Status of Petrale sole (*Eopsetta jordani*) along the US west coast in 2019

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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 during 1981-2014 range between 749-2,903 mt (Table XX, Figure XX). 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 (Figure XX). 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

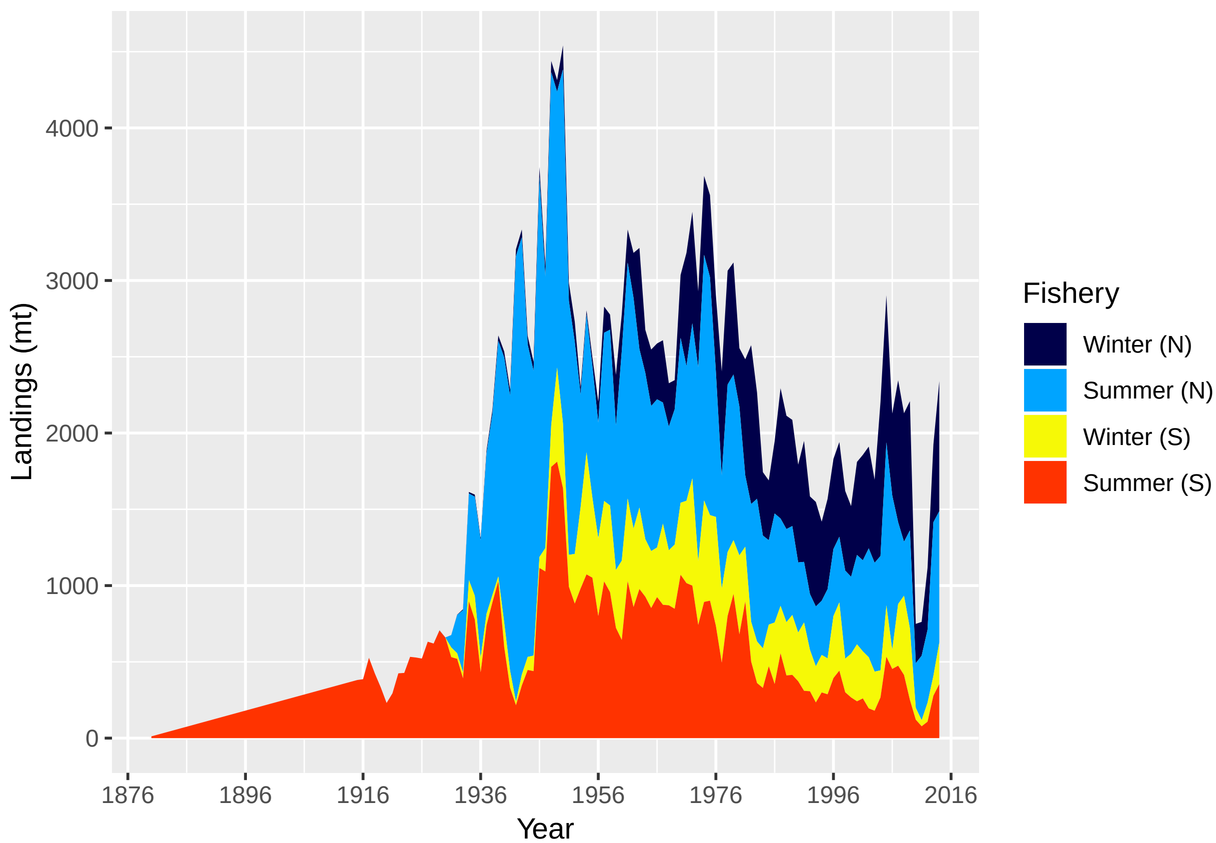

Figure a: Landings of petrale sole by the Northern and Southern winter and summer fleets of the US west coast. fig:Exec_catch1

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 3.30.03.XX). 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) early (1980, 1983, 1986, 1989, 1992) and late (1995, 1998, 2001, and 2004) Triennial bottom trawl survey and the Northwest Fisheries Science Center (NWFSC) 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. Additions to the model include 1) landings data for 2015 - 2018, 2) commercial composition data (age and length) for 2015 - 2018, 3) NWFSC groundfish trawl survey index for 2015 - 2018, and 4) age and length composition data from the NWFSC groundfish trawl survey.

Modifications from the previous assessment model include:

1. Survey indices were calculated using VAST.
2. Length-weight relationship parameters estimated outside of the stock assessment model from the NWFSC groundfish trawl survey data up to 2018 and input as fixed values.
3. Early commercial age data for OR and WA were not combined, consistent with the 2011 assessment.
4. Fitting using SS v.3.30.XX.
5. Model tuning to re-weight data.

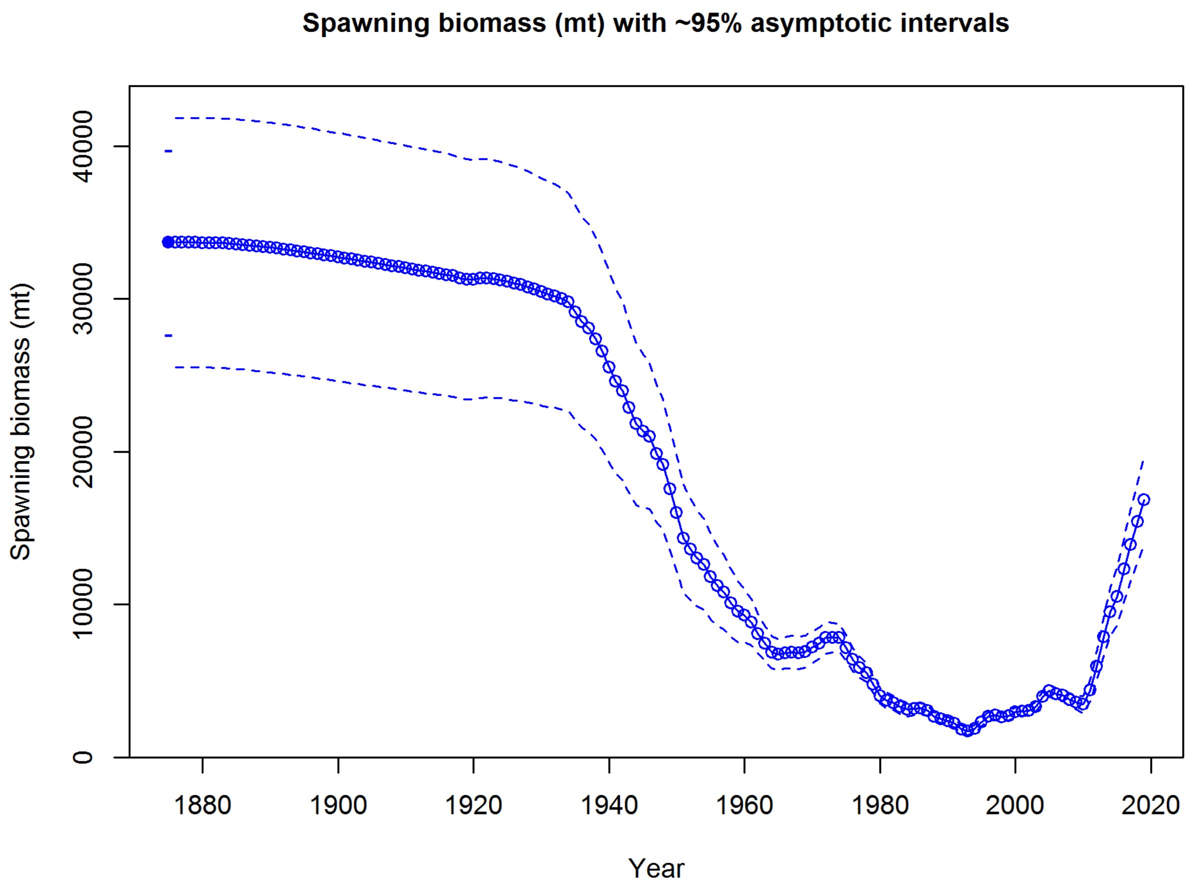

Figure b: Estimated time-series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model. fig:Spawnbio_all

Stock Biomass

stock-biomass

The predicted spawning output from the base model ...

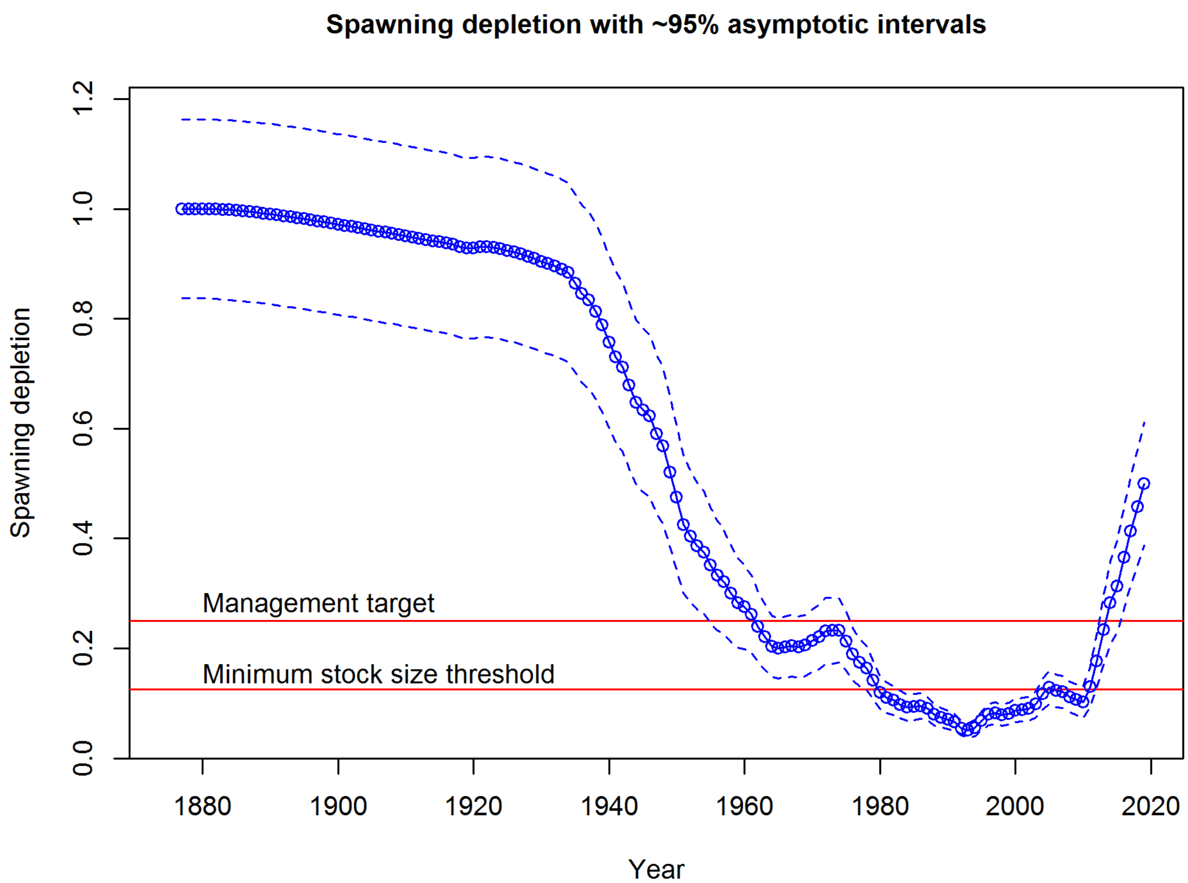

Figure c: Estimated time-series of relative spawning output (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model. fig:RelDeplete_all

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

tab:SpawningDeplete_mod1

Year	Spawning Output (mt)	~ 95% Confidence Interval	Estimated Depletion	~ 95% Confidence Interval
2010	3448	2895 - 4001	0.102	0.073 - 0.131
2011	4396	3691 - 5101	0.130	0.094 - 0.167
2012	5957	5020 - 6895	0.177	0.128 - 0.225
2013	7887	6641 - 9133	0.234	0.171 - 0.297
2014	9514	7942 - 11086	0.282	0.207 - 0.358
2015	10531	8672 - 12390	0.313	0.229 - 0.396
2016	12329	10225 - 14433	0.366	0.273 - 0.458
2017	13910	11567 - 16254	0.413	0.314 - 0.512
2018	15401	12797 - 18005	0.457	0.352 - 0.562
2019	16841	13924 - 19758	0.500	0.388 - 0.612

Recruitment

recruitment

Recruitment deviations were estimated for the entire assessment period…

Table c: Recent estimated trend in recruitment and estimated recruitment deviations determined from the base model. The recruitment deviations for 2016 and 2017 were fixed at zero within the model.

tab:Recruit_mod1

Year	Estimated Recruitment	~ 95% Confidence Interval	Estimated Recruitment Devs.	~ 95% Confidence Interval
2010	9787	6190 - 15473	-0.144	-0.509 - 0.220
2011	9683	5721 - 16387	-0.209	-0.654 - 0.236
2012	13760	7506 - 25228	0.067	-0.467 - 0.601
2013	12874	5985 - 27695	-0.060	-0.789 - 0.668
2014	14272	6300 - 32334	-0.000	-0.784 - 0.784
2015	14418	6351 - 32730	0.000	-0.784 - 0.784
2016	14621	6422 - 33289	0.000	-0.784 - 0.784
2017	14760	6470 - 33673	0.000	-0.784 - 0.784
2018	14867	6506 - 33972	0.000	-0.784 - 0.784
2019	14953	6534 - 34219	0.000	-0.784 - 0.784

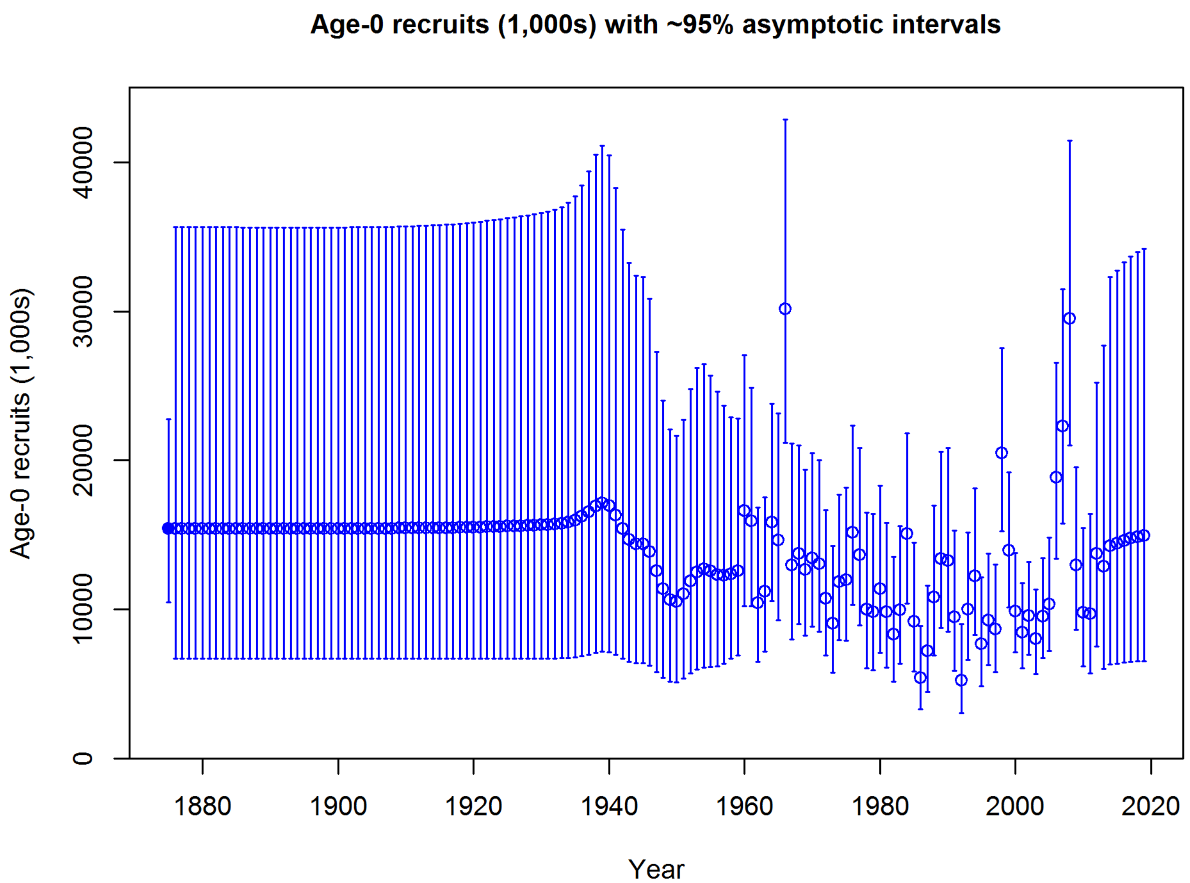

Figure d: Time-series of estimated petrale sole recruitments for the base model with 95% confidence or credibility intervals. fig:Recruits_all

Exploitation Status

exploitation-status

The spawning output of petrale sole...

