CENTER FOR INDEPENDENT EXPERTS (CIE) INDEPENDENT PEER REVIEW REPORT ON STAR PANEL 2 VIRTUAL MEETING – LINGCOD (NORTHERN AND SOUTHERN STOCKS), JULY 2021

Dr Cathy Dichmont

Catherine M. Dichmont
cathydichmont@gmail.com

This publication should be attributed to **Dichmont, C.M. 2021. Center for independent experts (CIE) independent peer review report on STAR panel 2 virtual meeting – lingcod (Northern and southern stocks), July 2021. Cathy Dichmont Consulting, Brisbane. Australia, 45 pp.**

Disclaimer

Contact Details

Name: Dr Catherine M. Dichmont
Email: cathydichmont@gmail.com

CONTENTS

1 EXECUTIVE SUMMARY

The STAR Panel 2 for the Northern and Southern lingcod (*Ophiodon elongatus*) stocks took place virtually between July 12 and 16, 2021 with STAR panel members Drs John Field (Chair), Will White, Matt Cieri and Cathy Dichmont, the Stock Assessment Team (STAT) and other observers. The review was very constructive with often difficult requests for additional work met and improved upon by the STAT. This included undertaking extensive further model runs over a short time frame. The STAT is thanked for a very constructive meeting.

The stock was last assessed in 2017. Both the 2017 and the present 2021 assessment used the assessment package, Stock Synthesis (Methot et al. 2020). In the case of the 2021 assessments, SS 3.30.17.01 was used. New boundaries between the Northern and Southern models were based on new genetic information. Commercial landings were updated and reconstructed further back in time compared to the 2017 assessment, and now start in 1889. As a result, the data are much more extensive and complete than the previous assessments where large parts of the data were extrapolated and interpolated. The remaining missing data were interpolated between years. Recreational data were also updated.

The assessments start at equilibrium and assumes the initial age structure in 1889 represents an unfished population. The likelihood components included in the model are catch, all fitted indices, discards, length compositions, age compositions, recruitments, parameter priors and parameter soft bounds. The lingcod assessments were sex specific, with separate male and female growth curves, natural mortality and steepness parameters estimated within the model. Age data were included in the model as conditional age-at-length compositions rather than the 2017 draft assessment approach of including these as marginal age data. This excluded the need to allocate unsexed fish to a sex class, or the assumption that the age data are representative.

The northern model data are characterized by containing longer time series and more data inputs. The California recreational data were new to the northern model because of the boundary change. Discards were only available for the commercial gear catches. Five abundance indices are available for the recent years, of which four were available for 2020.

The southern model had fewer data inputs and most of these have a shorter time series. Abundance indices, especially, are fairly short and only three of these extend to recent years. The southern model also only has a single source of conditional age-at-length compositions from the West Coast Groundfish Bottom Trawl Survey (WCGBTS).

There is a clear tension in the draft Northern base model between the relative importance placed within the model on these different sources of data. Most importantly, the model is sensitive to the relative weighting of the composition data in the model, and which data are included or not.

The Southern model draft base model recruitment deviations were characterised by large (unrealistic) increasing correlated trends leading up to the "main" period (1965-2018) where recruitment deviations are zero-centred. This result is likely to influence the steepness parameter and the age structure in the 1960s and 70s.

The review concentrated on addressing these above issues through 20 Panel requests for model runs to test a variety of alternate approaches. The requests for the Southern model mostly resolved the abovementioned issues with the Southern model and these changes are included in the final base Southern model. For the Northern model, age-varying growth and sex-specific selectivity were considered as appropriate possible causes of the tension in the model. The model was much more sensitive to the latter.

During the review, it was clear that addressing sex-specific selectivity would go part way to reducing the tension in the model, mainly produced by the age and length composition data in the Northern model. However, the implementation thereof was not simply a matter of providing an offset (with varying number of parameter options for flexibility) and that a much more nuanced option would need to be implemented in the future.

Without age data in the Southern model, estimating sex-specific selectivity would remain difficult. However, in principle there is no clear reason why some degree of sex-specific selectivity would not occur in the south, although one would not expect that the selectivities and other parameters would be same as in the Northern model.

Given the large (unrealistic) increasing correlated trends leading up to the "main" period (1965-2018) where recruitment deviations are zero-centred in the Southern model, several options were tested to decrease this auto-correlation. The best solution identified, given the time available, was removal of the early length composition data (which was found not be representative of the whole region) which seemed to resolve this issue.

Both final base models had retrospective patterns, especially the Northern model. For the Northern model, some of the peels extended beyond the uncertainty bounds of the final base model (data minus 4 and 5 years). The Southern model has a much higher uncertainty interval in the final base model, but the retrospective patterns showed that spawning stock size still changes even above the final model's confidence intervals (for data minus 4 and 5 years). Despite these model sensitivities, there was a degree of robustness on key management quantities such as the fraction unfished, especially in the Northern model.

The Northern model, particularly, is sensitive to structural changes. The decision table for the Northern model is unusual, but attempts to reflect the high and low natural states in the form of data- and structural uncertainty. The table for the Southern model is more traditional, following the model sensitivity to natural mortality.

The standard of the STAT's work addressing the previous STAR panel's recommendations was high and the STAT team has provided the best assessments based on the best available information that could be provided at this stage. The final base models are therefore recommended to be used for management purposes. Given the uncertainties, they should be classified as category 2 assessments.

2 BACKGROUND

The STAR Panel 2 for the Northern and Southern lingcod (*Ophiodon elongatus*) stocks took place virtually between July 12 to 16, 2021. In attendance were STAR panel members:

- John Field, National Marine Fisheries Service Southwest Fisheries Science Center (Chair)
- Will White, Oregon State University
- Matt Cieri, Center for Independent Experts
- Cathy Dichmont, Center for Independent Experts

The Stock Assessment Team (STAT) members:

1. For the South
    - Kelli Johnson, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
    - Ian Taylor, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle

- Brian Langseth, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
- Andi Stephens, National Marine Fisheries Service Northwest Fisheries Science Center, Newport
- Laurel Lam, Pacific States Marine Fisheries Commission, Seattle
- Melissa Monk, Southwest Fisheries Center, Santa Cruz
- John Budrick, California Department of Fish and Wildlife, San Carlos
- Melissa Haltuch, National Marine Fisheries Service Northwest Fisheries Science Center, Newport

2. For the North
    - Ian Taylor, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
    - Kelli Johnson, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
    - Brian Langseth, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
    - Andi Stephens, National Marine Fisheries Service Northwest Fisheries Science Center, Newport
    - Laurel Lam, Pacific States Marine Fisheries Commission, Seattle
    - Melissa Monk, Southwest Fisheries Center, Santa Cruz
    - Alison Whitman, Oregon Department of Fish and Wildlife, Newport
    - Melissa Haltuch, National Marine Fisheries Service Northwest Fisheries Science Center, Newport

Other scientists and managers involved in the stock assessment and management of the fisheries also attended. The meeting was available to the public for comment, and recorded.

The review was very constructive with often difficult requests for additional work met and improved upon by the STAT. This included undertaking extensive further model runs over a short time frame. The STAT is thanked for a very constructive meeting.

The Statement of Work that was provided to Dr Dichmont by the CIE (Appendix 1) required that CIE reviewers become familiar with all the materials provided, contribute the review week activities and Panel Report, and write their own individual report to the CIE.

The panel members were provided with material pertaining to assessment of the Northern and Southern stocks of lingcod as well as the Stock Synthesis (SS) code, data and output of the two models. The list of background material is provided in Appendix 3 (Heading 9.3).

Presentations on the resource biology, the various fisheries, changes to the 2021 assessments, overview of the data, modelling and results, and the STAT's response to the previous STAR panel review were provided.

More detailed work was undertaken during the review in the form of 20 Requests from the STAR panel, results and commentary to which were provided by the STAT and discussed by all present. Inputs were also provided by the Groundfish Management Team and other online participants. No general public comments were made.

3 DESCRIPTION OF THE INDIVIDUAL REVIEWER'S ROLE IN THE REVIEW ACTIVITIES

Prior to the workshop, the set of documents that was provided was downloaded and read. The code was run to check that the reviewer got the same answer as provided in the draft assessment report. Among this information, the web version of the model outputs and past STAR panel reports were beneficial. The reviewer also familiarised themselves with key documents such as the Groundfish and Coastal Pelagic Species Stock Assessment Review Process for 2021-2022 Terms of Reference.

The review workshop was held online from July 12 to 16, 2021. Rapporteur duties were divided amongst panel members and for those relevant to the reviewer, notes were taken, and key points were added to the panel report. Editing and additional comments were further provided on the panel report.

This report constitutes part of the reviewers' duties as a CIE representative on the STAR panel.

The CIE Terms of Reference of the review were:

1. Become familiar with the draft stock assessment documents, data inputs, and analytical models along with other pertinent information (e.g., previous assessments and STAR panel report when available) prior to review panel meeting.
2. Discuss the technical merits and deficiencies of the input data and analytical methods during the open review panel meeting.
3. Evaluate model assumptions, estimates, and major sources of uncertainty.
4. Provide constructive suggestions for current improvements if technical deficiencies or major sources of uncertainty are identified.
5. Determine whether the science reviewed is considered to be the best scientific information available.
6. When possible, provide specific suggestions for future improvements in any relevant aspects of data collection and treatment, modeling approaches and technical issues, differentiating between the short-term and longer-term time frame.
7. Provide a brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.

4 SUMMARY OF FINDINGS AGAINST EACH TOR FOR STAR

4.1 TOR 1: BECOME FAMILIAR WITH THE DRAFT STOCK ASSESSMENT DOCUMENTS, DATA INPUTS, AND ANALYTICAL MODELS ALONG WITH OTHER PERTINENT INFORMATION (E.G., PREVIOUS ASSESSMENTS AND STAR PANEL REPORT WHEN AVAILABLE) PRIOR TO REVIEW PANEL MEETING

4.1.1 Biology

Lingcod have faster population dynamics than many of the groundfish stocks on the US west coast and are characterised by faster growth, early maturing and higher natural mortalities (M) (Taylor et al., 2021). There are also key sex-specific differences in both behaviour and spatial distribution over time, including depth. Females grow faster and reach larger asymptotic sizes than males. Females tend to occupy the deeper habitats, especially when older, while males remain inshore on rockier habitat. Males aggregate in the fall and move to rocky shallow habitat where they guard potential nesting sites. The females move to these grounds to spawn and then appear to move back to the offshore, while the male guards the clutches until the eggs hatch. Lingcod have high site fidelity, but do move short distances to feed. Large females are less resident in an area. These movement patterns differentially expose males and females to different gear types and fisheries, depending on their ability to fish on hard ground or need to fish in deeper more offshore waters.

