

¹ Status of Pacific ocean perch (*Sebastodes 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	Total Landings	tab:Exec_catch
2007	0.15	83.65	45.12	4.05	0.58	133.55	
2008	0.39	58.64	16.61	15.93	0.80	92.36	
2009	0.92	58.74	33.22	1.56	2.72	97.17	
2010	0.14	58.00	22.29	16.87	1.68	98.98	
2011	0.12	30.26	19.66	9.17	1.94	61.14	
2012	0.18	30.41	21.79	4.52	1.62	58.51	
2013	0.08	34.86	14.83	5.41	1.71	56.89	
2014	0.18	33.91	15.82	3.92	0.57	54.40	
2015	0.12	38.05	11.41	8.71	1.59	59.88	
2016	0.23	40.81	13.12	10.30	3.10	67.56	

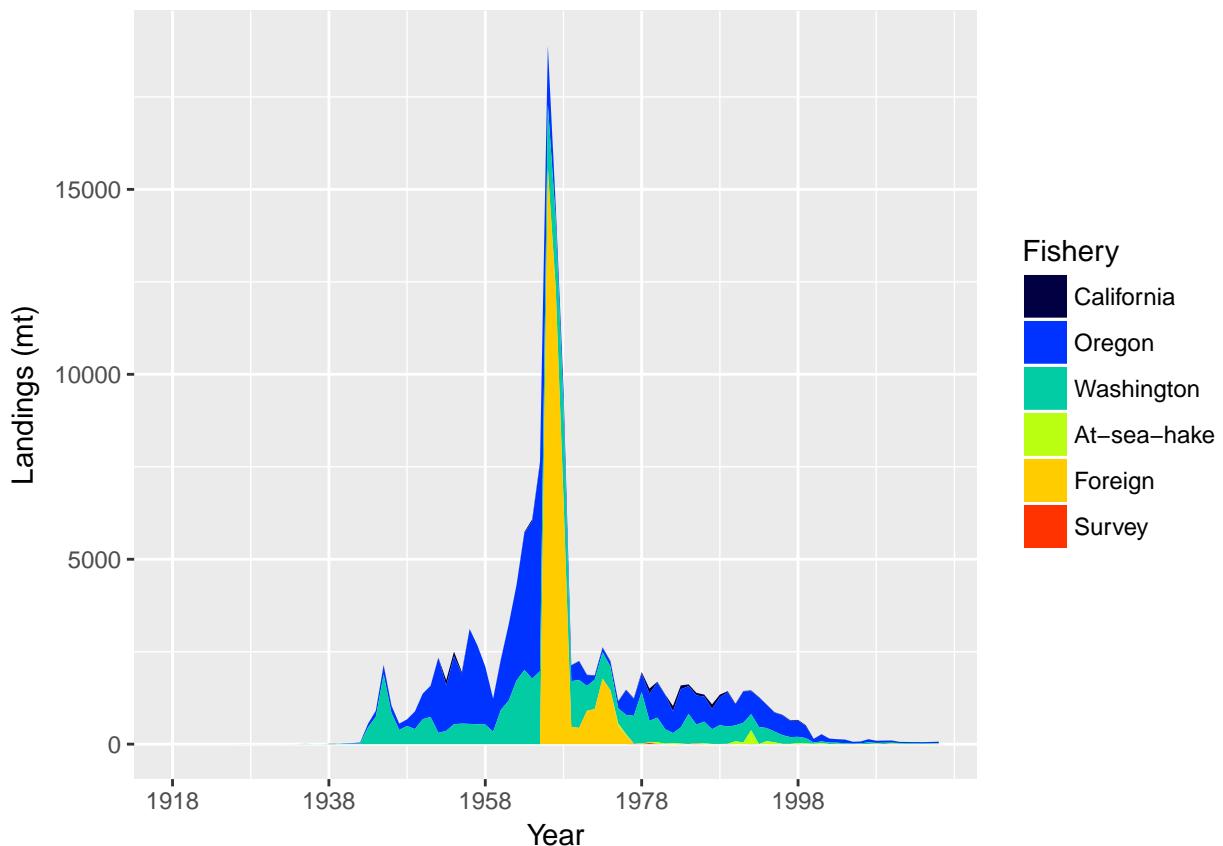


Figure a: Landings of Pacific ocean perch for California, Oregon, Washington, the Foreign fishery (1966-1976), At-Sea Hake fishery, and fishery independent surveys. fig:Exec_catch1

114 Data and Assessment

data-and-assessment

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

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

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

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

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

¹⁵⁴ As is always the case, overall uncertainty is greater than that predicted by a single model
¹⁵⁵ specification. Among other sources of uncertainty that are not included in the current model
¹⁵⁶ are the degree of connectivity between the stocks of Pacific ocean perch off of Vancouver
¹⁵⁷ Island, British Columbia and those in PFMC waters, and the effect of climatic variables on
¹⁵⁸ recruitment, growth and survival of Pacific ocean perch.

¹⁵⁹ A reference case was selected which adequately captures the central tendency for those sources
¹⁶⁰ of uncertainty considered in the model.

¹⁶¹ Stock Biomass

stock-biomass

¹⁶² Include: trends and current levels relative to virgin or historic levels, description of uncer-
¹⁶³ tainty-include table for last 10 years and graph with long term estimates.

¹⁶⁴ Spawning output Figure: Figure [b](#)

¹⁶⁵ Spawning output Table(s): Table [b](#)

¹⁶⁶ Relative depletion Figure: Figure [c](#)

¹⁶⁷ Example text (remove Models 2 and 3 if not needed - if using, remove the # in-line comments!!!)

¹⁶⁸ The estimated relative depletion level (spawning output relative to unfished spawning output)

¹⁶⁹ of the the base-case model in 2017 is 76.1% (~95% asymptotic interval: ± 53.8%-98.4%)

¹⁷⁰ (Figure [c](#)).

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

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

Spawning output with ~95% asymptotic intervals

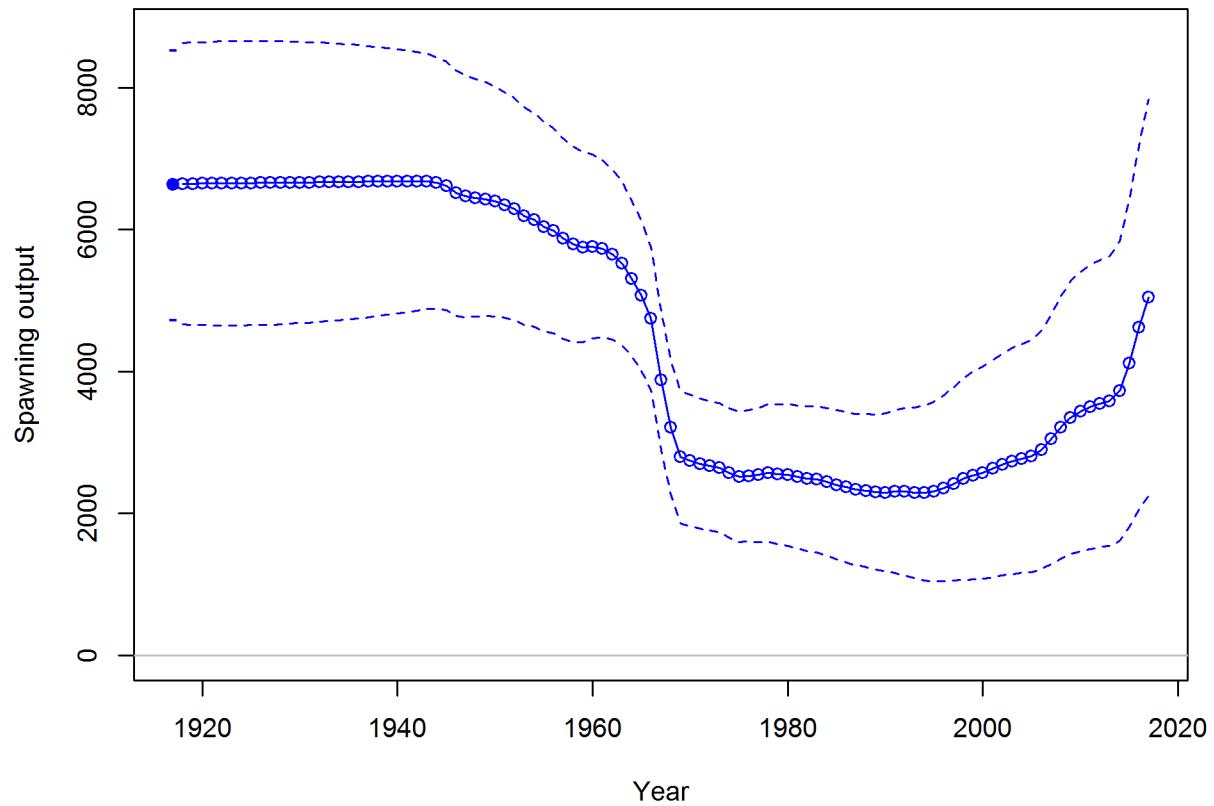


Figure b: Time series of spawning output trajectory (circles and line; median; light broken lines: 95% credibility intervals) for the base case assessment model. | [fig:Spawnbio_all](#)

Spawning depletion with ~95% asymptotic intervals

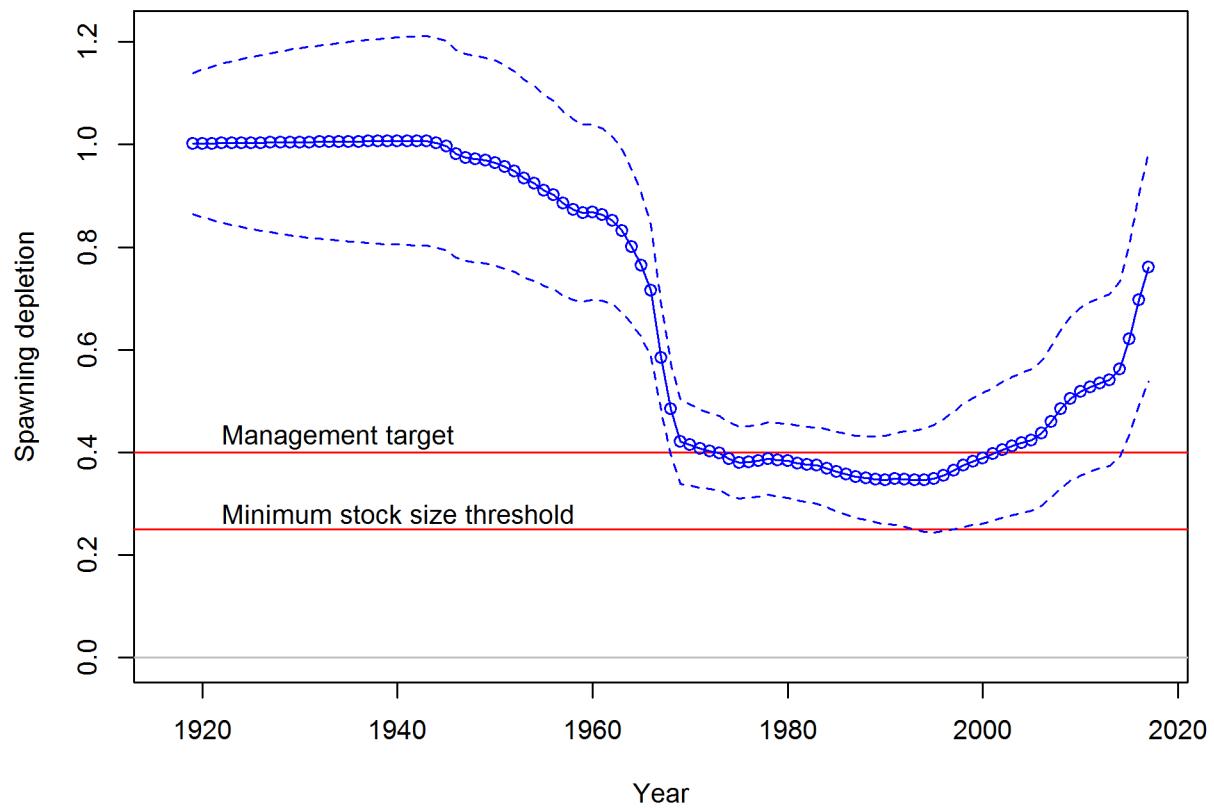


Figure c: Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. [fig:RelDeplete_all](#)

¹⁷¹ **Recruitment**

recruitment

¹⁷² Include: trends and current levels relative to virgin or historic levels-include table for last 10
¹⁷³ years and graph with long term estimates.

¹⁷⁴ Recruitment Figure: (Figure d)

¹⁷⁵ 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.	^{tab:Recruit_mod1}
2008	133246.00	75744 - 234402	2.84	2.542 - 3.145
2009	4814.00	2070 - 11196	-0.49	-1.254 - 0.267
2010	8279.00	4007 - 17102	0.04	-0.558 - 0.633
2011	16107.00	8067 - 32159	0.70	0.146 - 1.246
2012	2113.00	870 - 5132	-1.34	-2.173 - -0.507
2013	29278.00	13512 - 63442	1.20	0.525 - 1.872
2014	5078.00	1728 - 14918	-0.65	-1.748 - 0.441
2015	10096.00	2827 - 36059	-0.00	-1.372 - 1.367
2016	10520.00	2945 - 37581	0.00	-1.372 - 1.372
2017	10816.00	3031 - 38596	0.00	-1.372 - 1.372

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

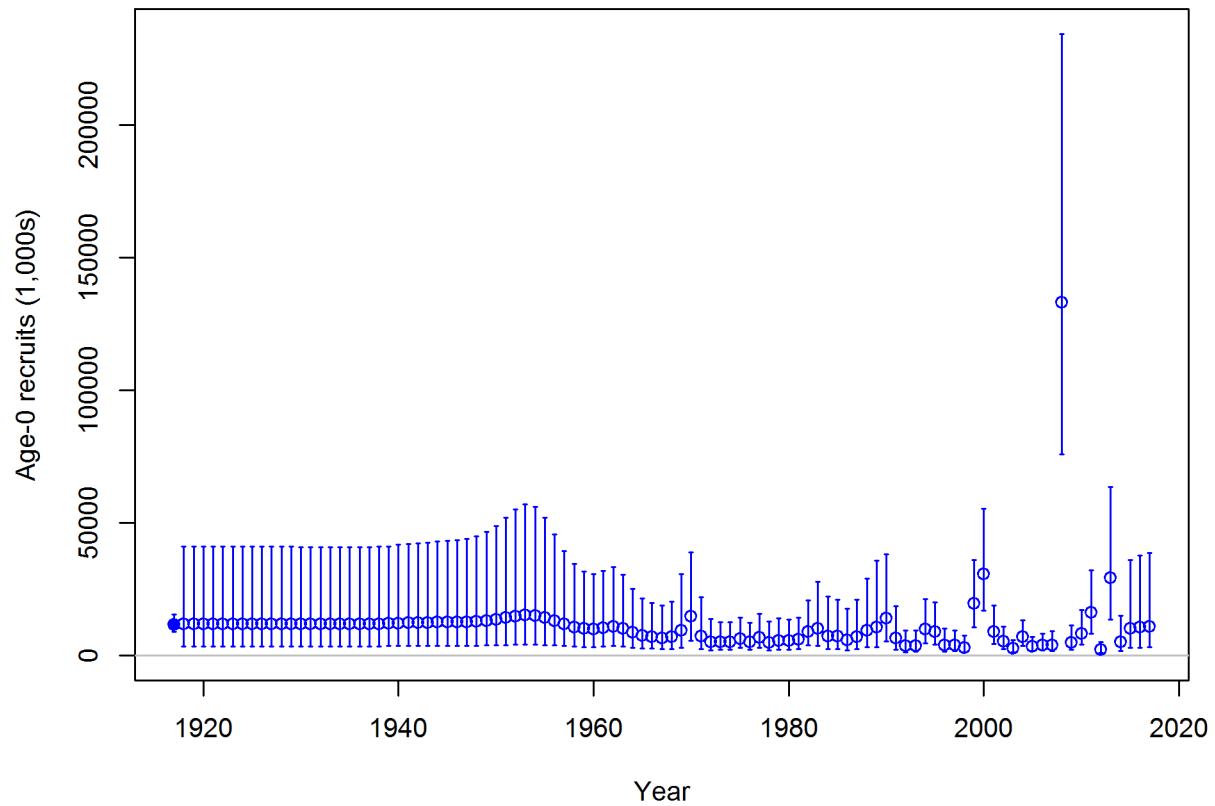


Figure d: Time series of estimated Pacific ocean perch recruitments for the base-case model with 95% confidence or credibility intervals. | [fig:Recruits_all](#)

¹⁷⁶ **Exploitation status**

exploitation-status

¹⁷⁷ **Include:** exploitation rates (i.e., total catch divided by exploitable biomass, or the annual
¹⁷⁸ SPR harvest rate) include a table with the last 10 years of data and a graph showing the
¹⁷⁹ trend in fishing mortality relative to the target (y-axis) plotted against the trend in biomass
¹⁸⁰ relative to the target (x-axis).

¹⁸¹ Exploitation Tables: Table [d](#), Table [??](#), Table [??](#) Exploitation Figure: Figure [e](#)).

¹⁸² A summary of Pacific ocean perch exploitation histories for base model is provided as Figure
¹⁸³ [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	0.104	0.046 - 0.162	0.002	0.001 - 0.003
2008	0.086	0.036 - 0.135	0.002	0.001 - 0.003
2009	0.113	0.046 - 0.181	0.003	0.001 - 0.004
2010	0.107	0.044 - 0.171	0.002	0.001 - 0.004
2011	0.037	0.016 - 0.058	0.001	0.000 - 0.001
2012	0.035	0.015 - 0.054	0.001	0.000 - 0.001
2013	0.033	0.014 - 0.051	0.001	0.000 - 0.001
2014	0.029	0.013 - 0.045	0.001	0.000 - 0.001
2015	0.028	0.013 - 0.044	0.001	0.000 - 0.001
2016	0.028	0.012 - 0.043	0.001	0.000 - 0.001

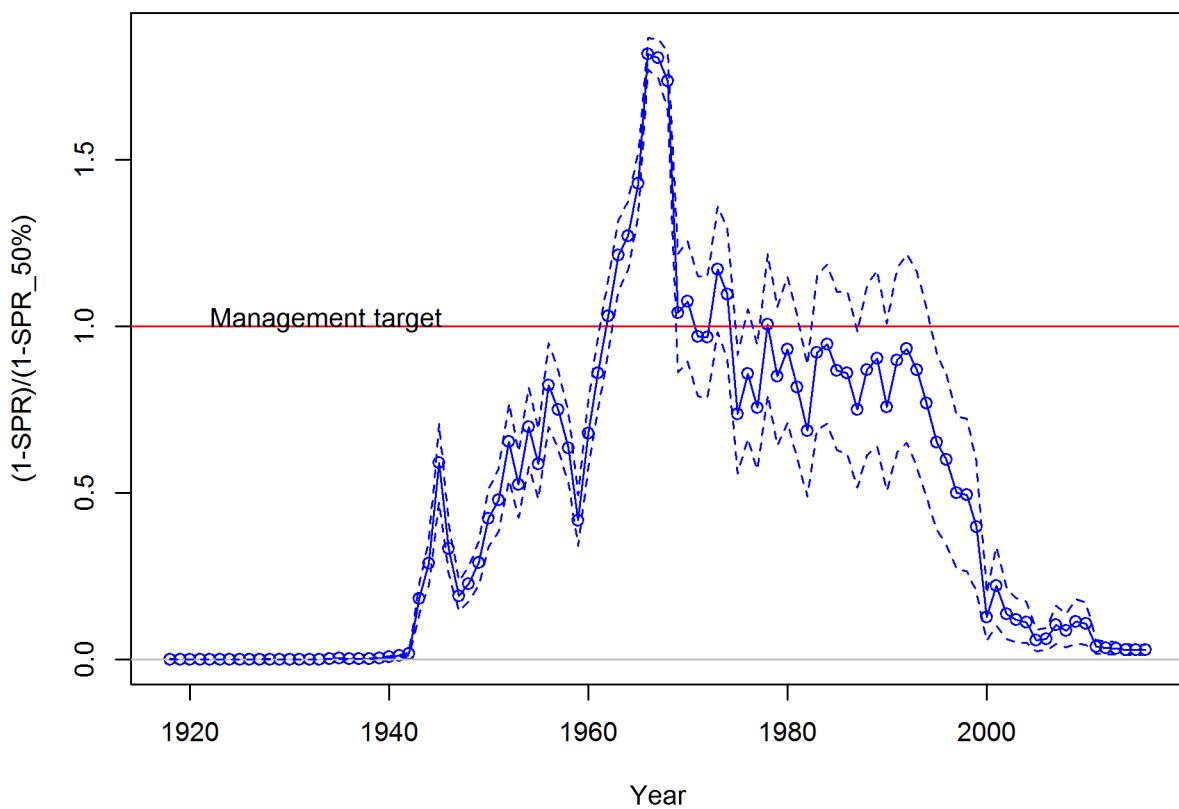


Figure e: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

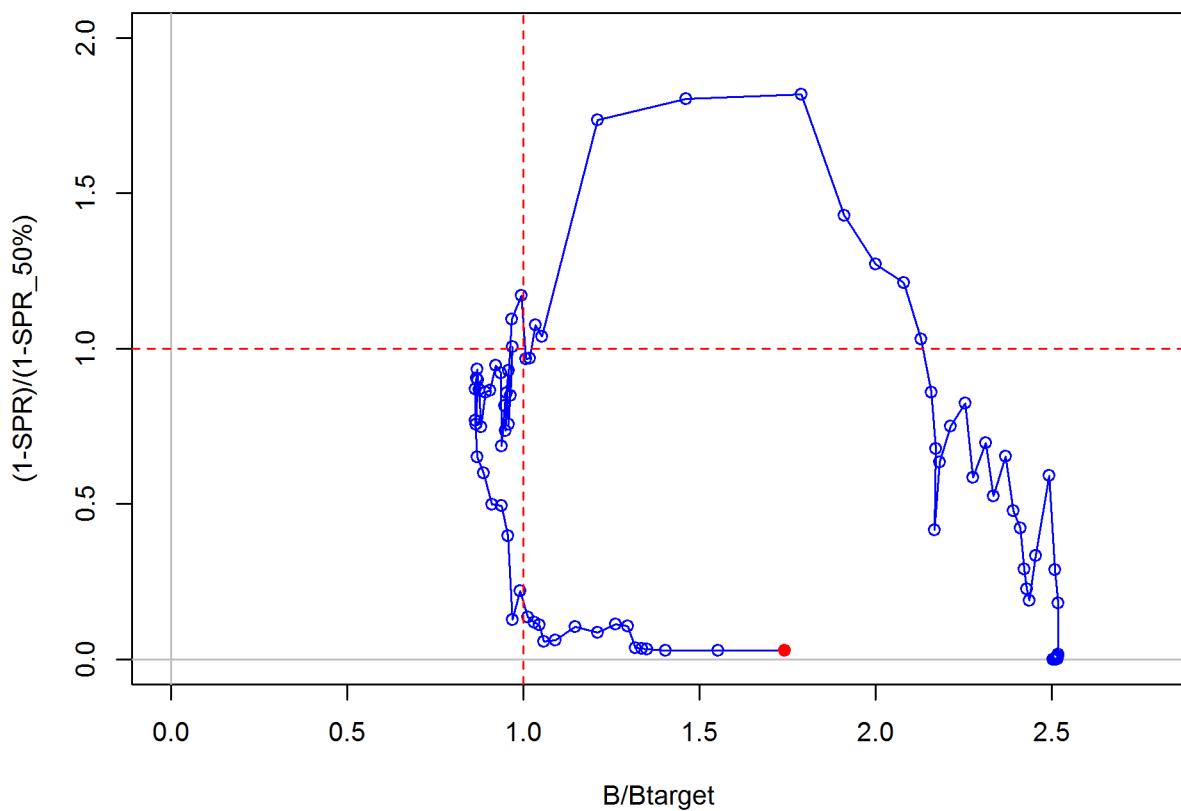


Figure f: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the unfished spawning biomass. | [fig:Phase_all](#)

¹⁸⁴ **Ecosystem Considerations**

ecosystem-considerations

¹⁸⁵ In this assessment, ecosystem considerations were. . . .

¹⁸⁶ **Reference Points**

reference-points

¹⁸⁷ **Include:** management targets and definition of overfishing, including the harvest rate that
¹⁸⁸ brings the stock to equilibrium at $B_{40\%}$ (the B_{MSY} proxy) and the equilibrium stock size
¹⁸⁹ that results from fishing at the default harvest rate (the F_{MSY} proxy). Include a summary
¹⁹⁰ table that compares estimated reference points for SSB, SPR, Exploitation Rate and Yield
¹⁹¹ based on SSBproxy for MSY, SPRproxy for MSY, and estimated MSY values

¹⁹² **Write intro paragraph**

¹⁹³ This stock assessment estimates that Pacific ocean perch in the Base model are above the
¹⁹⁴ biomass target, but above the minimum stock size threshold. **Add sentence about spawning**
¹⁹⁵ **output trend.** The estimated relative depletion level for **Model 1** in 2017 is 76.1% (~95%
¹⁹⁶ asymptotic interval: $\pm 53.8\%-98.4\%$, corresponding to an unfished spawning output of 5047
¹⁹⁷ million eggs (~95% asymptotic interval: 2259.24842947069-7835.07157052931 million eggs) of
¹⁹⁸ spawning output in the base model (Table e). Unfished age 3+ biomass was estimated to be
¹⁹⁹ 139810 mt in the base case model. The target spawning output based on the biomass target
²⁰⁰ ($SB_{40\%}$) is 2653.2 million eggs, which gives a catch of 1748.2 mt. Equilibrium yield at the
²⁰¹ proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 1764.8 mt.

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

Quantity	Estimate	95% Confidence Interval	tab:Ref_pts_mod1
Unfished spawning output (million eggs)	6633.1	4736.7 - 8529.5	
Unfished age 3+ biomass (mt)	139810	100052.5 - 179567.5	
Unfished recruitment (R_0 , thousands)	11665.7	8801.4 - 15462.1	
Spawning output(2017 million eggs)	5047.2	2259.2 - 7835.1	
Depletion (2017)	0.761	0.538 - 0.984	
Reference points based on SB_{40%}			
Proxy spawning output ($B_{40\%}$)	2653.2	1894.7 - 3411.8	
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.55	0.55 - 0.55	
Exploitation rate resulting in $B_{40\%}$	0.028	0.028 - 0.029	
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	1748.2	1252.4 - 2244	
Reference points based on SPR proxy for MSY			
Spawning output	2211	1578.9 - 2843.2	
SPR_{proxy}	0.5		
Exploitation rate corresponding to SPR_{proxy}	0.034	0.033 - 0.034	
Yield with SPR_{proxy} at SB_{SPR} (mt)	1764.8	1264.8 - 2264.8	
Reference points based on estimated MSY values			
Spawning output at MSY (SB_{MSY})	2315.7	1649.6 - 2981.8	
SPR_{MSY}	0.512	0.51 - 0.514	
Exploitation rate at MSY	0.032	0.032 - 0.033	
MSY (mt)	1766.7	1266.1 - 2267.4	

²⁰² **Management Performance**

management-performance

²⁰³ 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.

²⁰⁶ Management performance table: Table f

²⁰⁷ **Unresolved Problems And Major Uncertainties**

unresolved-problems-and-major-uncertainties

²⁰⁸ 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)	Total landings (mt)	<small>tab:mnmgt_perform</small> Estimated total catch (mt)
2007	900		150	133	157
2008	911		150	92	133
2009	1,160		189	94	190
2010	1,173		200	97	181
2011	1,026	981	180	60	61
2012	1,007	962	183	57	58
2013	844	807	150	55	57
2014	838	801	153	54	55
2015	842	805	158	58	59
2016	850	813	164	65	65

209 **Decision Table(s) (groundfish only)**

decision-tables-groundfish-only

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

212 OFL projection table: Table [g](#)

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

214 Yield curve: Figure \ref{fig:Yield_all}

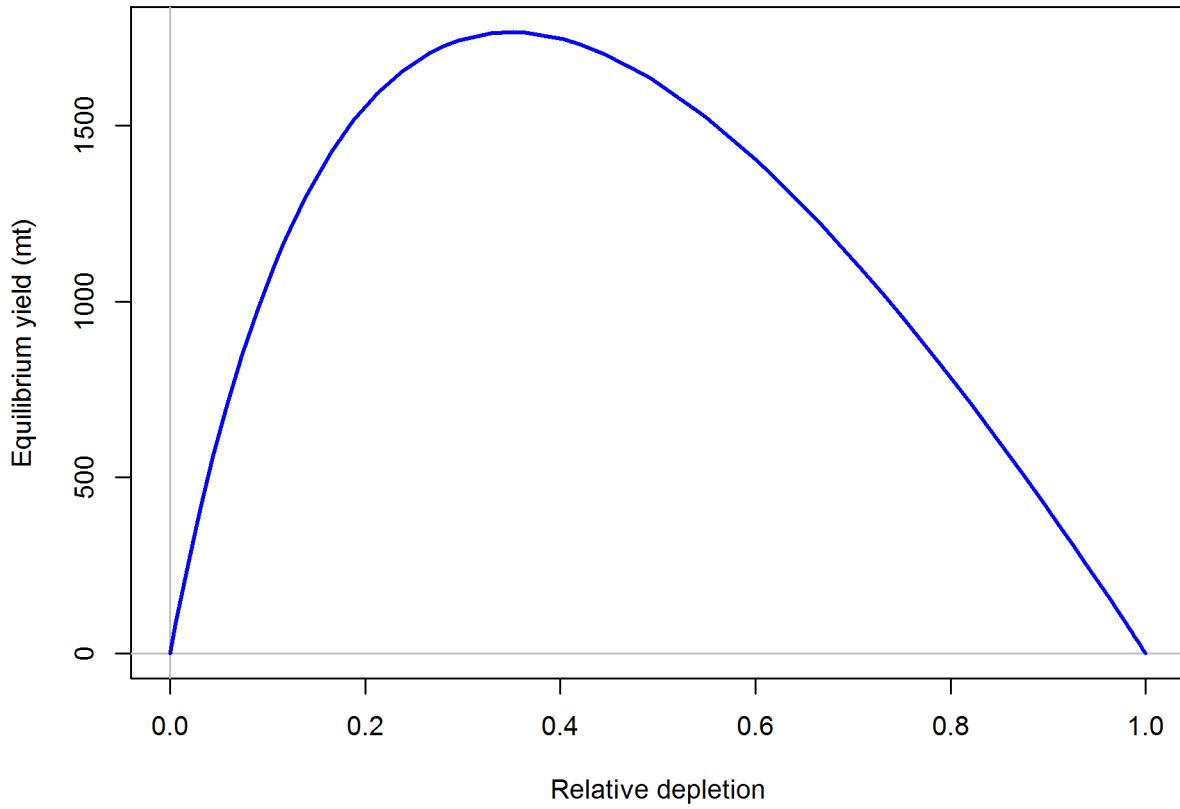


Figure g: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at... [fig:Yield_all](#)

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

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

		States of nature					
		Low 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.

	tab:base_summary									
Quantity	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Landings (mt)	911	1,160	1,173	1,026	1,007	844	838	842	850	964
Total Est. Catch (mt)	150	189	200	180	183	150	153	158	164	281
OFL (mt)	92	94	97	60	57	55	54	58	65	65
ACL (mt)	133	190	181	61	58	57	55	59	65	65
(1-SPR)(1-SPR _{50%})	0.09	0.11	0.11	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Exploitation rate	0	0	0	0	0	0	0	0	0	0
Age 3+ biomass (mt)	73810.2	74550.2	74832.0	88388.8	95169.1	102021.0	109119.0	114333.0	121131.0	125534.0
Spawning Output	3211	3346	3438	3500	3545	3584	3727	4118	4620	5047
95% CI	1362 - 5060	1425 - 5267	1467 - 5408	1496 - 5504	1521 - 5570	1544 - 5625	1618 - 5835	1812 - 6425	2054 - 7186	2259 - 7835
Depletion	0.484	0.504	0.518	0.528	0.534	0.540	0.562	0.621	0.697	0.761
95% CI	0.330 - 0.638	0.345 - 0.664	0.355 - 0.681	0.362 - 0.693	0.368 - 0.701	0.373 - 0.708	0.390 - 0.733	0.435 - 0.807	0.491 - 0.902	0.558 - 0.984
Recruits	133246	4814	8279	16107	2113	29278	5078	10096	10520	10816
95% CI	75744 - 234402	2070 - 11196	4007 - 17102	8067 - 32159	870 - 5132	13512 - 63442	1728 - 14918	2827 - 36059	2945 - 37581	3031 - 38596

²¹⁵ **Research And Data Needs**

research-and-data-needs

²¹⁶ Include: identify information gaps that seriously impede the stock assessment.

²¹⁷ We recommend the following research be conducted before the next assessment:

²¹⁸ 1. List item No. 1 in the list

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

²²⁰ **Rebuilding Projections**

rebuilding-projections

²²¹ Include: reference to the principal results from rebuilding analysis if the stock is overfished.

²²² This section should be included in the Final/SAFE version assessment document but is not

²²³ required for draft assessments undergoing review. See Rebuilding Analysis terms of reference

²²⁴ for detailed information on rebuilding analysis requirements.

225 **1 Introduction**

introduction

226 **1.1 Basic Information**

basic-information

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

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

242 Prior to 1966, the Pacific ocean perch resource off of the northern portion of the US West
243 Coast was harvested almost entirely by Canadian and United States vessels. Harvest was
244 negligible prior to 1940, reached 1,300 mt in 1950, 3,200 mt in 1961 and exceeded 7,600 mt in
245 1965. Catches increased dramatically after 1965, with the introduction of large distant-water
246 fishing fleets from the Soviet Union and Japan. Both nations employed large factory stern
247 trawlers as their primary method for harvesting Pacific ocean perch. Peak removals by all
248 foreign nations combined are estimated at over 15,000 mt in 1966 and remained over 12,000 mt
249 in 1967. These numbers are based upon a re-analysis of the foreign catch data (Rogers 2003),
250 which focused on deriving a more realistic species composition for catches previously identified
251 only as Pacific ocean perch. Catches declined rapidly following these peak years, and Pacific
252 ocean perch stocks were considered to be severely depleted throughout the Oregon-Vancouver
253 Island region by 1969 (Gunderson 1977, Gunderson et al. 1977). Landed harvest averaged
254 1,350 mt over the period 1977-94. Landings have continued to decline since 1994, primarily
255 due to more restrictive management (Table 1 and Figure 1).

256 Prior to 1977, Pacific ocean perch in the northeast Pacific were managed by the Canadian
257 Government in its waters and by the individual states in waters off of the United States. With
258 implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) in
259 1977, US territorial waters were extended to 200 miles from shore, and primary responsibility
260 for management of the groundfish stocks off Washington, Oregon and California shifted from
261 the states to the Pacific Fishery Management Council (PFMC) and the National Marine
262 Fisheries Service (NMFS). At that time, however, a Fishery Management Plan (FMP) for

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

272 Age estimates for Pacific ocean perch prior to the 1980s were made via surface ageing of
273 otoliths, which misses the very tight annuli at the edge of the otolith once the fish reaches near
274 maximum size. Ages are biased by around age 10-12, and maximum age was estimated to be
275 in the 20s, which lead to an overestimate of the natural mortality rate and the productivity
276 of the stock. Using break and burn methods, Pacific ocean perch have been aged to over
277 100 years, and we now know that the underlying assumptions of the early models were
278 overly optimistic about productivity. Research surveys have been used to provide fishery-
279 independent information about the abundance, distribution, and biological characteristics
280 of Pacific ocean perch. A coast-wide survey of the rockfish resource was conducted in 1977
281 (Gunderson and Sample 1980) and was repeated every three years through 2004 (referred to
282 as the ‘Triennial Survey’). The National Marine Fisheries Service (NMFS) coordinated a
283 cooperative research survey of the Pacific ocean perch stocks off Washington and Oregon
284 with the Washington Department of Fisheries (WDFW) and the Oregon Department of
285 Fish and Wildlife (ODFW) in March-May 1979 (Wilkins and Golden 1983). This survey
286 was repeated in 1985 (referred to as the Pacific ocean perch Survey). Two slope surveys
287 have been conducted off the West Coast in recent years, one using the research vessel Miller
288 Freeman, which ended in 2001 (referred to as the ‘AFSC Slope Survey’), and another ongoing
289 cooperative survey using commercial fishing vessels which began in 1998 as a DTS (Dover sole,
290 thornyhead and sablefish) survey, was expanded to other groundfish in 1999 (referred to as
291 the ‘NWFSC Slope Survey’). In 2003, this survey was expanded spatially to include the shelf.
292 This last survey, conducted by the NWFSC, continues to cover depths from 30-700 fathoms
293 (55-1280 meters) on an annual basis (referred to as the ‘NWFSC Shelf-Slope Survey’).

294 1.2 Summary of Management History

summary-of-management-history

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

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

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

309 1.3 Fisheries off Canada and Alaska

`fisheries-off-canada-and-alaska`

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

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

323 2 Data

`data`

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

326 2.1 Fishery-Independent Data:

`fishery-independent-data`

327 2.1.1 Northwest Fisheries Science Center (NWFSC) shelf-slope survey

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

328 The NWFSC shelf-slope survey is based on a random-grid design; covering the coastal waters
329 from a depth of 55 m to 1,280 m (Bradburn et al. 2011). This design uses four chartered
330 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.

370 **2.1.2 Northwest Fisheries Science Center (NWFSC) slope survey**
northwest-fisheries-science-center-nwfsc-slope-survey

- 371 The NWFSC slope survey covered waters throughout the summer from 183 m to 1280 m north
372 of $34^{\circ}30' S$, which is near Point Conception between 1999 and 2002. Tows conducted between
373 the depths of 183 and 549 m were used to create an index of abundance using a bayesian
374 delta-GLMM and the VAST delta-GLMM models. The estimated index of abundance is show
375 in Table 4. Based on the diagnostics the bayesian delta-GLMM, which does not account for
376 spatial effects, gamma distribution with year-vessel random effects was selected as the final
377 model. The Q-Q plot does not show any departures from the assumed distribution (Figure 6).
378 The trend of abundance across the four surveys years was generally flat with high estimated
379 annual variance.
- 380 Length and age compositions were available for 2001 and 2002 and were expanded based upon
381 the survey stratification (Tables 7 and 8. The expanded length frequencies from this survey
382 shows that primarily only large fish were captured both years (Figure 7). The majority of
383 fish observed by this survey were aged at greater than 10 years (Figure 8).

384 **2.1.3 Alaska Fisheries Science Center (AFSC) slope survey**
alaska-fisheries-science-center-afsc-slope-survey

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

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

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

403 **2.1.4 Triennial Bottom Trawl Survey**

triennial-bottom-trawl-survey

404 The triennial survey was first conducted by the AFSC in 1977 and spanned the time-frame
405 from 1977-2004. The survey's design and sampling methods are most recently described
406 in (Weinberg et al. 2002). Its basic design was a series of equally-spaced transects from
407 which searches for tows in a specific depth range were initiated. The survey design has
408 changed slightly over the period of time. In general, all of the surveys were conducted in the
409 mid-summer through early fall: the 1977 survey was conducted from early July through late
410 September; the surveys from 1980 through 1989 ran from mid-July to late September; the
411 1992 survey spanned from mid-July through early October; the 1995 survey was conducted
412 from early June to late August; the 1998 survey ran from early June through early August;
413 and the 2001 and 2004 surveys were conducted in May-July.

414 Haul depths ranged from 91-457 m during the 1977 survey with no hauls shallower than 91 m.
415 The surveys in 1980, 1983, and 1986 covered the West Coast south to 36.8° N latitude and a
416 depth range of 55-366 meters. The surveys in 1989 and 1992 covered the same depth range
417 but extended the southern range to 34.5° N (near Point Conception). From 1995 through
418 2004, the surveys covered the depth range 55-500 meters and surveyed south to 34.5° N. In
419 the final year of the triennial series (2004), the NWFSC's Fishery Resource and Monitoring
420 division (FRAM) conducted the survey and followed very similar protocols as the AFSC.

421 Given the different depths surveyed during 1977, the data from that year were not included
422 in this assessment. Water hauls (Zimmermann et al. 2003) and tows located in Canadian
423 waters were also excluded from the analysis of this survey. The data was examined for
424 varying distribution of length and/or ages of fish based upon the shift in survey timing and
425 little evidence was found of ontogenetic shifts in Pacific ocean perch during the summer
426 months. Pacific ocean perch are rarely encountered south of 40°*south* where the change in
427 southern range of the survey would have no impact on data collected regarding Pacific
428 ocean perch. Given these factors the Triennial survey was analyzed as a single time-series a
429 departure from how the previous assessment which split the time-series into an early
430 (1980-1992) and a late period (1995-2004).

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

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

⁴⁴² excluded from analysis. The available ages from the Triennial survey and the number of tows
⁴⁴³ where otoliths were collected are shown in Table 11. The expanded length frequencies from
⁴⁴⁴ this survey show an increase in small fish starting in 1995 (Figure 12). The age frequencies
⁴⁴⁵ provide clear evidence of large year-classes moving through the population from the 1999
⁴⁴⁶ and 2000 recruitment (Figure 13).

⁴⁴⁷ 2.1.5 Pacific ocean perch Survey

pacific-ocean-perch-survey

⁴⁴⁸ A survey targeted designed to sample Pacific ocean perch was conducted in 1979 and again
⁴⁴⁹ in 1985 (for a detailed description see (Ianelli et al. 1992)). An index of abundance was
⁴⁵⁰ estimated based on the data using the VAST delta-GLMM model. The estimated index of
⁴⁵¹ abundance is shown in Table 4. The lognormal distribution with random strata-year had the
⁴⁵² lowest AIC and was chosen as the final model. The Q-Q plot does not show any departures
⁴⁵³ from the assumed distribution (Figure 14). The index shows a clear decline in abundance
⁴⁵⁴ between the two survey years.

⁴⁵⁵ Length and age compositions were expanded based on the stratification. The survey had 125
⁴⁵⁶ and 126 Pacific ocean perch tows (Table 12) and ages were only available in 1985 due to
⁴⁵⁷ surface reads for the 1979 data (Table 13). The length frequencies for both years are highest
⁴⁵⁸ between the 30-45 cm range (Figure 15) with ages in 1985 having a large number of fish age
⁴⁵⁹ 40 and greater (Figure 16).

⁴⁶⁰ 2.2 Fishery-Dependent Data

fishery-dependent-data

⁴⁶¹ 2.2.1 Commercial Fishery Landings

commercial-fishery-landings

⁴⁶² Washington

⁴⁶³ Historical commercial fishery landings of Pacific ocean perch from Washington for the years
⁴⁶⁴ 1918-2016 were obtained from Theresa Tsou (WDFW) and Phillip Weyland (WDFW). This
⁴⁶⁵ assessment is the first Pacific ocean perch assessment to include a state provide historical
⁴⁶⁶ catch reconstruction and hence, the historical catches for Washington vary markedly from
⁴⁶⁷ those used in the 2011 assessment. Due to Recent landings (1981-2016) were obtained directly
⁴⁶⁸ from Washington state rather than from PacFIN (Pacific Fisheries Information Network
⁴⁶⁹ (PacFIN) due to identified missing catches not available within PacFIN for Pacific ocean
⁴⁷⁰ perch.

⁴⁷¹ Oregon

⁴⁷² Historical commercial fishery landings of Pacific ocean perch from Oregon for the years
⁴⁷³ 1892-1986 were obtained from Alison Dauble (ODFW). A description of the methods can be

474 found in Karnowski et al. (2014). Recent landings (1987-2016) were obtained from PacFIN
475 retrieval dated May 2, 2017}, Pacific States Marine Fisheries Commission, Portland, Oregon;
476 www.psmfc.org). The catch data in from the POP and POP2 categories contained within
477 PacFIN for Pacific ocean perch were used for this assessment. Additional catches from
478 1987-1999 for Pacific ocean perch under the UROCK category not yet available in PacFIN
479 were received directly from the state and combined with the catch data available for that
480 period within PacFIN.

481 California

482 Historical commercial fishery landings of Pacific ocean perch were obtained directly from
483 John Field at the SWFSC due to database issues for the historical period for the California
484 Cooperative Groundfish Survey, also known as CALCOM (128.114.3.187) for the years 1916-
485 1980. A description of the methods can be found in (Ralston et al. 2010). Recent landings
486 (1981-2016) were obtained from PacFIN (Pacific Fisheries Information Network (PacFIN)
487 retrieval dated May 2, 2017, Pacific States Marine Fisheries Commission, Portland, Oregon;
488 www.psmfc.org).

489 At-Sea Hake Fishery

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

501 Foreign Catches

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

508 2.2.2 Discards

discards

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

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

521 The second source is from the West Coast Groundfish Observer Program (WCGOP). This
522 program is part of the NWFSC and has been recording discard observations since 2003. Table
523 14 shows the discard ratios (discarded/(discarded + retained)) of Pacific ocean perch from
524 the WCGOP. Since 2011, when the trawl rationalization program was implemented, observer
525 coverage rates increased to nearly 100% for all the limited entry trawl vessels in the program
526 and discard rates declined compared to pre-2011 rates. Discard rates were obtained for both
527 the catch-share and the non-catch share sector for Pacific ocean perch. A single discard rate
528 was calculated by weighting discard rates based on the commercial landings by each sector.
529 Coeffienct of variations were calculated by bootstrapping vessels within ports because the
530 observer program randomly chooses vessels within porats to be observed in the non-catch
531 shares sectors. Discard length composition for the trawl fleet varied by year, with larger fish
532 being discarded prior to 2011 (Figure 17).

533 2.2.3 Historical Commercial Catch-per-unit effort

historical-commercial-catch-per-unit-effort

534 Data on catch-per-unit-effort (CPUE) in mt/hr from the domestic fishery were combined for
535 the INPFC Vancouver and Columbia areas (Table 15, from Gunderson (1977)). Although
536 these data reflect catch rates for the US fleet, the highest catch rates coincided with the
537 beginning of removals by the foreign fleet. This suggest that, barring unaccounted changes in
538 fishing efficiency during this period, the level of abundance was high at that time. A CV of
539 0.40 was used in this assessment to be consistent with the CV observed in the survey data.

540 2.2.4 Fishery Length And Age Data

fishery-length-and-age-data

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

547 16 and 17 show the number of trips and fish sampled, along with the calculated sample sizes.
548 Length and age data were acquired at the trip level, and then aggregated to the state level.
549 The sample sizes were calculated via the Stewart Method (Ian Stewart, pers. Comm.) which
550 for commercial fishery data is:

551 $\text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}}$ if $N_{\text{fish}}/N_{\text{trips}}$ is < 44

552 $\text{Input effN} = 7.06 * N_{\text{trips}}$ if $N_{\text{fish}}/N_{\text{trips}}$ is ≥ 44

553 2.3 Biological Data

biological-data

554 2.3.1 Natural mortality

natural-mortality

555 Historic Pacific ocean perch ages determined using scales and surface reading methods of
556 otoliths, resulted in estimates of natural mortality (M) of between 0.10 and 0.20 yr^{-1} with
557 a longevity less than 30 years(Gunderson 1977). Based on break-and-burn method of age
558 determination using otoliths, the maximum age of Pacific ocean perch was revised to be 90
559 years (Chilton and Beamish 1982). The updated understanding concerning Pacific ocean perch
560 longevity reduced the estimate of natural mortality based on Hoenig's (1983) relationship to
561 0.059 yr^{-1} . The previous assessment applied a prior distribution on natural mortality based
562 upon multiple life history correlates (including Hoenig's method, Gunderson gonadosomatic
563 index (1997), and McCoy and Gillooly's (2008) theoretical relationship) developed separately
564 for female and male Pacific ocean perch.

565 Hamel (2015) developed a method for combining meta-analytic approaches to relating the
566 natural mortality rate M to other life-history parameters such as longevity, size, growth rate
567 and reproductive effort, to provide a prior on M . In that same issue of ICESJMS, Then et al.
568 (2015), provided an updated data set of estimates of M and related life history parameters
569 across a large number of fish species, from which to develop an M estimator for fish species
570 in general. They concluded by recommending M estimates be based on maximum age alone,
571 based on an updated Hoenig non-linear least squares (nls) estimator $M=4.899A_{\text{max}}^{-.916}$.
572 The approach of basing M priors on maximum age alone was one that was already being used
573 for West Coast rockfish assessments. However, in fitting the alternative model forms relating
574 M to A_{max} , Then et al. (2015) did not consistently apply their transformation. In particular,
575 in real space, one would expect substantial heteroscedasticity in both the observation and
576 process error associated with the observed relationship of M to A_{max} . Therefore, it would
577 be reasonable to fit all models under a log transformation. This was not done. Reevaluating
578 the data used in Then et al. (2015) by fitting the one-parameter A_{max} model under a log-log
579 transformation (such that the slope is forced to be -1 in the transformed space (Hamel 2015)),
580 the point estimate for M is:

581
$$M = \frac{5.4}{A_{\text{max}}}$$

582 The above is also the median of the prior. The prior is defined as a lognormal with mean
583 $\ln(\frac{5.4}{A_{\max}})$ and SE = 0.4384343. Using a maximum age of 100 the point estimate and median
584 of the prior is 0.054. The maximum age was selected based on available age data from all
585 West Coast data sources. The oldest aged rockfish was 120 years, captured by the commercial
586 fishery in 2007. However, age data are subject to ageing error which could impact this
587 estimate of longevity. The selection of 100 years was based on the range of other ages
588 available with had multiple observations of fish between 90 and 102 years of age.

589 2.3.2 Sex ratio, maturation, and fecundity

sex-ratio-maturation-and-fecundity

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

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

606 2.3.3 Length-weight relationship

length-weight-relationship

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

611 2.3.4 Growth (length-at-age)

growth-length-at-age

612 The length-at-age was estimated for male and female Pacific ocean perch using data collected
613 from both fishery-dependent and -independent data sources that were collected from 1981-
614 2016. Figure 29 shows the lengths and ages for all years and all data as well as predicted

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

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

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

619 2.3.5 Ageing Precision And Bias

ageing-precision-and-bias

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

630 2.4 History Of Modeling Approaches Used For This Stock

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

631 2.4.1 Previous Assessments

previous-assessments

632 The status of Pacific ocean perch off British Columbia, Washington, and Oregon have been
633 periodically assessed since the intensive exploitation that occurred in the 1960s. Concerns
634 regarding Pacific ocean perch status off the coast the US west coast were raised in the late
635 1970s (Gunderson 1978, Gunderson (1981)) and in 1981 the PFMC adopted a 20-year plan
636 to rebuild the stock.

637 The 1992 assessment determined that Pacific ocean perch remained at low levels relative
638 to the population size in 1960 (Ianelli et al. 1992) and recommended additional harvest
639 restrictions to allow for stock rebuilding. The 1998 assessment (Ianelli and Zimmermann
640 1998) estimated that the stock was 13% of the unfished level, leading the National Marine
641 Fishery Service (NMFS) to declare the stock overfished in 1999. The formal rebuilding
642 plan was implemented in 2001. The rebuilding plan reduced the SPR harvest rate used to
643 determine catches to 0.864, relative to the PFMC rockfish default harvest (SPR = 0.50).
644 The last full assessment of Pacific ocean perch was conducted in 2011 (Hamel and Ono 2011)
645 which concluded that the stock was still well below the target biomass of $0.40SB_0$ estimating
646 the relative stock status at 19.1%.

