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Proceedings of the Newfoundland and Labrador and Central and Arctic Zonal Peer Review of the Northern and Striped Shrimp Assessment

Meeting date: February 12-14, 2019
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Chairperson: Cynthia McKenzie
Editor: Laura Wheeland

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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

The Zonal Peer Review Process for the Assessment of Northern and Striped Shrimp was held in St. John's, Newfoundland and Labrador (NL) February 12-14, 2019. The purpose of the process was to assess Northern Shrimp (*Pandalus borealis*) in SFAs 4-6 in the Eastern Assessment Zone (EAZ) and the Western Assessment Zone (WAZ) and Striped Shrimp (*Pandalus montagui*) in SFA 4, EAZ and WAZ.

The meeting was attended by staff from Fisheries and Oceans Canada (DFO) Science and Resources Management (Newfoundland and Labrador, Central and Arctic, and National Capital Regions), as well as participants from the fishing industry, the Provincial Department of Fisheries and Land Resources, academia, and Indigenous organizations.

INTRODUCTION

The Zonal Peer Review Process for the Assessment of Northern and Striped Shrimp was held in St. John's, Newfoundland and Labrador (NL) February 12-13, 2019. The status of Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas (SFAs) 4-6 has been assessed annually since 2015. Northern Shrimp in the Eastern and Western Assessment Zones, and Striped Shrimp (*Pandalus montagui*) in SFA 4 and the Eastern and Western Assessment Zones, is assessed on a biennial basis. In interim years, stock status updates are conducted.

The status of Northern Shrimp in SFAs 4-6 was last assessed in February 2018. A stock status update for shrimp in the Eastern and Western Assessment Zones and for Striped Shrimp in SFA 4 was held in February 2018.

Fisheries Management requested the Zonal Peer Review Process as the basis for harvest advice for the 2019/20 fishing season.

OVERVIEW OF THE PHYSICAL AND OCEANOGRAPHIC CONDITIONS ON THE NL SHELF

Presenter: F. Cyr

Abstract

Physical environment conditions for 2018 (large-scale atmospheric forcing and hydrographic response) were presented. Although the North Atlantic Oscillation (NAO) index was high, the annual air temperature average was normal for five sites around the Labrador Sea. This however, masks a warmer than normal winter (especially March) and a colder than average spring (May and July) caused by abnormal patterns in sea level pressure fields in the northern hemisphere. Ocean physical conditions in SFAs 4-6 generally exhibited cold anomalies at the surface and warm anomalies near the bottom. For example, the sea surface temperature (SST) was colder than normal in the Labrador Sea, despite warmer than normal temperatures in coastal Newfoundland and south of 47°N. The cold intermediate layer core temperature (defined as the minimum temperature within the monthly average profile) was about normal, but continues its cooling trend since about 2012. This recent cooling was preceded by a warming period that started after the cold conditions between the mid-1980's to the mid-1990's and driven by the winter North Atlantic Oscillation. The area of the shrimp bottom thermal habitat (2 to 4°C, a range typically inhabited by shrimp) within many areas of SFAs 4, 5 and 6 were above the long-term mean. For example, the area of the ocean floor occupied by water between 2 and 4°C was the second largest in NAFO divisions 2J3KLNO since 1980 (only exceeded by 2005). This suggests that thermal habitat is not currently a limiting factor for Northern Shrimp. At coastal Station 27, integrated temperature over the water column (0-176 m) was normal, but the salinity exhibited its largest negative (fresh) anomaly since the beginning of the time series in 1948.

Discussion

A participant asked for clarification if the NAO is calculated as a difference between two fixed points, or as a comparison of the minimum and maximum pressure locations. It was responded that there are a variety of ways to analyze this, but the analyses presented here used a method that compared the minimum and maximum pressure difference. This results from comparing different locations year over year.

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

Presenter: D. Belanger

Abstract

In 2018, the biomass of chlorophyll-a in the first 100 m of the water column was back above normal levels for the first time in 10 years. Positive chlorophyll-a anomalies were associated with an increase in nitrate concentration in the deeper layers (50-150 m) of the ocean in 2016-2017. However, low concentrations of deep nitrate observed across the shelf in 2018 may negatively affect chlorophyll biomass in the water column in 2019. Spring bloom indices derived from satellite data indicate that surface phytoplankton production was below the climatological average (1999-2015), with blooms occurring later than normal. Zooplankton biomass in 2018 was among the four consecutive lowest levels observed during the 1999-2018 time series, whereas abundance anomalies were among the highest in 20 years. Changes in the size-structure of the zooplankton community are driven by an overall decrease in the abundance of large, energy-rich, copepods (*Calanus finmarchicus*) concurrent with an increase in the abundance of small copepod taxa (*Pseudocalanus* spp. and *Oithona* spp.) in the fall.

Discussion

A participant asked about the relationship between nitrogen and chlorophyll-a (chl-a), and whether a lagged relationship exists between the two whereby nitrogen from one year could be used to forecast chl-a in a latter year. It was noted that while a lagged correlation exists there is variation intrinsic to the data (from sampling effort, spatial and temporal changes) and no direct relationship between the two is currently understood.

A participant asked if there may be a link between recent shifts to smaller zooplankton and larger amounts of fish in the RV survey, which may be feeding on larger zooplankton leading to lower numbers of these larger plankton species. It was clarified that the highest recent survey biomass values occurred earlier in the time series than lowest abundances of large zooplankton. It is not thought that increases in fish in the RV survey are driving observed declines in zooplankton biomass that are largely attributed to declines in the abundance of large zooplankton taxa.

