Fisheries and Oceans Canada / Pêches et Océans Canada

Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Proceedings Series 2018/003

Newfoundland and Labrador Region

Proceedings of the Stock Assessment of Northern cod (Divisions 2J3KL)

March 21-24 and March 30-31, 2016
St. John's, NL

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Rapporteur: Emilie Novaczek

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March 2018

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.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1701-1280

Correct citation for this publication:

DFO. 2018. Proceedings of the Stock Assessment of Northern cod (Divisions 2J3KL); March 21-24 and March 30-31, 2016. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2018/003.

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SUMMARY

A regional peer review process was held to assess the status of Atlantic Cod in Northwest Atlantic Fisheries Organization (NAFO) Divisions 2J3KL (Northern cod, hereafter) and to generate detailed scientific advice on the recovery and sustainable harvest of this resource. The Northern cod stock assessment meeting was held during March 21-24 and March 30-31, 2016 at the Northwest Atlantic Fisheries Centre in St. John’s, NL. The 2016 stock assessment represents the first time the Northern cod stock has been assessed using an integrated catch-at-age model.

This meeting reviewed existing knowledge on the stock, ecosystem considerations and the results of the new Northern Cod Assessment Model (NCAM). These proceedings contain abstracts of presentations from the meeting as well as summaries of the related discussions. Also included in these proceedings are the terms of reference (Appendix 1), meeting agenda (Appendix 2), and list of participants (Appendix 3).

Compte rendu de l’évaluation du stock de morue du nord (Divisions 2J3KL)

SOMMAIRE

Un processus d’examen régional par les pairs a eu lieu afin d’évaluer l’état du stock de morue franche (la morue du Nord, ci-après) dans les divisions 2J3KL de l’Organisation des pêches de l’Atlantique Nord-Ouest (OPANO) et pour générer des avis scientifiques détaillés sur le rétablissement et la pêche durable de cette ressource. La réunion d’évaluation du stock de morue du Nord a eu lieu du 21 au 24 mars 2016 et les 30 et 31 mars 2016 au Centre des pêches de l’Atlantique nord-ouest à St. John’s, Terre-Neuve-et-Labrador. L’évaluation du stock de 2016 constitue la première évaluation du stock de morue du Nord effectuée à l’aide d’un modèle intégré de prises selon l’âge.

Cette réunion a permis d’examiner les connaissances actuelles relatives au stock, les considérations en matière d’écosystèmes et les résultats du nouveau modèle d’évaluation du stock de morue du Nord. Le présent compte rendu contient des résumés d’exposés présentés dans le cadre de la réunion ainsi que des sommaires des discussions qui ont porté sur ces sujets. Ce compte rendu comprend aussi le cadre de référence (annexe 1), l’ordre du jour de la réunion (annexe 2) et la liste des participants (annexe 3).

INTRODUCTION

The Northern cod stock comprises Atlantic Cod (*Gadus morhua*) occurring within the Northwest Atlantic Fisheries Organization (NAFO) Divisions (Divs.) 2J and 3KL. The last full assessment of this stock was conducted in March 2013 (DFO 2013). A three year assessment schedule, with updates in the intervening years, has been adopted for Northern cod assessments. Accordingly, status updates were performed in 2014 (DFO 2014) and 2015 (DFO 2015). This meeting was held to fulfill the request of Fisheries Management for a stock assessment per the 3-year schedule in order to provide the Minister with advice on the status of Northern cod for the period April 1, 2016 – March 31, 2019. A Regional Peer Review Process held in December 2015 considered 14 potential data sources and multiple models of population dynamics for the Northern cod stock (DFO 2016). Based upon the conclusions of that meeting, an updated version of the Northern Cod Assessment Model (Cadigan 2015) was presented as the main tool for the 2016 assessment. The objectives of this meeting, as outlined in the Terms of Reference (Appendix 1) are:

- Provide an ecosystem overview (e.g., physical and biological oceanography, predators, prey) for the stock. If possible, this information should be integrated into the advice.
- Provide an assessment of the current status of cod in Divs. 2J3KL using information updated to 2016.
- Assess the current spawning stock biomass (SSB) relative to the Limit Reference Point (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.
- Identify the maximum level of annual removals that will enable a 50% growth in SSB over 2016-20 years with a high probability of success (>75%).
- DFO's Precautionary Approach (PA) framework indicates there is zero tolerance for preventable decline. Identify the level of removals that provide a very high probability (>95%) of continued stock growth over 2016-2018.
- Identify indicators to follow the stock status during the years without a full stock assessment, and identify events that would trigger an earlier-than-scheduled full assessment.
- 3 year management advice is requested covering the period 1 April 2016 - 31 March 2019.

PRESENTATIONS

OVERVIEW OF THE NORTHERN COD FISHERY 2013-2015

Presented by P. Williams

Resource Management and Aboriginal Fisheries (RMAF) presented an overview of the fishery results for both the NAFO Divs. 2J3KL Northern cod Stewardship/By-catch fishery, and the region-wide recreational groundfish fishery for the 2012 to 2015 time frame. This included a review of management measures, fisher participation and landings data for the 2012 to 2015 Northern cod Stewardship/By-catch fishery Management plan.

Northern cod are commercially harvested in a stewardship and by-catch fishery. Since 2011, this fishery has been conducted over a three week season. Harvesters are restricted to their homeports (within 12 miles). The season dates vary annually, from late July to September. The total catch in 2015 was 2900 metric tonnes, taken by 1700 license holders. Monitoring is conducted dockside, and Vessel Monitoring Systems (VMS) are required for all participating vessels. The by-catch of Northern cod in other fisheries is added to the total individual fishing quota (IQ).

CONSERVATION AND PROTECTION: REPORT ON THE STEWARDSHIP FISHERY

Presented by D. Walsh

Abstract

The Dockside Monitoring Program (DMP) collects accurate, independent, and timely information on the fishery. This program was initiated in the 1980s as a pilot project in the Gulf of St. Lawrence, and was fully implemented in the mid-1990s. In Newfoundland and Labrador, DMP services are provided by two companies: the Fish Harvesters Resource Center (FRC) and Atlantic Catch Data. Based on a review conducted in 2009 at the request of the FRC and industry, an updated DMP was implemented in 2010. The updated DMP uses a tiered monitoring system, wherein ports are prioritized based on catch proportion and perceived risk.

Discussion

Catch estimates have been excluded from recent Northern cod stock assessments (e.g DFO 2013), due to the reporting limitations, and concern about accuracy of the estimates.

Several participants from all sectors raised concern about unknown parameters in the catch data: the magnitude of mis-estimated catch, the size of unreported catches, and the prevalence of high-grading and discards (i.e. fishing mortalities that are not landed and therefore not monitored). Harvesters present at the meeting reported that at present discards are low in this fishery, because there is currently very little incentive for that practice. Participating harvesters described a fishery in which gillnets are deployed for short soak times (3-4 hours) and fish are retrieved alive and iced immediately to maximize quality and market price. However, there remains no mechanism to quantitatively estimate high-grading or discard rates for past years.

Current stock assessment model formulations consider a range of uncertainties around reported catch, allowing the model to estimate annual catch between 1-2 times the reported value for the commercial and recreational fishery combined. It was stressed that this parameter does imply that catch may be double the reported value in any given year; instead the range simply recognizes that reported catch cannot realistically capture the full scope of fishery mortality. Conservation and Protection reports indicate that <10% of catch remains unreported, however tagging data (presented later in the document), indicates a much higher rate of unreported catch (approximately 40%).

Harvesters suggested that there is an opportunity to improve DMP and Enforcement data reporting, and contribute to a more accurate catch estimate. The combination of these two programs results in a very high percentage of externally monitored landings, and thus reliable catch estimates that may support the survey indices for Northern cod stock performance. Better recording practices and data management may allow more detailed analysis of DMP and Enforcement reports in the future.

PHYSICAL OCEANOGRAPHIC ENVIRONMENT ON THE NEWFOUNDLAND AND LABRADOR SHELF, UPDATE FOR 2015

E. Colbourne, J. Holden, D. Senciall, W. Bailey and S. Snook

Presented by E. Colbourne

Abstract

The North Atlantic Oscillation (NAO) Index, an indicator of the direction and intensity of the winter wind field patterns over the Northwest Atlantic, remained in a positive phase in 2015, reaching a record high that resulted in in a strong arctic air outflow in the northwest Atlantic during the winter months and consequently lower than normal winter air temperatures. Sea ice extent increased substantially during winter 2014 with the first positive anomaly (higher-than-normal extent) observed in 16 years and in 2015 the total extent was about normal except for March and April when it was above normal. Annual sea-surface temperatures (SST) based on infrared satellite imagery across the Newfoundland and Labrador Shelves ranged from near-normal to below normal in some areas. The annual bottom (176 m) water temperature at the inshore monitoring station (Station 27) was below normal in 2015 by -0.7 standard deviations (SD), a significant decrease from the record high in 2011. The cold-intermediate layer (CIL; volume of < 0°C) in both 2014 and 2015 was at its highest level since 1985 on the Grand Bank during the spring. Spring bottom temperatures in 3Ps remained above normal by about 0.5^{o}C (0.8 SD) and were about normal on the Grand Banks. Fall bottom temperatures in 2J, 3K and 3LNO decreased from 2, 2.7, and 1.8 SD above normal in 2011 to 0.2 and 0.8 SD above normal in 2J and 3K and to -0.4 SD below normal in 3LNO in 2015, a significant decrease in the past 4 years. A standardized climate index derived from 28 meteorological, ice and ocean temperature and salinity time series declined for the 4th consecutive year, reaching the 7th lowest in 66 years and the lowest value since 1993.

Discussion

According to the composite climate index, 2015 represented the coldest ocean conditions in this area since 1994. The same index recorded the warmest ocean conditions on record for the Canadian Northwest Atlantic in 2006. Based on the NAO and projections of global change made by the Intergovernmental Panel on Climate Change (IPCC), it is expected that this area will warm significantly over the next two decades. Current conditions are less severe, but similar to the cold period of the mid-1990s which was a time of documented low productivity for this stock. The composite climate index shows a moderate correlation (0.5) with age 3 cod recruitment, and study of temperature on recruitment indices and abundance of other year classes is ongoing. However, the nature of this relationship is not certain. Temperature has a mechanistic effect on growth and body conditions, but a causal relationship between temperature and population abundance or recruitment has not been established for this stock. Several participants raised concern that this relationship lacks the robustness required to contribute to a stock assessment model (p-value, cohort tracking, and coefficient of variation were not reported). A more comprehensive analysis of temperature and recruitment is required for Northern cod before this relationship can be incorporated into the assessment model or scientific advice. As presented, the climate-recruitment relationship may support interpretation of survey and model results.

