Agenda Item H.5
Attachment 7
September 2019

Status of the sablefish stock in U.S. waters in 2019

DRAFT for submission to the Pacific Fisheries Management Council

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August 1st, 2019

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This document should be cited as follows:

Haltuch, M.A., Johnson, K.F., Tolimieri, N., Kapur, M.S., and Castillo-Jordán, C.A. 2019. Status of the sablefish stock in U.S. waters in 2019. Pacific Fisheries Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR. 358 p.

Contents

EXECUTIVE SUMMARY

STOCK

This assessment reports the status of the sablefish (*Anoplopoma fimbria*, or 'black cod') resource off the coast of the United States (U.S.) from southern California to the U.S.-Canadian border using data through 2018. The resource is modeled as a single stock, however sablefish do disperse to and from offshore sea mounts and along the coastal waters of the continental U.S., Canada, and Alaska and across the Aleutian Islands to the western Pacific. Their movement is not explicitly accounted for in this analysis.

ECOSYSTEM CONSIDERATIONS

This assessment includes ecological factors based on the idea that research focused on the linkages within a social-ecological system (SES) and how they increase or decrease sustainability can help inform the management of natural resources (Ostrom, 2009). The SES framework requires consideration of extractive goals and human activities at a level that allows for ecological sustainability while also considering human well-being. Thus, the SES framework facilitates the consideration of environmental and human impacts on sablefish as well as sablefish impacts on the ecosystem and humans (e.g., Levin et al. 2016). An extensive SES analysis for sablefish can be found in Appendix A. This document focuses on the four following topics, which highlight the major aspects considered:

1. results of a Climate Vulnerability Assessment (CVA), which motivates points 2 and 3;
2. environmental drivers of recruitment;
3. shifts in the latitudinal distribution of sablefish biomass and the effects of these shifts on availability of the stock to selected ports; and
4. interaction of the sablefish fishery with other species, specifically whale entanglements.

Points (1) and (2) address environmental impacts on sablefish. Point (3) addresses impacts of sablefish on humans, while point (4) addresses impacts of the sablefish fishery on other species in the ecosystem. Section 2 details the use of a sea-level index as a survey of age-0 recruitment within the stock assessment.

CATCHES

A variety of sources were used to reconstruct state-specific historical sablefish landings (i.e., fish brought to market), creating a series of landings from 1890 to present. In general, these reconstructions are more reliable than those for many other groundfish species because of the consistent identification of sablefish to the species level. Historical landings reconstructions for sablefish have been completed by California, Oregon, and Washington, extending landings to the beginning of the U.S. West Coast sablefish fishery.

Fishery discard rates and weights were fit within the assessment model, i.e., simultaneous estimation of total catches and other model parameters. This internal estimation can result in model estimates of total mortality that differ between stock assessments even when the landings inputs remain unchanged due to changes in fixed and estimated parameter values, priors, or parameterizations. Model estimates of fishery discards resulted in model estimated total dead catches that were an average of 2.65% larger than the landings input into the stock assessment model over the last decade.

Historically, sablefish landings were just below recent landings (<4,000 mt) until the end of the 1960s and were primarily harvested by fixed gear. Large catches (24,395 mt) by foreign vessels fishing pot gear in 1976 resulted in the largest landings reported in a single-year. A rapid rise in domestic pot and trawl landings followed this peak removal, such that, on average, nearly 8,400 mt of sablefish were landed per year between 1976 and 1990. Subsequently, annual landings have remained below 9,000 mt and been divided approximately 67/33% between fixed and trawl gears, respectively, during the most recent decade. An Individual Fishing Quota (IFQ) program, referred to as catch shares, was implemented for the U.S. West Coast trawl fleet beginning in 2011. Gear switching is allowed within the program such that fixed gear can be used to catch sablefish under trawl IFQ. This has resulted in changes in fleet behavior, the distribution of fishing effort, and discarding rates. Complete observer coverage on all vessels fishing IFQ quota became mandatory at the start of the program, while coverage in the other sectors remained stratified by port. The lack of historical observer coverage, and consequently information on total catch and age and length compositions, thus contributes to uncertainty regarding selectivity and retention during the historical period.

Table a. Recent sablefish landings by fleet (mt and relative %) and summed across fleets (mt).

Year	Fixed-gear		Trawl		Total
	mt	%	mt	%	mt
2009	3,889	55.95	3,062	44.05	6,951
2010	4,059	61.51	2,540	38.49	6,599
2011	4,421	71.86	1,731	28.14	6,152
2012	3,669	70.70	1,520	29.30	5,189
2013	2,585	64.78	1,405	35.22	3,990
2014	2,862	68.76	1,300	31.24	4,162
2015	3,540	70.65	1,471	29.35	5,011
2016	3,826	72.13	1,479	27.87	5,305
2017	3,637	68.52	1,671	31.48	5,308
2018	3,550	70.37	1,495	29.63	5,045