Table d: Recent trend in spawning potential ratio (1-SPR)/(1-SPR50) and summary exploitation rate for age 3+ biomass for petrale sole.

tab:SPR_Exploit_mod1

Year	(1-SPR)/ (1-SPR50%)	~ 95% Confidence Interval	Exploitation Rate	~ 95% Confidence Interval
2009	0.847	0.793 - 0.900	0.278	0.236 - 0.319
2010	0.672	0.583 - 0.762	0.099	0.080 - 0.117
2011	0.581	0.487 - 0.674	0.063	0.052 - 0.074
2012	0.592	0.503 - 0.682	0.074	0.061 - 0.086
2013	0.656	0.572 - 0.739	0.110	0.092 - 0.128
2014	0.654	0.571 - 0.736	0.124	0.103 - 0.145
2015	0.006	0.004 - 0.008	0.001	0.000 - 0.001
2016	0.005	0.004 - 0.007	0.000	0.000 - 0.001
2017	0.005	0.003 - 0.006	0.000	0.000 - 0.000
2018	0.004	0.003 - 0.005	0.000	0.000 - 0.000

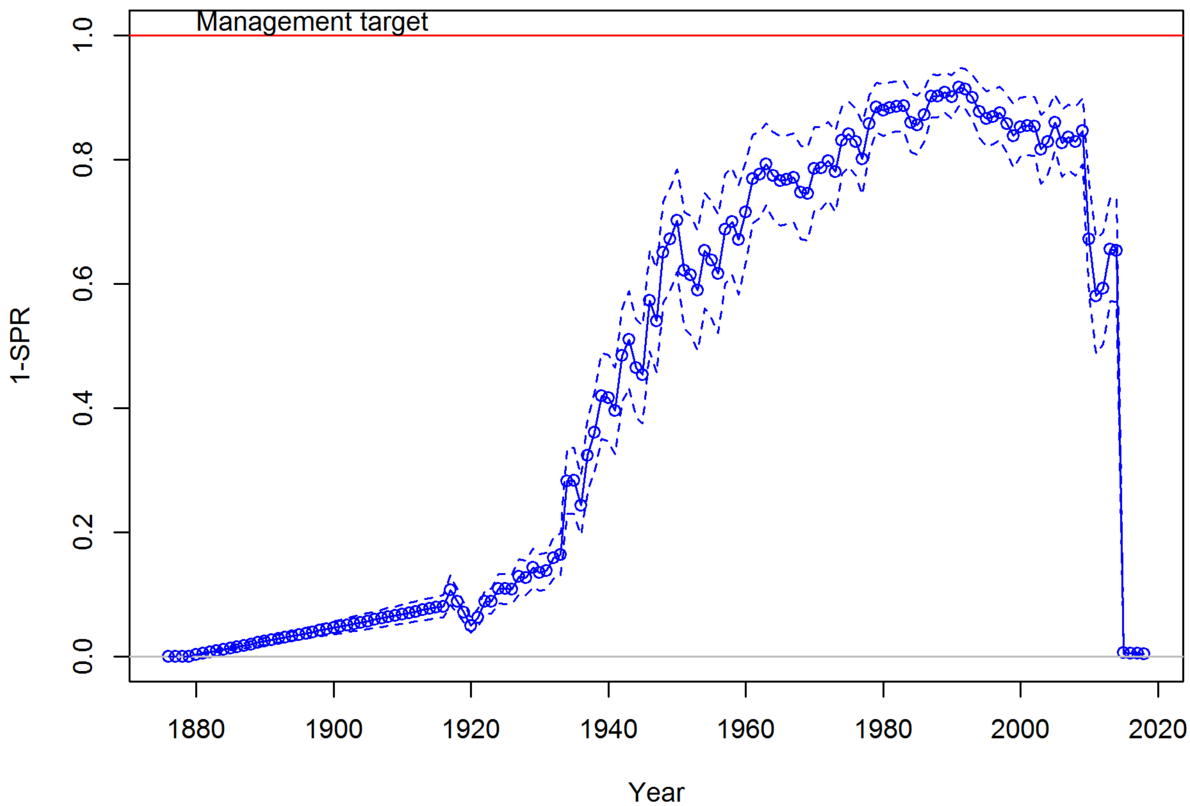

Figure e: Estimated relative spawning potential ratio (1-SPR)/(1-SPR30%) for the base model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess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

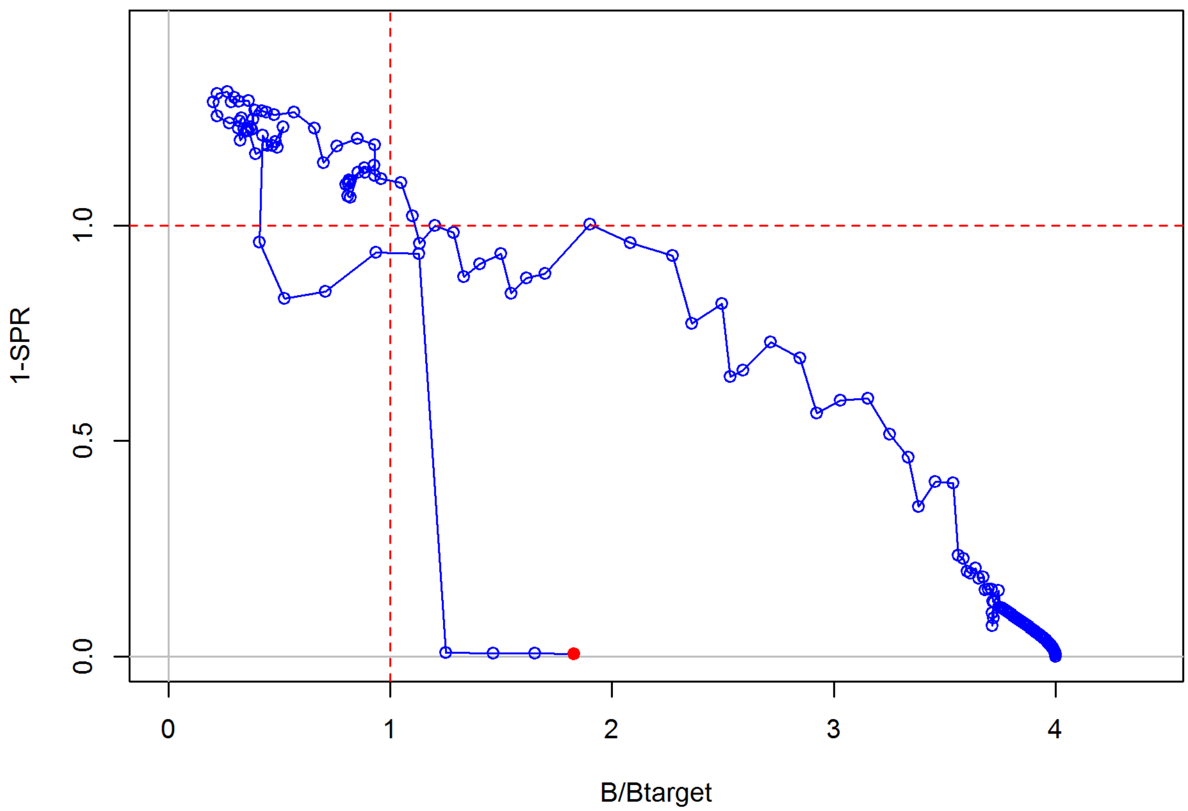

Figure f: Phase plot of estimated (1-SPR)/(1-SPR30%) vs. depletion (B/Btarget) for the base case model. The red circle indicates 2018 estimated status and exploitation for petrale sole. fig:Phase_all

Ecosystem Considerations

ecosystem-considerations

Reference Points

reference-points

This stock assessment estimates that the spawning output of petrale sole is above the management target. Due to reduced landing and the large 2008 year-class, an increasing trend in spawning output was estimated in the base model. The estimated depletion in 2019 is 50.0% (~ 95% asymptotic interval: ± 38.8%-61.2%), corresponding to an unfished spawning output of 16,841 mt (~ 95% asymptotic interval: 13,924-19,758 mt). Unfished age 3+ biomass was estimated to be 53,873.7 mt in the base model. The target spawning output based on the biomass target ($SB_{25\%}$) is 8,423.3 mt, with an equilibrium catch of 2,729.5 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{30\%}$ is 2,702.4 mt. Estimated MSY catch is at a 2,742.2 spawning output of 7,323.1 mt (21.7% depletion)

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 output (mt)	33693.4	27542.4	39844.4
Unfished age 3+ biomass (mt)	53873.7	45675.1	62072.3
Unfished recruitment (R0, thousands)	15430.6	9369.1	21492.1
Spawning output(2019 mt)	16841.1	13924	19758.2
Relative spawning output (depletion) (2019)	0.5	0.388	0.612
Reference points based on $\mathbf{SB_{25\%}}$			
Proxy spawning output ($B_{25\%}$)	8423.3	6885.6	9961.1
SPR resulting in $B_{25\%}$ ($SPR_{B25\%}$)	0.274	0.251	0.297
Exploitation rate resulting in $B_{25\%}$	0.166	0.147	0.186
Yield with $SPR_{B25\%}$ at $B_{25\%}$ (mt)	2729.5	2472.1	2986.8
Reference points based on SPR proxy for MSY			
Spawning output $SPR_{30\%}$	9329.8	7316.9	11342.7
Exploitation rate corresponding to $SPR_{30\%}$	0.151	0.125	0.178
Yield with $SPR_{30\%}$ at SB_{SPR} (mt)	2702.4	2414.6	2990.2
Reference points based on estimated MSY values			
Spawning output at MSY (SB_{MSY})	7323.1	5504.8	9141.4
SPR_{MSY}	0.242	0.18	0.304
Exploitation rate at MSY	0.187	0.157	0.216
MSY (mt)	2742.2	2502.5	2982

Management Performance

management-performance

Exploitation rates on petrale sole. . .

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	2,811	2433	2208	2323
2010	2,751	1200	749	914
2011	1,021	976	762	781
2012	1,275	1160	1116	1135
2013	2,711	2592	1925	1954
2014	2,774	2652	2341	2361
2015	3,073	2816	10	10
2016	3,208	2910	10	10
2017	3,208	3,136	10	10
2018	3,152	3,013	10	10

Unresolved Problems and Major Uncertainties

unresolved-problems-and-major-uncertainties

1. The current data for petrale sole weighted according to the Francis weighting...

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 output 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 Output (mt)	Relative Depletion
2019	4834	4640	16841	0.500
2020	4396	4219	15401	0.457
2021	4036	3873	14183	0.421
2022	3750	3599	13192	0.392
2023	3532	3389	12412	0.368
2024	3367	3231	11814	0.351
2025	3244	3113	11362	0.337
2026	3152	3025	11020	0.327
2027	3082	2958	10758	0.319
2028	3028	2906	10554	0.313
2029	2986	2865	10394	0.308
2030	2952	2832	10266	0.305

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 SPR50 catch stream is based on the equilibrium yield applying the SPR50 harvest rate.

`tab:Decision_table_mod1`

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

Research and Data Needs

research-and-data-needs

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

1. **Natural mortality**:
2. **Steepness**:
3. **Basin-wide understanding of stock structure, biology, connectivity, and distribution:**

Table i: Base model results summary.

tab:base_summary

Quantity	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
OFL (mt)	2,751	1,021	1,275	2,711	2,774	3,073	3,208	3,208	3,152	1
ACL (mt)	1200	976	1160	2592	2652	2816	2910	3,136	3,013	1
Landings (mt)	749	762	1116	1925	2341	10	10	10	10	
Total Est. Catch (mt)	914	781	1135	1954	2361	10	10	10	10	
(1-SPR)(1-$SPR_{50\%}$)	0.672	0.581	0.592	0.656	0.654	0.006	0.005	0.005	0.004	
Exploitation rate	0.099	0.063	0.074	0.110	0.124	0.001	0.000	0.000	0.000	
Age 3+ biomass (mt)	9271.69	12406.50	15359.80	17730.40	18994.80	19707.20	22306.10	24807.50	27178.10	29422.30
Spawning Output	3448	4396	5957	7887	9514	10531	12329	13910	15401	16841
95% CI	2895 - 4001	3691 - 5101	5020 - 6895	6641 - 9133	7942 - 11086	8672 - 12390	10225 - 14433	11567 - 16254	12797 - 18005	13924 - 19758
Relative Depletion	0.102	0.130	0.177	0.234	0.282	0.313	0.366	0.413	0.457	0.500
95% CI	0.073 - 0.131	0.094 - 0.167	0.128 - 0.225	0.171 - 0.297	0.207 - 0.358	0.229 - 0.396	0.273 - 0.458	0.314 - 0.512	0.352 - 0.562	0.388 - 0.612
Recruits	9787	9683	13760	12874	14272	14418	14621	14760	14867	14953
95% CI	6190 - 15473	5721 - 16387	7506 - 25228	5985 - 27695	6300 - 32334	6351 - 32730	6422 - 33289	6470 - 33673	6506 - 33972	6534 - 34219

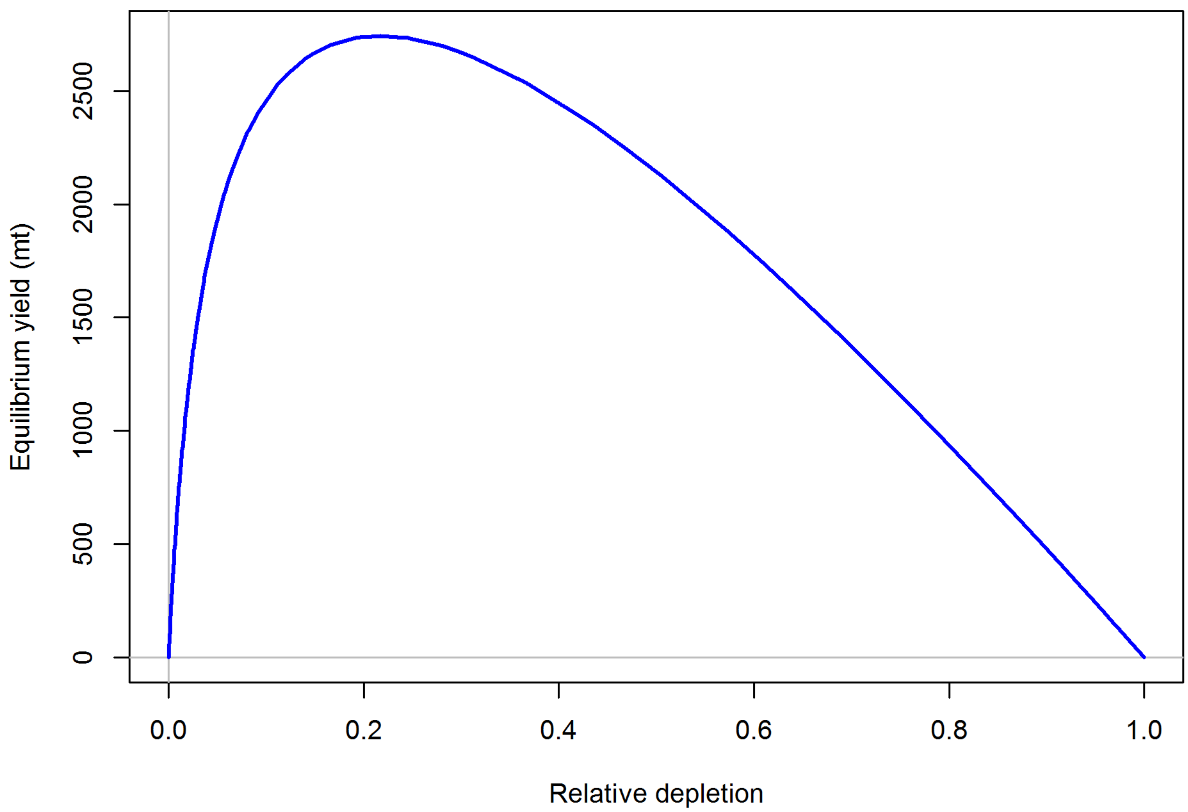

Figure g: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.89. fig:Yield_all

1 Introduction

introduction

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, (Hart 1973; 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; Hart 1973; Gates and Frey 1974; Love 1996; Eschmeyer and Herald 1983). In northern and central California petrale sole are dominant on the middle and outer continental shelf (Allen et al. 2006). 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.

There is little information regarding the stock structure of petrale sole off the U.S. Pacific coast. No genetic research has been undertaken for petrale sole and there is no other published research indicating separate stocks of petrale sole within U.S. waters. Tagging studies show adult petrale sole can move up to 350 - 390 miles, having the ability to be highly migratory with the possibility for homing ability (Alverson 1957; MBC Appl. Environ. Sci. 1987). Juveniles show little coast-wide or bathymetric movement while studies suggest that adults generally move inshore and northward onto the continental shelf during the spring and summer to feeding grounds and offshore and southward during the fall and winter to deep water spawning grounds (Hart 1973; MBC Appl. Environ. Sci. 1987; Horton 1989; Love 1996). Adult petrale sole can tolerate a wide range of bottom temperatures (Perry et al., 1994).

Tagging studies indicate some mixing of adults between different spawning groups. DiDonato and Pasquale (1970) reported that five fish tagged on the Willapa Deep grounds during the spawning season were recaptured during subsequent spawning seasons at other deepwater spawning grounds, as far south as Eureka (northern California) and the Umpqua River (southern Oregon). However, Pederson (1975) reported that most of the fish (97%) recaptured from spawning grounds in winter were originally caught and tagged on those same grounds.

Mixing of fish from multiple deep water spawning grounds likely occurs during the spring and summer when petrale sole are feeding on the continental shelf. Fish that were captured, tagged, and released off the northWest Coast of Washington during May and September were subsequently recaptured during winter from spawning grounds off Vancouver Island (British Columbia, 1 fish), Heceta Bank (central Oregon, 2 fish), Eureka (northern California, 2 fish), and Halfmoon Bay (central California, 2 fish) (Pederson, 1975). Fish tagged south of Fort Bragg (central California) during July 1964 were later recaptured off Oregon (11 fish), Washington (6 fish), and Swiftsure Bank (southwestern tip of Vancouver Island, 1 fish) (D.

Thomas, California Department of Fish and Game, Menlo Park, CA, cited by Sampson and Lee, 1999).

The highest densities of spawning adults off of British Columbia, as well as of eggs, larvae and juveniles, are found in the waters around Vancouver Island. Adults may utilize nearshore areas as summer feeding grounds and non-migrating adults may stay there during winter (Starr and Fargo, 2004).

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 2015 assessment provides a coast-wide status evaluation for petrale sole using data through 2014.

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 (Figure 2). 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 deepwater 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; Carison and Miller 1982; Reilly et al. 1994; Castillo 1995; Love 1996; Moser 1996a; Casillas et al. 1998). 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 Forrester 1971; Gregory and Jow 1976). The duration of the egg stage can range from approximately 6 to 14 days (Alderdice and Forrester 1971; Hart 1973; Love 1996, Casillas et al. 1998). 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 Forrester, 1971; Castillo et al., 1995). Predators of petrale sole eggs include planktonic invertebrates and pelagic fishes (Casillas et al. 1998).

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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 (Hart 1973; Eschmeyer and Herald 1983; Love et al. 2005) while the maximum observed break-and-burn age is 31 years (Haltuch et al. 2013).

1.3 Ecosystem Considerations

ecosystem-considerations-1

Petrale sole juveniles are carnivorous, foraging on annelid worms, clams, brittle star, mysids, sculpin, amphipods, and other juvenile flatfish (Ford 1965; Casillas et al. 1998; Pearsall and Fargo 2007). Predators on juvenile petrale sole include adult petrale sole as well as other larger fish (Ford 1965; Casillas et al. 1998) while adults are preyed upon by marine mammals, sharks, and larger fishes (Trumble 1995; Love 1996; Casillas et al. 1998).

One of the ambushing flatfishes, adult petrale sole have diverse diets that become more piscivorous at larger sizes (Allen et al. 2006). Adult petrale sole are found on sandy and sand-mud bottoms (Eschmeyer and Herald 1983) foraging for a variety of invertebrates including, crab, octopi, squid, euphausiids, and shrimp, as well as anchovies. hake, herring, sand lance, and other smaller rockfish and flatfish (Ford 1965; Hart 1973; Kravitz et al. 1977;

Birtwell et al. 1984; Reilly et al. 1994; Love 1996; Pearsall and Fargo 2007). In Canadian waters evidence suggests that petrale sole tend to prefer herring (Pearsall and Fargo 2007). On the continental shelf petrale sole generally co-occur with English sole, rex sole, Pacific sanddab, and rock sole (Kravitz et al. 1977).

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 (PDO) 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.

1.4 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 deepwater 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 deepwater 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 749 mt (Table 1, Figure 1).

