Agenda Item H.5
Attachment 21
September 2019

Catch update for Dover sole (*Microstomus pacificus*) along the U.S. West Coast.

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Catch update for Dover sole (*Microstomus pacificus*) along the U.S. West Coast.

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This is an assessment of Dover sole (*Microstomus pacificus*) that reside in the waters off California, Oregon and Washington from the U.S./Canadian border in the north to the U.S./Mexico border in the south. Dover sole are also harvested from the waters off British Columbia and in the Gulf of Alaska, and although those catches were not included in this assessment, it is not certain if those populations contribute to the biomass of Dover sole off of the U.S. West Coast.

Landings

Dover sole were first landed in California in the early part of the 20th century and the fishery began increasing landings in Oregon and Washington in the 1940's. Landings remained relatively constant throughout the 1950's and 1960's before increasing rapidly into the early 1990's. Subsequently, the landings declined (mostly in California) until 2007 when harvest guidelines increased the allowable catch (Figure a). Groundfish trawl fisheries land the majority of Dover sole while fixed gears, shrimp trawls, and recreational fisheries make up a very small amount of fishing mortality. Some discarding of Dover sole occurs in the fisheries, and appears to have different patterns based on location.

The landings in Table a for 2011-2018 were fixed by fleet according to values provided by the Pacific Fishery Management Council (PFMC) Groundfish Management Team (GMT). The discards for 2011-2017 were obtained from the Groundfish Mortality Report. Discards for 2018 were fixed at 1% of landings. The same assumption regarding discarding rates was applied to 2019 and 2020 forecast years. Landings plus discards is referred to as total removals. While the Dover sole assessment estimated discards in the model, the catch update set the total removals as forecasted total dead mortality for 2011 and beyond.

Table a: Total removals (mt) for the past 10 years for Dover sole by source.

Year	California	Oregon	Washington	Total Landings	Total Removals
2007	2,758.70	5,550.20	955.20	9,264.10	10,171.01
2008	2,992.10	7,259.60	951.90	11,203.60	12,245.12
2009	3,154.30	7,452.40	1,124.80	11,731.50	12,820.22
2010	2,613.60	6,878.90	882.10	10,374.60	11,313.38
2011	2,119.09	4,550.48	591.71	7,261.28	7,944.14
2012	1,886.48	4,230.04	655.84	6,772.36	7,407.01
2013	1,941.26	4,901.37	548.70	7,391.33	8,070.80
2014	1,715.77	4,065.05	230.46	6,011.27	6,571.43
2015	1,643.66	3,945.87	233.88	5,823.41	6,367.80
2016	1,566.58	4,868.52	311.65	6,746.75	7,350.58
2017	1,519.49	4,928.55	444.54	6,892.58	7,509.60
2018	1,426.83	4,120.22	368.82	5,915.87	6,457.19

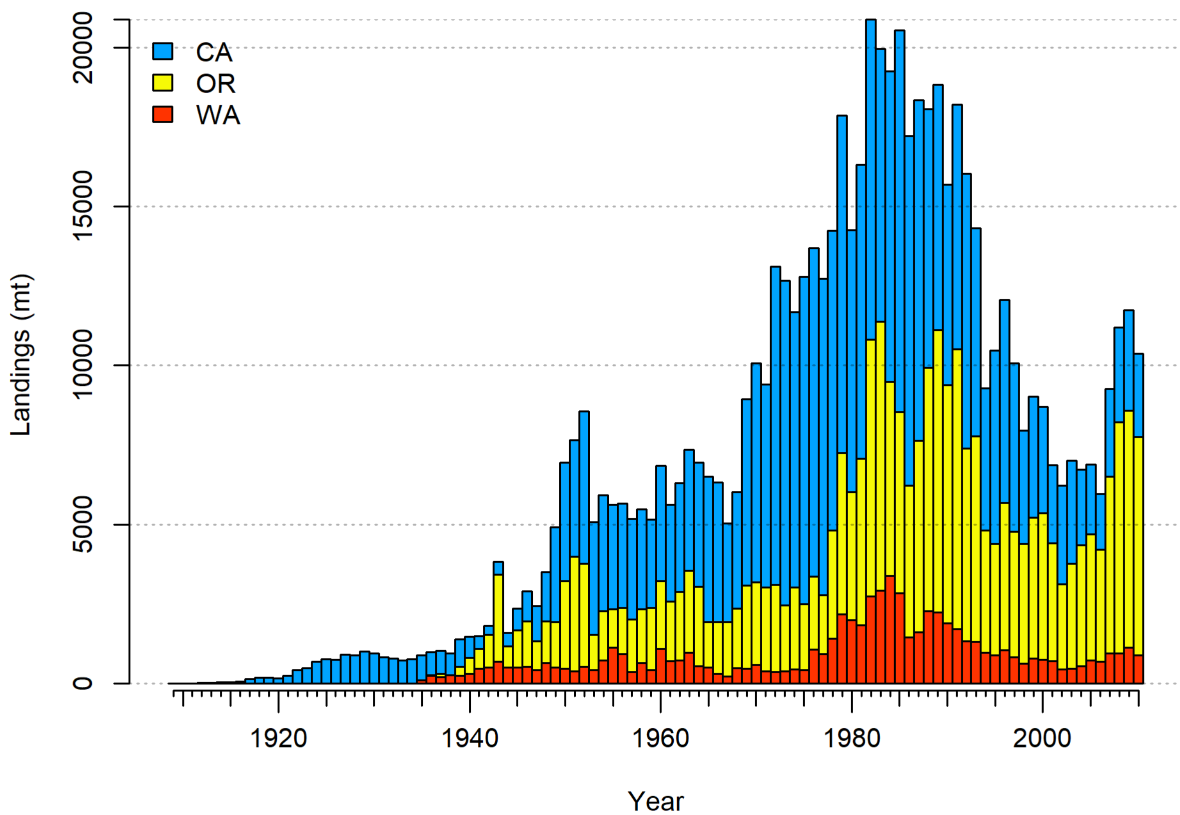

Figure a: 'Total removals by fleet off the U.S. West Coast.

