Photo from ODFW

2017 Assessment Update for the US West Coast Stock of Arrowtooth Flounder

Preparers:

David B. Sampson, Oregon State University
Owen S. Hamel, Northwest Fisheries Science Center
Katelyn Bosley, Northwest Fisheries Science Center
John Budrick, California Department of Fish and Wildlife
Lee Cronin-Fine, University of Washington
Lisa K. Hillier, Washington Department of Fish and Wildlife
Kristen E. Hinton, Washington Department of Fish and Wildlife
Melissa J. Krigbaum, University of Washington
Stacey Miller, Northwest Fisheries Science Center
Kristin M. Privitera-Johnson, University of Washington
Kirsten L. Ramey, California Department of Fish and Wildlife
Brett T. Rodomsky, Oregon Department of Fish and Wildlife
Laura K. Solinger, Humboldt State University
Alison D. Whitman, Oregon Department of Fish and Wildlife

15 May 2017

This report may be cited as:

Sampson, D.B., Hamel, O.S., Bosley, K., Budrick, J., Cronin-Fine, L., Hillier, L.K., Hinton, K.E., Krigbaum, M.J., Miller, S., Privitera-Johnson, K.M., Ramey, K., Rodomsky, B.T., Solinger, L.K., Whitman, A.D. 2017. 2017 Assessment Update for the US West Coast Stock of Arrowtooth Flounder. Pacific Fishery Management Council, Portland, OR. Available from http://www.pcouncil.org/groundfish/stock-assessments/

Executive Summary

Stock

This report is an update stock assessment for the US West Coast stock of arrowtooth flounder (*Atheresthes stomias*). This assessment treats the arrowtooth flounder off California, Oregon and Washington as a unit stock although this species also occurs off British Columbia and in the Gulf of Alaska and into the Bering Sea.

Catches

Arrowtooth flounder are caught primarily by trawlers operating out of ports in Washington and Oregon. Catches of arrowtooth flounder by trawlers from California are more limited. Because of their poor flesh quality, there are limited markets for arrowtooth flounder and many caught incidentally while fishing for other species are discarded at sea. Historically landed catches of arrowtooth flounder were primarily sold as animal food for mink ranches. Since the late 1970s landed catches of arrowtooth flounder have been used for human consumption, as fillets or as headed-and-gutted product. Significant but unreported quantities are caught and discarded at sea.

Table a. Recent landed catches (mt) of arrowtooth flounder by state, 2007-2016.

Year	California	Oregon	Washington
2007	59.7	1629.2	569.0
2008	44.5	2141.7	469.8
2009	45.4	2834.9	957.1
2010	67.7	2290.8	865.3
2011	86.2	1667.3	568.6
2012	99.3	1494.8	735.8
2013	117.7	1635.4	234.6
2014	75.1	1103.7	65.4
2015	92.2	1158.3	70.2
2016	58.3	986.0	53.9

