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Proceedings of the Maritimes Regional Advisory Meeting of the Identification of a Limit Reference Point for Southwest Nova Scotia/Bay of Fundy Atlantic Herring (*Clupea harengus*)

Meeting dates: November 12-13, 2020 and January 18, 2021
Location: Virtual meeting

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Canada

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 on the Identification of a Limit Reference Point for Southwest Nova Scotia/Bay of Fundy Atlantic Herring (*Clupea harengus*) was held on November 12–13, 2020, virtually using Microsoft Teams. As set out in the terms of reference (ToR) the focus was to consider limit reference points (LRP) in the context of the precautionary approach framework and identify a suitable LRP for testing operating models within a management strategy evaluation (MSE). The meeting reconvened on January 18, 2021 to discuss whether a static or dynamic reference point based on spawning stock biomass at maximum sustainable yield (SSB_{MSY}) would be more appropriate for evaluating management procedures. It was decided that a dynamic SSB_{MSY} would be adopted, solely to be used in the performance threshold to eliminate candidate management procedures in the MSE and that the use of dynamic reference points in determination of stock status is not appropriate.

Participation in this meeting included Fisheries and Oceans Canada (DFO) Science, DFO Resource Management, Indigenous Communities/Organizations, Non-Government Organizations, Fishing Industry, University of British Columbia modelling team, and external experts.

This proceedings document includes a summary of the presentations and is a record of the meeting discussions and conclusions. Additional publications from this meeting will be published on the Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat's (CSAS) website once it becomes available.

INTRODUCTION

Fisheries and Oceans Canada (DFO) is developing a modelling framework to provide science advice to resource managers, using management strategy evaluation (MSE), for the Southwest Nova Scotia/Bay of Fundy Atlantic Herring stock (SWNS/BoF Herring). Qualitative objectives have been defined for the fishery and key uncertainties in population and fishery dynamics have been captured in a reference set of operating models (OMs). Twenty-four OMs have been defined based on a cross of all levels of four axes of uncertainty (natural mortality rate, future growth, resilience, and inclusion of the southwest New Brunswick weir fishery catch and age composition data). The OMs have been conditioned to fishery catch and age composition data (1978–2018), an acoustic survey of spawning stock biomass (SSB) (1999–2018), and a larval survey as an index of spawning stock abundance (1972–1998, 2009) using a multi-fleet stock reduction analysis modelling approach (Carruthers et al. 2023). DFO and stakeholders are currently in the process of defining performance thresholds for evaluating candidate management procedures in the MSE.

DFO's fishery decision making framework incorporating the precautionary approach (PA) [DFO 2009] applies to key harvested stocks managed by DFO, including SWNS/BoF Herring. One component of the PA framework is to define reference points while taking into account uncertainty and risk, with the goal of avoiding serious harm to the productivity of the stock. DFO's PA framework is presented in the context of a stock assessment and aspects of the policy can be applied to an MSE framework. For example, a limit reference point (LRP) is used in the performance metric to remove candidate management procedures in the MSE that do not have a high probability of exceeding the LRP in the projection period.

This meeting was the third of four Science Advisory Process meetings to develop the MSE, and involved a peer-reviewed evaluation of LRPs to ensure that the selection of a management procedure (MP) in the MSE is compliant with DFO's PA framework and its objectives. The first meeting was in February 2019 and addressed the data inputs and indices of abundance for the SWNS/BoF Herring. The second meeting, in January 2020 and reconvened in May 2020, reviewed the structure and fitting of OMs to be used as the basis in the MSE.

The objectives of this meeting were:

- to review the definition of a limit reference point (LRP) in consideration of the PA framework;
- evaluate the suitability of candidate LRPs and identify the most appropriate LRP to meet the objectives of the PA framework for the reference set of 24 OMs; and
- review the role of the LRP in the MSE in relation to defining performance limits and determining stock status.

Following the November meeting, a key decision point in the implementation of the theoretical SSB at maximum sustainable yield (SSB_{MSY}) reference point was identified. Meeting participants reconvened on January 18, 2021 to discuss whether a static (equilibrium) or dynamic SSB_{MSY} would be more appropriate for evaluating the performance of management procedures in the MSE.

