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Proceedings for the Regional Peer Review for the Development of a new Precautionary Approach Framework for Northern Shrimp in the Newfoundland and Labrador Region

Meeting dates: May 15-17, 2019
Location: St. John’s, NL

Chairperson: Joanne Morgan
Editor: Katherine Skanes

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

A Regional Peer Review Process for the Development of a new Precautionary Approach (PA) Framework for Northern Shrimp in the Newfoundland and Labrador (NL) Region was held on May 15-17, 2019 in St. John's, NL. The purpose of the process was to attempt to improve upon existing assessment methodology for Northern Shrimp in Shrimp Fishing Areas (SFAs) 4 through 7.

The Regional Peer Review Process was to meet its goal by focusing on several specific objectives. These objectives were to review available Northern Shrimp data and productivity regimes, to review statistical assumptions for two proposed Northern Shrimp models (although only one was available), to review reference point methodologies and approaches for a new PA framework and to review methods for projecting metrics associated with reference points. The proposed PA framework and reference points were not accepted at the Canadian Science Advisory Secretariat (CSAS) meeting. Meeting participants concluded that they needed more data and time before they could recommend a new PA framework. The new model to assess the Northern Shrimp population in NL was provisionally accepted at the CSAS meeting pending a final review.

Participation included representatives from Fisheries and Oceans Canada (DFO) Science and Resource Management, the fishing industry, academia and an Indigenous group.

In addition to these Proceedings, a Research Document will be produced from this meeting, both of which will be posted on the DFO Science Advisory Schedule as they become available.

PRESENTATIONS

DATA REVIEW FOR NORTHERN SHRIMP FRAMEWORK MEETING

Presenter: K. Skanes

Abstract

This presentation discussed the various data sources that were utilized in the Northern Shrimp model as was presented at the Framework meeting. The model utilized data from two survey time series, Fisheries and Oceans Canada (DFO) fall multi-species surveys in Shrimp Fishing Areas (SFAs) 5–7 and Northern Shrimp Research Foundation shrimp surveys in SFA 4, along with landings data from each SFA.

An overview of general survey statistics was provided. This included a comparison of the number of allocated sets compared to the number successfully completed. Often, the full allocation is not successfully surveyed due to factors such as weather, vessel issues, or because sets are discarded during data quality control due to other factors that are deemed outside of accepted survey protocols. Generally, the survey start dates, end dates, and the number of days fishing is consistent through years, however these can be impacted by the same issues listed that affect surveying the full allocation of sets. Trends in various species (excluding labels by common species names) were presented for each SFA to demonstrate that year effects are not suspected; if year effects were an issue we would expect to see unusual survey catch rates in all species as well as all trends for all species going either up or down together. In addition to the survey data being utilized in the model, it is utilized during winter shrimp assessments to generate indices of biomass and, along with commercial landings data, to calculate exploitation rate indices.

Slides were included about landings data for Northern Shrimp. Fisheries for this species are executed by vessels registered in several provinces and compiled by a central data source to provide the full landings amount by SFA and vessel type (i.e., large versus small vessels). The figures included show that these landings may exceed the Total Allowable Catch (TAC) in a number of years, which occurs due to quota carryovers between years; a process permitting borrowing quota from years before or after a management year. Generally, the full quota is taken in each SFA annually. Ideally a model will benefit by using the landings as they are removed before and after surveys rather than those based on a full management year, however this is complicated for Northern Shrimp given that the fishery takes place year round and the data comes from multiple sources; dividing the landings in such a manner is problematic.

Discussion

It was noted that due to overlap in the assessment (February) and the commercial fishery (April 1 to March 31), catch information was incomplete during the assessment. The degree of completeness varied between SFA.

There was a question regarding changes in size structure, specifically on whether the proportion of female shrimp in the fishable population is relatively consistent over time. The presenter indicated that there has been little change in the proportion of females within the fishable population through time and that there have been no drastic changes in the size structure. It was explained that size based modelling attempts have been unsuccessful, and that there were no patterns in size structure changes for a model to track. It was noted that male to female ratios shift annually in the Arctic Region; however, there was no evidence or analysis to demonstrate the same annual shift in the SFA 4–7 stocks.

There were further questions about the commercial fishery regarding Nordmore Grid bar spacing in SFAs.

PRECAUTIONARY APPROACH FOR NORTHERN SHRIMP IN SFAS 4–6

Presenter: K. Skanes

Abstract

An overview of the processes, methods and meetings utilized for establishing the current Precautionary Approach (PA) Framework for Northern Shrimp in SFAs 4–6 was provided. This overview was based on publications available to the public and included a review of DFO accepted PA methodology. It then delved into meeting summaries from shrimp-specific meetings which were held over a number of years. Summary bullets from, and references for, each publication were provided. The final discussion focused on each SFA individually and included current biomass indices with a focus on time-frames from which reference points were developed, along with the PA plots from the February 2019 Assessment of Northern Shrimp.

Discussion

Part of the discussion following this presentation was centered around Marine Stewardship Council (MSC) certification. Timelines specific to particular species (i.e., their generation time) are important in any evaluation of the harvest control rule. By MSC standards, the shorter of 20 years or two generations is the expected recovery time for a species in a Critical Zone. In contrast, DFO fisheries management uses 1.5 to 2 generations as a reasonable timeframe, while the Northern Shrimp Integrated Fisheries Management Plan (IFMP) indicates recovery after six years. While age data are not available for shrimp, a generation is estimated to be five to eight years for Northern Shrimp in SFAs 4–7.

According to the IFMP, the goal of the PA for Northern Shrimp is to get out of the Critical Zone within six years. The maximum recommended exploitation rate in any year is 10% while a stock is in the Critical Zone.

It was expressed that MSC certification does not impact DFO science advice. Several participants were in agreement that a recovery point is desirable and should be, at a minimum, the MSC standard. It was also explained that due to Bill C-68, future DFO stock assessments will be legally required to have reference points and environmental variables (EVs) may be required. Participants discussed the possibility of having a specific range for a reference point rather than a single point based on environmental conditions.

A participant inquired about a working group meeting from 2013 that looked at how well the PA is working, noting that it was not discussed during the presentation. It was explained that the working group did draw some conclusions and worked to tackle harvest control rules. The PA and associated harvest control rules were neither accepted nor rejected by the working group. The conclusions of the working group were presented to the Northern Shrimp Advisory Committee (NSAC) in January 2014. Several participants asked to see what the harvest control rules, and other proposed decisions would look like when applied to the science assessment results. This was particularly true in SFA 6 which was experiencing biomass estimate declines at that time.

A participant asked why a 30%-based Limit Reference Point (LRP) is used instead of 40%. In contrast, the Northwest Atlantic Fisheries Organization (NAFO) PA, in the absence of a model, recommends utilizing 15% of the maximum observed female spawning stock biomass (SSB) as the proxy for the biomass limit reference point (B_{lim}). It was noted that the NAFO approach is much more cautious and, if the same approach were implemented for SFA 6, that fishery would have no commercial fishing at this time. Participants agreed that it was reasonable to conclude that the 30% utilized in setting LRPs for Northern Shrimp were a compromise between the Canadian literature-suggested 40% and the NAFO-required 15%. The two approaches; however, are not directly comparable and the 30% versus 40% question is subjective, whereas the NAFO approach was developed through rigorous scientific review.

The DFO standard for recovery is a minimum and is lower than the MSC standard. It was stated that the frameworks for other global shrimp stocks, perhaps in the Northeast Atlantic, could be of assistance in looking at generation time and recovery. It was noted that several other stocks (i.e., West Greenland or Skagerrak) are modeled, but also not below B_{lim}.

HISTORIC EVIDENCE OF PRODUCTIVITY CHANGES IN NORTHERN SHRIMP

Presenter: E. Pedersen

Abstract

Northern Shrimp stocks on the Newfoundland and Labrador shelves are thought to have been at substantially lower abundances prior to the collapse of groundfish stocks in the 1990s. As shrimp stocks were not as heavily exploited as they are currently, this would imply that the net productivity of shrimp stocks in this region were lower in the past then they had been in the last decade, which would mean that any modelling efforts should account for the possibility of varying productivity levels. However, the current multi-species survey, which used a small enough mesh size to catch shrimp, was not started until 1995. This was after the purported change in productivity, so there was limited scientific evidence of this productivity change. This talk addressed the data gap by using two lines of evidence to estimate how shrimp abundances had changed prior to the DFO multi-species survey.

The first line of evidence was based on targeted summer shrimp surveys that were conducted from 1979–90 in the Hawke, Cartwright, and Hopedale Channels (hereafter referred to as historical surveys). A statistical matching procedure was used to find only those trawls from the current multi-species survey that were close in both space and depth to the historical survey trawls, and both surveys were scaled based on tow duration and wingspread to convert biomass of shrimp per trawl into biomass per square km. To demonstrate that the matched surveys were catching similar populations of shrimp, length distributions for the current and historical series were compared; this demonstrated that the two trawls had similar patterns of catchability, but there was evidence that either the historical trawl had a higher catchability for very large shrimp (>25 mm carapace length [CL]) or that these size classes were just more abundant prior to 1995. The matched trawls for the two survey time series were converted into estimated average densities for each channel in each year (both before and after 1995) by using a Generalized Additive Model (GAM), a type of statistical smoothing procedure. The time series were scaled by the average 1979–90 biomass estimate to estimate the level of relative change in abundance. This line of evidence suggested that shrimp biomass increased between five and ten times from 1990 to 1995 in the Hawke Channel (the most southerly one in SFA 6), and between two and four times in the two more northerly channels (both in SFA 5). Potential issues with this line of evidence were also discussed: first, that the two surveys used different gears, and took place at different times of the year (the fall for current surveys and the summer for the historical surveys), and there was a gap in the time series from 1990 to 1995, making it difficult to ascertain the timing of the increase. This motivated the need for a second line of evidence to determine if productivity had changed.