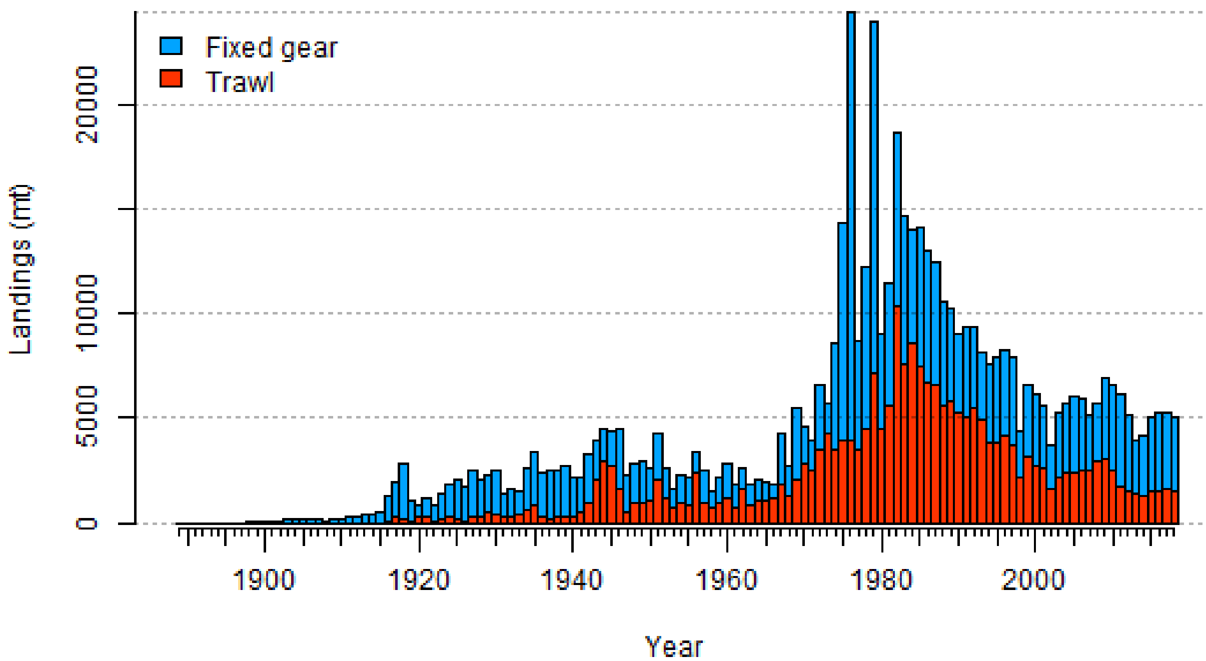

Figure a. Sablefish landings from 1890–2018 summarized by the gear types included in the base model, fixed-gear and trawl. Landings include those from foreign fleets, which are largely responsible for the peaks in 1976 and 1979.

DATA AND ASSESSMENT

The last benchmark stock assessment for sablefish took place during 2011, followed by an update assessment during 2015. Changes and additions between the 2015 update assessment and this assessment are listed in Section 3.2. This assessment used the most recent version of the Stock Synthesis modeling platform (3.30, released 2019-03-09). Primary data sources include landings and age-composition data from the retained catch. In recent years, data on the discarded portion of commercial catch are available, including discard lengths, rates, and mean observed individual body weight of the discarded catch. The relative index of abundance estimated from the National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center (NWFSC) West Coast Groundfish Bottom Trawl (WCGBT) Survey, which includes depths from 55-1,280 m, represents the primary source of information on the stock's trend and was updated to include the most recent data, covering the period 2003-2018. Note that the WCGBT Survey does not access the closed Cowcod Conservation areas in southern California. Other, discontinued, survey indices contribute information on trend and sablefish demographics: (a) NWFSC Slope Survey conducted from 1998-2002, (b) Alaska Fisheries Science Center (AFSC) Slope Survey (1997-2001), and (c) AFSC/NWFSC Triennial Shelf Survey (1980-2004). Additionally, an environmental time-series of sea level was used as a survey index of recruitment in the base model.

Of the externally estimated model parameters, (a) weight-length relationship, (b) maturity schedule, and (c) fecundity relationships, only the fecundity relationship was not updated. As in previous assessments, growth and natural mortality were estimated using sex-specific relationships. Uncertainty in recruitment was included by estimating a full time-series of deviations from the stock-recruitment curve. The 'one-way-trip' nature of the time-series does not facilitate estimation of the steepness parameter (h) of the stock-recruitment relationship. Therefore, h was fixed at 0.7, similar to values used on other groundfish stock assessments, and explored via sensitivity analyses.

During the 2011 assessment, a vast number of historical management actions were evaluated and condensed to a subset that were most likely to have had a direct influence on fishery behavior (either sorting and retention, selectivity, or both). These time periods were used to define time blocks to reduce the complexity of selectivity and retention parameterizations. This assessment utilized the same general structure as the 2011 assessment, with the addition of full retention for the trawl fishery after the implementation of the IFQ program.

Aging error, both precision and accuracy, was extensively investigated during the 2011 assessment but remains unresolved given the lack of an age validation study for sablefish. The age error analysis for this assessment used the same software and methods as the 2011 assessment. The larger number of between-lab reads from the AFSC and the NWFSC available for this assessment showed a small amount of variability between laboratories. Therefore, this analysis uses the between-lab reads as well as the double reads from the NWFSC, treating them both as unbiased but potentially non-linearly variable. The age imprecision was such that by age 50 observed ages could differ from true ages by up to 16-17 years. Therefore, the potential for underestimating or overestimating the age of the oldest fish still remains, and thus, the potential for aging bias remains a source of uncertainty.

STOCK BIOMASS

During the first half of the 20^{th} century it is estimated that sablefish were exploited at relatively modest levels. Modest catches continued until the 1960s, along with a higher frequency of above average, but uncertain, estimates of recruitment through the 1970s. The spawning stock biomass increased during the 1940s to 1970s. Subsequently, biomass is estimated to have declined between the mid-1970s and the early 2010s, with the largest peaks in harvests during the 1970s followed by harvests that were, on average, higher than pre-1970s harvest through the 2000s. At the same time, there were a higher frequency of generally lower than average recruitments from the 1980s forward. Despite estimates of harvest rates that were largely below overfishing rates from the 1990s forward and a few high recruitments from the 1980s forward, the spawning biomass has only recently begun to increase. This stock assessment does suggest spawner per recruitment rates higher than the target during some years from the 1990s forward for two reasons. First, there have been many years with lower than expected recruitment. Second, stock assessment estimates of unfished spawning biomass have been steadily declining in each subsequent assessment since 2007. Estimates of unfished biomass scale catch advice.

Although the relative trend in spawning biomass is robust to uncertainty in the leading model parameters, the productivity of the stock is uncertain due to confounding of natural mortality, absolute stock size, and productivity. The estimates of uncertainty around the point estimate of unfished stock size are large across the range of models explored within this assessment, suggesting that the unfished spawning biomass could range from just under 100,000 mt to over 200,000 mt. The point estimate of 2019 spawning biomass from the base model is 57,444 mt, however, the ∼95% interval ranges broadly from 32,776 to 82,112 mt. The point estimate of 2019 spawning biomass relative to an unfished state (i.e., depletion) from the base model is 39% of unexploited levels (∼95% interval: 26-52%).

Table b. Time series of spawning biomass (mt), age-0 recruitment (1000s), and depletion estimates from the base model and their associated 5% and 95% confidence intervals in parentheses.

