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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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TABLE OF CONTENTS

SUMMARY V

PRESENTATIONS 1

OCEAN CLIMATE IN NEWFOUNDLAND AND LABRADOR WATERS 1

Abstract 1

Discussion 1

OVERVIEW OF THE CHEMICAL AND BIOLOGICAL OCEANOGRAPHIC CONDITIONS ON THE NL SHELF 2

Abstract 2

Discussion 2

DRAFTING OF SCIENCE ADVISORY REPORT (SAR) BULLETS FOR ENVIRONMENTAL CONSIDERATIONS 3

ECOSYSTEM SUMMARY OF THE NEWFOUNDLAND-LABRADOR BIOREGION: TRENDS AND KEY INTERACTIONS WITH EMPHASIS ON THE ROLE OF SHRIMP 3

Abstract 3

Discussion 5

Drafting of Science Advisory Report (SAR) Bullets for Ecosystem Considerations 7

SHRIMP SIZE AT SEXUAL TRANSITION BASED ON TWO DATA SOURCES AND ESTIMATES OF FECUNDITY AT SIZE 7

Abstract 7

Discussion 7

POTENTIAL IMPACT OF CLIMATE CHANGE ON NORTHERN SHRIMP CONNECTIVITY AND HABITATS AND AN INTRODUCTION TO THE PANOMICS PROJECT 8

Abstract 8

Discussion 8

AN OVERVIEW OF THE SFA 4-6 SHRIMP POPULATION MODEL 9

Abstract 9

Discussion 9

SUMMARY OVERVIEW OF SFAS 4-6 NORTHERN SHRIMP 10

SURVEY OVERVIEW AND THE ASSESSMENT OF SFA 6 NORTHERN SHRIMP 10

Abstract 10

Discussion 10

Drafting of Science Advisory Report (SAR) Bullets for SFA 6 11

ASSESSMENT OF SFA 5 NORTHERN SHRIMP 11

Abstract 11

Discussion 11

Drafting of Science Advisory Report (SAR) Bullets for SFA 5 12

ASSESSMENT OF SFA 4 NORTHERN SHRIMP 12

Abstract 12

Discussion 13

Drafting of Science Advisory Report (SAR) Bullets for SFA 4 13

RESEARCH RECOMMENDATIONS 13

REFERENCES CITED 14

APPENDIX I: TERMS OF REFERENCE 15
APPENDIX II: LIST OF PARTICIPANTS 16
APPENDIX III: MEETING AGENDA 18

SUMMARY

A Zonal Peer Review Process for the assessment of Northern Shrimp in Newfoundland and Labrador (NL) was held on February 18-20, 2020 in St. John's, NL. The purpose of this meeting was to provide the most recent information concerning the status of Northern Shrimp (*Pandalus borealis*) stocks in the Shrimp Fishing Areas (SFAs) 4, 5 and 6.

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 Attendees are appended.

In addition to these Proceedings, publications to be produced from the meeting include a Science Advisory Report and a comprehensive Research Document, to be available online on the Canadian Science Advisory Secretariat website.

PRESENTATIONS

OCEAN CLIMATE IN NEWFOUNDLAND AND LABRADOR WATERS

Presenter: F. Cyr

Abstract

The North Atlantic Oscillation (NAO) index is a key indicator of the direction and intensity of the winter wind field patterns over the Northwest Atlantic. Despite being positive for a 6th consecutive year (since 2012, only 2013 was negative), most variables characterizing the NL climate were close to normal (the 1981-2010 average). The sea ice volume across the NL shelf was slightly below normal, characterized by a large negative anomaly in March-April, which also led to an early retreat on Newfoundland shelf. Annual sea surface temperature across the Northwest (NW) Atlantic was about normal, but characterized with slightly warmer than normal temperature in the north and colder than normal temperature in the south, especially during the first half of the year. Observations from the summer Atlantic Zone Monitoring Program (AZMP) oceanographic survey indicate that after a predominance of colder than average conditions since 2012, the volume of the cold intermediate layer (CIL, <0°C) was reduced along Bonavista and Flemish Cap section in 2019 (CIL along Seal Island section was normal this year but was reduced in 2018). The spatially averaged bottom temperature in Northwest Atlantic Fisheries Organization (NAFO) Divisions 2HJ3KLNO was also above normal, especially in 2J (+1.1 SD) and 3K (+1.0 SD). In the region surveyed by the Northern Shrimp Research Foundation (NSRF) near Hudson Strait and Baffin Island, the bottom temperature was slightly above normal.

Discussion

A participant asked if the ocean climate information presented by NAFO division could be presented at a smaller scale by SFAs. It was noted that this can be done in future assessments, especially for a parameter such as bottom temperature.

Since the composite climate index was not presented, a participant asked if it will be used in the future. It was clarified that this index is still being used, but was not ready for this assessment. The composite climate index will be presented at the AZMP meeting in April 2020 and included in that research document.

There was confusion over a possible mismatch in the NAO plots. A participant noted that from the NAO plots it appears temperatures at present are similar to the 1990s, while all other indices indicate it is slightly cooler, but far from the cold period in the 1990s. It was clarified that NAO is looking at large scale oceanic climate, as opposed to small-scale local conditions. The composite climate index would help clarify things further by combining the large scale and local conditions together to present a more accurate representation. It was noted that it is the winter NAO that is being presented, which is colder and similar to the 1990s. The average NAO for 2020 is close to normal.

A participant asked for information on the Atlantic Multidecadal Oscillation (AMO). It was noted that the AMO, which is the sea surface temperature over the entire Atlantic Ocean, is at a tipping point. At present, the AMO is sitting in a warm phase and entering a cooler phase, driven mostly by cooler water from the Labrador Sea.

