

A detailed illustration of a Red Porgy (Lutjanus campechanus) fish, shown in profile facing left. The fish has a robust, deep-bodied shape. Its coloration is primarily a vibrant reddish-orange, with lighter, almost white, areas on the belly and around the eyes. The dorsal fin is prominent, featuring a series of sharp, pointed spines. The pectoral fins are also visible, showing a similar reddish hue. The head is large with a prominent eye and a slightly open mouth. The overall appearance is that of a healthy, mature specimen.

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DRAFT SAFE

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

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85 Executive Summary

executive-summary

86 Stock

stock

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

97 Landings

landings

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

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

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

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

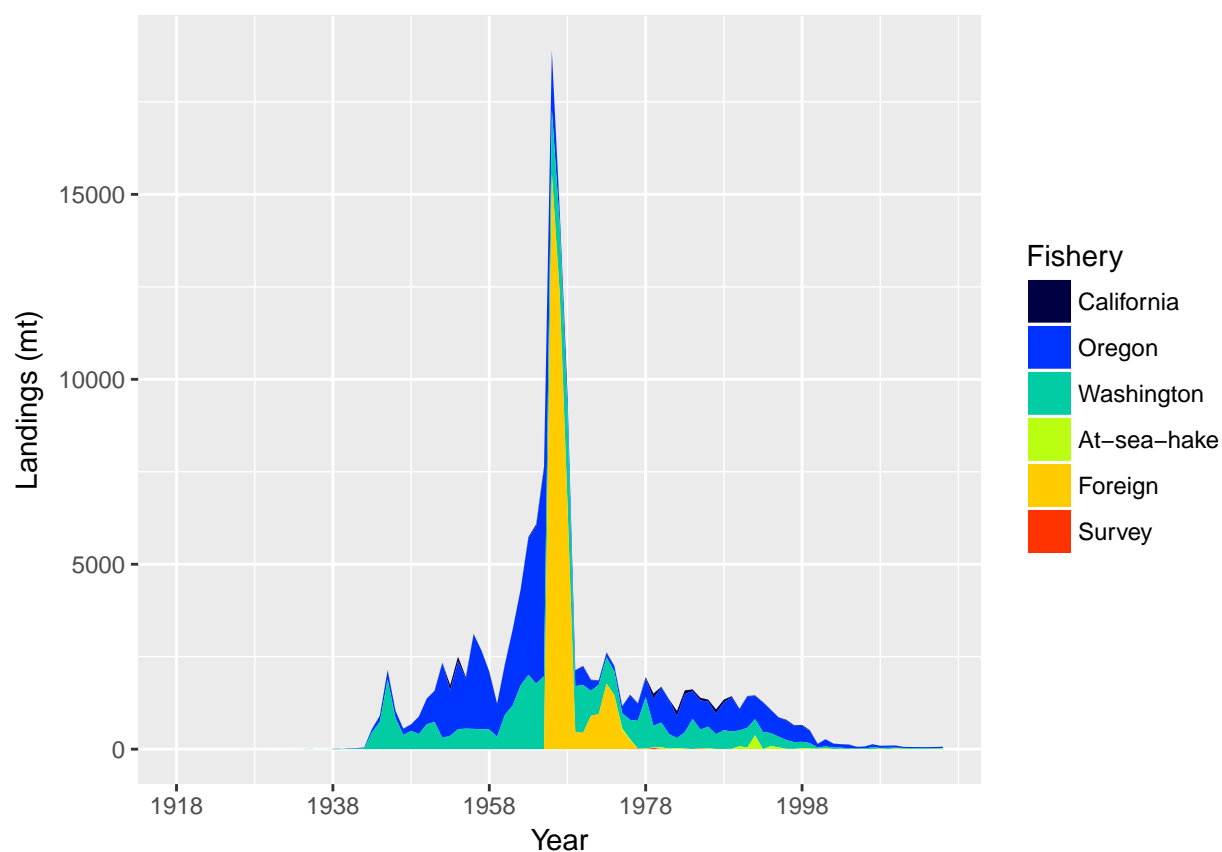


Figure a: Landings of Pacific ocean perch for California, Oregon, Washington, the Foreign fishery (1966-1976), At-Sea Hake fishery, and fishery independent surveys. fig:Exec_catch1

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

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

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

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

A number of sources of uncertainty are explicitly included in this assessment. For example, allowance is made for uncertainty in survey catchability coefficients. Furthermore, this assessment includes gender differences in growth, a non-linear relationship between individual spawner biomass and effective spawning output, and an updated relationship between length and maturity, based upon non-published information (M. Head, personal communication).

As is always the case, overall uncertainty is greater than that predicted by a single model specification. Among other sources of uncertainty that are not included in the current model are the degree of connectivity between the stocks of Pacific ocean perch off of Vancouver Island, British Columbia and those in PFMC waters, and the effect of climatic variables on recruitment, growth and survival of Pacific ocean perch.

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

Stock Biomass

stock-biomass

Include: trends and current levels relative to virgin or historic levels, description of uncertainty-include table for last 10 years and graph with long term estimates.

Spawning output Figure: Figure b
Spawning output Table(s): Table b
Relative depletion Figure: Figure c

Example text (remove Models 2 and 3 if not needed - if using, remove the # in-line comments!!!)
The estimated relative depletion level (spawning output relative to unfished spawning output) of the the base-case model in 2017 is 75.3% (~95% asymptotic interval: \pm 52.9%-97.7%) (Figure c).

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

tab:SpawningDeplete_mod1				
Year	Spawning Output (million eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	3175.00	1321 - 5028	0.48	0.327 - 0.642
2009	3313.00	1385 - 5242	0.50	0.342 - 0.668
2010	3409.00	1428 - 5389	0.52	0.353 - 0.687
2011	3474.00	1458 - 5489	0.53	0.360 - 0.699
2012	3522.00	1484 - 5560	0.54	0.366 - 0.708
2013	3563.00	1508 - 5618	0.54	0.372 - 0.715
2014	3697.00	1578 - 5816	0.56	0.388 - 0.739
2015	4063.00	1758 - 6368	0.62	0.430 - 0.809
2016	4535.00	1986 - 7085	0.69	0.484 - 0.899
2017	4939.00	2179 - 7698	0.75	0.529 - 0.977

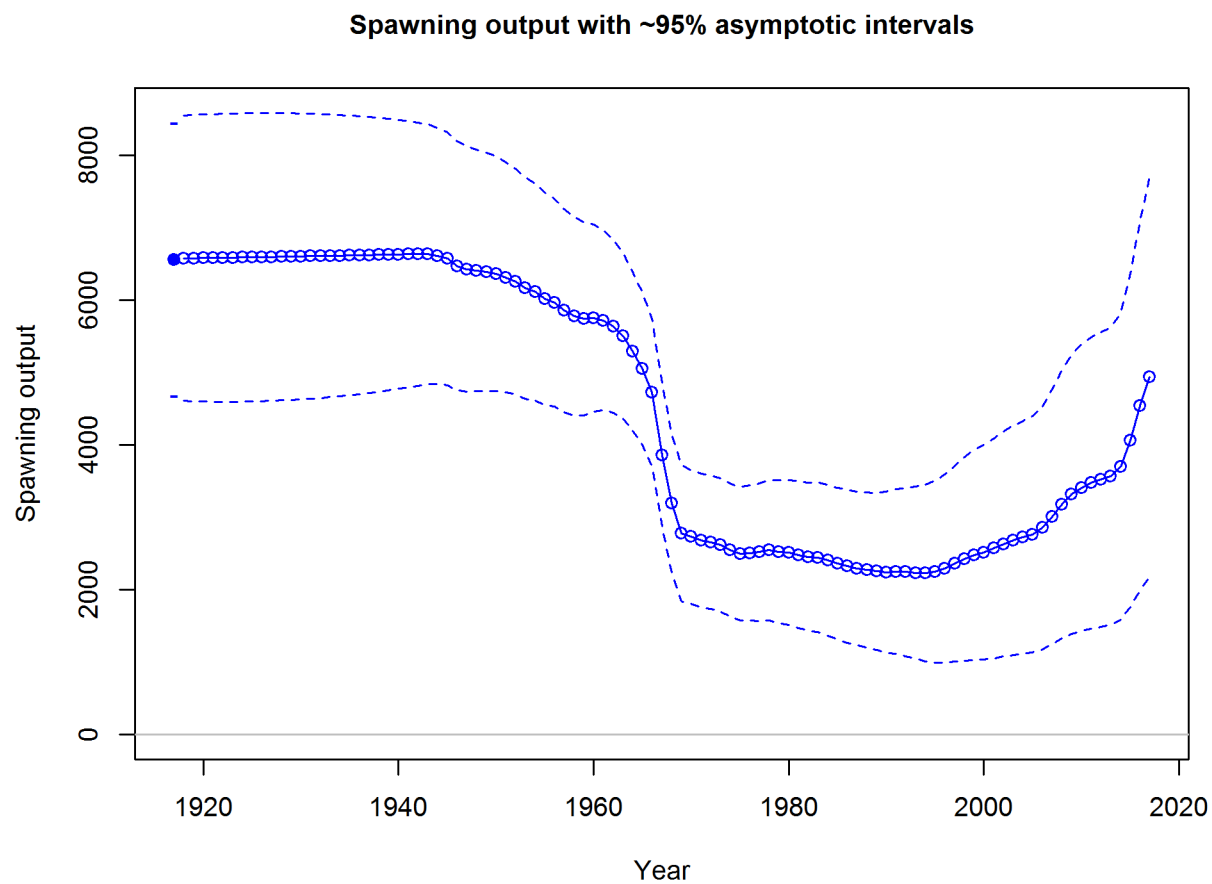


Figure b: Time series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model. fig:Spawnbio_all

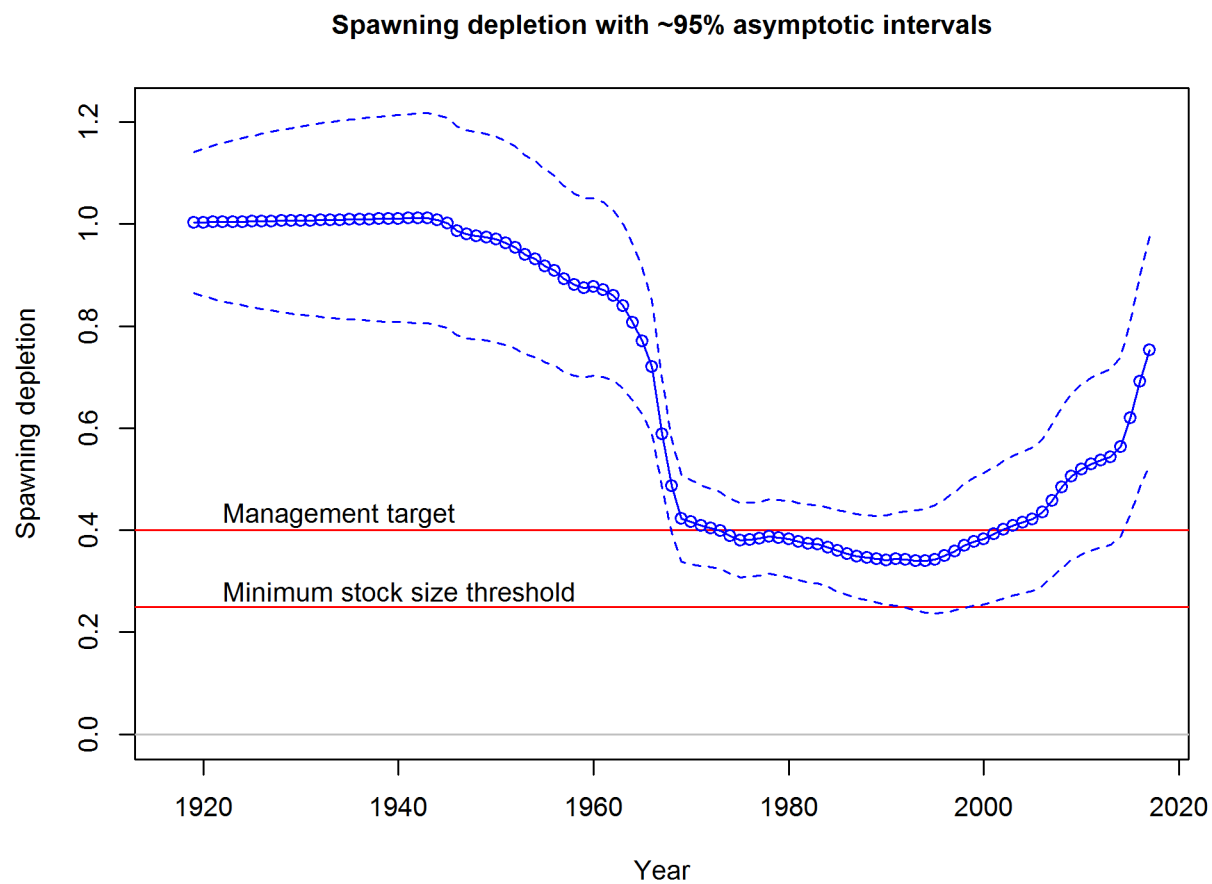


Figure c: Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. fig:RelDeplete_all

Recruitment

recruitment

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

Recruitment Figure: (Figure d)

Recruitment Tables: (Tables c)

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

Year	Estimated Recruitment	~ 95% confidence interval	Estimated Recruitment Devs.	~ 95% confidence interval
2008	127258.00	71750 - 225709	2.80	2.485 - 3.113
2009	4856.00	2030 - 11618	-0.48	-1.283 - 0.314
2010	7683.00	3639 - 16220	-0.04	-0.661 - 0.588
2011	14600.00	7244 - 29424	0.60	0.035 - 1.161
2012	2130.00	871 - 5206	-1.33	-2.173 - -0.492
2013	25607.00	11738 - 55865	1.06	0.382 - 1.747
2014	4445.00	1533 - 12885	-0.79	-1.862 - 0.289
2015	10066.00	2817 - 35967	-0.00	-1.372 - 1.366
2016	10478.00	2931 - 37454	0.00	-1.372 - 1.372
2017	10763.00	3014 - 38432	0.00	-1.372 - 1.372

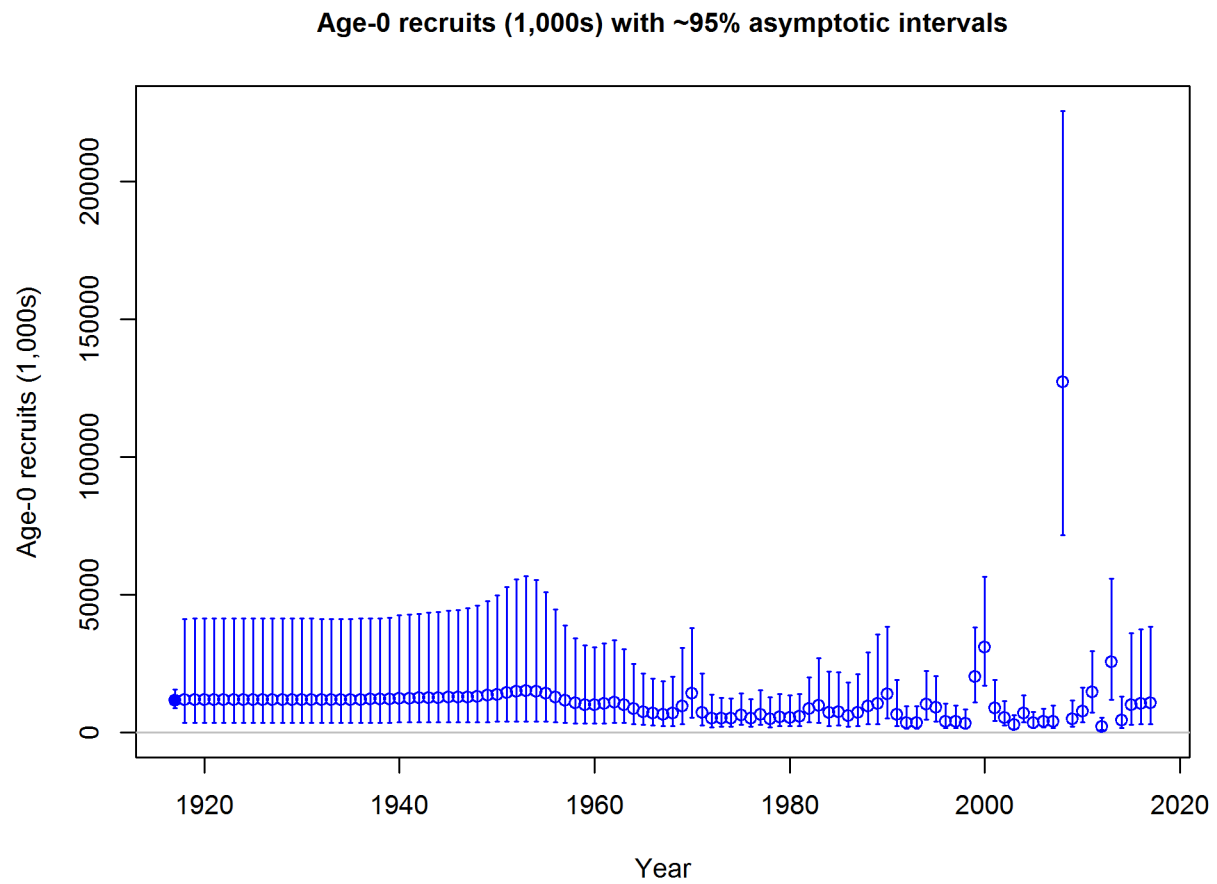


Figure d: Time series of estimated Pacific ocean perch recruitments for the base-case model with 95% confidence or credibility intervals. `fig:Recruits_all`

Exploitation status

exploitation-status

Include: exploitation rates (i.e., total catch divided by exploitable biomass, or the annual SPR harvest rate) include a table with the last 10 years of data and a graph showing the trend in fishing mortality relative to the target (y-axis) plotted against the trend in biomass relative to the target (x-axis).

Exploitation Tables: Table d, Table ??, Table ?? Exploitation Figure: Figure e).

A summary of Pacific ocean perch exploitation histories for base model is provided as Figure f.

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

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.105	0.046 - 0.164	0.002	0.001 - 0.003
2008	0.087	0.036 - 0.137	0.002	0.001 - 0.003
2009	0.114	0.046 - 0.183	0.003	0.001 - 0.004
2010	0.108	0.044 - 0.173	0.002	0.001 - 0.004
2011	0.037	0.016 - 0.059	0.001	0.000 - 0.001
2012	0.035	0.015 - 0.055	0.001	0.000 - 0.001
2013	0.033	0.014 - 0.052	0.001	0.000 - 0.001
2014	0.029	0.013 - 0.046	0.001	0.000 - 0.001
2015	0.029	0.013 - 0.045	0.001	0.000 - 0.001
2016	0.029	0.013 - 0.045	0.001	0.000 - 0.001

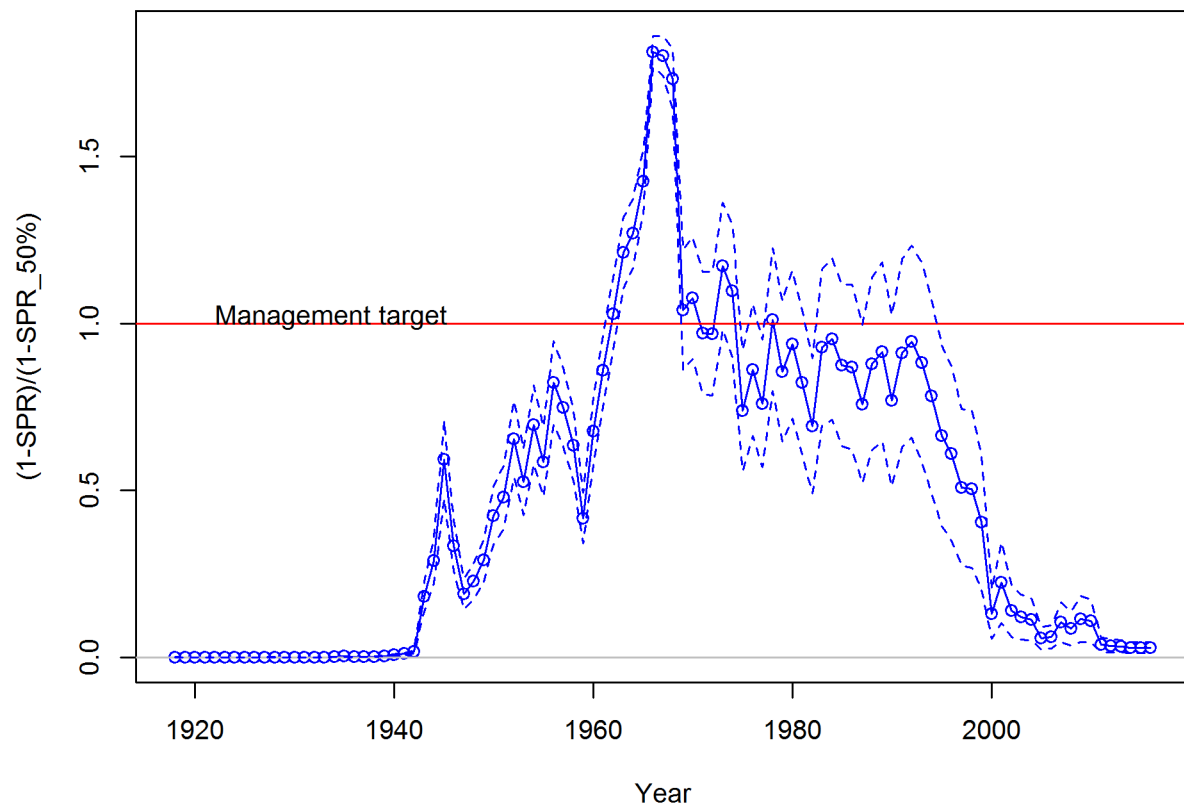


Figure e: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

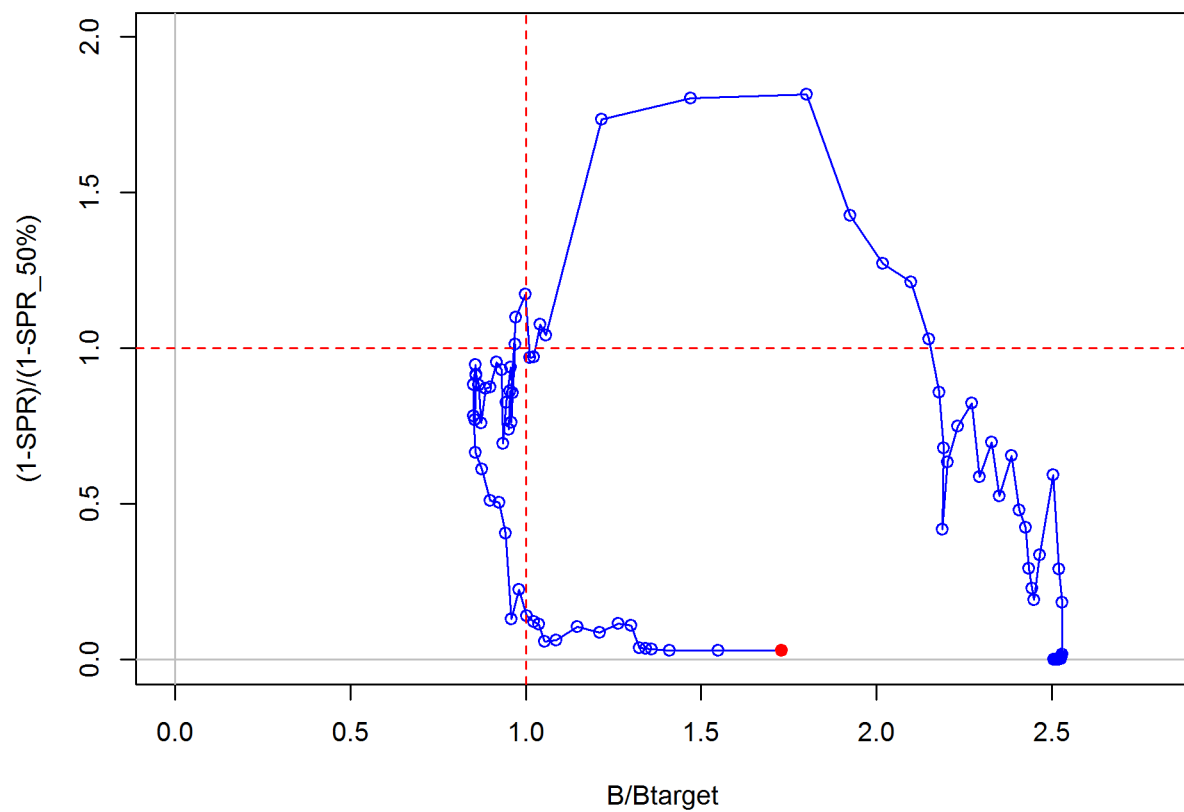


Figure f: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the unfished spawning biomass. fig:Phase_all

Ecosystem Considerations

ecosystem-considerations

In this assessment, ecosystem considerations were....

Reference Points

reference-points

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

Write intro paragraph

This stock assessment estimates that Pacific ocean perch in the Base model are above the biomass target, but above the minimum stock size threshold. **Add sentence about spawning output trend.** The estimated relative depletion level for **Model 1** in 2017 is 75.3% (~95% asymptotic interval: $\pm 52.9\%$ -97.7%, corresponding to an unfished spawning output of 4939 million eggs (~95% asymptotic interval: 2178.91231120822-7698.32768879178 million eggs) of spawning output in the base model (Table e). Unfished age 3+ biomass was estimated to be 138715 mt in the base case model. The target spawning output based on the biomass target ($SB_{40\%}$) is 2623.4 million eggs, which gives a catch of 1732.5 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 1749.5 mt.

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

Quantity	Estimate	tab:Ref_pts_mod1
		95% Confidence Interval
Unfished spawning output (million eggs)	6558.6	4675 - 8442.1
Unfished age 3+ biomass (mt)	138715	99107.7 - 178322.3
Unfished recruitment (R0, thousands)	11646	8776.5 - 15453.6
Spawning output(2017 million eggs)	4938.6	2178.9 - 7698.3
Depletion (2017)	0.753	0.529 - 0.977
Reference points based on SB_{40%}		
Proxy spawning output ($B_{40\%}$)	2623.4	1870 - 3376.8
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.55	0.55 - 0.55
Exploitation rate resulting in $B_{40\%}$	0.028	0.028 - 0.029
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	1732.5	1239 - 2226
Reference points based on SPR proxy for MSY		
Spawning output	2186.2	1558.3 - 2814
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.033	0.033 - 0.034
Yield with SPR_{proxy} at SB_{SPR} (mt)	1749.5	1251.6 - 2247.3
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	2286	1625.3 - 2946.7
SPR_{MSY}	0.511	0.509 - 0.513
Exploitation rate at MSY	0.032	0.032 - 0.033
MSY (mt)	1751.3	1252.8 - 2249.7

Management Performance

management-performance

Include: catches in comparison to OFL, ABC and OY/ACL values for the most recent 10 years (when available), overfishing levels, actual catch and discard. Include OFL(encountered), OFL(retained) and OFL(dead) if different due to discard and discard mortality.

Management performance table: Table f

Unresolved Problems And Major Uncertainties

unresolved-problems-and-major-uncertainties

TBD after STAR panel

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

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	tab:mnmgt_perform	
				Total landings (mt)	Estimated total catch (mt)
2007	-	-	150	133	157
2008	-	-	150	92	133
2009	-	-	189	94	190
2010	-	-	200	97	181
2011	-	-	180	60	61
2012	-	-	183	57	58
2013	-	-	150	55	57
2014	-	-	153	54	55
2015	-	-	158	58	59
2016	-	-	164	65	65

Decision Table(s) (groundfish only)

decision-tables-groundfish-only

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

OFL projection table: Table [g](#)

Decision table(s) Table [h](#), Table ??, Table ??

Yield curve: Figure [\ref{fig:Yield_all}](#)

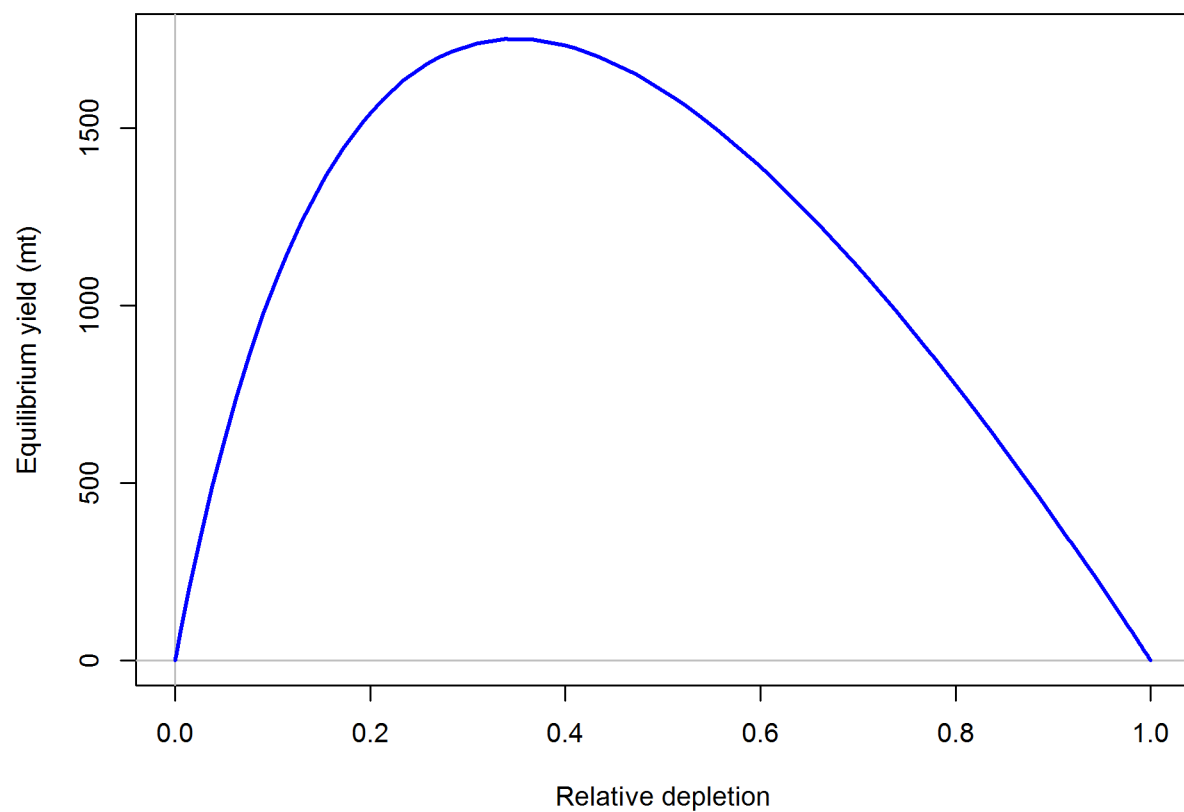


Figure g: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at... `fig:Yield_all`

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

Year	OFL	ACL	Spawning Output (million eggs)	tab:OFL_projection
				Relative Biomass
2017	4171	281	4939	0.753
2018	4402	281	5239	0.799
2019	4546	4346	5472	0.834
2020	4476	4279	5484	0.836
2021	4371	4178	5461	0.833
2022	4250	4063	5400	0.823
2023	4125	3944	5314	0.810
2024	4003	3827	5215	0.795
2025	3888	3717	5109	0.779
2026	3782	3615	4999	0.762
2027	3684	3521	4889	0.745
2028	3593	3435	4780	0.729

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.

tab:Decision_table_mod1

		States of nature					
		Low M 0.05		Base M 0.07		High M 0.09	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output
40-10 Rule, Low M	2019	-	-	-	-	-	-
	2020	-	-	-	-	-	-
	2021	-	-	-	-	-	-
	2022	-	-	-	-	-	-
	2023	-	-	-	-	-	-
	2024	-	-	-	-	-	-
	2025	-	-	-	-	-	-
	2026	-	-	-	-	-	-
	2027	-	-	-	-	-	-
	2028	-	-	-	-	-	-
40-10 Rule	2019	-	-	-	-	-	-
	2020	-	-	-	-	-	-
	2021	-	-	-	-	-	-
	2022	-	-	-	-	-	-
	2023	-	-	-	-	-	-
	2024	-	-	-	-	-	-
	2025	-	-	-	-	-	-
	2026	-	-	-	-	-	-
	2027	-	-	-	-	-	-
	2028	-	-	-	-	-	-
40-10 Rule, High M	2019	-	-	-	-	-	-
	2020	-	-	-	-	-	-
	2021	-	-	-	-	-	-
	2022	-	-	-	-	-	-
	2023	-	-	-	-	-	-
	2024	-	-	-	-	-	-
	2025	-	-	-	-	-	-
	2026	-	-	-	-	-	-
	2027	-	-	-	-	-	-
	2028	-	-	-	-	-	-
Average Catch	2019	-	-	-	-	-	-
	2020	-	-	-	-	-	-
	2021	-	-	-	-	-	-
	2022	-	-	-	-	-	-
	2023	-	-	-	-	-	-
	2024	-	-	-	-	-	-
	2025	-	-	-	-	-	-
	2026	-	-	-	-	-	-
	2027	-	-	-	-	-	-
	2028	-	-	-	-	-	-

Table i: Base model results summary.

