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Attachment 8
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Status of the U.S. sablefish resource in 2015

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Executive summary

Stock

This assessment update 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 2014. The resource is modeled as a single stock, however sablefish do disperse to some degree to and from offshore seamounts and along the coastal waters of the continental U.S., Canada, Alaska, and across the Aleutian Islands to the western Pacific and this is not explicitly accounted for in this analysis.

Catches

Historical sablefish landings were reconstructed from a variety of sources, and are generally more reliable than those for many other groundfish due to the consistent identification of sablefish by species. Uncertainty in historical landings (i.e., fish brought to market), primarily in the Washington-based fishery, stems from poor identification of fishing location (coastal U.S. waters, Canadian waters, or Alaskan waters). Given that sablefish are found from the southern tip of Baja Calfifornia to the north- central Bering Sea, fish landed in Washington ports are not necessarily caught off the coast of Washington. Revised reconstructions from California and Oregon, as well as a more limited analysis using Washington sources, for the 2011 assessment resulted in almost no change from landings used in previous sablefish assessments. Because discarding is explicitly modeled in the stock assessment, total catches (i.e., discards, drop offs, landings, etc.) are estimated simultaneously with other model parameters and derived quantities of management interest. Using an internal estimation approach, such as the one used here, can result in total mortality estimates that differ from those used by previous management and/or estimated using other methods.

Sablefish landings were small (<5,000 mt), and were primarily harvested by hook-and-line fisheries until the end of the 1960s. A very large catch by foreign vessels, fishing pot gear, in 1976 resulted in the largest single-year removal of over 25,000 mt from the stock. A rapid rise in domestic pot and trawl landings followed this peak removal, such that on average, nearly 14,000 mt of sablefish were landed per year between 1976 and 1990. Annual landings have remained below 10,000 mt in subsequent years, divided approximately 45% from hook-and-line, 17% from pot, and 38% from trawl gear during the most recent decade. In the last three years, since the implementation of the trawl catch share program, relative landings from the pot fishery have increased while trawl landings have decreased. Model estimates of discarding result in total dead catches that are an average of 5.08% larger than reported landings over the last decade. However, due to a lack of data regarding changes in selectivity and retention during the historical period (prior to the current observer program, which began in 2002), total catch and age and length composition of landings and discards for much of the time-series represent an important source of uncertainty in this stock assessment.

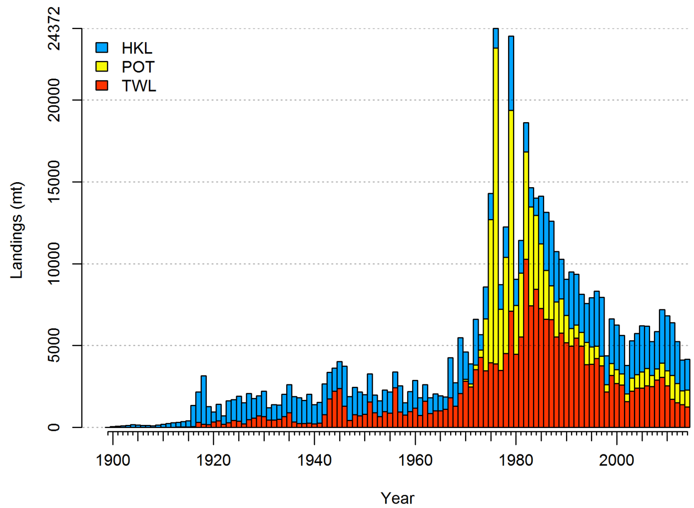

Figure 1: Sablefish landings history, 1900-2014. Fleet names indicate gear type (HKL = Hook-and-line, POT = Pot, and TWL = Trawl). Foreign fleets are included and are largely responsible for the peak landings in 1976 and 1979.

Table 1: Recent sablefish landings (mt) by fleet.

	Hook-and-Line		**Pot**		**Trawl**	
Year	mt	%	mt	%	mt	%
2001	2362	3.03	673	0.86	2596	3.33
2002	1749	2.25	472	0.61	1568	2.01
2003	2283	2.93	799	1.03	2213	2.84
2004	2515	3.23	816	1.05	2411	3.10
2005	2807	3.60	997	1.28	2399	3.08
2006	2604	3.34	1053	1.35	2538	3.26
2007	2060	2.65	688	0.88	2489	3.20
2008	2301	2.95	675	0.87	2892	3.71
2009	3274	4.20	863	1.11	3061	3.93
2010	3379	4.34	910	1.17	2539	3.26
2011	3231	4.15	1449	1.86	1724	2.21
2012	2561	3.29	1179	1.51	1498	1.92
2013	1865	2.39	846	1.09	1402	1.80
2014	1868	2.40	1032	1.32	1256	1.61

Data and assessment

This stock assessment is an update of the 2011 sablefish assessment, using the same data streams and general data analysis methods, structural choices, and assumptions as in that assessment. This assessment update did, however, make use of the most recent version of the Stock Synthesis modeling platform (3.24u, released 29 August, 2014). Primary data sources include landings and length- and age-frequency data from both the retained and, in recent years the discarded portion of the commercial catch. Discard rates as well as mean observed individual body weight in the discards are also included. The National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center (NWFSC) Shelf-Slope trawl survey relative biomass index is the primary source of stock trend information, updated to cover the period 2003-2014 and include depths from 55-1,280 m. Other (discontinued) survey indices contributing information on trend and sablefish demographics include: the NWFSC slope survey conducted from 1998-2002, the Alaska Fisheries Science Center (AFSC) slope survey (1997-2001), and the AFSC/NWFSC triennial shelf trawl survey (1980-2004). Environmental time-series including both sea-surface height (used in previous sablefish assessments) and zooplankton abundance were also investigated.

