Fisheries and Oceans Canada Science | Pêches et Océans Canada Sciences

Newfoundland and Labrador Region

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RESULTS AND RECOMMENDATIONS FROM THE ECOSYSTEM RESEARCH INITIATIVE – NEWFOUNDLAND AND LABRADOR'S EXPANDED RESEARCH ON ECOSYSTEM RELEVANT BUT UNDER-SURVEYED SPLICERS

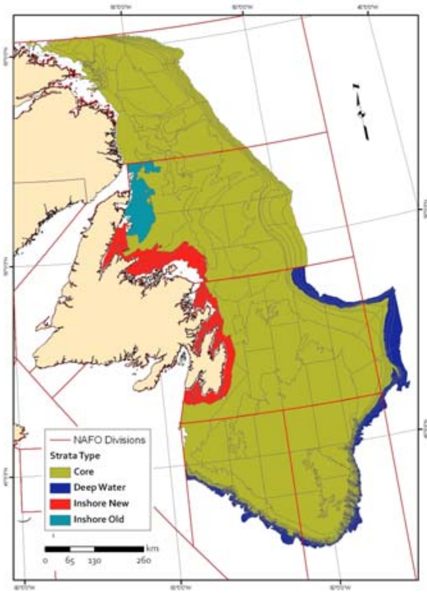

Figure 1: ERI-NEREUS Study Area indicating core, deep water and inshore strata and NAFO Divisions.

Context :

In August 2007 a Regional Committee of scientists initiated a process aimed to fill knowledge gaps in the Newfoundland and Labrador (NL) Fisheries and Oceans (DFO) Science program deemed key for the development of ecosystem approaches to fisheries in the NL region. This work evolved into the regional component of the DFO Ecosystem Research Initiative (ERI), the "Newfoundland and Labrador's Expanded Research on Ecosystem-relevant but Under-surveyed Splicers" (NEREUS).

The ERI-NEREUS program had the following objectives: 1) enhance the capability of NL surveys for providing information on ecosystem status and main trends by improving monitoring on forage fishes, non-commercial species, major benthic components, and trophic interactions, and 2) identify and track main pathways of energy in the NL system by integrating results from trophodynamic and statistical models with trends and patterns in ecosystem indicators. The geographic extent of this work encompasses the Newfoundland and Labrador Shelf, including the southern Labrador shelf, the northern Grand Bank and the Grand Bank Proper.

This Science Advisory report contains the results emerging from this program, as well as an examination of their implications for management, policy development and implementation, which were presented in a Canadian Science Advisory Secretariat regional advisory meeting on January 17-19, 2012. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

SUMMARY

- In August 2007 a Regional Committee of scientists initiated a process aimed at filling knowledge gaps in the NL DFO Science program which evolved into the regional component of the DFO Ecosystem Research Initiative (ERI), the "Newfoundland and Labrador's Expanded Research on Ecosystem-relevant but Under-surveyed Splicers" (NEREUS).

- Between 2008 and 2012, the ERI-NEREUS program added new or redesigned sampling components in DFO Research Vessel surveys, such as the collection and processing of acoustic information, implementation of a grab sampling program on the Grand Bank, a new scheme for sampling of stomach contents of key fish species, and expanded sampling of non-commercial species.

- The main outcomes of the ERI-NEREUS program, to date, include a description of status and trends in main forage fish species, as well as the structure and changes in the fish community; a characterization of main components of benthic communities; and an analysis of trophic interactions among key components of the NL marine community.

- Results of the grab sampling program conducted at 58 stations over three NAFO Divisions (3NLO) showed that a total of 12 phyla were represented with three phyla (Annelida, Arthropoda and Mollusca), accounting for 86% of all recorded taxa. Echinodermata dominated biomass (58% of total), particularly the sand dollar, *Echinarachnius parma* (69% of total echinoderm biomass). The overall biomass of 228 g/m^2 recorded in the NEREUS program is within the range of previous studies.

- Preliminary analysis of hydroacoustic data collected during fall bottom trawl surveys during 2008 indicated that auxillary acoustic may be useful to estimate availability to the bottom trawl of at least two forage species (Capelin and Sand Lance). New information on spatial variation of biological characteristics and feeding of forage species was collected and described.

- During the late 1980s and early 1990s most of the fish community in the Newfoundland and Labrador shelves marine ecosystem collapsed; the exceptions were small benthivore fish and especially shellfish, whose biomass increased significantly. Even though this collapse is often associated primarily with Atlantic cod in the early 1990s, declines in several functional groups started in the early 1980s. The collapse was observed throughout the system and involved commercial and non-commercial species alike. Current levels of some fish functional groups are still well below pre-collapse levels.