1.5 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 (see, for example, PFMC, 2002). Previous assessments of petrale sole in the U.S.-Vancouver and Columbia INPFC areas have been conducted by Demory (1984), Turnock et al. (1993), Sampson and Lee (1999), and Lai at al. (2005). 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. Based on the 2005 stock assessment results, ACLs were set at 3025 mt and 2919 mt for 2007 and 2008, respectively, with an ACT of 2499 mt for both years.

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, resulting in an overfished declaration for petrale sole and catch restrictions. Recent coast-wide annual landings have not exceeded the ACL (PFMC 2006).

The 2005 stock assessment estimated that petrale sole had 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 (SB) was not below 25% of the unfished spawning stock biomass (SB0)). 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 fishery for petrale sole (and groundfish in general) has been altered substantially by changes in fishery regulations implemented since 1998. Specifically, in 1996, the PFMC implemented 2-month cumulative vessel landing limits to reduce discards. Beginning in 2000, restrictions were placed on the use of large footropes (more than 8"). Large footrope gear has been prohibited from the waters inside of 275 m (150 fm) following the advent of rockfish conservation areas delineated by depth-based management lines. Although the January and February months of the winter petrale sole fishery have not been subject to vessel landing limits until recently, the 2-month limits restricted petrale sole landings from March through

October, and beginning in 2006 during November and February. The areas in which the winter petrale sole fishery has been allowed to operate have also been restricted by actions designed to reduce bycatch of slope rockfish. Effectively, many of the more marginal petrale sole winter fishing grounds were closed while the main fishing areas have remained open. Additionally, industry members indicated that after the 2003 vessel buyback program fishing effort for petrale sole during the winter declined. The skippers also indicated that small petrale limits during 2010 lead to large changes targeting strategies for petrale sole.

Area closures have been used by the PFMC for groundfish management since 2001. Current major area closures are: i) the Cowcod Conservation Areas (CCAs): adopted during 2000 and implemented in 2001; ii) the Yelloweye Rockfish Conservation Areas (YRCAs): the first was adopted during 2002 and implemented in 2003; and iii) the Rockfish Conservation Areas (RCAs) for several rockfish species: adopted during 2002, implemented as an emergency regulation during fall of 2002 and through regulatory amendment in 2003. Since then, RCAs have been specified continuously for regions north and south of 40o10' N latitude for trawl and fixed-gear groups. The boundaries of the RCAs are delineated by depth-based management lines, and may be changed throughout the year in an effort to achieve fishery management objectives. The area between 180 m and 275 m has been continuously closed to most all bottom groundfish trawling since the implementation of the RCAs. Vessels with exempted fishing permits (EFPs) issued under 50 CFR part 600 are allowed to operate in some conservation areas. Oregon EFP vessels were allowed to fish in the RCA using more selective 'pineapple'trawl gear (this gear has a longer headrope than footrope, allowing some rockfish a chance to escape capture) from February-October during 2003 and 2004. In pilot experiments, this gear was found to reduce the CPUE of some overfished rockfish and increase CPUE of flatfish relative to standard commercial flatfish gear (King et al. 2004). Beginning in 2005, this modified "selective flatfish" trawl gear has been required shoreward of the RCA, north of $40°10'$ N latitude. The skippers present at the 2011 pre-assessment workshop in Newport, OR indicated that, prior to the use of the pineapple trawl fishing took place around the clock. However, when using the pineapple trawl gear they only fish during the day because the skippers are unable to catch fish at night. The ACLs for several species under rebuilding plans have resulted in limited harvests of other groundfish in recent years.

Port sampling conducted by each state routinely samples market categories to determine the species composition of these mixed-species categories. Since 1967, various port sampling programs have been utilized by state and federal marine fishery agencies to determine the species compositions of the commercial groundfish landings off the U.S. Pacific coast (Sampson and Crone 1997). Current port sampling programs use stratified multi-stage sampling designs to evaluate the species compositions of the total landings in each market category, as well as for obtaining biological data on individual species (Crone 1995, Sampson and Crone 1997). An IFQ program, referred to as catch shares, was implemented for the trawl fleet beginning in 2011, resulting in changes in fleet behavior and the distribution of fishing effort.

1.6 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 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). Current landings of petrale sole in Canada are very low due to the effect of the non-directed fishery. 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.

The most recent assessment of petrale sole in British Columbia uses a single area combined sex delay-difference stock assessment model with knife edge recruitment (at 6 or 7 years old) and tuned to fishery CPUE, mean fish weight of the commercial landings, and a number of fishery independent surveys beginning in the early 1980s (P. Starr, pers. comm.). Stock predictions are based on average recruitment (P. Starr, pers. comm.) This assessment suggests that the stock is currently above the target reference point and that there is some evidence for above average recruitment (about 10% above average) since about 1996 (P. Starr, pers. comm.). Petrale sole in Canadian waters appear to have similar life history characteristics (Starr and Fargo 2004). The Canadian assessment has not been updated since the U.S. petrale sole 2011 assessment.

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 3. The data that were added or reprocessed for this assessment are:

1. Commerical catches (2015-2018)
2. Observed discard rates (2014-2017)

3. Northwest Fishereis Science Center Shelf-Slope Survey (2015-2018)

A description of each data source is provided below.

2.1 Fishery-Independent Data

`fishery-independent-data`

2.1.1 Northwest Fisheries Science Center (NWFSC) Shelf-Slope Survey

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

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 survey included the continental shelf (55-183 m) are considered (2003-2018), since the highest percent of positive survey tows with `r spp` are found on the continental shelf.

The NWFSC shelf-slope survey is based on a random-grid design; covering the coastal waters from a depth of 55 m to 1,280 m (Keller et al. 2007). 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.

ADD INFORMATION ON THE DATA USED FOR PETRALE Figure 3 Figure 4 Figure 7

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 **??** 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 survey from 2003-2018 generally show a strong cohort growing through 2005 and smaller fish entering the population beginning in 2007 rows (Figure XX).

Age distributions included bins from age 1 to age 17, with the last bin including all fish of greater age. Table **??** shows the number of ages taken by the survey. These data show the growth trajectory of females reaching a maximum size near 60 cm and males reaching a maximum size of about 54 cm (Figure XX). The marginal NWFSC shelf-slope 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 in 2008-2014 (Figure XX). 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.

2.1.2 Triennial Shelf Survey

`triennial-shelf-survey`

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

Haul depths ranged from 91-457 m during the 1977 survey with no hauls shallower than 91 m. The surveys in 1980, 1983, and 1986 covered the West Coast south to 36.8° N latitude and a depth range of 55-366 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 series, 2004, the NWFSC's Fishery Resource and Monitoring division (FRAM) conducted the survey and followed very similar protocols as the AFSC.

Due to changes in survey timing, the triennial shelf 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.

Petrale sole were encountered throughout the West Coast (Figure XX). Larger catch rates were observed around depths of 100 m but no trend in catch rate was apparent over latitude, other than low catch rates in the Conception INPFC area which was only partially sampled (Figure XX 17). An analysis of the mean length by depth also showed evidence of an ontogenetic movement of petrale to deeper water (Figure XX 18), and depth stratification similar to the strata used for the NWFSC survey was used for the early and late triennial shelf survey (Table 5 and 6).Strata were determined based on having an adequate sample size in each year-strata combination.

DESCRIBE VAST AND THE INDICES

Table 7

Size distributions were calculated following the same procedures as the NWFSC survey. The numbers of fish and number of hauls represented in each year of the survey are presented in

Table 10. The length frequency distributions generally show little trend, although there is evidence of small fish in 1992 and large fish in 2004 (Figure XX).

There are no petrale sole age data from the triennial shelf survey.

2.2 Fishery-Dependent Data

fishery-dependent-data

2.2.1 Commercial Fishery Landings

commercial-fishery-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. Discard estimates are shown in Table 11.

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 11 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. Post-ITQ, all catch-share vessels have 100% observer coverage and discarding is assumed to be known.

2.2.3 Foreign Landings

foreign-landings

2.2.4 Logbooks

logbooks

2.2.5 Fishery Length and Age Data

fishery-length-and-age-data

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

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

2.2.6 Historical Commercial Catch-Per-Unit Effort

historical-commercial-catch-per-unit-effort

2.3 Biological Data

biological-data

2.3.1 Natural Mortality

natural-mortality

2.3.2 Sex Ratio, Maturation, and Fecundity

sex-ratio-maturation-and-fecundity

2.3.3 Length-Weight Relationship

length-weight-relationship

2.3.4 Growth (Length-at-Age)

growth-length-at-age

2.3.5 Ageing Precision and Bias

ageing-precision-and-bias

2.4 History of Modeling Approaches Used for This Stock

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

2.4.1 Previous Assessments

previous-assessments

3 Assessment

assessment

3.1 General Model Specifications and Assumptions

general-model-specifications-and-assumptions

Stock Synthesis version 3.30.03.XX was used to estimate the parameters in the model. R4SS, version 1.XX.X, along with R version 3.3.2 were used to investigate and plot model fits. A summary of the data sources used in the model (details discussed above) is shown in Figure 3.

3.1.1 Changes Between the 2015 Update Assessment Model and Current Model

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

3.1.2 Summary of Fleets and Areas

summary-of-fleets-and-areas

3.1.3 Other Specifications

other-specifications

3.1.4 Modeling Software

modeling-software

The STAT team used Stock Synthesis version 3.30.03.XX developed by Dr. Richard Methot at the NWFSC (Methot and Wetzel 2013). This most recent version was used because it included improvements and corrections to older versions.

3.1.5 Priors

`priors`

3.1.6 Data Weighting

`data-weighting`

3.1.7 Estimated and Fixed Parameters

`estimated-and-fixed-parameters`

3.1.8 Key Assumptions and Structural Choices

`key-assumptions-and-structural-choices`

3.1.9 Bridging Analysis

`bridging-analysis`

3.1.10 Convergence

`convergence`

3.2 Base Model Results

`base-model-results`

3.2.1 Parameter Estimates

`parameter-estimates`

3.2.2 Fits to the Data

`fits-to-the-data`

3.2.3 Population Trajectory

`population-trajectory`

3.2.4 Uncertainty and Sensitivity Analyses

`uncertainty-and-sensitivity-analyses`

3.2.5 Retrospective Analysis

`retrospective-analysis`

3.2.6 Historical Analysis

`historical-analysis`

3.2.7 Likelihood Profiles

`likelihood-profiles`

3.2.8 Reference Points

`reference-points-1`

4 Harvest Projections and Decision Tables

`harvest-projections-and-decision-tables`

5 Regional Management Considerations

`regional-management-considerations`

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. **Natural mortality**:

7 Acknowledgments

acknowledgments

Many people were instrumental in the successful completion of this assessment and their contribution is greatly appreciated.

8 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	854	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	374	241
2001	691	597	308	260
2002	667	714	335	195
2003	544	713	256	180
2004	1010	750	177	267
2005	964	1069	337	533
2006	537	1012	125	454
2007	930	536	404	475
2008	842	354	519	414
2009	847	642	470	250
2010	258	292	78	121
2011	222	423	40	78
2012	406	478	124	108
2013	509	1007	130	278
2014	853	860	273	354
2015	0	0	0	10
2016	0	0	0	10
2017	0	0	0	10
2018	0	0	0	10

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	2,811	2433	2208	2323
2010	2,751	1200	749	914
2011	1,021	976	762	781
2012	1,275	1160	1116	1135
2013	2,711	2592	1925	1954
2014	2,774	2652	2341	2361
2015	3,073	2816	10	10
2016	3,208	2910	10	10
2017	3,208	3,136	10	10
2018	3,152	3,013	10	10

Table 3: Description of the data used to create the indices, the modeling platform used to generate the estimates, and the model configuration.

tab:strata

	Early Triennial	Late Triennial	NWFS Shelf-Slope
Depth	55-100, 100-400	55- 100, 100-500	55-100, 100-183, 183-549
Latitude	INPFC	INPFC	INPFC
Model	VAST	VAST	VAST
Error Structure			
Knots			
Spatial	Y		Y
Temporal	Y		Y
Vessel-Year	N		Y

Table 4: 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	47.00	49.00
Shallow Columbia	55	100	43.00	47.00
Shallow Eureka	55	100	40.50	43.00
Shallow Monterey	55	100	38.00	40.50
Shallow Conception	55	100	34.50	38.00
Mid Vancouver	100	183	47.00	49.00
Mid Columbia	100	183	43.00	47.00
Mid Eureka	100	183	40.50	43.00
Mid Monterey	100	183	38.00	40.50
Mid Conception	100	183	34.50	38.00
Deep Van/Col/Eur	183	549	40.50	49.00
Deep Montery	183	549	38.00	40.50
Deep Conception	183	549	34.50	38.00

Table 5: 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	43.00	49.00
Shallow Eureka	55	100	40.50	43.00
Shallow Mon/Con	55	100	34.50	40.50
Deep Van/Col/Eur	100	400	40.50	49.00
Deep Mon/Con	100	400	34.50	40.50

Table 6: 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	43.00	49.00
Shallow Eureka	55	100	40.50	43.00
Shallow Mon/Con	55	100	34.50	40.50
Deep Van/Col	100	500	43.00	49.00
Deep Eureka	100	500	40.50	43.00
Deep Mon/Con	100	500	34.50	40.50

Table 7: 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	-	-	-	-	1864	0.49	-	-	-	-
1983	-	-	-	-	2300	0.29	-	-	-	-
1986	-	-	-	-	2193	0.31	-	-	-	-
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	3234	0.27	-	-	-	-
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	2126	0.28	-	-	-	-
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	-	-	2407	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	-	-	3548	0.30	-	-
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	-	-	3832	0.30	-	-
2002	0.93	0.28	0.80	0.29	-	-	-	-	-	-
2003	1.02	0.28	0.85	0.29	-	-	-	-	18698	0.13
2004	1.63	0.28	1.71	0.31	-	-	9713	0.32	22866	0.12
2005	1.85	0.28	1.93	0.29	-	-	-	-	22056	0.11
2006	2.01	0.28	1.58	0.29	-	-	-	-	19276	0.12
2007	2.04	0.28	2.07	0.28	-	-	-	-	19428	0.12
2008	1.96	0.27	1.62	0.28	-	-	-	-	15981	0.12
2009	2.12	0.27	1.76	0.28	-	-	-	-	15893	0.12
2010	-	-	-	-	-	-	-	-	22700	0.11
2011	-	-	-	-	-	-	-	-	30022	0.10
2012	-	-	-	-	-	-	-	-	36628	0.12
2013	-	-	-	-	-	-	-	-	51165	0.12
2014	-	-	-	-	-	-	-	-	58504	0.11

Table 8: Summary of NWFSC shelf-slope survey length samples used in the stock assessment. The sample sizes were calculated according to Stewart and Hamel (2014), which determined that the approximate realized sample size for flatfish species was 3.09 fish per tow.

tab:NWcombo_Lengths

Year	Tows	Fish	Sample Size
2003	46	1426	111
2004	34	565	82
2005	38	526	92
2006	33	659	80
2007	50	628	121
2008	39	539	94
2009	46	471	111
2010	53	907	128
2011	53	921	128
2012	50	1175	121
2013	45	732	109
2014	52	991	126
2015	69	1165	167
2016	50	1150	121

Table 9: Summary of NWFSC shelf-slope survey age samples used in the stock assessment. The sample sizes were calculated according to Stewart and Hamel (2014), which determined that the approximate realized sample size for flatfish species was 3.09 fish per tow.

tab:NWcombo_Ages

Year	Tows	Fish	Sample Size
2003	45	432	109
2004	34	219	82
2005	38	257	92
2006	33	254	80
2007	50	439	121
2008	39	328	94
2009	45	331	109
2010	53	579	128
2011	53	674	128
2012	49	699	119
2013	44	553	106
2014	52	626	126
2015	68	840	165
2016	44	703	106

Table 10: Summary of Triennial survey length samples used in the stock assessment. The sample sizes were calculated according to Stewart and Hamel (2014), which determined that the approximate realized sample size for flatfish species was 3.09 fish per tow.

tab:Triennial_Lengths

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

Table 11: Summary of discard rates used in the model by each data source (continued on next page).

tab:Discard

Year	Source	Discard Rate	Standard Error
2007	WinterN	0.004	0.002
2004	WinterN	0.001	0.001
2008	WinterN	0.028	0.014
2005	WinterN	0.001	0.000
2002	WinterN	0.007	0.003
2009	WinterN	0.027	0.016
2006	WinterN	0.012	0.021
2003	WinterN	0.007	0.019
2010	WinterN	0.209	0.054
2011	WinterN	0.001	0.021
2012	WinterN	0.001	0.021
2013	WinterN	0.001	0.021
2014	WinterN	0.002	0.021
1985	WinterN	0.022	0.110
1986	WinterN	0.021	0.116
1987	WinterN	0.027	0.119
2004	SummerN	0.091	0.032
2005	SummerN	0.040	0.009
2002	SummerN	0.212	0.027
2006	SummerN	0.078	0.017
2003	SummerN	0.145	0.090
2007	SummerN	0.107	0.020
2008	SummerN	0.054	0.011
2009	SummerN	0.202	0.062
2010	SummerN	0.089	0.026
2011	SummerN	0.032	0.021
2012	SummerN	0.015	0.021
2013	SummerN	0.023	0.021
1985	SummerN	0.035	0.042
1986	SummerN	0.034	0.043
1987	SummerN	0.032	0.045

Year	Source	Discard Rate	Standard Error
2002	WinterS	0.035	0.025
2003	WinterS	0.006	0.003
2004	WinterS	0.025	0.052
2005	WinterS	0.006	0.006
2009	WinterS	0.021	0.015
2006	WinterS	0.075	0.043
2010	WinterS	0.278	0.060
2007	WinterS	0.018	0.014
2008	WinterS	0.010	0.006
2011	WinterS	0.001	0.021
2012	WinterS	0.003	0.021
2013	WinterS	0.000	0.021
2014	WinterS	0.000	0.021
2002	SummerS	0.058	0.016
2009	SummerS	0.023	0.008
2006	SummerS	0.038	0.016
2003	SummerS	0.036	0.013
2010	SummerS	0.056	0.012
2007	SummerS	0.065	0.021
2004	SummerS	0.033	0.015
2008	SummerS	0.026	0.015
2005	SummerS	0.012	0.003
2011	SummerS	0.041	0.021
2012	SummerS	0.013	0.021
2013	SummerS	0.004	0.021

Table 12: Summary of Winter North fishery length samples used in the stock assessment (continued on next page). Sample sizes were calculated according to method described above in Section 2.2.5.

