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

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Executive Summary

Stock

This assessment reports the status of the Petrale sole (*Eopsetta jordani*) off US coast of California, Oregon, and Washington using data through 2018.

Landings

Harvest of Petrale sole first began off the US west coast in 1876.

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.

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

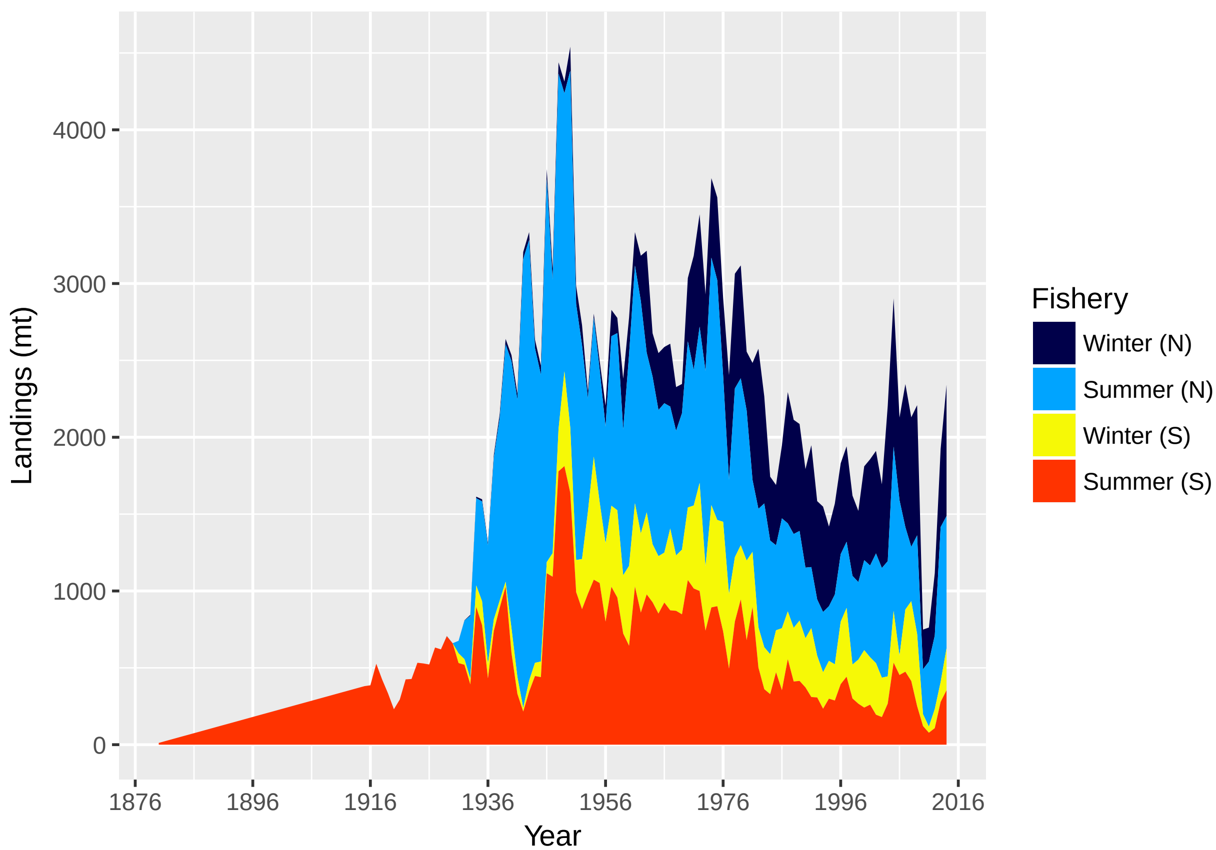

Figure a: Landings of Petrale sole by the Northern and Southern winter and summer fleets of the US west coast.

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) from 1876 to 2019 and forecasted beyond 2019.

Stock Biomass

The predicted spawning output from the base model ...

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

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

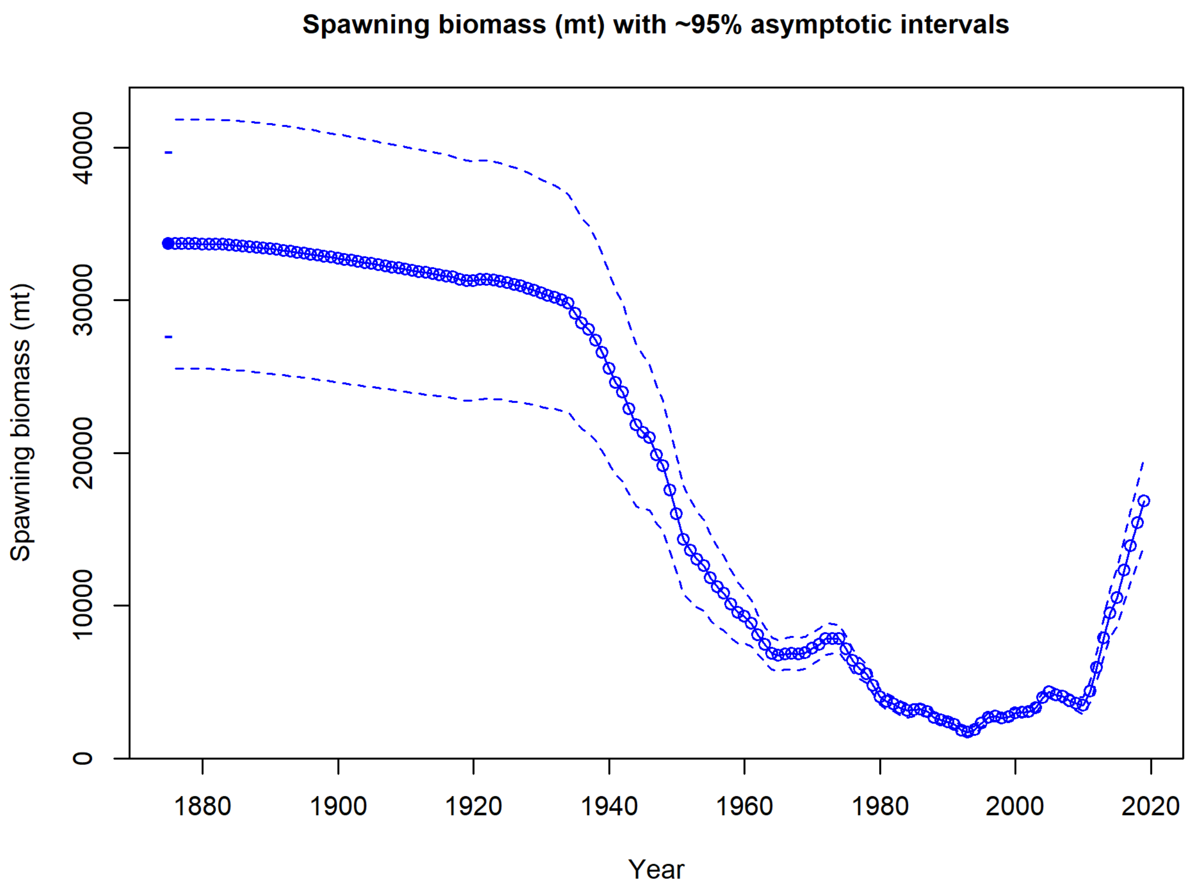

Figure b: Estimated time-series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model.

