

## **Depletion-Based Stock Reduction Analysis (DB-SRA) for Starry Flounder (*Platichthys stellatus*) in U.S. Waters off California, Oregon and Washington**

E.J. Dick<sup>1</sup>, Jim Hastie<sup>2</sup>, Patrick Mirick<sup>3</sup> and Tien-shui Tsou<sup>4</sup>

<sup>1</sup>NOAA Fisheries, Southwest Fisheries Science Center, Santa Cruz, CA. [edward.dick@noaa.gov](mailto:edward.dick@noaa.gov)

<sup>2</sup>NOAA Fisheries, Northwest Fisheries Science Center, Seattle, WA.

<sup>3</sup>Oregon Department of Fish and Wildlife, Newport, OR.

<sup>4</sup>Washington Department of Fish and Wildlife, Olympia, WA.

The only previous assessment for starry flounder (*Platichthys stellatus*) was developed by Ralston in 2005. That assessment utilized Stock Synthesis 2 (ver. 1.18) to model populations in two areas: California, and a Northern area comprised of Oregon and Washington. The 2005 assessment has been classified as Category 2 by the SSC, and due to its uncertainties and the time since the previous assessment, the SSC recommended Depletion-Based Stock Reduction Analysis (DB-SRA; Dick and MacCall, 2011) to inform the 2019-20 specifications, rather than continuing to rely on projections from the 2005 models.

### **Northern Area Model (OR-WA)**

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#### Revised Catch Estimates for Oregon and Washington

Although Ralston (2005) provided catch estimates back to 1929 in the northern area, only data from the period 1970-2004 were included in the model, with an assumed equilibrium catch of 782 mt (combined trawl and sport) prior to 1970. At the time of the 2005 assessment, Oregon and Washington landings data for starry flounder, individually, were not available prior to 1981. Ralston developed estimates for commercial landings in the Northern area using the relationship between catches of starry flounder and English sole in California, along with the ratio of Northern to Southern English sole landings that was being contemporaneously developed for the 2005 English sole assessment (Stewart, 2005). However, the North-South dividing line in the Stewart assessment was 40° 30' N. Lat., and about 35% of California starry flounder tonnage in the 1980s was landed in ports to the north. Consequently, a ratio of roughly 2:1 was used to estimate Oregon+Washington landed catch, where the appropriate ratio would have been about 0.9.

Since 2005, considerable efforts have been made in both Oregon and Washington to develop individual species landings time series. Existing commercial estimates for starry were available from 1932 in Oregon and 1970 in Washington. For purposes of this analysis, WDFW extended commercial starry landings in Washington back to 1889, using landings in flatfish market categories and the available percentage of rockfish catch occurring in PFMC waters (Table 1). A large number of intervening missing values between 1893 and 1922 (along with 1942) were replaced with a value of 10 mt, which was close to the average of non-missing years during that period. Recreational landings data were available from 1970 in Oregon, and from 1967 in Washington, however a gap from 1987 to 1989 was replaced with the average of surrounding years and a gap from 1968 to 1974 was replaced with a decreasing ramp of values that was extended back to 1956 (Table 1).

Commercial discards were handled in 3 stanzas. Since 2002, analysis by the West Coast Groundfish Observer Program of coastwide starry discard amounts were divided by state annually, in proportion with landed weight. Analysis of data from the Pikitch studies of the late-1980s indicated a discard rate of 4% (of landed catch) during that period (Patrick Mirick, pers. comm.). However, that rate was much lower than discard rates observed in many observed years, and aggregate discard during the first five years of observation (2002-06) was 35%. The intervening landings data indicated a substantial and sustained reduction of landings occurred in 1992, with a Northern total of 652 mt in 1991 (the largest amount since 1976) declining to 118 mt in 1992 (the smallest amount since the 1939 estimate). Since 1993, estimated total catch in the Northern area has not exceeded 108 mt. There was no change in management of starry flounder in 1992, however, discussion with state agency staff indicated this drop was likely the result of delivery limits imposed by processors, which could have increased discards. Consequently, the 4% rate estimated from the Pikitch data was used for all years up through 1991, and a ramp was used to increase discard (as a % of landings) from 11% in 1992 to 25% in 2001.

Revised estimates of total starry flounder removals in Oregon and Washington (landings and discard from the commercial and recreational sectors) are considerably lower than Ralston's (2005) estimates and pre-1970 equilibrium assumption (Figure 1).

