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

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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	92.36
2009	0.92	58.74	33.22	1.56	2.72	97.17
2010	0.14	58.00	22.29	16.87	1.68	98.98
2011	0.12	30.26	19.66	9.17	1.94	61.14
2012	0.18	30.41	21.79	4.52	1.62	58.51
2013	0.08	34.86	14.83	5.41	1.71	56.89
2014	0.18	33.91	15.82	3.92	0.57	54.40
2015	0.12	38.05	11.41	8.71	1.59	59.88
2016	0.23	40.81	13.12	10.30	3.10	67.56
2017	0.03	13.05	0.00	0.00	0.00	13.07

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.

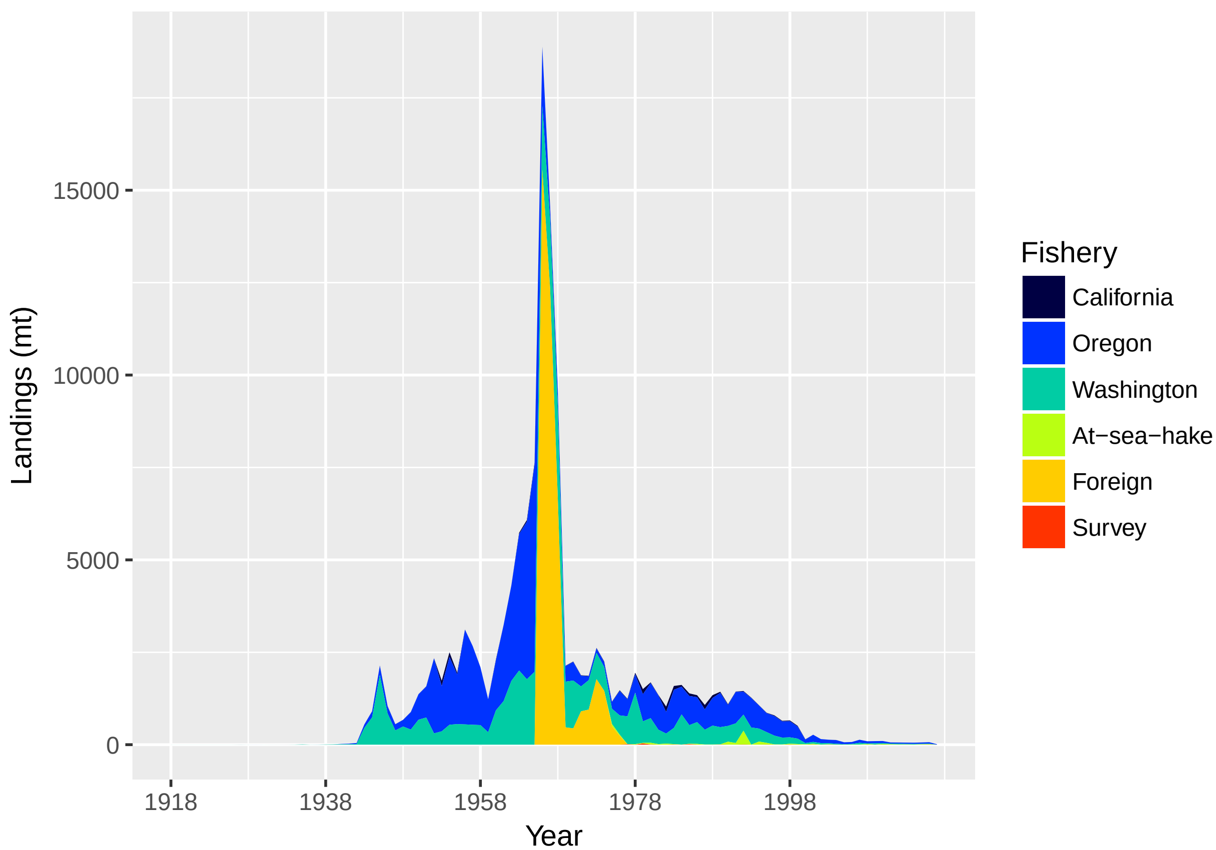

Figure a: Landings of Pacific ocean perch for California, Oregon, Washington, the Foriegn fishery (1966-1976), At-Sea Hake fishery, and fishery independent surveys. fig:Exec_catch1

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 75% (~95% asymptotic interval: ± 52.5%-97.6%) (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	2806.00	1219 - 4393	0.45	0.308 - 0.595
2009	2934.00	1277 - 4591	0.47	0.323 - 0.621
2010	3022.00	1316 - 4728	0.49	0.333 - 0.640
2011	3084.00	1343 - 4824	0.50	0.340 - 0.652
2012	3132.00	1368 - 4896	0.50	0.346 - 0.662
2013	3177.00	1391 - 4962	0.51	0.352 - 0.670
2014	3325.00	1464 - 5187	0.54	0.370 - 0.700
2015	3720.00	1650 - 5790	0.60	0.416 - 0.781
2016	4226.00	1888 - 6565	0.68	0.474 - 0.886
2017	4663.00	2093 - 7234	0.75	0.525 - 0.976

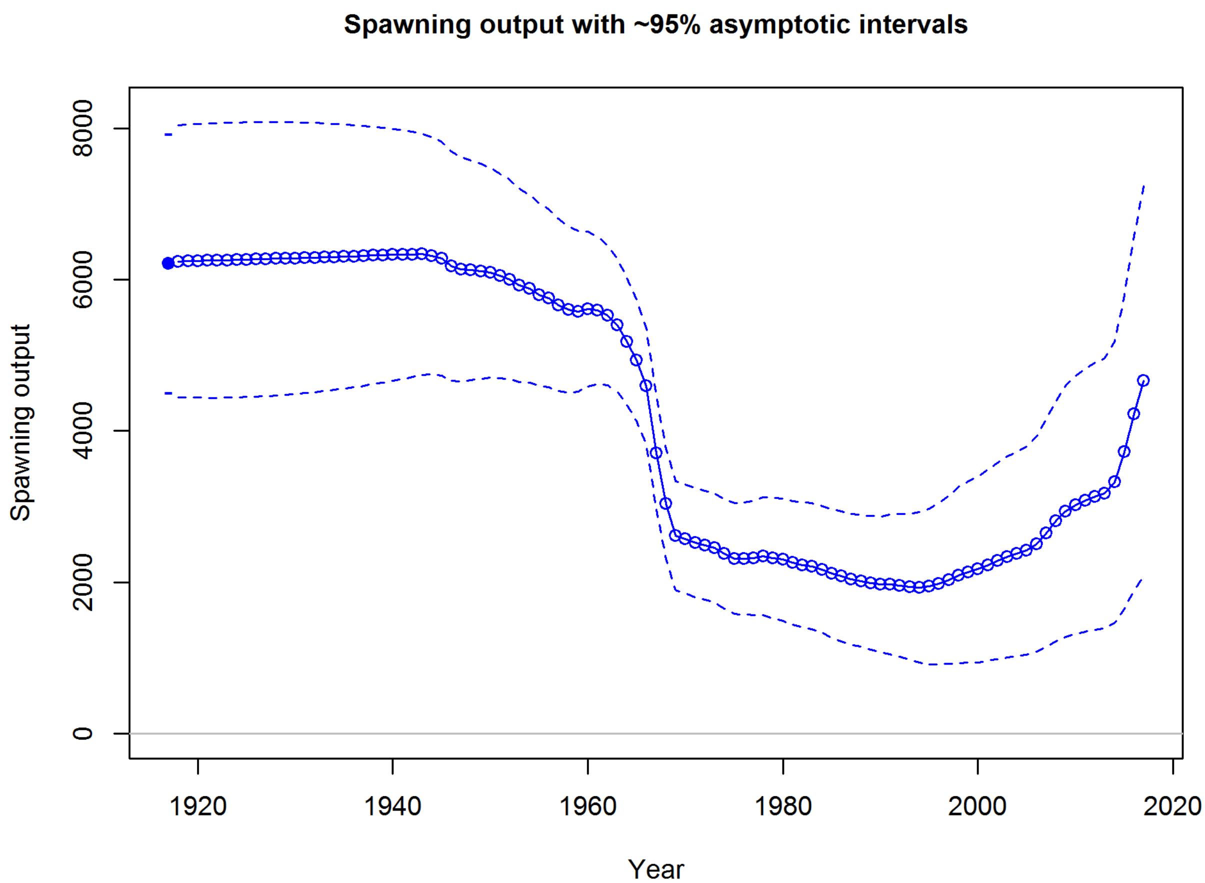

Figure b: Time series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model. fig:Spawnbio_all

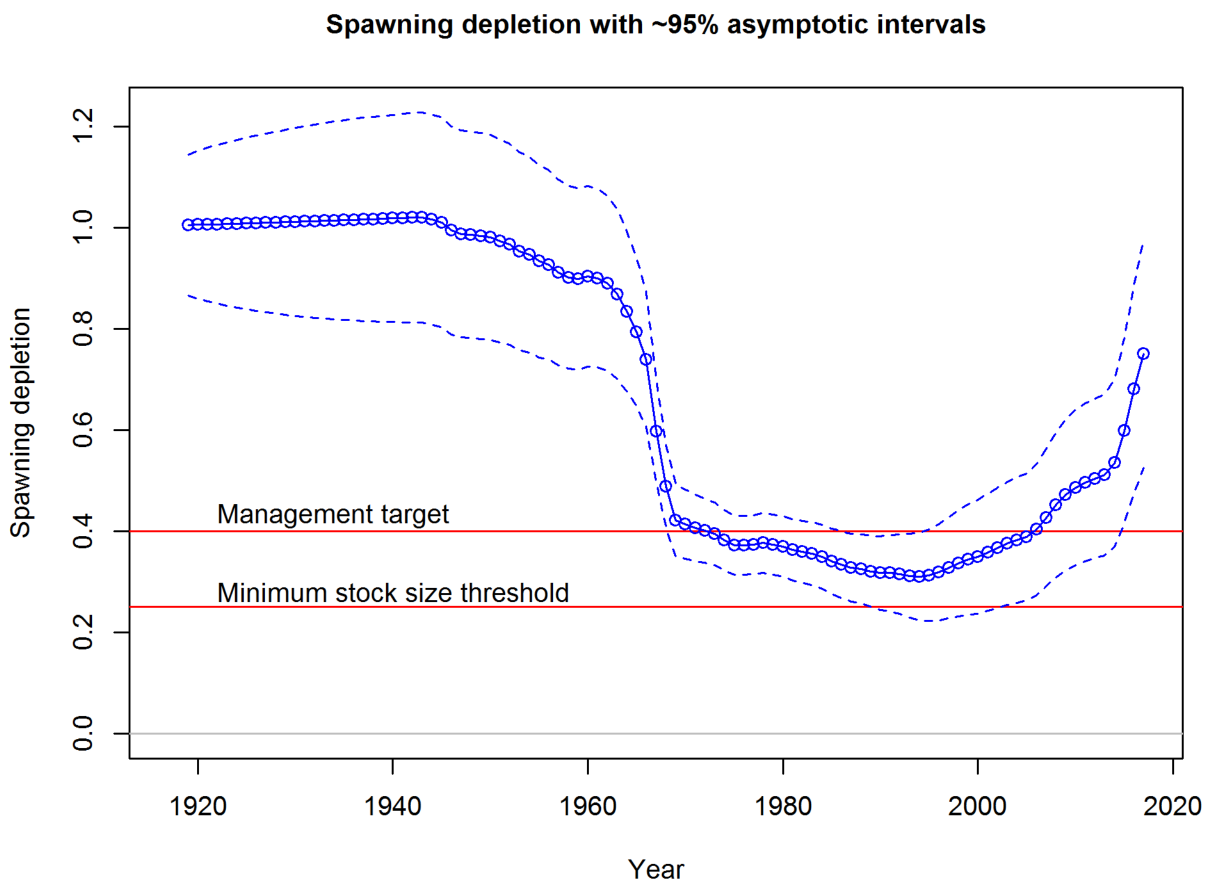

Figure c: Estimated relative depletion with approximate 95% asymptotic confidnce intervals (dashed lines) for the base case assessment model. fig:RelDeplete_all

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	134138.00	77084 - 233420	2.92	2.670 - 3.177
2009	5240.00	2209 - 12430	-0.34	-1.121 - 0.445
2010	8428.00	4082 - 17399	0.12	-0.458 - 0.708
2011	16150.00	8238 - 31661	0.77	0.260 - 1.275
2012	2182.00	899 - 5298	-1.24	-2.070 - -0.411
2013	26321.00	12549 - 55209	1.16	0.536 - 1.781
2014	4263.00	1487 - 12223	-0.77	-1.828 - 0.296
2015	9510.00	2669 - 33877	-0.00	-1.371 - 1.362
2016	9984.00	2797 - 35634	0.00	-1.372 - 1.372
2017	10302.00	2890 - 36723	0.00	-1.372 - 1.372

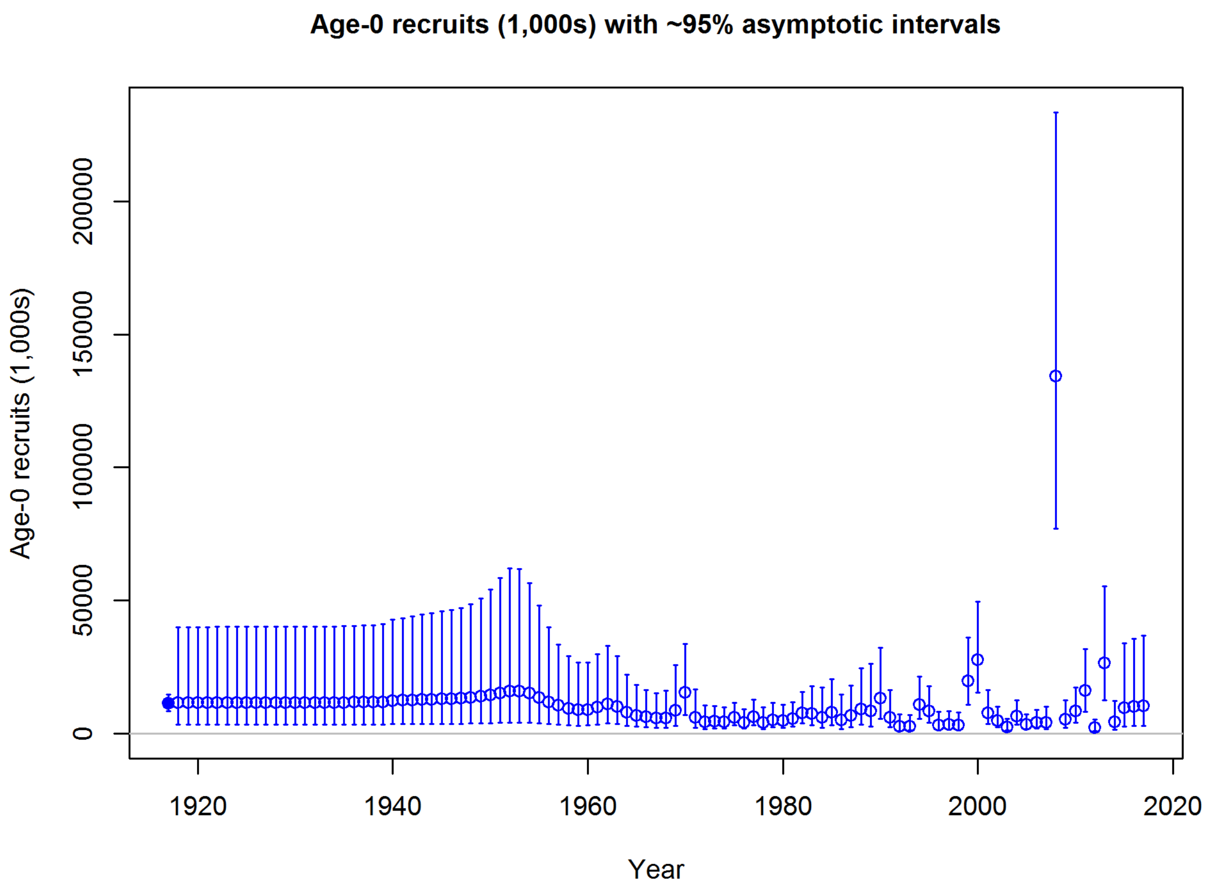

Figure d: Time series of estimated Pacific ocean perch recruitments for the base-case model with 95% confidence or credibility intervals. fig:Recruits_all

Exploitation status

exploitation-status

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

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

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

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

tab:SPR_Exploit_mod1

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.117	0.054 - 0.181	0.002	0.001 - 0.004
2008	0.096	0.042 - 0.151	0.002	0.001 - 0.003
2009	0.131	0.055 - 0.207	0.003	0.001 - 0.005
2010	0.124	0.053 - 0.195	0.003	0.001 - 0.004
2011	0.042	0.019 - 0.066	0.001	0.000 - 0.001
2012	0.039	0.018 - 0.061	0.001	0.000 - 0.001
2013	0.037	0.017 - 0.057	0.001	0.000 - 0.001
2014	0.032	0.014 - 0.050	0.001	0.000 - 0.001
2015	0.031	0.014 - 0.048	0.001	0.000 - 0.001
2016	0.030	0.014 - 0.047	0.001	0.000 - 0.001

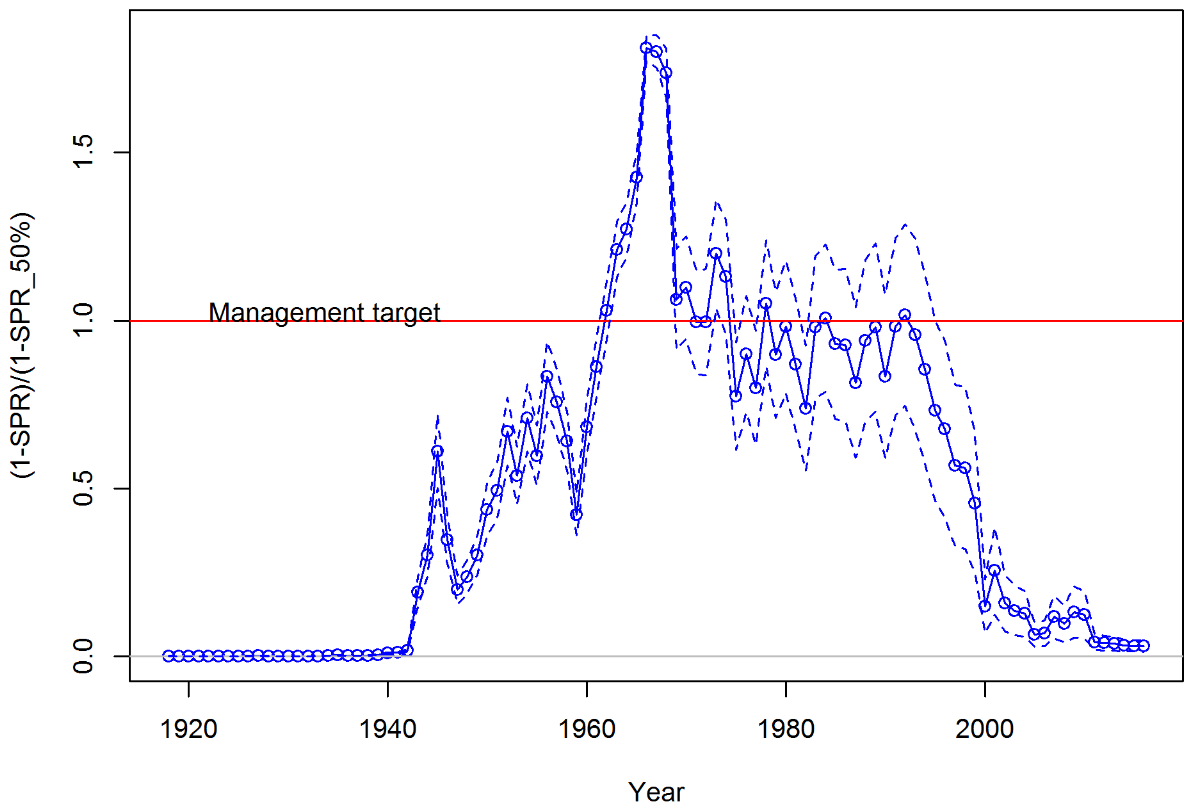

Figure e: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

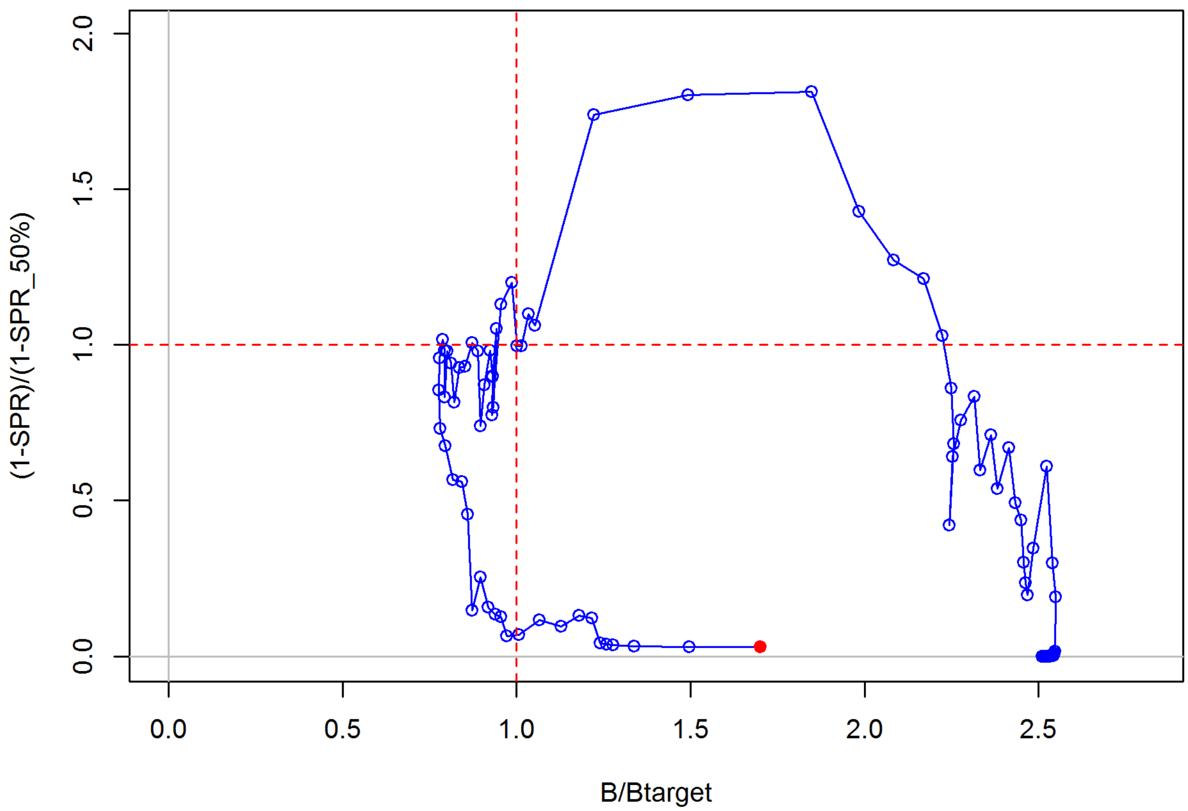

Figure f: Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 50% (the SPR target). Relative depletion is the annual spawning biomass divided by the unfished spawning biomass. fig:Phase_all

Ecosystem Considerations

`ecosystem-considerations`

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

Reference Points

`reference-points`

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

Write intro paragraph

This stock assessment estimates that Pacific ocean perch in the Base model are above the biomass target, but above the minimum stock size threshold. Add sentence about spawning output trend. The estimated relative depletion level for Model 1 in 2017 is 75% (˜95% asymptotic interval: ± 52.5%-97.6%, corresponding to an unfished spawning output of 4663 million eggs (˜95% asymptotic interval: 2092.85483211479-7233.60516788521 million eggs) of spawning output in the base model (Table e). Unfished age 3+ biomass was estimated to be 132334 mt in the base case model. The target spawning output based on the biomass target ($SB_{40\%}$) is 2486 million eggs, which gives a catch of 1657.1 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 1674.7 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)	6215	4502.1 - 7927.9
Unfished age 3+ biomass (mt)	132334	95967.1 - 168700.9
Unfished recruitment (R0, thousands)	11158.5	8492.2 - 14662
Spawning output(2017 million eggs)	4663.2	2092.9 - 7233.6
Depletion (2017)	0.75	0.525 - 0.976
Reference points based on $\mathbf{SB_{40\%}}$		
Proxy spawning output ($B_{40\%}$)	2486	1800.8 - 3171.1
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.55	0.55 - 0.55
Exploitation rate resulting in $B_{40\%}$	0.028	0.028 - 0.028
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	1657.1	1202.2 - 2112
Reference points based on SPR proxy for MSY		
Spawning output	2071.7	1500.7 - 2642.6
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.033	0.033 - 0.034
Yield with SPR_{proxy} at SB_{SPR} (mt)	1674.7	1215.2 - 2134.1
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	2157.8	1561 - 2754.7
SPR_{MSY}	0.51	0.509 - 0.512
Exploitation rate at MSY	0.032	0.032 - 0.033
MSY (mt)	1676.1	1216.2 - 2136

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	133	157
2008	-	-	150	92	132
2009	-	-	189	94	195
2010	-	-	200	97	185
2011	-	-	180	60	61
2012	-	-	183	57	58
2013	-	-	150	55	57
2014	-	-	153	54	55
2015	-	-	158	58	59
2016	-	-	164	65	65

Decision Table(s) (groundfish only)

decision-tables-groundfish-only

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

OFL projection table: Table g

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

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

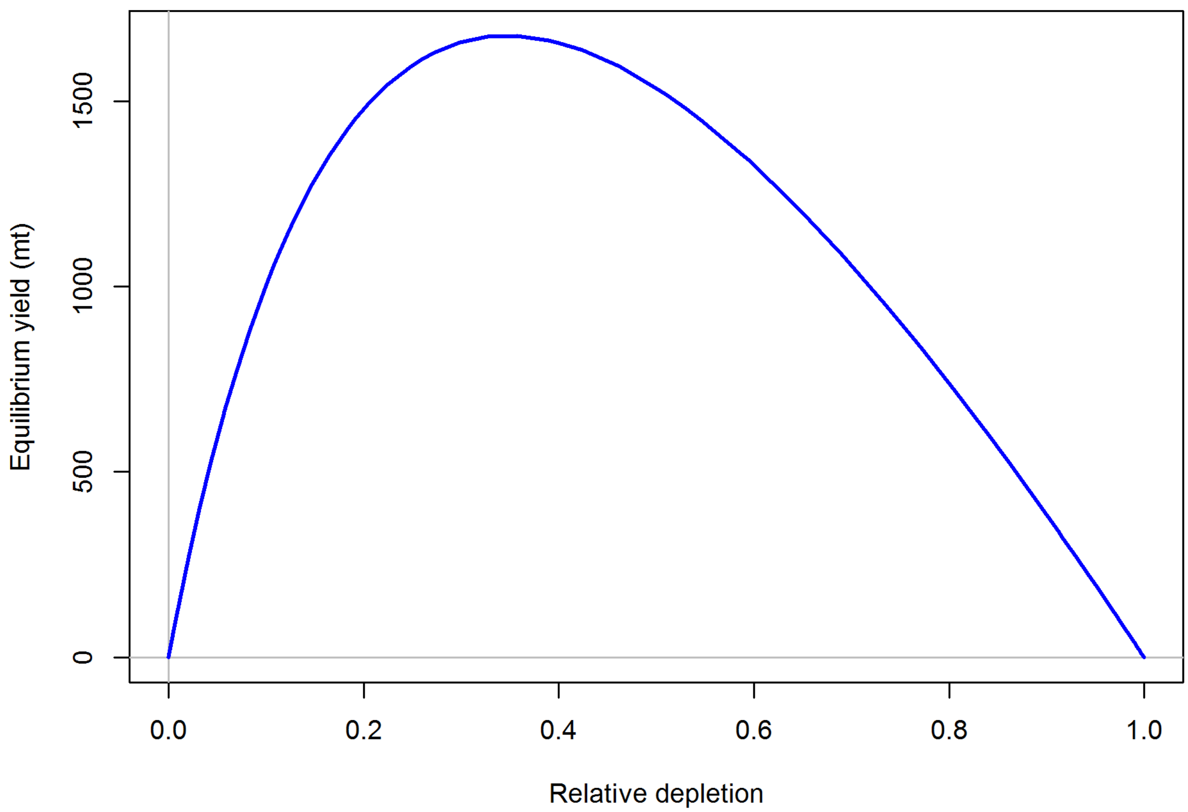

Figure g: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at... fig:Yield_all

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

tab:OFL_projection

Year	OFL	ACL	Spawning Output (million eggs)	Relative Biomass
2017	4040	281	4663	0.750
2018	4285	281	4996	0.804
2019	4440	4245	5261	0.846
2020	4390	4197	5306	0.854
2021	4305	4116	5309	0.854
2022	4200	4015	5267	0.847
2023	4085	3906	5194	0.836
2024	3969	3795	5103	0.821
2025	3858	3688	5001	0.805
2026	3753	3588	4894	0.787
2027	3655	3494	4784	0.770
2028	3562	3405	4674	0.752

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
40-10 Rule, Low M	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
40-10 Rule	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
40-10 Rule, High M	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Average Catch	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-

Table i: Base model results summary.

tab:base_summary

Quantity	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Landings (mt)	-	-	-	-	-	-	-	-	-	-
Total Est. Catch (mt)	150	189	200	180	183	150	153	158	164	281
OFL (mt)	92	94	97	60	57	55	54	58	65	
ACL (mt)	132	195	185	61	58	57	55	59	65	
(1-SPR)(1-$SPR_{50\%}$)	0.10	0.13	0.12	0.04	0.04	0.04	0.03	0.03	0.03	
Exploitation rate	0	0	0	0	0	0	0	0	0	
Age 3+ biomass (mt)	66049.1	66877.3	67298.3	81202.1	88190.3	95247.2	102557.0	107978.0	114692.0	119055.0
Spawning Output	2806	2934	3022	3084	3132	3177	3325	3720	4226	4663
95% CI	1219 - 4393	1277 - 4591	1316 - 4728	1343 - 4824	1368 - 4896	1391 - 4962	1464 - 5187	1650 - 5790	1888 - 6565	2093 - 7234
Depletion	0.451	0.472	0.486	0.496	0.504	0.511	0.535	0.599	0.680	0.750
95% CI	0.308 - 0.595	0.323 - 0.621	0.333 - 0.640	0.340 - 0.652	0.346 - 0.662	0.352 - 0.670	0.370 - 0.700	0.416 - 0.781	0.474 - 0.886	0.525 - 0.976
Recruits	134138	5240	8428	16150	2182	26321	4263	9510	9984	10302
95% CI	77084 - 233420	2209 - 12430	4082 - 17399	8238 - 31661	899 - 5298	12549 - 55209	1487 - 12223	2669 - 33877	2797 - 35634	2890 - 36723

Research And Data Needs

research-and-data-needs

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

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

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

Rebuilding Projections

rebuilding-projections

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

1 Introduction

introduction

1.1 Basic Information

basic-information

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

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

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

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

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

1.2 Summary of Management History

summary-of-management-history

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

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

1.3 Fisheries off Canada and Alaska

fisheries-off-canada-and-alaska

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

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

2 Data

data

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

2.1 Fishery-Independent Data:

fishery-independent-data

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

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

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

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

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

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

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

2.1.2 Northwest Fisheries Science Center (NWFSC) slope survey

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

The NWFSC slope survey covered waters throughout the summer from 183 m to 1280 m north of 34°30′ S, which is near Point Conception between 1999 and 2002. Tows conducted between the depths of 183 and 549 m were used to create an index of abundance using the VAST delta-GLMM model. The estimated index of abundance is show in Table 4. The lognormal distribution with random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot does not show any departures from the assumed distribution (Figure XXXX). } The trend of abundance across the four surveys years was generally flat with high estimated annual variance.

Length and age compositions were available for 2001 and 2002 and were expanded based upon the survey stratification (Tables 7 and 8. The expanded length frequencies from this survey shows that primarily only large fish were captured both years (Figure 6). The majority of fish observed by this survey were aged at greater than 10 years (Figure 7).

2.1.3 Alaska Fisheries Science Center (AFSC) slope survey

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

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

An index of abundance was estimated based on the data using the VAST delta-GLMM model. The estimated index of abundance is shown in Table 4. The lognormal distribution with random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot does not show any departures from the assumed distribution (Figure 8). The trend in the indices was generally flat over time.

Length compositions were available for each year the survey was conducted. No age data were available from this survey. The expanded length frequencies from this survey were generally of larger fish (>30 cm), expect for 1997 where the highest frequency of fish were between 20 and 30 cm for both females and males (Figure 9).

2.1.4 Triennial Bottom Trawl Survey

`triennial-bottom-trawl-survey`

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

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

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

An index of abundance was estimated based on the data using the VAST delta-GLMM model. The estimated index of abundance is shown in Table 4. The lognormal distribution with random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot does not show any departures from the assumed distribution (Figure 10). The index shows a decline in abundance in the early years of the time-series and abundance remaining flat for the latter years.

Length and age compositions were expanded based upon the stratification. The number of tows with length data ranged from 17 in 1986 to 81 in 1998 10. Ages were read using surface reading methods until 1989 when the break-and-burn method replaced surface reads as the best method to age Pacific ocean perch. Unfortunately, surface reading of Pacific ocean perch otoliths results in significant underestimates of age. Due to this, these otolith were excluded from analysis. The available ages from the Triennial survey and the number of tows where otoliths were collected are shown in Table 11. The expanded length frequencies from this survey show an increase in small fish starting in 1995 (Figure 11). The age frequencies provide clear evidence of large year-classes moving through the population from the 1999 and 2000 recruitment (Figure 12).

2.1.5 Pacific ocean perch Survey

`pacific-ocean-perch-survey`

A survey targeted designed to sample Pacific ocean perch was conducted in 1979 and again in 1985 (for a detailed description see (Ianelli et al. 1992). An index of abundance was estimated based on the data using the VAST delta-GLMM model. The estimated index of abundance is shown in Table 4. The lognormal distribution with random strata-year had the lowest AIC and was chosen as the final model. The Q-Q plot does not show any departures from the assumed distribution (Figure 13). The index shows a clear decline in abundance between the two survey years.