A switch in zooplankton community composition from *Calanus* spp. to *Oithona* spp. was reported, and a participant asked whether this composition is expected to persist. The mechanism for the decline in *Calanus* spp. and increase in *Oithona spp*. is not understood at this time and therefore projections cannot be made on future zooplankton community composition. However it was noted that the diet of these two groups are different so there is not likely to be significant competition between the two. In addition, *Calanus* spp. may be able to take advantage of a higher abundance of the *Oithona* spp. by feeding on these smaller copepods. It was also noted that other small non-copepod zooplankton (e.g., echinoderm larvae) and earlier stages of copepods (e.g., nauplii) not represented in the presented data are also highly abundant.

A participant asked for clarification on the mesh size used in sampling the zooplankton in the present analyses. Two nets are used, a 200-micron and 70-micron net, with presented data exclusively from the larger mesh. It was noted that this gear is likely to under-sample smaller taxa and early stages of larger taxa and therefore observed increases in the abundance of small zooplankton may be more pronounced than captured in available data.

A participant asked whether the described changes in zooplankton community composition and biomass may be linked to global warming. It was noted that despite large scale ocean warming, the Northeast Coast of Newfoundland and waters off Labrador have been experiencing temperatures that are at or below climatological averages (1981-2010). Colder temperatures may be expected to lead to an increase in *Calanus finmarchicus* given their temperature preferences, but this has not been observed in this area.

It was noted that data presented on biological oceanographic conditions are collected further south (primarily collected in SFA 4, some data collected from northern portions of SFA 6) than where most of the shrimp data being considered at this assessment are from (EAZ, WAZ, SFAs 4-6), and therefore it is uncertain how trends observed in the oceanographic data reflect conditions in more northerly areas. It was noted that within the area included in the biological oceanographic sampling, anomalies tend to all be in the same direction within a year (i.e., all positive, all negative, or near-normal) so trends observed in one area may be indicative of trends at a larger spatial scale.

A participant asked what could be expected in the coming years with respect to biological oceanographic conditions and resulting productivity in this area, and whether changes are driven by melting arctic ice. It was noted that the observed low salinity in 2018 is thought to be related to high ice melt in the Arctic, as periods of record high temperatures in the Arctic have coincided with record low salinities in Newfoundland waters. Given large scale climate forcing (e.g., NAO), physical conditions are likely to be more predictable than biological conditions. It was noted that the shift observed in the zooplankton community across recent years was entirely unexpected, and the drivers of this remain unknown.

SPATIOTEMPORAL PATTERNS OF NORTHERN SHRIMP SIZE AT FIRST TRANSITION: RELATION TO DENSITY AND ENVIRONMENTAL VARIABILITY

Presenter: A. Beita-Jiménez

Abstract

Numerous stock collapses worldwide have revealed that declines in stock productivity are often preceded or accompanied by significant changes in species life history traits such as length or age at maturity. The mechanisms of changes in life history and whether these changes are reversible remains unclear for many species. Previous studies on Northern Shrimp detected a decreasing trend in length at first transition (L50) during a period of decreasing biomass. However, this stock is now experiencing a sharp decrease in biomass that can be related to changes in life history. In this study we evaluated the variation in shrimp size at sexual transition during a 20 year period encompassing both increasing and decreasing population productivity.

We evaluated:

1. if trends in shrimp size at sexual transition continued decreasing or the trend has changed and;
2. if the variation in shrimp size at sexual transition were caused by population density or temperature.

Our results show that population density seems to be the main factor affecting L50. Shrimp size at sexual transition was significantly reduced during the period of high stock density and that the current decrease in stock abundance was accompanied by an increase in size at transition. These trends are contrary to previously documented trends in size at transition of *P. borealis* in other regions during periods of low biomass. Ongoing work will help reveal the mechanisms

governing variation in Northern Shrimp life history and the relation with the population productivity.

Discussion

A participant asked whether there is evidence for a link between size and egg quality/quantity in shrimp, similar to that understood for finfish. Estimates of fecundity at size for Northern Shrimp are published from the 1980s (Parsons and Tucker 1986) which indicate higher egg quality and quantity produced by larger individuals. This may have implications for this stock given observed changes in size at maturity and lower maximum size. Samples have been collected in recent surveys and will be analysed aiming to update this relationship between fecundity and size.

NORTHERN SHRIMP LARVAL DISPERSAL WITHIN THE NORTHWEST ATLANTIC REGION

Presenter: N. Le Corre

Abstract

The results of two biophysical modeling investigations of larval dispersal and associated connectivity patterns during the pelagic larval phase (2–3 months) of Northern Shrimp (*Pandalus borealis)* provided insight into the patterns of connectivity on the Newfoundland and Labrador Shelves and throughout the Labrador Sea Basin. Simulations of Northern Shrimp larvae among Newfoundland and Labrador (NL) management areas (SFA 4-6) (Le Corre et al. 2019) demonstrated that larvae may travel several hundreds of kilometres (from North to South) prior to settlement, resulting in low retention rates and in a high degree of connectivity among SFAs. This indicates that Northern Shrimp management units in Newfoundland and Labrador Shelves should be considered as a metapopulation.