The terms of reference (ToR) for this meeting are presented in Appendix A. Participants in this meeting included DFO Science, DFO Ecosystem Management, Province of Nova Scotia, Province of New Brunswick, Indigenous Communities / Organizations, Fishing Industry, non-government organizations, and external experts (Appendix B). This virtual meeting was held from November 12–13, 2020, and January 18, 2021, using Microsoft Teams (MS Teams) (Agenda presented in Appendix C).

PRESENTATIONS AND DISCUSSION

DAY 1: NOVEMBER 12, 2020

Rapporteurs: M. Greenlaw and T. McIntyre

The meeting began with the Chair, Kent Smedbol, introducing himself and the reviewers, followed by an introduction of the meeting participants. The invited expert reviewers were Daniel Duplisea and Elisabeth Van Beveren (DFO Science, Quebec Region); Noel Cadigan (Fisheries and Marine Institute of Memorial University of Newfoundland); and Jaclyn Cleary (DFO Science, Pacific Region). The Chair reviewed the Canadian Science Advisory Secretariat (CSAS) Guidelines for peer-review meetings the use of MS Teams, followed by a review of the meeting objectives and the Terms of Reference.

Identification of a Limit Reference Point for Southwest Nova Scotia/Bay of Fundy Atlantic Herring (*Clupea harengus*)(Working Paper)

Presenter: T. Barrett

Introduction

The SWNS/BoF Herring stock is currently undergoing modelling framework using an MSE approach. The MSE modeling framework consists of a reference set of 24 operating models (OMs) that represent uncertainties in natural mortality rate, resilience, future growth and stock structure (weir catches). During a review of the OM conditioning in May 2020, it was decided that a peer reviewed Limit Reference Point (LRP) was required to define limits and targets for the stock. The LRP will be used as a performance threshold for eliminating MPs that do not have a high probability of avoiding serious harm to the productivity of the stock. Serious harm is usually defined as some level of recruitment overfishing. The performance threshold will be a probability statement with an associated time period.

During discussion, it was clarified that the objective was to define an approach (empirical or theoretical) for selecting an LRP. The issue of positive growth in the projection period was raised and the participants were assured that this would be addressed in the robustness sets.

An increase in surplus production was observed through the 1970s and 1980s followed by lower production values from 1985 onward. A change point analysis indicated a shift in mean recruitment with a lack of high recruitment events since 1990. The high recruitment events in the 1970s and 1980s do not appear to be related to stock size

A reviewer asked what was the origin of the stock caught by the weir and shutoff (nearshore seining closing off a small embayment) fisheries. The origin of these fish is not known, although there is speculation that these are of United States origin. The uncertainty in the contribution of these landings (weir and shutoff) to the stock is represented as an axis of uncertainty in the MSE: in one OM they are all included with the SWNS/BoF stock and in another they are all excluded. The weir catch was analyzed during the development of the OMs (Carruthers et al. 2023) and found to be almost negligible. In answer to a question about how growth was estimated, it was clarified that growth was based on the mean weights-at-age from the commercial fishery.

All catches are included when considering selectivity and these are estimated for each year. Selectivity was temporally stable for each fleet under the assumptions of dome-shaped selectivity, except for the purse seine fleet (flat-topped selectivity).

Methods: Candidate LRP Categories

The objective is to select a method of defining an LRP that is compliant with the PA framework and its objectives, i.e. avoid serious harm to the production of the stock and avoid recruitment overfishing. Two approaches were described. The first can be categorized as empirical, based on a historical biomass from which the stock has recovered or below which recruitment dynamics are unknown. The other is a theoretical approach, defining an equilibrium biomass at a fishing mortality rate based on the concepts of maximum sustainable yield (MSY), yield-per-recruit, spawning potential ratio (SPR), and replacement fishing mortality rate, as well as LRPs based on unfished biomass. The two primary challenges in selecting an LRP to represent a threshold for recruitment overfishing for this stock are 1) the lack of a stock recruitment relationship (SR) in the data and a lack of recruitment data at very low biomass, and 2) violation of the assumptions of equilibrium caused by changes in growth and age-at-maturity over time.