#### Depletion-Based Stock Reduction Analysis (DB-SRA)

In addition to a time series of historical removals, DB-SRA requires an estimate of age at maturity and distributions of four quantities: natural mortality ( $M$ ),  $F_{MSY} / M$ ,  $B_{MSY}/B_0$ , and stock depletion in units of unfished biomass ( $\Delta$ ). The quantity commonly known to the PFMC as "depletion" is equal to  $1-\Delta$ . Parameters for the four input distributions and age at maturity (3 years) were derived from Ralston (2005) or conventions in place for previous applications of DB-SRA (Table 2). The last assessment estimated that the starry flounder stock off Oregon and Washington (the "northern" model) was at 44% of unfished spawning output in 2005 (depletion = 0.44), which is the assumed average depletion in the DB-SRA analysis ( $\Delta = 0.56 = 1 - 0.44$ ).

Ralston (2005) estimated proxy MSY for the Oregon and Washington stock to be 818 mt. We began our analysis by approximating the equilibrium assumption in Ralston's model by fixing catches from 1800 to 1969 at 782 mt (the sum of Ralston's equilibrium commercial and sport removals) in the DB-SRA model, and using Ralston's 1970-2004 total removals from the northern area. Median MSY from DB-SRA conditioned on this catch series is 752 mt (~95% highest density interval of 707-810 mt), only 8% less than Ralston's estimate. Using the revised catch time series (Figure 1) and input parameters (Table 2), median MSY from DB-SRA is 298 mt (~95% highest density interval of 237-359 mt), which reflects the change in scale of historical removals.

Starry flounder in waters off Oregon and Washington was last assessed over 10 years ago, and current status is highly uncertain. However, the last assessment estimated starry flounder in the northern area to be above target biomass, and total removals in the area have not exceeded 108 mt (< MSY) since 1993. This suggests that the revised DB-SRA estimate of MSY (298 mt) is a suitable proxy for Oregon and Washington's contribution to the starry flounder overfishing limit in 2019 and 2020 (Table 5).

## California Model

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### Revised Catch Estimates for California

Ralston (2005) provided California catch estimates back to 1916, but only data from the period 1970-2004 were included in the model, with an assumed equilibrium catch of 380 mt (combined trawl and sport) prior to 1970. Characteristics of the revised California catch time series (Table 3, Figure 2) include:

- Updated commercial landings from 1900-2016
  - Heimann and Carlisle (1970) reported landings for starry flounder, 1916-1968
  - Updated CALCOM landings from 1969-2016
  - Linear ramp from 0.1 mt in 1900 to first reported value in 1916
  - Assumed discard rate of 31.3% based on NWFSC (GEMM) estimates (2002-2015)
- Updated recreational removals (catch + discard) from 1900-2016
  - Revised RecFIN removals from 2005-2016 ([www.recfin.org](http://www.recfin.org))
  - Landings reported by Ralston (2005) for the period 1947-2004
  - Assumed equilibrium catch of 37.6 mt prior to 1947 (similar approach to Ralston 2005)

### Depletion-Based Stock Reduction Analysis (DB-SRA)

In addition to a time series of historical removals, DB-SRA requires an estimate of age at maturity and distributions of four quantities: natural mortality ( $M$ ),  $F_{MSY} / M$ ,  $B_{MSY}/B_0$ , and stock depletion in units of unfished biomass ( $\Delta$ ). The quantity commonly known to the PFM as “depletion” is equal to  $1-\Delta$ . Parameters for the four input distributions and age at maturity (3 years) were derived from Ralston (2005) or conventions in place for previous applications of DB-SRA (Table 4). The last assessment estimated that the starry flounder stock off the coast of California (the “southern” model) was at 62% of unfished spawning output in 2005 (depletion = 0.62), which is the assumed average depletion in the DB-SRA analysis ( $\Delta = 0.38 = 1 - 0.62$ ).

Given an assumed, average stock status of 62% of unfished spawning output in 2005 and low removals relative to historical levels after 2004, trends in population size predicted by DB-SRA must increase, on average, after 2005. Fishing at  $F_{MSY}$  will therefore produce yields greater than MSY. Ralston (2005) estimated proxy MSY for the California stock to be 396 mt based on Stock Synthesis (version 2). The DB-SRA median estimate of MSY is 353 mt (~95% highest density interval of 295-526 mt) using the revised catch time series (commercial plus recreational; Table 3, Figure 2) and input parameters (Table 4).

Average catch of starry flounder over the past two decades (~35 mt) is an order of magnitude smaller than the available estimates of MSY. The stock was last assessed over 10 years ago, and current status is highly uncertain. However, the last assessment estimated starry flounder in California to be above target biomass, suggesting that MSY (353 mt) is a suitable proxy for California’s contribution to the starry flounder overfishing limit in 2019 and 2020 (Table 5).