All externally estimated model parameters, including those defining the weight- length relationship, maturity schedule, and fecundity relationships, have been revisited and, in some cases, revised from the values used in previous assessments. The assessment explicitly estimates parameters describing dimorphic growth and mortality differences between male and female sablefish. Recruitment uncertainty is included via a full time-series of estimated deviations from the stock-recruit curve. Uncertainty in leading parameters such as natural mortality, the unexploited equilibrium level of the stock-recruit function, and catchability coefficients of the survey indices are explicitly included in the model results. Due to the one-way-trip nature of the time-series it was not possible to estimate the steepness parameter (h) of the stock-recruitment relationship, so this quantity was fixed at a value of 0.6 and explored via sensitivity analyses. Aging error, including both precision and accuracy, was extensively investigated during the 2011 assessment. The potential for underestimating the age of the oldest fish was not resolved with available data, and therefore aging bias also remains an important source of uncertainty. Sablefish are caught throughout the depth and geographic range of the survey and calculation of the relative biomass in the southern area is of particular management interest. To account for both the spatial and temporal variation in sablefish density and irregularity in sampling a delta-Generalized Linear Mixed Effects Model (delta-GLMM) with Gaussian Markov random fields was used to provide an index of abundance. The delta-GLMM method accommodates both spatial and spatiotemporal variation through the use of Gaussian Markov random fields.

During the 2011 full assessment, a vast number of historical management actions were condensed down to those that seemed most likely to have had a direct influence on fishery behavior (either sorting and retention, selectivity, or both) to reduce the complexity in modeling fishery dynamics. The 2011 base-case model, which forms the basis for this this update, attempted to parsimoniously represent these changes in selectivity and retention with the fewest number of parameters possible, requiring that among-parameter correlations remained low and estimation behavior robust. Furthermore, the time-block for retention, with respect to the trawl fishery, was updated to assume full retention to match the adoption of the West Coast Groundfish Trawl Catch Share Program in 2011.

Stock biomass

Sablefish are estimated to have been exploited at a modest level through the first half of the 20^{th} century. Following a period of recruitments, estimated to have been above average, but highly uncertain, the spawning stock biomass rebounded to nearly unexploited levels in the late 1970s. Large harvests during those years, and lower average recruitment throughout the 1980s and early-1990s, are estimated to have caused the stock to decline continuously between 1976 and 2001, despite harvest rates that were below the current OFL rate from 1983 through 2001. Following higher recruitments in 1995, 1999, and 2000, the spawning biomass increased slightly during the early-2000s, but has continued to decline since 2005, due, in large part, to extremely poor recruitments from 2002 to 2007. The relative spawning biomass is estimated to be at only 33% of unexploited levels in 2015; however this value is highly uncertain (∼95% intervals range from 2.23-5.85%). Although the relative trend in spawning biomass is quite robust to uncertainty in the leading model parameters, the productivity of the stock is highly uncertain due to confounding of mortality, absolute stock size, and productivity. The estimated spawning biomass in 2015 is 54,330 mt, however, the ∼95% interval ranges broadly from 22,570 to 86,090 mt reflecting little information in the data about absolute stock size. SB was projected to fall by 6% from 2011 to 2015 in the last assessment, and the current assessment estimates that the decline was actually 9%. But since, SB_0 is 19% lower in the current assessment, the stock is somewhat less depleted than was estimated in 2011, even with the greater rate of decline. The higher rate of decline in the current assessment appears primarily due to the 2010-11 recruitments being estimated at only 58% of their combined numbers in the 2011 assessment.

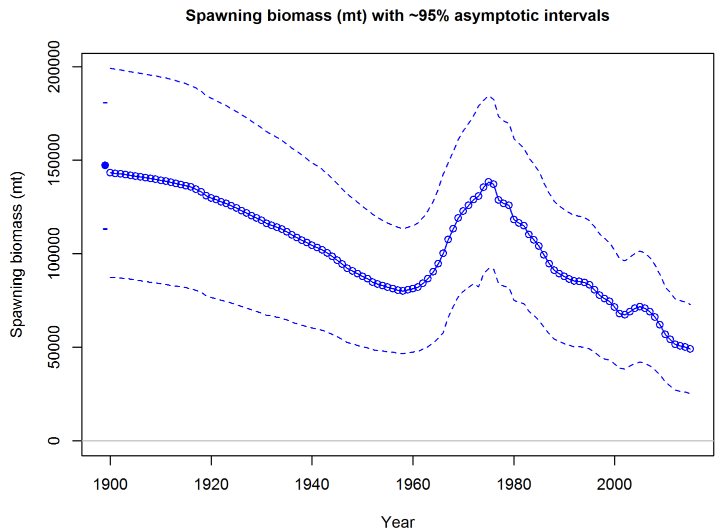

Figure 2: Estimated spawning biomass time-series (1900-2015) for the base-case model (circles) with with ∼95% intervals (dashed lines).