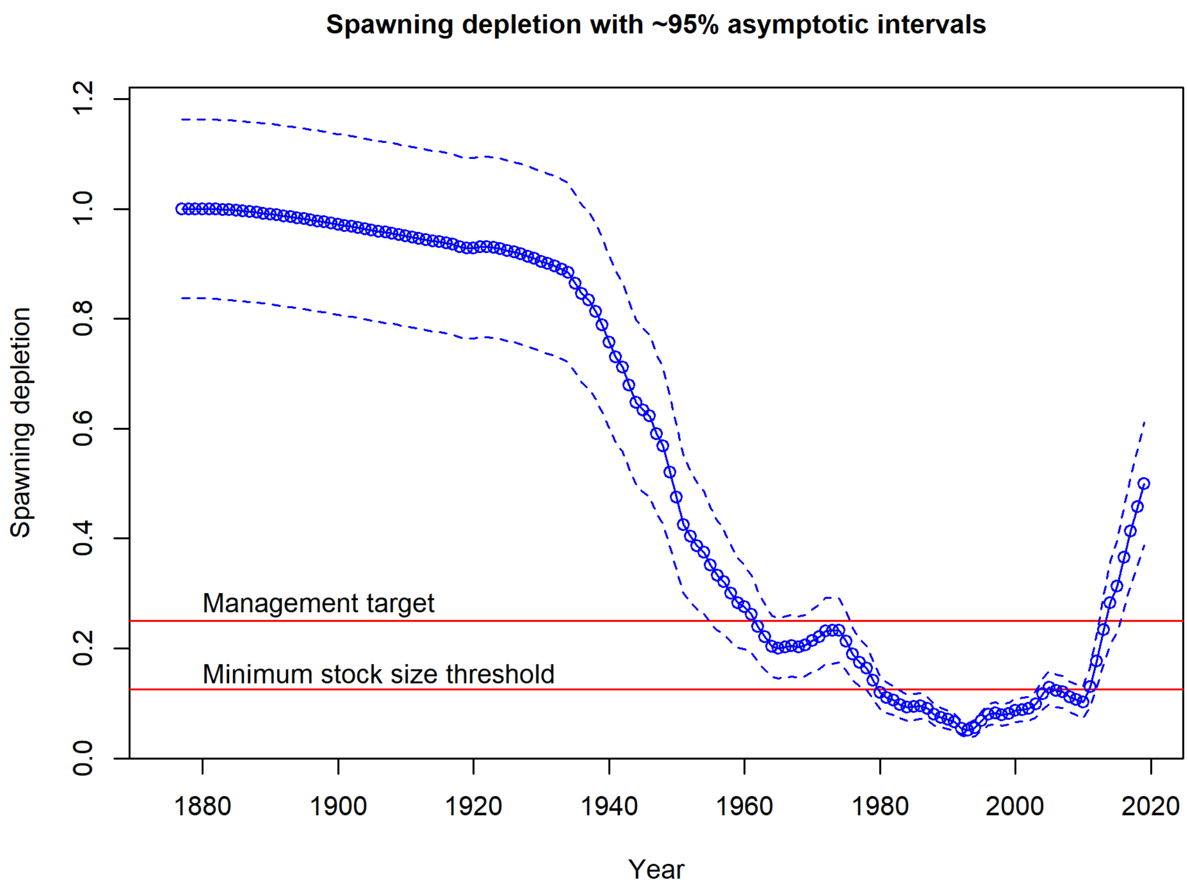

Figure c: Estimated time-series of relative spawning output (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model.

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.

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

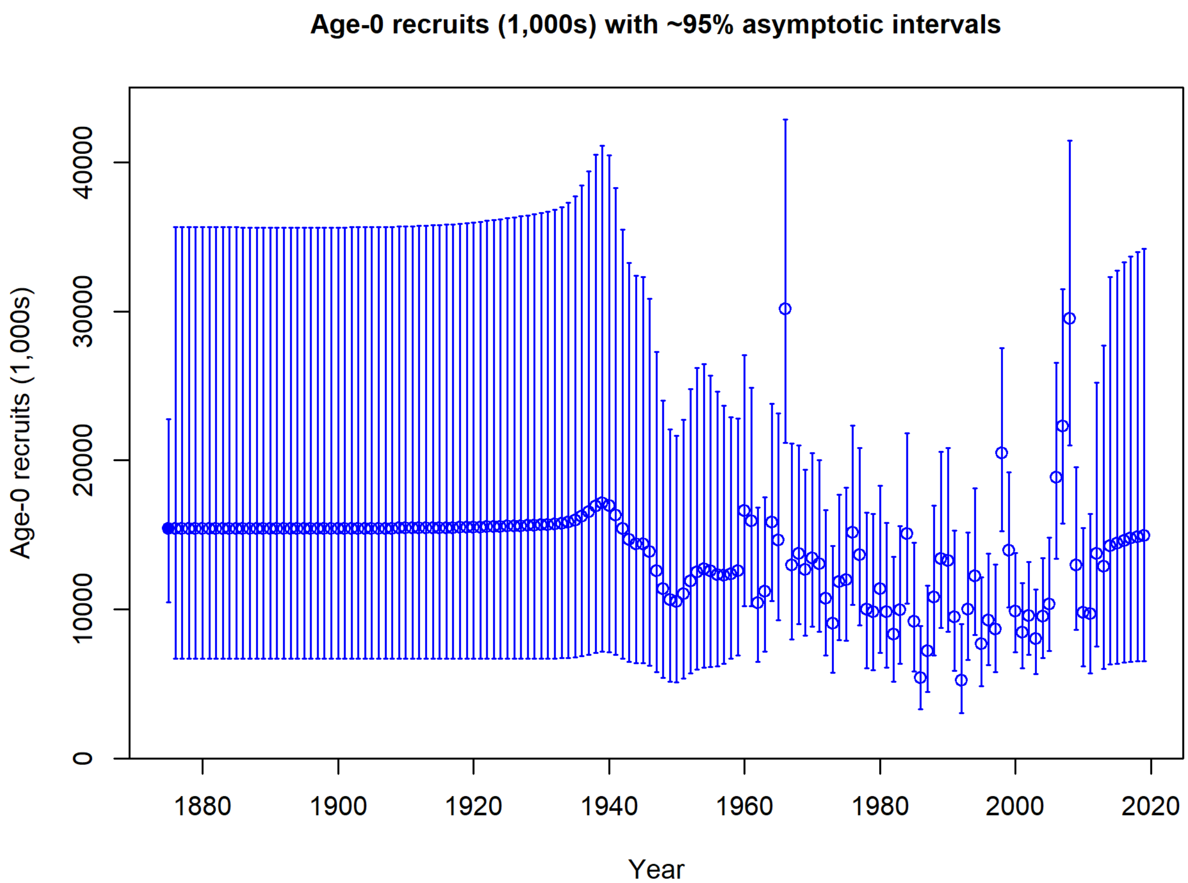

Figure d: Time-series of estimated Petrale sole recruitments for the base model with 95% confidence or credibility intervals.

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.

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

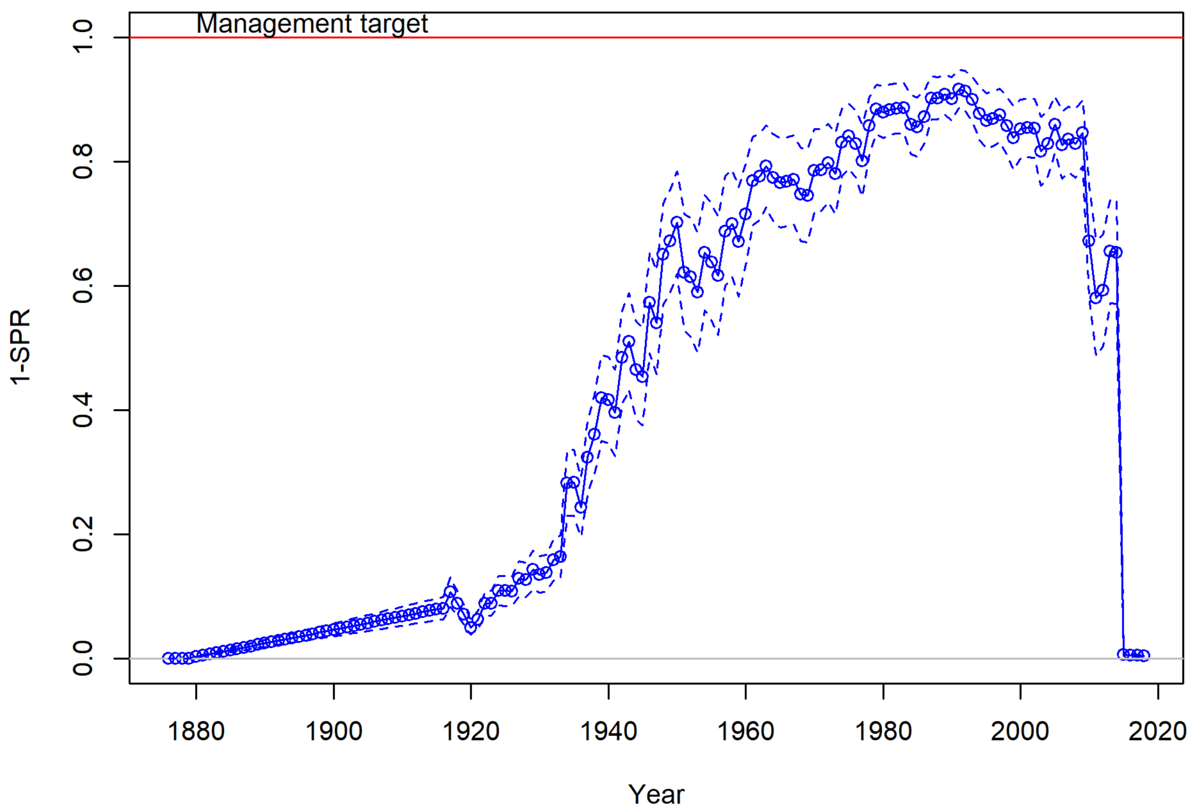

Figure e: Estimated relative spawning potential ratio (1-SPR)/(1-SPR30%) for the base model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess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