Length and age compositions were expanded based on the stratification. The survey had 125 and 126 Pacific ocean perch tows (Table 12) and ages were only available in 1985 due to surface reads for the 1979 data (Table 13). The length frequencies for both years are highest between the 30-45 cm range (Figure 14) with ages in 1985 having a large number of fish age 40 and greater (Figure 15).

2.2 Fishery-Dependent Data

`fishery-dependent-data`

2.2.1 Commercial Fishery Landings

`commercial-fishery-landings`

Washington

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

Oregon

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

California

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

At-Sea Hake Fishery

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

Foreign Catches

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

2.2.2 Discards

`discards`

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

The second source is from the West Coast Groundfish Observer Program (WCGOP). This program is part of the NWFSC and has been recording discard observations since 2003. Table 14 shows the discard ratios (discarded/(discarded + retained)) of Pacific ocean perch from the WCGOP. Since 2011, when the trawl rationalization program was implemented, observer coverage rates increased to nearly 100% for all the limited entry trawl vessels in the program and discard rates declined compared to pre-2011 rates. Discard rates were obtained for both the catch-share and the non-catch share sector for Pacific ocean perch. A single discard rate was calculated by weighting discard rates based on the commercial landings by each sector. Coeffienct of variations were calculated by bootstrapping vessels within ports because the observer program randomly chooses vessels within porats to be observed in the non-catch shares sectors. Discard length composition for the trawl fleet varied by year, with larger fish being discarded prior to 2011 (Figure 16).

2.2.3 Historical Commercial Catch-per-unit effort

`historical-commercial-catch-per-unit-effort`

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

2.2.4 Fishery Length And Age Data

`fishery-length-and-age-data`

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

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

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

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

2.3 Biological Data

biological-data

2.3.1 Natural mortality

natural-mortality

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

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

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

The above is also the median of the prior. The prior is defined as a lognormal with mean $ln(\frac{5.4}{A_{\max}})$ and SE = 0.4384343. Using a maximum age of 100 the point estimate and median of the prior is 0.054.

2.3.2 Sex ratio, maturation, and fecundity

`sex-ratio-maturation-and-fecundity`

Examining all biological data sources, the sex ratio of young fish are within 5% of 1:1 by either length or age (Figures 21 and 22), and hence this assessment the sex ratio at birth was assumed to be 1:1. This assessment assumed a logistic maturity-at-length curve based on analysis of 537 fish maturity samples collected from the NWFSC shelf-slope survey. This is revised from the previous assessment which assumed maturity-at-age based on the work of Hannah and Parker (Hannah and Parker 2007). Additionally, the new maturity-at-length curve is based on the estimate of functional maturity an approach that classifies rockfish maturity with developing oocytes as mature or immature based on the proportion of vitellogenin in the cytoplasm and the measured frequency of atretic cells (M. Head, personal communication). The 50% size-at-maturity was estimated at 32.1 cm with maturity asymptoting to one for larger fish (Figure 23). Comparison between the maturity-at-age used in the previous assessment and the updated functional maturity-at-length is shown in Figure 24.

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 25.

2.3.3 Length-weight relationship

`length-weight-relationship`

The length-weight relationship for Pacific ocean perch was estimated outside the model using all biological data available from fishery and fishery-independent data sources where the female weight-at-length in grams was estimated at $0.0000104L^{3.09}$ and males at $0.0000105L^{3.08}$ where L is length in cm (Figures 26 and 27).

2.3.4 Growth (length-at-age)

`growth-length-at-age`

The length-at-age was estimated for male and female Pacific ocean perch using data collected from both fishery-dependent and -independent data sources that were collected from 1981-2016. Figure 28 shows the lengths and ages for all years and all data as well as predicted von Bertalanffy fits to the data. Females grow larger than males and sex specific growth parameters were estimated at the following values:

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

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

2.3.5 Ageing Precision And Bias

ageing-precision-and-bias

Uncertainty surrounding the ageing-error process for Pacific ocean perch was incorporated by estimating ageing error by age. Age-composition data used in the model were from break-and-burn otolith reads aged by the Cooperative Ageing Project (CAP) in Newport, Oregon. Break-and-burn double reads of more than 1500 otoliths were provided by the CAP lab. An ageing error estimate was made based on these double reads using a computational tool specifically developed for estimating ageing error (Punt et al. 2008), and using release 1.0.0 of the R package nwfscAgeingError (Thorson et al. 2012) for input and output diagnostics, publicly available at: https://github.com/nwfsc-assess/nwfscAgeingError. A non-linear standard error was estimated by age where there is more variability in the estimated age of older fish was estimated (Table 20, Figure 29).

2.4 History Of Modeling Approaches Used For This Stock

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

2.4.1 Previous Assessments

previous-assessments

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

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

2.4.2 Previous Assessment Recommendations

previous-assessment-recommendations

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

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

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

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

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

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

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

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

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

STAT response: California and Oregon have ungone extensive work to create historical catch reconstructions. This is the first assessment for Pacific ocean perch which includes a Washington historical catch reconstruction. The data used in this assessment represent Washington state's current best estimate for historical catches. Both California and Washington are conducting research to estimate uncertainty surround historical catches which could be used to propegate uncertainty within the assessment.

3 Assessment

assessment

3.1 General Model Specifications and Assumptions

general-model-specifications-and-assumptions

Stock Synthesis v3.30.01.12 was used to estimate the parameters in the model. R4SS, revision 1.26.0, along with R version 3.3.2 were used to investigate and plot model fits. A summary of the data sources used in the model (details discussed above) is shown in Figure 2.

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

3.1.1 Changes between the 2011 assessment model and current model

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

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

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

Selectivity in this model is assumed to be length-based and is modeled using double-normal for all fleets, expect the Pacific ocean perch survey which retained the previous assessment assumption of logistic selectivity. The previous assessment mirrored selectivity amont the Pacific ocean perch and both slope surveys (AFSC and NWFSC). This assessment allow for survey specific estimated double-normal selectivity.

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

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

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

3.1.2 Summary of Fleets and Areas

summary-of-fleets-and-areas

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

The majoirty of removals of Pacific ocean perch were observed by eht bottom trawl fishery with fixed gear accounting for a small fraction of the catches avaiable within PacFIN. Trawl and fixed gears were combined into a coast-wide fleet. For the period from 1918 to the early 1990s, prior to the introduction of trip limits for rockfish, limited discarding of Pacific ocean perch was assumed. Observations of Pacific ocean perch in the Pikitch et al. (1988) data

(1986-1987) allowed for a formal analysis of discard rates which were applied to the historical period of the fishery. Foreign trawl catches (1966-1976) was modeled as a single fleet. The at-sea fishery operates as a mid-water fishery targeting Pacific whiting but encounters Pacific ocean perch as a bycatch species. This fleet was also modeled as a single fleet.

3.1.3 Other Specifications

other-specifications

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

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

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

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

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

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

3.1.4 Modeling Software

`modeling-software`

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

3.1.5 Priors

`priors`

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

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

3.1.6 Data Weighting

`data-weighting`

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

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

3.1.7 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.

3.1.8 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 **??**

3.2 Model Selection and Evaluation

`model-selection-and-evaluation`

3.2.1 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).

3.2.2 Alternate Models Considered

`alternate-models-considered`

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

3.2.3 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 24 shows the results of running 100 jitters for each pre-STAR base model....

3.3 Response To The Current STAR Panel Requests

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

Request No. 1: Add after STAR panel.

Rationale: Add after STAR panel.

STAT Response: Add after STAR panel.

Request No. 2: Add after STAR panel.

Rationale: Add after STAR panel.

STAT Response: Add after STAR panel.

Request No. 3: Add after STAR panel.

Rationale: Add after STAR panel.

STAT Response: Add after STAR panel.

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.

3.4 Base Model Results

`base-model-results`

Table **??**

3.4.1 Uncertainty and Sensitivity Analyses

uncertainty-and-sensitivity-analyses

Table 25

3.4.2 Retrospective Analysis

retrospective-analysis

3.4.3 Likelihood Profiles

likelihood-profiles

3.4.4 Reference Points

reference-points-1

Intro sentence or two....(Table 26).

Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 1674.7 mt. Table e shows the full suite of estimated reference points for the northern area model and Figure g shows the equilibrium yield curve.

4 Harvest Projections and Decision Tables

harvest-projections-and-decision-tables

Table f

Model 1 Projections and Decision Table (groundfish only) (Table 27

Table h

Model 2 Projections and Decision Table (groundfish only)

Model 3 Projections and Decision Table (groundfish only)

5 Regional Management Considerations

regional-management-considerations

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

6 Research Needs

`research-needs`

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

7 Acknowledgments

`acknowledgments`

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

8 Tables

tables

Table 1: 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	0.1	0.0	0.8	0.0	0	0.0
1918	0.1	0.0	1.1	0.0	0	0.0
1919	0.0	0.0	0.4	0.0	0	0.0
1920	0.0	0.0	0.3	0.0	0	0.0
1921	0.0	0.0	0.3	0.0	0	0.0
1922	0.0	0.0	0.1	0.0	0	0.0
1923	0.0	0.0	0.2	0.0	0	0.0
1924	0.1	0.0	0.5	0.0	0	0.0
1925	0.1	0.0	0.6	0.0	0	0.0
1926	0.1	0.0	1.0	0.0	0	0.0
1927	0.1	0.0	1.4	0.0	0	0.0
1928	0.1	0.1	1.2	0.0	0	0.0
1929	0.3	0.1	0.7	0.0	0	0.0
1930	0.2	0.1	0.9	0.0	0	0.0
1931	0.4	0.1	0.4	0.0	0	0.0

Year	California	Oregon	Washington	At-Sea Hake	Foreign	Research
1932	0.3	0.1	0.4	0.0	0	0.0
1933	0.6	0.1	0.5	0.0	0	0.0
1934	0.4	0.0	2.3	0.0	0	0.0
1935	0.4	0.1	7.7	0.0	0	0.0
1936	0.2	0.2	1.6	0.0	0	0.0
1937	0.5	0.4	2.0	0.0	0	0.0
1938	0.6	0.1	5.1	0.0	0	0.0
1939	0.9	0.4	8.7	0.0	0	0.0
1940	0.9	9.1	12.2	0.0	0	0.0
1941	1.3	14.0	13.6	0.0	0	0.0
1942	0.4	26.6	18.6	0.0	0	0.0
1943	1.0	94.3	453.6	0.0	0	0.0
1944	2.8	164.5	739.3	0.0	0	0.0
1945	6.7	247.1	1887.1	0.0	0	0.0
1946	7.3	193.2	845.9	0.0	0	0.0
1947	2.6	167.2	385.3	0.0	0	0.0
1948	3.9	177.8	491.1	0.0	0	0.0
1949	2.0	472.9	409.5	0.0	0	0.0
1950	1.5	690.1	675.7	0.0	0	0.0
1951	4.3	840.1	735.1	0.0	0	0.0
1952	2.9	2030.5	305.6	0.0	0	0.0
1953	145.6	1223.5	361.6	0.0	0	0.0
1954	123.2	1837.5	538.8	0.0	0	0.0
1955	48.8	1346.4	555.6	0.0	0	0.0
1956	3.8	2563.8	548.2	0.0	0	0.0
1957	1.6	2128.1	538.5	0.0	0	0.0
1958	2.9	1564.9	530.4	0.0	0	0.0
1959	1.5	892.6	337.0	0.0	0	0.0
1960	19.6	1358.8	928.1	0.0	0	0.0
1961	1.1	2061.9	1179.8	0.0	0	0.0
1962	0.6	2584.9	1725.2	0.0	0	0.0
1963	32.5	3693.9	2006.0	0.0	0	0.0
1964	46.1	4261.6	1770.7	0.0	0	0.0
1965	34.9	5627.8	1972.1	0.0	0	0.0
1966	5.2	1591.2	1725.5	0.0	15561	0.0
1967	17.8	354.7	1861.0	0.0	12357	0.0
1968	21.9	466.4	2501.2	0.0	6639	0.0
1969	8.4	422.3	1236.0	0.0	469	0.0
1970	8.7	507.4	1293.3	0.0	441	0.0
1971	12.2	290.4	673.6	0.0	902	0.0
1972	11.4	105.3	796.5	0.0	950	0.0
1973	11.9	121.2	713.1	0.0	1773	0.0
1974	15.7	136.7	641.8	0.0	1457	0.0
1975	11.4	181.3	413.9	62.3	496	0.0
1976	17.1	663.7	521.1	31.9	239	0.0

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

Table 2: West Coast history of regulations.

tab:Regs

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

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

tab:mnmgt_perform_tables

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Total landings (mt)	Estimated total catch (mt)
2007	-	-	150	133	157
2008	-	-	150	92	132
2009	-	-	189	94	195
2010	-	-	200	97	185
2011	-	-	180	60	61
2012	-	-	183	57	58
2013	-	-	150	55	57
2014	-	-	153	54	55
2015	-	-	158	58	59
2016	-	-	164	65	65

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

tab:Index_Summary

	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	0.64	-	-	-	-	-	-
1983	-	-	8974	0.59	-	-	-	-	-	-
1985	34645	0.29	-	-	-	-	-	-	-	-
1986	-	-	2977	0.65	-	-	-	-	-	-
1989	-	-	4873	0.65	-	-	-	-	-	-
1992	-	-	3207	0.64	-	-	-	-	-	-
1995	-	-	2724	0.62	-	-	-	-	-	-
1996	-	-	-	-	7621	0.51	-	-	-	-
1997	-	-	-	-	3807	0.51	-	-	-	-
1998	-	-	4163	0.63	-	-	-	-	-	-
1999	-	-	-	-	4694	0.50	2201	0.48	-	-
2000	-	-	-	-	4243	0.53	2010	0.50	-	-
2001	-	-	1494	0.63	4187	0.49	2290	0.57	-	-
2002	-	-	-	-	-	-	1646	0.58	-	-
2003	-	-	-	-	-	-	-	-	9646	0.38
2004	-	-	2922	0.67	-	-	-	-	5284	0.41
2005	-	-	-	-	-	-	-	-	7528	0.41
2006	-	-	-	-	-	-	-	-	6010	0.43
2007	-	-	-	-	-	-	-	-	6268	0.38
2008	-	-	-	-	-	-	-	-	3867	0.41
2009	-	-	-	-	-	-	-	-	2745	0.38
2010	-	-	-	-	-	-	-	-	5404	0.36
2011	-	-	-	-	-	-	-	-	7533	0.36
2012	-	-	-	-	-	-	-	-	9289	0.36
2013	-	-	-	-	-	-	-	-	8093	0.36
2014	-	-	-	-	-	-	-	-	4914	0.36
2015	-	-	-	-	-	-	-	-	5752	0.33
2016	-	-	-	-	-	-	-	-	11770	0.38

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

tab:POP_Ages

Year	Tows	Fish	Sample Size
1985	29	1635	70

Table 14: 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 15: Summary of the commercial catch-per-unit effort time-series used in the stock assessment.

tab:CPUE_Summary

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

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

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

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

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

tab:Comm_Ages

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

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

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

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

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

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

tab:Age_Error

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

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

tab:Model_setup

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

Table 22: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
NatM_p_1_Fem_GP_1	0.05	-5	(0.02, 0.1)			Log_Norm (-2.92, 0.44)
L_at_Amin_Fem_GP_1	20.83	3	(15, 25)	OK	0.14	None
L_at_Amax_Fem_GP_1	41.40	2	(35, 45)	OK	0.13	None
VonBert_K_Fem_GP_1	0.17	3	(0.1, 0.4)	OK	0.00	None
CV_young_Fem_GP_1	1.32	5	(0.03, 5)	OK	0.06	None
CV_old_Fem_GP_1	2.69	5	(0.03, 5)	OK	0.11	None
Wtlen_1_Fem	0.00	-99	(0, 3)			None
Wtlen_2_Fem	3.09	-99	(2, 4)			None
Mat50%_Fem	32.10	-99	(20, 40)			None
Mat_slope_Fem	-1.00	-99	(-2, 4)			None
Eggs_scalar_Fem	0.00	-99	(0, 6)			None
Eggs_exp_len_Fem	4.98	-99	(-3, 5)			None
NatM_p_1_Mal_GP_1	0.05	-5	(0, 0.3)			Normal (0.05, 0.1)
L_at_Amin_Mal_GP_1	20.83	-2	(6, 68)			None
L_at_Amax_Mal_GP_1	38.77	2	(13, 122)	OK	0.00	None
VonBert_K_Mal_GP_1	0.20	3	(0.04, 1.09)	OK	0.03	None
CV_young_Mal_GP_1	1.32	-5	(0, 742.07)			None
CV_old_Mal_GP_1	2.38	5	(0, 742.07)	OK	0.06	None
Wtlen_1_Mal	0.00	-99	(0, 3)			None
Wtlen_2_Mal	3.08	-99	(2, 4)			None
CohortGrowDev	1.00	-99	(0, 2)			None
FracFemale_GP_1	0.50	-99	(0.01, 0.99)			None
SR_LN(R0)	9.32	1	(5, 20)	OK	0.14	None
SR_BH_steep	0.50	-2	(0.2, 1)			Full_Beta (0.72, 0.15)
SR_sigmaR	0.70	-6	(0.5, 1.2)			None
SR_regime	0.00	-99	(-5, 5)			None

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Table 22: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SR_autocorr	0.00	-99	(0, 2)			None
Early_InitAge_18	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_17	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_16	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_15	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_14	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_13	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_12	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_11	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_10	0.01	3	(-6, 6)	act	0.70	dev (NA, NA)
Early_InitAge_9	0.02	3	(-6, 6)	act	0.71	dev (NA, NA)
Early_InitAge_8	0.02	3	(-6, 6)	act	0.71	dev (NA, NA)
Early_InitAge_7	0.02	3	(-6, 6)	act	0.71	dev (NA, NA)
Early_InitAge_6	0.02	3	(-6, 6)	act	0.71	dev (NA, NA)
Early_InitAge_5	0.02	3	(-6, 6)	act	0.71	dev (NA, NA)
Early_InitAge_4	0.02	3	(-6, 6)	act	0.71	dev (NA, NA)
Early_InitAge_3	0.02	3	(-6, 6)	act	0.71	dev (NA, NA)
Early_InitAge_2	0.02	3	(-6, 6)	act	0.71	dev (NA, NA)
Early_InitAge_1	0.02	3	(-6, 6)	act	0.71	dev (NA, NA)
LnQ_base_Fishery(1)	-12.38	-1	(-15, 15)			None
LnQ_base_POP(4)	-0.02	-1	(-15, 15)			None
LnQ_base_Triennial(5)	-1.74	-1	(-15, 15)			None
Q_extraSD_Triennial(5)	0.38	2	(0, 0.5)	OK	0.15	None
LnQ_base_AFSCSlope(6)	-2.35	-1	(-15, 15)			None
LnQ_base_NWFSCSlope(7)	-3.01	-1	(-15, 15)			None
LnQ_base_NWFSCcombo(8)	-2.53	-1	(-15, 15)			None

Continued on next page

Table 22: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Q_extraSD_NWFSCcombo(8)	0.04	2	(0, 0.5)	OK	0.07	None
SizeSel_P1_Fishery(1)	37.22	1	(20, 45)	OK	0.18	None
SizeSel_P2_Fishery(1)	-5.00	-2	(-6, 4)			None
SizeSel_P3_Fishery(1)	3.44	3	(-1, 9)	OK	0.10	None
SizeSel_P4_Fishery(1)	-1.65	-3	(-9, 9)			None
SizeSel_P5_Fishery(1)	-3.50	-4	(-5, 9)			None
SizeSel_P6_Fishery(1)	0.90	2	(-5, 9)	OK	0.27	None
Retain_P1_Fishery(1)	28.37	1	(15, 45)	OK	0.27	None
Retain_P2_Fishery(1)	1.03	1	(0.1, 10)	OK	0.10	None
Retain_P3_Fishery(1)	6.61	1	(-10, 10)	OK	0.80	None
Retain_P4_Fishery(1)	0.00	-3	(0, 0)			None
SizeSel_P1_ASHOP(2)	49.50	1	(20, 49.5)	HI	0.00	None
SizeSel_P2_ASHOP(2)	-5.00	-2	(-6, 4)			None
SizeSel_P3_ASHOP(2)	4.95	3	(-1, 9)	OK	0.14	None
SizeSel_P4_ASHOP(2)	1.00	-3	(-1, 9)			None
SizeSel_P5_ASHOP(2)	-4.35	-4	(-9, 9)			None
SizeSel_P6_ASHOP(2)	999.00	-2	(-5, 999)			None
SizeSel_P1_POP(4)	24.61	1	(20, 70)	OK	1.94	None
SizeSel_P2_POP(4)	12.17	3	(0.001, 50)	OK	3.53	None
SizeSel_P1_Triennial(5)	27.65	1	(20, 45)	OK	3.57	None
SizeSel_P2_Triennial(5)	-5.00	-2	(-6, 4)			None
SizeSel_P3_Triennial(5)	5.50	-3	(-1, 9)			None
SizeSel_P4_Triennial(5)	3.24	3	(-1, 9)	OK	1.69	None
SizeSel_P5_Triennial(5)	-5.00	-4	(-5, 9)			None
SizeSel_P6_Triennial(5)	-0.68	2	(-5, 9)	OK	0.45	None
SizeSel_P1_AFSCSlope(6)	22.06	1	(20, 45)	OK	4.95	None

Continued on next page

Table 22: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SizeSel_P2_AFSCSlope(6)	-5.00	-2	(-6, 4)			None
SizeSel_P3_AFSCSlope(6)	1.43	3	(-1, 9)	OK	4.38	None
SizeSel_P4_AFSCSlope(6)	1.00	-3	(-1, 9)			None
SizeSel_P5_AFSCSlope(6)	-9.00	-4	(-9, 9)			None
SizeSel_P6_AFSCSlope(6)	999.00	-2	(-5, 999)			None
SizeSel_P1_NWFSCSlope(7)	36.24	1	(20, 45)	OK	1.63	None
SizeSel_P2_NWFSCSlope(7)	-5.00	-2	(-6, 4)			None
SizeSel_P3_NWFSCSlope(7)	1.85	3	(-1, 9)	OK	1.26	None
SizeSel_P4_NWFSCSlope(7)	1.00	-3	(-1, 9)			None
SizeSel_P5_NWFSCSlope(7)	-9.00	-4	(-9, 9)			None
SizeSel_P6_NWFSCSlope(7)	999.00	-2	(-5, 999)			None
SizeSel_P1_NWFSCcombo(8)	21.47	1	(18, 49.5)	OK	4.01	None
SizeSel_P2_NWFSCcombo(8)	-5.00	-2	(-6, 4)			None
SizeSel_P3_NWFSCcombo(8)	2.89	3	(-1, 9)	OK	2.06	None
SizeSel_P4_NWFSCcombo(8)	1.00	-3	(-1, 9)			None
SizeSel_P5_NWFSCcombo(8)	-9.00	-4	(-9, 9)			None
SizeSel_P6_NWFSCcombo(8)	999.00	-2	(-5, 999)			None
Retain_P3_Fishery(1)_BLK1repl_1918	3.91	4	(-10, 10)	OK	0.07	None
Retain_P3_Fishery(1)_BLK1repl_1992	2.29	4	(-10, 10)	OK	0.36	None
Retain_P3_Fishery(1)_BLK1repl_2002	1.74	4	(-10, 10)	OK	0.12	None
Retain_P3_Fishery(1)_BLK1repl_2008	0.63	4	(-10, 10)	OK	0.28	None
Retain_P3_Fishery(1)_BLK1repl_2009	-0.06	4	(-10, 10)	OK	0.23	None

tab:model_params

Table 23: Likelihood components from the base model

tab:like

Likelihood Component	Value
Total	1711.21
Survey	-26.74
Discard	-33.92
Length-frequency data	262.73
Age-frequency data	1493.8
Recruitment	14.34
Forecast Recruitment	0
Parameter Priors	1

Table 24: 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 26: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 re-cruits	Estimated total catch (mt)	1-SPR	Exp. rate
1918	133147	6241	132439	1.00	11411	0	0	0
1919	133219	6244	132510	1.00	11421	1	0	0
1920	133293	6247	132584	1.00	11431	0	0	0
1921	133369	6250	132659	1.00	11441	0	0	0
1922	133447	6254	132736	1.00	11452	0	0	0
1923	133527	6257	132815	1.00	11462	0	0	0
1924	133608	6261	132896	1.00	11473	0	0	0
1925	133691	6264	132979	1.00	11484	1	0	0
1926	133776	6268	133063	1.00	11494	1	0	0
1927	133863	6272	133149	1.00	11505	1	0	0
1928	133950	6275	133236	1.01	11515	1	0	0
1929	134040	6279	133325	1.01	11525	1	0	0
1930	134132	6283	133416	1.01	11535	1	0	0
1931	134225	6287	133508	1.01	11545	1	0	0
1932	134320	6292	133602	1.01	11555	1	0	0
1933	134416	6296	133698	1.01	11567	1	0	0
1934	134514	6300	133795	1.01	11580	1	0	0
1935	134611	6304	133892	1.01	11598	3	0	0
1936	134704	6309	133984	1.01	11624	8	0	0
1937	134806	6313	134084	1.01	11662	2	0	0
1938	134909	6318	134186	1.01	11715	3	0	0
1939	135014	6322	134288	1.01	11789	6	0	0
1940	135121	6326	134391	1.01	12286	10	0.005	0
1941	135231	6330	134490	1.01	12407	23	0.005	0
1942	135361	6334	134595	1.01	12542	30	0.01	0
1943	135519	6336	134745	1.02	12682	47	0.095	0
1944	135210	6315	134428	1.01	12808	563	0.15	0.004
1945	134605	6276	133815	1.01	12920	930	0.305	0.007
1946	132823	6177	132025	0.99	13003	2196	0.175	0.017
1947	132274	6136	131469	0.98	13160	1073	0.1	0.008
1948	132315	6124	131504	0.98	13425	569	0.12	0.004
1949	132313	6110	131490	0.98	13837	690	0.15	0.005
1950	132180	6090	131337	0.98	14441	907	0.22	0.007
1951	131657	6050	130786	0.97	15190	1403	0.245	0.011
1952	131055	6003	130143	0.96	15844	1621	0.335	0.012
1953	129847	5923	128893	0.95	15862	2400	0.27	0.019
1954	129467	5877	128485	0.94	15004	1777	0.355	0.014
1955	128488	5799	127520	0.93	13509	2566	0.3	0.02

Table 26: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 re-cruits	Estimated total catch (mt)	1-SPR	Exp. rate
1956	128218	5755	127314	0.92	11848	2003	0.415	0.016
1957	126803	5662	125995	0.91	10429	3201	0.38	0.025
1958	125810	5601	125100	0.90	9397	2741	0.32	0.022
1959	125258	5580	124628	0.89	8851	2156	0.21	0.017
1960	125366	5611	124790	0.90	8950	1264	0.34	0.01
1961	124098	5593	123544	0.90	9887	2368	0.43	0.019
1962	121633	5526	121059	0.89	11058	3327	0.515	0.027
1963	117915	5396	117285	0.86	9986	4421	0.605	0.038
1964	112683	5181	112019	0.83	7853	5877	0.635	0.052
1965	107095	4933	106513	0.79	6700	6232	0.715	0.059
1966	99885	4595	99418	0.74	6169	7829	0.905	0.079
1967	81569	3710	81165	0.59	5628	18969	0.9	0.234
1968	67798	3037	67425	0.49	5795	14651	0.87	0.217
1969	59123	2616	58765	0.42	8542	9712	0.53	0.165
1970	58053	2570	57632	0.41	15302	2183	0.55	0.038
1971	56948	2522	56331	0.40	5929	2300	0.5	0.041
1972	56450	2490	55657	0.40	4219	1905	0.5	0.034
1973	56148	2453	55807	0.39	4499	1888	0.6	0.034
1974	54941	2374	54675	0.38	4379	2643	0.565	0.048
1975	53985	2311	53704	0.37	5931	2275	0.385	0.042
1976	53996	2313	53703	0.37	4139	1183	0.45	0.022
1977	53546	2320	53201	0.37	6292	1507	0.4	0.028
1978	53224	2342	52937	0.38	3988	1263	0.525	0.024
1979	52047	2317	51692	0.37	5103	1999	0.45	0.039
1980	51274	2297	51009	0.37	4865	1507	0.49	0.03
1981	50206	2257	49892	0.36	5509	1724	0.435	0.035
1982	49458	2228	49140	0.36	7680	1381	0.37	0.028
1983	49036	2212	48659	0.35	7382	1057	0.49	0.022
1984	48117	2167	47649	0.35	6030	1625	0.505	0.034
1985	47304	2117	46863	0.34	7781	1659	0.465	0.035
1986	46832	2077	46436	0.33	5047	1412	0.465	0.03
1987	46491	2038	46048	0.33	6590	1375	0.41	0.03
1988	46512	2017	46167	0.32	9078	1106	0.47	0.024
1989	46301	1991	45853	0.32	8294	1378	0.49	0.03
1990	46149	1970	45586	0.32	13222	1469	0.415	0.032
1991	46551	1969	45973	0.32	6064	1124	0.49	0.024
1992	46782	1956	46087	0.31	2702	1479	0.51	0.032
1993	47087	1936	46766	0.31	2691	1567	0.48	0.034

Table 26: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 re-cruits	Estimated total catch (mt)	1-SPR	Exp. rate
1994	47371	1929	47183	0.31	10792	1418	0.425	0.03
1995	47740	1941	47446	0.31	8421	1180	0.365	0.025
1996	48295	1978	47676	0.32	3172	952	0.34	0.02
1997	48997	2033	48559	0.33	3407	880	0.285	0.018
1998	49715	2093	49515	0.34	3080	716	0.28	0.014
1999	50211	2135	49963	0.34	19708	721	0.23	0.014
2000	50852	2170	50370	0.35	27597	563	0.075	0.011
2001	52231	2226	50926	0.36	7747	160	0.125	0.003
2002	54263	2282	52880	0.37	4799	293	0.08	0.006
2003	56879	2335	56452	0.37	2473	178	0.07	0.003
2004	59309	2374	59039	0.38	6500	155	0.065	0.003
2005	61523	2416	61311	0.39	3416	146	0.035	0.002
2006	63490	2504	63135	0.40	4109	76	0.035	0.001
2007	65143	2649	64920	0.42	3993	84	0.06	0.001
2008	66625	2806	66049	0.45	134138	157	0.05	0.002
2009	68934	2934	66877	0.47	5240	132	0.065	0.002
2010	73536	3022	67298	0.48	8428	195	0.06	0.003
2011	81599	3084	81202	0.49	16150	185	0.02	0.002
2012	88806	3132	88190	0.50	2182	61	0.02	0.001
2013	96082	3177	95247	0.51	26321	58	0.02	0.001
2014	103032	3325	102557	0.53	4263	57	0.015	0.001
2015	109267	3720	107978	0.60	9510	55	0.015	0.001
2016	115044	4226	114692	0.68	9984	59	0.015	0.001
2017	119655	4663	119055	0.75	10302	65	0.055	0.001
2018	123267	4996	122641	0.80	10517	-	-	-
2019	126112	5261	125467	0.84	10675	-	-	-
2020	124373	5306	123717	0.85	10700	-	-	-
2021	122166	5309	121503	0.85	10702	-	-	-
2022	119668	5267	119003	0.84	10678	-	-	-
2023	117011	5194	116347	0.83	10636	-	-	-
2024	114297	5103	113635	0.82	10582	-	-	-
2025	111595	5001	110935	0.80	10520	-	-	-
2026	108950	4894	108294	0.78	10453	-	-	-
2027	106393	4784	105741	0.77	10382	-	-	-
2028	103939	4674	103291	0.75	10309	-	-	-

tab:Timeseries_mod1

Table 25: Sensitivity of the base model

tab:Sensitivity_model1

Label	Base	Harmonic weights	h fixed at prior	Estimate M	Split Trien-nial	Old Ma-turity	Old Fe-cundity	Canadian Data	State Data
Total Likelihood	1710.07	3577.28	1711.64	1710.07	1708.10	1711.22	1710.23	1895.79	1868.28
Survey Likelihood	-26.79	-27.64	-26.10	-26.79	-28.99	-26.75	-26.64	-26.73	-27.74
Discard Likelihood	-33.87	-16.74	-34.03	-33.88	-33.91	-33.92	-33.89	-31.88	-33.89
Length Likelihood	261.73	1502.82	263.24	261.78	261.29	262.72	261.80	396.20	346.97
Age Likelihood	1493.88	2094.09	1493.50	1493.87	1494.36	1493.83	1493.84	1538.57	1565.31
Recruitment Likelihood	14.13	23.75	14.91	14.10	14.34	14.33	14.12	18.63	16.75
Forecast Recruitment Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parameter Priors Likelihood	1.00	1.00	0.13	1.00	1.00	1.00	1.00	1.00	0.88
Parameter Deviation Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
log(R0)	9.32	9.17	9.38	9.35	9.36	9.32	9.33	9.19	9.20
SB Virgin	6271.59	5536.41	6581.18	6336.66	6476.77	6104.39	15512600.00	5396.25	5525.96
SB 2017	4710.12	3599.86	6619.56	4886.55	5074.80	4715.28	15243900.00	2953.81	3649.91
Depletion 2017	0.75	0.65	1.01	0.77	0.78	0.77	0.98	0.55	0.66
Total Yield	1682.99	1453.65	2371.62	1720.74	1744.77	1670.84	1861.28	1475.89	1485.95
Steepness	0.50	0.50	0.72	0.50	0.50	0.50	0.50	0.50	0.50
Natural Mortality - Female	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Length at Amin - Female	20.83	20.92	20.84	20.83	20.83	20.83	20.83	20.70	20.83
Length at Amax - Female	41.45	41.66	41.41	41.45	41.41	41.40	41.45	41.27	41.44
Von Bert. k - Female	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
SD young - Female	1.31	1.37	1.32	1.31	1.32	1.32	1.31	1.30	1.31
SD old - Female	2.69	2.83	2.69	2.69	2.69	2.69	2.69	2.82	2.69
Natural Mortality - Male	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Length at Amin - Male	20.83	20.92	20.84	20.83	20.83	20.83	20.83	20.70	20.83
Length at Amax - Male	38.77	38.82	38.78	38.77	38.78	38.77	38.77	38.55	38.84
Von Bert. k - Male	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.19
SD young - Male	1.31	1.37	1.32	1.31	1.32	1.32	1.31	1.30	1.31
SD old - Male	2.43	2.70	2.38	2.43	2.38	2.38	2.43	2.37	2.45

Table 27: Projection of potential OFL, spawning biomass, and depletion for the base case model.