Biomass estimates

- B_{lim} - biomass below which mean recruitment declines or stock dynamics are uncertain (SSB_{1978}; SSB_{2007})
  - $SSB_{hist;}$ a historical minimum SSB value for which the stock has recovered or remained stable
  - $SSB_{0.5R0}$: the SSB for which recruitment declines to 50% R_0 in the SR relationship
- $B_{recover}$ - biomass below which the stock has been observed to recover or remained stable

Equilibrium (the average SSB that results from fishing at a specific fishing mortality rate)

- MSY: the largest catch that can be continuously removed from the stock assuming constant environmental conditions. Reference points based on F_{MSY}. SSB_{MSY} is the average SSB from fishing at F_{MSY}.
- SSB_{MSY} is time varying - depends on growth, natural mortality rate (M), steepness (h) of the SR, maturity and selectivity.
- Growth, maturity, and selectivity of the last 3 years is used to estimate SSB_{MSY}
- SSB_{MSY} falls below the minimum observed SSB for some OMs.
- SSB_{MSY} is a theoretical reference point that uses the OM assumed SR relationship (depends on h) and assumes the SSB is proportional to egg production. We have not been able to evaluate this assumption in the absence of fecundity data. Unfished Biomass
- Equilibrium SSB assuming F = 0
- Common LRPs are based on 20% or 30% $SSB_{unfished}$
- Proxy for SSB_{MSY} and the relationship between SSB_{MSY} /SSB_0 and h is approximately linear
- If we pick a couple OMs and calculate these reference points, 20% or 30% falls around SSB_{MSY} (20% for h = 0.95 and 30% for h = 0.65).
- $SSB_{unfished}$ is time varying, depends on growth, M, h, and selectivity
- Growth and selectivity of the last 3 years is used to estimate $SSB_{unfished}$
- SSB_0, assuming conditions in the first 5 years, declines with decreasing growth scenarios
- A proportion of $B_{unfished}$ can be used as a proxy for SSB_{MSY} and the proportion depends on h

- A generic proportion of $SSB_{unfished}$ does not represent the same level of protection to recruitment for all OMs
- Changes over time

Per recruit

- Yield per-recruit (YPR)- equilibrium SSB based on F_{max} and $F_{0.1}$
- Reference points for growth overfishing (not recruitment overfishing)
- Used as proxies for F_{MSY}
- SSB per-recruit: $F_{x\%}$ - X% decrease in SPR relative to the SPR at F = 0
- Used as a proxy for F_{MSY}
- Different percentages have been chosen, for example, 50% and 35%.

Replacement fishing mortality rate

- Objective to avoid recruitment overfishing
- Idea - persistence of a population requires that each recruited year class replaces the SSB of its parents on average.
- F_{rep}, the average ratio of recruitment to SSB. Replacement of recruits on average
- In absence of SR relationship - recruitment can be estimates by the median observed recruitment
- Calculated two ways - all data and data after 1990
- It is an empirical approach and ignores the SR relationship in the OMs
- In general, similar to SSB_{min}

Following the presentation, the Chair highlighted that the presenter had been tasked with tabling a variety of reference points in a neutral way. The participants were asked to discuss the pros and cons of the reference points and select a preferred candidate if there was consensus.

A reviewer asked why average productivity conditions over the last three years were used to calculate MSY rather than a longer time frame. The default option in the software was used and a different time frame could be proposed. Another reviewer commented that a Beverton-Holt SR was used to estimate YPR and asked whether a Ricker equation or resampling the recruitment time series had been considered. The choice of SR only affected the reference points and had no effect on simulated recruitment scenarios. The model was dominated by recruitment error, even using low and high h due to the high recruitment variability. Other ways to model recruitment would be to randomly sample it from the historical distribution or use different time periods for the historical distribution. No specific pattern was investigated but autocorrelation was accounted for in the projected recruitment. Two scenarios to investigate in the future are autocorrelation and using recruitment deviations from two different time periods (entire time series and after 1990).

