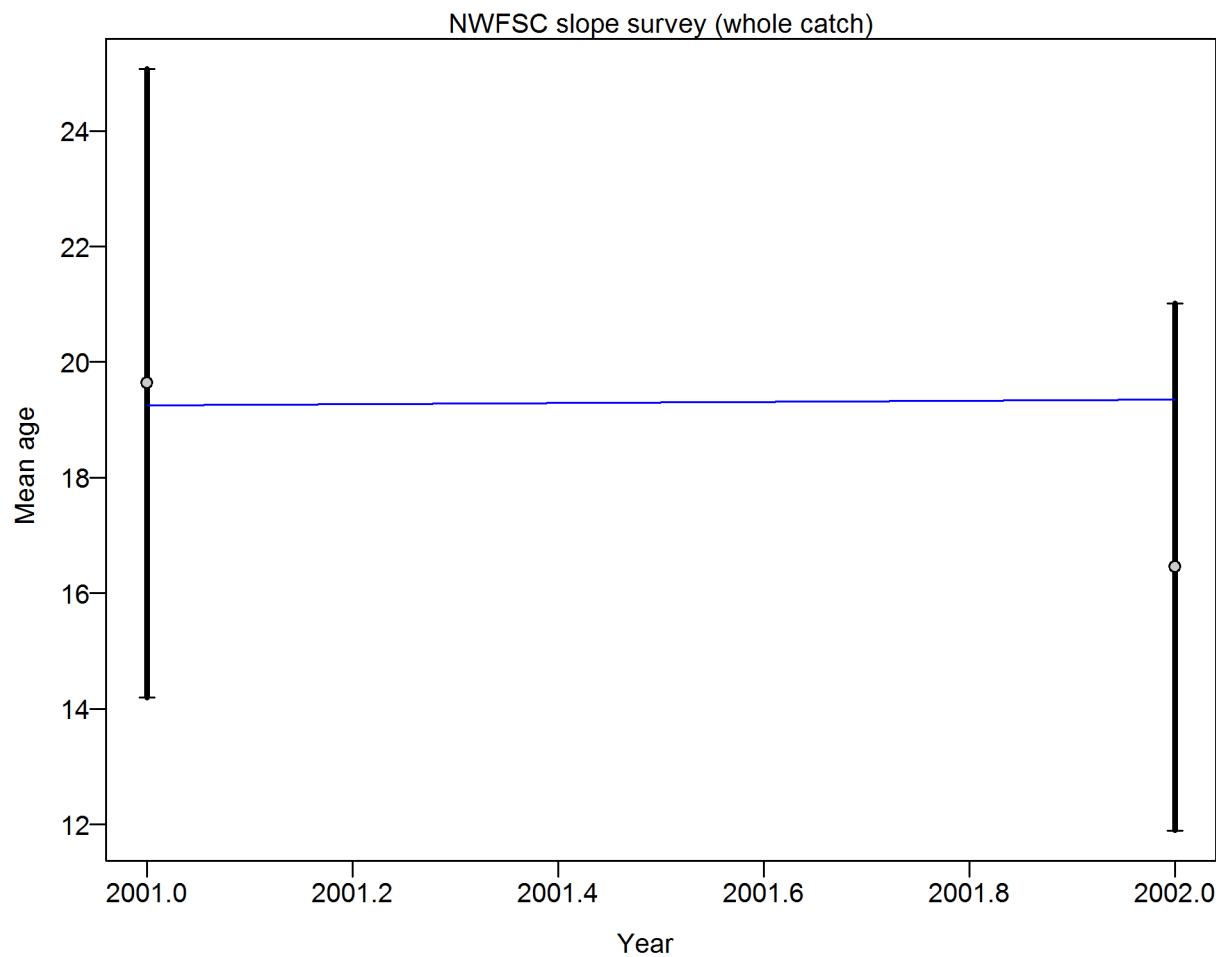


Figure 73: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for age data from NWFSC slope survey: 0.9992 (0.9992_Inf)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138.

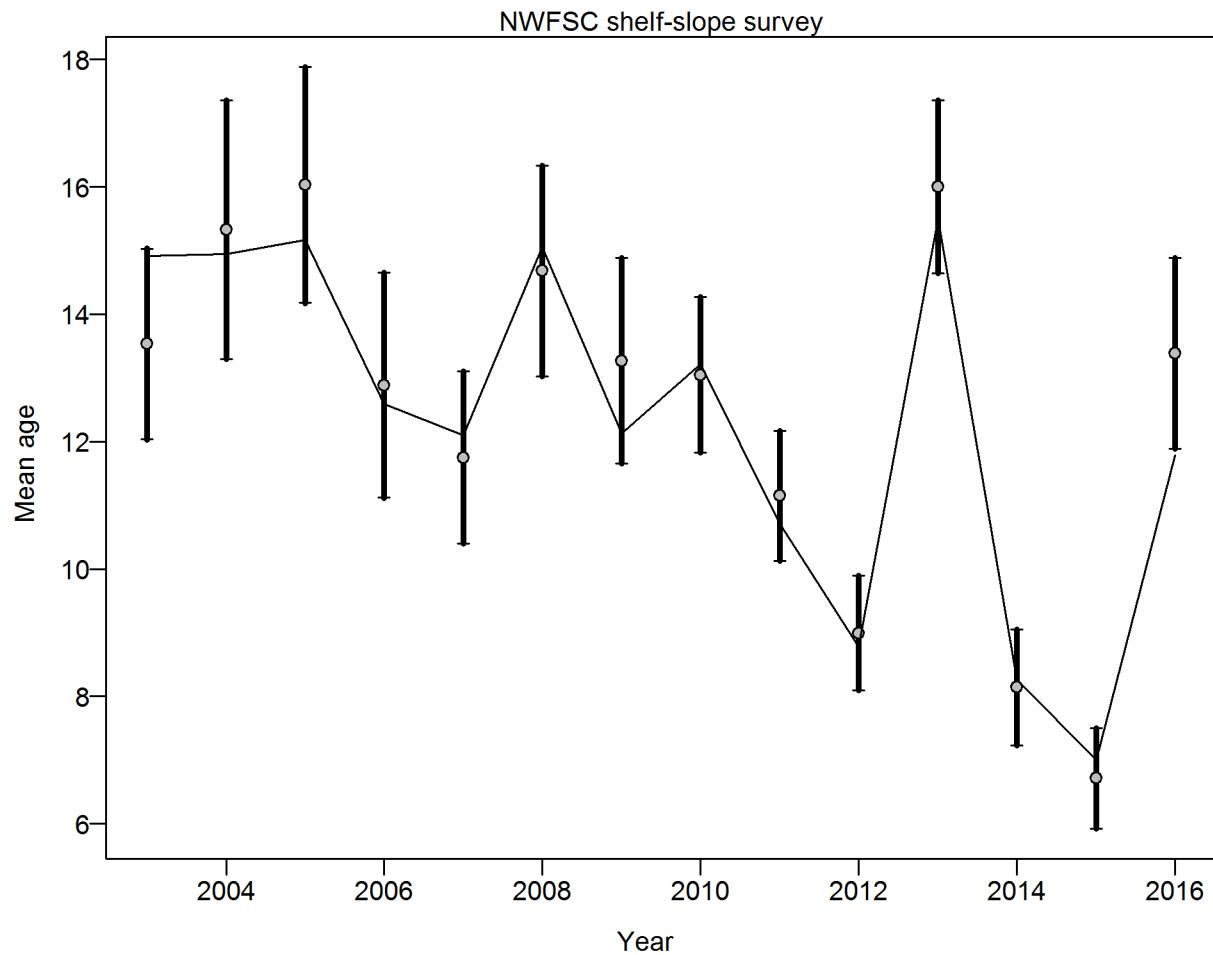


Figure 74: Francis data weighting method TA1.8 for conditional age [data:NWFSC](#) shelf_slope survey Suggested sample size adjustment (with 95% interval) for conditional age_at_length data from NWFSC shelf_slope survey: 1.0038 (0.5962_3.13) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138.

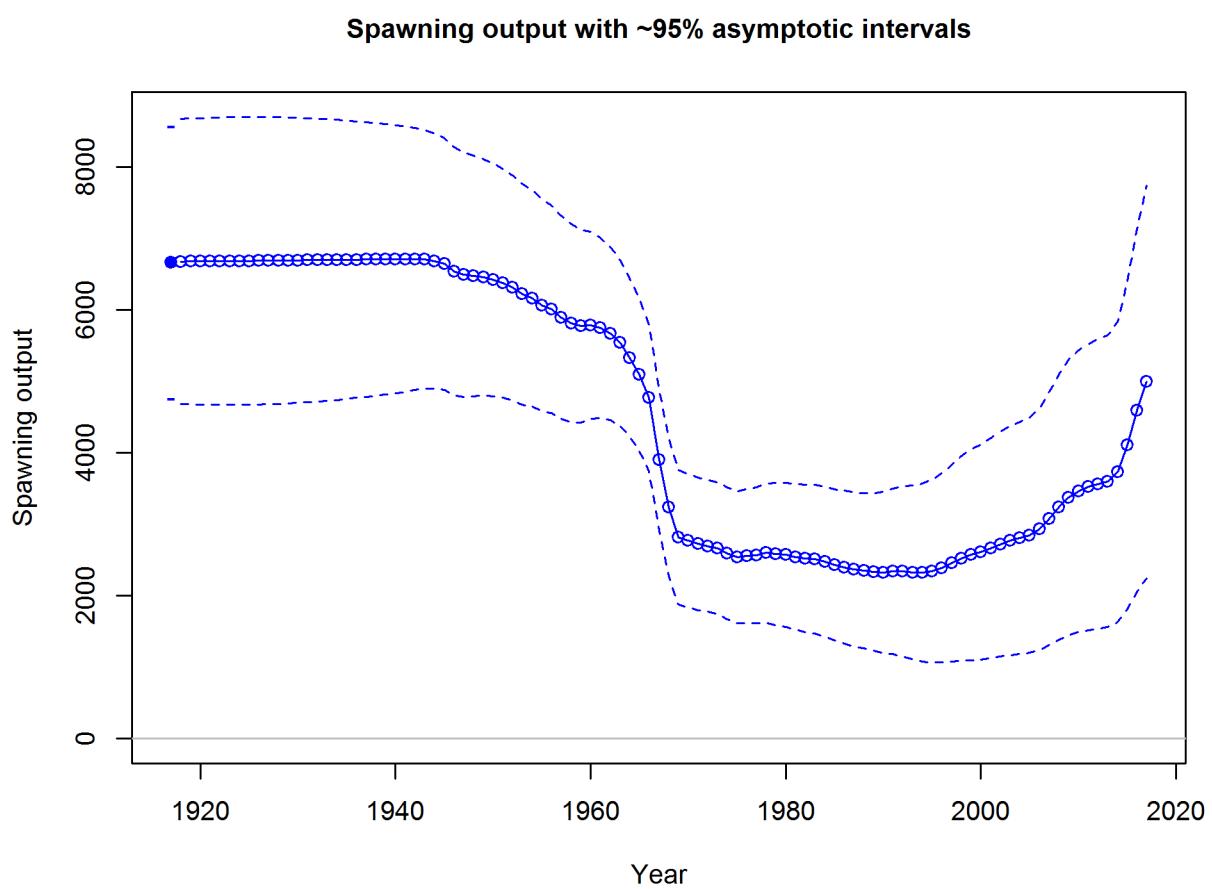


Figure 75: Estimated time-series of spawning output for Pacific ocean perch.

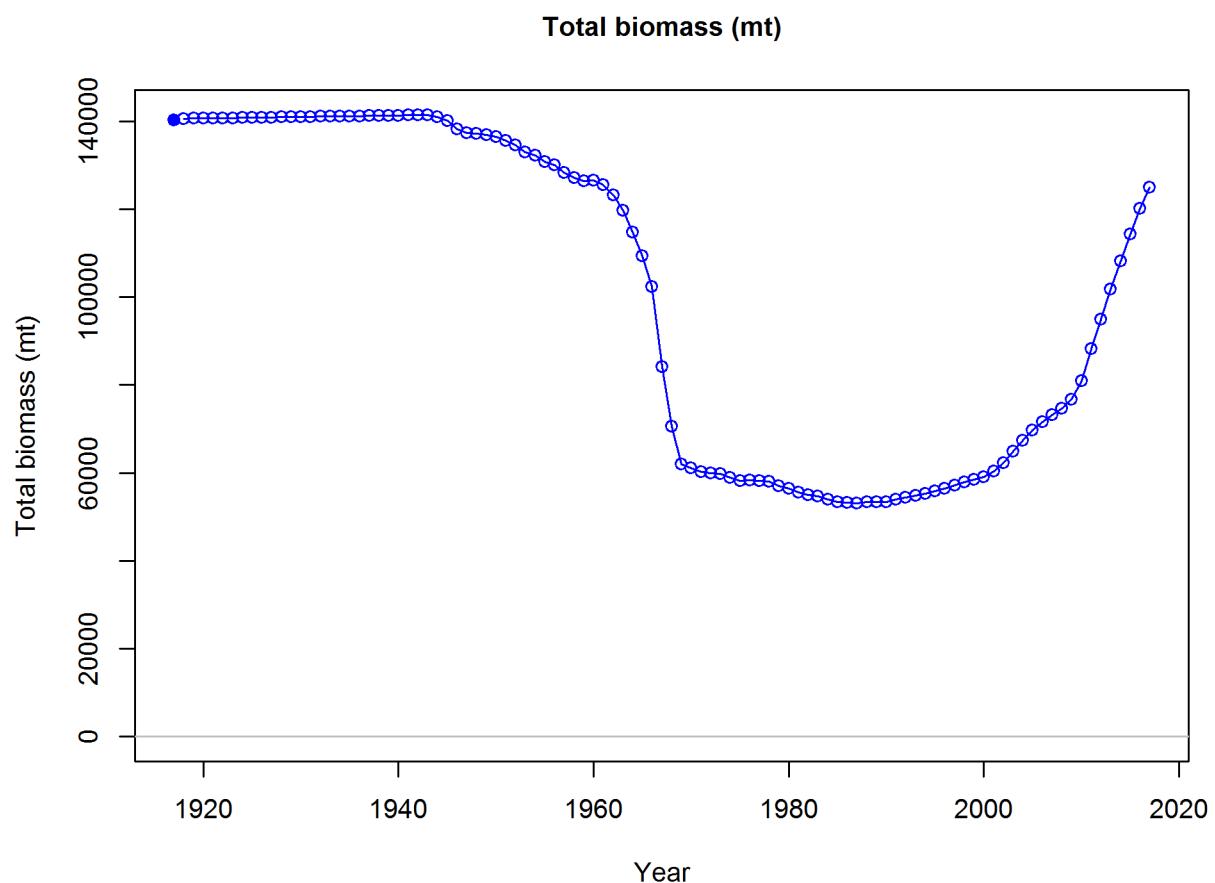


Figure 76: Estimated time-series of total biomass for Pacific ocean perch.

