Status of petrale sole (*Eopsetta jordani*) along the U.S. west coast in 2019

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Stock

stock

This assessment reports the status of the petrale sole (*Eopsetta jordani*) off U.S. coast of California, Oregon, and Washington using data through 2018. While petrale sole are modeled as a single stock, the spatial aspects of the coast-wide population are addressed through geographic separation of data sources/fleets where possible. There is currently no genetic evidence suggesting distinct biological stocks of petrale sole off the U.S. coast. The limited tagging data available to describe adult movement suggests that petrale sole may have some homing ability for deep water spawning sites but also have the ability to move long distances between spawning sites, inter-spawning season, as well as seasonally.

Landings

landings

While records do not exist, the earliest catches of petrale sole are reported in 1876 in California and 1884 in Oregon. In this assessment, fishery removals have been divided among 4 fleets: 1) winter North trawl, 2) summer North trawl, 3) winter South trawl, and 4) summer South trawl. Landings for the North fleet are defined as fish landed in Washington and Oregon ports. Landings for the South fleet are defined as fish landed in California ports. Recent annual catches between 1981-2018 range between 755 and 3008 mt per year and the most recent year landing are shown in Table a. Petrale sole are caught nearly exclusively by trawl fleets; non-trawl gears contribute less than 3% of the catches. Based on the 2005 assessment, annual catch limits (ACLs) were reduced to 2499 mt for 2007-2008. Following the 2009 assessment ACLs were further reduced to a low of 976 mt for 2011 and have subsequently increased to a high value of 3,136 for 2017. From the inception of the fishery through the war years, the vast majority of catches occurred between March and October (the summer fishery), when the stock is dispersed over the continental shelf. The post-World War II period witnessed a steady decline in the amount and proportion of annual catches occurring during the summer months (March-October). Conversely, petrale sole catch during the winter season (November-February), when the fishery targets spawning aggregations, has exhibited a steadily increasing trend since the 1940s. From the mid-1980s through the early 2000s, catches during the winter months were roughly equivalent to or exceeded catches throughout the remainder of the year, whereas during the past 10 years the relative catches during the winter and summer have been more variable across years (a). petrale sole are a desirable market species and discarding has historically been low.

Table a: Landings (mt) for the past 10 years for petrale sole by source.
tab:Exec_catch

Year	Winter (N)	Summer (N)	Winter (S)	Summer (S)	Total Landings
2009	846.71	641.75	469.66	250.38	2208.49
2010	258.09	292.34	77.60	120.95	748.98
2011	221.60	423.11	39.59	77.70	762.00
2012	406.05	477.71	124.46	107.63	1115.85
2013	509.04	1007.26	130.10	278.35	1924.74
2014	852.90	860.31	273.40	354.19	2340.80

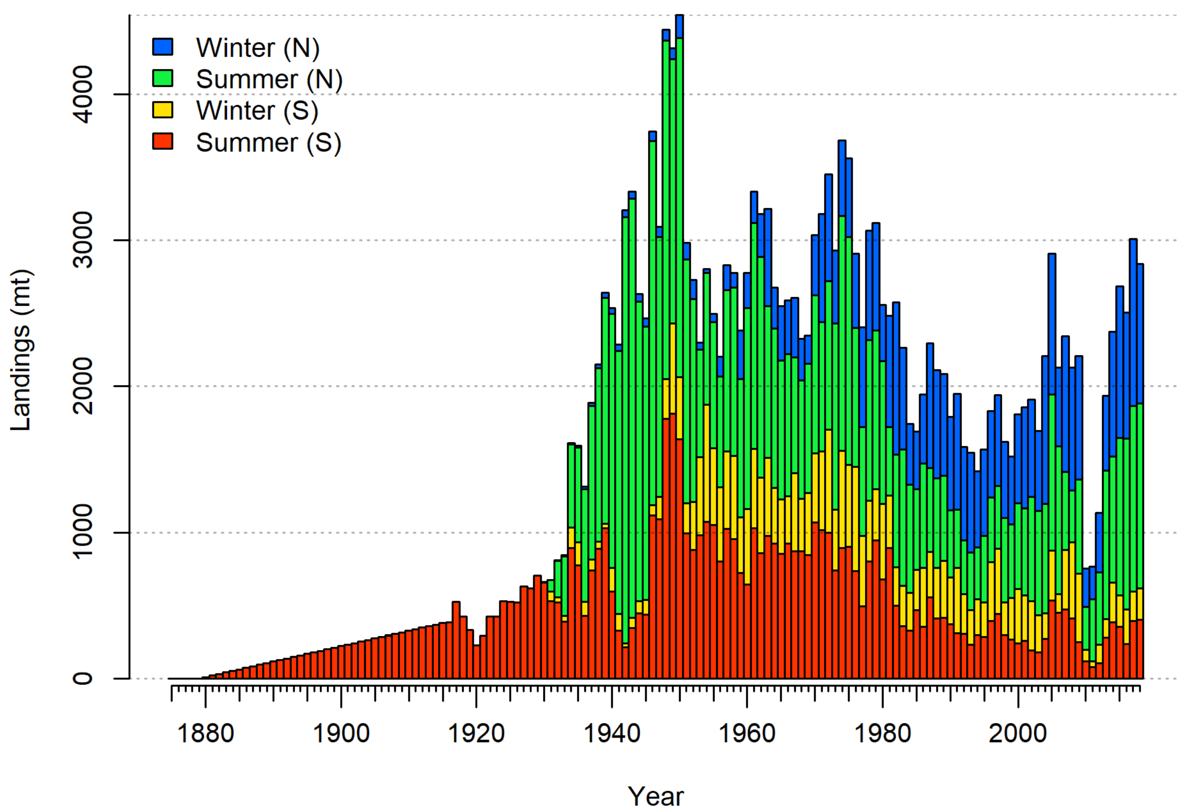

Figure a: 'Landings of by the Northern and Southern winter and summer fleets of the US west coast. fig:Exec_catch1

Data and Assessment

data-and-assessment

This an update assessment for petrale sole, which was last assessed in 2013 and updated in 2015. The update assessment was conducted using the length- and age-structured modeling software Stock Synthesis (version 3.30.13). The coastwide population was modeled allowing separate growth and mortality parameters for each sex (a two-sex model) with the fishing year beginning on November 1 and ending on October 31. The fisheries are structured seasonally based on winter (November to February) and summer (March to October) fishing seasons due to the development and growth of the wintertime fishery, which began in the 1950s. In recent decades wintertime catches have often exceed summertime catches. The fisheries modeled as the North Winter and North Summer, where the north includes both Washington and Oregon, and South Winter and South Summer encompasses California fisheries.

The model includes catch, length- and age-frequency data from the trawl fleets as well as standardized winter fishery catch-per-unit-effort (CPUE) indices. Biological data are derived from both port and on-board observer sampling programs. The National Marine Fisheries Service (NMFS) AFSC/NWFSC West Coast Triennial Shelf Survey early (1980, 1983, 1986, 1989, 1992) and late period (1995, 1998, 2001, and 2004) and the NWFSC West Coast Groundfish Bottom Trawl Survey (2003-2018) relative biomass indices and biological sampling provide fishery independent information on relative trend and demographics of the petrale sole stock.

Updated Data

updated-data

The base stock assessment model structure is consistent with the 2013 assessment and the 2015 update, except as noted here. Modifications from the previous assessment model include:

1. Model fitting using latest version of Stock Synthesis (SS v.3.30.13).
2. Added commercial fishery catch data (2015-2018).
3. Updated historical composition data from the commercial fishery (length and age data) and new data (2015 - 2018) expanded to trip and catch based on current best practices.
4. Updated discard rate, average weight, and discard length composition data (2014-2017).
5. NWFSC West Coast Groundfish Bottom Trawl Survey index of abundance was calculated using VAST.
6. Updated NWFSC West Coast Groundfish Bottom Trawl Survey length and age data (2015-2018) with all years data expanded to the tow and strata.
7. AFSC/NWFSC West Coast Triennial Shelf Survey early and late index of abundance were calculated using VAST.

8. Model tuning to re-weight data.

9. Length-weight relationship parameters estimated outside of the stock assessment model from the NWFSC West Coast Groundfish Bottom Trawl Survey data up to 2018 and input as fixed values.

10. Update the natural mortality prior for female and male fish.

Stock Biomass

stock-biomass

Petrale sole were lightly exploited during the early 1900s, but by the 1950s the fishery was well developed and showing clear signs of depletion and declines in catches and biomass (Figures a and b). The rate of decline in spawning biomass accelerated through the 1930s-1970s reaching minimums generally around or below 10% of the unexploited levels during the 1980s through the early 2000s (Figure c). The petrale sole spawning stock biomass is estimated to have increased in recent year due to reduced catches during rebuilding and in response to above average recruitment in 2006, 2007, and 2008. The 2019 estimated spawning biomass relative to unfished equilibrium spawning biomass is above the target of 25% of unfished spawning biomass at 32.3% (∼ 95% asymptotic interval: ± 21.9%-42.6%).

Table b: Recent trend in estimated spawning biomass (mt) and estimated relative spawning biomass (depletion).

tab:SpawningDeplete_mod1

Year	Spawning Biomass (mt)	˜ 95% Confidence Interval	Estimated Relative Spawning Biomass	˜ 95% Confidence Interval
2010	3494	2845 - 4143	0.114	0.077 - 0.152
2011	4414	3606 - 5222	0.144	0.098 - 0.191
2012	5904	4858 - 6950	0.193	0.132 - 0.255
2013	7751	6410 - 9091	0.254	0.174 - 0.333
2014	9284	7682 - 10886	0.304	0.209 - 0.398
2015	10202	8441 - 11962	0.334	0.231 - 0.436
2016	10439	8593 - 12284	0.342	0.237 - 0.446
2017	10531	8606 - 12457	0.345	0.240 - 0.449
2018	10213	8186 - 12240	0.334	0.231 - 0.437
2019	9867	7682 - 12052	0.323	0.219 - 0.426

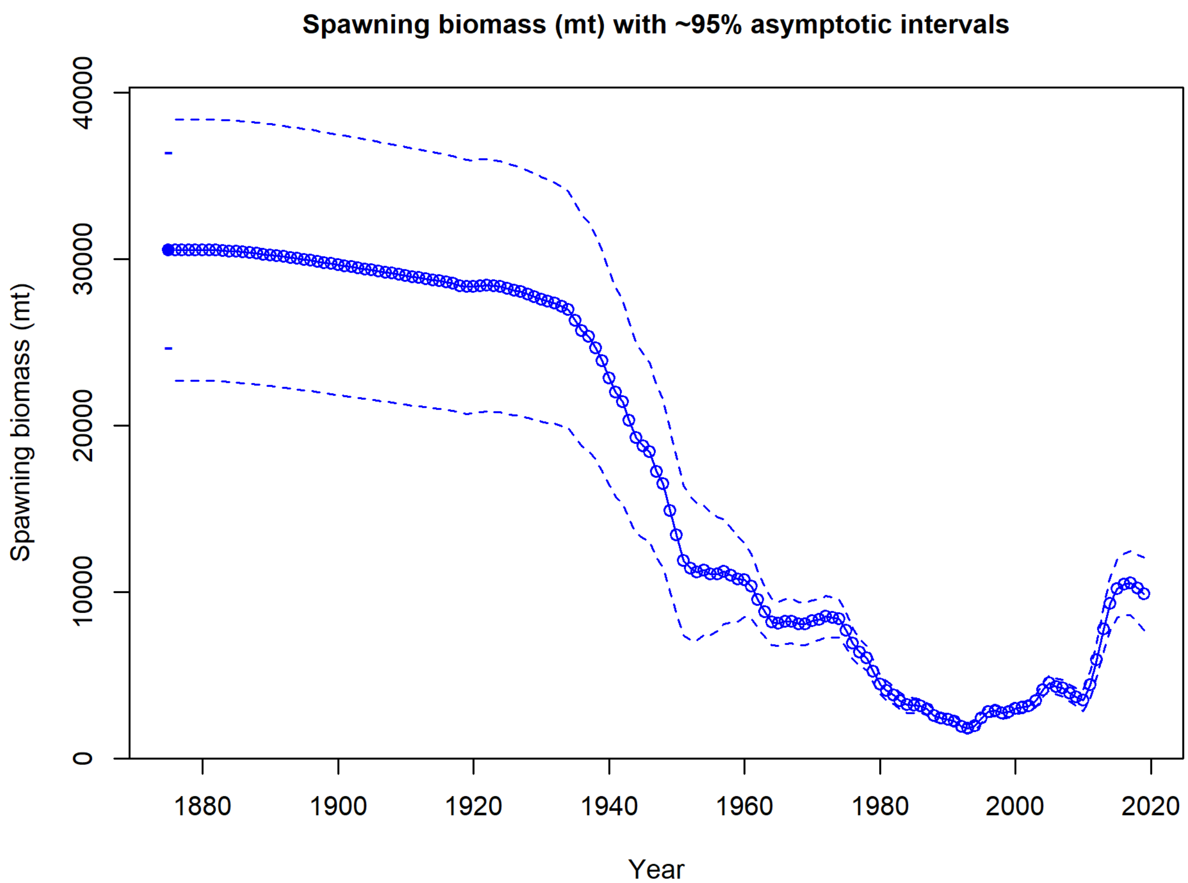

Figure b: Estimated time-series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model. fig:Spawnbio_all

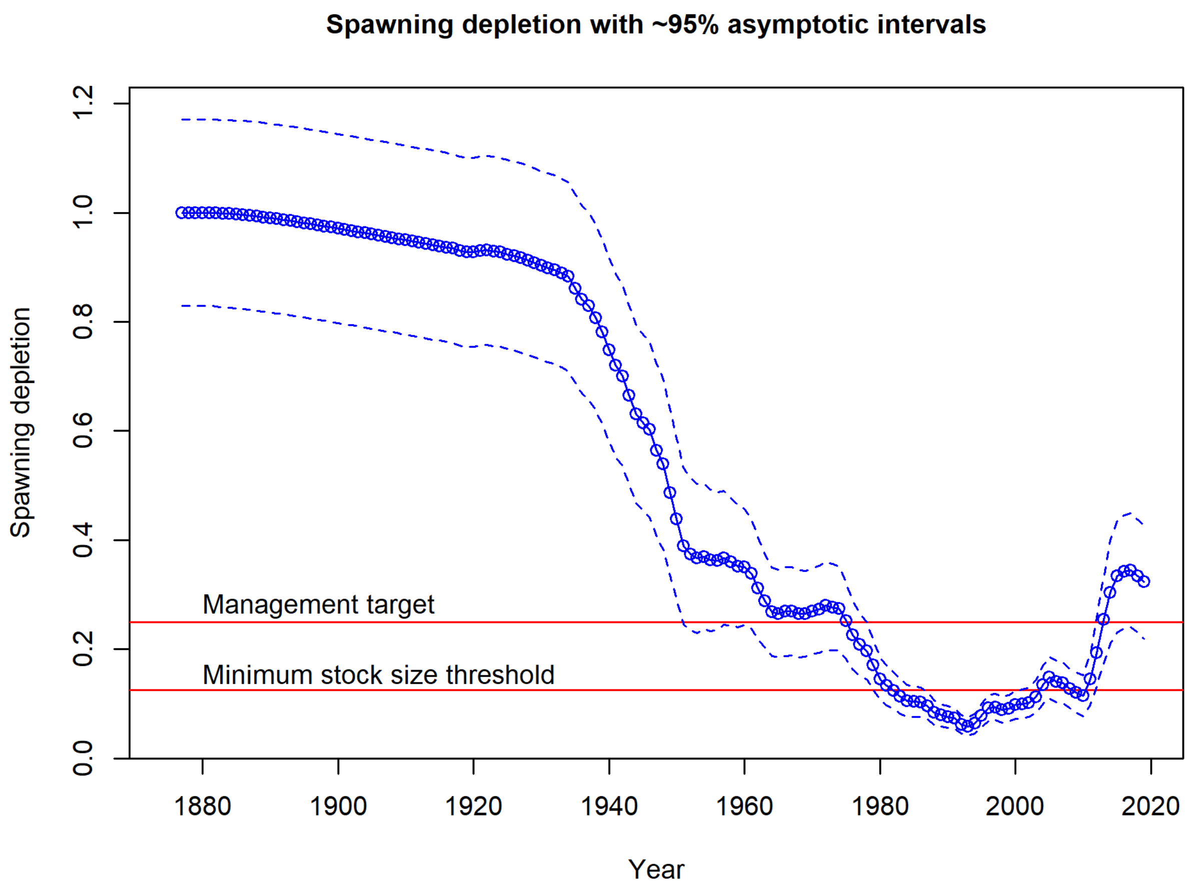

Figure c: Estimated time-series of relative spawning biomass (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model. fig:RelDeplete_all

Recruitment

recruitment

Annual recruitment was treated as stochastic, and estimated as annual deviations from log-mean recruitment where mean recruitment is the fitted Beverton-Holt stock recruitment curve. The time-series of estimated recruitments shows a relationship with the decline in spawning biomass, punctuated by larger recruitments (Figure d) in 2006, 2007, and 2008. The five largest estimated recruitment estimated with the model (in ascending order) occurred in 2006, 2007, 1998, 1966, and 2008. The four lowest recruitments estimated within the model (in ascending order) occurred in 1986, 1992, 1973, and 1987.

Table c: Recent estimated trend in recruitment and estimated recruitment deviations determined from the base model. The recruitment deviations for 2018 and 2019 were fixed at zero within the model.

tab:Recruit_mod1

Year	Estimated Recruitment	~ 95% Confidence Interval	Estimated Recruitment Devs.	~ 95% Confidence Interval
2010	11740	7281 - 18929	-0.083	-0.411 - 0.244
2011	13434	8205 - 21994	-0.014	-0.358 - 0.330
2012	19781	12473 - 31372	0.306	0.002 - 0.609
2013	12763	7331 - 22221	-0.183	-0.631 - 0.265
2014	13826	7883 - 24251	-0.130	-0.586 - 0.325
2015	13751	7464 - 25334	-0.149	-0.664 - 0.366
2016	13924	6927 - 27992	-0.160	-0.771 - 0.451
2017	15071	6851 - 33154	-0.104	-0.837 - 0.630
2018	17012	7437 - 38914	0.000	-0.784 - 0.784
2019	16935	7409 - 38710	0.000	-0.784 - 0.784

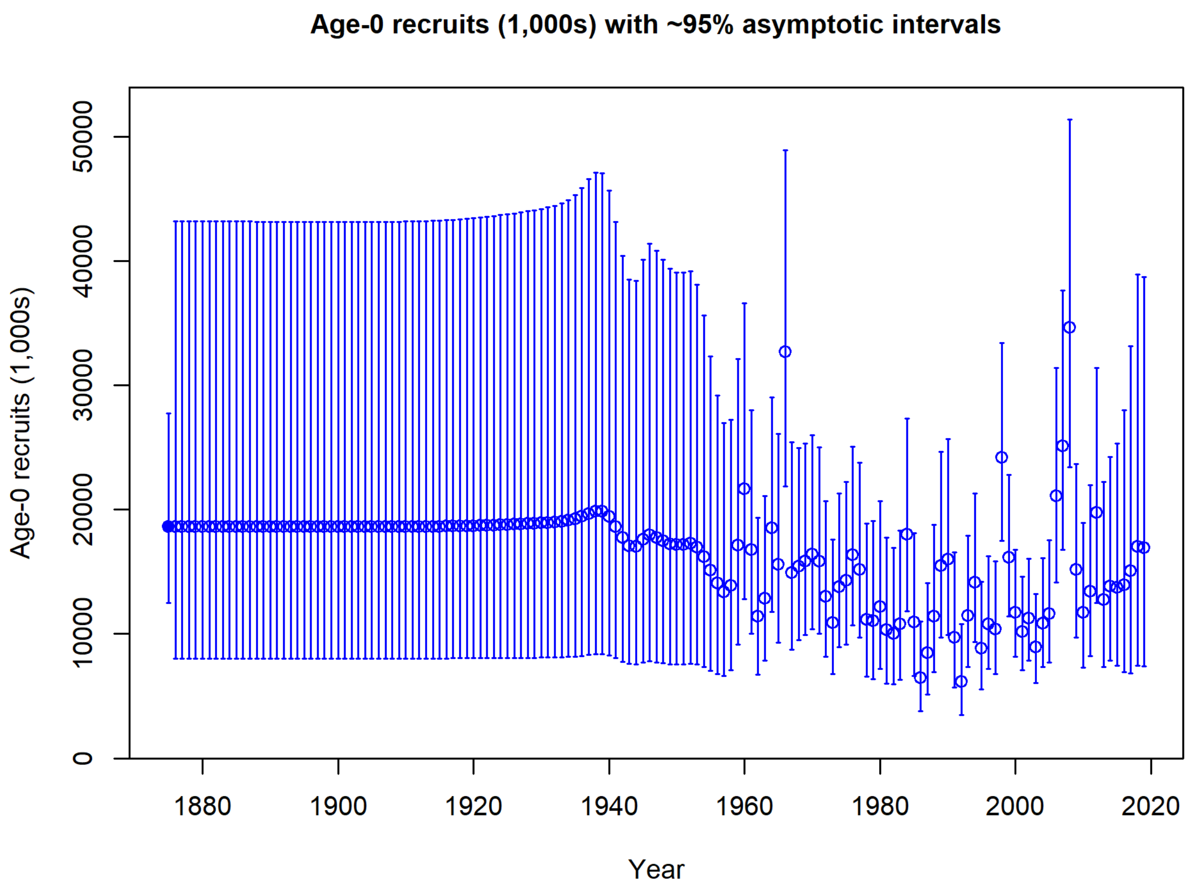

Figure d: Time-series of estimated petrale sole recruitments for the base model with 95% confidence or credibility intervals. fig:Recruits_all

Exploitation Status

exploitation-status

The relative spawning biomass of of petrale sole was estimated to have dropped below the management target (25%) for the first time in 1976. The stock continued to decline and first fell below the minimum stock size threshold level of 12.5% in 1982. The relative spawning biomass remained around the threshold stock size until approximately 2010, with the stock reaching its lowest relative spawning biomass level in 1993 at 5.8%. In 2009 petrale sole was formally declared overfished. Fishing mortality rates sharply declined during the rebuilding period relative to previous year rates which exceeded the target (Figure e). After reduced harvests, the 2015 update stock assessment estimated the stock to have rebuilt to the management target (25%) in 2014. This update estimates that the relative spawning biomass exceed 25% in 2013 with harvest rates in the most recent years remaining just under of the target rate (Figure e).

Table d: Recent trend in spawning potential ratio 1-SPR and summary exploitation rate for age 3+ biomass for petrale sole.

tab:SPR_Exploit_mod1

Year	1-SPR	˜ 95% Confidence Interval	Exploitation Rate	˜ 95% Confidence Interval
2009	0.822	0.757 - 0.888	0.271	0.223 - 0.318
2010	0.625	0.521 - 0.728	0.091	0.072 - 0.111
2011	0.552	0.446 - 0.658	0.062	0.049 - 0.075
2012	0.568	0.466 - 0.671	0.074	0.060 - 0.089
2013	0.632	0.535 - 0.730	0.111	0.090 - 0.131
2014	0.633	0.537 - 0.729	0.126	0.104 - 0.149
2015	0.644	0.549 - 0.738	0.138	0.113 - 0.163
2016	0.618	0.521 - 0.714	0.129	0.105 - 0.153
2017	0.654	0.561 - 0.747	0.155	0.126 - 0.185
2018	0.649	0.555 - 0.743	0.152	0.121 - 0.183

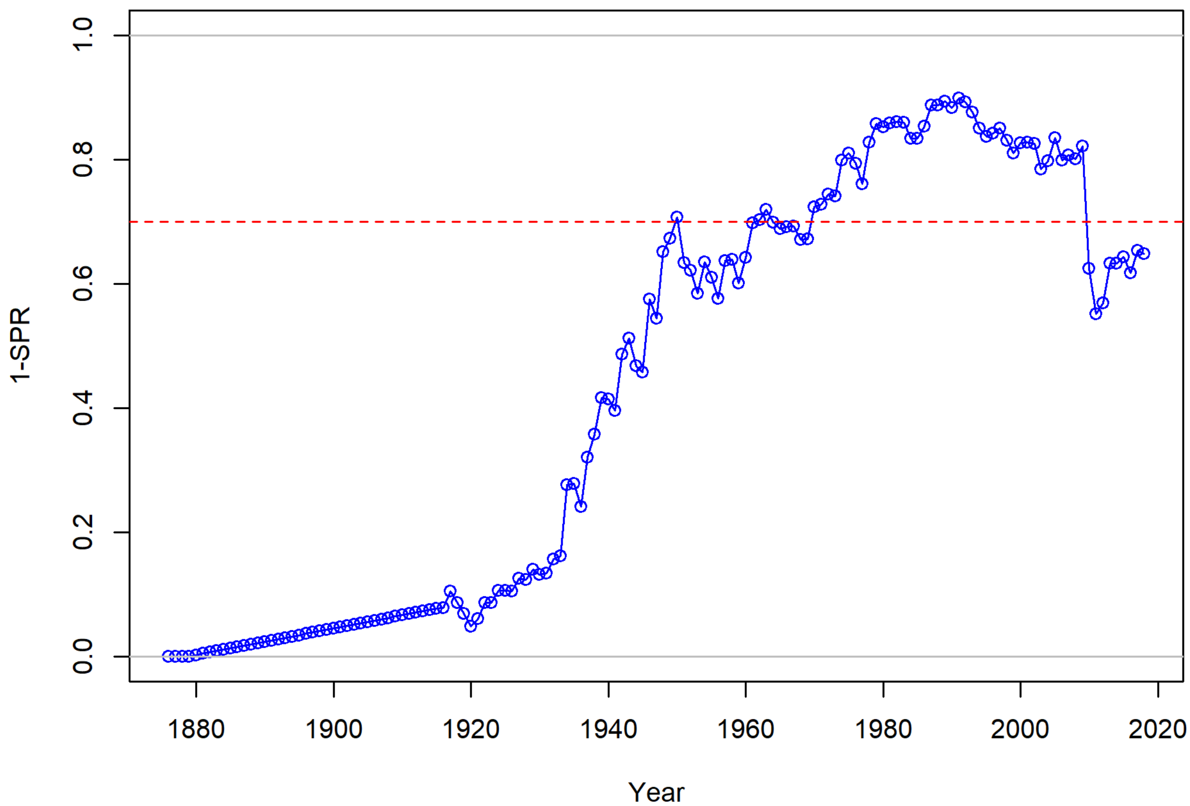

Figure e: Estimated relative spawning potential ratio 1-SPR for the base model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR30% harvest rate. The last year in the time-series is 2018. fig:SPR_all

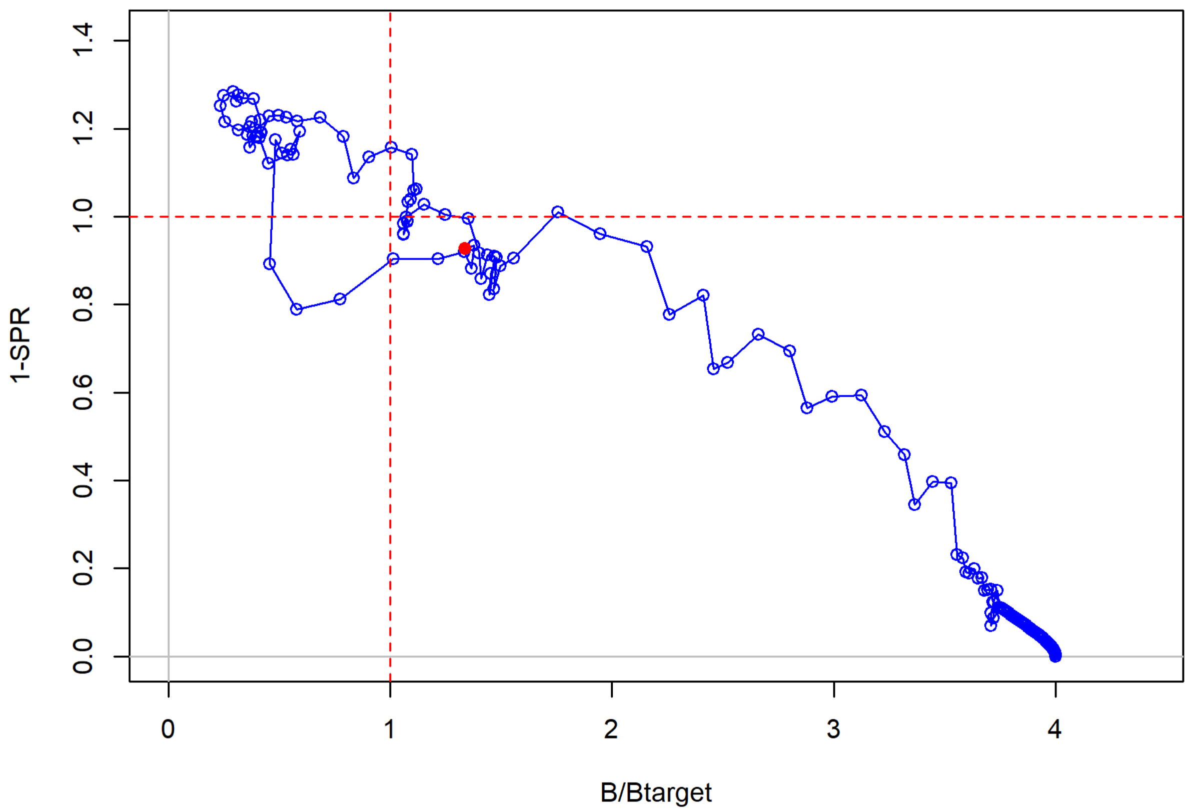

Figure f: Phase plot of estimated 1-SPR(%) vs. relative spawning biomass (B/Btarget) for the base case model. The red circle indicates 2018 estimated status and exploitation for petrale sole. fig:Phase_all

Ecosystem Considerations

ecosystem-considerations

Ecosystem factors have not been explicitly modeled in this assessment, but there are several aspects of the California current ecosystem that may impact petrale sole population dynamics and warrant further research. Castillo (1992) and Castillo et al. (1995) suggest that density-independent survival of early life stages is low and show that offshore Ekman transportation of eggs and larvae may be an important source of variation in year-class strength in the Columbia INPFC area. The effects of the Pacific Decadal Oscillation on California current temperature and productivity (Mantua et al. 1997) may also contribute to non-stationary recruitment dynamics for petrale sole. The prevalence of a strong late 1990s year-class for many West Coast groundfish species suggests that environmentally driven recruitment variation may be correlated among species with relatively diverse life history strategies. Although current research efforts along these lines are limited, a more explicit exploration of ecosystem processes may be possible in future petrale sole stock assessments if resources are available for such investigations.

Reference Points

reference-points

This stock assessment estimates that the spawning biomass of petrale sole is above the management target. Due to reduced landings and the large 2008 year-class, an increasing trend in spawning biomass was estimated in the base model. The estimated depletion in 2019 is 32.3% ($\sim$ 95% asymptotic interval: $\pm$ 21.9%-42.6%), corresponding to an spawning biomass of 9,867 mt ($\sim$ 95% asymptotic interval: 7,682-12,052 mt). Unfished age 3+ biomass was estimated to be 49,439.6 mt in the base model. The target spawning biomass based on the biomass target ($SB_{25\%}$) is 7,638.7 mt, with an equilibrium catch of 2,830.3 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{30\%}$ is 2,819.8 mt. Estimated MSY catch is at a 2,835.9 spawning biomass of 7,005.9 mt (22.9% relative spawning biomass).

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

tab:Ref_pts_mod1

Quantity	**Estimate**	**~2.5% Confidence Interval**	**~97.5% Confidence Interval**
Unfished spawning biomass (mt)	30554.7	24634.6	36474.8
Unfished age 3+ biomass (mt)	49439.6	41597	57282.2
Unfished recruitment (R0, thousands)	18626.7	11147.4	26106
Spawning biomass(2019 mt)	9867.3	7682.4	12052.2
Relative spawning biomass (depletion) (2019)	0.323	0.219	0.426
Reference points based on $\mathbf{SB_{25\%}}$			
Proxy spawning biomass ($B_{25\%}$)	7638.7	6158.7	9118.7
SPR resulting in $B_{25\%}$ ($SPR_{B25\%}$)	0.286	0.258	0.313
Exploitation rate resulting in $B_{25\%}$	0.182	0.163	0.2
Yield with $SPR_{B25\%}$ at $B_{25\%}$ (mt)	2830.3	2624.2	3036.4
Reference points based on SPR proxy for MSY			
Spawning biomass $SPR_{30\%}$	8096.3	6199.3	9993.3
Exploitation rate corresponding to $SPR_{30\%}$	0.173	0.145	0.2
Yield with $SPR_{30\%}$ at SB_{SPR} (mt)	2819.8	2590.1	3049.5
Reference points based on estimated MSY values			
Spawning biomass at MSY (SB_{MSY})	7005.9	5242.2	8769.6
SPR_{MSY}	0.266	0.201	0.331
Exploitation rate at MSY	0.195	0.164	0.225
MSY (mt)	2835.9	2641.9	3029.9

Management Performance

management-performance

The 2009 stock assessment estimated petrale sole to be at 11.6% of unfished spawning stock biomass in 2010. Based on the 2009 stock assessment, the 2010 coast-wide ACL was reduced to 1,200 mt to reflect the overfished status of the stock and the 2011 coast-wide overfishing limit (OFL) and ACL were set at 1,021 mt and 976 mt, respectively (Table f).

Recent coast-wide annual landings have not exceeded the ACL. The 2009, 2011, and 2013 full assessments estimated that petrale sole have been below the management target since the 1960s and below the overfished threshold between the early 1980s and the early 2000s with fishing mortality rates in excess of the current F-target for flatfish of SPR30%. The 2015 update assessment estimated that the stock had recovered with the relative spawning biomass exceeding the management target.

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

tab:mnmgt_perform

Year	OFL (mt; ABC prior to 2011)	ACL (mt; OY prior to 2011)	Total Landings (mt)	Estimated Total Catch (mt)
2009	2811	2433	2209	2329
2010	2751	1200	755	867
2011	1021	976	768	791
2012	1275	1160	1135	1159
2013	2711	2592	1936	1973
2014	2774	2652	2373	2398
2015	3073	2816	2686	2727
2016	3208	2910	2506	2543
2017	3208	3136	3008	3050
2018	3152	3013	2840	2882

Unresolved Problems and Major Uncertainties

unresolved-problems-and-major-uncertainties

Parameter uncertainty is explicitly captured in the asymptotic confidence intervals reported throughout this assessment for key parameters and management quantities. These intervals reflect the uncertainty in the model fit to the data sources included in the assessment, but do not include uncertainty associated with alternative model configurations, weighting of data sources (a combination of input sample sizes and relative weighting of likelihood components), or fixed parameters.

There are a number of major uncertainties regarding model parameters that have been explored via sensitivity analysis. The most notable explorations involved the sensitivity of model estimates to:

1. Value of female natural mortality.
2. Sex ratio between female and male petrale sole.
3. Changes in estimated based on alternative data weighting approaches.

Additionally, to date a reconstructed historical Washington catch history has not been included in the petrale sole stock assessment. Washington state is currently undergoing efforts to determine historical catches.

Decision Table

decision-table

Model uncertainty has been described by the estimated uncertainty within the base model and by the sensitivities to different model structure.

Table g: Projections of potential OFL (mt) and ABC (mt) and the estimated spawning biomass and relative depletion based on ABC removals. The 2019 and 2020 removals are set at the harvest limits currently set by management of XXX mt per year.

tab:OFL_projection

Year	OFL	ABC	Spawning Biomass (mt)	Relative Depletion
2019	3436	3301	9867	0.323
2020	3189	3065	9191	0.301
2021	2987	2870	8630	0.282
2022	2843	2731	8235	0.270
2023	2764	2655	8035	0.263
2024	2742	2633	8009	0.262
2025	2757	2648	8087	0.265
2026	2790	2680	8201	0.268
2027	2824	2713	8304	0.272
2028	2851	2738	8379	0.274
2029	2869	2756	8427	0.276
2030	2880	2766	8455	0.277

Table h: Decision table summary of 10-year projections beginning in 2021 for alternate states of nature based on an axis of uncertainty for the base model. The removals in 2019 and 2020 were set at the defined management specification of XXX mt for each year assuming full attainment. The range of natural mortality values corresponded to the 12.5 and 87.5th quantile from the uncertainty around final spawning biomass. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. The SPR30 catch stream is based on the equilibrium yield applying the SPR30 harvest rate.

tab:Decision_table_mod1

			States of nature					
			Low State		Base		High State	
	Year	Catch	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
ABC	2021							
	2022							
	2023							
	2024							
	2025							
	2026							
	2027							
	2028							
	2029							
	2030							
SPR target = 0.34	2021							
	2022							
	2023							
	2024							
	2025							
	2026							
	2027							
	2028							
	2029							
	2030							

Research and Data Needs

research-and-data-needs

Progress on a number of research topics and data issues would substantially improve the ability of this assessment to reliably and precisely model petrale sole population dynamics in the future:

1. In the past many assessments have derived historical catches independently. The states of California and Oregon have completed comprehensive historical catch reconstructions. At the time of this assessment, a comprehensive historical catch reconstruction is not available for Washington. Completion of a Washington catch reconstruction would provide the best possible estimated catch series that accounts for all the catch and better resolves historical catch uncertainty for flatfish as a group.

2. Due to limited data, new studies on the maturity relationships for petrale sole would be beneficial.

3. Where possible, historical otolith samples aged using a combination of surface and break-and-burn methods should be re-aged using the break-and-burn method. Early surface read otoliths should also be re-aged using the break-and-burn method. Historical otoliths aged with a standard method will allow the further evaluation of the potential impacts of consistent under ageing using surface methods, changes in selectivity during early periods of time without any composition information, and potential changes in growth.

4. Studies on stock structure and movement of petrale sole, particularly with regard to the winter-summer spawning migration of petrale sole and the likely trans-boundary movement of petrale sole between U.S. and Canadian waters seasonally.

5. The extent of spatial variability on productivity processes such as growth, recruitment, and maturity is currently unknown and would benefit from further research.

Table i: Base model results summary.

tab:base_summary

Quantity	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
OFL (mt)	2751	1021	1275	2711	2774	3073	3208	3208	3152	1
ACL (mt)	1200	976	1160	2592	2652	2816	2910	3136	3013	1
Landings (mt)	755	768	1135	1936	2373	2686	2506	3008	2840	
Total Est. Catch (mt)	867	791	1159	1973	2398	2727	2543	3050	2882	
1-SPR	0.625	0.552	0.568	0.632	0.633	0.644	0.618	0.654	0.649	
Exploitation rate	0.091	0.062	0.074	0.111	0.126	0.138	0.129	0.155	0.152	
Age 3+ biomass (mt)	9487.05	12726.80	15602.80	17806.70	18973.00	19748.50	19715.50	19637.00	18918.70	18265.30
Spawning Biomass	3494	4414	5904	7751	9284	10202	10439	10531	10213	9867
95% CI	2845 - 4143	3606 - 5222	4858 - 6950	6410 - 9091	7682 - 10886	8441 - 11962	8593 - 12284	8606 - 12457	8186 - 12240	7682 - 12052
Relative Depletion	0.114	0.144	0.193	0.254	0.304	0.334	0.342	0.345	0.334	0.323
95% CI	0.077 - 0.152	0.098 - 0.191	0.132 - 0.255	0.174 - 0.333	0.209 - 0.398	0.231 - 0.436	0.237 - 0.446	0.240 - 0.449	0.231 - 0.437	0.219 - 0.426
Recruits	11740	13434	19781	12763	13826	13751	13924	15071	17012	16935
95% CI	7281 - 18929	8205 - 21994	12473 - 31372	7331 - 22221	7883 - 24251	7464 - 25334	6927 - 27992	6851 - 33154	7437 - 38914	7409 - 38710

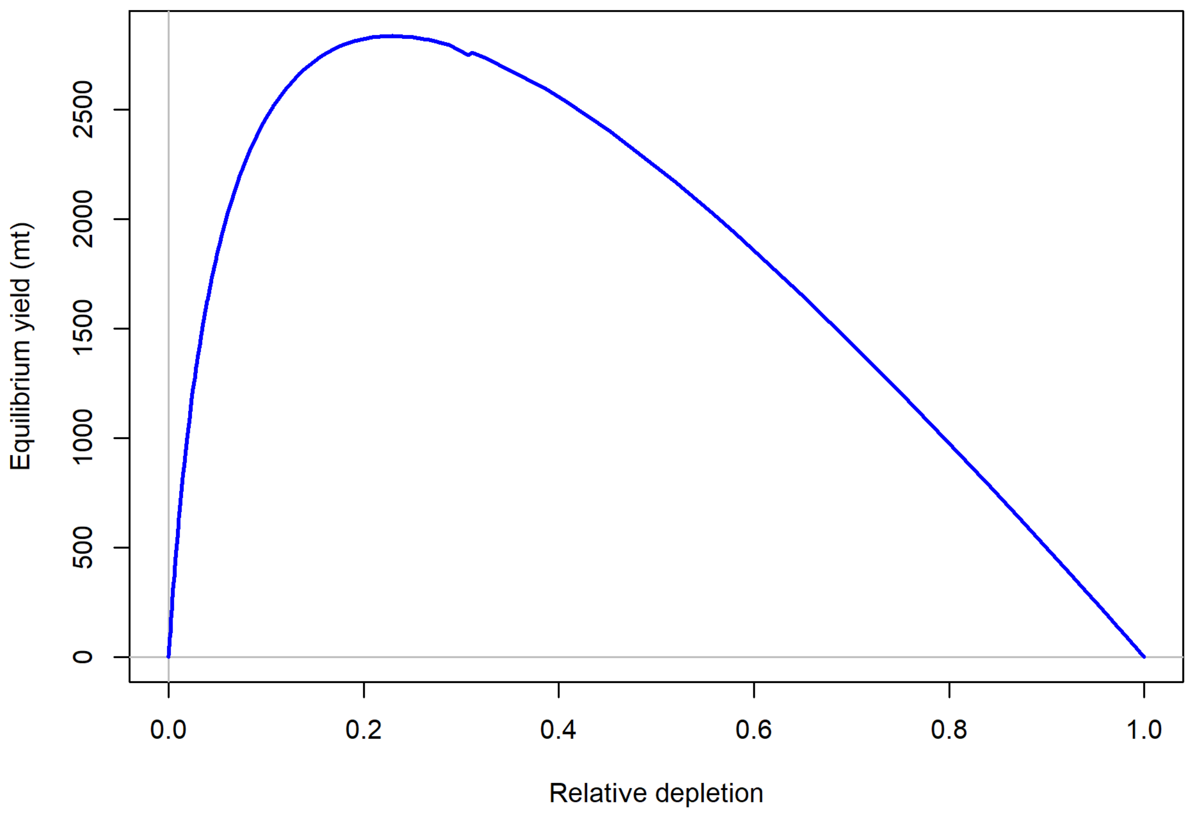

Figure g: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.84. fig:Yield_all

1 Introduction

introduction

This updated assessment does not attempt to reiterate all background information for petrale sole presented in the 2013 assessment document. Instead, only a few key assumptions are restated, along with a detailed description of changes made during the course of the update. Those interested in a more complete description of petrale sole life-history and the details of previous assessments should refer to the 2013 assessment (Haltuch et al. 2013b).

1.1 Basic Information

basic-information

Petrale sole (*Eopsetta jordani*) is a right-eyed flounder in the family Pleuronectidae ranging from the western Gulf of Alaska to the Coronado Islands, northern Baja California (Kramer et al. 1995, Love et al. 2005) with a preference for soft substrates at depths ranging from 0-550 m (Love et al. 2005). Common names include brill, California sole, Jordan's flounder, cape sole, round nose sole, English sole, soglia, petorau, nameta, and tsubame garei (Smith 1937, Gates and Frey 1974, Eschmeyer and Herald 1983, Love 1996). In northern and central California petrale sole are dominant on the middle and outer continental shelf. PacFIN fishery logbook data show that adults are caught in depths from 18 to 1,280 m off the U.S. West Coast with a majority of the catches of petrale sole being taken between 70-220 m during March through October, and between 290-440 m during November through February.

Past assessments completed by Demory (1984,), Turnock et al. (1993), and Sampson and Lee (1999) considered petrale sole in the Columbia and U.S.-Vancouver INPFC areas a single stock. Sampson and Lee (1999) assumed that petrale sole in the Eureka and Monterey INPFC areas represented two additional distinct socks. The 2005 petrale sole assessment assumed two stocks, northern (U.S.-Vancouver and Columbia INPFC areas) and southern (Eureka, Monterey and Conception INPFC areas), to maintain continuity with previous assessments. Three stocks (West Coast Vancouver Island, Queen Charlotte Sound, and Heceta Strait) are considered for petrale sole in the waters off British Columbia, Canada (Starr and Fargo 2004). The 2009, 2011, 2013, and 2015 assessments integrate the previously separate north-south assessments to provide a coast-wide status evaluation. The decision to conduct a single-area assessment is based on strong evidence of a mixed stock from tagging studies, a lack of genetic studies on stock structure, and a lack of evidence for differences in growth between the 2005 northern and southern assessment areas and from examination of the fishery size-at-age data, as well as confounding differences in data collection between Washington, Oregon, and California. This 2019 update assessment provides a coast-wide status evaluation for petrale sole using data through 2018.

Fishing fleets are separated both geographically and seasonally to account for spatial and seasonal patterns in catch given the coast-wide assessment area. The petrale sole fisheries possess a distinct seasonality, with catches peaking during the winter months, so the fisheries are divided into winter (November-February) and summer (March-October) fisheries. Note that the "fishing year" for this assessment (November 1 to October 31) differs from the standard calendar year. The U.S.-Canadian border is the northern boundary for the assessed stock, although the basis for this choice is due to political and current management needs rather than the population dynamics. Given the lack of clear information regarding the status of distinct biological populations, this assessment treats the U.S. Petrale sole resource from the Mexican border to the Canadian border as a single coast-wide stock.

1.2 Life History

life-history

Petrale sole spawn during the winter at several discrete deep water sites (270-460 m) off the U.S. West Coast, from November to April, with peak spawning taking place from December to February (Harry 1959, Best 1960, Gregory and Jow 1976, Castillo et al. 1993, Reilly et al. 1994, Love 1996). Females spawn once each year and fecundity varies with fish size, with one large female laying as many as 1.5 million eggs (Porter 1964). Petrale sole eggs are planktonic, ranging in size from 1.2 to 1.3 mm, and are found in deep water habitats at water temperatures of 4-10 degrees C and salinities of 25-30 ppt (Best 1960, Ketchen and Forrester 1966, Alderdice and Forrest 1971, Gregory and Jow 1976). The duration of the egg stage can range from approximately 6 to 14 days (Alderdice and Forrest 1971, Love 1996). The most favorable conditions for egg incubation and larval growth are 6-7 degrees C and 27.5-29.5 ppt (Ketchen and Forrester 1966, Alderdice and Forrest 1971, Castillo 1995).

Adult petrale sole achieve a maximum size of around 50 cm and 63 cm for males and females, respectively (Best 1963, Pedersen 1975). The maximum length reported for petrale sole is 70 cm (Eschmeyer and Herald 1983, Love et al. 2005) while the maximum observed break-and-burn age is 31 years (Haltuch et al. 2013b).

1.3 Historical and Current Fishery Information

historical-and-current-fishery-information

Petrale sole have been caught in the flatfish fishery off the U.S. Pacific coast since the late 19th century. The fishery first developed off of California where, prior to 1876, fishing in San Francisco Bay was by hand or set lines and beach seining (Scofield 1948). By 1880 two San Francisco based trawler companies were running a total of six boats, extending the fishing grounds beyond the Golden Gate Bridge northward to Point Reyes (Scofield 1948). Steam trawlers entered the fishery during 1888 and 1889, and four steam tugs based out of San Francisco were sufficient to flood market with flatfish (Scofield 1948). By 1915 San Francisco and Santa Cruz trawlers were operating at depths of about 45-100 m with catches averaging 10,000 lbs per tow or 3,000 lbs per hour (Scofield 1948). Flatfish comprised approximately 90% of the catch with 20-25% being discarded as unmarketable (Scofield 1948). During 1915 laws were enacted that prohibited dragging in California waters and making it illegal to possess a trawl net from Santa Barbara County southward (Scofield 1948). By 1934 twenty 56-72 foot diesel engine trawlers operated out of San Francisco fishing between about 55 and 185 m (Scofield 1948). From 1944-1947 the number of California trawlers fluctuated between 16 and 46 boats (Scofield 1948). Although the flatfish fishery in California was well developed by the 1950s and 1960s, catch statistics were not reported until 1970 (Heimann and Carlisle 1970). In this early California report petrale sole landings during 1916 to 1930 were not separated from the total flatfish landings.

The earliest trawl fishing off Oregon began during 1884-1885, and the fishery was solidly established by 1937, with the fishery increasing rapidly during WWII (Harry and Morgan, 1961). Initially trawlers stayed close to the fishing grounds adjacent to Newport and Astoria, operating at about 35-90 m between Stonewall Bank and Depoe Bay. Fishing operations gradually extended into deep water. For example, Newport-based trawlers were commonly fishing at about 185 m in 1949, at about 185-365 m by 1952, and at about 550 m by 1953.

Alverson and Chatwin (1957) describe the history of the petrale sole fishery off of Washington and British Columbia with fishing grounds ranging from Cape Flattery to Destruction Island. Petrale sole catches off of Washington were small until the late 1930s with the fishery extending to about 365 m following the development of deep water rockfish fisheries during the 1950s.

By the 1950s the petrale sole fishery was showing signs of depletion with reports suggesting that petrale sole abundance had declined by at least 50% from 1942 to 1947 (Harry 1956). Sampson and Lee (1999) reported that three fishery regulations were implemented during 1957-67: 1) a winter closure off Oregon, Washington and British Columbia, 2) a 3,000 lb per trip limit, and 3) no more than two trips per month during 1957. With the 1977 enactment of the Magnuson Fishery Conservation and Management Act (MFCMA) the large foreign-dominated fishery that had developed since the late 1960s was replaced by the domestic fishery that continues today. Petrale sole are harvested almost exclusively by bottom trawls in the U.S. West Coast groundfish fishery. Recent petrale sole catches exhibit marked seasonal variation, with substantial portions of the annual harvest taken from the spawning grounds during December and January. Evidence suggests that the winter fishery on the deep water spawning grounds developed sporadically during the 1950s and 1960s as fishers discovered new locations (e.g., Alverson and Chatwin (1957); Ketchen and Forrester (1966)). Both historical and current petrale sole fisheries have primarily relied upon trawl fleets. Fishery removals were divided among 4 fleets: 1) winter North trawl, 2) summer North trawl, 3) winter South trawl, and 4) summer South trawl. Landings for the North fleet are defined as fish landed in Washington and Oregon ports. Landings for the South fleet are defined as fish landed in California ports.

Historical landings reconstructions show peak catches from the summer fishery occurred during the 1940s and 1950s and subsequently declined, during which time the fleet moved to fishing in deeper waters during the winter. After the period of peak landings during the 1940s and 1950s, total landings were somewhat stable until about the late 1970s, and then generally declined until the mid-2000s. (Table 1, Figure 1). During 2009 the fishery was declared overfished and during 2010 management restrictions limited the catch to 755 mt (Table 1, Figure 1). Recent years overfishing limit (OFL), annual catch limit (ACL), landings, and estimated total dead are shown in Table 2.

1.4 Summary of Management History and Performance

summary-of-management-history-and-performance

Beginning in 1983 the Pacific Fishery Management Council (PFMC) established coast-wide annual catch limits (ACLs) for the annual harvests of petrale sole in the waters off the U.S. West Coast. The first assessment of West Coast petrale sole occurred in 1984 (Demory 1984). Based on the 1999 assessment a coast-wide ACL of 2,762 mt was specified and remained unchanged between 2001 and 2006.

The 2005 assessment of petrale sole stock assessment split the stock into two areas, the northern area that included U.S.-Vancouver and Columbia INPFC areas and the southern area that included the Eureka, Monterey and Conception INPFC areas (Lai et al. 2005). While petrale sole stock structure is not well understood, CPUE and geographical differences between states were used to support the use of two separate assessment areas. In 2005 petrale sole were estimated to be at 34 and 29% of unfished spawning stock biomass in the northern and southern areas, respectively. In spite of different models and data, the biomass trends were qualitatively similar in both areas, providing support for a coast-wide stock. This assessment estimated that petrale sole had historically been below the Pacific Council's minimum stock size threshold of 25% of unfished biomass from the mid-1970s until just prior to the completion of the assessment, with estimated harvest rates in excess of the target fishing mortality rate implemented for petrale sole at that time (F40%). However, the 2005 stock assessment determined that the stock was in the precautionary zone and was not overfished (i.e., the spawning stock biomass was not below 25% of the unfished spawning stock biomass). Based on the 2005 stock assessment results, ACLs were set at 3,025 mt and 2,919 mt for 2007 and 2008, respectively, with an ACT of 2,499 mt for both years.

In comparison to the 1999 assessment of petrale sole, the 2005 assessment represented a significant change in the perception of petrale sole stock status. The stock assessment conducted in 1999 (Washington-Oregon only) estimated the spawning stock biomass in 1998 at 39% of unfished stock biomass. Although the estimates of 1998 spawning-stock biomass were little changed between the 1999 and 2005 (Northern area) assessments, the estimated depletion in the 2005 assessment was much lower. The change in status between the 1999 and 2005 analyses was due to the introduction of a reconstructed catch history in 2005, which spanned the entire period of removals. The 1999 stock assessment used a catch history that started in 1977, after the bulk of the removals from the fishery had already taken place. Thus the 1999 stock assessment produced a more optimistic view of the petrale stock's level of depletion. The stock's estimated decline in status between the 2005 and 2009 assessments was driven primarily by a significant decline in the trawl-survey index over that period. The 2011 assessment concluded that the stock status continued to be below the target of 25% of unfished biomass.

The 2009 coast-wide stock assessment estimated that the petrale sole stock had declined from its 2005 high to 11.6% of the unfished spawning stock biomass (Haltuch and Hicks 2009). The petrale sole was declared overfished based on newly adopted management targets (e.g., target spawning biomass for flatfish stocks defined as 25% and overfished threshold of 12.5%

of unfished spawning stock biomass) resulting in a rebuilding plan and catch restrictions for petrale sole. The stock was declared rebuilt based on the results of the 2015 update stock assessment which estimated the coastwide biomass at 30.7% of unfished spawning stock output with ACLs of 3,136 and 3,013 in 2017 and 2018 respectively (Stawitz et al. 2015).

For additional information on changes in the petrale sole fishery please see the 2013 stock assessment (Haltuch et al. 2013b).

1.5 Fisheries off Canada and Alaska

fisheries-off-canada-and-alaska

The Canadian fishery developed rapidly during the late 1940s to mid-1950s following the discovery of petrale sole spawning aggregations off the West Coast of Vancouver Island (Anon 2001). Annual landings of petrale sole in British Columbia peaked at 4,800 mt in 1948 but declined significantly after the mid-1960s (Anon 2001). By the 1970s, analysis conducted by Pederson (1975) suggested that petrale sole abundance was low and abundance remained low into the 1990s. In the early 1990s vessel trip quotas were established to try to halt the decline in petrale sole abundance (Anon 2001). Winter quarter landings of petrale sole were limited to 44,000 lb per trip during 1985-91; to 10,000 lb per trip during 1991-95; and to 2,000 lb per trip in 1996. Biological data collected during 1980-1996 showed a prolonged decline in the proportion of young fish entering the population (Anon 2001). Therefore, no directed fishing for petrale sole has been permitted in Canada since 1996 due to a continuing decline in long term abundance (Fargo 1997, Anon 2001). As of 2005 petrale sole off of British Columbia were treated as three "stocks" and were still considered to be at low levels. The recent assessments for the Canadian stocks have been based on catch histories and limited biological data.

In Alaska petrale sole are not targeted in the Bering Sea/Aleutian Island fisheries and are managed as a minor species in the "Other Flatfish" stock complex.

2 Data

data

Data used in the petrale sole assessment are summarized in Figure 2. The data that were added or reprocessed for this assessment are:

1. Commercial catches (2015-2018 added);
2. Commercial length and age data (all years reprocessed, 2015-2018 added);
3. Observed discard rates, average weights, and lengths (2002-2017 reprocessed, 2014-2017 added);

4. AFSC/NWFSC West Coast Triennial Shelf Survey early and late indices of abundance and length composition data (1980-2004 reprocessed); and

5. NWFSC West Coast Groundfish Bottom Trawl Survey index of abundance, length and age composition data (2003-2018 reprocessed, 2015-2018 added).

A description of each data source is provided below.

2.1 Fishery-Independent Data

`fishery-independent-data`

2.1.1 NWFSC West Coast Groundfish Bottom Trawl Survey

`nwfsc-west-coast-groundfish-bottom-trawl-survey`

Three sources of information are produced by this survey: an index of relative abundance, length-frequency distributions, and age-frequency distributions. Only years in which the NWFSC West Coast Groundfish Bottom Trawl Survey included the continental shelf (55-183 m) are considered (2003-2018), since the highest percent of positive survey tows with petrale sole are found on the continental shelf.

The NWFSC West Coast Groundfish Bottom Trawl 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 industry chartered vessels per year, assigned to a roughly equal number of randomly selected grid cells and divided into two 'passes' of the coast that are executed from north to south. Two vessels fish during each pass, which are conducted from late May to early October each year. This design therefore incorporates both vessel-to-vessel differences in catchability as well as variance associated with selecting a relatively small number (˜700) of possible cells from a very large set of possible cells spread from the Mexican to the Canadian border.

The NWFSC West Coast Groundfish Bottom Trawl Survey commonly encounters petrale sole along the U.S West Coast, except south of Point Conception (Figure 3). The catch-per-unit-effort estimated from the survey is roughly constant north of 38° (Figure 4). The survey does fish shallower than 54 m and no petrale sole were caught deeper than 550 m. Figure 5 shows that the postie tows catch rate by depth peaks between 100-200 meters and declines as depth increases.

The data from the NWFSC West Coast Groundfish Bottom Trawl Survey was analyzed using a spatio-temporal delta model implemented as an R package, VAST (Thorson and Barnett 2017), which is 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 data to account for the random selection of commercial vessels used during sampling (Helser et al. 2004, Thorson and Ward 2013). Spatial variation was approximated using 250 knots, and the model used 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 stratification is provided in Table 3.

The estimated index of abundance is shown in Table 4. For contrast, the 2015 model estimated, the 2019 design based, and the 2019 VAST indices are shown in Figure 6. 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 7). The index for the NWFSC West Coast Groundfish Bottom Trawl Survey shows an increase in the population between 2009 and 2014 and roughly stable through 2017, and decrease in the most recent year.

Length bins from 12 to 62 cm in 2 cm increments were used to summarize the length frequency of the survey catches in each year. Table 5 shows the number of lengths taken by the survey. The first bin includes all observations less than 14 cm and the last bin includes all fish larger than 62 cm. The length frequency distributions for the NWFSC West Coast Groundfish Bottom Trawl Survey from 2003-2018 generally show a strong cohort growing through 2005 and smaller fish entering the population beginning in 2007 rows with a large 2014 cohort entering the populations (Figure 8).

Age distributions included bins from age 1 to age 17, with the last bin including all fish of greater age. Table 6 shows the number of ages taken by the survey. The marginal NWFSC West Coast Groundfish Bottom Trawl Survey age-compositions, which allow for easier viewing of strong cohorts, show the strong 1998 cohort ageing from 2003 to 2007, with younger fish appearing between 2008-2014 (Figure 9). The exception to this is the female composition in 2005, where only one female fish was aged from the tow with the largest catch rate. The expansion of numbers to tow can greatly affect the marginal age distribution, but does not have as much effect on the conditional age-at-length data.

The input sample sizes for length and marginal age-composition data for all fishery-independent surveys were calculated based on the approach used in the 2013 full and 2015 update assessment as:

$$N = (0.138 * (\sum^N fish_y / \sum^N tows_y) + 1) * \sum^N tows_y$$

where fish is the number of petrale sole by year y and the total number of tows by year. The effective sample size of conditional-age-at-length data was set at the number of fish at each length by sex and by year. The conditional-age-at-length data were not expanded and were binned by according to length, age, sex, and year.

2.1.2 AFSC/NWFSC West Coast Triennial Shelf Survey
afscnwfsc-west-coast-triennial-shelf-survey

The AFSC/NWFSC West Coast Triennial Shelf Survey (referred to as the Triennial Survey for short) 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 m. 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 m and surveyed south to 34.5° N. In the final year of the Triennial Survey series, 2004, the NWFSC's Fishery Resource and Monitoring division (FRAM) conducted the survey and followed very similar protocols as the Alaska Fisheries Science Center (AFSC).

Due to changes in survey timing, the Triennial Survey data have been split into independent early (1980-1992) and late (1995-2004) survey time series. The splitting of this time series was investigated during the 2009 STAR panel due to the changes in survey timing and the expected change in petrale sole catchability because of the stock's seasonal onshore-offshore migrations (Cook et al. 2009). For these reasons, as well as because the split improved fits to the split time series and made small changes to the estimation of the selectivity curves, the 2009 STAR panel supported the split.

The Triennial Survey commonly encounters petrale sole along the U.S West Coast (Figure 10). The catch-per-unit-effort estimated from the survey is roughly constant across the surveyed latitudes (Figure 11). Additionally, petrale sole were captured across the survey depths between 55-500 m (Figure 12).

The data from the petrale sole was analyzed using a spatio-temporal delta model implemented as an R package, VAST (Thorson and Barnett 2017), described above in Section 2.1.1. Spatial variation was approximated using 250 knots, and the model used the bias-correction algorithm (Thorson and Kristensen 2016) in Template Model Builder (Kristensen et al. 2016). The index of abundance was estimated using VAST seperately for the early and late periods of the survey. The stratifications are provided in Tables 7 and 8.

The estimated index of abundance is shown in Table 4. For contrast, the 2015 model estimated, the 2019 design based, and the 2019 VAST indices are shown in Figure 14. The lognormal distribution with random strata-year and vessel effects had the lowest AIC and was chosen as the final model for both the early and late time periods. The Q-Q plots do not show any departures from the assumed distribution (Figures 15 and 16). The index for the Triennial Survey across the early and late period shows an slight increase in the population between 1980 and 2001 with a spike in the final year of 2004.

Length bins from 12 to 62 cm in 2 cm increments were used to summarize the length frequency of the survey catches in each year. Table 9 shows the number of lengths taken by the survey. The first bin includes all observations less than 14 cm and the last bin includes all fish larger than 62 cm. The length frequency distributions for the Triennial Survey from 1980-2004 are shown in Figures 17 and 18.

There are no petrale sole age data from the Triennial Survey.

The input sample sizes for length data were calculated using the same approach for the NWFSC West Coast Groundfish Bottom Trawl Survey data described in Section 2.1.1.

2.2 Fishery-Dependent Data

`fishery-dependent-data`

2.2.1 Commercial Fishery Landings

`commercial-fishery-landings`

All landings for this update assessment were summarized by port of landing, where available, as well as for a northern fleet consisting of Washington and Oregon and a southern fleet consisting of California. Landings for Washington and Oregon are summed into a single northern fleet due to the fact that vessels commonly fish and land in each other's waters and ports.

The PacFIN database (1981-2018 for California and Washington; 1987-2018 for Oregon) extracted XXX ADD DATE XXX. Historical catches were not updated from the previous assessment in 2013. The 2013 assessment historical Washington catches were obtained from WDFW landings reconstruction for 1935, 1939 and 1949- 1969 (pers. comm. T. Tsou and G. Lippert) and the Pacific Marine Fisheries Commission (PMFC) Data Series for 1956-1980 (PFMC 1979). The 2013 assessment historical Oregon landings were obtained from reconstruction for 1932 to 1986 (Karnowski et al. 2014). The 2013 assessment historical California landings used catch reconstruction data extending from 1931-1980 (Ralston et al. 2010) and California Department of Fish and Game (CDFG) Fish Bulletins for 1916-1930 landings (Heimann and Carlisle 1970) as reconstructed by Lai et al. (2005). The California fishery began in 1876 but no landings data are available from 1876-1915. Therefore a linear interpolation between landings of 1 ton in 1876 and the landings recorded for 1916 are used to filling this period.

Landings for the fishing year, beginning on 1 November, are summarized by fleet in Table 1 and Figure 1. The landings of petrale sole by gear types other than groundfish-trawl have been inconsequential, averaging less than 2.5% of the coast-wide landings. The non-trawl landings are included in the trawl landings.

2.2.2 Discards

discards

Data on discards of petrale sole are available from two different data sources. The earliest source is referred to as 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 (personal communication, NWFSC, NOAA) in the form of ratios of discard weight to retained weight of petrale sole and sex-specific length frequencies. The Pikitch discard estimates were applied to both the summer and winter northern fisheries and are shown in Table 10.

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 10 shows the discard ratios (discarded/(discarded + retained)) of petrale sole from 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 petrale sole. A single discard rate was calculated by weighting discard rates based on the commercial landings by each sector. Coefficient of variations were calculated for the non-catch shares sector and pre-catch share years by bootstrapping vessels within ports because the observer program randomly chooses vessels within ports to be observed. The discard rates from WCGOP are shown in Table 10.

Starting in 2015 a small number of vessels switched to electronic monitoring discards at sea (4, 7, and 8 vessels in 2015, 2016, and 2017 respectively) rather than a human observer and as of this update assessment only 3 years of data are available. Discarding rates at sea of petrale sole by these vessels were very low, near zero. This update assessment did not evaluate these data to estimate an electronic monitoring specific discard rate, but rather applied the discard ratio from the observed vessels in the WCGOP database. Future assessments should evaluate this assumption in greater detail.

Discard mean body weight data were obtained from the WCGOP data and used in this update assessmet for each of the four fishing fleets. The mean body weight of discarded fish from each fleet are shown in Figures 19 - 22. The summer fisheries, both north and south, had relatively large sample numbers which is reflected in a lower CV by year relative to the winter fisheries.

Discard length composition data were obtained from the WCGOP data and used in this update assessment to estimate retention curves for each of the four fishing fleets. The discard length data from each fleet are shown in Figures 23 and 24.

The data, historical and current, provided by the WCGOP are updated annually based on the most recent standards of QA/QC methods. Hence, these data can have minor changes over time. To ensure the data from the years since the last update assessment (2014-2018) were consistent with the earlier data, data from all years were replaced based to reflect the current standings of the WCGOP data.

2.2.3 Foreign Landings

`foreign-landings`

The impact of landings of petrale sole by foreign fishing fleets prior to the institution of the exclusive economic zone (EEZ) of the U.S. West Coast is currently not quantified and remains an area for research.

2.2.4 Historical Commercial Catch-Per-Unit Effort/Logbooks

`historical-commercial-catch-per-unit-effortlogbooks`

Commercial logbook data for petrale sole was first used to construct CPUE indices of abundance in the 1999 assessment for Oregon fleets from 1987-1997 (Sampson and Lee 1999). Since the first inclusion 1999, the commercial CPUE indices were extended and or updated based on management changes and new statistical methods through 2009. For additional information on the use of CPUE indices in the assessment of petrale sole please see the 2013 assessment (Haltuch et al. 2013b).

CPUE calculations for the Winter fishery on aggregations of petrale sole described in the 2013 assessment were retained for this assessment (Haltuch et al. 2013b) (Figures 26 and 27). Two CPUE indices from 1987-2009 with catchability modeled as a power function are used in this update assessment, one for the north and south winter fisheries.

2.2.5 Fishery Length and Age Data

`fishery-length-and-age-data`

The PacFIN BDS database contains data from Oregon Department of Fish and Wildlife (ODFW; 1966-present) and Washington Department of Fish and Wildlife (WDFW; 1955-present), but only 1986-present data from California Department of Fish and Game (CDFG). The CDFG data set for the years 1948-1992 was extracted and provided from CALCOM by Brenda Erwin (CDFG) in 2011.

The historical Oregon data for petrale sole has change substantially since 2015. The state has identified samples across years that were not collected according to the state's standardized sampling protocal that were included in PacFIN due to error. These samples likely represent samples that were collected for special projects. Oregon has removed some of these samples for petrale sole from PacFIN, but not all as of 2019. To remove the remaining non-standard samples, Oregon PacFIN data was filtered according to the "Sample Quality" based on directions from Ali Whitman at ODFW where samples with a sample quality code of 63 represent non-standardized samples. Filtering out these records removed all Oregon samples from 1966-1970 and 1972-1975 and a portion of samples from 1971.

Commercial length-frequency distributions based on the fishing year were developed for each state for which observations were available. For each fleet, the raw observations (compiled from the PacFIN and CalCOM databases) were expanded to the sample level, to allow for any fish that were not measured, then to the trip level to account for the relative size of the landing from which the sample was obtained. The expanded length observations were then expanded by the landings in each state for the combined Washington and Oregon fleet. Age frequencies were computed in the same manner, except that age observations for Washington and Oregon were not combined due to aging error considerations.

Length and age data collected from commercial landings for each fleet are summarized by the number of trips and fish sampled by year (Tables 11 and 12). Figures 23, 24, and 25 show plots of the commercial length and age composition data across time for each fishery fleet.

The calculation for input sample sizes for the commercial length and age data was done to be consistent with the 2015 update assessment. The input sample size for commercial lengths and ages were set equal to the number of trips by year for each fleet.

2.3 Biological Data

biological-data

2.3.1 Natural Mortality

natural-mortality

The instantaneous rate of natural mortality for a wild fish population is notoriously difficult to estimate. One accepted method is to examine the age distribution of an unexploited or lightly exploited stock. This method cannot readily be applied to petrale sole given the long history of exploitation off the U.S. West Coast. Ketchen and Forrester (1966) estimated that the natural mortality coefficients were 0.18-0.26 yr^{-1} for males and 0.19-0.21 yr^{-1} for females based on a catch curve analysis of 1943-1945 Washington trawl data from Swiftsure Bank, off the southwest corner of Vancouver Island. However, petrale sole catches were relatively high during mid-1940s through the 1950s. Starr and Fargo (2004) estimated the instantaneous rate of natural mortality (M) using Hoenig's method (Hoenig 1983) estimating M values of 0.22 and 0.15 yr^{-1} were estimated given maximum ages of 20 and 30 years, respectively.

An archived set of commercial samples, collected from Northern California between the late 1950s and early 1980s, recently found that multiple samples were aged between 20-31 years old, suggesting a similar range of M values for U.S. West Coast petrale sole. U.S. stock assessments prior to 2009 and current British Columbia stock assessments assumed a value of $M = 0.2$ yr^{-1} for both sexes. The 2013 stock assessment used a meta-analysis value produced the following normal prior distributions for females (mean = 0.151, sd = 0.16) and males (0.206, sd = 0.218) based on early research by Owen Hamel (pers. comm.) with maximum age for females and males of 32 and 29 years, respectively.

Hamel (2015) refined and published a method for combining meta-analytic approaches relating the M rate 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 *ICES Journal of Marine Science*, 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 estimator $M = 4.899A_{max}^{-0.916}$. 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. Re-evaluating 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 distribution with mean $ln(5.4/A_{\max})$ and SE = 0.438.

The natural mortality prior was updated for this update assessment using the above approach. Maximum age was assumed to be 32 and 29 years for females and males, respectively, the same assumption applied in the 2013 assessment. Using the Hamel et al. approach above, the prior value for females in regular space is 0.169 and for males is 0.186.

2.3.2 Maturation and Fecundity

`maturation-and-fecundity`

Petrale sole maturity-at-length information is generally sparse in space and time, has not been collected in a systematic fashion across time, is of varying quality, and does not always agree between studies. It is possible that maturity may have changed over time. However, it is not possible to assess this quantitatively owing to differences in when historical samples on which maturity ogives could be based were taken, and how maturity stage (visual vs. histological) was determined. The 2005 petrale sole assessment used the most recent study for the West Coast of the U.S. that was based on observations collected during 2002 from Oregon and

Washington (Hannah et al. 2002). The 50% size-at-maturity was estimated at 33.1 cm with maturity asymptoting to 1.0 for larger fish (Figure 28).

To date, there has been limited information regarding fecundity at age or length of petrale sole. The 2013 stock assessment assumed that fecundity of female petrale sole was equal to biomass (Figure 29). Since the last full assessment, new research has been done examining the fecundity of petrale sole (Lefebvre et al. in press). The study concluded a difference in fecundity between California and Washington petrale sole where a 40 cm fish in California is more fecund compared to northern fish of the same size (Figure 30). However, northern fish of the largest size were more fecund relative to fish in California. The current petrale sole model is a single area coastwide model, which assumes fish along the U.S. have the same biology (e.g. natural mortality, growth, fecundity). The estimates of fecundity for petrale sole were considered new data and based on the guidelines for update stock assessments, these data were not included in the base model. However, a sensitivity to including these data was provided. The next full assessment should include the new data about fecundity at length.

2.3.3 Sex Ratio

`sex-ratio`

Past assessments of petrale sole have assumed a 50% sex ratio between females and males off the U.S West Coast. Similarly, Canadian data from the 2004 published stock assessment also suggests sex ratios of petrale sole in British Columbia are generally 50% males and 50% females (Starr and Fargo 2004). To be consistent with the full assessment this update assessment retains the equal sex ratio assumption. However, examining the NWFSC West Coast Groundfish Bottom Trawl Survey data the proportion of females in the population across the mid-range lengths is approximately 0.40 with the proportion increasing to 1 at the largest lengths due to dimorphic growth (Figure 31). The next full assessment should evaluate the sex ratio for petrale sole.

2.3.4 Length-Weight Relationship

`length-weight-relationship`

The length-weight relationship for petrale sole was estimated outside the model using all biological data available from the NWFSC West Coast Groundfish Bottom Trawl Survey data, where the female weight-at-length in grams was estimated at 2.08e-06$L^{3.47}$ and males at 3.05e-06$L^{3.36}$ where L is length in cm (Figures 32).

2.3.5 Growth (Length-at-Age)

`growth-length-at-age`

The length-at-age was estimated for male and female petrale sole. Figure 33 shows the lengths and ages as well as predicted von Bertalanffy fits to the data from the fishery and the NWFSC West Coast Groundfish Bottom Trawl Survey data. Females grow larger than males and sex-specific growth parameters were estimated at the following values:

XXX DOUBLE CHECK THESE VALUES WHEN AGES ARRIVE XXX

$$\text{Females } L_\infty = 54;\ k = 0.16$$

$$\text{Males } L_\infty = 41;\ k = 0.25$$

These values were used as starting parameter values within the base model prior to estimating each parameter for male and female petrale sole.

2.3.6 Ageing Precision and Bias

ageing-precision-and-bias

Historically, petrale sole otoliths have been read by multiple ageing labs using surface and break and burn methods. In order to conduct a comprehensive estimation of ageing bias and imprecision, the 2009 assessment compiled and analyzed all of the available double-read data from the state of Oregon, the Cooperative Aging Project (CAP), and the Washington Department of Fish and Wildlife (WDFW), as well information from a bomb radiocarbon age validation study for petrale sole off the U.S. West Coast (Haltuch and Hicks 2009, Haltuch et al. (2013a)).

The 2013 stock assessment applied read method and lab specific ageing error vectors (Haltuch et al. 2013b). The same approach to ageing error based on data source are age reading method applied in the 2013 assessment was applied in this update stock assessment. The ageing error vectors are shown in Tables 13 and 14. For a detailed description please see the 2013 stock assessment (Haltuch et al. 2013b).

2.3.7 Environmental and Ecosystem Data

environmental-and-ecosystem-data

This update assessment did not evaluate potential ecosystem data and methodologies for petrale sole.

3 Assessment Model

assessment-model

3.1 History of Modeling Approaches Used for This Stock

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

Early stock assessments only assessed petrale sole in the combined U.S.-Vancouver and Columbia INPFC areas, i.e. petrale sole in these areas were treated as a unit stock, using time series of data that began during the 1970s (Demory 1984, Turnock et al. 1993). The first assessment used stock reduction analysis and the second assessment used the length-based Stock Synthesis model. The third petrale sole assessment utilized the hybrid length-and-age-based Stock Synthesis 1 model, using data from 1977-1998 (Sampson and Lee 1999). During the 1999 stock assessment an attempt was made to include separate area assessments for the Eureka and Monterey INPFC areas but acceptable models could not be configured due to a lack of data (Sampson and Lee 1999).

The 2005 petrale sole assessment was conducted as two separate stocks, the northern stock encompassing the U.S. Vancouver and Columbia INPFC areas and the southern stock including the Eureka, Monterey and Conception INPFC areas, using Stock Synthesis 2, a length-age structured model. Both the northern- and southern-area models specified the fishing year as beginning on November 1 and continuing through October 31 of the following year, with a November-February winter fishery and a March-October summer fishery. Landings prior to 1957 were assumed to have been taken during the summer season in years where monthly data were not available to split the catches seasonally. The complete catch history was reconstructed for petrale sole for the 2005 stock assessment, with the northern area model starting in 1910 and the southern area model in 1876. In 2005, the STAR panel noted that the petrale sole stock trends were similar in both northern and southern areas, in spite of the different modeling choices made for each area, and that a single coast-wide assessment should be considered. The 2009 and 2011 assessments treated petrale sole as a single coast-wide stock, with the fleets and landings structured by state (WA, OR, CA) area of catch. During the 2011 STAR panel concerns were raised regarding the difficulty of discriminating landings from Washington and Oregon waters, particularly in light of the Oregon historical landings reconstruction that includes a summary of data by port of landing but not by catch area, due to the fact that the Oregon and Washington vessels commonly fish in each other's waters and land in each other's ports. The availability of the historical comprehensive landings reconstruction for Oregon by port of landing lead the STAR panel to recommend combining the Washington and Oregon fleets within the coast-wide stock assessment using port of landing rather than catch area. Starting with the 2013 stock assessment, the coast-wide stock assessment now summarizes petrale sole landings by the port of landing and combines Washington and Oregon into a single fleet (Haltuch et al. 2013b). The 2015 this 2019 update assessment assumes the same approach as the 2013 stock assessment.

3.2 General Model Specifications and Assumptions

`general-model-specifications-and-assumptions`

Stock Synthesis version 3.30.03.13 was used to estimate the parameters in the model (Methot and Wetzel 2013). R4SS, version 1.33.2, along with R version 3.4.3 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.

3.2.1 Changes Between the 2015 Update and Current Assessment Model

changes-between-the-2015-update-and-current-assessment-model

As with the 2013 petrale sole stock assessment, the current model is implemented as a single-area model. The current update assessment has been upgraded to a new version of SS (3.30.13). A thorough description of the 2013 assessment model, which is used in this update assessment, is presented separately below; this section linking the two models is intended to clearly identify where substantive changes were made. These changes include:

1. Fitting using SS v.3.30.13.
2. Added commercial fishery catch data (2015-2018).
3. Added composition data from the commercial fishery (length and age data 2015-2018) and recalculated data expansions based upon the current methods.
4. Reprocessed all discard data sources and added discard rate, average weight, and length composition data (2014-2017).
5. Added 2015-2018 NWFSC West Coast Groundfish Bottom Trawl Survey data and calculated the index of abundance VAST.
6. Added NWFSC West Coast Groundfish Bottom Trawl Survey length and age data 2015-2018.
7. Triennial Survey early and late indices of abundance were calculated using VAST.
8. Model tuning to re-weight data.
9. Length-weight relationship parameters estimated outside of the stock assessment model from the NWFSC West Coast Groundfish Bottom Trawl Survey data up to 2018 and input as fixed values.
10. Update the natural mortality prior for female and male fish.

The general model set-up is described in Table 15.

3.2.2 Summary of Fleets and Areas

summary-of-fleets-and-areas

Fishery removals were divided among 4 fleets: 1) winter North trawl, 2) summer North trawl, 3) winter South trawl, and 4) summer South trawl. Landings for the North fleet are defined as fish landed in Washington and Oregon ports. Landings for the South fleet are defined as fish landed in California ports. Other removals are very small and are included in the trawl fishery removals. The data available for each fleet are described in Figure 2.

3.2.3 Priors

priors

Priors were applied only to parameters for steepness (h) and natural mortality (M). The steepness prior is based on the Myers (1999) meta-analysis of flatfish steepness and the natural mortality prior is based on a meta-analysis completed by Hamel (2015). The prior for steepness assumed a beta distribution with a mean equal to 0.80 (Figure 35).

The natural mortality prior was updated for this update assessment using the Hamel meta-analysis approach. Maximum age was assumed to be 32 and 29 years for females and males (Figure 34), respectively, the same assumption regarding maximum age as applied in the 2013 assessment.

3.2.4 Data Weighting

data-weighting

Length and conditional-age-at-length compositions from the NWFSC West Coast Groundfish Bottom Trawl Survey were fit along with length and marginal age compositions from the fishery and the Triennial Survey. Length data started with a input sample size determined from the equation listed in Sections 2.1.1 (survey data) and 2.2.5 (fishery data). It was assumed for conditional-age-at-length data that each age was a random sample within the length bin and the model started with a sample size equal to the number of fish in that length bin.

The update assessment model was weighted using the McAllister and Ianelli (1997) method (Harmonic Mean weighting), consistent with the 2015 update assessment. The McAllister and Ianelli data weight approach looks at the difference between individual observations and predictions. A sensitivity was performed examining the difference between alternative weighting approaches. The weights applied to each length and age data set for the base model are shown in Table 16.