Year	Spawning biomass		Age-0 recruitment		Depletion	
2010	60,844	(37,227-84,462)	15,081	(8,933-21,230)	0.41	(0.29-0.53)
2011	56,030	(33,653-78,407)	4,821	(2,413-7,229)	0.38	(0.27-0.49)
2012	54,048	(32,029-76,066)	3,803	(1,612-5,994)	0.37	(0.26-0.48)
2013	53,475	(31,512-75,439)	29,761	(17,536-41,985)	0.36	(0.25-0.47)
2014	53,617	(31,615-75,620)	5,103	(2,320-7,885)	0.36	(0.25-0.47)
2015	53,172	(31,289-75,054)	11,678	(6,017-17,339)	0.36	(0.25-0.47)
2016	52,469	(30,588-74,350)	56,319	(32,578-80,061)	0.36	(0.24-0.47)
2017	53,373	(30,839-75,906)	1,644	(5-3,284)	0.36	(0.25-0.48)
2018	54,624	(31,340-77,909)	3,719	(0-9,716)	0.37	(0.25-0.49)
2019	57,444	(32,776-82,112)	12,857	(0-48,750)	0.39	(0.26-0.52)

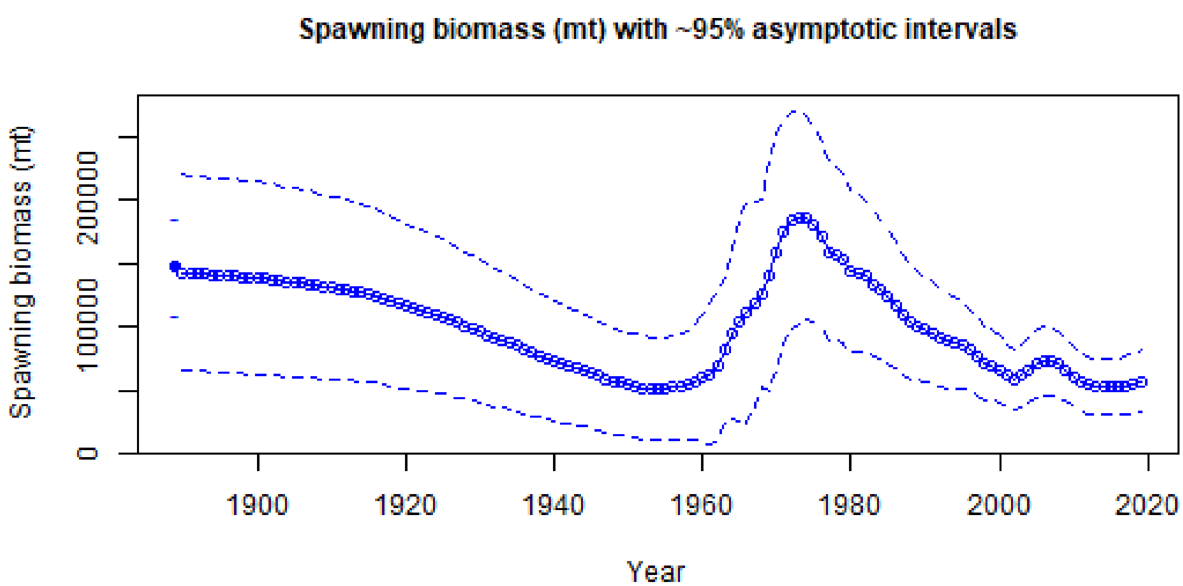

Figure b. Time series of estimated sablefish spawning biomass (mt) from the base model (circles) with ∼95% intervals (dashed lines).

RECRUITMENT

Sablefish recruitment is estimated to be quite variable with large amounts of uncertainty in individual recruitment events. A period with generally higher frequencies of strong recruitments spans from the early 1950s through the 1970s, followed by a lower frequency of large recruitments during 1980 forward, contributing to stock declines. The period with a higher frequency of high recruitments contributed to a large increase in stock biomass that has subsequently declined throughout much of the 1970s forward. Less frequent large recruitments during the mid-1980s through 1990 slowed the rate of stock decline, with another series of large recruitments during 1999 and 2000 leading to a leveling off in the stock decline. The above-average cohorts from 2008, 2010, 2013, and 2016 are contributing to a slightly increasing spawning stock size. The 2016 cohort is estimated to be the largest since the mid-1970s.

