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Proceedings of the Regional Peer Review for the Stock Assessment of Northern Cod (Division 2J3KL)

Meeting dates: March 26–29, 2019
Location: St. John's, NL

Chairperson: Brian Healey
Editor: Sanaollah Zabihi-Seissan

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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

A Regional Peer Review Process for the assessment of Northern cod (*Gadus morhua*) in Northwest Atlantic Fisheries Organization (NAFO) Division 2J3KL was held in St. John's, Newfoundland and Labrador (NL) on March 26–29, 2019. The purpose of the process was to assess the status of Northern cod in NAFO Division 2J3KL in order to inform management decisions for the 2019 fishing season.

Detailed rapporteur's notes of the discussion that followed each presentation were produced. This Proceedings Report includes abstracts and summaries of meeting discussions, as well as a list of research recommendations. The meeting Terms of Reference, agenda, and list of participants are appended.

PRESENTATIONS

OVERVIEW OF THE PHYSICAL OCEANOGRAPHIC CONDITIONS ON THE NL SHELF

Presenter: F. Cyr

Abstract

Physical environment conditions for 2018 (large-scale atmospheric forcing and hydrographic response) are presented. Although the North Atlantic Oscillation (NAO) index was high, annual air temperature average was normal for five cities 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. Driven by these air temperatures, sea ice volume near Newfoundland was below normal from early March to mid-April, and close to normal for the rest of the season. The annual sea surface temperatures were colder than normal in offshore regions around Newfoundland and Labrador (NL), a tendency observed since 2015. 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-1980s to the mid-1990s and driven by the winter NAO. Bottom temperatures in 3KLNOPs (spring) and 2J3KLNO (fall) were slightly above average. At the coastal Station 27, averaged 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

It was asked what the implications are of the lower-than-normal strength of the Labrador current and inquired whether that could lead to increased heat retention in the water. The presenter explained that the Labrador current was stronger than normal as a result of increased input of fresh water into the system. Although the Labrador current strength had been decreasing for some time prior to 2016, it has increased since then.

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

Presenter: D. Bélanger

Abstract

In 2018, the biomass of chlorophyll-*a* in the first 100 m of the water column returned to above normal levels across the NL shelves for the first time since 1999. Positive chlorophyll-*a* anomalies were associated with an increase in recent years of nitrate concentration in the deeper layers (50–150 m) of the ocean. 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 in 2018 was below normal across the study region for a fourth consecutive year, with near normal conditions of bloom peak timing and duration. Zooplankton biomass remained mostly below normal 2018 despite a notable increase after three consecutive time series record lows, whereas zooplankton abundance anomalies were among the highest in 20 years. Changes in zooplankton community size-structure observed in recent years are driven by a low abundance

of large, energy-rich, copepods (*Calanus finmarchicus*) concurrent with an important increase in the abundance of small copepod taxa (*Pseudocalanus* spp. and *Oithona* spp.) in the fall. Overall, primary and secondary production indices indicate limited productivity at lower trophic levels on the NL shelves.

Discussion

A participant asked what is the difference in energy content between *Oithona* spp. and the other zooplankton species. The answer was that *Calanus finmarchicus* has the highest energy content due to its larger size and oil sack compared to *Oithona* spp. and *Pseudocalanus* spp. *Pseudocalanus* spp. is a good indicator of zooplankton abundance as it is a preferred prey species. Although there was a decrease in overall biomass, there is an increase in the abundance of smaller lower quality zooplankton such as *Oithona* spp. Participants inquired if this would have an impact on fish populations or would fish simply have to eat more smaller zooplankton. Fish would possibly need more time foraging and the shift in zooplankton timing could affect foraging fish.

A concern was raised about the abundances of zooplankton measured in the summer and fall, and if they were representative of similar areas. The presenter explained that the measurements should be representative of the shelf and that general trends from Station 27 are similar to other areas.

It was asked if match-mismatch analyses were conducted. There is usually a relationship between the timing of blooms and the presence of grazers, but the regressions currently did not show a clear trend. A factor that may blur potential trends is if bloom timings are off for *Calanus finmarchicus*, the adults may eat their young.

One of the survey boxes of the chlorophyll blooms survey overlapped with an area associated with aggregations of age 1 cod. A participant asked if that survey box saw blooms year to year, but the presenter was unsure if that was the case. A research recommendation was generated based on this observation. On the same topic, someone asked if the differences in surface temperatures in different areas affect zooplankton populations. The presenter explained that there is definitely an effect and recent trends in zooplankton populations are probably due to colder waters. Although there is no clear answer as of yet, we are seeing variations in zooplankton populations due to temperature, salinity, etc.

KEY PREY (CAPELIN)

Presenter: H. Murphy

Abstract

The annual 2J3KL Capelin (*Mallotus villosus*) stock assessment occurred March 19–20, 2019, at the Northwest Atlantic Fisheries Centre (St. John's, NL). The 2J3KL Capelin stock assessment is based on two main indices: the spring offshore acoustic survey and inshore larval index. The 2018 Capelin spring acoustic abundance index increased relative to 2017, but was still only ~25% of the post-collapse (since 1991) high in 2014. Distribution of Capelin during the spring acoustic survey in 2018 was more concentrated inshore and shifted towards the northwest portion of Northwest Atlantic Fisheries Organization (NAFO) Division 3L compared to recent years. The age structure of the Capelin stock has truncated with few age-4's and no older age classes in recent years. The condition of Capelin was above average in 2018 potentially indicating good feeding conditions and/or low abundance of Capelin. The Capelin larval abundance index has been low for five consecutive years. The larval abundance index suggests that the 2018 year class may be small. The Capelin fishery took the entire Total

Allowable Catch (TAC) in 2018 (19,823 t) with few age-4+ Capelin in the 2018 fishery samples. A forecast model which incorporates the Capelin larval abundance index, adult fall Capelin condition, and the timing of sea ice retreat predicts that the spring acoustic abundance index will increase again in 2019 but decrease in 2020. The results of the forecast model, in conjunction with the results of the spring 2018 acoustic survey and environmental data, suggest that the amount of Capelin available to the fishery in 2019 should be similar to that of 2018.

Discussion

A participant asked if the Capelin model will be able to predict future declines in the Capelin stock in Newfoundland and Labrador, and how confident we can be in the predictions. The presenter followed up by explaining that the environmental factors have many different effects on pelagic fish stocks. Although this model helps detect trends, there will always be uncertainty associated with model outputs. The main drivers of variation in the model seem to be the larval coefficient which is available two years in advance. The consensus from the discussion was that projections should be more conservative and limit data to two years.

A question was asked about if there was a relationship between spawning time and age of Capelin. Smaller fish produce fewer eggs that are potentially of lower quality. More research needs to be conducted on the implication of younger fish spawning and how that affects hatching.

Concerns were raised about the reduction of Capelin stocks in relation to northern cod. Harvesters are no longer seeing large amounts of Capelin spawning in Labrador, which could cause cod to eat smaller crabs and shrimp, in turn affecting those fisheries. The presenter acknowledged the concerns and elaborated that the Capelin seem to be contracting south. Although current research has yet to find an effect of fishing on Capelin stocks, they are an important food source for other species, and it may be beneficial to have a lower limit put in place to regulate the small fishery.

A participant inquired about the relationship between the spring acoustic survey, the model and what is available for the fishery. The response was that since the collapse of Capelin, there is a stronger relationship between the acoustic survey and spawning since more young individuals will probably be spawning the following year. This may change with the maturation of the population offshore.

OVERVIEW OF 2018 FISHERY

Presenter: J. Diamond

Abstract

Abstract not provided.

Discussion

It was pointed out during the presentation that there were no slides on catches by NAFO division. The presenter explained that it is already included in the report and that it will also be included in future presentations during CSAS meetings.

Some clarification was requested about the change in allowed gear. In terms of nets, the limit used to be 6 but it is now 12. There was an increase in the number of hooks allowed on longlines from 2,000 to 5,000. There are no limits on cod pots. There was an increase in allowed gillnets to 15 in 2018 starting on September 30. To be eligible for the 15 gillnets, harvesters would need to opt into the fall-only fishery.