BIOLOGICAL OCEANOGRAPHIC ENVIRONMENT ON THE NEWFOUNDLAND AND LABRADOR SHELF, UPDATE FOR 2015

G. Maillet, P. Pepin, S. Fraser, G. Doyle, A. Robar, J. Holden, J. Higdon

Presented by G. Maillet

Abstract

Zooplankton abundance on the Grand Bank-Newfoundland Shelf, based on the Continuous Plankton Recorder (CPR) survey, indicate increasing levels during 2011-14. Although some decline in standing stocks of keystone calanoid copepods have been observed in 2014-2015, the abundance of other key functional zooplankton taxa has generally been above normal compared to the standard reference period (1999-2010) during 2009-15 across the standard Atlantic Zone Monitoring Program (AZMP) sections. Zooplankton biomass based on AZMP sections has declined significantly in 2015 with the lowest level observed in the 17-year time series. The reduction in biomass levels of zooplankton is likely related to lower abundance of the abundant larger arctic calanoid copepods in recent years. Although zooplankton biomass has declined, the abundance indices based on CPR and AZMP suggest stable prey levels that may support feeding of early life stages of Northern cod.

Discussion

Plankton surveys are considered here as a partial index of prey availability for Northern cod. The longest existing time-series of continuous plankton recorder data has been collected by commercial cargo vessels moving between Iceland and the East coast of the United States. This dataset provides near-surface plankton abundance since the 1960s, with a gap in sampling between the late 1970s and early 1990s. Surface plankton stocks in general have been increasing since 2001, following a period of relative low abundance in 2003-09. The Atlantic Zonal Monitoring Program provides depth-integrated plankton data, with similar trends. *Calanus spp*., an important prey species, has been increasing in abundance since the mid-2000s, though a slight decline was documented in 2014-15. Zooplankton biomass is also recorded along the NAFO Standard Sections. Biomass was high between 2002 and 2011, but reached a 17-year low in 2015. This appears to be the result of a transition from large Arctic zooplankton to dominance of smaller copepod species. The increasing abundance of age 3 cod between 2000 and 2012 coincides with stable or above average zooplankton populations.

UPDATE ON THE STATUS OF CAPELIN IN NAFO SUBAREA 2 AND DIVISION 3KL DURING 2016

F. Mowbray, P. Regular, B. Slaney and C. Bourne

Presented by F. Mowbray

Abstract

The status of capelin (*Mallotus villosus*) in NAFO Divisions 2J3KL was last assessed in February 2015, covering the time period up to and including 2014. This presentation included 2015 updates to the following elements of that assessment: abundance index, distribution and biological characteristics from the spring Div. 3L acoustic survey (1982-2015), distribution of capelin from the fall Divs. 2J3KLNO bottom trawl surveys (1995-2015), capelin spawning times (1978-2015) and larval production indices (1982-2015). The spring acoustic capelin survey is conducted during the month of May in Div. 3L, targeting the main distribution area of immature capelin. Ages 2 and 3 dominate the survey catches. Capelin age 4 and older, plus some of the maturing age 2 and 3s are poorly recruited to the survey as they tend to be distributed outside the surveyed area. The acoustic abundance has fluctuated markedly over time from a peak of 6 million t in the late 1990s to a low of 25,000 t in 2010. In the last three years the index has shown some improvement peaking in 2014 at near 20% of the 1980s levels. However abundance in 2015, while still superior to 1991-2012 period, showed larger than usual declines in the 2012 and 2013 year classes. Current abundance of age 2s suggests that age 3 capelin in 2016 will be maintained at recent levels or lower. The poor survival of this 2013 cohort was coincident with delayed gonad development, with gonad weights in the survey being the lowest since 1996 when weighing of gonads at sea commenced. Changes in abundance were paralleled with changes in capelin distribution. Capelin surveyed in May 2015 tended to be found in deeper water and further offshore than the last two years, similar to patterns common in the 2000s. The fall distribution of capelin also changed in 2015 reverting to a pattern common during the periods of low abundance in the 1990s and 2000s, with the center of mass located in northern Div. 3L and few capelin present in Div. 2J. Larval indices for both the 2014 and 2015 cohorts are at the lowest levels in the series (2003-15). These observed declines in larval production, in combination with the poor survival of the 2013 cohort, suggest that overall capelin abundance in 2016-17 is likely to decline.

Discussion

Capelin represent an important prey for Northern cod. The fall 2014 survey indicated late gonadal development and late spawning was anticipated in 2015. The 2014-15 recruitment indices are at the lowest of the entire time series. Late and patchy spawning was recorded in 2015. Poor recruitment over the past two years and poor survival in 2015-16 have led researchers to suggest that the stock will return to low abundance and distribution similar to the early 2000s. It is unclear how the 2011 vessel change may have influenced the index. Overall, availability of capelin as prey for Northern cod has improved since the very low levels of the 1990s, but remains well below pre-collapse levels.

The short lifespan of capelin limits projections to a two year forecast, which is not compatible with the three-year assessment schedule for Northern cod. However, information on the capelin stock performance may be useful as context for interpretation of model results and projections.

MARINE MAMMAL PREDATOR DYNAMICS

Presented by G. Stenson and A. Buren

Discussion

Consumption of cod by marine mammal predators is investigated through a bioenergetic model. The abundance and gross required energy for harp seal at each age were calculated, and adjusted according to the amount of time spent in the study area and seal diet composition. Seal distribution and habitat use are derived from satellite telemetry. Total consumption is greater in the winter season, estimated at 3.7 Mt of total biomass (all species) annually among 7.5 million harp seals. Harp Seal diet includes Atlantic Cod, Arctic Cod, herring, capelin, sandlance, flatfish, and shrimp. Atlantic Cod make up approximately 140,000 t of the annual total. It was noted by the presenter and other researchers that this figure cannot be meaningfully compared to Northern cod SSB estimates. Harp Seals prey primarily on 1 and 2 year-old cod, which do not contribute to estimated SSB. Capelin is the main prey species for Harp Seals.

Diet among marine mammals varies over time, and the figures presented here are general estimates. Data of offshore diet composition are limited. The main conclusion is that there is no measurable impact of marine mammal predators on Northern cod stocks. Predation by seals was not found to be a significant driver of Northern cod between 1985 and 2007, and there is no indication that the impact of seal predation has changed since that time. It is generally assumed that natural mortality within the assessment model accounts for predation, however without tagging information on the early age classes, this is difficult or impossible to demonstrate. One participant noted that the magnitude of consumption estimates of cod by seals was large compared to the estimate of spawning stock biomass from NCAM.

Information on cod predation by marine mammals was presented to provide context to the analysis of Northern cod, however predation is not included explicitly in the current assessment model.

ECOSYSTEM OVERVIEW

Presented by M. Koen-Alonso

Abstract

The NL Bioregion large marine ecosystem can be described in terms of four Ecosystem Production Units (EPUs). Northern cod straddles across two of them (Divs. 2J3K and 3LNO). The ecosystem changes observed in the 1990s can be linked to a combination of historical overfishing, and a regime shift. These changes involved the collapse of the groundfish community, not just Northern cod, and the increase in shellfish. The collapse period also involved a decline in fish size. Consistent signals of rebuilding of the groundfish community appeared in the mid/late-2000s.These signals are also associated with an increase in fish size. Changes in the fish community show a coherent internal structure; increases in small fish and shellfish are associated with declines in forage and large fishes. The 2J3K and 3LNO EPUs are still in a reduced productivity state. Current groundfish biomass is still below pre-collapse levels. Given their current productivity state, these EPUs are near full exploitation for standard demersal components (common commercial groundfishes and shellfish).

In the 2010s the overall biomass has shown a moderate decreasing signal linked to a reduction in shellfish; the dominance of groundfishes has increased, and shellfish decreased. The overall biomass of the groundfish community has been relatively stable in the 2010s; the increases in

cod imply a higher dominance within groundfishes, mostly at the expense of plank-piscivores (redfish).

Some signals in 3LNO (e.g. increasing dominance of silver hake) suggest that the structure of the fish community may not necessarily be similar to the pre-collapse period. The current rebuilding of groundfishes can be associated with an increase of capelin, and reduction of shrimp in the diets. Since 2013, the role of other prey seems to be increasing. The fluctuations in Northern cod total mortality estimated from RV surveys, and natural mortality estimated from the NCAM assessment model are significantly correlated with availability of capelin, and with the quality of the prey field, measured as the ratio between shrimp and capelin RV biomasses.

Total food consumption by the fish community in 2J3KL has increased since the mid-1990s, but it peaked in the mid-2000s, and has declined since. This peak and decline is associated with shellfish food consumption. Total consumption by finfishes has been relatively stable during the 2010s. This implies an increase in the fraction of the total consumption associated with finfishes. Although cod is an important predator (~20% of the total consumption by 2015), other core species (redfish, turbot, American Plaice) have had an equal or more important role in terms of food consumption in recent years.

Discussion

Ecosystem structure, trends, exploitation level, and trophic interactions were investigated for the general bioregions of the Newfoundland Shelf (Divs. 2J3K) and the Grand Banks (Divs. 3LNO).

Ecosystem regime shifts were documented in the 1920s and 1990s, driven by changes in ocean climate and high fishing pressure. The regime shift of the 1990s is defined by the collapse of groundfish and the subsequent dominance of shellfish. Recent surveys indicate that groundfish are slowly rebuilding, however Divs. 2J3K and 3LNO remain in a reduced-biomass state, far below pre-collapse levels. As groundfish have increased, a simultaneous decrease has been observed in shellfish biomass. Growth is not consistent among all fish species, however.

Fish community dynamics were analyzed according to fish functional groups, defined by size and feeding habitats: small benthivores (eg. sculpin); medium benthivores (e.g. Yellowtail Flounder); large benthivores (e.g. Thorny Skate); piscivores (e.g. Atlantic Cod); plankton-piscivores (e.g. Arctic Cod); planktivores (e.g. Capelin); and shellfish.

