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

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Executive Summary

Stock

This assessment reports the status of the petrale sole (*Eopsetta jordani*) off the 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

While records do not exist, the earliest catches of petrale sole are reported in 1876 in California and 1884 in Oregon. In this assessment, fishery removals have been divided among 4 fleets: 1) Winter North trawl, 2) Summer North trawl, 3) Winter South trawl, and 4) Summer South trawl. Landings for the North fleet are defined as fish landed in Washington and Oregon ports. Landings for the South fleet are defined as fish landed in California ports. Recent annual catches between 1981-2018 range between 755 and 3008 mt per year and the most recent year landings are shown in Table a. The landings are summarized into winter and summer fleets where winter is defined as November to February and summer running from March to October. Petrale sole are caught nearly exclusively by trawl fleets; non-trawl gears contribute only a small fraction of the catches across all years.

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 (Table a). Petrale sole are a desirable market species and discarding has historically been low.

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

Year	Winter (N)	Summer (N)	Winter (S)	Summer (S)	Total Landings
2009	847	642	470	250	2209
2010	264	292	78	121	755
2011	224	427	40	78	768
2012	410	494	124	108	1135
2013	513	1045	130	280	1967
2014	853	861	273	386	2373
2015	1040	1077	215	354	2686
2016	865	1168	237	235	2506
2017	1142	1271	201	393	3008
2018	957	1262	218	402	2840

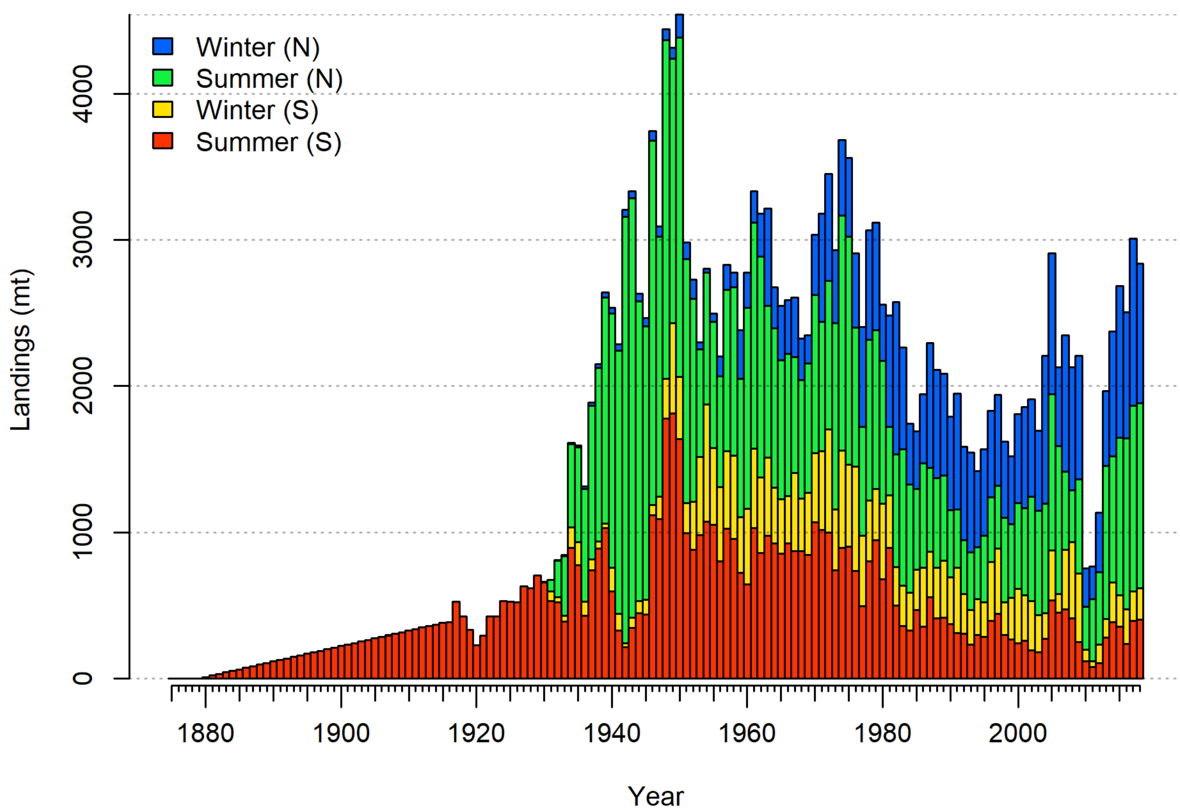

Figure a: 'Landings of by the Northern and Southern winter and summer fleets off the U.S. west coast.