There was a question regarding whether there was any information on pH. It was confirmed that monitoring of ocean acidification began in 2014, and these numbers should be released in a report in 2020.

There was a question regarding whether any work was conducted specifically on the cold intermediate layer. It was noted that data from Station 27 integrates the entire water column, and is a very close index for the cold intermediate layer. No clear trends have been observed with regards to changes in the depth of this layer. There are noted trends regarding temperature, where generally it was very warm in the 1960s and changed to a cold period in the 1990s. In the last two years the temperature of this layer appears to be rising again.

OVERVIEW OF THE CHEMICAL AND BIOLOGICAL OCEANOGRAPHIC CONDITIONS ON THE NL SHELF

Presenter: D. Belanger

Abstract

Biogeochemical oceanographic conditions on the NL Shelf in 2019 are reviewed and compared to large-scale spatial and temporal trends observed since the beginning of the AZMP. Ocean colour satellite data indicated that spring bloom timing was late in northern Labrador, early in southern Labrador and on the northeast Newfoundland shelf, and near normal on the northern Grand Banks. Total spring bloom production (magnitude) was near to below normal (average of 1998-2015) in 2019, continuing a trend that started in the early-2010s. In situ data collection from the AZMP monitoring program show that summer integrated nitrate (50-150 m) and chlorophyll (0-100 m) inventories were mainly above normal (average of 1999-2015) and, in most cases, at their highest levels since 2015. No data on the abundance and biomass of zooplankton on the Labrador Shelf were available at the time of the assessment. Partial data suggested a decrease in zooplankton abundance and biomass on the Grand Bank based on the summer data collection but this trend will not be confirmed until all seasonal surveys are completed. Data from Station 27 indicated that spring abundance of large, energy-rich, *Calanus finmarchicus* and small, numerically dominant *Pseudocalanus* spp. copepods was below the long-term (1999-2015) average on the Grand Bank.

Discussion

A participant reported that the Arctic Region has been observing a small, deep-water, fall algal bloom that is not detectable by satellite, in addition to the large spring bloom. It was asked whether there was a way to examine this using the Research Vessel (RV) survey, and it was noted that at present this is not possible due to issues with timing and coverage. The RV survey collects chlorophyll throughout the water column; however, if the fall bloom does not line up with the survey dates it would be missed. In addition, the fall survey is concentrated on the Grand Banks (3Ps), and stops just south of Labrador.

As a follow up, a participant asked if this small bloom remains throughout the fall in the Arctic. It was noted that this bloom appears to have started relatively recently. A secondary bloom is triggered by having increased sunlight available due to the late formation of ice, as well as an excess of nitrates available at the end of the season. Researchers are looking into the importance of this for overall production.

There was a question regarding whether it was possible to separate data for biomass and production. It was noted that at present there are no ways to separate these indices.

With regards to the results presented on seasonal patterns and trends in abundance, a participant pointed out a large departure in the 95% confidence intervals from the average abundance line. Clarification on the underlining historical data was requested. It was noted that these data are plotted by groups of five years for the entire time series. A positive trend has been observed since 1999, where the group moves from below to above the average line. For

the past two years a secondary spring peak has been observed, creating a second generation of *C. finmarchicus* and *Pseduocalanus spp.,* both of which are typically annual species coming up in the fall.

A participant asked if the physical sampling has been corrected to peak timing based on satellite imagery. It was reported that the physical sampling uses the raw data, so it is subject to variation depending on where the density is sliced.

As the spring bloom in the North is largely obscured by ice, a participant asked if there is value in shifting the satellite imagery analysis to the fall when ice would not be a concern. It was clarified that the spring satellite imagery was presented to complement the spring bloom indices. Even with improved satellite imagery in the fall, the bloom concentrations are not high enough to derive fall bloom indices. However, fall satellite imagery can be presented alongside raw data for chlorophyll concentrations.

A participant asked for clarification as to whether the noted changes in the zooplankton community composition, from *Calanus* spp. to *Oithona* spp., was a food quality issue. It was noted that *Oithona* spp. have lower energetic qualities than *Calanus* spp.; however, it was highlighted that there was also an increase in *Pseudocalanus* spp. which does have quality lipid and energy contents.

A participant asked if there is any information on how energy from primary production is distributed amongst zooplankton species. This information is unknown.

DRAFTING OF SCIENCE ADVISORY REPORT (SAR) BULLETS FOR ENVIRONMENTAL CONSIDERATIONS

There was discussion surrounding what specific copepod species Northern Shrimp feed on. It was noted that this is relatively unknown other than they feed on a wide range of foods including zooplankton and detritus. Therefore, it was decided to acknowledge and include the facts about the shrimp's changing ecosystem in the report; however, the data will be excluded from the final calculations as there is insufficient information to justify its inclusion. It was indicated that the potential impact of the changing ecosystem on shrimp may be included once future research is conducted.