tab:WN_Lengths

Year	Trips	Fish	Sample Size
1966	1	238	7
1967	5	1020	35
1968	3	912	21
1969	4	1213	28
1970	13	1830	92
1971	22	4698	155
1972	23	4561	162
1973	17	4134	120
1974	20	4806	141
1975	19	3637	134
1976	21	3677	148
1977	32	4846	226
1978	52	7715	367
1979	34	3414	240
1980	55	5425	388
1981	40	3921	282
1982	48	4824	339
1983	39	3944	275
1984	31	3102	219
1985	45	4508	318
1986	40	4002	282
1987	43	3053	304
1988	9	601	64
1989	16	798	113
1990	12	599	85
1991	8	216	38
1994	43	2608	304
1995	49	3161	346
1996	64	3085	452
1997	76	3570	537
1998	56	3450	395
1999	58	2812	409
2000	49	2004	326
2001	59	1696	293
2002	50	1666	280
2003	67	1661	296
2004	53	1202	219
2005	51	1277	227
2006	59	1486	264
2007	81	2248	391
2008	101	3058	523
2009	107	3207	550
2010	134	2872	530
2011	100	1943	368
2012	97	1873	355
2013	117	2167	416
2014	140	2850	533
2015	110	2504	456
2016	131	2158	429

Table 13: Summary of Summer North fishery length samples used in the stock assessment (continued on next page). Sample sizes were calculated according to method described above in Section 2.2.5.

tab:SN_Lengths

Year	Trips	Fish	Sample Size
1966	1	238	7
1967	5	1020	35
1968	3	912	21
1969	4	1213	28
1970	13	1830	92
1971	22	4698	155
1972	23	4561	162
1973	17	4134	120
1974	20	4806	141
1975	19	3637	134
1976	21	3677	148
1977	32	4846	226
1978	52	7715	367
1979	34	3414	240
1980	55	5425	388
1981	40	3921	282
1982	48	4824	339
1983	39	3944	275
1984	31	3102	219
1985	45	4508	318
1986	40	4002	282
1987	43	3053	304
1988	9	601	64
1989	16	798	113
1990	12	599	85
1991	8	216	38
1994	43	2608	304
1995	49	3161	346
1996	64	3085	452
1997	76	3570	537
1998	56	3450	395
1999	58	2812	409
2000	49	2004	326
2001	59	1696	293
2002	50	1666	280
2003	67	1661	296
2004	53	1202	219
2005	51	1277	227
2006	59	1486	264
2007	81	2248	391
2008	101	3058	523
2009	107	3207	550
2010	134	2872	530
2011	100	1943	368
2012	97	1873	355
2013	117	2167	416
2014	140	2850	533
2015	110	2504	456
2016	131	2158	429

Table 14: Summary of Winter South fishery length samples used in the stock assessment (continued on next page). Sample sizes were calculated according to method described above in Section 2.2.5.

tab:WS_Lengths

Year	Trips	Fish	Sample Size
1966	1	238	7
1967	5	1020	35
1968	3	912	21
1969	4	1213	28
1970	13	1830	92
1971	22	4698	155
1972	23	4561	162
1973	17	4134	120
1974	20	4806	141
1975	19	3637	134
1976	21	3677	148
1977	32	4846	226
1978	52	7715	367
1979	34	3414	240
1980	55	5425	388
1981	40	3921	282
1982	48	4824	339
1983	39	3944	275
1984	31	3102	219
1985	45	4508	318
1986	40	4002	282
1987	43	3053	304
1988	9	601	64
1989	16	798	113
1990	12	599	85
1991	8	216	38
1994	43	2608	304
1995	49	3161	346
1996	64	3085	452
1997	76	3570	537
1998	56	3450	395
1999	58	2812	409
2000	49	2004	326
2001	59	1696	293
2002	50	1666	280
2003	67	1661	296
2004	53	1202	219
2005	51	1277	227
2006	59	1486	264
2007	81	2248	391
2008	101	3058	523
2009	107	3207	550
2010	134	2872	530
2011	100	1943	368
2012	97	1873	355
2013	117	2167	416
2014	140	2850	533
2015	110	2504	456
2016	131	2158	429

Table 15: Summary of Summer South fishery length samples used in the stock assessment (continued on next page). Sample sizes were calculated according to method described above in Section 2.2.5.

tab:SS_Lengths

Year	Trips	Fish	Sample Size
1966	1	238	7
1967	5	1020	35
1968	3	912	21
1969	4	1213	28
1970	13	1830	92
1971	22	4698	155
1972	23	4561	162
1973	17	4134	120
1974	20	4806	141
1975	19	3637	134
1976	21	3677	148
1977	32	4846	226
1978	52	7715	367
1979	34	3414	240
1980	55	5425	388
1981	40	3921	282
1982	48	4824	339
1983	39	3944	275
1984	31	3102	219
1985	45	4508	318
1986	40	4002	282
1987	43	3053	304
1988	9	601	64
1989	16	798	113
1990	12	599	85
1991	8	216	38
1994	43	2608	304
1995	49	3161	346
1996	64	3085	452
1997	76	3570	537
1998	56	3450	395
1999	58	2812	409
2000	49	2004	326
2001	59	1696	293
2002	50	1666	280
2003	67	1661	296
2004	53	1202	219
2005	51	1277	227
2006	59	1486	264
2007	81	2248	391
2008	101	3058	523
2009	107	3207	550
2010	134	2872	530
2011	100	1943	368
2012	97	1873	355
2013	117	2167	416
2014	140	2850	533
2015	110	2504	456
2016	131	2158	429

Table 16: Summary of Winter North fishery age samples used in the stock assessment. Sample sizes were calculated according to method described above in Section 2.2.5.

tab:WN_Ages

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

Table 17: Summary of Summer North fishery age samples used in the stock assessment. Sample sizes were calculated according to method described above in Section 2.2.5.

tab:SN_Ages

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

Table 18: Summary of Winter South fishery age samples used in the stock assessment. Sample sizes were calculated according to method described above in Section 2.2.5.

tab:WS_Ages

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

Table 19: Summary of Summer South fishery age samples used in the stock assessment. Sample sizes were calculated according to method described above in Section 2.2.5.

tab:SS_Ages

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

Table 20: Estimated ageing error vectors used in the assessment model

V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
	Age Error 1		Age Error 2		Age Error 3		Age Error 4		Age Error 5		Age Error 6	
True Age	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	0.3	0.17	0.2	0.12	0.5	0.13	0.5	0.13	0.5	0.15	0.0	0.00
1	1.3	0.17	1.3	0.12	1.4	0.13	1.5	0.13	1.5	0.15	0.7	0.00
2	2.4	0.23	2.4	0.18	2.4	0.25	2.4	0.27	2.5	0.30	2.0	0.08
3	3.4	0.29	3.4	0.25	3.3	0.38	3.4	0.40	3.5	0.45	3.2	0.17
4	4.5	0.36	4.4	0.32	4.3	0.51	4.4	0.53	4.5	0.60	4.4	0.26
5	5.4	0.44	5.4	0.40	5.2	0.64	5.4	0.67	5.5	0.75	5.4	0.35
6	6.4	0.52	6.4	0.49	6.2	0.76	6.3	0.80	6.5	0.90	6.4	0.46
7	7.4	0.61	7.3	0.59	7.1	0.89	7.3	0.93	7.5	1.05	7.4	0.56
8	8.3	0.71	8.3	0.70	8.1	1.02	8.3	1.07	8.6	1.20	8.2	0.67
9	9.2	0.81	9.1	0.82	9.0	1.14	9.3	1.20	9.6	1.35	9.0	0.79
10	10.1	0.92	10.0	0.96	10.0	1.27	10.3	1.33	10.6	1.51	9.8	0.92
11	10.9	1.04	10.9	1.11	10.9	1.40	11.2	1.47	11.6	1.66	10.5	1.05
12	11.8	1.18	11.7	1.27	11.9	1.53	12.2	1.60	12.6	1.81	11.1	1.19
13	12.6	1.32	12.5	1.45	12.8	1.65	13.2	1.74	13.6	1.96	11.7	1.34
14	13.4	1.48	13.2	1.66	13.8	1.78	14.2	1.87	14.6	2.11	12.3	1.49
15	14.2	1.64	14.0	1.88	14.7	1.91	15.1	2.00	15.6	2.26	12.8	1.66
16	14.9	1.82	14.7	2.12	15.7	2.03	16.1	2.14	16.6	2.41	13.3	1.83
17	15.7	2.02	15.4	2.39	16.6	2.16	17.1	2.27	17.6	2.56	13.8	2.01

tab:Age_Error

Table 21: 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
Starting year of estimated recruitment	1959
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
Triennial Early survey	Double Normal
Triennial Late survey	Double Normal
NWFSC shelf-slope 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 22: 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 23: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
NatM_p_1_Fem_GP_1	0.145225	6	(0.005, 0.5)	OK	0.02	Log_Norm (-1.888, 0.3333)
L_at_Amin_Fem_GP_1	15.845	2	(10, 45)	OK	0.43	None
L_at_Amax_Fem_GP_1	54.4466	3	(35, 80)	OK	0.41	None
VonBert_K_Fem_GP_1	0.133126	2	(0.04, 0.5)	OK	0.01	None
SD_young_Fem_GP_1	0.188842	3	(0.01, 1)	OK	0.01	None
SD_old_Fem_GP_1	0.0261186	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	0.154074	6	(0.005, 0.6)	OK	0.02	Log_Norm (-1.58, 0.3326)
L_at_Amin_Mal_GP_1	16.5356	2	(10, 45)	OK	0.32	None
L_at_Amax_Mal_GP_1	43.2138	3	(35, 80)	OK	0.41	None
VonBert_K_Mal_GP_1	0.202	2	(0.04, 0.5)	OK	0.01	None
SD_young_Mal_GP_1	0.136535	3	(0.01, 1)	OK	0.01	None
SD_old_Mal_GP_1	0.047	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)	9.64411	1	(5, 20)	OK	0.20	None
SR_BH_steep	0.886714	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	0.000000528495	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_30	0.000000611006	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_29	0.000000706397	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_28	0.000000816424	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_27	0.000000943504	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_26	0.00000109007	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_25	0.0000012592	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_24	0.00000145403	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_23	0.00000167871	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_22	0.00000193731	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_21	0.0000022349	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_20	0.00000257722	3	(-4, 4)	act	0.40	dev (NA, NA)

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Early_InitAge_19	0.00000297037	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_18	0.00000342164	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_17	0.00000393927	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_16	0.00000453191	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_15	0.00000521008	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_14	0.00000598481	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_13	0.00000686874	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_12	0.00000787562	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_11	0.00000902076	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_10	0.000010321	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_9	0.0000117949	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_8	0.0000134619	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_7	0.000015342	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_6	0.0000174561	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_5	0.0000198321	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_4	0.000022511	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_3	0.0000255426	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_2	0.0000289766	3	(-4, 4)	act	0.40	dev (NA, NA)
Early_InitAge_1	0.0000328658	3	(-4, 4)	act	0.40	dev (NA, NA)
LnQ_base_WinterN(1)	-6.45763	1	(-20, 5)	OK	2.46	None
Q_power_WinterN(1)	-0.188646	3	(-5, 5)	OK	0.32	None
LnQ_base_WinterS(3)	-1.15355	1	(-20, 5)	OK	2.12	None
Q_power_WinterS(3)	-0.875184	3	(-5, 5)	OK	0.27	None
LnQ_base_TriEarly(5)	-0.701485	-1	(-15, 15)			None
Q_extraSD_TriEarly(5)	0.162458	5	(0.001, 2)	OK	0.10	None
LnQ_base_TriLate(6)	-0.321808	-1	(-15, 15)			None
Q_extraSD_TriLate(6)	0.18423	4	(0.001, 2)	OK	0.11	None
LnQ_base_NWFSC(7)	1.18496	-1	(-15, 15)			None
LnQ_base_WinterN(1)_BLK5add_2004	0.50935	3	(-0.99, 0.99)	OK	0.18	Normal (0, 0.5)
LnQ_base_WinterN(1)_dev_se	99	-5	(0.0001, 2)			Normal (99, 0.5)
LnQ_base_WinterN(1)_dev_autocorr	0	-6	(-0.99, 0.99)			Normal (0, 0.5)
LnQ_base_WinterS(3)_BLK5add_2004	0.63472	3	(-0.99, 0.99)	OK	0.22	Normal (0, 0.5)
LnQ_base_WinterS(3)_dev_se	99	-5	(0.0001, 2)			Normal (99, 0.5)
LnQ_base_WinterS(3)_dev_autocorr	0	-6	(-0.99, 0.99)			Normal (0, 0.5)
Size_DblN_peak_WinterN(1)	47.4519	1	(15, 75)	OK	0.86	None
Size_DblN_top_logit_WinterN(1)	3	-3	(-5, 3)			None
Size_DblN_ascend_se_WinterN(1)	3.95961	2	(-4, 12)	OK	0.14	None
Size_DblN_descend_se_WinterN(1)	14	-3	(-2, 15)			None
Size_DblN_start_logit_WinterN(1)	-999	-4	(-15, 5)			None

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Size_DblN_end_logit_WinterN(1)	-999	-4	(-5, 5)			None
Retain_L_infl_WinterN(1)	26.2995	1	(10, 40)	OK	2.66	None
Retain_L_width_WinterN(1)	1.6456	2	(0.1, 10)	OK	0.47	None
Retain_L_asymptote_logit_WinterN(1)	9.10901	4	(-10, 10)	OK	15.53	None
Retain_L_maleoffset_WinterN(1)	0	-2	(-10, 10)			None
SzSel_Male_Peak_WinterN(1)	-9.20159	3	(-15, 15)	OK	0.71	None
SzSel_Male_Ascend_WinterN(1)	-1.14011	4	(-15, 15)	OK	0.20	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)	53.4978	1	(15, 75)	OK	1.33	None
Size_DblN_top_logit_SummerN(2)	3	-3	(-5, 3)			None
Size_DblN_ascend_se_SummerN(2)	5.35125	2	(-4, 12)	OK	0.11	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)	30.6935	1	(10, 40)	OK	0.35	None
Retain_L_width_SummerN(2)	1.24031	2	(0.1, 10)	OK	0.20	None
Retain_L_asymptote_logit_SummerN(2)	9.53634	4	(-10, 10)	OK	12.16	None
Retain_L_maleoffset_SummerN(2)	0	-2	(-10, 10)			None
SzSel_Male_Peak_SummerN(2)	-13.8296	3	(-20, 15)	OK	1.04	None
SzSel_Male_Ascend_SummerN(2)	-1.94386	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)	41.3517	1	(15, 75)	OK	1.48	None
Size_DblN_top_logit_WinterS(3)	3	-3	(-5, 3)			None
Size_DblN_ascend_se_WinterS(3)	4.62019	2	(-4, 12)	OK	0.11	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)	28.9028	1	(10, 40)	OK	0.53	None
Retain_L_width_WinterS(3)	1.54071	2	(0.1, 10)	OK	0.41	None
Retain_L_asymptote_logit_WinterS(3)	4.06707	4	(-10, 10)	OK	2.19	None
Retain_L_maleoffset_WinterS(3)	0	-2	(-10, 10)			None
SzSel_Male_Peak_WinterS(3)	-14.9943	3	(-15, 15)	LO	0.18	None
SzSel_Male_Ascend_WinterS(3)	-2.5614	4	(-15, 15)	OK	0.34	None
SzSel_Male_Descend_WinterS(3)	0	-4	(-15, 15)			None
SzSel_Male_Final_WinterS(3)	0	-4	(-15, 15)			None

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
SzSel_Male_Scale_WinterS(3)	1	-4	(-15, 15)			None
Size_DblN_peak_SummerS(4)	42.9054	1	(15, 75)	OK	1.41	None
Size_DblN_top_logit_SummerS(4)	3	-3	(-5, 3)			None
Size_DblN_ascend_se_SummerS(4)	4.76612	2	(-4, 12)	OK	0.17	None
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)	28.9753	1	(10, 40)	OK	0.34	None
Retain_L_width_SummerS(4)	1.17814	2	(0.1, 10)	OK	0.17	None
Retain_L_asymptote_logit_SummerS(4)	9.48579	4	(-10, 10)	OK	13.27	None
Retain_L_maleoffset_SummerS(4)	0	-2	(-10, 10)			None
SzSel_Male_Peak_SummerS(4)	-10.7592	3	(-15, 15)	OK	1.42	None
SzSel_Male_Ascend_SummerS(4)	-1.5039	4	(-15, 15)	OK	0.32	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)	35.2821	1	(15, 61)	OK	1.20	None
Size_DblN_top_logit_TriEarly(5)	3	-2	(-5, 3)			None
Size_DblN_ascend_se_TriEarly(5)	4.23223	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)	-3.64025	2	(-15, 15)	OK	1.11	None
SzSel_Male_Ascend_TriEarly(5)	-0.52011	2	(-15, 15)	OK	0.23	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)	36.5398	1	(15, 61)	OK	0.87	None
Size_DblN_top_logit_TriLate(6)	3	-2	(-5, 3)			None
Size_DblN_ascend_se_TriLate(6)	4.63706	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)	-2.74342	2	(-15, 15)	OK	0.91	None
SzSel_Male_Ascend_TriLate(6)	-0.112703	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)	43.0692	1	(15, 61)	OK	0.89	None