Data and Assessment

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

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

Updated Data

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

1. Commercial catches (2015-2018 added);
2. Commercial length and age data (all years reprocessed, 2015-2018 added);
3. Observed discard rates, average weights, and lengths (2002-2017 reprocessed, 2014-2017 added);
4. AFSC/NWFSC West Coast Triennial Shelf Survey early and late indices of abundance and length composition data (1980-2004 reprocessed);
5. NWFSC West Coast Groundfish Bottom Trawl Survey index of abundance, length and age composition data (2003-2018 reprocessed, 2015-2018 added);
6. Model tuning to re-weight data using the McAllister and Iannelli approach (same approach applied in the 2013 assessment);

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

8. The natural mortality prior for female and male fish was updated; and,

9. Model fitting using latest version of Stock Synthesis (SS v.3.30.13).

Stock Biomass

Petrale sole were lightly exploited during the early 1900s, but by the 1950s, the fishery was well developed with the stock showing declines in biomass and catches (Figures a and b). The rate of decline in spawning biomass accelerated through the 1970s reaching minimums generally around or below 10% of the unexploited levels during the 1980s through the early 2000s (Figure c). The petrale sole spawning stock biomass is estimated to have increased in recent years due to reduced catches during rebuilding and in response to above average recruitment in 2006, 2007, and 2008. The 2019 estimated spawning biomass relative to unfished equilibrium spawning biomass is above the target of 25% of unfished spawning biomass, at 39.1% ($\sim$ 95% asymptotic interval: $\pm$ 28.2%-50.1%) (Table b).

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

Year	Spawning Biomass (mt)	~ 95% Confidence Interval	Estimated Relative Spawning Biomass	~ 95% Confidence Interval
2010	4227	3452 - 5002	0.127	0.087 - 0.166
2011	5378	4414 - 6342	0.161	0.111 - 0.211
2012	7205	5958 - 8452	0.216	0.150 - 0.281
2013	9488	7888 - 11087	0.284	0.199 - 0.369
2014	11433	9524 - 13341	0.342	0.241 - 0.443
2015	12691	10603 - 14778	0.380	0.270 - 0.490
2016	13206	11039 - 15374	0.395	0.283 - 0.508
2017	13519	11293 - 15745	0.405	0.292 - 0.518
2018	13365	11077 - 15653	0.400	0.289 - 0.511
2019	13078	10689 - 15467	0.391	0.282 - 0.501

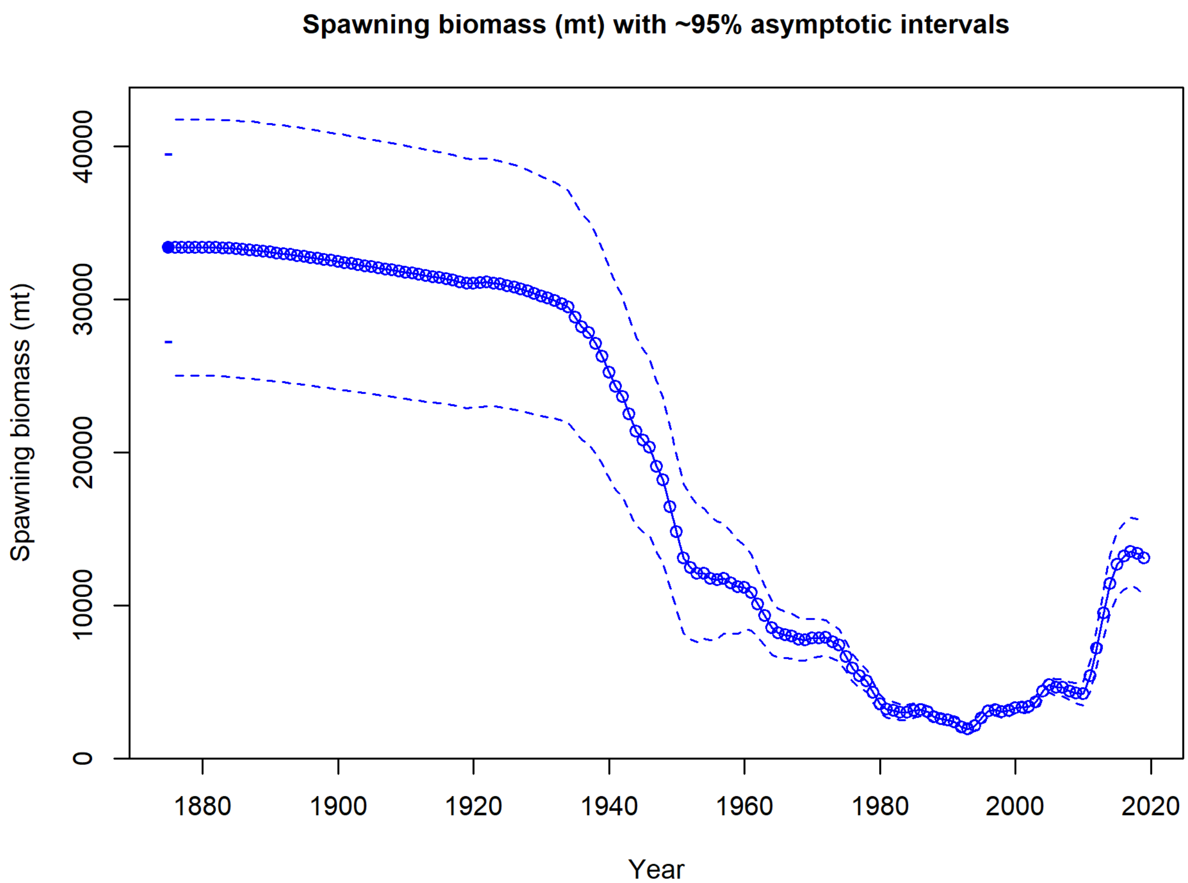

Figure b: Estimated time-series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model.

