Agenda Item H.5
Attachment 6
September 2019

Longnose Skate Stock Assessment Review (STAR) Panel Report

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June 3-7, 2019

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Overview

A Stock Assessment Review (STAR) panel met during 3-7 June 2017 at the Northwest Fisheries Science Center (NWFSC) auditorium in Seattle, Washington to review a draft stock assessment for longnose skate (*Beringraja rhina*). The assessment had been prepared by a stock assessment team (STAT) led by Dr. Vlada Gertseva of the NWFSC and was documented in Gertseva et al. (2019). The Panel operated under the Pacific Fishery Management Council's (PFMC) Terms of Reference for stock assessment reviews (PFMC 2019a). This same panel also reviewed a draft assessment for big skate (*Beringraja binoculata*).

Of the eleven skate species present in the northeast Pacific off the US West Coast, longnose skate comprises the majority of fishery and survey catches. They are most common at depths ranging from 150 to 400 m and tend to be found deeper than big skate, which are the second most commonly caught skate species off the US West Coast. The longnose skate off the US West Coast are treated in the assessment as a unit stock, because there is no information from tagging or genetics studies to support a more complicated structure.

An individual female longnose skate deposits her egg-cases onto the sea floor at intervals over a period of months and egg deposition at the stock level appears to occur continuously throughout the year. The eggs incubate within the egg cases for several months. Egg cases from longnose skate contain only a single embryo; whereas egg cases from big skate contain about two embryos on average. Upon hatching, the new-born skate (both species) is similar in appearance to an adult (i.e., no metamorphosis from larval to adult form).

Maximum age of longnose skate is reported as 26 years for British Columbia and 25 years for the Gulf of Alaska. The assessment assumes a maximum age of 26 years. Longnose skate can grow to attain total lengths (TL) of more than 150 cm. Length at 50% maturity was taken as 101.5 cm (TL) in the assessment. The STAT described the species as being an "equilibrium strategist" because it has "a low fecundity and late maturation, and, thus, low intrinsic rate of increase."

Prior to the mid-1990s the landings of longnose skate were relatively limited, apparently due to a lack of market opportunities; the vast majority of the skates that were caught were discarded at sea. There was a dramatic change in market conditions with the annual landed catch increasing from an average of 140 mt during 1985-1995 (coastwide) to an average of 1390 mt during 1996-1999. Peak annual landings were slightly greater than 2000 mt in 1997. Regular at-sea observations of longnose skate discards did not begin until 2002. Discard observations in earlier years were sporadic, with the first occurring in 1985.

Longnose skate off the US West Coast were assessed once previously, in 2007 using the Stock Synthesis 2 software (Gertseva and Schirripa 2008). During the 2007 STAR Panel meeting the assessment model underwent several changes.

- It was simplified to have one sex and constant recruitment.
- The 2004 AFSC Triennial survey index value was identified as being anomalously high.
- The Panel noted that the size-at-age data suggested almost linear growth.
- The assumed value for natural mortality (M) was changed from 0.1^{-y} to 0.2^{-y}.
- The Panel noted that the estimate of length at 50% maturity (from Thompson 2006) was significantly higher than an estimate from a B.C. study (McFarlane and King 2006).

- Alternative longnose skate catch series (landings plus dead discards) were developed to reflect the uncertainty in the catch time series.
- During the 2007 review, the Panel and STAT developed an informative prior distribution for the catchability coefficient (survey-*Q*) associated with the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS), which the STAT had assumed to be 1.0 in the pre-STAR assessment model. The "overall best guess" for the survey-*Q* was 0.83 with bounds of (0.53, 1.43), corresponding to a normal prior on ln(*Q*) with mean = -0.188 and standard deviation = 0.187.

The 2019 STAR Panel concluded that the final base model developed during the 2019 STAR meeting is appropriate for use by management and constitutes the best available science. Due to the paucity of age-compositional data and consequent lack of annual recruitment deviations, the Panel considers this to be a category 2 assessment. Further, the biomass indices in the model were only weakly informative regarding scale and trends were not well fit by the model. The main sources of information determining $\ln(R_0)$ were tension between the length compositional data and the priors distributions for *M* and WCGBT Survey-*Q*. The Panel applauds the STAT team for their well-structured presentation of the assessment and the competent work completed before and during the STAR meeting.

Summary of Data and Assessment Models

For the most part, the new assessment for longnose skate follows the same basic structure as used in the 2007 assessment: single coastwide stock; combined-sex model; growth is estimated; no recruitment deviations; and an informative prior distribution on the survey-*Q* for the WCGBTS, which is the primary source of fishery-independent information. Natural mortality is estimated within the Stock Synthesis model using an informative prior, whereas it was fixed in the 2007 assessment. The STAT used the Stock Synthesis (SS) version 3.30.13 software; the 2007 assessment used SS version 2.00e.

Catch series and fishing fleet structure

A major change from the 2007 assessment was the use of a new catch reconstruction approach, reviewed during a Council-sponsored workshop in March (PFMC 2019b). The 2007 assessment derived historical catch estimates by dividing reported annual landings by an assumed retention fraction. The new assessment derived historical catch estimates (for years prior to 2009) on the basis of a linear regression model (R^2 = 95.7%) developed from West Coast Groundfish Observer Program (WCGOP) estimates of total annual mortality of longnose skate (landings plus dead discards) versus total annual mortality estimates of Dover sole for the period 2009-2017.

Fishing removals in the model are taken by four fishing fleets: the current commercial fishing fleet (1995-2018); the tribal fishing fleet (1987-2018); an historical discard fishing fleet (up to and including 1994); and an historical landed-catch fishing fleet (up to and including 1994). In the 2007 assessment there was a single fishing fleet. The model assumes that there is full retention of longnose skate by the tribal fishing fleet

Discards data

The WCGOP provides data on at-sea discards by the commercial fisheries. Although the program was implemented in 2001, prior to 2009 there was no requirement to sort longnose skate from other skate species and landings of skates were reported on fish tickets as unspecified skate. Consequently, prior to 2009 the WCGOP, which primarily collects information on fish discarded at sea, could not provide estimates of discard rates because there were no reported landings of longnose skate to match with the discards of longnose skate. However, the WCGOP provided length compositions for discarded longnose skate (2006-2017) that informed the length-based retention function estimated by the model.

Two earlier studies also provided information on skate discard rates, the study by Pikitch et al. (1988) collected at-sea information during 1985 to 1987 from the Columbia statistical area and ODFW's Enhanced Data Collection Project collected similar information during 1995 to 1999 from trawl vessels operating off Oregon, primarily on vessels targeting the DTS complex (Dover sole, thornyheads, and sablefish).

The assessment model assumes 50% survival of the longnose skate discarded at sea. The WCGOP also assumes 50% survival of longnose skate discarded at sea when it derives estimates of total annual mortality for longnose skate.

Survey indices

The new assessment includes biomass indices from four bottom trawl surveys: the Alaska Fisheries Science Center (AFSC) Triennial shelf survey (every third year, starting with 1980 and ending with 2004, when the survey was conducted by the NWFSC); the AFSC slope survey (1997, 1999, 2000, and 2001); the NWFSC slope survey (annually from 1999 to 2002); the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS or WCGBT survey) (annually from 2003 to 2018). Biomass indices from these same trawl surveys had been included in the 2007 assessment. The trawl survey biomass indices were derived using the Vector Autoregressive Spatial Temporal (VAST) delta-model (Thorson 2019).