3.2.5 Estimated and Fixed Parameters

estimated-and-fixed-parameters

There were 304 estimated parameters in the base model. These included one parameters for R_0, natural mortality, steepness, growth, selectivity, retention, time blocking of the fleets and the surveys, commercial CPUE catchability, recruitment deviations, and forecast recruitment deviations (Table 17).

Fixed parameters in the model were as follows. The standard deviation of recruitment deviates was fixed at 0.40. Maturity-at-length was fixed as described above in Section 2.3.2. Length-weight parameters were fixed at estimates using all length-weight observations (Figure 32).

3.2.6 Key Assumptions and Structural Choices

key-assumptions-and-structural-choices

All structural choices for stock assessment models are likely to be important under some circumstances. In this update assessment update these choices are generally made to be consistent with the previous assessment (Haltuch et al. 2013b). Major choices in the structuring of this stock assessment model include a coast-wide model with seasonal fleet structure for two regions, north and south, splitting the Triennial Survey into an early and late time period, and estimates of selectivity and retention curves for each fleet.

3.2.7 Bridging Analysis

bridging-analysis

The exploration of models began by bridging from the 2015 update assessment to Stock Synthesis version 3.30.03.13, which produced no discernible difference (Figure 36).

3.2.8 Convergence

convergence

Proper convergence was determined by starting the minimization process from dispersed values of the maximum likelihood estimates to determine if the model found a better minimum. Starting parameters were jittered by 10%. This was repeated 50 times and a better minimum was not found (Table 18). The model did not experience convergence issues when provided reasonable starting values. Through the jittering done as explained above and likelihood profiles, we are confident that the base model as presented represents the best fit to the data given the assumptions made. There were no difficulties in inverting the Hessian to obtain estimates of variability, although much of the early model investigation was done without attempting to estimate a Hessian.

3.3 Base Model Results

base-model-results

The base model parameter estimates along with approximate asymptotic standard errors are shown in Table 17 and the likelihood components are shown in Table 19. Estimates of derived reference points and approximate 95% asymptotic confidence intervals are shown in Table 20. Estimates of stock size over time are shown in Table 21.

3.3.1 Parameter Estimates

parameter-estimates

Natural mortality be sex was estimated directly within the model. Natural mortality was estimated to be 0.162 for female fish and 0.174 for male fish. In comparison the estimates from the 2015 assesment were 0.145 and 0.154 for female and male fish, respectively.

Steepness was also estimated within the model, consistent with the approach applied in the 2013 full and 2015 update assessment. The estimate of steepness from the Beverton-Holt stock recruitment curve was estimated at 0.84. The previous update assessment estimated a steepness of 0.89.

The estimates of maximum length and the von Bertanlaffy growth coefficient, k, were less than the external estimates for males and female but were well within the 95% confidence interval given the estimated uncertainty (Table 17). The estimated k for female fish was consistent with the value estimated in the 2015 update assessment (0.135 versus 0.134), but the estimated k for male fish was higher than the value estimated in 2015 (0.216 versus 0.203). The majority of growth for female and male petrale sole growth occurs at younger ages, reaching near maximum length by age 10-15, depending upon sex, with female petrale sole reaching larger maximum lengths (Figure 37). The spawning output estimated was equal to the spawning weight of female fish (Figure 38).

Selectivity curves were estimated for the fishery and survey fleets. The estimated selectivities for the fishery fleets are shown in Figure 39. All fishery selectivities were estimated to be asymptotic, reaching maximum selectivity for fish between 35 and 40 cm. Shifts in selectivities for were estimated for each fleet fishery were estimated based on time blocks assumed in the 2013 assessment (Figure 39). The estimated retention curves for each fleet based on the historical time blocks and discarded length composition data are shown in Figure 40. Sex specific survey selectivities were assumed to be asymptotic and are shown in Figure 41.

The catchability for each of the winter CPUE time series were estimated as power functions. The Winter North base catchability value was estimated at 0.006 with the exponent parameter at -0.354. The Winter South base catchability value was estimated at 0.255 with the exponent parameter at -0.849.

Additional survey variability, process error added directly to each year's input variability, for the Triennial Survey, both early and late, was estimated within the model. The model estimated a added variance of 0.341 for the early time period of and 0.236 for the late period.

The time-series of estimated recruitments shows a relationship with the decline in spawning output, punctuated by larger recruitments (Figures 42 and 43) in recent years (2006, 2007, and 2008). There is little information regarding recruitment prior to 1960 and the uncertainty in those estimates is expressed in the model. The five largest estimated recruitment estimated with the model (in ascending order) occurred in 2006, 2007, 1998, 1966, and 2008. The four lowest recruitments estimated within the model (in ascending order) occurred in 1986, 1992, 1973, and 1987.

3.3.2 Fits to the Data

fits-to-the-data

There are numerous types of data for which the fits are discussed: fishery CPUE, survey abundance indices, discard data (rates, mean body weights, and length compositions), length-composition data for the fisheries and surveys, marginal age compositions for the fisheries, and conditional age-at-length observations for the NWFSC West Coast Groundfish Bottom Trawl Survey.

The fit to the CPUE for the winter fisheries is show in Figures 46, 47, 48, and 49. The model fits both of the CPUE time-series relatively well. The fits to the survey indices are shown in Figures 50, 51, and 52. In order to fit the early and the late periods of the Triennial Survey extra standard error was required. The trend in the early time-series of the Triennial Survey was generally not consistent with other data within the model. The final year, 2004, in the late period of the Triennial Survey was under fit by the model. The petrale sole survey index from the NWFSC West Coast Groundfish Bottom Trawl Survey was generally fit well. However, the most recent year, 2018 data point was over fit by the model.

The observed WCGOP discard rates (Figures 53 - 56) were fit by each fishery using time blocks. The time blocks on the discard data was based on those define in the 2013 assessment (Haltuch et al. 2013a) with the final block starting in 2011 being extended through the final model year. The discarding rates over time by each fleet are shown in Figure 57. Fits to the discard rates for the northern fleets from the Pikitch data in 1985-1987 were either under (Figure 53) or over fit (Figure 54) which is consistent to the estimates from the 2015 update assessment. Fits to the WCGOP observed mean body weights are shown in Figures 58 - 61. The fits to the discard mean body weights to the summer fleets were generally better than the data from the winter fisheries which had more variable observations and lower number of observations (hence larger annual uncertainties).

Fits to the length data are shown based on the proportions of lengths observed by year and the Pearson residuals-at-length for all fleets. Detailed fits to the length data by year and fleet are provided in Appendix A, section 11. Aggregate fits by fleet are shown in Figure 62. There are a few things that stand out when examining the aggregated length composition data. First, the sexed discard lengths from the Pikitch study appear to be poorly fit by the model but this is related to small sample sizes. However, the unsexed discard lengths from the WCGOP data for each fleet were fit well by the model.

Discard lengths from WCGOP were fit well by the model and show no obvious pattern in the residuals (Figures 63 - 66). The residuals to the fishery lengths clearly showed the growth differential between males and females where the majority of positive residuals at larger sizes were from female fish (Figures 67 - 70). Notably, the Summer North fishery has a large positive residual pattern for male fish between 1966-1980. A similar pattern in the Pearson residuals was observed in the 2013 full and the 2015 update assessment (Haltuch et al. 2013b, Stawitz et al. 2015). The residuals for each of the surveys are shown in Figures 71, 72, and 73. The Pearson residuals from the NWFSC West Coast Groundfish Bottom Trawl Survey shows indications of the 2008 cohort moving through the population. Length data were weighted according to the McAllister Ianelli Harmonic mean weights. The relationship between the observed (input) sample size to the effective sample sizes after weighting are shown in Figures 77 - 80.

Age data were fitted to as marginal age compositions for the fishery fleets.The NWFSC West

Coast Groundfish Bottom Trawl Survey ages were treated as conditional age-at-length data to facilitate the estimation of growth within the model. The aggregated fits to the marginal age data are shown in Figure 81. The aggregated age data were general fit well for the fishery fleets, however, the peaks of each of the age data were often under fit by the model which was also observed in the 2013 assessment (Haltuch et al. 2013b). Detailed fits to the age data by year and fleet are provided in Appendix B, section 12. The Pearson residuals for the fishery fleets are shown in Figures 82 - **??**.

The observed and expected conditional age-at-length fits for NWFSC West Coast Groundfish Bottom Trawl Survey are shown in Figures 86 - **??**. The fits generally match the observations. The Pearson residuals are shown in Figure 90 and 91.

The age data were also weighted according to the McAllister Ianelli Harmonic mean weights. The relationship betwen the observed (input) sample size to the effective sample sizes after weighting are shown in Figures 95 - 95.

3.3.3 Population Trajectory

`population-trajectory`

The predicted spawning biomass is given in Table 21 and plotted in Figure 96. The predicted spawning biomass time series shows a strong decline from the late-1930s through the mid-1960s, followed by a small recovery through the mid-1970s, and another decline to its lowest point during the early 1990s. This general pattern of stock decline is coincident with increasing catches and the movement of the fishery from the south to the north, and from summer fishing in shallow waters to winter fishing on spawning aggregations in deeper waters. From the mid-1990s through 2005 the stock increased slightly, then declined through 2010 (Figure 96). The stock has increased strongly since 2010 in response to reduced catches and in response to above average recruitment in 2006, 2007, and 2008. The estimated total biomass follows the same genera trend as observed in the spawning biomass (Figure 97). The 2019 estimated spawning biomass relative to unfished equilibrium spawning biomass is above the target of 25% of unfished spawning biomass at 32.3% (Figure 98). Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning biomass is generaly low. The standard deviation of the log of the spawning output in 2019 is 0.11.

Recruitment deviations were estimated for the entire time-series that was modeled (Figure 42 and discussed in Section 3.3.1) and provide a realistic portrayal of uncertainty. The time series of estimated recruitments shows a relationship with the decline in spawning output, punctuated by larger recruitments in 2006, 2007, and 2008. The five largest estimated recruitment estimated with the model (in ascending order) occurred in 2006, 2007, 1998, 1966, and 2008. The four lowest recruitments estimated within the model (in ascending order) occurred in 1986, 1992, 1973, and 1987. The stock-recruit curve resulting from a value of estimated steepness, 0.84, is shown in Figure 99 with estimated recruitments also shown.

3.3.4 Sensitivity Analyses

`sensitivity-analyses`

A number of sensitivity analyses were conducted. Each of the sensitivities conducted was a single exploration from the base model assumptions and/or data, and were not performed in a cumulative fashion.

1. Fix natural mortality value for female fish at a lower value of ??.
2. Fix natural mortality value for female fish at a higher value of ??.
3. Use the natural mortality prior for female and male fish used in the 2015 update assessment, natural mortality estimated.
4. Use the coastwide fecundity relationship for petrale sole estimated by Lefebvre et al. (in press).
5. Estimate the sex ratio between female and male fish within the model.
6. Data weight according to the Francis method using the weighting values shown in Table 23.
7. Data weight according to the Dirichlet method where the estimated parameters are shown in Table 24.

Likelihood values and estimates of key parameters from each sensitivity are available in Table 22. Plots of the estimated time-series of spawning biomass and relative spawning biomass are shown in Figures 100 and 101

3.3.5 Retrospective Analysis

`retrospective-analysis`

A five-year retrospective analysis was conducted by running the model using data only through 2014, 2015, 2016, 2017 and 2018 (Figures 102, 103, and 104). he initial scale of the spawning biomass trended upward relative to the base model. Overall, no alarming patterns were present in the retrospective analysis.

3.3.6 Historical Analysis

`historical-analysis`

The estimated summary biomass from previous assessments since 2005 are shown in Figure 105. The current assessment estimated a slight increase in initial spawning biomass compared to previous assessments.

3.3.7 Likelihood Profiles

likelihood-profiles

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

For steepness, the negative log-likelihood supported values between 0.70 - 0.95 (Figure 106). Likelihood components by data source show that the age data support a higher steepness value. The surveys generally provide very little information concerning steepness. The relative spawning biomass for petrale sole diverges most during the middel of the time series based on the assumed values of steepness with the final status generally being above the management target biomass (Figure 107).

The negative log-likelihood was minimized at a female natural mortality value of ??, but the 95% confidence interval extends over values ranging from ?? - ??. Male natural mortality was estimated in the likelihood profile. The age and length data likelihood contribution was minimized at natural morality values ranging from ??-?? (Figure **??**). The relative spawning biomass for petrale sole widely varied across alternative values of natural mortality (Figure 109).

In regards to values of R_0, the negative log-likelihood was minimized at approximately $\log(R_0)$ of 9.83 (Figure 110).

3.3.8 Reference Points

reference-points-1

Reference points were calculated using the estimated selectivities and catch distributions among fleets in the most recent year of the model (2018). Sustainable total yields (landings plus discards) were 2,819.8 mt when using an $SPR_{30\%}$ reference harvest rate and with a 95% confidence interval of 2,590.1 mt based on estimates of uncertainty. The spawning biomass equivalent to 25% of the unfished spawning output ($SB_{25\%}$) was 7,638.7.

The predicted spawning biomass from the base model generally showed a decline beginning during the 1950s and reaching a low in spawning biomass in 1993 with the stock declining to 5.8% relative stock size (Figures 96 and 98). Since 20010, the spawning biomass has been increasing due to small catches and above average recruitment. The 2019 spawning biomass relative to unfished equilibrium spawning biomass is above the target of 25% of unfished (Figure 98). The fishing intensity, 1-SPR, exceeded the current harvest rate limit ($SPR_{30\%}$) throughout the late 1970s until approximately 2010 as seen in Figure 111. Recent exploitation rates on petrale sole were estimated to be less than target levels.

Table 20 shows the full suite of estimated reference points for the base model and Figure 112 shows the equilibrium curve based on a steepness value estimated at 0.84.

4 Harvest Projections and Decision Tables

harvest-projections-and-decision-tables

5 Regional Management Considerations

regional-management-considerations

Currently petrale sole are managed using a coast-wide harvest; therefore this assessment does not provide a recommended method for allocating harvests regionally. The resource is modeled as a single stock. There is currently no genetic evidence that there are distinct biological stocks of petrale sole off the U.S. coast and the limited tagging data that describes adult movement suggests that movement may be significant across depth and latitude.

6 Research Needs

research-needs

There are many areas of research that could be improved to benefit the understanding and assessment of petrale sole. Below, are issues that are considered of importance.

1. In the past many assessments have derived historical catches independently. The states of California and Oregon have completed comprehensive historical catch reconstructions. At the time of this assessment, a comprehensive historical catch reconstruction is not available for Washington. Completion of a Washington catch reconstruction would provide the best possible estimated catch series that accounts for all the catch and better resolves historical catch uncertainty for flatfish as a group.
2. Due to limited data, new studies on both the maturity and fecundity relationships for petrale sole would be beneficial.
3. The effect of the implementation of the IFQ (catch shares) program that began during 2011 on fleet behavior, including impacts on discards, fishery selectivity, and fishing locations would benefit from further study.
4. Studies on stock structure and movement of petrale sole, particularly with regard to the winter-summer spawning migration of petrale sole and the likely trans-boundary movement of petrale sole between U.S. and Canadian waters seasonally.
5. The extent of spatial variability on productivity processes such as growth, recruitment, and maturity is currently unknown and would benefit from further research.

7 Acknowledgments

acknowledgments

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9 Tables

`tables`

Table 1: Landings for each fleet for the modeled years.

tab:Comm_Catch

Year	Winter North	Summer North	Winter South	Summer South
1875	0	0	0	0
1876	0	0	0	1
1877	0	0	0	1
1878	0	0	0	1
1879	0	0	0	1
1880	0	0	0	12
1881	0	0	0	22
1882	0	0	0	33
1883	0	0	0	43
1884	0	0	0	54
1885	0	0	0	64
1886	0	0	0	75
1887	0	0	0	85
1888	0	0	0	96
1889	0	0	0	106
1890	0	0	0	117
1891	0	0	0	128
1892	0	0	0	138
1893	0	0	0	149
1894	0	0	0	159
1895	0	0	0	170
1896	0	0	0	180
1897	0	0	0	191
1898	0	0	0	201
1899	0	0	0	212
1900	0	0	0	223
1901	0	0	0	233
1902	0	0	0	244
1903	0	0	0	254
1904	0	0	0	265
1905	0	0	0	275
1906	0	0	0	286
1907	0	0	0	296
1908	0	0	0	307
1909	0	0	0	318
1910	0	0	0	328
1911	0	0	0	339
1912	0	0	0	349
1913	0	0	0	360
1914	0	0	0	370

Year	Winter North	Summer North	Winter South	Summer South
1915	0	0	0	381
1916	0	0	0	386
1917	0	0	0	526
1918	0	0	0	424
1919	0	0	0	333
1920	0	0	0	230
1921	0	0	0	294
1922	0	0	0	425
1923	0	0	0	427
1924	0	0	0	533
1925	0	0	0	528
1926	0	0	0	522
1927	0	0	0	632
1928	0	0	0	620
1929	0	2	0	706
1930	0	1	0	659
1931	0	81	63	531
1932	2	251	36	520
1933	6	408	39	392
1934	10	568	139	896
1935	14	650	155	777
1936	16	770	95	432
1937	20	1051	75	741
1938	27	1187	48	890
1939	35	1545	31	1029
1940	39	1737	162	597
1941	41	1803	111	331
1942	46	2919	24	216
1943	51	2867	72	345
1944	55	2047	86	447
1945	60	1866	102	439
1946	64	2492	72	1116
1947	69	1778	154	1093
1948	74	2315	273	1778
1949	76	1809	617	1812
1950	156	2322	424	1638
1951	118	1666	208	993
1952	131	1390	326	882
1953	46	737	533	981
1954	27	903	801	1073

Year	Winter North	Summer North	Winter South	Summer South
1955	57	863	526	1052
1956	137	759	508	801
1957	171	1103	527	1027
1958	99	1152	568	957
1959	332	947	379	723
1960	241	1374	520	644
1961	217	1547	542	1029
1962	295	1512	515	859
1963	663	1038	534	978
1964	282	1090	378	927
1965	370	950	374	853
1966	366	972	325	925
1967	409	793	532	874
1968	284	811	361	871
1969	190	887	421	848
1970	412	1081	472	1071
1971	743	883	540	1016
1972	730	1017	703	1000
1973	497	1272	417	742
1974	517	1611	665	893
1975	539	1559	561	901
1976	506	951	713	737
1977	682	743	484	495
1978	746	1098	419	801
1979	734	1086	353	945
1980	382	976	518	680
1981	761	468	360	895
1982	1041	771	262	502
1983	696	935	273	361
1984	416	739	260	329
1985	392	553	273	471
1986	474	714	403	355
1987	855	573	311	556
1988	743	610	349	411
1989	696	583	393	415
1990	641	460	319	373
1991	793	397	448	310
1992	640	366	272	307
1993	685	392	237	234
1994	518	355	246	299

Year	Winter North	Summer North	Winter South	Summer South
1915	0	0	0	381
1916	0	0	0	386
1917	0	0	0	526
1918	0	0	0	424
1919	0	0	0	333
1920	0	0	0	230
1921	0	0	0	294
1922	0	0	0	425
1923	0	0	0	427
1924	0	0	0	533
1925	0	0	0	528
1926	0	0	0	522
1927	0	0	0	632
1928	0	0	0	620
1929	0	2	0	706
1930	0	1	0	659
1931	0	81	63	531
1932	2	251	36	520
1933	6	408	39	392
1934	10	568	139	896
1935	14	650	155	777
1936	16	770	95	432
1937	20	1051	75	741
1938	27	1187	48	890
1939	35	1545	31	1029
1940	39	1737	162	597
1941	41	1803	111	331
1942	46	2919	24	216
1943	51	2867	72	345
1944	55	2047	86	447
1945	60	1866	102	439
1946	64	2492	72	1116
1947	69	1778	154	1093
1948	74	2315	273	1778
1949	76	1809	617	1812
1950	156	2322	424	1638
1951	118	1666	208	993
1952	131	1390	326	882
1953	46	737	533	981
1954	27	903	801	1073

Year	Winter North	Summer North	Winter South	Summer South
1995	591	454	236	287
1996	591	440	406	394
1997	621	430	448	442
1998	522	577	221	300
1999	463	504	287	267
2000	610	586	372	241
2001	691	597	308	260
2002	667	714	335	195
2003	544	713	256	180
2004	1010	750	177	271
2005	964	1069	343	533
2006	537	1012	125	454
2007	930	536	404	475
2008	842	354	519	414
2009	847	642	470	250
2010	264	292	78	121
2011	224	427	40	78
2012	410	494	124	108
2013	513	1013	130	280
2014	853	860	273	386
2015	1040	1077	215	354
2016	865	1168	237	235
2017	1142	1271	201	393
2018	957	1262	218	402

Table 2: Recent trend in estimated total catch relative to management guidelines. The estimated total catch includes the total landings plus the model estimated discard mortality based upon discard rate data.

tab:mnmgt_perform_tables

Year	OFL (mt; ABC prior to 2011)	ACL (mt; OY prior to 2011)	Total landings (mt)	Estimated total catch (mt)
2009	2811	2433	2209	2329
2010	2751	1200	755	867
2011	1021	976	768	791
2012	1275	1160	1135	1159
2013	2711	2592	1936	1973
2014	2774	2652	2373	2398
2015	3073	2816	2686	2727
2016	3208	2910	2506	2543
2017	3208	3136	3008	3050
2018	3152	3013	2840	2882

Table 3: Description of the strata used to create the indices for the NWFSC Shelf-Slope survey.

tab:strata_nwfsc

Strata	Depth Lower Bound	Depth Upper Bound	Latitude South	Latitude North
Shallow Vancouver	55	100	47.5	49.0
Shallow Columbia	55	100	43.0	47.5
Shallow Eureka	55	100	40.5	43.0
Shallow Monterey	55	100	36.0	40.5
Shallow Conception	55	100	34.5	36.0
Mid Vancouver	100	183	47.5	49.0
Mid Columbia	100	183	43.0	47.5
Mid Eureka	100	183	40.5	43.0
Mid Monterey	100	183	36.0	40.5
Mid Conception	100	183	34.5	36.0
Deep Van/Col/Eur	183	549	40.5	49.0
Deep Montery	183	549	36.0	40.5
Deep Conception	183	549	32.0	36.0

Table 4: Summary of the fishery-independent 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

	Winter N.		Winter S.		Triennial Early		Triennial Late		NWFSC Combo	
Year	Obs	SE	Obs	SE	Obs	SE	Obs	SE	Obs	SE
1980	-	-	-	-	1512	0.49	-	-	-	-
1983	-	-	-	-	2380	0.45	-	-	-	-
1986	-	-	-	-	2249	0.46	-	-	-	-
1987	1.09	0.28	1.08	0.56	-	-	-	-	-	-
1988	1.16	0.27	0.91	0.33	-	-	-	-	-	-
1989	0.92	0.27	0.53	0.43	3569	0.43	-	-	-	-
1990	0.76	0.28	0.96	0.46	-	-	-	-	-	-
1991	0.86	0.27	0.90	0.36	-	-	-	-	-	-
1992	0.56	0.28	0.59	0.68	2226	0.43	-	-	-	-
1993	0.56	0.27	0.86	0.35	-	-	-	-	-	-
1994	0.50	0.28	0.71	0.30	-	-	-	-	-	-
1995	0.66	0.28	0.90	0.30	-	-	2636	0.33	-	-
1996	0.77	0.29	1.25	0.30	-	-	-	-	-	-
1997	0.85	0.28	0.82	0.28	-	-	-	-	-	-
1998	1.01	0.29	0.93	0.31	-	-	3836	0.32	-	-
1999	0.71	0.29	0.83	0.29	-	-	-	-	-	-
2000	0.67	0.28	0.62	0.29	-	-	-	-	-	-
2001	0.83	0.27	0.66	0.29	-	-	4362	0.33	-	-
2002	0.93	0.28	0.80	0.29	-	-	-	-	-	-
2003	1.02	0.28	0.85	0.29	-	-	-	-	19970	0.13
2004	1.63	0.28	1.71	0.31	-	-	10662	0.33	26767	0.14
2005	1.85	0.28	1.93	0.29	-	-	-	-	26795	0.12
2006	2.01	0.28	1.58	0.29	-	-	-	-	22288	0.12
2007	2.04	0.28	2.07	0.28	-	-	-	-	21003	0.13
2008	1.96	0.27	1.62	0.28	-	-	-	-	17597	0.12
2009	2.12	0.27	1.76	0.28	-	-	-	-	18270	0.12
2010	-	-	-	-	-	-	-	-	26860	0.12
2011	-	-	-	-	-	-	-	-	36324	0.12
2012	-	-	-	-	-	-	-	-	42005	0.12
2013	-	-	-	-	-	-	-	-	58743	0.13
2014	-	-	-	-	-	-	-	-	65532	0.12
2015	-	-	-	-	-	-	-	-	59015	0.12
2016	-	-	-	-	-	-	-	-	64522	0.12
2017	-	-	-	-	-	-	-	-	66101	0.12
2018	-	-	-	-	-	-	-	-	46594	0.12

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

Year	Tows	Fish	Sample Size
2003	197	2837	589
2004	212	3346	674
2005	278	4555	907
2006	247	3668	753
2007	257	3409	727
2008	254	3037	673
2009	273	3375	739
2010	322	6018	1152
2011	320	6176	1172
2012	295	5372	1036
2013	218	3445	693
2014	332	4822	997
2015	312	4236	897
2016	309	4385	914
2017	314	4261	902
2018	291	3783	813

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

Year	Tows	Fish	Sample Size
2003	173	765	279
2004	167	723	267
2005	237	752	341
2006	236	774	343
2007	196	690	291
2008	222	736	324
2009	255	766	361
2010	295	794	405
2011	289	799	399
2012	269	777	376
2013	217	843	333
2014	318	766	424
2015	291	751	395

Table 7: Description of the strata used to create the indices for the Triennial Early (1980 - 1992) survey.

tab:strata_tri_early

Strata	Depth Lower Bound	Depth Upper Bound	Latitude South	Latitude North
Shallow Van/Col	55	100	43.0	49.0
Shallow Eureka	55	100	40.5	43.0
Shallow Mon/Con	55	100	32.0	40.5
Deep Van/Col/Eur	100	400	40.5	49.0
Deep Mon/Con	100	400	32.0	40.5

Table 8: Description of the strata used to create the indices for the Triennial Late (1995-2004) survey.

tab:strata_tri_late

Strata	Depth Lower Bound	Depth Upper Bound	Latitude South	Latitude North
Shallow Van/Col	55	100	43.0	49.0
Shallow Eureka	55	100	40.5	43.0
Shallow Mon/Con	55	100	32.0	40.5
Deep Van/Col	100	500	43.0	49.0
Deep Eureka	100	500	40.5	43.0
Deep Mon/Con	100	500	36.0	40.5
Deep Con	100	500	32.0	36.0

Table 9: Summary of Triennial survey length samples used in the stock assessment.
tab:Triennial_Lengths

Year	Tows	Fish	Sample Size
1980	1	16	3
1983	2	30	6
1986	36	540	111
1989	141	1419	337
1992	116	1015	256
1995	145	1369	334
1998	236	2624	598
2001	254	3016	670
2004	239	4676	884

Table 10: Summary of discard rates used in the model by each data source (continued on next page).

tab:Discard

Year	Fleet	Discard Rate	Standard Error	Data Source
1985	WinterN	0.022	0.110	Pikitch
1986	WinterN	0.021	0.116	Pikitch
1987	WinterN	0.027	0.119	Pikitch
2002	WinterN	0.008	0.001	WGCOP
2003	WinterN	0.004	0.002	WGCOP
2004	WinterN	0.003	0.002	WGCOP
2005	WinterN	0.002	0.001	WGCOP
2006	WinterN	0.006	0.003	WGCOP
2007	WinterN	0.012	0.005	WGCOP
2008	WinterN	0.022	0.012	WGCOP
2009	WinterN	0.027	0.014	WGCOP
2010	WinterN	0.119	0.023	WGCOP
2011	WinterN	0.002	0.015	WGCOP
2012	WinterN	0.001	0.015	WGCOP
2013	WinterN	0.001	0.015	WGCOP
2014	WinterN	0.003	0.015	WGCOP
2015	WinterN	0.001	0.015	WGCOP
2016	WinterN	0.001	0.015	WGCOP
2017	WinterN	0.003	0.015	WGCOP
2018	WinterN	0.001	0.015	WGCOP
2019	WinterN	0.001	0.015	WGCOP
1985	SummerN	0.035	0.042	Pikitch
1986	SummerN	0.034	0.043	Pikitch
1987	SummerN	0.032	0.045	Pikitch
2002	SummerN	0.186	0.023	WGCOP
2003	SummerN	0.105	0.022	WGCOP
2004	SummerN	0.083	0.023	WGCOP
2005	SummerN	0.042	0.008	WGCOP
2006	SummerN	0.078	0.015	WGCOP
2007	SummerN	0.116	0.021	WGCOP
2008	SummerN	0.051	0.016	WGCOP
2009	SummerN	0.206	0.067	WGCOP
2010	SummerN	0.099	0.029	WGCOP
2011	SummerN	0.037	0.015	WGCOP
2012	SummerN	0.022	0.015	WGCOP
2013	SummerN	0.017	0.015	WGCOP
2014	SummerN	0.026	0.015	WGCOP
2015	SummerN	0.006	0.015	WGCOP
2016	SummerN	0.017	0.015	WGCOP
2017	SummerN	0.007	0.015	WGCOP

Year	Fleet	Discard Rate	Standard Error	Data Source
2002	WinterS	0.035	0.016	WGCOP
2003	WinterS	0.012	0.001	WGCOP
2004	WinterS	0.013	0.033	WGCOP
2005	WinterS	0.033	0.004	WGCOP
2006	WinterS	0.071	0.035	WGCOP
2007	WinterS	0.012	0.003	WGCOP
2008	WinterS	0.013	0.010	WGCOP
2009	WinterS	0.024	0.009	WGCOP
2010	WinterS	0.052	0.031	WGCOP
2011	WinterS	0.001	0.015	WGCOP
2012	WinterS	0.001	0.015	WGCOP
2013	WinterS	0.003	0.015	WGCOP
2014	WinterS	0.001	0.015	WGCOP
2015	WinterS	0.001	0.015	WGCOP
2016	WinterS	0.003	0.015	WGCOP
2017	WinterS	0.006	0.015	WGCOP
2018	WinterS	0.001	0.015	WGCOP
2019	WinterS	0.001	0.015	WGCOP
2002	SummerS	0.058	0.016	WGCOP
2003	SummerS	0.033	0.011	WGCOP
2004	SummerS	0.033	0.014	WGCOP
2005	SummerS	0.012	0.003	WGCOP
2006	SummerS	0.038	0.014	WGCOP
2007	SummerS	0.065	0.023	WGCOP
2008	SummerS	0.026	0.014	WGCOP
2009	SummerS	0.023	0.006	WGCOP
2010	SummerS	0.056	0.007	WGCOP
2011	SummerS	0.041	0.015	WGCOP
2012	SummerS	0.013	0.015	WGCOP
2013	SummerS	0.004	0.015	WGCOP
2014	SummerS	0.004	0.015	WGCOP
2015	SummerS	0.010	0.015	WGCOP
2016	SummerS	0.004	0.015	WGCOP
2017	SummerS	0.008	0.015	WGCOP

Table 11: Summary of fishery length samples used in the stock assessment (continued on next page).

tab:Fishery_Lengths

	Winter N.		Summer N.		Winter S.		Summer S.	
Year	Trips	Fish	Trips	Fish	Trips	Fish	Trips	Fish
1948							4	203
1949					10	477	4	183
1950								
1951								
1952								
1953								
1954								
1955	1	507						
1956			1	534				
1957								
1958								
1959								
1960			1	644				
1961								
1962							3	150
1963								
1964					1	49	22	897
1965					2	49	14	583
1966	1	100	35	2104	8	275	33	1396
1967	4	200	42	2428	20	908	44	1815
1968	11	562	49	4027	11	500	87	3414
1969	10	779	52	3400	14	468	49	1907
1970	9	743	53	3731	13	462	29	920
1971	9	883	11	1982	7	250	37	1180
1972	3	705	30	4776	23	942	39	1435
1973	2	440	18	2176	12	424	41	1469
1974	2	554	37	8316	31	1226	35	1133
1975	10	2192	23	4509	11	325	19	873
1976	1	379	4	1054	12	525	26	1255
1977	2	320	21	2406	8	400	38	1816
1978	4	778	21	2454	17	787	33	1649
1979	2	219	23	2437	7	350	13	601
1980	9	1022	44	4431	6	297	81	4042
1981	10	1000	37	3695	36	1774	65	3134
1982	5	498	17	1699	26	1294	34	1434
1983	4	408	1	100	26	1324	33	1600
1984	3	412			13	603	19	943
1985			5	499	13	650	17	825
1986	3	300	9	893	10	499	32	1602
1987	7	502	16	805	20	1000	29	1450
1988	4	199	8	401	12	600	12	531
1989	10	499	13	652	18	883	18	900
1990	4	200	11	551	4	200	2	76
1991	11	425	7	277	24	890	2	82
1992	4	173	11	428	12	368		
1993	7	217	8	296				
1994	9	339	9	371	1	1		
1995	8	301	2	66				
1996	3	102	4	168				
1997	5	203	11	416				

	Winter N.		Summer N.		Winter S.		Summer S.	
Year	Trips	Fish	Trips	Fish	Trips	Fish	Trips	Fish
1998	5	166	22	1004				
1999	9	330	15	702				
2000	14	544	24	1012				
2001	18	659	18	786			9	289
2002	9	398	31	1257	15	443	10	252
2003	20	723	35	1368	7	215	30	475
2004	27	876	30	1328	12	248	15	431
2005	25	772	35	1492	9	201	36	966
2006	16	754	51	2638	26	735	47	1059
2007	37	1487	46	2402	42	1111	103	2971
2008	61	2035	36	2124	58	1801	97	2442
2009	43	1541	66	2860	62	1635	62	1597
2010	38	1374	59	1795	31	719	52	1356
2011	33	1015	47	2019	18	639	23	400
2012	35	1148	44	1954	32	1027	40	1125
2013	44	1756	52	2300	37	1601	43	1930
2014	52	1762	64	2421	42	1719	49	1672
2015	76	2629	60	2386	32	1081	62	2026
2016	27	835	39	1071	39	1353	70	2306
2017	42	1620	74	2790	31	1137	85	2489
2018	54	1586	93	2654	24	1007	77	2663
2019	28	624			9	413		

Table 12: Summary of fishery age samples used in the stock assessment (continued on next page).

tab:Fishery_Ages

	Winter N.		Summer N.		Winter S.		Summer S.	
Year	Trips	Fish	Trips	Fish	Trips	Fish	Trips	Fish
1960			1	168				
1961								
1962								
1963								
1964								
1965								
1966			34	1925	8	165	27	649
1967	4	200	42	2415	13	326	11	273
1968	11	560	44	2784			56	1340
1969	10	549	50	2592	8	158	31	765
1970	8	572	52	2895	10	251	29	711
1971	5	338	10	1284	6	150	37	930
1972	3	527	29	3467	23	559	38	965
1973	2	393	18	2015	12	298	38	959
1974	2	198	32	3146	29	742	34	838
1975	9	864	20	1902	9	201	18	473
1976	1	99	4	400	12	300	23	575
1977	2	198	19	1849	8	200	33	822
1978	4	406	16	1653	9	216	32	800
1979			21	2215	5	125	11	271
1980	7	623	38	3701	6	151	50	1245
1981	8	791	37	3672	18	450	27	677
1982	5	442	16	744	1	25	18	352
1983	3	288	1	95	12	352	8	193
1984	2	209			6	148	3	74
1985			5	444	2	50	4	100
1986	3	246	9	761	4	92	16	377
1987	7	422	16	574	10	235	12	291
1988	4	98	8	256	5	123	6	148
1989	10	426	12	507	2	50		
1990	4	160	11	272	2	50	1	38
1991	11	233	7	151	15	456		
1992	4	158	11	424	1	33		
1993	7	217	8	296				
1994	9	339	9	371				
1995	8	299	2	66				
1996	3	102	4	165				
1997	5	203	10	376				
1998	5	166	22	999				
1999	6	234	13	607				
2000	6	287	12	560				
2001	6	258	11	498				
2002	9	396	20	833				
2003	12	418	26	1070	1	39	5	55
2004	15	558	24	1060	1	2	4	96
2005	5	244	18	873	5	112	10	217
2006	5	248	14	696	2	51	7	154
2007	9	370	24	1018			5	97
2008	7	265	26	1078	7	124	18	300
2009	32	626	39	684	4	51	3	78

	Winter N.		Summer N.		Winter S.		Summer S.	
Year	Trips	Fish	Trips	Fish	Trips	Fish	Trips	Fish
2010	25	413	34	540				
2011	12	205	42	845			8	26
2012	32	388	40	835	10	215	1	34
2013	39	604	46	832	2	87	3	102
2014	46	764	24	616	1	39		
2015	47	622	48	811				
2016	13	157						
2017	6	295	7	338				

Table 13: Estimated ageing error vectors applied to ages read by the Cooperative Aging Project lab used in the assessment model.

tab:age_error1

	Break and Burn		Surface		Combo		Surface Pre-1990	
True Age	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	0.26	0.17	0.16	0.12	0.47	0.13	0.00	0.00
1	1.35	0.17	1.27	0.12	1.42	0.13	0.71	0.00
2	2.41	0.23	2.35	0.18	2.37	0.25	2.02	0.08
3	3.44	0.29	3.41	0.25	3.32	0.38	3.24	0.17
4	4.45	0.36	4.43	0.32	4.27	0.51	4.38	0.26
5	5.44	0.44	5.42	0.40	5.22	0.64	5.44	0.35
6	6.41	0.52	6.39	0.49	6.17	0.76	6.44	0.46
7	7.35	0.61	7.33	0.59	7.12	0.89	7.36	0.56
8	8.28	0.71	8.25	0.70	8.07	1.02	8.22	0.67
9	9.18	0.81	9.14	0.82	9.02	1.14	9.03	0.79
10	10.06	0.92	10.01	0.96	9.97	1.27	9.78	0.92
11	10.92	1.04	10.85	1.11	10.92	1.40	10.48	1.05
12	11.76	1.18	11.67	1.27	11.87	1.53	11.14	1.19
13	12.58	1.32	12.47	1.45	12.82	1.65	11.75	1.34
14	13.38	1.48	13.24	1.66	13.77	1.78	12.32	1.49
15	14.17	1.64	14.00	1.88	14.72	1.91	12.85	1.66
16	14.94	1.82	14.73	2.12	15.67	2.03	13.35	1.83
17	15.68	2.02	15.45	2.39	16.62	2.16	13.81	2.01

Table 14: Estimated ageing error vectors applied to ages read by Washington Department of Fish and Wildlife used in the assessment model.

tab:age_error2

	Combo		Surface		Break and Burn	
True Age	Mean	SD	Mean	SD	Mean	SD
0	0.49	0.13	0.13	0.10	0.50	0.15
1	1.46	0.13	1.32	0.10	1.51	0.15
2	2.44	0.27	2.47	0.21	2.52	0.30
3	3.42	0.40	3.58	0.31	3.52	0.45
4	4.39	0.53	4.64	0.41	4.53	0.60
5	5.37	0.67	5.67	0.52	5.53	0.75
6	6.35	0.80	6.66	0.62	6.54	0.90
7	7.32	0.93	7.62	0.72	7.55	1.05
8	8.30	1.07	8.54	0.83	8.55	1.20
9	9.28	1.20	9.43	0.93	9.56	1.35
10	10.25	1.33	10.28	1.03	10.57	1.51
11	11.23	1.47	11.11	1.13	11.57	1.66
12	12.21	1.60	11.90	1.24	12.58	1.81
13	13.18	1.74	12.67	1.34	13.59	1.96
14	14.16	1.87	13.41	1.44	14.59	2.11
15	15.14	2.00	14.12	1.55	15.60	2.26
16	16.11	2.14	14.81	1.65	16.60	2.41
17	17.09	2.27	15.47	1.75	17.61	2.56

Table 15: Specifications of the model for petrale sole.

tab:Model_setup

Model Specification	Base Model
Starting year	1876
Population characteristics	
Maximum age	40
Gender	2
Population lengths	4-78 cm by 2 cm bins
Summary biomass (mt)	Age 3+
Data characteristics	
Data lengths	12-62 cm by 2 cm bins
Data ages	1-17 ages
Minimum age for growth calculations	2
Maximum age for growth calculations	17
First mature age	3
Fishery characteristics	
Fishing mortality method	Hybrid
Maximum F	3
Catchability - Fishery	Power
Catchability - Survey	Analytical estimate
Winter North selectivity	Double Normal
Summer North selectivity	Double Normal
Winter South selectivity	Double Normal
Summer South selectivity	Double Normal
AFSC/NWFSC West Coast Triennial Shelf Survey - early	Double Normal
AFSC/NWFSC West Coast Triennial Shelf Survey - late	Double Normal
NWFSC West Coast Groundfish Bottom Trawl Survey	Double Normal
Fishery time blocks	
Fishery selectivity	1876-1972,1973-1982, 1983-1992, 1993-2002, 2003-2010, 2011-2018
Winter retention	1876-2002, 2003-2009, 2010, 2011-2018
Summer retention	1876-2002, 2003-2008, 2009-2010, 2011-2018

Table 16: Data weights applied when using harmonic data weighting.

tab:harm

Fleet	Lengths	Ages
Winter North		
Summer North		
Winter South		
Summer South		
Triennial Early survey		-
Triennial Late survey		-
NWFSC shelf-slope survey		

Table 17: 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	0.161992	6	(0.005, 0.5)	OK	0.02	Log_Norm (-1.7793, 0.438)
L_at_Amin_Fem_GP_1	15.8915	2	(10, 45)	OK	0.42	None
L_at_Amax_Fem_GP_1	53.9424	3	(35, 80)	OK	0.40	None
VonBert_K_Fem_GP_1	0.135371	2	(0.04, 0.5)	OK	0.01	None
SD_young_Fem_GP_1	0.189896	3	(0.01, 1)	OK	0.01	None
SD_old_Fem_GP_1	0.0250563	4	(0.01, 1)	OK	0.01	None
Wtlen_1_Fem_GP_1	0.00000208	-3	(-3, 3)			Normal (0.00000208, 0.8)
Wtlen_2_Fem_GP_1	3.4737	-3	(1, 5)			Normal (3.4737, 0.8)
Mat50%_Fem_GP_1	33.1	-3	(10, 50)			Normal (33.1, 0.8)
Mat_slope_Fem_GP_1	-0.743	-3	(-3, 3)			Normal (-0.743, 0.8)
Eggs/kg_inter_Fem_GP_1	1	-3	(-3, 3)			Normal (1, 1)
Eggs/kg_slope_wt_Fem_GP_1	0	-3	(-3, 3)			Normal (0, 1)
NatM_p_1_Mal_GP_1	0.174411	6	(0.005, 0.6)	OK	0.02	Log_Norm (-1.6809, 0.438)
L_at_Amin_Mal_GP_1	16.4779	2	(10, 45)	OK	0.33	None
L_at_Amax_Mal_GP_1	42.1411	3	(35, 80)	OK	0.41	None
VonBert_K_Mal_GP_1	0.216	2	(0.04, 0.5)	OK	0.01	None
SD_young_Mal_GP_1	0.134634	3	(0.01, 1)	OK	0.01	None
SD_old_Mal_GP_1	0.053	4	(0.01, 1)	OK	0.01	None
Wtlen_1_Mal_GP_1	0.00000305	-3	(-3, 3)			Normal (0.00000305, 0.8)
Wtlen_2_Mal_GP_1	3.36054	-3	(-3, 5)			Normal (3.36054, 0.8)
CohortGrowDev	1	-4	(0, 1)			None
FracFemale_GP_1	0.5	-99	(0.01, 0.99)			None
SR_LN(R0)	9.83235	1	(5, 20)	OK	0.20	None
SR_BH_steep	0.839916	5	(0.2, 1)	OK	0.05	Normal (0.8, 0.09)
SR_sigmaR	0.4	-99	(0, 2)			Normal (0.9, 5)
SR_regime	0	-2	(-5, 5)			Normal (0, 0.2)
SR_autocorr	0	-99	(0, 0)			None
Early_InitAge_31	0.000000278911	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_30	0.000000327699	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_29	0.000000384942	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_28	0.000000452078	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_27	0.000000530781	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_26	0.000000622998	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_25	0.000000730985	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_24	0.000000857355	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_23	0.00000100513	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_22	0.00000117777	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_21	0.00000137929	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_20	0.00000161425	3	(-4, 4)	act	0.40	dev (NA, NA)

Continued on next page

Table 17: 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)
Early_InitAge_19	0.00000188786	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_18	0.00000220604	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_17	0.00000257549	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_16	0.00000300378	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_15	0.00000349937	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_14	0.00000407165	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_13	0.00000473103	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_12	0.00000548896	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_11	0.00000635795	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_10	0.00000735162	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_9	0.00000848451	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_8	0.00000977139	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_7	0.0000112258	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_6	0.0000128609	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_5	0.0000146966	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_4	0.0000167694	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_3	0.0000191253	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_2	0.0000218083	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_1	0.0000248635	3	(-4, 4)	act	0.40	dev (NA, NA)
LnQ_base_WinterN(1)	-5.11324	1	(-20, 5)	OK	3.14	None
Q_power_WinterN(1)	-0.353898	3	(-5, 5)	OK	0.41	None
LnQ_base_WinterS(3)	-1.36603	1	(-20, 5)	OK	2.34	None
Q_power_WinterS(3)	-0.849303	3	(-5, 5)	OK	0.30	None
LnQ_base_TriEarly(5)	-0.803067	-1	(-15, 15)			None
Q_extraSD_TriEarly(5)	0.340847	5	(0.001, 2)	OK	0.15	None
LnQ_base_TriLate(6)	-0.254844	-1	(-15, 15)			None
Q_extraSD_TriLate(6)	0.236348	4	(0.001, 2)	OK	0.12	None
LnQ_base_NWFSC(7)	1.33092	-1	(-15, 15)			None
LnQ_base_WinterN(1)_BLK5add_2004	0.547816	3	(-0.99, 0.99)	OK	0.22	Normal (0, 0.5)
LnQ_base_WinterS(3)_BLK5add_2004	0.623155	3	(-0.99, 0.99)	OK	0.22	Normal (0, 0.5)
Size_DblN_peak_WinterN(1)	49.1595	1	(15, 75)	OK	0.92	None
Size_DblN_top_logit_WinterN(1)	3	-3	(-5, 3)			None
Size_DblN_ascend_se_WinterN(1)	4.28513	2	(-4, 12)	OK	0.13	None
Size_DblN_descend_se_WinterN(1)	14	-3	(-2, 15)			None
Size_DblN_start_logit_WinterN(1)	-999	-4	(-15, 5)			None
Size_DblN_end_logit_WinterN(1)	-999	-4	(-5, 5)			None
Retain_L_infl_WinterN(1)	24.2848	1	(10, 40)	OK	1.42	None
Retain_L_width_WinterN(1)	1.44101	2	(0.1, 10)	OK	0.19	None
Retain_L_asymptote_logit_WinterN(1)	9.99652	4	(-10, 10)	HI	0.11	None

Continued on next page

Table 17: 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)
Retain_L_maleoffset_WinterN(1)	0	-2	(-10, 10)			None
SzSel_Male_Peak_WinterN(1)	-11.5865	3	(-15, 15)	OK	0.78	None
SzSel_Male_Ascend_WinterN(1)	-1.51838	4	(-15, 15)	OK	0.18	None
SzSel_Male_Descend_WinterN(1)	0	-4	(-15, 15)			None
SzSel_Male_Final_WinterN(1)	0	-4	(-15, 15)			None
SzSel_Male_Scale_WinterN(1)	1	-4	(-15, 15)			None
Size_DblN_peak_SummerN(2)	54.4414	1	(15, 75)	OK	1.27	None
Size_DblN_top_logit_SummerN(2)	3	-3	(-5, 3)			None
Size_DblN_ascend_se_SummerN(2)	5.43766	2	(-4, 12)	OK	0.10	None
Size_DblN_descend_se_SummerN(2)	14	-3	(-2, 15)			None
Size_DblN_start_logit_SummerN(2)	-999	-4	(-15, 5)			None
Size_DblN_end_logit_SummerN(2)	-999	-4	(-5, 5)			None
Retain_L_infl_SummerN(2)	30.2865	1	(10, 40)	OK	0.36	None
Retain_L_width_SummerN(2)	1.30185	2	(0.1, 10)	OK	0.11	None
Retain_L_asymptote_logit_SummerN(2)	5.74848	4	(-10, 10)	OK	0.35	None
Retain_L_maleoffset_SummerN(2)	0	-2	(-10, 10)			None
SzSel_Male_Peak_SummerN(2)	-14.0633	3	(-20, 15)	OK	0.97	None
SzSel_Male_Ascend_SummerN(2)	-1.9821	4	(-15, 15)	OK	0.18	None
SzSel_Male_Descend_SummerN(2)	0	-4	(-15, 15)			None
SzSel_Male_Final_SummerN(2)	0	-4	(-15, 15)			None
SzSel_Male_Scale_SummerN(2)	1	-4	(-15, 15)			None
Size_DblN_peak_WinterS(3)	44.2878	1	(15, 75)	OK	1.74	None
Size_DblN_top_logit_WinterS(3)	3	-3	(-5, 3)			None
Size_DblN_ascend_se_WinterS(3)	4.4519	2	(-4, 12)	OK	0.27	None
Size_DblN_descend_se_WinterS(3)	14	-3	(-2, 15)			None
Size_DblN_start_logit_WinterS(3)	-999	-4	(-15, 5)			None
Size_DblN_end_logit_WinterS(3)	-999	-4	(-5, 5)			None
Retain_L_infl_WinterS(3)	28.9561	1	(10, 40)	OK	0.57	None
Retain_L_width_WinterS(3)	1.44014	2	(0.1, 10)	OK	0.29	None
Retain_L_asymptote_logit_WinterS(3)	4.86774	4	(-10, 10)	OK	0.94	None
Retain_L_maleoffset_WinterS(3)	0	-2	(-10, 10)			None
SzSel_Male_Peak_WinterS(3)	-12.2823	3	(-15, 15)	OK	1.77	None
SzSel_Male_Ascend_WinterS(3)	-1.8526	4	(-15, 15)	OK	0.50	None
SzSel_Male_Descend_WinterS(3)	0	-4	(-15, 15)			None
SzSel_Male_Final_WinterS(3)	0	-4	(-15, 15)			None
SzSel_Male_Scale_WinterS(3)	1	-4	(-15, 15)			None
Size_DblN_peak_SummerS(4)	45.2206	1	(15, 75)	OK	1.29	None
Size_DblN_top_logit_SummerS(4)	3	-3	(-5, 3)			None
Size_DblN_ascend_se_SummerS(4)	4.89214	2	(-4, 12)	OK	0.15	None

Continued on next page

Table 17: 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)
Size_DblN_descend_se_SummerS(4)	14	-3	(-2, 15)			None
Size_DblN_start_logit_SummerS(4)	-999	-4	(-15, 5)			None
Size_DblN_end_logit_SummerS(4)	-999	-4	(-5, 5)			None
Retain_L_infl_SummerS(4)	29.2437	1	(10, 40)	OK	0.33	None
Retain_L_width_SummerS(4)	1.4909	2	(0.1, 10)	OK	0.12	None
Retain_L_asymptote_logit_SummerS(4)	5.79317	4	(-10, 10)	OK	0.89	None
Retain_L_maleoffset_SummerS(4)	0	-2	(-10, 10)			None
SzSel_Male_Peak_SummerS(4)	-11.8309	3	(-15, 15)	OK	1.28	None
SzSel_Male_Ascend_SummerS(4)	-1.83638	4	(-15, 15)	OK	0.29	None
SzSel_Male_Descend_SummerS(4)	0	-4	(-15, 15)			None
SzSel_Male_Final_SummerS(4)	0	-4	(-15, 15)			None
SzSel_Male_Scale_SummerS(4)	1	-4	(-15, 15)			None
Size_DblN_peak_TriEarly(5)	34.4179	1	(15, 61)	OK	1.10	None
Size_DblN_top_logit_TriEarly(5)	3	-2	(-5, 3)			None
Size_DblN_ascend_se_TriEarly(5)	4.05668	1	(-4, 12)	OK	0.20	None
Size_DblN_descend_se_TriEarly(5)	14	-2	(-2, 15)			None
Size_DblN_start_logit_TriEarly(5)	-999	-4	(-15, 5)			None
Size_DblN_end_logit_TriEarly(5)	-999	-4	(-5, 5)			None
SzSel_Male_Peak_TriEarly(5)	-3.30159	2	(-15, 15)	OK	1.07	None
SzSel_Male_Ascend_TriEarly(5)	-0.488328	2	(-15, 15)	OK	0.25	None
SzSel_Male_Descend_TriEarly(5)	0	-3	(-15, 15)			None
SzSel_Male_Final_TriEarly(5)	0	-3	(-15, 15)			None
SzSel_Male_Scale_TriEarly(5)	1	-4	(-15, 15)			None
Size_DblN_peak_TriLate(6)	36.7376	1	(15, 61)	OK	0.90	None
Size_DblN_top_logit_TriLate(6)	3	-2	(-5, 3)			None
Size_DblN_ascend_se_TriLate(6)	4.65333	1	(-4, 12)	OK	0.11	None
Size_DblN_descend_se_TriLate(6)	14	-2	(-2, 15)			None
Size_DblN_start_logit_TriLate(6)	-999	-4	(-15, 5)			None
Size_DblN_end_logit_TriLate(6)	-999	-4	(-5, 5)			None
SzSel_Male_Peak_TriLate(6)	-2.59651	2	(-15, 15)	OK	0.92	None
SzSel_Male_Ascend_TriLate(6)	-0.0842824	2	(-15, 15)	OK	0.14	None
SzSel_Male_Descend_TriLate(6)	0	-3	(-15, 15)			None
SzSel_Male_Final_TriLate(6)	0	-3	(-15, 15)			None
SzSel_Male_Scale_TriLate(6)	1	-4	(-15, 15)			None
Size_DblN_peak_NWFSC(7)	43.5751	1	(15, 61)	OK	0.83	None
Size_DblN_top_logit_NWFSC(7)	3	-2	(-5, 3)			None
Size_DblN_ascend_se_NWFSC(7)	5.18139	1	(-4, 12)	OK	0.07	None
Size_DblN_descend_se_NWFSC(7)	14	-2	(-2, 15)			None
Size_DblN_start_logit_NWFSC(7)	-999	-4	(-15, 5)			None

Continued on next page

Table 17: 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)
Size_DblN_end_logit_NWFSC(7)	-999	-4	(-5, 5)			None
SzSel_Male_Peak_NWFSC(7)	-5.93554	2	(-15, 15)	OK	0.71	None
SzSel_Male_Ascend_NWFSC(7)	-0.502877	2	(-15, 15)	OK	0.08	None
SzSel_Male_Descend_NWFSC(7)	0	-3	(-15, 15)			None
SzSel_Male_Final_NWFSC(7)	0	-3	(-15, 15)			None
SzSel_Male_Scale_NWFSC(7)	1	-4	(-15, 15)			None
Size_DblN_peak_WinterN(1)_BLK1add_1973	-0.201894	4	(-31.6, 28.4)	OK	0.88	Normal (0, 14.2)
Size_DblN_peak_WinterN(1)_BLK1add_1983	-1.23738	4	(-31.6, 28.4)	OK	0.81	Normal (0, 14.2)
Size_DblN_peak_WinterN(1)_BLK1add_1993	-1.32607	4	(-31.6, 28.4)	OK	0.63	Normal (0, 14.2)
Size_DblN_peak_WinterN(1)_BLK1add_2003	-0.388152	4	(-31.6, 28.4)	OK	0.46	Normal (0, 14.2)
Size_DblN_peak_WinterN(1)_BLK1add_2011	-0.119181	4	(-31.6, 28.4)	OK	0.48	Normal (0, 14.2)
Retain_L_infl_WinterN(1)_BLK2add_2003	0.477145	4	(-16.19, 13.81)	OK	3.61	Normal (0, 6.905)
Retain_L_infl_WinterN(1)_BLK2add_2010	5.78079	4	(-16.19, 13.81)	OK	2.87	Normal (0, 6.905)
Retain_L_infl_WinterN(1)_BLK2add_2011	2.22632	4	(-16.19, 13.81)	OK	1.73	Normal (0, 6.905)
Retain_L_width_WinterN(1)_BLK2add_2003	0.437634	4	(-1.601, 8.299)	OK	0.33	Normal (0, 0.8005)
Retain_L_width_WinterN(1)_BLK2add_2010	0.571584	4	(-1.601, 8.299)	OK	0.74	Normal (0, 0.8005)
Retain_L_width_WinterN(1)_BLK2add_2011	-0.510919	4	(-1.601, 8.299)	OK	0.20	Normal (0, 0.8005)
Retain_L_asymptote_logit_WinterN(1)_BLK2repl_2003	7.37374	4	(-10, 10)	OK	1.70	None
Retain_L_asymptote_logit_WinterN(1)_BLK2repl_2010	2.08428	4	(-10, 10)	OK	0.40	None
Retain_L_asymptote_logit_WinterN(1)_BLK2repl_2011	9.02851	4	(-10, 10)	OK	1.02	None
Size_DblN_peak_SummerN(2)_BLK1add_1973	-2.75604	4	(-38.8, 21.2)	OK	0.85	Normal (0, 10.6)
Size_DblN_peak_SummerN(2)_BLK1add_1983	-4.93864	4	(-38.8, 21.2)	OK	1.12	Normal (0, 10.6)
Size_DblN_peak_SummerN(2)_BLK1add_1993	-5.7762	4	(-38.8, 21.2)	OK	1.16	Normal (0, 10.6)
Size_DblN_peak_SummerN(2)_BLK1add_2003	-4.12696	4	(-38.8, 21.2)	OK	0.67	Normal (0, 10.6)
Size_DblN_peak_SummerN(2)_BLK1add_2011	-1.53447	4	(-38.8, 21.2)	OK	0.62	Normal (0, 10.6)
Retain_L_infl_SummerN(2)_BLK3add_2003	0.15738	4	(-20.679, 9.321)	OK	0.52	Normal (0, 4.6605)
Retain_L_infl_SummerN(2)_BLK3add_2009	1.77908	4	(-20.679, 9.321)	OK	0.55	Normal (0, 4.6605)
Retain_L_infl_SummerN(2)_BLK3add_2011	-1.06712	4	(-20.679, 9.321)	OK	0.51	Normal (0, 4.6605)
Retain_L_width_SummerN(2)_BLK3add_2003	0.106445	4	(-1.0278, 8.8722)	OK	0.22	Normal (0, 0.5139)
Retain_L_width_SummerN(2)_BLK3add_2009	0.142802	4	(-1.0278, 8.8722)	OK	0.23	Normal (0, 0.5139)
Retain_L_width_SummerN(2)_BLK3add_2011	0.228908	4	(-1.0278, 8.8722)	OK	0.16	Normal (0, 0.5139)
Retain_L_asymptote_logit_SummerN(2)_BLK3repl_2003	5.51708	4	(-10, 10)	OK	0.97	None
Retain_L_asymptote_logit_SummerN(2)_BLK3repl_2009	6.86695	4	(-10, 10)	OK	6.44	None
Retain_L_asymptote_logit_SummerN(2)_BLK3repl_2011	5.96198	4	(-10, 10)	OK	0.58	None
Size_DblN_peak_WinterS(3)_BLK1add_1973	-6.07356	4	(-25.422, 34.578)	OK	2.15	Normal (0, 12.711)
Size_DblN_peak_WinterS(3)_BLK1add_1983	-0.393954	4	(-25.422, 34.578)	OK	1.18	Normal (0, 12.711)
Size_DblN_peak_WinterS(3)_BLK1add_1993	2.96858	4	(-25.422, 34.578)	OK	1.66	Normal (0, 12.711)
Size_DblN_peak_WinterS(3)_BLK1add_2003	0.859894	4	(-25.422, 34.578)	OK	0.85	Normal (0, 12.711)
Size_DblN_peak_WinterS(3)_BLK1add_2011	1.91596	4	(-25.422, 34.578)	OK	0.99	Normal (0, 12.711)

Continued on next page

Table 17: 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)
Retain_L_infl_WinterS(3)_BLK2add_2003	-2.31652	4	(-18.816, 11.184)	OK	1.34	Normal (0, 5.592)
Retain_L_infl_WinterS(3)_BLK2add_2010	1.40756	4	(-18.816, 11.184)	OK	1.65	Normal (0, 5.592)
Retain_L_infl_WinterS(3)_BLK2add_2011	-3.95341	4	(-18.816, 11.184)	OK	2.49	Normal (0, 5.592)
Retain_L_width_WinterS(3)_BLK2add_2003	0.34367	4	(-1.0443, 8.8557)	OK	0.37	Normal (0, 0.52215)
Retain_L_width_WinterS(3)_BLK2add_2010	0.118141	4	(-1.0443, 8.8557)	OK	0.46	Normal (0, 0.52215)
Retain_L_width_WinterS(3)_BLK2add_2011	-0.387615	4	(-1.0443, 8.8557)	OK	0.48	Normal (0, 0.52215)
Retain_L_asymptote_logit_WinterS(3)_BLK2repl_2003	8.47752	4	(-10, 10)	OK	9.50	None
Retain_L_asymptote_logit_WinterS(3)_BLK2repl_2010	5.69214	4	(-10, 10)	OK	8.51	None
Retain_L_asymptote_logit_WinterS(3)_BLK2repl_2011	6.98104	4	(-10, 10)	OK	1.60	None
Size_DblN_peak_SummerS(4)_BLK1add_1973	-8.19143	4	(-28.0793, 31.9207)	OK	2.13	Normal (0, 14.0397)
Size_DblN_peak_SummerS(4)_BLK1add_1983	-8.6809	4	(-28.0793, 31.9207)	OK	2.90	Normal (0, 14.0397)
Size_DblN_peak_SummerS(4)_BLK1add_1993	-0.797364	4	(-28.0793, 31.9207)	OK	1.39	Normal (0, 14.0397)
Size_DblN_peak_SummerS(4)_BLK1add_2003	0.932051	4	(-28.0793, 31.9207)	OK	0.74	Normal (0, 14.0397)
Size_DblN_peak_SummerS(4)_BLK1add_2011	0.680221	4	(-28.0793, 31.9207)	OK	0.85	Normal (0, 14.0397)
Retain_L_infl_SummerS(4)_BLK3add_2003	-1.86903	4	(-19.055, 10.945)	OK	0.84	Normal (0, 5.4725)
Retain_L_infl_SummerS(4)_BLK3add_2009	-2.00786	4	(-19.055, 10.945)	OK	1.14	Normal (0, 5.4725)
Retain_L_infl_SummerS(4)_BLK3add_2011	-2.12954	4	(-19.055, 10.945)	OK	0.90	Normal (0, 5.4725)
Retain_L_width_SummerS(4)_BLK3add_2003	0.305622	4	(-0.876, 9.024)	OK	0.22	Normal (0, 0.438)
Retain_L_width_SummerS(4)_BLK3add_2009	0.176878	4	(-0.876, 9.024)	OK	0.26	Normal (0, 0.438)
Retain_L_width_SummerS(4)_BLK3add_2011	0.0539534	4	(-0.876, 9.024)	OK	0.21	Normal (0, 0.438)
Retain_L_asymptote_logit_SummerS(4)_BLK3repl_2003	9.13443	4	(-10, 10)	OK	12.97	None
Retain_L_asymptote_logit_SummerS(4)_BLK3repl_2009	9.7475	4	(-10, 10)	OK	7.09	None
Retain_L_asymptote_logit_SummerS(4)_BLK3repl_2011	9.9577	4	(-10, 10)	HI	1.31	None

tab:model_params

Table 18: Results from 50 jitters from the base model.

tab:jitter

Status	Base.Model
Returned to base case	
Found local minimum	
Found better solution	
Total	50

Table 19: Likelihood components from the base model

tab:like

Likelihood Component	Value
Total	1455.79
Survey	-77.56
Discard	-225.63
Mean-body weight data	-158.25
Length-frequency data	904.37
Age-frequency data	1036.37
Recruitment	-28.68
Forecast Recruitment	0.03
Parameter Priors	5.09
Parameter Softbounds	0.04

Table 20: Summary of reference points and management quantities for the base case.

tab:Ref_pts

Quantity	**Estimate**	**~2.5% Confidence Interval**	**~97.5% Confidence Interval**
Unfished spawning biomass (mt)	30554.7	24634.6	36474.8
Unfished age 3+ biomass (mt)	49439.6	41597	57282.2
Unfished recruitment (R0, thousands)	18626.7	12518.1	27716.1
Spawning biomass(2019 mt)	9867.3	7682.4	12052.2
Depletion (2019)	0.323	0.219	0.426
Reference points based on $\mathbf{SB_{40\%}}$			
Proxy spawning biomass ($B_{25\%}$)	7638.7	6158.7	9118.7
SPR resulting in $B_{25\%}$ ($SPR_{B25\%}$)	0.286	0.258	0.313
Exploitation rate resulting in $B_{25\%}$	0.182	0.163	0.2
Yield with $SPR_{B25\%}$ at $B_{25\%}$ (mt)	2830.3	2624.2	3036.4
Reference points based on SPR proxy for MSY			
Spawning biomass	8096.3	6199.3	9993.3
SPR_{proxy}			
Exploitation rate corresponding to SPR_{proxy}	0.173	0.145	0.2
Yield with SPR_{proxy} at SB_{SPR} (mt)	2819.8	2590.1	3049.5
Reference points based on estimated MSY values			
Spawning bioamss at MSY (SB_{MSY})	7005.9	5242.2	8769.6
SPR_{MSY}	0.266	0.201	0.331
Exploitation rate at MSY	0.195	0.164	0.225
MSY (mt)	2835.9	2641.9	3029.9

Table 21: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning biomass (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exploit. rate
1876	49,440	30,555	48,800	1.00	18,627	1	0	0
1877	49,439	30,554	48,800	1.00	18,627	1	0	0
1878	49,438	30,554	48,799	1.00	18,627	1	0	0
1879	49,437	30,553	48,798	1.00	18,628	1	0	0
1880	49,437	30,553	48,797	1.00	18,628	12	0	0
1881	49,426	30,545	48,786	1.00	18,628	23	0	0
1882	49,406	30,532	48,766	1.00	18,627	33	0.003	0.001
1883	49,377	30,512	48,738	1.00	18,627	44	0.003	0.001
1884	49,341	30,487	48,701	1.00	18,626	55	0.003	0.001
1885	49,298	30,457	48,658	1.00	18,626	65	0.003	0.001
1886	49,248	30,422	48,608	1.00	18,625	76	0.006	0.002
1887	49,193	30,384	48,553	0.99	18,624	87	0.006	0.002
1888	49,132	30,342	48,493	0.99	18,623	98	0.006	0.002
1889	49,068	30,297	48,429	0.99	18,622	108	0.006	0.002
1890	49,000	30,248	48,360	0.99	18,621	119	0.006	0.002
1891	48,928	30,198	48,288	0.99	18,620	130	0.009	0.003
1892	48,853	30,145	48,214	0.99	18,619	141	0.009	0.003
1893	48,776	30,090	48,136	0.98	18,618	151	0.009	0.003
1894	48,696	30,034	48,057	0.98	18,617	162	0.009	0.003
1895	48,614	29,976	47,975	0.98	18,616	173	0.009	0.004
1896	48,531	29,916	47,892	0.98	18,615	184	0.012	0.004
1897	48,446	29,856	47,806	0.98	18,614	195	0.012	0.004
1898	48,359	29,794	47,720	0.98	18,613	205	0.012	0.004
1899	48,272	29,732	47,633	0.97	18,613	216	0.012	0.005
1900	48,183	29,669	47,544	0.97	18,612	227	0.012	0.005
1901	48,094	29,605	47,455	0.97	18,612	238	0.015	0.005
1902	48,004	29,540	47,365	0.97	18,611	248	0.015	0.005
1903	47,913	29,476	47,274	0.96	18,611	259	0.015	0.005
1904	47,822	29,410	47,183	0.96	18,612	270	0.015	0.006
1905	47,731	29,345	47,092	0.96	18,612	281	0.018	0.006
1906	47,639	29,279	47,000	0.96	18,613	291	0.018	0.006
1907	47,547	29,213	46,908	0.96	18,614	302	0.018	0.006
1908	47,455	29,146	46,816	0.95	18,616	313	0.018	0.007
1909	47,363	29,080	46,724	0.95	18,618	324	0.018	0.007
1910	47,271	29,014	46,632	0.95	18,621	334	0.021	0.007
1911	47,179	28,947	46,540	0.95	18,624	345	0.021	0.007
1912	47,088	28,881	46,448	0.95	18,628	356	0.021	0.008
1913	46,996	28,814	46,357	0.94	18,633	367	0.021	0.008
1914	46,906	28,748	46,266	0.94	18,638	377	0.024	0.008
1915	46,815	28,682	46,175	0.94	18,645	388	0.024	0.008
1916	46,725	28,617	46,085	0.94	18,652	394	0.024	0.009
1917	46,641	28,555	46,001	0.93	18,661	537	0.03	0.012
1918	46,433	28,409	45,792	0.93	18,668	432	0.027	0.009
1919	46,343	28,341	45,702	0.93	18,679	340	0.021	0.007
1920	46,352	28,341	45,711	0.93	18,694	235	0.015	0.005
1921	46,467	28,411	45,825	0.93	18,712	299	0.018	0.007
1922	46,518	28,441	45,876	0.93	18,731	433	0.027	0.009
1923	46,443	28,387	45,800	0.93	18,749	436	0.027	0.01
1924	46,374	28,336	45,730	0.93	18,768	543	0.033	0.012
1925	46,212	28,222	45,568	0.92	18,787	539	0.033	0.012
1926	46,072	28,120	45,427	0.92	18,808	532	0.033	0.012
1927	45,954	28,032	45,309	0.92	18,832	644	0.039	0.014

Table 21: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning biomass (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exploit. rate
1928	45,747	27,884	45,101	0.91	18,856	632	0.036	0.014
1929	45,574	27,757	44,928	0.91	18,882	721	0.042	0.016
1930	45,340	27,588	44,692	0.90	18,910	673	0.039	0.015
1931	45,179	27,467	44,530	0.90	18,946	688	0.039	0.015
1932	45,029	27,350	44,379	0.90	18,989	822	0.048	0.019
1933	44,781	27,163	44,130	0.89	19,042	857	0.048	0.019
1934	44,539	26,973	43,887	0.88	19,131	1640	0.084	0.037
1935	43,600	26,312	42,946	0.86	19,259	1622	0.084	0.038
1936	42,770	25,713	42,112	0.84	19,445	1331	0.072	0.032
1937	42,310	25,351	41,648	0.83	19,678	1914	0.096	0.046
1938	41,384	24,665	40,715	0.81	19,869	2184	0.108	0.054
1939	40,324	23,878	39,647	0.78	19,860	2678	0.126	0.068
1940	38,938	22,855	38,257	0.75	19,434	2569	0.123	0.067
1941	37,821	22,000	37,143	0.72	18,623	2315	0.12	0.062
1942	37,080	21,408	36,420	0.70	17,727	3242	0.147	0.089
1943	35,577	20,317	34,944	0.66	17,085	3377	0.153	0.097
1944	34,051	19,271	33,447	0.63	17,050	2672	0.141	0.08
1945	33,239	18,772	32,653	0.61	17,582	2503	0.138	0.077
1946	32,584	18,413	31,995	0.60	17,963	3805	0.171	0.119
1947	30,712	17,244	30,106	0.56	17,751	3148	0.162	0.105
1948	29,524	16,484	28,909	0.54	17,503	4525	0.195	0.157
1949	27,115	14,878	26,508	0.49	17,257	4412	0.201	0.166
1950	24,942	13,412	24,343	0.44	17,160	4643	0.213	0.191
1951	22,705	11,885	22,113	0.39	17,164	3054	0.189	0.138
1952	22,093	11,425	21,503	0.37	17,273	2797	0.186	0.13
1953	21,790	11,202	21,201	0.37	16,951	2367	0.174	0.112
1954	21,912	11,295	21,322	0.37	16,181	2888	0.189	0.135
1955	21,541	11,088	20,965	0.36	15,105	2570	0.183	0.123
1956	21,451	11,063	20,904	0.36	14,068	2267	0.174	0.108
1957	21,592	11,219	21,082	0.37	13,386	2904	0.192	0.138
1958	21,048	10,988	20,570	0.36	13,872	2851	0.192	0.139
1959	20,457	10,756	19,992	0.35	17,137	2435	0.18	0.122
1960	20,192	10,709	19,690	0.35	21,658	2840	0.192	0.144
1961	19,576	10,334	18,959	0.34	16,766	3413	0.21	0.18
1962	18,561	9,536	17,856	0.31	11,393	3257	0.21	0.182
1963	17,840	8,807	17,301	0.29	12,855	3299	0.216	0.191
1964	17,126	8,186	16,721	0.27	18,499	2765	0.21	0.165
1965	16,893	8,096	16,414	0.26	15,563	2627	0.207	0.16
1966	16,798	8,220	16,173	0.27	32,710	2661	0.207	0.165
1967	16,768	8,233	16,123	0.27	14,915	2682	0.207	0.166
1968	16,972	8,087	15,975	0.26	15,421	2398	0.201	0.15
1969	17,638	8,085	17,122	0.26	15,854	2432	0.201	0.142
1970	18,321	8,242	17,788	0.27	16,417	3153	0.216	0.177
1971	18,290	8,336	17,742	0.27	15,835	3288	0.219	0.185
1972	18,038	8,541	17,480	0.28	13,025	3555	0.222	0.203
1973	17,407	8,459	16,885	0.28	10,902	3132	0.222	0.186
1974	16,897	8,390	16,463	0.27	13,807	3949	0.24	0.24
1975	15,362	7,679	14,967	0.25	14,283	3808	0.243	0.254
1976	13,780	6,899	13,302	0.23	16,377	3122	0.237	0.235
1977	12,768	6,368	12,264	0.21	15,187	2561	0.228	0.209
1978	12,345	6,021	11,794	0.20	11,138	3302	0.249	0.28
1979	11,294	5,226	10,802	0.17	11,032	3423	0.258	0.317

Table 21: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning biomass (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exploit. rate
1980	10,128	4,435	9,747	0.15	12,172	2855	0.255	0.293
1981	9,419	4,068	9,033	0.13	10,311	2765	0.258	0.306
1982	8,704	3,803	8,300	0.12	10,034	2770	0.258	0.334
1983	7,955	3,454	7,602	0.11	10,772	2454	0.258	0.323
1984	7,429	3,199	7,075	0.10	17,986	1911	0.249	0.27
1985	7,385	3,170	6,968	0.10	10,962	1871	0.249	0.269
1986	7,448	3,142	6,884	0.10	6,464	2133	0.255	0.31
1987	7,330	2,937	6,985	0.10	8,491	2563	0.267	0.367
1988	6,756	2,558	6,518	0.08	11,405	2360	0.267	0.362
1989	6,260	2,409	5,946	0.08	15,485	2304	0.267	0.387
1990	5,762	2,326	5,342	0.08	15,973	1961	0.264	0.367
1991	5,636	2,230	5,106	0.07	9,723	2133	0.27	0.418
1992	5,511	1,894	5,010	0.06	6,145	1807	0.267	0.361
1993	5,742	1,785	5,431	0.06	11,468	1681	0.264	0.309
1994	6,105	1,943	5,855	0.06	14,126	1544	0.255	0.264
1995	6,556	2,405	6,147	0.08	8,861	1674	0.252	0.272
1996	6,877	2,801	6,428	0.09	10,797	1929	0.252	0.3
1997	6,936	2,863	6,618	0.09	10,373	2051	0.255	0.31
1998	6,865	2,718	6,489	0.09	24,170	1739	0.249	0.268
1999	7,128	2,797	6,679	0.09	16,132	1621	0.243	0.243
2000	7,720	3,002	6,950	0.10	11,710	1915	0.249	0.275
2001	8,292	3,050	7,771	0.10	10,177	1980	0.249	0.255
2002	8,917	3,122	8,525	0.10	11,236	2067	0.249	0.242
2003	9,434	3,434	9,078	0.11	8,955	1795	0.234	0.198
2004	10,066	4,110	9,695	0.13	10,870	2294	0.24	0.237
2005	10,088	4,523	9,766	0.15	11,630	3015	0.252	0.309
2006	9,275	4,306	8,890	0.14	21,088	2215	0.24	0.249
2007	9,107	4,222	8,638	0.14	25,131	2404	0.243	0.278
2008	8,985	3,906	8,227	0.13	34,665	2180	0.24	0.265
2009	9,529	3,681	8,610	0.12	15,169	2329	0.246	0.271
2010	10,536	3,494	9,487	0.11	11,740	867	0.186	0.091
2011	13,224	4,414	12,727	0.14	13,434	791	0.165	0.062
2012	16,022	5,904	15,603	0.19	19,781	1159	0.171	0.074
2013	18,309	7,751	17,807	0.25	12,763	1973	0.189	0.111
2014	19,603	9,284	18,973	0.30	13,826	2398	0.189	0.126
2015	20,194	10,202	19,748	0.33	13,751	2727	0.192	0.138
2016	20,190	10,439	19,716	0.34	13,924	2543	0.186	0.129
2017	20,111	10,531	19,637	0.34	15,071	3050	0.195	0.155
2018	19,406	10,213	18,919	0.33	17,012	2882	0.195	0.152
2019	18,796	9,867	18,265	0.32	16,935	-	-	-

tab:Timeseries_mod1

Table 22: Sensitivity of the base model.

tab:sens_table

Label	Base	Low M	High M	Old M Prior	Fecundity	Sex Ratio	Francis	Dirichlet
Total Likelihood	1436.480	1436.480	1436.480	1436.480	1436.480	1436.480	1436.480	1436.480
Survey Likelihood	-77.916	-77.916	-77.916	-77.916	-77.916	-77.916	-77.916	-77.916
Discard Likelihood	-227.795	-227.795	-227.795	-227.795	-227.795	-227.795	-227.795	-227.795
Discard Mean Body Wt.	-159.144	-159.144	-159.144	-159.144	-159.144	-159.144	-159.144	-159.144
Length Likelihood	899.982	899.982	899.982	899.982	899.982	899.982	899.982	899.982
Age Likelihood	1023.080	1023.080	1023.080	1023.080	1023.080	1023.080	1023.080	1023.080
Recruitment Likelihood	-28.852	-28.852	-28.852	-28.852	-28.852	-28.852	-28.852	-28.852
Forecast Recruitment Likelihood	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Parameter Priors Likelihood	7.054	7.054	7.054	7.054	7.054	7.054	7.054	7.054
log(R0)	9.938	9.938	9.938	9.938	9.938	9.938	9.938	9.938
SB Virgin	31106.300	31106.300	31106.300	31106.300	31106.300	31106.300	31106.300	31106.300
SB 2019	9907.260	9907.260	9907.260	9907.260	9907.260	9907.260	9907.260	9907.260
Depletion 2019	0.318	0.318	0.318	0.318	0.318	0.318	0.318	0.318
Total Yield - SPR 30	2990.590	2990.590	2990.590	2990.590	2990.590	2990.590	2990.590	2990.590
Steepness	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814
Natural Mortality - Female	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168
Length at Amin - Female	15.822	15.822	15.822	15.822	15.822	15.822	15.822	15.822
Length at Amax - Female	53.978	53.978	53.978	53.978	53.978	53.978	53.978	53.978
Von Bert. k - Female	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
SD young - Female	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190
SD old - Female	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
Natural Mortality - Male	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168
Length at Amin - Male	15.822	15.822	15.822	15.822	15.822	15.822	15.822	15.822
Length at Amax - Male	53.978	53.978	53.978	53.978	53.978	53.978	53.978	53.978
Von Bert. k - Male	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
SD young - Male	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190
SD old - Male	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024

Table 23: Data weights applied when using Francis data weighting in the base model. The data weights were acquired after a single model weighting iteration.

tab:francis

Fleet	Lengths	Ages
Winter North		
Summer North		
Winter South		
Summer South		
Triennial Early survey		-
Triennial Late survey		-
NWFSC shelf-slope survey		

Table 24: Data weights applied when using Dirichlet data weighting.

tab:dirichlet

Fleet	Lengths	Ages
Winter North		
Summer North		
Winter South		
Summer South		
Triennial Early survey		-
Triennial Late survey		-
NWFSC shelf-slope survey		

Table 25: Projection of potential OFL, spawning biomass, and depletion for the base case model. The removals in 2017 and 2018 were set at the defined management specification of XXX mt for each year assuming full attainment.

tab:Forecast_mod1

Year	OFL (mt)	ACL (mt)	Spawning Biomass	Depletion (%)
2019	4753	4340	5741	83.3
2020	4632	4229	5745	83.4
2021	4499	4108	5723	83.1
2022	4364	3984	5666	82.2
2023	4230	3862	5586	81.1
2024	4105	3748	5494	79.8
2025	3991	3644	5395	78.3
2026	3889	3551	5292	76.8
2027	3797	3467	5188	75.3
2028	3712	3389	5084	73.8