Table 2: Recent trend in estimated sablefish spawning biomass, recruitment, and relative depletion level.

Year	Spawning biomass (mt)	∼95% interval	Estimated recruitment (1000s)	∼95% interval	Estimated depletion	∼95% interval
2005	71,638	41,998-101,279	588	185-991	49 %	33-64 %
2006	70,829	41,392-100,265	1,672	895-2,449	48 %	33-64 %
2007	68,893	39,969-97,818	1,198	515-1,880	47 %	32-62 %
2008	66,028	38,018-94,038	27,163	17,233-37,093	45 %	30-60 %
2009	62,042	35,195-88,889	1,704	706-2,701	42 %	28-56 %
2010	56,828	31,319-82,337	16,589	9,821-23,356	39 %	25-52 %
2011	54,188	29,234-79,143	5,275	2,747-7,804	37 %	24-50 %
2012	51,457	27,137-75,776	4,061	1,760-6,363	35 %	22-48 %
2013	50,631	26,414-74,848	41,745	22,626-60,863	34 %	22-47 %
2014	50,044	25,961-74,127	3,482	70-6,895	34 %	21-47 %
2015	49,071	25,206-72,936	12,624	0-36,706	33 %	21-46 %

Recruitment

Sablefish recruitment is estimated to be quite variable over the historical record; however uncertainty in individual recruitment events is large. Within this variability, the average recruitment is estimated to have declined steadily between the 1970s and 2007. Recruitments during the 1980s were, on average, roughly an order of magnitude higher than the very poor recent cohorts estimated between 2002 and 2005. It appears that large 1995, 1999, and 2000 year classes briefly slowed the rate of stock decline in the early 2000s and above-average cohorts from 2008, 2010, and 2013 are currently moving through the population. More specifically, the 2013 cohort appears to be one of the top ten largest recruitments events in the history of the fishery. However, only the 2008 cohort has begun to mature and thus their contribution to the trend in spawning biomass remains minimal. Furthermore, the size of the 2010 cohort has been downgraded by 20% in the current assessment compared to the estimate from 2011, and the current estimate of the 2011 year class is less than one-third of the average-recruitment amount assumed in the last assessment.

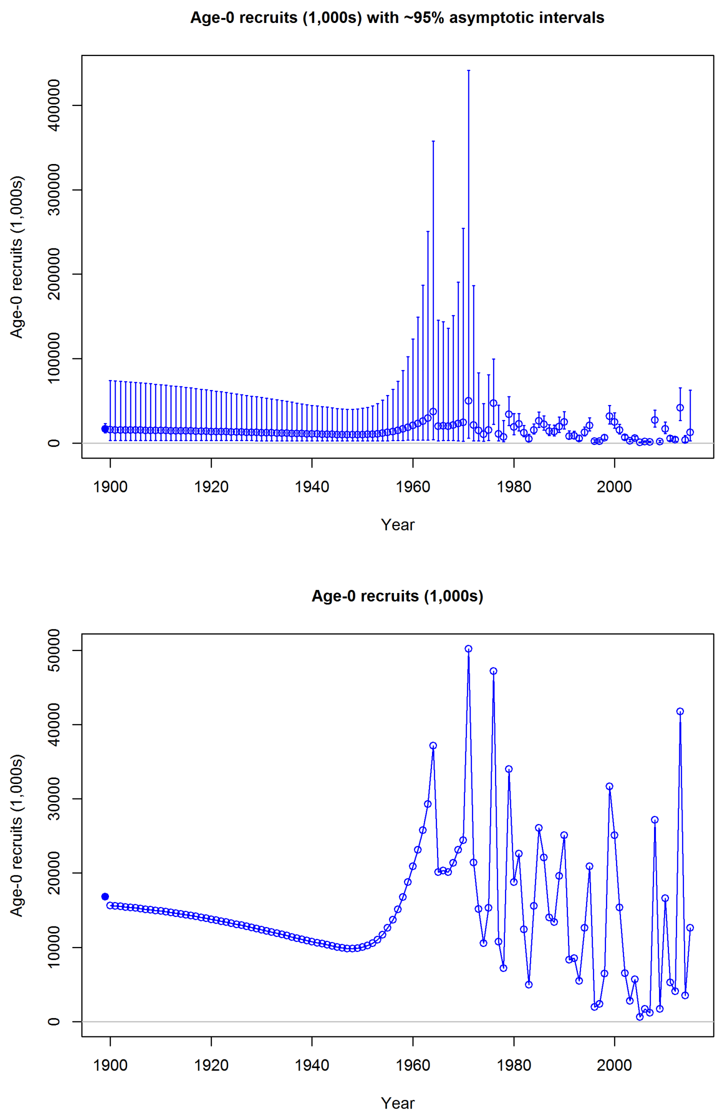

Figure 3: Time series of estimated sablefish recruitments for the base-case model (solid line) with ∼95% intervals (vertical lines; upper panel) and without intervals (lower-panel) to better visualize recent estimated trends.