tab:Forecast_mod1

Year	OFL (mt)	ACL (mt)	Age 3+ biomass (mt)	Spawning Output	Depletion
2017	4040	281	119055	4663	0.75
2018	4285	281	122641	4996	0.80
2019	4440	4245	125467	5261	0.85
2020	4390	4197	123717	5306	0.85
2021	4305	4116	121503	5309	0.85
2022	4200	4015	119003	5267	0.85
2023	4085	3906	116347	5194	0.84
2024	3969	3795	113635	5103	0.82
2025	3858	3688	110935	5001	0.80
2026	3753	3588	108294	4894	0.79
2027	3655	3494	105741	4784	0.77
2028	3562	3405	103291	4674	0.75

9 Figures

figures

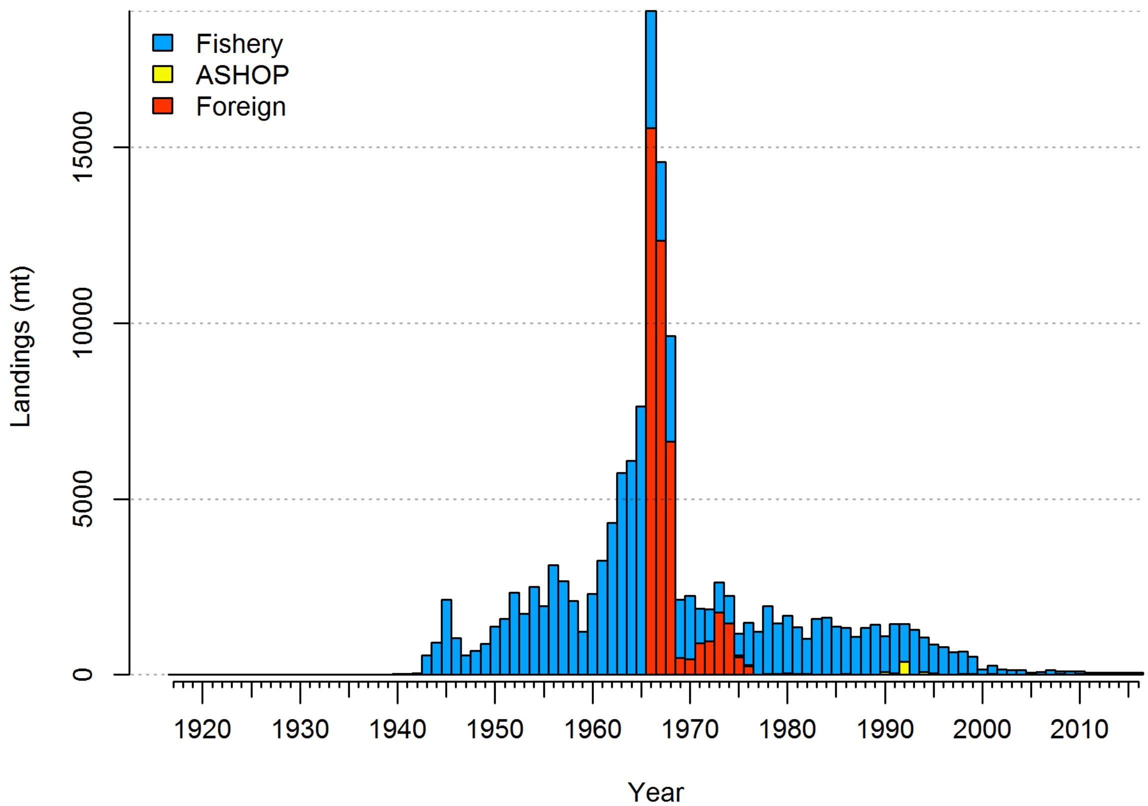

Figure 1: Total catches Pacific ocean perch through 2016. fig:Catch

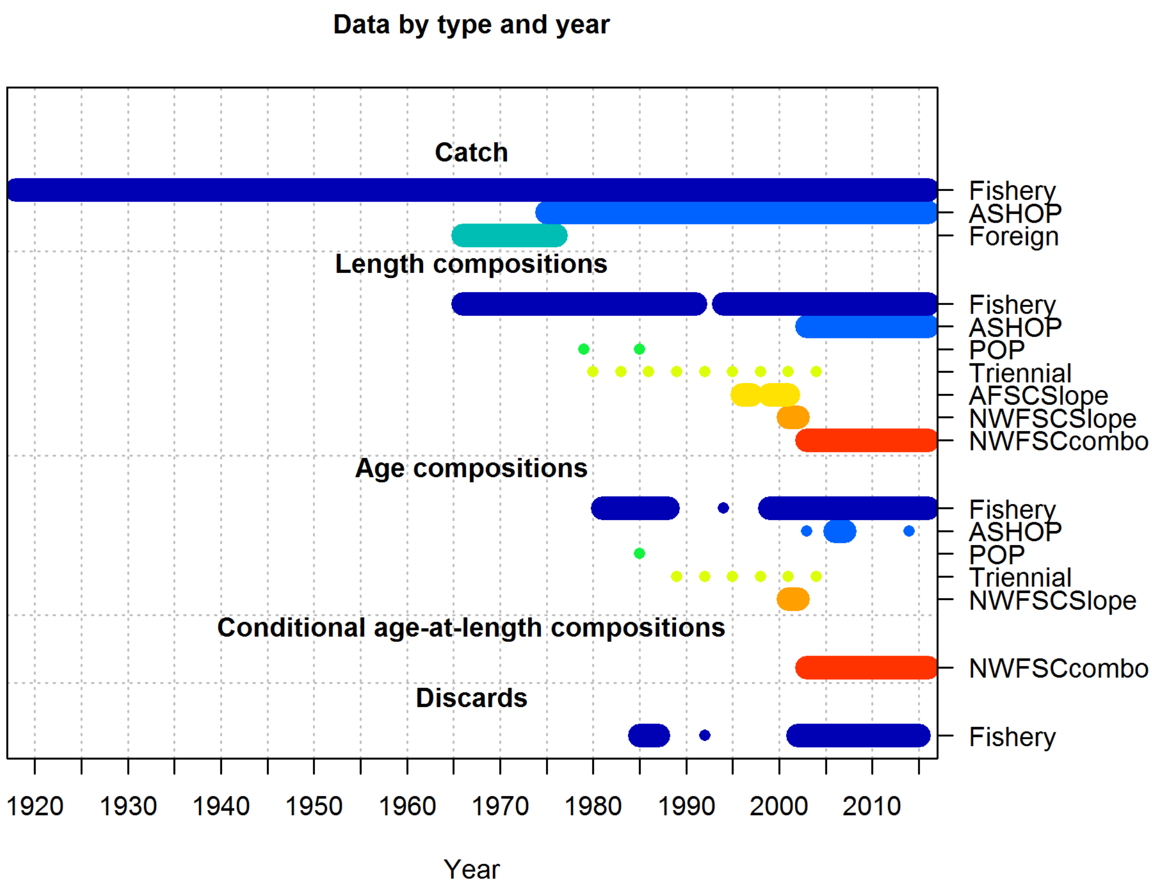

Figure 2: Summary of data sources used in the Base model. fig:data_plot

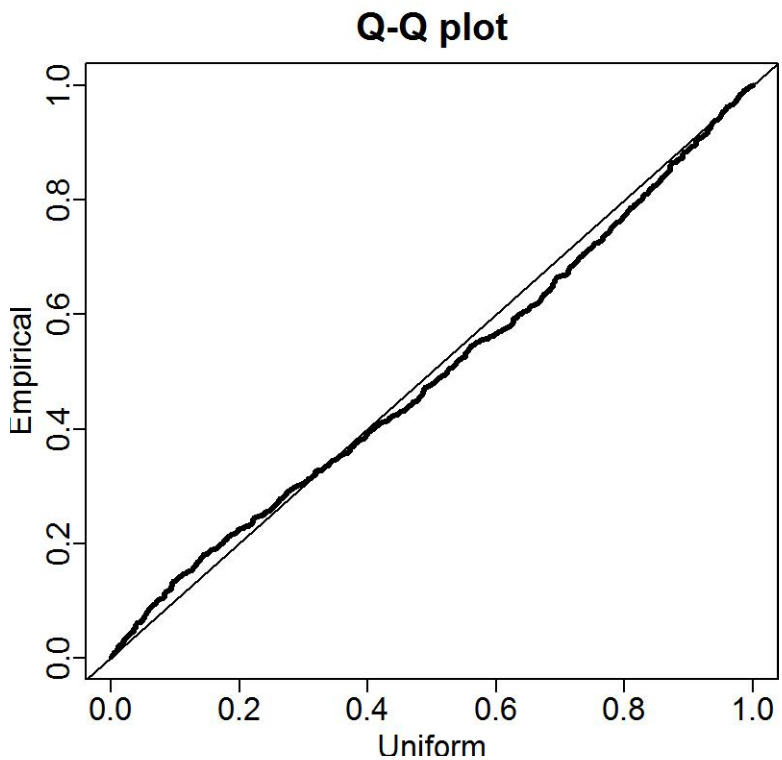

Figure 3: Q-Q plots for the VAST lognormal distribution for the NWFSC shelf-slope survey. fig:nw_qq

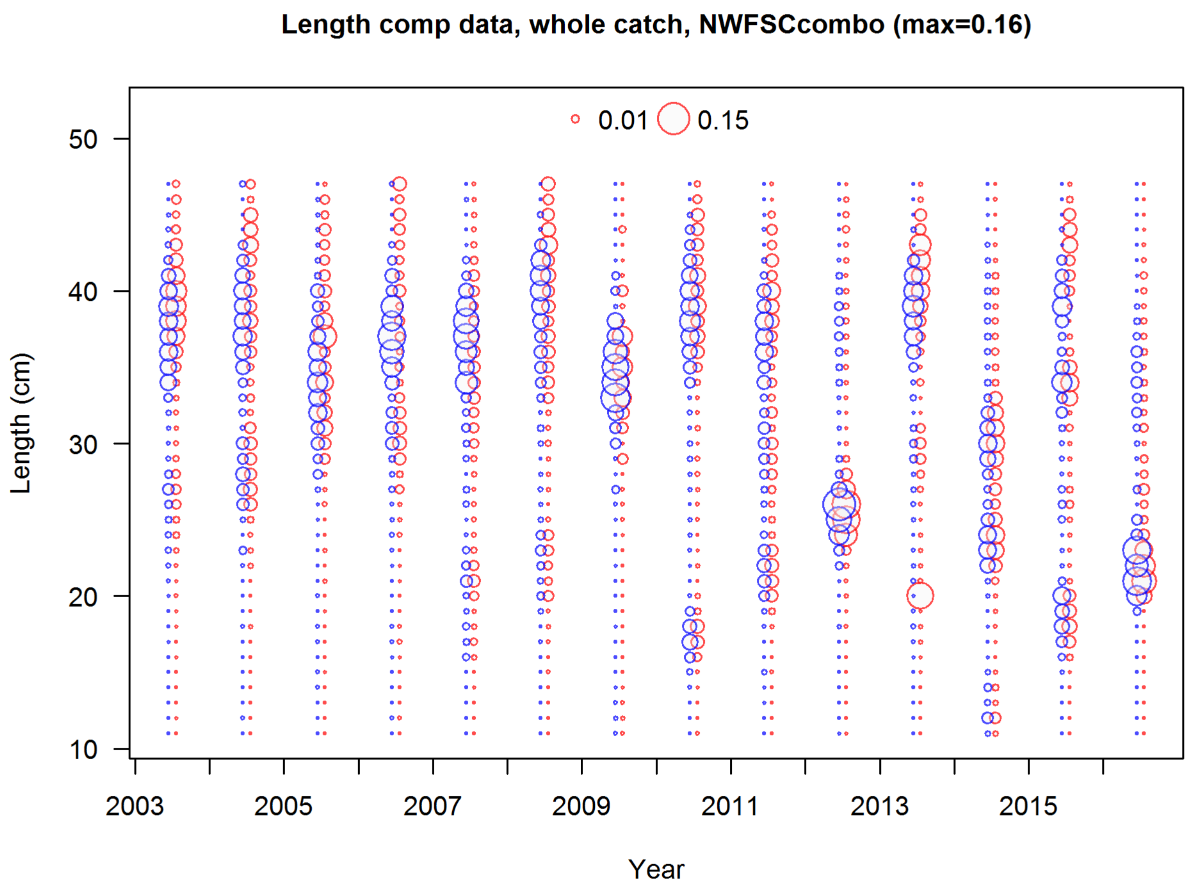

Figure 4: NWFSC shelf-slope survey length frequency distributions for Pacific ocean perch. fig:nw_Length

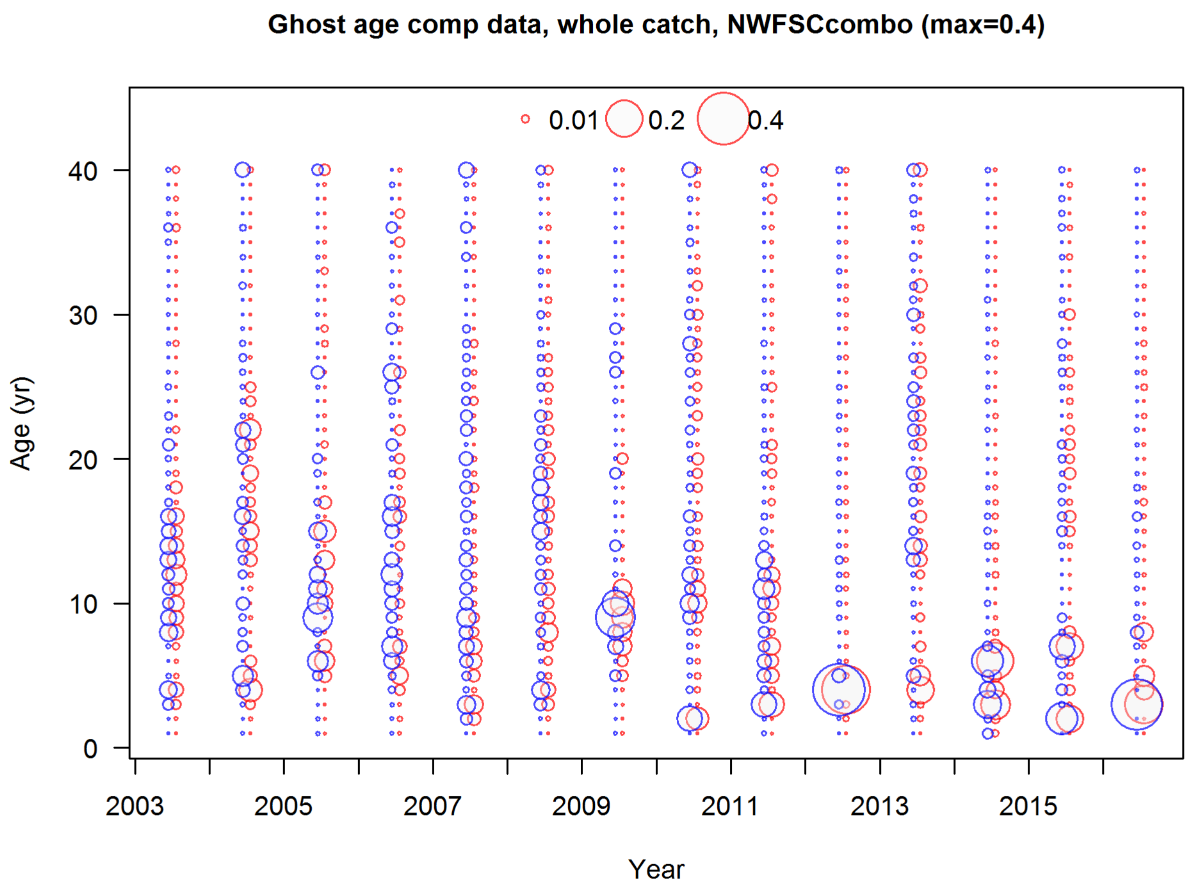

Figure 5: NWFSC shelf-slope survey age frequency distributions for Pacific ocean perch. fig:nw_Age

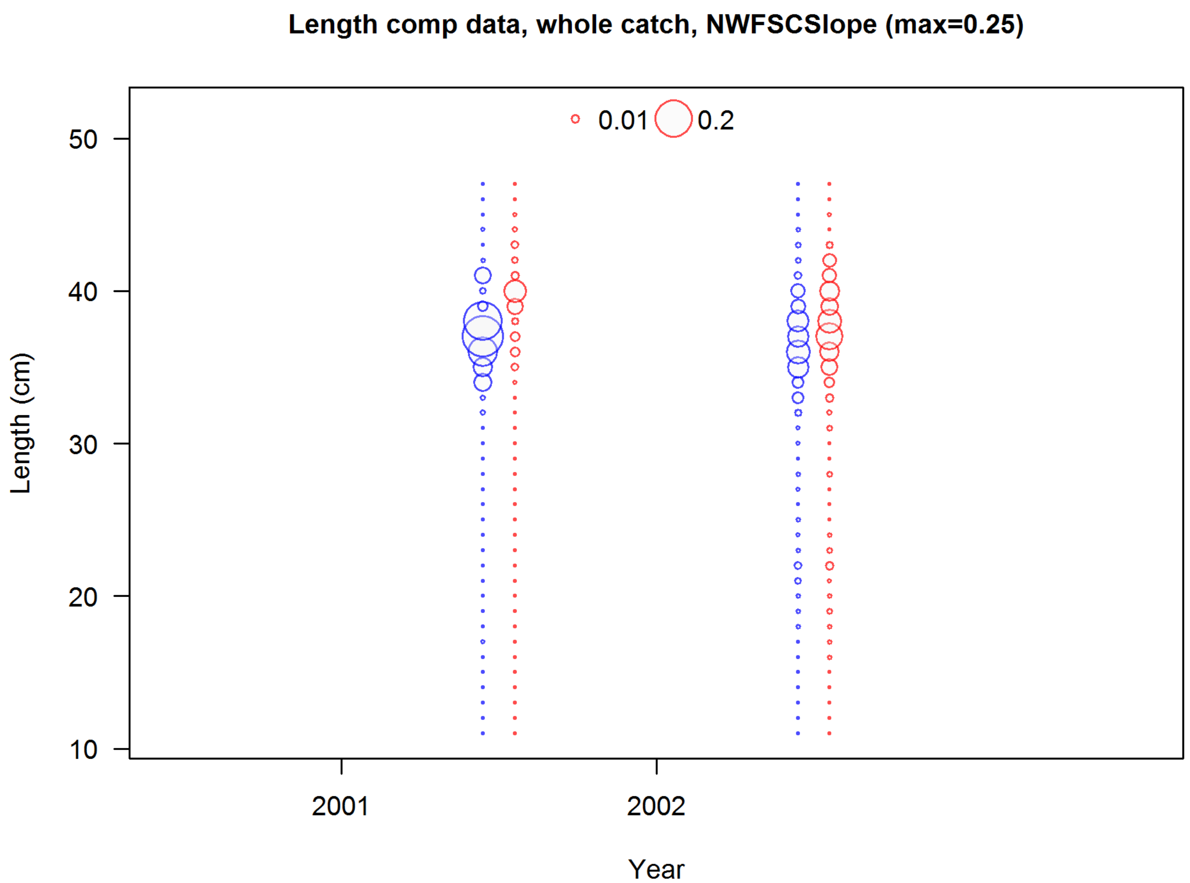

Figure 6: NWFSC slope survey length frequency distributions for Pacific ocean perch. fig:nw_slope_Le

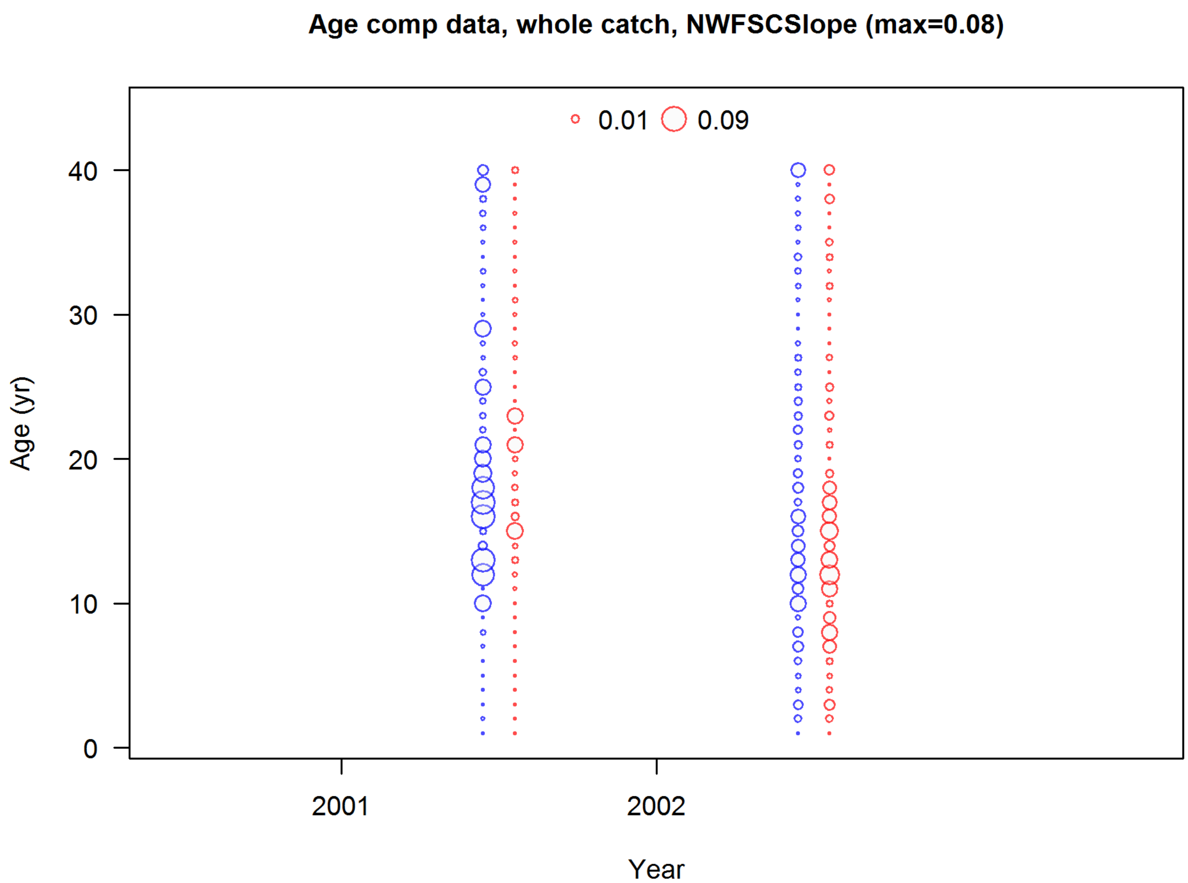

Figure 7: NWFSC slope survey age frequency distributions for Pacific ocean perch. fig:nw_slope_Age

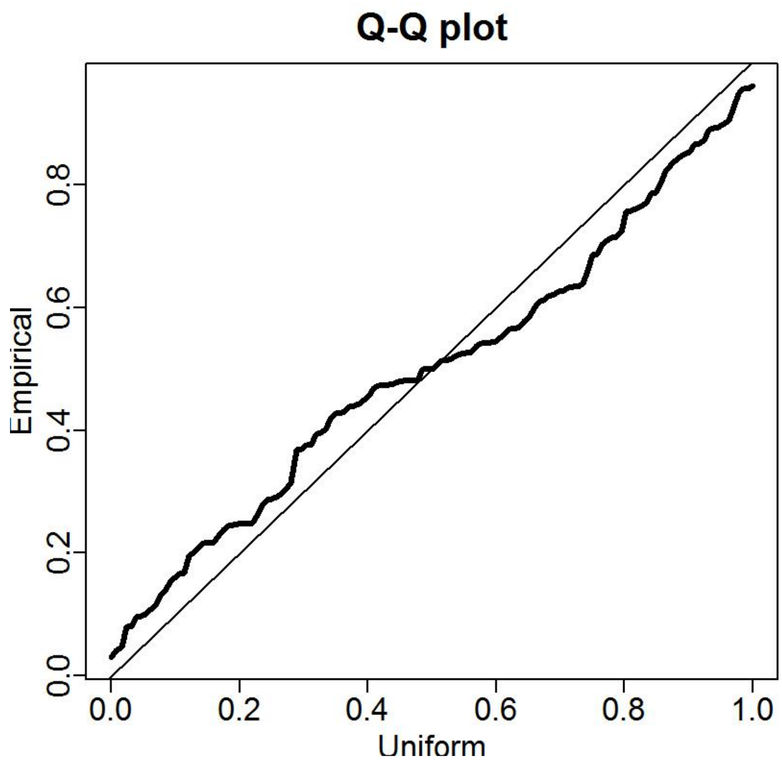

Figure 8: Q-Q plots for the VAST lognormal distribution for the AFSC slope survey. fig:afsc_qq

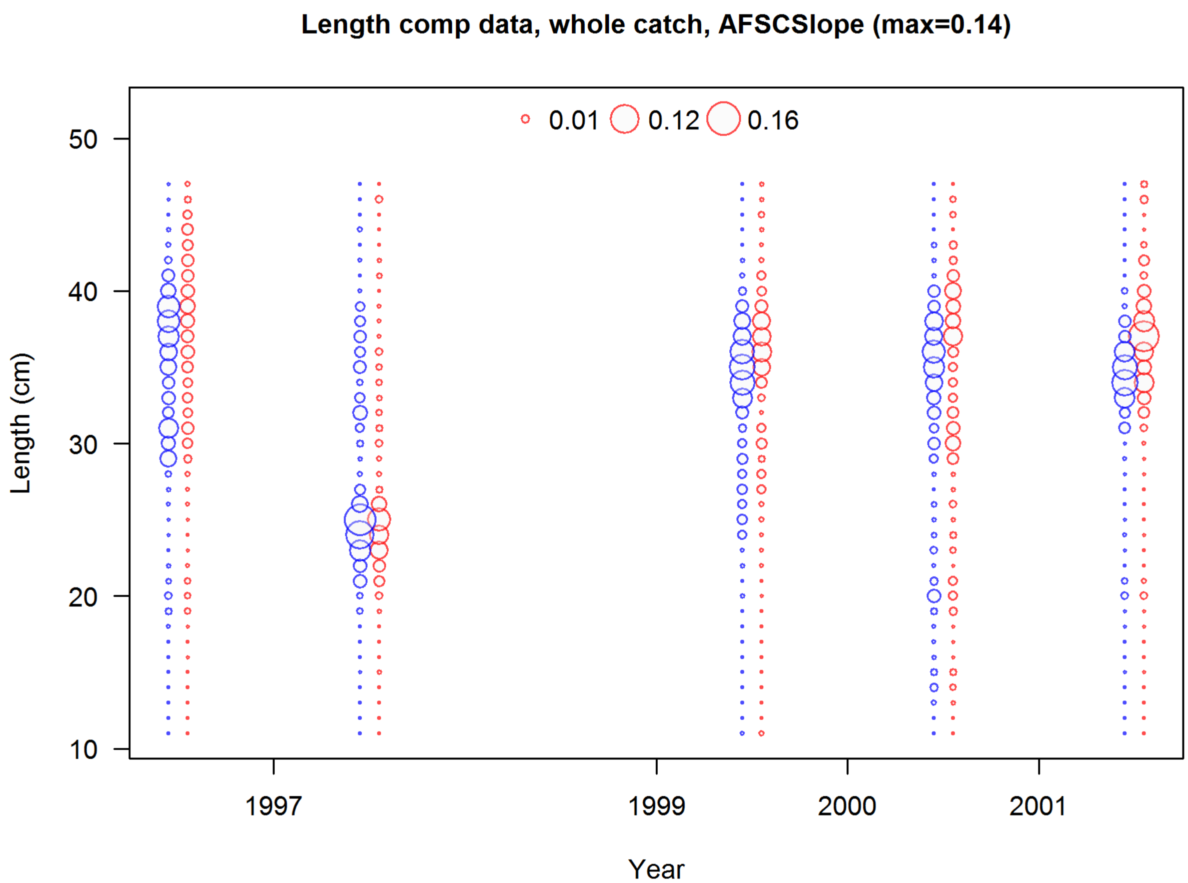

Figure 9: AFSC slope survey length frequency distributions for Pacific ocean perch. fig:afsc_Length

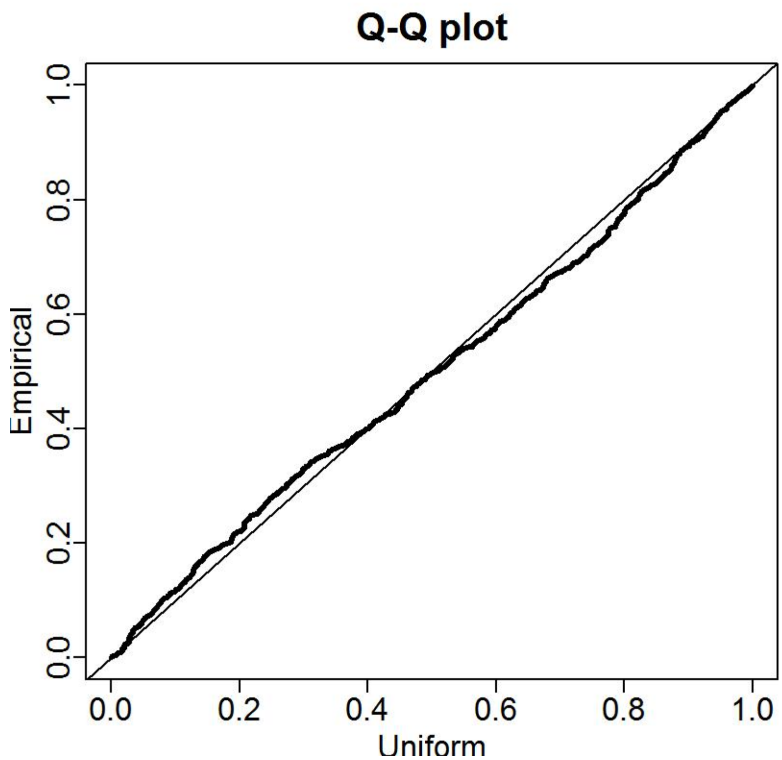

Figure 10: Q-Q plots for the VAST lognormal distribution for the Triennial survey. fig:tri_qq

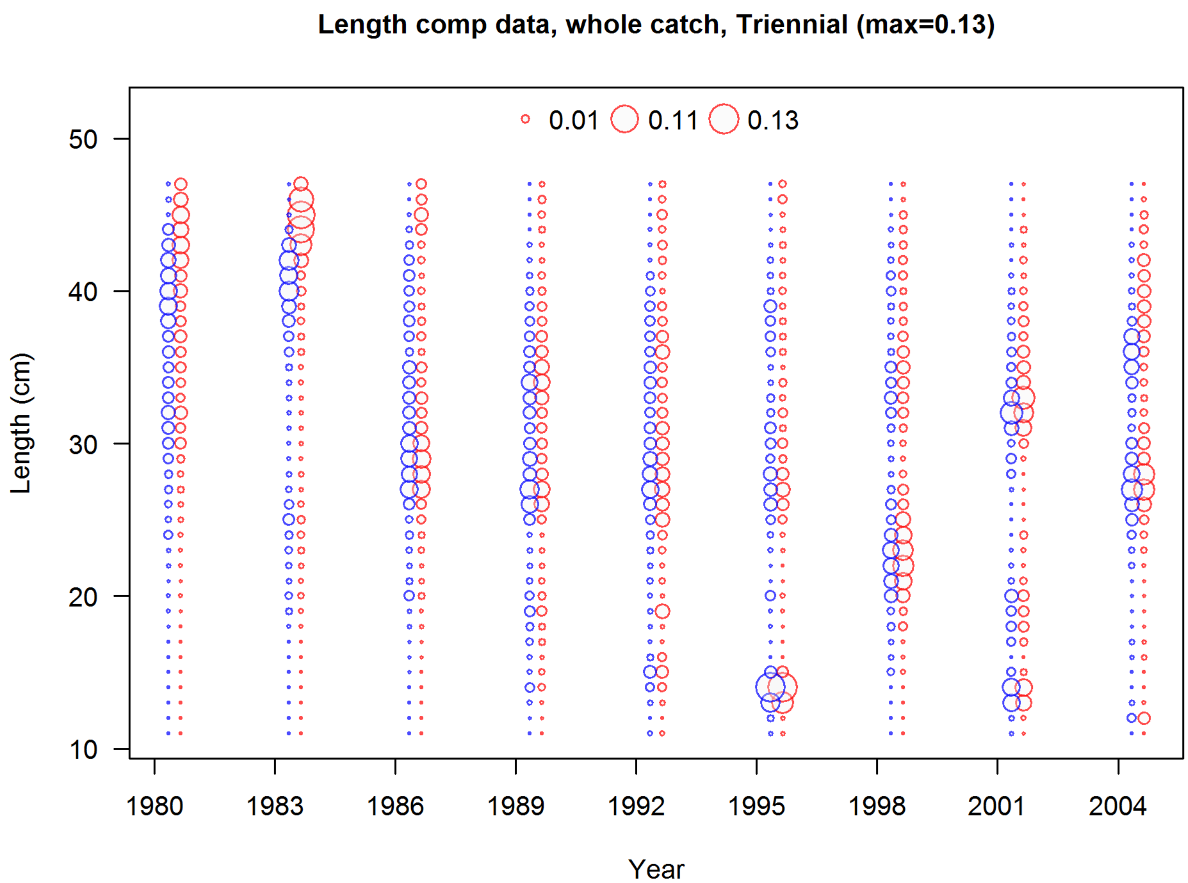

Figure 11: Triennial survey length frequency distributions for Pacific ocean perch. fig:Tri_Length