Data and Assessment

Dover sole was last assessed in 2011, and estimated to be at 83.7% of unfished spawning biomass (Hicks and Wetzel 2011). The 2011 assessment of Dover sole used Stock Synthesis (version V3.21).Population parameters were estimated using fishery landings, length data, and age data from state-specific fishing fleets, abundance indices and length data from the National Marine Fisheries Service (NMFS) triennial survey and the Alaska Fishery Science Center (AFSC) slope survey, and abundance indices, length data, and age data from the Northwest Fisheries Science Center (NWFSC) slope and West Coast Groundfish Bottom Trawl surveys. The Triennial survey was split into two series (1980-1992 and 1995-2004) based on changes in survey timing. The extension of the NWFSC shelf/slope survey was new to this assessment and added a considerable amount of information, including age data which were fit in the model as conditional age-at-length vectors. Additionally, recent data on discarding collected by the West Coast Groundfish Observer Program (WCGOP), including length data, were used to determine retention curves and selectivity for the commercial fleets.

The base case model estimated parameters for male and female selectivity and retention curves based on length for all of the state-specific fishing fleets, gender-specific selectivity curves for the four surveys, length-at-age relationships for males and females, natural mortality for males and females, and recruitment deviations starting in 1910. A steepness parameter was fixed at 0.8 and not estimated.

Although there is a plethora of data available for Dover sole, which were used in this assessment, there is little information about natural mortality, steepness, and historical recruitment. Estimates of steepness are uncertain partly because the stock has not been fished to low levels. Uncertainty in natural mortality (M) appears to be related to some inconsistencies between length data and age data. These data indicate that larger fish tend to be caught deeper, at least in the summer, but there was no trend of age with depth. There was, however, a trend in sex ratio with depth (as seen in the data collected from the NWFSC West Coast Groundfish Bottom Trawl survey). The data also showed differences in the overall sex ratios, with age data typically showing a higher proportion of females than the length data. This could be related to sampling and age data being more variable because fewer are sampled, but there also appears to be some behavioral aspects which may contribute to sampled data showing skewed sex ratios. Nevertheless, the uncertainty in M translates to a considerable amount of uncertainty in the estimates of spawning biomass. Finally, there is little information about the levels of historical recruitment mostly due to a lack of historical length or age data. This uncertainty was included in the predictions from this assessment.

All assumptions from the 2011 assessment were retained here. Catches from 2011 - 2018 were based on estimates of landings provided by the GMT. Discard mortality by year (2011-2017) was obtained from the West Coast Groundfish Mortality Report and were added to the landed values. Discard mortality was assumed to be equal to 1% of the landings for 2018-2020. Removals in the projection years, 2019 and 2020, were set equal to GMT projected landings. The removals from 2021-2030 were not set equal to ABC, but rather were capped at a fixed value of 50,000 mt, based on predicted ACL values for Dover sole.

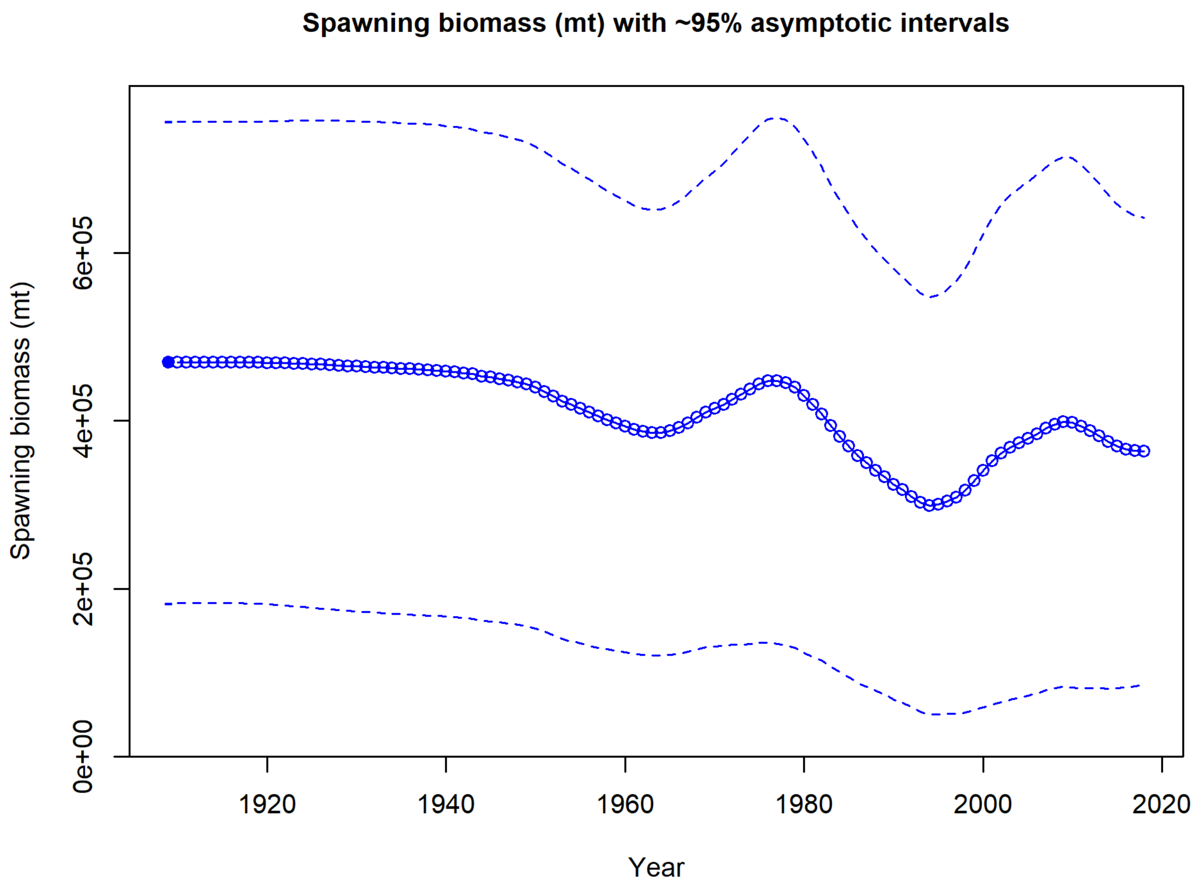

Figure b: Estimated time-series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the catch update model.

