ICES WGNARS REPORT 2011

SCICOM STEERING GROUP ON REGIONAL SEA PROGRAMMES

ICES CM 2011/SSGRSP:01

REF. SCICOM

Report of the Working Group on the Northwest Atlantic Regional Sea (WGNARS)

8–10 February 2011

Halifax, Canada

ICES
International Council for the Exploration of the Sea
CIEM
Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Recommended format for purposes of citation:

ICES. 2011. Report of the Working Group on the Northwest Atlantic Regional Sea (WGNARS), 8–10 February 2011, Halifax, Canada. ICES CM 2011/SSGRSP:01. 65 pp.
https://doi.org/10.17895/ices.pub.9007

Contents

Executive summary

The second meeting of Working Group on the Northwest Atlantic Regional Sea (WGNARS) chaired by Steve Cadrin, USA, and Catherine Johnson, Canada, was built on the foundations made in 2010 to inventory information available for integrated ecosystem assessment, and the 2011 meeting assimilated information to be used as indicators and thresholds for ecosystem-based management of human activities. WGNARS is fortunate to have well developed ocean observation systems, ecosystem surveys and habitat studies, but is challenged to develop meaningful integration of the information. Similar to the inspiration of St Francis Assisi to do the impossible in the first stage of WGNARS (ICES, 2010c), the second stage of integrated ecosystem assessment was motivated by Warren Bennis's guidance on leadership:

"We have more information now than we can use, and less knowledge and understanding than we need…The true measure of any society is not what it knows but what it does with what it knows."

The Working Group on the Northwest Atlantic Regional Sea (WGNARS) is one of several regional sea programmes within ICES. WGNARS was formed in 2009 with a long-term objective of developing an integrated ecosystem assessment of the Northwest Atlantic Ocean. In 2011, the short-term goal was to continue to develop the scientific support for an integrated assessment of the Northwest Atlantic region to support ecosystem approaches to science and management.

The infrastructure available for IEA was inventoried in 2010 (ICES, 2010c) with a focus on ocean observation systems, ecosystem surveys and habitat information. Previous WG decisions were recognized with respect to forms of integration: 1) considering the entire ecosystem, from the physical environment to apex predators; 2) human pressures will be included, and advice will be provided to manage human activities separately by sector; and 3) socio-economic aspects will be incorporated to better define ecosystem objectives. The spatial scope will be hierarchical, with a focus on the Northwest Atlantic continental shelf, but expanded to inshore or offshore areas as required by the objective at hand.

The initiative to inventory programs for ocean observation, ecosystem surveys and habitat studies continued in 2011, with a program description for the Ocean Tracking Network (OTN) and ocean modelling capabilities. The WGNARS and Northwest Atlantic OTN meetings were coordinated so that WGNARS members could attended the OTN meeting, and the OTN program could be presented to WGNARS. The OTN provides one opportunity to investigate regional connectivity of marine resources and integrate ocean observation systems across the region. The ocean model descriptions demonstrated the importance of the Arctic Ocean in ecosystem dynamics of the Northwest Atlantic.

Several case studies were presented that integrate information from multiple ocean observation, ecosystem survey sources to demonstrate holistic ecosystem approaches to evaluating ecosystem productivity, biodiversity and climate effects. Case studies included network analysis, habitat evaluations, and ecological interactions of the North Atlantic Oscillation/*Calanus*/right whales. Network analysis shows promise for supporting marine spatial planning and many other ecosystem-based management strategies. Habitat studies effectively integrate geological, ecological and oceanographic information and processes for place-based evaluations of the ecosystem. The cusk and NAO/*Calanus*/whale case studies demonstrated an integration of biodiver-

sity (cusk and right whales are threatened species), climate, ecosystem surveys, thermal habitat, bottom habitat, and oceanography.

