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

Chantel R. Wetzel[1]
Kelli Johnson[1]
Lee Cronin-Fine[2]

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

[3]University of Washington, School of Aquatic and Fishery Sciences

DRAFT SAFE
Disclaimer: This information is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It has not been formally disseminated by NOAA Fisheries. It does not represent and should not be construed to represent any agency determination or policy.

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

Contents

???

Executive Summary

executive-summary

Stock

stock

This assessment reports the status of the Pacific ocean perch (*Sebastes alutus*) speciess off rockfish off the U.S. West Coast from Northern California to the Canadian Border using data through 2017. Pacific ocean perch are most abundant in the Gulf of Alaska and have observed off of Japan, in the Bering Sea, and south to Baja California, although they are sparse south of Oregon and rare in southern California. Composition data indicate that good recruitment years coincide in Oregon and Washington. To date, no significant genetic differences have been found in the range covered by this assessment.

Landings

landings

The first year that harvest of Pacific ocean perch exceeded 1 mt off the U.S. West Coast first occured in 1929. Catches ramped up in the 1940s with large removals in Washington waters. During the 1950s the removals primarly occured in Oregon waters with catches from Washington declining following the 1940s. The largest removals in 1966-1968 were largely a result of harvest by foreing vessels. The fishery proceed with more moderate removals ranging between 1,200 to 2,600 metric tons per year between 1969 to 1980. Removals generally decined from 1981 to 1994 to between 1,000 and 1,700 metric tons per year. Pacific ocean perch was declared overfished in 1999 resulting in large reduction in harvest in recent years since the declaration.

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

tab:Exec_catch

Year	California	Oregon	Washington	At-sea Hake	Research	Total Landings
2007	0.15	83.65	45.12	4.05	0.58	133.55
2008	0.39	58.64	16.61	15.93	0.80	92.37
2009	0.92	58.75	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	33.92	15.82	3.92	0.57	54.41
2015	0.12	38.12	11.41	8.71	1.59	59.95
2016	0.19	34.15	13.12	10.30	0.12	57.87

Data and Assessment

data-and-assessment

This a new full assessment for Pacific ocean perch which was last assessed in 2011. In this assessment, all aspects of the model including catches, data, and modelling assumptions were re-evaluated as much as possible. The assessment was conducted using the length- and age-structured modeling software Stock Synthesis (version 3.30). The coastwide population was modeled assuming separate growth and mortality parameters for each sex (a two-sex model) from 1918 to 2017, and forecasted beyond 2017.

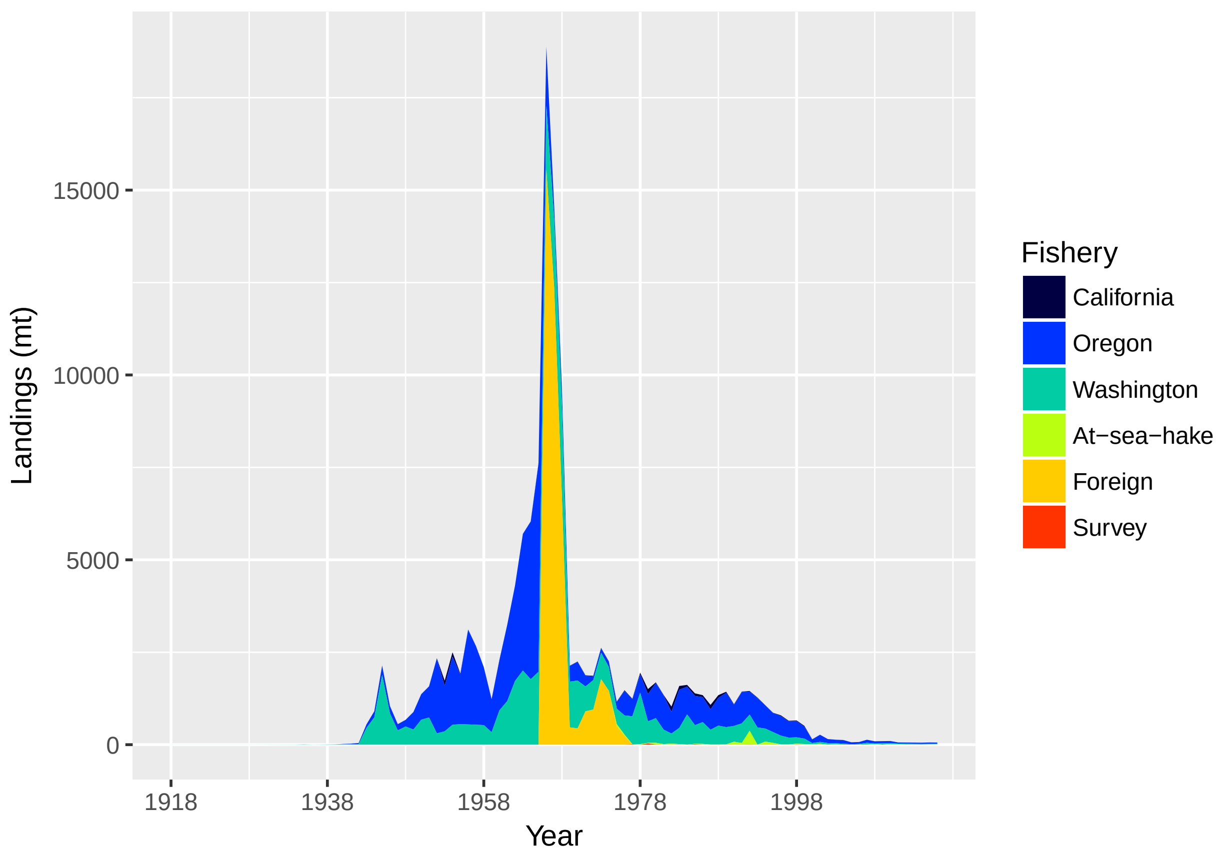


Figure a: Landings of Pacific ocean perch for California, Oregon, Washington, the Foriegn fishery (1966-1976), At-Sea Hake fishery, and fishery independent surveys. fig:Exec_catch1

Stock Biomass

stock-biomass

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

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

Example text (remove Models 2 and 3 if not needed - if using, remove the # in-line comments!!!) The estimated relative depletion level (spawning output relative to unfished spawning output) of the the base-case model in 2017 is 17.2% (~95% asymptotic interval: ± -3.43%-37.9%) (Figure c).

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

tab:SpawningDeplete_mod1

Year	Spawning Output (million eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	541.00	-65 - 1146	0.10	-0.010 - 0.205
2009	565.00	-74 - 1204	0.10	-0.012 - 0.215
2010	581.00	-86 - 1248	0.10	-0.014 - 0.223
2011	594.00	-97 - 1286	0.11	-0.016 - 0.230
2012	610.00	-104 - 1324	0.11	-0.017 - 0.237
2013	627.00	-110 - 1364	0.11	-0.018 - 0.244
2014	666.00	-122 - 1453	0.12	-0.020 - 0.260
2015	752.00	-145 - 1649	0.14	-0.024 - 0.296
2016	861.00	-175 - 1897	0.15	-0.029 - 0.340
2017	955.00	-204 - 2114	0.17	-0.034 - 0.379

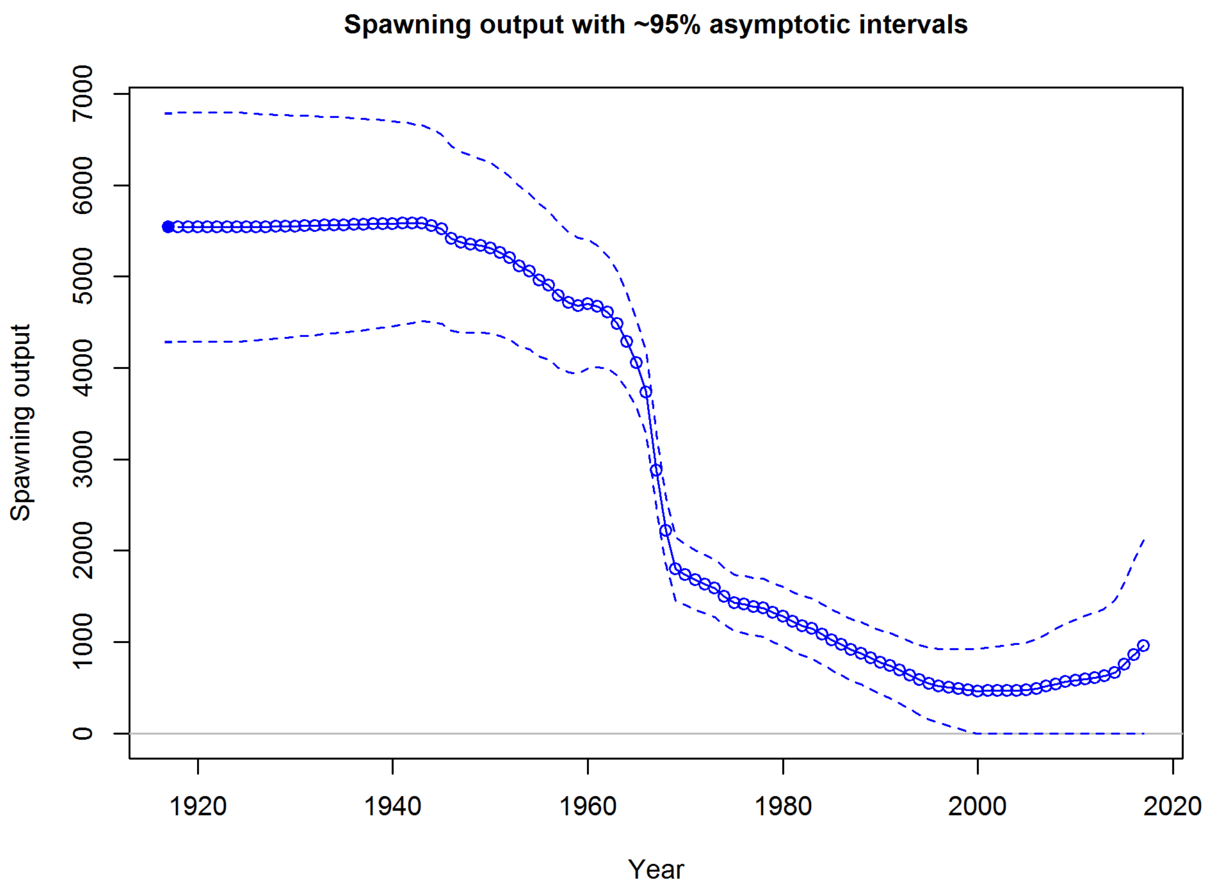


Figure b: Time series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model. fig:Spawnbio_all

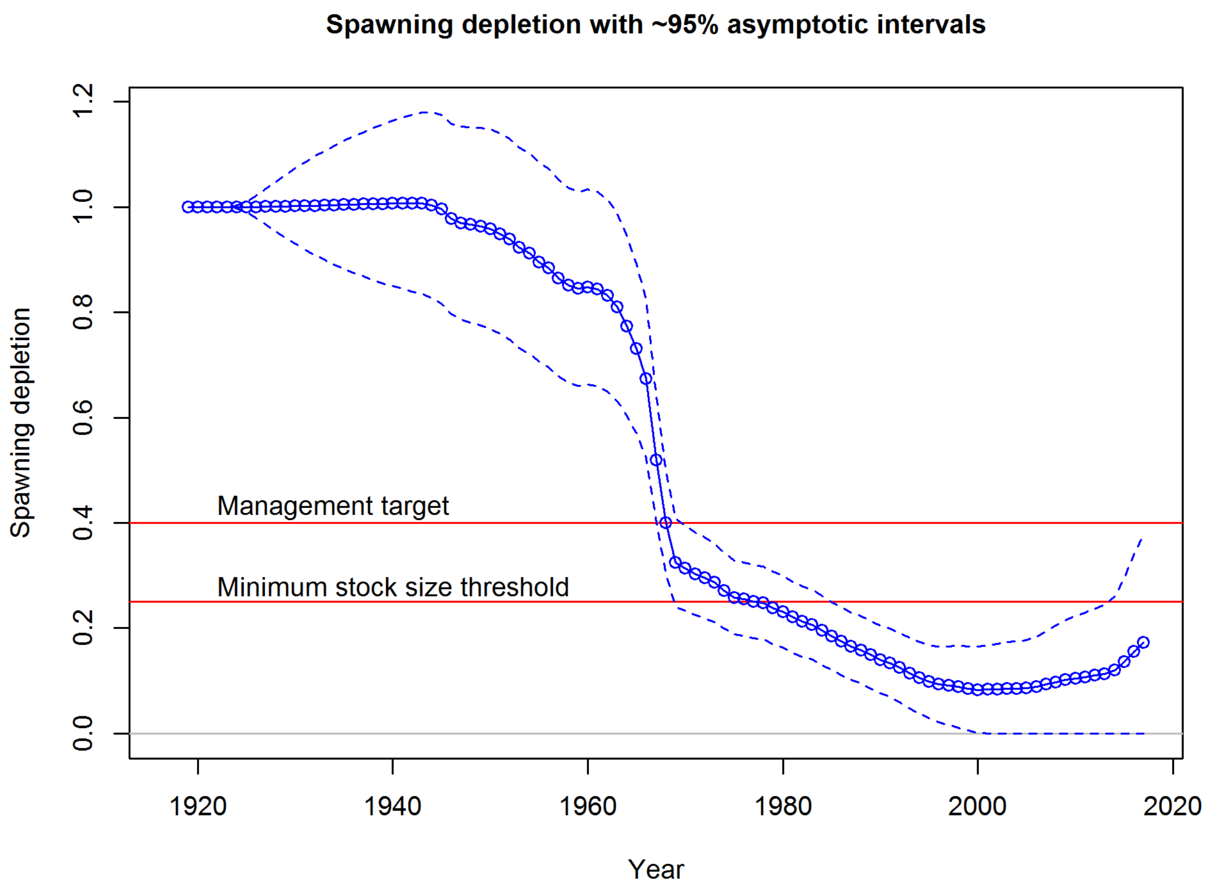


Figure c: Estimated relative depletion with approximate 95% asymptotic confidnce intervals (dashed lines) for the base case assessment model. fig:RelDeplete_all

Recruitment

recruitment

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

Recruitment Figure: (Figure d)
Recruitment Tables: (Tables c)

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

tab:Recruit_mod1

Year	Estimated Recruitment	˜ 95% confidence interval	Estimated Recruitment Devs.	˜ 95% confidence interval
2008	29804.00	9242 - 96115	2.98	2.580 - 3.389
2009	612.00	150 - 2489	-0.96	-1.948 - 0.027
2010	1322.00	308 - 5668	-0.23	-1.336 - 0.868
2011	1724.00	411 - 7240	-0.01	-1.045 - 1.030
2012	1478.00	338 - 6458	-0.20	-1.322 - 0.912
2013	2217.00	493 - 9971	0.16	-1.019 - 1.335
2014	1713.00	370 - 7935	-0.17	-1.406 - 1.061
2015	2272.00	463 - 11142	0.00	-1.372 - 1.372
2016	2558.00	525 - 12469	0.00	-1.372 - 1.372
2017	2799.00	689 - 11373	0.00	-0.970 - 0.970

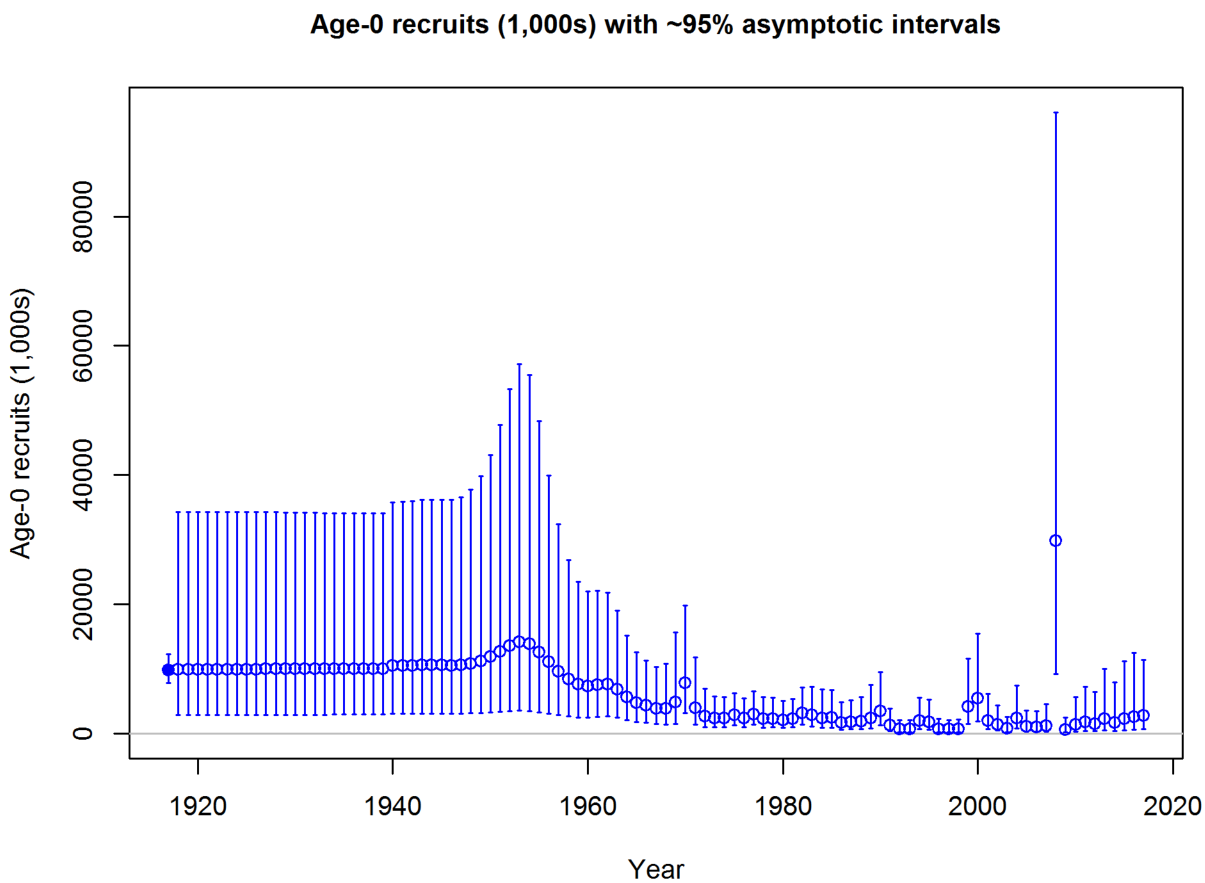


Figure d: Time series of estimated Pacific ocean perch recruitments for the base-case model with 95% confidence or credibility intervals. fig:Recruits_all

Exploitation status

exploitation-status

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

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

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

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

tab:SPR_Exploit_mod1

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.506	0.065 - 0.948	0.012	-0.001 - 0.025
2008	0.429	0.031 - 0.827	0.010	-0.001 - 0.021
2009	0.548	0.056 - 1.040	0.014	-0.002 - 0.031
2010	0.517	0.042 - 0.992	0.013	-0.002 - 0.029
2011	0.199	-0.014 - 0.412	0.004	-0.001 - 0.008
2012	0.184	-0.015 - 0.384	0.003	-0.001 - 0.007
2013	0.172	-0.016 - 0.361	0.003	-0.001 - 0.006
2014	0.151	-0.017 - 0.319	0.003	-0.001 - 0.006
2015	0.147	-0.019 - 0.313	0.003	-0.001 - 0.006
2016	0.128	-0.019 - 0.276	0.002	-0.001 - 0.005

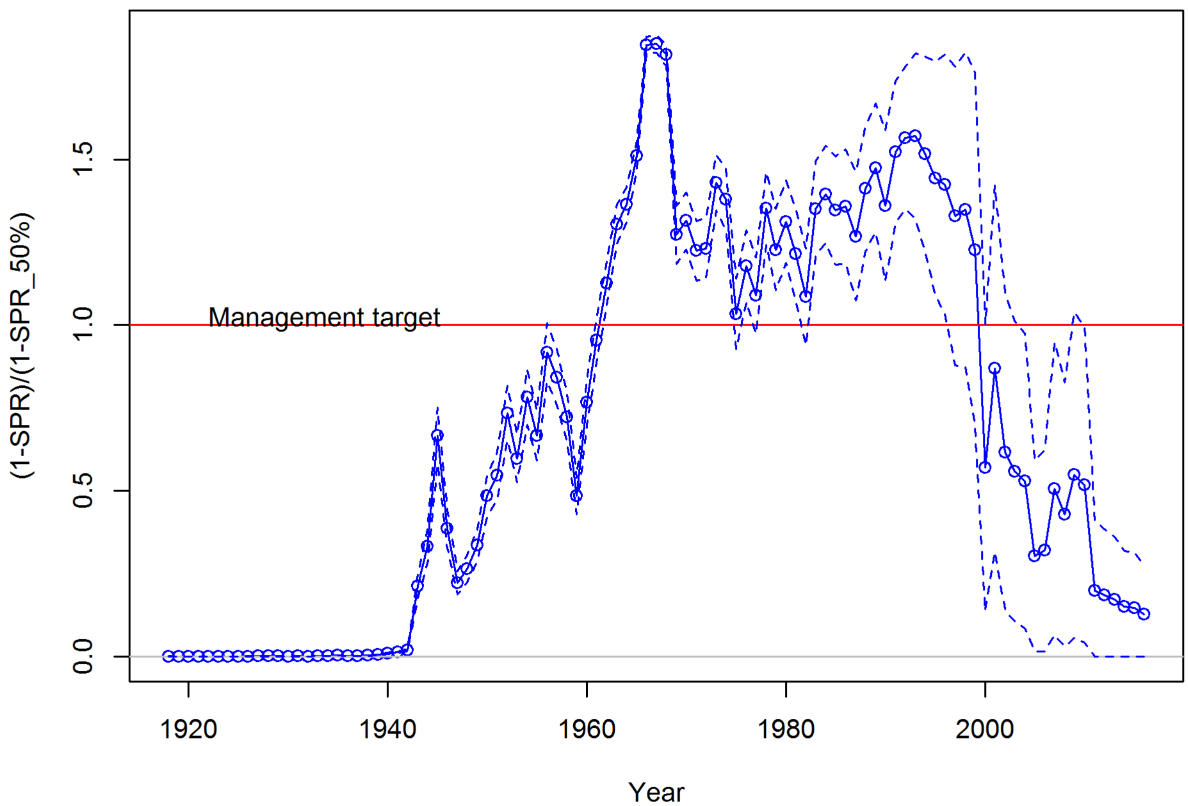


Figure e: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

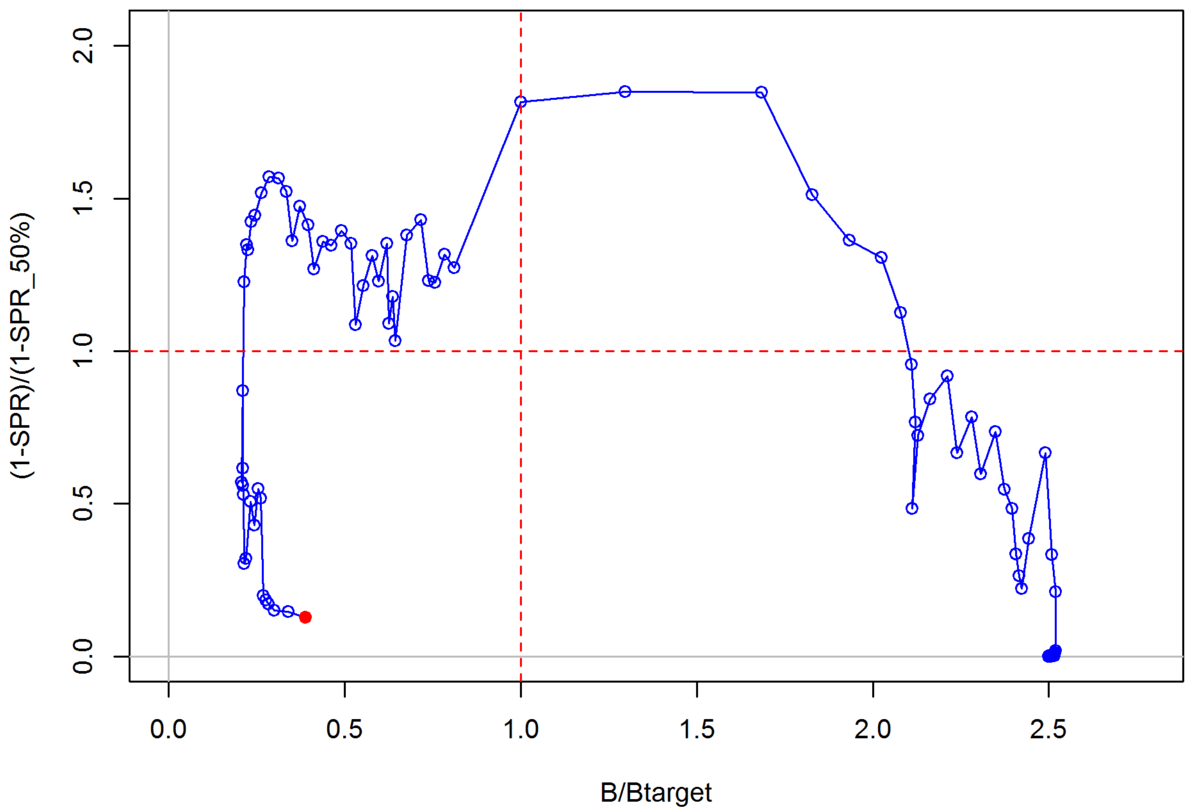


Figure f: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the unfished spawning biomass. fig:Phase_all

Ecosystem Considerations

ecosystem-considerations

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

Reference Points

reference-points

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

Write intro paragraph

This stock assessment estimates that Pacific ocean perch in the Base model are below the biomass target, but below the minimum stock size threshold. Add sentence about spawning output trend. The estimated relative depletion level for Model 1 in 2017 is 17.2% (~95% asymptotic interval: ± -3.43%-37.9%, corresponding to an unfished spawning output of 955 million eggs (~95% asymptotic interval: -204.203617683797-2114.3436176838 million eggs) of spawning output in the base model (Table e). Unfished age 3+ biomass was estimated to be 119982 mt in the base case model. The target spawning output based on the biomass target ($SB_{40\%}$) is 2216.5 million eggs, which gives a catch of 756.9 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 0 mt.

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

tab:Ref_pts_mod1

Quantity	Estimate	95% Confidence Interval
Unfished spawning output (million eggs)	5541.4	4287.1 - 6795.6
Unfished age 3+ biomass (mt)	119982	93835.3 - 146128.7
Unfished recruitment (R0, thousands)	9768	7803.3 - 12227.4
Spawning output(2017 million eggs)	955.1	-204.204 - 2114.3
Depletion (2017)	0.172	-0.034 - 0.379
Reference points based on $\mathbf{SB_{40\%}}$		
Proxy spawning output ($B_{40\%}$)	2216.5	1714.9 - 2718.2
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.711	0.588 - 0.834
Exploitation rate resulting in $B_{40\%}$	0.015	0.007 - 0.023
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	756.9	341.7 - 1172
Reference points based on SPR proxy for MSY		
Spawning output	0	0 - 0
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.033	0.033 - 0.034
Yield with SPR_{proxy} at SB_{SPR} (mt)	0	0 - 0
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	2355.2	1703.1 - 3007.2
SPR_{MSY}	0.723	0.585 - 0.862
Exploitation rate at MSY	0.014	0.005 - 0.023
MSY (mt)	758.8	349 - 1168.7

Management Performance

management-performance

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

Management performance table: Table f

Unresolved Problems And Major Uncertainties

unresolved-problems-and-major-uncertainties

TBD after STAR panel

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

tab:mnmgt_perform

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Total landings (mt)	Estimated total catch (mt)
2007	-	-	150	134	158
2008	-	-	150	92	134
2009	-	-	189	97	195
2010	-	-	200	99	184
2011	-	-	180	61	61
2012	-	-	183	59	59
2013	-	-	150	57	58
2014	-	-	153	54	55
2015	-	-	158	60	60
2016	-	-	164	58	58

Decision Table(s) (groundfish only)

decision-tables-groundfish-only

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

OFL projection table: Table g

Decision table(s) Table h, Table **??**, Table **??**

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

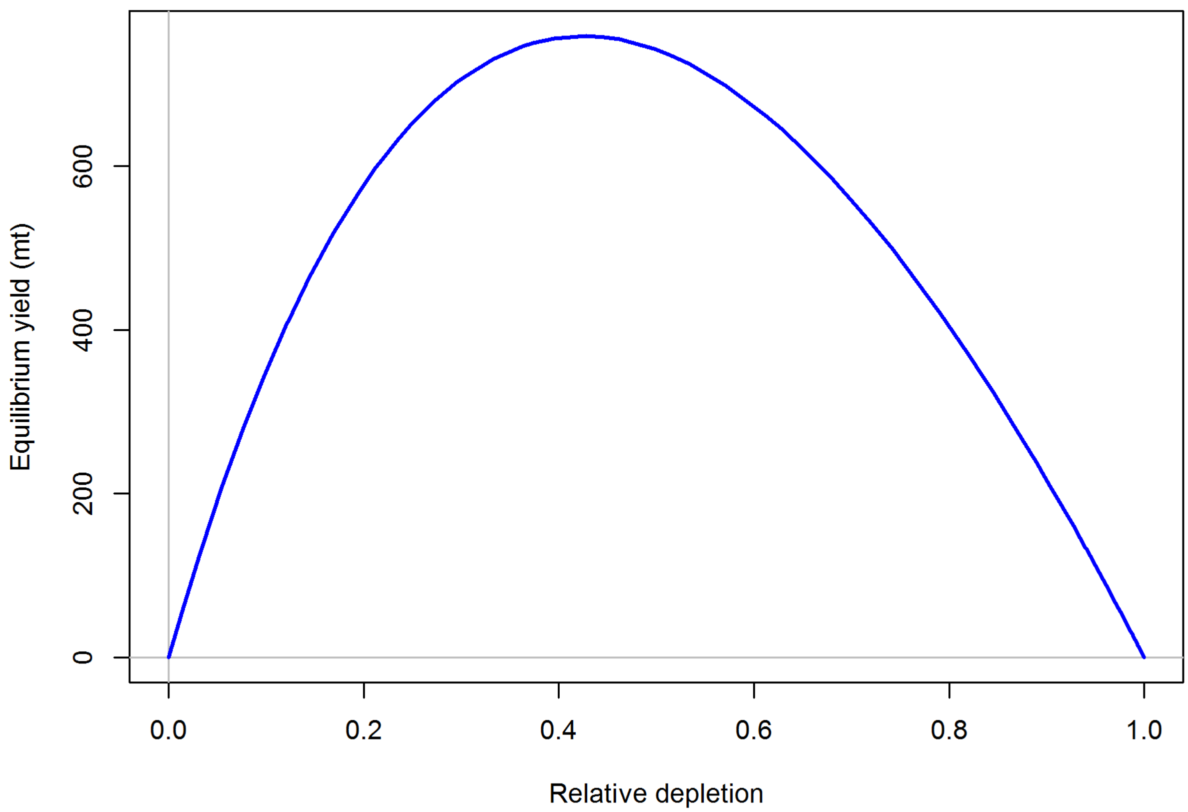


Figure g: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at... fig:Yield_all

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

tab:OFL_projection

Year	OFL	ACL	Spawning Output (million eggs)	Relative Biomass
2017	832	445	955	0.172
2018	877	504	1009	0.182
2019	898	536	1043	0.188
2020	899	549	1062	0.192
2021	892	549	1073	0.194
2022	880	545	1077	0.194
2023	869	539	1078	0.195
2024	861	533	1078	0.195
2025	855	529	1078	0.194
2026	851	527	1077	0.194
2027	850	526	1077	0.194
2028	849	526	1078	0.194

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

`tab:Decision_table_mod1`

			States of nature					
			Low M 0.05		Base M 0.07		High M 0.09	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
40-10 Rule,	2022	-	-	-	-	-	-	-
Low M	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
40-10 Rule	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
40-10 Rule,	2022	-	-	-	-	-	-	-
High M	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
Average	2022	-	-	-	-	-	-	-
Catch	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)	-	-	-	-	-	-	-	-	-	-
Total Est. Catch (mt)	150	189	200	180	183	150	153	158	164	281
OFL (mt)	92	97	99	61	59	57	54	60	58	
ACL (mt)	134	195	184	61	59	58	55	60	58	
(1-SPR)(1-$SPR_{50\%}$)	0.43	0.55	0.52	0.20	0.18	0.17	0.15	0.15	0.13	
Exploitation rate	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	
Age 3+ biomass (mt)	13473.2	13686.3	13792.6	17067.0	18608.1	20132.8	21551.5	22764.1	23842.4	24691.7
Spawning Output	541	565	581	594	610	627	666	752	861	955
95% CI	-65 - 1146	-74 - 1204	-86 - 1248	-97 - 1286	-104 - 1324	-110 - 1364	-122 - 1453	-145 - 1649	-175 - 1897	-204 - 2114
Depletion	0.098	0.102	0.105	0.107	0.110	0.113	0.120	0.136	0.155	0.172
95% CI	-0.010 - 0.205	-0.012 - 0.215	-0.014 - 0.223	-0.016 - 0.230	-0.017 - 0.237	-0.018 - 0.244	-0.020 - 0.260	-0.024 - 0.296	-0.029 - 0.340	-0.034 - 0.379
Recruits	29804	612	1322	1724	1478	2217	1713	2272	2558	2799
95% CI	9242 - 96115	150 - 2489	308 - 5668	411 - 7240	338 - 6458	493 - 9971	370 - 7935	463 - 11142	525 - 12469	689 - 11373

Research And Data Needs

research-and-data-needs

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

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

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

Rebuilding Projections

rebuilding-projections

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

1 Introduction

introduction

1.1 Basic Information

basic-information

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

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

Prior to 1966, the Pacific ocean perch resource off of the northern portion of the U.S. West Coast was harvested almost entirely by Canadian and United States vessels. Harvest was negligible prior to 1940, reached 1,300 mt in 1950, 3,200 mt in 1961 and exceeded 7,600 mt in 1965. Catches increased dramatically after 1965, with the introduction of large distant-water fishing fleets from the Soviet Union and Japan. Both nations employed large factory stern trawlers as their primary method for harvesting Pacific ocean perch. Peak removals by all foreign nations combined are estimated at over 15,000 mt in 1966 and remained over 12,000 mt in 1967. These numbers are based upon a re-analysis of the foreign catch data (Rogers 2003), which focused on deriving a more realistic species composition for catches previously identified only as Pacific ocean perch. Catches declined rapidly following these peak years, and Pacific ocean perch stocks were considered to be severely depleted throughout the Oregon-Vancouver Island region by 1969 (Gunderson 1977, Gunderson et al. 1977). Landed harvest averaged 1,350 mt over the period 1977-94. Landings have continued to decline since 1994, primarily due to more restrictive management (Figure 2).

Prior to 1977, Pacific ocean perch in the northeast Pacific were managed by the Canadian Government in its waters and by the individual states in waters off of the United States. With implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1977, U.S. territorial waters were extended to 200 miles from shore, and primary responsibility for management of the groundfish stocks off Washington, Oregon and California shifted from the states to the Pacific Fishery Management Council (PFMC) and the National Marine Fisheries Service (NMFS). At that time, however, a Fishery Management Plan (FMP) for the west coast groundfish stocks had not yet been approved. In the interim, the state agencies worked with the PFMC to address conservation issues. In 1981, the PFMC adopted a management strategy to rebuild the depleted Pacific ocean perch stocks to levels that would produce Maximum Sustainable Yield (MSY) within 20 years. On the basis of cohort analysis (Gunderson 1978), the PFMC set Acceptable Biological Catch (ABC) levels at 600 mt for the US portion of the Vancouver INPFC area and 950 mt for the Columbia INPFC area. To implement this strategy, the states of Oregon and Washington each established landing limits for Pacific ocean perch. Trawl trip limits of various forms remained in effect through 2010 (Table 1).

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

1.2 Summary of Management History

summary-of-management-history

Include: Summary of management history (e.g., changes in mesh sizes, trip limits, or other management actions that may have significantly altered selection, catch rates, or discards).

Include: Management performance, including a table or tables comparing Overfishing Limit (OFL), Annual Catch Limit (ACL), Harvest Guideline (HG) [CPS only], landings, and catch (i.e., landings plus discard) for each area and year.

