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Proceedings of the Regional Peer Review of the Assessment of Divisions 2J+3KL Capelin

Meeting dates: March 11-13, 2020
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Foreword

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

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SUMMARY

The Regional Peer Review Process on the status of Capelin was held March 11-13, 2020 in St. John's, Newfoundland and Labrador (NL). The purpose was to assess the stock status of Capelin (*Mallotus villosus*) in Northwest Atlantic Fisheries Organization (NAFO) Subarea 2 and Divisions (Divs.) 3KL.

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

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

PRESENTATIONS

DEEPWATER SPAWNING

Presenter: E. Carruthers

Abstract

Many marine systems are wasp-waist, whereby energy flow to predators is funneled through one or a few forage species at the intermediate trophic level. Alterations in distribution and density patterns of these forage species can affect marine food webs in unpredictable ways. In coastal Newfoundland, a forage fish species, Capelin (*Mallotus villosus*), occupies this key trophic level. Newfoundland Capelin undergo an annual migration from offshore waters to spawn within coastal embayments. Capelin are thought to primarily spawn on beaches but can also spawn in deeper water (5–40 m). However, little is known about the spatial extent of deep-water spawning sites. The objective of this study was to collaborate with Capelin fishers to identify the number and location of deep-water spawning sites throughout the south and east coasts of Newfoundland. Data were collected from fisher interviews and boat-based sampling to locate deep-water spawning sites. Most interviewed fish harvesters (56/67) reported deep-water spawning in their area, and the majority of those (31/56) said that Capelin shifted between beach and deep-water habitats inter-annually and over a longer time period. Using information from fisher interviews, boat-based surveys in a portion of the study area (eastern Placentia Bay and southern Bonavista Bay), located seven active deep-water spawning sites in 2019. Deep-water spawning sites were confirmed by both underwater video and egg sampling. Over a broader scale, fishers' knowledge interviews also identified previously documented deep-water spawning sites in Trinity and Notre Dame Bays. The results of this study indicate that deep-water spawning sites likely occur coast-wide, with physical evidence confirming an additional seven active deep-water spawning sites in 2019, suggesting high inter-annual variability in use of these sites.

Discussion

There was a short discussion surrounding water temperature and Capelin spawning sites. Capelin move from beach spawning sites to deeper water once water temperature reaches 12ºC (Templeman 1948, Nakashima and Wheeler 2002, Crook et al. 2017). Previous research was referenced which has found that, as a result of warmer water, the spawning period is shorter on the beach compared to demersal sites. A participant mentioned that the majority of spawning they see takes place at demersal sites, and that bottom temperature appears to be the triggering factor.

DEVELOPING INDICATORS FOR BEACH QUALITY: QUANTIFYING CAPELIN EGG CONCENTRATION IN PLACENTIA AND CONCEPTION BAYS

Presenter: J. Randall

Abstract

Capelin (*Mallotus villosus*) is a key forage fish species in the Newfoundland marine ecosystem that spawns at nearshore demersal sites and along coastal beaches. Numerous variables influence beach spawning site selection including both environmental (e.g., sediment size, sea surface temperature) and biological (e.g., fish size) factors. This study examines spawning success, assessed by egg development and concentration, as a function of sediment size at 27

Capelin spawning sites in Conception and Placentia Bays in 2018 and 2019. Pebble (4–31.5 mm) was found to be the dominant particle size in both bays, ranging from 17.7–90.6% of the sediment composition. Within each bay, the average proportion of pebble and very coarse sand, the preferred substrate size for Capelin spawning (~2.0 mm), increased slightly from 2018 to 2019. Egg concentration varied greatly by site and between years, ranging from 4–681 eggs/cm^3 (Little Lawn Beach and Spout Cove) in 2018 and 14–271 eggs/cm^3 (Small Point and Jobs Cove) in 2019. Egg development also varied among sites but also reflected differences in the delay in spawning time in 2019 with the majority of eggs sampled in the more developed eyed-stage compared to the primarily early-stage eggs in 2018. This work provides a baseline for Capelin spawning site success in eastern Newfoundland and highlights the need for continuous sampling to detect inter-annual patterns among Capelin spawning beach sites.

Discussion

There was a short discussion about Capelin spawning habitat. While not always recognized from a habitat protection perspective, coarse sand as well as flat rock slabs have been identified as preferential spawning sites for Capelin in some regions. The importance of long term monitoring to identify these ecologically significant areas, which vary regionally, was emphasized. The question of whether or not this type of monitoring could be used to identify potential areas suitable for beach restoration was raised. It was discussed that while some suitable sites have been identified, others are not eligible due to anthropogenic issues such as residual infrastructure.

Another brief discussion occurred regarding the determination of egg concentration at spawning sites. A point was made that the spatial extent of the beach being used for spawning, as well as difficulty in identifying peak spawning, could influence the determined egg concentration. Additional factors such as wave action and beach orientation were also identified as being potential influencing factors. It was concluded that such variables could be accounted for, and future work could be done by stratifying samples across the beach and extrapolating for beach area.