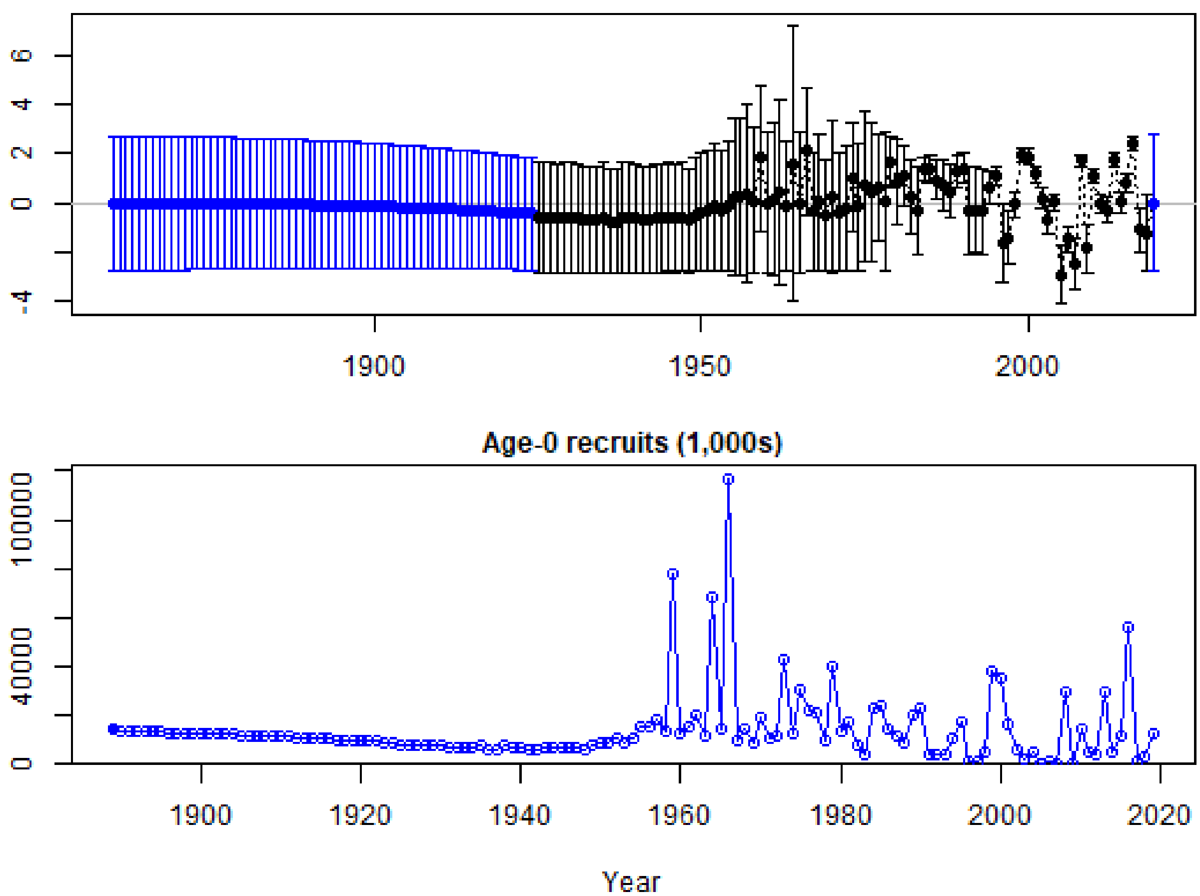

Figure c. Time series of estimated recruitment deviations from the base model (solid line) with ∼95% intervals (vertical lines; upper panel) and recruitment without intervals (lower-panel).

REFERENCE POINTS

Unfished spawning biomass was estimated to be 147,729 mt (109,022-186,436, ∼95% interval). The abundance of sablefish was estimated to have dropped below the target reference point of 40% of this estimated value of unfished spawning biomass during the 2000s and generally remained below the target through 2018. The estimate of the target spawning stock biomass was 59,092 (43,609-74,574, ∼95% interval), which gives a catch of 7,363 mt (4,269-10,456, ∼95% interval). The stock was estimated to be just below the target stock size in the beginning of 2019 at 57,444 mt (32,776-82,112, ∼95% interval). The stock was estimated to be above the depletion level that would lead to maximum yield. The estimate of the stock's current level of depletion was 38.9%.

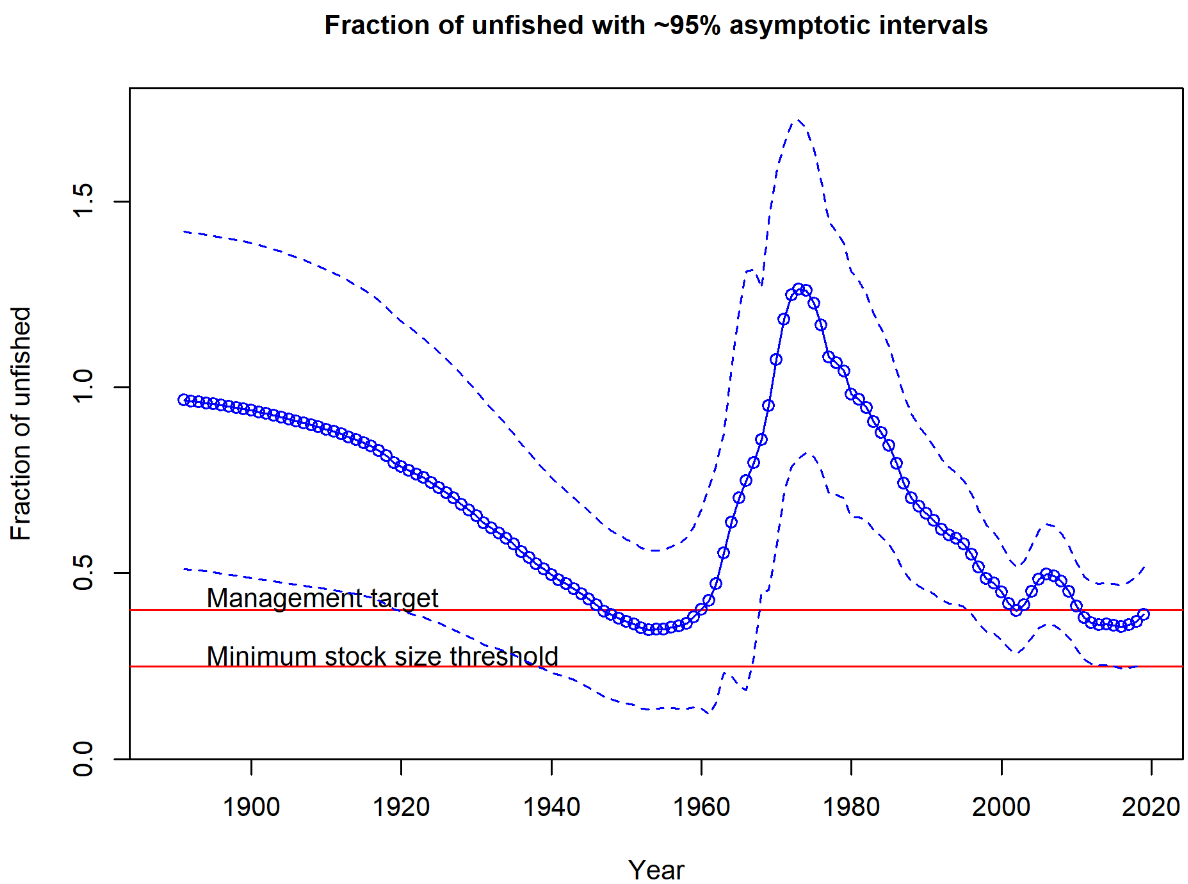

Figure d. Time series of estimated depletion (i.e., spawning biomass relative to unfished spawning biomass) from the base model (circles) with ∼ 95% intervals (dashed lines).

EXPLOITATION STATUS

Equilibrium yield at the fishing mortality that leads to the maximum sustainable yield (F_{MSY}) is 8,077 mt (4,684-11,470, ∼95% interval).

Although the estimated productivity and absolute scale of the stock are poorly informed by the available data and are, therefore, sensitive to changes in model structure and treatment of data, all sensitivity or alternate models evaluated showed a declining trend in biomass since the 1970s followed by a recent increase in biomass. The spawner potential ratio (SPR) exceeded the fishing mortality target/overfishing level ($SPR_{45\%}$) that stabilizes the stock at the target (i.e., $1-SPR/[1-SPR_{45\%}]$) during the late 2000s and early 2010s, while since 2015 it has been between 83 and 95%.