OVERVIEW OF ENFORCEMENT ISSUES 2015–2018

Presenter: K. Bungay

Abstract

In 2016 and 2017, fishery officer effort for 2J3KL cod increased significantly from previous monitoring levels due to changes in the management of the fishery (i.e., longer season with weekly limits). However, fishery officer effort dropped in 2018 in line with a decrease in fishing activity. Overall violations noted in the fishery dropped in 2018 from what was recorded in the previous two years – more in line with what was noted in 2015. Recreational groundfish fishery officer effort has been holding fairly steady for the last four years, except for 2016 when Conservation and Protection (C&P) increased monitoring in one area of the NL Region. Violations in the recreational groundfish fishery (40 for 2018) are on par with previous years and correspond with the monitoring effort placed on the fishery and participation levels (weather and catch rates). At-sea observer coverage and dockside monitoring coverage noted no significant change from previous years.

Discussion

Several questions about the data collected by C&P were asked. It was noted that the range of monitoring flights during the recreational fishery span the whole range of Newfoundland and Labrador. The overall season was longer due to weekly limits which affected C&P monitoring hours. A participant asked if C&P had the enforcement data available by month, which they did.

A concern was raised about the fact that fishing pressure from the recreational fishery was not recorded directly as is the case from the commercial fishery. It was explained that the Science Advisory Report (SAR) will acknowledge that there is not enough quantitative information on recreational fishery removals. A research recommendation related to estimating recreational fishery removals was added to the proceedings.

LOGBOOK DATA

Presenter: L. Wheeland

Abstract

Catch and effort data for cod fishery is available through logbooks completed by fishers at sea, and include information on type and amounts of gear used, locations and timing of fishing activity, and weight of fish caught. Median catch rates from <35’ vessels fishing longlines (kg/hook), and gill nets (kg/net) indicated a general increase in catch rates from 2010 to 2015 in NAFO Divisions 2J and 3K, followed by a subsequent decrease, while catch rates in 3L have remained relatively steady throughout the series. Catch rates for >35’ vessels fishing gillnets in Divs. 3KL have increases since 2010. However, as catch rates reflect both stock status and changes to management plans and the subsequent fishery, it is uncertain to what degree logbook catch rates are indicative of trends in stock size.

Discussion

A concern was raised that comparing yearly fishing seasons with varying lengths could artificially skew catch rates. Years where fishing seasons extended further into the fall could have lower overall catch rates due to the later months potentially having smaller catches. A discussion resulting from this comment concluded that although true, the change in seasonality

of the fishery may not significantly impact the trends shown in Catch Per Unit Effort (CPUE). The CPUE takes into account any changes in the fishery (more nets) at different periods.

CITIZEN SCIENCE (DOCKSIDE OUTREACH OF RECREATIONAL FISHERY)

Presenter: H. Rockwood

Abstract

In recent years, removals by the recreational groundfish fishery in NL were identified as a knowledge gap for Atlantic cod stock assessment. To help rectify this, a citizen science pilot project employing high school students from coastal communities in Newfoundland was developed in 2017 to help improve understanding of these removals. In 2018, the project was renewed, and Fisheries and Oceans Canada (DFO) Science hired 27 grade 11 and 12 students with an interest in biology to work in pairs sampling in 12 communities. At the beginning of August 2018, DFO NL released the NL recreational cod fishing log that individuals could use to self-report their catch in areas where and at times when samplers were not present. At the end of the season, all data were collected and compiled into a central database. The Avalon Peninsula had the highest data collection rates because this region had the largest number of student applicants, the most centralized floating wharf systems, and the most fishers landing round or gutted catch which were easily measured. The mean lengths landed in different communities were not significantly different and the catch rates among communities were not significantly different. The average length of fish landed as well as the fishing activity generally decreased over the course of the season. Wind strength was found to have a significant impact on fishing activity. A Poisson regression model had good predictive power using weather, community population, eCapelin sightings, commercial landings, day of week, and time in season as parameters. The project continues to work toward filling a knowledge gap with regards to removals by recreational fishers, engaging communities and future scientists, and informing future efforts to quantify recreational removals.

Discussion

A participant asked what the ratio was between sampled vs. non sampled recreational fishing vessels. The presenter specified that there was less than 5% of vessels not sampled at the observed docks. Another participant inquired about the method of determining age of cod sampled. The presenter explained that they use the same weight/length ratio every year to determine catch at age of the cod. It was pointed out that the mean weight between years in communities differ, but the mean lengths are the same. The presenter explained that the weights may be skewed due to a few larger fish. A participant noted that it may also be due to fish condition.

Participants voiced that they would like to see this monitoring program continue and asked about the next steps. One participant asked if it would be possible to extrapolate the results to the entire province. This would ideally be possible, but it is still a work in progress. The presenter explained that they are hoping to add to the time series and include other organizations such as World Wildlife Fund (WWF) to help create a more reliable estimate of recreational fishery removals.

One participant asked if it would be possible to integrate this data with C&P data to get a broader estimate of the impact of the recreational fishery. Students at the docks conducting the survey ask vessels if they had been sampled by enforcement officers. The monitoring program is coordinated with C&P to ensure no overlap to avoid double counting vessels. Participants

suggested the survey could be further coordinated with C&P to ensure more coverage and corroborate numbers.

A concern was raised about the daily timing of the survey: how did the organizers know that the times when students were sampling were the times where recreational harvesters were the most active. The presenter responded that they had consulted communities ahead of time and that those times were when people were out fishing cod. Students in September were sampling after school in the afternoon and thus sampled much less frequently than when they were present on the wharf earlier in the day. The number of communities sampled each year was limited by the number of students working as part of the program. Many communities had a few students that applied but lived far from the wharfs, limiting the number of communities participating in the program. Communities that managed to participate in the program at least one year were easier to resample as students from the year before were more likely to return the second year. Recruiting new students in new communities is more difficult.

RECREATIONAL FISHERY SAMPLING

Presenter: D. Ings

Abstract

Conservation and Protection Fishery Officers sample fish lengths of cod caught during the summer recreational fishery. This information is used to construct the size and age distribution of estimated removals (using age-length keys from other sampling). Simple summaries and distributions of the length measurements over 2017–18 were provided, with a focus on aggregated values over NAFO Division and sampling location (dockside versus at sea). A total of 3,958 fish measurements were available, of which, roughly two thirds (2,519) were measured at-sea. In most instances, the size distribution was slightly smaller for fish measured at sea compared to dockside, consistent with some degree of high-grading. In particular, the data for Div. 3L in 2018 showed a pronounced difference in the size distribution, with fewer small cod in dockside samples.

Discussion

Measurements for this presentation came from Fisheries Officers encountering fishing vessels during the recreational cod fishery. A participant noticed that the sample size from the fisheries officers seemed much larger than the sample size of the student run dockside survey, and asked if both data sets could be used in conjunction to obtain a reliable estimate of recreational fishery removals. Although more data are available from the fisheries officers, sample sizes are too small to obtain a reliable estimate. Another participant suggested that since we have three or four data sources for the recreational fishery, we should be able to combine them to get a reliable estimate of the recreational cod fishery removals. A note was made to include a research recommendation on creating a framework to estimate recreational fishery removals based on these different sources of data. It was mentioned that it will be important to have a sampling framework even with all of the data and measurements from the various sources.

FISH HARVESTER QUESTIONNAIRE

Presenter: E. Carruthers

Abstract

Over 200 cod fish harvesters were contacted during the 2019 phone survey with 177 responding to the survey, with 10% of responses from 2J, and the remainder of responses split

evenly between 3K and 3L. Overall harvesters reported similar catch rates in 2018 compared with 2017. Harvesters from 3K reported both higher catch rates and excellent cod condition. 3K and 3L harvesters reported a high abundance of Capelin in 2018, whereas in 2017 most 3K harvesters reported Capelin were scarce or not present. High abundances of Squid and Mackerel were also reported for 3K in 2018. Reporting rates for low value (yellow) tags was 42% (11/26), whereas all high value (pink) tags were returned (5/5).