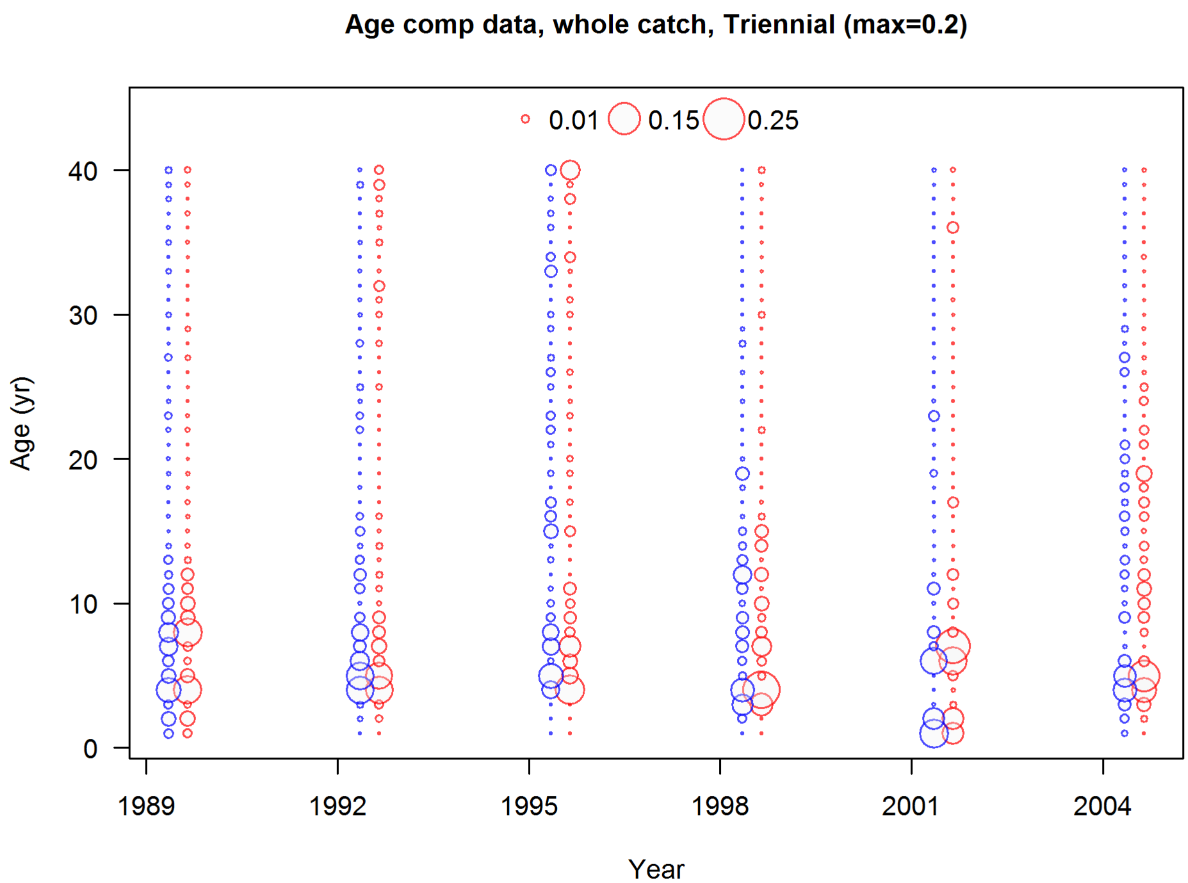

Figure 12: Triennial survey age frequency distributions for Pacific ocean perch. fig:Tri_Age

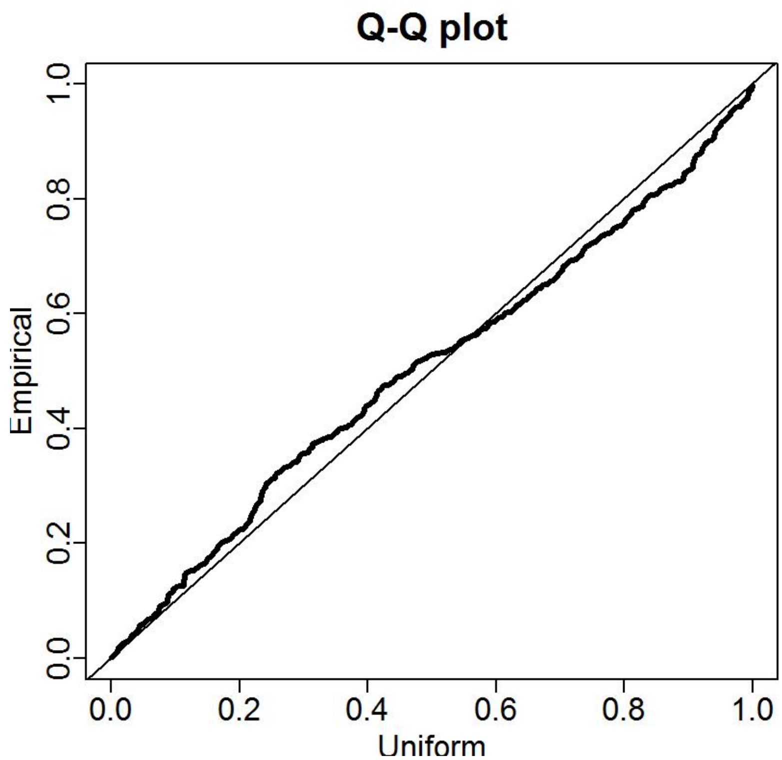

Figure 13: Q-Q plots for the VAST lognormal distribution for the Pacific ocean perch survey.
fig:pop_qq

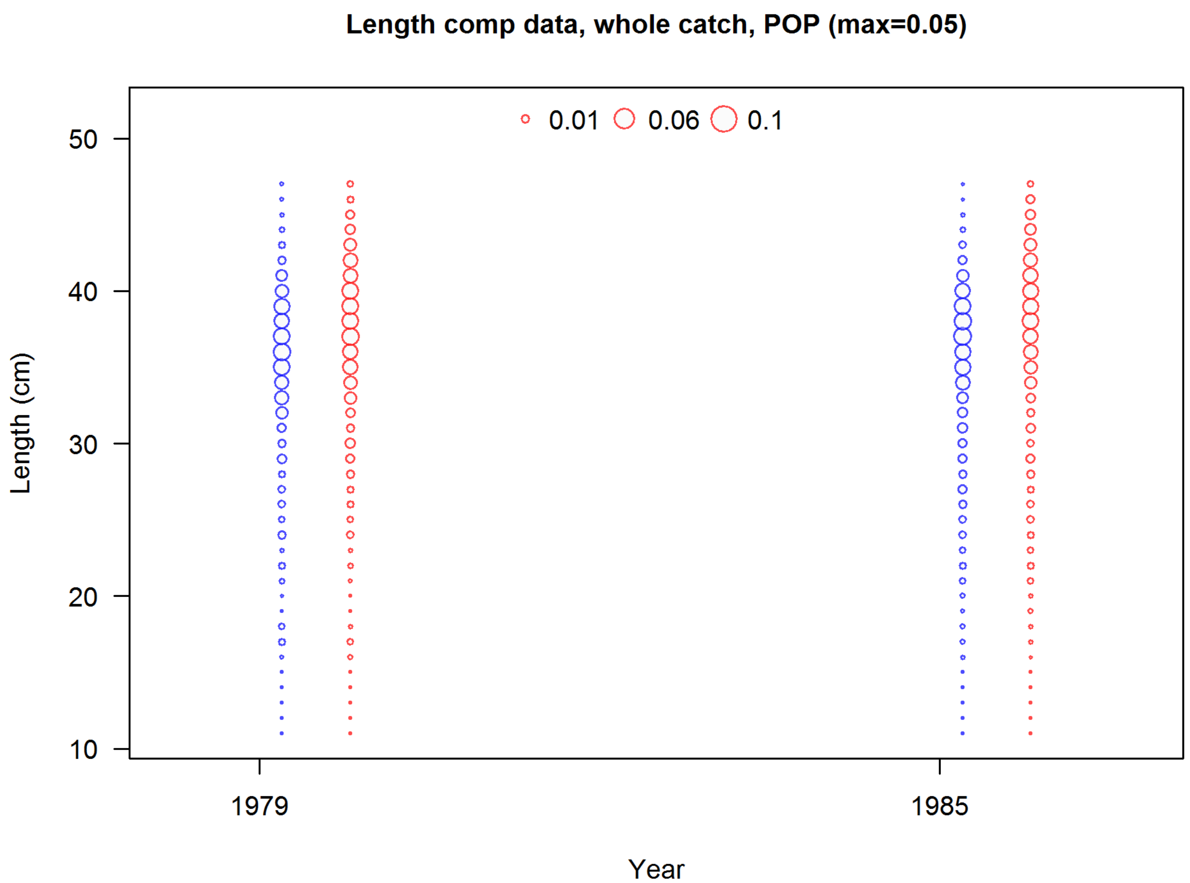

Figure 14: Pacific ocean perch survey length frequency distributions for Pacific ocean perch. fig:POP_Lengt

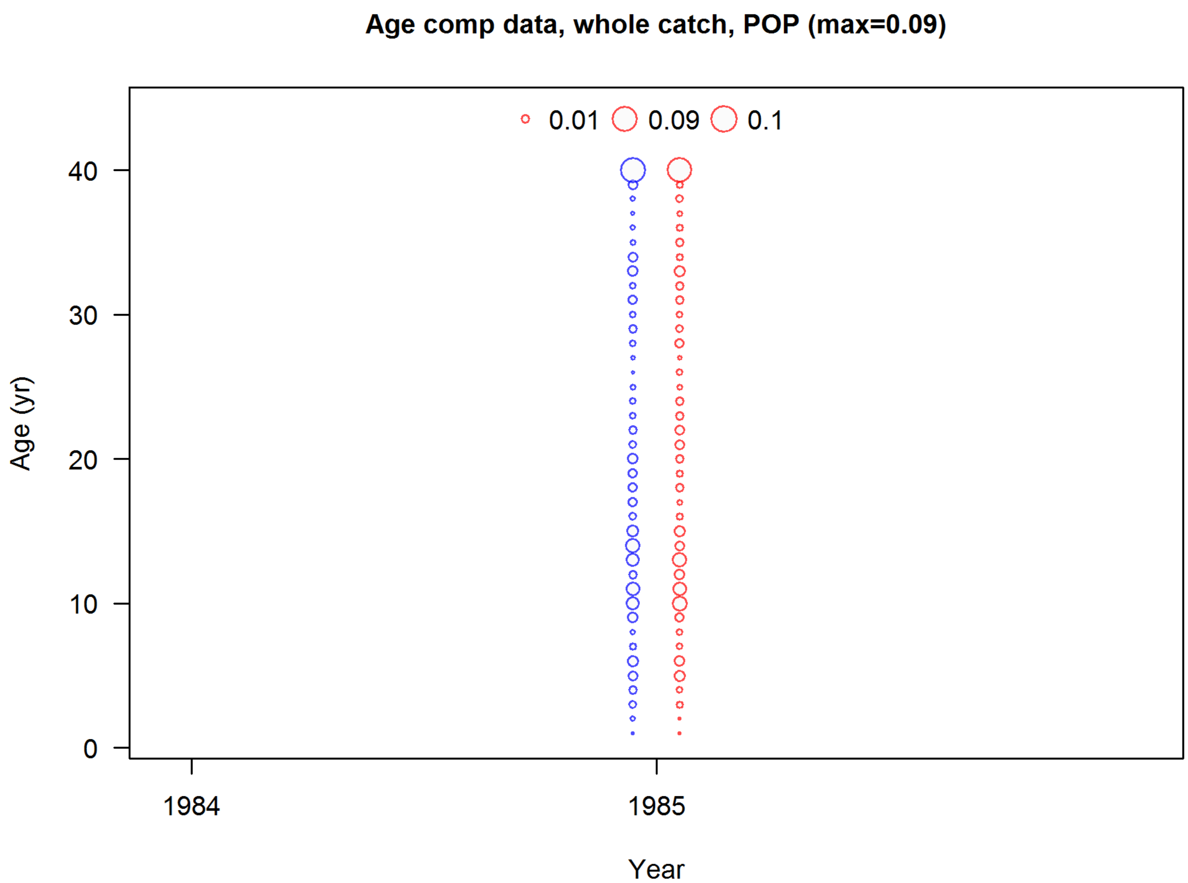

Figure 15: Pacific ocean perch survey age frequency distributions for Pacific ocean perch. fig:POP_Age

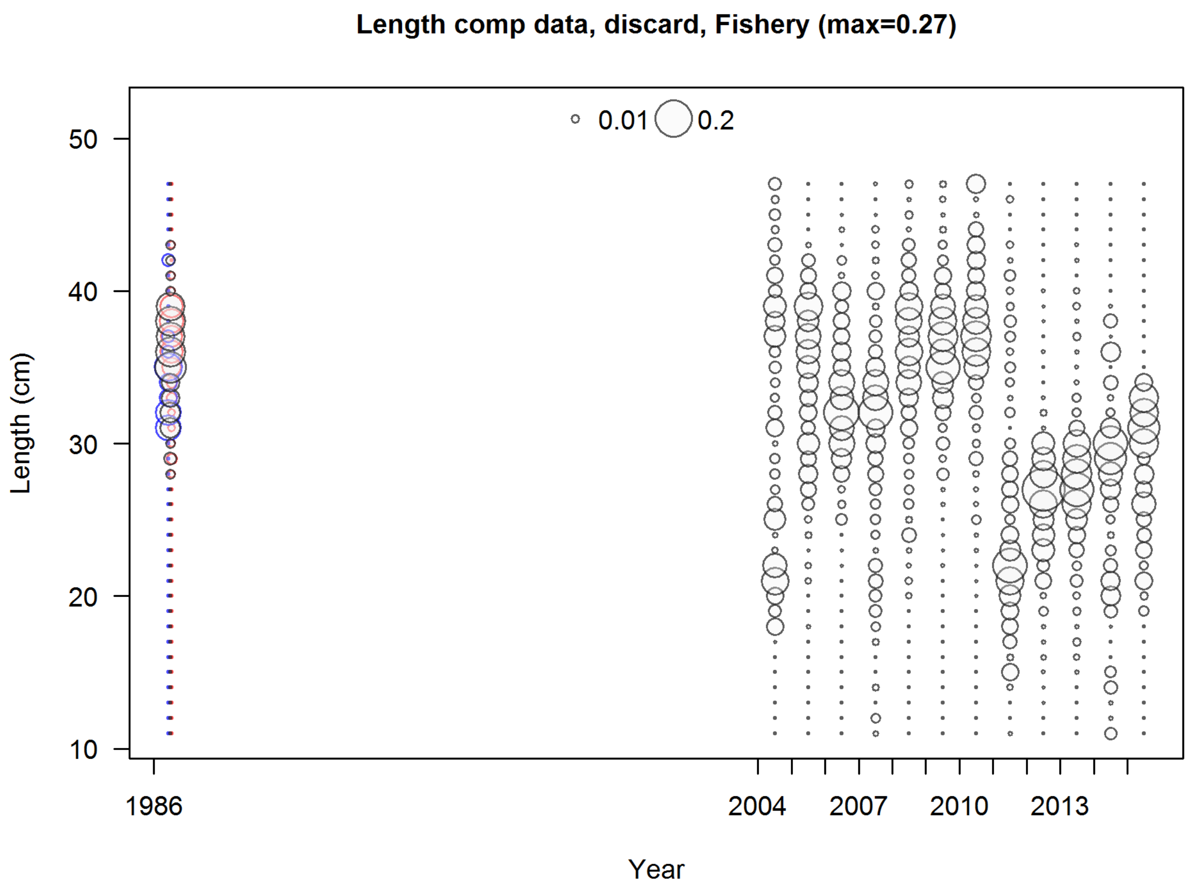

Figure 16: Discard length frequency distributions from WCGOP for Pacific ocean perch. fig:WCGOP_disc

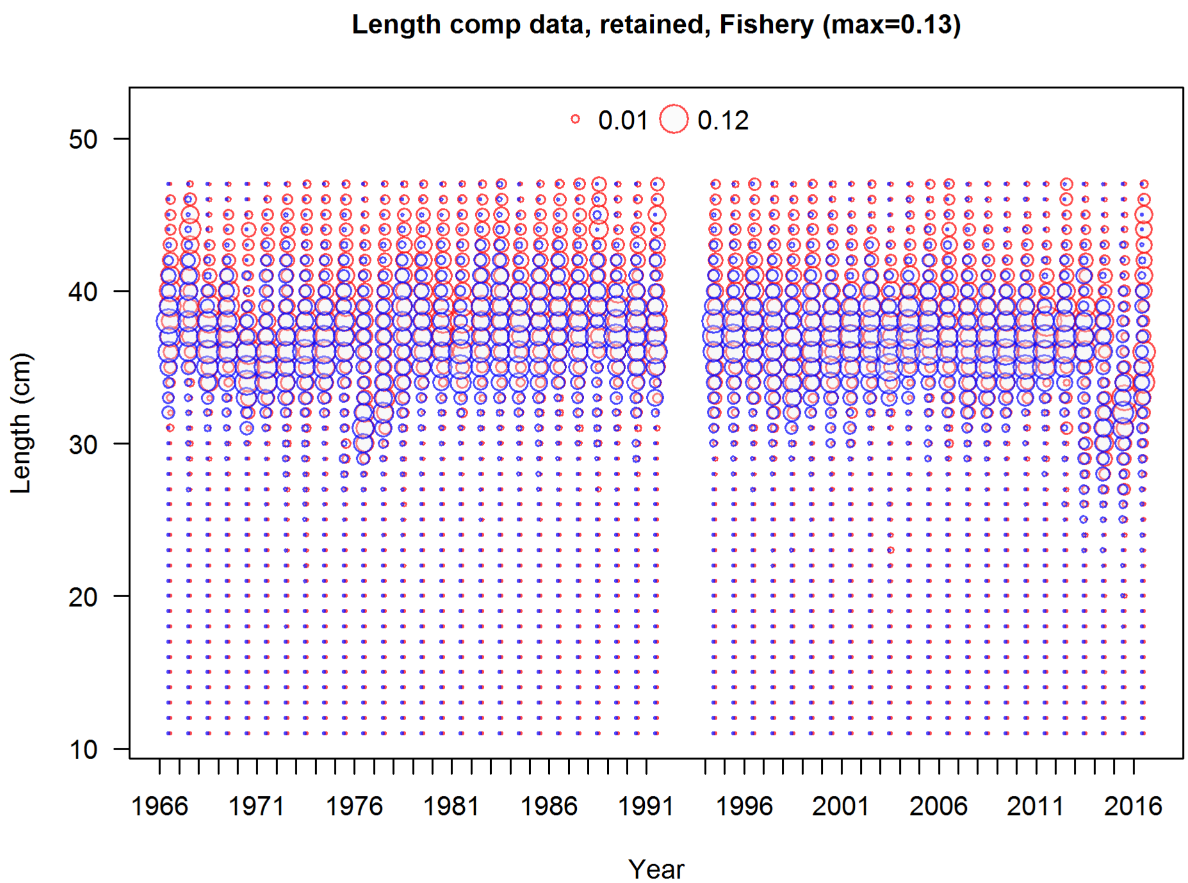

Figure 17: Commercial fishery length frequency distributions for Pacific ocean perch. fig:Comm_Length

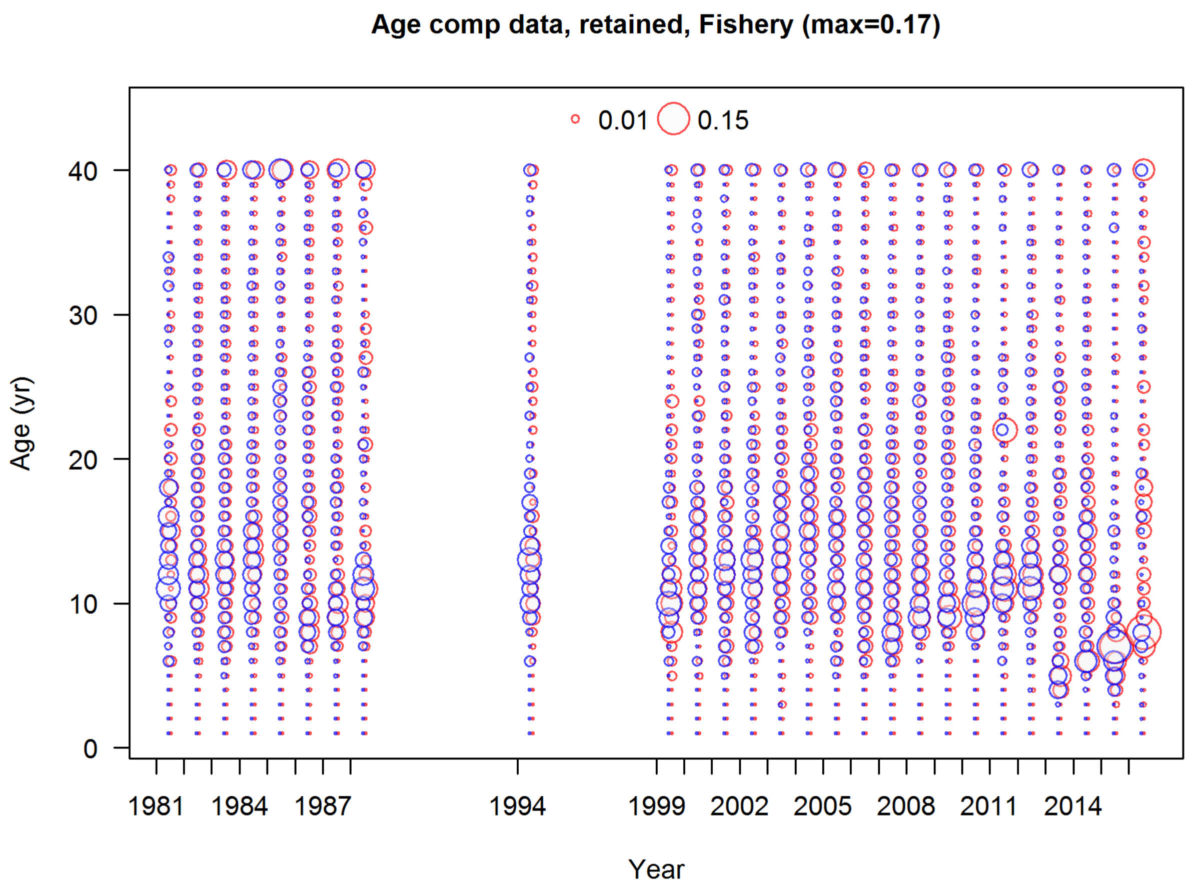

Figure 18: Commercial fishery age frequency distributions for Pacific ocean perch. fig:Comm_Age

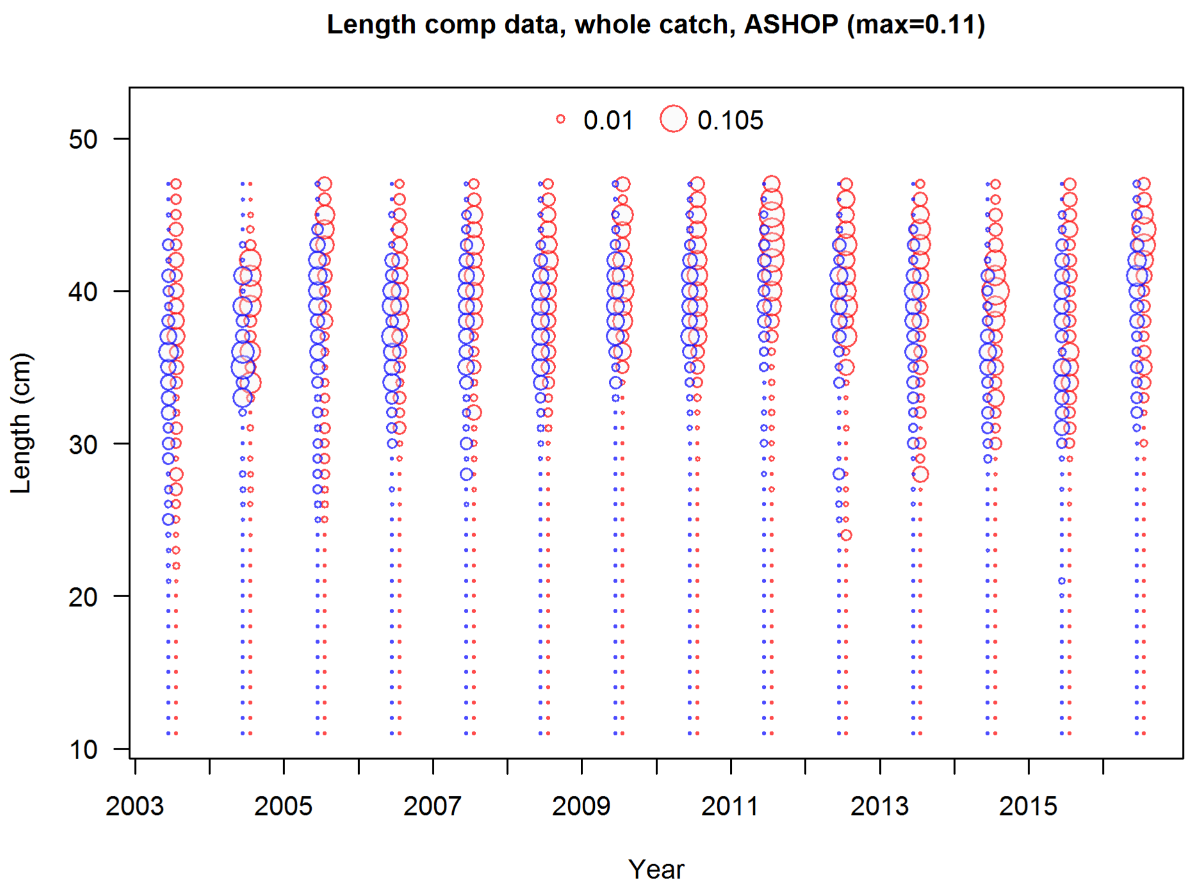

Figure 19: At-Sea hake fishery length frequency distributions for Pacific ocean perch. fig:ASHOP_Lengt

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

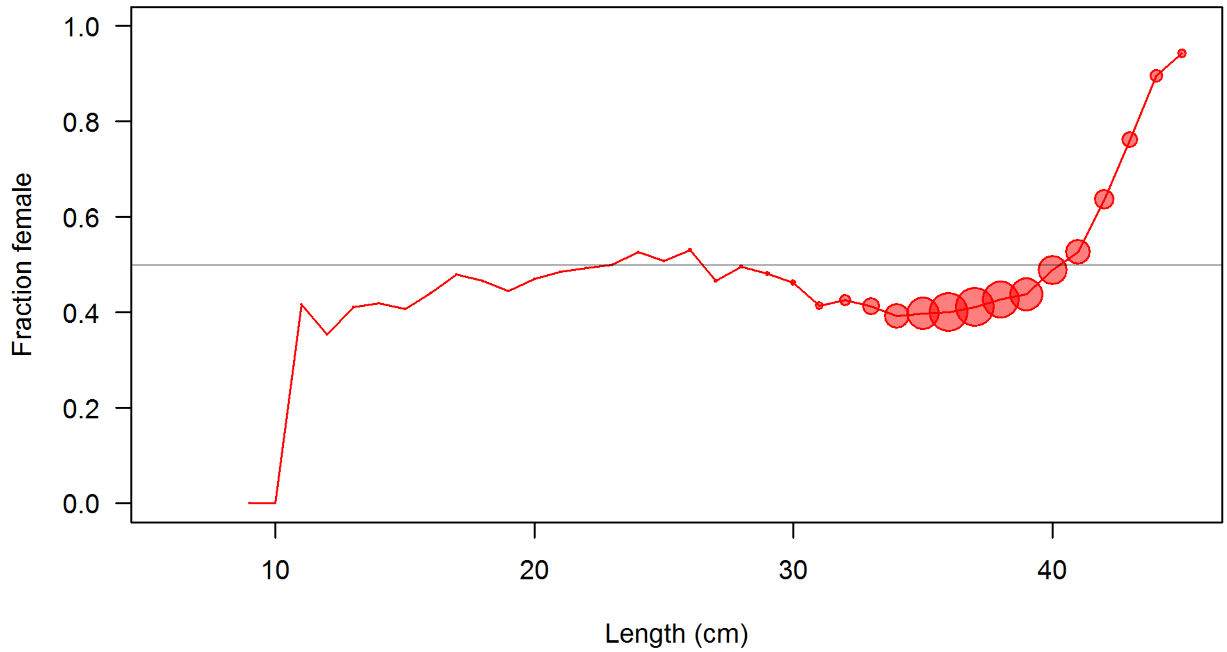

Figure 21: The estimated sex ratio of Pacific ocean perch at length from all biological data sources. fig:sexratio

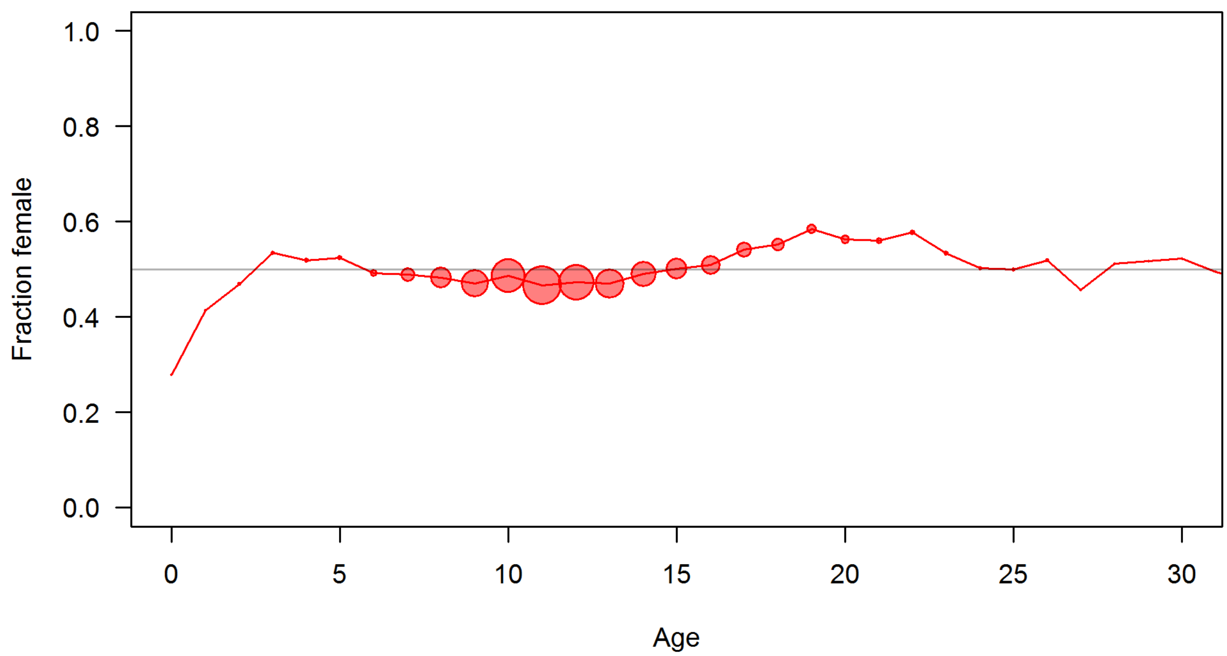

Figure 22: The estimated sex ratio of Pacific ocean perch at age from all biological data sources. fig:sexratio_Age

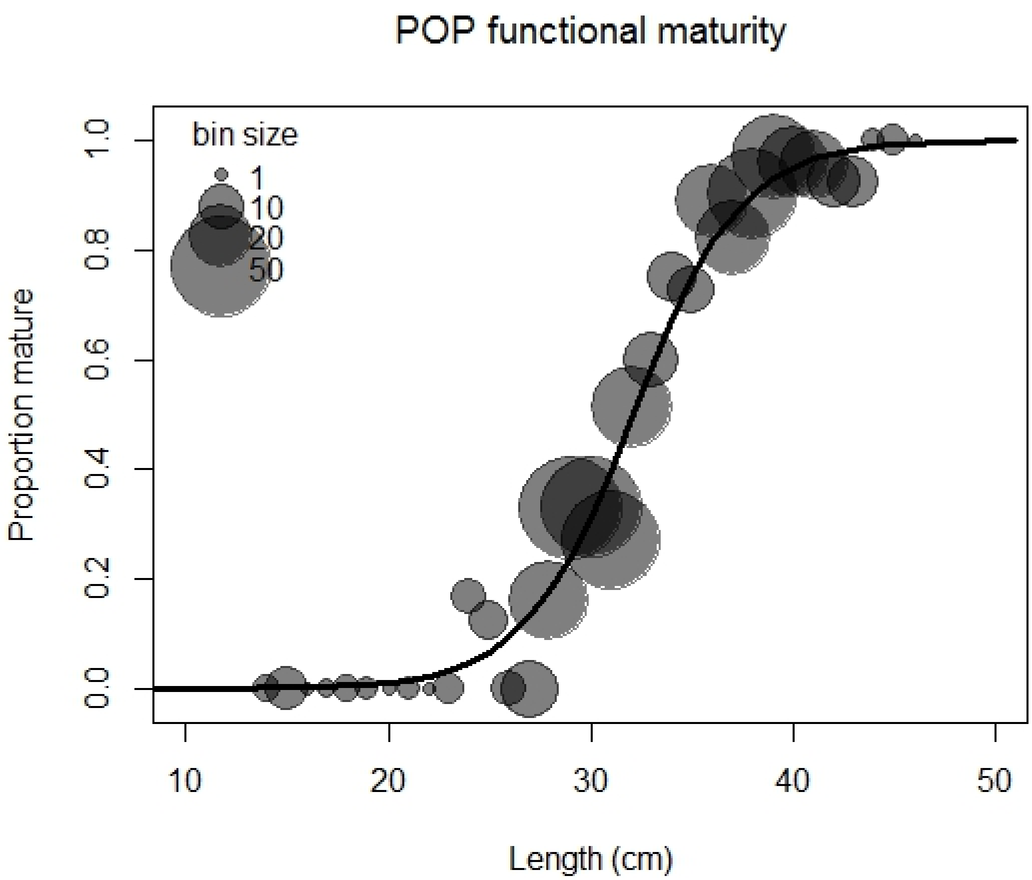

Figure 23: The estimated functional maturity Pacific ocean perch at length. fig:mat