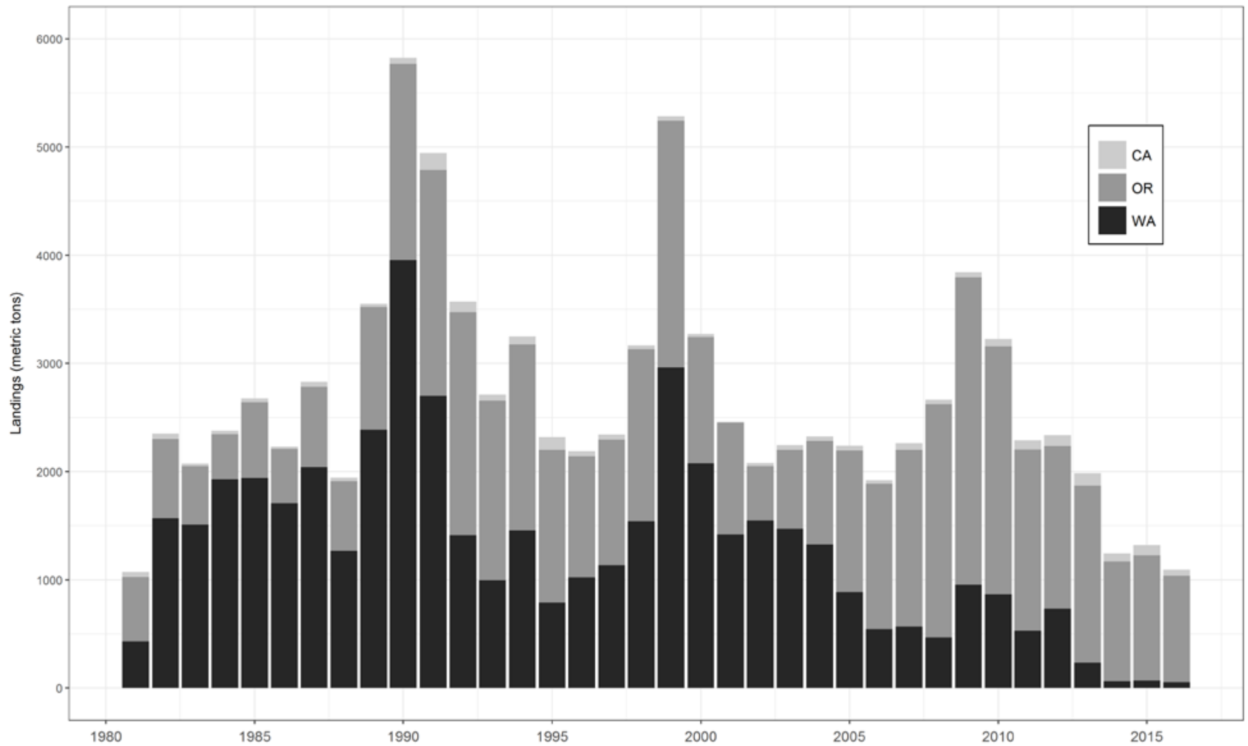

Figure a. Landings of arrowtooth flounder by state, 1981 to 2016.

Data and assessment

This assessment updates the last full assessment for arrowtooth flounder, which was completed in 2007. The assessment model, which uses a new release of the Stock Synthesis software (Version 3.30.03.03), follows the same structure as the 2007 assessment with catches partitioned to three fleets: a “mink-food” fleet that accounts for all landed catches of arrowtooth flounder from the outset of the assessment period (1916) through 1980; a “fillet” fleet that accounts for all landed catches of arrowtooth flounder from 1981 through 2016; and a “discard” fleet that accounts for arrowtooth flounder caught and discarded while fishing for Dover sole, English sole, and petrale sole throughout the assessment period. Catches assigned to the fillet fleet include an estimate of fish discarded at sea. Catches assigned to the discard fleet were derived on the basis of the landed catches of Dover sole, English sole, and petrale sole, as was done in the 2007 assessment. Compared to the 2007 assessment, the current update assessment had many more years of at-sea observations of discards on which to base the estimated proportions of arrowtooth flounder discarded in association with landed catches of arrowtooth flounder (by the fillet fleet) and the estimated ratio of arrowtooth flounder discarded relative to the landed catches of Dover sole, English sole, and petrale sole (by the discard fleet), but there remains great uncertainty regarding the magnitude and biological characteristics (length and sex) of the discarded catches, especially for years prior to the start of regular at-sea observations of discards.

As in the 2007 assessment, there are four sources of fishery independent information: the Triennial shelf survey (1980-2001); the Alaska Fisheries Science Center (AFSC) slope survey (1997, 1999-2001); the Northwest Fisheries Science Center (NWFSC) slope survey (1999-2002);

and the NWFSC slope-shelf survey (2003-2016). The 2007 assessment had only four sets of annual observations from the NWFSC slope-shelf survey, whereas this update has 14.

The assessment model includes observed age- and length-compositions by sex from the fillet fleet and more limited observations from the discard fleet. Length-compositions were also available for all surveys except the NWFSC slope survey. Age readings from otoliths were available for some years for the landed catches by the fillet fleet and for the NWFSC slope-shelf survey.

The assessment model treats the sexes separately to account for the large differences in growth, with female arrowtooth flounder attaining much larger sizes than males. Also, the sexes have distinct assumed rates of natural mortality (0.216 yr^{-1} for females; 0.30 yr^{-1} for males), based on an updated meta-analysis of the relationship between natural mortality and maximum age for other flatfish species.

With very few exceptions (noted in the main text) the update assessment model conforms almost exactly to the structure and configuration of the 2007 stock assessment model. However, there have been significant revisions to the data used in the 2007 assessment and this update include many more years of observations of sex, length and age compositions.

Stock Biomass

The base case assessment model estimates that the spawning biomass underwent a period of fairly rapid decline during the 1970s and subsequent increase through the 1980s, reaching a peak of almost 76 thousand mt in 1991, well above the estimated unfished level of spawning biomass (65,448 mt). After 1991 the spawning biomass declined to a low in 2010 of 29.6 thousand mt, the second lowest value in the series. Since 2010 the spawning biomass has been increasing steadily and is estimated to be almost 57 thousand mt at the start of 2017, almost 87% of the unfished level and well above the minimum stock size threshold of 12.5% for Council managed flatfish species.

Table b. Abundance estimates for arrowtooth flounder, 2007-2016.

Year	Spawning biomass (mt)	~95% Interval			Relative depletion
2007	39,750	32,159	-	47,342	60.7%
2008	37,066	29,397	-	44,734	56.6%
2009	34,124	26,423	-	41,824	52.1%
2010	29,626	21,507	-	37,746	45.3%
2011	30,771	21,431	-	40,111	47.0%
2012	33,898	23,002	-	44,793	51.8%
2013	37,306	24,676	-	49,937	57.0%
2014	38,876	25,030	-	52,722	59.4%
2015	41,095	25,896	-	56,294	62.8%
2016	46,983	28,978	-	64,989	71.8%
2017	56,710	34,243	-	79,178	86.6%