Reference points

Unfished female spawning biomass was estimated to be 147,209 mt, but this value is highly uncertain (∼95% interval: 113,472-180,946 mt). The management target stock size ($SB_{40\%}$) is therefore 58,884 mt, and the overfished threshold ($SB_{25\%}$) is 36,802 mt. Total and age-4+ biomass at unexploited equilibrium were estimated to be 432,047 and 405,032 mt respectively. Because the steepness parameter is not estimated in this assessment, the uncertainty in equilibrium yields at the following reference points is grossly underestimated. Maximum sustainable yield (MSY), conditioned on current fishery selectivity and allocations, was estimated to occur at a spawning stock biomass of 43,149 (29% of unfished female spawning biomass), and produce a dead MSY catch (excluding discarded fish that are predicted to have survived) of 7,639 mt. However, the yield MSY varies almost linearly with steepness. Maximum sustainable yield is estimated to be achieved at an SPR of 41. This is very close to the yield, 7,290 mt, generated by the SPR (50%) that stabilizes the stock at the $SB_{40\%}$ target. The fishing mortality target/overfishing level (SPR = 45%) results in an intermediate equilibrium yield of 7,565 mt at a spawning biomass of 50,051 mt (34 % of the unfished equilibrium).

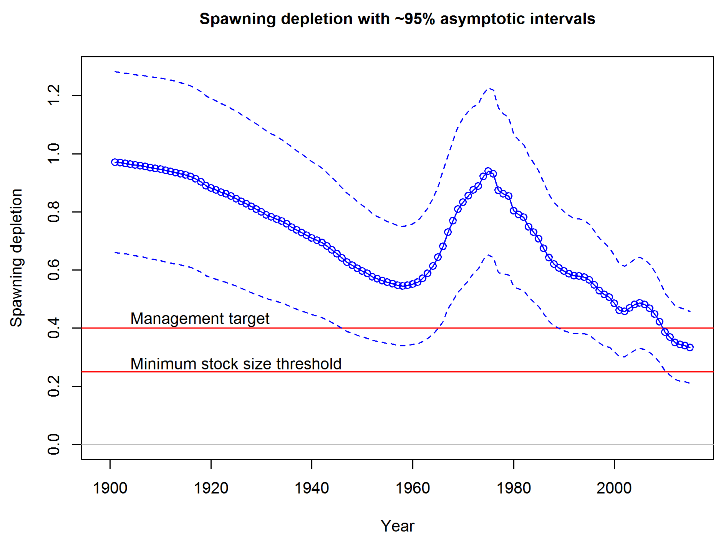

Figure 4: Time series of estimated relative spawning depletion from the base-case model (circles) with $\sim$ 95% interval (dashed lines).

Exploitation status

The coast-wide abundance of sablefish was estimated to have dropped below the SB_{40}% management target between 2009 and 2010 and is currently declining. The cause of this trend appears to be primarily due to relatively poor recruitments, as the fishing intensity remained below relative SPR target rates between 1988 and 2008. Although the estimated productivity and absolute scale of the stock are very poorly informed by the available data and are therefore highly sensitive to changes in model structure and treatment of data, all sensitivity or alternate models evaluated showed a current declining trend in biomass and increasing trend in fishing mortality.

Table 3: Recent trend in relative spawning potential ratio (1-SPR/1-SPR$_{Target=0.45}$) and relative exploitation rate (catch/biomass of age-4 and older fish).

Year	Relative SPR	~95% interval	Relative exploitation rate	~95% interval
2005	78%	55-102%	2.8%	1.7-4%
2006	80%	56-104%	2.9%	1.7-4.1%
2007	74%	51-97%	2.6%	1.5-3.7%
2008	87%	62-112%	3%	1.8-4.3%
2009	109%	82-136%	4.1%	2.3-5.8%
2010	112%	85-140%	4.2%	2.3-6%
2011	113%	85-140%	4.2%	2.3-6.2%
2012	101%	73-130%	3.3%	1.8-4.7%
2013	85%	58-113%	2.7%	1.5-4%
2014	84%	56-112%	2.7%	1.5-4%

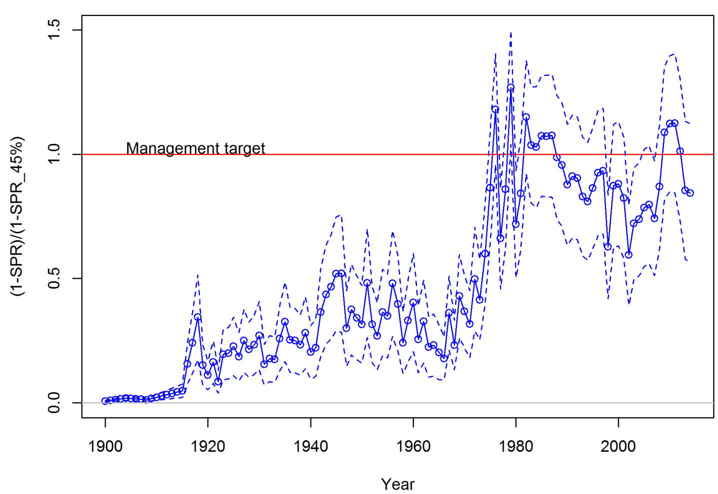

Figure 5: Time series of estimated relative spawning potential ratio (1-SPR/1-SPR$_{Target=0.45}$) for the base-case model (round points) with ~95% intervals (dashed lines). Values of relative SPR above 1.0 (100% in the table above) reflect harvests in excess of the current overfishing proxy.