Management performance table: (Table f)

A summary of these values as well as other base case summary results can be found in Table i.

1.3 Fisheries off Canada, Alaska, and/or Mexico

fisheries-off-canada-alaska-andor-mexico

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

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

2 Assessment

assessment

2.1 Data

data

Data used in the Pacific ocean perch assessment are summarized in Figure 1. A description of each data source is provided below.

2.1.1 Commercial Fishery Landings

commercial-fishery-landings

Washington

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

Oregon

Historical commercial fishery landings of Pacific ocean perch from Oregon for the years 1892-1986 were obtained from Alison Dauble (ODFW). A description of the methods can be found in Karnowski et al. (2014). Recent landings (1987-2016) were obtained from PacFIN retrieval dated March 3, 2015, Pacific States Marine Fisheries Commission, Portland, Oregon; www.psmfc.org). The catch data in from the POP and POP2 categories contained within PacFIN for Pacific ocean perch were used for this assessment. Additional cathes from 1987-1999 for Pacific ocean perch under the UROCK category not yet available in PacFIN were received directly from the state and combined with the catch data available for that period within PacFIN.

California

Historical commercial fishery landings of Pacific ocean perch were obtained from the online database of the California Cooperative Groundfish Survey, also known as CALCOM (128.114.3.187) for the years 1916-1980. A description of the methods can be found in (Ralston et al. 2010). Recent landings (1981-2016) were obtained from PacFIN (Pacific Fisheries Information Network (PacFIN) retrieval dated March 3, 2015, Pacific States Marine Fisheries Commission, Portland, Oregon; www.psmfc.org).

At-sea fishery

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

Foreign

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

Discards

Data on discards of Pacific ocean perch are available from two different data sources. The earliest source is called the Pikitch data and comes from a study organized by Ellen Pikitch that collected trawl discards from 1985-1987 (Pikitch et al. 1988). The northern and southern boundaries of the study were 48°42′ N latitude and 42°60′ N. latitude respectively, which is primarily within the Columbia INPFC area (Pikitch et al. 1988 , Rogers and Pikitch 1992). Participation in the study was voluntary and included vessels using bottom, midwater, and shrimp trawl gears. Observers of normal fishing operations on commercial vessels collected the data, estimated the total weight of the catch by tow and recorded the weight of species retained and discarded in the sample. Results of the Pikitch data were obtained from John Wallace (NWFSC, personal communication) in the form of ratios of discard weight to retained weight of Pacific ocean perch and sex-specific length frequencies. Discard estimates are shown in Table 3.

The second source is from the West Coast Groundfish Observer Program (WCGOP). This program is part of the NWFSC and has been recording discard observations since 2003. Table 3 shows the discard ratios of Pacific ocean perch from the WCGOP. Since 2011, when the trawl rationalization program was implemented, observer coverage rates increased to nearly 100% for all the limited entry trawl vessels in the program and discard rates declined compared to pre-2011 rates. Discard rates were obtained for both the catch-share and the non-catch share sector for Pacific ocean perch. A single discard rate was calculated by weighting discard rates based on the commercial landings by each sector. Discard length composition for the trawl fleet varied by year, with larger fish being discarded prior to 2011 (Figure ??).

2.1.2 Abundance Indices

abundance-indices

2.1.3 Fishery-Dependent Data:

fishery-dependent-data

Historical Commercial Catch-per-unit effort

Data on catch-per-unit-effort (CPUE) in mt/hr from the domestic fishery were combined for the INPFC Vancouver and Columbia areas (Table 17 from Gunderson (1977)). Although these data reflect catch rates for the US fleet, the highest catch rates coincided with the beginning of removals by the foreign fleet. This suggest that, barring unaccounted changes in fishing efficiency during this period, the level of abundance was high at that time. A CV of 0.40 was used in this assessment to be consistent with the CV observed in the survey data.

2.1.4 Fishery-Independent Data:

fishery-independent-data

Northwest Fisheries Science Center (NWFSC) shelf-slope survey

The NWFSC shelf-slope survey is based on a random-grid design; covering the coastal waters from a depth of 55 m to 1,280 m (Bradburn et al. 2011). This design uses four chartered industry vessels in most years, assigned to a roughly equal number of randomly selected grid cells. The survey, which has been conducted from late-May to early-October each year, is divided into two 2-vessel passes of the coast, which are executed from north to south. This design therefore incorporates both vessel-to-vessel differences in catchability as well as variance associated with selecting a relatively small number (~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 spatial delta-generalized linear mixed model (delta-GLMM) (Thorson and Barnett 2017). Predicted fish biomass density is derived as the product of a "delta" portion for the probability of a non-zero catch and a second portion for the magnitude of the non-zero catches. Further, the geostatistical GLMM framework can accommodate spatial autocorrelation. Additional information about the approach and the software package it is implemented in are available from www.fishstats.org. describe VAST

The estimated index of abundance is shown in Table 18.

Northwest Fisheries Science Center (NWFSC) slope survey

The NWFSC slope survey covered waters throughout the summer from 183 m to 1280 m north of 34°30′ S, which is near Point Conception. The survey strata used to expand the biomass data for this assessment are shown in Table 5.

The estimated index of abundance is shown in Table 18.

Alaska Fisheries Science Center (AFSC) slope survey

The AFSC slope survey operated during autumn (October-November) aboard the R/V Miller Freeman. Partial survey coverage of the U.S. west coast occurred during 1988-96 and complete coverage (north of 34°30′ S) during 1997, 1999, 2000, and 2001. Only the four years of consistent and complete surveys plus 1996, which surveyed north of 43° N latitude to the U.S.-Canada border, were used in this assessment. The number of tows with length data ranged from 19 in 2000 to 48 in 1996 8. Because a large number of positive tows occurred in 1996, it was decided to include that year, which surveyed from 43° N latitude to the U.S.-Canada border. Therefore, only tows from 43° N latitude to the U.S.-Canada border were used.

The estimated index of abundance is shown in Table 18.

Triennial Bottom Trawl Survey

The triennial survey was first conducted by the AFSC in 1977 and spanned the time-frame from 1977-2004. The survey's design and sampling methods are most recently described in

(Weinberg et al. 2002). Its basic design was a series of equally-spaced transects from which searches for tows in a specific depth range were initiated (Figure 5). The survey design has changed slightly over the period of time (Table 4, Figure 3). In general, all of the surveys were conducted in the mid-summer through early fall: the 1977 survey was conducted from early July through late September; the surveys from 1980 through 1989 ran from mid-July to late September; the 1992 survey spanned from mid-July through early October; the 1995 survey was conducted from early June to late August; the 1998 survey ran from early June through early August; and the 2001 and 2004 surveys were conducted in May-July (Figure 4).

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

Given the different depths surveyed during 1977, the data from that year were not included in this assessment. Water hauls (Zimmermann et al. 2003) and tows located in Canadian waters were also excluded from the analysis of this survey. The survey was analyzed as an early series (1980-1992) and a late series (1995-2004), as has been done in other West Coast rockfish assessments.

Describe whether the time-series was split or retained as one index

The estimated index of abundance is shown in Table 18.

Pacific ocean perch Survey

A survey targeted designed to sample Pacific ocean perch was conducted in 1979 and again in 1985. The estimated index of abundance is shown in Table 18.

2.1.5 Biological Parameters and Data

`biological-parameters-and-data`

Length And Age Compositions

Include: Sample size information for length and age composition data by area, year, gear, market category, etc., including both the number of trips and fish sampled.

Length compositions were provided from the following sources, by region, with brief descriptions below:

- Commercial fishery - landed: 1966-2016

- Commercial fishery - discard: 2004-2015
- At-sea hake fishery: 2003-2016
- Pacific ocean perch Survey: 1979 and 1985
- Triennial Survey: 1980, 1983, 1986, 1989, 1992, 1995, 1998, 2001, 2004
- AFSC Slope Survey: 1996-2001
- NWFS Slope Survey: 2001-2002
- NWFSC Shelf-Slope Survey: 2003-2016

Commercial: PacFIN

Research: NWFSC shelf-slope survey

Research: NWFSC slope survey

Age Structures

Age structure data were available from the following sources:

Model Region 1

- Source No. 1 (*ex. research, commercial dead fish, live fish, etc*, date range (ex. 2010-2011)
- Source No. 2 (*ex. research, commercial dead fish, live fish, etc*, date range (ex. 2010-2011)
- etc...
- Begin sublist if desired
  - Sublist source No. 1
  - Sublist source No. 2
  - etc...
- Back to main list, next Source
- Last Source

Natural mortality

Historic Pacific ocean perch ages determined using scales and surface reading methods of otoliths, resulted in estimates of natural mortality of between 0.10 and 0.20yr^{-1} with a longevity less than 30 years(Gunderson 1977). Based on break-and-burn method of age determination using otoliths, the maximum age of Pacific ocean perch was revised to be 90 years (Chilton and Beamish 1982). The updated understanding concerning Pacific ocean perch longevity reduced the estimate of natural mortality based on Hoenig's (1983) relationship to 0.059yr^{-1}. The previous assessment applied a prior distribution on natural mortality based upon multiple life history correlates (including Hoenig's method, Gunderson gonadosomatic index (1997), and McCoy and Gillooly's (2008) theoretical relationship) developed separately for female and male Pacific ocean perch. This assessment also applied a prior on natural mortality. However, the prior and standard deviation were generated as a non-linear function of maximum age as developed by Then et al. (2015) and modified by Owen Hamel which greatly improved the fit to the underlying age data to create the 'Hamel-Then' prior. A maximum age of 100 was used in the development of the prior where female natural memorability was set equal to 0.054 and male natural mortality estimated as an offset from females at 0.053.

Sex ratio, maturation, and fecundity

Examining all biological data sources, the sex ratio of young fish are within 5% of 1:1 by either length or age (Figure 3 and 4), and hence this assessment the sex ratio at birth was assumed to be 1:1. This assessment assumed a logistic maturity-at-length curve based on analysis of 537 fish maturity samples collected from the NWFSC shelf-slope survey. This is revised from the previous assessment which assumed maturity-at-age based on the work of Hannah and Parker (Hannah and Parker 2007). Additionally, the new maturity-at-length curve is based on the estimate of functional maturity an approach that classifies rockfish maturity with developing oocytes as mature or immature based on the proportion of vitellogenin in the cytoplasm and the measured frequency of atretic cells (M. Head, personal communication). The 50% size-at-maturity was estimated at 32.1 cm with maturity asymptoting to one for larger fish.

The fecundity-at-age has also been updated from the previous assessment based on new research. Dick (2017) estimated new fecundity relationships for select West Coast stocks where fecundity for Pacific ocean perch was estimated equal to $0L^{4.98}$ in millions of eggs. Spawning output at length is shown in Figure 7.

Length-weight relationship

The length-weight relationship for Pacific ocean perch was estimated outside the model using all biological data available from fishery and fishery-independent data sources where the female weight-at-length in grams was estimated at $0.0000098L^{3.11}$ and males at $0.0000094L^{3.12}$ where L is length in cm.

Growth (length-at-age)

Write if estimated or fixed in the final model

Aging Precision And Bias

2.1.6 Environmental Or Ecosystem Data Included In The Assessment

`environmental-or-ecosystem-data-included-in-the-assessment`

2.2 History Of Modeling Approaches Used For This Stock

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

2.2.1 Previous Assessments

`previous-assessments`

2.2.2 Previous Assessment Recommendations

`previous-assessment-recommendations`

Include: Response to STAR panel recommendations from the most recent previous assessment.

Recommendation 1: blah blah blah.

STAT response: blah blah blah....

Recommendation 2: blah blah blah.

STAT response: blah blah blah....

Recommendation 3: blah blah blah., etc.

STAT response: Continue recommendations as needed

2.3 Model Description

`model-description`

2.3.1 Transition To The Current Stock Assessment

`transition-to-the-current-stock-assessment`

Include: Complete description of any new modeling approaches

Below, we describe the most important changes made since the last full assessment and explain rationale for each change.:

1. Change No. 1. *Rationale*: blah blah blah.
2. Change No. 2. *Rationale*: blah blah blah.
3. Change No. 3. *Rationale*: Continue list as needed.

2.3.2 Definition of Fleets and Areas

definition-of-fleets-and-areas

We generated data sources for each of the models. Fleets by model include:

Commercial: The commercial fleets include…

Recreational: The recreational fleets include…

Research: Research derived-data include…

2.3.3 Summary of Data for Fleets and Areas

summary-of-data-for-fleets-and-areas

2.3.4 Modeling Software

modeling-software

The STAT team used Stock Synthesis version 3.30.01.13 by Dr. Richard Methot at the NWFSC (Methot and Wetzel 2013). This most recent version was used, since it included improvements and corrections to older versions.

2.3.5 Data Weighting

data-weighting

Citation for Francis method (Francis and Hilborn 2011)
Citation for Ianelli-McAllister harmonic mean method (McAllister and Ianelli 1997)

2.3.6 Priors

priors

Citation for Hamel prior on natural mortality (Hamel 2015)

2.3.7 General Model Specifications

general-model-specifications

Citation for posterior predictive fecundity relationship from Dick (2009) and (2017)
Model data, control, starter, and forecast files can be found in Appendices A-D.

2.3.8 Estimated And Fixed Parameters

estimated-and-fixed-parameters

A full list of all estimated and fixed parameters is provided in Tables…. Estimated and fixed parameters tables currently read in from .csv file, EXAMPLE: Table **??**

2.4 Model Selection and Evaluation

`model-selection-and-evaluation`

2.4.1 Key Assumptions and Structural Choices

`key-assumptions-and-structural-choices`

Include: Evidence of search for balance between model realism and parsimony. Comparison of key model assumptions, include comparisons based on nested models (e.g., asymptotic vs. domed selectivities, constant vs. time-varying selectivities).

2.4.2 Alternate Models Considered

`alternate-models-considered`

Include: Summary of alternate model configurations that were tried but rejected.

2.4.3 Convergence

`convergence`

Include: Randomization run results or other evidence of search for global best estimates.

Convergence testing through use of dispersed starting values often requires extreme values to actually explore new areas of the multivariate likelihood surface. Jitter is a SS option that generates random starting values from a normal distribution logistically transformed into each parameter's range (Methot and Wetzel 2013). Table 22 shows the results of running 100 jitters for each pre-STAR base model....

2.5 Response To The Current STAR Panel Requests

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

Request No. 1: Add after STAR panel.

> **Rationale:** Add after STAR panel.
>
> **STAT Response:** Add after STAR panel.

Request No. 2: Add after STAR panel.

> **Rationale:** Add after STAR panel.
>
> **STAT Response:** Add after STAR panel.

Request No. 3: Add after STAR panel.

> **Rationale:** Add after STAR panel.
>
> **STAT Response:** Add after STAR panel.

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

- **Item No. 1**
- **Item No. 2**
- **Item No. 3, etc.**

Rationale: Add after STAR panel.

STAT Response: Continue requests as needed.

2.6 Model 1

model-1

2.6.1 Model 1 Base Case Results

model-1-base-case-results

Table **??**

2.6.2 Model 1 Uncertainty and Sensitivity Analyses

model-1-uncertainty-and-sensitivity-analyses

Table 23

2.6.3 Model 1 Retrospective Analysis

model-1-retrospective-analysis

2.6.4 Model 1 Likelihood Profiles

model-1-likelihood-profiles

2.6.5 Model 1 Harvest Control Rules (CPS only)

model-1-harvest-control-rules-cps-only

2.6.6 Model 1 Reference Points (groundfish only)

model-1-reference-points-groundfish-only

Intro sentence or two. . . .(Table 24).

Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 0 mt. Table e shows the full suite of estimated reference points for the northern area model and Figure g shows the equilibrium yield curve.

3 Harvest Projections and Decision Tables

harvest-projections-and-decision-tables

Table f

Model 1 Projections and Decision Table (groundfish only) (Table 25

Table h

Model 2 Projections and Decision Table (groundfish only)

Model 3 Projections and Decision Table (groundfish only)

4 Regional Management Considerations

regional-management-considerations

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

5 Research Needs

research-needs

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

6 Acknowledgments

acknowledgments

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

7 Tables

tables

Table 1: West Coast history of regulations.

tab:Regs

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

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

Table 2: Landings for each state (all gears combined), the At-Sea Hake fishery, the Foreign fleet, and research.

tab:Comm_Catch

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	0.0	0.0	0.8	0.0	0	0.0
1918	0.0	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	0.0	0.0	0.5	0.0	0	0.0
1925	0.0	0.0	0.6	0.0	0	0.0
1926	0.0	0.0	1.0	0.0	0	0.0
1927	0.0	0.0	1.4	0.0	0	0.0
1928	0.0	0.1	1.2	0.0	0	0.0
1929	0.0	0.1	0.7	0.0	0	0.0
1930	0.0	0.1	0.9	0.0	0	0.0
1931	0.0	0.1	0.4	0.0	0	0.0

Year	California	Oregon	Washington	At-Sea Hake	Foreign	Research
1932	0.0	0.1	0.4	0.0	0	0.0
1933	0.0	0.1	0.5	0.0	0	0.0
1934	0.0	0.0	2.3	0.0	0	0.0
1935	0.0	0.1	7.7	0.0	0	0.0
1936	0.0	0.2	1.6	0.0	0	0.0
1937	0.0	0.4	2.0	0.0	0	0.0
1938	0.0	0.1	5.1	0.0	0	0.0
1939	0.0	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	0.5	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	4.0	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	145.9	1223.5	361.6	0.0	0	0.0
1954	123.5	1837.5	538.8	0.0	0	0.0
1955	23.0	1346.4	555.6	0.0	0	0.0
1956	3.8	2563.8	548.2	0.0	0	0.0
1957	1.4	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	10.5	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	3.9	3693.9	2006.0	0.0	0	0.0
1964	7.7	4261.6	1770.7	0.0	0	0.0
1965	17.7	5627.8	1972.1	0.0	0	0.0
1966	1.9	1591.2	1725.5	0.0	15561	0.0
1967	9.5	354.7	1861.0	0.0	12357	0.0
1968	11.5	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	12.0	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	17.2	663.7	521.1	31.9	239	0.0

Year	California	Oregon	Washington	At-Sea Hake	Foreign	Research
1977	16.8	457.1	752.0	3.8	0	11.9
1978	42.6	498.7	1391.5	15.4	0	0.0
1979	137.0	735.9	581.4	15.1	0	34.5
1980	19.3	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	623.8	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	436.6	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	107.1	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	83.6	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	34.1	13.1	10.3	0	0.1

Table 3: Summary of discard rates used in the model by each data source.

tab:Discard

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

Table 4: 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	5426	388
1981	40	3921	282
1982	48	4824	339
1983	39	3944	275
1984	31	3103	219
1985	45	4509	318
1986	40	4005	282
1987	43	3056	304
1988	9	602	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	68	1685	301
2004	53	1202	219
2005	50	1270	225
2006	59	1486	264
2007	81	2248	391
2008	101	3058	523
2009	108	3208	551
2010	131	2829	521
2011	100	1944	368
2012	97	1873	355
2013	117	2168	416
2014	140	2850	533
2015	107	2459	446
2016	92	1271	267

Table 5: Summary of At-Sea hake fishery length samples used in the stock assessment.
tab:ASHOP_Lengths

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

Table 6: Summary of Pacific ocean perch survey length samples used in the stock assessment.
tab:POP_Lengths

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

Table 7: Summary of Triennial survey length samples used in the stock assessment.
tab:TriennialLengths

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

Table 8: Summary of AFSC slope survey length samples used in the stock assessment.
tab:AFSC_Lengths

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

Table 9: Summary of NWFSC slope survey length samples used in the stock assessment.
tab:NWslope_Lengths

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

Table 10: Summary of NWFSC shelf-slope survey length samples used in the stock assessment.
tab:NWcombo_Lengths

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

Table 11: Summary of commercial fishery age samples used in the stock assessment.
tab:Comm_Ages

Year	Trips	Fish	Sample Size
1981	11	1027	78
1982	40	2776	282
1983	33	3320	233
1984	27	2625	191
1985	21	2097	148
1986	17	1696	120
1987	24	1196	169
1988	4	200	28
1994	8	238	41
1999	18	863	127
2000	14	677	99
2001	40	1349	226
2002	38	1414	233
2003	41	1333	225
2004	30	854	148
2005	37	1018	177
2006	49	1259	223
2007	63	1825	315
2008	44	1129	200
2009	76	1549	290
2010	53	1258	227
2011	86	1251	259
2012	7	331	49

Table 12: Summary of At-sea hake fishery age samples used in the stock assessment.
tab:ASHOP_Ages

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

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

Year	Tows	Fish	Sample Size
1985	29	1635	70

Table 14: Summary of Triennial survey age samples used in the stock assessment.
tab:Triennial_Ages

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

Table 15: Summary of NWFSC slope survey age samples used in the stock assessment.
tab:NWslope_Ages

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

Table 16: Summary of NWFSC shelf-slope survey age samples used in the stock assessment.
tab:NWFcombo_Ages

Year	Tows	Fish	Sample Size
2003	45	265	109
2004	34	149	82
2005	38	192	92
2006	33	170	80
2007	50	228	121
2008	39	218	94
2009	45	190	109
2010	53	292	128
2011	53	258	128

Table 17: Summary of the commercial catch-per-unit effort time-series used in the stock assessment.

tab:CPUE_Summary

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

Table 18: Summary of the fishery-independant biomass/abundance time-series used in the stock assessment. The standard error includes the input annual standard error and model estimated added variance.

tab:Index_Summary

	POP		Triennial		AFSC Slope		NWFSC Slope		NWFSC Shelf-Slope	
Year	Obs	SE	Obs	SE	Obs	SE	Obs	SE	Obs	SE
1979	56461	0.27	-	-	-	-	-	-	-	-
1980	-	-	10384	0.39	-	-	-	-	-	-
1983	-	-	8974	0.34	-	-	-	-	-	-
1985	34645	0.29	-	-	-	-	-	-	-	-
1986	-	-	2977	0.40	-	-	-	-	-	-
1989	-	-	4873	0.40	-	-	-	-	-	-
1992	-	-	3207	0.39	-	-	-	-	-	-
1995	-	-	2724	0.37	-	-	-	-	-	-
1996	-	-	-	-	7621	0.51	-	-	-	-
1997	-	-	-	-	3807	0.51	-	-	-	-
1998	-	-	4163	0.38	-	-	-	-	-	-
1999	-	-	-	-	4694	0.50	2201	0.48	-	-
2000	-	-	-	-	4243	0.53	2010	0.50	-	-
2001	-	-	1494	0.38	4187	0.49	2290	0.57	-	-
2002	-	-	-	-	-	-	1646	0.58	-	-
2003	-	-	-	-	-	-	-	-	9940	0.41
2004	-	-	2922	0.42	-	-	-	-	4870	0.44
2005	-	-	-	-	-	-	-	-	7782	0.44
2006	-	-	-	-	-	-	-	-	5722	0.46
2007	-	-	-	-	-	-	-	-	5913	0.41
2008	-	-	-	-	-	-	-	-	3710	0.44
2009	-	-	-	-	-	-	-	-	2754	0.41
2010	-	-	-	-	-	-	-	-	4943	0.39
2011	-	-	-	-	-	-	-	-	7417	0.39
2012	-	-	-	-	-	-	-	-	8326	0.40
2013	-	-	-	-	-	-	-	-	7566	0.39
2014	-	-	-	-	-	-	-	-	4720	0.39
2015	-	-	-	-	-	-	-	-	5317	0.36

Table 19: 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	0.156238	31.5	2.77229
1.5	0.156238	32.5	2.85394
2.5	0.24885	33.5	2.93526
3.5	0.341073	34.5	3.01623
4.5	0.43291	35.5	3.09687
5.5	0.524363	36.5	3.17717
6.5	0.615432	37.5	3.25713
7.5	0.70612	38.5	3.33675
8.5	0.796429	39.5	3.41605
9.5	0.886359	40.5	3.49501
10.5	0.975913	41.5	3.57364
11.5	1.06509	42.5	3.65194
12.5	1.1539	43.5	3.72991
13.5	1.24233	44.5	3.80756
14.5	1.33039	45.5	3.88488
15.5	1.41809	46.5	3.96188
16.5	1.50542	47.5	4.03855
17.5	1.59238	48.5	4.11491
18.5	1.67897	49.5	4.19094
19.5	1.76521	50.5	4.26666
20.5	1.85108	51.5	4.34205
21.5	1.9366	52.5	4.41714
22.5	2.02175	53.5	4.49191
23.5	2.10655	54.5	4.56636
24.5	2.191	55.5	4.64051
25.5	2.27509	56.5	4.71434
26.5	2.35883	57.5	4.78786
27.5	2.44221	58.5	4.86108
28.5	2.52525	59.5	4.93399
29.5	2.60794	60.5	5.0066
30.5	2.69029		

Table 20: 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).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)	NA
1	NatM_p_1_Fem_GP_1	0	-2.000	(0.02, 0.1)			Log_Norm	Log_Norm (-2.9
2	L_at_Amin_Fem_GP_1	21	-3.000	(15, 25)			No_prior	None
3	L_at_Amax_Fem_GP_1	42	2.000	(35, 45)	OK	0	No_prior	None
4	VonBert_K_Fem_GP_1	0	3.000	(0.1, 0.4)	OK	0	No_prior	None
5	CV_young_Fem_GP_1	1	5.000	(0.03, 5)	OK	0	No_prior	None
6	CV_old_Fem_GP_1	3	5.000	(0.03, 5)	OK	0	No_prior	None
7	Wtlen_1_Fem	0	-50.000	(0, 3)			No_prior	None
8	Wtlen_2_Fem	3	-50.000	(2, 4)			No_prior	None
9	Mat50%_Fem	32	-50.000	(20, 40)			No_prior	None
10	Mat_slope_Fem	-1	-50.000	(-2, 4)			No_prior	None
11	Eggs_scalar_Fem	0	-50.000	(0, 6)			No_prior	None
12	Eggs_exp_len_Fem	5	-50.000	(-3, 5)			No_prior	None
13	NatM_p_1_Mal_GP_1	0	2.000	(0, 0.3)	OK	0	Normal	Normal (0.05, 0
14	L_at_Amin_Mal_GP_1	21	-2.000	(6, 68)			No_prior	None
15	L_at_Amax_Mal_GP_1	39	2.000	(13, 122)	OK	0	No_prior	None
16	VonBert_K_Mal_GP_1	0	3.000	(0.04, 1.09)	OK	0	No_prior	None
17	CV_young_Mal_GP_1	1	5.000	(0, 742.07)	OK	0	No_prior	None
18	CV_old_Mal_GP_1	2	5.000	(0, 742.07)	OK	0	No_prior	None
19	Wtlen_1_Mal	0	-50.000	(0, 3)			No_prior	None
20	Wtlen_2_Mal	3	-50.000	(2, 4)			No_prior	None
24	CohortGrowDev	1	-50.000	(0, 2)			No_prior	None
25	FracFemale_GP_1	0	-99.000	(0.000001, 0.999999)			No_prior	None
26	SR_LN(R0)	9	1.000	(5, 20)	OK	0	No_prior	None
27	SR_BH_steep	0	2.000	(0.2, 1)	OK	0	Full_Beta	Full_Beta (0.76
28	SR_sigmaR	1	-6.000	(0.5, 1.2)			No_prior	None
29	SR_regime	0	-50.000	(-5, 5)			No_prior	None

Continued on next page

Table 20: 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).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)	NA
30	SR_autocorr	0	-50.000	(0, 2)			No_prior	None
154	LnQ_base_Fishery(1)	-12	-1.000	(-15, 15)			No_prior	None
155	LnQ_base_POP(4)	1	-1.000	(-15, 15)			No_prior	None
156	LnQ_base_Triennial(5)	-1	-1.000	(-15, 15)			No_prior	None
157	Q_extraSD_Triennial(5)	0	2.000	(0, 0.5)	OK	0	No_prior	None
158	LnQ_base_AFSCSlope(6)	-1	-1.000	(-15, 15)			No_prior	None
159	LnQ_base_NWFSCSlope(7)	-1	-1.000	(-15, 15)			No_prior	None
160	LnQ_base_NWFSCcombo(8)	-1	-1.000	(-15, 15)			No_prior	None
161	Q_extraSD_NWFSCcombo(8)	0	2.000	(0, 0.5)	OK	0	No_prior	None
162	SizeSel_P1_Fishery(1)	38	2.000	(20, 45)	OK	1	No_prior	None
163	SizeSel_P2_Fishery(1)	-5	-2.000	(-6, 4)			No_prior	None
164	SizeSel_P3_Fishery(1)	4	3.000	(-1, 9)	OK	0	No_prior	None
165	SizeSel_P4_Fishery(1)	-2	3.000	(-9, 9)	OK	5	No_prior	None
166	SizeSel_P5_Fishery(1)	-4	4.000	(-5, 9)	OK	0	No_prior	None
167	SizeSel_P6_Fishery(1)	1	2.000	(-5, 9)	OK	0	No_prior	None
168	Retain_P1_Fishery(1)	29	1.000	(15, 45)	OK	0	No_prior	None
169	Retain_P2_Fishery(1)	1	1.000	(0.1, 10)	OK	0	No_prior	None
170	Retain_P3_Fishery(1)	1	1.000	(-10, 10)	OK	31441	No_prior	None
171	Retain_P4_Fishery(1)	0	-3.000	(0, 0)			No_prior	None
172	SizeSel_P1_ASHOP(2)	50	2.000	(20, 49.5)	HI	0	No_prior	None
173	SizeSel_P2_ASHOP(2)	-5	-2.000	(-6, 4)			No_prior	None
174	SizeSel_P3_ASHOP(2)	5	3.000	(-1, 9)	OK	0	No_prior	None
175	SizeSel_P4_ASHOP(2)	1	3.000	(-1, 9)	OK	6113	No_prior	None
176	SizeSel_P5_ASHOP(2)	-5	4.000	(-9, 9)	OK	2	No_prior	None
177	SizeSel_P6_ASHOP(2)	999	-2.000	(-5, 999)			No_prior	None
178	SizeSel_P1_POP(4)	24	2.000	(20, 70)	OK	3	No_prior	None

Continued on next page

Table 20: 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).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)	NA
179	SizeSel_P2_POP(4)	12	3.000	(0.001, 50)	OK	5	No_prior	None
180	SizeSel_P1_Triennial(5)	29	2.000	(20, 45)	OK	4	No_prior	None
181	SizeSel_P2_Triennial(5)	-5	-2.000	(-6, 4)			No_prior	None
182	SizeSel_P3_Triennial(5)	4	3.000	(-1, 9)	OK	2	No_prior	None
183	SizeSel_P4_Triennial(5)	2	3.000	(-1, 9)	OK	3	No_prior	None
184	SizeSel_P5_Triennial(5)	-1	4.000	(-5, 9)	OK	1	No_prior	None
185	SizeSel_P6_Triennial(5)	-1	2.000	(-5, 9)	OK	1	No_prior	None
186	SizeSel_P1_AFSCSlope(6)	37	2.000	(20, 45)	OK	4	No_prior	None
187	SizeSel_P2_AFSCSlope(6)	-5	-2.000	(-6, 4)			No_prior	None
188	SizeSel_P3_AFSCSlope(6)	5	3.000	(-1, 9)	OK	1	No_prior	None
189	SizeSel_P4_AFSCSlope(6)	1	3.000	(-1, 9)	OK	6113	No_prior	None
190	SizeSel_P5_AFSCSlope(6)	-9	-4.000	(-9, 9)			No_prior	None
191	SizeSel_P6_AFSCSlope(6)	999	-2.000	(-5, 999)			No_prior	None
192	SizeSel_P1_NWFSCSlope(7)	36	2.000	(20, 45)	OK	2	No_prior	None
193	SizeSel_P2_NWFSCSlope(7)	-5	-2.000	(-6, 4)			No_prior	None
194	SizeSel_P3_NWFSCSlope(7)	2	3.000	(-1, 9)	OK	2	No_prior	None
195	SizeSel_P4_NWFSCSlope(7)	1	3.000	(-1, 9)	OK	6113	No_prior	None
196	SizeSel_P5_NWFSCSlope(7)	-9	-4.000	(-9, 9)			No_prior	None
197	SizeSel_P6_NWFSCSlope(7)	999	-2.000	(-5, 999)			No_prior	None
198	SizeSel_P1_NWFSCcombo(8)	50	2.000	(20, 49.5)	HI	0	No_prior	None
199	SizeSel_P2_NWFSCcombo(8)	-5	-2.000	(-6, 4)			No_prior	None
200	SizeSel_P3_NWFSCcombo(8)	7	3.000	(-1, 9)	OK	1	No_prior	None
201	SizeSel_P4_NWFSCcombo(8)	1	3.000	(-1, 9)	OK	6310	No_prior	None
202	SizeSel_P5_NWFSCcombo(8)	-4	4.000	(-9, 9)	OK	7	No_prior	None
203	SizeSel_P6_NWFSCcombo(8)	999	-2.000	(-5, 999)			No_prior	None
204	Retain_P3_Fishery(1)_BLK1repl_1918	4	1.000	(-10, 10)	OK	0	No_prior	None

Continued on next page

Table 20: 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).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)	NA
205	Retain_P3_Fishery(1)_BLK1repl_1992	2	1.000	(-10, 10)	OK	0	No_prior	None
206	Retain_P3_Fishery(1)_BLK1repl_2002	2	1.000	(-10, 10)	OK	0	No_prior	None
207	Retain_P3_Fishery(1)_BLK1repl_2008	1	1.000	(-10, 10)	OK	0	No_prior	None
208	Retain_P3_Fishery(1)_BLK1repl_2009	-0	1.000	(-10, 10)	OK	0	No_prior	None
209	Retain_P3_Fishery(1)_BLK1repl_2011	7	1.000	(-10, 10)	OK	2	No_prior	None

tab:model_params

Table 21: Likelihood components from the base model

tab:like

Likelihood Component	Value
Total	1328.59
Survey	-28.92
Discard	-38.1
Length-frequency data	175.01
Age-frequency data	1208.1
Recruitment	8.86
Forecast Recruitment	0
Parameter Priors	3.64

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

Year	Total biomass (mt)	Spawning output (million eggs) (mt)	Summary biomass 3+	Relative biomass	Age-0 re-cruits	Estimated total catch (mt)	1-SPR	Exp. rate
1918	119983	5541	119351	1.00	9915	0.0	0.00	0
1919	119984	5541	119350	1.00	9918	1.3	0.00	0
1920	119990	5541	119350	1.00	9921	0.5	0.00	0
1921	120006	5541	119366	1.00	9923	0.4	0.00	0
1922	120031	5541	119390	1.00	9926	0.4	0.00	0
1923	120063	5541	119422	1.00	9929	0.3	0.00	0
1924	120102	5541	119461	1.00	9931	0.3	0.00	0
1925	120148	5542	119506	1.00	9934	0.6	0.00	0
1926	120198	5543	119557	1.00	9937	0.8	0.00	0
1927	120253	5545	119611	1.00	9940	1.2	0.00	0
1928	120311	5547	119669	1.00	9943	1.6	0.00	0
1929	120372	5549	119730	1.00	9945	1.4	0.00	0
1930	120436	5551	119793	1.00	9947	1.4	0.00	0
1931	120500	5554	119858	1.00	9948	1.3	0.00	0
1932	120565	5557	119923	1.00	9949	1.4	0.00	0
1933	120631	5560	119988	1.00	9949	1.1	0.00	0
1934	120695	5562	120053	1.00	9948	1.8	0.00	0
1935	120758	5565	120115	1.00	9948	3.2	0.00	0
1936	120814	5568	120171	1.00	9950	8.8	0.00	0
1937	120875	5571	120232	1.01	9955	2.3	0.00	0
1938	120934	5574	120291	1.01	9965	3.4	0.00	0
1939	120988	5577	120345	1.01	9980	6.5	0.00	0
1940	121037	5579	120392	1.01	10472	11.3	0.01	0
1941	121080	5581	120428	1.01	10500	23.6	0.01	0
1942	121133	5582	120456	1.01	10532	31.1	0.02	0
1943	121203	5583	120525	1.01	10563	47.3	0.21	0
1944	120789	5559	120108	1.00	10568	564.2	0.33	0
1945	120053	5517	119371	1.00	10564	933.0	0.67	0.01
1946	118109	5416	117426	0.98	10523	2203.8	0.39	0.02
1947	117368	5372	116686	0.97	10602	1081.3	0.22	0.01
1948	117189	5355	116507	0.97	10826	572.3	0.26	0
1949	116930	5336	116240	0.96	11218	694.7	0.34	0.01
1950	116509	5309	115801	0.96	11826	909.8	0.48	0.01
1951	115671	5260	114935	0.95	12640	1405.0	0.55	0.01
1952	114736	5204	113956	0.94	13558	1621.4	0.74	0.01
1953	113188	5113	112355	0.92	14146	2401.3	0.60	0.02
1954	112480	5055	111595	0.91	13828	1777.2	0.78	0.02

