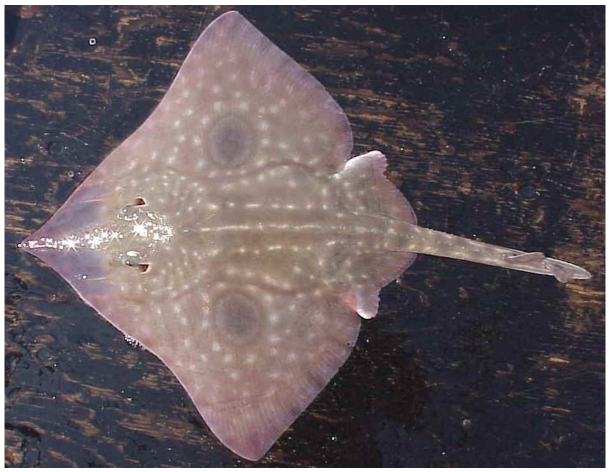
Agenda Item H.5
Attachment 3
September 2019

Status of Big Skate (*Beringraja binoculata*) Off the U.S. Pacific Coast in 2019



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Acronyms used in this Document

ABC	Allowable Biological Catch
ACL	Annual Catch Limit
AFSC	Alaska Fisheries Science Center
CDFW	California Department of Fish and Wildlife
DFO	Canada's Department of Fisheries and Oceans
DW	Disk Width
IFQ	Individual Fishing Quota
IPHC	International Pacific Halibut Commission
ISW	Interspiracular Width
NMFS	National Marine Fisheries Service
NWFSC	Northwest Fisheries Science Center
ODFW	Oregon Department of Fish and Wildlife
OFL	Overfishing Limit
OY	Optimum Yield
PacFIN	Pacific Fisheries Information Network
PFMC	Pacific Fishery Management Council
SPR	Spawning Potential Ratio
SSC	Scientific and Statistical Committee
SWFSC	Southwest Fisheries Science Center
TL	Total Length
VAST	Vector Autoregressive Spatio-Temporal Package
WCGBT	West Coast Groundfish Bottom Trawl Survey
WCGOP	West Coast Groundfish Observer Program
WDFW	Washington Department of Fish and Wildlife

Status of Big Skate (*Beringraja binoculata*) Off the U.S. Pacific Coast in 2019

Contents

Executive Summary

Stock

This assessment reports the status of the Big Skate (*Beringraja binoculata*) resource in U.S. waters off the West Coast using data through 2018. A map showing the area of the U.S. West Coast Exclusive Economic Zone covered by this stock assessment is provided in Figure a.

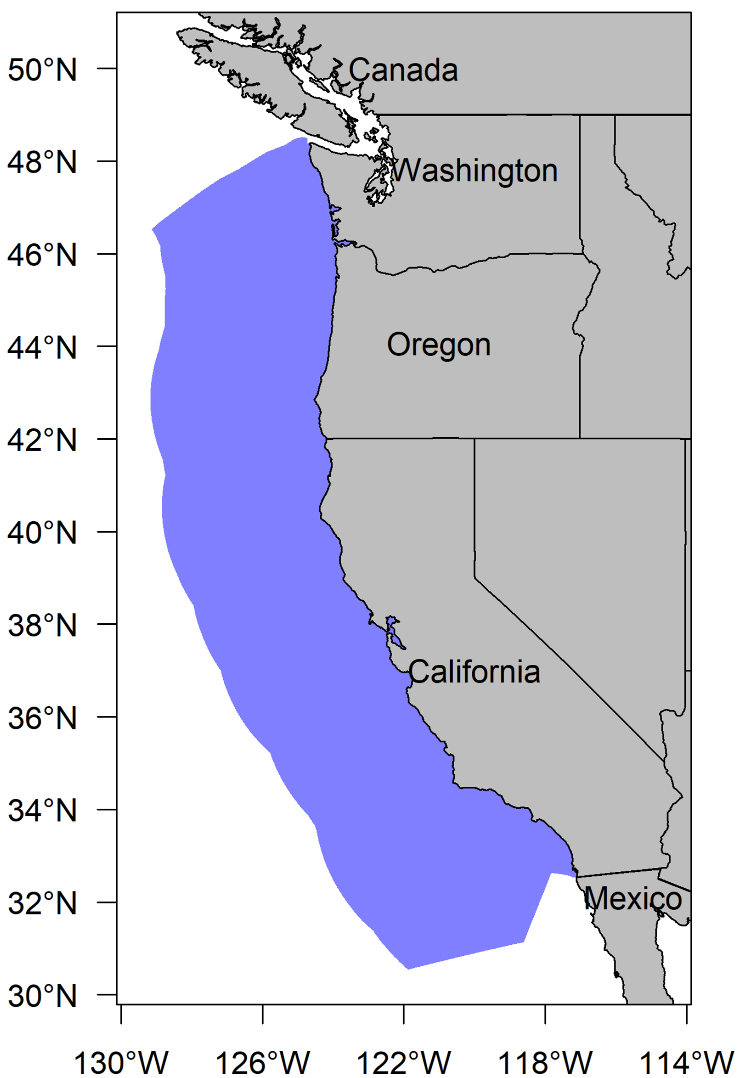

Figure a: U.S. West Coast Exclusive Economic zone covering the area in which this stock assessment is focused.

Catches

The majority of Big Skate catch was discarded prior to 1995 when markets for Big Skate and Longnose Skate developed, landings increased, and discarding decreased. The majority of the discards were unrecorded and the landings were in the unspecified skates category. The landings from prior to 1995 were reconstructed separately in each of the three coastal states for this assessment. In general the methods all relied on differences in depth distribution of the different skates species (primarily Big Skate and Longnose Skate). Discards during this period prior to 1995 were estimated outside the model based on an assumption that the average discard rate during the period 1950–1994 was equal to that for Longnose Skate. The current fishery, beginning in 1995, has less uncertainty in landings, lower discard rates, and more data on discards. The discards are estimated within the model for this period using a time-varying retention function. Big Skate have only been landed in their own species category in the past few years (starting in 2015).