- Trophic structure indicators clearly show a transition from a large fish community to one of shrimp and small fish.

- Long time series on condition are only available for some commercially important species and generally indicate that fish were in better condition in the 1980s and into the early 1990s; the mid 1990s and early 2000s appear to be a period of poor fish condition; and condition seems to have improved in the late 2000s.

- In the mid 1990s, the contribution of Capelin to the diet of fish predators was reduced, while that of shrimp increased. Diets of some fish predators on the Grand Bank have been dominated by Sand Lance in recent years. For smaller/younger predators, amphipods are an important prey.

- Fishing appears as a consistent and significant driver of the trajectories of five key fish species of the NL marine community during the early-mid 1980s to the mid 1990s, and still remains as an important driver in more recent times (mid 1990s to 2008) when fisheries have been targeting mainly shrimp and crab. Environmental variables also appear as significant drivers, but their effect is less consistent than that observed for fishing.

- A study examined the relationship between seasonal sea ice dynamics, capelin biomass and timing of spawning to probe the hypothesis that capelin is environmentally regulated via food availability. The study found evidence of a regime shift and indicates that ice dynamics are a major driver of capelin dynamics. These findings suggest regulation of energy flow is bottom-up.

- A study on the drivers of Northern Cod trajectory tested competing hypotheses for patterns in the variation of the Northern Cod stock biomass since 1985: the roles of fisheries removals, predation by harp seals, and the availability of capelin, which is a key prey for cod. Among the factors considered, patterns of variation in stock biomass of Northern Cod appear to be influenced by fisheries and the availability of capelin, but not by seal predation.

- Relevant information from ERI-NEREUS results should be explicitly incorporated into stock assessments whenever possible (e.g., effects on natural mortality) and could be used to assist managers in the formulation of appropriate ecosystem-related questions.

- Information from ERI-NEREUS could be used to address longer term strategic and conceptual questions in relation to sustainable management of ecosystem goods (e.g., fisheries yields) and services (e.g., biodiversity).

- Future policy development related to the ecosystem approach would benefit from Regional scientific knowledge and expertise. Good communication within Regions and between Regions and National Headquarters is key to the development of ecosystem approach policy and frameworks.

- Comprehensive monitoring is fundamental to continuing with an ecosystem approach to science, but there should be a cost-benefit analysis of collecting additional information from new sources.

- Analysis of existing data must be assigned the top priority in any further effort on this research program.

- Ecosystem-based management will require more data, and the development of new tools and approaches as compared with the traditional single-species approach to management. Therefore more dedicated resources and increased collaboration will be required.

- A stable funding source, including appropriate human resources, tools and equipment, is key to implementing an ecosystem research program on the level of ERI-NEREUS.

- Key recommendations for future directions include the re-establishment of a national ERI network, and conducting a national review of ERI programs. Such a review would allow the application of what was learned in ERI-NEREUS to other Regions, and vice versa.

INTRODUCTION

In August 2007 a Regional Committee of scientists initiated a process aimed at filling knowledge gaps in the Newfoundland and Labrador (NL) Fisheries and Oceans (DFO) Science program deemed key for the development of ecosystem approaches to fisheries in the NL region. This work evolved into the regional component of the DFO Ecosystem Research Initiative (ERI), the "Newfoundland and Labrador's Expanded Research on Ecosystem-relevant but Under-surveyed Splicers" (NEREUS).

The ERI-NEREUS program was designed to 1) enhance the capability of Newfoundland and Labrador (NL) surveys for providing information on ecosystem status and main trends by improving monitoring on forage fishes, non-commercial species, major benthic components and trophic interactions, and 2) identify and track main pathways of energy in the NL system by integrating results from trophodynamic and statistical models with trends and patterns in ecosystem indicators.

Between 2008 and 2012, the ERI-NEREUS program added new or redesigned sampling components in DFO Research Vessel (RV) surveys, such as the collection and processing of acoustic information, implementation of a grab sampling program on the Grand Bank, a new scheme for sampling of stomach contents of key fish species, and expanded sampling of non-commercial species. In terms of analyses, some of the work has included the study of the diet in key fish species, changes in the structure of the fish community, and modelling of the role of environmental and anthropogenic drivers in the dynamics of core fish species. Two major examples are the development of a Northern Cod model to assess the simultaneous impacts of capelin, fisheries and harp seal predation, as well as the study of the linkages between bottom-up process and the regulation of capelin, the key forage species in the NL ecosystem.

The main outcomes of the program to date are:

- status and trends in main forage fish species have been described;
- structure and changes in the fish community have been described
- main components of benthic communities have been characterized and patterns described; and
- trophic interactions among key components of the NL marine community have been analysed.