EARLY LIFE HISTORY

Presenter: A. Tripp

Abstract

Identifying natal origin of animals is vital for understanding the relative productivity of natal sites and dispersal among sites (connectivity). Given the high dispersal potential and small size of marine fish larvae, natural tags, such as otolith trace element concentrations, are often used to identify natal origin. The natal origins of Capelin (*Mallotus villosus*) that spawn in embayments along the east and south coasts of Newfoundland are currently unknown. We investigated whether larval Capelin otolith chemistry differs spatially and temporally across these embayments. Capelin larvae were either field-reared or sampled as pre-emergent larvae from spawning beach sediments in Notre Dame Bay (2014, 2015, 2018, 2019), Trinity Bay (2018, 2019), Placentia Bay (2019), St. Mary's Bay (2019), and Witless Bay (2019). Trace element concentrations (i.e., Mg, Mn, Zn, Sr, Ba) in sagittal otoliths were quantified using Laser Ablation Inductively Coupled Plasma-Mass Spectrometry (LA ICP-MS). Larval Capelin displayed region-specific otolith chemical signatures with high classification success (70–88%), despite inter-annual variation within regions. Previous research revealed that larval Capelin also displayed spawning habitat-specific otolith chemical signatures, allowing us to distinguish between Capelin larvae reared at beach and deep-water (15–40 m) spawning habitats. We found that annual larval production was similar at a beach (9.4 per m^3) and deep-water

(14.0 per m^3) spawning site in Notre Dame Bay during 2019, suggesting that the relative contribution of these spawning habitats to Capelin recruitment may be similar at this location. These findings suggest that quantifying chemical signatures in the pre-hatch region of adult otoliths could be used to determine natal origin and, thus, quantify habitat-specific and region-specific productivity and connectivity among regions.

Discussion

There was a short discussion surrounding the identification of spawning sites via otolith microchemical analysis. Previous research has characterized differences in signatures between beach and deep water spawning sites. However, identification of the pre-hatch region in adult otoliths has proved to be a challenge. It was mentioned that identifying signatures in fish which are growing and going through physiological changes would be more difficult than identifying signatures in adults of the same age. The relative contribution of demersal versus beach spawning remains a source of uncertainty, and was identified as a key research interest.

Another brief discussion was had regarding multiple spawning events. It was noted that multiple spawning events have been known to take place at both beach and demersal sites. However, because many fish die after spawning, successive spawning events may not be the same fish spawning.

WEAVING WAYS OF KNOWING TO BETTER UNDERSTAND CHANGES IN CAPELIN SPAWNING DYNAMICS ALONG THE LABRADOR COAST

Presenter: C. Boaler

Abstract

Capelin (*Mallotus villosus*) is not only a central food source in marine systems, but also holds important subsistence and commercial value. Despite the importance of Capelin, both ecologically and economically, spawning behaviour and shifts in spatial distribution remain largely unknown to science. In recent years, there have been verbal accounts from Indigenous and local peoples of Labrador and Quebec Lower North Shore (QLNS) of inter-annual variability in spawning timing, locations, and tactics. Schools are no longer appearing in areas where Capelin traditionally spawned on beaches, or in some limited cases, have been observed spawning in deeper waters. Through knowledge-holder interviews and participatory mapping, we have documented spatial and temporal variability in Capelin spawning in Labrador and the eastern QLNS over time. Timing of Capelin spawning has shifted in the season up to four weeks later, and the duration of Capelin spawning has decreased from up to five weeks to as little as a day-or-two for a given spawning episode. Further, beach utilization has decreased dramatically, leading to community concerns related both to subsistence and commercial availability of Capelin and their piscivorous predators, as well as overall ecosystem health; this trend is especially alarming considering the lack of identified deep-water spawning grounds comparative to observations from the island portion of the NL province. Colonial regimes, such as residential schools and forced resettlement, in Indigenous communities has disrupted the continuity of Indigenous knowledge related to Capelin, as well as other species and overall understanding of local ecosystems. By including non-western scientific knowledge sources in stock assessment and management processes, we can provide a more comprehensive, holistic view of ecosystem health which, when properly applied, can lead to more robust management decisions that benefit all pillars of fisheries sustainability: economic, institutional, biological, and social. Future research will include a representation of how these changes in Capelin spawning dynamics impact community wellbeing, and a full analysis of how weaving ways of knowledge can be

effectively and respectfully implemented in decision-making-processes regarding North Atlantic fisheries.

Discussion

There was a discussion surrounding the observed decrease in Capelin beach spawning along the Labrador Coast since the late-1980s to early-1990s. It was suggested that Capelin have moved to spawn in deeper water. However, there was a lack of information regarding demersal spawning sites in Labrador. This was attributed to less active commercial Capelin fishing in Labrador compared to Newfoundland, and thus, a reduced capacity to survey Capelin spawning at depth. This brought forward the question of what it means to see Capelin, and that definitions of seeing may vary across regions. Predator abundance and predation were noted as being two indirect ways of observing Capelin presence. In addition to the observed decrease in beach spawning in Labrador, there was discussion regarding shifts in the duration and timing of Capelin spawning in Labrador from 2–3 weeks in June to 3–7 days in July, along with a variation in spawning locations year-to-year. This again brought up questions of detectability and demersal spawning in Newfoundland and Labrador, and were highlighted as research interests and put forward as research recommendations.