In the current fishery (since 1995), annual total landings of Big Skate have ranged between 135-528 mt, with landings in 2018 totaling 173 mt.

Table a: Recent Big Skate landings (mt)

Year	Landings
2008	366.0
2009	205.7
2010	196.2
2011	268.4
2012	269.6
2013	135.0
2014	372.4
2015	331.5
2016	411.5
2017	277.6
2018	172.6

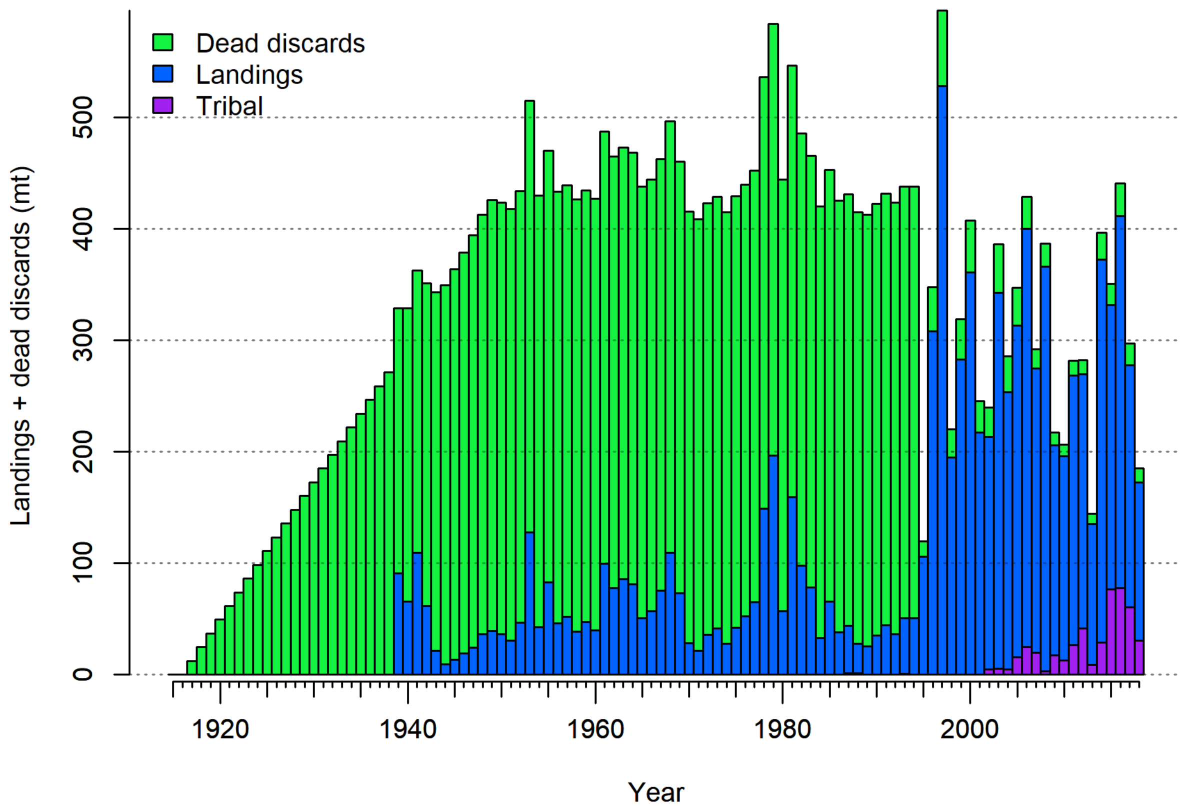

Figure b: Estimated catch history of Big Skate. Discards prior to 1995 were estimated outside the model while those from 1995 onward are estimated internally based on a time-varying retention function.

Data and Assessment

This the first full assessment for Big Skate. It is currently managed using an OFL which was based on a proxy for F_{MSY} and the average survey biomass for the years 2010–2012. This assessment uses the newest version of Stock Synthesis available prior to the review meeting (3.30.13.02). The model begins in 1916, and assumes the stock was at an unfished equilibrium that year. The choice of 1916 is based on the first year of the California catch reconstruction.

The assessment relies on two bottom trawl survey indices of abundance, the Triennial Survey from which an index covering the period 1980–2004 was used here and the West Coast Groundfish Bottom Trawl (WCGBT) Survey, which began in 2003 and for which data is available through 2018. The triennial survey shows an increasing trend over the 25 year period it covers, which the model is not able to fit as this includes the period when trawl fishing in this area was at its most intense and the model stock is expected to have been declining. The WCGBT Survey also shows an increasing trend, with the 5 most recent observations (2014–2018) all falling in the top 6 ever observed (2004 was the 5th highest observation). The model estimates an increasing trend during this period but the slope is more gradual than the trend in the survey observations. The misfit to these survey indices could be due to some combination of incorrect estimation of the catch history, variability in recruitment which is not modeled here, or biological or ecological changes which are also not represented in the model.

Length composition data from the fishery is available starting in 1995 but is sparse until the most recent 10 years. Most of the ages are also from 2008 onward. This limits the ability of the model to estimate any changes in composition of the population during the majority of the history of the fishery. Estimates of discard rates and mean body weight of discards are available for the years 2002 onward and discard length compositions are available starting in 2010.

The age and length data provide evidence for growth patterns and sex-specific differences in selectivity that are unusual among groundfish stocks that have been assessed within the U.S. West Coast and are not found in Longnose Skate, where the data show little difference between the sexes. Growth appears to be almost linear and similar between females and males up to about age 7 or over 100 cm at which point male growth appears to stabilize while females continue to grow. However, in spite of the similar growth pattern for ages prior to 7, males are observed more frequently in the length bins associated with these ages, with the 70–100 cm length bins showing more than 60% males in many years. Sex-specific differences in selectivity were included in the model in order to better match patterns in the sex ratios in the length composition data and a new "growth cessation model" was used to model growth as it provided much better fits than the von Bertalanffy growth function. The length and age data do not cover enough years or show enough evidence of distinct cohorts to reliably estimate deviations in recruitment around the stock-recruit curve, so recruitment in the final model is based directly on the Beverton-Holt stock-recruit curve. Steepness of this stock-recruit curve was not well-informed by the model so was fixed at the 0.4 value used in a previous Longnose Skate stock assessment.