The new assessment also included a survey biomass index derived from the International Pacific Halibut Commission (IPHC) bottom longline survey, conducted in 1999 and annually since 2001. The IPHC longline survey, which covered fixed stations in shelf waters off Washington and Oregon, was not considered by the 2007 assessment.

Compositional data

Length compositional data were available from the current commercial fishing fleet landings (1995-2018) and discards (2006-2017), the WCGBT survey (2003-2018), the Triennial shelf survey (1998, 2001, and 2004), the AFSC slope survey (1997 and 1999-2001), and the IPHC longline survey (2014 only). The selection curves for the historical landed catch fishing fleet, the historical discard fishing fleet, and the tribal fishing fleet were all "mirrored" from the current commercial fishing fleet. The selection curve for the NWFSC slope survey was mirrored from the AFSC slope survey. Conditional-age-at-length compositional data (based on limited numbers of fish, less than 350 per year) were available from the WCGBT survey (2003, 2011, and 2012) and the current commercial fishing fleet (2004).

Maturity and weight-length relationships

Length at maturity was calculated from 211 samples collected and scored (based on macroscopic examination) by the WCGBT survey. Weight-at-length data collected from fisheries sampling and by the WCGBT and AFSC Triennial surveys were used to estimate a length-weight relationship for longnose skate. The weight- length relationships were very similar between the two sexes and the sexes were combined in the SS model.

Bridging analysis

The STAT did not present any formal bridging analysis to show the transition from the 2007 assessment to the new assessment. A graphical comparison of the depletion trajectories, presented to the Panel on Day 1 of the review, indicated general similarities between the two assessments' predictions of relative spawning biomass. The 2007 assessment model estimated an unfished spawning biomass (*SB*) of 7034 mt and a 2007 *SB* of 4634 mt (2007 depletion of 65.9%), whereas the corresponding estimates from the pre-STAR assessment base model were 36,088 and 29,380 mt (2007 depletion of 81.4%).

The assessment model

The assessment is a single-sex, length- and age-based age-structured model that estimated dynamics starting in 1916 with the assumption of equilibrium with no fishing prior to the start of the model. The model assumes a spatially homogenous unit stock in the waters off the US West Coast. Annual recruitment deviations were fixed at zero, meaning that annual recruitment values were taken directly from the recruitment-spawning biomass relationship, which was a Beverton & Holt curve with steepness fixed at 0.4. Natural mortality was estimated within the model using an informative prior based on Hamel (2015) and a maximum age of 26 years. Catchability for the WCGBT survey was estimated within the model using the prior developed as part of the 2007 assessment. The parameters controlling growth (in length), including its variability, were freely estimated in the model.

For years prior to 1995, dead discards of longnose skate were derived outside of the model using the relationship between annual total mortality of longnose skate and annual total mortality of Dover sole. For the years from 1995 forward the model produced annual estimates of the discard fraction and the associated dead discards, informed by at-sea observations of discard fractions and a logistic, length-based retention curve. A discard mortality rate of 50% was assumed. Length-based selectivity for all four fishing fleets was based on the selection curve estimated for the current fishing fleet, informed by length compositions of retained and discarded fish. The model used the double-normal function for fishery selectivity and assumed the curve was asymptotic in form. The model allowed for constrained annual deviations (1995-2017) in the parameter controlling the upper asymptote of the logistic retention function.

The assessment model used the Dirichlet-Multinomial likelihood function (Thorson et al. 2017), with one estimated parameter for scaling each composition data source (for weighting the compositional data) and estimated an extra standard deviation parameter for the Triennial survey.

The base model underwent a number of changes as a result of explorations during the STAR meeting. The final agreed base model was well structured, was thoroughly investigated by the STAT, and is the best currently available for the formulation of management advice.

Treatment of uncertainty

The final base model included estimates of uncertainty for estimated parameters and derived quantities such as spawning output and depletion. The STAT also explored uncertainty of the base model results using likelihood profiles across the key parameters M, steepness (h), $\ln(R_0)$, and survey-Q (for the WCGBTS). The likelihood profile for $\ln(R_0)$ showed relatively small changes in total log-likelihood across a fairly wide range of values for $\ln(R_0)$, indicating the available data were relatively uninformative regarding population scale, with all the information coming from tension between the length-composition data (favoring lower values for $\ln(R_0)$) and the survey indices and priors on M and survey-Q (favoring higher values for $\ln(R_0)$).

Requests by the STAR Panel and Responses by the STAT

The pre-STAR draft assessment document was very complete and the STAT's opening presentation to the STAR Panel anticipated many questions regarding the draft model's results. This allowed for an efficient and effective review that could quickly identify the most important questions and allocate review time accordingly. The STAT provided thorough responses to all requests.

Requests below are provided sequentially by the day of the request. Responses from the STAT (which were generally delivered the following day) are given below each request. The bolded sentences within each Response (if any) are major conclusions drawn by the STAR Panel that were considered important in the construction of the final base model. Figures from the responses are also often given.

Request No. 1*: Provide a table of historical landings, discards, what was inputted into SS [Stock Synthesis], and what was estimated in SS.*

Rationale: The current assessment document does not provide this detail.

STAT Response:

The STAT provided a figure clarifying that (a) landings and dead discards during the "historical period" (1916-1994) were hard-wired (not estimated by SS), (b) landings during the modern era (1995-2018) were hard-wired, (c) discards during the modern era were based on discard rates estimated within the SS model, and (d) the model assumed a 50% discard mortality rate in both eras.

Request No. 2*: Provide runs with survey q estimated with diffuse priors (CV = 0.25 & 0.5) and recruitment deviations estimated. Provide plots of the priors of the base model and the runs with alternative CVs.*

Rationale: [The] current prior seems too tight and seems to be constraining the model. Recruitment deviations may provide plausible fits to the increasing survey indices.

STAT Response:

The STAT provided the runs requested. The posterior of the survey-Q closely matched the prior of the survey-Q for all considered runs (e.g., Figure 1, left panel). This is undesirable because it means that no information exists to inform survey-Q and the prior is determining the estimated value (and thereby the biomass scale for the stock). Even when changing the prior on q and estimating recruitment deviations, the changes in estimated spawning output over time among models were not large (Figure 1, right panel).

