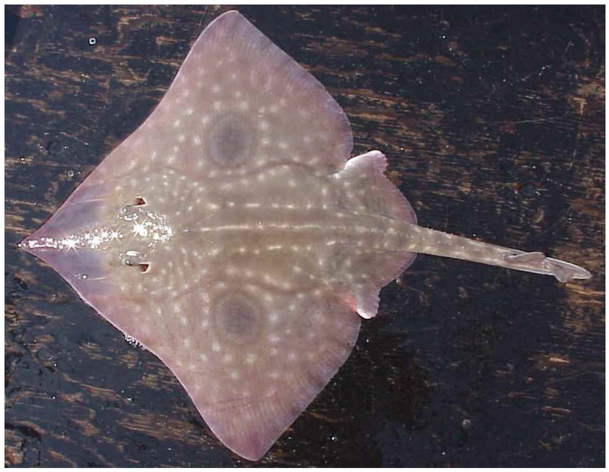
Status of Big Skate (*Beringraja binoculata*) Off the U.S. Pacific Coast in 2019



Ian G. Taylor[1]
Vladlena Gertseva[1]
Andi Stephens[2]
Joseph Bizzarro[3]

[1]Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112

[2]Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2032 S.E. OSU Drive Newport, Oregon 97365

[3]Southwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 110 Shaffer Road, Santa Cruz, California 95060

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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.

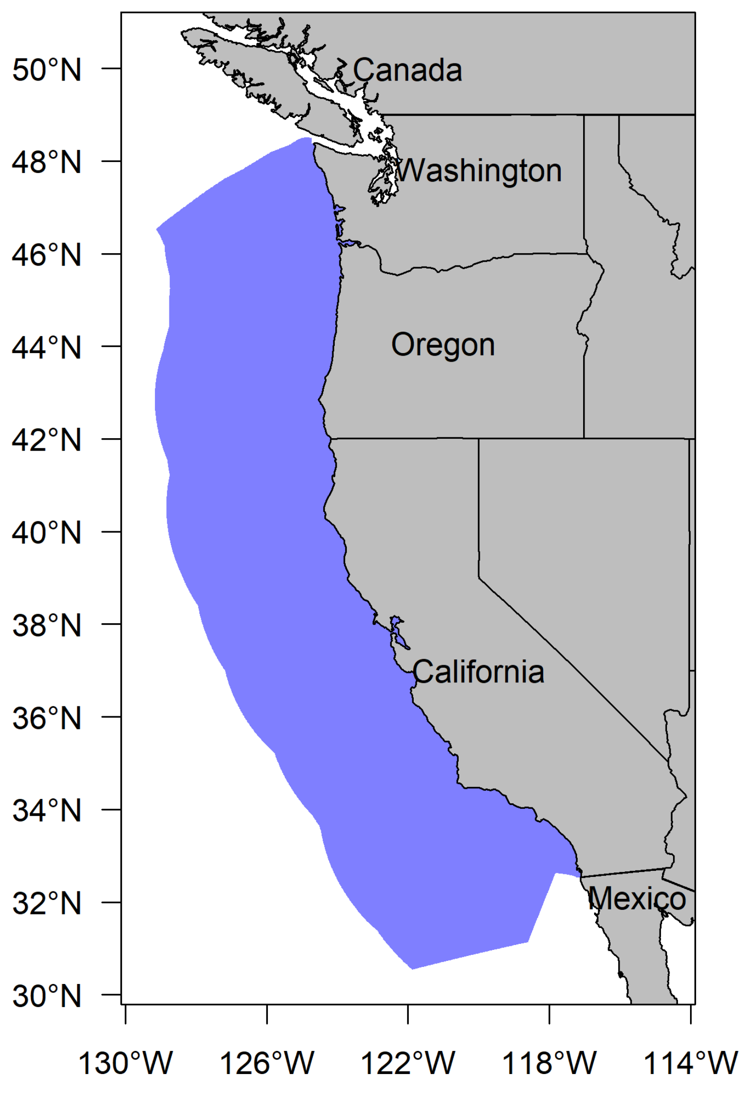

Figure a: U.S. West Coast Exclusive Economic zone covering the area in which this stock assessment is focused.