## References

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## Tables

*Table 1. Summary of all catch data used in the 2017 starry flounder assessment for waters off Oregon and Washington.*

Year	Commercial				Recreational		Commercial + Recreational			Ralston	
	Landings (mt)		Discard <sup>2</sup> % of Lnd	Total (mt)		catch (mt)		Total catch (mt)			2005 OR+WA mt <sup>3</sup>
	OR	WA <sup>1</sup>		OR	WA	OR	WA	OR	WA	OR+WA	
1889		4.3	4%		4.5				4.5	4.5	
1890		5.5	4%		5.7				5.7	5.7	
1891		7.9	4%		8.2				8.2	8.2	
1892		7.6	4%		7.9				7.9	7.9	
1893		10	4%		10.4				10.4	10.4	
1894		10	4%		10.4				10.4	10.4	
1895		4.4	4%		4.6				4.6	4.6	
1896		10	4%		10.4				10.4	10.4	
1897		10	4%		10.4				10.4	10.4	
1898		10	4%		10.4				10.4	10.4	
1899		1.1	4%		1.2				1.2	1.2	
1900		10	4%		10.4				10.4	10.4	
1901		10	4%		10.4				10.4	10.4	
1902		10	4%		10.4				10.4	10.4	
1903		10	4%		10.4				10.4	10.4	
1904		16.4	4%		17.0				17.0	17.0	
1905		10	4%		10.4				10.4	10.4	
1906		10	4%		10.4				10.4	10.4	
1907		10	4%		10.4				10.4	10.4	
1908		23.3	4%		24.2				24.2	24.2	
1909		10	4%		10.4				10.4	10.4	
1910		10	4%		10.4				10.4	10.4	
1911		10	4%		10.4				10.4	10.4	
1912		10	4%		10.4				10.4	10.4	
1913		10	4%		10.4				10.4	10.4	
1914		10	4%		10.4				10.4	10.4	
1915		2.1	4%		2.2				2.2	2.2	
1916		10	4%		10.4				10.4	10.4	
1917		10	4%		10.4				10.4	10.4	
1918		10	4%		10.4				10.4	10.4	
1919		10	4%		10.4				10.4	10.4	
1920		10	4%		10.4				10.4	10.4	
1921		10	4%		10.4				10.4	10.4	
1922		10	4%		10.4				10.4	10.4	
1923		16.1	4%		16.7				16.7	16.7	
1924		18.6	4%		19.4				19.4	19.4	
1925		20.2	4%		21.0				21.0	21.0	
1926		11.5	4%		12.0				12.0	12.0	
1927		8.0	4%		8.4				8.4	8.4	
1928		10.1	4%		10.6				10.6	10.6	
1929		8.6	4%		9.0				9.0	9.0	782.0
1930		7.6	4%		7.9				7.9	7.9	782.0
1931		9.0	4%		9.3				9.3	9.3	782.0
1932	2.6	5.3	4%	2.7	5.5			2.7	5.5	8.2	782.0
1933	1.2	28.6	4%	1.3	29.8			1.3	29.8	31.1	782.0

Table 1. Summary of all catch data used in the 2017 starry flounder assessment for waters off Oregon and Washington (cont.).