Stock Biomass

Spawning biomass of Dover sole was estimated to be 364738 million eggs in 2019 (∼ 95% asymptotic interval: ± 87158-642318 million eggs), or 77.6% of unfished spawning biomass (∼ 95% asymptotic interval: ± 64.4%-90.9%; Table b). Relative spawning biomass (depletion) is a ratio of the estimated spawning biomass in a particular year relative to estimated unfished, equilibrium spawning biomass. Spawning biomass declined slightly between the 1970s and early 1990s (Figures b and c). The trend in spawning biomass in 2019 is well above the management target (25% of unfished spawning biomass), but the precision of that estimate is low relative to other management reference points (e.g. the SPR30% proxies for target spawning biomass and maximum yield).

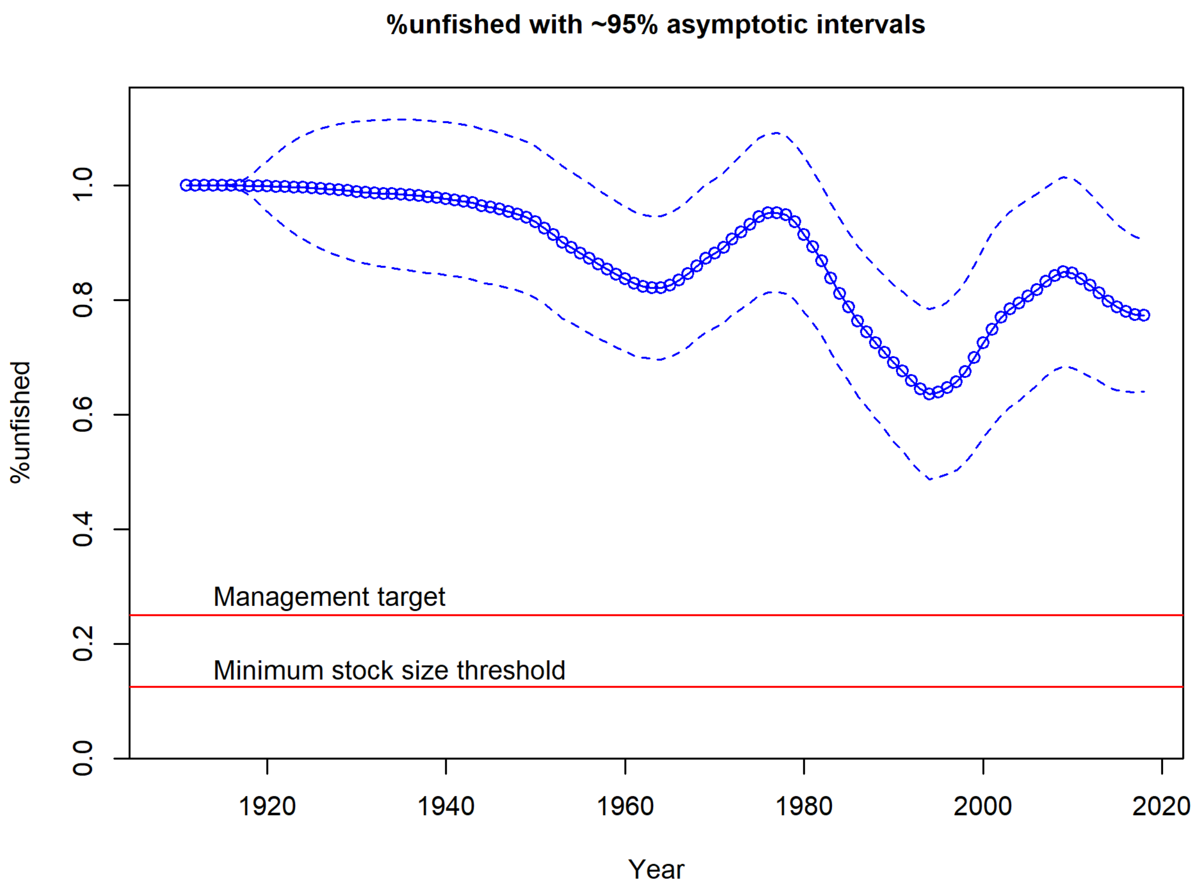

Figure c: Estimated time-series of relative spawning biomass (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for the catch update model.

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

Year	Spawning Biomass (mt)	~ 95% Confidence Interval	Relative Spawning Biomass	~ 95% Confidence Interval
2010	397836	82407 - 713265	0.847	0.681 - 1.012
2011	393507	81481 - 705533	0.837	0.674 - 1.001
2012	388162	81341 - 694983	0.826	0.666 - 0.986
2013	381867	81136 - 682598	0.813	0.658 - 0.968
2014	375078	80613 - 669543	0.798	0.648 - 0.949
2015	369882	81113 - 658651	0.787	0.642 - 0.932
2016	366348	82212 - 650484	0.780	0.640 - 0.919
2017	364097	83365 - 644829	0.775	0.639 - 0.910
2018	363458	84871 - 642045	0.774	0.640 - 0.907
2019	364738	87158 - 642318	0.776	0.644 - 0.909

Recruitment

There is little information regarding recruitment prior to 1960, and the uncertainty in these estimates is expressed in the model. Estimates of recruitment appear to oscillate between periods of low recruitment and periods of high recruitment (Table cand Figure d). The five largest recruitments were predicted in the years 2000, 1992, 1988, 1965, and 1991. The five smallest recruitments were predicted in 2003, 2002, 2004, 2006, and 1974.

In this catch update the recruitment was estimated from the stock-recruitment curve with no deviations for the years of 2011 - 2019.

Table c: Recent estimated trend in recruitment and estimated recruitment deviations determined from the base model. The recruitment deviations for 2011-2019 were fixed at zero within the model.