Consumption rates and potential production of each functional group were modeled based on stomach contents and biomass indices from the DFO RV fall survey data. The Atlantic Cod fishery decline of the 1990s dramatically reduced overall biomass in the system. Over the last decade, a slow rebuilding of cod has been documented, however this recovery is not homogenous throughout the study area. Shellfish dominate biomass in the northern unit, while piscivores are experiencing a more significant recovery in Divs. 2J3K than 3LNO. Shrimp biomass stocks increased in the mid-1990s, to peak in 2006. In 2015, shrimp returned to their lowest levels since 1995. The increase of piscivores is dominated by Atlantic Cod, while other species like Greenland Halibut remain relatively stable. Small and medium benthivore biomass is also increasing, driven mainly by American Plaice and Yellowtail Flounder. Overall, biomass of groundfish species increased between 2005 and 2012, and has been stable since, however biomass remains well below pre-collapse levels.

Stomach contents analyses indicate that cod diet composition has shifted over time. Between 2008 and 2012, cod diet was dominated by shrimp and capelin, with moderate levels of sandlance. Overall this period is characterized by low diet diversity. In recent years (2013-15), cod diet has been dominated by capelin, amphipods (mainly among small cod), and flatfish (among large cod of Div. 3L). This period is characterized by greater diet diversity across

Northern cod age classes and across geographic range. Based on energetic considerations, capelin are an extremely valuable food source. While cod represent an important predator of capelin and other forage species, redfish, Greenland Halibut, and American Plaice are also significant consumers in the ecosystem. Feeding studies of Greenland Halibut indicate that capelin is more prevalent in the stomachs of Greenland Halibut than Atlantic Cod and capelin remained an important diet component across the time series despite declines in capelin biomass. American Plaice diet differs geographically; shrimp are dominant in the Northern component of the stock and capelin dominate in the South. Among redfish species, shrimp and amphipods are key prey items, however in recent years shrimp has declined while the proportion of capelin has increased.

Several commercial species are linked by trophic interactions, however current stock assessments lack the mechanisms to incorporate these links in scientific advice. NCAM results generated for this assessment indicate that Northern cod are subject to dramatic changes in natural mortality. Ecosystem level analysis suggests that there is a good correlation between capelin and cod survival, however the available data is not sufficient for capelin to contribute directly to the current NCAM formulation. Suggestions for how to apply ecosystem data to the assessment varied; measures of cod condition from the fall and spring surveys may improve model fit, or capelin stock performance may provide context for interpretation of cod assessment models. If, for instance, capelin are projected to perform poorly then cod may not be expected to maintain current growth rates.

CURRENT DATA ON THE NORTHERN COD STOCK

CATCH AND CATCH AT AGE

Presented by D. Ings

Abstract

A review of data from the stewardship and commercial (bycatch) fisheries plus the sentinel survey indicated that reported landings for the 2015/16 management year was 4436 t. No estimate of removals by the recreational fishery was available. A summary of catch sampling levels for the period 2009 to 2015 showed that data were available annually for all but a small proportion of the gillnet landings, but sampling rates were considerably lower and declining for handlines and line trawls. For the stewardship and commercial fisheries, length frequency data collected at sea were similar to those collected dockside. In contrast, fish lengths recorded during recreational fisheries tended to be higher in dockside relative to at sea samples indicating that high-grading had occurred widely. Catch at age analyses showed that ages five to eight were most abundant in the landings, which is a typical pattern for gillnet-dominated fisheries. Since the late 1990s, weights at age for ages 2 to 12 have been stable at levels comparable to the highest values observed in the time series. The 2001 and 2002 cohorts track temporally in the catch at age analyses. While subsequent cohorts cannot be tracked, results suggest that they may have increased survival rates.

Discussion

Length and age sampling of the catch is conducted throughout the season and stock area, both at sea and through dockside monitoring. The sentinel survey remains a significant source of information for the catch at age estimates. The gillnet catch is well represented for the 2009-15 period, however hand line and trawl are not as well sampled. This discrepancy may alter the results slightly but the majority of the catch is taken by gillnet. Observed and expected length frequencies for commercial samples match well, indicating that high-grading is not significant in this fishery in the recent period. The catch-at-age data between 2013 and 2015 are dominated by age 6 and 7 cod. Weight at age appears to be very consistent in the early age classes, however it becomes more variable in the older classes. During the high productivity phase of the 1980s, weight-at-age was higher among Northern cod, and declined in the 1990s. Over the last decade, weight-at-age has varied without clear trend.

Total estimated landings in 2015 were 4017 t from the stewardship fishery, 268 t from the sentinel survey, and 97 t in by-catch (30 t from Canadian vessels and 67 t from foreign fleets). Since 2006, overall reported landings have ranged from 2,700 to 4,900 t. A higher proportion of older fish are present since the 2011 catch compared to several years prior to that. Meanwhile, recruitment appears low for the incoming age 5 year class.

CATCH RATE TRENDS FROM LOG-BOOKS FOR VESSELS < 35 FT

Presented by J. Brattey

Abstract

Catch and effort data for the < 35 ft. sector, from log-books for the 1998-2002 commercial fishery and the 2006-2015 stewardship fishery, were examined. There was a general decline in the percentage of logbooks returned from ~90% in 2006 to ~65% in 2015, although the most recent values (2015) are provisional as not all log-books have been returned. The total number of catch rate entries (for gillnets) in the logbook database now exceeds 100,000, and for most unit areas in most years there are several hundred entries; the exceptions were Subdiv. 2Jm where there are few harvesters, and St. Mary's Bay (3Lq) where few harvesters have fished in recent years. Median gillnet catch rates (kg/net) with 10th and 90th percentiles by unit area were presented. These showed an overall declining catch rate trend in the 1998-2002 commercial fisheries. The trend was reversed in the 2006-2012 stewardship fisheries, although most areas showed a dip in catch rates around 2009-10. Catch rates increased substantially between 2011 and 2015 in northern areas, i.e. southern Labrador (2Jm), White Bay (3Kd), Notre Dame Bay (3Kh) and the Twillingate-Fogo area (3Ki). High catch rates but no recent trend was evident in Bonavista Bay (3La) and Trinity Bay (3Lb), and lower catch rates but no trend was observed in Conception Bay (3Lf) and the eastern Avalon (3Lj).

Discussion

The logbook program was designed to record the gear used and total catch weight at a time when there was very little information available for the fishery. The return rate on logbooks has been in decline, with a simultaneous reduction in the fleet's landings and number of participants. In the Northern portion of the area, catch rates derived from the logbook data indicate low catch during 2009-10, with a substantial increase during 2011-15. The Central/Southern portion of the stock has maintained relatively consistent catch rates over the last decade.

FISH HARVESTER QUESTIONNAIRE 2013-2015

Presented by E. Carruthers (Fish, Food, and Allied Workers)

Abstract

Canadian fixed-gear fish harvesters' perspectives on the 2015 cod stewardship fishery in Divs. 2J3KL were compiled based on the results of the telephone survey conducted by the FFAW. A stratified random survey of active cod harvesters resulted in 170 survey responses distributed throughout 2J, 3K, and 3L, corresponding to 23, 66, and 81 harvesters respectively.

Surveyed harvesters had, on average, 36 years' experience fishing cod. 81% of surveyed harvesters fished in <35' vessels, most of whom fished gillnets.

Harvesters from all three NAFO divisions reported that cod were more abundant in 2015 than in the late 1980s, with over 80% of harvesters in 2J and 3K reporting excellent catch rates. Over 80% of harvesters in 3L reported catch rates were either good or excellent. Similarly, over 80% of harvesters in 2J3K reported cod condition, meaning cod fatness or health, were in excellent condition. 3L harvesters reported cod were in good or excellent condition.

Regional differences were noted in reported abundance of capelin, with the majority of 3K harvesters reporting good abundance of capelin and an increasing trend. Responses from 2J and 3L were more varied. Reported herring abundance also varied across 2J3KL. By contrast, all harvesters reported low abundance of squid and mackerel.

Ten percent of the surveyed harvesters caught a tagged cod in 2015. Of those, 60% reported returning the tag.

Discussion

Harvesters of 2J3KL are interviewed annually in a randomly assigned phone survey, stratified by NAFO area. In total, 511 harvesters have been contacted and 170 have participated. The interview asks harvesters to comment on abundance, catch rate, and the condition of Northern cod. The average participant is a 50 year old male harvester, with 30 years experience in the fishery. The late 1980s are used as a benchmark in the interview. All divisions report that cod were more abundant in 2015 than the 1980s. Representatives from the fishery present at the meeting supported this statement.

Capelin made up the majority of cod stomach contents in all NAFO Divisions, with a small proportion of herring and sandlance. When asked about tagged cod, 20 participants reported tags in their catch and just over half reported returning tags. Almost all the respondents report gillnets as the primary gear type, but most also used hand lines and trawls. Soak times on the nets ranged from less than an hour to 24 hours. Additional measures of effort are not currently available, however the harvesters attending the meeting reported a shift of time per gear.

RECREATIONAL FISHERY 2013-15

Presented by B. Healey and D. Ings

Abstract

Conservation and Protection (C&P) Fishery Officers sample fish lengths of cod caught during the summer recreational fishery. This information is used to appropriately 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 2013-15 were provided, with a focus on aggregated values over NAFO Division and sampling location (dockside versus at-sea). A total of 14,120 fish measurements were available, of which just over half (7302) 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. 3K during 2013 and Div. 3L in 2015 showed pronounced difference in the size distribution by sample location, with fewer small cod in dockside samples.

Discussion

Data availability for the recreational catch is very inconsistent. The zonal interchange file format (ZIFF) database is missing recreational fishery landings. From 2006 onwards, there are four years with recreational catch estimates included; most years report a very small catch (300 t), but the estimate spiked in 2008 (1000 t).

The size composition of the recreational catch is well sampled by C&P officers in some years (ex. N=3900 in 2013). In general, larger fish are recorded in dockside checks than at sea. The difference between mean length-at-sea and dockside indicates that high-grading is occurring in this fishery. Mortality rates for discards in this fishery are unknown, but are expected to vary widely depending on the handling practice. Researchers were not confident that there would be high survival of small cod discards, even when released quickly. Post tagging mortality is about 22% under very careful handling in warm temperatures; it is expected that discard mortality would be significantly higher.