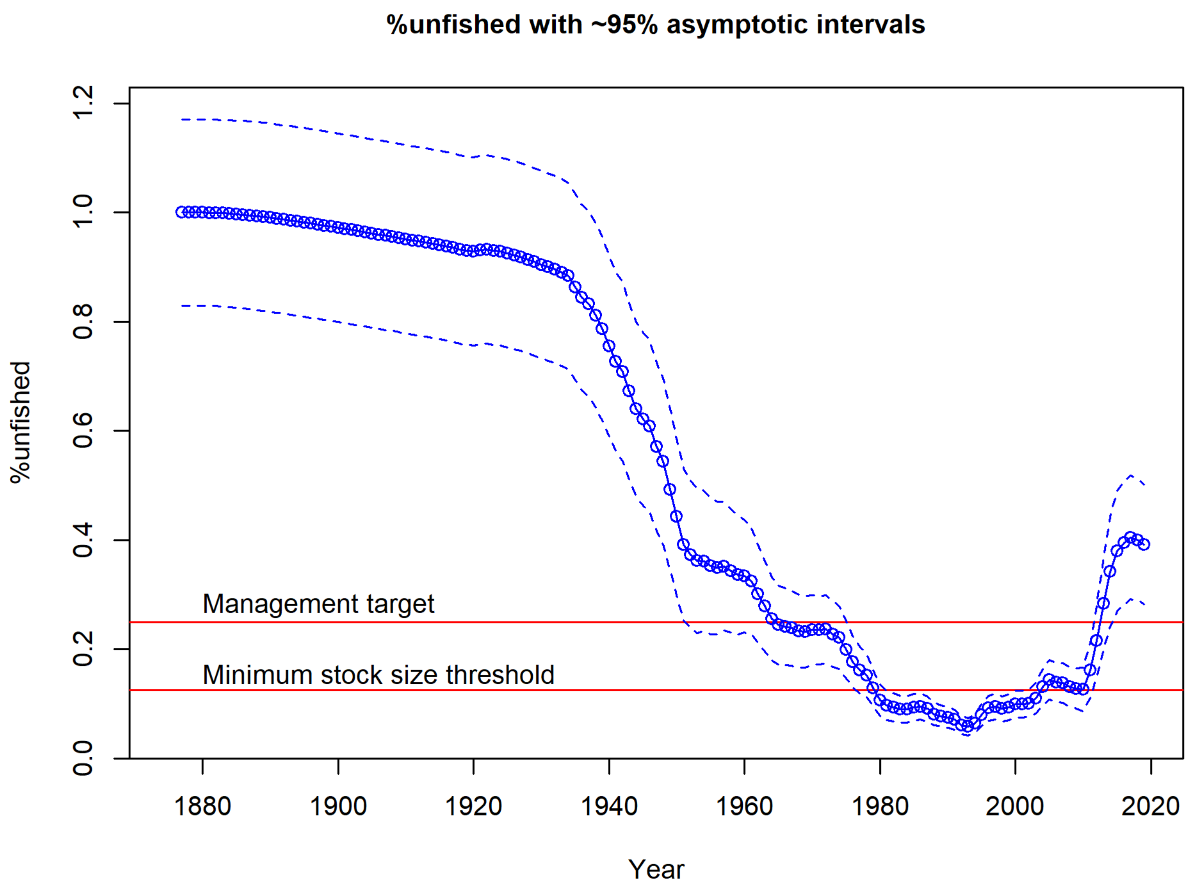

Figure c: Estimated time-series of relative spawning biomass (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for the base assessment model.

Recruitment

Annual recruitment was treated as stochastic, and estimated as annual deviations from log-mean recruitment where mean recruitment is the fitted Beverton-Holt stock recruitment curve. The time-series of estimated recruitments shows a relationship with the decline in spawning biomass, punctuated by larger recruitments in 2006, 2007, and 2008 (Figure d). However, recruitment in recent years (2013 - 2017) is estimated to be less than the expected mean recruitment indicating an absence of strong incoming recruitment (Table c).

The five largest estimated recruitments estimated within the model (in ascending order) occurred in 2006, 1998, 1966, 2007, and 2008. The four lowest recruitments estimated within the model (in ascending order) occurred in 1986, 1992, 1987, and 2003.