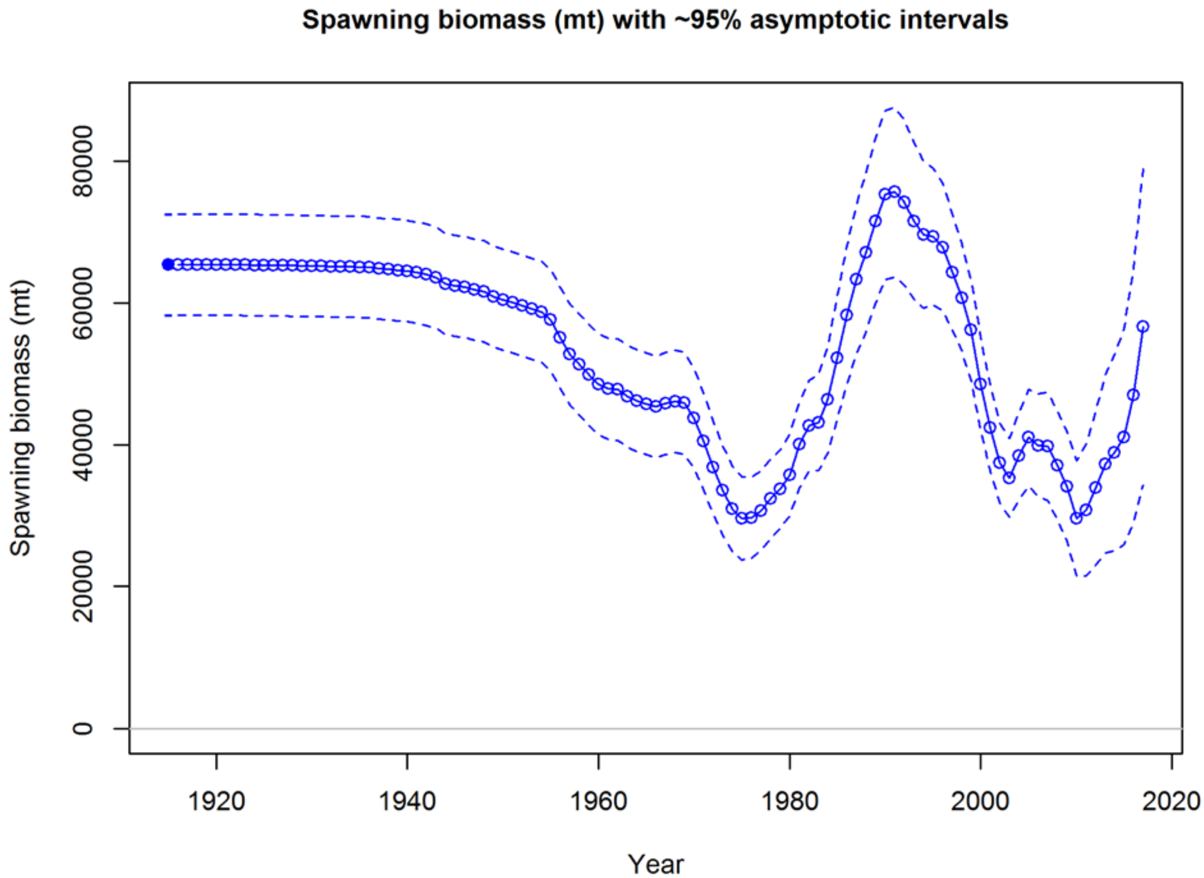

Figure b. Estimated spawning biomass of arrowtooth flounder, 1916-2016.

Recruitment

The update assessment model followed the configuration of the 2007 assessment in allowing recruitment estimates to start deviating in 1965 from the average values predicted by the spawner-recruit curve. The initial deviations resulted in a period of low recruitment through the late 1960s followed by a period of generally high recruitment during the late 1970s and early 1980s, low recruitment during the 1990s (except for a very high recruitment in 1999), and then very high recruitment during 2011 to 2013.

Table c. Estimated age-0 recruitment for arrowtooth flounder, 2007-2016

Year	Age 0 recruits, thousands	~95% Interval		
2007	36,830	21,905	-	61,925
2008	91,791	65,127	-	129,372
2009	20,910	11,266	-	38,809
2010	31,862	19,606	-	51,779
2011	114,024	78,006	-	166,673
2012	135,892	90,339	-	204,415
2013	155,499	99,298	-	243,509
2014	8,232	2,972	-	22,803
2015	31,214	8,344	-	116,762
2016	49,955	10,414	-	239,636
2017	50,277	10,481	-	241,181