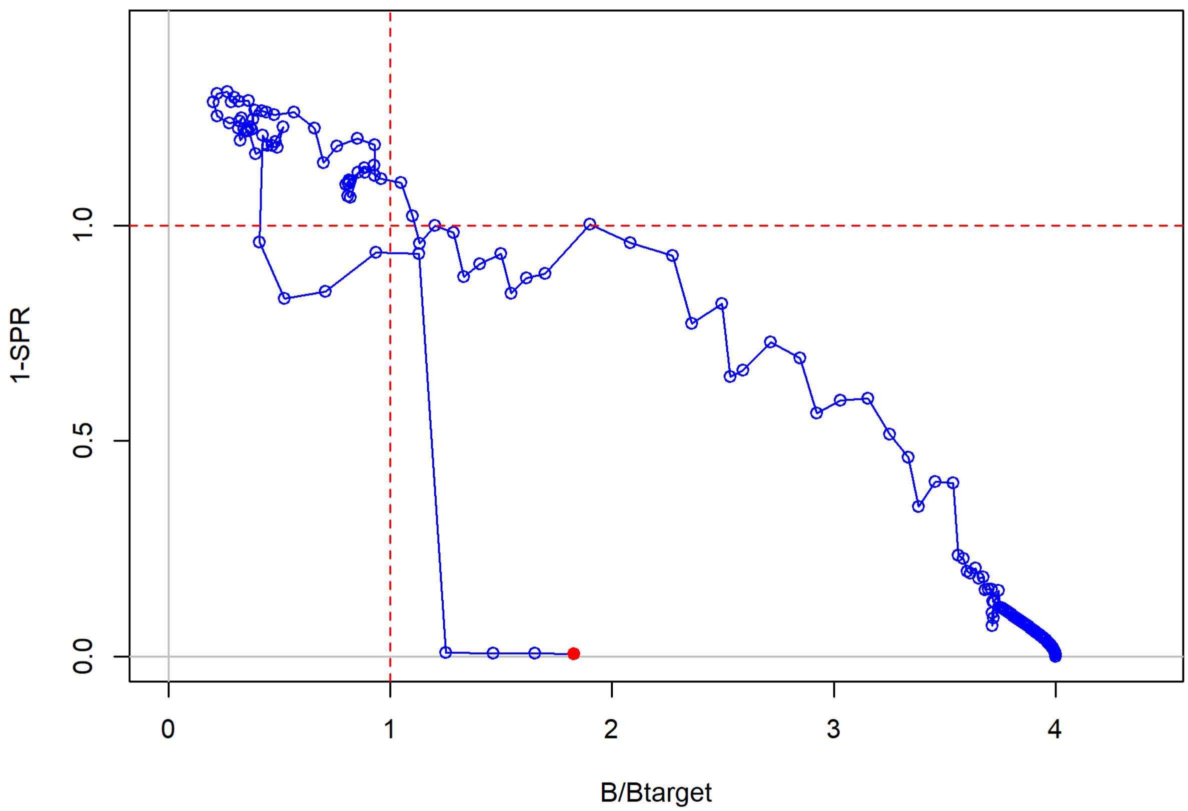

Figure f: Phase plot of estimated (1-SPR)/(1-SPR30%) vs. depletion (B/Btarget) for the base case model. The red circle indicates 2018 estimated status and exploitation for Petrale sole.

Ecosystem Considerations

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.

Quantity	**Estimate**	**~95% 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	9329.8	7316.9 - 11342.7
$SPR_{30\%}$	0.3	
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

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.

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

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

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.

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.

			States of nature					
			M = 0.04725		M = 0.054		M = 0.0595	
	Year	Catch	Spawning Output	Depletion (%)	Spawning Output	Depletion (%)	Spawning Output	Depletion (%)
ABC	2019	4340	3944	62.9	5741	83.3	7505	96.8
	2020	4229	3909	62.4	5745	83.4	7542	97.3
	2021	4108	3858	61.6	5723	83.1	7546	97.3
	2022	3984	3784	60.4	5666	82.2	7503	96.8
	2023	3862	3695	59.0	5586	81.1	7427	95.8
	2024	3748	3600	57.4	5494	79.7	7332	94.6
	2025	3644	3502	55.9	5395	78.3	7226	93.2
	2026	3551	3404	54.3	5292	76.8	7113	91.8
	2027	3467	3308	52.8	5188	75.3	6996	90.3
	2028	3389	3213	51.3	5084	73.8	6879	88.7
SPR50	2019	1822	3944	62.9	5741	83.3	7505	96.8
	2020	1822	4022	64.2	5857	85.0	7654	98.7
	2021	1822	4083	65.1	5946	86.3	7768	100.2
	2022	1822	4117	65.7	5996	87.0	7830	101.0
	2023	1822	4131	65.9	6016	87.3	7852	101.3
	2024	1822	4133	65.9	6017	87.3	7848	101.2
	2025	1822	4125	65.8	6004	87.1	7824	100.9
	2026	1822	4110	65.6	5979	86.8	7786	100.4
	2027	1822	4090	65.3	5947	86.3	7736	99.8
	2028	1822	4067	64.9	5908	85.8	7679	99.1

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.

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

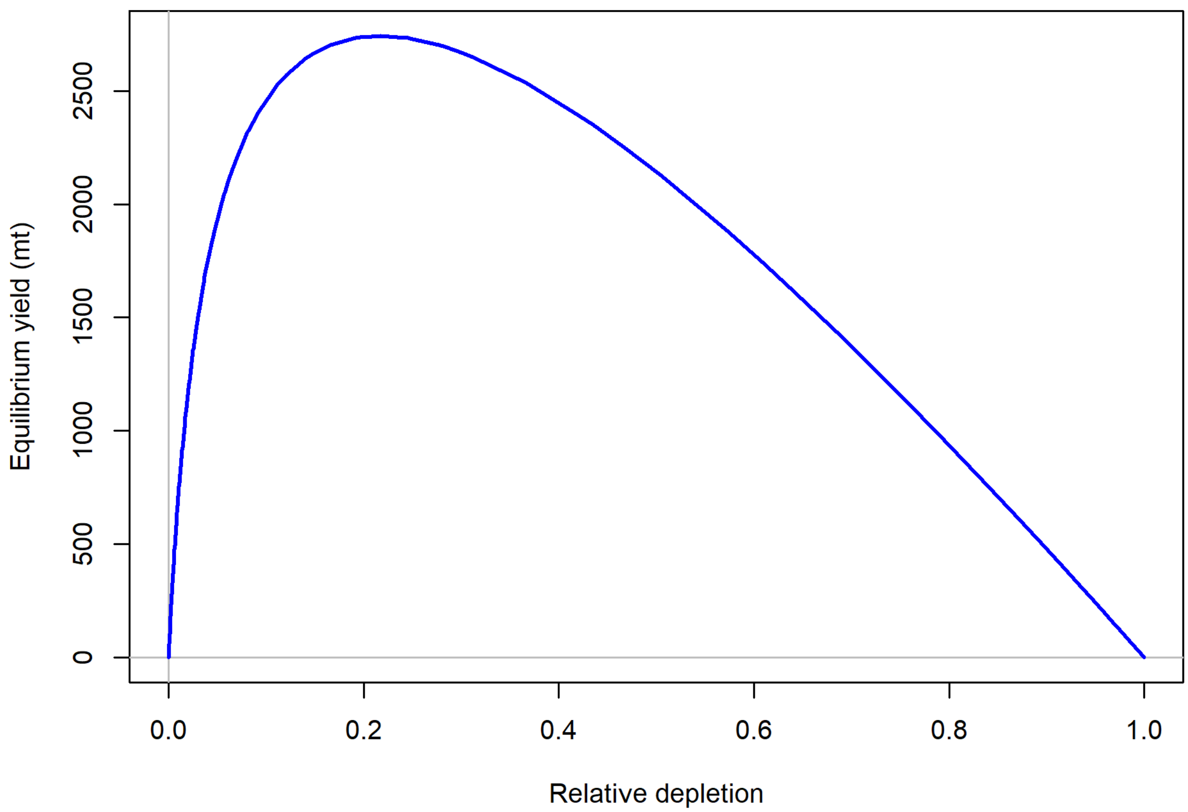

Figure g: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.89.

1 Introduction

1.1 Distribution and Stock Structure

1.2 Historical and Current Fishery

1.3 Summary of Management History and Performance

1.4 Fisheries off Canada and Alaska

2 Data

Data used in the Petrale sole assessment are summarized in Figure 2. A description of each data source is provided below.

2.1 Fishery-Independent Data

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

2.1.2 Northwest Fisheries Science Center (NWFSC) Slope Survey

2.1.3 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.

Although the Triennial shelf survey was used in the 2011 assessment, it was not used in the final base model for the current assessment for a number of reasons. First, there were concerns regarding the varying sampling and targeting of specific species by year across the time-series. Secondly, the Triennial shelf survey targeted the shelf of the West Coast and would not be expected to sample well slope species such as Petrale sole. There were limited observations of Petrale sole relative to other surveys (e.g. NWFSC shelf-slope survey) and the length and age distributions varied in such a manner that would indicate either poor sampling of Petrale sole or inconsistent sampling of the population.

2.2 Fishery-Dependent Data

2.2.1 Commercial Fishery Landings

Washington

Oregon

California

2.2.2 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 **??**.