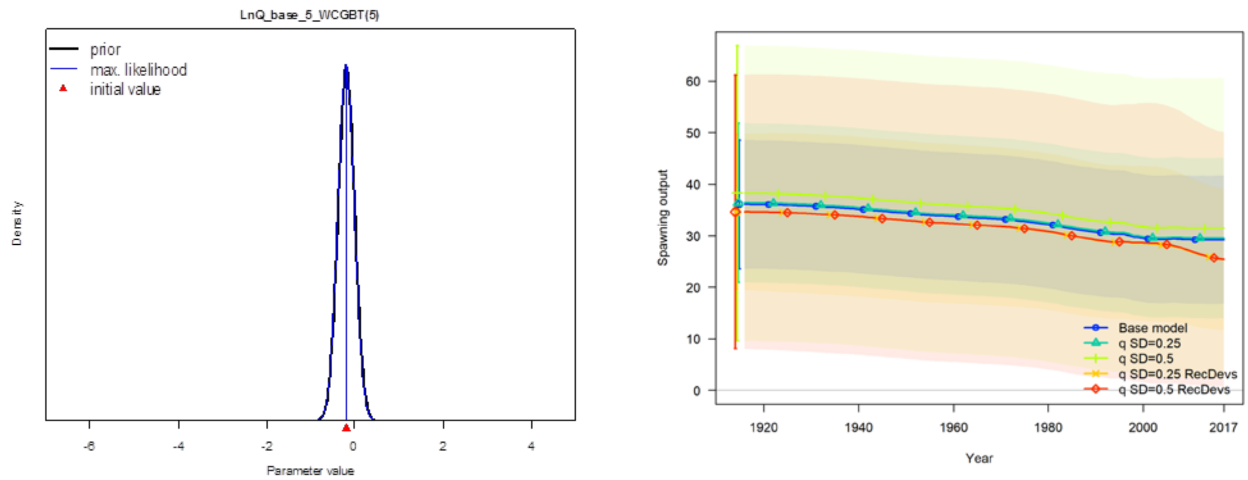

Figure 1. Comparison of prior and posterior distributions for survey-*Q* *(left panel), illustrating the lack of information in the data regarding this key parameter. Changing the CV on the survey-*Q* prior had little influence on the assessment results (right panel), nor did allowing recruitment deviations.

The inability to fit the increasing trend in the survey data probably arises from a conflict among data sources. The survey length composition data change very little over the period for which observations are available (1995 to present), despite a large drop in dead catch from the late 1990s to the 2000s. This implies that the fishery is not impacting the population structure to any great degree. However, the survey index of abundance increases by 31% from 2003 to 2018 as catches decline by roughly 27 tons per year (Figure 2).

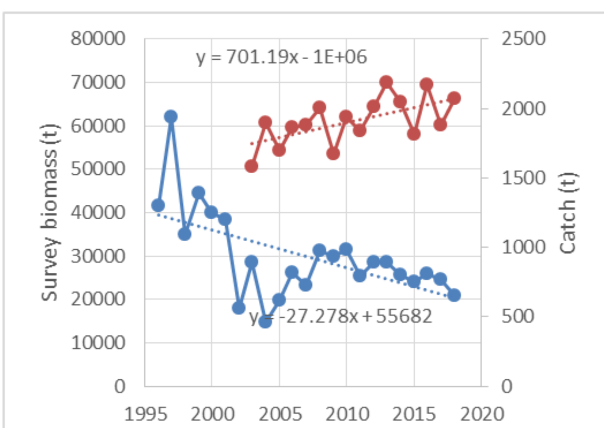

Figure 2. Increasing trends in survey biomass (in red) versus decreasing trends in annual dead catches.

The current prevailing paradigm in stock assessment is to down-weight length composition data in order to fit survey indices of abundance (e.g., see Francis 2011). However, the assessments presented to this panel display the opposite character: they eschew the survey indices in favor of the length composition data. This is a critical modeling hurdle that should be addressed in future iterations of this assessment. Consideration of the expected influence of the somewhat peculiar recruitment dynamics (constant recruitment throughout the year) on observed length composition data might offer a potential research path.

Request No. 3*: Correct the table of sensitivities to reflect actual spawning biomasses. Add estimates of MSY and more detailed likelihood components (e.g., by fleet). Add details of sensitivity runs that alternatively leave out datasets (i.e., all indices, all length comps., all age comps., and mean weights).*

Rationale: Provide greater and more consistent details of sensitivities that have been run.

STAT Response:

An updated table as requested by the panel was provided in an Excel file (see Table 14 in the post-STAR assessment document). Leaving out data sets in turn did not reveal particular sensitivity to any one set. The greatest sensitivity was to the survey selectivity assumption (asymptotic) and the WCGBT survey-*Q* (prior/no prior). *SPR* reference points were robust to all sensitivity cases while biomass quantities (SB_0 and SSB_{2019}) were highly sensitive to parameters affecting scale (survey-*Q* and selectivity).

Request No. 4*: Provide a correlation matrix of estimated parameters for the current base model.*

Rationale: [There was] concern that the priors may be affected [by] other parameter estimates and [the Panel wanted] to explore whether there are redundant parameters.

STAT Response:

The STAT team presented a slide with correlations between some parameters and natural mortality. Maximum size, fishery selectivity, and unfished recruitment were closely correlated to natural mortality. Examination (following the STAR Meeting) of the final base model's parameter correlation matrix indicated a strong correlation between ln(R_0) and ln(WCGBT Survey-*Q*) (r = -955). The value of the second most extreme correlation coefficient was -0.898.

Request No. 5*: Explore the selectivity assumption for the West Coast Bottom Trawl Survey – force all surveys to be asymptotic and provide fits to the data and comparison plots.*

Rationale: To explore the effects of domed selection for the West Coast Bottom Trawl Survey.

Context: Dome-shaped selectivity produces "cryptic" (unobservable) biomass that can inflate the biomass estimates and understate the impact of the fishery on the population.

STAT Response:

Forcing the surveys to be asymptotic resulted in a stock that was further depleted than the base model (~85% vs. 70%; Figure 3). However, the models with asymptotic selectivity did not fit the data as well as those with dome-shaped selectivity (change in total log-likelihood of 18.4 units). This, coupled with the fact that the largest individuals captured in the fishery are larger than the largest individuals captured in the survey led the STAT team to argue that dome-shaped selectivity is appropriate for this assessment.

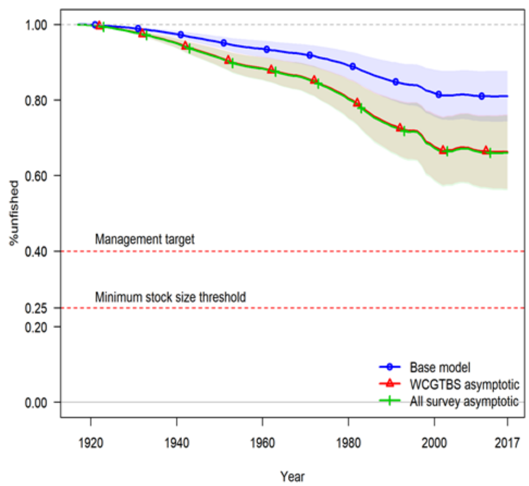

Figure 3. Comparison of models with asymptotic selection for only the WCGBTS survey or for all surveys with the base model (domed survey selection).

Request No. 6: *Provide evidence of anomalously high abundance indices in the 2004 AFSC survey for flatfish species.*

Rationale: To confirm the [STAT's] assertion that flatfish species were similarly affected [in the 2004 survey].

STAT Response:

The STAT provided a figure (not shown here) illustrating that the 2004 Triennial index values were unusually high (the highest observed in the Triennial series) for Dover sole, petrale sole, and English sole (both north and south).