The second line of evidence presented was from a long-term cod diet data set, that has been consistently recorded across NAFO Divisions 2J3KL (SFA 6, 7 and southern SFA 5) every year since 1979. This data consisted of the average fraction of sampled cod stomachs where shrimp were present as the primary prey item (hereafter referred to as shrimp diet fraction). For each year of the current time series (since 1995), the shrimp diet fraction was regressed against the total weight of shrimp observed in SFA 6 using a generalized linear model (GLM) with Gamma distributed errors. The GLM was then used to forecast what biomass was expected to give the same shrimp diet fraction from the 1979–95 period. This forecast was compared to the observed biomass from the current time series. This line of evidence indicated that shrimp biomass in SFA 6 increased between two to five times from 1990 to 1995, and peaked in the mid-2000s around two to eight times the abundance of the 1979–90 period. Caveats with this method were also discussed: it relies on the assumption of linearity between diet fraction and log-population abundance of shrimp, and it assumes that the feeding behaviour of cod did not change in the study period.

Finally, evidence on potential changes in ecosystem variables were presented. This included the decline in groundfish biomass from the late-1980s to 1995, shifts from a warmer, fresher climate index to a colder one in the 1980s on the Newfoundland shelf, and declines in forage fish species and zooplankton abundances.

It is important to note that this research does not imply that the ecosystem has returned to its 1979–90 state. Groundfish abundance remains low and shrimp exploitation is much higher than it was during that period of time. Additionally, the exact cause of shrimp population increases/decreases is not clear merely from these analyses.

Discussion

Most information presented, along with questions and discussion, were endeavoring to account for the perceived large increase in shrimp abundance and biomass estimated from the shrimp surveys in the 1980s to the multi-species survey in the 1990s. This was necessary in an effort to determine maximum population growth rates (R_{max}), which were utilized in analyses later in the meeting.

The Campelen 1800 trawl was implemented for multi-species surveys in 1995 and it demonstrated far higher catches than the Sputnik trawl used in prior shrimp surveys, noting that there were no shrimp surveys from 1990–94. An important difference between the two surveys was that the shrimp surveys directed specific channels in which there was a commercial fishery, while the multi-species survey targeted a broad spatial scale. All analyses held the assumption that both survey trawls had a catchability of 100%; however, this is not accurate; the true catchability of the survey trawl on shrimp is unknown. Despite other differences in survey gear and protocols, there was an evident high increase in shrimp abundance from the shrimp survey to the multi-species survey. There were concerns about the differences in surveys and their conclusions; however, the meeting presenter had standardized to swept area and felt that the difference was a good estimate of the population change.

There were several questions related to cod stomach data such as how these data were collected, analyzed and utilized. This data was collected from groundfish surveys, which utilized an Engels trawl (large sized mesh that did not capture shrimp), prior to the commencement of the multi-species survey in 1995. Data collection continued during the multi-species survey (1995–present). The highest three prey items were recorded in stomachs while at sea, with some fish stomachs being completely analyzed in a lab (i.e., called stomachs). Both data sets are noisy, but comparable. The data presented was based on the fraction of cod that had shrimp as one of the top three prey items with the theory that the more shrimp that are present in a population, then the more that will be evident in predator stomachs. This analysis is confounded by the availability of more desirable high-energy prey (i.e., capelin, herring), spatial overlap of cod/shrimp, migration patterns of cod and the rations of abundance of cod to shrimp. However, the meeting participants agreed that the diet analyses was a worthwhile piece of evidence for Northern Shrimp population growth.

There was concern over the spatial distribution of the fishery, understanding that the shrimp fishery was limited to a few offshore channels, while the surveys covered a broad spatial scale. The presenter had attempted several times to look at spatial patterns of fishing, although these analyses were not available during the meeting. It was concluded that spatial coverage of the fishery had not changed a lot over time but changes in areas would be anticipated due to economics of fishing in areas of low abundance and the improvements in fishing technology and methodology. As an example, the presenter had commented that commercial catch per unit effort (CPUE) continued to rise after biomass started to fall and that analyses of commercial CPUE can be distorted due to better fishing practices. An industry representative concluded that technology had not greatly changed from the 1980s to the 1990s and that fish harvesters would occasionally attempt fishing outside the main channels, yielding poor catch rates in the 1980s but excellent ones in the 1990s. Additionally, that participant noted that there were periods of time (when shrimp were abundant) during which fishing vessels would explore fishing in different areas and, as a result, could selectively target larger (i.e., higher value) shrimp.

The discussion on spatial overlap led into questions regarding the change in commercial CPUE between the 1980s and the 1990s. It was noted that available science advisory reports demonstrate a significant increase in large-vessel CPUE (in SFA 6) from the late-1980s to 1995. A figure was displayed demonstrating an analysis of commercial data limited to the three channels, in which some channels demonstrated high increases in catch rates. There were clear differences in the changes within each of the three channels, with the changes in the Hopedale Channel being the most unclear.

All meeting participants agreed that there were more shrimp from 1995 onwards than in the late-1980s given the clear evidence presented. However, there was significant discussion on the magnitude of the change as some people felt that this was also important. It was apparent from the different evidence presented that the increase was somewhere between three and 10 times from the 1980s to the 1990s. Unfortunately, the exact number was difficult to pin-point and the changes between different channels were not the same. It should be noted that no meeting participant was agreeable with using an increase of 10 times. Despite the difficulties on quantifying the increase and concerns with differences between channels, the presenter noted that the proposed PA framework presentation (later on the agenda), assumed an increase of 4.5 times between 1990 and 1995; equivalent to an R_{max} of 0.3.

SURPLUS PRODUCTION MODELS

Presenter: E. Pedersen

Abstract

To understand the causes of large-scale changes in Northern Shrimp stocks, it is necessary to model how different potential ecosystem factors and fishing pressure have interacted to affect these stocks. To effectively predict how Northern Shrimp abundances may change in the future, any model needs to be predictive, mechanistic, take ecosystem factors into account, should allow predictions to be made at relevant spatial scales and include model uncertainty. This presentation covered efforts to model the dynamics of Northern Shrimp using spatially explicit surplus production models (SPM).

The models tested focused on estimating surplus productivity, i.e., the amount of new shrimp biomass produced in each location remaining after net of losses to natural mortality and fishing. The modelling approach used a discretization procedure to break the four focal regions (SFA 4–7) into smaller patches (Voronoi polygons). For each patch for each year, shrimp abundance in each patch was calculated using a spatially explicit smoothing model (a GAM). These were converted into productivity estimates by subtracting the log of estimated biomass plus estimated catch in each patch in each year from the log of biomass in the previous year. Ecosystem predictors, including predator (cod, turbot, and redfish) densities, bottom temperatures, and estimated patterns of recruitment (based off of prior dispersal simulation studies) were also spatially smoothed for each year to estimate patch-specific values for these models. These predictors were converted into SFA-level predictors by averaging across all of the patches in each SFA. Other ecosystem predictors that were not sampled at smaller spatial scales, including zooplankton biomass, phytoplankton bloom magnitude, and North Atlantic Oscillation (NAO), were converted into an annual time series for each SFA. Not all of these predictors were incorporated into the final model, as there was evidence that they did not influence shrimp productivity changes at the smaller patch-level.

Several SPMs were tested. All models were fit as GAMs, assuming that residual surplus production was t-distributed, to allow for the possibility of occasional large positive or negative productivity values. All models included a patch-specific intercept and a patch-specific density-dependence term (accounting for the effect of previous biomass on productivity in each year). Tested models included an autoregressive model with lag-1 terms, where all ecosystem predictors were incorporated, a simplified lag-1 model with terms for previous biomass, cod density, and climate (represented by the NAO index), a spatial lag-1 model, where effects of ecosystem predictors could change in space, and a multi-lag model, testing for effects longer than one year of predictors on productivity.

The best model, based on out-of-sample predictive ability, was the simplified lag-1 model. It was able to predict the dynamics of shrimp productivity in six years that had been held out from the model fitting procedure: 2006–08 and 2016–18. In general, the model performed best in SFAs 5 and 6. It tended to overestimate productivity in SFA 4 in the later years, and underestimated population declines in SFA 7.

Discussion

Further description of the spatial approach was requested by an attendee. It was explained by the presenter that the model uses multiple patches to break SFAs into smaller units to provide finer scale and detail, then these patches are aggregated to inform on the SFAs. This decreases the likelihood of missing small scale trends that might not be seen when looking at each SFA as a whole. The polygons go all the way to shore but the nearshore have low biomass and little impact. The patches have similar numbers of trawl observations in an attempt to equalize trawl effort. Depth is incorporated into the polygons in that all trawls used are depth stratified. Higher resolution work was considered for channels (in some years the fishery was contained to the channels), but the model wouldn’t fit to lower concentrations in other areas and so this approach was abandoned.

It was further explained that the model assumes that from one year to the next large changes could be seen in the survey. It pulls near patches together in time, but also distant years together, to avoid artificially adding a density dependence term that doesn’t exist. This is essentially a white noise process to cull inter-annual survey error. In the absence of evidence of change, it pulls toward a common mean, reducing the chance of a single survey really pulling the survey estimate down or up.

The presenter also explained how year effects were addressed before feeding into production model. Participants discussed how the model was smoothing the data. When discussing model validation, it was noted that sources of recruitment are not included in the model. It was explained for participants that density of shrimp, catch, and recruitment are spatially resolved at the SFA level.

Participants discussed climate variables and it was explained that phytoplankton and zooplankton abundance are likely drivers of stock growth. Both phytoplankton and zooplankton data were used to avoid possible timing issues with only using the zooplankton data. It was also noted that phytoplankton is surface water indicator whereas zooplankton is measured throughout the water column. All indicators were scaled, and the model only used summer Atlantic Zone Monitoring Program (AZMP) data for consistency reasons. It was highlighted that the model indicates Atlantic cod, Greenland Halibut, Redfish, and American Plaice seem to be the main predators of shrimp. Predator levels were only done by GAM and not Ogmap. It was suggested that a proportion of diet metric could be incorporated for different species, however concerns were raised as it is unknown what weights should be allotted to each species. A participant suggested that Thorny Skate should be investigated as a predator as well. Participants discussed the usage of cod data in the model. It was suggested to include groundfish abundance data instead of using only cod data in the future.

Participants discussed how well the model fit SFAs with and without the cod and NAO data. It was suggested that in SFA 4, the model may be more influenced by NAO data than cod data. A participant added that seal predation of shrimp in the north may be a factor and that shrimp are being found in turbot stomachs in SFA 5.