Quantity	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	tab:base summary
Landings (mt)	-	-	-	-	-	-	-	-	-	-	-
Total Est. Catch (mt)	150	189	200	180	183	150	153	158	164	164	281
OFL (mt)	92	94	97	60	57	55	54	58	65	65	65
ACL (mt)	133	190	181	61	58	57	55	59	65	65	65
(1-SPR)(1-SPR _{50%})	0.09	0.11	0.11	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Exploitation rate	0	0	0	0	0	0	0	0	0	0	0
Age 3+ biomass (mt)	73638.5	74422.3	74753.5	87776.7	94210.9	100641.0	107215.0	112020.0	118091.0	121939.0	121939.0
Spawning Output	3175	3313	3409	3474	3522	3563	3697	4063	4535	4939	4939
95% CI	1321 - 5028	1385 - 5242	1428 - 5389	1458 - 5489	1484 - 5560	1508 - 5618	1578 - 5816	1758 - 6368	1986 - 7085	2179 - 7698	2179 - 7698
Depletion	0.484	0.505	0.520	0.530	0.537	0.543	0.564	0.620	0.692	0.753	0.753
95% CI	0.327 - 0.642	0.342 - 0.668	0.353 - 0.687	0.360 - 0.699	0.366 - 0.708	0.372 - 0.715	0.388 - 0.739	0.430 - 0.809	0.484 - 0.899	0.529 - 0.977	0.529 - 0.977
Recruits	127258	4856	7683	14600	2130	25607	4445	10066	10478	10763	10763
95% CI	71750 - 225709	2030 - 11618	3639 - 16220	7244 - 29424	871 - 5206	11738 - 55865	1533 - 12885	2817 - 35967	2931 - 37454	3014 - 38432	3014 - 38432

Research And Data Needs

research-and-data-needs

Include: identify information gaps that seriously impede the stock assessment.

We recommend the following research be conducted before the next assessment:

1. List item No. 1 in the list
2. List item No. 2 in the list, etc.

Rebuilding Projections

rebuilding-projections

Include: reference to the principal results from rebuilding analysis if the stock is overfished. This section should be included in the Final/SAFE version assessment document but is not required for draft assessments undergoing review. See Rebuilding Analysis terms of reference for detailed information on rebuilding analysis requirements.

1 Introduction

introduction

1.1 Basic Information

basic-information

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

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

Prior to 1966, the Pacific ocean perch resource off of the northern portion of the US West Coast was harvested almost entirely by Canadian and United States vessels. Harvest was negligible prior to 1940, reached 1,300 mt in 1950, 3,200 mt in 1961 and exceeded 7,600 mt in 1965. Catches increased dramatically after 1965, with the introduction of large distant-water fishing fleets from the Soviet Union and Japan. Both nations employed large factory stern trawlers as their primary method for harvesting Pacific ocean perch. Peak removals by all foreign nations combined are estimated at over 15,000 mt in 1966 and remained over 12,000 mt in 1967. These numbers are based upon a re-analysis of the foreign catch data (Rogers 2003), which focused on deriving a more realistic species composition for catches previously identified only as Pacific ocean perch. Catches declined rapidly following these peak years, and Pacific ocean perch stocks were considered to be severely depleted throughout the Oregon-Vancouver Island region by 1969 (Gunderson 1977, Gunderson et al. 1977). Landed harvest averaged 1,350 mt over the period 1977-94. Landings have continued to decline since 1994, primarily due to more restrictive management (Table 1 and Figure 1).

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

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

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

1.2 Summary of Management History

summary-of-management-history

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

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

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

1.3 Fisheries off Canada and Alaska

fisheries-off-canada-and-alaska

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

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

2 Data

data

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

2.1 Fishery-Independent Data:

fishery-independent-data

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

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

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

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

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

The smallest Pacific ocean perch tend to occur in the shallower depths (< 200 m) with only larger individuals occurring at depths deeper than 300 m. Data collected by the NWFSC Shelf-Slope survey between depths of 55 - 549 m and north of 42° and south of 49° were stratified to generate an index of abundance from 2003-2016. The estimated index of abundance is shown in Table 4. The lognormal distribution with random strata-year and vessel effects had the lowest AIC and was chosen as the final model. The Q-Q plot does not show any departures from the assumed distribution (Figure 3). The indices for the NWFSC shelf-slope survey show a tentative decline in the population between 2003 and 2009, with an increasing trend in biomass between the 2009 and 2016 median point estimates.

Length, age, and conditional age-at-length compositions were expanded based upon the stratification. The number of tows with length data ranged from 33 in 2006 to 69 in 2015 (Table 5) where ages were collected for Pacific ocean perch in nearly every tow (Table 6). The expanded length frequencies from this survey show an increase in small fish starting in 2010 (Figure 4). The age frequencies provide clear evidence of large year-classes moving through the population from the 1999, 2000, and 2008 recruitment; with early indications of a large 2013 recruitment (Figure 5).

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

2.1.2 Northwest Fisheries Science Center (NWFSC) slope survey

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

The NWFSC slope survey covered waters throughout the summer from 183 m to 1280 m north of 34°30' S, which is near Point Conception between 1999 and 2002. Tows conducted between the depths of 183 and 549 m were used to create an index of abundance using a bayesian delta-GLMM and the VAST delta-GLMM models. The estimated index of abundance is shown in Table 4. Based on the diagnostics the bayesian delta-GLMM, which does not account for spatial effects, gamma distribution with year-vessel random effects was selected as the final model. The Q-Q plot does not show any departures from the assumed distribution (Figure 6). The trend of abundance across the four survey years was generally flat with high estimated annual variance.

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

2.1.3 Alaska Fisheries Science Center (AFSC) slope survey

alaska-fisheries-science-center-afsc-slope-survey

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

An index of abundance was estimated based on the data using the VAST delta-GLMM model. The estimated index of abundance is shown in Table 4. The lognormal distribution with random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot does not show any departures from the assumed distribution (Figure 9). The trend in the indices was generally flat over time.

Length compositions were available for each year the survey was conducted. No age data were available from this survey. The expanded length frequencies from this survey were generally of larger fish (> 30 cm), except for 1997 where the highest frequency of fish were between 20 and 30 cm for both females and males (Figure 10).

2.1.4 Triennial Bottom Trawl Survey

triennial-bottom-trawl-survey

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

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

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

An index of abundance was estimated based on the data using the VAST delta-GLMM model. The estimated index of abundance is shown in Table 4. The lognormal distribution with random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot does not show any departures from the assumed distribution (Figure 11). The index shows a decline in abundance in the early years of the time-series and abundance remaining flat for the latter years.

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

excluded from analysis. The available ages from the Triennial survey and the number of tows where otoliths were collected are shown in Table 11. The expanded length frequencies from this survey show an increase in small fish starting in 1995 (Figure 12). The age frequencies provide clear evidence of large year-classes moving through the population from the 1999 and 2000 recruitment (Figure 13).

2.1.5 Pacific ocean perch Survey

pacific-ocean-perch-survey

A survey targeted designed to sample Pacific ocean perch was conducted in 1979 and again in 1985 (for a detailed description see (Ianelli et al. 1992). An index of abundance was estimated based on the data using the VAST delta-GLMM model. The estimated index of abundance is shown in Table 4. The lognormal distribution with random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot does not show any departures from the assumed distribution (Figure 14). The index shows a clear decline in abundance between the two survey years.

Length and age compositions were expanded based on the stratification. The survey had 125 and 126 Pacific ocean perch tows (Table 12) and ages were only available in 1985 due to surface reads for the 1979 data (Table 13). The length frequencies for both years are highest between the 30-45 cm range (Figure 15) with ages in 1985 having a large number of fish age 40 and greater (Figure 16).

2.2 Fishery-Dependent Data

fishery-dependent-data

2.2.1 Commercial Fishery Landings

commercial-fishery-landings

Washington

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

Oregon

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

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

California

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

At-Sea Hake Fishery

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

Foreign Catches

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

2.2.2 Discards

discards

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

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

The second source is from the West Coast Groundfish Observer Program (WCGOP). This program is part of the NWFSC and has been recording discard observations since 2003. Table 14 shows the discard ratios (discarded/(discarded + retained)) of Pacific ocean perch from the WCGOP. Since 2011, when the trawl rationalization program was implemented, observer coverage rates increased to nearly 100% for all the limited entry trawl vessels in the program and discard rates declined compared to pre-2011 rates. Discard rates were obtained for both the catch-share and the non-catch share sector for Pacific ocean perch. A single discard rate was calculated by weighting discard rates based on the commercial landings by each sector. Coefficient of variations were calculated by bootstrapping vessels within ports because the observer program randomly chooses vessels within ports to be observed in the non-catch shares sectors. Discard length composition for the trawl fleet varied by year, with larger fish being discarded prior to 2011 (Figure 17).

2.2.3 Historical Commercial Catch-per-unit effort

historical-commercial-catch-per-unit-effort

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

2.2.4 Fishery Length And Age Data

fishery-length-and-age-data

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

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

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

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

2.3 Biological Data

biological-data

2.3.1 Natural mortality

natural-mortality

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

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

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

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

2.3.2 Sex ratio, maturation, and fecundity

sex-ratio-maturation-and-fecundity

Examining all biological data sources, the sex ratio of young fish are within 5% of 1:1 by either length or age (Figures 22 and 23), and hence this assessment the sex ratio at birth was assumed to be 1:1. This assessment assumed a logistic maturity-at-length curve based on analysis of 537 fish maturity samples collected from the NWFSC shelf-slope survey. This is revised from the previous assessment which assumed maturity-at-age based on the work of Hannah and Parker (Hannah and Parker 2007). Additionally, the new maturity-at-length curve is based on the estimate of functional maturity an approach that classifies rockfish maturity with developing oocytes as mature or immature based on the proportion of vitellogenin in the cytoplasm and the measured frequency of atretic cells (M. Head, personal communication). The 50% size-at-maturity was estimated at 32.1 cm with maturity asymptoting to one for larger fish (Figure 24). Comparison between the maturity-at-age used in the previous assessment and the updated functional maturity-at-length is shown in Figure 25.

The fecundity-at-age has also been updated from the previous assessment based on new research. Dick (2017) estimated new fecundity relationships for select West Coast stocks where fecundity for Pacific ocean perch was estimated equal to $0L^{4.98}$ in millions of eggs. Spawning output at length is shown in Figure 26.

2.3.3 Length-weight relationship

length-weight-relationship

The length-weight relationship for Pacific ocean perch was estimated outside the model using all biological data available from fishery and fishery-independent data sources where the female weight-at-length in grams was estimated at $0.0000104L^{3.09}$ and males at $0.0000105L^{3.08}$ where L is length in cm (Figures 27 and 28).

2.3.4 Growth (length-at-age)

growth-length-at-age

The length-at-age was estimated for male and female Pacific ocean perch using data collected from both fishery-dependent and -independent data sources that were collected from 1981-2016. Figure 29 shows the lengths and ages for all years and all data as well as predicted

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

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

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

2.3.5 Ageing Precision And Bias

ageing-precision-and-bias

Uncertainty surrounding the ageing-error process for Pacific ocean perch was incorporated by estimating ageing error by age. Age-composition data used in the model were from break-and-burn otolith reads aged by the Cooperative Ageing Project (CAP) in Newport, Oregon. Break-and-burn double reads of more than 1500 otoliths were provided by the CAP lab. An ageing error estimate was made based on these double reads using a computational tool specifically developed for estimating ageing error (Punt et al. 2008), and using release 1.0.0 of the R package `nwfscAgeingError` (Thorson et al. 2012) for input and output diagnostics, publicly available at: <https://github.com/nwfsc-assess/nwfscAgeingError>. A non-linear standard error was estimated by age where there is more variability in the estimated age of older fish was estimated (Table 20, Figure 30).

2.4 History Of Modeling Approaches Used For This Stock

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

2.4.1 Previous Assessments

previous-assessments

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

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

2.4.2 Previous Assessment Recommendations

previous-assessment-recommendations

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

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

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

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

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

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

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

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

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

STAT response: California and Oregon have undergone extensive work to create historical catch reconstructions. This is the first assessment for Pacific ocean perch which includes a Washington historical catch reconstruction. The data used in this assessment represent Washington

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

3 Assessment

assessment

3.1 General Model Specifications and Assumptions

general-model-specifications-and-assumptions

Stock Synthesis **v3.30.03.03** was used to estimate the parameters in the model. R4SS, revision 1.26.0, along with R version 3.3.2 were used to investigate and plot model fits. A summary of the data sources used in the model (details discussed above) is shown in Figure 2.

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

3.1.1 Changes between the 2011 assessment model and current model

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

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

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

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

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

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

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

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

3.1.2 Summary of Fleets and Areas

summary-of-fleets-and-areas

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

The majority of removals of Pacific ocean perch were observed by the bottom trawl fishery with fixed gear accounting for a small fraction of the catches available within PacFIN. Trawl

and fixed gears were combined into a coast-wide fleet. For the period from 1918 to the early 1990s, prior to the introduction of trip limits for rockfish, limited discarding of Pacific ocean perch was assumed. Observations of Pacific ocean perch in the Pikitch et al. (1988) data (1986-1987) allowed for a formal analysis of discard rates which were applied to the historical period of the fishery. Foreign trawl catches (1966-1976) was modeled as a single fleet. The at-sea fishery operates as a mid-water fishery targeting Pacific whiting but encounters Pacific ocean perch as a bycatch species. This fleet was also modeled as a single fleet.

3.1.3 Other Specifications

other-specifications

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

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

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

The recommended selectivity type in Stock Synthesis is the double normal and 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.

Time blocks for the bottom trawl, midwater trawl, and hook-and-line fishery are provided in Table 21. Fishery selectivity retention has changed over the modeled period due to management changes. The time block on the retention curves for the trawl 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

modeling-software

The STAT team used Stock Synthesis version 3.30.03.03 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.

3.1.5 Priors

priors

A prior distribution was developed for the natural mortality parameter from an analysis of a maximum age of 100 years. The analysis was performed by Owen Hamel (pers comm, 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 0.4384343.

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

3.1.6 Data Weighting

data-weighting

The base case was weighted such that the various data sources were mostly consistent with each other in terms of the relationship between input and effective sample sizes. Length and age-at-length compositions from the NWFSC shelf-slope survey were fit along with length and marginal age compositions from the fishery fleets. Length data started with a sample size determined from the equation listed in Section 2.2.4 and 2.1.1. Age-at-length data assumed that each age was a random sample within the length bin and started with a sample size equal to the number of fish in that length bin. One extra variability parameter that was added to the input variance was estimated for the Triennial and the NWFSC shelf-slope survey indices. Vessels present in the WCGOP data were bootstrapped to provide uncertainty of the total discards (Table 14).

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

3.1.7 Estimated And Fixed Parameters

estimated-and-fixed-parameters

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

Fixed parameters in the model were as follows. Steepness was fixed at 0.50. A sensitivity analysis and a likelihood profile were done for steepness. Natural mortality was fixed at 0.054 for females and males, which is the median of the prior. The standard deviation of recruitment deviates was fixed at 0.70. Maturity at age was fixed as described in Section 2.3.2. Length-weight parameters were fixed at estimates using all length-weight observations (Figure 28).

Dome-shaped selectivity was explored for both the fishery and the surveys. Older Pacific ocean perch are often found in deeper waters and may move into areas that limit their availability to fishing gear, especially trawl gear. Domed shape selectivity was assumed for the fishery fleet and the Triennial survey. The final base model assumed asymptotic selectivity for the at-sea hake fishery, and all other surveys.

3.2 Model Selection and Evaluation

model-selection-and-evaluation

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

3.2.1 Key Assumptions and Structural Choices

key-assumptions-and-structural-choices

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

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

3.2.2 Alternate Models Considered

alternate-models-considered

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

This assessment estimated discards in the model, so time was spent investigating time blocks for changes in selectivity and retention to match the limited discard data as best as possible. Using major changes in management and observed changes in landings, a set of blocks for retention was found for the bottom trawl fleets. In the spirit of parsimony, we used as few blocks as possible, allowed blocks only for time periods with data, and added new blocks

when we felt they were justified by changes in management and they improved the fit to the data.

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

3.2.3 Convergence

convergence

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

3.3 Response To The Current STAR Panel Requests

response-to-the-current-star-panel-requests

Request No. 1: Add after STAR panel.

Rationale: Add after STAR panel.

STAT Response: Add after STAR panel.

Request No. 2: Add after STAR panel.

Rationale: Add after STAR panel.

STAT Response: Add after STAR panel.

Request No. 3: Add after STAR panel.

Rationale: Add after STAR panel.

STAT Response: Add after STAR panel.

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

924

- 925 • Item No. 1
- 926 • Item No. 2
- 927 • Item No. 3, etc.

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

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

930 **3.4 Base Model Results**

base-model-results

931 The base model parameter estimates along with approximate asymptotic standard errors are
932 shown in Table 23 and the likelihood components are shown in Table 24. Estimates of key
933 derived parameters and approximate 95% asymptotic confidence intervals are shown in Table
934 25.

935 **3.4.1 Uncertainty and Sensitivity Analyses**

uncertainty-and-sensitivity-analyses

936 Table 26

937 **3.4.2 Retrospective Analysis**

retrospective-analysis

938 **3.4.3 Likelihood Profiles**

likelihood-profiles

939 **3.4.4 Reference Points**

reference-points-1

940 Intro sentence or two... (Table 27).

941 Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 1749.5 mt.
942 Table e shows the full suite of estimated reference points for the northern area model and
943 Figure g shows the equilibrium yield curve.

4 Harvest Projections and Decision Tables

harvest-projections-and-decision-tables

Table [f](#)

Model 1 Projections and Decision Table (groundfish only) (Table [28](#)

Table [h](#)

Model 2 Projections and Decision Table (groundfish only)

Model 3 Projections and Decision Table (groundfish only)

5 Regional Management Considerations

regional-management-considerations

1. For stocks where current practice is to allocate harvests by management area, a recommended method of allocating harvests based on the distribution of biomass should be provided. The MT advisor should be consulted on the appropriate management areas for each stock.
2. Discuss whether a regional management approach makes sense for the species from a biological perspective.
3. If there are insufficient data to analyze a regional management approach, what are the research and data needs to answer this question?

6 Research Needs

research-needs

1. Research need No. 1
2. Research need No. 2
3. Research need No. 3
4. etc.

7 Acknowledgments

acknowledgments

Teresa Tsou (WDFW), Philip Wyland (WDFW), Ali Whitman (ODFW), Patrick Mirrick (ODFW), Patrick McDonald (CAPS), Vanessa Tuttle (ASHOP), Beth Horness (NWFSC), Kayleigh Sommers (NWFSC), Jason Jannot (NWFSC)

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

Year	California	Oregon	Washington	At-Sea Hake	Foreign	tab:Comm_Catch
						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	521.1 ₄₄	31.9	239	0.0

Year	California	Oregon	Washington	At-Sea Hake	Foreign	Research
1977	16.7	457.1	752.0	3.8	0	11.9
1978	42.5	498.7	1391.5	15.4	0	0.0
1979	136.7	735.9	581.4	15.1	0	34.5
1980	19.2	948.6	666.2	47.0	0	4.6
1981	10.8	929.7	390.3	15.4	0	0.0
1982	145.9	584.0	273.0	28.3	0	0.0
1983	102.0	1032.7	437.7	10.9	0	4.4
1984	47.6	750.4	815.7	2.3	0	0.9
1985	70.9	789.5	503.2	11.4	0	13.6
1986	52.8	676.5	588.9	19.8	0	1.4
1987	120.9	550.0	399.4	5.4	0	0.0
1988	75.4	749.8	509.8	4.5	0	0.5
1989	29.5	927.8	466.2	4.3	0	4.2
1990	18.3	567.8	427.2	80.9	0	0.0
1991	8.4	853.2	530.1	46.1	0	0.0
1992	15.3	623.4	435.2	373.3	0	4.9
1993	11.0	797.8	464.7	0.9	0	0.2
1994	6.7	626.4	352.0	83.8	0	0.0
1995	9.2	515.0	289.8	46.6	0	2.8
1996	18.4	531.1	236.7	6.3	0	1.2
1997	15.8	439.1	184.9	6.4	0	0.1
1998	21.6	436.7	172.4	22.3	0	3.8
1999	19.8	326.8	145.8	16.5	0	1.4
2000	6.8	95.1	33.0	10.1	0	0.6
2001	0.5	193.4	51.8	21.0	0	2.8
2002	0.8	107.0	39.5	3.9	0	0.3
2003	0.2	94.6	30.2	6.3	0	3.6
2004	2.1	97.7	22.3	1.1	0	2.5
2005	0.1	51.2	10.4	1.7	0	1.8
2006	0.2	52.2	15.8	3.1	0	1.2
2007	0.2	83.7	45.1	4.0	0	0.6
2008	0.4	58.6	16.6	15.9	0	0.8
2009	0.9	58.7	33.2	1.6	0	2.7
2010	0.1	58.0	22.3	16.9	0	1.7
2011	0.1	30.3	19.7	9.2	0	1.9
2012	0.2	30.4	21.8	4.5	0	1.6
2013	0.1	34.9	14.8	5.4	0	1.7
2014	0.2	33.9	15.8	3.9	0	0.6
2015	0.1	38.1	11.4	8.7	0	1.6
2016	0.2	40.8	13.1	10.3	0	3.1
2017	0.0	13.0	0.0	0.0	0	0.0

Table 2: West Coast history of regulations.

tab:Regs

Date	Area	Regulation
11/10/1983	Columbia	Closed Columbia area to Pacific ocean perch fishing until the end of the year, as 950 mt OY for this species has been reached;
11/10/1983	Vancouver	retained 5,000-pound trip limit or 10% of total trip weight on landings of Pacific ocean perch in the Vancouver area.
1/1/1984	ALL	Continued 5,000-pound trip limit or 10% of total trip weight on Pacific ocean perch as specified in FMP. Fishery to close when area OYs are reached (see action effective November 10, 1983 above).
8/1/1984	Vancouver 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;
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 Sebastes 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: 4,000pounds 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 including 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)	tab:mnmgmt_perform_tables	
				Total landings (mt)	Estimated total catch (mt)
2007	-	-	150	133	157
2008	-	-	150	92	133
2009	-	-	189	94	190
2010	-	-	200	97	181
2011	-	-	180	60	61
2012	-	-	183	57	58
2013	-	-	150	55	57
2014	-	-	153	54	55
2015	-	-	158	58	59
2016	-	-	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.

tab:Index_Summary										
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	0.60	-	-	-	-	-	-
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	0.68	-	-	-	-	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	0.36
2013	-	-	-	-	-	-	-	-	8093	0.35
2014	-	-	-	-	-	-	-	-	4914	0.35
2015	-	-	-	-	-	-	-	-	5752	0.32
2016	-	-	-	-	-	-	-	-	11770	0.37

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

tab:NWcombo_Lengths			
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.

tab:NWcombo_Ages			
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.

tab:NWslope_Lengths			
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.

tab:NWslope_Ages			
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.

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

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

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

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

tab:Triennial_Ages			
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.

tab:POP_Lengths			
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

tab:POP_Ages

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

tab:Discard

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

tab:CPUE_Summary		
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.

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

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

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

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

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

tab:ASHOP_Lengths			
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.

tab:ASHOP_Ages			
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

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

Table 21: Specifications of the base model for ‘r spp’.

tab:Model_setup	
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
Minimum 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	-
Found local minimum	-
Found better solution	-
Error in likelihood	-
Total	100

tab:jitter

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	0.05	-5	(0.02, 0.1)			Log_Norm (-2.92, 0.44)
L_at_Amin_Fem_GP_1	20.82	3	(15, 25)	OK	0.15	None
L_at_Amax_Fem_GP_1	41.51	2	(35, 45)	OK	0.16	None
VonBert_K_Fem_GP_1	0.17	3	(0.1, 0.4)	OK	0.01	None
CV_young_Fem_GP_1	1.33	5	(0.03, 5)	OK	0.07	None
CV_old_Fem_GP_1	2.58	5	(0.03, 5)	OK	0.12	None
Wtlen_1_Fem	0.00	-99	(0, 3)			None
Wtlen_2_Fem	3.09	-99	(2, 4)			None
Mat50%_Fem	32.10	-99	(20, 40)			None
Mat_slope_Fem	-1.00	-99	(-2, 4)			None
Eggs_scalar_Fem	0.00	-99	(0, 6)			None
Eggs_exp_len_Fem	4.98	-99	(-3, 5)			None
NatM_p_1_Mal_GP_1	0.05	-5	(0, 0.3)			Normal (0.05, 0.1)
L_at_Amin_Mal_GP_1	20.82	-2	(6, 68)			None
L_at_Amax_Mal_GP_1	38.80	2	(13, 122)	OK	0.00	None
VonBert_K_Mal_GP_1	0.20	3	(0.04, 1.09)	OK	0.04	None
CV_young_Mal_GP_1	1.33	-5	(0, 742.07)			None
CV_old_Mal_GP_1	2.32	5	(0, 742.07)	OK	0.07	None
Wtlen_1_Mal	0.00	-99	(0, 3)			None
Wtlen_2_Mal	3.08	-99	(2, 4)			None
CohortGrowDev	1.00	-99	(0, 2)			None
FracFemale_GP_1	0.50	-99	(0.01, 0.99)			None
SR_LN(R0)	9.36	1	(5, 20)	OK	0.15	None
SR_BH_steep	0.50	-2	(0.2, 1)			Full_Beta (0.72, 0.15)
SR_sigmaR	0.70	-6	(0.5, 1.2)			None
SR_regime	0.00	-99	(-5, 5)			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	0.00	-99	(0, 2)			None
Early_InitAge_18	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_17	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_16	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_15	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_14	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_13	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_12	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_11	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_10	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_9	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_8	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_7	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_6	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_5	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_4	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_3	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_2	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_1	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
LnQ_base_Fishery(1)	-12.37	-1	(-15, 15)			None
LnQ_base_POP(4)	-0.11	-1	(-15, 15)			None
LnQ_base_Triennial(5)	-1.84	-1	(-15, 15)			None
Q_extraSD_Triennial(5)	0.39	2	(0, 0.5)	OK	0.15	None
LnQ_base_AFSCSlope(6)	-2.47	-1	(-15, 15)			None
LnQ_base_NWFSCSlope(7)	-2.82	-1	(-15, 15)			None
LnQ_base_NWFSCcombo(8)	-2.61	-1	(-15, 15)			None

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Q.extraSD_NWFSCcombo(8)	0.03	2	(0, 0.5)	OK	0.07	None
SizeSel_P1_Fishery(1)	37.97	1	(20, 45)	OK	0.18	None
SizeSel_P2_Fishery(1)	-5.00	-2	(-6, 4)			None
SizeSel_P3_Fishery(1)	3.71	3	(-1, 9)	OK	0.13	None
SizeSel_P4_Fishery(1)	-1.65	-3	(-9, 9)			None
SizeSel_P5_Fishery(1)	-3.50	-4	(-5, 9)			None
SizeSel_P6_Fishery(1)	0.59	2	(-5, 9)	OK	0.33	None
Retain_P1_Fishery(1)	28.29	1	(15, 45)	OK	0.34	None
Retain_P2_Fishery(1)	1.07	1	(0.1, 10)	OK	0.13	None
Retain_P3_Fishery(1)	6.81	1	(-10, 10)	OK	1.20	None
Retain_P4_Fishery(1)	0.00	-3	(0, 0)			None
SizeSel_P1_ASHOP(2)	49.50	1	(20, 49.5)	HI	0.15	None
SizeSel_P2_ASHOP(2)	-5.00	-2	(-6, 4)			None
SizeSel_P3_ASHOP(2)	5.02	3	(-1, 9)	OK	0.20	None
SizeSel_P4_ASHOP(2)	1.00	-3	(-1, 9)			None
SizeSel_P5_ASHOP(2)	-4.35	-4	(-9, 9)			None
SizeSel_P6_ASHOP(2)	999.00	-2	(-5, 999)			None
SizeSel_P1_POP(4)	24.60	1	(20, 70)	OK	2.40	None
SizeSel_P2_POP(4)	11.55	3	(0.001, 50)	OK	4.31	None
SizeSel_P1_Triennial(5)	27.65	1	(20, 45)	OK	5.03	None
SizeSel_P2_Triennial(5)	-5.00	-2	(-6, 4)			None
SizeSel_P3_Triennial(5)	5.50	-3	(-1, 9)			None
SizeSel_P4_Triennial(5)	3.26	3	(-1, 9)	OK	2.34	None
SizeSel_P5_Triennial(5)	-5.00	-4	(-5, 9)			None
SizeSel_P6_Triennial(5)	-0.72	2	(-5, 9)	OK	0.63	None
SizeSel_P1_AFSCSlope(6)	21.83	1	(20, 45)	OK	6.89	None

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SizeSel_P2_AFSCSlope(6)	-5.00	-2	(-6, 4)			None
SizeSel_P3_AFSCSlope(6)	1.33	3	(-1, 9)	OK	6.56	None
SizeSel_P4_AFSCSlope(6)	1.00	-3	(-1, 9)			None
SizeSel_P5_AFSCSlope(6)	-9.00	-4	(-9, 9)			None
SizeSel_P6_AFSCSlope(6)	999.00	-2	(-5, 999)			None
SizeSel_P1_NWFSCSlope(7)	36.08	1	(20, 45)	OK	2.30	None
SizeSel_P2_NWFSCSlope(7)	-5.00	-2	(-6, 4)			None
SizeSel_P3_NWFSCSlope(7)	1.82	3	(-1, 9)	OK	1.84	None
SizeSel_P4_NWFSCSlope(7)	1.00	-3	(-1, 9)			None
SizeSel_P5_NWFSCSlope(7)	-9.00	-4	(-9, 9)			None
SizeSel_P6_NWFSCSlope(7)	999.00	-2	(-5, 999)			None
SizeSel_P1_NWFSCcombo(8)	21.25	1	(18, 49.5)	OK	5.70	None
SizeSel_P2_NWFSCcombo(8)	-5.00	-2	(-6, 4)			None
SizeSel_P3_NWFSCcombo(8)	2.86	3	(-1, 9)	OK	3.06	None
SizeSel_P4_NWFSCcombo(8)	1.00	-3	(-1, 9)			None
SizeSel_P5_NWFSCcombo(8)	-9.00	-4	(-9, 9)			None
SizeSel_P6_NWFSCcombo(8)	999.00	-2	(-5, 999)			None
Retain_P3_Fishery(1)_BLK1repl_1918	3.99	4	(-10, 10)	OK	0.10	None
Retain_P3_Fishery(1)_BLK1repl_1992	2.31	4	(-10, 10)	OK	0.37	None
Retain_P3_Fishery(1)_BLK1repl_2002	1.72	4	(-10, 10)	OK	0.12	None
Retain_P3_Fishery(1)_BLK1repl_2008	0.61	4	(-10, 10)	OK	0.28	None
Retain_P3_Fishery(1)_BLK1repl_2009	-0.02	4	(-10, 10)	OK	0.24	None
tab:model_params						

Table 24: Likelihood components from the base model

Likelihood Component	Value
Total	1456.43
Survey	-25.97
Discard	-34.33
Length-frequency data	133.49
Age-frequency data	1370.56
Recruitment	11.67
Forecast Recruitment	0
Parameter Priors	1

tab:like

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

Quantity	Estimate	tab:Ref_pts
		95% Confidence Interval
Unfished spawning output (million eggs)	6558.6	4675 - 8442.1
Unfished age 3+ biomass (mt)	138715	99107.7 - 178322.3
Unfished recruitment (R0, thousands)	11646	8776.5 - 15453.6
Spawning output(2017 million eggs)	4938.6	2178.9 - 7698.3
Depletion (2017)	0.753	0.529 - 0.977
Reference points based on SB_{40%}		
Proxy spawning output ($B_{40\%}$)	2623.4	1870 - 3376.8
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.55	0.55 - 0.55
Exploitation rate resulting in $B_{40\%}$	0.028	0.028 - 0.029
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	1732.5	1239 - 2226
<i>Reference points based on SPR proxy for MSY</i>		
Spawning output	2186.2	1558.3 - 2814
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.033	0.033 - 0.034
Yield with SPR_{proxy} at SB_{SPR} (mt)	1749.5	1251.6 - 2247.3
<i>Reference points based on estimated MSY values</i>		
Spawning output at MSY (SB_{MSY})	2286	1625.3 - 2946.7
SPR_{MSY}	0.511	0.509 - 0.513
Exploitation rate at MSY	0.032	0.032 - 0.033
MSY (mt)	1751.3	1252.8 - 2249.7

