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Proceedings of the Regional Peer Review for the Assessment of Divisions 2J+3KL Capelin and Evaluation of Proposed Limit Reference Points

Meeting dates: March 6–10, 2023
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Chairpersons: Nadine Wells and Elizabeth Coughlin
Editor: Aimee Kinsella

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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

The Regional Peer Review Process on the status of Capelin (*Mallotus villosus*) and the evaluation of proposed limit reference points was a hybrid meeting held March 6–10, 2023. The purpose was to assess the stock status of Capelin in Northwest Atlantic Fisheries Organization (NAFO) Divisions 2J3KL and evaluate proposed limit references points (LRPs).

These Proceedings include an abstract and summary of discussion for each presentation, as well as a list of research recommendations. The meeting terms of reference, agenda, and list of participants are appended.

In addition to these Proceedings, publications to be produced from the meeting include a Science Advisory Report and two Research Documents which will be available on the DFO Canadian Science Advisory Secretariat Website.

INTRODUCTION

Fishery-independent survey data (spring acoustic survey, larval survey, biological characteristics from the spring acoustic and fall bottom-trawl surveys, and citizen science beach spawning diary program) were used to assess the status of Capelin (*Mallotus villosus*) in Northwest Atlantic Fisheries Organization (NAFO) Divisions (Div.) 2J3KL up to and including 2022. There was no commercial Capelin fishery in 2022 due to market reasons. In 2022, the 2J3KL Capelin acoustic biomass index was above the post-collapse median and similar to 2018 and 2019, but well below the recent stock high of 2013–14 and a fraction of the 1980s median; Capelin were feeding well, but immature fish were growing fast with a high proportion maturing at age-2; spawning timing was typical of the post-collapse period; and the Bellevue Beach (BB) larval index improved compared to recent years and was similar to the time series mean. Capelin fall relative condition was the highest in the time series, but the 2022 condition value may not be directly comparable to prior years due to an earlier than usual sampling time in Div. 3K in 2022 due to the Comparative Fishing Program. Therefore, the Capelin forecast model results can only be described qualitatively due to uncertainty in the 2022 condition value. The Capelin acoustic biomass index in 2023 is expected to be at or above the level of 2022. A 640 kt Capelin acoustic biomass index was selected as the Limit Reference Point (LRP) below which the Capelin stock is likely at risk of serious harm and is the level necessary to support the growth of the Northern cod (*Gadus morhua*) stock to levels last seen in 1983–89 (reference period for the Northern cod LRP). Since 1991, with the exception of 2013 and 2014, the Capelin stock has been in the Critical Zone. Consistent with the Fisheries and Oceans Canada (DFO) decision-making framework, incorporating the precautionary approach (PA) requires that removals from all sources be kept at the lowest possible level until the stock clears the Critical Zone.

PRESENTATIONS

OCEAN CLIMATE VARIABILITY ON THE NEWFOUNDLAND AND LABRADOR SHELF

Presenter: F. Cyr

Abstract

An overview of physical oceanographic conditions in the Newfoundland and Labrador (NL) Region with a focus on Divisions (Div.) 2J3KL until 2022 is presented. The ocean climate on the NL shelf undergoes important fluctuations at decadal time scales. Using a recently developed climate index, 2022 ranked as the ninth warmest year on record. In Div. 2J3KL, record warm surface and bottom temperatures were recorded in 2022. The year 2021 was ranked as the second warmest year on record for the same metrics.

A new analysis is presented that shows that NL ecosystem productivity from primary producers to piscivorous fish changes in relative synchronicity with the climate of the northern hemisphere over decadal time scales.

Discussion

Concerns were expressed about a perceived mismatch in data for sea ice conditions between what was presented and what was measured in the field in 2022. According to a survey of harvesters that was published in March 2022, sea ice conditions were the poorest they had been in four decades, while conditions were observed to be normal in the presented findings. In response, it was stated that there was a huge wind event in March 2022 that piled all of the ice on the coast that could have corresponded to the observations made in the March survey. It was also noted that February 2022 was an extremely cold month and that this timeframe corresponded to when the ice broke up offshore.

There was a discussion about the cold intermediate layer (CIL) and the distribution of Capelin. A participant mentioned that in the Gulf of St. Lawrence, presence of Capelin is usually associated with colder temperatures, but in NL, the CIL is not favorable for Capelin. It was stated that the CIL is generally centered at the same depth in NL, and while the depth does not change, the CIL can vary in thickness. It was then noted that Capelin can avoid the CIL. While Capelin can tolerate cooler temperatures (-1°C), they do not have anti-freeze enzymes. It was stated that the CIL is getting thinner which may impact Capelin in the long term.

The new analysis relating NL ecosystem productivity to the cumulative sum of the Newfoundland and Labrador Climate Index (NLCI) sparked extensive discussion. A participant stated that it is surprising there is a close relationship between fish (pelagic and groundfish) biomasses and broadscale climate indices and inquired if it would make any difference which year the groundfish surplus production model starts, and if there was a specific criteria for directional change in the cumulative sum of the NLCI. In response, it was stated that the close relationship between fish biomasses and broadscale climate indices is not because of the temperature, but because of primary and secondary production. When it is warmer, plankton blooms are earlier and more zooplankton correlates to higher abundance of pelagic and groundfish species. For the cumulative sum analysis, there needs to be at least three years in a row of the same sign (positive or negative) to demonstrate any change in the cumulative sum of the NLCI.

A participant stated that if there is a stronger match with phytoplankton, it takes time for it to enter the biomass, so some kind of lag is expected although these data are not currently lagged. These data are looked at from a magnifier on changes from one year to the next which goes beyond temperature because changes in temperature also mean changes in ocean circulation on a large scale. It was asked if short-term projections of the NLCI could be used to inform fisheries productivity in the short term. In response, it was stated that once we go into one phase or regime it usually lasts a few years, and because there is a lot of inertia in the ocean, when the sub-polar gyre is in motion, it cannot be slowed down easily. We are in a period now of warming climate and this can be used for a short-term prediction of ecosystem productivity.