BEHAVIOURAL RESPONSE OF MARINE FISH AND ZOOPLANKTON EXPOSED TO ARTIFICIAL LIGHT DURING ACOUSTIC SURVEYS

Presenter: M. Geoffroy

Abstract

Almost all biological samples taken at sea during the night are sampled within an artificial light beam. Recent studies have demonstrated that normal working light from a ship may impact fish and zooplankton behaviour down to at least 200 m depth. However, the more detailed responses of marine organisms and their interactions with artificial light remain unknown, which precludes quantifying biases resulting from sampling fish and zooplankton from a lit vessel. In January 2020, during the polar night, we conducted *in situ* experiments in western Svalbard by turning lights from a research vessel on and off and deploying an acoustic probe equipped with light sources of different colours. When exposed to a white spot light from the vessel or the probe, fish initially avoided the first 120 m from the light source. Individual fish started venturing into the light field within minutes and part of the fish population reoccupied their initial distribution after two hours of continuous light exposure, but another part of the population remained deeper. Fish also avoided blue and red light, but remained closer to a red light source compared to the white light. Zooplankton exposed to white light from the vessel avoided the upper 15 m and aggregated at the periphery of the light beam, presumably to feed on smaller prey "trapped" in the light beam. At one location, fish and zooplankton abundance was >2.5-fold lower when measured from a ship cruising at 10 knots with search beams on compared to lights off. This study suggests that

1. biases in biological sampling conducted from a lit ship persist several hours after arriving on station;
2. pelagic organisms avoid high-intensity visible light; and
3. marine organisms can avoid ships during acoustic-based stock assessment surveys.

Discussion

There was a short discussion surrounding Capelin avoidance to ship light. It was noted that previous work has proposed that Capelin do not avoid ship light. Referencing past observations on acoustic surveys, it was suggested that Capelin appear to avoid the trawl rather than ship light. However, it was noted that light avoidance is a concern, as well as a point of interest for future research. Particularly, in heavy ice years when search lights are used more frequently. It was theorized that due to light attenuation in the water column, fish at the surface could be startled by the light, causing those underneath them to dive down and creating a chain reaction. If this is the reason why Capelin are typically distributed below the level of light penetration at night, it would suggest that the absence of ship light(s) may result in shallower distribution of Capelin during the night. A participant commented that other pelagic fisheries have had success drawing fish in with lighting, but that it was dependent on the type, or spectrum, of light used.

OCEAN CLIMATE IN NEWFOUNDLAND AND LABRADOR WATERS

Presenter: F. Cyr

Abstract

The Newfoundland and Labrador climate experiences important fluctuations at decadal time scales, with potential impacts on ecosystem productivity. The mid-1960s was the warmest period on record, and the early-1990s, when the Capelin stock collapsed, was the coldest, and has been linked to a regime shift in the ecosystem. The warmer than average 2000s corresponded to a modest build-up of Capelin, but it was followed by another colder period (2014–17), where declines in Capelin and other fish stocks were observed. These cold and less productive conditions on the Newfoundland and Labrador Shelf are associated with positive phases of the North Atlantic Oscillation (NAO) and changes in large-scale ocean circulation (e.g., increased Labrador Current transport).

Discussion

There was a discussion regarding whether or not oceanographic modelling could be used to project Capelin biomass in the context of stock assessments. It was noted that while this type of modelling has been done for other stocks, forecasting Capelin biomass would be uniquely challenging due to the susceptibility of lower trophic level species to changing oceanographic conditions. Additionally, given that the species being modeled is changing on a slower time scale than the environment is, there was discussion about how the length of the time series and changing the reference period from 1980–2010 to 1990–2020 may impact the analyses of oceanographic variables. It was highlighted that due to climate change there have been more dramatic oscillations in the parameters used in such modeling in recent years (e.g., temperature). This was counterpointed by the fact that the baseline will always be shifting, and that it is the relative, rather than the absolute, values which will signal changes in either a positive or negative direction. There was high interest in this research, and it was suggested it be included in the bullets. However, given that some of the research was preliminary it was decided that it would be more suitable to include in the research recommendations.

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

Presenter: D. Bélanger

Abstract

Biogeochemical oceanographic conditions on the NL Shelf and the Grand Banks in 2019 are reviewed in the context of broad-scale spatial and temporal observed since the beginning the Atlantic Zone Monitoring Program (AZMP). Spring bloom magnitude (total production) was near to below normal on the northeast Newfoundland Shelf (NAFO Div. 3K) and the northern Grand Bank (NAFO Div. 3L) in 2019, although blooms generally started earlier and lasted longer than usual. Nitrate and *chlorophyll a* inventories were near to above normal, continuing a trend that started 2–4 years ago. Total zooplankton abundance has been increasing across the NL shelf and the Grand Bank since the start of the monitoring program in 1999. Zooplankton biomass decreased during the early 2010s but has been increasing since 2015 to reach near to above-normal levels across the region in 2018. Limited data availability at the time of the assessment did not allow zooplankton abundance and biomass estimations for 2019. The abundance of large *Calanus finmarchicus* copepods has remained mostly below normal in NAFO Divs. 2J3KL since 2014, which contrasts with an increase in the abundance of small copepod taxa (*Pseudocalanus* spp., *Oithona* spp. and *Temora longicornis*) during the same period. The AZMP data indicate that zooplankton community size structure over the past ~5 years was characterized by an overall decrease in the average size of zooplanktonic organisms, along with an important increase in the abundance of small copepods, especially in the fall.

Discussion

Participants discussed changes in size and species distribution of Calanoid copepods and how this relates to production availability to Capelin. It was noted that while the abundance of *C. finmarchicus* remains relatively stable year-round, abundances of *C. hyperboreus* and *C. glacialis* peak in the summer, with very low abundances in the fall and winter. A participant questioned whether changes in methods of species identification can lead to pseudo-temporal shifts in species distribution. It was clarified that given a stable biomass, changes in the energy content per biomass ratio would reduce the energy transfer to fish in terms of catchability. Future research quantifying the lipid concentrations of Calanoid species was recommended by participants.