647 2.4.2 Previous Assessment Recommendations

previous-assessment-recommendations

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

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

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

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

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

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

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

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

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

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

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

686 3 Assessment

assessment

687 3.1 General Model Specifications and Assumptions

general-model-specifications-and-assumptions

688 Stock Synthesis v3.30.03.03 was used to estimate the parameters in the model. R4SS, revision
689 1.26.0, along with R version 3.3.2 were used to investigate and plot model fits. A summary
690 of the data sources used in the model (details discussed above) is shown in Figure 2.

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

693 3.1.1 Changes between the 2011 assessment model and current model

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

694 The current model for Pacific ocean perch has many made many similar assumptions to the
695 2011 assessment but differs in some key ways. This assessment disaggrated the fleets into
696 a trawl/other gear, at-sea hake, historical foreign fleet, and research fleets. The previous
697 assessment implemented a single fleet where removal from all sources were aggregated together.
698 The seperating of fleets applied in this assessment allowed for differing assumptions regarding
699 current and historical discarding practices. Although there are no compositional data available
700 from the foreign fleet, it is assumed that very little discarding to no discarding of fish occured.
701 Additionally, the at-sea hake fishery removals are represent both discarded and retained fish
702 and hence an additional discard rate would not be appropriate. Similar logic was applied in
703 regard to survey and research removals.

704 The historical landing used in the model differs from those used in 2011. The assessment
705 includes the first state provided historical reconstruction landings for Washington state.
706 The historical reconstruction provided Pacific ocean perch landing within Washington state
707 starting in 1916 and have significantly larger removals in the 1940s relative to those used in
708 2011. Given the increase in historical removals prior to 1940, the 2011 model starting year,
709 the starting year for modeling the stock was revised to 1918, the first year Pacific ocean perch
710 landings exceeded 1 mt, for this assessment. Explorations were conducted relative to the
711 model starting year and no differences were found between the 1918 start year compared to
712 starting the model in 1892, the first record of Pacific ocean perch landings between California,
713 Oregon, and Washington catch data.

714 Selectivity in this model is assumed to be length-based and is modeled using double-normal
715 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 base 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 base 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 eht bottom trawl fishery with fixed gear accounting for a small fraction of the catches available within PacFIN. Trawl

754 and fixed gears were combined into a coast-wide fleet. For the period from 1918 to the early
755 1990s, prior to the introduction of trip limits for rockfish, limited discarding of Pacific ocean
756 perch was assumed. Observations of Pacific ocean perch in the Pikitch et al. (1988) data
757 (1986-1987) allowed for a formal analysis of discard rates which were applied to the historical
758 period of the fishery. Foreign trawl catches (1966-1976) was modeled as a single fleet. The
759 at-sea fishery operates as a mid-water fishery targeting Pacific whiting but encounters Pacific
760 ocean perch as a bycatch species. This fleet was also modeled as a single fleet.

761 **3.1.3 Other Specifications**

other-specifications

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

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

779 The specification of when to estimate recruitment deviations is an assumption that likely
780 affects model uncertainty. It was decided to estimate recruitment deviations from 1900-2014
781 to appropriately quantify uncertainty. The earliest length-composition data occur in 1966
782 and the earliest age data were in 1981. The most informed years for estimating recruitment
783 deviations were from about the mid-1970s to about 2011. The period from 1900-1974 was fit
784 using an early series with little or no bias adjustment, the main period of recruitment deviates
785 occurred from 1975-2014 with an upward and downward ramping of bias adjustment, and
786 2015 onward was fit using forecast recruitment deviates with little bias adjustment. Methot
787 and Taylor (2011) summarize the reasoning behind varying levels of bias adjustment based
788 on the information available to estimate the deviates. Recruitment deviation was assumed to
789 be 0.70.

790 The recommended selectivity type in Stock Synthesis is the double normal and was used in
791 this assessment for the all fleets, except the Pacific ocean perch survey which was assumed

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

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

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

802 3.1.4 Modeling Software

modeling-software

803 The STAT team used Stock Synthesis version 3.30.03.03 by Dr. Richard Methot at the
804 NWFSC (Methot and Wetzel 2013). This most recent version was used, since it included
805 improvements and corrections to older versions.

806 3.1.5 Priors

priors

807 A prior distribution was developed for the natural mortality parameter from an analysis
808 of a maximum age of 100 years. The analysis was performed by Owen Hamel (pers comm,
809 NWFSC, NOAA) and used data from Then et al. (2015) to provide a lognormal distribution
810 for natural mortality. The median of the lognormal prior is 0.054 and has a standard error of
811 0.4384343.

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

822 **3.1.6 Data Weighting****data-weighting**

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

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

840 **3.1.7 Estimated And Fixed Parameters****estimated-and-fixed-parameters**

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

846 Fixed parameters in the model were as follows. Steepness was fixed at 0.50. A sensitivity
847 analysis and a likelihood profile were done for steepness. Natural mortality was fixed at
848 0.054 for females and males, which is the median of the prior. The standard deviation of
849 recruitment deviates was fixed at 0.70. Maturity at age was fixed as described in Section
850 2.3.2. Length-weight parameters were fixed at estimates using all length-weight observations
851 (Figure 28).

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

857 **3.2 Model Selection and Evaluation**

model-selection-and-evaluation

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

863 **3.2.1 Key Assumptions and Structural Choices**

key-assumptions-and-structural-choices

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

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

874 **3.2.2 Alternate Models Considered**

alternate-models-considered

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

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

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

892 Natural mortality was also investigated and a new prior was developed assuming a maximum
893 age of 100 years for females and males. The previous assessment estimated male natural
894 mortality as an offset from female natural mortality which was fixed at the median of the
895 2011 prior. This assessment attempted to estimate natural mortality for both sexes using the
896 2017 updated prior, but there was little to no information on natural mortality within the
897 data and hence opted to fix the value for females. Upon additional exploration, the model
898 estimated very little difference in male natural mortality relative to females (< 0.002) and
899 in the interest of selecting the model that fit the data with the fewest parameters required,
900 males were fixed equal to the female natural mortality.

901 3.2.3 Convergence

convergence

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

910 3.3 Response To The Current STAR Panel Requests

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

911 Request No. 1: Add after STAR panel.

912

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

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

915 Request No. 2: Add after STAR panel.

916

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

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

919 Request No. 3: Add after STAR panel.

920

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

922 **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 ??

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 28).

941 Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 1764.8 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.

944 **4 Harvest Projections and Decision Tables**

harvest-projections-and-decision-tables

945 Table [f](#)

946 Model 1 Projections and Decision Table (groundfish only) (Table [29](#))

947 Table [h](#)

948 Model 2 Projections and Decision Table (groundfish only)

949 Model 3 Projections and Decision Table (groundfish only)

950 **5 Regional Management Considerations**

regional-management-considerations

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

959 **6 Research Needs**

research-needs

- 960 1. Research need No. 1
- 961 2. Research need No. 2
- 962 3. Research need No. 3
- 963 4. etc.

964 **7 Acknowledgments**

acknowledgments

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

₉₆₈ 8 Tables

tables

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

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

Year	California	Oregon	Washington	At-Sea Hake	Foreign	Research
1932	0.3	0.1	0.4	0.0	0	0.0
1933	0.6	0.1	0.5	0.0	0	0.0
1934	0.4	0.0	2.3	0.0	0	0.0
1935	0.4	0.1	7.7	0.0	0	0.0
1936	0.2	0.2	1.6	0.0	0	0.0
1937	0.5	0.4	2.0	0.0	0	0.0
1938	0.6	0.1	5.1	0.0	0	0.0
1939	0.9	0.4	8.7	0.0	0	0.0
1940	0.9	9.1	12.2	0.0	0	0.0
1941	1.3	14.0	13.6	0.0	0	0.0
1942	0.4	26.6	18.6	0.0	0	0.0
1943	1.0	94.3	453.6	0.0	0	0.0
1944	2.8	164.5	739.3	0.0	0	0.0
1945	6.7	247.1	1887.1	0.0	0	0.0
1946	7.3	193.2	845.9	0.0	0	0.0
1947	2.6	167.2	385.3	0.0	0	0.0
1948	3.9	177.8	491.1	0.0	0	0.0
1949	2.0	472.9	409.5	0.0	0	0.0
1950	1.5	690.1	675.7	0.0	0	0.0
1951	4.3	840.1	735.1	0.0	0	0.0
1952	2.9	2030.5	305.6	0.0	0	0.0
1953	145.6	1223.5	361.6	0.0	0	0.0
1954	123.2	1837.5	538.8	0.0	0	0.0
1955	48.8	1346.4	555.6	0.0	0	0.0
1956	3.8	2563.8	548.2	0.0	0	0.0
1957	1.6	2128.1	538.5	0.0	0	0.0
1958	2.9	1564.9	530.4	0.0	0	0.0
1959	1.5	892.6	337.0	0.0	0	0.0
1960	19.6	1358.8	928.1	0.0	0	0.0
1961	1.1	2061.9	1179.8	0.0	0	0.0
1962	0.6	2584.9	1725.2	0.0	0	0.0
1963	32.5	3693.9	2006.0	0.0	0	0.0
1964	46.1	4261.6	1770.7	0.0	0	0.0
1965	34.9	5627.8	1972.1	0.0	0	0.0
1966	5.2	1591.2	1725.5	0.0	15561	0.0
1967	17.8	354.7	1861.0	0.0	12357	0.0
1968	21.9	466.4	2501.2	0.0	6639	0.0
1969	8.4	422.3	1236.0	0.0	469	0.0
1970	8.7	507.4	1293.3	0.0	441	0.0
1971	12.2	290.4	673.6	0.0	902	0.0
1972	11.4	105.3	796.5	0.0	950	0.0
1973	11.9	121.2	713.1	0.0	1773	0.0
1974	15.7	136.7	641.8	0.0	1457	0.0
1975	11.4	181.3	413.9	62.3	496	0.0
1976	17.1	663.7	521.144	31.9	239	0.0

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

Table 2: West Coast history of regulations.

tab:Regs

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Year	Tows	Fish	Sample Size	tab:POP_Ages
1985	29	1635	70	

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

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

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

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

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

`tab:Comm_Lengths`

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

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

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

`tab:Comm_Ages`

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

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

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

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

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

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

tab:Age_Error

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

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

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

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

`tab:jitter`

Status	Base.Model
Returned to base case	-
Found local minimum	-
Found better solution	-
Error in likelihood	-
Total	100

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
NatM_p_1.Fem.GP_1	0.05	-5	(0.02, 0.1)	OK	0.14	Log-Norm (-2.92, 0.44)
L_at_Amin_Fem.GP_1	20.78	3	(15, 25)	OK	0.14	None
L_at_Amax_Fem.GP_1	41.60	2	(35, 45)	OK	0.15	None
VonBert_K.Fem.GP_1	0.17	3	(0.1, 0.4)	OK	0.00	None
CV_young_Fem.GP_1	1.34	5	(0.03, 5)	OK	0.06	None
CV_old.Fem.GP_1	2.56	5	(0.03, 5)	OK	0.12	None
Wtlen_1.Fem	0.00	-99	(0, 3)	None	None	None
Wtlen_2.Fem	3.09	-99	(2, 4)	None	None	None
Mat50%_Fem	32.10	-99	(20, 40)	None	None	None
Mat_slope_Fem	-1.00	-99	(-2, 4)	None	None	None
Eggs_scalar_Fem	0.00	-99	(0, 6)	None	None	None
Eggs_exp_len_Fem	4.98	-99	(-3, 5)	None	None	Normal (0.05, 0.1)
NatM_p_1.Mal.GP_1	0.05	-5	(0, 0.3)	None	None	None
L_at_Amin_Mal.GP_1	20.78	-2	(6, 68)	None	None	None
L_at_Amax_Mal.GP_1	38.90	2	(13, 122)	OK	0.00	None
VonBert_K.Mal.GP_1	0.20	3	(0.04, 1.09)	OK	0.03	None
CV_young_Mal.GP_1	1.34	-5	(0, 742.07)	None	None	None
CV_old.Mal.GP_1	2.29	5	(0, 742.07)	OK	0.06	None
Wtlen_1.Mal	0.00	-99	(0, 3)	None	None	None
Wtlen_2.Mal	3.08	-99	(2, 4)	None	None	None
CohortGrowDev	1.00	-99	(0, 2)	None	None	None
FracFemale.GP_1	0.50	-99	(0.01, 0.99)	None	None	None
SR_LN(R0)	9.36	1	(5, 20)	OK	0.14	None
SR_BH_stEEP	0.50	-2	(0.2, 1)	Full_Beta (0.72, 0.15)	None	None
SR_sigmaR	0.70	-6	(0.5, 1.2)	None	None	None
SR_regime	0.00	-99	(-5, 5)	None	None	None

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SR_autocorr	0.00	-99	(0, 2)			None
Early_InitAge_18	0.00	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_17	0.00	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_16	0.00	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_15	0.00	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)	-12.31	-1	(-15, 15)			None
LnQ_base_POP(4)	-0.12	-1	(-15, 15)			None
LnQ_base_Triennial(5)	-1.83	-1	(-15, 15)			None
Q_extraSD_Triennial(5)	0.39	2	(0, 0.5)	OK	0.15	None
LnQ_base_AFSCSlope(6)	-2.49	-1	(-15, 15)			None
LnQ_base_NWEFSCSlope(7)	-2.85	-1	(-15, 15)			None
LnQ_base_NWFSCCombo(8)	-2.62	-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_NWFSC combo(8)	0.03	2	(0, 0.5)	OK	0.07	None
SizeSel_P1_Fishery(1)	37.96	1	(20, 45)	OK	0.18	None
SizeSel_P2_Fishery(1)	-5.00	-2	(-6, 4)	OK	0.13	None
SizeSel_P3_Fishery(1)	3.68	3	(-1, 9)	OK	None	None
SizeSel_P4_Fishery(1)	-1.65	-3	(-9, 9)	None	None	None
SizeSel_P5_Fishery(1)	-3.50	-4	(-5, 9)	None	None	None
SizeSel_P6_Fishery(1)	0.50	2	(-5, 9)	OK	0.31	None
Retain_P1_Fishery(1)	28.28	1	(15, 45)	OK	0.34	None
Retain_P2_Fishery(1)	1.08	1	(0.1, 10)	OK	0.13	None
Retain_P3_Fishery(1)	6.97	1	(-10, 10)	OK	1.36	None
Retain_P4_Fishery(1)	0.00	-3	(0, 0)	None	None	None
SizeSel_P1_ASHOP(2)	49.49	1	(20, 49.5)	II	0.16	None
SizeSel_P2_ASHOP(2)	-5.00	-2	(-6, 4)	None	None	None
SizeSel_P3_ASHOP(2)	5.06	3	(-1, 9)	OK	0.18	None
SizeSel_P4_ASHOP(2)	1.00	-3	(-1, 9)	None	None	None
SizeSel_P5_ASHOP(2)	-4.35	-4	(-9, 9)	None	None	None
SizeSel_P6_ASHOP(2)	999.00	-2	(-5, 999)	None	None	None
SizeSel_P1_POP(4)	24.47	1	(20, 70)	OK	2.24	None
SizeSel_P2_POP(4)	11.17	3	(0.001, 50)	OK	4.04	None
SizeSel_P1_Triennial(5)	27.64	1	(20, 45)	OK	5.03	None
SizeSel_P2_Triennial(5)	-5.00	-2	(-6, 4)	None	None	None
SizeSel_P3_Triennial(5)	5.50	-3	(-1, 9)	OK	2.29	None
SizeSel_P4_Triennial(5)	3.30	3	(-1, 9)	OK	None	None
SizeSel_P5_Triennial(5)	-5.00	-4	(-5, 9)	OK	0.64	None
SizeSel_P6_Triennial(5)	-0.78	2	(-5, 9)	OK	6.45	None
SizeSel_P1_AFSCSlope(6)	21.70	1	(20, 45)	OK	6.45	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)	OK	6.47	None
SizeSel.P3_AFSCSlope(6)	1.24	3	(-1, 9)	OK	6.47	None
SizeSel.P4_AFSCSlope(6)	1.00	-3	(-1, 9)	None	None	None
SizeSel.P5_AFSCSlope(6)	-9.00	-4	(-9, 9)	None	None	None
SizeSel.P6_AFSCSlope(6)	999.00	-2	(-5, 999)	None	None	None
SizeSel.P1_NWFSCSlope(7)	35.96	1	(20, 45)	OK	2.22	None
SizeSel.P2_NWFSCSlope(7)	-5.00	-2	(-6, 4)	None	None	None
SizeSel.P3_NWFSCSlope(7)	1.78	3	(-1, 9)	OK	1.85	None
SizeSel.P4_NWFSCSlope(7)	1.00	-3	(-1, 9)	None	None	None
SizeSel.P5_NWFSCSlope(7)	-9.00	-4	(-9, 9)	None	None	None
SizeSel.P6_NWFSCSlope(7)	999.00	-2	(-5, 999)	None	None	None
SizeSel.P1_NWFFSCCombo(8)	21.35	1	(18, 49.5)	OK	5.84	None
SizeSel.P2_NWFFSCCombo(8)	-5.00	-2	(-6, 4)	None	None	None
SizeSel.P3_NWFFSCCombo(8)	2.86	3	(-1, 9)	OK	3.06	None
SizeSel.P4_NWFFSCCombo(8)	1.00	-3	(-1, 9)	None	None	None
SizeSel.P5_NWFFSCCombo(8)	-9.00	-4	(-9, 9)	None	None	None
SizeSel.P6_NWFFSCCombo(8)	999.00	-2	(-5, 999)	None	None	None
Retain_P3_Fishery(1)_BLK1rep1_1918	3.98	4	(-10, 10)	OK	0.09	None
Retain_P3_Fishery(1)_BLK1rep1_1992	2.30	4	(-10, 10)	OK	0.37	None
Retain_P3_Fishery(1)_BLK1rep1_2002	1.72	4	(-10, 10)	OK	0.12	None
Retain_P3_Fishery(1)_BLK1rep1_2008	0.61	4	(-10, 10)	OK	0.28	None
Retain_P3_Fishery(1)_BLK1rep1_2009	-0.02	4	(-10, 10)	OK	0.24	None

tab:meet-param

Table 24: Likelihood components from the base model

`tab:like`

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

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

Quantity	Estimate	95% Confidence Interval	<small>tab:Ref_pts</small>
Unfished spawning output (million eggs)	6633.1	4736.7 - 8529.5	
Unfished age 3+ biomass (mt)	139810	100052.5 - 179567.5	
Unfished recruitment (R0, thousands)	11665.7	8801.4 - 15462.1	
Spawning output(2017 million eggs)	5047.2	2259.2 - 7835.1	
Depletion (2017)	0.761	0.538 - 0.984	
Reference points based on SB_{40%}			
Proxy spawning output ($B_{40\%}$)	2653.2	1894.7 - 3411.8	
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.55	0.55 - 0.55	
Exploitation rate resulting in $B_{40\%}$	0.028	0.028 - 0.029	
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	1748.2	1252.4 - 2244	
Reference points based on SPR proxy for MSY			
Spawning output	2211	1578.9 - 2843.2	
SPR_{proxy}	0.5	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.034	0.033 - 0.034	
Yield with SPR_{proxy} at SB_{SPR} (mt)	1764.8	1264.8 - 2264.8	
Reference points based on estimated MSY values			
Spawning output at MSY (SB_{MSY})	2315.7	1649.6 - 2981.8	
SPR_{MSY}	0.512	0.51 - 0.514	
Exploitation rate at MSY	0.032	0.032 - 0.033	
MSY (mt)	1766.7	1266.1 - 2267.4	

Table 26: Sensitivity of the base model

tab:Sensitivity1

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

Table 27: Sensitivity of the base model

tab:Sensitivity2

Label	Base	Split Trien- nial	CPUE	Remove Data	Canadian search Lengths	VWA Re- search Lengths	OR Special Projects
Total Likelihood	1726.16	1724.43	1738.84	1829.66	1747.71	1793.59	
Survey Likelihood	-25.51	-27.89	-12.72	-25.85	-26.03	-26.02	
Discard Likelihood	-34.22	-34.22	-34.21	-33.27	-34.17	-34.27	
Length Likelihood	135.74	135.54	135.66	184.34	156.08	166.78	
Age Likelihood	1636.59	1637.33	1636.69	1690.28	1637.74	1671.26	
Recruitment Likelihood	12.54	12.65	12.40	13.13	13.08	14.81	
Forecast Recruitment Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	
Parameter Priors Likelihood	1.00	1.00	1.00	1.00	1.00	1.00	
Parameter Deviation Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	
log(R0)	9.36	9.40	9.36	9.36	9.33	9.28	
SB Virgin	6633.08	6884.08	6594.29	6687.07	6356.26	6128.38	
SB 2017	5047.16	5434.58	4992.37	4757.21	4673.44	4392.80	
Depletion 2017	0.76	0.79	0.76	0.71	0.74	0.72	
Total Yield	1764.80	1830.92	1754.69	1773.31	1705.62	1626.60	
Steepness	0.50	0.50	0.50	0.50	0.50	0.50	
Natural Mortality - Female	0.05	0.05	0.05	0.05	0.05	0.05	
Length at Amin - Female	20.78	20.78	20.78	20.75	20.77	20.80	
Length at Amax - Female	41.60	41.60	41.59	41.68	41.52	41.62	
Von Bert. k - Female	0.17	0.17	0.17	0.17	0.17	0.17	
SD young - Female	1.34	1.34	1.34	1.35	1.34	1.33	
SD old - Female	2.56	2.56	2.56	2.54	2.56	2.58	
Natural Mortality - Male	0.05	0.05	0.05	0.05	0.05	0.05	
Length at Amin - Male	20.78	20.78	20.78	20.75	20.77	20.80	
Length at Amax - Male	38.90	38.91	38.90	38.96	38.87	38.93	
Von Bert. k - Male	0.20	0.20	0.20	0.20	0.20	0.20	
SD young - Male	1.34	1.34	1.34	1.35	1.34	1.33	
SD old - Male	2.29	2.29	2.29	2.28	2.30	2.35	

Table 28: 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	140160	6644	139432	1.00	11773	0	0	0
1919	140191	6646	139462	1.00	11777	1	0	0
1920	140222	6647	139494	1.00	11781	0	0	0
1921	140255	6648	139526	1.00	11785	0	0	0
1922	140288	6650	139559	1.00	11790	0	0	0
1923	140322	6651	139593	1.00	11794	0	0	0
1924	140357	6653	139627	1.00	11798	0	0	0
1925	140392	6654	139662	1.00	11802	1	0	0
1926	140428	6656	139698	1.00	11806	1	0	0
1927	140464	6658	139734	1.00	11810	1	0	0
1928	140500	6659	139770	1.00	11813	1	0	0
1929	140538	6661	139807	1.00	11817	1	0	0
1930	140576	6663	139844	1.00	11820	1	0	0
1931	140614	6664	139883	1.00	11822	1	0	0
1932	140653	6666	139922	1.00	11825	1	0	0
1933	140693	6668	139961	1.00	11828	1	0	0
1934	140732	6670	140000	1.00	11832	1	0	0
1935	140770	6671	140038	1.00	11837	3	0	0
1936	140802	6673	140070	1.00	11847	8	0	0
1937	140842	6675	140109	1.00	11862	2	0	0
1938	140881	6677	140147	1.00	11886	3	0	0
1939	140918	6678	140183	1.01	11919	6	0	0
1940	140954	6680	140217	1.01	12146	10	0.005	0
1941	140983	6681	140242	1.01	12203	23	0.005	0
1942	141018	6681	140265	1.01	12269	30	0.01	0
1943	141056	6681	140300	1.01	12341	47	0.09	0
1944	140602	6656	139842	1.00	12405	562	0.145	0.004
1945	139822	6614	139058	1.00	12466	929	0.295	0.007
1946	137832	6512	137064	0.98	12511	2194	0.165	0.016
1947	137052	6466	136280	0.97	12620	1072	0.095	0.008
1948	136839	6448	136062	0.97	12813	569	0.115	0.004
1949	136558	6426	135773	0.97	13116	690	0.145	0.005
1950	136122	6396	135323	0.96	13560	906	0.21	0.007
1951	135270	6345	134450	0.95	14128	1401	0.24	0.01
1952	134310	6287	133460	0.95	14724	1619	0.325	0.012
1953	132711	6194	131826	0.93	15069	2398	0.26	0.018
1954	131916	6135	131000	0.92	14941	1775	0.35	0.014
1955	130512	6042	129584	0.91	14203	2564	0.295	0.02

Table 28: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exp. rate
1956	129852	5981	128942	0.90	12989	2002	0.41	0.016
1957	128117	5871	127262	0.88	11722	3198	0.375	0.025
1958	126915	5791	126135	0.87	10675	2739	0.315	0.022
1959	126275	5750	125569	0.87	10004	2154	0.21	0.017
1960	126415	5761	125766	0.87	9845	1264	0.34	0.01
1961	125275	5728	124657	0.86	10252	2367	0.43	0.019
1962	123003	5651	122386	0.85	10774	3327	0.515	0.027
1963	119505	5519	118864	0.83	10117	4420	0.605	0.037
1964	114480	5309	113829	0.80	8593	5877	0.635	0.052
1965	109077	5071	108480	0.76	7553	6231	0.715	0.057
1966	102042	4747	101530	0.71	7030	7828	0.91	0.077
1967	83867	3877	83412	0.58	6588	18969	0.9	0.227
1968	70229	3212	69803	0.48	6869	14651	0.87	0.21
1969	61697	2793	61280	0.42	9376	9712	0.52	0.158
1970	60813	2747	60334	0.41	14602	2183	0.535	0.036
1971	59909	2700	59263	0.41	7299	2300	0.485	0.039
1972	59604	2671	58826	0.40	5143	1905	0.485	0.032
1973	59479	2639	59064	0.40	5037	1888	0.585	0.032
1974	58489	2568	58173	0.39	5064	2643	0.545	0.045
1975	57748	2516	57433	0.38	6344	2275	0.37	0.04
1976	57966	2527	57636	0.38	5048	1183	0.43	0.021
1977	57717	2541	57341	0.38	6659	1507	0.38	0.026
1978	57590	2572	57256	0.39	4884	1263	0.505	0.022
1979	56599	2555	56214	0.38	5599	1998	0.425	0.036
1980	56021	2544	55707	0.38	5514	1507	0.465	0.027
1981	55123	2513	54778	0.38	5878	1723	0.41	0.031
1982	54527	2491	54173	0.37	8884	1380	0.345	0.025
1983	54257	2482	53841	0.37	10035	1057	0.46	0.02
1984	53504	2444	52943	0.37	7130	1624	0.47	0.031
1985	52905	2402	52332	0.36	7183	1658	0.435	0.032
1986	52705	2368	52266	0.36	5839	1412	0.43	0.027
1987	52596	2335	52171	0.35	7017	1375	0.375	0.026
1988	52807	2320	52421	0.35	9406	1107	0.435	0.021
1989	52778	2302	52302	0.35	10569	1379	0.45	0.026
1990	52787	2295	52177	0.35	14046	1469	0.38	0.028
1991	53355	2308	52663	0.35	6385	1123	0.45	0.021
1992	53782	2305	53046	0.35	3456	1478	0.465	0.028
1993	54258	2292	53911	0.34	3469	1567	0.435	0.029

Table 28: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exp. rate
1994	54699	2290	54469	0.34	9862	1418	0.385	0.026
1995	55205	2308	54888	0.35	9012	1180	0.325	0.022
1996	55849	2354	55266	0.35	3880	952	0.3	0.017
1997	56573	2418	56100	0.36	3814	879	0.25	0.016
1998	57307	2487	57070	0.37	2935	716	0.245	0.013
1999	57798	2535	57535	0.38	19539	721	0.2	0.013
2000	58403	2574	57923	0.39	30595	562	0.065	0.01
2001	59724	2630	58388	0.40	8937	160	0.11	0.003
2002	61725	2685	60195	0.40	5185	293	0.07	0.005
2003	64401	2736	63916	0.41	2597	179	0.06	0.003
2004	66917	2772	66628	0.42	6944	155	0.055	0.002
2005	69212	2810	68989	0.42	3345	147	0.03	0.002
2006	71239	2896	70867	0.44	3865	76	0.03	0.001
2007	72918	3046	72703	0.46	3723	85	0.05	0.001
2008	74370	3211	73810	0.48	133246	157	0.045	0.002
2009	76575	3346	74550	0.50	4814	133	0.055	0.002
2010	80990	3438	74832	0.52	8279	190	0.055	0.003
2011	88763	3500	88389	0.53	16107	181	0.02	0.002
2012	95774	3545	95169	0.53	2113	61	0.015	0.001
2013	102857	3584	102021	0.54	29279	58	0.015	0.001
2014	109633	3727	109119	0.56	5078	57	0.015	0.001
2015	115762	4118	114333	0.62	10096	55	0.015	0
2016	121528	4620	121131	0.70	10520	59	0.015	0
2017	126167	5047	125534	0.76	10816	65	0.055	0.001
2018	129828	5369	129171	0.81	11017	-	-	-
2019	132735	5625	132062	0.85	11166	-	-	-
2020	130783	5657	130099	0.85	11184	-	-	-
2021	128376	5654	127685	0.85	11182	-	-	-
2022	125691	5606	124999	0.84	11155	-	-	-
2023	122860	5528	122169	0.83	11110	-	-	-
2024	119983	5431	119294	0.82	11054	-	-	-
2025	117128	5324	116442	0.80	10990	-	-	-
2026	114343	5211	113661	0.78	10921	-	-	-
2027	111655	5096	110977	0.77	10848	-	-	-
2028	109081	4981	108407	0.75	10772	-	-	-

tab:Timeseries_mod1

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

Year	OFL (mt)	ACL (mt)	Age 3+ biomass (mt)	Spawning Output	tab:Forecast_mod1
2017	4306	281	125534	5047	0.76
2018	4559	281	129171	5369	0.81
2019	4719	4515	132062	5625	0.85
2020	4654	4453	130099	5657	0.85
2021	4552	4356	127685	5654	0.85
2022	4431	4240	124999	5606	0.85
2023	4302	4116	122169	5528	0.83
2024	4172	3992	119294	5431	0.82
2025	4048	3873	116442	5324	0.80
2026	3932	3762	113661	5211	0.79
2027	3826	3660	110977	5096	0.77
2028	3727	3566	108407	4981	0.75

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figures

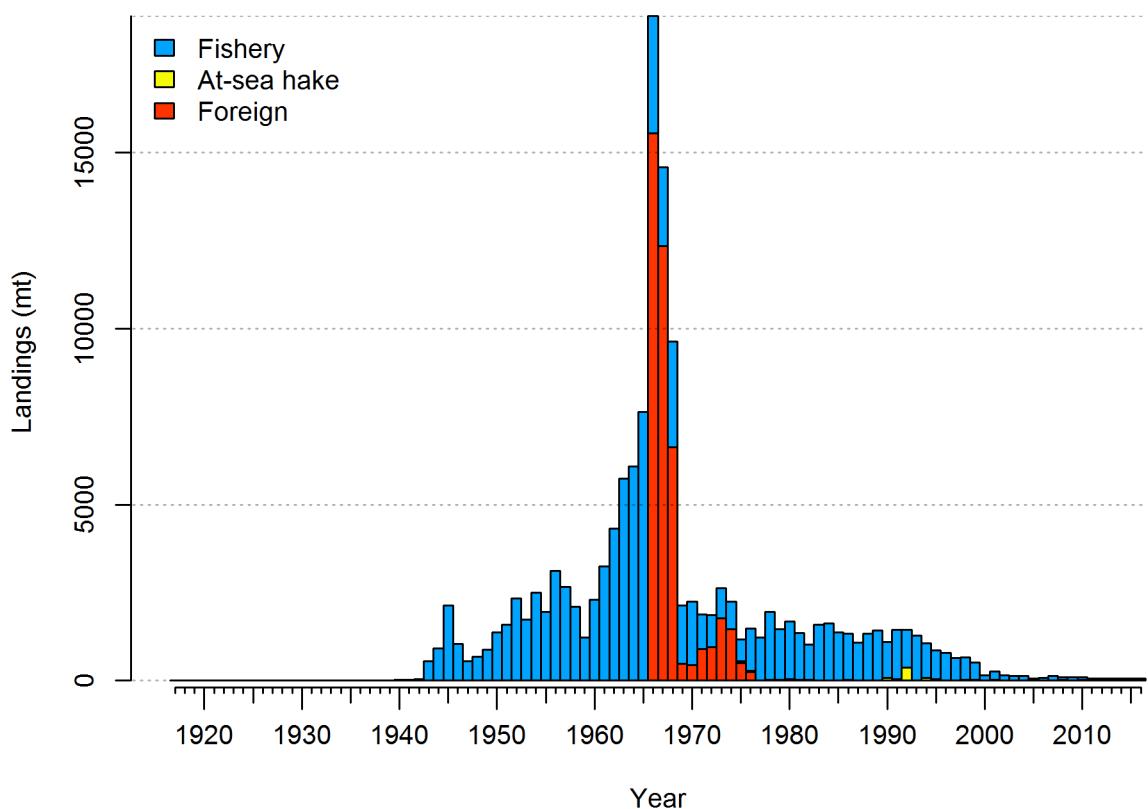


Figure 1: Total catches Pacific ocean perch through 2016. fig:Catch

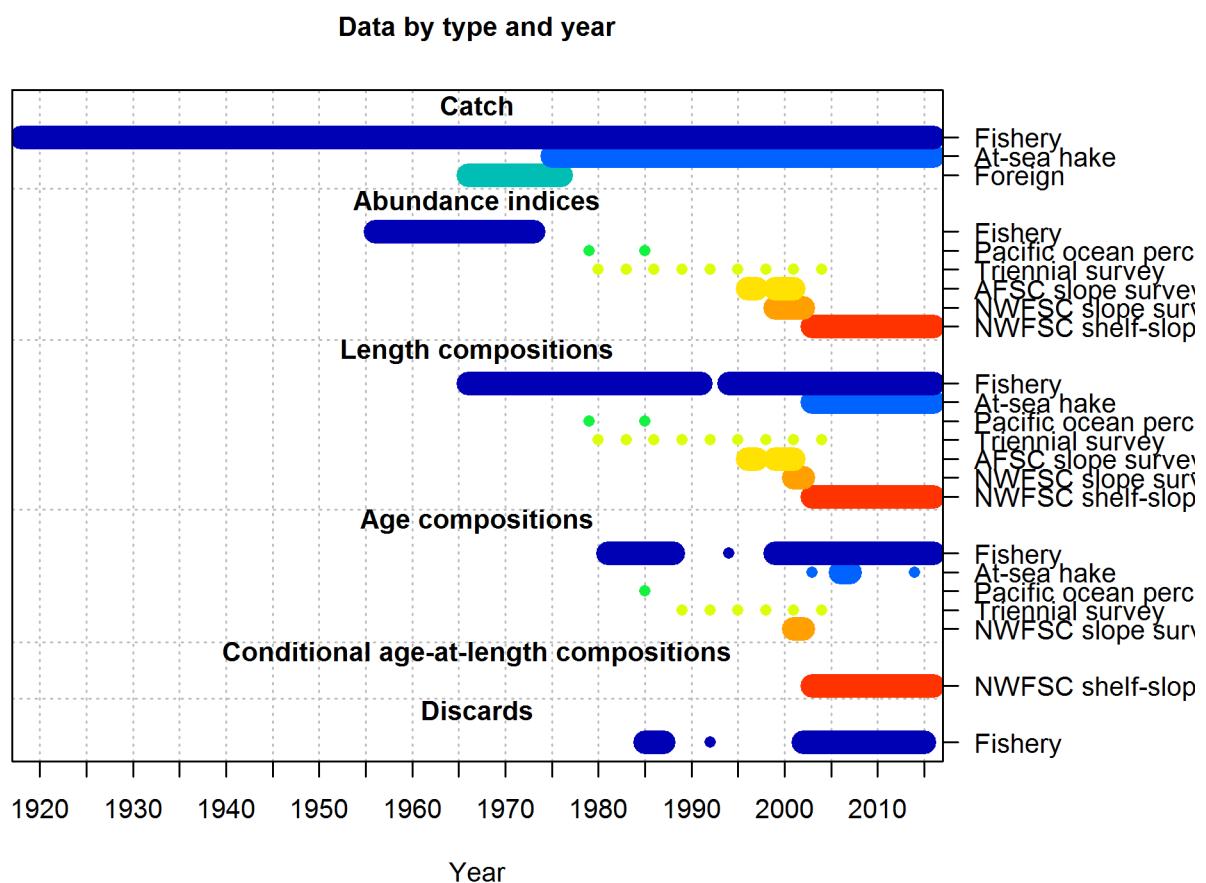


Figure 2: Summary of data sources used in the Base model. `fig:data_plot`

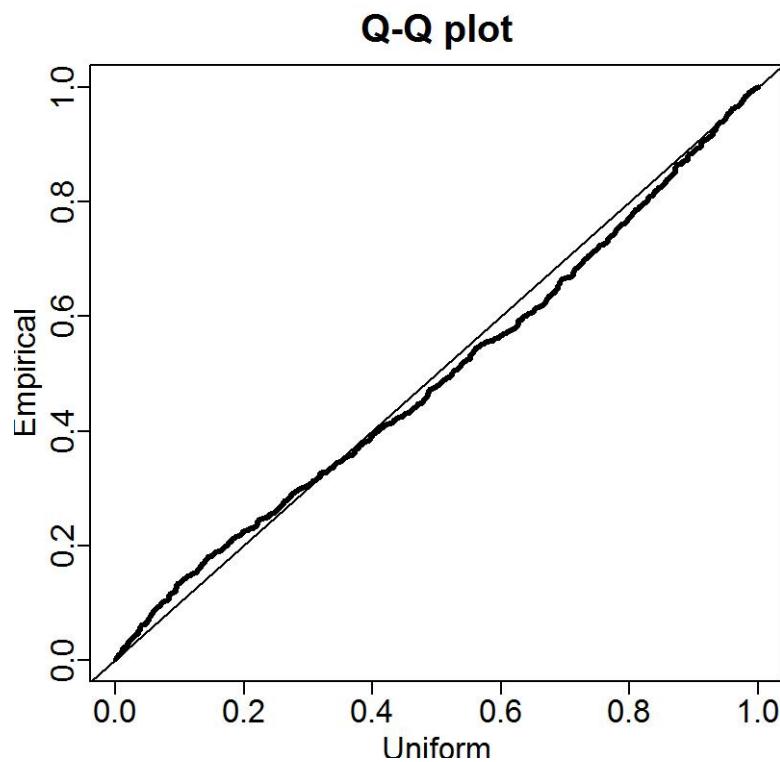


Figure 3: Q-Q plots for the VAST lognormal distribution for the NWFSC shelf-slope survey. fig:nw_qq

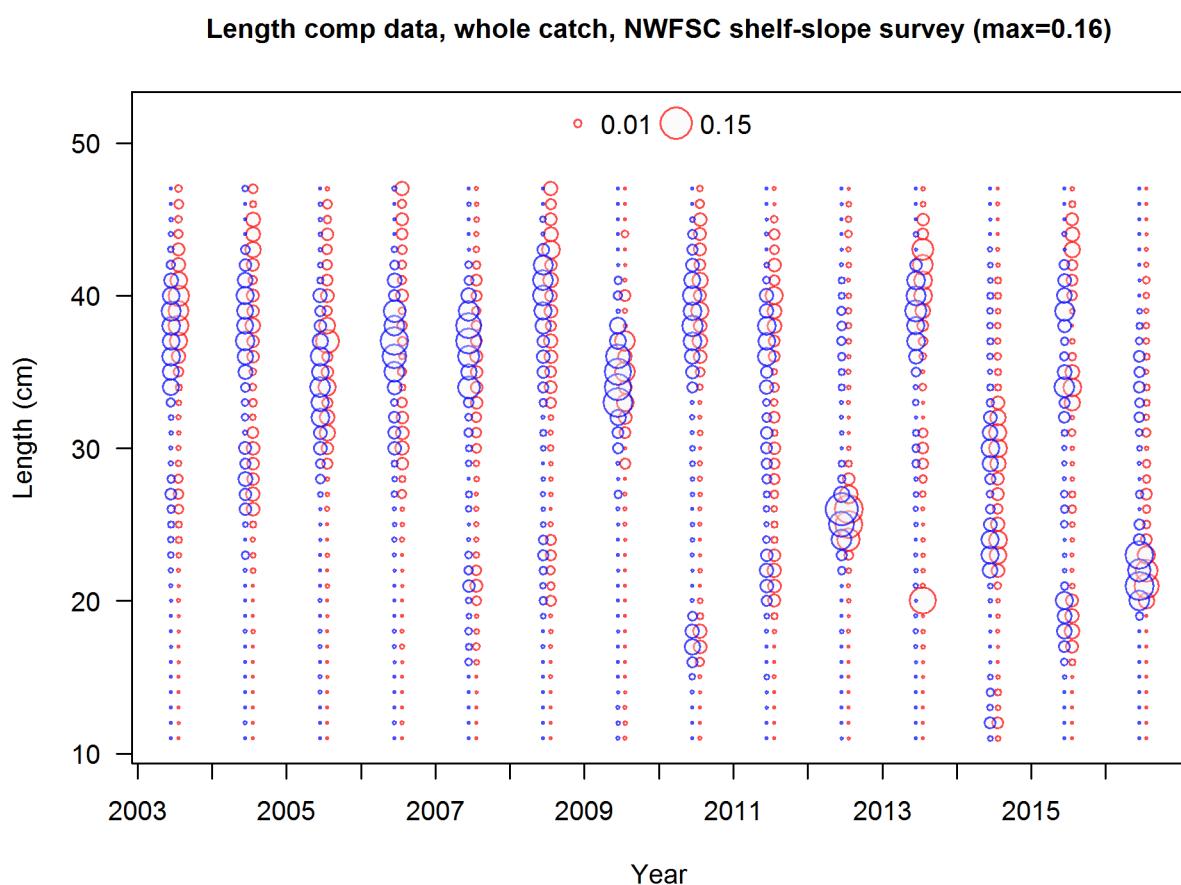


Figure 4: NWFSC shelf-slope survey length frequency distributions for Pacific ocean perch. fig:nw_Length

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

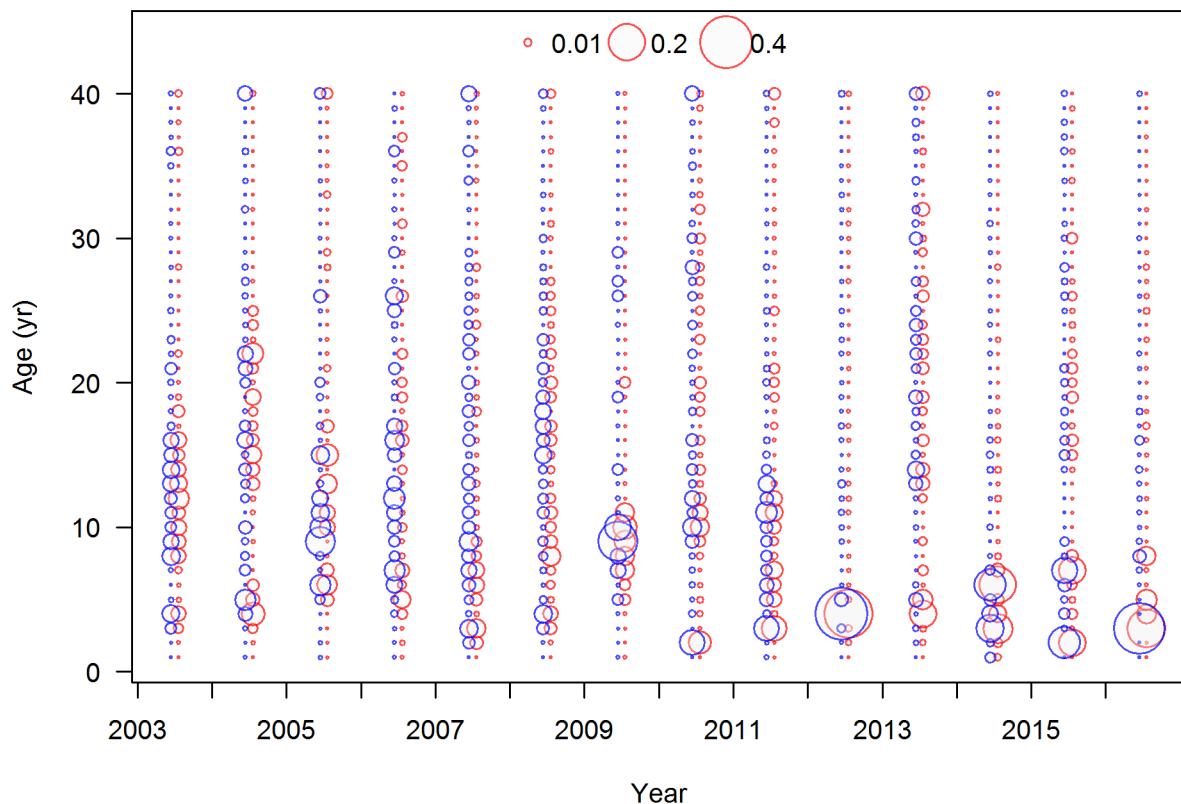


Figure 5: NWFSC shelf-slope survey age frequency distributions for Pacific ocean perch. fig:nw_Age

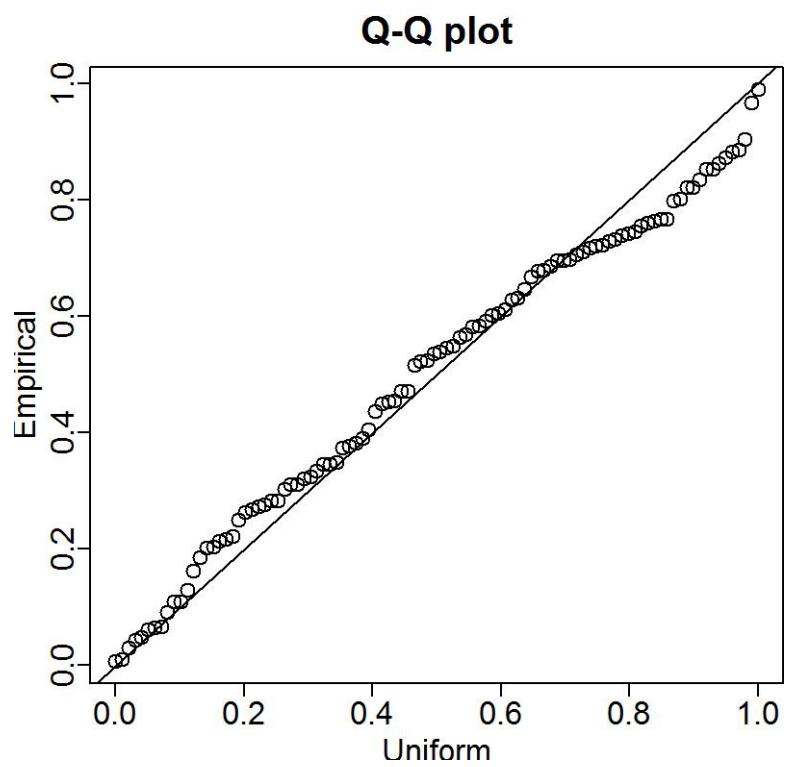


Figure 6: Q-Q plots for the VAST lognormal distribution for the NWFSC slope survey. `fig:nw_slope_q`

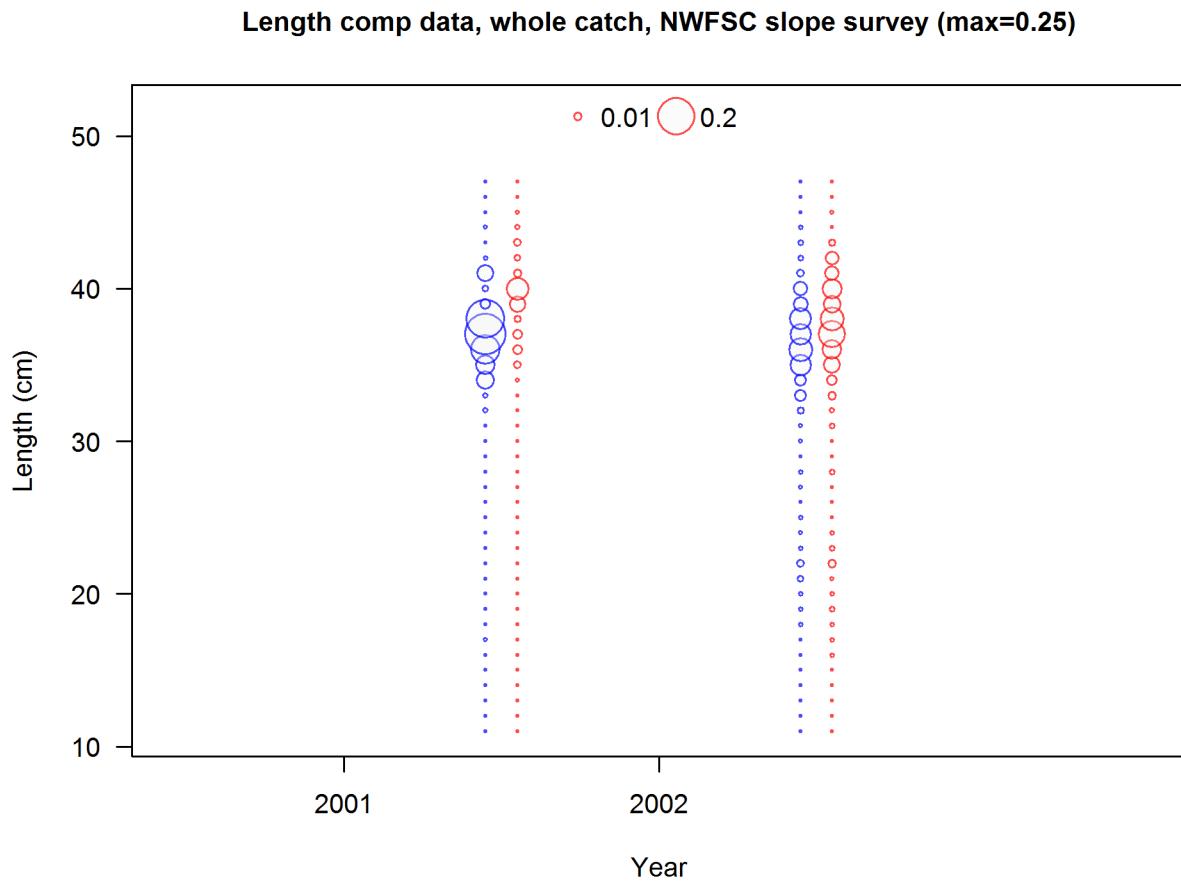


Figure 7: NWFSC slope survey length frequency distributions for Pacific ocean perch. fig:nw_slope_L