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

Year	Estimated Recruitment	~ 95% Confidence Interval	Estimated Recruitment Devs.	~ 95% Confidence Interval
2010	12637	8002 - 19956	-0.134	-0.446 - 0.177
2011	15344	9888 - 23810	-0.002	-0.288 - 0.283
2012	22946	15296 - 34420	0.339	0.097 - 0.581
2013	13483	8315 - 21863	-0.239	-0.610 - 0.132
2014	13529	8178 - 22379	-0.261	-0.660 - 0.138
2015	12792	7177 - 22801	-0.330	-0.817 - 0.158
2016	16460	8550 - 31688	-0.102	-0.674 - 0.469
2017	16517	7577 - 36006	-0.122	-0.853 - 0.610
2018	19018	8362 - 43254	0.000	-0.784 - 0.784
2019	18972	8346 - 43127	0.000	-0.784 - 0.784

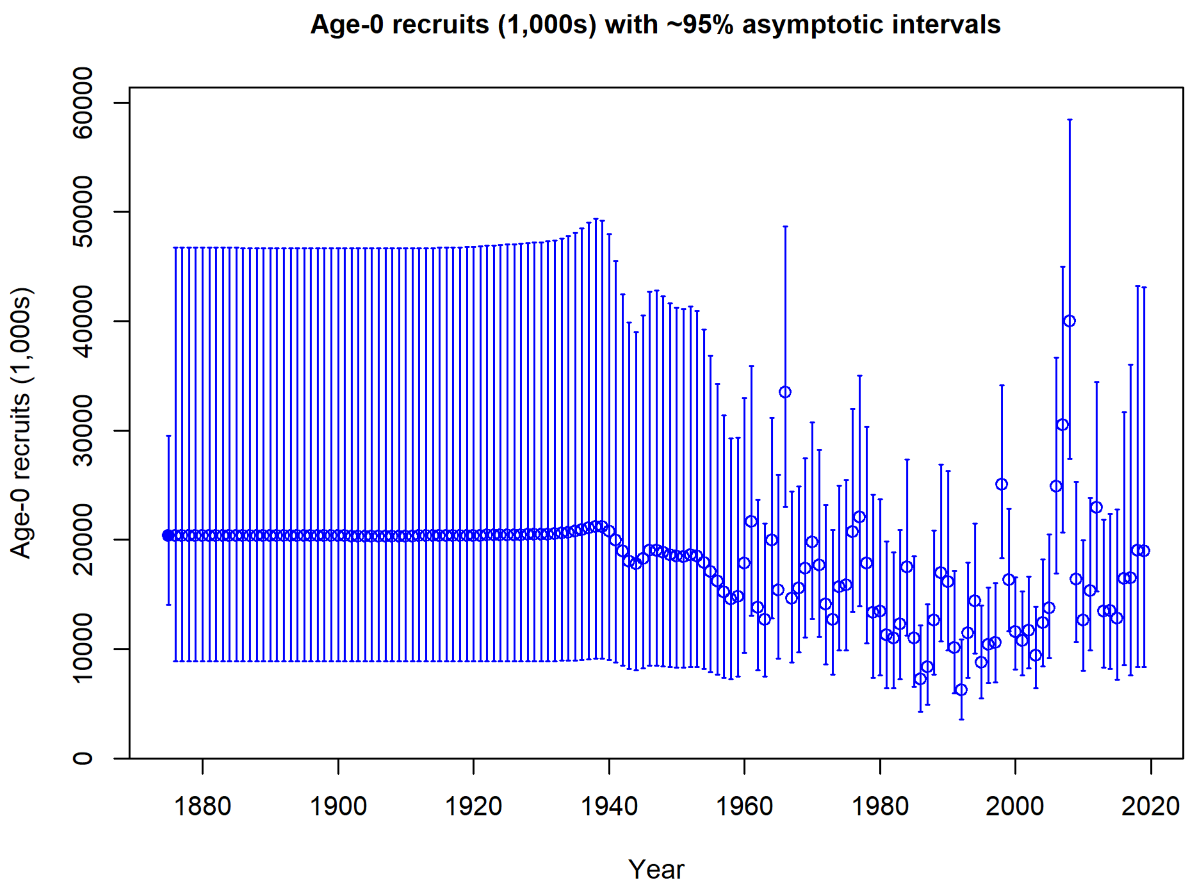

Figure d: Time-series of estimated petrale sole recruitments for the base model with 95% confidence or credibility intervals.

Exploitation Status

The relative spawning biomass of petrale sole was estimated to have dropped below the management target (25%) for the first time in 1965. The stock continued to decline and first fell below the minimum stock size threshold level of 12.5% in 1980 (although, at the time the management target and thresholds were not set at the current values of 25% and 12.5%). The relative spawning biomass remained around the threshold stock size until approximately 2010, with the stock reaching its lowest relative spawning biomass level in 1993 at 5.8%. In 2009 petrale sole was formally declared overfished. Fishing mortality rates sharply declined during the rebuilding period, relative to previous year rates, which exceeded the target (Figure e). After reduced harvests, the 2015 update stock assessment estimated the stock to have rebuilt to the management target (25%) in 2014. This update estimates that the relative spawning biomass exceeded 25% in 2013 with harvest rates in the most recent years remaining under of the target rate (Table d and Figures e and f).