A strong initiative was made to determine socio-economic components of an integrated ecosystem assessment, and the session on social sciences led to a broader consideration of objectives, indicators and thresholds. Candidate indicators of ecosystem status were identified that reflect important patterns in the physical environment, trophic dynamics, and system productivity. Indicators were intended to coordinate ocean observation systems, ecosystem survey data and information on habitats throughout the Northwest Atlantic region. As such, integrated analyses of the relationships between physical and biological aspects of the Northwest Atlantic ecosystem (e.g. predictable state changes, climate impacts, biodiversity, and community analyses) were initiated. Candidate thresholds were considered for each indicator.

The principal product of the 2011 WGNARS meeting was a comprehensive list of indicators. More importantly WGNARS recognized that indicators represent a triad of drivers to reflect major ecosystem features and processors. All candidate indicators were categorized into 1) human drivers (e.g. fishing, contaminants); 2) internal drivers (e.g. trophodynamics, biodiversity); and 3) external drivers (e.g. climate, oceanography). A general approach to thresholds was developed with a focus on those that could eventually lead to management actions.

1 Opening of the Meeting

The venue for the meeting was the Bedford Institute of Oceanography (BIO), a major Canadian government ocean research facility located in Dartmouth, Nova Scotia. Established in 1962 as Canada's first, and currently largest, federal centre for oceanographic research, BIO derives its name from the Bedford Basin, an inland bay comprising the northern part of Halifax Harbour, upon which it is located. The WG was fortunate to have introductions and welcomes from Alain Vezina (founding co-chair of WGNARS), as well as Mike Sinclair, ICES President. Alain succeeded Mike as the Regional Director of Science for the Maritimes Region of the Department of Fisheries and Oceans. Alain noted the influence of change in the Arctic on the ecosystems of the Northwest Atlantic, and he discussed the increasing importance of integrating science and policy at a regional and national level in Canada. DFO currently has an Ecosystem Approach to Management framework in place; the challenge is to operationalize it.

2 Development and Adoption of the agenda

The agenda was formed by the steering committee to meet the terms of reference, and the organization of this report reflects the schedule of topics. Background presentations included a description of WGNARS and the Regional Seas Program, an update on Integrated Ecosystem Assessment in the US, an overview of the NAFO WG on Ecosystem Approach to Fishery Management (WGEAFM), the State of the Environment Reporting for Ocean Management in the Canadian Maritimes Region, and a summary of ecosystem status reports in the northeast US.

The next session focused on socio-economic components of an integrated ecosystem assessment of the Northwest Atlantic, including an update on ICES Study Group on Integration of Economics, Stock Assessment and Fisheries Management (SGIMM) and presentations by social scientists Tony Charles, Larry Hildebrand and Patricia Clay. Most of the agenda was devoted to determining candidate indicators of ecosystem status that reflect important patterns in the physical environment, trophic dynamics, and system productivity and initiating integrated analyses of the relationships between physical and biological aspects of the Northwest Atlantic ecosystem. A session was devoted to habitat and spatial planning. The final session formed conclusions and identified the next steps for WGNARS.

3 Introduction – the Ecosystem Approach to Management (EAM) and required science support (ToR a)

3.1 Background of WGNARS and the Regional Seas Program – Steve Cadrin and Yvonne Walther

As an orientation to the 2011 Working Group objectives, ICES, the ICES Science Plan, the ICES Regional Sea Programme, the 2010 WGNARS Report, and the plans for a Benchmark Workshop on Integrated Ecosystem Assessment were presented. Background information is summarized here to help introduce new scientists in the Northwest Atlantic region to WGNARS. ICES coordinates and promotes marine research on oceanography, the marine environment, the marine ecosystem, and on living marine resources in the North Atlantic. Members of the ICES community now include all coastal states bordering the North Atlantic. ICES is a network of more than 1600 scientists from 200 institutes linked by an intergovernmental agreement to add value to national research efforts. Scientists working through ICES gather information about the marine ecosystem. This information is developed into unbiased, non-political advice. The 20 member countries that fund and support ICES use this advice to help them manage the North Atlantic Ocean and adjacent seas. The ICES Mission is to advance the scientific capacity to give advice on human activities affecting marine ecosystems.