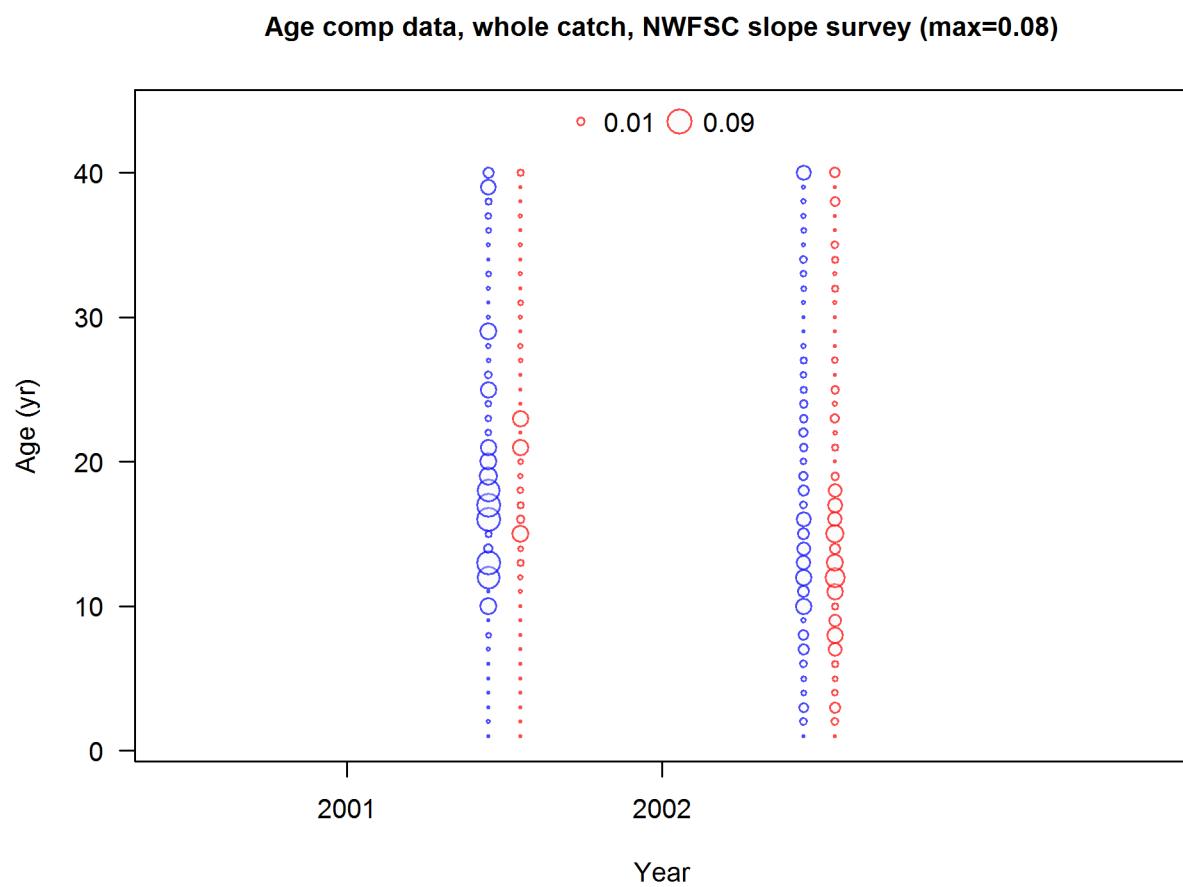


Figure 8: NWFSC slope survey age frequency distributions for Pacific ocean perch. `fig:nw_slope_Age`

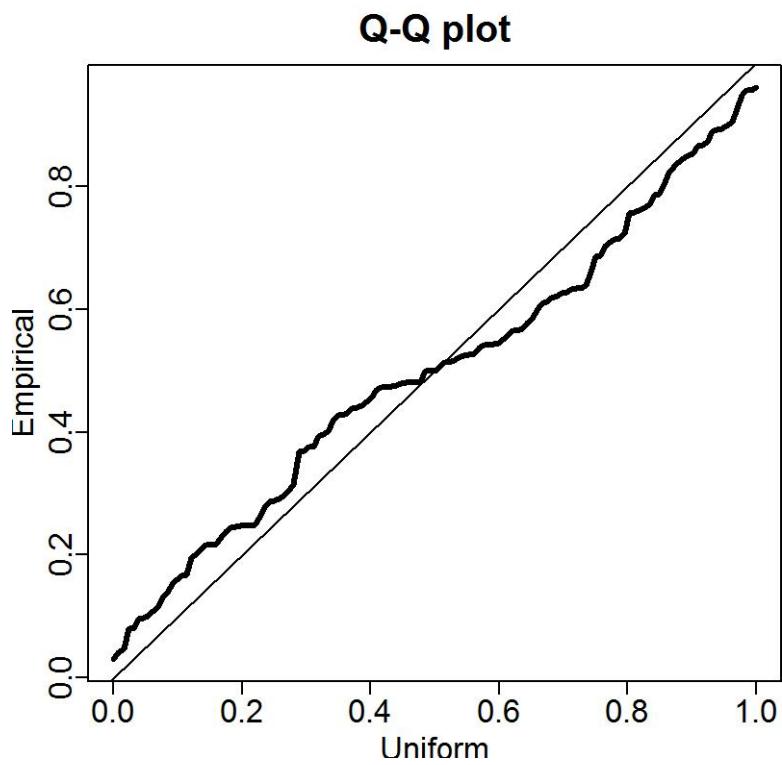


Figure 9: Q-Q plots for the VAST lognormal distribution for the AFSC slope survey. fig:afsc_qq

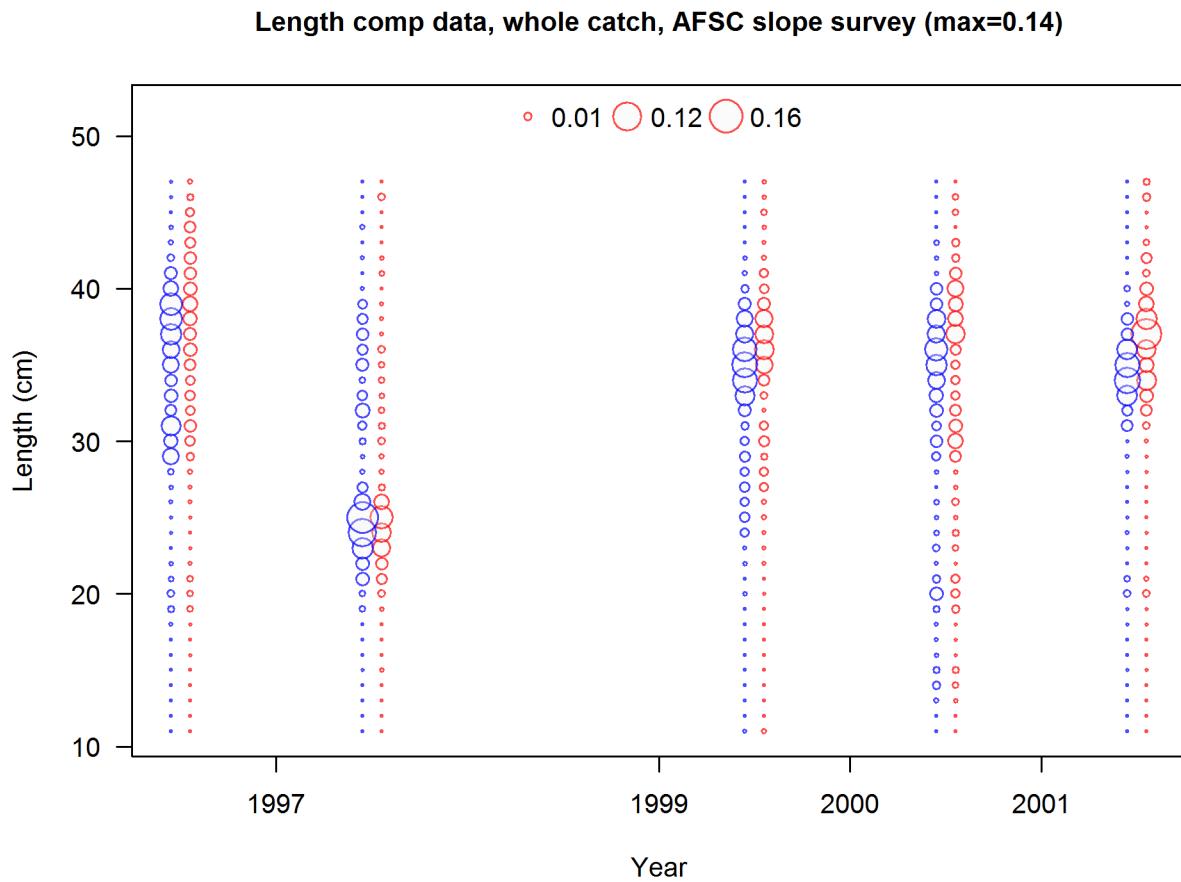


Figure 10: AFSC slope survey length frequency distributions for Pacific ocean perch. fig:afsc_Length

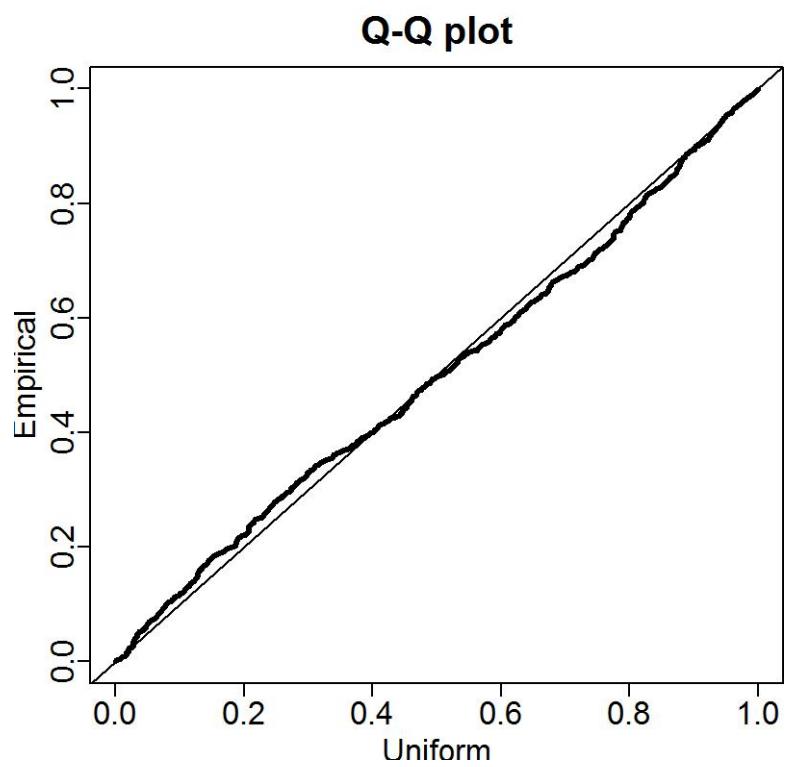


Figure 11: Q-Q plots for the VAST lognormal distribution for the Triennial survey. fig:tri_qq

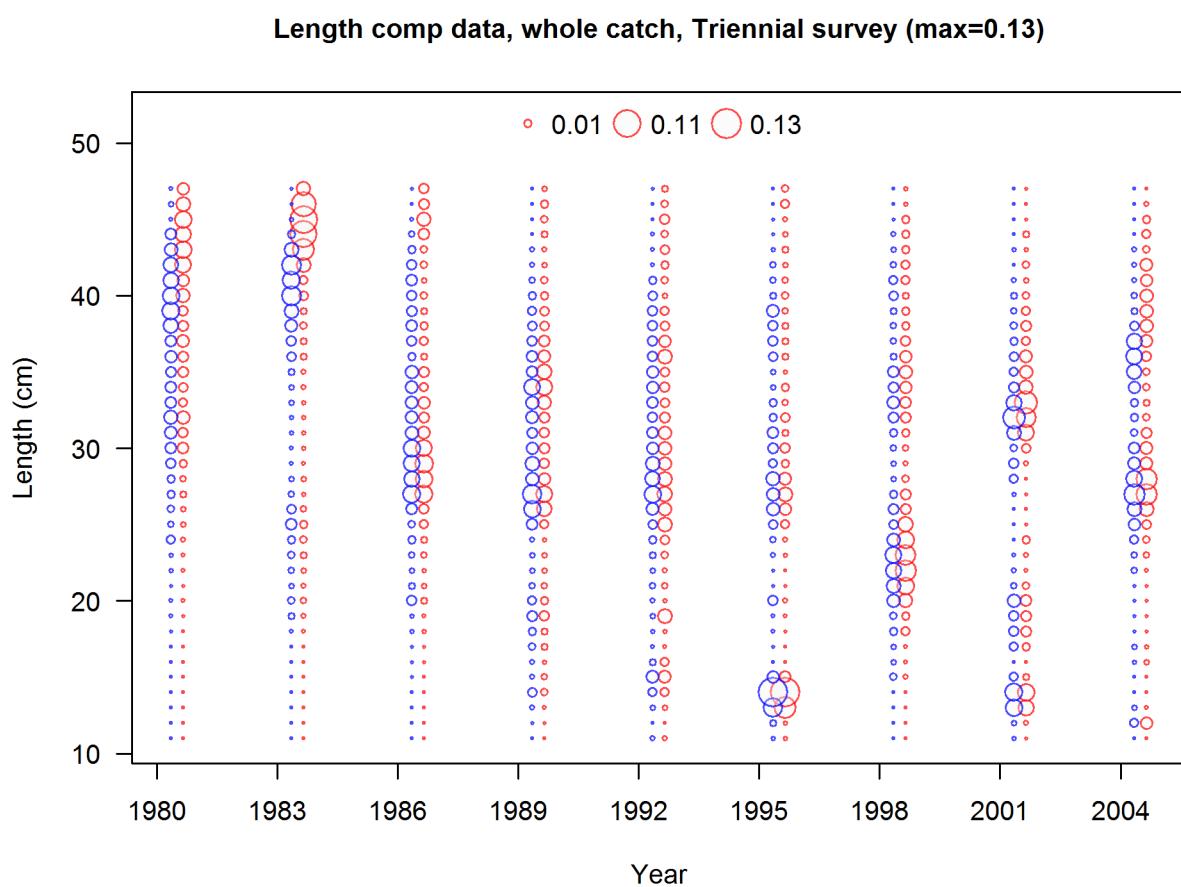


Figure 12: Triennial survey length frequency distributions for Pacific ocean perch. `fig:Tri_Length`

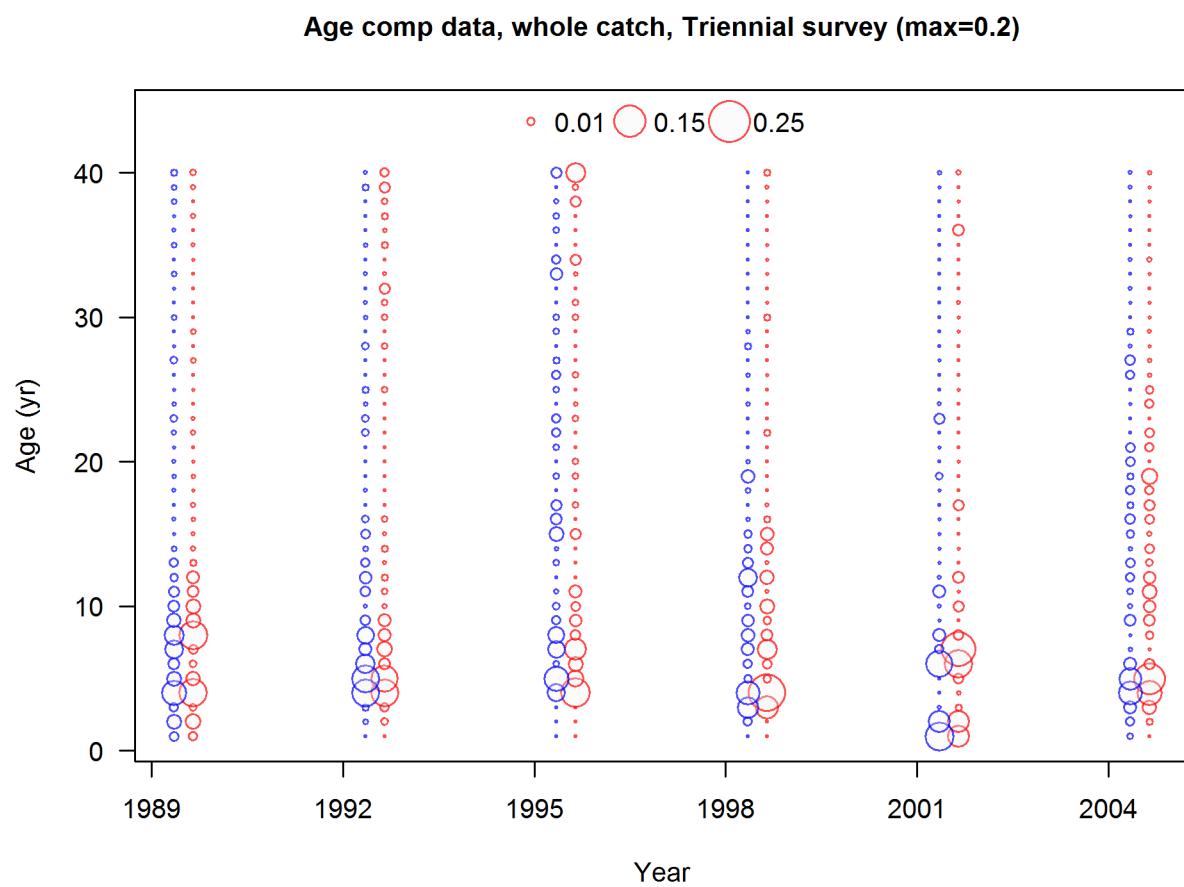


Figure 13: Triennial survey age frequency distributions for Pacific ocean perch. `fig:Tri_Age`

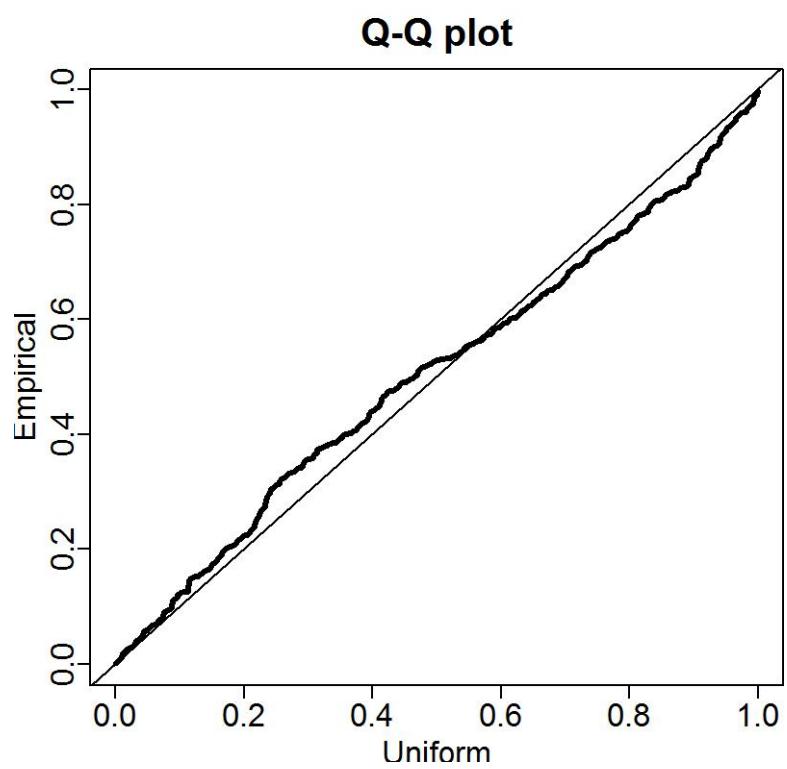


Figure 14: Q-Q plots for the VAST lognormal distribution for the Pacific ocean perch survey.
fig:pop_qq

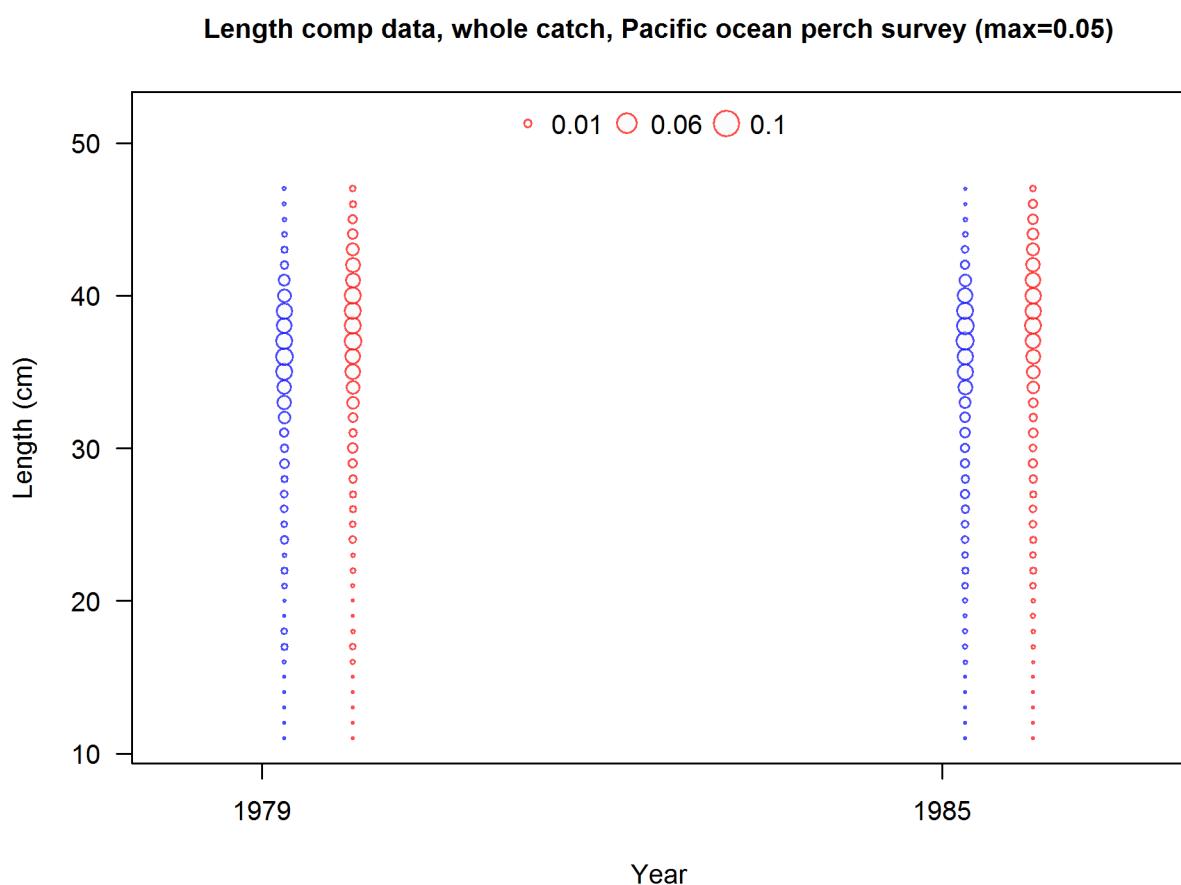


Figure 15: Pacific ocean perch survey length frequency distributions for Pacific ocean perch. fig:POP_Length

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

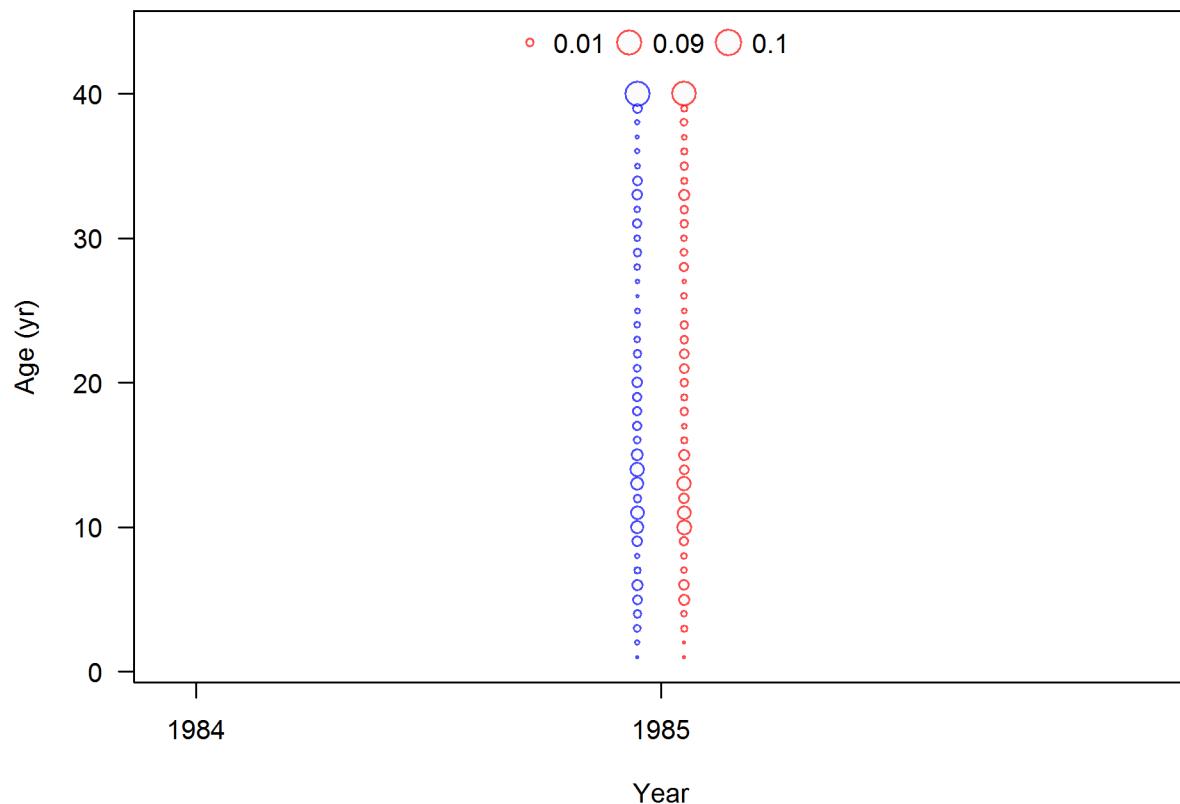


Figure 16: Pacific ocean perch survey age frequency distributions for Pacific ocean perch. fig:POP_Age

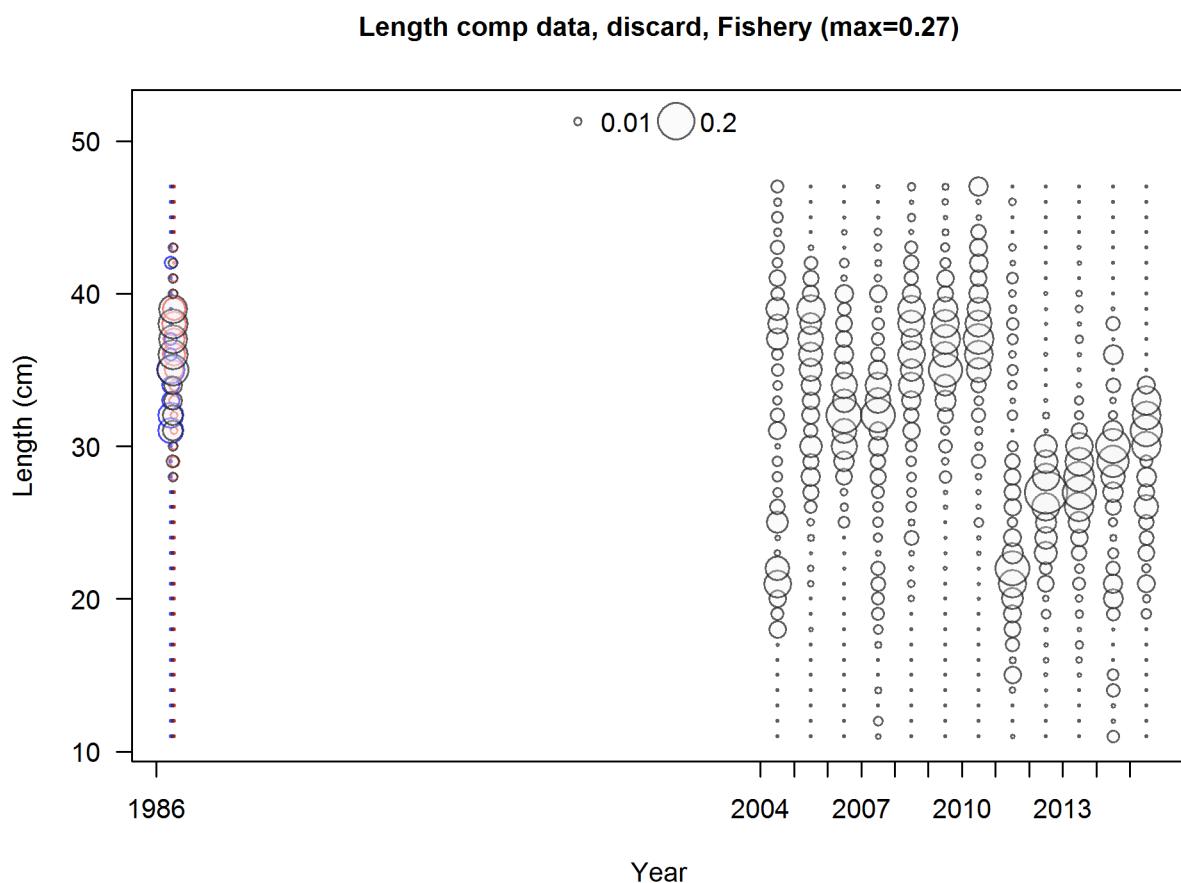


Figure 17: Discard length frequency distributions from WCGOP for Pacific ocean perch. fig:WCGOP_disc

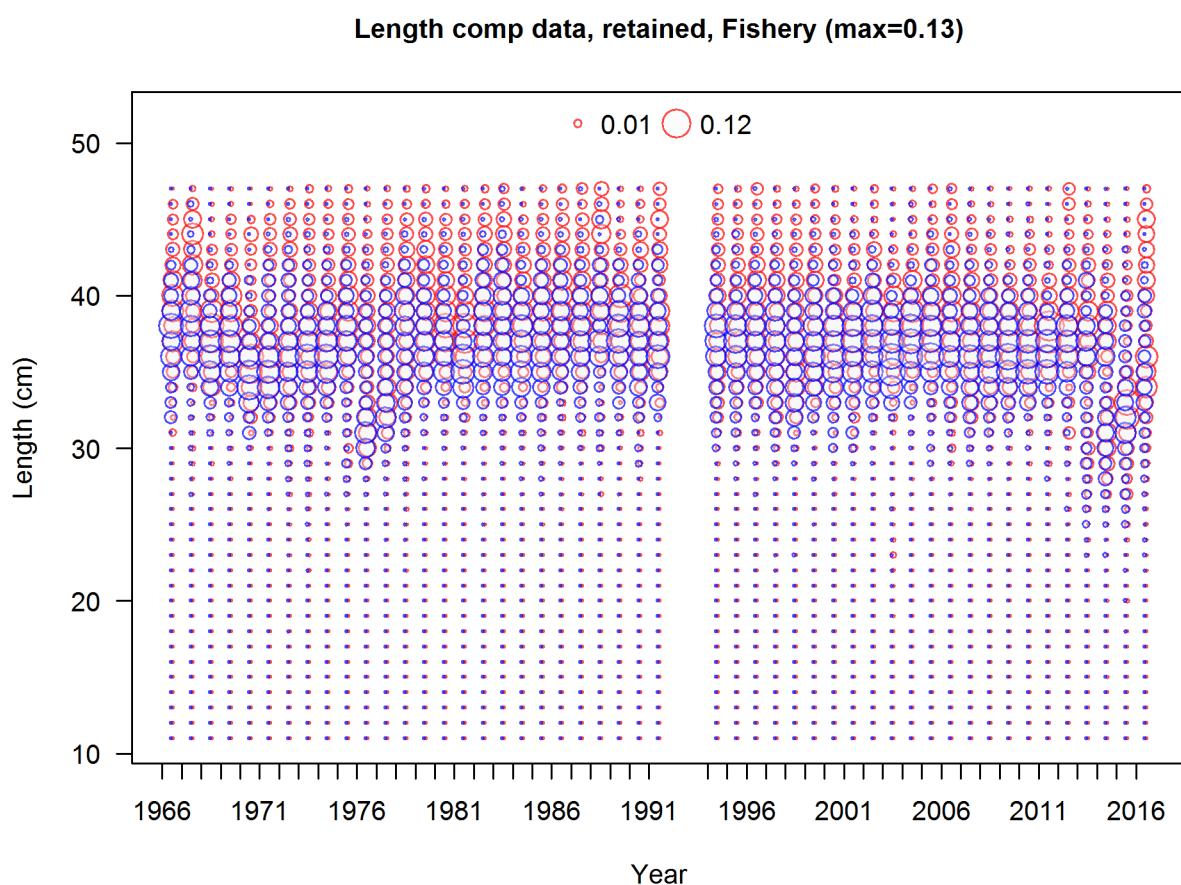


Figure 18: Commercial fishery length frequency distributions for Pacific ocean perch. `fig:Comm_Length`

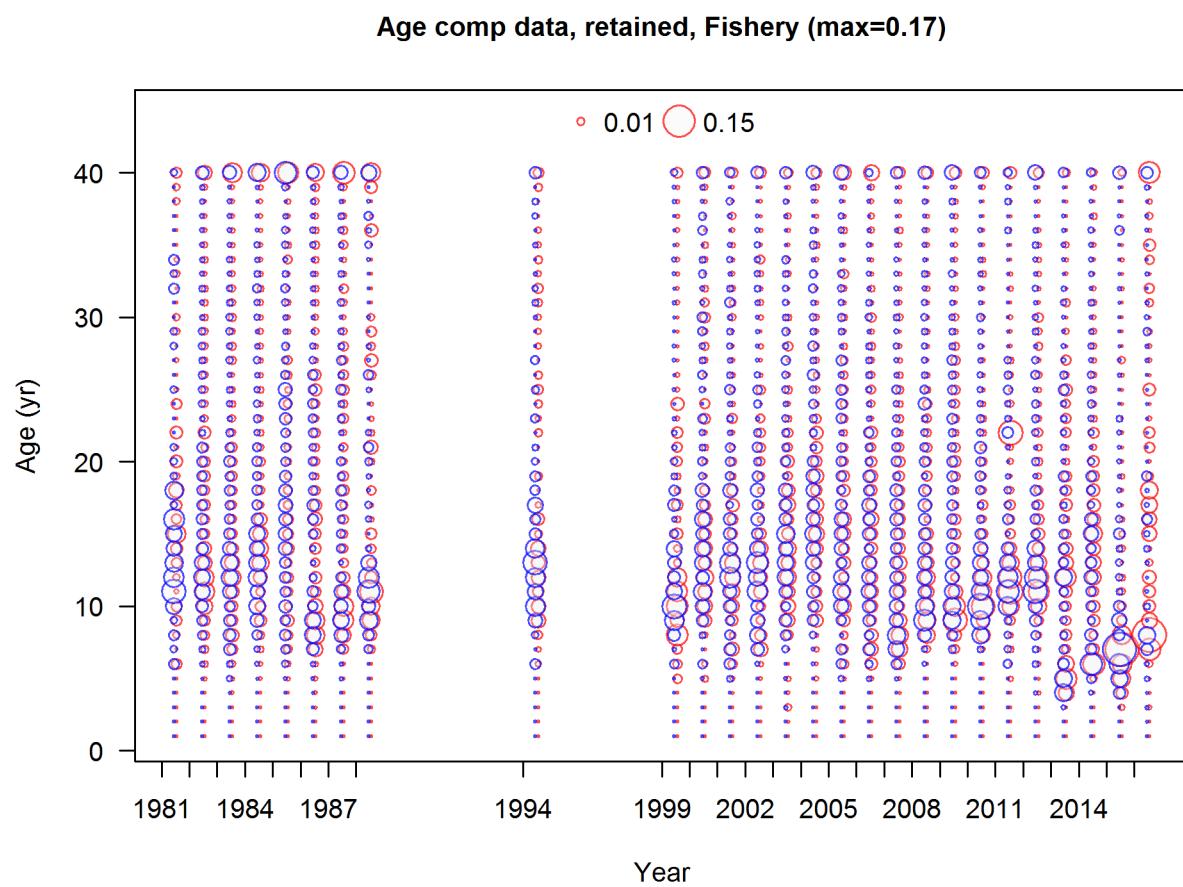


Figure 19: Commercial fishery age frequency distributions for Pacific ocean perch. fig:Comm_Age

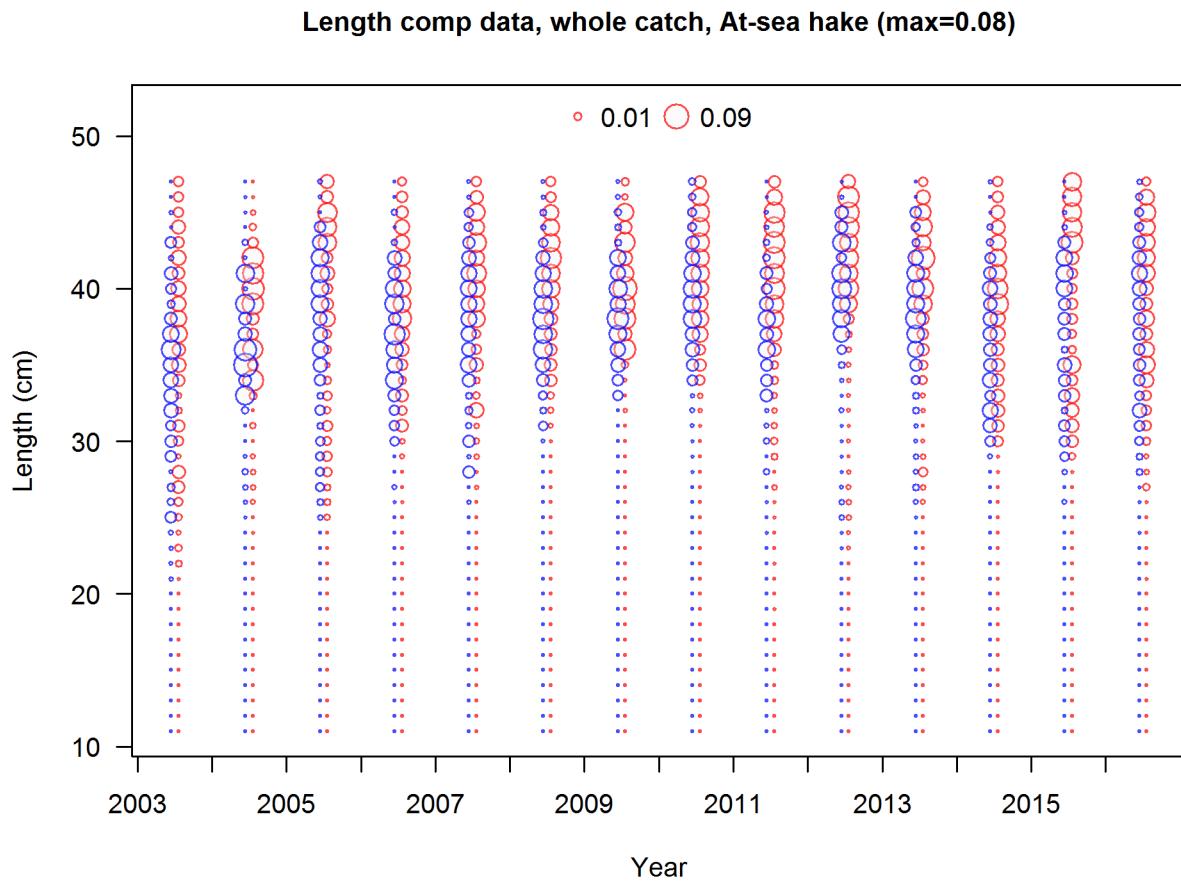


Figure 20: At-Sea hake fishery length frequency distributions for Pacific ocean perch. fig:ASHOP_Length

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

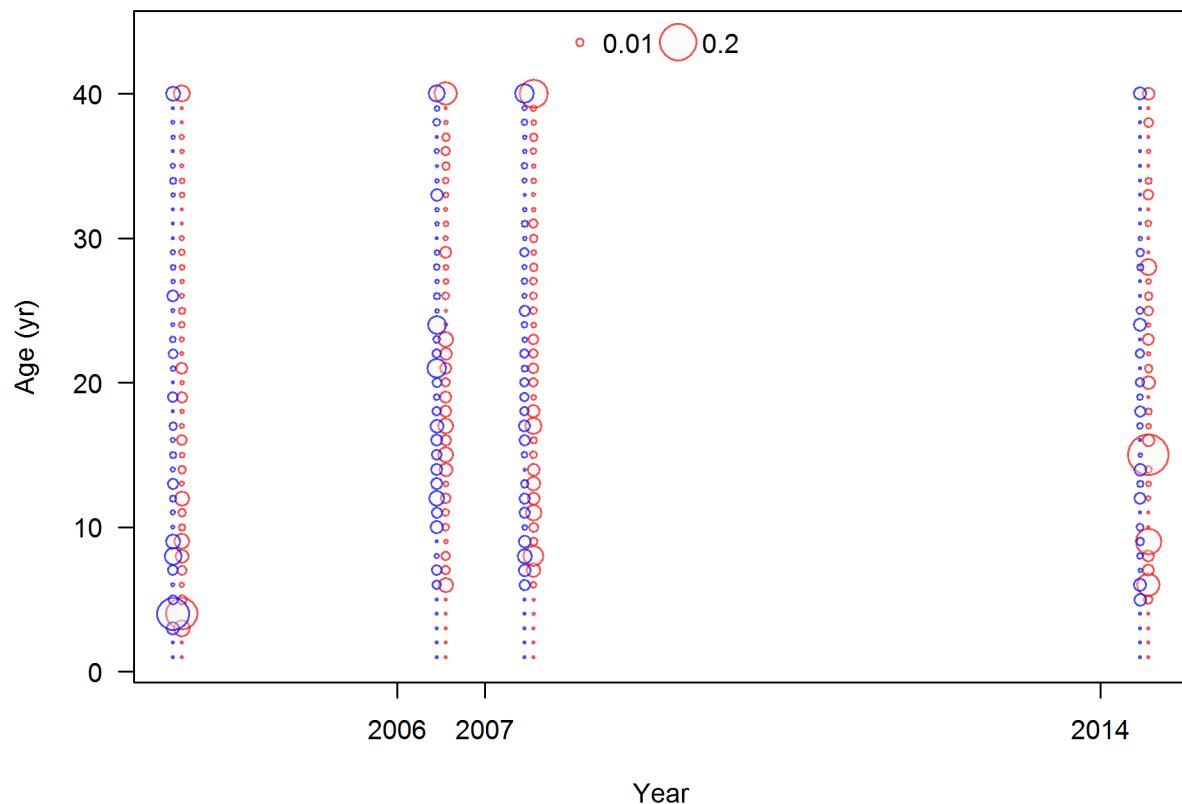


Figure 21: At-Sea hake fishery age frequency distributions for Pacific ocean perch. fig:ASHOP_Age

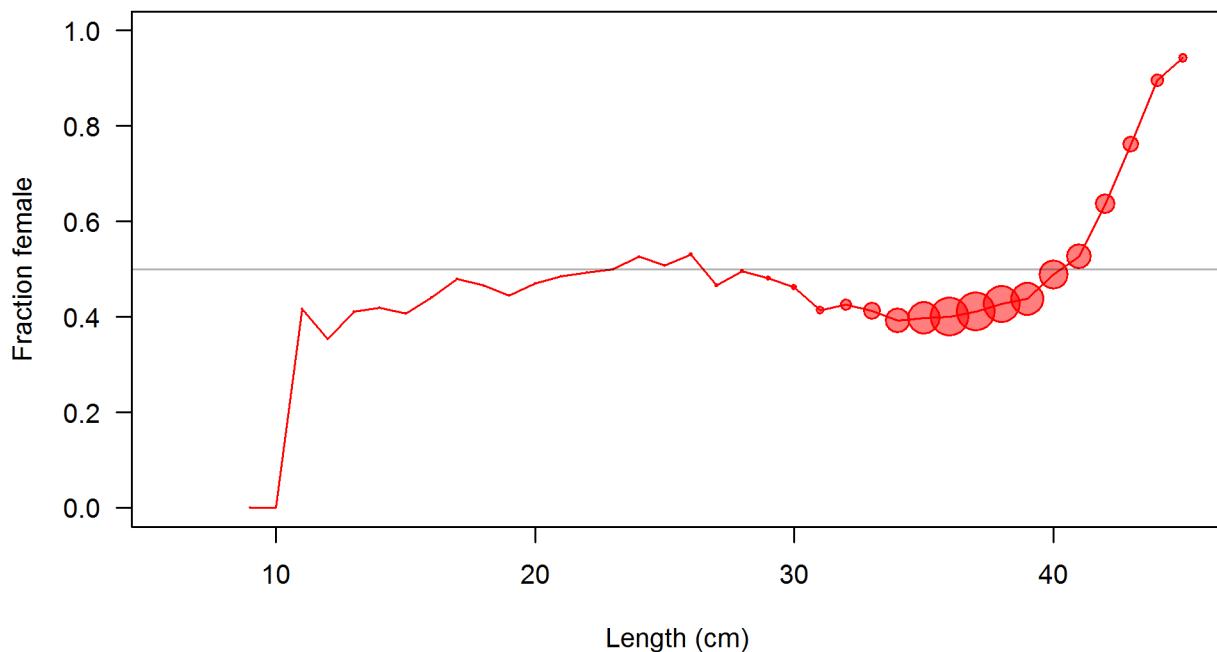


Figure 22: The estimated sex ratio of Pacific ocean perch at length from all biological data sources. | [fig:sexratio](#)

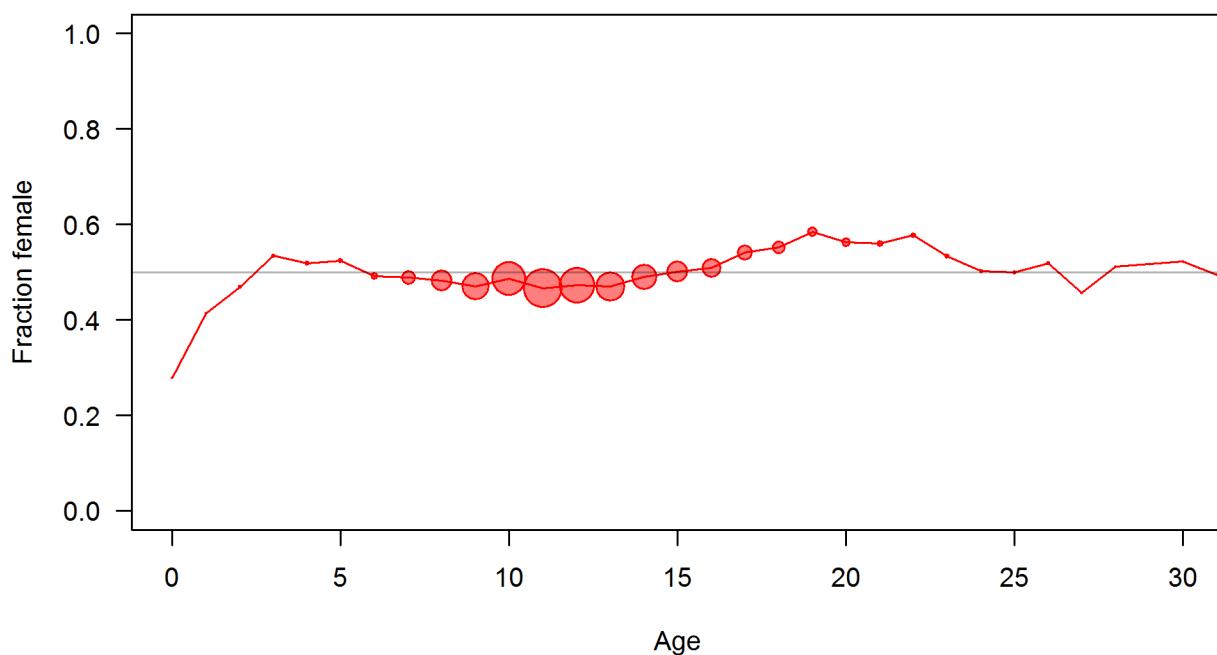


Figure 23: The estimated sex ratio of Pacific ocean perch at age from all biological data sources. | [fig:sexratio_Age](#)

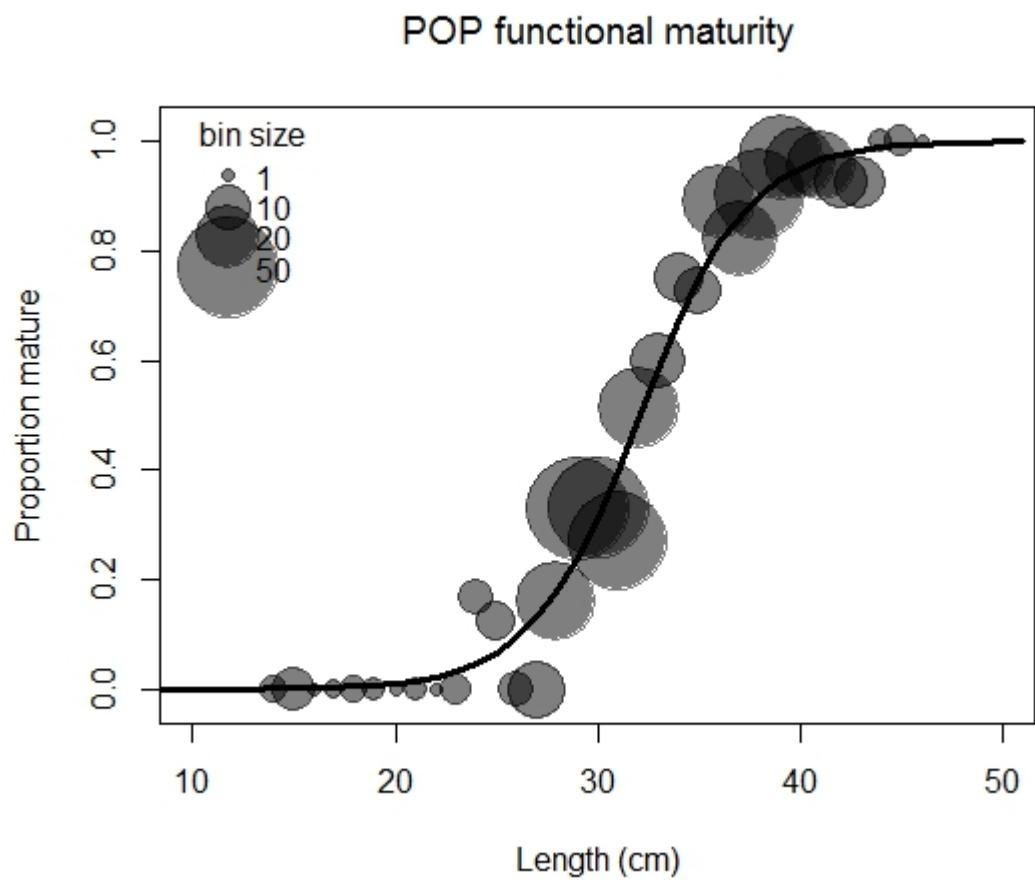


Figure 24: The estimated functional maturity of Pacific ocean perch at length. fig:mat