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 **??** 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 Fishery Length and Age Data

2.2.3.1 Commercial Fishery

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

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

2.2.4 Historical Commercial Catch-Per-Unit Effort

2.3 Biological Data

2.3.1 Natural Mortality

2.3.2 Sex Ratio, Maturation, and Fecundity

2.3.3 Length-Weight Relationship

2.3.4 Growth (Length-at-Age)

2.3.5 Ageing Precision and Bias

2.4 History of Modeling Approaches Used for This Stock

2.4.1 Previous Assessments

3 Assessment

3.1 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 2.

3.1.1 Changes Between the 2015 Update Assessment Model and Current Model

3.1.2 Summary of Fleets and Areas

3.1.3 Other Specifications

3.1.4 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

3.1.6 Data Weighting

3.1.7 Estimated and Fixed Parameters

3.1.8 Key Assumptions and Structural Choices

3.1.9 Bridging Analysis

3.1.10 Convergence

3.2 Base Model Results

3.2.1 Parameter Estimates

3.2.2 Fits to the Data

3.2.3 Population Trajectory

3.2.4 Uncertainty and Sensitivity Analyses

3.2.5 Retrospective Analysis

3.2.6 Historical Analysis

3.2.7 Likelihood Profiles

3.2.8 Reference Points

4 Harvest Projections and Decision Tables

5 Regional Management Considerations

6 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

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

8 Figures

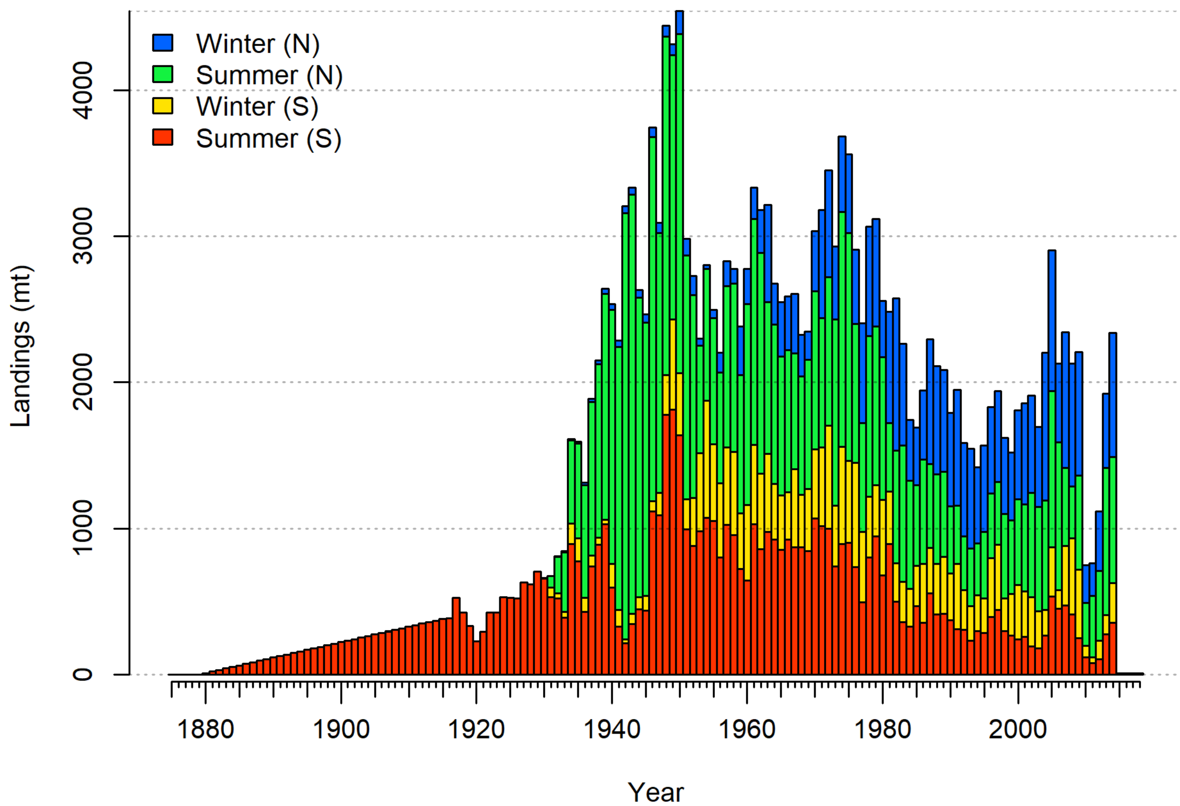

Figure 1: Total catches Petrale sole through 2016.

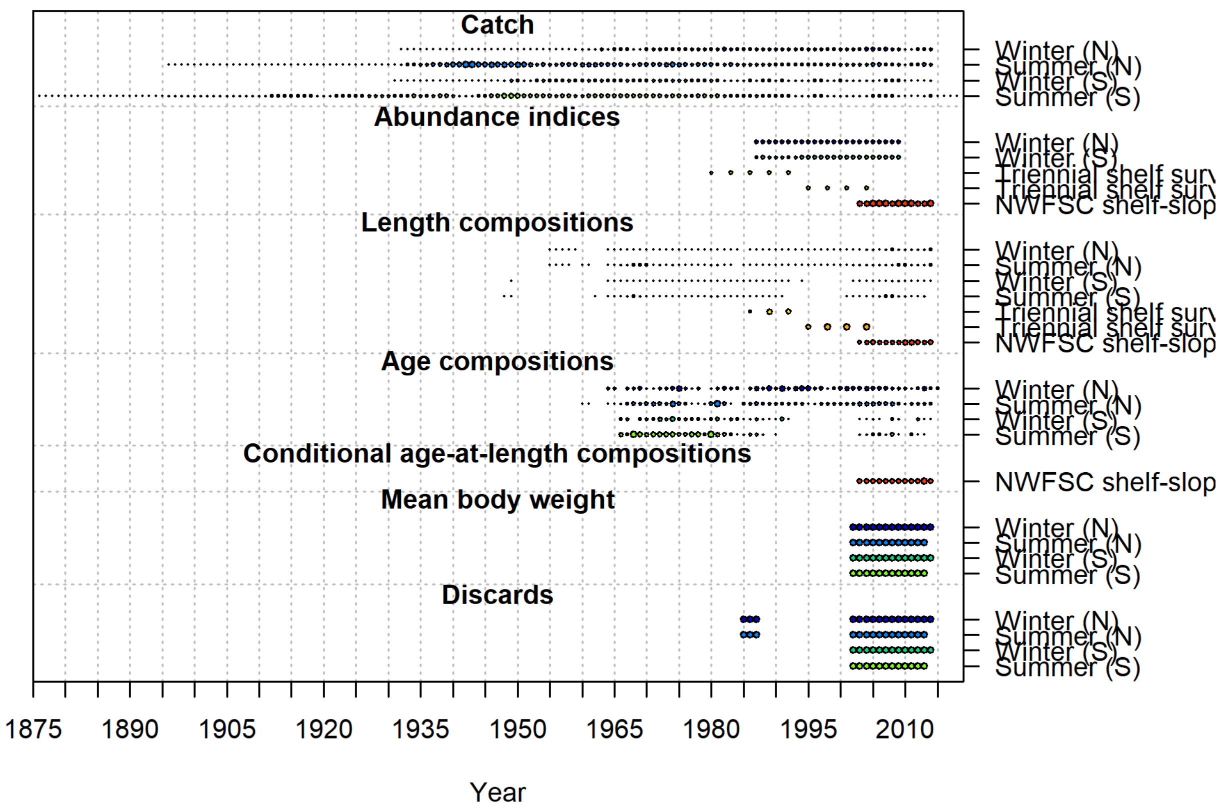

Figure 2: Summary of data sources used in the base model.