Analysis of North Atlantic biological particle-tracking model simulations aimed to provide information on large-scale larval-connectivity (NAFO areas 0 to 4) across the range of *P. borealis* adults on Greenland and Northeastern Canada shelves. Simulations showed that the highest settlement and self-settlement (retention) rates were consistently observed on the northern part of Greenland shelf and on the southern parts of the Newfoundland shelf (SFA 6 and 7), generally in areas with weaker currents. On the Canadian shelves, simulations suggested that Northern Shrimp larvae originating in the north (source: Arctic, SFA 4 and 5), with high potential settlement success, represent an important source of the potential settlers to southern populations (mostly directed towards SFA 6). The principal connectivity linkages remain consistent among simulation years, while minor larval connections demonstrate proportionally more variability. The evaluation of the impact of water temperature through different experimental larval development scenarios showed that pelagic larval duration (PLD) does not affect the main larval settlement pattern observed throughout the Labrador Sea Basin, but some areas were more sensitive to PLD variations. For example, areas 1CD and 3KL showed higher settlement densities when larvae travelling in colder and warmer waters were assigned longer and shorter PLD, respectively.

Discussion

A participant asked about extremely low retention of shrimp within certain SFAs, and whether this indicates that there would be no relationship between abundance of shrimp within an SFA and recruitment in that same area. It was clarified that the proportion of larval retention within an SFA from the model does depend on how settlement is considered within the model, though

trends are consistent. It was noted that the near 100% loss of larvae from some SFAs in the model presented at the previous assessment was likely related to low number of simulated larval releases in this SFA and the location of these being along the shelf edge in an area of relatively strong current, by comparison with the simulations from the presented large-scale model. Participants stressed the need to undertake research to groundtruth the results of this model. It was also noted that the model may underestimate retention within individual SFAs.

A participant noted that the presented models provide an estimate of the proportion of larvae that are retained within or leave a region. It was asked if complementary work is being undertaken to assess what fraction of settlers observed within a region come from different places, and the implications of this for assessment and reference points. It was confirmed that work is ongoing to address these questions.

There were questions with regard to how larval behaviour is handled in the dispersal models. It was clarified that modeled behaviour is based on published literature and includes diel vertical migrations and depth changes with age (see Le Corre et al. 2019 for full details). However it was noted that there is uncertainty in these behaviours due to a lack of research in this area, and a directed study of larval behaviour and shrimp life history could be useful in refining this modelling. The presenter mentioned that some simulation testing has been done with the models by varying dispersion parameters and while there are changes in absolute values the patterns of north to south movements and low retention have been robust to these tests.

TOWARDS NEW MODELS FOR NORTHERN SHRIMP

Presenter: E. Pedersen

Abstract

Declines in Northern Shrimp stocks, especially in SFA 6 but also more recent declines in SFAs 4 and 5, have driven requests to develop new population models for these stocks, as the current management framework is not based on a predictive population model and is unable to adapt to changing ecosystem conditions. This presentation reviewed the background of the current approach to managing this species, then discussed the two proposed shrimp population models currently in development for these stocks to address this issue. The proposed models are designed to be predictive, mechanistic, ecosystem-based, and clearly incorporate uncertainty and natural variability in population dynamics. The first model discussed was a spatial surplus production model, and the second was a spatially structured length-based population model. The presentation reviewed how different drivers would affect population dynamics in each model, and discussed how model results would be translated into suggested management rules.

Discussion

This presentation was prefaced by a statement that this initial discussion of these new models is meant to inform those at the current stock assessment about the intention of models that will be considered in detail at the upcoming Framework meeting for Northern Shrimp, and that substantive discussion on the models will be held at that time.

A participant asked if it was the intention for both models to be used going forward, or whether one or the other will be chosen as the assessment model. It was noted that this would be a decision of the upcoming Framework meeting, but that the proposal will be to go forward with both models and develop decision-making considering forecasts from both models.

A participant asked for clarification on how results from the first model considered feed into the second, and whether this leads to the output of one model being inherently linked to the other. It was noted that the only input to the second model that comes from the first is predation estimates, all other data are independent of the results of the first. The models also operate at different scales. However, many of the input datasets are common to both models. This will be further explored at the Framework meeting.

A participant asked whether data from the 1980s-early 1990s are being included in these models, and if so, how. It was clarified that data from this period are included and are used to inform on how quickly the population can grow, as well as used as a validation set to predict with given environmental and predation effects. A participant noted that much of the 1980s had been identified as a period of low abundance, but wondered what evidence is available for this period as it is prior to the start of the DFO trawl survey for shrimp in this area, and the fishery at the time was focused on new northern areas so may not be representative of the stock area. It was noted that there are four lines of evidence that led to the conclusion of the 1980s being a low abundance period:

1. Fishery CPUE data;
2. trawl data from the DFO Fall survey (prior to the Campelen period used in the assessment);
3. presence of shrimp in cod diet samples from the DFO Fall Survey, and,
4. a surplus production model that has been projected backwards.

There were questions on how these models will be used to create reference points for these stocks. This is an issue that will be considered in detail at the Framework, and substantive discussion on reference points was not held at this assessment.