It was highlighted that since Capelin exhibit density-dependent growth, prey availability may be a limiting factor, but to what extent remains unknown. A participant asked whether zooplankton was included in the forecast model, and it was clarified that a model formulation including the primary prey item for larval Capelin was examined, but did not perform as well as other formulations without this variable. Zooplankton prey for adult Capelin was not directly considered in the model, but the timing of ice retreat is considered a proxy for the onset of the spring bloom which is related to timing of zooplankton availability for Capelin for spring feeding. There was a recommendation that more research on zooplankton and how it relates to Capelin biomass should be conducted.

STRUCTURE, TRENDS AND ECOLOGICAL INTERACTIONS IN THE MARINE COMMUNITY OF THE NEWFOUNDLAND-LABRADOR BIOREGION

Presenters: M. Koen-Alonso/H. Munro

Abstract

Ecosystem organization is hierarchical and nested. Within the large marine ecosystem defined by the Newfoundland and Labrador bioregion, four Ecosystem Production Units (EPUs) have been delineated, the Labrador Shelf (NAFO Divs. 2GH), the Newfoundland Shelf (NAFO

Divs. 2J3K), the Grand Bank (NAFO Divs. 3LNO), and southern Newfoundland (NAFO Sub-Div. 3Ps). These EPUs coarsely define functional ecosystems, and are used as geographic boundaries for the examination of ecosystem structure, trends, ecological interactions, and ecosystem-level productivity.

Fisheries Production Potential (FPP), estimated from Ecosystem Production Potential (EPP) models for the Newfoundland Shelf and Grand Bank EPUs were used to derive an indicator for the upper boundary of sustainable aggregated catches within these EPUs. This indicator, the Total Catch Index (TCI) is calculated by functional guilds (aggregates of species based on position within the food web energy pathways), and used to evaluate if realized catches are consistent with sustainable aggregate levels. The results indicate that historical catches of the planktivore guild, where Capelin is included, were near or briefly above the TCI in the 1960s and 1970s, but catches have been consistently below TCI in recent decades. However, catches of the benthivore and piscivore guilds have been above TCIs both historically and during recent decades. These results indicate that during 1995–2018 these ecosystems have experienced fishing levels that could have eroded the functionality of the ecosystems.

The ecosystem structure of NAFO Divs. 2J3KLNO 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 appeared earlier in 3LNO, and later in 2J3K. While some improvement from the 2016–17 low levels seem to be happening, current total biomass has not yet returned to the 2010–15 level. 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.

Capelin and shrimp are important prey items for cod, Turbot, American Plaice, and redfish. The dominance of Capelin and shrimp in the diets has generally tracked their relative availability. However, declines in shrimp are often associated with increases of Capelin in the diet, and vice versa. The reductions of Capelin in the diets observed in 2017–19 seem to have prompted modest increases of shrimp in the diet despite the low shrimp availability. The reduced availability of both Capelin and shrimp 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.

The probability of Capelin in the diet of cod and Turbot can be a useful complement to evaluate the status of Capelin in 2J3KL. Models of the 3L Capelin acoustic biomass and abundance as a function of the average probability of Capelin in the stomachs of these predators, using a model structure derived from a generic predator functional response formulation, indicated that these diet signals are consistent with a rapid collapse of Capelin availability in the early-1990s, modest improvements in the late-2000s and early-2010s, and declining levels in recent years.

These changes in Capelin availability are an important driver of the Northern cod stock. The CapCod model, a simple bioenergetic-allometric model for Northern cod driven by fishing and Capelin availability, provides a good fit to the cod dynamics, while the cod natural mortality patterns derived from CapCod are consistent with the ones from the Northern cod assessment model (NCAM), indicating that availability of Capelin is an important driver of cod natural

mortality. This highlights the importance of Capelin for the rebuilding of this iconic stock, and more broadly for the rebuilding of the groundfish community.

Food consumption by the fish community was estimated using a suite of consumption models aiming at characterizing a likely consumption envelope at the ecosystem level. Results indicate that the estimated total food consumption by predatory fishes has been relatively stable in 2011-15, but has declined since.

Combining these estimates of total consumption with diet compositions allows approximating the consumption of Capelin by the fish community. Consumption on Capelin showed an increasing trend until 2015, and has decreased afterwards, while consumption of shrimp peaked in 2011. Consumption of Capelin has been larger than consumption of shrimp since 2013, but this reversed in 2019.

The ratio of the estimated Capelin consumed by the fish community and the Capelin biomass from acoustic surveys provides a relative index of predation mortality by fishes. Predation mortality on Capelin peaked in 2010, and declined afterwards despite the increasing consumption in 2010–15. Predation mortality and consumption have declined in 2017–19, with predation mortality in 2019 being the lowest in the time series.

Fishing impacts on Capelin were estimated to be around 10–20% that of fish predation in the in the 1996–2008 period, declined to ~2% by 2015, and have increased since, reaching 14% in 2019. Under these conditions, fishing impacts are relatively more likely to have an influence on stock status.

Overall, results indicate that the order of magnitude of the estimated Capelin consumption and availability are fairly consistent with each other, indicating that the 3L acoustic survey effectively measures a sizable fraction of the Capelin biomass. Capelin appears fully utilized by the ecosystem, with fishing representing a comparatively small component. However, when Capelin biomass is low, the potential impact of fishing on the stock is augmented. Under these conditions, fishing impacts are relatively more likely to have an influence on stock status, especially because fishing level does not respond to Capelin availability in the same way as predation does, and fishing occurs on the spawning component that has already survived the bulk of the ecosystem predation.

Discussion

This presentation was delivered in sections and thus there were multiple lengthy periods of discussion related to four major topics: ecosystem production modelling, ecosystem trends and structure, diet, and consumption estimates.