Discussion

A participant asked for how many years had the fish harvester questionnaire taken place. The presenter responded that it had begun in the late-1990s to early-2000s with some questions having been changed during the times series and others were left unchanged. Some during the meeting expressed an interest to see the results of the questionnaire presented along the entire time series. The presenter raised the issue that some of the data will be quite variable along the time series and will need to be thought about carefully before being interpreted. Another participant asked when the questions pertaining to tags first started, to which the presenter responded that it would have commenced in the late-1990s or early-2000s when there was a transition to the phone survey.

DISCARDS IN SHRIMP FISHERY / CATCH AND CATCH AT AGE

Presenter: B. Rogers

Abstract

Cod lengths and otoliths from the various sectors of the commercial fishery were sampled in an effort to obtain representative lengths and otoliths from each commercial area fished for each gear type and fishing period. These samples were used to determine the age composition and mean length-at-age of cod landings by gear, unit area, and quarter. Extensive additional sampling of Sentinel fishery catches is conducted by Sentinel fishers following a separate protocol. All major sectors of the fishery were sampled for lengths and sampling was generally well distributed in the inshore. Length and otolith samples, along with their associated catch, were then combined to create catch-weighted age frequencies which were then scaled up to each component of the fishery (i.e., inshore linetrawl, offshore otter trawl, etc.) and eventually scaled up to the entire fishery using total landings.

The at-sea observer (ASO) sampling program indicates a number of cod being caught in the shrimp fishery. These cod are measured as per the sampling protocol for the ASO program and length frequencies are available; however, catches are not recorded in the region catch database (ZIF). Catch can be estimated directly from logbook data but scaling the catch up to a fishery wide estimate remains problematic. The primary concerns surrounding this scaling up are issues with the minimum weight recorded (1 kg); missing catch for length frequencies; differing catchability between large and small vessels; percentage of observer coverage on different vessel classes. Better estimates of cod bycatch might be obtained through modeling of CPUE, based on effort from logbooks. Determining the quantity of small (<30 cm) cod being removed from the system as bycatch in the shrimp fishery might help clarify unexpected patterns of decline observed in Northern cod.

Discussion

It was noticed that there was a lack of age 6 cod present in the catch at age. This is slightly problematic since the 2012 year class was thought to have been large. The presenter suggested that this could be an anomaly and that we might see that age class come up in the

next few years. Some participants showed an interest in seeing error bars associated with weights at age presented during future presentations. A participant pointed out that it seemed that some strata or cells were missing from the data and wondered why that was the case and if you record these instances. It would be important to quantify the uncertainty associated with this lack of data for the stock assessment model. The presenter responded that the missing strata and cells are recorded in the catch at age program, and it is possible to recreate the analyses based on that information. The presenter agreed that more could be recorded in terms of how the integration of the data could affect the results.

A participant asked about the source of data for the cod bycatch from the shrimp fishery. The presenter explained that the data is included in the log book data although there are some issues associated with it. It could also be extracted from the observer data which are different. Even with the added grates, there are still cod bycatch in the shrimp fishery, although smaller fish. The catch proportion of cod bycatch by age is not included in the Northern Cod Assessment Model (NCAM) since some lengths do not have a frequency and could not be scaled up. A question was asked about if the bycatch data differentiates between Atlantic Cod and Arctic Cod. They would be classified as different species, however if the data simply recorded “cod”, then it would be classified as Atlantic cod by default.

There seems to be a substantial change in the percentage of gillnets sampled. The summer fishery usually has the most gillnets sampled. A participant asked if this difference was due to the fishery extending into the fall, where there is a lower sampling coverage. After discussion, participants concluded that this is possibly due to the fishery extending into the fall or possibly a trend detected by the Sentinel fishery.

Someone asked if the commercial fishery used 5.5 inch nets, to which multiple participants answered yes and also the more commonly used 6 inch nets. The use of larger mesh sizes could contribute to the increase in the age distribution of cod in the dataset.

Comparing the weight at age of commercial versus RV survey catches, it seemed that the overall patterns are similar but diverge ages 3–4. This probably in part due to gear selectivity components OT vs. GN (discard data from shrimp fishery was not included). Starting at age-7, weight at age is higher in the Research Vessel (RV) survey compared to the fishery. That could have implications for fishing mortality in the NCAM model. A participant suggested to compare the mid-year NCAM weights to the commercial data. Something that could be done in the future is to look at if weights are consistent based on season.

RV SURVEY RESULTS (INDEX TRENDS, BIOLOGICAL)

Presenter: K. Dwyer

Abstract

The Northern cod stock (NAFO Divs. 2J3KL) that inhabits waters off southern Labrador and eastern Newfoundland eastward to the edge of the continental shelf is monitored using the DFO Fall RV survey and is an important data input to the NCAM.

In 2018, the fall RV survey was carried out from September to December and there were 310 index sets (<400 m), slightly fewer than the last five years, but still thought to be representative for the cod index.

Both the abundance and biomass indices in 2018 were 551 million fish and 448 kt, up from 2017 but still only 31% of the 1980s. Increases were mainly in Divisions 2J and 3K. The numbers at age from the survey indicated that the age structure of cod in the RV survey continued to improve (increased range of ages with more young fish observed).

The distribution of fish in the offshore is usually widespread throughout the continental shelf in the fall of the year, but some years indicate that fish are more aggregated towards the edge of the shelf. There are few cod found in southern 3L. In recent years, young fish (age-1) are observed off the Northeast tip of the Island in fall, in the St. Anthony Basin, and tend to be distributed more evenly across the shelf after age-2.

Relative gutted condition improved in 2018 from 2016 and 2017 in all ages examined in Divisions 2J3KL. Low liver condition was observed in 2016 in Divisions 2J3K, but this returned to above average in 2018. Mean length and mean weight at age are generally below average in 2017 and 2018 compared to 2013–15. There was a decline in average deviation from mean weight (ages-3–7) since 2013, with the last three years being well below average. Cod are maturing at about age-5 (age at 50% maturity, A50) in 2018.

Discussion

A large amount of older cod were present in one survey tow and a participant asked if that was an anomaly. The presenter explained that there is no significant changes to the trends if that specific tow is removed or included in the data, and it was therefore included.

When referring to the average deviation of weights-at-age, another participant asked if the averages presented were updated every year or calculated from a fixed time series. It was confirmed that the averages presented were calculated from the entire time series. Since the time series is approximately 40 years, the averages will not be significantly affected by a single year. However, compounding effects may arise year after year.

NEWMAN SOUND PRE-RECRUITS

Presenter: B. Gregory

Abstract

We qualitatively assessed the relative strength of three cohorts (2016–18) of Atlantic Cod based on abundance of demersal age-0 and 1 juveniles in Newman Sound, Bonavista Bay in summer and autumn of two years (2017–18) at nearshore sites (<10 m deep) using a seine net. Our assessment was based on comparisons with abundance of Atlantic cod sampled at 6–12 sites, every two weeks from July until November, from 1995–2018. Analysis of annual length frequency and abundance data indicated that age-0 Atlantic cod settled in the nearshore in several distinct pulses, a typical pattern along the Newfoundland coast. In 2017, the first pulse of age-0 individuals settled in mid-July; subsequent pulses followed two months later and were numerically weak. In 2018, the first settlement pulse was weak and was detected in early August; similar to 2017, second and subsequent pulses also arrived two months later and were weak as well. In contrast, the 2016 and 2017 cohorts were above average abundance as age-1 fish in 2017 and 2018, respectively. Abundances at age-0 and 1 in Newman Sound in 2017 and 2018 suggest that 2016 and 2017 cohorts will be moderate to strong, relative to other cohorts in the time series. Due to low abundances of the first and subsequent settlement pulses, the 2018 cohort appears weak in comparison with others in the 23 year Newman Sound time series. Lower than average age-0 mortality rates within season were observed during each of the past three years (2016–18) compared to other years within our 23 years of monitoring. In addition, results of a companion study we conducted at eight additional coastal sites in Trinity Bay and Notre Dame Bay in 2017–18, supported our long-held view that settlement pulse structure of Atlantic Cod in Newman Sound, Bonavista Bay is typical of broad patterns by age-0 juvenile cod along the northeast Newfoundland coast. The Newman Sound age-0 and age-1 abundances (1999–2015 cohorts) are significantly correlated with the NCAM model results at age-2 and

age-3, especially between age-0 and age-2. The direction of inter-annual change of age-0 across adjacent cohorts was significantly correlated with NCAM age-2 and 3 results ~90% of years.