Table 24: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs) (mt)	Summary biomass 3+	Relative biomass	Age-0 re-cruits	Estimated total catch (mt)	1-SPR	Exp. rate
1955	111211	4963	110306	0.90	12608	2567.3	0.67	0.02
1956	110719	4903	109850	0.88	11092	2004.5	0.92	0.02
1957	109165	4794	108380	0.87	9576	3202.8	0.84	0.03
1958	108120	4718	107433	0.85	8388	2743.7	0.72	0.03
1959	107600	4682	107004	0.84	7618	2158.0	0.48	0.02
1960	107811	4700	107282	0.85	7338	1266.0	0.77	0.01
1961	106695	4675	106207	0.84	7483	2370.8	0.96	0.02
1962	104400	4609	103924	0.83	7585	3331.5	1.13	0.03
1963	100827	4486	100345	0.81	6798	4426.2	1.31	0.04
1964	95665	4285	95192	0.77	5579	5883.4	1.36	0.06
1965	90047	4053	89631	0.73	4764	6237.0	1.51	0.07
1966	82732	3734	82387	0.67	4313	7833.8	1.85	0.1
1967	64276	2876	63979	0.52	3841	18970.1	1.85	0.3
1968	50324	2217	50055	0.40	3821	14651.6	1.82	0.29
1969	41444	1796	41195	0.32	4861	9713.6	1.27	0.24
1970	40135	1739	39864	0.31	7857	2184.2	1.32	0.05
1971	38719	1679	38365	0.30	3981	2302.2	1.22	0.06
1972	37770	1635	37331	0.30	2628	1905.8	1.23	0.05
1973	36895	1587	36661	0.29	2338	1888.8	1.43	0.05
1974	35149	1501	34984	0.27	2331	2643.3	1.38	0.08
1975	33670	1429	33519	0.26	2855	2274.5	1.03	0.07
1976	33187	1411	33029	0.25	2330	1183.0	1.18	0.04
1977	32281	1386	32104	0.25	2998	1507.7	1.09	0.05
1978	31532	1374	31372	0.25	2236	1270.3	1.35	0.04
1979	29977	1321	29796	0.24	2285	1999.6	1.23	0.07
1980	28842	1281	28697	0.23	2062	1533.2	1.31	0.05
1981	27450	1224	27306	0.22	2232	1726.8	1.21	0.06
1982	26366	1179	26228	0.21	3164	1381.5	1.09	0.05
1983	25583	1147	25424	0.21	2820	1057.9	1.35	0.04
1984	24240	1086	24043	0.20	2369	1627.7	1.39	0.07
1985	22910	1023	22735	0.18	2420	1659.9	1.35	0.07
1986	21839	969	21688	0.17	1661	1422.1	1.36	0.07
1987	20827	917	20683	0.17	1799	1375.3	1.27	0.07
1988	20086	877	19976	0.16	1906	1106.0	1.41	0.06
1989	19054	828	18936	0.15	2392	1378.4	1.47	0.07
1990	17940	776	17807	0.14	3431	1471.1	1.36	0.08
1991	17204	742	17038	0.13	1241	1123.2	1.52	0.07

Table 24: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs) (mt)	Summary biomass 3+	Relative biomass	Age-0 re-cruits	Estimated total catch (mt)	1-SPR	Exp. rate
1992	16155	692	15972	0.12	676	1477.3	1.57	0.09
1993	15055	633	14984	0.11	643	1568.0	1.57	0.1
1994	14027	584	13981	0.11	1939	1414.9	1.52	0.1
1995	13198	545	13135	0.10	1802	1178.5	1.44	0.09
1996	12574	520	12454	0.09	672	952.9	1.42	0.08
1997	12029	501	11932	0.09	623	880.1	1.33	0.07
1998	11613	490	11570	0.09	629	715.9	1.35	0.06
1999	11136	473	11087	0.09	4111	723.1	1.23	0.07
2000	10817	460	10715	0.08	5420	563.4	0.57	0.05
2001	10980	466	10701	0.08	1963	160.2	0.87	0.01
2002	11191	465	10900	0.08	1359	295.1	0.62	0.03
2003	11616	469	11501	0.08	751	179.1	0.56	0.02
2004	12027	471	11945	0.09	2363	157.4	0.53	0.01
2005	12424	474	12352	0.09	1049	148.1	0.30	0.01
2006	12862	489	12732	0.09	950	77.1	0.32	0.01
2007	13277	514	13210	0.09	1143	85.5	0.51	0.01
2008	13608	541	13473	0.10	29804	157.8	0.43	0.01
2009	14167	565	13686	0.10	612	133.8	0.55	0.01
2010	15232	581	13793	0.10	1322	194.8	0.52	0.01
2011	17119	594	17067	0.11	1724	184.1	0.20	0.01
2012	18700	610	18608	0.11	1478	61.5	0.18	0
2013	20242	627	20133	0.11	2217	59.1	0.17	0
2014	21658	666	21552	0.12	1713	57.8	0.15	0
2015	22900	752	22764	0.14	2272	55.4	0.15	0
2016	23963	861	23842	0.16	2558	60.1	0.13	0
2017	24844	955	24692	0.17	2799	58.3	0.67	0
2018	25207	1009	25037	0.18	2935	-	-	-
2019	25400	1043	25216	0.19	3018	-	-	-
2020	25481	1062	25290	0.19	3066	-	-	-
2021	25498	1073	25302	0.19	3091	-	-	-
2022	25484	1077	25286	0.19	3102	-	-	-
2023	25462	1078	25262	0.19	3105	-	-	-
2024	25442	1078	25241	0.19	3104	-	-	-
2025	25430	1078	25229	0.19	3103	-	-	-
2026	25428	1077	25227	0.19	3103	-	-	-
2027	25435	1077	25235	0.19	3103	-	-	-
2028	25450	1078	25250	0.19	3103	-	-	-

Table 24: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs) (mt)	Summary biomass 3+	Relative biomass	Age-0 re-cruits	Estimated total catch (mt)	1-SPR	Exp. rate

tab:Timeseries_mod1

Table 23: Sensitivity of the base model to dropping or down-weighting data sources and alternative assumptions about growth.

tab:Sensitivity_model1

Label	Base (Francis weights)	Harmonic mean weights	Drop index	Drop ages	Down-weight lengths	Free size Age0	Free CV Amin	External growth
TOTAL_like	-	-	-	-	-	-	-	-
Catch_like	-	-	-	-	-	-	-	-
Equil_catch_like	-	-	-	-	-	-	-	-
Survey_like	-	-	-	-	-	-	-	-
Length_comp_like	-	-	-	-	-	-	-	-
Age_comp_like	-	-	-	-	-	-	-	-
Parm_priors_like	-	-	-	-	-	-	-	-
SSB_Unfished_thousand_mt	-	-	-	-	-	-	-	-
TotBio_Unfished	-	-	-	-	-	-	-	-
SmryBio_Unfished	-	-	-	-	-	-	-	-
Recr_Unfished_billions	-	-	-	-	-	-	-	-
SSB_Btgt_thousand_mt	-	-	-	-	-	-	-	-
SPR_Btgt	-	-	-	-	-	-	-	-
Fstd_Btgt	-	-	-	-	-	-	-	-
TotYield_Btgt_thousand_mt	-	-	-	-	-	-	-	-
SSB_SPRtgt_thousand_mt	-	-	-	-	-	-	-	-
Fstd_SPRtgt	-	-	-	-	-	-	-	-
TotYield_SPRtgt_thousand_mt	-	-	-	-	-	-	-	-
SSB_MSY_thousand_mt	-	-	-	-	-	-	-	-
SPR_MSY	-	-	-	-	-	-	-	-
Fstd_MSY	-	-	-	-	-	-	-	-
TotYield_MSY_thousand_mt	-	-	-	-	-	-	-	-
RetYield_MSY	-	-	-	-	-	-	-	-
Bratio_2015	-	-	-	-	-	-	-	-
F_2015	-	-	-	-	-	-	-	-
SPRratio_2015	-	-	-	-	-	-	-	-
Recr_2015	-	-	-	-	-	-	-	-
Recr_Virgin_billions	-	-	-	-	-	-	-	-
L_at_Amin_Fem_GP_1	-	-	-	-	-	-	-	-
L_at_Amax_Fem_GP_1	-	-	-	-	-	-	-	-
VonBert_K_Fem_GP_1	-	-	-	-	-	-	-	-
CV_young_Fem_GP_1	-	-	-	-	-	-	-	-
CV_old_Fem_GP_1	-	-	-	-	-	-	-	-

Table 25: Projection of potential OFL, spawning biomass, and depletion for the base case model.

tab:Forecast_mod1

Year	OFL contriubtion (mt)	ACL landings (mt)	Age 3+ biomass (mt)	Spawning Output	Depletion
2017	832	326	24692	955	0.17
2018	877	370	25037	1009	0.18
2019	898	394	25216	1043	0.19
2020	899	404	25290	1062	0.19
2021	892	406	25302	1073	0.19
2022	880	403	25286	1077	0.19
2023	869	399	25262	1078	0.19
2024	861	396	25241	1078	0.19
2025	855	393	25229	1078	0.19
2026	851	391	25227	1077	0.19
2027	850	391	25235	1077	0.19
2028	849	391	25250	1078	0.19

8 Figures

figures

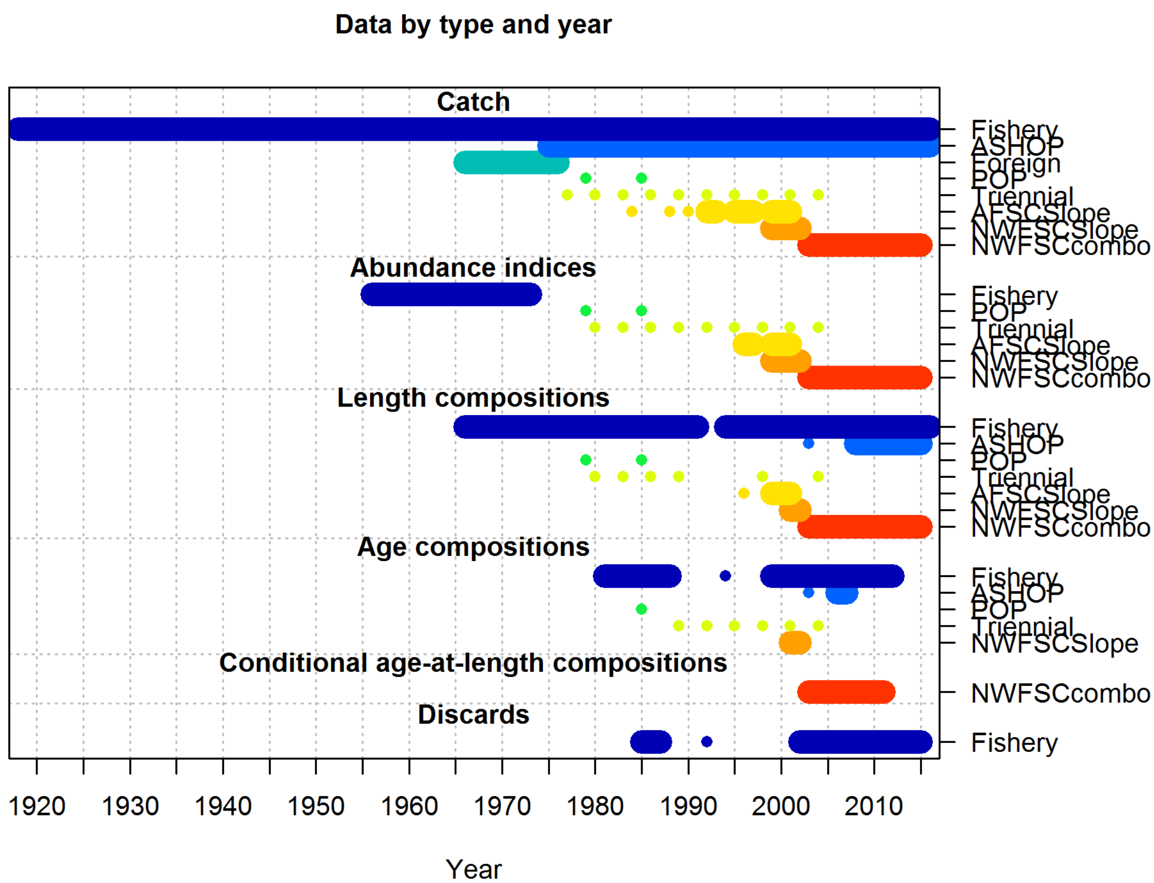


Figure 1: Summary of data sources used in the Base model. fig:data_plot

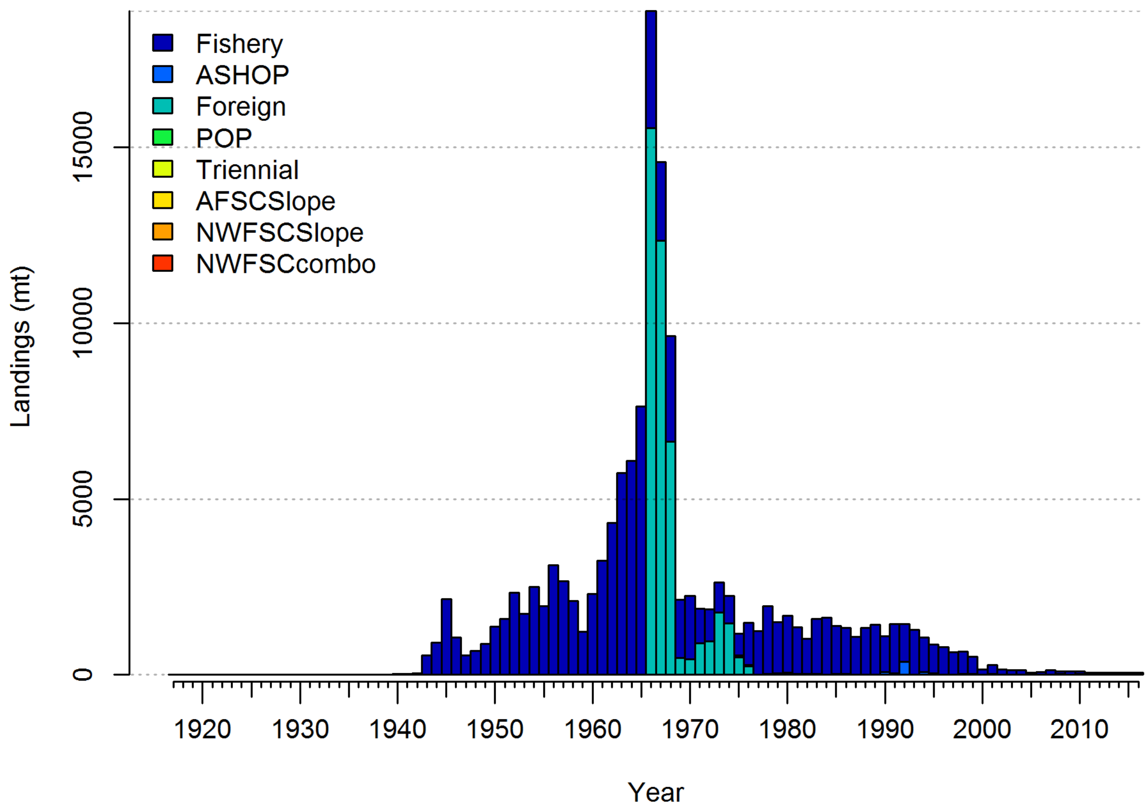


Figure 2: Total catches Pacific ocean perch through 2016. fig:Catch

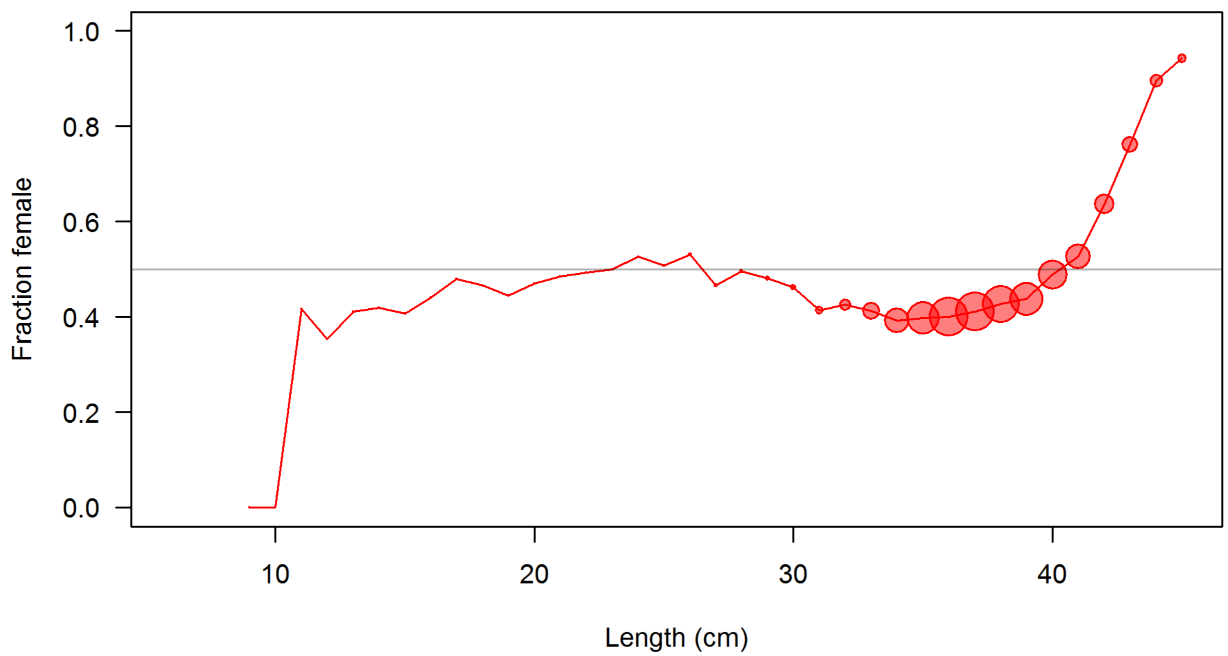


Figure 3: The estimated sex ratio of Pacific ocean perch at length from all biological data sources. fig:sexratio

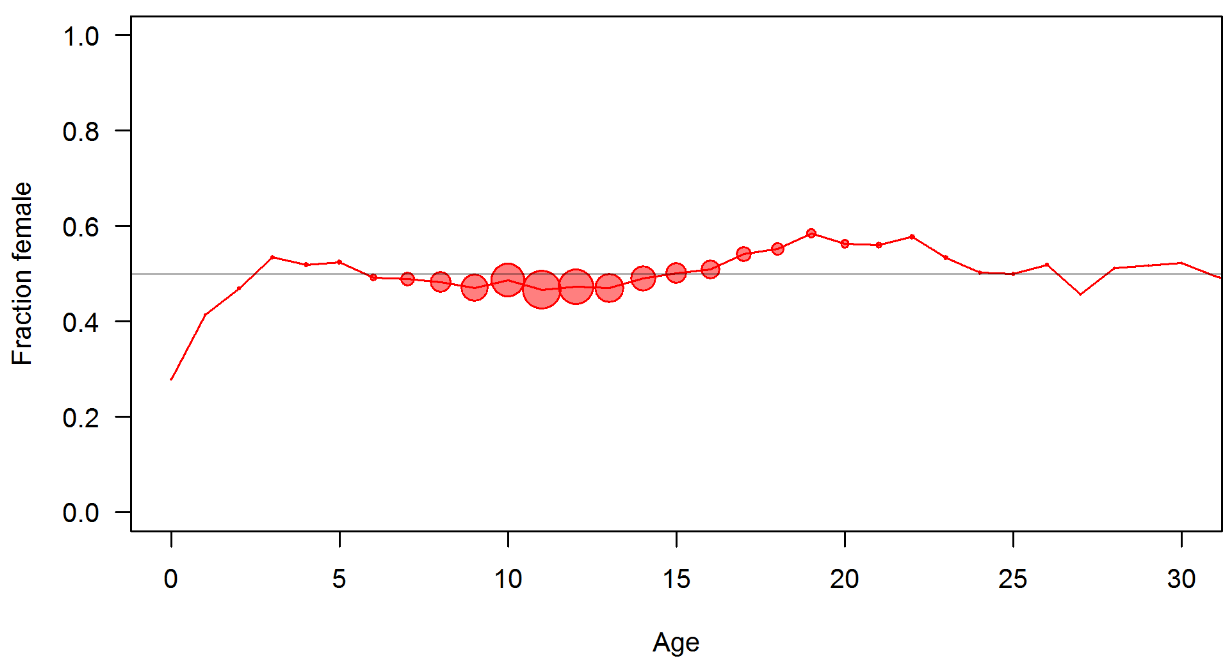


Figure 4: The estimated sex ratio of Pacific ocean perch at age from all biological data sources. fig:sexratio_Age

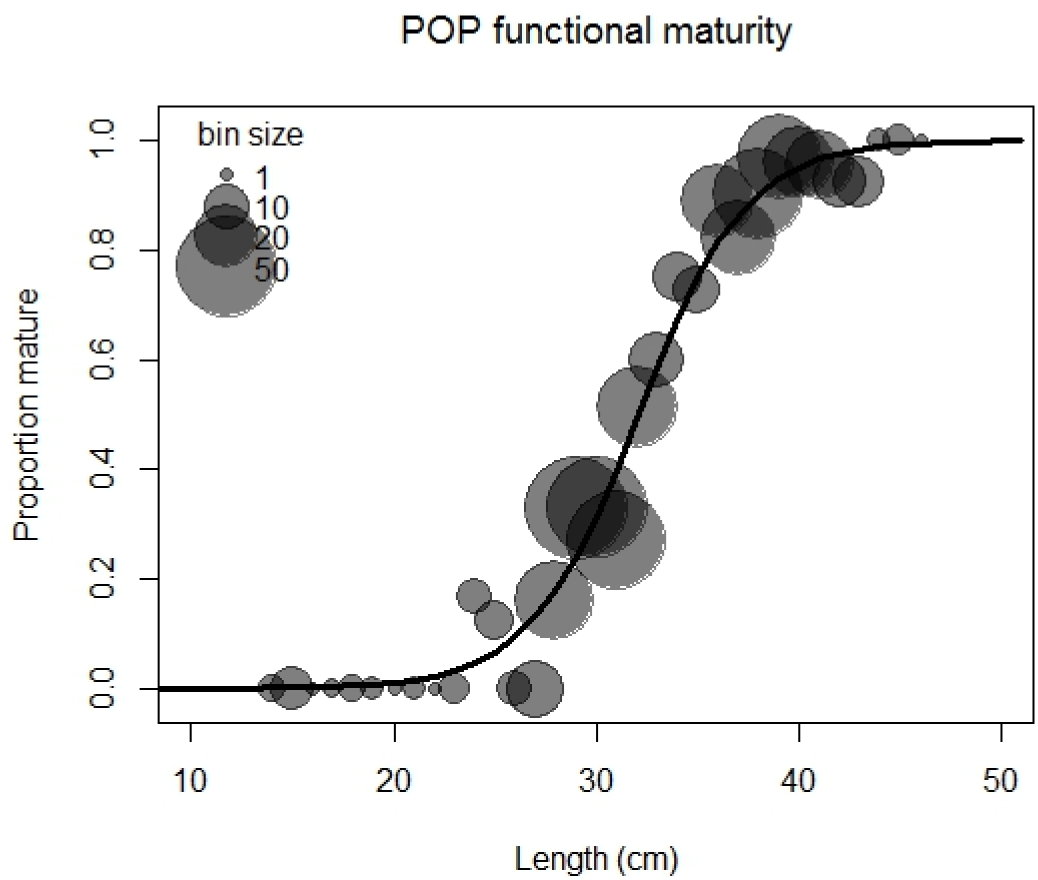


Figure 5: The estimated functional maturity Pacific ocean perch at length. fig:mat

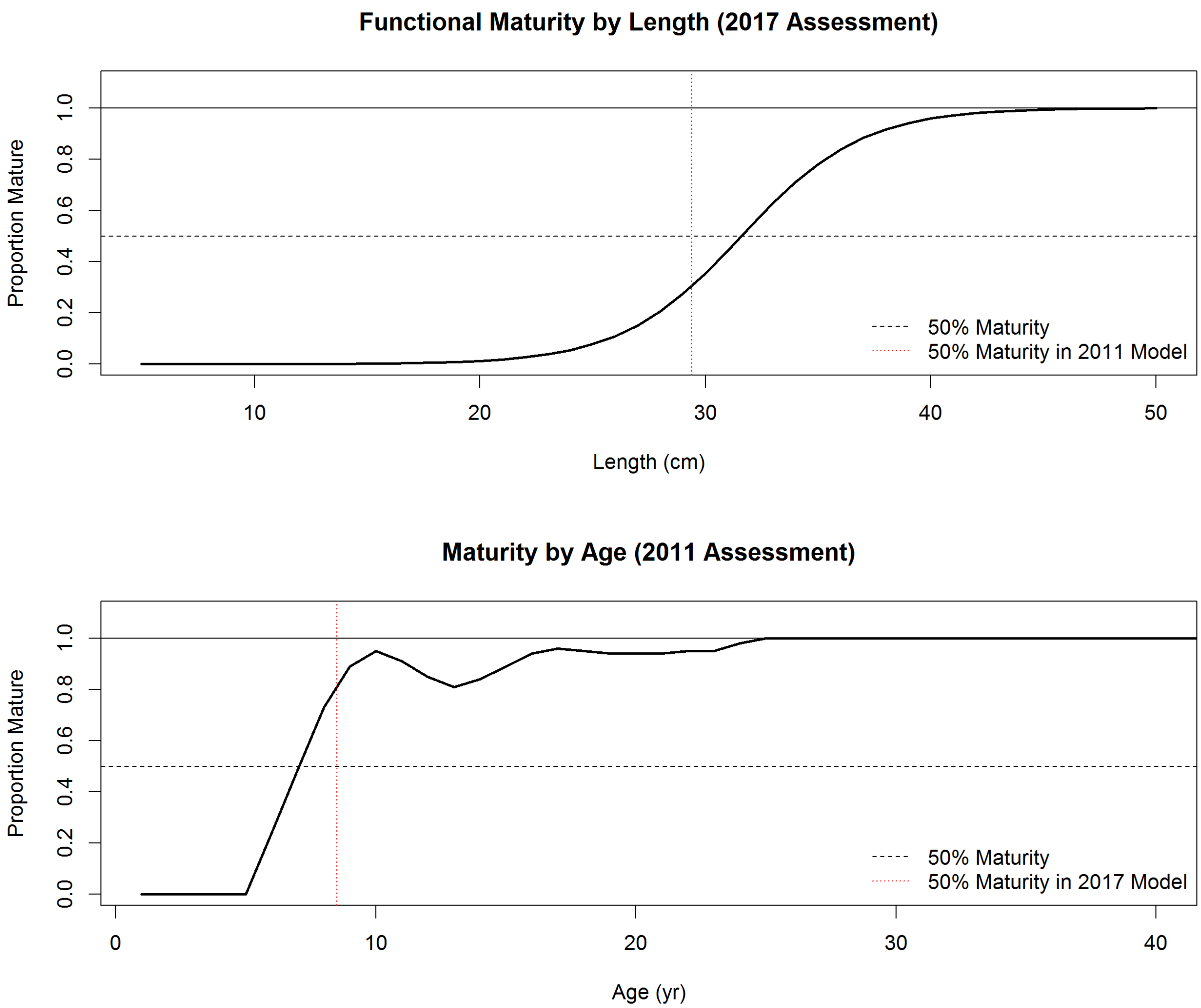


Figure 6: Comparison between estimated maturity-at-length used in this assessment and maturity-at-age applied in the 2011 assessment of Pacific ocean perch. fig:mat_compare

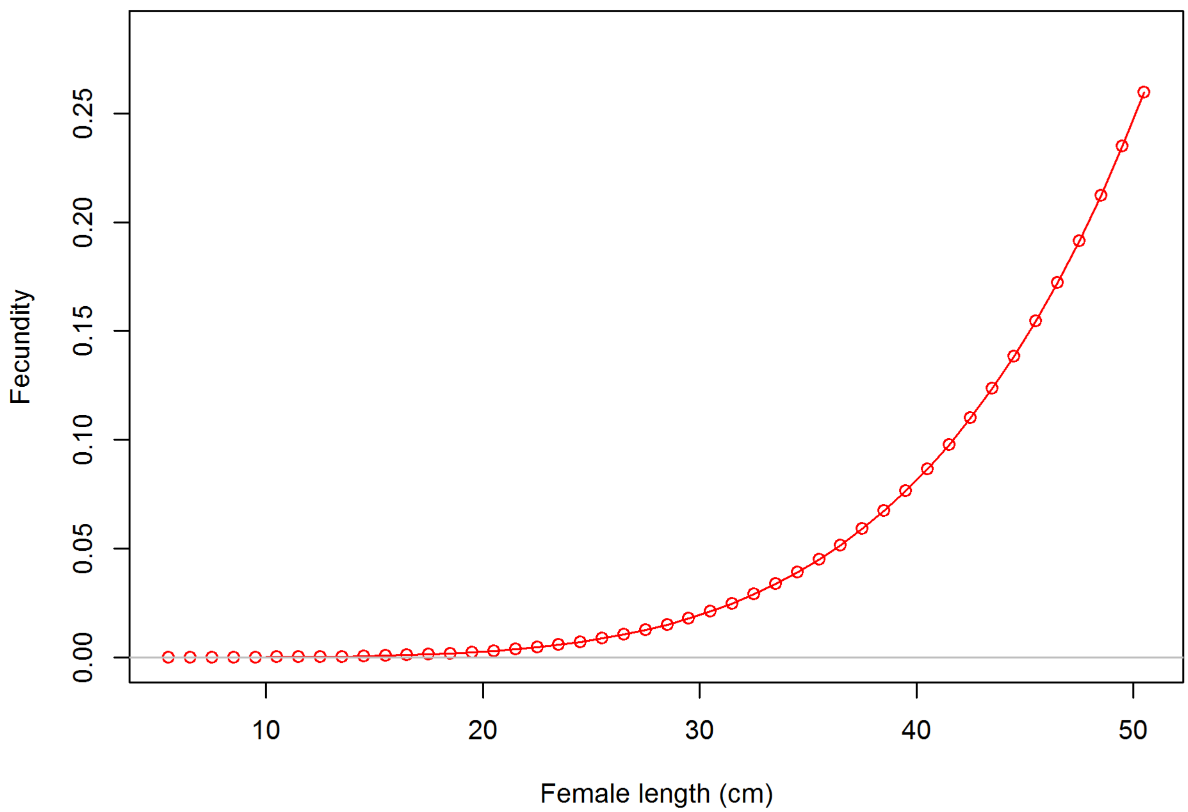
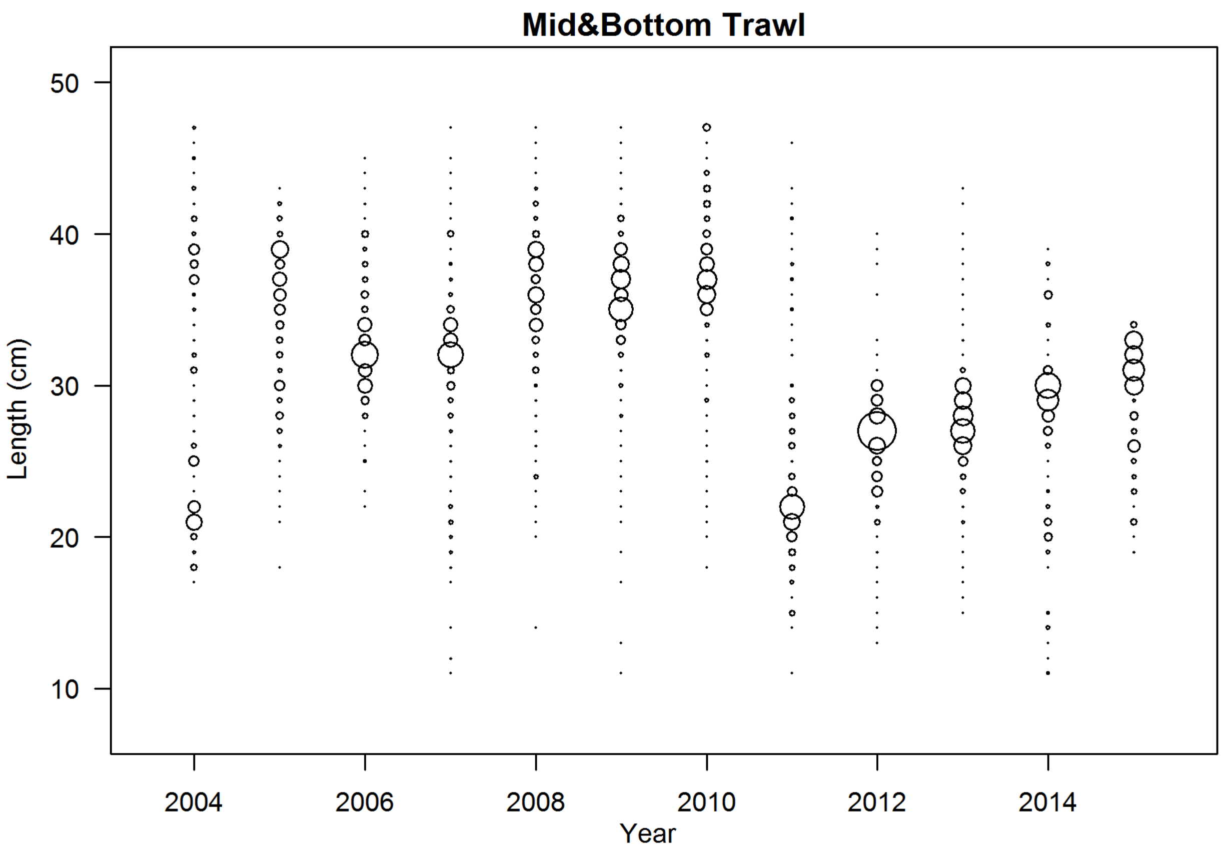


Figure 7: Fecundity at length of Pacific ocean perch in the Base model. fig:fecundity


Mid&Bottom Trawl
Length (cm)
50
40
30
20
10
2004
2006
2008
2010
2012
2014
Year

590

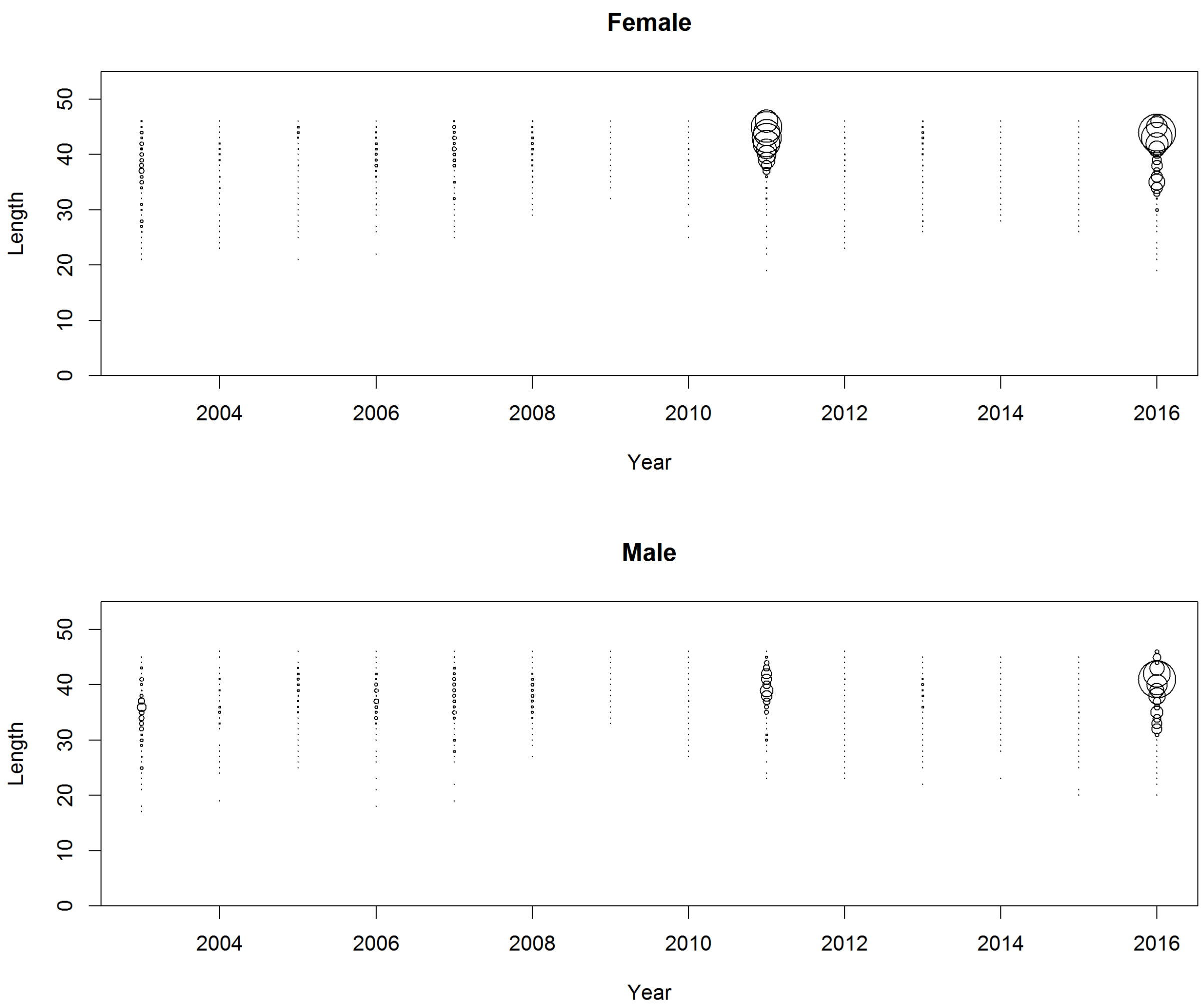


Figure 8: At-Sea hake fishery length frequency distributions for Pacific ocean perch. fig:ASHOP_Lengt