Year	Commercial				Recreational		Commercial + Recreational			Ralston	
	Landings (mt)		Discard <sup>1</sup>	Total (mt)		catch (mt)		Total catch (mt)			2005
	OR	WA	% of Lnd	OR	WA	OR	WA	OR	WA	OR+WA	OR+WA mt <sup>2</sup>
1934	0.5	2.3	4%	0.5	2.4			0.5	2.4	2.9	782.0
1935	1.3	106.6	4%	1.3	110.9			1.3	110.9	112.2	782.0
1936	5.1	23.9	4%	5.3	24.9			5.3	24.9	30.1	782.0
1937	25.6	2.4	4%	26.6	2.5			26.6	2.5	29.1	782.0
1938	0.5	4.2	4%	0.5	4.3			0.5	4.3	4.9	782.0
1939	79.7	3.6	4%	82.9	3.8			82.9	3.8	86.7	782.0
1940	143.2	7.3	4%	149.0	7.6			149.0	7.6	156.6	782.0
1941	171.0	6.8	4%	177.8	7.0			177.8	7.0	184.8	782.0
1942	198.2	10	4%	206.2	10.4			206.2	10.4	216.6	782.0
1943	364.7	9.4	4%	379.3	9.8			379.3	9.8	389.1	782.0
1944	366.0	52.9	4%	380.7	55.0			380.7	55.0	435.6	782.0
1945	442.9	48.1	4%	460.6	50.0			460.6	50.0	510.6	782.0
1946	569.3	57.8	4%	592.1	60.1			592.1	60.1	652.2	782.0
1947	292.5	85.7	4%	304.2	89.1			304.2	89.1	393.3	782.0
1948	640.8	132.2	4%	666.5	137.5			666.5	137.5	804.0	782.0
1949	127.2	48.2	4%	132.3	50.2			132.3	50.2	182.5	782.0
1950	157.7	112.7	4%	164.0	117.2			164.0	117.2	281.3	782.0
1951	150.2	108.0	4%	156.3	112.4			156.3	112.4	268.6	782.0
1952	95.0	104.0	4%	98.8	108.2			98.8	108.2	207.0	782.0
1953	104.4	66.3	4%	108.6	69.0			108.6	69.0	177.5	782.0
1954	150.8	68.4	4%	156.8	71.2			156.8	71.2	228.0	782.0
1955	126.1	126.5	4%	131.1	131.6			131.1	131.6	262.7	782.0
1956	57.8	134.9	4%	60.1	140.3	1		60.1	141.3	201.4	782.0
1957	151.4	107.0	4%	157.4	111.3	2		157.4	113.3	270.7	782.0
1958	215.9	75.9	4%	224.5	79.0	4		224.5	83.0	307.5	782.0
1959	123.6	72.8	4%	128.6	75.7	5		128.6	80.7	209.3	782.0
1960	105.3	91.5	4%	109.6	95.2	6		109.6	101.2	210.7	782.0
1961	179.4	97.5	4%	186.6	101.4	7		186.6	108.4	295.0	782.0
1962	325.9	82.5	4%	338.9	85.8	8		338.9	93.8	432.7	782.0
1963	146.2	87.5	4%	152.0	91.0	9		152.0	100.0	252.0	782.0
1964	247.3	66.4	4%	257.2	69.0	10		257.2	79.0	336.3	782.0
1965	181.9	58.2	4%	189.1	60.5	12		189.1	72.5	261.7	782.0
1966	222.5	40.6	4%	231.4	42.2	14		231.4	56.2	287.6	782.0
1967	141.2	105.7	4%	146.9	109.9	15.4		146.9	125.3	272.2	782.0
1968	206.8	160.9	4%	215.1	167.3	16		215.1	183.3	398.4	782.0
1969	198.5	55.3	4%	206.4	57.5	17		206.4	74.0	280.5	782.0
1970	270.8	41.1	4%	281.6	42.7	1.5	17	283.1	59.7	342.8	47.3
1971	282.7	34.1	4%	294.0	35.4	1.5	18	295.5	53.4	349.0	30.0
1972	237.1	49.5	4%	246.6	51.5	1.5	19	248.1	70.5	318.6	37.5
1973	210.4	42.4	4%	218.8	44.1	1.5	20	220.3	64.1	284.4	48.0
1974	276.2	332.1	4%	287.3	345.4	1.5	21	288.8	366.4	655.2	39.8
1975	399.5	108.2	4%	415.5	112.5	1.5	24.2	417.0	136.7	553.7	32.3
1976	787.9	39.1	4%	819.4	40.6	1.5	15.2	820.9	55.8	876.8	30.8
1977	335.7	116.8	4%	349.1	121.5	1.5	55.1	350.7	176.6	527.2	28.5
1978	491.7	146.7	4%	511.4	152.6	1.5	28.2	512.9	180.7	693.6	30.8
1979	283.5	130.4	4%	294.8	135.7	1.5	10.4	296.3	146.1	442.4	36.8
1980	193.2	138.7	4%	201.0	144.3	16.8	1.9	217.7	146.2	363.9	128.3
1981	400.6	170.1	4%	416.6	176.9	49.1	8.3	465.7	185.2	650.9	96.8
1982	217.9	211.5	4%	226.6	220.0	23.1	6.3	249.8	226.2	476.0	36.8

Table 1. Summary of all catch data used in the 2017 starry flounder assessment for waters off Oregon and Washington (cont.).