Ecosystem Production Modelling

Comparisons were made between the CapCod model and Ecopath/Ecosim. It was discussed that while the CapCod model shares many features with these other models, the main difference is that CapCod operates under the assumption that the ecological system is not at equilibrium. It was stated that the CapCod model also operates under the assumption that prior to the 1980s there was a fully functioning and highly productive ecosystem. Whether or not this assumption could be more representative of a productivity anomaly, rather than a baseline, was brought into question. The reasoning behind this assumption was then discussed. Prior to the 1980s, the ecosystem had been fished at relatively high levels, and the fact that those levels of catch were sustained over a relatively long period of time speaks to a system that was at least capable of substantial production in order to keep up without collapsing earlier; thus, it is an optimistic assumption to say that the 1980s was a fully functioning ecosystem. It was also discussed that for the analysis, functional yields on a macroscale are obtained from a core set

of strata which have been consistently sampled over time; this type of overarching analysis of production potential provides a stability that is able to account for circumstances such as in 2019 when the Research Vessel (RV) survey was not fully completed in 2J and 3K.

Ecosystem Trends and Structure

A participant inquired to what extent having a limited understanding of the local biomasses of mackerel and herring, marine mammals (i.e., seals and cetaceans), and squid would have on the models. A point was made that because mackerel and herring tend to be more closely associated with coastal ecosystems in Newfoundland waters compared to other regions, the estimate of how much biomass was missing from these two groups was not expected to change the understanding on the scale of these analyses. This raised the question of what role seasonality plays in our understanding of these species' distributions, which was then highlighted as being a knowledge gap. For cetaceans and marine mammals, it was discussed that while data on their biomass do exist from aerial surveys, information is lacking with regards to a time series of their distribution as well as their consumption on a spatial scale.

Diet

Recent research has linked decreased fecundity and increased abortion rates in seals to a decreased availability of Capelin (Stenson et al. 2016). This led to the question: to what extent are seals being looked at as a predator of Capelin? It was discussed that while predation of Capelin by seals is taken into account, information on the offshore diet of seals is lacking due to the limited ability to collect offshore seal stomachs. Therefore, statistical modelling is used to quantify such estimates. Another unrelated discussion was had regarding an observation that Capelin were largely absent from predator diets, namely Turbot, between 1976–77 where otherwise in the time series it was relatively consistent. It was speculated that this could be due to a number of variables such as changes in distribution, poor productivity due to the environmental conditions, and/or heavy fishing activity.

Consumption Estimates

Analyses suggest that Capelin predation has decreased as a consequence of reduced Capelin availability. It was discussed that while removals of Capelin from fishing are low compared to removals of consumption by the ecosystem, analyses show that at a low stock size there is an increased potential for the fishery to impact the stock. However, the relative impact of fishing compared to consumption, in terms of both Capelin availability and ecosystem dynamics as a whole, remains unknown. It was noted that the fishery takes place just before spawning, resulting in not only the removal of Capelin biomass but the removal of potential biomass as well. However, how much potential biomass is lost due to the fishery remains unknown. It was also noted that the proportion of Capelin removed from the fishery versus via predation throughout the duration of the fishery remains unknown, adding that the majority of Capelin die during spawning, discontinuing the biomass regardless.

FISHERY LANDING AND BIOLOGICAL DATA

Presenter: F. Mowbray

Abstract

Not provided.

Discussion

Following the presentation, a participant noted that in 2019 there appeared to be larger Capelin in 3K than 3L, and that every year the Capelin seem to be relatively smaller in the south compared to northern distributions, adding that spawning seems to be getting deeper in offshore sites. It was concurred that generally, what was seen last season in the landings was similar to the observations of the harvesters.

SPAWNING AND LARVAL INDEX

Presenter: H. Murphy

Abstract

Year-class strength and recruitment of Capelin is related to survival of the early life stages. Consequently, data on spawning timing and larval abundance are collected annually. Capelin spawning data is collected from two sources: reference beaches in both Conception Bay (Bryant's Cove; 1978–2019) and Trinity Bay (Bellevue Beach; 1990–2019); and a spawning diary network along the southern and northeastern coasts of the island of Newfoundland. Capelin beach spawning has been persistently up to a month later since the collapse in the Capelin population in the early-1990s which may result in a mismatch between ideal environmental conditions and larval occurrence. In 2019, peak beach spawning was July 14 on the northeast coast, which was a few days later than 2018 (July 11) and was considered average for the post-collapse period. There was similar peak beach spawning timing in Div. 3L and Div. 3K with spawning along the southern coast a few days earlier. The Bellevue beach larval index is collected each summer from the start to the end of larval emergence. The larval index is used in the Capelin forecast model as recruitment is positively related to the Bellevue larval abundance index. In 2019, the larval index was below average, suggesting 2019 will be a small year class. This is the sixth consecutive low larval abundance year.

Discussion

There was a discussion surrounding demersal spawning, regional differences in spawning patterns, factors affecting year class strength, and inshore versus offshore Capelin.

A participant mentioned that they have not seen beach spawning in roughly 20 years in their area. It was also noted that some meeting participants referred to demersal sites as being between 10–15 m while others said to have observed spawning at depths greater than 15 m. In general, demersal spawning (i.e., when and where it takes place and how much it contributes to recruitment) was highlighted as being a source of uncertainty in the assessment and was identified as being an ongoing point of interest and ongoing research was recommended.