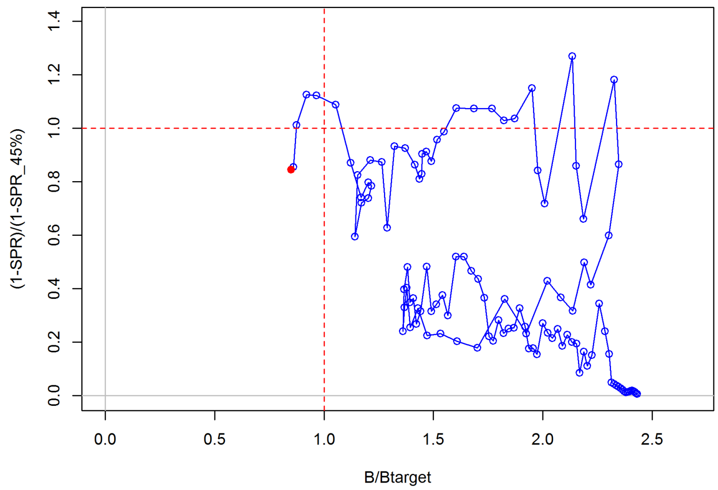

Figure 6: Estimated relative spawning potential ratio relative to the proxy target/limit of 45% vs. estimated spawning biomass relative to the proxy 40% level from the base-case model. Higher spawning output occurs on the right side of the x-axis, higher exploitation rates occur on the upper side of the y-axis. The filled circle indicates 2014.

Management performance

The sablefish fishery has been managed with a rich history of seasons, size-limits, trip-limits, and a complex permit system. Coast-wide yield-targets have been divided among the different gears (hook-and-line, pot, and trawl), fishery sectors (including both limited entry and open access), as well as north and south of 36° latitude. Peak catches occurred in the late 1970s just prior to the imposition of the first catch limits. Since 2005, the total estimated dead catch has been only 63% of the sum of the OFLs (ABCs at the time) and 74% of the ACLs (OYs at the time). In only one year of the last 10 years, 2008, does the dead catch estimated in the assessment exceed the ACL (and OFL) by 4% (2%).

Table 4: Recent trend in sablefish landings and estimated total dead catch (mt) relative to OFL (ABCs at the time) and ACLs (OYs at the time).

Year	OFL (mt)[1]	ACL (mt)[1]	Landings (mt)	Estimated dead catch (mt)[2]
2005	8471	7761	6203	6537.77
2006	8175	7634	6195	6508.40
2007	6210	5934	5237	5493.03
2008	6058	5934	5868	6158.67
2009	9914	8423	7198	7718.91
2010	9217	7729	6828	7273.60
2011	8808	6813	6404	6733.72
2012	8623	6605	5238	5497.94
2013	6621	5451	4113	4311.34
2014	7158	5909	4156	4453.90
2015	7857	6512		

[1]Includes both the southern and northern management areas where separate values were applied.

[2]Includes discards estimated within the stock assessment and therefore may differ from total mortality reports used by management.

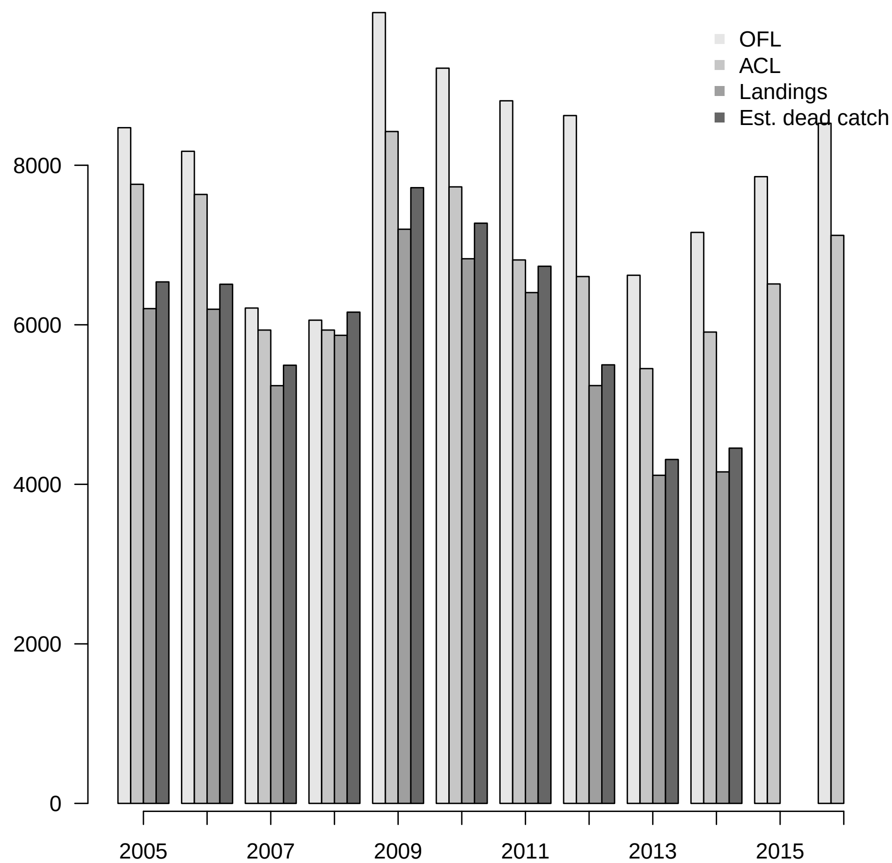

Figure 7: Recent (and current) sablefish OFLs (ABCs prior to 2011), and ACLs (OYs prior to 2011), in relation to recent total landings and estimated total dead catch (excludes discarded fish that are predicted to have survived) from the base-case model.