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

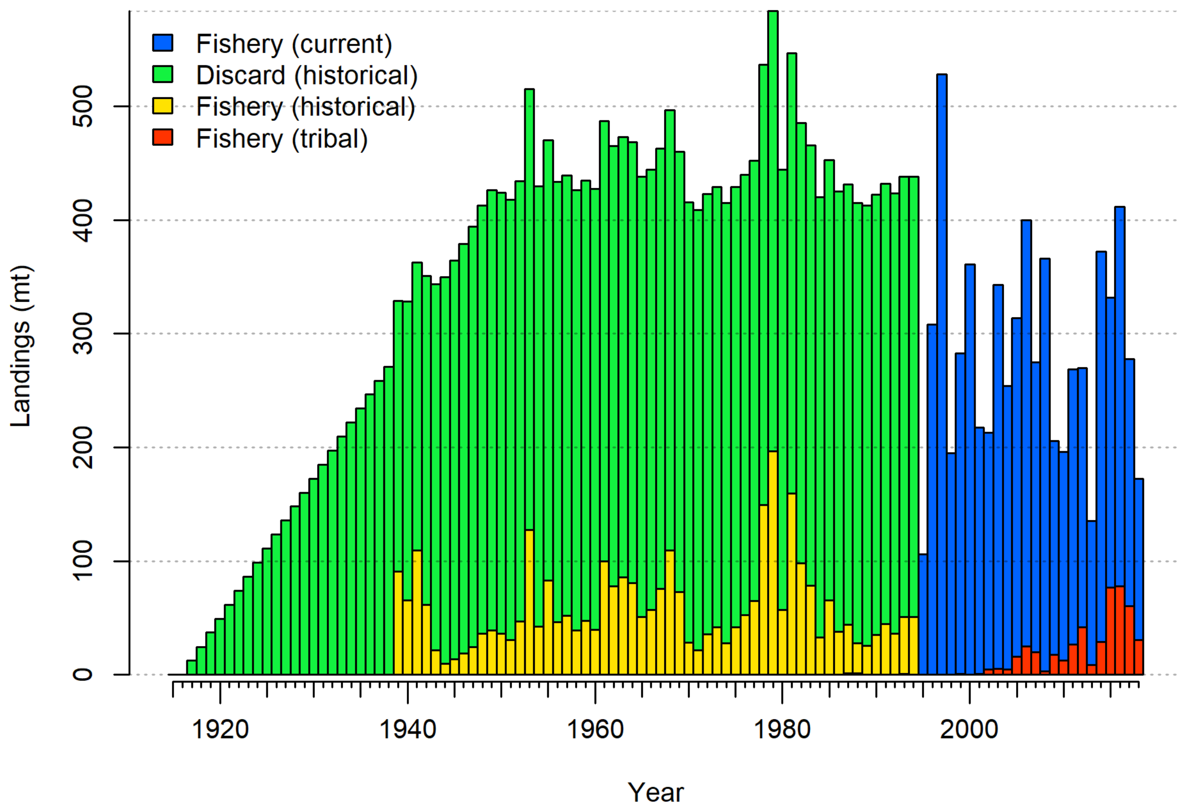

Figure b: Catch history of Big Skate in the model.

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 (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 Califonia 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 stock would 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 not modeled.

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 value used in a previous Longnose Skate stock assessment (Gertseva, V and Schirippa, MJ 2007).

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 0.83) 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.