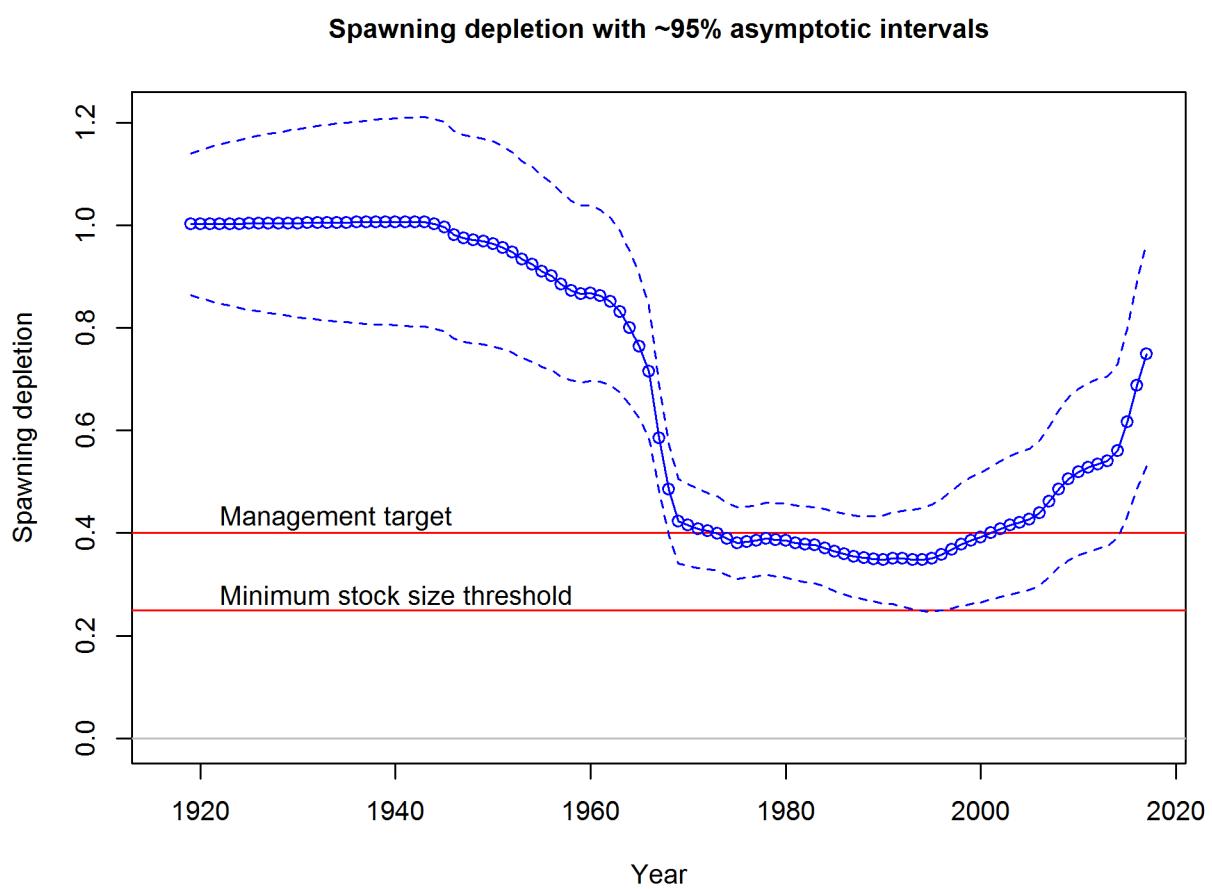


Figure 77: Estimated time-series of relative biomass for Pacific ocean perch.

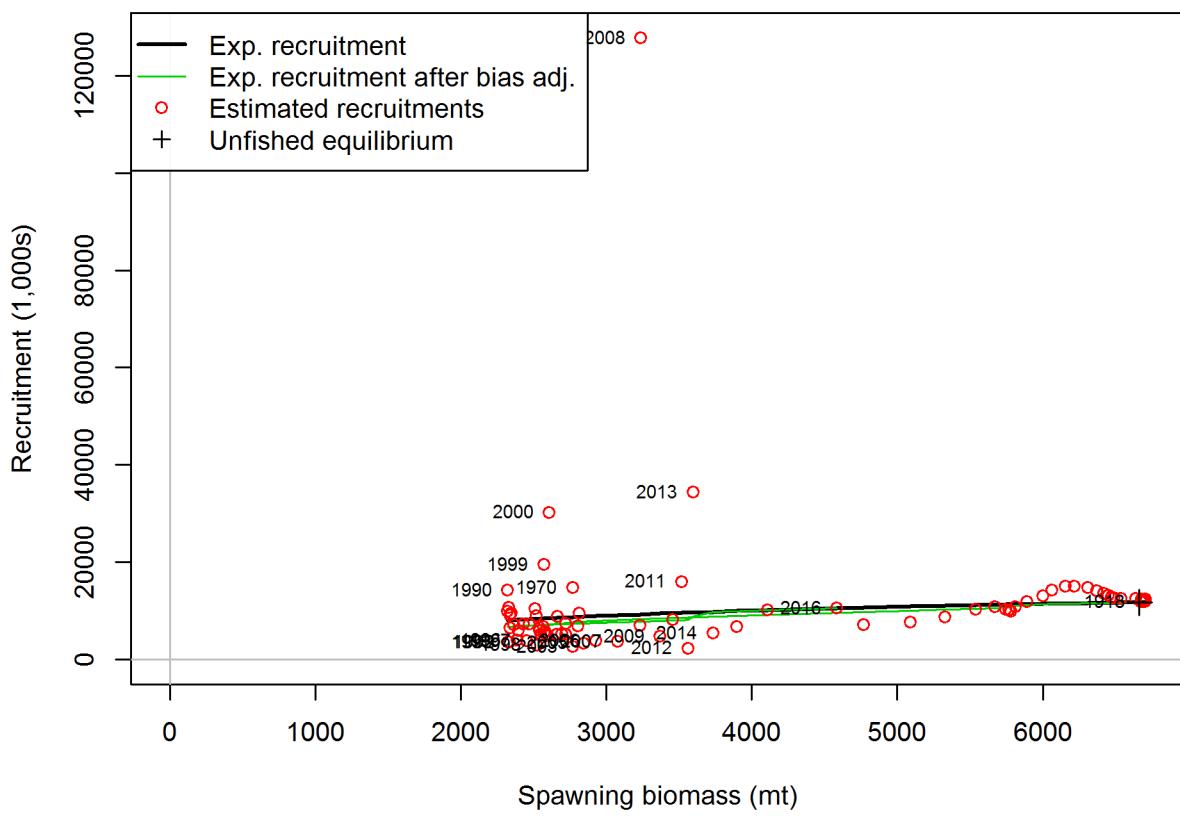


Figure 78: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution

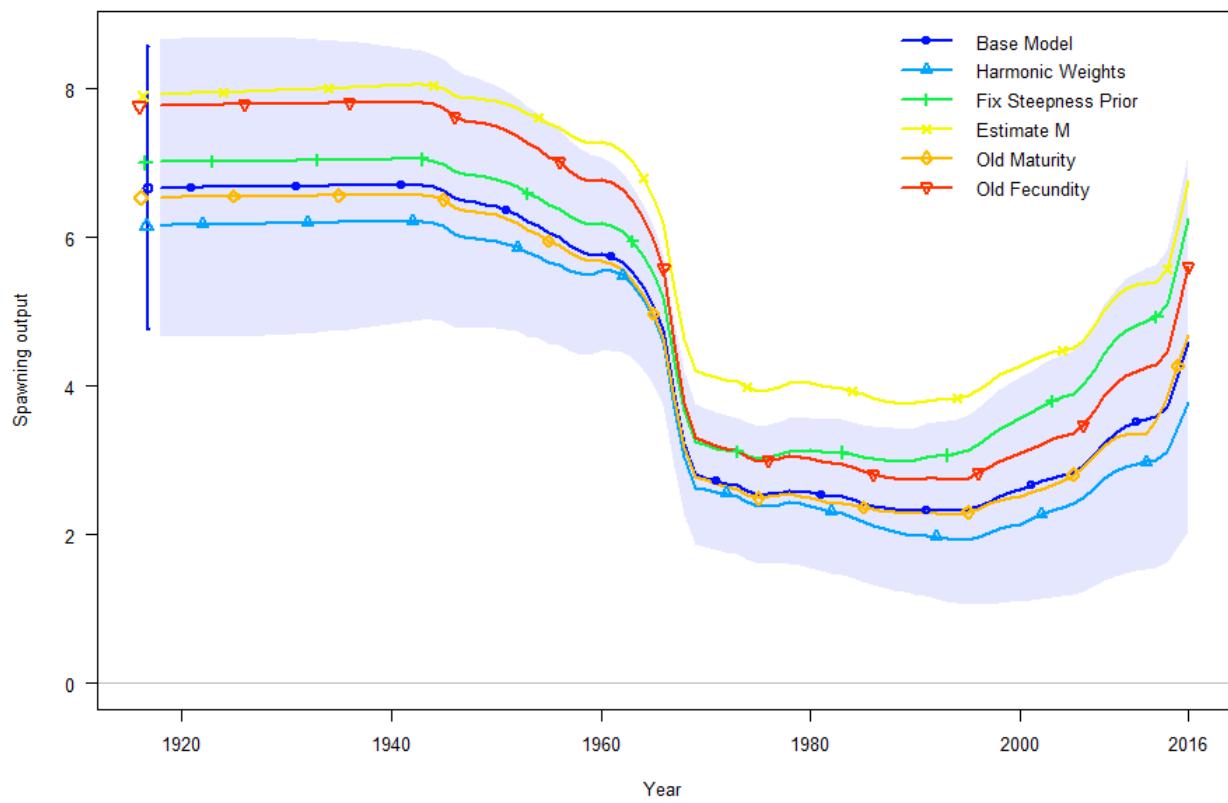


Figure 79: Time-series of spawning output for model sensitivities for Pacific ocean perch.

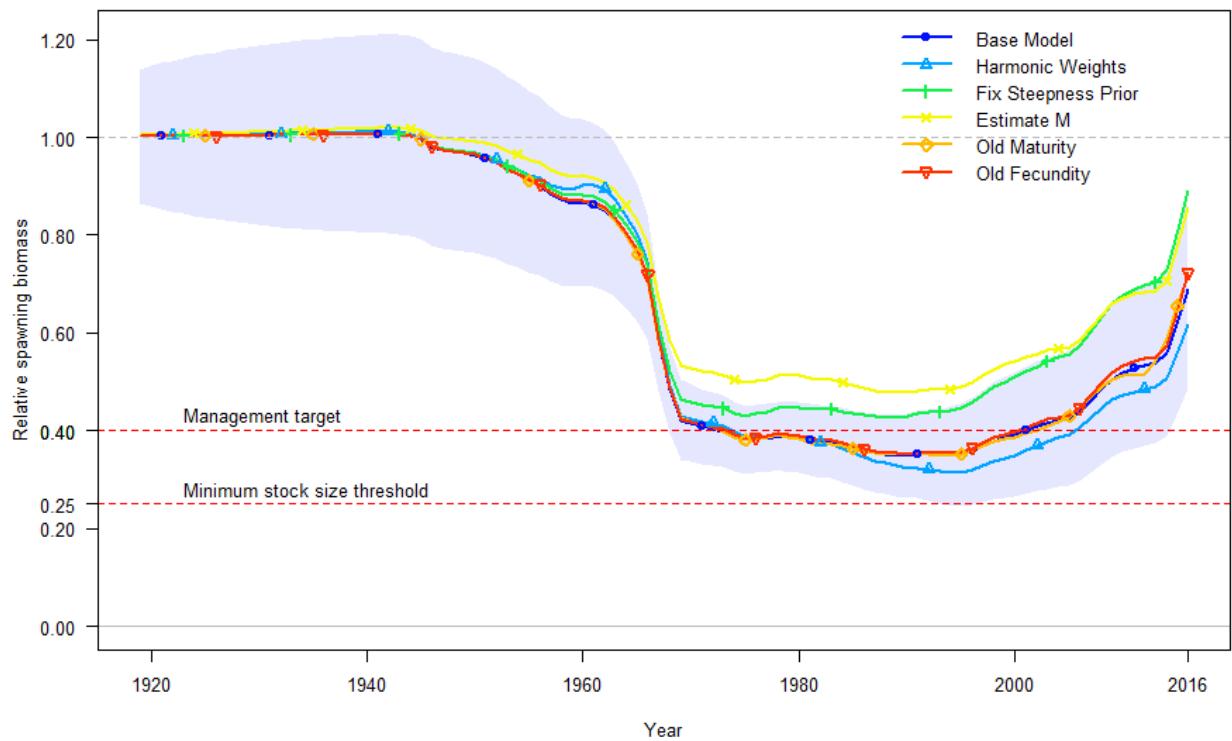


Figure 80: Time-series of relative biomass for model sensitivities for Pacific ocean perch.

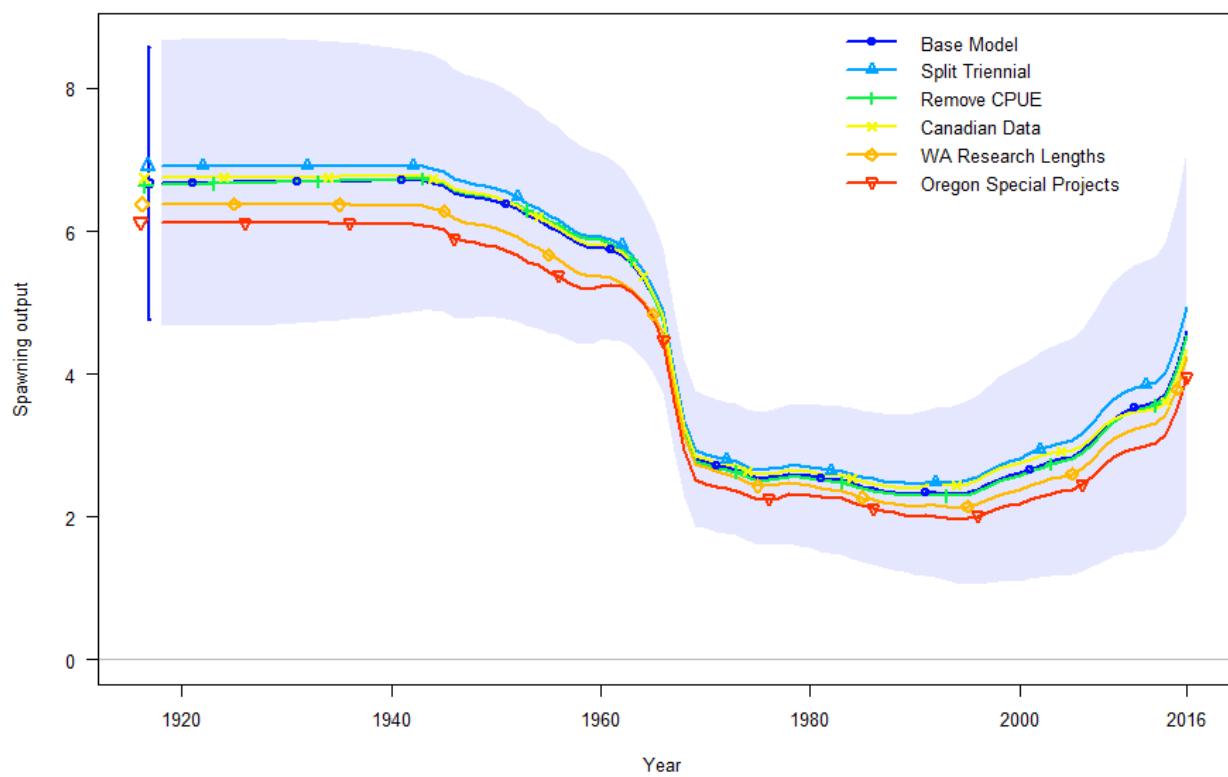


Figure 81: Time-series of spawning output for model sensitivities for Pacific ocean perch.