Comparisons were made between spawning patterns around the island of Newfoundland and along the Labrador coast. Some participants noted that in Newfoundland, historically larger fish would come in to spawn first, with smaller fish spawning afterwards. However, in recent years the opposite has been observed. It was suggested that the reverse appears to be taking place in Labrador where historically, smaller fish spawned before larger fish whereas nowadays larger fish spawn before smaller fish. Furthermore, while spawning duration appears to have increased over the years in Newfoundland, the opposite has been observed in Labrador.

It was asked to what extent stock recruitment and spawning stock biomass may relate to year class strength. As was mentioned in the presentation, research completed at Bellevue Beach has found little relationship between egg density and larval emergence. In regard to spawning stock biomass and the timing of spawning, it was hypothesized that it may be the quality of

spawning stock coming to spawn rather than the timing of their spawning that has an effect on year class strength.

A question was raised about the terminology used to describe inshore versus offshore Capelin and if there are indeed stocks of Capelin which spend their full lives either near shore or offshore. A participant commented that while Capelin have always been differentiated using such terminology, whether or not they are different stocks is unknown. A series of seasonal surveys done in Trinity Bay was referenced which found that the majority of Capelin in the bay year-round were age-1 or immature age-2 Capelin, except for June to July when maturing Capelin moved into the bay to spawn. Thus, it was thought that it might not be different stocks but different levels of maturity or age composition which are seen throughout parts of the year in the inshore versus offshore areas.

MONITORING SURVEY RESULTS AND BIOLOGICAL DATA

Presenter: F. Mowbray

Abstract

The assessment of the 2J3KL Capelin (*Mallotus villosus*) stock included fisheries and ecosystem data to the fall of 2019, and the sea ice data available to March 2020. Data sources reviewed included spring 3L acoustic surveys, inshore larval surveys, multispecies bottom trawl surveys, and fishery catches. Following the collapse of this stock in the early-1990s, the spring acoustic survey abundance index declined by an order of magnitude. Coincidentally the size-at-age of younger Capelin increased and the age at maturity decreased. There have been no strong indications of recovery of the stock since. The 2019 spring acoustic abundance index was at a similar level to 2017 and was consistent with values observed during the period of lowest values during the early-2000s. Age-3 fish comprised a larger than usual portion of the spring survey abundance and fishery catches in 2019. Patterns in Capelin distribution, growth and maturation were consistent with the interpretation that the surveyed cohorts were weak (2018) to moderate (2017) in strength. Due to the high proportion of maturing age-2 fish which are not likely to survive, few age-3 spawners are expected in 2020. The larval index has indicated poor production for the last 5 years including the two cohorts entering the fishery in 2020. However fewer empty stomachs in adults suggests that feeding success has improved moderately in the last 3–4 years, which may lead to an improvement in post-larval survival. The forecast model predicts that the Capelin biomass index for the 2020 spring acoustic survey will likely decline compared to 2019, returning to low biomass levels similar to that seen in 2017.

Discussion

There was a lengthy discussion surrounding several topics including the state of the ecosystem, Capelin condition and age distribution, changes in technology, density dependent growth, survey coverage, and fullness classification of stomachs.

It was questioned whether Capelin could once again attain biomass levels observed in the late-1980s, prior to the regime shift. Participants observed that while the ecosystem is in a depressed state compared to the 1980s, it cannot be assumed that a threshold has been crossed and the ecosystem cannot return to that level of productivity; the change from a heavily shellfish dominated ecosystem to a more groundfish dominant ecosystem from the mid-2000s to the 2010s is an expected shift to see if you were going back to an ecosystem similar in function to the 1980s. However, a concurrence was reached that for the current assessment, the probability of the ecosystem returning to such levels of biomass in a short period of time would be low. Participants also discussed shifting baselines and that disparities in the reference points

used can lead to vastly different overarching statements about the current status of the ecosystem.

With regards to Capelin age distribution and condition, it was highlighted that the highest proportion of age-1 Capelin over the course of the time series was observed in 3L during the fall multi species survey in 2019. It was asked whether this observation could be the result of vertical segregation of capelin by size or age. It was discussed that data from the fall multi species survey shows a mix of size and age ranges, and that this is consistent year to year, but that northward latitudinal migration does appear to be size dependent. However, Capelin are thought to unlikely be vertically age segregated. Referencing a previous presentation, a connection was made between the consistency in trends in the condition of age-1 and 2 Capelin relative to the abundance of different size zooplankton. It was then asked how spring condition is observed and if it relates to the proportion of age-3 females in the fishery the following year. The responses were that roe percentage is strongly correlated to condition and that currently there is no research being done to look at what might be causing fluctuations in the proportion of age-3 Capelin year to year.

In reference to the upcoming introduction of a new survey vessel, it was asked how changes in technology are being considered in analyses. It was discussed that there have been numerous technological changes over the years and confidence levels have not always been consistent; thus, extrapolation techniques are already being used to account for these. However, looking at new ways to estimate the data temporally with statistical modelling based on changes in technologies over time was still suggested as a potentially worthwhile research recommendation.

With regards to density-dependent growth, it was inquired that if Capelin abundance has increased, but not returned to the levels observed in the 1980s, then why would lower growth be observed in a year? It was discussed that food availability might be an issue, but whether it is a matter of patch size or availability remains unknown. Furthermore, there has been a diversification in diet among many species which suggests that food availability is scarce. It was also suggested that it might take several consecutive years of ideal environmental conditions for the stock to rebound to levels similar to that of the pre-collapse era. A point was also made that research is lacking on interspecific competition with other forage fishes (e.g., sandlance) and predation of Capelin by seabirds.