Table 26: Sensitivity of the base model

Label	Base	Harmonic weights	h fixed at prior	Estimate M	Split Triennial	Old Mortality	tab:Sensitivity_model1			
							Old Fe-cundity	Canadian Data	State Data	
Total Likelihood	1710.07	3577.28	1711.64	1710.07	1708.10	1711.22	1710.23	1895.79	1868.28	
Survey Likelihood	-26.79	-27.64	-26.10	-26.79	-28.99	-26.75	-26.64	-26.73	-27.74	
Discard Likelihood	-33.87	-16.74	-34.03	-33.88	-33.91	-33.92	-33.89	-31.88	-33.89	
Length Likelihood	261.73	1502.82	263.24	261.78	261.29	262.72	261.80	396.20	346.97	
Age Likelihood	1493.88	2094.09	1493.50	1493.87	1494.36	1493.83	1493.84	1538.57	1565.31	
Recruitment Likelihood	14.13	23.75	14.91	14.10	14.34	14.33	14.12	18.63	16.75	
Forecast Recruitment Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Parameter Priors Likelihood	1.00	1.00	0.13	1.00	1.00	1.00	1.00	1.00	0.88	
Parameter Deviation Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
log(R0)	9.32	9.17	9.38	9.35	9.36	9.32	9.33	9.19	9.20	
SB Virgin	6271.59	5536.41	6581.18	6336.66	6476.77	6104.39	15512600.005396.25		5525.96	
SB 2017	4710.12	3599.86	6619.56	4886.55	5074.80	4715.28	15243900.002953.81		3649.91	
Depletion 2017	0.75	0.65	1.01	0.77	0.78	0.77	0.98	0.55	0.66	
Total Yield	1682.99	1453.65	2371.62	1720.74	1744.77	1670.84	1861.28	1475.89	1485.95	
Steepness	0.50	0.50	0.72	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	0.05	0.05	0.05	
Length at Amin - Female	20.83	20.92	20.84	20.83	20.83	20.83	20.83	20.70	20.83	
Length at Amax - Female	41.45	41.66	41.41	41.45	41.41	41.40	41.45	41.27	41.44	
Von Bert. k - Female	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	
SD young - Female	1.31	1.37	1.32	1.31	1.32	1.32	1.31	1.30	1.31	
SD old - Female	2.69	2.83	2.69	2.69	2.69	2.69	2.69	2.82	2.69	
Natural Mortality - Male	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
Length at Amin - Male	20.83	20.92	20.84	20.83	20.83	20.83	20.83	20.70	20.83	
Length at Amax - Male	38.77	38.82	38.78	38.77	38.78	38.77	38.77	38.55	38.84	
Von Bert. k - Male	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.19	
SD young - Male	1.31	1.37	1.32	1.31	1.32	1.32	1.31	1.30	1.31	
SD old - Male	2.43	2.70	2.38	2.43	2.38	2.38	2.43	2.37	2.45	

Table 27: 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
1918	139238	6575	138506	1.00	11808	0	0	0
1919	139284	6577	138551	1.00	11814	1	0	0
1920	139331	6579	138598	1.00	11820	0	0	0
1921	139380	6581	138646	1.00	11826	0	0	0
1922	139430	6584	138696	1.00	11833	0	0	0
1923	139481	6586	138746	1.00	11840	0	0	0
1924	139533	6588	138798	1.00	11846	0	0	0
1925	139586	6590	138851	1.00	11853	1	0	0
1926	139640	6593	138905	1.00	11860	1	0	0
1927	139695	6595	138959	1.00	11866	1	0	0
1928	139751	6597	139014	1.00	11872	1	0	0
1929	139807	6600	139070	1.00	11879	1	0	0
1930	139865	6603	139128	1.00	11885	1	0	0
1931	139924	6605	139187	1.00	11890	1	0	0
1932	139985	6608	139246	1.01	11896	1	0	0
1933	140046	6611	139307	1.01	11902	1	0	0
1934	140107	6613	139368	1.01	11909	1	0	0
1935	140168	6616	139428	1.01	11919	3	0	0
1936	140223	6618	139484	1.01	11932	8	0	0
1937	140287	6621	139546	1.01	11951	2	0	0
1938	140350	6624	139609	1.01	11979	3	0	0
1939	140413	6627	139670	1.01	12017	6	0	0
1940	140474	6629	139729	1.01	12305	10	0.005	0
1941	140531	6631	139780	1.01	12368	23	0.005	0
1942	140596	6633	139831	1.01	12442	30	0.01	0
1943	140669	6634	139900	1.01	12522	47	0.09	0
1944	140255	6610	139481	1.01	12595	563	0.145	0.004
1945	139518	6570	138740	1.00	12666	929	0.295	0.007
1946	137578	6469	136795	0.98	12720	2194	0.165	0.016
1947	136850	6425	136062	0.98	12838	1072	0.095	0.008
1948	136692	6408	135900	0.97	13040	569	0.115	0.004
1949	136470	6388	135669	0.97	13343	690	0.145	0.005
1950	136096	6360	135280	0.97	13773	907	0.21	0.007
1951	135309	6312	134472	0.96	14304	1402	0.24	0.01
1952	134414	6256	133549	0.95	14831	1620	0.325	0.012
1953	132879	6166	131982	0.94	15076	2399	0.265	0.018
1954	132142	6109	131218	0.93	14847	1775	0.35	0.014
1955	130784	6019	129854	0.92	14050	2564	0.295	0.02

Table 27: 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
1956	130151	5962	129246	0.91	12836	2002	0.41	0.015
1957	128424	5854	127575	0.89	11604	3198	0.375	0.025
1958	127207	5777	126433	0.88	10608	2739	0.315	0.022
1959	126534	5738	125831	0.87	9996	2154	0.21	0.017
1960	126627	5750	125978	0.87	9899	1264	0.34	0.01
1961	125434	5716	124814	0.87	10346	2367	0.43	0.019
1962	123112	5638	122489	0.86	10816	3327	0.515	0.027
1963	119571	5504	118924	0.84	10055	4420	0.605	0.037
1964	114512	5291	113857	0.80	8518	5876	0.635	0.052
1965	109078	5051	108482	0.77	7493	6231	0.715	0.057
1966	102014	4725	101504	0.72	6979	7827	0.905	0.077
1967	83811	3856	83358	0.59	6557	18968	0.9	0.228
1968	70155	3192	69730	0.49	6872	14650	0.865	0.21
1969	61613	2774	61196	0.42	9434	9712	0.52	0.159
1970	60716	2728	60237	0.41	14096	2183	0.54	0.036
1971	59797	2681	59153	0.41	7170	2301	0.485	0.039
1972	59466	2652	58710	0.40	5097	1905	0.485	0.032
1973	59297	2620	58886	0.40	4992	1888	0.585	0.032
1974	58255	2548	57941	0.39	5020	2643	0.55	0.046
1975	57460	2495	57146	0.38	6274	2275	0.37	0.04
1976	57625	2505	57296	0.38	4973	1183	0.43	0.021
1977	57325	2516	56953	0.38	6531	1507	0.38	0.026
1978	57144	2543	56815	0.39	4827	1262	0.505	0.022
1979	56108	2524	55729	0.38	5548	1998	0.43	0.036
1980	55463	2510	55152	0.38	5419	1506	0.47	0.027
1981	54525	2476	54182	0.38	5721	1723	0.41	0.032
1982	53892	2453	53544	0.37	8587	1381	0.345	0.026
1983	53582	2443	53178	0.37	9702	1057	0.465	0.02
1984	52783	2403	52239	0.37	7109	1624	0.475	0.031
1985	52132	2358	51572	0.36	7371	1658	0.435	0.032
1986	51869	2323	51427	0.35	5923	1411	0.435	0.027
1987	51717	2289	51280	0.35	7095	1375	0.38	0.027
1988	51898	2271	51505	0.35	9443	1107	0.44	0.021
1989	51849	2251	51368	0.34	10414	1379	0.46	0.027
1990	51847	2239	51237	0.34	13831	1469	0.385	0.029
1991	52411	2250	51727	0.34	6495	1124	0.455	0.022
1992	52832	2246	52101	0.34	3506	1478	0.475	0.028
1993	53301	2232	52947	0.34	3522	1567	0.44	0.03

Table 27: 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
1994	53739	2230	53505	0.34	10256	1418	0.39	0.026
1995	54250	2248	53924	0.34	9028	1181	0.33	0.022
1996	54913	2293	54309	0.35	3937	952	0.305	0.018
1997	55674	2357	55197	0.36	3860	879	0.255	0.016
1998	56446	2425	56205	0.37	3222	716	0.25	0.013
1999	56980	2474	56709	0.38	20289	721	0.205	0.013
2000	57644	2514	57138	0.38	30894	562	0.065	0.01
2001	59050	2572	57672	0.39	8763	160	0.11	0.003
2002	61164	2629	59617	0.40	5261	293	0.07	0.005
2003	63945	2682	63464	0.41	2742	179	0.06	0.003
2004	66532	2722	66236	0.41	6934	155	0.055	0.002
2005	68891	2763	68661	0.42	3436	147	0.03	0.002
2006	70975	2852	70601	0.43	3940	76	0.03	0.001
2007	72705	3006	72484	0.46	3885	85	0.05	0.001
2008	74189	3175	73639	0.48	127258	157	0.045	0.002
2009	76377	3313	74422	0.50	4856	133	0.055	0.002
2010	80661	3409	74754	0.52	7683	190	0.055	0.003
2011	88142	3474	87777	0.53	14600	181	0.02	0.002
2012	94770	3522	94211	0.54	2130	61	0.02	0.001
2013	101402	3563	100641	0.54	25607	58	0.015	0.001
2014	107678	3697	107215	0.56	4445	57	0.015	0.001
2015	113278	4063	112020	0.62	10066	55	0.015	0
2016	118460	4535	118091	0.69	10478	59	0.015	0.001
2017	122572	4939	121939	0.75	10763	65	0.055	0.001
2018	125781	5239	125125	0.80	10956	-	-	-
2019	128314	5472	127642	0.83	11095	-	-	-
2020	126242	5484	125560	0.83	11102	-	-	-
2021	123800	5461	123112	0.83	11089	-	-	-
2022	121154	5400	120465	0.82	11053	-	-	-
2023	118417	5314	117730	0.81	11002	-	-	-
2024	115674	5215	114989	0.79	10941	-	-	-
2025	112978	5109	112296	0.78	10875	-	-	-
2026	110365	4999	109688	0.76	10804	-	-	-
2027	107856	4889	107183	0.74	10730	-	-	-
2028	105461	4780	104792	0.73	10655	-	-	-

tab:Timeseries_mod1

Table 28: Projection of potential OFL, spawning biomass, and depletion for the base case model.

Year	OFL (mt)	ACL (mt)	Age 3+ biomass (mt)	Spawning Output	tab:Forecast_mod1 Depletion
2017	4171	281	121939	4939	0.75
2018	4402	281	125125	5239	0.80
2019	4546	4346	127642	5472	0.83
2020	4476	4279	125560	5484	0.84
2021	4371	4178	123112	5461	0.83
2022	4250	4063	120465	5400	0.82
2023	4125	3944	117730	5314	0.81
2024	4003	3827	114989	5215	0.80
2025	3888	3717	112296	5109	0.78
2026	3782	3615	109688	4999	0.76
2027	3684	3521	107183	4889	0.75
2028	3593	3435	104792	4780	0.73

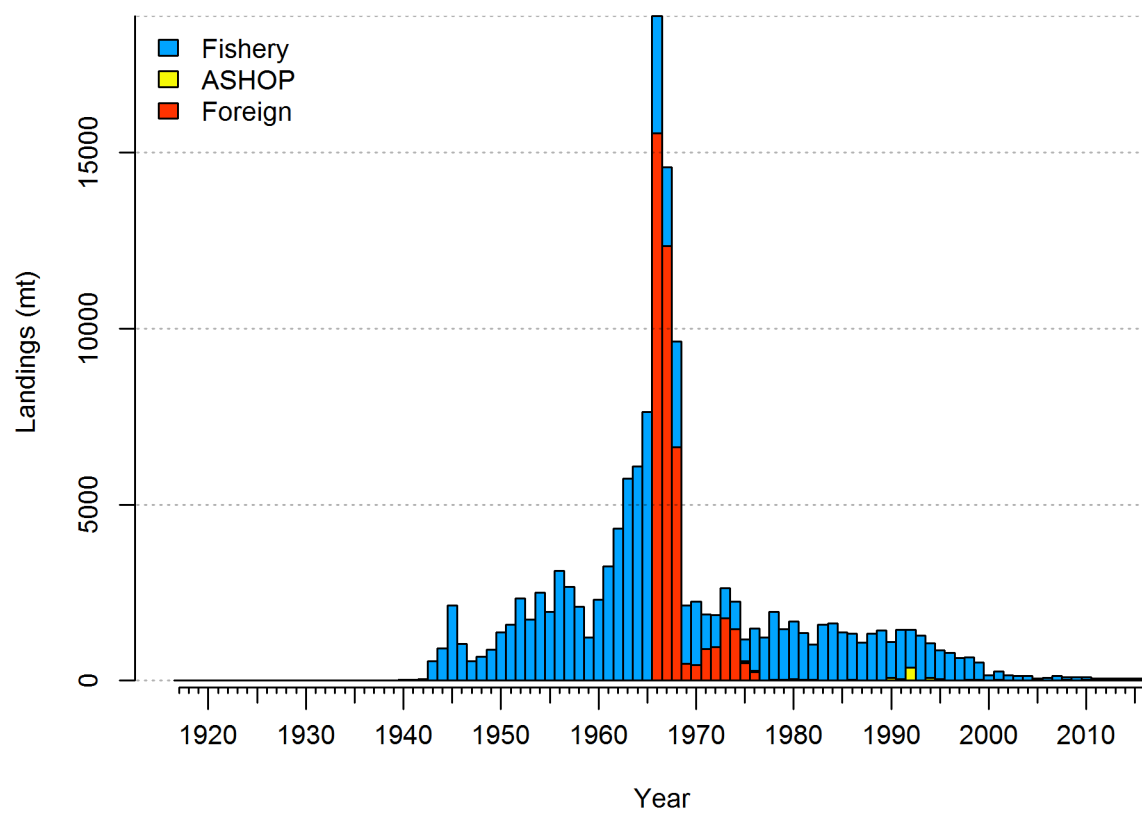


Figure 1: Total catches Pacific ocean perch through 2016. ^{fig: Catch}

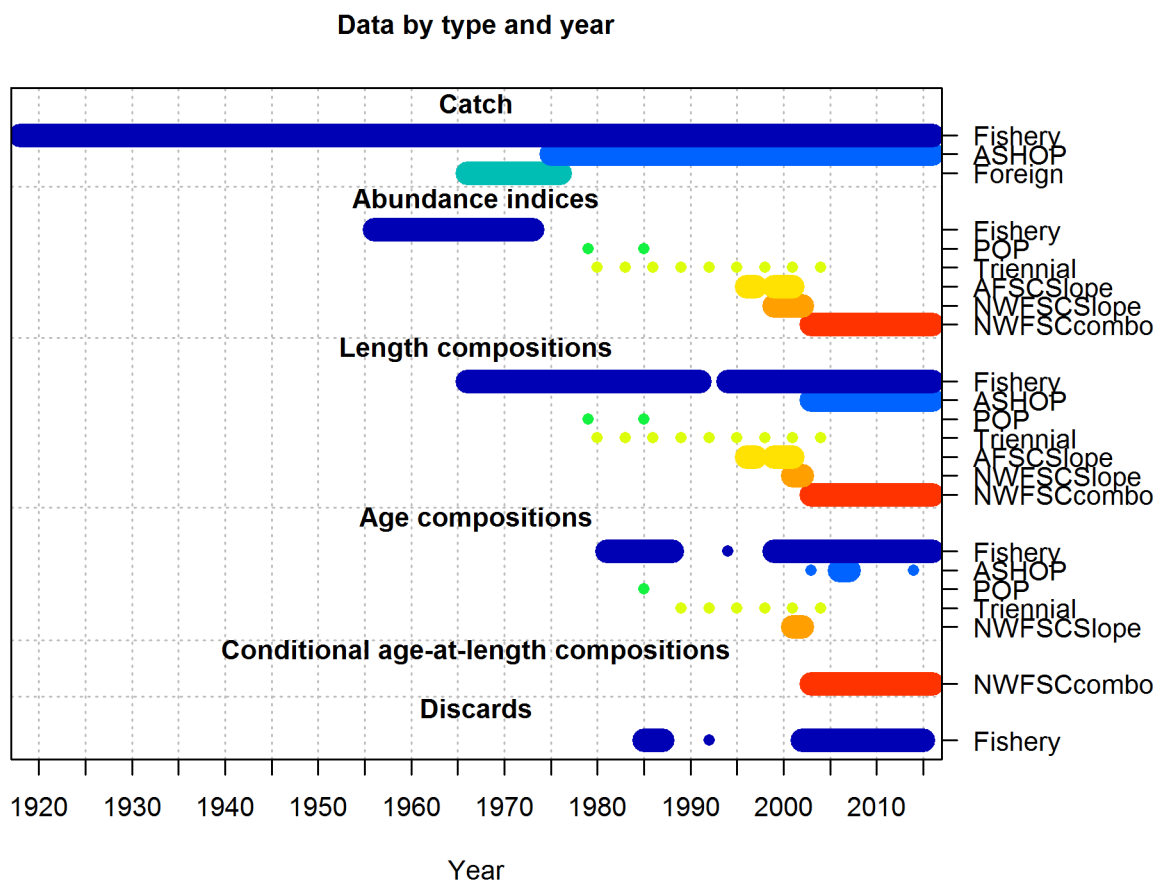


Figure 2: Summary of data sources used in the Base model. fig:data_plot

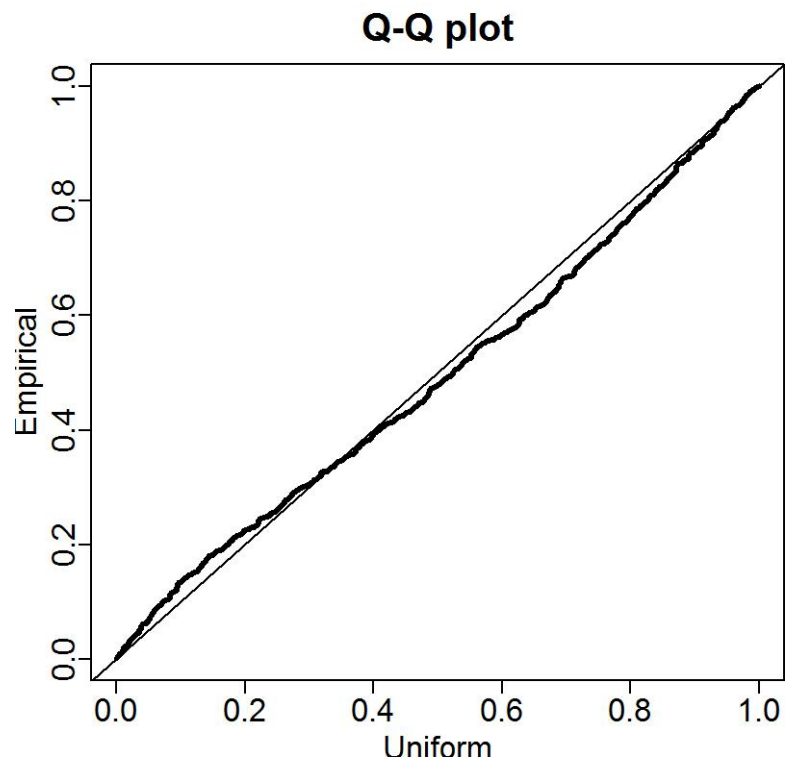


Figure 3: Q-Q plots for the VAST lognormal distribution for the NWFSC shelf-slope survey. fig:nw_qq

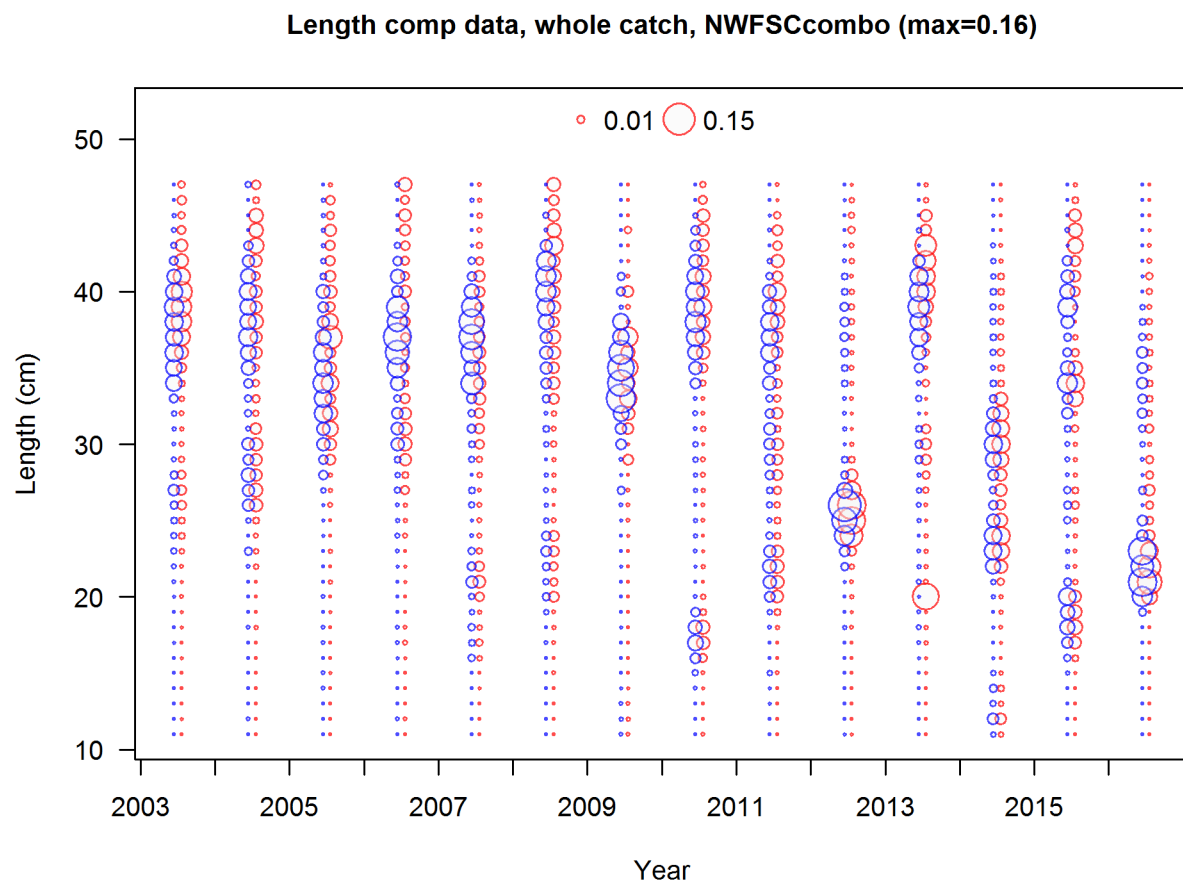


Figure 4: NWFSC shelf-slope survey length frequency distributions for Pacific ocean perch. fig:nw_Length

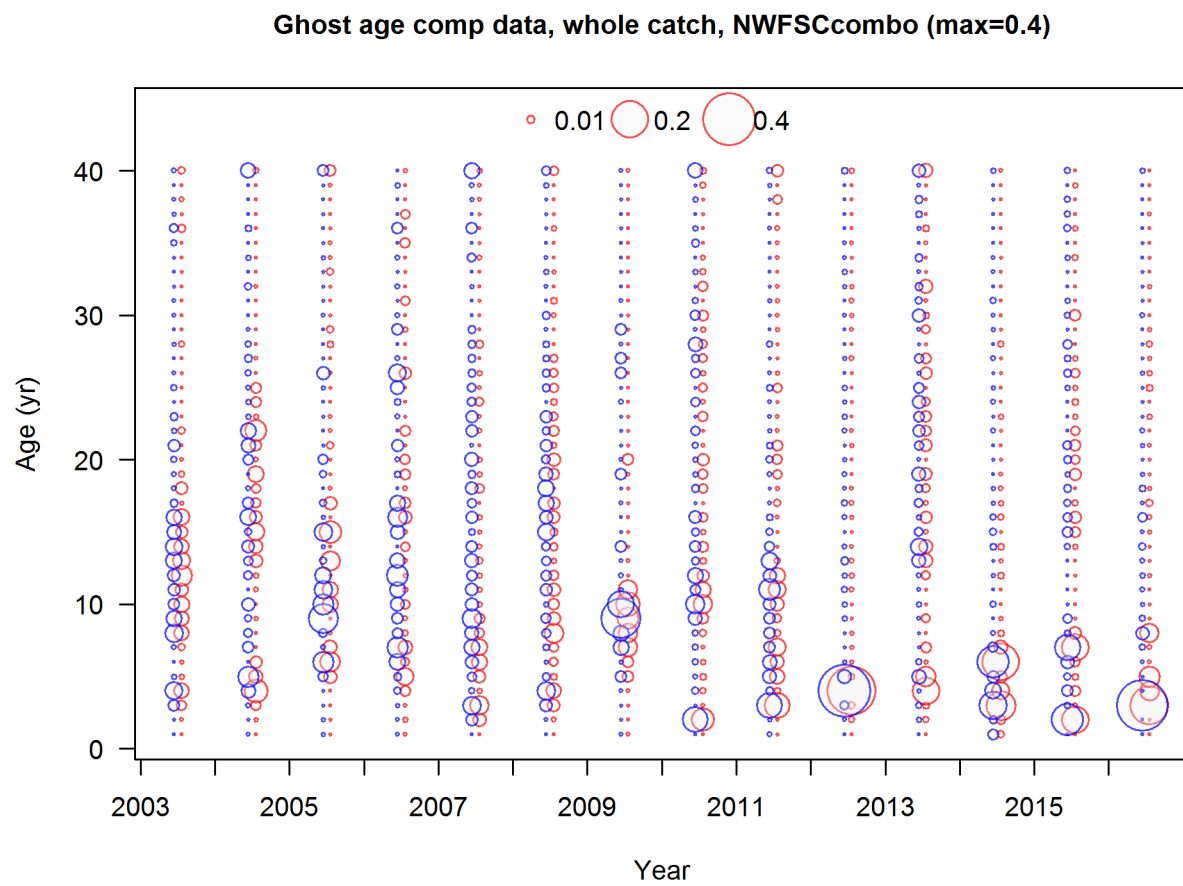


Figure 5: NWFSC shelf-slope survey age frequency distributions for Pacific ocean perch. fig:nw_Age

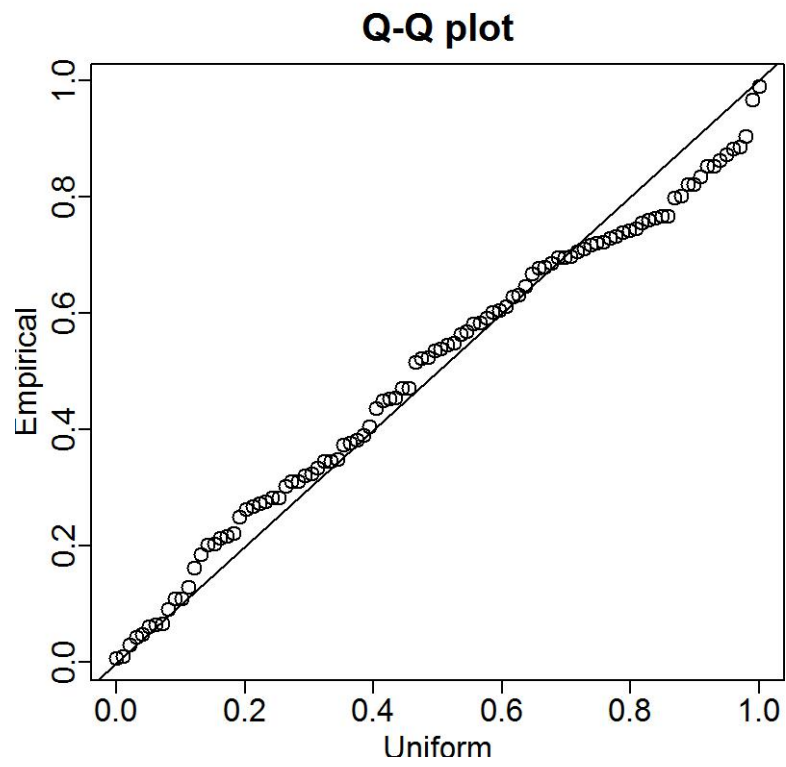


Figure 6: Q-Q plots for the VAST lognormal distribution for the NWFSC slope survey. fig:nw_slope_q

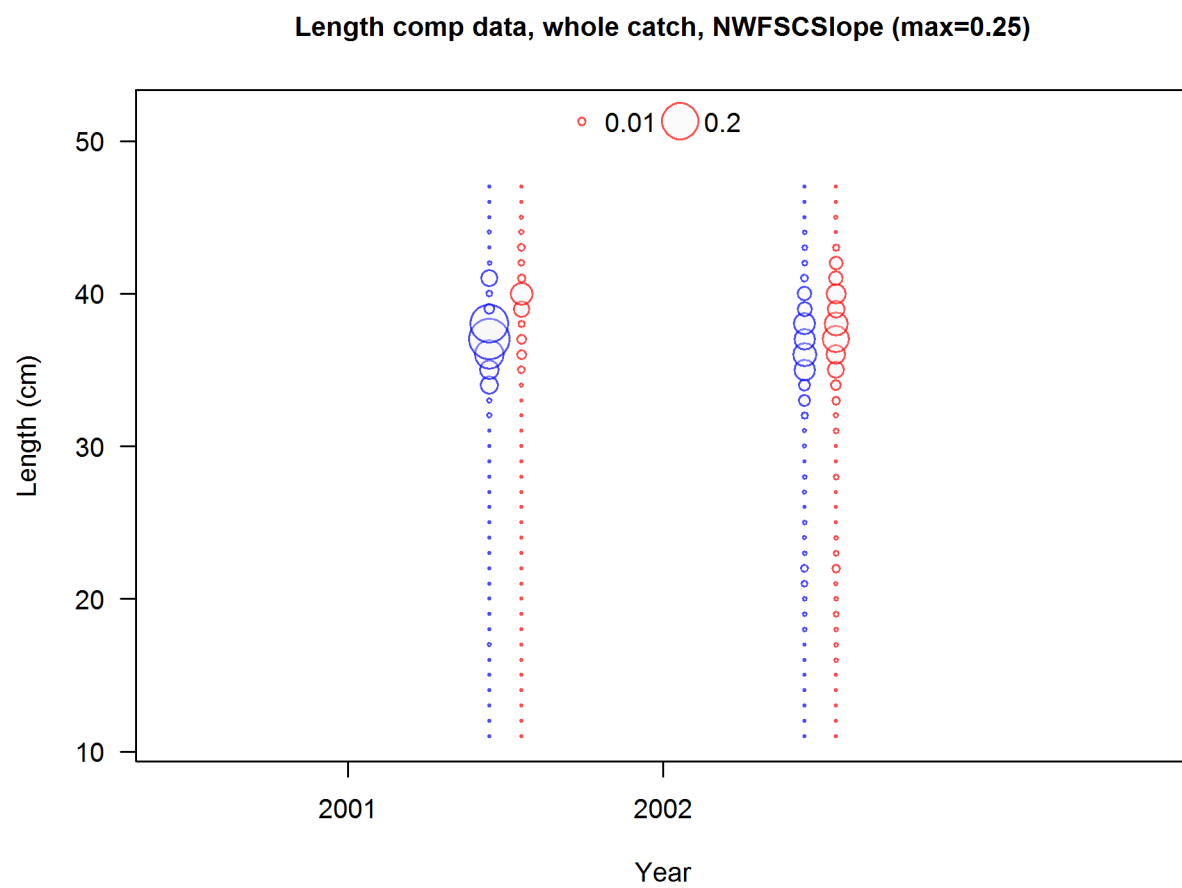


Figure 7: NWFSC slope survey length frequency distributions for Pacific ocean perch. fig:nw_slope_L

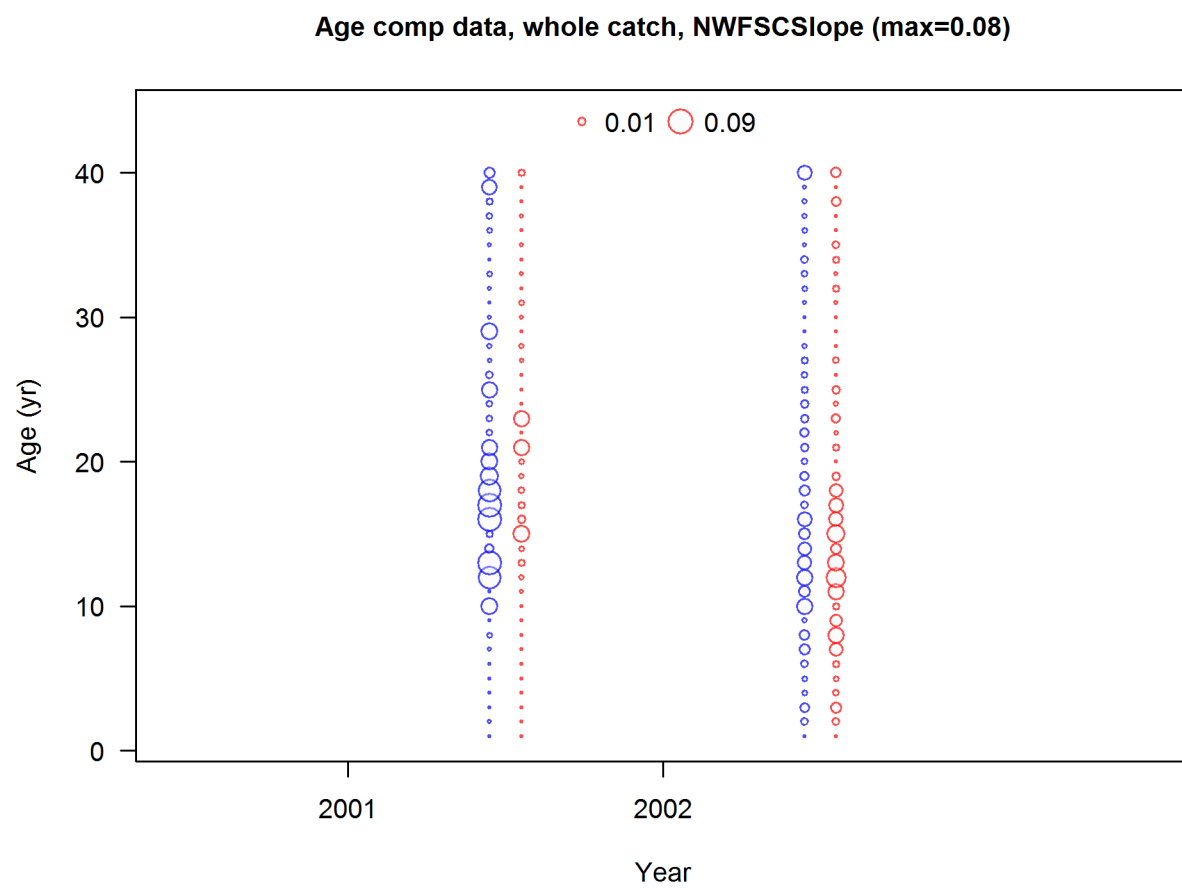


Figure 8: NWFSC slope survey age frequency distributions for Pacific ocean perch. fig:nw_slope_Age