Stock Biomass

The 2018 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 %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 output and (spawning biomass relative to unfished equilibrum spawning biomass)

Year	Spawning Output (mt)	~ 95% confidence interval	Estimated %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)

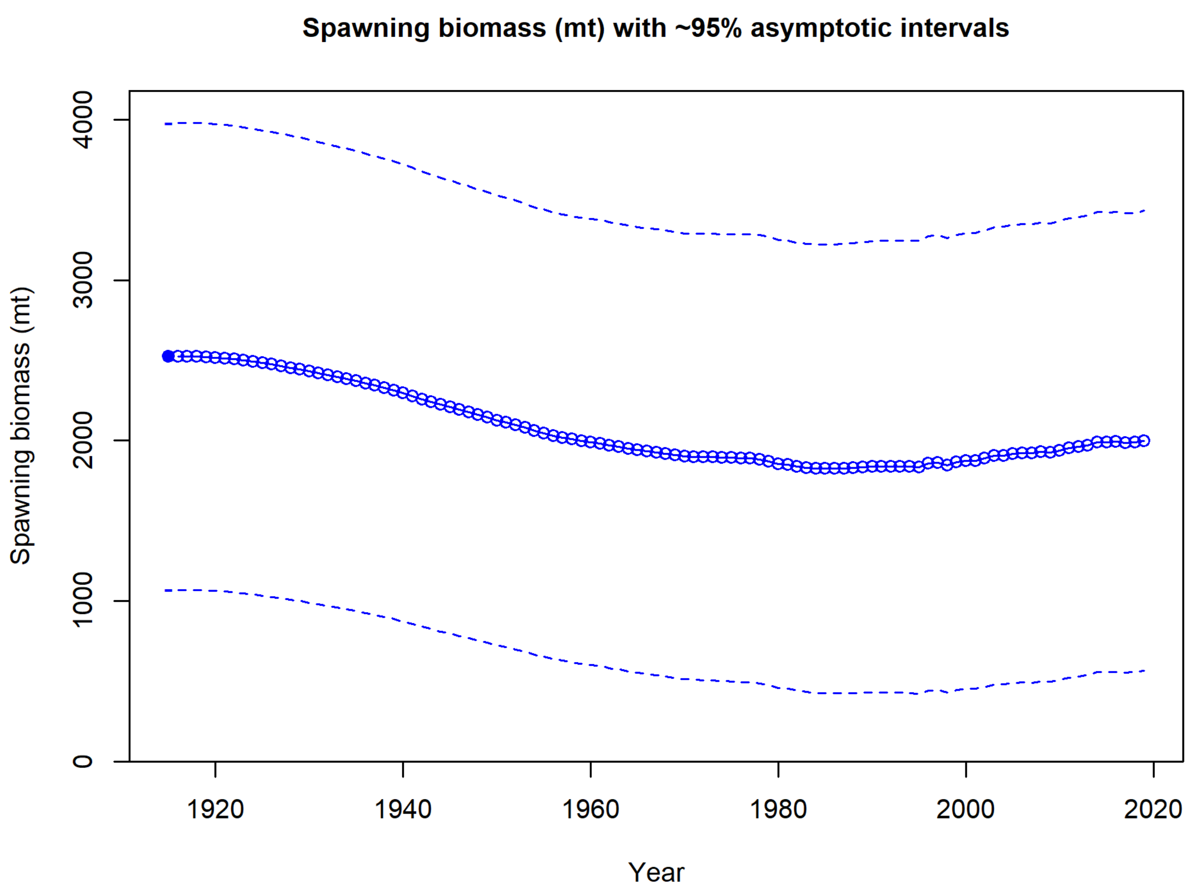

Figure c: Time series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model.

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)