The meeting participants were asked to discuss how the LRP will be used in the MSE:

- Define a performance threshold. A minimum standard that an MP must meet would be a high probability that P(SSB > LRP) after ~2 generations.

- How will the LRP be defined? It will be defined consistent with the PA framework. The SSB needs to be above the LRP and the probability needs to be high, for example, > 90% in projection years 10 to 20.
- A performance threshold for removing MPs that do not meet the criteria.
- Stock Status: Stock status will be determined for each OM.
- Will end up with uncertainty in the stock status (e.g., in 12 of the 24 OMs the stock status could be in the cautious zone, and for the rest of the OMs the stock status could be in the critical zone), and stock status is not reported each year.

A reviewer recommended including a panel showing recruitment deviations over time (Figure 4 of working paper) to help differentiate recent years of above or below average recruitment.

Another reviewer asked about the difference in our expectations for the core OMs and the robustness set. The criteria are applied to all the OMs. An MP must meet the performance threshold for the reference set in order to be considered further, but not the robustness set.

It was suggested that there be two performance metrics objectives: one for when the stock fell below the LRP and one for when it was above. We want the stock to stay above the LRP. Also, that the time frame should be explicit, for example, 10 years rather than two generations because different OMs have different generation times. Mean generation time is about 5 years for the models that have been fitted for the MSE.

A reviewer asked how we will assess the current stock status relative to the current reference point if we are proposing assigning stock status to each OM. The presenter answered that the stock status would not be generated annually but at a point in time. An MP with a high probability of not putting the stock below the LRP would be applied for a fixed period of time (for example, 3 or 5 years). After that time period for which the MP is used for, we would go back and recondition the OMs and see where we are in terms of stock status after that time frame.

Differences between LRPs in MSE and stock assessment were discussed. In an MSE, a level of precaution in performance thresholds (in units of absolute biomass) is captured by the uncertainties in the different OMs. Another level of precaution is captured by the selection of the method of defining the performance threshold.

There was a lot of discussion about using an empirical or theoretical approach to defining the reference points. There was general support for using an LRP based on empirical values (B_{lim}, $B_{recover}$) as laid out in the working paper, rather than a theoretical MSY. However, concern was expressed that an empirical LRP approach such as using B_{lim} is independent of the SR relationship. Other issues raised with an empirical LRP were that they are defined in time and therefore insensitive to a regime shift. It was also noted that International Council for the Exploration of the Sea (ICES) do not use $B_{recover}$. A reviewer recommended that the LRP should be based on SR information and looking at the output from the various OMs, considering a breakpoint, as used in the hockey stick model (like the ICES approach). A participant asked why the OMs were defined to have future recruitment based on the recruitment deviations after 1990s only. One of the presenters noted that the OMs that use recruitment over the entire time series are already included in the robustness set of OMs.

The science leads were asked to present a table of the pros and cons for the two approaches on the second day.

It was stressed that any reporting about the approach must indicate that these decisions are specific to the SWNS/BoF Herring stock. There are other stocks where changes in M are so

great that it would be an impossible target to meet some historical SSB value and, therefore, this approach would not be appropriate in those cases.

DAY 2: NOVEMBER 13, 2020

Rapporteur: M. Greenlaw

The Chair summarized the discussion from the previous day. The objectives of the meeting and their status at the end of Day 1 are:

- The decisions on how the LRP will be used in the MSE are complete (except for the item of OMs below the LRP that need time to get above the LRP in the performance threshold);
- Considerations for an assessment framework vs. an MSE framework are complete;
- Decision for empirical versus theoretical approach for setting LRP are incomplete.

Remaining decisions are

- The method for estimating the LRP;
- Whether to use static vs. time varying and what time periods are appropriate;
- Levels and probabilities to be used in the performance threshold;
- Draft summary bullets for the Science Advisory Report that address the ToR and decision points listed above.