Request No. 7: *Provide spatial residual plots for the VAST indices.*

Rationale: Diagnostic to confirm there were no strange [spatial] residual patterns and lack of fit.

STAT Response:

The STAT provided a figure (not shown here) with spatial plots of annual Pearson residuals by knot (position) for the encounter probability and the magnitude of the positive catch rates. Visual inspection of the plots did not indicate any particular aberrations other than a possible tendency for strong negative residuals to occur off Southern California.

Request No. 8: *Provide a growth cessation model and include likelihood components to understand the source of informative data. Provide a growth cessation model that explores alternative growth patterns with differing degrees of transition. Provide a plot of mean observed length at age vs. fitted length at age for the growth cessation model with fully estimated parameters as in the current base model.*

Rationale: To better understand the sources of information that are leading to the estimated growth model.

Context: The base model for the big skate assessment used a "growth cessation model" as a simple approach for mimicking the pattern apparent of essentially linear growth in the plots of length versus age. For the sake of consistency, it would be advantageous if both skate assessments employed the same approach to modeling growth. The growth cessation model, which is a recent addition to the options for modeling growth in the Stock Synthesis software, is described in Maunder et al. (2018).

<u>STAT Response</u>:

The STAT provided a tabular comparison with the base model of two different forms of the growth cessation model that differed in the rapidity of the transition from the increasing linear segment to the linear horizontal segment. The version with a rapid transition provided a marginally improved fit to the data (a decrease of 2.6 log-likelihood units).

The STAT also provided a graphical comparison (Figure 4) of the fits to the observations of mean length-at-age by two models. One was for the pre-STAR base model, which used iterative approaches for estimating data weights: the McAllister-Ianelli approach for the current fishery age-composition data and IPHC length-composition data, and the Francis approach for all other compositional data. The other growth curve was from a new version of the pre-STAR base model that used the Dirichlet multinomial formulation to estimate data weighting parameters. The STAT informed the Panel that this new model formulation resulted in a more reasonable estimates of natural mortality (M = 0.22, corresponding to a maximum age of 22 years, versus M = 0.13 from the pre-STAR base model, corresponding to a maximum age of 40 years) and that the total log-likelihood profile over ln(R_0) was no longer dominated by the prior for survey-Q.

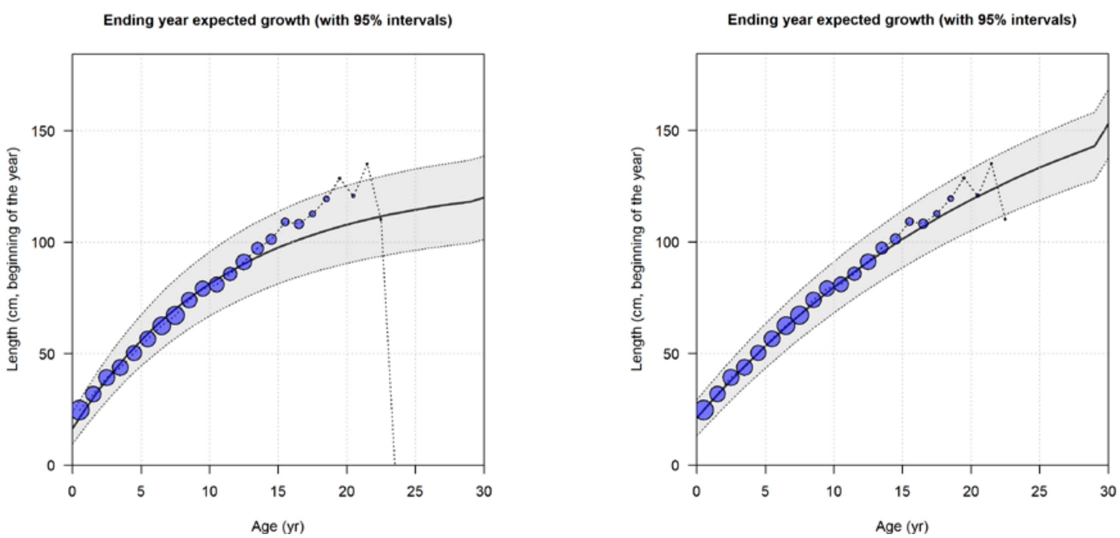

Figure 4. Plots of the observed mean lengths-at-age versus the model-predicted growth. The left panels shows the growth predicted by the pre-STAR base model; the right panel shows the predicted growth from a new version of the pre-STAR base model that used the Dirichlet multinomial for data weighting.

The STAR Panel agreed that the revised base model seemed a promising candidate for the final base model.

Request No. 9*: Provide a model that has a finer time blocking of catch multipliers for historical discards.*

Rationale: To better understand how assumed catch history influences survey index trends.

STAT Response:

The STAT produced a tabular summary (Table 1) of likelihood components, key estimated parameters, and key derived quantities for the pre-STAR base model and two alternative models, one with estimated historical catch multipliers by decade and the other with the decadal catch multipliers plus one additional time-block that split the 1980s between 1984 and 1985.

Table 1. Comparison of the pre-STAR base model with two alternatives that estimated catch multipliers to the historical catches (pre-1995).

	Base model	Catch multiplier by decade	Catch multiplier additional block
TOTAL_like	114.976	114.911	114.94
Survey_like	-55.9341	-56.131	-56.0374
Length_comp_like	201.395	201.414	201.405
Age_comp_like	37.7117	37.6523	37.6743
Parm_priors_like	0.51311	0.599081	0.55704
NatM_p_1	0.133377	0.133186	0.133312
L_at_Amin	16.4003	16.4104	16.4071
L_at_Amax	118.814	118.888	118.863
VonBert_K	0.0891087	0.088909	0.088989
SD_young	3.58567	3.58707	3.5872
SD_old	9.52764	9.49868	9.50856
SR_LN(R0)	9.22114	9.2208	9.22109
SR_BH_steep	0.4	0.4	0.4
SR_sigmaR	0.3	0.3	0.3
LnQ_base_5_WCGBT(5)	-0.204211	-0.198523	-0.20114
Catch_Mult		0.998362	0.998332
Catch_Mult		0.995497	0.995413
Catch_Mult		0.990461	0.990277
Catch_Mult		0.984708	0.984412
Catch_Mult		0.977652	0.977212
Catch_Mult		0.955169	0.953966
Catch_Mult		0.776848	0.942019
Catch_Mult			0.85202
Catch_Mult		0.953831	0.953708
Dead_Catch_MSY	2107.78	2111.27	2109.18
Ret_Catch_MSY	1881.54	1885.4	1883.19
SSB_Virgin_thousand_mt	36.087	36.28	36.175
SSB_2018_thousand_mt	29.246	29.075	29.143

Bratio_2019	0.811673	0.802901	0.806997
SPRratio_2018	0.192491	0.193812	0.193233

The addition of the multipliers on the historical catches had little effect on the model results. The change in log-likelihood was less than one unit, implying little information in the observed data to support a different series of historical catches. The STAT provided a figure (not shown here) indicating that the models with the catch multipliers had no visible effect on the model fits to the WCBTS index.

Request No. 10*: Provide a table of derived reference points (e.g., FMSY) across a range of fixed steepness values.*

Rationale: To better understand the influence of the steepness assumption on management reference points.