Lingcod are top predators and cannibalistic, feeding opportunistically on a variety of pelagic and demersal fish, crustaceans and cephalopods. Their feeding strategies differ by latitude, sex, environmental factors, depth and size.

Additional aging data in 2021, allowed for additional maturity at age and length curves to be produced for both males and females, which showed similar ogives by age and bigger differences by length. Sex specific growth curves were estimated within the model.

A key finding using newer genetic techniques (Longo et al. 2020) was that there are two genetic clines of lingcod along the west coast of North America with no clear break between the two areas, and with an area of admixed individuals in northern California (CA). These findings suggested a north-south stock break could be chosen in a few areas, but that of Cape Mendocino was chosen to split the 2 stock assessments – it is an area of a potential biogeographical break and aligns with the Individual Fishing Quota (IFQ) boundaries. A possible boundary further south may compromise the data available to the Southern assessment. This change in boundary means that the 2021 assessment results are not directly comparable to the previous assessment and that California (CA) recreational catches and indices are relevant to the Northern model for the first time. As a result, no bridging analyses between the present and 2017 assessment were provided.

The above describes a complex biology that would make any assessment have high information requirements to disentangle.

4.1.2 Fisheries

There are several fisheries, both recreational and commercial, that catch lingcod (Taylor et al., 2021). In most of these fisheries, lingcod is a valuable component of the catch but not the only target species. Bottom fish trawl and longline are the two main gear types in the commercial fisheries, whereas the recreational fisheries are dominated by hook-line and spear methods mainly off commercial passenger fishing vessels (CPFVs) and private/rental boats. The recreational fisheries data are collected within each State and therefore indices were created by States. Those for the commercial gear were separated into Trawl and Fixed gear indices. The Californian recreational lingcod landings have surpassed the commercial landings for several decades.

Although not included, there are fisheries both further north (Canada and Alaska) and south (Mexico) whose data are not included in these assessments. An assessment of lingcod has been applied in Canada, but has not been recently updated. Data collection and assessment is not complete or available for the Mexican fisheries which is mainly of artisanal fleets.

Several management measures have been undertaken over time as lingcod became heavily exploited, including trip limits, a limited entry sector, changes to the coastwide Acceptable Biological Catch (ABC), spatial and temporal closures and minimum size to the commercial fisheries. The limited entry trawl sector became a catch share program with 100% observer coverage. The recreational sector regulations also changed substantially over time concentrating on minimum sizes and daily bag limits, not always the same in each State. In-season closures were also applied in Oregon.

4.1.3 Summary of the data used in the assessments

The Northern stock assessment had more data available than the Southern model. The STAT team conceded that these data are not always informative on key parameters and this point is clear from the review findings.

The available indices for the Northern and Southern assessments are provided below (from the respective stock assessment reports):

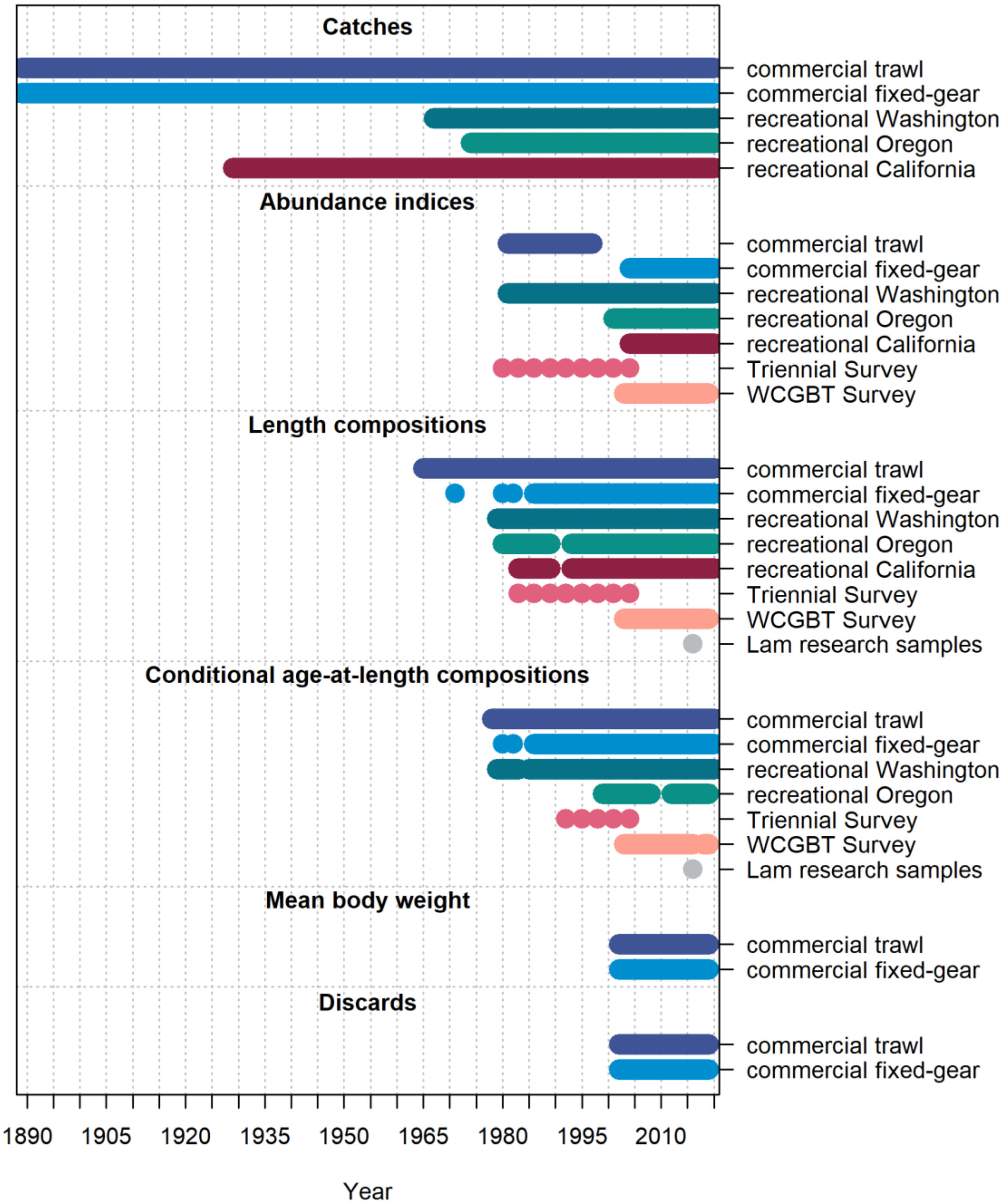

Figure 1: Available data for the Northern Model (Source: Taylor et al., 2021).

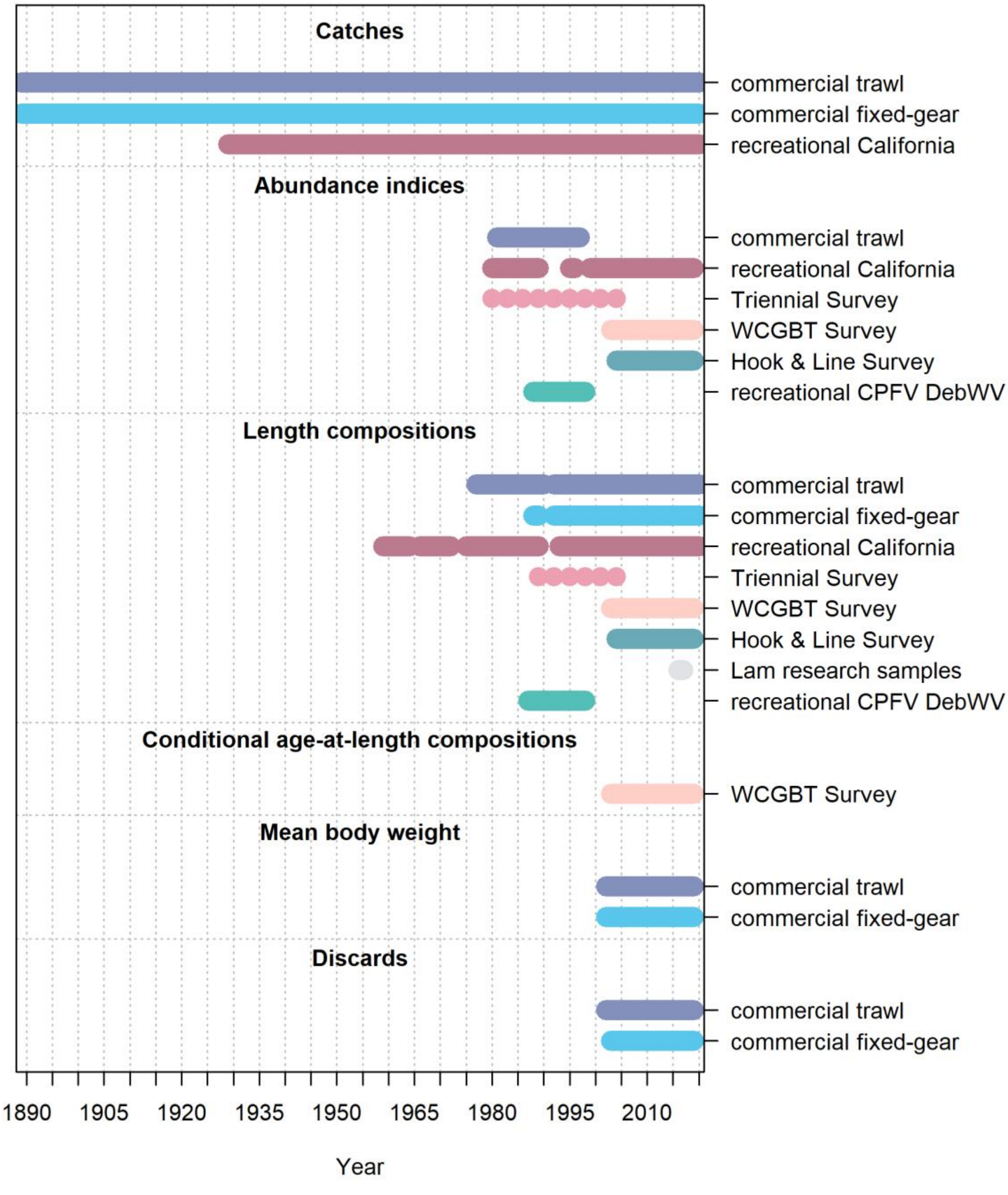

Figure 2: Available data to the Southern model (Source: Taylor et al., 2021a)

The northern model data are characterized by containing longer time series and more data inputs. The CA recreational data were new to the northern model because of the boundary change. Discards were only available for the commercial gear catches. Five abundance indices are available for the recent years, of which four were available for 2020.