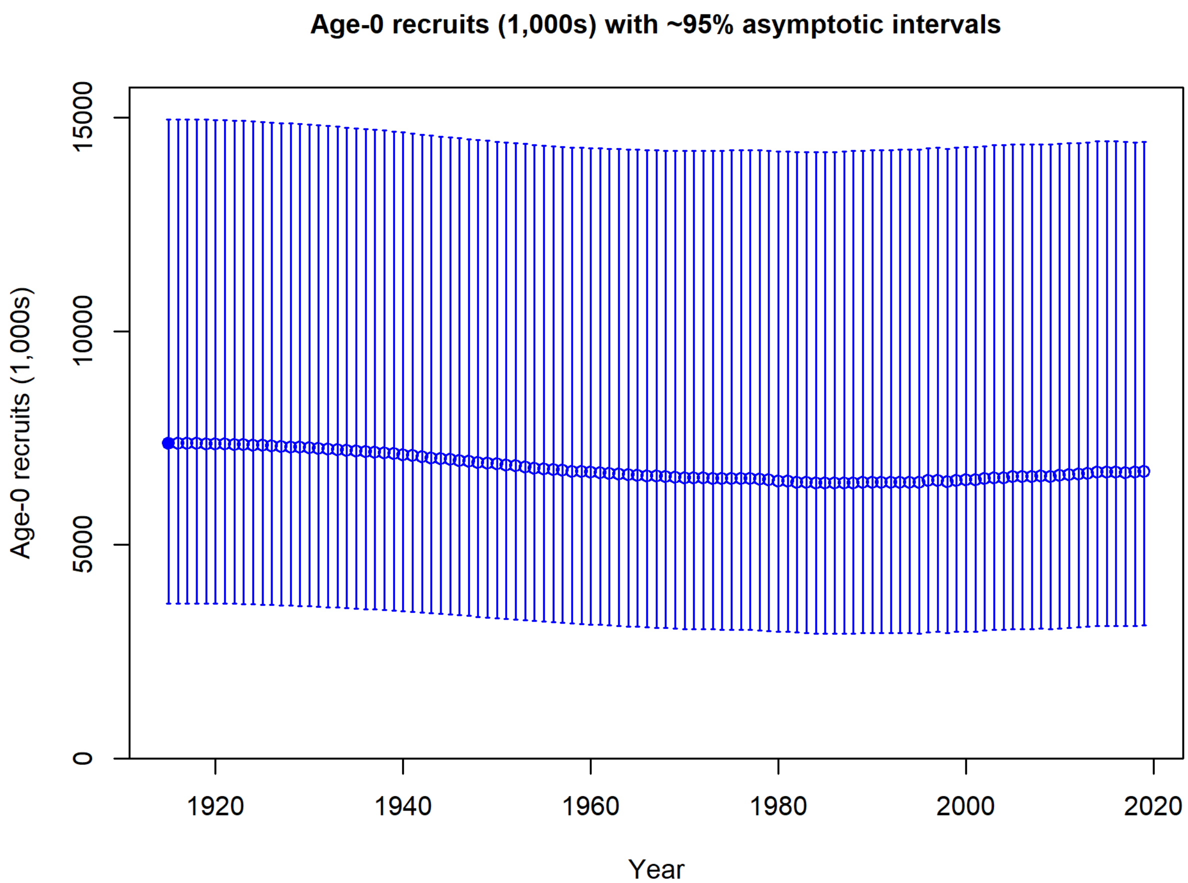

Figure d: Time series of estimated Big Skate recruitments for the base-case model with 95% confidence or credibility intervals.

Exploitation Status

Harvest rates estimated by the base model indicate catch levels have been below the limits that would be associated with the Spawning Potential Ratio (SPR) = 50% limit (corresponding to a relative fishing intensity of 100%) (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 exploitation rate of age 2+ fish has been below 3% 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)