GROUNDFISH ACOUSTIC SURVEYS OF THE CELTIC EXPLORER

Presented by G. Rose

Discussion

A groundfish acoustic survey was conducted to collect biomass estimates of offshore spawning cod aggregations in Divs. 2J3KL in 2015 on the *RV Celtic Explorer*, led by the Marine Institute Centre for Fisheries Ecosystem Research. The survey investigated vertical and horizontal behaviour of the spawning aggregations in order to quantify distribution and abundance of cod in the survey area. Large individuals from the aggregations were also tagged with Floy and pop-up satellite archival (PSAT) tags. For this survey the *RV Celtic Explorer* is outfitted with an EK60 echosounder that operates at 38 Hz. Campelen and Irish mid-water trawls were conducted to confirm composition of the acoustic signal. The survey was conducted May 6-30, 2015, in the Bonavista corridor with some limitations due to ice cover in the northern extent of the study area. The Bonavista Corridor was selected based on almost 20 years of study indicating that this area is a key spawning area for Northern cod; the stock remained in relatively high abundance longer in this area during the collapse, and early rebuilding of the stock began in the same area.

The echograms collected in this survey were compared to spawning aggregations recorded pre-1993, and which could not be found for some time post-collapse. The return of historical spawning aggregations may represent a return to pre-collapse behavioural patterns among Northern cod. Targeted trawl sets were deployed to test signal composition, which was found to be almost exclusively cod within the spawning aggregations. Analysis of the acoustic data included integration of backscatter within each nautical mile for comparison with historical acoustic surveys of the Bonavista Corridor. The conversion of backscatter data to density is made through a model of target strength, supported by extensive literature on acoustic target strength for cod and other gadoids. Though they are calculated through slightly different methods, the target strength model derived for this study agrees well with models developed by Ermolchev (2009). There was much discussion on the “dead zone”. A correction for the acoustic “dead zone” is also performed, based on the assumption that the mean density of the bottom five metres of acoustic data extended down to the true seafloor. This correction may add up to 20% to the overall biomass estimate of an aggregation, though it is difficult to get an accurate estimate. The majority of the biomass is assumed to be distributed high in the water during the spawning behavior, well within the accurately sampled range of the acoustic survey.

The survey is conducted along transects in 200-500 m of water. The resulting data is the constructed into a lattice of 10 nm x 10 nm with a mean value applied to each grid cell. Northern cod appear to be more widespread, and more densely aggregated in the Bonavista Corridor than previously thought. Dense aggregations were also recorded in the Notre Dame Channel, an unexpected result of the survey. The 5+ age classes (spawning stock biomass) dominate the biomass in the Bonavista Corridor. The total biomass estimate for 2015 was 325,000 t.

Representatives from the fishing sector asked about the depth distribution of cod in the Hawke Channel and Notre Dame Channel, and a potential link to a perceived decline in shellfish in that area since 2010. Researchers agreed that cod are likely feeding heavily on shrimp in that area. The acoustic survey collected data from 300-450 m. It was hypothesized that cod are also distributed in shallower waters, however ice extent limited the reach of the survey. Harvesters also reported high densities of juvenile cod in commercial trawlers and crab pots in the Notre Dame Channel and St. Anthony Basin. These findings agree with the fall multispecies survey indices which suggest that distribution of juvenile cod is much broader than the spring acoustic survey spawning stock biomass estimates. The acoustic survey presented measures large cod in the water column; it is not a good tool for the measure of juveniles, which are generally found in closer association with the seafloor. Harvesters encouraged increased scientific surveys in the Notre Dame Channel, where they are experiencing an increase in cod resources.

The acoustic survey may offer significant information to the stock assessment model. However, it remains unclear if the acoustic SSB estimate is best applied as an overall biomass estimate, a minimum estimate, an index for the whole stock, an index for a portion of the stock, etc. A meeting of external experts is scheduled for the summer of 2016 to discuss this issue and provide review on methods and uncertainties in the estimate.

EFFICACY OF THE CAMPELEN TRAWL

Presented by S. Walsh

Abstract

A re-occurring survey issue regarding Northern cod, in NAFO Div. 2J3KL is: can the Campelen 1800 (shrimp) survey trawl catch large cod in a 15-minute tow? Earlier tow duration experiments using the old DFO survey trawl (Engel 145 High Lift otter trawl) in 1990 and 1991 found that there was no significant difference in catch rates and length composition of cod in 15 vs. 30 minute tows. Noteworthy, was the fact that the number of large cod were fewer in the population at the time but were present in both 15 and 30 minute tows in the 1990 experiment. Norway uses the same Campelen trawl, with different trawl doors, in its Barents Sea cod (and other groundfish and shrimp) surveys and its Campelen tow duration experiments, produced similar conclusions about cod.

Graphical presentations of population length frequencies of cod in both the 2015 Barents Sea and the Northeast Newfoundland shelf surveys showed remarkable similarities, especially for cod ranging from 75-110 cm. In addition, length frequencies of cod obtained from 7 and 12 minute Campelen tows on large aggregations, during tagging experiments, showed large amounts of cod from 85–110 cm. Similarly, the CFER cod acoustic population length frequency estimates in the Bonavista Corridor, ground-truthed from catches taken in ~10 minute tows by the large mesh-wide swept area GOV trawl, showed they were sampling the same length frequency as the 2J3KL survey estimates using the Campelen trawl, especially for cod 60-120 cm.

The overall conclusion is that there is no evidence, or otherwise (no cod fishers at the meeting questioned the results), to demonstrate that the Campelen trawl cannot catch very large cod in quantities sufficient to derive an accurate population length frequency from a 15 minute tow. Norwegian scientists have expressed the same conclusion (pers. comm.).

Discussion

Campelen trawls are currently used by several scientific surveys, including the Newfoundland and Labrador waters, the Barents Sea and the Northern Gulf. The GOV trawl, commonly used among international surveys, is very similar. Pre-1995, the DFO survey used the commercial Engels trawl. When the survey changed from Engels to Campelen, comparative catchability studies were conducted. The Campelen delivers a very different catchability for small cod. Both trawl types yielded very similar catch results for the larger cod. However, it should be noted that few very large cod were available at the time of the survey.

Previous work on tow duration found no significant differences in catch per minute between tow durations for all species (Godo et al. 1990). Short tows result in faster processing of samples, availability of more resources for biological sampling, less damage on survey gear, and a reduction in fish mortality. Current multispecies survey tows last 15 minutes, at 3 knots. The presenter recommended further study on survey catchability. Recent research suggests that effective fishing height may be 20 m, instead of the previously thought 4 m due to avoidance behavior. The fundamental question is whether the trawl sample is representative of the population? Participants supported a proposal for further comparative fishing research and/or survey trawl research.

FISHERIES AND OCEANS RV SURVEY RESULTS

Presented by J. Brattey

Abstract

A summary of information on Divs. 2J3KL cod from the autumn DFO trawl survey was presented, updated with the latest information from the 2015 survey. The latest survey was finished on time and all strata were fished. Age-aggregated indices of abundance, biomass, and spawning biomass all show a similar pattern, with an increasing trend and 2015 values were highest since the moratorium. The presentation covered various aspects of survey results, age-disaggregated catch rate trends, recruitment and pre-recruit trends, total mortality rates, distribution of survey catches, and biological information (length-at-age, weight-at-age, body and liver condition indices, and age at maturity).

Discussion

The 2015 DFO Fall Survey achieved good coverage, with 337 completed index sets. All survey strata were sampled and the timing of the survey was within the normal range. Abundance estimates from the survey have been increasing in recent years. Similarly, the biomass index is the highest since the moratorium, and 25% of the level recorded in the 1980s. Spawning stock biomass (SSB) has reached 39.4% the average survey index in the 1980s, a high for recent years. Most of the improvement in stock performance was recorded in the Northern component of the survey area. The increasing trend is promising, but it should be noted that the stock remains at about a third of estimates for the 1980s.

Post-moratorium, pre-recruits up to the 2001 year-class showed low abundance and poor survival. The 2002-10 year classes remained low, but showed improved survival to age 3 and 4. The current 2012-13 year classes are much stronger, but do not yet contribute to SSB. If this survival trend continues, there is potential for an increased rate of stock growth. The shift to a growing stock with similar structure to the pre-decline is very recent. Researchers stressed that there is a long way to go for rebuilding of Northern cod. Liver condition was low in the 1990s, but has increased and stabilized recently. Information on condition appears to agree well with capelin stocks.

NEWMAN SOUND PRE-RECRUITS

Presented by K. Dalley

Abstract

Over the past 20 seasons, demersal age 0 and 1 year old Atlantic Cod (*Gadus morhua*) in the nearshore (< 10 m deep) have been surveyed using a seine net, to conduct a qualitative assessment of the strength of these year-classes. This assessment was based on comparisons with abundance of Atlantic Cod sampled at 6 to 13 sites, every 2 weeks during July until November, from 1995-2015 in Newman Sound, Bonavista Bay. Analysis of annual length frequency and abundance data indicates that age 0 Atlantic Cod settled in the nearshore in several distinct recruitment pulses; the first pulse arriving in early July in 2013 & 2015, but late (i.e. September) in 2014. Second and subsequent pulses followed the first by as much as a month and a half later. Strong pulse structure throughout the sampling period typically has resulted in the production of a strong cohort as measured independently during other surveys. The age 0 abundance in Newman Sound in 2013 and 2015 suggests that these two cohorts will also be moderate to strong, relative to other cohorts in the 20 year-long time series. The 2013 cohort was the strongest in the time series in terms of mean abundance per set, timing of settlement, and strength of its recruitment pulse structure. This pre-recruit survey data indicates that stronger than average year classes have been produced during each of the past 4 years, compared to the 20 years of monitoring data.

Discussion

Young cod (age 0-1) are distributed nearshore (< 10 m). Dive surveys and submersible camera surveys almost always found age 0 fish within the first 10 m. Age 1s were recorded inshore at night, shifting out to 20-40 m during the day. Sampling of small fish (< 10 cm) is a limitation of the multispecies survey. The research conducted in Newman Sound uses a complimentary set of methods to meet this data gap.