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Size_DblN_top_logit_NWFSC(7)	3	-2	(-5, 3)			None
Size_DblN_ascend_se_NWFSC(7)	5.17712	1	(-4, 12)	OK	0.08	None
Size_DblN_descend_se_NWFSC(7)	14	-2	(-2, 15)			None
Size_DblN_start_logit_NWFSC(7)	-999	-4	(-15, 5)			None
Size_DblN_end_logit_NWFSC(7)	-999	-4	(-5, 5)			None
SzSel_Male_Peak_NWFSC(7)	-5.64121	2	(-15, 15)	OK	0.77	None
SzSel_Male_Ascend_NWFSC(7)	-0.457461	2	(-15, 15)	OK	0.09	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	-0.688296	4	(-31.6, 28.4)	OK	0.75	Normal (0, 14.2)
Size_DblN_peak_WinterN(1)_BLK1add_1983	-2.45449	4	(-31.6, 28.4)	OK	0.74	Normal (0, 14.2)
Size_DblN_peak_WinterN(1)_BLK1add_1993	-1.92897	4	(-31.6, 28.4)	OK	0.66	Normal (0, 14.2)
Size_DblN_peak_WinterN(1)_BLK1add_2003	-0.917011	4	(-31.6, 28.4)	OK	0.57	Normal (0, 14.2)
Size_DblN_peak_WinterN(1)_BLK1add_2011	-0.582325	4	(-31.6, 28.4)	OK	0.61	Normal (0, 14.2)
Retain_L_infl_WinterN(1)_BLK2add_2003	-3.00112	4	(-16.19, 13.81)	OK	4.38	Normal (0, 6.905)
Retain_L_infl_WinterN(1)_BLK2add_2010	5.09177	4	(-16.19, 13.81)	OK	3.03	Normal (0, 6.905)
Retain_L_infl_WinterN(1)_BLK2add_2011	-0.297993	4	(-16.19, 13.81)	OK	2.77	Normal (0, 6.905)
Retain_L_width_WinterN(1)_BLK2add_2003	0.345301	4	(-1.601, 8.299)	OK	0.50	Normal (0, 0.8005)
Retain_L_width_WinterN(1)_BLK2add_2010	0.486194	4	(-1.601, 8.299)	OK	0.72	Normal (0, 0.8005)
Retain_L_width_WinterN(1)_BLK2add_2011	-0.799192	4	(-1.601, 8.299)	OK	0.47	Normal (0, 0.8005)
Retain_L_asymptote_logit_WinterN(1)_BLK2repl_2003	7.42439	4	(-10, 10)	OK	2.21	None
Retain_L_asymptote_logit_WinterN(1)_BLK2repl_2010	1.48813	4	(-10, 10)	OK	0.47	None
Retain_L_asymptote_logit_WinterN(1)_BLK2repl_2011	9.6108	4	(-10, 10)	OK	1.05	None
Size_DblN_peak_SummerN(2)_BLK1add_1973	-1.977	4	(-38.8, 21.2)	OK	0.77	Normal (0, 10.6)
Size_DblN_peak_SummerN(2)_BLK1add_1983	-5.51487	4	(-38.8, 21.2)	OK	1.08	Normal (0, 10.6)
Size_DblN_peak_SummerN(2)_BLK1add_1993	-5.56794	4	(-38.8, 21.2)	OK	1.08	Normal (0, 10.6)
Size_DblN_peak_SummerN(2)_BLK1add_2003	-3.5376	4	(-38.8, 21.2)	OK	0.68	Normal (0, 10.6)
Size_DblN_peak_SummerN(2)_BLK1add_2011	-1.2146	4	(-38.8, 21.2)	OK	0.67	Normal (0, 10.6)
Retain_L_infl_SummerN(2)_BLK3add_2003	-0.102783	4	(-20.679, 9.321)	OK	0.53	Normal (0, 4.6605)
Retain_L_infl_SummerN(2)_BLK3add_2009	1.37648	4	(-20.679, 9.321)	OK	0.58	Normal (0, 4.6605)
Retain_L_infl_SummerN(2)_BLK3add_2011	-2.10256	4	(-20.679, 9.321)	OK	0.59	Normal (0, 4.6605)
Retain_L_width_SummerN(2)_BLK3add_2003	0.0976239	4	(-1.0278, 8.8722)	OK	0.26	Normal (0, 0.5139)
Retain_L_width_SummerN(2)_BLK3add_2009	0.256144	4	(-1.0278, 8.8722)	OK	0.27	Normal (0, 0.5139)
Retain_L_width_SummerN(2)_BLK3add_2011	0.314495	4	(-1.0278, 8.8722)	OK	0.23	Normal (0, 0.5139)
Retain_L_asymptote_logit_SummerN(2)_BLK3repl_2003	5.03826	4	(-10, 10)	OK	0.74	None
Retain_L_asymptote_logit_SummerN(2)_BLK3repl_2009	5.03315	4	(-10, 10)	OK	1.47	None
Retain_L_asymptote_logit_SummerN(2)_BLK3repl_2011	7.80579	4	(-10, 10)	OK	2.33	None
Size_DblN_peak_WinterS(3)_BLK1add_1973	-2.45756	4	(-25.422, 34.578)	OK	2.39	Normal (0, 12.711)

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Size_DblN_peak_WinterS(3)_BLK1add_1983	3.73714	4	(-25.422, 34.578)	OK	1.67	Normal (0, 12.711)
Size_DblN_peak_WinterS(3)_BLK1add_1993	7.53015	4	(-25.422, 34.578)	OK	1.88	Normal (0, 12.711)
Size_DblN_peak_WinterS(3)_BLK1add_2003	5.10183	4	(-25.422, 34.578)	OK	1.54	Normal (0, 12.711)
Size_DblN_peak_WinterS(3)_BLK1add_2011	5.84389	4	(-25.422, 34.578)	OK	1.62	Normal (0, 12.711)
Retain_L_infl_WinterS(3)_BLK2add_2003	-3.36625	4	(-18.816, 11.184)	OK	1.65	Normal (0, 5.592)
Retain_L_infl_WinterS(3)_BLK2add_2010	3.89582	4	(-18.816, 11.184)	OK	1.54	Normal (0, 5.592)
Retain_L_infl_WinterS(3)_BLK2add_2011	-4.58878	4	(-18.816, 11.184)	OK	2.99	Normal (0, 5.592)
Retain_L_width_WinterS(3)_BLK2add_2003	0.37731	4	(-1.0443, 8.8557)	OK	0.42	Normal (0, 0.52215)
Retain_L_width_WinterS(3)_BLK2add_2010	0.10348	4	(-1.0443, 8.8557)	OK	0.46	Normal (0, 0.52215)
Retain_L_width_WinterS(3)_BLK2add_2011	-0.0333518	4	(-1.0443, 8.8557)	OK	0.62	Normal (0, 0.52215)
Retain_L_asymptote_logit_WinterS(3)_BLK2repl_2003	6.56919	4	(-10, 10)	OK	2.33	None
Retain_L_asymptote_logit_WinterS(3)_BLK2repl_2010	2.38578	4	(-10, 10)	OK	1.51	None
Retain_L_asymptote_logit_WinterS(3)_BLK2repl_2011	5.68242	4	(-10, 10)	OK	1.62	None
Size_DblN_peak_SummerS(4)_BLK1add_1973	-5.21452	4	(-28.0793, 31.9207)	OK	1.67	Normal (0, 14.0397)
Size_DblN_peak_SummerS(4)_BLK1add_1983	-7.57553	4	(-28.0793, 31.9207)	OK	2.82	Normal (0, 14.0397)
Size_DblN_peak_SummerS(4)_BLK1add_1993	0.313191	4	(-28.0793, 31.9207)	OK	2.04	Normal (0, 14.0397)
Size_DblN_peak_SummerS(4)_BLK1add_2003	3.03797	4	(-28.0793, 31.9207)	OK	1.49	Normal (0, 14.0397)
Size_DblN_peak_SummerS(4)_BLK1add_2011	2.51447	4	(-28.0793, 31.9207)	OK	1.63	Normal (0, 14.0397)
Retain_L_infl_SummerS(4)_BLK3add_2003	-1.62454	4	(-19.055, 10.945)	OK	0.99	Normal (0, 5.4725)
Retain_L_infl_SummerS(4)_BLK3add_2009	-1.19525	4	(-19.055, 10.945)	OK	1.32	Normal (0, 5.4725)
Retain_L_infl_SummerS(4)_BLK3add_2011	-0.404496	4	(-19.055, 10.945)	OK	0.91	Normal (0, 5.4725)
Retain_L_width_SummerS(4)_BLK3add_2003	0.620496	4	(-0.876, 9.024)	OK	0.24	Normal (0, 0.438)
Retain_L_width_SummerS(4)_BLK3add_2009	0.347709	4	(-0.876, 9.024)	OK	0.26	Normal (0, 0.438)
Retain_L_width_SummerS(4)_BLK3add_2011	0.260948	4	(-0.876, 9.024)	OK	0.24	Normal (0, 0.438)
Retain_L_asymptote_logit_SummerS(4)_BLK3repl_2003	9.15396	4	(-10, 10)	OK	11.68	None
Retain_L_asymptote_logit_SummerS(4)_BLK3repl_2009	8.32342	4	(-10, 10)	OK	11.14	None
Retain_L_asymptote_logit_SummerS(4)_BLK3repl_2011	9.76153	4	(-10, 10)	OK	6.66	None
LnQ_base_WinterN(1)_DEVmult_1987	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1988	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1989	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1990	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1991	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1992	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1993	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1994	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1995	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1996	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1997	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_1998	0		(NA, NA)			dev (NA, NA)

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

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
LnQ_base_WinterN(1)_DEVmult_1999	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2000	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2001	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2002	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2003	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2004	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2005	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2006	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2007	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2008	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterN(1)_DEVmult_2009	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1987	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1988	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1989	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1990	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1991	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1992	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1993	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1994	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1995	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1996	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1997	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1998	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_1999	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2000	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2001	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2002	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2003	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2004	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2005	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2006	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2007	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2008	0		(NA, NA)			dev (NA, NA)
LnQ_base_WinterS(3)_DEVmult_2009	0		(NA, NA)			dev (NA, NA)

tab:model_params

Table 24: 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 25: Likelihood components from the base model

tab:like

Likelihood Component	Value
Total	1734.38
Survey	-76.89
Discard	-167.68
Mean-body weight data	-80.85
Length-frequency data	830.54
Age-frequency data	1034.82
Recruitment	-24.47
Forecast Recruitment	0.01
Parameter Priors	7.48
Parameter Softbounds	0.04

Table 26: 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 output (mt)	33693.4	27542.4	39844.4
Unfished age 3+ biomass (mt)	53873.7	45675.1	62072.3
Unfished recruitment (R0, thousands)	15430.6	10458.2	22767.1
Spawning output(2019 mt)	16841.1	13924	19758.2
Depletion (2019)	0.5	0.388	0.612
Reference points based on $\mathbf{SB_{40\%}}$			
Proxy spawning output ($B_{25\%}$)	8423.3	6885.6	9961.1
SPR resulting in $B_{25\%}$ ($SPR_{B25\%}$)	0.274	0.251	0.297
Exploitation rate resulting in $B_{25\%}$	0.166	0.147	0.186
Yield with $SPR_{B25\%}$ at $B_{25\%}$ (mt)	2729.5	2472.1	2986.8
Reference points based on SPR proxy for MSY			
Spawning output SPR_{proxy}	9329.8	7316.9	11342.7
Exploitation rate corresponding to SPR_{proxy}	0.151	0.125	0.178
Yield with SPR_{proxy} at SB_{SPR} (mt)	2702.4	2414.6	2990.2
Reference points based on estimated MSY values			
Spawning output at MSY (SB_{MSY})	7323.1	5504.8	9141.4
SPR_{MSY}	0.242	0.18	0.304
Exploitation rate at MSY	0.187	0.157	0.216
MSY (mt)	2742.2	2502.5	2982

Table 27: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exploit. rate
1876	53,874	33,694	53,326	1.00	15,431	1	0	0
1877	53,873	33,693	53,325	1.00	15,431	1	0	0
1878	53,872	33,692	53,324	1.00	15,431	1	0	0
1879	53,872	33,692	53,323	1.00	15,431	1	0	0
1880	53,871	33,691	53,322	1.00	15,432	12	0	0
1881	53,860	33,684	53,312	1.00	15,432	22	0	0
1882	53,840	33,670	53,291	1.00	15,431	33	0.003	0.001
1883	53,810	33,650	53,262	1.00	15,431	44	0.003	0.001
1884	53,772	33,625	53,224	1.00	15,431	55	0.003	0.001
1885	53,727	33,594	53,179	1.00	15,431	65	0.003	0.001
1886	53,675	33,558	53,126	1.00	15,431	76	0.006	0.001
1887	53,616	33,518	53,068	0.99	15,430	87	0.006	0.002
1888	53,552	33,474	53,004	0.99	15,430	97	0.006	0.002
1889	53,483	33,426	52,935	0.99	15,430	108	0.006	0.002
1890	53,410	33,375	52,861	0.99	15,429	119	0.006	0.002
1891	53,332	33,322	52,784	0.99	15,429	129	0.009	0.002

Table 27: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exploit. rate
1892	53,251	33,265	52,703	0.99	15,428	140	0.009	0.003
1893	53,167	33,207	52,618	0.99	15,428	151	0.009	0.003
1894	53,080	33,146	52,531	0.98	15,428	162	0.009	0.003
1895	52,990	33,083	52,442	0.98	15,428	172	0.012	0.003
1896	52,898	33,019	52,350	0.98	15,427	183	0.012	0.003
1897	52,804	32,953	52,256	0.98	15,427	194	0.012	0.004
1898	52,709	32,887	52,161	0.98	15,427	204	0.012	0.004
1899	52,612	32,819	52,064	0.97	15,427	215	0.012	0.004
1900	52,514	32,750	51,966	0.97	15,428	226	0.015	0.004
1901	52,415	32,680	51,866	0.97	15,428	237	0.015	0.005
1902	52,315	32,609	51,766	0.97	15,428	247	0.015	0.005
1903	52,214	32,538	51,666	0.97	15,429	258	0.015	0.005
1904	52,112	32,467	51,564	0.96	15,430	269	0.015	0.005
1905	52,010	32,394	51,462	0.96	15,431	279	0.018	0.005
1906	51,908	32,322	51,359	0.96	15,433	290	0.018	0.006
1907	51,805	32,249	51,256	0.96	15,435	301	0.018	0.006
1908	51,702	32,176	51,153	0.95	15,437	312	0.018	0.006
1909	51,599	32,103	51,050	0.95	15,439	322	0.021	0.006
1910	51,496	32,030	50,947	0.95	15,442	333	0.021	0.007
1911	51,392	31,956	50,844	0.95	15,446	344	0.021	0.007
1912	51,289	31,883	50,740	0.95	15,450	354	0.021	0.007
1913	51,187	31,810	50,638	0.94	15,455	365	0.021	0.007
1914	51,084	31,736	50,535	0.94	15,460	376	0.024	0.007
1915	50,982	31,663	50,433	0.94	15,466	387	0.024	0.008
1916	50,881	31,591	50,332	0.94	15,473	392	0.024	0.008
1917	50,785	31,521	50,236	0.94	15,480	534	0.033	0.011
1918	50,564	31,369	50,014	0.93	15,487	430	0.027	0.009
1919	50,460	31,293	49,910	0.93	15,497	338	0.021	0.007
1920	50,457	31,284	49,907	0.93	15,508	234	0.015	0.005
1921	50,562	31,347	50,011	0.93	15,521	298	0.018	0.006
1922	50,606	31,372	50,054	0.93	15,535	431	0.027	0.009
1923	50,524	31,313	49,972	0.93	15,548	434	0.027	0.009
1924	50,448	31,258	49,895	0.93	15,562	541	0.033	0.011
1925	50,277	31,139	49,725	0.92	15,576	536	0.033	0.011
1926	50,126	31,032	49,572	0.92	15,591	530	0.033	0.011
1927	49,995	30,938	49,442	0.92	15,608	642	0.039	0.013
1928	49,772	30,782	49,218	0.91	15,624	630	0.039	0.013
1929	49,582	30,646	49,027	0.91	15,642	718	0.042	0.015
1930	49,326	30,466	48,770	0.90	15,661	670	0.042	0.014
1931	49,141	30,332	48,585	0.90	15,686	687	0.042	0.014
1932	48,963	30,201	48,406	0.90	15,721	820	0.048	0.017
1933	48,685	30,000	48,127	0.89	15,768	855	0.048	0.018
1934	48,411	29,797	47,852	0.88	15,853	1638	0.084	0.034
1935	47,426	29,120	46,865	0.86	15,997	1620	0.084	0.035
1936	46,538	28,498	45,973	0.85	16,228	1329	0.072	0.029
1937	46,017	28,107	45,446	0.83	16,550	1909	0.096	0.042
1938	45,026	27,393	44,447	0.81	16,910	2177	0.108	0.049
1939	43,899	26,572	43,308	0.79	17,142	2669	0.126	0.062
1940	42,449	25,513	41,846	0.76	16,968	2565	0.126	0.061
1941	41,272	24,617	40,665	0.73	16,304	2311	0.12	0.057
1942	40,502	23,987	39,904	0.71	15,412	3231	0.144	0.081
1943	38,996	22,880	38,423	0.68	14,682	3368	0.153	0.088

Table 27: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exploit. rate
1944	37,490	21,830	36,948	0.65	14,406	2666	0.138	0.072
1945	36,720	21,342	36,200	0.63	14,380	2498	0.135	0.069
1946	36,111	21,015	35,599	0.62	13,860	3793	0.171	0.107
1947	34,245	19,889	33,739	0.59	12,572	3141	0.162	0.093
1948	32,990	19,157	32,507	0.57	11,367	4515	0.195	0.139
1949	30,379	17,545	29,942	0.52	10,642	4412	0.201	0.147
1950	27,826	16,002	27,428	0.47	10,528	4631	0.21	0.169
1951	25,040	14,316	24,662	0.42	11,016	3040	0.186	0.123
1952	23,756	13,607	23,377	0.40	11,893	2786	0.183	0.119
1953	22,684	13,013	22,285	0.39	12,482	2363	0.177	0.106
1954	21,996	12,617	21,569	0.37	12,693	2892	0.195	0.134
1955	20,823	11,827	20,378	0.35	12,559	2570	0.192	0.126
1956	20,035	11,209	19,585	0.33	12,341	2275	0.186	0.116
1957	19,623	10,816	19,178	0.32	12,274	2917	0.207	0.152
1958	18,690	10,111	18,252	0.30	12,382	2873	0.21	0.157
1959	17,888	9,532	17,450	0.28	12,558	2454	0.201	0.141
1960	17,570	9,277	17,126	0.28	16,631	2869	0.213	0.168
1961	16,954	8,831	16,478	0.26	15,926	3449	0.231	0.209
1962	15,926	8,083	15,343	0.24	10,430	3295	0.234	0.215
1963	15,195	7,450	14,668	0.22	11,210	3344	0.237	0.228
1964	14,496	6,866	14,117	0.20	15,860	2802	0.231	0.198
1965	14,321	6,740	13,890	0.20	14,645	2662	0.231	0.192
1966	14,322	6,830	13,757	0.20	30,151	2689	0.231	0.196
1967	14,430	6,882	13,808	0.20	12,986	2729	0.231	0.198
1968	14,781	6,817	13,833	0.20	13,745	2438	0.225	0.176
1969	15,629	6,917	15,162	0.21	12,649	2491	0.222	0.164
1970	16,502	7,202	16,021	0.21	13,453	3216	0.237	0.201
1971	16,633	7,460	16,177	0.22	13,035	3335	0.237	0.206
1972	16,498	7,812	16,024	0.23	10,720	3602	0.24	0.225
1973	15,914	7,832	15,469	0.23	9,056	3102	0.234	0.201
1974	15,520	7,836	15,150	0.23	11,843	3915	0.249	0.258
1975	14,098	7,163	13,756	0.21	11,974	3774	0.252	0.274
1976	12,617	6,396	12,194	0.19	15,157	3103	0.249	0.254
1977	11,685	5,874	11,238	0.17	13,639	2549	0.24	0.227
1978	11,343	5,540	10,818	0.16	9,990	3276	0.258	0.303
1979	10,409	4,770	9,951	0.14	9,846	3393	0.264	0.341
1980	9,385	4,018	9,031	0.12	11,374	2847	0.264	0.315
1981	8,816	3,715	8,456	0.11	9,829	2740	0.264	0.324
1982	8,276	3,542	7,884	0.11	8,326	2757	0.267	0.35
1983	7,695	3,287	7,356	0.10	9,946	2485	0.267	0.338
1984	7,255	3,110	6,945	0.09	15,053	1933	0.258	0.278
1985	7,274	3,151	6,888	0.09	9,192	1879	0.258	0.273
1986	7,376	3,199	6,886	0.09	5,397	2144	0.261	0.311
1987	7,251	3,048	6,951	0.09	7,193	2555	0.27	0.367
1988	6,659	2,680	6,452	0.08	10,830	2358	0.27	0.366
1989	6,127	2,506	5,844	0.07	13,416	2303	0.273	0.394
1990	5,591	2,372	5,188	0.07	13,288	1962	0.27	0.378
1991	5,423	2,223	4,951	0.07	9,484	2148	0.276	0.434
1992	5,228	1,836	4,787	0.05	5,212	1825	0.273	0.381
1993	5,402	1,708	5,094	0.05	10,017	1693	0.27	0.332
1994	5,746	1,851	5,524	0.05	12,254	1552	0.264	0.281
1995	6,205	2,296	5,836	0.07	7,664	1684	0.261	0.289

Table 27: Time-series of population estimates from the base model.