Participants had several questions pertaining to estimating catchability (Q). The model does not estimate Q, but rather assumes that Q = 1. It was highlighted that the model can only predict one year into the future, and that length structure would need to be incorporated for the model to predict further.

A participant brought forward concerns that the working paper for the model was heavily focused on SFA 6. It was explained that that was due to the history of framework and that Northern Shrimp in SFA 6 is the only stock in the Critical Zone. There was a recommendation by a participant for more survey coverage in SFA 4.

The reviewers of the meeting articulated some concerns with the model's fit and residual patterns, but felt that the model should proceed. They suggested that the model is somewhat capturing signals about predation and environment which are not currently being captured in the stock assessment.

PROPOSED REFERENCE POINTS AND HARVEST CONTROL RULES

Presenter: E. Pedersen

Abstract

Currently, SFAs 4–6 are managed using a PA with reference points based on the geometric mean estimated biomass during what was considered productive periods. This approach assumes that shrimp stocks will tend to maintain consistent levels of productivity over time, and declines below the upper stock reference (USR) and LRP would be driven only by population fluctuations or over-exploitation. The newly developed SPM suggests that the assumption of constant productivity over time was likely flawed, and that shrimp stock productivity has been declining over the last decade. This presentation proposed a new framework that incorporated the possibility of varying productivity levels into reference points.

The proposed framework was designed around setting reference points based on the time it would take the fishery to recover back to some productive level under ideal conditions, based on the assumption that populations would be at a high risk of overfishing both when their population levels were low and when the population's ability to increase from declines was low. The key parameters in the proposed framework were the estimated maximum rate of population growth (R_{max}), the maximum carrying capacity of each SFA in the time series (K_{max}), and the number of years to return to K_{max} when growing at R_{max} used to set thresholds for biomass for the USR and LRP for each SFA. R_{max} was estimated using the average change in biomass observed between 1990 and 1995 in SFA 6 using the historical biomass indicators. K_{max} was estimated using the proposed SPM. The proposed framework would have a given stock be in the Cautious (Critical) Zone if the population would take at least 5 to10 years to return to K_{max}, or if at current productivity levels it was forecast to be below that level in the next year.

Two alternate approaches for calculating reference points were discussed. The first assumed that populations would grow exponentially at R_{max} until reaching K_{max} under ideal conditions. The second approach assumed that populations would grow logistically, and the final reference points were based off the biomass where yield was assumed to be maximum (B_{msy}), at half of K_{max}. Both approaches gave very similar thresholds for setting reference points, but the B_{msy} approach would result in slightly lower biomass thresholds (USR and LRP).

The other component of the presented framework focused on how to include uncertainty when setting reference points. The proposed approach was to base the current status of the system on biomass and productivity levels that the model estimated that there was at least a 75% chance that the true levels were above. This was suggested so to reduce the risk that, due to measurement error, the fishery was evaluated as being in the Healthy Zone when its true stock status was in the Cautious or Critical Zones.

Discussion

The presenter explained that the current shrimp population-estimate tool (Ogmap) does not account for declining growth rates near carrying capacity. Alternate criteria was explored by participants – the time it would take to reach half of max carrying capacity. The presenter explained that the framework allows for the suggestion that a population can recover to high levels, and that the reference points are based on the best case scenario.

A reviewer commented that the uncertainty around R_{max} was important to note and it was questioned whether this R_{max} was comparable to other R_{max} values for other systems. The presenter suggested it was potentially consistent with others and could be below. R_{max} can be as high as 1.6 in some systems for particular species, and choosing a higher R_{max} would be picking a more conservative framework. The presenter explained the difference between using R_{max} and K_{max} and using current R and current K.

Participants discussed the amount of risk that should be built into the reference points. It was explained that being in the 25th percentile means 75% likelihood the stock would be above B_{lim}. Some participants felt that using the 25th percentile sets risk management into the framework, and may not be the best route forward as they indicated that risk management is not a DFO Science issue.

Participants questioned whether the model could show the difference in fishing pressures on the stock. It was explained that yes it could, but not instantly as the reference points were based on time to reach certain targets and was based on no fishing. In the current framework, harvest of 10% is allowed even in Critical Zone and the time to recovery would be much longer than 10 years.

A participant questioned why total biomass was used rather than SSB or fishable biomass. It was explained that the model could be run on any of the biomass metrics, however the outcome is the same regardless of which is used. The survey catch weight of fishable sized shrimp is always larger than the survey catch weight of smaller shrimp.

Participants stated that it is unusual for a production model to be tuned with total biomass. It was recommended to view commercial length compositions and it was explained that commercial length composition has been very stable over a long period of time.

A group member was concerned about imbedding an alternative into the model. The presenter assured that the choice would be expressed in an assessment, and it would be clear that the point chosen was either the modeled point or the point observed from the survey.

Much of the discussion pertained to the appropriate values for $R_{max.}$ A reviewer reiterated that this model has a time varying R, and depends on cod density and NAO data. Another option suggested was to use current R, but this meant that not being able to return to K_{max}.

There was some hesitation from participants about using only data from a productive time period. It was explained that reference points cannot be based on periods of low productivity.

REVIEWER REPORTS

1. The reviewers accepted the proposed assessment model, conditional on checking some assumptions that the reviewers were interested in. They agreed that the model is useful for giving stock assessment advice and should be included in future Northern Shrimp stock assessments; however, is not ideal for management advice at this time. This meets our obligations under the Northern Shrimp Rebuilding Plan for SFA 6.
2. The reviewers agreed in principle with the proposed management framework. They thought it was a useful way of managing this stock, especially with the issues of changing productivity. A standard approach (of setting a fixed Maximum Sustainable Yield Biomass, B_{msy}) doesn't make sense for this fishery.
3. The reviewers were not sure that the approach we took to determine what the reference parameters, R_{max} and K_{max} , was the right one. There was an extensive discussion on how these might be set, and the reviewers were not able to agree on a single proposed method that would work for setting these values. As such, they did not think the framework itself was ready to be implemented for this fishery, before addressing these issues.
4. The reviewers recommended that we create a working group with the purpose of deciding how reference parameters should be set for these stocks.

CONCLUSIONS

- The proposed PA framework and reference points were not accepted at the Canadian Science Advisory Secretariat (CSAS) meeting. Meeting participants concluded that they needed more data and time before they could recommend a new PA framework. It was suggested that reference points should be based on $B_{msy.}$
- The new model to assess the Northern Shrimp population in Newfoundland and Labrador was provisionally accepted at the CSAS meeting pending a final review.
- This model is innovative and the first of its kind for shrimp in Canada. It is ecosystem-based and includes factors such as climate and oceanographic conditions, and the abundance of predators to determine Stock status. More work needs to be done, but when finalized, it will allow DFO Science to predict how the population of shrimp is changing over time.

APPENDIX I – PRESENTATION ON PROPOSED REFERENCE POINTS

Note that the section on Proposed Harvest Control Rules in the original presentation has been removed from the following, as it was neither presented nor discussed at the meeting.

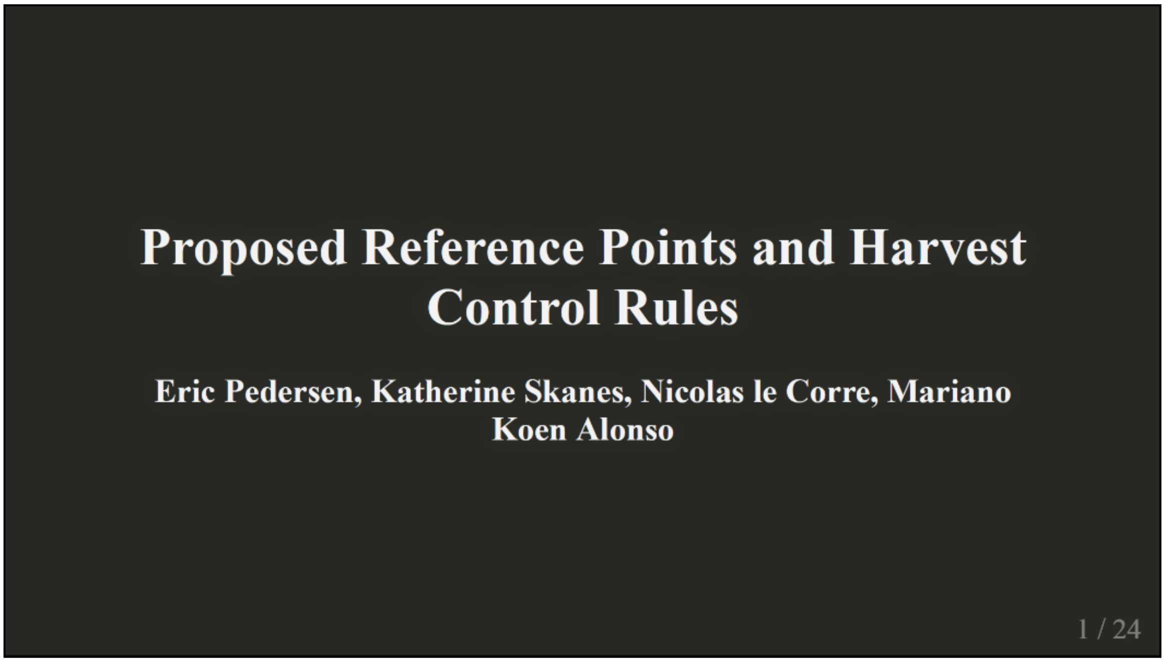

Figure A1. Proposed reference points and harvest control rules.