The final model has 44 estimated parameters, most of which are related to selectivity (including sex-specific differences), time-varying retention, and growth (including sex-specific differences). The remaining 7 parameters include natural mortality, equilibrium recruitment, an extra survey uncertainty parameter for each of the two surveys, and three catchability parameters, where the Triennial Survey is assumed to have a change in catchability starting in 1995 due to changes in survey design.

The scale of the population is not reliably informed by the data due to the combination of surveys that show trends which can't be matched by the structure of the model, and length and age data which inform growth and selectivity but provide relatively little information about changes in stock structure over time. Therefore, a prior on catchability of the WCGBT Survey (centered at 0.701) was applied in order to provide more stable results.

Although the assessment model requires numerous simplifying assumptions, it represents an improvement over the simplistic status-quo method of setting management limits, which relies on average survey biomass and an assumption about F_{MSY}. The use of an age-structured model with estimated growth, selectivity, and natural mortality likely provides a better estimate of past dynamics and the impacts of fishing in the future than the status-quo approach.

Stock Biomass

The 2019 estimated spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished spawning biomass at 79.2% (95% asymptotic interval: $\pm$ 65.5%-92.9%) (Figure c and Table b). Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning biomass is high, although even the lower range of the 95% interval for fraction unfished is above the 40% reference point, and all sensitivity analyses explored also show the stock to be at a relatively high level.

Table b: Recent trend in beginning of the year spawning biomass and fraction unfished (spawning biomass relative to unfished equilibrum spawning biomass)

Year	Spawning Biomass (mt)	~ 95% confidence interval	Fraction Unfished	~ 95% confidence interval
2010	1938.7	(507.5-3369.9)	0.768	(0.616-0.92)
2011	1952.3	(519.8-3384.9)	0.773	(0.624-0.922)
2012	1960.1	(527.3-3393)	0.776	(0.628-0.924)
2013	1969.0	(535.8-3402.1)	0.780	(0.634-0.926)
2014	1991.1	(556-3426.2)	0.789	(0.648-0.93)
2015	1990.4	(556.3-3424.5)	0.788	(0.647-0.929)
2016	1992.8	(559.1-3426.6)	0.789	(0.649-0.929)
2017	1984.9	(552.5-3417.3)	0.786	(0.645-0.927)
2018	1987.9	(555.4-3420.4)	0.787	(0.647-0.927)
2019	1999.3	(565.7-3433)	0.792	(0.655-0.929)

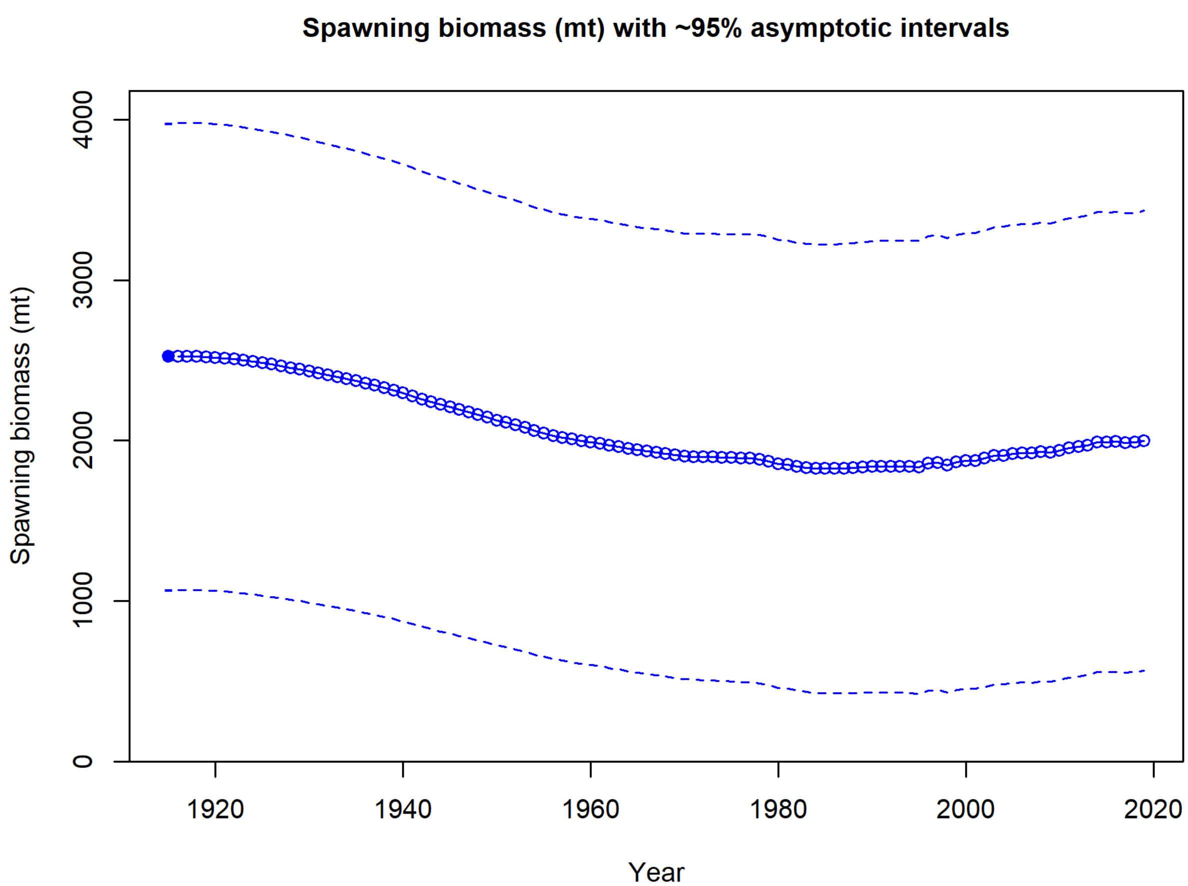

Figure c: Time series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model.