Table 26: Decision table summary of 10-year projections beginning in 2021 for alternate states of nature based on an axis of uncertainty for the base model. The removals in 2017 and 2018 were set at the defined management specification of 281 mt for each year assuming full attainment. Columns range over low, mid, and high states of nature over natural mortality, 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_back`

			States of nature					
			M = 0.04725		M = 0.054		M = 0.0595	
	Year	Catch	Spawning Biomass	Depletion (%)	Spawning Biomass	Depletion (%)	Spawning Biomass	Depletion (%)
	2021							
	2022							
	2023							
ABC	2024							
	2025							
	2026							
	2027							
	2028							
	2029							
	2030							
	2021							
	2022							
	2023							
SPR	2024							
target =	2025							
0.34	2026							
	2027							
	2028							
	2029							
	2030							

10 Figures

figures

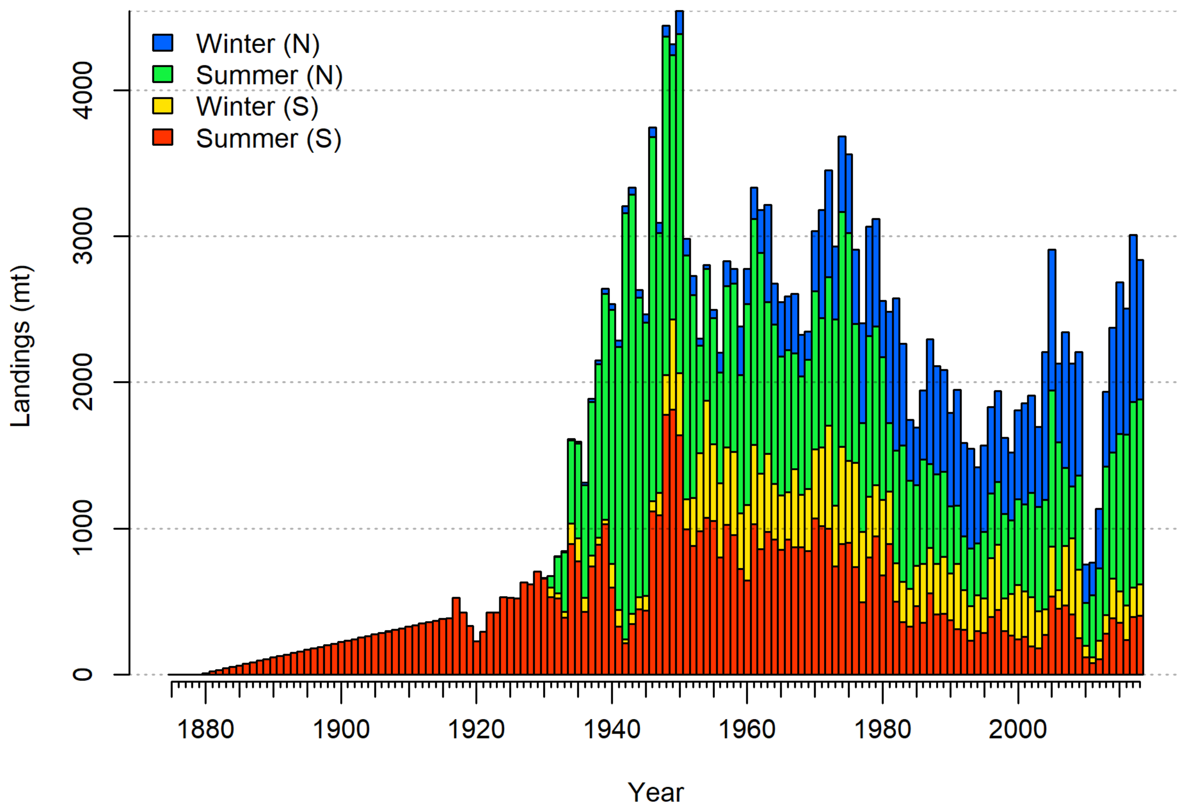

Figure 1: Total catches petrale sole. fig:Catch

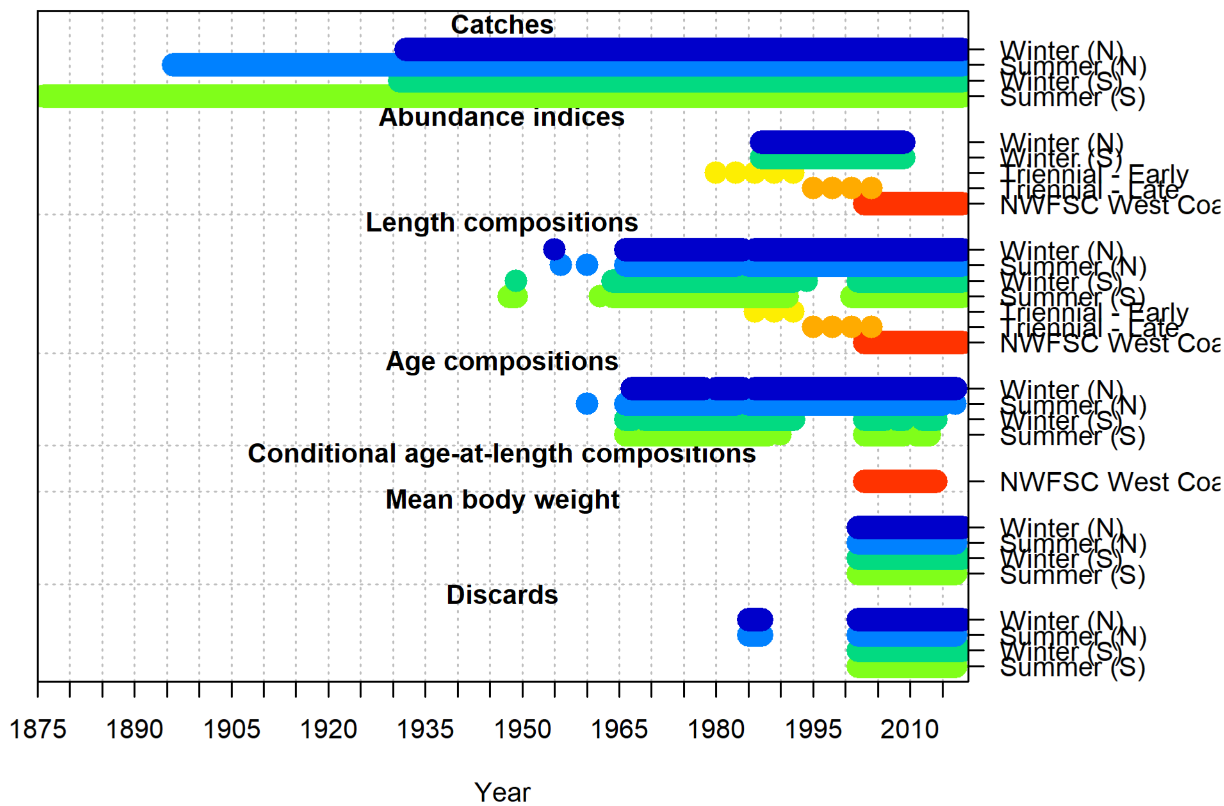

Figure 2: Summary of data sources used in the base model. fig:data_plot

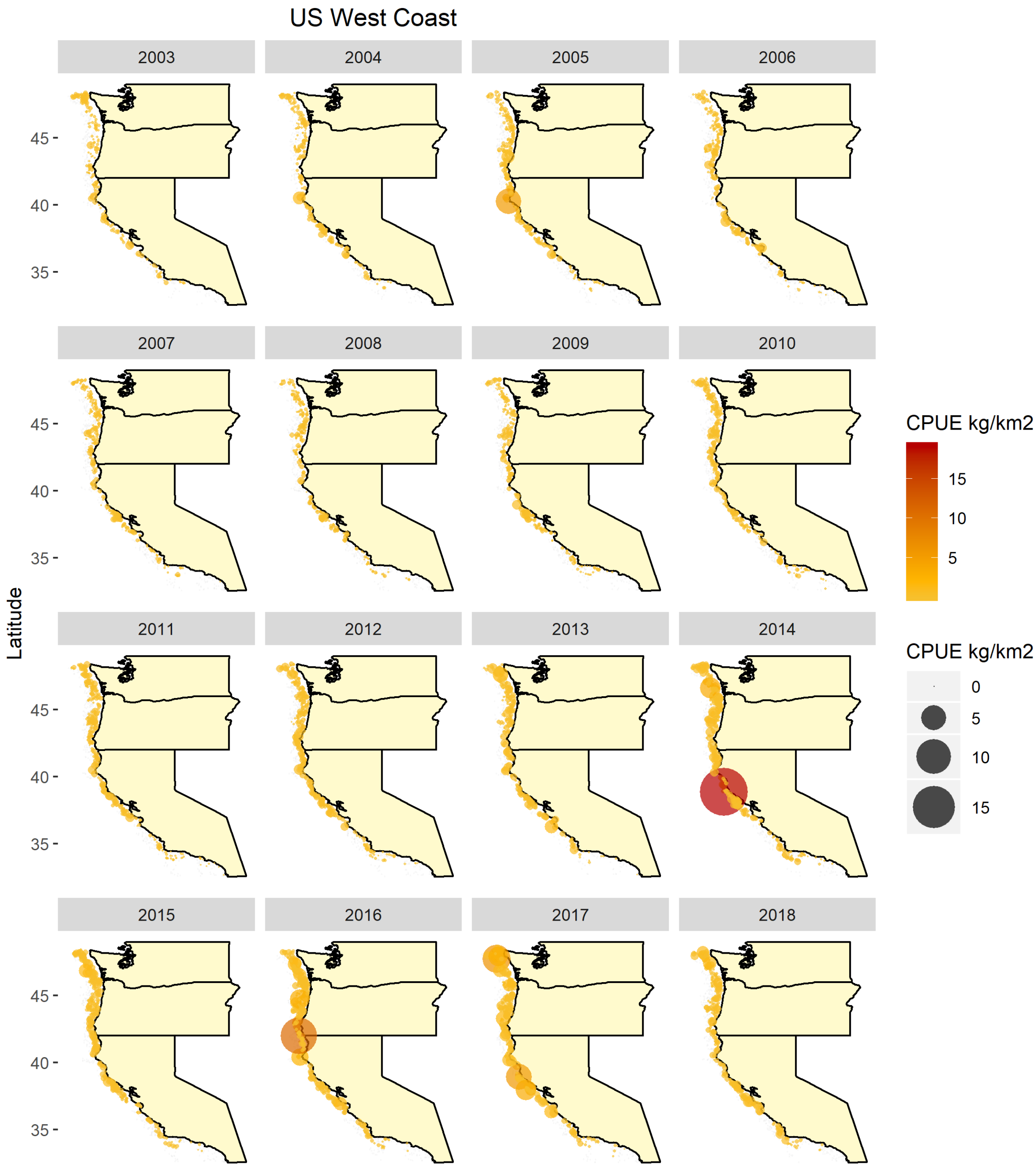

Figure 3: Map of the catch-per-unit-effort across by year for the NWFSC West Coast Groundfish Bottom Trawl Survey data. fig:nw_map

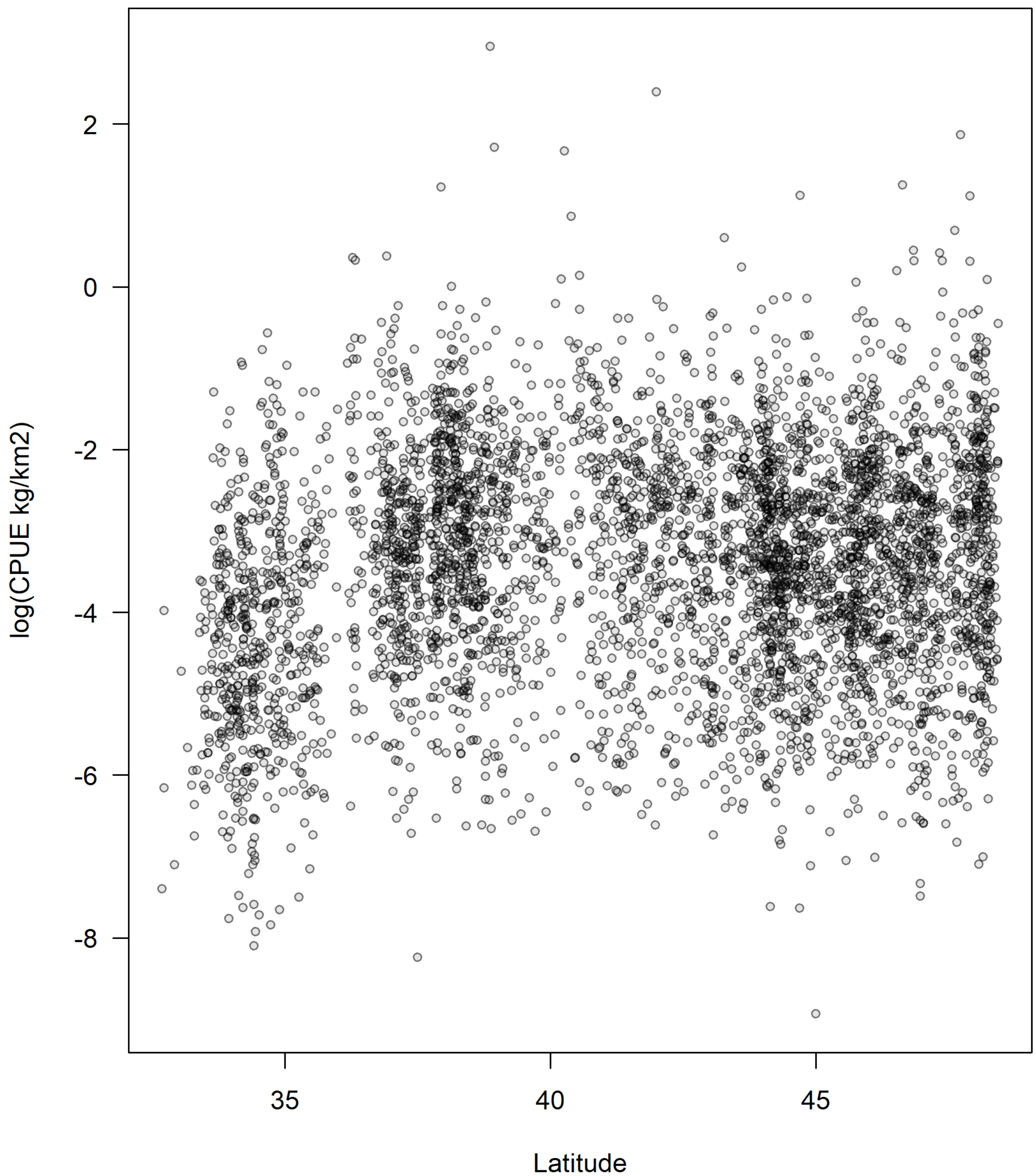

Figure 4: Catch-per-unit-effort (in log space) by latitude for the NWFSC West Coast Groundfish Bottom Trawl Survey data. fig:nw_cpue_lat

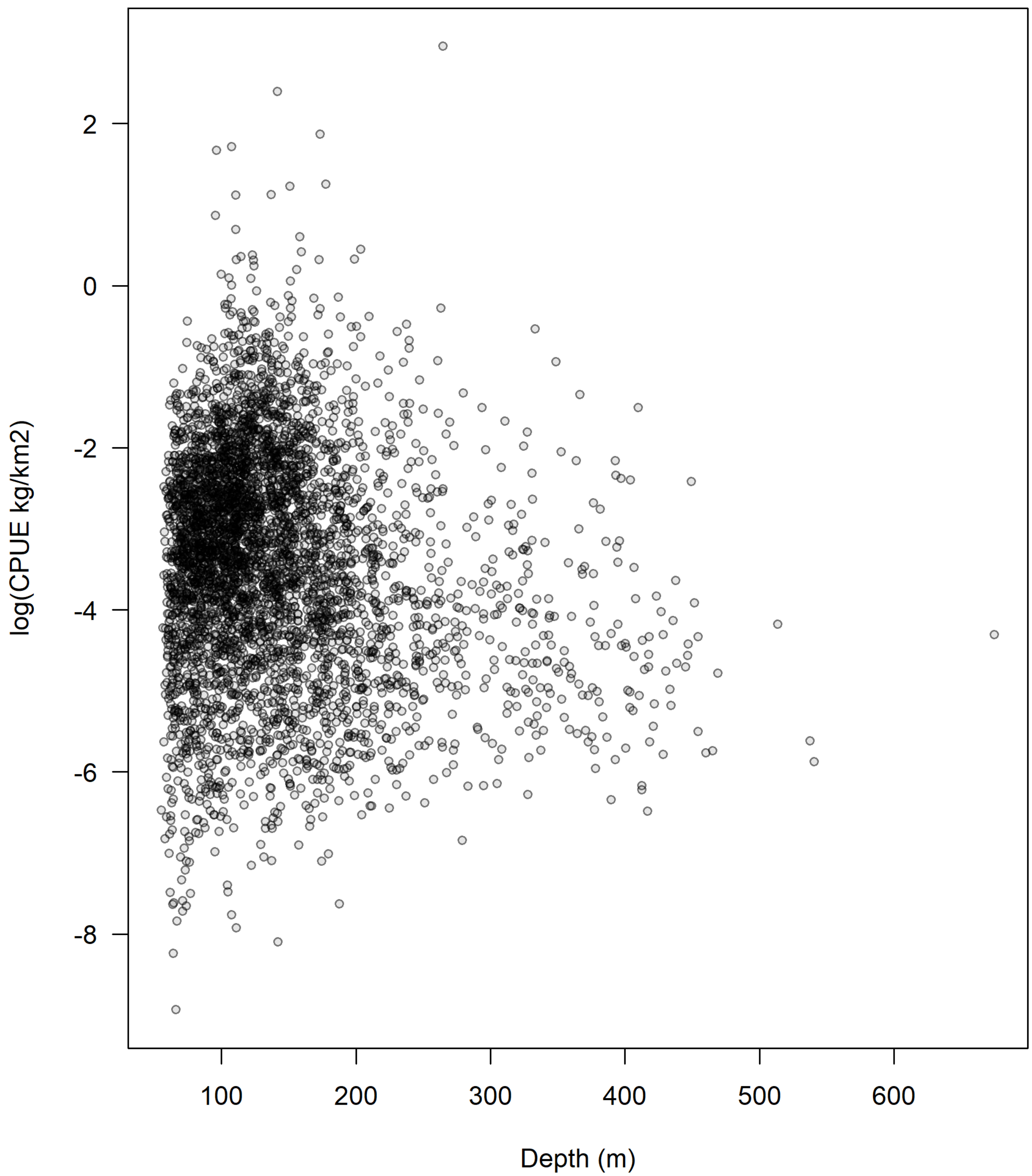

Figure 5: Catch-per-unit-effort (in log space) by depth for the NWFSC West Coast Groundfish Bottom Trawl Survey data. fig:nw_cpue_depth

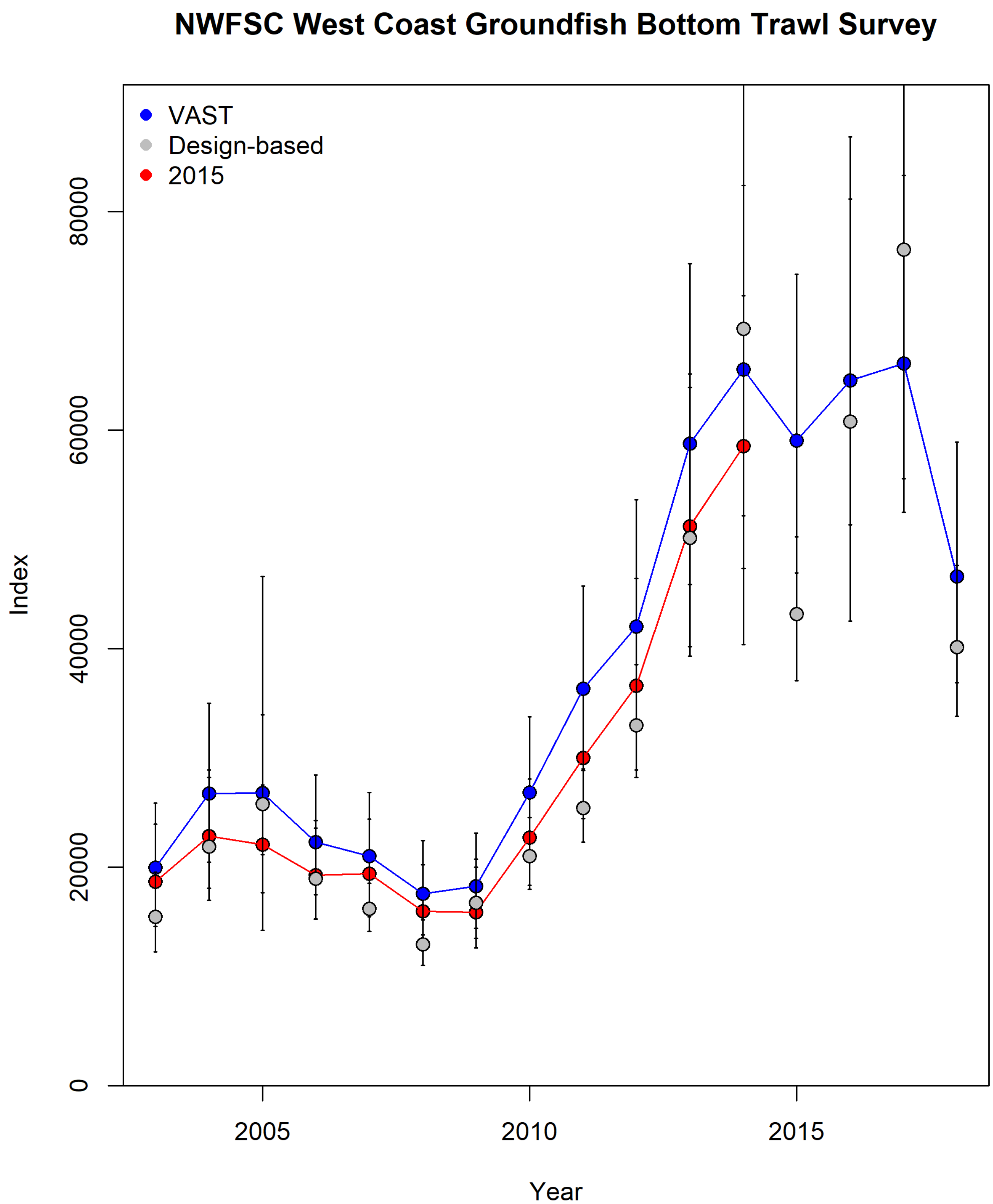

Figure 6: Estimated index of abundance from the NWFSC West Coast Groundfish Bottom Trawl Survey data compared to the design-based index and the index from the 2015 update assessment. fig:nw_index

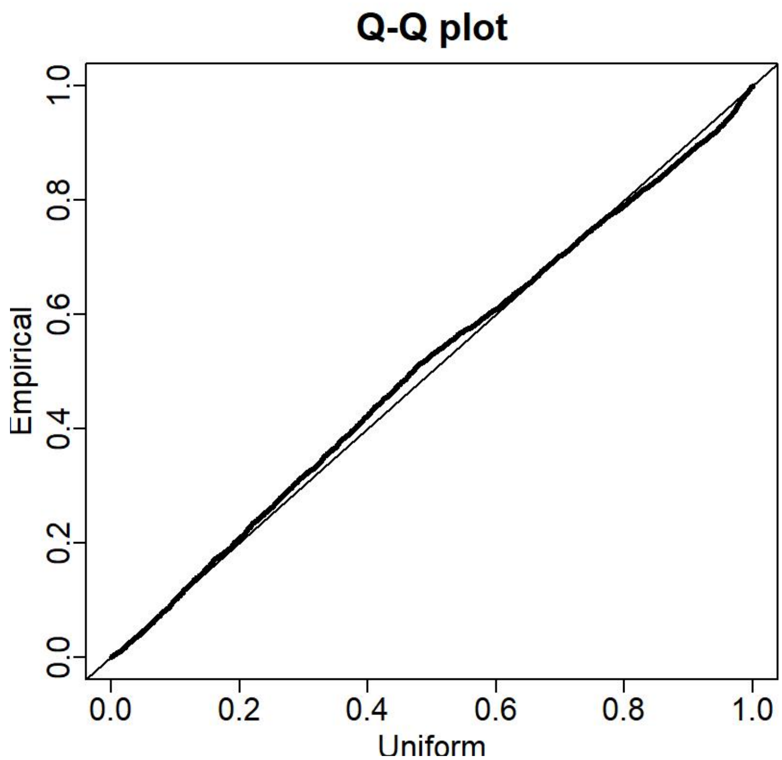

Figure 7: QQ plot for the NWFSC West Coast Groundfish Bottom Trawl Survey data. fig:nw_qq

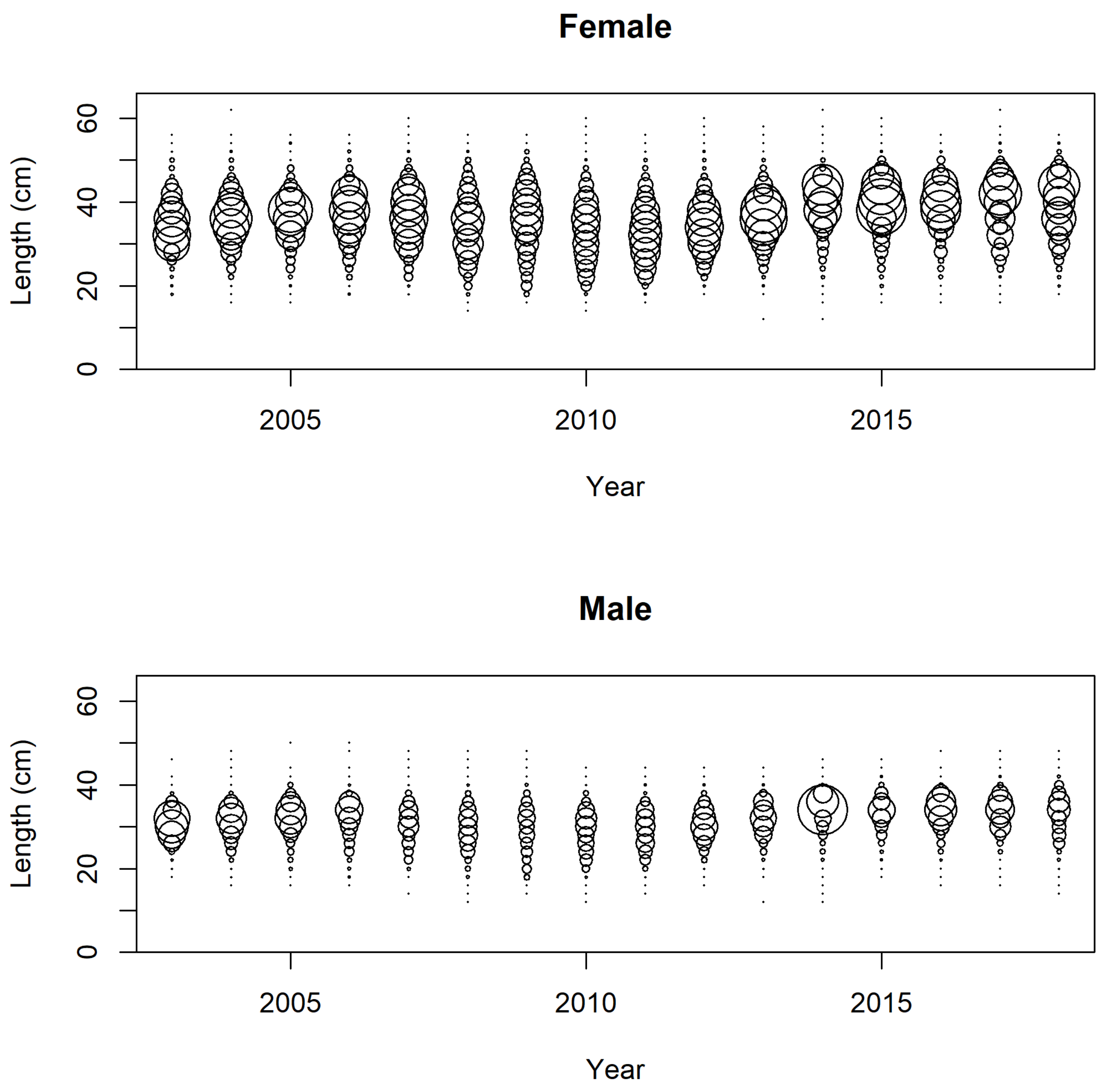

Figure 8: Length frequency by sex for the NWFSC West Coast Groundfish Bottom Trawl Survey data. fig:nw_len_freq

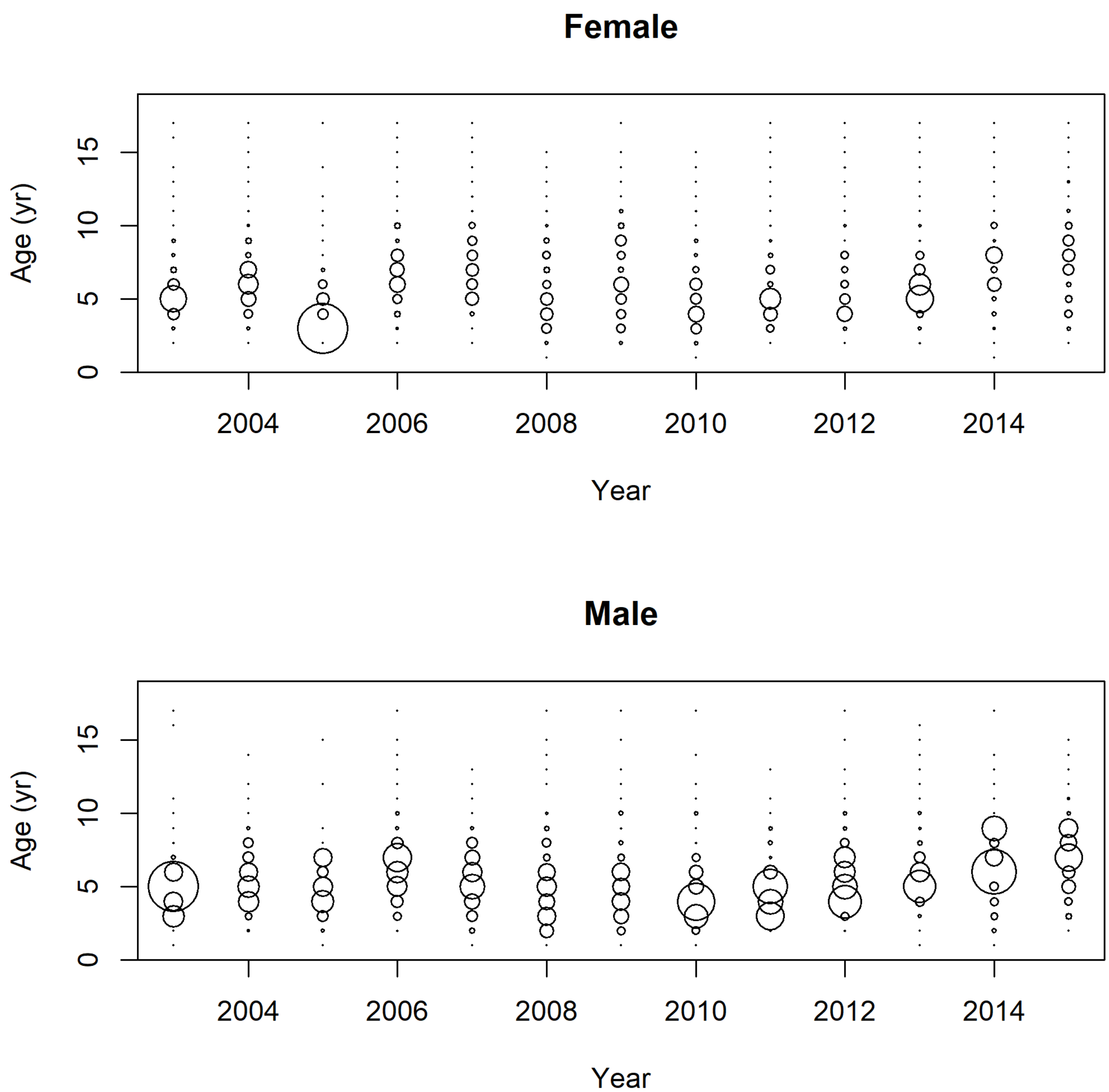

Figure 9: Age frequency by sex for the NWFSC West Coast Groundfish Bottom Trawl Survey data. fig:nw_age_freq

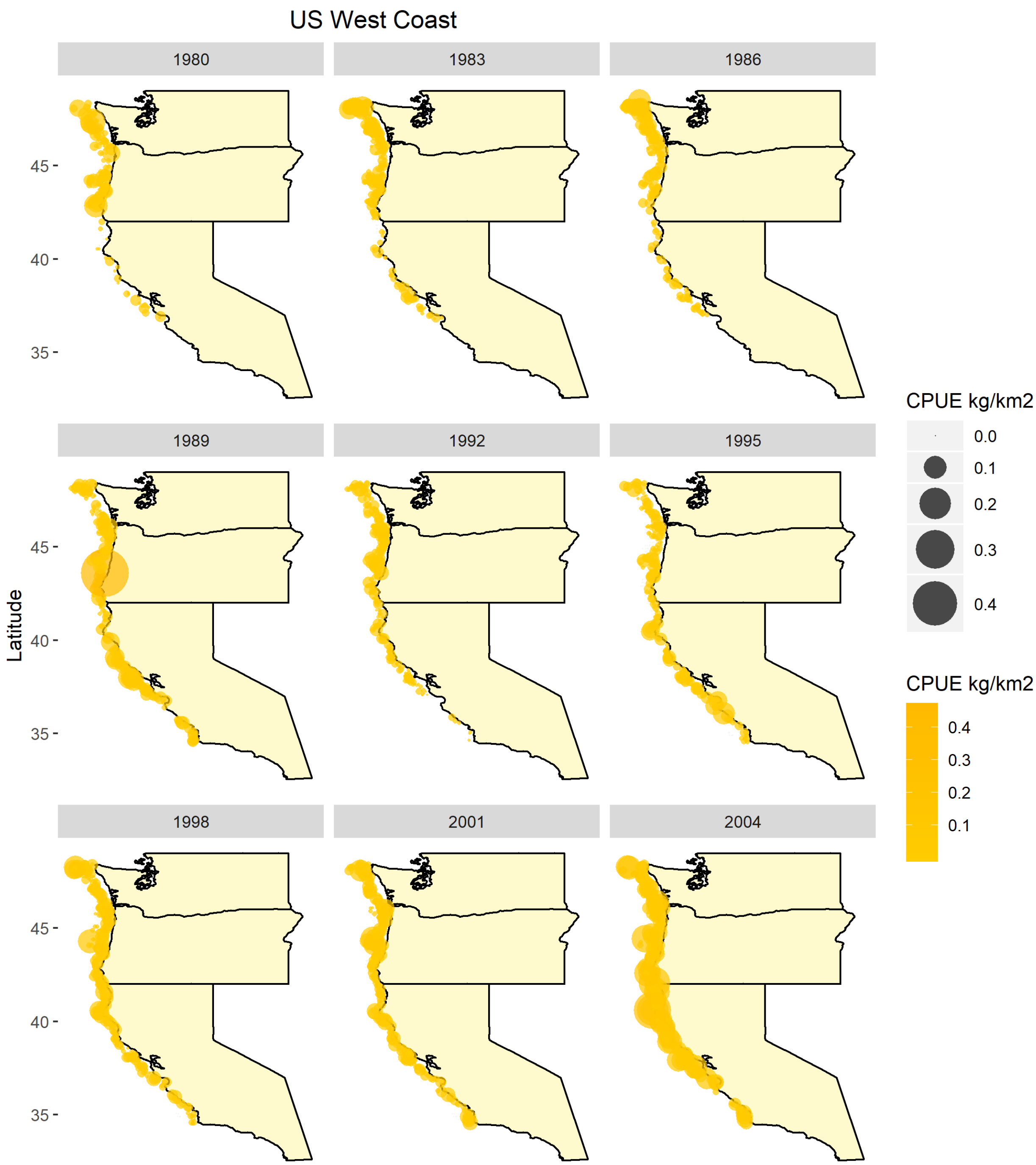

Figure 10: Map of the catch-per-unit-effort across by year for the Triennial Survey data. fig:tri_map

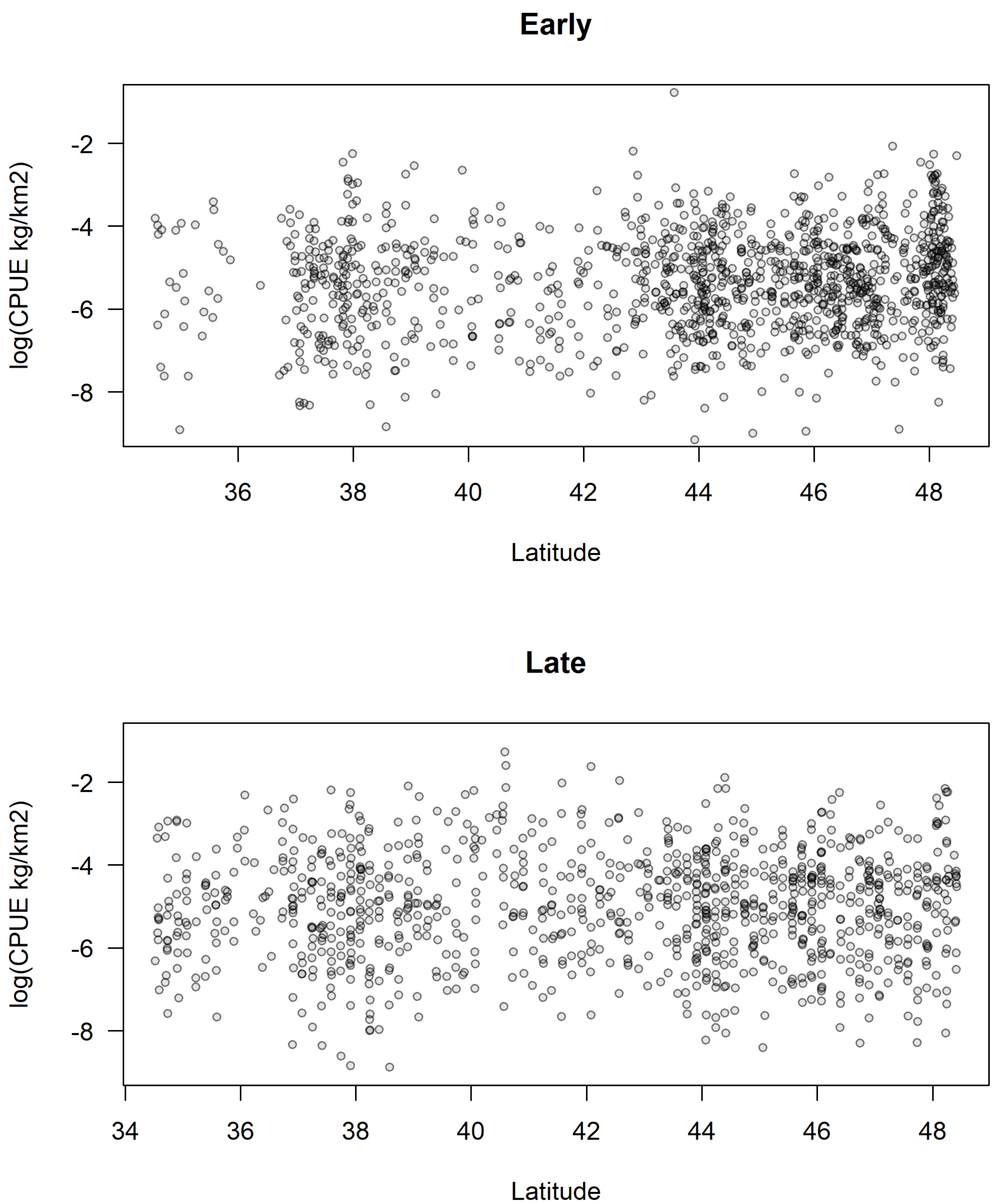

Figure 11: Catch-per-unit-effort (in log space) by latitude for the Triennial Survey data. fig:tri_cpue_l

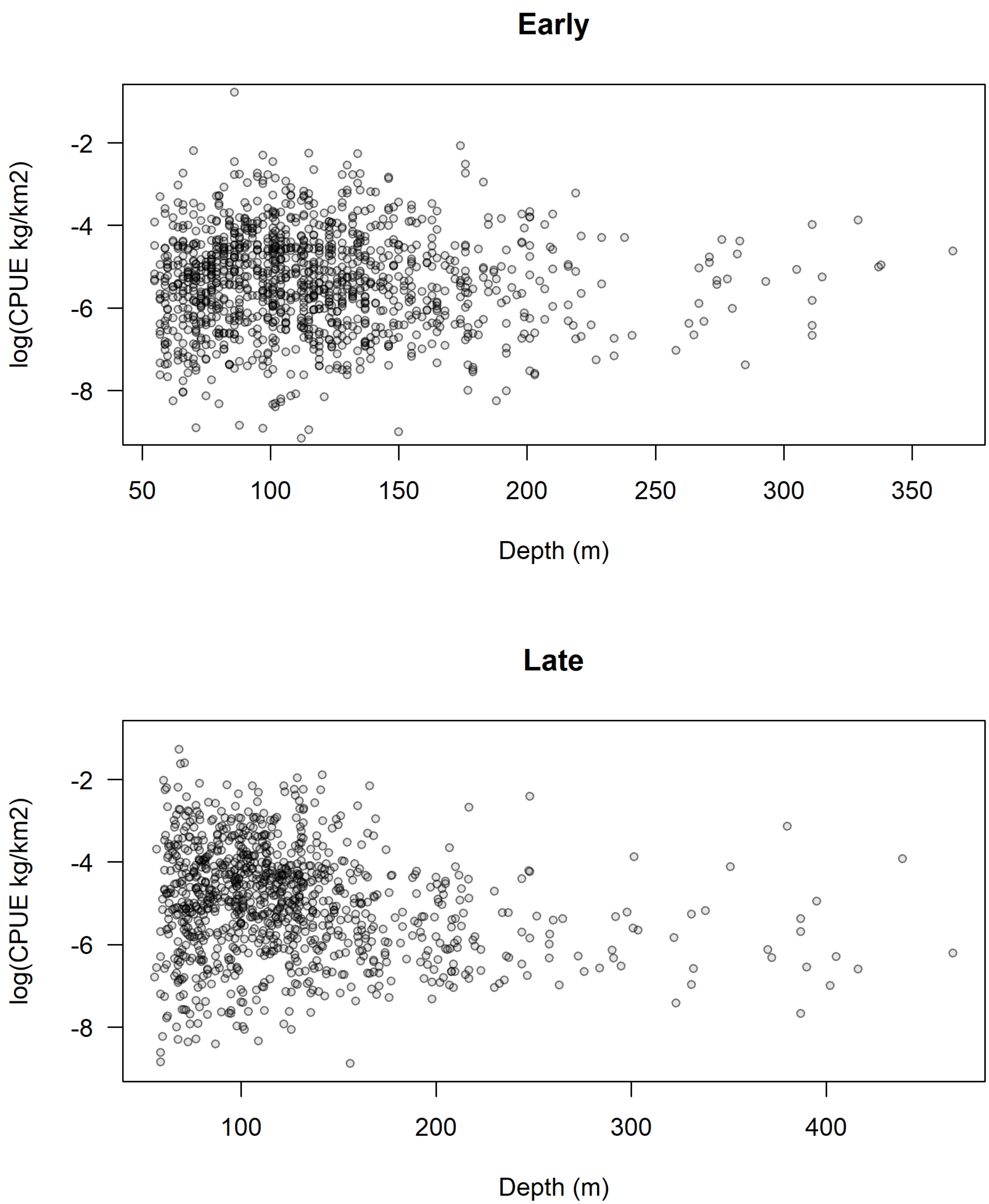

Figure 12: Catch-per-unit-effort (in log space) by depth (m) for the Triennial Survey data. fig:tri_cpue_

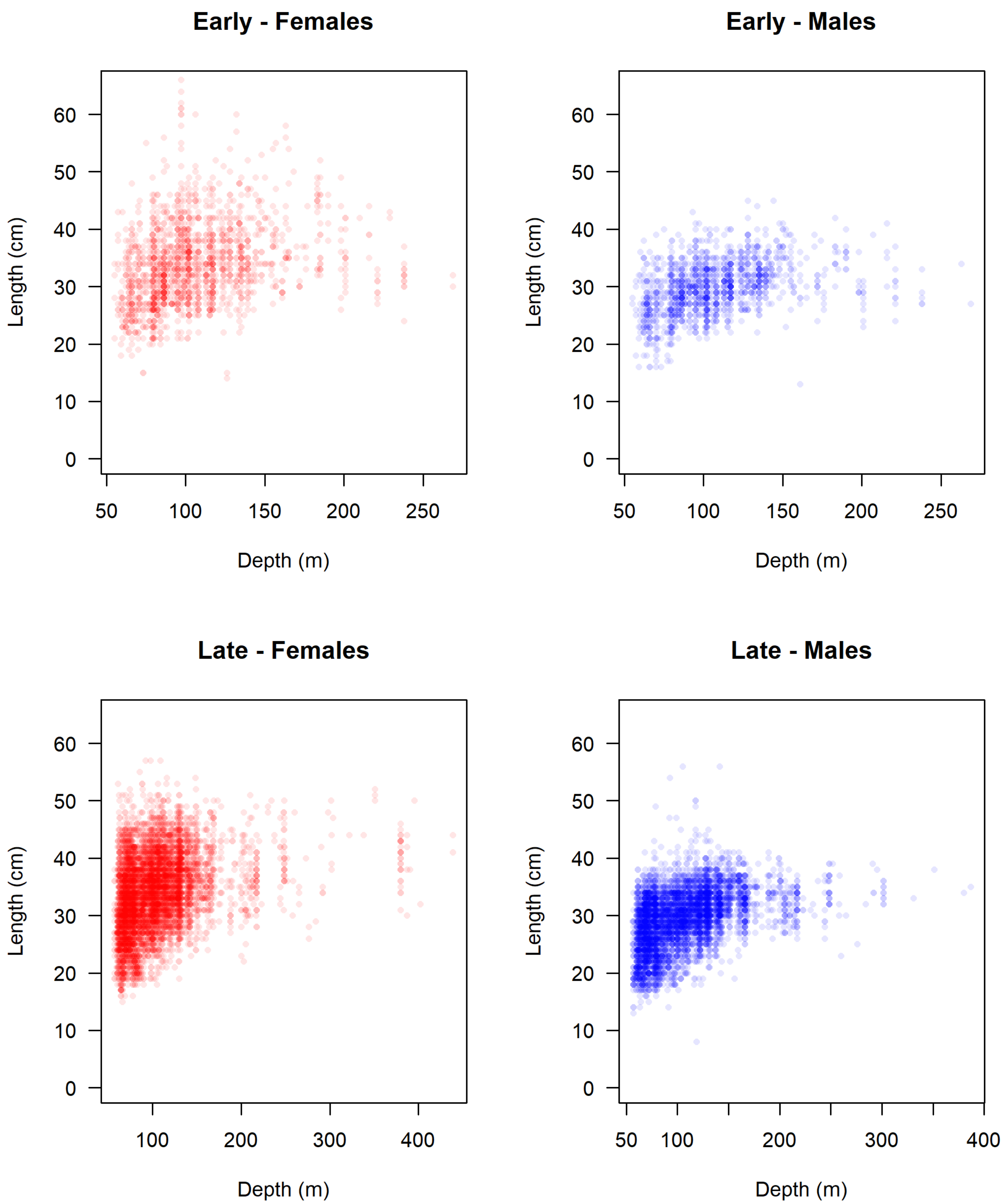

Figure 13: Length (cm) by depth (m) for the Triennial Survey data. fig:tri_size_depth

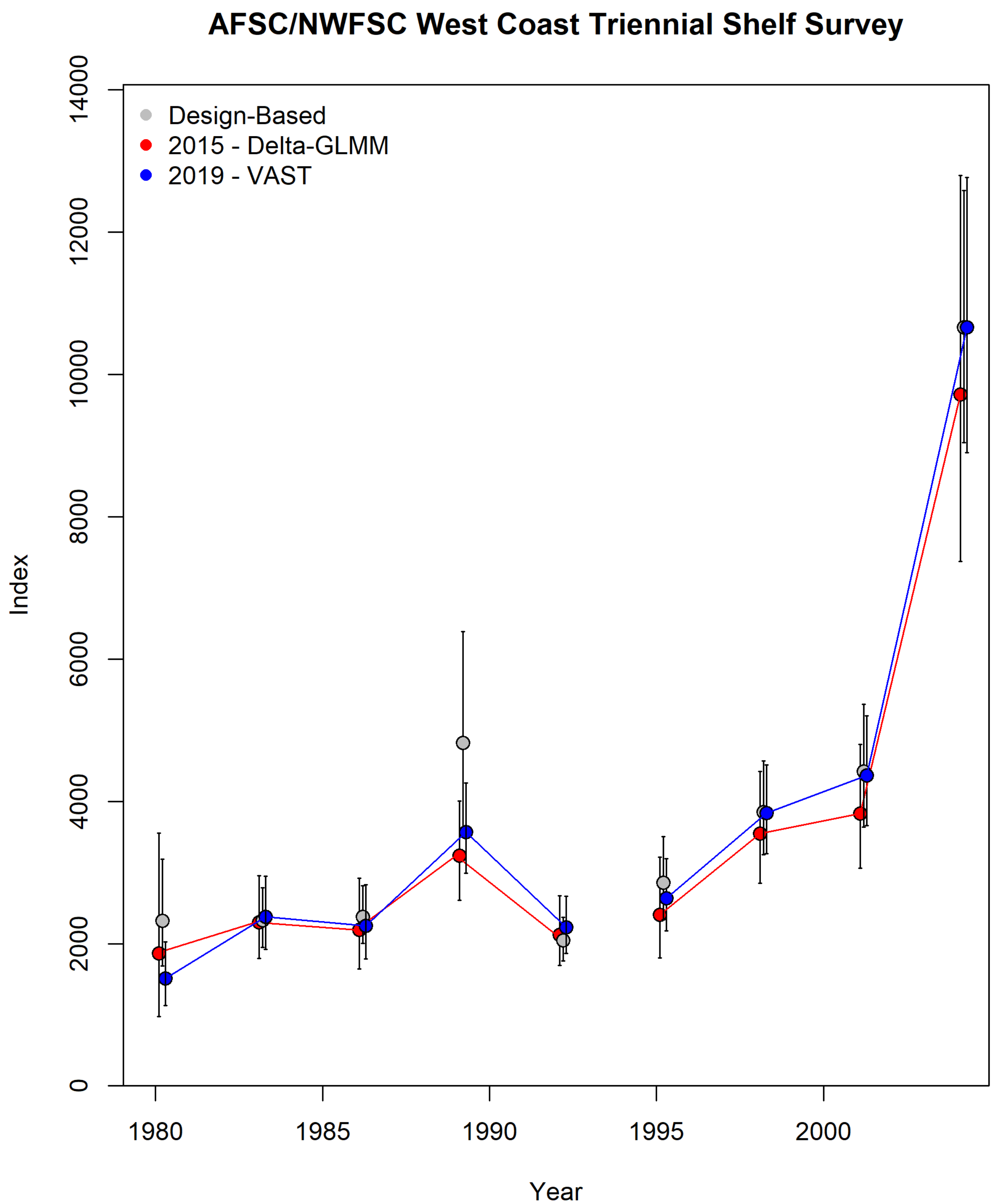

Figure 14: Estimated index of abundance from the Triennial Survey data compared to the design-based index and the index from the 2015 update assessment. fig:tri_index

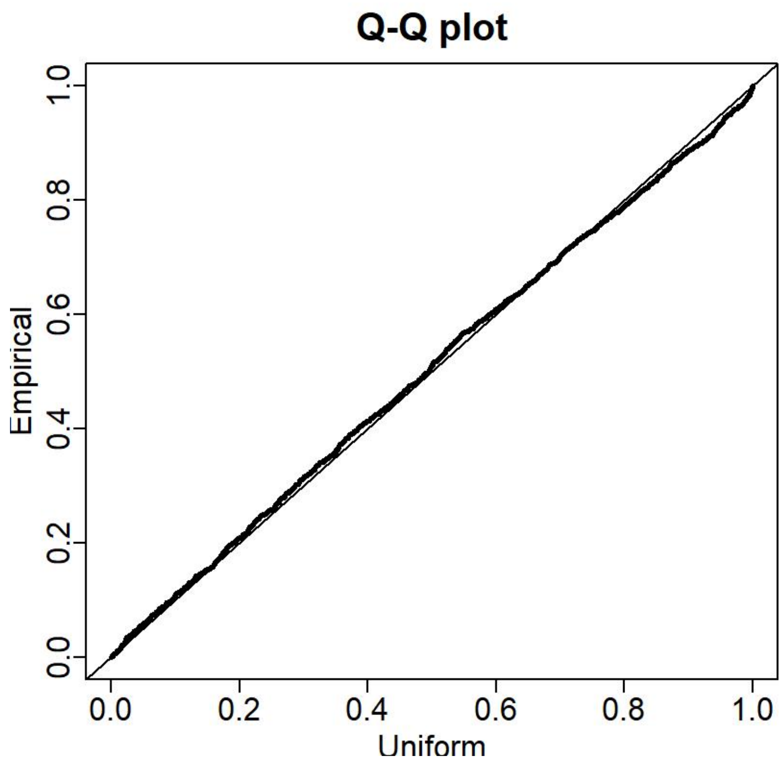

Figure 15: QQ plot for the Triennial Early Survey data. fig:tri_early_qq

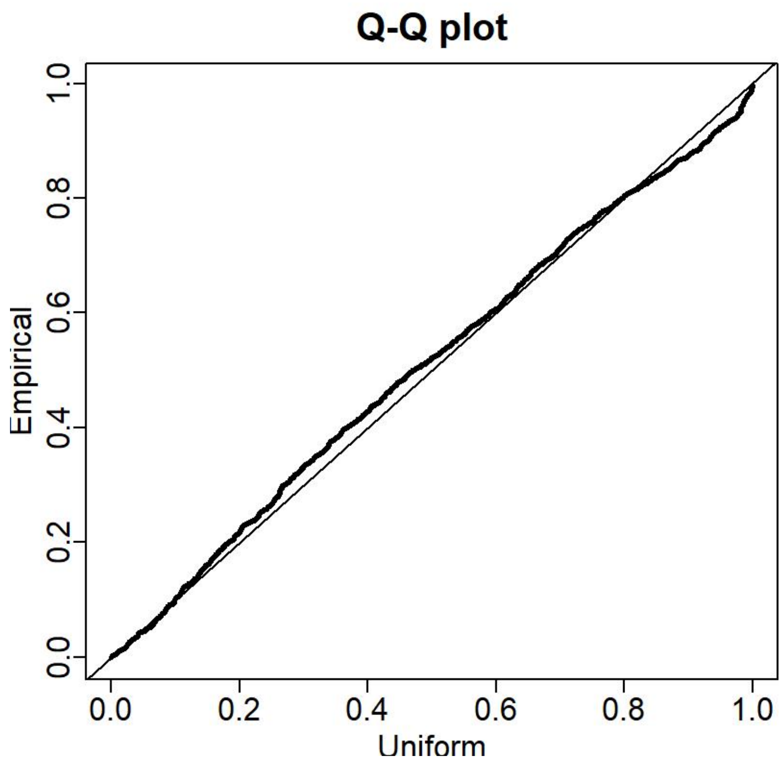

Figure 16: QQ plot for the Triennial Late Survey data. fig:tri_late_qq

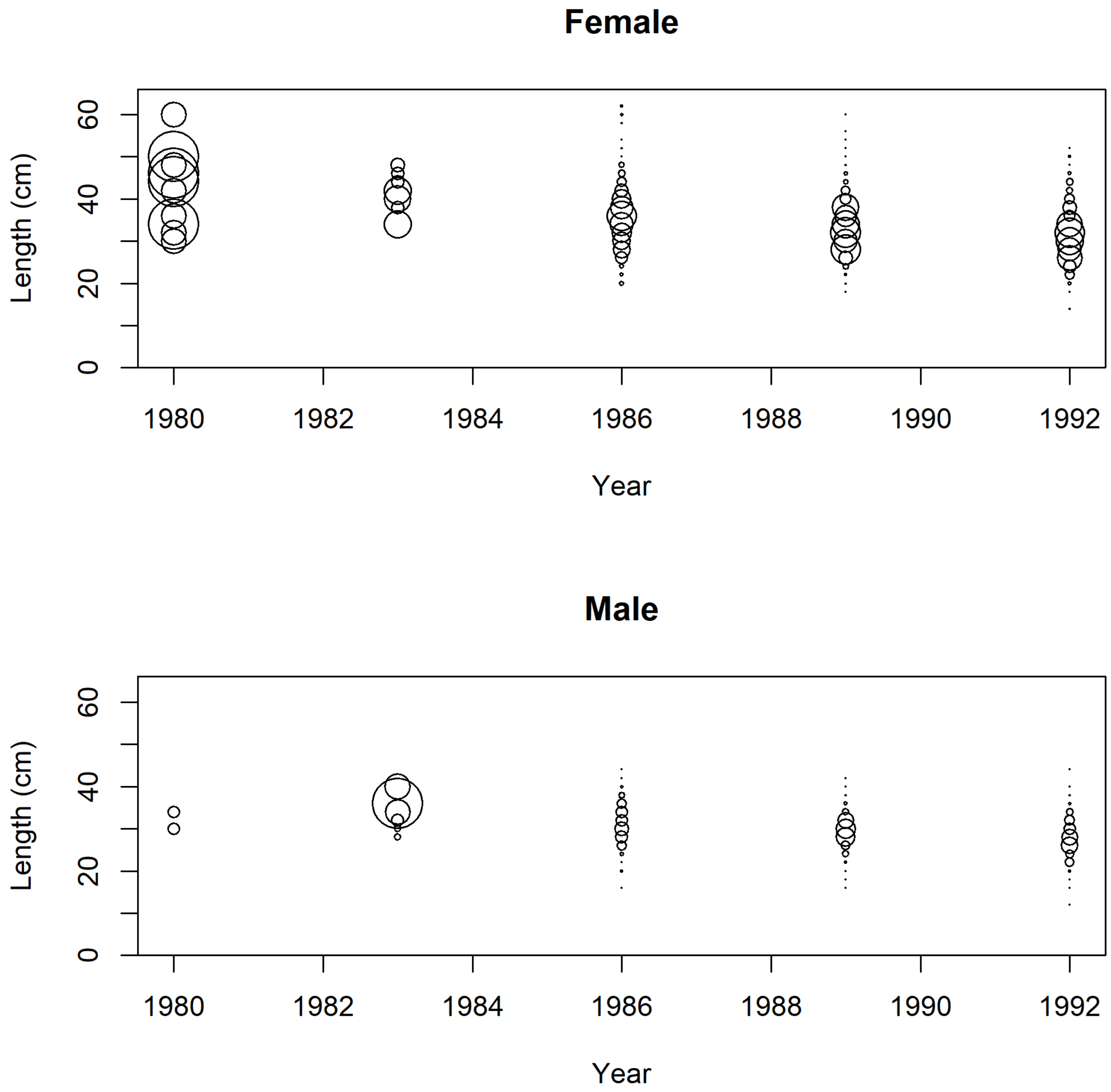

Figure 17: Length frequency by sex for the Triennial Early Survey data. fig:tri_early_len_fre

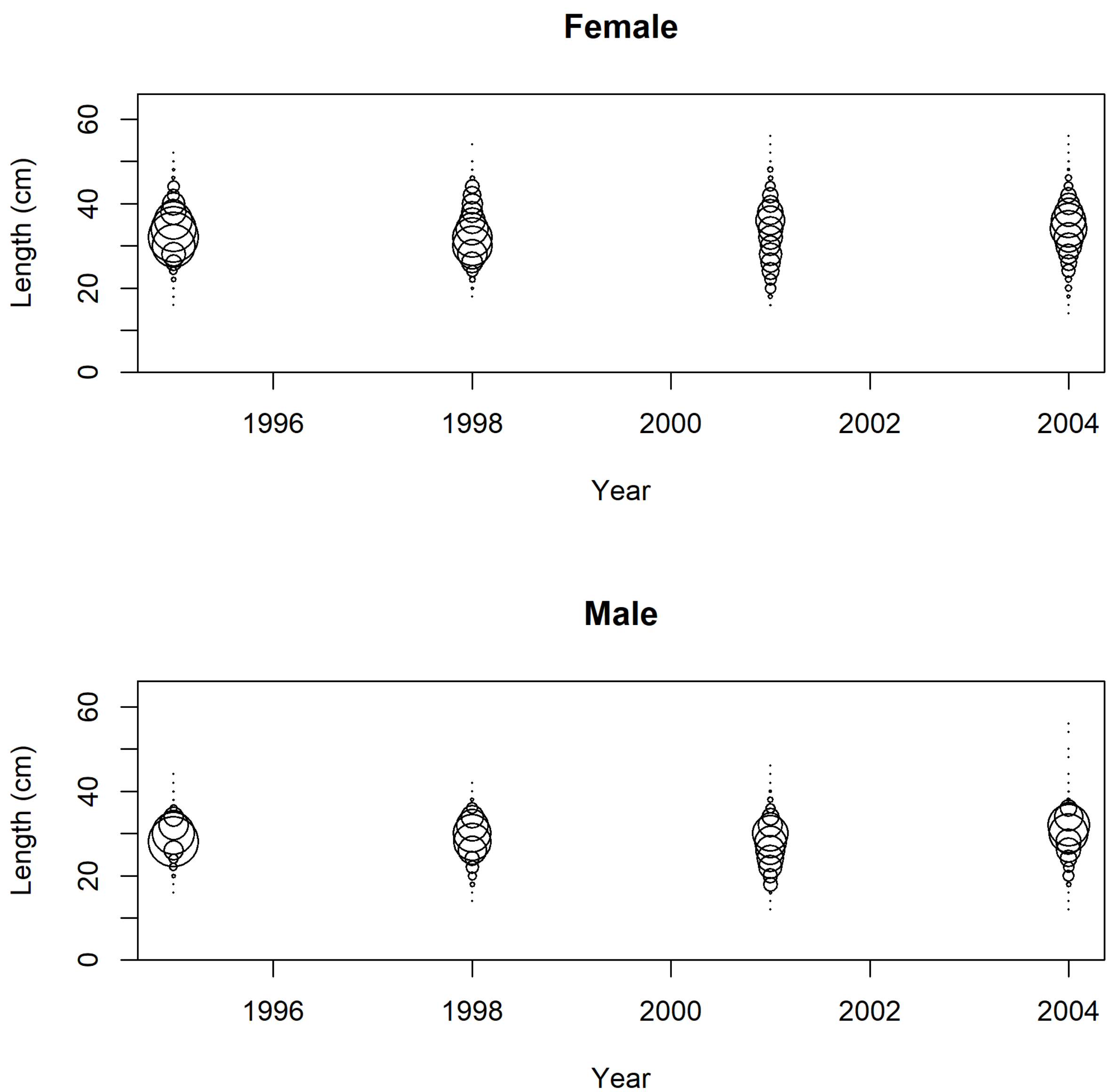

Figure 18: Length frequency by sex for the Triennial Late Survey data. fig:tri_late_len_freq

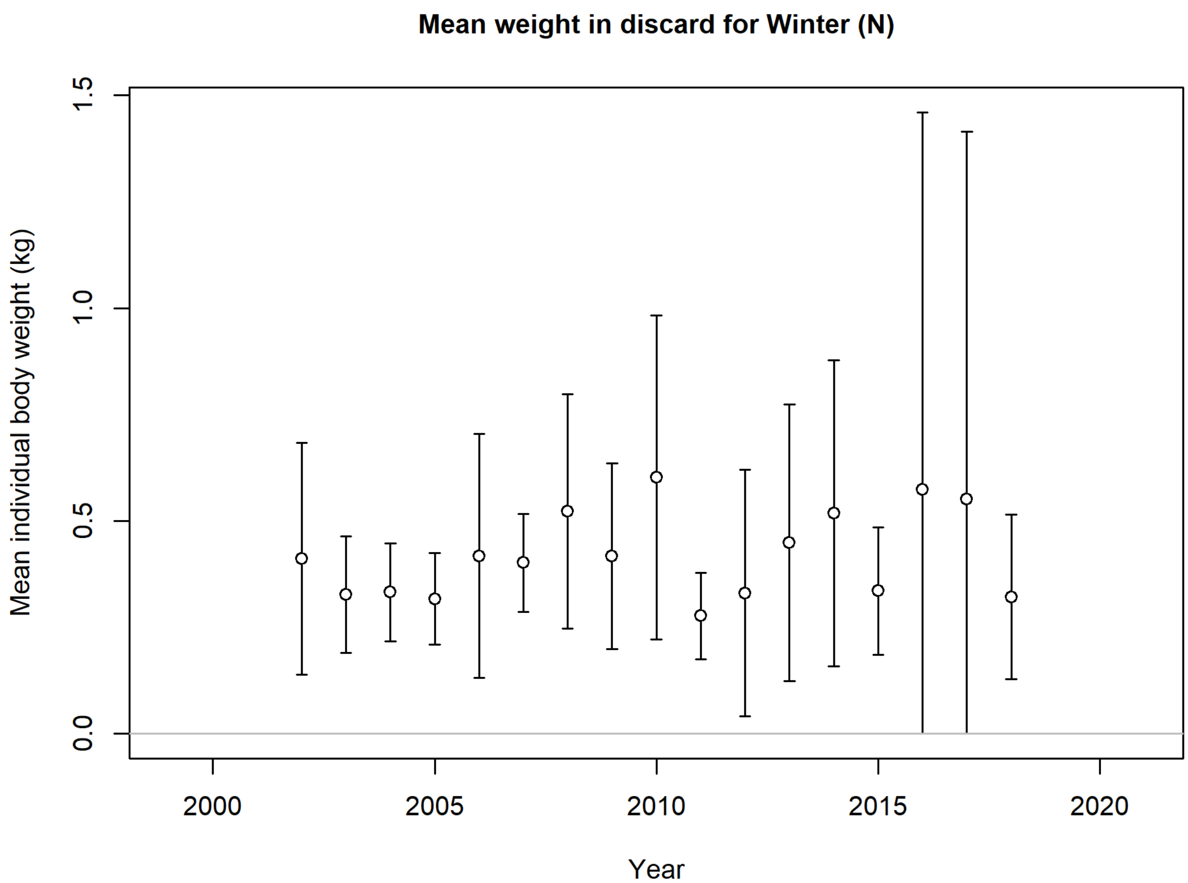

Figure 19: Northern winter fishery mean body weights of discarded fish for petrale sole. fig:nw_bodywt

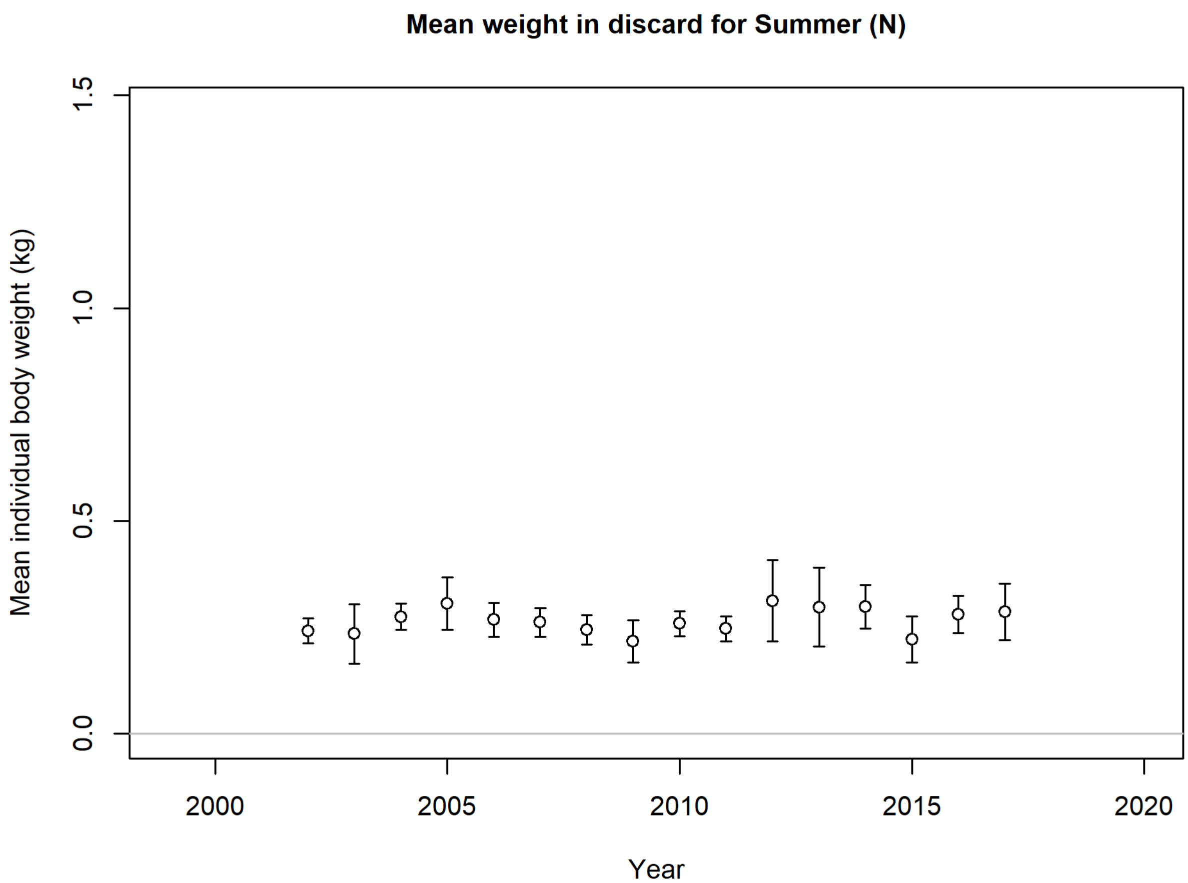

Figure 20: Northern summer fishery mean body weights of discarded fish for petrale sole. fig:ns_bodywt

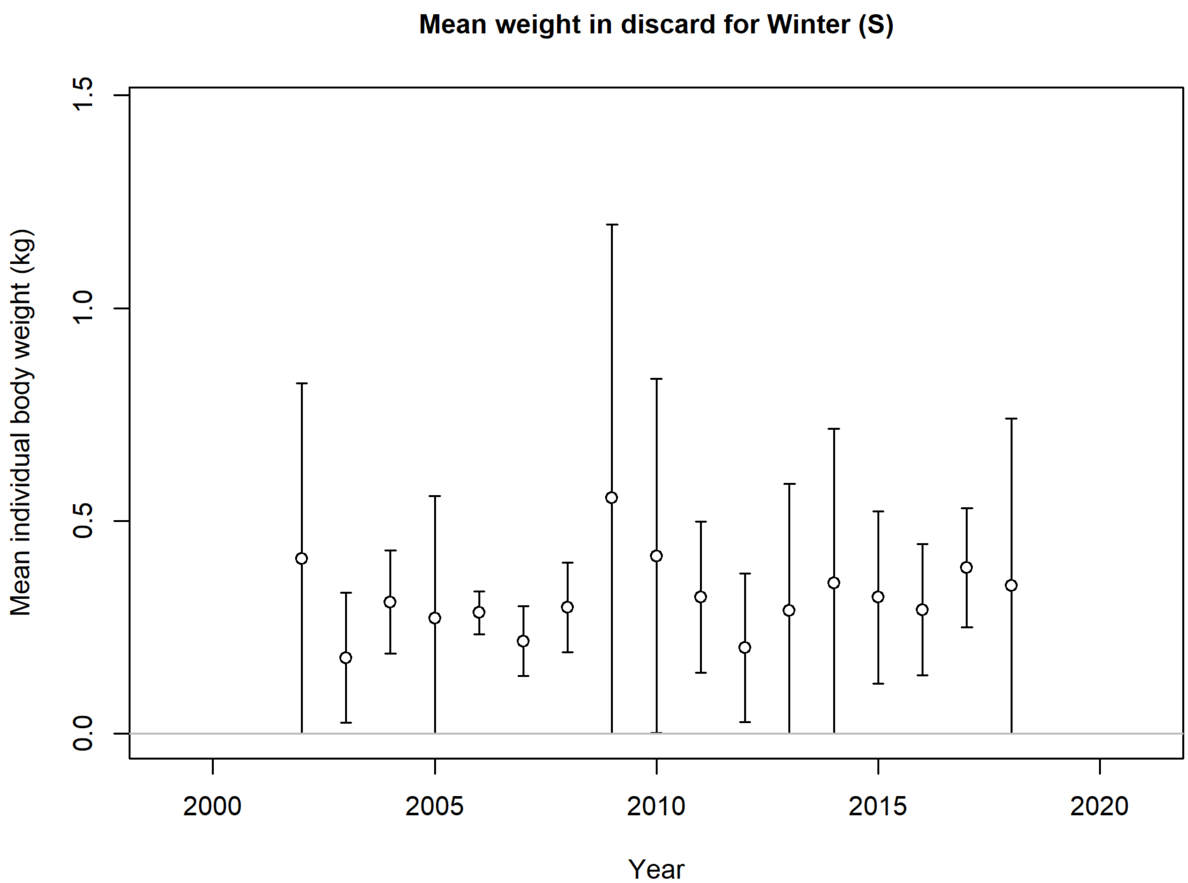

Figure 21: Southern winter fishery mean body weights of discarded fish for petrale sole. fig:sw_bodywt

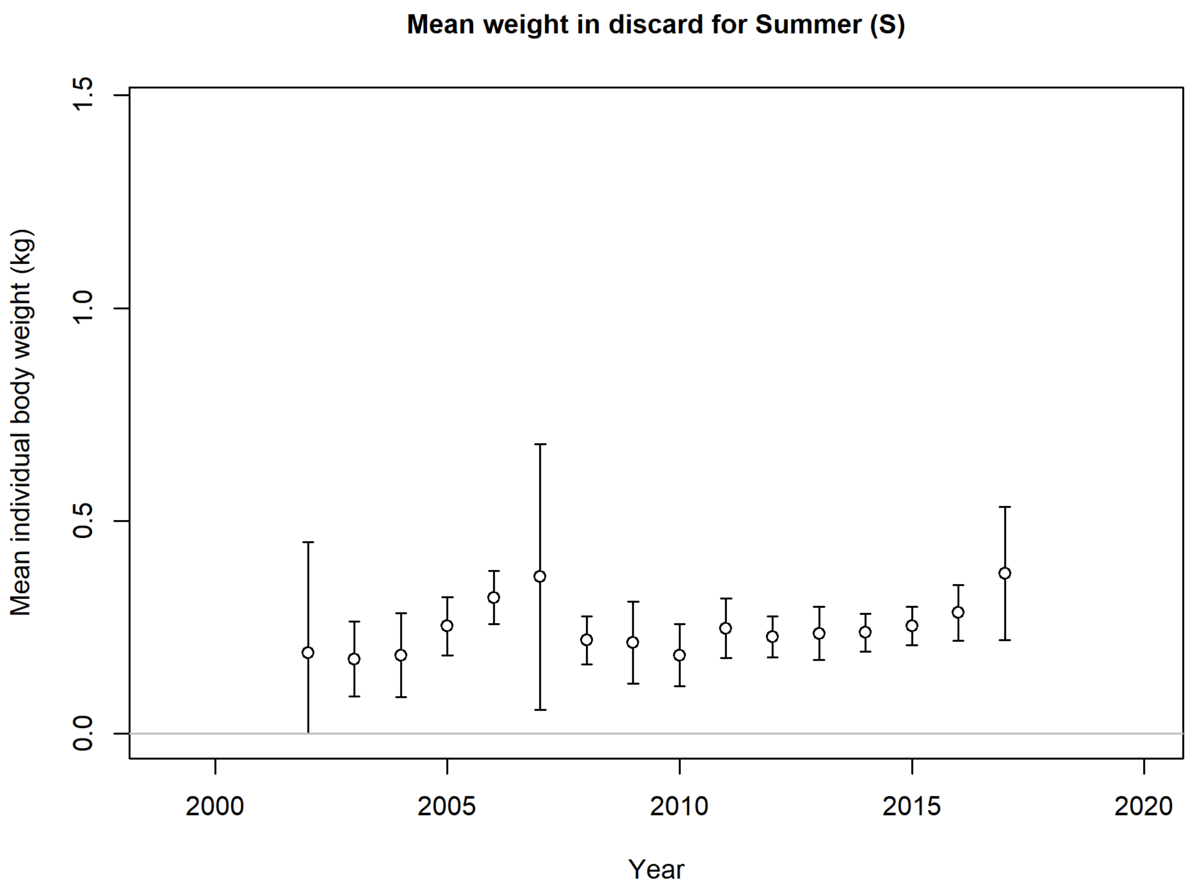

Figure 22: Southern summer fishery mean body weights of discarded fish for petrale sole. fig:ss_bodywt

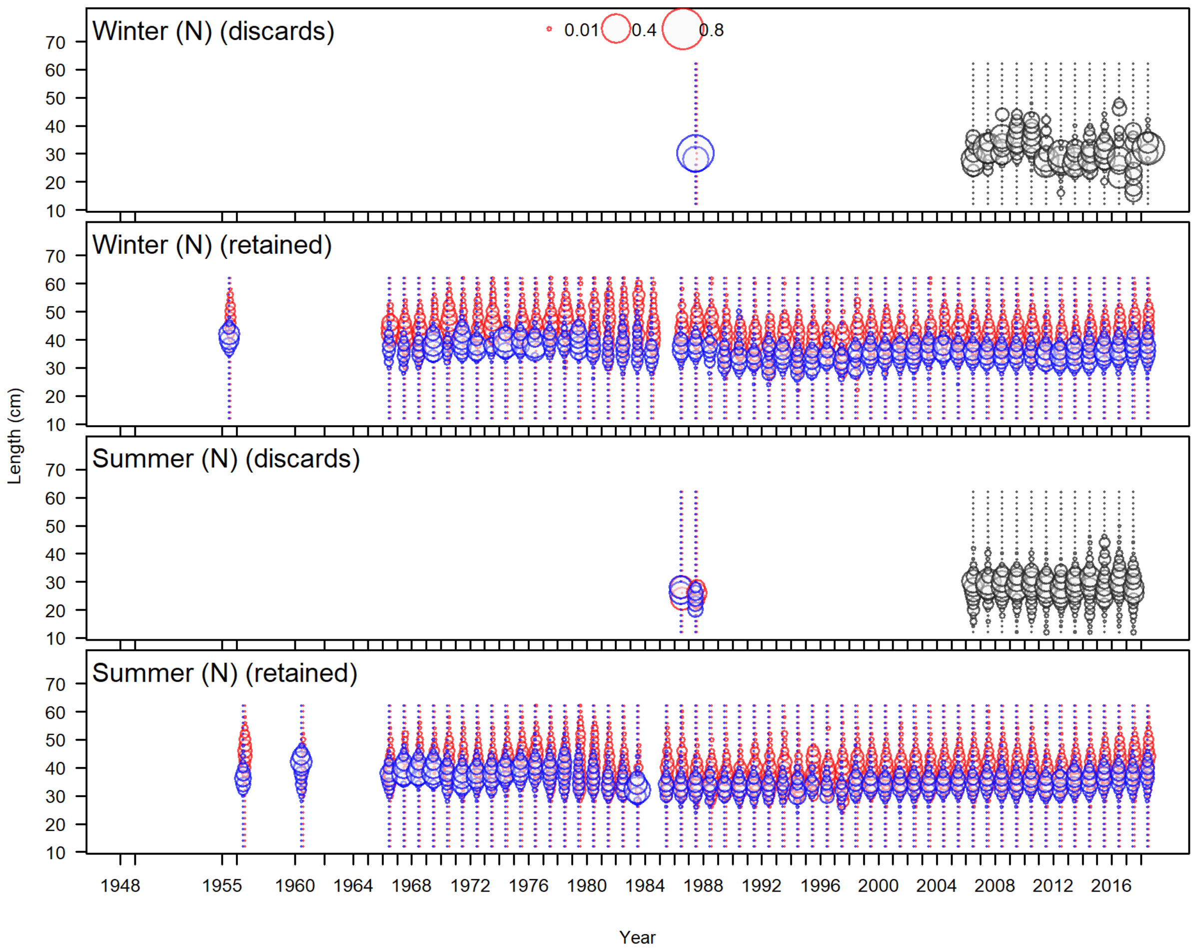

Figure 23: Northern fishery, winter and summer, retained and discarded length frequency distributions for petrale sole. fig:north_lengths