Table c. Estimates of total dead catch (mt), relative 1-spawning potential ratio (SPR; 1-SPR/1-SPR$_{Target=0.45\%}$), and exploitation rate (catch/biomass of age-4+) from the base model. Approximate 95% intervals follow in parentheses.

Year	Total catch	Rel. 1-SPR		Exploitation rate	
2009	7,373	1.006	(0.737-1.275)	0.045	(0.028-0.062)
2010	7,018	1.051	(0.778-1.323)	0.047	(0.029-0.065)
2011	6,251	1.094	(0.829-1.360)	0.046	(0.028-0.064)
2012	5,280	0.934	(0.668-1.200)	0.036	(0.022-0.050)
2013	4,052	0.799	(0.545-1.053)	0.029	(0.018-0.041)
2014	4,240	0.801	(0.545-1.058)	0.030	(0.018-0.041)
2015	5,091	0.923	(0.650-1.195)	0.037	(0.022-0.051)
2016	5,403	0.954	(0.675-1.233)	0.041	(0.024-0.057)
2017	5,424	0.859	(0.584-1.133)	0.036	(0.022-0.051)
2018	5,132	0.825	(0.552-1.098)	0.035	(0.021-0.050)

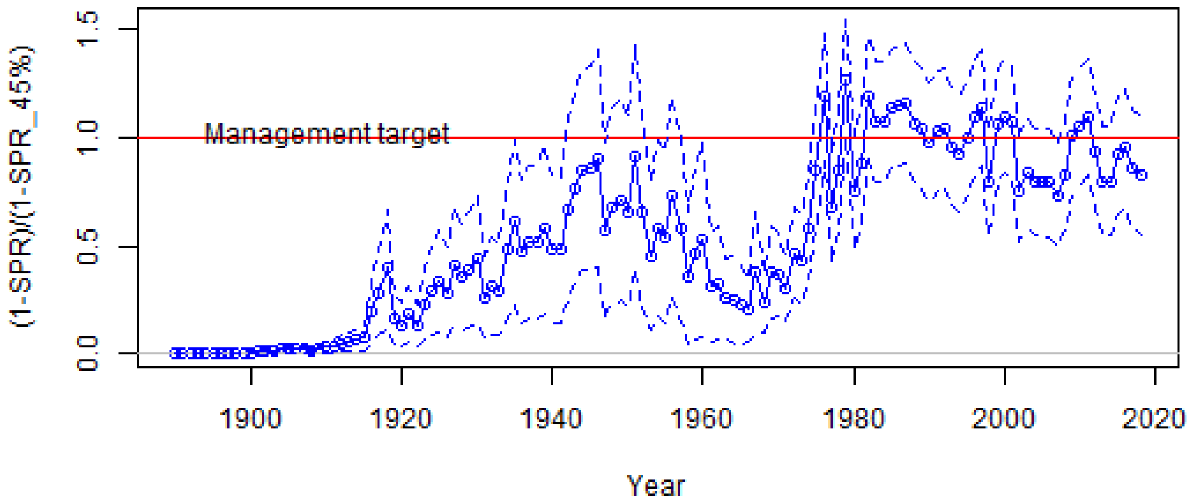

Figure e. Time series of estimated relative spawning potential ratio (1-SPR/1-SPR$_{Target=0.45\%}$) from the base model (points) with ∼95% intervals (dashed lines). Values above 1.0 (red, horizontal line) reflect harvests in excess of the current overfishing proxy.

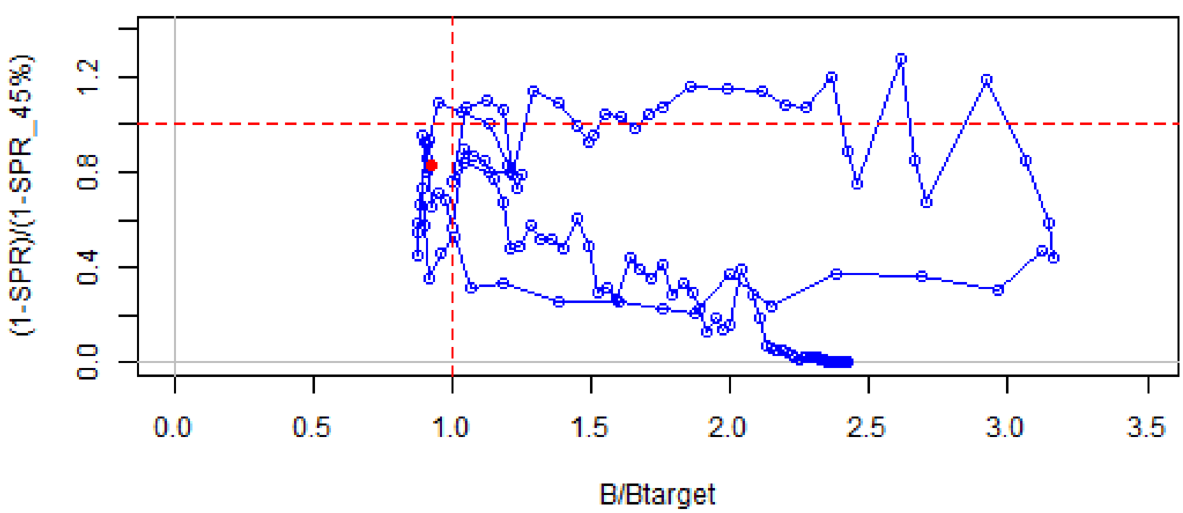

Figure f. Estimated relative spawning potential ratio (1-SPR/1-SPR$_{Target=0.45\%}$) vs. estimated spawning biomass relative to the proxy 40% level from the base model. Higher spawning output occurs on the right side of the x-axis, higher exploitation rates occur on the upper side of the y-axis. The filled, red circle indicates the last year of available data, 2018.

MANAGEMENT PERFORMANCE

Sablefish management includes a rich history of seasons, size-limits, trip-limits, and a complex permit system. Managers divide coast-wide yield targets from sablefish stock assessment among the fleets, fishery sectors (including both limited entry and open access), as well as north and south of 36° N latitude. Peak catches occurred during the late 1970s just prior to the imposition of the first catch limits. Over the last decade, the total estimated dead catch has been 55% of the sum of the overfishing limits (previously termed ABCs) and 65% of the annual catch limits (previously termed OYs).