STAT Response:

Steepness, which is fixed to 0.4 in the assessment, was discussed quite a bit by the panel. This relatively low value is based on the notion that skates are low fecundity species that are vulnerable to overfishing. However, the available science supporting this idea is limited and there are very few (if any) time series of stock (*S*) and recruitment (*R*) estimates for skate species. However, a steepness value of 0.4 seems low. A steepness value of 0.2 means that there is a linear relationship between *S* and *R* going through (0,0), and, consequently, no level of fishing would be sustainable in the Stock Synthesis model because the stock-recruitment relationship is the only possible source of density dependence; there is no possibility of density-dependence in growth, maturity or natural mortality. The assumed value for steepness is very close to the limiting value of 0.2. The STAT provided results from a sensitivity analysis (Table 2).

Table 2. Sensitivity of the base model to steepness.

Steepness	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
SSB_unfished	38,832	36,087	35,098	34,685	34,499	34,414	34,378	34,367
Totbio_unfished	186,662	171,837	166,330	163,936	162,789	162,210	161,916	161,772
SmryBio_unfished	185,379	170,678	165,222	162,853	161,720	161,150	160,861	160,722
Recr_unfished	11,207	10,109	9,673	9,469	9,361	9,299	9,262	9,238
SSB_Btgt	15,533	14,435	14,039	13,874	13,800	13,766	13,751	13,747
SPR_Btgt	75%	63%	55%	50%	46%	44%	42%	40%
Fstd_Btgt	0.016	0.026	0.033	0.038	0.042	0.046	0.048	0.051
SSB_MSY	16,959	13,956	12,048	10,501	9,058	7,557	5,765	3,506
SPR_MSY	0.76531	0.61671	0.50744	0.41896	0.34158	0.26838	0.19081	0.10200
Fstd_MSY	0.0145	0.0263	0.0373	0.0482	0.0600	0.0742	0.0946	0.1326
Dead_Catch_MSY	1,299	2,108	2,787	3,414	4,030	4,675	5,418	6,548
Ret_Catch_MSY	1,171	1,882	2,462	2,984	3,479	3,971	4,491	5,160
B_MSY / SSB_unfished	0.44	0.39	0.34	0.30	0.26	0.22	0.17	0.10

From this table is clear that F_{MSY} ("Fstd_MSY" in the table) increases almost 10-fold when steepness increases from 0.3 to 1.0. Also SPR_MSY, B_MSY/SSB_unfished, Dead_catch_MSY and Ret_Catch_MSY are similarly very sensitive to the assumed steepness. Thus, as expected, steepness is a very important parameter for the OFL or ABC. In contrast, the estimated time series of biomass, recruitment and fishing pressure are rather insensitive to steepness.

Evidence from the Northeast Atlantic shows that most skate stocks can survive very heavy fishing pressure (probably several times the fishing pressure on longnose skate), but some skate stocks cannot. Now that fishing pressure in the Northeast Atlantic on a general scale is reduced, skate stocks have rebounded to some extent. Thus, this can be regarded as indirect evidence that the steepness of the S-R curve is not as low as 0.4 but rather in the range 0.5 – 0.7. A proper and relevant meta-analysis of the situation in the Northeast Atlantic has not yet been conducted, however.

Request No. 11*: Provide the diagnostics, fits, and the likelihood profiles associated with the new model with Dirichlet weighting. For the likelihood profiles, do not allow the Dirichlet weights to change from the maximum likelihood values. Also, do not let the estimated SDs for the surveys to change from their maximum likelihood estimates.*

Rationale: To confirm the model with Dirichlet weights better estimates scale without relying as heavily on the survey-*Q* prior for the WCGBTS. There is a need to understand what is driving this counter-intuitive result. This may provide the basis for a new base model.

STAT Response:

The STAT provided a series of slides showing results from fitting a new potential base model, including fits to the indices, fits to the length compositional data, fits to the observations of discard rates and the mean weights of the discarded fish. The STAT and Panel also explored the set of r4ss output plots. There were no indications of gross discrepancies between the observed data and the model fits to those data. However, the STAR Panel was concerned that the new model was unable to mimic the gradual increasing trend in the WCGBTS biomass (Figure 5).

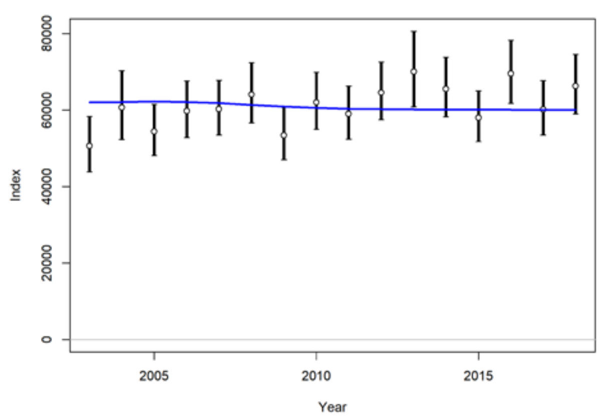

Figure 5. Fit of the new potential base model (with Dirichlet data weighting) to the WCGBT Survey index.

Nonetheless, the STAT and STAR Panel agreed that the new model was a good candidate for the final base model for the assessment.

Additional evidence in support of the new candidate base model were (a) a limited set of jitter runs (25 runs) that found no better fitting model when starting from different values for the estimated parameters, (b) a 5-year retrospective analysis that showed no strong retrospective pattern, (c) a likelihood profile over M that showed strong support in the data for a value of M near 0.2^{-y}, (d) a likelihood profile over h that showed some support in the data for a value of h near 0.4, and (e) a likelihood profile over $\ln(R_0)$ that showed modest support for a value of $\ln(R_0)$ near 9.5.

The STAT presented a tabular comparison of results for the pre-STAR base model and the new potential base model (Table 3) that indicated quite large changes in one's perception of the stock.

Table 3. Comparison of the pre-STAR model (labelled "Old") and the new potential base model ("New"). The two models differed only in the type of data weighting they used.

Label	Old	New
TOTAL_like	115	1,583
Survey_like	-56	-54
Length_comp_like	201	1,230
Age_comp_like	38	463
Parm_priors_like	0.513	5.860
NatM_p_1_Fem_GP_1	0.133	0.218
L_at_Amin_Fem_GP_1	16	21
L_at_Amax_Fem_GP_1	119	146
VonBert_K_Fem_GP_1	0.089	0.039
SD_young_Fem_GP_1	3.586	4.185
SD_old_Fem_GP_1	9.528	7.559
SR_LN(R0)	9.221	9.469
SR_BH_steep	0.4	0.4
SR_sigmaR	0.3	0.3
SR_regime	0.000	0.000
SR_autocorr	0	0
LnQ_base_5_WCGBT(5)	0	0
Dead_Catch_MSY	2,108	1,030
Ret_Catch_MSY	1,882	939
SSB_Virgin_thousand_mt	18.04	6.13
SSB_2018_thousand_mt	14.62	3.44
Bratio_2019	81%	57%
SPRratio_2018	19%	48%

Request No. 12*: Repeat the run #11 with no survey q prior and a run with the mean of the survey q prior of 2.0.*

Rationale: To ensure the model is capable of estimating [stock biomass] scale.