Beach seine data have been collected in Newman Sound over a twenty year time-series (1995-2015). Age 0-1 cod coexist in structured nearshore habitat, primarily within eelgrass beds. Of the beach seine time series, 2013 yielded the highest cohort, and 2006 the lowest. 2011-15 showed consistently high densities of age 0 cod. There is a high correlation between the age 0 and age 1 anomalies. Age 0 performance is a poor predictor of the older age classes perhaps due to overwintering survival.

SENTINEL SURVEY RESULTS

Presented by B. Healey

Abstract

A detailed overview of catch per unit effort (CPUE) from the sentinel survey was provided by gear type and area for years 1996-2015. A total of 52 sites (i.e. fishing enterprises) participated. Gillnet sampling was the predominant activity; only four participants used linetrawl, with limited sampling at two of these locations. Results were summarized separately for gillnets (the mesh sizes, 5.5 and 3.25 inches, are analyzed independently) and linetrawl. In recent years, the CPUE obtained in 3.25 inch gillnets has been relatively stable in Divs. 2J and 3L, but has shown some increase in Div. 3K. For 5.5 inch gillnets, CPUE has increased several-fold in both Divs. 2J and 3K, yet remains stable in Div. 3L. Available length frequency data indicate an increasing size range in all three gears. The CPUE data are standardized using a generalized linear model (poisson distribution with log link), with fixed nested interaction effects of month

within site, and age within year. The amount of gear used is treated as an offset variable. Where sufficient data permits, the analysis is conducted in three sub-areas, termed 'Northern' (unit areas 2Jm, 3Ka, 3Kd), 'Central' (3Kh, 3Ki, 3La, 3Lb) and 'Southern' (3Lf, 3Lj, 3Lq) to better account for within stock differences in CPUE. In the Central area, the CPUE for 5.5 inch gillnets has increased consistently and is currently about three times that of a decade ago. After a period of decline at the beginning of the survey, the CPUE for the 3.25 inch gillnet has been relatively stable. Linetrawl results indicate a more than 50% increase between 2014 and 2015, but recall sampling activity for this gear is quite limited. In the Southern area, 5.5 inch gillnet CPUE has declined in the past few years. After an extended period of steady decline, the 3.25 inch gillnet increased dramatically from 2014 to 2015 to more than twice the previous time-series maximum. In the Northern area, both the 5.5 and 3.25 inch gillnet show a marked difference since 2011; subsequent results are much higher than the earlier portion of the time-series. Age-specific results reveal that the increases are not due to one or two stronger cohorts supporting improvement. In general all gear types show an age structure with increased numbers of older cod.

Discussion

Overall effort in the sentinel survey has declined over time. Large, older fish have become more common in the survey in recent years, and there was a considerable increase in the number of cod caught in 2014-15. Harvesters agreed; those who participated in sentinel survey report that 2013-15 yielded greater catches in fewer sets when compared to the previous 15 years. The impacts of seasonal and long term distribution changes on sentinel survey catchability are uncertain. In general, the recent trends from this survey agree well with the DFO multispecies survey but there is less agreement for the earlier portions of the time-series (1995-2002).

OVERVIEW OF TAGGING DATA

Presented by J. Brattey

Abstract

An overview of the cod tagging databases was presented. Two databases exist covering the periods 1954-1993 and 1997-2016. Tagging has been conducted primarily to investigate cod migration patterns and stock structure and to estimate harvest rates. The more recent database (1997-2016) includes recaptures from double tagging experiments (to estimate tag loss rates) and high-reward tagging (to estimate tag reporting rates) and experimental work to investigate the rate of initial tagging mortality under various conditions of capture (water temperature, depth). Two published reporting rate models were fitted to the time series of high and low reward recaptures to estimate trends in tag reporting rates over time (1997-2015) and to compare reporting rates between commercial and recreational fishers. Both models showed a decline in reporting rates over time, but the random walk model gave lower estimates for the recent period for both the combined data and the commercial data alone, compared with the independent year effects model. Recreational reporting rates were the same for both models (0.5) and showed no trend. The random walk model yielded “smoother” estimates, less of a retrospective pattern, and no pattern in the residuals, and was chosen as the preferred model. Tags returned from commercial and recreational harvesters during the stewardship fishery (2006-2015) were adjusted by respective model-predicted reporting rates to estimate the total number of tags returned each year from each sector of the fishery. This analysis showed the recreational fishers returned, on average, 30% (range 13 to 54%) of the tags returned by commercial harvesters, indicating that a substantial fraction of total removals were due to recreational fishing.

Discussion

In a system where total catch remains uncertain, tags provide an independent estimate of exploitation rate. The high/low reward program was established in 1997 and has continued without changes since that time. A cumulative total of 152,000 tags have been deployed, and 24,000 recovered, including about 6,500 in the Northern cod stock area.

Tagging experiments involve only fish which are at least 45 cm; 80% of tag deployments are low reward, and 20% are high reward. Experimentally derived tag shedding rates are 22% in the first year, and 5% in the second. Tag mortality is dependent on depth and time of year; 3% in October to June and up to 22% in July to September in waters < 200 m. Over the past decade, about 77% of tags returns are from commercial vessels and 23% from the recreational fishery. The percentage of tag returns from the recreational fishery has remained generally high, despite increases in permitted catch. Assuming tags are equally available to each fishery, tag returns may be used to extrapolate from the estimated commercial catch to generate recreational catch estimates. However the impact of inshore/offshore distribution shifts on availability of tagged fish to each fishery is unknown.

All analysis of tag data is based on the assumption that 100% of the high reward tags are returned. Harvest rates calculated from tag returns deliver a measure of exploitation per tagging area, not fishing area, i.e. the harvest rates give an indication of the fraction of cod tagged in an area that are harvested, irrespective of where the recaptures come from in subsequent years.

Acoustic Telemetry in NAFO Divs. 2J3KL

Acoustic receivers are installed in arrays in Divs. 2J3KL. Fish are tagged with acoustic transmitters and the hydrophones (moored receivers) record and store the unique ID code, time and date when a tagged fish passes within its recording radius. These arrays are able to generate a time series of many pings for years at a time, a significant increase in the amount of information available from traditional Floy tags. In addition, the data provided are not fishery-dependent. Most active hydrophone arrays are moored inshore; at present only two are located offshore. Acoustic tags with active capacity of 3000 days were deployed in Divs. 3K and 3L in 2009-10, where fish appeared offshore later than other stock components. In 2012 tagging was carried out in Div. 3L, in which 900-day tags were deployed. In this case, fish that were tagged inshore were also recorded by the offshore receivers. Within 2 years of data collection, there is a very clear pattern of inshore/offshore movement, however the fish completely disappear from the array in February and March. Researchers suggest that they are moving further offshore at this time. In general, it appears that the historical seasonal migration pattern has resumed, and the timing is broadly similar to observations made pre-moratorium.

Acoustic Telemetry in the Gilbert Bay MPA

Acoustic tags were deployed in the Gilbert Bay Marine Protected Area (MPA) to support a study of stock mixing at the MPA boundaries. Between 2012 and 2014, 94 individuals were tagged, and most were detected by inshore and offshore hydrophone arrays. The tagged fish showed broad movements, ranging from Gilbert Bay (late summer) to the Grey Islands (early fall) to the Hawke Channel closed zone (winter). The Hawke Channel closure does appear to be protecting cod, particularly during the winter. Researchers hypothesize that the migration is driven by a combination of factors, including capelin availability. The cod appear to follow capelin, and capelin stocks have been performing well in the years when the inshore/offshore migration was observed to return.

NORTHERN COD ASSESSMENT MODEL

RESPONSES TO RESEARCH RECOMMENDATIONS FROM THE 2015 NORTHERN COD FRAMEWORK REVIEW MEETING ON THE NCAM ASSESSMENT MODEL

Presented by N. Cadigan

A state-space integrated assessment model developed for Northern cod was reviewed in detail at the Northern cod Framework Review Meeting, held in St. John's, NL during November 30 to December 4, 2015. This model is referred to as NCAM-Northern Cod Assessment Model. Four independent external reviewers participated in the framework meeting and contributed research recommendations that were provided in the proceedings report of Framework Review meeting. In this presentation responses were provided to many of these recommendations. This involved some new analyses which are summarized below.

A recommendation from two reviewers was to change the baseline M (natural mortality) values used in NCAM to be consistent with the M estimates produced by NCAM. This was completed and it did not result in much difference in model estimates for the historic data period, but it did result in substantially different projections. These did not increase as much when the baseline M's were the medians of previous estimates. This seems like a better model formulation and the author suggests that it be used in NCAM formulations for the 2016 Northern cod RAP.

A reviewer was concerned about the high levels of M for some years estimated by NCAM. The reviewer suggested to '*assume a constant (or nearly so) M and look for other places in the model to account for the changes in the population'*. This was done by running an NCAM formulation with no change in M but with much wider bounds on catches and more catch measurement error. This formulation was set up to model Z (total mortality) using F (fishing mortality) because M was fixed. This model fit substantially worse, particularly to the tagging data used by NCAM. This indicates substantial evidence in the fishery catch, stock surveys, and tagging data for Northern cod that M has not been constant since 1983. Recent estimates of SSB and recruitment were substantially different between the two models, and historic F's were also very different.

A reviewer was concerned with the use of a censored likelihood for catches and the Laplace approximation method used by the software NCAM is implemented with (i.e. TMB). The reviewer suggested an alternative approach that was '*possibly easier to solve in terms of the Laplace approximation'*. This approach was implemented and the overall NCAM results were similar and the results did not indicate serious estimation issues related to using the Laplace approximation with a censored likelihood.

NCAM UPDATES

Presented by N. Cadigan

Abstract

This presentation provides a brief review of NCAM – a state-space integrated assessment model developed for Northern cod. This review covers the data used by the model, including basic likelihood equations used for model estimation, and model changes since the 2015 Northern cod Framework Review Meeting. These 'fine-tuning' changes have been anticipated and it is common for this to happen when a model is first applied in a stock assessment.

Change 1: Addition of monthly landings data during 1983-2015

NCAM uses monthly landings data to determine how much fishing mortality to apply to tag-return data in the same year that fish were tagged. For illustration purposes, only a rough approximation of the distribution of monthly landings was used at the 2015 framework meeting. Adding the actual monthly data accounted for substantial variation in tag-return data. This new data was used in all model formulations to be presented at the 2016 stock assessment.