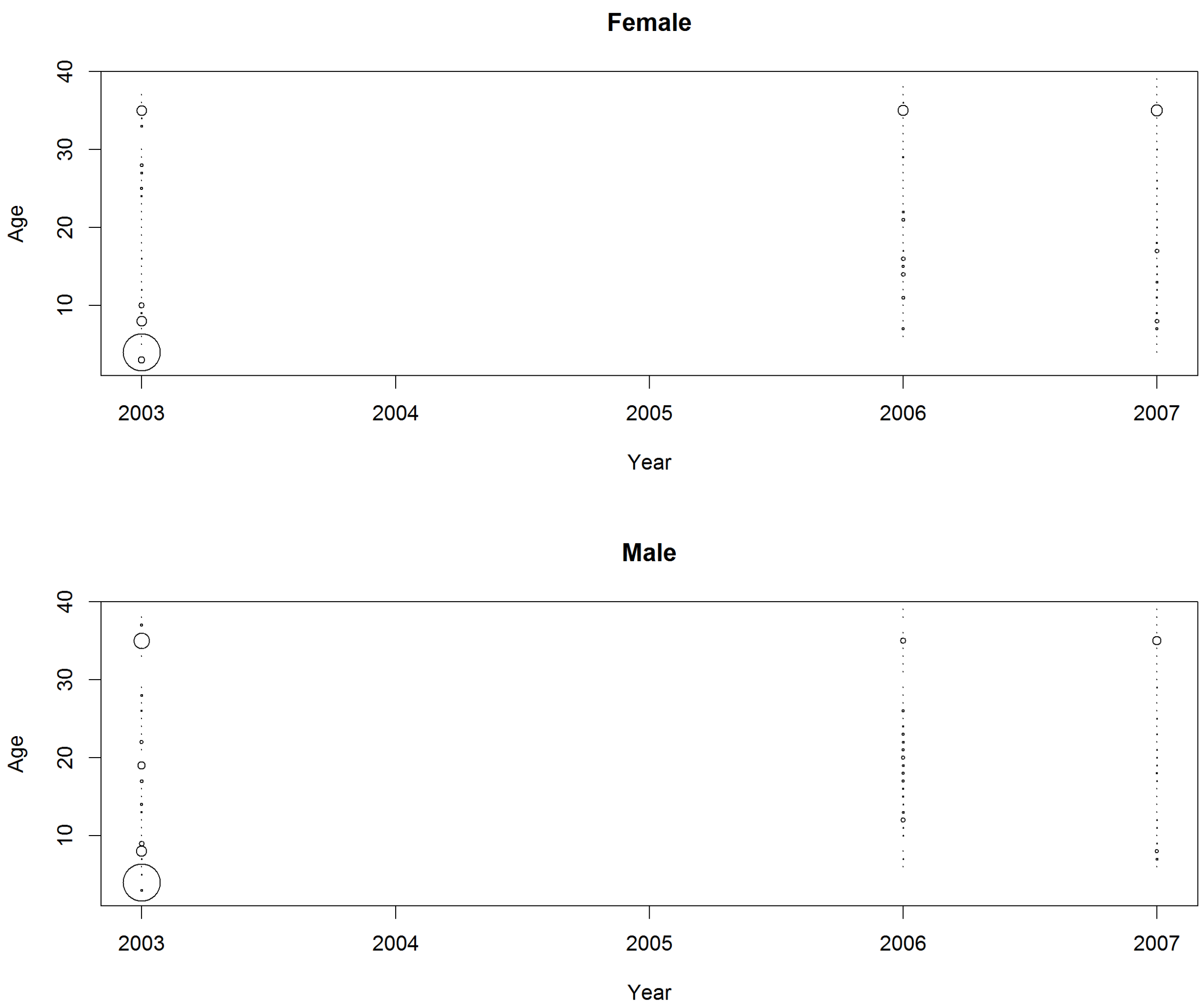


Figure 9: At-Sea hake fishery age frequency distributions for Pacific ocean perch. fig:ASHOP_Age

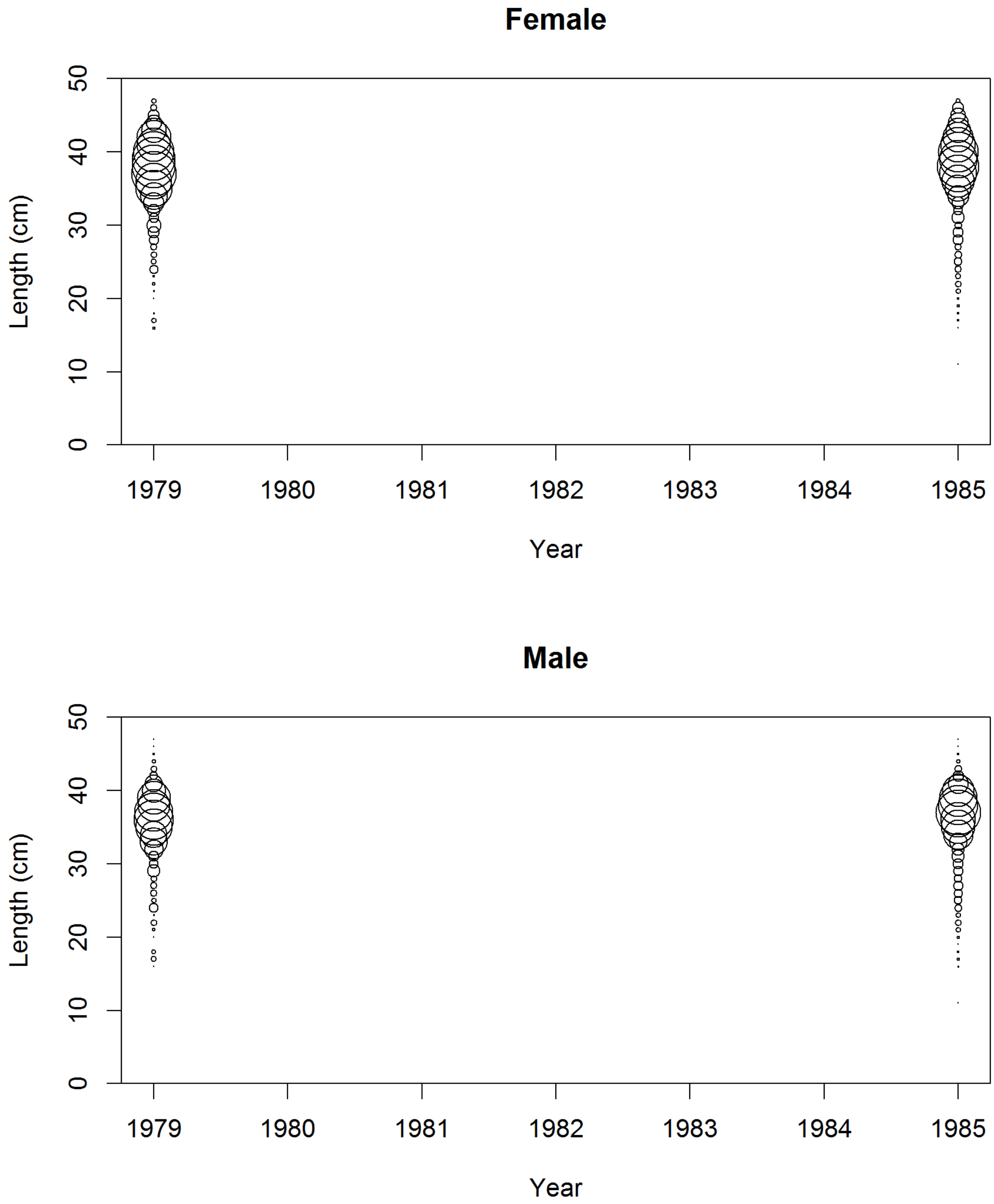


Figure 10: Pacific ocean perch survey length frequency distributions for Pacific ocean perch. fig:POP_Lengt

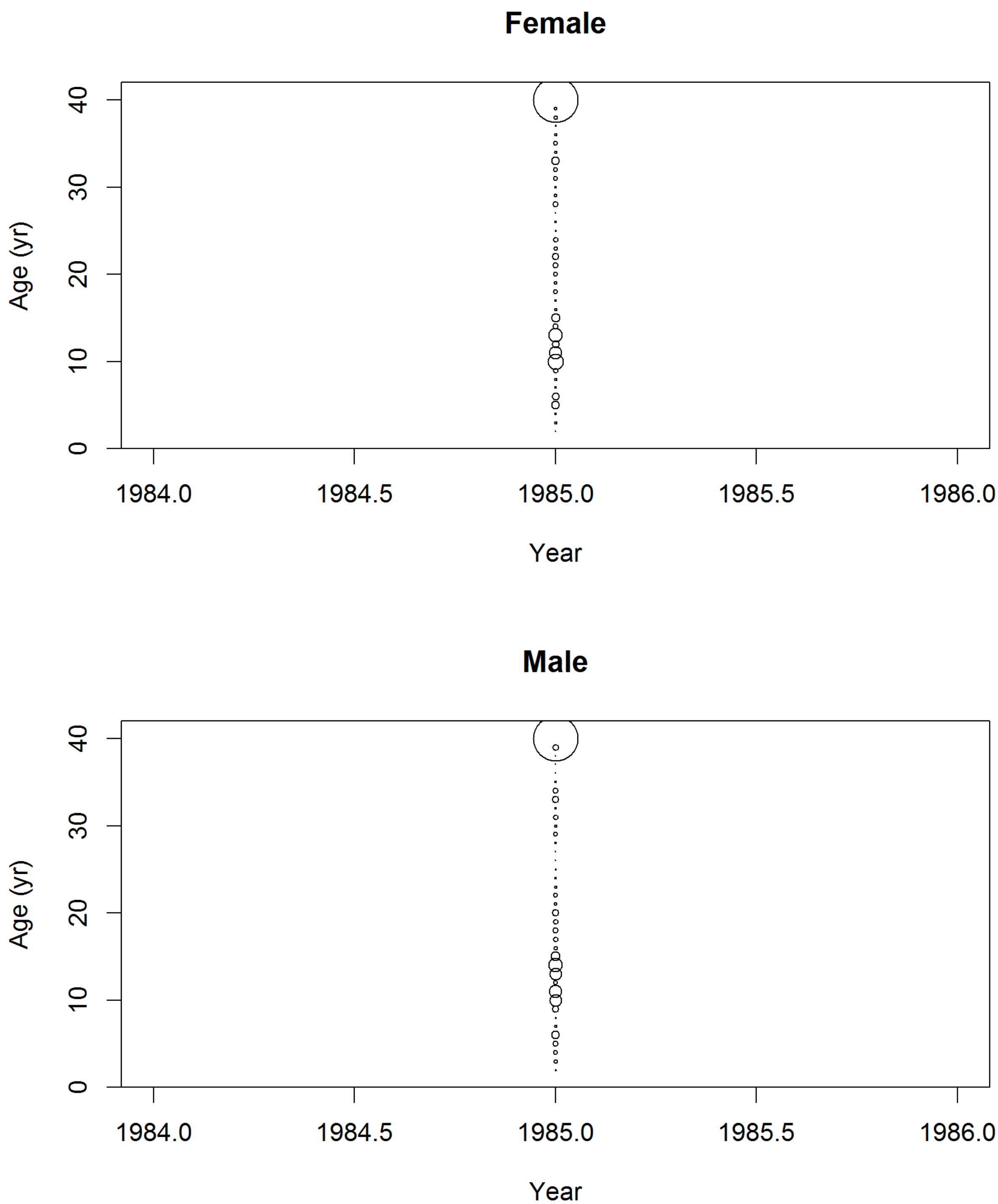


Figure 11: Pacific ocean perch survey age frequency distributions for Pacific ocean perch. fig:POP_Age

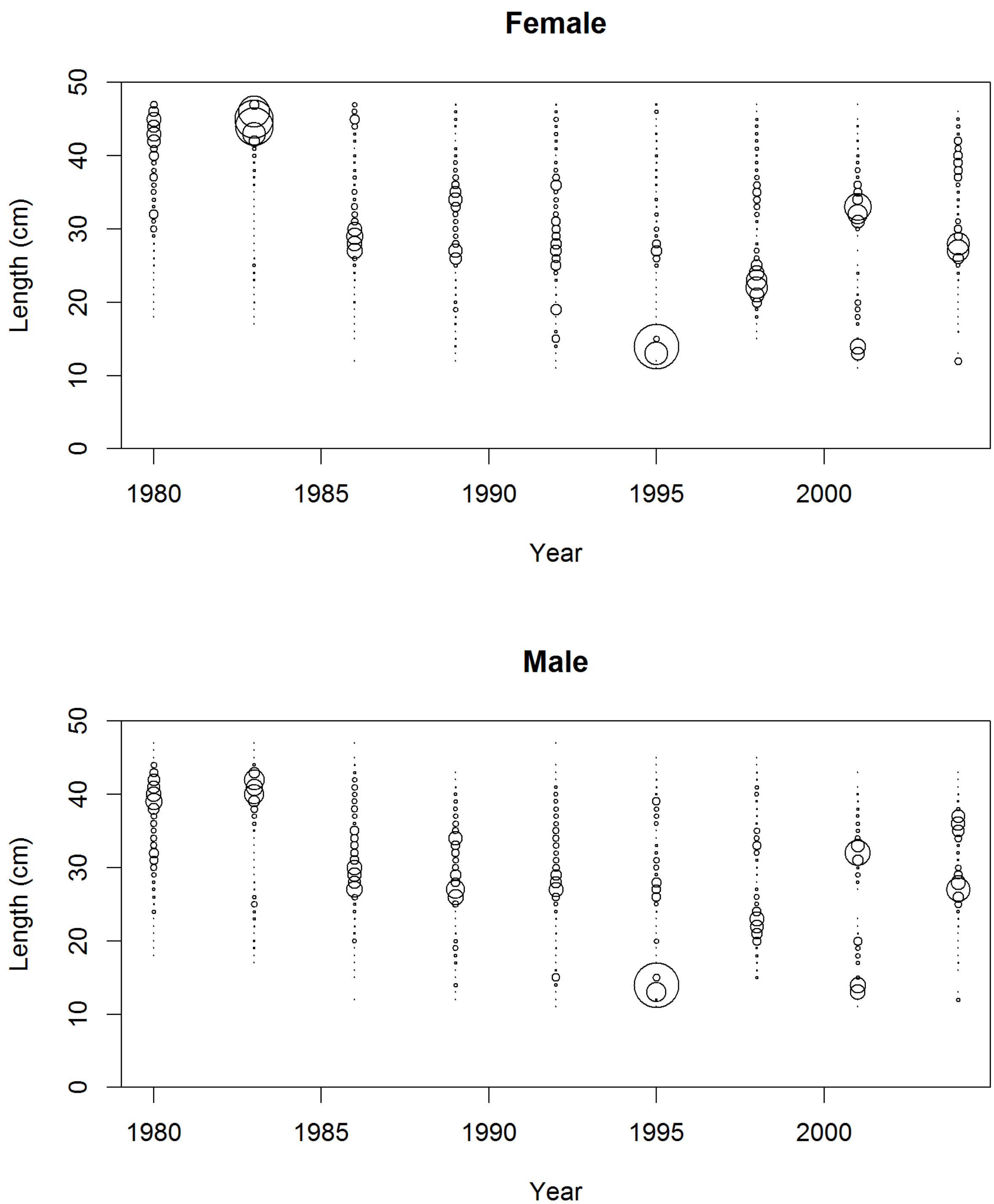


Figure 12: Triennial survey length frequency distributions for Pacific ocean perch. fig:Tri_Length

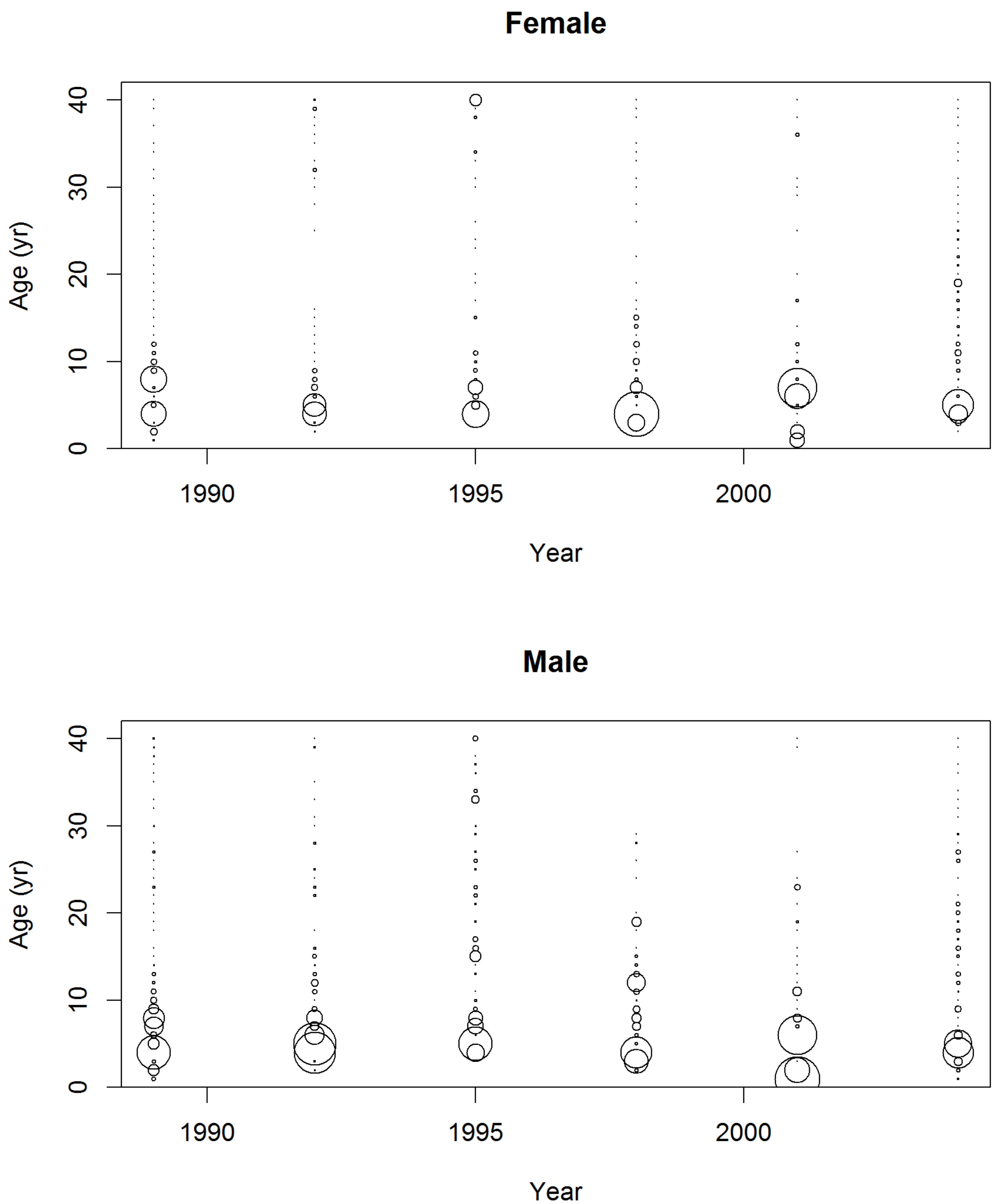


Figure 13: Triennial survey age frequency distributions for Pacific ocean perch. fig:Tri_Age

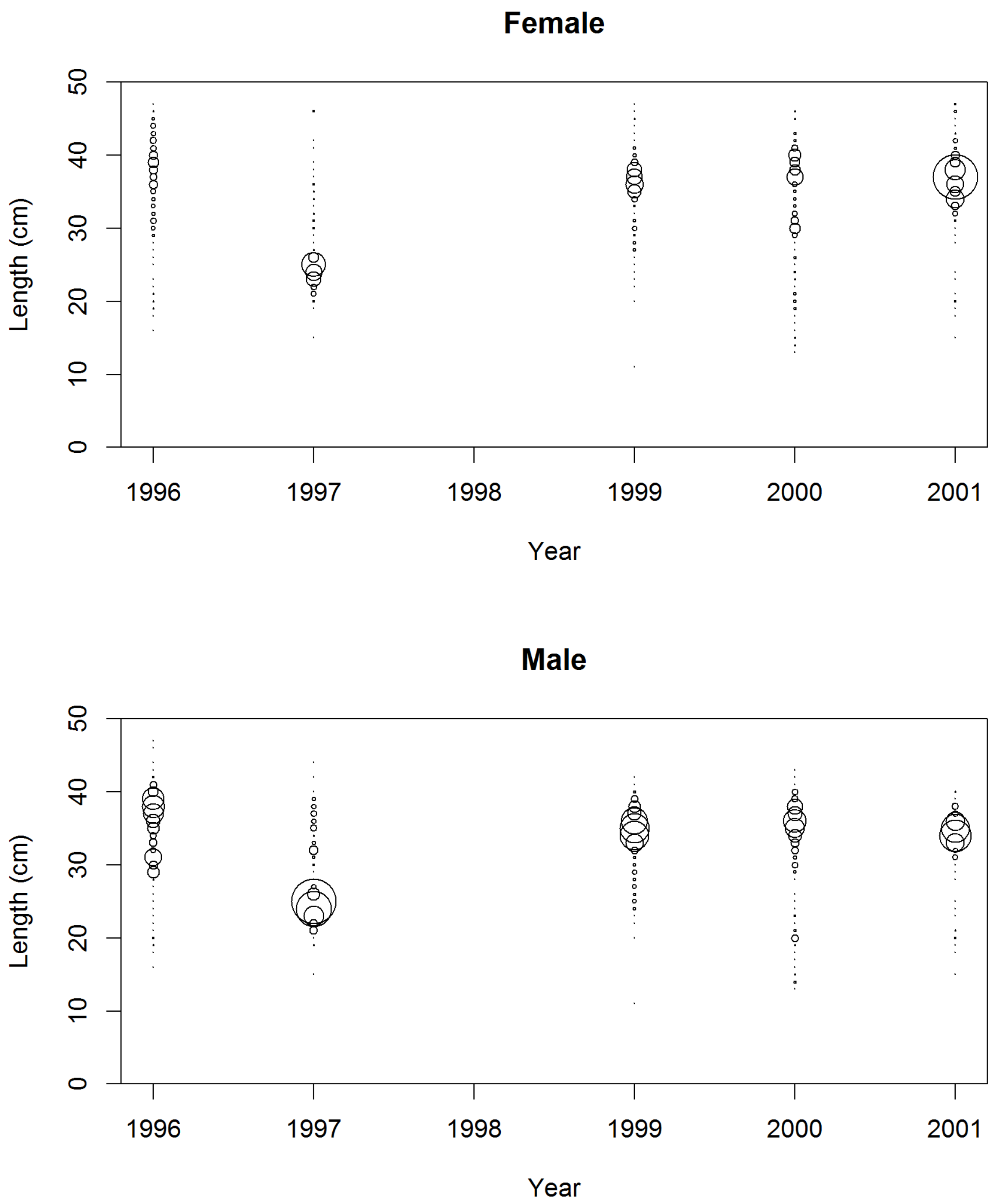


Figure 14: AFSC slope survey length frequency distributions for Pacific ocean perch. fig:afsc_Length

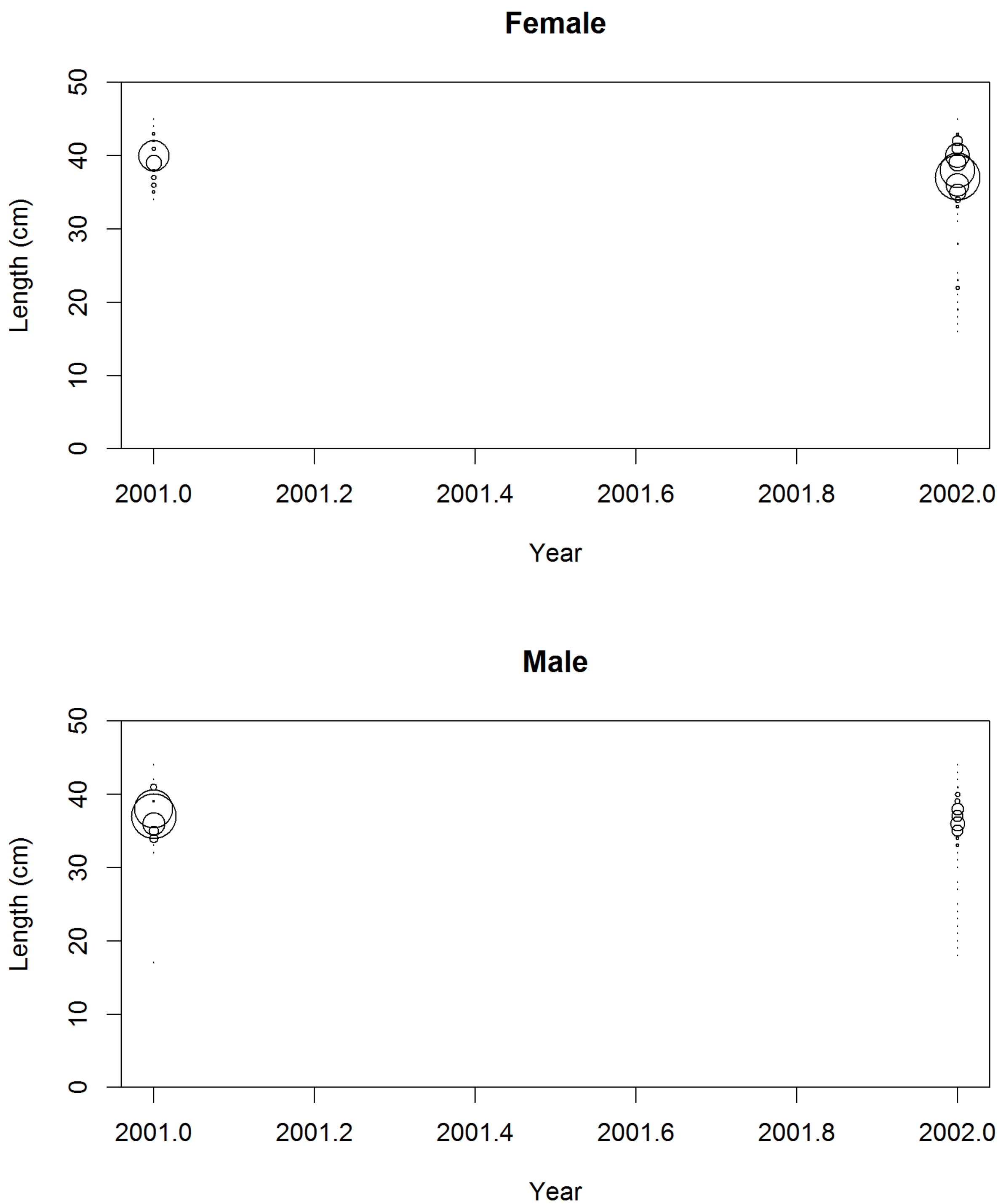


Figure 15: NWFSC slope survey length frequency distributions for Pacific ocean perch. fig:nw_slope_L

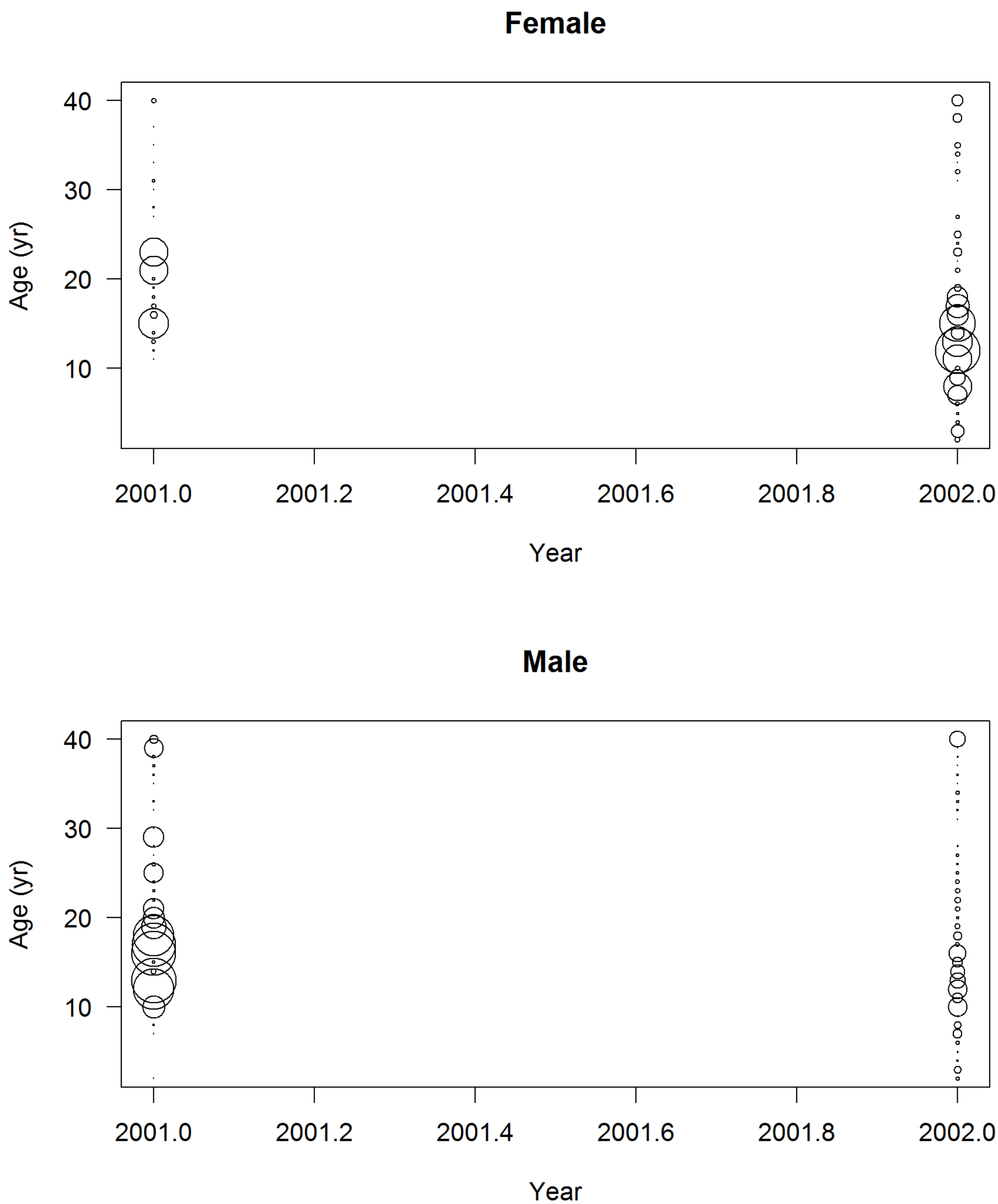


Figure 16: NWFSC slope survey age frequency distributions for Pacific ocean perch. fig:nw_slope_Age

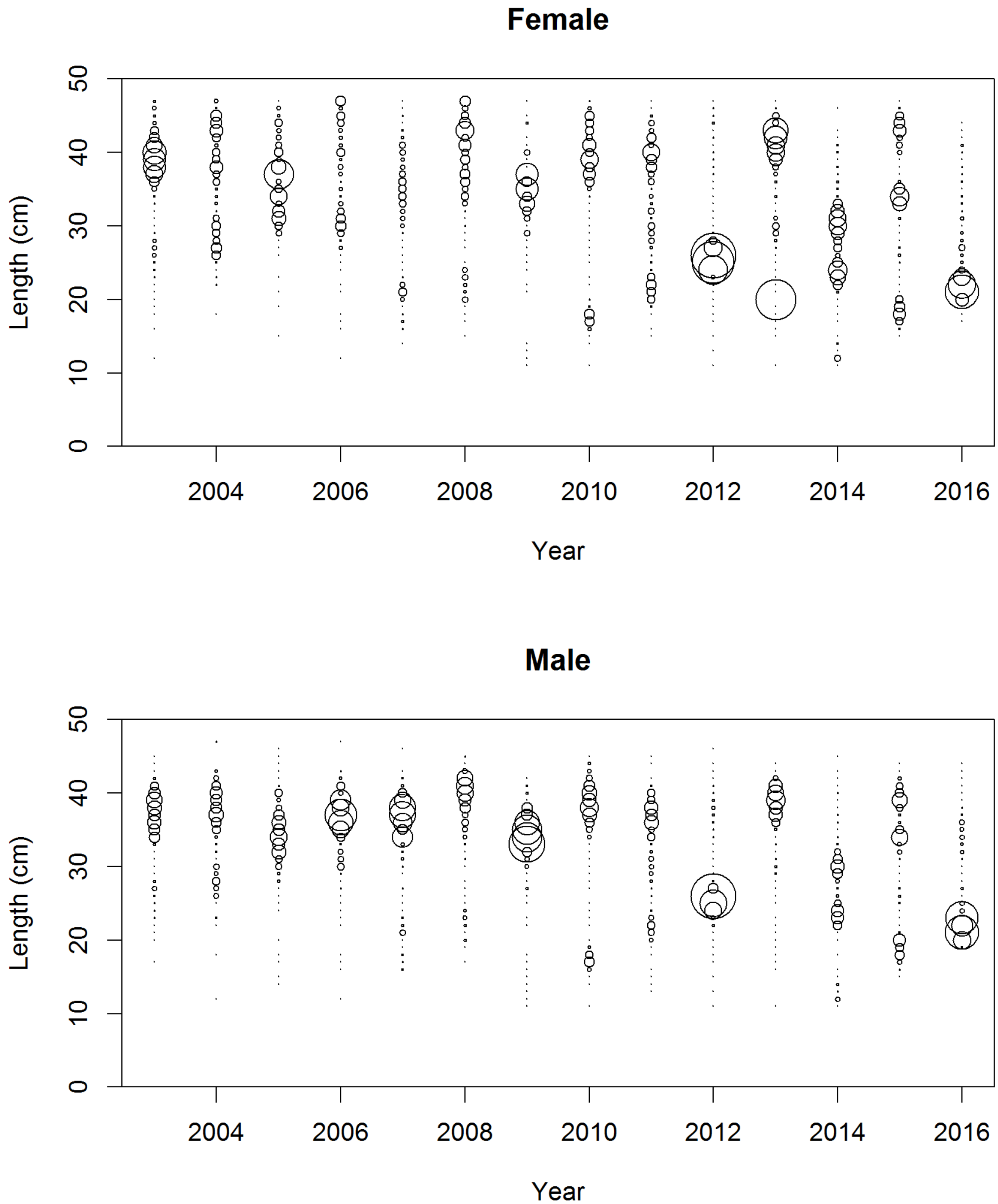


Figure 17: NWFSC shelf/lope survey length frequency distributions for Pacific ocean perch. fig:nw_Length