BIOLOGICAL OCEANOGRAPHIC CONDITIONS ON THE NEWOFUNDLAND AND LABRADOR SHELF

Presenter: D. Belanger

Abstract

Increased nutrient availability, higher phytoplankton and zooplankton biomass, and higher abundance of large and energy-rich *Calanus* copepods are indicative of improved productivity at the lower trophic level in recent years with potential positive impacts on the energy transfer to higher trophic levels and on overall ecosystem productivity.

Discussion

It was mentioned that when dealing with small scale plankton data such as these, caution should be taken when looking at short-term seasonality (one, two, or three years) because in this timeframe, zooplankton are not yet evenly distributed in the water column. Fundamentally, the current situation is similar to the late 1990s and 2000s, where there was a drastic increase in abundance of small copepods. It was noted that the increase of total zooplankton biomass is likely driven by bottom-up processes as demonstrated in an earlier presentation that related the cumulative sum of the NLCI to *Calanus* spp. abundance.

A participant inquired if different prey fields are required for large and small sized copepods. It was noted that different species of copepods have different diets; smaller taxa can feed more on elements of the microbial loop such as ciliates and tiny phytoplankton, whereas larger *Calanus* spp. are much more oriented towards large phytoplankton. Different zooplankton species have various seasonal cycles. *Oithona similis* reproduces throughout the year, *Pseudocalanus spp.* are more abundant in the fall, and *Calanus* spp. are more abundant in the summer and less so in the fall when late stage pre-diapause organisms are observed. A participant responded they were thinking more in terms if the fluctuations in copepod abundances could be an indication of changes in the lower trophic levels; for example, more small copepods equals more small phytoplankton species available. It was stated that satellite data can be used to look at different size classes of phytoplankton because each size class sends a different reflecting signal and there is currently work being done on this research question.

ECOSYSTEM SUMMARY OF THE NEWFOUNDLAND-LABRADOR BIOREGION WITH EMPHASIS IN THE ROLE OF CAPELIN

M. Koen-Alonso, H. Munroe, R. Deering, and J. Mercer

Presenter: M. Koen-Alonso

Abstract

No abstract provided.

Discussion

There was a discussion surrounding potential discrepancies in stock trends between the fall bottom-trawl survey and the spring acoustic survey in recent years that could be attributed to changes in catchability of Capelin in the bottom trawl survey which may be related to changes in the CIL (i.e., Capelin is higher in the water column). A participant inquired if there is confidence that the bottom trawl survey is sufficiently tracking Capelin stock trends. It was mentioned that in 2010 and 2011, there were notable consistencies between the spring acoustic survey and RV fall survey (lagged data); however, looking at the years 2012–15, the signals from these surveys are not in sync. A respondent stated that the interpolated values are due to missed acoustic surveys and the discrepancies that are seen here between the research vessel (RV) and acoustic surveys may be due to the missing acoustic data. Overall, the bottom trawl survey is picking up changes in the stock that help fill in data gaps when acoustic surveys are missed.

BIOLOGY, SPAWNING, AND LARVAL INDEX

Presenter: H. Murphy

Abstract

In 2022, 16 beaches were monitored in the DFO Capelin beach spawning diary citizen science program with three beaches recording no spawning behavior (one beach in 3Ps and two beaches in 3K). Median peak (high intensity) beach spawning was July 8, 2022, which is similar to the long-term median (July 9 from 1991–2020) but was approximately two weeks later than in 2021 (median peak spawning day: June 22). However, median first day of spawning was June

22, 2022 which is earlier than average (July 4) but spawning intensity was considered low to moderate by citizen scientists. Year-class strength is predicted to be weak in 2022 based on beach spawning timing that was similar to the post-collapse median.

Larval surface tows have been conducted at five fixed stations in nearshore waters (<20 m) off BB, Trinity Bay since 2001. The age-2 recruitment index from the offshore spring acoustic survey, which was lagged by two years in order to compare survivors of the same cohort, is positively related to the BB surface tow index (Murphy et al. 2018), and the BB larval index is a parameter in the most parsimonious forecast model (Lewis et al. 2019). In 2022, the BB larval index (1322 ± 387.7 ind. m^{-3}) reached its highest level since 2013 and was similar to the time series mean (1439.5 ind. m^{-3}; 2001–21). This is the ninth consecutive low larval abundance year (2014–22) and includes all year-classes available to the fishery in 2023.

Discussion

A participant inquired if two spawning waves was typical. In response, it was stated that while this is not seen every year, often there is a first wave of large fish followed by a second wave of smaller fish. In the absence of the commercial fishery this year, the only data on the spawners were from DFO sampling at spawning beaches.

There was a discussion surrounding spawning timing and notable differences between stock areas. It was inquired if beaches are being monitored in the Gulf of St. Lawrence and what could be driving the shift in spawning timing. It was mentioned that in the Gulf, the first spawning events occur in an estuary and as the water temperature warms in the spring, spawners move eastwards and finish on the west coast of Newfoundland. In response, it was stated that it isn’t just a temperature cue to trigger spawning, but rather it is a combination of factors including the size of the spawners.

A participant inquired when looking at the average overall spawning date, is there a relationship between the proportion that are spawning in 3Ps versus 3K and has there been a shift in the proportion of Capelin that are spawning in 3Ps that would change the average spawning date. There is no evidence of a shift in proportion of the stock spawning in 3Ps versus 3K, but there are few beaches monitored in 3Ps. It was further inquired on the timing of beach versus deep-water spawning. Spawning in the deep water sites can happen five to seven days later than beach spawning; however, sometimes spawning in these two habitats can happen simultaneously. Additionally, larval emergence is later from the deep water spawning habitats because it takes longer for those eggs to develop and hatch at cooler temperatures.