ECOSYSTEM SUMMARY OF THE NEWFOUNDLAND-LABRADOR BIOREGION: TRENDS AND KEY INTERACTIONS WITH EMPHASIS ON THE ROLE OF SHRIMP

Presenter: H. Munro and M. Koen Alonso

Abstract

The ecosystem structure of the NL bioregion can be divided into four Ecosystem Production Units (EPUs): the Labrador Shelf (2GH), the Newfoundland Shelf (2J3K), the Grand Bank (3LNO), and southern Newfoundland (3Ps). These EPUs coarsely represent functional ecosystems, and are used as geographic boundaries for the estimation of fisheries production potential (FPP) using ecosystem production potential models. Estimated FPP distributions, together with proxies for the current productivity state of the EPU, have been used to provide guidance on the upper limit of total catches, aggregated by fish functional guilds, for the 2J3K and 3LNO EPUs. These functional guilds closely resemble the fish functional groups typically used to describe ecosystem status and trends, but represent a higher level of aggregation; for example, the Benthivore Guild includes all benthivore fish functional groups (small, medium, and large) plus the shellfish functional group (i.e. shrimp and Snow Crab). These analyses indicated that Benthivore Guild catches, where shrimp is included, were consistently above the

guidance level in 2J3K, but mostly below it in 3LNO since the mid-1990s. However, Benthivore Guild catches have dropped below the guidance upper limit since 2015 in both EPUs. Piscivore Guild total catches have been above the guidance level in the Grand Bank (3LNO) in the 1996-2004 period, and since 2015. These results indicate that during the 1995-2019 period these ecosystems have experienced fishing levels that have the potential to erode ecosystem functionality.

The ecosystem structure of the Newfoundland Shelf and Grand Bank changed in the 1990s with the collapse of the groundfish community, and the increase in shellfish. Even with the increases in shellfish, total biomass never rebuilt to pre-collapse levels. Starting in the mid to late-2000s there were consistent signals of rebuilding of the groundfish community which coincided with modest improvements in capelin, and the beginning of a decline in shellfish. The finfish biomass in the 2010s was relatively stable until 2014-15, when it started to show signals of decline. This signal appears earlier in the Grand Bank (3LNO), and later in the Newfoundland Shelf (2J3K). While some improvement is becoming apparent since the lows in 2016-17, current total biomass has not yet returned to the 2010-15 level. From a Shellfish perspective, improvements are being observed in Snow Crab, but shrimp reached the lowest RV biomass in the time series in 2019. Overall, it seems that the conditions that led to the start of a rebuilding of the groundfish community have eroded. This may be linked to the simultaneous reductions in capelin and shrimp availability, as well as other changes in ecosystem conditions.

The RV survey time series in 2H is incomplete and the signal is not entirely consistent, but it seems clear that the overall biomass has decreased in 2015-19. This decrease was originally driven by a decline in plankpiscivores (redfish), but in more recent years declines in shellfish (shrimp) have also played a role. Unlike 2J3K, the fish community in this Division remains dominated by shellfish, but there are signals of change with recent trends in shellfish. It seems that the fish community is starting to undergo structural changes similar to those observed in 2J3K in the late-2000s and early-2010s. Small and medium benthivores have declined in recent years, while large benthivores were on the rise (although a decline was observed 2019). There is no clear trend among piscivores; this functional group is highly dominated by turbot in this area. The planktivores signal shows very low biomass levels since 2015, and is dominated by oceanic species like lanternfishes and black herring, hinting at potential pelagic connections between the shelf and the nearby Labrador Sea ecosystem. Within the context of a rather noisy time series, shrimp shows a clear decline over the last three years.

Capelin and shrimp are important prey items for cod, turbot, American plaice, and redfish. The dominance of shrimp in the diets has generally declined as the shrimp stock declined; these declines are often associated with increases of capelin in the diet. Conversely, the reductions of capelin in the diets observed in 2017-19 seem to have prompted modest increases of shrimp despite the low shrimp availability. The reduced availability of both shrimp and capelin in recent years has also translated into more diversified diets, with increasing cannibalism in both cod and turbot. Average stomach content weights for cod and turbot have also declined since the mid-2010s, suggesting increased limitations in general food availability. This supports the idea that declines in total biomass observed in recent years appear to be associated with bottom-up processes.

From a predation and impacts perspective, total food consumption by predators (medium and large benthivores, piscivores, and plank-piscivores fish functional groups) in 2J3KL, was estimated based on food requirements and, if food availability is limited, actual consumption would be expected to be lower than these estimates. Results indicate that total food consumption by predators was stable between 2011-15, but has declined somewhat since. Predation on shrimp showed an increasing trend until 2011 and decreased afterwards, but the 2017-19 estimates suggest that consumption may have modestly increased in the last couple of

years. Predation mortality increased rapidly in 2008-11, decreased afterwards but has increased again in 2018-19. Current level of predation mortality is the highest since the start of this time series in 1995. The potential relative impact of fishing with respect to predation has been variable in the 1995-2019 period, with a median value around 20%, a peak around 40% in 2002-04, and recent values around 5%. Under current ecosystem conditions, fishing is unlikely to be a main driver of the stock, but it could now be more influential on stock declines than it was in the past.

In terms of shrimp productivity in 2J3KL, shrimp per capita net production has declined since the mid-1990s. Consistent with previous results, fishing has detectable indirect impacts on shrimp net production with lags of two to four years, and predation has impacts with lags one to three years. Based on the current results, and the observed trends in the identified drivers, shrimp per capita net production would be expected to remain around current values in the coming one to three years.

The historical build-up of shrimp was driven by a combination of favorable environmental conditions and reduced predation. Shrimp is an important forage species, and the trend in predation mortality in the near future is highly associated with the availability of alternative prey like capelin. Current predation mortality on shrimp in 2J3KL is estimated to be at an all-time high. Under current ecosystem conditions (i.e. low shrimp biomass, high predation pressure), fishing is unlikely to be a dominant driver for shrimp in 2J3KL, but it could now be more influential on stock declines than it was in the past.

Discussion

It was reported that historically there have been two ecosystem crashes which lead to regime shifts, and a participant asked for further information regarding the 1920s crash. It was noted that this research came from a paper published by Buren *et al.* (2014), which characterized regime shifts using oceanographic variables. It is well known that there was a biological shift in community structure in the 1990s, and cumulative temperature going back to the beginning of the century displayed a similar trend in the 1920s. However, it was clarified that it is not known for certain if this same biological change is true for the 1920s.