The ICES Science Plan for 2009–2013 has several components that are directly related to the objectives of WGNARS:

- Understanding Ecosystem Functioning: Climate change processes and predictions of impacts; Biodiversity and the health of marine ecosystems; the role of coastal-zone habitat in population dynamics of commercially exploited species; Sensitive ecosystems as well as rare and data-poor species; Integration of surveys in support of ecosystem approaches to management; …
- Understanding Interactions of Human Activities with Ecosystems: Impacts of fishing on marine ecosystems; Population and community level impacts of habitat changes in the coastal zone; …
- Development of Options for Sustainable Use of Ecosystems: Marine living resource management tools; Operational modelling combining oceanographic, ecosystem, and population processes; Marine spatial planning, including the effectiveness of management practices (e.g. MPAs), and its role in the conservation of biodiversity; …

Within the ICES organizational structure, WGNARS is an expert group under the guidance of the Steering Group on Regional Seas Programme (SSGRSP), which reports to the Science Committee (SCICOM). However, WGNARS and SSGRSP are developing the scientific basis for future advice on marine resource management, and will eventually have more intimate linkages to the ICES Advisory Committee (ACOM). The SSGRSP promotes interactions among subsidiary expert groups (Figure 3.1.1) with focus on benchmarking, guidelines and tangible products for advice, development of ecosystem health issues (e.g. biodiversity, contaminants), integrated modelling, multidisciplinary initiatives and coordination with external organizations with regional interest. The SSGRSP encourages publications from WGNARS, entrepreneurism for funding, marketing within ICES science and advisory groups as well as stakeholder groups, and participation from non ICES scientists.

One contribution of WGNARS is for the Workshop on Benchmarking Integrated Ecosystem Assessments (WKBEMIA), planned for 30 November – 1 December 2011 in Copenhagen. The objective of WKBEMIA is to start a process on how to Benchmark Integrated Ecosystem Assessment (IEA) based on results in ongoing Integrated Ecosystem Assessments Expert Groups. The workshop will make a brief review on the various concepts of Integrated Ecosystem Assessments including an evaluation of suitability to ICES needs in terms Science and Advice; review the Integrated Ecosystem Assessments in the ongoing Regional Expert Groups, with regards to methods, models and results; identify a common framework which will act as a guideline for Integrated Ecosystem assessments performed in ICES; and identify the need of supporting data, processes and products.

WGNARS leadership is from the co-Chairs (Steve Cadrin and Catherine Johnson) and a steering Committee that has leaders for ocean observation and climate (Jon Hare, Charles Hannah and Dave Hebert), ecosystem surveys and biodiversity (Jason Link and Ken Frank) as well as habitat and spatial management (John Manderson). The intention of the WGNARS proposal was to provide a venue for communication among researchers and ecosystem programs. WGNARS should complement existing programs and serve an advisory role in the governance of ecosystem programs in the Northwest Atlantic region. Governance of WGNARS itself should be through the co-chairs and steering committee. WGNARS should be inclusive to all relevant scientists, programs and stakeholders.

Spatial and temporal scopes of WGNARS will be multi-scale. Boundary decisions will have exceptions that need to be considered for some processes or applications. A multi-scale, hierarchical approach was agreed upon in which the continental shelf would be the main focus for agenda setting and determining participants, but data and processes outside that scope (e.g. estuaries, deep sea) would be considered as adjacent tiers as needed. WGNARS will recommend terms of reference on a year-by-year basis, but a longer-term perspective will be needed to coordinate existing data, identify gaps or limitations and recommend improvements within a 5 to 10 year time horizon. The SSGRSP timeline includes the 2011 Benchmark Workshop (WKBEMIA), to be followed by internal ICES workshops on integrated assessments, then stakeholder workshops on integrated assessments.

Several aspects of integration were considered by WGNARS. The ecosystem will be considered from the physical environment to apex predators. Advice will be provided to manage human activities separately by sector, because governance structures are not in place to provide integrated advice. Socio-economic aspects will be incorporated to promote the definition of ecosystem objectives.