The program has also provided additional benefits at the broader Regional scale such as the improved collaboration and integration among research groups as well as improved methodologies for sampling, processing, and analysis of data which have led to a more integrated picture of the NL ecosystem.

A key component of the meeting was the review and evaluation conducted by two review teams: one comprised of DFO Science staff from NL Region, and one comprised of external scientists and DFO Science staff from other Regions. Their input was also important in formulating the conclusions and recommendations from this meeting.

ASSESSMENT

Key findings from the ERI-NEREUS Program

This section of the report focuses on the following Term of Reference:
Term of Reference 1: Provide a synthesis of key findings from the ERI-NEREUS Program.

Ecoregions and lower trophic levels

There is a high degree of spatial structure in the regional plankton and fish distributions that are associated with the stability of hydrography and currents. There is a strong cross-shelf gradient in biological characteristics, and the Newfoundland and Labrador Shelf (NLS) and Grand Bank (GB) appear to show some degree of separation. Trends in the abundance of lower trophic levels have been weak during period 1999 – 2011, although there are indications of higher overall abundance of zooplankton during this period. Environmental drivers on the GB are reflected in the balance of warm-cold water species, whereas on NLS drivers are reflected in the relative contribution of basin (Labrador Sea) versus shelf species. Water mass characteristics such as salinity (freshwater, sea-ice) and stratification play an important role in governing seasonal dynamics.

There is regional coherence in a decadal pattern of variation in total copepod abundance across Atlantic Zone. The period of 1960s-70s had lower phytoplankton standing stock and higher abundance of most *Calanus* groups than during the 1990s-2000s.

Benthic communities

A benthic grab sampling program was designed and implemented during routine DFO multispecies surveys to compliment other components of the ERI-NEREUS program by acquiring knowledge of benthic species assemblages and patterns in benthic biomass and biodiversity throughout the Grand Bank. Sampling was restricted to the Spring multispecies survey because of the difficulty of conducting grabs during Fall weather conditions.

Over the three-year period, a total of 158 grab samples were collected and processed from 58 grab sample stations representing 25 survey strata and three Northwest Atlantic Fisheries Organization (NAFO) Divisions (3LNO). A total of 455 benthic macroinvertebrate taxa were identified from 22,000 specimens.

A total of 12 phyla were represented with three phyla (Annelida, Arthropoda and Mollusca) accounting for 86% of all recorded taxa. The Annelida was the most species rich phylum (39% of all species) and polychaetes accounted for 99% of all Annelid taxa. Amphipods accounted for 60% of Arthropod taxa while gastropods and bivalves accounted for 51% and 43%, respectively, of Mollusc taxa. This pattern of dominance in species richness by these three phyla is typical of Northwest Atlantic continental shelves dominated by sandy substrate.

The two phyla, Annelida and Arthropoda, which were dominant in terms of species richness, were minor components of total biomass whereas the species-poor Echinodermata dominated biomass (58% of total), particularly the sand dollar, *Echinarachnius parma* (69% of total echinoderm biomass).

Cumulative species curves, showing the cumulative number of different species observed as each new sample is added, showed that species accumulated more rapidly in Div. 3O than in

3N. Also, the curves did not reach their asymptote, indicating that potentially more species could be added with additional sampling.

Average biomass ranged from approximately 26 g/0.1m^2 in Divs. 3L and 3N, to 14 g/0.1m^2 in 3O, but did not differ significantly between divisions. The test for concordance between abiotic and biotic explanatory variables indicated a significant relationship, although it was not overly strong. The combination of variables showing the highest correlation was sample volume, water depth, and percent volume of pebbles.

The overall average biomass of 228 g/m^2 recorded in the NEREUS program is within the range of previous studies. Although it was not possible to make an accurate comparison of results from all studies given differences in some of the sampling locations, some broad trends were found.

A comparison of grab samples to bottom trawl samples from similar locations could be completed for only some species due to trawl sampling problems for some species as well as inconsistencies in recording of benthos in the earlier part of the trawl time series. However, this would be a worthwhile exercise to determine the benefits of conducting bottom grabs over collecting benthic information from trawl data.

Forage fish species

Forage fish species, including Capelin (*Mallotus villosus),* Arctic Cod *(Boreogadus saida)* and Sand Lance *(Ammodytes dubius)* are commonly taken in bottom trawl surveys conducted in NAFO Divisions 2J3KLNO. Arctic Cod are the largest of these species and are found primarily in the northern portion of the survey area, while Sand Lance are mostly found in divisions 3L and 3N. Capelin are the most widely distributed of all three species and are found in all divisions, although most of the biomass is concentrated in 3K. However, due to their vertical distribution and poor catchability in the Campelen trawl, abundance of these forage species cannot be reliably estimated using trawl data alone.