Recruitment

Recruitment was assumed to follow the Beverton-Holt stock recruit curve with the steepness parameter fixed at $h = 0.4$, so uncertainty in estimated recruitment is due to uncertainty in the estimated unfished equilibrium recruitment R_0 as well as uncertainty in growth and mortality (Figure d and Table c).

Table c: Recent recruitment for the model.

Year	Estimated Recruitment (1,000s)	~ 95% confidence interval
2010	6617	(3044 - 14385)
2011	6637	(3059 - 14402)
2012	6649	(3068 - 14411)
2013	6662	(3077 - 14420)
2014	6694	(3102 - 14448)
2015	6693	(3102 - 14443)
2016	6697	(3105 - 14442)
2017	6685	(3098 - 14426)
2018	6689	(3102 - 14426)
2019	6706	(3115 - 14438)

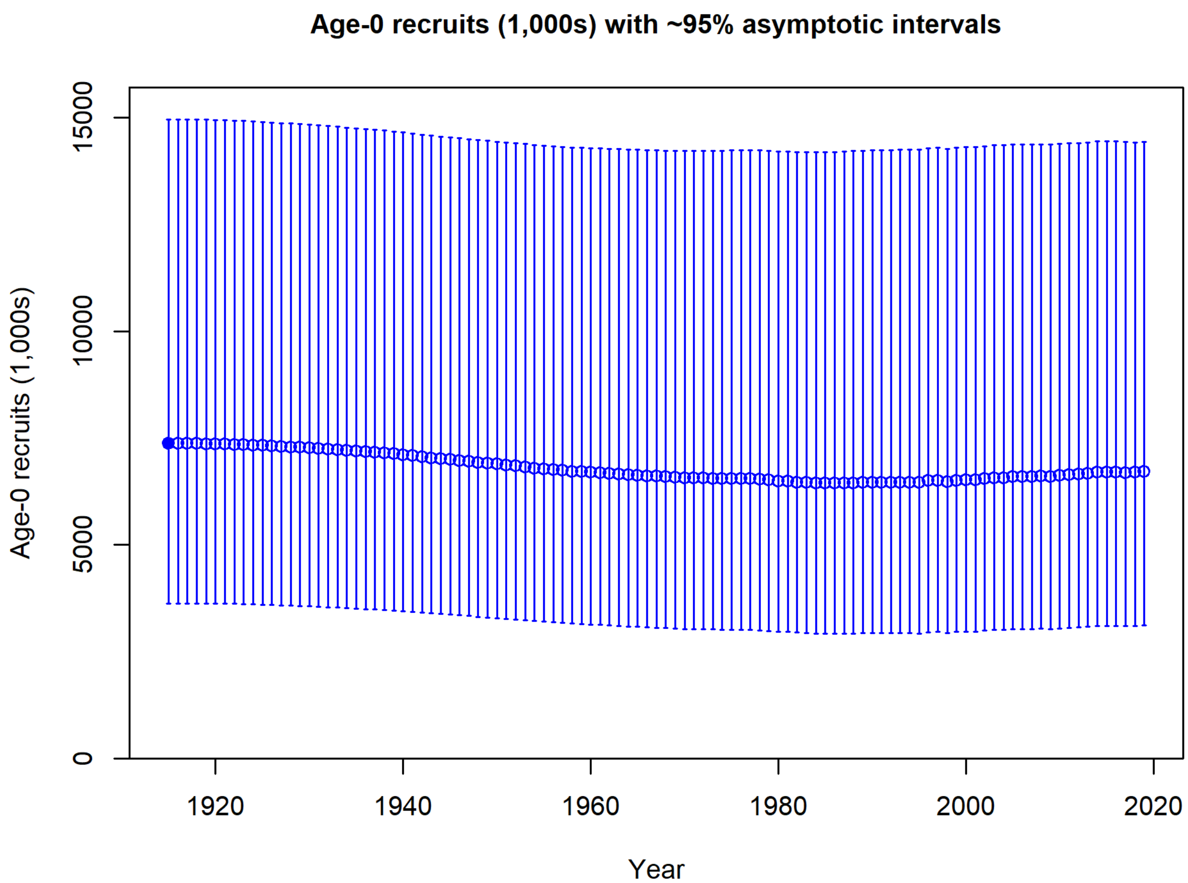

Figure d: Time series of estimated Big Skate recruitments for the base-case model with 95% confidence or credibility intervals.

Exploitation Status

Harvest rates estimated by the base model indicate catch levels have been below the 100% relative fishing intensity upper limit defined as $(1 - SPR)/(1 - SPR_{target})$ (Table d and Figures e and f). SPR is calculated as the lifetime spawning potential per recruit at a given fishing level relative to the lifetime spawning potential per recruit with no fishing. The annual exploitation rate of age 2+ fish has been below 2% over the recent 10-year period.

Table d: Recent trend in spawning potential ratio and exploitation for Big Skate in the model. Relative fishing intensity is (1-SPR) divided by 50% (the SPR target) and exploitation is catch divided by age 2+ biomass.