Year	Estimated Recruitment	~ 95% Confidence Interval
2010	376517	150161 - 944086
2011	376215	150036 - 943357
2012	375833	149894 - 942339
2013	375371	149719 - 941118
2014	374857	149519 - 939800
2015	374451	149377 - 938659
2016	374169	149291 - 937784
2017	373987	149244 - 937166
2018	373935	149254 - 936843
2019	374039	149339 - 936831

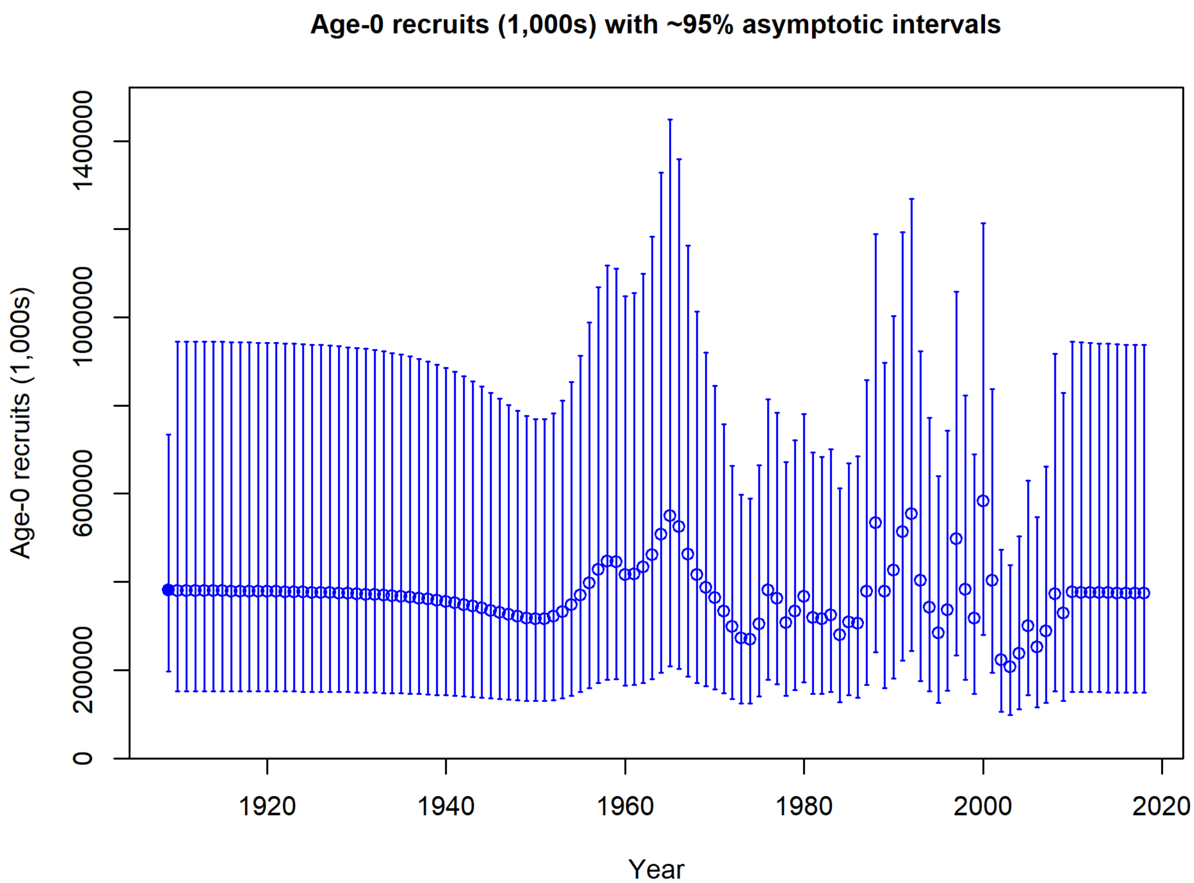

Figure d: Time-series of estimated Dover sole recruitments for the base model with 95% confidence or credibility intervals.

Exploitation Status

The spawning biomass of Dover sole reached a low in the mid 1990's before beginning to increase during the 2000's (Table d and Figures e and f). Landings since the last assessment in 2011 have been high, but well below the OFL, resulting in a low exploitation rate and a slight decline in spawning biomass in recent years (Figure g). The estimated relative biomass has remained above the 25% of unfished spawning biomass target and it is unlikely that the stock has ever fallen below this threshold. Throughout the 1970's, 1980's, and 1990's the exploitation rate and SPR generally increased, but never exceeded current estimates of the harvest rate limit (SPR30%). Recent exploitation rates on Dover sole have been small, even after management increased catch levels in 2007.

Table d: Recent trend in spawning potential ratio and summary exploitation rate for 5+ biomass for Dover sole.

Year	1-SPR	˜ 95% Confidence Interval	Exploitation Rate	˜ 95% Confidence Interval
2009	0.170	0.057 - 0.283	0.019	0.006 - 0.032
2010	0.155	0.051 - 0.259	0.017	0.005 - 0.029
2011	0.115	0.036 - 0.195	0.012	0.004 - 0.021
2012	0.110	0.034 - 0.186	0.011	0.004 - 0.019
2013	0.121	0.039 - 0.203	0.013	0.004 - 0.021
2014	0.102	0.032 - 0.171	0.010	0.003 - 0.017
2015	0.100	0.032 - 0.167	0.010	0.003 - 0.017
2016	0.114	0.038 - 0.190	0.011	0.004 - 0.019
2017	0.116	0.039 - 0.192	0.012	0.004 - 0.019
2018	0.100	0.033 - 0.167	0.010	0.003 - 0.017
2019	0.112	0.038 - 0.186	0.011	0.004 - 0.019