Since 2008 hydro-acoustic data has been collected during fall bottom trawl surveys. Preliminary analysis of these data, presented previously, indicated that at least two of these forage species (Capelin and Sand Lance) may be identified and tracked acoustically. Acoustic data quality issues due to bubble attenuation and other sources of interference were found to be a concern, but an initial analysis of the 2008 data indicated that the acoustic data may be adequate for use in the development of an integrated trawl/acoustic estimate for these species. Nonetheless, multiple years of data will be needed before its reliability can be properly assessed. Previously-presented survey results from the directed spring capelin acoustic surveys (1985-2010) were also reviewed in the context of the usefulness of these results as an index of capelin abundance.

New information on the biological characteristics and feeding of forage species captured during the fall bottom trawl surveys showed that the size composition of Arctic Cod and Sand Lance were found to vary little among divisions, while capelin exhibited a marked latitudinal cline, with the largest capelin occurring in 2J. There was considerable overlap in diet between capelin and Sand Lance, but less overlap with Arctic Cod. Copepods, mostly *Calanus* species, were the dominant prey item for capelin, although euphausiids and amphipods also played an important role, particularly for larger capelin. Capelin diet varied among years and areas, but with no trend. Diet composition of Sand Lance was highly dependent on fish length, with copepods dominating the diet of smaller fish, while intermediate-size Sand Lance consumed a wide variety of prey types, and large Sand Lance consumed primarily amphipods, chaetognaths and polychaetes. Fish was also an important prey for Sand Lance in 3L. Arctic Cod of all sizes were found to feed predominantly on amphipods (mostly *Thermisto* sp.), with shrimp and fish also contributing substantially to their diet.

The proportion of sampled fish with empty stomachs was highest for Sand Lance and lowest for Arctic Cod, varying among years. The total fullness index (TFI) for Arctic Cod was highest in 2010, while it was highest in 2009 for capelin and Sand Lance. TFI decreased with latitude for Arctic Cod, with the highest TFI occurring in division 3L where abundance was lowest. Likewise the TFI of capelin was low in the division with the highest densities (3K), and high in division 3N. There was no spatial trend in TFI of Sand Lance.

Changes in the structure of the fish community

As part of the ERI-NEREUS program sampling of both commercial and non-commercial species (fish and invertebrates) was improved during fall research trawl surveys from 2008-2010. This involved recording individual lengths and weights for non-commercial species, standardized collection of abundance and biomass for major benthic components, and the collection and processing of stomach samples for five groundfish species.

Trajectories in the fish community

During the late 1980s and early 1990s most of the fish community in the Newfoundland and Labrador shelves marine ecosystem collapsed; the exceptions were small benthivore fish and especially shellfish, whose biomass increased significantly. Even though this collapse is often associated primarily with Atlantic Cod in the early 1990s, declines in plankti-piscivores, and medium and large benthivores started in the early 1980s. The collapse was more dramatic in the northern regions, but was observed throughout the system and involved commercial and non-commercial species alike. Most fish functional groups showed significant declines in their biomass/abundance (BA) ratios. This generally means a loss of large fish. In recent years (~2004-2007), some fish functional groups increased from their very low levels of the mid-1990s., However, those increases stalled after 2007 and current levels are still well below pre-collapse levels. Increases in the BA ratio were also observed in recent years, especially in the northern area, but these responses are less consistent among fish functional groups; shellfish BA ratios appear to have decreased significantly in the late 1990s and early 2000s.

Ecosystem indicators

Trophic structure indicators do not necessarily correlate consistently with total biomass and/or abundance. Most trophic structure indicators are highly correlated among themselves, regardless if they are focused on trophic level (TL) or fish size. These indicators clearly show a transition from a large fish community to one of shrimp and small fish. Some signs of reversal in these patterns are observed in recent years. Since TL-based indicators rely on external sources (e.g., Fishbase), and size of the fish in the community can be estimated from RV surveys, a size-based indicator derived from survey data appears to be the best option for developing a trophic structure indicator to complement basic RV indices.

Condition analysis

Information on condition for the broad fish community is only available for 2008-2010. Long time series on condition are scarce, and those that exist focus on commercially-important species. Based on these series, some general patterns seem to emerge:

- Fish were in better condition in the 1980s and into the early 1990s.
- The mid 1990s and early 2000s appears to be a period of poorer fish condition.
- Condition seems to have improved in the late 2000s.