Year	Commercial			Recreational		Commercial + Recreational			Ralston		
	Landings (mt)		Discard <sup>1</sup> % of Lnd	Total (mt)		catch (mt)		Total catch (mt)			2005 OR+WA mt <sup>2</sup>
	OR	WA		OR	WA	OR	WA	OR	WA	OR+WA	
1983	195.7	49.2	4%	203.5	51.2	9.8	0.4	213.3	51.6	<b>264.9</b>	21.8
1984	107.3	25.8	4%	111.6	26.8	0.9	0.1	112.5	26.9	<b>139.4</b>	12.8
1985	358.0	194.5	4%	372.4	202.3	0.9	0.6	373.3	202.8	<b>576.1</b>	11.3
1986	97.6	72.2	4%	101.6	75.1	1.3	1.3	102.9	76.4	<b>179.3</b>	9.0
1987	90.7	94.9	4%	94.4	98.7	2.4	<b>1.3</b>	96.8	100.0	<b>196.8</b>	8.3
1988	143.3	135.0	4%	149.1	140.4	1.5	<b>1.3</b>	150.6	141.7	<b>292.3</b>	8.3
1989	195.0	273.8	4%	202.8	284.7	0.8	<b>1.3</b>	203.5	286.0	<b>489.6</b>	12.0
1990	106.1	186.1	4%	110.3	193.6		2.1	110.3	195.7	<b>306.0</b>	9.8
1991	325.3	326.3	4%	338.3	339.3		1.2	338.3	340.5	<b>678.8</b>	7.5
1992	70.8	47.5	11%	78.6	52.8		1.5	78.6	54.3	<b>132.9</b>	5.3
1993	74.5	41.6	12%	83.4	46.6		0.9	83.4	47.5	<b>130.9</b>	3.0
1994	62.8	8.7	13%	71.0	9.8		0.5	71.0	10.3	<b>81.2</b>	0.0
1995	37.1	13.2	14%	42.3	15.0		0.7	42.3	15.8	<b>58.0</b>	0.0
1996	26.7	3.8	15%	30.8	4.3		0.5	30.8	4.9	<b>35.6</b>	0.0
1997	53.7	9.0	17%	62.9	10.5		0.6	62.9	11.1	<b>74.0</b>	2.3
1998	52.3	0.7	19%	62.2	0.9		0.2	62.2	1.1	<b>63.3</b>	3.0
1999	21.8	0.4	21%	26.4	0.5		0.3	26.4	0.8	<b>27.2</b>	2.3
2000	21.7	3.5	23%	26.7	4.4		0.1	26.7	4.5	<b>31.2</b>	0.0
2001	7.3	0.1	25%	9.1	0.1	0.0	0.4	9.1	0.5	<b>9.6</b>	6.0
2002	18.3	0.4	88%	34.4	0.8	0.1	0.6	34.4	1.4	<b>35.9</b>	11.3
2003	18.0	0.1	8%	19.3	0.1	0.1	0.5	19.4	0.7	<b>20.1</b>	6.0
2004	67.4	4.0	49%	100.3	5.9	0.2	0.6	100.5	6.5	<b>107.1</b>	6.0
2005	17.4	3.5	23%	21.4	4.3	0.1	0.8	21.5	5.0	<b>26.5</b>	
2006	48.8	1.9	5%	51.5	2.0	0.1	0.5	51.5	2.6	<b>54.1</b>	
2007	7.3	1.3	13%	8.3	1.5	0.0	0.5	8.3	1.9	<b>10.2</b>	
2008	2.9	0.3	25%	3.6	0.4	0.0	0.4	3.6	0.8	<b>4.4</b>	
2009	4.6	0.2	14%	5.3	0.2	0.0	0.9	5.3	1.1	<b>6.4</b>	
2010	10.1	7.3	5%	10.6	7.7	0.0	0.7	10.7	8.4	<b>19.0</b>	
2011	8.1	0.0	33%	10.8	0.0	0.1	0.8	10.9	0.8	<b>11.7</b>	
2012	7.3	0.0	9%	8.0	0.0	0.0	2.0	8.1	2.0	<b>10.0</b>	
2013	1.5	0.2	14%	1.7	0.3	0.0	1.7	1.7	1.9	<b>3.7</b>	
2014	9.7	0.0	6%	10.3	0.0	0.0	3.0	10.3	3.0	<b>13.2</b>	
2015	5.3	11.1	5%	5.6	11.7	0.0	3.5	5.6	15.2	<b>20.8</b>	
2016	10.6	0.0	16%	12.3	0.0	0.0	8.2	12.3	8.2	<b>20.5</b>	

Sum of catch (mt) in current assessment

**20,786**

Sum of catch (mt) in the 2005 assessment

**32,832**

<sup>1</sup> For years without Washington commercial records from 1893 to 1922, the average of years with recorded landings from 1889 to 1930 was used. During 1926-32, the general 'Flatfish' market category was assumed to be all flounder, as there was all a 'Sole' category. In 1924-25, 1933, and 1935-36, only the 'Flounder' category was used, and it was assumed to be comprised of 50% sole species.

<sup>2</sup> Discard prior to 1992 was assumed to be 4%, based on Pikitch data; WCGOP estimates used for 2002 onward, and a ramp used in between. The jump in assumed rate from 1991 to 1992 reflects the sharp drop in landings, that may have resulted from lower dealer landing limits.

<sup>3</sup> Ralston set equilibrium catch at 782 mt from the beginning of the 2005 assessment (1929) through 1969.

Table 2: DB-SRA parameter distributions for Oregon-Washington starry flounder

Quantity	Distribution	Parameters	Basis
M	Lognormal	Mean = 0.3, SD=0.4	Ralston 2005
$F_{MSY} / M$	Lognormal	Mean= 0.8, SD=0.1	Dick and MacCall, 2010
$B_{MSY} / B_0$	Beta	Mean = 0.25, SD = 0.05	PFMC flatfish proxy
$\Delta$ (2005)	Beta	Mean = 0.56, SD = 0.1	Ralston 2005



Table 3. Revised total removals (mt) of starry flounder for California. See text for details and sources.