STAT Response:

The STAT produced a set of slides comparing results of the three runs. A graph of the distribution for the maximum likelihood estimate of ln(survey-*Q*) (Figure 6) indicated that there was information in the new potential base model (run #11) regarding the WCGBT survey-*Q* and therefore the stock's biomass scale. The WCGBT survey-*Q* was estimated to be 3.3 for the run with no prior. The two alternative runs predicted steeper declines in spawning biomass and were less consistent with the slightly increasing trend in the WCGBTS index than the new potential base model.

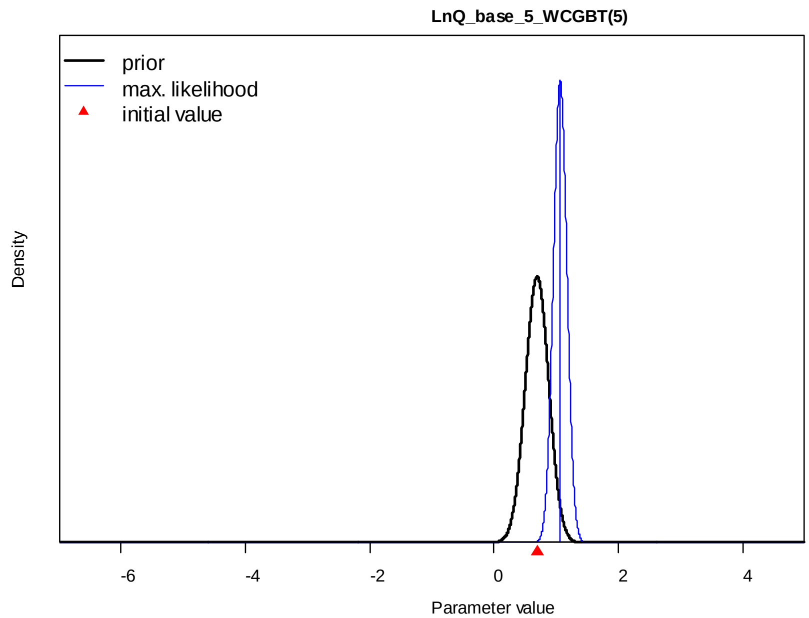

Figure 6. Maximum likelihood estimate for the ln(WCGBT Survey-*Q*) parameter compared with the prior for the distribution that informed the estimate. The lognormal prior had a log-scale mean value of 0.693 (median value of 2.0 for survey-*Q*).

Request No. 13*: Rerun the Dirichlet model (run #11) with the IPHC survey removed and with no added variance on the West Coast Bottom Trawl Survey.*

Rationale: To understand the influence of the IPHC survey, which has a conflicting trend compared to the West Coast Bottom Trawl Survey.

STAT Response:

Removing the IPHC data had almost no effect on the model fits.

Request No. 14*: Rerun the Dirichlet model (run #11) with the application of finer time blocking and the catch multipliers in historical discards (run #9).*

Rationale: To understand the influence of historical removals on survey index trends.

STAT Response:

The STAT presented results comparing the new potential base model (run #11) with three alternative runs that explored different patterns of estimated catch multipliers for the historical catches. One had estimated catch multipliers for each decade prior to 1990. A second run blocked the historical catches into two periods (changing at 1950). The third run allowed catch multipliers in the modern era (1995 to 2008). The depletion trajectory was sensitive to changes in the historical catches but not to the change in catches during the modern era (Figure 7)

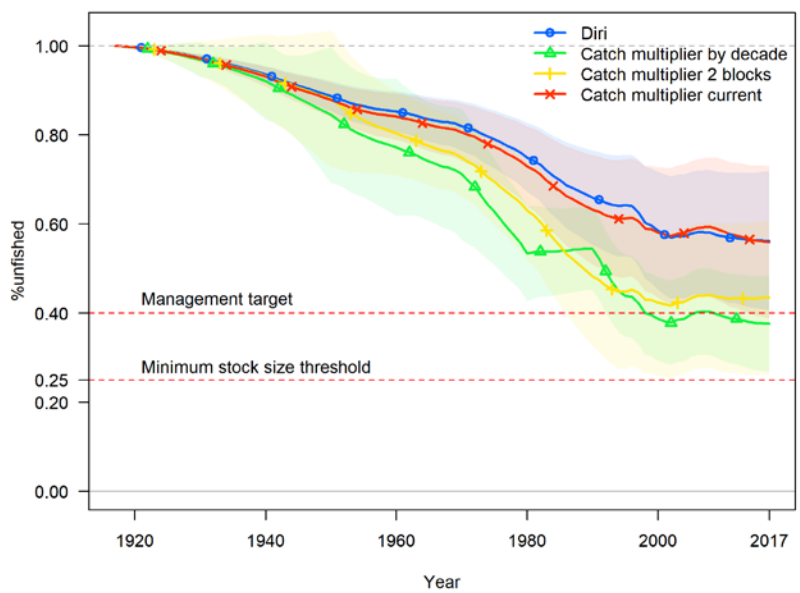

Figure 7. Comparison of depletion trajectories from the new potential base model (labelled “Diri” and alternative versions that estimated catch-multipliers using different time-blocking patterns.

None of the alternative runs provided appreciable improvements in the total log-likelihood or in the fits to the WCGBTS index.

Request No. 15*: Provide runs that remove the composition data (lambdas = 0) to force the model to be an age-structured production model, specified as follows:*

a) Use model run #11 (Dirichlet weighting), fix the selectivities, retention, and growth (the only estimated parameters will be ln(R0) and log q for the West Coast Bottom Trawl Survey;

b) Add the finer time blocking to run#15a;

c) Model run #15b with the IPHC survey removed;

d) Provide the steepness likelihood profile for run #15c;

e) Model run #15c with estimated recruitment deviations.

Rationale: To force the model to better fit the indices and to understand the influence of [the] assumed catch history.

Context: The STAR panelists were concerned by the apparent inability of the base model (and all the variants considered) to fit the increasing trend evident in the WCGBTS index.

STAT Response:

The STAT did not have sufficient time to complete this task during the STAR meeting.

After considering the results from Requests 11-14, the STAT and STAR Panelists agreed that the model as configured for run #11should be the final base model. This model was configured the same as the pre-STAR base model but used the Dirichlet multinomial approach for weighting the compositional data.

The STAT and STAR Panel agreed that uncertainty in the decision table should be bracketed using the WCGBT ln(survey-*Q*) as the major access of uncertainty (illustrated in Table 4).

Table 4. The three states of nature proposed for the decision table.