Diet analysis

There have been clear temporal and spatial patterns in the diets of fish predators. Capelin was a dominant prey for Atlantic Cod and Greenland Halibut in the 1980s and early 1990s in the northern area. In the mid 1990s, the contribution of capelin to the diet was reduced, while that of shrimp increased. Shrimp has become an important forage species and in recent years, both Atlantic Cod and American Plaice diets have been dominated by shrimp in northern areas. Greenland Halibut and Redfish also consume shrimp in this region, although diets on the Grand Bank have been dominated by Sand Lance in recent years. Sand Lance dominate the diet of Yellowtail Flounder in 3LNO, American Plaice in 3L, and Atlantic Cod in 3NO. For smaller/younger predators, amphipods are an important prey. Redfish diet in 3L and 3N has been dominated by amphipods in recent years, and its diet in general is mostly amphipods and shrimps. Among benthic invertebrates, brittle/basket stars and other echinoderms, as well as polychaetes, are important prey for American Plaice and Yellowtail Flounder. For those areas with data available (3LN), recent diets for these two predators appear to have a lower proportion of invertebrates and a higher proportion of fish than in previous years. The northern Grand Bank (3L) often shows transition diets in predator species.

Marine mammals

Consumption of Atlantic Cod by harp seals off the east coast of Newfoundland and Labrador in NAFO Divisions 2J3KL was estimated by integrating information on the numbers at age, age-specific energy requirements, seasonal distribution, and diet of harp seals in the area. Abundance was estimated using a population model integrating pup production between the late 1970s and 2004, annual estimates of reproductive rates from 1954-1998, and data on age-specific removals from 1952-2008. Energy requirements of the population were estimated using a simple allometric model based on body mass obtained from monthly, sex-specific growth curves. The proportion of energy obtained in 2J3KL was estimated using data obtained from satellite telemetry and traditional tagging studies. The diet of harp seals in nearshore and offshore waters during winter (October – March) and spring (April – September) was determined by reconstructing the wet weight of stomachs collected in 1982 and 1986-2007. The impact of different diet determination methods was explored by estimating consumption using a multinomial regression approach (MNR) and fatty acid signatures (FAS). Uncertainty in the consumption estimates was approximated by incorporating the uncertainty in the numbers at ages, diets, energy requirements, and seasonal distribution.

Total prey consumption by harp seals in 2J3KL during 2008 was estimated to be approximately 4.2 million tonnes. However, this estimate was imprecise with 95% CI being 3.2 million – 5.4 million tonnes. Consumption of individual prey species varied greatly depending upon the assumed diet; there were significant differences in the proportion of each prey species in the diet determined by the various methods. The different methods of estimating diet did not change the estimates of total biomass, but did result in significant differences in the consumption estimates for individual prey species.

Capelin were one of the most important prey species for harp seals in 2008. Based upon the average diet, capelin consumption was estimated to be approximately 1.26 million (95% C.I. 939,000 – 1,651,000) tonnes. Similar estimates were obtained using the MNR diet, while the FAS diet resulted in a much lower estimate. Consumption of Arctic Cod, another important prey, was estimated to be 239,000 (95% C.I. 84,000 – 531,000) tonnes in 2008. In contrast to the average which suggests an increase over time, the MNR model suggested a trend in consumption, increasing from 1965 to 1986 and then declining to a very low level by 2008. The estimates of Atlantic Cod consumption were highly dependent upon the diet assumed. A total of 134,600 (95% C.I. 68,000 – 237,000) tonnes was estimated to have been consumed based upon the average diet. The multinomial diet approach suggested cod consumption increased from very low levels at the beginning of the series to extremely high, but uncertain, amounts in 2008 (565,000, 95% C.I. 75,000 – 1,112,000 tonnes). However, this estimate is dependent upon the appropriateness of using nearshore data to estimate diets in offshore areas where prey availability differs and likely overestimates cod consumption. Very little cod was found in the diets derived using fatty acid samples and as a result, consumption was extremely low (<1,500 tonnes).

Harp seal growth rates and maximum body size was lower in the 1990s than in the 1980s which, if continued, suggests that current energy requirements, and the resulting consumption, are overestimated. Other predators, particularly fish and cetaceans, also consume large amounts of prey and must be considered when trying to understand the impact of predation on components of the Northwest Atlantic ecosystem.