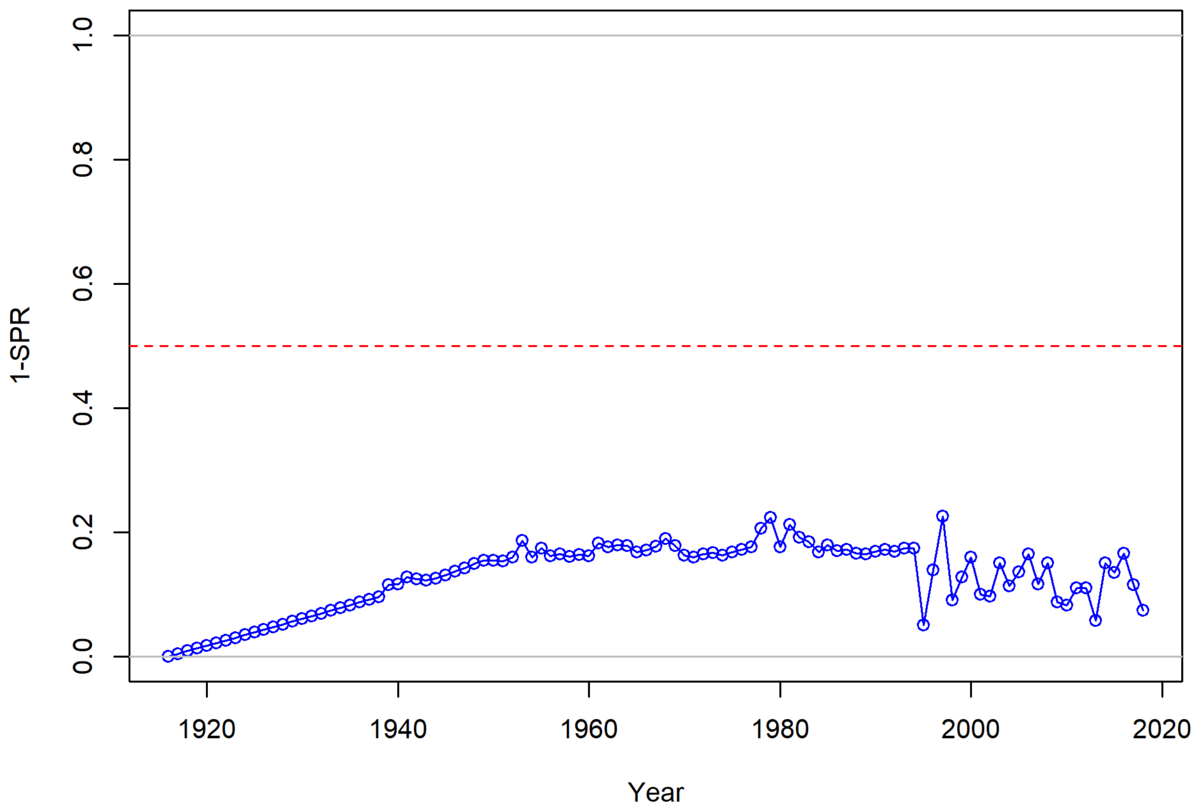

Figure e: Estimated Spawning Potential Ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