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

Year	1-SPR	~ 95% Confidence Interval	Exploitation Rate	~ 95% Confidence Interval
2009	0.793	0.724 - 0.861	0.232	0.190 - 0.273
2010	0.570	0.469 - 0.670	0.075	0.060 - 0.091
2011	0.498	0.399 - 0.597	0.051	0.041 - 0.061
2012	0.515	0.419 - 0.612	0.061	0.049 - 0.072
2013	0.584	0.491 - 0.677	0.092	0.076 - 0.108
2014	0.578	0.485 - 0.670	0.103	0.085 - 0.120
2015	0.580	0.489 - 0.672	0.110	0.092 - 0.129
2016	0.549	0.458 - 0.640	0.102	0.085 - 0.119
2017	0.584	0.495 - 0.673	0.122	0.102 - 0.143
2018	0.573	0.484 - 0.662	0.119	0.098 - 0.140

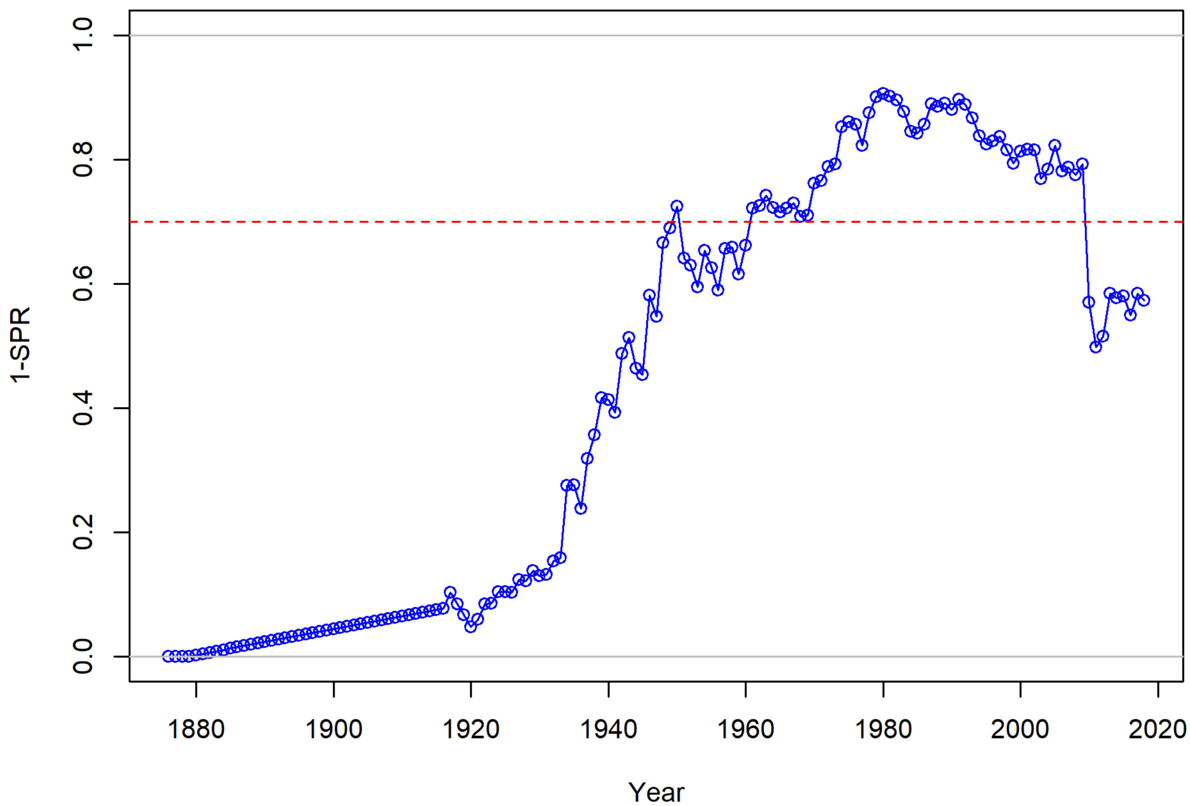

Figure e: Estimated relative spawning potential ratio 1-SPR for the base model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