A discussion arose around the two spawning waves that were previously mentioned. It was stated that the egg quality was much better in the first spawning wave compared to the second spawning wave and that environmental conditions deteriorate and predation increases when spawning is later. A participant explained that fertilization experiments observed that there was a high hatch success from eggs that were taken from the beach the same day, but eggs that were put in a tank for a week prior to fertilization experiments have a lower hatch rate. It was concluded that the egg quality decreases quickly. It was observed that Capelin will come into beaches ready to spawn, and for some reason will hold onto their eggs and the egg quality will deteriorate. It was stated that this process is called over-ripening and it is common in different fish species and not exclusive to Capelin. It was also suggested not to look at egg quality from just a single spawning area as there may be some variability in fish that spawn early on the beaches across the stock area.

A participant mentioned that there have been reports of Capelin spawning further north (outside of 2J) and inquired how the Div. 2GH population will be assessed. In response, it was stated that Divisions 2GH are poorly covered in the Capelin research program and that there is some coverage in Div. 2H from the RV surveys. It was suggested that DFO increase their effort to cover the entire Capelin stock area.

There was a discussion surrounding time-series anomalies for the BB larval index. It was inquired why the 2002 to 2012 average was used to standardize the data and not the entire time series because the larval index value seems to be increasing since 2020. It was mentioned that the 2002 to 2022 time series average would be presented the next day. A participant suggested that the trend in standardized anomalies will likely be similar regardless of which years are used to standardize the data.

SPRING ACOUSTIC SURVEY (METHODS, ABUNDANCE/BIOMASS AND PERCENT MATURE, AND DIET)

Presenter: H. Murphy

Abstract

In 2022, the spring acoustic survey covered most of the survey area, but the survey was split into two portions. The first leg of the survey was conducted on the Canadian Coast Guard Ship (CCGS) *Capt. Jacques Cartier* (May 2–14) using an EK-80 echosounder, and the second leg was completed on the CCGS *Teleost* (May 23–30) using an EK-60 echosounder. During the 2022 survey, the majority of strata were surveyed (except strata E and F), and Capelin were most dense in coastal strata with a second, lower density band along the shelf break. The Capelin acoustic biomass index in 2022 was 262 kt (90% confidence interval [CI]: 177–448 kt), which was similar to 2018 and 2019 (288.9 kt and 282.4 kt, respectively). Since the collapse of the stock in 1991, the median annual Capelin acoustic biomass index was 156 kt, well below the pre-collapse 1985–90 median (3,704 kt). The spring acoustic abundance index in 2022 was 26.6 billion fish, which was higher than the 1991–2019 median (18.3 billion fish).

In anticipation of LRP development, we standardized our approach for calculating the spring acoustic biomass index. The development of this revised spring acoustic biomass index included a review of previous abundance indices, areal coverage of the surveys, and the methodology used to convert abundance to biomass. Median biomass estimates were similar between the revised and original time series in most years and were generally well within the uncertainty range of one another except in 2000. We used the revised acoustic biomass estimates in this assessment.

In the 2022 spring acoustic survey, age-2 fish dominated the catch (~75%) with a similar proportion of age-1 and age-3 sampled. Similar to recent years, very few age-4 and no age-5+ fish were sampled. In 2022, 67% of female age-2 fish were maturing and would have spawned in summer 2022. Due to a large proportion of fish dying after their first spawning event (semelparity), the high proportion of age-2 fish maturing since 1991 has resulted in an age-truncated stock.

Copepods are the main prey item for 2J3KL Capelin. While there is interannual variability in Frequency of Occurrence (FO) of small and large copepods, large copepods typically dominate the diet. In 2017–19, there was a notable increase in FO of small copepods, while FO of small copepods decreased again in 2022.

Discussion

A participant raised concerns that the acoustic target strength (TS) relationship needs to be re-evaluated since the NL Region uses a different TS compared to Iceland and Norway. The NL

Region had a framework meeting for the acoustic survey in the early 2010s but a re-evaluation of the TS is warranted.

A participant asked how the acoustic biomass was estimated prior to 1999. Length-weight relationships were not calculated using the Capelin sampled onboard in the spring acoustic survey due limitations in data collection onboard, but rather data from the commercial fishery, bycatch in the shrimp fishery, and the spring multispecies (MS) bottom trawl survey were used instead.

SPRING ACOUSTIC SURVEY (AGE STRUCTURE OF SPAWNERS SAMPLED AT BEACH SITES)

H. Murphy and A. Adamack

Presenter: H. Murphy

Abstract

Age and size structure of spawning fish is usually inferred from commercial catches. With no commercial fishery in 2022, biological data from the fishery were not available. In the 2022 beach samples, the majority of spawners were age-3 (54%), and mean length and standard deviation (pooled by sex and age) ranged from 162±17.7 mm Total Length (TL) in Div. 3Ps to 173±16.9 mm TL in Div. 3K.

Discussion

No discussion.

FALL MS SURVEY (AGE, CONDITION, AND DIET)

H. Murphy and A. Adamack

Presenter: H. Murphy

Abstract

Inconsistencies in fall MS survey coverage during the last two years resulted in a lack of sampling in Div. 3L in 2021, and many unsampled strata in 2022 due to the Comparative Fishing Program. Consequently, a change in the way the Capelin condition index is calculated was required. In order to accommodate for the unequal sampling effort across NAFO Divisions in the past two years, relative condition for Capelin was calculated separately by age class (ages 1 and 2), sex, and NAFO Division. Relative condition was averaged across sexes within each age class by NAFO Division and then across age classes by NAFO Division and then across NAFO Divisions. In 2022, the fall relative condition value was the highest (1.11) in the time series (1998–2022). The previous high value for the time series was 1.06 (2021) and the mean relative condition value for the time series (1998–2021) is 1.01 with a standard deviation of 0.036. Given that the highest value of the time series coincided with the change in sampling protocol in 2022, its potential impact on condition warranted further investigation. The actual magnitude of the 2022 condition value is unclear due to changes in timing of sampling, which affects our estimate of relative condition by an unknown amount making it difficult to accurately compare this year's relative condition value to prior years.