The southern model had fewer data inputs and most of these have a shorter time series. Abundance indices, especially, are fairly short and only three of these extend to recent years (those without the 2020-year index due to COVID-19). The southern model also only has a single source of conditional age-at-length (CAAL) compositions from the West Coast Groundfish Bottom Trawl Survey (WCGBTS). Commercial landings were updated and reconstructed further back in time compared to the 2017 assessment, and now start in 1889. As a result, the data are much more extensive and complete than the previous assessments where large parts of the data were extrapolated and interpolated. The remaining missing data were interpolated between years. Recreational data were also updated.

The commercial trawl index was analysed similarly to the previous assessment by applying the vector-autoregressive spatio-temporal (VAST) model of Thorston and Barnett (2016). Only the new border changed in the analyses. Of note is that the model was applied coastwide and then an index for each stock was predicted from the model.

The other fishery dependent indices available to each stock assessment were re-analysed with the updated data using a consistently applied Bayesian delta-GLM modelling framework. These model the catch occurrence (i.e., whether lingcod were caught or not) and the positive catch component of the data. Several distributional assumptions and predictors were tested for each component; and AIC, BIC and other approaches (such as quantile-quantile (QQ) plots) were used to select the best model. Uncertainty in the final index was developed using the *rstanarm* package in R (Goodrich et al. 2019) while considering the correlation structure between and within the parameters of the two components. For the Northern stock, the indices developed included the Oregon nearshore index, the Washington recreational index, Oregon recreational boat survey index, Oregon at sea CPFV index, the MRFSS Dockside CPFV Index, California onboard observer survey (not undertaken in 2020), and the Deb Wilson-Vanderberg Index. The latter was separated from the Californian index because the Deb Wilson-Vanderberg index includes aging data used in the model. The South model recreational indices included the MRFSS Dockside CPFV Index, the Californian Observer Survey (not used, survey also not undertaken in 2020) and the Deb Wilson-Vanderberg Index.

Fishery independent surveys included the NWFSC West Coast Groundfish Bottom Trawl Survey and the AFSC/NWFSC West Coast Triennial Shelf Survey (also a bottom trawl survey). Indices from both surveys were developed for each stock assessment using the VAST model, but applied separately for each index and stock. An index based on the NWFSC Hook and Line Survey in the Southern California Bight was developed using a Bayesian delta-GLM model and included in the Southern model. An index based on the California Cooperative Fisheries Research Survey (CCFRP), a hook and line survey that takes place both inside and outside of the California Marine Protected Area network was developed but not used in the model.

The commercial fixed gear fishery only occurs in the Northern stock, however both the northern and southern models used commercial trawl indices developed in the 2017 assessment (unchanged from that assessment apart from the boundary change). The Northern stock assessment was fit to seven indices of abundance and the Southern used six.

Length compositions and Conditional age-at-length (CAAL) compositions are available for both commercial fleets; and the Washington, Oregon and Californian recreational fleets (noting that there are no age data for the CA recreational fleets). The latter data are appropriately allocated to the north and south stocks. Commercial trawl length-composition data started in 1965 in the north and 1977 in the south. Data collection for the commercial fixed gear (FG) in the north began in 1986 (with additional samples in 1971, 1980 and 1982), and began in 1992 in the south (with additional samples in 1988 and 1989). There are three sets of length compositions per fleet, female, male and unsexed and two sets of CAAL per fleet, male and female. This structure is unlike the previous draft base assessment where unsexed individuals were split to sex assuming a 50:50 ratio irrespective of length.

Survey observed length-composition data were expanded to account for sub-sampling of tows, and this expansion was stratified by depth. The input sample sizes for length for all the survey data were calculated according to Stewart and Hamel (2014). Survey age-composition data were included in the model as CAAL distribution by sex and year and were not expanded. The largest age bin of 20 years was treated as a plus group. Although several CAAL indices were available to the Northern model, only those from the WCGBT survey were available to the Southern model.

Discard rates were modelled for the commercial data only using data from the West Coast Groundfish Observer Program, which started in 2002. Observer coverage rates were relatively low in the early period but increased to nearly 100% for all the limited entry vessels since 2011. A single annual discard rate was calculated for each fleet per year. For the recreational data, catch is input as for retained catch and the estimated dead discard catches combined (assuming 7% mortality rate from all discards).

In response to the 2017 STAR panel recommendations, natural mortality (M) and steepness (*h*) are estimated within the model. These parameters are both notoriously difficult to estimate, as such a prior for M was calculated using the Hamel-Then approach of calculating the maximum age from the 99.9 percentile of male and females ages in the PacFin database. Unlike the previous assessment that used the maximum age observed in the data (21 years for both males and females), the new approach calculated maximum ages of 18 and 13 for females and males respectively. Prior means were 0.3 for females and 0.415 for males applied across all ages. This was a significant increase from the previous assessment for both sexes. The draft base model estimated natural mortality rates were 0.41 for females and males in the northern model; for the southern model the estimates were 0.23 and 0.25 for females and males respectively.

A further 2017 STAR panel recommendation resulted in the re-calculation of ageing error, which shows little ageing error between analysts, laboratories and years.

Mean weight-at-age from WCGBBT survey were analysed to track a single age over time with respect to their mean weight to investigate the possibility of time-varying growth. The younger ages' growth rates are quite flat, whereas mean weights at ages 5 and 6 show signs of changes over time. However, these potential changes need to be considered in conjunction with the larger standard errors associated with the mean weight of older ages.

4.1.4 Model description and structure

The stock was last assessed in 2017. Both the 2017 and 2021 assessment used the assessment package, Stock Synthesis. In the case of the 2021 assessments, SS 3.30.17.01 was used. The lingcod assessments were sex specific, with separate male and female growth curves, M and steepness parameters estimated within the model. Age data were included in the model as CAAL compositions rather than the 2017 draft assessment approach of including these as marginal age data. This excluded the need to allocate unsexed fish to a sex class, or the assumption that the age data are representative. The model starts at equilibrium and assumes the initial age structure in 1889 represents an unfished population. The likelihood components included in the model are catch, indices, discards, length compositions, age compositions, recruitments, parameter priors and parameter soft bounds.

Selectivity of all the fleets was modelled as double normal functions to allow both asymptotic and dome shaped selectivity. The parameter controlling the width at the top was set to a very small value. A complex set of time blocks were used for each fleet depending on the management measures in place. The model often hit some bounds and convergence issues were most often related to selectivity. The most common response was to fix asymptotic selectivity if the estimated parameters estimated asymptotic selectivity, thus reducing the number of parameters being estimated.

Retention was modelled for commercial trawl and fixed gear fleets using a logistic function estimating two of the possible four parameters, being the length at 50% retention and the slope of the ascending curve. Asymptotic retention was fixed at 100% and retention was not sex specific. Only the length at 50% retention was allowed to change over time, whereas the slope parameter remained fixed after 1998. Commercial fishery retention parameters prior to 1998 were fixed at values that would achieve 100% retention.

Prior distributions were included for male and female M, and for steepness which was based on the prior distribution used in the Pacific Hake assessment.

Standard deviations of recruitment deviations were fixed at 0.6. A tuning algorithm indicated little change was needed from the starting value and the results were relatively insensitive to changes in these values. The maturity ogive was fixed and so too were length-weight parameters.

The STAT utilized three primary diagnostic tests while developing the base models:

a. Likelihood profiles to highlight conflicts within the data,

b. using the SS3 jitter function to ensure that models had converged to the true minimum likelihood, and

c. Correlations of Bayesian posteriors (although this model is a Maximum Likelihood Estimation, the STAT was able to undertake Bayesian analyses on the posterior estimates using MCMC in order to identify "inefficient" parameters).

The above diagnostic tests made it clear that there was strong autocorrelation among several of the parameters, particularly among a number of selectivity parameters.

4.1.5 Previous STAR panel comments

Commentary on how the STAT addressed the previous STAR panel comments was extensive and mainly complete. Those that remain are discussed in Section 5.2 – Recommendations.

4.2 ToR 2. Discuss the technical merits and deficiencies of the input data and analytical methods during the open review panel meeting

4.2.1 ToR conclusion

The data as used for the final model represent the best available to this assessment.

4.2.2 Detail

The reconstruction of the historical landings data as allowed the model to start at virgin stock size. The data for the 2017 were extending back in time using a linear extrapolation whereas the 2021 assessment uses a reconstruction of the data as best as were available from several data sources. Although there is still some expansion and interpolation, this dataset is a major improvement on that of 2017.

However, although there was some additional information provided to address the 2017 STAR panel recommendation that the catches in Mexico and Canada should be considered, this remains a recommendation. The Mexican data may be lacking but there are some data from USA fishers fishing in Mexico in the relevant USA databases. They could provide a basis for an investigation into the lower scale of the fisheries in Mexico. On-going dialogue with Mexico to establish data collection may be useful beyond lingcod. To the northern boundary of the Northern model, more progress is possible. There is already a Canadian lingcod assessment, although not updated recently. To work with Canada to move toward a joint model would be beneficial, again well beyond lingcod.

Recommendation 1. Calculate the lingcod catch of USA fishers in Mexico from the available databases. This will give a start to estimating the lower scale of the lingcod fishery in Mexico. Undertake engagement with Mexico for multi-lateral collection of the scale of the fishery in Mexico.

Recommendation 2. Work with Canadian counterparts to develop a joint Northern lingcod assessment in light of the new genetic results.