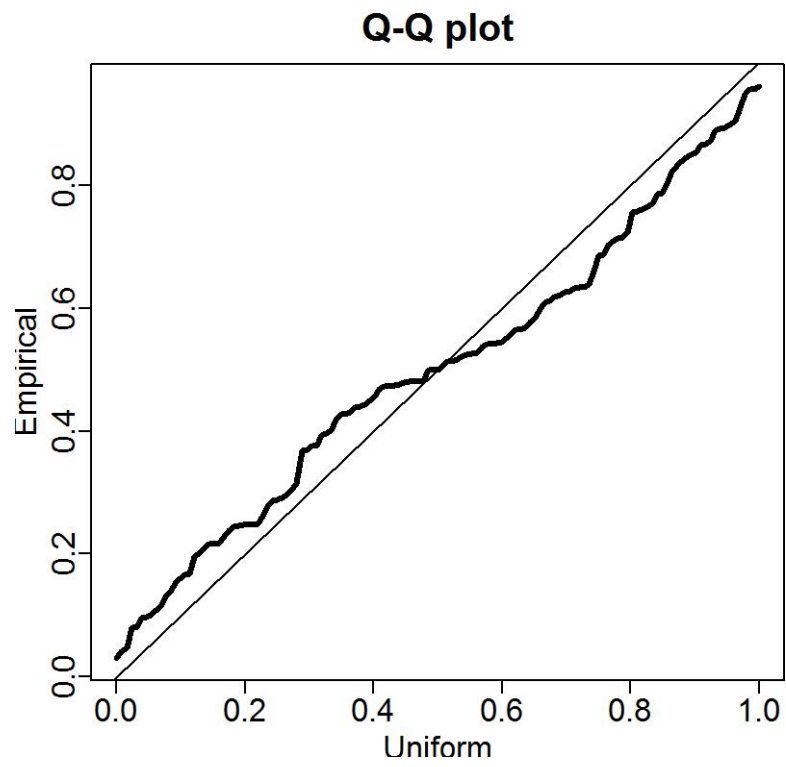


Figure 9: Q-Q plots for the VAST lognormal distribution for the AFSC slope survey. fig:afsc_qq

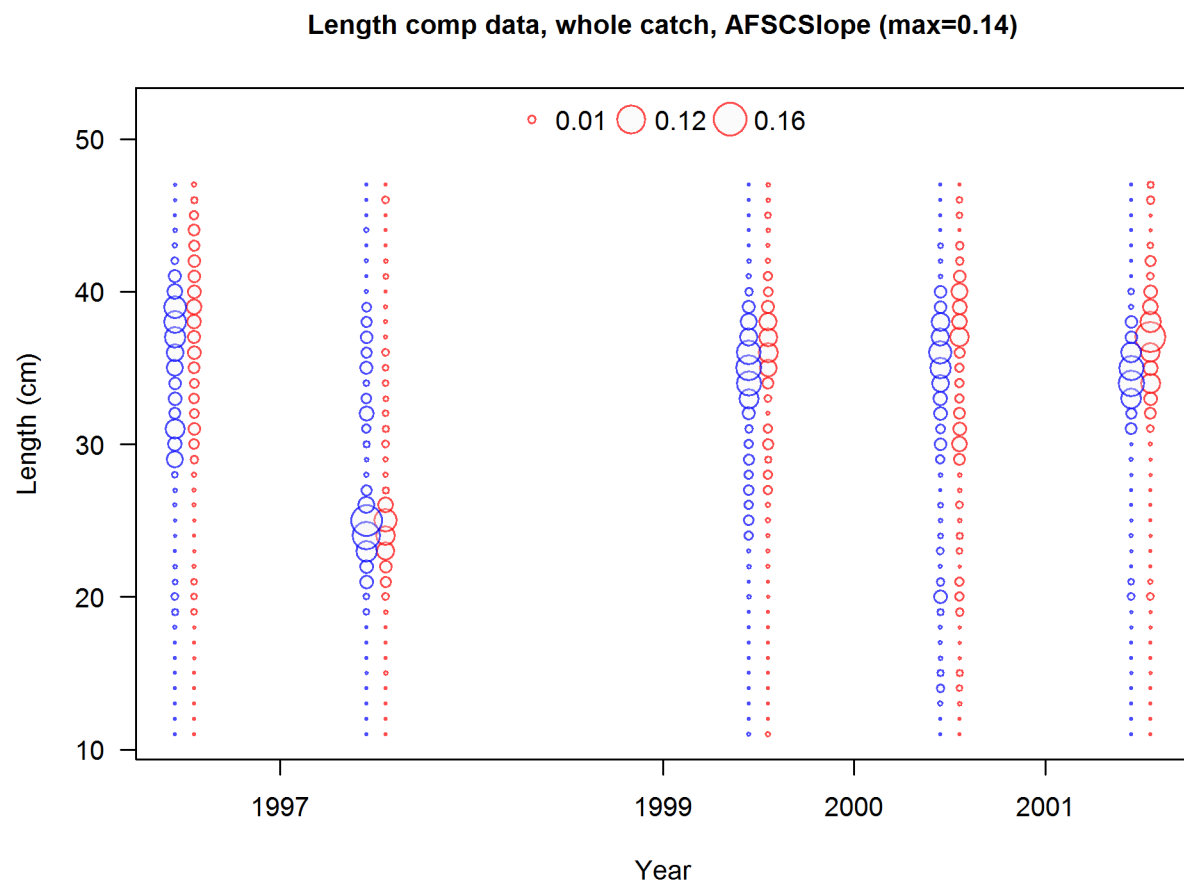


Figure 10: AFSC slope survey length frequency distributions for Pacific ocean perch. fig:afsc_Length

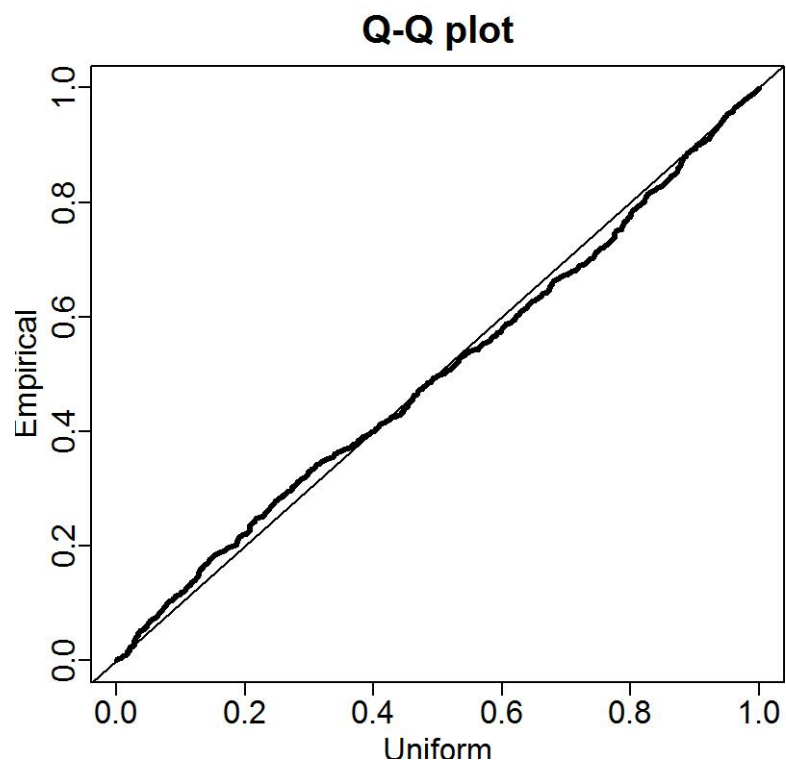


Figure 11: Q-Q plots for the VAST lognormal distribution for the Triennial survey. ^{fig:tri_qq}

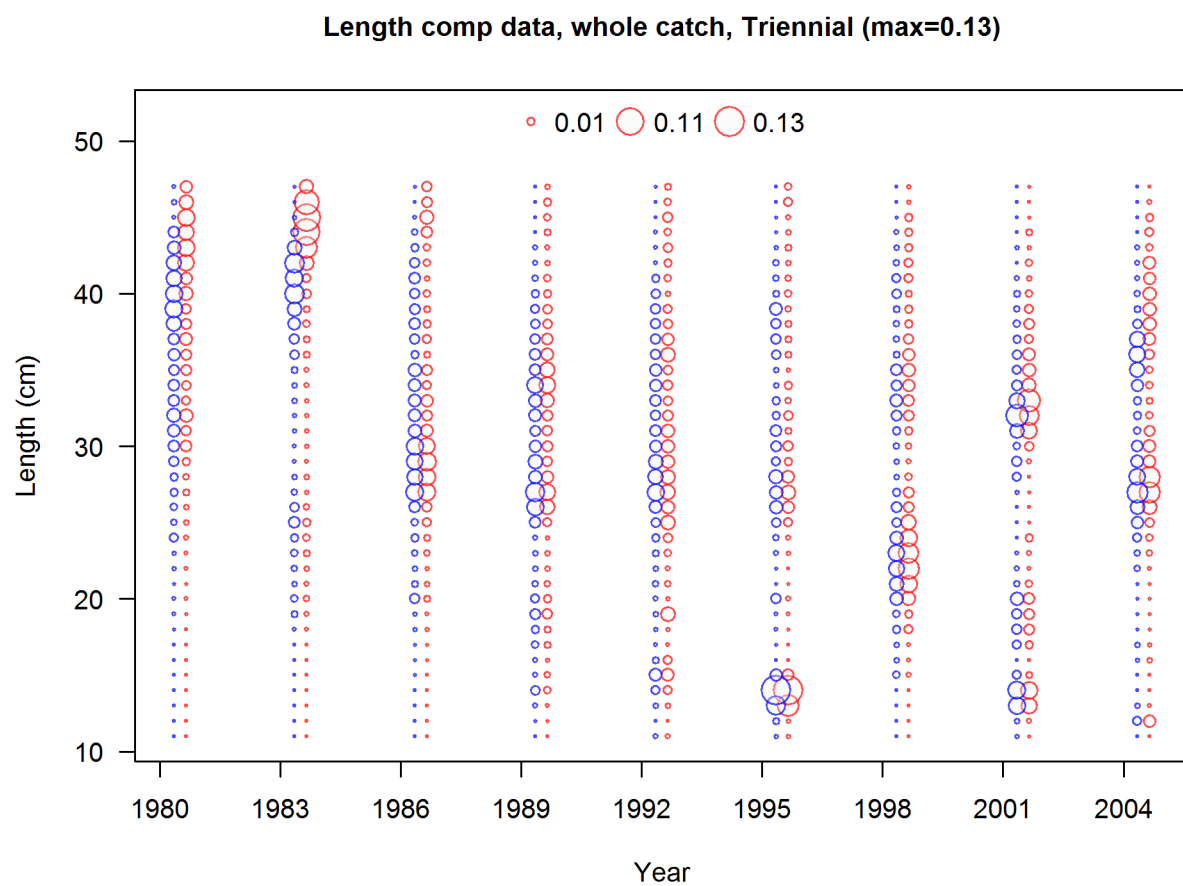


Figure 12: Triennial survey length frequency distributions for Pacific ocean perch. fig:Tri_Length

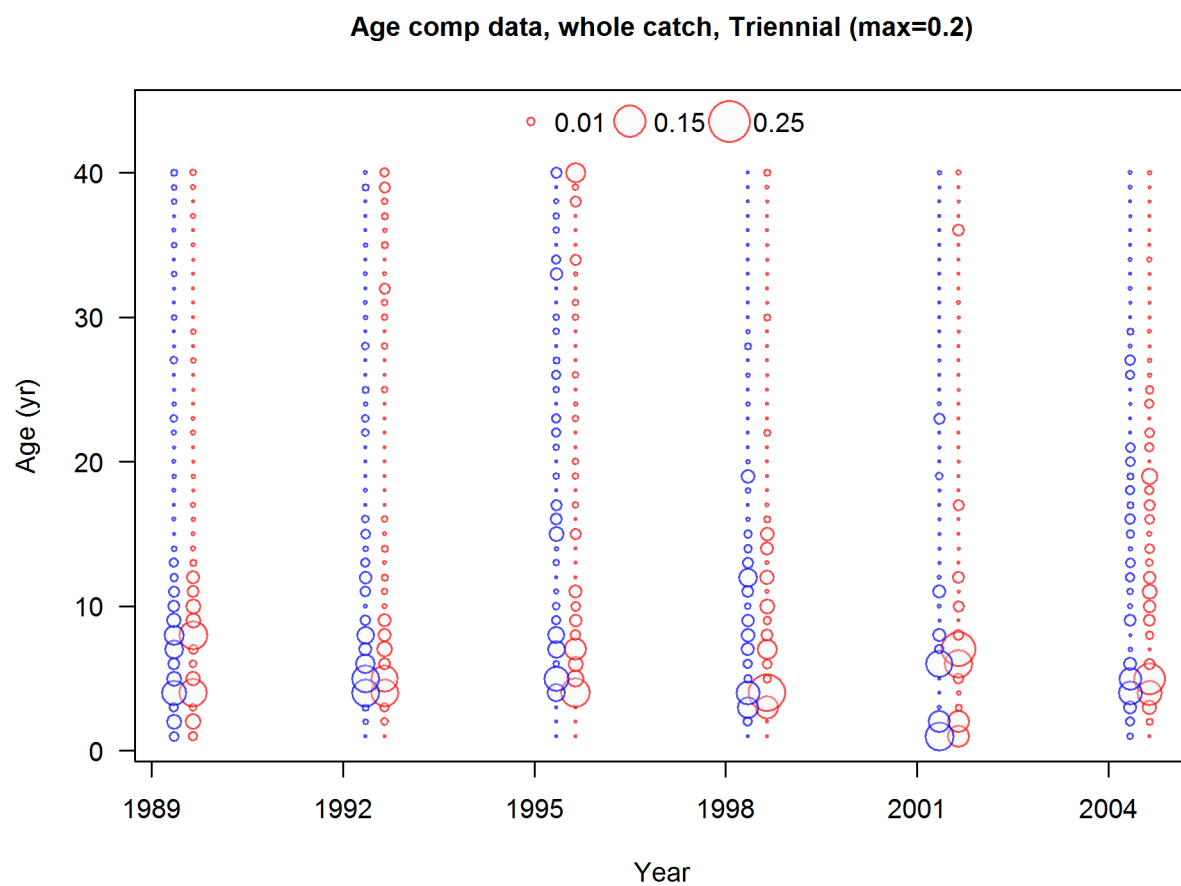


Figure 13: Triennial survey age frequency distributions for Pacific ocean perch. fig:Tri_Age

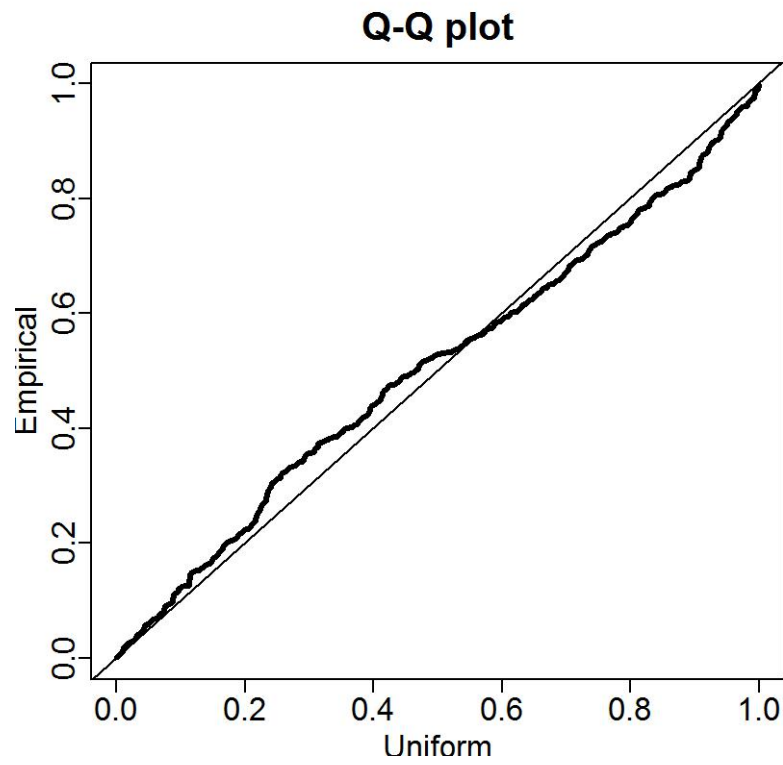


Figure 14: Q-Q plots for the VAST lognormal distribution for the Pacific ocean perch survey.
fig:pop_qq

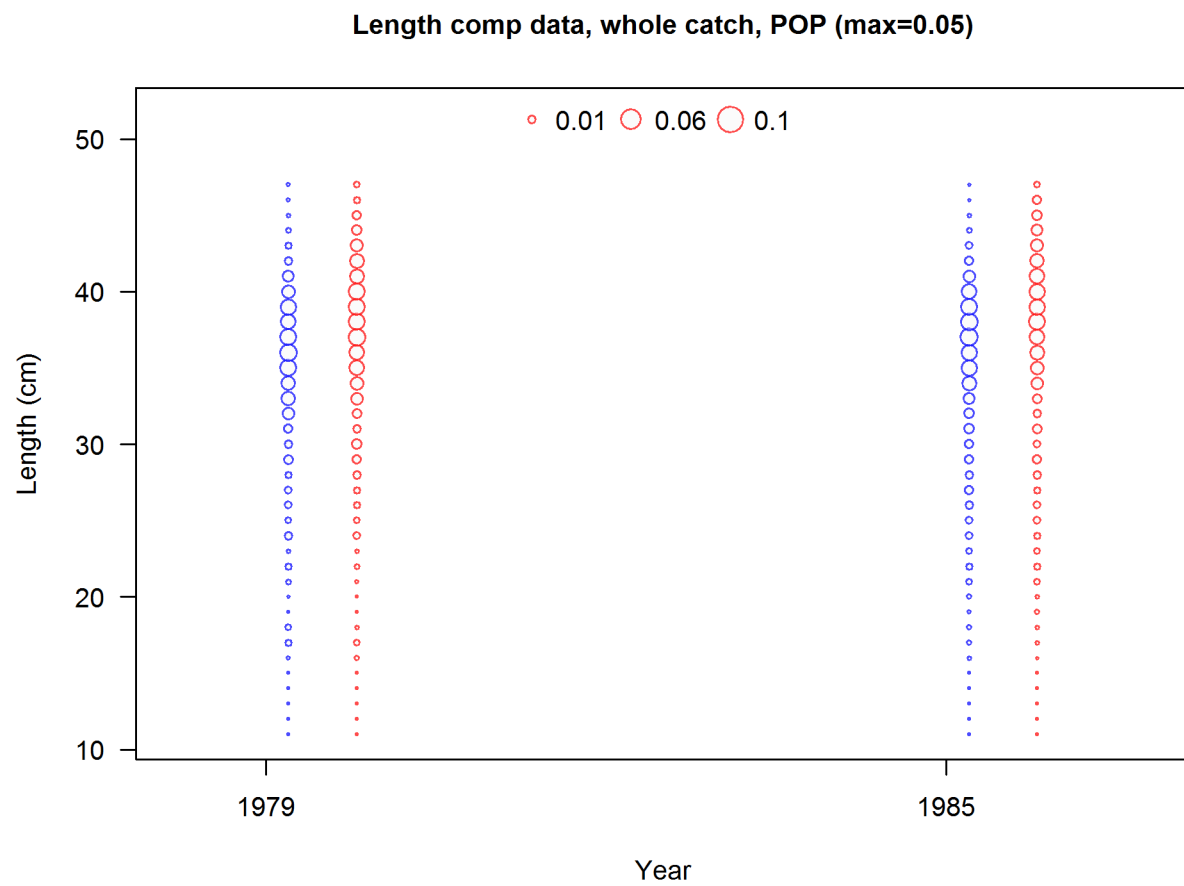


Figure 15: Pacific ocean perch survey length frequency distributions for Pacific ocean perch. fig:POP_Length

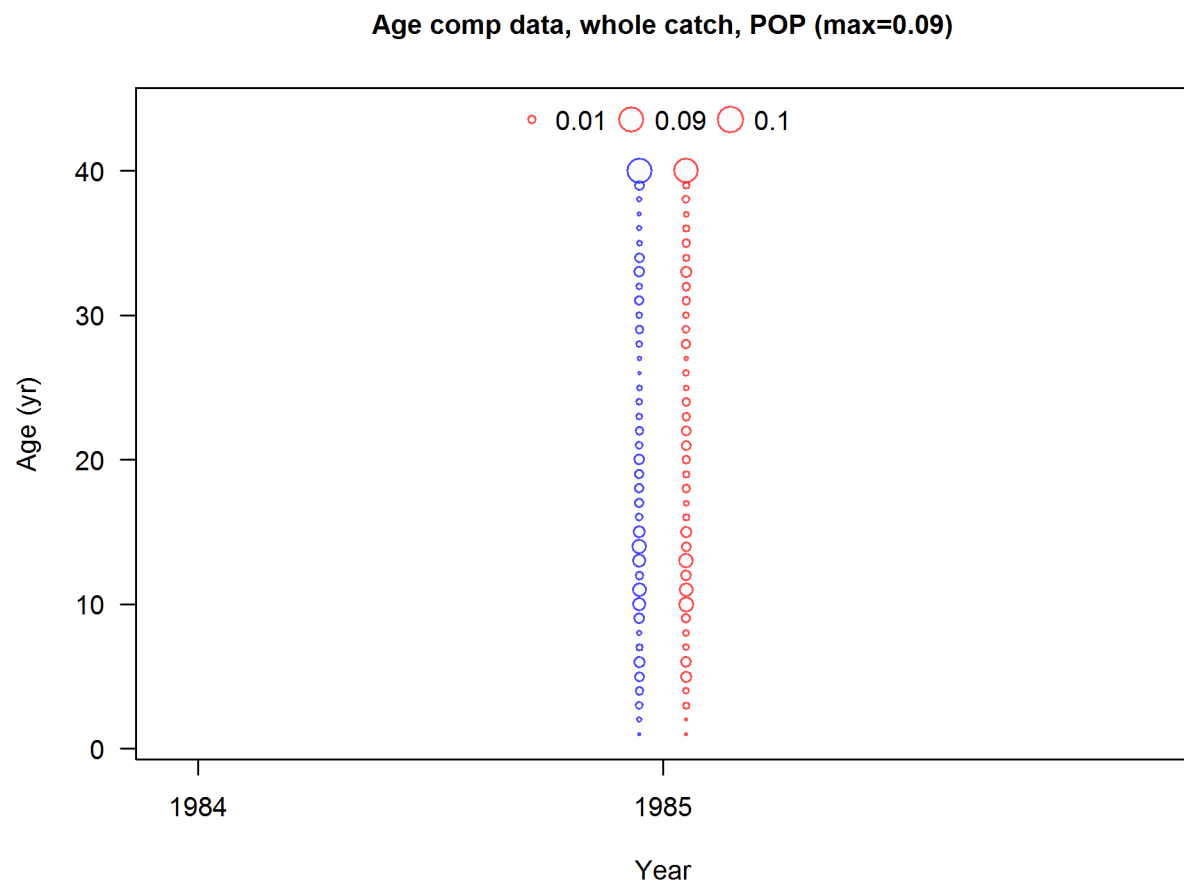


Figure 16: Pacific ocean perch survey age frequency distributions for Pacific ocean perch. fig:POP_Age

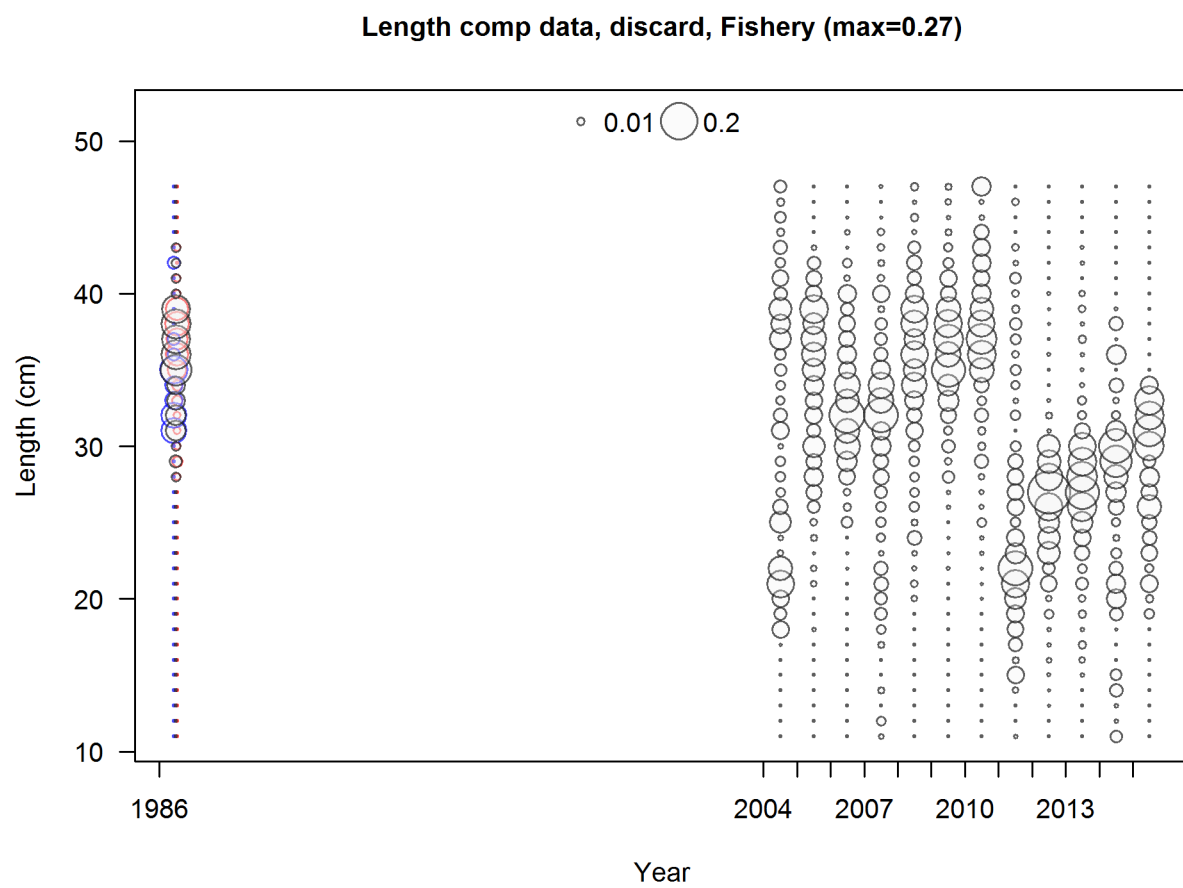


Figure 17: Discard length frequency distributions from WCGOP for Pacific ocean perch. fig:WCGOP_dis

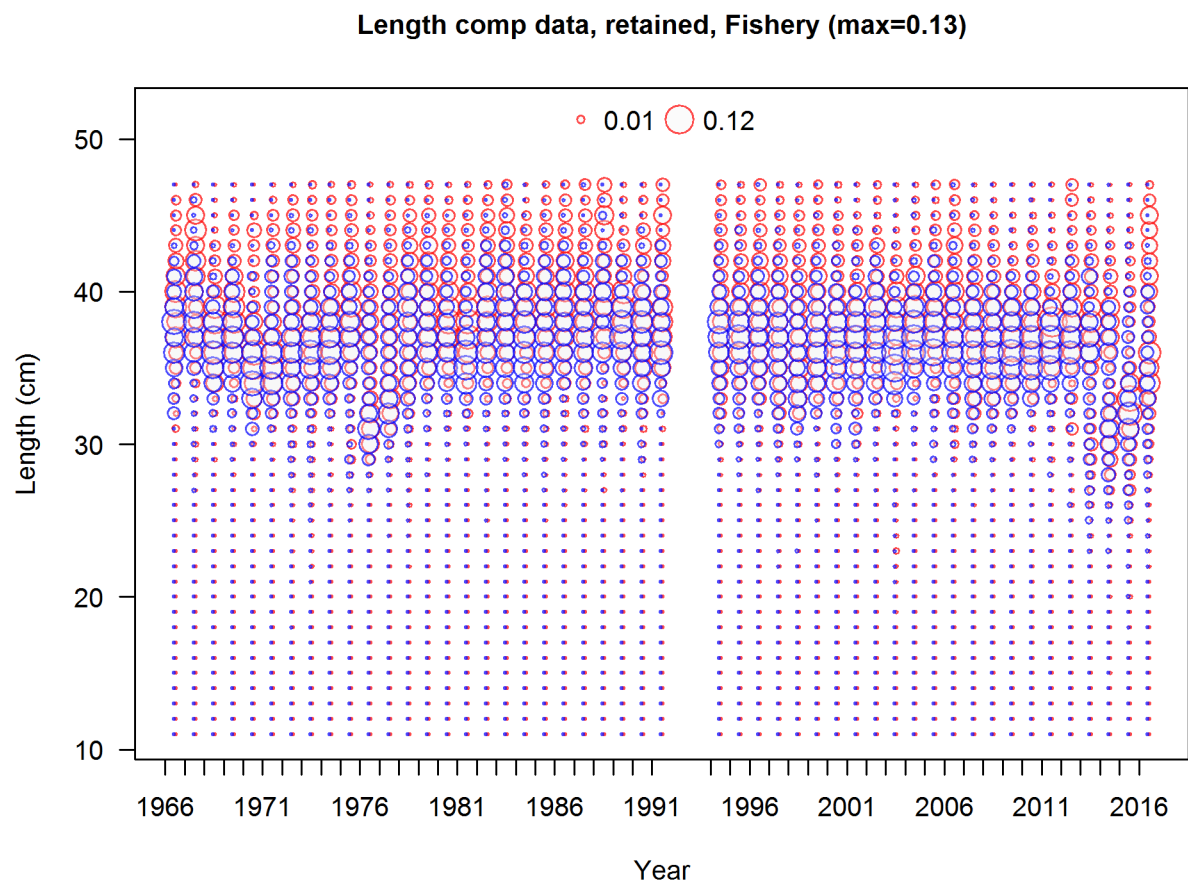


Figure 18: Commercial fishery length frequency distributions for Pacific ocean perch. fig:Comm_Length