Change 2: Baseline M's

Another change to NCAM involved the values for baseline M's that it used. These baseline M's only affect estimated M's when there is little or no information (i.e. ages and years) to estimate M's. Baseline M's affect projected M's. NCAM runs using 2014 and 2015 data and with original or revised baseline M's were compared. The revised baseline M's were the age-specific median M's from NCAM runs that used original values. Differences in NCAM results were small and it was demonstrated that differences in 2014 SSB (estimated using 2014 or 2015 data) were related to differences in stock weights-at-age and proportions mature-at-age provided at the 2015 framework meeting and at the 2016 stock assessment.

Change 3: Tag reporting rates

A reviewer recommendation from the 2015 Northern cod Framework Review was to include uncertainty about tag reporting rates in NCAM. This was done by considering the reporting rates in NCAM as random effects, and adding a likelihood component for these report rates. The likelihood was based on the externally derived estimates and their estimated covariance matrix. A log-normal likelihood approximation was used. Also, NCAM uses information from low- and high-reward tags so a combined reporting rate (λ_{comb}) should be used: $\lambda_{comb} = 0.8x\lambda_{low} + 0.2x\lambda_{high} = 0.8x\lambda_{low} + 0.2$. This was based on the 4:1 ratio of low- and high-reward tags applied. This change resulted in slightly lower estimates of stock size and slightly higher estimates of F.

Change 4: F incomplete mixing of tagged fish

NCAM estimates of tag-returns in the release year often differ substantially from observations, even with the addition of monthly landings data which helped explain a substantial amount of this variation. It seems possible that NCAM could over-estimate M in an attempt to account for these differences. Incomplete mixing of tagged and un-tagged fish in the release year has been identified in the tagging literature as a problem. As a solution, NCAM was modified so that a random effect was included in the F used to estimate tag-returns in the release year, to account for incomplete mixing. In effect, the F in the release year for each tagging experiment was allowed to vary from the overall stock F to account for possible under- or over-exploitation of tagged fish due to incomplete mixing. This change was applied sequentially to the model including uncertainty in reporting rates (i.e. Change 3). This resulted in increases in estimates of stock size and decreases in estimates of F; however, stock status (SSB/B_{lim}) or estimates of M hardly changed. Accounting for incomplete mixing resulted in a substantial improvement in model fit.

Change 5: F auto-correlation

A reviewer recommendation from the 2015 Northern cod Framework Review was to evaluate NCAM sensitivity to the assumed value of yearly auto-correlation in age-specific F's. This was addressed by changing NCAM to estimate this auto-correlation. This change was applied sequentially to the last model (i.e. Change 4). The previously assumed auto-correlation was 0.9 and the estimate from the new NCAM formulation increased to 0.99. This also resulted in a substantial improvement in overall model fit. This change resulted in increases in estimates of stock size and decreases in estimates of F; however, stock status (SSB/B_{lim}) or estimates of M hardly changed.

Change 6. M deviations

M is modelled as auto-correlated (over ages and years) random effects in NCAM. The M process error variance is fairly large and is an important source of variability in the projections. Hence, this stochastic process needs to be considered carefully. The large M-deviations in 1991-94 contribute to the M process error variation. It may not be reasonable to expect that M changes of similar magnitude to 1991-1994 will occur again in the next 3-5 years. A way to remove this source of variation is to change the baseline M’s and use higher values for 1991-94 than for other years. This change was applied to the last model formulation (e.g. Change 5). It resulted in a slight improvement in overall model fit and a small reduction of M process error standard deviation (0.28 to 0.26), but otherwise the two NCAM models produced very similar results.

Change 7. Recruitment deviations

NCAM treats recruitment as random, with two mean levels pre- and post-1992. A reviewer from the 2015 Northern cod Framework Review recognized that this assumption will have to change in the future in response to future changes in SSB and potential impacts on recruitment. A more immediate issue related to this is auto-correlation in recruitment residuals. This has been apparent in all NCAM models and should be accounted for. This may also result in better fits to survey indices if there are temporal trends in recruitment. This was addressed by changing the independent random deviations in NCAM recruitment to simple random-walk deviations. This change was applied to the last formulation (i.e. Change 6) and resulted in little change in model output overall, except for an increase in the size of the 2012-13 year classes, better fits to the DFO RV indices at ages 2-4 in the last few years, and consequently an improvement in overall model fit.

Discussion

A framework meeting was convened to conduct an expert review of potential data inputs and models for an assessment of Northern cod in December 2015. At the close of that meeting, reviewers made suggestions and requested further information on the performance and formulation of NCAM. Responses to those reviews were presented by model author Dr. Noel Cadigan.

NCAM is an integrated state-space population dynamics model. Data inputs include upper and lower bounds on reported catch (1983-2015), catch-age composition proportions (ages 2-14), landings by month, DFO multispecies survey indices, inshore sentinel survey, inshore acoustic biomass and age compositions, and tagging data (116,000 releases and 11,000 recaptures). Some modeled parameters are also included; maturity at age, beginning and mid-year weight at age, and baseline natural mortality. At the framework meeting, reviewers voiced concern about estimates of natural mortality (M). There is insufficient information to estimate M for the youngest age groups. Cohort tracking does not deliver M estimates, but can indicate changes in M. Estimates of M by NCAM for all ages were consistently higher than baseline input values, which may indicate that it is appropriate to increase baseline M. Diagnostic model runs with various M values showed that baseline M input does not significantly alter current stock performance estimates, however it does impact estimates of the stocks historical level and stock projections into the future. A model run with a lower baseline M will project more rapid stock increase, for example. Future research may contribute a mechanism for measuring changes in M and/or better understanding of migratory dynamics that will improve this parameter.

It was also suggested that fishery age composition could be estimated in separate time blocks, pre- and post-moratorium; however, it is not yet clear if this partitioning would generate more reliable estimates. Year-by-year measures of uncertainty may also be applied to future model runs. The current NCAM formulation includes the Smith Sound acoustic survey age composition data directly, because the sampling strategy is well understood and easily applied. However, this is not the case for all age composition data, as the sampling design is often much more complex. More detailed information on survey specific uncertainties may offer a practical way to improve NCAM.

In the NCAM results, predicted vs. observed catch is extremely variable. Predicted catch has been placed under a random walk function, wherein each predicted value is related to the previous, which reduced variation slightly. If the goal of the model is to track reported catch, there has to be substantial variation in F, which would be achieved if the model was reformulated to estimate F freely each year. If a large fraction of the true catch is not fully monitored (i.e. the recreational fishery), it is likely that the age compositions are not the same as the reported catch. Without additional information, however, the model treats recreational catch estimates as homogenous like the monitored commercial catch. NCAM was adjusted to include information on monthly landing, and allowing the tagging mortality in the release to act as a random factor. It was suggested by participants that conversion of the tagged fish length to age could be incorporated within NCAM and this was done so that tag return information could be cohort based and integrated with other information in NCAM.

Between 1991-94, natural mortality was significantly higher than the historical mean, or any estimate of M since. Participants noted that a key question asked of this model is whether a similar M event is likely to be repeated. Anecdotal information from the history of the fishery indicates that large natural mortality events, like the one that contributed at some level to the stock collapse of the early 1990s; while a rare event, may occur roughly every century. History records indicate that the fishery disappeared in the early-1700s for roughly a decade, and reports from the late-1800s suggest another crisis. In the more recent records, early fisheries and environmental monitoring indicate that the stock has undergone two regime shifts, the first in the 1920s and a second at the time of the 1990s stock collapse. Given the history of the stock, and the decadal scale of major environmental forcing like the North Atlantic Oscillation, participants agreed that another natural mortality event of the same scale is unlikely in the near future (5-10 years). However, unexpected natural mortality events are possible and researchers agreed that cautious management would limit exploitation to a level that left sufficient biomass in the stock to be resilient to variations in natural mortality rate. Participants also noted that although natural mortality is an important factor for this stock, Cadigan (2015) is one of the first papers to provide analyses suggesting that the stock collapse was a natural event. The causes of the collapse are still debated and other published work concludes that the collapse was entirely fishing (Myers et al. 1996) or due to the combined impact of broad chronic overfishing, acute overfishing in some key stock components, and natural mortality driven by underlying environmental changes caused a rapid decline.

It was accepted that overall catches are higher than the final reports that are incorporated into the catch statistics tables. Meeting participants agreed that a realistic lower bound for total catch in the assessment model would be 1.1-1.2 x the reported value. The identification of an appropriate upper bound for catch was discussed extensively. As presented, NCAM considers an upward bound on predicted catch at twice the reported value, however this upper limit is only reached a few times throughout the time series. Harvesters were not comfortable with the implication that catch could be double the reported value, and asserted that catch estimates are much more accurate in recent years than earlier in the time series. It was proposed that the catch bounds be partitioned into time periods where reported catch was more or less certain.

Accordingly, the modeled catch bounds were updated as follows: between1983-91 modeled catch bounds are 1.1-1.5 x reported (to account for discards), and between 1992-2005 catch bounds are 1.1-2 x reported (acknowledging unknown and variable catch). In the most recent years (2006-present), catch bounds are adjusted year-by-year based on the ratio of recreational to commercial tagging data in tag returns. This calculation serves as an adjustment to reported catch values that accounts for any high grading that occurs in the fishery. In years when there is no recreational catch estimate available, the upper bound is increased to 1.57 x reported.

NCAM RESULTS AND PROJECTIONS

Presented by N. Cadigan

Abstract

An important outcome of the 2016 Northern cod stock assessment was an agreement on the catch bounds to be used in NCAM – a state-space integrated assessment model developed for Northern cod. These new catch bounds were used in a model formulation using previous values for baseline M's, and then these baselines M's were updated in a new NCAM formulation. This was done with and without using an M-shift for 1991-94. All models produce very similar estimates of stock size and mortality rates. Compared to models with the illustrative catch bounds used in the 2015 framework meeting, the new catch bounds resulted in some substantial changes in NCAM estimates of total catch weight. The M-shift model produced a slightly better fit and is the formulation recommended to provide harvest advice for Northern cod. A plethora of NCAM fit diagnostics were presented to demonstrate that this model fits the productivity data for Northern cod very well. Associated with this, there was little evidence of a retrospective pattern in estimates of stock size or mortality rates.