With regards to survey coverage, it was discussed that limitations do exist because simultaneous surveys do not take place in each assessment area and thus Fisheries and Oceans Canada (DFO) Science is not able to pinpoint the total distribution of the stock at a given moment. Furthermore, as was discussed in a previous assessment, surveying more bays and further inshore into Trinity Bay remains a research interest.

With regards to fullness classification of stomachs, it was brought to attention that shifts in data could be a result of how stomach fullness is called between samplers. Furthermore, it was suggested that different prey sizes could have an effect on fullness. The importance of consistency was stressed, and it was suggested that how classifications are done between both individuals and groups be looked into.

CAPELIN FORECAST MODEL

Presenter: A. Adamack

Abstract

The Capelin forecast modeling suite was introduced at the 2018 Assessment of Capelin in 2J3KL and uses a Bayesian predictive modeling approach (Lewis et al. 2019). The objective of the forecast models is to predict the biomass index for the spring acoustic survey of the current year and provide a forecast of the biomass index for the following year. The data used in the forecast models included various combinations of the emergent larval abundance index and *Pseudocalanus* density from two years prior, the relative condition of age-1 and age-2 Capelin from the preceding fall, and the timing of sea ice retreat in the current year. Two new variables, proportion of age-2 capelin maturing, and biomass of immature age-2 capelin, were investigated as potential additions to the forecast model, but were not found to improve overall model fit, and were therefore not included in the analysis. For the 2020 assessment, the models were fit using data collected through to the completion of the 2019 spring acoustic survey. The best fit model had an $R^2 = 0.68$ and was used to forecast the Capelin biomass index for spring 2020, using the 2018 larval index, the 2019 fall condition index for adult Capelin, and the timing of sea ice retreat in spring 2020, as of March 3. The best fit forecast model predicts that the spring acoustic capelin biomass index for 2020 is likely to decline relative to the 2019 biomass index to levels roughly on par with the 2017 biomass index. The forecast is not expected to be strongly affected by any potential changes in the timing of sea ice retreat due to observations after the March 3 sea ice measurements.

Discussion

There was a discussion surrounding concerns about atypical data, what the model actually represents, and the probability of an increase or decline in the acoustic spring biomass index.

It was discussed that the 2010 spring acoustic survey was suspected to have missed a lot of the Capelin; furthermore, 2010 was the earliest ice year on record for the time series. Concerns were raised about how data from 2010 might influence the model. It was discussed that these concerns had already been taken into account and that survey issues aside, the trend remains the same.

A question of clarification was asked regarding what the model actually represents and to what extent it is able to project the total stock biomass. It was discussed that the model represents the acoustic spring survey biomass index and that while exactly how much of the total biomass the survey captures is unknown, the probability of Capelin being identified in predator stomachs tracks very well with the index. This suggests that the index picks up a clear trajectory of the biomass as well as the majority of the biomass.

A point was made that any value within the prediction interval for the spring acoustic biomass index in 2020 is possible, to which it was asked if it would be possible to quantify the probability of an increase or decline in the index. The probability was determined and included in the summary bullets.

REVIEWER REPORT

Presenter: Höskuldur Björnsson

The model used for prediction does not nessecarily make sense when trying to explain causally the relationships, as you would expect time of ice retreat to apply to the winter when Capelin are age 0–1. Autocorrelation of the time of ice retreat (development with time) could lead to little effect of moving the time of ice retread back or forth by one year. Looking at the figure in the draft working paper of the positive effect of early spawning, it could be a proxy for something

else reducing with time, but spawning has been delayed with time. Figure 4 in Lewis et al. (2019) demonstrates well how large the effect of t_{ice} is.

The prediction model uses condition of adult Capelin in the autumn as a factor. This in principle does not apply to the same cohort that the larvae index applies to, but is probably some measure of feeding conditions the year before that might also apply to age-1 Capelin. In summary, the model has two factors (t_{ice} and autumn condition) that could in principle be called mortality proxies.

Larval abundance has often been considered as a measure of the spawning stock producing them rather than the offspring of the spawning stock, but can apply to both if a spawning stock – recruitment relationship exists.

Increased proportion mature of age-2 Capelin is a concern in the predictions if mature age-2 fish are behaving differently from other mature Capelin and observed in the spring acoustic survey. Also, modelling based on stomach samples from cod and turbot indicates that the stock size in 2019 is smaller than the survey estimate.

Catch rates of this Capelin stock have usually been low and the catch has been near 20 kt in recent years. Value of Capelin products is currently high so harvesters might be willing to spend relatively high effort to catch Capelin. In 2020, Newfoundland and Labrador was the only province producing Capelin products in the north Atlantic (the preliminary quota for Iceland is for 2021). The most pessimistic picture of the stock size (stomach data) indicates that we might be in a position where catches may have to be limited.

The meeting included many interesting discussions on causes of recruitment failure, predation models, and biology of capelin in general.

RESEARCH RECOMMENDATIONS

- Relative contribution and spatial-temporal extent of demersal versus beach spawning.
- Light avoidance, especially in heavy ice years when search lights are used more frequently.
- Incorporating oceanographic conditions and modeling into the assessment.
- Quantification of lipid/caloric content of zooplankton.
- Zooplankton (abundance, distribution, species) and how these relate to Capelin biomass.
- New methods for temporal analyses of data which take into account changes in sampling technology over time.
- Interspecific competition (e.g., forage fish) and predation (e.g., seabirds).
- Expand acoustic surveys (i.e., more bays and further inshore into Trinity Bay).
- Consistency of fullness classification of stomachs.
- Spawning time relative to fishing activity.
- Effect of spawning time versus quality of spawning stock on year class strength.
- Existence of inshore populations of Capelin in the bays of Labrador.
- Application of geostatistical estimation of the acoustic index.
- Incorporate local knowledge into research (i.e., Traditional Ecological Knowledge).
- Temporal trends of migration extent in relation to fish size.