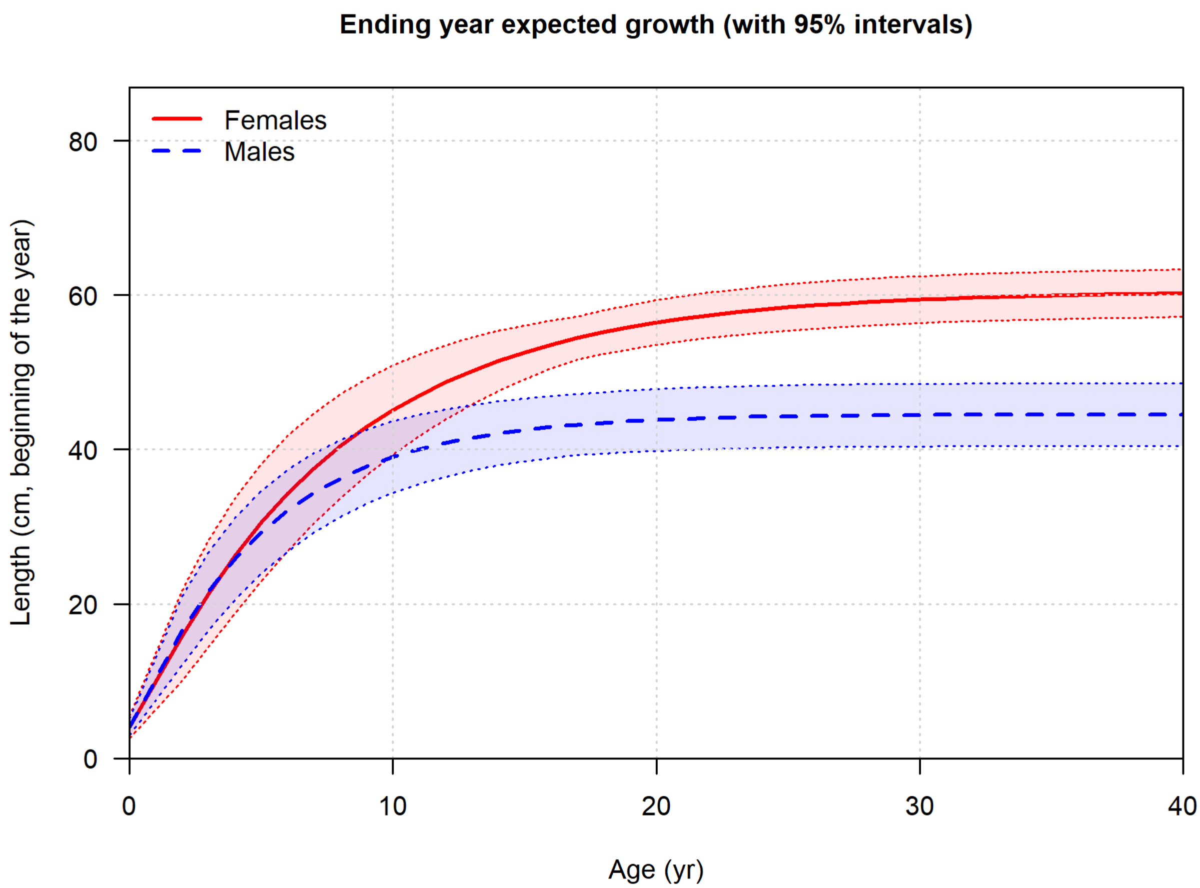

Figure 3: Estimated length-at-age for male and female for Petrale sole with estimated CV.

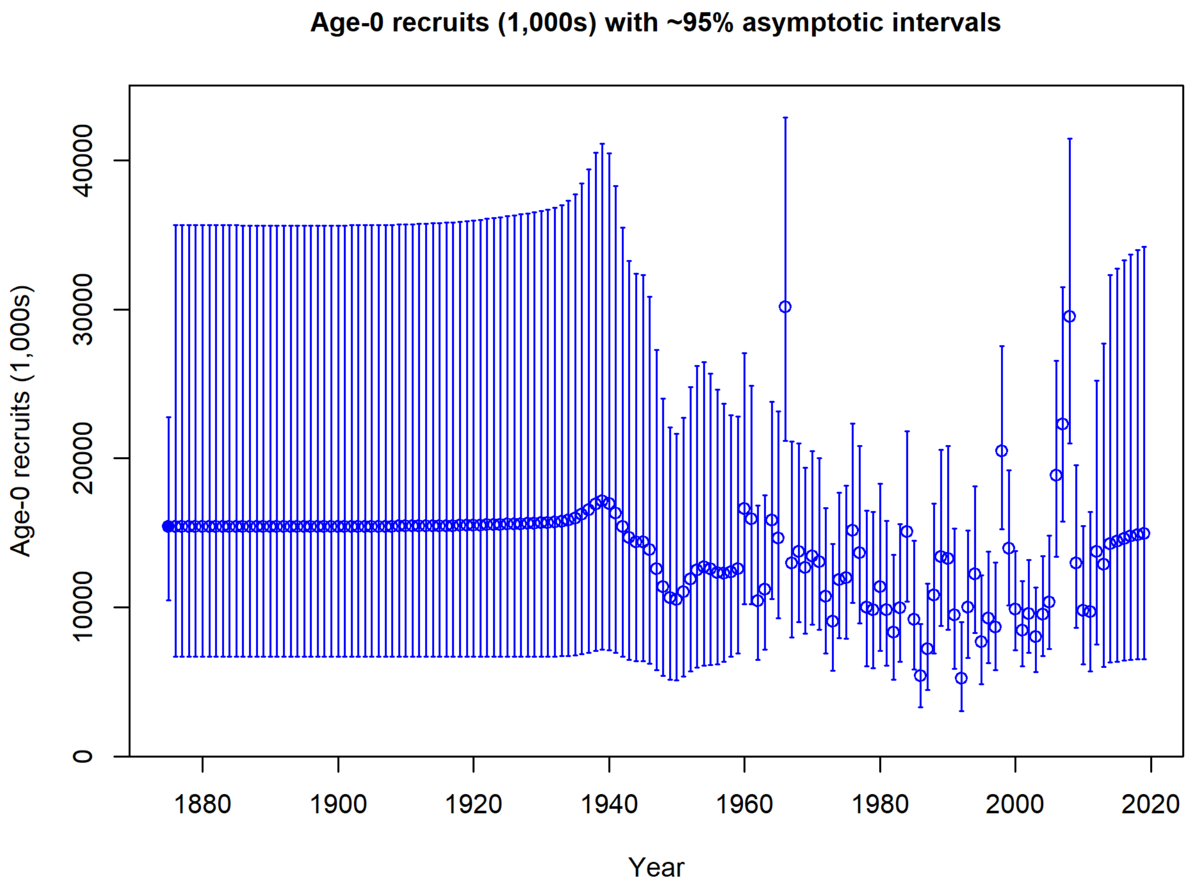

Figure 4: Estimated time-series of recruitment for Petrale sole.

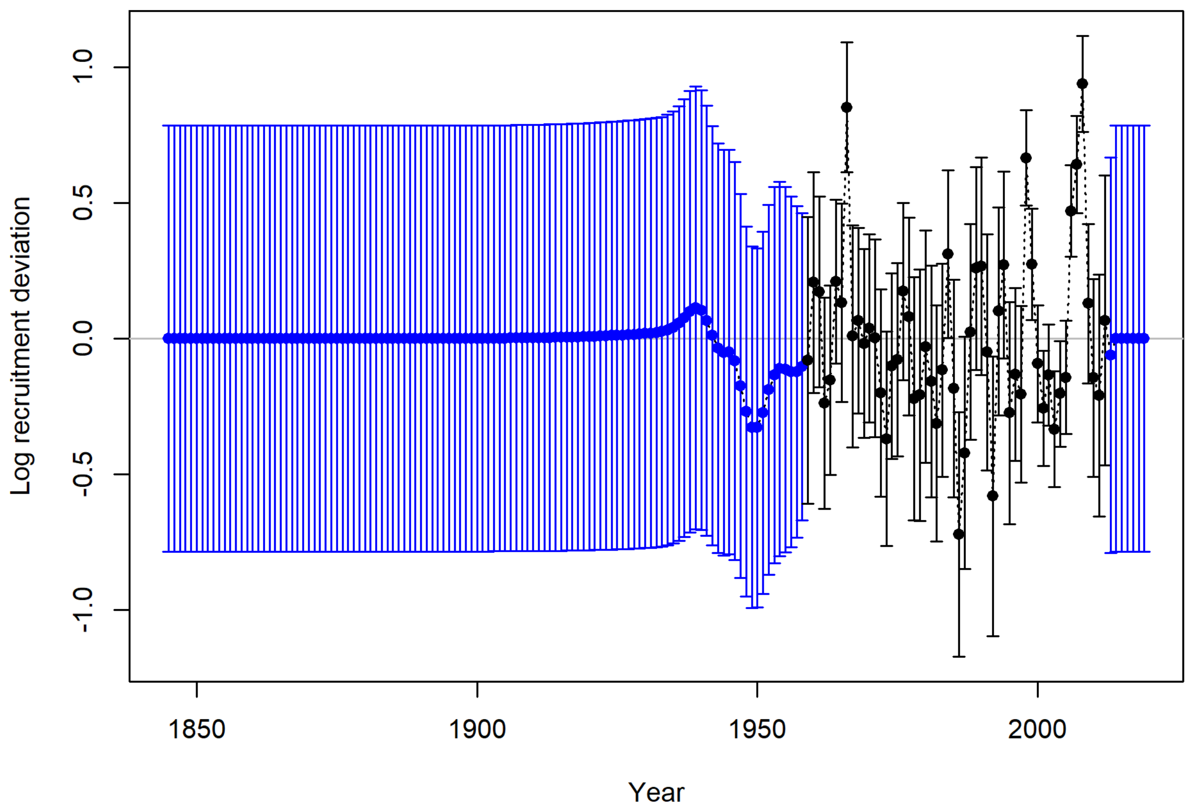

Figure 5: Estimated time-series of recruitment deviations for Petrale sole.