Three and five-year projection results from this model were presented for a range of catch-multipliers. The projection results were focused on change in SSB compared to the 2015 level, change in SSB compared to B_{lim}, the probability that SSB will exceed B_{lim}, the probability of 28% SSB growth in three years or 50% growth in five years, and the probability that the projected SSB will be less than the 2015 level.

Discussion

NCAM results and projection summaries were presented to meet the Terms of Reference objectives given for this meeting, reporting on a: the level of catch that allows continued stock growth (> 95% probability); and b: the level of catch that enables 50% growth in SSB 2016-2020 (> 75% probability).

As history has shown, this system is very difficult to predict and the five year projections were calculated with very high coefficients of variation (CVs). For example, the CV on 5 year projected spawning biomass was as high as 80%, implying highly uncertain results. If projections are restricted to three years, there is reduced uncertainty in the projection results. The 5-year projection window relies on assumed recruitment levels; at three years, the model employs observed recruitment values. As such, projections were discussed in two ways: 3-year and 5-year projections. Based on risk analyses projected into the next three years, there is very little chance that the Northern cod stock will drop below the 2015 levels.

Model runs were conducted to identify harvest rates that would support at least 28% stock increase in the next three years, in addition to 50% growth over 5 years. The 28% growth within 3 years was set as a threshold to be consistent with the broader goal of doubling stock biomass by 2025. There is high probability of achieving the 3-year recovery milestone (28% growth) for Northern cod at up to 3X the current catch. However, the uncertainty of the 5-year projection delivers a less optimistic result: under any catch scenario, there is less than 75% probability of reaching the 5-year recovery milestone (50% growth). Participants considered this issue, of 3-year or 5-year projections, to be a critical one. The 3-year results offer more certainty, and can be calculated based observed data (ex. measured recruitment). The 5-year results are more uncertain, and rely on predicted parameters (ex. future recruitment), however that uncertainty may offer a useful perspective for managers and may lead to management decisions that are better aligned with the precautionary principle. The positive trend in the 3-year projection based mainly on a pulse of biomass in the system that will grow as those individuals age. After that cohort growth, there is not sufficient certainty that high recruitment will be sustained, or that forage biomass (i.e.: capelin) will support continued high growth. It should also be noted that the estimated growth rate under the 3-year projection is at least 30% per year, which is slightly above the estimated maximum growth rate for Atlantic Cod and therefore may be overly optimistic. Current estimated growth in the survey biomass has reached upper limit known growth rates for Atlantic Cod. This is likely caused by very successful recruitment among one or two cohorts, and does not represent a realistic expectation for the growth rate for this stock over a longer period. Therefore, it was decided that 5-year projection results would not be reliable for advice on stock growth.

Participants noted that the terms of reference lacked reference to the probability of exceeding the Biomass Limit Reference Point (B_{lim}). SSB in 2015 was 34% of B_{lim}. Probability calculations on exceeding B_{lim} were requested by meeting participants and calculated within the timeframe of the meeting. Within a 3-year projection window, there is low probability (< 4%) that SSB will decline to below the 2015 level under harvest rates up to five times the current catch. Some participants were surprised at the optimism of these projections, but given that current F's are so low (0.014) even 5 times the current catch would still generate quite low Fs and not push the stock below 2015 levels with high probability. Even under the 3-year projection, the Northern cod stock will grow to about 60-66% of B_{lim} and has a low probability (5-8%) of reaching the limit reference point and enter the cautious zone by 2018 under any harvest rate.

ADDITIONAL PRESENTATIONS

DRIVERS OF FISHERY COLLAPSE

Presented by Anna Winter

Abstract

Interplay of stock productivity and fishing activity (potentially) lead to the collapse of the Northern cod fishery. Although overexploitation has been accepted as the primary cause of fisheries collapse, many degraded stocks show only weak signs of recovery to reduced fishing pressure. Alternative stressors such as climate or depensation have been proposed as drivers of stock collapse but are not necessarily governing stock recovery. With a simple age-structured population model for a cod-like fishery we aim to build a conceptual framework which analyzes the interaction between different individual productivity functions and fishing activity. We reveal the importance of stochastic fishing pressure for stock collapse especially if the population shows an Allee effect: mortality fluctuations can push the population below the threshold of depensation thus accelerating the stock's degradation even if the average fishing intensity is not high. The model is aimed to be applied to the Northern cod fishery. Apart from stock productivity functions, different harvesting strategies as well as socio-economic factors will be considered as potential drivers of the fisheries collapse.

Discussion

Fisheries collapse is driven by a combination of interacting factors, including environmental conditions (ex. sea surface temperature is relevant for both collapse and recovery), exploitation rate, and Allee effect. The Allee effect, which refers to the reduced growth rate and recruitment which that occurs at low population densities, may be related to mate-finding problems, loss of schooling behavior, or higher adult mortality (Keith and Hutchings 2012). Environmental conditions, particularly temperature, influence growth rate and recruitment. The crucial questions is how these bottom up effects (climate, density-related behavior, etc.) interact with top-down drivers, like fishing strategy, gear type, and catch rate. For example, a stock with a strong Allee effect will not support high and constant fishing mortality. Allee effect is crucial if harvest rate is fixed, and becomes even more important if the population size also fluctuates due to natural mortality. Winter is developing a Ph.D thesis which will investigate the Allee threshold for several cod stocks, including Northern cod.

REVIEWER COMMENTS

Dr. Andy Edwards is a stock assessment expert and an employee of Fisheries and Oceans working on Groundfish stocks on Canada's Pacific coast. Dr. Edwards was invited to attend the Northern Cod stock assessment meeting and provide independent review of the stock assessment process and to provide a summary of his review comments.

Presented by A. Edwards

Reviewers and meeting participants commended NCAM as an impressive stock assessment tool and the result of an immense amount of work. The reviewer thanked harvesters present at the meeting for adding valuable context to the discussion of catch estimates and potential sources of uncertainty in the stock assessment model.

Most questions and concerns raised during review were addressed in the presentations summarized above. The role of predation on this stock remains somewhat unclear; a seemingly significant amount of biomass is removed, without measurable impact on abundance. Among many opportunities for further research highlighted during this meeting, investigation of predator dynamics and consumption levels may contribute to further understanding of this stock.

Some suggestions were also made for the improvement of future model runs. Managers may find the comparison of a zero catch scenario useful for decision making. The reviewer also agreed with several meeting participants that the 5-year projections, as requested in the Terms of Reference, introduced an unacceptable amount of uncertainty into the advice. Meeting participants agreed to present the 5-year projections as requested, with 3-year projections included to provide a more reliable, though shorter term outlook on the stock potential.

Review comments also noted that it will be a significant amount of work to transfer maintenance and execution of NCAM from Noel Cadigan and the Centre for Fisheries Ecosystem Research to Fisheries and Oceans Canada. The reviewer cautioned DFO representatives against underestimating the resources required to fully understand and operate a model of this complexity.

CONCLUSIONS/DISCUSSION ON ASSESSMENT TRIGGERS

One of the goals of this meeting was to identify indicators with which to follow stock status in the years between full assessments every three years, and to identify the events that would trigger an assessment out of schedule. Participants agreed that assessment triggers should be very precise, and involve basic biological features. The precautionary approach suggests that a threshold should be identified, and that if the stock appears to drop below that at any time, a full assessment would be required. In this case, some very basic biological features should be chosen as key indicators. Distribution is an extremely important feature of stock performance, and may be of equal importance to abundance, however it is difficult to quantify an assessment threshold. The fundamental goal of the 3-year assessment schedule is to reduce the time and resources spent on assessments during the intervening years. In this scenario then, an ideal assessment trigger would be some estimate or index that requires relatively little data preparation, processing and analysis. Ideally, the indicator could be calculated and used to inform a decision before the stock update meeting is scheduled, thus avoiding a situation where time and resources are spent on both an update, and a full assessment in the same year. It was suggested that a threshold of SSB may be useful; it is a relatively easy calculation from the multispecies survey data and provides a widely used index of the current stock performance. This was dismissed due to the ageing required to occur in order to calculate SSB. An acceptable level of risk would have to be identified in order to set a threshold value.

Previous stock updates that occurred between assessment years have examined updates on all multispecies survey indices, sentinel survey, and tagging data. The effort required to generate these updates are trivial in some cases (abundance, biomass, length compositions), but labour intensive for some; catch at age, for example, requires aging analysis of thousands of otoliths. Fishing mortality, for example, may be a useful way to determine whether a stock assessment is required, however there is no way to obtain this estimate without the full assessment. It was also proposed that the role of environmental or prey conditions may act as assessment triggers, however it remains unclear what thresholds would be set on environmental variables. Similarly, capelin biomass was discussed as a potential trigger for Northern cod stock assessment; if there is a sharp decline in a key prey species, this raises concern about the stock performance. However, participants could not readily identify a meaningful threshold, and many raised concern that the natural variability in annual capelin biomass estimates may obscure the underlying signal. It was generally agreed, however, that the significance of capelin as a high quality prey species and the cod-capelin trophic relationship could provide useful information, when considered in combination with other assessment triggers.

Substantial change in the estimated biomass may not necessarily require re-assessment, if this change (growth or decline) reflects the projected values that direct management decisions. It was agreed through extensive discussion, that stock performance beyond the model's projected bounds, and thus beyond the scope of management decisions, should trigger re-assessment and the formulation of new management advice. There is high probability that the survey indices will increase by at least 20% in the next year; as such, participants agreed that if there is no measureable growth, or if there is any measure of decline, a full assessment should be conducted.

A combination of three indices were discussed and proposed by participants as the tools for determining whether to perform a full assessment during an interim year.

1. If the survey biomass index falls below the minimum modeled predictions, and/or;
2. The measured capelin biomass is in decline, and/or;
3. The reported fisheries removals are above the modeled values,

4. A full assessment would be recommended outside of the 3-year schedule.

Generally, the model results indicate that natural mortality is a significant driver of Northern cod stock production, perhaps more important than fishing mortality. However, participants cautioned that any fishing where tags are not returned, where there is high-grading, unreported fishing by international fleets, etc., are considered as de-facto natural mortality by this model. In NCAM, M refers to unreported deaths, which may or may not always be natural mortality. Further study of the tagging data was recommended. A better understanding of where tags are reported, and by which fleets may offer insight into the coverage and reliability of tag reports, and how distribution shifts have impacted stock availability to the survey or the fishery.