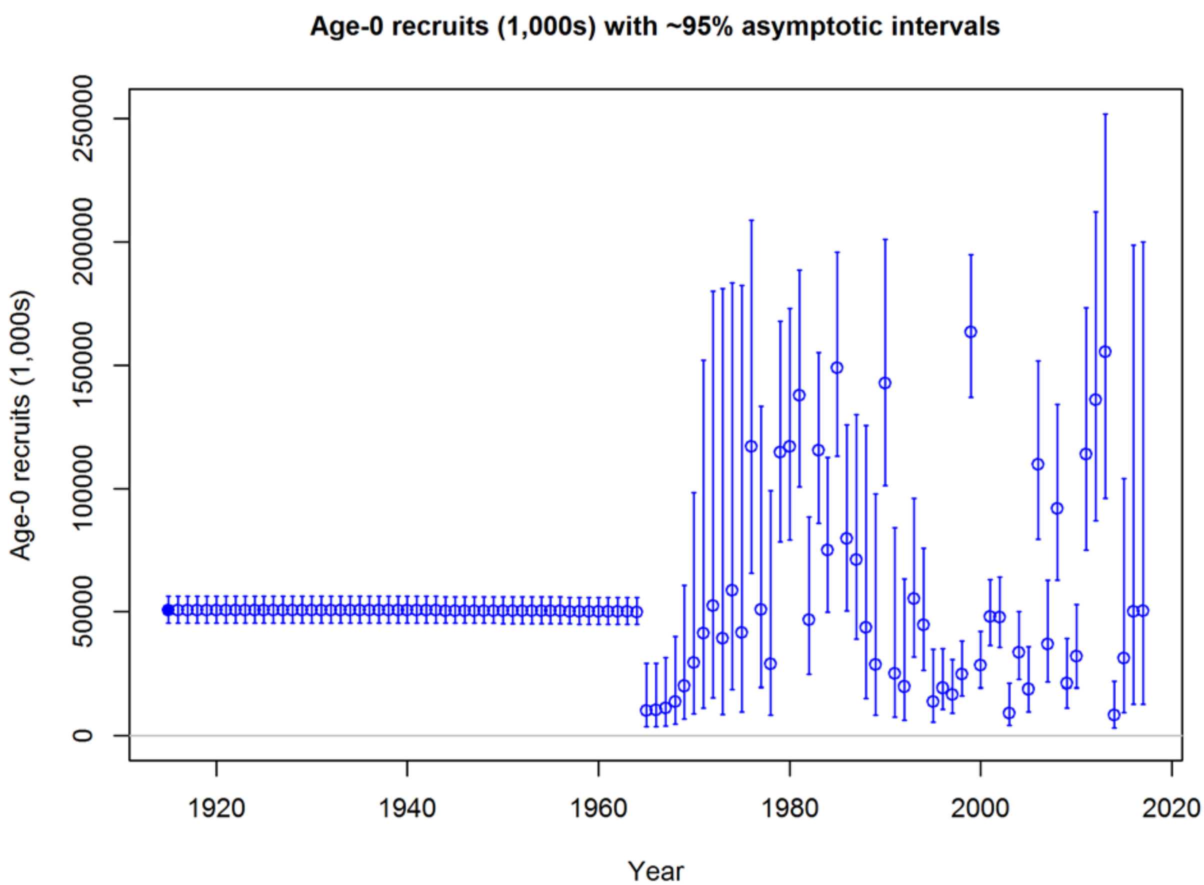

Figure c. Estimated recruitment of arrowtooth flounder, 1916-2016.

Exploitation status

The spawning potential ratio (SPR) measures the relative impact of exploitation on the stock in terms of the reduction in spawning potential relative to an unfished stock, which would have an SPR value of 1. The series of estimates of (1-SPR) from the base model indicate that exploitation has been below the management target rate of 70% (100% - 30%) for the entire assessment period and currently is relatively low.

Table d. Recent catches, spawning potential ratio (SPR) estimates and estimated exploitation rate (catch / Age 3+ biomass).

Year	Catches	Age 3+ biomass	Estimated SPR	Exploitation Rate
2007	4716.2	58876.8	0.575	8.01%
2008	4365.0	59745.8	0.585	7.31%
2009	7936.3	46684.4	0.410	17.00%
2010	4513.2	55953.8	0.530	8.07%
2011	3059.0	62757.1	0.624	4.87%
2012	2892.6	64917.4	0.655	4.46%
2013	2901.4	66240.1	0.674	4.38%
2014	2196.7	71387.5	0.748	3.08%
2015	2038.1	73471.6	0.777	2.77%
2016	1898.6	75638.1	0.809	2.77%
2017	13804	43930.3	0.380	31.4%