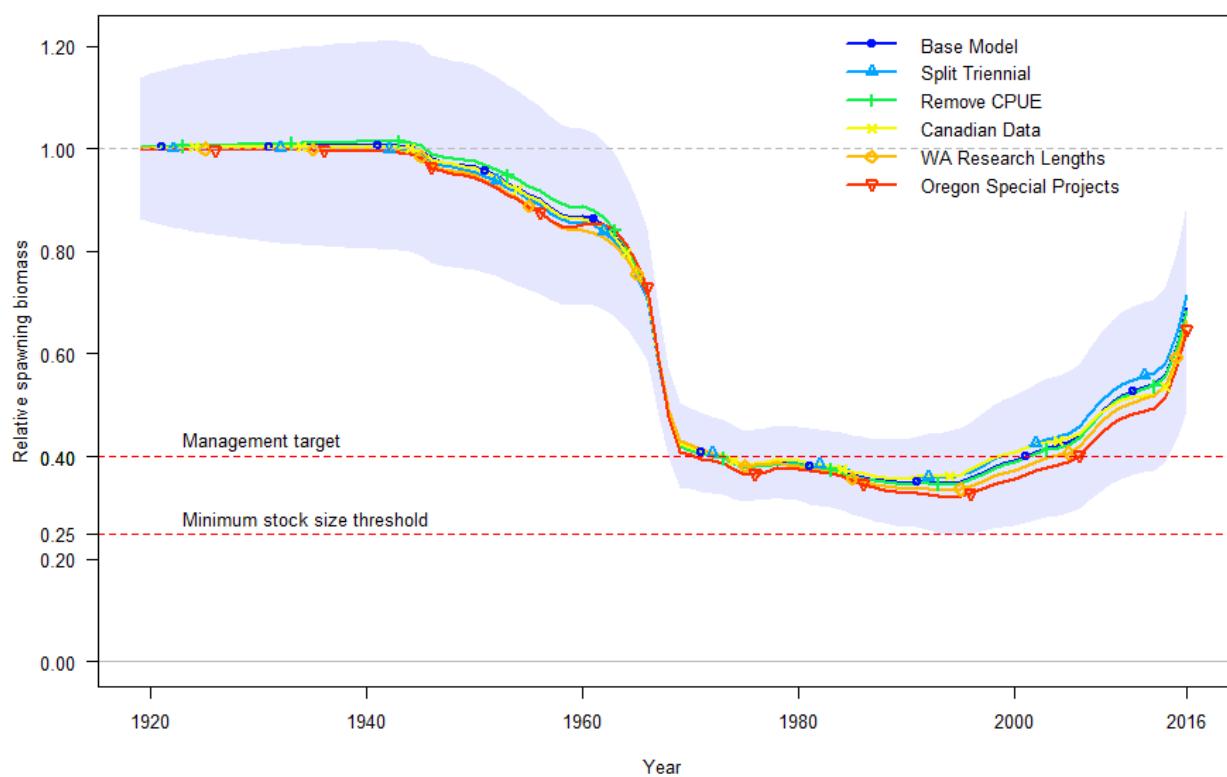


Figure 82: Time-series of relative biomass for model sensitivities for Pacific ocean perch.

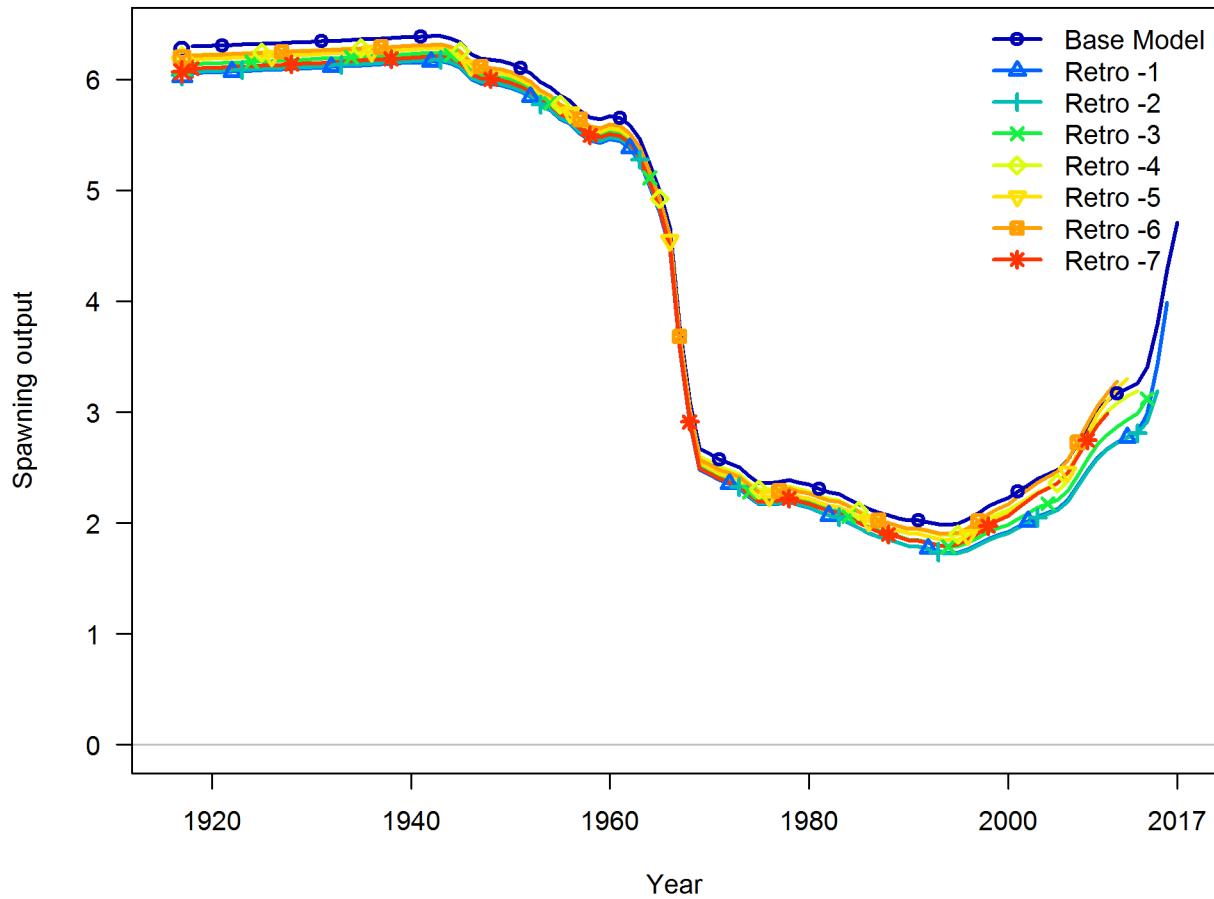


Figure 83: Retrospective pattern for spawning output.

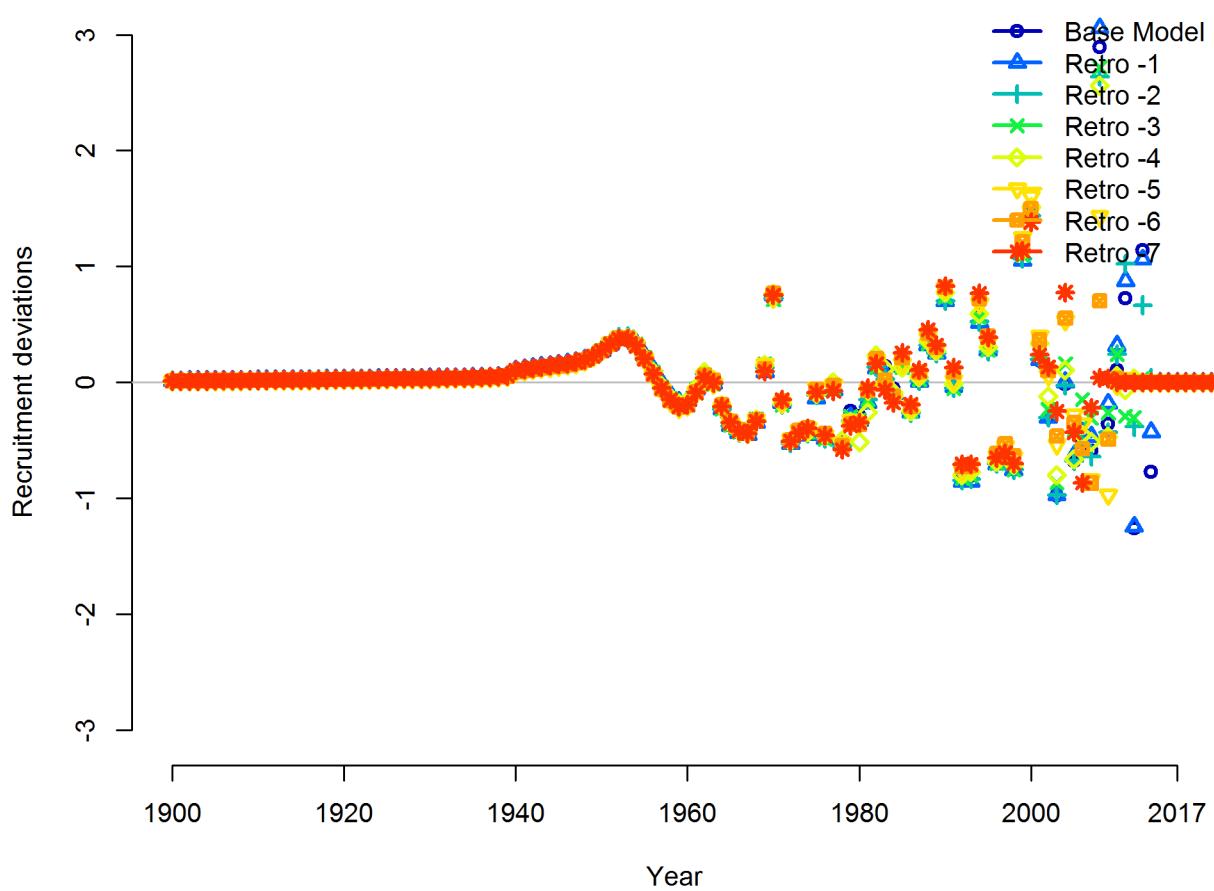


Figure 84: Retrospective pattern for estimated recruitment deviations.

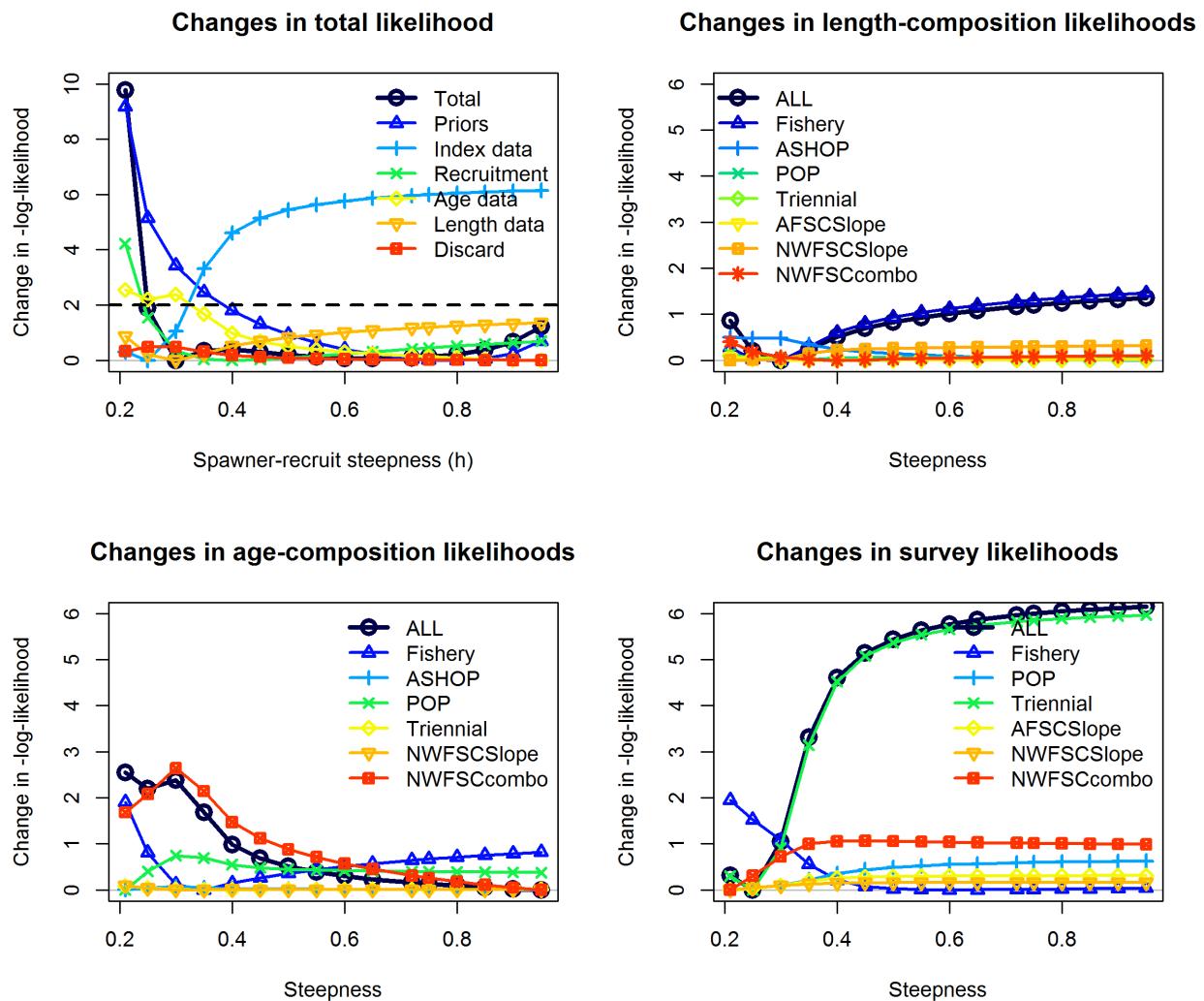


Figure 85: Likelihood profile across steepness values.