Year	Total biomass (mt)	Spawning output (million eggs)	Summary biomass 3+	Relative biomass	Age-0 recruits	Estimated total catch (mt)	1-SPR	Exploit. rate
1996	6,538	2,686	6,135	0.08	9,278	1936	0.261	0.316
1997	6,609	2,768	6,325	0.08	8,685	2057	0.261	0.325
1998	6,539	2,643	6,207	0.08	20,481	1746	0.258	0.281
1999	6,785	2,729	6,395	0.08	13,960	1626	0.252	0.254
2000	7,334	2,941	6,656	0.09	9,890	1923	0.255	0.289
2001	7,837	2,986	7,371	0.09	8,435	1986	0.255	0.269
2002	8,397	3,035	8,055	0.09	9,564	2079	0.255	0.258
2003	8,865	3,305	8,558	0.10	8,015	1789	0.246	0.209
2004	9,506	3,950	9,176	0.12	9,522	2285	0.249	0.249
2005	9,574	4,345	9,278	0.13	10,325	3002	0.258	0.324
2006	8,824	4,131	8,474	0.12	18,853	2210	0.249	0.261
2007	8,717	4,060	8,286	0.12	22,276	2400	0.252	0.29
2008	8,642	3,766	7,942	0.11	29,498	2175	0.249	0.274
2009	9,204	3,584	8,371	0.11	12,984	2323	0.255	0.278
2010	10,199	3,448	9,272	0.10	9,787	914	0.201	0.099
2011	12,845	4,396	12,406	0.13	9,683	781	0.174	0.063
2012	15,710	5,957	15,360	0.18	13,760	1135	0.177	0.074
2013	18,104	7,887	17,730	0.23	12,874	1954	0.198	0.11
2014	19,478	9,514	18,995	0.28	14,272	2361	0.195	0.124
2015	20,175	10,531	19,707	0.31	14,418	10	0.003	0.001
2016	22,815	12,329	22,306	0.37	14,621	10	0.003	0
2017	25,322	13,910	24,808	0.41	14,760	10	0	0
2018	27,699	15,401	27,178	0.46	14,867	10	0	0
2019	29,948	16,841	29,422	0.50	14,953	-	-	-

tab:Timeseries_mod1

Table 28: Sensitivity of the base model.

tab:Sensitivity1

Label	Base	Low M	High M	Harmonic weights	Dirichlet weights	NA
Total Likelihood						
Survey Likelihood						
Discard Likelihood						
Length Likelihood						
Age Likelihood						
Recruitment Likelihood						
Forecast Recruitment Likelihood						
Parameter Priors Likelihood						
Parameter Deviation Likelihood						
log(R0)						
SB Virgin						
SB 2017						
Depletion 2017						
Total Yield - SPR 50						
Steepness						
Natural Mortality - Female						
Length at Amin - Female						
Length at Amax - Female						
Von Bert. k - Female						
SD young - Female						
SD old - Female						
Natural Mortality - Male						
Length at Amin - Male						
Length at Amax - Male						
Von Bert. k - Male						
SD young - Male						
SD old - Male						

Table 29: 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 30: 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 31: 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 Output	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 32: 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 Output	Depletion (%)	Spawning Output	Depletion (%)	Spawning Output	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							

9 Figures

figures

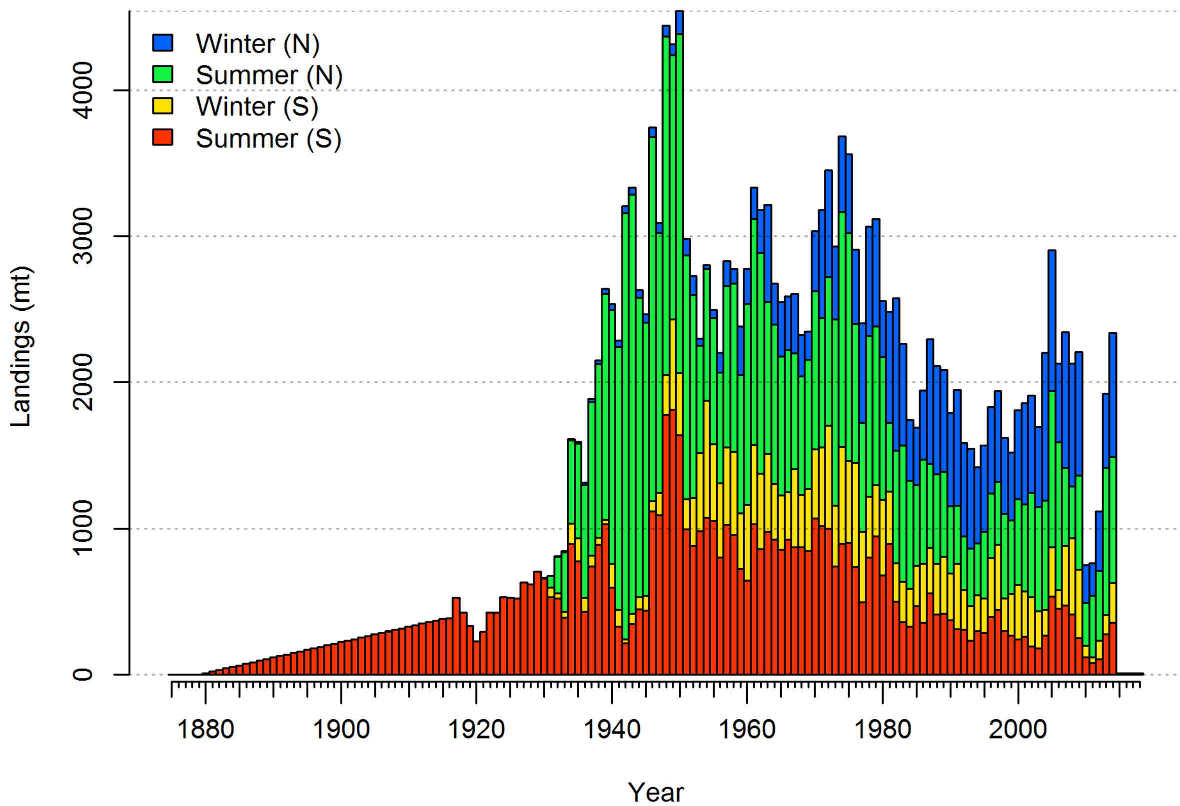

Figure 1: Total catches petrale sole. fig:Catch

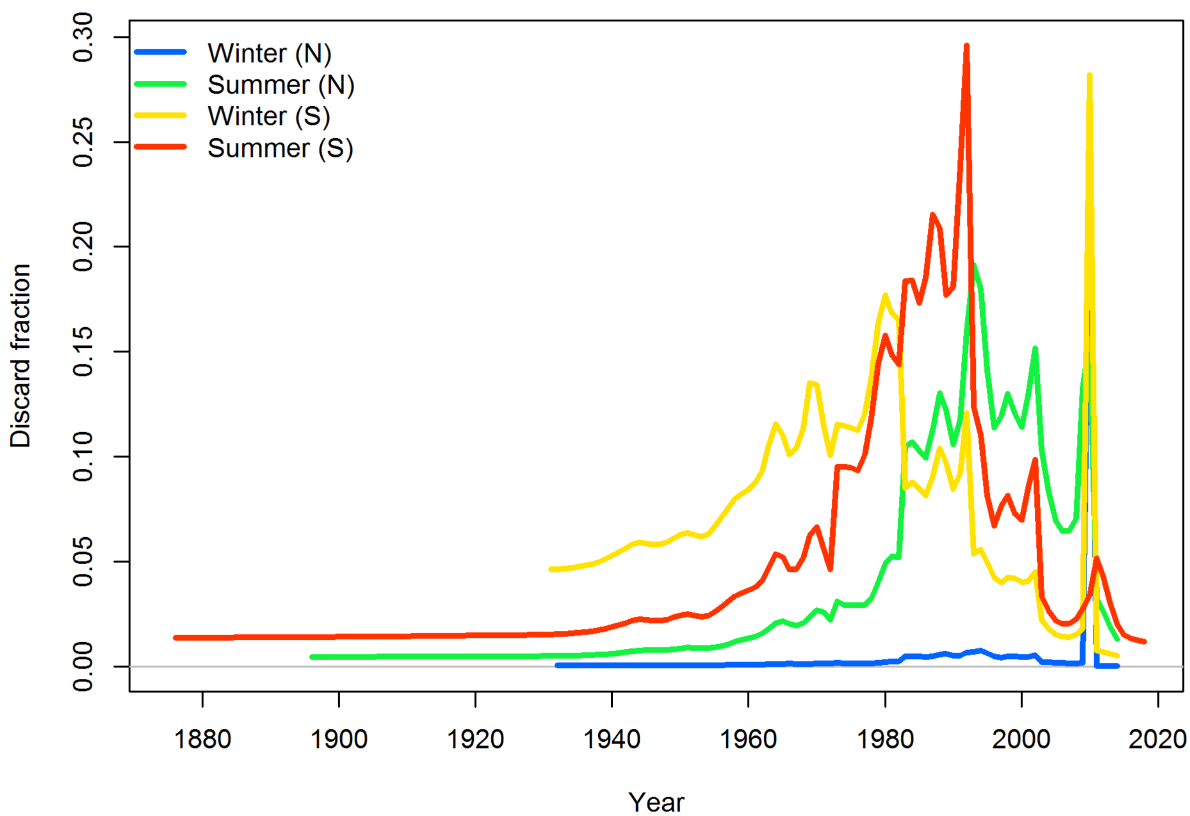

Figure 2: Discard rates by fleet for petrale sole. fig:Discard

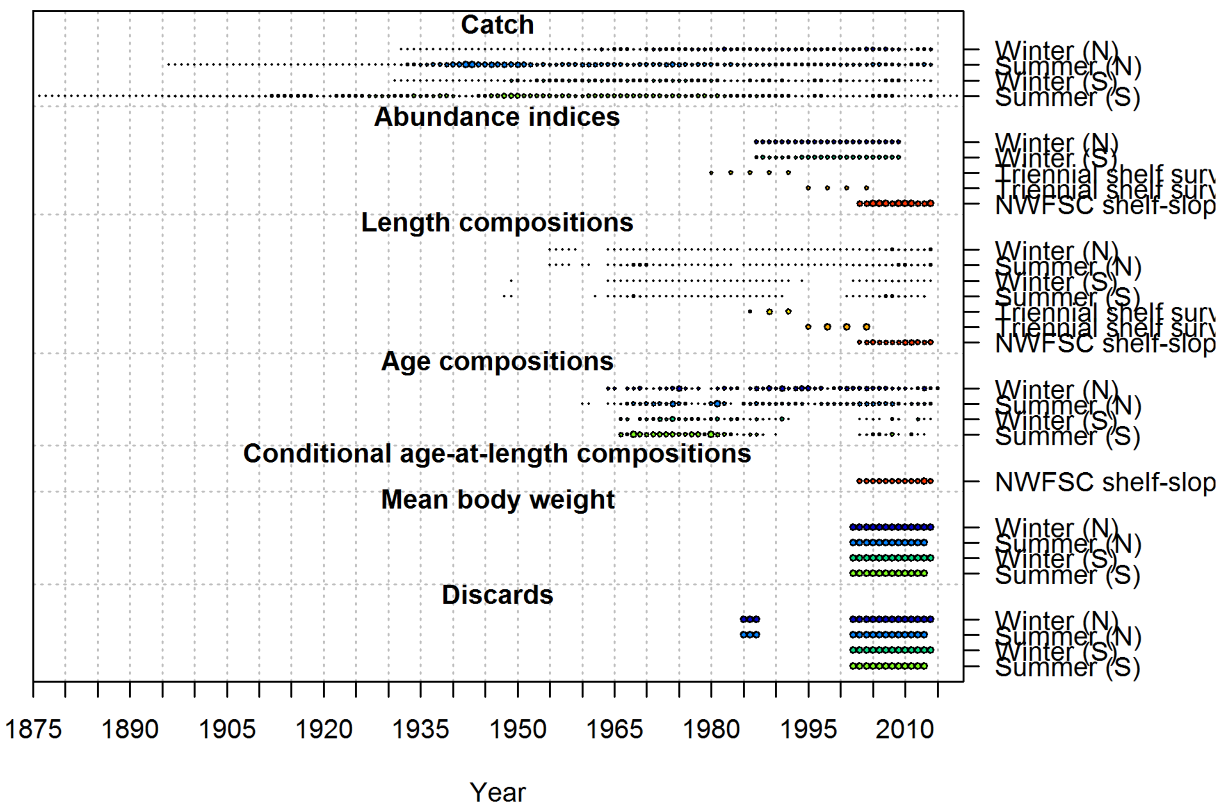

Figure 3: Summary of data sources used in the base model. fig:data_plot

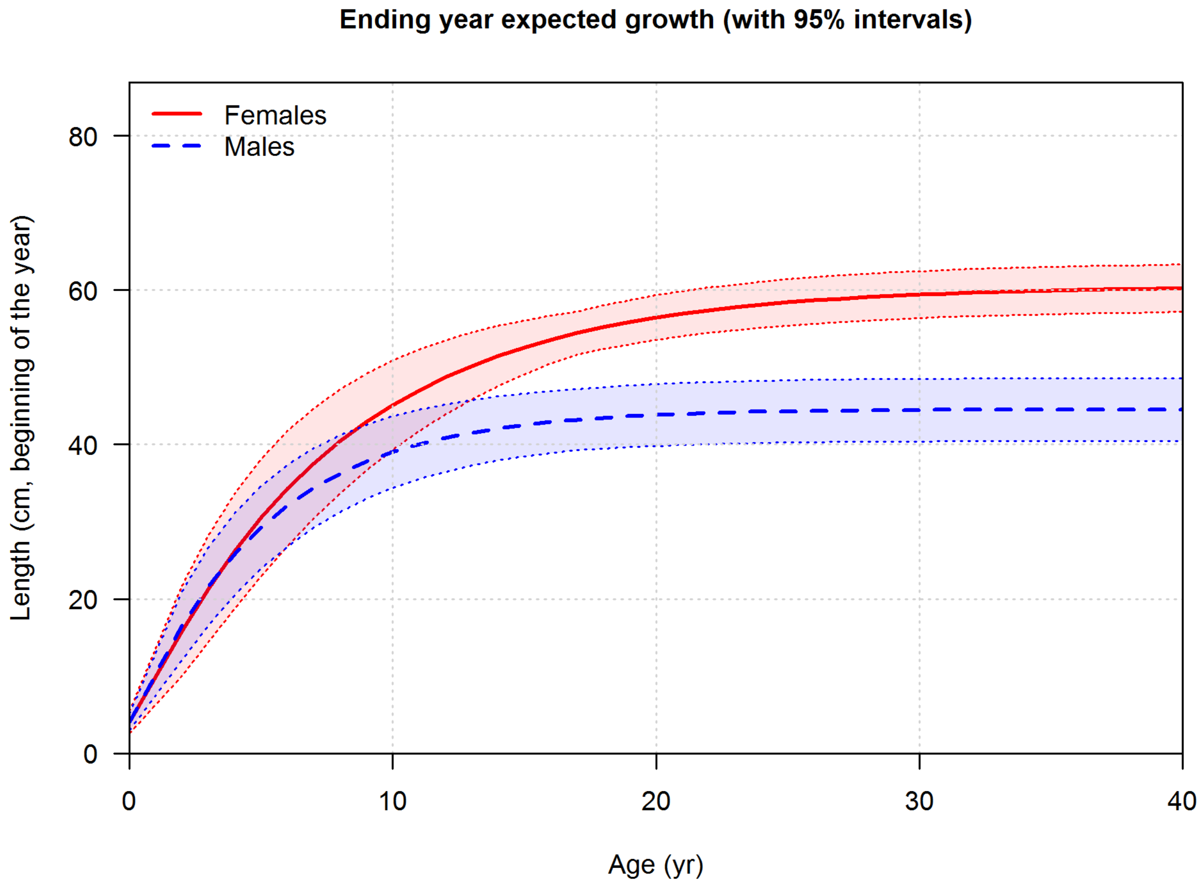

Figure 4: Estimated length-at-age for male and female for petrale sole with estimated CV. fig:sizeatage