Table d. Recent trend in overfishing limits (OFLs), annual catch limits (ACLs), landings, and estimated (est.) total dead catch (mt). Limits are summed across the southern and northern management areas where separate values were applied. Dead catch includes discards, which are estimated within the stock assessment, and therefore, dead catch may differ from total mortality reports used by management.

Year	OFL	ACL	Landings	Est. dead catch
2009	9,914	8,423	6,951	7,372.96
2010	9,217	7,729	6,599	7,017.63
2011	8,808	6,813	6,152	6,251.04
2012	8,623	6,605	5,189	5,280.13
2013	6,621	5,451	3,990	4,051.93
2014	7,158	5,909	4,162	4,239.63
2015	7,857	6,512	5,011	5,091.38
2016	8,526	7,121	5,305	5,402.67
2017	8,050	7,117	5,308	5,424.41
2018	8,329	7,419	5,045	5,131.61
2019	8,489	7,596		

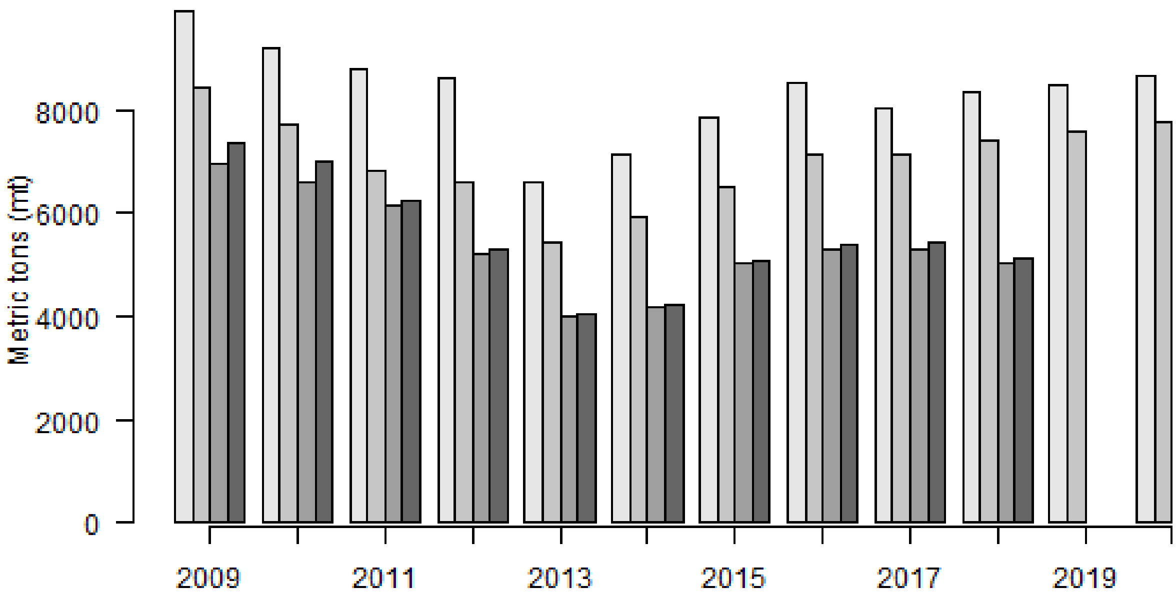

Figure g. Recent (and current) sablefish overfishing limits (OFLs; lightest gray) and annual catch limits (ACLs; light gray) compared to recent landings (gray) and estimated dead catch (dark gray) from the base model. Dead catch excludes discarded fish that are predicted to have survived.

UNRESOLVED PROBLEMS AND MAJOR UNCERTAINTIES

The data available for sablefish off the U.S. West Coast are not informative with respect to absolute size and productivity. This is, in part, due to the one-way-trip nature of the historical series (i.e., a slow and steady decline in spawning biomass), which can be consistent with a larger less productive stock, a smaller more productive stock, or many combinations in between. While the historical catches provide some information about the minimum stock size necessary to remove the catches from the population, there is limited information in the data regarding the upper limit of the stock size. The above factors are also confounded by movement of sablefish between the region included in this assessment and regions to the north. Likelihood profiles, parameter estimates, and general model behavior illustrate that small changes in many parameters can result in different management reference points. However, because leading model parameters, such as natural mortality, selectivity, and historical recruitments, are estimated within the stock assessment model, the uncertainty about these estimates remains large and typically overlapped among the investigated models. The uncertainty will remain until a more informative time-series, better quality demographic and biological information are accumulated, or a range-wide analysis is completed for sablefish.

Uncertainty in the current aging methods (both bias and imprecision), as well as relatively sparse fishery sampling, result in age data that potentially variable. Furthermore, because sablefish grow rapidly, nearing asymptotic length in their first decade of life, length data is not particularly informative about historical patterns in recruitment. The patterns observed in historical sablefish recruitment suggest that the stock trajectory (via shifts in recruitment strength) is closely linked to productivity regimes in the California Current. Uncertainty in future environmental conditions, changes in the timing, dynamics, and productivity of the California Current ecosystem via climate change or cycles similar to the historical period should be considered a significant source of uncertainty in all projections of stock status.

The ongoing WCGBT Survey is a fairly precise relative index of abundance over a broad demographic component of the stock, but it does not survey the entire stock as sablefish reside in waters deeper than 1280 m, the survey limit, and to the north. Therefore, a portion of the stock is unobserved. This index has the potential to inform future stock assessments about the scale of the population relative to catches being removed, however such information will require contrast in the observed survey trend.

HARVEST PROJECTIONS

Previous sablefish stock assessments have been designated as Category 1 stock assessments. Thus, projections and decision tables are based on P^*=0.4 and the values of sigma adopted by the Pacific Fisheries Management Council for stock projections. The time series of multiplicative buffer fractions that are a function of P^* and the time series of sigmas provide the multipliers on the overfishing limit, these values are all less than 1. The multipliers are combined with the 40-10 harvest control rule to calculate overfishing limits, acceptable biological catches, and annual catch limits. The total catches in 2019 and 2020 were set at the Pacific Fisheries Management Council Groundfish Management Team requested values, just below that Pacific Fisheries Management Council annual catch limits for sablefish. The average 2016-2018 catches were used to distribute catches among the fisheries.