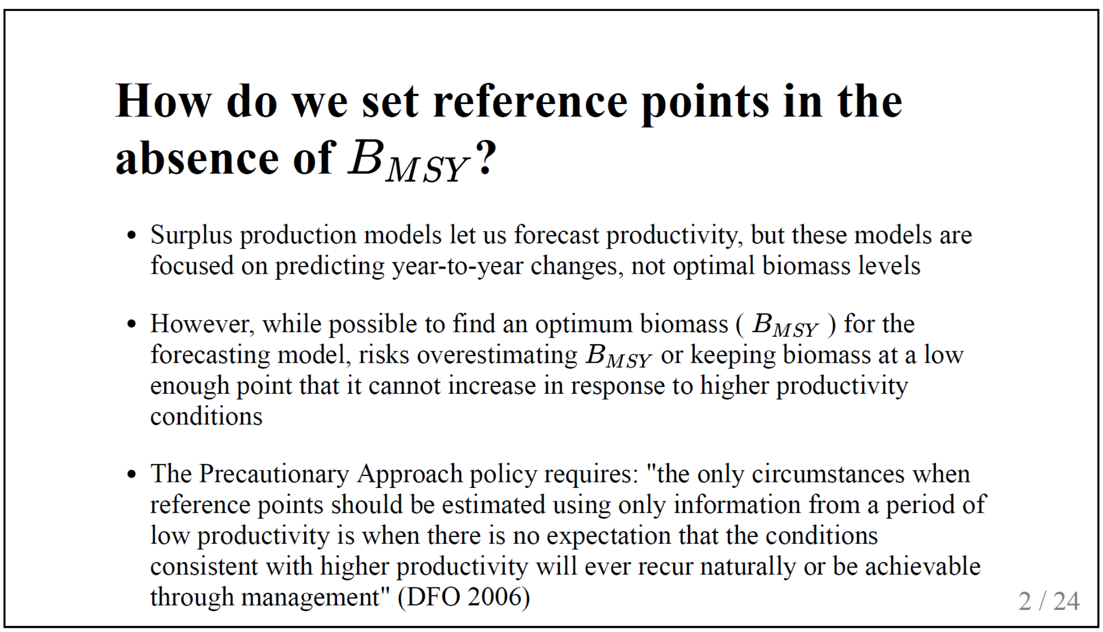

Figure A2. Surplus production models let us forecast productivity, but these models are focused on predicting year-to-year changes, not optimal biomass levels. However, while possible to find an optimum biomass (B_{MSY}) for the forecasting model, risks overestimating B_{MSY} or keeping biomass at a low enough point that it cannot increase in response to higher productivity conditions. The Precautionary Approach policy requires: "the only circumstances when reference points should be estimated using only information from a period of low productivity is when there is no expectation that the conditions consistent with higher productivity will ever recur naturally or be achievable through management".

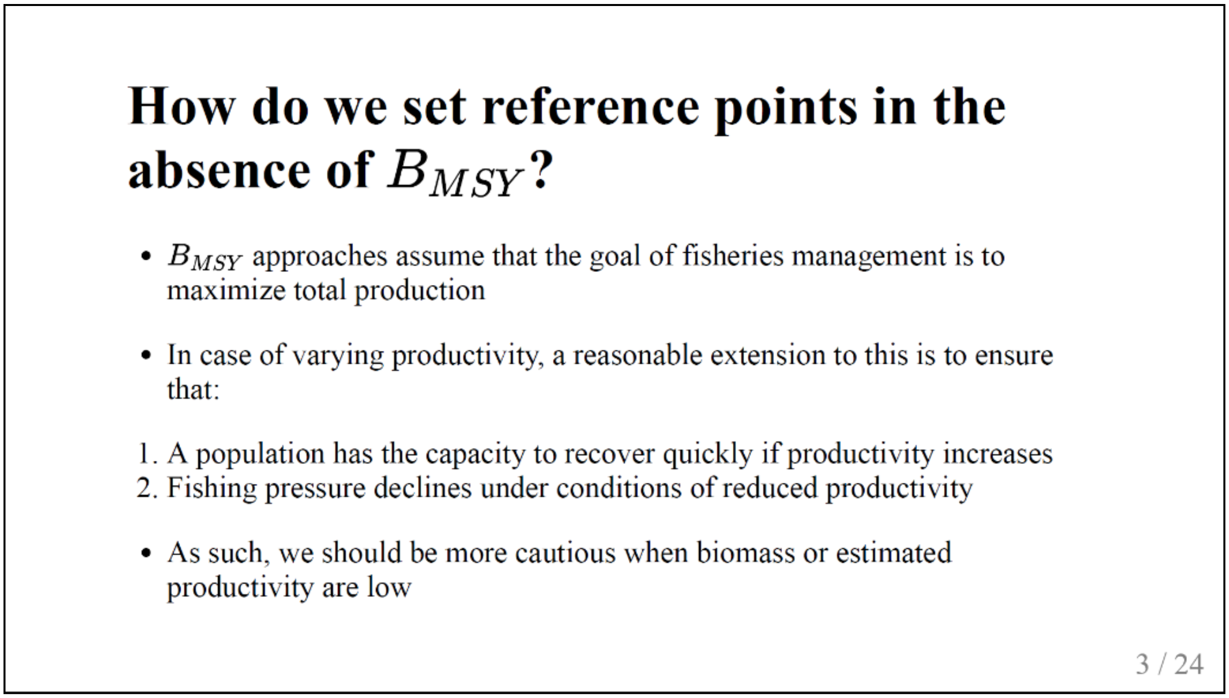

Figure A3. B_{MSY} approaches assume that the goal of fisheries management is to maximize total production. In case of varying productivity, a reasonable extension to this is to ensure that: (1) a population has the capacity to recover quickly if productivity increases, and (2) fishing pressure declines under conditions of reduced productivity. As such, we should be more cautious when biomass or estimated productivity are low.

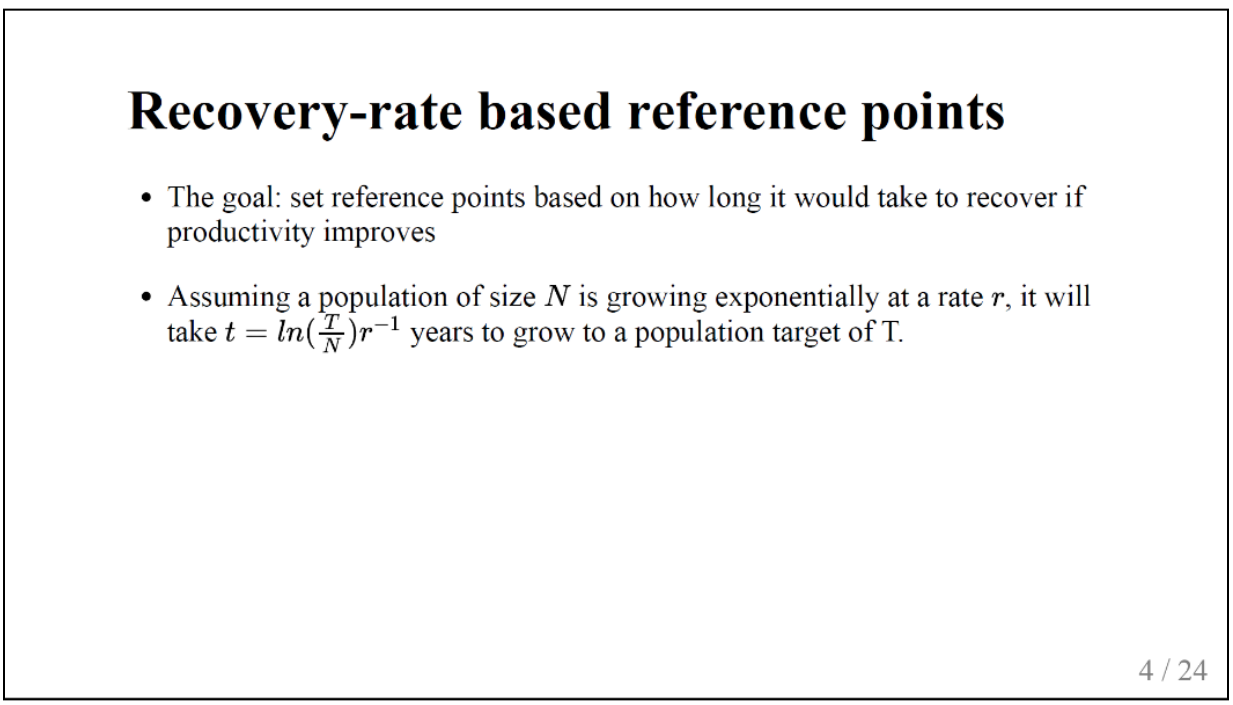

Figure A4. The goal: set reference points based on how long it would take to recover if productivity improves. Assuming a population of size N is growing exponentially at a rate r, it will take $t = ln(T/N)r^{-1}$ years to grow to a population target of T.

Recovery-rate based reference points

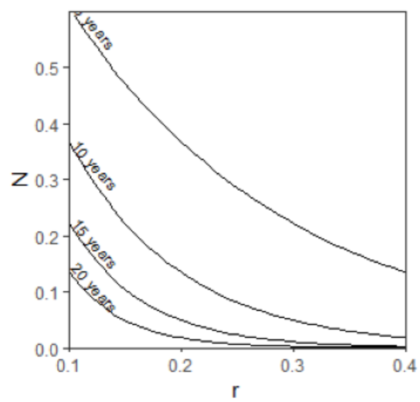

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Figure A5. Recovery-rate based reference points graph.

Recovery-rate based reference points: alternate proposal

- Current proposed reference points do not account for declining growth rates near carrying capacity (theoretically not possible to reach K)
- Alternate criteria: time in would take to reach half of maximum carrying capacity (theoretical B_{MSY})
- Equals $t = ln(\frac{T-N}{N})r^{-1}$
- For a given fixed time to reach threshold, value will be a fixed fraction of the previous threshold, regardless of r and K

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Figure A6. Current proposed reference points do not account for declining growth rates near carrying capacity (theoretically not possible to reach K). Alternate criteria: time it would take to reach half of maximum carrying capacity (theoretical B_{MSY}). Equals t = ln((T-N)/N) r^{-1} . For a given fixed time to reach threshold, value will be a fixed fraction of the previous threshold, regardless of r and K.