Discussion

A participant asked if the decrease in mortality was linked to zooplankton abundances shifting later in the fall. The presenter responded that it is possible but probably not always the case as zooplankton abundances do not always shift later in the fall and there are also spring plankton blooms. Cod spawn multiple times in the season and there could be variations in the recruitment pulses survival depending on the winter conditions. Similar to zooplankton, cod survival seems to have follow Capelin abundance as there was a low in 2010 and then an increase in 2011.

Based on the presentation, a participant asked if mild winters or late starting winters were important for pre-recruit cod. Both scenarios have been investigated and when winter starts early, fish have less time to grow. Last winter was quite cold, which could lead to a loss in 2018.

A participant asked about the source of the offshore abundance data presented and what was the deviance presented in those results. The presenter explained that they are RV data standardized catch records across years. Age of cod was extracted using an age-length key. The deviance presented in the results is that of the mean.

It was pointed out that in 2006, the pre-recruits showed up at the right time in the figures but that there seemed to be high mortality that year. The explanation given was that it was a very warm year where shallow waters were warmer than usual. During the study that year, the total pre-recruit catch for the whole season was equivalent to one days catch on a good year. The presenter elaborated that when the age-0 cod do poorly, we see the same trend with the 2–3 age cod later in the NCAM model. A participant added that the natural mortality (M) of age-0 cod is similar to that of ages-2–5 cod in 3L. M could potentially be modelled by cohort rather than size as it is possibly related to environmental factors. This was the first year where the comparison of age-0 cod with age-2–3 cod from NCAM was possible in this study.

A suggestion was given to link this pre-recruit data to the Sentinel survey. The Sentinel survey could use smaller gillnets to corroborate this data. The presenter explained that there used to be gillnetting done in the 1990s but that was discontinued for unknown reasons. Smaller gillnets were apparently more visible to fish and were therefore avoided. Researchers are not averse to trying gillnetting again. A comment was made that last year the Sentinel survey used small gillnets in the south and detected year 2 cod.

SENTINEL SURVEY

Presenter: L. Mello

Abstract

Catch rates and biological information of Atlantic cod from the Sentinel survey program in NAFO Divs. 2J3KL are updated for 2018. Temporal trends in gillnet (3¼ and 5½ inch mesh) and linetrawl unstandardized catch rates were initially similar for all gears, with relatively high values at the beginning of each time-series, followed by sharp declines in the late-1990s to early-2000s. Catch rates for small mesh gillnet and linetrawl oscillated around or below the historical mean catch rate thereafter, and increased for large mesh gillnet until 2014–15. Catch rates for all gears declined since then. Mean catch rate for small mesh gillnet was consistently higher than that of large mesh gillnet for most of the time-series.

Standardized age-disaggregated catch rate for large mesh gillnet in the Northern area was stable at low levels in 1995–2004 (mostly ≤6 year-old fish), then increased rapidly and peaked in 2015 before declining over 2016–17. The contribution of ≥7 year-old fish increased considerably since 2012. Catch rates in the Central area were higher at the beginning of the time-series (mostly 6–8 year old fish), declined rapidly to their lowest values in 2002, and then followed a pattern similar to that of the Northern area. Catch rates in the Southern area declined rapidly over 1998–2002, then remained stable at low levels. Catch rates for small mesh gillnet in Northern and Central areas indicated patterns similar to those of large mesh size gillnet. In the Southern area, catch rates declined until 2014, then increased by several folds over 2015–16. Temporal trend for linetrawl (Central area) was also similar to those of gillnets in Northern and Central areas (mostly 3–8 year old fish). Three to five year old fish were well-represented in 1995–2008, but declined thereafter. Age-aggregated catch rates showed patterns similar to those of age-disaggregated estimates in all cases.

Large mesh gillnet and linetrawl captured larger fish from specific size ranges, whereas the small mesh gillnet retaining small and large fish from multiple length-classes. Indices of physiological condition for both males and females cod (Fulton's condition factor [K], Hepatosomatic Index [HSI], and Gonadosomatic Index) varied seasonally and annually.

Total removals (control plus experimental sites, all gears combined) of Atlantic Cod caught in Divs. 2J3KL Sentinel surveys (1995–2017) peaked at 388 t in 1998, declined to 92 t in 2003, reached 270 t annually over 2012–15, and then declined to 173 t in 2017. Several fish species were recorded as Sentinel bycatch in 1995–2017: American Plaice (*Hippoglossoides platessoides*) and Winter Flounder (*Pseudopleuronectes americanus*) were the most common in large mesh gillnet.

Discussion

A participant pointed out that the line trawl sets are close to zero now, meaning there needs to be caution when comparing the different gear types (line trawl along time series or compared to other gear types). The presenter explained that the most representative data is from large gillnets and that there needs to be caution when interpreting line trawls. Another participant commented that the percentage of sets with no cod are increasing which is counterintuitive when these results are compared to the increase in cod catch rates in the RV survey data. The presenter mentioned that we are seeing more catches but then also we are seeing more sets with no cod. There is a low number of age-2 cod.

Discussions around the patterns emerging from the Sentinel survey ensued where several participants made comments. The seasonal patterns of the Sentinel data were clear, and it would be interesting to compare these patterns across years. There has been changes in the sampling procedure in terms of number of samples in each month which will have an impact on the HSI and K. It may be useful to use a relative index and include month as a factor to ensure that sampling variation is taken into account. It seemed that more samples were taken during months where body condition was lower. There might be a yearly effect underlying the seasonal patterns. A participant suggested to look at the relationship between cod condition and productivity results. Someone asked if the Sentinel survey accounts for shifts in time between years and if so how. The presenter explained that the effect of season and time is accounted for in the model as covariates. However, if there were differences within a month, that would not be taken into account.

A question was asked about how the final index was calculated and how confident we are that the Sentinel data is representative of the stock. The concern is that there may be problems in terms of how much each area contributes to the index. Each region needs to be represented in

the index. When the data is pooled, it may not represent the population as a whole (heavily weighted towards central area).

Compared to the fall RV survey, it seemed that there was a decrease in length/weight, but condition remained good. There seems to be a decline in cod condition in the Sentinel survey. A participant asked if that was due to differences in months surveyed and suggested looking at the spring RV in 3L to see if seasonal patterns are similar. The presenter explained that the estimates presented here include June to November and would therefore not see seasonal variability.

With the seeming reduction of Sentinel activity, a participant asked if that was in part due to communities no longer being surveyed, suggesting that it might be worthwhile to standardize and remove communities that are not sampled every year. It was confirmed that communities do not necessarily participate in the Sentinel survey every year. However, when the index is standardized (control for site), it still shows the same pattern of results.

As for catch rates, the last three years have seen a decrease which could be due to the presence of the commercial fishery according to a participant. There are more nets out and so that may lower the catch rates of the Sentinel fishery through a competition effect. Since we have the fishing effort for each year, we could incorporate that with the Sentinel survey to detect if the commercial fishery does have a competing effect on the survey.

A concern was raised regarding if the gear used could lead to selectivity for certain aged cod in the Sentinel survey. A few suggestions were given to account for this selectivity such as comparing results to the RV survey catch at length, tweak the annual catchability of fish by age or extract results from NCAM and bring them back into the Sentinel survey. On this subject, the presenter added that there are various sources of noise to these data and that it is important to look at them at a broad scale. Similar trends are seen between control and experimental sites which give more strength to the findings.

Looking at the spatial distribution of catch rates, participants asked if there has been any changes to the spatial distribution of catch rates offshore. The presenter responded that there seems to be more fish in the north but that it is difficult determine if that is in terms of density or actual distribution. A participant suggested to look at RV survey results to determine if the RV survey is also seeing a northward distribution shift in cod populations. The meeting was reminded that the purpose of the Sentinel survey is to survey the inshore waters. A participant asked if there has been an apparent spatial shift in Capelin populations, like cod from south to north. The presenter explained that Capelin seem to be shifting south and inshore in recent years but that is variable from year to year. A participant clarified that the Capelin first went north, then south and then contracted.