Current medium-term projections from the base model under the Pacific Fisheries Management Council 40-10 harvest control rule estimate that the stock will remain above the target stock size of 40% of the estimated unfished spawning biomass during the projection period. Projections are provided through 2030 (Table e).

Forecasts from the 2015 assessment update projected the spawning biomass to increase by 9.3% from 2015 to 2019 given specified harvests, whereas the current assessment estimated the increase at 8.0%. Estimates of unexploited spawning biomass are 2% lower than that estimated in 2015 and 19% lower than the 2011 estimate. Percent of unfished biomass in 2019 was estimated at 39%, while the 2015 stock assessment forecasted it to be 38%.

Table e. The sablefish stock assessment is a Category 1 stock assessment, thus projections and decision tables are based on using $P^* = 0.40$ and the Pacific Fisheries Management Council (PFMC) approved time series of sigma values for stock projections that provide the multipliers on the over fishing limit (OFL), these values are all less than 1. The OFL multipliers are combined with the 40-10 harvest control rule, where applicable, to calculate OFLs and Annual Catch Limits (ACLs). Note that the Acceptable Biological Catches (ABCs) and ACLs are equal because the stock is estimated to be above 40% of the unfished spawning biomass. Therefore, ABCs are not displayed. The total catches in 2019 and 2020 were set at the PFMC Groundfish Management Team requested values of 6,145.4 mt for 2019 and 6,287.9 mt for 2020, just below the PFMC agreed ACLs for sablefish. The average 2016-2018 catch was used to distribute catches among the fisheries.

Year	OFL (mt)	ACL (mt)	Spawning biomass (mt)	Depletion
2019	8,489	7,596	57,444	38.88 %
2020	8,648	7,755	63,350	42.88 %
2021	9,402	8,208	68,120	46.11 %
2022	9,040	7,811	68,778	46.56 %
2023	8,877	7,599	68,177	46.15 %
2024	8,713	7,388	67,482	45.68 %
2025	8,579	7,207	66,984	45.34 %
2026	8,479	7,055	66,691	45.14 %
2027	8,411	6,930	66,555	45.05 %
2028	8,368	6,837	66,525	45.03 %
2029	8,346	6,752	66,564	45.06 %
2030	8,339	6,679	66,652	45.12 %

DECISION TABLE

The decision table reports 12-year projections for alternate states of nature (columns) and management options (rows). The results of this table are conditioned on the Groundfish Management Team specified catches for 2019 and 2020, which are just below the already-specified annual catch limits approved by the Pacific Fisheries Management Council.

Uncertainty in management quantities for the decision table was characterized using the asymptotic standard deviation for the 2019 spawning biomass from the base model. Specifically, the 2019 spawning biomass for the high and low states of nature are given by the base model mean $\pm 1.15 \cdot$standard deviation (i.e., the 12.5th and 87.5th percentiles). A search across fixed values of R_0 was used to attain the 2019 spawning biomass values for the high and low states of nature. The mid-level catch streams were based on the 40-10 harvest control rule. At the request of the Groundfish Management Team representative at the STAR panel, the high and low catch streams were set using the Category 1 values of $P^* = 0.45$ and $P^* = 0.35$, respectively.

Spawning stock biomass in 2019 ranges across the three states of nature from 42,968 to 71,915 mt, with corresponding stock status between 38% to 41% of the unfished stock size. The decision table suggests that all catch scenarios under both the base and high state of nature result in increases in stock size such that the stock remains either at or above the target stock size at the end of the projection period. However, all catch scenarios under the low state of nature result in declines in stock size throughout the projection period, maintaining the stock within the precautionary zone.

Table f. Decision table of 12-year projections of spawning stock biomass (SSB) and % unfished (depletion) for alternative states of nature (columns) and management options (rows) beginning in 2019. The low and high states of nature are based on the 2019 SSB $\pm$ 1.15·base model SSB standard deviation. The fixed value of unfished recruitment was used to find each state of nature. The results are conditioned on the 2019 and 2020 catches, provided by the Pacific Fisheries Management Council Groundfish Management Team (GMT), being achieved exactly. The low and high catch streams are based on the GMT's requested P* values of 0.35 and 0.45.

			Low state (0.25)		Base (0.5)		High state (0.25)	
Catch scenario	Year	Total catch	SSB	Depletion	SSB	Depletion	SSB	Depletion
P*=0.35	2019	6,145	42,968	38%	57,444	39%	71,915	41%
	2020	6,288	47,594	42%	63,350	43%	79,161	45%
	2021	7,644	51,414	45%	68,120	46%	84,950	49%
	2022	7,269	51,922	46%	69,059	47%	86,290	50%
	2023	7,064	51,094	45%	68,740	47%	86,292	50%
	2024	6,849	49,847	44%	68,316	46%	86,367	50%
	2025	6,668	48,544	43%	68,079	46%	86,781	50%
	2026	6,513	47,297	41%	68,038	46%	87,474	50%
	2027	6,382	46,136	40%	68,145	46%	88,349	51%
	2028	6,279	45,063	40%	68,354	46%	89,327	51%
	2029	6,182	44,064	39%	68,629	46%	90,356	52%
	2030	6,105	43,135	38%	68,953	47%	91,411	53%
P*=0.4	2019	6,145	42,968	38%	57,444	39%	71,915	41%
	2020	6,288	47,594	42%	63,350	43%	79,161	45%
	2021	8,208	51,414	45%	68,120	46%	84,950	49%
	2022	7,811	51,636	45%	68,778	47%	86,008	49%
	2023	7,599	50,517	44%	68,177	46%	85,727	49%
	2024	7,388	48,988	43%	67,482	46%	85,532	49%
	2025	7,207	47,411	42%	66,984	45%	85,685	49%
	2026	7,055	45,902	40%	66,691	45%	86,129	49%
	2027	6,930	44,489	39%	66,555	45%	86,761	50%
	2028	6,837	43,169	38%	66,525	45%	87,503	50%
	2029	6,752	41,925	37%	66,564	45%	88,300	51%
	2030	6,679	40,750	36%	66,652	45%	89,126	51%
P*=0.45	2019	6,145	42,968	38%	57,444	39%	71,915	41%
	2020	6,288	47,594	42%	63,350	43%	79,161	45%
	2021	8,791	51,414	45%	68,120	46%	84,950	49%
	2022	8,375	51,342	45%	68,488	46%	85,717	49%
	2023	8,158	49,920	44%	67,594	46%	85,142	49%
	2024	7,946	48,097	42%	66,618	45%	84,666	49%
	2025	7,758	46,241	41%	65,851	45%	84,551	49%
	2026	7,614	44,468	39%	65,304	44%	84,740	49%
	2027	7,499	42,799	38%	64,918	44%	85,125	49%
	2028	7,401	41,226	36%	64,643	44%	85,624	49%
	2029	7,331	39,739	35%	64,445	44%	86,188	50%
	2030	7,275	38,320	34%	64,296	44%	86,782	50%