- Representation of the stock in the 3L survey.

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Crook, K.A., Maxner, E., and Davoren, G.K. 2017. Temperature-based spawning habitat selection by capelin (*Mallotus villosus*) in Newfoundland. ICES J. Mar. Sci.74(6): 1622–1629.

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APPENDIX I: TERMS OF REFRENCE

Assessment of Divisions 2J+3KL Capelin

Regional Peer Review - Newfoundland and Labrador Region

March 11-13, 2020
St. John's NL

Chairperson: Laura Wheeland

Context

Divisions 2J+3KL Capelin was last assessed in 2019 (DFO 2019).

The current assessment is requested by Fisheries Management to inform the development of management measures for the stock for the upcoming fishing season.

Objectives

Provide an index of Capelin abundance for 2020. In support of an index, the following items will be reviewed:

- Report on physical, chemical, and biological oceanographic conditions.
- Review information on historical catches up to and including the 2019 fishery.
- Analyze trends in abundance from the spring acoustic survey and larval recruitment index.
- Review behavioural information on occurrence, distribution, and spawning times.
- Analyze biological information on sizes, ages, maturities, and condition.
- Provide update from Capelin forecast model.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Participation

- Fisheries and Oceans Canada (DFO) Science and Fisheries Management
- Newfoundland and Labrador Department of Fisheries and Land Resources
- Nunatsiavut Government
- Indigenous groups
- Fishing Industry
- Academia
- Non-governmental organizations

References

DFO. 2019. Assessment of 2J3KL Capelin in 2018. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/048.

APPENDIX II: AGENDA

Chair: Laura Wheeland, DFO Science

March 11-13, 2020

Memorial Room - Northwest Atlantic Fisheries Centre
80 East White Hills Road, St. John's

Wednesday, March 11

Time	Topic	Presenter
09:00	Opening remarks, Terms of Reference and agenda	Chair
-	Presentation: Deepwater spawning	E. Carruthers
-	Presentation: Developing Indicators for Beach Quality: Quantifying Capelin Egg Concentration in Placentia and Conception Bays	J. Randall
-	Presentation: Early life history	A. Tripp
-	Presentation: Weaving ways of knowing to better understand changes in Capelin spawning dynamics along the Labrador coast	C. Boaler
-	Presentation: Behavioral response of marine fish and zooplankton exposed to artificial light during acoustic surveys	M. Geoffroy
-	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
12:00	LUNCH	
-	Presentation: Structure, trends and ecological interactions in the marine community of the Newfoundland-Labrador bioregion	M. Koen-Alonso/H. Munro
-	Presentation: Fishery • Landings • Biological data (catch)	F. Mowbray
-	Presentation: Spawning and larval index	H. Murphy
-	Presentation: Monitoring survey results and biological characteristics	F. Mowbray

Thursday, March 12

Time	Topic	Presenter
9:00	Presentation: Capelin forecast model	A. Adamack
-	Reviewer Reports	G. Davoren & H. Björnsson
-	Summary and Conclusions	ALL
-	LUNCH	
-	Drafting of Science Advisory Report (SAR) Summary Bullets	ALL
-	Drafting of Research Recommendations	ALL
-	Upgrading of working paper to Research Document	ALL
-	ADJOURN	

***Friday, March 13**

March 13 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.
- 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.

APPENDIX III: LIST OF PARTICIPANTS

NAME	AFFILIATION
Erika Parrill	DFO-NL – Centre for Science Advice
Laura Wheeland	DFO-NL – Science
Erin Dunne	DFO-NL – Resource Management
Aaron Adamack	DFO-NL – Science
Andrew Cuff	DFO-NL – Science
Christina Bourne	DFO-NL – Science
David Bélanger	DFO-NL – Science
Fran Mowbray	DFO-NL – Science
Frédéric Cyr	DFO-NL – Science
Hannah Munro	DFO-NL – Science
Hannah Murphy	DFO-NL – Science
Hannah Polaczek	DFO-NL – Science
Karen Dwyer	DFO-NL – Science
Keith Lewis	DFO-NL – Science
Mariano Koen-Alonso	DFO-NL – Science
Meredith Terry	DFO-NL – Science
Nicolas Le Corre	DFO-NL – Science
Paul Regular	DFO-NL – Science
Paula Lundrigan	DFO-NL – Science
Nancy Pond	NL Fisheries and Land Resources
Höskuldur Björnsson	Iceland – Marine Environmental Research Institute
George Russell	Nunatukavut Community Council
Dennis Chaulk	Fish, Food and Allied Workers Union
Eldred Woodford	Fish, Food and Allied Workers Union
Erin Carruthers	Fish, Food and Allied Workers Union
Steven Miller	Fish, Food and Allied Workers Union
Chelsea Boaler	MUN – Marine Institute
Jessica Randall	MUN – Marine Institute
Jin Gao	MUN – Marine Institute
Julek Chawarski	MUN – Marine Institute
Maxime Geoffroy	MUN – Marine Institute

NAME	AFFILIATION
Tyler Eddy	MUN – Marine Institute
Ashley Tripp	University of Manitoba
Gail Davoren	University of Manitoba
Scott Morrison	University of Manitoba
Victoria Neville	World Wildlife Fund Canada