Year	Relative fishing intensity	˜ 95% confidence interval	Exploitation rate	˜ 95% confidence interval
2009	0.174	(0.059-0.289)	0.010	(0.003-0.016)
2010	0.165	(0.057-0.273)	0.009	(0.003-0.015)
2011	0.220	(0.079-0.362)	0.012	(0.004-0.02)
2012	0.220	(0.079-0.361)	0.012	(0.004-0.02)
2013	0.115	(0.04-0.191)	0.006	(0.002-0.01)
2014	0.300	(0.114-0.486)	0.017	(0.006-0.028)
2015	0.269	(0.1-0.437)	0.015	(0.005-0.025)
2016	0.332	(0.128-0.537)	0.019	(0.007-0.031)
2017	0.231	(0.084-0.379)	0.013	(0.004-0.021)
2018	0.147	(0.052-0.243)	0.008	(0.003-0.013)

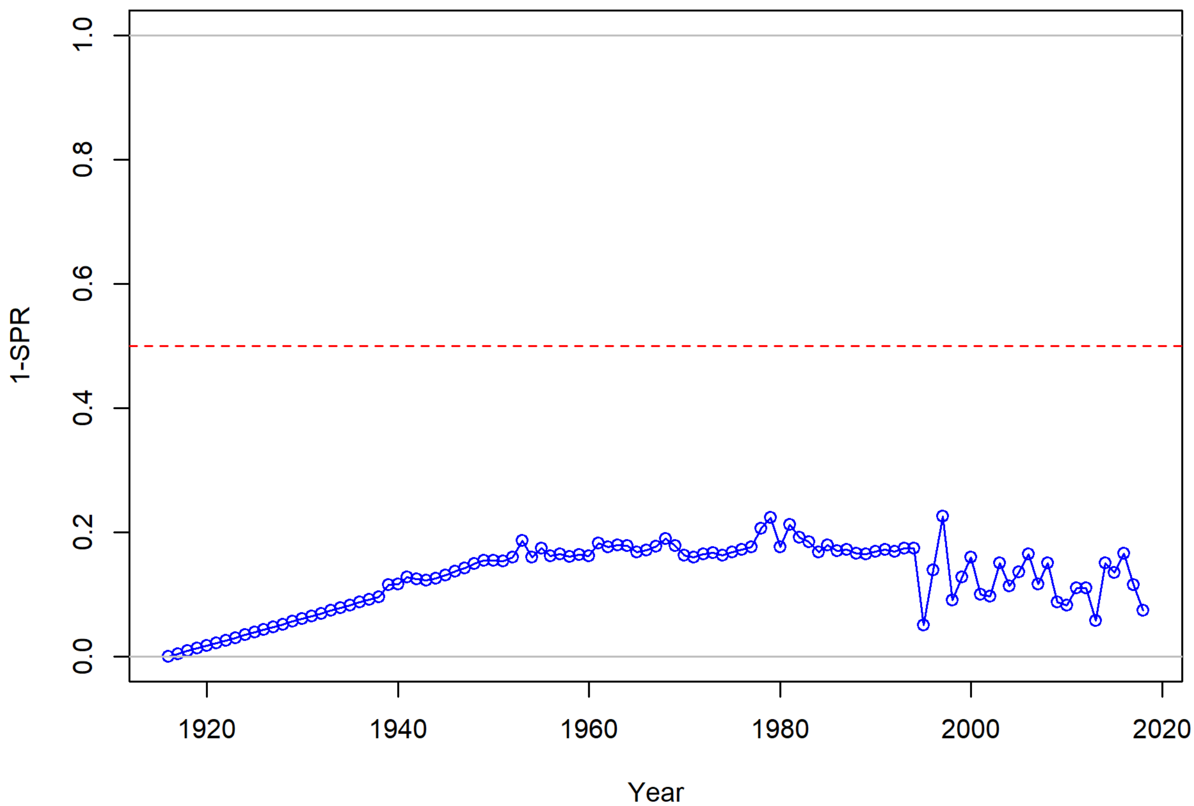

Figure e: Estimated Spawning Potential Ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$ harvest rate. The last year in the time series is 2018.

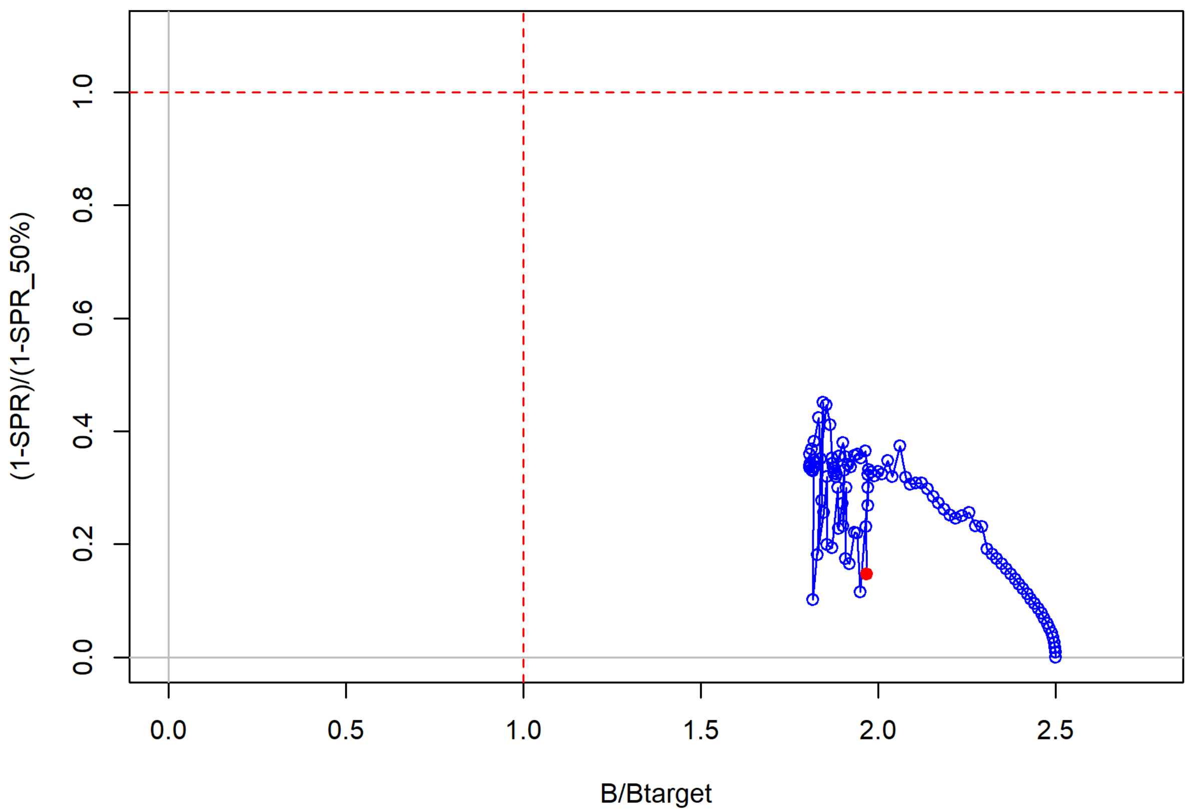

Figure f: Phase plot of biomass vs. fishing intensity.