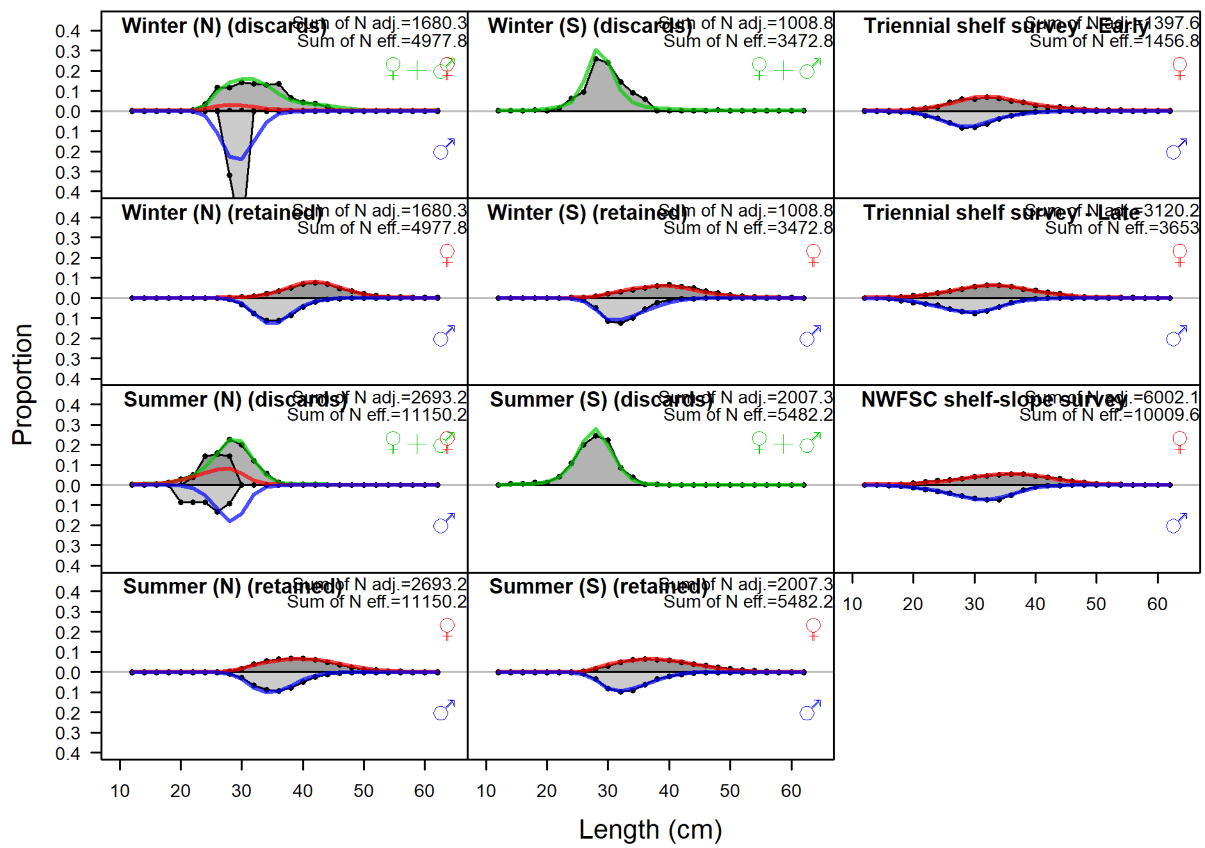

Figure 6: Length compositions aggregated across time by fleet. Labels 'retained' and 'discard' indicate retained or discarded samples for each fleet. Panels without this designation represent the whole catch. The Triennial shelf survey length data were not used in the final model, but the implied model fits are shown.

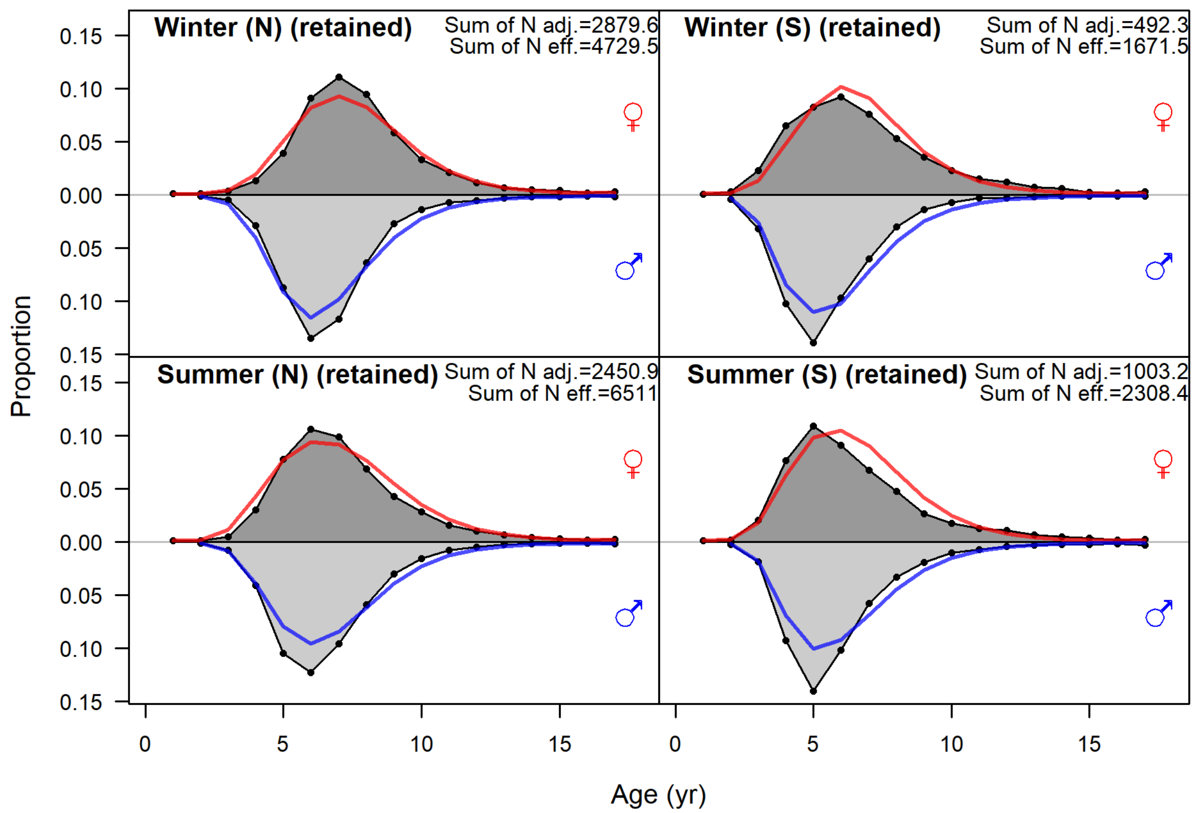

Figure 7: Age compositions aggregated across time by fleet. The Triennial shelf survey age data were not used in the final model, but the implied model fits are shown.

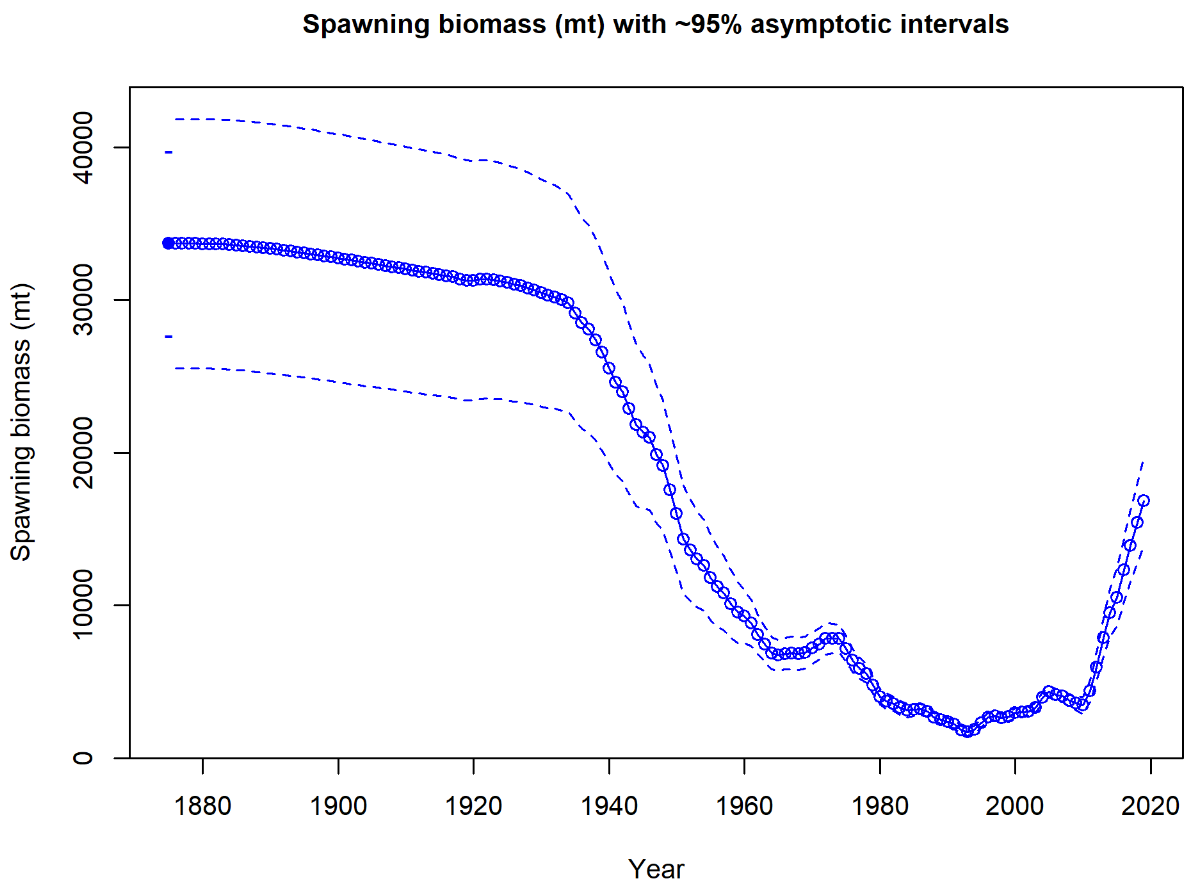

Figure 8: Estimated time-series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for Petrale sole.