The Chair re-iterated that if consensus is not reached on a new LRP then the previous LRP for the stock would continue to be used. T. Barrett showed the R/SSB relationship for specific periods. Hockey stick SR were not calculated as there did not appear to be a point at which recruitment declined. In the working paper, it was assumed that recruitment was flat over the "observed" range of SSB and would drop down to the origin at the point of minimum "observed" SSB and mean recruitment over the time series. There appeared to be either no change point or the change point is at a very high SSB value, well above what might be considered a logical LRP value.

A participant noted that the OMs had an assumed SR relationship and that the hockey stick SR was being fitted to modeled data. A reviewer responded that the recruitment points are estimated with deviation. There are almost never direct estimates of recruitment and people almost always fit models to these data. There are issues to doing this and ICES would usually fit segmented regression to this kind of data.

The question was raised about how to deal with the OM that is much below the LRP and having a MP that does not get above the LRP in 10 years that would be penalized. Options proposed were:

- > 90% in projection years 10 to 20;
- 90% in projections years 10 to 20 if < LRP and 90% in projection all years if > LRP;
- 90% in projection all years if > LRP and positive growth trajectory in SSB if < LRP (pass/fail).

A reviewer suggested a longer time frame might be required. They also asked whether there was concern about having an MP that results in positive growth, but does not achieve a point above the LRP. Did people currently applying MSE have concerns with this and did they meet the threshold in their evaluations. Both of these have been observed in the MSE for Pacific Herring. In one situation, it is used as a clear breakpoint, and in another where rebuilding has

been slow, it is not used as a clear breakpoint. The view is that including more than one statement is acceptable at this stage of the work.

The pros and cons of an empirical (SSB_{lim}: SSB_{2007}) or theoretical (SSB_{MSY}) approach were discussed next. It was noted that SR relationships are assumed to be true in the OMs. Selection of SSB_{2007} ignores the assumed dynamics in the OMs. Maintenance of recruitment below that value is ignored.

Points of consideration for each approach were as follows:

Empirical SSB_{lim}

- Value below which SR dynamics are unknown
- Does not rely on SR relationship
- Among OMs different levels of precaution are implied in terms of drop in recruitment
- Looking at each plot of SSB vs. time, feels like a point we do not want to get to
- Fixed in time

Theoretical SSB_{MSY}

- The SR relationship is known and specified in the OMs
- The same level of precaution can be applied in all OMs (in terms of recruitment relative to unfished recruitment [R_0])
- A level to be avoided can also be captured using the MSY approach
- Time-varying - changes in growth, maturity, future recruitment

Amongst the reviewers, one preferred the empirical approach but not an LRP such as $B_{recover}$ because stocks often recover due to events before $B_{recover}$ and it is not the properties of SSB that may produce that recovery (for example, perhaps there were good year classes preceding the recovery year). They supported using the SSB_{MSY} but not the way it was being implemented, that is, the 3-year time frame. They suggested doing stochastic MSY calculations rather than deterministic ones. They also favoured an empirical LRP based on hockey stick or breakpoint, level of SSB where evidence of recruitment is impaired over the range of reality that is being considered.

Another reviewer raised two questions about using SSB_{MSY}. The first one is that if MSY productivity levels are used and the fishing rate is applied homogeneously over the population, overexploitation of the population over different spawning grounds is possible. The second concerned calculation of MSY. It was not stochastic, but you can go forward and include density dependence in the future. The presenter answered that there are tools in place to avoid targeting specific populations. The industry has their own management measures that set limits on each of the spawning grounds.

A participant asked how MSY is calculated in the projections. A reviewer cautioned that we should not use SSB_{MSY} that extrapolates outside the range of SR data, without the thorough simulation evaluation of the MPs.

Positive attributes for a theoretical approach are that the SSB_{MSY} is close to the SSB_{2007} value and is hovering around an acceptable value for an LRP whether h is 0.65 or 0.95. Also, SSB_{MSY} (and not a proportion of SSB_{MSY}) has been recommended as the LRP for forage fish (Sainsbury 2008). The difficulty pointed out by the authors was when there are substantial differences

among the OMs and a fixed SSB in time is used (i.e., SSB_{2007}) to compare performance of MPs among the OMs. Using a fixed SSB (for example, an empirical LRP like SSB_{2007} in each OM) the fishing mortality works out to be very different in terms of realized fishing removals in different OMs. Some participants suggested it is more appropriate to use an LRP that is relative to the productivity assumed in the OM.