Reference Points

This stock assessment estimates that Big Skate is above the biomass target ($B_{40\%}$), and well above the minimum stock size threshold ($B_{25\%}$). The estimated fraction unfished level for the base model in 2019 is 79.2% (95% asymptotic interval: ± 65.5%-92.9%, relative to an unfished spawning biomass of 2,525 mt (95% asymptotic interval: 1,068-3,981 mt) (Table e). Unfished age 2+ biomass was estimated to be 27,268 mt in the base case model. The target spawning biomass ($B_{40\%}$) is 1,010 mt, which corresponds with an equilibrium yield of 701 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR = 50\%$ is 590 mt (Figure g).

Table e: Summary of reference points and management quantities for the base case model.

Quantity	**Estimate**	**Low 2.5% limit**	**High 2.5% limit**
Unfished spawning biomass (mt)	2,525	1,068	3,981
Unfished age 2+ biomass (mt)	27,268	12,854	41,683
Unfished recruitment (R_0, thousands)	7,366	1,974	12,759
Spawning biomass (2019 mt)	1,999	566	3,433
Fraction unfished (2019)	0.792	0.655	0.929
Reference points based on $\mathbf{B_{40\%}}$			
Spawning biomass ($B_{40\%}$)	1,010	427	1,592
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.625	0.625	0.625
Exploitation rate resulting in $B_{40\%}$	0.048	0.042	0.055
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	701	316	1,086
Reference points based on $SPR = 50\%$ ***proxy for MSY***			
Spawning biomass (mt)	505	214	796
SPR_{proxy}	0.5		
Exploitation rate corresponding to $SPR = 50\%$	0.071	0.061	0.08
Yield with $SPR = 50\%$ at $B_{SPR=50\%}$ (mt)	590	266	915
Reference points based on estimated MSY values			
Spawning biomass at MSY (B_{MSY})	944	393	1,496
SPR_{MSY}	0.609	0.604	0.614
Exploitation rate at MSY	0.051	0.045	0.057
Dead Catch MSY (mt)	703	316	1,089
Retained Catch MSY (mt)	650	294	1,005

Ecosystem Considerations

Big Skate have broad thermal tolerances and are broadly distributed, occurring from the southeastern Bering Sea to southern Baja California and the Gulf of California. They have been reported at depths of 2-501 m but are most common on the inner continental shelf (< 100 m). Big Skates are opportunistic predators with highly variable spatio-temporal trophic roles.

In this assessment, neither environmental nor ecosystem considerations were explicitly included in the analysis. This is primarily due to a lack of relevant data or results of analyses that could contribute ecosystem-related quantitative information for the assessment.

Management Performance

Annual Catch Limits have only been in place for Big Skate in recent years and total catch, including discards has remained below these limits with the exception of 2014, where in retrospect the catch was above the ACL although still below the Overfishing Limit (Table f).

Table f: Recent trend in total catch (mt) relative to the management guidelines. Big skate was managed in the Other Species complex in 2013 and 2014, designated an Ecosystem Component species in 2015 and 2016, and managed with stock-specific harvest specifications since 2017. Estimated total mortality includes dead discards estimated in the model (assuming a discard mortality rate of 50%).

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	Landings (mt)	Estimated total mortality (mt)
2009				205.7	217.2
2010				196.2	206.6
2011				268.4	282.0
2012				269.6	282.4
2013	458	317.9	317.9	135.0	144.3
2014	458	317.9	317.9	372.5	396.9
2015				331.6	350.6
2016				411.5	440.7
2017	541	494.0	494.0	277.6	297.2
2018	541	494.0	494.0	172.6	185.4
2019	541	494.0	494.0		
2020	541	494.0	494.0		

Unresolved Problems and Major Uncertainties

The data provide little information about the scale of the population, necessitating the use of a prior on catchability to maintain stable model results. During the review panel the prior was updated from the one developed in the 2007 Longnose Skate stock assessment to better account for Big Skate occurrences in shallower water than the surveyed region, but further refinement of this prior could be considered in the future.

There is little evidence that the population is overfished or experiencing overfishing, but forecasts of overfishing limits vary considerably among the sensitivity analyses explored (though all remain well above the recent average catch).

The fit to the length data was significantly improved by estimating a difference between female and male selectivity, with females having a lower maximum selectivity than males, but the behavioral processes that might contribute to this difference are not understood.

Scientific uncertainty

The Sigma values associated with the 2019 spawning biomass (calculated from the normal approximation and converted to the log-standard deviation of a lognormal distibution) was 0.35, well below the minimum 1.0 value associated with Category 2, the most likely classification for this assessment.

Decision Table

The catchability of the WCGBT Survey was chosen as the axis of uncertainty during the STAR panel given the importance of this value in determining the scale of the population and the influence of the prior distribution on this quantity. The high state of nature had $log(q) = -0.766$, $q = 0.465$ and was chosen based on 1.15 units of standard deviation in the estimated $log(q)$ parameter from the base model. The 2019 spawning biomass for the high state of nature was close to the 87.5% quantile of the base model. The low state of nature had $log(q) = 0.223$, $q = 1.250$ and was chosen to approximate the 12.5% quantile of the 2019 spawning biomass in the base model as the method of using 1.15 units of standard deviation was closer to the 25% quantile.

Based on input from the Groundfish Management Team representative to the STAR panel, the catch streams chosen for the decision table were a constant catch of 250 mt per year (based on recent low catch values), a constant catch of 494 mt per year (based on the status-quo harvest limits), and the ACL = ABC from the base model assuming a Category 2 sigma and P* = 0.45.