Year	Recreational	Commercial (includes 31.3% discard)	Year	Recreational	Commercial (includes 31.3% discard)
1900	37.6	0.1	1959	17.3	623.5
1901	37.6	17.0	1960	13.0	154.3
1902	37.6	33.9	1961	20.8	187.8
1903	37.6	50.8	1962	20.0	201.4
1904	37.6	67.7	1963	17.8	310.5
1905	37.6	84.6	1964	32.2	250.7
1906	37.6	101.5	1965	35.1	225.4
1907	37.6	118.3	1966	45.1	226.7
1908	37.6	135.2	1967	54.1	518.6
1909	37.6	152.1	1968	51.8	509.9
1910	37.6	169.0	1969	45.4	223.1
1911	37.6	185.9	1970	54.8	165.5
1912	37.6	202.8	1971	35.3	169.1
1913	37.6	219.7	1972	44.3	392.9
1914	37.6	236.6	1973	56.3	425.8
1915	37.6	253.4	1974	46.5	299.3
1916	37.6	270.3	1975	38.3	426.7
1917	37.6	686.0	1976	36.0	703.8
1918	37.6	487.7	1977	33.8	589.7
1919	37.6	259.5	1978	36.0	490.5
1920	37.6	286.8	1979	43.5	588.9
1921	37.6	174.9	1980	84.0	441.4
1922	37.6	321.1	1981	29.3	389.8
1923	37.6	303.1	1982	38.3	269.3
1924	37.6	226.2	1983	38.3	308.7
1925	37.6	354.0	1984	24.0	341.8
1926	37.6	397.7	1985	14.3	331.4
1927	37.6	351.4	1986	24.8	238.6
1928	37.6	238.2	1987	51.8	167.9
1929	37.6	345.9	1988	42.0	157.8
1930	37.6	232.9	1989	21.8	122.2
1931	37.6	101.1	1990	18.0	69.2
1932	37.6	323.9	1991	14.3	68.5
1933	37.6	272.8	1992	10.5	63.0
1934	37.6	319.9	1993	6.8	39.6
1935	37.6	390.8	1994	3.8	22.9
1936	37.6	370.0	1995	3.8	19.5
1937	37.6	580.5	1996	3.0	36.1
1938	37.6	323.3	1997	3.0	60.5
1939	37.6	440.3	1998	6.0	80.6
1940	37.6	478.9	1999	3.8	63.1
1941	37.6	358.3	2000	5.3	38.1
1942	37.6	220.4	2001	9.0	65.0
1943	37.6	301.0	2002	5.3	39.5
1944	37.6	218.3	2003	6.8	39.0
1945	37.6	201.0	2004	6.8	45.8
1946	37.6	303.4	2005	3.4	50.9
1947	29.0	313.9	2006	1.4	30.5
1948	36.8	241.4	2007	0.4	17.9
1949	47.1	212.2	2008	0.8	14.0
1950	65.6	544.2	2009	0.8	22.5
1951	109.2	672.3	2010	0.6	17.9
1952	79.5	355.8	2011	1.2	9.2
1953	144.5	299.3	2012	0.9	6.5
1954	107.9	298.1	2013	0.9	7.2
1955	87.2	387.2	2014	1.7	15.3
1956	53.3	223.6	2015	0.8	10.4
1957	43.2	300.4	2016	0.3	6.1
1958	20.6	280.6			

Table 4: DB-SRA parameter distributions for California starry flounder.

Quantity	Distribution	Parameters	Basis
M	Lognormal	Mean = 0.3, SD=0.4	Ralston 2005
FMSY / M	Lognormal	Mean= 0.8, SD=0.1	Dick and MacCall, 2010
BMSY / B0	Beta	Mean = 0.25, SD = 0.05	PFMC flatfish proxy
D (2005)	Beta	Mean = 0.38, SD = 0.1	Ralston 2005

Table 5. DB-SRA Estimates of MSY and 2019 OFLs for Starry Flounder in OR-WA and CA.

The estimated median MSY values, which are substantially higher than recent catch, are recommended for use as OFL's in 2019-20.

**Oregon-Washington (revised landings)**

2019 OFL assumes 18.19 mt total removals in 2017 and 2018

	Median	HDI_95_lower	HDI_95_upper
MSY	298	237	359
OFL (2019)	859	477	1,273

**California (NOTE: corrected median MSY)**

2019 OFL assumes 11.6 mt total removals in 2017 and 2018

	Median	HDI_95_lower	HDI_95_upper
MSY	354*	295	526
OFL (2019)	1,167	692	2,158

\* Median MSY previously reported for CA (370 mt) was from the Ralston 2005 catch stream.