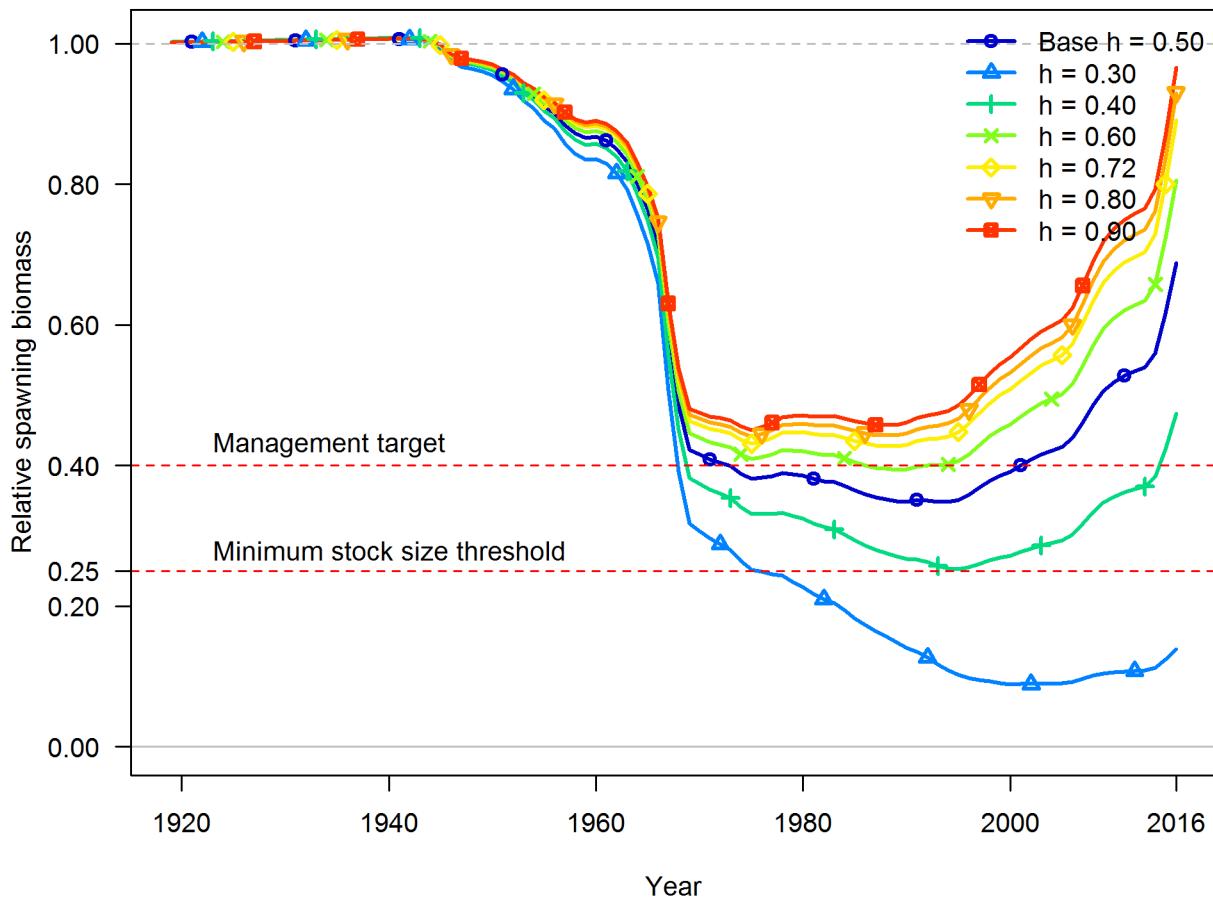


Figure 86: Trajectories of relative biomass across values of steepness.

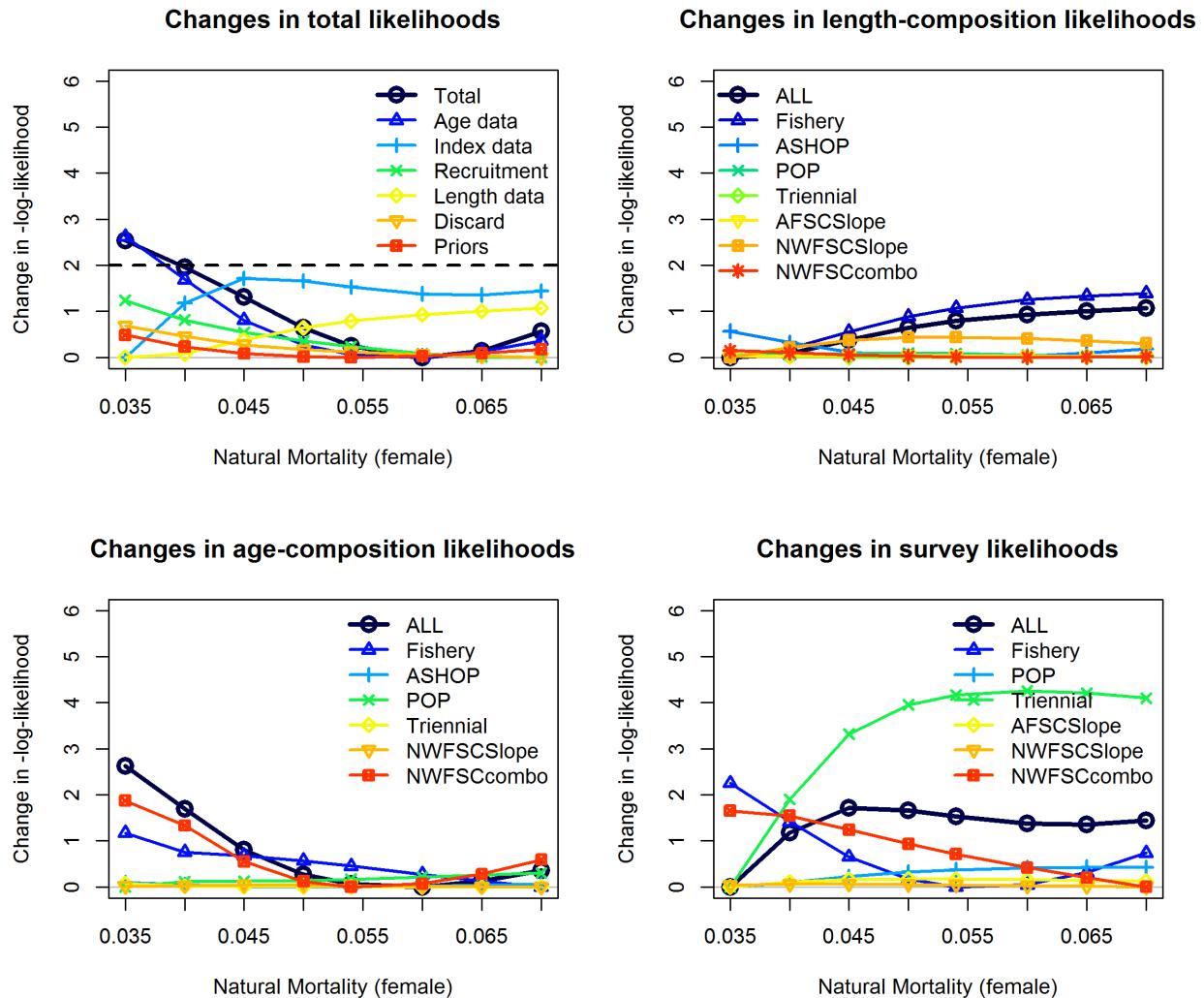


Figure 87: Likelihood profile across natural mortality values.

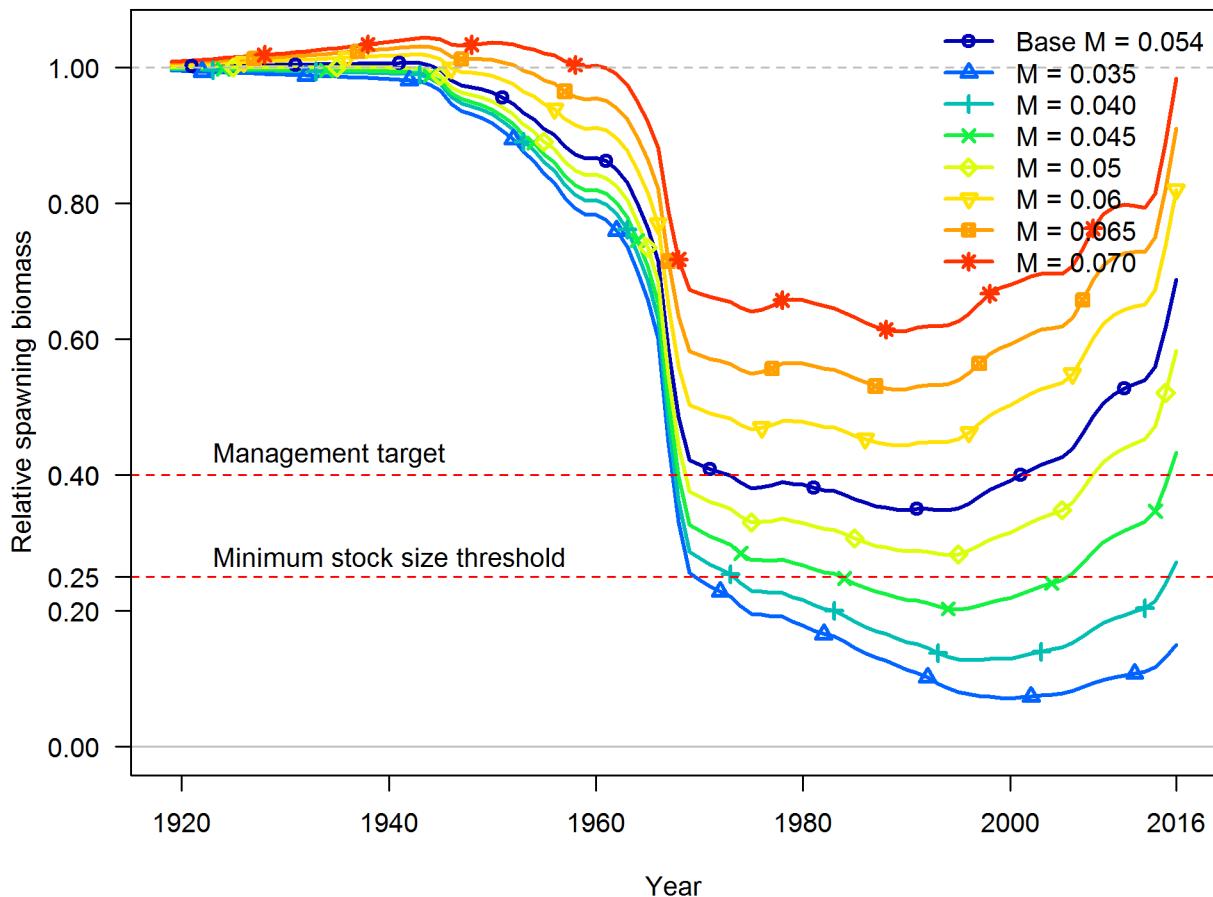


Figure 88: Trajectories of relative biomass across values of natural mortality.

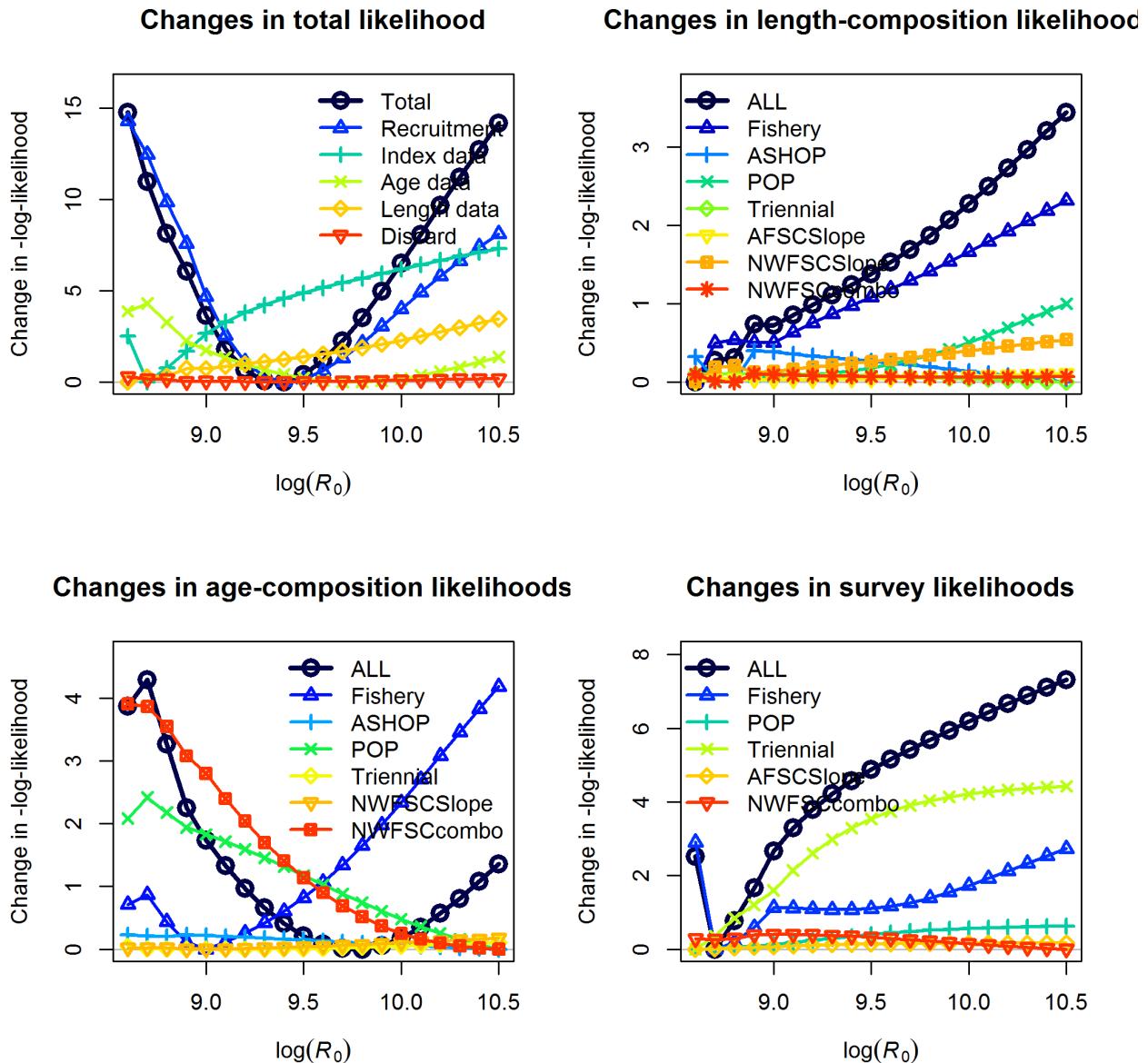


Figure 89: Likelihood profile across R_0 values.