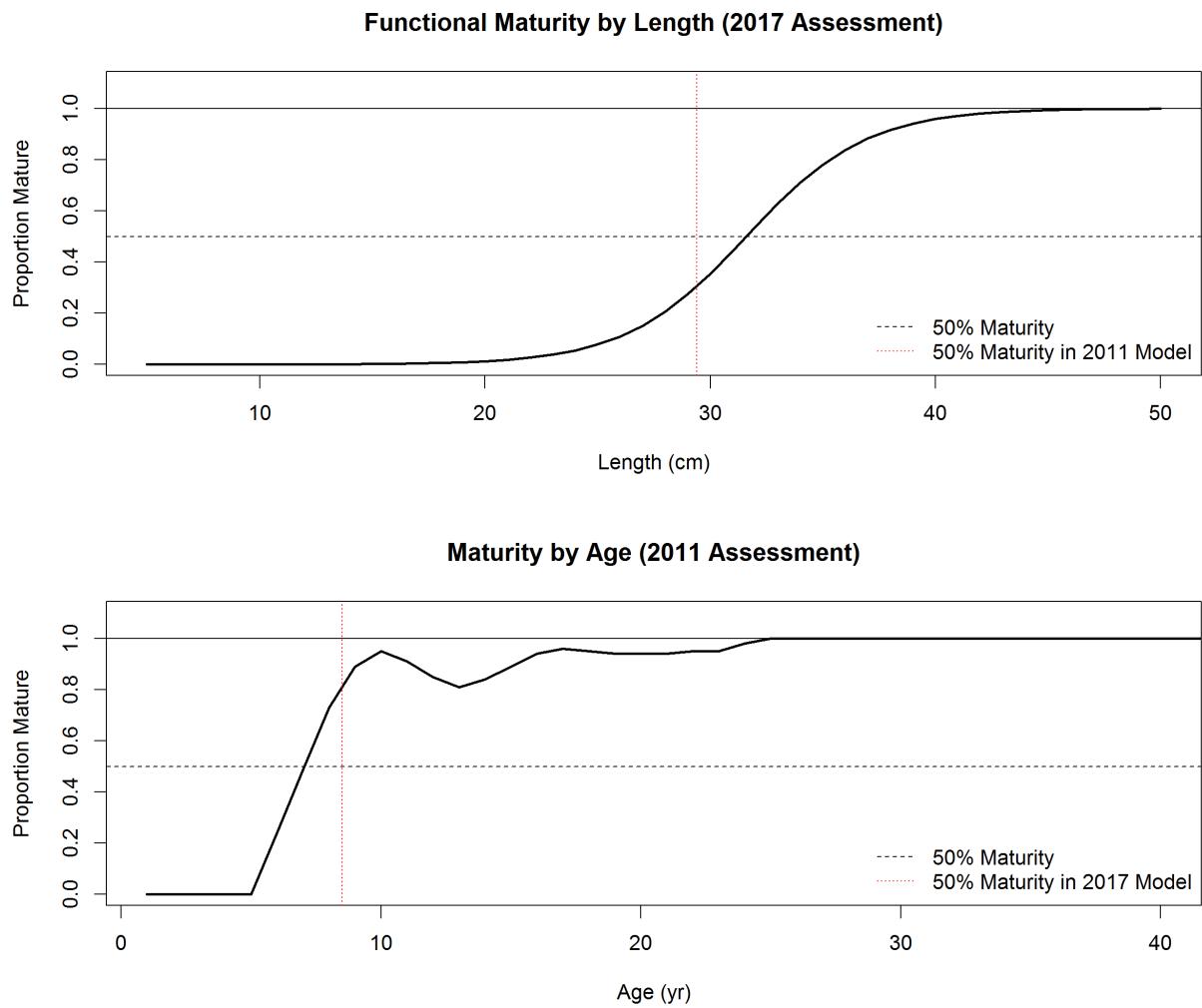


Figure 25: Comparison between estimated maturity-at-length used in this assessment and maturity-at-age applied in the 2011 assessment of Pacific ocean perch. `fig:mat_compare`

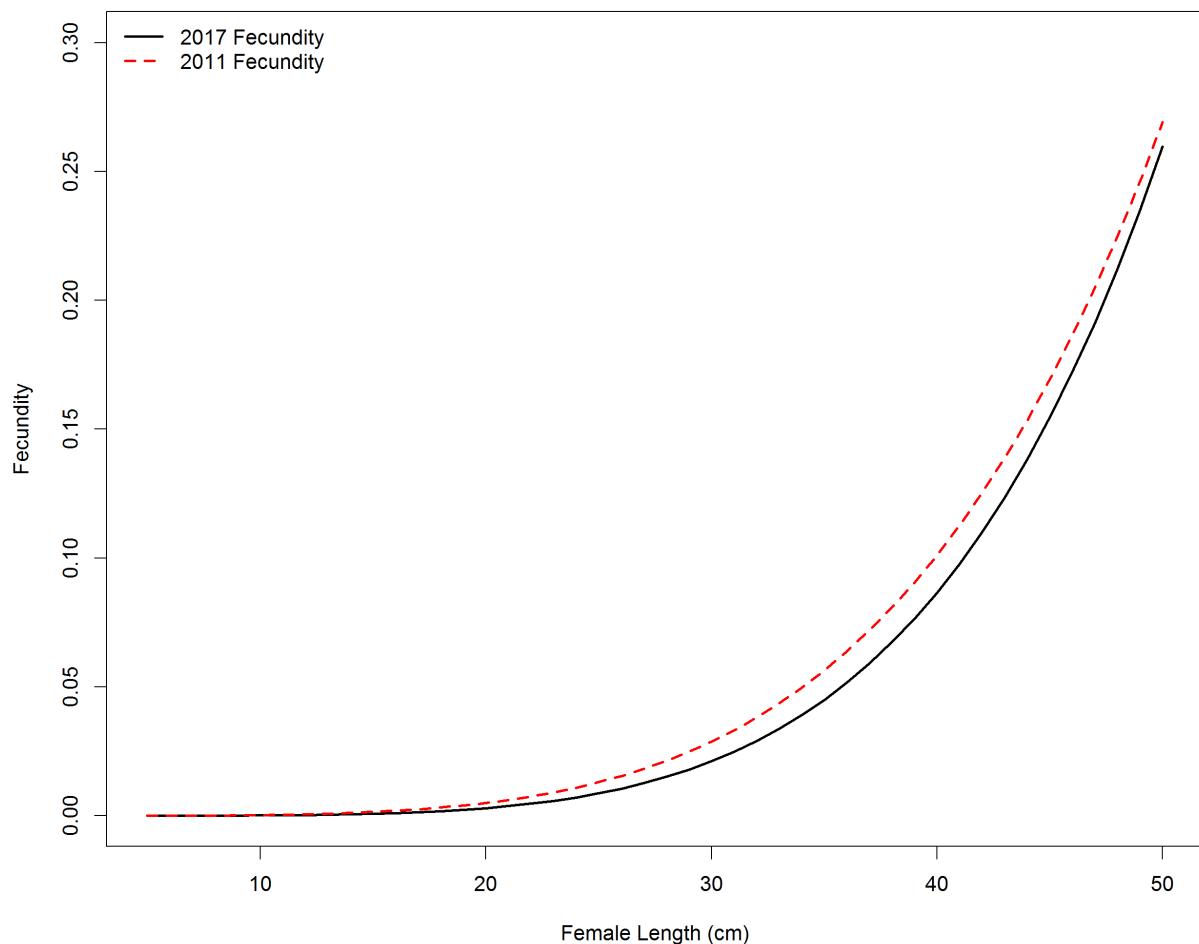


Figure 26: Fecundity at length of Pacific ocean perch in the Base model. [fig:fecundity](#)

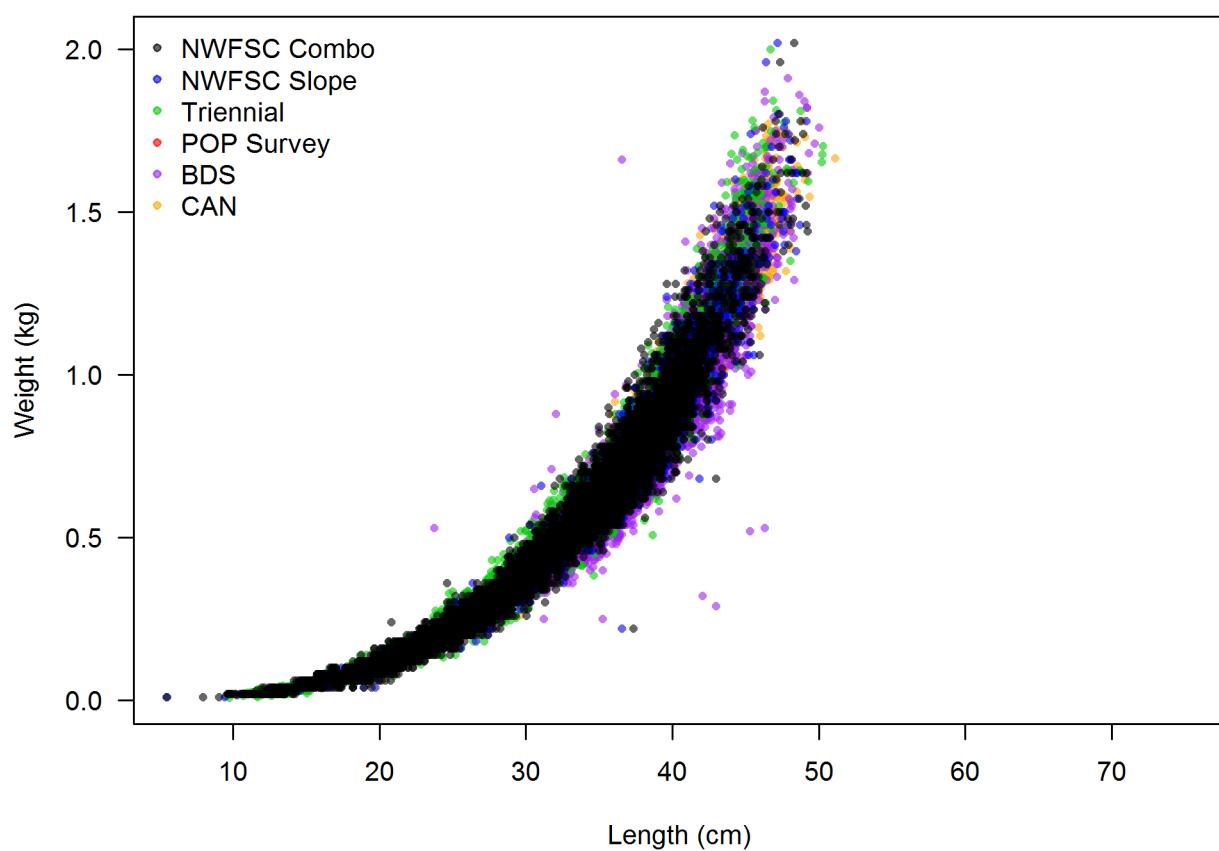


Figure 27: Weight-at-length for Pacific ocean perch from all data sources. `fig:Wt_len`

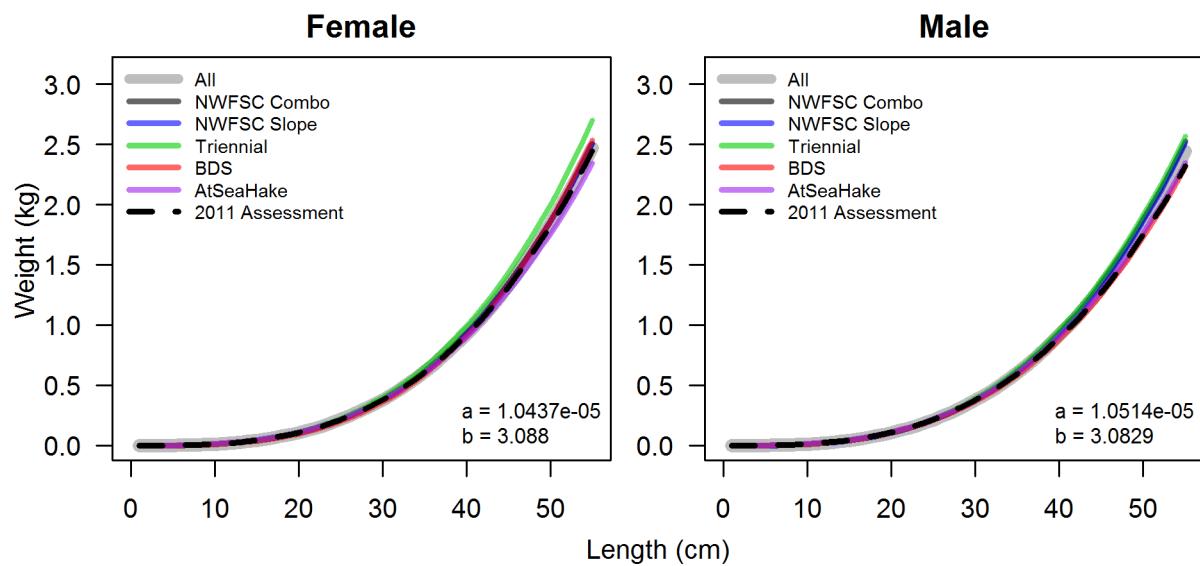


Figure 28: Estimated weight-at-length for Pacific ocean perch from all data sources. `fig:Wt_len_pred`

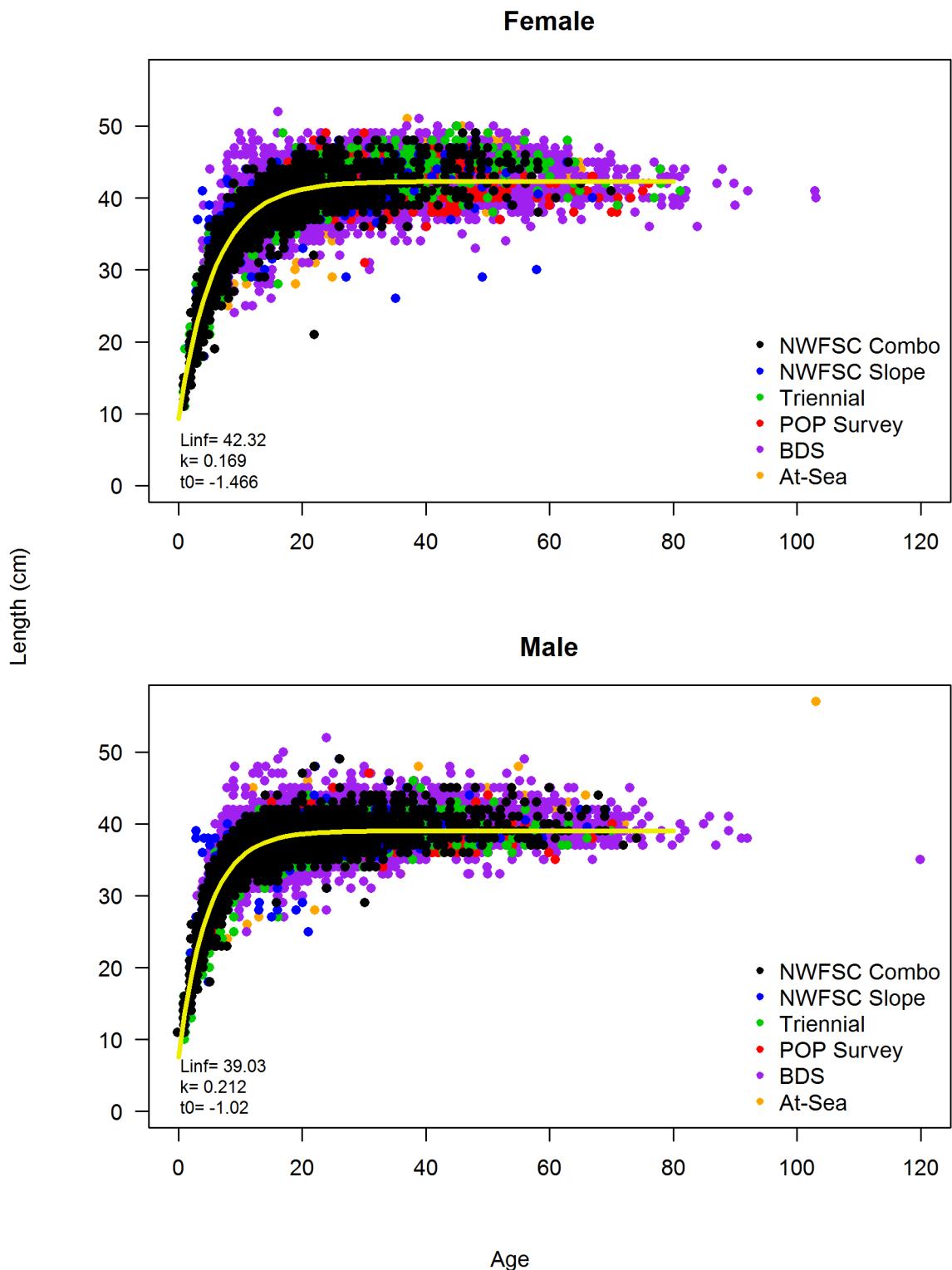


Figure 29: Estimated length-at-age for Pacific ocean perch from all data sources. fig:Len_Age

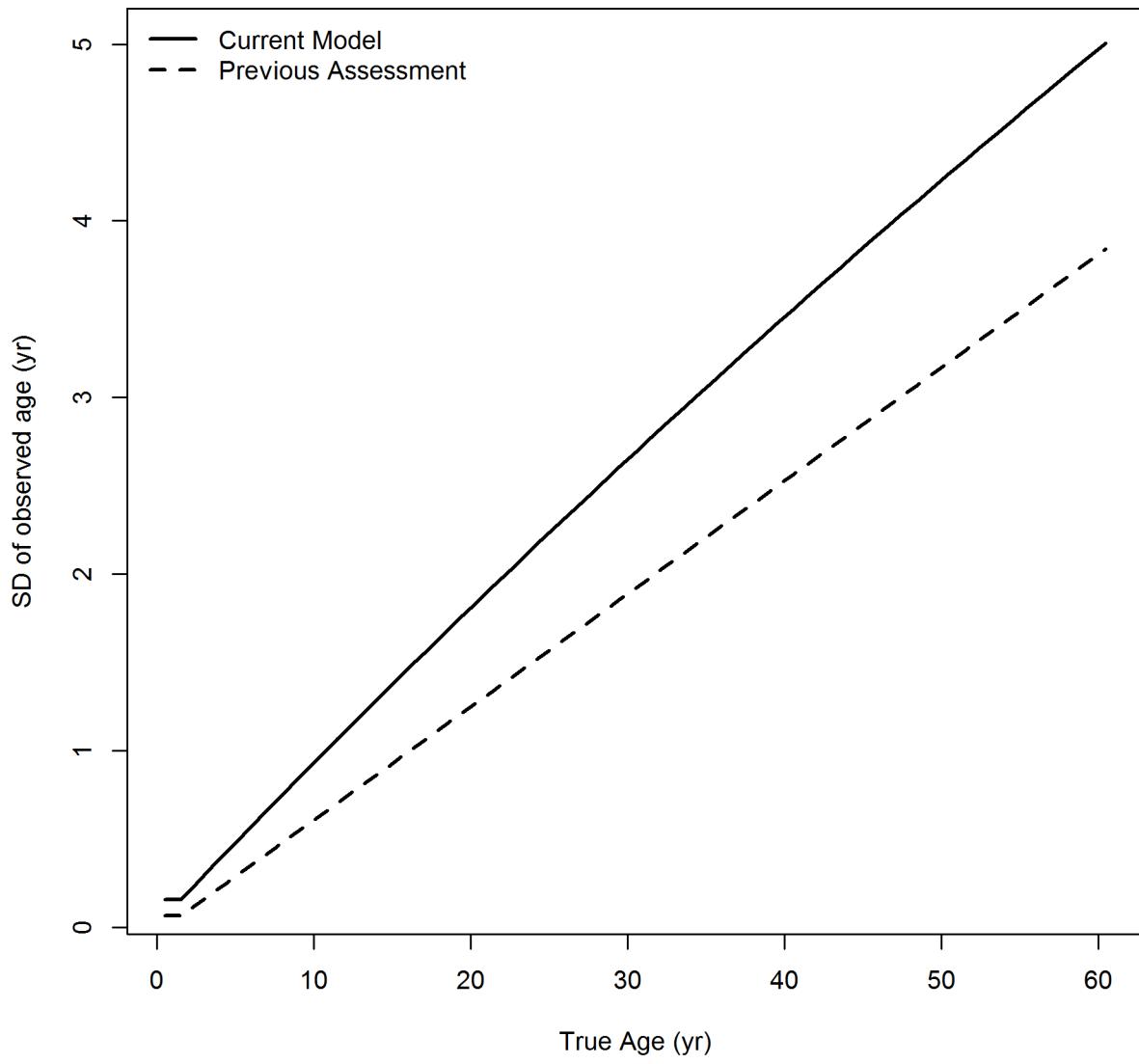


Figure 30: The estimated ageing error used in this assessment compared to the ageing error assumed in the previous assessment for Pacific ocean perch. [fig:Age_Error](#)

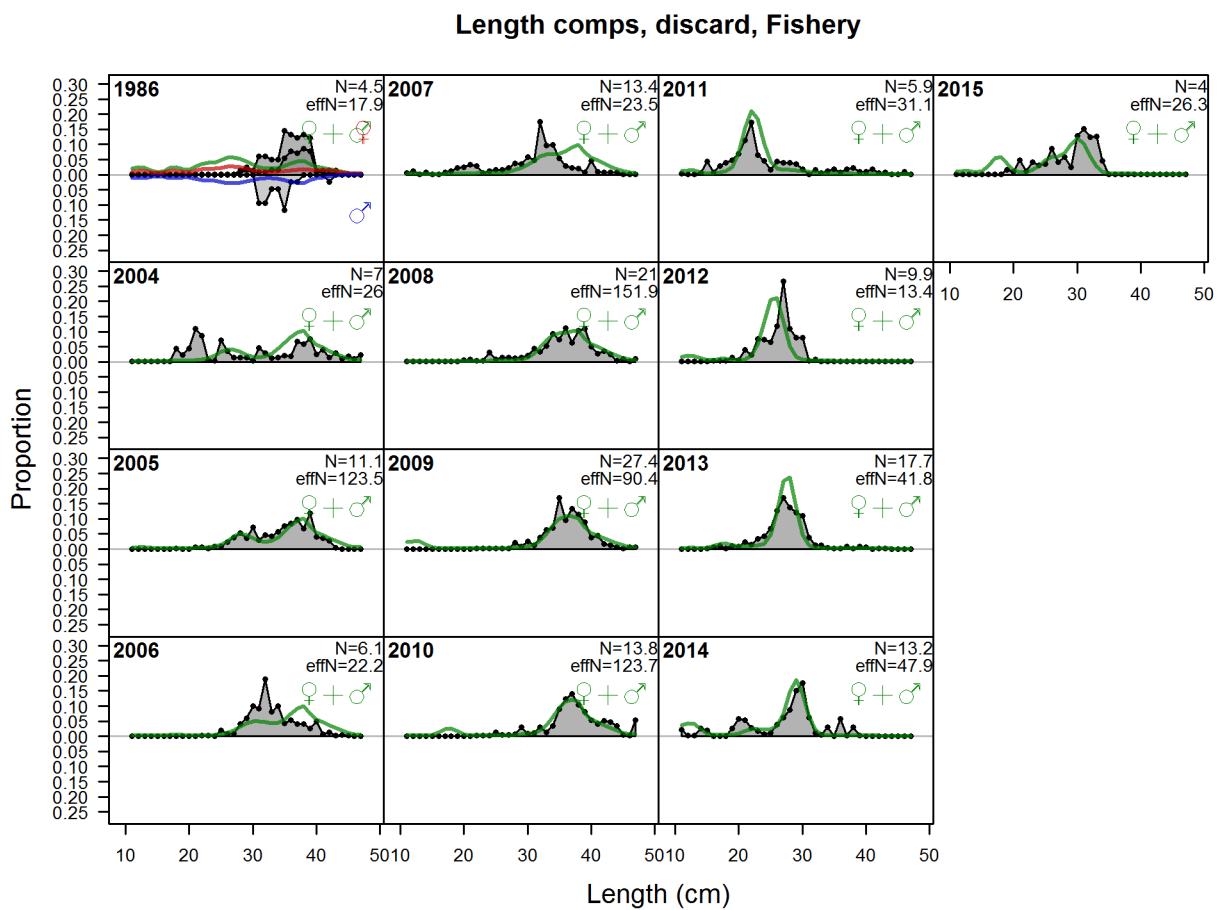


Figure 31: Length comps, discard, Fishery fig:mod1_1_comp_lenfit_flt1mkt1

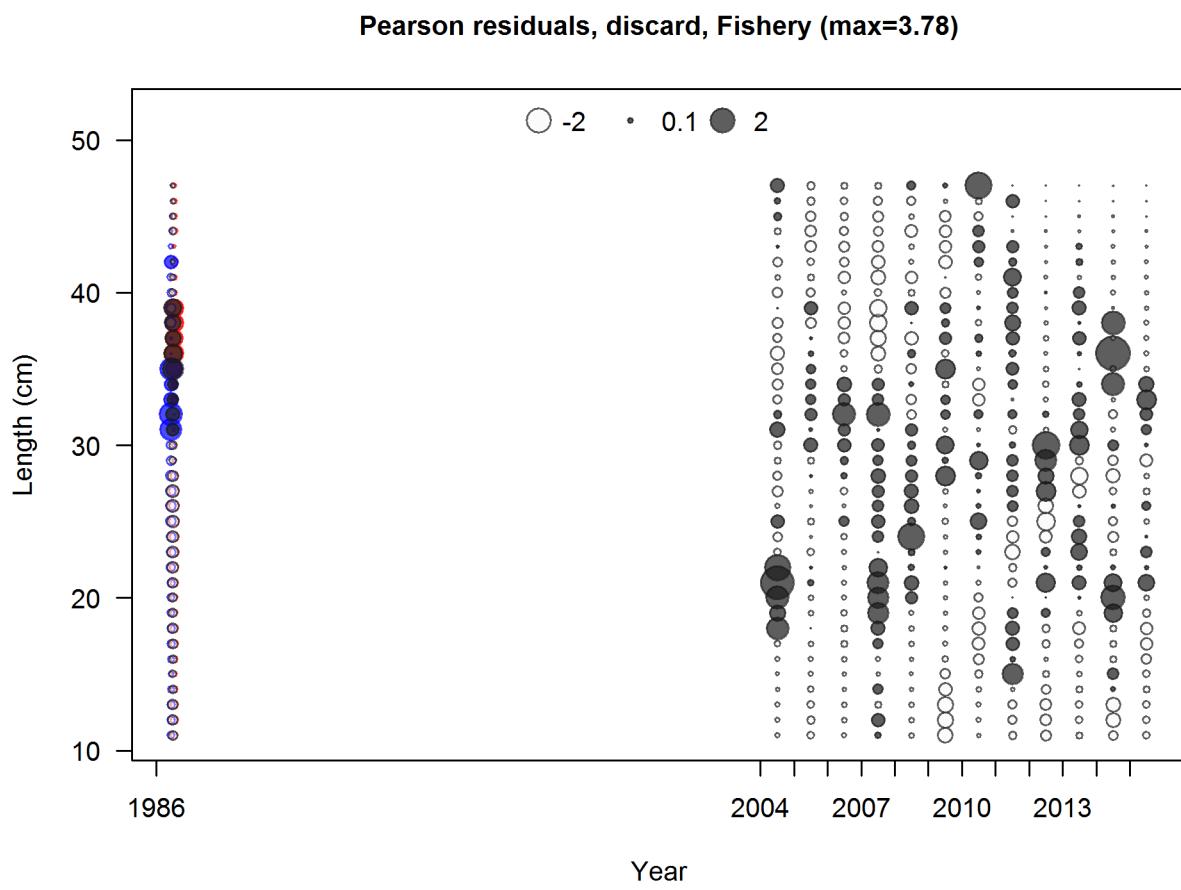


Figure 32: Pearson residuals, discard, Fishery (max=3.78)
 Closed bubbles are positive residuals (observed $>$ expected) and open bubbles are negative residuals (observed $<$ expected). [fig:mod1_2_comp_lenfit_residsfitlmkt1](#)

N-EffN comparison, Length comps, discard, Fishery

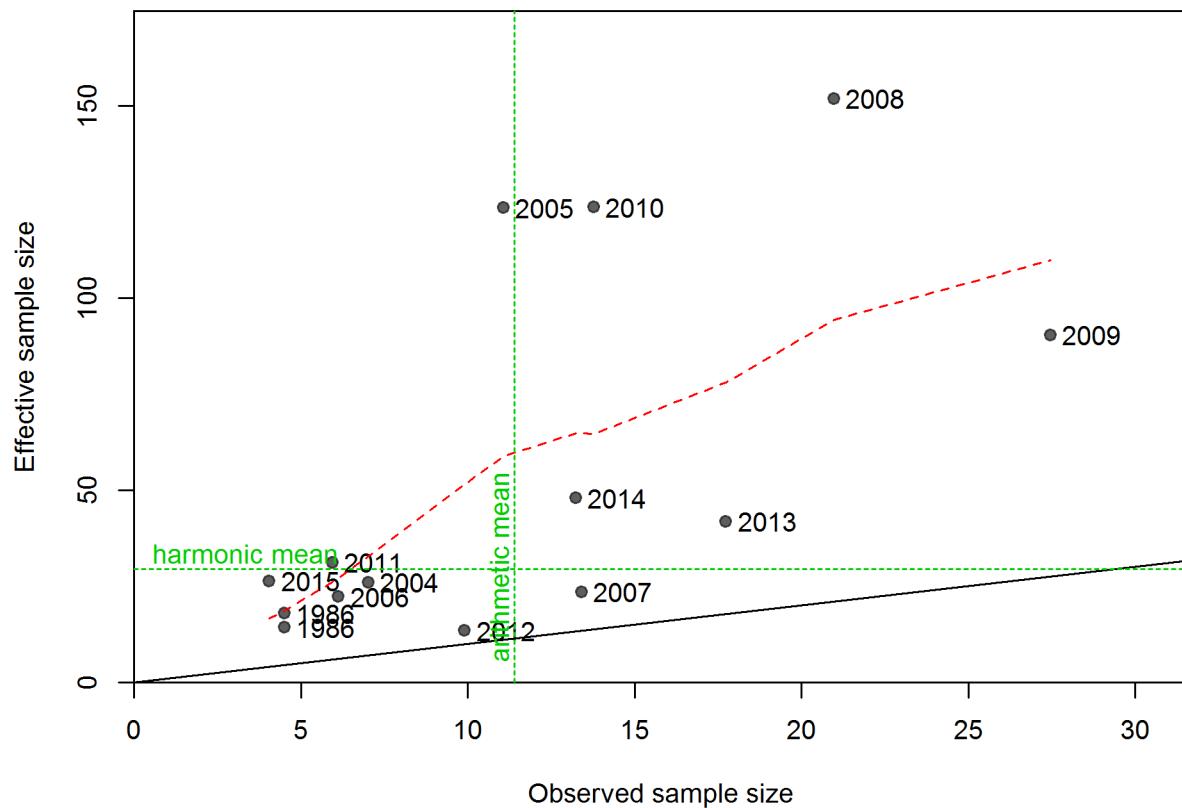


Figure 33: N_EffN comparison, Length comps, discard, Fishery fig:mod1_3_comp_lenfit_sa

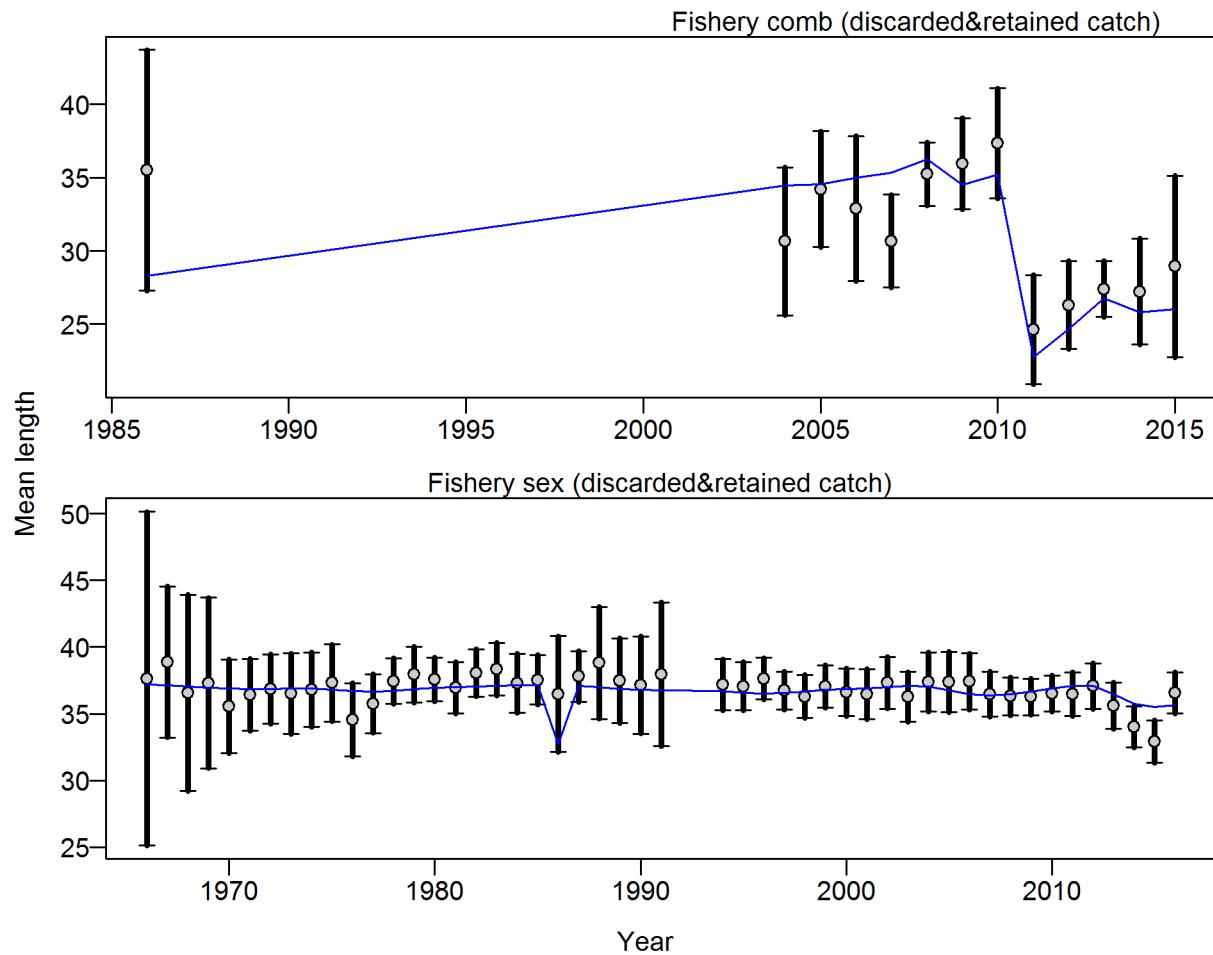


Figure 34: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.9951 (0.6717_1.7889) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models, Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:mod1_4_comp_lenfit_data_weighting_TA1.8_Fishery](#)

Length comps, retained, Fishery

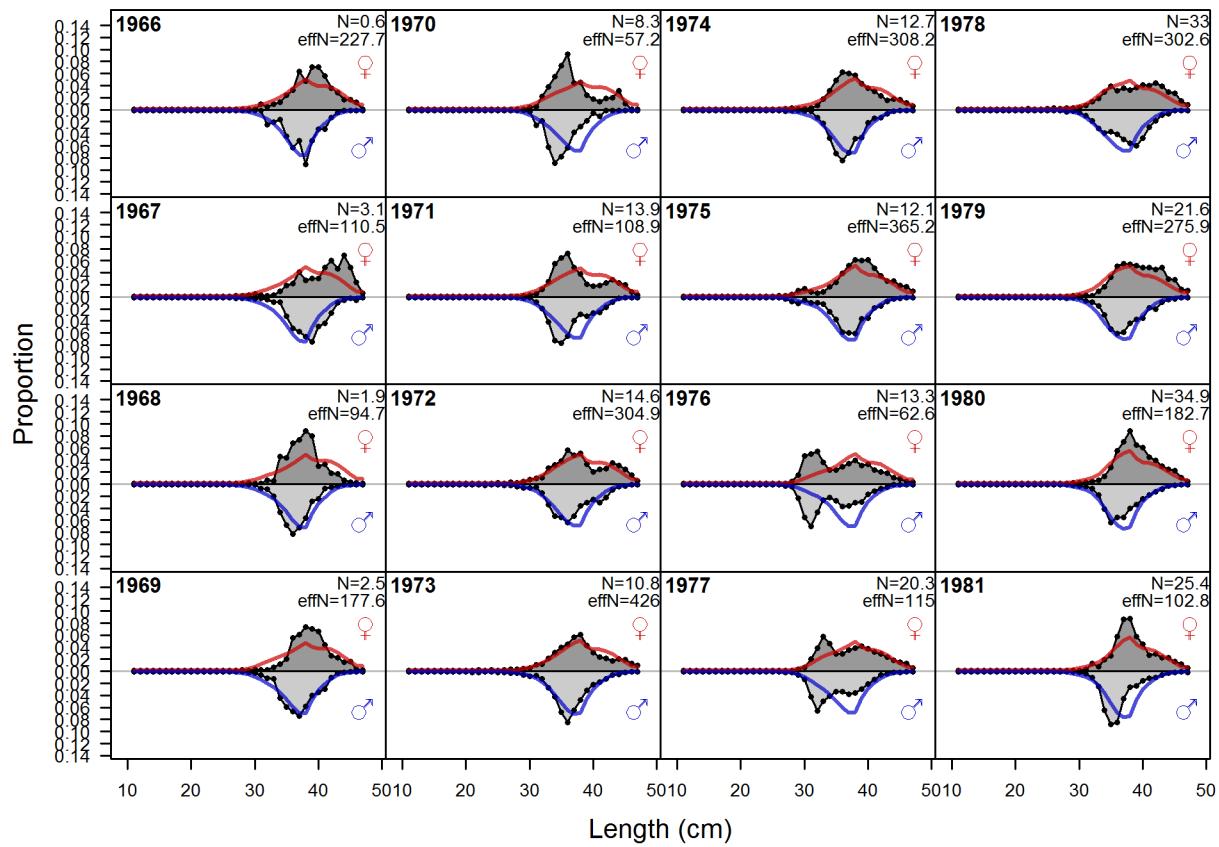


Figure 35: Length comps, retained, Fishery (plot 1 of 4) `fig:mod1_5_comp_lenfit_flt1m`

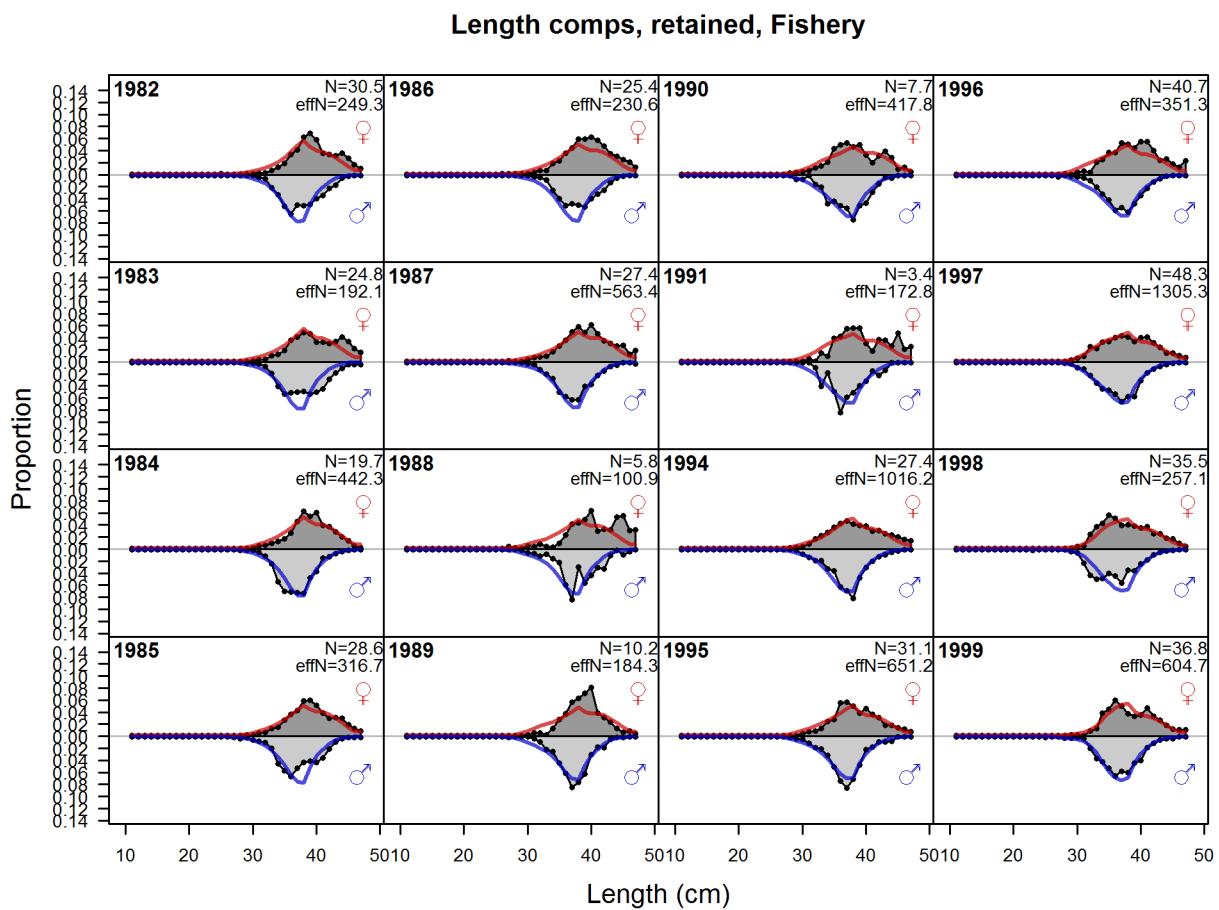


Figure 36: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4) fig:mod1_6_comp_lenfit

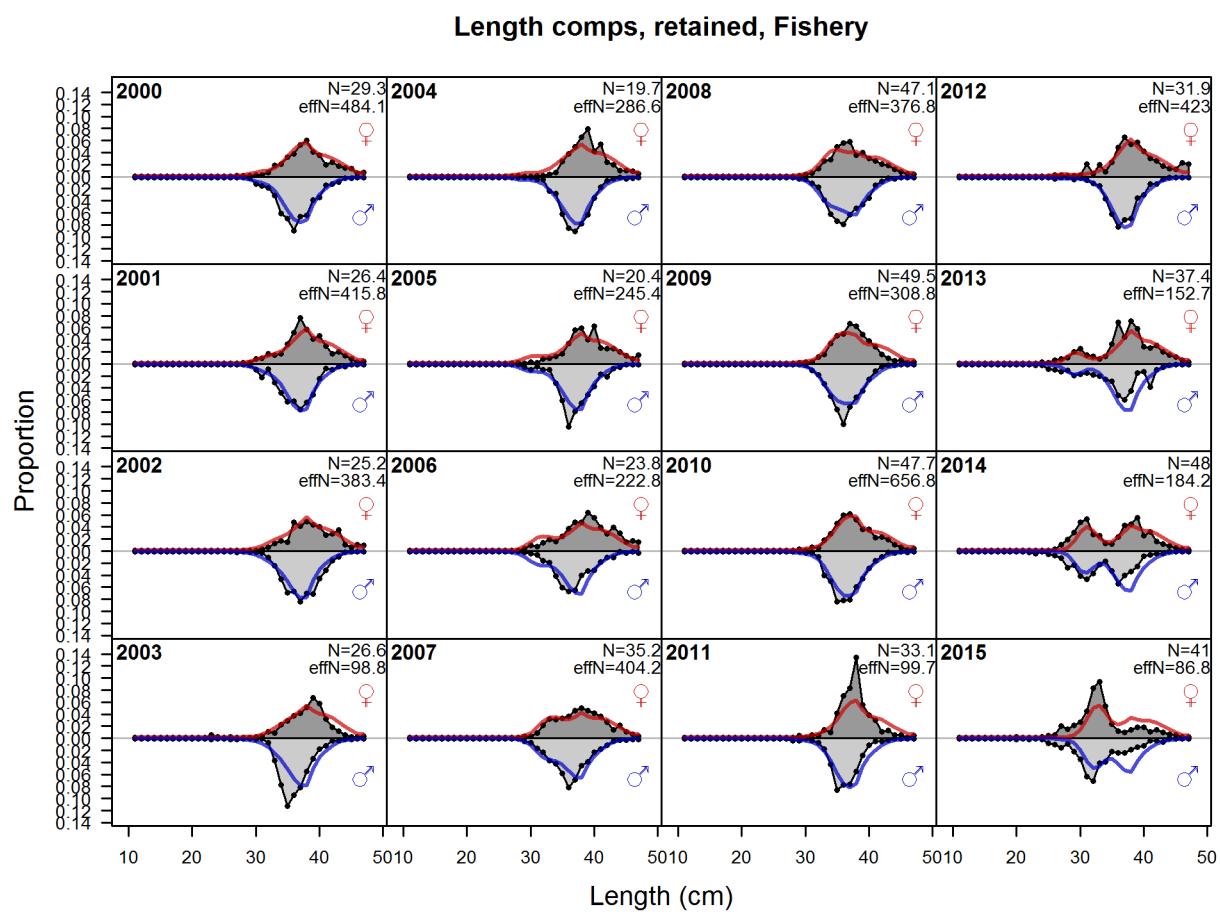
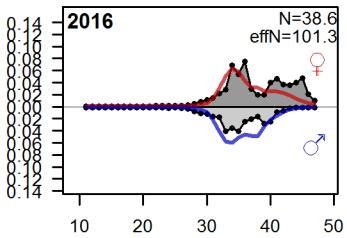


Figure 37: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4) (plot 3 of 4) fig:mod1_7_comp_

Proportion

Length comps, retained, Fishery



Length (cm)

Figure 38: Length comps, retained, Fishery (plot 1 of 4) (plot 2 of 4) (plot 3 of 4) (plot 4 of 4)
Fig:mod1_8_comp_lehfit_flt1mk2_page4

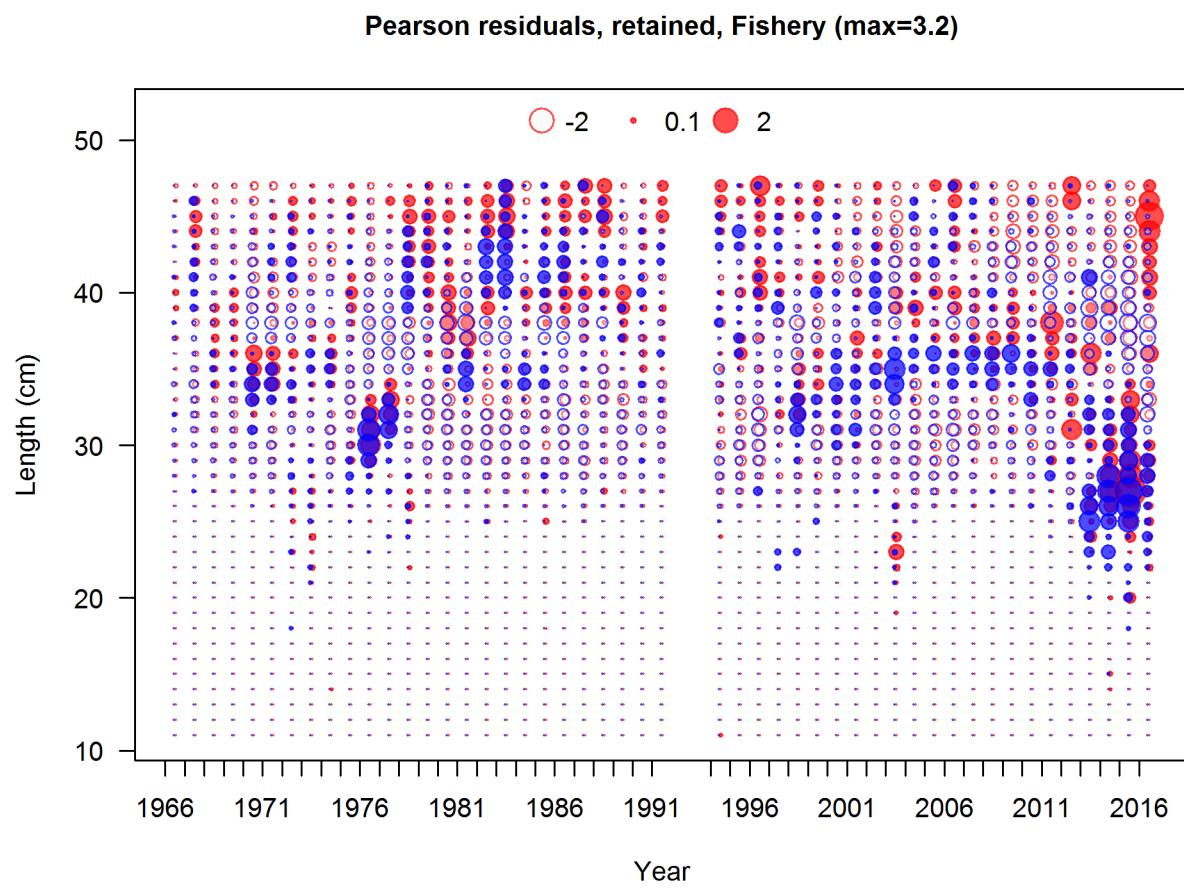


Figure 39: Pearson residuals, retained, Fishery (max=3.2) (plot 4 of 4)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:mod1_9_comp_lenfit_residsfit1mkt2_page4](#)