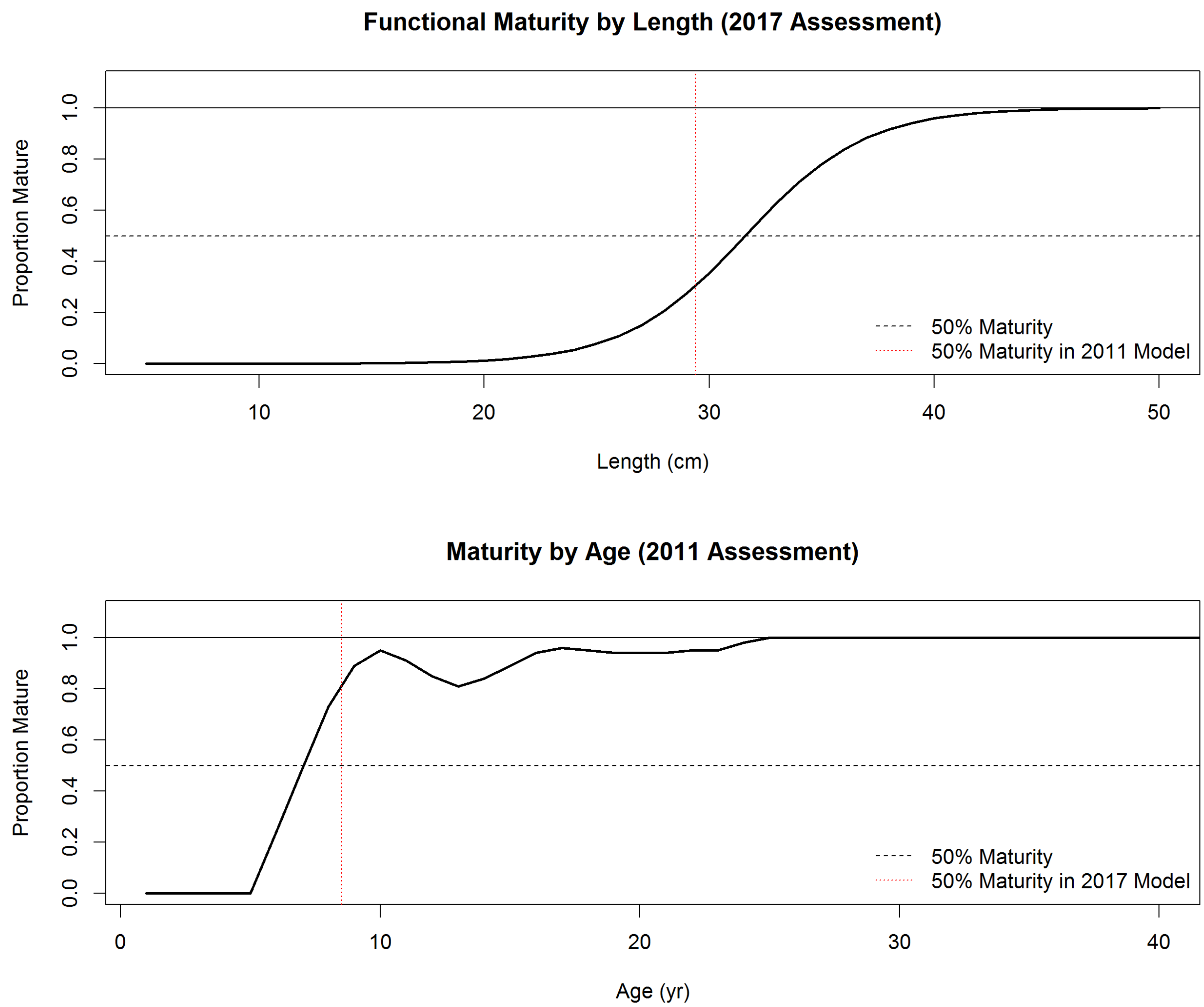

Figure 24: Comparison between estimated maturity-at-length used in this assessment and maturity-at-age applied in the 2011 assessment of Pacific ocean perch. fig:mat_compare

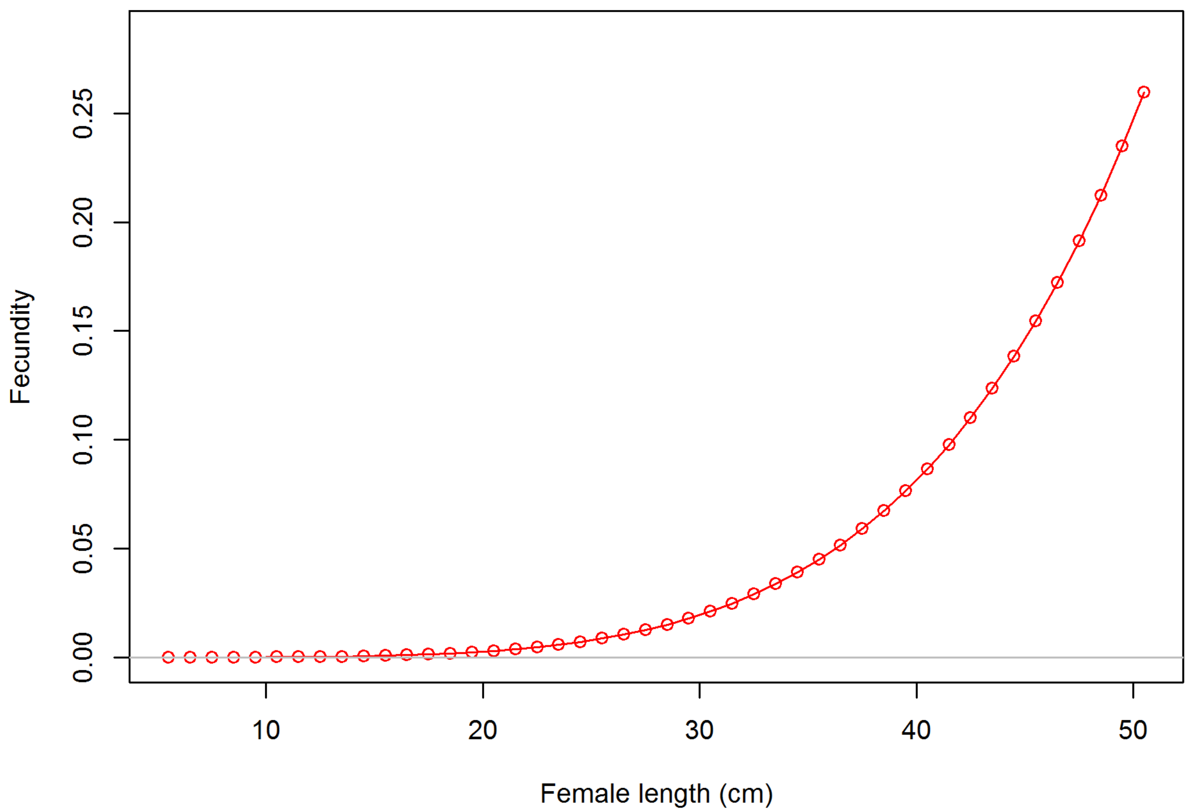

Figure 25: Fecundity at length of Pacific ocean perch in the Base model. fig:fecundity

NA fig:mod1_35_NA

NA fig:mod1_36_NA

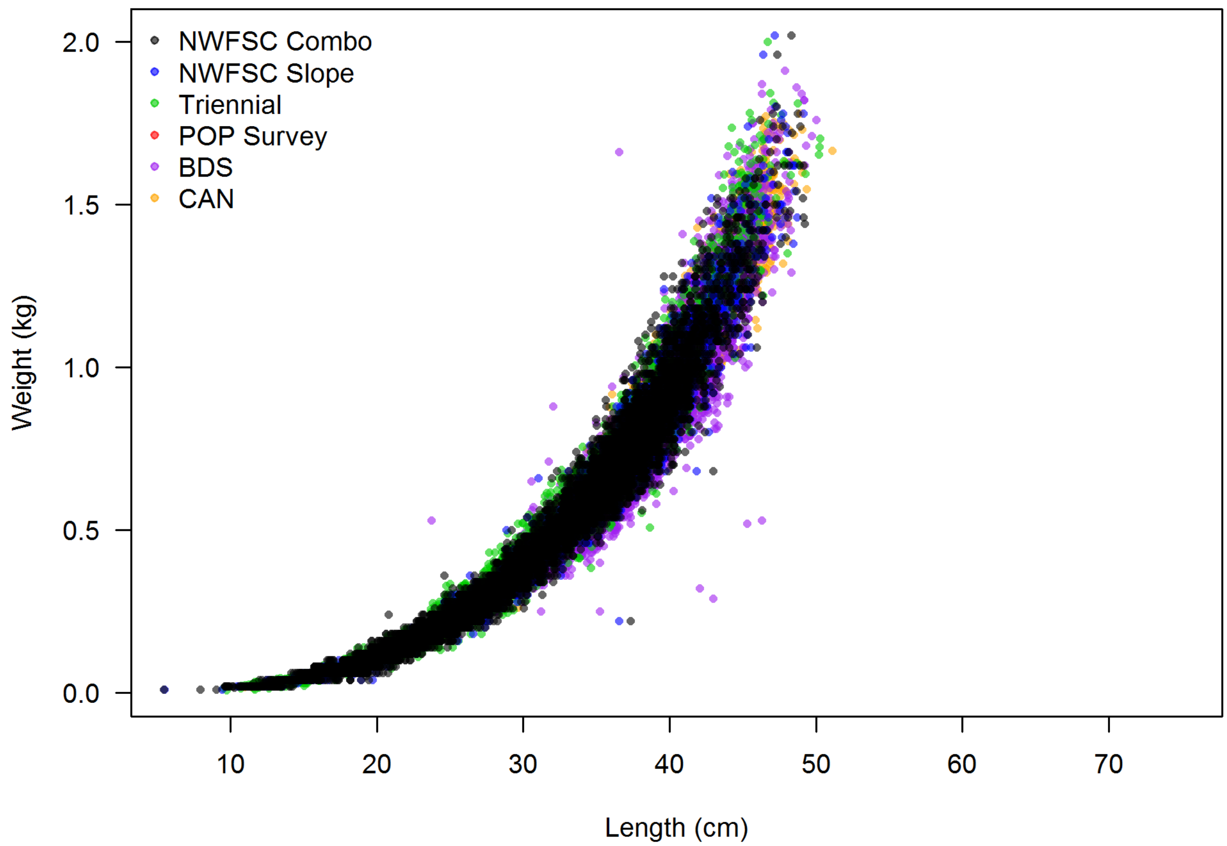

Figure 26: Weight-at-length for Pacific ocean perch from all data sources. fig:Wt_len

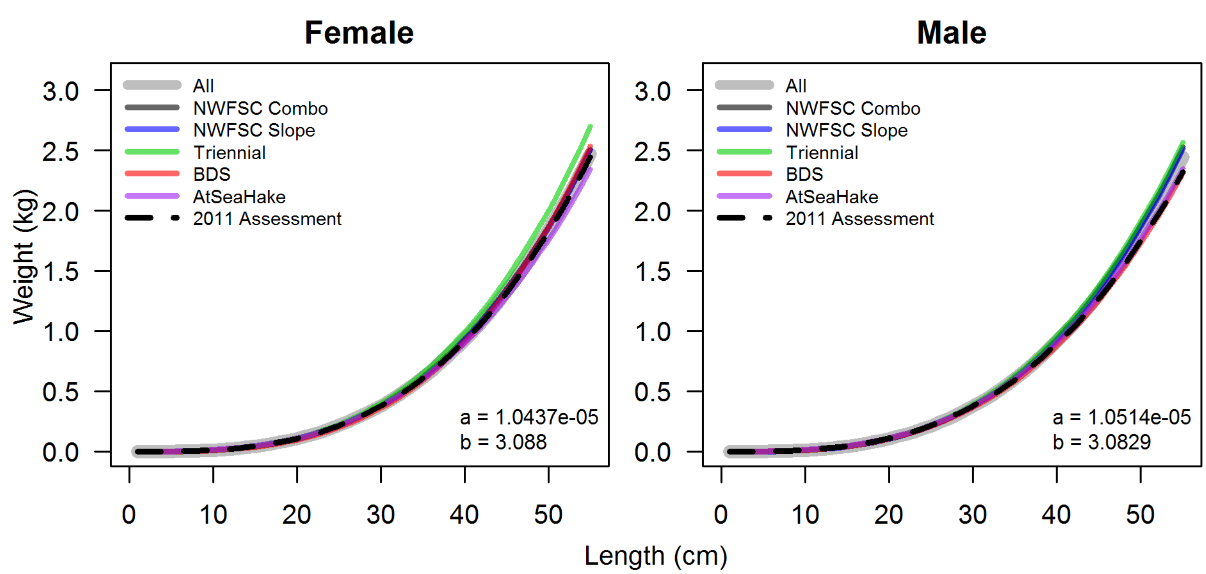

Figure 27: Estimated weight-at-length for Pacific ocean perch from all data sources. fig:Wt_len_pred

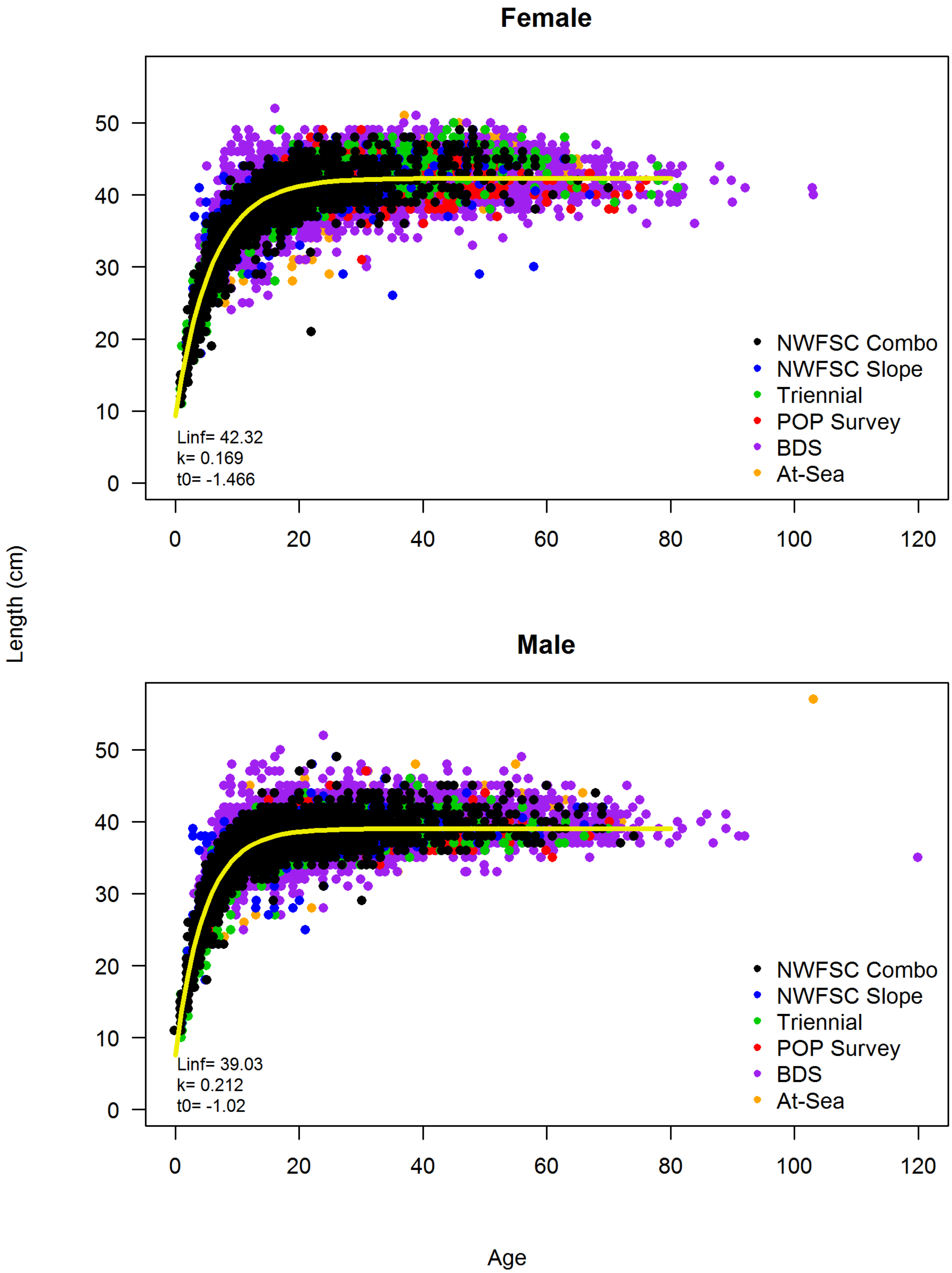

Figure 28: Estimated length-at-age for Pacific ocean perch from all data sources. fig:Len_Age

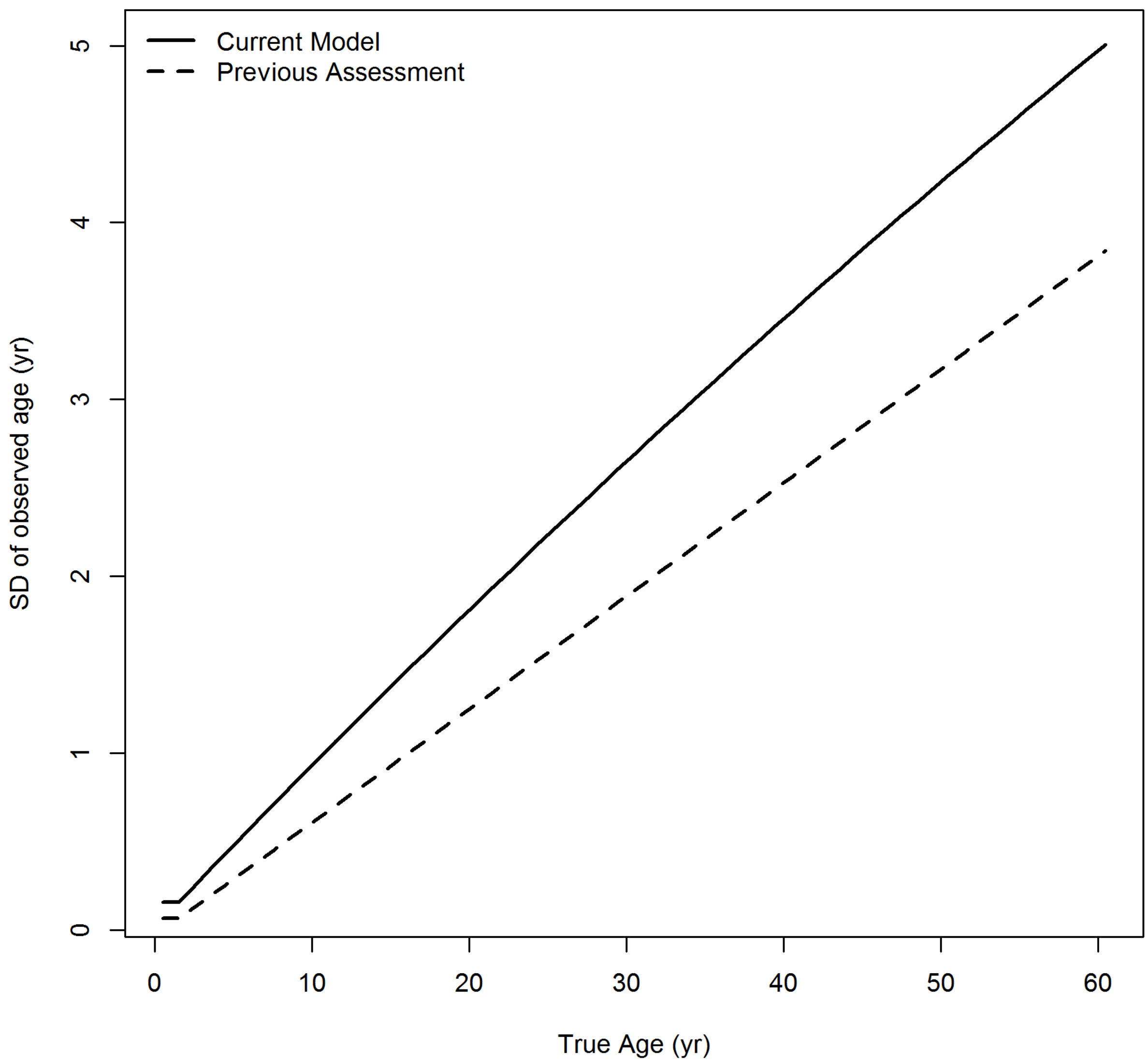

Figure 29: The estimated ageing error used in this assessment compared to the ageing error assumed in the previous assessment for Pacific ocean perch. fig:Age_Error

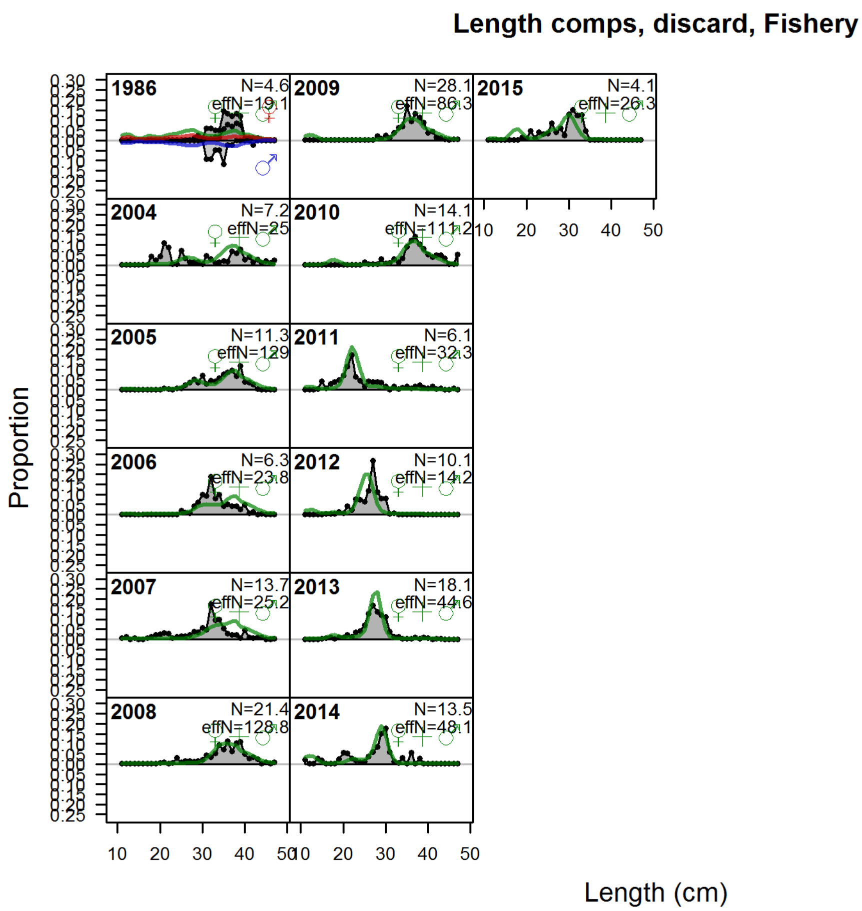

Figure 30: Length comps, discard, Fishery fig:mod1_1_comp_lenfit_flt1mkt1

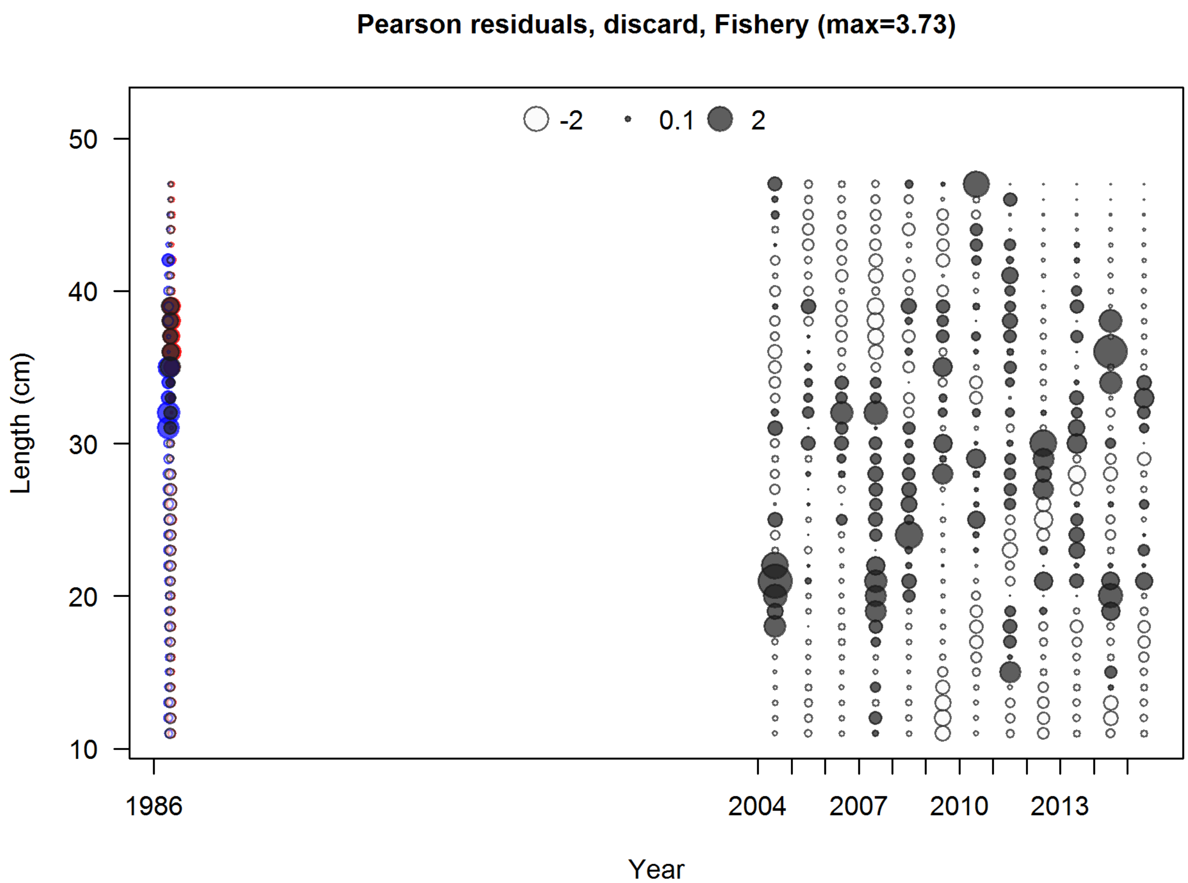

Figure 31: Pearson residuals, discard, Fishery (max=3.73)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_2_comp_lenfit_residsflt1mkt1

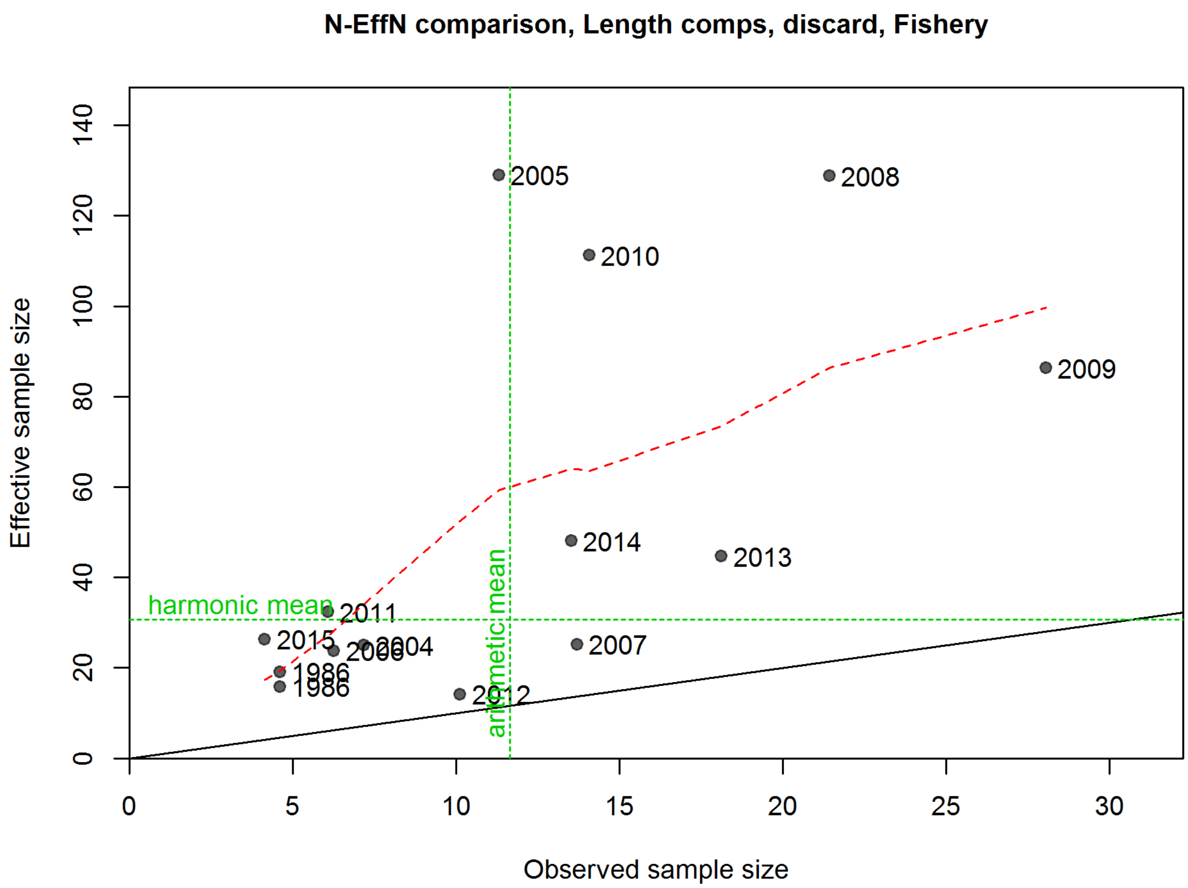

Figure 32: N_EffN comparison, Length comps, discard, Fishery fig:mod1_3_comp_lenfit_sa

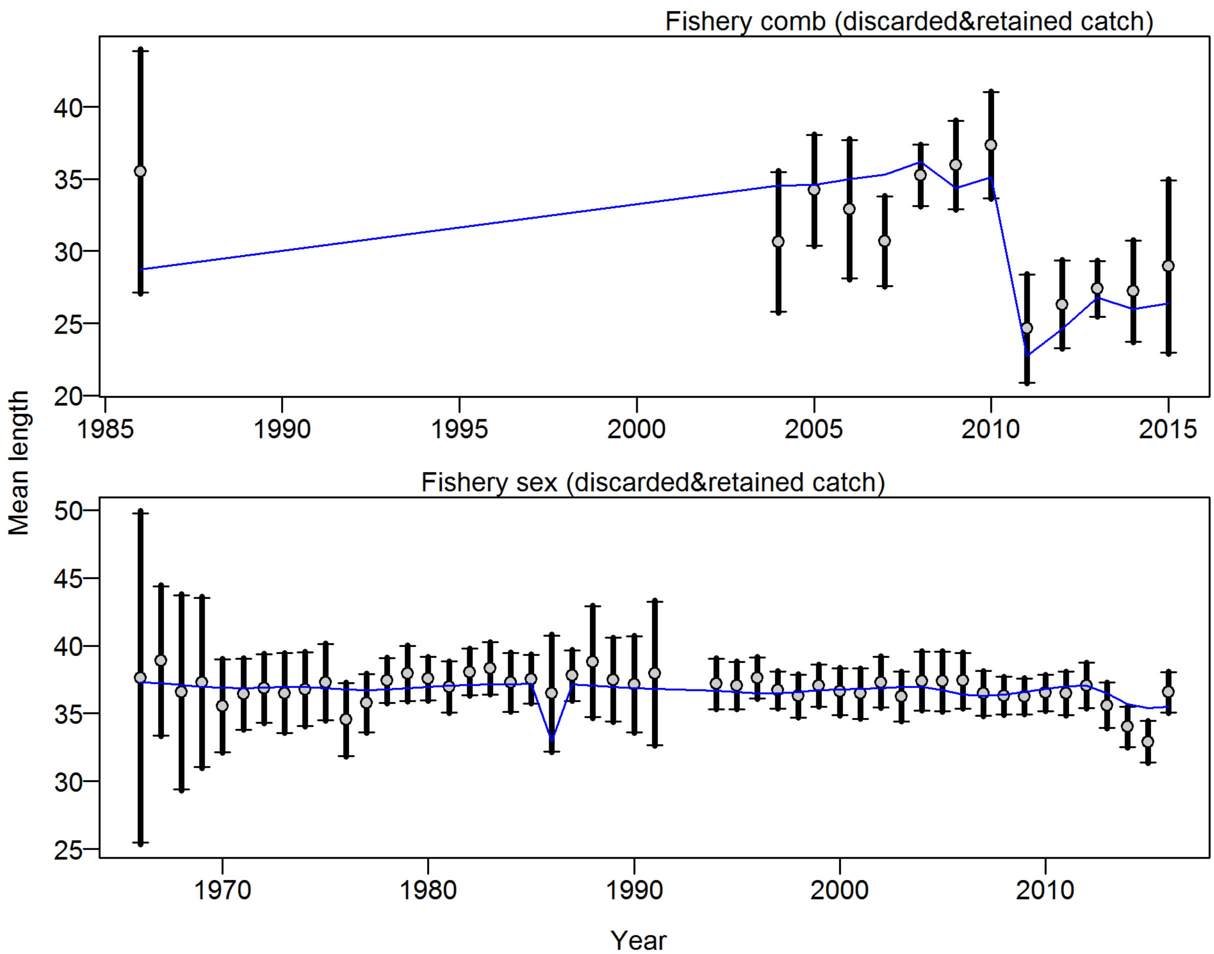

Figure 33: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 1.0278 (0.6831_1.8626) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. fig:mod1_4_comp_lenfit_data_weighting_TA1.8_Fishery