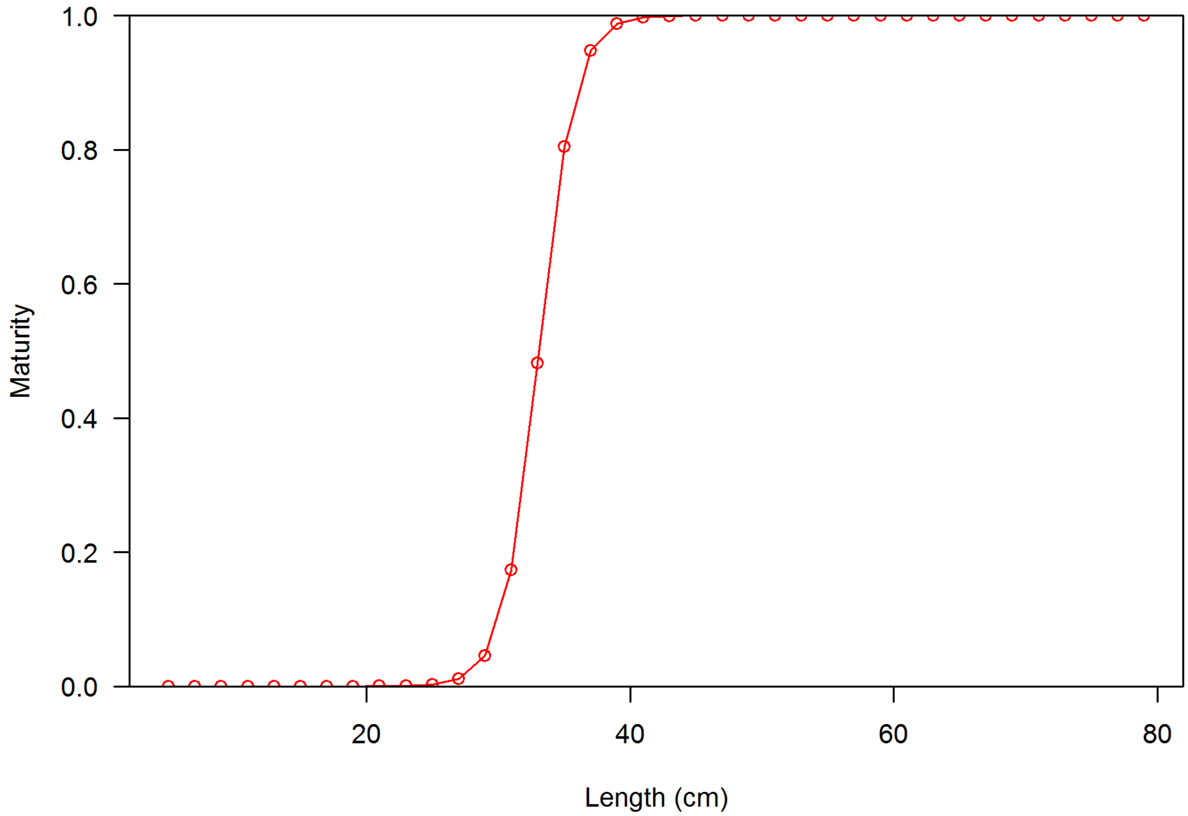

Figure 5: Estimated maturity-at-length for petrale sole. fig:maturity

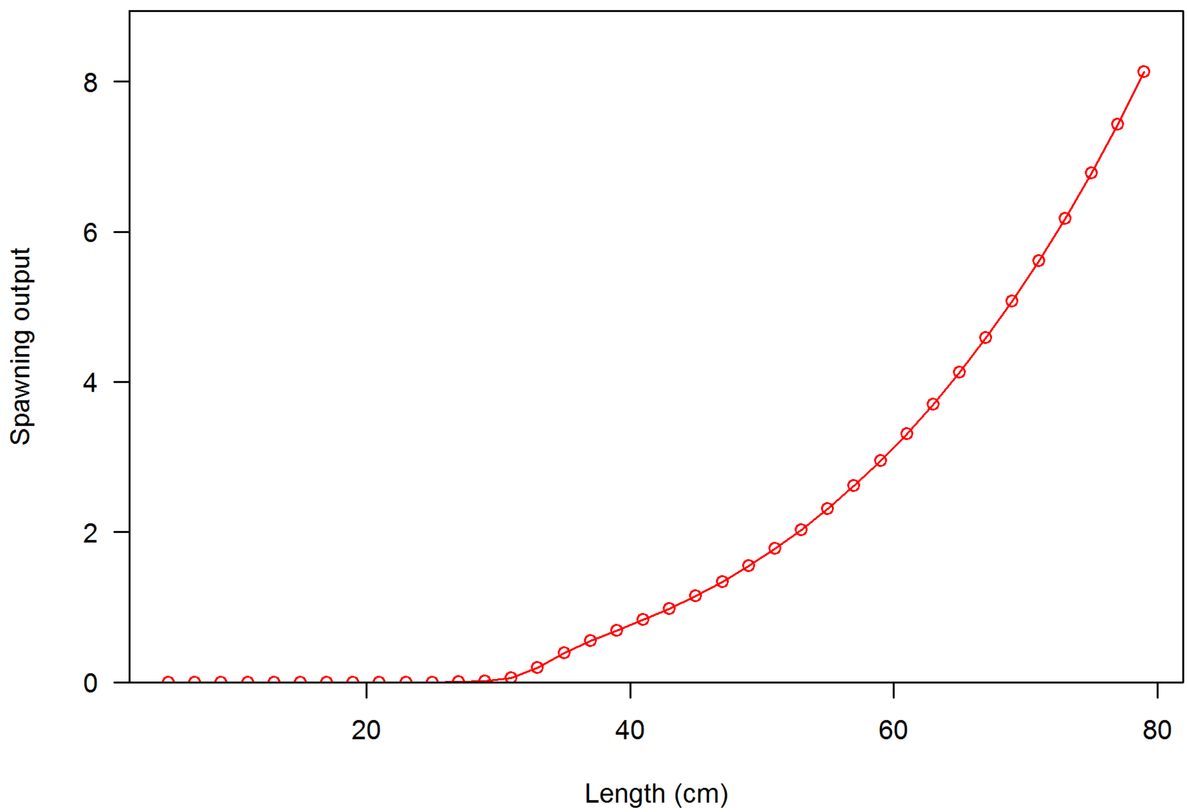

Figure 6: Estimated spawning output-at-length for female petrale sole. fig:spawnoutlen

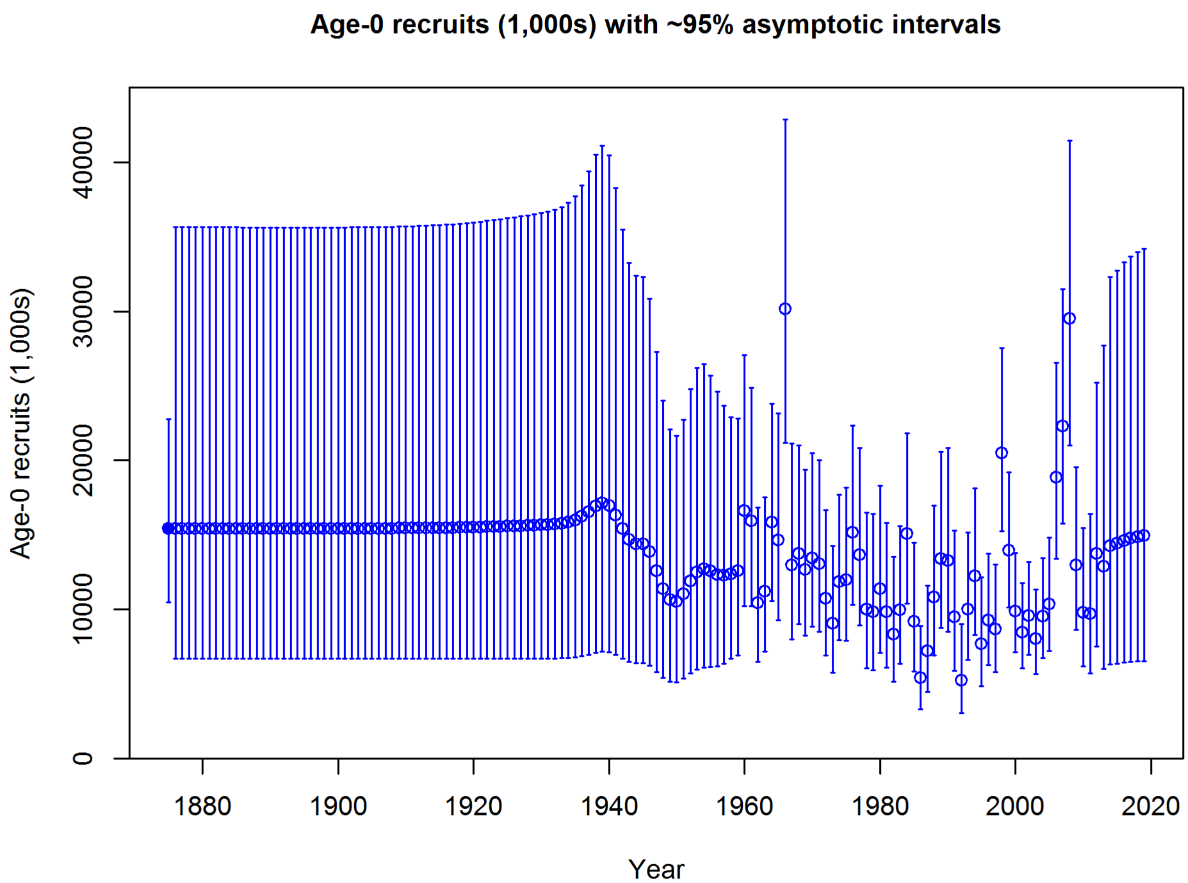

Figure 7: Estimated time-series of recruitment for petrale sole. fig:recruits

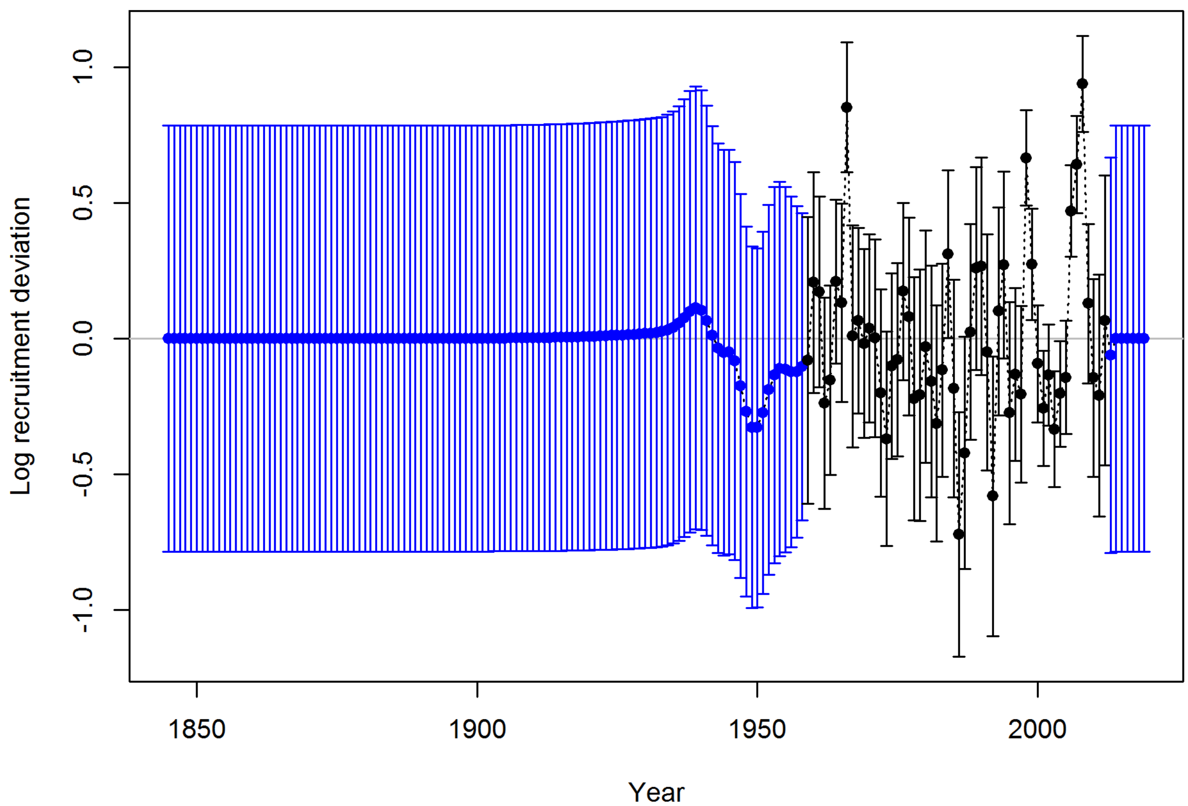

Figure 8: Estimated time-series of recruitment deviations for petrale sole. fig:recdevs

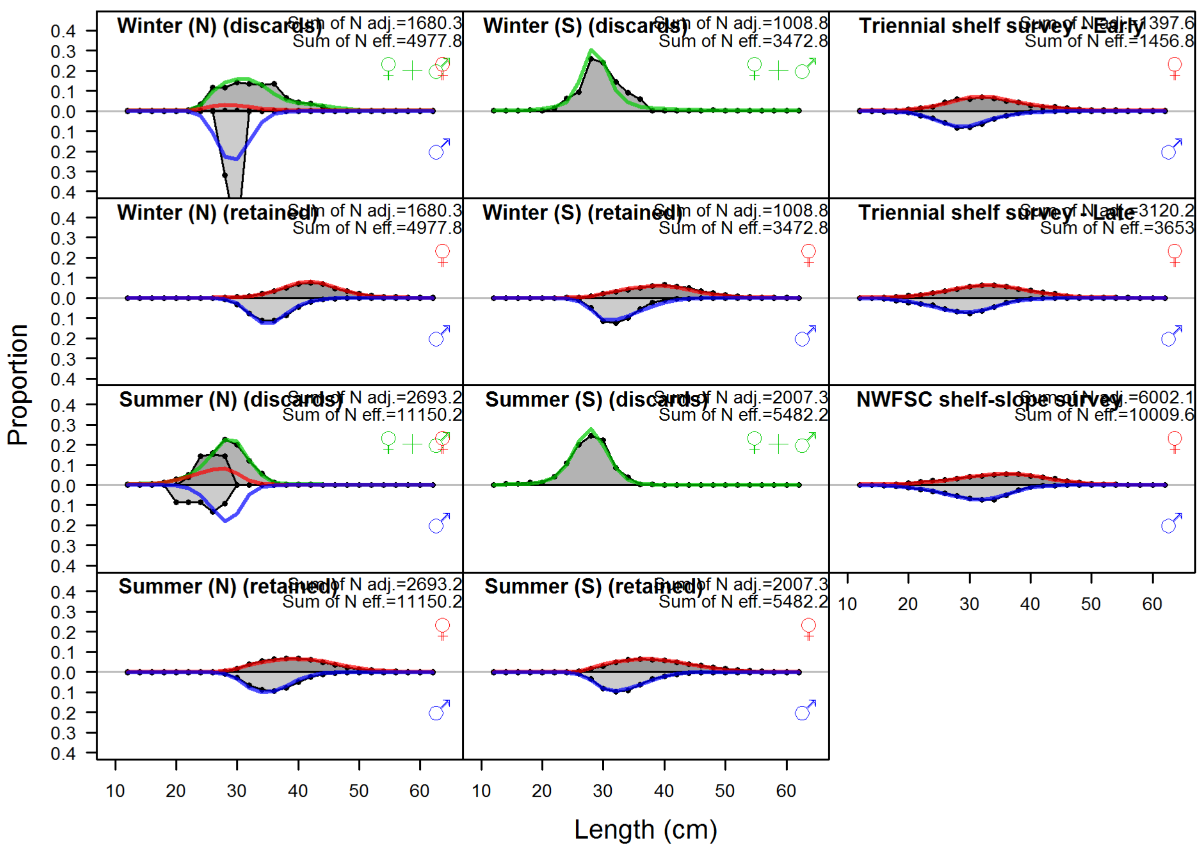

Figure 9: Length compositions aggregated across time by fleet. Labels 'retained' and 'discard' indicate retained or discarded samples for each fleet. Panels without this designation represent the whole catch. The Triennial shelf survey length data were not used in the final model, but the implied model fits are shown. fig:length_agg

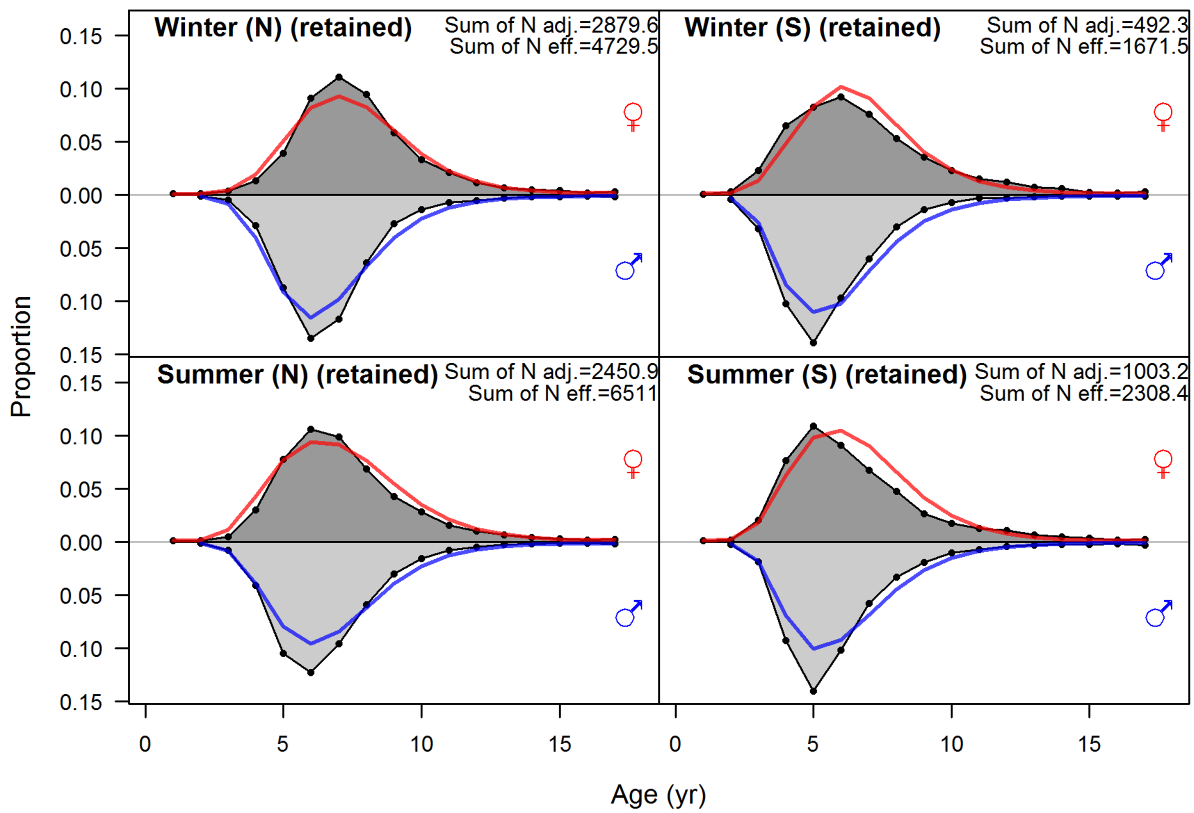

Figure 10: Age compositions aggregated across time by fleet. The Triennial shelf survey age data were not used in the final model, but the implied model fits are shown. fig:age_agg