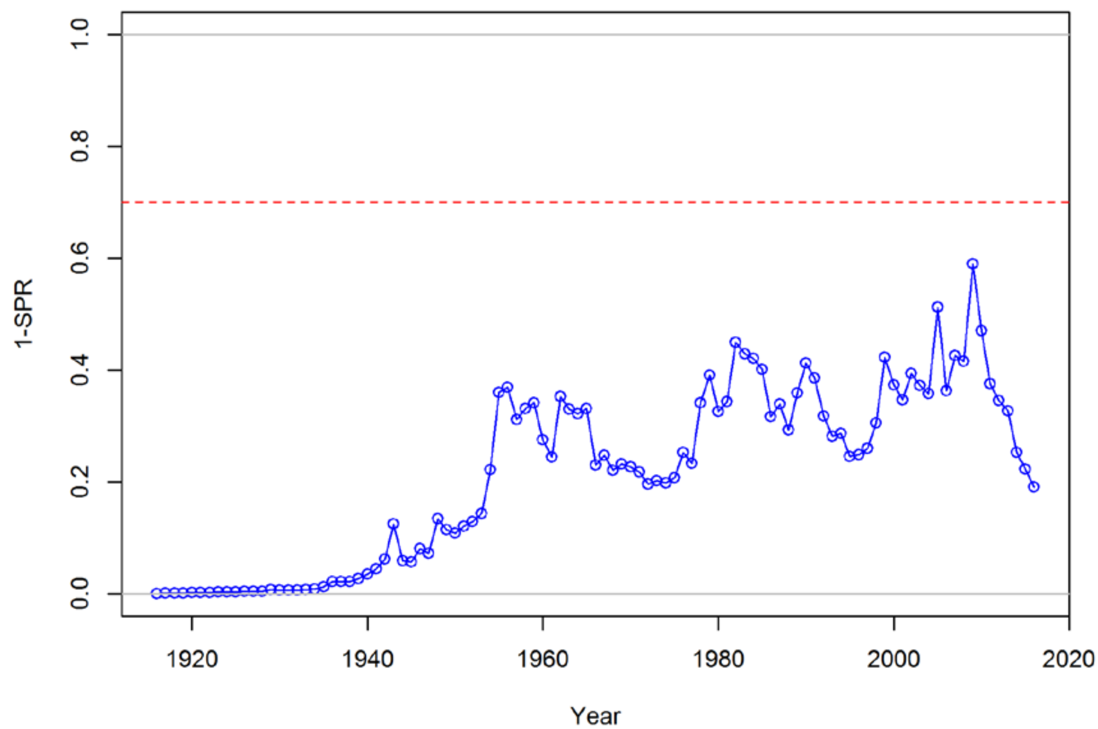

Figure d. Times series of estimated spawning potential ratio (SPR) rates.

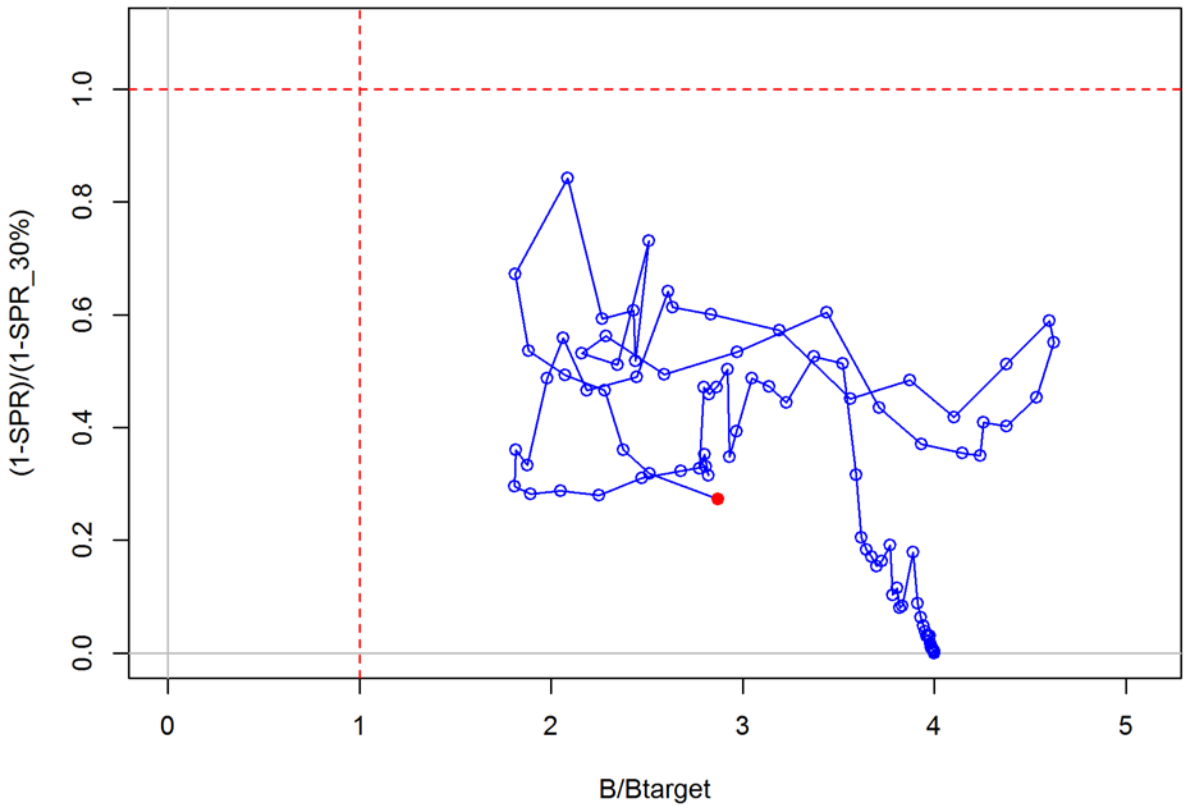

Figure e. Phase plot of the relative depletion (biomass status) versus the relative spawning potential ratio (SPR) rate (exploitation status). The red point represents the ending year of the assessed period, 2016.