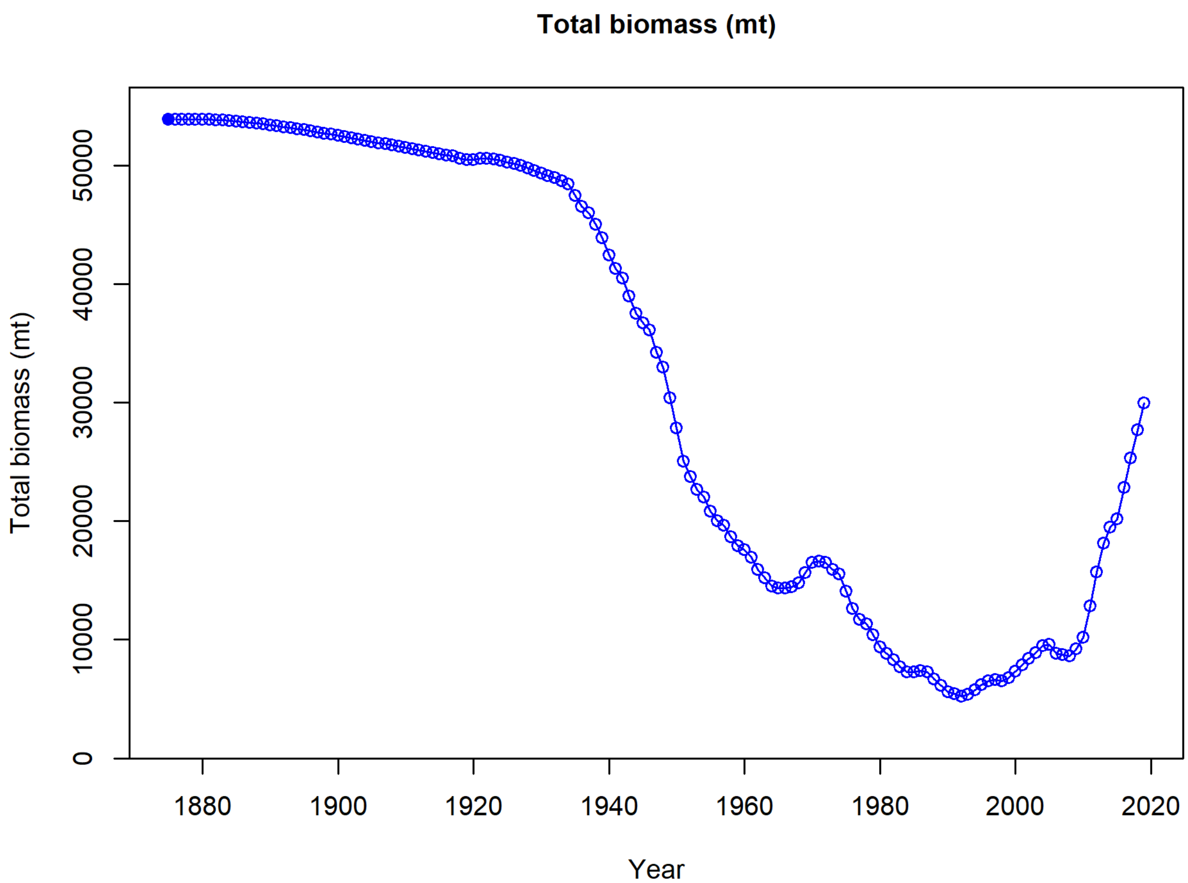

Figure 9: Estimated time-series of total biomass for Petrale sole.

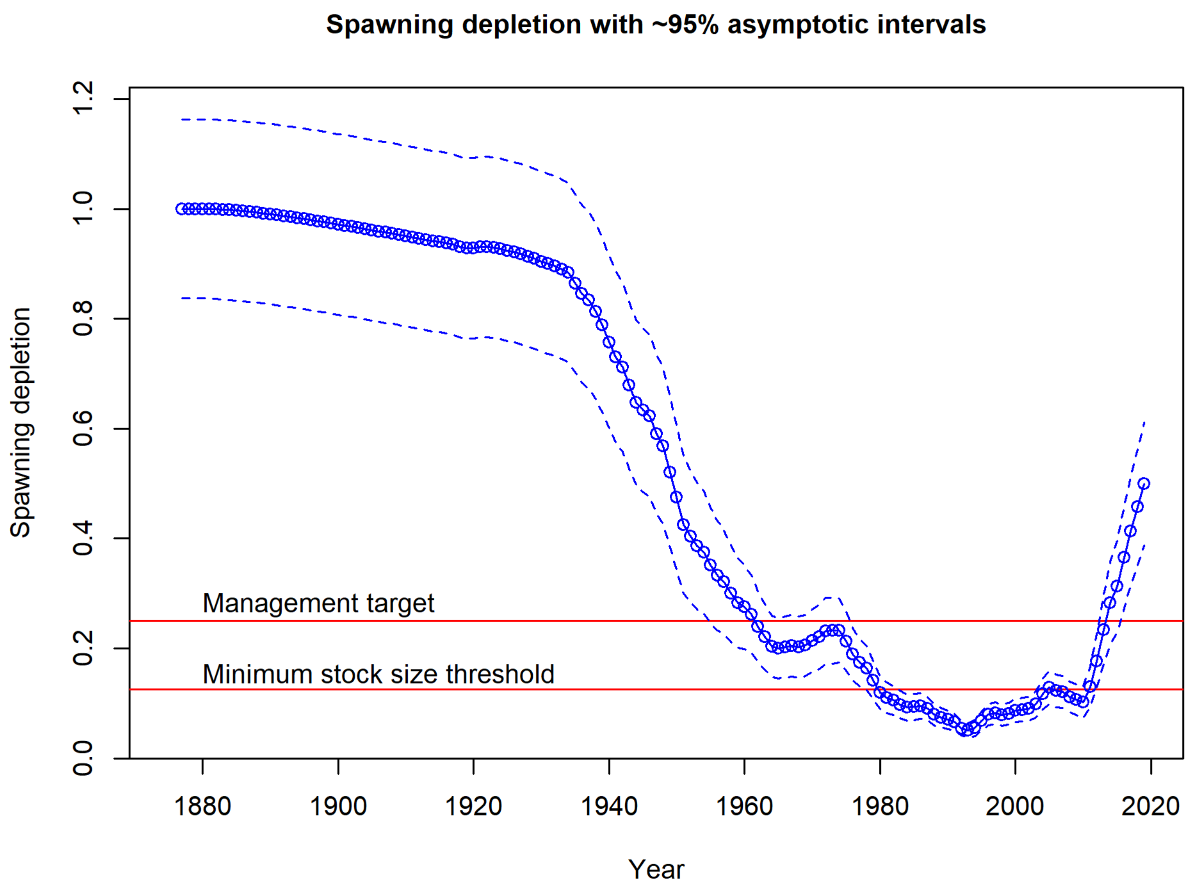

Figure 10: Estimated time-series of relative spawning output (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for Petrale sole.