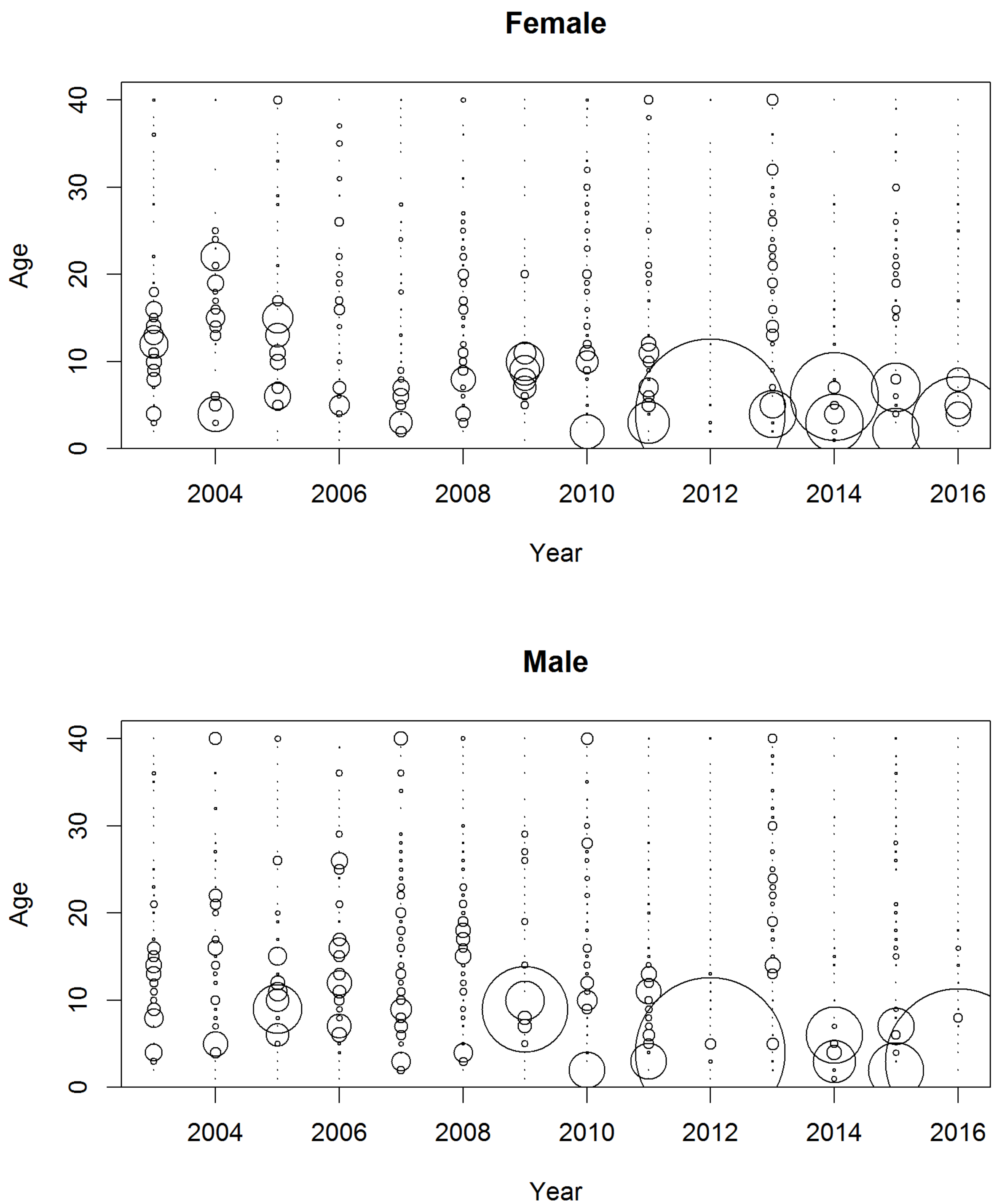


Figure 18: NWFSC shelf/slope survey age frequency distributions for Pacific ocean perch. fig:nw_Age

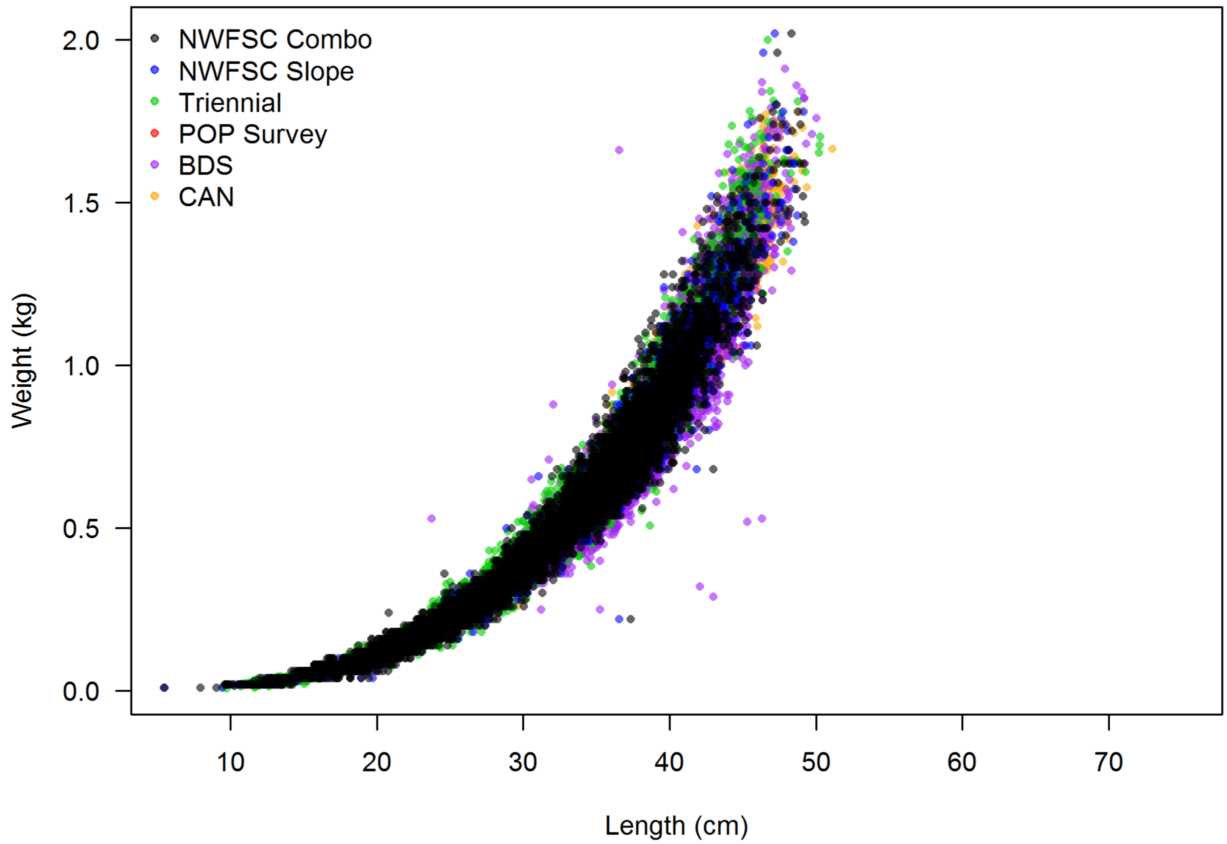


Figure 19: Weight-at-length for Pacific ocean perch from all data sources. fig:Wt_len

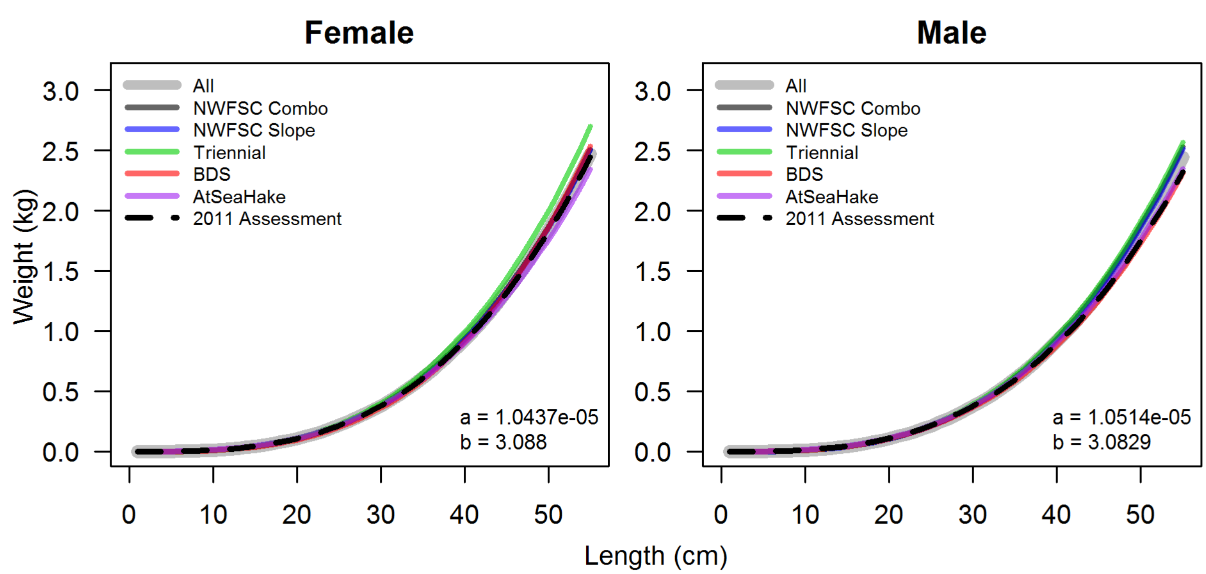


Figure 20: Estimated weight-at-length for Pacific ocean perch from all data sources. fig:Wt_len_pred

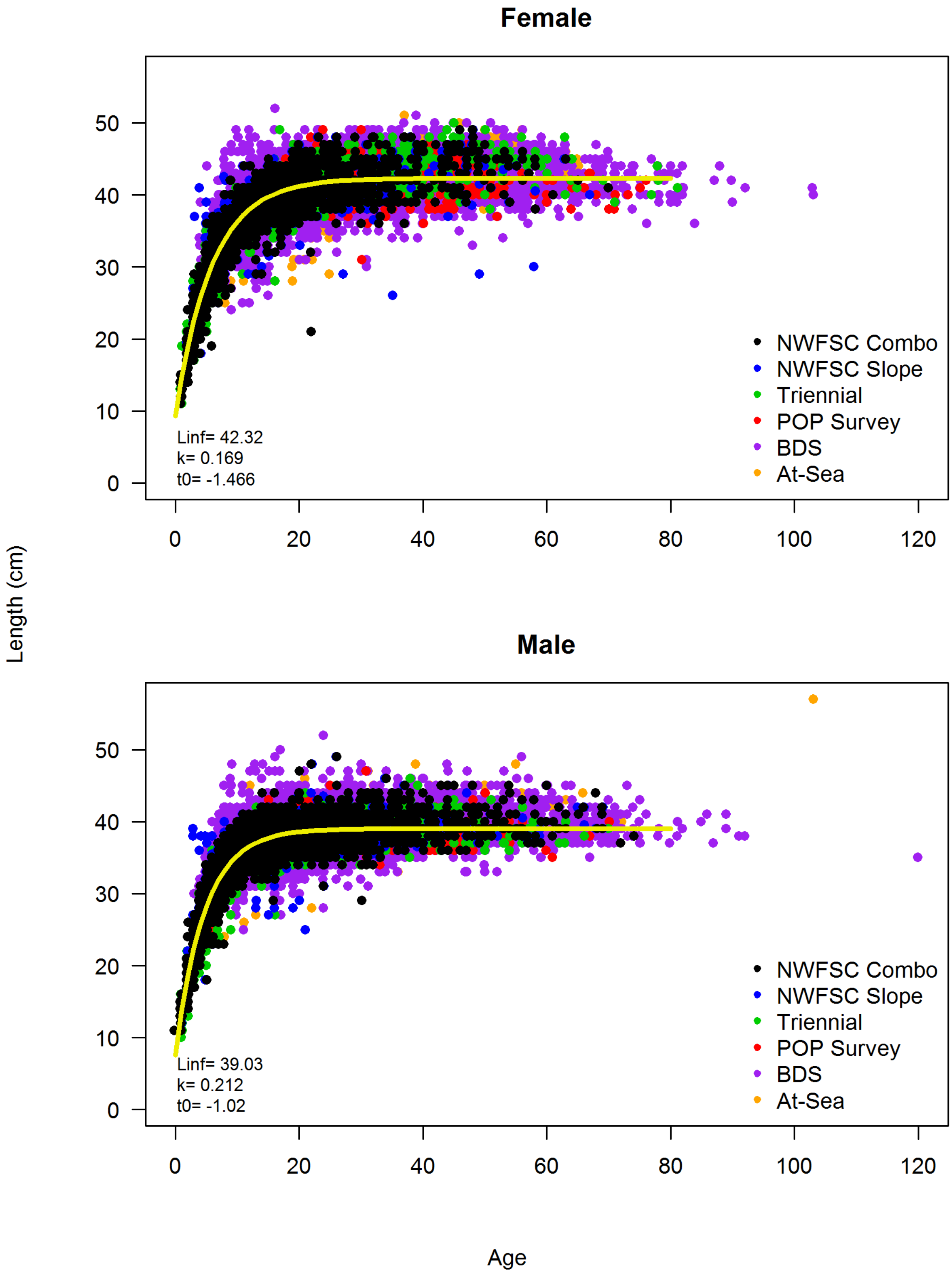


Figure 21: Estimated length-at-age for Pacific ocean perch from all data sources. fig:Len_Age

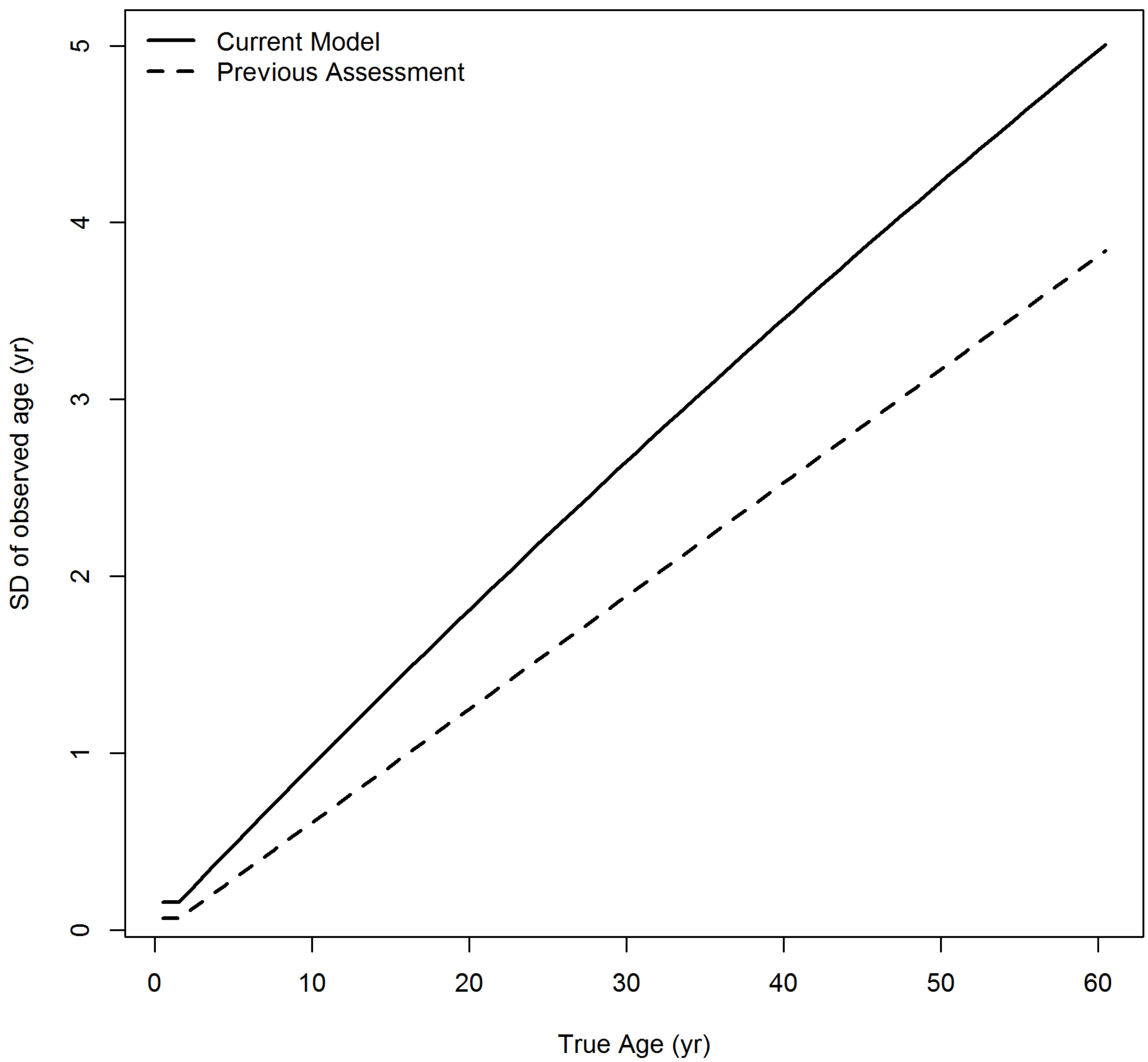


Figure 22: The estimated ageing error used in this assessment compared to the ageing error assumed in the previous assessment for Pacific ocean perch. fig:Age_Error

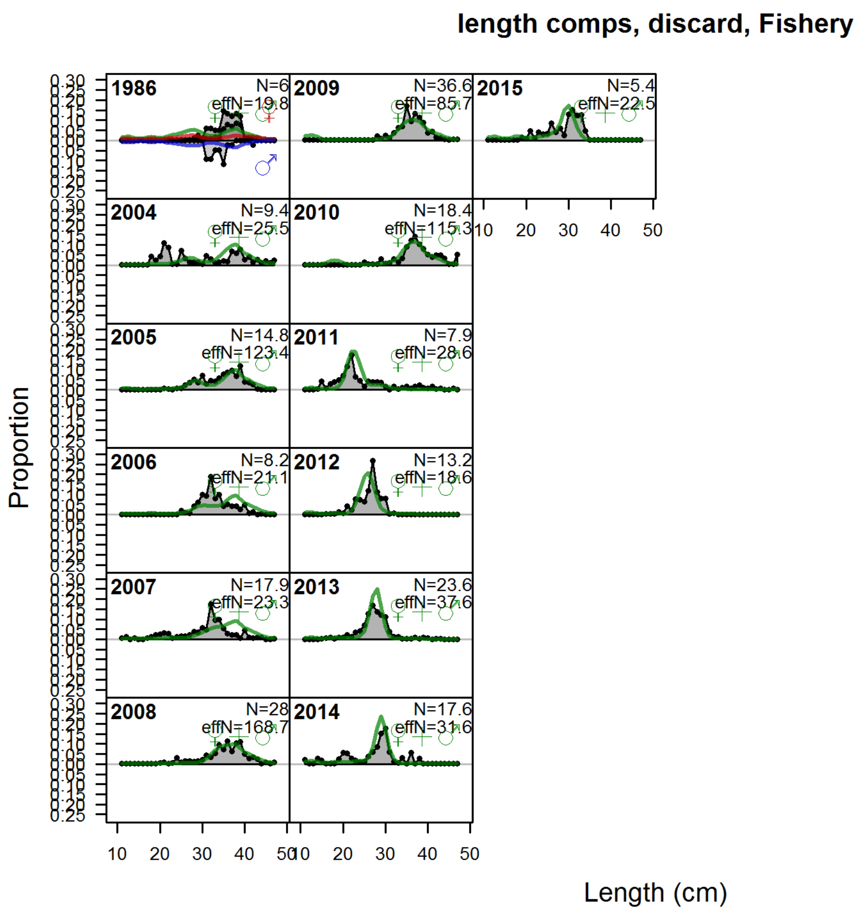


Figure 23: length comps, discard, Fishery fig:mod1_1_comp_lenfit_flt1mkt1

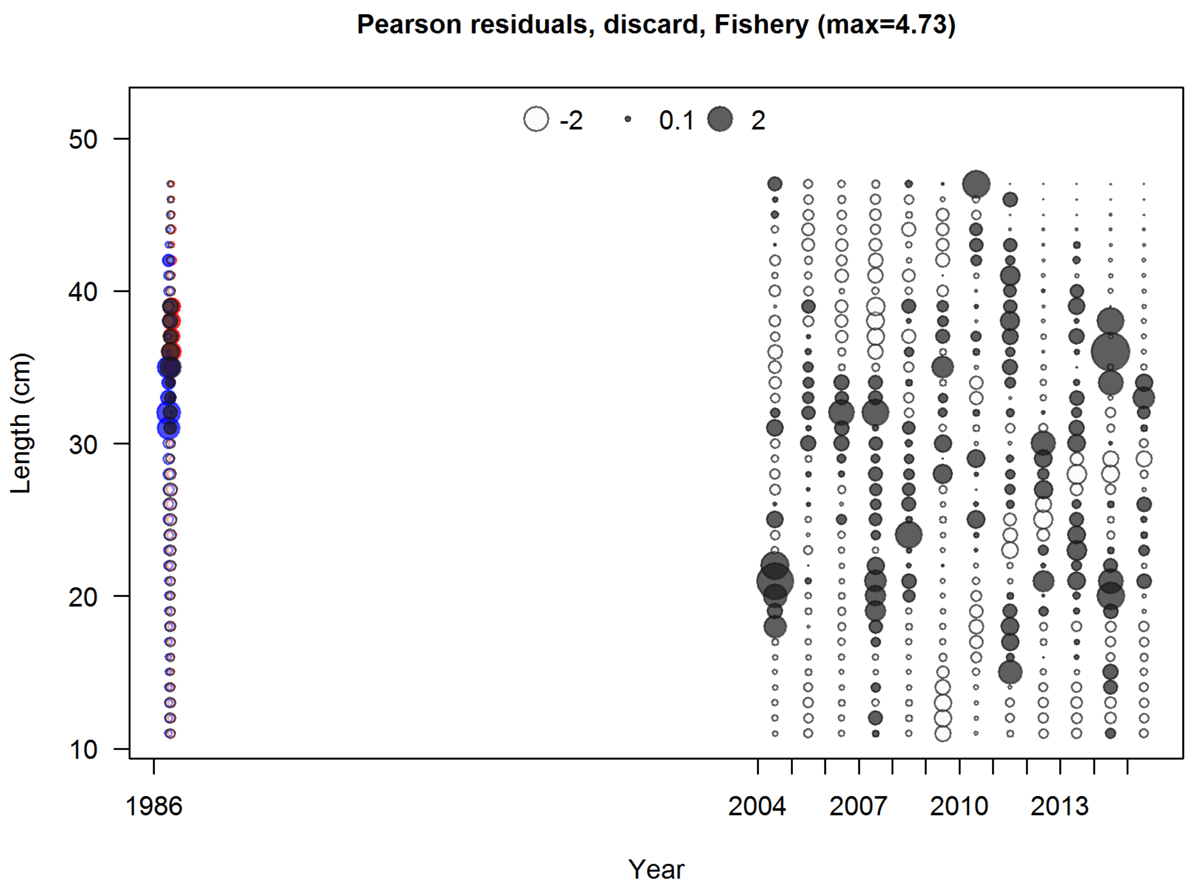


Figure 24: Pearson residuals, discard, Fishery (max=4.73)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_2_comp_lenfit_residsflt1mkt1

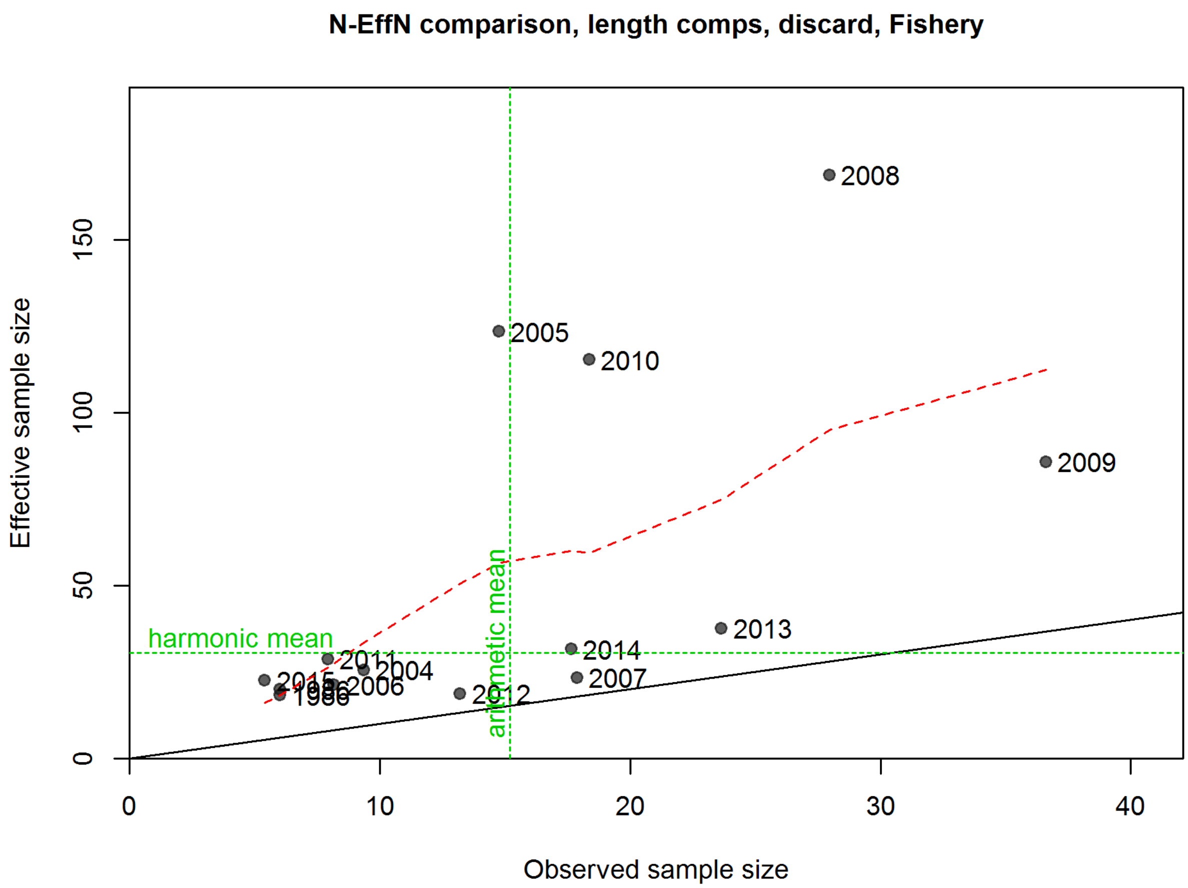


Figure 25: N_EffN comparison, length comps, discard, Fishery fig:mod1_3_comp_lenfit_sa

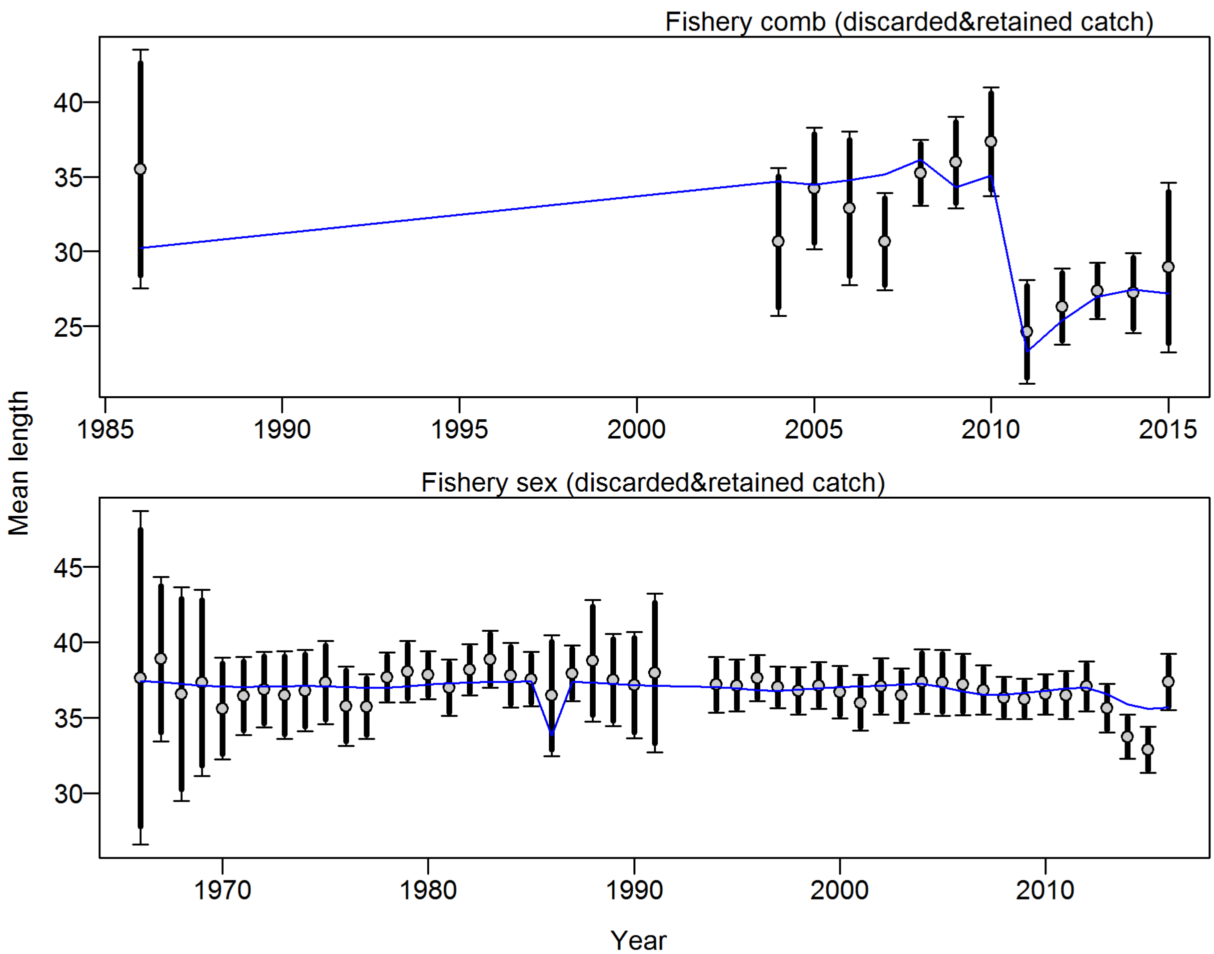


Figure 26: Francis data weighting method TA1.8 Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.7915 (0.5121_1.5052) fig:mod1_4_comp_lenfit_data_weig

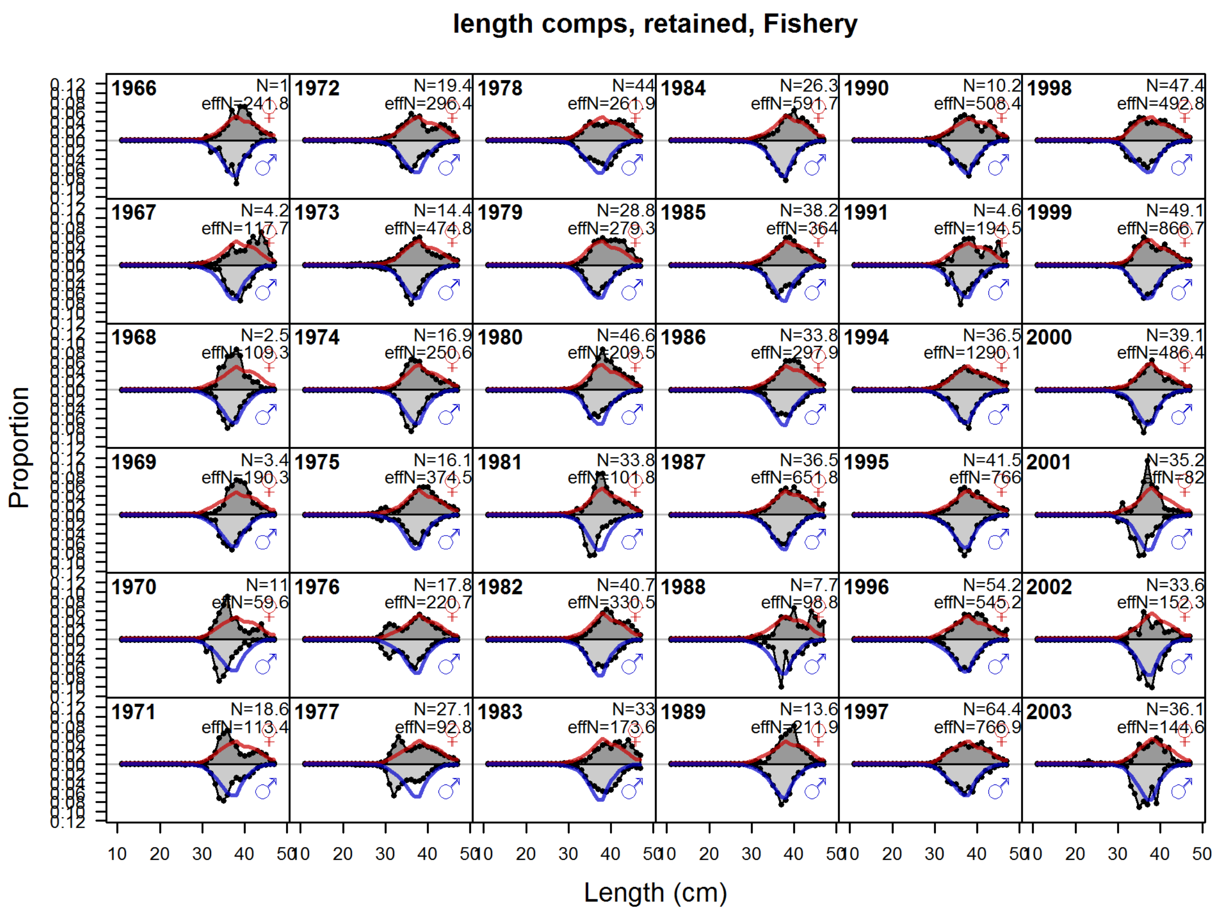


Figure 27: length comps, retained, Fishery (plot 1 of 2) fig:mod1_5_comp_lenfit_flt1ml

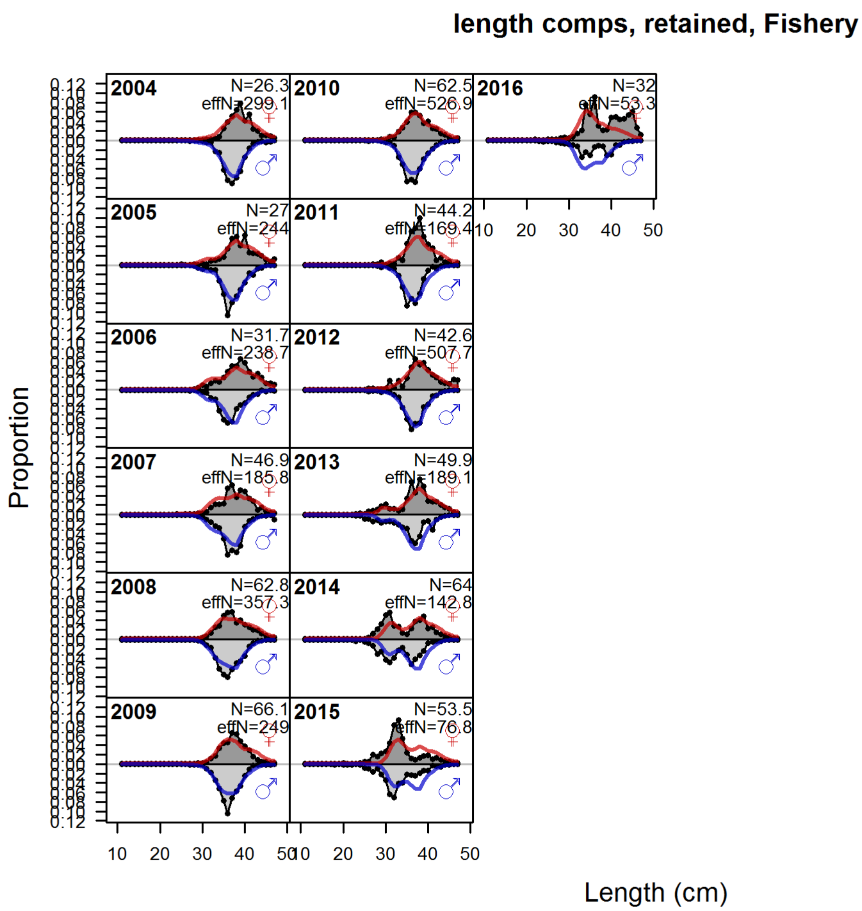


Figure 28: length comps, retained, Fishery (plot 2 of 2) fig:mod1_6_comp_lenfit_flt1ml