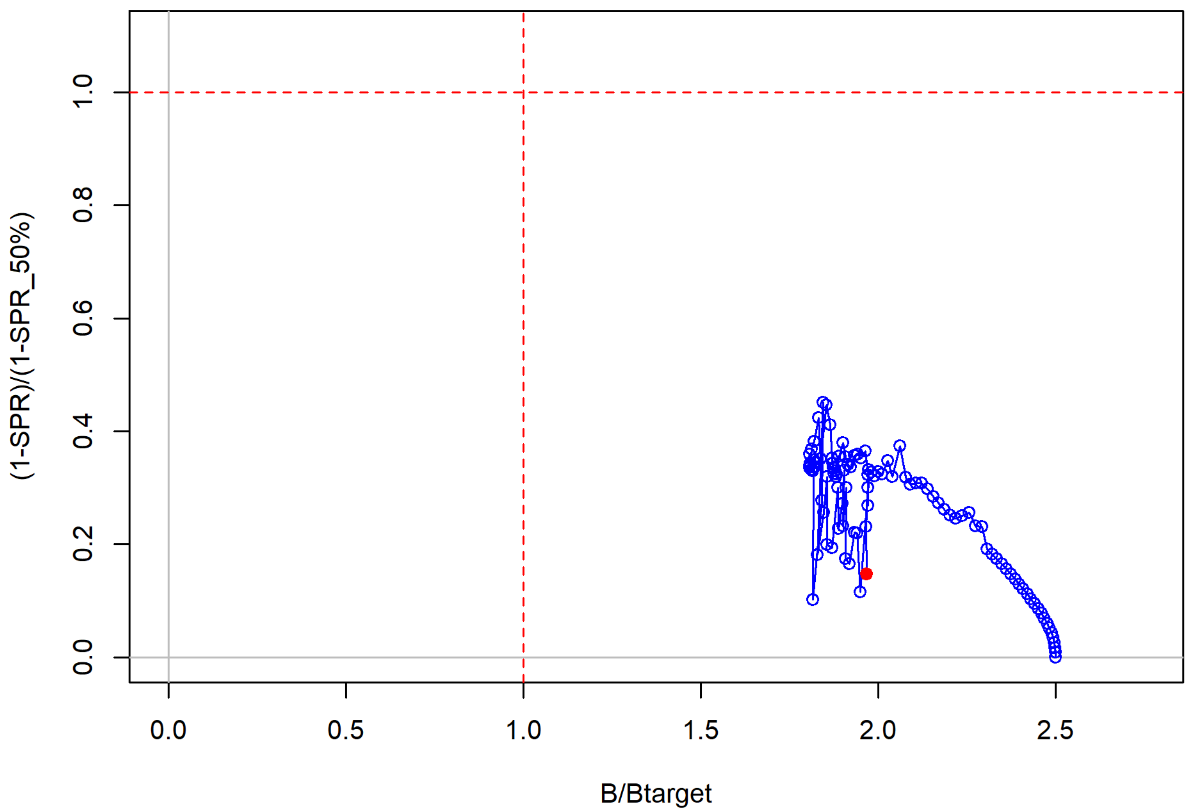

Figure f: Phase plot of biomass vs. fishing intensity.

Reference Points

This stock assessment estimates that Big Skate in the model is above the biomass target ($B_{40\%}$), and well above the minimum stock size threshold ($B_{25\%}$). The estimated %unfished level for the base model in 2019 is 79.2% (95% asymptotic interval: ± 65.5%-92.9%, corresponding to an unfished spawning biomass of 1999 mt (95% asymptotic interval: 566-3433 mt) of spawning biomass in the base model (Table e). Unfished age 2+ biomass was estimated to be 2,936 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 output (mt)	2,525	1,068	3,981
Unfished age 2+ biomass (mt)	2,936	1,363	4,509
Unfished recruitment (R_0, thousands)	7,366	1,974	1,276
Spawning output (2018 mt)	1,988	555	3,420
Depletion (2018)	0.787	0.648	0.927
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 discards estimated in the model with an assumed 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. The prior was developed for the 2007 Longnose Skate stock assessment and has not been revised to account for any differences between the two species.

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.

Decision Table

Template in Table h and associated discussion to be filled in during the STAR panel

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.

Year	Landings (mt)	Estimated total mortality (mt)	OFL (mt)	ACL (mt)	Buffer
2019	313.2	336.3	541.0	494.0	1.000
2020	313.2	336.3	541.0	494.0	1.000
2021	1370.7	1472.8	1677.0	1472.8	0.874
2022	1288.6	1387.2	1595.6	1387.2	0.865
2023	1224.5	1320.4	1532.5	1320.4	0.857
2024	1174.9	1268.1	1485.2	1268.1	0.849
2025	1135.7	1226.0	1449.2	1226.0	0.841
2026	1101.9	1189.5	1419.0	1189.5	0.833
2027	1071.9	1156.8	1391.4	1156.8	0.826
2028	1041.5	1123.8	1364.5	1123.8	0.818
2029	1011.7	1091.5	1338.0	1091.5	0.810
2030	983.7	1061.1	1311.7	1061.1	0.803

Table h: Summary of 10-year projections beginning in 2020 for alternate states of nature based on an axis of uncertainty for the model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. An entry of ”–” indicates that the stock is driven to very low abundance under the particular scenario.

			States of nature					
			Low State		Base State		High State	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
Default harvest, for Low State	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Default harvest, for Base State	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Default harvest, for High State	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-
Average Catch	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-
	2021	-	-	-	-	-	-	-
	2022	-	-	-	-	-	-	-
	2023	-	-	-	-	-	-	-
	2024	-	-	-	-	-	-	-
	2025	-	-	-	-	-	-	-
	2026	-	-	-	-	-	-	-
	2027	-	-	-	-	-	-	-
	2028	-	-	-	-	-	-	-

Table i: Base case results summary.