N-EffN comparison, Length comps, retained, Fishery

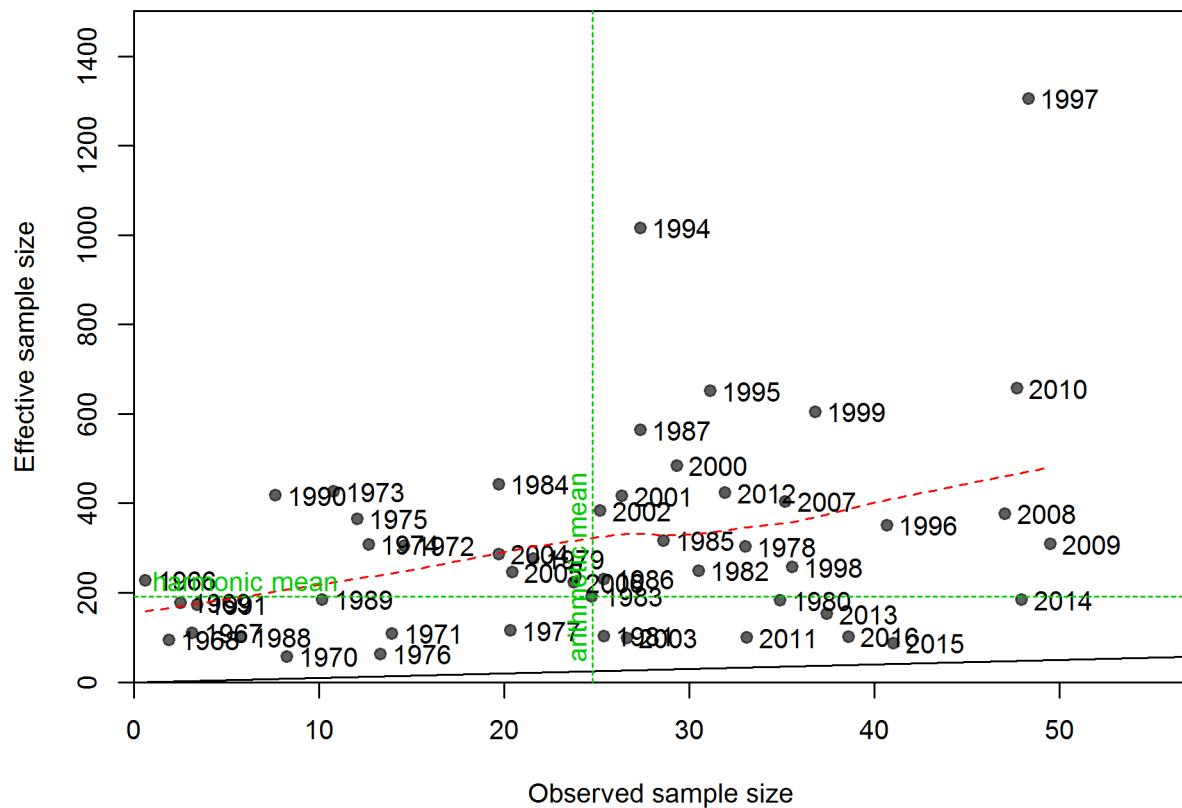


Figure 40: N_EffN comparison, Length comps, retained, Fishery fig:mod1_10_comp_lenfit_s

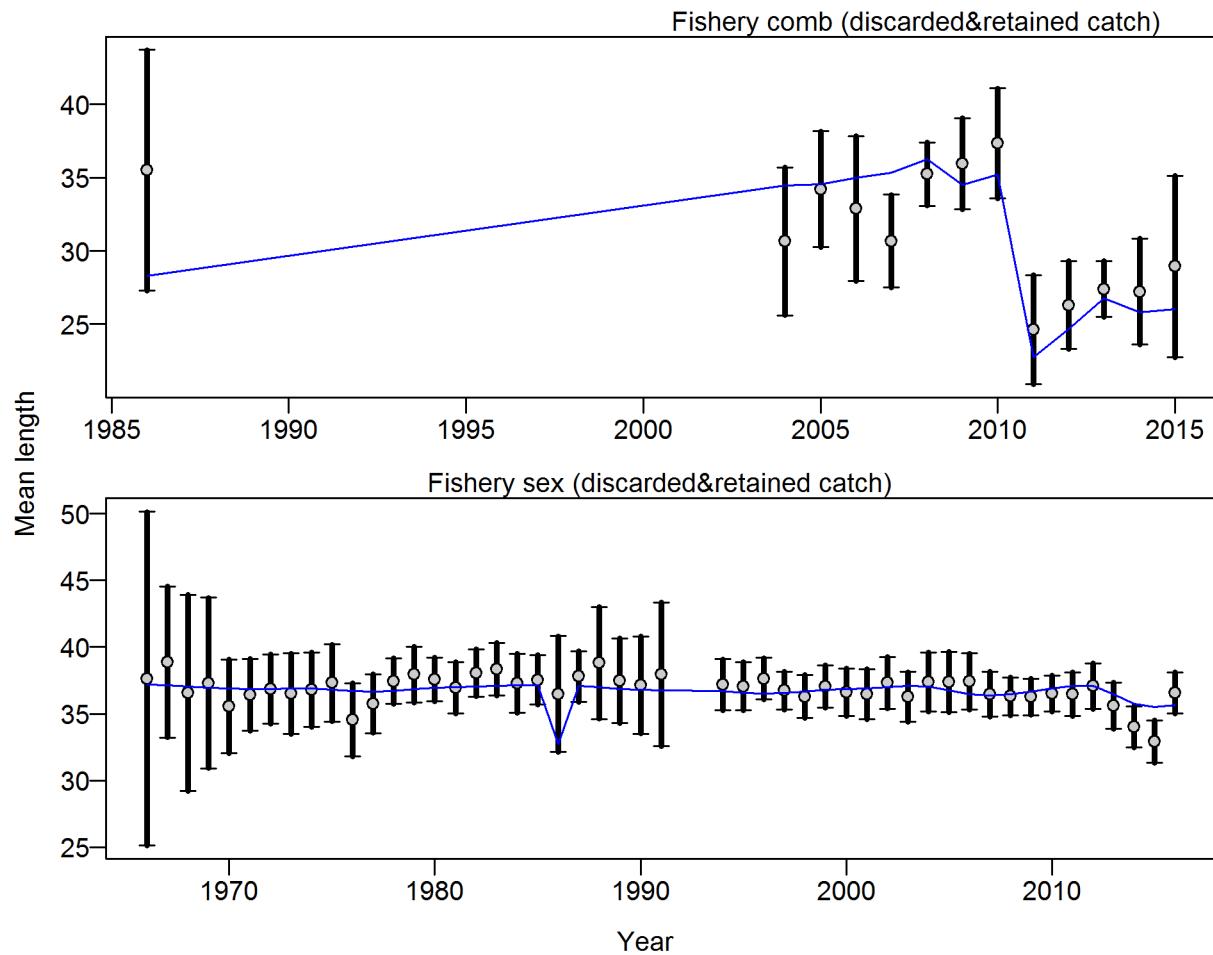


Figure 41: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.9951 (0.6641_1.7332) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:mod1_11_comp_lenfit_data_weighting_TA1.8_Fishery](#)

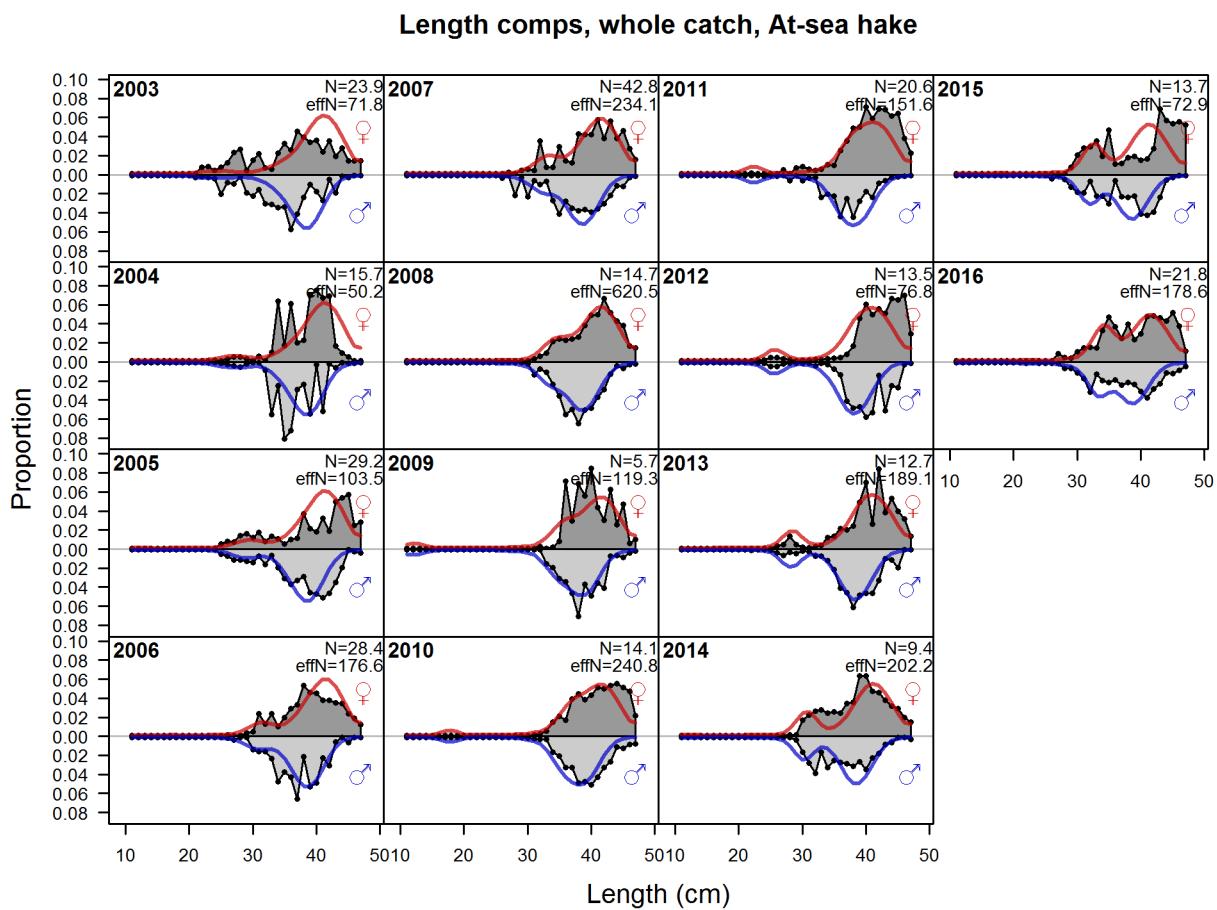


Figure 42: Length comps, whole catch, At_sea hake fig:mod1_12_comp_lenfit_flt2mk

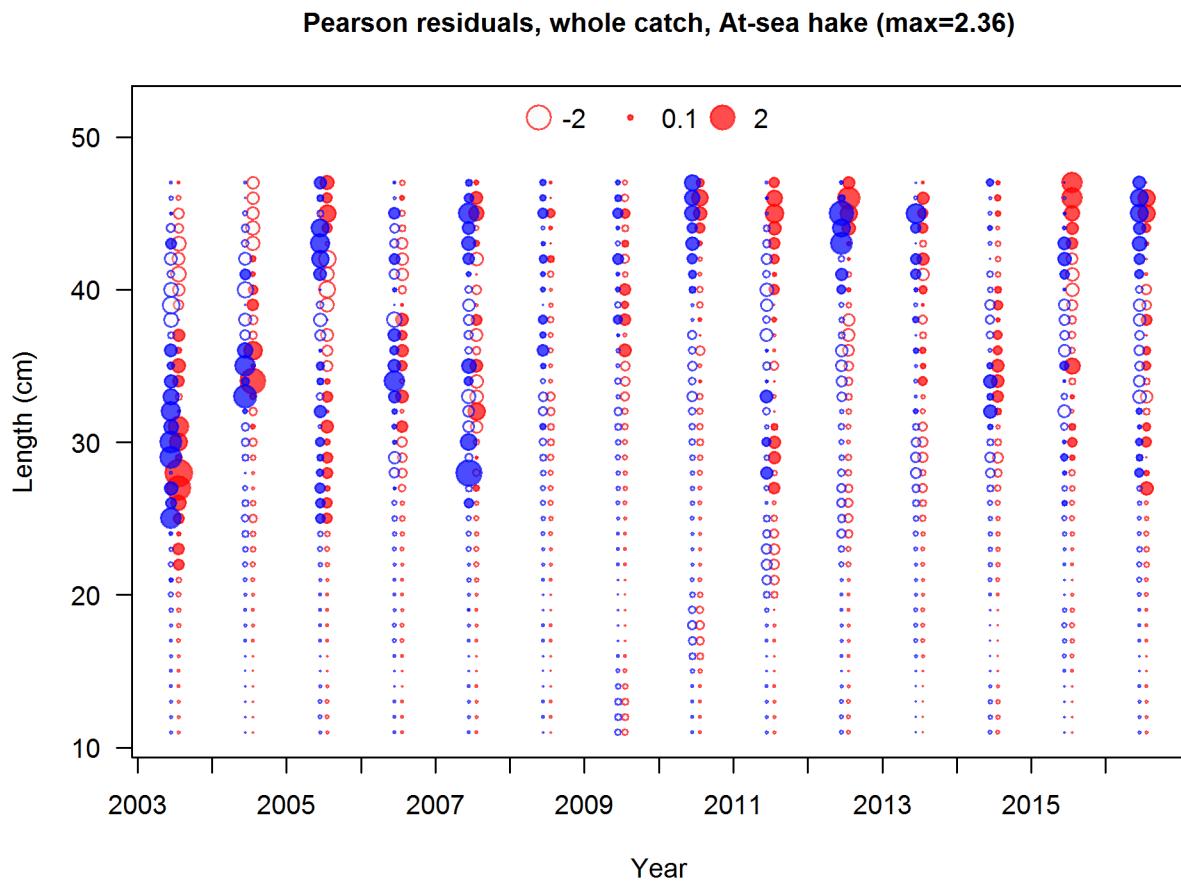


Figure 43: Pearson residuals, whole catch, At_sea hake (max=2.36)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:mod1_13_comp_lenfit_residsfit2mkt0](#)

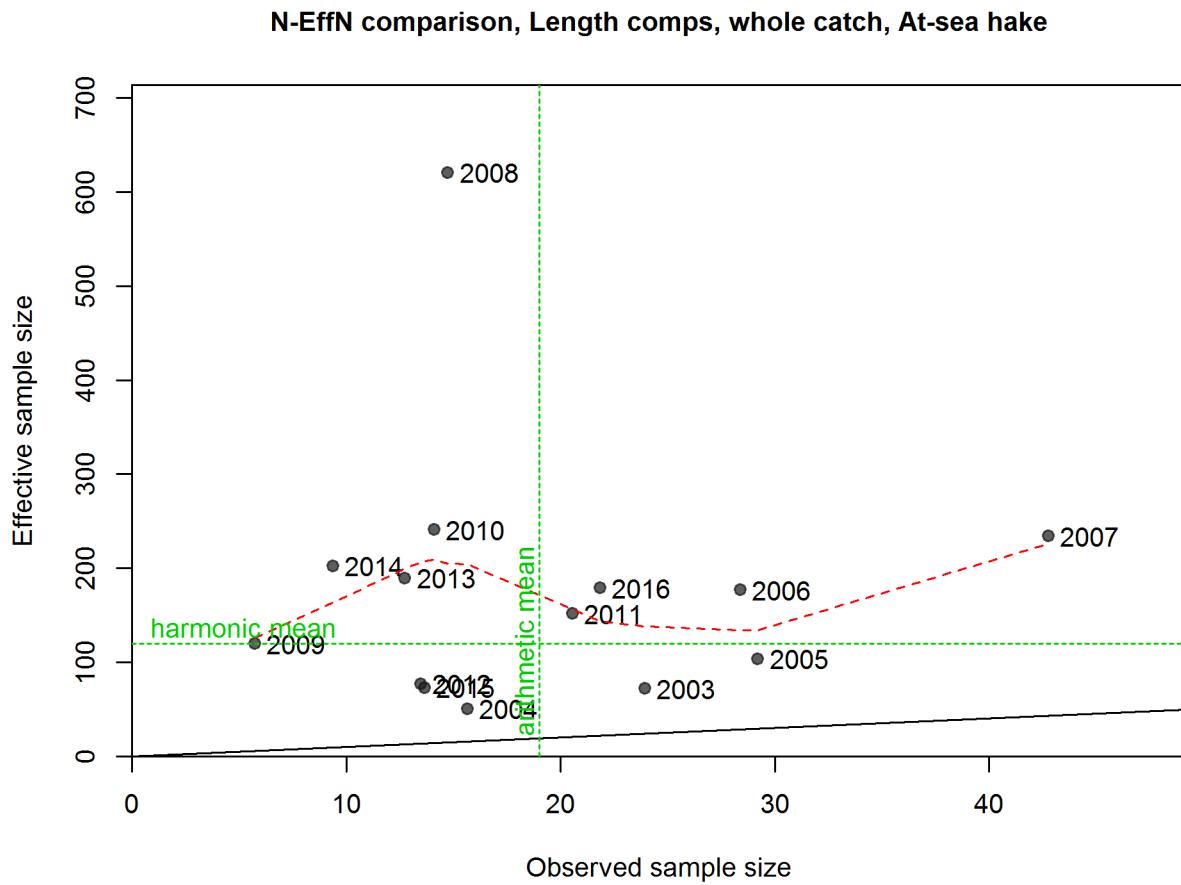


Figure 44: N_EffN comparison, Length comps, whole catch, At_sea hake fig:mod1_14_comp_lenf

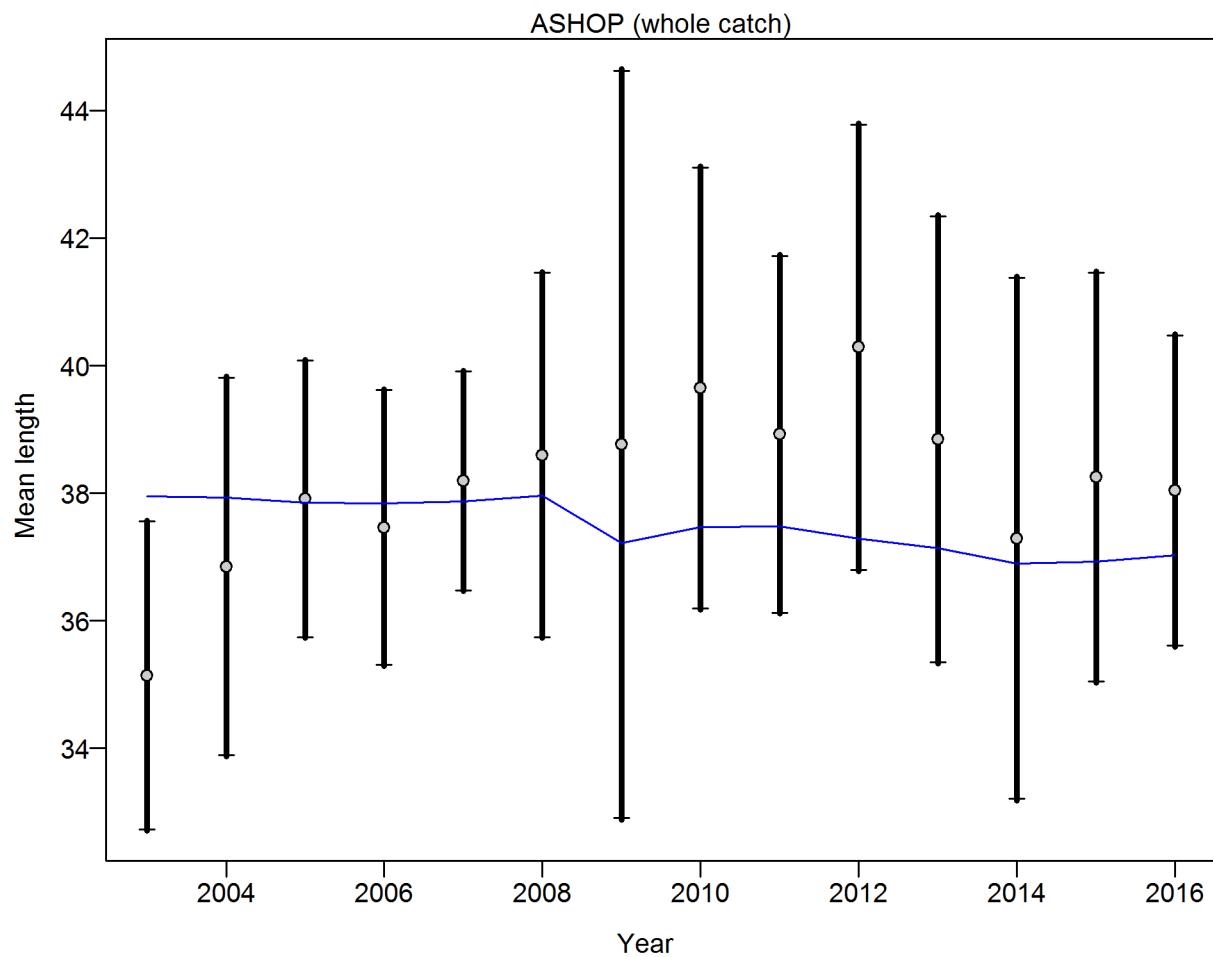
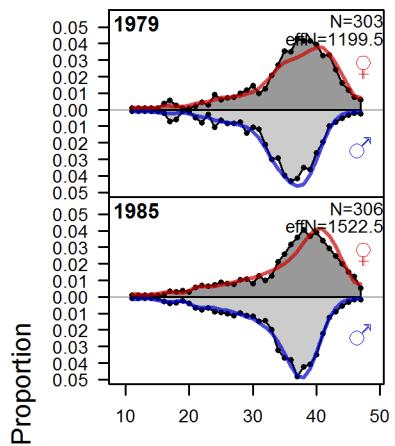


Figure 45: Francis data weighting method TA1.8: At_sea hake Suggested sample size adjustment (with 95% interval) for len data from At_sea hake: 1.0115 (0.5174_4.5976) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. | [fig:mod1_15_comp_lenfit_data_weighting_TA1.8_At-sea_hake](#)

Length comps, whole catch, Pacific ocean perch survey



Length (cm)

Figure 46: Length comps, whole catch, Pacific ocean perch survey | [fig:mod1_16_comp_lenfit](#)

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

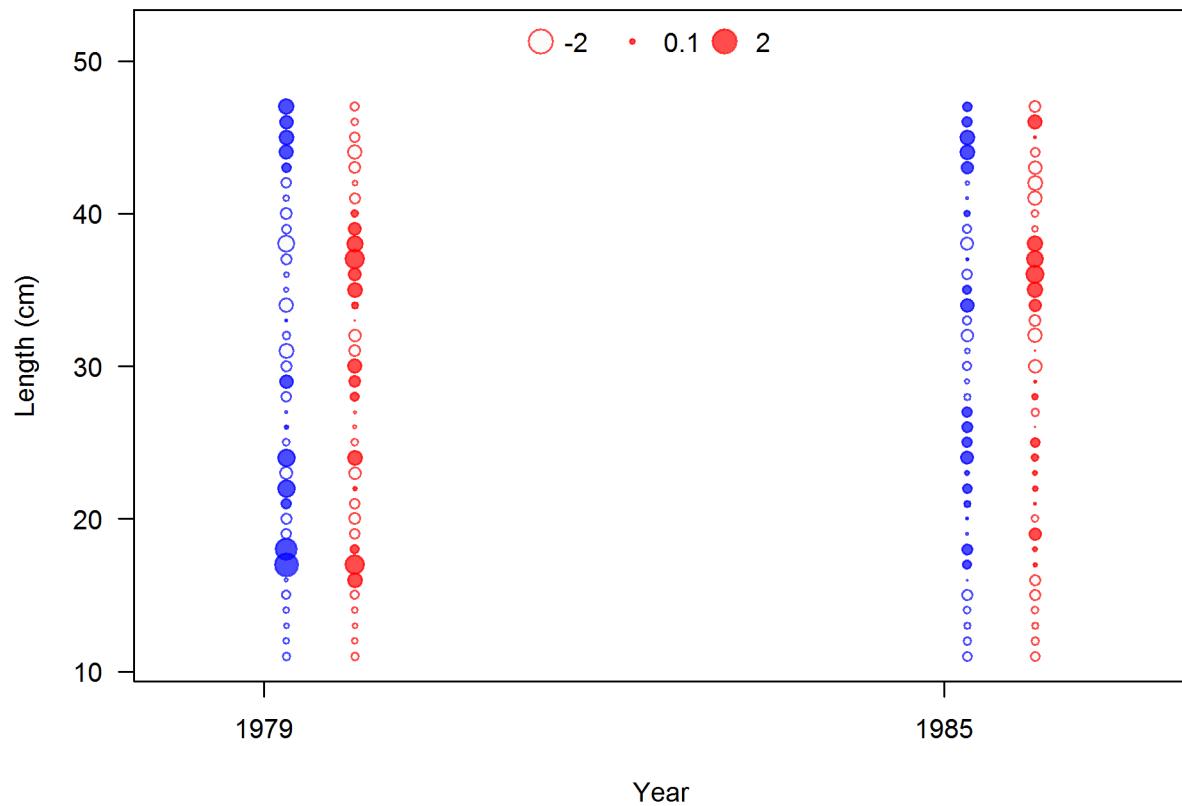


Figure 47: Pearson residuals, whole catch, Pacific ocean perch survey (max=1.74)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:mod1_17_comp_lenfit_residsfit4mkt0](#)

N-EffN comparison, Length comps, whole catch, Pacific ocean perch survey

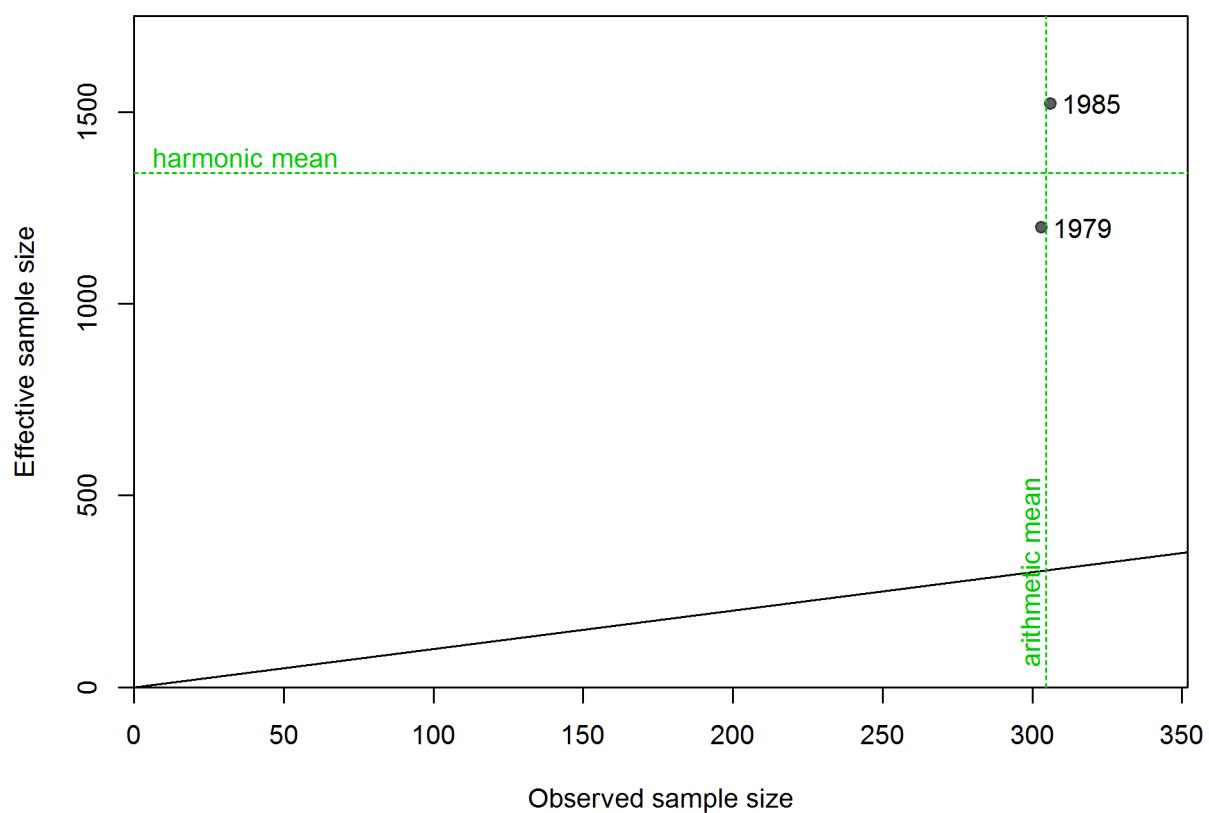


Figure 48: N_EffN comparison, Length comps, whole catch, Pacific ocean perch survey fig:mod1_18_c

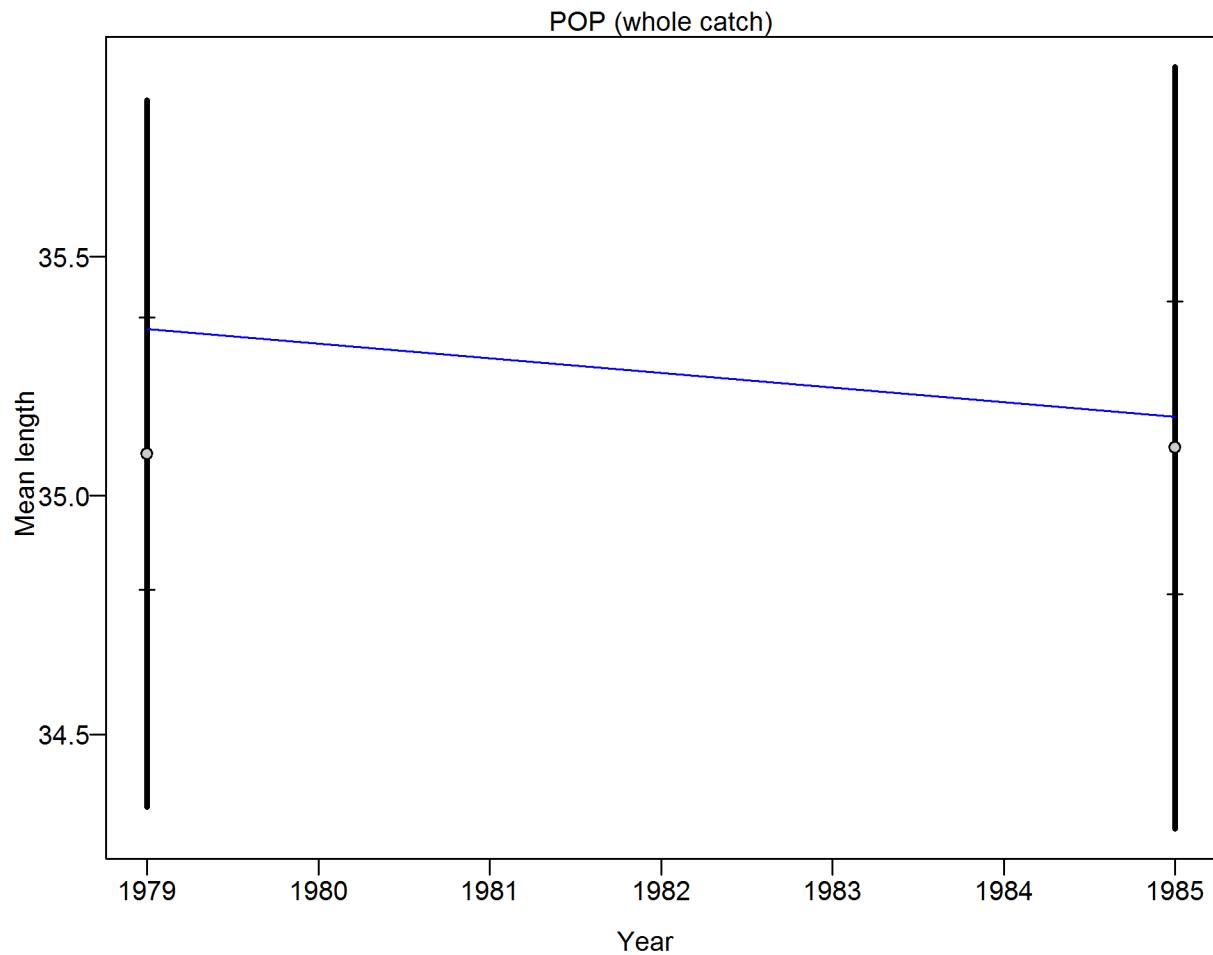


Figure 49: Francis data weighting method TA1.8: Pacific ocean perch survey Suggested sample size adjustment (with 95% interval) for len data from Pacific ocean perch survey: 6.7496 (6.7496_Inf) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124–1138. fig:mod1_19_comp_lenfit_da

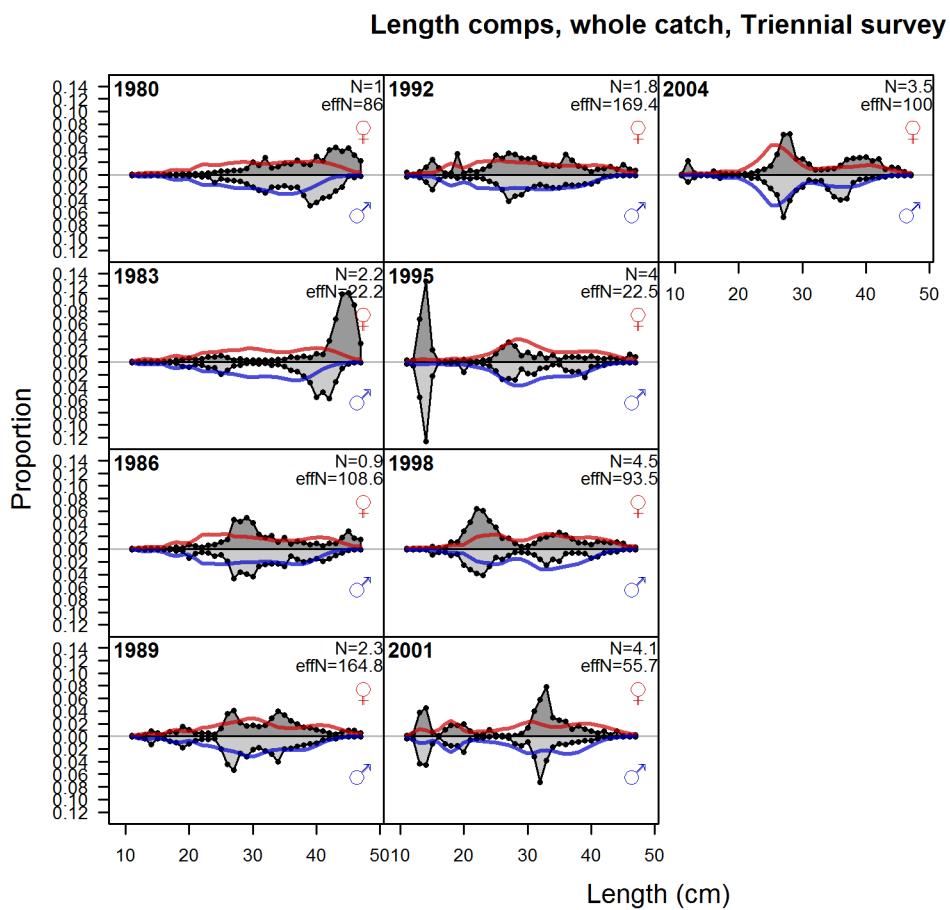


Figure 50: Length comps, whole catch, Triennial survey | [fig:mod1_20_comp_lenfit_flt5](#)

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

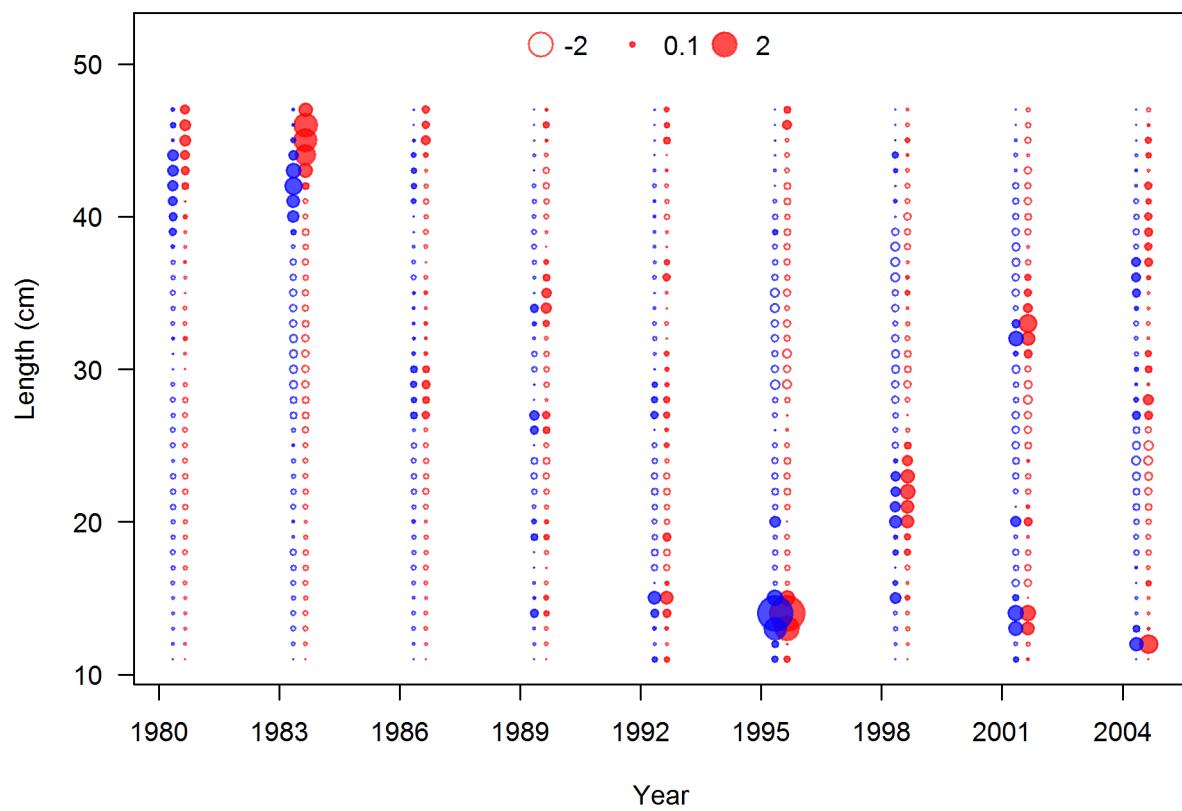


Figure 51: Pearson residuals, whole catch, Triennial survey (max=4.01)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:mod1_21_comp_lenfit_residsfit5mkt0](#)

N-EffN comparison, Length comps, whole catch, Triennial survey

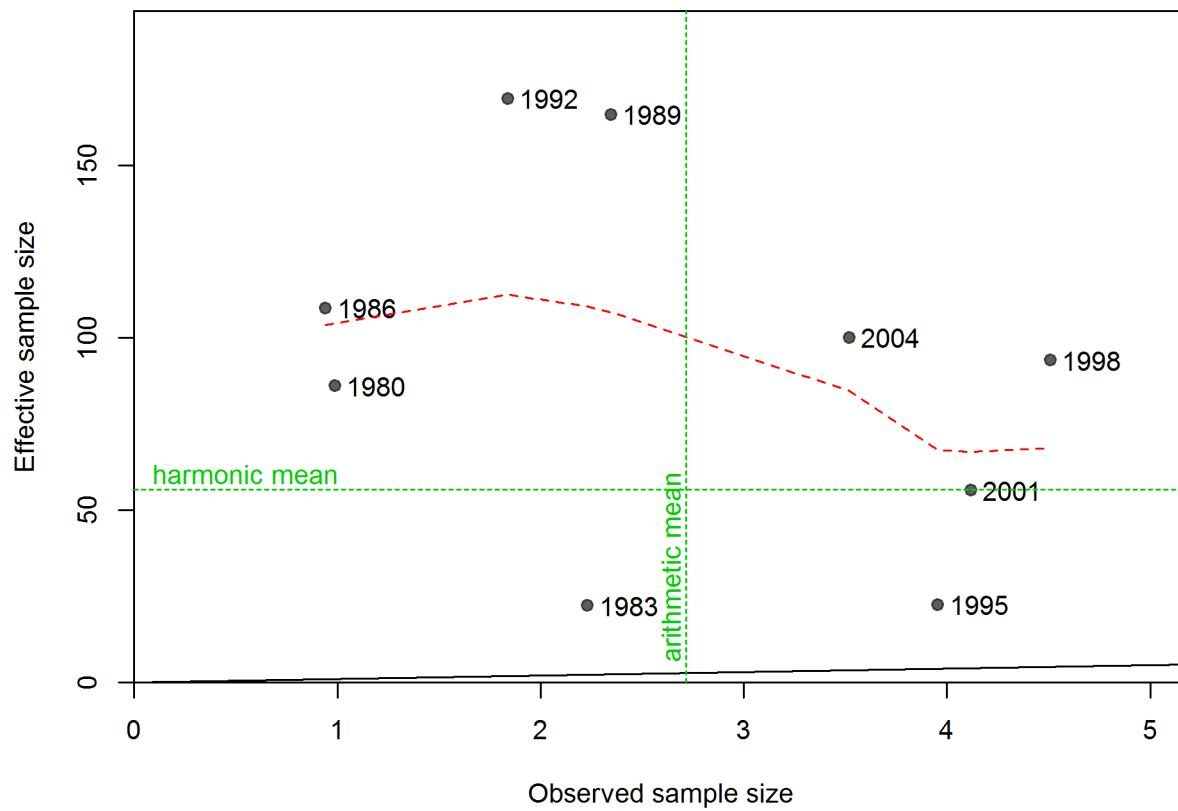


Figure 52: N_EffN comparison, Length comps, whole catch, Triennial survey fig:mod1_22_comp_le

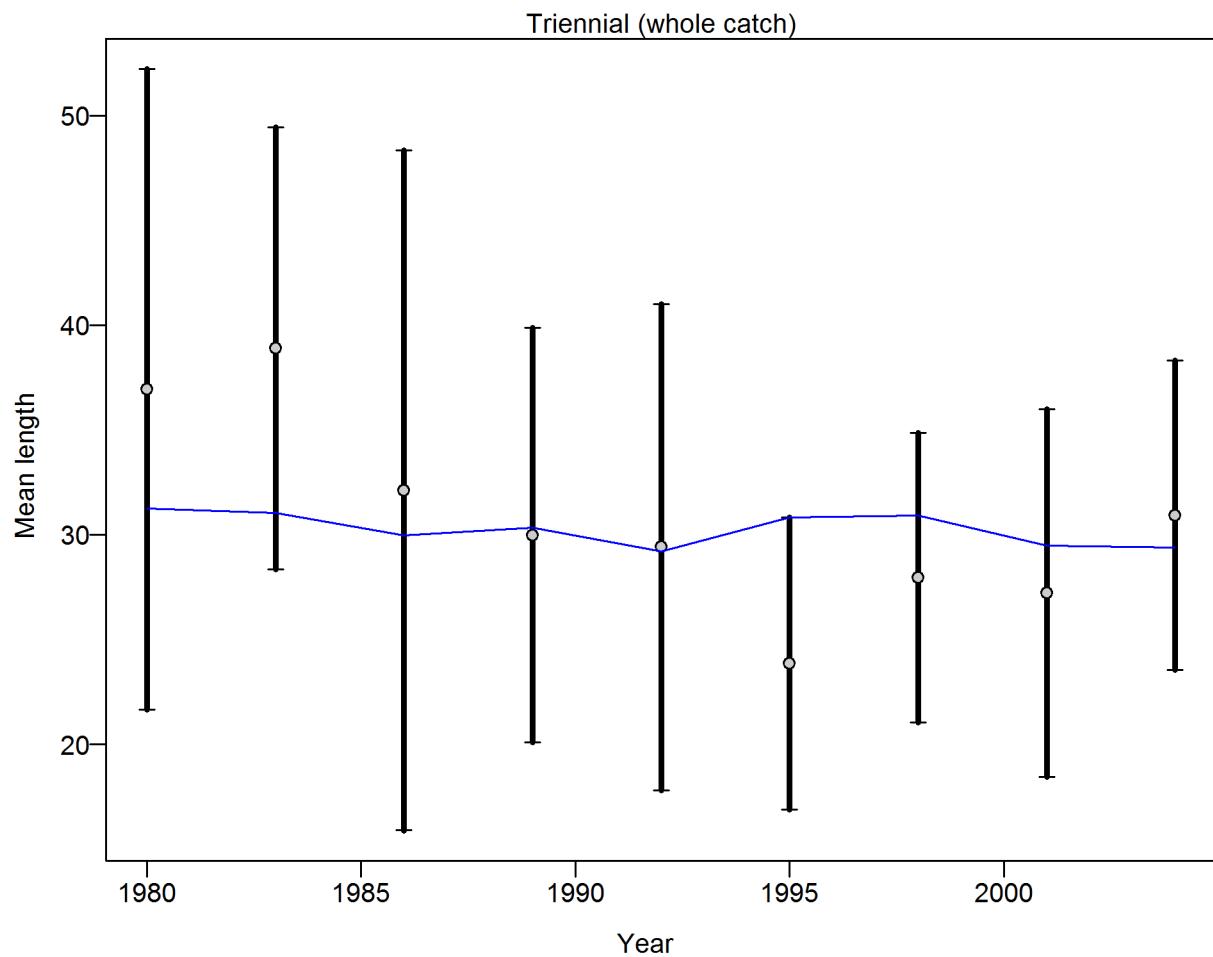


Figure 53: Francis data weighting method TA1.8: Triennial survey Suggested sample size adjustment (with 95% interval) for len data from Triennial survey: 1.0004 (0.5531_6.1809)
 For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:mod1_23_comp_lenfit_data_weighting](#)

Length comps, whole catch, AFSC slope survey

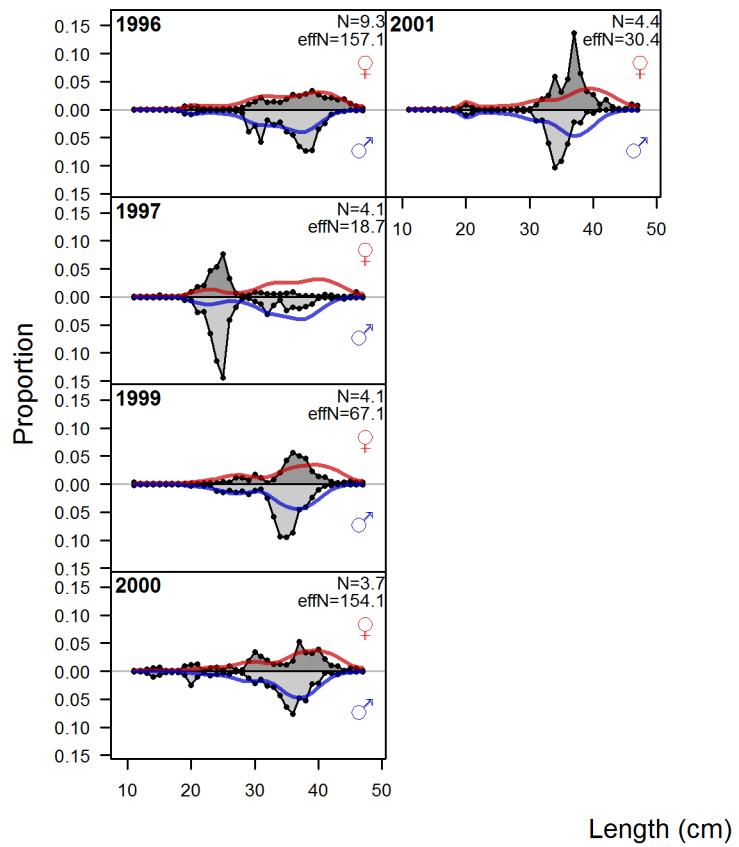


Figure 54: Length comps, whole catch, AFSC slope survey

`fig:mod1_24_comp_lenfit_flt`

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

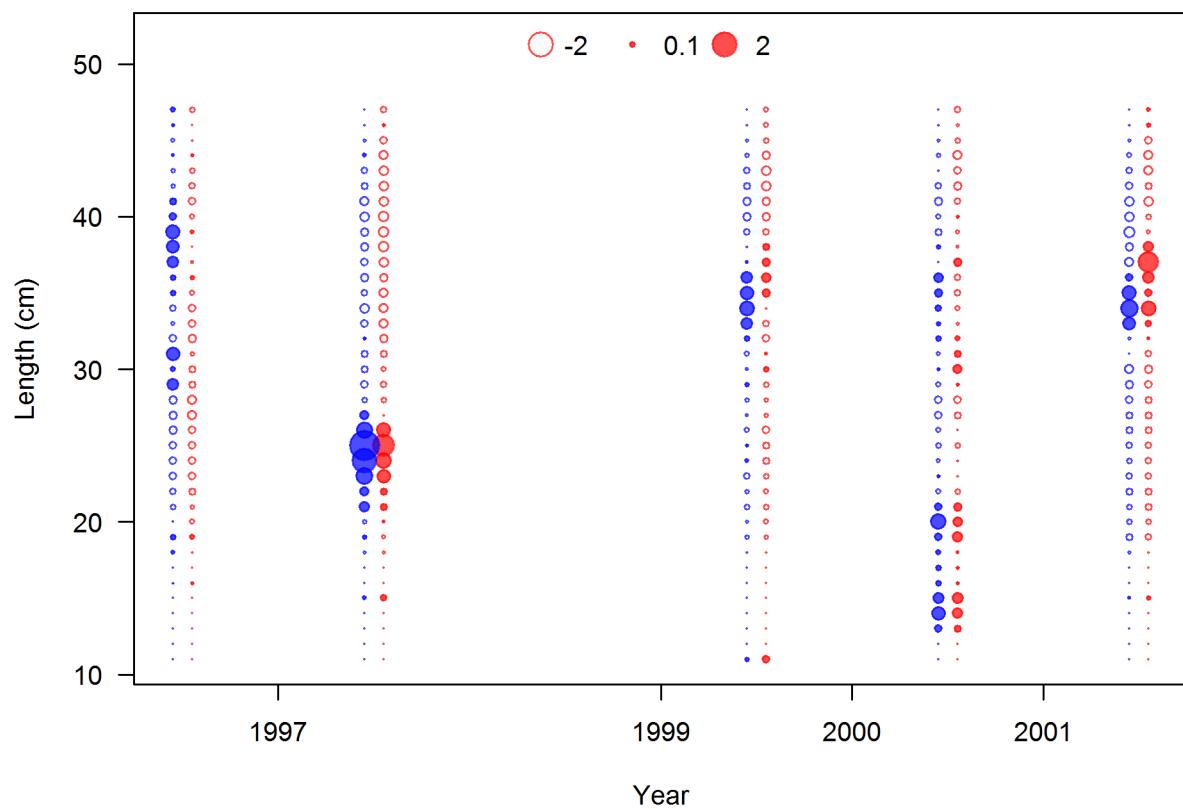


Figure 55: Pearson residuals, whole catch, AFSC slope survey (max=2.91)
Closed bubbles are positive residuals (observed $>$ expected) and open bubbles are negative residuals (observed $<$ expected). [fig:mod1_25_comp_lenfit_residsflt6mkt0](#)