From the fall MS time series (1980–2020), proportion of empty stomachs was calculated based on a scalar index of stomach fullness (0 = empty, 1–4 levels of fullness) recorded for undissected 'called' stomachs. Based on these called stomachs, the median proportion of

empty stomachs increased in the post-collapse period (0.46 in the pre-collapse period and 0.54 in the post-collapse period). In 2017–18, the median proportion of empty stomachs was at an all-time low (0.08) but increased again in 2019–20.

Discussion

There was concern voiced regarding whether the mean relative condition data should be used. It was then requested that condition by NAFO Division and sex be presented. Condition in 2022 was higher in 2J and 3K but below average for 3L. It was inquired if the number of samples vary from year to year. Due to the sampling protocol (sample obtained from the largest catch in each superstrata), the number of fish sampled in each year is similar when a full MS survey is conducted.

There was a discussion surrounding Capelin diet and if the proportion of empty and full stomachs is an indicator of stock health. The proportion of full stomachs has increased in recent years, similar to the pre-collapse period. It was noted that this could be an indication that there are improved foraging conditions for Capelin.

CAPELIN FORECAST MODEL

Presenter: A. Adamack

Abstract

The Capelin forecast model suite (Lewis et al. 2019) builds on two prior Capelin models (Buren et al. 2014, Murphy et al. 2018) by combining key features of the models within a common Bayesian framework which is then used to generate predictions of the Capelin biomass index from the spring acoustic survey. As the fall 2022 condition value is well outside the range of data used to fit the forecast model, the 2023 forecast model results can only be described qualitatively due to uncertainty in the 2022 condition value. Based on these simulations, the Capelin acoustic biomass index in 2023 is expected to be at or above the level of 2022.

Discussion

It was noted that the recent high condition values coincide with some of the highest sea surface temperature values on record. It was questioned if the decline in the forecast for 2023 and 2024 is a function of setting the condition value to the long term mean as opposed to the higher than average value in 2022. It was clarified that the model forecast for 2023 uses the 2022 condition value while the 2024 forecast uses the average condition value. For the first time, the Cohort Strength Adult Mortality (CSAM)1 model (includes two parameters: larval densities and fall condition) had the highest R^2 value; however, the CSAM 3 model (includes three parameters: larval densities, fall condition, and timing of sea ice retreat) has always had the better fit and has been chosen in the past. The difference in these two model runs is the inclusion of the timing of sea ice retreat (not included in CSAM 1 model).

It was inquired if the extreme condition value for 2022 is biased due to the change in the sampling design (i.e., comparative fishing experiments). In 2022, sampling in 3K happened about a month earlier, which was found to have a negligible impact on relative condition. The relative condition of all fish in 2022 was in the upper bounds of the data. A participant cautioned that data used from paired sets can also introduce bias as these data are not completely independent. This is not an issue for Capelin since the largest catch from each superstrata was used.

It was noted that the high 2022 condition value has not been calculated in the same way as the other values due to gaps in spatial coverage of the MS survey due to the comparative fishing program. The analyses suggest there may be some impacts on condition due to changes in spatial coverage, and timing and distribution of samples across NAFO Division. While there was no indication that condition was poor in 2022, it was recommended to not use the 2022 value in the model because the value was outside the range of data in which the model was built.

A participant suggested using a high value from the observed range of condition values instead of the actual 2022 condition value. It was cautioned that there needs to be clear rationale for eliminating a data point. It was reiterated that before the results of the model forecast are discussed, the group needed to settle on if the condition value for 2022 is accepted or not. The consensus was that the 2022 value should not be accepted because of the aforementioned uncertainty.

A participant stated that there is an issue with being dogmatic about statistical significance with regards to using a 95% CI for a parameter. It was clarified that the CSAM 2 model does not use the condition parameter; therefore, in order to understand the impact of condition in the CSAM model suite, the CSAM 2 model needs to be compared to CSAM 3 model and we found that condition is significant in the CSAM 3 model, regardless of the CI for the parameter. It was highlighted that a range of potential condition values could be considered to investigate the impact of condition on the model suite.

A participant then highlighted that detailed samples are collected by superstrata and it is highly variable where the fish are present in 2J due to low catch rates and inconsistent sampling in 2022. With regards to 3K, it was clarified that there are 12 super strata in 3K and one sample from each was chosen for detailed sampling in 2022; therefore, sampling is consistent with regards to the amount of fish sampled. It was then expressed that 3L demonstrates a bigger question mark than 3K due to a lack of samples during the comparative fishing program in 2021–22. Therefore, this participant argued there isn't adequate rationale to discard the 2022 condition value.

It was suggested that the model be recalculated using the previous series high point for 3K; however, there is no way to correct for 3L due to coverage issues in 2021 and 2022. It was further suggested to take the average of the last 3 years and use that going forward. A sensitivity analysis was completed and it was discussed that a possible doubling of biomass with small changes in condition was observed and this demonstrates that the 2022 condition value should not be used.

There was a discussion about condition declining during the season. Fall condition by day was shown and it was observed that the data was a flat line, which isn't enough to say there is a decrease or increase over time. These data only look at the later part of the year. A participant added condition looked to peak around October and demonstrate a very slow decline (if any) from there. The 2022 data could be a year effect or a reflection of a real trend. The rate of decline was calculated (0.2) and this rate of decline is insufficient to explain the high observed condition value in 2022.