It was highlighted that it seemed that landings in Labrador have dropped, and participants were wondering if that could be partially due to competition with the commercial fishery. They noticed that larger fish were caught early in the season while they caught smaller fish with hand lines in the Fall. Harvesters are possibly seeing an increase in catch rates in the south contrary to the Sentinel survey. The presenter mentioned that there could be local variability that could explain these different results.

TAGGING OF NORTHERN COD

Presenter: G. Robertson

Abstract

An overview of the recent Northern cod tagging program was presented, with a focus on the last 12 seasons (2007–18). Over 42,000 t-bar tags have been deployed in 2J3KL since 2007, with annual numbers ranging from 1,655 to 6,540. The ratio of low reward (yellow tags - $10) and high reward tags (pink tags - $100) has been consistent at 4:1 (low to high reward) over this period. Between 2007 and 2018 tagging in 2J3KL has focused inshore, with efforts near Twillingate, Cape Bonavista, western Trinity Bay and Motion Bay occurring in most years. Timing of the tagging generally occurred between July and November, but was inconsistent across years, with tagging occurring mainly before the fishing season (July) in some years or mainly after (October) the fishing season in others. Returns of tags from fishers were relatively low, ranging from 6–8% of all high reward tags deployed. Timing of tag returns from fishers followed expected patterns, generally occurring in the fishing season, peaking in August or September. Not surprisingly, gill nets and handlines were the most common gears used to catch tagged fish. Location of tag returns generally reflected the location of tagging, including in years subsequent to tagging. Reporting rates since 2015 appears to be stable, at just under 50%. The ratio of tags returned by recreational fishers compared to commercial sources has varied annually, but has stabilized around 0.25 in recent years. Due to the consistent tagging at specific sites over the last 12 years, a Brownie tag recovery analysis was possible. Patterns in fishing and natural mortality were similar to those obtained from NCAM.

Discussion

A participant asked who conducted the 2018 tagging since it was done slightly later in the year compared to previous years. The presenter explained that most of the tagging was done by the Fish, Food and Allied Workers (FFAW; they did over half of the tags) and that the difference in tagging time is not detrimental for the estimates as it takes a long period of time to get estimates. A comment was made that it has been the same people doing the tagging consistently and so that would not contribute to the differences seen between 2018 and other years.

A question was asked about the involvement of harvesters and if they are actively made aware of the purpose and usefulness of tags. There seemed to be higher tag returns back in the 1990s. The public often contacts DFO to ask what they are supposed to do with the tags. The lack of public knowledge of the tagging program may be contributing to the decrease in return rates. A participant suggested that the return rates could be increased by reaching out to the public. Outreach to the public has been done in the past. Usually when the recreational fishery notes go out, tagging information is included. The students participating in the citizen science dockside survey would ask the public if they had tags and had the envelops necessary to collect them. Students recorded the number of tags.

It was pointed out that the length distribution of tagged cod in 2018 was very different from other years. The presenter explained that fish in 2018 were mostly tagged later in the season and other presentations showed that fish caught later in the season were smaller. This could cause the difference seen between the 2018 and remainder of the data.

A participant asked to where the fish tagged offshore had moved. For the fish tagged in 2J, they remained in the same area. The tags put out in the offshore were mostly non-transmitter tags. Eighteen out of 1,400 tagged fish were collected in 3K while the others remain unknown. As for the tags that were able to be tracked through telemetry, it seemed that most fish remained around until fall while a few remained all year round. It is important to keep in mind that not all of the telemetry data was presented because it is quite specific and not generalizable.

A participant pointed out that it seems like a disproportionate number of tags are caught with hand lines and was wondering why that was the case. The presenter explained that with gillnets, a tagged fish may not get seen compared to hand lines. The recreational fishery uses hand lines and so that would explain why we see that. Sometimes tags can also get removed when fish are ripped from the nets. Another question was posed about what the procedure was if a tag was returned by a plant worker. The presenter explained that in that case, the field is left open as fish could be from anywhere.

The northern cod tagging program has matured into a stable and consistent program that has used similar methods since 1997 and is mostly conducted at similar sites across years. This consistently allows for additional modeling approaches, including traditional Brownie methods (Brownie et al. 1985), which provides a means to examine the tagging data independent of NCAM. From these analyses, and examining the output from NCAM with the tagging data excluded, indicates that the tagging data is an important input into NCAM, and has strong influence on estimates for F and M. It is recommended that the tagging program remain consistent, with tagging at key sites, to provide the needed inputs for NCAM. Although reporting rates have declined, they appear to be still well estimated, and not an immediate concern. Although efforts to keep reporting rates as high as possible are always worthwhile, as low reporting rates lead to reduced number of tags available for analysis (and so reducing precision of the estimates). Based on ratios of tags returned from commercial and recreational sources, it appears that the recreational fishery is smaller than commercial sources in recent years, but is still a significant source of removals.

NCAM – EXPLORATIONS INTO NATURAL MORTALITY (M)

Presenter: P. Regular

Abstract

Northern cod are affected by multiple anthropogenic and ecological factors. The Northern cod assessment model attempts to account for these factors by estimating the rate at which cod are removed from the population via fishing (F) and other factors not associated with fishing (M). Estimates of M from the model are highly variable and the main factors contributing to M have yet to be determined. Common concerns include losses from the following factors: unreported fisheries removals, predation by harp seals, effects of temperature, and starvation from lack of prey.

Unreported fishery removals are potentially a large component of the 1991–94 spike in M. This aligns with a period where the combined capacity of both the domestic and foreign fleets could take a significant portion of the population (Shelton and Lilly 2000). Mis-reporting was thought to be an issue at the time as well. The models use of catch censoring and tagging data, however, may partially address this issue (Cadigan 2015). M estimates provided by the model are therefore assumed to largely represent losses of cod from natural causes. Research continues to ensure that this is a valid assumption.

Harp seals are known to consume cod and the population of seals has been increasing since the 1980s. If predation mortality is a large component of natural mortality (M), then M estimates are expected to increase as the harp seal population increases. However, contrary to expectations, there was no clear relationship between the M (ages-2+) estimates produced by the model and the population estimates of harp seals. While seals undoubtedly have an impact on cod, this and previous work indicates that the relative impacts of seals may be small in comparison to other factors such as the availability of prey (Buren et al. 2014). Impacts may be relatively minor because cod are a small portion of the diet of seals, and they primarily consume

juveniles (Hammill and Stenson 2000). Also, seals may be preying on the weakest individuals in the cod population as they are the easiest to catch. Seal predation may therefore be compensatory rather than additive because they are preying on the "doomed surplus" (Errington 1946, Boyce et al. 1999). The potential impacts of seal predation on younger fish requires further research as does the potential role of the "doomed surplus" hypothesis.

Cold temperatures may have played an important role in the decline of cod (Drinkwater 2002). Recent temperatures have been approaching those last observed through the late-1980s (Cyr et al. 2019), creating concern that climate may again limit the growth of the cod population. Potential links between core cold intermediate layer (CIL) temperature (Cyr et al. 2019) and M estimates were explored, and M was expected to increase as temperatures decreased. Results indicate a slight negative association; however, the strength and mechanistic links of the relationship requires further investigation.

Previous research has indicated that the dynamics of the Northern cod population are driven primarily by fishery removals and prey availability (Buren et al. 2014). Key prey items were evaluated using the "called" stomach data from the RV (spring 3L, fall 2J3KL) and Sentinel surveys. These data provide a course view of trends in the diet of cod as a portion of the fish caught in these surveys are sub-sampled and stomachs are visually assessed to determine primary prey content. Across the whole time series, Capelin, sand lance (*Ammodytes americanus*), Redfish (*Sebastes* spp.), cod and plaice were the most common fish prey, and shrimp, amphipods, crab, euphasiids and brittlestars were the most common invertebrate prey. Empty stomach were also common as were other categories (e.g., unknown fish, digested). Overall, Capelin and shrimp were clearly the most prevalent prey items with shrimp being more common in the fall than the spring or summer, and Capelin being more common in the summer and spring than the fall. Shrimp were also more common in the diet of younger cod (ages-2–4), and diets tended to shift towards fish as cod aged (5+). These observations echo findings from previous work (e.g., Rose and O'Driscoll 2002, Dawe et al. 2012, Krumsick and Rose 2012).