RESEARCH AND DATA NEEDS

Most of the research needs listed below entail investigations that need to take place outside of the routine assessment cycle and require additional resources to be completed.

1. Not all of the available sablefish otoliths were aged for this stock assessment because of time constraints resulting from the federal government furlough, and, in some cases, the sample sizes of aged fish are lower than what would be ideal. Resources should be provided to age otolith samples from years with missing age data or small sample sizes.

2. A transboundary stock assessment and the management framework to support such assessments would be beneficial given the migratory nature and broad distribution of sablefish along the Pacific Rim. A transboundary assessment would likely improve the ability to estimate the scale of the population, particularly during the early modeled period.

3. Investigation of environmental covariates for recruitment on a stock-wide, northeast Pacific scale.

4. Continuation of the annual WCGBT Survey will provide information on stock trends and incoming recruitments. A longer survey time series may improve the precision of estimates of absolute stock size and productivity into the future.

5. Age validation is needed to verify the level of age bias present in the data, if any.

6. Investigate aging methods that could prove more precise than current break-and-burn methods. More accurate age data would facilitate tracking cohorts to older ages, improving estimates of historical year-class strengths.

7. Research on understanding the interactions between spatial patterns in sablefish growth, fishery size selectivity, and movement across the Northeast Pacific began during 2019 and are ongoing. The results of this research should be considered in future benchmark stock assessments.

8. Anecdotal information, such as the large 1947 recruitment reported by central California sport fisherman, along with historical records could be investigated to provide additional information on historical patterns of recruitment.

Table g. Summary of sablefish reference points as estimated using the base model. Yields include discard mortality. Given steepness is a fixed parameter, the uncertainty in these reference points remains an underestimation.

Quantity	Estimated value	∼95% intervals
Unfished total biomass (mt)	350,340	244,366-456,314
Unfished 4+ biomass (mt)	327,697	231,618-423,776
Unfished spawning biomass (SB_0, mt)	147,729	109,022-186,436
Unfished recruitment (R_0, thousands)	15,022	7,633-22,411
Current depletion	38.88%	26.10-51.67%
Reference points based on $SB_{40\%}$		
MSY Proxy spawning biomass ($SB_{40\%}$, mt)	59,092	43,609-74,574
Relative spawning depletion at $SB_{40\%}$	40.00%	
SPR resulting in $SB_{40\%}$	50.00%	
Exploitation rate resulting in $SB_{40\%}$	4.64%	3.89-5.40%
Yield with $SPR_{SB40\%}$ at $SB_{40\%}$ (mt)	7,363	4,269-10,456
Reference points based on SPR proxy for MSY		
Spawning biomass at $SPR_{MSY-proxy}$ (SPR_{proxy}, mt)	56,728	41,865-71,591
Relative spawning depletion at SPR_{proxy}	38.40%	
SPR_{proxy}	45.00%	
Exploitation rate corresponding to SPR_{proxy}	4.88%	4.09-5.67%
Yield with SPR_{proxy} at SB_{SPR} (mt)	7,488	4,342-10,633
Reference points based on estimated MSY values		
Spawning biomass at MSY (SB_{MSY}, mt)	36,734	27,093-46,375
Relative spawning depletion at SB_{MSY}	24.87%	
SPR_{MSY}	32.92%	32.71-33.12%
Exploitation rate corresponding to SPR_{proxy}	7.49%	6.29-8.69%
Yield with SPR_{proxy} at SB_{SPR} (mt)	8,077	4,684-11,470

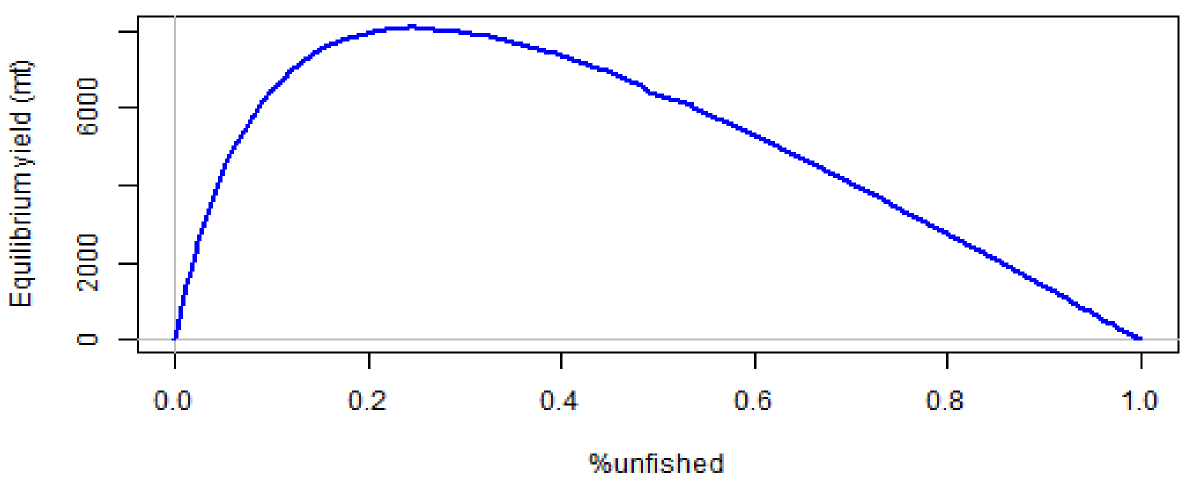

Figure h. Equilibrium yield curve (total dead catch) for the base model.