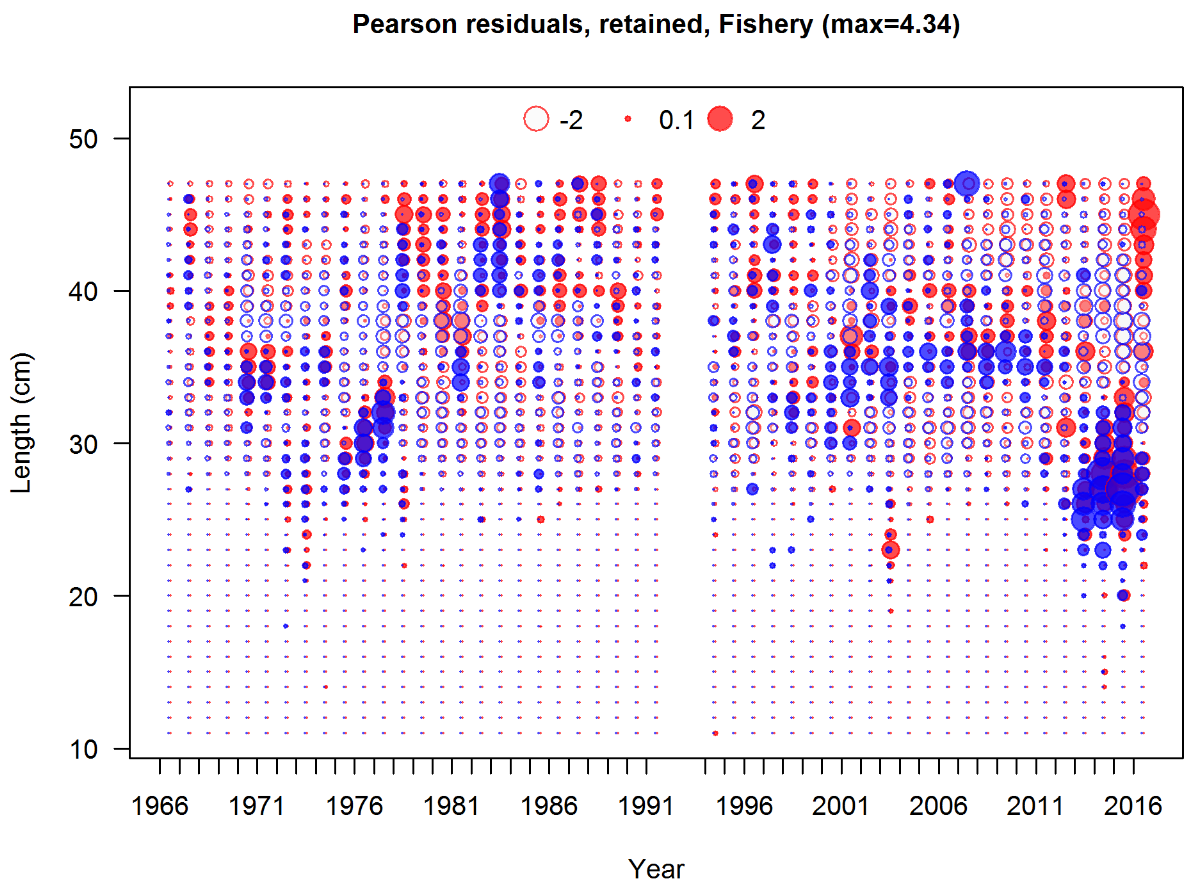


Figure 29: Pearson residuals, retained, Fishery (max=4.34) (plot 2 of 2)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_7_comp_lenfit_residsflt1mkt2_page2

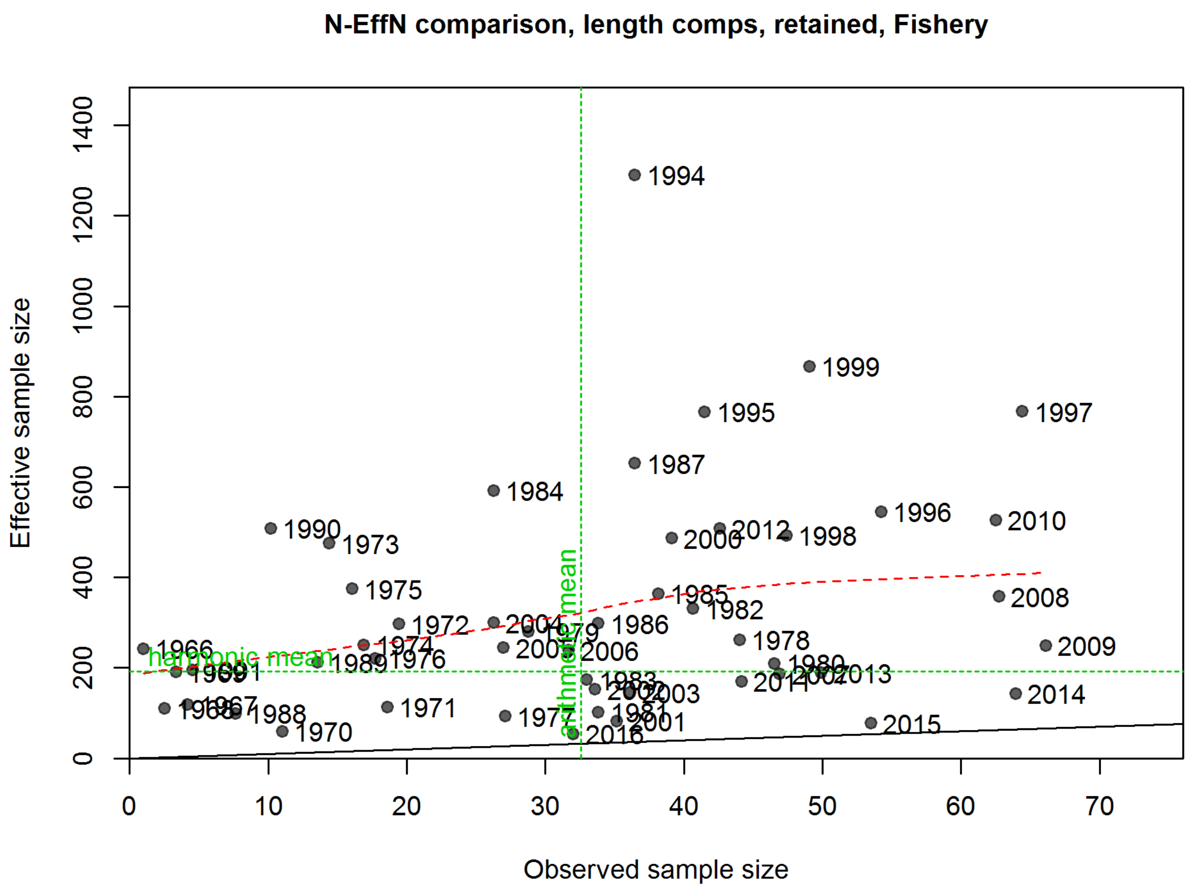


Figure 30: N_EffN comparison, length comps, retained, Fishery fig:mod1_8_comp_lenfit_sa

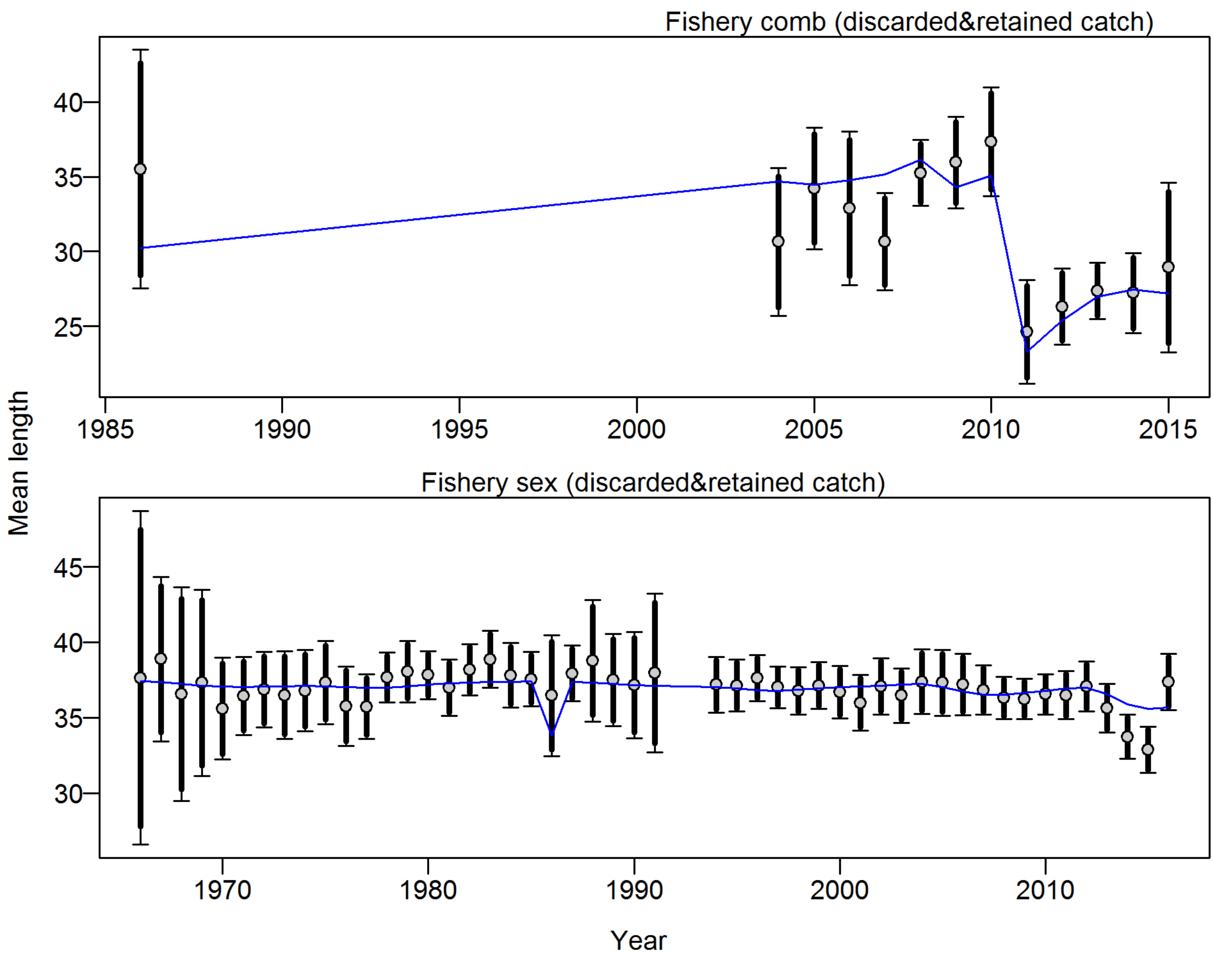


Figure 31: Francis data weighting method TA1.8 Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 0.7915 (0.5023_1.512) fig:mod1_9_comp_lenfit_data_weigh

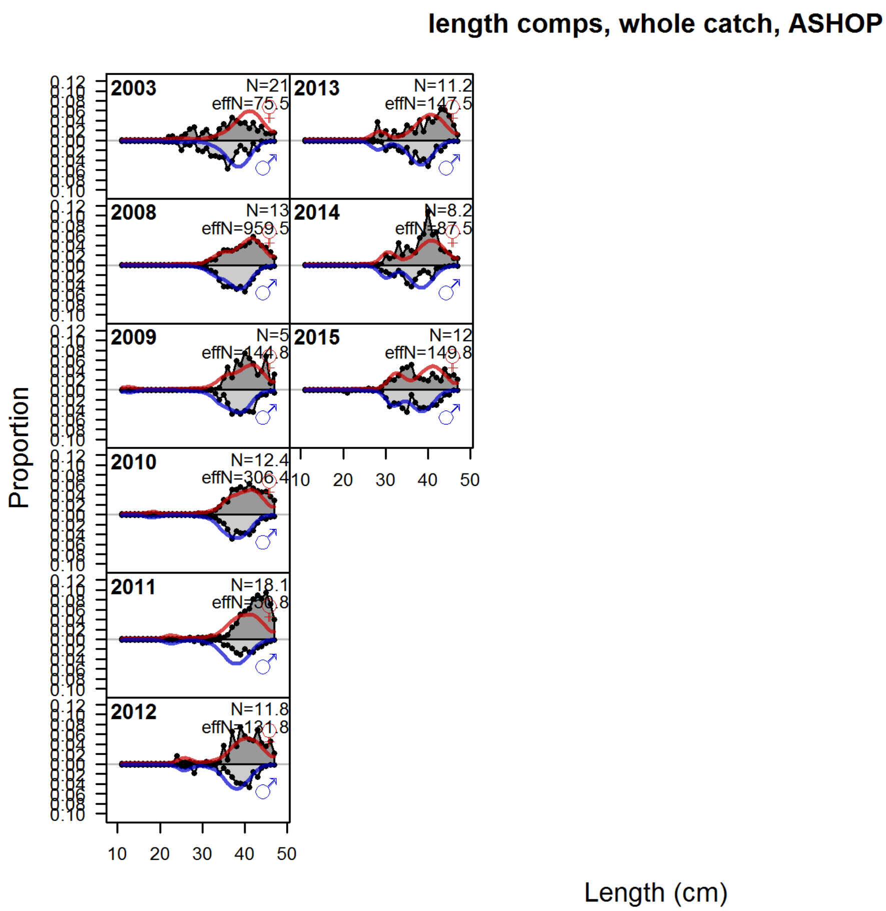


Figure 32: length comps, whole catch, ASHOP fig:mod1_10_comp_lenfit_flt2mkt0

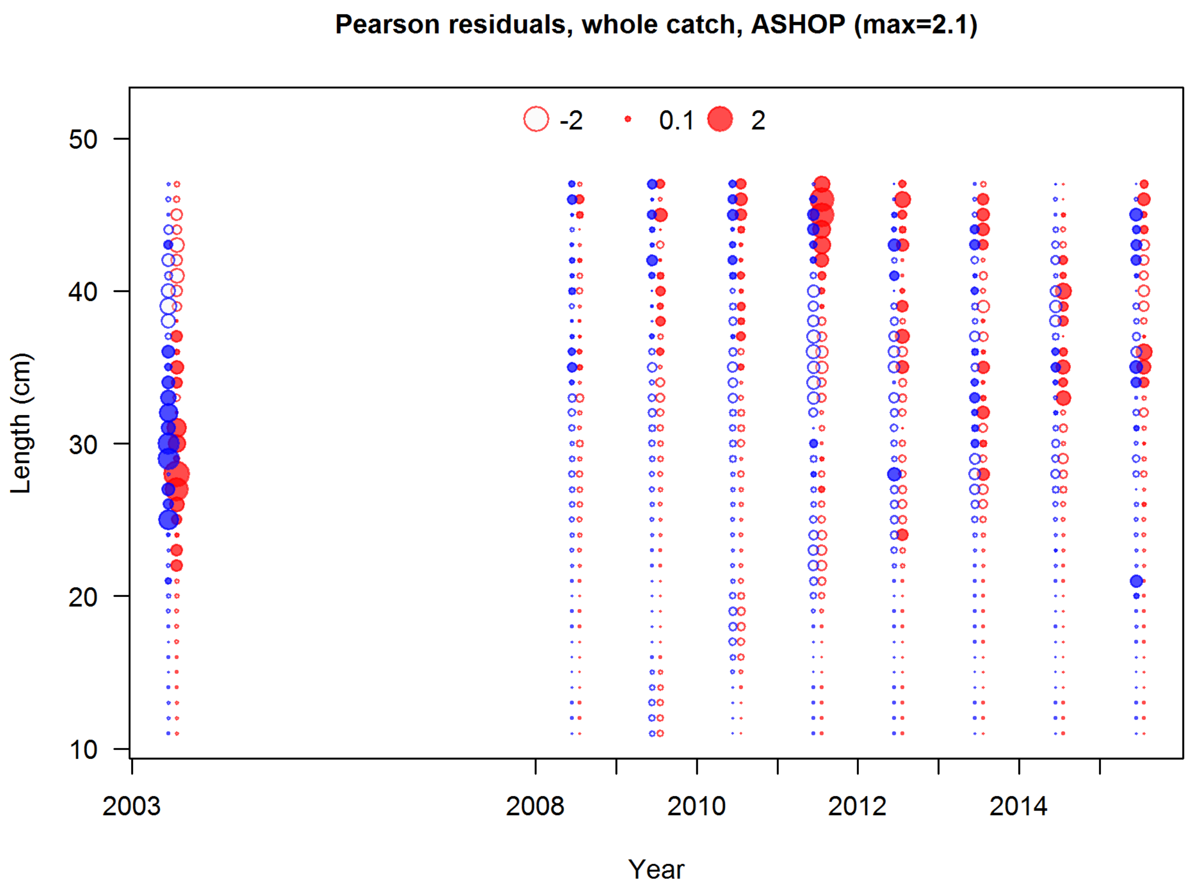


Figure 33: Pearson residuals, whole catch, ASHOP (max=2.1)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_11_comp_lenfit_residsflt2mkt0

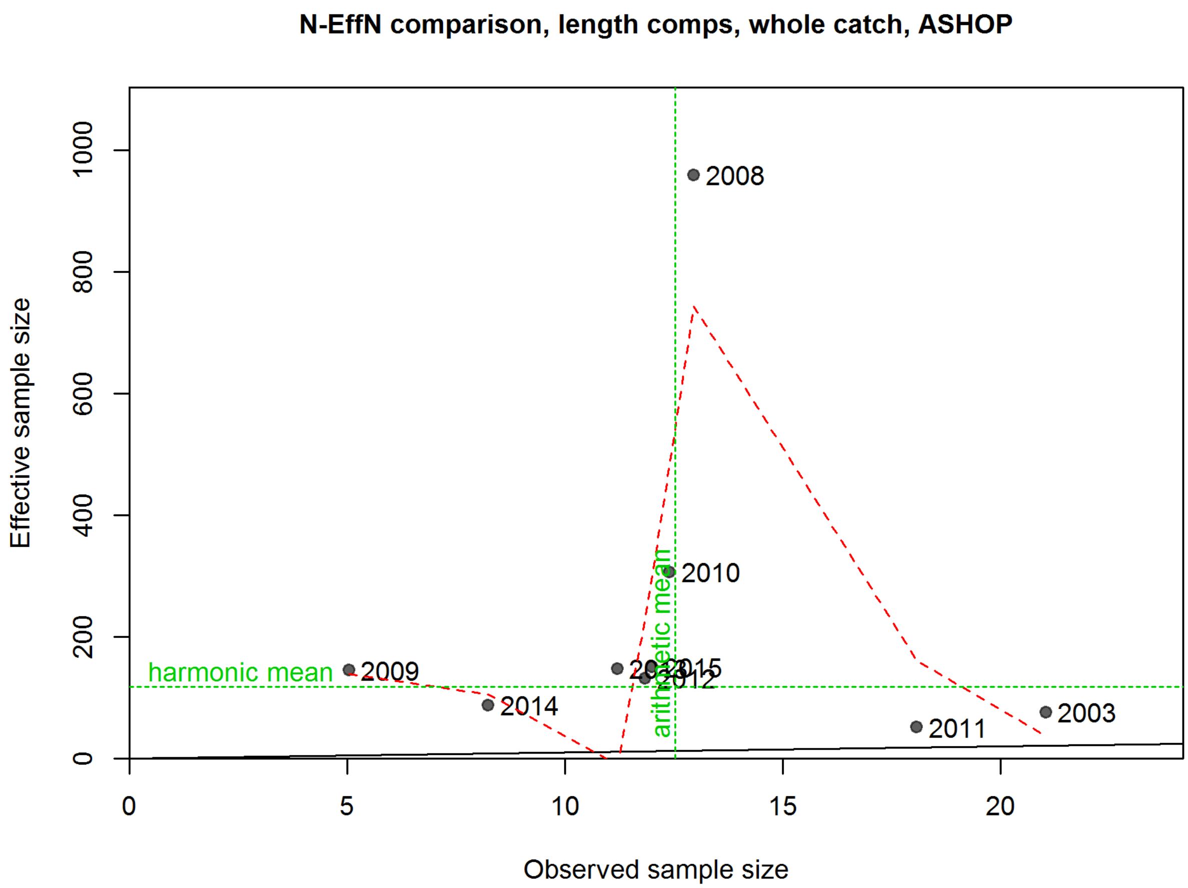


Figure 34: N_EffN comparison, length comps, whole catch, ASHOP fig:mod1_12_comp_lenfit

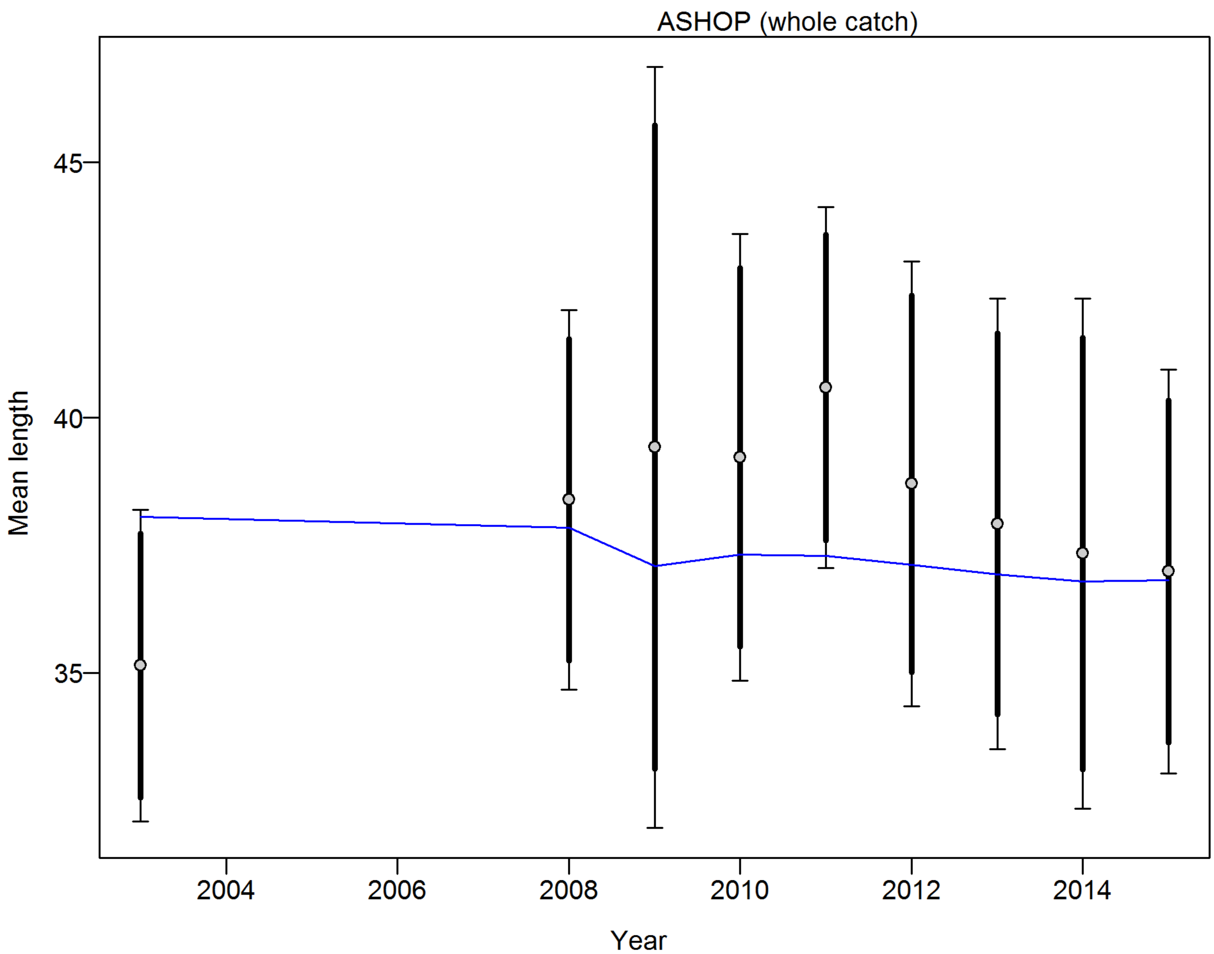


Figure 35: Francis data weighting method TA1.8 ASHOP Suggested sample size adjustment (with 95% interval) for len data from ASHOP: 0.7167 (0.3546_12.9798) fig:mod1_13_comp_lenfit_data_we

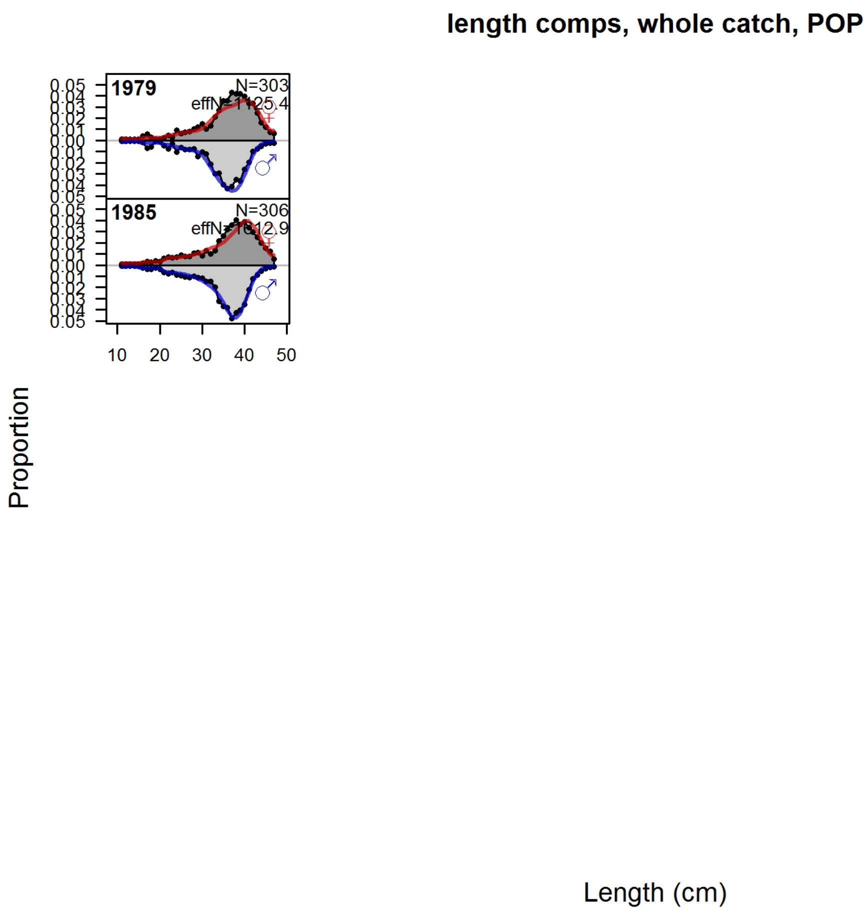


Figure 36: length comps, whole catch, POP fig:mod1_14_comp_lenfit_flt4mkt0

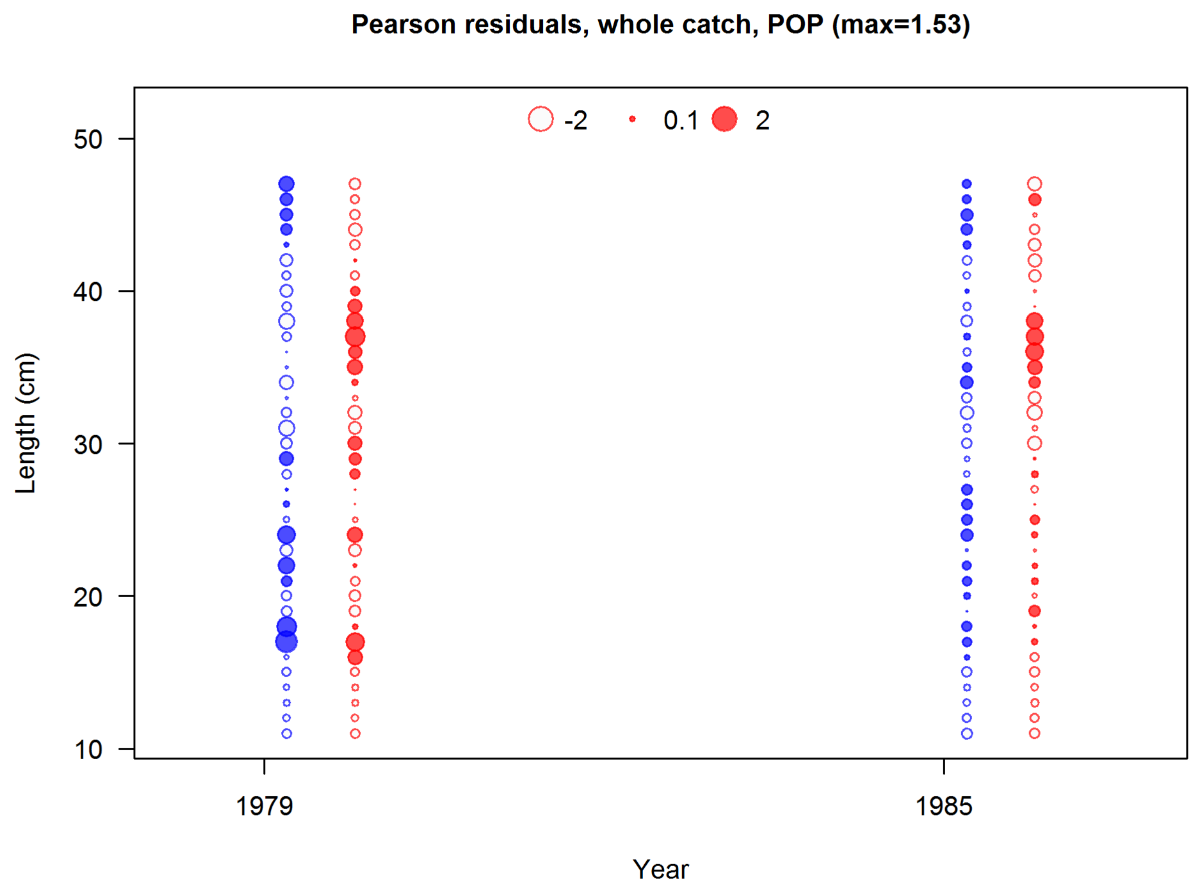


Figure 37: Pearson residuals, whole catch, POP (max=1.53)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_15_comp_lenfit_residsflt4mkt0

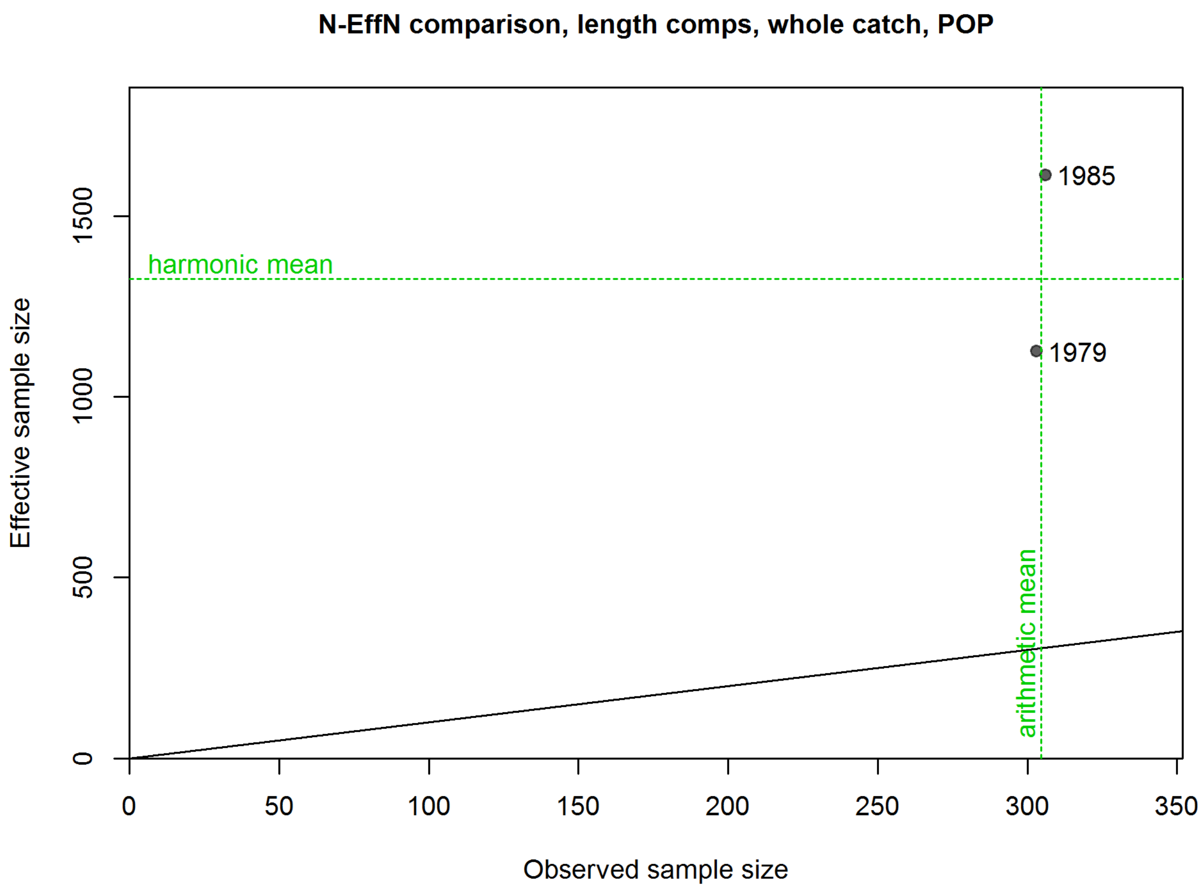


Figure 38: N_EffN comparison, length comps, whole catch, POP fig:mod1_16_comp_lenfit_s