The consensus was that the LRP should be based on a theoretical approach because this is consistent with an MSE. The empirical approach is disconnected from the OMs and suggests that the OMs are not trusted, but then it does not make sense to use these OMs to evaluate the MPs.

Method

A reviewer reiterated their concerns with using SSB_{MSY} calculations for equilibrium yield because there was no evidence that recruitment was connected with stock size. They were uncomfortable using MSY calculations that extrapolate below the range of SSB that has been observed in the history of the OM. A WG member acknowledged that the likelihood profile on alternate h values was completely flat.

The time period for estimating SSB_{MSY} was discussed: A reviewer suggested using as long a time series as possible because this was consistent with the PA framework and there is no guidance on how to change reference points when productivity varies. Two generations as the basis for projections was suggested but the consensus was to use as long a time period as possible.

The consensus was to use a static SSB_{MSY} (using biological data over the entire time series) rather than one that was time-varying.

Levels and probabilities for performance threshold

There was a discussion about the tradeoff between the level of SSB and probability of being at the level. If the LRP is defined as something to avoid, then one would want to have a high probability, so the proportion of SSB should be chosen first. Defaulting to the PA framework, there should be a 75–95% of being above the LRP.A starting point $P(SSB > SSB_{MSY}) > 75\%$ in years 10–20 was suggested. A probability of 95% was also discussed; it was consistent with ICES practices but would cause more MPs to fail. After some discussion about risk tolerance and probabilities used by ICES and the United States, there was consensus to use 75% as the minimum value and between 75 and 95% as the range of possibilities.

Time frame

The generation time suggested in the PA framework is 1.5–2 generations, which corresponds to approximately ten years for two generations for Herring. There was discussion about allowing the simulations to run longer than ten years, so as not to eliminate OMs that start below the LRP. A range was suggested rather than a cut off. A proposal for >75% in year 10 and year 15 was considered and accepted by the group. SSBMSY as the LRP was discussed by the group. One of the WG members noted that it is a high value for a reference point, but there was some agreement among the reviewers that it was appropriate for a forage fish. A reviewer cited a report from the Lenfest Forage Fish Task Force (Pikitch et al. 2012) that recommended SSB_{MSY} as an LRP for forage fish. Sainsbury (2008) was cited for setting a target reference point for forage fish between SSB_{MSY} and $SSB_{unfished}$. The LRP has usually been set at 0.4 SSB_{MSY} for gadids and 0.4 SSB_{MSY} is the default LRP in the PA framework (DFO 2009) in the absence of stock-specific information to inform on reference points. The Marine Stewardship Council requirement is for low trophic level stocks to be maintained at a default level of 75% of the

unexploited level. The final consensus was for 70% SSB_{MSY} with a greater than 75% probability in each year beginning in year 10 of the 25-year projection period.

DAY 3: JANUARY 18, 2021

Rapporteur: M. Greenlaw

The meeting began with a discussion of what is achievable for SSB_0 under a no fishing situation using the assumed dynamics for the projection period (i.e., long-term SSB under a projection of F = 0) . The performance of an equilibrium/static SSB_0 with mean recruitment and mean biological parameters was compared to a dynamic SSB_0 assuming no fishing. The dynamic SSB_0 was estimated using annual recruitment deviations and annual biological parameters and selectivity. A key question is what is assumed to be achievable in the projection period. Early on in the time series the dynamic SSB_0 is very high because of high recruitment deviations. Equilibrium is based on mean historical conditions, growth maturity, and selectivity and recruitment. Here, equilibrium SSB_0 is on average unachievable in the projections.