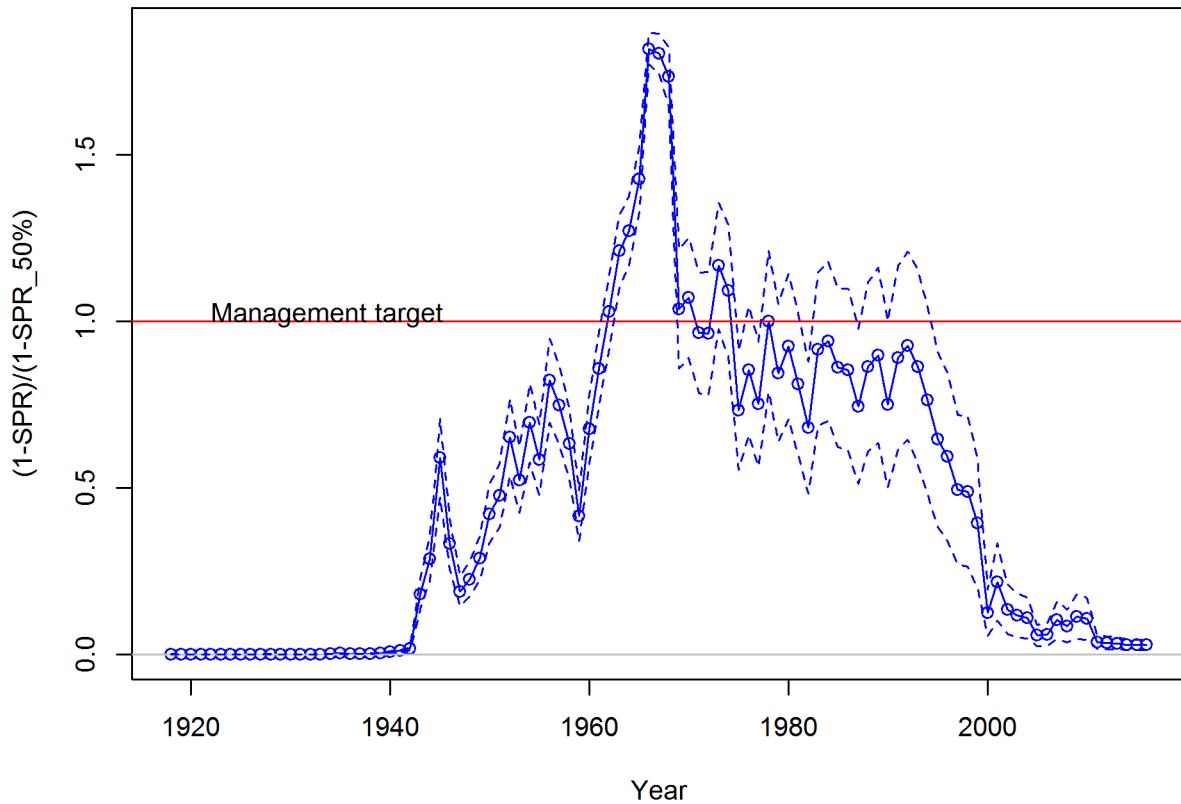


Figure 90: Estimated spawning potential ratio $(1-\text{SPR})/(1-\text{SPR}_{50\%})$ for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR50% harvest rate. The last year in the time series is 2016.

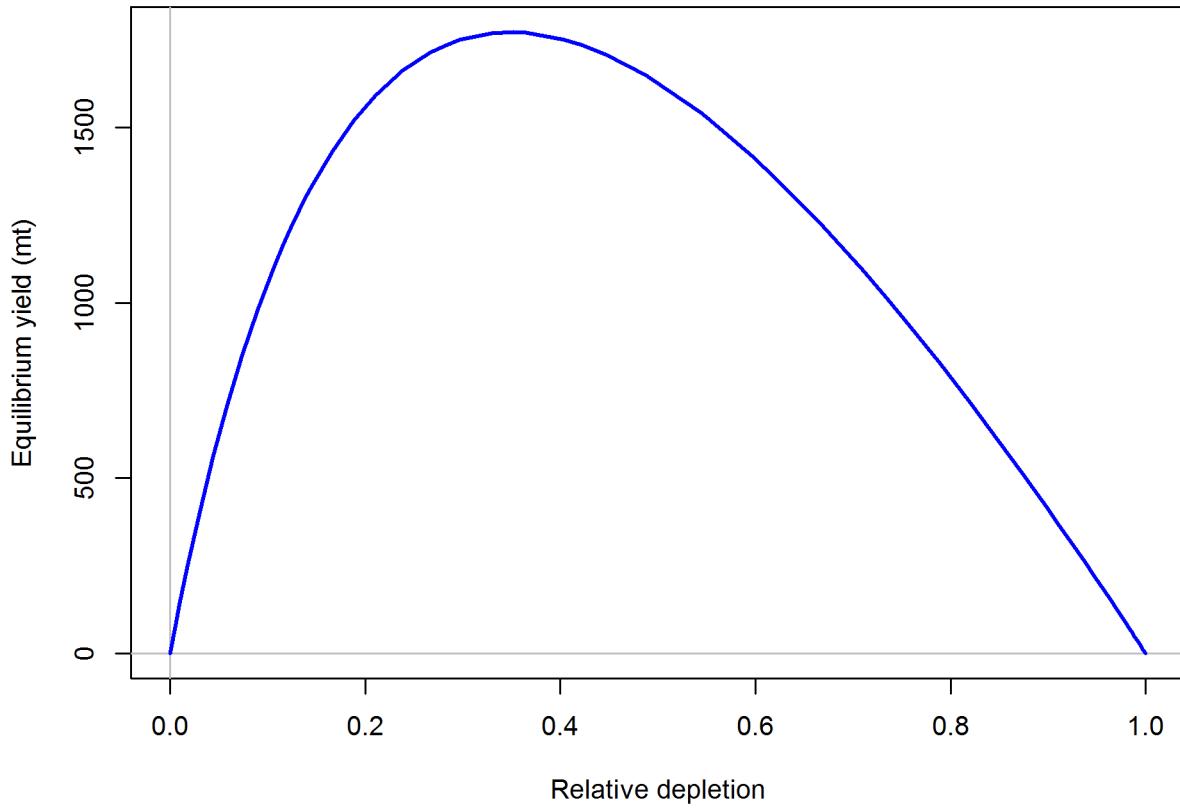


Figure 91: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.50.

1303 **10 Appendix A. Detailed Fit to Length Composition**
1304 **Data**

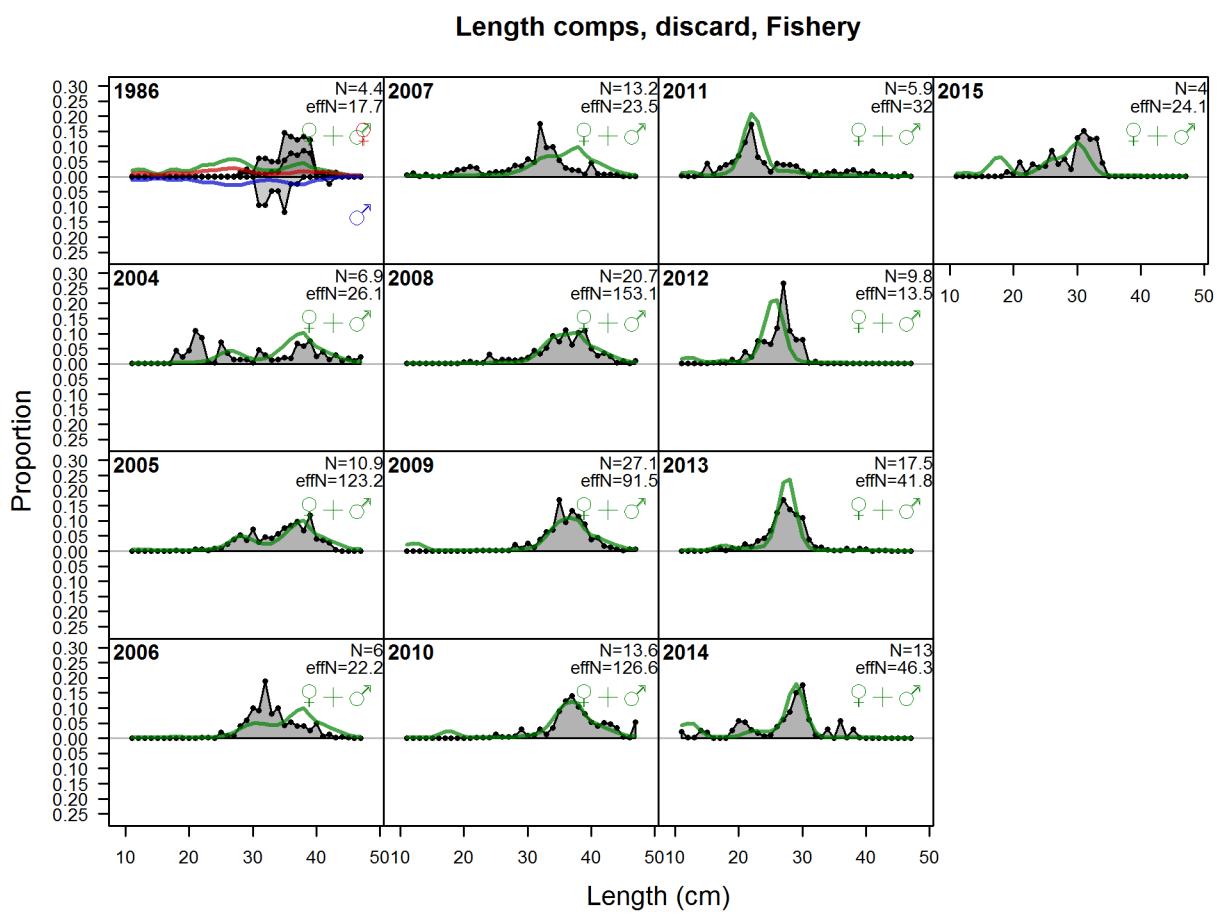


Figure 92: Length comps, discard, Fishery

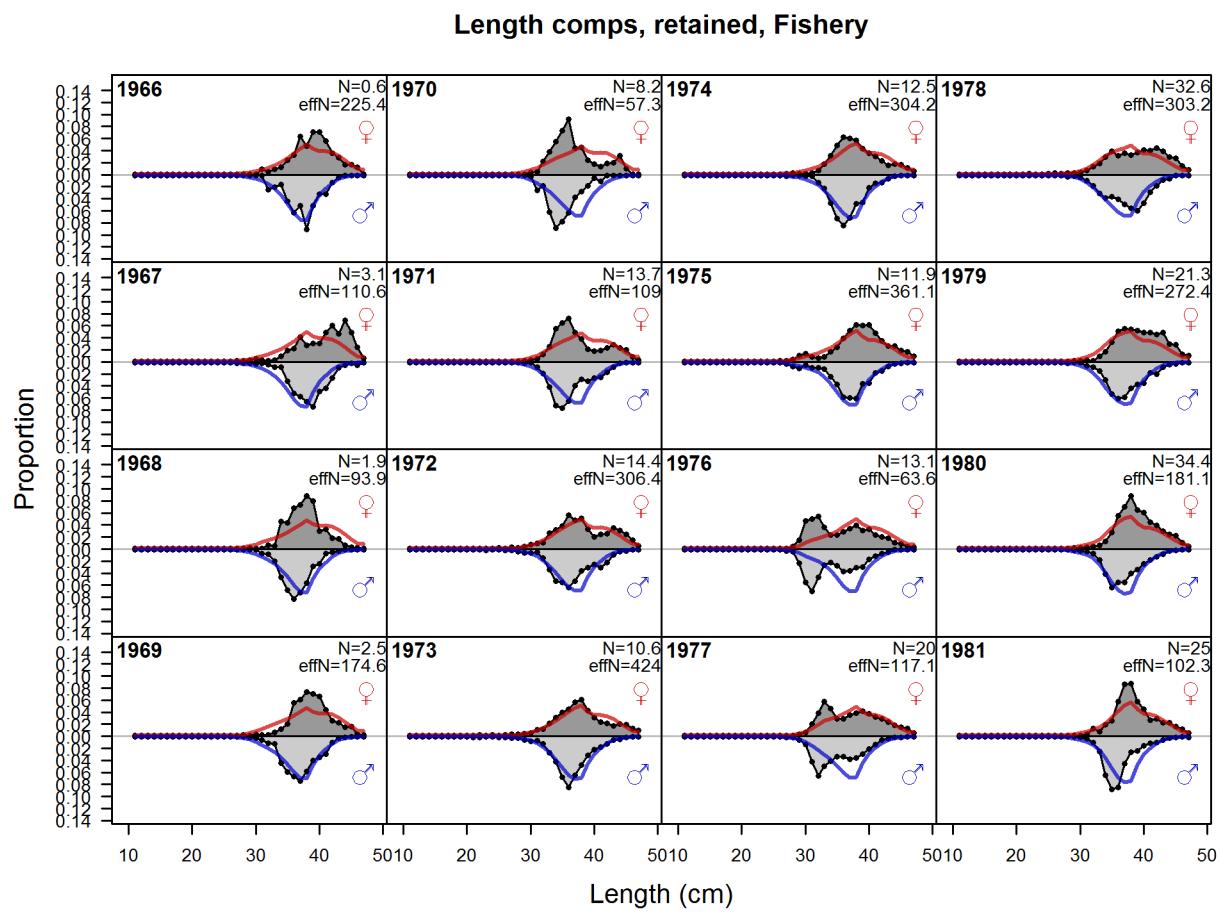


Figure 93: Length comps, retained, Fishery (plot 1 of 4)