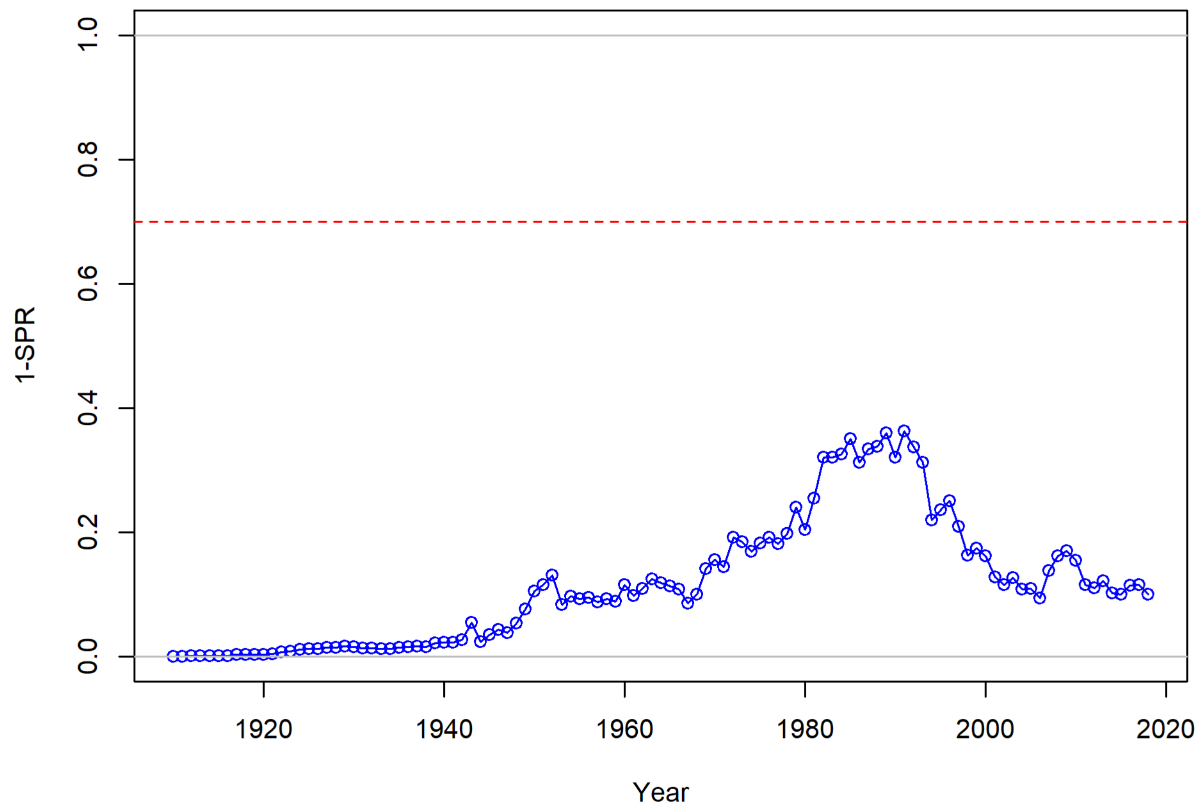

Figure e: Estimated relative spawning potential ratio 1-SPR for the catch update model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the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

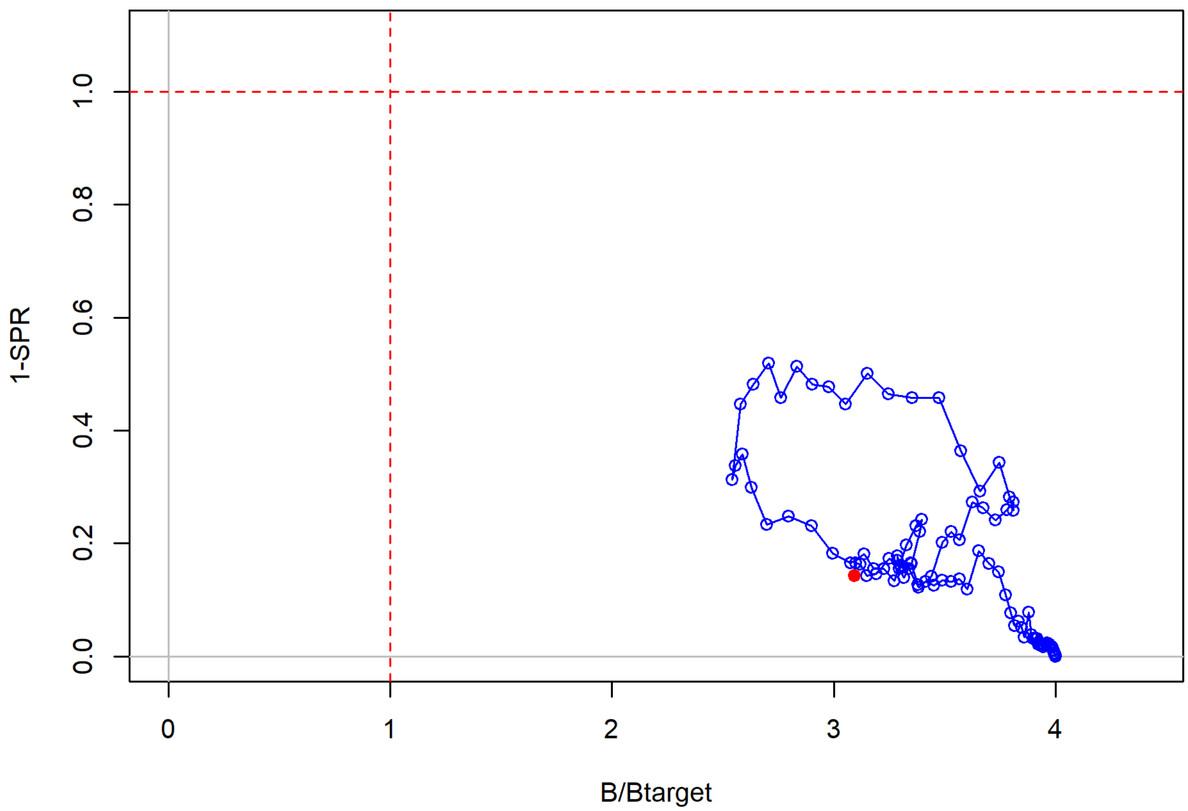

Figure f: Phase plot of estimated 1-SPR vs. relative spawning biomass (B/Btarget) for the catch update model. The red circle indicates 2018 estimated status and exploitation for Dover sole.