The 2010 WGNARS report (ICES 2010c) provides an extensive inventory of information available for integrated ecosystem assessment of the Northwest Atlantic. Recommendations from 2010 were to monitor common 'core variables' in ocean observation systems, apply multiple oceanographic models to the entire Northwest Atlantic to support ensemble analysis of large-scale features, intersessional coordination of Northwest Atlantic OOS's, continue the 'East Coast of North America Strategic Assessment Program' and expand it beyond trawl surveys and other countries, contribute to a workshop on the scientific support for Marine Spatial Planning, and invite social scientists to WGNARS meetings to help propose a workshop on the socio-economic aspects of an IEA in the NW Atlantic

Goals for the 2011 WGNARS meeting are:

- Continue to develop the scientific support for an integrated assessment of the Northwest Atlantic region to support ecosystem approaches to science and management;
- Determine candidate indicators of ecosystem status that reflect important patterns in the physical environment, trophic dynamics, and system productivity;
- Coordinate ocean observation systems, ecosystem survey data and information on habitats throughout the Northwest Atlantic region;
- Initiate integrated analyses of the relationships between physical and biological aspects of the Northwest Atlantic ecosystem (e.g. predictable state changes, climate impacts, biodiversity, community analyses);
- Propose candidate thresholds for each indicator;
- Determine socio-economic components of an integrated ecosystem assessment of the Northwest Atlantic.

- Review the work of other integrated assessment activities in ICES (e.g. WGIAB and WGINOSE) as well as in ongoing research projects.

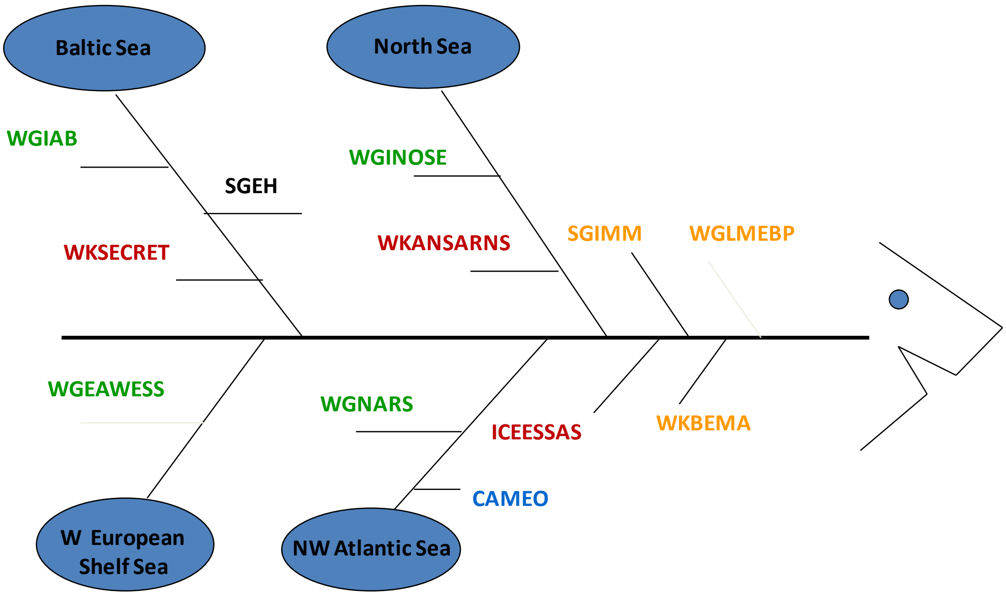

Figure 3.1.1. Relationship of expert groups in the ICES Regional Seas Programme, see Table 3.1.1 for definition of acronyms.

Table 3.1.1. Expert groups in the ICES Regional Seas Programme.