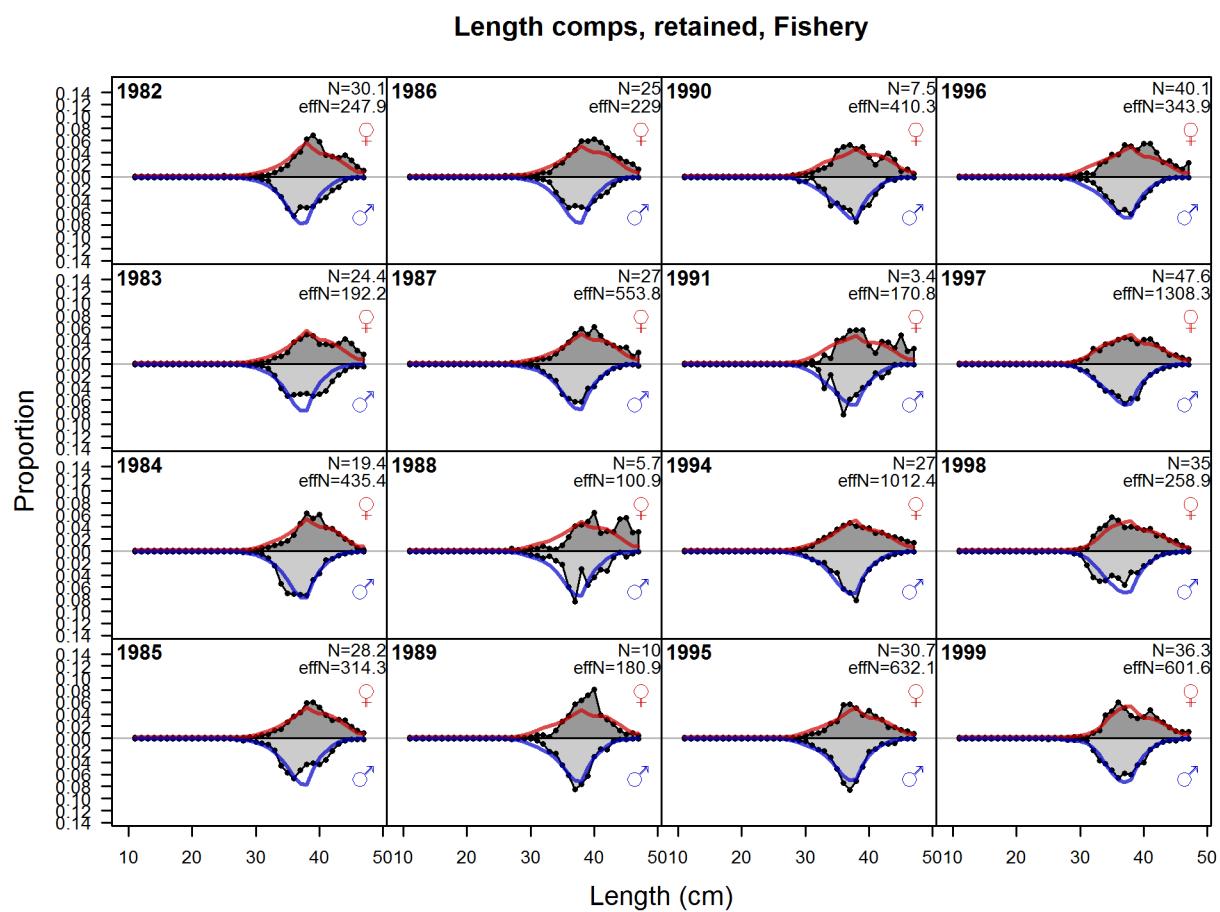


Figure 94: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4)

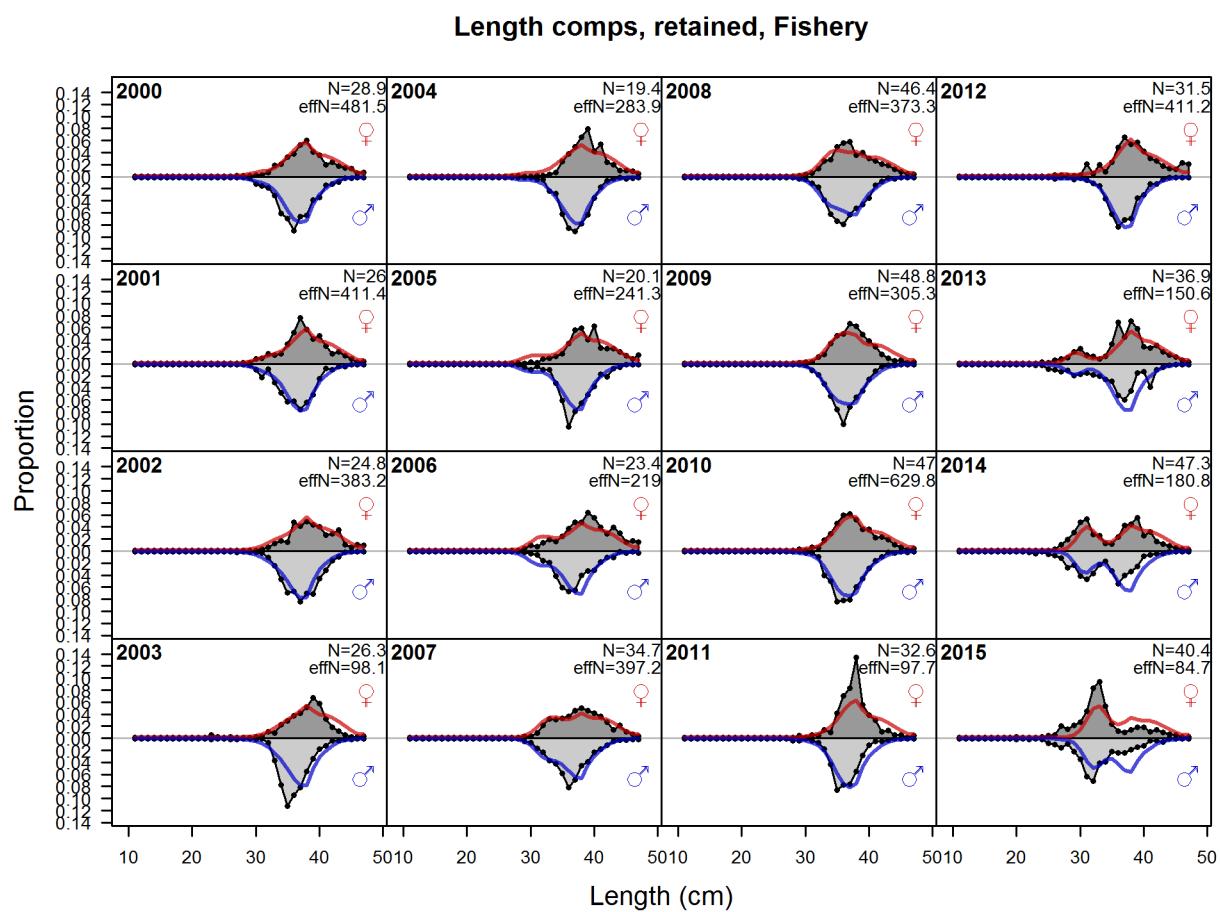
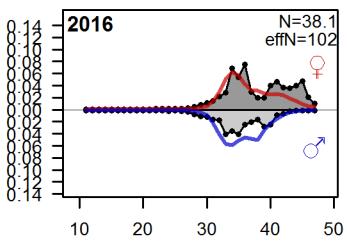


Figure 95: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4) (plot 3 of 4)

Proportion

Length comps, retained, Fishery



Length (cm)

Figure 96: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4) (plot 3 of 4) (plot 4 of 4)