REVIEW OF THE SHRIMP AGING PROJECT

Presenter: E. Pedersen

Abstract

Results from a study on estimating Northern Shrimp age-at-length were presented. Shrimp aging was conducted by Dr. Raouf Kilada, from the University of New Brunswick, and consisted of counting growth rings on shrimp eye stalks. Northern Shrimp were collected from SFA 2 and 4-7, across a range of size classes and including both male and female shrimp. Aging was conducted blind, with the aging analyst not knowing the length, sex, or origin of the eye stalk being counted, to prevent biases in the counting process. Results were presented on statistical analyses relating band counts to shrimp lengths (to infer age-at-length curves). There was evidence of a positive relationship between length and band count, but the relationship varied substantially between areas, and between life stages. Given the data, it was difficult to determine the sources of the error, and the magnitude of variability meant that the inferred length-at-age curve would not be directly useful for estimating age distributions of shrimp from field samples. However, the estimated growth curve parameters will be used as prior parameter estimates in the proposed shrimp population models.

Discussion

A participant asked for clarification on whether the presented age-at-length relationships could be used to back-calculate ages from recorded length frequencies. Given the large uncertainty around the relationship this is not possible from current data. Large variation in the number of bands at length may be driven in part by variation in environmental conditions experienced by

individual shrimp. It was suggested that less interconnected areas may have tighter relationships between length and band number, and that follow up studies may be useful to inform on this.

A participant expressed concern that there are two intrinsic processes happening in this aging study: how length varies with age, and how the perception of band count varies with age, and noted that these need to be disentangled to get a true understanding of length at age. It was confirmed that there is currently no mechanism with which to separate these two effects. An examination of band number at length may help to determine how often errors in the interpretation of bands is occurring (e.g., occurrence of single band counts among very large individuals), but directed studies (e.g., lab-rearing shrimp in conditions similar to the natural environment) would be the best way to do so though the feasibility of these is limited at this time. It was clarified that the length at age relationship presented here is used only as a prior within the Bayesian modelling framework, and the model will adjust from these values to reflect the data which will account for some of the uncertainty and variation that exists in the interpretation of band count vs. age.

It was noted that based on presented relationships it appears that shrimp from the south are growing slower than those in the north, which may not be expected given colder northerly temperatures. This relationship is confounded by depth preferences, and length-based depth preferences are evident in this population. In addition, density dependence may be a factor impacting growth rates among the areas and is not accounted for in these analyses. It was noted that the cold intermediate layer off Newfoundland can be colder than that off Labrador, but also clarified that most shrimp sampled were likely to have come from between 2-4°C, the preferred thermal range of *P. borealis* across this region. In addition, a sampling bias may be impacting the computed relationships as more smaller shrimp were collected in more southerly areas.

AN OVERVIEW OF DATA SOURCES UTILIZED IN THE SFA 4-6 SHRIMP ASSESSMENT

Presenter: J. Pantin

Abstract

Analyses were presented based on data from the DFO fall multispecies survey, the Northern Shrimp Research Foundation (NSRF) summer shrimp survey and from both the large and small vessel sectors, by SFAs, providing a comparison of the 2018 survey and fishing season and the previous 10 years.

The percent of completed survey sets in SFA 6 was lower in 2018 due to extensive weather delays which resulted in large portions of NAFO Division 3K being cut from the DFO fall multispecies survey. A similar percent of completed survey sets was seen in 2008 due to extensive mechanical delays. Almost all (98.4%) allocated survey sets were completed in SFA 5 in 2018, as well as by the NSRF survey in SFA 4 (96.2%). The timing and days spent fishing for the 2018 DFO fall multispecies survey and NSRF summer shrimp survey were consistent with previous years. Trends in biomass (standardized to the mean) from various commercial and non-commercial groundfish and shellfish/invertebrate species showed no consistent trend among all species in 2018 indicating there was no survey year effect in any of the SFAs in this year.

An analysis of fishery data was presented for both the large vessel and small vessel shrimp fishing sectors, by SFA. Large vessel commercial data is mainly based upon observer data while small vessel data is based on logbooks, as only a small percentage of the catch is

covered by observer trips (less than 10%). For both small vessel logbooks and large vessel observer data, the percent of the TAC accounted for by these data sources at the time of analysis was low and therefore preliminary. Maps were presented showing the fishing locations and survey set locations for both small vessel logbook data in SFA 6 and large vessel observer data in SFAs 4-6 indicating that survey sets covered the commercial fishing grounds. Seasonal fishing patterns of the small vessel sector for Northern Shrimp in SFA 6 indicates this is predominantly a summer fishery which is consistent over the past 10 years. Seasonal fishing patterns of the large vessel sector for Northern Shrimp indicates this is predominantly a spring and winter fishery, especially in recent years, in SFA 6, predominantly a year round fishery in SFA 5, and predominantly a summer and fall fishery in SFA 4. Examination of the regions of registry for the large vessel sector targeting Northern Shrimp shows the majority of the fishing tows were completed by vessels registered to the Newfoundland and Labrador (NL) region and the Maritimes and Quebec (MAR and QC) region in SFAs 4-6 over the past 10 years, with more activity by Central and Arctic (C&A) region vessels in SFA 5. Comparison of Northern Shrimp catch and effort data shows no patterns between these two variables in any of the SFAs. Seasonal fishing patterns of the large vessel sector for Striped Shrimp in SFA 4 indicates this is predominantly a summer and fall fishery. Examination of the regions of registry for the large vessel sector targeting Striped Shrimp shows the majority of the fishing tows were completed by vessels registered to the NL region and the MAR and QC region in SFA 4 over the past 10 years. Comparison of Striped Shrimp catch and effort data shows no patterns between these two variables in SFA 4.