There was a discussion regarding the use of average predictions from the top two models in the suite. It was cautioned to not make probabilistic statements based on these models and projections due to uncertainty/extrapolating outside the data bounds. Consensus was reached that more qualitative statements be used to describe the model forecast for 2023 and 2024 due to uncertainty about the validity of the 2022 condition value.

LRP BACKGROUND (REGUME SHIFT AND DATA TIME FRAME, ECOSYSTEM ROLE, AND DATA LIMITATIONS)

Presenter: K. Lewis

Abstract

Limit reference points (LRPs) are an important tool for managing fisheries. In Canada, LRPs are being determined for commercial fish stocks to align with the Fish Stocks Provisions (FSP) of the revised Fisheries Act (R.S.C., 1985, c. F-14). Determining a robust LRP is especially critical for forage fish species due to their commercial value, the critical position they occupy in marine food webs linking the energy produced by plankton to higher tropic levels, and their vulnerability to overfishing. The main purpose of this presentation is to detail the process for evaluating and determining a LRP for Northwest Atlantic Fisheries Organization (NAFO) Divisions 2J3KL Capelin (hereafter 2J3KL Capelin), a small, short-lived forage fish in the Northwest Atlantic. Specifically, we overview the relevant legislation and policies surrounding LRPs in Canada, best practices for establishing and evaluating LRPs, the considerations and challenges unique to 2J3KL Capelin and the Northwest Atlantic ecosystem, and the data sets available for this stock.

Discussion

A participant expressed that the rationale for single states and alternate states is unclear in the presentation and should be fully described in the research document.

The stock-recruitment relationship presented did not follow a Ricker or Beverton-Holt relationship and the age at maturation has changed over time for this stock. It was stated that Oceana produced a forage fish report using a surplus production model and it was inquired if this modelling approach was used for 2J3KL Capelin. It was considered and assigned reliability scores based on the outputs.

A participant voiced concern in using a Bayesian state-space surplus production model for Capelin. There was a discussion surrounding how this model fails to capture the fluctuations in Capelin relative abundance in response to different fisheries (offshore versus inshore). If this model was considered in the future, it was suggested to use a larger range for the prior values, specifically for this R-selected short-lived species. It was confirmed that this model is not the most reliable approach due to data limitations for 2J3KL Capelin. It was asked whether a length-integrated mixed effect model was considered. This model type was considered, but was not used due to data limitations and the nature of the fishery.

There was a discussion surrounding dynamic reference points. It was stated that this would be difficult to implement because there is no well-established framework and could result in a changing baseline for the LRP which may cause harm to the stock.

LRP RESULTS (APPROACHES THAT FAILED, THAT MIGHT WORK, RECCOMMENDED APPROACH, AND SUMMARY)

Presenter: K. Lewis

Abstract

We considered a suite of potential LRPs for 2J3KL Capelin including more conventional approaches based on theoretical or historical proxies for biomass at maximum sustainable yield (MSY) and unfished biomass (B_0), recruitment, and historical trends, as well as newer methods such as multi-indicator, length-based, and ecosystem approaches. Three approaches met the

criteria of being feasible, reliable, and plausible, and were, therefore, considered valid: $B_{recover}$ based on the 1982 survey which was the lowest Capelin biomass index to produce average recruitment; an historical proxy for B_0 based on the median value of the highest Capelin biomass in the survey time series (1985–90); and an ecosystem approach based on the capcod model (capcod hereafter). Briefly, capcod predicts the biomass of Northern cod (*Gadus morhua*; cod hereafter) based on the biomass index of 2J3KL Capelin in the previous year using a bioenergetic-allometric approach. Capcod effectively explained these dynamics (R^2 = 0.92) and diagnostics suggested the assumptions of the model were valid.

Discussion

There were concerns expressed of using $B_{recover}$ based on the 1982 April acoustic survey index. The reliability and timing of the 1982 survey was discussed and it was mentioned that since this is the only pre-collapse value in this time series that shows such a strong recovery after a stock low, there is a significant amount of weight on this point. It was mentioned that historical data have been considered and there was a decline in biomass in the late 70's and early 80's, but these data are from other acoustic surveys that are not comparable to DFO's spring acoustic survey. It was stated that it is a challenge to base LRP decisions on one isolated value. It was discussed if the 1982 value was a possible underestimation of biomass given fish are expected to be heavier in May than April and it was further questioned if the age structure of cohorts tracked from 1982–83. Cohort tracking has been used previously for confirmation that acoustic surveys are working. A participant recommended to not track cohorts due to the survey coverage, but to look at the size, age, and proportion of maturing Capelin. These data may be challenging to retrieve.

A participant cautioned that $B_{recover}$ may be the weakest reference point because it assumes that the growth of the stock at one point in time in the 1980s is reflective of stock conditions now. $B_{recover}$ is not based on a stock recruitment relationship. However, when a stock is able to recover in the face of high removals as it did in 1982, there is potentially strong support for $B_{recover}$.

There was a discussion surrounding the pros and cons of the three potential LRP approaches. $B_{recover}$ was considered the less favourable approach because it is strongly influenced by a single data point with no replication and, combined with the timing of the survey (1982), makes this a weak LRP candidate. A participant was opposed to rejecting $B_{recover}$ due to the importance of historical information. It was confirmed that the pros are weak and cons are strong for this approach and in conclusion, $B_{recover}$ was rejected.

A participant expressed that there will always be arguments surrounding whether it is B_0 or B_{MSY}, and that it is a leap to assume that this was a virgin stock in the 1980s after a sustained period of commercial fishing that started in the 1970s. B_0 could be considered as a valid approach since the 1980s was a highly productive period.