Ecosystem considerations

Studies that examined ecosystem interactions of fishes in the California Current System (CCS) have classified arrowtooth flounder into the functional group of "large flatfish", with Pacific halibut and petrale sole. This group is the highest trophic level flatfish in the CCS. While arrowtooth flounder is both a predator and prey of Pacific halibut in the Gulf of Alaska, in the CCS the only significant trophic interaction between these species is predation by halibut of juvenile arrowtooth flounder. Overall, arrowtooth flounder has the strongest potential for trophic interactions as a predator of many macroinvertebrates and juvenile fishes in the CCS. Neither this update assessment nor the 2007 stock assessment included any form of explicit ecosystem interactions in the assessment model.

Reference Points

The update assessment model estimated that the unfished stock of arrowtooth flounder would have spawning biomass for 65448.2 mt, Age-0 recruitment of 50487.8 thousand recruits, and the Age-3+ summary biomass of 88804.5 mt.

Table e. Key reference points for arrowtooth flounder.

		95% confidence limits	
Unfished stock	Estimate	Lower	Upper
Spawning biomass (mt)	65448.2	58305.7	72590.7
Age-0 recruits (thousands of fish)	50487.8	45075.1	55900.5
Summary (Age-3+) biomass (mt)	88804.5	79172.4	98436.6

	Yield reference points		
	SB25%	SPR30%	MSY est.
Spawning Potential Ratio (SPR)	0.2704	0.3000	0.1990
Exploitation rate	0.2029	0.1843	0.2606
Yield	6774.8	6634.9	6943.4
Spawning biomass (mt)	16362.0	18355.3	11558.7
SSB / SSB0	25.0%	28.0%	17.7%

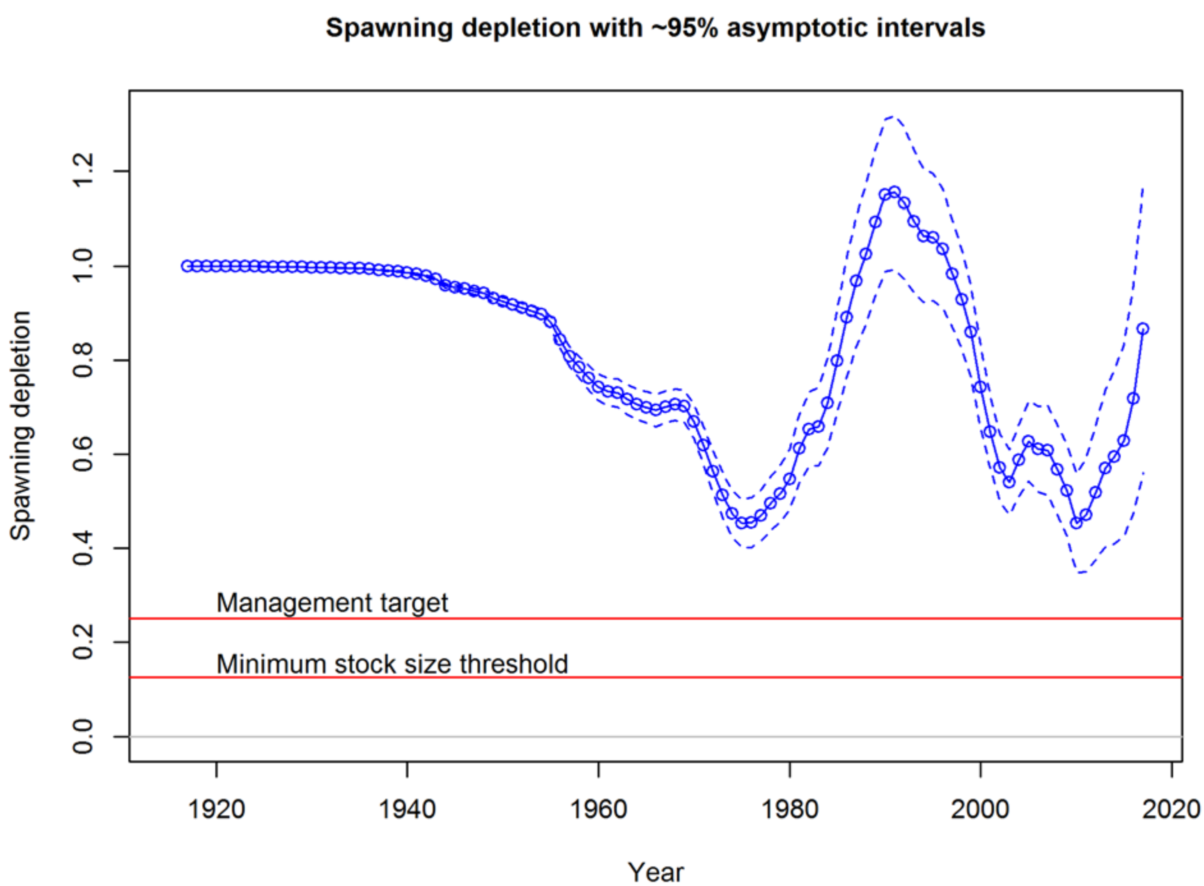

Figure f. Estimated relative depletion for arrowtooth flounder.