Discussion

A comment was made that observed patterns in the proportion of fishing by month shows a reaction by the offshore fleet to ongoing changes in shrimp distribution. Observations from industry indicate that shrimp are more highly seasonal in the offshore than they have been historically.

OVERVIEW AND AN ASSESSMENT OF NORTHERN SHRIMP (*PANDALUS BOREALIS*) IN SHRIMP FISHING AREA 6 IN 2018

Presenter: K. Skanes

Abstract

The bottom trawl fishery for Northern Shrimp (*Pandalus borealis*) off the coast of Labrador began in the mid-1970s, primarily in the Hopedale and Cartwright Channels (SFA 5), expanding north to SFA 4 and south to SFA 6 through the 1980s. The fishery for Striped Shrimp (*Pandalus montagui*) began in SFA 4 in the mid-2000s but is primarily taken as by-catch during the Northern Shrimp fishery in that area.

The assessment made use of survey data from DFO Fall Multispecies bottom trawl survey, NSRF Summer shrimp survey, and from the Atlantic Zonal Monitoring Program (AZMP) along with fishery data from observer and logbook datasets and from the Canadian Atlantic Quota Report (CAQR). Together these provided information on catch rates, distribution, exploitation rate, biomass, and potential environmental drivers. There is little information on recruitment, particularly given recent research demonstrating the strong larval drift from north to south on the Newfoundland and Labrador shelf.

The status of SFA 6 Northern Shrimp resource has been of concern for several years with biomass and abundance indices declining since 2006 and low commercial catch rates for the past few years. The female SSB index was in the cautious zone of the precautionary approach

framework from 2013/14 to 2016/17 and has been in the critical zone since then. Until 2018 (no 2019 update was available at the time of the assessment), ecosystem analysis of predation and various environmental variables indicated that production was low and predation levels were high on SFA 6 Northern Shrimp.

Discussion

There were no questions or comments from participants on the presentation.

During the drafting of bullets a participant inquired about the implications of observed differences in the rates of change for fishable and female biomass from 2017 to 2018 and whether this divergence is unusual. While no single driver of this change could be identified, this divergence may be a reflection of poor incoming recruitment, an indicator of relatively more larger males within the fishable biomass, or may result from increased variability in growth rates. It was noted that there was a relatively high amount of female shrimp <17.5mm in the survey in 2018. There was no evidence that this divergence resulted from a survey effect in the 2018 survey. A table was presented showing the rates of change in the female and fishable biomass indices over the series which indicated that this pattern has been observed previously in this stock, though 2018 had the highest magnitude of difference.

AN ASSESSMENT OF NORTHERN SHRIMP (*PANDALUS BOREALIS*) IN SHRIMP FISHING AREA 5 IN 2018

Presenter: K. Skanes

Abstract

The status of the SFA 5 Northern Shrimp resource had not been of concern during previous assessments, however there is increasing concern for the resource. Biomass and abundance indices have been slowly declining, with some fluctuations in the series, since 2001. Large vessel fishing performance does not appear to reflect the same trend in survey indices. The female SSB index will enter the cautious zone of the precautionary approach framework in 2019/20. Similar ecosystem research as that of SFA 6 Northern Shrimp applies to (at minimum) the NAFO Division 2J portion of the shrimp resource.

Discussion

The exploitation rate in 2017/2018 was higher than that projected (i.e. exploitation rate index based on the TAC being taken) in the previous assessment. This was attributed to higher catches resulting from quota bridging within the fishery. It was noted that there have been large swings in bridging within the fleet in recent years. This practice is anticipated to continue as long as the stock is not in the critical zone of the PA. Projected exploitation rate for the next year assumes the TAC is taken, and not exceeded, therefore realized exploitation may be greater than the presented value if catches exceed TAC level.

AN ASSESSMENT OF NORTHERN SHRIMP (*PANDALUS BOREALIS*) AND STRIPED SHRIMP (*PANDALUS MONTAGUI)* IN SHRIMP FISHING AREA 4 IN 2018

Presenter: K. Skanes

Abstract

The status of SFA 4 Northern Shrimp, while in the healthy zone, had a high chance of the female SSB index having been in the cautious zone during the previous assessment. There is

concern for the resource at this time. Biomass and abundance indices, slowly declining since 2012, have reached the lowest levels of the survey time series and exploitation rate index was at record high levels in 2018/19. The stock had entered the cautious zone (below the half way point) of the precautionary approach framework in 2018/19 with a slight chance of being in the critical zone.

The status of SFA 4 Striped Shrimp is not of concern, however there is less information available regarding this stock than others and the species is largely caught as bycatch from the Northern Shrimp fishery in that area. Biomass and abundance indices have reached the highest levels in the survey time series and exploitation remains low. Given the strong currents in this area there is no reliable female SSB index (i.e., the female biomass index as presented does not necessarily lead to recruits in this area) and subsequently there is no precautionary approach framework in place.

Discussion

Northern Shrimp

It was asked whether biomass by strata in the survey was being examined in relation to temperature within the strata at the time of the survey, as distribution is tied to available temperatures. This has not been done for this assessment, but will be considered in the research recommendations.

The area of the Hatton Basin Closure has been removed from the survey and analysis. It was asked whether there was a high biomass in this area in the last year that it was surveyed (2017). It was noted that catch rates in the Hatton Basin area have typically been small, but excluding this area will lead to lower biomass estimates simply because a smaller area is being accounted for.