There was a discussion surrounding the proxy B_0 approach. It was stated that B_0 is a challenging concept to communicate because it is difficult to say if the 1980s time period is reflective of unfished biomass. It was argued that B_0 is a better reference point than $B_{recover}$ due to a clear rationale for the time period chosen (late 1980s), which was a known productive period. The proxy approach (B_0) is more favorable because it uses more data points than $B_{recover}$. It was further highlighted that B_0 is a proxy using average biomass of the 1980s and could be considered somewhere between B_0 and B_{MSY}, but closer to B_0. It was cautioned that using B_0 or a different approach that is based on assumptions of carrying capacity and growth can result in arbitrary decisions.

A participant recommended removing the 1990 value as a B_{MSY} proxy due to the value being close to the collapse period, which would impact the calculation of B_{MSY}. Another participant disagreed with removing the value and elaborated that this value should be taken as a reflection of B_0 rather than B_{MSY}.

It was cautioned that historical landings for Capelin are not an accurate representation of removals at that time. There were substantial discards in the 1980s due to the roe fishery targeting females. It was further suggested to use a multiplier of 0.3 rather than 0.2 for B_0, to adjust for some degree of a fished state during this period. Another participant agreed with a multiplier of 0.3 and confirmed that 0.3 is used for herring stocks.

A participant discussed that there was a peak in lengths and weights in the mid to late 80's, and once the collapse occurred, there was a decrease in lengths and weights in the stock. This may be evidence that Capelin was at carrying capacity in 1990. It was suggested that if we accept the 80's period as a proxy for B_0 with the 0.3 multiplier, the LRP would be feasible, reliable within the constraints of data/variance, and potentially plausible.

A participant expressed that there needs to be a further discussion encompassing serious harm. It was mentioned that the LRP should represent an upper bound of what should be avoided for serious harm, and there was a request to see confidence intervals (CI) around these proposed LRPs. It was confirmed that CIs are generally not done for LRPs because LRPs are considered absolute values.

CAPCOD MODEL (MODEL STRUCTURE, DIAGNOSTICS, AND OUTPUT)

Presenter: M. Koen-Alonso

Abstract

No abstract provided.

Discussion

A participant cautioned that the capcod model is based entirely on how cod is impacted by Capelin and not how Capelin is impacted by cod. Based on LRP values shown (current LRP of cod and corresponding Capelin LRP), there's no feedback in terms of other predators on Capelin. It was clarified that Northern cod is acting as a proxy for all finfish predation in the NL ecosystem.

It was suggested that the collapse created an altered stock that no longer includes the genes that would allow fish to mature later and an element of the population may have been lost. It was stated that when the fishery collapsed, the Capelin population was still tens of billions of individuals and with that size of a population, the chance of losing alleles would be slim, and there may not be concern that genetic function of Capelin was lost. This would mean we are in a continuous state and not an altered state, as previously mentioned. A participant stated that the LRP value needs to reflect the purpose of choosing the model approach, and demonstrate that we are possibly dealing with a different stock than the 1980s, which has implications for the ecosystem and species depending on it.

A participant responded that in this model, cod is being used as an indicator of productivity for the ecosystem (the acoustic survey index is a proxy for total Capelin biomass) and it was mentioned that the Capelin stock may be severely depressed and is showing all the associated demographic features of that (i.e., early maturation, delayed spawning, truncated age structure). A participant supported capcod as an approach to the Capelin LRP and it was stated that managing Capelin needs to be considered within an ecosystem-based management approach, which this model provides. It was cautioned that using capcod means that the goal of this management approach is to support the cod at its LRP rather than manage Capelin. However, there needs to be a sufficient Capelin biomass available to support other fishery stocks above their LRPs.

A participant inquired what the impact would be on other stocks, specifically the recovery of predators, if the Capelin stock improves, and if the cod and Capelin stock spatial overlap would change. It was confirmed that if cod improves, we should see improvements in the biomass of the other functional groups according to positive correlations seen in the 2J3KL RV biomass indices.

There were concerns expressed that estimations of RV biomass of cod are inflated. It was confirmed that this model is fitted to the original RV biomass time series. Cod landings are also included in capcod.

A participant inquired how the model interacts with species such as Northern Shrimp because, historically, shrimp is also prey for cod. It was noted that it's unlikely that including shrimp in the model would dramatically change the results of capcod. The natural mortality (M) in the model is density-dependent and varies with biomass levels.

There were concerns expressed regarding the how the consumption value was calculated and used in capcod. Consumption is estimated in the model.

There was an extensive discussion about capcod and concerns were expressed towards this model potentially introducing serious harm to Capelin. It was mentioned that these concerns need to be explicit (demographic impairment of the Capelin stock itself). A participant highlighted that this is a radical shift in how we think about LRPs, and it could be beneficial to look at a suite of approaches that are not only focused on cod. It was noted that capcod has been applied in another systems (i.e., Barents Sea) and that the parameter values are almost identical between the two systems, further emphasizing the importance of Capelin to cod dynamics. Concerns were raised in using cod as a proxy for other predator fish species in a complex system. A participant responded that this ecosystem is fairly cohesive and behaves as a unit. Because LRPs are revisited on a regular basis, moving in this direction does not mean this is a gross misrepresentation of the ecosystem.

There was a discussion surrounding the use of capcod and it was suggested to use a value to account for the presence of an environmental ceiling on Capelin recovery potential and a timeline of the potential of cod (predator stock) response. A participant mentioned that there are too many assumptions involved and they would prefer to use a more simple approach versus the more complicated capcod approach.

A participant inquired about the effect of a change in the cod LRP since there is a Northern cod framework meeting planned. If the cod LRP changes, then this will impact the Capelin LRP if capcod is chosen as the model for the Capelin LRP.