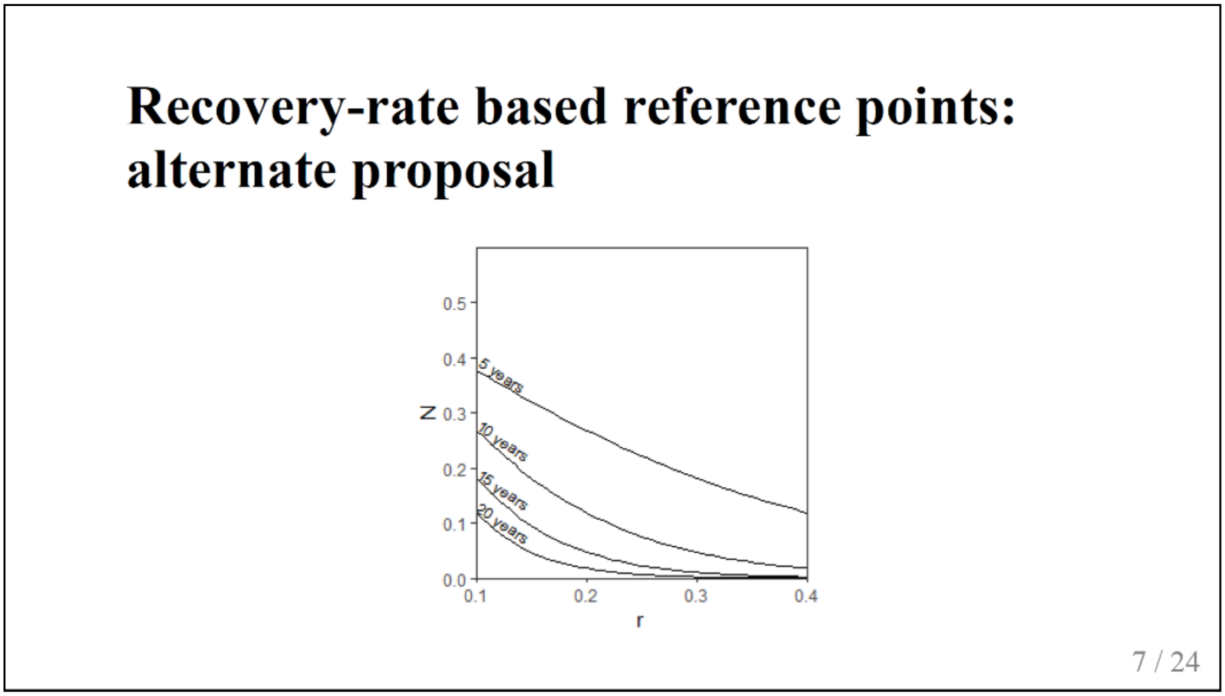

Figure A7. Recovery-rate based reference points: alternate proposal graph.

Recovery-rate based reference points

- Three key variables for this framework:

1. The maximum observed net productivity r_{max}, determining how quickly the population could recover
2. The maximum observed carrying capacity K_{max}, determining what to potentially aim for
3. Acceptable time to recovery back to target

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Figure A8. Three key variables for this framework: (1) the maximum observed net productivity r_{max}, determining how quickly the population could recover; (2) the maximum observed carrying capacity K_{max}, determining what to potentially aim for; and (3) acceptable time to recovery back to target.

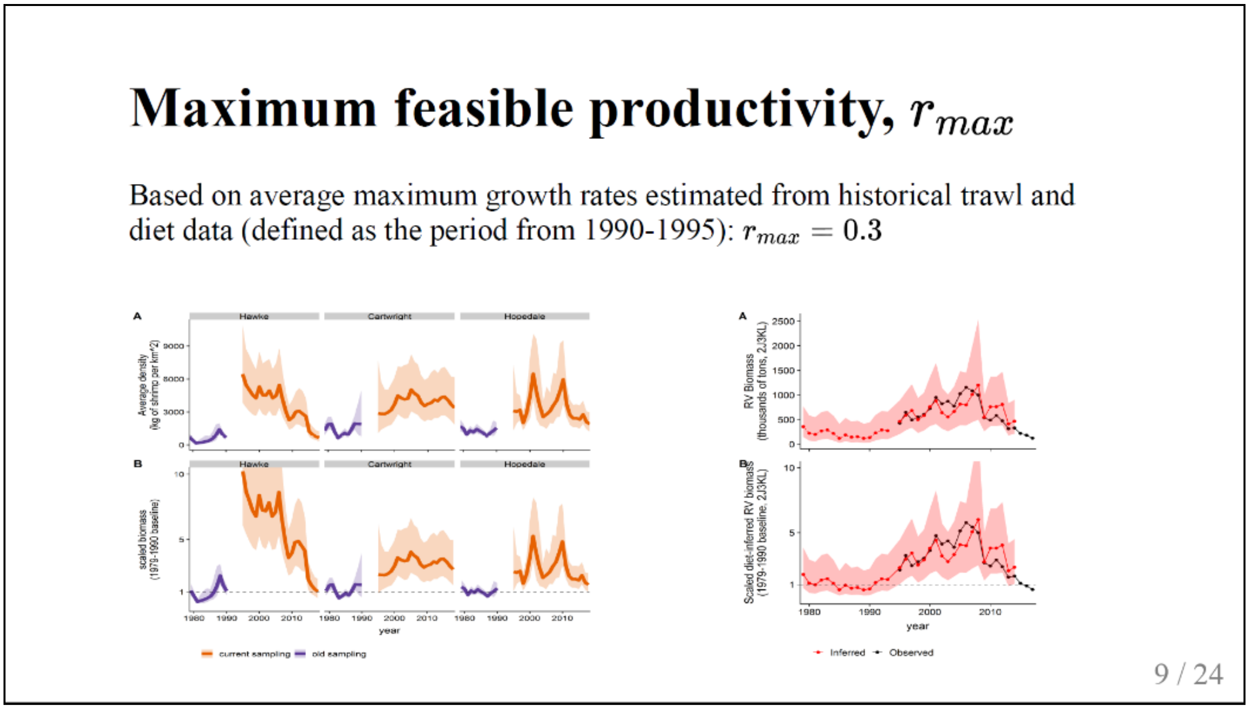

Figure A9. Maximum feasible productivity, r_{max}. Based on average maximum growth rates estimated from historical trawl and diet data (defined as the period from 1990–95): r_{max}=0.3. Upper left: average density, bottom left: scaled biomass, upper right: RV biomass, bottom right: scaled diet-inferred RV biomass.

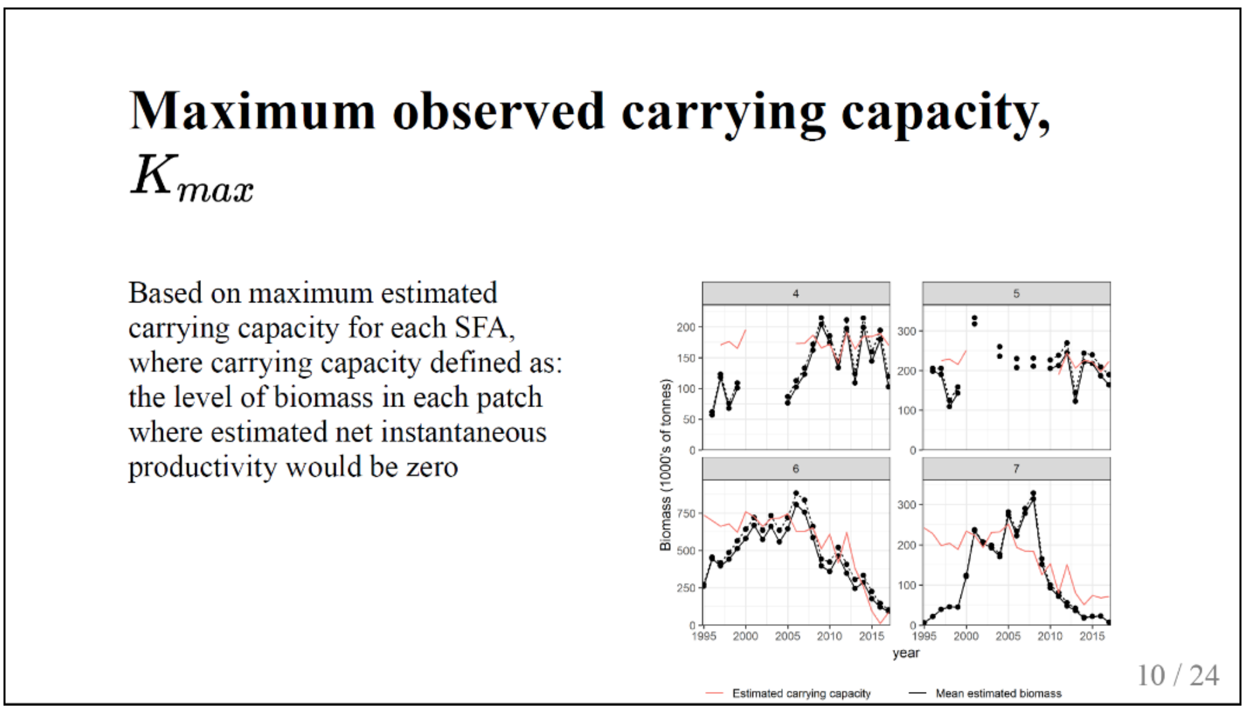

Figure A10. Maximum observed carrying capacity, K_{max}. Based on maximum estimated carrying capacity for each SFA, where carrying capacity defined as: the level of biomass in each patch where estimated net instantaneous productivity would be zero.

How do we account for uncertainty in stock status?

- Any stock status indicator is always known only with uncertainty; we will never know the exact size of the population
- Typical population estimates are based around the mean, median, or mode of the distribution of possible population estimates
- When the mean estimate is right at a threshold level, it means there is a relatively high probability that the true population might actually be below that threshold

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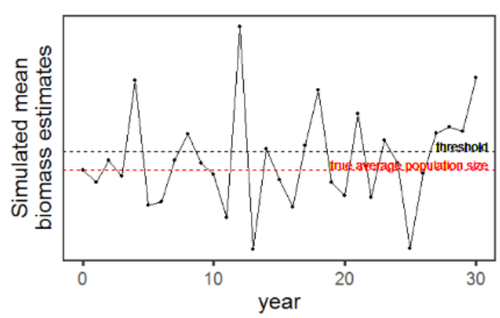
Figure A11. Any stock status indicator is always known only with uncertainty; we will never know the exact size of the population. Typical population estimates are based around the mean, median, or mode of the distribution of possible population estimates. When the mean estimate is right at a threshold level, it means there is a relatively high probability that the true population might actually be below that threshold.