A participant asked about the higher peak in 2018 in female length frequencies relative to recent years. It was clarified that these length frequencies are by proportion, with the higher peak reflective of there being significantly more females than males in the 2018 survey, though it was noted that female biomass decreased from 2017 to 2018.

A participant asked if a proxy for MSY is available for this stock. There is not at this time.

A participant commented that the stability in large vessel commercial CPUE indices doesn't match the decline in other stock indicators. It was noted that commercial CPUE often experiences hyperstability, with decreases in stock size not reflected in catch rates until after other fishery independent indicators are already showing declines. It was also noted that there have been a couple of years of declines in the CPUE in SFA 4, though data for 2018/19 are not yet complete.

Questions were asked about the causes of the ongoing declines in survey indices. While effort is being put into examining ecosystem effects, at this time it is unknown what factor or combination of factors have been driving this decline. There was no evidence that observed declines in shrimp were resulting from a survey effect. It was noted that there is little available information on predation in this area, though stomachs were collected from finfish in 2018 and will be analyzed for a future assessment. A participant commented that the Harp seal herd swims through these SFAs annually on their migrations, but we don't have a good understanding on their diet as they move through. This SFA also sees the highest intermingling of *P. borealis* and *P. montagui* among SFAs 4-6 and it was noted that commercial harvesters have been less able to predict where each species would be during the fishery (i.e., in areas where they had historically caught only one species, they might catch only the other). It was also noted that high exploitation rates and changes in lower trophic levels (phytoplankton and

zooplankton) may be playing a role. Water temperatures may also be a factor, though it was noted that the available thermal habitat envelope was larger than usual in 2018.

It was noted by participants from industry that it would be useful to have representative(s) from the offshore fleet at these stock assessment meetings to provide insight from what is being observed in the offshore, particularly from SFA 4 where little scientific data are available relative to the amount of data collected in SFA 6.

In the absence of a model that is able to project for this stock, it was asked how to best deal with approaches for a sustainable fishery in the next year. It was noted that the declining trend has been ongoing since around 2012, but without a model with predictive capacity there is no way to forecast at this point with any confidence.

Striped Shrimp

A graph was presented which split commercial catches into directed and bycatch for Striped Shrimp, and commercial CPUE data presented for this species in SFA 4 only included sets that had been marked as directed. This distinction in the landings came from observer records, however it was unclear if the observer would have assumed if it was directed for one species or the other based on what was most abundant in the catch, or if they were directed by the vessel captain and therefore it was felt by participants that these distinctions may not be reliable or accurate.

It was commented that in the presented maps of distribution of Northern and Striped Shrimp there appeared to be a spatial separation between these two species. It was noted that this seemed unusual given the broader thermal tolerance of Striped Shrimp, and asked whether Striped Shrimp may be displacing Northern Shrimp in some areas. Data are not available from which to determine if one species may displace the other, but examining the spatial distribution of these two species (and associated predators) would be considered in the research recommendations. It was noted by a participant that Striped Shrimp are often considered by industry to move in response to changing food and/or temperature more than Northern Shrimp, therefore an examination of Striped Shrimp may provide earlier insights into changes than looking at Northern Shrimp distributions.

A bullet was proposed stating that Female SSB was unknown in this area. Participants asked for clarification on why this would be unknown. It was noted that given particularly strong currents in the area and high tidal influence, limited larval retention and high movements between areas increase uncertainty for this SFA. Participants noted that these factors are applicable to all SFAs, and uncertainties apply more to recruitment than to SSB estimations. It was agreed by the meeting to include a bullet which provided the Female SSB Index.

A bullet was proposed stating the exploitation level if the allowed bycatch level had been taken. A participant noted that this level has never been taken in this SFA so questioned the applicability of this point. It was noted that this indicated that the set bycatch level is at an acceptable amount, given that if it had been taken the exploitation level would still be within those considered appropriate for this stock within the management framework.

DRAFTING OF BULLETS AND CONCLUSIONS FOR NORTHERN AND STRIPED SHRIMP IN SFAS 4-6

A participant was asked for clarification as to why a bullet states that low zooplankton *may* impact the transfer of energy to higher trophic levels rather than *will*. It was noted that at this point there are no studies that show this direct link, but that this link is inferred. It was also noted that available data on zooplankton does not extend into SFAs 4 and 5, though trends from SFA 6 are thought to be reflective of a broader spatial scale.

Further discussion was held on potential causes of the observed declines in shrimp, and it was reiterated that cause(s) cannot be determined at this time. It was noted that temperature is not thought to be a limiting factor currently, as the area of available thermal habitat has been high in recent years. It was also noted that while an update on predation was not available at this meeting, the magnitude of observed changes in the biomass of groundfish is not likely to be sufficient to result in the observed decline in shrimp, though caution was advised about making inferences based on changes in the level of predators in an area without looking at associated diet of these predators. Participants commented that a thorough examination of all available data to help inform on the causes of these declines should be made a research recommendation.

A participant asked whether the observed change in the proportion of male to female is an indicator of impaired recruitment, and given that the presented dispersion modelling indicates that larvae in these SFAs largely originate in more northern areas, asked about current trends in *P. borealis* in the Eastern and Western Assessment zones. It was noted that currently no direct link can be made between the biomass in the WAZ/EAZ with biomass in SFA 4, and that environment and predation could also be contributing factors.