Projected Landings, OFLs and Time-varying ACLs

Potential OFLs projected by the model are shown in Table g. These values are based on an SPR target of 50%, a P* of 0.45, and a time-varying Category 2 Sigma which creates the buffer shown in the right-hand column. The OFL and ACL values for 2019 and 2020 are the current harvest specifications (also shown in Table f) while the landings for 2019 and 2020 represent the average landings over the most recent 5 years (2014–2018).

Table g: Projections of landings, total mortality, OFL, and ACL values. For 2019 and 2020, mortality estimates were provided by the Groundfish Management Team based on recent trends in catch. For 2021 and beyond, estimated total mortality is assumed equal to the ACL in each year.

Year	Landings (mt)	Estimated total mortality (mt)	OFL (mt)	ACL (mt)	Buffer
2019	225.2	241.3	541.0	494.0	
2020	225.3	241.3	541.0	494.0	
2021	1374.8	1476.8	1689.6	1476.8	0.874
2022	1290.6	1389.0	1605.8	1389.0	0.865
2023	1224.8	1320.5	1540.8	1320.5	0.857
2024	1174.0	1267.1	1492.4	1267.1	0.849
2025	1134.3	1224.4	1455.9	1224.4	0.841
2026	1100.3	1187.7	1425.8	1187.7	0.833
2027	1070.2	1155.0	1398.3	1155.0	0.826
2028	1039.9	1122.0	1371.6	1122.0	0.818
2029	1010.1	1089.7	1345.3	1089.7	0.810
2030	982.0	1059.3	1319.2	1059.3	0.803

Table h: Summary of 12-year projections beginning in 2019 for alternate states of nature based the axis of uncertainty for the model. Columns range over low, mid, and high states of nature associated with WCGBT Survey catchability values of 0.960 for the low state, 0.668 for the base state, and 0.465 for the high state (where higher catchability is associated with lower stock size). Rows range over different assumptions of catch levels.

			States of nature					
			Low State (q=0.960)		Base State (q=0.668)		High State (q=0.465)	
	Year	Catch	Spawning Biomass	Fraction Unfished	Spawning Biomass	Fraction Unfished	Spawning Biomass	Fraction Unfished
Low catch, 250 mt	2019	241.3	1130	0.629	1999	0.792	2829	0.854
	2020	241.3	1137	0.633	2005	0.794	2834	0.855
	2021	250.0	1145	0.638	2012	0.797	2840	0.857
	2022	250.0	1154	0.643	2019	0.800	2847	0.859
	2023	250.0	1165	0.649	2028	0.803	2856	0.862
	2024	250.0	1177	0.655	2039	0.808	2865	0.865
	2025	250.0	1189	0.662	2049	0.812	2875	0.868
	2026	250.0	1200	0.668	2057	0.815	2882	0.870
	2027	250.0	1208	0.673	2063	0.817	2888	0.872
	2028	250.0	1214	0.676	2067	0.819	2891	0.873
	2029	250.0	1218	0.678	2070	0.820	2894	0.873
	2030	250.0	1223	0.681	2074	0.821	2896	0.874
Middle catch, 494 mt	2019	241.3	1130	0.629	1999	0.792	2829	0.854
	2020	241.3	1137	0.633	2005	0.794	2834	0.855
	2021	494.0	1145	0.638	2012	0.797	2840	0.857
	2022	494.0	1131	0.630	1997	0.791	2825	0.853
	2023	494.0	1119	0.623	1984	0.786	2812	0.849
	2024	494.0	1107	0.617	1971	0.781	2799	0.845
	2025	494.0	1095	0.610	1958	0.776	2786	0.841
	2026	494.0	1082	0.602	1944	0.770	2772	0.836
	2027	494.0	1066	0.594	1929	0.764	2756	0.832
	2028	494.0	1051	0.585	1914	0.758	2740	0.827
	2029	494.0	1038	0.578	1900	0.753	2727	0.823
	2030	494.0	1027	0.572	1890	0.749	2717	0.820
Default harvest, for base state	2019	241.3	1130	0.629	1999	0.792	2829	0.854
	2020	241.3	1137	0.633	2005	0.794	2834	0.855
	2021	1476.8	1145	0.638	2012	0.797	2840	0.857
	2022	1389.0	1040	0.579	1908	0.756	2737	0.826
	2023	1320.5	943	0.525	1812	0.718	2642	0.797
	2024	1267.1	852	0.475	1724	0.683	2554	0.771
	2025	1224.5	768	0.428	1641	0.650	2471	0.746
	2026	1187.7	690	0.384	1563	0.619	2394	0.722
	2027	1155.0	620	0.345	1492	0.591	2323	0.701
	2028	1122.0	560	0.312	1432	0.567	2263	0.683
	2029	1089.6	512	0.285	1385	0.549	2218	0.669
	2030	1059.3	473	0.263	1353	0.536	2187	0.660

Table i: Base case results summary.

Quantity	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Landings (mt)	225.2	225.3	1374.8	1290.6	1224.8	1174.0	1134.3	1100.3	1070.2	1039.9
Total Est. Catch (mt)	241.3	241.3	1476.8	1389.0	1320.5	1267.1	1224.4	1187.7	1155.0	1122.0
OFL (mt)	541.0	541.0	1689.6	1605.8	1540.8	1492.4	1455.9	1425.8	1398.3	1371.6
ACL (mt)	494.0	494.0	1476.8	1389.0	1320.5	1267.1	1224.4	1187.7	1155.0	1122.0
(1-SPR)(1-$SPR_{50\%}$)	0.16	0.22	0.22	0.12	0.30	0.27	0.33	0.23	0.15	
Exploitation rate	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	
Age 2+ biomass (mt)	22838.5	22993.9	23136.9	23191.8	23240.0	23409.4	23327.4	23308.8	23217.2	23278.8
Spawning Biomass	1938.7	1952.3	1960.1	1969.0	1991.1	1990.4	1992.8	1984.9	1987.9	1999.3
95% CI	(507.5-3369.9)	(519.8-3384.9)	(527.3-3393)	(535.8-3402.1)	(556-3426.2)	(556.3-3424.5)	(559.1-3426.6)	(552.5-3417.3)	(555.4-3420.4)	(565.7-3433)
Fraction Unfished	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
95% CI	(0.616-0.92)	(0.624-0.922)	(0.628-0.924)	(0.634-0.926)	(0.648-0.93)	(0.647-0.929)	(0.649-0.929)	(0.645-0.927)	(0.647-0.927)	(0.655-0.929)
Recruits	6617	6637	6649	6662	6694	6693	6697	6685	6689	6706
95% CI	(3044 - 14385)	(3059 - 14402)	(3068 - 14411)	(3077 - 14420)	(3102 - 14448)	(3102 - 14443)	(3105 - 14442)	(3098 - 14426)	(3102 - 14426)	(3115 - 14438)