How do we account for uncertainty in stock status?



- Use the 25th percentile of the predicted distribution of indicators to account for this uncertainty

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Figure A12. Use the 25th percentile of the predicted distribution of indicators to account for this uncertainty. Simulated mean biomass estimates over time.

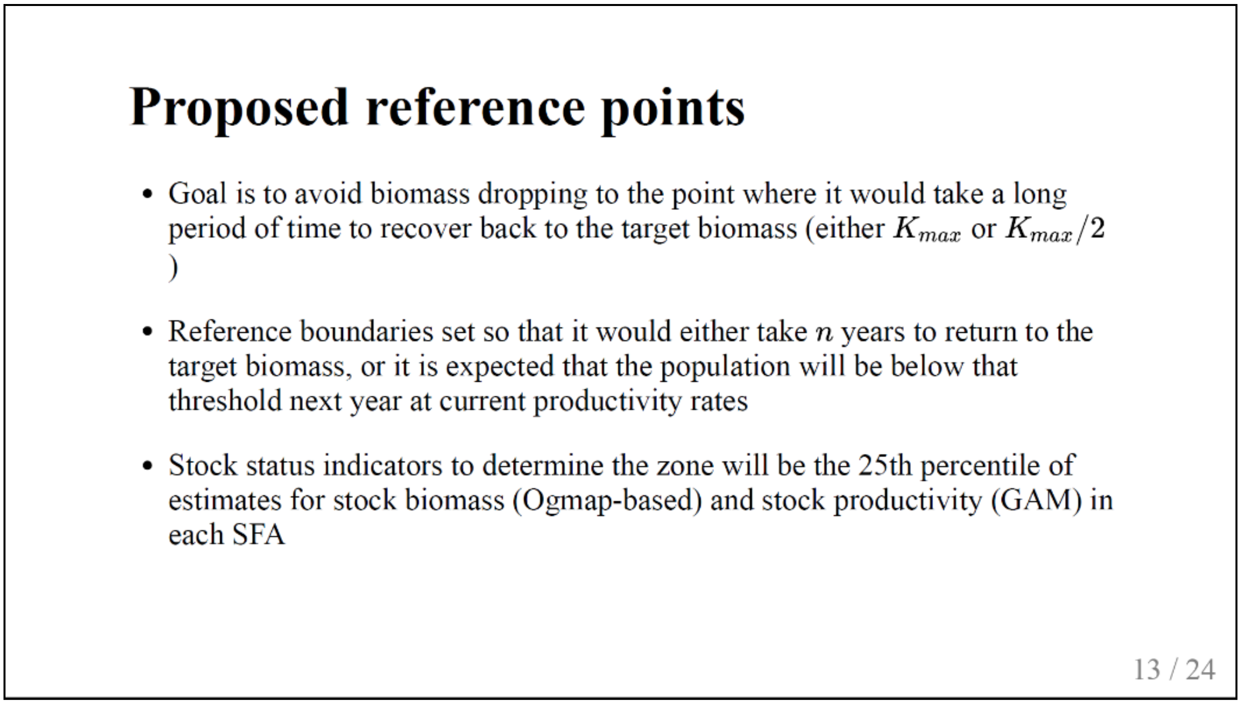

Figure A13. Goal is to avoid biomass dropping to the point where it would take a long period of time to recover back to the target biomass (either K_{max} or $K_{max}/2$). Reference boundaries set so that it would either taken years to return to the target biomass, or it is expected that the population will be below that threshold next year at current productivity rates. Stock status indicators to determine the zone will be the 25th percentile of estimates for stock biomass (Ogmap-based) and stock productivity (GAM) in each SFA.

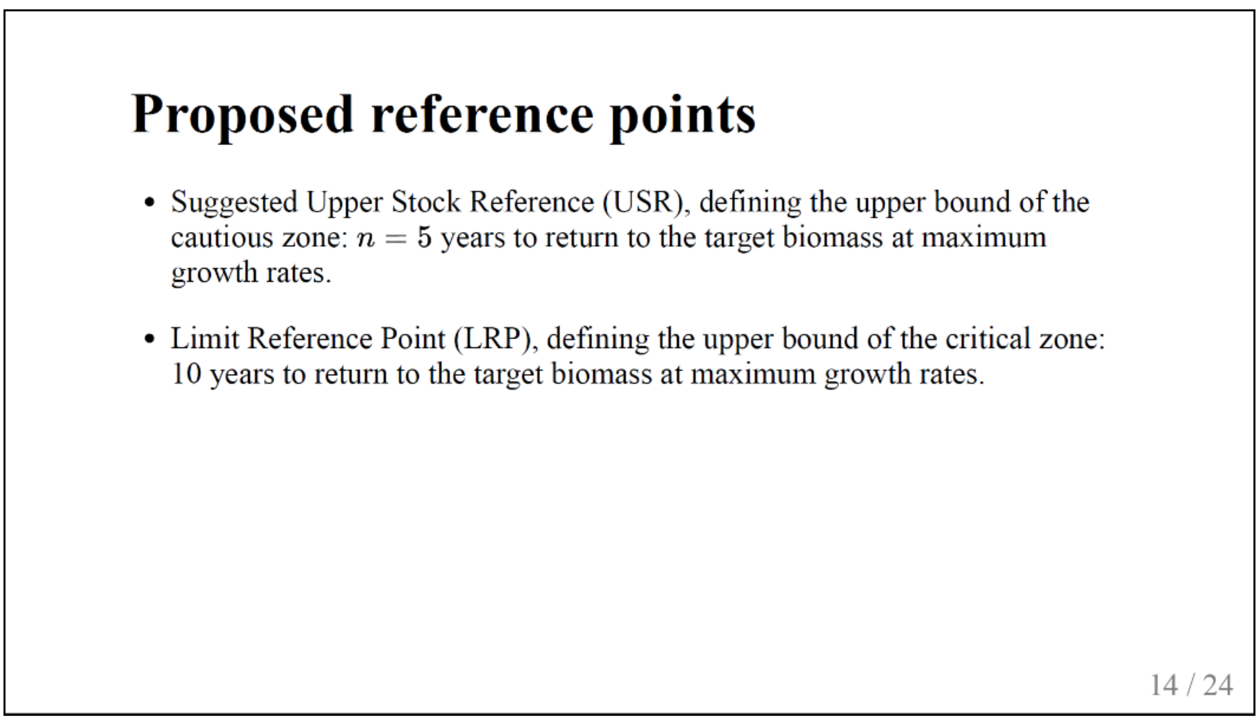

Figure A14. Suggested Upper Stock Reference (USR), defining the upper bound of the Cautious Zone: n=5 years to return to the target biomass at maximum growth rates. Limit Reference Point (LRP), defining the upper bound of the Critical Zone: 10 years to return to the target biomass at maximum growth rates.

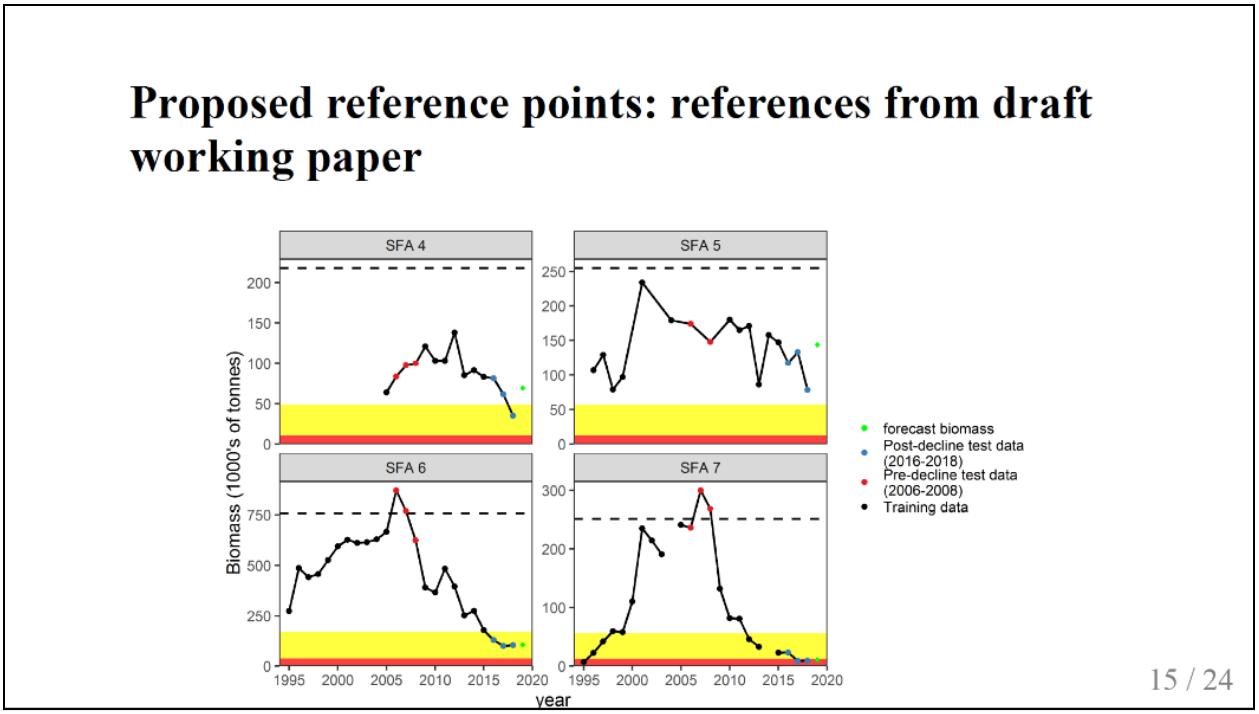

Figure A15. Proposed reference points: approach from draft working paper graph.