2019 ASSESSMENT OF NORTHERN SHRIMP (*PANDALUS BOREALIS*) AND STRIPED SHRIMP (*PANDALUS MONTAGUI*) IN THE EASTERN AND WESTERN ASSESSMENT ZONES (SFAS NUNAVUT, NUNAVIK AND DAVIS STRAIT)

Presenter: W. Walkusz

Abstract

The assessment includes 2018 survey biomass indices, fishery data, and fishery exploitation rate indices for Northern Shrimp (*Pandalus borealis*) and Striped Shrimp (*Pandalus montagui*) from the Eastern and Western Assessment Zones (EAZ and WAZ).

Pandalus borealis stock in the EAZ is currently in the Healthy Zone within the Integrated Fisheries Management Plan Precautionary Approach (IFMP PA) framework.

Pandalus montagui in the EAZ, over the last three years, remained in the healthy zone. Previously the resource has shown wide fluctuations year to year in the female SSB index. As a result, caution is advised when setting the TAC.

Pandalus borealis in the WAZ is currently not assessed with a PA framework. Its fishable biomass increased by 101% in 2018, putting the resource above the long-term mean.

Pandalus montagui in the WAZ is currently not assessed with a PA framework. Its fishable biomass increased by 77% in 2018, putting the resource above the long-term mean.

Discussion

Discussion was held on continuing the use of indices from previous years that include the survey points within the Hatton Basin area, where this area has now been excluded from the survey. It was concluded that there was no need to adjust these previous indices excluding the Hatton Basin area, as biomass indices with this excluded area only change by roughly 1%.

A participant asked about the biomass indices in the Resolution Island Study Area East (RISA-E), noting that catches in this area are larger than the biomass index. It was noted that RISA-E contains areas from multiple assessment zones, and that the scale of RISA is small relative to the overall Eastern Assessment Zone or SFA 2. It was also noted that the RISA area is not a closed system, with shrimp moving in and out of it. It was noted that the management of this

fishery does not deal with the RISA-E and RISA-W areas, but as the EAZ and WAZ, and encouraged future assessments of these stocks to align data analyses with the newer management boundaries.

It was noted that the TAC for Northern Shrimp in the Eastern Assessment Zone has not been taken since 1999, and is not expected to be taken going forward given the allotment of a portion of the quota for experimental fishing.

It was agreed by participants to add the percentage of change in biomass indices from 2017 to 2018 to the bullets, but commented that year-over-year changes can be associated with variability in survey indices and the perception of these changes may shift with more years of data. It was also noted that the confidence intervals on the indices from 2017 and 2018 completely overlap, so the perception of large increase from the point estimate may be an artifact of the uncertainty in the indices.

A participant commented that 2018 was the first time industry observed notable concentrations of *P*. *borealis* in the EAZ.

Discussion was held as to whether there is a scientific explanation available at this time for why *P. borealis* is increasing in the EAZ/WAZ but decreasing in SFAs 4-6. No conclusion could be made at this time. It was noted that the last two assessments of the WAZ showed particularly cold waters which may have been anticipated to favour Striped Shrimp over Northern Shrimp, but this was not observed. In 2018 there was higher inflow of warmer water into the WAZ, which would favour Northern Shrimp.

RESEARCH RECOMMENDATIONS

- Further modelling on larval dispersion by:
    1. undertaking a directed study of larval behavior and life history to better inform dispersion modelling;
    2. determine the fraction of larvae settling in a region that come from different areas, and the implication of this for assessments and reference points; and,
    3. aim to groundtruth modelling results using other data sources (e.g., genetics, survey data, size frequencies from fisheries data).
- Investigate developing a recruitment index for Northern Shrimp and examine potential stock-recruit relationships.
- Complete an aging study on Striped Shrimp.
- Continue ongoing predation studies across SFAs, and expand these into where data are currently limited. Include consideration of both finfish and seals in predation work going forward.
- Undertake research to characterize the diet of Northern and Striped Shrimp.
- Examine the spatial overlap between Northern and Striped Shrimp, and potential relationships between shrimp and finfish distributions.
- Undertake a detailed examination of factors that may help to explain the observed declines in shrimp biomass and changes in production, including, but not necessarily limited to: temperature, predation, exploitation, zooplankton dynamics, and ocean current patterns.

- Establish a working group to discuss what sampling platforms are available in the northern areas (e.g., SFAs 4-5) and what samples may be collected from these in order to address some of the knowledge gaps in these regions.
- Investigate and refine thermal habitats as they pertain to Northern and Striped Shrimp.
- Investigate the locations of commercial fishing activity in the WAZ relative to the survey area, and consider expanding the survey in the WAZ into southern Ungava Bay.
- Examine the seasonality of shrimp distributions within and across SFAs.

REFERENCES CITED

Le Corre, N., Pepin, P., Han, G., Ma, Z., and P.V.R. Snelgrove. 2019. Assessing connectivity patterns among management units of the Newfoundland and Labrador shrimp population. Fish Oceanogr. 28:183–202.

Parsons, D.G., and G.E. Tucker. 1986. Fecundity of Northern Shrimp, *Pandalus borealis* (Crustacea, Decapoda) in areas of the Northwest Atlantic. Fishery Bulletin, 84:8.