NCAM incorporates a significant amount of diverse datasets, and generates a good approximation of reality. However, not every variable important to Northern cod can be captured by the model. This is often because the information is not yet in a form that can be included in the model (e.g. skey prey dynamics). There is room to develop the stock assessment further. Harvesters and researchers agreed that monitoring of the recreational catch must be a priority for the Northern cod stock. The recreational fishery presents an uncertain, but likely substantial portion of fishery removals. There is an urgent need for more accurate measurements and reporting of this catch.

The general findings of the NCAM analysis are that the stock is in a period of high growth, and recruitment is strong at present. Although there is general optimism about rebuilding of Northern cod stock, concern was raised regarding model scenarios projecting 5 times the current catch. The current policy on a stock in the critical zone, like Northern cod, is that harvest should be maintained as low as possible. Some participants questioned whether the statement conflicted with the spirit of that policy. However, the results of the model remain the best available and objective tool for scientific advice on stock status. The information is presented in full to managers.

REFERENCES CITED

Cadigan, N. G. 2015. A state-space stock assessment model for Northern cod, including under-reported catches and variable natural mortality rates. Can. J. Fish. Aquat. Sci. 92: 1-13.

DFO. 2011. Proceedings of the Newfoundland and Labrador Regional Atlantic Cod Framework Meeting: Reference Points and Projection Methods for Newfoundland cod stocks; November 22-26, 2010. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2010/053.

DFO. 2013. Stock Assessment of Northern (2J3KL) Cod in 2013. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/014.

DFO. 2014. Northern (2J3KL) Cod Stock Update. DFO Can. Sci. Advis. Sec. Sci. Rep. 2014/030.

DFO. 2015. Northern (NAFO Divs. 2J3KL) Cod Stock Update. DFO Can. Sci. Advis. Sec. Sci. Rep. 2015/018.

DFO. 2016. Stock Assessment of Northern cod (NAFO Divs. 2J3KL) in 2016. DFO Can. Sci. Advis. Sec. Advis. Rep. 2016/026.

Ermolchev, V. A., 2009. Methods and results of *in situ* target-strength measurements of Atlantic cod (*Gadus morhua*) during combined trawl-acoustic surveys. ICES Journal of Marine Science, 66, 1225–1232.

Godo, O. R., Pennington, M., Volstad, J. H. 1990. Effect of tow duration on length composition of trawl catches. Fisheries Research, 9(2), 165-179.

Keith, D. M., Hutchings, J., A. 2012. Population dynamics of marine fishes at low abundance. Canadian Journal of Fisheries and Aquatic Sciences, 69(7), 1150-1163.

Myers, R.A., Hutchings, J. A., Barrowman, N. J. 1996. Hypotheses for the decline of cod in the North Atlantic. Mar. Ecol. Prog. Ser. Vol. 138, 293-308.

APPENDIX 1: TERMS OF REFERENCE

STOCK ASSESSMENT OF NORTHERN COD (DIVS. 2J3KL)

Regional Peer Review Process - Newfoundland and Labrador Region

March 21–24 and March 30-31, 2016
St. John's, NL

Chairperson: Ben Davis

Context

The status of Northwest Atlantic Fisheries Organization (NAFO) Divisions 2J3KL Atlantic Cod (i.e., Northern cod) was last fully assessed in March 2013 (DFO 2013). An update was completed in 2014 (DFO 2014) and 2015 (DFO 2015). In November 2010 a limit reference point, as described in the decision-making framework developed by Fisheries and Oceans Canada (DFO) for the application of precaution in the fishery, was determined (DFO 2011). A Regional Peer Review Process was held November 30 - December 4, 2015 to review multiple models of population dynamics, and to discuss the utility of various data sets available for assessing this stock (DFO 2016, *in prep.)*. A stock assessment, in accordance with the Sustainable Fisheries Framework, is requested by Fisheries Management to provide the Minister with advice on the status of the stock covering the period 1 April 2016 - 31 March 2019.

Objectives

- Provide an ecosystem overview (e.g., physical and biological oceanography, predators, prey) for the stock. If possible, this information should be integrated into the advice.
- Provide an assessment of the current status of cod in Divs. 2J3KL using information updated to 2016.
- Assess the current spawning stock biomass (SSB) relative to the Limit Reference Point (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.
- Identify the maximum level of annual removals that will enable a 50% growth in SSB over 2016-2020 years with a high probability of success (>75%).
- DFO's Precautionary Approach (PA) framework indicates there is zero tolerance for preventable decline. Identify the level of removals that provide a very high probability (>95%) of continued stock growth over 2016-2018.
- Identify indicators to follow the stock status during the years without a full stock assessment, and identify events that would trigger an earlier-than-scheduled full assessment.
- 3 year management advice is requested covering the period 1 April 2016 - 31 March 2019.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Participation

- Fisheries and Oceans Canada (DFO) Science and Fisheries Management
- Province of Newfoundland and Labrador Department of Fisheries and Aquaculture
- Non-Governmental Organizations
- Industry Representatives

- Academia
- Aboriginal Groups
- Other invited experts

References

DFO. 2011. Proceedings of the Newfoundland and Labrador Regional Atlantic Cod Framework Meeting: Reference Points and Projection Methods for Newfoundland cod stocks; November 22-26, 2010. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2010/053.

DFO. 2013. Stock Assessment of Northern (2J3KL) Cod in 2013. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/014.

DFO. 2014. Northern (2J3KL) Cod Stock Update. DFO Can. Sci. Advis. Sec. Sci. Resp. 2014/030.

DFO. 2015. Northern (NAFO Divs. 2J3KL) Cod Stock Update. DFO Can. Sci. Advis. Sec. Sci. Resp. 2015/018.

APPENDIX 2: AGENDA

Regional Peer Review Process: Stock Assessment of Northern (2J3KL) Cod

Memorial Meeting Room

NAFC, St. John’s

March 21-24 & 30-31, 2016

Chairperson: Ben Davis

Monday, March 21 (0900-1700)

Activity	Presenter
Opening/Chair remarks (0900)	B. Davis
Introductions/ ToR	B. Davis
Overview of fishery 2013-2015	P. Williams (RMAF)
Conservation and Protection overview	D. Walsh (C&P)
Physical and biological oceanography overview	G. Maillet
Key prey (capelin)	F. Mowbray
Large predators / Cod Drivers	A. Buren
Ecosystem Overview	M. Koen-Alonso
Catch and Catch at age	D. Ings
< 35’ Logbook	J. Brattey
Fish harvester questionnaire, 2013 – 2015	E. Carruthers (FFAW)
Hydro-Acoustic Studies (CE Surveys)	G. Rose

Tuesday, March 22 (0900-1700)

Activity	Presenter
Efficacy of Campelen Trawl	S. Walsh
RV Survey Results (index trends, biological data)	J. Brattey
Newman Sound pre-recruits	K. Dalley
Sentinel survey	B. Healey
Tag reporting rates	J. Brattey/C. Konrad
Tagging and telemetry results	J. Brattey/C. Morris
NCAM - new developments (Framework Recommendations)	N. Cadigan
NCAM - results and projections	N. Cadigan

Wednesday, March 23 (0900-1700)

Activity	Presenter
NCAM - further discussion	N. Cadigan
Drivers of Fisheries Collapse	A. Winter (U. of Oslo)
Drafting of Science Advisory Report Bullets	All

Thursday, March 24 (0900-1700)

Activity	Presenter
Drafting of Science Advisory Report	All
Reviewer Comments	A. Edwards

Wednesday, March 30 (0900-1700)

Activity	Presenter
Science Advisory Report (if Required)	All

Thursday, March 31 (0900-1700)

Activity	Presenter
Science Advisory Report (if Required)	All

APPENDIX 3: PARTICIPANT LIST

Name	Affiliation
John Brattey	DFO Science-NL Region
Bill Broderick	Fish, Food and Allied Workers Union (FFAW)
Tom Brown	Marine Institute - Centre for Ecosystems Research
Alejandro Buren	DFO Science-NL Region
Noel Cadigan	Marine Institute - Centre for Ecosystems Research
Erin Carruthers	Fish, Food and Allied Workers Union (FFAW)
David Coffin	DFO Resource Management-NL Region
Peter Crocker	Torngat Fish Producers Co-op
Basil Dalley	Icewater Seafoods
Kate Dalley	DFO Science-NL Region
Ben Davis	DFO Science-NL Region
Tony Doyle	FFAW-Harvester
Karen Dwyer	DFO Science-NL Region
Shelley Dwyer	DFA Government of Newfoundland and Labrador
Andrew Edwards	DFO Science-Pacific Region
Bob Gregory	DFO Science-NL Region
Brian Healey	DFO Science-NL Region
Danny Ings	DFO Science-NL Region
Leon King	DFO -NL Region
Mariano Koen-Alonso	DFO Science-NL Region
Christoph Konrad	Marine Institute - Centre for Ecosystems Research
Eugene Lee	DFO Science-NL Region
George Lilly	DFO Science-NL Region
Gary Maillet	DFO Science-NL Region
James Meade	DFO – Centre for Science Advice, NL Region
Joanne Morgan	DFO Science-NL Region
Corey Morris	DFO Science-NL Region
Fran Mowbray	DFO Science-NL Region
Darrell Mullowney	DFO Science-NL Region
Glen Newbury	FFAW-Harvester
Emilie Novaczek	Rapporteur- Memorial University of Newfoundland
Gilbert Penney	FFAW-Harvester
Randy Randell	FFAW-Harvester
Paul Regular	DFO Science-NL Region
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Peter Shelton	DFO Science-NL Region
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Dennis Slade	Icewater Seafoods
Lyndon Small	FFAW-Harvester
Don Stansbury	DFO Science-NL Region
Garry Stenson	DFO Science-NL Region
Darrell Tucker	Harbour Grace Shrimp Co. - FGOH
Kris Vascotto	Groundfish Enterprise Allocation Council
Daryl Walsh	DFO Fisheries Management-NL Region
Steve Walsh	DFO Science-NL Region
Keith Watts	Torngat Fish Producers Co-op
Patricia Williams	DFO Resource Management-NL Region
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