	Low state	Base	High state
LnQ_WCGBT	0.72	0.45	0.18
Catchability (q)	2.06	1.50	1.19
SSB_Virgin_thousand_mt	10.81	12.25	14.40
SSB_2018_thousand_mt	5.05	6.89	9.33
Bratio_2019	0.47	0.57	0.65
SSB_unfished	10,809	12,252	14,400
Totbio_unfished	64,008	75,400	91,086
SmryBio_unfished	62,305	73,298	88,471
SSB_Btgt	4,324	4,901	5,760
SSB_MSY	4095.14	4631.63	5434.96
SPR_MSY	0.611793	0.611261	0.610892
Fstd_MSY	0.0277629	0.0278747	0.0279785
Dead_Catch_MSY	869.609	1029.77	1249.38
Ret_Catch_MSY	796.899	939.249	1135.08

Note: The low and high states of nature in the table above use values for survey-*Q* based on the 12.5th and 87.5th percentiles from the prior distribution. For the low state of nature in the final decision table the survey-Q value was changed to 2.16 to match the estimated 12.5th percentile for the base model's estimate of the 2019 spawning biomass.

***Request No. 16**: Catch streams for the decision table should be as follows:*

a) Assume the 2017-2018 average total catch for 2019 and 2020 catches

b) Low catch stream: 1,000 mt/year

c) The default harvest control rule: 2,000 mt/year

d) High catch stream: ACL = ABC (P = 0.45)* *e) Use the category 2 sigma schedule recommended by the SSC (see Table 3 of the March SSC Report).*

Rationale: To define the removal assumptions in the decision table.

STAT Response:

In the final assessment document the STAT used the catch streams specified in this request.

Description of the Base Model and Alternative Models used to Bracket Uncertainty

The base model

The final base model for longnose skate was structured as having one area, one season, and one sex, and covered the period 1916-2018, with catches beginning in 1916 from an unfished, equilibrium age-distribution. The model has no recruitment deviations, meaning annual recruitment values were drawn from the underlying Beverton and Holt recruitment-spawning biomass function, for which steepness (*h*) was fixed at 0.4. Natural mortality (*M*) was estimated using a log-normal prior with a median value of 0.2077^{-y} (on the arithmetic scale), corresponding to a maximum age of 26 years. The model used an internal structure for ages that ranged from zero to an accumulator age of 23 y and an internal structure for lengths that ranged from 5 to 165 cm in 5-cm increments. Parameters defining length-at-age and its variability were fully estimated.

Fishery removals were modeled using four fishing fleets to account for (1) dead discards of skates during a historical period (1916-1994), (2) landed catches during the historical period, (3) landed catches and dead discards during the modern era (1995-2018), and (4) Tribal catches (full retention assumed) during the modern era. The discarding process was modeled using a length-based retention function that included an estimated parameter for the horizontal asymptote that could vary annually during the period 1995 to 2016 and during a time-block for 2017-2018. Fishing fleet selection and retention curves were estimated for fishing during the modern era and applied as the selection and retention curves for fishing during the historical period. The model assumed a time-invariant 50% discard mortality fraction.

The final base model was informed by survey biomass indices from (1) the AFSC Triennial shelf bottom trawl survey (every third year during 1980-2004), (2) the AFSC slope bottom trawl survey (1997-2001, excluding 1998), (3) the NWFSC slope bottom trawl survey (1999-2002), (4) the NWFSC's WCGBT shelf-slope survey (2003-2018), and (5) the IPHC longline survey (1999 and 2001-2018). Length-compositional data to inform length-selection curves for the surveys were available for the AFSC Triennial survey (2001 and 2004), the AFSC slope survey (1997, 1999-2002), and the WCGBT survey (2003-2018). The selection curve for the NWFSC slope survey was mirrored from the AFSC slope survey. The selection curves for all the surveys used the double-normal form with estimated parameters for the *Peak, Ascending slope*, and *Descending slope*. The survey selection curves had domed shapes except for the curves for the IPHC longline survey and AFSC Triennial surveys, which were essentially asymptotic.

Length compositional data to inform length-based selection and retention curves for all fishery removals were available from the current commercial fishing fleet's landings (1995-2018) and discards (2006-2017). The length-compositions for 1995-2003 were based on samples from

Oregon, which was the only state taking species compositions of skates prior to 2004, when Washington began. Length-composition data from California landings did not begin until 2009. The selection curves for all fishing fleets used the double-normal form and an assumed asymptotic shape.

Data to inform the discard processes took the form of annual observations of length-composition from fishery discards (2006-2017, WCGOP), mean body weights (2002-2017, WCGOP), observations of annual discard fractions (2009-2017), and estimates of annual discard fractions (1995-2008). The estimated discard fractions were derived from annual estimates of total catches and landings of longnose skate, with the predicted catches based on a linear regression model relating annual total mortality of longnose skate with annual total mortality of Dover sole (WCGOP estimates for 2009-2017).

Conditional age-at-length compositional data to inform growth (primarily) were available mostly from the WCGBTS (2003, 2011, and 2012, a total of 910 fish). Such data were available from the commercial fishing fleet's landings during 2004 (140 fish).

In the final base model the weights for the length- and conditional age-at-length compositional data were estimated using the Dirichlet multinomial approach and the model had estimated extra_SD parameters for the Triennial shelf survey and the IPHC longline survey indices.

Following the STAR meeting the STAT conducted additional jitter runs to confirm convergence of the final base model. The STAT did not find a better fitting model than the one reviewed on the final day of the STAR.

Bracketing uncertainty

The STAR and STAT agreed that the decision table should use the WGCBT survey-*Q* parameter as the major access of uncertainty, with the corresponding survey-*Q* values for the low and high states of nature taken from the 12.5th and 87.5th percentiles of the prior distribution for survey-*Q*. After the STAR Panel meeting the STAT determined that the survey-Q value for the low state of nature (2.06) resulted in an estimate for 2019 spawning biomass (SB_{2019}) that was less extreme than the value consistent with the 12.5th percentile implied by the base model's estimate of SB_{2019}. Consequently, for the decision table in the assessment document revised after the STAR meeting, for the low state of nature the STAT used the more extreme value for the survey-Q value (2.16).

Recommended sigma value and the basis for the recommendation

The sigma value (the ln-scale coefficient of variation for SB_{2019}, measuring scientific uncertainty) from the final base model was 0.2683, which is less than the default sigma value recommended by the Council's Scientific and Statistical Committee for category 1 stocks (0.5) or category 2 stocks (1.0). The STAR Panel recommends using the default sigma value for catch projections for longnose skate.

Recommended assessment category

Given that the final base model for longnose skate does not include sufficient compositional data to reliably estimate recruitment deviations, the STAR Panel recommends assigning the longnose skate assessment to category 2 (sub-category d: *Full age-structured assessment, but results are substantially more uncertain than assessments used in the calculation of the P* buffer*).

Recommendation on the next assessment for this stock

The STAR Panel recommends that the next assessment for longnose skate could be an update assessment, given the caveat that future fishing removals remain well below the OFL. The status of this stock appears to be well above the management target, skates are not high-value targets, and it seems unlikely that the status of this stock will change markedly in the next decade. Further, it seems unlikely that a category 1 assessment for longnose skate could be developed until several years of additional age-compositional data have accumulated.