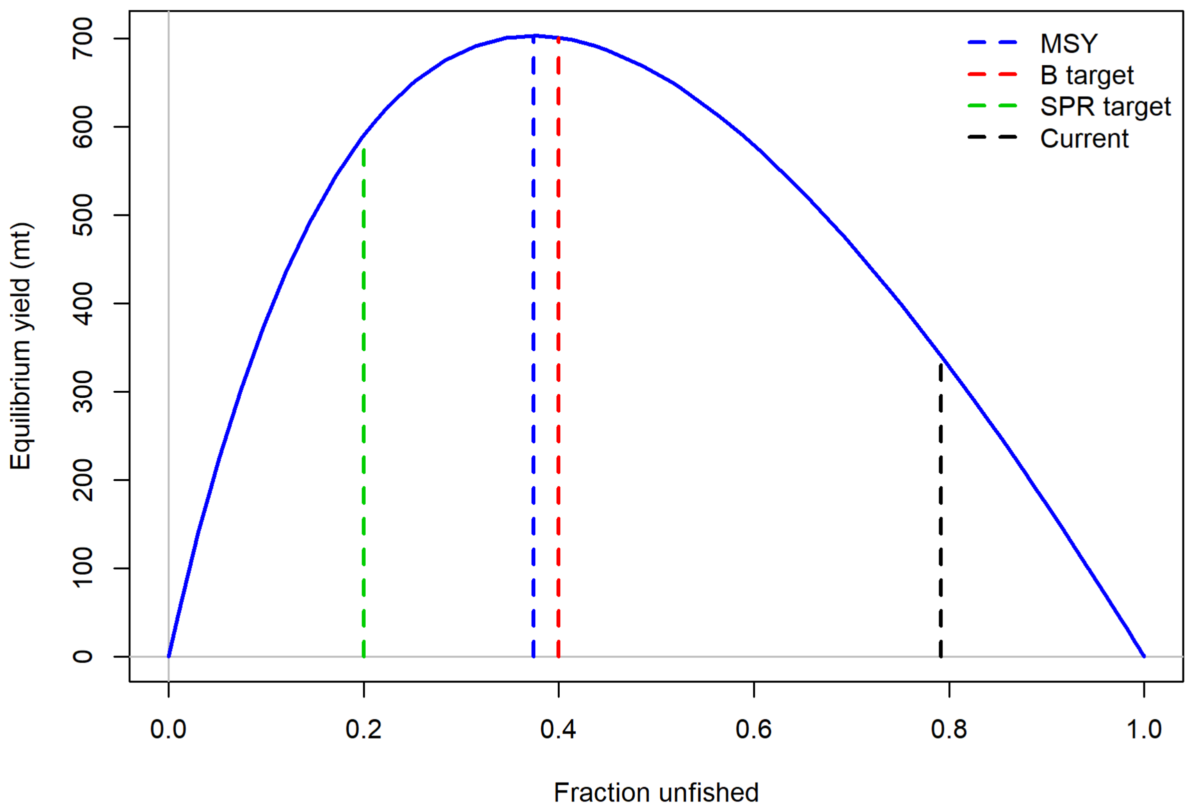

Figure g: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and retention with steepness fixed at 0.4.

Research and Data Needs

We recommend the following research be conducted before the next assessment.

1. **Extend all ongoing data streams used in this assessment.** A longer fishery-independent index from a continued WCGBT Survey with associated compositions of length and age-at-length will improve understanding of dynamics of the stock. Continued sampling of lengths and ages from the landed catch and lengths, mean body weights, and discard rates from the fishery will be even more valuable for the years ahead now that Big Skate are landed as a separate market category and the estimates will be more precise.

2. **Investigate factors contributing to estimated lower selectivity for females than males.** Sex-specific differences in selectivity were included in the base model to better fit differences in sex ratios in the length composition data but the behavioral processes that might contribute to this pattern are not understood and other explanations for the sex ratios are possible.

3. **Pursue additional approaches for estimating historical discards.** The approaches used here were based on averages applied over a period of decades. The catch reconstructions conducted for each state were much more sophisticated, but were applied only to the subset of the catch that was landed. Reconstructed spatial patterns of fishing effort could be used to estimate changes in total mortality over time.

4. **Improve understanding of links between Big Skate on the U.S. West Coast and other areas.** Tagging studies in Alaska indicated that Big Skate are capable of long distance movements. A better understanding of links through tagging in other areas and genetic studies could highlight strengths or weaknesses of the status-quo approach.

5. **Conduct studies of mortality of discarded skates in commercial fisheries.** Estimates of discard mortality for skates in general could be improved.

6. **Improve understanding of catch history and population dynamics of California Skate.** California Skate is the third most commonly occurring Skate in California waters after Longnose Skate and Big Skate and the catch reconstruction indicated that the center of abundance for California Skate is centered around San Francisco, where the fishery was strongest in the early years. If California Skate is found to be at a low biomass compared to historical levels it would have implications for the catch reconstruction of the other two species, as well as suggesting that management of California Skate should be a higher priority.