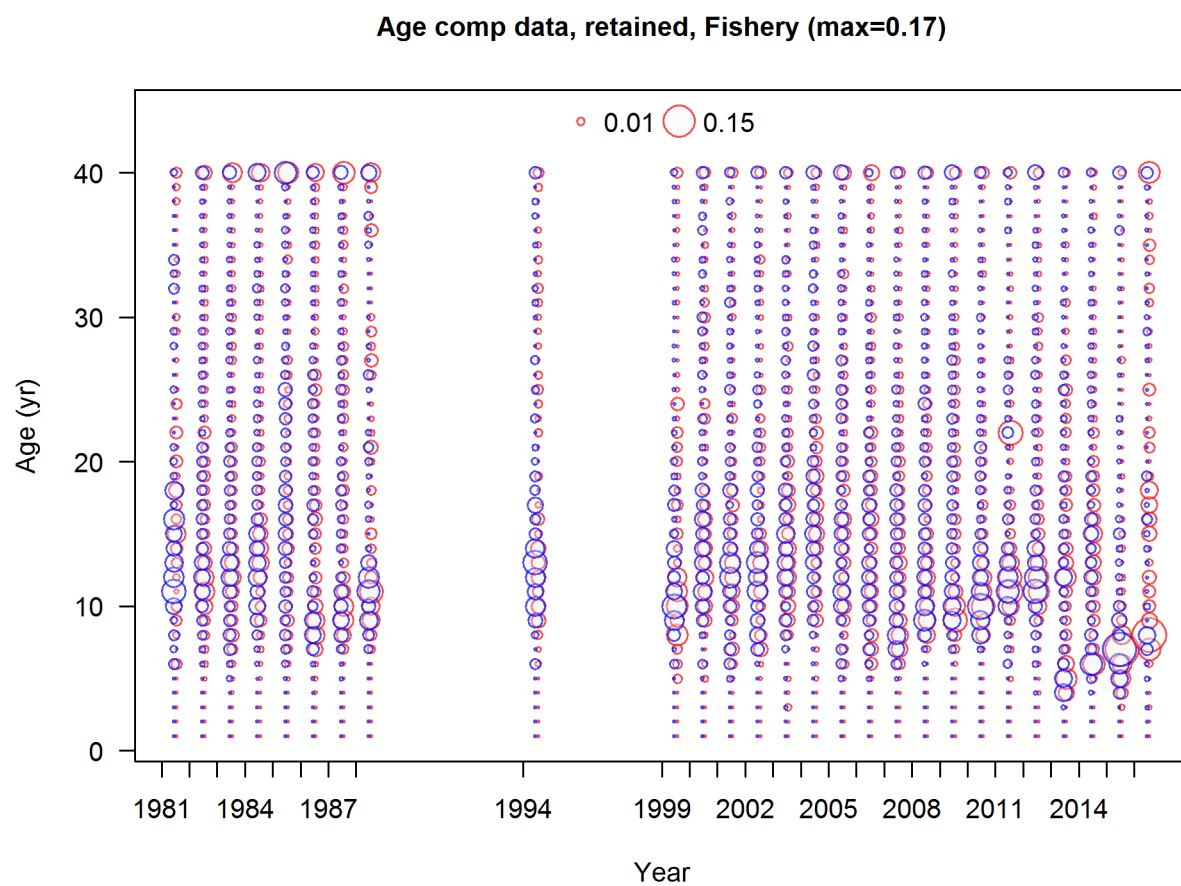


Figure 19: Commercial fishery age frequency distributions for Pacific ocean perch. fig:Comm_Age

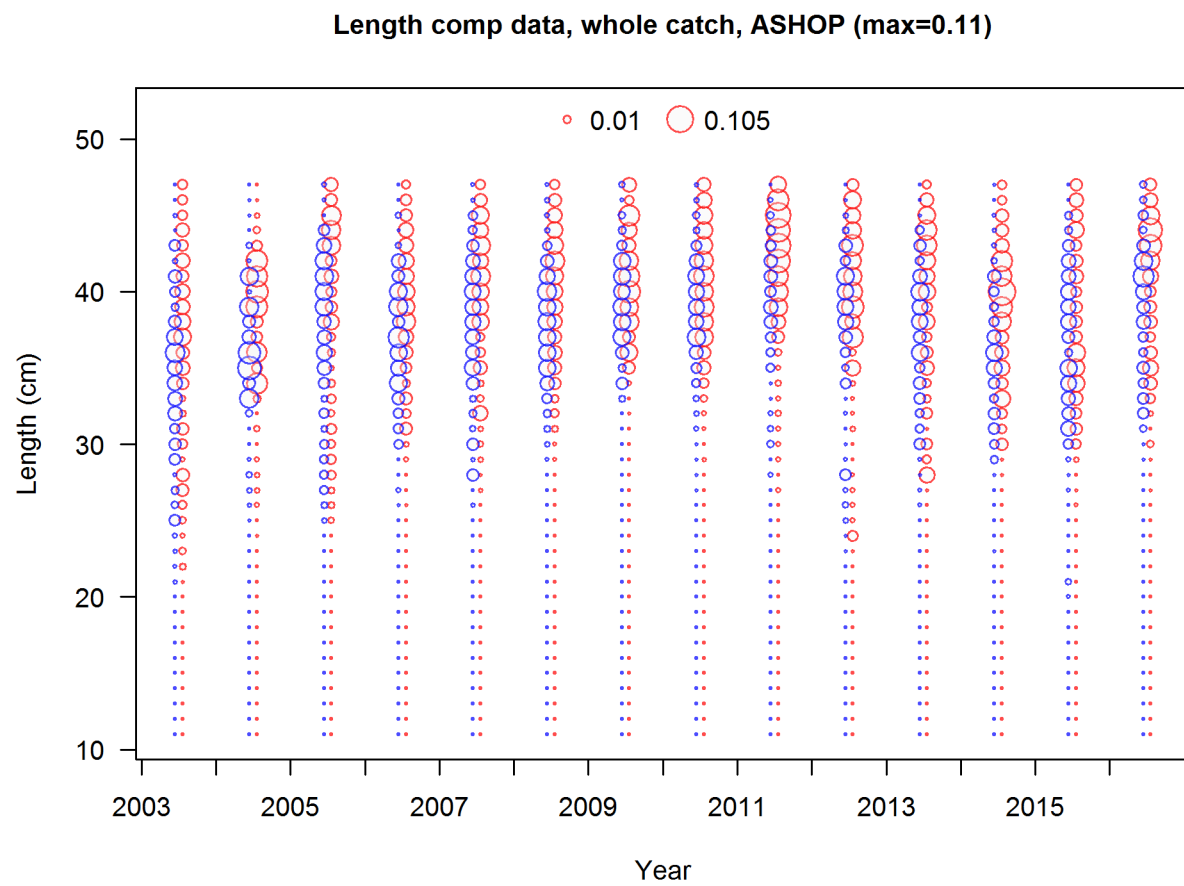


Figure 20: At-Sea hake fishery length frequency distributions for Pacific ocean perch. fig:ASHOP_Length

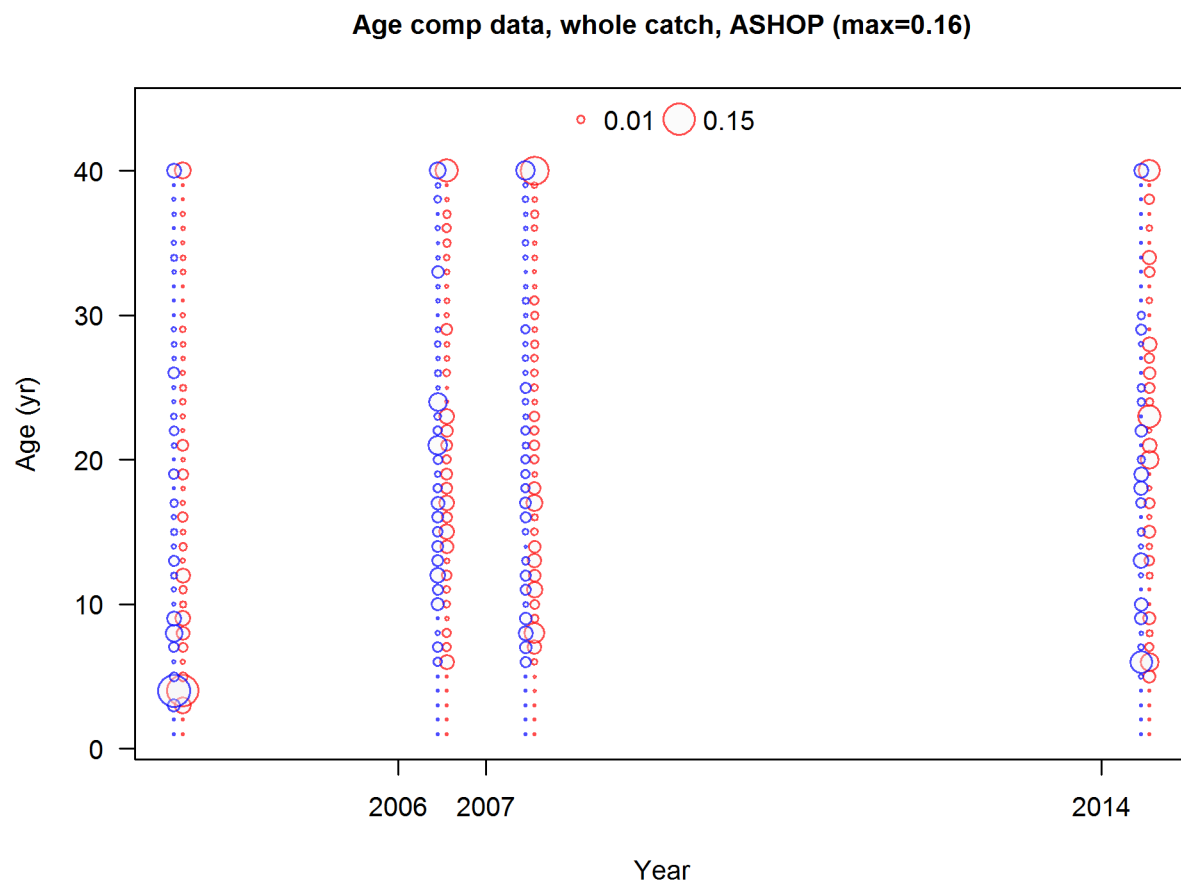


Figure 21: At-Sea hake fishery age frequency distributions for Pacific ocean perch. fig:ASHOP_Age

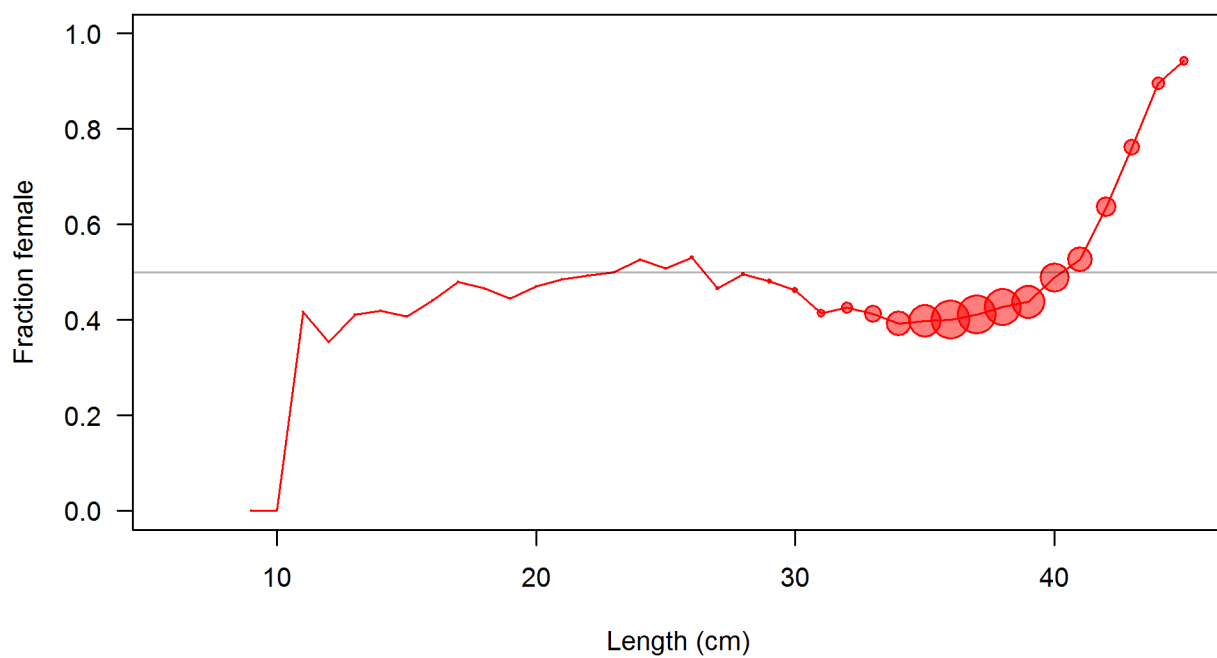


Figure 22: The estimated sex ratio of Pacific ocean perch at length from all biological data sources. `fig:sexratio`

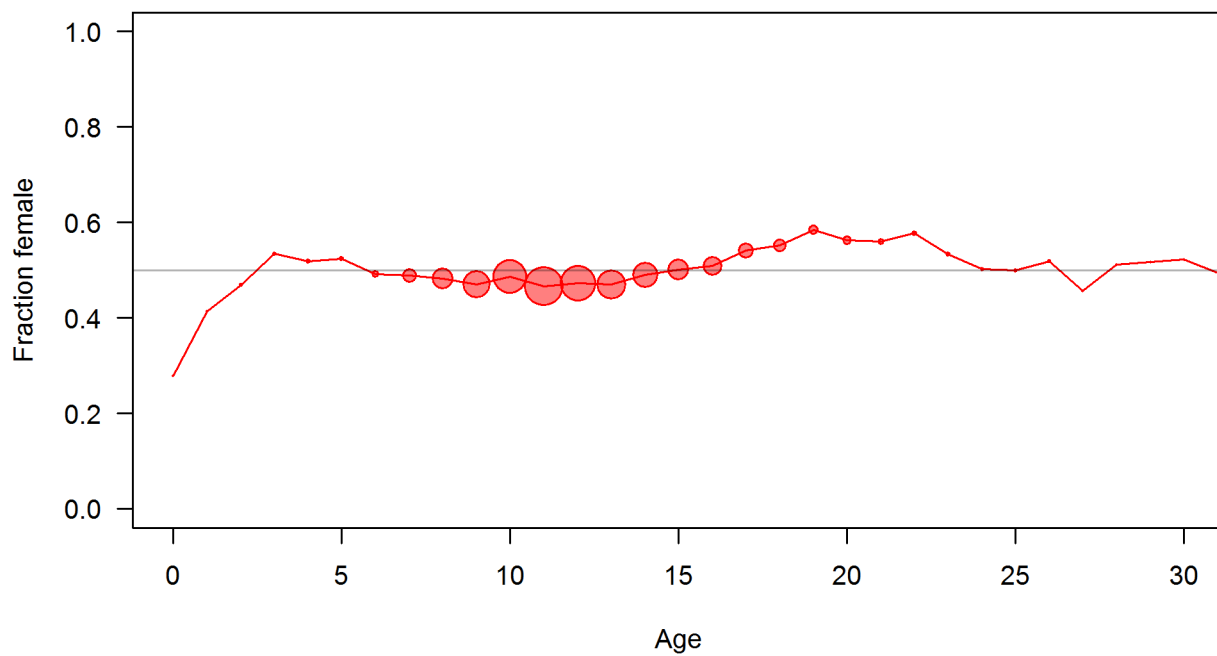


Figure 23: The estimated sex ratio of Pacific ocean perch at age from all biological data sources. `fig:sexratio_Age`

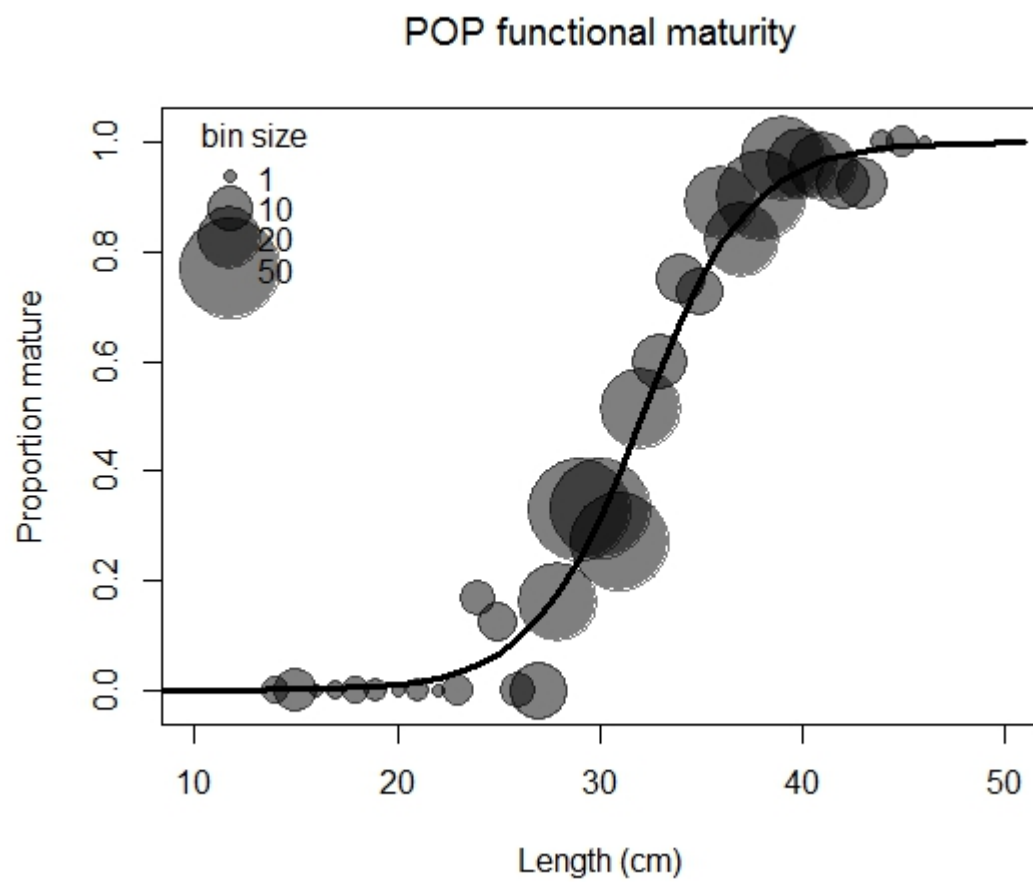


Figure 24: The estimated functional maturity Pacific ocean perch at length. ^{fig:mat}

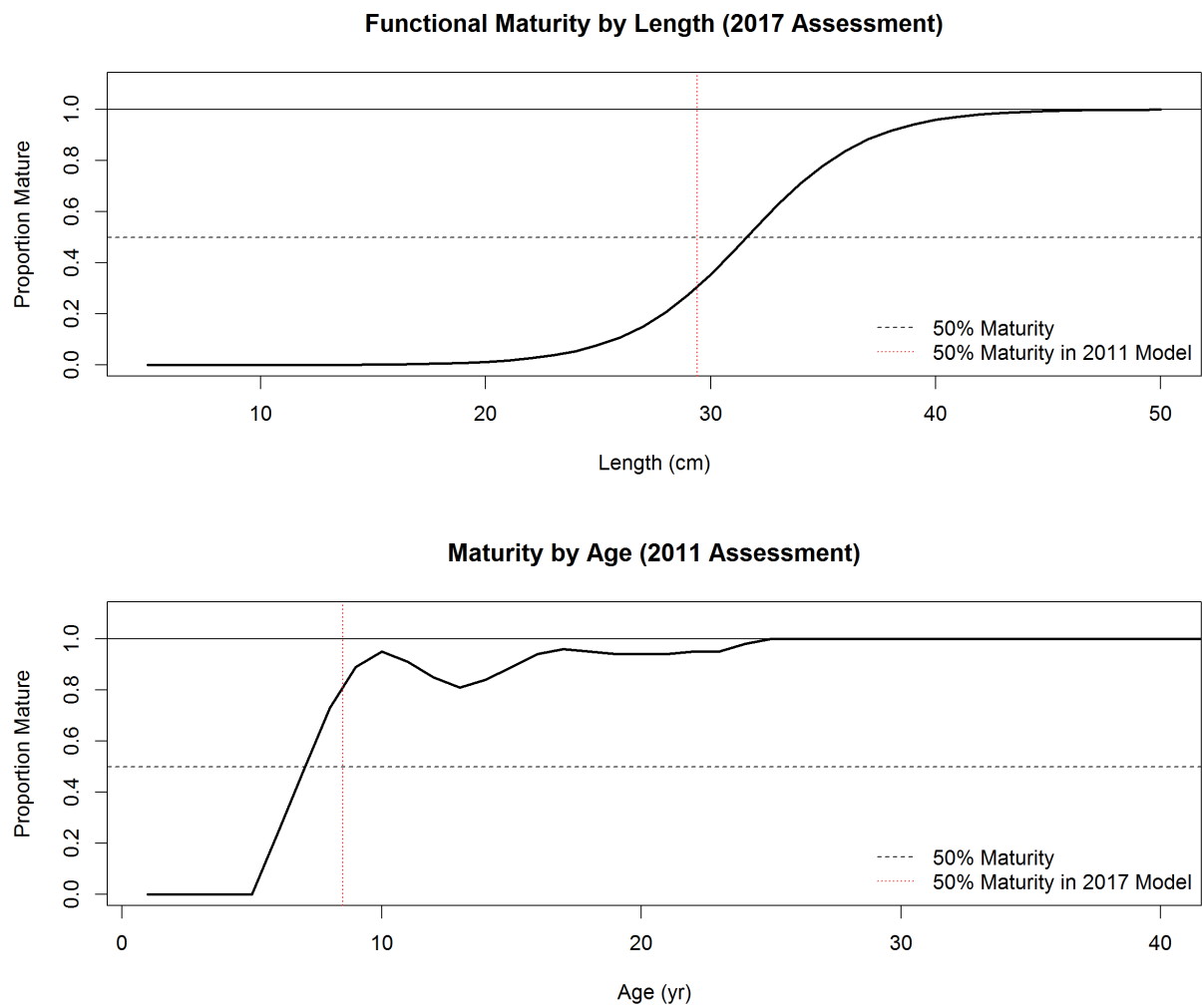


Figure 25: Comparison between estimated maturity-at-length used in this assessment and maturity-at-age applied in the 2011 assessment of Pacific ocean perch. fig:mat_compare

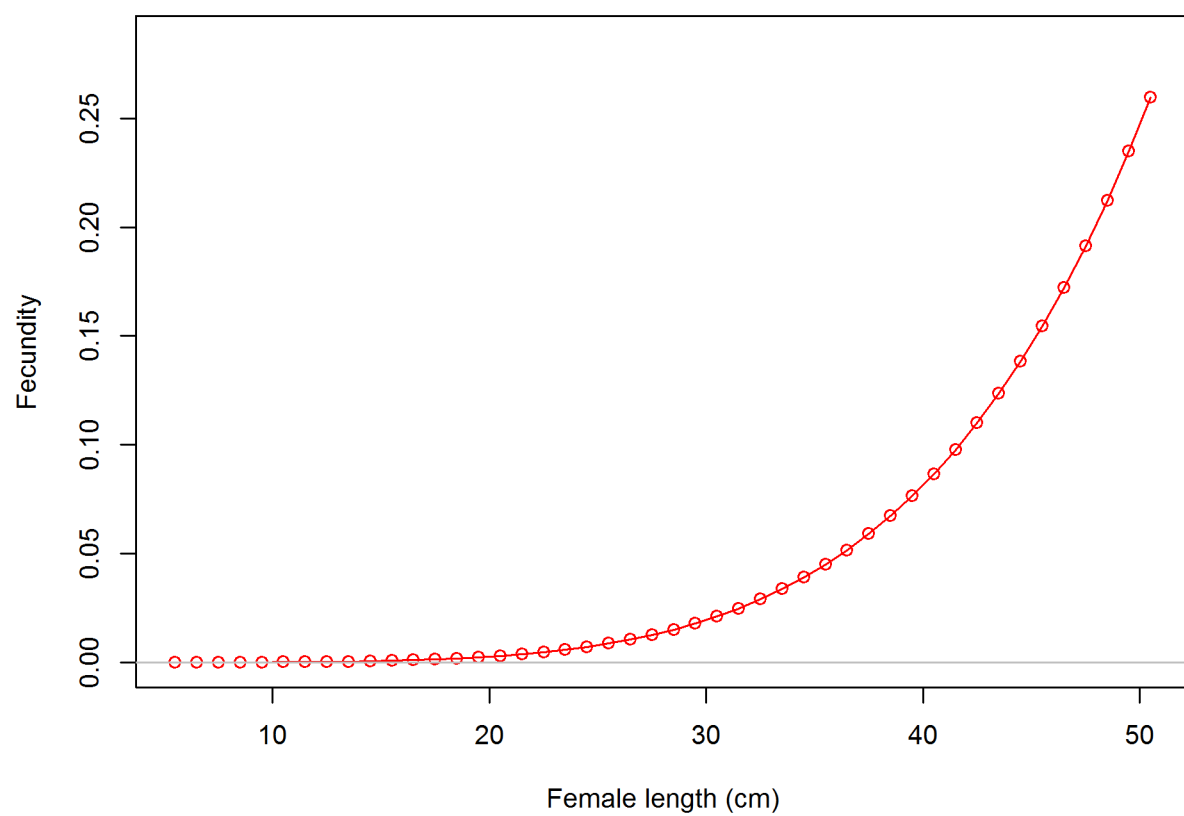


Figure 26: Fecundity at length of Pacific ocean perch in the Base model. ^{fig:fecundity}

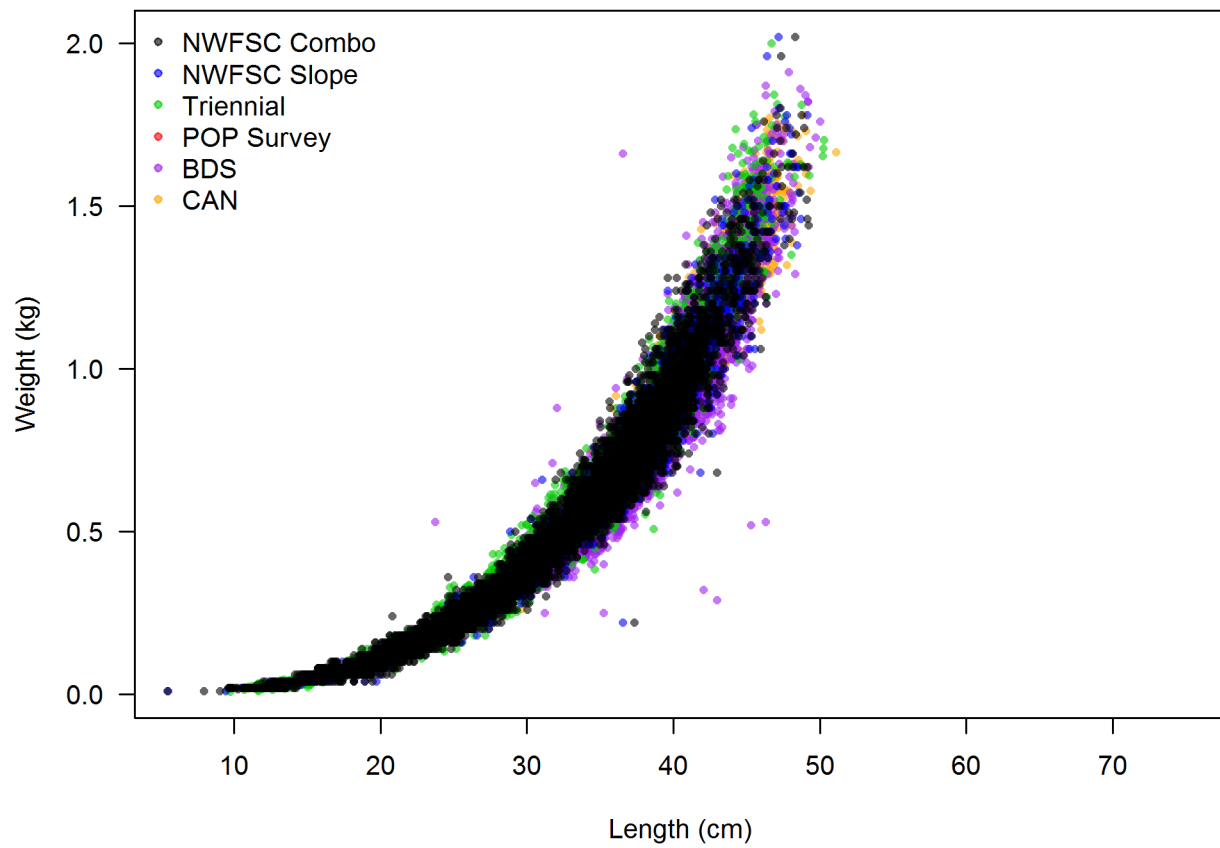


Figure 27: Weight-at-length for Pacific ocean perch from all data sources. ^{fig:Wt_len}

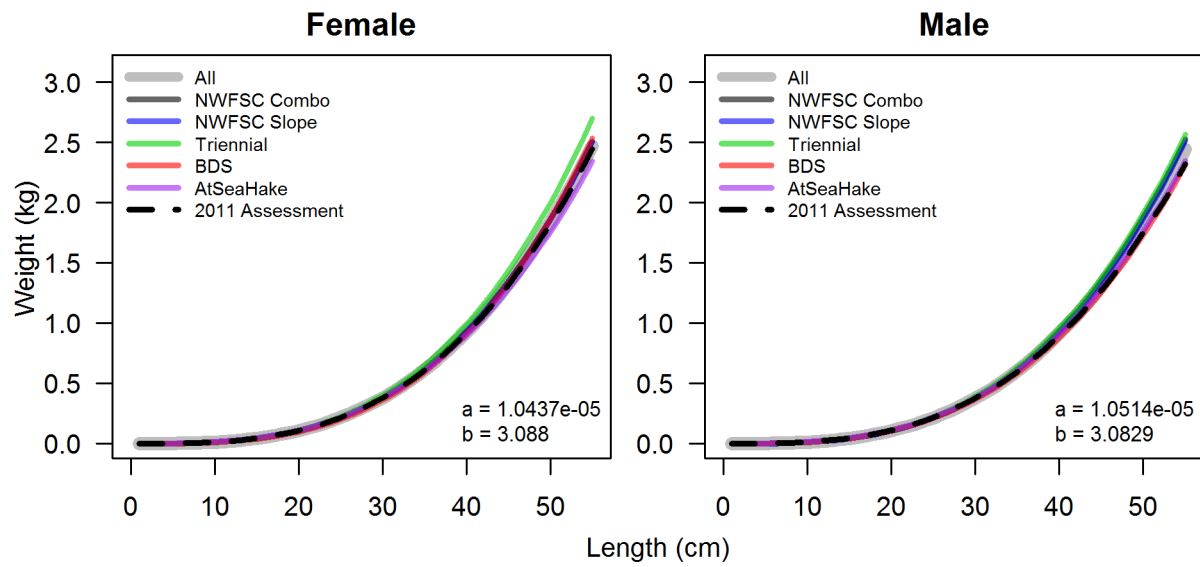


Figure 28: Estimated weight-at-length for Pacific ocean perch from all data sources. fig:Wt_len_pred

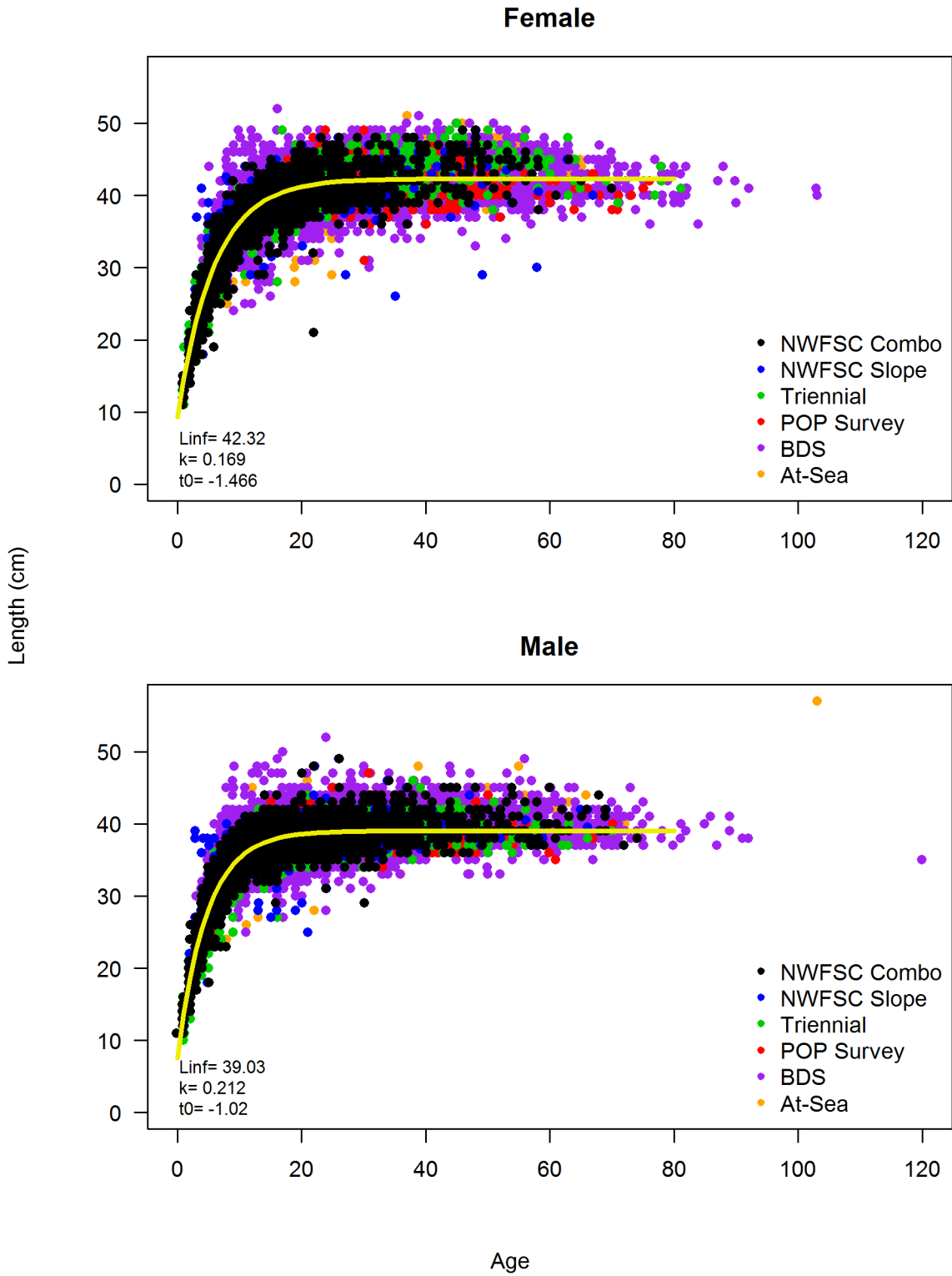


Figure 29: Estimated length-at-age for Pacific ocean perch from all data sources. ^{fig:Len_Age}