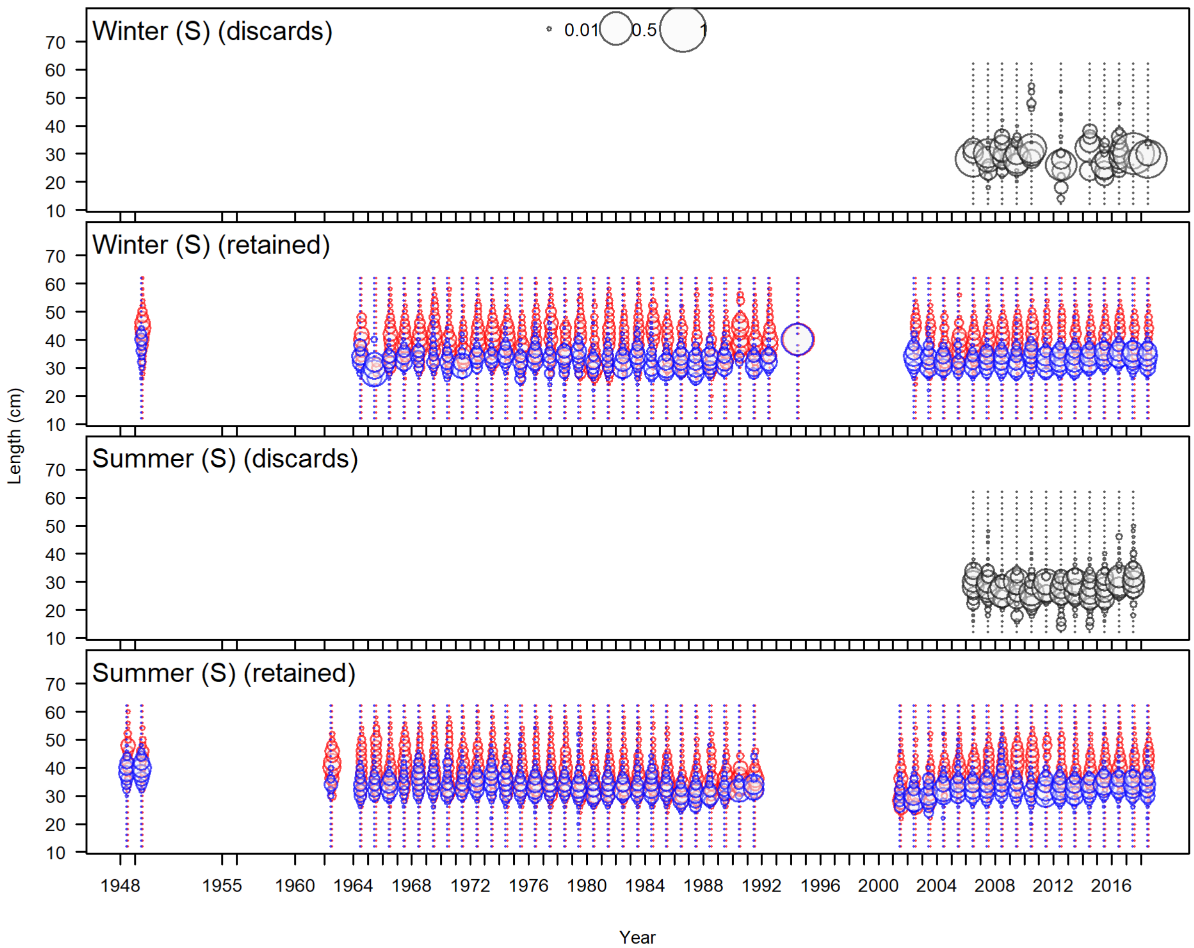

Figure 24: Southern fishery, winter and summer, retained and discarded length frequency distributions for petrale sole. fig:south_lengths

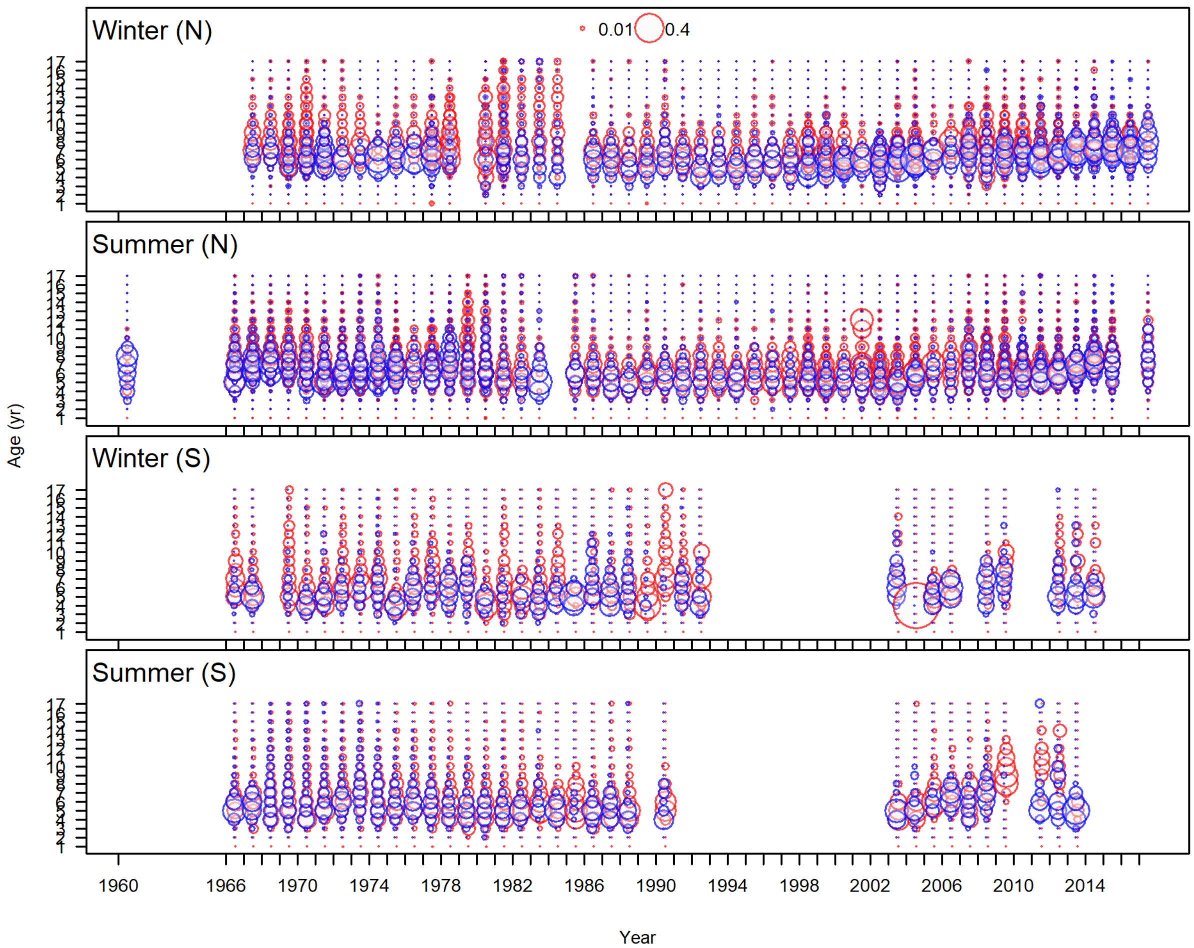

Figure 25: Commercial fishery age frequency distributions for petrale sole. fig:comm_ages

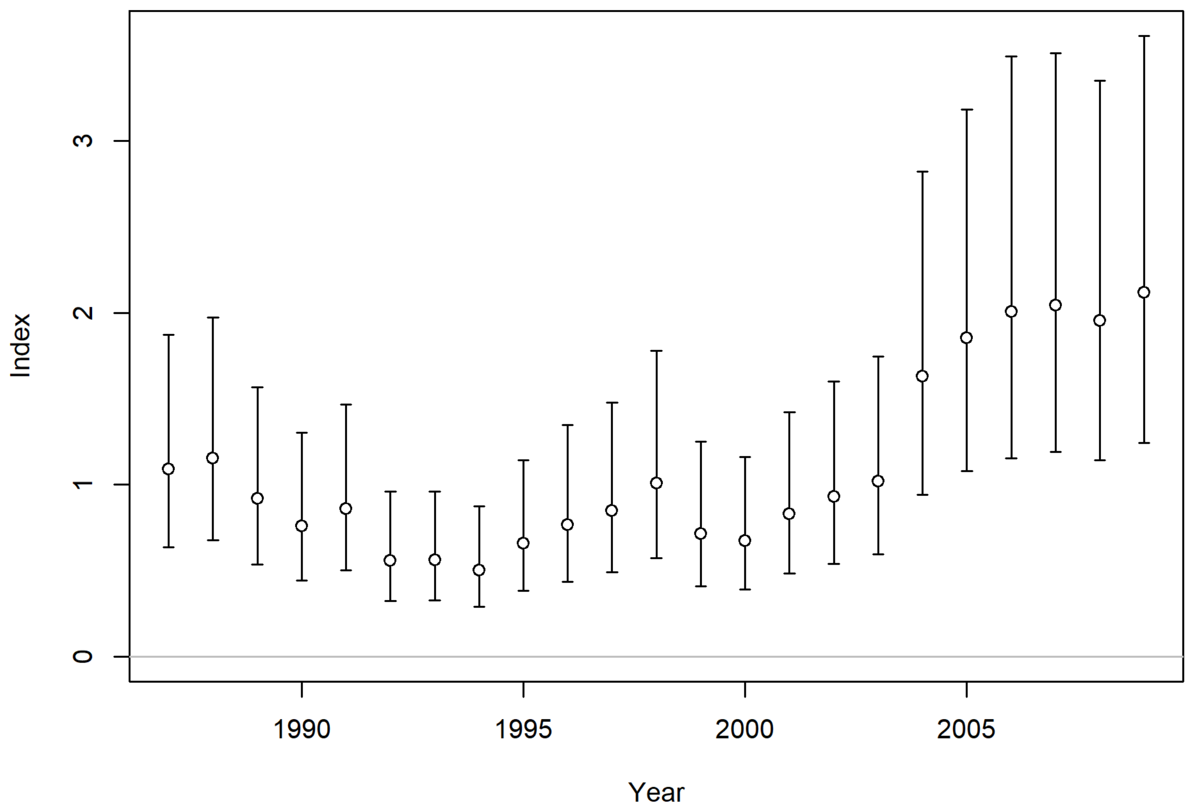

Figure 26: The Northern Winter fishery catch-per-unit-effort based on logbook data for petrale sole. fig:north_cpue

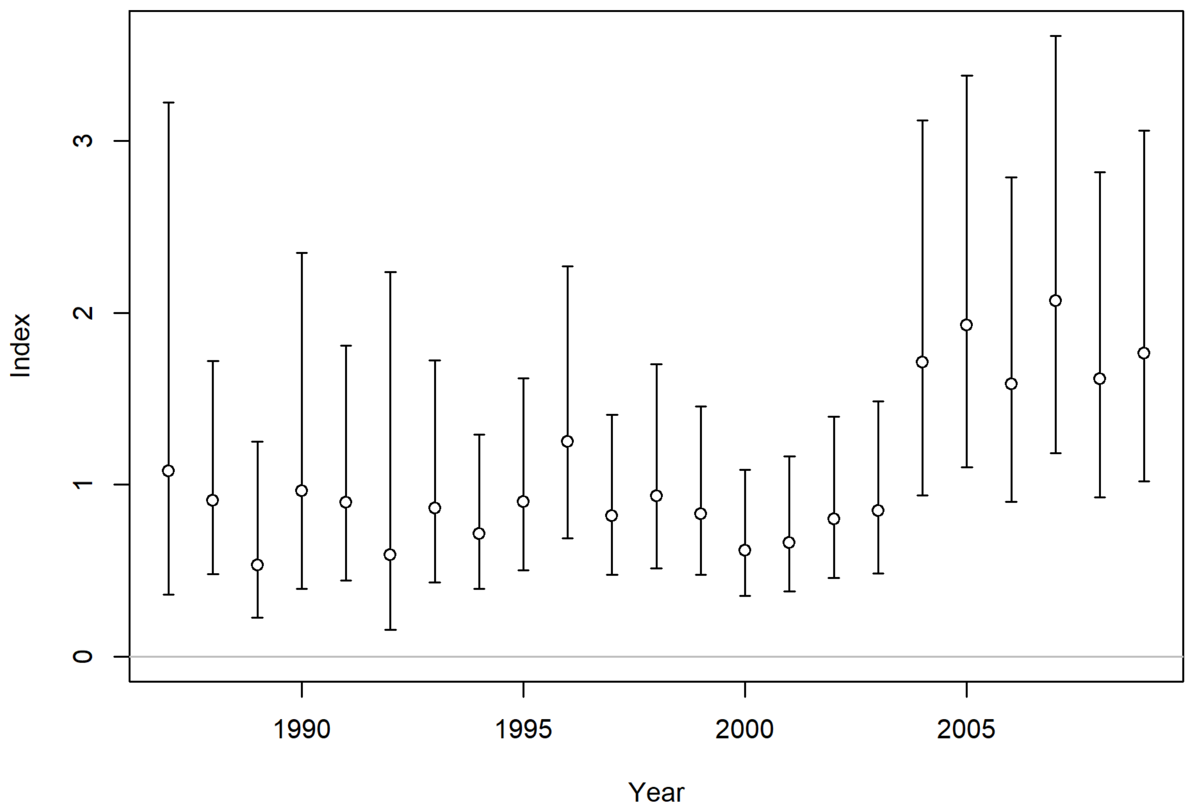

Figure 27: The Southern Winter fishery catch-per-unit-effort based on logbook data for petrale sole. fig:south_cpue

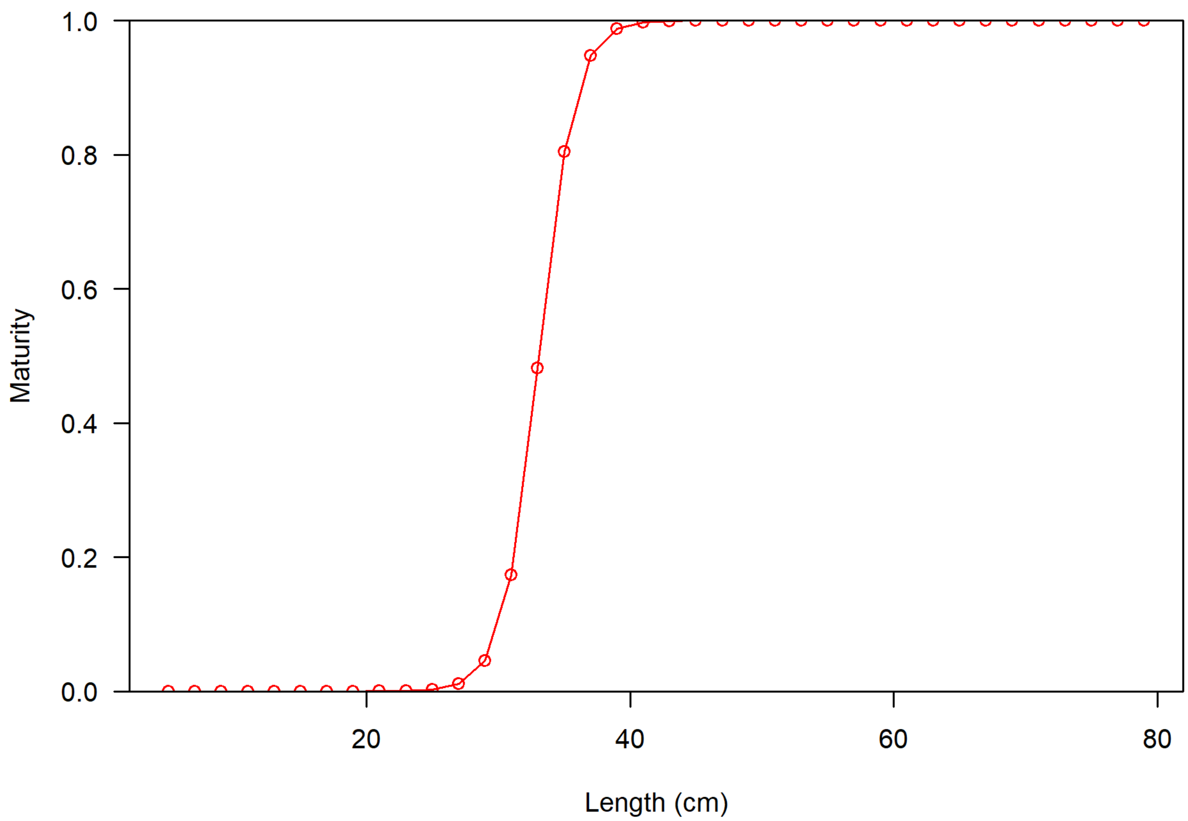

Figure 28: Estimated maturity-at-length for petrale sole. fig:maturity

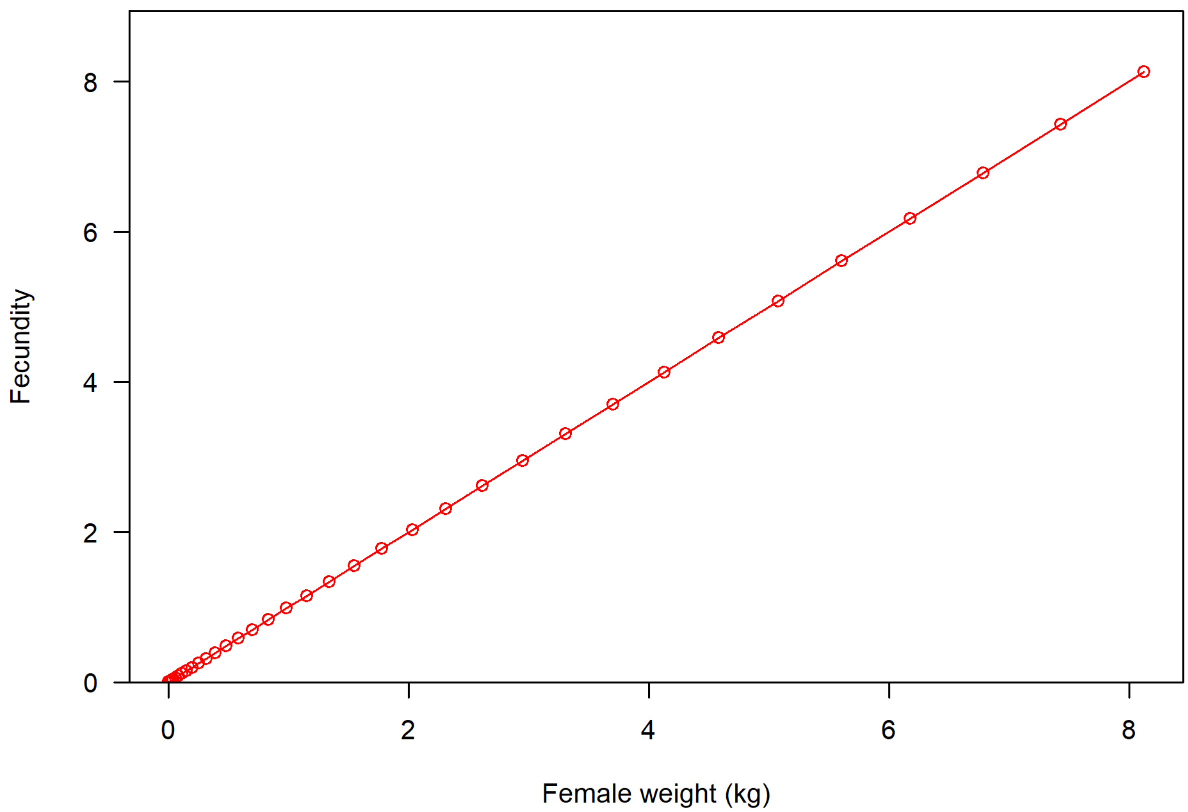

Figure 29: Fecundity-at-length assumed in the model for petrale sole. fig:fecundity_model

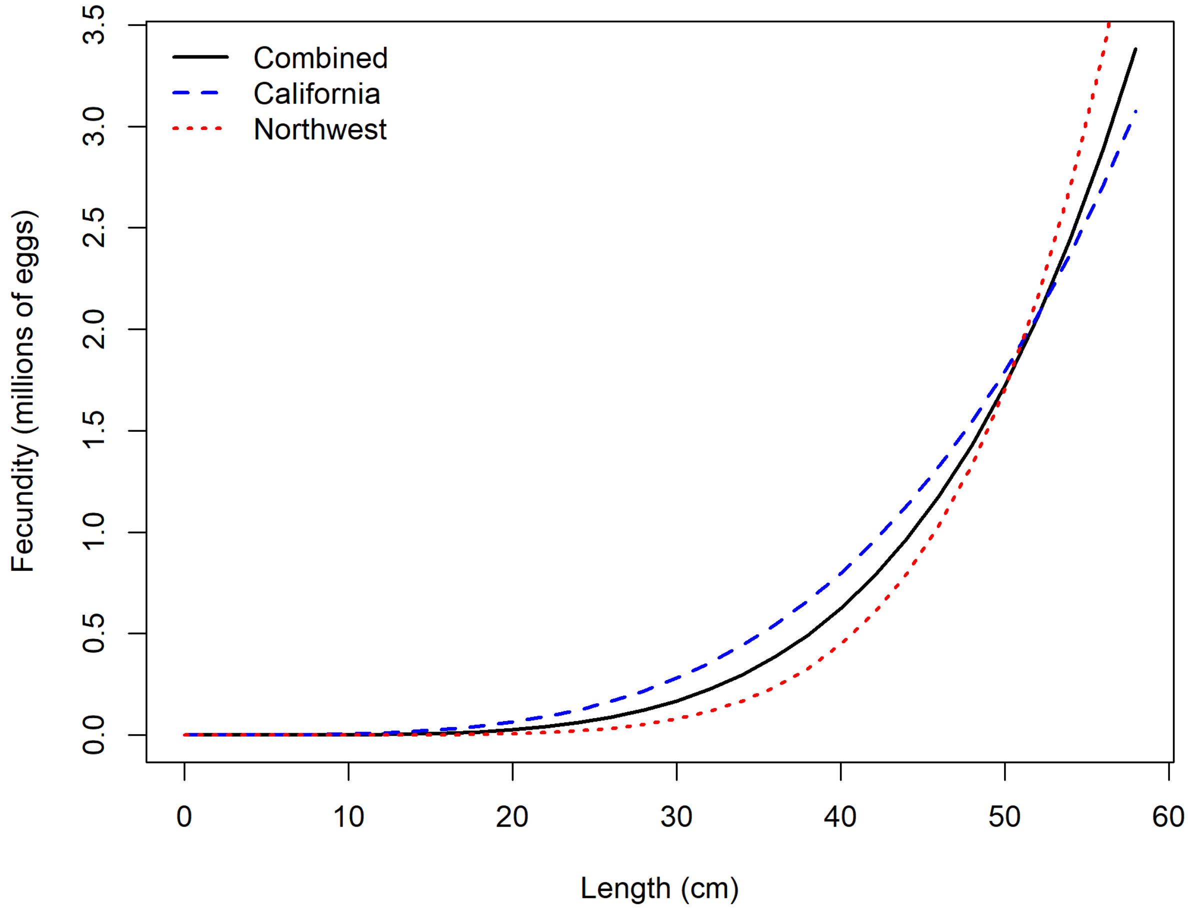

Figure 30: Estimated fecundity-at-length for petrale sole based on Lefebvre et al. (in press). fig:fecundity

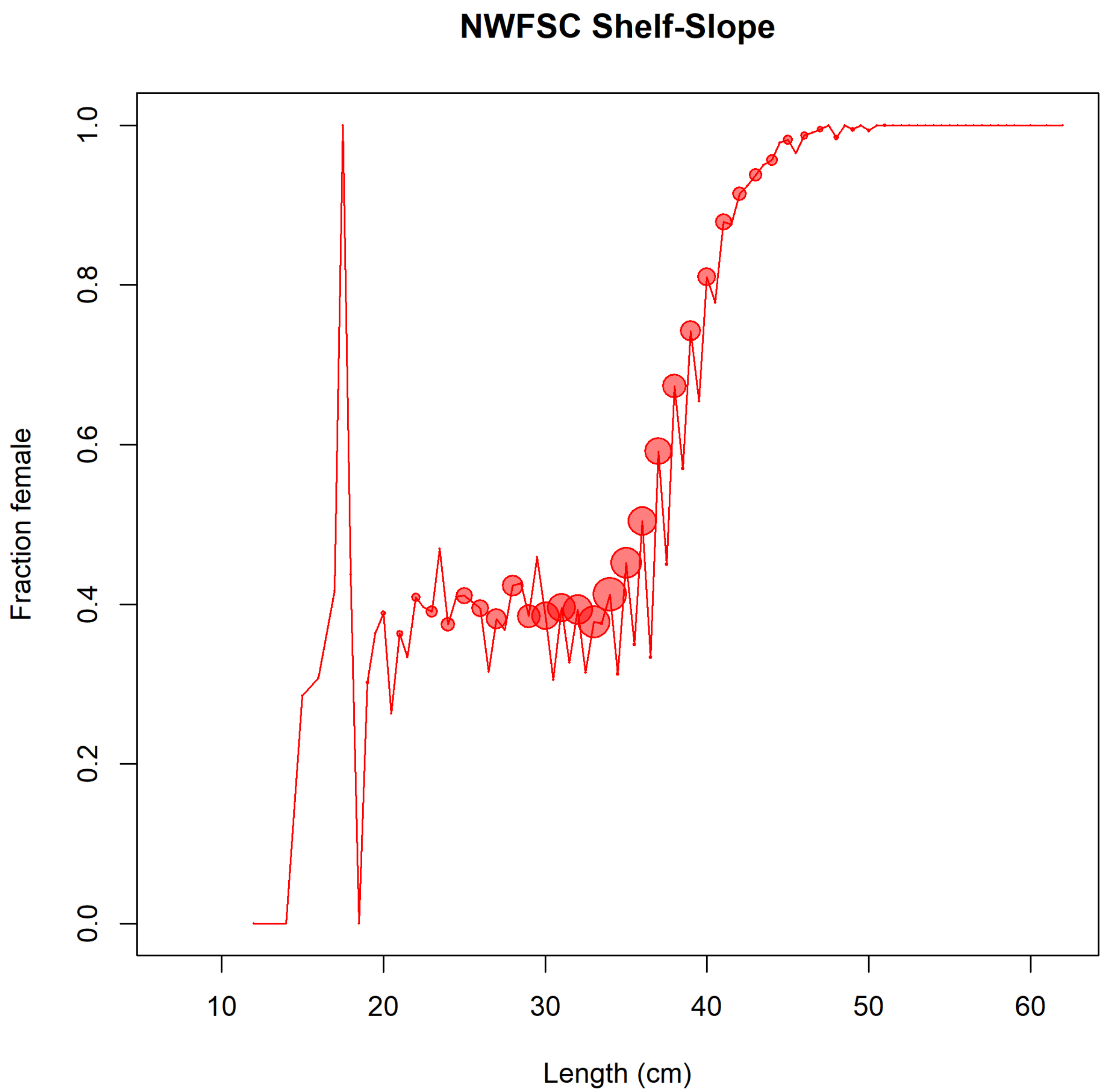

Figure 31: Estimated proportion of female fish collected by the NWFSC shelf-slope survey across all years for petrale sole. fig:sex_ratio

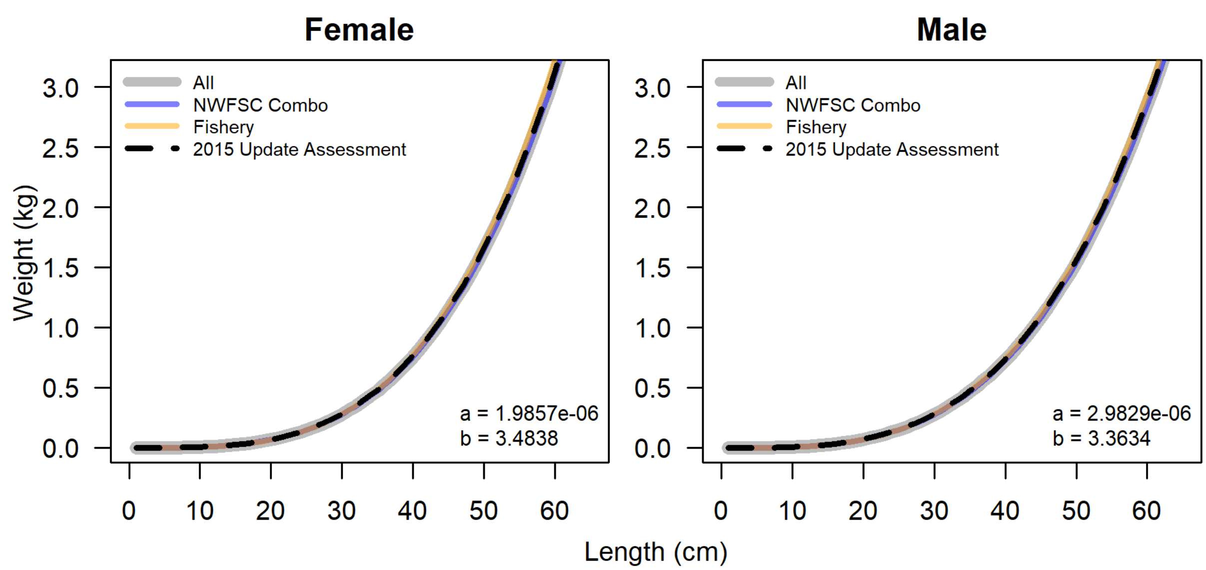

Figure 32: Estimated weight-at-length for female and male petrale sole. fig:wt_length

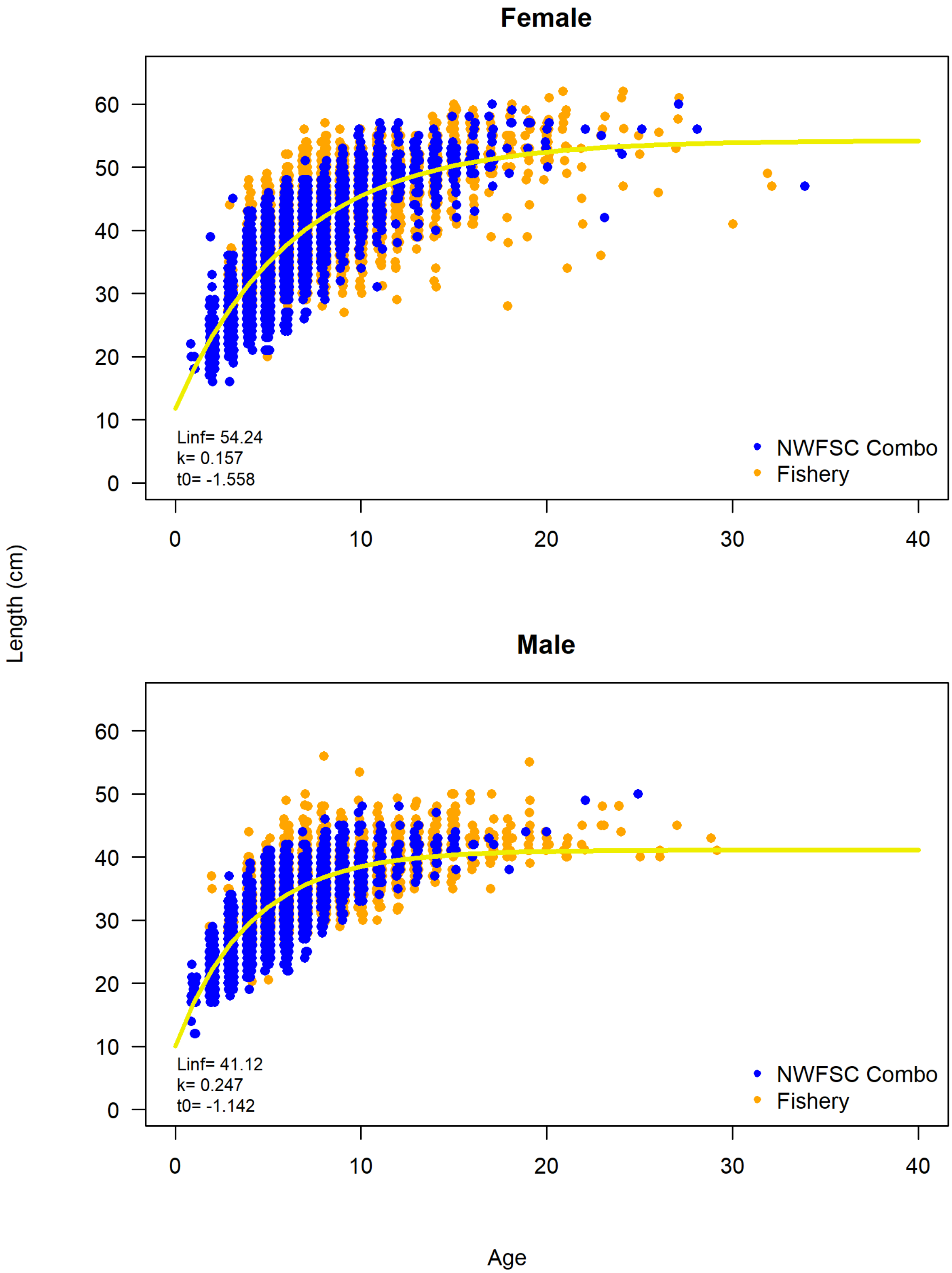

Figure 33: Length-at-age across data sources for female and male petrale sole. fig:length_age

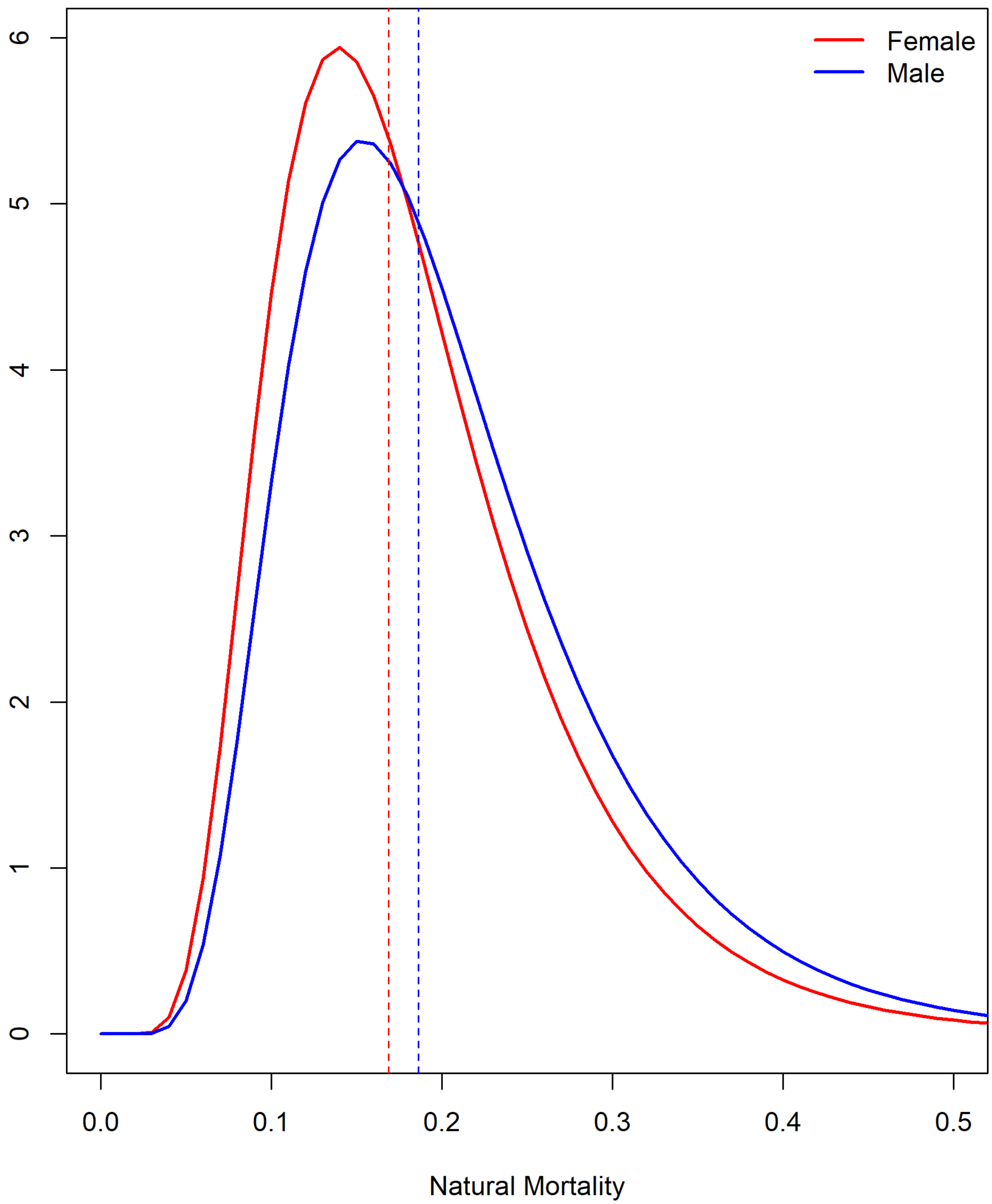

Figure 34: Prior distribution for natural mortality for female and male petrale sole. fig:m_prior

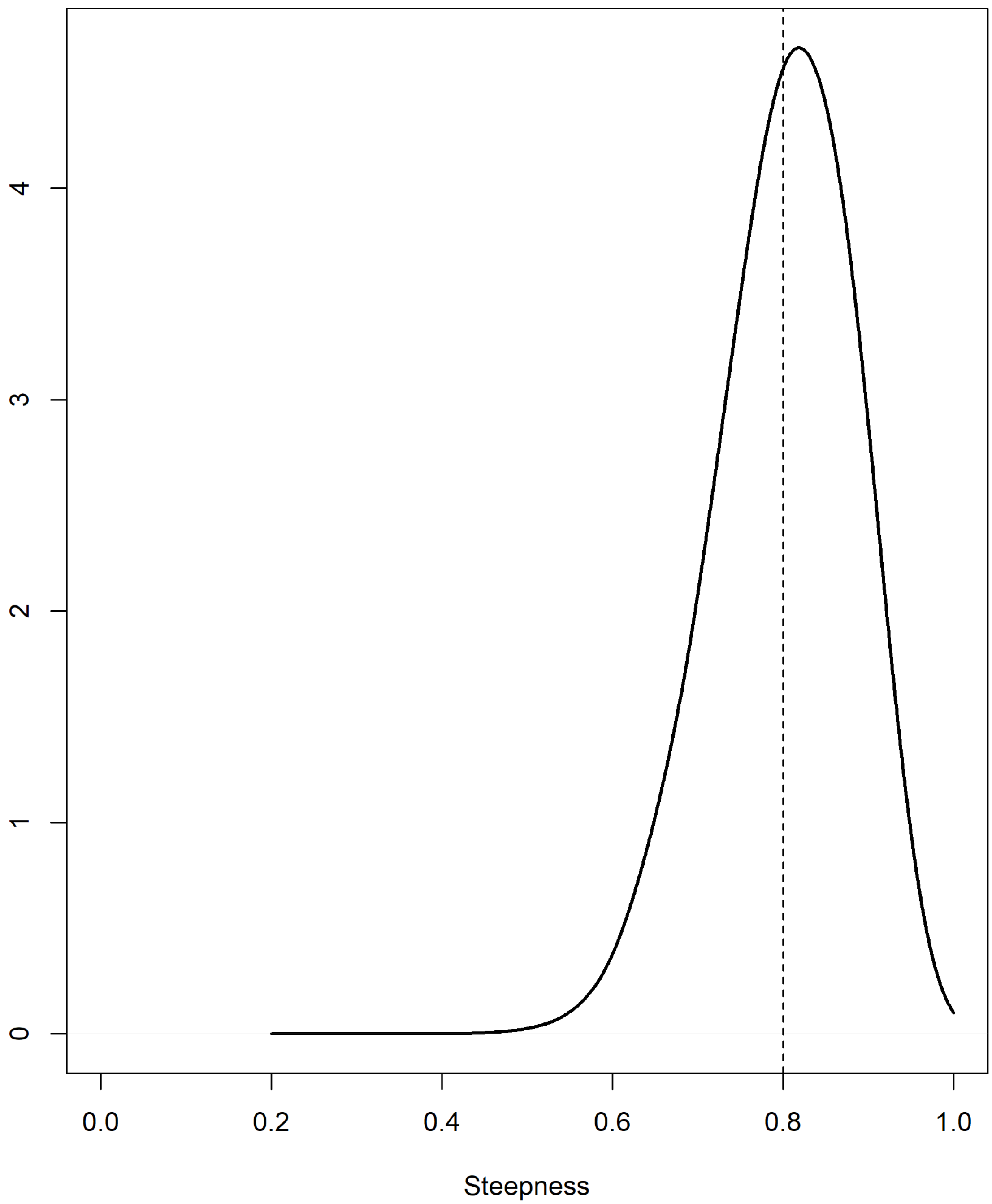

Figure 35: Prior distribution for steepness petrale sole. fig:h_prior

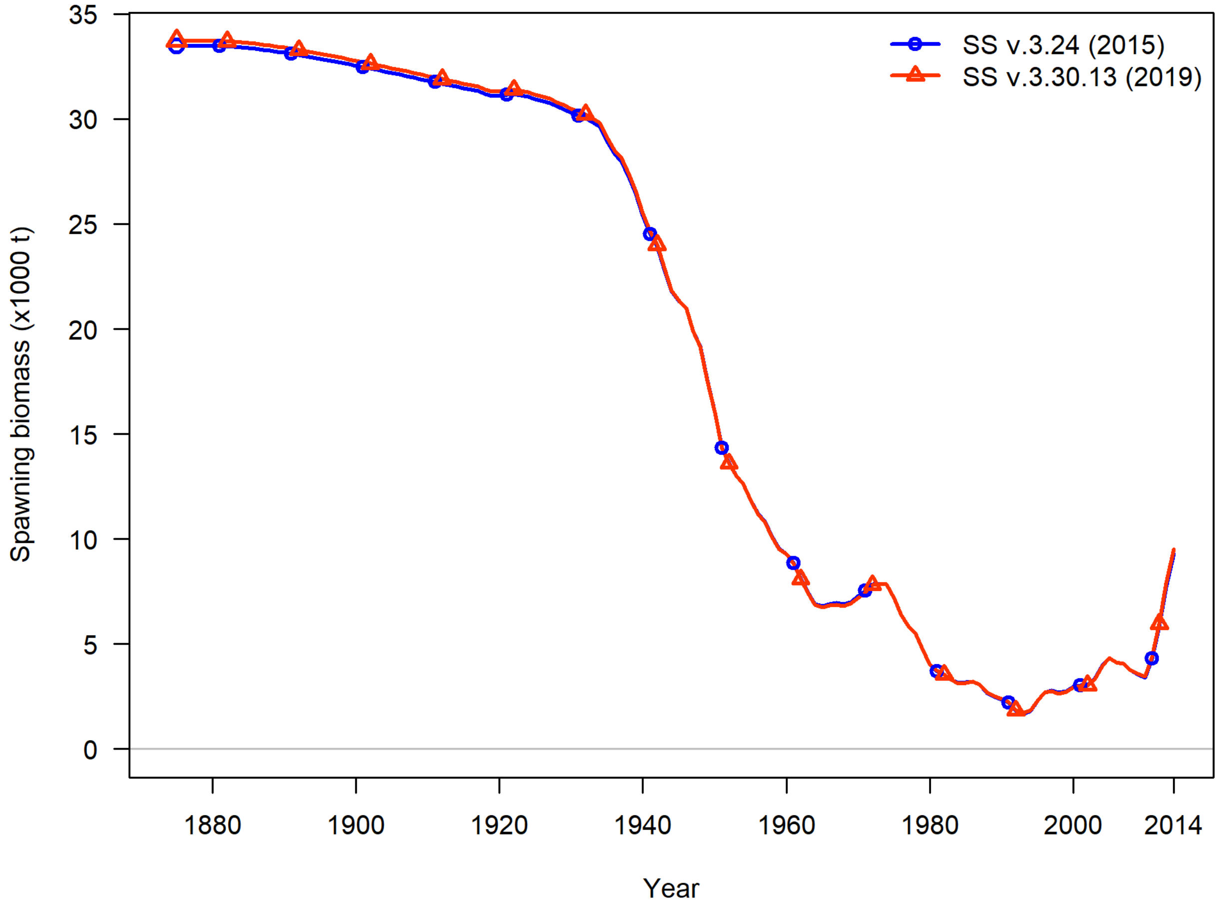

Figure 36: Comparison of model bridging estimates from Stock Synthesis version 3.30.13 and 3.24U for petrale sole for the 2015 assessment. fig:bridge

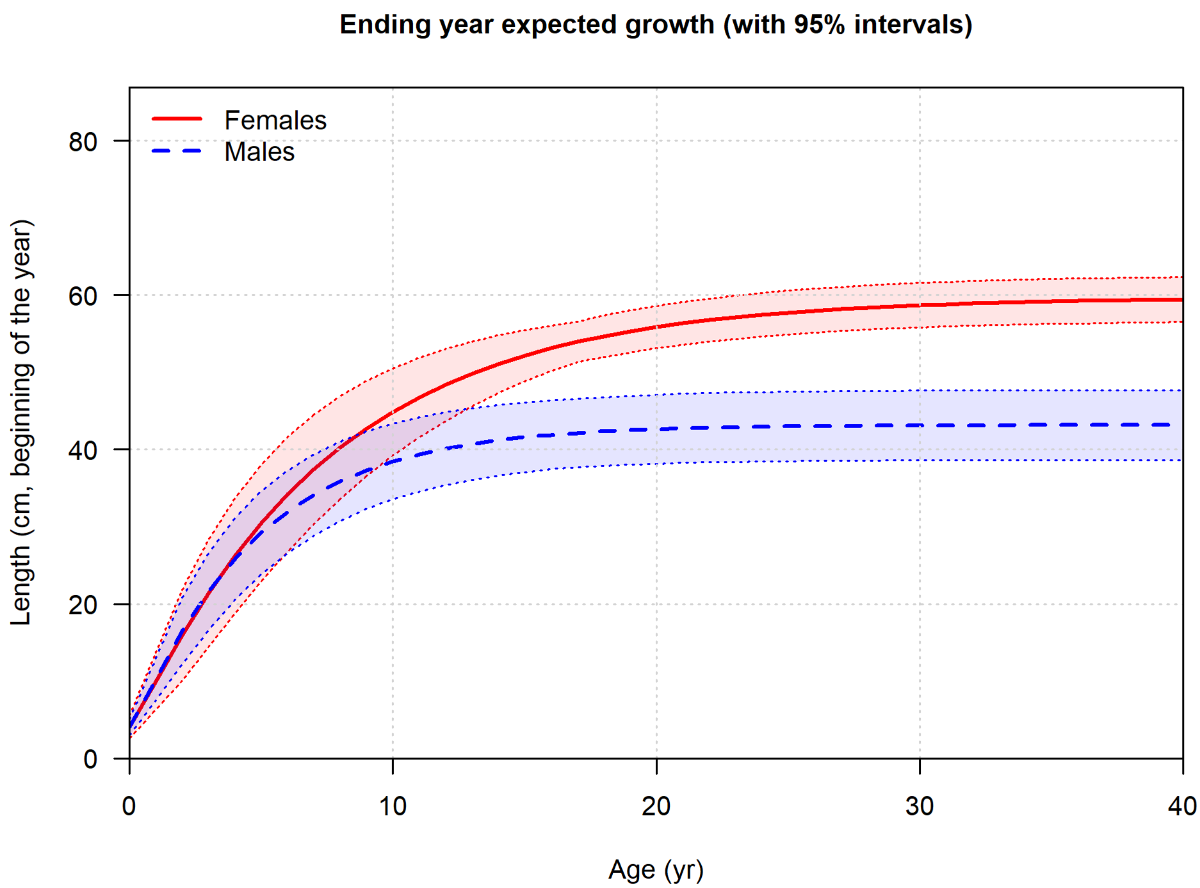

Figure 37: Estimated length-at-age for male and female for petrale sole with estimated CV. fig:sizeatage

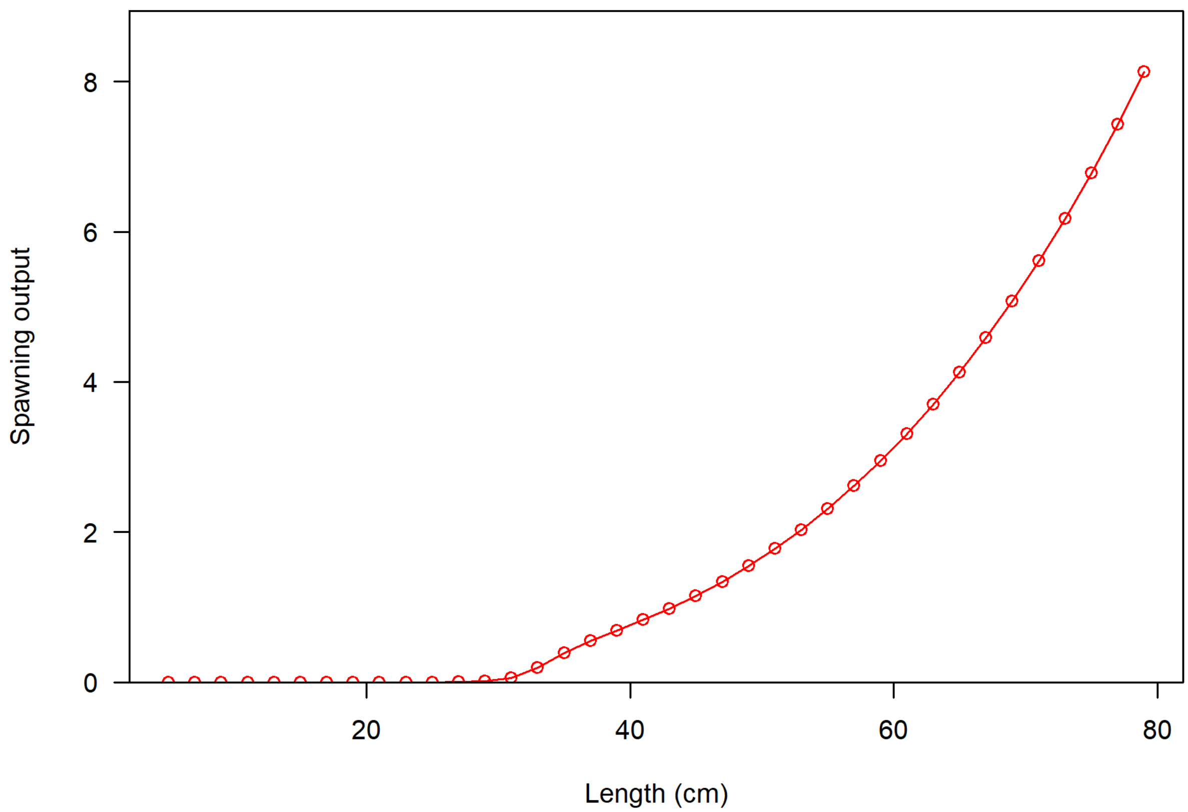

Figure 38: Estimated spawning output-at-length for female petrale sole. fig:spawnoutlen

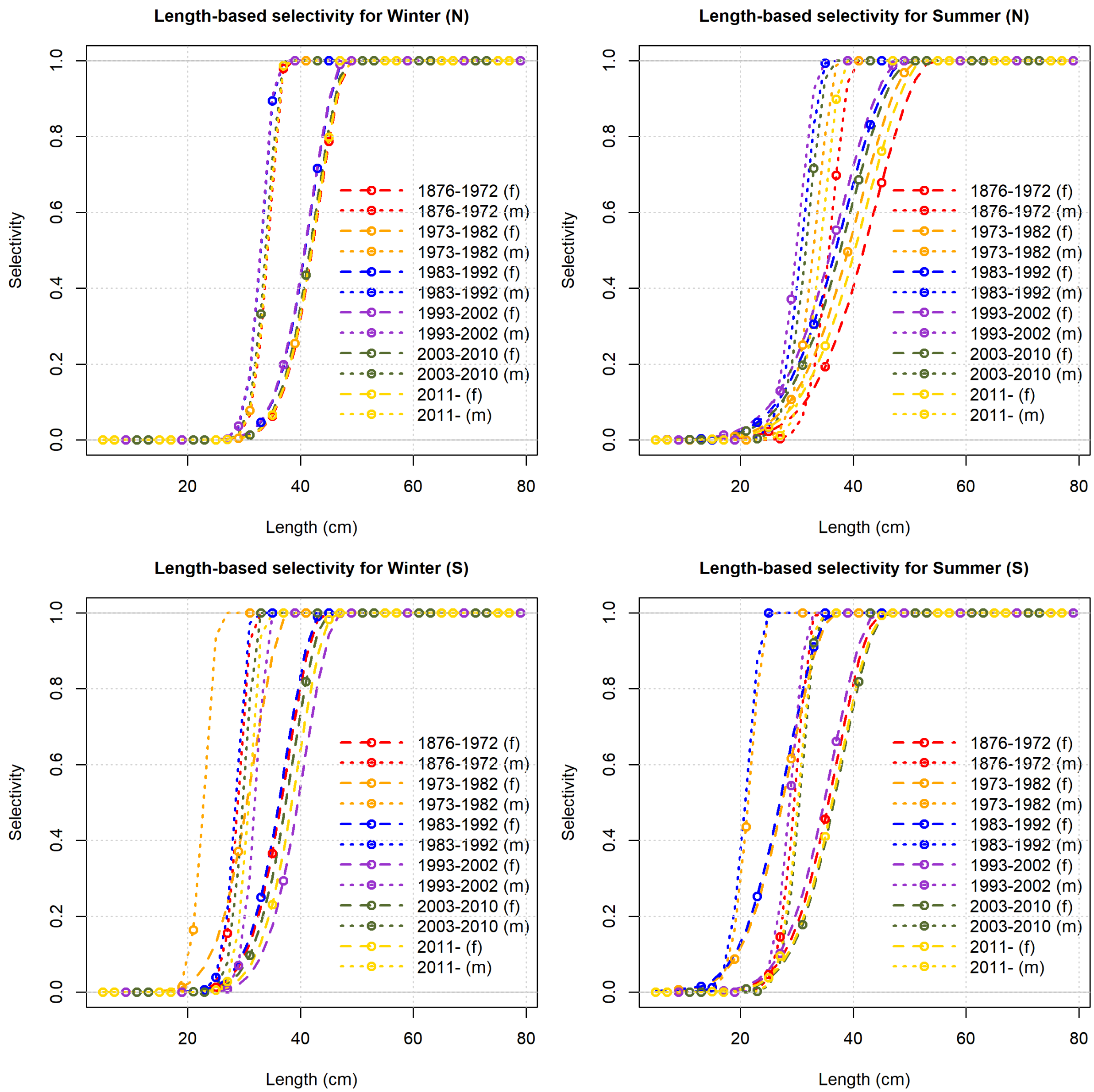

Figure 39: Estimated selectivity for each commerical fleet over the assessment period for female and male petrale sole. [fig:fish_selex]

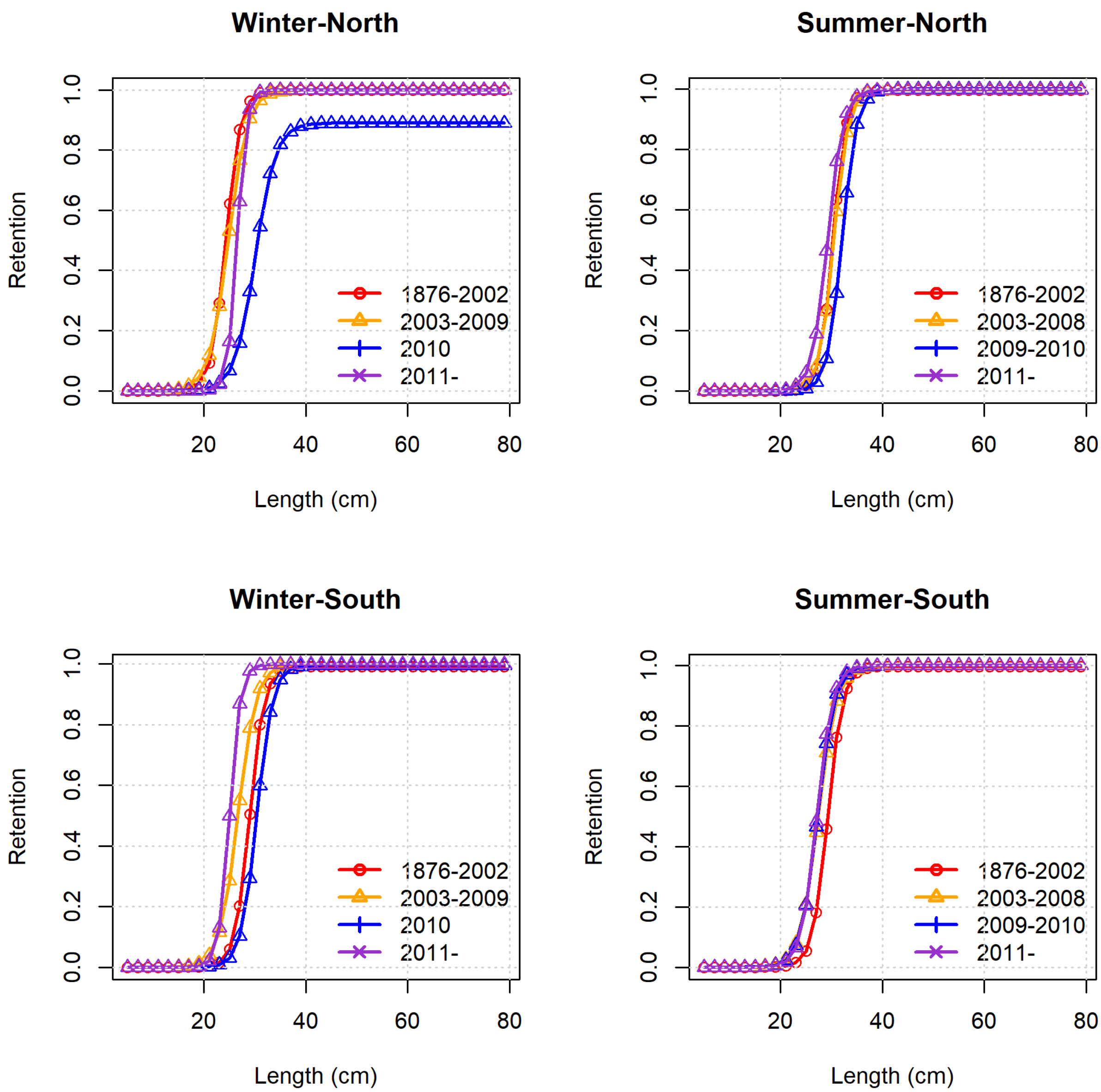

Figure 40: Estimated retention for each commerical fleet over the assessment period for petrale sole. Retention was not estimated to be sex-specific. fig:fish_reten

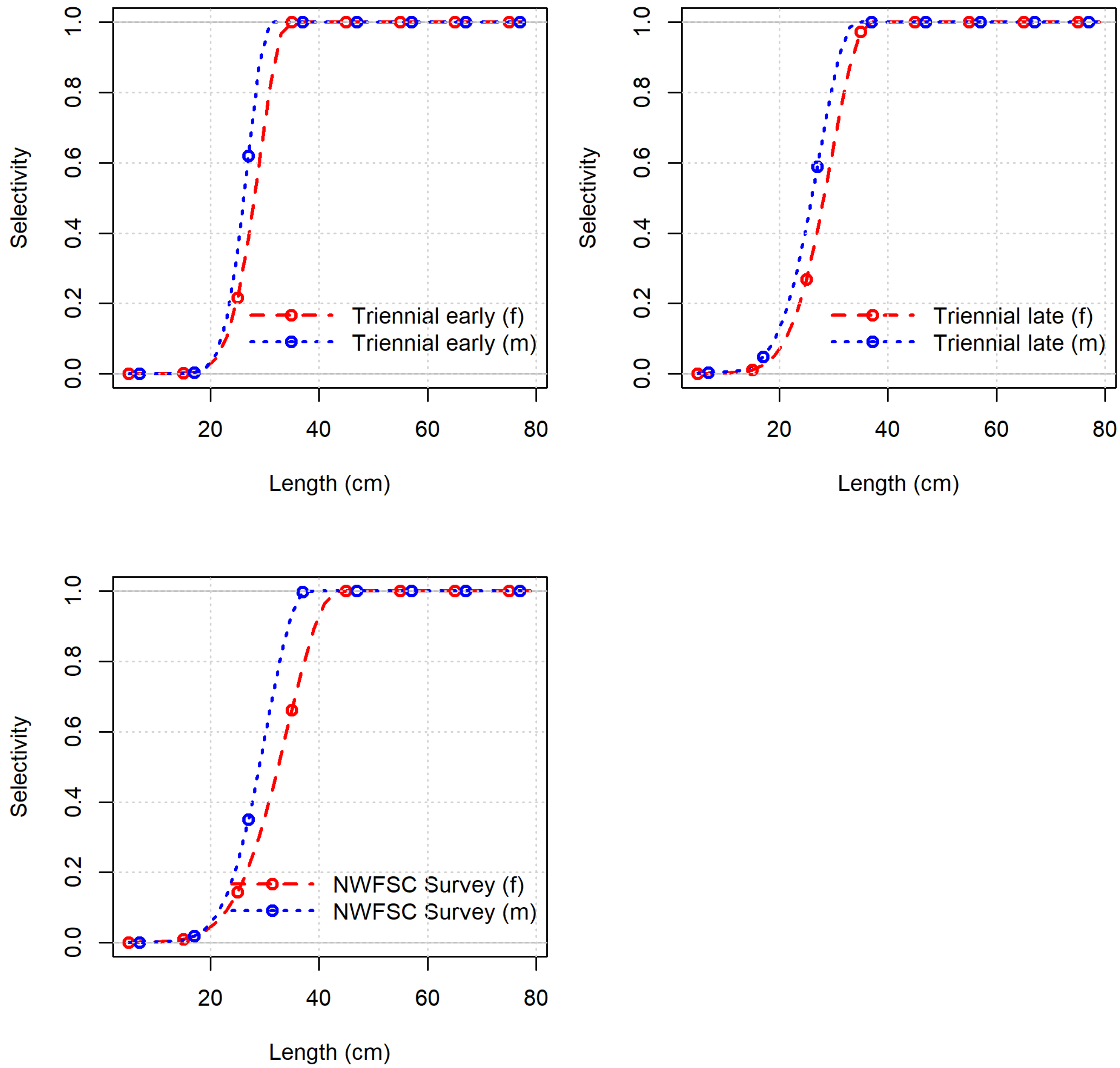

Figure 41: Estimated selectivity for each survey over the assessment period for female and male petrale sole. fig:survey_selex

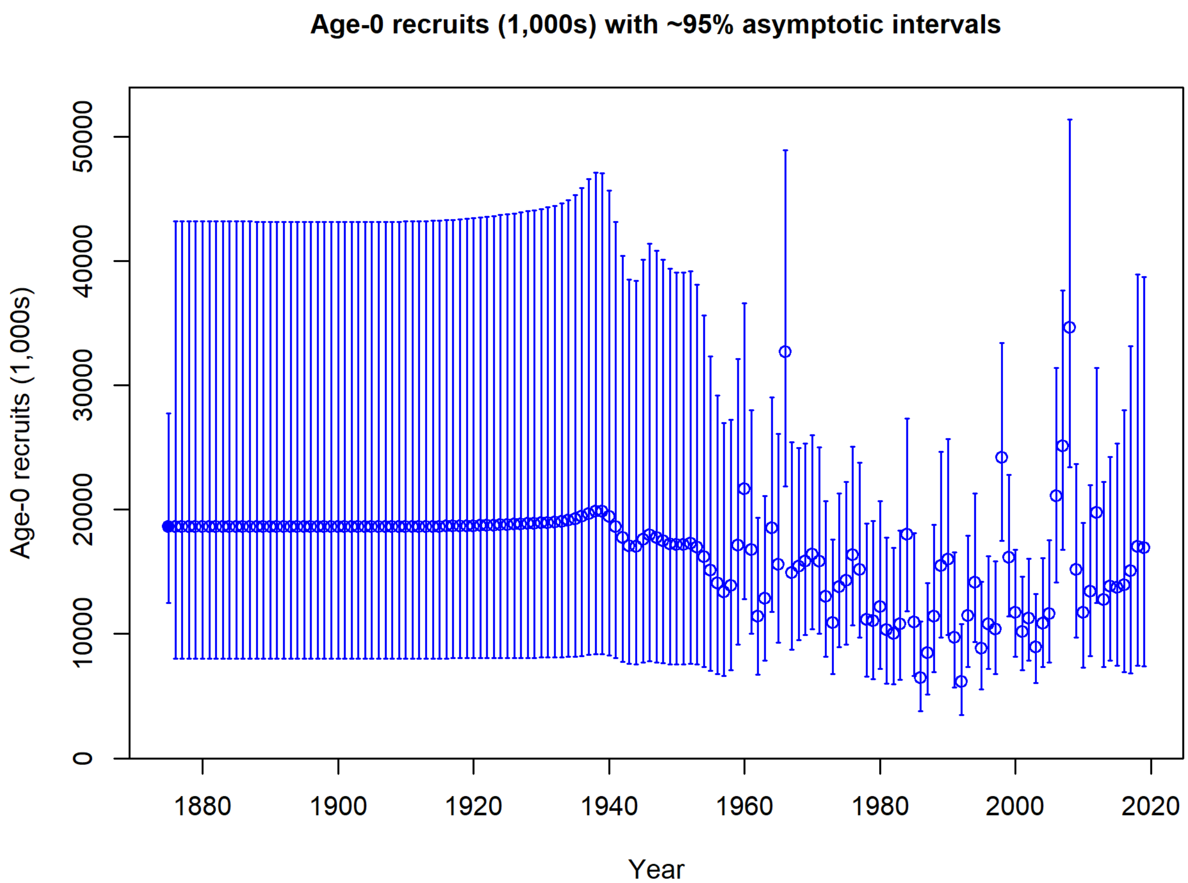

Figure 42: Estimated time-series of recruitment for petrale sole. fig:recruits

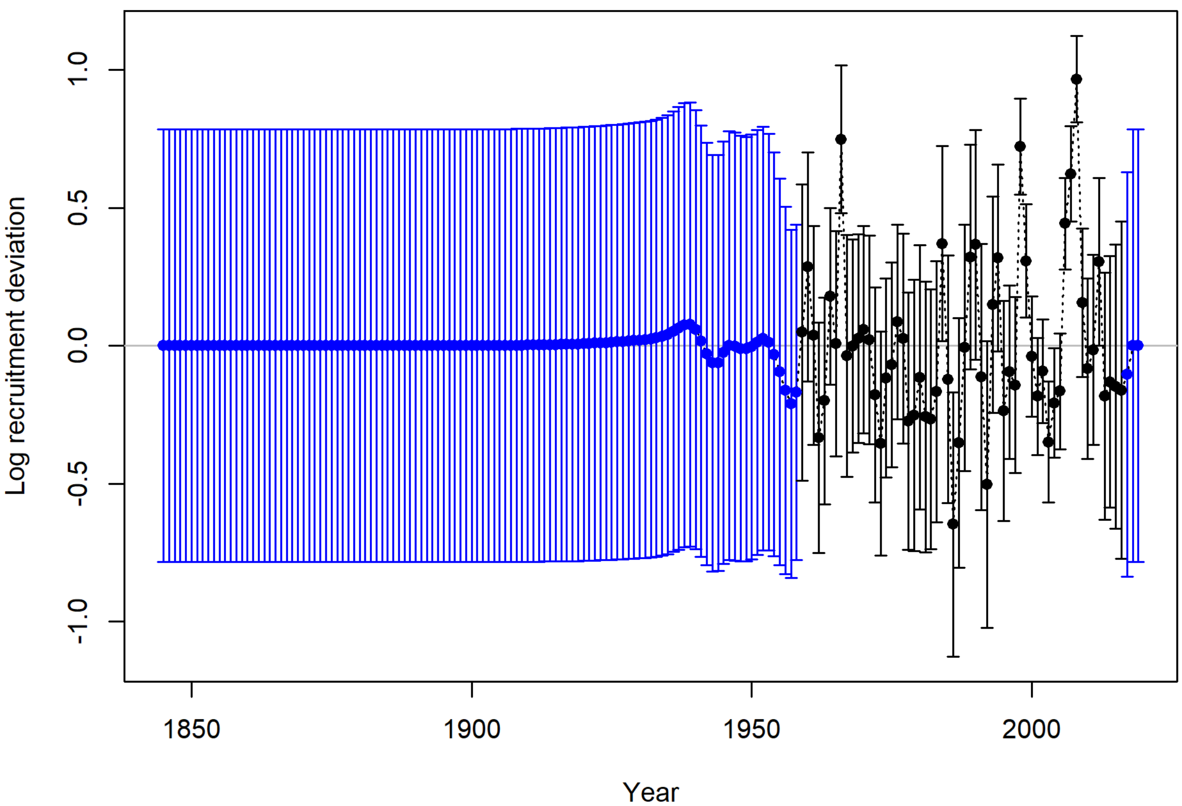

Figure 43: Estimated time-series of recruitment deviations for petrale sole. fig:recdevs

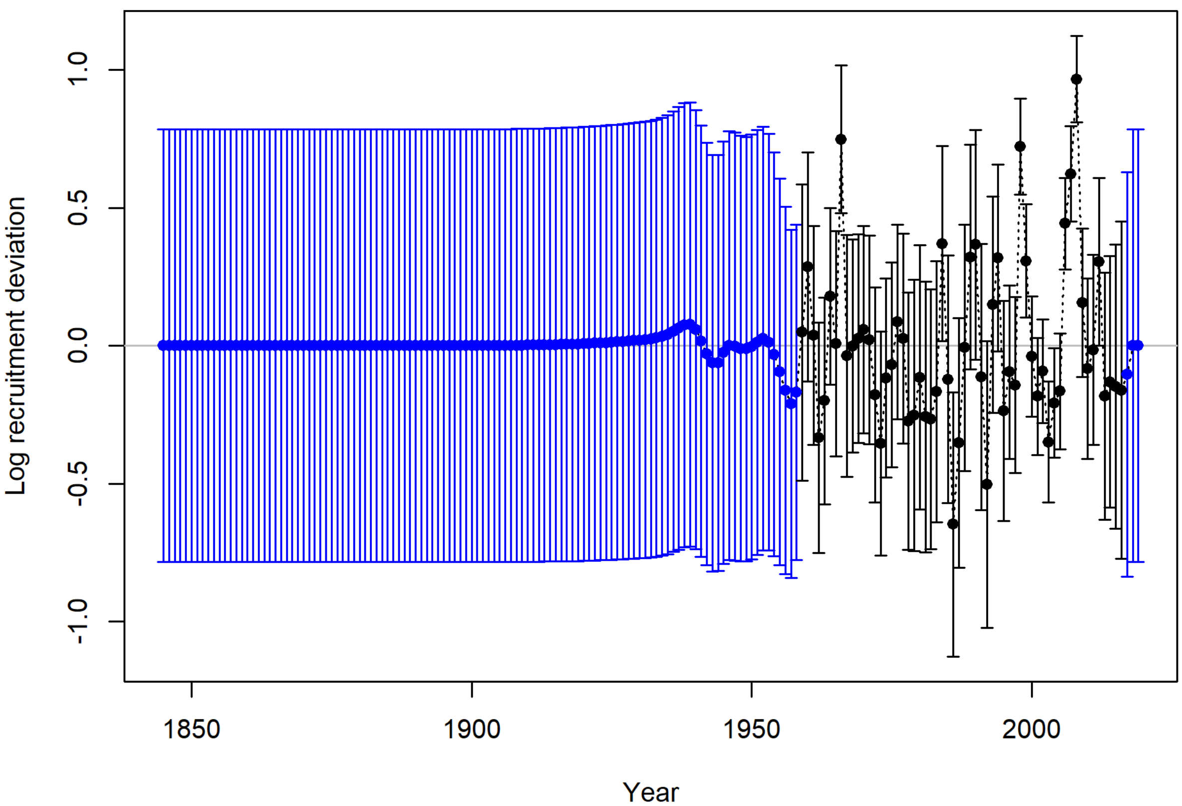

Figure 44: Estimated recruitment deviations. fig:rec_devs

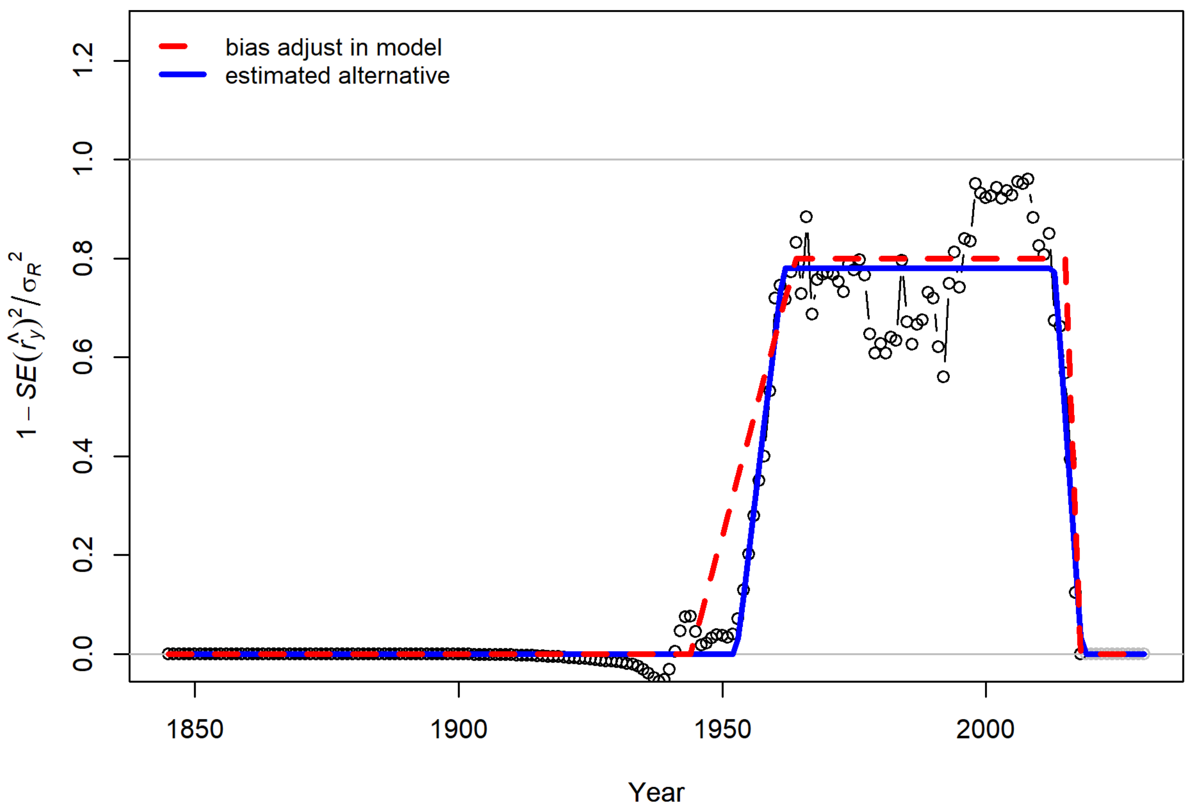

Figure 45: Recruitment bias adjustment in the model. fig:bias_adjust

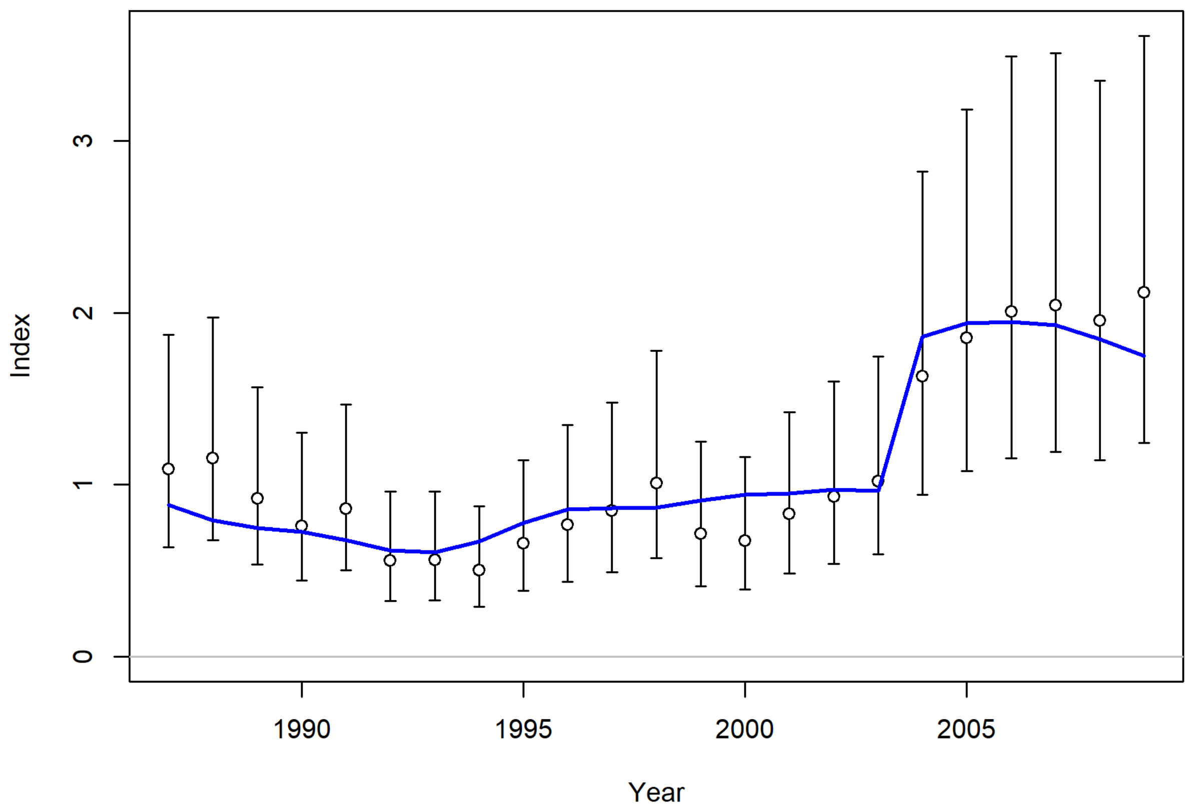

Figure 46: Fit to the Winter North catch-per-unit-effort time series for petrale sole. fig:fit_wn_cpue

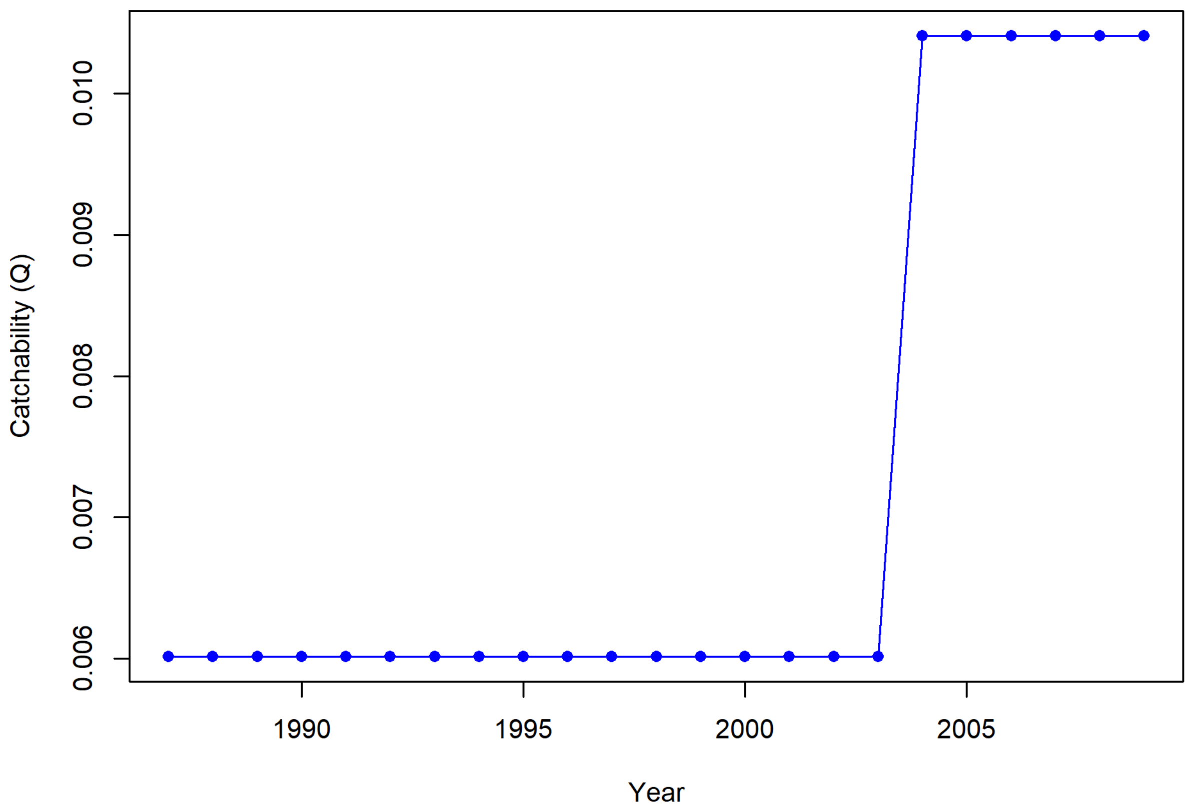

Figure 47: Catchability to the Winter North catch-per-unit-effort time series. fig:q_north