N-EffN comparison, Length comps, whole catch, AFSC slope survey

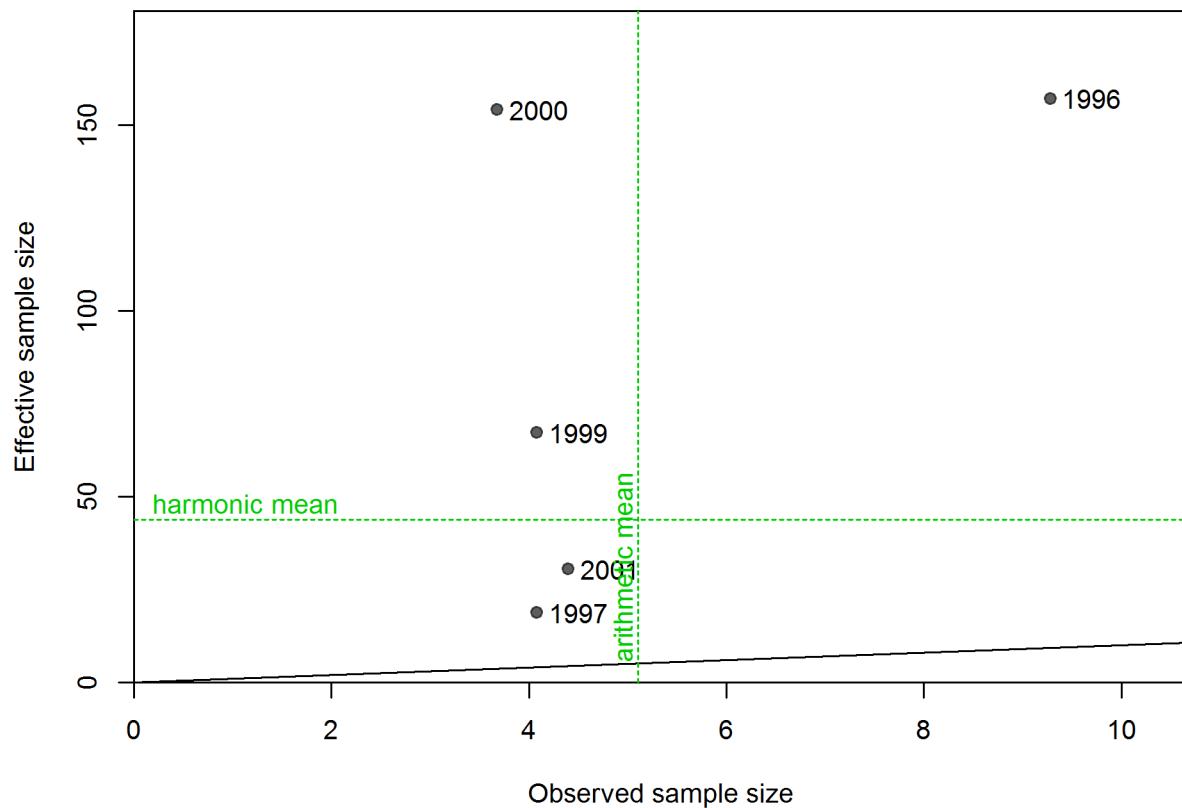


Figure 56: N_EffN comparison, Length comps, whole catch, AFSC slope survey `fig:mod1_26_comp_1`

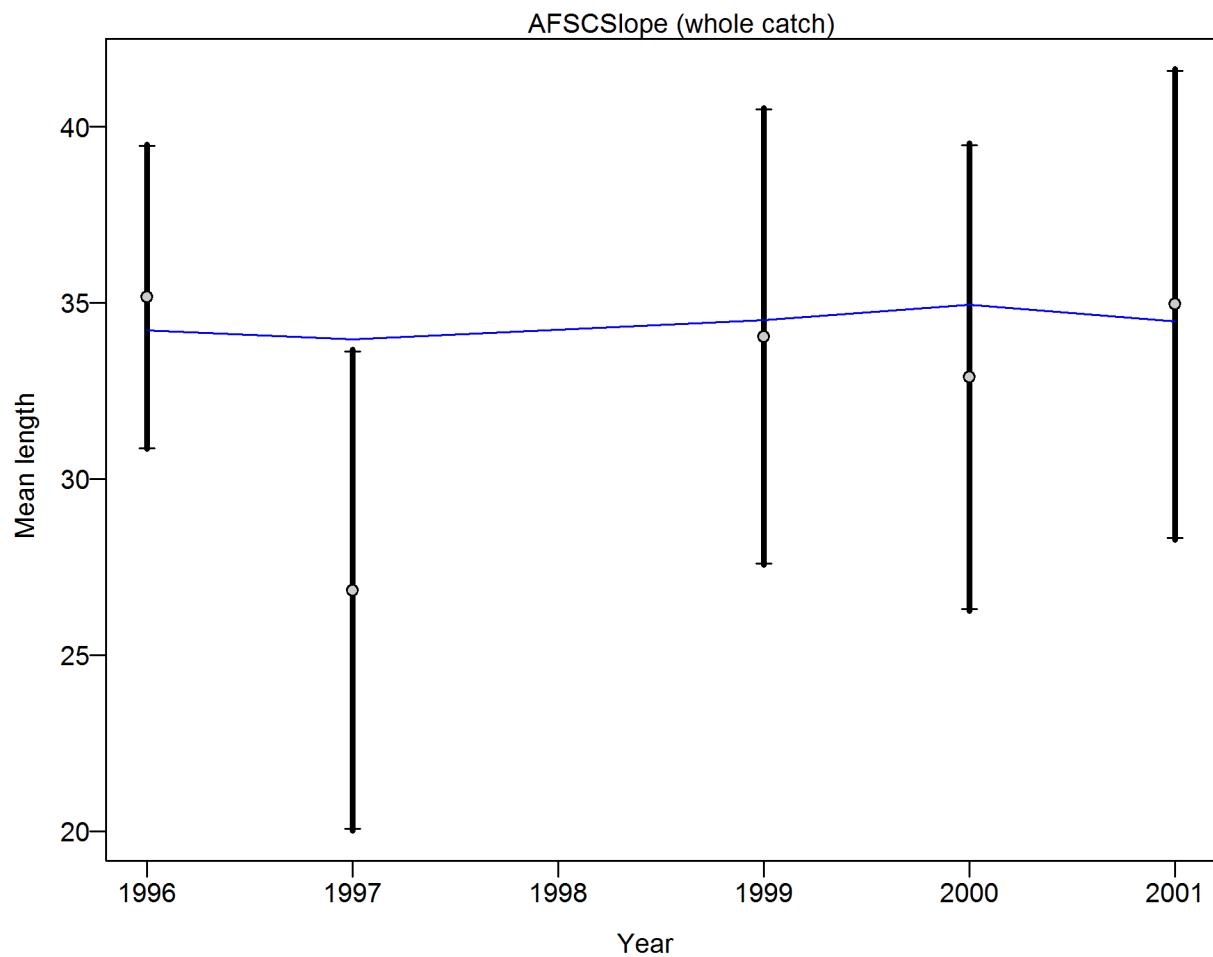
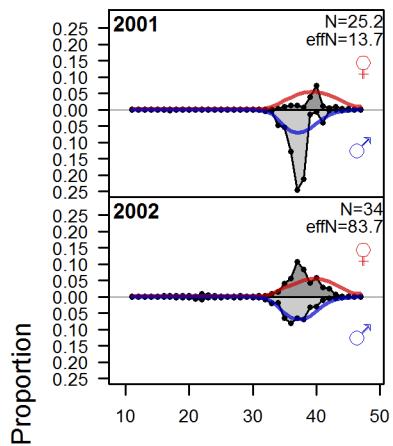


Figure 57: Francis data weighting method TA1.8: AFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from AFSC slope survey: 1.0151 (0.5934_22.3848)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:mod1_27_comp_lenfit_data_weighting](#)

Length comps, whole catch, NWFSC slope survey



Length (cm)

Figure 58: Length comps, whole catch, NWFSC slope survey

`fig:mod1_28_comp_lenfit_f1`

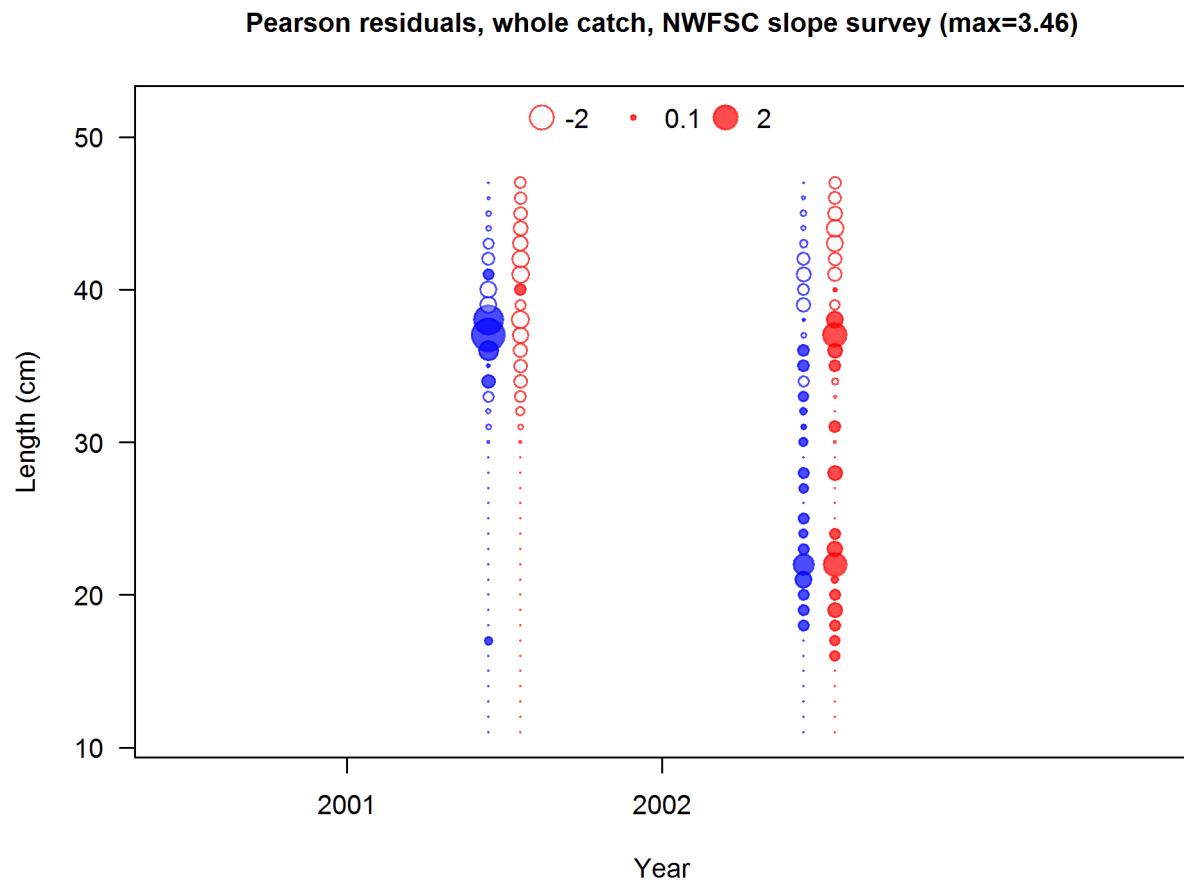


Figure 59: Pearson residuals, whole catch, NWFSC slope survey (max=3.46)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:mod1_29_comp_lenfit_residsfit7mkt0](#)

N-EffN comparison, Length comps, whole catch, NWFSC slope survey

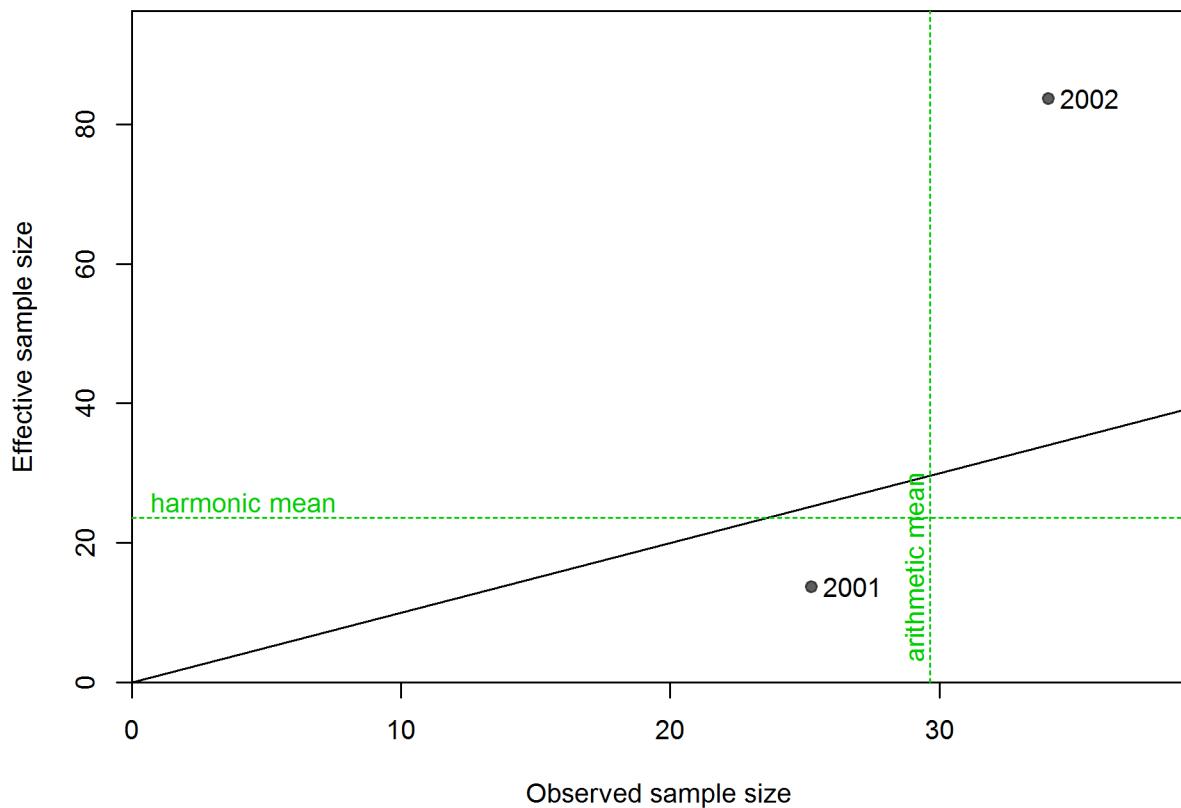


Figure 60: N_EffN comparison, Length comps, whole catch, NWFSC slope survey fig:mod1_30_comp

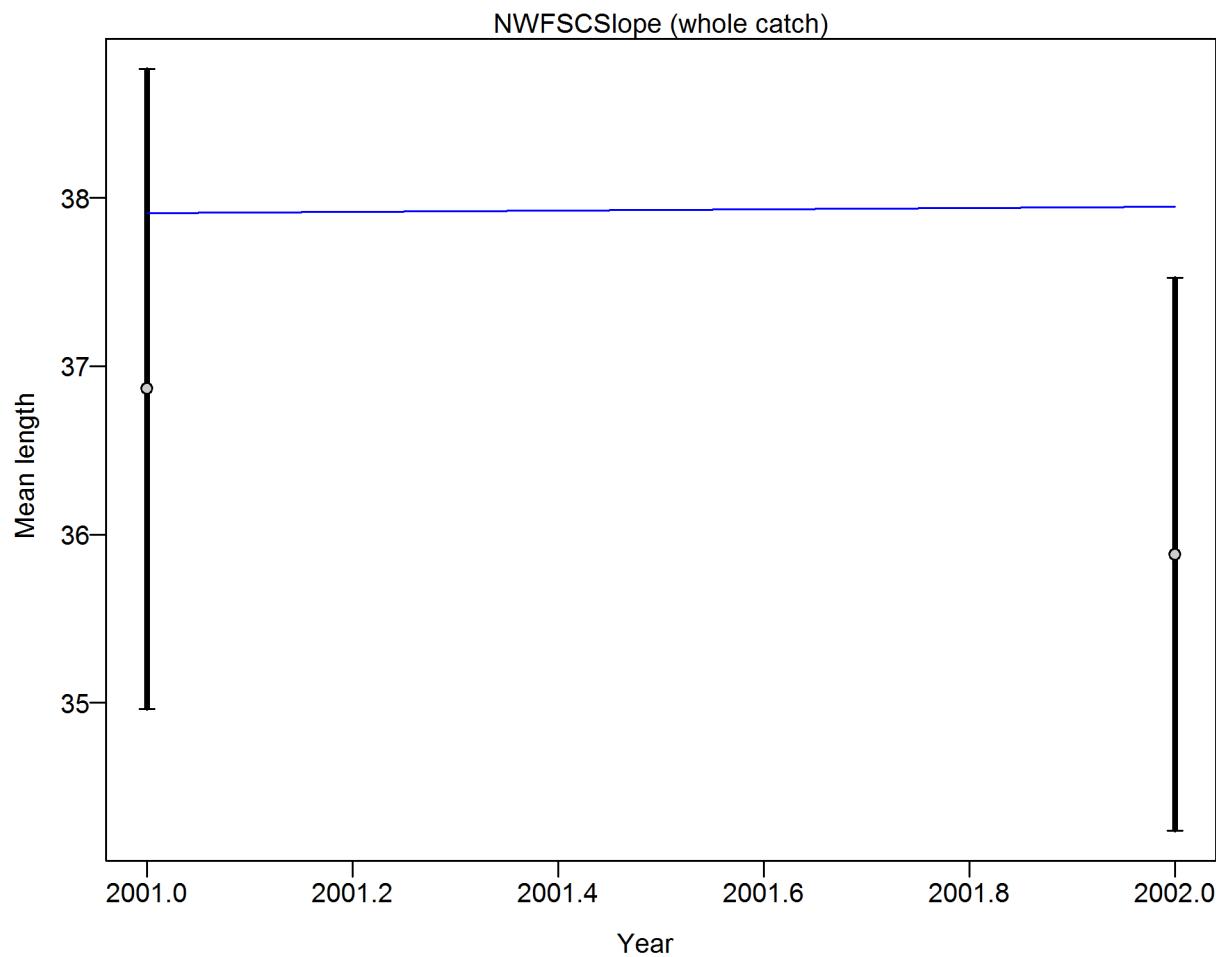


Figure 61: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC slope survey: 0.9922 (0.9922_Inf)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. [fig:mod1_31_comp_lenfit_data_weighting](#)

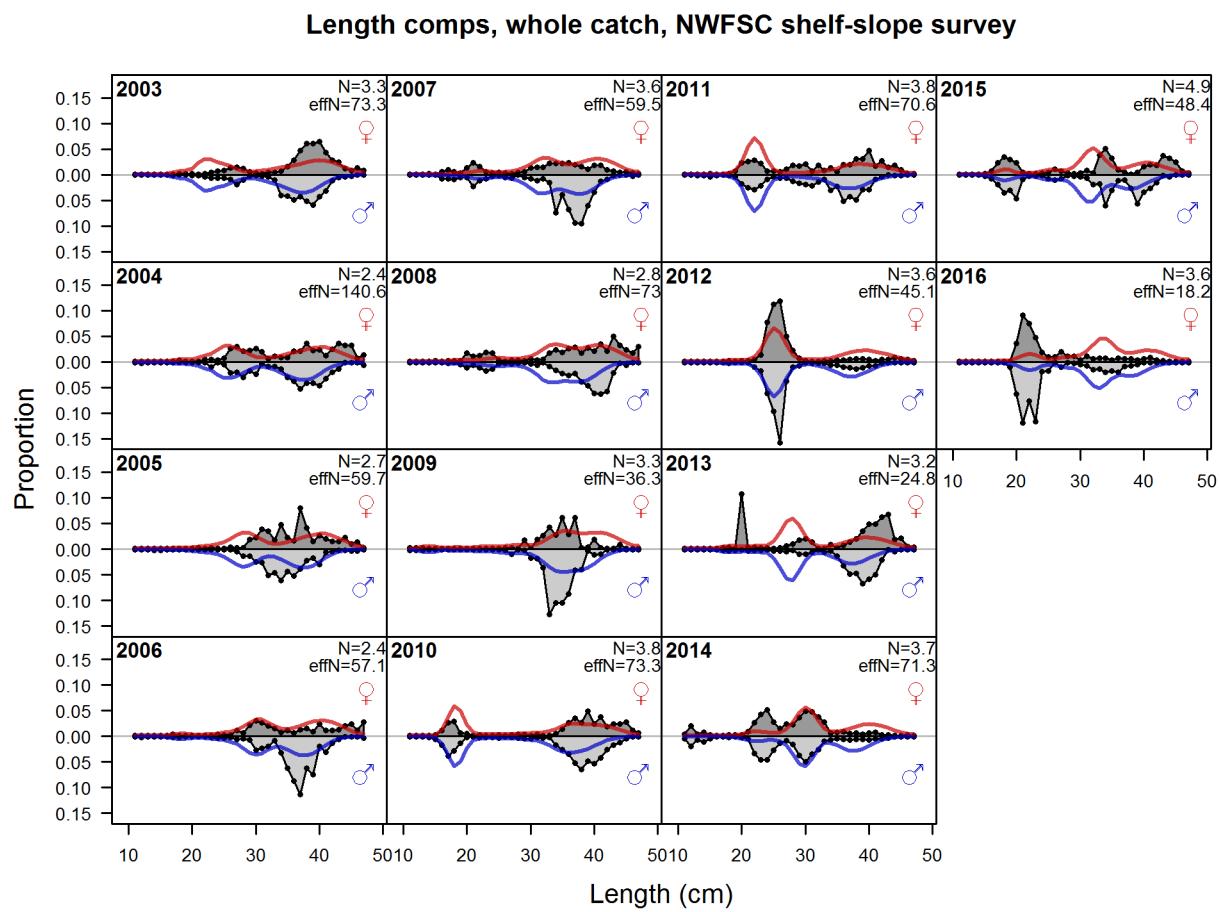


Figure 62: Length comps, whole catch, NWFSC shelf_slope survey fig:mod1_32_comp_lenfit

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

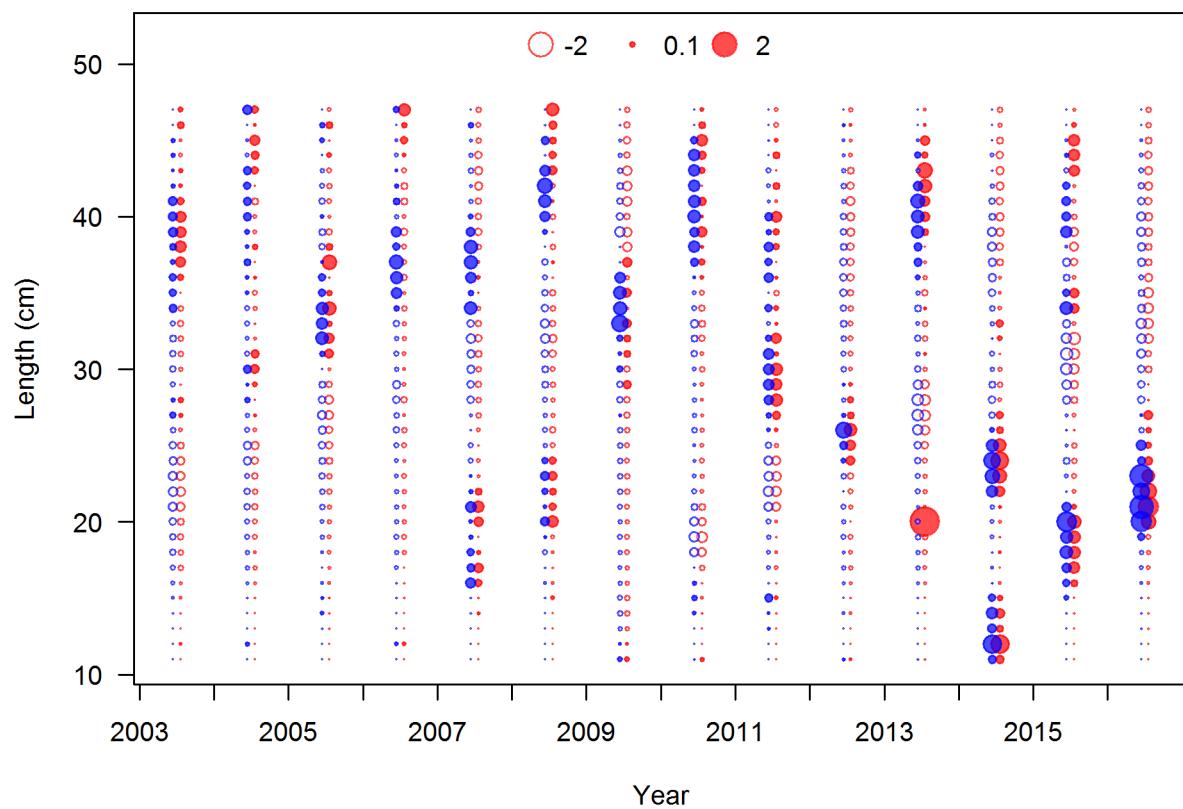


Figure 63: Pearson residuals, whole catch, NWFSC shelf_slope survey (max=2.74)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:mod1_33_comp_lenfit_residsfit8mkt0](#)

N-EffN comparison, Length comps, whole catch, NWFSC shelf-slope survey

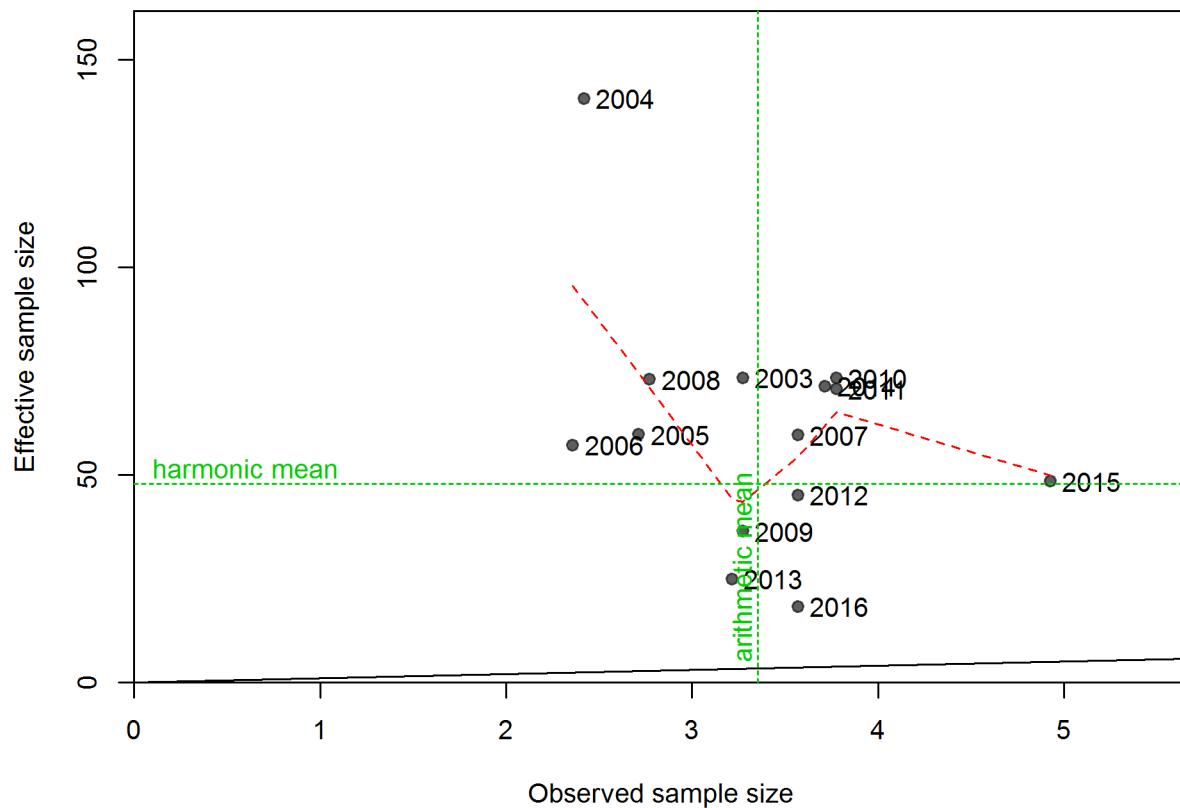


Figure 64: N_EffN comparison, Length comps, whole catch, NWFSC shelf_slope survey fig:mod1_34_c

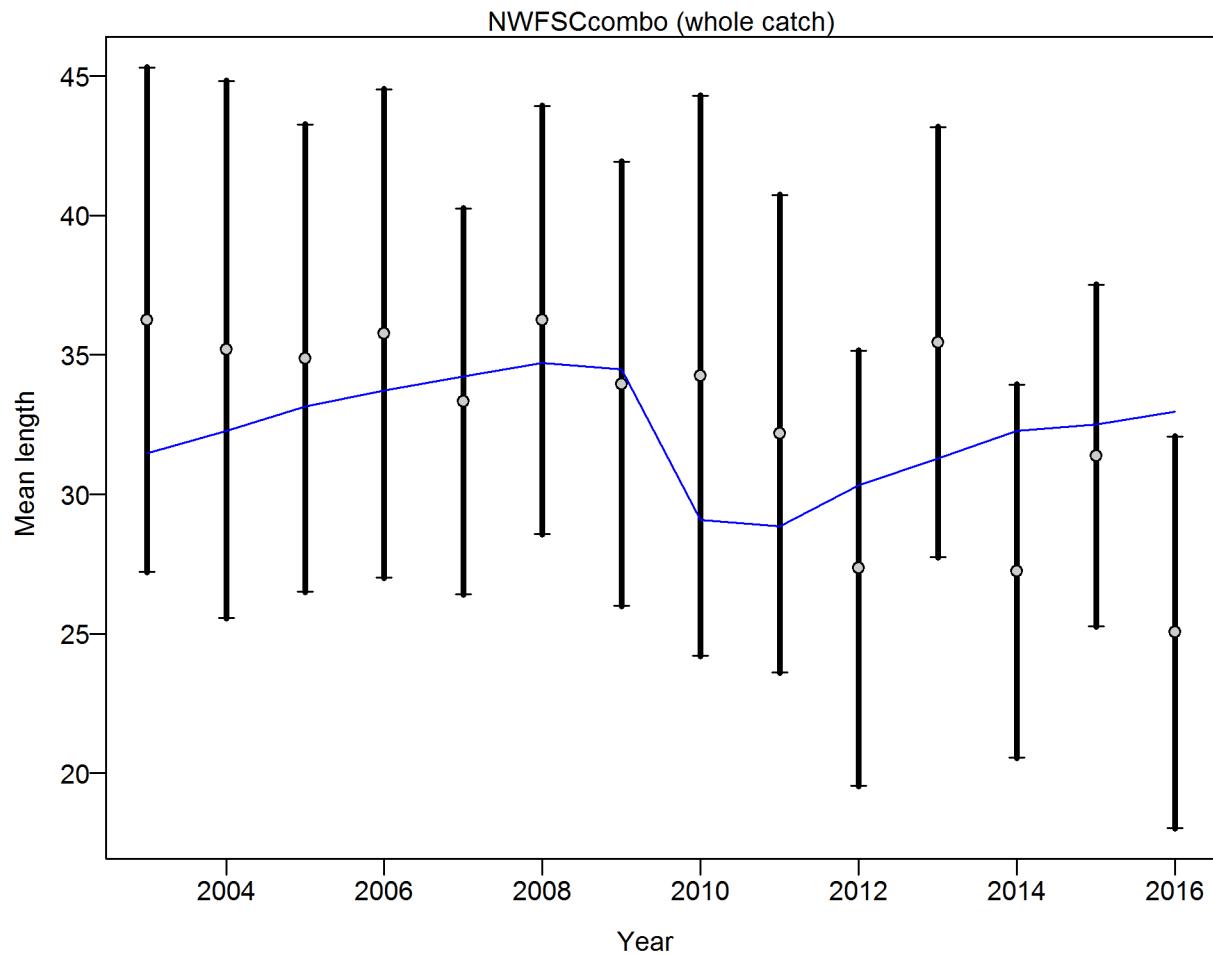


Figure 65: Francis data weighting method TA1.8: NWFSC shelf_slope survey Suggested sample size adjustment (with 95% interval) for len data from NWFSC shelf_slope survey: 1.0055 (0.5865_3.8836) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:mod1_35_comp](#)

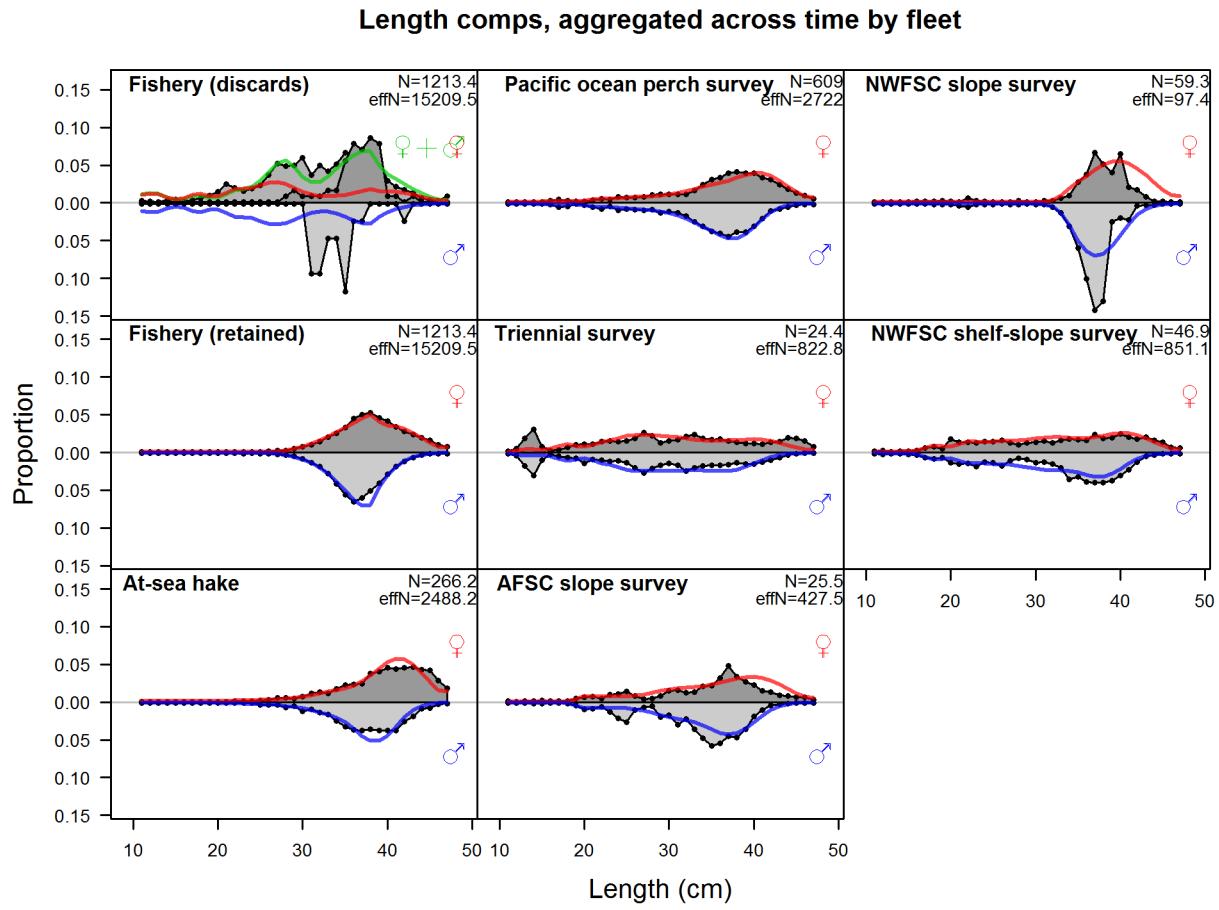


Figure 66: Length comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. [fig:mod1_36_comp_lenfit_aggregated_across_time](#)

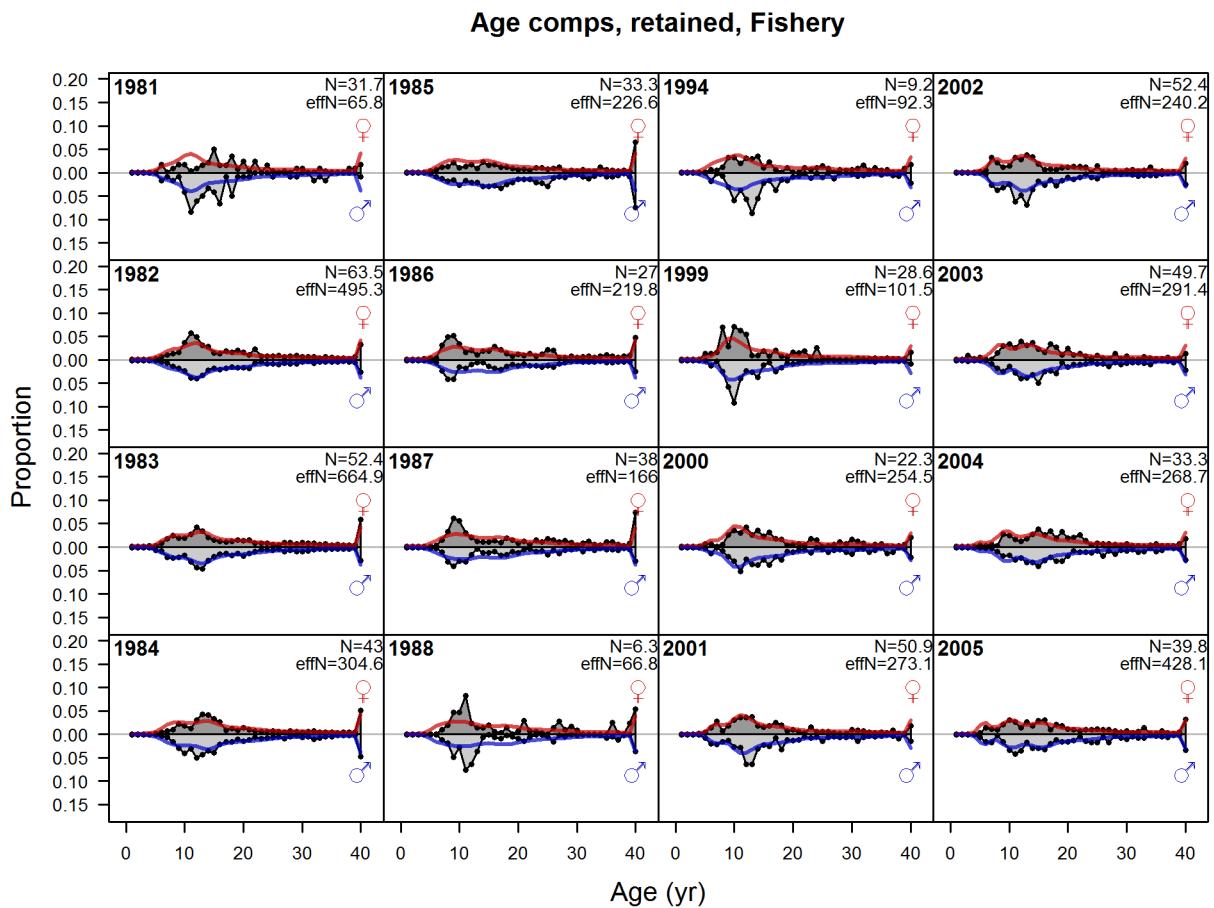


Figure 67: Age comps, retained, Fishery (plot 1 of 2) fig:mod1_1_comp_agefit_flt1mk

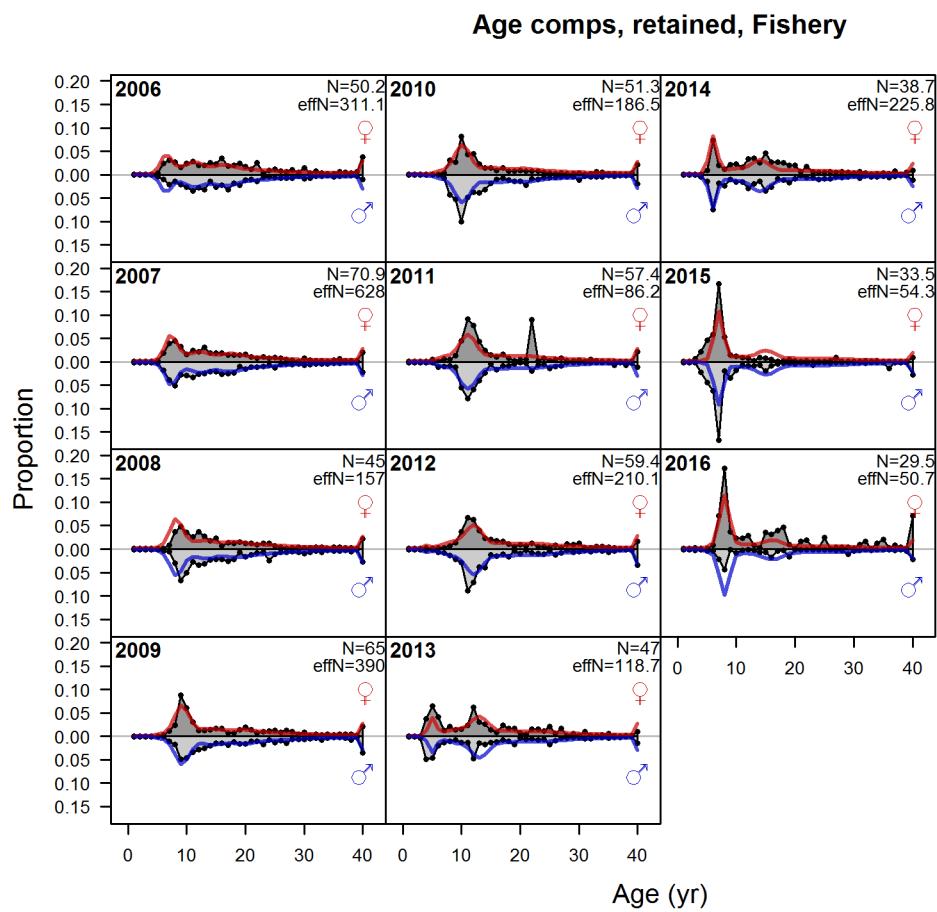


Figure 68: Age comps, retained, Fishery (plot 1 of 2) (plot 2 of 2) `fig:mod1_2_comp_agefit_f`

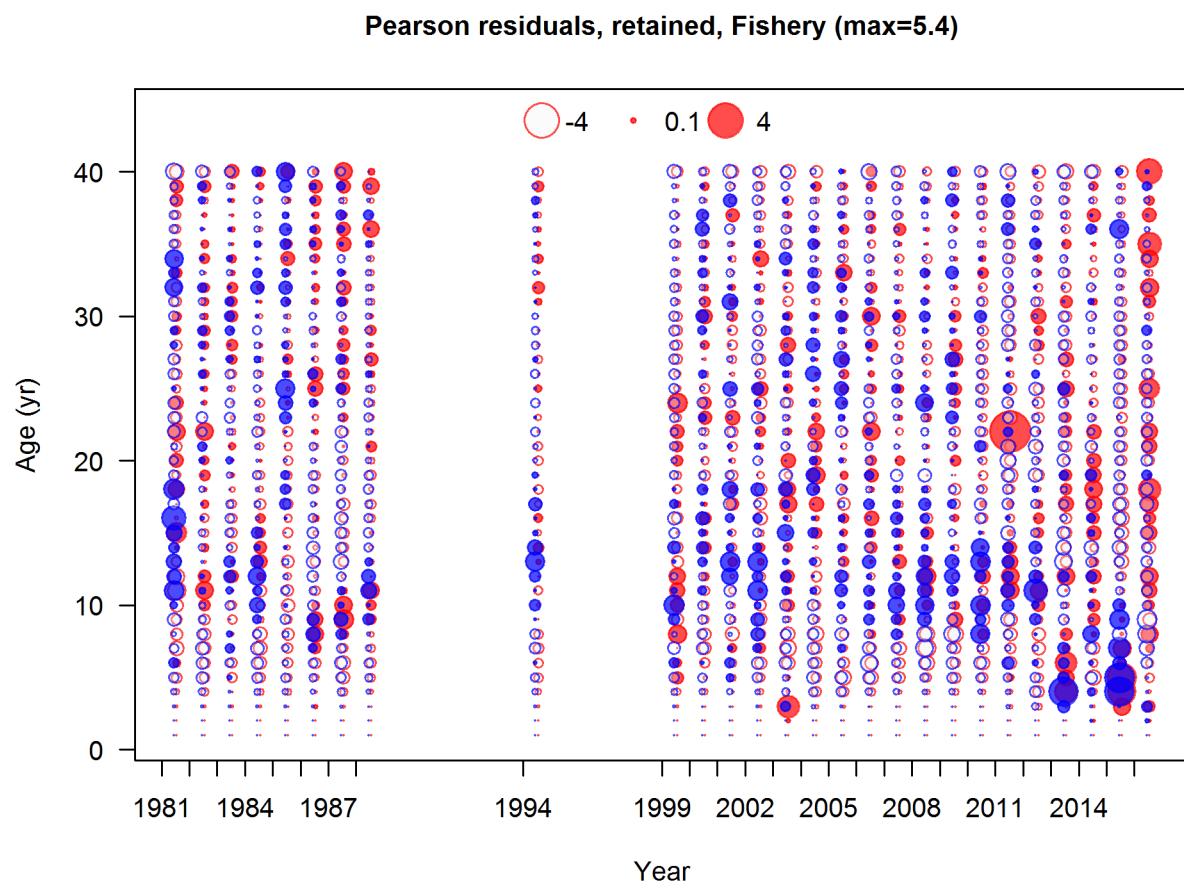


Figure 69: Pearson residuals, retained, Fishery (max=5.4) (plot 2 of 2)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:mod1_3_comp_agefit_residsfit1mkt2_page2](#)

N-EffN comparison, Age comps, retained, Fishery

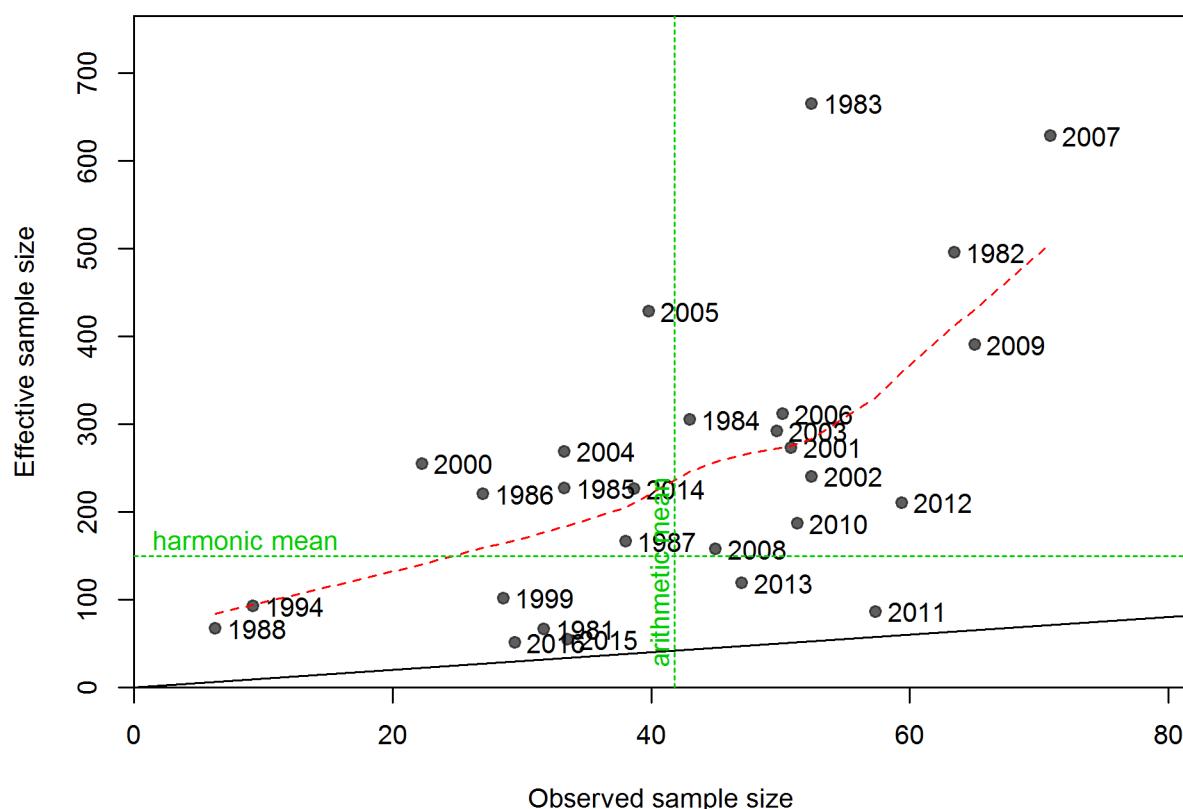


Figure 70: N_EffN comparison, Age comps, retained, Fishery fig:mod1_4_comp_ägefit_sam

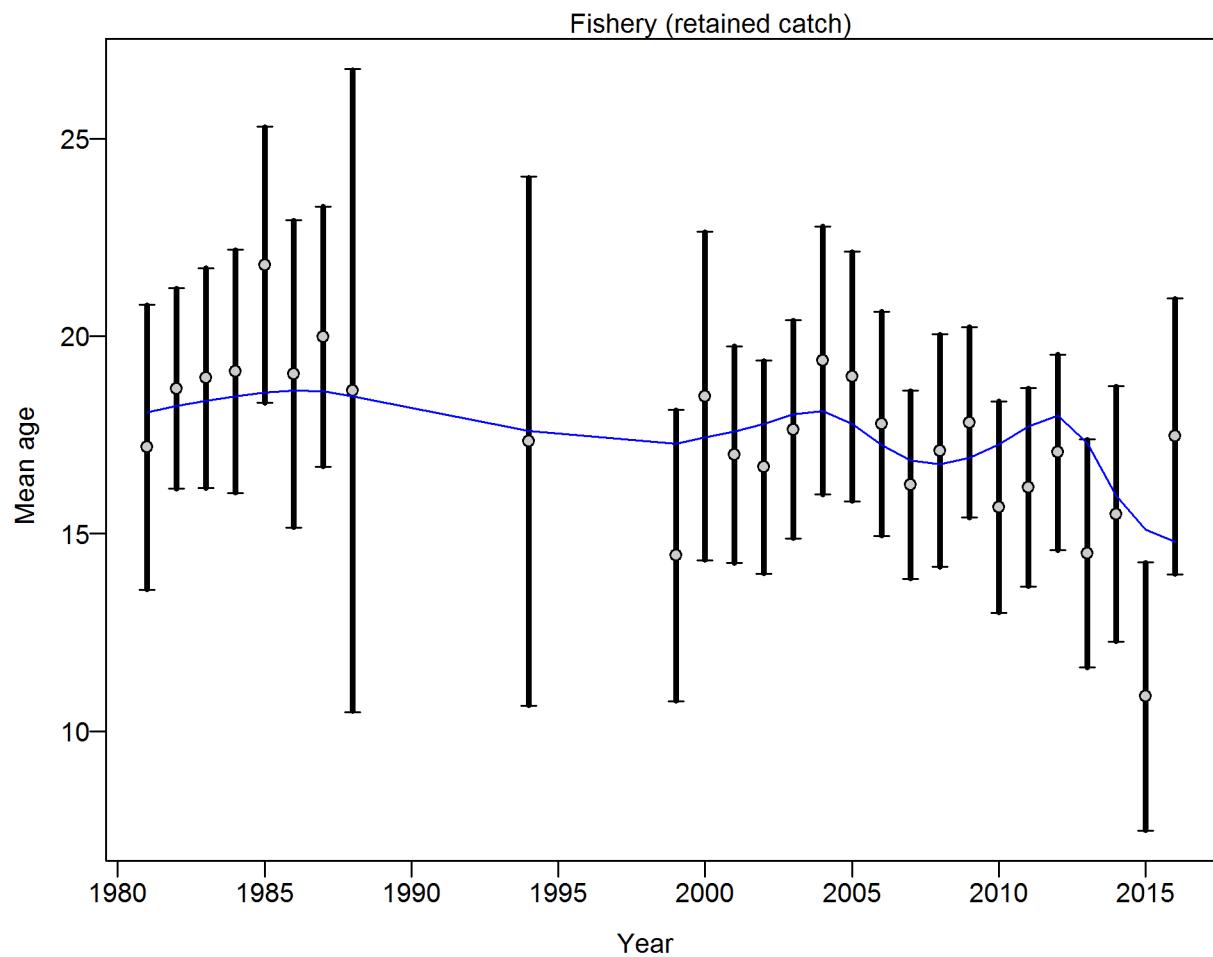


Figure 71: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for age data from Fishery: 0.9921 (0.6443_1.9072) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Can. J. Fish. Aquat. Sci.* 68: 1124_1138. [fig:mod1_5_comp_agefit_data_weighting_TA1.8_Fishery](#)