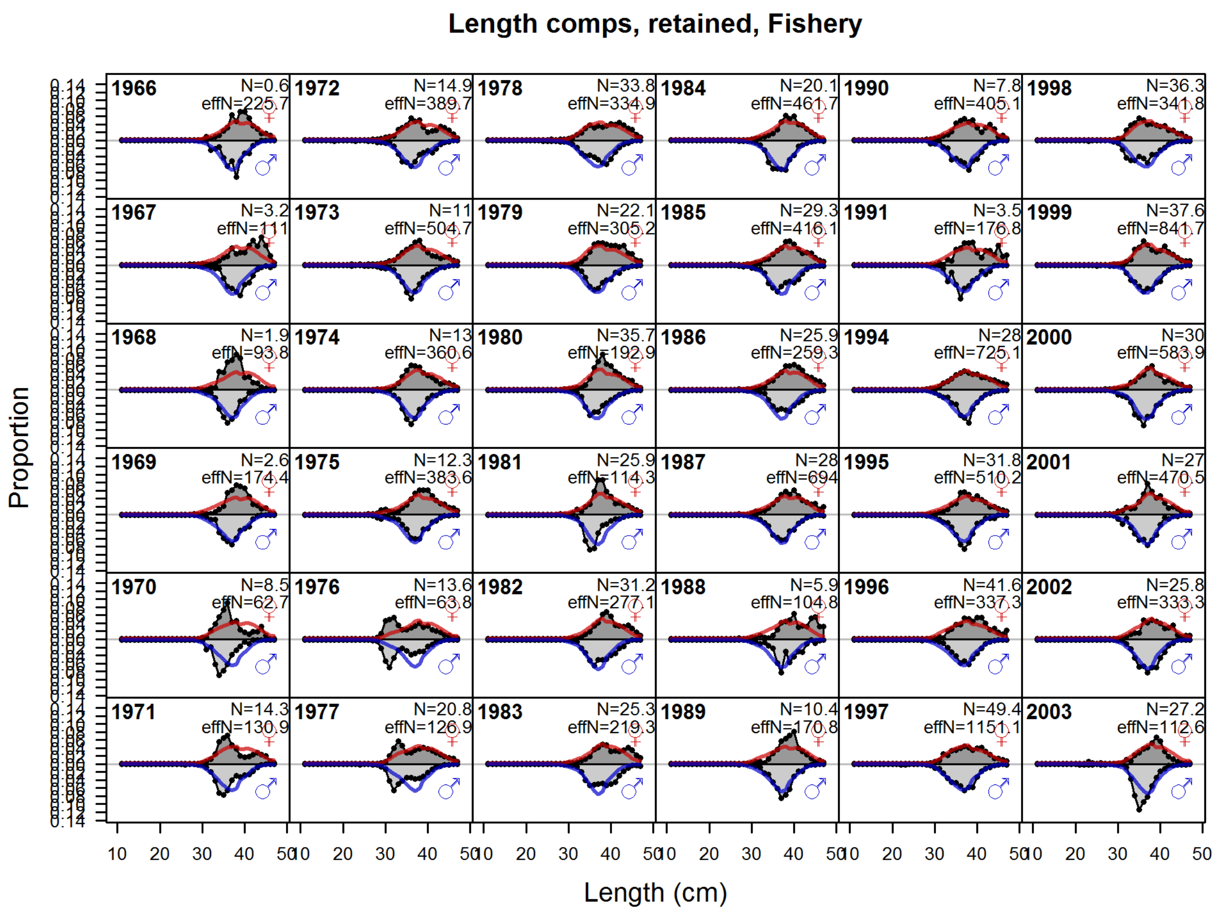

Figure 34: Length comps, retained, Fishery (plot 1 of 2) fig:mod1_5_comp_lenfit_flt1m

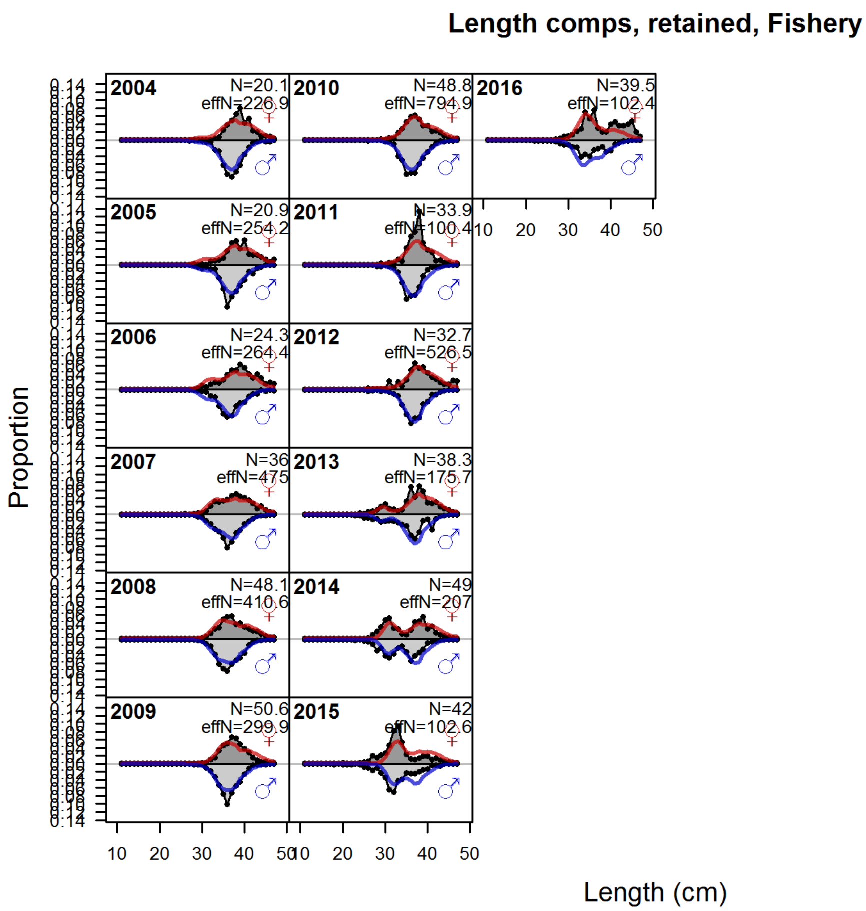

Figure 35: Length comps, retained, Fishery (plot 1 of 2) (plot 2 of 2) fig:mod1_6_comp_lenfit

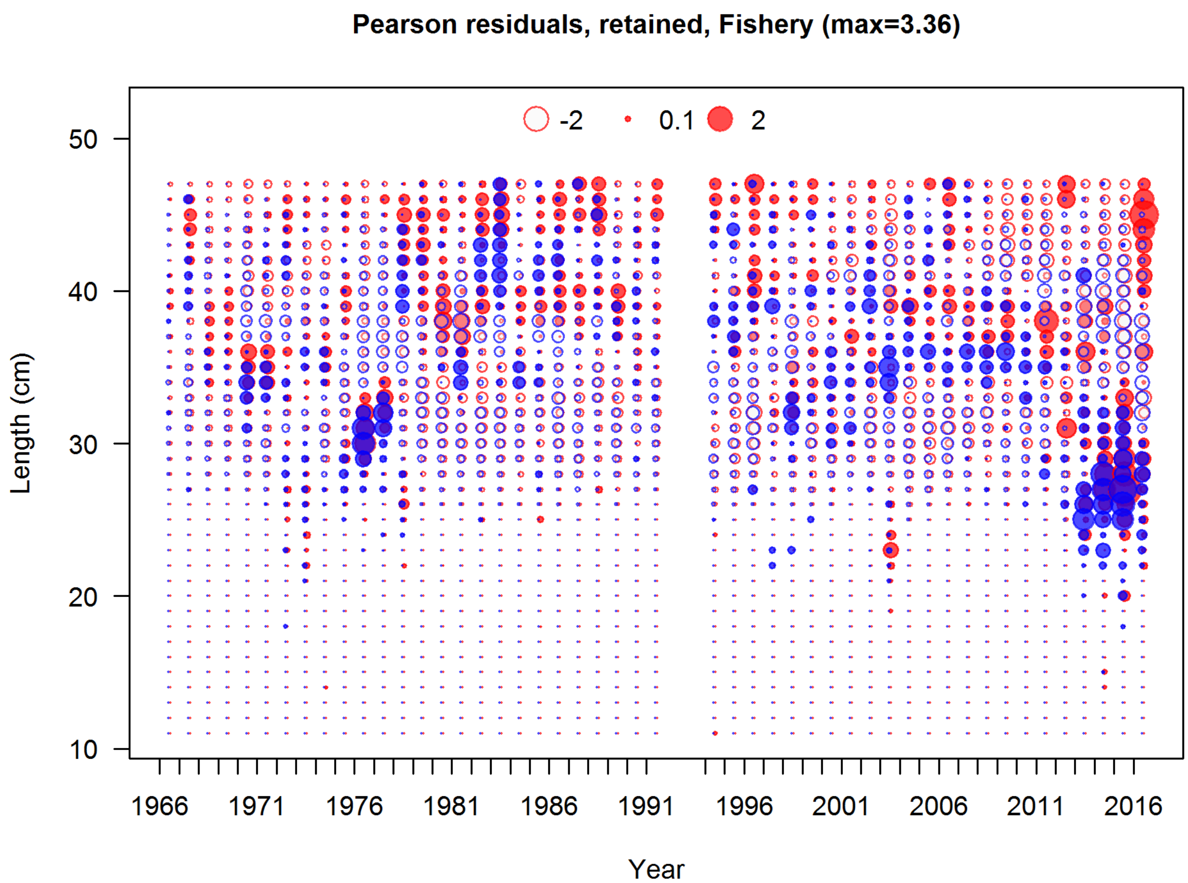

Figure 36: Pearson residuals, retained, Fishery (max=3.36) (plot 2 of 2)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_7_comp_lenfit_residsflt1mkt2_page2

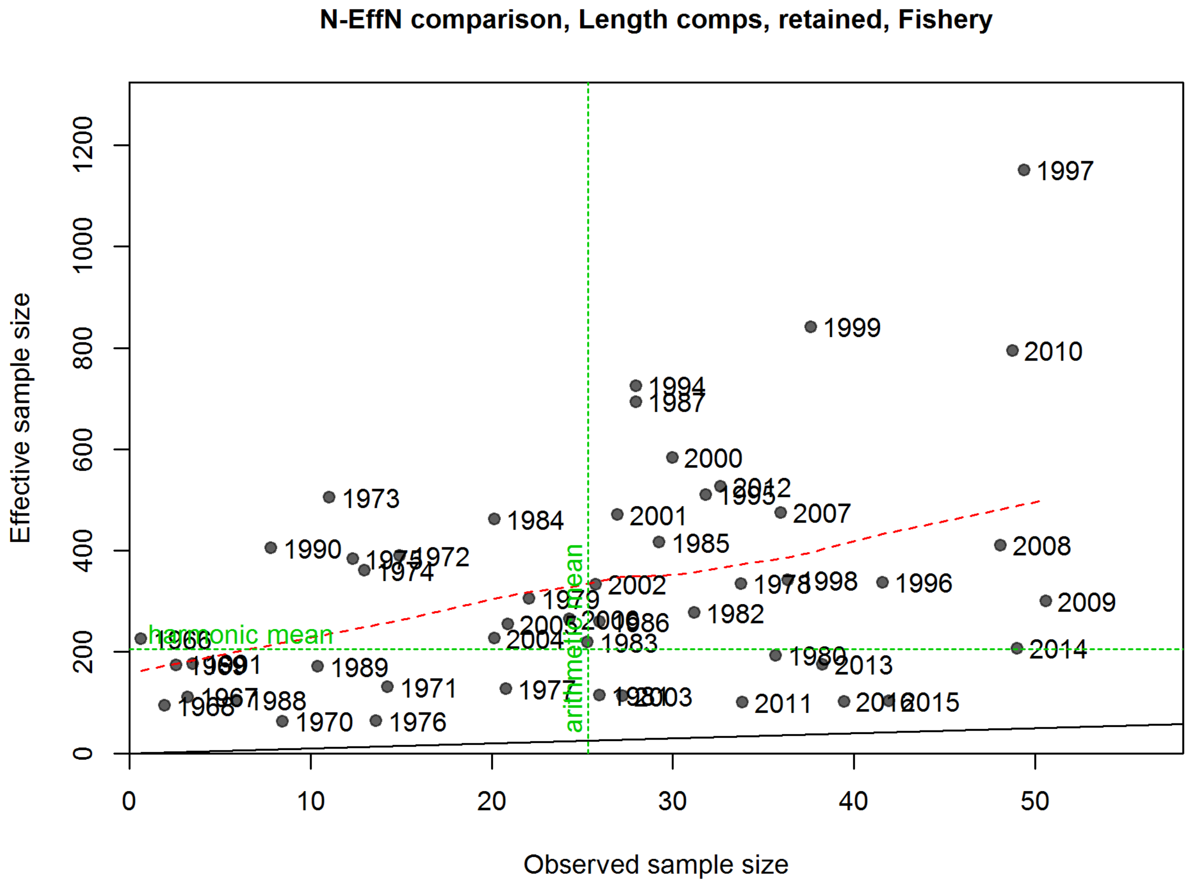

Figure 37: N_EffN comparison, Length comps, retained, Fishery fig:mod1_8_comp_lenfit_sa

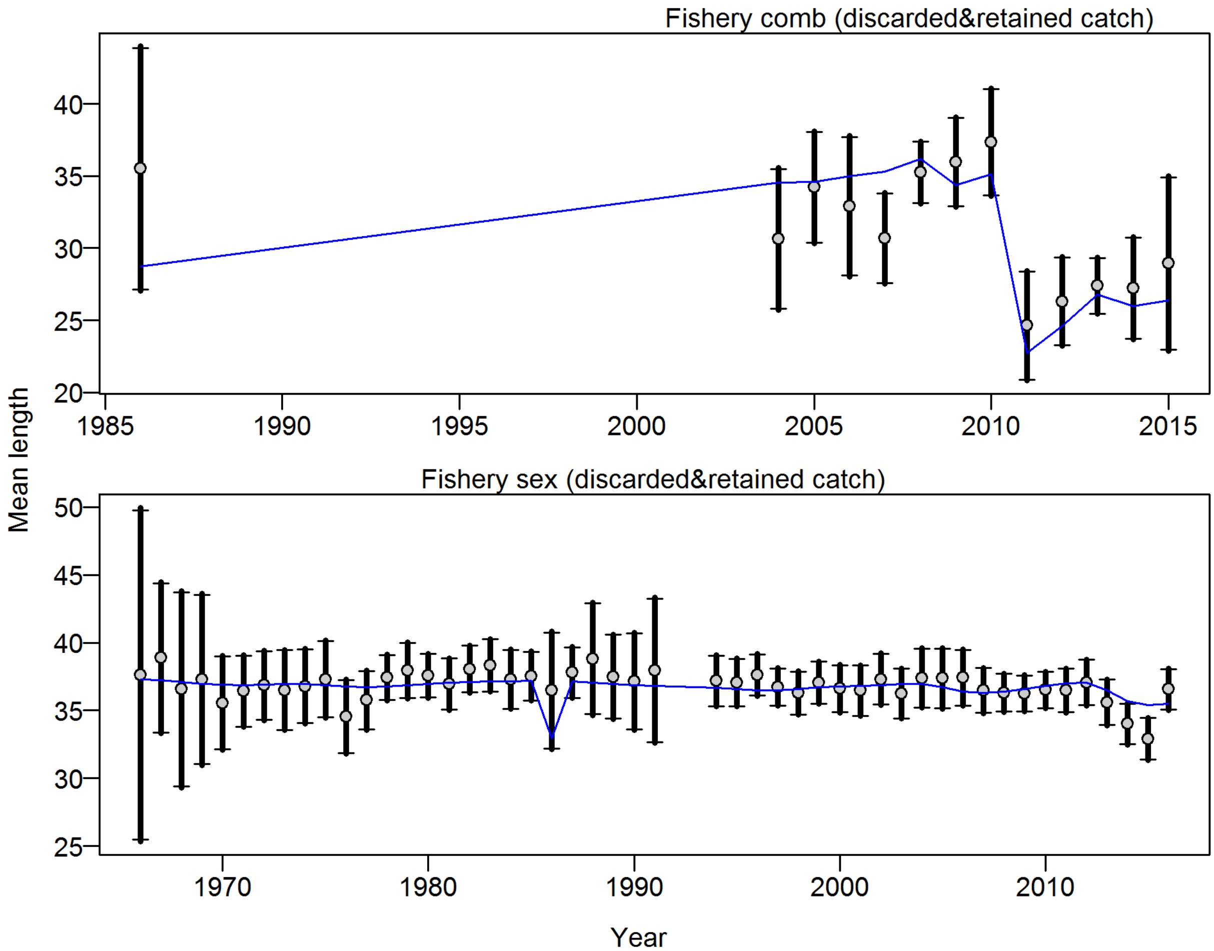

Figure 38: Francis data weighting method TA1.8: Fishery Suggested sample size adjustment (with 95% interval) for len data from Fishery: 1.0278 (0.6659_1.8952) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. fig:mod1_9_comp_lenfit_data_weighting_TA1.8_Fishery

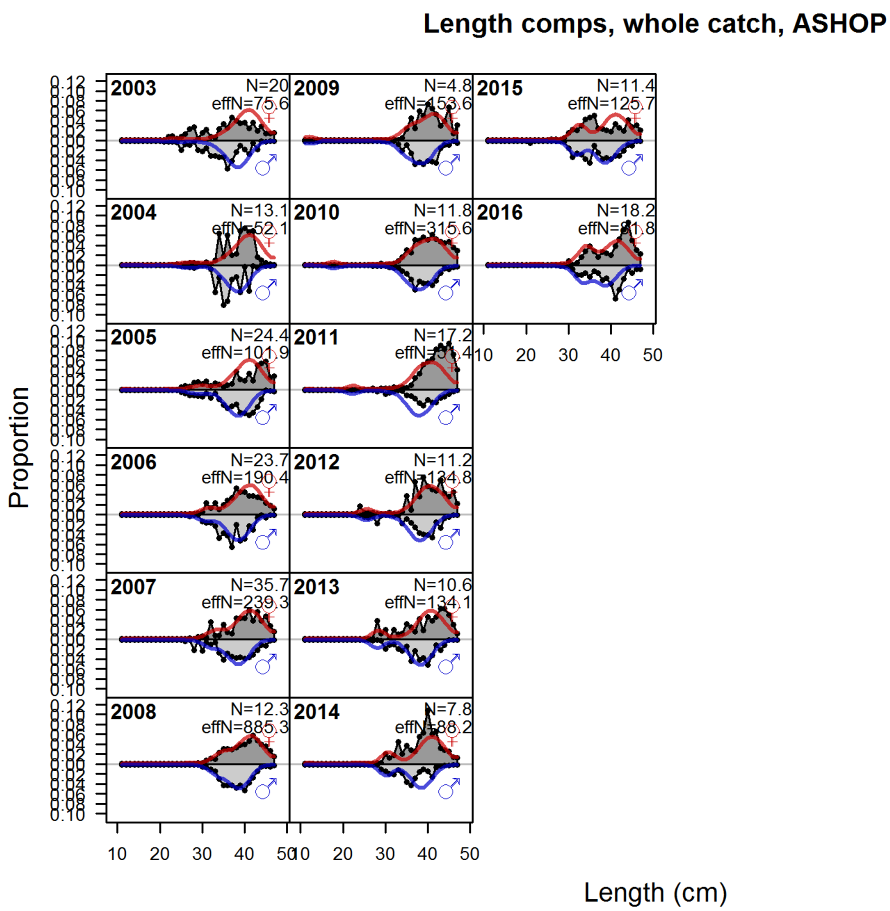

Figure 39: Length comps, whole catch, ASHOP fig:mod1_10_comp_lenfit_flt2mkt0

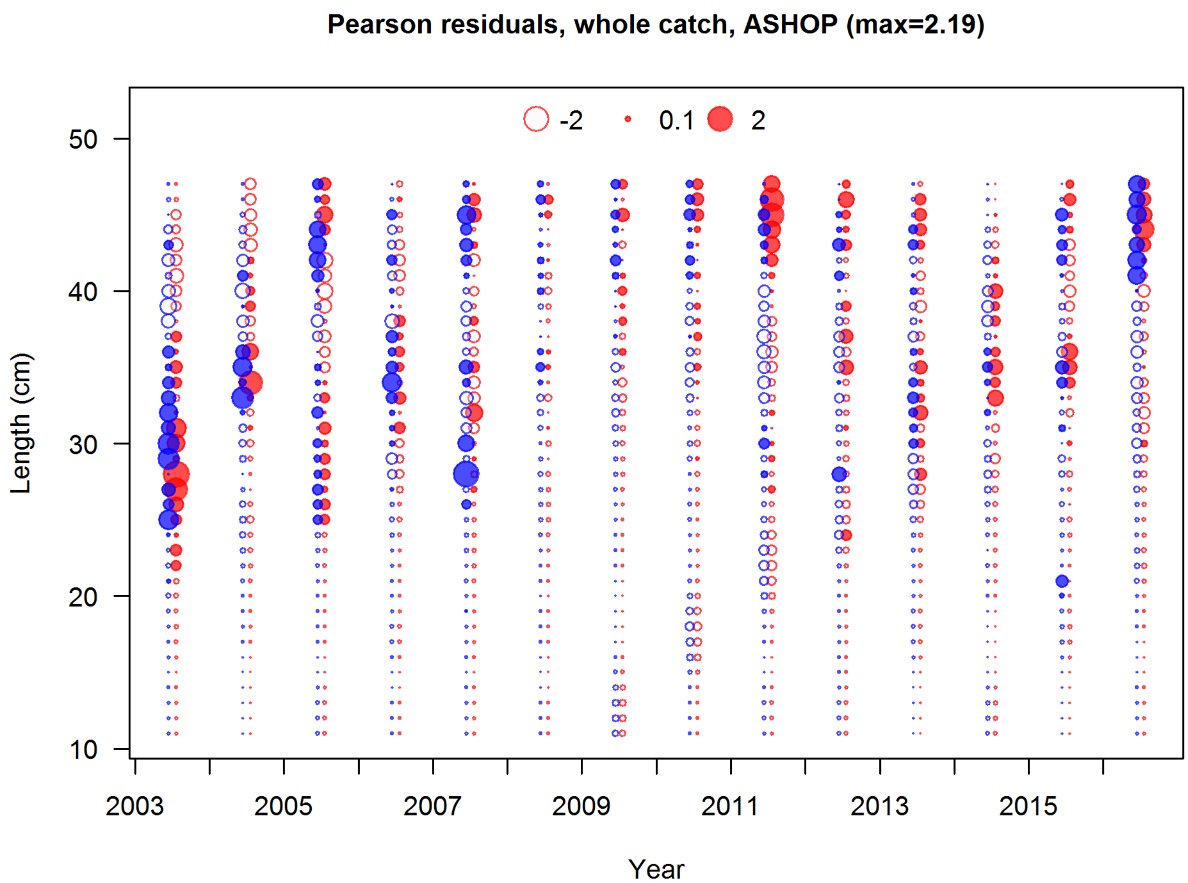

Figure 40: Pearson residuals, whole catch, ASHOP (max=2.19)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_11_comp_lenfit_residsflt2mkt0

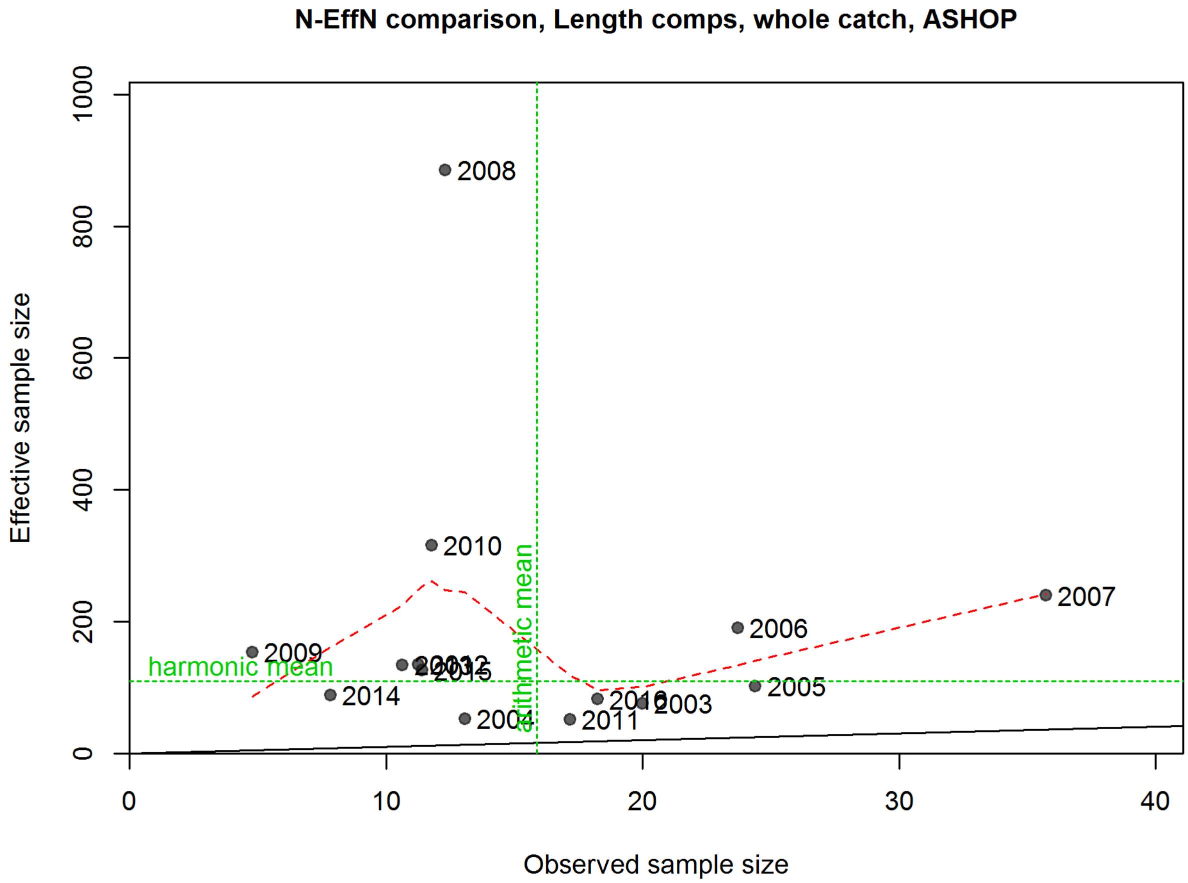

Figure 41: N_EffN comparison, Length comps, whole catch, ASHOP fig:mod1_12_comp_lenfit

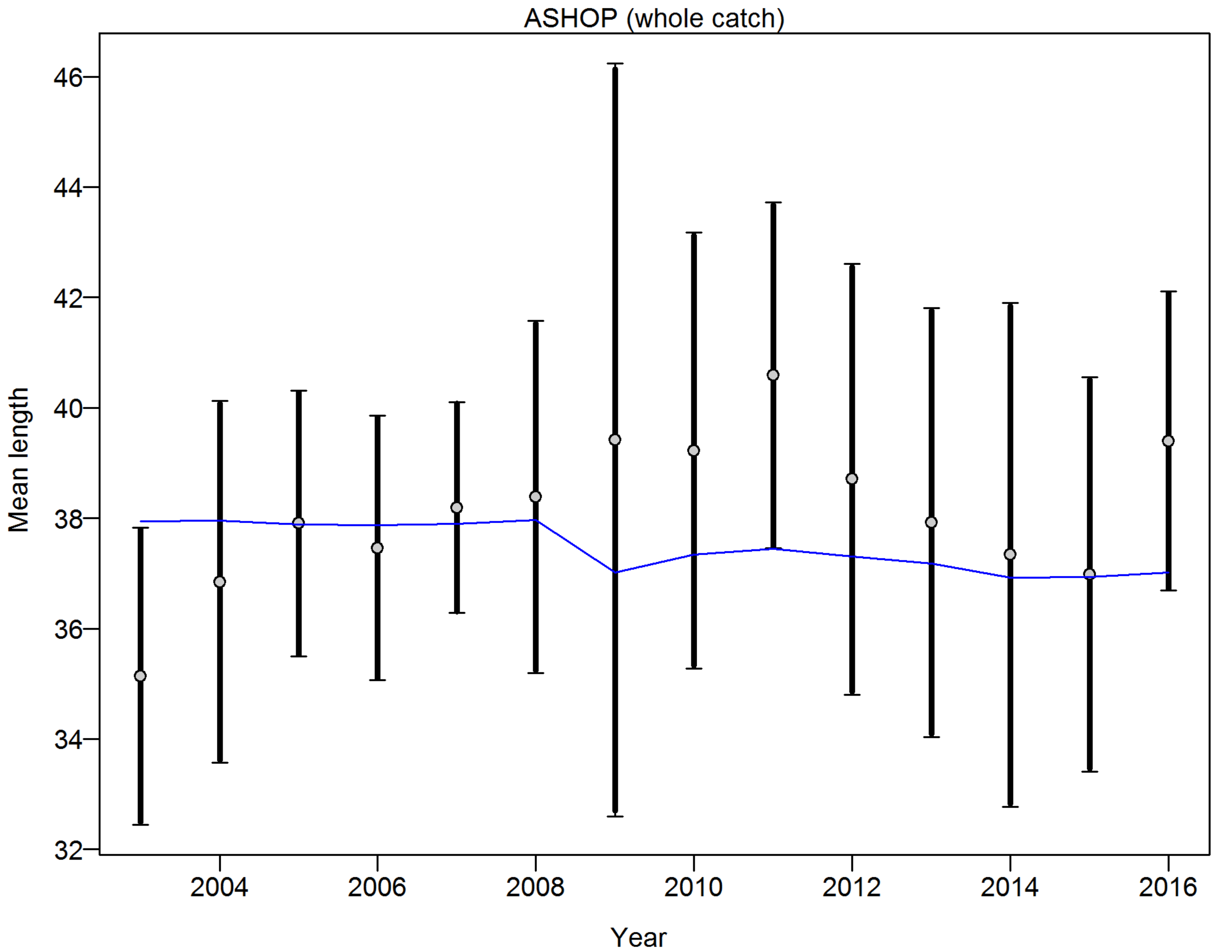

Figure 42: Francis data weighting method TA1.8: ASHOP Suggested sample size adjustment (with 95% interval) for len data from ASHOP: 0.9715 (0.5174_4.1709) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. fig:mod1_13_comp_lenfit_data_weighting_TA1.8_ASHOP

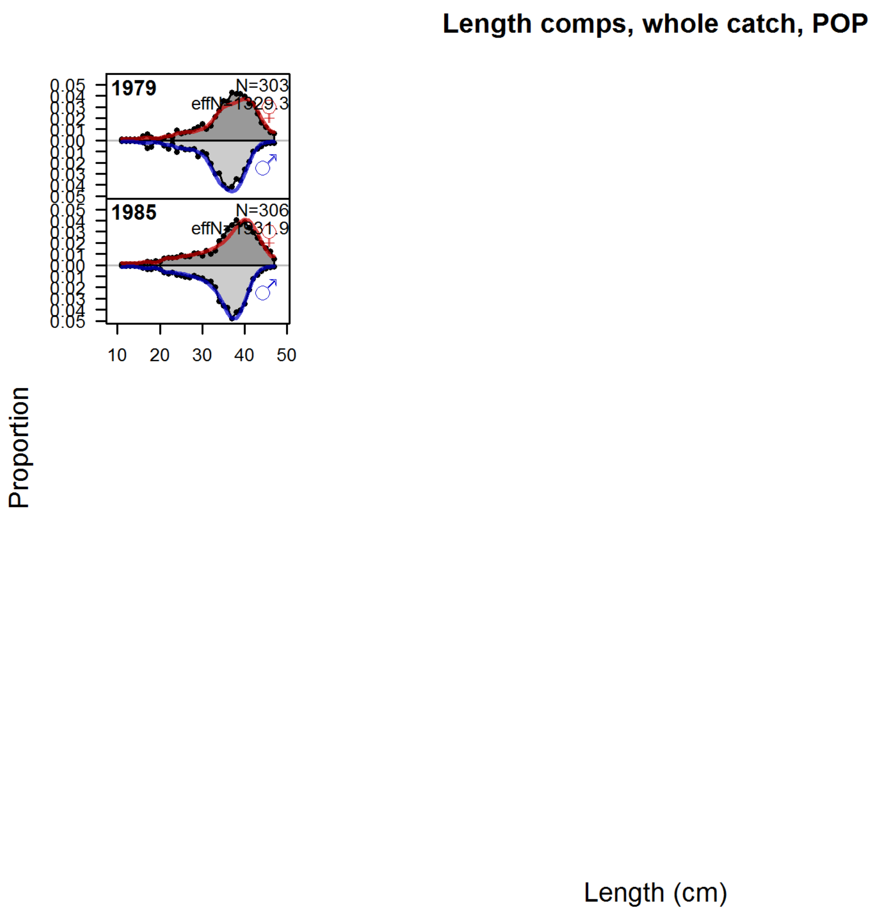

Figure 43: Length comps, whole catch, POP fig:mod1_14_comp_lenfit_flt4mkt0

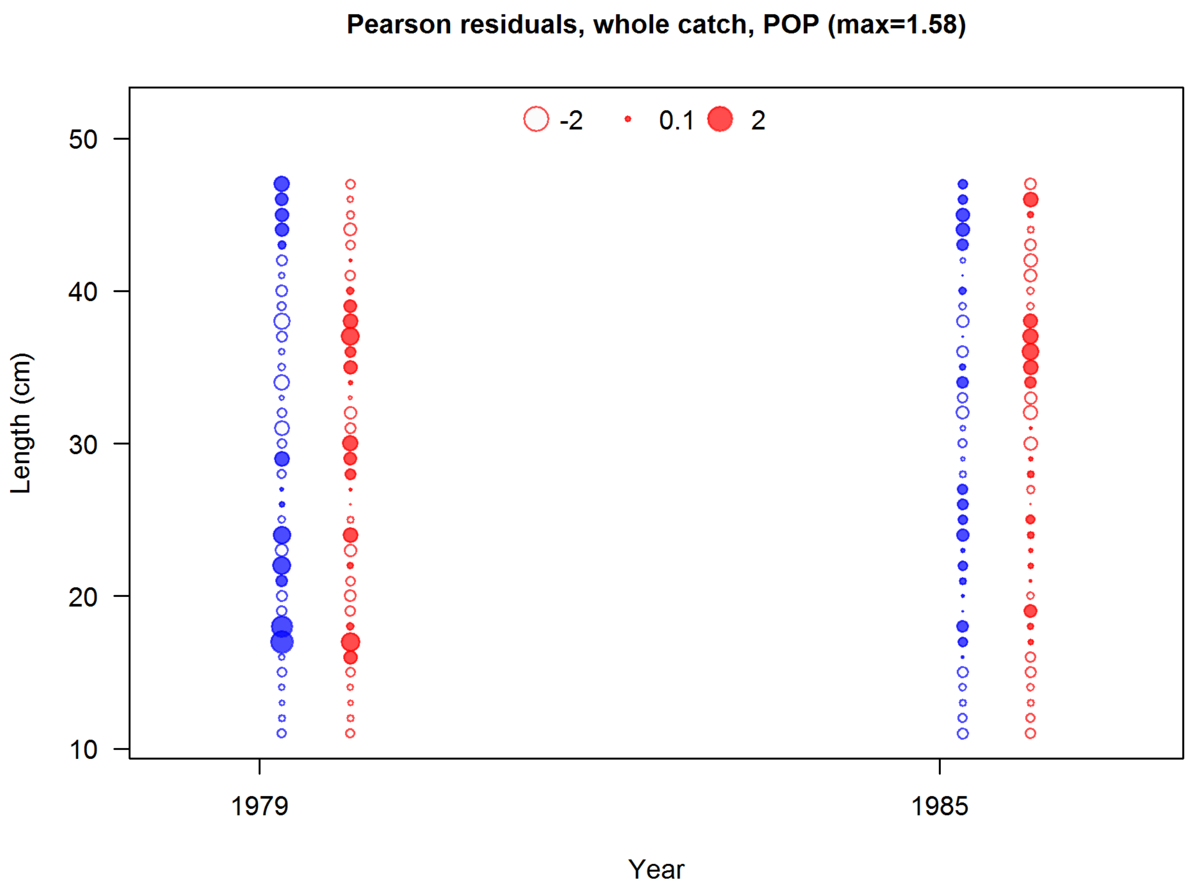

Figure 44: Pearson residuals, whole catch, POP (max=1.58)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_15_comp_lenfit_residsflt4mkt0