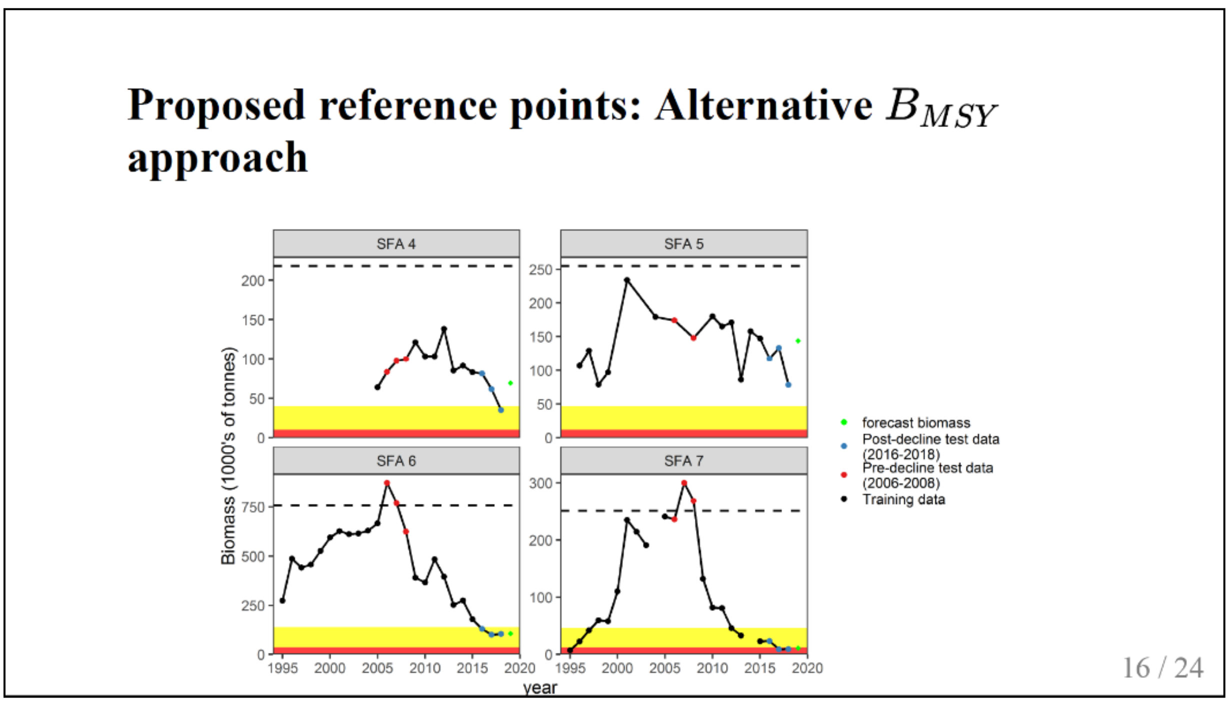

Figure A16. Proposed reference points: Alternative B_{MSY} approach graph.

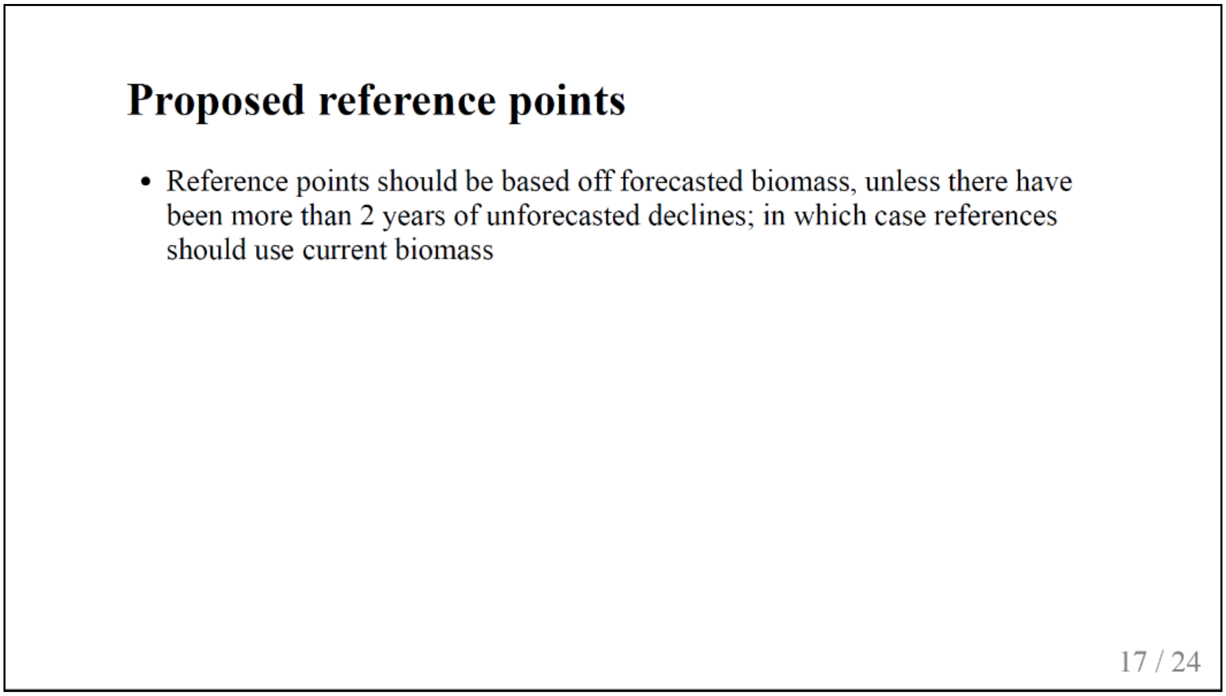

Figure A17. Reference points should be based off forecasted biomass, unless there have been more than 2 years of unforecasted declines; in which case references should use current biomass.

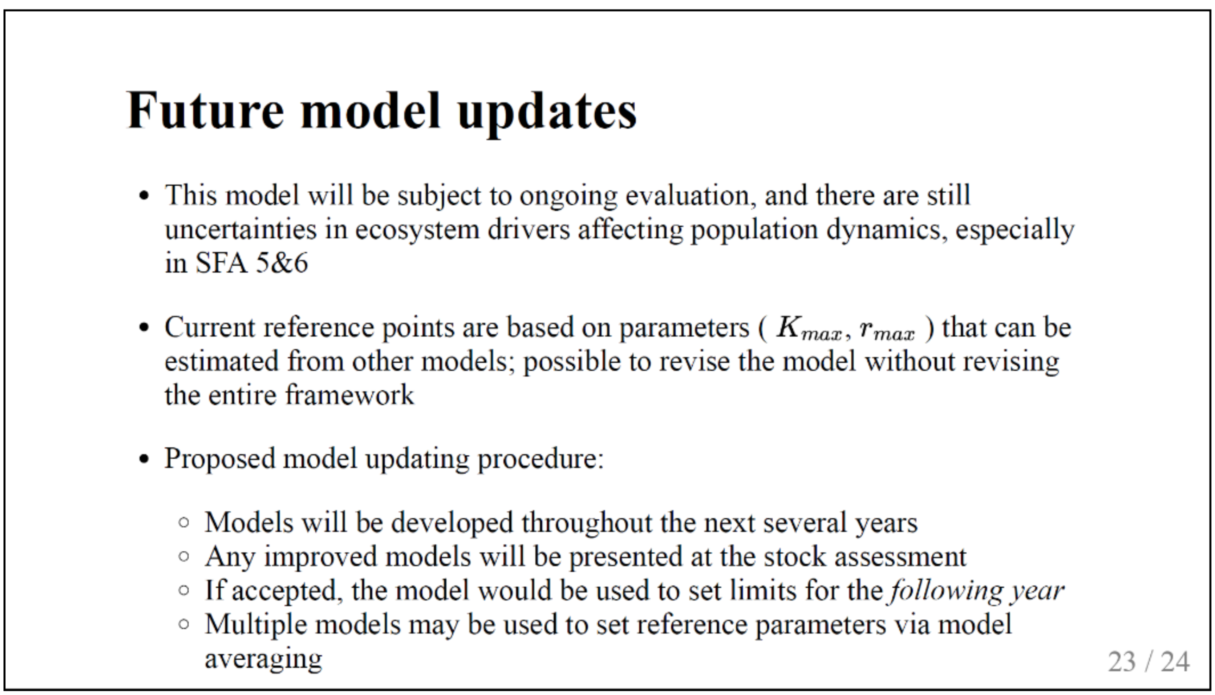

Figure A18. This model will be subject to ongoing evaluation, and there are still uncertainties in ecosystem drivers affecting population dynamics, especially in SFAs 5&6. Current reference points are based on parameters (K_{max}, r_{max})that can be estimated from other models; possible to revise the model without revising the entire framework. Proposed model updating procedure: (1) models will be developed throughout the next several years; (2) any improved models will be presented at the stock assessment; (3) if accepted, the model would be used to set limits for the following year; (4) multiple models may be used to set reference parameters via model averaging.