A participant noted that the RV bottom trawl survey did not record crustaceans prior to 1995, and asked how this was corrected for in the RV scaled biomass. It was clarified that this was not accounted for in this particular analysis; however, preliminary work looking at shrimp biomass in the 1980s found it slightly higher than present day. It was also noted that this analysis does not apply any penalty for the pre-collapse period, as all calculations prior to the 1990s assume a fully functional ecosystem.

A participant asked to clarify the term ‘fully functional’. It was clarified that ‘fully functional’ is used to describe a best case scenario, where everything flows effectively in terms of ecosystem functionality. The Ecosystem Production Potential (EPP) model assumes that the cumulative production in any given trophic level will effectively move up following a transfer efficiency. In practice, each level of the model should contain sufficient biomass to account for all the available production generated by lower trophic levels, and this biomass then becomes available to the next trophic level. The reality is less productive than this scenario, and it is this difference in potential that the model is designed to capture.

There was discussion over the total RV biomass index being used as a proxy for productivity. A participant asked for clarification as to why the highest productivity value is at the beginning of the 1980s when groundfish was in decline. It was clarified that the production over biomass ratio (PB ratio) equates to how much production is created out of a unit of biomass in a given period of time, typically a year. This value is often assumed to be constant. It was noted that the same

idea can be applied to productivity at the ecosystem level, whereby if the PB ratio at the ecosystem level can be assumed as a constant, then any correction will be a linear function of the biomass. Based on that rationale, changes in biomass will mirror the changes in production. It was clarified this does not refer to per capita production in terms of biomass last year versus biomass this year.

There was a question on whether the upward trend in 3LNO shellfish over the past three years was mostly due to crab or shrimp. It was clarified that the majority of the upward trend in 3LNO shellfish is associated with crab. The conclusion from the 3L shrimp assessment last November (2019) was that over the past several years there has been no major changes in shrimp.

Observations from the fishing industry report a noticeable increase in squid, mackerel, and herring. A participant asked whether the RV survey has been able to observe any signals from those species in the past. It was clarified that squid would be grouped with invertebrates, which are not currently represented in the time series. However, the RV survey does collect information on squid, and a large increase in biomass has been observed over the past few years. Work is ongoing to incorporate invertebrates into this analysis. It was noted that herring and mackerel are less frequently observed in the RV surveys, as these species tend to be coastally distributed in the NL region, with the exception of the 3Ps area.

A participant asked how changes in RV survey coverage over the years was dealt with when analyzing structures and trends in fish community. It was noted that to address the changes in coverage, a series of core strata were selected that have been systematically covered over time, thus eliminating the highly variable areas. In addition, each year where that coverage of those core strata fall below a certain threshold is excluded from the analysis.

There was a question regarding the inclusion of marine mammals and seabirds in the consumption model presented. Marine mammals are not currently included in this model; however, they have been investigated in the past. It was noted there are good consumption estimates available for harp seals and reasonable estimates available for other seal species. There are also limited estimates of large whale and small cetacean abundances over time, as these mammals have large foraging grounds. It is estimated that the total food consumed per year by marine mammals in general is 8 million tonnes. Seabirds are studied by Environment and Climate Change Canada, and collaboration with that department was suggested in order to incorporate those data into the consumption model. There are figures available for seabird consumption, and the order of magnitude is thought to be much smaller than that by fish or mammals. It was confirmed that work is ongoing to address these questions.

There was a question regarding what period the reference index encompasses for RV biomass by fish functional groups. It was clarified that the reference index for the detailed analysis is from 1995 onward due to the change in survey gear from the Engels to Campelen trawl. Incorporating data from previous years in this analysis would require scaling and conversion factors, which do not exist for all species. It was noted that reasonable scaling factors have been calculated for the overall biomass in the system.

A participant asked for clarification on how shellfish biomass was estimated based on the analysis of stomach contents. The probability of shrimp found in the diet is calculated by analyzing the abundance of shrimp in the preliminary ‘called stomach’ observations of cod and turbot at sea. This probability is then used to back-calculate the expected biomass for shrimp. It was confirmed that these are preliminary results, and work is ongoing in the lab to generate accurate shrimp abundance.

A participant noted the reconstructed shellfish biomass indices for present day levels, while in decline, are at the same level as they were in the 1980s pre-collapse period. It was clarified that this is only referring to NAFO areas 2J3KL.

A participant noted warm temperatures are thought to clear the gut faster and asked if temperature was taken into consideration when looking at stomach emptiness. It was noted that temperature is not factored in at present. It was suggested that any observed changes in temperature would have little effect, as the highest weights captured from stomach contents can be seen between 2010-15 when temperatures were higher than present day. It was also noted that stomach emptiness is not factored into the estimation of consumption as there are only data for two species, cod and turbot.

Drafting of Science Advisory Report (SAR) Bullets for Ecosystem Considerations

There was discussion surrounding the stomach analysis research presented at the framework meeting that was not captured in the assessment and bullets. It was decided to review select key graphs and figures that came out of the framework meeting and draft a bullet that incorporates this information.

A participant asked for clarification on whether a bullet is referring to the rate of predation or total predation mortality. It was noted this is in reference to the rate of predation, not consumption. This was clarified by referring to it as shrimp predation mortality rate.

A participant commented that there appears to be more weight related to ecosystems processes this year, highlighting a higher proportion of summary bullets. It was clarified that the layout is similar to the last assessment and is focused on a balanced approach.