Analysis of common trends in key fish species

The influence of environmental variables and fisheries impacts on the trajectories of five key fish species of the Newfoundland-Labrador marine community was explored using dynamic factor analysis (DFA). The species considered for this analysis were Atlantic Cod, Greenland Halibut, American Plaice, Redfish and Yellowtail Flounder. Four sets of time series were considered for analysis on the basis of geographical area, season, and gear employed in the research survey. For each dataset (area, gear and time period), several DFA models with different combinations of common trends and explanatory variables were explored. Models were selected using the Akaike Information Criterion (AIC). The results indicated that there were common trends in the biomass trajectories of the five fish species in all areas and time periods. Negative trends were found to occur from the early-mid 1980s to the mid 1990s, while positive trends characterized the period from the mid 1990s to 2008. Fishing appears as a consistent and significant driver in the earlier period, but also still remains as an important driver in the more recent one, during which fisheries have been targeting mainly shrimp and crab. The North Atlantic Oscillation (NAO), sea surface temperature at Station 27 (ST27-SST) and the Composite Environmental Index (CEI) also appear as significant drivers, but their effect is less consistent than that observed for fishing. By region, the CEI appears as a driver in the north (2J3KL), while ST27-SST, and to a lesser extent NAO, appear more relevant in the Grand Bank (3LNO).

Environmental regulation of capelin

This study examined the relationship between seasonal sea ice dynamics, capelin biomass and timing of spawning to probe the hypothesis that capelin is environmentally regulated via food availability. The study found evidence of a regime shift and indicates that ice dynamics are a major driver of capelin dynamics. Fishing was not a major driver during the period considered for this study (~1980s – 2010). The suggested mechanism is a match-mismatch in timing of the onset of the spring bloom of phytoplankton and the emergence of *Calanus* from diapause. This suggests regulation of energy flow is bottom-up. Further study into the mechanisms involved is required.

Drivers of Northern Cod trajectory

The objective of this study was to test competing hypotheses for the patterns in the variation of the Northern Cod stock biomass since 1985: the roles of fisheries removals, predation by harp seals, and the availability of capelin, which is a key prey for cod. Among the factors considered, patterns of variation in stock biomass of Northern Cod appear to be influenced by fisheries and the availability of capelin, but not by seal predation. The interplay between the two influential drivers could not be fully resolved, in part resulting from the absence of capelin surveys during the 1990s and 2006.

Use of ERI-NEREUS results in current management processes

Term of Reference 2: Examine how ERI-NEREUS results can be used in the context of scientific advice for current management decision processes.

Most current decision processes related to an ecosystem approach to management (EAM) focus on more general questions coming from recent ecosystem-based policies and frameworks, such as the role of forage species, by-catch, and identification of protected areas and species.

However, as ERI-NEREUS activities contribute to enhanced understanding of the ecosystem, more explicit questions and advice may be incorporated. Results of ERI-NEREUS have been or are being used to address specific management questions, which include the definition of Ecologically and Biologically Significant Areas (EBSAs), delineation of ecoregions and candidate ecosystem-level production units (NAFO), as well as supporting the NAFO process aimed at the identification of potential closed areas for coral and sponge protection. Results from ERI-NEREUS have also been used as part of the support DFO provides to industry for eco-certification applications.

Relevant information from ERI-NEREUS results should be explicitly incorporated into stock assessments whenever possible (e.g., effects on natural mortality) and should be used to assist managers in the formulation of appropriate ecosystem-related questions.

Implications for management frameworks and policy development

Term of Reference 3: Examine the implications of ERI-NEREUS findings for the development and implementation of integrated ecosystem-oriented management frameworks and possible implications for policy development.

Information from ERI-NEREUS could be used to address longer term strategic and conceptual questions in relation to the sustainable management of ecosystem goods and services. These goods and services can be thought of in terms of the benefits that accrue from the functioning of healthy and productive ecosystems, such as fisheries yields and biodiversity. There is also some benefit in considering approaches used in organizations such as NAFO; compatible perspectives by DFO and NAFO will be necessary to successfully implement Ecosystem-Based Management (EBM) in the NL Region.

Future policy development related to the ecosystem approach would benefit from early input from Regional scientific knowledge and expertise. National policy direction relating to the ecosystem approach will influence the types of data needed, and the subsequent scientific advice. This should be accounted for in the Regional planning process. Also, an overarching and comprehensive national policy on how DFO will develop and implement EBM, beyond what is covered by the Sustainable Fisheries Framework, would benefit the Regional Science planning process.

Good communication should exist between Regions and NHQ on various approaches and policy development. As well, improved, more formal communication between Fisheries Management, Oceans, and Science is required to develop an ecosystem approach framework. An ecosystem approach will require both enhanced and closer collaboration between management and science sectors, as well as enhanced research activities.