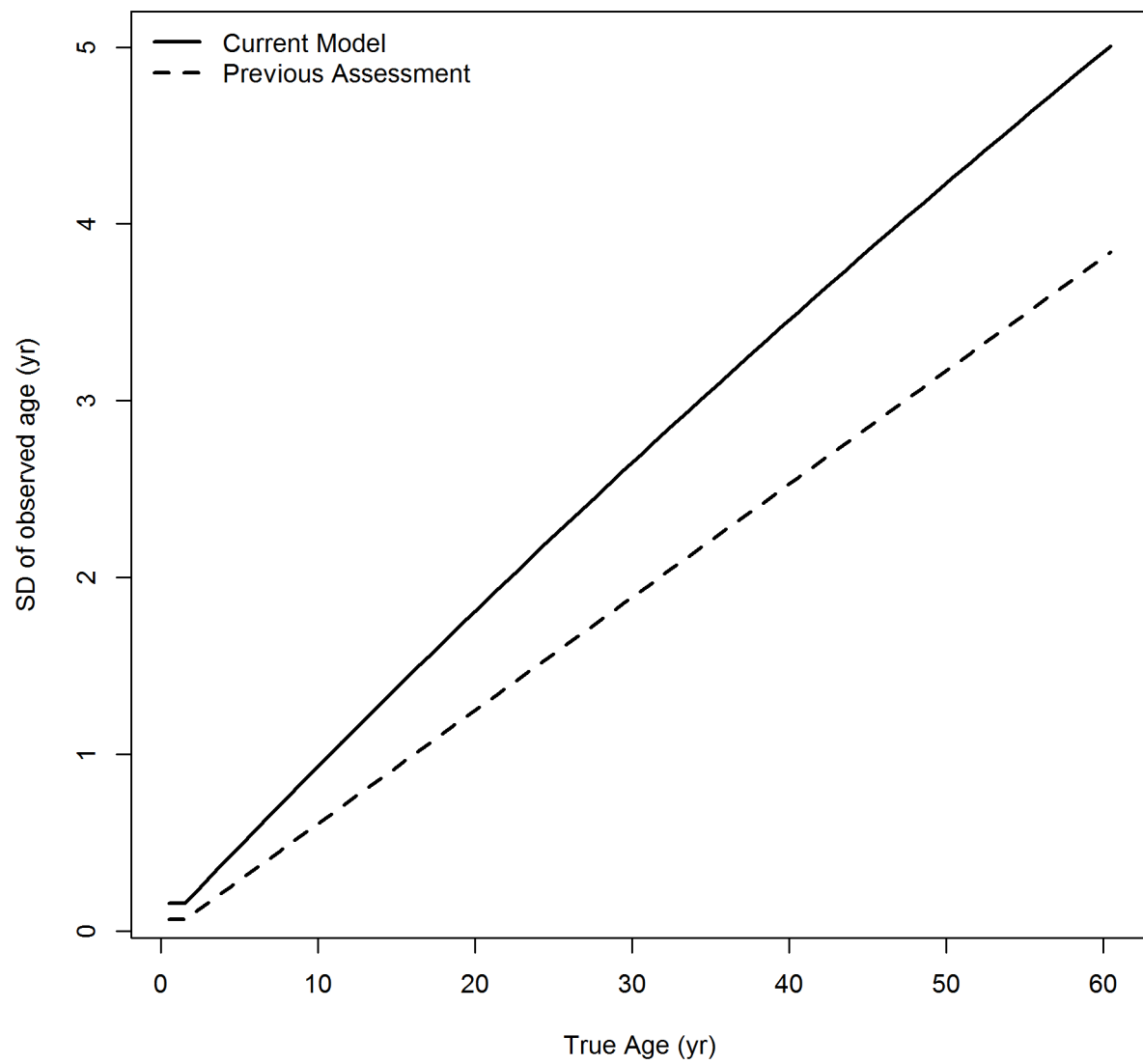


Figure 30: The estimated ageing error used in this assessment compared to the ageing error assumed in the previous assessment for Pacific ocean perch. fig:Age_Error

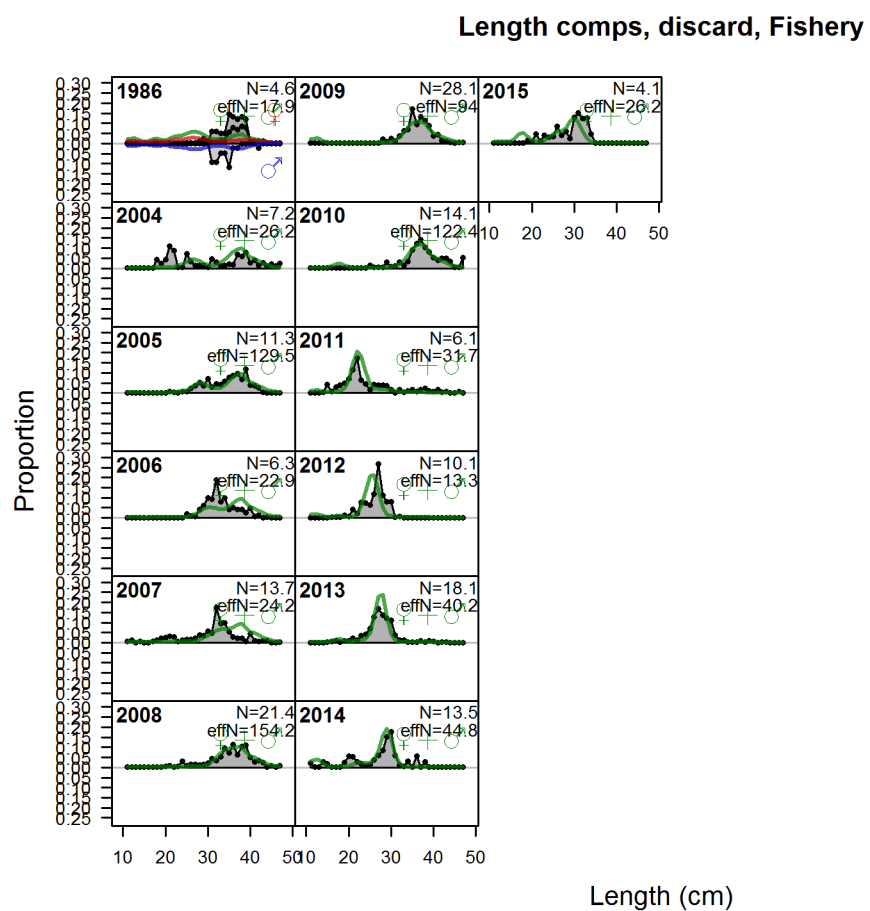


Figure 31: Length comps, discard, Fishery ^{fig:mod1_1_comp_lenfit_flt1mkt1}

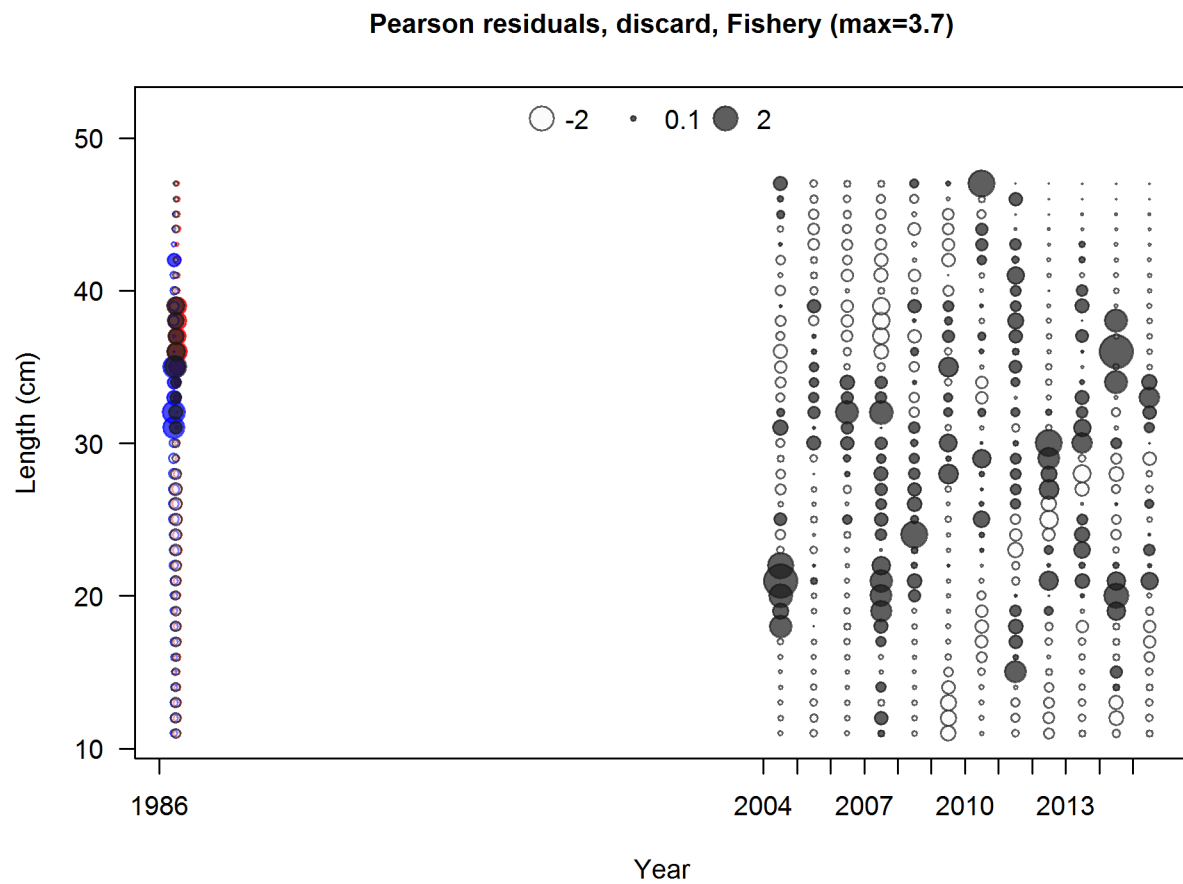


Figure 32: Pearson residuals, discard, Fishery (max=3.7)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).
 fig:mod1_2_comp_lenfit_residsfit1mkt1

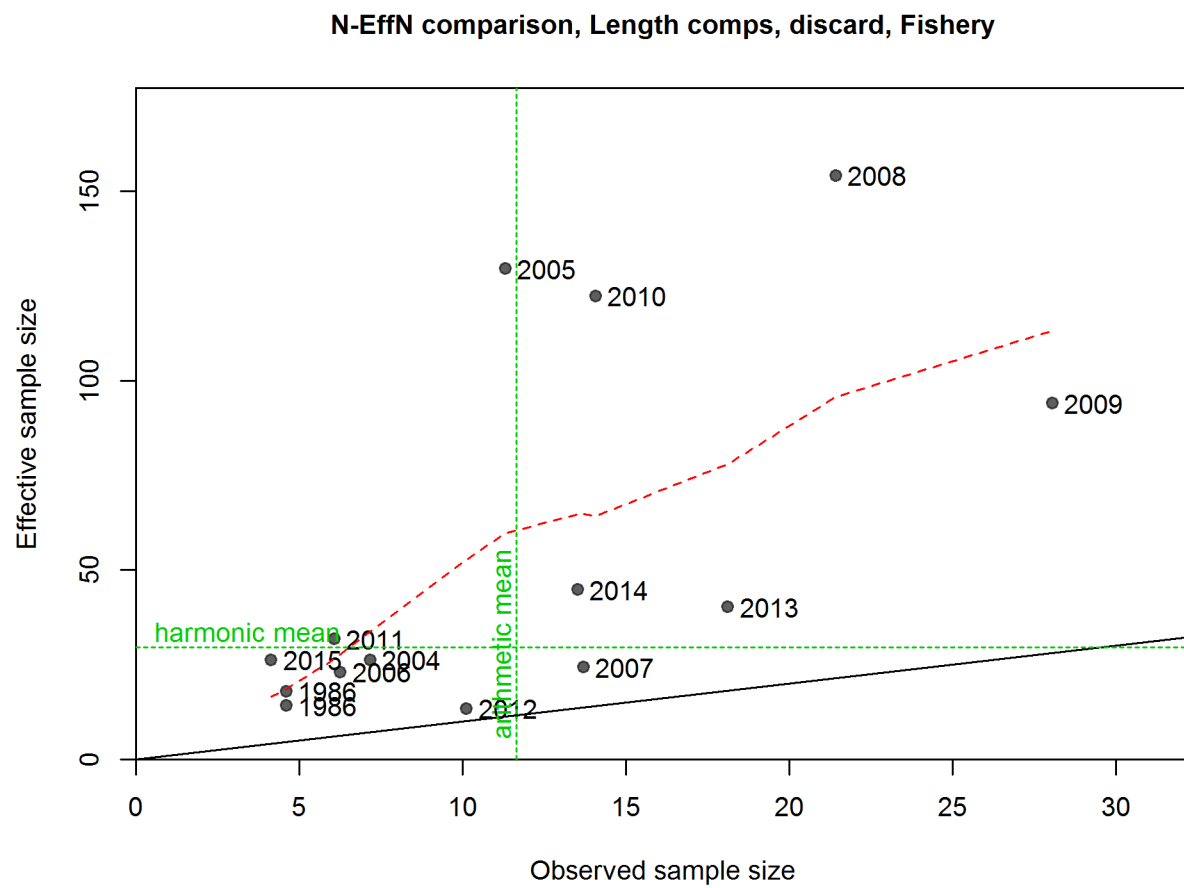


Figure 33: N-EffN comparison, Length comps, discard, Fishery | fig:mod1_3_comp_lenfit_sa

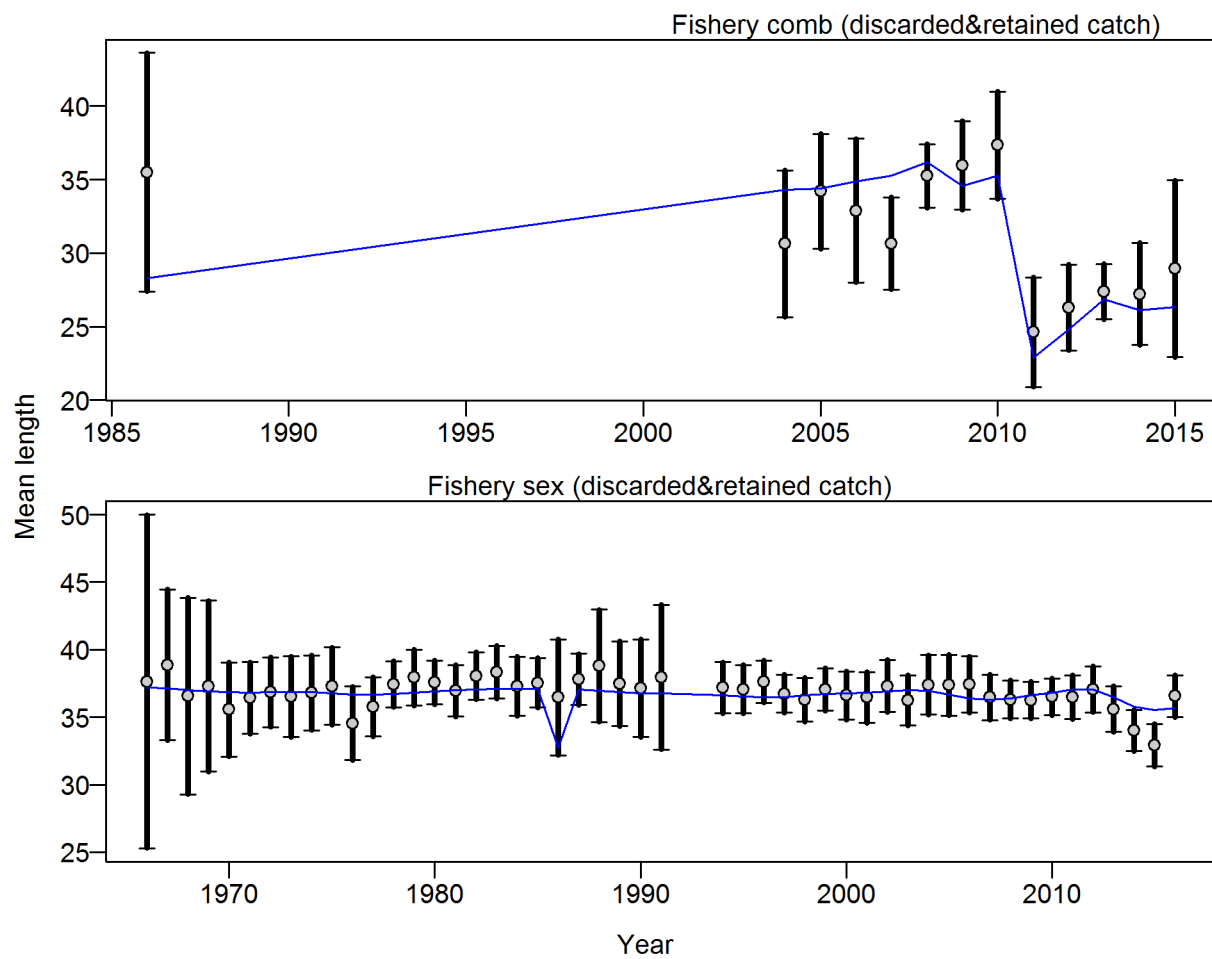


Figure 34: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.9912 (0.6564-1.8145) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. | fig:mod1_4_comp_lenfit_data_weighting_TA1.8_Fishery

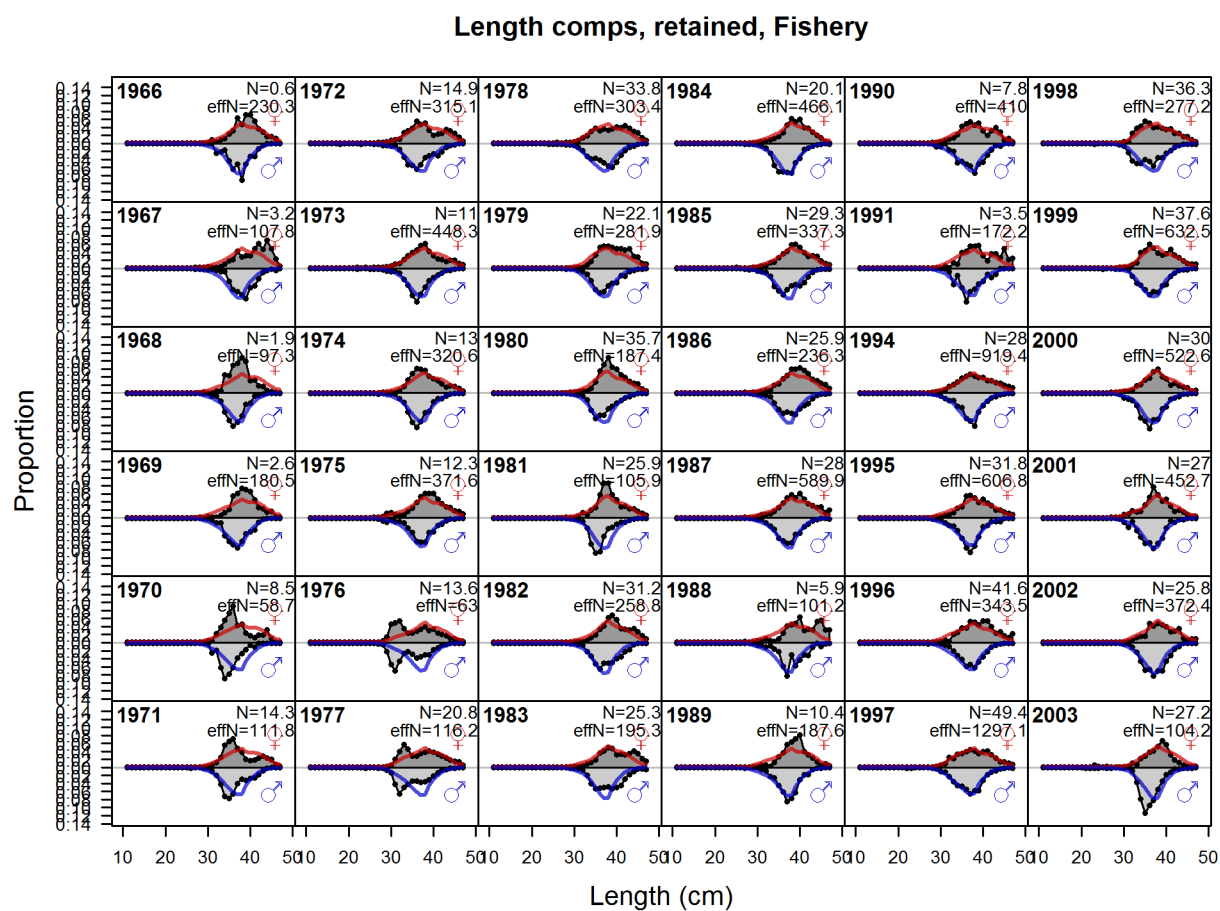


Figure 35: Length comps, retained, Fishery (plot 1 of 2) fig:mod1_5_comp_lenfit_flt1m

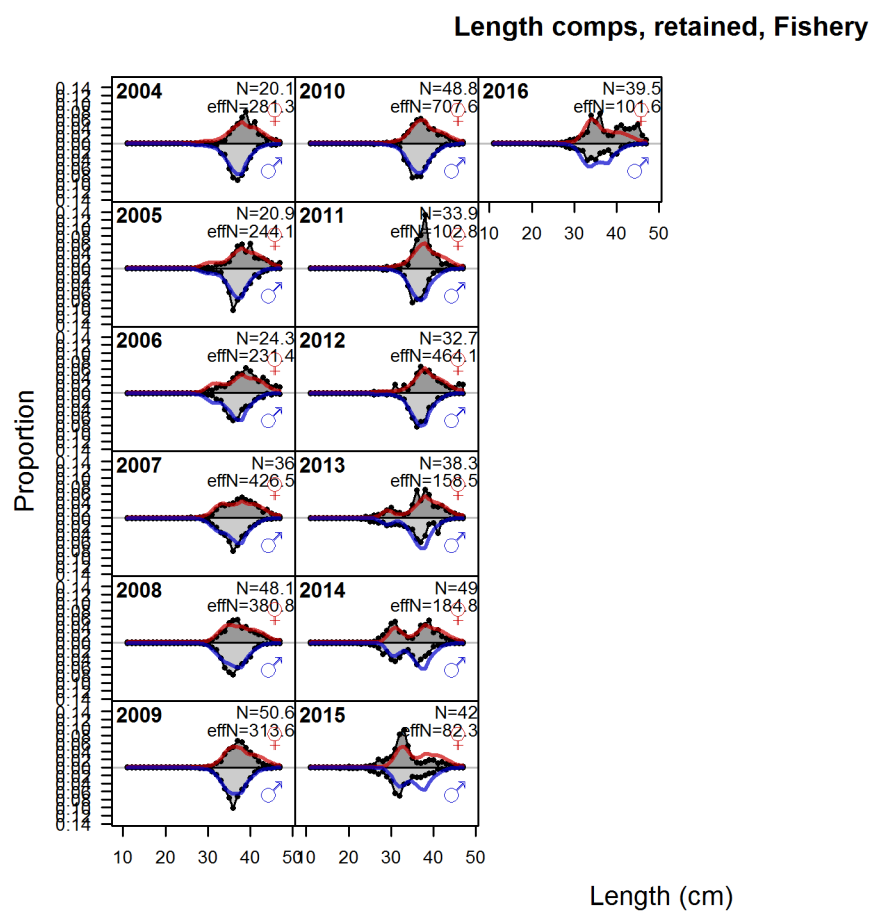


Figure 36: Length comps, retained, Fishery (plot 1 of 2) (plot 2 of 2) ^{fig:mod1_6_comp_lenfit}

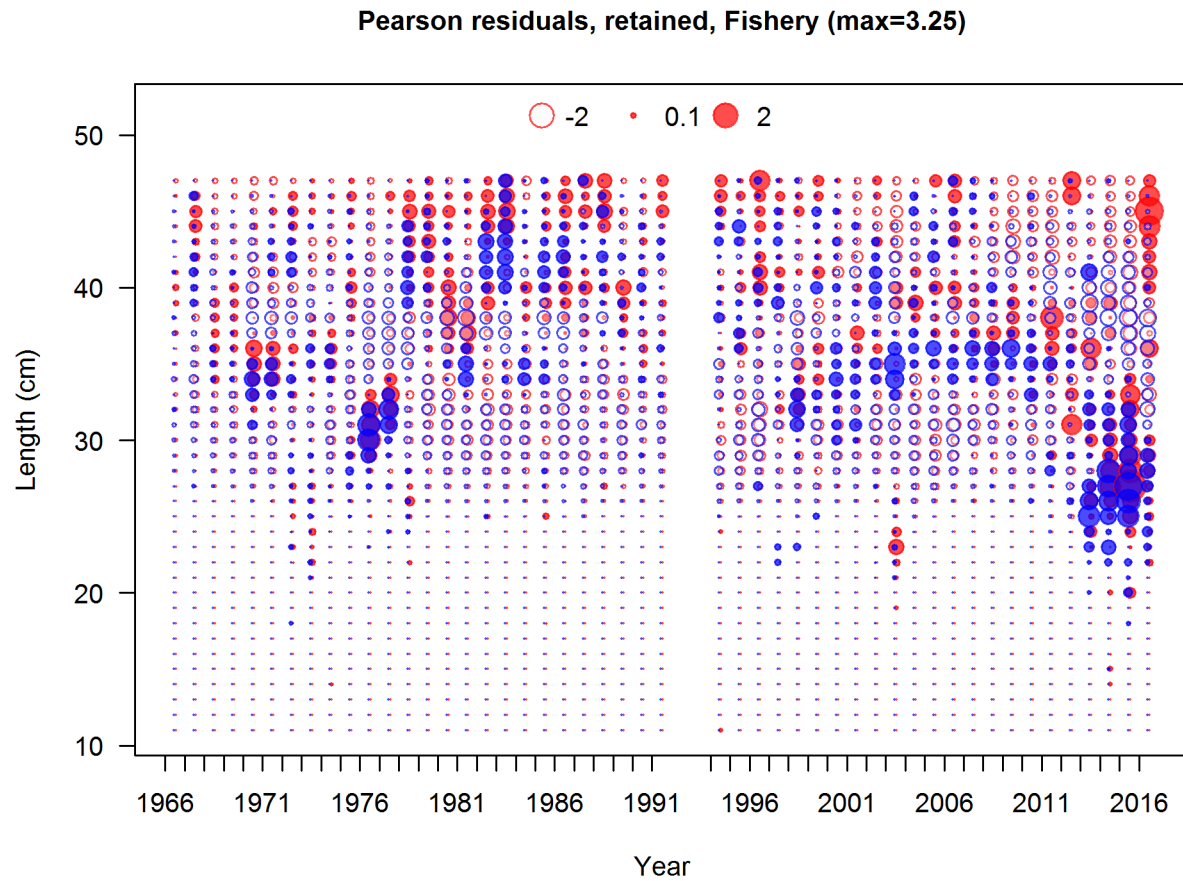


Figure 37: Pearson residuals, retained, Fishery (max=3.25) (plot 2 of 2)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_7_comp_lenfit_residsflt1mkt2_page2

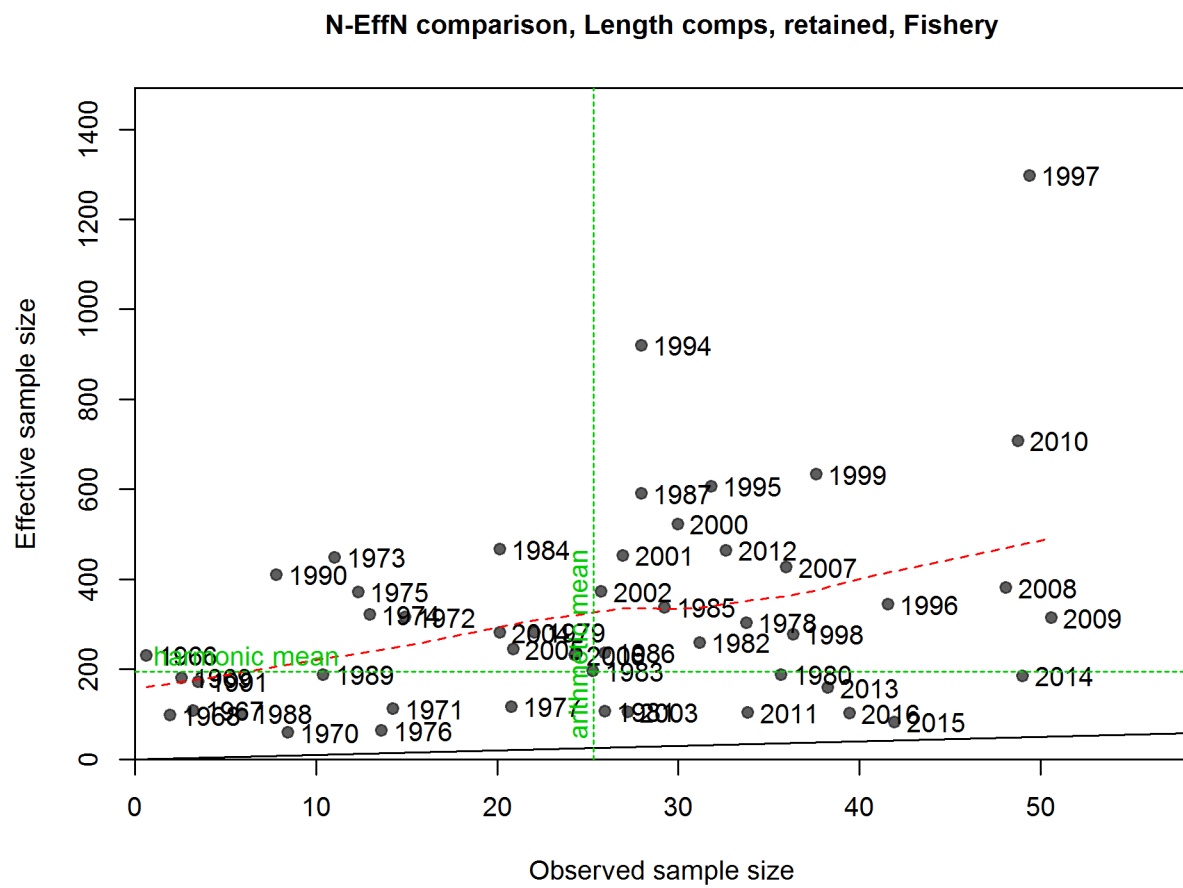


Figure 38: N-EffN comparison, Length comps, retained, Fishery fig:mod1_8_comp_lenfit_sa