There was discussion surrounding the predictive part outlined in a bullet, and a participant asked for clarification if this statement was based on the shrimp population model. It was clarified that while the statement may be consistent with the shrimp population model, it is solely based off the consumption analysis. The analysis is based on lagged correlations, and the signals show no obvious trend in the next two to three years depending on the variable considered. The prediction comes from the correlations remaining flat and suggesting no changes.

A participant asked for clarification as to why a bullet states that fishing could now be more influential on stock decline. It was explained the last biomass point on the consumption model does not take into consideration catch and will remain about the same next year. Therefore, by adding catch to that value next year a decline can be expected instead of remaining constant.

SHRIMP SIZE AT SEXUAL TRANSITION BASED ON TWO DATA SOURCES AND ESTIMATES OF FECUNDITY AT SIZE

Presenter: A. Beita-Jimenez

Abstract

No abstract was provided.

Discussion

A participant asked for clarification as to why the L50 was used for calculating the spawning stock biomass (SSB) and not the female biomass. It was noted that female biomass is used for the stock assessments. However, in the literature there is a commonly used equation that

incorporates the L50. Modelling sexual transition in this way may provide additional information that biomass alone would not.

It was noted that the survey data are from very specific times of the year, whereas observer data are spread throughout the year. A participant asked if there is any temporal influence. It was clarified that for the fecundity studies samples were all taken in the fall, so timing would not be a factor. However, this may have an influence when looking at the sexual transition data.

A participant asked if a relationship exists between the amount and weight of eggs for fecund females. It was noted that egg size changes through development in each individual. However, fecundity studies only use eggs in the first stage, so it can be assumed most would have a similar egg volume.

A participant asked for clarification on whether anything was done to adjust for spatial distribution. It was noted that some studies have identified fecundity as a variable both spatially and temporally. This project is only looking at SFA 6 and at this point has not addressed any spatial component.

POTENTIAL IMPACT OF CLIMATE CHANGE ON NORTHERN SHRIMP CONNECTIVITY AND HABITATS AND AN INTRODUCTION TO THE PANOMICS PROJECT

Presenter: N. Le Corre

Abstract

The effect of climate change on ocean circulation and environmental conditions will likely impact important bentho-pelagic fisheries species which have a limited habitat range and a prolonged larval dispersal phase. Based on projections from a regional scale ice-ocean model forced under RCP8.5 climate change scenario, we investigated spatial distribution variability of Northern Shrimp preferred habitat and larval settlement patterns in the NL waters for the next 70 years. Our projections of ocean temperature revealed the persistence of major shelf-scale processes, but a gradual increase of yearly bottom water temperature by more than 4°C by 2090. Such warming led to an expansion of thermal preferred habitat for Northern Shrimp from 2010-50 over the continental shelf prior to a decline and shift towards more coastal and southern areas from 2060-90. The modification of the Northern Shrimp habitat distribution, associated with changes in the ocean circulation features, impacted settlement patterns from larval dispersal simulation and temperature encountered by larvae in different ways. During the projection period, the historically most important area was mostly negatively impacted in terms of thermal habitat and potential settlement, whereas other less important areas, to the north and the shallow area to the south, received more settlers in comparison with the historical period. Our study demonstrated the important role of shelf-scale processes in determining larval connectivity and suggest the need to use regional scale ocean models while assessing potential impact of climate change on ecosystems. During this meeting, we also presented a short introduction to the PANOMICs project which aims at characterizing population structure and metabolic response of Northern Shrimp using genomics.

Discussion

A participant noted that the presented model provides an estimate of the proportion of larvae that are retained within a region. It was asked if complementary work is being undertaken to assess what fraction of settlers observed within a region come from different areas. It was confirmed that work is ongoing to address these questions. Some work has been conducted releasing larvae everywhere in the northwestern Atlantic Ocean (NAFO divisions

0AB1ABCDEF2GHJ3KL), and observing which proportion settle in SFA 6 (Le Corre et al. 2020). However, this is only based on four years of data, after that only projections are available. It was recognized that there is room for improving the spatial model with larval connectivity.

A participant noted that the presented models look at suitable habitats for larval settlement and retention. It was asked if complementary work is being undertaken to assess what fraction of settlers are also initially coming from suitable habitat. It was noted that the model does not yet take this into account; however, work is ongoing to find a way to integrate both concepts.

There was discussion surrounding the scale of connectivity and how this research is being used in the shrimp population model. It was noted that if connectivity were to be added to the model, the scale is larger than the model itself (SFAs 4-6), and larvae from the Arctic and Greenland would have to be considered for full coverage of larval input. There was consensus that connectivity should be incorporated into the shrimp population model.

AN OVERVIEW OF THE SFA 4-6 SHRIMP POPULATION MODEL

Presenter: K. Baker

Abstract

In May 2019, a population model for Northern Shrimp in SFAs 4-6 was tentatively accepted with a requirement for additional analyses and further review. In January 2020, a post-meeting review of the additional analyses was completed and the model was accepted for use in the annual assessment for predicting future productivity, but not for use in the management of the fishery. The population model considers Northern Shrimp biomass densities (and predictors, where possible) at a patch level to predict change in biomass (i.e., net productivity) one year in advance. While the original analyses explored a variety of potential predictors and time lags, the final forecasting model used a spatially-explicit GAM with a spatially varying intercept and spatially varying density-dependence term to determine that the change in Northern Shrimp biomass is a function of shrimp density, Atlantic Cod (*Gadus morhua*) density, alternate prey (Redfish-*Sebastes spp*. and Greenland Halibut-*Reinhardtius hippoglossoides*) density, and the North Atlantic Oscillation in the previous year. Future modifications of the model will focus on attempting to improve fit in the most northerly SFAs, by considering other taxa (e.g., Thorny Skate-*Amblyraja radiata*) and the Arctic Oscillation. Research remains ongoing toward the development of an updated limit reference point for Northern Shrimp in SFAs 4-7.