The decision to be revisited in this meeting is whether to use a static or dynamic SSB_{MSY}:

- Static -using mean historical recruitment which is not achievable and relevant for MP testing. Variability in recruitment results in variability in SSB/SSB_{MSY}. Assumes historical growth and maturity in the SSB_{MSY} calculations.
- Dynamic SSB_{MSY} - uses simulation specific recruitment deviations, and represents what is assumed to be achievable in the projections. Variability in recruitment is captured in SSB_{MSY}. Accounts for environmental change.

A reviewer noted that DFO has not considered dynamic reference points in the PA framework and there are implications in setting a precedent. In other cases, dynamic reference points have included changes in productivity over larger time periods but not from year-to-year. Using annual reference points cancels out a large part of the variance in productivity.

A reviewer expressed concern with dynamic reference points in the context of the DFO PA framework and their use to define an LRP, but dynamic reference points may be suitable for evaluating MPs in an MSE and evaluating the performance of different harvest strategies. It must be clear that a dynamic reference is to be used to evaluate the performance of MPs and not used as an LRP to evaluate stock status in an assessment.

Concern was expressed by another reviewer about accepting a dynamic reference point because it was an MSE, because precedent is very important in DFO. The context would be taken more as a fish stock assessment than this is an MSE and a best model approach. They asked whether, instead of a dynamic reference point, B_0 regimes could be simulated instead? The difference between this and dynamic B_0 is that model choices are required on the regime (for example, the breakpoint) and that is conceptually important.

Atlantic Bluefin Tuna was presented as an example of using dynamic reference points for a MSE evaluation. In the absence of any comparable framework to the Canadian PA framework, the International Commission for the Conservation of Atlantic Tunas (ICCAT) working group looked at OM projections, some with a 5x increase in mean recruitment and others with a halving of mean recruitment and agreed to dynamic reference points because there were no other candidates.

The implications of using dynamic reference points, or regime shifts were discussed. There was agreement was that dynamic reference points were preferable to a regime shift. An appendix to the Science Advisory Report was suggested with clear language to clarify that a dynamic SSB_{MSY} would be adopted as a performance threshold to evaluation the performance of MPs in

the simulation environment of the MSE and would not be used as an LRP or metric of stock status. A comparison of the dynamic SSB_{MSY} estimates to static SSB_{MSY} estimates (for different productivity regimes) was requested to be included in the Science Advisory Report.

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APPENDIX A: TERMS OF REFERENCE

Identification of a Limit Reference Point for Southwest Nova Scotia/Bay of Fundy Atlantic Herring (*Clupea harengus*)

Regional Peer Review – Maritimes Region
November 12-13, 2020
Virtual Meeting

Meeting Chair: Kent Smedbol

Context

Fisheries and Oceans Canada (DFO) is currently developing an "assessment" framework using management strategy evaluation (MSE) for the southwest Nova Scotia/Bay of Fundy Atlantic Herring stock (SWNS/BoF Herring). Qualitative objectives have been defined for the fishery and key uncertainties in fishery dynamics have been captured in a reference set of operating models (OMs). Twenty-four OMs have been defined based on a cross of all levels of four axes of uncertainty (natural mortality, future growth, resilience, and inclusion of the southwest New Brunswick weir fishery catch and composition data). The OMs have been conditioned to fishery catch and composition data (1978-2018), an acoustic survey of spawning stock biomass (1999-2018), and a larval survey as an index of spawning stock abundance (1972-1998, 2009) using a multi-fleet stock reduction analysis modelling approach (Carruthers et al. 2020). DFO and stakeholders are currently in the process of defining performance metrics for evaluating candidate management procedures in the MSE.

DFO's fishery decision making framework incorporating the precautionary approach (DFO 2009) applies to key harvested stocks managed by DFO, including SWNS/BoF Herring. One component of the framework, herein referred to as the PA framework, is to define reference points while taking into account uncertainty and risk. The PA framework includes general guidance for defining limit reference points (LRPs) as well as a set of provisional reference points based on fixed proportions of biomass at maximum sustainable yield.

During discussions of performance thresholds for evaluating the performance of candidate management procedures in the MSE, the need to conduct a peer-reviewed evaluation of LRPs was identified to ensure that the selection of a management procedure in the MSE is compliant with the PA framework and its objectives.