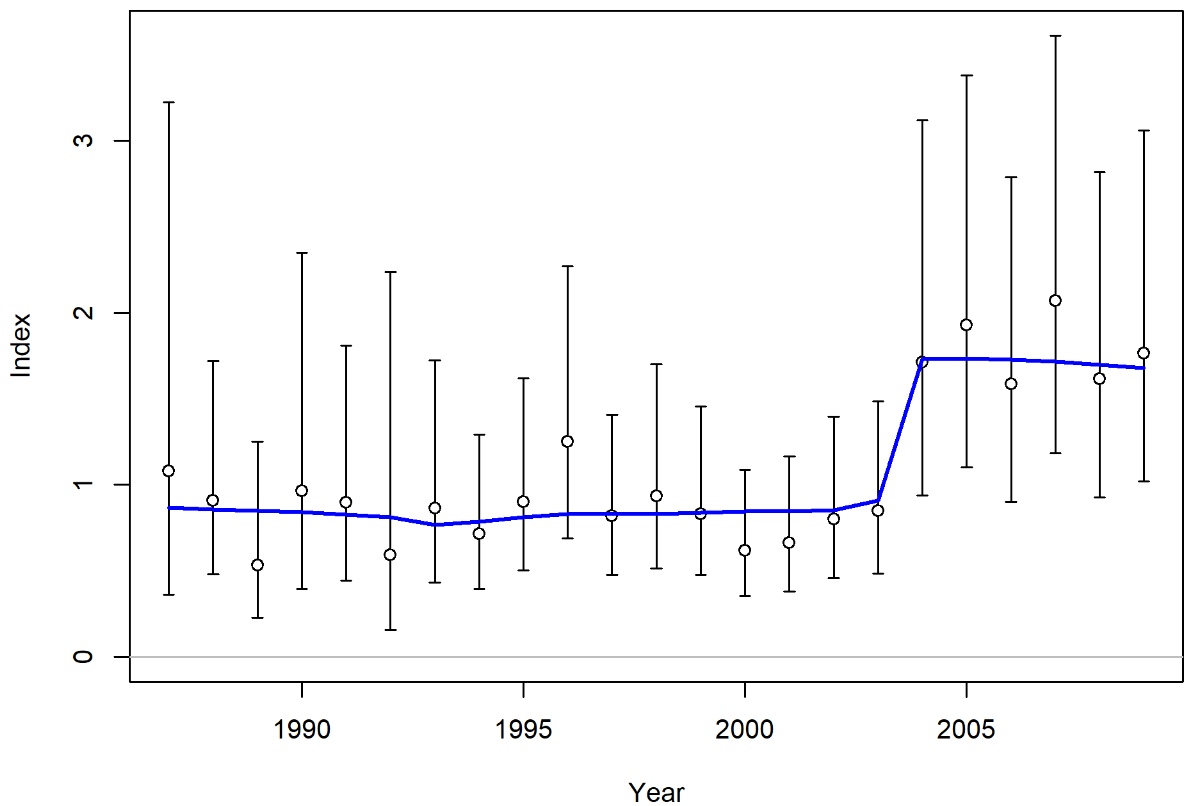

Figure 48: Fit to the Winter South catch-per-unit-effort time series for petrale sole. fig:fit_ws_cpue

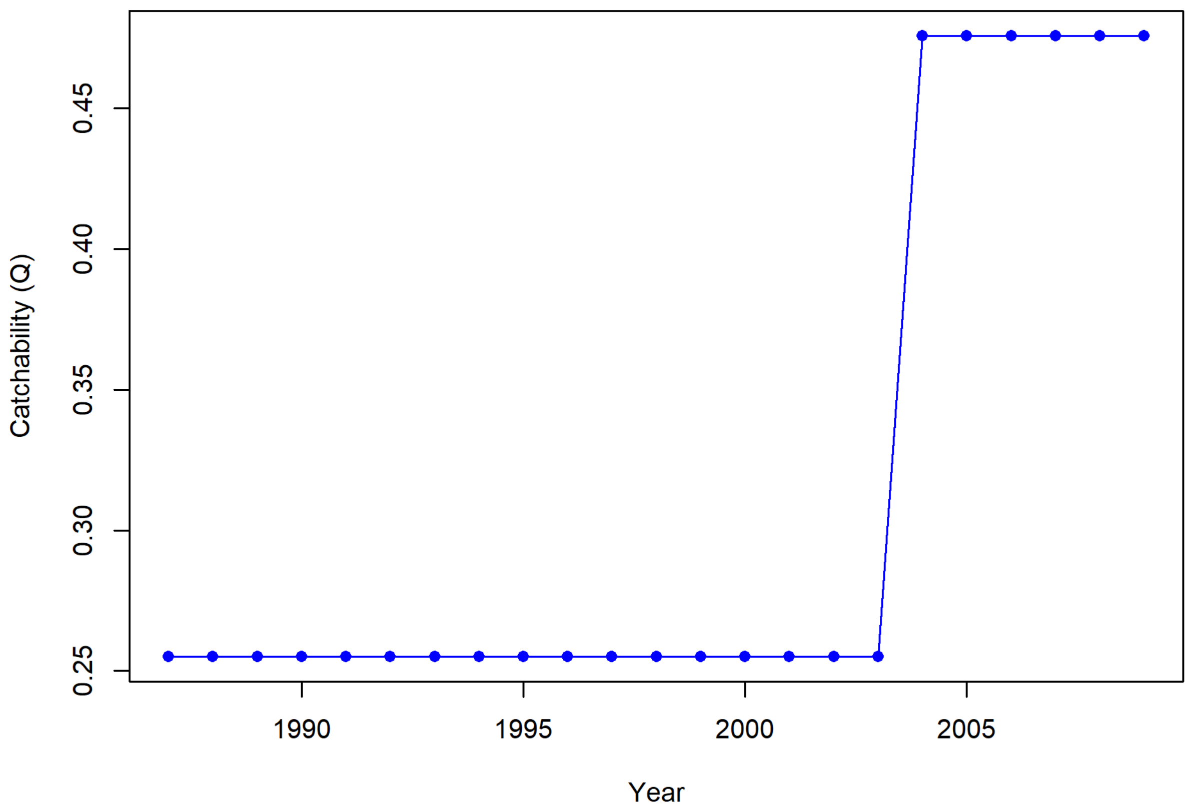

Figure 49: Catchability to the Winter South catch-per-unit-effort time series. fig:q_south

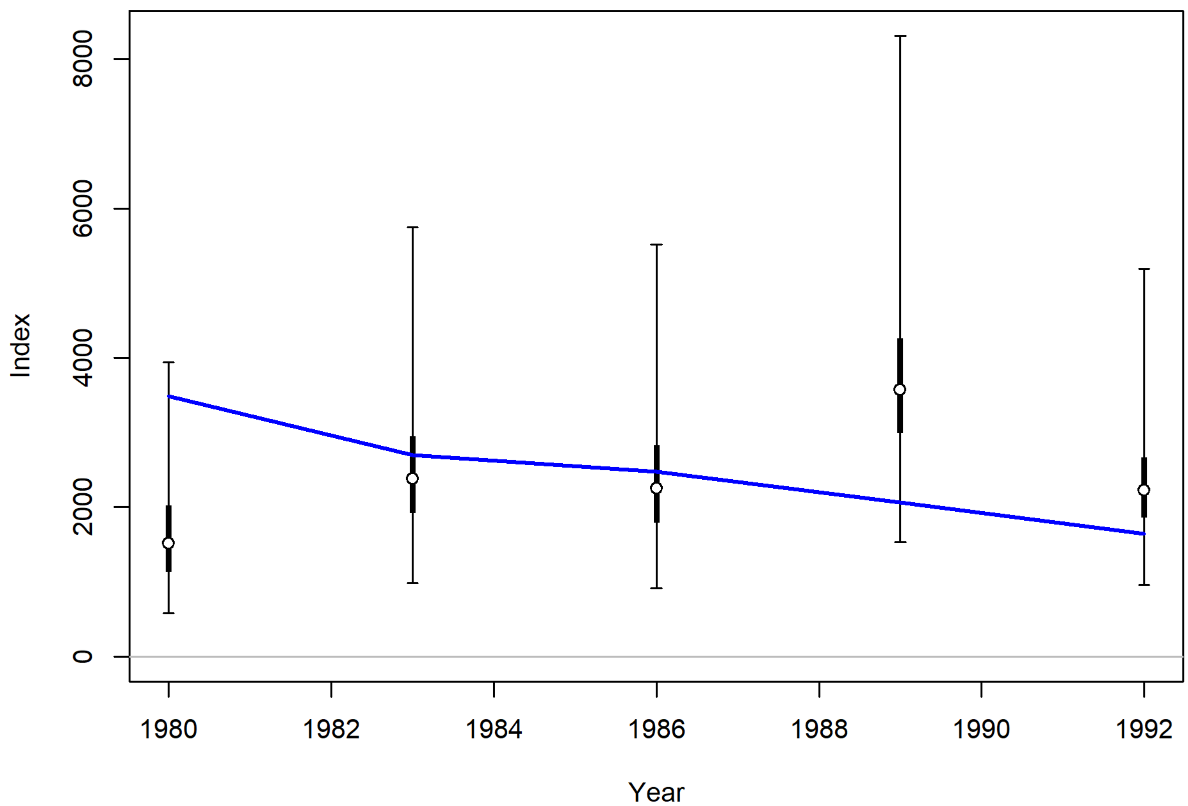

Figure 50: Fit to the Triennial Survey Early time series for petrale sole. fig:fit_tri_early

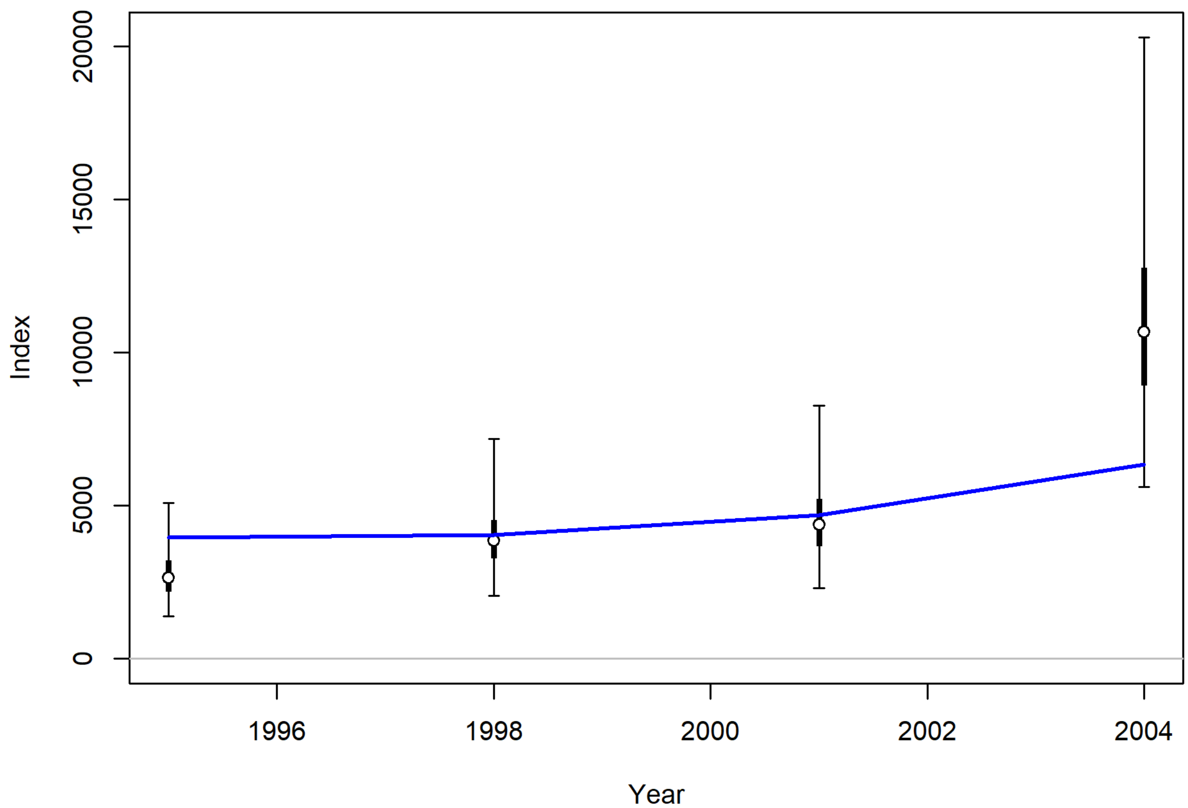

Figure 51: Fit to the Triennial Survey Late time series for petrale sole. fig:fit_tri_late

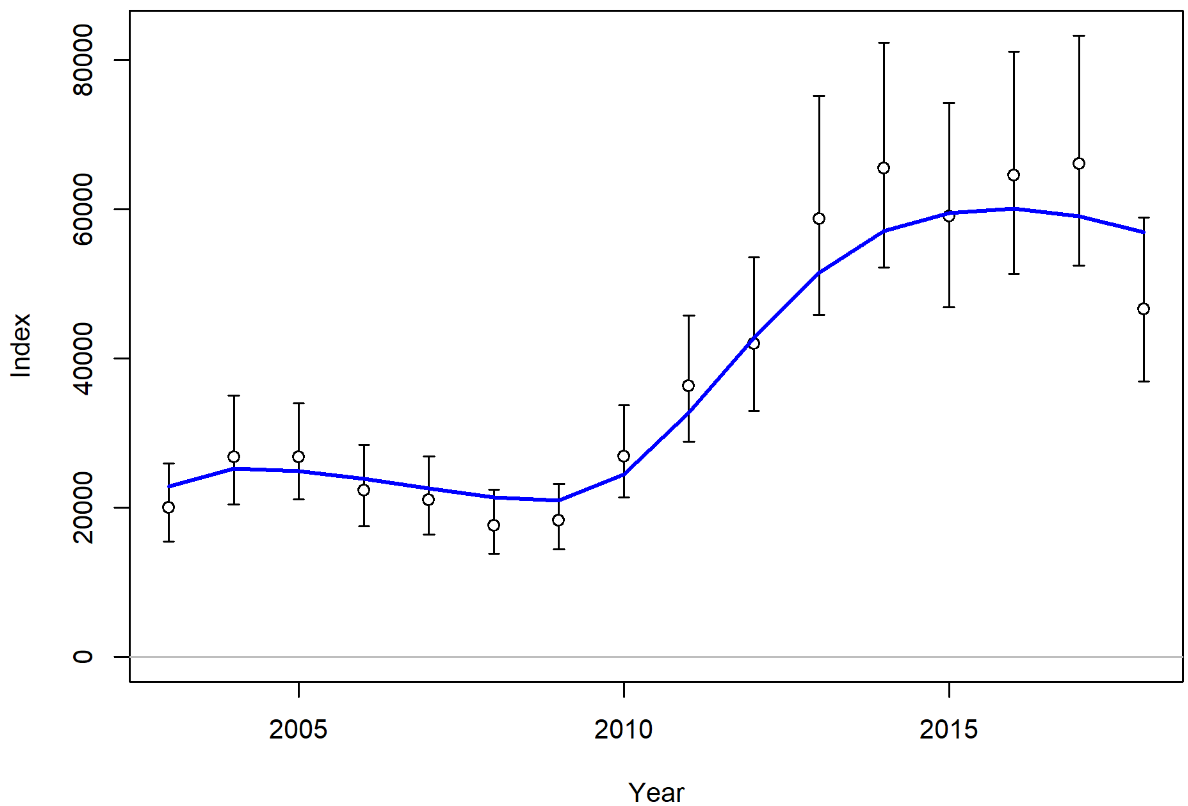

Figure 52: Fit to the NWFSC West Coast Groundfish Bottom Trawl Survey time series for petrale sole. fig:fit_nwfsc_survey

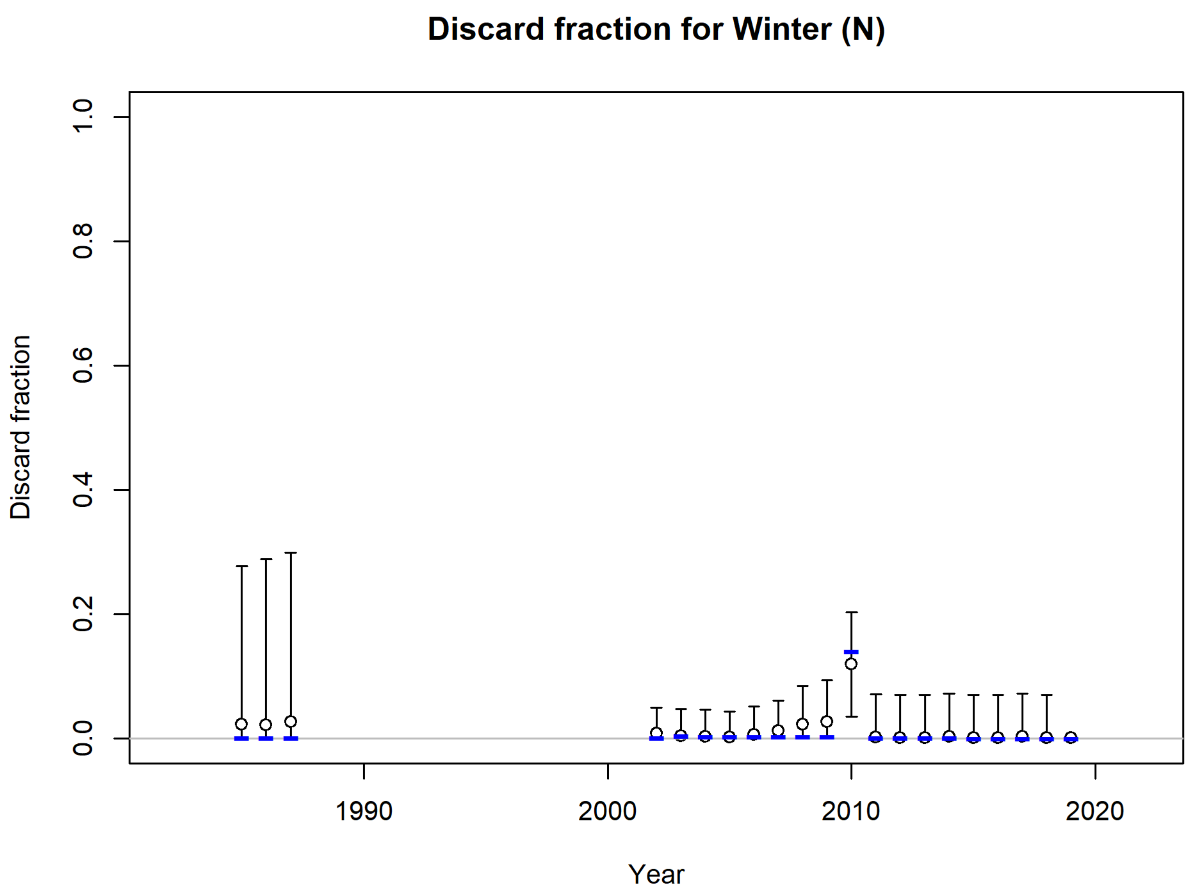

Figure 53: Fit to the discard rates for the Winter North fleet for petrale sole. fig:fit_wn_discard

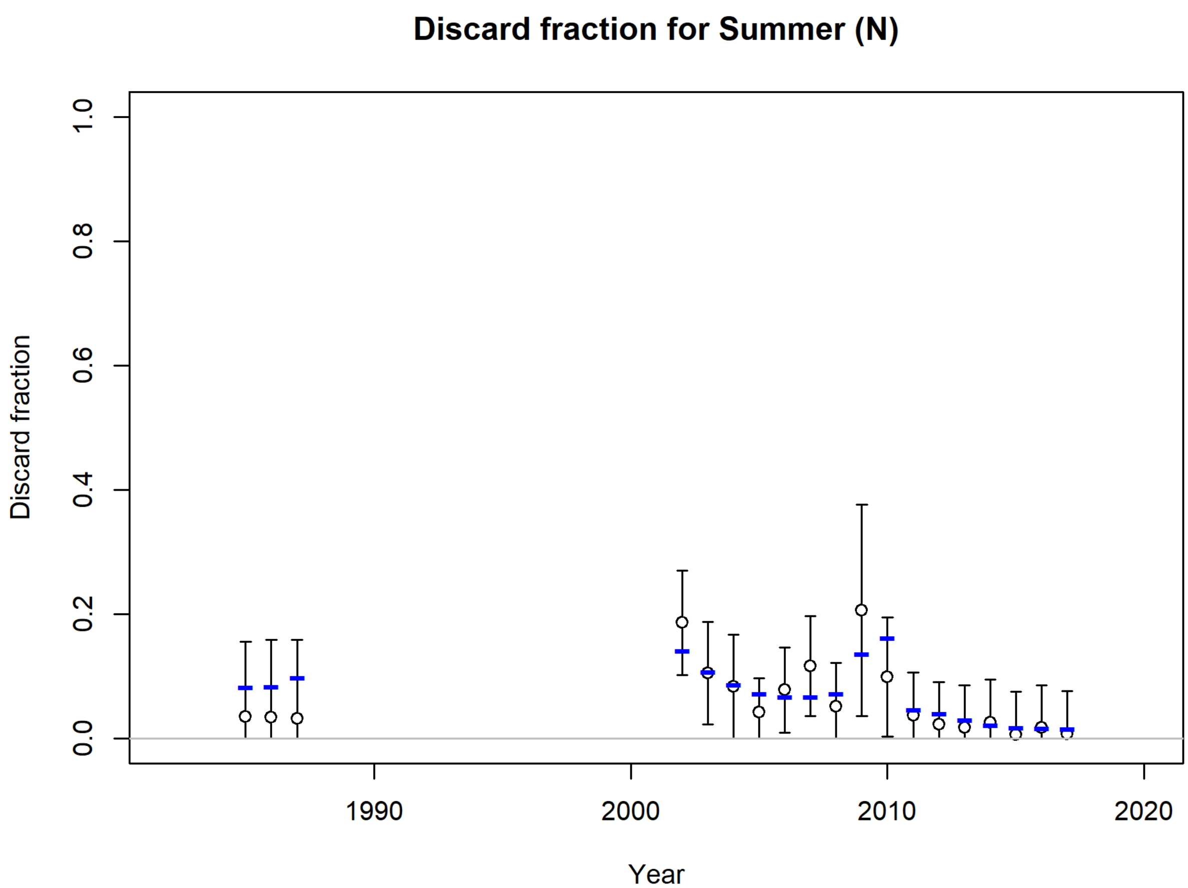

Figure 54: Fit to the discard rates for the Summer North fleet for petrale sole. fig:fit_sn_discard

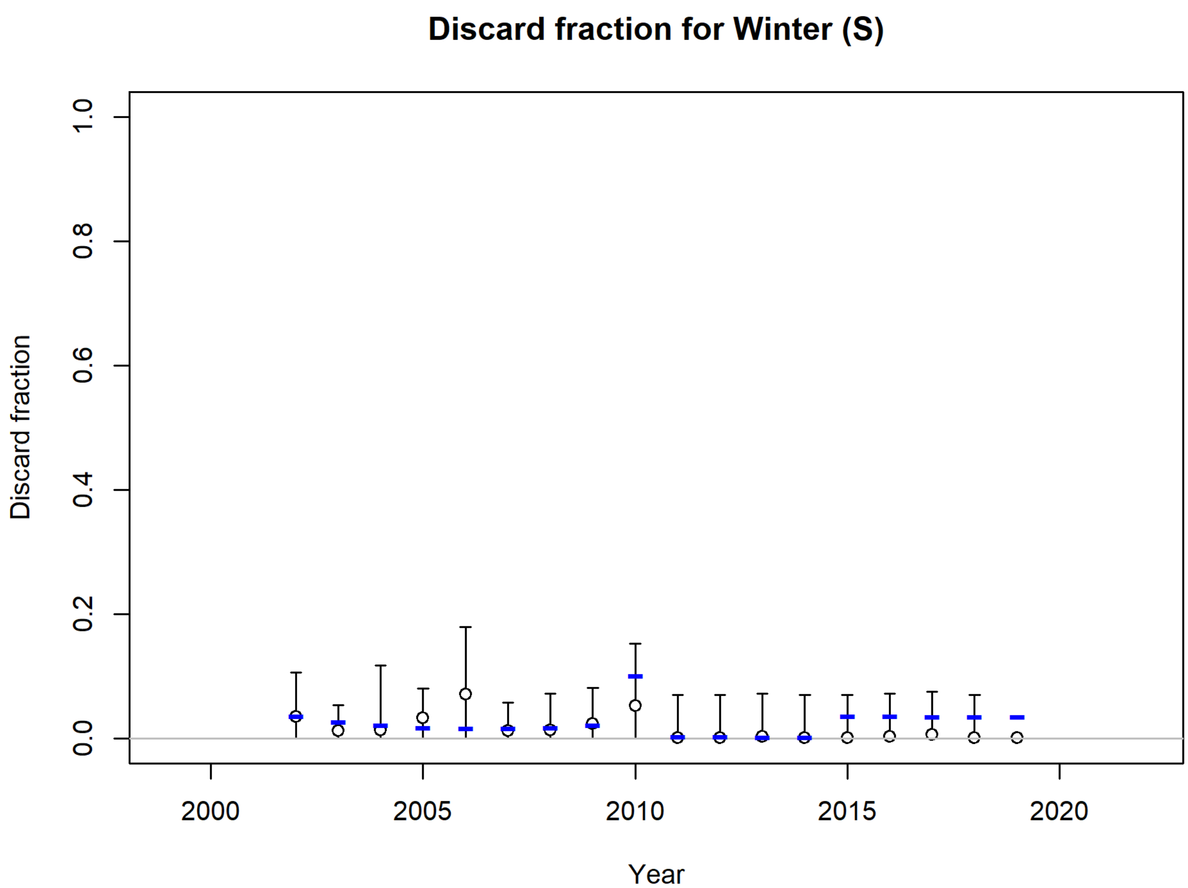

Figure 55: Fit to the discard rates for the Winter South fleet for petrale sole. fig:fit_ws_discard

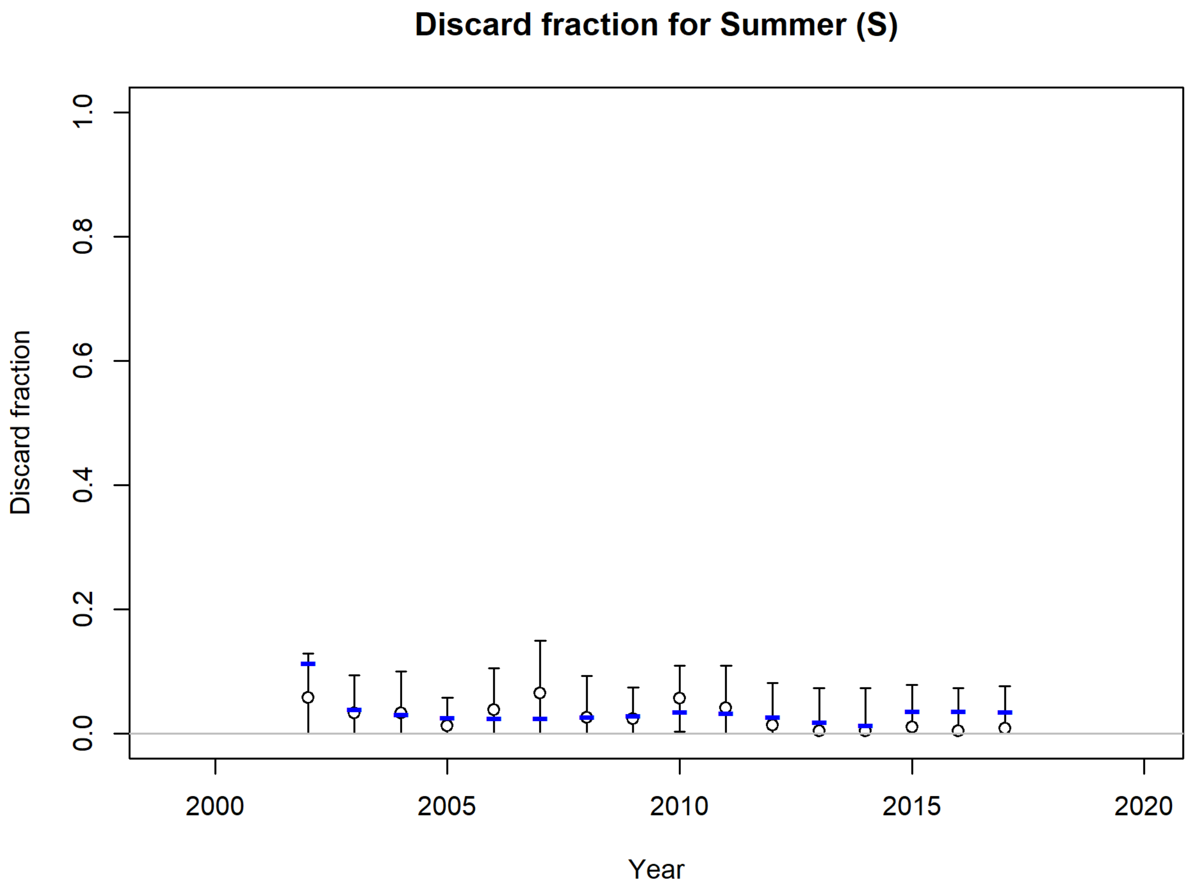

Figure 56: Fit to the discard rates for the Summer South fleet for petrale sole. fig:fit_ss_discard

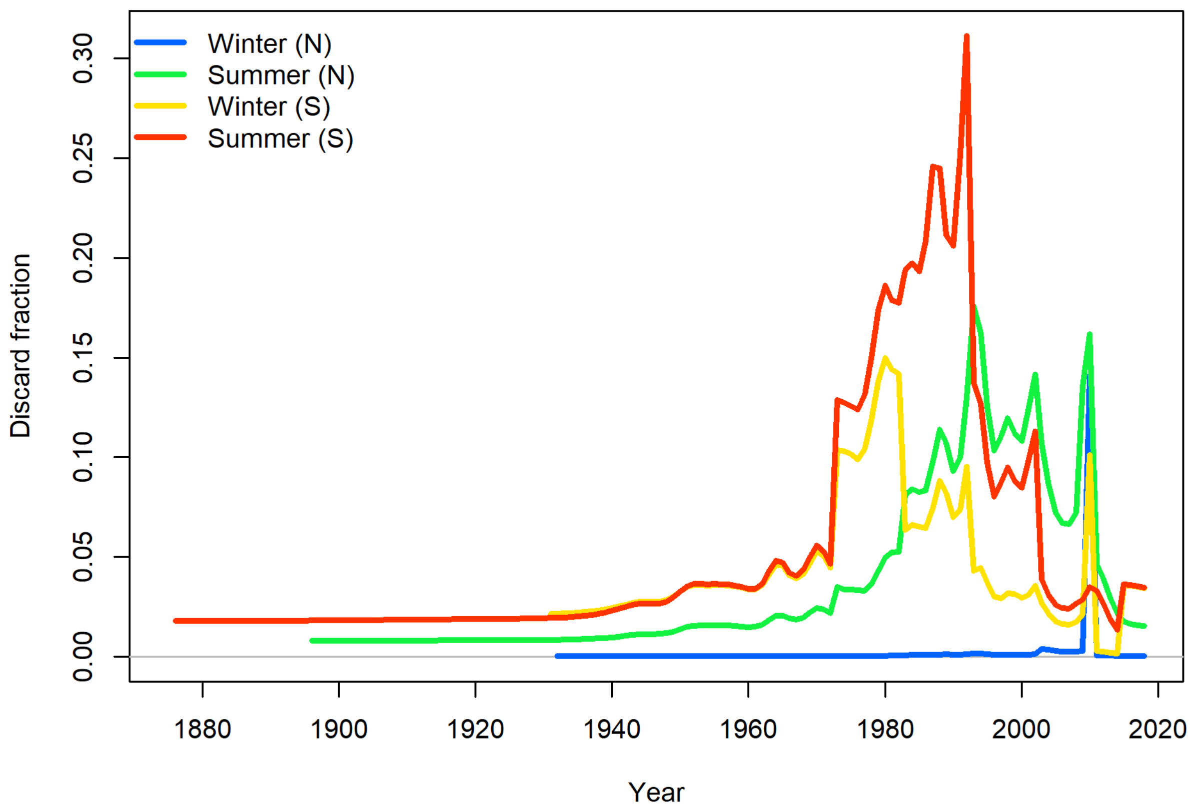

Figure 57: Discard rates by fleet for petrale sole. fig:Discard

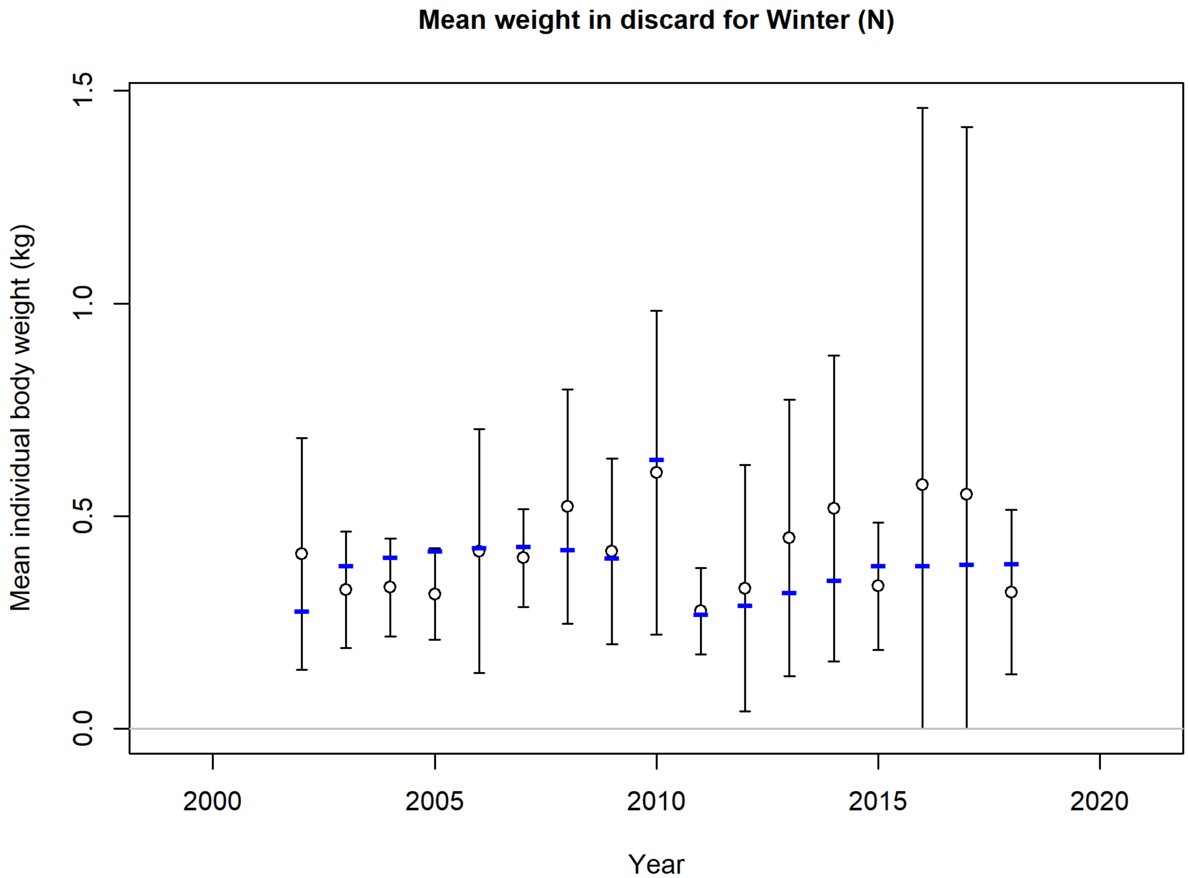

Figure 58: Fit to the Northern winter fishery mean body weights of discarded fish for petrale sole. fig:nw_bodywt_fit

Figure 59: Fit to the Northern summer fishery mean body weights of discarded fish for petrale sole. fig:ns_bodywt_fit

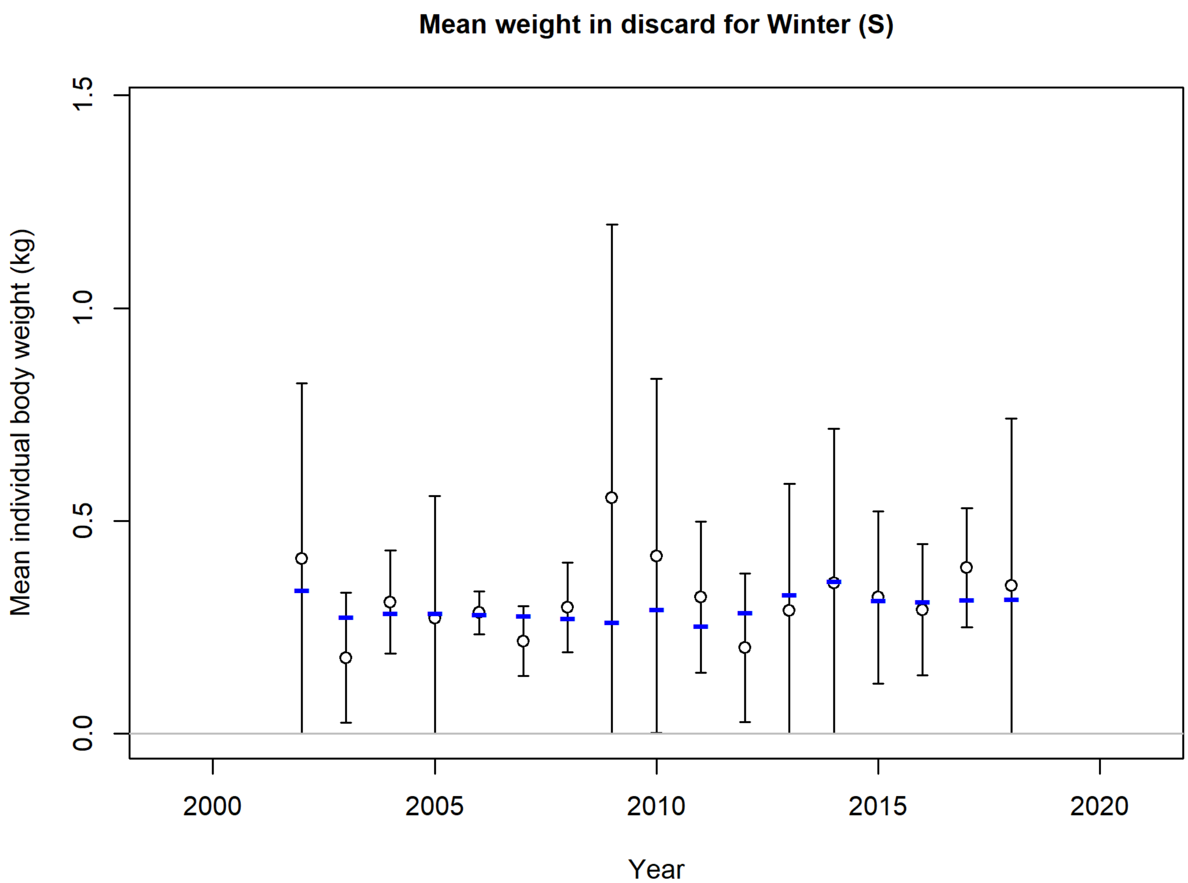

Figure 60: Fit to the Southern winter fishery mean body weights of discarded fish for petrale sole. fig:sw_bodywt_fit

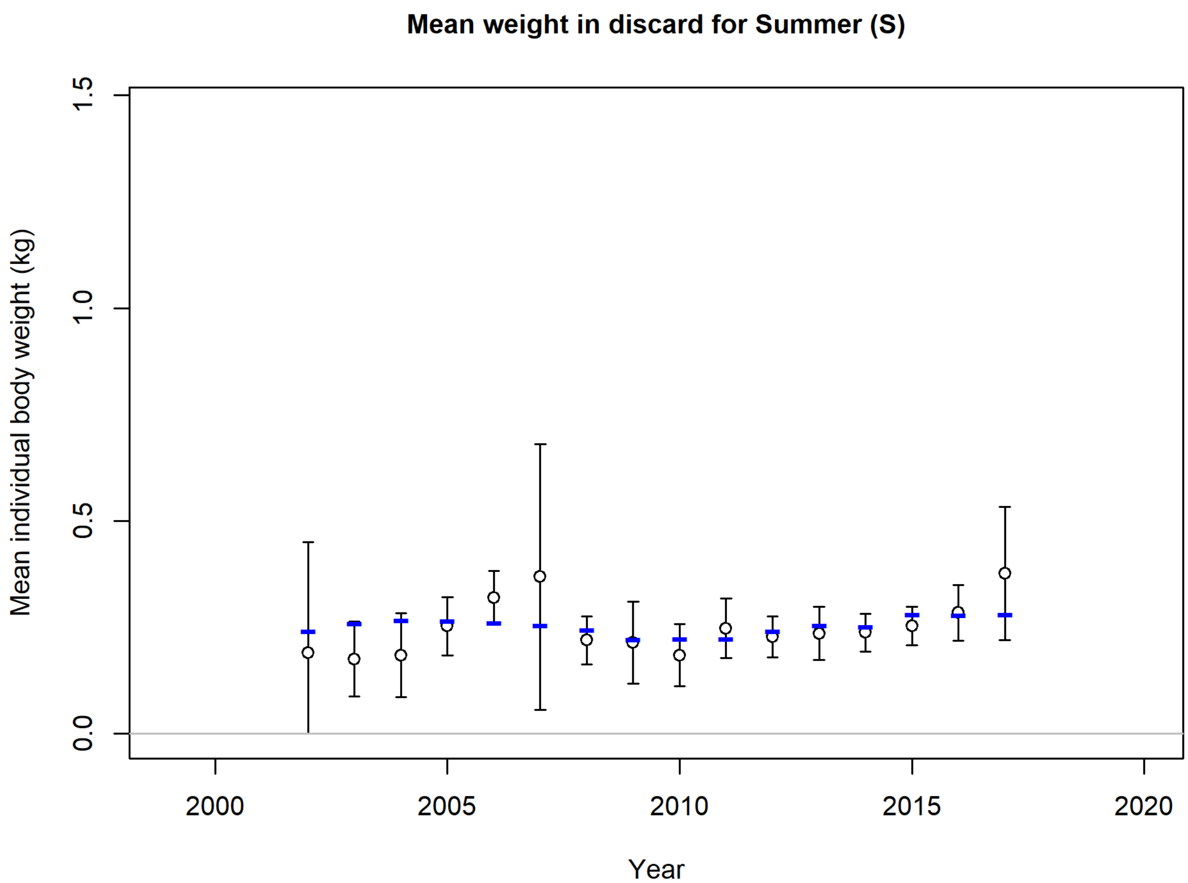

Figure 61: Fit to the Southern summer fishery mean body weights of discarded fish for petrale sole. fig:ss_bodywt_fit

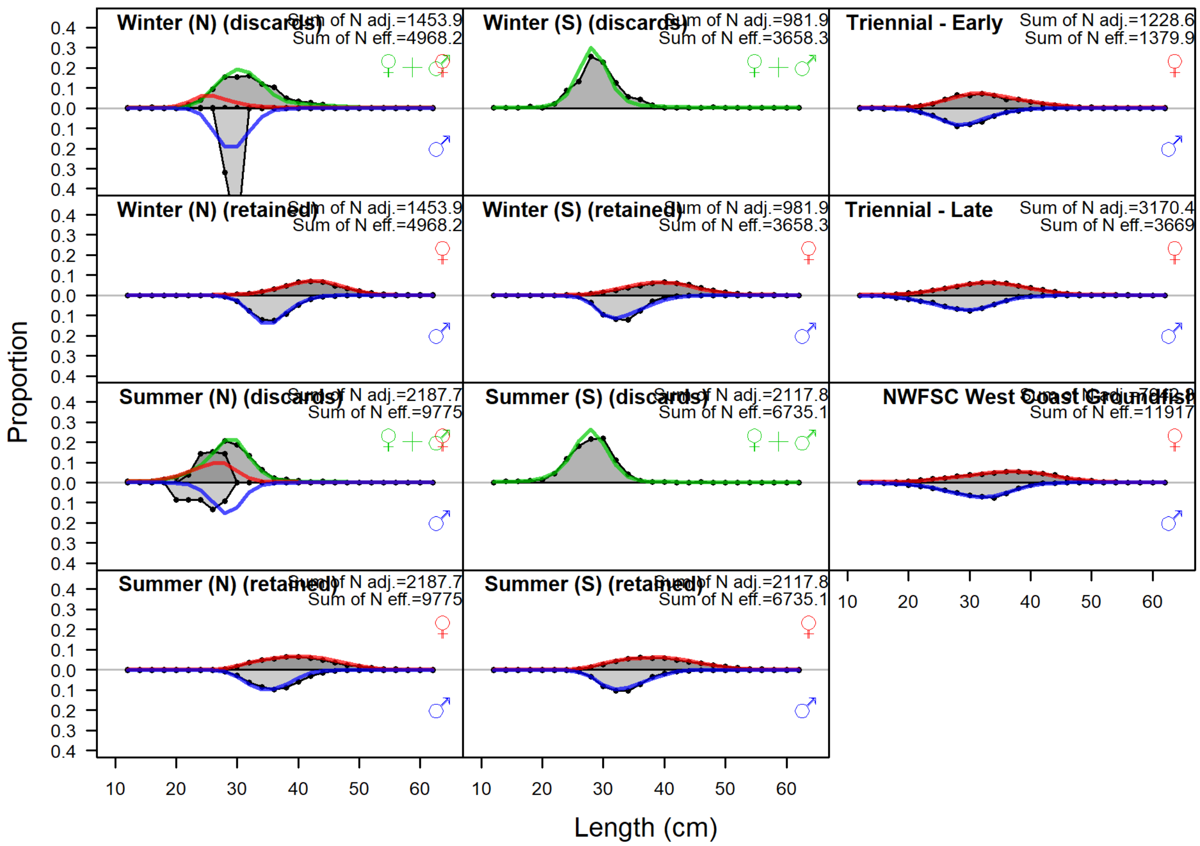

Figure 62: Length compositions aggregated across time by fleet. Labels 'retained' and 'discard' indicate retained or discarded samples for each fleet. Panels without this designation represent the whole catch. fig:length_agg

Figure 63: Pearson residuals, discard, Winter (N) (max=7.19)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:discard_wn_len_pearson

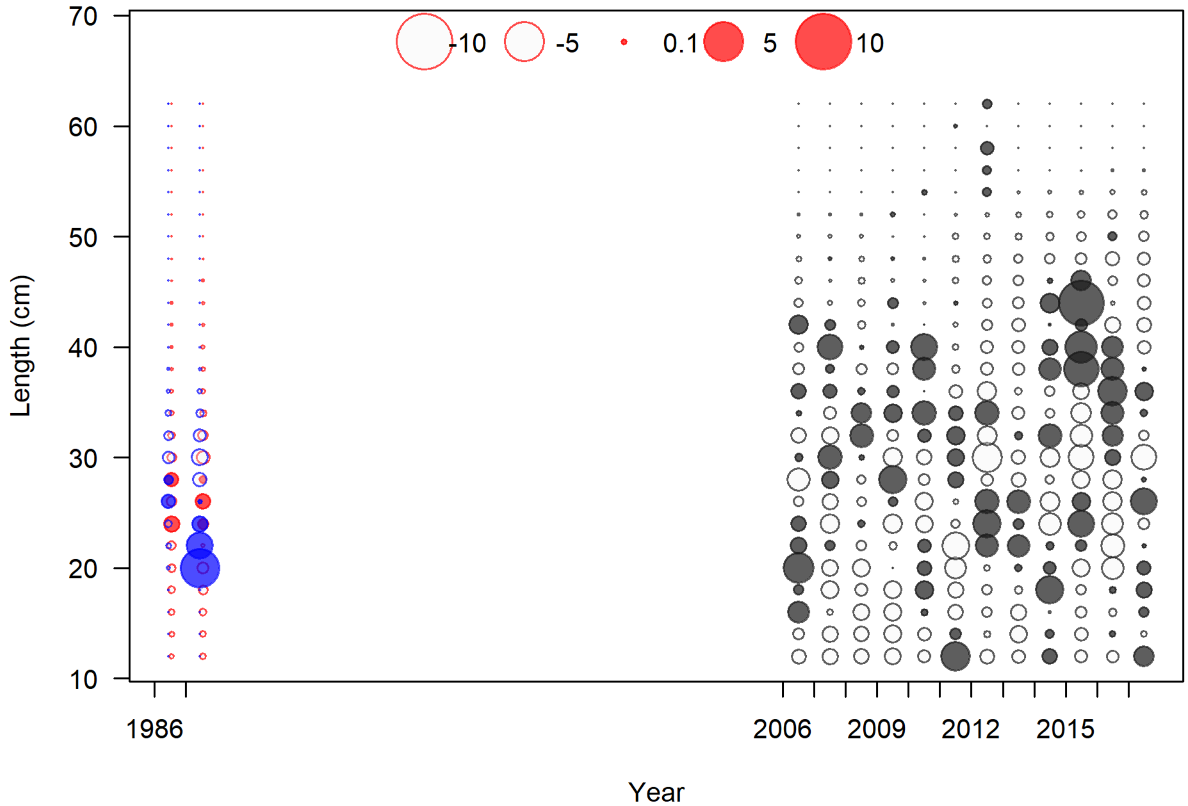

Figure 64: Pearson residuals, discard, Summer (N) (max=6.6)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:discard_sn_len_pearson

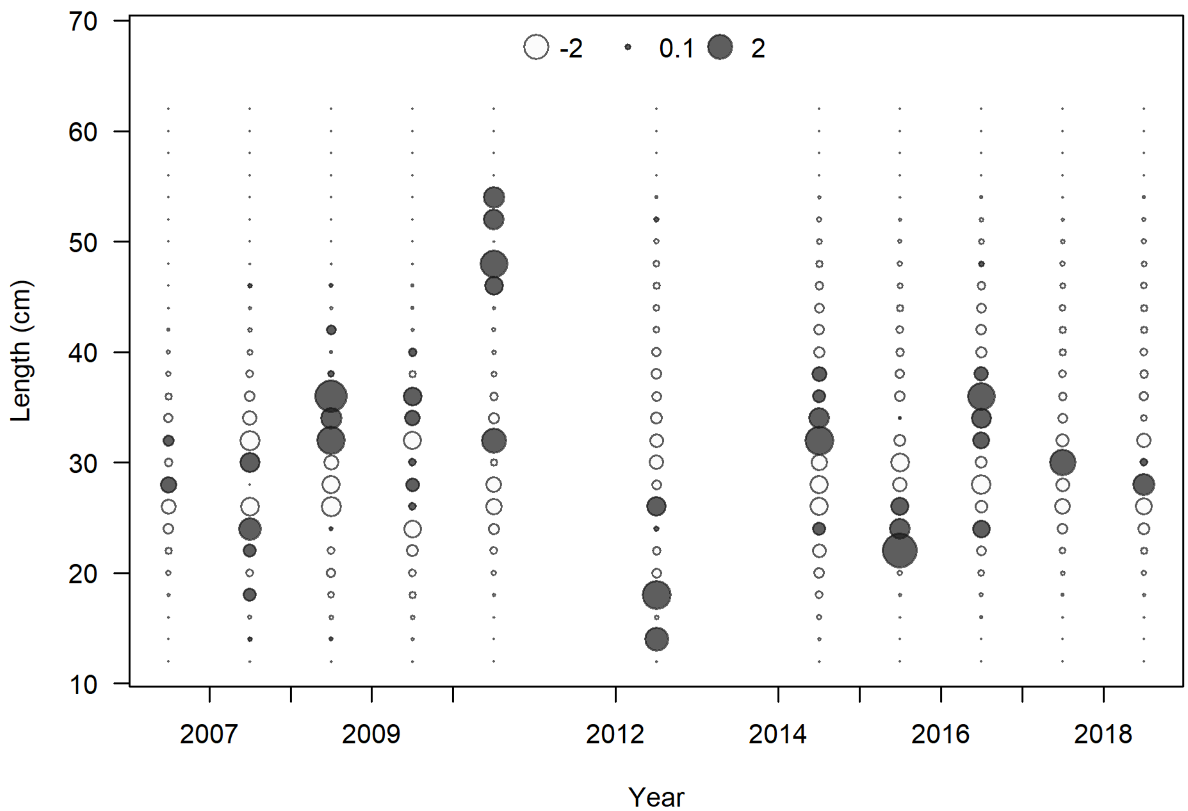

Figure 65: Pearson residuals, discard, Winter (S) (max=3.81)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:discard_ws_len_pearson

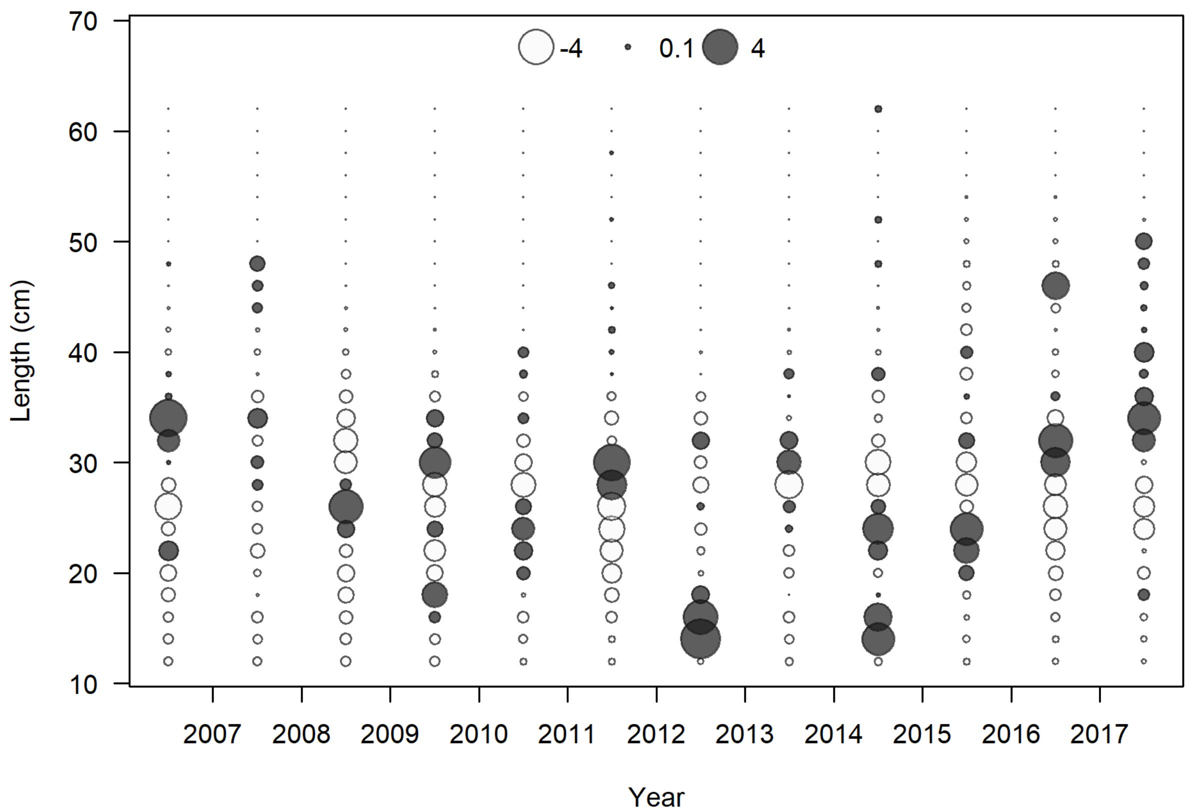

Figure 66: Pearson residuals, discard, Summer (S) (max=5.02)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:discard_ss_len_pearson

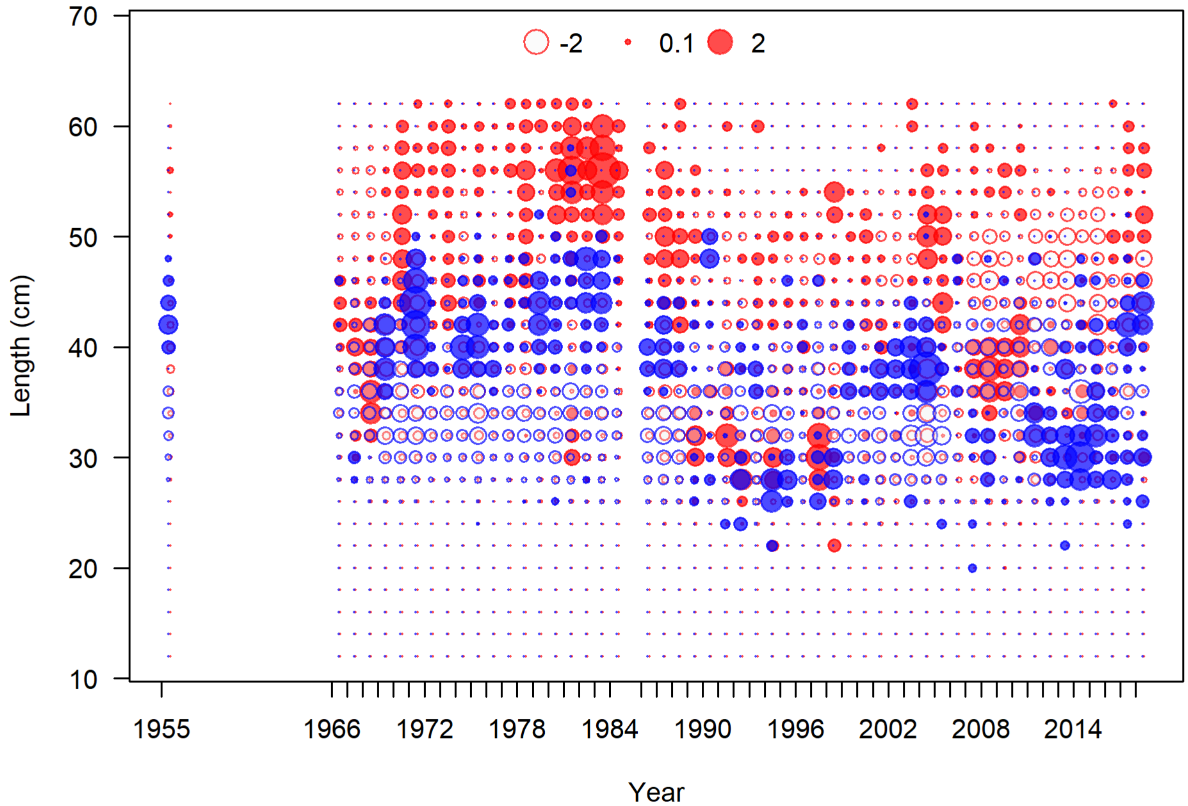

Figure 67: Pearson residuals, retained, Winter (N) (max=3.93) (plot 4 of 4)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:wn_len_pearson

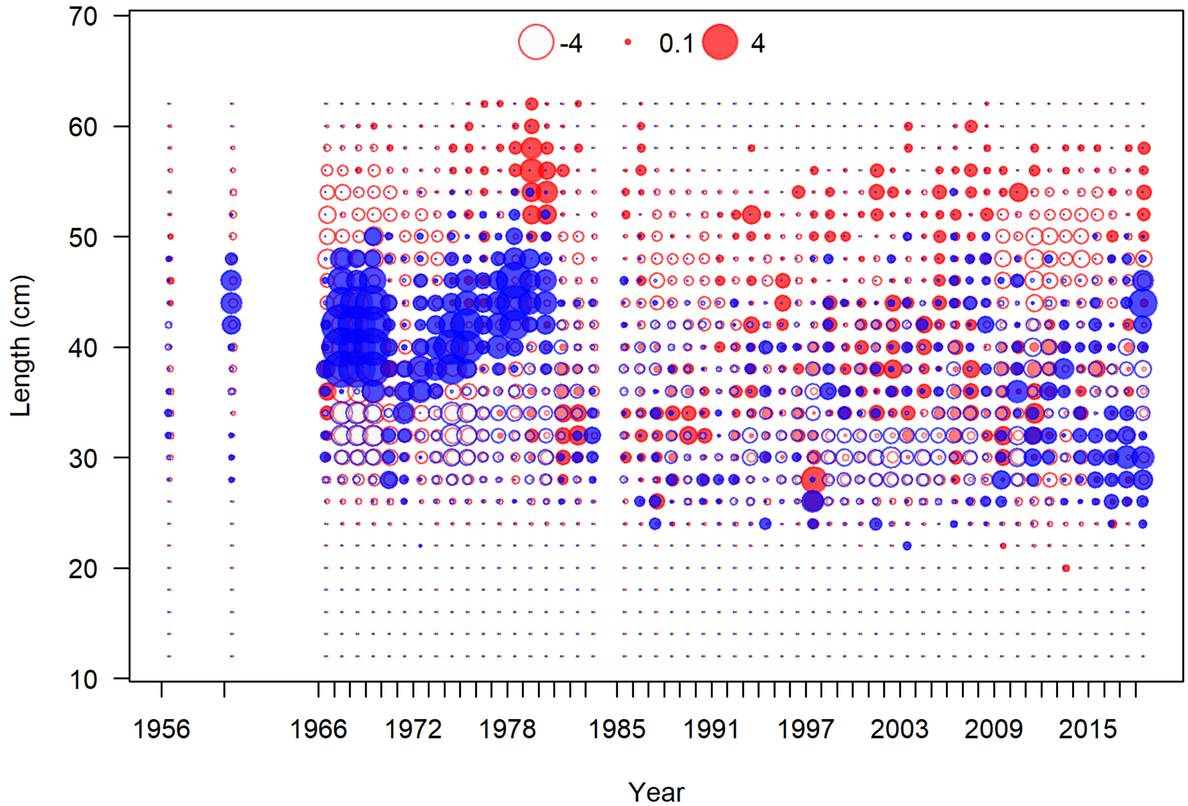

Figure 68: Pearson residuals, retained, Summer (N) (max=5.15) (plot 4 of 4)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:sn_len_pearson

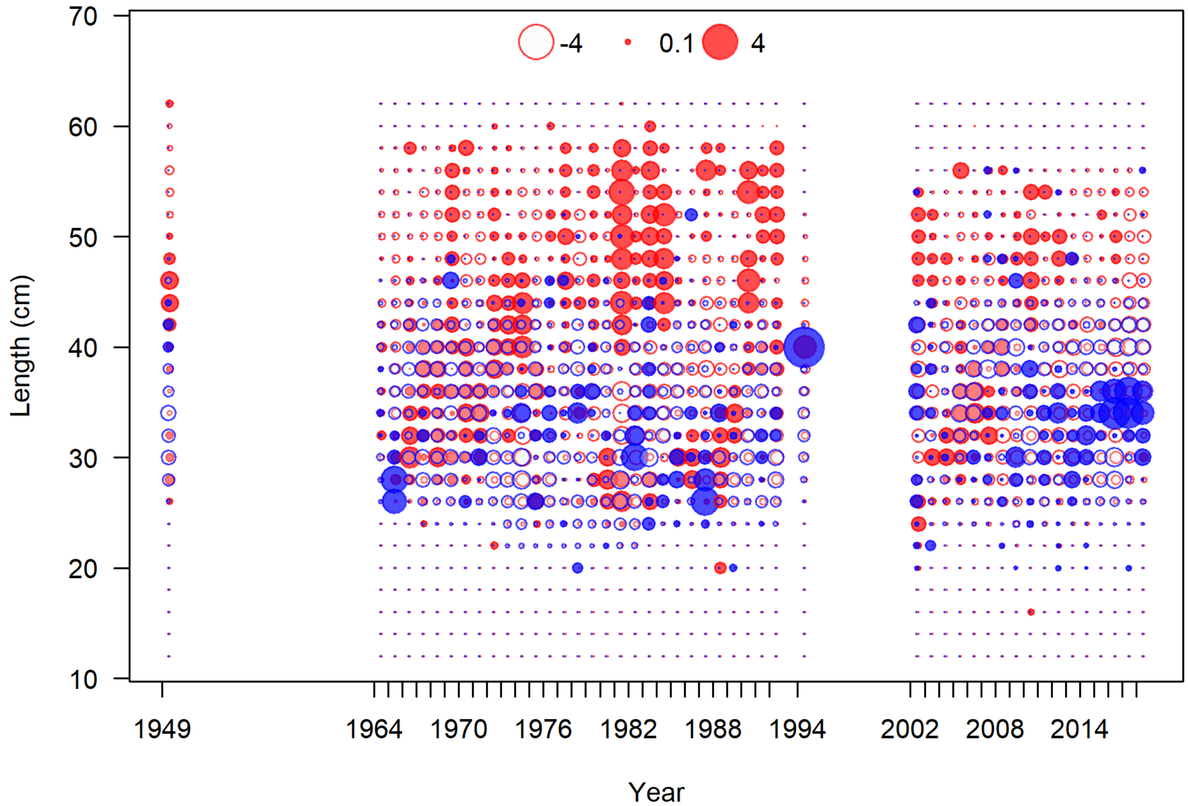

Figure 69: Pearson residuals, retained, Winter (S) (max=5.1) (plot 3 of 3)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:ws_len_pearson

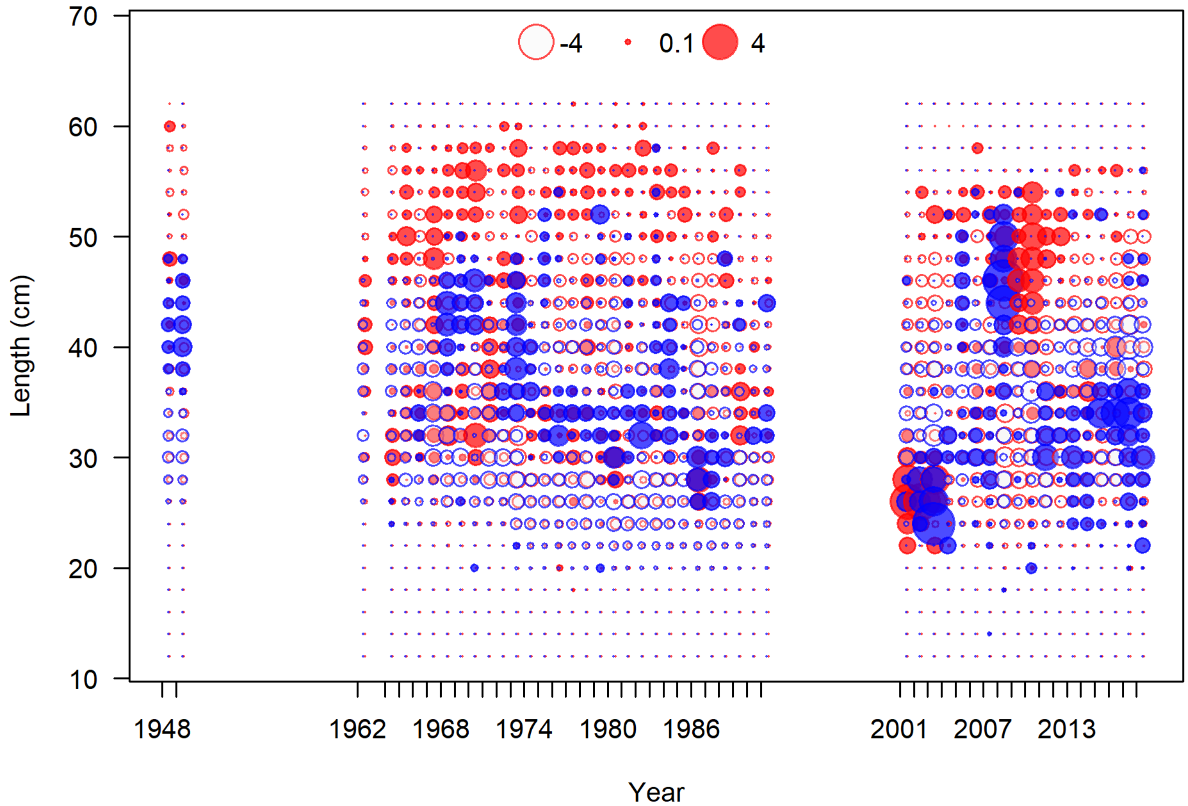

Figure 70: Pearson residuals, retained, Summer (S) (max=5.63) (plot 4 of 4)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:ss_len_pearson

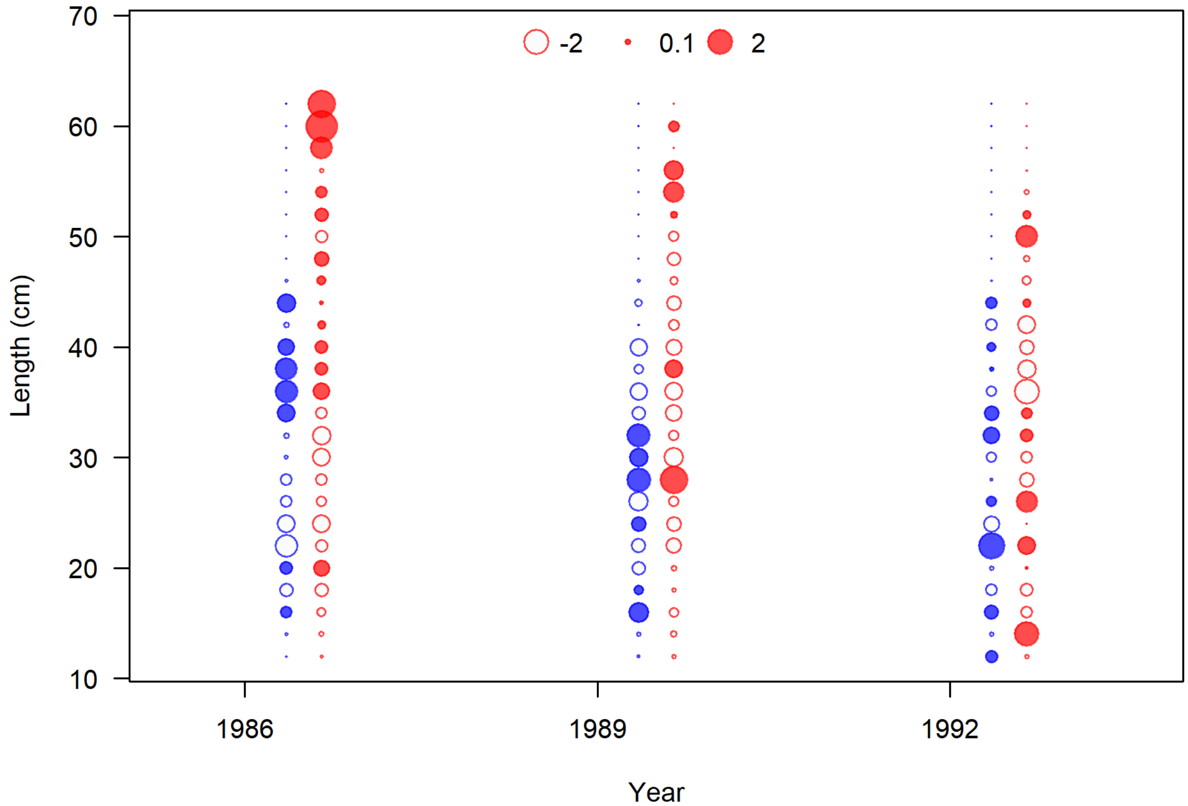

Figure 71: Pearson residuals, whole catch, Triennial _ Early (max=3.16)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:tri_early_len_pearson

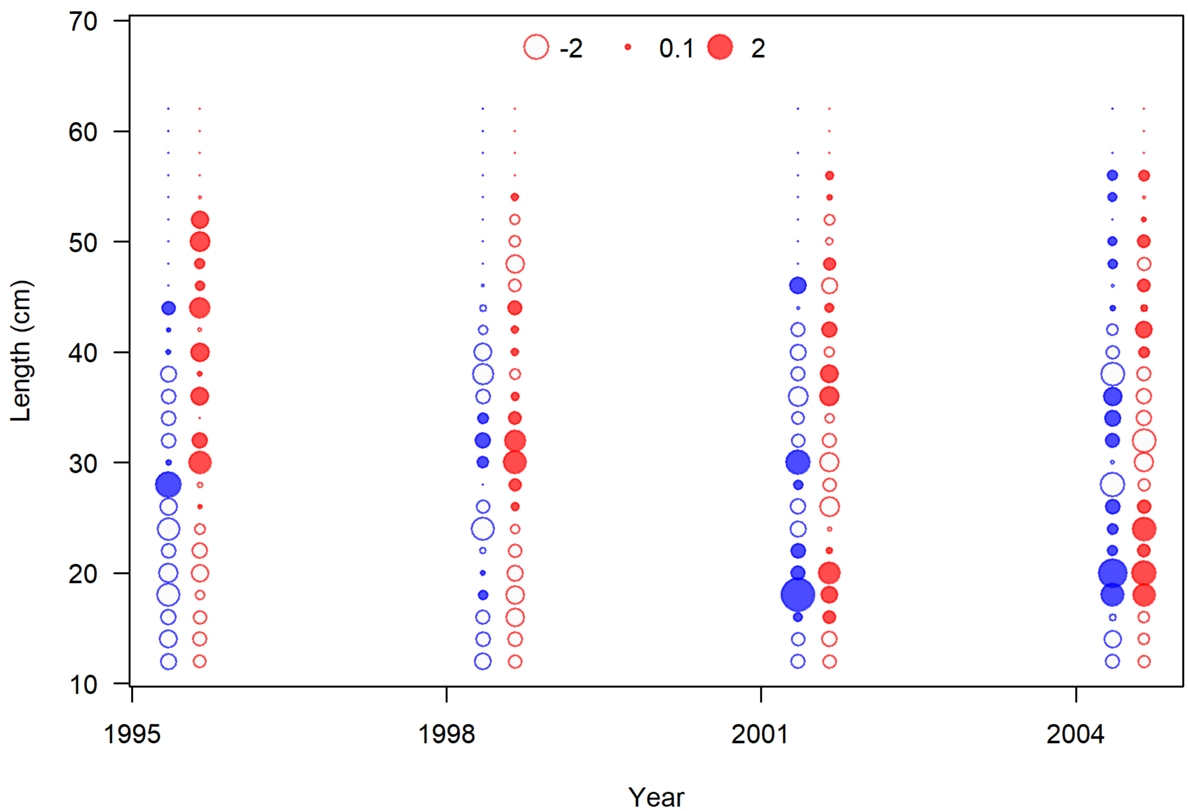

Figure 72: Pearson residuals, whole catch, Triennial _ Late (max=3.54)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:tri_late_len_pearson

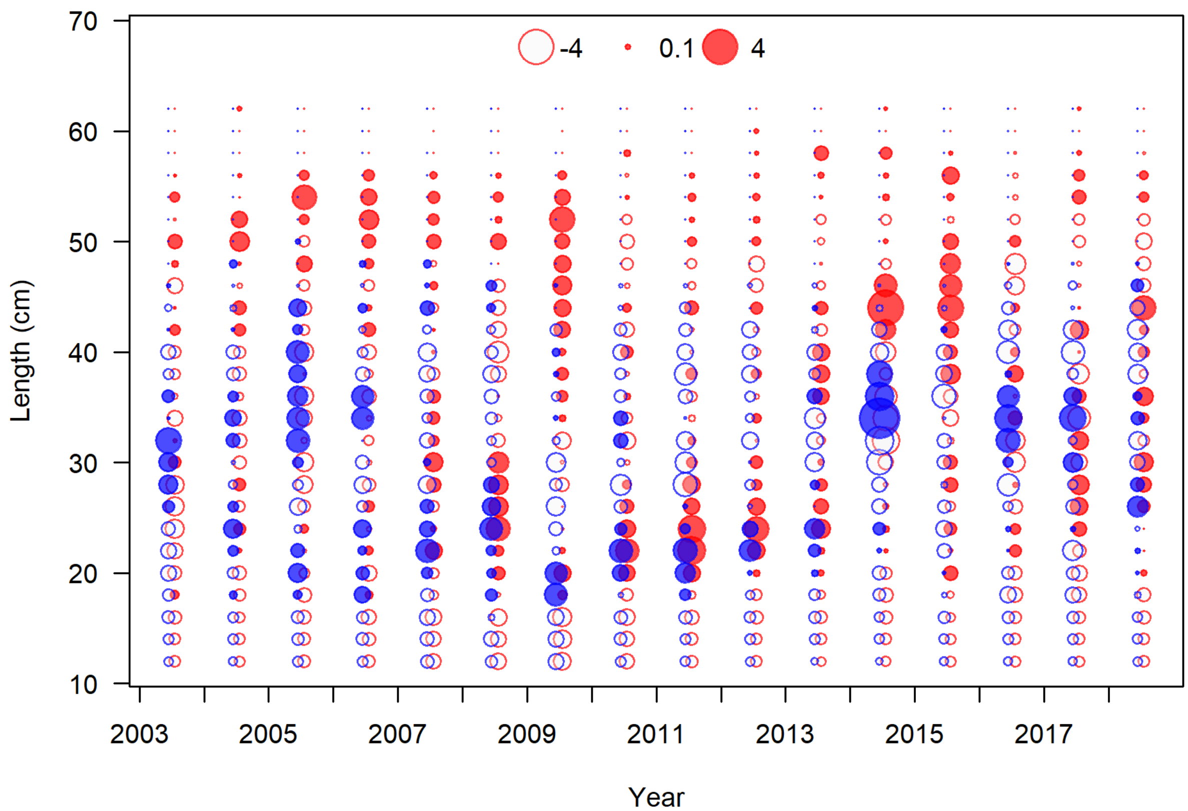

Figure 73: Pearson residuals, whole catch, NWFSC West Coast Groundfish Bottom Trawl Survey (max=5.11)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:nwfsc_combo_len_pearson

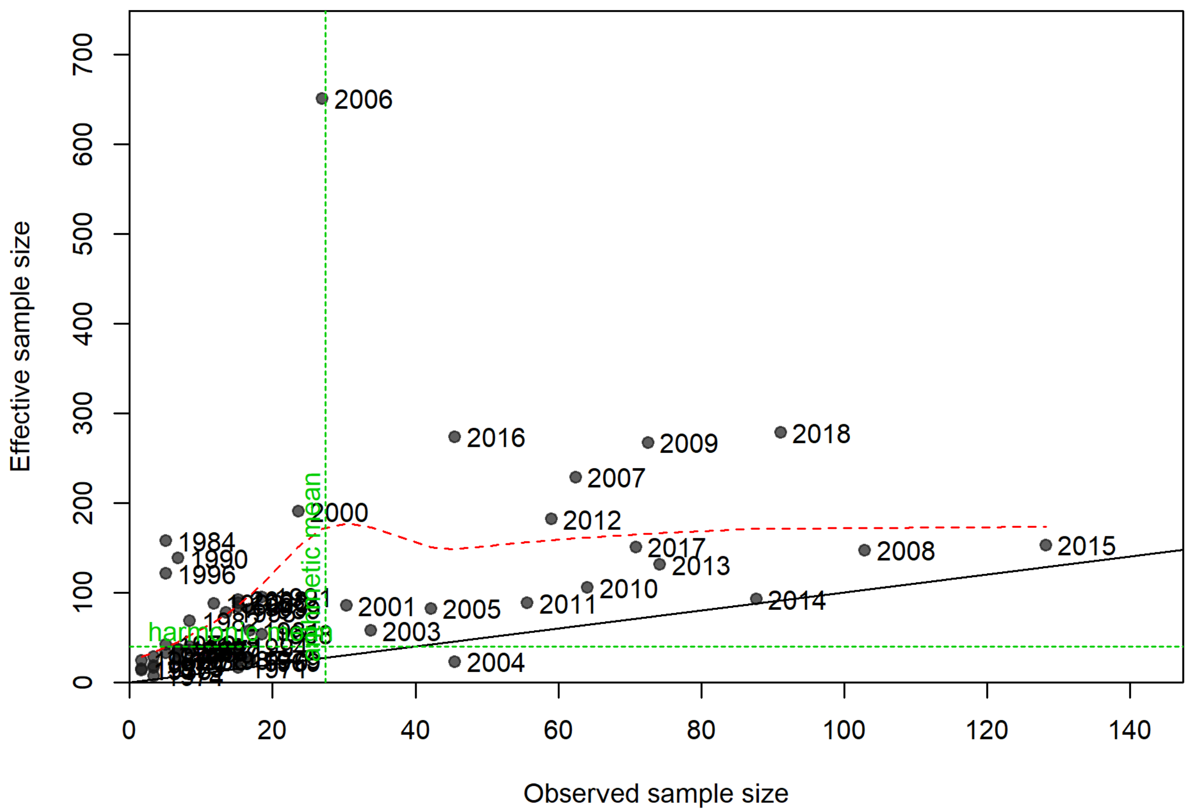

Figure 74: McAllister and Ianelli (harmonic mean) weighting for the Winter North fishery length data. fig:harm_mean_wn