Age comps, whole catch, At-sea hake

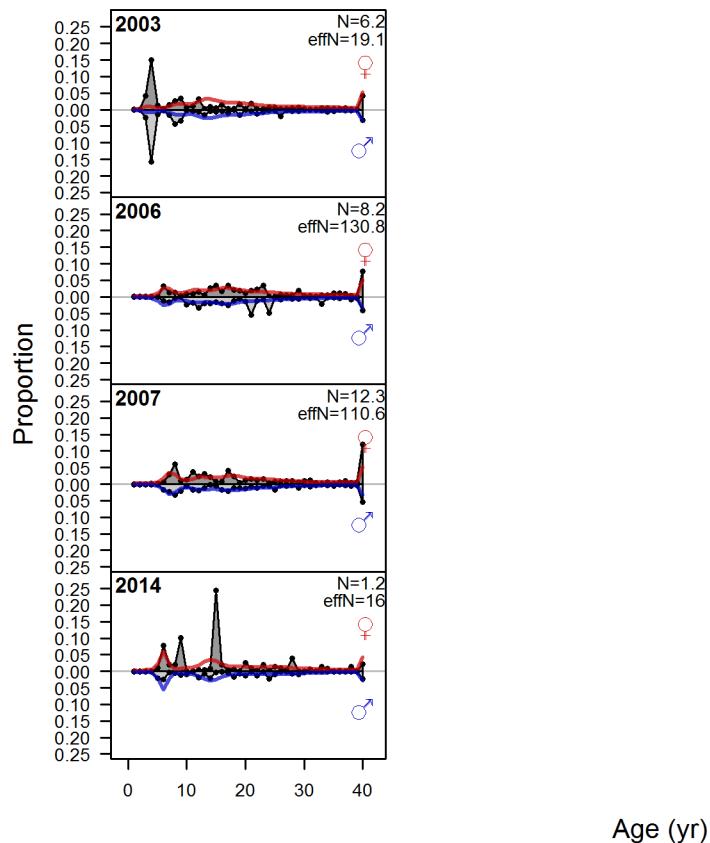


Figure 72: Age comps, whole catch, At-sea hake | [fig:mod1_6_comp_agefit_flt2mkt0](#)

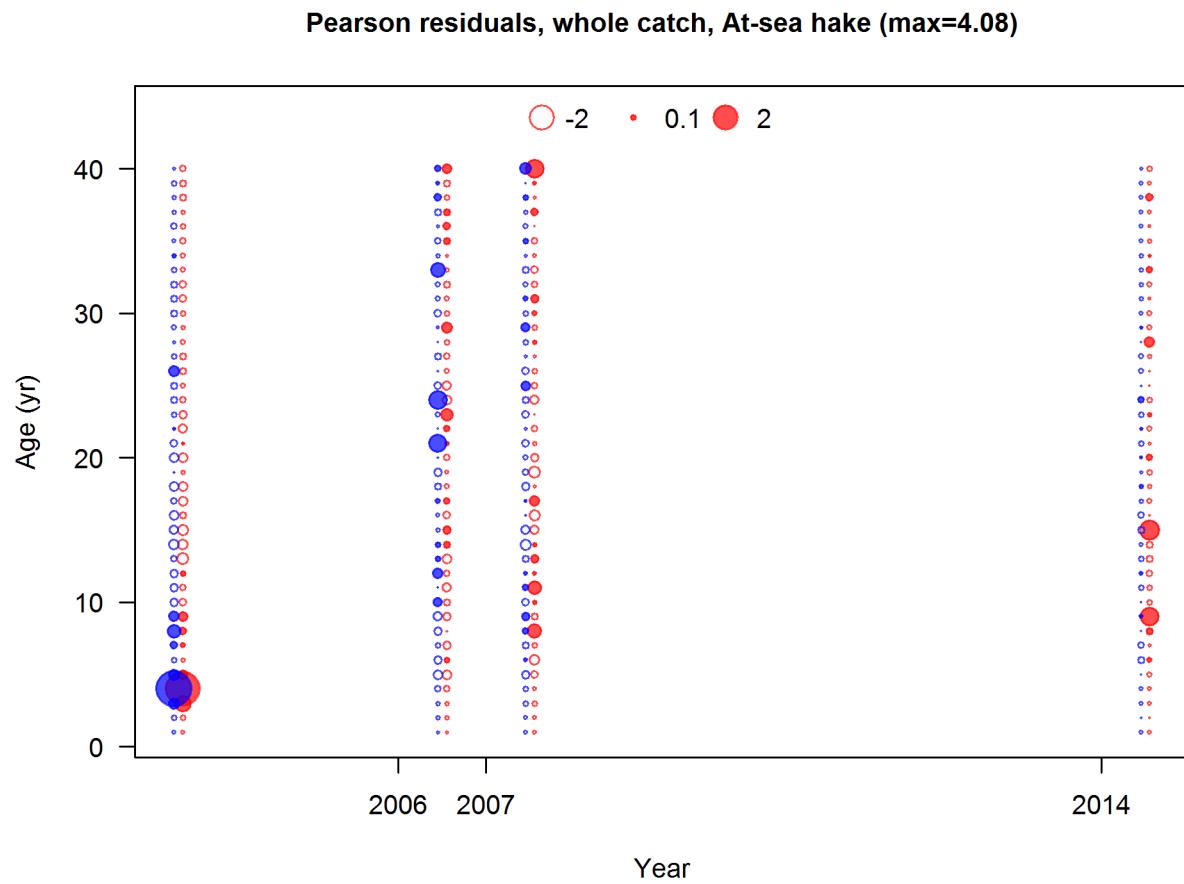


Figure 73: Pearson residuals, whole catch, At_sea hake (max=4.08)
 Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:mod1_7_comp_agefit_residsfit2mkt0](#)

N-EffN comparison, Age comps, whole catch, At-sea hake

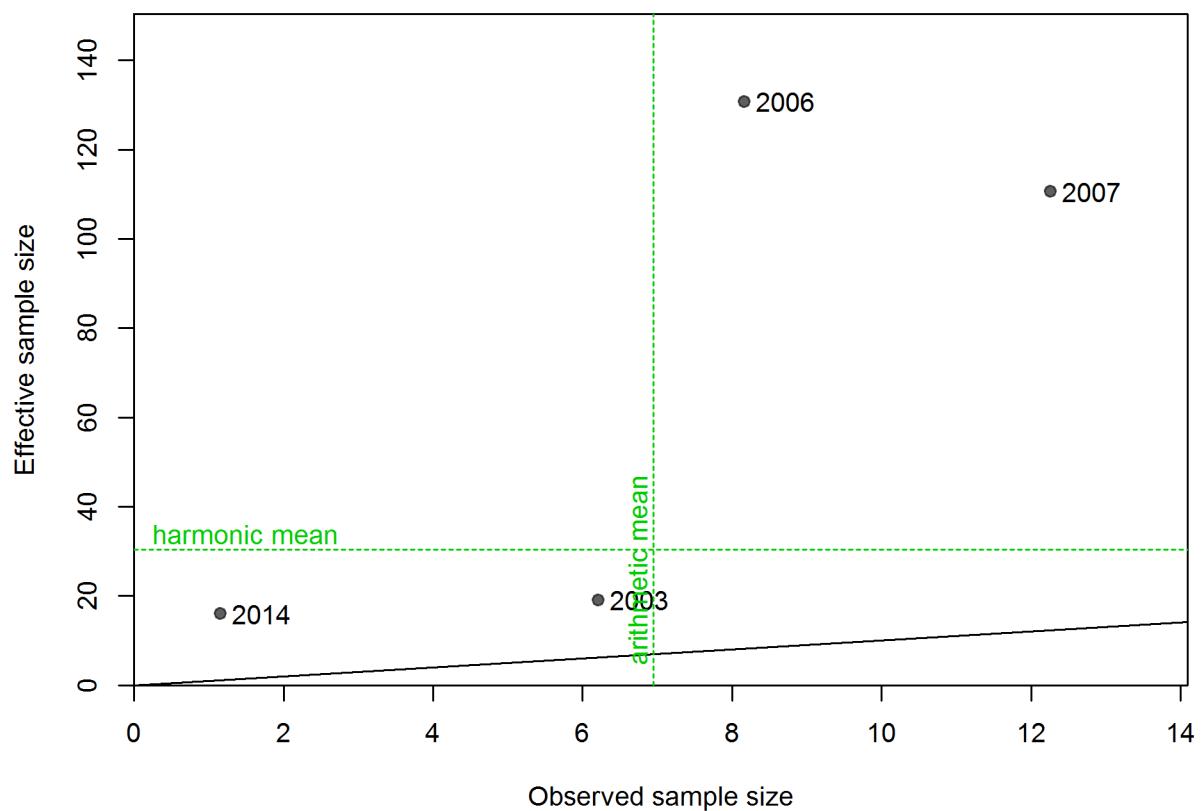


Figure 74: N_EffN comparison, Age comps, whole catch, At_sea hake fig:mod1_8_comp_agefit

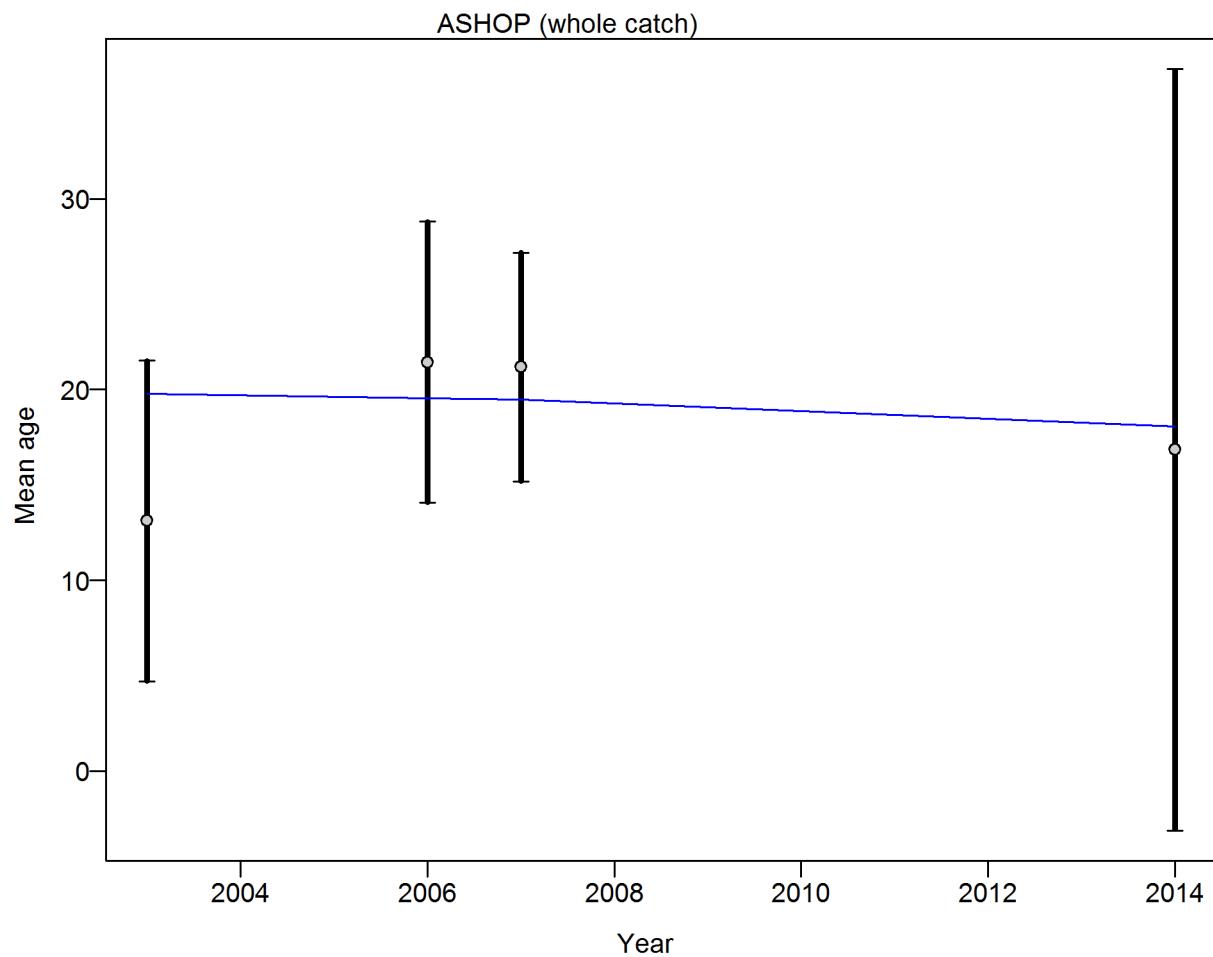
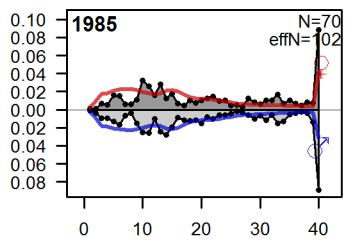


Figure 75: Francis data weighting method TA1.8: At_sea hake Suggested sample size adjustment (with 95% interval) for age data from At_sea hake: 0.9921 (0.6619_1420.3157)
 For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. [fig:mod1_9_comp_agefit_data_weighting_T](#)

Proportion

Age comps, whole catch, Pacific ocean perch survey



Age (yr)

Figure 76: Age comps, whole catch, Pacific ocean perch survey `fig:mod1_10_comp_agefit_f`

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

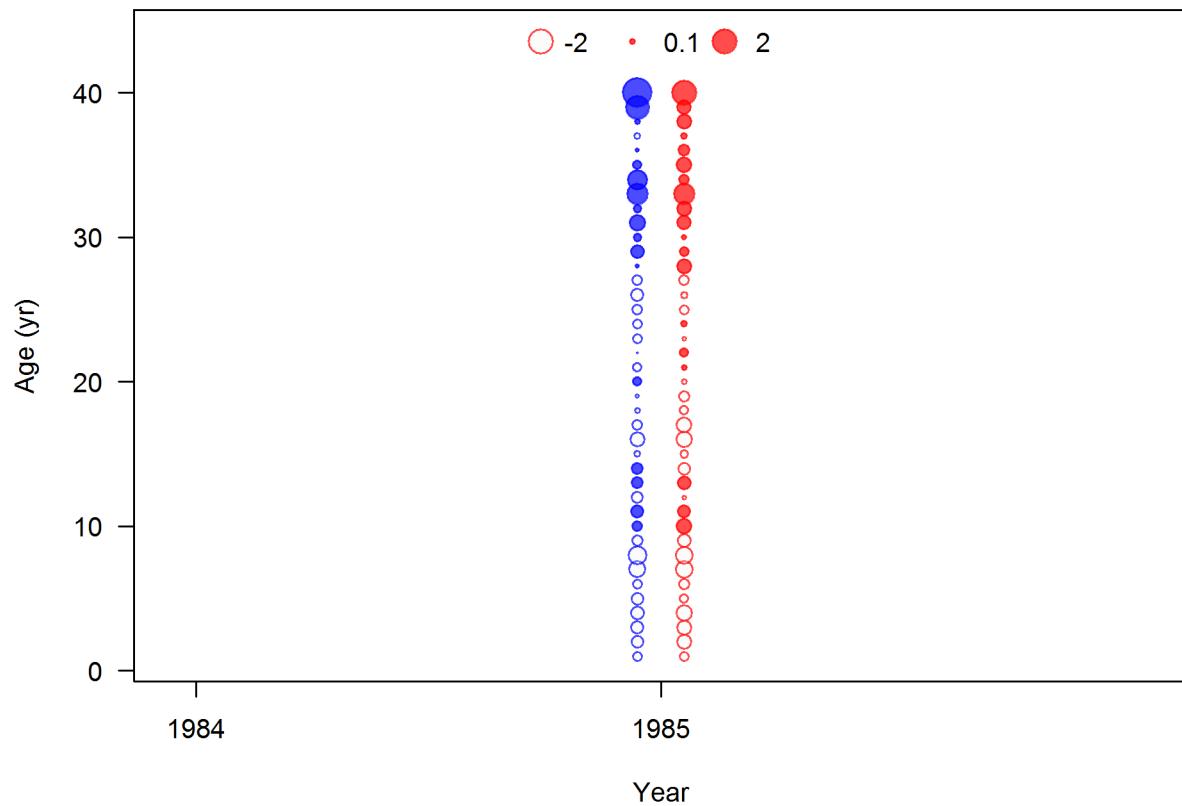


Figure 77: Pearson residuals, whole catch, Pacific ocean perch survey (max=2.76)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). [fig:mod1_11_comp_agefit_residsfit4mkt0](#)

N-EffN comparison, Age comps, whole catch, Pacific ocean perch survey

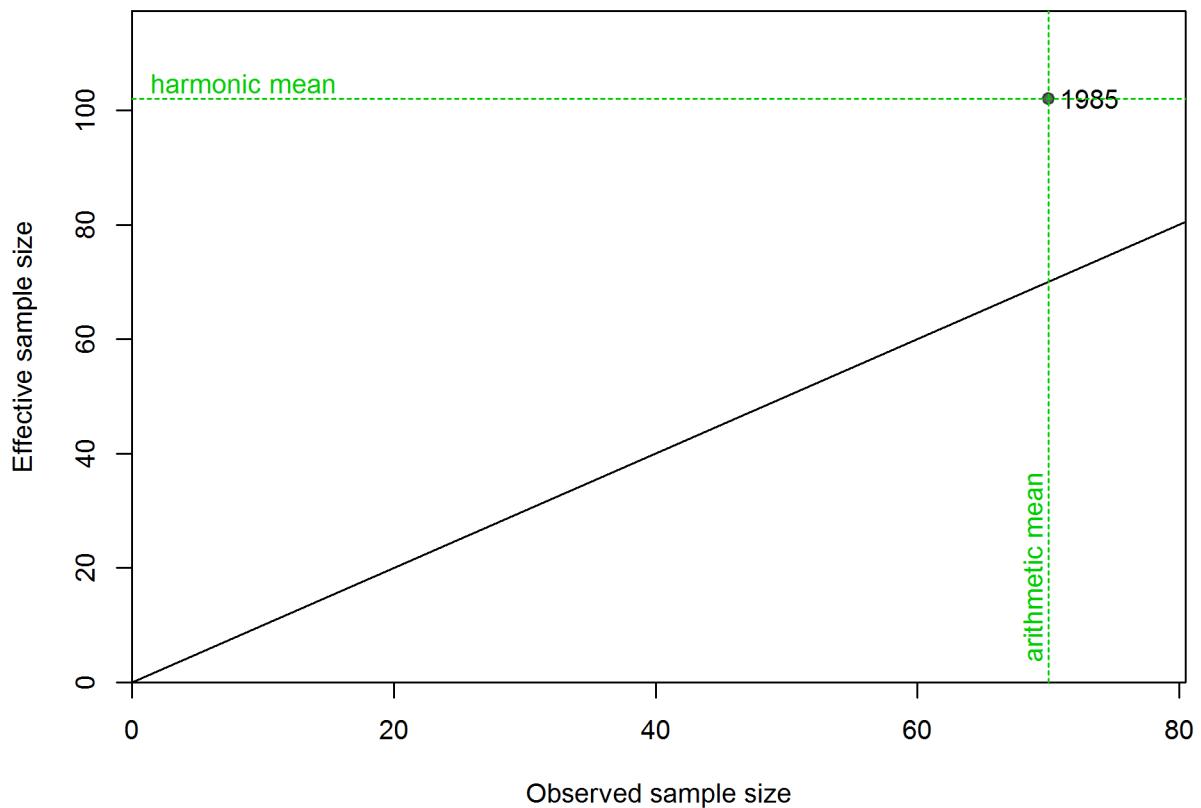
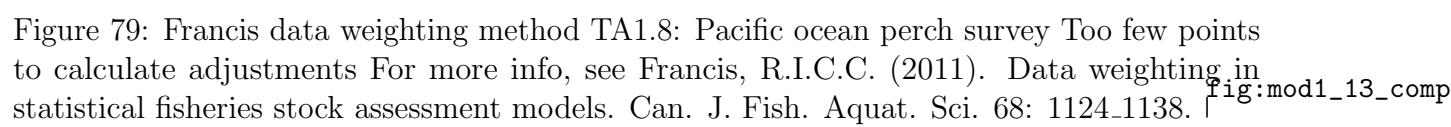


Figure 78: N_EffN comparison, Age comps, whole catch, Pacific ocean perch survey fig:mod1_12_comp

Figure 79: Francis data weighting method TA1.8: Pacific ocean perch survey Too few points to calculate adjustments For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. 

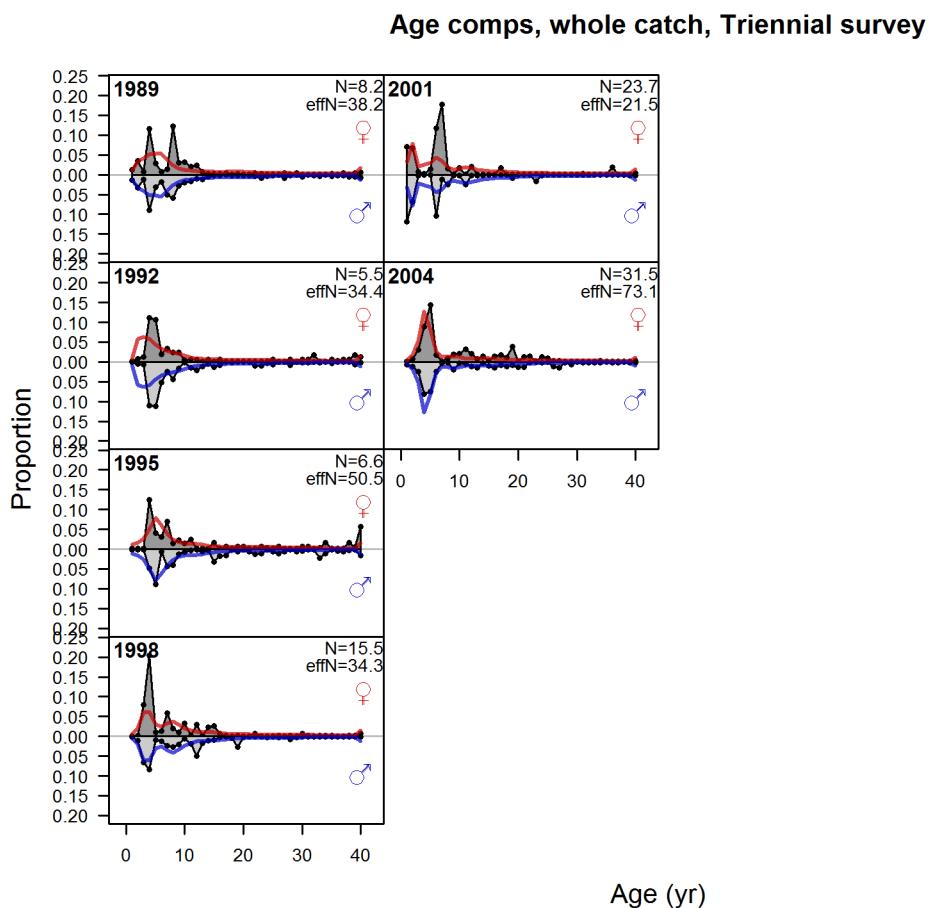


Figure 80: Age comps, whole catch, Triennial survey fig:mod1_14_comp_agefit_flt5mk

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

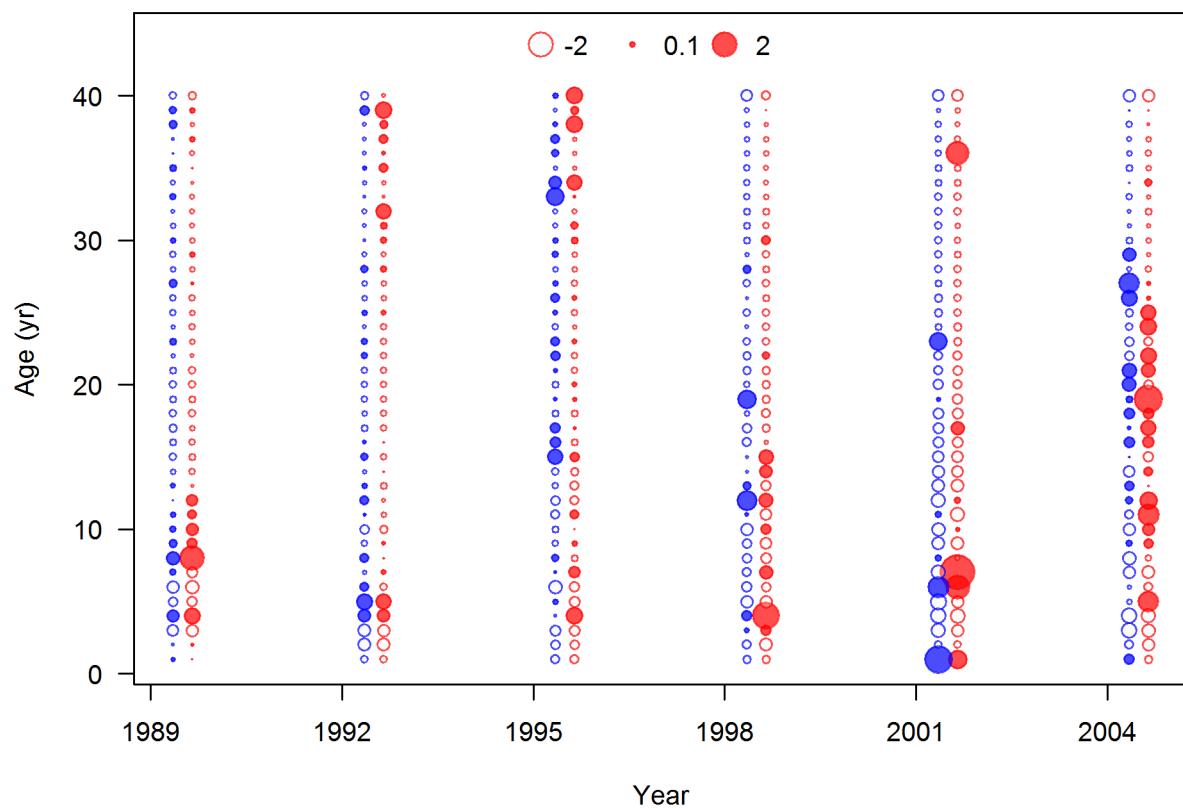


Figure 81: Pearson residuals, whole catch, Triennial survey (max=3.75)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_15_comp_agefit_residsfit5mkt0

N-EffN comparison, Age comps, whole catch, Triennial survey

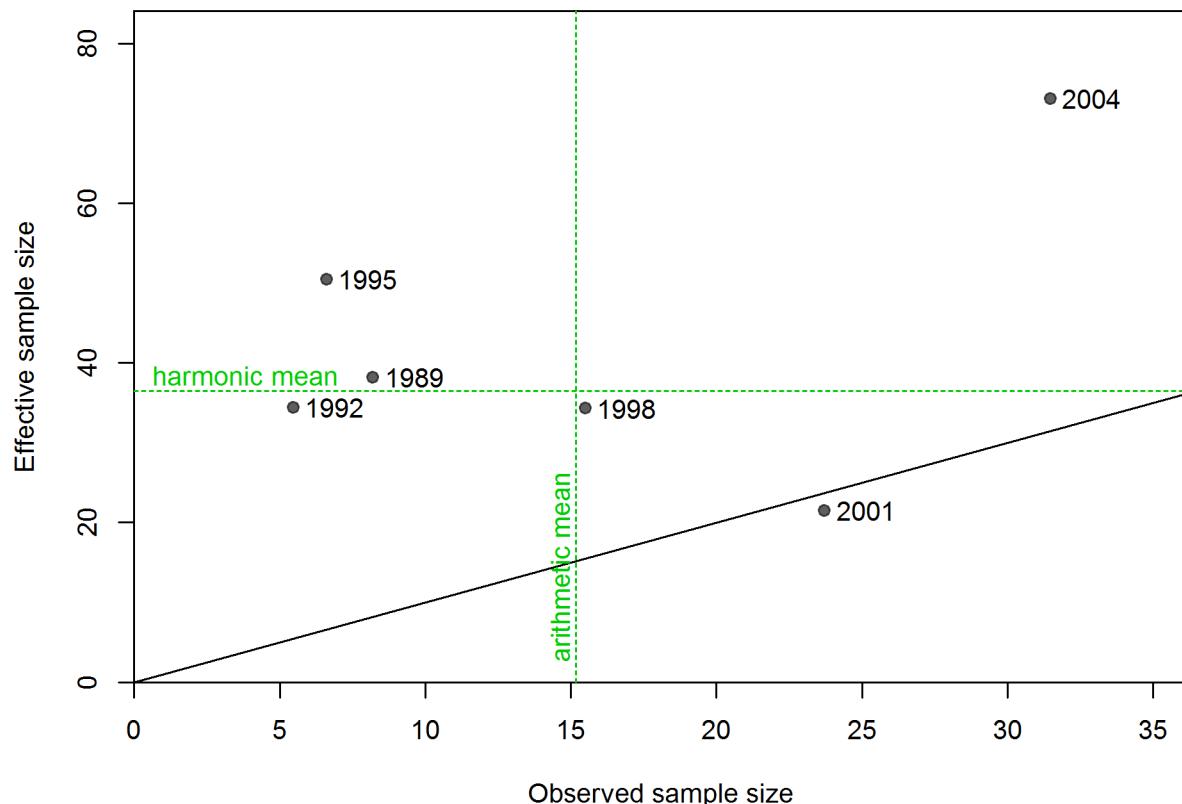


Figure 82: N_EffN comparison, Age comps, whole catch, Triennial survey fig:mod1_16_comp_age

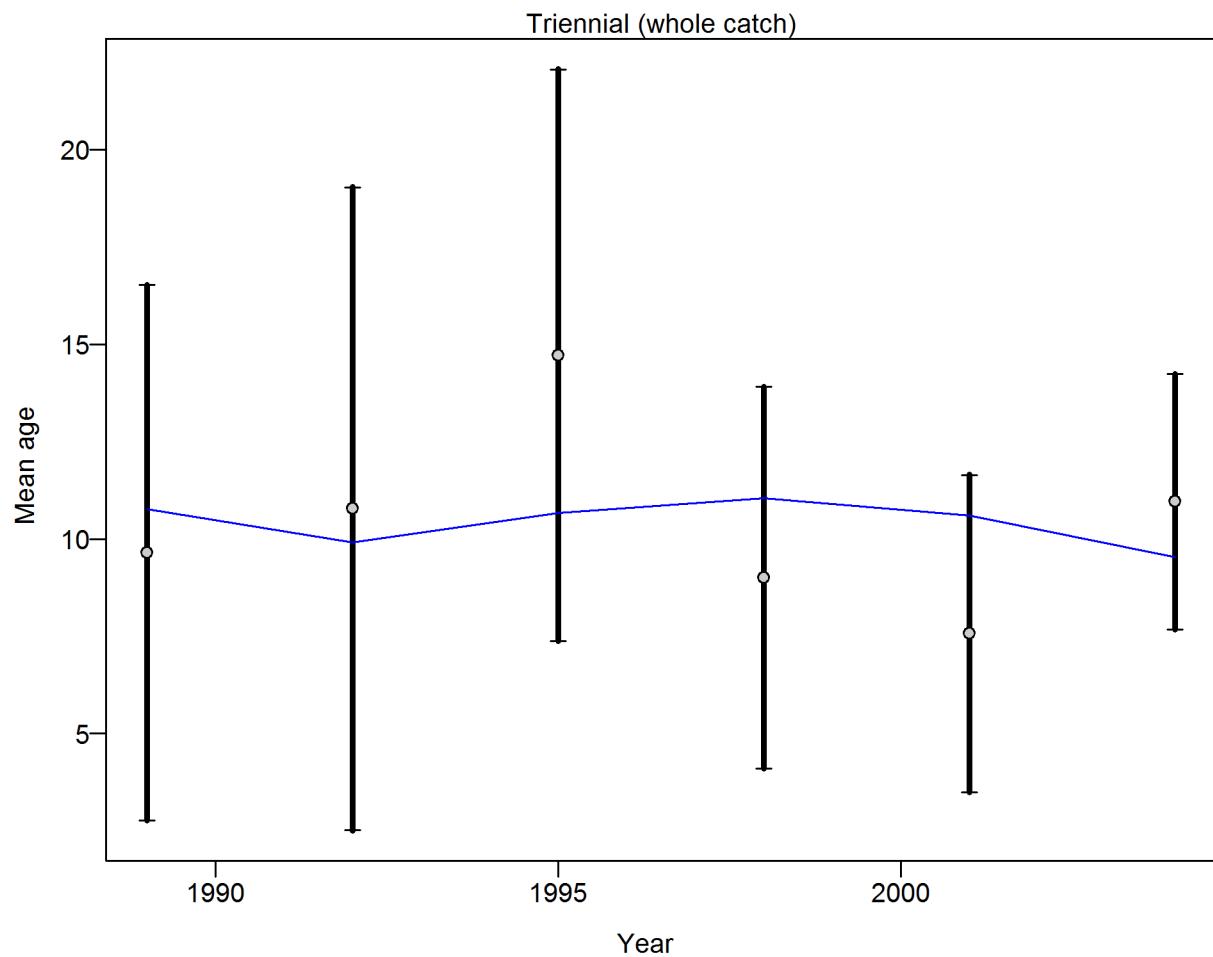


Figure 83: Francis data weighting method TA1.8: Triennial survey Suggested sample size adjustment (with 95% interval) for age data from Triennial survey: 1.0019 (0.648–5.8026)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124–1138. [fig:mod1_17_comp_agefit_data_weighting](#)

Age comps, whole catch, NWFSC slope survey

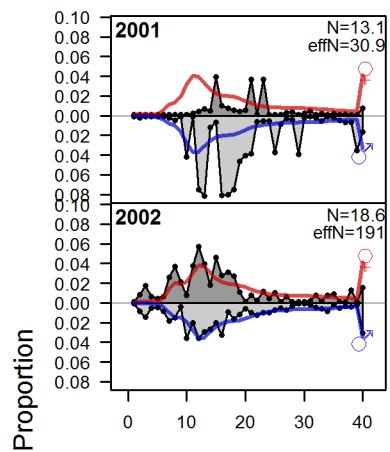


Figure 84: Age comps, whole catch, NWFSC slope survey [fig:mod1_18_comp_agefit_flt](#)

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

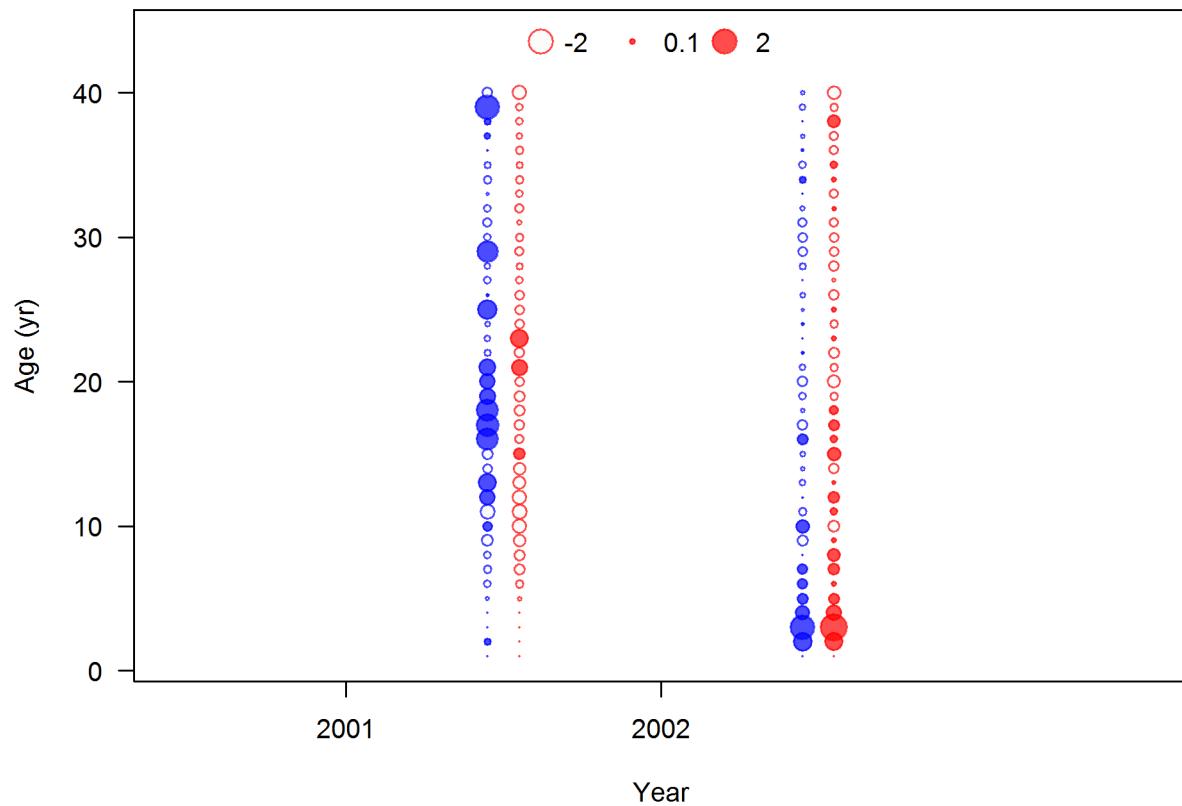


Figure 85: Pearson residuals, whole catch, NWFSC slope survey (max=2.34)
Closed bubbles are positive residuals (observed $>$ expected) and open bubbles are negative residuals (observed $<$ expected). [fig:mod1_19_comp_agefit_residsfit7mkt0](#)

N-EffN comparison, Age comps, whole catch, NWFSC slope survey

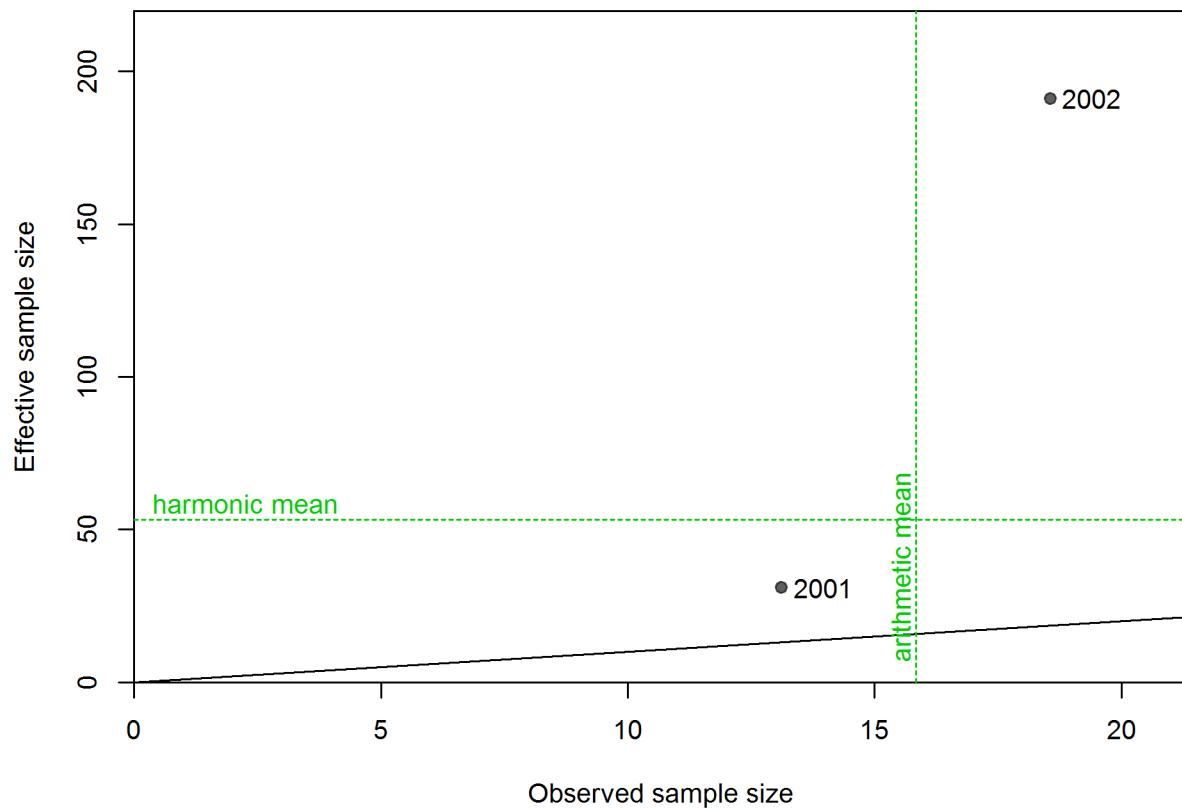


Figure 86: N_EffN comparison, Age comps, whole catch, NWFSC slope survey | [fig:mod1_20_comp_a](#)

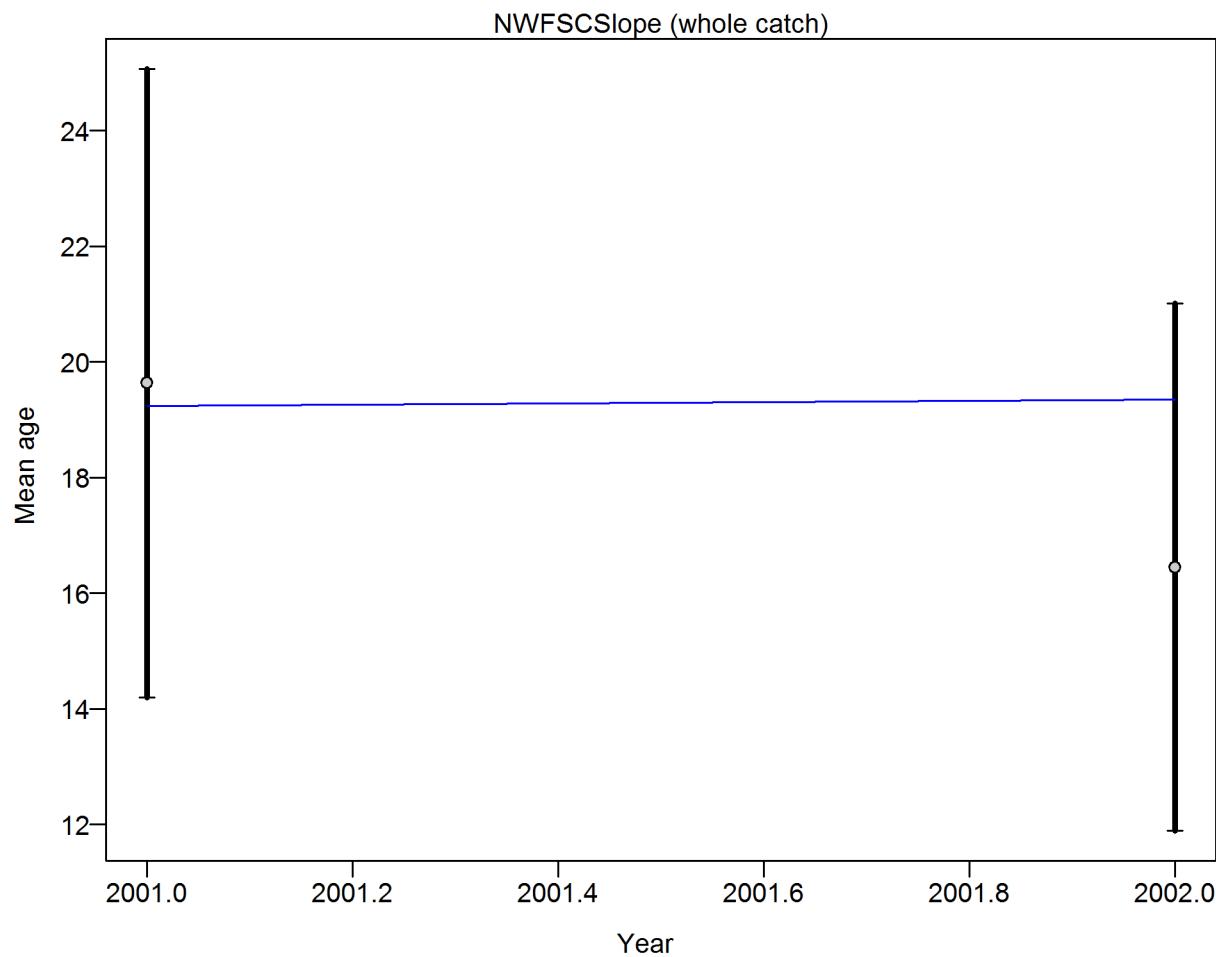


Figure 87: Francis data weighting method TA1.8: NWFSC slope survey Suggested sample size adjustment (with 95% interval) for age data from NWFSC slope survey: 0.9998 (0.9998_Inf)
For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138. [fig:mod1_21_comp_agefit_data_weighting](#)

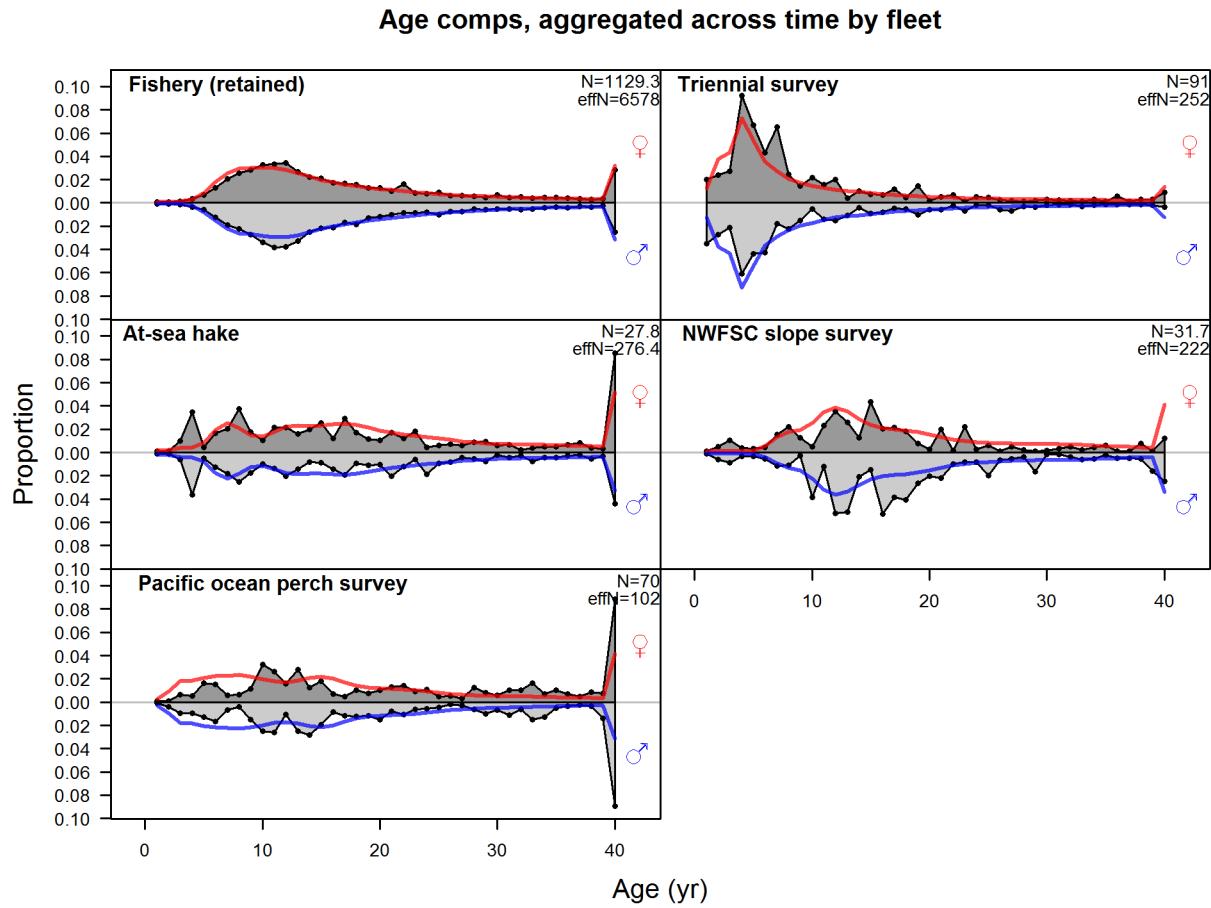


Figure 88: Age comps, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch.

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

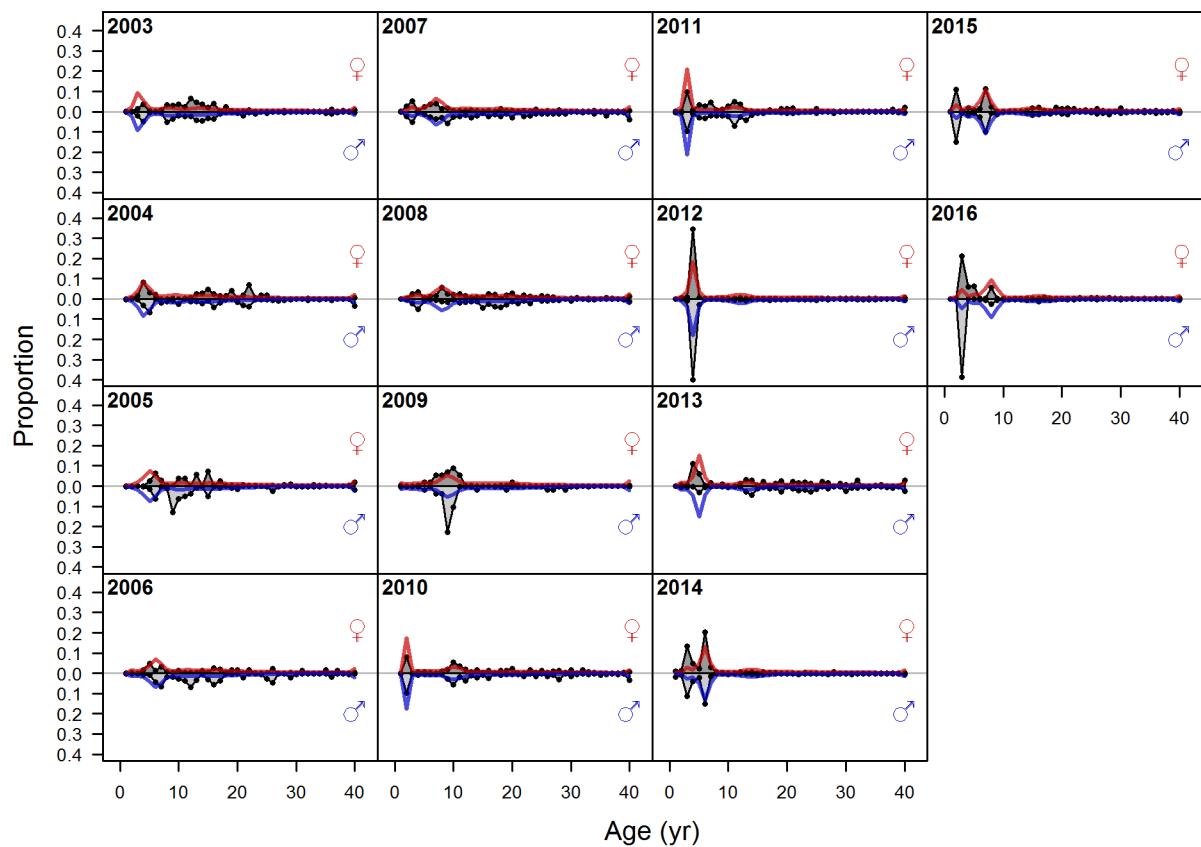


Figure 89: Ghost age comps, whole catch, NWFSC shelf_slope survey `fig:mod1_23_comp_gstags`

Figure 90: Pearson residuals, whole catch, NWFSC shelf_slope survey (max=NA)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative
residuals (observed < expected). 