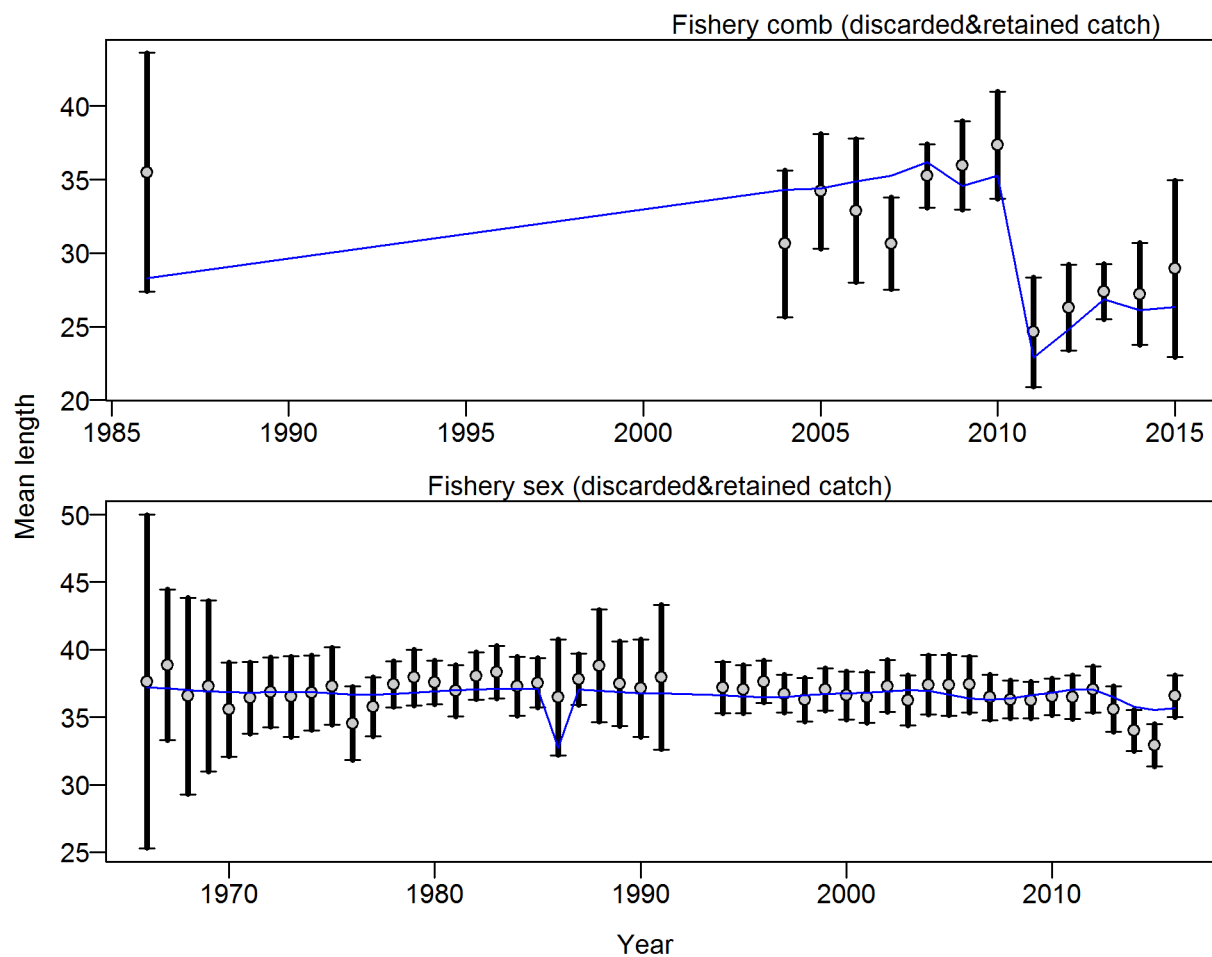


Figure 39: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.9912 (0.648-1.8415) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models, Can. J. Fish. Aquat. Sci. 68: 1124-1138.
 fig:mod1_9_comp_lenfit_data_weighting-TA1.8_Fishery

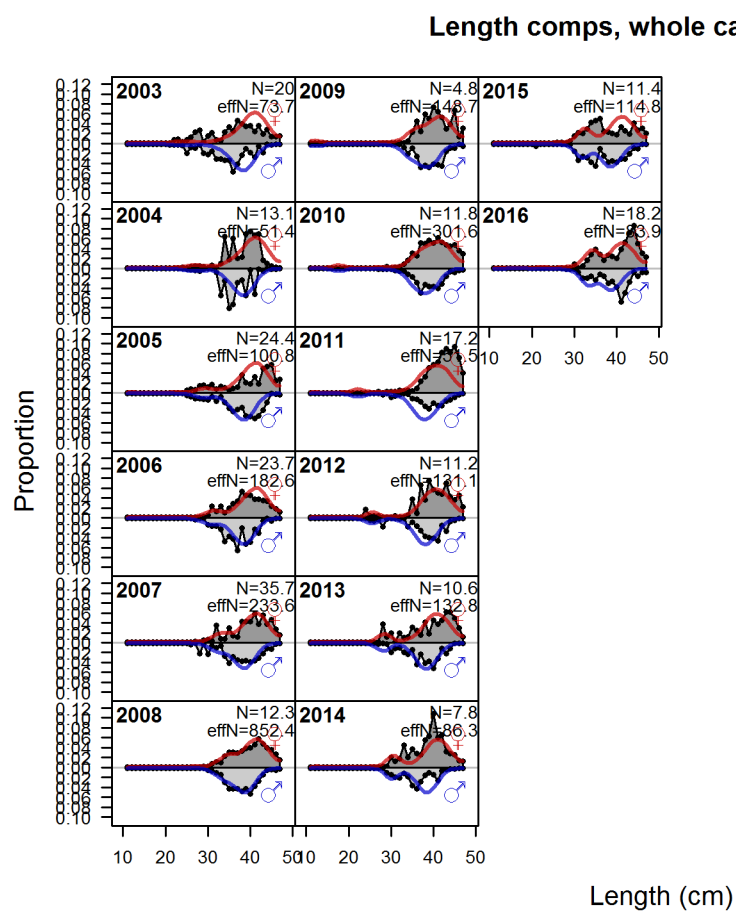


Figure 40: Length comps, whole catch, ASHOP fig:mod1_10_comp_lenfit_flt2mkt0

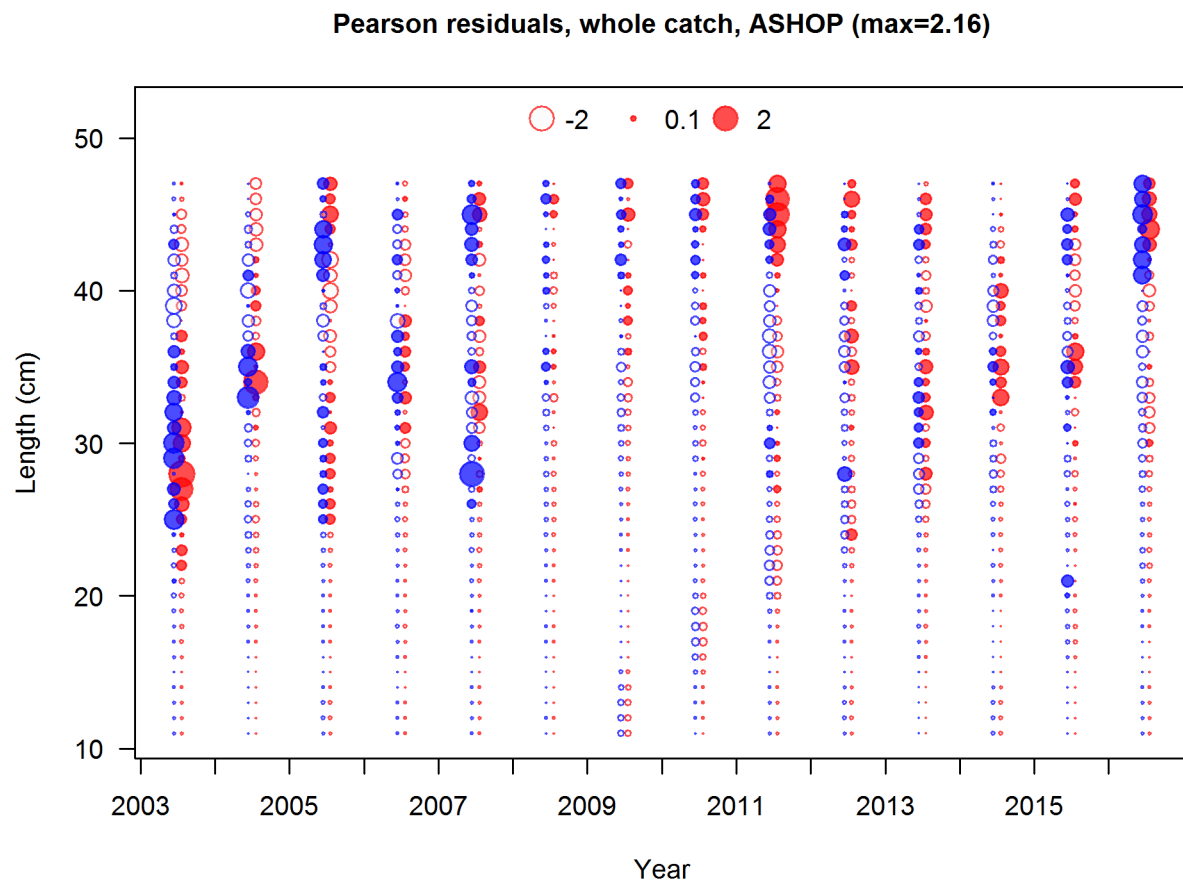


Figure 41: Pearson residuals, whole catch, ASHOP (max=2.16)

Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_11_comp_lenfit_residsfit2mkt0

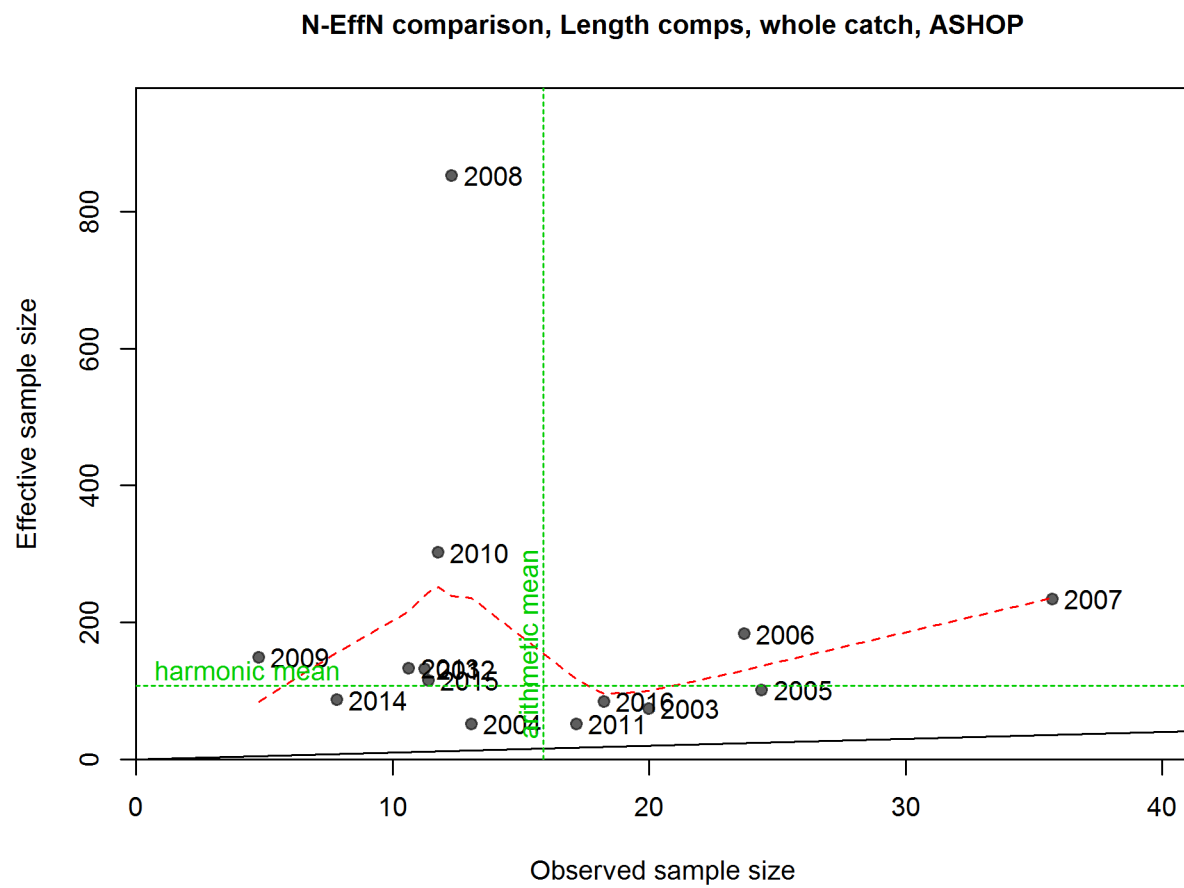


Figure 42: N-EffN comparison, Length comps, whole catch, ASHOP fig:mod1_12_comp_lenfit

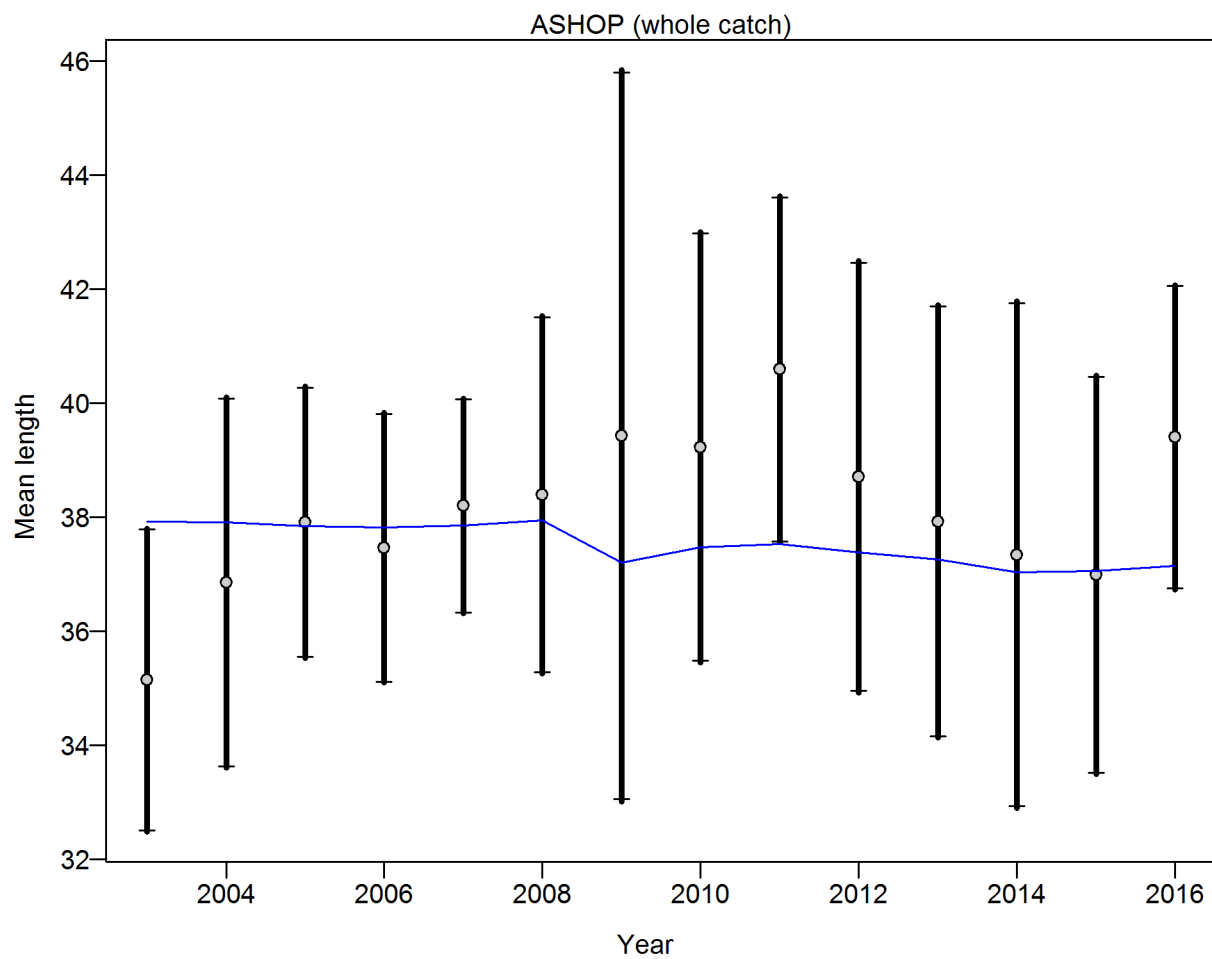


Figure 43: Francis data weighting method TA1.8: ASHOP Suggested sample size adjustment (with 95% interval) for len data from ASHOP: 1.0145 (0.5321-4.5796) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. | fig:mod1_13_comp_lenfit_data_weighting_TA1.8_ASHOP

Length comps, whole catch, POP

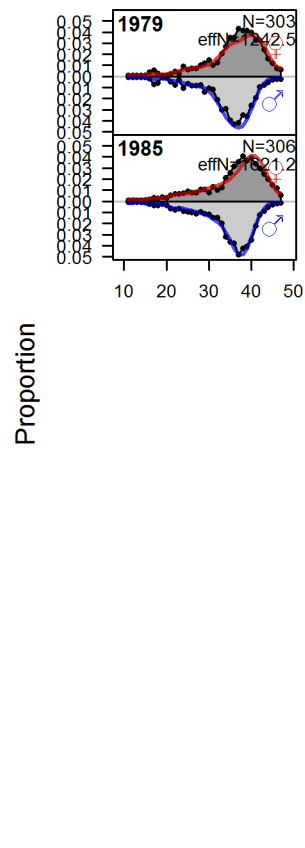


Figure 44: Length comps, whole catch, POP fig:mod1_14_comp_lenfit_flt4mkt0

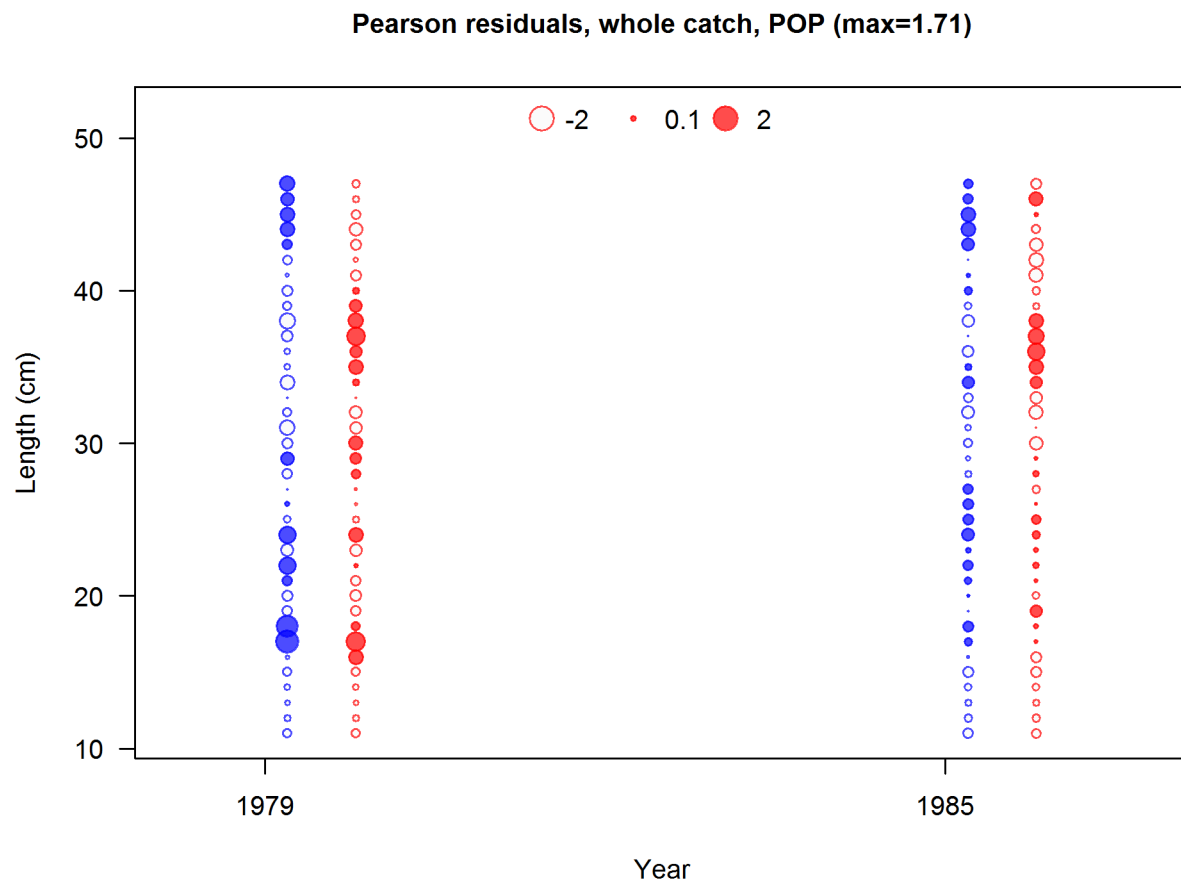


Figure 45: Pearson residuals, whole catch, POP (max=1.71)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).
 fig:mod1_15_comp_lenfit_residsfit4mkt0

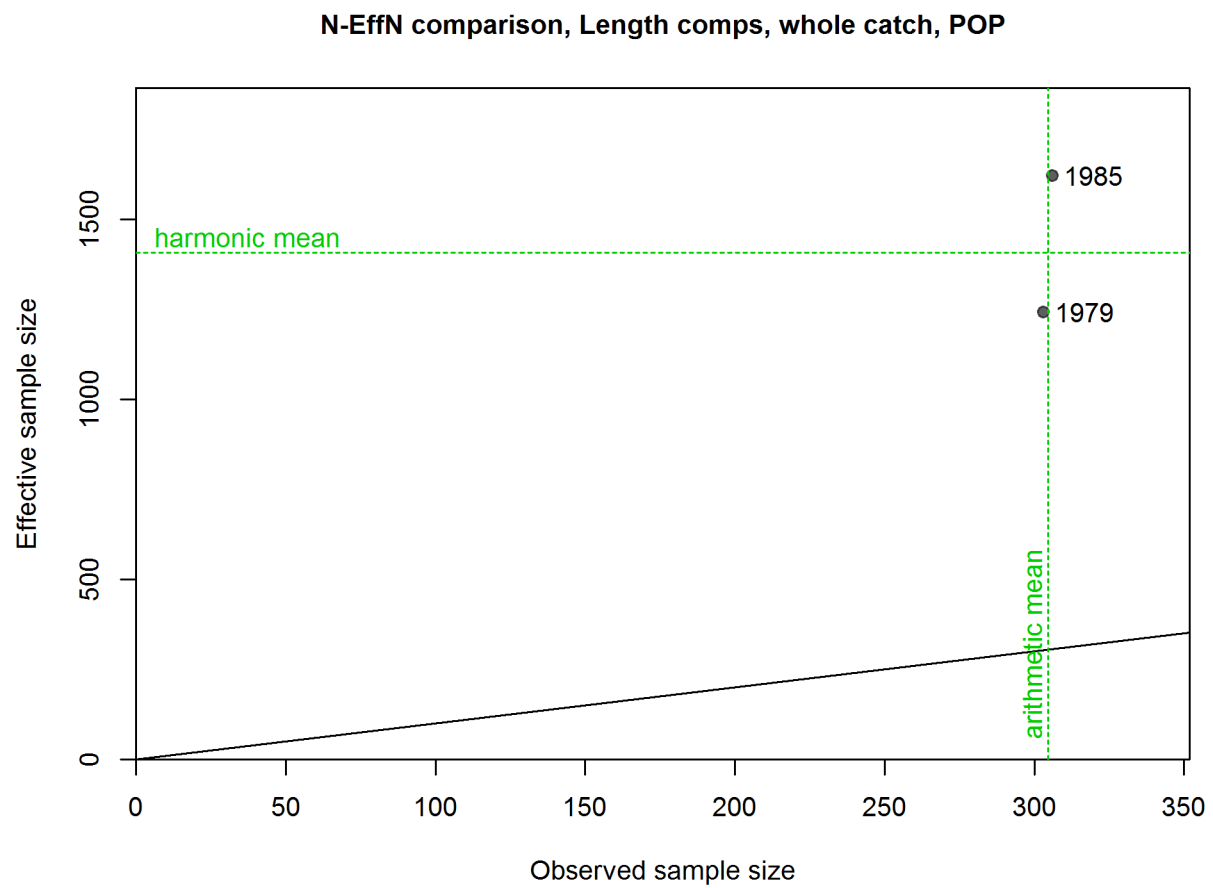


Figure 46: N_EffN comparison, Length comps, whole catch, POP fig:mod1_16_comp_lenfit_

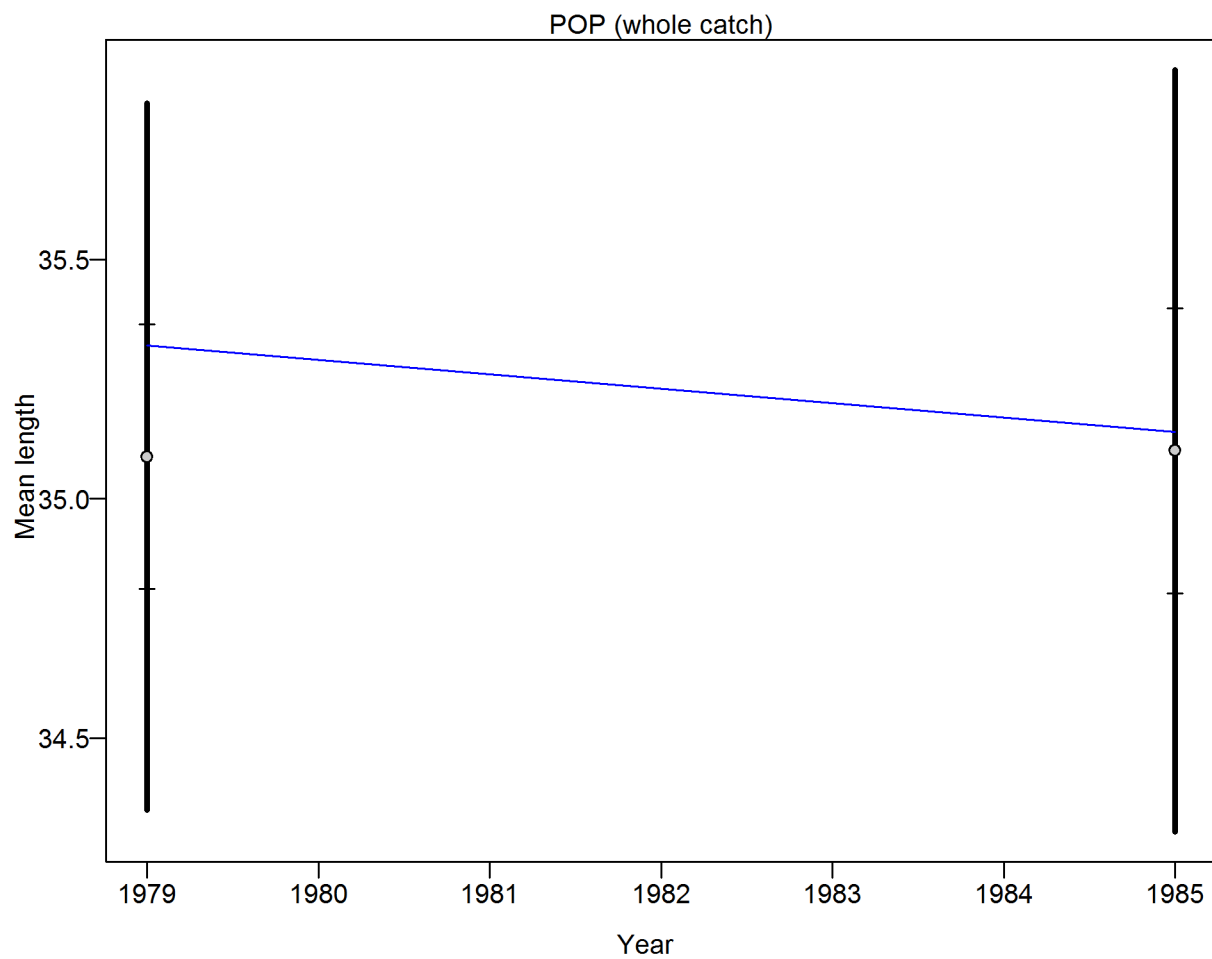


Figure 47: Francis data weighting method TA1.8: POP Suggested sample size adjustment (with 95% interval) for len data from POP: 7.1361 (7.1361_Inf) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138.
 fig:mod1_17_comp_lenfit_data_weighting-TA1.8_POP

Length comps, whole catch, Triennial

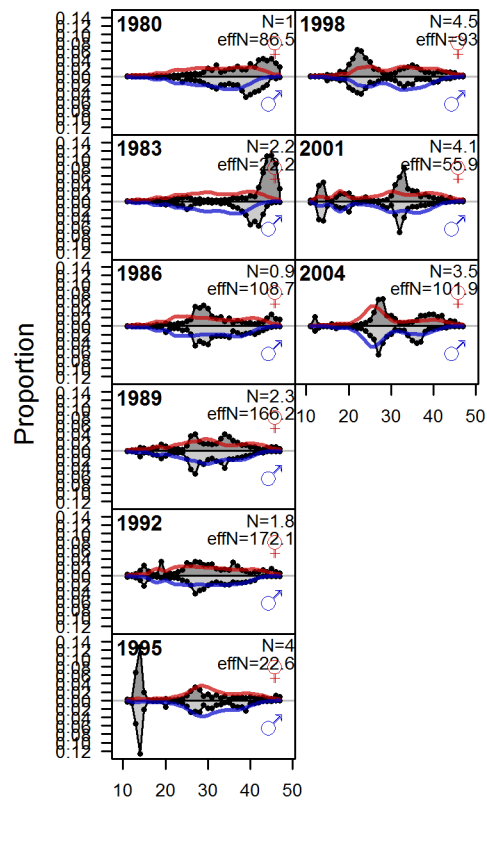


Figure 48: Length comps, whole catch, Triennial fig:mod1_18_comp_lenfit_flt5mkt

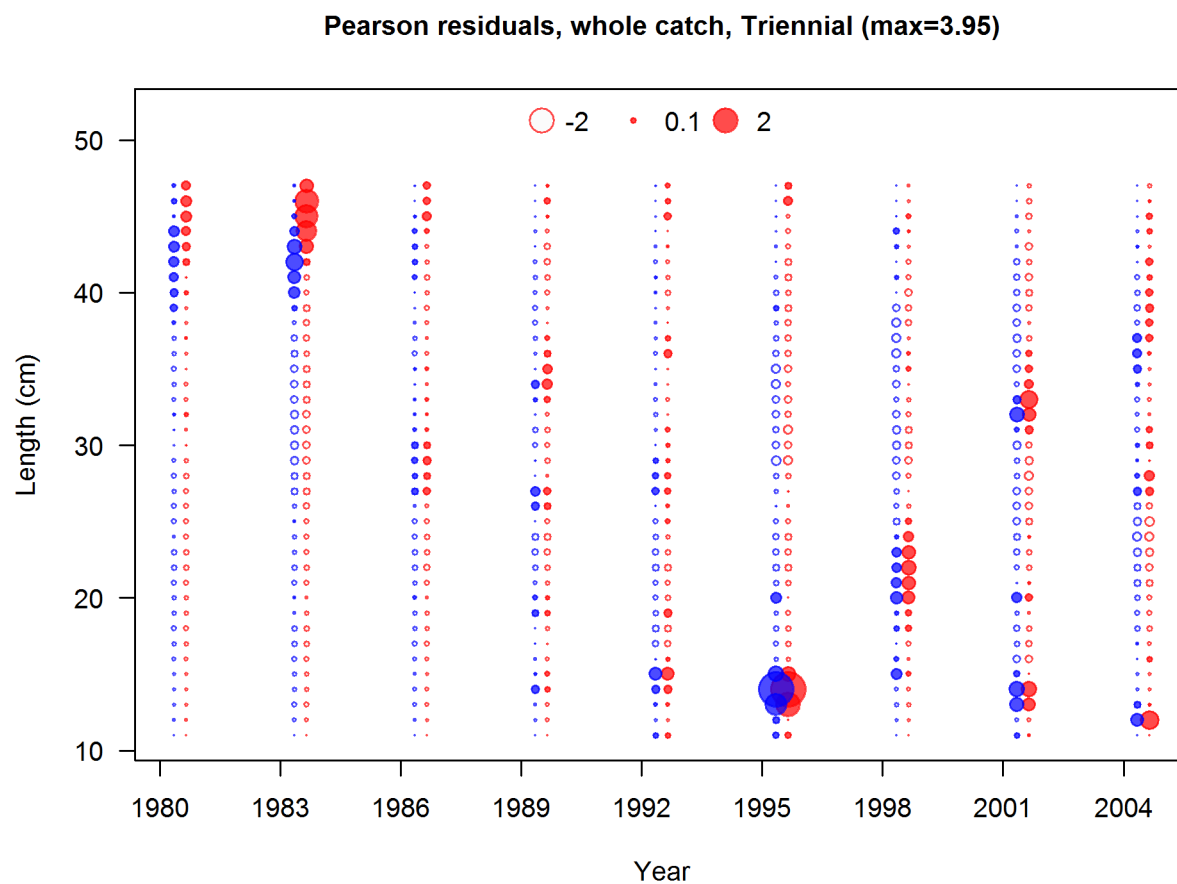


Figure 49: Pearson residuals, whole catch, Triennial (max=3.95)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).
 fig:mod1_19_comp_lenfit_residsfit5mkt0