## Figures

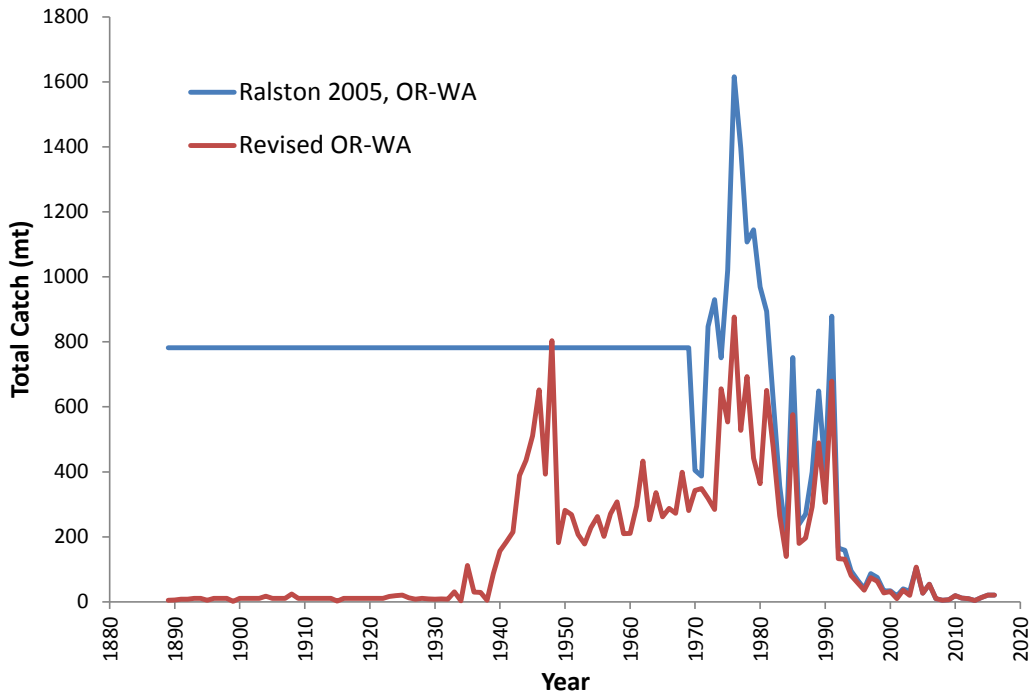


Figure 1. Revised time series of Oregon and Washington commercial and recreational starry flounder removals, 1889-2016, with comparison to removals and equilibrium assumption from Ralston (2005).

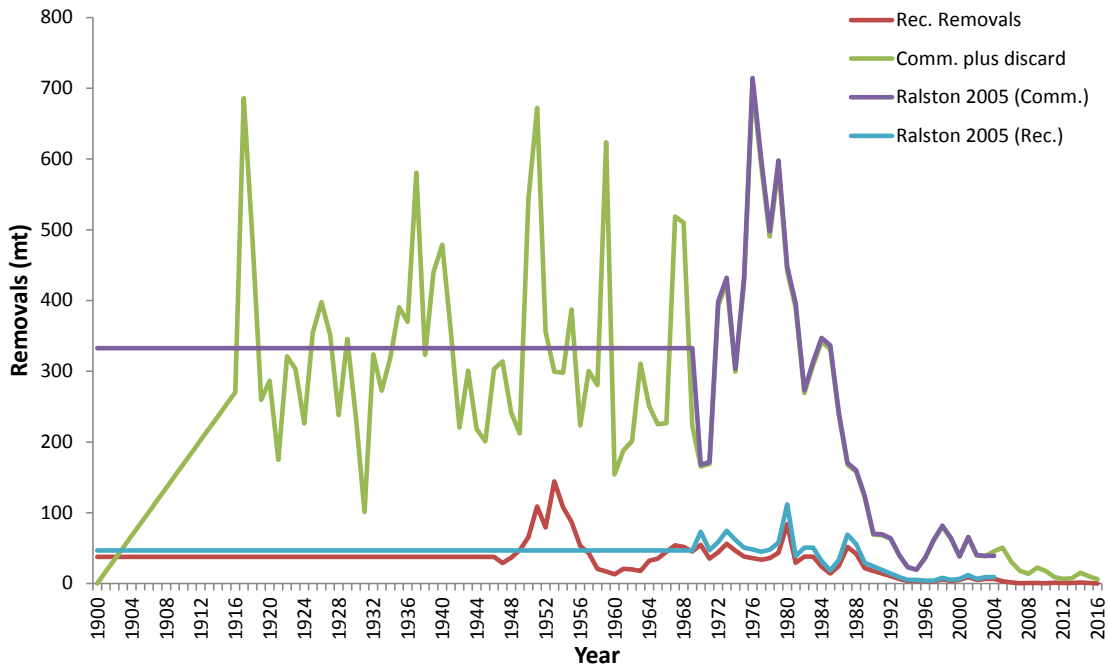


Figure 2. Revised time series of California commercial and recreational starry flounder removals, 1900-2016, with comparisons to removals assumed by Ralston (2005).