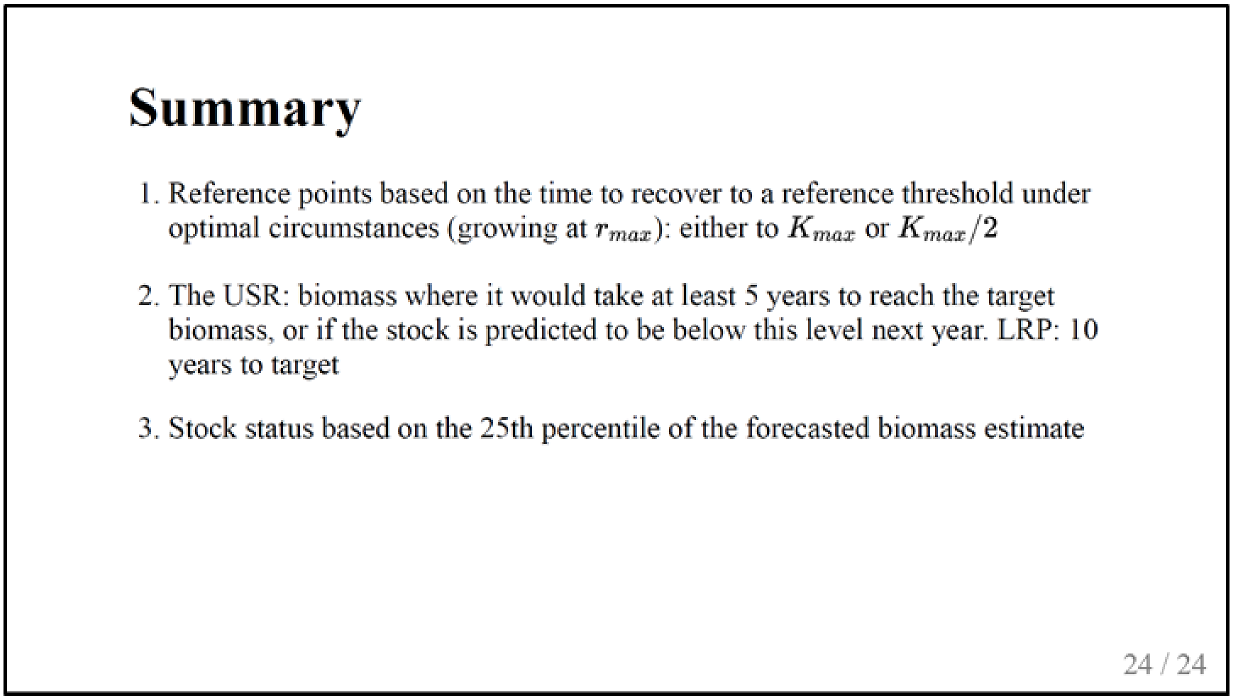

Figure A19. (1) reference points based on the time to recover to a reference threshold under optimal circumstances (growing at r_{max}): either to K_{max} or $K_{max}/2$; (2) the USR: biomass where it would take at least 5 years to reach the target biomass, or if the stock is predicted to be below this level next year, LRP: 10 years to target; (3) stock status based on the 25th percentile of the current biomass estimate; (4) recommended that maximum removal rates not exceed 20%of exploitable biomass under any circumstances; (5) HCR rule: exploitation should drop off smoothly from the top to bottom of the Cautious Zone, and exploitation rates should be zero within the Critical Zone.

APPENDIX II – TERMS OF REFERENCE

Development of a new Precautionary Approach Framework for Northern Shrimp in the Newfoundland and Labrador Region

Regional Peer Review – Newfoundland and Labrador Region

May 15-17th, 2019
St. John's, NL

Chairperson: Joanne Morgan

Context

The Precautionary Approach (PA) is a general philosophy to managing threats of serious or irreversible harm where there is scientific uncertainty. The application of precaution requires increased risk avoidance where there are risks of serious harm and high uncertainty. These conditions often apply in fisheries; therefore precaution should be incorporated in fisheries management.

Canada is committed domestically and internationally to the use of PA in fishery decision-making. Over the last few years, there have been several initiatives in Canada to define the PA in a fisheries context, to identify benchmarks that would be consistent with the approach and to apply it in fisheries management. The fundamental principles guiding this approach have been outlined in two key documents produced by the Department of Fisheries and Oceans (DFO):

1. The 2006 Science Advisory Report that identifies the minimal requirements for harvesting strategies to be compliant with the PA (DFO 2006); and
2. The 2009 Decision-Making Framework Incorporating the Precautionary Approach (DFO 2009a) - a policy document to guide the incorporation of PA principles in the management of Canadian fisheries.

To be compliant with the PA, fisheries management plans should include harvest strategies that incorporate a science-based Limit Reference Point (LRP), as well as Upper Stock Reference (USR) and removal reference points. It is expected that the management decisions should respect the indicated actions in each of the stock zones (i.e., Healthy, Cautious, and Critical) in relation to these points.

Northern Shrimp (*Pandalus borealis*) in SFAs 4–6 are currently managed under a PA framework established following recommendations of a prior working group (DFO 2009b), where the Northern Shrimp LRP was defined as 30%, and the USR as 80%, of the geometric mean of the spawning stock biomass (SSB) index of what was considered a productive time period. The time period varies for each SFA. SFA 7 is assessed and managed through the Northwest Atlantic Fisheries Organization (NAFO) and subsequently follows the PA prescribed by that group (NAFO 2004); B_{lim} is 15% of the maximum observed SSB index and no directed fishing is suggested once the stock falls below that level.

Following rapid declines of Northern Shrimp biomass in SFA 6 along with increasing biomass of Atlantic Cod (one of the major predators of Northern Shrimp), concerns were raised about the appropriateness of these reference points, and if they should be updated given changing ecosystem conditions. The reference points were re-evaluated in 2017 through a Regional Science Response peer review process (DFO 2017), where the conclusion was that there was some evidence that environmental factors affecting shrimp productivity may have changed since 2009; however, in the absence of a predictive population model for this species that incorporated ecosystem factors, it was concluded that there was not sufficient evidence to change the reference points.

DFO Science in the Newfoundland and Labrador Region has developed spatially explicit population models for Northern Shrimp in SFAs 4–7 to address this gap and assist with the re-evaluation of shrimp reference points. DFO Resource Management requested this Regional Peer Review process to review the methodology for estimating the population size of Northern Shrimp in SFAs 4–7. No provision of management advice will occur during the framework meeting, rather management advice will be provided through the February 2020 Northern Shrimp Stock Assessment.

Objective

The key objectives of this meeting are to review the proposed population models and define LRPs, consistent with the PA, for Northern Shrimp in SFAs 4–7.

Specifically, the following objectives have been set:

1. Review sources of data used in the models, and the evidence for changes in shrimp productivity during various time periods;
2. Review scientific and statistical assumptions for the two proposed Northern Shrimp models (spatial surplus production and spatial length-structured ecosystem model);
3. Review reference point methodologies and proposed approaches for the identification of reference points for the NL Northern Shrimp stocks, and determine which approaches will be included in the final framework;
4. Review methods for projecting metrics (i.e.: biomass, predation pressure, etc.) associated with reference points for the NL Northern Shrimp stocks, and determine how these metrics will be incorporated into future stock assessments.

Expected Publications

- Research Document
- Proceedings

Expected Participation

The meeting will be highly technical in nature and the discussions and review will require participants that are familiar with a broad range of quantitative assessment and modeling techniques. Consistent with the participation guidelines for Canadian Science Advisory Secretariat (CSAS) processes, attendance is by invitation only.

To contribute materials and analyses and to assist in the framework review, participation is expected from:

- DFO Science and Resource Management Branches
- Academia and invited non-DFO experts in modelling and statistical analyses
- Other experts as deemed necessary

References

DFO. 2006. A Harvest Strategy Compliant with the Precautionary Approach. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/023.

DFO. 2009a. A Fishery Decision-Making Framework Incorporating the Precautionary Approach.

DFO. 2009b. Proceedings of the Precautionary Approach Workshop on Shrimp and Prawn Stocks and Fisheries; November 26-27, 2008. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/031.

DFO. 2017. Review of Reference Points used in the Precautionary Approach for Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Area 6. DFO Can. Sci. Advis. Sec. Sci. Resp. 2017/009.

NAFO. 2004. NAFO Precautionary Approach Framework. Serial No. N5069. NAFO/FC Doc. 04/18. 5 p.

APPENDIX III – AGENDA

Regional Peer Review Process - Development of a new Precautionary Approach Framework for Northern Shrimp in the Newfoundland and Labrador Region

Chair: Joanne Morgan

May 15-17, 2019
Memorial Room – Northwest Atlantic Fisheries Centre
80 East White Hills Road, St. John's

Wednesday, May 15 (09:00-17:00)

Activity	Presenter
Opening, Terms of Reference and Introductions	Chair
Presentation: Data Review	K. Skanes
Presentation: Review of Previous Shrimp Framework	K. Skanes
Presentation: Historical trends in shrimp dynamics	E. Pedersen

Thursday, May 16 (09:00-17:00)

Activity	Presenter
Presentation: Ecosystem Predictors and Spatial Surplus Production Model	E. Pedersen
Presentation: Proposed Reference Points and Harvest Control Rules	E. Pedersen

Friday, May 17 (09:00-1:00)

Activity	Presenter
Continued discussion on presentations	ALL
Reviewer Reports	J. Fisher, D. Deslauriers, A. Cook, N. Cadigan
Summary Conclusions	ALL
Upgrading of working paper to research document	Centre for Science Advice
Next steps	Centre for Science Advice
ADJOURN	Chair

Notes:

- This agenda is fluid and may change.
- Breaks will occur at 10:30 and 2:30.
- Lunch will occur from 12:00-1:00 and is not provided. Food and beverages can be purchased from the cafeteria.

APPENDIX IV – LIST OF PARTICIPANTS

Name	Affiliation
Bruce Chapman	Canadian Association of Prawn Producers
Erika Parrill	DFO – Centre for Science Advice, NL Region
Jennifer Duff	DFO – Communications, NL Region
Leigh Edgar	DFO – Resource Management, National Capital Region
David Small	DFO – Resource Management, NL Region
David Deslauriers	DFO – Science, Central and Arctic Region
Wojciech Walkusz	DFO – Science, Central and Arctic Region
Geoff Evans	DFO – Science, Emeritus
Adam Cook	DFO – Science, Maritimes Region
Brittany Beauchamp	DFO – Science, National Capital Region
Brian Healey	DFO – Science, NL Region
Danny Ings	DFO – Science, NL Region
Darrell Mullowney	DFO – Science, NL Region
Divya Varkey	DFO – Science, NL Region
Eric Pedersen	DFO – Science, NL Region
Joanne Morgan	DFO – Science, NL Region
Julia Pantin	DFO – Science, NL Region
Katherine Skanes	DFO – Science, NL Region
Krista Baker	DFO – Science, NL Region
Mariano Koen-Alonso	DFO – Science, NL Region
Paul Regular	DFO – Science, NL Region
Peter Upward	DFO – Science, NL Region
Sana Zabihi-Seissan	DFO – Science, NL Region
Erin Carruthers	Fish, Food and Allied Workers Union (FFAW)
Rendell Genge	FFAW Harvester
Dwight Russell	FFAW Harvester
Jon Fisher	Marine Institute, Memorial University of Newfoundland
Noel Cadigan	Marine Institute, Memorial University of Newfoundland
Keith Coady	Northern Coalition Corporation / Qikiqtaaluk Corporation
Aaron Dale	Torngat Joint Fisheries Board