EXPERT GROUP	NAME
CAMEO	Comparative Analysis of Marine Ecosystem Organization
WGIAB	ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea
SGEH	Study Group for the development of Integrated Monitoring and Assessment of Ecosystem Health in the Baltic Sea
SGIMM	Study Group on Integration of Economics, Stock Assessment and Fisheries Management
WGEAWESS	Working Group on Ecosystem Assessment of Western European Shelf Seas
WGINOSE	Working Group on Integrated Assessments of the North Sea
WGLMEBP	Working Group on Large Marine Ecosystem Program Best Practices
WGNARS	Working Group on the Northwest Atlantic Regional Sea
WKANSARNS	Workshop on anchovy, sardine and climate variability in the North Sea and adjacent areas
WKBEMIA	Workshop on Benchmarking Integrated Ecosystem Assessments
ICESSAS	Workshop on Ecosystem Studies of the Sub-arctic Seas
WKSECRET	Workshop on Including Socio-Economic considerations into the Climate-recruitment framework developed for clupeids in the Baltic Sea

3.2 NOAA's Integrated Ecosystem Assessment (IEA) program – Rebecca Shuford

The US National Oceanic and Atmospheric Administration (NOAA) approach to Integrated Ecosystem Assessments (IEAs) offers a way to better manage resources to achieve economic and societal objectives. IEAs provide a sound scientific basis for EBM. They are "a synthesis and quantitative analysis of information on relevant physical, chemical, ecological, and human processes in relation to specified management objectives" (Levin, *et al.*, 2009). The resulting analyses, done at scales relevant to management questions, provide resource managers with information to make more informed and effective management decisions.

IEAs, as NOAA defines them, provide a process to work closely with stakeholders and managers to identify priority management issues and provide robust decision-support information. IEAs integrate diverse ecosystem data, including socio-economic information, to analyse ecosystem and community status relative to a defined issue then predict future status based on forecasts of natural ecosystem variability coupled with evaluation of alternate management strategies. Through this process the benefits and risks to social and ecological sectors – the trade-offs – of alternate management actions are evaluated and defined to inform stakeholders and managers in their decisions. Through continued evaluation of performance, the IEA process allows adaptive management.

The primary objective of IEAs is to make comprehensive information available to inform management decisions. Examples of important information include:

- assessments of status and trends of the ecosystem condition, including ecosystem services;
- assessments of activities or elements in an ecosystem that can stress the ecosystem;
- prediction of the future condition of the ecosystem under stress if no management action is taken;

- prediction of the future condition of the stressed ecosystem under different management scenarios and evaluation of success of management actions to achieve the desired target.

NOAA's IEA approach and program concept have been under development for several years. A national framework has been defined and provides IEA practitioners a consistent, yet flexible, architecture to meet regional needs. NOAA is building a national IEA program that will include eight regions whose geographic boundaries are based on US Large Marine Ecosystems. At present, formal IEA work is being conducted to develop and implement IEAs in five regions: the California Current, the Gulf of Mexico, the Northeast Shelf, as well as the Alaska Complex and the Pacific Islands. The remaining three regions (Southeast Shelf, Caribbean, and Great Lakes) will follow as the program grows.

While IEAs are in their early stages, transfer of the architecture, methods, and information occurs across regions, including sharing of best practices and lessons learned. Thus progress is iterative as experience is gained. Additionally, in a fiscally limited environment, regions have been leveraging expertise in framework areas where they already have some capacity to build on. The resulting progress has enabled building of key infrastructure and will support implementation of the full process over time. However the ability to implement proposed "next steps" are influenced by continued fiscal considerations.

NOAA's IEA approach is an iterative decision-support process that uses diverse data and ecosystem models. Once EBM objectives are agreed to by resource managers and stakeholders, models are used to simulate the future outcome of potential management actions. These outcomes allow a comparison of the possible economic and ecological trade-offs to guide management decisions. After a management plan has been implemented, the process can be repeated in future to evaluate the effectiveness of the plan (adaptive management), and identify knowledge and data gaps. Each step of the IEA contributes to this process to provide for better management of ocean and coastal resources through an ecosystem-based approach.

Steps in the IEA Process (Figure 3.2.1)

Scoping: The scoping process involves broad stakeholder involvement to identify critical ecosystem management objectives and targets as well as stressors and pressures at a scale relevant to the ecosystem and management questions being assessed. This step is important because ecosystem issues cross ecological, social, jurisdictional and political boundaries.