**Appendix**  
**Details of reconstructions for Washington Commercial and Recreational Landings**

Table A-1. Data used to inform assumptions needed to develop a commercial landings history for starry flounder in Washington.

Year	Percentage of flatfish-category landings estimated to have been caught in waters managed by the PFMC (i.e., excluding catch from Canadian and Puget Sound waters)				Flounder market-category landings (mt)		Starry % of total
	All Flatfish	Flounder market category			Arrowtooth	Starry	
		Starry	Arrowtooth	All			
1970	35%	22%	6%	16%	6.4	39.0	86%
1971	36%	15%		15%		31.7	100%
1972	35%	14%	55%	17%	18.3	47.2	72%
1973	42%	11%	42%	21%	75.4	39.8	35%
1974	49%	46%	77%	50%	82.0	326.7	80%
1975	48%	23%	83%	25%	19.2	106.0	85%
1976	55%	11%	79%	32%	122.0	36.8	23%
1977	55%	19%	84%	29%	59.6	112.2	65%
1978	67%	33%	90%	54%	171.3	143.1	46%
1979	73%	23%	74%	48%	301.2	127.3	30%
1980	72%	23%	90%	49%	219.1	135.8	38%
1970-75 avg.	41%	22%	53%	<b>24%<sup>1</sup></b>			<b>76%<sup>2</sup></b>

<sup>1</sup> 24% of historical fish weight in the 'Flounder' market category was assumed to have been caught in PFMC waters.

<sup>2</sup> 76% of the historical fish weight in the 'Flounder' market was assumed to be starry flounder.

Table A-2. Summary of recreational catch data used in the 2017 starry flounder assessment for waters off Oregon and Washington.

Year	Washington		OR-mt	OR+WA mt
	# of fish	Derived mt <sup>1</sup>		
1956	missing	1		1.0
1957	missing	2		2.0
1958	missing	4		4.0
1959	missing	5		5.0
1960	missing	6		6.0
1961	missing	7		7.0
1962	missing	8		8.0
1963	missing	9		9.0
1964	missing	10		10.0
1965	missing	12		12.0
1966	missing	14		14.0
1967	11,598	15.4		15.4
1968	missing	16		16.0
1969	missing	16.5		16.5
1970	missing	17	1.5	18.5
1971	missing	18	1.5	19.5
1972	missing	19	1.5	20.5
1973	missing	20	1.5	21.5
1974	missing	21	1.5	22.5
1975	18,187	24.2	1.5	25.7
1976	11,400	15.2	1.5	16.7
1977	41,409	55.1	1.5	56.6
1978	21,167	28.2	1.5	29.7
1979	7,836	10.4	1.5	11.9
1980	1,466	1.9	16.8	18.7
1981	6,250	8.3	49.1	57.4
1982	4,721	6.3	23.1	29.4
1983	327	0.4	9.8	10.2
1984	75	0.1	0.9	1.0
1985	431	0.6	0.9	1.5
1986	969	1.3	1.3	2.6
1987	missing	1.3	2.4	3.7
1988	missing	1.3	1.5	2.8
1989	missing	1.3	0.8	2.1
1990	1,560	2.1	0.0	2.1
1991	884	1.2	0.0	1.2
1992	1,147	1.5	0.0	1.5
1993	707	0.9	0.0	0.9
1994	359	0.5	0.0	0.5
1995	542	0.7	0.0	0.7

Table A-2. Summary of recreational catch data used in the 2017 starry flounder assessment for waters off Oregon and Washington (cont.).

Year	Washington		OR-mt	OR+WA mt
	# of fish	Derived mt <sup>1</sup>		
1996	400	0.5	0.0	0.5
1997	451	0.6	0.0	0.6
1998	188	0.2	0.0	0.2
1999	212	0.3	0.0	0.3
2000	105	0.1	0.0	0.1
2001	316	0.4	0.0	0.4
2002	486	0.6	0.1	0.7
2003	398	0.5	0.1	0.6
2004	482	0.6	0.2	0.9
2005	569	0.8	0.1	0.9
2006	410	0.5	0.1	0.6
2007	340	0.5	0.0	0.5
2008	287	0.4	0.0	0.4
2009	662	0.9	0.0	0.9
2010	533	0.7	0.0	0.7
2011	576	0.8	0.1	0.9
2012	1,489	2.0	0.0	2.0
2013	1,263	1.7	0.0	1.7
2014	2,229	3.0	0.0	3.0
2015	2,614	3.5	0.0	3.5
2016	6,137	8.2	0.0	8.2

<sup>1</sup> Numbers of fish reported by WDFW were converted to weight using an average weight of 1.33 kg/fish, obtained from early Oregon records. Centered (red) values are assumed for years lacking count data.