Unresolved problems and major uncertainties

The available data for sablefish are largely uninformative about the absolute size and productivity of the stock. This is largely due to the one-way-trip nature of the historical series: a slow and steady decline in spawning biomass consistent with a larger less productive stock, a smaller more productive stock, or many combinations in between. Historical catches provide some information about the minimum stock size needed to have supported the observed time-series but little information about the upper bounds for the stock size. Likelihood profiles, parameter estimates, and general model behavior illustrate that small changes in many parameters can result in differing point estimates for management reference points, however the uncertainty about these estimates remains large unless leading model parameters, such as natural mortality, survey catchability, as well as historical recruitments, are fixed at arbitrarily selected values. This assessment includes the uncertainty for these unknown quantities, with the exception of steepness. This uncertainty will remain until a more informative time-series and better quality demographic and biological information is accumulated for the stock.

Uncertainty in the properties of current aging methods (both potential bias and imprecision), as well as relatively sparse fishery sampling, result in age data that are less reliable than would be preferred. Similarly, because sablefish grow very rapidly and reach near-asymptotic length in their first decade of life, length-frequency 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 NWFSC Shelf-Slope trawl survey is a fairly precise relative index of abundance over a broad demographic component of the sablefish stock (although not the entire stock, as some of the stock resides in waters deeper than 1260 m, the limit of the survey, and is therefore unobserved). This index has the potential to inform future stock assessments about the scale of the sablefish population relative to the catches being removed (assuming these are enumerated reasonably accurately), however such information will require contrast in the observed declining survey trend. Therefore, although there is the potential to considerably reduce the current uncertainty in sablefish stock size and dynamics, it will likely take several years of contrasting trend in the survey to do so.

Forecasts

The reported forecasts are based on the application of the 40-10 harvest control rule and the $F_{45}\%$ overfishing limit/target (OFL). In addition, a reduction to the OFL of 8.7% was applied representing the application of a $P*$ of 0.40 and the Category 1 stock proxy uncertainty σ of 0.36 (but without applying an additional buffer for management uncertainty). These values reflect the Pacific Fishery Management Council (PFMC) decisions made during the November 2011 meeting.

This projection is intended to provide a yardstick with which to gauge the likely trajectory of the stock. Catch allocation used for the forecast reflects the average distribution of fishing intensity among fleets (hook-and- line, pot, and trawl) during 2012-2014 and it is also assumed that discarding and retention behavior does not differ from recent years (supplementary analyses provided to the GMT did indicate some sensitivity to these assumptions). A representation of the uncertainty about projected stock sizes is presented in the decision table along with two markedly different alternative catch streams.

Current forecasts predict a slow increase in the spawning stock, with a relatively large probability that the stock will remain below the target spawning biomass for several more years as the 2008, 2010, and 2013 cohorts fully mature. Forecast values are highly uncertain, and given this uncertainty, and the number of years the stock is projected to remain at low levels, it is possible that the stock will be assessed to be below the overfished threshold during the next several cycles. However, additional trawl survey observations may help to better inform the estimate of the 2008, 2010, and 2013 cohort sizes. The full implications of the current uncertainty in stock trajectory and scale can be best evaluated in the decision table in the following section (the central panel of which duplicates the following table).

Table 5: Projection of potential sablefish OFL, ACL, and estimated spawning biomass and depletion for the base-case model based on the 40:10 correction to the F_{45}% overfishing limit/target (OFL) and an 8.7% reduction to approximate the P* approach. Catch allocation used for the forecast reflects the average distribution of fishing intensity among fleets (hook-and-line, pot, and trawl) during 2012-2013.

Year	OFL[1] (mt)	ABC[1] (mt)	ACL[1] (mt)	Spawning biomass (mt)	Relative depletion
2015	7857	7173	6512	6512	33%
2016	8526	7784	7121	7121	35%
2017	7596	6935	6602	51469	35%
2018	7879	7194	6902	52503	36%
2019	8050	7350	7086	53162	36%
2020	8217	7502	7253	53544	36%
2021	8286	7565	7323	53727	36%
2022	8185	7473	7238	53812	37%
2023	8105	7400	7172	53913	37%
2024	8070	7368	7148	54039	37%
2025	8043	7343	7131	54182	37%
2026	8018	7320	7116	54330	37%

[1]OFL/ABC/ACL values for 2015 and 2016 have already been adopted, and are not based on the results of this assessment.