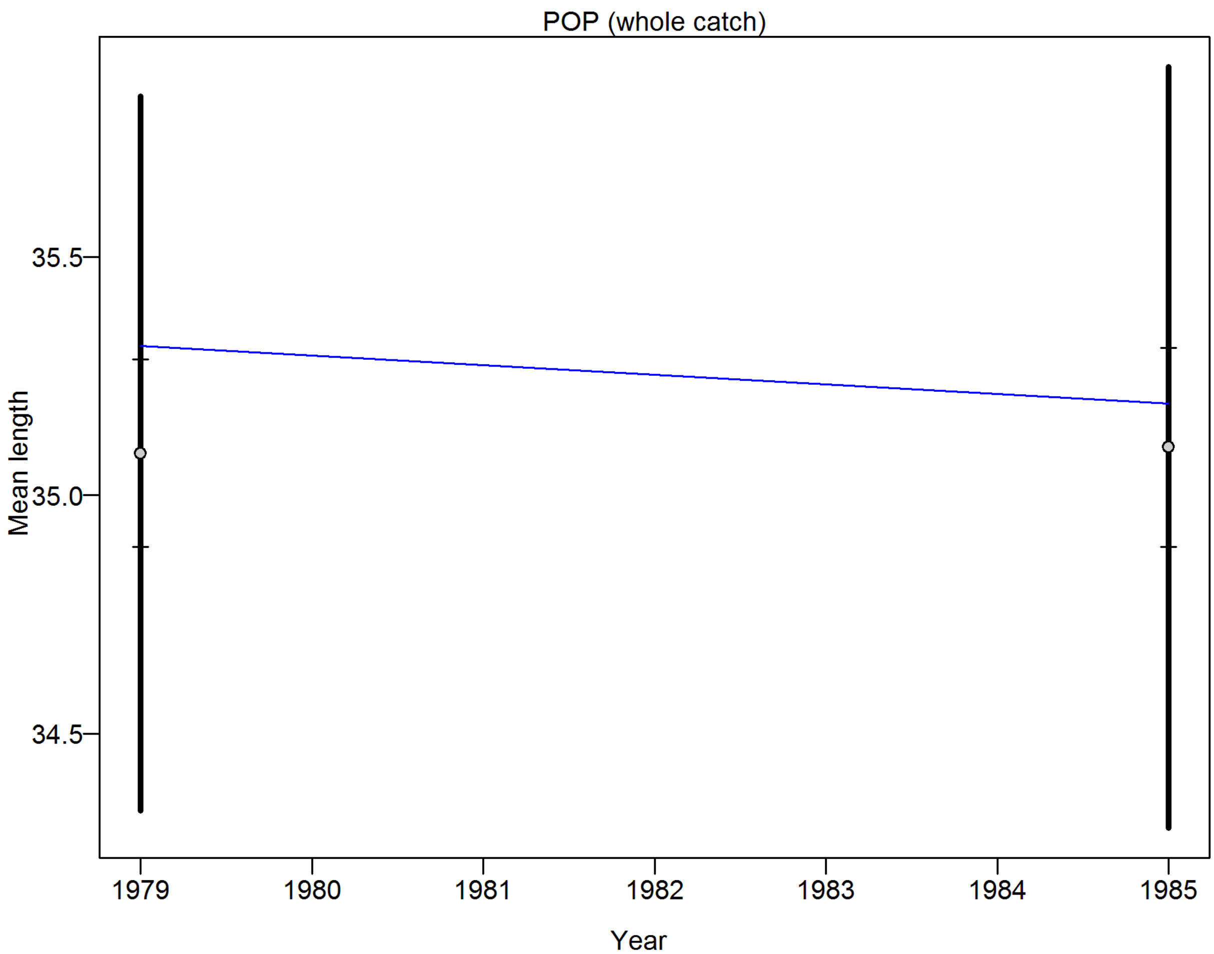


Figure 39: Francis data weighting method TA1.8 POP Suggested sample size adjustment (with 95% interval) for len data from POP: 14.5452 (14.5452_Inf) fig:mod1_17_comp_lenfit_data_weighti

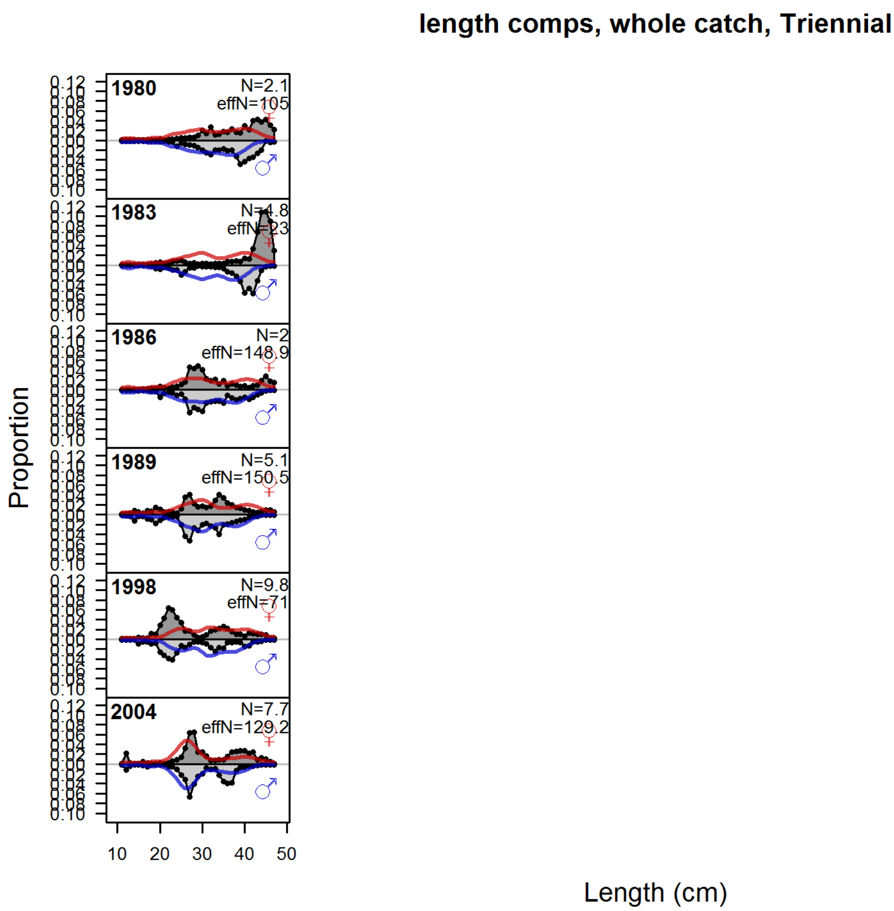


Figure 40: length comps, whole catch, Triennial fig:mod1_18_comp_lenfit_flt5mkt0

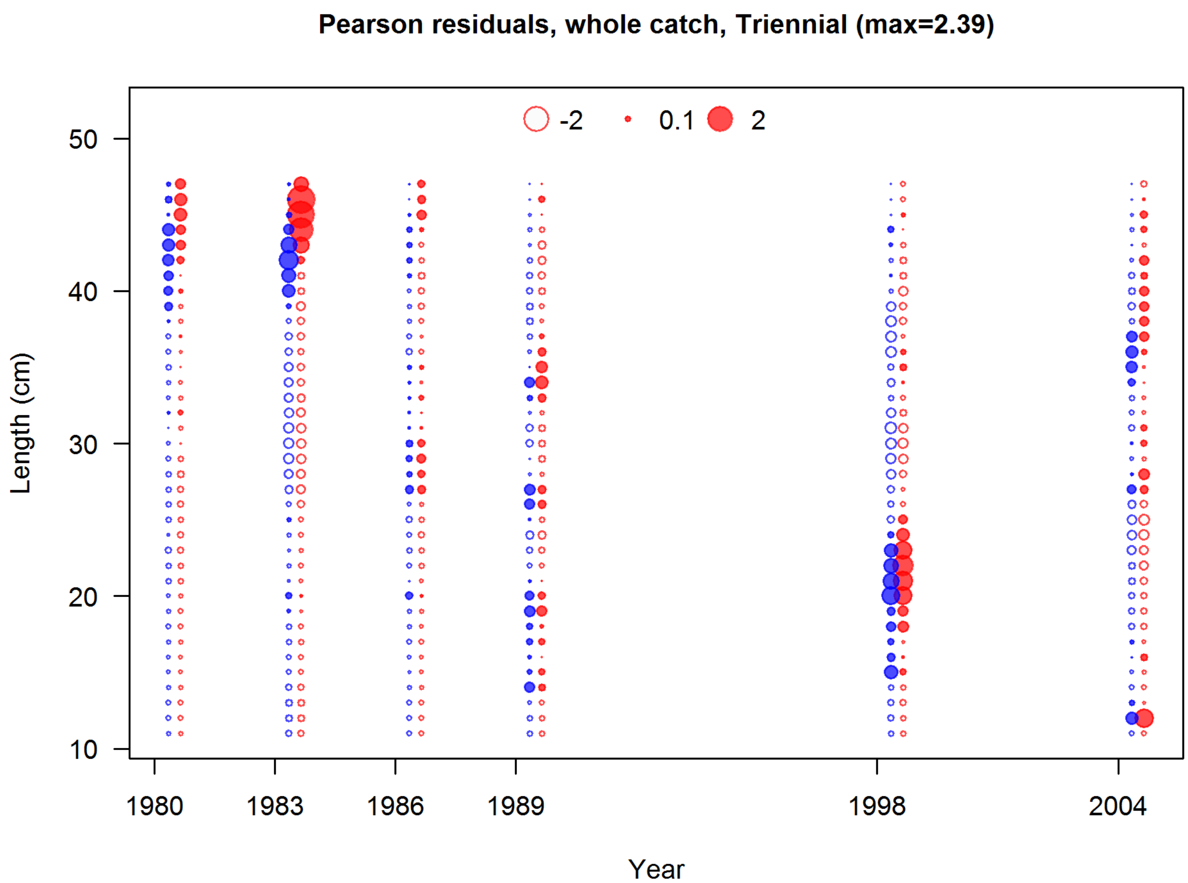


Figure 41: Pearson residuals, whole catch, Triennial (max=2.39)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_19_comp_lenfit_residsflt5mkt0

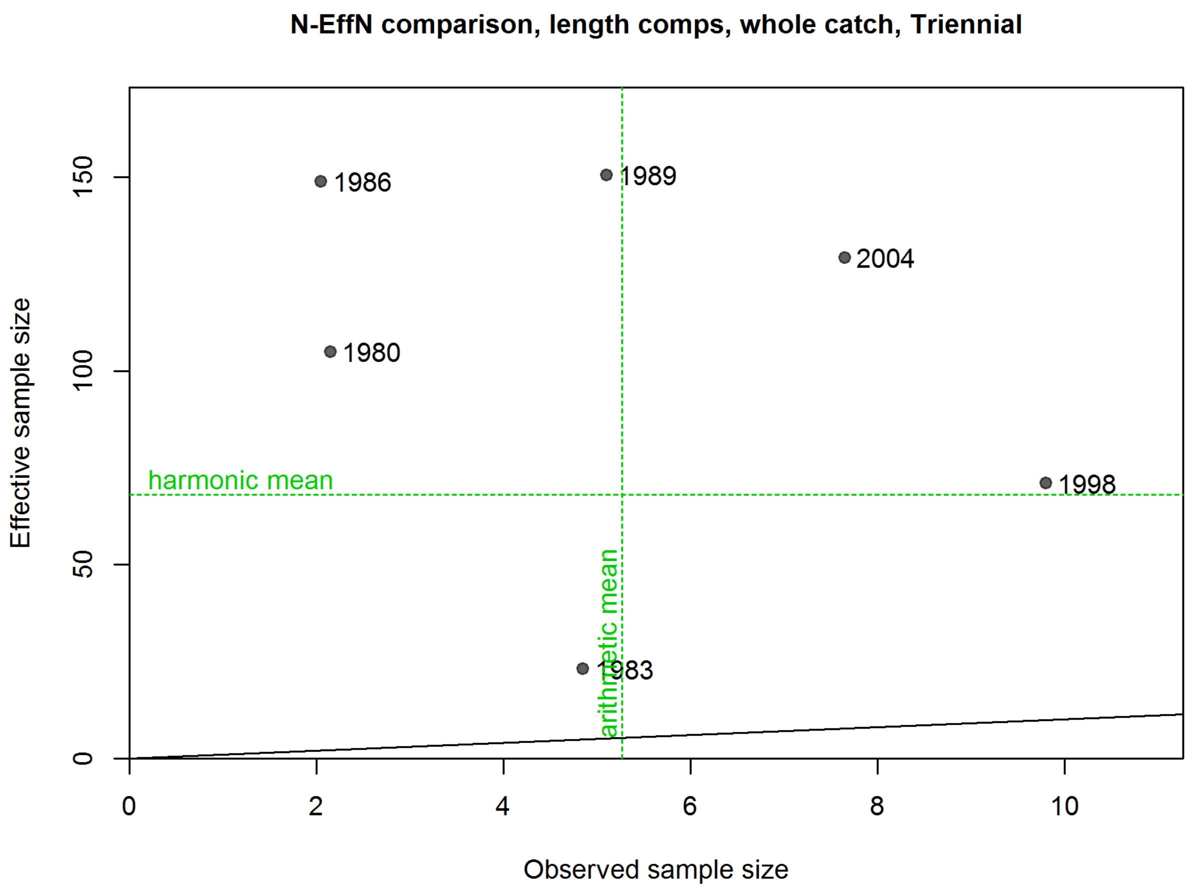


Figure 42: N_EffN comparison, length comps, whole catch, Triennial fig:mod1_20_comp_lenfit

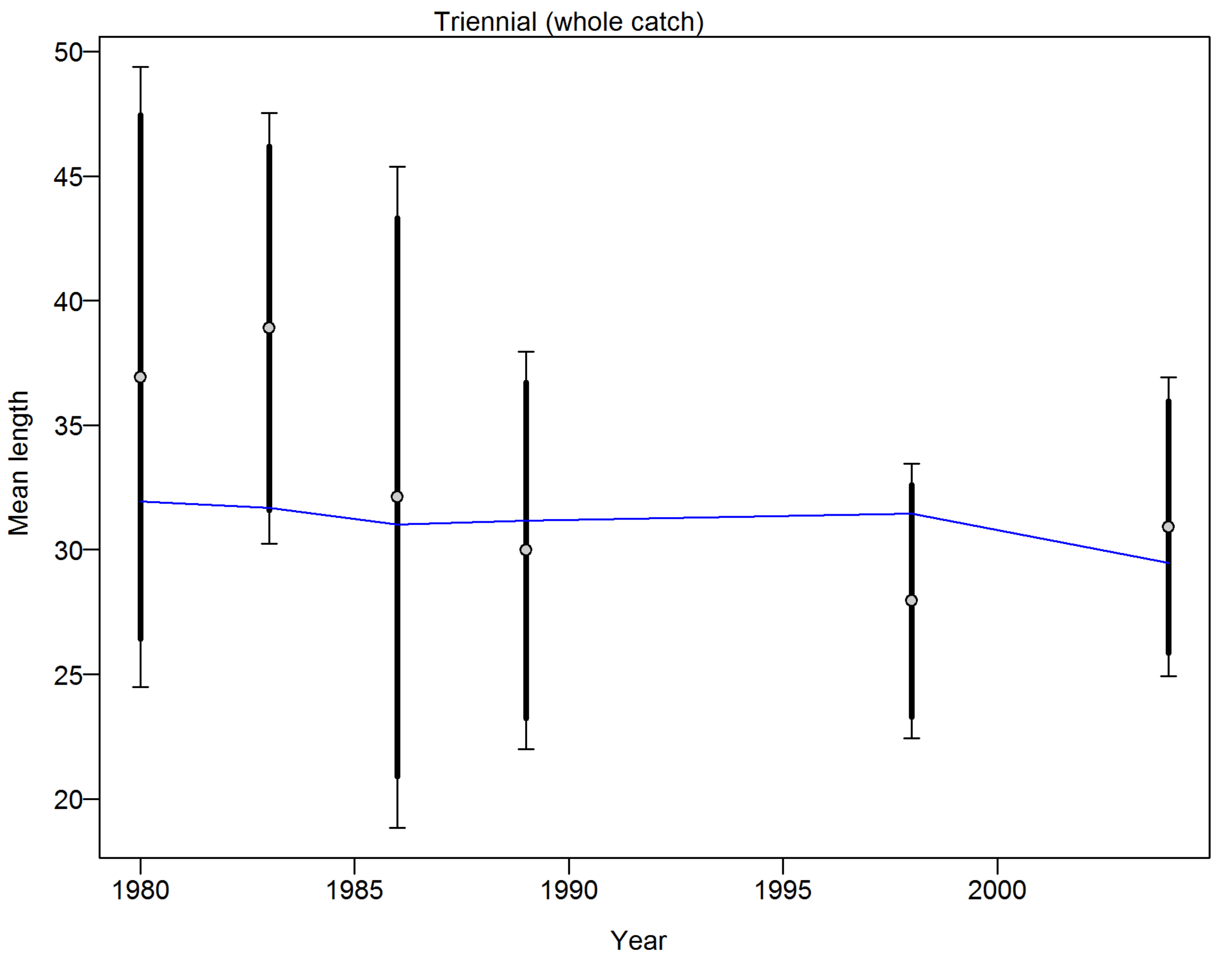


Figure 43: Francis data weighting method TA1.8 Triennial Suggested sample size adjustment (with 95% interval) for len data from Triennial: 0.7141 (0.3985_7.591) fig:mod1_21_comp_lenfit_data_we

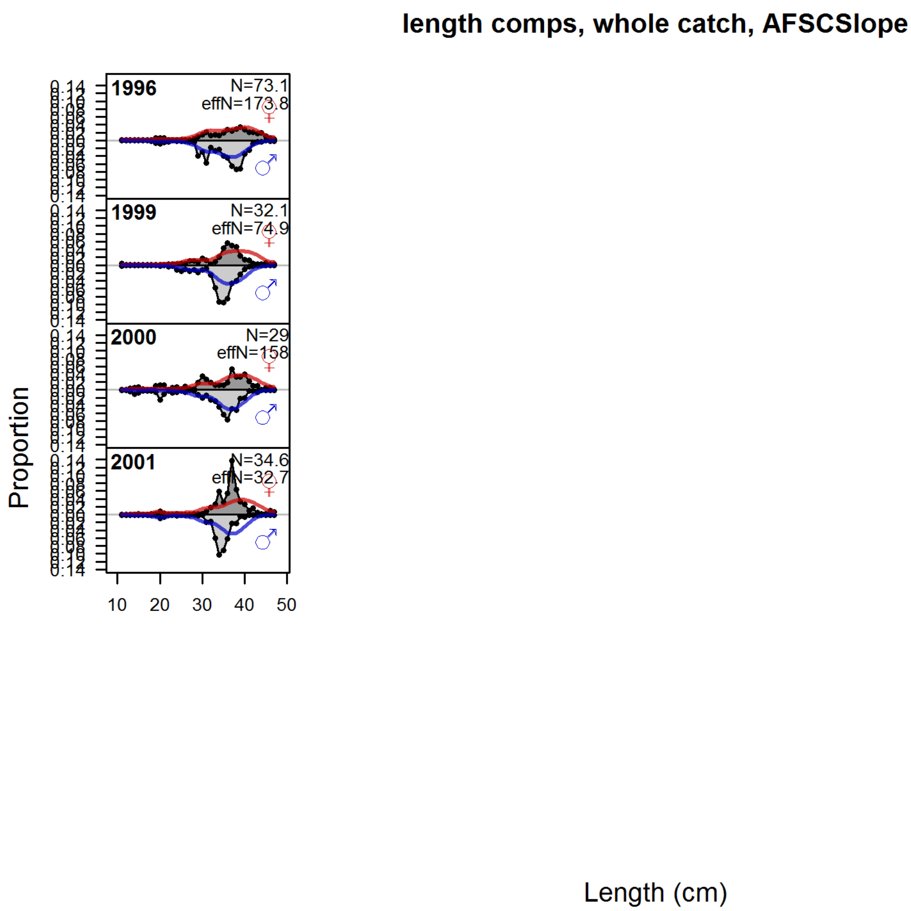


Figure 44: length comps, whole catch, AFSCSlope fig:mod1_22_comp_lenfit_flt6mkt

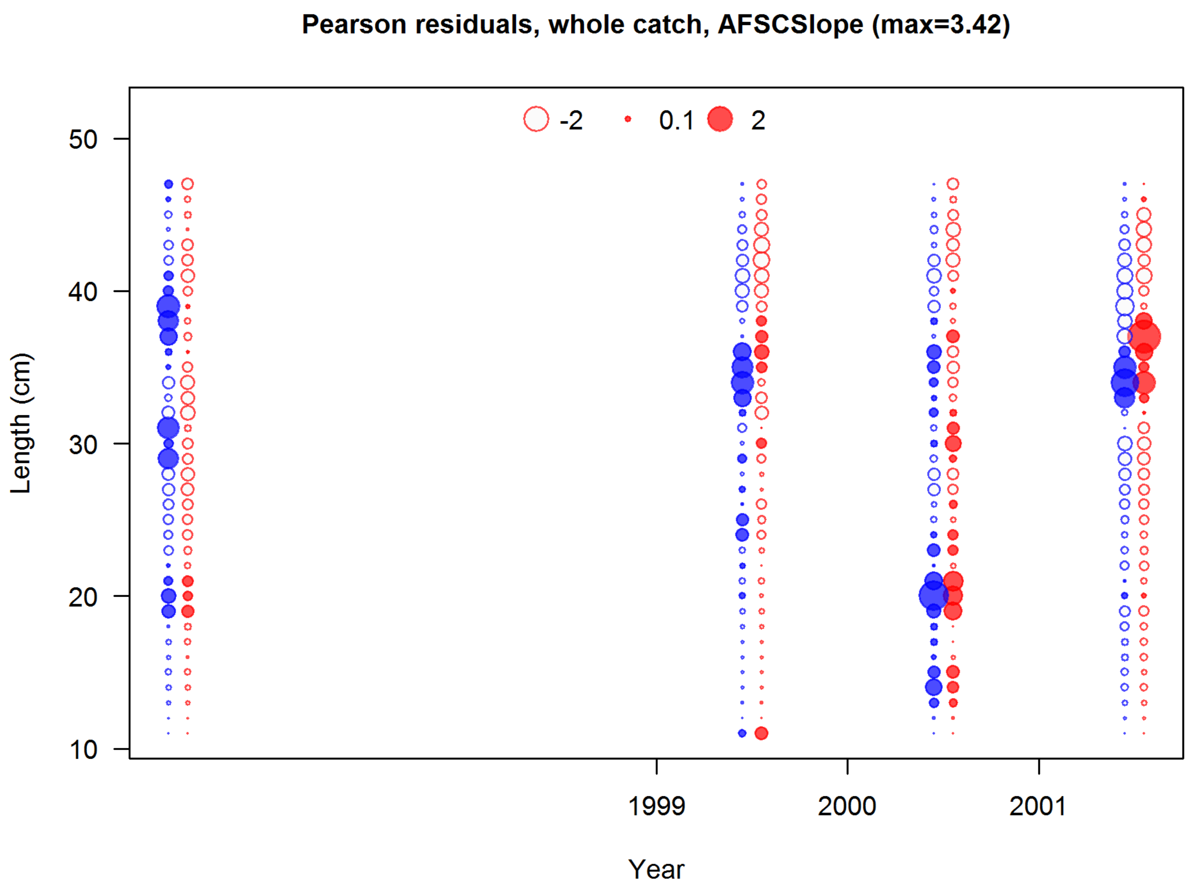


Figure 45: Pearson residuals, whole catch, AFSCSlope (max=3.42)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_23_comp_lenfit_residsflt6mkt0

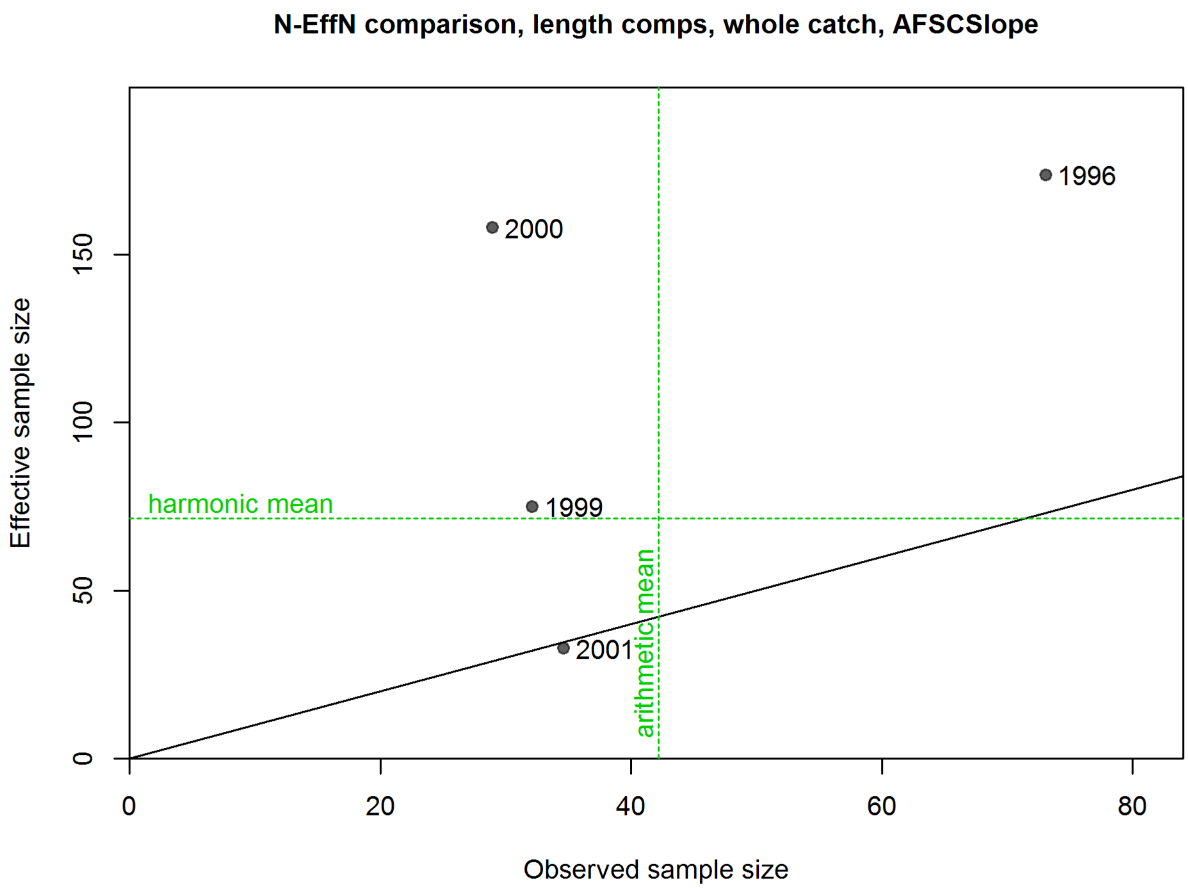


Figure 46: N_EffN comparison, length comps, whole catch, AFSCSlope [fig:mod1_24_comp_lenf

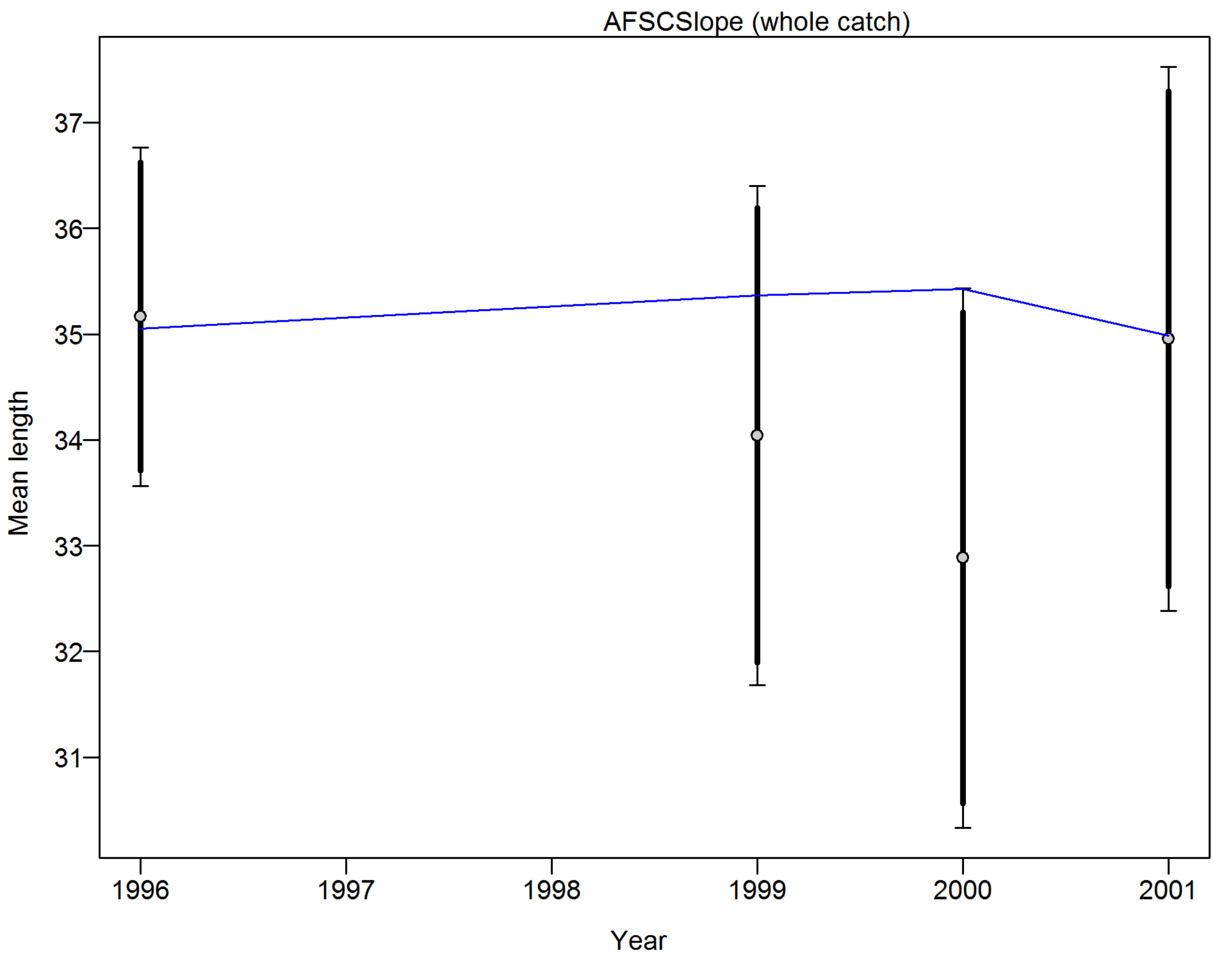


Figure 47: Francis data weighting method TA1.8 AFSCSlope Suggested sample size adjustment (with 95% interval) for len data from AFSCSlope: 0.8305 (0.5489_130.952) fig:mod1_25_comp_lenfit_dat

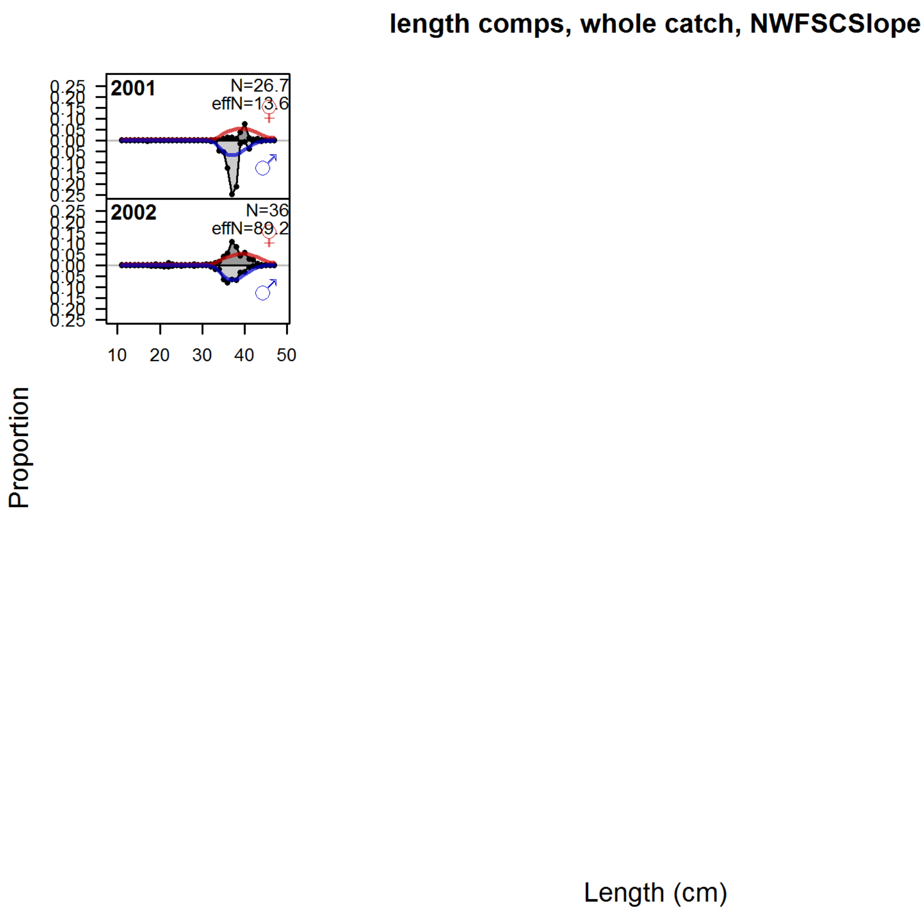


Figure 48: length comps, whole catch, NWFSCSlope fig:mod1_26_comp_lenfit_flt7mk

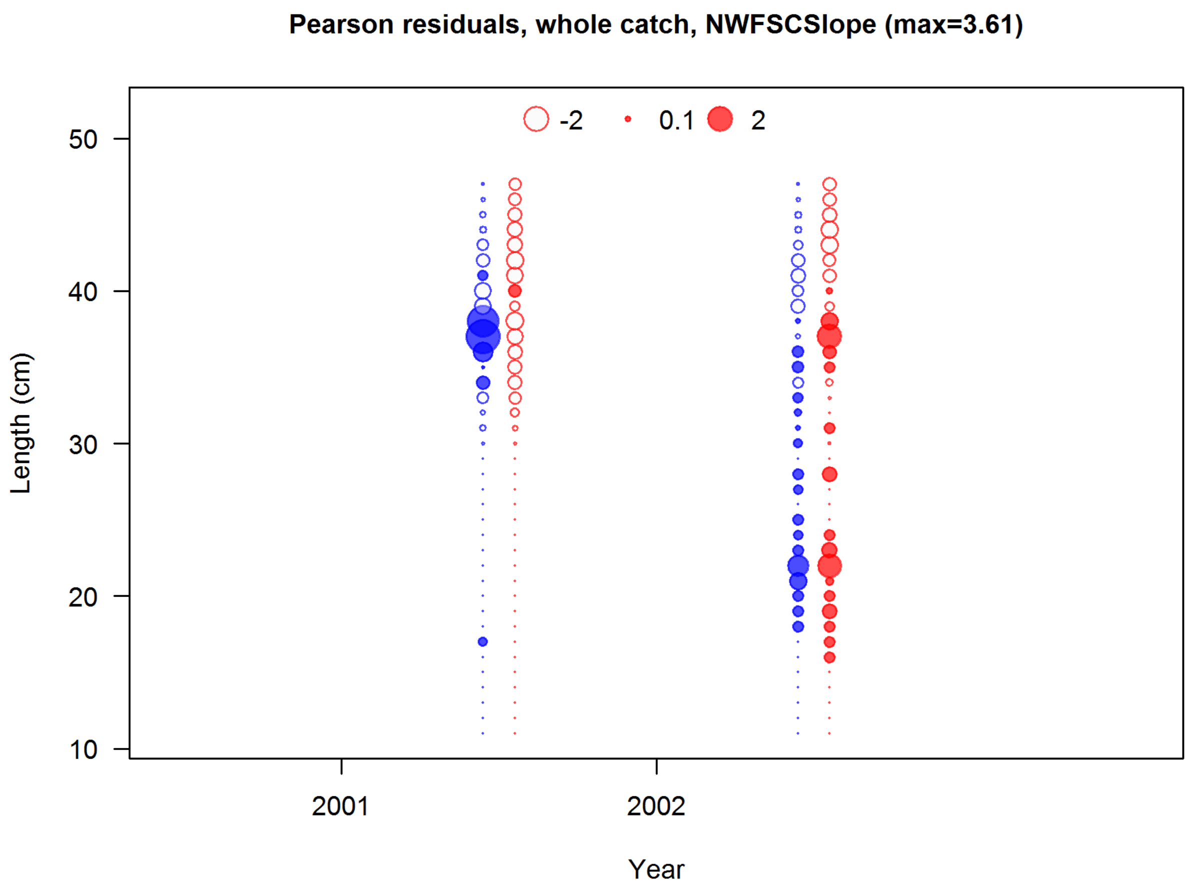


Figure 49: Pearson residuals, whole catch, NWFSCSlope (max=3.61)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_27_comp_lenfit_residsflt7mkt0