Given the importance of shrimp and Capelin to cod, it was expected that declines in the availability of shrimp and Capelin will be matched by increases in M. Explorations revealed a negative relationship between the number of Capelin available per cod against average cod mortality; however, there were no clear links between shrimp and cod. Though the prevalence of shrimp in the diet of cod may be equal to or, at times, greater than the prevalence of Capelin, this result suggests that the availability of Capelin is more important to survival than the availability of shrimp. This may be because Capelin are a critical prey item when cod are going through an energetic bottleneck before spawning in the spring. The link with shrimp may also be unclear because initial explorations focused on average natural mortality across all ages, however, the availability of shrimp may disproportionately affect younger cod. Regardless of the relative importance of shrimp or Capelin, these preliminary results imply that cod are dying of starvation. If this is the case, trends in body condition should reflect trends in average natural mortality if starvation mortality is a large component of M.

To explore potential links between body condition and natural mortality, Fulton's K was calculated using the Fall 2J3KL, Spring 3L and Sentinel survey data. Fulton's K was based on gutted weight, for a less variable assessment of condition (Dutil and Lambert 2000), and the proportion of cod with a $K < 0.65$ was considered an index of starvation mortality (Dutil and Lambert 2000, Casini et al. 2016). As expected, the greatest proportions of starving cod were observed through the critical spring period. The proportion of cod in poor condition was much lower during the fall survey and there were no clear links between the fall starvation index and M. Parallel patterns between the starvation index and M were apparent using both the spring 3L and June and July data from the Sentinel survey. Associations were strong for most of the time series; however, the starvation index and M estimates diverge to a degree in recent years. This

divergence may be related to distributional shifts as neither the spring or Sentinel surveys cover the entire range of the 2J3KL stock. Nevertheless, these results suggests that starvation mortality is a significant component of M.

In summary, preliminary explorations indicate that cod mortality tends to be lower when there are sufficient Capelin per cod. Cod mortality also tends to be lower when there are fewer fish in poor condition, especially in the spring and summer. Taken together, results suggest that if there are insufficient prey, cod starve and die. These results are in line with a growing body of research that concludes that Capelin are important for Northern cod (Rose and O'Driscoll 2002, Sherwood et al. 2007, Buren et al. 2014, Mullowney and Rose 2014). While other factors are undoubtedly at play, their effects are either unknown (unreported fishing) or unclear (seal predation). Despite noise introduced by other factors and partial snapshots of condition and Capelin availability, signals revealed here imply that starvation is a non-trivial component of M estimated by NCAM.

Discussion

Cod are not as present in 3L in recent years. The timing of the survey in spring would likely give a better indication of condition in cod relative to survival because in the fall cod are at their best condition (after the summer of feeding); however, the spring survey covers only a small portion of the total stock area. The presenter elaborated that we are seeing a shift in the center of Capelin abundance northward. Cod that stayed in 3L may have had lower conditions compared to cod that followed the Capelin north.

Participants commented that there should have been a plot showing the relationship between the proportion of Capelin in cod stomachs and the condition/starvation of cod. It seems that years with higher amounts of Capelin in cod stomachs also corresponded to years with the highest M, which is counterintuitive. The presenter elaborated on this by citing a paper by G. Lilly (1994). There were times where proportion of Capelin were high but not in the most dense aggregations of cod. The localized abundances of prey away from predators could be leading to starvation, explaining these results. The few cod that were in these locally abundant prey areas would have fewer competitors and therefore would have lower mortality rates. Another participant commented that it is important to be cautious when interpreting diet data as they are proportions and not abundances. High proportions may be due to high abundances or nothing else was eaten.

During the discussion, the topic of cod predation by seals was brought up. A participant commented that most people in rural areas think seals are affecting cod stocks and more communication is needed with these communities. It was noted that research on the impacts of seal predation on cod stocks has been shared and findings communicated with the public, but there has been a reluctance to accept the results. In early assessments, seal consumption seemed higher than cod abundance which may be caused by issues with catchability. Since seals eat more juvenile cod, it would be expected that there would be a larger effect on recruitment, but results do not support that. Including seal in the stock assessment will probably not explain a substantial amount of variation.

Harp seal reproduction crashed in the 1990s before increasing with fluctuations. A participant noted that those trends are similar to cod mortality rates, which is interesting.

It was pointed out that the current method to calculate starvation does not include cod that were starving but recovered, and participants asked if there were modelling methods that could account for that. The presenter responded that there may be, such as using fish within the 5th percentile, although not ideal. Another participant mentioned that unreported catch seem to be well accounted for in the model using important tagging data. The participant asked how this

relates to the known fishing mortality. A participant asked that there be more ecosystem level presentations next year as it has been very helpful in the past.

NCAM – UPDATE, RESULTS AND PROJECTIONS

Presenter: P. Regular

Abstract

The Northern cod assessment is based on a state-space population dynamics model (NCAM) that integrates much of the existing information about the productivity of the stock. The model integrates information from DFO RV autumn trawl surveys (1983–2018), Sentinel fishery surveys (1995–2018), inshore acoustic surveys (1995–2009), fishery catch age compositions (1983–2018), partial fishery landings (1983–2018), and tagging (1983–2017).

The abundance of Northern cod remained low for more than a decade after the collapse and moratorium in 1992, but increased in recent time. The latest assessment indicated that stock abundance (ages-2+) has increased from 233 million cod in 2005 to 954 million cod (95% CI, 564–1,614) in 2019. Recruitment (age-2) increased from lowest estimated levels of 36 million fish in 1995 to an average of 302 million in 2014–18. This recent average is 23% of the pre-collapse period of the 1980s. Total biomass (ages-2+) shows a similar trend to abundance and increased from 87 Kt in 2005 to 588 Kt (95% CI, 457–756) in 2019.

Spawning stock biomass (SSB) declined rapidly in the late-1980s and early-1990s and has remained low but shows an increasing trend in the last decade. Spawning stock biomass has increased from 26 Kt in 2005 to 398 Kt (95% CI, 306–518 Kt) in 2019. Spawning stock biomass has been well into the critical zone of the Precautionary Approach Framework since the stock collapse; the stock is currently 48% of B_{lim} in 2019 (95% CI, 37–63%). Three-year projections with catch ranging from zero to 1.3 times the model estimated catch for 2018 (14 Kt) indicated that the probability that SSB will reach the Limit Reference Point (LRP) by 2022 ranges between 6–9%. The probability of the stock in 2022 being greater than 2019 ranged from 63–73%.

Discussion

Participants asked about the current state of changes to the NCAM model and the xteNCAM model. The presenter explained that details on the inner workings of the model were discussed at the LRP meeting. Some progress has been made in terms of integrating cod tagging data in the xteNCAM model. There are talks of including spatial data going back to the 1970s but that would require more work and careful consideration. These modifications would require changes to the model structure and would possibly require a framework meeting. For now, NCAM was used to analyze the current status of cod stocks. A participant commented their opinion that it is disappointing to have to wait for a framework meeting to include historical data in the model. A suggestion was given to possibly include xteNCAM in the fall framework meeting.

When looking at the inputs, it was pointed out that the trends between 2018 and 2019 were similar. Mortality still seems to be high between the two years, but SSB decreased. It was thought that last year had a higher than usual M due to skinny fish etc. which was corroborated by harvesters as well. This year saw slightly lower mortality although still relatively high. A concern was raised that it is odd to see such large changes between years and it seems we are playing catch up with the survey. The last few years have seen a lot of variation, but it does not seem to be a substantial prior to those years. Wording on these uncertainties and variations should be included in the recommendations, keeping in mind that they may stabilize when data is added in retro-actively. A question was asked about why the relative difference was used and

not the absolute difference. The presenter answered that the literature uses relative difference because absolute difference would address the magnitude but not the bias. Another question was asked about why catchability from the RV survey remained the same at each peak in the time series. The presenter explained that there was an assumption in the model that the catchability was the same although different gear was used.