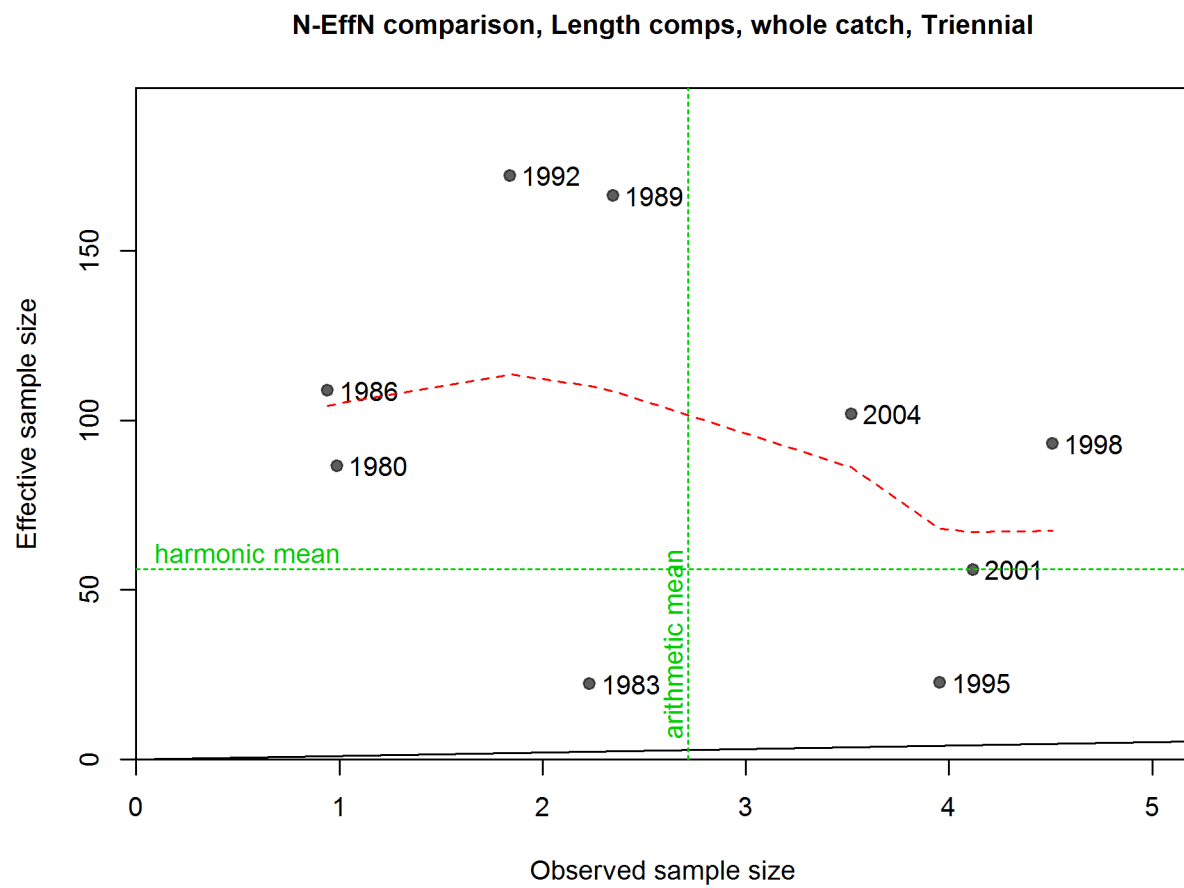


Figure 50: N-EffN comparison, Length comps, whole catch, Triennial fig:mod1_20_comp_lenfi

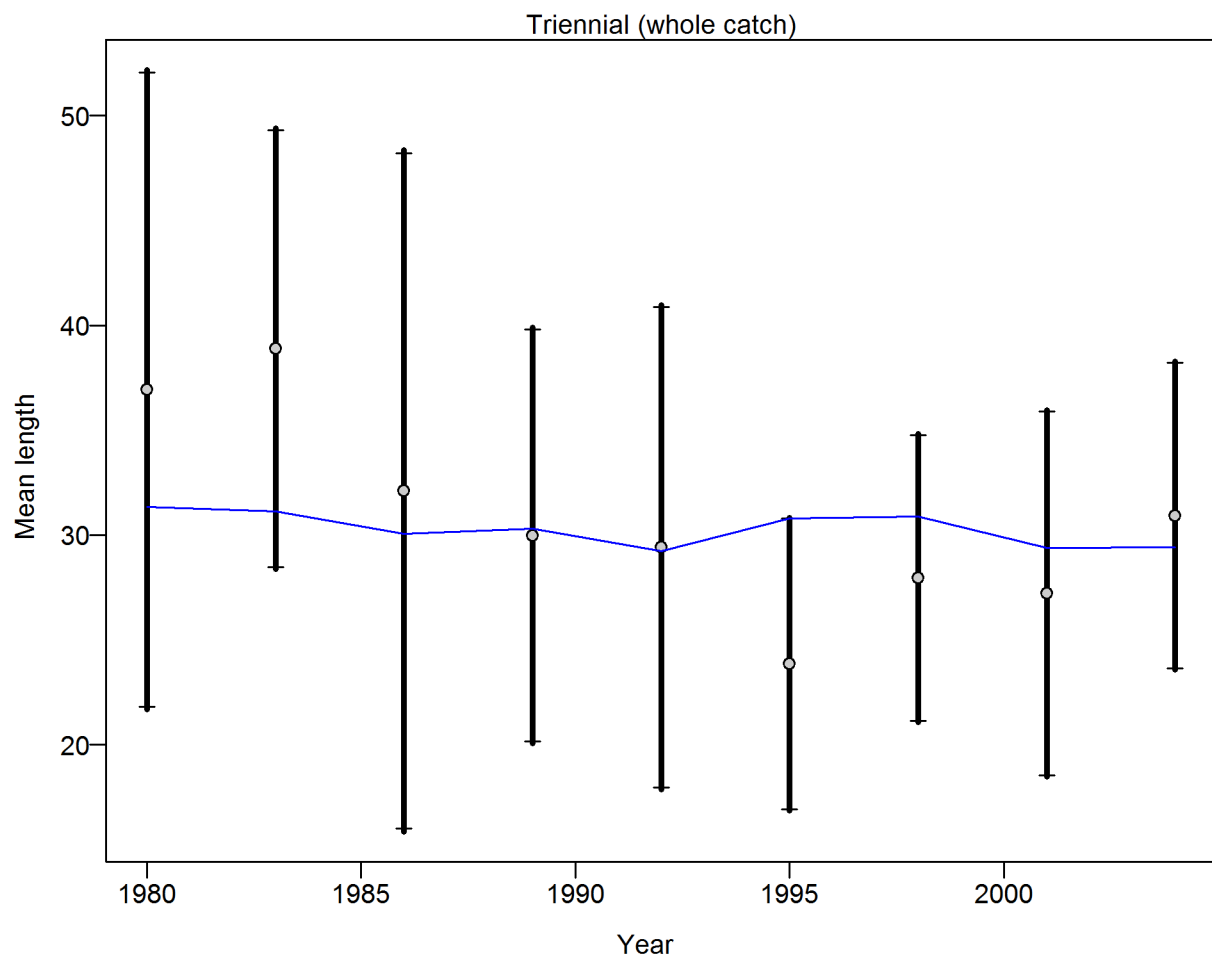


Figure 51: Francis data weighting method TA1.8: Triennial Suggested sample size adjustment (with 95% interval) for len data from Triennial: 1.0167 (0.5447_5.8308) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. | fig:mod1_21_comp_lenfit_data_weighting-TA1.8-Triennial

Length comps, whole catch, AFSCSlope

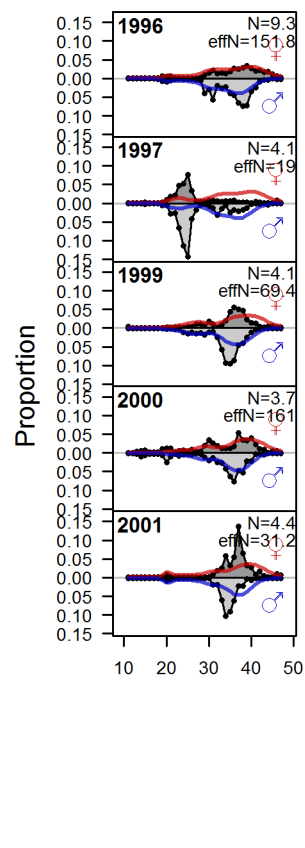


Figure 52: Length comps, whole catch, AFSCSlope | fig:mod1_22_comp_lenfit_flt6mk

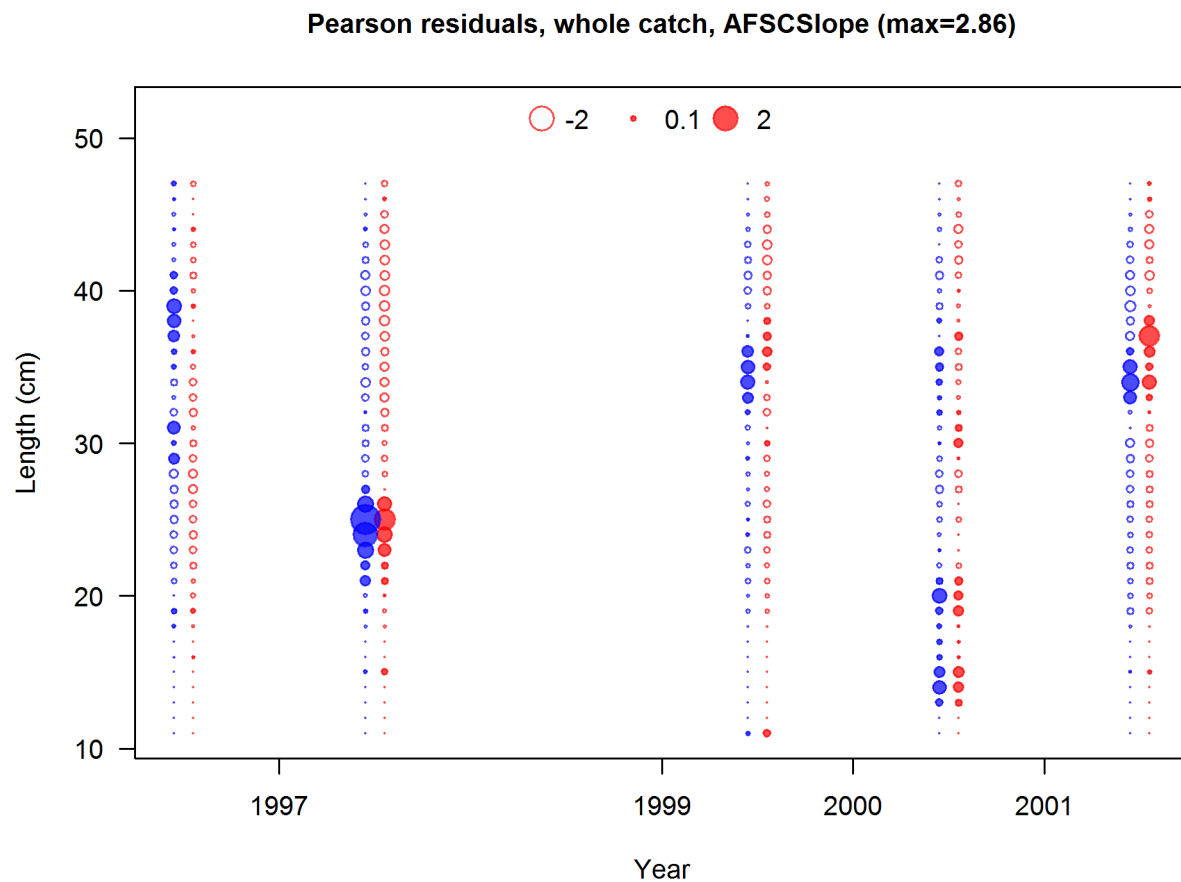


Figure 53: Pearson residuals, whole catch, AFSCSlope (max=2.86)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).
 fig:mod1_23_comp_lenfit_residsfit6mkt0

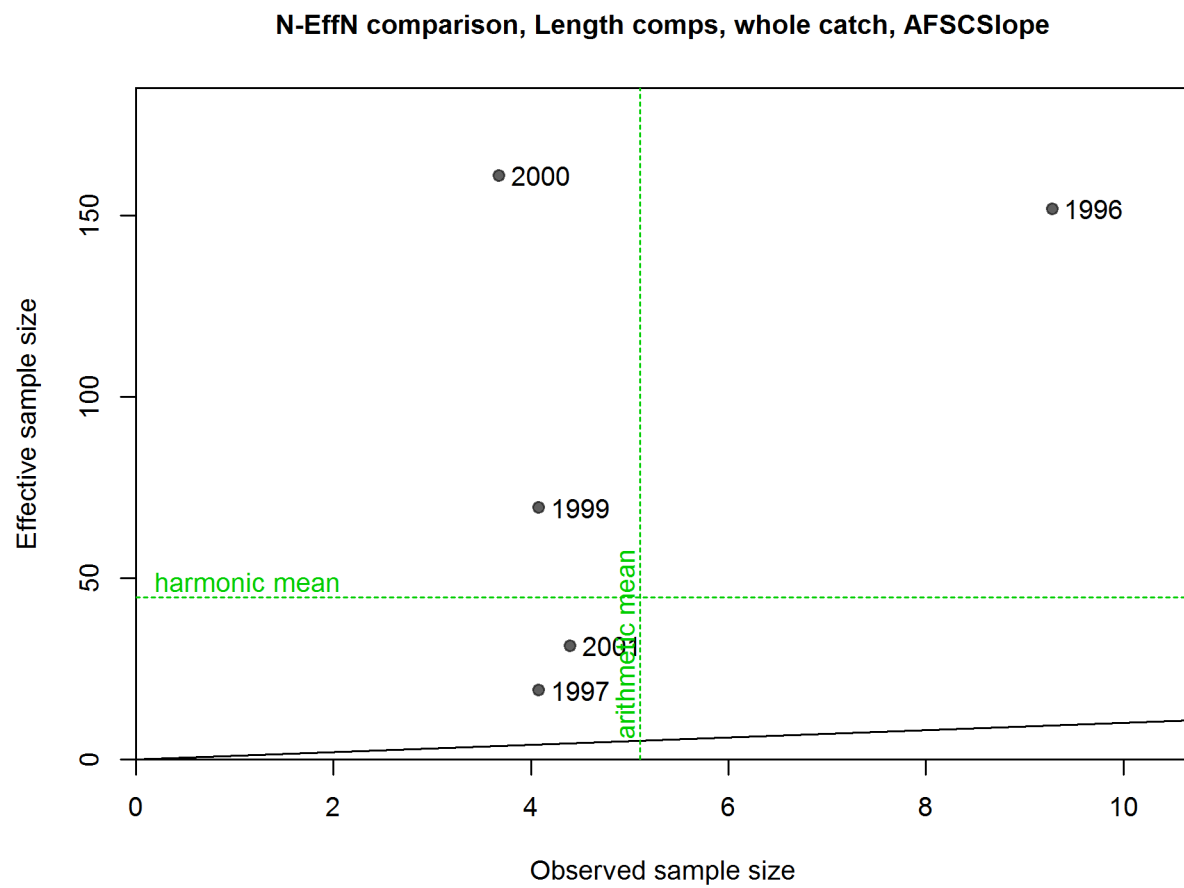


Figure 54: N_EffN comparison, Length comps, whole catch, AFSCSlope fig:mod1_24_comp_lenf

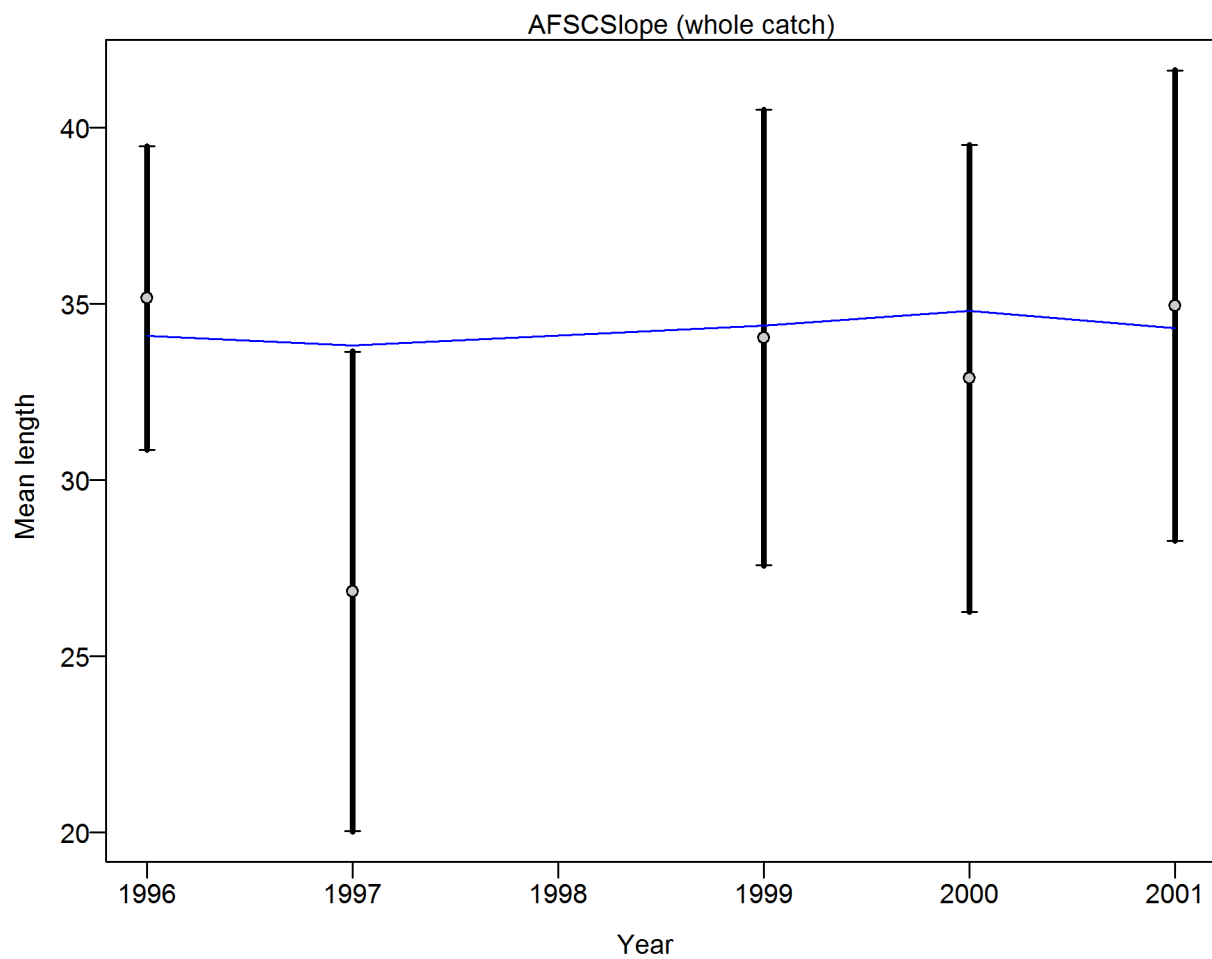


Figure 55: Francis data weighting method TA1.8: AFSCSlope Suggested sample size adjustment (with 95% interval) for len data from AFSCSlope: 1.0029 (0.5859_22.5669) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. | fig:mod1_25_comp_lenfit_data_weighting_TA1.8_AFSC

Length comps, whole catch, NWFSCSlope

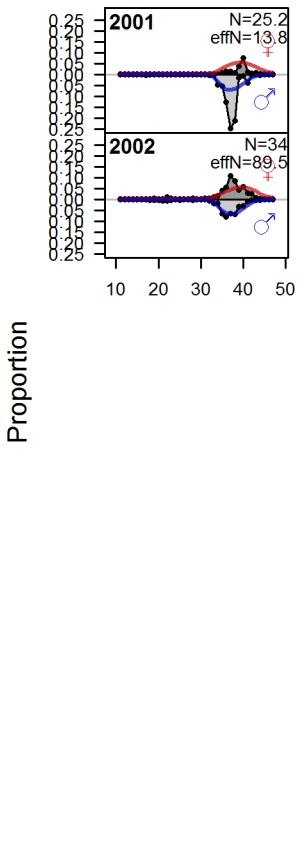


Figure 56: Length comps, whole catch, NWFSCSlope | fig:mod1_26_comp_lenfit_flt7m

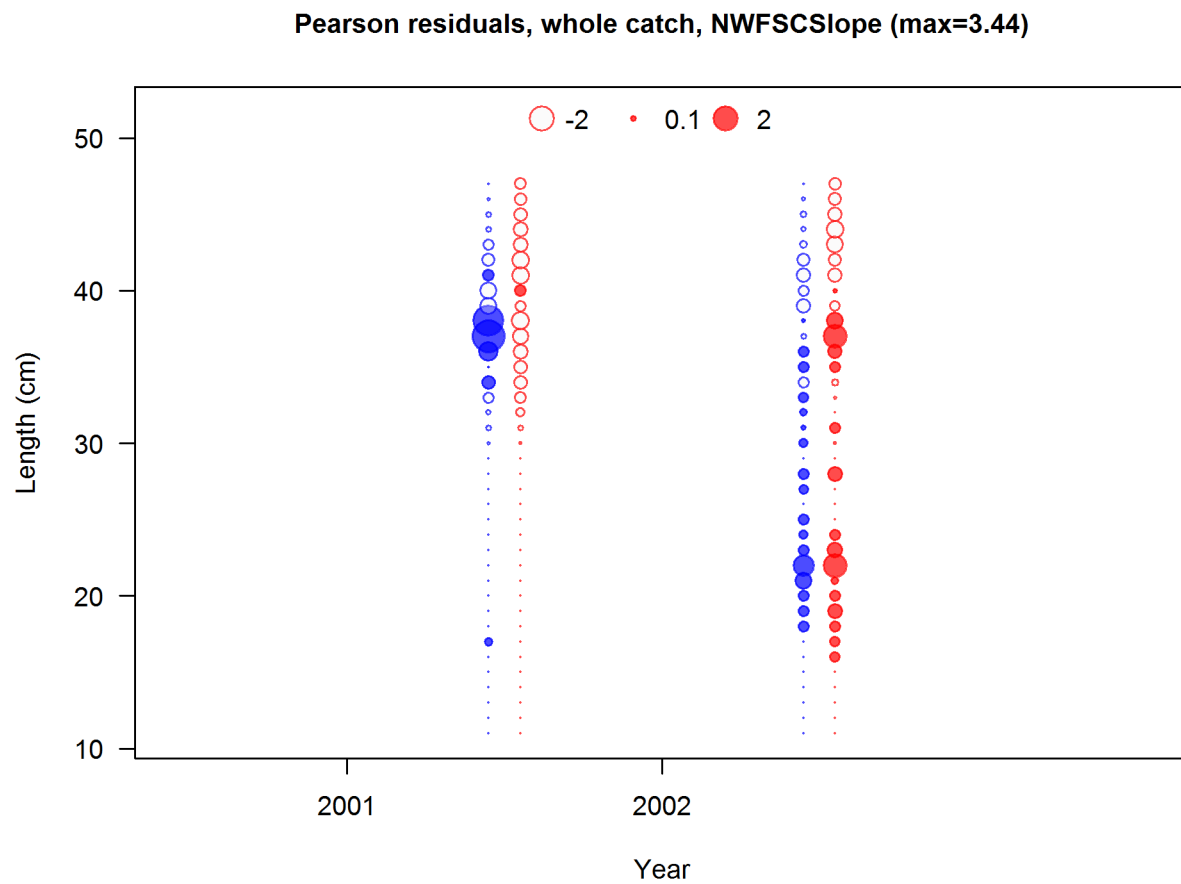


Figure 57: Pearson residuals, whole catch, NWFSCSlope (max=3.44)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).
 fig:mod1_27_comp_lenfit_residsfit7mkt0

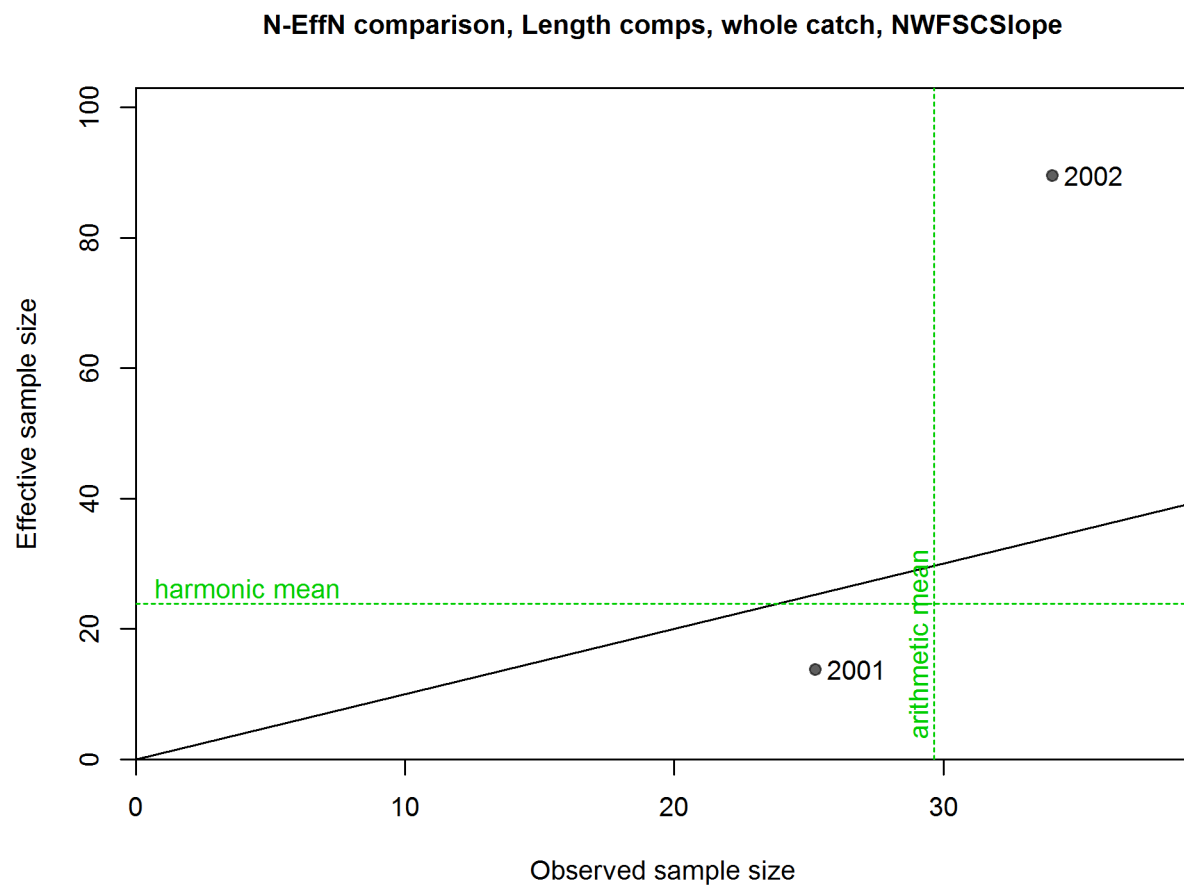


Figure 58: N_EffN comparison, Length comps, whole catch, NWFSCSlope fig:mod1_28_comp_len

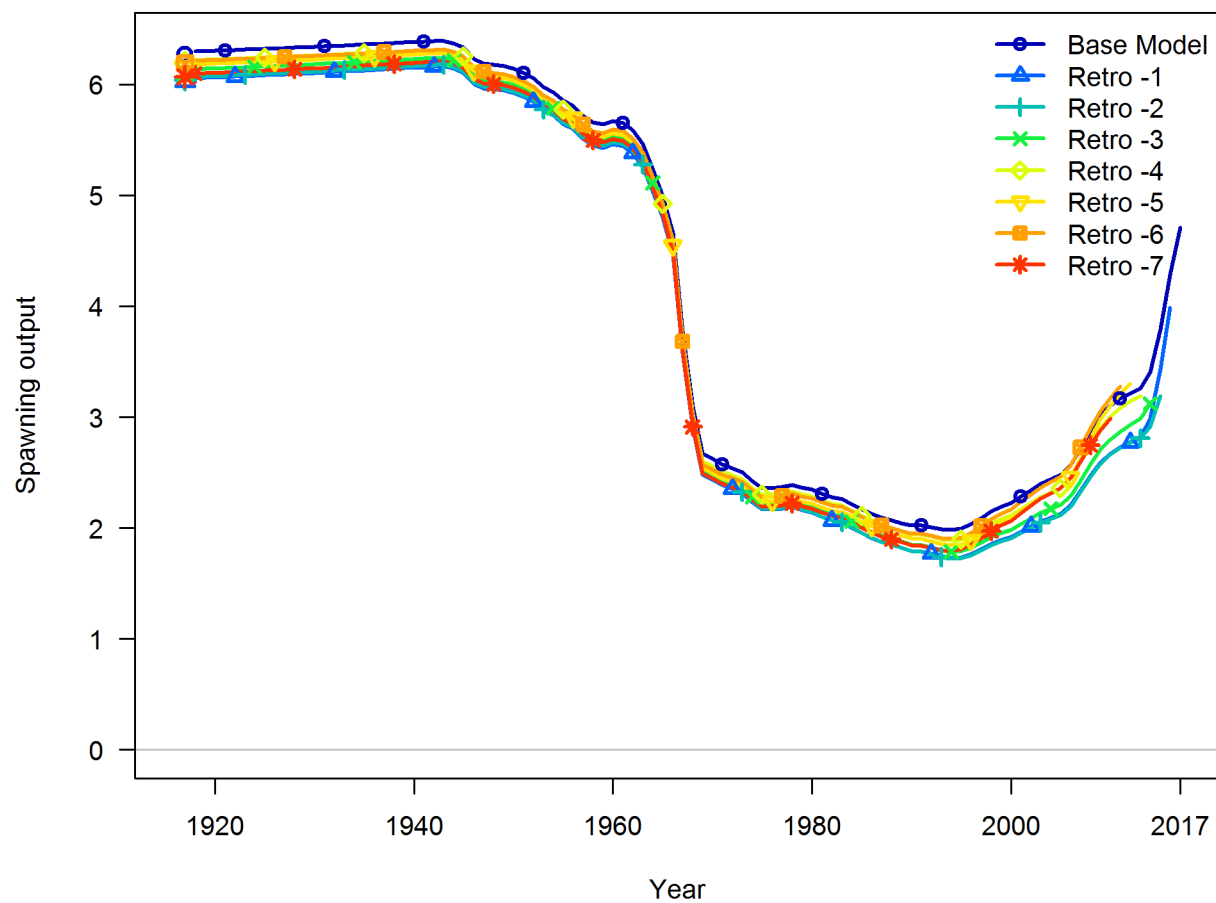


Figure 59: Retrospective pattern for spawning output. `fig:retro_sb`

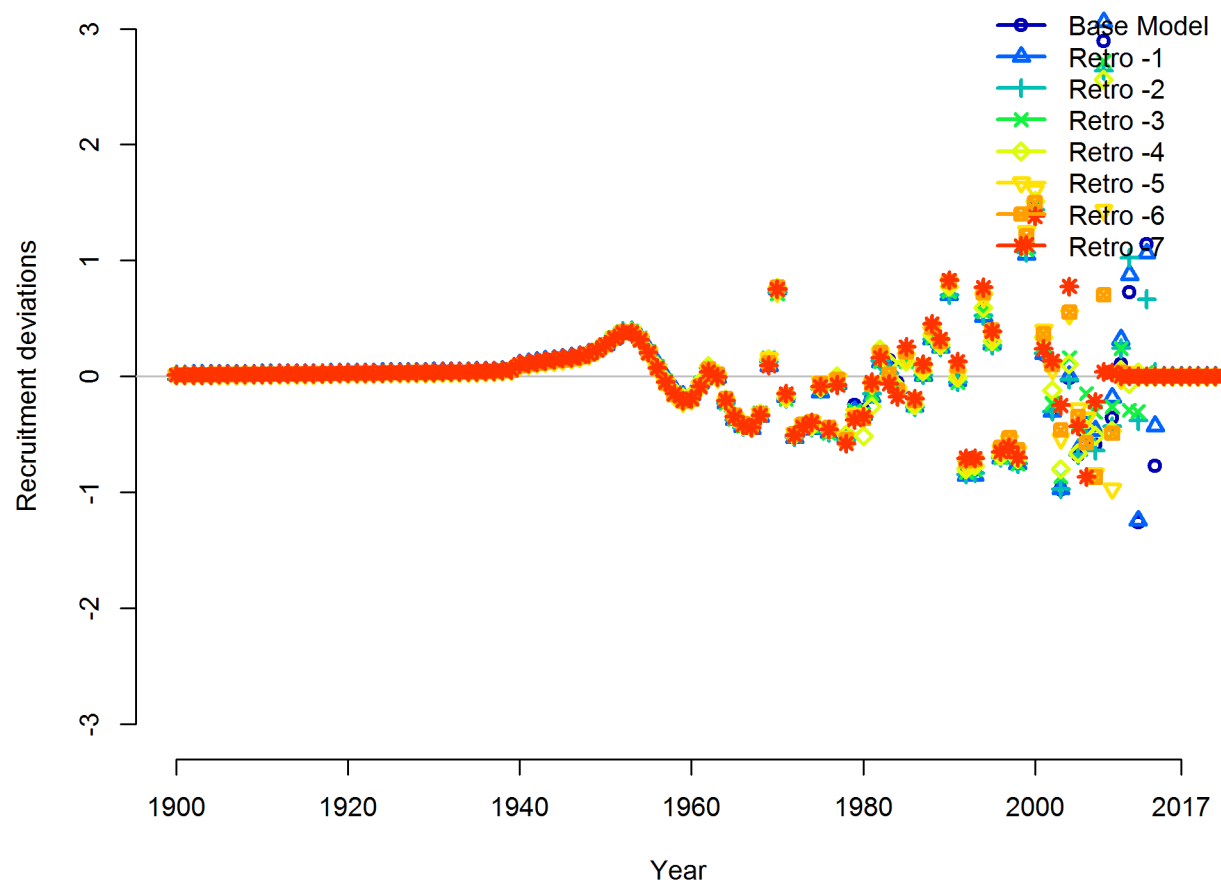


Figure 60: Retrospective pattern for estimated recruitment deviations. fig:retro_recdev

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