An interesting discovery during the review was the possible extent of the live trade fishery. This would significantly impact model settings as one would expect fisher behaviour such as location and gear selectivity would change relative to a dead FG fleet. The possibility of separating the live trade fishery from the remaining FG fleet would be an important consideration for the next assessment. This fishery may also not be well represented in the age and length composition data, which could further complicate the use of this data when combined with other (dead) FG data.

Recommendation 3. Investigate the extent of the live trade FG fishery and consider the merits of separating this fishery from the FG fleet. Re-analyse the age and size composition data in the context of separating the dead and live FG data.

The commercial trawl index was analysed similarly to the previous assessment by applying the vector-autoregressive spatio-temporal (VAST) model applied coastwide and then an index for each stock was predicted from the model. All the other indices were calculated by stock region i.e., independent of the other region. The commercial trawl index should be updated for the next assessment using this separate approach.

Recommendation 4. Analyse the commercial trawl data by individual stock rather than both stocks combined.

Information provided (although not fully checked) on the proportion of fish that have been measured relative to those that were also aged was not always balanced by length bin. Thus, the length compositions using the aged fish are, at times, very different to the length composition using the length data only. Some of this lack of balance in the composition data could be a degradation of implementing good protocol as sampling practicalities apply, but it also noted that sample size has changed over time (Figure 3).

The panel noted the discrepancy between the two sources (age or length) used to calculate length compositions was visibly different for the Fixed Gear (FG) sector especially between 1999-2011, and sensitivity of the draft base Northern Model to the FG age data was requested by removing all the FG age data or only those between 1999-2011. Removing the FG ages of the years 1999-2011 made no difference and results were similar to the draft base case. However, removing all the FG ages had a large impact on the results by increasing the spawning biomass (although there was not a large impact on the fraction of unfished trends relative to the new base model). These results highlight that the source of tension in the model is not from the period 1999-2011 but more likely the earlier data, where there are fewer alternative sources of information. This is discussed further in ToR 3.

It is noted that the proportion of fish measured and aged relative to only aged has changed over time. For example, the WA trawl data provided during the review workshop showed that the proportion of measured fish that were aged was low in the 1970s and even lower after 2010 (excluding 2020 where all fish measured were aged but from an understandably small sample size) (Figure 3). However, there is also an overall trend in recent years of sampling fewer ages.

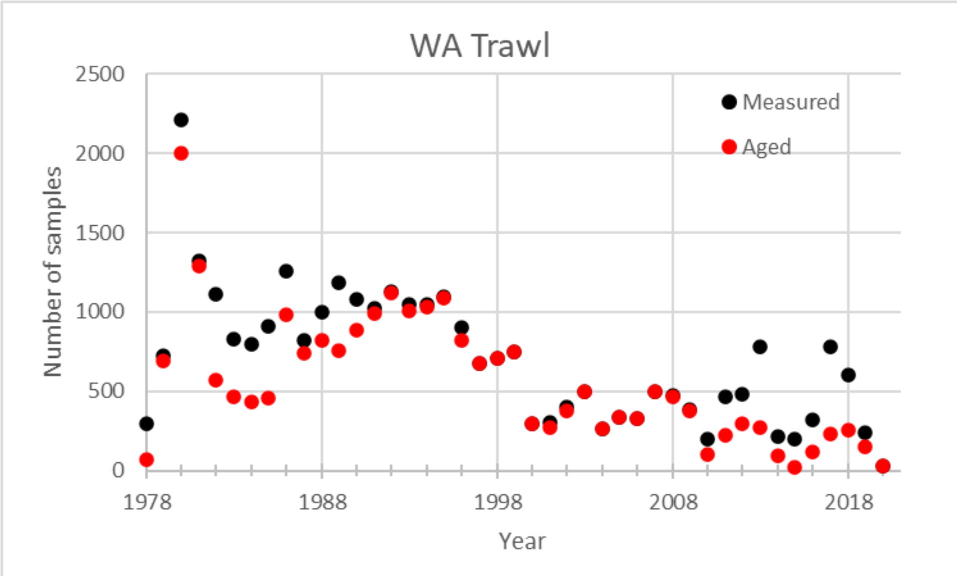

Figure 3: WA Trawl length and age composition sample size by year (source: provided during the workshop and therefore preliminary).

Adding the age data as CAAL in the assessment avoids some of this problem of lack of representativeness, but it does highlight that there are issues with the sampling protocol, or more importantly, some underlying dynamics are not being captured, even though depth was a stratum in the analyses. The latter is of concern as simulation studies undertaken by Lee et al. (2019) found that the use of CAAL data, instead of marginal ages, does not fully resolve issues of data that are not representative of the population age structure. Furthermore, if some underlying dynamics are not fully included in the model it can also lead to bias and uncertainty in the model estimates. This issue is discussed further in ToR 3.

Recommendation 5. The VAST method used to standardise some of the indices includes a component of spatio-temporal auto-correlation. Depth was also often a factor in the final Bayesian delta-GLM analyses. These results reflect the biological information that there are depth and time differences in the movement between the sexes, and these would be affecting the representativeness of the composition data. It is usual that age and length data are not standardised, but in this fishery some form of in-depth analysis of the biology of the species relative to the composition data is warranted as a high priority, in the north model particularly.

Recommendation 6. Investigating the fishery dependent age and length composition sampling protocols would be beneficial in light of the above findings.

Trawl discard rates were based on the West Coast Groundfish Observer Program, which started in 2002. Discard fraction prior to the catch share program being implemented in 2011 was much higher than during the catch share program where observer coverage was 100% for those vessels in the catch share program. The expected trawl discard fraction from the Northern model is higher than that observed for the period 2002-2009. When the removals of the total dead discard (a combination of retention rate estimates and discard mortality) and total retained catch figures were provided during the workshop (Request 4) for both the Northern and Southern models, they showed an unrealistically high dead discard proportion in the Northern model than would be expected, given available data. This could reflect an incorrect assumption of little discard prior to 1999 and/or model issues of using the same data weight for retained and discard catches. Since length composition data from discards are better sampled than that from retained, it would be of real benefit that SS could weight these two components separately.

Several options to better represent trawl discards in the Northern model were investigated during the review, but not finalised. This remains a research need.

Recommendation 7. Effort should be made to reconstruct historical (pre-1999) discards.

Recommendation 8. Future versions of Stock Synthesis should allow separate weighting of discarded and retained catches. If this does not address the poor representation of dead discards in the Northern model, then other options such as those considered during the review week should be considered.

An error was identified with the calculation of the WA recreational fishery dead discards that were added to the recreational landings, which was corrected during the workshop. This became the accepted dataset and model input. The Northern model was not sensitive to this change.

The maximum age of males and females are a key input to the calculation of M. The approach changed for 2021 to use the 99.9th percentile of aged fish in the PacFin database. The resultant maximum age parameter of 18 and 13 female and males respectively is understandably lower than the previously used figure of 21 years for both (using the maximum age of a fish observed). However, this figure using Otolith age and the maximum age seen in an Alaskan specimen is 36 years old.

Recommendation 9. Work is on-going on the difference between ages using fin ray versus otoliths. This work is supported.

There is some concern with using the 99.9%ile in the PacFin database to calculate the maximum age parameter when this included gear estimated to be dome shaped. Alternatively, using data from shallower sources may also bias the calculation of this parameter. Investigating different sources of age data especially in time blocks where selectivity is more asymptotic may be useful.

Recommendation 10. Further investigate the calculation of maximum age using data from a period where selectivity is more asymptotic. Other approaches to the calculation of M could be considered, including tagging.

Although there was tension in the model between the age and length data in the Northern model, there are little or no age data per fishery in the Southern model. Although the length data are reasonably informative in this model, age data as well as length data are preferred. However, data collection protocols should be well described and adhered to so that they are representative of sex and size.

Recommendation 11. Collection of ageing data for the southern fisheries is a high data priority. Ensure that these are representative.

4.3 ToR 3. Evaluate model assumptions, estimates, and major sources of uncertainty

There is a clear tension in the Northern model between the relative importance placed within the model on these different sources of data. Most importantly, the model is sensitive to the relative weighting of the composition data in the model, and which data are included or not. For example, when the Dirichlet-multinomial (DM) weighting approach (rather than that from Francis, 2011) was applied to the draft base model and to models run during the review week, these consistently upweighted the composition data. Since the version of the draft base model using DM weighting did not fit survey data well, it is not recommended. When all fishery ages were removed, spawning biomass increased although early and recent unfished fraction trends were comparable. M was further reduced. The survey indices were a better fit. When both the DM weighting was applied and fishery ages were removed, the spawning biomass and fraction unfished were much higher than in the other runs, and M was the lowest. Tests with the FG age data (as discussed in ToR 2) highlighted that the conflict in the model related to the recent (2012 onwards) age compositions and those prior to 1999.

The mean weight calculations showed some potential for time varying growth, at least for larger sizes. This is further discussed in ToR 4.

There is likely to be a series of issues in the data, some already mentioned in ToR 2. In addition, there are likely to be key assumptions within the structure of the model that could be contributing to the tension within the model – time-varying growth, age-varying M and sex-specific selectivity – each discussed further in ToR 4 below.

Although this data tension does not exist in the Southern model to such a degree, likely due to lack of age data, there is no reason why the above dynamics would not apply if more extensive age data existed for this stock.

The Southern model draft base model recruitment deviations were characterised by large (unrealistic) increasing correlated trends leading up to the “main” period (1965-2018) where recruitment deviations are zero-centred. This result is likely to influence the steepness parameter and the age structure in the 1960s and 70s.

The North model especially had strong retrospective patterns, and these are discussed further below.

Also of note is that the North model estimate of dead discarded catches in the early period does not match that observed and this issue is also discussed.

4.4 ToR 4. Provide constructive suggestions for current improvements if technical deficiencies or major sources of uncertainty are identified

It should be clearly stated that the package Stock Synthesis 3 is internationally accepted as one of the best age- and length-based integrated models. The implementation of SS for lingcod was found to be appropriate and of a high standard with all expected tests completed.

However, the data are the cause of high model sensitivity to the different data, especially the age and length composition data in the Northern model. Several causes of the uncertainty are possible, all of which are discussed in ToR 7.