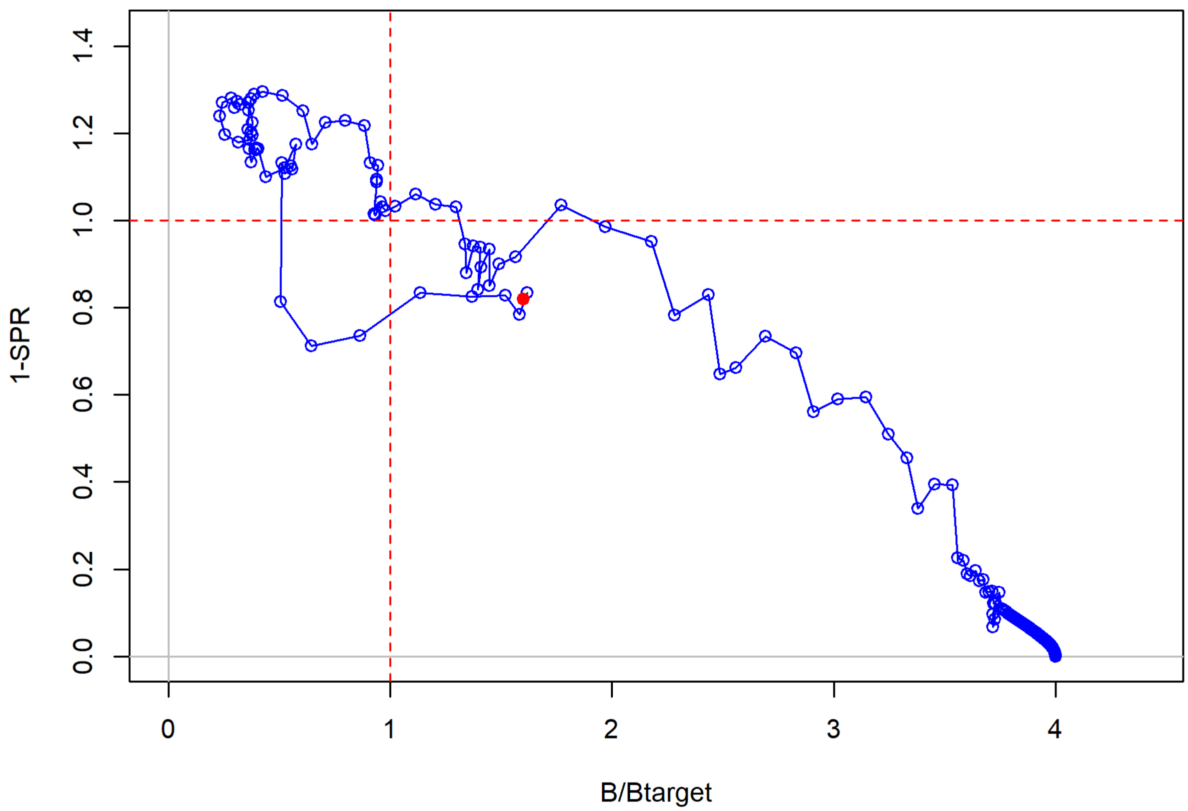

Figure f: Phase plot of estimated 1-SPR(%) vs. relative spawning biomass (B/Btarget) for the base case model. The red circle indicates 2018 estimated status and exploitation for petrale sole.

Ecosystem Considerations

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

Reference Points

This update stock assessment estimates that the spawning biomass of petrale sole is above the management target. Due to reduced landings and a series of above average recruitments (2006, 2007, and 2008), an increasing trend in spawning biomass was estimated in the base model with a decline in the start of the year spawning biomass estimate in 2019. The estimated relative spawning biomass in 2019 is 39.1% ($\sim$ 95% asymptotic interval: $\pm$ 28.2%-50.1%), corresponding to an spawning biomass of 13,078 mt ($\sim$ 95% asymptotic interval: 10,689-15,467 mt) (Table e). Unfished age 3+ biomass was estimated to be 54,086.6 mt in the base model.

The target spawning biomass based on the biomass target ($SB_{25\%}$) is 8,351.5 mt, with an equilibrium catch of 3,148.5 mt (Table e). Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{30\%}$ is 3,135.2 mt. Estimated MSY catch is at a 3,156.7 spawning biomass of 7,563.3 mt (22.6% relative spawning biomass).

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

Quantity	Estimate	~2.5% Confidence Interval	~97.5% Confidence Interval
Unfished spawning biomass (mt)	33405.9	27188.1	39623.7
Unfished age 3+ biomass (mt)	54086.6	45524.9	62648.3
Unfished recruitment (R0, thousands)	20361.1	12720.2	28002
Spawning biomass(2019 mt)	13077.7	10688.8	15466.6
Relative spawning biomass (depletion) (2019)	0.391	0.282	0.501
Reference points based on $\mathbf{SB_{25\%}}$			
Proxy spawning biomass ($B_{25\%}$)	8351.5	6797	9905.9
SPR resulting in $B_{25\%}$ ($SPR_{B25\%}$)	0.285	0.26	0.31
Exploitation rate resulting in $B_{25\%}$	0.182	0.163	0.2
Yield with $SPR_{B25\%}$ at $B_{25\%}$ (mt)	3148.5	2887.6	3409.4
Reference points based on SPR proxy for MSY			
Spawning biomass $SPR_{30\%}$	8866.2	6954.6	10777.7
Exploitation rate corresponding to $SPR_{30\%}$	0.173	0.147	0.198
Yield with $SPR_{30\%}$ at SB_{SPR} (mt)	3135.2	2849.4	3420.9
Reference points based on estimated MSY values			
Spawning biomass at MSY (SB_{MSY})	7563.3	5677.6	9448.9
SPR_{MSY}	0.263	0.202	0.323
Exploitation rate at MSY	0.196	0.166	0.227
MSY (mt)	3156.7	2909.6	3403.8

Management Performance

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

Recent coast-wide annual landings have not exceeded the ACL. The 2009, 2011, and 2013 full assessments estimated that petrale sole have been below the management target since the 1960s and below the overfished threshold between the early 1980s and 2009 with fishing mortality rates in excess of the current F-target for flatfish of $SPR_{30\%}$. The 2015 update assessment estimated that the stock had recovered with the relative spawning biomass exceeding the management target.

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

Year	OFL (mt; ABC prior to 2011)	ACL (mt; OY prior to 2011)	Total Landings (mt)	Estimated Total Catch (mt)
2009	2811	2433	2209	2334
2010	2751	1200	755	869
2011	1021	976	768	785
2012	1275	1160	1135	1153
2013	2711	2592	1967	1995
2014	2774	2652	2373	2392
2015	3073	2816	2686	2704
2016	3208	2910	2506	2523
2017	3208	3136	3008	3026
2018	3152	3013	2840	2857

Unresolved Problems and Major Uncertainties

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

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

1. The value of natural mortality by sex.
2. The current sex ratio between female and males in the population of petrale sole.
3. Fecundity estimates based upon new research for petrale sole and measured differences in fecundity between northern and southern fish.
4. Changes in the model estimates based on alternative data weighting approaches.