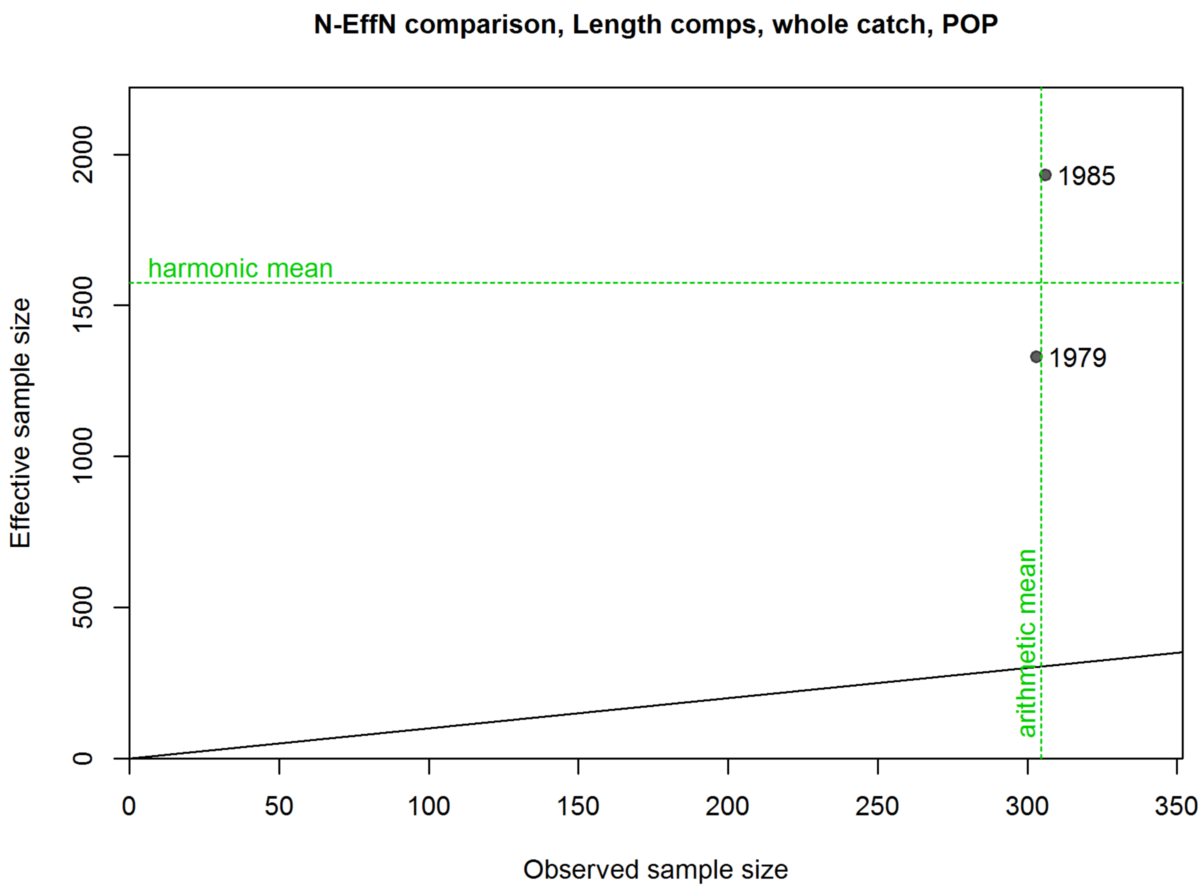

Figure 45: N_EffN comparison, Length comps, whole catch, POP fig:mod1_16_comp_lenfit_

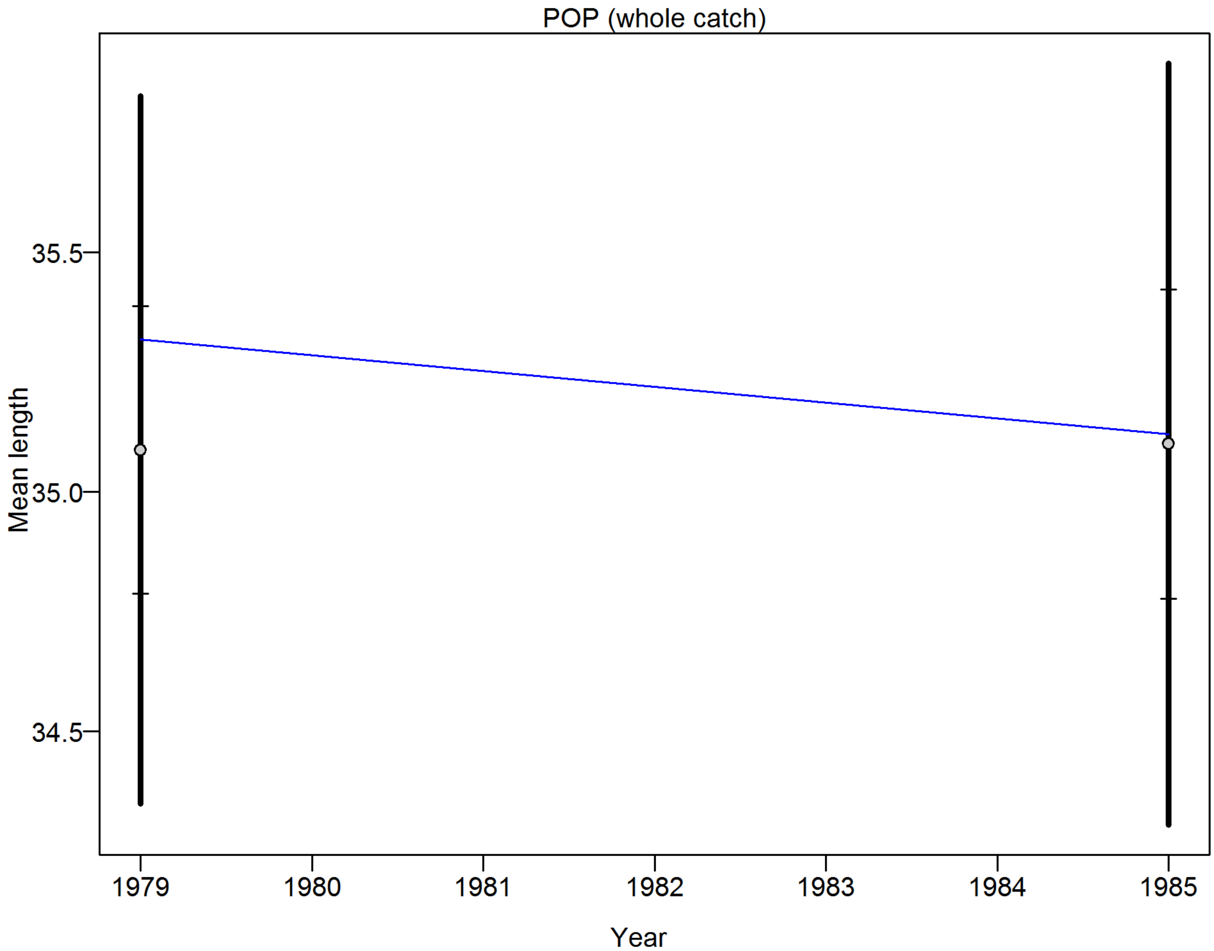

Figure 46: Francis data weighting method TA1.8: POP Suggested sample size adjustment (with 95% interval) for len data from POP: 6.0537 (6.0537_Inf) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. fig:mod1_17_comp_lenfit_data_weighting_TA1.8_POP

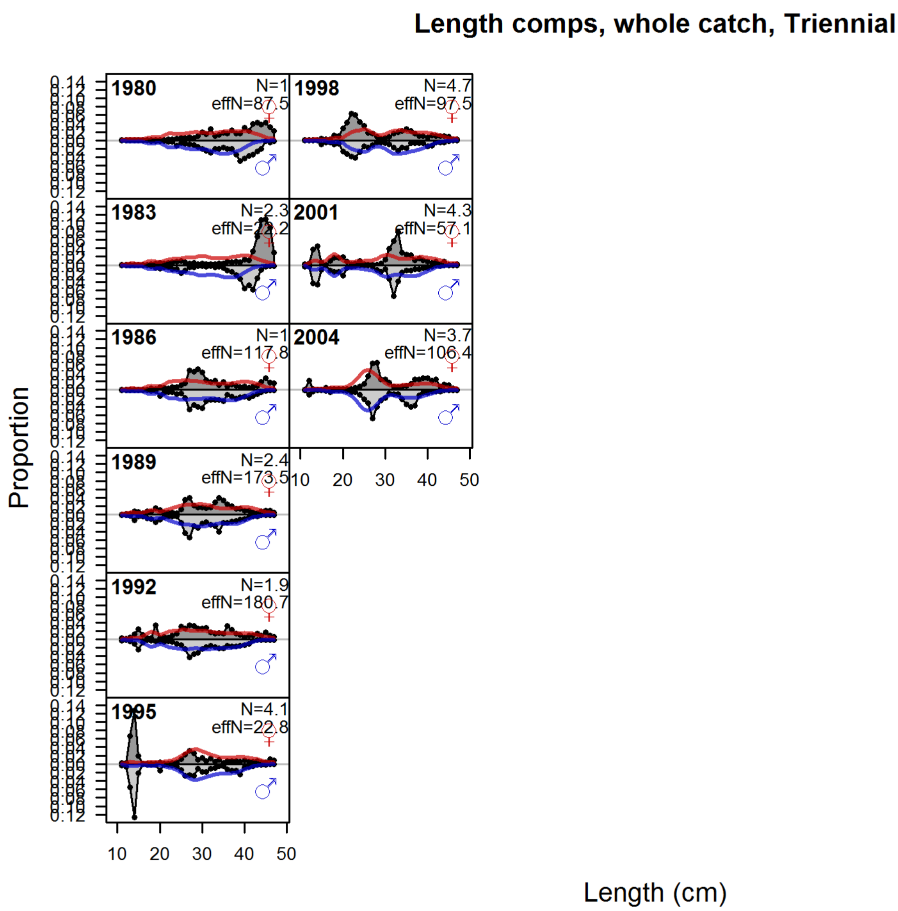

Figure 47: Length comps, whole catch, Triennial fig:mod1_18_comp_lenfit_flt5mkt0

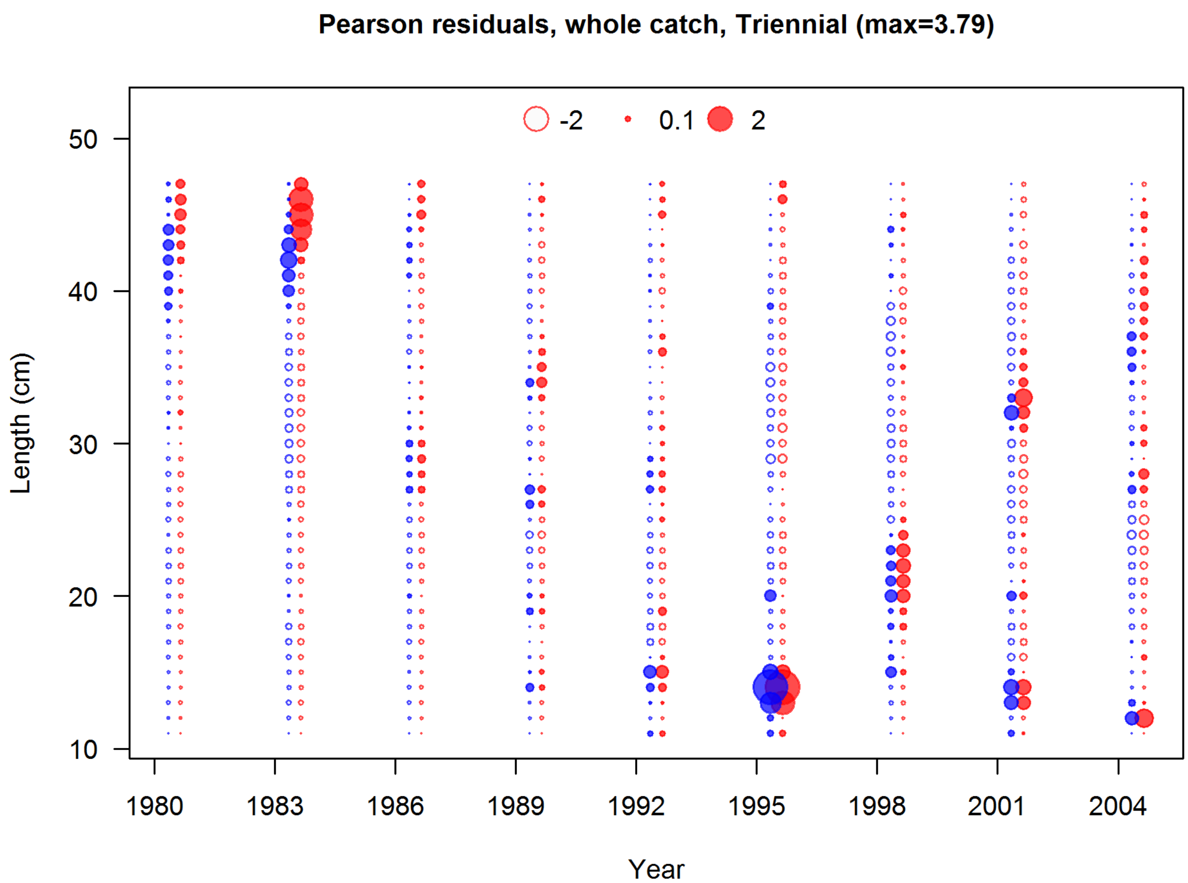

Figure 48: Pearson residuals, whole catch, Triennial (max=3.79)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_19_comp_lenfit_residsflt5mkt0

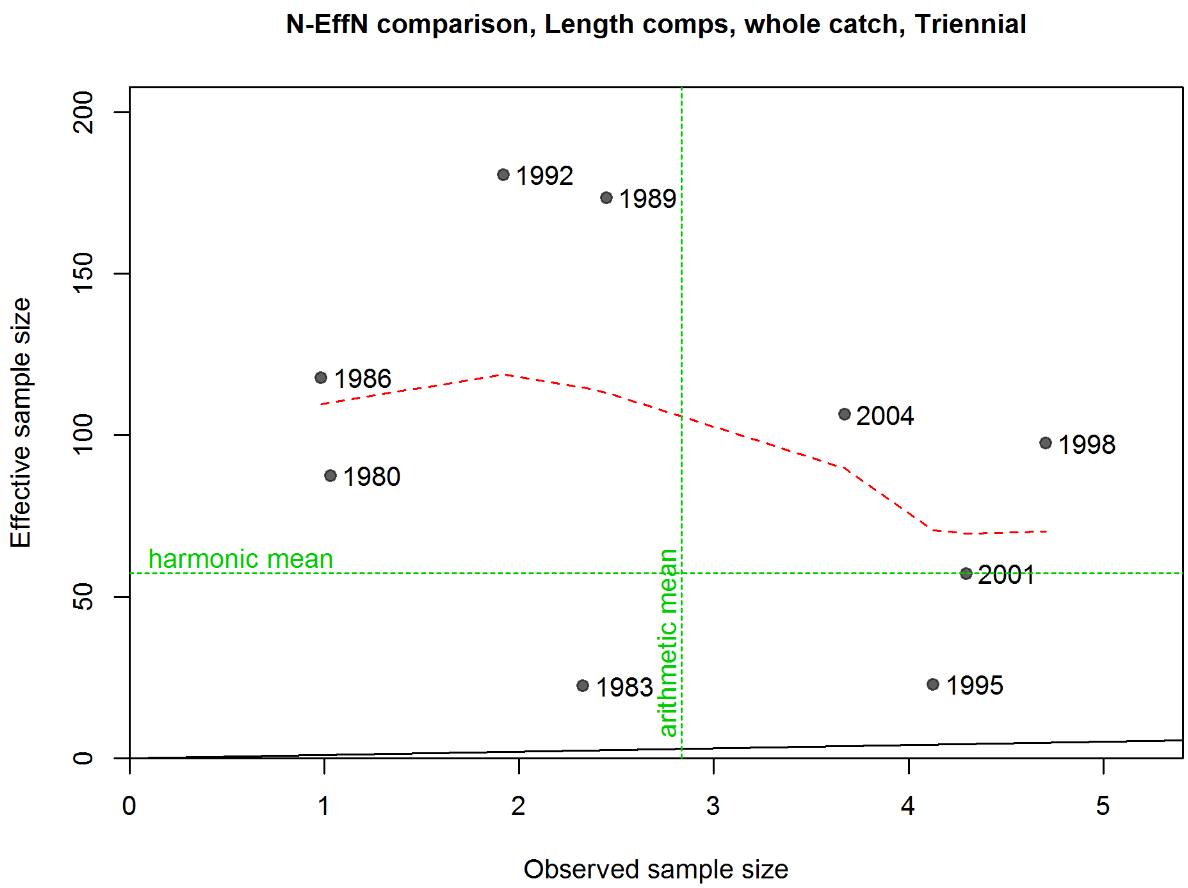

Figure 49: N_EffN comparison, Length comps, whole catch, Triennial fig:mod1_20_comp_lenfi

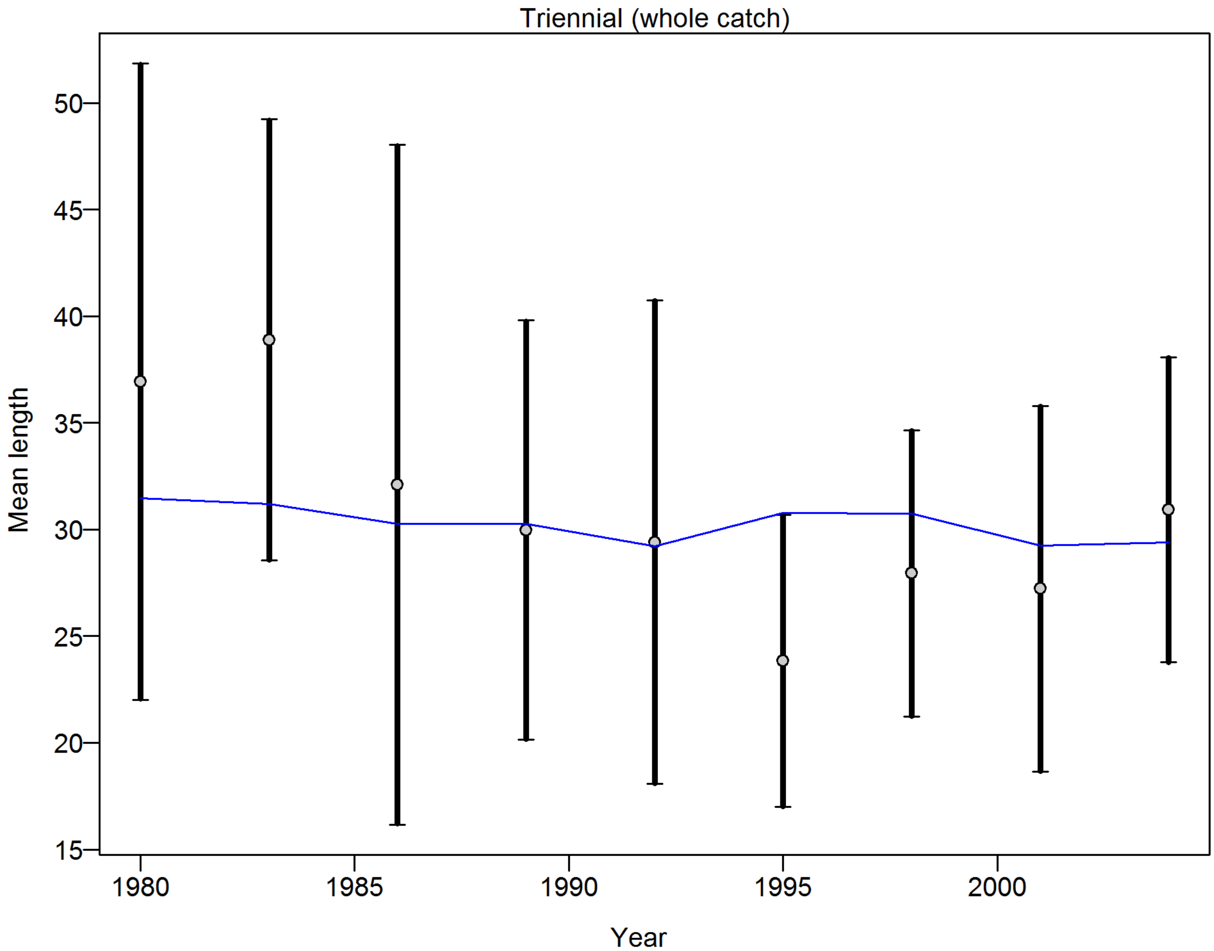

Figure 50: Francis data weighting method TA1.8: Triennial Suggested sample size adjustment (with 95% interval) for len data from Triennial: 0.9935 (0.53_6.6425) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. fig:mod1_21_comp_lenfit_data_weighting_TA1.8_Triennial

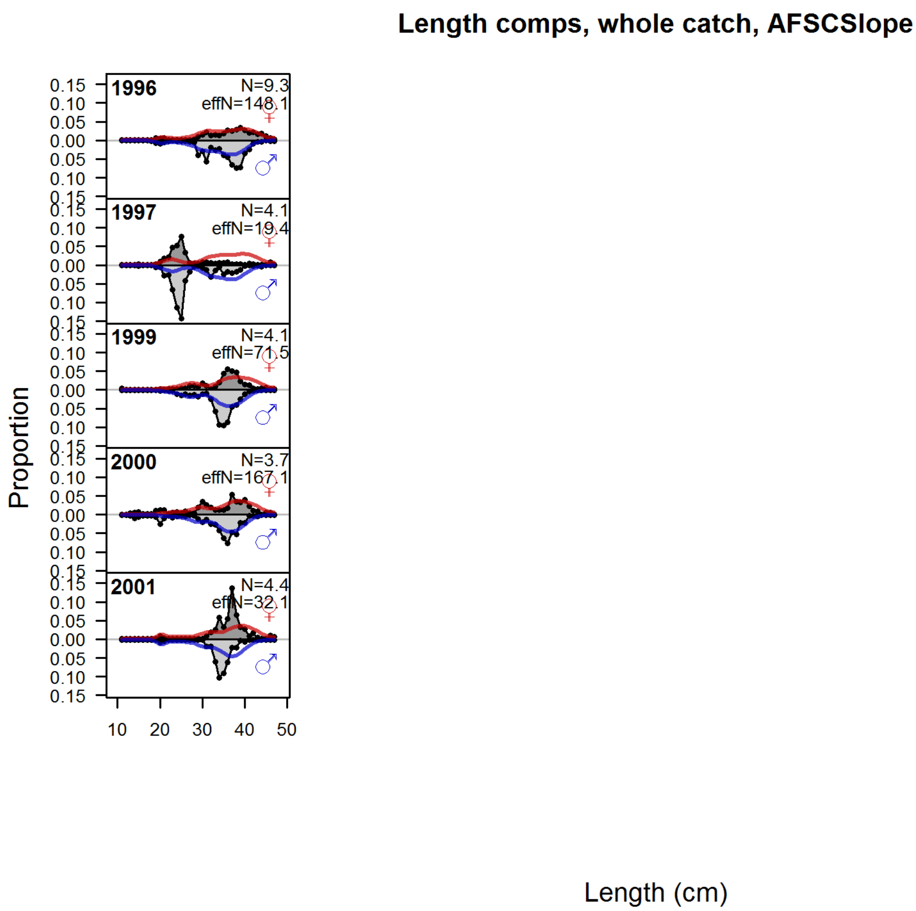

Figure 51: Length comps, whole catch, AFSCSlope fig:mod1_22_comp_lenfit_flt6mkt

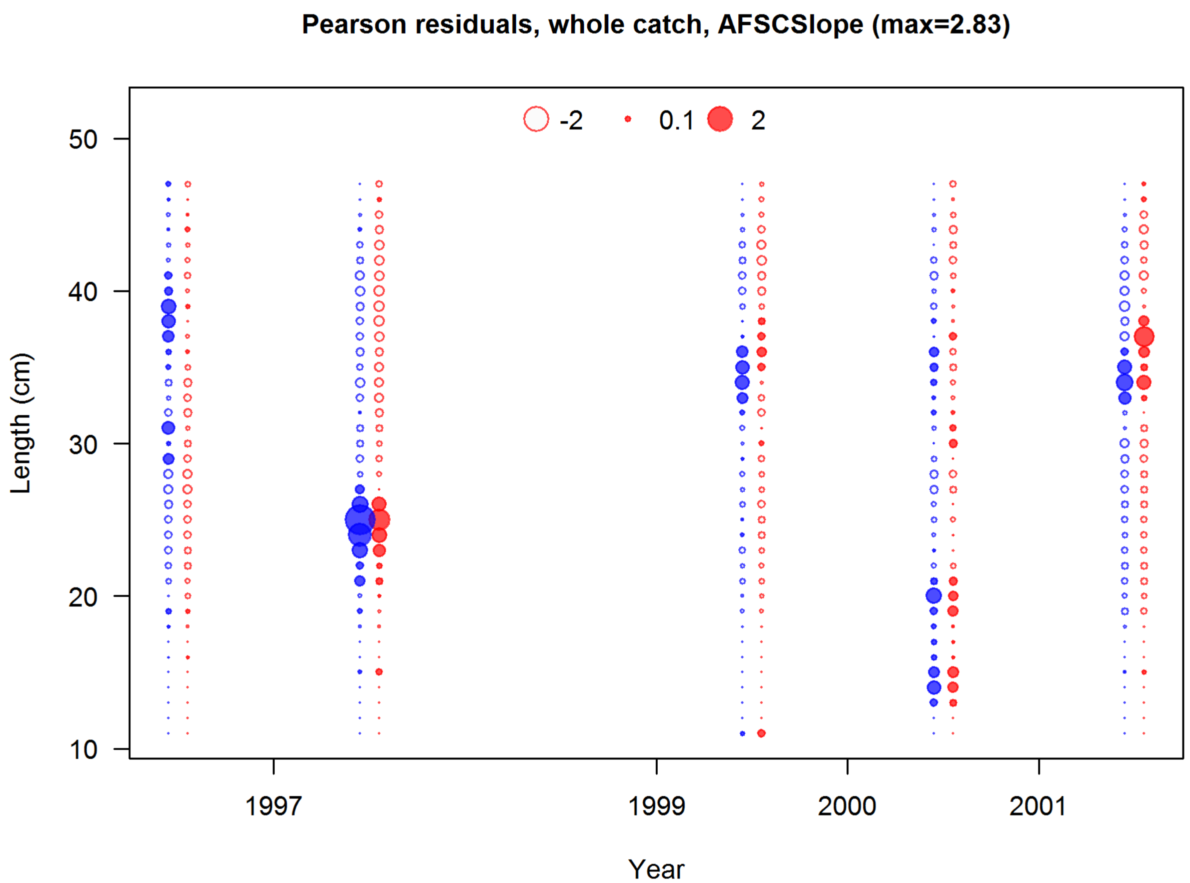

Figure 52: Pearson residuals, whole catch, AFSCSlope (max=2.83)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_23_comp_lenfit_residsflt6mkt0

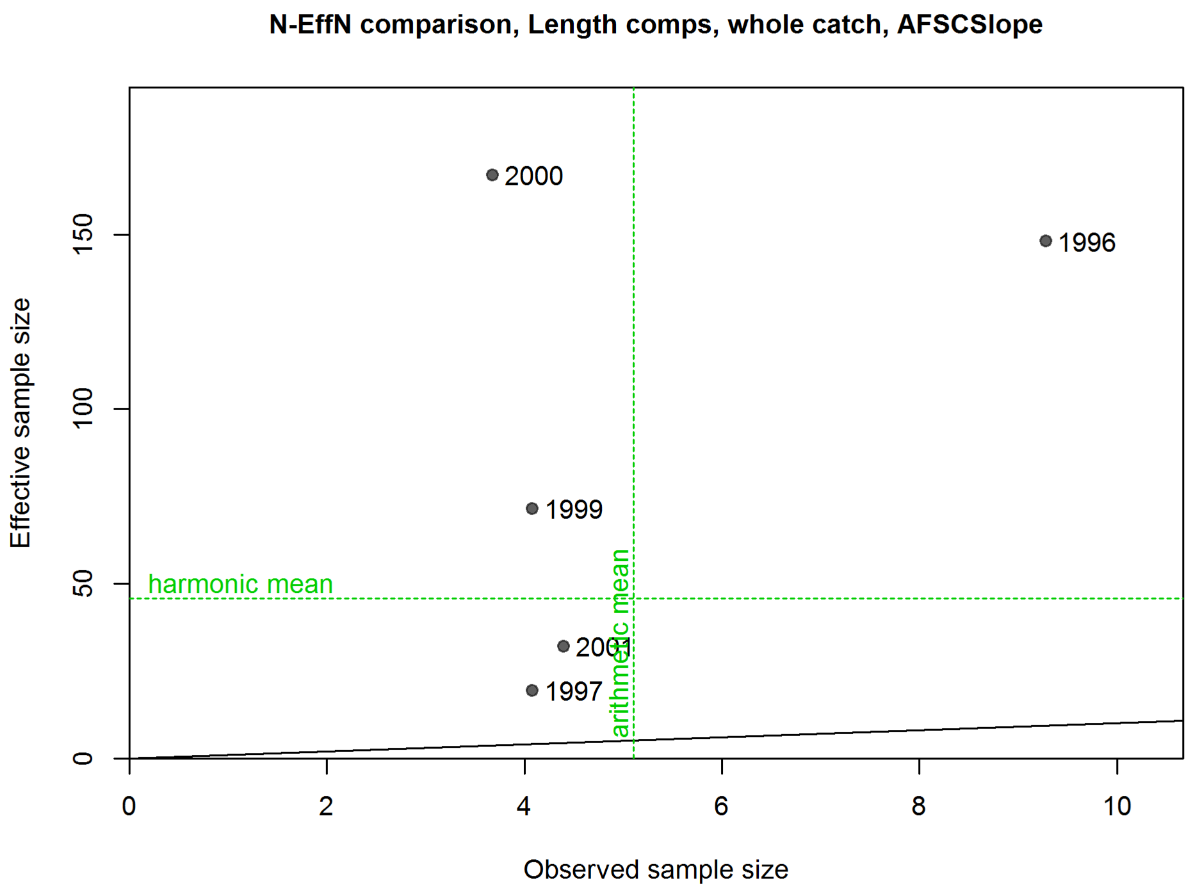

Figure 53: N_EffN comparison, Length comps, whole catch, AFSCSlope fig:mod1_24_comp_lenf

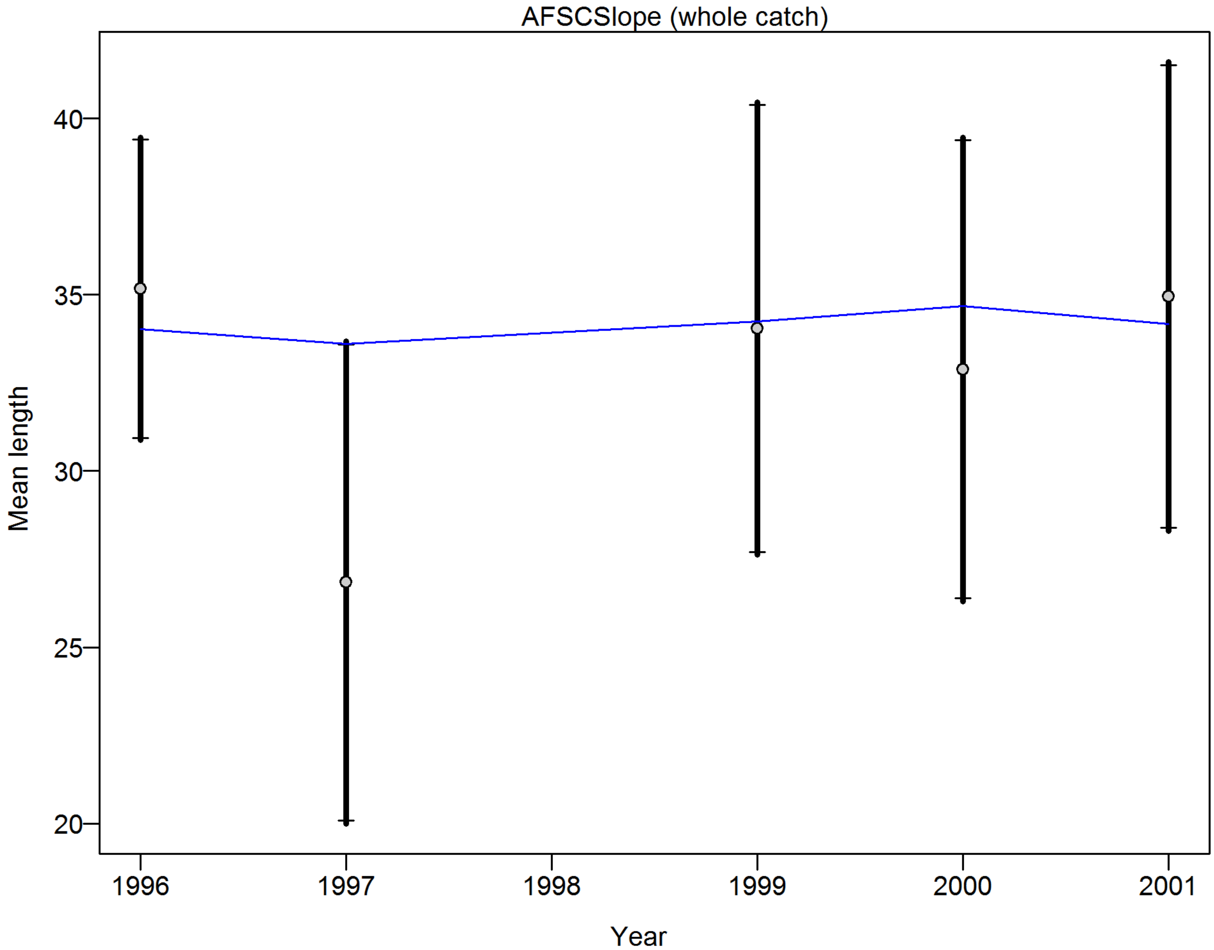

Figure 54: Francis data weighting method TA1.8: AFSCSlope Suggested sample size adjustment (with 95% interval) for len data from AFSCSlope: 1.0261 (0.6002_22.4243) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. fig:mod1_25_comp_lenfit_data_weighting_TA1.8_AFSC