Indicators: Develop and test indicators that reflect ecosystem attributes and stressors, providing the basis to assess the status of and trends in the state of the ecosystem and to evaluate management scenarios, trade-offs, socio-economic impacts, and management performance. Long-term, sustained monitoring of indicators is necessary for tracking the status and trends in the condition of the ecosystem and to evaluate any changes as a result of management actions.

Risk Analysis: Analysis is performed, often through ecosystem models, to evaluate the risk posed by human activities and natural processes on the identified indicators. This helps determine the likelihood that pressure on the ecosystem will cause an indicator to reach or remain in an undesirable state, and its ability to recover.

Assessment of Ecosystem Status: Results of the risk analysis for each individual indicator are integrated during the assessment phase to quantify the status of the ecosystem relative to the baseline condition or to management objectives and targets.

Management Strategy Evaluation: An ecosystem modelling framework is used to evaluate the potential for different management strategies to influence the status of system indicators and to explore and predict how ecosystems respond to change, including from management actions. This step facilitates analysis of trade-offs and helps resource managers understand how different management strategies may change the status of the natural and human components of the ecosystem, better informing their decisions.

Monitoring and Evaluation: Once the manager selects and implements a management action, continual monitoring and assessment of ecosystem indicators is important to help determine whether or not management strategies are successful; enables adaptive management.

For more information on NOAA's Integrated Ecosystem Assessment program and regional activities, visit the IEA website at: http://www.st.nmfs.noaa.gov/iea