Quantity	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Landings (mt)	313.2	313.2	1370.7	1288.6	1224.5	1174.9	1135.7	1101.9	1071.9	1041.5
Total Est. Catch (mt)	336.3	336.3	1472.8	1387.2	1320.4	1268.1	1226.0	1189.5	1156.8	1123.8
OFL (mt)	541.0	541.0	1677.0	1595.6	1532.5	1485.2	1449.2	1419.0	1391.4	1364.5
ACL (mt)	494.0	494.0	1472.8	1387.2	1320.4	1268.1	1226.0	1189.5	1156.8	1123.8
(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 Output	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)
Depletion	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)

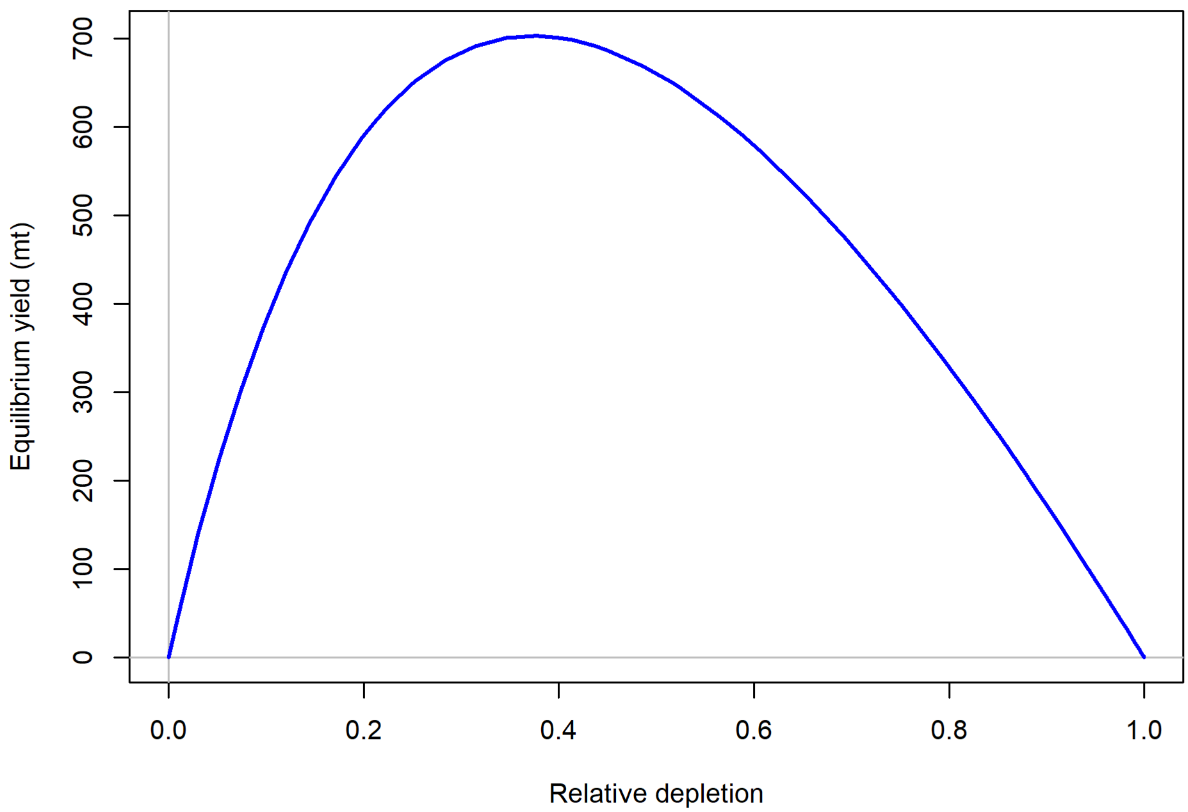

Figure g: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and retention with steepness fixed at 0.4.

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. **Investigate the distribution of Big Skate shallower than the 55 m limit of the WCGBT Survey.** This would help with interpretation of the biomass estimates from the survey and potentially refining the associated prior on catchability.

4. **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.

5. **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.

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

7. **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.

Gertseva, V and Schirippa, MJ. 2007. Status of the Longnose Skate (*Raja rhina*) off the continental US Pacific Coast in 2007. Pacific Fishery Management Council, Portland, OR. Available from {http://www.pcouncil.org/groundfish/stock-assessments/}.