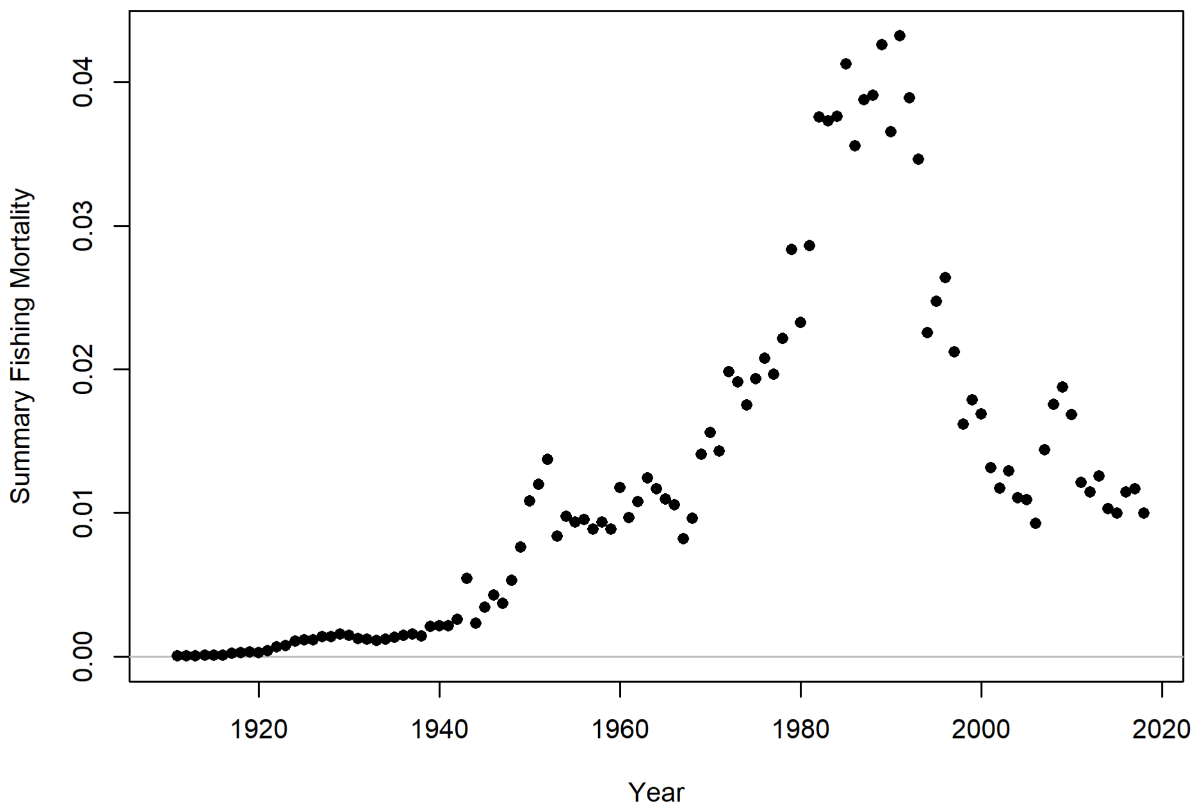

Figure g: Time-series of estimated summary harvest rate (total catch divided by age 5+ and older biomass) with approximate 95% asymptotic confidence intervals (grey lines).

Ecosystem Considerations

Ecosystem data were not explicitly included in this catch update. See the 2011 assessment for additional information (Hicks and Wetzel 2011).

Reference Points

Reference points and management quantities for Dover sole catch update are listed in Table e). In 2019, spawning biomass relative to unfished spawning biomass ("depletion") is estimated at 77.6% ($\sim$ 95% asymptotic interval: $\pm$ 64.4%-90.9%). The target spawning biomass based on the biomass target ($SB_{40\%}$) is 117,467 mt, with an equilibrium catch of 34,750.9 mt (Table e). Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 34,742.9 mt. Estimated MSY catch is 34,757.4 at a spawning biomass of 114,398 mt (24.3% relative spawning biomass).

Table e: Summary of reference points and management quantities for the catch update.

Quantity	**Estimate**	**~2.5% Confidence Interval**	**~97.5% Confidence Interval**
Unfished spawning biomass (mt)	469866	182741.1	756990.9
Unfished age 5+ biomass (mt)	821271	391411.7	1251130.3
Unfished recruitment (R0, thousands)	380777	197450	734318.3
Spawning biomass(2019 mt)	364738	87158.1	642317.9
Relative spawning biomass (depletion) (2019)	0.776	0.644	0.909
Reference points based on $\mathbf{SB_{25\%}}$			
Proxy spawning biomass ($SB_{25\%}$)	117467	45685.9	189248.1
SPR resulting in $SB_{25\%}$ ($SPR_{SB25\%}$)	0.297	0.297	0.297
Exploitation rate resulting in $SB_{25\%}$	0.129	0.12	0.138
Yield with $SPR_{SB25\%}$ at $SB_{25\%}$ (mt)	34750.9	15404	54097.8
Reference points based on SPR proxy for MSY			
Spawning biomass	119033	46294.8	191771.2
$SPR_{30\%}$			
Exploitation rate corresponding to $SPR_{30\%}$	0.128	0.119	0.136
Yield with $SPR_{30\%}$ at SB_{SPR} (mt)	34742.9	15403.4	54082.4
Reference points based on estimated MSY values			
Spawning biomass at MSY (SB_{MSY})	114398	45642.1	183153.9
SPR_{MSY}	0.291	0.286	0.296
Exploitation rate at MSY	0.131	0.122	0.141
MSY (mt)	34757.4	15401.1	54113.7

Management Performance

Total removals in recent years have been well below the OFL (Table f). Currently, for Dover sole the ACL adopted by management is below the Acceptable Biological Catch (ABC) recommended by the last full assessment in 2011. Overall, Dover sole have been lightly exploited and the spawning biomass has remained well above the management target.

Table f: Recent trend in total removals (mt) relative to the management guidelines.

Year	OFL (mt)	ABC (mt)	ACL (mt)	Total Landings (mt)	Total Removals (mt)
2011	44400	42843	25000	7261	7944
2012	44826	42843	25000	6772	7407
2013	92955	88865	25000	7391	8071
2014	77774	74352	25000	6011	6571
2015	66871	63929	50000	5823	6368
2016	59221	56615	50000	6747	7351
2017	89702	85755	50000	6893	7510
2018	90282	86310	50000	5916	6457
2019	91102	87094	50000	6756	7388

Unresolved Problems and Major Uncertainties

The 2011 Dover sole assessment cited the following items as the major uncertainties (Hicks and Wetzel 2011).