Decision Table

The decision table reports 12-year projections for alternate states of nature (columns) and management options (rows) beginning in 2017. The results of this table are conditioned on the already-specified ACLs for 2015 and 2016 being achieved exactly. It is common to select an 'axis of uncertainty' from leading parameters, model structure or historical catch levels, to best bracket the range of possible states of nature. For this assessment, due to the explicit inclusion of uncertainty in natural mortality, survey catchability, and scale of the stock-recruit function, asymptotic intervals are very broad. In 2011, steepness was evaluated as a possible axis of uncertainty, but even a broad range (from 0.3-0.9) underrepresented the forecast uncertainty relative to that implied by the parameter uncertainty already included. Therefore, the percentiles of the asymptotic distribution are used to describe the relative probabilities among the states of nature. Low and high columns are based on the 12.5^{th} and 87.5^{th} percentiles of the distribution about the maximum likelihood estimates for: depletion, relative SPR (in reverse order to match depletion; i.e., larger values implying greater relative fishing intensity are reported first), and spawning biomass from the base-case model. Catch allocation used for the forecast reflects the average distribution of fishing intensity among fleets (hook-and-line, pot, and trawl) during 2012-2013.

The probability that the stock is already overfished ($<25\%B_0$) in 2015, based upon the estimated status and asymptotic uncertainty is 8%) (Table 9). Further, given any status much below the estimated current spawning biomass, the stock is not projected to increase appreciably over the duration of these forecasts.

Table 6: Decision table of 12-year projections for alternate states of nature (columns) and management options (rows) beginning in 2017. The percentiles of the asymptotic distribution are used to describe the relative probabilities among the states of nature. Values of relative SPR that exceed 100% indicate overfishing; order is reversed to maintain the 'lower-to-higher' pattern consistent with other quantities, i.e., larger values implying greater relative fishing intensity are reported on the left side of the table. The results of this table are conditioned on the already-specified ACLs for 2015 and 2016 being achieved exactly.

Management alt			**State of nature**								
			12.5^{th} pctl			Max likelihood est.			87.5^{th} pctl		
	Year	Dead catch (mt)	Depl	Rel SPR	Spawning biomass (mt)	Depl	Rel SPR	Spawning biomass (mt)	Depl	Rel SPR	Spawning biomass (mt)
12.5^{th}	2017	4053	27%	80%	36215	35%	64%	51469	43%	49%	66724
pctl	2018	4389	28%	81%	37517	36%	66%	53472	45%	50%	69427
40:10	2019	4659	29%	83%	38423	37%	67%	55174	46%	50%	71925
catch	2020	4914	29%	85%	38913	38%	67%	56605	48%	49%	74296
	2021	5091	29%	87%	39061	39%	68%	57816	49%	49%	76572
	2022	5143	29%	89%	38994	40%	68%	58878	51%	48%	78761
	2023	5188	29%	91%	38849	41%	69%	59869	52%	47%	80890
	2024	5244	29%	92%	38682	41%	69%	60813	54%	47%	82944
	2025	5293	29%	93%	38521	42%	70%	61717	55%	47%	84913
	2026	5334	29%	94%	38375	43%	70%	62583	56%	46%	86792
	2017	6602	27%	110%	36215	35%	91%	51469	43%	73%	66724
	2018	6902	27%	111%	36565	36%	92%	52518	44%	73%	68470
40:10	2019	7086	27%	113%	36440	36%	92%	53190	45%	71%	69939
catch	2020	7253	27%	114%	35897	36%	92%	53587	46%	70%	71277
	2021	7323	26%	116%	35050	37%	92%	53796	47%	68%	72542
	2022	7238	26%	118%	34052	37%	92%	53909	48%	67%	73765
	2023	7172	25%	119%	33057	37%	92%	54027	49%	65%	74997
	2024	7148	24%	120%	32105	37%	92%	54162	49%	64%	76219
	2025	7131	24%	121%	31210	37%	92%	54312	50%	63%	77414
	2026	7116	23%	122%	30366	37%	92%	54469	51%	63%	78572
87.5^{th}	2017	9151	27%	130%	36215	35%	111%	51469	43%	92%	66724
pctl	2018	9415	27%	132%	35614	35%	112%	51564	43%	92%	67513
40:10	2019	9514	26%	134%	34466	35%	112%	51213	44%	90%	67959
catch	2020	9592	25%	137%	32913	34%	113%	50593	44%	89%	68274
	2021	9556	24%	139%	31101	34%	113%	49821	44%	87%	68541
	2022	9334	22%	141%	29207	33%	113%	49009	44%	85%	68811
	2023	9157	21%	143%	27394	33%	113%	48276	45%	83%	69157
	2024	9051	20%	145%	25685	32%	113%	47619	45%	82%	69553
	2025	8968	19%	146%	24071	32%	114%	47023	45%	81%	69975
	2026	8897	17%	148%	22535	32%	114%	46471	46%	80%	70407

Research and Data Needs

The following research could improve the ability of this assessment to reliably model sablefish population dynamics in the future:

1. Continue the annual NWFSC Shelf-Slope trawl survey time-series. Future improvements in the precision of estimates of absolute stock size and productivity are reliant upon observing some contrast in stock trend (other than a one-way trip) with an unbroken survey index. Only a longer, more informative survey time-series will provide stock-specific and data-based information on the steepness parameter governing the sablefish stock and recruitment relationship.

2. Investigate aging methods that could prove more precise than current break-and-burn methods. If age data were more accurate, cohorts could be better tracked to older ages and estimates of historical year-class strengths may be improved. Further studies to investigate the potential for bias in aging methods should be conducted; these results will have a strong effect on natural mortality estimates.