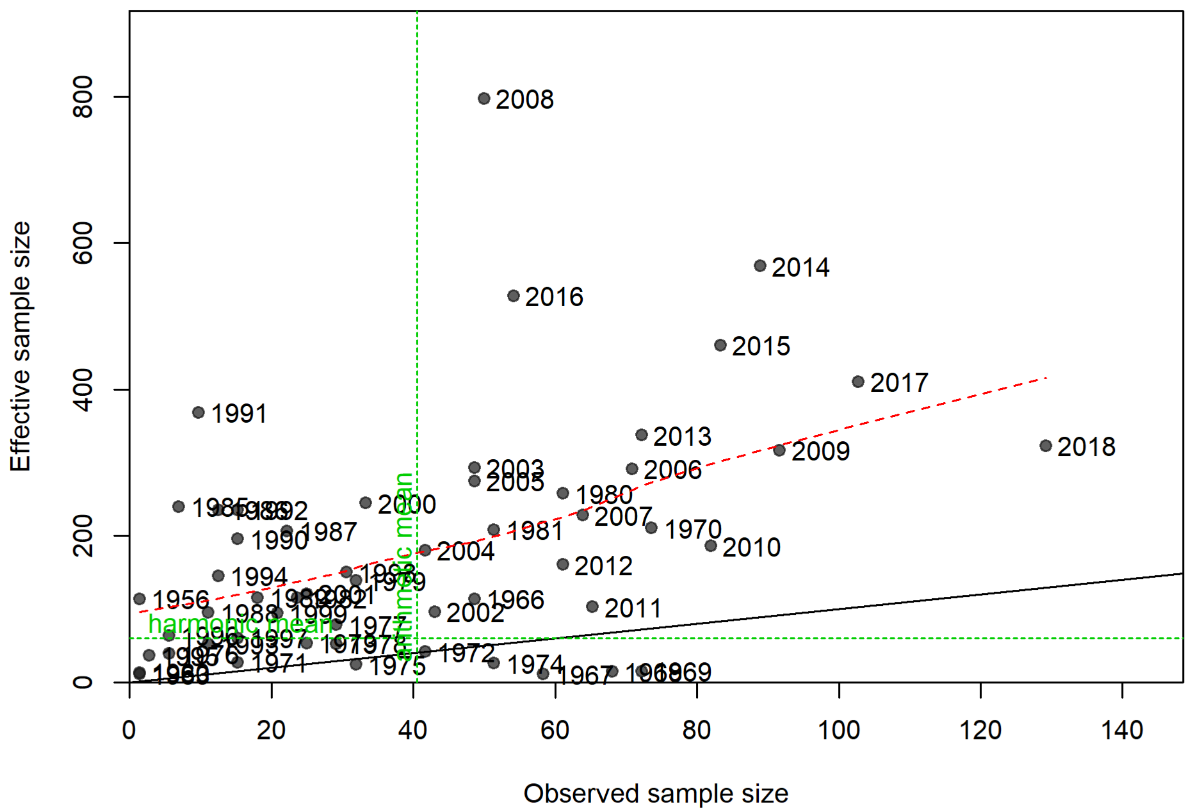

Figure 75: McAllister and Ianelli (harmonic mean) weighting for the Summer North fishery length data. fig:harm_mean_sn

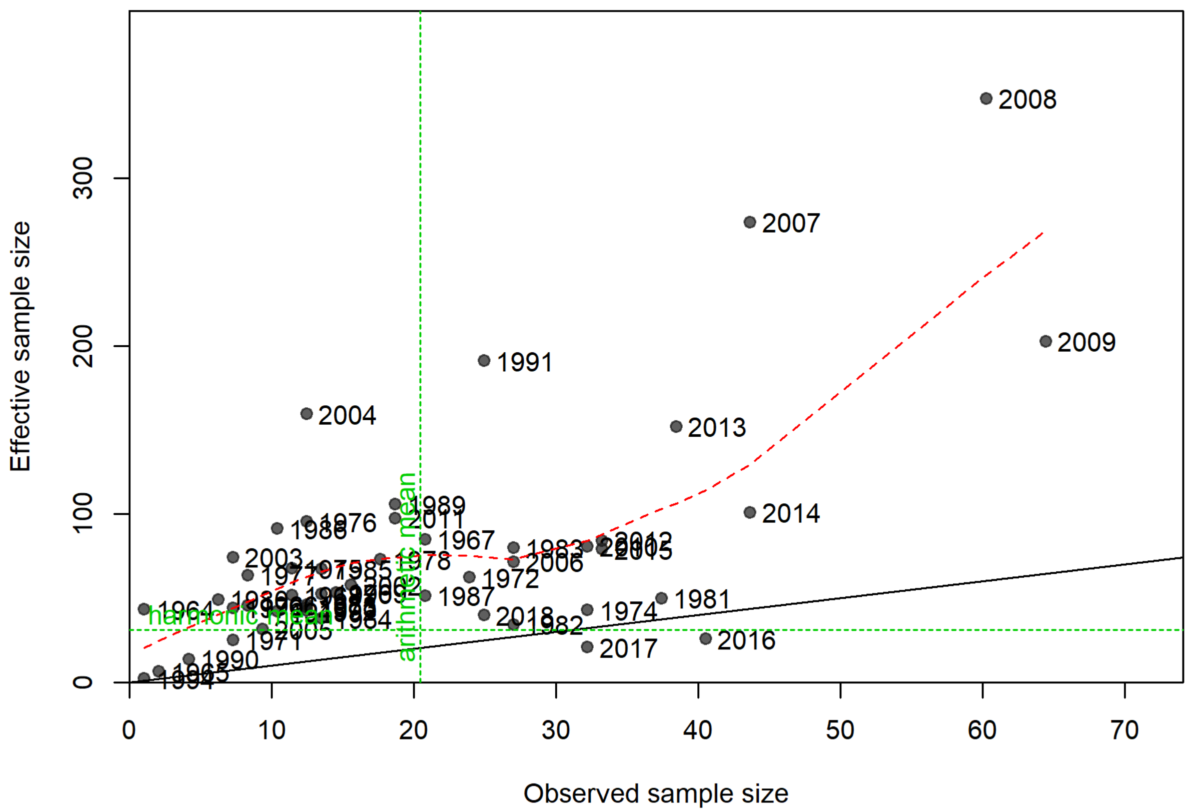

Figure 76: McAllister and Ianelli (harmonic mean) weighting for the Winter South fishery length data. fig:harm_mean_ws

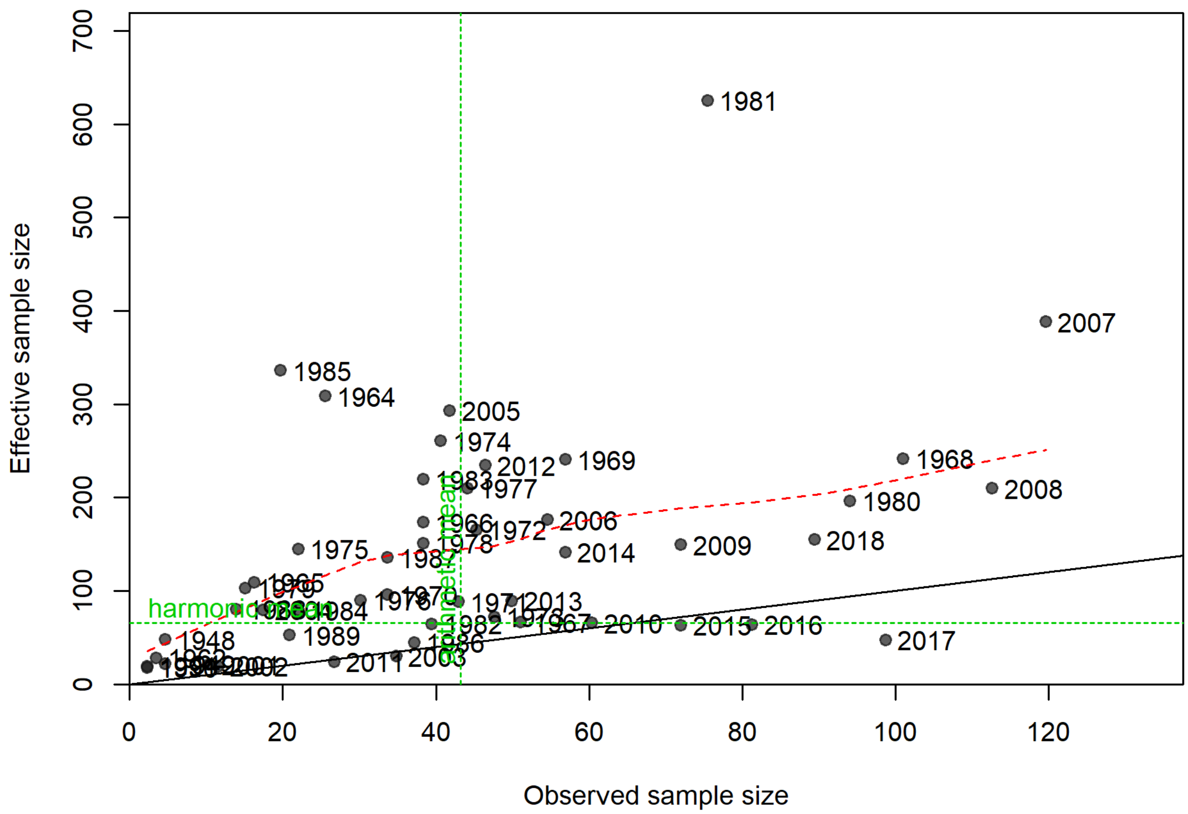

Figure 77: McAllister and Ianelli (harmonic mean) weighting for the Summer South fishery length data. fig:harm_mean_wn

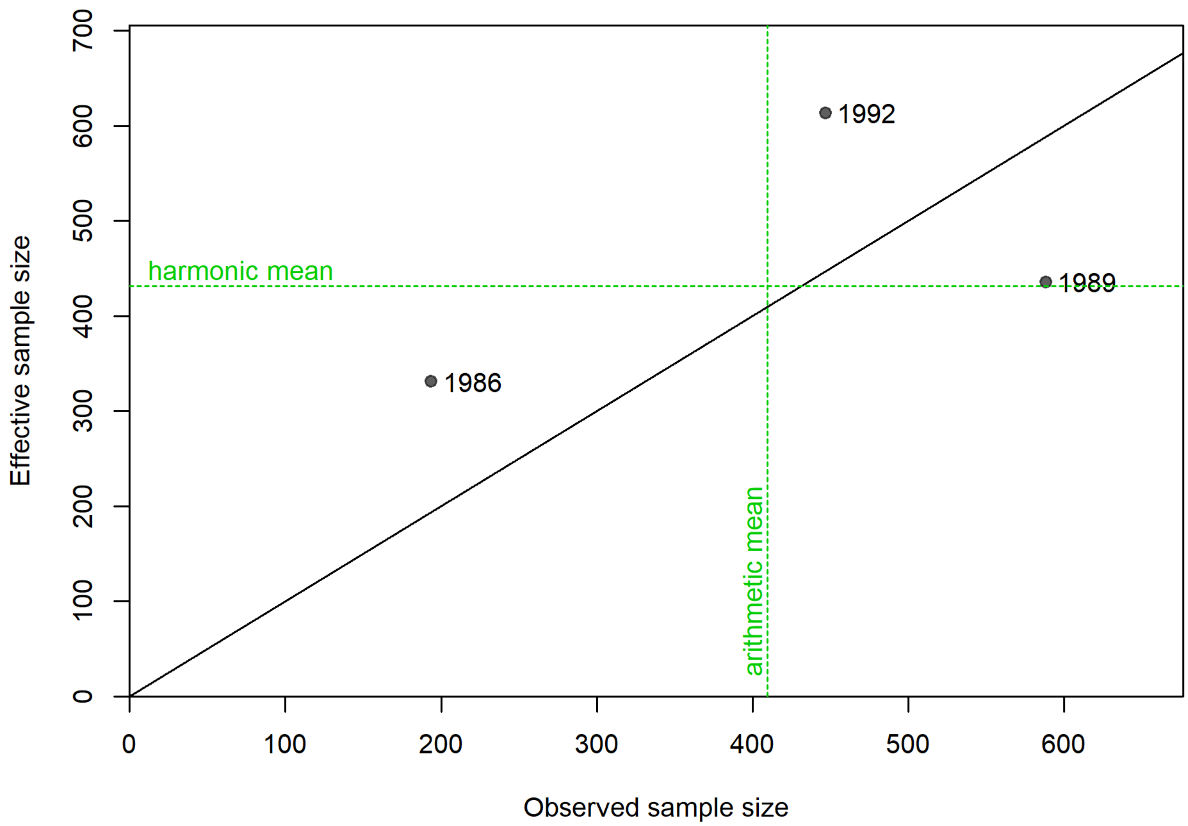

Figure 78: McAllister and Ianelli (harmonic mean) weighting for the Triennial Survey - early length data. fig:harm_mean_tri_early

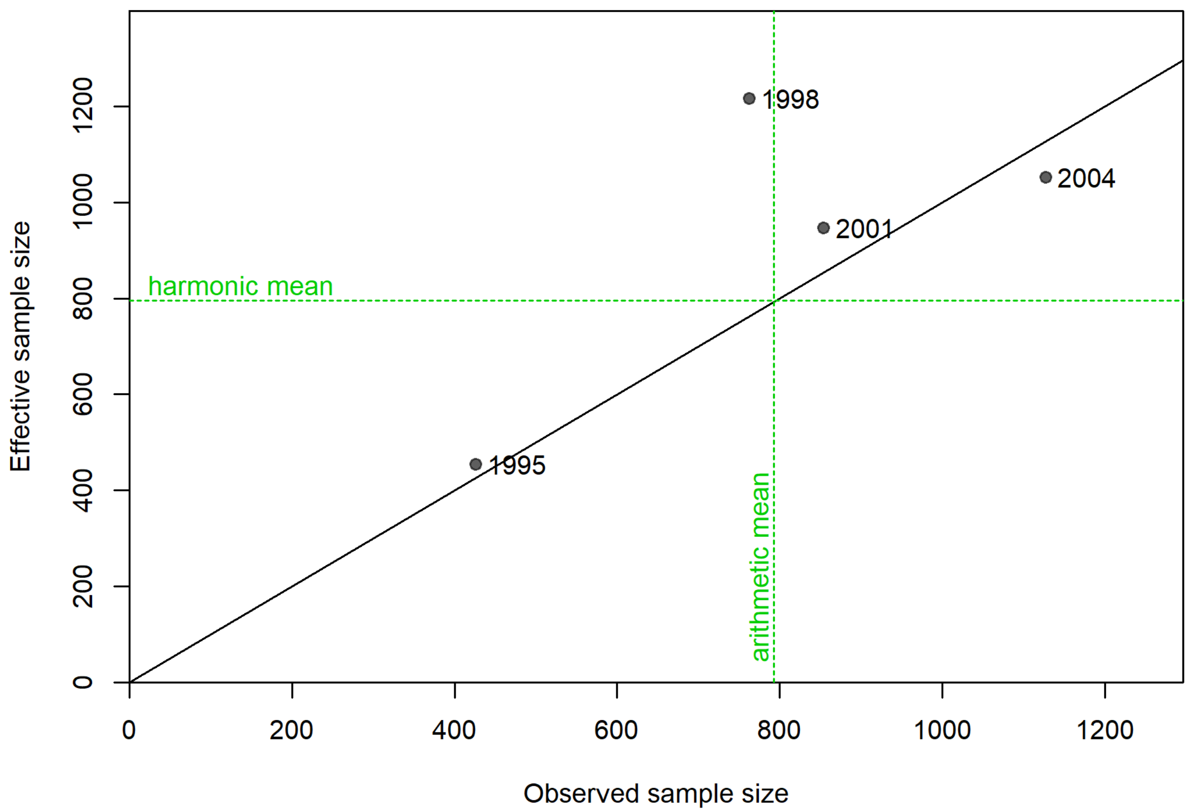

Figure 79: McAllister and Ianelli (harmonic mean) weighting for the Triennial Survey - late length data. fig:harm_mean_tri_late

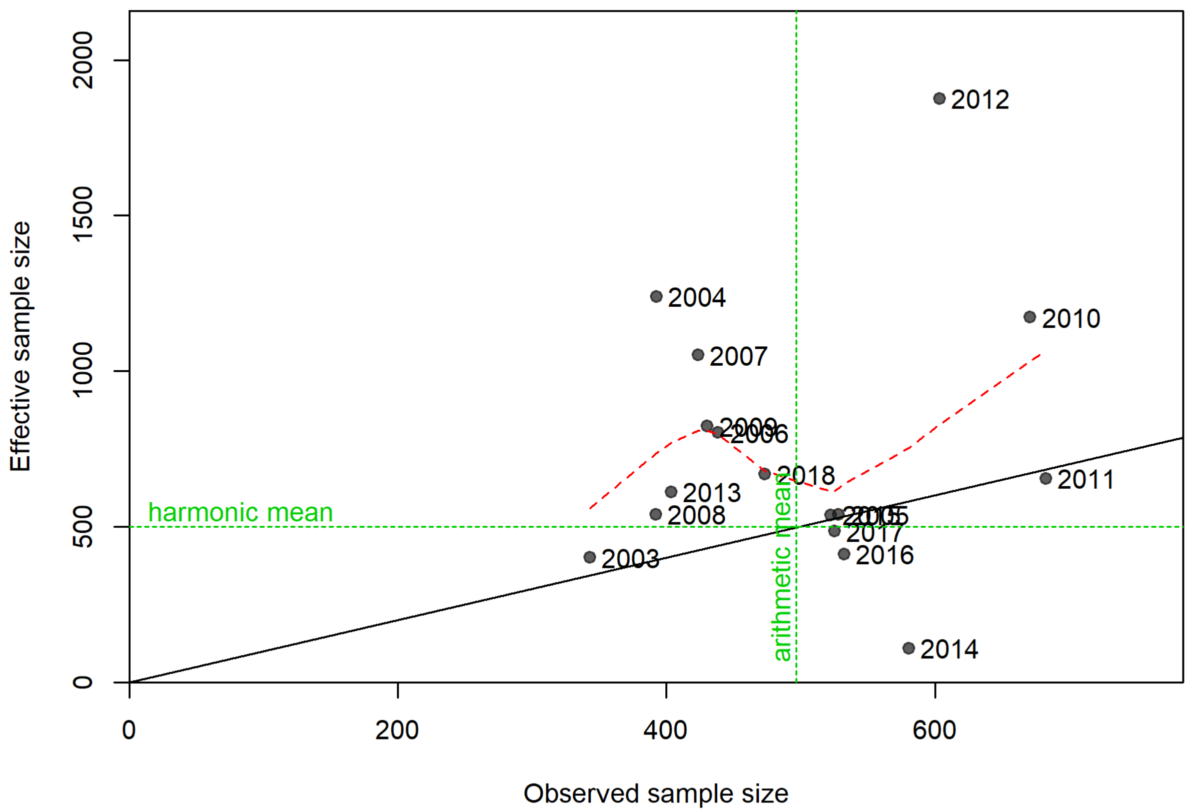

Figure 80: McAllister and Ianelli (harmonic mean) weighting for the NWFSC West Coast Groundfish Bottom Trawl Survey length data. fig:harm_mean_nwfsc

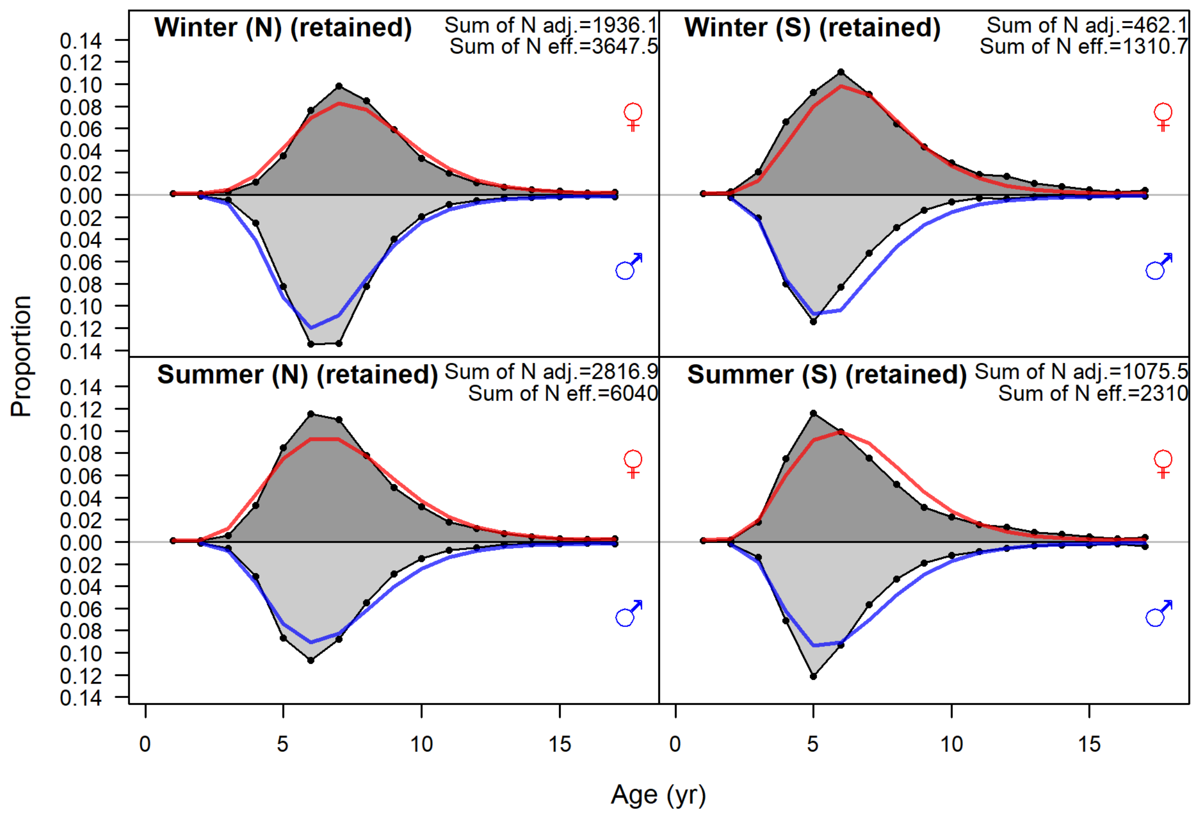

Figure 81: Age compositions aggregated across time for each fishery fleet. fig:age_agg

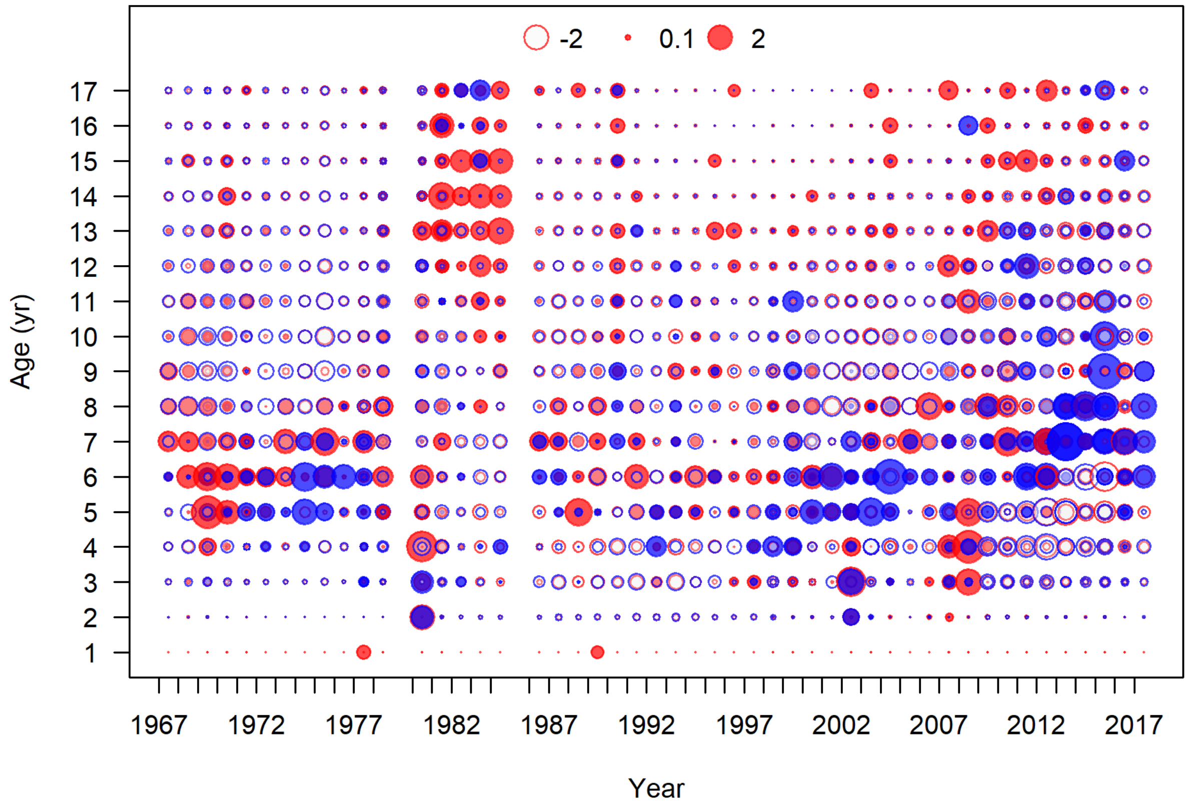

Figure 82: Pearson residuals, retained, Winter (N) (max=4.57) (plot 5 of 5)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:wn_age_pearson

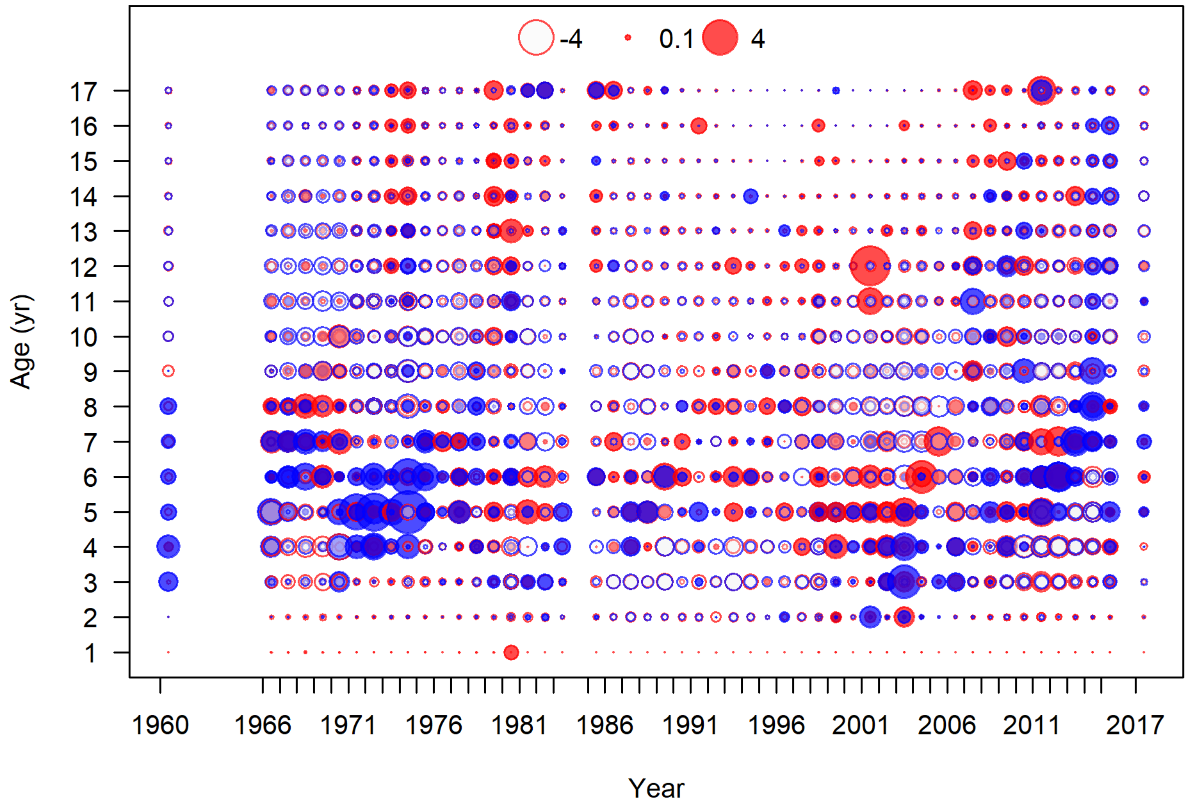

Figure 83: Pearson residuals, retained, Summer (N) (max=5.9) (plot 5 of 5)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:sn_age_pearson

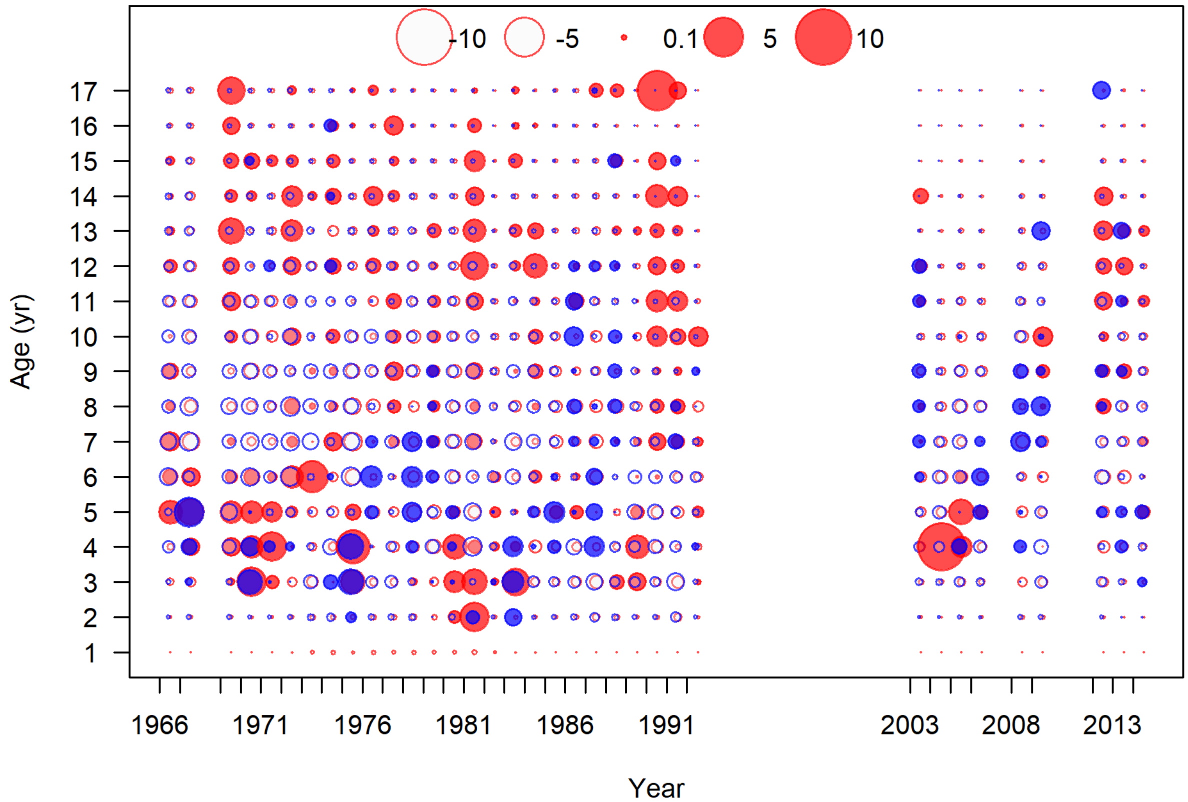

Figure 84: Pearson residuals, retained, Winter (S) (max=7.4) (plot 3 of 3)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:ws_age_pearson

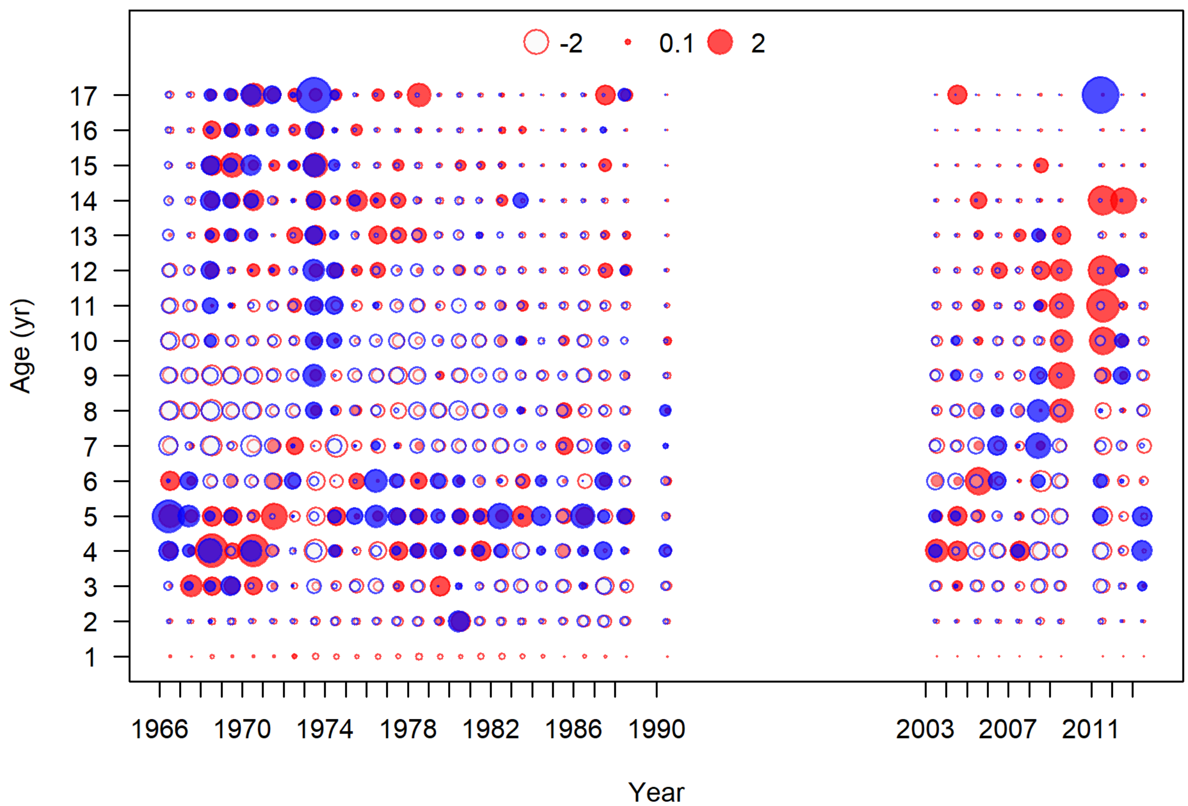

Figure 85: Pearson residuals, retained, Summer (S) (max=4.31) (plot 3 of 3)
Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). fig:ss_age_pearson

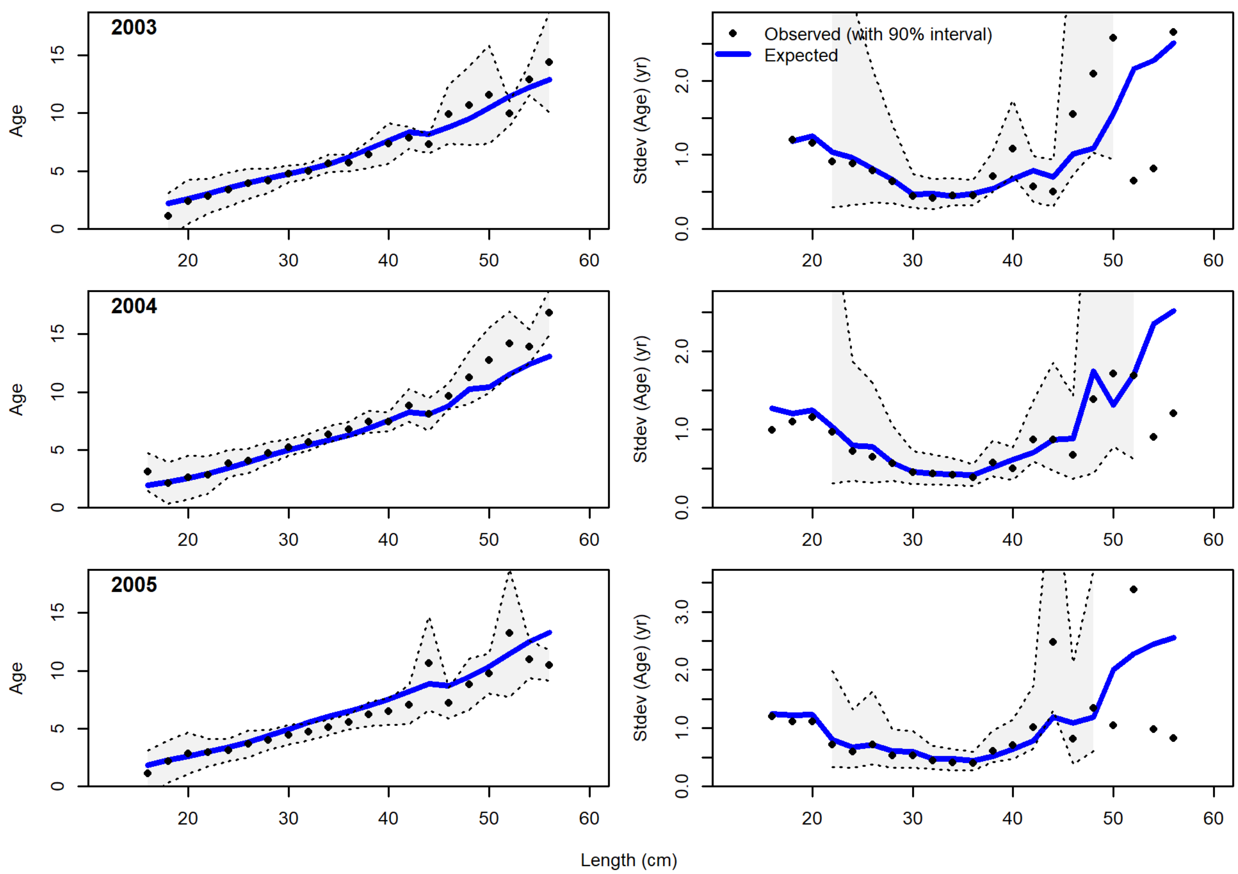

Figure 86: Conditional AAL plot, whole catch, NWFSC West Coast Groundfish Bottom Trawl Survey (plot 1 of 4) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution. fig:nwfsc_combo_andre_1

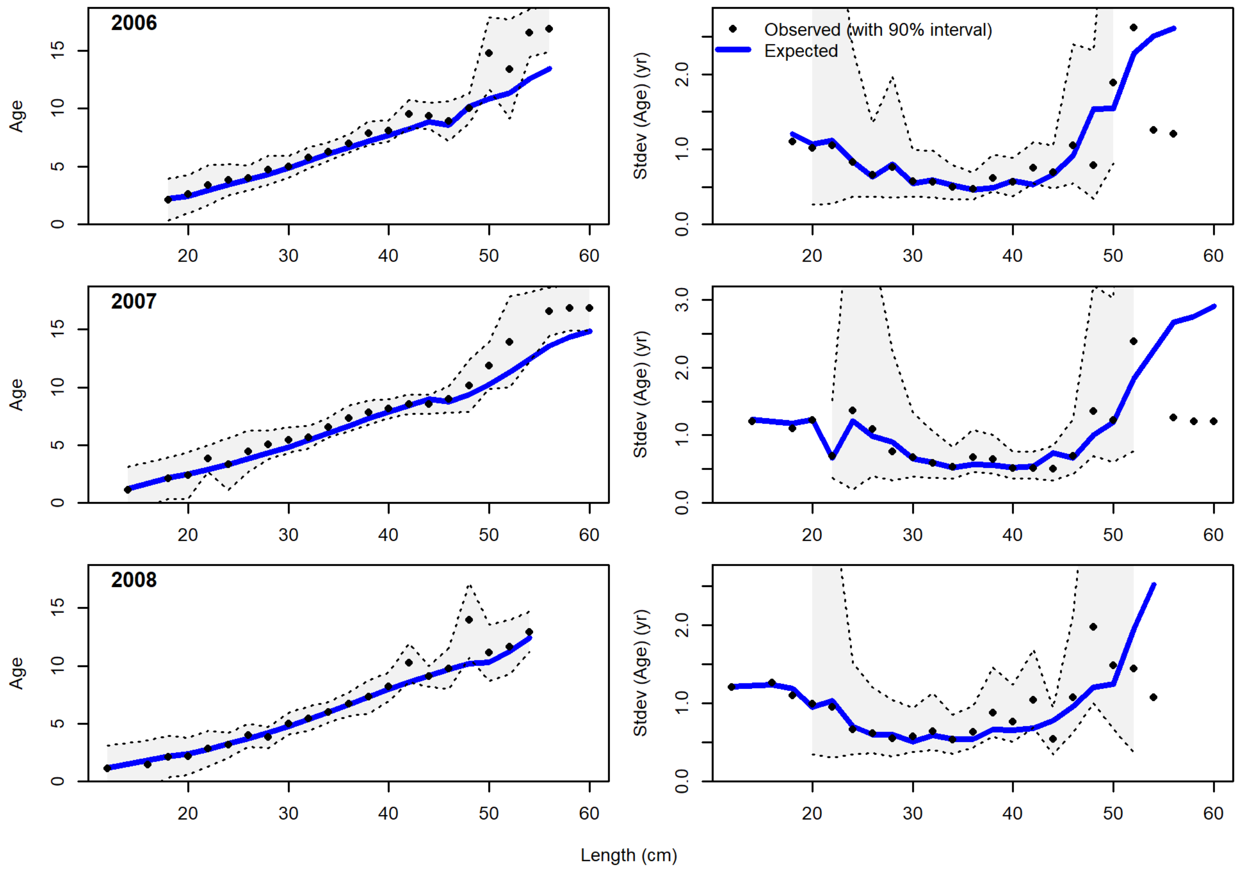

Figure 87: Conditional AAL plot, whole catch, NWFSC West Coast Groundfish Bottom Trawl Survey (plot 2 of 4) fig:nwfsc_combo_andre_2

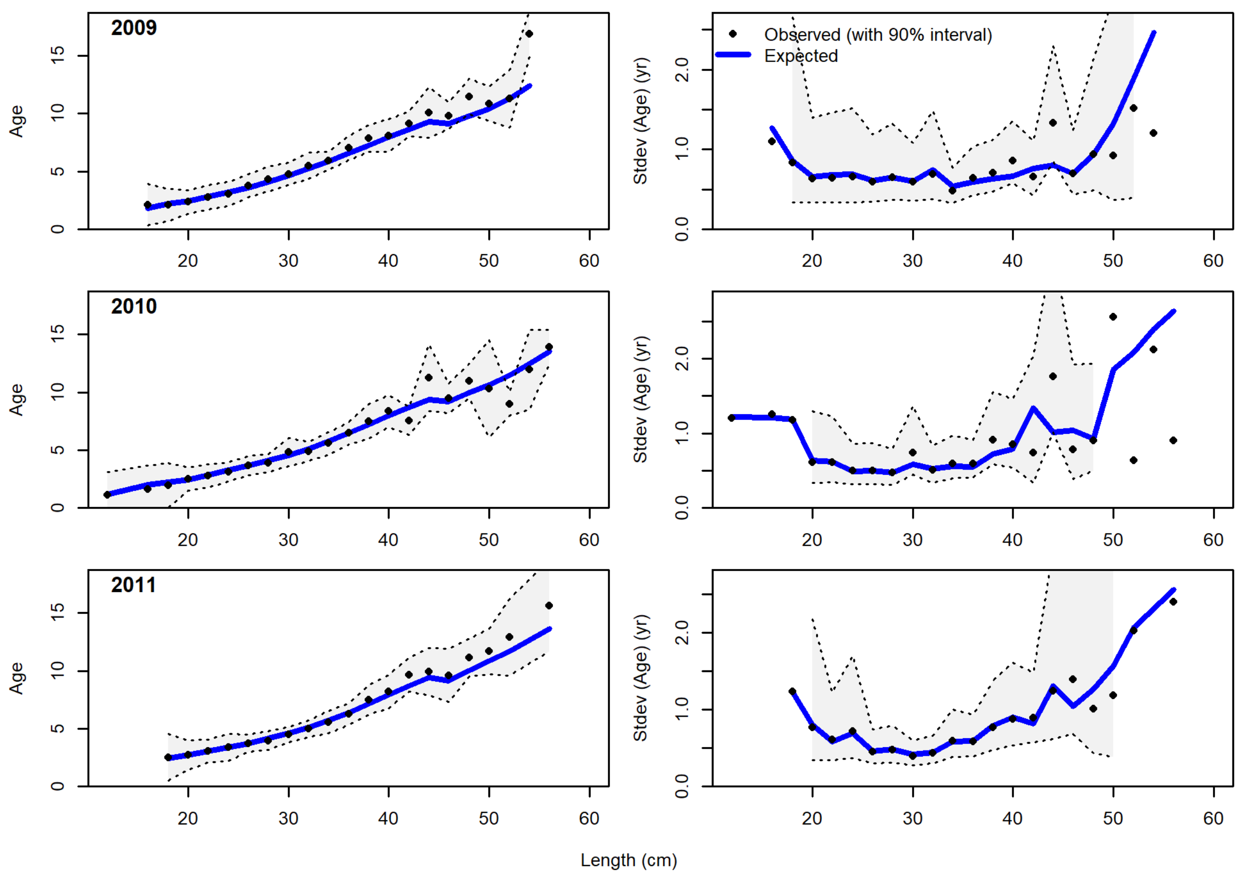

Figure 88: Conditional AAL plot, whole catch, NWFSC West Coast Groundfish Bottom Trawl Survey (plot 3 of 4) fig:nwfsc_combo_andre_3

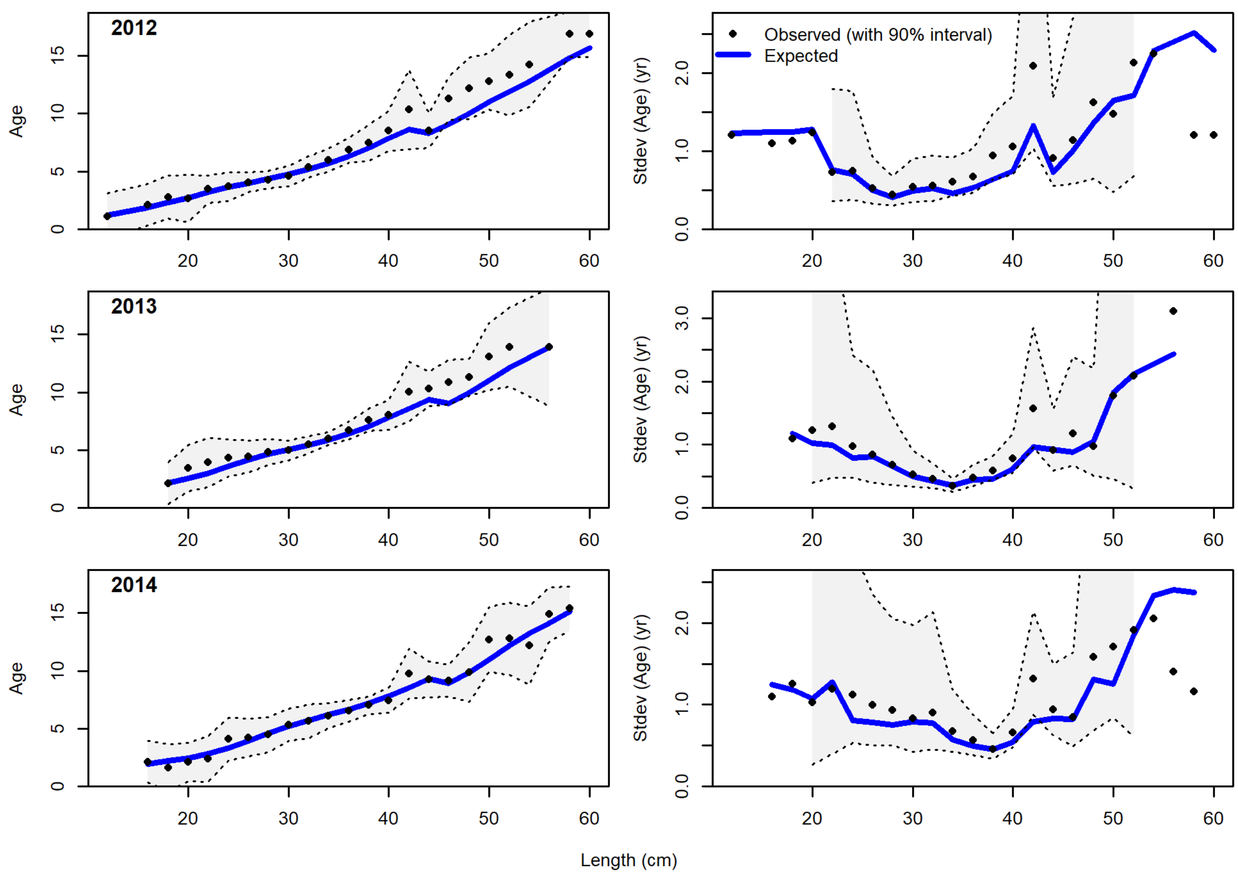

Figure 89: Conditional AAL plot, whole catch, NWFSC West Coast Groundfish Bottom Trawl Survey (plot 4 of 4) fig:nwfsc_combo_andre_4

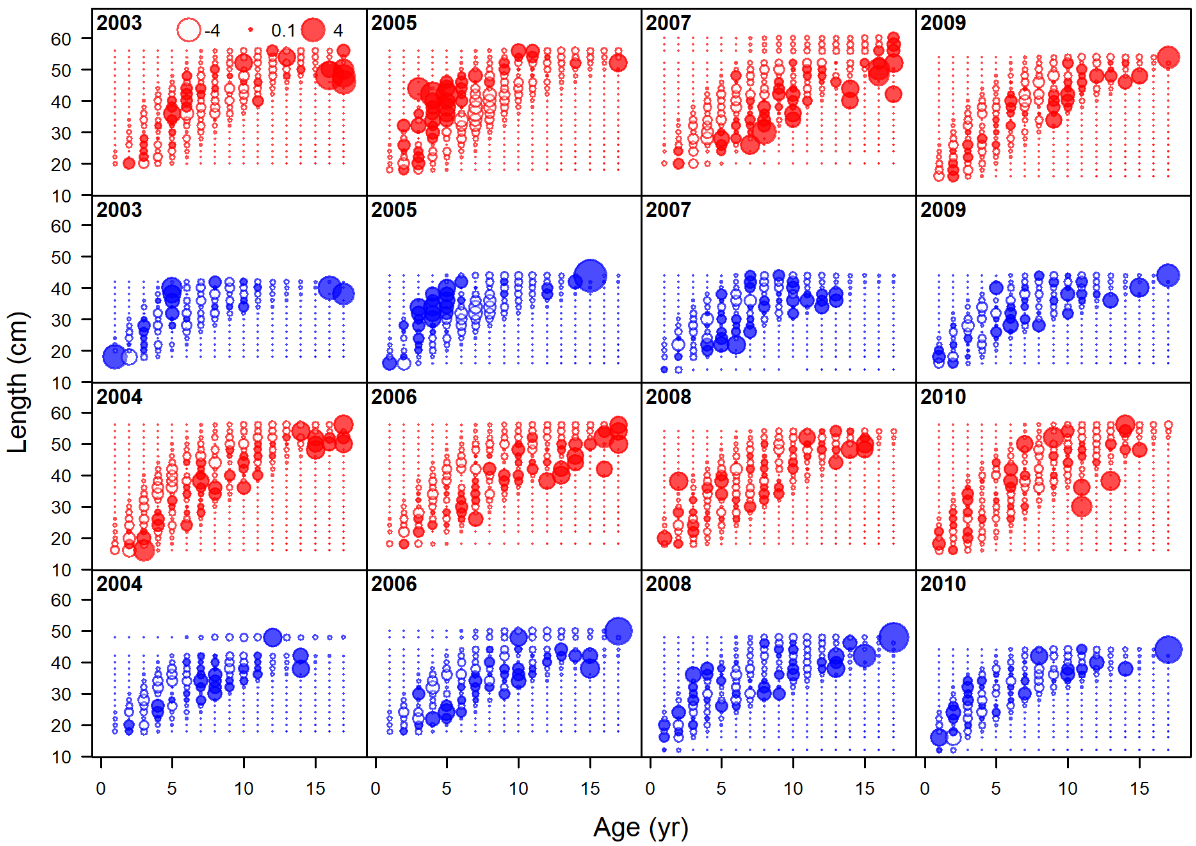

Figure 90: Pearson residuals, whole catch, NWFSC West Coast Groundfish Bottom Trawl Survey (max=7.72) (plot 1 of 2) fig:nwfsc_combo_pearson_1

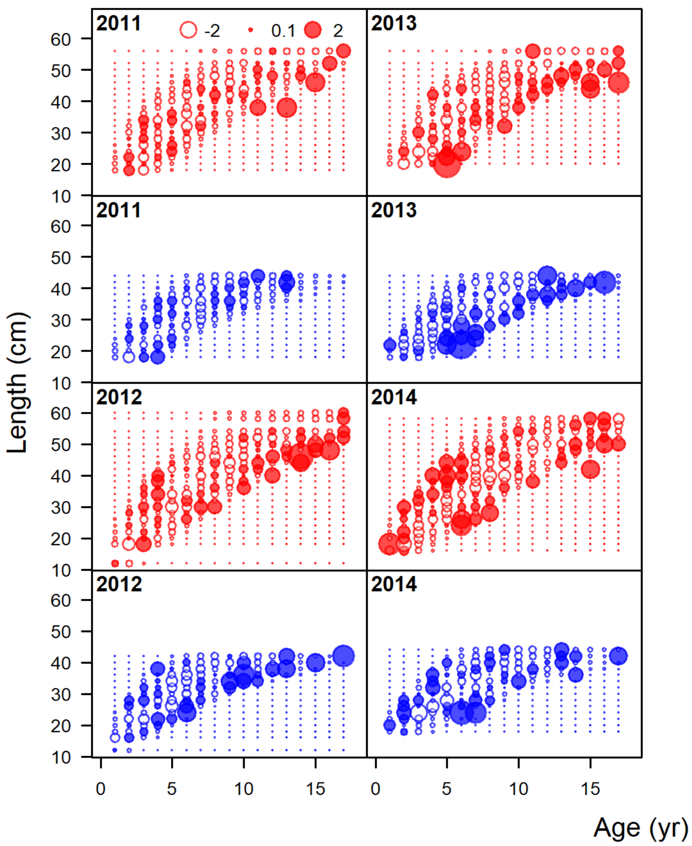

Figure 91: Pearson residuals, whole catch, NWFSC West Coast Groundfish Bottom Trawl Survey (max=7.72) (plot 1 of 2) (plot 2 of 2) fig:nwfsc_combo_pearson_2

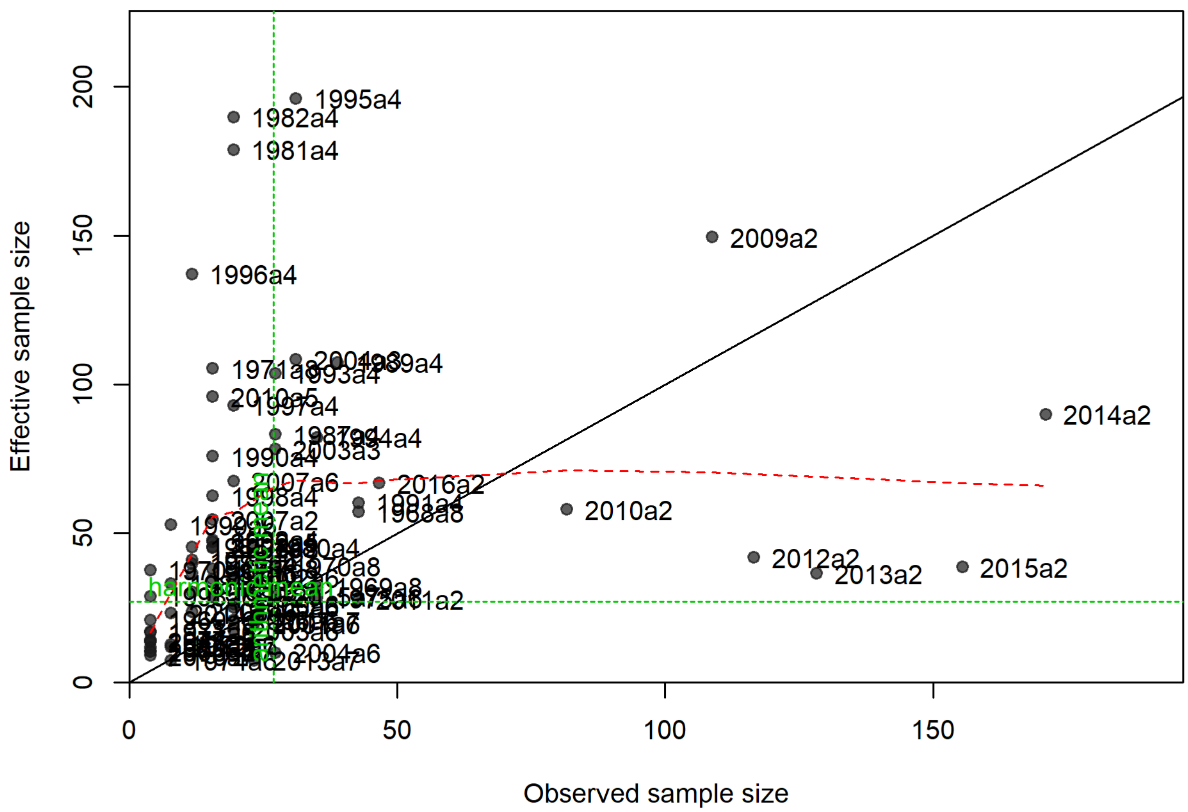

Figure 92: McAllister and Ianelli (harmonic mean) weighting for the Winter North fishery age data. fig:harm_mean_wn_age

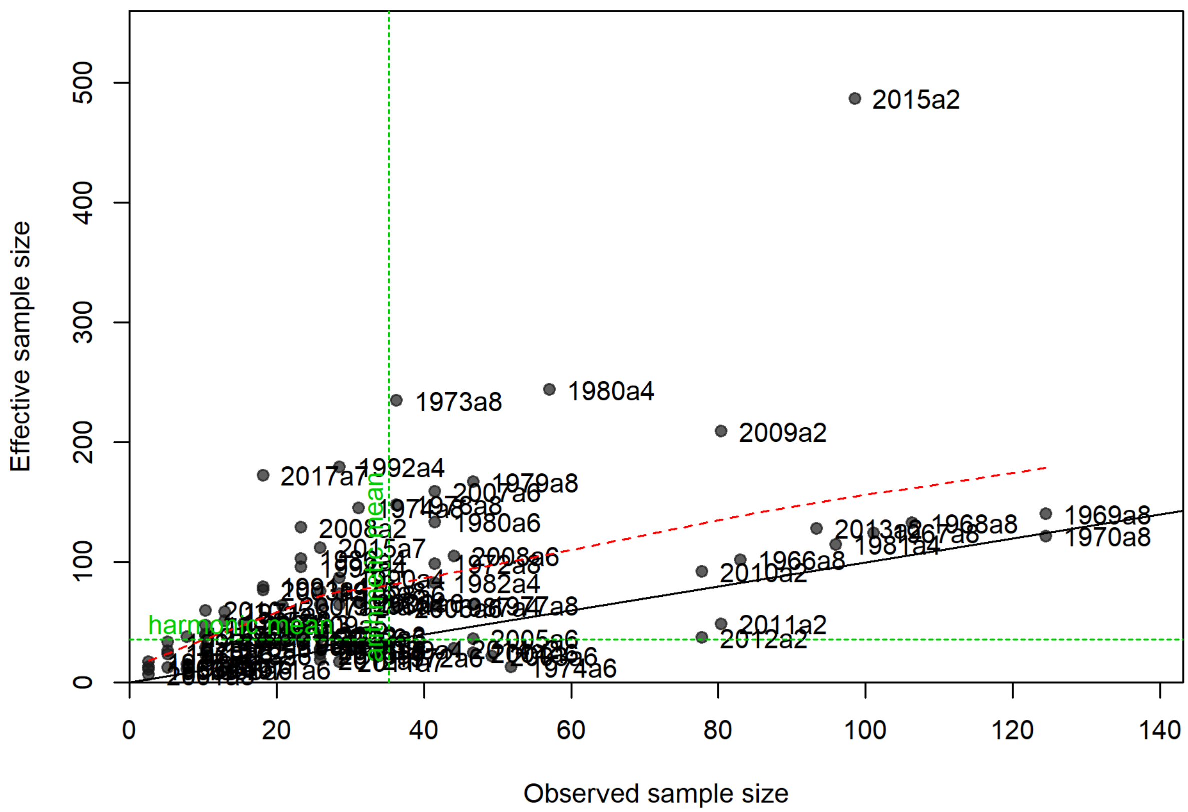

Figure 93: McAllister and Ianelli (harmonic mean) weighting for the Summer North fishery age data. fig:harm_mean_sn_age

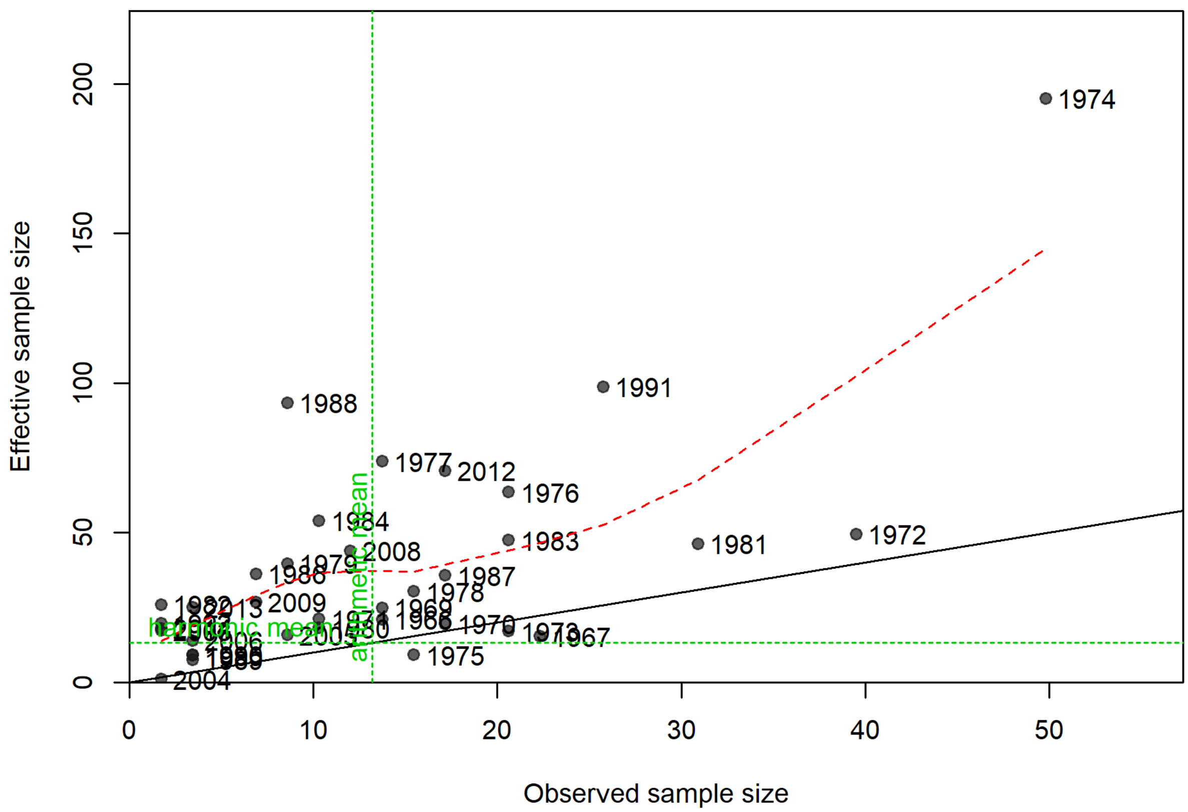

Figure 94: McAllister and Ianelli (harmonic mean) weighting for the Winter South fishery age data. fig:harm_mean_ws_age

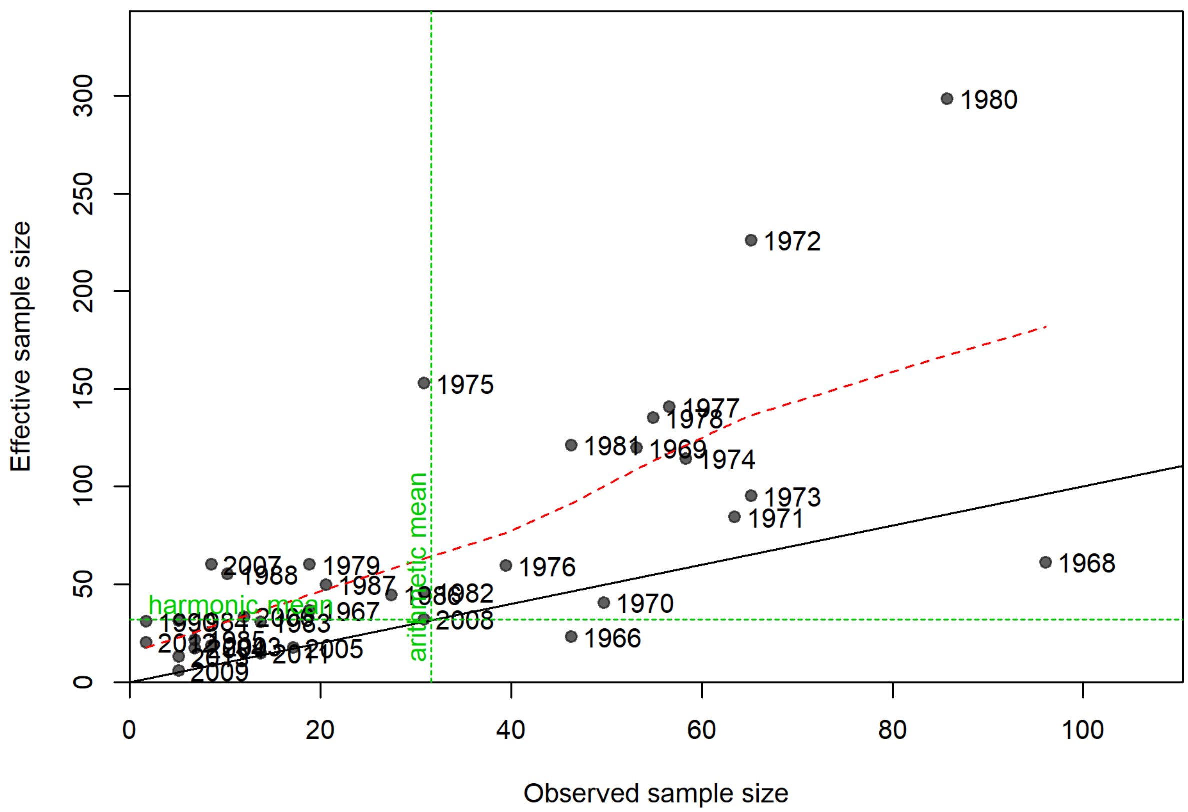

Figure 95: McAllister and Ianelli (harmonic mean) weighting for the Summer South fishery age data. fig:harm_mean_wn_age

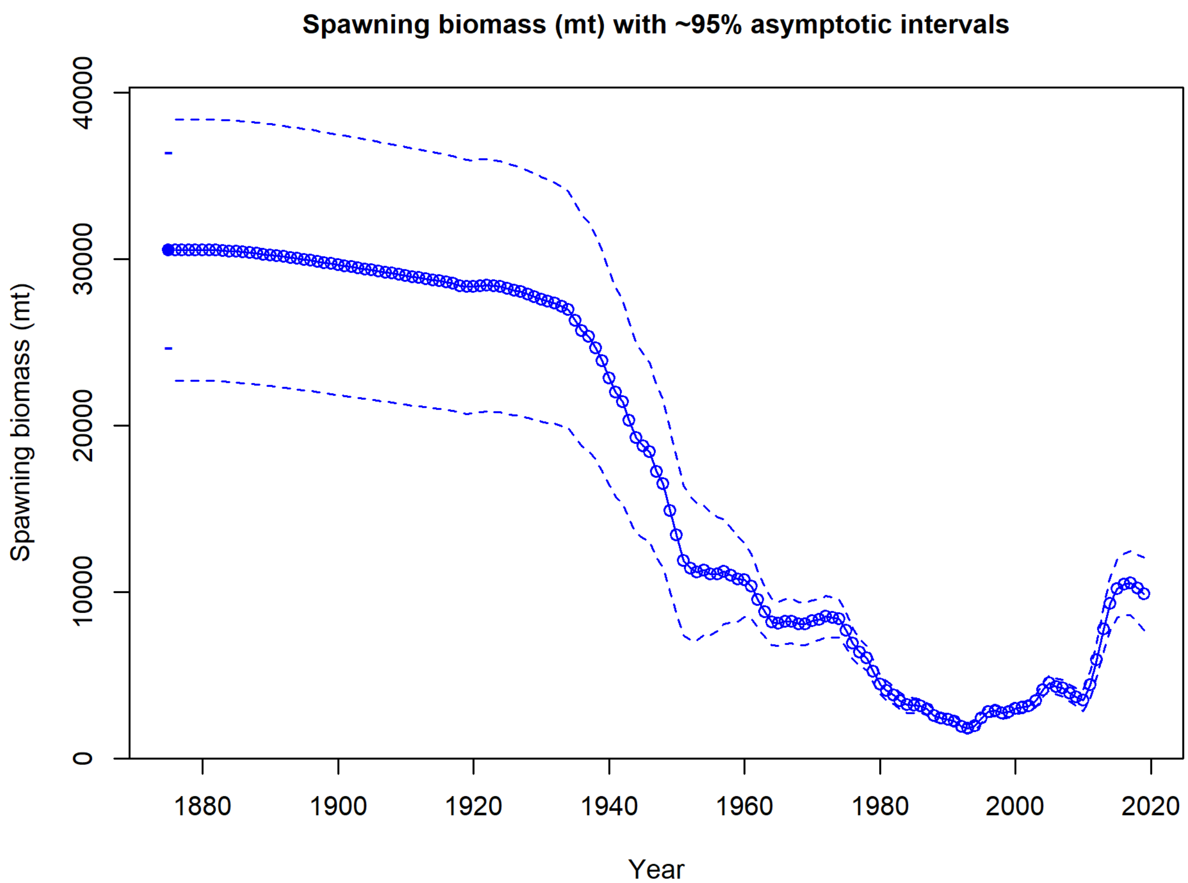

Figure 96: Estimated time-series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for petrale sole. fig:ssb

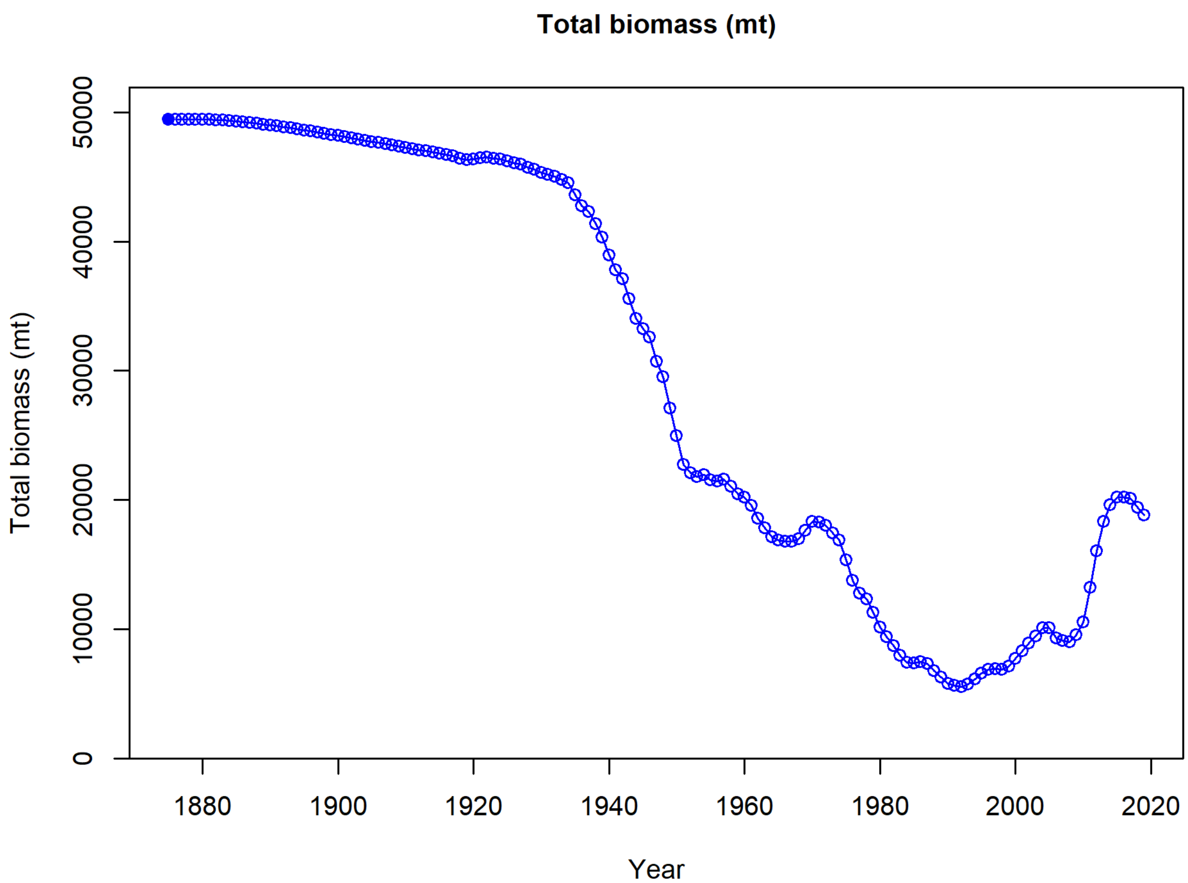

Figure 97: Estimated time-series of total biomass for petrale sole. fig:total_bio

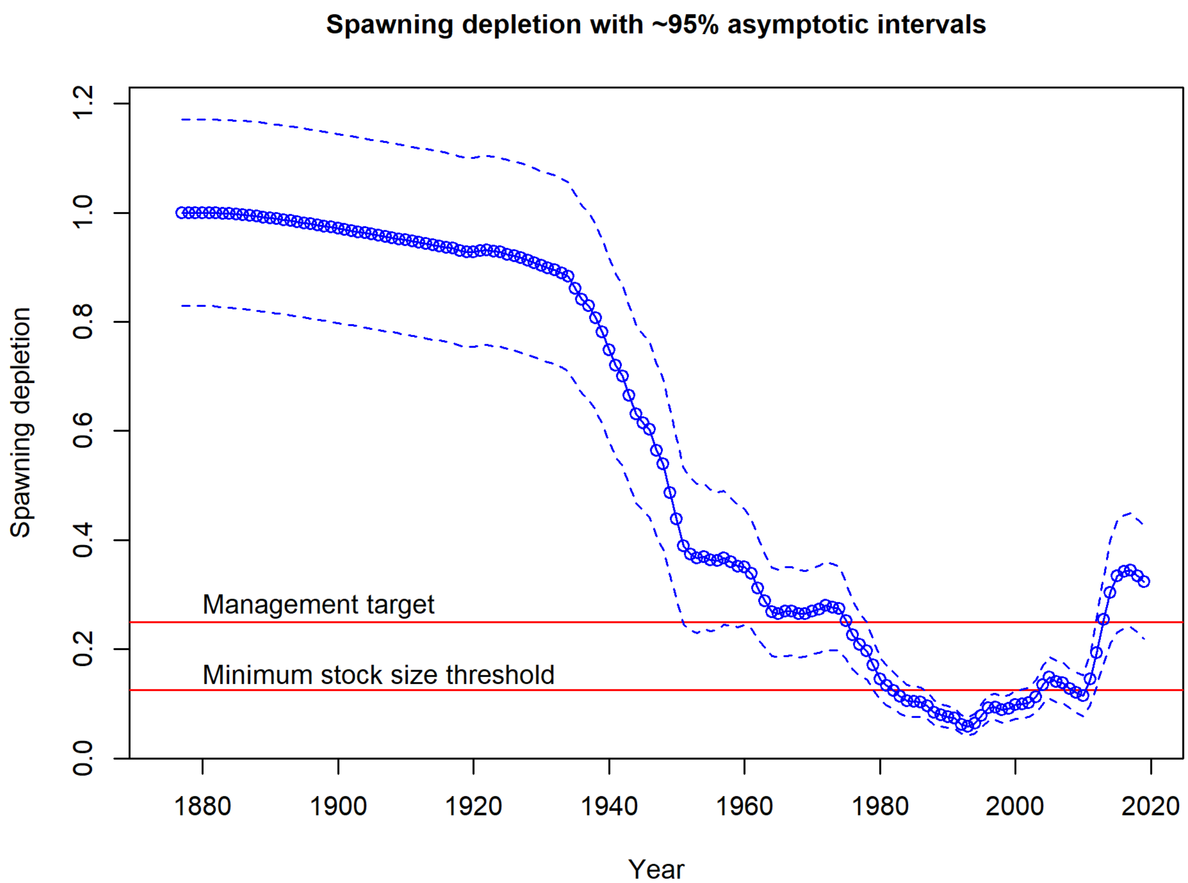

Figure 98: Estimated time-series of relative spawning biomass (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for petrale sole. fig:depl

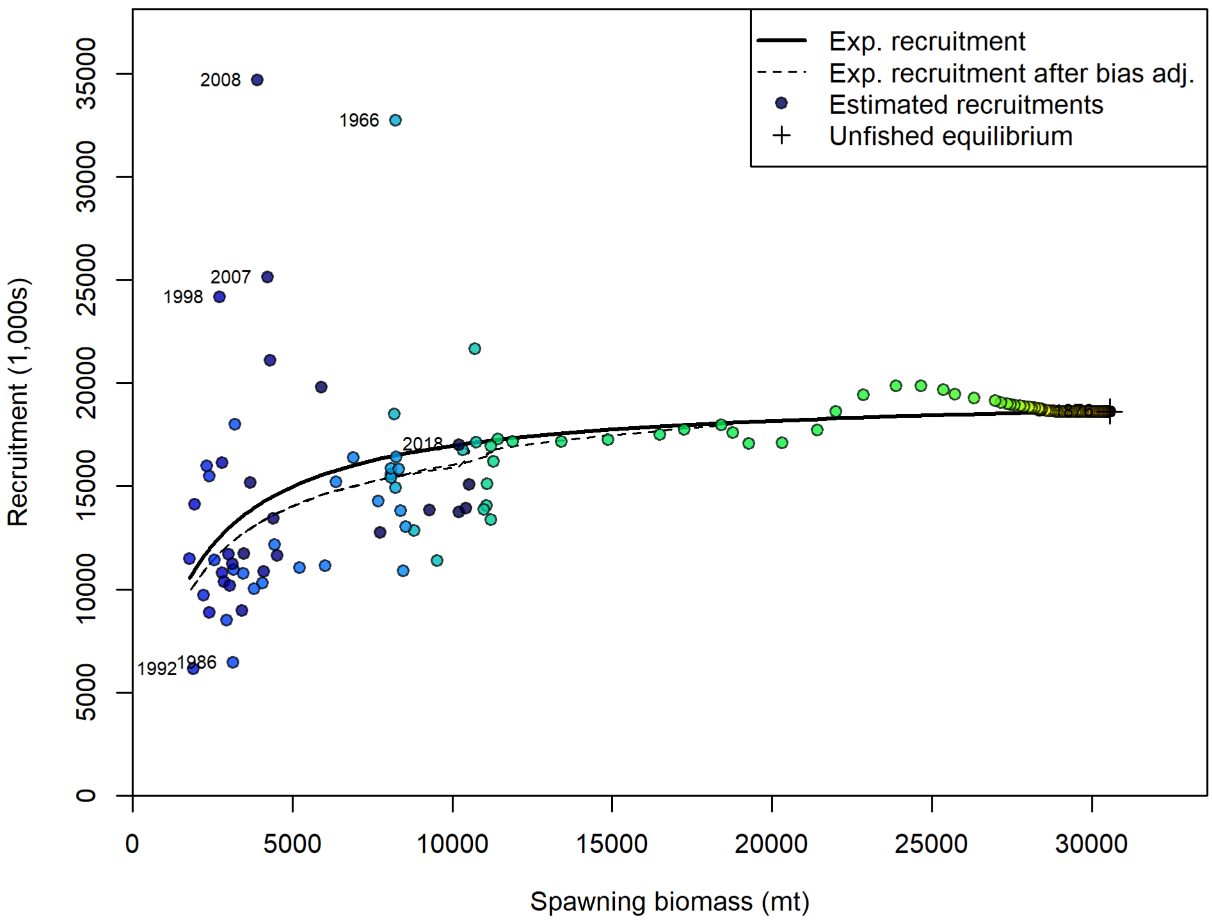

Figure 99: Estimated recruitment (colored circles) and the assumed stock-recruit relationship (solid black line). The dashed line shows the effect of the bias correction for the lognormal distribution. fig:stock_recruit_curve