As part of the necessary dialogue between scientists and managers, both groups need to be cognizant of the potential for “distortion of concepts” in the interface between management and science. Some terms and words are used by different sectors (e.g. scientists and managers) assuming that the underlying ideas described by them are identical; however, often the full complexity and extent of the intended meaning in a scientific context is not the same when the term is carried through for use in a management context. It is essential for successful EBM policy development that underlying concepts of an ecosystem approach are well understood and that implementation does not “lose anything in translation”.

Future research topics and directions

Term of Reference 4: Identify future research topics and directions required to provide the science base for integrated ecosystem assessment in the NL region.

The response to this ToR can be summarized under several headings, as follows, and includes input from both review teams:

Data collection/sampling

Monitoring is fundamental to continuing with an ecosystem approach to science, but there should be cost-benefit analyses of collecting additional information from new sources. Some of the analyses that are required to answer questions about the ecosystem will require continued ERI data collection in order to have sufficient time series. At the same time, to facilitate proper data management, all RV data should be integrated into relational databases.

Annual surveys that extend the existing time series for forage species should be a continued priority. Length-based sampling of all species, and identification of invertebrates, should also continue on the multispecies trawl surveys. It was recognized that additional comparative fishing between Engel and Campelen trawls would potentially increase the time series of comparable data across a broad range of species. However, there are a number of noteworthy challenges associated with this, not the least of which is availability of vessel time and resources to conduct the work.

Currently, estimates of abundance and length composition of forage species such as capelin, Sand Lance and Arctic Cod, critical to bio-energetic and trophic dynamic modeling, are being reported from catches by the Campelen survey trawl. It is therefore imperative to validate whether these survey catches can accurately reflect annual trends in size composition and biomass of each species. The combined use of acoustics and trawling can be used in this validation and compared with the work from other countries.

Recognizing the value of hydro-acoustic data for forage species, and the ability to collect such data on the multispecies surveys, the extent to which hydro-acoustic data processing can be automated should be investigated.

Benthic data that were previously collected using different techniques should be compared and, if appropriate, alternative sampling techniques should be considered for measuring the benthos. This could be compared with work from other countries. It is important to validate whether the Campelen survey trawl used in the ecosystem surveys can be accepted as a benthic sampler. Currently this is being investigated by researchers at the Institute of Marine Research in Bergen, Norway, who also use the same Campelen trawl.

Finally, a "checklist" should be produced of all the ERI-related sampling equipment and techniques that could easily be employed or deployed, with or without a successor program to ERI-NEREUS.

Analysis/modelling

As noted previously, some of the analyses that are required to answer questions about the ecosystem will require continued ERI data collection in order to have sufficient time series.

Analysis of existing data must be assigned the top priority in any further effort on this research program, as opposed to other activities. More detailed analyses on the other commercial (Greenland Halibut, Redfish, Yellowtail Flounder) and/ or predominant forage species (Sand Lance, shrimp, Arctic Cod) would be useful. This could include exploration of acoustic results for Arctic Cod, Sand Lance and other species. Methods should also be explored to integrate acoustic and trawl data, e.g. Bayesian approaches.

To examine size changes in capelin, energetic consequences and how their trophic roles change should be considered. Benthic productivity should be compared across samples/time periods and standardized in some way. Diet analyses should continue; this work should also include an assessment to determine the optimal approach to diet studies given the logistical constraints (e.g. comparison between estimates based on the examination of dominant prey in stomachs, all prey, or a combination of these approaches).

Interpretation and synthesis of program results

Additional weight of evidence is required to support mechanisms implicit in the bioenergetic (cod-capelin-seal) model. For example, other plausible hypotheses should be explored in the consumption patterns of seals. This analysis should be strengthened by including additional weight of evidence for implied hypotheses.

To help with synthesis of program results, linkages between all of the ERI components should be shown, and compared with how the components were intended to integrate at the outset of the ERI program. An overarching document concerning the net gains from the program should be produced, along with a synthesis of the ERI results produced from this meeting.

Recommendations for management and future planning

Efforts should be made to re-establish a meaningful ERI national network. A national review of ERI programs should be carried out, where it would be useful to apply what was learned in NEREUS to other Regions, and vice versa. Increased emphasis needs to be placed on interactions with client groups (e.g., FAM, Oceans), along with continued or increased collaboration with academia. An overarching and comprehensive policy framework for how DFO will implement EBM, which could provide linkages to existing policies (e.g. Sustainable Fisheries Framework), as well as guide the development of new ones, should be developed.

ERI-NEREUS data enables Science to address more questions than before, but it is still not sufficient. Ecosystem science needed for EBM will require more data and the development of new tools and approaches as compared with the traditional single-species approach to management, and therefore more dedicated resources and increased collaboration will be required. Finally, it was agreed that stable funding, including appropriate human resources is key to implementing an ecosystem research program at the scope of ERI-NEREUS.