Management performance

The 2007 stock assessment estimated arrowtooth flounder to be at 79% of the estimated unfished spawning biomass (95% CI: 58.1%-99.5%). Based on that assessment, the 2009 coast-wide ACL was increased from 5,800 mt to 11,267 mt. Following the 2009 assessment of petrale sole and based on analysis and advice of the Scientific and Statistical Committee (SSC), the Council adopted new default reference points for West Coast flatfish species: an FMSY proxy of F30%, a BMSY target of B25%, and a minimum stock size threshold (MSST) of B12.5% (half of BMSY). Fishing mortality rates (measured in terms of SPR) have been below the current F-target for flatfish of SPR30% and the current assessment estimates that arrowtooth flounder at the start of 2017 are 86.6% of the estimated unfished spawning biomass and will be slightly larger at the start of 2018 if 2017 catches attain the ACL. Recent coast-wide annual landings have not exceeded the ACL.

Table g. Recent total catches and commercial landings (mt) relative to the management guidelines. Estimated total catch reflects the commercial landings plus estimated discards.

Year	OFL *	ABC	ACL *	Coastwide landings	Coastwide catch **
2000	5800	-	-	3597	4910
2001	5800	-	-	2705	3849
2002	5800	-	-	3086	4256
2003	5800	-	-	3006	3640
2004	5800	-	5800	2597	3447
2005	5800	-	5800	2456	6564
2006	5800	-	5800	2085	3653
2007	5800	-	5800	2473	4716
2008	5800	-	5800	2804	4365
2009	11267	-	11267	4277	7936
2010	10112	-	10112	3620	4513
2011	18211	-	15174	2482	3059
2012	14460	12049	12049	2452	2893
2013	7391	6157	6157	2335	2901
2014	6912	5758	5758	1639	2197
2015	6599	5497	5497	1609	2038
2016	6396	5328	3241	1341	1899
2017	16571	13804	13804		

* Prior to 2011, the OFL was referred to as "ABC" and the ACL was referred to as "OY".

** Total catch as estimated in this assessement does not represent the official estimation of total mortality as conducted each year by the NMFS, NWFSC West Coast Groundfish Observer Program (WCGOP). The NWFSC's Total Mortality Report represents the estimation of total mortality each year to determine the official stock status related to overfishing.

Unresolved problems and major uncertainties

This update assessment used almost the exact same model configuration and structure as used in the 2007 assessment, which greatly constrained how both assessment models could account for certain features of the data, such as a preponderance of female arrowtooth flounder in the fillet fleet catches. According to the 2007 assessment document, the stock assessment team (STAT) went to the stock assessment review (STAR) with a draft assessment model that included a retention curve for the fillet fishery and had length-composition observations for fish discarded on trips that also landed arrowtooth flounder (i.e., the fillet fleet) as data to inform the retention curve. The STAT's draft assessment model was also configured to estimate discard rates based on observations of the fractions of the arrowtooth flounder catches retained and landed by the fillet fleet. However, due to poor model performance and other reasons described in the 2007 assessment document and STAR Panel report, during the 2007 STAR meeting the STAT adopted the simpler model structure inherited by the current update assessment: no retention curve for the fillet fleet and estimated discards by this fleet are added to its catch stream. This structure and the additional assumption that all fishery selection curves are asymptotic and constant through time greatly limits how the assessment model can account for observed changes in the length compositions. Although it's unclear that a different model structure would resolve various discrepancies that were evident in the fit of the update assessment model to the available data (e.g., rather poor residual patterns in the fits to the NWFSC slope/shelf survey biomass index and in the fits to most of the compositional data), future assessment should explore whether the current simplified model structure may be inadvertently distorting the results.

Decision table

The decision table considers the uncertainty in 'states of nature' regarding natural mortality rates (*M*) for females and males, which is a departure from the 2007 assessment. The 2007 decision table considered uncertainty in both natural mortality rates and past catches and this approach produced very extreme high and low states. The decision table here uses three states of nature based on the natural mortality prior and observations of maximum age for female and male arrowtooth flounder.

In developing the states of nature, we attempted to provide high and low states that each represented about 25% of the probability space, with the base model representing the other 50%. To do this, when considering uncertainty in a single parameter, it is common to set the high and low states at the 12.5% and 87.5% quantiles of the prior distribution (or other measure of uncertainty distribution) for that parameter, which corresponds to points 1.15 standard deviations from the median. In the natural mortality prior the data used in its development through meta-analysis were subject to error, implying that the prior included both variability in the relationship between maximum age and *M* and error in the estimates of maximum age and *M* that inform the prior. We assumed half of the variance in the relationship was due to this error and therefore used *M* values for the high and low states that were ± 1.15 x 0.707 x SD from the median (in log space).

The three states of nature were therefore: (1) the low state (female *M* = 0.15, male *M* = 0.21), (2) the base case (female *M* = 0.216, male *M* = 0.30), and (3) the high state (female *M* = 0.31, male M = 0.43). ABC catch streams were developed from each of these states of nature for 2019 through 2028, assuming ACL catches are removed in 2017 and 2018, a P* of 0.45 and a category 1 stock designation. These catch streams are applied to each state of nature, with the results highlighting the uncertainty in the absolute scale of the stock and the impact of assuming one state when another is true.