Objectives

The objectives of this meeting are to:

- review the definition of an LRP in consideration of the PA framework;
- evaluate the suitability of candidate LRPs and identify the most appropriate LRP to meet the objectives of the PA framework for the reference set of 24 OMs; and
- review the role of the LRP in the MSE in relation to defining performance limits and determining stock status.

Expected Publications

- Proceedings
- Research Document

Participation

- DFO Science

- DFO Resource Management
- DFO Ecosystem Management
- Industry stakeholders
- Provincial government
- Non-government Organizations
- Indigenous groups

References

Carruthers, T.R., Hordyk, A.R., Huynh, Q.C., Singh, R., and Barrett, T.J. 2023. A framework for conditioning operating models for the Southwest Nova Scotia/Bay of Fundy spawning component of 4VWX Herring. Can. Sci. Advis. Sec. Res. Doc. 2023/022.

DFO. 2009. A fishery decision-making approach incorporating the Precautionary Approach. Fisheries and Oceans Canada. Date modified: 2009-03-23.

APPENDIX B: LIST OF PARTICIPANTS

Participant	Affiliation
Barrett, Tim	DFO Maritimes, Science
Berges, Benoit	Wageningen University & Research, Netherlands
Brushett, Rebecca	Ecology Action Centre
Cadigan, Noel	Fisheries and Marine Institute of Memorial University of Newfoundland
Carruthers, Tom	Blue Matter Science
Cieri, Matthew	Maine Department of Marine Resources
Cleary, Jaclyn	DFO Pacific, Science
Cogliati, Karen	DFO National Capital, Science
Couture, John	Unama'ki Institute of Natural Resources
Dalton, Alex	DFO Maritimes, Science
Debertin, Allan	DFO Maritimes, Science
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Duplisea, Dan	DFO Quebec, Science
Greenlaw, Michelle	DFO Maritimes, Science
Hatt, Terry	New Brunswick Agriculture, Aquaculture and Fisheries
Hawkshaw, Sarah	DFO Pacific, Science
Hayman, Timothy	DFO Maritimes, Resource Management
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Joseph, Tamara	Mi'gmawe'l Tplu'taqnn Incorporated (MTI)
Kaiser, Tim	Scotia Garden Seafood Inc.
Kelly, Brianne	World Wildlife Fund (WWF)-Canada
Landriault, Marc	Comeau Seafoods
McDermid, Jenni	DFO Gulf, Science
McIntyre, Tara	DFO Maritimes, Science
Melvin, Gary	Herring Science Council
Mitchell, Vanessa	Maritime Aboriginal Peoples Council
Munden, Jenna	Herring Science Council
Murphy, Hannah	DFO Newfoundland and Labrador, Science
Quigley, Sara	DFO Maritimes, Resource Management
Saulnier, Billy	Comeau's Sea Foods Limited
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Elisabeth Van Beveren	DFO Quebec, Science

APPENDIX C: AGENDA

AGENDA (November 12)	
12:30 – 12:45	
Introductions	Lead: Kent Smedbol
Welcome and introduction of the reviewers	
12:45 – 1:00	
Presentation	Lead: Kent Smedbol
CSAS Presentation and review of TOR	
1:00 - 1:30	
Presentation	Lead: Tim Barrett
Presentation of working paper	
1:30 – End of day	
Discussion	Lead: Tim Barrett
• How the LRP will be used in the MSE • Considerations for an “assessment framework” vs. “MSE framework” • Empirical approach vs. theoretical approach • Method (e.g. B_{lim} or F_{rep}) (e.g., MSY vs. YPR) • Static vs. time-varying and what time periods are appropriate • Levels and probabilities to be used in the performance threshold	
AGENDA (November 13)	
12:30 – 12:45	
Introduction	Lead: Kent Smedbol
Recap	
12:45	
Continuation of Discussion	Lead: Tim Barrett
End of Day	
Review and Finalization of SAR	Lead: Kent Smedbol