There was a discussion concerning the choice of a LRP based on a relationship to another species and a participant expressed concerns towards capcod failing to consider the reproductive capacity and harm to the Capelin stock. The DFO Forage Fish Policy (Policy on New Fisheries for Forage Species (dfo-mpo.gc.ca)) was used to clarify the point that when a forage fish stock reaches the level when it is demographically impaired, it is logical to assume that the ecological role of that species is already impaired or at risk of becoming impaired.

A participant reiterated concerns on using Northern cod biomass estimates from the 1980s. The cod data for capcod come directly from the RV survey and the only extra input was the conversion factor for the change in trawls in 1996 so there was no model used for extrapolation of the cod stock biomass.

The group reached consensus that capcod has solid logic and is a well-fitting model; therefore, capcod was the model chosen to estimate the Capelin LRP. $B_{recover}$ and B_0 are both trying to avoid a point where depensation may be happening (post-1990). The LRPs using $B_{recover}$ and B_0 are similar to capcod, despite these approaches being conceptually different. Less concern was expressed with regards to proving the stock is impaired because there is an assumption that it is already impaired.

Using the capcod model with Northern cod as an ecosystem indicator, a Capelin LRP of 640 kt in the Capelin acoustic biomass index was selected.

RESEARCH RECOMMENDATIONS

1. Examine the effect of stomach fullness (weight) on condition.
2. Examine the frequency of empty stomachs in earlier years using the scalar stomach fullness indicator recorded at the time of sampling.
3. Gather more information on biomass levels in the 1980's from multiple data sets including diet studies and how capelin can respond to improved feeding conditions.
4. Examine the role of the environment (climate, lower trophic levels) on the productivity of the stock including research and literature.
5. Review and update the capelin forecast model suite.
6. Discuss ways to deal with out-of-range values and how to manage them in a forecast eg. moving averages.
7. Understand impact of constant parameters in CAPCOD model and value of natural mortality (mB^2) on capelin required to support cod and other predators.
8. Continue the development of the age structured model.

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Buren, A.D., Koen-Alonso, M., Pepin, P., Mowbray, F., Nakashima, B., Stenson, G., Ollerhead, N., and Montevecchi, W.A. 2014. Bottom-up regulation of capelin, a keystone forage species. PLoS One. 9: 1–11.

Lewis, K.P., Buren, A.D., Regular, P.M., Mowbray, F.K., and Murphy, H.M. 2019. Forecasting capelin *Mallotus villosus* biomass on the Newfoundland shelf. Mar. Ecol. Prog. Ser. 616: 171–183.

Murphy, H.M., Pepin, P., Robert, D. 2018. Re-visiting the drivers of capelin recruitment in Newfoundland since 1991. Fish. Res. 200: 1–10.

APPENDIX I: TERMS OF REFERENCE

Assessment of Divisions 2J+3KL Capelin and Evaluation of Proposed Limit Reference Points

Regional Peer Review - Newfoundland and Labrador Region

March 6-10, 2023
Virtual Meeting

Co-Chairs: Nadine Wells and Elizabeth Coughlan

Context

Divisions 2J+3KL Capelin was last assessed in 2021 (DFO 2022) and an update was done in 2022 (DFO 2023). The current assessment is requested by Fisheries Resource Management to inform the development of management measures for the stock for the upcoming fishing season, and to review and establish a Limit Reference Point (LRP) for this stock based on established LRP approaches.

Objectives

Provide advice on the sustainability of the stock and select an LRP for 2J3KL Capelin. The following items will be reviewed:

- Consider ecosystem status where the assessed Capelin stock occurs based on an overview of relevant summaries of oceanographic conditions, biological community structure and trends, and pertinent knowledge of ecological interactions (e.g., predator, prey) and stressors (e.g., anthropogenic impacts).
- Review information on historical catches up to and including the 2021 fishery (there was no fishery in 2022).
- Review results of the 2022 Spring Acoustic Survey.
- Review revisions to the Capelin forecast model and discuss forecast for 2023.
- Assessment of the 2J3KL Capelin stock including the relative status of abundance, recruitment and biomass. Update indices of biological/behavioural characteristics of the stock.
- Review and establish an LRP from a suite of proposed approaches.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Documents

Expected Participation

- Fisheries and Oceans Canada (DFO) Science and Fisheries Management
- Newfoundland and Labrador Department of Fisheries, Forestry and Agriculture
- Indigenous groups
- Fishing Industry
- Academia

- Non-governmental organizations

References

DFO. 2022. Assessment of 2J3KL Capelin in 2020. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/013.

DFO. 2023. 2022 Stock Status Update for Capelin in NAFO Divisions 2J3KL. DFO Can. Sci. Advis. Sec. Sci. Resp. 2023/010.

APPENDIX II: AGENDA

Assessment of NAFO Divisions 2J+3KL Capelin and Evaluation of Proposed Limit Reference Points

CSAS Regional Peer Review (RPR)

Virtual Meeting – MS Teams Platform

March 06 – 10, 2023

Co-Chairs: Nadine Wells and Elizabeth Coughlan (DFO Science)

Monday, March 06

Time	Topic	Presenter
1000	Opening remarks	Atef Mansour
1010	CSAS Opening Slides and Roundtable	Co-Chairs
1040	Physical Oceanography up to 2022	Frederic Cyr
1110	Biological Oceanography up to 2022	David Belanger
1140	**Lunch Break**	**All**
1240	Ecosystem Summary to 2021	Mariano Koen-Alonso
1340	*2J-3KL Capelin Assessment:* - Biology - Spawning - Larval Index	Hannah Murphy
1420	*2J-3KL Capelin Assessment* (Spring Acoustic Survey**)** - Methods - Abundance/Biomass - % Mature and Diet	Hannah Murphy
1500	*2J-3KL Capelin Assessment* - Spring Acoustic Biomass Re-analysis	Aaron Adamack
1600	**Adjourn**	**All**