Discussion

A participant expressed concern that this is a spatial model, but it is missing explicit transport terms. It was noted that larval transport was considered in the original model, but it did not come out as a significant predictor, primarily due to the scale of the spatial data. Future work includes finding a way to collect Arctic data on an annual basis to feed into this model to see if that would improve the fit and predictive power.

There was a question regarding whether a retrospective analysis was attempted using the model. It was confirmed that retrospective analyses were conducted using test data to assess the predictive power. As part of these analyses, multiple years were removed and the results were then compared to other models.

There was discussion about how this model and information is to be used. It was noted that the model is not yet ready to be incorporated into the precautionary approach framework or management decisions. The general conclusion was that it provides some additional information

on Northern Shrimp, and going forward work will continue so the model can be formally incorporated into the assessment.

SUMMARY OVERVIEW OF SFAS 4-6 NORTHERN SHRIMP

Presenter: K. Skanes

During the assessment in 2020, data were presented including shrimp biomass/abundance indices from surveys, survey catch rates of known shrimp predators, commercial fishery catch per unit effort (CPUEs), exploitation rate indices, bottom temperatures, sea surface temperatures, spring phytoplankton bloom dynamics for SFAs 4-6, and zooplankton biomass and community structure for SFA 6 and part of SFA 5. Preliminary ecosystem analyses had demonstrated correlations between exploitation rate, predation, shrimp consumption, composite environmental index and dynamics of the spring phytoplankton bloom with subsequent shrimp per capita net production (DFO 2018). The May 2019 Shrimp Framework Meeting presented further research demonstrating that changes in NAO and biomass of predators (Atlantic Cod, Redfish and Greenland Halibut) are significant predictors of subsequent shrimp production on a smaller scale (i.e., Voroni polygons). The specific causes of declining trends in SFAs 4-6 is not fully understood and the requirement for further research is recognized.

It should be noted that the survey coverage in fall 2019 was greatly impacted mainly by weather, but to some extent vessel issues. This led to coverage below the allocated survey sets by survey strata. Analysis was undertaken for the assessment due to the poor 2019 survey coverage in SFAs 5-6. These analyses demonstrated that biomass estimates would not have been exceedingly different had the survey coverage been equally poor in previous survey years. Subsequently, the biomass estimates were accepted for delivery of science advice.

SURVEY OVERVIEW AND THE ASSESSMENT OF SFA 6 NORTHERN SHRIMP

Presenter: K. Skanes

Abstract

There is concern for the current status of this resource. The female SSB index declined by 25% from 2018-19 and it is currently in the Critical Zone for the fourth consecutive year, based on the Precautionary Approach (PA) Framework. This follows three consecutive years of the female SSB index declining while in the Cautious Zone. The Integrated Fisheries Management Plan (IFMP) states that the exploitation rate should not exceed 10% while the female SSB index is in the Critical Zone.

Fishery removal effects may become relatively high given the low level of net shrimp production after predator removals of shrimp in recent years. Thus, fishing mortality can be very important for determining whether gains (production) exceed losses (predation and fishing) and hence whether the stock increases or decreases. Recent environmental and ecosystem conditions along with harvest rates have not permitted the stock to increase.

Discussion

A comment was made that the main reason the catch rates for the offshore fleets in the summer were so low was due to ice cover. Observations from the fishing industry noted that typically the large vessel fleet focuses on SFA 5 in the winter; however, the ice in the last couple of years has not allowed them to get into the typical fishing areas of SFAs 5 or 6. This year in particular, the SFA 5 quota had already been caught but there was no alternative SFA to access due to ice cover and they were forced to stay in SFA 5. It was noted that normally by this time (i.e., winter

of the current management year) the large vessel fleet have taken most of their catch, but this year they have only taken 36% of the Total Allowable Catch (TAC) in SFA 6.

There was discussion surrounding the Ogmap test run analysis for the RV survey data. It was clarified that for each test run, sets were randomly eliminated through computer generation to exactly mimic the 2019 coverage loss with respect to the number of sets by strata. The overall conclusion is that estimates from the test runs are within the confidence bounds, especially within recent years. While there is a chance the biomass may be overestimated, it is still felt to be a reliable estimate of what was actually realized in SFA 6.

A participant asked whether the issues with the 2019 RV survey pertains to SFA 6 only. It was clarified that the issues with the 2019 RV survey impacts both SFAs 5 and 6.

A participant asked what the total predicted biomass is based on. It was clarified that the predicted biomass is based on f=0. The 2019 projection takes into account catch from the previous year but does not take any catch out of the next year. It was pointed out by a participant that there is a difference between the Ogmap estimated value, which is an actual estimate from the survey and therefore will have an impact from fishing, and the model estimate, which is projecting the biomass without that catch data.

A participant asked if it was possible to view the model trajectory alone as an overlay. It was noted that it is not possible at present because it is not a simple overlay on the existing data. The model trajectory is based on the Ogmap estimate and the resulting change in productivity, not the change in productivity from the biomass estimate in the model. It would require resampling Ogmap several times to come up with the uncertainty estimate.

Drafting of Science Advisory Report (SAR) Bullets for SFA 6

There was discussion surrounding a bullet detailing the sources of uncertainty that resulted from limited RV survey coverage. It was proposed to move this bullet to the beginning summary section under ‘sources of uncertainty’, and clarify the differences between SFA 5 and 6.