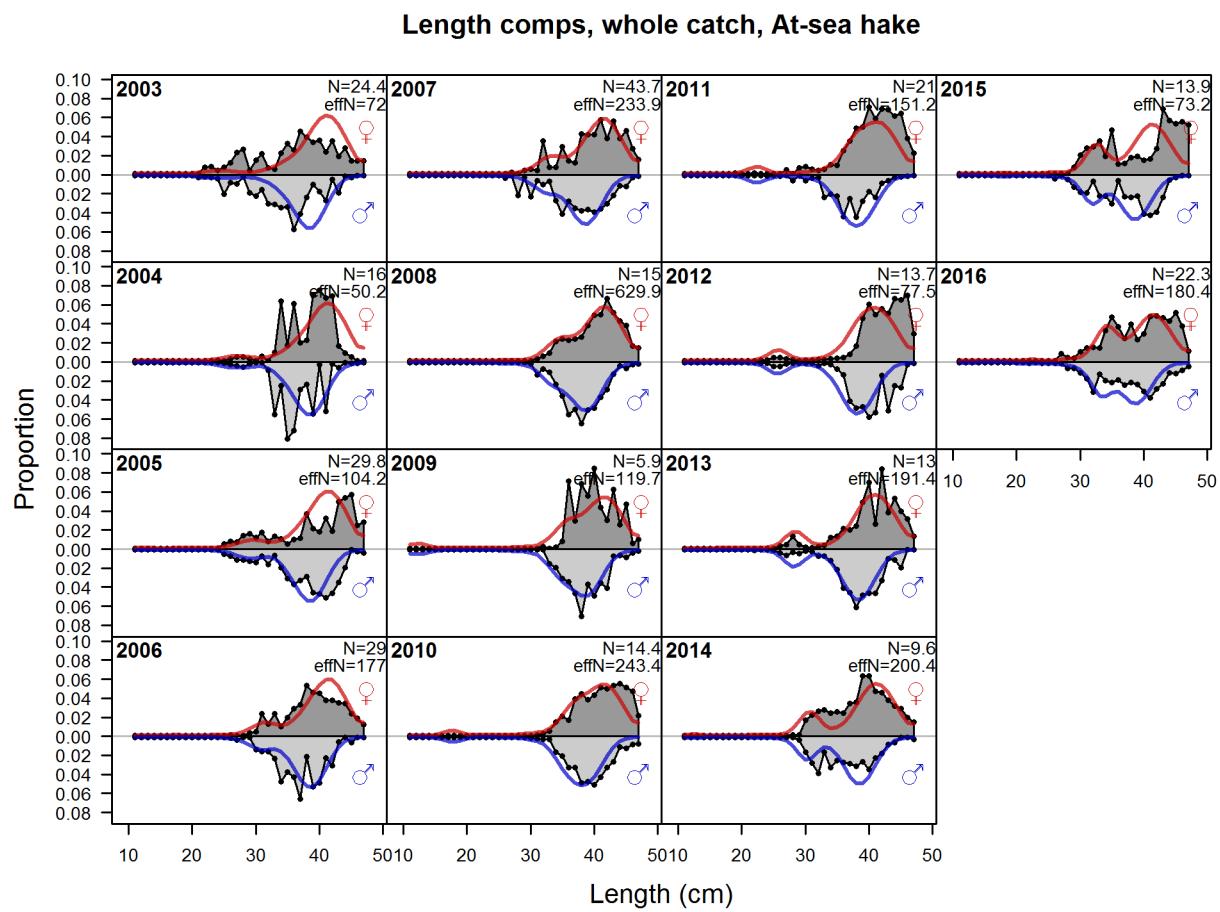


Figure 97: Length comps, whole catch, At_sea hake

Length comps, whole catch, Pacific ocean perch survey

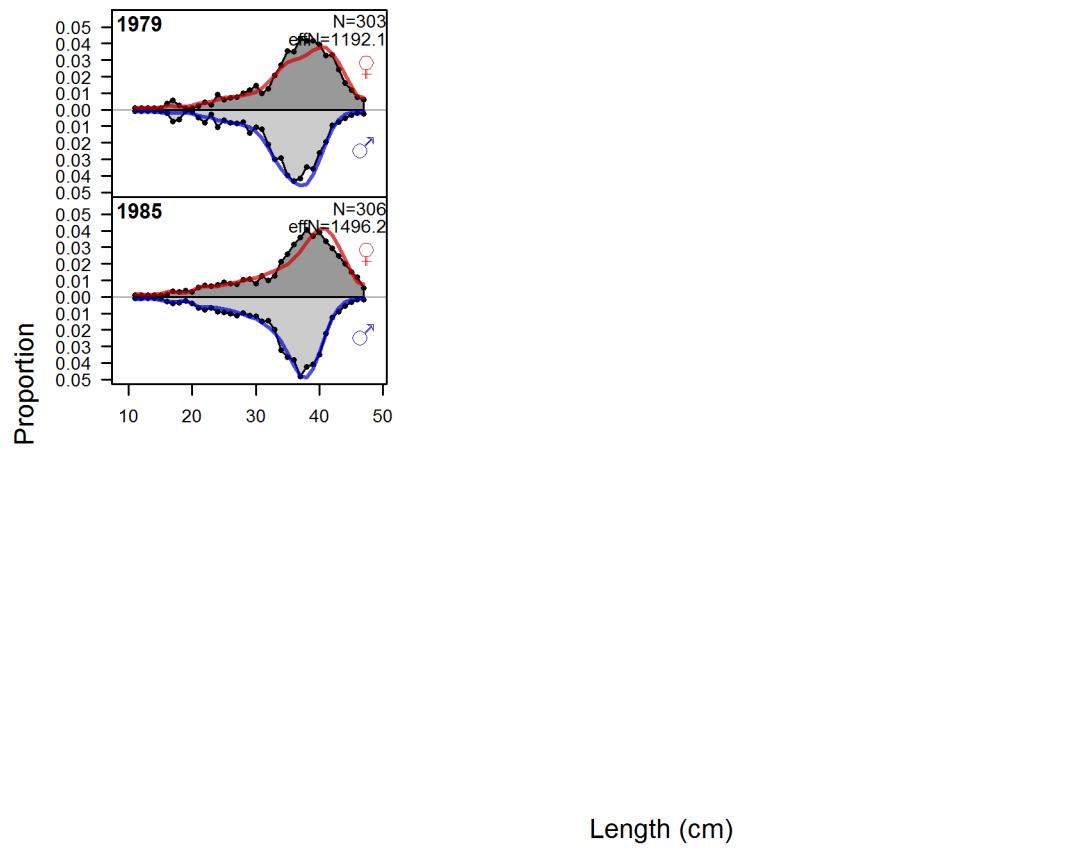


Figure 98: Length comps, whole catch, Pacific ocean perch survey

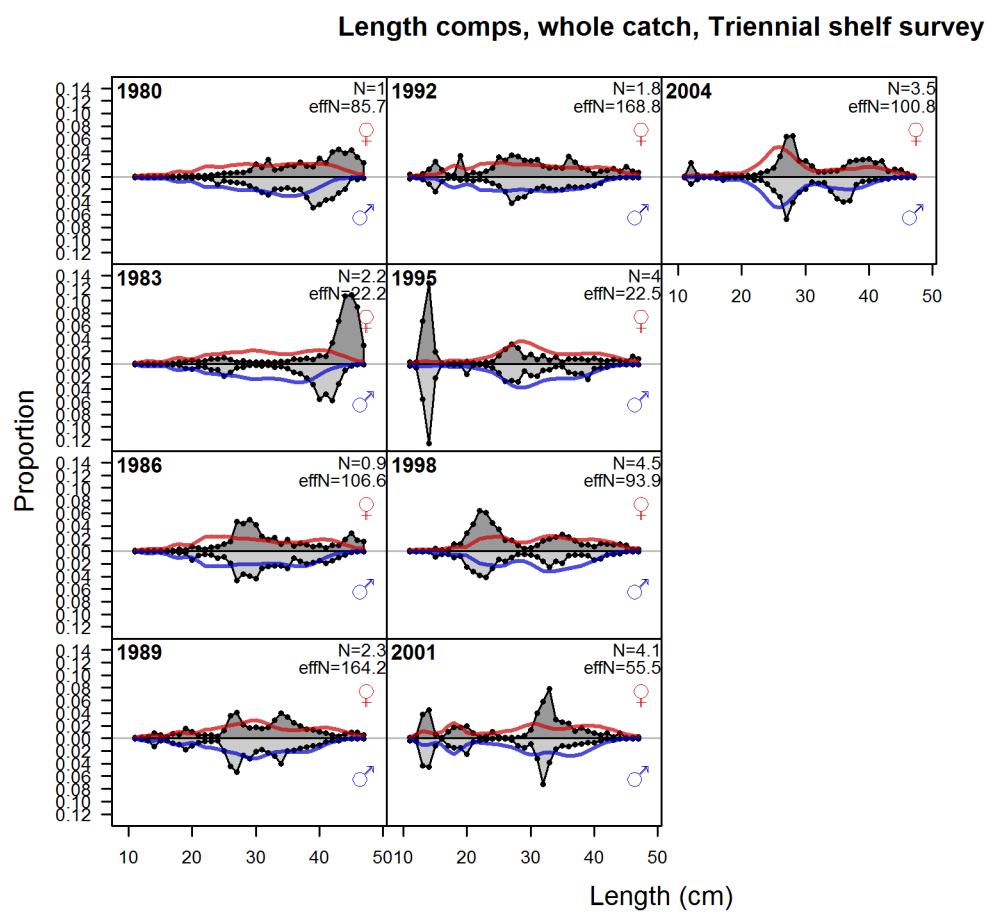


Figure 99: Length comps, whole catch, Triennial shelf survey

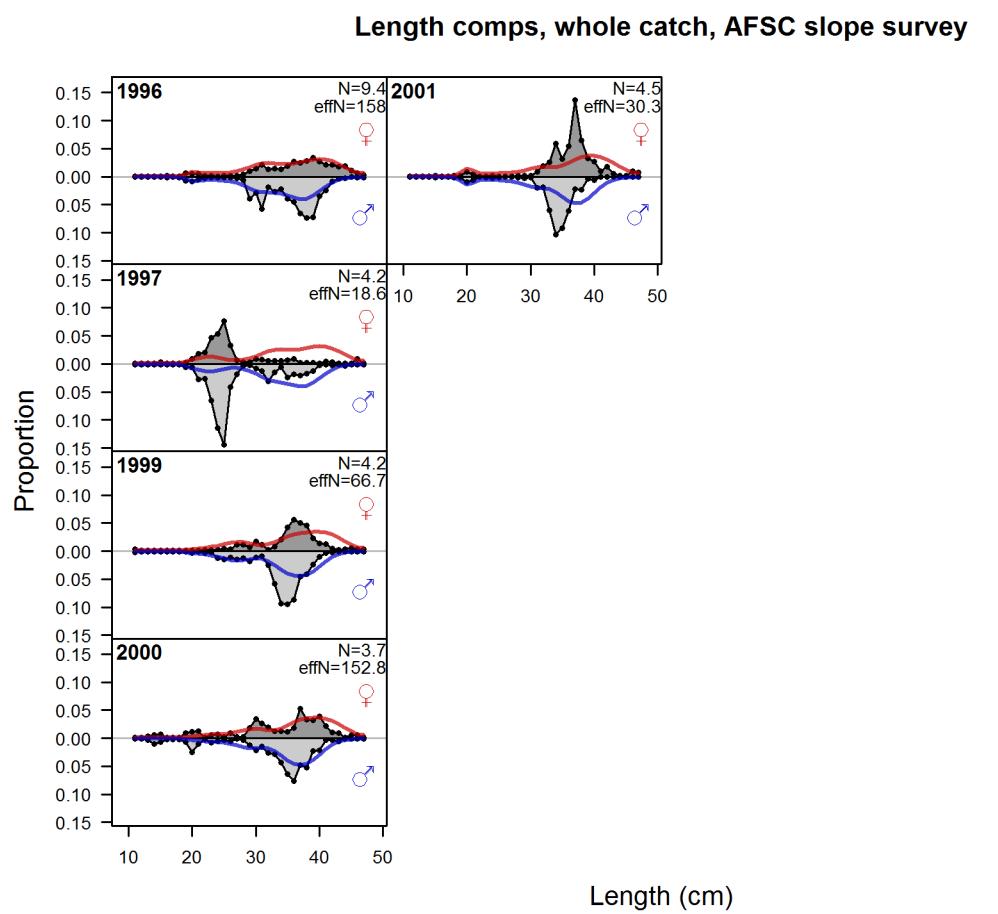


Figure 100: Length comps, whole catch, AFSC slope survey

Length comps, whole catch, NWFSC slope survey

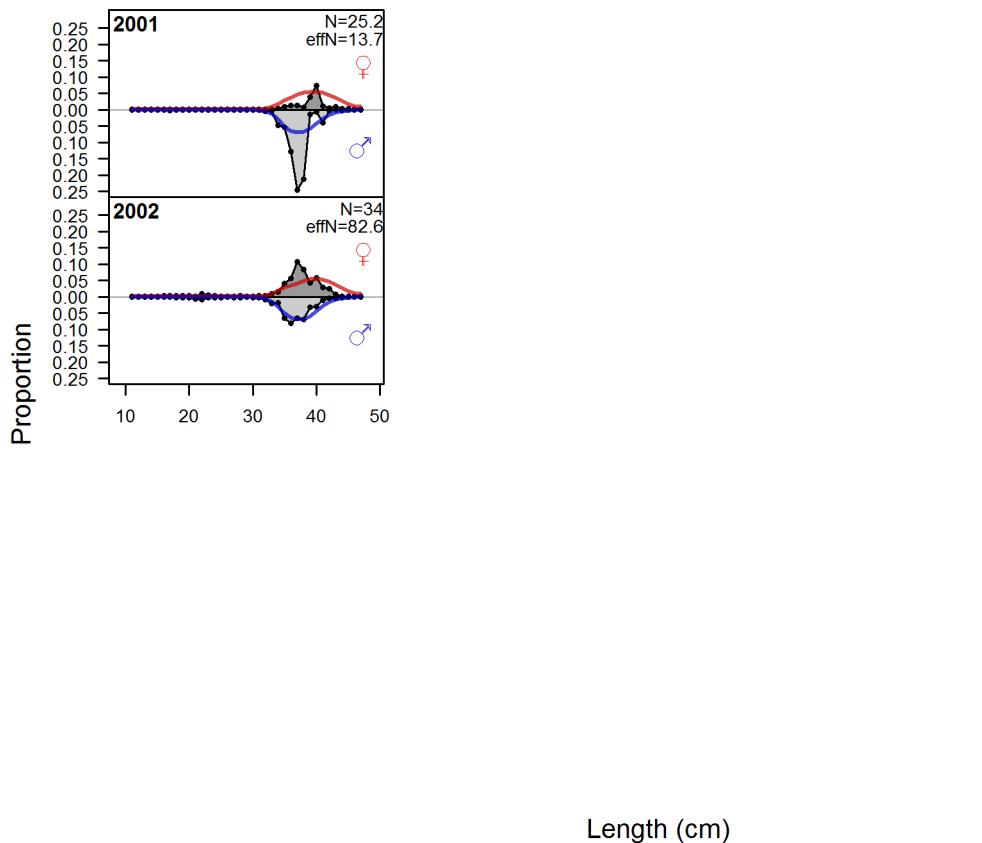


Figure 101: Length comps, whole catch, NWFSC slope survey

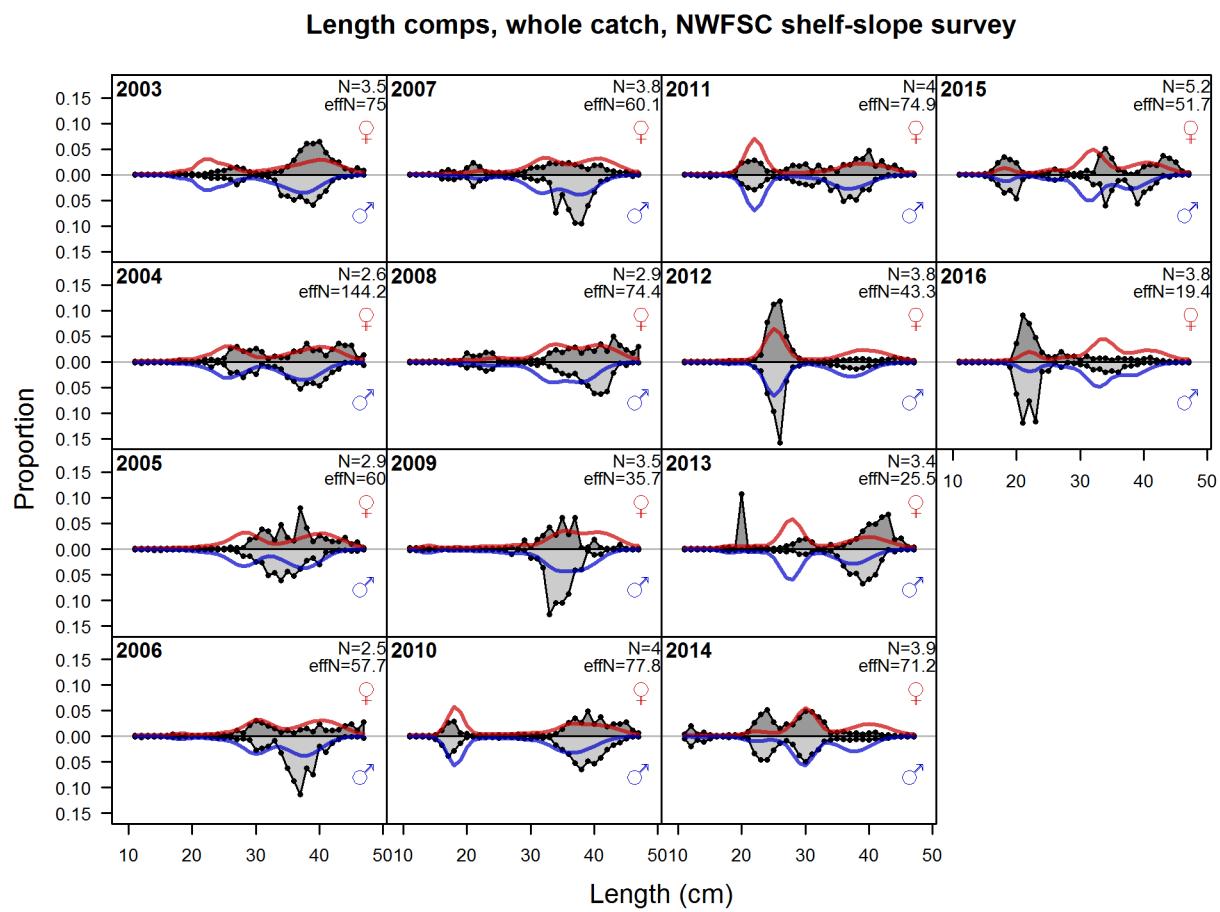


Figure 102: Length comps, whole catch, NWFSC shelf_slope survey

1305 11 Appendix B. Detailed Fit to Age Composition Data

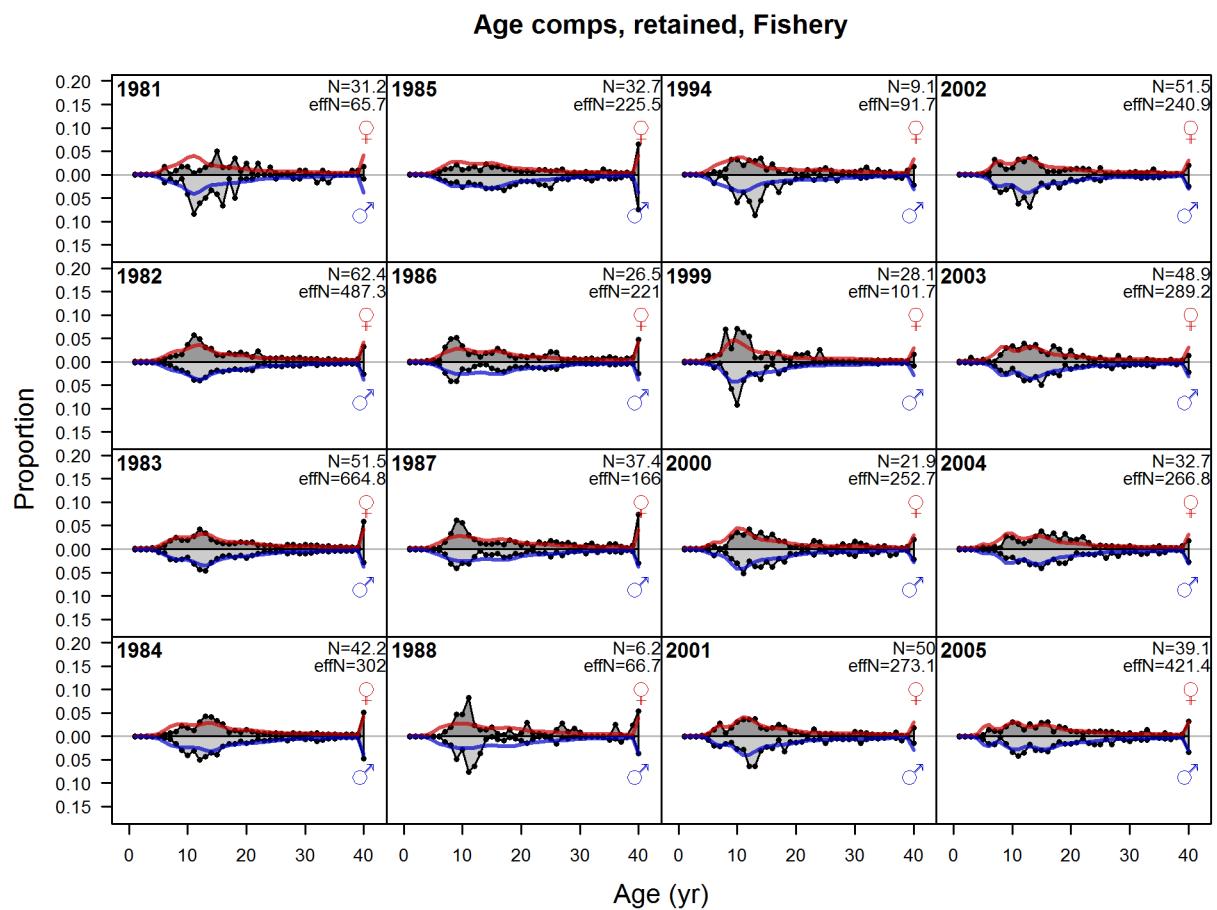


Figure 103: Age comps, retained, Fishery (plot 1 of 2)