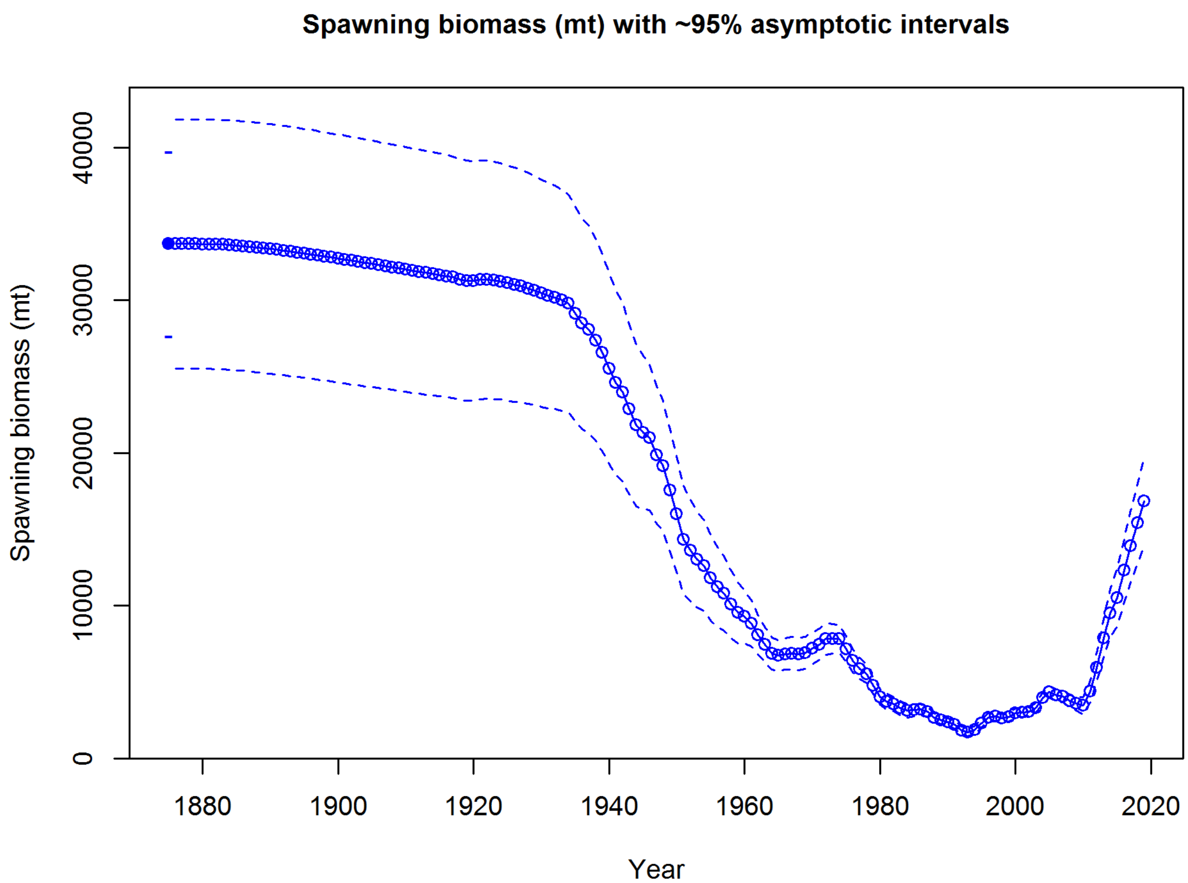

Figure 11: Estimated time-series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for petrale sole. fig:ssb

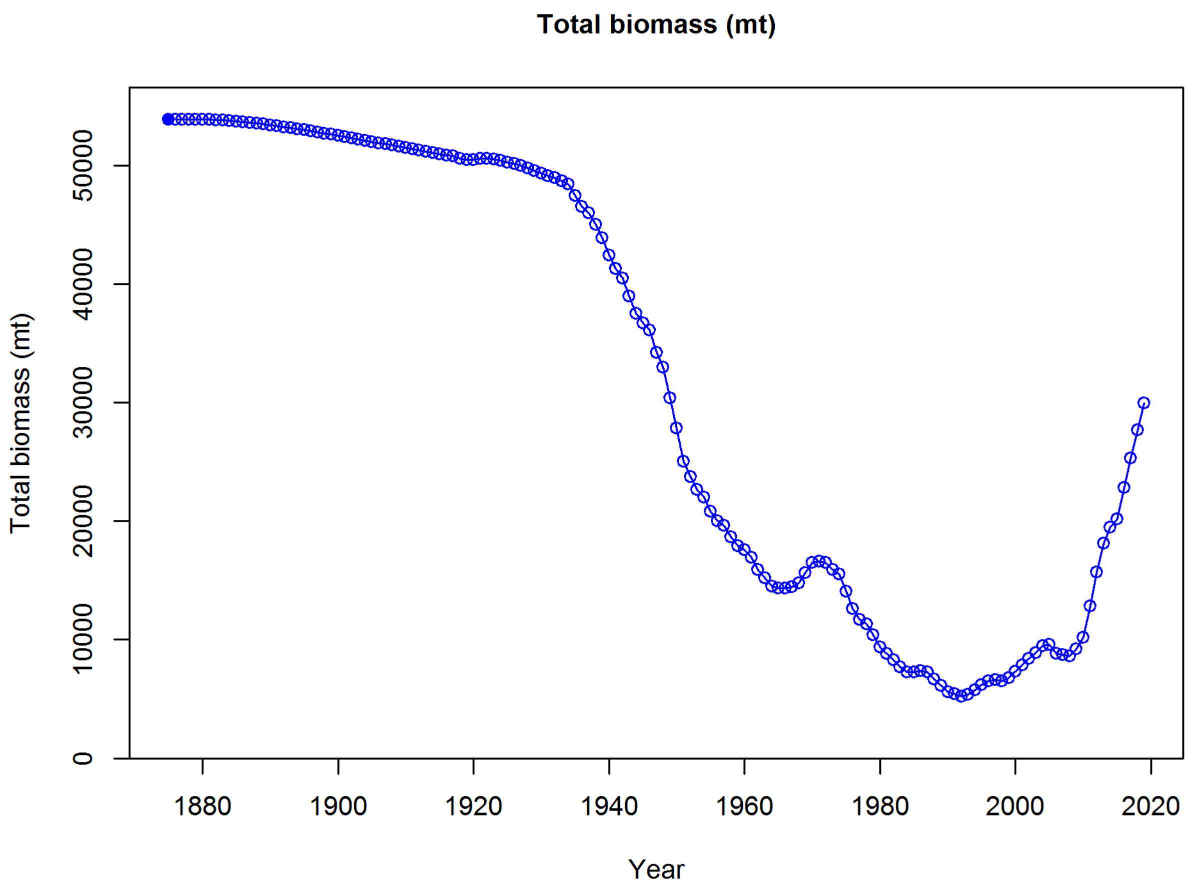

Figure 12: Estimated time-series of total biomass for petrale sole. fig:total_bio

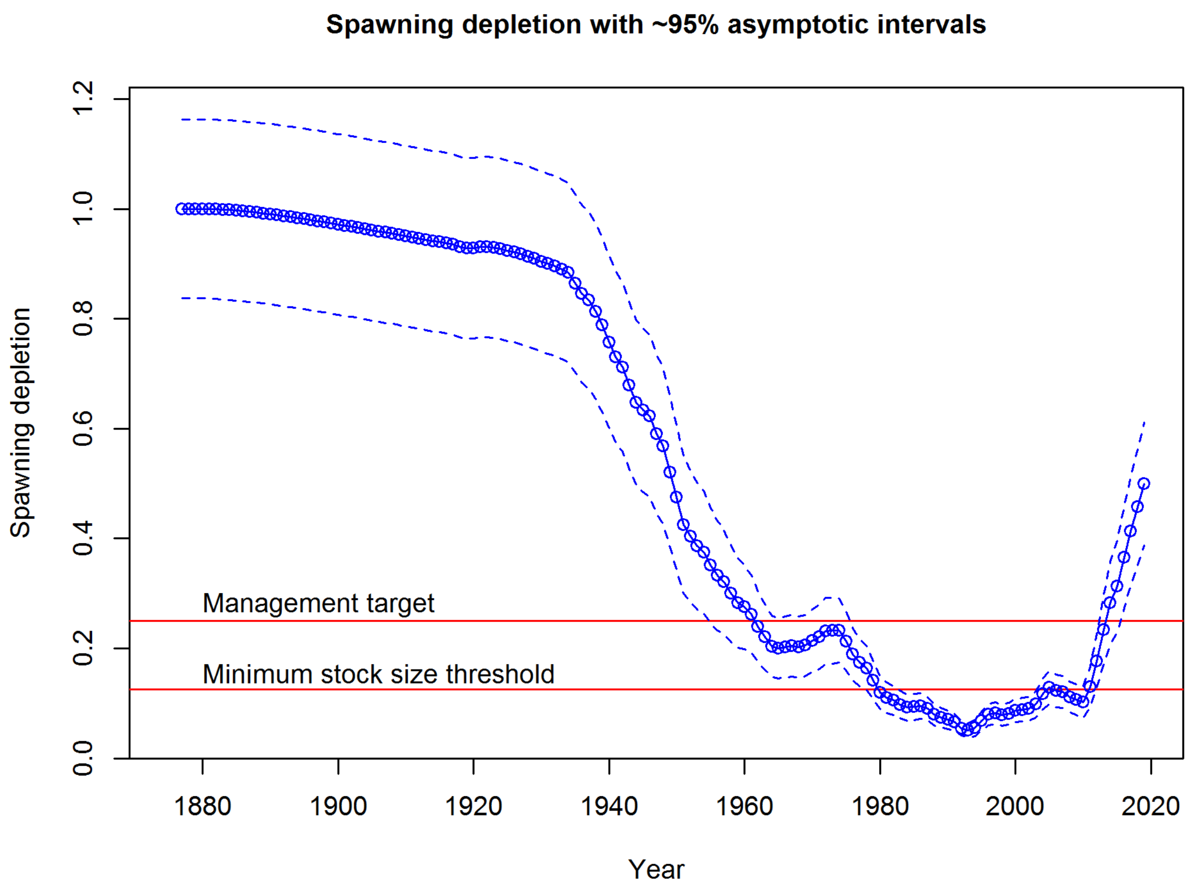

Figure 13: Estimated time-series of relative spawning output (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for petrale sole. fig:depl

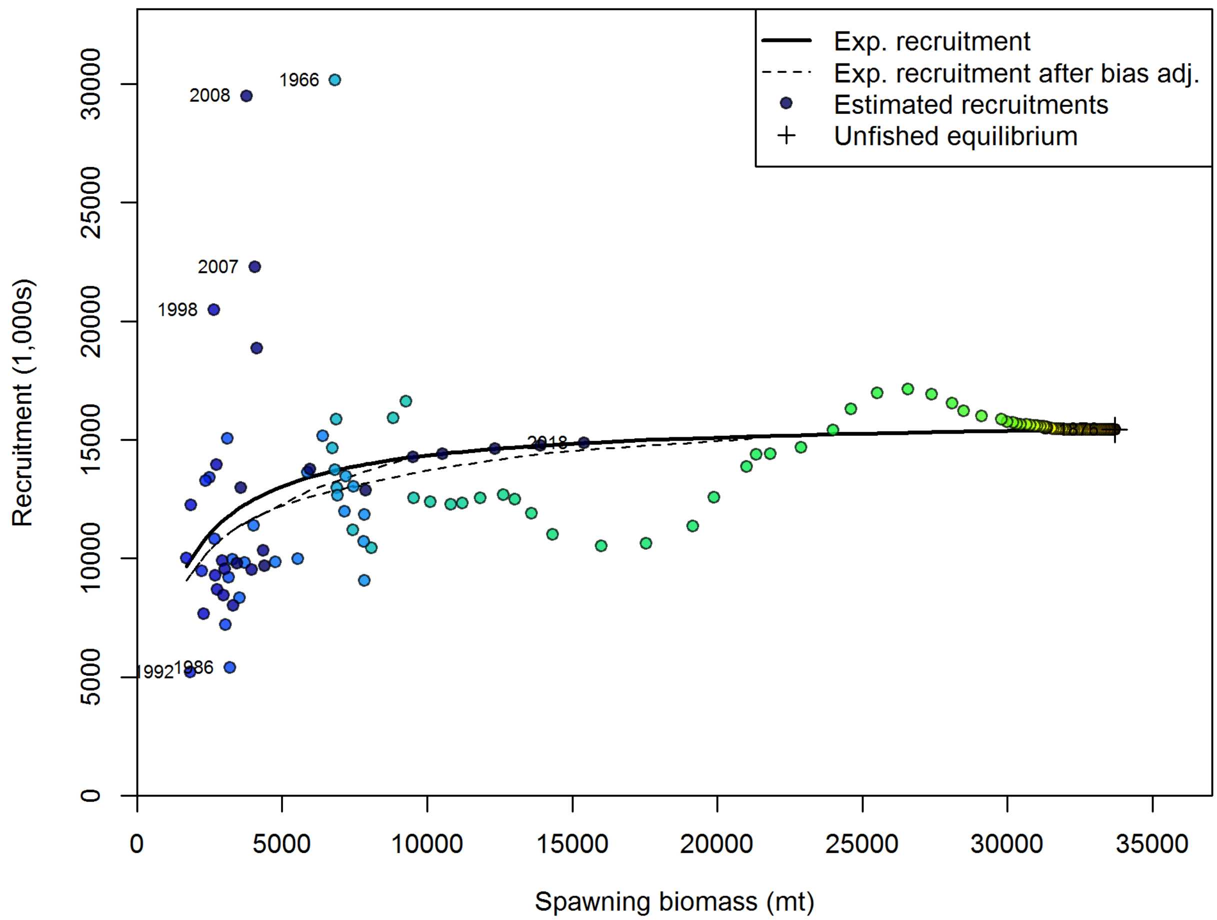

Figure 14: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution
fig:stock_recruit_curve

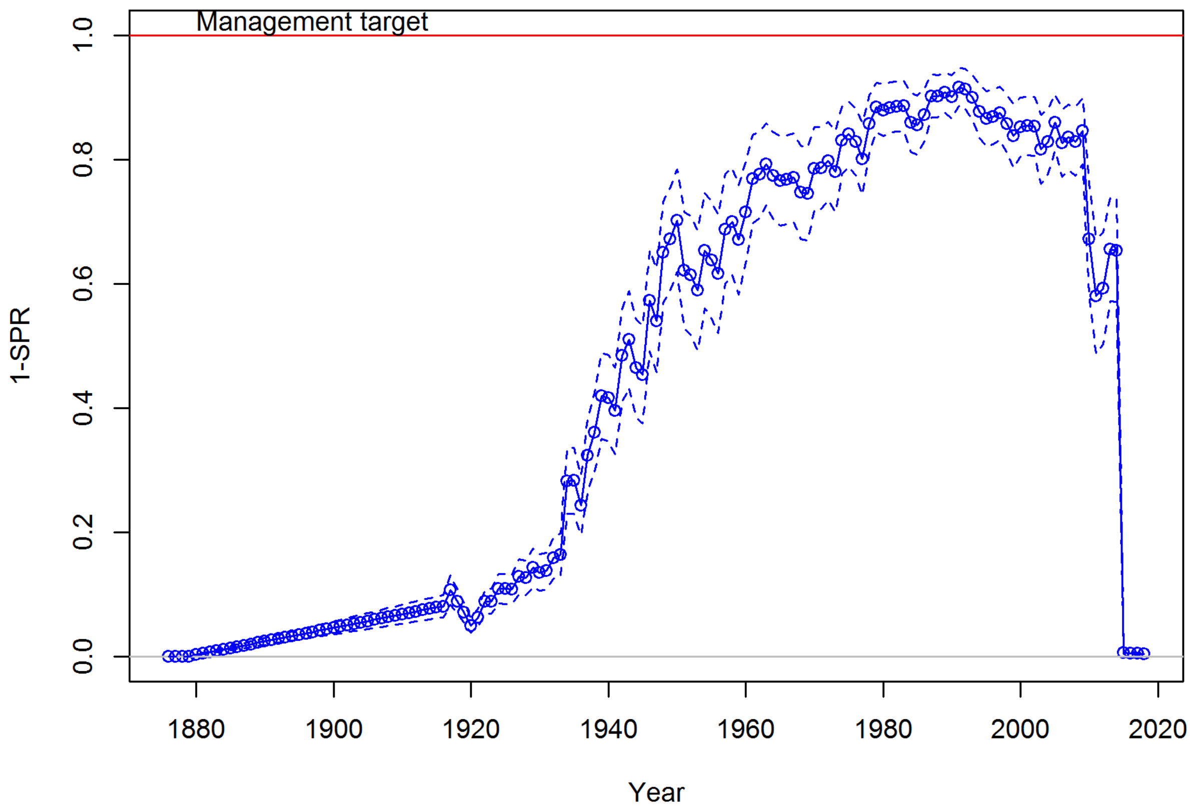

Figure 15: Estimated spawning potential ratio (1-SPR)/(1-SPR30%) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR30% harvest rate. The last year in the time series is 2018. fig:SPR

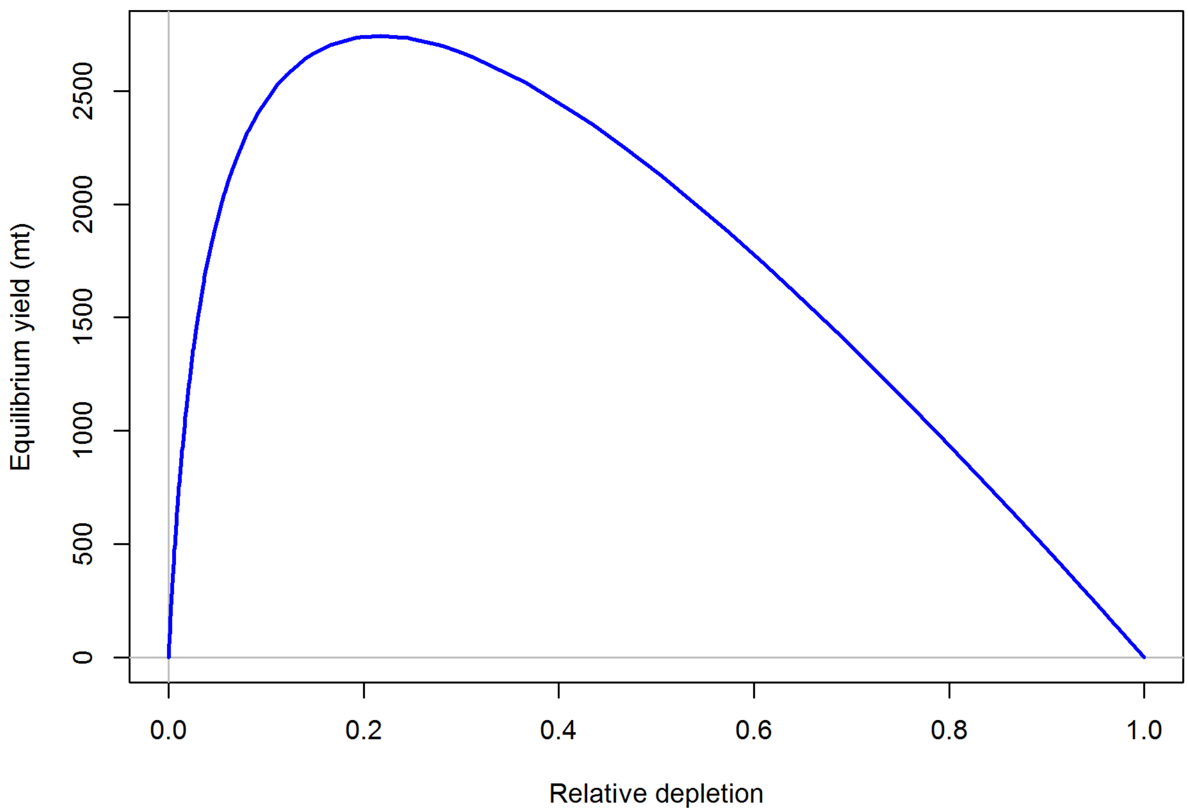

Figure 16: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.89. fig:yield

10 References

references

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