- The base case model was developed with the goal of balancing parsimony with realism and fitting the data. There were, however, some pieces of data that were fit poorly. Specifically, the commercial length and age data for the Washington and Oregon fleets showed some unsatisfactory patterns. It is uncertain if these patterns are related to a lack of fit due to retention curves, selectivity curves, or growth. It is possible that Dover sole exhibit different life-history patterns in the north and the model is unable to capture these differences without introducing additional complexity.

- Natural mortality was estimated in this assessment for the first time in the history of U.S. West Coast Dover sole assessments. A prior was developed for gender-specific natural mortality, which had a median larger than values assumed in previous assessments. Additionally, the estimates from the base case model were larger than previous assumed values and natural mortality for males was uncertain. However, the 95% joint confidence interval from the joint likelihood profile over female and male natural mortality parameters did not encompass the 0.09 values assumed for female and male M in the 2005 assessment. It would be useful to investigate the life-history of Dover sole as well as the length and age data to determine if the larger values of M are reasonable

- Recruitment was estimated over the entire time series and although was uncertain, it showed an interesting pattern in the early years by dipping down below average recruitment before the era in which recruitment deviates could be somewhat estimated. These patterns may indicate model misspecification, but it may also be an indication that the stock may have been below unfished equilibrium biomass when fishing mortality really began to increase. This may be caused by greater than assumed historical fishing levels, or a period of low recruitment preceding the start of the fishery. Given that estimated recruitment from more recent periods shows periods of low and high recruitments, it may be that a period of low recruitment occurred prior to 1960.

- Dover sole life-history parameters exhibit strong relationships with depth that indicate the stock is more complex than the model assumes. Small fish are found in shallow water, while mid-sized and larger fish are found in middle and deeper depths. There is not a trend of larger fish being found deeper, but there is a trend of fewer smaller fish found deeper. In addition, there is a pattern of sex ratio by depth with more males found in middle depths and more females found in shallow and deeper depths. These patterns are apparent in the summer fisheries and surveys, and there is some evidence that the patterns change in the winter during the spawning season. It is uncertain how the patterns affect the data (they may be a cause of the bimodal length distributions seen in the slope surveys) and if these patterns can be effectively modeled to produce better fits to the data and better predictions of biomass.

Decision Table

Projections of OFL (mt), ABC (mt), age 5+ biomass (mt), spawning biomass, and relative spawning biomass (depletion), are shown for the default harvest control rule in Table g. The removals for 2019 and 2020 were set equal to forecasted landings provided by the GMT with a 1% discard mortality added. The 2021-2030 removals were set equal to the predicted future ACLs, 50,000 mt, as provided by the GMT. The ACL in 2029 and 2030 would exceed the predicted ABC value, based on adjusting the OFL with the year specific σ_y if there is not a new assessment.

The decision table was based on uncertainty around female natural mortality and steepness same as what was done in the 2011 assessment (Hicks and Wetzel 2011). The decision table explores three alternative catch streams: 1) total mortality by year equal to 50,000 mt, 2) total mortality by year equal to 25,000 mt, and 3) total mortality by year equal to 8,000 mt (Table h).

Table g: Projections of the OFL (mt), ABC (mt), ACL (mt) and the estimated spawning biomass and relative spawning biomass based on removals. The 2019 and 2020 OFL and ABC values are based on the catch update projections with the new sigma policy applied, not the current adopted harvest specifications.

Year	OFL	ABC	ACL	Spawning Biomass (mt)	Relative Biomass
2019	91570	83237	7388	364738	0.776
2020	92539	83655	7388	366621	0.780
2021	93547	84192	50000	369170	0.786
2022	87540	78436	50000	351983	0.749
2023	81931	73082	50000	334563	0.712
2024	76756	68083	50000	317127	0.675
2025	72031	63603	50000	299922	0.638
2026	67749	59551	50000	283168	0.603
2027	63882	55897	50000	267031	0.568
2028	60388	52598	50000	251620	0.536
2029	57217	49607	50000	236990	0.504
2030	54319	46877	50000	223146	0.475

Table h: Decision table summary of 12-year projections beginning in 2019 for alternate states of nature based on an axis of uncertainty about female and male natural mortality for the base model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels.

			States of nature					
			Mf = 0.11 Mm = 0.125		Mf = 0.117 Mm = 0.142		Mf = 0.12 Mm = 0.159	
	Year	Catch	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
ACL = 50000 mt	2019	7388	238652	0.698	364738	0.776	635859	0.839
	2020	7388	240707	0.704	366621	0.780	637438	0.841
	2021	50000	243181	0.711	369170	0.786	640260	0.845
	2022	50000	225956	0.661	351983	0.749	623377	0.823
	2023	50000	208276	0.609	334563	0.712	606599	0.801
	2024	50000	190390	0.557	317127	0.675	590047	0.779
	2025	50000	172571	0.505	299922	0.638	573901	0.757
	2026	50000	155062	0.453	283168	0.603	558337	0.737
	2027	50000	138057	0.404	267031	0.568	543485	0.717
	2028	50000	121696	0.356	251620	0.536	529431	0.699
	2029	50000	106062	0.310	236990	0.504	516211	0.681
	2030	50000	91186	0.267	223146	0.475	503818	0.665
ACL = 25000 (mt)	2019	7388	238652	0.698	364738	0.776	635859	0.839
	2020	7388	240707	0.704	366621	0.780	637438	0.841
	2021	25000	243181	0.711	369170	0.786	640260	0.845
	2022	25000	237707	0.695	363841	0.774	635428	0.839
	2023	25000	232221	0.679	358631	0.763	630966	0.833
	2024	25000	226765	0.663	353538	0.752	626771	0.827
	2025	25000	221404	0.647	348600	0.742	622812	0.822
	2026	25000	216204	0.632	343863	0.732	619088	0.817
	2027	25000	211213	0.618	339362	0.722	615607	0.812
	2028	25000	206463	0.604	335122	0.713	612373	0.808
	2029	25000	201967	0.591	331148	0.705	609379	0.804
	2030	25000	197720	0.578	327434	0.697	606614	0.801
ACL = 8000 (mt)	2019	7388	238652	0.698	364738	0.776	635859	0.839
	2020	7388	240707	0.704	366621	0.780	637438	0.841
	2021	8000	243181	0.711	369170	0.786	640260	0.845
	2022	8000	245590	0.718	371806	0.791	643539	0.849
	2023	8000	248075	0.725	374608	0.797	647211	0.854
	2024	8000	250546	0.733	377440	0.803	651038	0.859
	2025	8000	252950	0.740	380218	0.809	654861	0.864
	2026	8000	255254	0.746	382890	0.815	658581	0.869
	2027	8000	257440	0.753	385426	0.820	662138	0.874
	2028	8000	259502	0.759	387813	0.825	665498	0.878
	2029	8000	261437	0.764	390045	0.830	668645	0.882
	2030	8000	263248	0.770	392123	0.835	671574	0.886