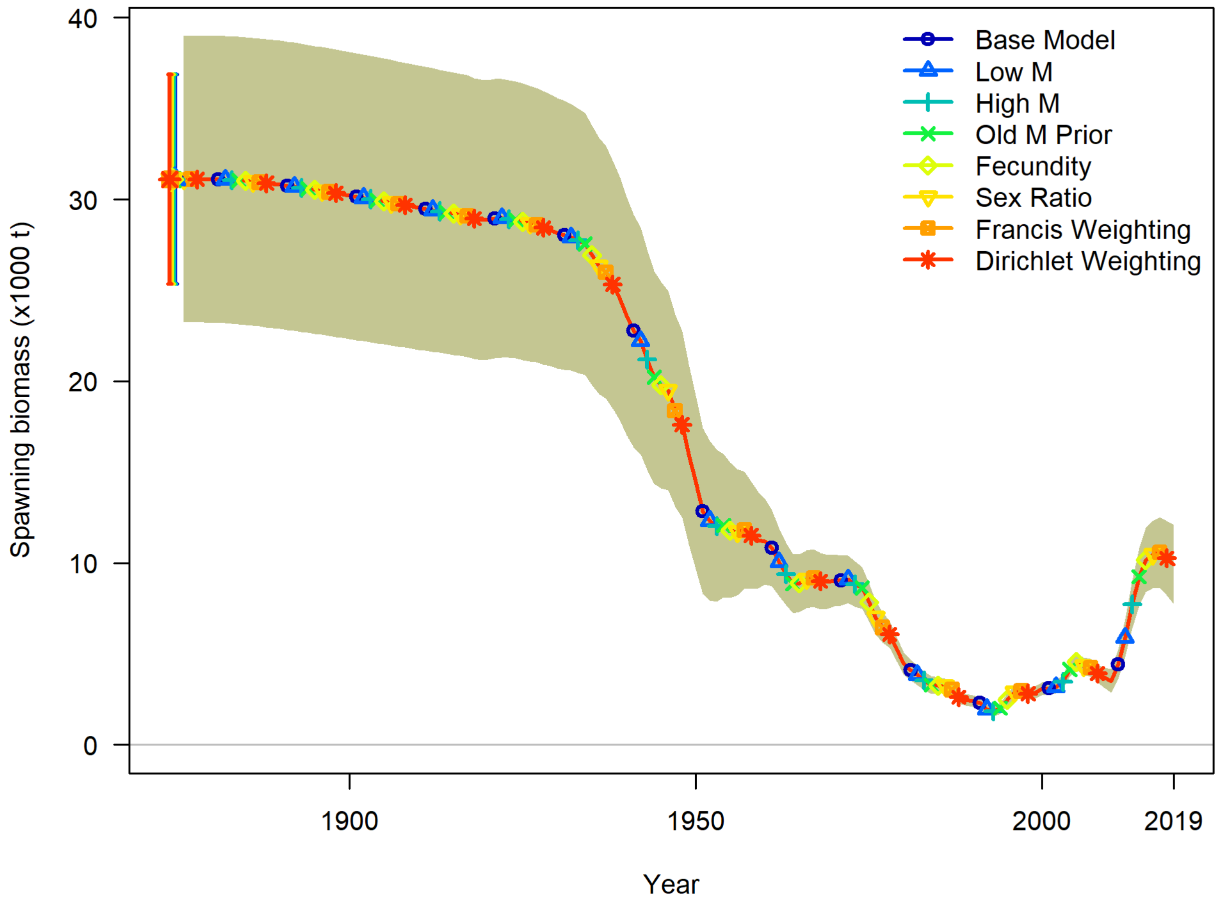

Figure 100: Estimate spawning biomass for the base model and each sensitivity. fig:sens_ssb

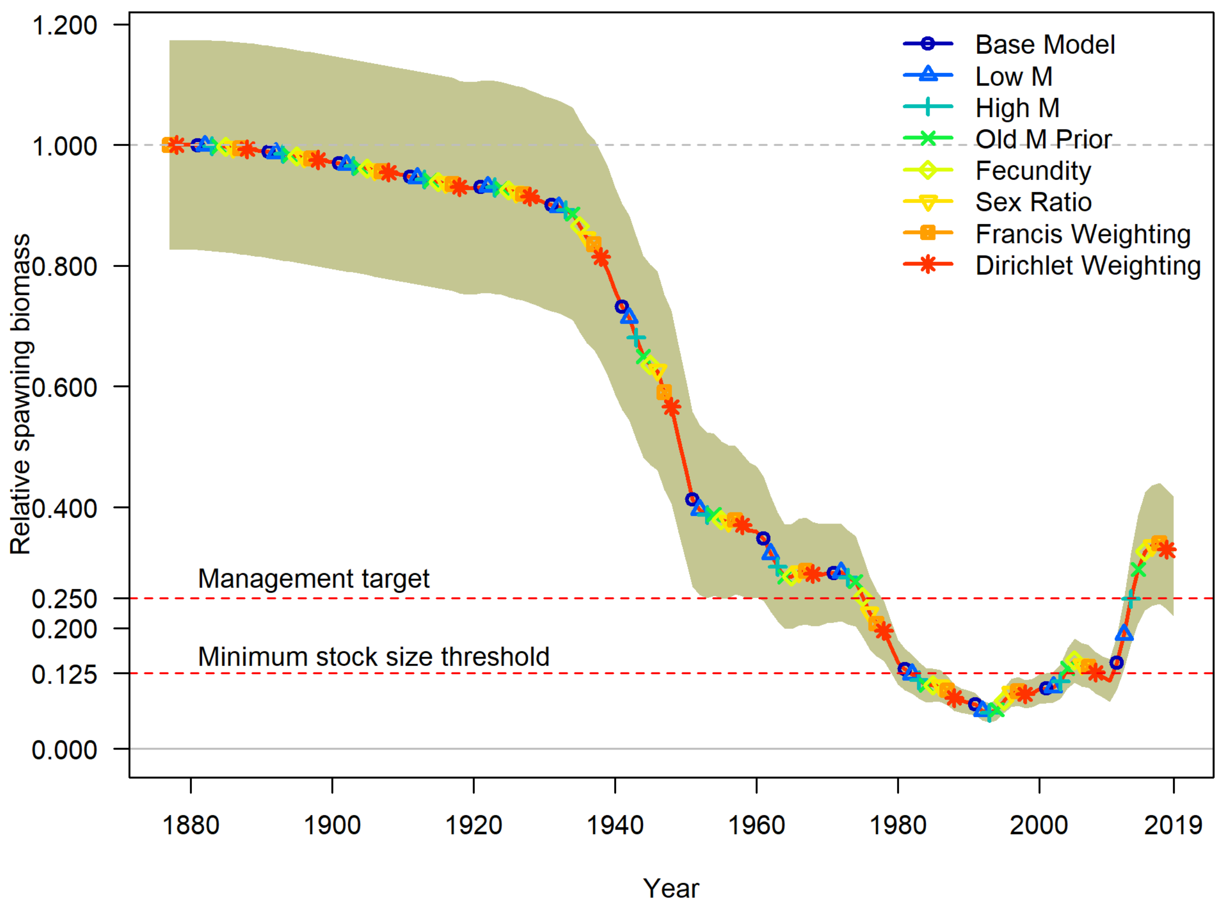

Figure 101: Estimate relative spawning biomass for the base model and each sensitivity. fig:sens_depl

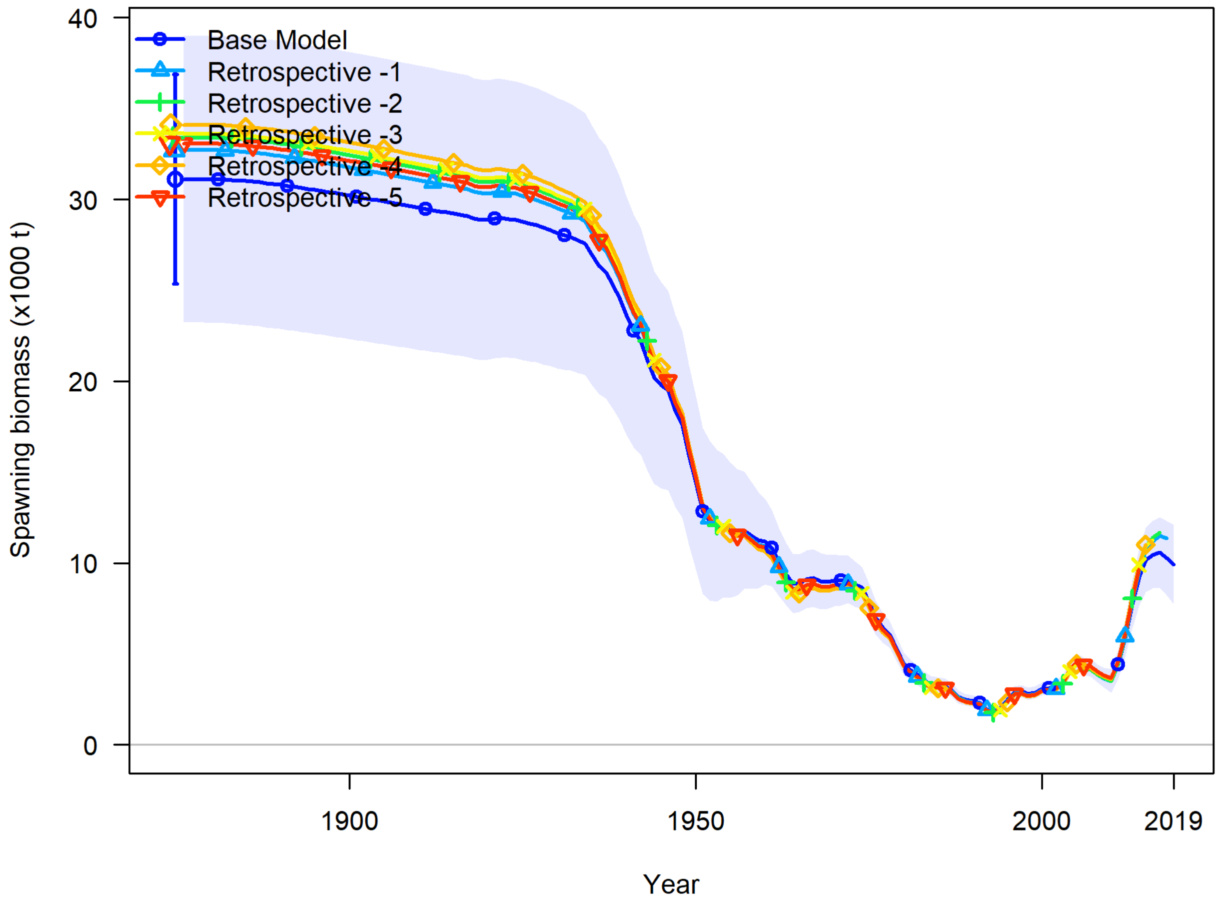

Figure 102: Retrospective pattern for spawning biomass. fig:retro_ssb

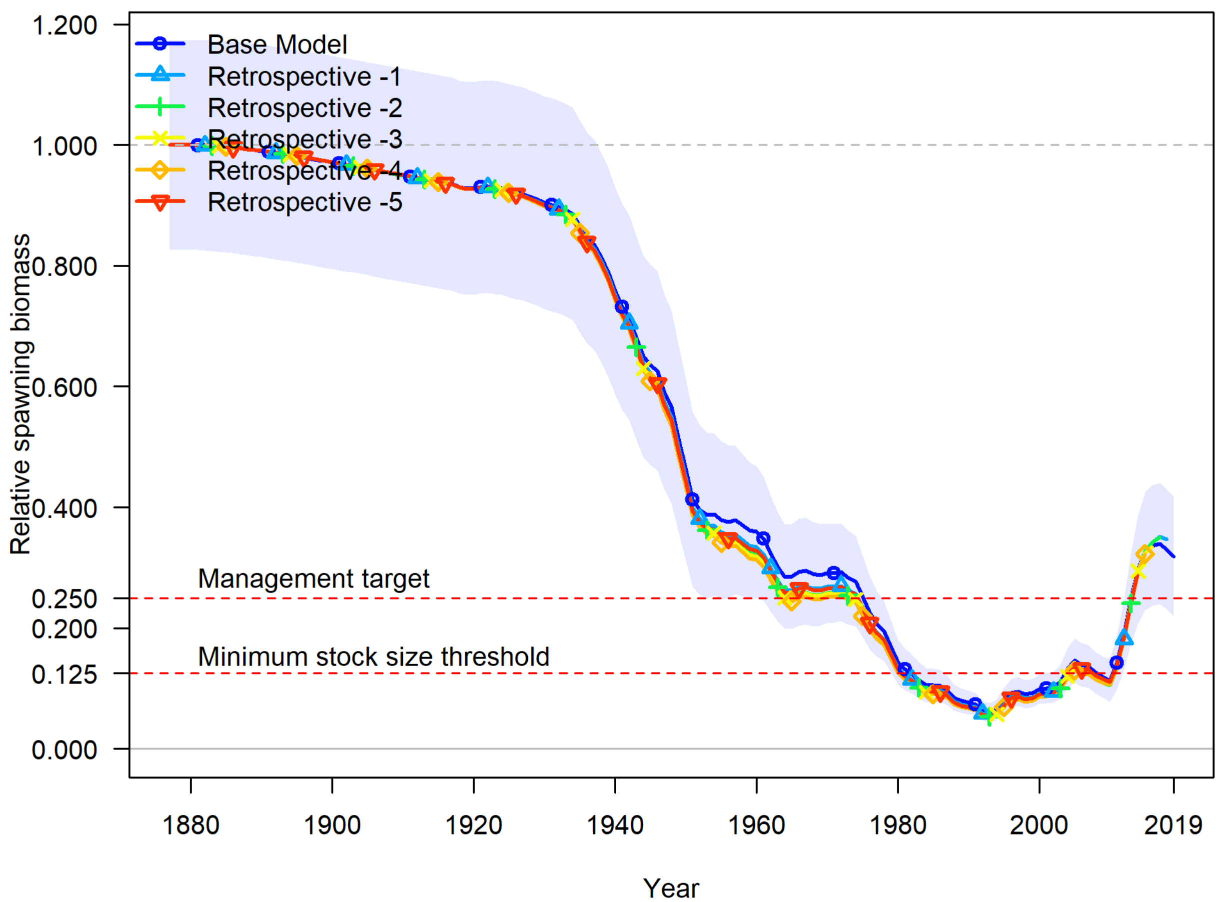

Figure 103: Retrospective pattern for relative spawning biomass. fig:retro_depl

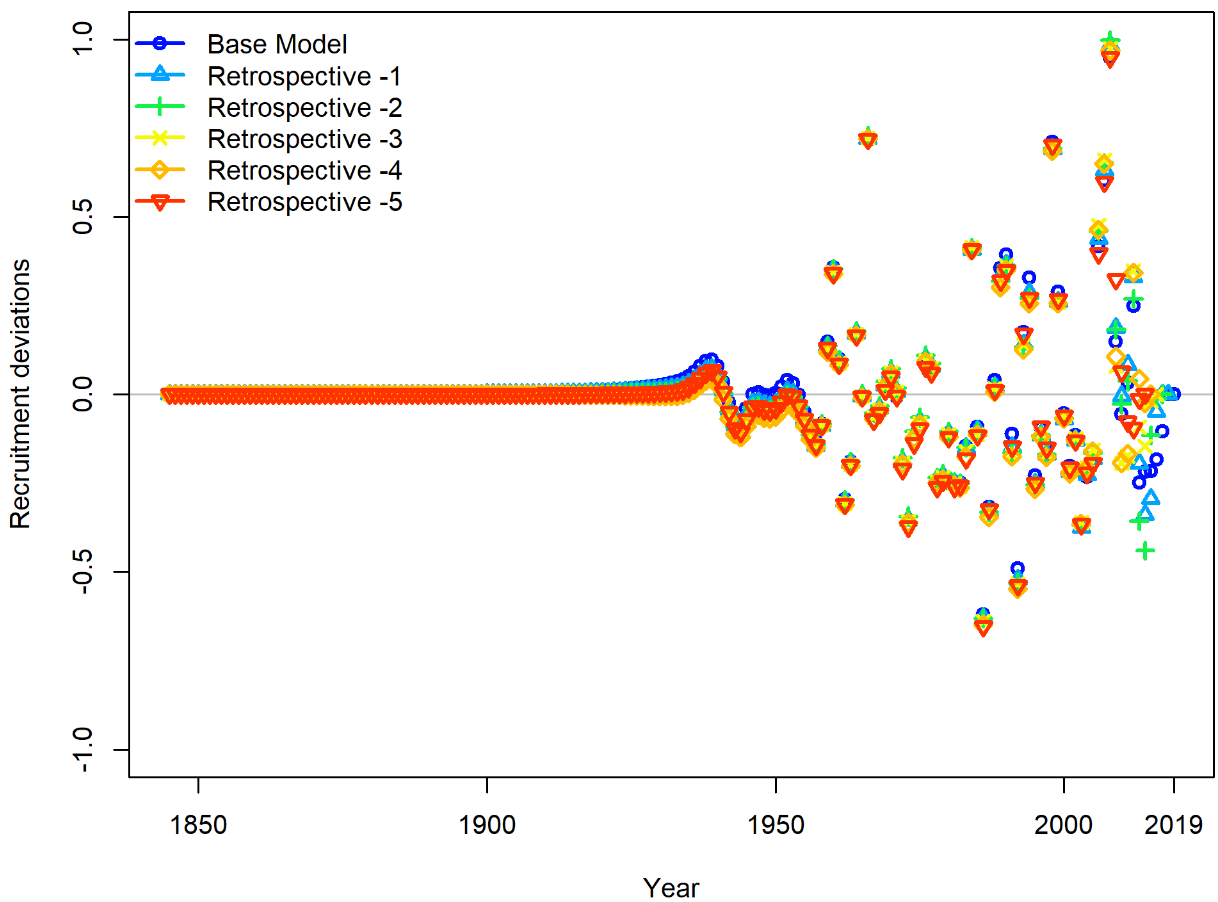

Figure 104: Retrospective pattern for estimated recruitment deviations. fig:retro_recdev

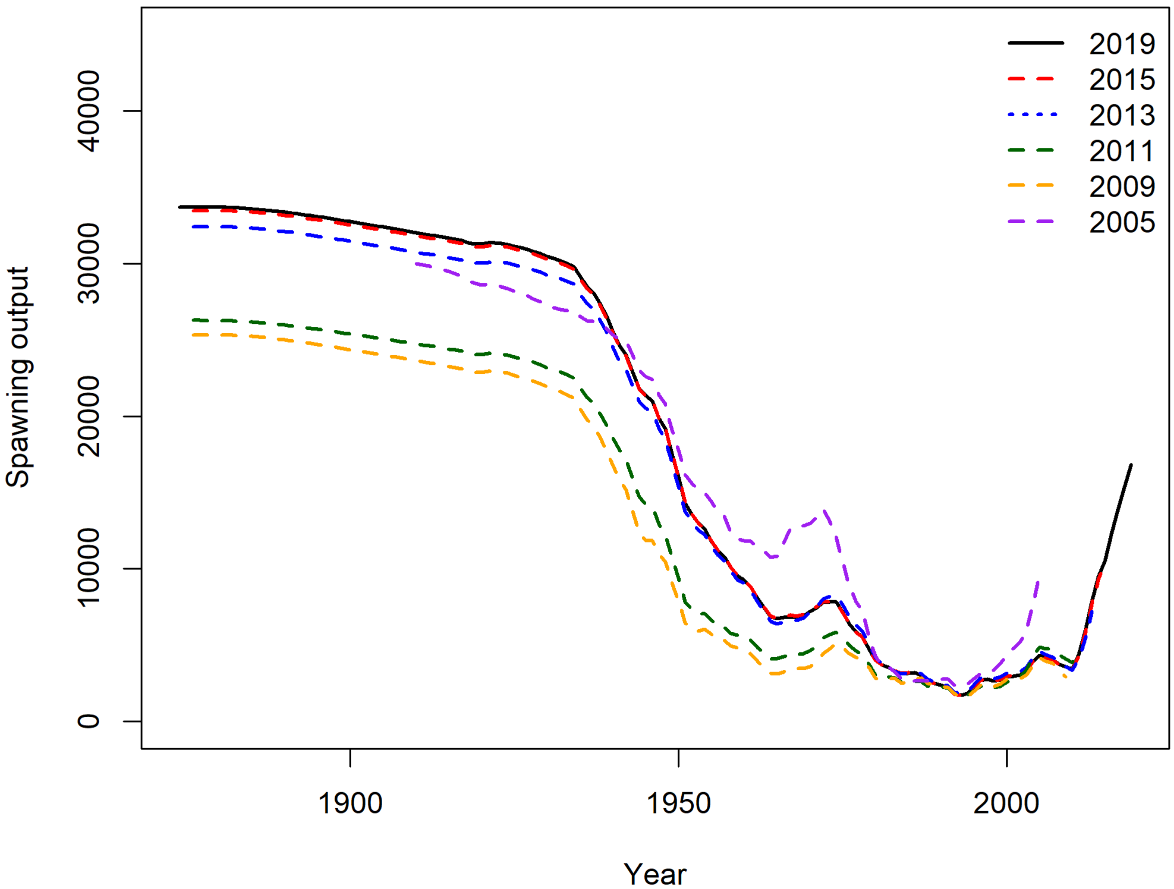

Figure 105: Pattern for estimated spawning biomass from each assessment since 2005. fig:historical_

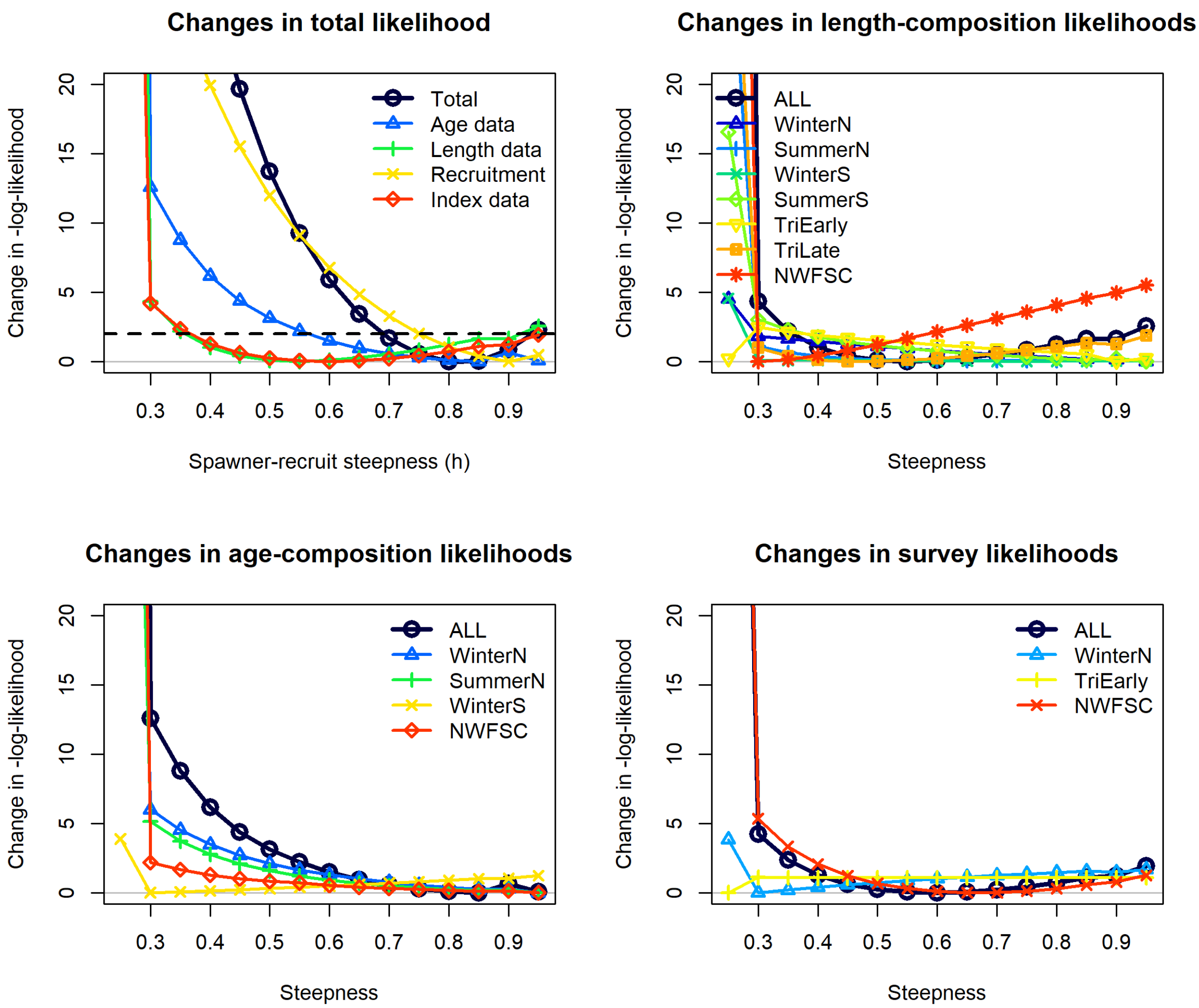

Figure 106: Likelihood profile across steepness values. fig:piner_h

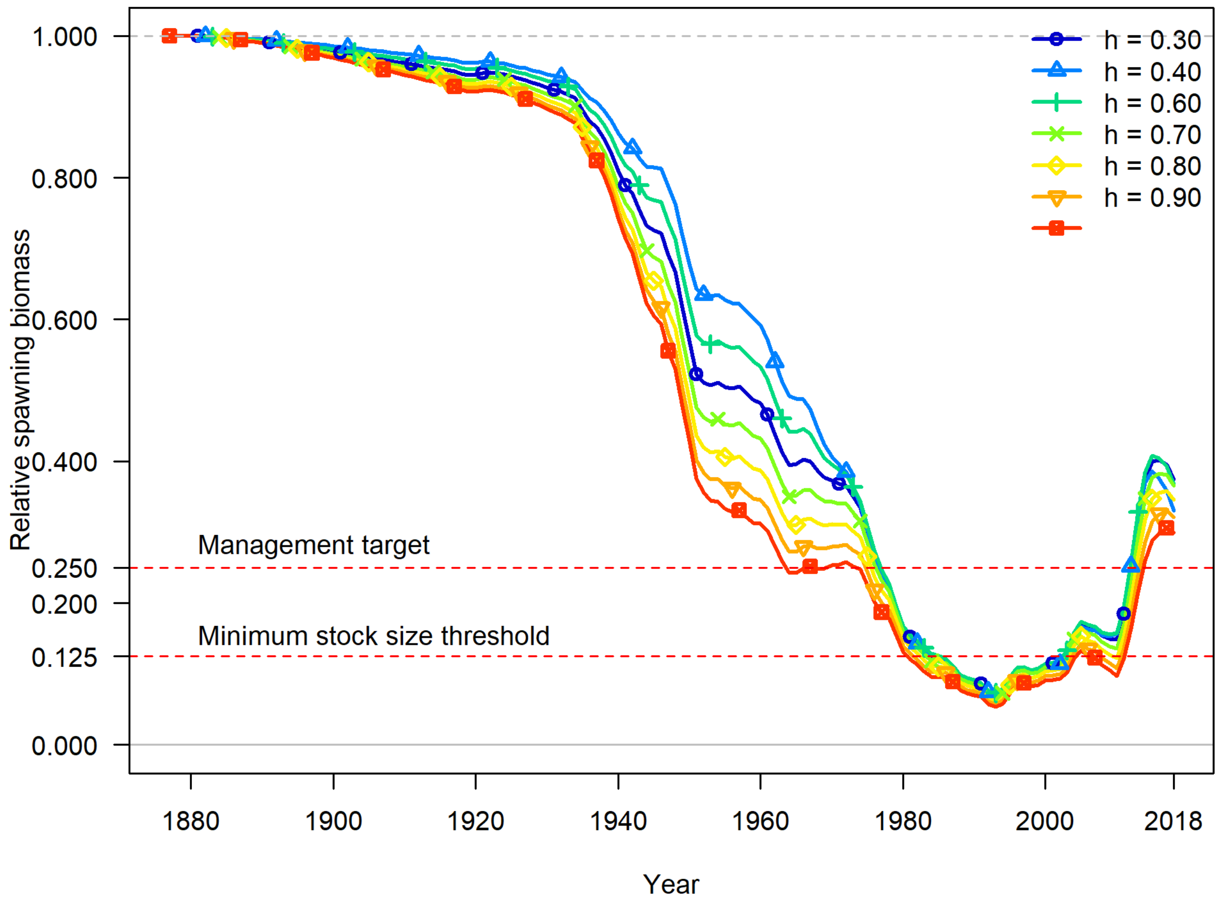

Figure 107: Trajectories of relative spawning biomass across values of steepness. fig:h_trajectory

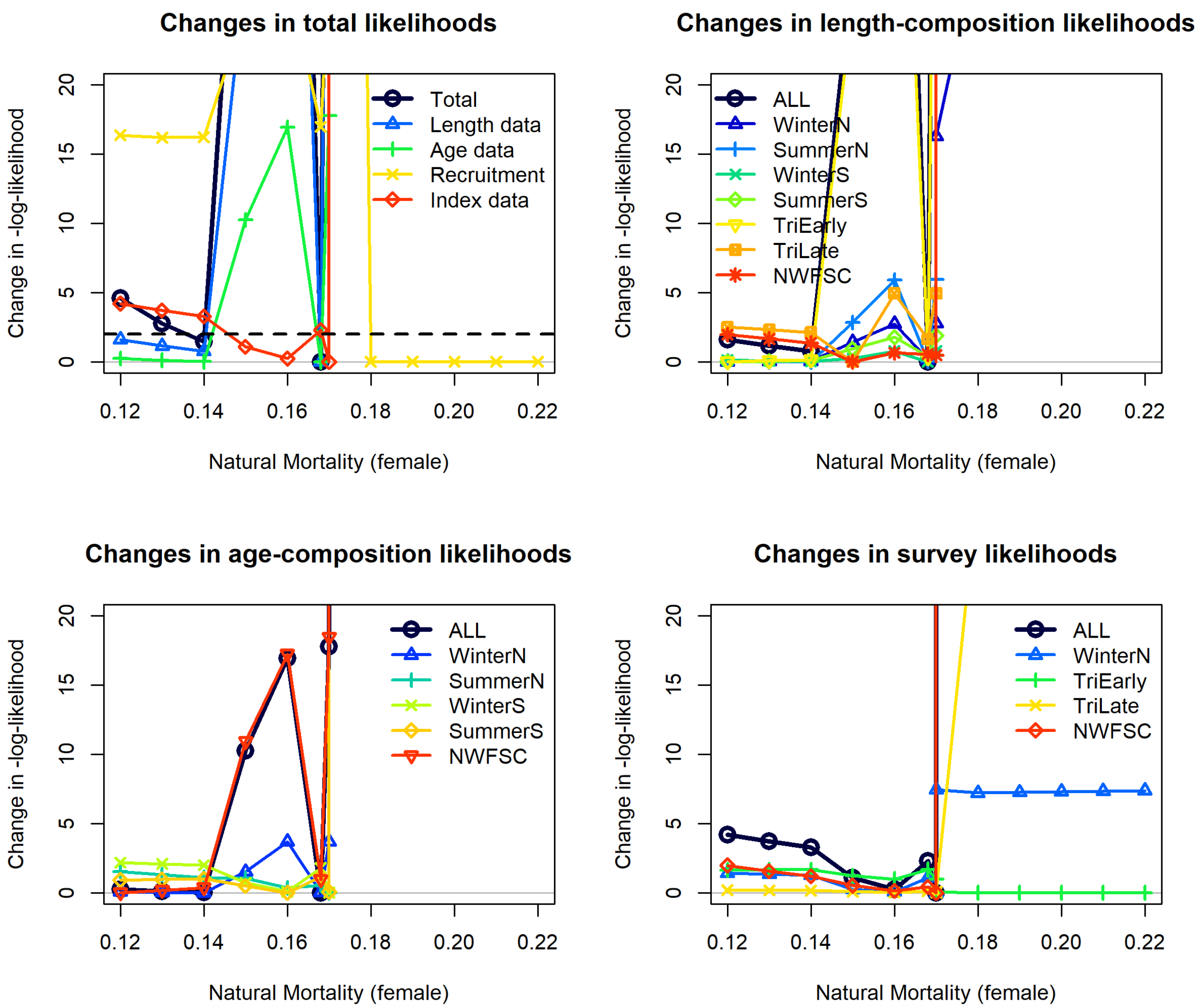

Figure 108: Likelihood profile across female natural mortality values. Male natural mortality was estimated. fig:m_like

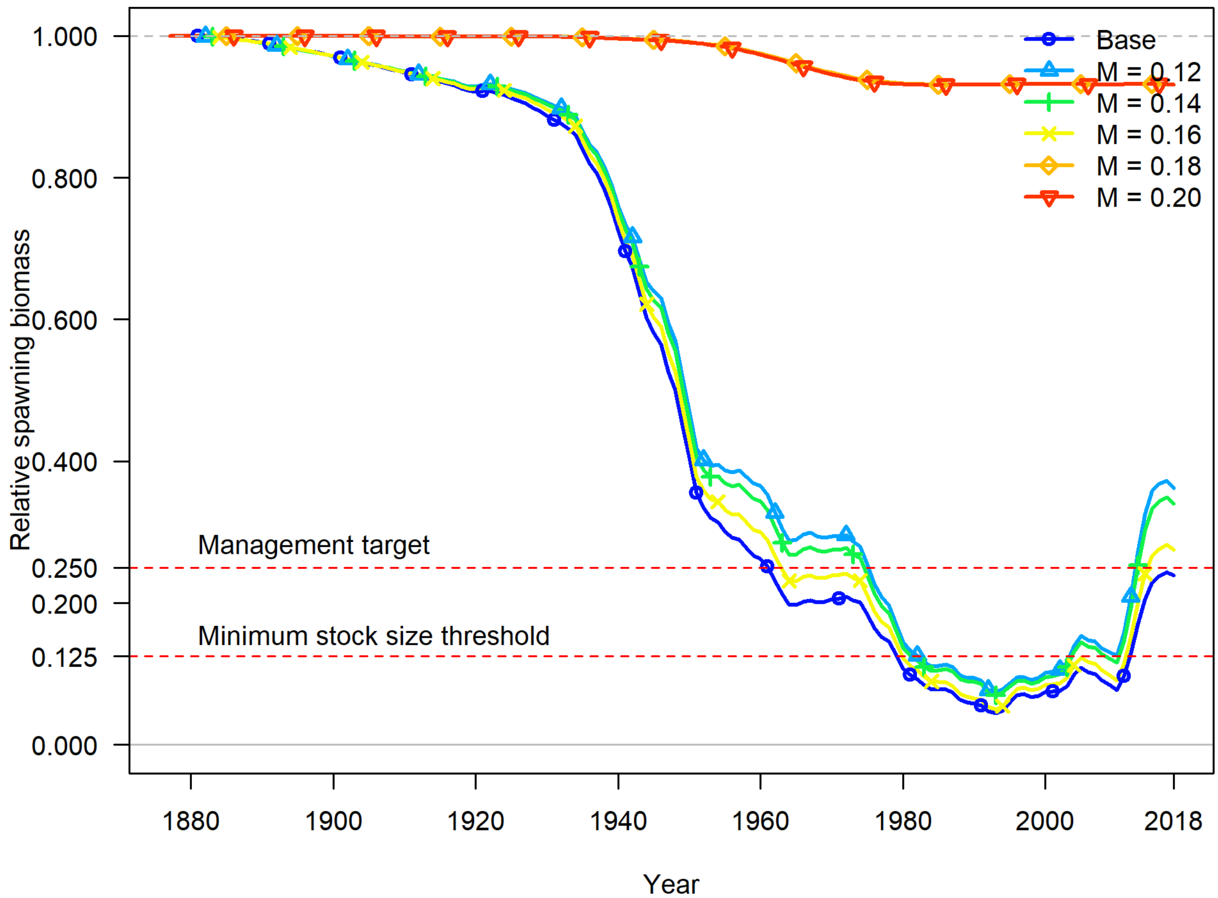

Figure 109: Trajectories of relative spawning biomass across values of natural mortality. fig:m_trajecto

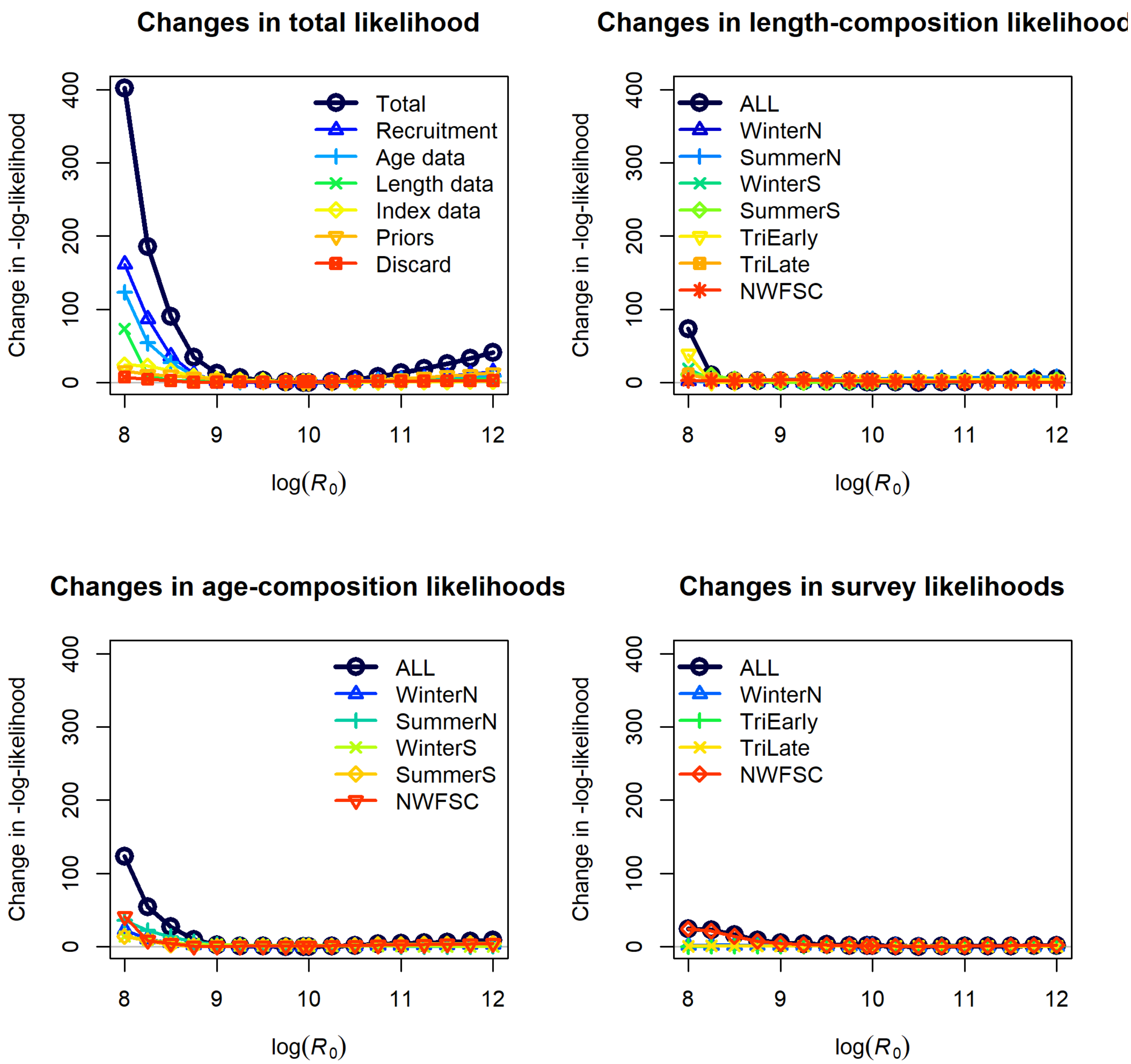

Figure 110: Likelihood profile across R_0 values. fig:piner_R0

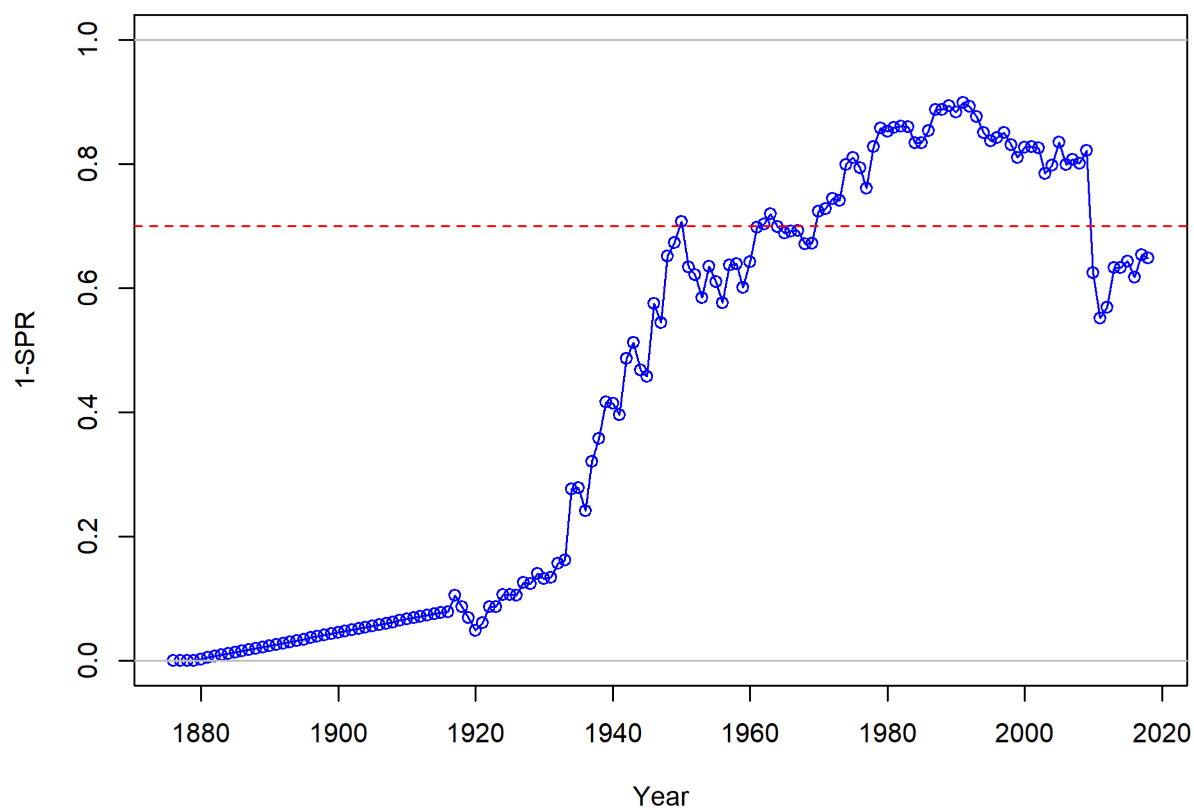

Figure 111: Estimated relative spawning potential ratio 1-SPR for the base model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR30% harvest rate. The last year in the time-series is 2018. fig:SPR_all_fig

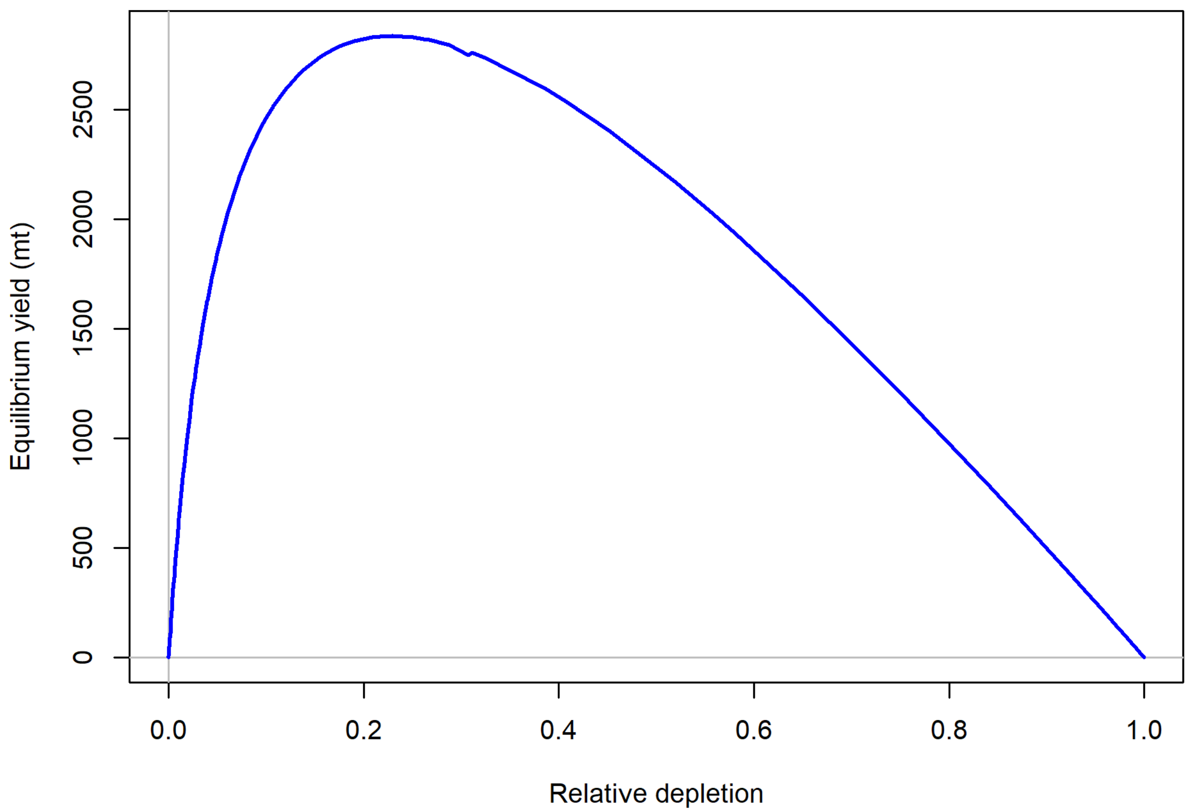

Figure 112: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness estimated at 0.84. fig:yield

11 Appendix A. Detailed Fit to Length Composition Data

appendix-a.-detailed-fit-to-length-composition-data

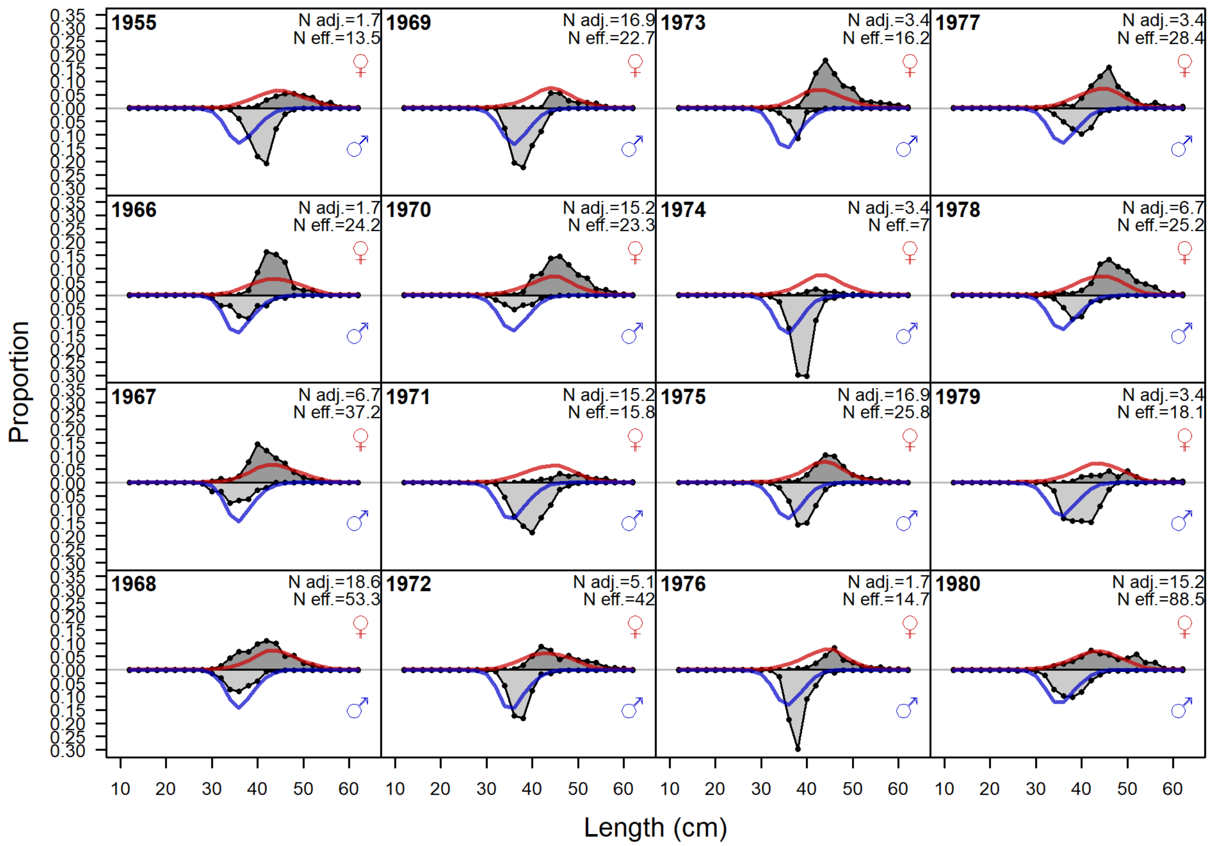

Figure 113: Length comps, retained, Winter (N) (plot 1 of 4). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

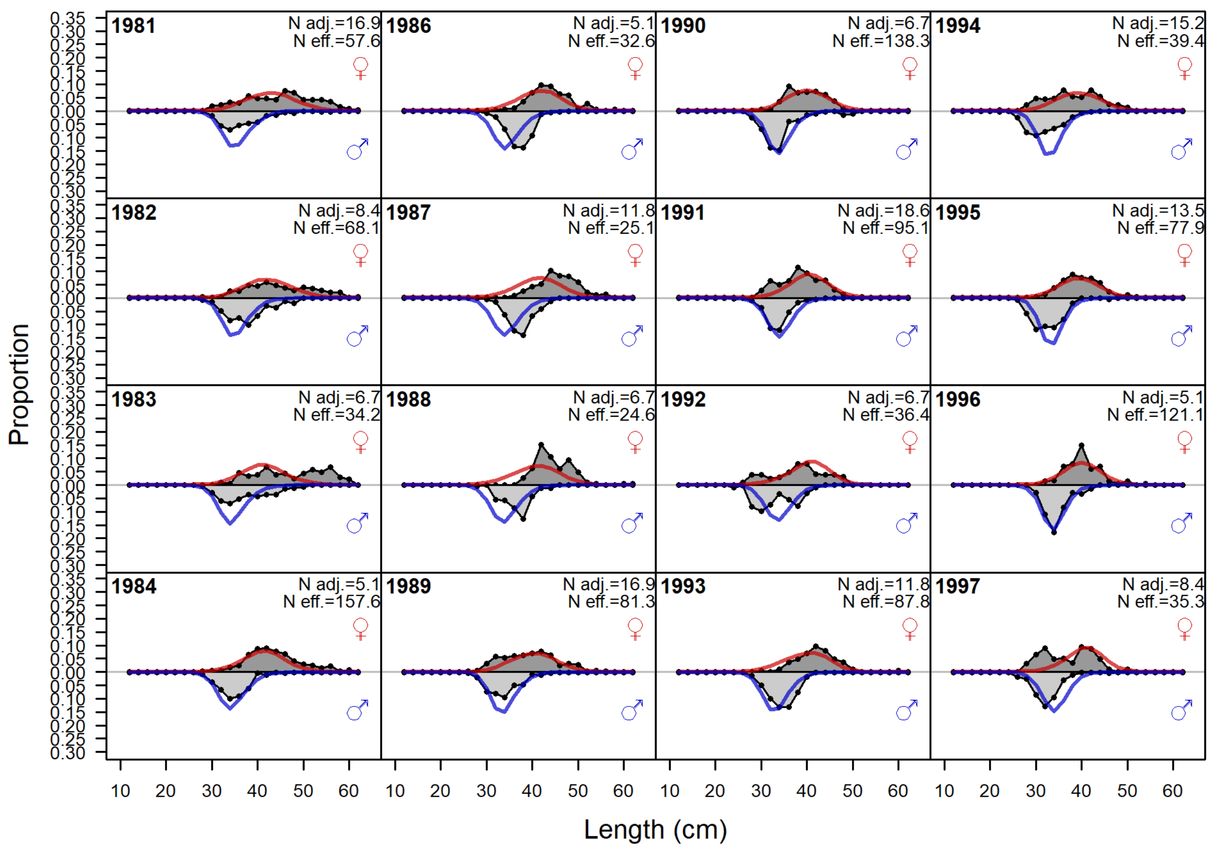

Figure 114: Length comps, retained, Winter (N) (plot 2 of 4) fig:length_fits

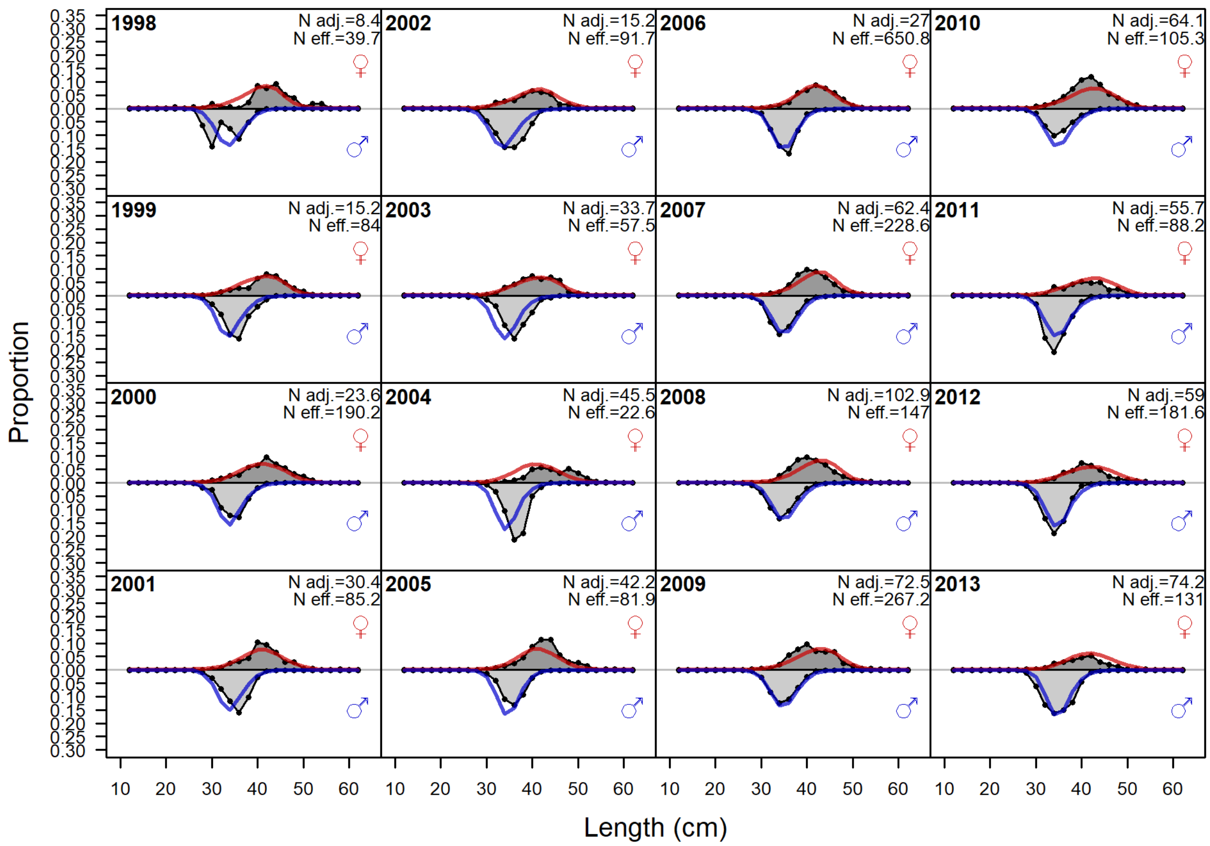

Figure 115: Length comps, retained, Winter (N) (plot 3 of 4) fig:length_fits

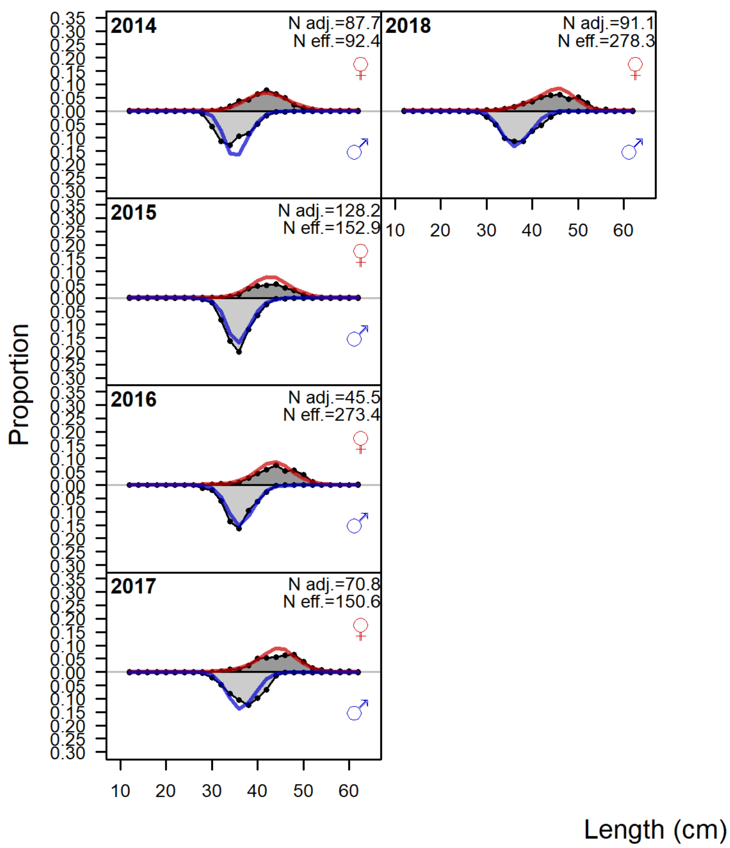

Figure 116: Length comps, retained, Winter (N) (plot 4 of 4) fig:length_fits

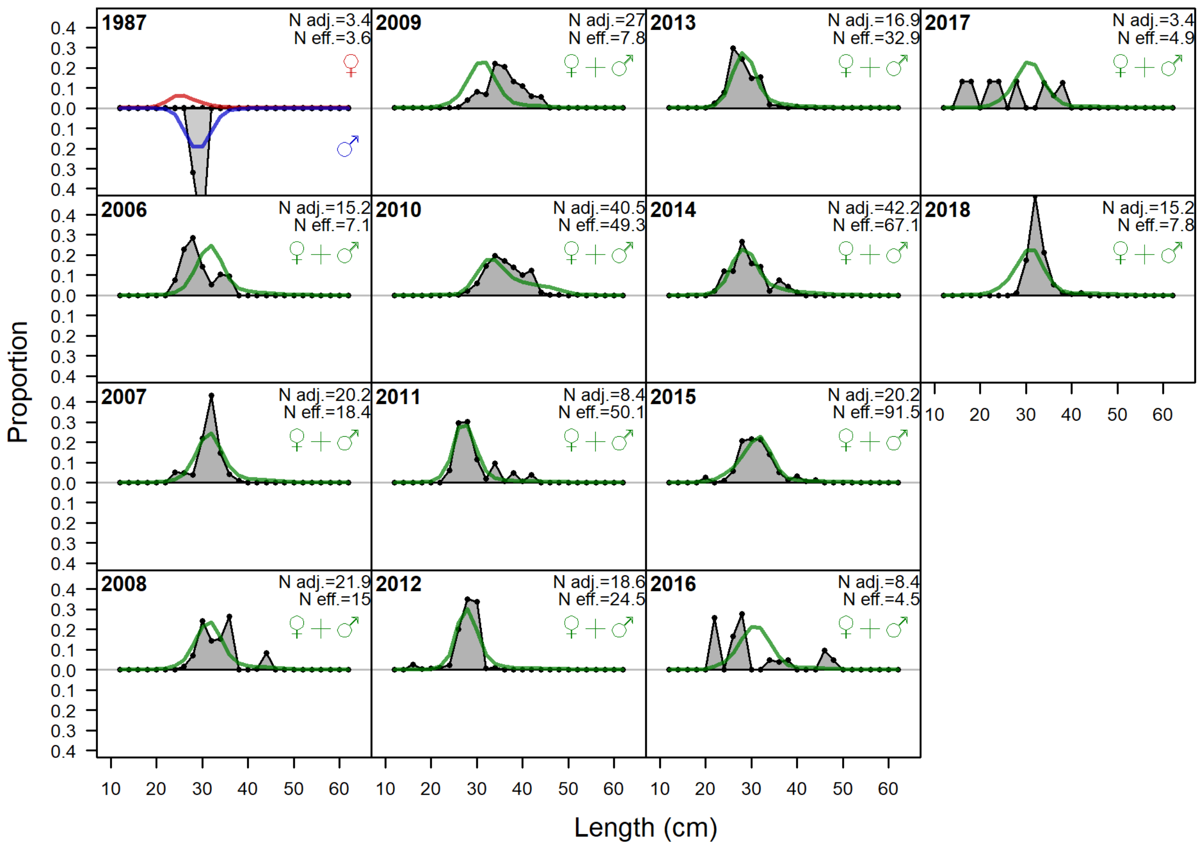

Figure 117: Length comps, discard, Winter (N). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

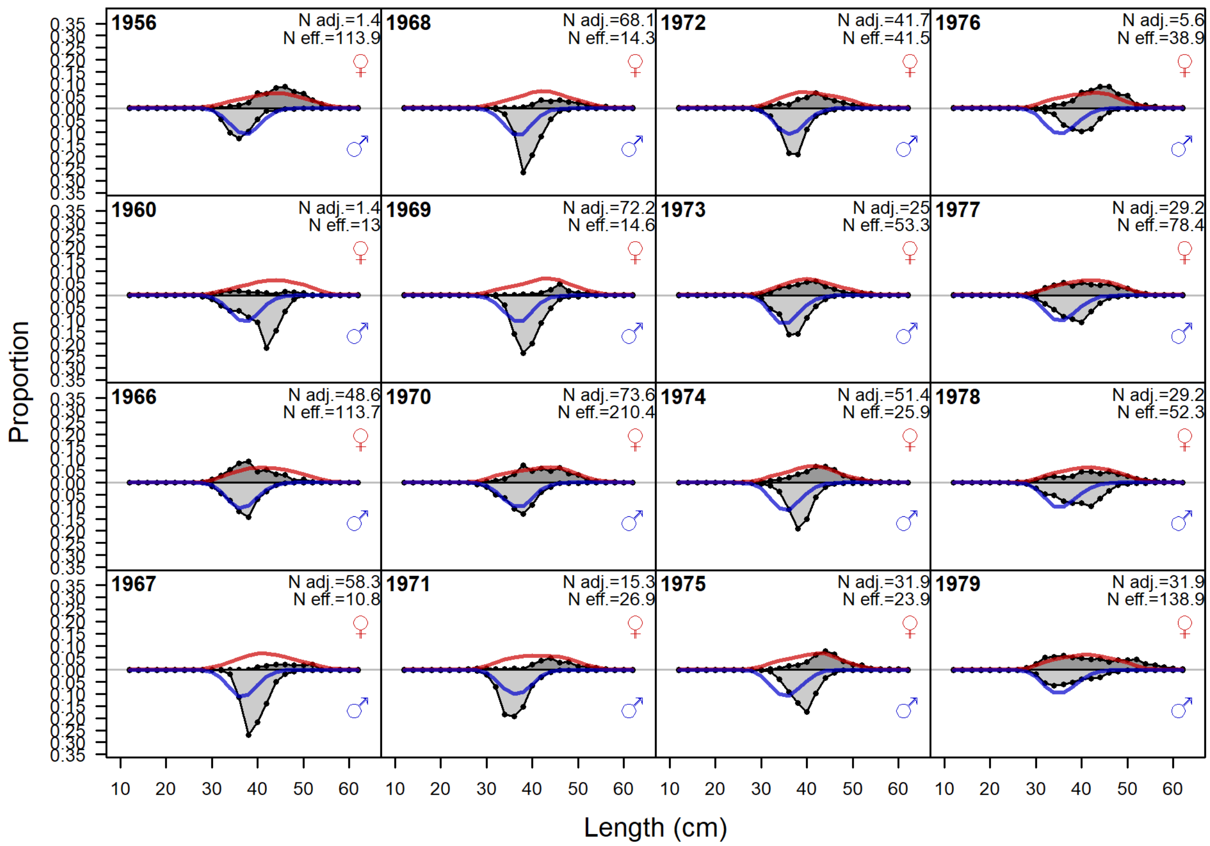

Figure 118: Length comps, retained, Summer (N) (plot 1 of 4). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

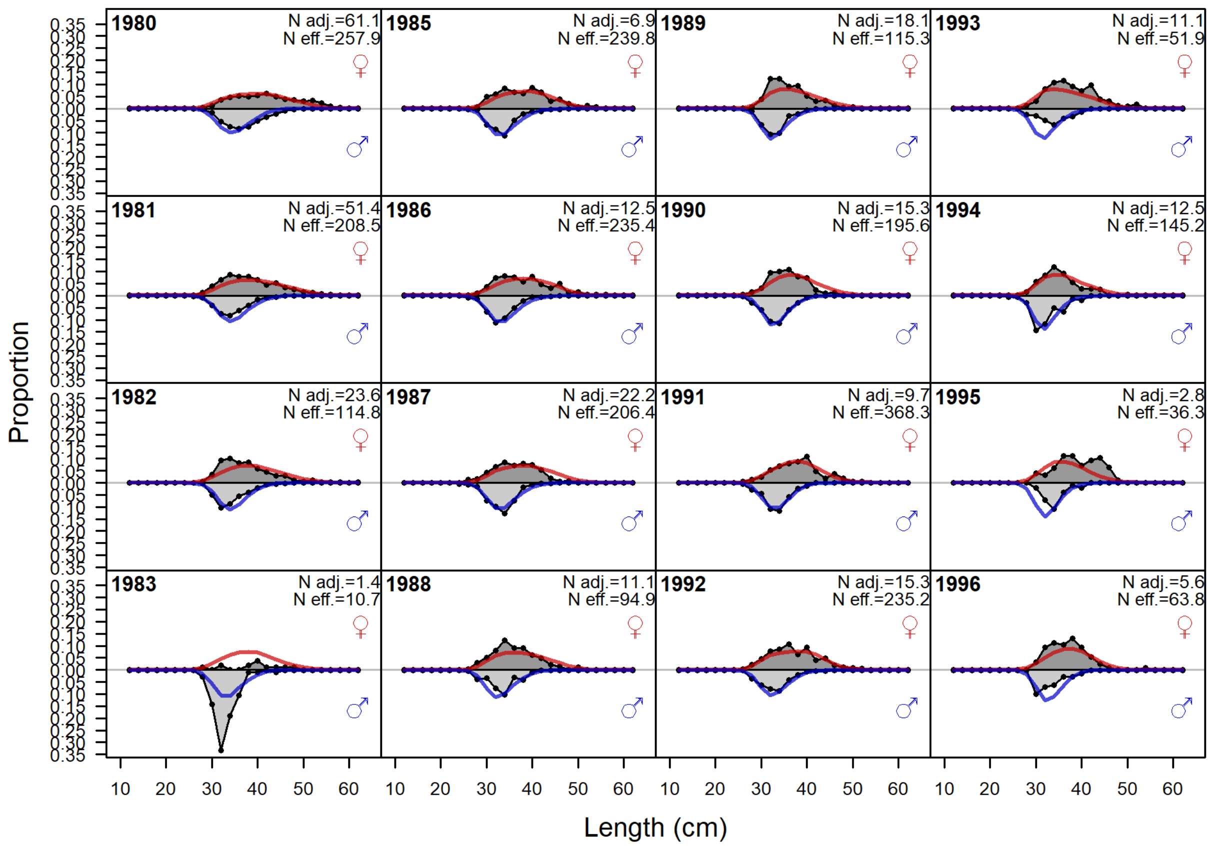

Figure 119: Length comps, retained, Summer (N) (plot 2 of 4) fig:length_fits

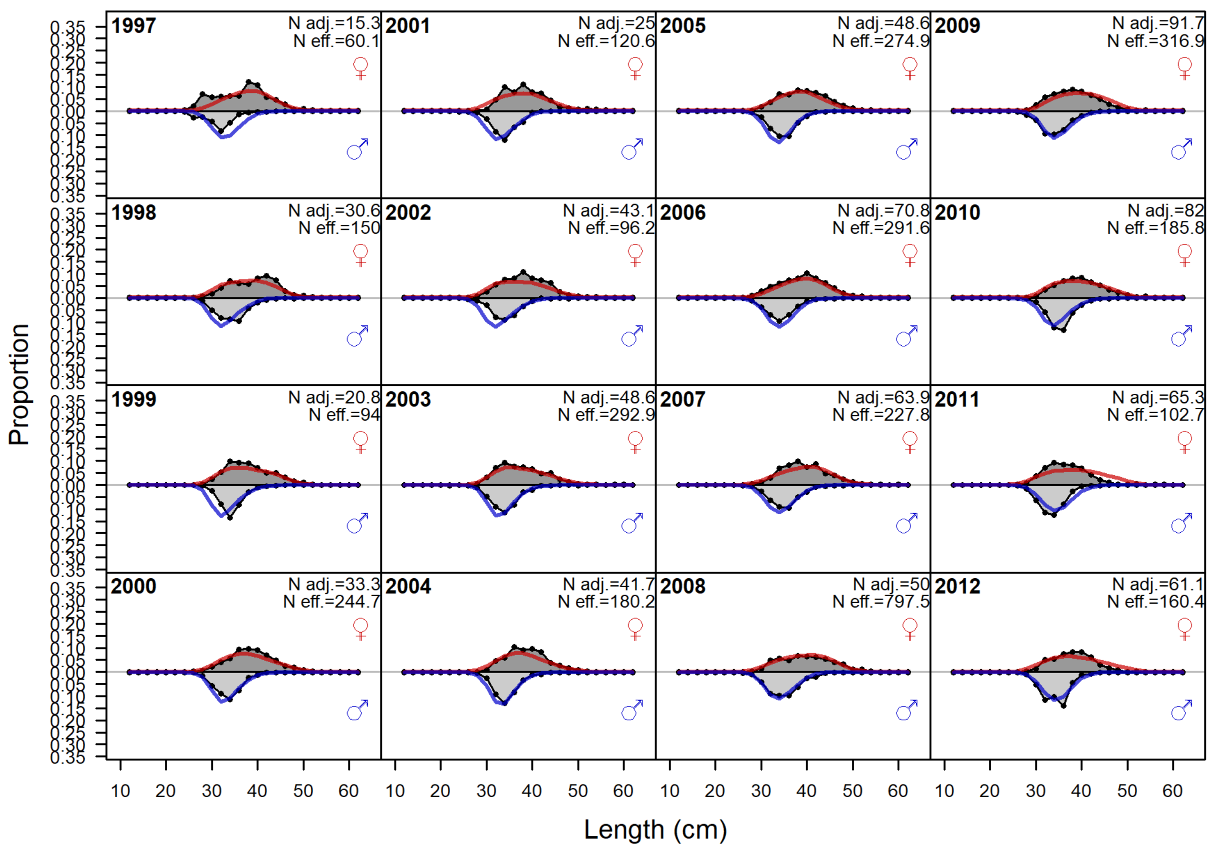

Figure 120: Length comps, retained, Summer (N) (plot 3 of 4) fig:length_fits

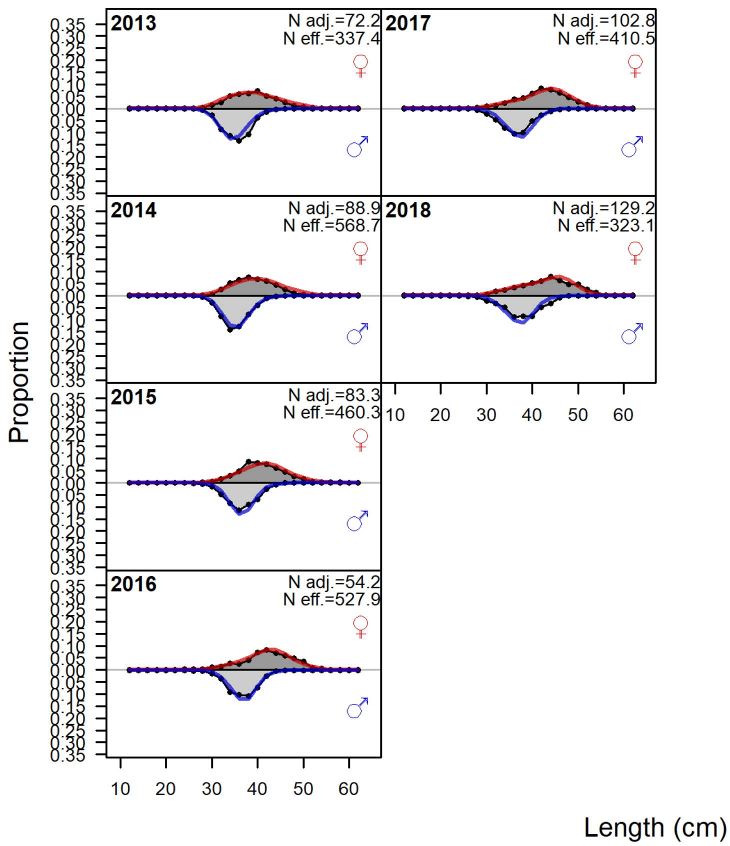

Figure 121: Length comps, retained, Summer (N) (plot 4 of 4) fig:length_fits

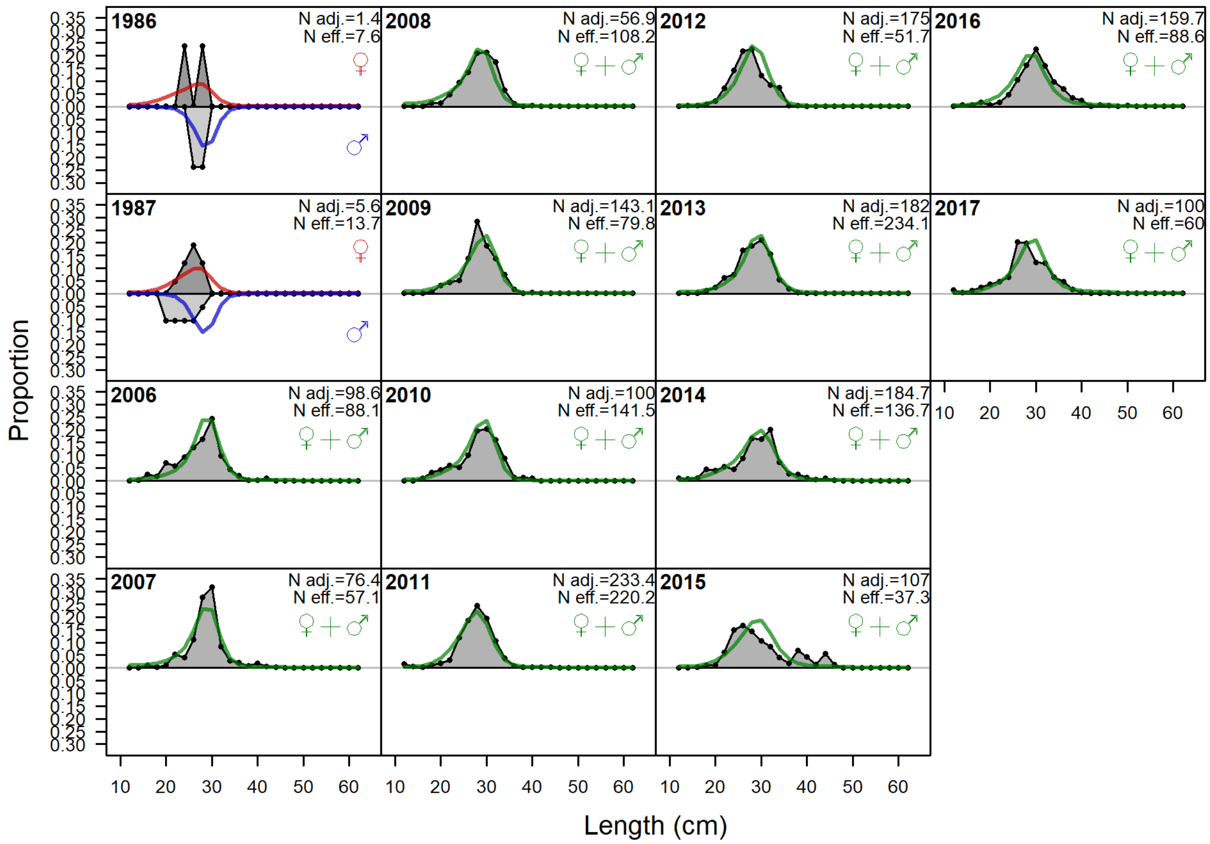

Figure 122: Length comps, discard, Summer (N). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

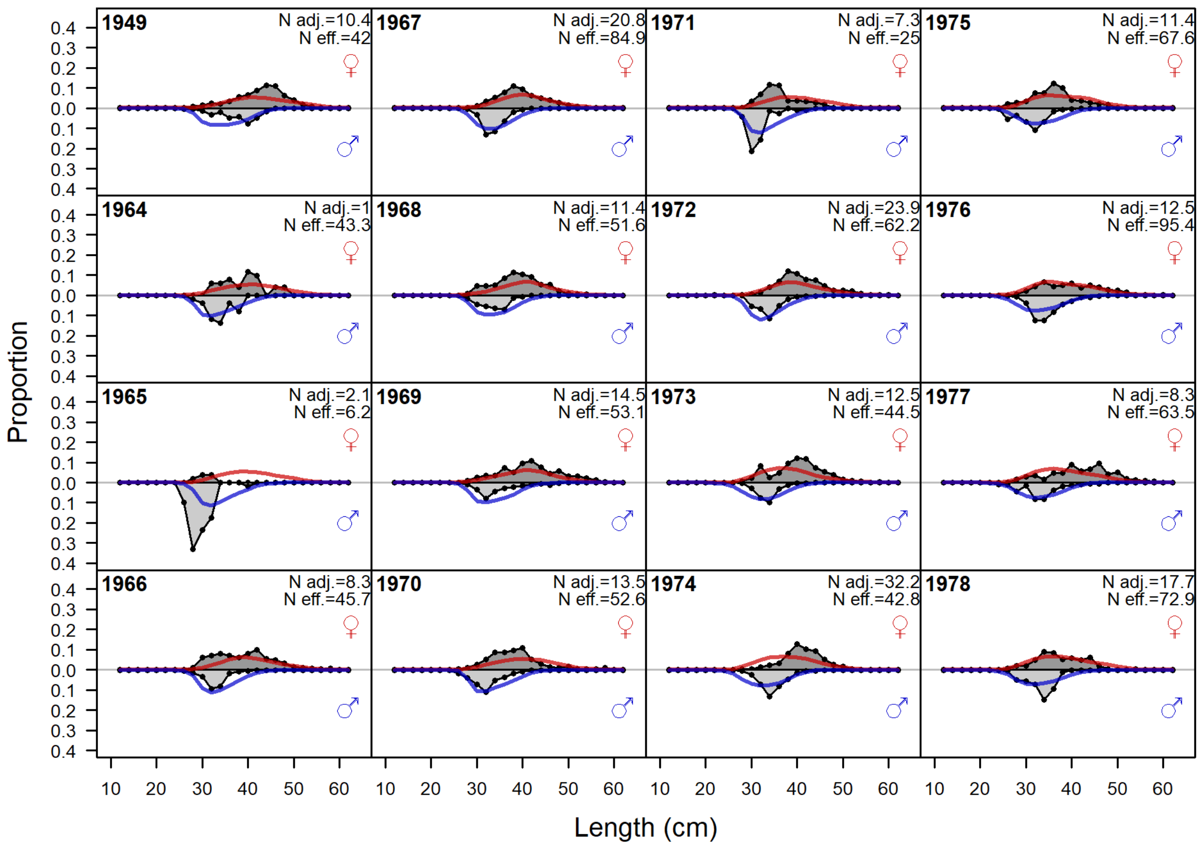

Figure 123: Length comps, retained, Winter (S) (plot 1 of 3). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