APPENDIX I – LIST OF PARTICIPANTS

Name	Affiliation
Alastair O'Reilly	Northern Coalition
Andres Beita-Jiménez	Marine Institute
Arnault LeBris	Marine Institute
Brian Burke	Nunavut Fisheries Association
Brian McNamara	Newfoundland Resources Ltd.
Brittany Beauchamp	DFO Science Nation Capital Region
Bruce Chapman	Canadian Association of Prawn Producers
Craig Taylor	Torngat Wildlife, Plants & Fisheries Secretariat
Cynthia McKenzie	DFO Science, NL Region
Darrell Mullowney	DFO Science, NL Region
Darren Sullivan	DFO Science, NL Region
David Belanger	DFO Science, NL Region
Derek Butler	Association of Seafood Producers
Derek Osborne	DFO Science, NL Region
Elizabeth Coughlan	DFO Science, NL Region
Eric Pedersen	DFO Science, NL Region
Erika Parrill	CSA NL Region
Erin Carruthers	Fish, Food and Allied Workers Union
Frankie Jean-Gagnon	Nunavik Marine Wildlife Board
Frederic Cyr	DFO Science, NL Region
Geoff Evans	DFO Science Emeritus
Jennifer Duff	DFO Communications, NL Region
Julia Pantin	DFO Science, NL Region
Katherine Skanes	DFO Science, NL Region
Keith Watts	Torngat Fish Coop. (NC)
Kevin Guest	DFO Communications, NL Region
Krista Baker	DFO Science, NL Region
Laura Wheeland	DFO Science, NL Region
Leigh Edgar	DFO Resource Management, National Capital Region
Mark Simpson	DFO Science, NL Region
Martin Henri	DFO Resource Management, NL Region
Nelson Bussey	Harvester
Nicolas Le Corre	DFO Science, NL Region
Peter Rose	Makivik Corporation
Pierre Pepin	DFO Science, NL Region
Rick Lambe	Baffin Fisheries Coalition
Rob Coombs	NunatuKavut Community Council
Roderick Pye	Harvester
Sana Zabihi-Seisson	DFO Science, NL Region
Sheila Atchison	DFO Science C&A Region
Todd Broomfield	Nunatsiavut Government
Tom Dooley	Fisheries and Land Resources, Govt NL
William Coffey	DFO Science, NL Region
Wojciech Walkusz	DFO Science C&A Region

APPENDIX II – TERMS OF REFERENCE

Terms of Reference

Northern and Striped Shrimp Assessment

Zonal Peer Review - Newfoundland and Labrador, and Central and Arctic Regions

February 12-15, 2019
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. Northern Shrimp in the Eastern and Western Assessment Zones, and Striped Shrimp (*Pandalus montagui*) in SFA 4 and the Eastern and Western Assessment Zones, is assessed on a biennial basis. In interim years, stock status updates are conducted.

The status of Northern Shrimp in SFAs 4-6 was last assessed in February 2018 (DFO 2018a). A stock status update for shrimp in the Eastern and Western Assessment Zones and for Striped Shrimp in SFA 4 was held in February 2018 (DFO 2018bc).

Fisheries Management has requested the current assessment as the basis for harvest advice for the 2019/20 fishing season.

Objectives

- Assess the status of the stock based on available indicators for Northern Shrimp in SFAs 4 to 6 (NAFO Div. 2G to 3K), as well as Striped Shrimp in SFA 4.
- Assess the status of the stock based on available indicators for Northern and Striped Shrimp in the Eastern and Western Assessment Zones.

Expected Publications

- Science Advisory Reports
- Proceedings
- Research Documents

Participation

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

References

DFO. 2018a. An Assessment of Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas 4-6 in 2017. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/018.

DFO. 2018b. Stock Status Update of Striped Shrimp (*Pandalus montagui*) in SFA 4. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/011.

DFO. 2018c. Update of Stock Status Indicators for Northern Shrimp, *Pandalus borealis,* and Striped Shrimp, *Pandalus montagui*, in the Western and Eastern Assessment Zones, February 2018. DFO Can. Sci. Advis. Sec. Resp. 2018/012.

APPENDIX III – AGENDA

Tuesday, February 12, 2019

Time	Activity	Presenter
9:00	Welcome/Opening	C. McKenzie (Chair)
-	Presentation: Overview of the physical oceanographic conditions on the NL Shelf	F. Cyr
-	Presentation: Overview of the chemical and biological oceanographic conditions on the NL Shelf	D. Belanger
-	Spatiotemporal patterns of northern shrimp size of first transition and its relation to density and environmental variability	A. Beita-Jiménez
-	Northern shrimp larval dispersal within the Northwest Atlantic region	N. Le Corre
-	Update on Model Progress and aging analysis for SFAs 4-6 Northern Shrimp	E. Pedersen
-	An overview of data sources utilized in the SFA 4-6 Shrimp Assessment	J. Pantin
-	Presentation: Assessment of SFA 6 Northern Shrimp	K. Skanes
-	Drafting of Science Advisory Report (SAR) bullets for SFA 6	All

Wednesday, February 13, 2019

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 and Striped Shrimp	K. Skanes
-	Drafting of SAR bullets for SFA 4	All

Thursday, February 14, 2019

Time	Activity	Presenter
9:00	Presentation: Assessment of Northern & Striped Shrimp in the EAZ/WAZ	W. Walkusz
-	Drafting of SAR bullets for EAZ/WAZ	All
-	Research Recommendations	All
-	Upgrading of Working Papers	All
-	Adjourn	C. McKenzie

Friday, February 15, 2019

A fourth day (February 15) 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.