CONCLUSIONS AND ADVICE

Relevant information from ERI-NEREUS results should be explicitly incorporated into stock assessments whenever possible and could be used to assist managers in the formulation of appropriate ecosystem-related questions. Information from ERI-NEREUS could also be used to address longer term strategic and conceptual questions in relation to sustainable management of ecosystem goods and services.

Future policy development related to the ecosystem approach would benefit from early input from Regional scientific knowledge and expertise. Good communication on ecosystem approach frameworks and policy development should exist between the Regions and National Headquarters (NHQ) as well as among Sectors within Regions.

Analysis of existing data must be assigned the top priority in any further effort on this research program. Monitoring is fundamental to continuing the science needed for an ecosystem approach to management, but there should be cost-benefit analysis of collecting additional information from new sources.

The ecosystem science needed for EBM requires more data, and the development of new tools and approaches when compared with the science needed for traditional single-species management, and therefore more dedicated resources and increased collaboration will be required. A stable funding source, including human resources, tools and equipment, is key for implementing an ecosystem research program at the scope of ERI-NEREUS.

Recommendations for future direction include re-establishment of a national ERI network, and conducting a national review of ERI programs, applying what was learned in ERI-NEREUS to other Regions and vice versa. The need for an overarching and comprehensive EBM policy framework at the national level was also identified.

OTHER CONSIDERATIONS

Overviews of current policies, tools, and guidelines used in support of EBM were presented. These focused on the perspectives the Fisheries Management and Oceans sectors of DFO, as well as an overview of recent work in NAFO Scientific Council.

Fisheries Management (FM) uses Science advice and information in support of EBM. An ecosystem approach requires that fisheries management decisions consider the impact of the fishery not only on the target species, but also on non-target species, seafloor habitats, and the ecosystems of which these species are a part. This ecosystem advice and information currently feeds into the Integrated Fisheries Management Plan (IFMP) for each fishery, the Sustainable Fisheries Framework (SFF), and Regional DFO Eco-certification support provided to industry. IFMPs consider information concerning issues such as by-catch, species interactions, habitat, and climate change. The SFF also requires this information for policy development and implementation, and might consider such information as mortality of discards, environmental conditions, and species interactions. Nonetheless, at the present time there are no formal mechanisms linking individual IFMPs and their specific objectives; this makes addressing the potential need for trade-offs among fisheries operating within the same ecosystem difficult. DFO is also committed to supporting the fishing industry in their applications for eco-certification. "Minimizing environmental impacts" is one of three principles applied in the assessment methodology of the Marine Stewardship Council, which considers the structure, productivity, function and diversity of the ecosystem on which the fishery depends.

Oceans Programs operate under the *Oceans Act* to promote sustainable use, the ecosystem approach, the precautionary approach and collaboration. Under Integrated Management (IM) it is necessary to develop and implement integrated management plans. Available tools include Marine Protected Areas (MPAs)/MPA Networks, coral conservation strategy, etc., but IM is to be implemented within existing regulatory mechanisms. The draft IM Plan for the Placentia Bay-Grand Banks Large Ocean Management Area (LOMA) is strategic level and includes ecosystem objectives related to productivity, biodiversity, and marine environmental quality. Science work on conservation objectives, EBSAs, Ecologically Significant Species, depleted species, etc. has been a significant contribution. IM is supposed to transition from the LOMA scale to a larger bioregional scale. To progress with this, continued collaboration and engagement with Science will be required to move from strategic levels of IM to operational levels (e.g., indicators, thresholds, conservation targets), and to assist with MPA network and IM work at bioregional scales (e.g. identification of EBSAs, conservation objectives, etc.). Continued collaboration and engagement with FM will be needed to address coral conservation issues and to examine linkages between SFF requirements and potential implementation via IM and MPAs.

NAFO is in the process of further developing its roadmap for an ecosystem approach to fisheries. It is an objective-driven approach that considers long-term ecosystem sustainability in a place-based framework, and explicitly addresses trade-offs, i.e., recognizing the many, and often competing, human interests in fisheries and marine ecosystems. Practical steps include definition of adequate spatial management units and management tools, and the definition of ecosystem state and function processes. A three-tier hierarchical process was outlined, going from overall ecosystem fishery production to single-species yields. The three tiers are: 1. Determination of fisheries production potential at the ecosystem level; 2. Allocation of the production among target species (multispecies trade-offs); and, 3. Validation/verification of sustainability at the single-stock level.

SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, (Regional advisory meeting of January 17-19, 2012 on Ecosystem Research Initiative (ERI) – NEREUS Program). Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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