Tuesday, March 07

Time	Topic	Presenter
1000	Summary of Day 1 (March 06).	Co-Chairs
1015	*2J-3KL Capelin Assessment* Age Structure of Spawners Sampled at Beach Sites	Hannah Murphy
1030	*2J-3KL Capelin Assessment* (Fall MS Survey) - Age - Condition - Diet	Hannah Murphy
1100	*2J-3KL Capelin Assessment* - Capelin Forecast Model	Aaron Adamack
1215	**Lunch Break**	**All**
1315	Summary Bullets/SAR Review	All-Hannah Murphy
1600	**Adjourn**	**All**

Wednesday, March 08

Time	Topic	Presenter
1000	Summary of Day 2 (March 07)	Co-chairs
1015	*LRP Background* - Regime Shift and Data Time Frame - Ecosystem Role - Data Limitations	Keith Lewis
1200	**Lunch Break**	**All**
1300	*DFO LRP SAR Material* - Approaches - Criteria	Keith Lewis
1600	**Adjourn**	**All**

Thursday, March 09, 2023

Time	Topic	Presenter
1000	Review of Day 3 (March 08)	Co-chairs
1015	*LRP Approaches (species specific)* - Invalid approaches - Plausible approaches - Summary	Keith Lewis
1200	**Lunch Break**	**All**
1300	*Capcod Model (alternate LRP Approach)* - Model structure - Diagnostics - Output	Mariano Koen-Alonso
1600	**Adjourn**	**All**

Friday, March 10, 2023

Time	Topic	Presenter
1000	Review of Day 4 (March 09)	Co-chairs
1015	Evaluation of Proposed Capelin LRP	Keith Lewis
1200	**Lunch Break**	**All**
1300	Final Review of Summary Bullets for Capelin SAR Review of LRP Section in SAR Research Recommendations for Proceedings Doc.	All
1500	Reviewers' reports	A. Buren; M. Boudreau
1530	Upgrading of Working Papers Next Steps	All
1600	**Adjourn**	**All**

APPENDIX III: LIST OF MEETING PARTICIPANTS

NAME	AFFILIATION
Nadine Wells	DFO-NL – Science (Co-Chair)
Elizabeth Coughlan	DFO-NL – Science (Co-Chair)
Hannah Murphy	DFO-NL – Science (Capelin Stock-Lead)
Keith Lewis	DFO-NL – Science (Capelin LRP-Lead)
Aimee Kinsella	DFO-NL – Science (Rapporteur)
Erin Dunne	DFO-NL – Resource Management (Client)
Eugene Lee	DFO-NL – Science - Centre for Science Advice
Hilary Rockwood	DFO-NL – Science - Centre for Science Advice
Victoria Neville	DFO-NL – Science - Centre for Science Advice
Christina Bourne	DFO-NL – Science (Pelagic Section Head)
Brian Healey	DFO-NL – Science (Manager Aquatic Resources)
Karen Dwyer	DFO-NL – Science (Groundfish Section Head)
Kailey Noonan	DFO-NL – Resource Management
Fran Mowbray	DFO-NL – Science
Frédéric Cyr	DFO-NL – Science
David Belanger	DFO-NL – Science
Hannah Munro	DFO-NL – Science
Ryan Critch	DFO-NL – Communications
Chelsie Tricco	DFO-NL – Science
Ron Lewis	DFO-NL – Science
Aaron Adamack	DFO-NL – Science
Nancy Soontiens	DFO-NL – Science
Meredith Schofield	DFO-NL – Science
Fatemeh Hatefi	DFO-NL – Science
Changheng Chen	DFO-NL – Science
Samantha Trueman	DFO-NL – Science
Jared Penny	DFO-NL – Science
Mariano Koen-Alonso	DFO-NL – Science
Jonathan Coyne	DFO-NL – Science
Brandi O'Keefe	DFO-NL – Science
Pierre Pepin	DFO-NL – Science
Paul Regular	DFO-NL – Science
Rajeev Kumar	DFO-NL – Science
Marc Legresley	DFO-NL – Science
Divya Varkey	DFO-NL – Science
Brandon Tilley	DFO-NL – Science
Paula Lundrigan	DFO-NL – Science
Sanaollah Zabihi-Seissan	DFO-NL – Science
Dwight Drover	DFO-NL – Science
Robert Deering	DFO-NL – Science
Vladislav Petrusevich	DFO-NL – Science
Rick Rideout	DFO-NL – Science
Kelly Antaya	DFO-NL – Science
Janine O'Reilly	DFO-NL – Science
Shani Rousseau	DFO-QC – Science

NAME	AFFILIATION
Mathieu Boudreau	DFO-QC – Science (Internal Reviewer)
Elisabeth Van Beveren	DFO-QC – Science
Jenness Cawthray	DFO-NCR – Science
Karen Cogliati	DFO-NCR – Science
Emma Corbett	Provincial Gov. NL – Fisheries, Forestry, and Aquaculture
Erin Carruthers	Fish Food & Allied Workers Union (FFAW)
Nathan Jones	FFAW Harvester 3K Mobile Gear
Ivan Batten	FFAW Harvester 3L Fixed Gear
Rob Coombs	Nunavut Community Council
Gail Davoren	University of Manitoba
Gabrielle Perugini	Memorial University of NL – Marine Institute
Ashley Tripp	University of Manitoba
Alejandro Buren	Instituto Antártico Argentino (External Reviewer)
Craig Purchase	Memorial University of NL
Jennifer Herbig	Memorial University of NL – Marine Institute
Tyler Eddy	Memorial University of NL – Marine Institute
Ranjan Wagle	Memorial University of NL
Chelsea Boaler	Memorial University of NL
Gemma Rayner	Oceans North
Rebecca Schijins	Oceana