Table h. Decision table for arrowtooth flounder based on status quo catches during 2017 and 2018, projected catches for 2019-2028, and alternative assumptions about the female and male natural mortality rates (see text for details). Columns range over low, mid, and high states of nature, and rows range over catch streams from those states of nature. ABCs are based upon the assumptions that P*=0.45 and σ=0.36 for a category 1 designation, and the ACLs are taken in 2017 (13,804mt) and 2018 (13,743mt).

			State of nature					
			Low M_{female} = 0.15 M_{male} = 0.21		Base case M_{female} = 0.216 M_{male} = 0.30		High M_{female} = 0.31 M_{male} = 0.43	
Relative probability of ln(SB_2013)			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion
ABC catches from “Low” state of nature	2019	8,103	35,586	0.68	52,226	0.80	124,842	0.68
	2020	7,728	32,491	0.62	48,580	0.74	118,797	0.64
	2021	7,033	28,859	0.55	44,745	0.68	117,510	0.64
	2022	6,263	25,559	0.49	41,676	0.64	120,398	0.65
	2023	5,587	22,884	0.44	39,491	0.60	125,275	0.68
	2024	5,061	20,852	0.40	38,087	0.58	130,821	0.71
	2025	4,673	19,368	0.37	37,291	0.57	136,330	0.74
	2026	4,395	18,303	0.35	36,933	0.56	141,443	0.77
	2027	4,197	17,543	0.33	36,874	0.56	146,002	0.79
	2028	4,054	16,997	0.32	37,008	0.57	149,964	0.81
Base Case ABC catches	2019	17,873	35,586	0.68	52,226	0.80	124,842	0.68
	2020	14,632	25,124	0.48	40,700	0.62	111,344	0.60
	2021	11,697	16,550	0.31	31,930	0.49	105,796	0.57
	2022	9,575	10,459	0.20	26,382	0.40	106,846	0.58
	2023	8,305	6,455	0.12	23,277	0.36	111,299	0.60
	2024	7,630	3,861	0.07	21,666	0.33	117,034	0.63
	2025	7,281	2,122*	0.04*	20,835	0.32	122,864	0.67
	2026	7,090	0	0	20,366	0.31	128,226	0.70
	2027	6,969	0	0	20,053	0.31	132,924	0.72
	2028	6,880	0	0	19,813	0.30	136,946	0.74
ABC catches from “High” state of nature	2019	65,934	35,586	0.68	52,226	0.80	124,842	0.68
	2020	41,117	0	0	3,194	0.05	73,971	0.40
	2021	29,796	0	0	0	0	54,540	0.30
	2022	26,736	0	0	0	0	51,249	0.28
	2023	27,127	0	0	0	0	52,964	0.29
	2024	27,973	0	0	0	0	54,686	0.30
	2025	28,342	0	0	0	0	55,210	0.30
	2026	28,279	0	0	0	0	54,869	0.30
	2027	28,046	0	0	0	0	54,300	0.29
	2028	27,842	0	0	0	0	53,894	0.29

* The model removed 7,489 mt in 2024 (98% of the 7,630 mt in the forecast for that year).

Research and data needs

Addressing the following research and data needs could improve future assessments of arrowtooth flounder.

1. *Reevaluation and reconstruction of historical flatfish removals, including arrowtooth flounder*. Historical estimates of discards are a large contributor to total removals. The current modelling exercise of using co-occurring flatfish species as predictors of discard could use further exploration. The arrowtooth flounder catch history for Washington should be reconstructed using all available data including catch by gear and by region. The reconstruction should include an envelope of high and low values to set bounds for exploration of alternative catch histories. As has been recommended previously by a variety of STAR Panels, the reconstruction of historical landings needs to be done comprehensively (i.e., with other species) to ensure efficiency and consistency.
2. *Reevaluation of the value of stock-recruitment steepness for arrowtooth*. In the base case model, steepness was set at 0.902 based on Dorn's meta-analysis (personal communication). While model results are not sensitive to the value of steepness, it would have an effect on MSY calculations and OFL and ABC values at lower stock sizes.
3. *Research to provide information on survey catchability*. The absolute scale of the stock is still quite uncertain. The calculated catchability associated with the NWFSC trawl survey ranges from 0.2 to 0.8 across the three states of nature.
4. *Evaluation of stock boundaries and the feasibility of a bilateral assessment with Canadian scientists*. This could perhaps be accomplished through the Technical Subcommittee (TSC) of the US Canada groundfish working group.
5. *Evaluation of maturity and fecundity relationships*. New studies on both the maturity and fecundity relationships for arrowtooth flounder would be beneficial. The maturity versus length relationship used in this update and the 2007 assessment is based on a study done in 1993.
6. *Age-reading of otoliths from the fishery off California*. A collection of unread arrowtooth flounder otoliths that is available for fish landed in California should be read to provide possibly more representative age-at-length compositions for the fishery. The fishery age-at-length compositions in this update assessment were based entirely on fish landed in Oregon and Washington.
7. *Evaluation of the spatial variability of productivity processes*. The extent of spatial variability on productivity processes such as growth, recruitment, and maturity is currently unknown and would benefit from further research. This stock shows clear evidence of a latitudinal gradation in abundance and other traits.