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

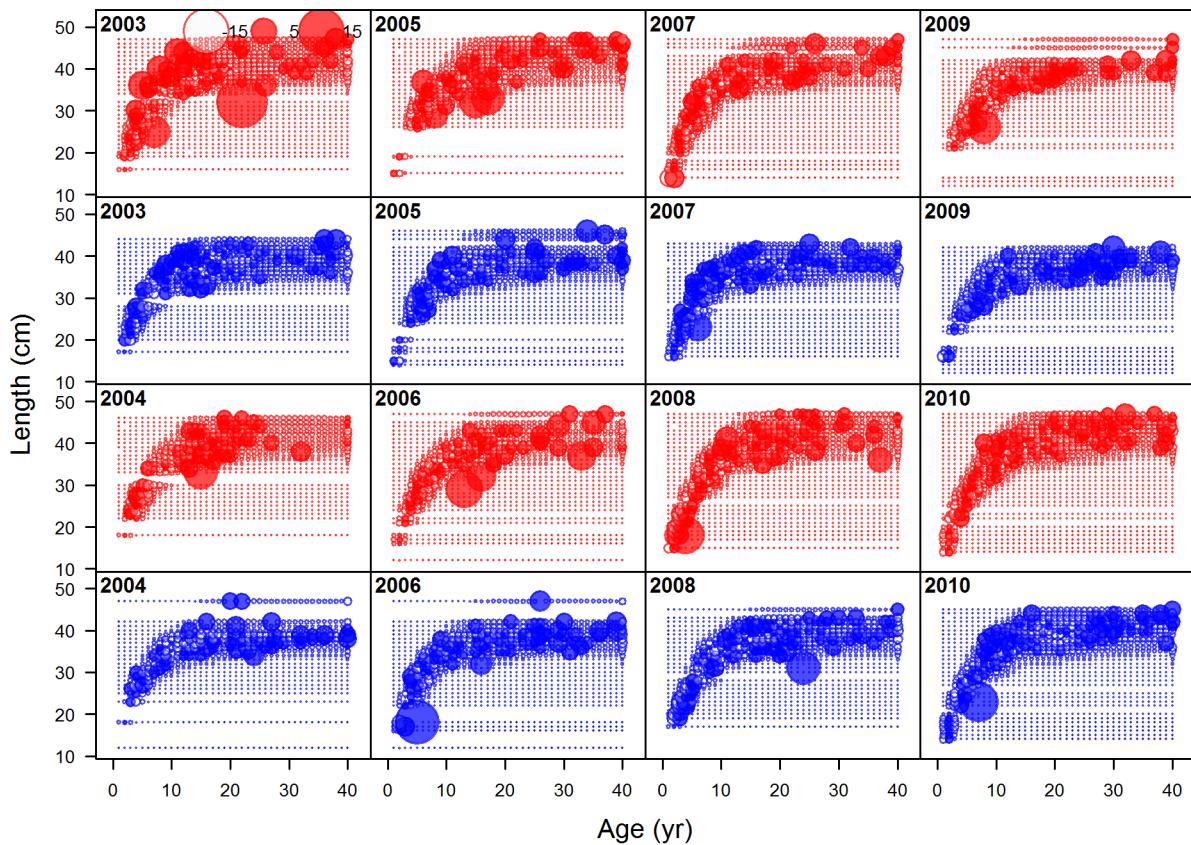


Figure 91: Pearson residuals, whole catch, NWFSC shelf-slope survey (max=18.49) (plot 1 of 2) | [fig:mod1_1_comp_condAALfit_residsflt8mkt0_page1](#)

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

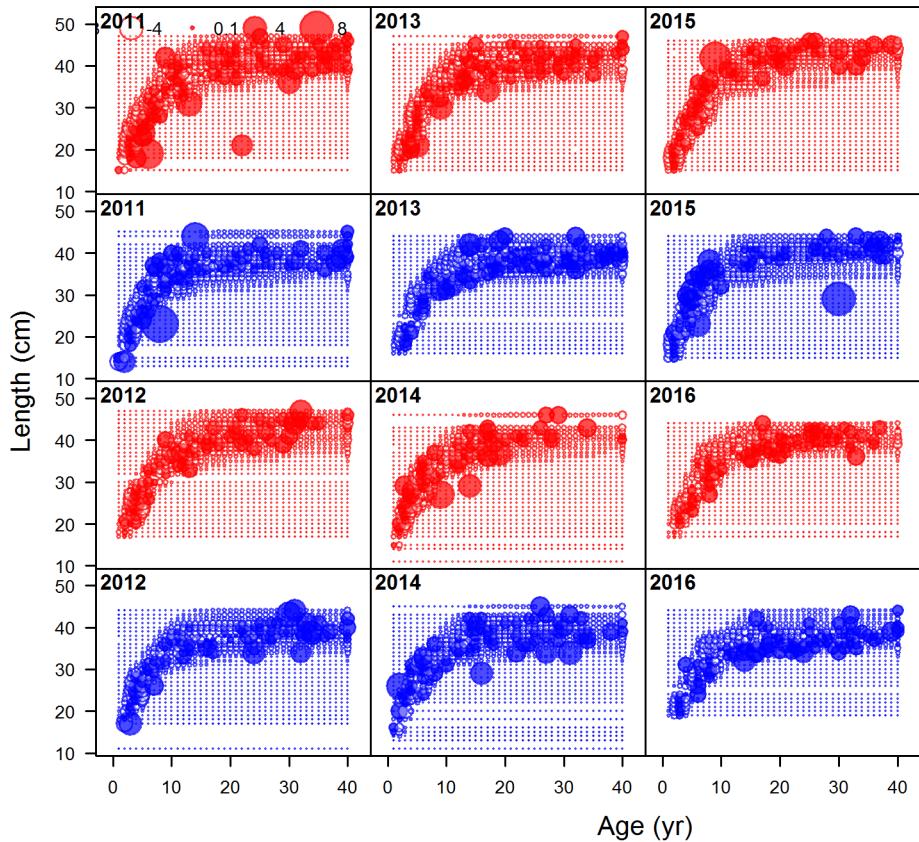


Figure 92: Pearson residuals, whole catch, NWFSC shelf-slope survey (max=18.49) (plot 1 of 2) (plot 2 of 2) | [fig:mod1_2_comp_condAALfit_residsflt8mkt0_page2](#)

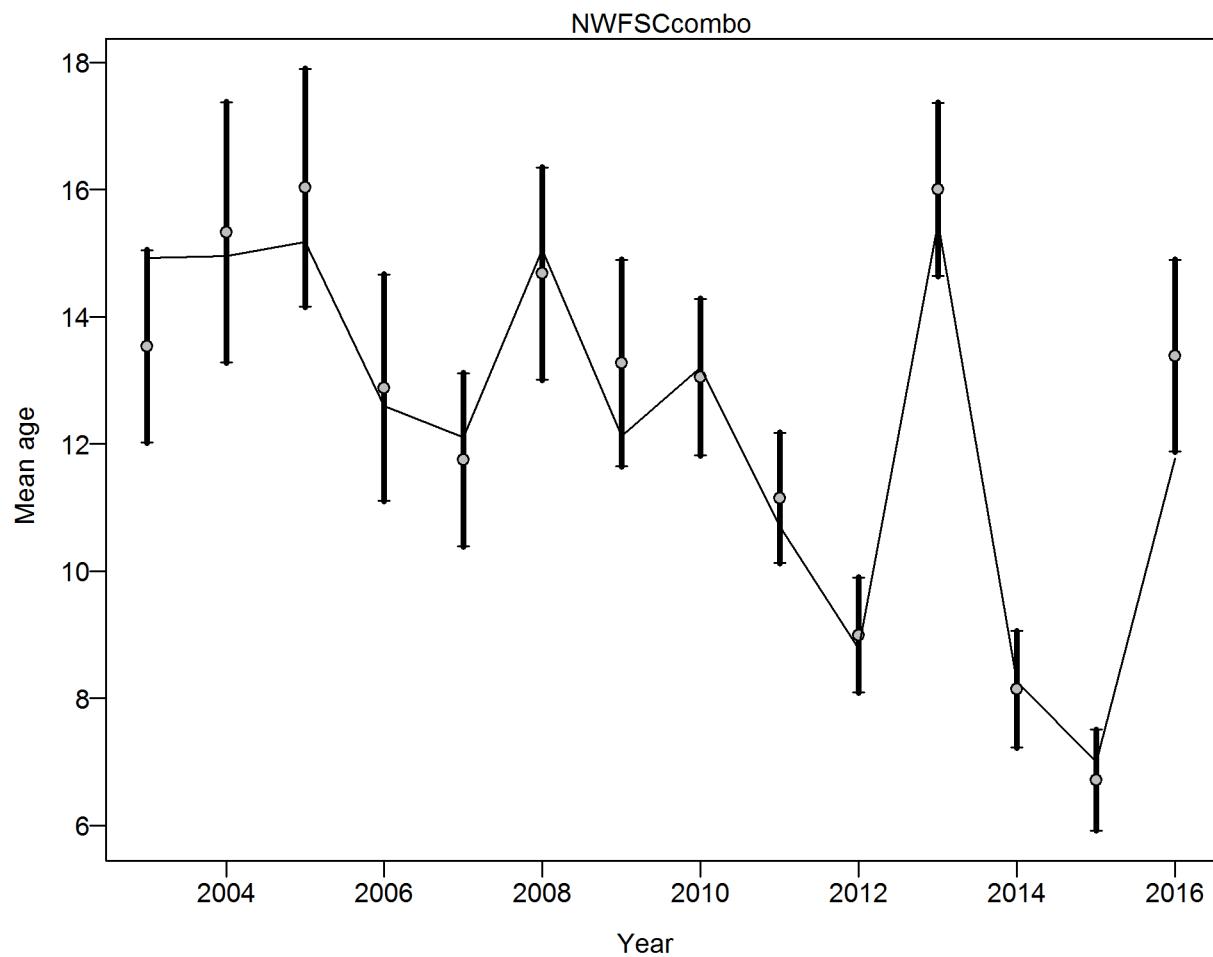


Figure 93: Francis data weighting method TA1.8 for conditional age [data:NWFSC](#) shelf_slope survey Suggested sample size adjustment (with 95% interval) for conditional age_at_length data from NWFSC shelf_slope survey: 1.0131 (0.5772_2.8579) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Can. J. Fish. Aquat. Sci.* 68: 1124_1138. | [fig:mod1_3_comp_condAALfit_data_weighting_TA1.8_condAgeNWFSC_shelf-slope](#)

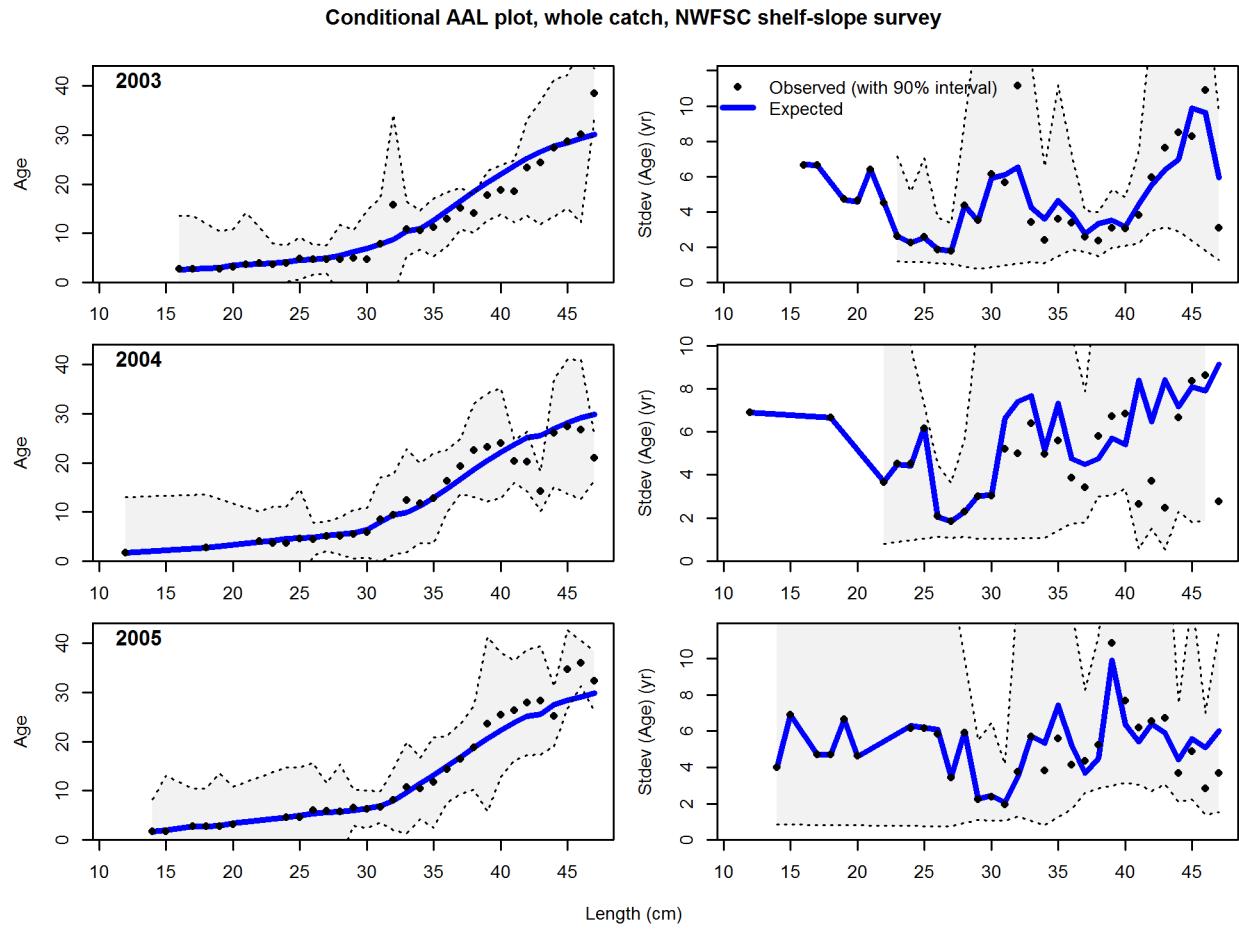


Figure 94: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 1 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution. `fig:mod1_4_comp_condAALfitAndre_plotsf1t8mkt0_page1`

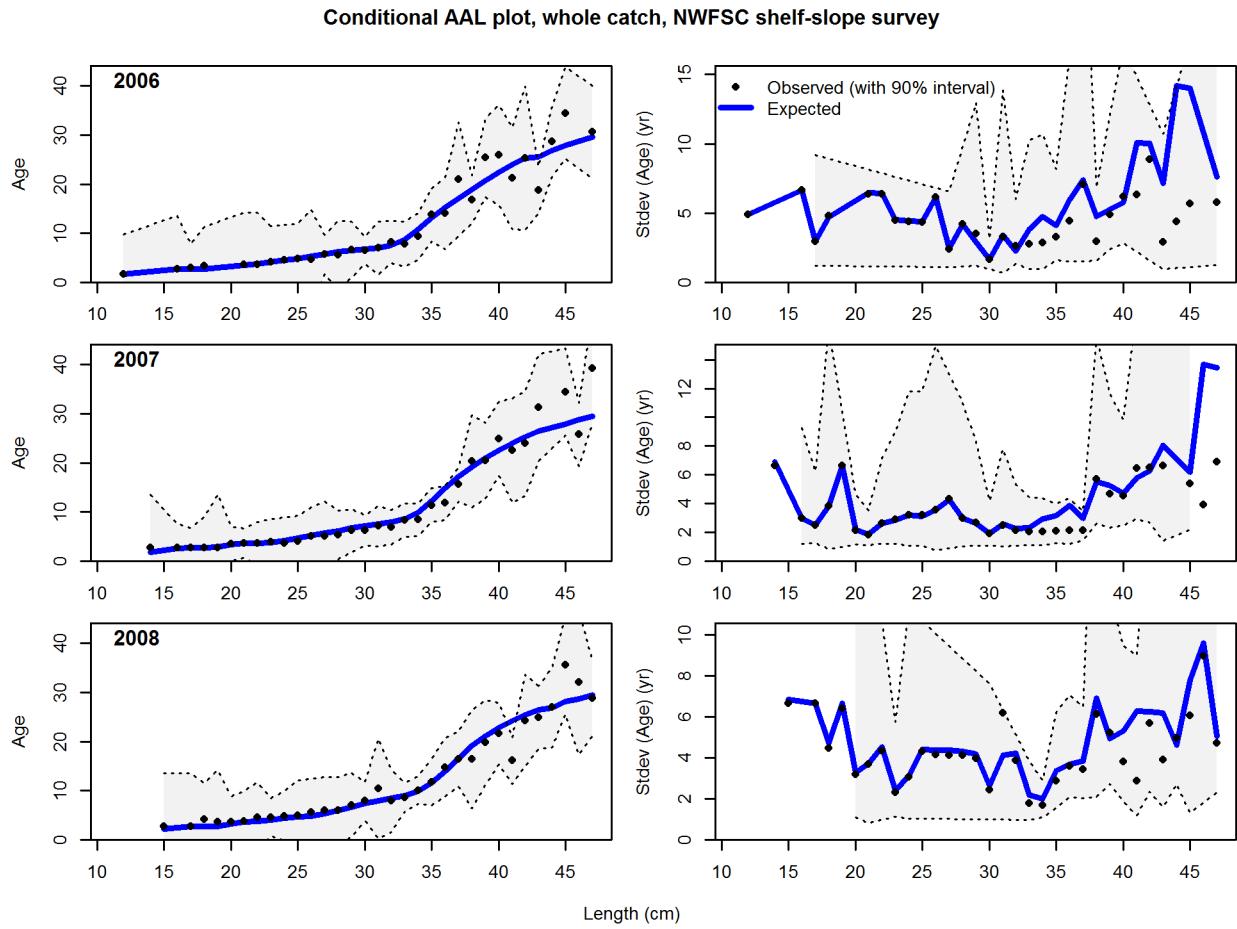


Figure 95: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 2 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution. | [fig:mod1_5_comp_condAALfitAndre_plotsflt8mkt0_page2](#)

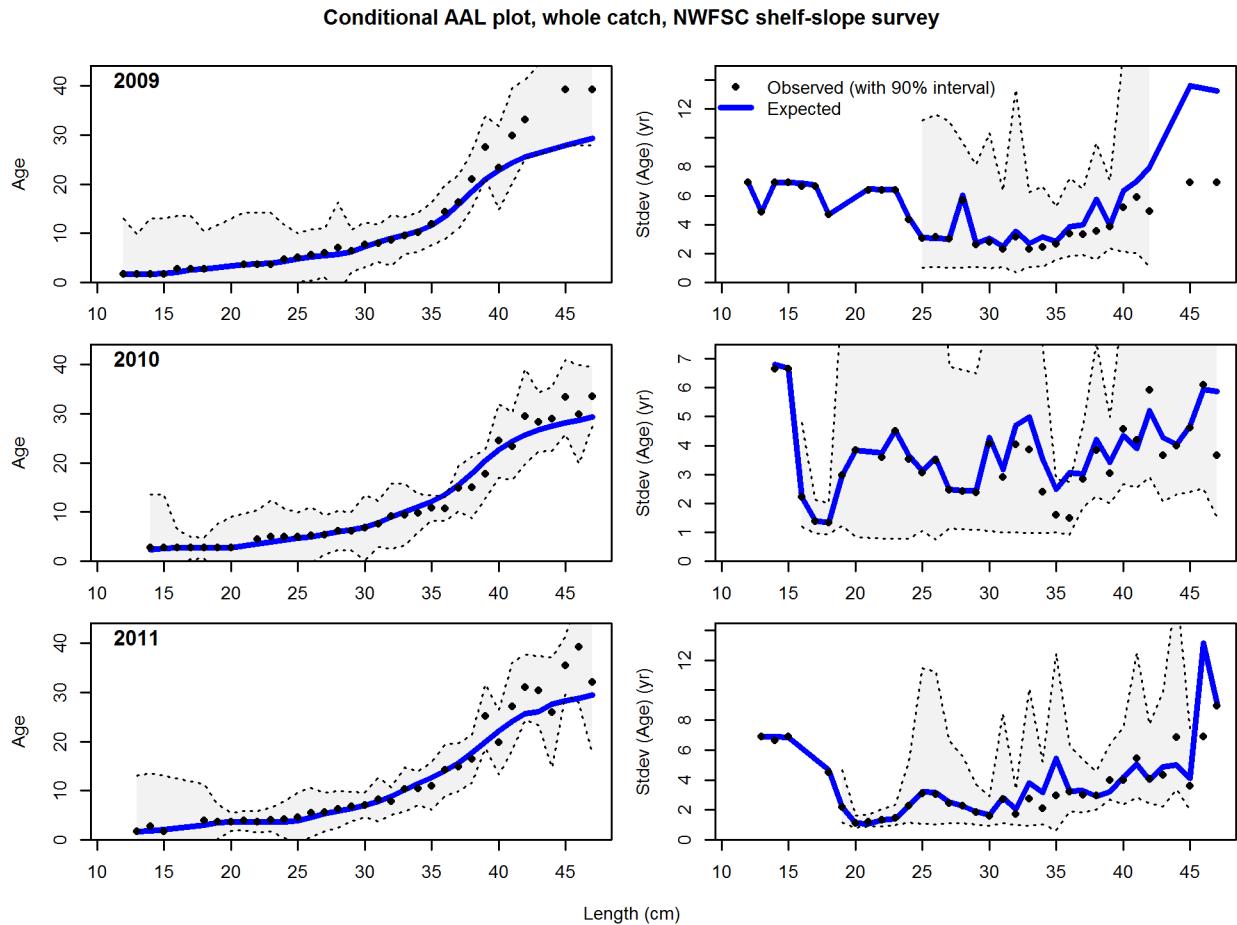


Figure 96: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 3 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution. [fig:mod1_6_comp_condAALfitAndre_plotsflt8mkt0_page3](#)

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

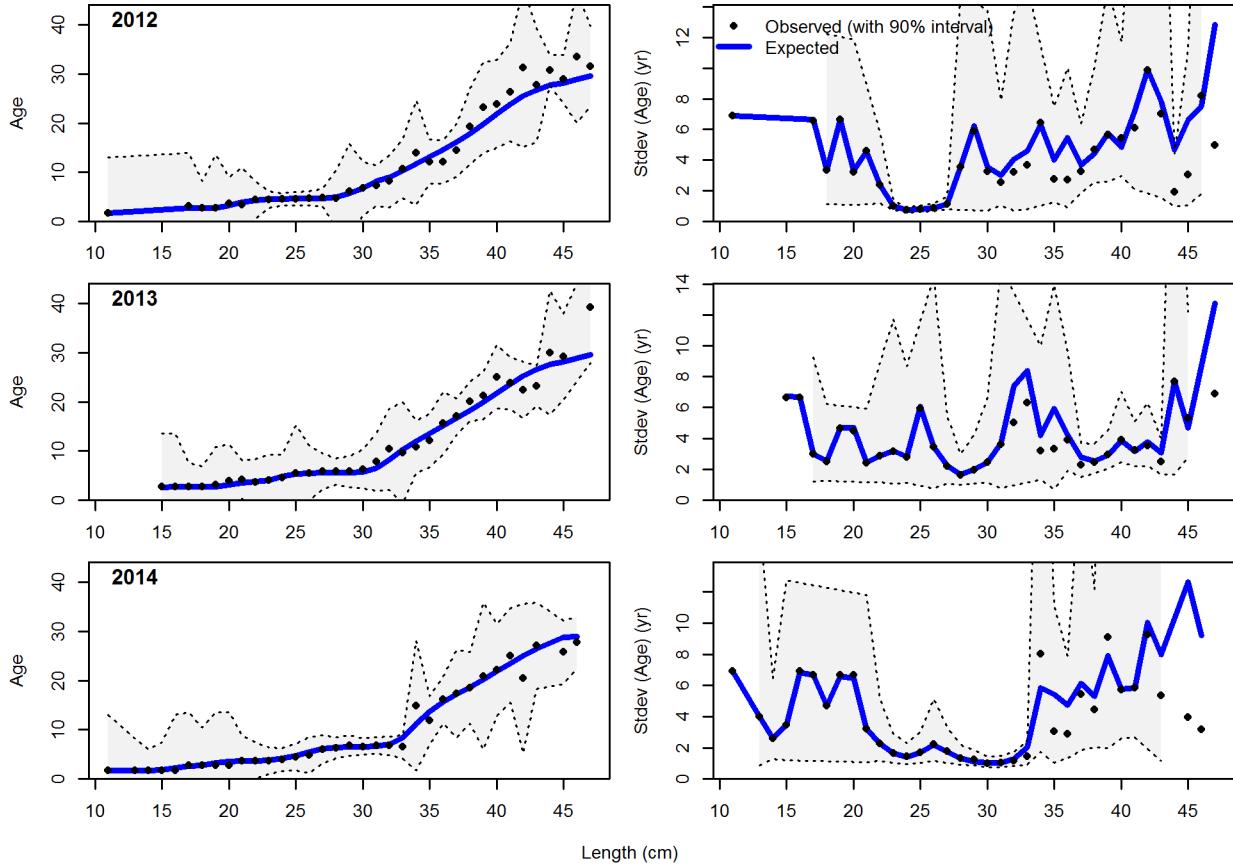


Figure 97: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 4 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution.

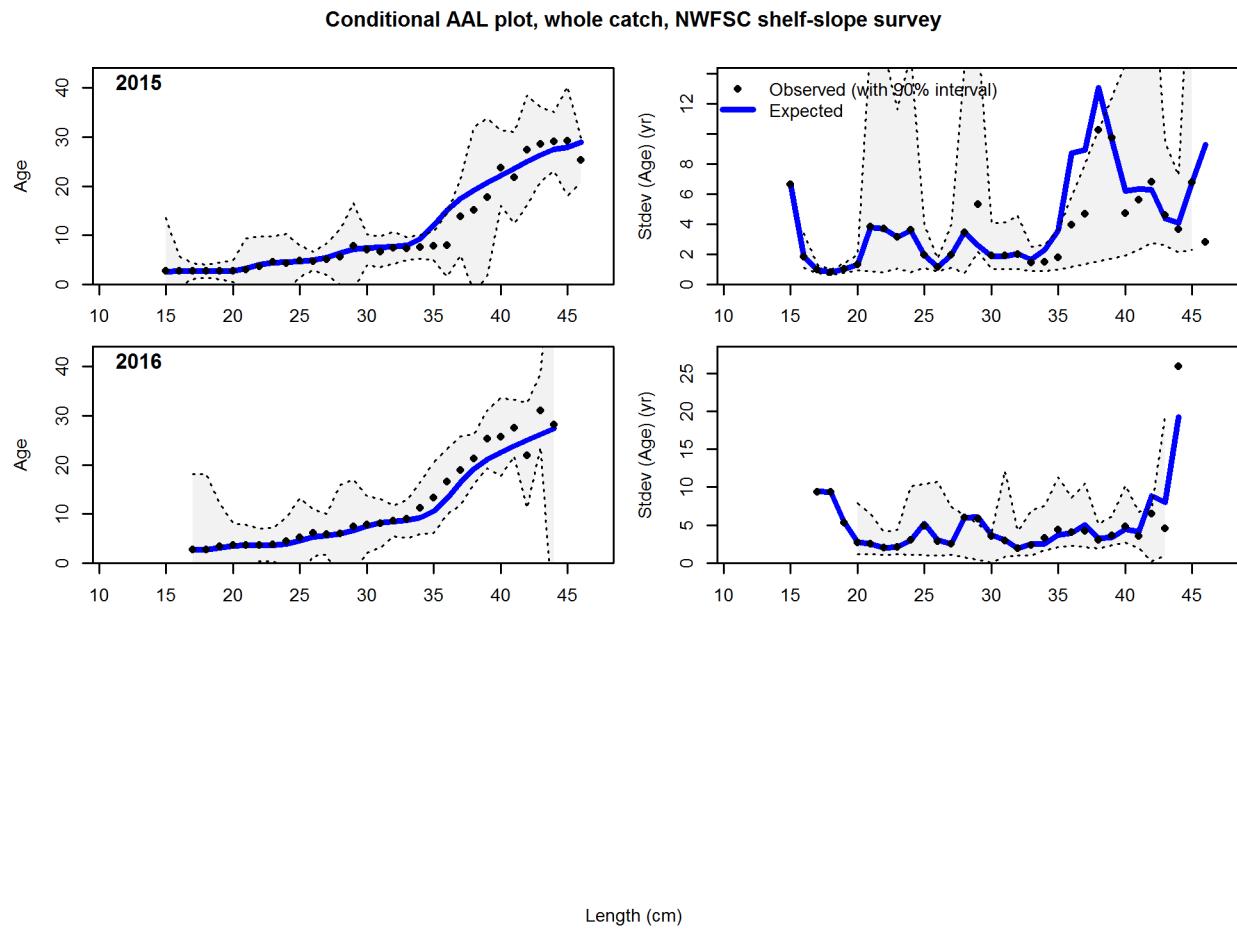


Figure 98: Conditional AAL plot, whole catch, NWFSC shelf-slope survey (plot 5 of 5) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi-square distribution. [fig:mod1_8_comp_condAALfitAndre_plotsflt8mkt0_page5](#)

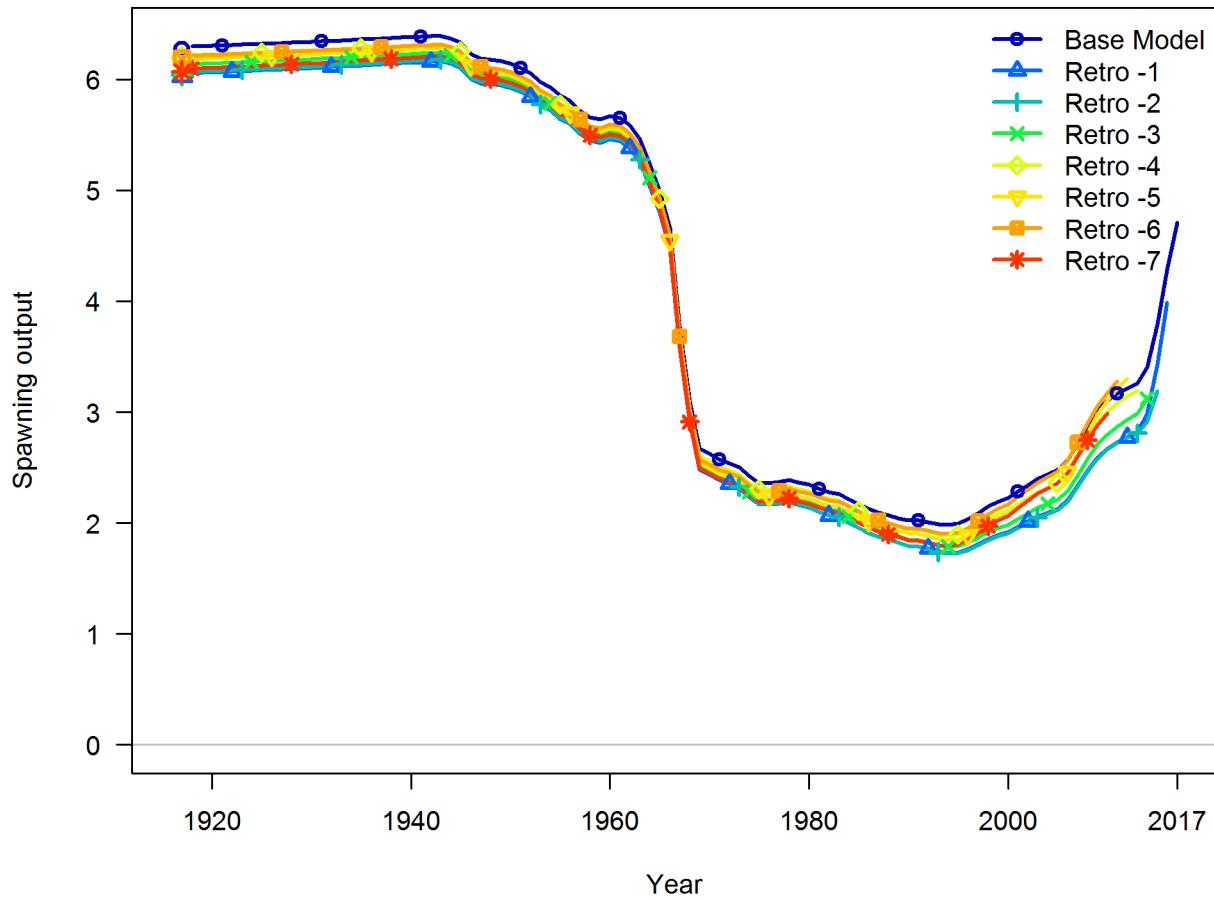


Figure 99: Retrospective pattern for spawning output. [fig:retro_sb](#)

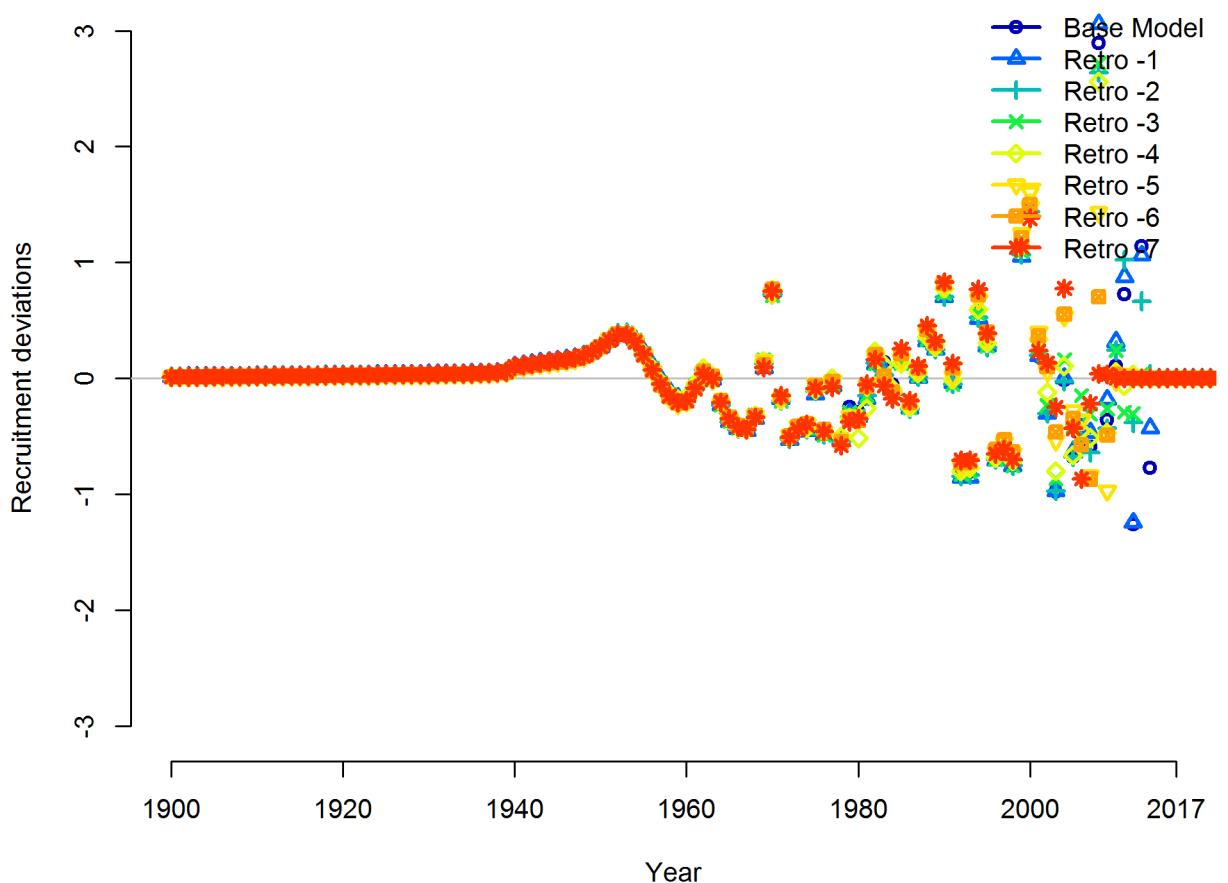


Figure 100: Retrospective pattern for estimated recruitment deviations. `fig:retro_recdev`

970 References

references

- 971 Bradburn, M., Keller, A., and Horness, B. 2011. The 2003 to 2008 US West Coast bottom
972 trawl surveys of groundfish resources off Washington, Oregon, and California: Estimates
973 of distribution, abundance, length, and age composition. US Department of Commerce,
974 National Oceanic; Atmospheric Administration, National Marine Fisheries Service.
- 975 Chilton, D.E., and Beamish, R.J. 1982. Age determination methods for fishes studied by the
976 Groundfish Program at the Pacific Biological Station. [Ottawa:] Minister of Supply; Services
977 Canada.
- 978 Dick, E., Beyer, S., Mangel, M., and Ralston, S. 2017. A meta-analysis of fecundity in
979 rockfishes (genus *Sebastodes*). *Fisheries Research* **187**: 73–85. doi: [10.1016/j.fishres.2016.11.009](https://doi.org/10.1016/j.fishres.2016.11.009).
- 980 Dick, E.J. 2009. Modeling the Reproductive Potential of Rockfishes (*Sebastodes* Spp.). ProQuest.
981 Available from [http://books.google.com/books?hl=en&lr=&id=0d6-3rhfynkC&oi=fnd&pg=PR7&dq=%22Synthesis+of+findings+regarding+the+reproductive%22+%22C:+Linear+interpolation+algorithms%22+%22for+yellowtail+rockfish+\(S.+flavidus\)%22+%22greater+than+zero,+based+on+the+2-level+relative+fecundity%22+%22A:+Methods+for+data+recovery+from+published%22+&ots=NR0UylgymD&sig=58IaN_a3pJeYTPYVmJ1NYMABmvE](http://books.google.com/books?hl=en&lr=&id=0d6-3rhfynkC&oi=fnd&pg=PR7&dq=%22Synthesis+of+findings+regarding+the+reproductive%22+%22C:+Linear+interpolation+algorithms%22+%22for+yellowtail+rockfish+(S.+flavidus)%22+%22greater+than+zero,+based+on+the+2-level+relative+fecundity%22+%22A:+Methods+for+data+recovery+from+published%22+&ots=NR0UylgymD&sig=58IaN_a3pJeYTPYVmJ1NYMABmvE) [accessed 27 February 2017].
- 987 Francis, R.C., and Hilborn, R. 2011. Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* **68**(6): 1124–1138. doi: [10.1139/f2011-025](https://doi.org/10.1139/f2011-025).
- 990 Gunderson, D.R. 1977. Population biology of Pacific ocean perch, *Sebastodes alutus*, stocks
991 in the WashingtonQueen Charlotte Sound region and their response to fishing. *Fishery
992 Bulletin* **75**: 369–403. Available from <http://fishbull.noaa.gov/75-2/gunderson.pdf> [accessed
993 27 February 2017].
- 994 Gunderson, D.R. 1978. Results of cohort analysis for Pacific ocean perch stocks off British
995 Columbia, Washington, and Oregon and an evaluation of alternative rebuilding strategies for
996 these stocks. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200,
997 Portland, OR 97220.
- 998 Gunderson, D.R. 1981. An updated cohort analysis for Pacific ocean perch stocks off
999 Washington and Oregon. Unpublished report, Pacific Fishery Management Council, 7700
1000 Ambassador Place NE, Suite 200, Portland, OR 97220.
- 1001 Gunderson, D.R. 1997. Trade-off between reproductive effort and adult survival in oviparous
1002 and viviparous fishes. *Canadian Journal of Fisheries and Aquatic Sciences* **54**(5): 990–
1003 998. Available from <http://www.nrcresearchpress.com/doi/abs/10.1139/f97-019> [accessed 27

- 1004 February 2017].
- 1005 Gunderson, D.R., and Sample, T.M. 1980. Distribution and abundance of rockfish off
1006 Washington, Oregon and California during 1977. Northwest; Alaska Fisheries Center, National
1007 Marine Fisheries Service. Available from <http://spo.nmfs.noaa.gov/mfr423-4/mfr423-42.pdf>
1008 [accessed 28 February 2017].
- 1009 Gunderson, D.R., Westrheim, S., Demory, R., and Fraidenburg, M. 1977. The status of
1010 Pacific ocean perch (*Sebastes alutus*) stocks off British Columbia, Washington, and Oregon
1011 in 1974.
- 1012 Hamel, O.S. 2015. A method for calculating a meta-analytical prior for the natural mortality
1013 rate using multiple life history correlates. ICES Journal of Marine Science: Journal du
1014 Conseil **72**(1): 62–69. doi: [10.1093/icesjms/fsu131](https://doi.org/10.1093/icesjms/fsu131).
- 1015 Hamel, O.S., and Ono, K. 2011. Stock Assessment of Pacific Ocean Perch in Waters off of
1016 the U.S. West Coast in 2011. Pacific Fishery Management Council, 7700 Ambassador Place
1017 NE, Suite 200, Portland, OR 97220.
- 1018 Hannah, R., and Parker, S. 2007. Age-modulated variation in reproductive development
1019 of female Pacific Ocean perch (*Sebastes alutus*) in waters off Oregon. Alaska Sea Grant,
1020 University of Alaska Fairbanks. pp. 1–20. doi: [10.4027/bamnpr.2007.01](https://doi.org/10.4027/bamnpr.2007.01).
- 1021 Helser, T., Punt, A.E., and Methot, R.D. 2004. A generalized linear mixed model analysis of
1022 a multi-vessel fishery resource survey. **70**: 251–264.
- 1023 Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery
1024 Bulletin **82**: 898–903. Available from <http://fishbull.noaa.gov/81-4/hoenig.pdf> [accessed 28
1025 February 2017].
- 1026 Ianelli, J.N., and Zimmermann, M. 1998. Status and future prospects for the Pacific ocean
1027 perch resource in waters off Washington and Oregon as assessed in 1998. Pacific Fishery
1028 Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.
- 1029 Ianelli, J.N., Ito, D.H., and Wilkins, M. 1992. Status and future prospects for the Pacific
1030 ocean perch resource in waters off Washington and Oregon as assessed in 1992. Pacific Fishery
1031 Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.
- 1032 Karnowski, M., Gertseva, V., and Stephens, A. 2014. Historical Reconstruction of Oregon's
1033 Commercial Fisheries Landings. Oregon Department of Fish; Wildlife, Salem, OR.
- 1034 Kristensen, K., Nielsen, A., Berg, C.W., Skaug, H.J., and Bell, B. 2016. TMB: Automatic
1035 Differentiation and Laplace Approximation. Journal of Statistical Software **70**: 1–21.
- 1036 McAllister, M.K., and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and
1037 the sampling - importance resampling algorithm. Canadian Journal of Fisheries and Aquatic

- 1038 Sciences **54**: 284–300. Available from <http://www.nrcresearchpress.com/doi/pdf/10.1139/f96-285> [accessed 10 March 2017].
- 1040 McCoy, M.W., and Gillooly, J.F. 2008. Predicting natural mortality rates of plants and
1041 animals. Ecology Letters **11**(7): 710–716. doi: [10.1111/j.1461-0248.2008.01190.x](https://doi.org/10.1111/j.1461-0248.2008.01190.x).
- 1042 Methot, R.D., and Wetzel, C.R. 2013. Stock synthesis: A biological and statistical framework
1043 for fish stock assessment and fishery management. Fisheries Research **142**: 86–99. doi:
1044 [10.1016/j.fishres.2012.10.012](https://doi.org/10.1016/j.fishres.2012.10.012).
- 1045 Methot, R.D., Taylor, I.G., and Chen, Y. 2011. Adjusting for bias due to variability of
1046 estimated recruitments in fishery assessment models. Canadian Journal of Fisheries and
1047 Aquatic Sciences **68**(10): 1744–1760. doi: [10.1139/f2011-092](https://doi.org/10.1139/f2011-092).
- 1048 Pikitch, E.K., Erickson, D.L., and Wallace, J.R. 1988. An evaluation of the effectiveness
1049 of trip limits as a management tool. Northwest; Alaska Fisheries Center, National Marine
1050 Fisheries Service NWAFC Processed Report. Available from <https://www.afsc.noaa.gov/Publications/ProcRpt/PR1988-27.pdf> [accessed 28 February 2017].
- 1051
- 1052 Punt, A.E., Smith, D.C., KrusicGolub, K., and Robertson, S. 2008. Quantifying age-reading
1053 error for use in fisheries stock assessments, with application to species in Australia's southern
1054 and eastern scalefish and shark fishery. Canadian Journal of Fisheries and Aquatic Sciences
1055 **65**(9): 1991–2005. doi: [10.1139/F08-111](https://doi.org/10.1139/F08-111).
- 1056 Ralston, S., Pearson, D.E., Field, J.C., and Key, M. 2010. Documentation of the California
1057 catch reconstruction project. US Department of Commerce, National Oceanic; Atmospheric
1058 Adminstration, National Marine.
- 1059 Rogers, J. 2003. Species allocation of *Sebastodes* and *Sebastolobus* species caught by for-
1060 eign countries off Washington, Oregon, and California, U.S.A. in 1965-1976. Unpublished
1061 document.
- 1062 Rogers, J.B., and Pikitch, E.K. 1992. Numerical definition of groundfish assemblages caught
1063 off the coasts of Oregon and Washington using commercial fishing strategies. Canadian
1064 Journal of Fisheries and Aquatic Sciences **49**(12): 2648–2656. Available from <http://www.nrcresearchpress.com/doi/abs/10.1139/f92-293> [accessed 9 March 2017].
- 1065
- 1066 Seeb, L.W., and Gunderson, D.R. 1988. Genetic variation and population structure of Pacific
1067 ocean perch (*Sebastes alutus*). Canadian Journal of Fisheries and Aquatic Sciences **45**(1):
1068 78–88. Available from <http://www.nrcresearchpress.com/doi/abs/10.1139/f88-010> [accessed
1069 28 February 2017].
- 1070 Stewart, I.J., and Hamel, O.S. 2014. Bootstrapping of sample sizes for length- or age-
1071 composition data used in stock assessments. Canadian Journal of Fisheries and Aquatic

- 1072 Sciences **71**(4): 581–588. doi: [10.1139/cjfas-2013-0289](https://doi.org/10.1139/cjfas-2013-0289).
- 1073 Then, A.Y., Hoenig, J.M., Hall, N.G., and Hewitt, D.A. 2015. Evaluating the predictive
1074 performance of empirical estimators of natural mortality rate using information on over 200
1075 fish species. ICES Journal of Marine Science **72**(1): 82–92. doi: [10.1093/icesjms/fsu136](https://doi.org/10.1093/icesjms/fsu136).
- 1076 Thorson, J.T., and Barnett, L.A.K. 2017. Comparing estimates of abundance trends and
1077 distribution shifts using single- and multispecies models of fishes and biogenic habitat. ICES
1078 Journal of Marine Science: Journal du Conseil: fsw193. doi: [10.1093/icesjms/fsw193](https://doi.org/10.1093/icesjms/fsw193).
- 1079 Thorson, J.T., and Kristensen, K. 2016. Implementing a generic method for bias correction
1080 in statistical models using random effects, with spatial and population dynamics examples.
1081 Fisheries Research **175**: 66–74. doi: [10.1016/j.fishres.2015.11.016](https://doi.org/10.1016/j.fishres.2015.11.016).
- 1082 Thorson, J.T., and Ward, E.J. 2014. Accounting for vessel effects when standard-
1083 izing catch rates from cooperative surveys. Fisheries Research **155**: 168–176. doi:
1084 [10.1016/j.fishres.2014.02.036](https://doi.org/10.1016/j.fishres.2014.02.036).
- 1085 Thorson, J.T., Shelton, A.O., Ward, E.J., and Skaug, H.J. 2015. Geostatistical delta-
1086 generalized linear mixed models improve precision for estimated abundance indices
1087 for West Coast groundfishes. ICES Journal of Marine Science **72**(5): 1297–1310. doi:
1088 [10.1093/icesjms/fsu243](https://doi.org/10.1093/icesjms/fsu243).
- 1089 Thorson, J.T., Stewart, I.J., and Punt, A.E. 2012. nwfscAgeingError: A user interface in R
1090 for the Punt et al. (2008) method for calculating ageing error and imprecision. Available
1091 from: <http://github.com/nwfsc-assess/nwfscAgeingError/>.
- 1092 Weinberg, J.R., Rago, P.J., Wakefield, W.W., and Keith, C. 2002. Estimation of tow distance
1093 and spatial heterogeneity using data from inclinometer sensors: An example using a clam
1094 survey dredge. Fisheries Research **55**(1–3): 49–61. doi: [10.1016/S0165-7836\(01\)00292-2](https://doi.org/10.1016/S0165-7836(01)00292-2).
- 1095 Wilkins, M., and Golden, J. 1983. Condition of the Pacific ocean perch resource off Washington
1096 and Oregon during 1979: Results of a cooperative trawl survey. North American Journal of
1097 Fisheries Management **3**: 103–122.
- 1098 Withler, R., Beacham, T., Schulze, A., Richards, L., and Miller, K. 2001. Co-existing
1099 populations of Pacific ocean perch, *Sebastodes alutus*, in Queen Charlotte Sound, British
1100 Columbia. Marine Biology **139**(1): 1–12. doi: [10.1007/s002270100560](https://doi.org/10.1007/s002270100560).
- 1101 Zimmermann, M., Wilkins, M., Weinberg, K., Lauth, R., and Shaw, F. 2003. Influence of
1102 improved performance monitoring on the consistency of a bottom trawl survey. ICES Journal
1103 of Marine Science **60**(4): 818–826. doi: [10.1016/S1054-3139\(03\)00043-2](https://doi.org/10.1016/S1054-3139(03)00043-2).