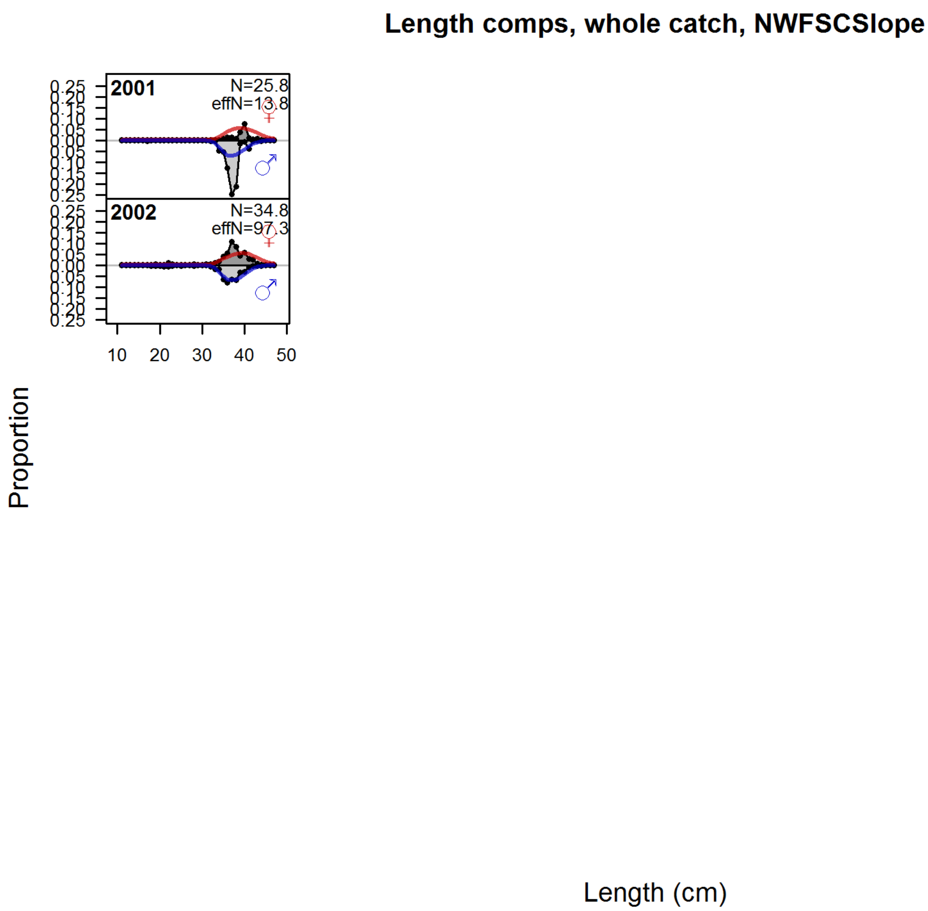

Figure 55: Length comps, whole catch, NWFSCSlope fig:mod1_26_comp_lenfit_flt7ml

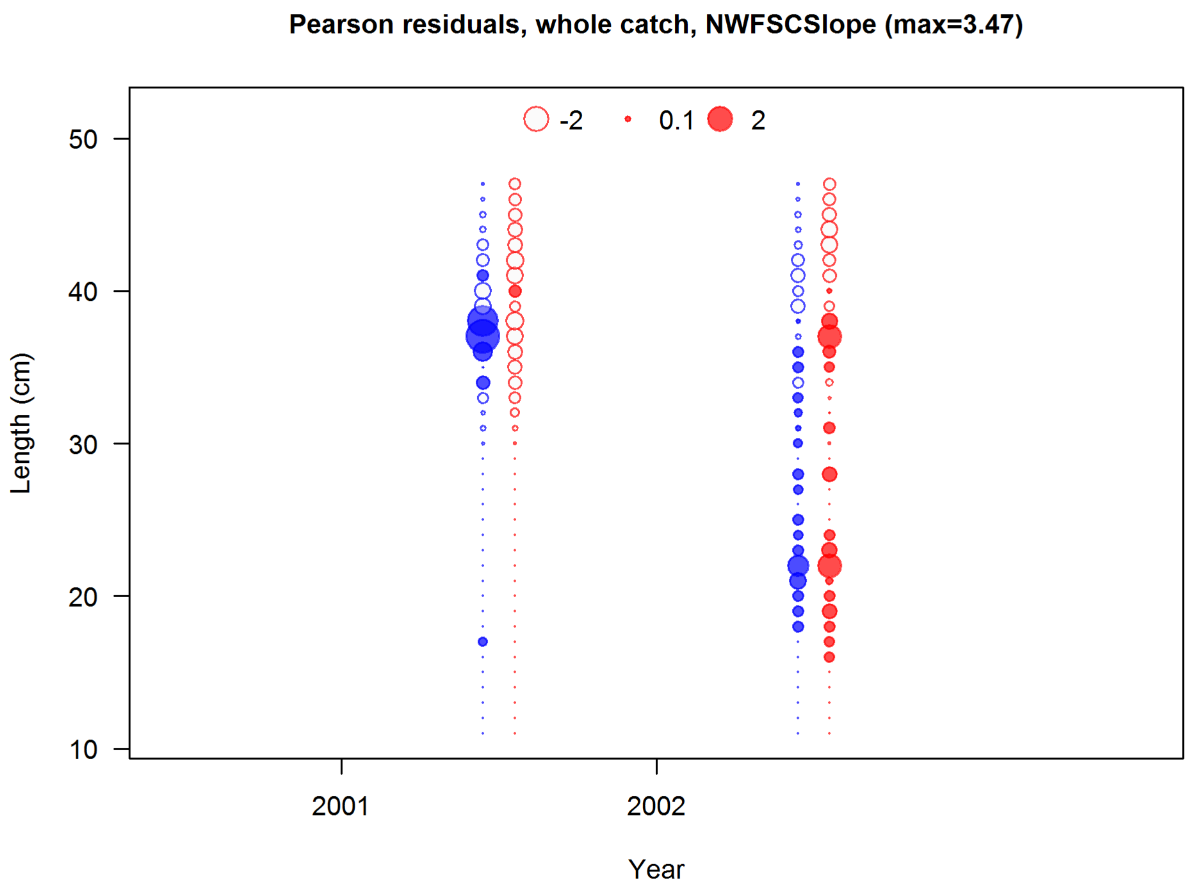

Figure 56: Pearson residuals, whole catch, NWFSCSlope (max=3.47)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_27_comp_lenfit_residsflt7mkt0

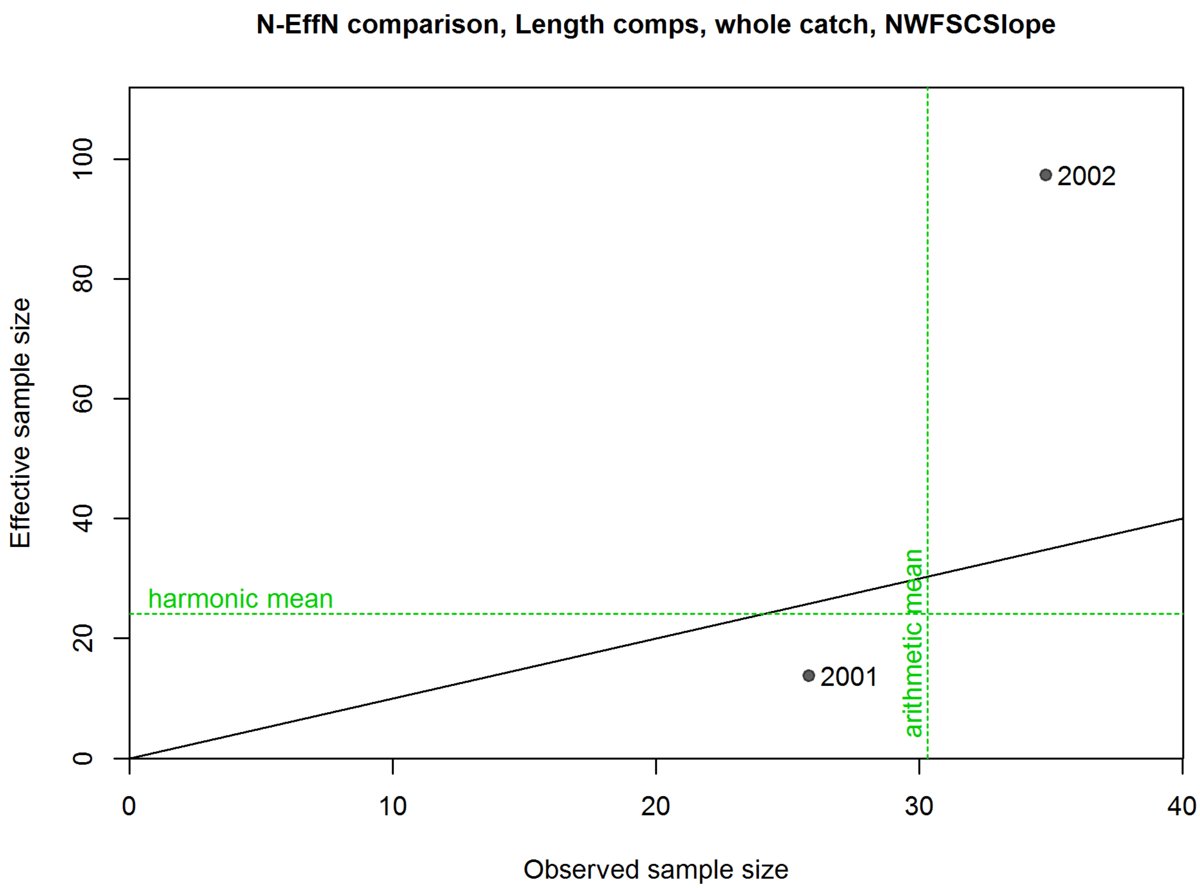

Figure 57: N_EffN comparison, Length comps, whole catch, NWFSCSlope fig:mod1_28_comp_len

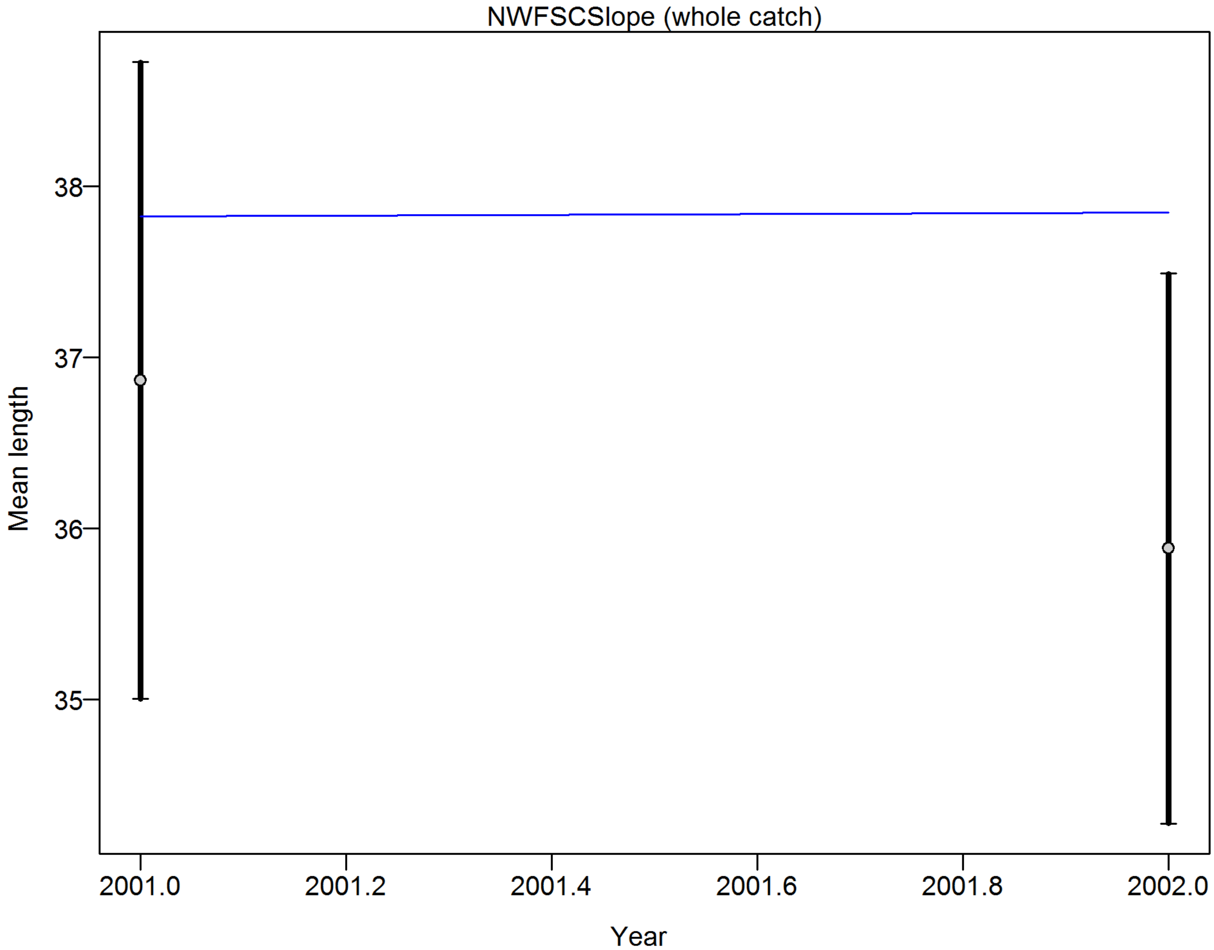

Figure 58: Francis data weighting method TA1.8: NWFSCSlope Suggested sample size adjustment (with 95% interval) for len data from NWFSCSlope: 0.9981 (0.9981_Inf) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. fig:mod1_29_comp_lenfit_data_weighting_TA1.8_NWFS

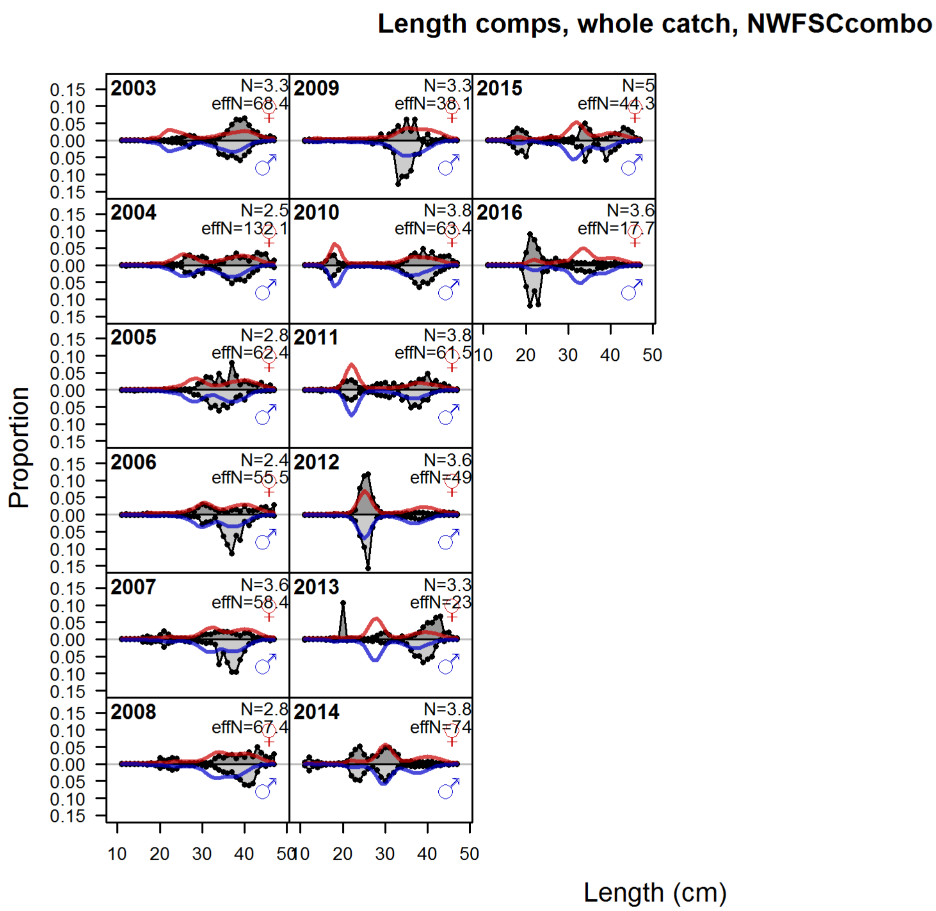

Figure 59: Length comps, whole catch, NWFSCcombo fig:mod1_30_comp_lenfit_flt8m

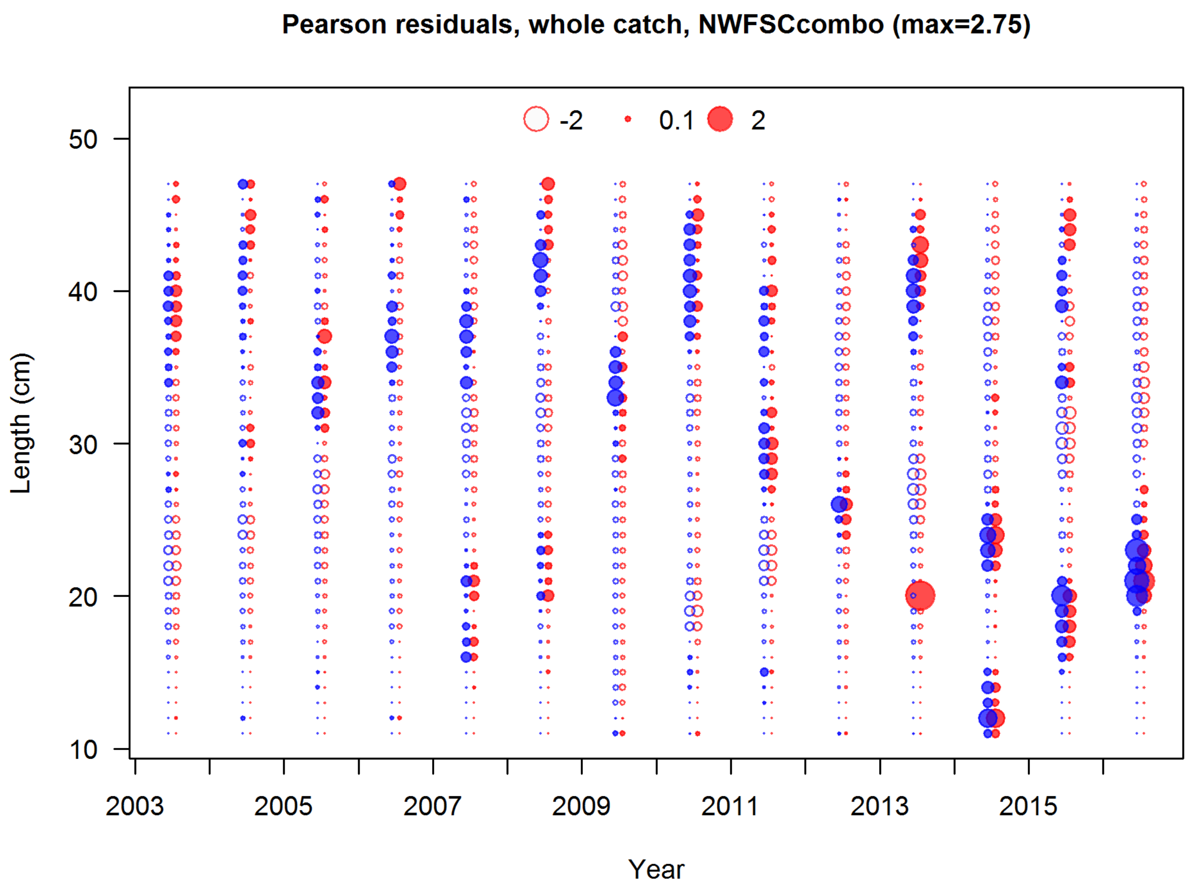

Figure 60: Pearson residuals, whole catch, NWFSCcombo (max=2.75)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:mod1_31_comp_lenfit_residsflt8mkt0

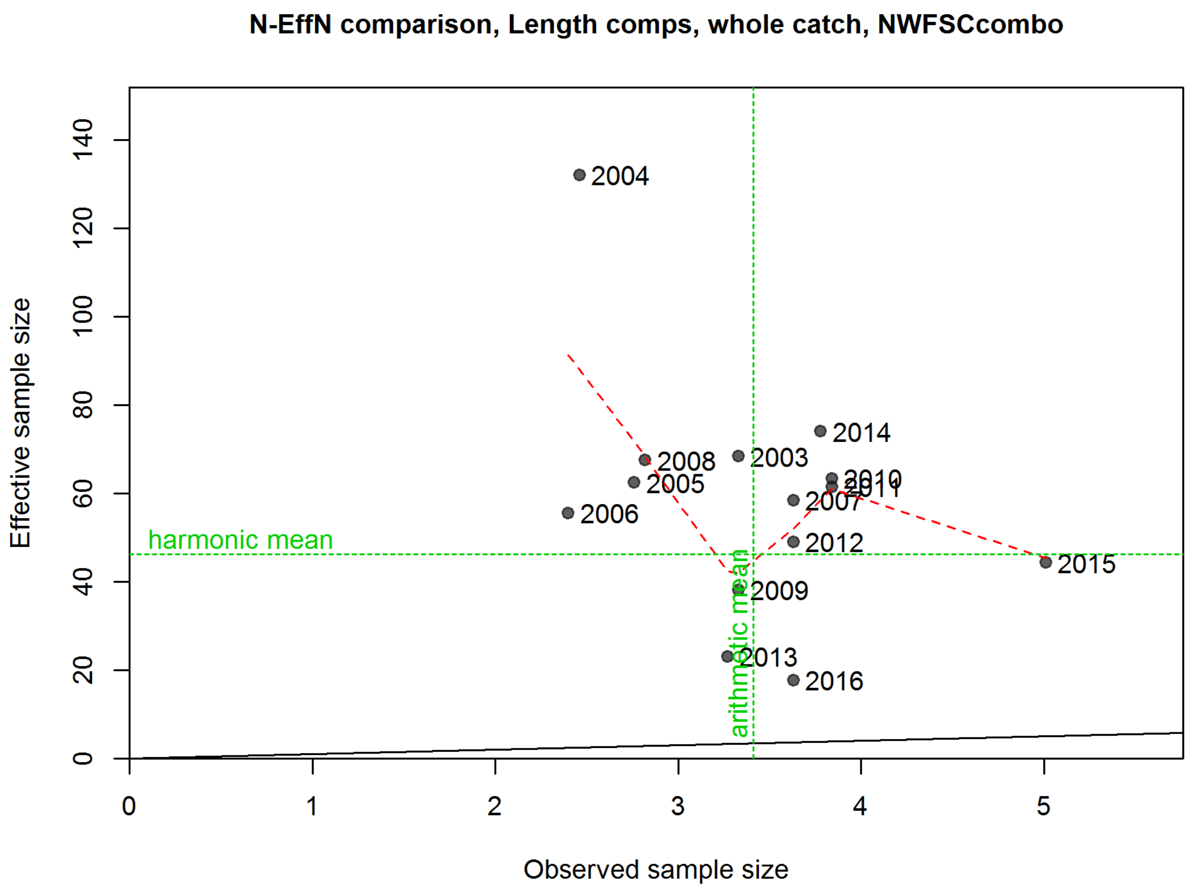

Figure 61: N_EffN comparison, Length comps, whole catch, NWFSCcombo fig:mod1_32_comp_ler

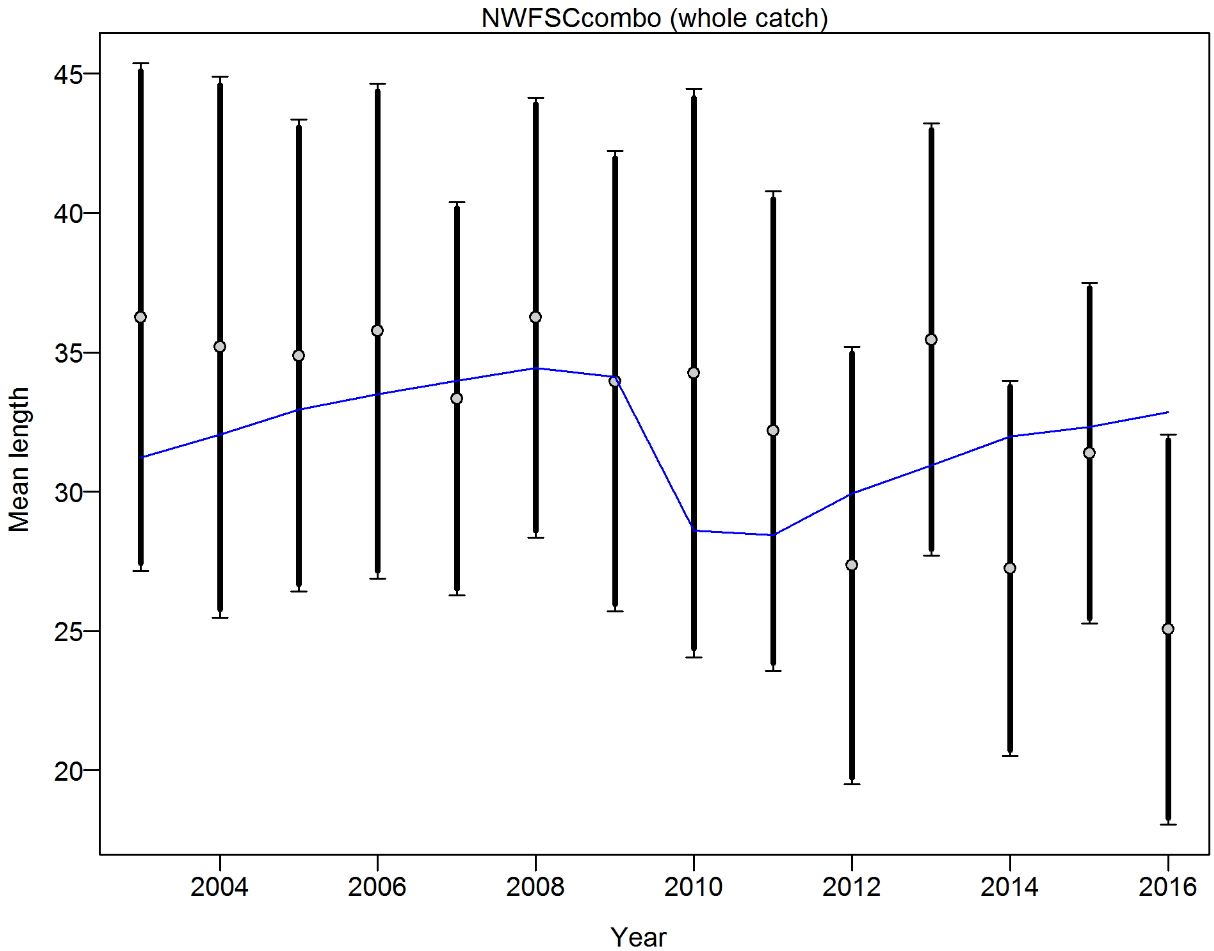

Figure 62: Francis data weighting method TA1.8: NWFSCcombo Suggested sample size adjustment (with 95% interval) for len data from NWFSCcombo: 0.939 (0.5631_3.8596) For more info, see Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124_1138. fig:mod1_33_comp_lenfit_data_weighting_TA1.8_NWFS

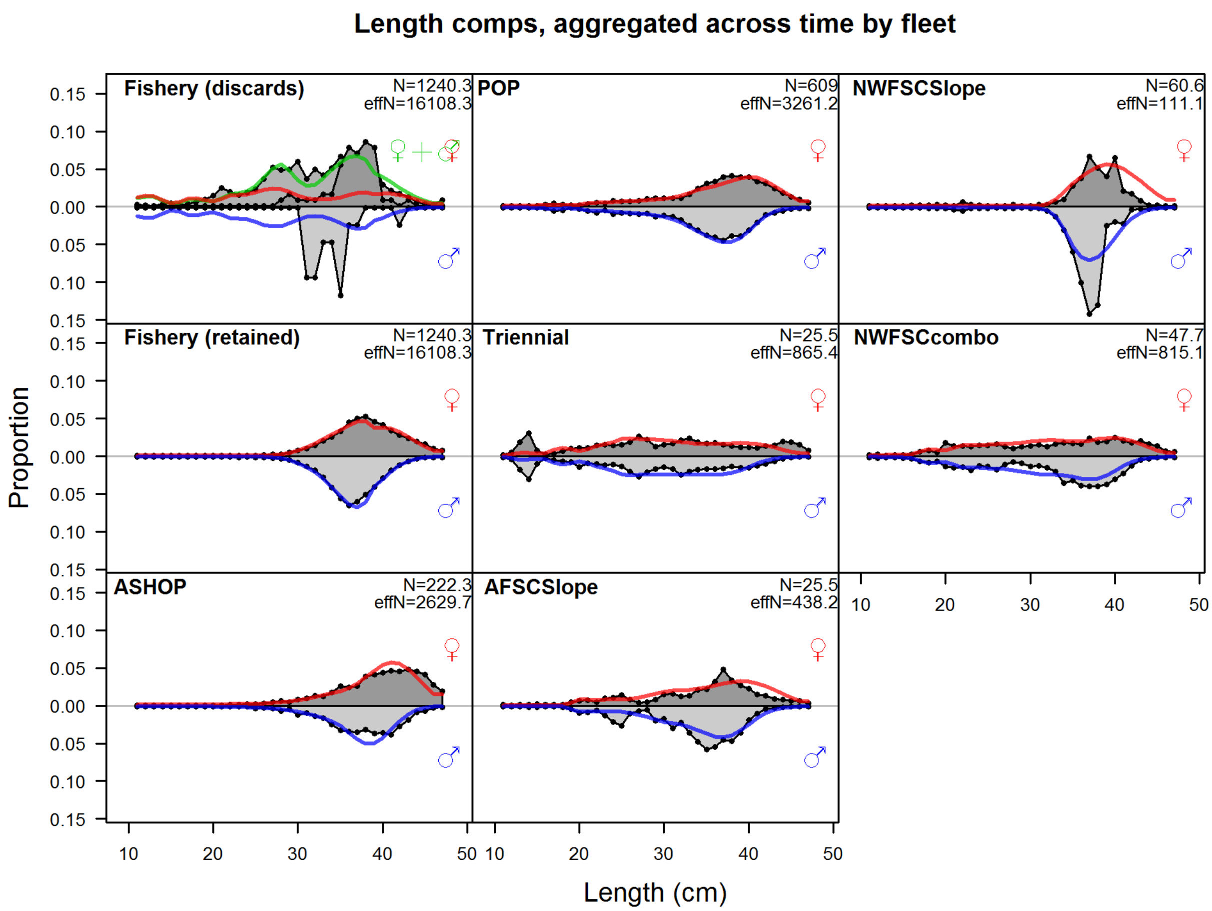

Figure 63: Length comps, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. fig:mod1_34_comp_lenfit__aggregated_across_time

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. 1981. An updated cohort analysis for Pacific ocean perch stocks off Washington and Oregon. Unpublished report, 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.

Hamel, O.S., and Ono, K. 2011. Stock Assessment of Pacific Ocean Perch in Waters off of the U.S. West Coast in 2011. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.

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.

Helser, T., Punt, A.E., and Methot, R.D. 2004. A generalized linear mixed model analysis of a multi-vessel fishery resouce survey. **70**: 251–264.

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].

Ianelli, J.N., and Zimmermann, M. 1998. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 1998. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.

Ianelli, J.N., Ito, D.H., and Wilkins, M. 1992. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 1992. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.

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

Kristensen, K., Nielsen, A., Berg, C.W., Skaug, H.J., and Bell, B. 2016. TMB: Automatic Differentiation and Laplace Approximation. Journal of Statistical Software **70**: 1–21.

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].

Punt, A.E., Smith, D.C., KrusicGolub, K., and Robertson, S. 2008. Quantifying age-reading error for use in fisheries stock assessments, with application to species in Australia's southern and eastern scalefish and shark fishery. Canadian Journal of Fisheries and Aquatic Sciences **65**(9): 1991–2005. doi: 10.1139/F08-111.

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].

Stewart, I.J., and Hamel, O.S. 2014. Bootstrapping of sample sizes for length- or age-composition data used in stock assessments. Canadian Journal of Fisheries and Aquatic Sciences **71**(4): 581–588. doi: 10.1139/cjfas-2013-0289.

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.

Thorson, J.T., and Kristensen, K. 2016. Implementing a generic method for bias correction in statistical models using random effects, with spatial and population dynamics examples. Fisheries Research **175**: 66–74. doi: 10.1016/j.fishres.2015.11.016.

Thorson, J.T., and Ward, E.J. 2014. Accounting for vessel effects when standardizing catch rates from cooperative surveys. Fisheries Research **155**: 168–176. doi: 10.1016/j.fishres.2014.02.036.

Thorson, J.T., Shelton, A.O., Ward, E.J., and Skaug, H.J. 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES Journal of Marine Science **72**(5): 1297–1310. doi: 10.1093/icesjms/fsu243.

Thorson, J.T., Stewart, I.J., and Punt, A.E. 2012. nwfscAgeingError: A user interface in R for the Punt et al. (2008) method for calculating ageing error and imprecision. Available from: http://github.com/nwfsc-assess/nwfscAgeingError/.

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.