Technical Merits of the Assessment

- The assessment used SS3 as the modelling framework, which allowed the STAT to include a variety of disparate data in a single analysis. Parameters were estimated via maximum likelihood to appropriately weight the data components and priors were applied to incorporate external information on natural mortality and the WCGBT survey-*Q*. Uncertainty in the estimates was characterized by the asymptotic variances of the parameter estimates. SS3 is a well-established and tested approach and appropriate for the assessment.
- The draft assessment document for longnose skate was well constructed and thorough in its description of the draft base model brought to the STAR and the underlying data that informed the assessment.
- The STAT's approach for estimating historical catches of longnose skate using total mortality estimates for Dover sole was innovative and an improvement over the approach used for the 2007 assessment.
- The STAT used the relatively new feature in Stock Synthesis of catch-multipliers as a mechanism for exploring uncertainty associated with the historical catches. The STAR Panel views this as an important technical improvement over the usual approach of doubling or halving the historical catch series. That said, however, uncertainty in the catch history did not appear to be incorporated into the final base model's estimates of uncertainty.
- The STAT was very responsive to the STAR Panel's requests and the STAT demonstrated considerable skill revising the draft base model in response to Panel requests, producing presentations to illustrate the relevant results, and working with the Panel to develop an acceptable base model that addressed the major concerns raised during the review.
- The final base model incorporates several sources of uncertainty that typically are very challenging to include: uncertainty in natural mortality (*M*) and uncertainty in survey-*Q*.
- For the final base model the log-likelihood profile over *M* suggests that this elusive parameter was robustly estimated, despite the paucity of age-compositional data.
- The STAT presented a systematic series of sensitivity analysis runs that considered the principal sources of uncertainty. The analyses considered the influence of data components (indices, length compositions and conditional age) and model specifications (*M*, growth, data weighting and recruitment assumptions) in the principal stock metrics. The results of these sensitivities were plotted to show where the estimates lie in the range of uncertainty as derived from the reference base model. This provided a very clear indication of the main issues resulting in uncertainty.
- The retrospective runs, which sequentially removed data from the assessment model, did not reveal any major problems. However, the analysis illustrated the dependence of the

assessment on the catch data that were assumed to be known without error. Jitter analyses suggested that the model had converged on the lowest negative log-likelihood.

Technical Deficiencies of the Assessment

- Overall, there were no serious technical deficiencies with this new assessment for longnose skate, which made good use of the available data and available modeling approaches. That said, some STAR Panelists were concerned by the model's poor fit to the WCGBTS index, which suggested an increasing trend in biomass. The STAT was unsuccessful at finding a model configuration that matched the increasing trend.
- Given the great uncertainty surrounding historical catches of longnose skate, it seems overly cumbersome to start the model from an unfished state in the far-distant past.
- The log-likelihood profile over steepness (h) indicated weak support for the 0.4 value assumed by the STAT.
- The log-likelihood profile over $\ln(R_0)$ indicated there is scant data to inform the model on the overall scale of biomass.
- The final base model was surprisingly sensitive to the choice of data weighting. The STAT's decision to use the Dirichlet multinomial approach (with support from the STAR Panel) was mostly driven by the poor results from data weighting in the pre-STAR base model, which used a combination of the McAllister & Ianelli approach (for the current fishery age-composition data and the IPHC length-composition data) and the Francis method (for all other compositional data).
- The lack of any recruitment signal in the length compositions and limited age data (confined to a few recent years) meant that it was not possible to estimate recruitment deviations around the stock-recruitment function. The assessment therefore used deterministic values derived from the Beverton Holt curve and most recruitment is simulated to be near the plateau of this curve. This means that the estimated population trajectory is largely driven by a stable age structure conditioned on a constant value of M, time-invariant selectivity, and an assumption about steepness.
- As the estimated fishing mortality rate is negligible (compared to M), much of the stock dynamics are driven by factors external to the fishery. Whatever the true level of M, it is likely to vary over time; because M cannot be reliably included in the model dynamically (as there are no supporting data) the interpretation of hindcast stock trends is extremely difficult.

Areas of Disagreement Regarding STAR Panel Recommendations

Among STAR Panel members (including GAP, GMT, and PFMC representatives):

None.

Between the STAR Panel and the STAT Team:

None.

Management, Data, or Fishery Issues raised by the GMT or GAP Representatives During the STAR Panel Meeting

None.

Unresolved Problems and Major Uncertainties

The *Technical Deficiencies* section above describes several modeling issues that warrant further consideration. Below are some other, slightly more general issues that the final base model left unresolved.

- Longnose skate off the U.S. West Coast may be a fraction of a much large population extending into Canada or even Alaska. Modelling only a part of the total population might contribute to the lack of correspondence between the survey indices and other data sources, as seen in the ln(R_0) profiles and the model's weak support for the assumed steepness (0.4). While this comment is not intended to reflect badly on the STAT's capabilities, it is important to recognize that stock structure could potentially be a major source of uncertainty regarding the assessment results.
- The prior distribution for the WCGBT survey-*Q*, which was developed "on-the-fly" by the 2007 STAR Panel, was influential and provided much of the information on the biomass scale in the assessment.

Recommendations for Future Research and Data Collection

Data needs

- Ages - Estimate additional ages for longnose skate, which would better inform the age-structured model. The NWFSC ageing lab is currently able to age skate vertebrae, and many structures have already been collected across several years in surveys and fisheries.
- Maturity - Generate additional maturity data using the most accurate/precise method developed in Research Need #3, below.

Research needs

- Survey-*Q* (high priority) - Develop a well-informed prior on survey catchability, as this parameter is highly influential upon the assessment model. Evaluate longnose skate behavior/interaction with trawl gear, and distribution among habitats, to better understand catchability by survey gear types, and ultimately provide more precise estimates of abundance from the surveys.
- Alternative models (high priority) - Explore alternative model formulations that could provide better fits to the increasing trend in the biomass index from the WCGBT survey. What biological mechanisms are needed to produce model results that are consistent with the WCGBTS?
- Maturity - Conduct studies incorporating histological analysis into evaluation of skate maturity, which would evaluate error and bias in macroscopic evaluation, and develop a feasible method which would produce the most accurate and consistent maturity data. Histological examination is widely accepted the best available approach, while macroscopic

evaluation (used up to this point), has been demonstrated to be less accurate, precise and more prone to reader bias (Vitale et al. 2006, Brown-Peterson et al. 2011, Kjesbu 2009).

- Life history - Conduct studies to better quantitatively understand the life history of longnose skates; e.g., to inform time-varying estimation of natural mortality and recruitment. Research to better estimate of growth, as well as enhanced understanding of reproduction (e.g., frequency, seasonality, number or eggs per year) is also needed. Studies to better understand longnose skate productivity and accurately inform stock-recruit steepness for this species would also be beneficial.
- Catch - Continue to explore methods to estimate historical removals of longnose skate and associated uncertainty, particularly model-based solutions where feasible.
- Discard mortality - Conduct studies to evaluate survival rates of discarded longnose skate, especially with trawl gear, so that total fishing mortality can be estimated more accurately.
- Movement and migration - Conduct spatial studies of movement and migration of longnose skate, with special attention to potential extent of movement across the U.S.-Canada border.
- Genetics - Conduct genetic studies to evaluate the potential for stock structure of longnose skate in the waters off the U.S. Pacific Coast.

Acknowledgements

The STAR Panel is grateful to Stacey Miller for helping to organize the STAR Panel meeting and for providing logistical support during the meeting.

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