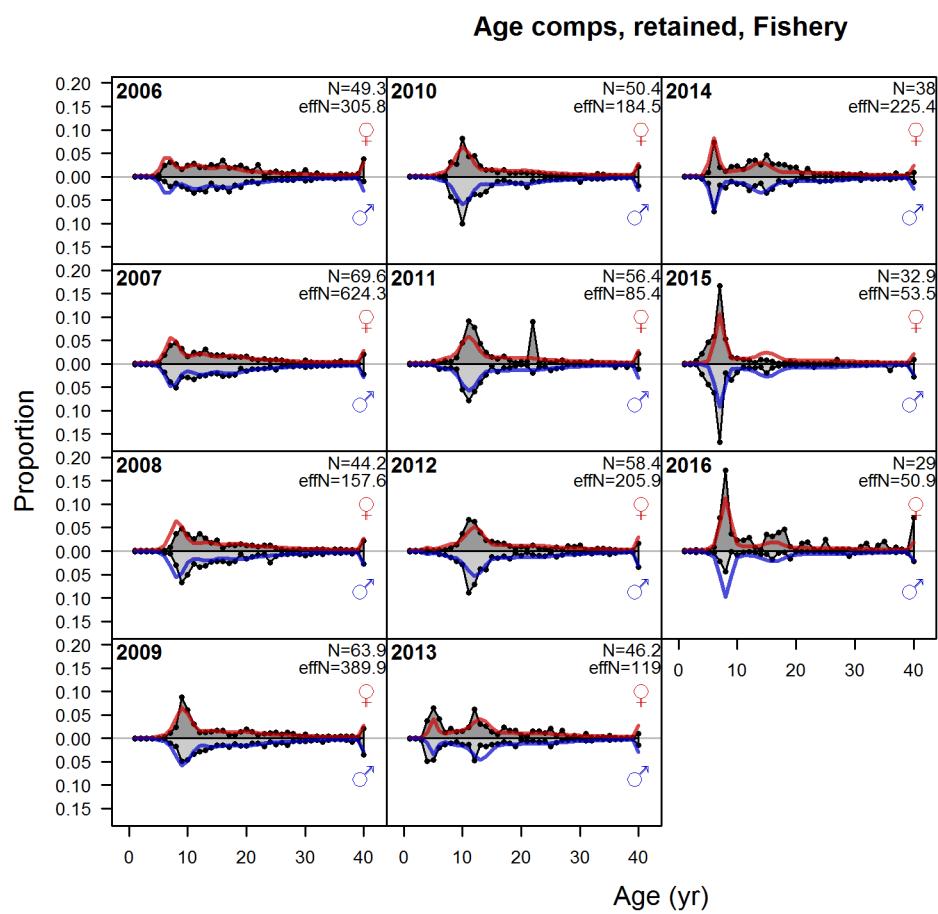


Figure 104: Age comps, retained, Fishery (plot 1 of 2) (plot 2 of 2)

Age comps, whole catch, At-sea hake

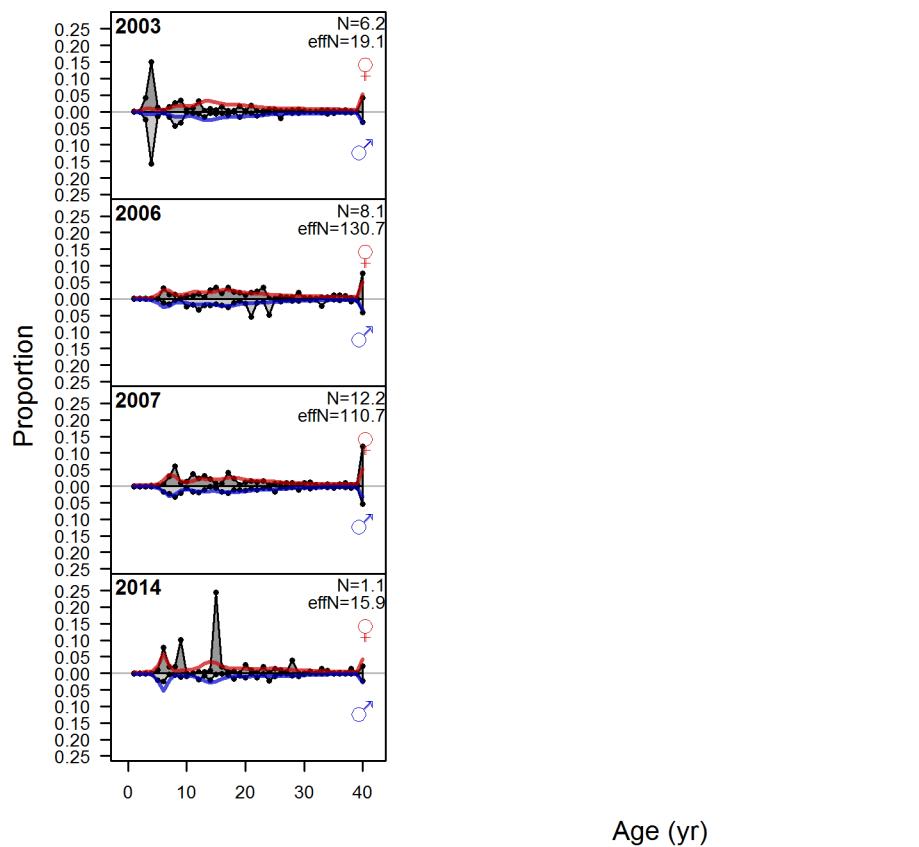
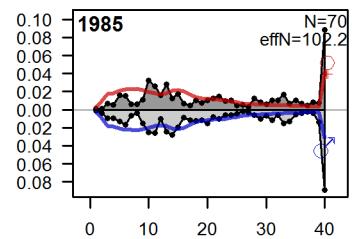


Figure 105: Age comps, whole catch, At_sea hake

Age comps, whole catch, Pacific ocean perch survey



Age (yr)

Figure 106: Age comps, whole catch, Pacific ocean perch survey

Age comps, whole catch, Triennial shelf survey

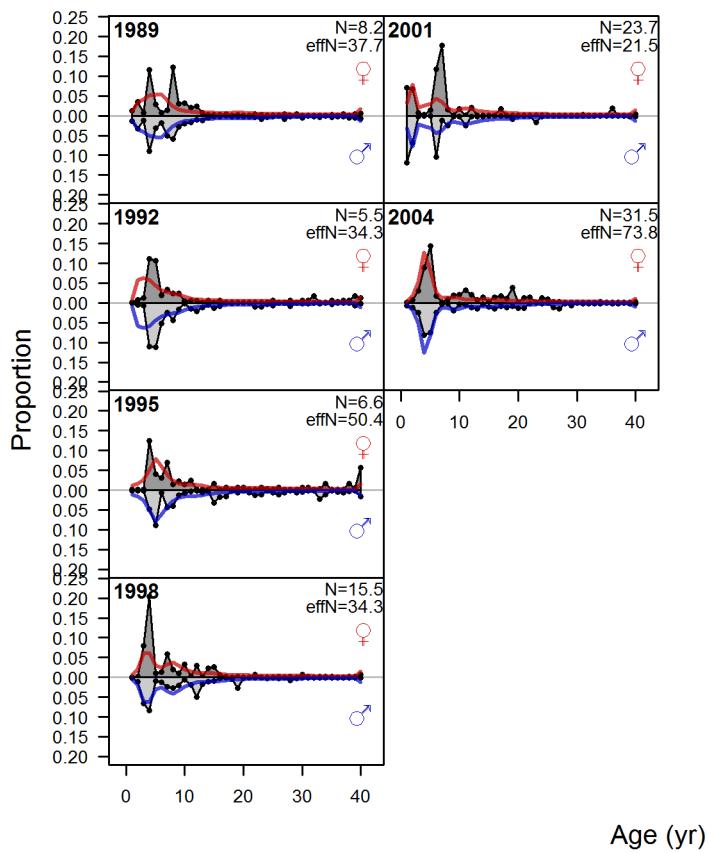


Figure 107: Age comps, whole catch, Triennial shelf survey

Age comps, whole catch, NWFSC slope survey

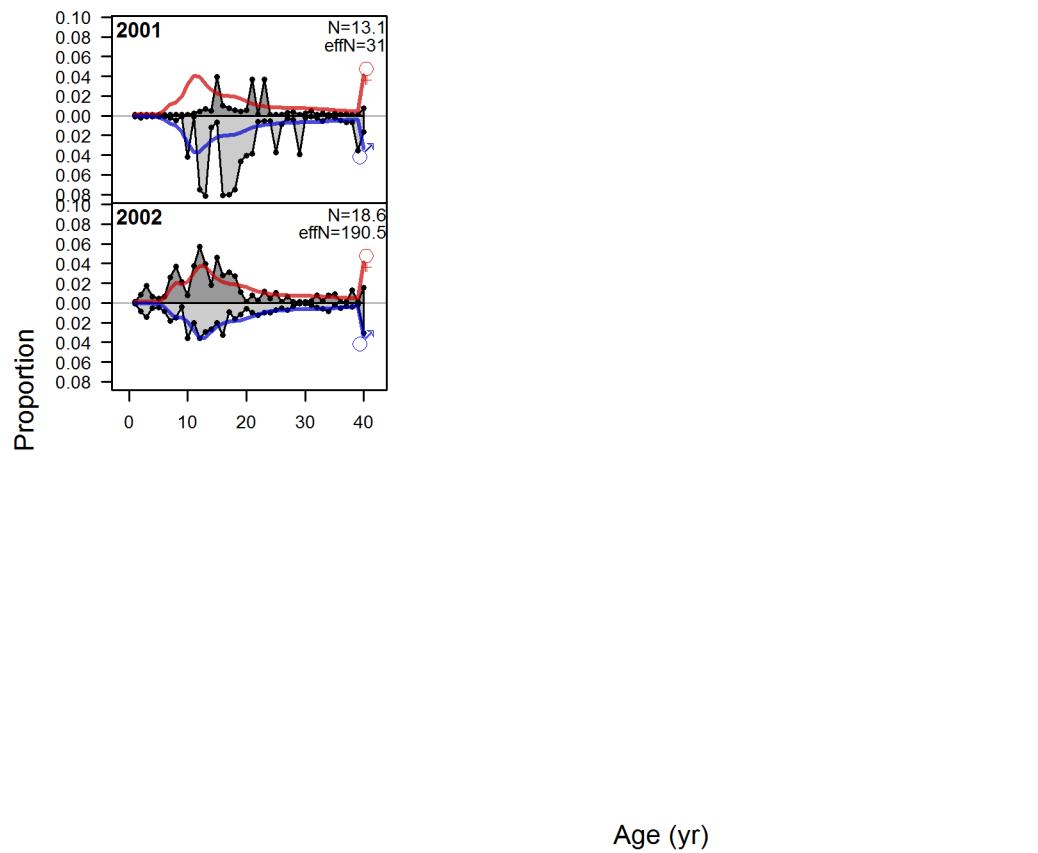


Figure 108: Age comps, whole catch, NWFSC slope survey

Pearson residuals, female, retained, comparing across fleets

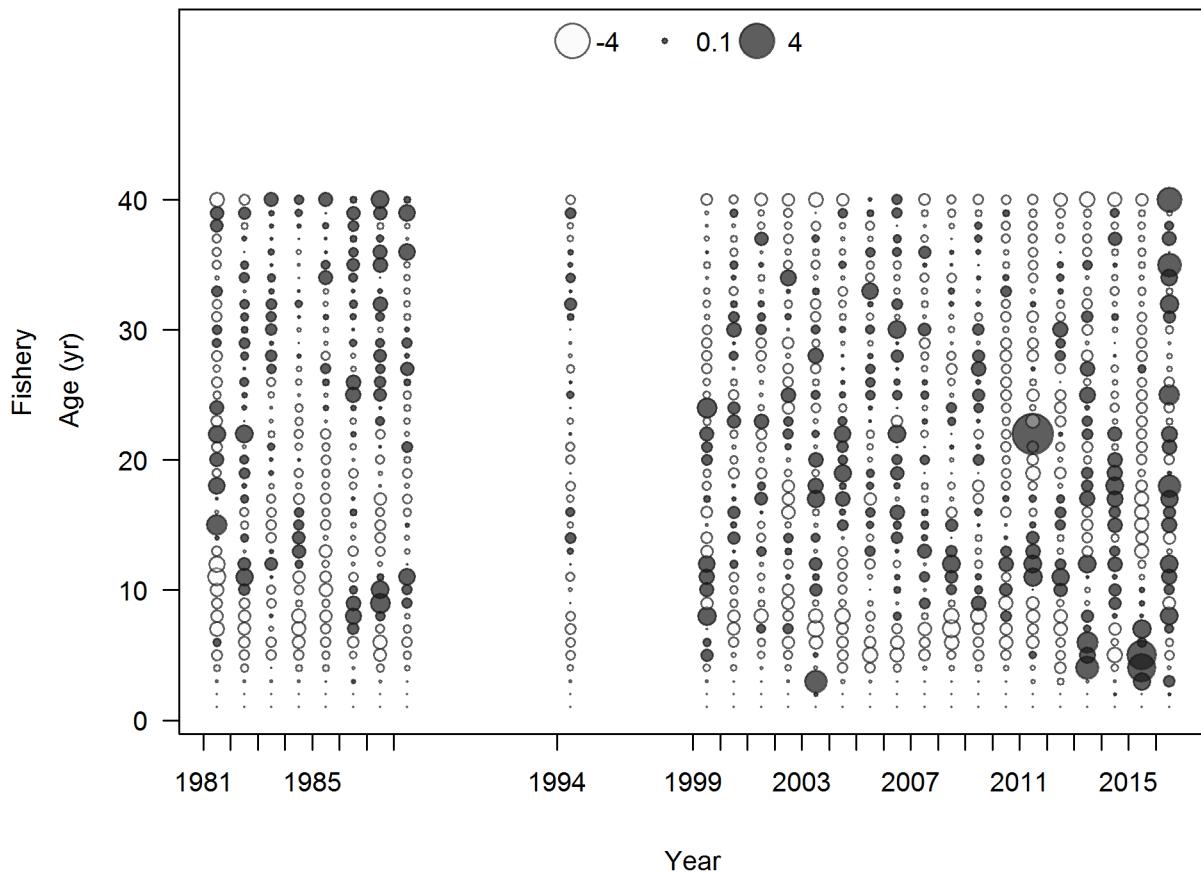


Figure 109: Note: this plot doesn't seem to be working right for some models. Pearson residuals, female, retained, comparing across fleets

Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

1306 **12 References**

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