ASSESSMENT OF SFA 5 NORTHERN SHRIMP

Presenter: K. Skanes

Abstract

There is concern for the current status of this resource. Biomass indices in SFA 5 have been declining since 2010, although with annual variability. The fishable biomass index decreased by 20% and the female SSB index increased by 16% between 2018-19, both are amongst lowest levels of the survey time series. Female SSB index is in the Healthy Zone within the PA Framework with 33% probability of being in the cautious zone. If the 22,100 t TAC is maintained and taken in 2020-21, then the exploitation rate index will be 34%.

Discussion

Questions were asked about the Ogmap test run analysis. It was asked if the higher biomass estimates from two to three years ago would impact the results and drive up values. It was noted that it is possible that the sets that were driving the actual biomass estimates two to three years ago were in completely different strata and not affected at all. However, it was confirmed there is also uncertainty surrounding the analysis.

A participant asked if the missing strata from the RV survey could be highlighted on the large vessel CPUE chart. The intent being to visualize the entire time series of the biomass by strata,

looking specifically at the areas that were affected by a loss of coverage. These areas were highlighted for participants. However, it was noted with Ogmap any nearby strata will also be affected.

A participant asked for clarification with regards to the low CPUE values. The question was whether vessels are going to less desirable areas or were fishing at less desirable times. It was clarified that it is likely a combination of both. Industry reported less access due to ice, specifically in some of the more desirable areas, which lead to more searching around. A participant echoed that the data overstate the abundance available to vessels.

A participant asked for further clarification on how the biomass was overestimated. It was clarified that based on test runs, where coverage was randomly omitted, Ogmap was fairly consistent in overestimating the biomass estimate by 10%. It was noted that there was more variability in SFA 5 than SFA 6.

A comment was made that over the years there has always been missing data. A question was asked if this has caused shrimp biomass to be overestimated in the past. It was noted that this year is an exception. In the past there may have been a few RV sets that were missed, often in 3L, as it is where the RV survey finishes. The 2019 RV survey missed important sets in 2HJ3K, areas that are historically completed. Therefore, this is the first time conducting this test run analysis. The red line in the analysis indicates what was accepted in the past, and based on that red line the test runs show a likely overestimation of this year's biomass. It was also noted that every year is subject to uncertainty, which is why error bars are included.

A participant asked if the NAO is used as a variable in Ogmap, and it was clarified that it is not. However, NAO is used as a variable in the shrimp population model in which it lags by one year.

A participant asked how the distribution of males versus females differs. It was clarified the distribution does not differ, at least not at the time when the RV survey is conducted.

Drafting of Science Advisory Report (SAR) Bullets for SFA 5

There was discussion surrounding a bullet detailing the sources of uncertainty that resulted from limited RV survey coverage. It was proposed to move the bullet to the beginning summary section under sources of uncertainty, and clarify the differences between SFA 5 and 6. The intention is to highlight that the recommendation and advice has more uncertainty than usual, particularly in SFA 5, due to poor survey coverage.

A participant asked if it is possible to correct the estimated biomass, as it is overestimated by 10% due to poor survey coverage. It was noted that adjusting the biomass was discussed, but this suggestion was ultimately rejected due to the uncertainty surrounding the exact value of overestimation, as it may be 10% or less. Furthermore, considering the confidence intervals, adjusting it by 10% either way likely will not impact the scope of uncertainty.

ASSESSMENT OF SFA 4 NORTHERN SHRIMP

Presenter: K. Skanes

Abstract

There is concern for the current status of this resource. Biomass indices in SFA 4 have been declining since 2012, although with some annual variability. The fishable biomass index increased by 29% and the female SSB increased by 23% from 2018-19; however, both are amongst the lowest levels in the survey time series. Exploitation rate indices had been increasing from 2012-13 to 2018-19 until declining in 2019-20, corresponding to a reduced TAC.

Female SSB index in 2019 was in the Cautious Zone, for the second consecutive year, with a 6% probability of having been in the Critical Zone.

Discussion

A participant asked if the biomass prediction from the model includes the projected catches for the present year. It was clarified that the model does not include the projected values for the present year, nor does it include these values from the previous year.

There was confusion regarding the precautionary approach framework arising from the statement that the female SSB index has a 71% chance of being in the healthy zone, based on the confidence intervals. It was noted that this would need to be looked into further.

There was discussion regarding what data are included in the shrimp population model to generate the projected results. It was clarified that the model predicts from Ogmap. In 2019 the projected value is being drawn from the 2018 Ogmap value, and in 2020 the projected value is being drawn from the 2019 Ogmap value.

Drafting of Science Advisory Report (SAR) Bullets for SFA 4

There were no questions or comments from participants on the drafting of these bullets.

RESEARCH RECOMMENDATIONS

- Conduct a satellite image analysis of the fall algal bloom, specifically covering the Northern areas.
- Investigate if changes in bottom and surface temperatures are having a possible match-mismatch effect on shrimp.
- Undertake research to characterize the diet of Northern Shrimp. Investigate how changes in timing and zooplankton community structure could have an impact.
- Investigate the effects of spatial distribution on fecundity.
- Further modelling on larval dispersion by:
    - determining the fraction of larvae settling in a region of suitable habitat that come from suitable habitat;
    - building on the spatial model for connectivity;
    - aiming to ground truth modelling results using other data sources (e.g., genetics).
- Investigate larval dispersal every year to establish recruitment index on current biomass.
- Investigate male to female ratios and correlations further.
- Investigate how the distribution of fishing effort has changed between periods when stock was high versus the past few years using Vessel Monitoring System (VMS) data.
- Continue work on shrimp population model (e.g., genetics study, expand scale of connectivity, more testing and validating).
- Communication recommendation: Participants felt there is merit in having an environmental and ecosystem session early in the year prior to the assessments. Following each assessment create a summary of the outcomes, and highlight the information that directly relates to the species.