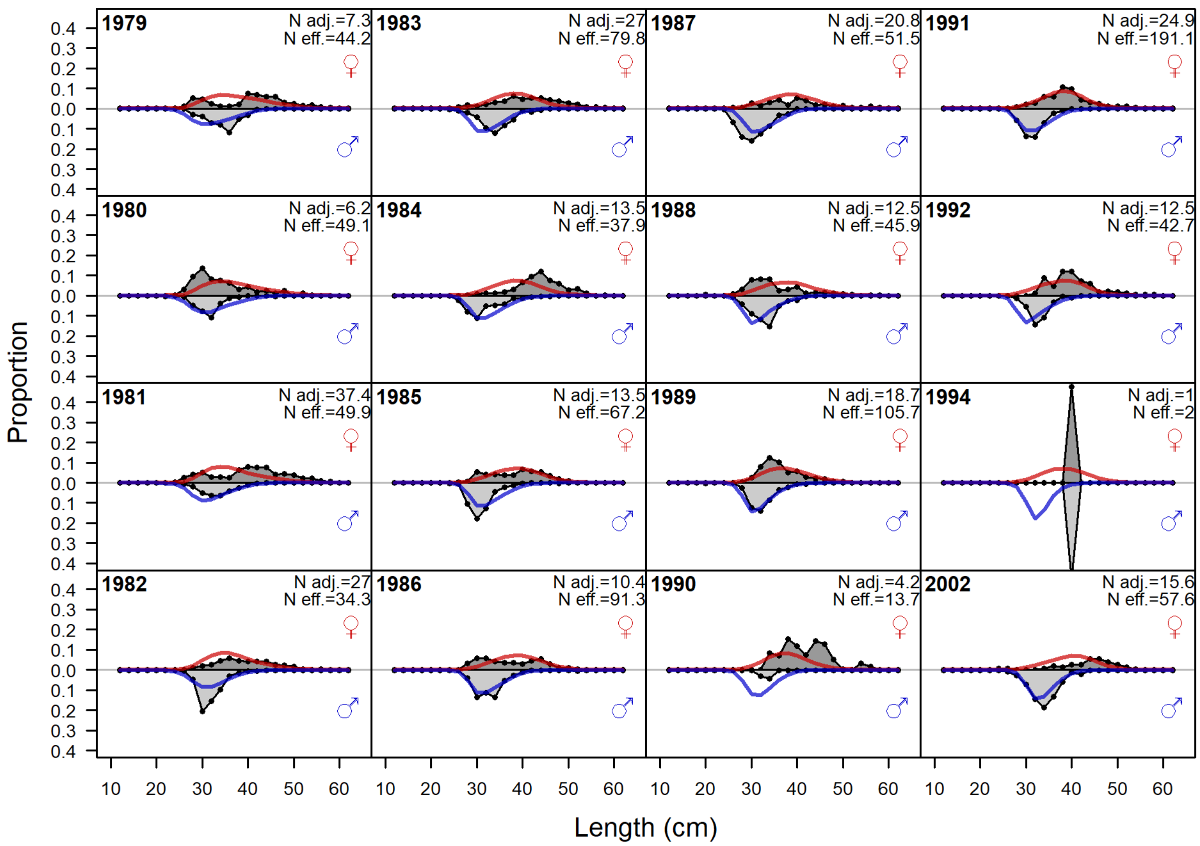

Figure 124: Length comps, retained, Winter (S) (plot 2 of 3) fig:length_fits

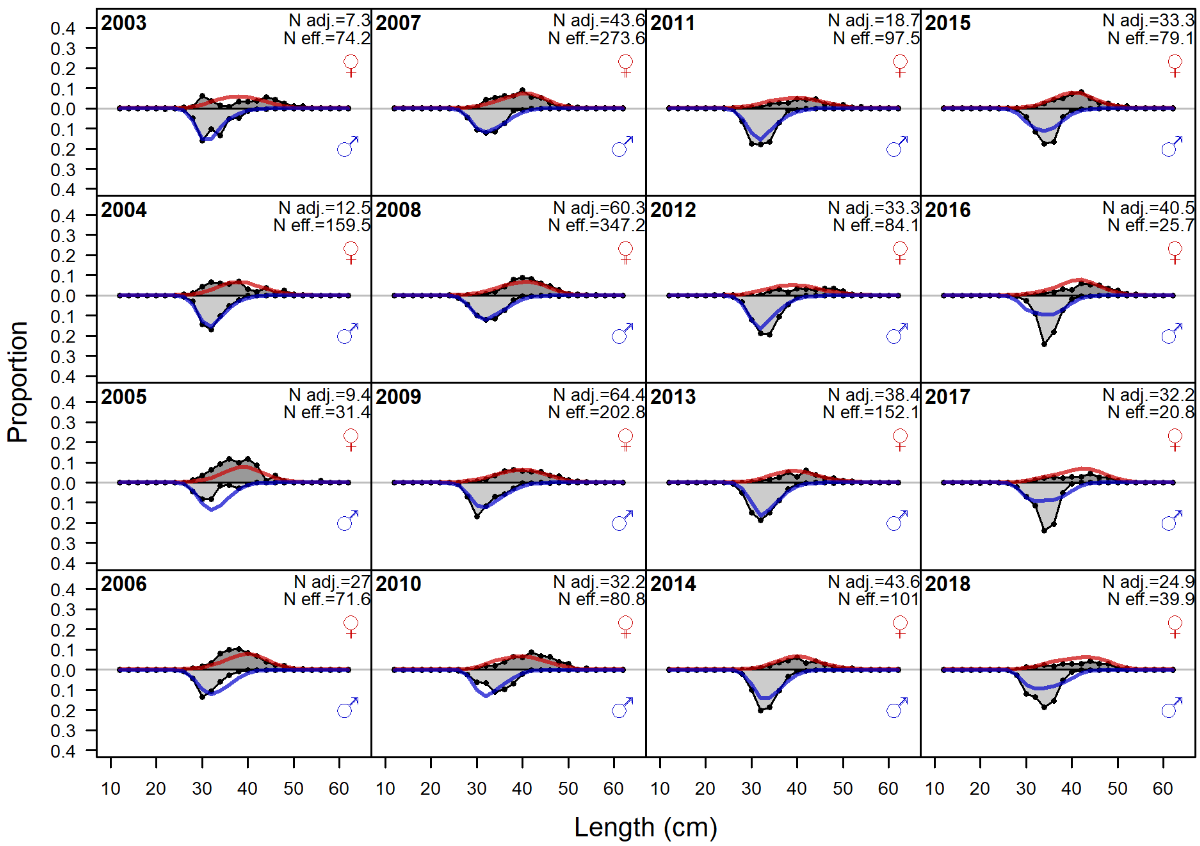

Figure 125: Length comps, retained, Winter (S) (plot 3 of 3) fig:length_fits

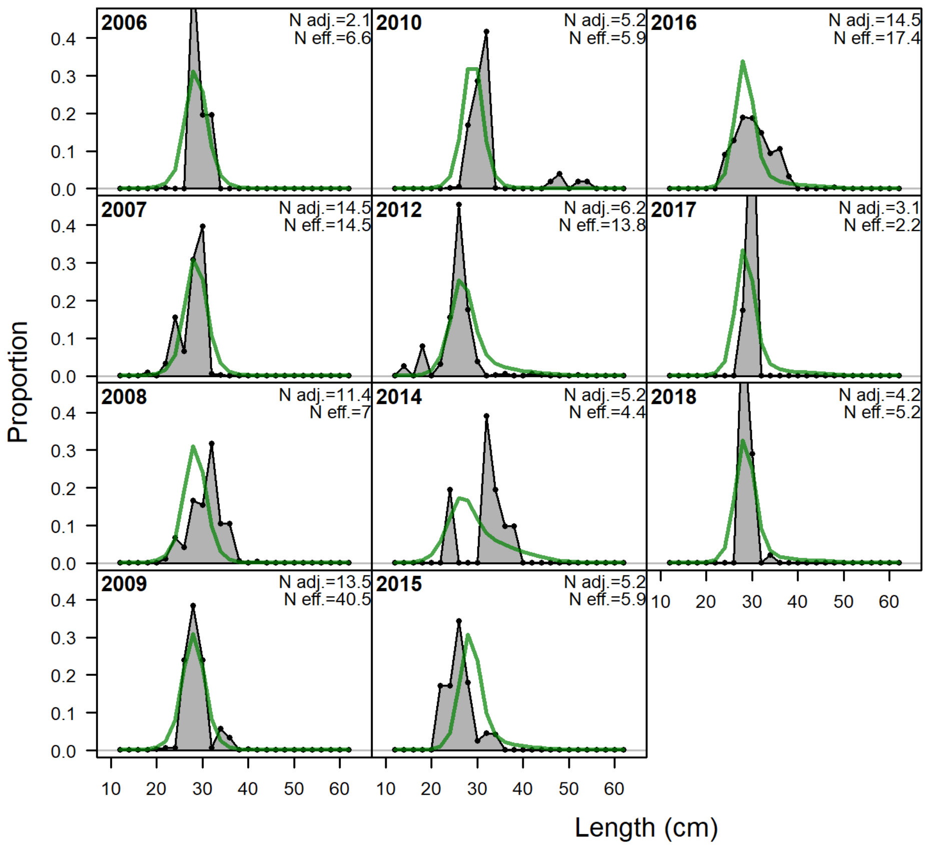

Figure 126: Length comps, discard, Winter (S). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

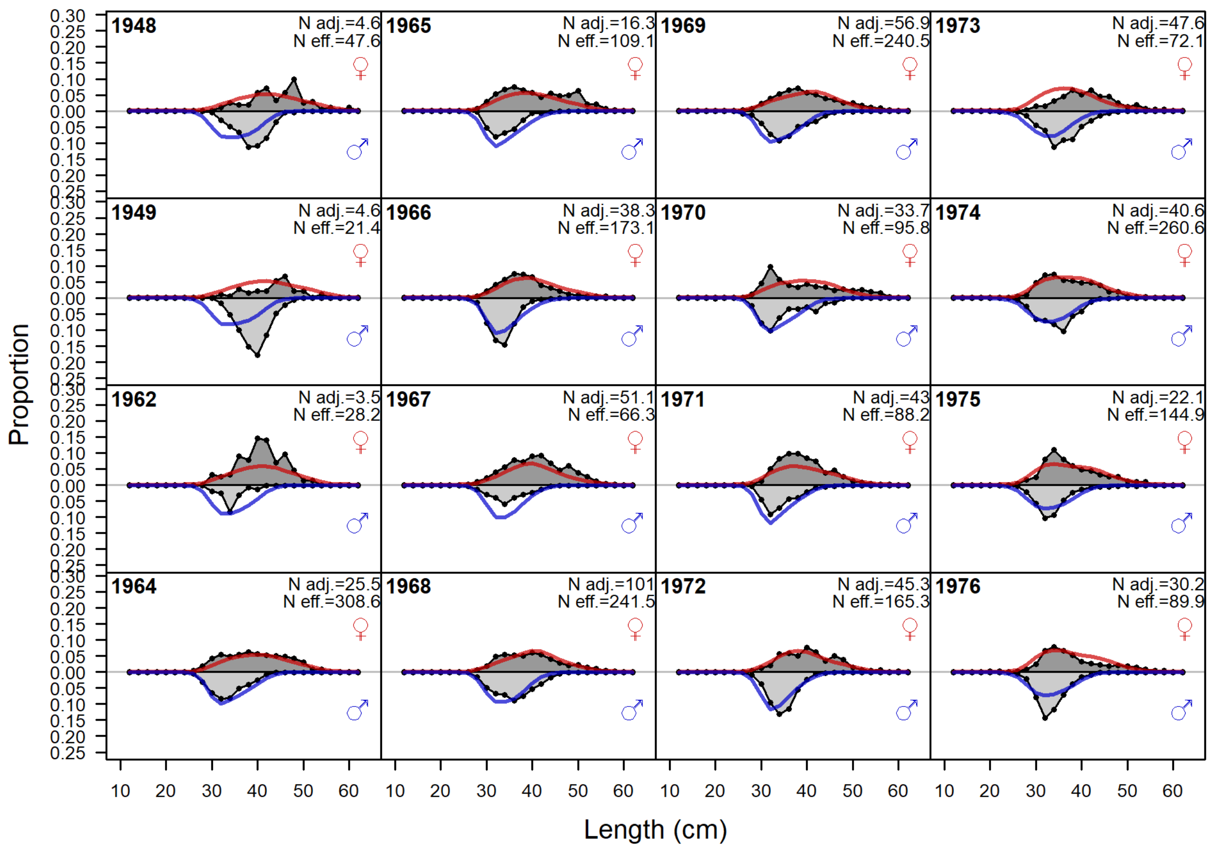

Figure 127: Length comps, retained, Summer (S) (plot 1 of 4). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

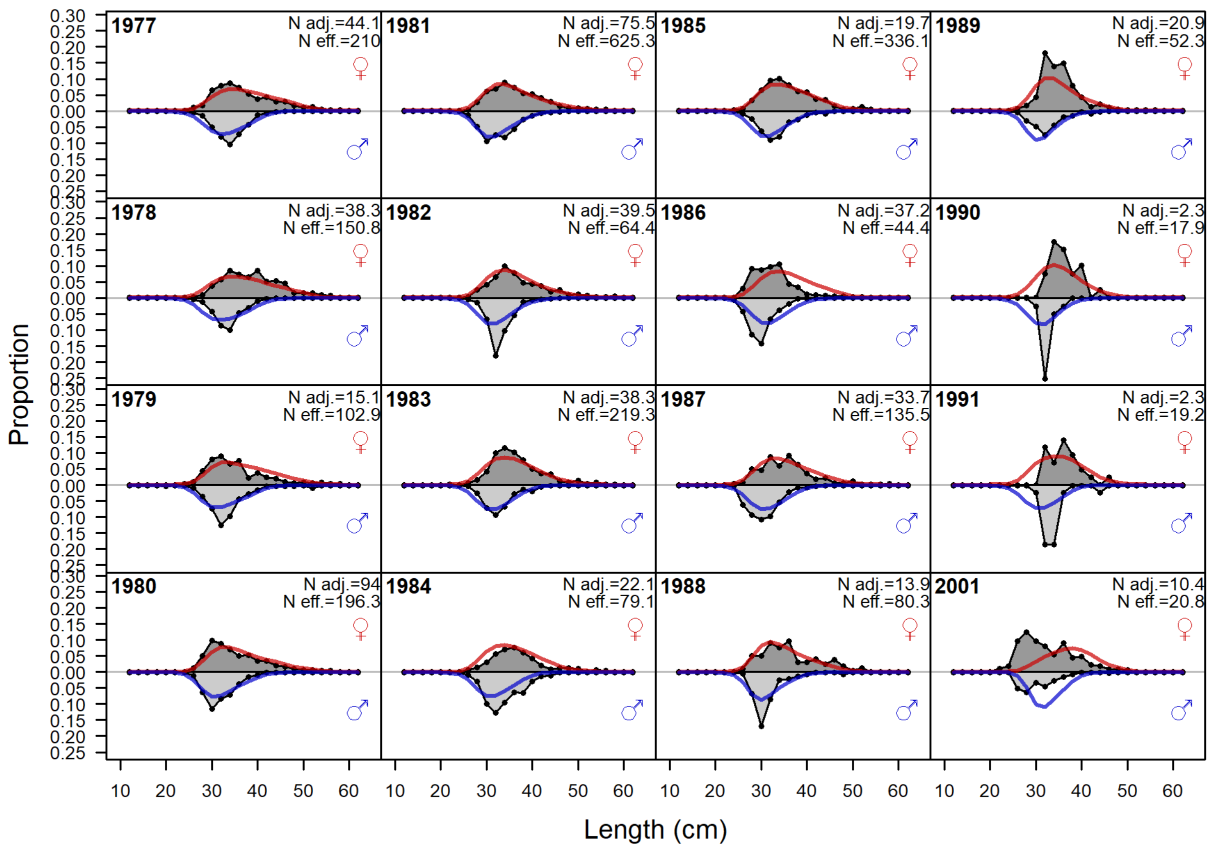

Figure 128: Length comps, retained, Summer (S) (plot 2 of 4) fig:length_fits

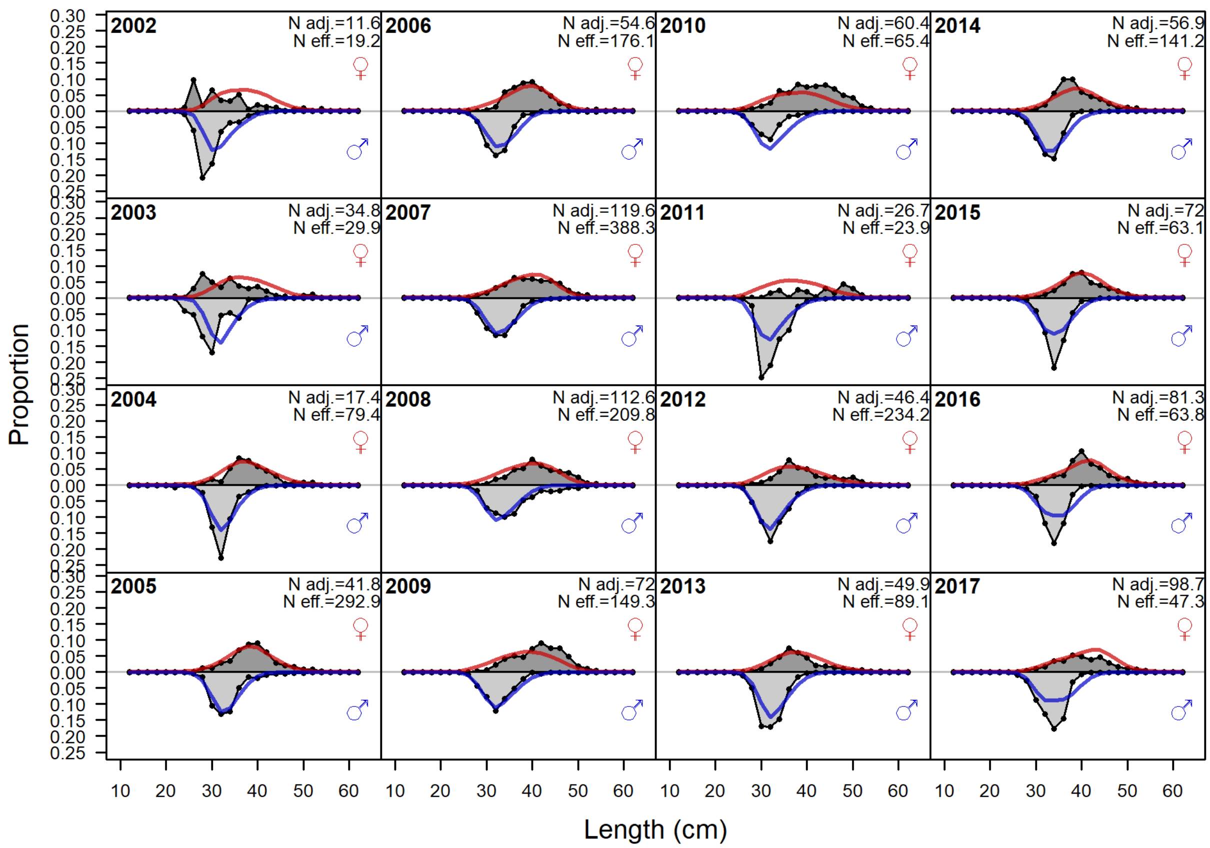

Figure 129: Length comps, retained, Summer (S) (plot 3 of 4) fig:length_fits

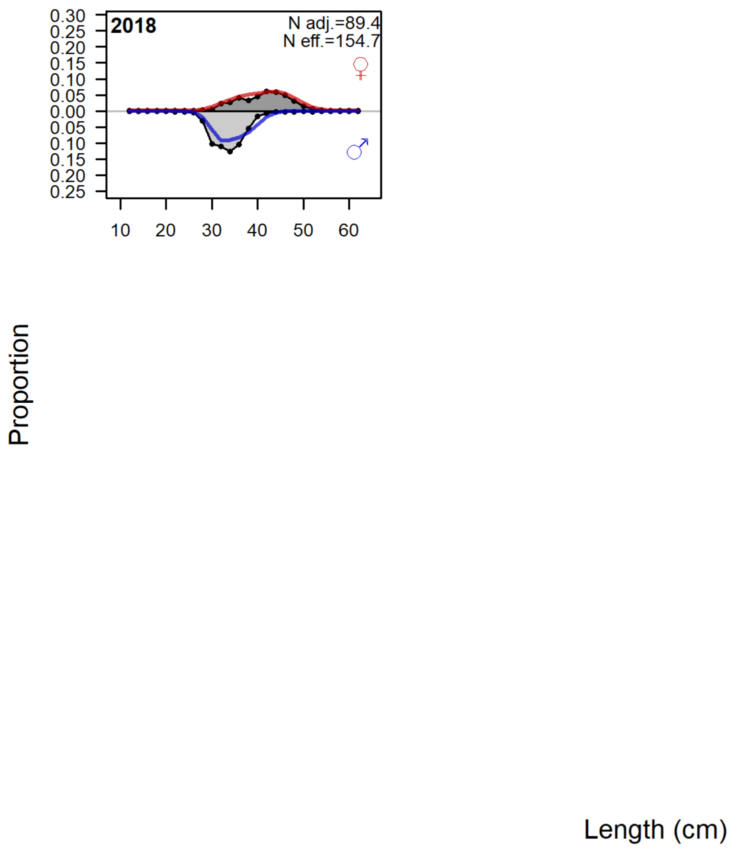

Figure 130: Length comps, retained, Summer (S) (plot 4 of 4) fig:length_fits

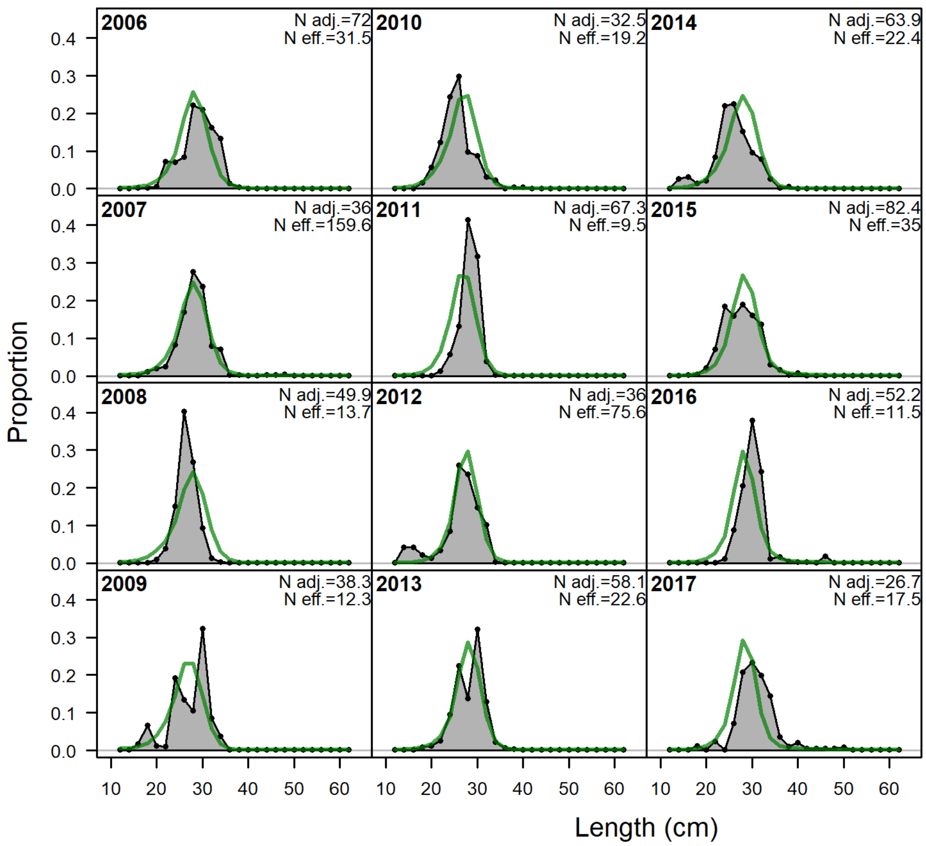

Figure 131: Length comps, discard, Summer (S). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

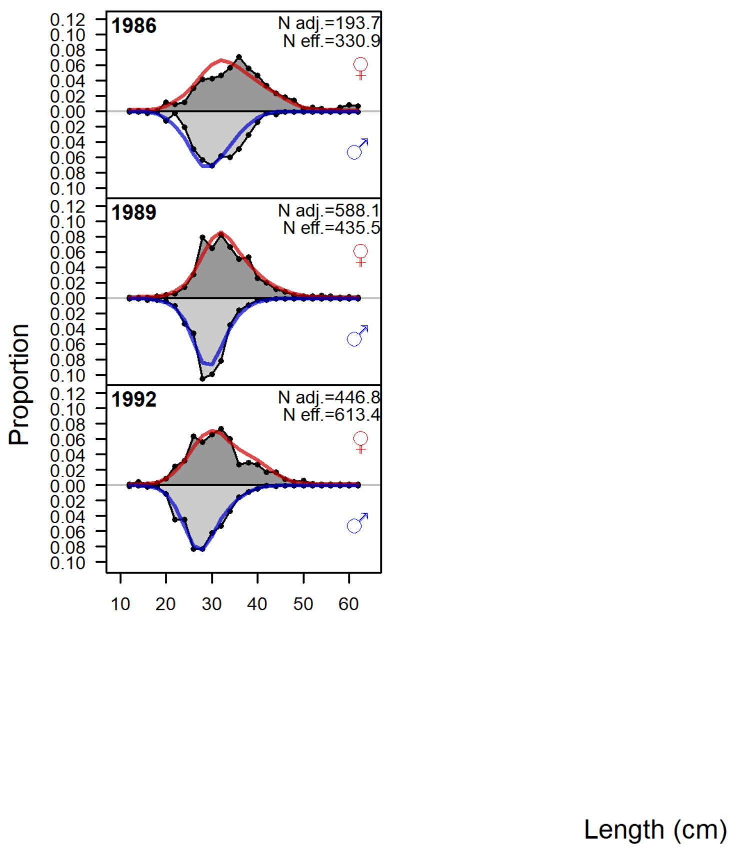

Figure 132: Length comps, whole catch, Triennial _ Early. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

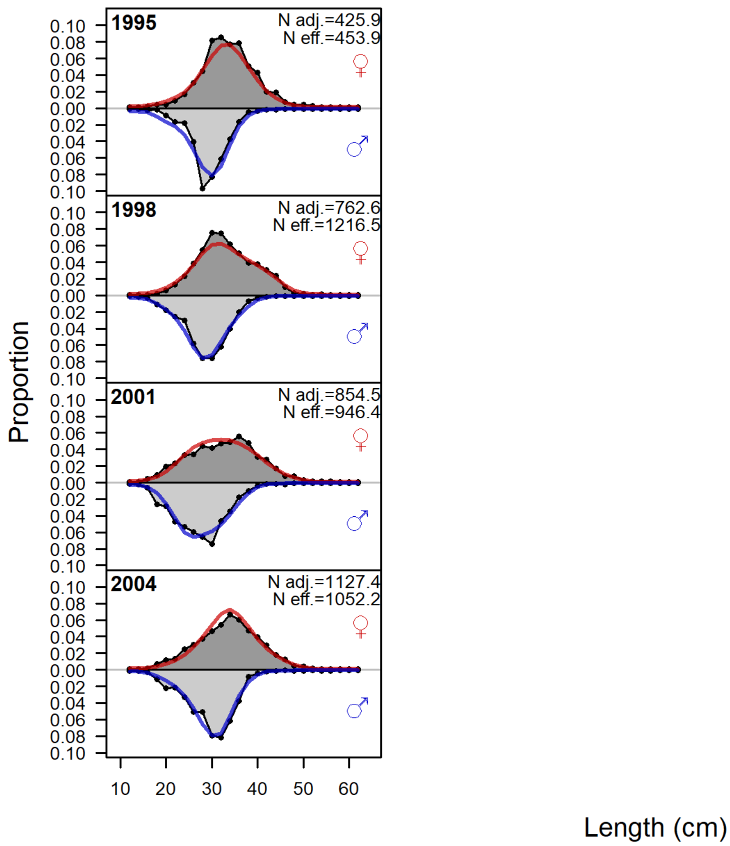

Figure 133: Length comps, whole catch, Triennial _ Late. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

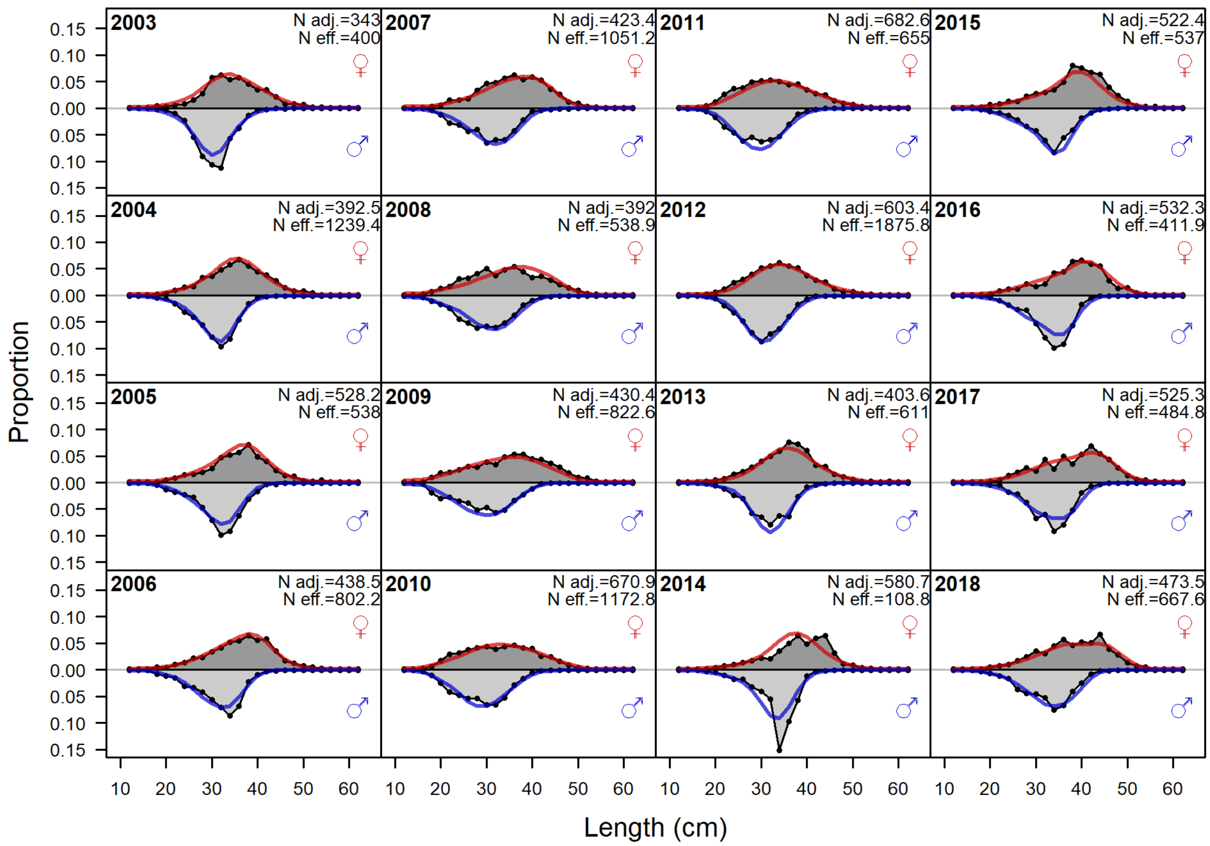

Figure 134: Length comps, whole catch, NWFSC West Coast Groundfish Bottom Trawl Survey. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:length_fits

12 Appendix B. Detailed Fit to Age Composition Data

appendix-b.-detailed-fit-to-age-composition-data

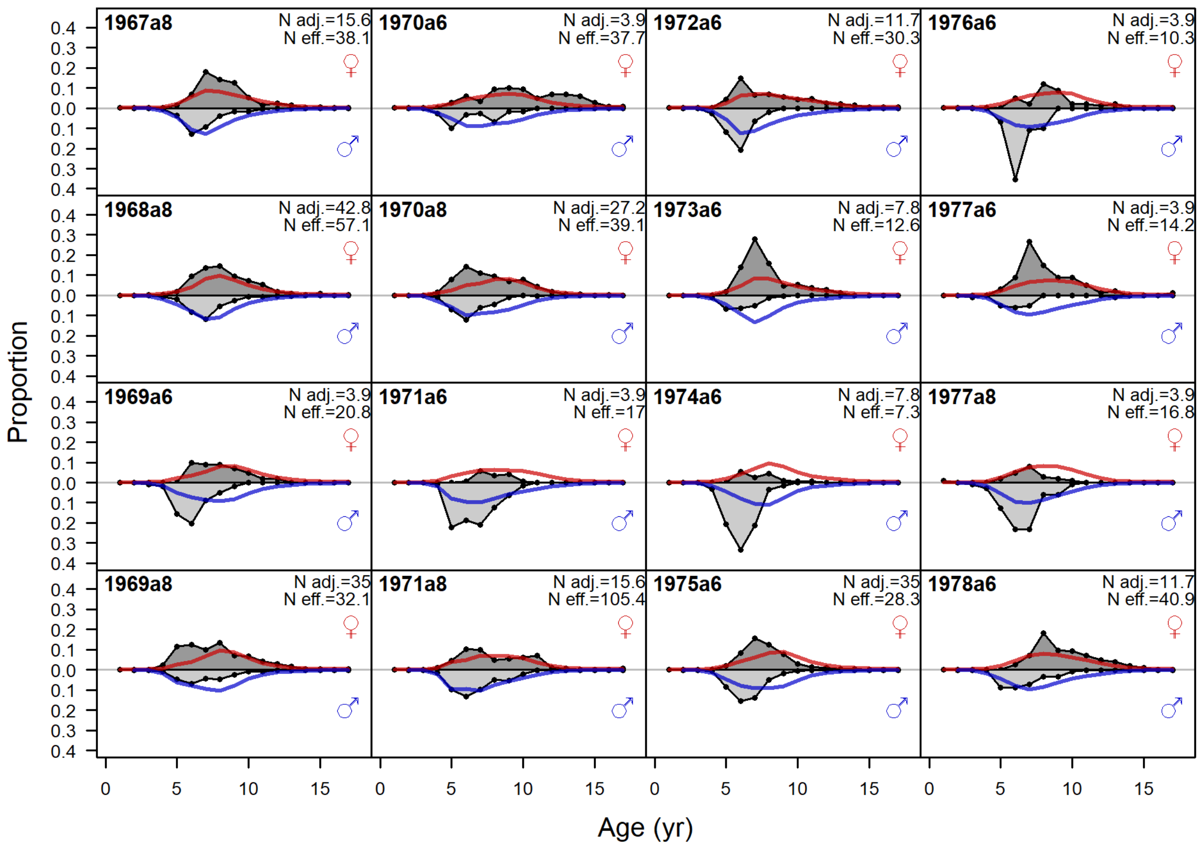

Figure 135: Age comps, retained, Winter (N) (plot 1 of 5). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:age_fits

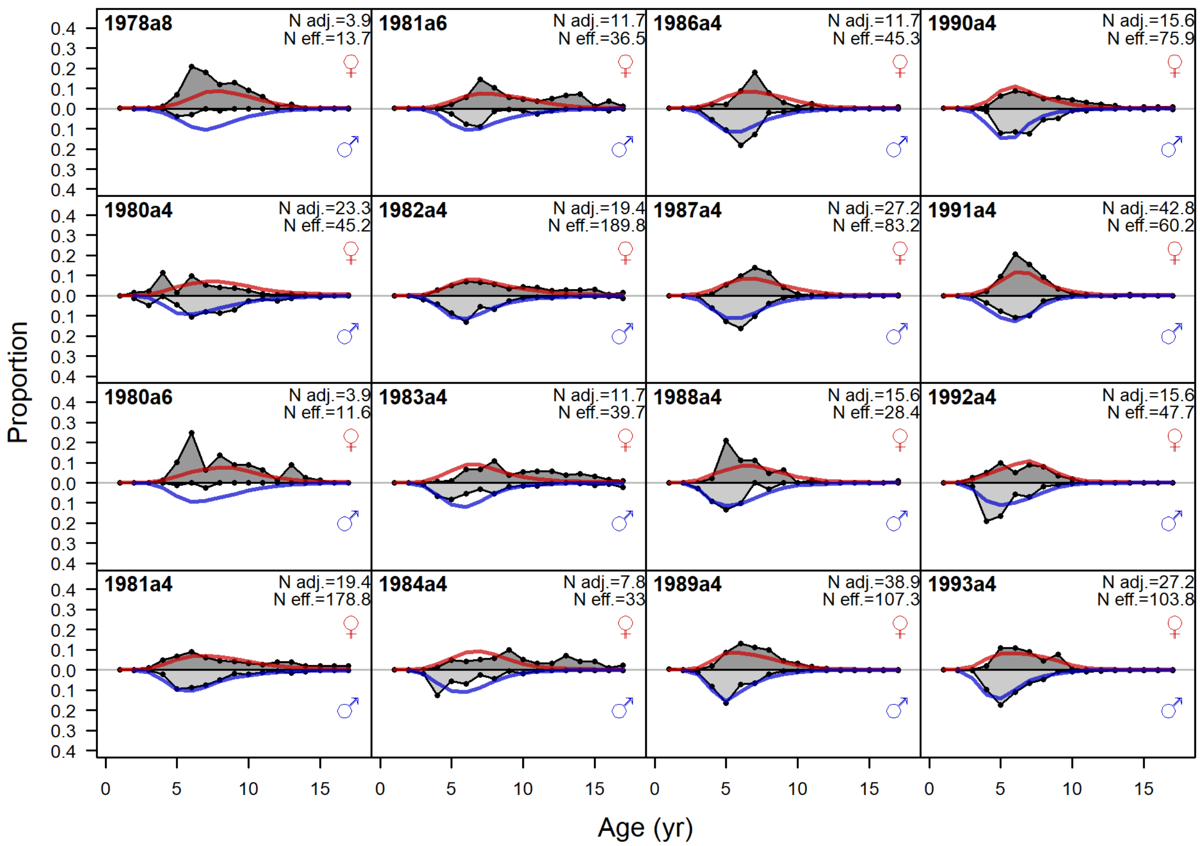

Figure 136: Age comps, retained, Winter (N) (plot 2 of 5) fig:age_fits

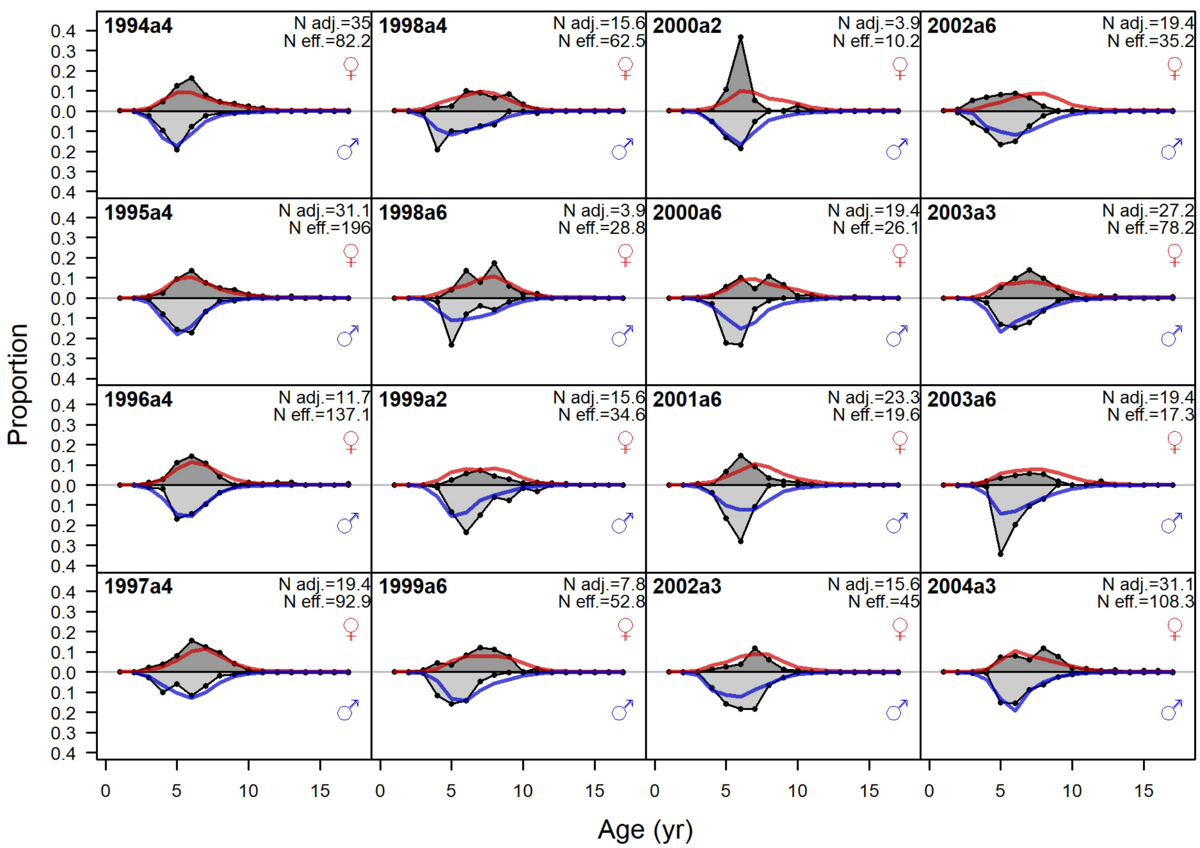

Figure 137: Age comps, retained, Winter (N) (plot 3 of 5) fig:age_fits

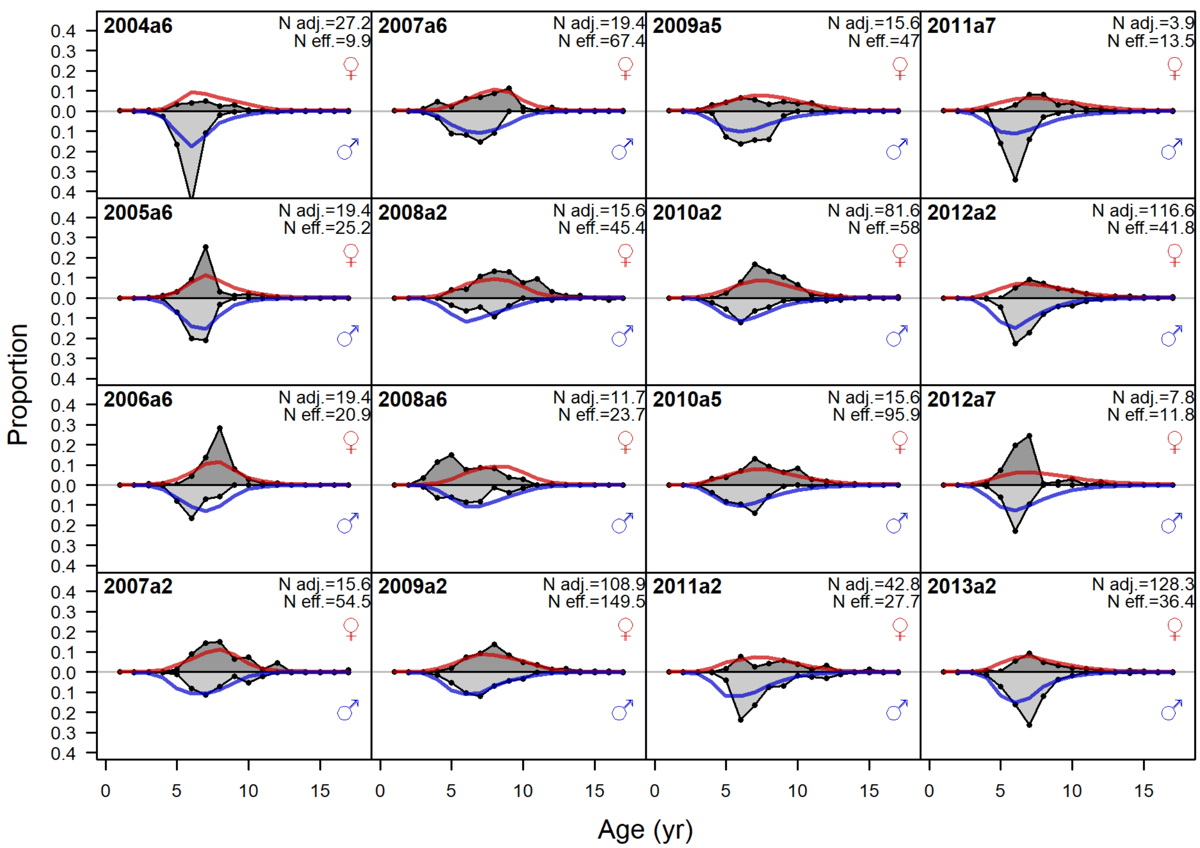

Figure 138: Age comps, retained, Winter (N) (plot 4 of 5) fig:age_fits

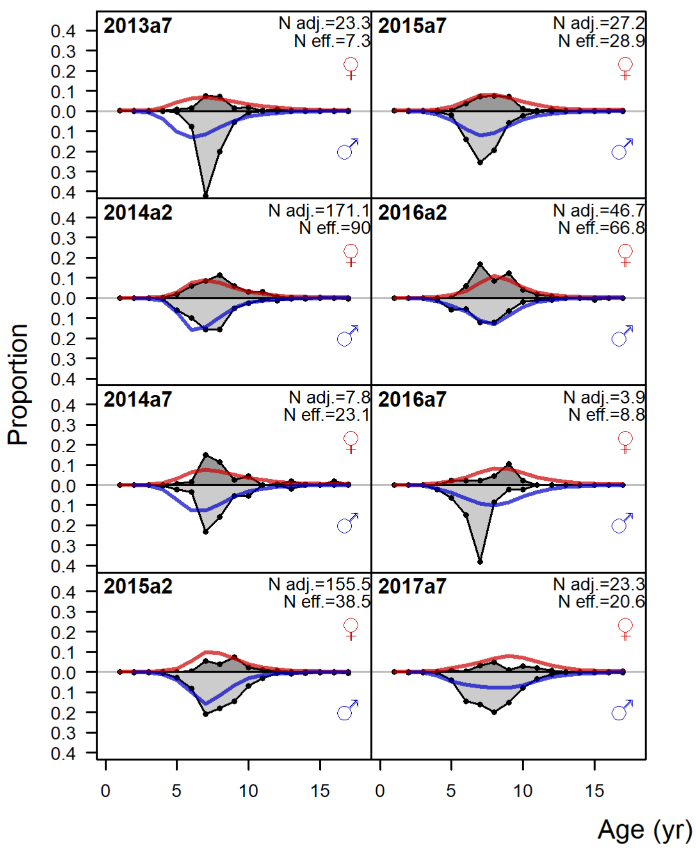

Figure 139: Age comps, retained, Winter (N) (plot 5 of 5) fig:age_fits

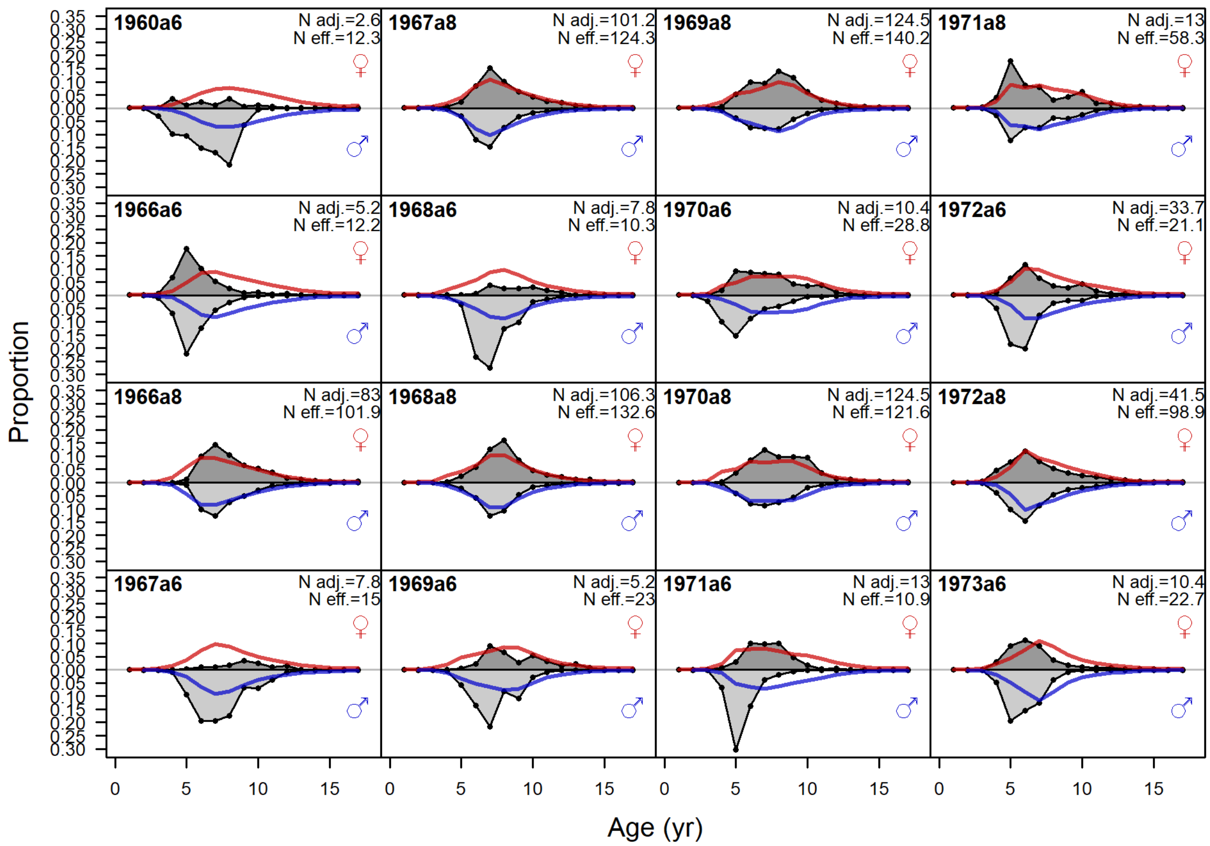

Figure 140: Age comps, retained, Summer (N) (plot 1 of 5). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:age_fits

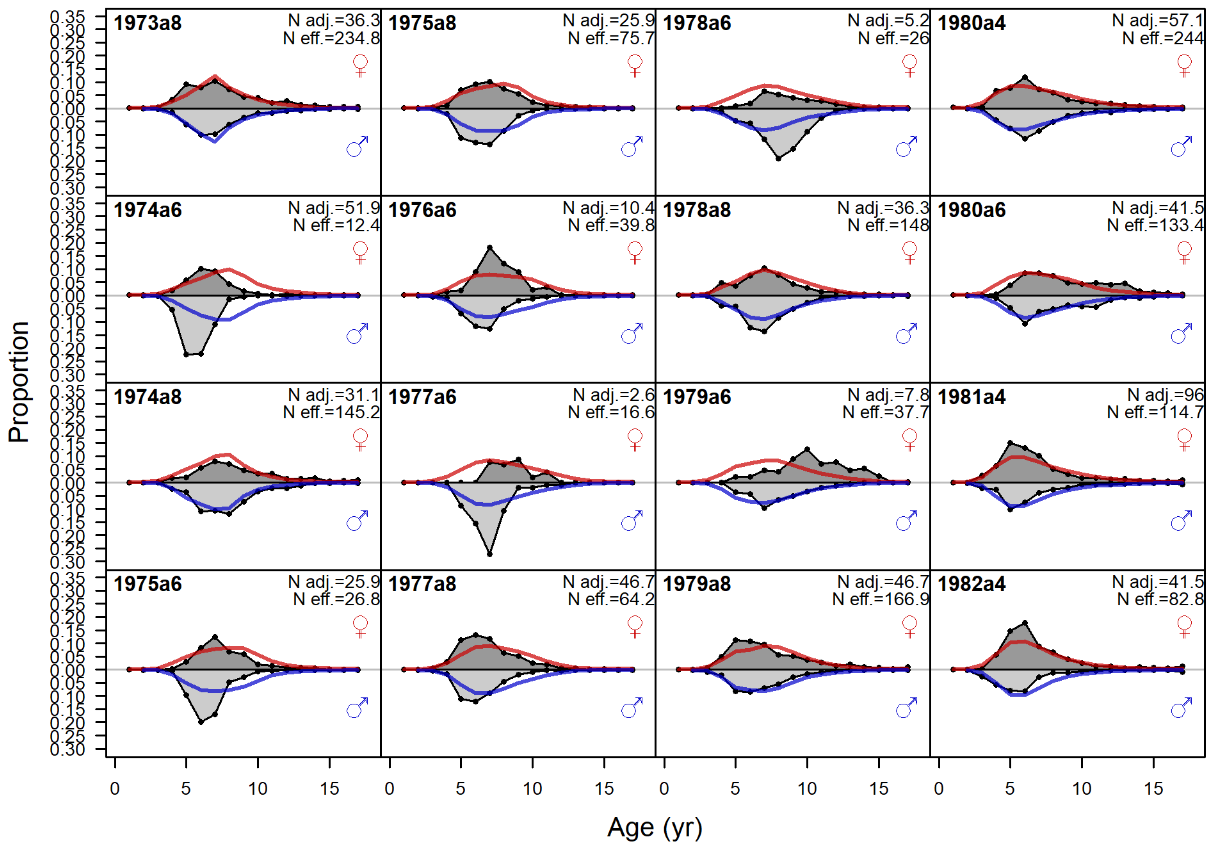

Figure 141: Age comps, retained, Summer (N) (plot 2 of 5) fig:age_fits

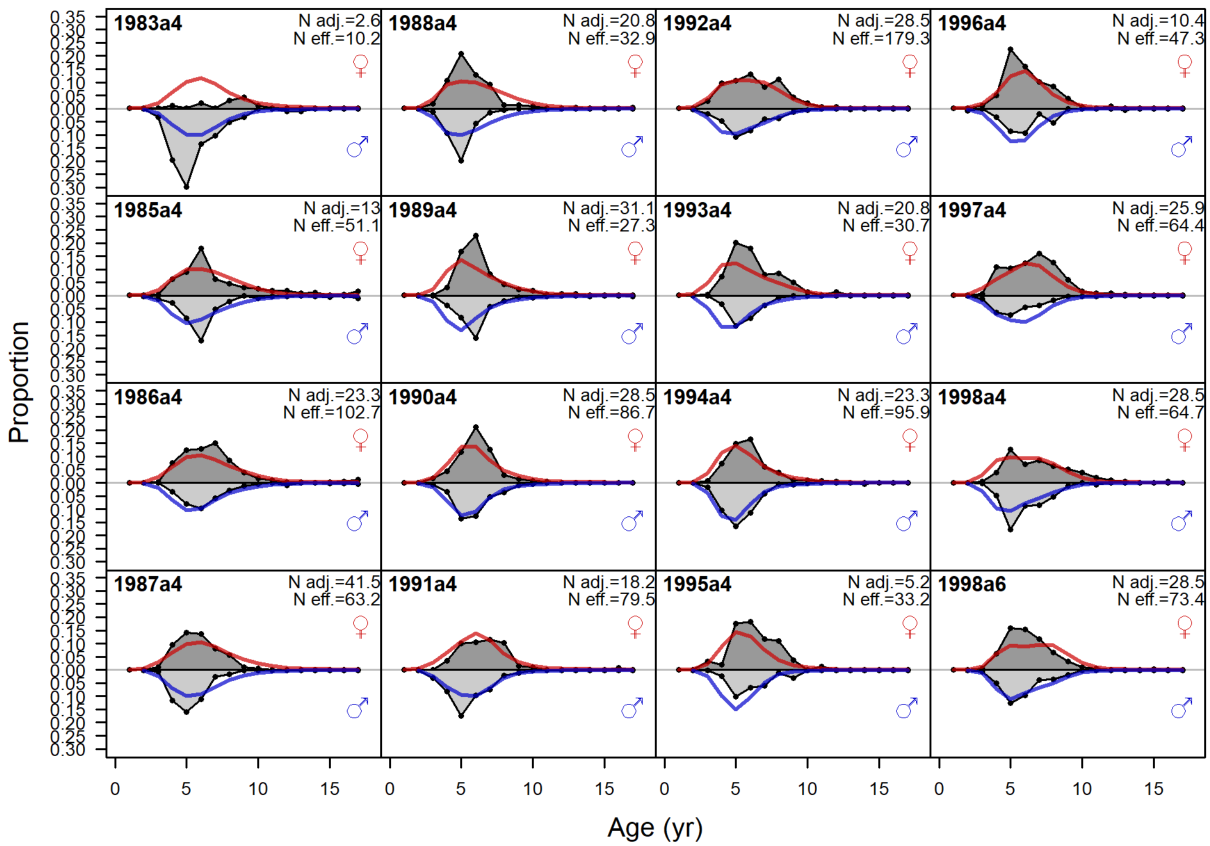

Figure 142: Age comps, retained, Summer (N) (plot 3 of 5) fig:age_fits

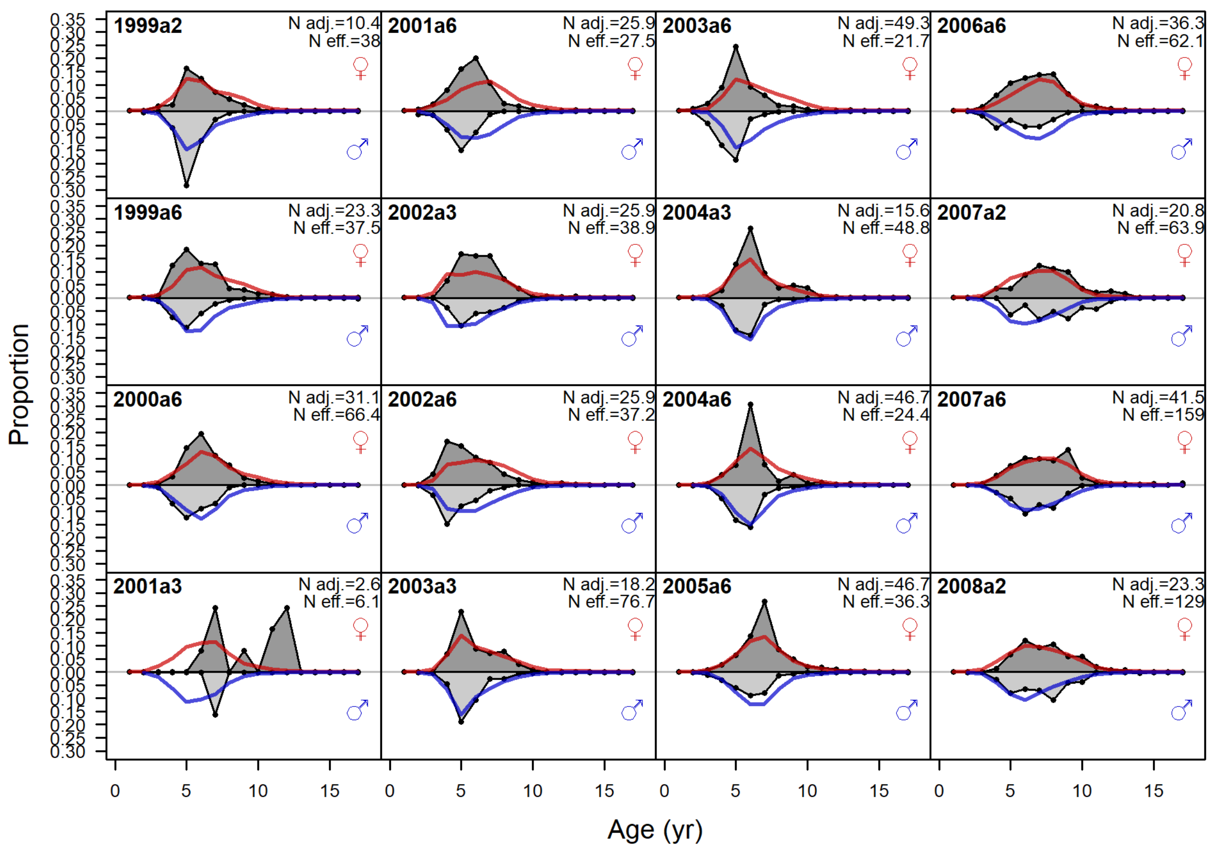

Figure 143: Age comps, retained, Summer (N) (plot 4 of 5) fig:age_fits

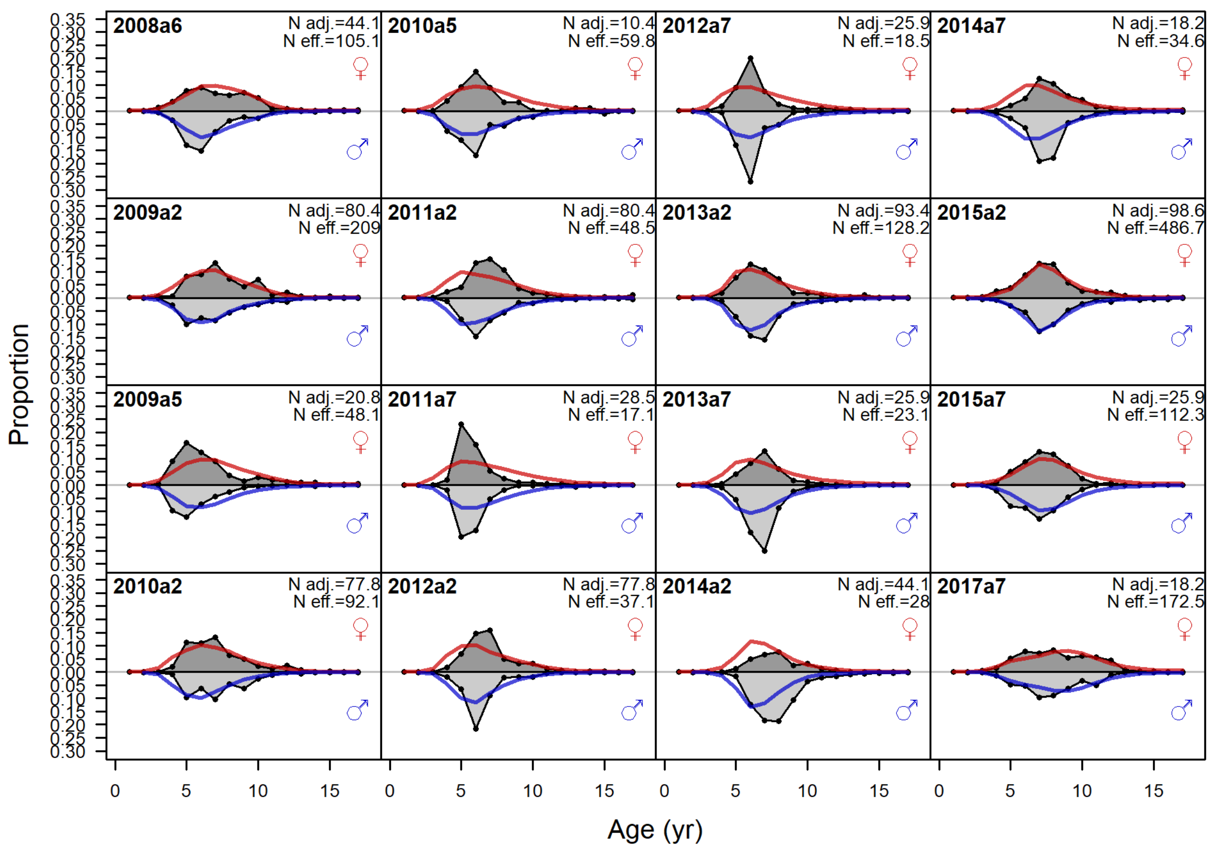

Figure 144: Age comps, retained, Summer (N) (plot 5 of 5) fig:age_fits

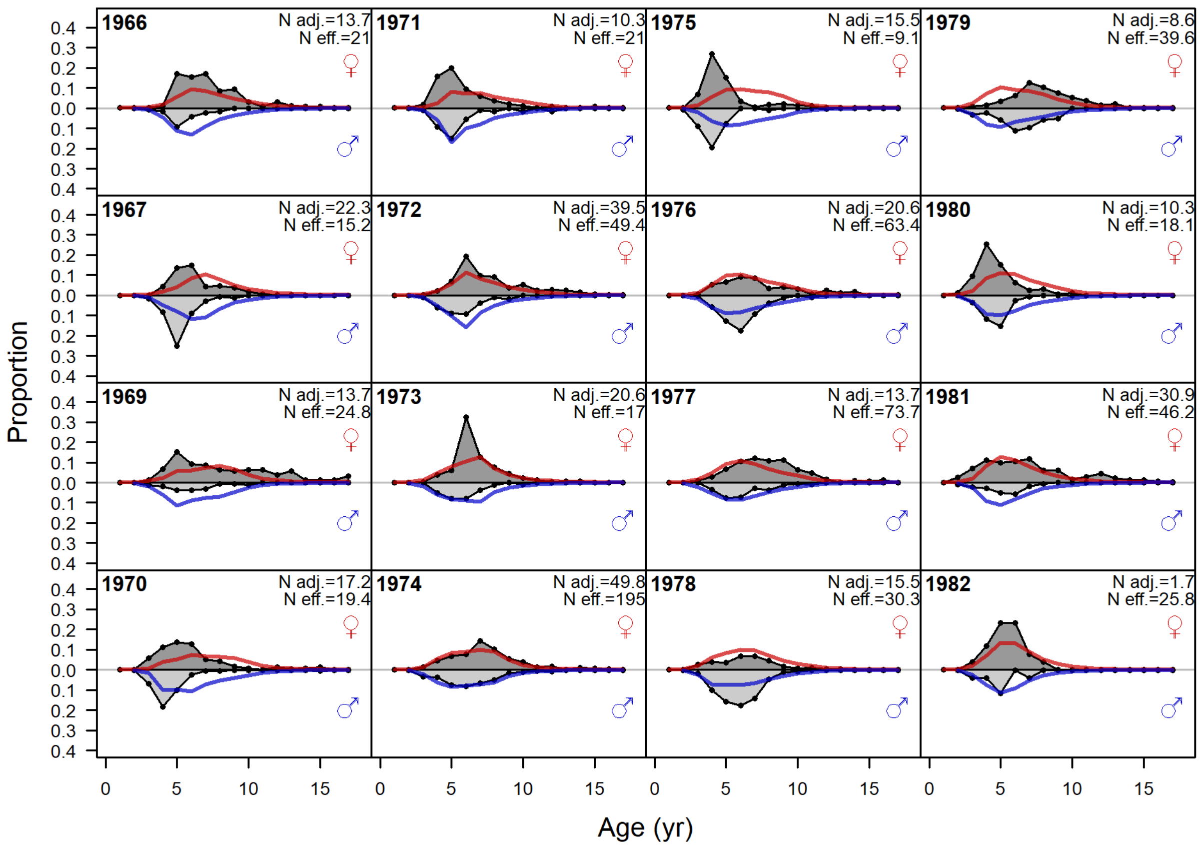

Figure 145: Age comps, retained, Winter (S) (plot 1 of 3). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:age_fits

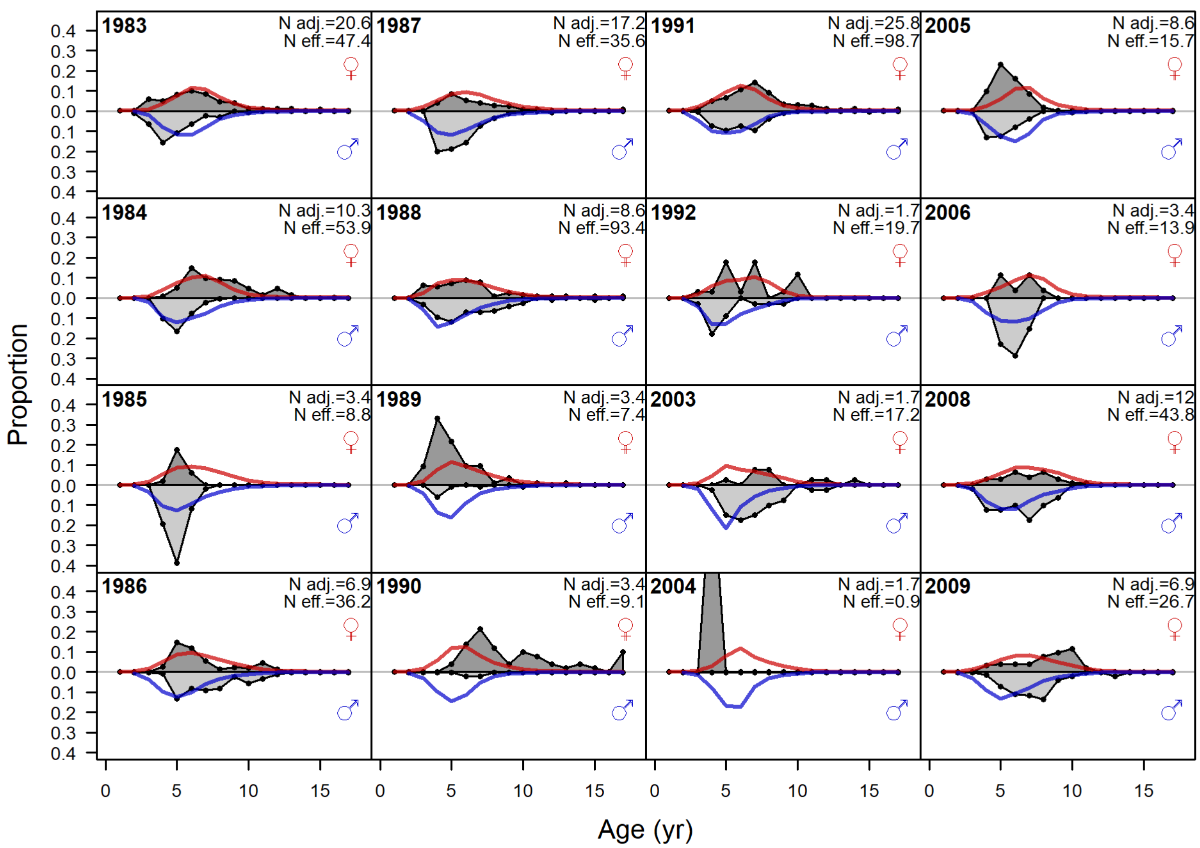

Figure 146: Age comps, retained, Winter (S) (plot 2 of 3) fig:age_fits

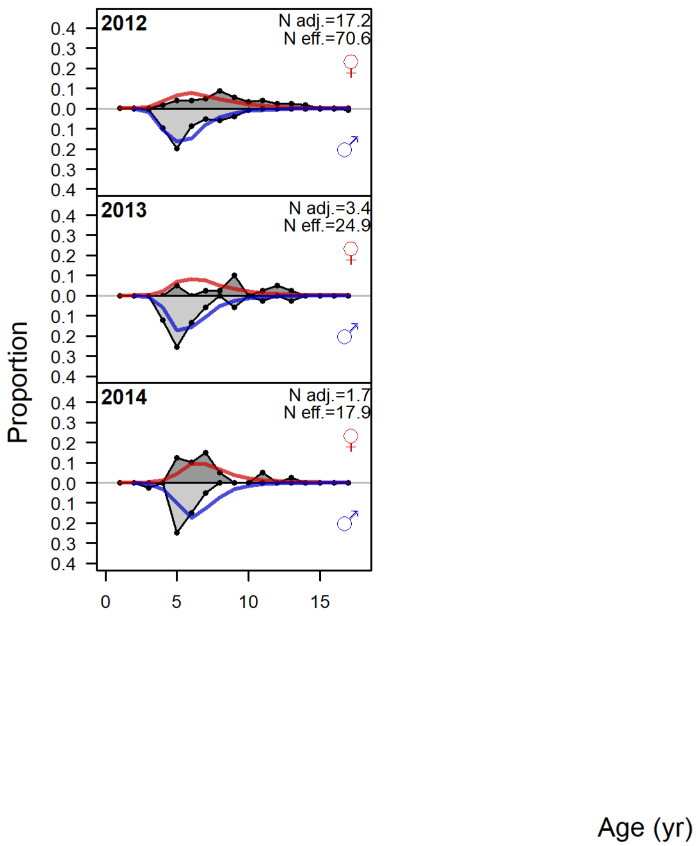

Figure 147: Age comps, retained, Winter (S) (plot 3 of 3) fig:age_fits

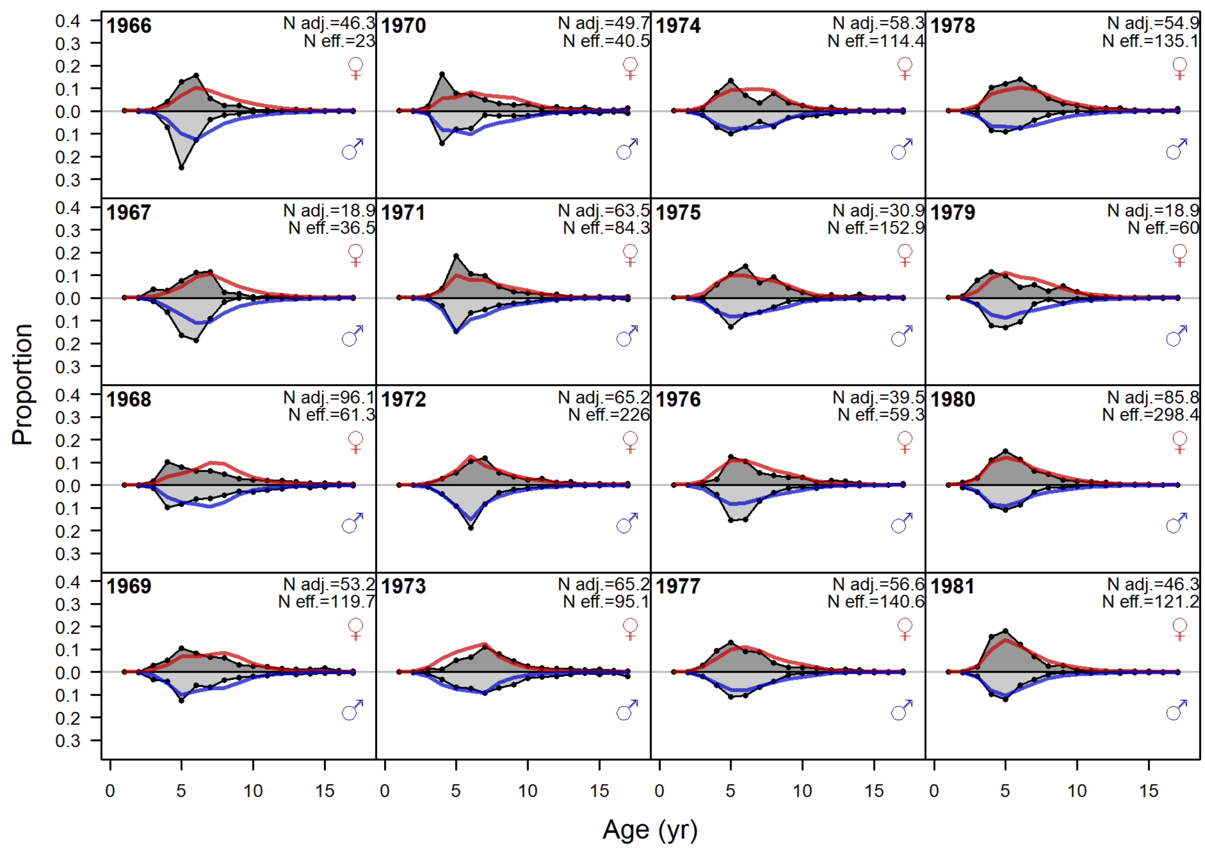

Figure 148: Age comps, retained, Summer (S) (plot 1 of 3). 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:age_fits

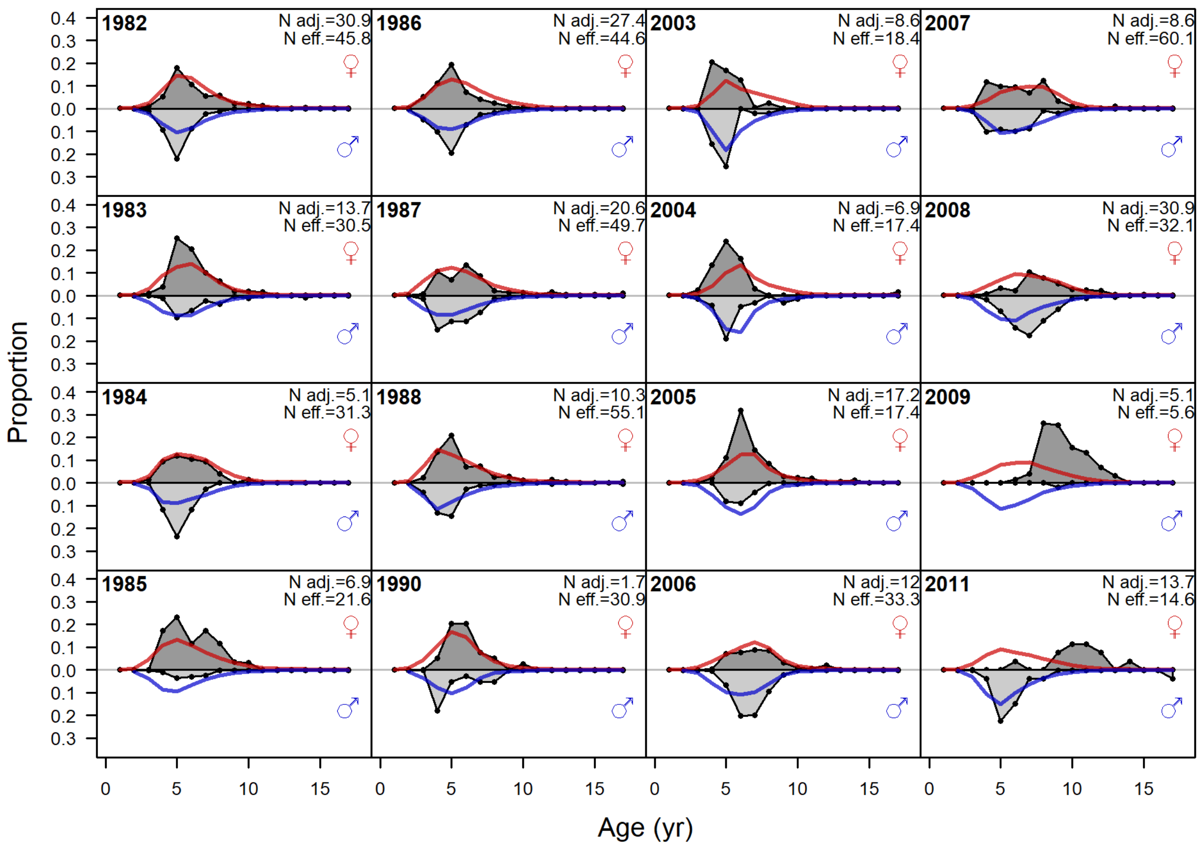

Figure 149: Age comps, retained, Summer (S) (plot 2 of 3) fig:age_fits

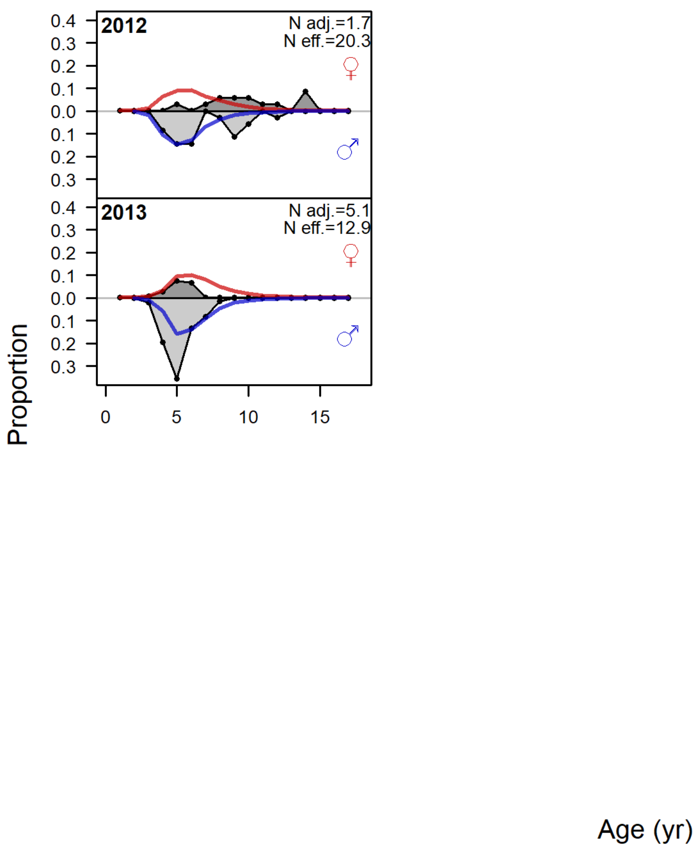

Figure 150: Age comps, retained, Summer (S) (plot 3 of 3) fig:age_fits

13 Appendix C. List of Auxiliary Files Available

`appendix-c.-list-of-auxiliary-files-available`

The listed files are also available as auxiliary files to accompany the assessment document:

1. Numbers at age for female and male petrale sole (Petrale natagef.csv and Petrale natagem.csv)
2. The petrale sole Stock Synthesis 3.30.13 model files
   (a) 2019petrale.dat
   (b) 2019petrale.ctl
   (c) forecast.ss
   (d) starter.ss

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