Before the review, it was not immediately obvious what the source of this model sensitivity (tension) is, but test runs of all the options suggested by the reviewer were undertaken during the review workshop, being:

- Understanding more about the DM weighting and why the results are sensitive to this approach,
- Removing data from different periods e.g., the middle or early age composition data from some of the fleets (e.g., FG) where there are clear length-composition differences between the age or length data,
- Investigating sex-specific selectivity in the fisheries' data,
- Investigating further time varying selectivity blocks in the Southern model to address the recruitment deviations just prior to the "main" recruitment deviation period, and
- Understanding the reasons for the retrospective patterns in the models.

All these were addressed during the review week and are discussed in ToR 7.

4.5 ToR 5. Determine whether the science reviewed is considered to be the best scientific information available

The Northern and Southern final model at the end of the STAR panel review workshop can be used for management purposes, but the degree of sensitivity and uncertainty in these assessments mean that the assessments should be classified into Category 2 assessments. Given the extent of changes required to the data and the assessments in the medium term, the next assessment should be considered as a benchmark assessment. This is a very complex resource and so are the associated fisheries, making it difficult to assess. However, the present models can be considered the best scientific information currently available for the formulation of management advice. It is particularly important to note, that many of the tests showed that there is some level of stability in the recent management quantities, such as the fraction unfished.

4.6 ToR 6. When possible, provide specific suggestions for future improvements in any relevant aspects of data collection and treatment, modeling approaches and technical issues, differentiating between the short-term and longer-term time frame

The recommendations in all the Terms of References are listed below. Most of these recommendations fall into the medium to long-term and as such they are divided into High, Medium and Lower priorities. It should be noted that Lower priorities may be quick to undertake so should also be considered. The recommendations are also ordered within their category.

4.6.1 High

1. Collection of ageing data for the southern fisheries is a high data priority. Ensure that these are representative.
2. Undertake a major review of the age and length data, understanding the interaction between the fishery and the resource by space and time as is being done for the standardised indices, investigating time-varying growth (although perhaps a lower priority given the findings in the review), age/length-varying M and most importantly and as a priority, sex-specific selectivity.

3. Investigate options of including the above findings from the Northern model into the Southern model, considering its lack of age data.
4. Investigate the extent of the live trade FG fishery and consider the merits of separating this fishery from the FG fleet. Re-analyse the age and size composition data in the context of separating the dead and live FG data.
5. Investigating the fishery dependent age and length composition sampling protocols would be beneficial in light of the review findings.

4.6.2 Medium

6. Work with Canadian counterparts to develop a joint Northern lingcod assessment in light of the new genetic results.
7. Investigate what the causes of the recruitment deviation pattern in the early length composition data in the Southern model are and test whether removal is the best option (or not)
8. Future versions of Stock Synthesis should allow separate weighting of discarded and retained catches. If this does not address the poor representation of dead discards in the Northern model, then other options such as those considered during the review week should be considered.
9. Effort should be made to reconstruct historical (pre-1999) discards.
10. Work is on-going on the difference between ages using fin ray versus otoliths. This work is supported.
11. Further investigate the calculation of maximum age using data from a period where selectivity is more asymptotic. Other approaches to the calculation of M could be considered, including tagging.
12. Calculate the lingcod catch of USA fishers in Mexico from the available databases. This will give a start to estimating the scale of the lingcod fishery in Mexico. Undertake engagement with Mexico for multi-lateral collection of the scale of the fishery in Mexico.

4.6.3 Low

13. Analyse the commercial trawl data by individual stock rather than combined stocks.

4.6.4 Priorities of a general nature

1. Much more consideration needs to be given on how best to implement retrospective analyses in models that include time blocks and address parameter inefficiencies, for example. Only peeling back 1 year of data is not really reflecting how the assessment would be done at that time and may not reflect the model sensitivity to the loss of a year’s data. This means that some form of re-tuning and changes to settings (e.g., time blocks) may need to be undertaken in retrospective analyses. However, how much of this change is required before it becomes a completely new assessment is still open for discussion and should be considered.
2. Providing an approach of comparing the likelihood in retrospective analyses of common elements and time periods (i.e., what is comparable between models) would provide a quick approach to decipher the causes behind model sensitivities in retrospective analyses. This information is presently provided in SS, but not automatically provided in packages such as r4ss.

3. Future versions of Stock Synthesis should allow separate weighting of discarded and retained catches.

4.7 ToR 7. Provide a brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations

Over the period of the review, 20 Panel requests were addressed. The below are not in time sequence, but rather grouped according to topic. It should be noted that much of the effort on the Northern model was to address the tension in the model due to the age and length composition data, whereas that for the Southern model focused on the recruitment deviation patterns observed in the draft base model.

4.7.1.1 Time varying growth

The mean weight calculations at age showed some potential for time varying growth, at least for larger sizes. This possibility was investigated by removing the earlier age data from the Northern model prior to 1990 and then prior to 2000. If this time-varying growth had occurred, then ages and length composition data over a long period would cause conflict within the model. Although the removal of these data changes the absolute spawning biomass values, there is little change to the recent fraction of unfished trends compared to fairly large differences in the 1960s and 1970s. The early recruitments have been informed by the data that have been removed. All these sensitivity runs provide similar M values (above 0.4) and do not point to the model being highly sensitive to this possibility.

4.7.1.2 Age or length-varying M

During the workshop, a sensitivity test was run applying length-varying Lorenzon M. This approach assumes that M varies over the life of a fish through various processes and assumes that M is inversely proportional to length. The reference age was set at age 8 – the age of about 80-90% of the maximum age. Allowing for a variable natural mortality with age for fish less than age 8 could result in a more realistic estimate of natural morality for smaller and immature fish. It is well documented that natural mortality tends to be negatively correlated with body size. This request was applied to both the Northern and Southern model. The Lorenzen function did not dramatically change the trajectory of the spawner biomass for either the Northern or Southern stocks, and had less effect than the use of a sex selectivity offset in the North. In the Southern model some management quantities were different to the draft base model, especially the fraction unfished in 2021 and the spawning biomass. However, it was noted that the Southern model was very sensitive, and gave unrealistic results, when changing the reference age of the mortality prior although this may be due to the Southern model not having ageing data. Although length-varying selectivity cannot be discounted, this issue should be further investigated as part of the work on sex-specific selectivity.

Recommendation 12. Investigate length-varying M as part of the investigations on sex-specific selectivity.

When an informative prior was set to the Day 4 Northern model by dividing the standard deviation of the prior on M by 2, there was little impact, and the model was almost unchanged.

4.7.1.3 Sex-specific selectivity

Given the complex space-time varying dynamics of the fisheries and lingcod, it is likely that there would be sex-specific selectivity particularly in the fishing fleets. The panel and STAT investigated several options during the review workshop:

- Add a female offset to allow for sex-specific selectivity – although this does relieve some of this tension between the age and length composition data, the results show unrealistically low female peak selectivity (20% that of the males for the FG fishery) indicating a large proportion of the female population cannot be selected by the gear. Male M was 66% greater than females in the North.
- Add a female offset but formulate with an additional parameter to allow for a flat top in the selectivity – no real impact as estimated flat top parameter was small, similar to values when these were fixed.
- Female offsets with no FG ages (Northern model only) - spawning biomass scale was similar to the mid-week base model, but there was a large change to the pattern in the fraction unfished. As above, female M was lower than male M. The results showed that FG data are not providing information on recruitment.
- Add female offset for fisheries (not survey indices) as the selectivity differences appear to be greater for the fishery data than the surveys – the change to the Southern model is fairly dramatic with regard to spawner biomass in the early period, but there was little change to the trend until recent years for the sex-specific selectivity model compared to the Day 3 base model. In the Northern model, adding sex-specific selectivity to the fishing fleets affected the spawning biomass and fraction unfished after about 1940. The selectivity patterns estimated were slightly improved but still remain unrealistic. The overall fit in the Northern model was improved, but not in the Southern model. The results highlight that the Southern model does not have sufficient data to estimate sex-specific selectivity.
- For all the above runs, all previous settings from the base model were kept e.g., fixed parameters, selectivity blocks etc. A step wise approach to move from the Day 3 base model to a sex-selectivity model that is free (free peak and descending limbs of the sex-selectivity curves) was undertaken: steps were a) fix the commercial trawl selectivity to be asymptotic for all blocks, b) make the descending slope of the function equal for all blocks, c) setting the descending slope of the selectivity function sex-specific and equal for all blocks, d) setting the descending slope of the function equal for all blocks within the rec fleets, e) setting the descending slope of function sex-specific and equal for all blocks within the recreational fleets (called model 417 in the workshop), f) setting the descending slope of function sex-specific, g) setting the scale and descending slope of the function sex-specific for fisheries only (model 420), and h) making the peak and descending slope of the selectivity function sex-specific for fisheries only (model 421): The above sets of models had differences in complexity and number of parameters. In general, the different sex-specific selectivity models led to much lower estimates of M for both sexes than the base model (except model 421) and higher spawning stock size. The first set of models did not have enough flexibility and therefore the fit to the data decreased. The last three are the most complex models. Implausible selectivity results remain for these runs, for example some of the estimated selectivities had a knife-edge descending slope and very narrow male selectivity on small animals. The selectivity function also changed depending on implementation. One of the "best" options of this set being model 417 still produced unacceptable results. The most complex model considered had sex-dependent variation in both the peak and descending limb of the selectivity curves, and it did produce selectivity curves that could be consistent with a fixed-gear targeting of smaller inshore males.

- For the North model only, the model 417 was run with an informative prior by dividing the standard deviation on the base model prior by 2 – this resulted in little change to the model.

The key findings with all these runs were that implementing sex-specific selectivity would not be easily completed in a workshop and that the model is sensitive to how the selectivity is implemented. There is a continual trade-off between for example, M, growth and selectivity. Although these models often make very large improvements to the likelihood fits, M particularly is scaling up and down. Likelihood profiles on model 417 showed that the Northern model had a bimodal surface producing a low M or high M state. The prior value of M is the least preferred, using the negative-log-likelihood.

Given all these options above, it was clear that sex-specific selectivity would go part way to addressing the tension in the model mainly produced by the age and length composition data in the Northern model. However, the implementation thereof was not simply a matter of providing an offset (with varying number of parameter options for flexibility) and that a much more nuanced option would need to be implemented. As discussed in the above headings, sex-specific selectivity may not be the only dynamic issue to address. Thus, the next assessment should be a major review of the age and length data themselves, understanding the interaction between the fishery and the resource by space and time and how these influence the composition data (as is being done for the standardised indices), investigating time-varying growth (although perhaps a lower priority given the findings), age-varying M and as a priority, reviewing the implementation of sex-specific selectivity.