REFERENCES CITED

Buren, A.D., Koen-Alonso, M., Pepin, P., Mowbray, F., Nakashima, B., Stenson, G., Ollerhead, N. and W.A. Montevecchi. 2014. Bottom-up regulation of capelin, a keystone forage species. PLoS One, 9(2):p.e87589.

Le Corre, N., Pepin, P., Burmeister, A., Walkusz, W., Skanes, K., Wang, Z., Brickman, D., and P.V.R. Snelgrove. 2020. Larval connectivity of northern shrimp (*Pandalus borealis*) in the Northwest Atlantic. Canadian Journal of Aquatic and Fisheries Sciences. 77(8):2019-0454.

APPENDIX I: TERMS OF REFERENCE

Assessment of Northern Shrimp in Shrimp Fishing Areas (SFAs) 4, 5 and 6

Regional Peer Review-Newfoundland and Labrador Region

February 18-20, 2020
St. John's, NL

Chairperson: Cynthia McKenzie, DFO Science

Context

The status of Northern Shrimp (Pandalus borealis) in Shrimp Fishing Areas (SFAs) 4-6 has been assessed annually since 2015. The status of Northern Shrimp in SFAs 4-6 was last assessed in February 2019 (DFO 2019). Fisheries Management has requested the current assessment as the basis for harvest advice for the 2020-21 fishing season.

Objectives

- Assess the status of the stock based on available indicators for Northern Shrimp in SFAs 4 to 6 (NAFO Divisions 2G to 3K).

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Participation

- DFO-Science and Resource Management Branches
- Government of Newfoundland and Labrador-Department of Fisheries and Land Resources
- Government of Nunatsiavut
- Indigenous groups
- Fishing Industry
- Academia
- Other invited experts

References

DFO. 2019. An Assessment of Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas 4–6 and of Striped Shrimp (*Pandalus montagui*) in Shrimp Fishing Area 4 in 2018. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/027.

APPENDIX II: LIST OF PARTICIPANTS

Name	Affiliation
Alastair O'Reilly	Northern Coalition
Andres Beita-Jiménez	Marine Institute
Andrew Cuff	DFO Science, NL Region
Arnault LeBris	Marine Institute
Brian Burke	Nunavut Fisheries Association
Brian Healey	DFO Science, NL Region
Brittany Beauchamp	DFO Science, Nation Capital Region
Bruce Chapman	Canadian Association of Prawn Producers
Courtney D'Aoust	DFO Resource Management, National Capital Region
Connie Dobbin-Vincent	DFO Resource Management, NL Region
Colin Webb	Nunatsiavut Government
Chad Strugnell	Harvester
Craig Taylor	Torngat Wildlife, Plants & Fisheries Secretariat
Cynthia McKenzie	Chair
Darrell Mullowney	DFO Science, NL Region
Darren Sullivan	DFO Science, NL Region
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Derek Butler	Association of Seafood Producers
Derek Osborne	DFO Science, NL Region
Elizabeth Coughlan	DFO Science, NL Region
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Erika Parrill	Center for Science Advice, NL Region
Erin Carruthers	Fish, Food and Allied Workers Union

Name	Affiliation
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Gary Maillet	DFO Science, NL Region
Hannah Munro	DFO Science, NL Region
Hugo Bourdages	Reviewer
Katherine Skanes	DFO Science, NL Region
Keith Watts	Torngat Fish Coop.
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Mariano Koen-Alonso	DFO Science, NL Region
Mark Simpson	DFO Science, NL Region
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Nelson Bussey	Harvester
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Tyler Eddy	Marine Institute
William Coffey	DFO Science, NL Region
Wojciech Walkusz	DFO Science, Central and Arctic Region

APPENDIX III: MEETING AGENDA

Tuesday, February 18, 2020

Time	Activity	Presenter
9:00	Welcome/Opening	C. McKenzie (Chair)
-	Presentation: Ocean climate in Newfoundland and Labrador waters	F. Cyr
-	Presentation: Overview of the chemical and biological oceanographic conditions on the NL Shelf	D. Belanger
-	Newfoundland & Labrador Ecosystem Overview	H. Munro/M. Koen Alonso
-	Shrimp Size at Sexual Transition based on Two Data Sources and Estimates of Fecundity at Size	A. Beita-Jiménez
-	Potential Impact of Climate Change on Northern Shrimp Connectivity and Habitats and an Introduction to the PANOMICS project	N. Le Corre
-	An Overview of the SFA 4-6 Shrimp Population Model	K. Baker
-	Presentation: Survey Overview and the Assessment of SFA 6 Northern Shrimp	K. Skanes
-	Drafting of Science Advisory Report (SAR) bullets for SFA 6	All

Wednesday, February 19, 2020

Time	Activity	Presenter
9:00	Presentation: Assessment of SFA 5 Northern Shrimp	K. Skanes
-	Drafting of SAR bullets for SFA 5	All
-	Presentation: Assessment of SFA 4 Northern Shrimp	K. Skanes

Time	Activity	Presenter
-	Drafting of SAR bullets for SFA 4	All
-	Research Recommendations	All
-	Upgrading of Working Papers	All
-	Adjourn	C. McKenzie

Thursday, February 20, 2020

A third day (February 20) has been added in the event of winter weather related delays, NAFC building closure due to a storm, and/or extra time is required for discussion.

Notes:

- Health breaks will occur at 10:30 a.m. and 2:30 p.m. Coffee and tea can be purchased from the cafeteria in the NAFC.
- Lunch (not provided) will normally occur 12:00-1:00 p.m.
- Agenda remains fluid-breaks to be determined as meeting progresses.
- This agenda may change.