Additionally, a reconstructed historical Washington catch history has not been included in the petrale sole stock assessment. Washington state is currently undergoing efforts to determine historical catches for petrale sole and the next stock assessment is likely to incorporate these new historical catch estimates.

Decision Table

The forecast of stock abundance and yield was developed using the base model. The total catches in 2019 and 2020 are set at values provided by the Groundfish Management Team (GMT) of the PFMC at 2908 and 2845 mt, respectively. The management adopted ACL values for these years are 2921 and 2857 mt. The exploitation rate for 2021 and beyond is based upon an SPR of 30% and the 25:5 harvest control rule. The average exploitation rates, across recent years, by fleet as provided by the GMT were used to distribute catches during the forecast period.

Uncertainty in the forecasts is based upon the three states of nature based on the likelihood profile of female natural mortality (M). The low and high values for natural mortality were chosen using a change of 1.2 negative log-likelihood units (75% interval) from the minimum value to correspond midpoints of the lower 25% probability and upper 25% probability regions from the base model. Based on the profile the range of uncertainty around natural mortality were selected at a low value of 0.130 yr^{-1} and high of 0.185 yr^{-1}.

Catches during the projection period under the current harvest control rule are projected to start at 4115 mt and decline over the projection period to 3093 mt, in the base model, as the stock declines towards that target spawning biomass (Table g). Across the low and high states of nature the under the current harvest control rule, the relative biomass (depletion) range between 0.24 - 0.34 by the end of the 12-year projection period (Table h).

Table g: Projections of potential OFL (mt) and ABC (mt) and the estimated spawning biomass and relative spawning biomass based on ABC removals. The 2019 and 2020 ABC and OFL values shown are based on current harvest specifications, rather than the updated model estimates.

Year	OFL	ABC	Spawning Biomass (mt)	Relative Biomass
2019	3042	2908	13078	0.391
2020	2976	2845	12558	0.376
2021	4402	4115	12019	0.360
2022	3936	3660	10799	0.323
2023	3634	3365	10038	0.300
2024	3470	3199	9655	0.289
2025	3402	3120	9523	0.285
2026	3392	3097	9527	0.285
2027	3406	3096	9580	0.287
2028	3425	3097	9635	0.288
2029	3442	3098	9677	0.290
2030	3452	3093	9701	0.290

Table h: Decision table summary of 10-year projections beginning in 2021 for alternate states of nature based on an axis of uncertainty about female natural mortality for the base model. The removals in 2019 and 2020 were set at the defined management specification of 2908 and 2845 mt, respectively, assuming full attainment. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. The ABC catch stream is based on the equilibrium yield applying the SPR30 harvest rate.

			States of nature					
			M = 0.13		M = 0.159		M = 0.185	
	Year	Catch	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
ABC	2021	4115	11517	0.308	12019	0.360	12572	0.414
	2022	3660	10361	0.277	10798	0.323	11279	0.371
	2023	3365	9603	0.257	10039	0.301	10502	0.346
	2024	3199	9179	0.246	9659	0.289	10140	0.334
	2025	3120	8985	0.241	9533	0.285	10046	0.331
	2026	3097	8923	0.239	9545	0.286	10088	0.332
	2027	3096	8918	0.239	9606	0.288	10173	0.335
	2028	3097	8929	0.239	9671	0.289	10249	0.337
	2029	3098	8938	0.239	9720	0.291	10301	0.339
	2030	3093	8939	0.239	9752	0.292	10328	0.340
SPR target = 0.34	2021	3451	11517	0.308	12019	0.360	12572	0.414
	2022	3188	10764	0.288	11193	0.335	11668	0.384
	2023	3017	10286	0.275	10697	0.320	11140	0.367
	2024	2927	10052	0.269	10486	0.314	10928	0.360
	2025	2891	9991	0.268	10470	0.313	10926	0.360
	2026	2893	10028	0.269	10556	0.316	11025	0.363
	2027	2909	10103	0.271	10675	0.320	11150	0.367
	2028	2924	10184	0.273	10790	0.323	11260	0.371
	2029	2937	10257	0.275	10886	0.326	11344	0.373
	2030	2944	10318	0.276	10961	0.328	11401	0.375
SPR target = 0.4	2021	2690	11517	0.308	12019	0.360	12572	0.414
	2022	2592	11228	0.301	11648	0.349	12115	0.399
	2023	2537	11105	0.297	11486	0.344	11906	0.392
	2024	2522	11140	0.298	11519	0.345	11916	0.392
	2025	2534	11287	0.302	11680	0.350	12066	0.397
	2026	2567	11489	0.308	11900	0.356	12274	0.404
	2027	2604	11702	0.313	12127	0.363	12482	0.411
	2028	2636	11905	0.319	12334	0.369	12663	0.417
	2029	2664	12088	0.324	12513	0.375	12810	0.422
	2030	2686	12248	0.328	12664	0.379	12925	0.425

Research and Data Needs

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

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

2. Due to limited data, new studies on the maturity at length or age for petrale sole would be beneficial.

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

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

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

Table i: Base model results summary.