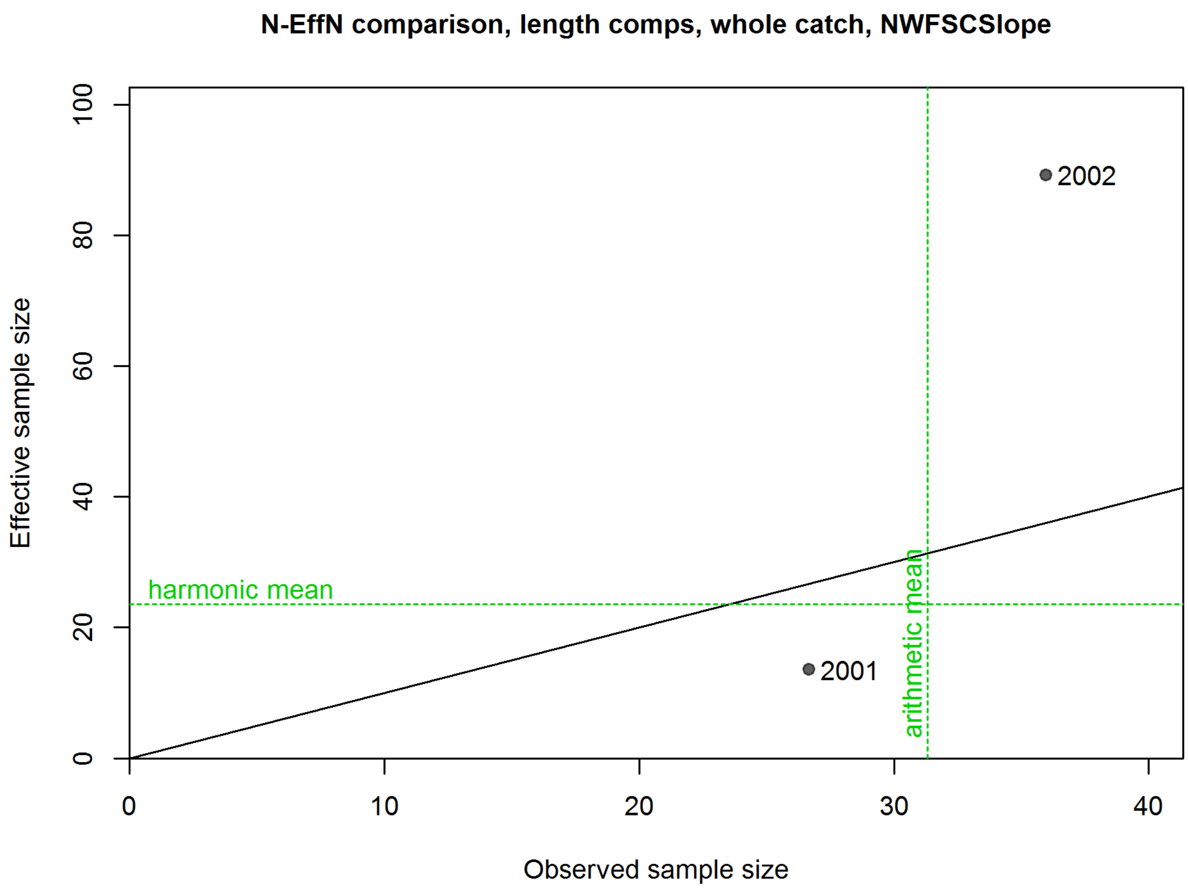


Figure 50: N_EffN comparison, length comps, whole catch, NWFSCSlope fig:mod1_28_comp_len

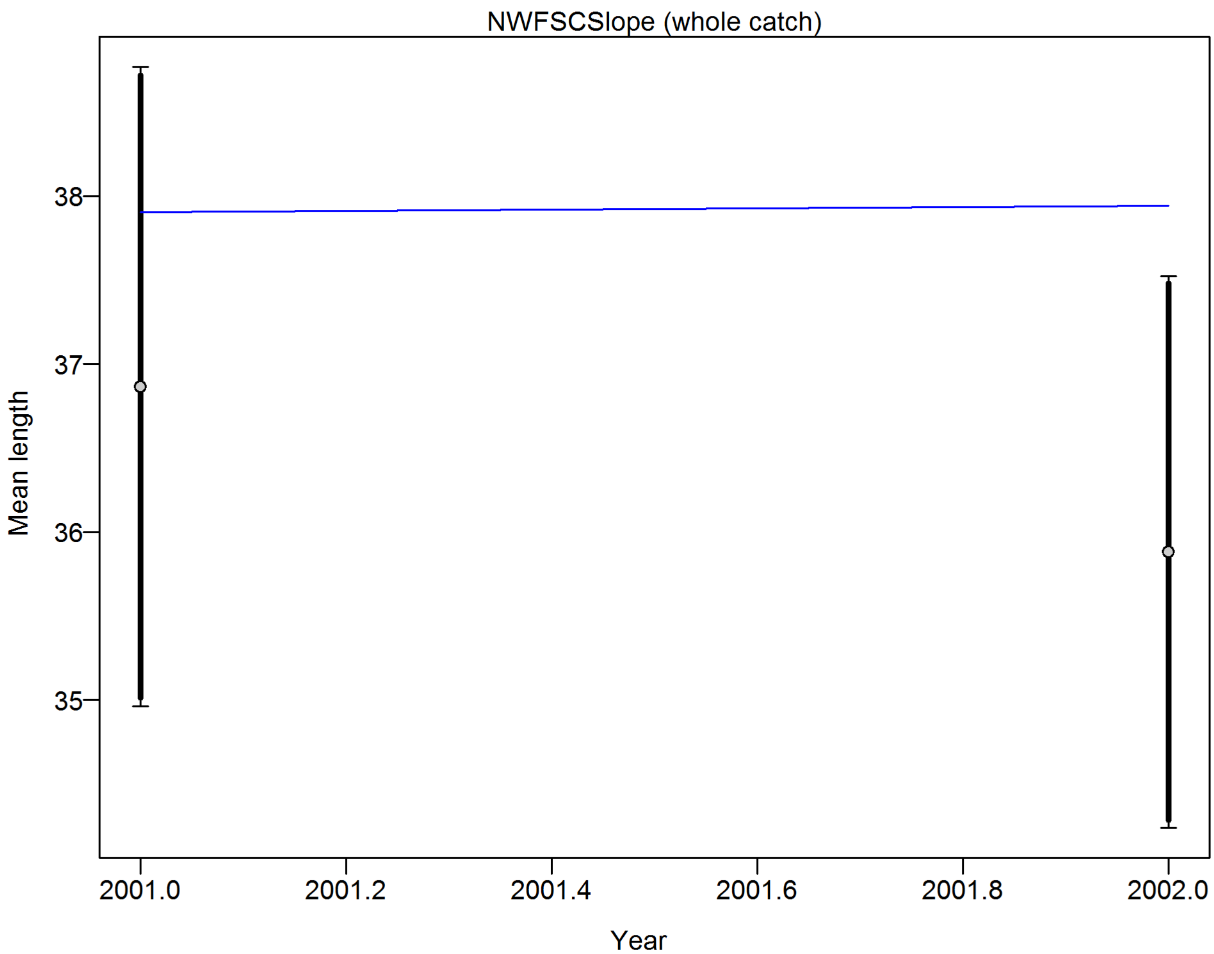


Figure 51: Francis data weighting method TA1.8 NWFSCSlope Suggested sample size adjustment (with 95% interval) for len data from NWFSCSlope: 0.9488 (0.9488_Inf) fig:mod1_29_comp_l

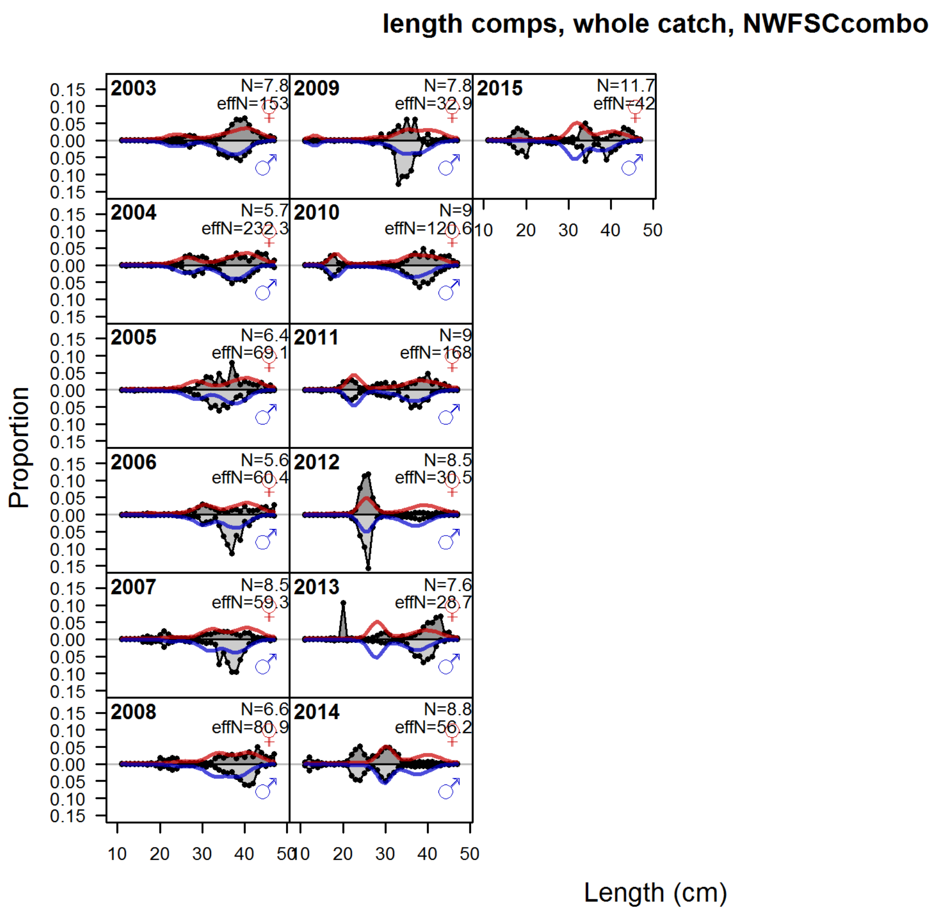


Figure 52: length comps, whole catch, NWFSCcombo fig:mod1_30_comp_lenfit_flt8m

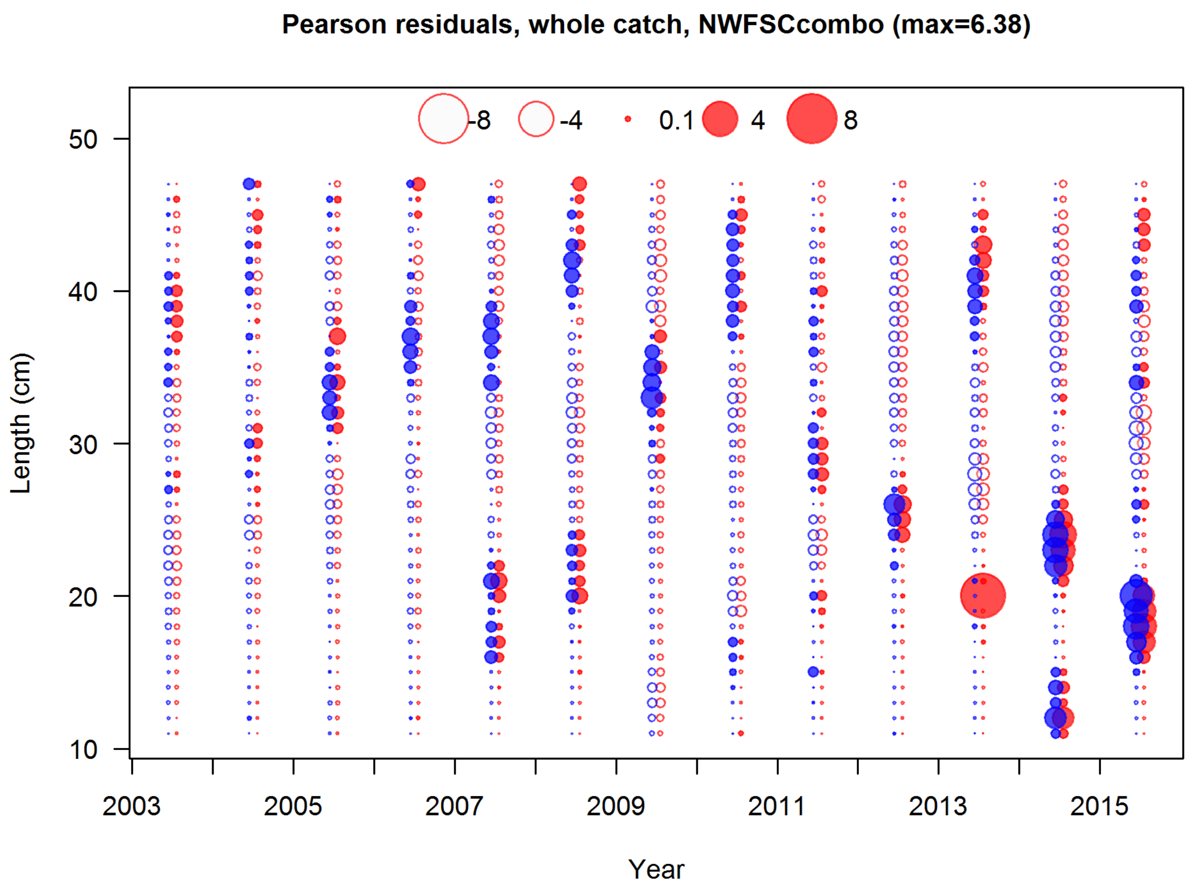


Figure 53: Pearson residuals, whole catch, NWFSCcombo (max=6.38)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_31_comp_lenfit_residsflt8mkt0

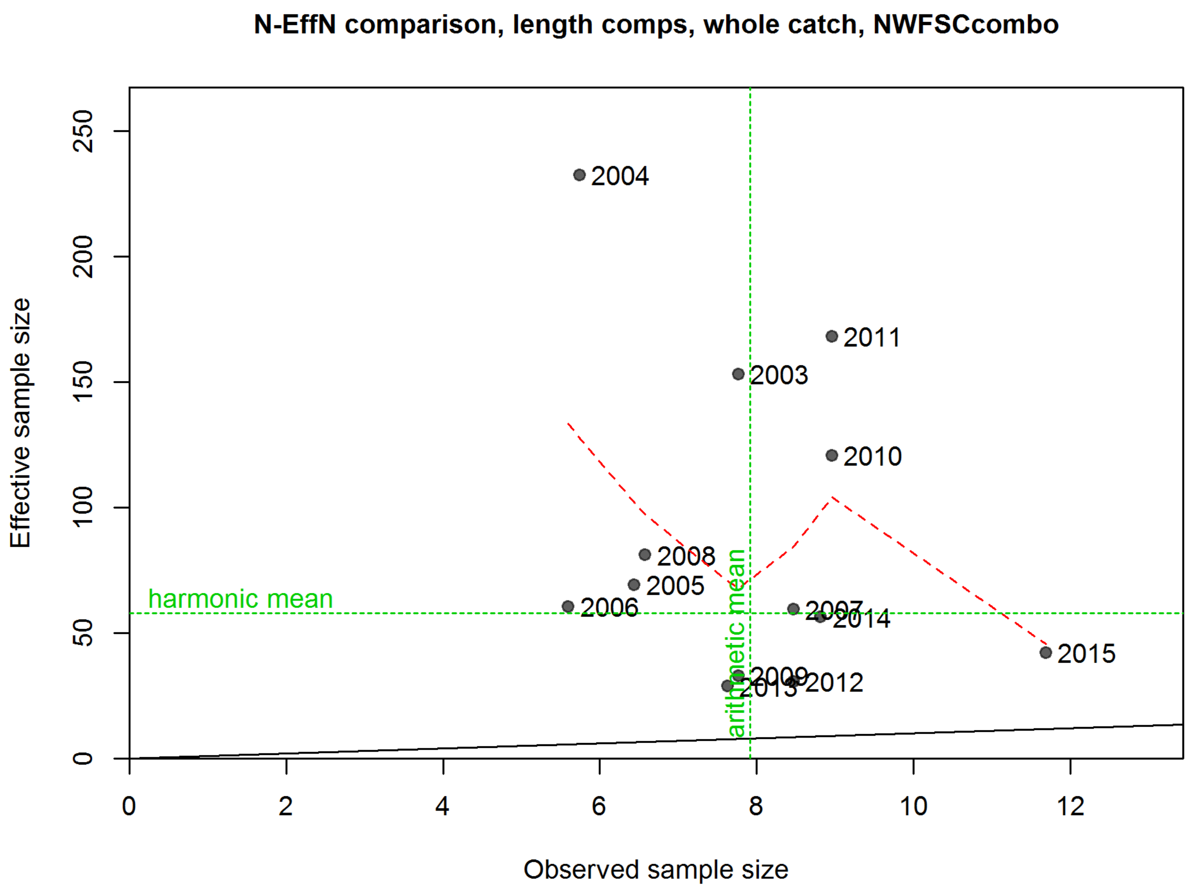


Figure 54: N_EffN comparison, length comps, whole catch, NWFSCcombo fig:mod1_32_comp_len

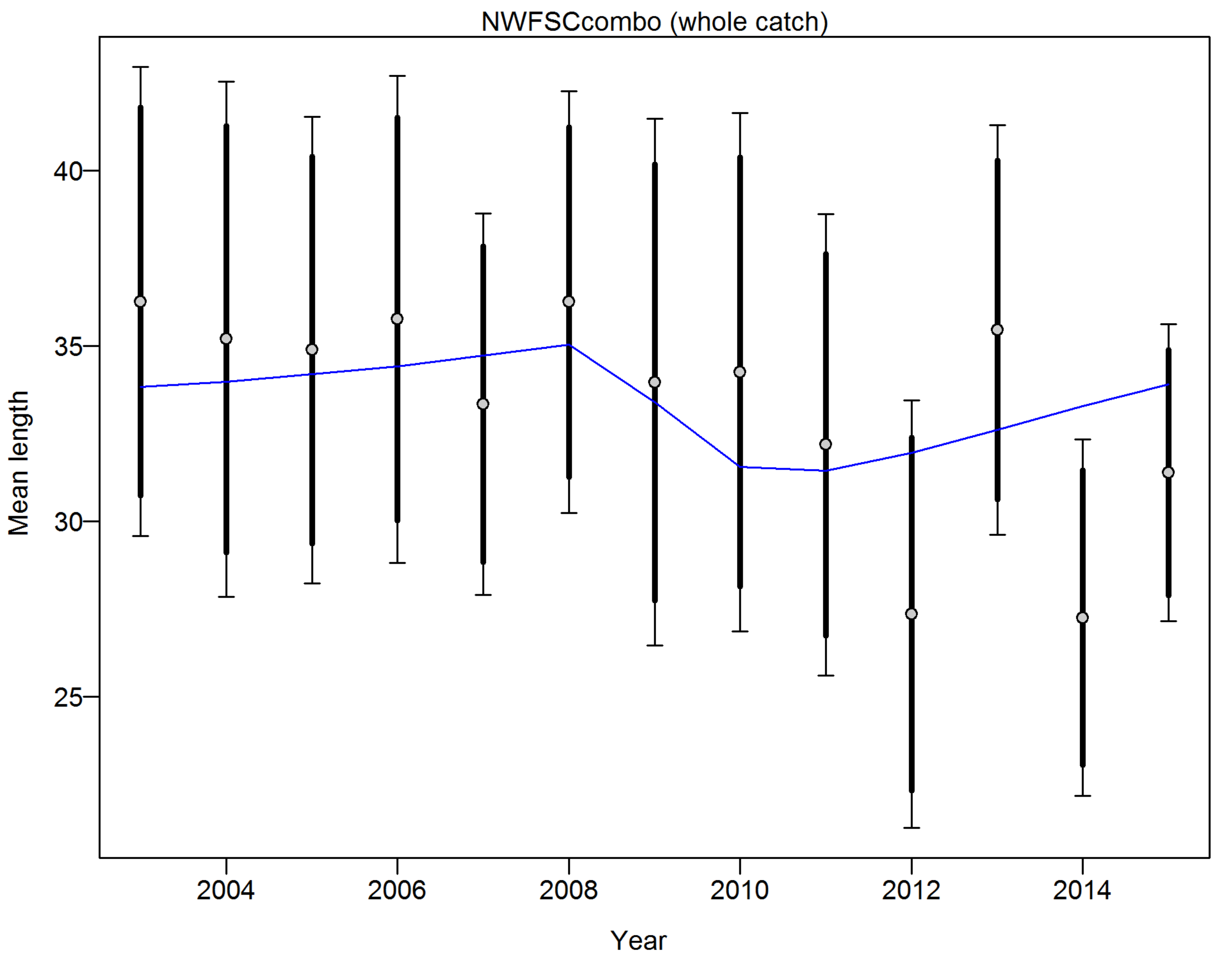


Figure 55: Francis data weighting method TA1.8 NWFSCcombo Suggested sample size adjustment (with 95% interval) for len data from NWFSCcombo: 0.686 (0.4115_4.3289) fig:mod1_33_com

length comps, discard, aggregated across time by fleet

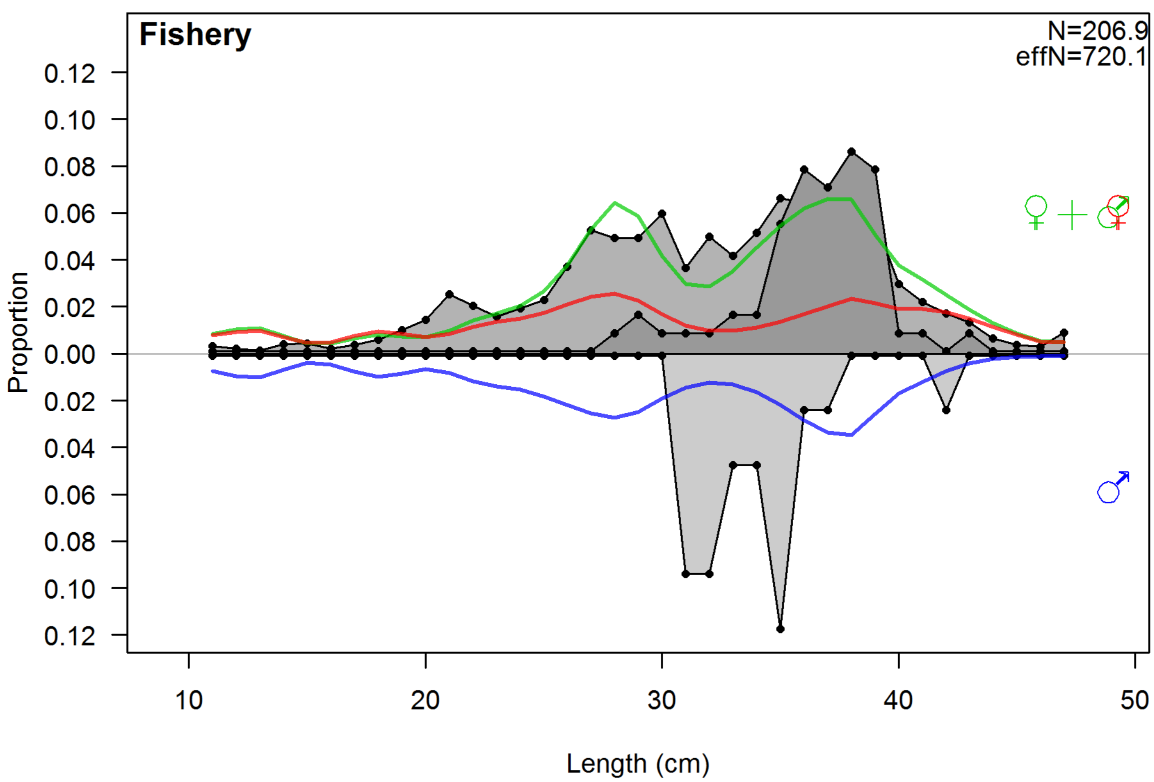


Figure 56: length comps, discard, aggregated across time by fleet fig:mod1_34_comp_lenfit_

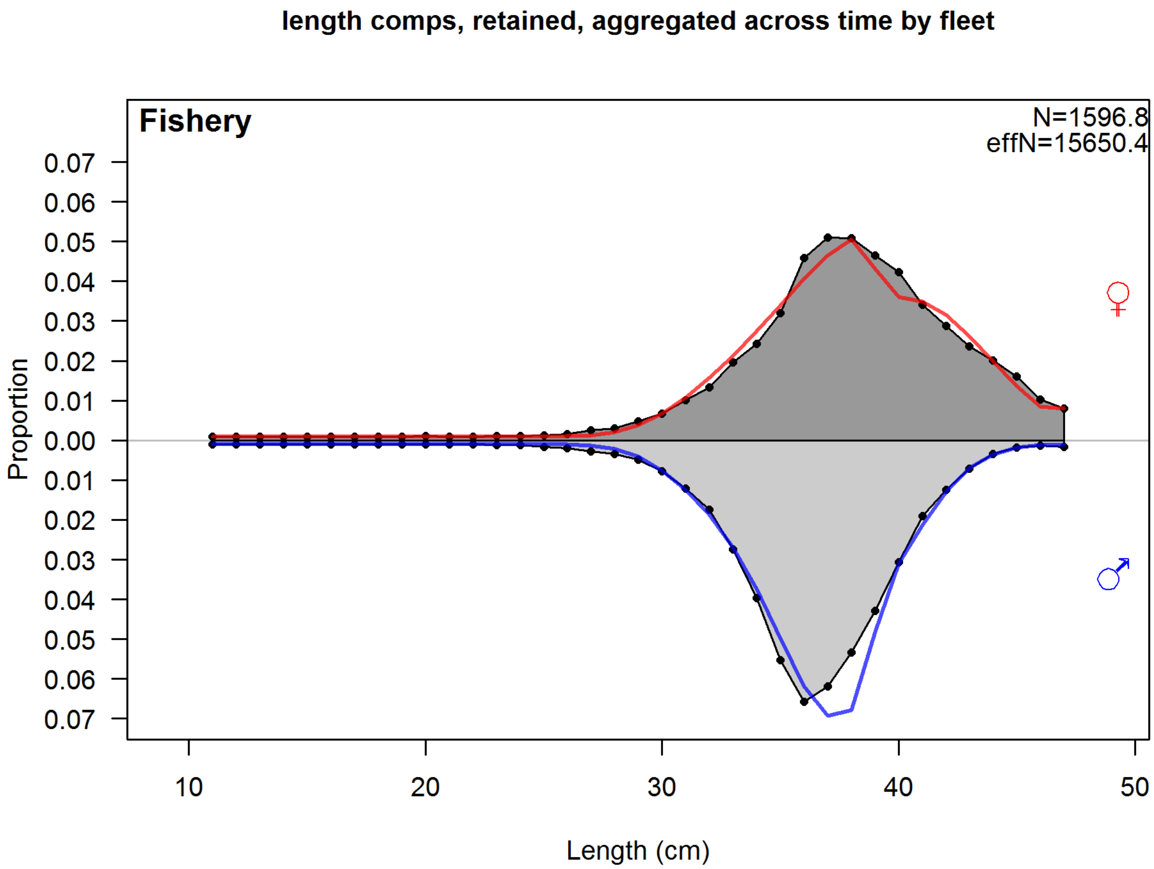


Figure 57: length comps, retained, aggregated across time by fleet fig:mod1_35_comp_lenfit_

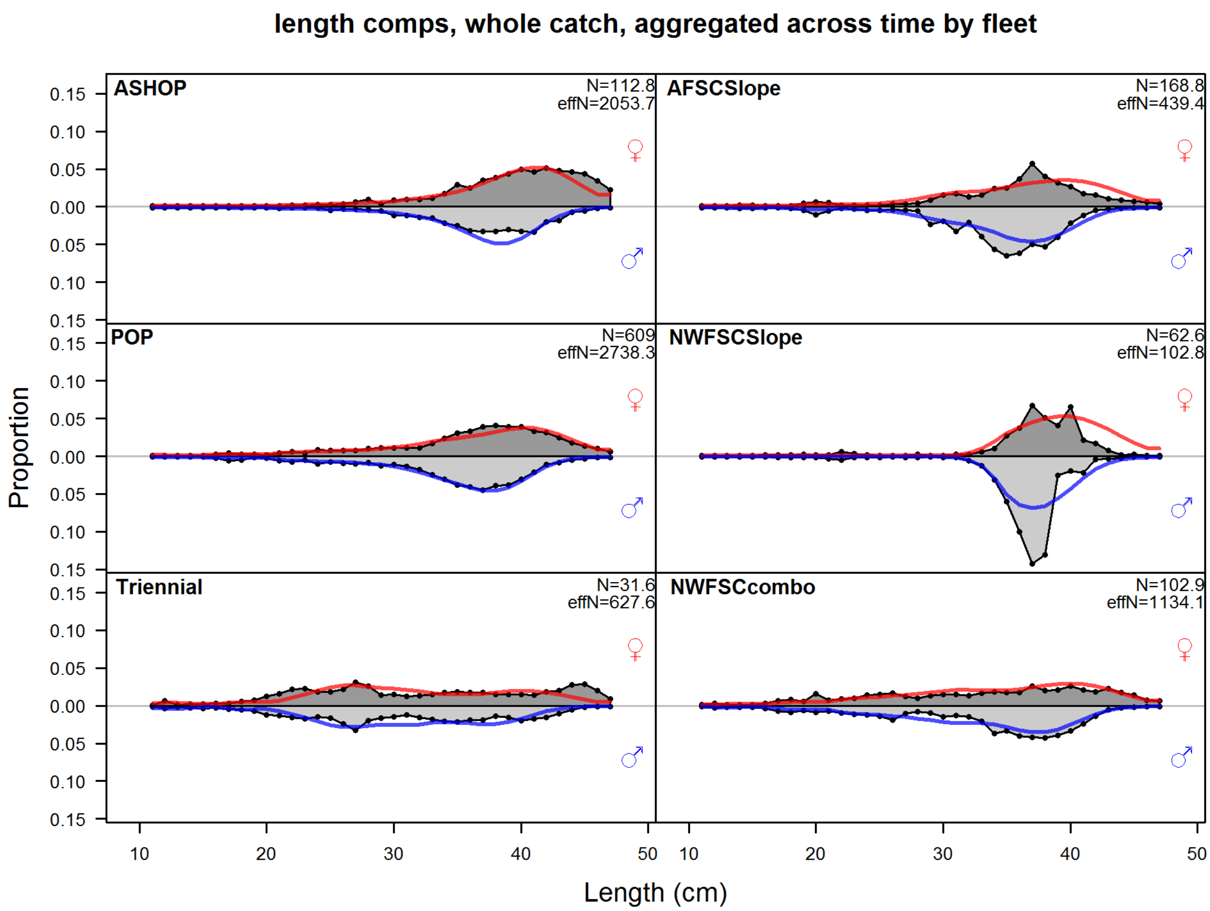


Figure 58: length comps, whole catch, aggregated across time by fleet fig:mod1_36_comp_lenfi

References

references

Bradburn, M., Keller, A., and Horness, B. 2011. The 2003 to 2008 US West Coast bottom trawl surveys of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, length, and age composition. US Department of Commerce, National Oceanic; Atmospheric Administration, National Marine Fisheries Service.

Chilton, D.E., and Beamish, R.J. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. [Ottawa:] Minister of Supply; Services Canada.

Dick, E., Beyer, S., Mangel, M., and Ralston, S. 2017. A meta-analysis of fecundity in rockfishes (genus *Sebastes*). Fisheries Research **187**: 73–85. doi: 10.1016/j.fishres.2016.11.009.

Dick, E.J. 2009. Modeling the Reproductive Potential of Rockfishes (*Sebastes* Spp.). ProQuest. 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 [accessed 27 February 2017].

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.

Gunderson, D.R. 1977. Population biology of Pacific ocean perch, *Sebastes alutus*, stocks in the WashingtonQueen Charlotte Sound region and their response to fishing. Fishery Bulletin **75**: 369–403. Available from http://fishbull.noaa.gov/75-2/gunderson.pdf [accessed 27 February 2017].

Gunderson, D.R. 1978. Results of cohort analysis for Pacific ocean perch stocks off British Columbia, Washington, and Oregon and an evaluation of alternative rebuilding strategies for these stocks. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.

Gunderson, D.R. 1997. Trade-off between reproductive effort and adult survival in oviparous and viviparous fishes. Canadian Journal of Fisheries and Aquatic Sciences **54**(5): 990–998. Available from http://www.nrcresearchpress.com/doi/abs/10.1139/f97-019 [accessed 27 February 2017].

Gunderson, D.R., and Sample, T.M. 1980. Distribution and abundance of rockfish off Washington, Oregon and California during 1977. Northwest; Alaska Fisheries Center, National

Marine Fisheries Service. Available from http://spo.nmfs.noaa.gov/mfr423-4/mfr423-42.pdf [accessed 28 February 2017].

Gunderson, D.R., Westrheim, S., Demory, R., and Fraidenburg, M. 1977. The status of Pacific ocean perch (*Sebastes alutus*) stocks off British Columbia, Washington, and Oregon in 1974.

Hamel, O.S. 2015. A method for calculating a meta-analytical prior for the natural mortality rate using multiple life history correlates. ICES Journal of Marine Science: Journal du Conseil **72**(1): 62–69. doi: 10.1093/icesjms/fsu131.

Hannah, R., and Parker, S. 2007. Age-modulated variation in reproductive development of female Pacific Ocean perch (*Sebastes alutus*) in waters off Oregon. Alaska Sea Grant, University of Alaska Fairbanks. pp. 1–20. doi: 10.4027/bamnpr.2007.01.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin **82**: 898–903. Available from http://fishbull.noaa.gov/81-4/hoenig.pdf [accessed 28 February 2017].

Karnowski, M., Gertseva, V., and Stephens, A. 2014. Historical Reconstruction of Oregon's Commercial Fisheries Landings. Oregon Department of Fish; Wildlife, Salem, OR.

McAllister, M.K., and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and the sampling - importance resampling algorithm. Canadian Journal of Fisheries and Aquatic Sciences **54**: 284–300. Available from http://www.nrcresearchpress.com/doi/pdf/10.1139/f96-285 [accessed 10 March 2017].

McCoy, M.W., and Gillooly, J.F. 2008. Predicting natural mortality rates of plants and animals. Ecology Letters **11**(7): 710–716. doi: 10.1111/j.1461-0248.2008.01190.x.

Methot, R.D., and Wetzel, C.R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research **142**: 86–99. doi: 10.1016/j.fishres.2012.10.012.

Pikitch, E.K., Erickson, D.L., and Wallace, J.R. 1988. An evaluation of the effectiveness of trip limits as a management tool. Northwest; Alaska Fisheries Center, National Marine Fisheries Service NWAFC Processed Report. Available from https://www.afsc.noaa.gov/Publications/ProcRpt/PR1988-27.pdf [accessed 28 February 2017].

Ralston, S., Pearson, D.E., Field, J.C., and Key, M. 2010. Documentation of the California catch reconstruction project. US Department of Commerce, National Oceanic; Atmospheric Adminstration, National Marine.

Rogers, J. 2003. Species allocation of *Sebastes* and *Sebastolobus* species caught by foreign countries off Washington, Oregon, and California, U.S.A. in 1965-1976. Unpublished document.

Rogers, J.B., and Pikitch, E.K. 1992. Numerical definition of groundfish assemblages caught off the coasts of Oregon and Washington using commercial fishing strategies. Canadian 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].

Seeb, L.W., and Gunderson, D.R. 1988. Genetic variation and population structure of Pacific ocean perch (*Sebastes alutus*). Canadian Journal of Fisheries and Aquatic Sciences **45**(1): 78–88. Available from http://www.nrcresearchpress.com/doi/abs/10.1139/f88-010 [accessed 28 February 2017].

Then, A.Y., Hoenig, J.M., Hall, N.G., and Hewitt, D.A. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science **72**(1): 82–92. doi: 10.1093/icesjms/fsu136.

Thorson, J.T., and Barnett, L.A.K. 2017. Comparing estimates of abundance trends and distribution shifts using single- and multispecies models of fishes and biogenic habitat. ICES Journal of Marine Science: Journal du Conseil: fsw193. doi: 10.1093/icesjms/fsw193.

Weinberg, J.R., Rago, P.J., Wakefield, W.W., and Keith, C. 2002. Estimation of tow distance and spatial heterogeneity using data from inclinometer sensors: An example using a clam survey dredge. Fisheries Research **55**(1–3): 49–61. doi: 10.1016/S0165-7836(01)00292-2.

Wilkins, M., and Golden, J. 1983. Condition of the Pacific ocean perch resource off Washington and Oregon during 1979: Results of a cooperative trawl survey. North American Journal of Fisheries Management **3**: 103–122.

Withler, R., Beacham, T., Schulze, A., Richards, L., and Miller, K. 2001. Co-existing populations of Pacific ocean perch, Sebastes alutus , in Queen Charlotte Sound, British Columbia. Marine Biology **139**(1): 1–12. doi: 10.1007/s002270100560.

Zimmermann, M., Wilkins, M., Weinberg, K., Lauth, R., and Shaw, F. 2003. Influence of improved performance monitoring on the consistency of a bottom trawl survey. ICES Journal of Marine Science **60**(4): 818–826. doi: 10.1016/S1054-3139(03)00043-2.