Without age data in the Southern model, estimating sex-specific selectivity would remain difficult. However, in principle there is no clear reason why some degree of sex-specific selectivity would not occur in the south. On the other hand, there is no reason to expect the selectivities and other parameters to be same as in the Northern model. The differences in selectivity in the survey between the Northern and Southern final models reflect the differences in the size composition of the survey. For example, in the Triennial survey in the Northern model there are fewer small animals than in the Southern model (although the Triennial surveys does not cover the whole CA coast). There are differences in the bathymetry between the North and South regions that could mean differences in the space-time dynamics of the resource and how the fisheries and surveys interact over time. This again reflects that there are spatial scale processes that are not fully captured in these assessments.

Recommendation 13. Undertake a major review of the age and length data, understanding the interaction between the fishery and the resource by space and time as is being done for the standardised indices, investigating time-varying growth (although perhaps a lower priority given the findings in the review), age-varying M and most importantly and as a priority, sex-specific selectivity.

Recommendation 14. Investigate options of including the findings from the Northern model into the Southern model, considering its lack of age data.

4.7.1.4 Southern model recruitment deviations

Given the large (unrealistic) increasing correlated trends leading up to the “main” period (1965-2018) where recruitment deviations are zero-centred, several options were tested to decrease this auto-correlation to something similar to the Northern model:

- The “main” recruitment deviation period was extended back to 1955 – this autocorrelation still occurred before the start of the “main” period. Most of the information for this period is obtained from the CA recreational fishery.
- Add a selectivity block for the CA recreational fishery between 1959 and 1972 when these data were only from a small part of the CA coastline, but keep the “main” period as per the draft base model – this had little impact on the draft base model.
- Remove the early CA recreational length composition data - changes in key parameters included a shift in female M to 0.17, male M to 0.23; steepness increased slightly. Mainly this removes the recruitment deviation autocorrelated peak recruitment before the “main” period and was accepted as the potential new base case.
- As above, but re-tuning and adjusting the recruitment deviations of the above model without the 1959-1972 length composition data – this model showed that there was some poor behaviour from the Triennial survey ascending selectivity limb hitting the lower bound. While this run removed the large recruitment deviation as shown before, it produced a worse fit to the indices, lower female M and higher virgin spawning stock size.
- As above, but an extra standard deviation was added to the Triennial survey index to accommodate hitting one of the selectivity parameter’s bounds: - interestingly, adding this extra standard deviation to the Triennial survey allowed the model to better fit the data without fixing more parameters. The weights on the WCGBTS composition data increased while those on the Triennial survey decreased, thus better fitting to the longest and most representative survey compared to the Triennial survey.

During these tests, it was clear that the virgin stock size estimate was quite sensitive to model settings with respect to early composition data. There were also unrealistically high and auto-correlated recruitment deviations just prior to the “main” period. Only removal of the early length composition data seemed to resolve this issue. The final re-tuned and re-weighted model fit the data that are longest and most representative better.

The Southern model tests showed the DWV index and composition data was unusually influential to the results both in terms of spawning biomass and fraction unfished. However, this reviewer supports the finding that the DWV index is representative of the region as it has good spatial coverage and its influence on the model is likely to be important.

Recommendation 15. Investigate what the causes of the recruitment deviation pattern in the early length composition data in the Southern model are and test whether removal is the best option (or not).

The model described in the last dot point above had convergence issues when the diagnostics such as jitters and likelihood profiles were undertaken. Further changes to the bounds and estimating parameters that were fixed in the Triennial survey were run and these convergence issues were avoided. This model became the final base case and is supported.

4.7.1.5 Final models

The final base model of both the Northern and Southern models were:

North - corrected WA recreational mortality estimates to calculate the landings, no sex-specific selectivity, model retuned and reweighted, and:

South – early length composition data (1959-1972) removed, model retuned with additional standard deviation added to the Triennial survey, estimated previously fixed Triennial survey selectivity parameters, changing some bounds.

Retrospective analyses of the final Northern model (back 5 years) with Mohn's rho values showed significant scaling issues. This reviewer supports the view that a simple peeling back of the data by year and showing the results, inflates the retrospective pattern in complex integrated models. This is especially true, for example, when the data within a time block become very short as peels increase. Thus, some re-tuning and structural changes to blocks would need to be undertaken, but the scale and type needs much more thought.

Recommendation 16. Much more consideration needs to be made on how best to implement retrospective analyses in models that include time blocks and address parameter inefficiencies, for example. Only peeling back 1 year of data is not effectively reflecting how the assessment would be done at that time and may not reflect the model sensitivity to the loss of a year's data. This means that some form of re-tuning and adjustments to settings (e.g., time blocks) may need to be undertaken in retrospective analyses. However, how much of this change is required before it becomes a completely new assessment, is still open for discussion and should be considered.

Recommendation 17. Provide an approach of comparing the likelihood in retrospective analyses of common elements and time periods (i.e., what is comparable between models). This would provide a quick approach to decipher the causes behind model sensitivities in retrospective analyses. This information is presently provided in SS, but not automatically provided in packages such as r4ss.

It is noted that both above recommendations involve most assessments and are not specific to these assessments.

For the North model, some of the peels extended beyond the uncertainty bounds of the final base model (data minus 4 and 5 years). This means the final base model does not characterise the uncertainty in the model. There was, however, some stability in the fraction unfished. Given these patterns, the Mohn's rho results and all the sensitivity runs highlighting the conflict in the data, especially between the age and length composition data, this reviewer supports and re-iterates that the assessment, although data rich, may be information poor for key parameters such as growth, M, steepness and selectivity. This means that the assessment should be classed as a category 2 assessment.

The Southern model has a much higher uncertainty interval in the final model, but the retrospective patterns show that spawning stock size still changes even above the final model's confidence intervals (for data minus 4 and 5 years). There was also some uncertainty in the fraction unfished with the data-3 year's peel being most divergent.

Thus, for both models, the recent data are providing scaling information in the models which partly explains their sensitivity to spawning biomass in the retrospective analyses. However, there is also some degree of stability in the fraction unfished, reflecting that there is more information in the relative change in biomass and recruitment over time.

Given the above sensitivity tests, the decision table decided upon in the STAR workshop is appropriate, being centred on both observation (through removing the fishery dependent age data from the model) and structural model uncertainty (through including sex-specific selectivity as per model 420) in the Northern model, and a classic sensitivity table on M for the Southern model.

The Northern model therefore covers the two clear axes of uncertainty that have been highlighted during the review week. The data uncertainty reflects the tension within the model of which composition data to weight that, then describes uncertainty in spawning biomass scale and productivity. The second axis is the structural uncertainty which reflects that some specific underlying resource space-time dynamic has not been included in the model. This axis is the highest source of uncertainty. The high state of nature is represented by excluding the fishery-dependent age data (as per the 2017 assessment) and the low is represented by adding sex-specific selectivity. Ironically both these two states represent M values lower than the final base model, but their steepness values are either side of the final base model. The resultant Maximum Sustainable Yield values are also quite different. As expected, these differences show different trajectories in the decision table.

The Southern model decision table high and low states of nature are based on the high and low quantiles obtained from the likelihood profile on female M. Most of the model trajectories in the decision table show a stable or declining trend, all of which are within the precautionary zone of 25% to 40% of unfished.

Based on the list of high and medium priorities provided, the next assessments would fall into a benchmark rather than an update.

5 CONCLUSIONS AND RECOMMENDATIONS IN ACCORDANCE WITH THE TORS.

5.1 CONCLUSIONS

The final lingcod models are characterised by being data rich but information poor. This means that key quantities such as M and steepness can be estimated within the model, but their estimated values are very sensitive to assumptions on model structure and which input data to include in the model. Although this sensitivity is more obvious in the Northern model, this is likely to be more a reflection of the lack of age composition data in the Southern model.

Despite these model sensitivities, there was a degree of robustness on key management quantities such as the fraction unfished, especially in the Northern model – as reflected by these generally being within the confidence bounds of the final base model – however it is acknowledged that the decision tables would reflect different pathways, depending on the assumptions used. This finding reflects that there are some informative indices of relative abundance in both final models.

The standard of work addressing the previous STAR panel's recommendations is high and the STAT team have provided the best assessments based on the best available information that could be provided at this stage.

The final model shows that the Northern stock has not been overfished in the past and is at about 64% of the unfished level in 2021. The final Southern model shows that there was a period where the stock was overfished in the 1990s, but are at target levels in 2021.

The decision table for the Northern model is unusual, but attempts to reflect the high and low natural states in the form of data and structural uncertainty. The table for the Southern model is more traditional, along with the model sensitivity of M.

The above comments highlight that the models, although data rich, cannot be considered as a Category 1 assessment and should be classed in Category 2. This better addressed the uncertainty inherent in these assessments.

5.2 RECOMMENDATIONS

The below are the recommendation in order as they appear in the document. These are prioritised in ToR 6.

6 REVIEW PROCESS

The background documents and assessments were provided on 1 July for the review week starting on 12 July, which provided a fairly short time to review all the work, but was found to be adequate. Of great value was that the actual model and *r4ss* model outputs were also provided. This meant one could generate one's own graphs and also view more extensive outputs than provided in the report. The presentations during the first day of the meeting were a good synthesis of the work without taking too much of the review time, and allowed for clarity on any technical issues. The review week was undertaken in a spirit of willingness to solve the issues within both models. The STAT went beyond what would normally be expected, undertook 20 Requests (some of them complex to implement) and often returned with additional work to address the spirit of the request. The panel worked well together and there were no points of disagreement. The same is true between all members present which meant the meeting was constructive and productive. The chair should be complemented for facilitating this result. Each panel member took turns to be rapporteur and write up sections for the report. This means that the panel report was well advanced by the end of the review. Final model results were provided on the 24th of July after the meeting, which was appropriate given that final requests were still being held on the last day and the chosen new base case would need to be checked after the review. This was a very interesting and inspiring review.

There was some difficulty with the entire meeting being online (appropriately so given the circumstances). This reviewer was in a time zone shifted by 7 hours (the meeting started at 1:30 am), which was practically harder than being there in person, but the process went well despite this difficulty. Luckily major internet connections were generally maintained although dropouts were inevitable. The meeting was well managed by the chair especially and online meeting protocols were well maintained.