Quantity	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
OFL (mt)	2751	1021	1275	2711	2774	3073	3208	3208	3152	3042
ACL (mt)	1200	976	1160	2592	2652	2816	2910	3136	3013	2921
Landings (mt)	755	768	1135	1967	2373	2686	2506	3008	2840	
Total Est. Catch (mt)	869	785	1153	1995	2392	2704	2523	3026	2857	
1-SPR	0.570	0.498	0.515	0.584	0.578	0.580	0.549	0.584	0.573	
Exploitation rate	0.075	0.051	0.061	0.092	0.103	0.110	0.102	0.122	0.119	
Age 3+ biomass (mt)	11515.0	15463.3	18960.3	21683.2	23276.7	24487.5	24741.5	24774.1	23996.7	23350.8
Spawning Biomass	4227	5378	7205	9488	11433	12691	13206	13519	13365	13078
95% CI	3452 - 5002	4414 - 6342	5958 - 8452	7888 - 11087	9524 - 13341	10603 - 14778	11039 - 15374	11293 - 15745	11077 - 15653	10689 - 15467
Relative Depletion	0.127	0.161	0.216	0.284	0.342	0.380	0.395	0.405	0.400	0.391
95% CI	0.087 - 0.166	0.111 - 0.211	0.150 - 0.281	0.199 - 0.369	0.241 - 0.443	0.270 - 0.490	0.283 - 0.508	0.292 - 0.518	0.289 - 0.511	0.282 - 0.501
Recruits	12637	15344	22946	13483	13529	12792	16460	16517	19018	18972
95% CI	8002 - 19956	9888 - 23810	15296 - 34420	8315 - 21863	8178 - 22379	7177 - 22801	8550 - 31688	7577 - 36006	8362 - 43254	8346 - 43127

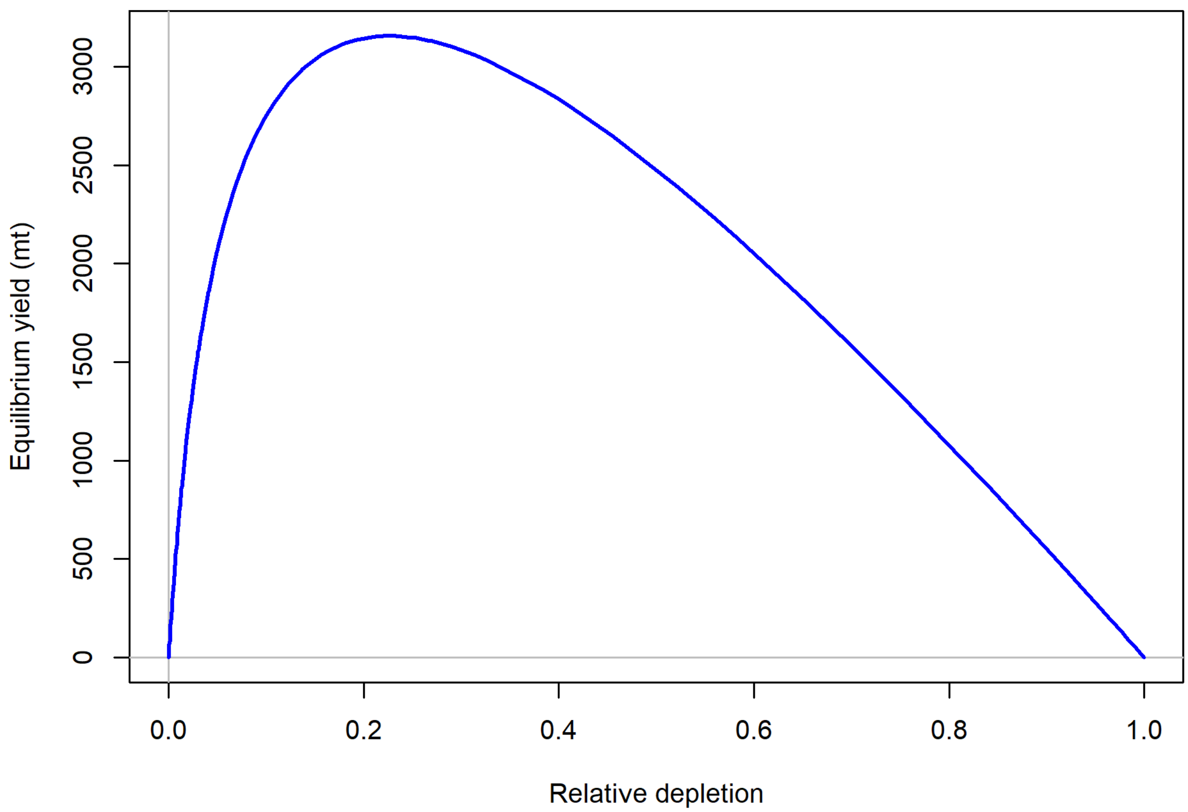

Figure g: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness estimated at 0.84.