3. Evaluate potential causes of residual patterns in the fit to larger cohorts in the age data (particularly the 1999 and 2000 cohorts) and for residual patterns in the fit to the size data.

4. Model results were quite sensitive to changes in the maturity schedule, yet the available information is very outdated, in addition to being variable among sources, years and regions. The routine collection of samples to refine estimates of biological parameters, particularly maturity and fecundity would greatly benefit the reliability of this assessment.

5. Age sampling from the commercial fishery has generally been sparse compared to other groundfish and relative to the importance of this stock to west coast fisheries. Work toward further standardization of state and federal biological sampling programs would make the data more informative, by reducing sampling variability. For example, during most of the last 30 years at least one state has collected sexed-length observations, while at least one has not. If an increased fraction of both the catch was available for sampling at-sea, or in-port in a non-dressed form, then more consistent demographic information could result.

6. Continued refinement of the historical landings estimates for Washington, subsequent to the large data entry of historical fish-ticket information currently underway, will likely produce a more accurate time-series of mortality and would complement the completed efforts to reconstruct California and Oregon landings.

7. Given the migratory nature and broad distribution of sablefish along the Pacific Rim, it is important to continue to evaluate the spatial aspects of the assessments, including the northern boundary with Canada, and the

connectivity with offshore seamounts. A joint assessment with Canadian and Alaskan scientists could be warranted, following the approach taken by the International Pacific Halibut Commission.

8. Continue to evaluate methods to capture information regarding environmental and ecosystem variability in stock assessments. Further, historical records of particularly large year classes (e.g., 1947 reported by sport fishermen in central California) could be investigated to better inform the historical period.

9. Assessments prior to 2011 relied upon independent databases for collecting and analyzing biological sampling from the three states. Washington, California, and Oregon have now loaded all available data into PacFINs Biological Data System, where it can be retrieved and analyzed in a consistent and documented format. However, information is still missing from some records, and a small number of samples were unsuitable for analysis due to incomplete or jumbled records. An effort to either repair or remove any unreliable information could improve the speed and accuracy of future analyses.

10. There is uncertainty in the accuracy of the dressed to whole weight conversions used in some situations to estimate fishery landings. Following Oregons lead, this topic should be investigated, and total landed catch estimates adjusted, according to the best available conversion information (Table 7).

Table 7: Summary of sablefish reference points from the base-case model. Yields include discard mortality. Because steepness is a fixed parameter, the uncertainty in these reference points is grossly underestimated.

Quantity	Estimated value	~95% interval
Unfished total biomass (mt)	432,047	367,420-496,674
Unfished 4+ biomass (mt)	405,032	344,894-465,170
Unfished spawning biomass (SB_0, mt)	147,209	127,408-167,010
Unfished recruitment (R_0, thousands)	16,832	13,584-20,079
Reference points based on $SB_{40\%}$		
MSY Proxy spawning biomass ($SB_{40\%}, mt$)	58,884	50,963-66,804
Relative spawning depletion at $SB_{40\%}$	40%	
SPR resulting in $SB_{40\%}$	50%	
Exploitation rate resulting in $SB_{40\%}$	4%	3.6-4.1%
Yield with $SPR_{SB40\%}$ (mt)	7,290	6,029-8,552
Reference points based on SPR **proxy for** MSY		
Spawning biomass at $SPR_{MSY-proxy}$ (SPR_{SPR}, mt)	50,051	43,319-56,783
Relative spawning depletion at SPR_{SPR}	34%	
$SPR_{MSY-proxy}$	41%	
Exploitation rate corresponding to SPR	5%	4.2-4.9%
Yield with $SPR_{MSY-proxy}$ at SB_{SPR} (mt)	7,565	6,256-8,873
Reference points based on estimated MSY **values**		
Spawning biomass at MSY (SB_{MSY}, mt)	43,149	37,313-48,984
Relative spawning depletion at SB_{MSY}	29%	
SPR_{MSY}	41%	41-41.2%
Exploitation rate corresponding to SPR_{MSY}	5%	4.9-5.6%
MSY (mt)	7,639	6,319-8,960

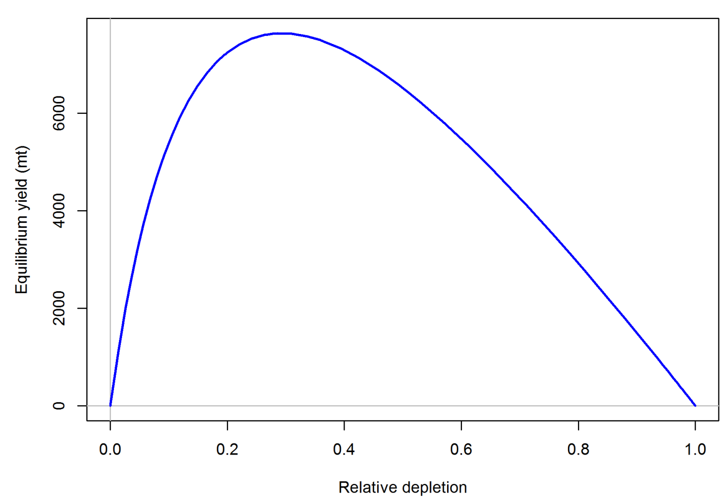

Figure 8: Equilibrium yield curve (total dead catch) for the base-case model.