7 APPENDIX 1: CIE STATEMENT OF WORK

7.1 ATTACHMENT A: STATEMENT OF WORK

Performance Work Statement

External Independent Peer Review by the Center for Independent Experts

Stock Assessment Review (STAR) Panel 2 - Virtual

Lingcod (Northern and Southern stocks)

July 12-16, 2021

7.1.1 Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards.

(http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).

Further information on the CIE program may be obtained from www.ciereviews.org.

7.1.2 Scope:

The National Marine Fisheries Service and the Pacific Fishery Management Council will hold three stock assessment review (STAR) panels and potentially one mop-up panel if needed, to evaluate and review benchmark assessments of Pacific coast groundfish stocks. The goals and objectives of the groundfish STAR process are to:

1) ensure that stock assessments represent the best available scientific information and facilitate the use of this information by the Council to adopt OFLs, ABCs, ACLs, (HGs), and ACTs;
2) meet the mandates of the Magnuson-Stevens Fisheries Conservation and Management Act (MSA) and other legal requirements;
3) follow a detailed calendar and fulfil explicit responsibilities for all participants to produce required reports and outcomes;
4) provide an independent external review of stock assessments;
5) increase understanding and acceptance of stock assessments and peer reviews by all members of the Council family;
6) identify research needed to improve assessments, reviews, and fishery management in the future; and
7) use assessment and review resources effectively and efficiently.

Lingcod was last assessed in 2017 in two separate single-stock assessment models, addressing the stock in Washington and Oregon in the north, and the California stock in the south. That assessment estimated relative depletion of the northern stock at 57.9% of unfished biomass. The southern stock depletion was estimated at 32.1%, which falls within the precautionary zone for Pacific Fishery Management Council stocks. Lingcod are large opportunistic top predators in the nearshore demersal ecosystem of the northeast Pacific Ocean and are valued both commercially and recreationally in the U.S. groundfish fishery. They range from Kodiak Island, Alaska to Baja California, Mexico. The historical centre of abundance is in the waters off British Columbia and Washington State. Male and female lingcod exhibit different life-histories in that the males guard nests in shallow water for 5-7 weeks in the fall, while the females remain in deeper water; accordingly, the sexes are represented independently in the model. Lingcod are harvested commercially by trawl and longline gear, and recreationally by hook-and-line and spear. In California, the recreational fishery accounts for more than 90% of the landings; in Washington and Oregon the landings are more evenly divided between the recreational and commercial fisheries.

Assessments for these stocks will provide the basis for the management of the groundfish fisheries off the West Coast of the U.S., including providing scientific basis for setting OFLs and ABCs as mandated by the Magnuson-Stevens Act. The technical review will take place during a formal, public, multiple-day virtual meeting of fishery stock assessment experts. Participation of an external, independent reviewer is an essential part of the review process. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

7.1.3 Requirements:

Two CIE reviewers will participate in the stock assessment review panel. One CIE reviewer, requested herein, shall conduct an impartial and independent peer review of the assessments described above and in accordance with the Performance Work Statement (PWS) and ToRs herein. Additionally, one "common" CIE reviewer will participate in all STAR panels held in 2021 and the PWS and ToRs for the "common" CIE reviewer are included in **Attachment A**.

The CIE reviewers shall be active and engaged participants throughout panel discussions and able to voice concerns, suggestions, and improvements, while respectfully interacting with other review panel members, advisors, and stock assessment technical teams. The CIE reviewers shall have excellent communication skills in addition to working knowledge and recent experience in fish population dynamics; with experience in the integrated-analysis modeling approach, using age- and size- (and possibly spatially-) structured models, and methods for quantifying uncertainty. Familiarity with environmental, ecosystem and climatic effects on population dynamics and distribution may also be beneficial. The CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

7.1.4 Tasks for Reviewers:

The CIE reviewer shall complete the following tasks in accordance with the PWS and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the NMFS Contracting Officer Representative (COR), who forwards this information to the NMFS Project Contact no later than the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the PWS and ToRs to the CIE reviewer. The NMFS Project Contact is responsible for providing the CIE reviewer with the background documents, reports, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the PWS in advance of the panel review meeting. Any changes to the PWS or ToRs must be made through the COR prior to the commencement of the peer review.

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the PWS scheduled deadlines specified herein. The CIE reviewer shall read all documents in preparation for the peer review.

Documents to be provided to the CIE reviewers prior to the STAR Panel meeting include:

- The current draft stock assessment reports;
- Previous stock assessments and STAR Panel reports for the assessments to be reviewed;
- The Pacific Fishery Management Council's Scientific and Statistical Committee's Terms of Reference for Stock Assessments and STAR Panel Reviews;
- Stock Synthesis (SS) Documentation;
- Additional supporting documents as available;
- An electronic copy of the data, the parameters, and the model used for the assessments (if requested by reviewer).

Test: Additionally, two weeks prior to the peer review, the CIE reviewers will participate in a test to confirm that they have the necessary technical specifications provided in advance of the panel review meeting.

Panel Review Meeting: The CIE reviewer shall conduct the independent peer review in accordance with the PWS and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the PWS and ToRs cannot be made during the peer review, and any PWS or ToRs modifications prior to the peer review shall be approved by the COR and CIE Lead Coordinator.**

Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the review panel's virtual meeting, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., video or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: The CIE reviewer shall complete an independent peer review report in accordance with the PWS. Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Annex 1**. The CIE reviewer shall complete the independent peer review addressing each ToR as described in **Annex 2**.

Other Tasks – Contribution to Summary Report: The CIE reviewer should assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. The Chair is not provided by the CIE under this contract. A CIE reviewer is not required to reach a consensus with other members of the Panel, and should provide a brief summary of the reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

7.1.5 Place of Performance:

The CIE reviewers shall conduct an independent peer review during the panel review meeting scheduled for the dates of July 12-16, 2021. Due to current uncertainties in the state of the COVID-19 pandemic at that time, this meeting will be conducted as a virtual meeting, with technical assistance provided by staff from the Pacific Fishery Management Council.

7.1.6 Period of Performance:

The period of performance shall be from the time of award through **August 2021**. The CIE reviewers' duties shall not exceed 14 days to complete all required tasks.

7.1.7 Schedule of Milestones and Deliverables:

CIE shall complete the tasks and deliverables described in this PWS in accordance with the following schedule.

Schedule	**Deliverables and Milestones**
Within two weeks of the award	Contractor selects and confirms reviewers. This information is sent to the COR, who then transmits this to the NMFS Project Contact
Approximately two weeks later	Contractor provides the pre-review documents to the CIE reviewers
July 12-16, 2021	**Virtual Panel Review Meeting**

Approximately two weeks later	Contractor receives draft reports
Within two weeks of receiving draft reports	Contractor submits final CIE independent peer review reports to the COR

7.1.8 Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards:

(1) The reports shall be completed in accordance with the required formatting and content; (2) The reports shall address each TOR as specified; and (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

7.1.9 Travel:

No travel is necessary, as this meeting is being held remotely.

7.1.10 Restricted or Limited Use of Data:

The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:

Andi Stephens, NMFS Project Contact
National Marine Fisheries Service,
Newport, OR 97365
Andi.Stephens@noaa.gov
Phone: 843-709-9094

7.1.11 Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Performance Work Statement
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

7.1.12 Annex 2: Terms of Reference for the Peer Review

Stock Assessment Review (STAR) Panel 2

The specific responsibilities of the STAR panel are to:

1. Become familiar with the draft stock assessment documents, data inputs, and analytical models along with other pertinent information (e.g., previous assessments and STAR panel report when available) prior to review panel meeting.
2. Discuss the technical merits and deficiencies of the input data and analytical methods during the open review panel meeting.
3. Evaluate model assumptions, estimates, and major sources of uncertainty.
4. Provide constructive suggestions for current improvements if technical deficiencies or major sources of uncertainty are identified.
5. Determine whether the science reviewed is considered to be the best scientific information available.
6. When possible, provide specific suggestions for future improvements in any relevant aspects of data collection and treatment, modeling approaches and technical issues, differentiating between the short-term and longer-term time frame.
7. Provide a brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.

7.1.13 **Annex 3: Tentative Agenda**

Final Agenda to be provided two weeks prior to the meeting with draft assessments and background materials.

Stock Assessment Review (STAR) Panel 2 - Virtual

July 12-16, 2021

---

8 Appendix 2: Final Agenda

Stock Assessment Review (STAR) Panel for Lingcod

Pacific Fishery Management Council

Online Meeting

July 12-16, 2021

Times listed in the agenda are Pacific Daylight Time and subject to change during the course of the meeting at the discretion of the STAR Panel Chair. Meeting materials, instructions for joining the webinar, and other information can be found on the Pacific Fishery Management Council's website.

Break times will be determined by the chair. A dedicated public comment agenda item has been scheduled for each day.

Monday, July 12, 2021 – 8:30 AM

Early Log-In to Resolve Connection Issues

(8:30 a.m.)

Welcome and Introductions

(8:45 a.m.)

• Roll Call, Introductions, Announcements, etc.	John Field, Chair
• Review Terms of Reference	
• Review and Approve Agenda	
• Review Virtual Formal Operational Guideline	Todd Phillips
• Assign Writing Duties	John Field

Overview and Inputs to the Lingcod Stock Assessments

(9:15 a.m.)

1. Overview of Lingcod North and South Stock Status	Ian Taylor
2. Lingcod Biology and Stock Structure	Ian Taylor

– Break (10:15) –

Overview continued

(10:30)

3. Catch History and Fleet Structure Kelli Johnson

4. Fishery-Independent and Fishery-Dependent Data Kelli Johnson

– Lunch (12:00 – 1:00 p.m.) –

Modeling and Results of the Lingcod Stock Assessments

(1:00 p.m.)

5. Lingcod North: Assessment Modeling, Performance, & Results Ian Taylor

Monday, July 12, 2021 – continued

6. Lingcod South: Assessment Modeling, Performance, & Results Kelli Johnson

– Break (3:00 pm) –

Public Comment Period

(3:15 pm)

STAR Panel Discussion and Requests to Stock Assessment Team

(3:30 p.m.)

Adjourn for day

(4:00 p.m.)