Someone asked what would have been the biological explanation for large change in catchability in the Sentinel survey. The presenter answered that it may possibly be related to the northward expansion of the stock since the coverage of 2J is possibly not great, but it is difficult to presently know. In a follow up question, participants asked if only the central area Sentinel survey data is integrated into NCAM. The answer was no, however, the central area sample size is by far the largest. This skews the results towards the trends of the central area. The Sentinel survey showed similar trends, but the magnitude differs from the RV survey (the Sentinel survey results doubled while the RV survey results increased by five times).

Another participant asked if the inertia of the model remained fixed or changed with years. The distributions may differ year to year due to factors such as prey (i.e., Capelin). In some years, there may be more or less spatial overlap with prey, which could increase growth or cause starvation. The presenter answered that the degree of inertia is time invariant (fixed). The model would be getting that information implicitly but would not know the spatial variation nor the causes. Estimating the correlation parameters would be difficult, especially using different time blocks. It was suggested to look for periods where there is the most weight gain. That time would correspond to when we should be looking for overlap between cod and their prey.

Looking at the residuals from the RV data component, a comment was made that they do not look great. The problem is that the Sentinel survey and fishery did not see recruitment while the RV survey did record some. It seems that most of these younger fish are found in the northern part of the RV survey (generally in Div. 3K). If the Sentinel survey is only representative of the inshore, modifications may be required as to how it is included in NCAM. Other suggestions were given to look at the discrepancies between RV and Sentinel survey trends such as looking at how the age specific differences could impact the residuals. If there is no recruitment detected in the survey, NCAM will most likely ignore the information since the Sentinel survey is contradictory to the findings. One suggestion was to retro-actively remove certain age classes since the NCAM model seemed to be overfitting the catch proportions by age. The presenter explained that it could be done, however age-2 cod are treated differently in the model, meaning that it should be done carefully. The standard deviation of the younger age groups could be manually increased. This would lessen the weight of younger age groups in the model. It is important to remember that catch data of age-2–3 cod are not compared between Sentinel survey, fishery and RV survey since the Sentinel survey and fishery do not catch fish of that age. One suggestion for additional data on age-2–3 cod be integrated from the shrimp by-catch. Increasing the data on age-2–3 cod would require re-evaluation of how this data is integrated into NCAM at a later date. A participant suggested running the model without the random walk to see the impact of not including the Sentinel survey. The presenter explained that the model was run without the Sentinel survey to see how the fit would change. The model simply does not have the flexibility to account for changes in age groups available to the sentinel survey as it assumes that the shape of Sentinel survey catchability is the same through time. What can change is the overall availability as the random walk can increase or decrease Sentinel survey catchability. When data from the Sentinel survey is no longer used, the conflict goes away (residual patterns improve) but we still lack an understand of *why* younger fish are falling out of the Sentinel survey but not the RV survey.

When the Sentinel survey data was removed from the NCAM model, there was a dip in the residuals in the catch proportion at age, which was problematic. The current status of the stock

increased slightly. This demonstrates that there are some consequences with the removal of the Sentinel survey data from the NCAM model. There were small differences between the retroactive analysis with and without the Sentinel survey data. Questions arose around the implementation of the Sentinel survey data. One participant asked if the effort of the Sentinel survey changes throughout the years, as the difference in timing may impact the proportion of different age groups being caught by the survey. The presenter responded that this has not been looked at yet. The bubble plots showed little changes with or without the Sentinel survey data, but could be interpreted as a slight improvement. It seemed that most of the model improved except for recruitment. A participant noted that it is important to remember that removing the Sentinel survey data from the model has more implications than simply affecting the residuals. It implies small yet potentially significant changes to catchability. It may also affect the mortality rate of older fish. Removing the Sentinel survey data from NCAM reduced the absolute level of B_{lim} to around 700,000 t. By removing catches of 2–3 year old cod, it is anticipated that it will improve the overall fit of the model.

Another exploratory modification to NCAM consisted in modifying the process around how F is estimated by separating ages-2–4 cod from older cod. By separating the age-2–4 cod, the standard deviation was higher for that younger age group. The reason we see larger variability is due to catches of ages-2–4 cod being more incidental in the fishery. This alteration flattened out residuals for catch at age. The model predicted smaller values for aged-2–4 cod, which underestimates the results from the RV survey. This modification to the NCAM model did not fix the conflict between the RV and Sentinel surveys. There are some minimal differences in F between these model predictions and those from the original NCAM model.

One last exploratory modification to NCAM was conducted where both the Sentinel survey was removed, and F was decoupled for aged-2–4 cod from the rest of the population. The fit to catch at age results were similar to the output from the model with the modified F parameter but there was an overall improvement in residuals for the RV survey. The difference between this run and the base NCAM run was that it increased the probability of reaching B_{lim} compared to the base run. With these modifications there is 0 to 0.5% probability of reaching B_{lim} compared to 0 to 0.15% with the base run. This highlights the importance of including text explaining that model structure and data has an impact on stock status. A participant noted it will be important to include risk in the text. The conflict between the data seemed to have been minimized with these alterations to NCAM. It seemed that there were less errors and residual issues were greatly reduced. A participant asked a question about the difference in stiffness of M and F, how they are allowed to vary and if they can change independently. The presenter explained that the rigidity of the parameters is informed by the data and is “self-weighing”. A change in F or M should have similar effects on the other. However, NCAM tends to want F to be smoother than M over time due to past trends. If the environment became stable and the fishery was not, this assumption in the model would become incorrect. Prior large shifts in M were considered as one off events and similar changes could be made again if similar events occur.

A participant raised a concern that these small changes to NCAM should be evaluated to see how they affect the outcome before making any conclusions. Simply comparing models with imposed smoothness may be a concern, as well as removing an important component. Removing an important component such as the Sentinel survey (i.e., inshore data) without serious examination may impact the results in unknown ways. There has not been many overwintering cod in the inshore in recent years, which is reflected in the Sentinel survey. The RV survey seems to currently better represent the entire stock. This was echoed by others who responded that the fishery is seeing more fish offshore and catching more cod using lines compared to gillnets. Another participant had a concern that the improvements resulting from the removal of the Sentinel survey data is superficial as important patterns in the population

may be ignored with the exclusion of these data. It was explained that this would be a concern if the Sentinel survey was missing a non-trivial portion of the population in the inshore and was highly variable. The presenter responded to these concerns by reminding participants that the data sources for NCAM were agreed upon prior to this meeting. The issue may not be the data sources but rather how the model is able to handle them. It's hard to know biologically why the catchability is declining in the Sentinel survey data. There may be a mismatch between the Sentinel survey data and recent cohorts of cod in the stock. Ideally, the structure of NCAM could be modified to account for the residual patterns. Removing the Sentinel survey data would not be ideal as it serves as a "second opinion" of the stock's condition. There may however be a shift in the number of fish available to the Sentinel survey. The presenter recommended keeping the Sentinel survey in NCAM to avoid the model chasing the RV survey. A participant commented that they found the Sentinel survey data important for a number of reasons. The Sentinel survey was started to gather information on the inshore stock. The competition of all the gear prior to the spreading of the fishery period may explain why there is an apparent mismatch between the Sentinel and RV surveys.

The retrospective analyses from the modified exploratory NCAM runs yielded similar results to the base NCAM run. A participant suggested to only retain cod age groups that are well caught by the Sentinel survey (only keeping 5+ aged cod). Another participant noted that they do not see a difference in the amount NCAM is being pulled in one direction by the RV survey data, with or without the modified standard deviations or removal of the Sentinel survey data. Therefore, time needs to be taken to properly weigh the consequences of making these changes to the NCAM model. The consensus was that although it seemed that NCAM fit better without the Sentinel survey data, it is difficult to determine if the model fits better or it is due to reduced variability. More time is required to look into the potential repercussions of making these types of modifications to NCAM. The base NCAM run will remain as the source for recommendations for the stock assessment, but the uncertainties associated with the experimental runs will be included in the report. A participant suggested that attempts be made to validate the Sentinel survey and improve its fit into NCAM. As it stands, none of the experimental NCAM runs have significant implications for management at this time. With a potential benchmark possibly in the fall, some answers to questions surrounding the Sentinel survey, xteNCAM, etc. may be answered.