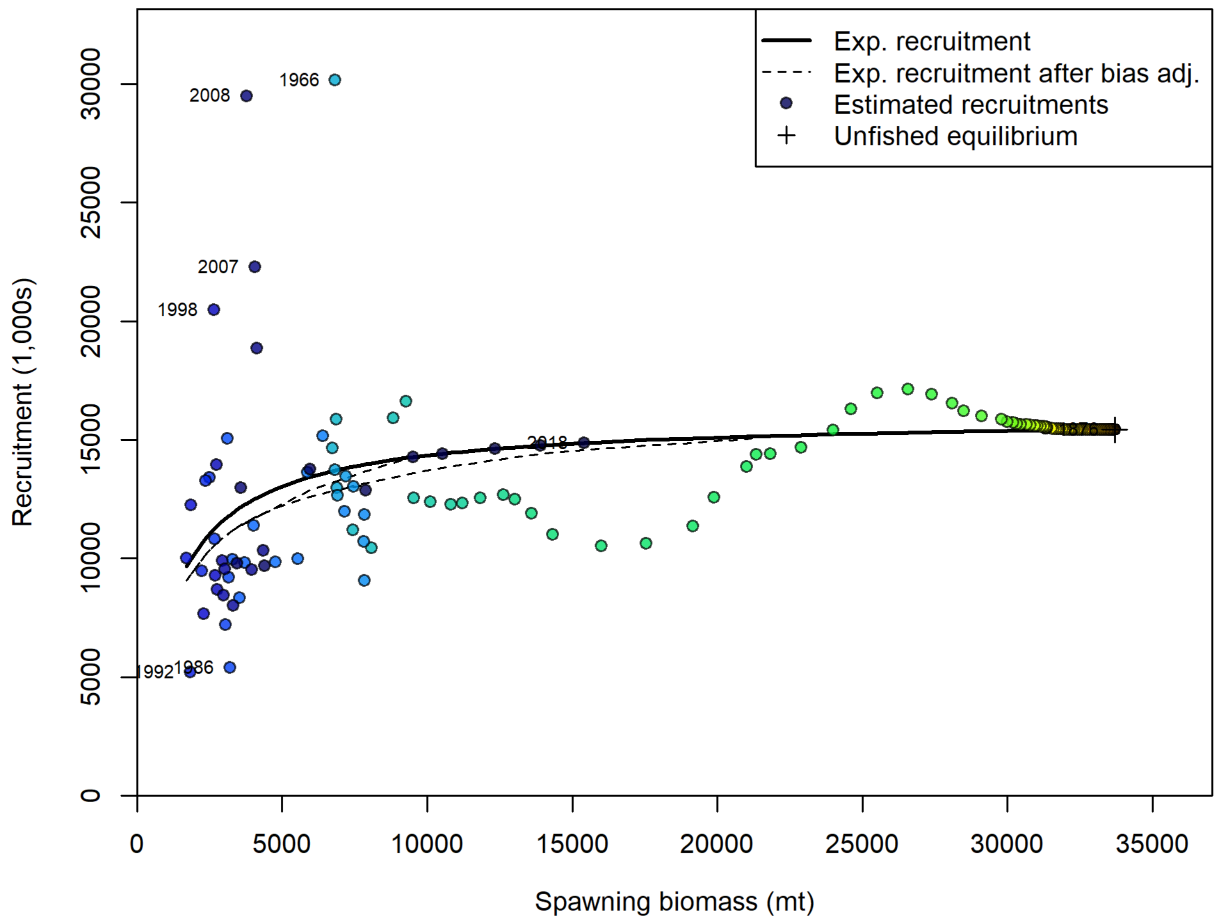

Figure 11: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line). The green line shows the effect of the bias correction for the lognormal distribution

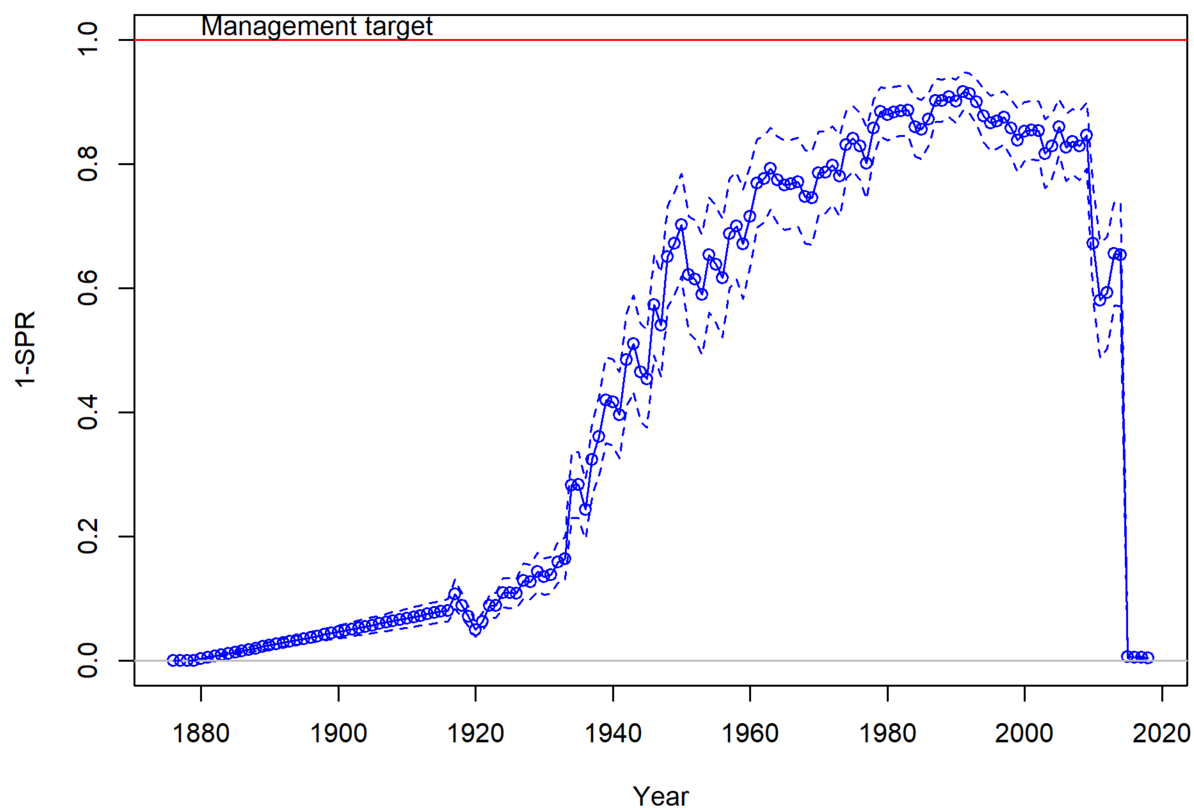

Figure 12: Estimated spawning potential ratio (1-SPR)/(1-SPR30%) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR30% harvest rate. The last year in the time series is 2018.

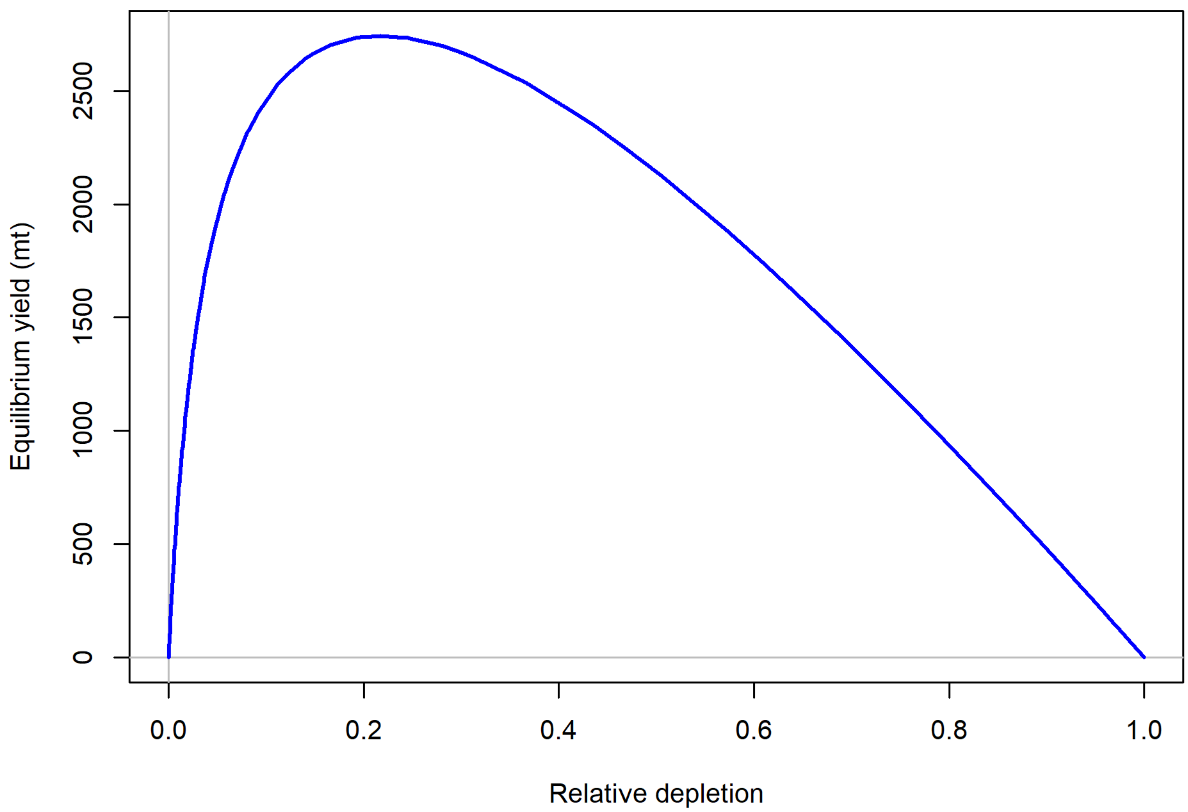

Figure 13: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.89.

9 References

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