Tuesday, July 13, 2021 – 8:30 AM

Early Log-In to Resolve Connection Issues

(8:30 a.m.)

1. Review Day 1 and STAR Panel Discussion

(8:45 a.m.)

2. Stock Assessment Team (STAT) presentations of Model Runs and Analyses

a. Lingcod North Ian Taylor/Kelli Johnson

b. Lingcod South

(9:30 a.m.)

– Break (10:15) –

– Lunch (12:00 – 1:30 p.m.) –

3. STAR Panel Discussion and Requests for Model Runs / Analyses

(1:30 p.m.)

– Break (3:00 pm) –

Public Comment Period

(3:15 p.m.)

STAR Panel Discussion and Planning (continued)

(3:30 p.m.)

Adjourn for day

(4:00 p.m.)

Wednesday, July 14, 2021 — 8:30 AM

Early Log-In to Resolve Connection Issues

(8:30 a.m.)

Review Day 2 and STAR Panel Discussion

(8:45 a.m.)

2. STAT presentations of Model Runs and Analyses Ian Taylor/Kelli Johnson

a. Lingcod North

b. Lingcod South

(9:00 a.m.)

– Break (10:15) –

– Lunch (12:00 – 1:30 p.m.) –

3. STAR Panel Discussion and Requests for Model Runs / Analyse

(1:30 p.m.

– Break (3:00 pm) –

Public Comment Period

(3:15 p.m.)

STAR Panel Discussion and Planning (continued)

(3:30 p.m.)

Adjourn for day

(4:00 p.m.)

Thursday, July 15, 2021 —8:30 AM

Early Log-In to Resolve Connection Issues

(8:30 a.m.)

Review Day 3 and STAR Panel Discussion

(8:45 a.m.)

2. STAT presentations of Model Runs and Analyses Ian Taylor/Kelli Johnson

a. Lingcod North

b. Lingcod South

(9:00 a.m.)

– Break (10:15) –

– Lunch (12:00 – 1:30 p.m.) –

3. STAR Panel Discussion

a. Additional model runs/analyses (as needed)

b. Panel/STAT Agree on Final Base Model

c. Decision Table Developed

(1:30 p.m.)

– Break (3:00 pm) –

Public Comment Period

(3:15 p.m.)

Thursday, July 15, 2021 —continued

STAR Panel Discussion (continued)

(3:30 p.m.)

Adjourn for day

(4:00 p.m.)

Friday, July 16, 2020 — 8:30 AM

Early Log-In to Resolve Connection Issues

(8:30 a.m.)

1. Review Decision Tables

a. Lingcod North

b. Lingcod South

(8:45 a.m.)

– Break (10:15) –

2. Discuss STAR Panel Report Draft

a. Review as appropriate

b. Agree on Process for Completion of Report (due by Aug 15)

(11:00 a.m.)

– Lunch (12:00 – 1:30 p.m.) –

3. Continue STAR Panel Report Drafting (as needed)
– Break (3:00 pm) –

4. STAR Panel Adjourns

(4:00 p.m.)

PFMC

06/17/21

9 APPENDIX 3: PANEL MEMBERSHIP, LIST OF PARTICIPANTS AND DOCUMENTS

9.1 PANEL MEMBERSHIP

In attendance were STAR panel members:

- John Field, National Marine Fisheries Service Southwest Fisheries Science Center (Chair)
- Will White, Oregon State University
- Matt Cieri, Center for Independent Experts
- Cathy Dichmont, Center for Independent Experts

9.2 LIST OF PARTICIPANTS

The Stock Assessment Team (STAT) members:

3. For the South
   - Kelli Johnson, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
   - Ian Taylor, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
   - Brian Langseth, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
   - Andi Stephens, National Marine Fisheries Service Northwest Fisheries Science Center, Newport
   - Laurel Lam, Pacific States Marine Fisheries Commission, Seattle
   - Melissa Monk, Southwest Fisheries Center, Santa Cruz
   - John Budrick, California Department of Fish and Wildlife, San Carlos
   - Melissa Haltuch, National Marine Fisheries Service Northwest Fisheries Science Center, Newport
4. For the North
   - Ian Taylor, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
   - Kelli Johnson, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
   - Brian Langseth, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle
   - Andi Stephens, National Marine Fisheries Service Northwest Fisheries Science Center, Newport
   - Laurel Lam, Pacific States Marine Fisheries Commission, Seattle
   - Melissa Monk, Southwest Fisheries Center, Santa Cruz
   - Alison Whitman, Oregon Department of Fish and Wildlife, Newport
   - Melissa Haltuch, National Marine Fisheries Service Northwest Fisheries Science Center, Newport

9.3 LIST OF REVIEW WORKSHOP WORKING PAPERS AND DOCUMENTS

Before workshop

Stock synthesis executable, data and SS output for both Northern and Southern Stocks.

Jagielo, T.H., Wallace, F.R. 2005. Assessment of Lingcod (*Ophiodon elongatus*) for the Pacific Fishery Management Council in 2005. Washington Department of Fish and Wildlife, Washington, USA, 153 pp.

Conser, R., Francis, C., Mikura, D. Mohn, R., Culver, B., Leipzig, P. and Saelens, M. 2005. Star Panel Report: Lingcod. Northwest Fisheries Science Center, Seattle, USA, 7 pp.

Dorn, M., Conser, R., Hamel, O., Berkely, S., Mohn, R., Piner, K., Ralston, S., Devore, J. and Leipzig, P. 2005. Lingcod STAR panel Report. Alaskan Fisheries Science Center, Seattle, USA, 5 pp.

Hamel, O.S., Sethi, S.A., and Wadswort, T.F. 2009. Status and Future Prospects for Lingcod in Waters of Washington, Oregon, and California as Assessed in 2009. Northwest Fisheries Science Center, Seattle, USA, 458 pp.

Wespestad, V., Maguire, J.J., Smith, S., Ianello, J. 2009. Lingcod STAR Panel Report. Seattle, USA, 9 pp.

Haltuch, M.A., Wallace, J., Akselrud, C.A., Nowlis, J., Barnett, L.A.K., Valero, J.L., Tsou, T-S. and Lam, L. 2018. 2017 Lingcod Stock Assessment. Northwest Fisheries Science Center, Seattle, USA, 295 pp.

Sampson, D., Apostolaki, P., Hall, N. and Piner, K. 2017. Lingcod Stock Assessment Review (TSAR) Panel Report, Northwest Fisheries Science Center, USA, 35 pp.

Lingcod_Tables_26June_2018.xlsx

Acronyms Used in West Coast Groundfish Assessments, 1pp.

Methot, R.D., Wetzel, C.R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research. 142: 86-99. https://doi.org/10.1016/j.fishres.2012.10.012.

Monk, M.H., Miller, R.R., Field, J., Dick, E.J., Wilson-Vandenberg, D. and Reilly, P.2016. Documentation for California Department of Fish and Wildlife's onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in Northern and Central California (1987-1998) as a relational database. NMFS, Santa Cruz, USA, 69 pp.

Miller, S., Stephens, A., Whitmire, C. and Hastie, J. 2021. Overview of West Coast Groundfish Fishery-Independent Surveys. NMFS, Washington, USA, 19 pp.

Methot, R.D., Wetzel, C.R., Taylor, I.G. and Doering, K. 2020. Stock Synthesis User Manual Version 3.30.16. NOAA Fisheries, Seattle, USA, 216 pp.

Pacific Fishery Management Council, 2020. Term of Reference for the Groundfish and Coastal Pelagic Species Stock Assessment Review Process for 2021-2022. Pacific Fisheries Management Council, USA, 64 pp.

Thorson, J.T., Barnett, L.A. 2017. Comparing estimates of abundance trends and distribution shifts using single- and multispecies models of fishes and biogenic habitat. ICES Journal of Marine Science, 74(5): 1311-1321.

Provided during workshop (apart from Requests)

Lingcod all lengths prop vs lengths with ages proportions 2017 STAR. xlsx

Its update: Lingcod all lengths prop vs lengths with ages proportions 2021 STAR. xlsx

GMT_GEMM_2002-2019_Lingcod_N_trawl.xlsx

10 Appendix 4: References

Francis, R.I.C.C. 2017. Revisiting data weighting in fisheries stock assessment models. Fisheries Research. 192: 5-15.

Goodrich, B., Gabry, J., Ali, I., and Brilleman, S. 2020. Rstanarm: Bayesian applied regression modeling via Stan.

Lee, H., Piner, K.R., Taylor, I.G. and Kitakado, T. 2019. On the use of conditional age at length data as a likelihood component in integrated population dynamics models. Fisheries Research, 216:204-211.https://doi.org/10.1016/j.fishres.2019.04.007.

Longo, G.C., Lam, L., Basnett, B., Samhouri, J., Hamilton, S., Andrews, K., Williams, G., Goetz, G., McClure, M., and Nichols, K.M. 2020. Strong population differentiation in lingcod (Ophiodon elongatus) is driven by a small portion of the genome. Evolutionary applications 13(10): 2536–2554.

Methot, R.D., Wetzel, C.R., Taylor, I.G. and Doering, K. 2020. Stock Synthesis User Manual Version 3.30.16. NOAA Fisheries, Seattle, 221 pp.

Stewart, I.J., and Hamel, O.S. 2014. Bootstrapping of sample sizes for length- or age composition data used in stock assessments. Canadian Journal of Fisheries and Aquatic Sciences 71(4): 581–588.

Taylor, I.G., K.F. Johnson, B.J. Langseth, A. Stephens, L.S. Lam, M.H. Monk, A.D. Whitman, M.A. Haltuch. 2021. Status of lingcod (Ophiodon elongatus) along the northern U.S. west coast in 2021. Pacific Fisheries Management Council, Portland, Oregon. 293p.

Taylor, I.G., K.F. Johnson, B.J. Langseth, A. Stephens, L.S. Lam, M.H. Monk, J.E. Budrick, M.A. Haltuch. 2021. Status of lingcod (Ophiodon elongatus) along the southern U.S. west coast in 2021a. Pacific Fisheries Management Council, Portland, Oregon. 187p.

Thorson, J.T., and Barnett, L.A.K. 2017. Comparing estimates of abundance trends and distribution shifts using single- and multispecies models of fishes and biogenic habitat. ICES Journal of Marine Science 74(5): 1311–1321.