Participants also discussed forecasting for the next one or three years. Based on the discussion, the base NCAM model will be used for the forecasting. Some participants preferred one year instead of three as the uncertainty around the predicted values was quite high by year three. Even if risk factors are included with the three year projections, readers may overlook them and focus on the predicted values which may be more inaccurate. Another reason is that it is difficult to account for the effect of Capelin stocks on the cod populations in years two to three. Others preferred three years as it was more useful for the industry and there was not an abnormally high M this year. It was also noted that three years was what was requested in the terms of reference. The consensus was to use the three year projections but to also include risk and uncertainties associated with the data and model to give full context to readers.

RESEARCH RECOMMENDATIONS

- Conduct a broad review of NCAM –including but not necessarily limited to: xteNCAM possibilities, +/- various indices, spatial considerations, catchability, small fish, and others.
- Look into relationship between chlorophyll satellite images, zooplankton and distribution of age-1 cod.
- Explore recreational fishery removals using science, C&P and citizen science.

- Look at the results from the phone survey of harvesters along the time series.
- Continue investigations into the drivers of M (space too).
- Explore spatial distribution of cod during fall RV survey & telemetry.
- Conduct a review of the Sentinel survey methodology and analyses (e.g., controls for area, year, seasonal effects, seasonal variation in sampling, spatial variation, competition between fishery and Sentinel).
- Newman Sound pre-recruit index was significantly correlated by cohort with NCAM age-2 and age-3 over the 23-year time series. Its role in the assessment needs to be further investigated and refined, given the contribution of recruitment on NCAM projection uncertainty.

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APPENDIX I – TERMS OF REFERENCE

Stock Assessment of Northern Cod (Divs. 2J3KL)
Regional Peer Review Process - Newfoundland and Labrador Region
March 26–29, 2019
St. John's, NL

Chairperson: Brian Healey, DFO Science

Context

The last stock assessment for Northern cod was completed in March 2018 (Fisheries and Oceans Canada [DFO] 2018). In January 2019, a Regional Peer Review Process was held to evaluate the Limit Reference Point (LRP) for Northern cod (DFO 2019). The peer review meeting reached a consensus that the method for determining the LRP and the reference point itself remained valid. Detailed advice on the status of the stock was requested by Fisheries Management Branch to inform recommendations to the Minister for management decisions for the 2019 fishing season.

Objectives

- Report on physical, chemical, and biological oceanographic conditions.
- Assess the current spawning stock biomass (SSB) relative to the LRP (B_{lim}), total biomass, strength of year-classes entering the exploitable population in the next 1 to 3 years, exploitation rate, fishing and natural mortality, distribution, and other relevant biological characteristics.
- Identify the major sources of uncertainty, where applicable.
- To assist in the development of the management measures for 2019, conduct three year projections of Spawning Biomass relative to the limit reference point (with 95% CIs) assuming total removals are (0.7, 0.85, 1.0, 1.15, and 1.3) times the 2018 value.
- DFO's Precautionary Approach (PA) Framework indicates there is zero tolerance for preventable decline. Identify the level of removals that provide a high probability (>95%) of continued stock growth over the medium to long term (5–10 years). If possible, provide the levels of removals that provide a 0.95 probability of 0, 25, 50 and 75% growth from the 2019 estimate of spawner biomass.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Documents

Participation

- Fisheries and Oceans Canada (DFO) Science and Fisheries Management
- Newfoundland and Labrador Department of Fisheries and Land Resources
- Industry
- Academia
- Indigenous Groups
- Non-Governmental Organizations

- Other invited experts

References

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APPENDIX II – AGENDA

Regional Peer Review Process – Stock Assessment of Northern Cod (Divs. 2J3KL)
Memorial Room
Northwest Atlantic Fisheries Centre, St. John's
March 26-29*, 2019

Chairperson: Brian Healey

Tuesday, March 26 (0900-1700)

Activity	Presenter
Opening, Terms of Reference and Introductions	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
Presentation: Key prey (capelin)	H. Murphy
Presentation: Overview of 2018 fishery	J. Diamond
Presentation: Overview of enforcement issues 2015-2018	K. Bungay
Presentation: Logbook data	L. Wheeland
Presentation: Citizen Science (dockside outreach of Recreational Fishery)	H. Rockwood
Presentation: Recreational Fisheries sampling	D. Ings
Presentation: Fish harvester questionnaire	E. Carruthers
Presentation: Discards in shrimp fishery	B. Rogers
Presentation: Catch and catch at age	B. Rogers
Presentation: RV survey results (index trends, biological)	K. Dwyer

Wednesday, March 27 (0900-1700)

Activity	Presenter
Presentation: Newman Sound pre-recruits	B. Gregory
Presentation: Sentinel Survey	L. Mello
Presentation: Tagging of Northern cod	G. Robertson

Activity	Presenter
Presentation: NCAM – explorations into Natural Mortality (M)	P. Regular
Presentation: NCAM – update, results and projections	P. Regular
Discussion on results and framework	ALL

Thursday, March 28 (0900-1700)

Activity	Presenter
Science Advisory Report Bullets	ALL
Research Recommendations	ALL
Upgrading of working papers to research documents	E. Parrill
Next steps	E. Parrill
ADJOURN	Chair

***Friday, March 29 (0900-1700)** – March 29 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:

- This agenda is fluid and may change.
- Breaks will occur at 10:30 and 2:30.
- Lunch will occur from 12:00-1:00 and is not provided. Food and beverages can be purchased from the cafeteria.

APPENDIX III – LIST OF PARTICIPANTS

Name	Affiliation
Aaron Adamack	DFO-NL – Science
Alton Rumbolt	FFAW Harvester
Basil Goodyear	FFAW Harvester
Ben Davis	DFO-NL – Science
Bob Gregory	DFO-NL – Science
Bob Rogers	DFO-NL – Science
Brian Healey	DFO-NL – Science
Chelsey Karbowski	Oceans North
Christina Bourne	DFO-NL – Science
Danny Ings	DFO-NL – Science
Darienne Lancaster	DFO-NL – Science
David Bélanger	DFO-NL – Science
Deborah Austin	DFO-NCR – Science
Devan Archibald	Oceana Canada
Divya Varkey	DFO-NL – Science
Ellen Careen	DFO-NL – Resource Management
Erika Parrill	DFO-NL – Centre for Science Advice
Erin Carruthers	Fish, Food and Allied Workers Union (FFAW)
Evelyn MacRobert	DFO-NL – Science
Frédéric Cyr	DFO-NL – Science
Garry Stenson	DFO-NL – Science
Greg Robertson	DFO-NL – Science
Hannah Murphy	DFO-NL – Science

Name	Affiliation
Heather Penney	DFO-NL – Science
Hilary Rockwood	DFO-NL – Science
James Baird	NL Groundfish Industry Development Council
Jenna Makrides	DFO-NL – Science
Jennifer Duff	DFO-NL – Communications
Joanne Morgan	DFO-NL – Science
Julie Diamond	DFO-NL – Resource Management
Karen Dwyer	DFO-NL – Science
Kate Dalley	DFO-NL – Science
Keith Lewis	DFO-NL – Science
Kerry Bungay	DFO-NL – Conservation and Protection
Kierstyn Rideout	DFO-NL – Science
Kris Vascotto	Atlantic Groundfish Council
Laura Wheeland	DFO-NL – Science
Luiz Mello	DFO-NL – Science
Noel Cadigan	Memorial University of Newfoundland – Marine Institute
Paul Regular	DFO-NL – Science
Rick Rideout	DFO-NL – Science
Rob Coombs	NunatuKavut Community Council
Sanaollah Zabihi-Seissan	DFO-NL – Science
Tom Bird	Memorial University of Newfoundland
Tom Dooley	Fisheries and Land Resources, Gov. NL
Wade Clarke	FFAW Harvester