Table i: Base model results summary.

Quantity	2011	2012	2013	2014	2015	2016	2017	2018	2019
OFL (mt)	44400	44826	92955	77774	66871	59221	89702	90282	91102
ACL (mt)	25000	25000	25000	25000	50000	50000	50000	50000	50000
Removals (mt)	7944	7407	8071	6571	6368	7351	7510	6457	7388
1-SPR	0.115	0.110	0.121	0.102	0.100	0.114	0.116	0.100	0.112
Exploitation rate	0.012	0.011	0.013	0.010	0.010	0.011	0.012	0.010	0.011
Age 5+ biomass (mt)	657004	647248	643715	638536	639009	641389	644218	647978	653479
Spawning Biomass	393507	388162	381867	375078	369882	366348	364097	363458	364738
95% CI	81481 - 705533	81341 - 694983	81136 - 682598	80613 - 669543	81113 - 658651	82212 - 650484	83365 - 644829	84871 - 642045	87158 - 642318
Relative Depletion	0.837	0.826	0.813	0.798	0.787	0.780	0.775	0.774	0.776
95% CI	0.674 - 1.001	0.666 - 0.986	0.658 - 0.968	0.648 - 0.949	0.642 - 0.932	0.640 - 0.919	0.639 - 0.910	0.640 - 0.907	0.644 - 0.909
Recruits	376215	375833	375371	374857	374451	374169	373987	373935	374039
95% CI	150036 - 943357	149894 - 942339	149719 - 941118	149519 - 939800	149377 - 938659	149291 - 937784	149244 - 937166	149254 - 936843	149339 - 936831

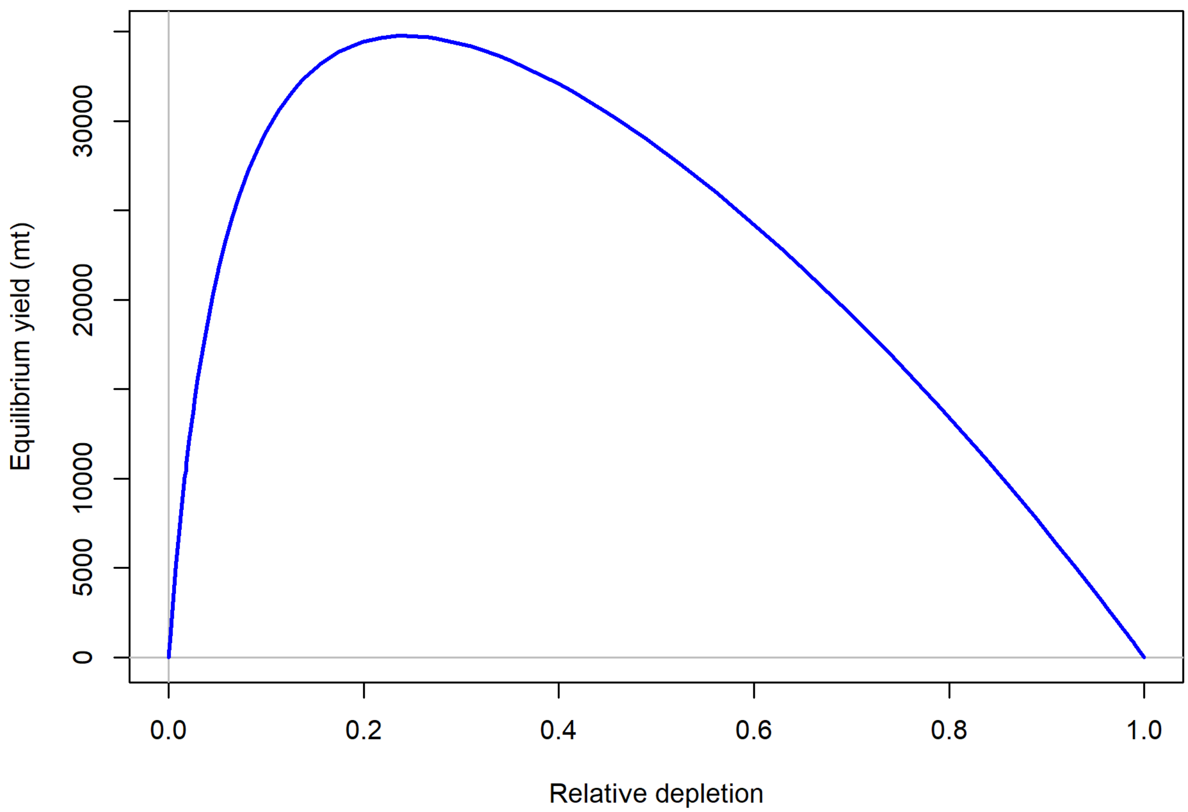

Figure h: Equilibrium yield curve for the catch update model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.80.

References

Hicks, A.C., and Wetzel, C.R. 2011. The status of Dover sole (*Microstomus pacificus*) along the U.S. West Coast in 2011. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.