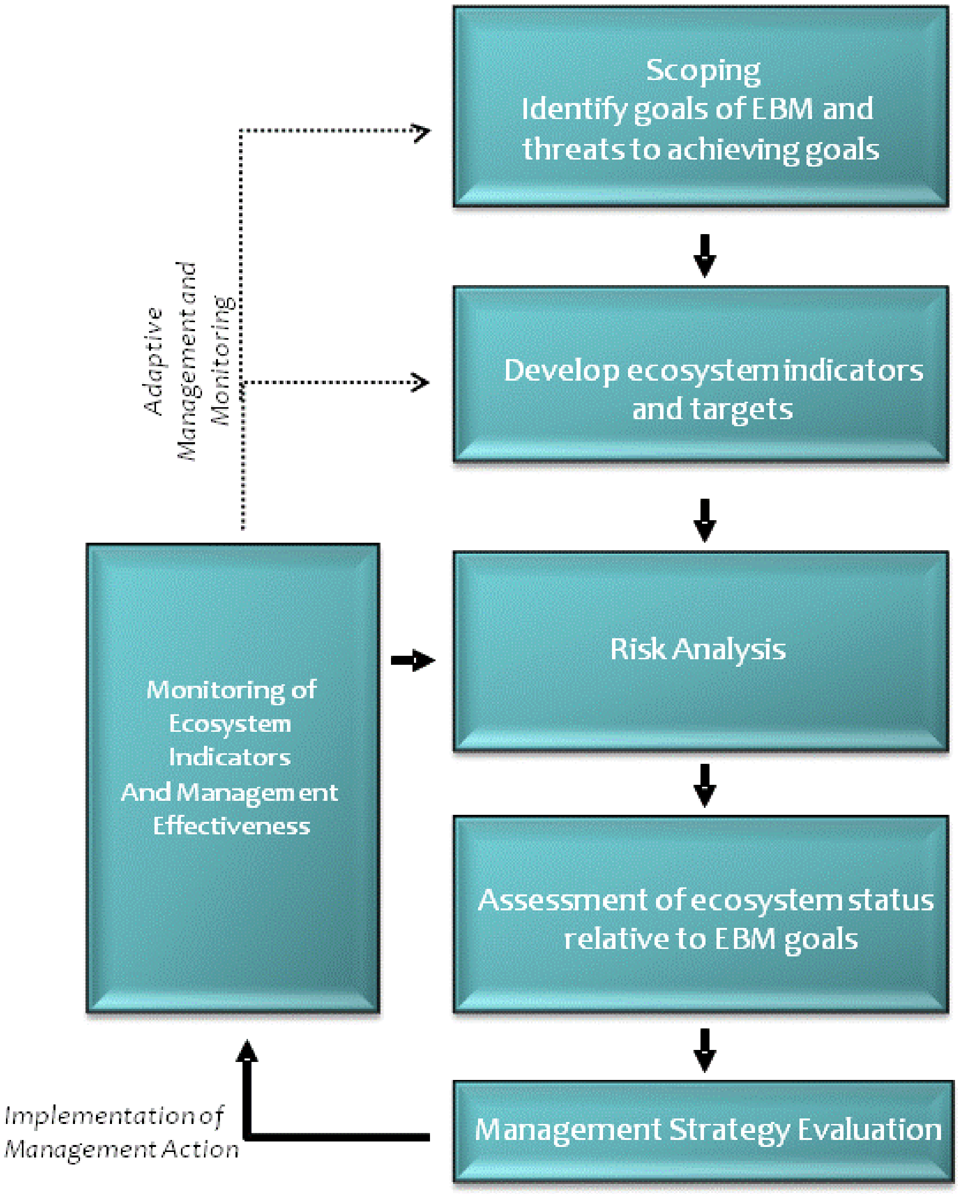

Figure 3.2.1. Diagram of an Integrated Ecosystem Assessment, adapted from Levin *et al.* (2009).

3.3 Overview of history and activities of the NAFO SC Working Group on Ecosystem Approaches to Fisheries Management (WGEAFM) – Mariano Koen-Alonso

The Northwest Atlantic Fisheries Organization (NAFO) is the Regional Fisheries Management Organization (RFMO) in charge of managing fisheries resources in the Northwest Atlantic outside the EEZ of the coastal states. NAFO is essentially organized around three main bodies, the General Council (GC), which is responsible for the supervision and coordination of the organizational, administrative, financial and other internal affairs of NAFO, the Fisheries Commission (FC) which is responsible for the management and conservation of the fishery resources of the NAFO Regulatory Area (NRA), and the Scientific Council (SC) which is responsible for the provision of scientific advice related to the fisheries of the NAFO Convention Area, including environmental and ecological factors affecting these fisheries. Each one of these bodies has one or more standing committees in charge of specific subjects, but they can also create *ad hoc* working groups for addressing particular issues.

In this context, and knowing that principles of ecosystem approaches to fisheries were embedded in the new NAFO Convention and would be used to guide its future work, SC created in 2007 the Working Group on Ecosystem Approaches to Fisheries Management (WGEAFM). Briefly put, WGEAFM underlying objective is to explore ways to develop an ecosystem approach to fisheries suitable for, and adapted to, the NAFO context. In addition to this goal, WGEAFM also provides advice to SC on specific ecosystem-related issues. For example, during its first meeting (Dartmouth, 26–30 May 2008), WGEAFM started to address issues concerning Vulnerable Marine Ecosystems (VMEs) raised by the United Nations General Assembly (UNGA) Resolution 61/105. Since then, WGEAFM has continued addressing specific requests related to VMEs, as well as developing the knowledge base needed for developing ecosystem approaches to fisheries.

WGEAFM currently operates within a set of long term Themes and Terms of Reference that were approved by NAFO SC in June 2010 and will be systematically addressed by the working group over several meetings. These Themes and ToRs build on the "Roadmap for Developing an Ecosystem Approach to Fisheries for NAFO" proposed by WGEAFM in its second meeting (Vigo, 1–5 February 2010).

The "Roadmap to EAF" indicates that an EAF for NAFO should be: a) objective driven, b) focused on long-term ecosystem and stock sustainabilities, c) place-based, and d) addressing trade-offs among human activities explicitly.

At the core of the EAF there is a need for developing Integrated Ecosystem Assessments (IEAs), where IEA can be defined as "a synthesis and quantitative analysis of information on relevant physical, chemical, ecological, and human processes in relation to specified ecosystem management objectives" (Levin *et al*., 2009).

When EAF implementation is considered, the "Roadmap to EAF" indicates that IEAs can be linked to three practical sets of activities: a) definition of geographical management units, b) determination of ecosystem state and function, and c) development of management tools (Figure 3.3.1).

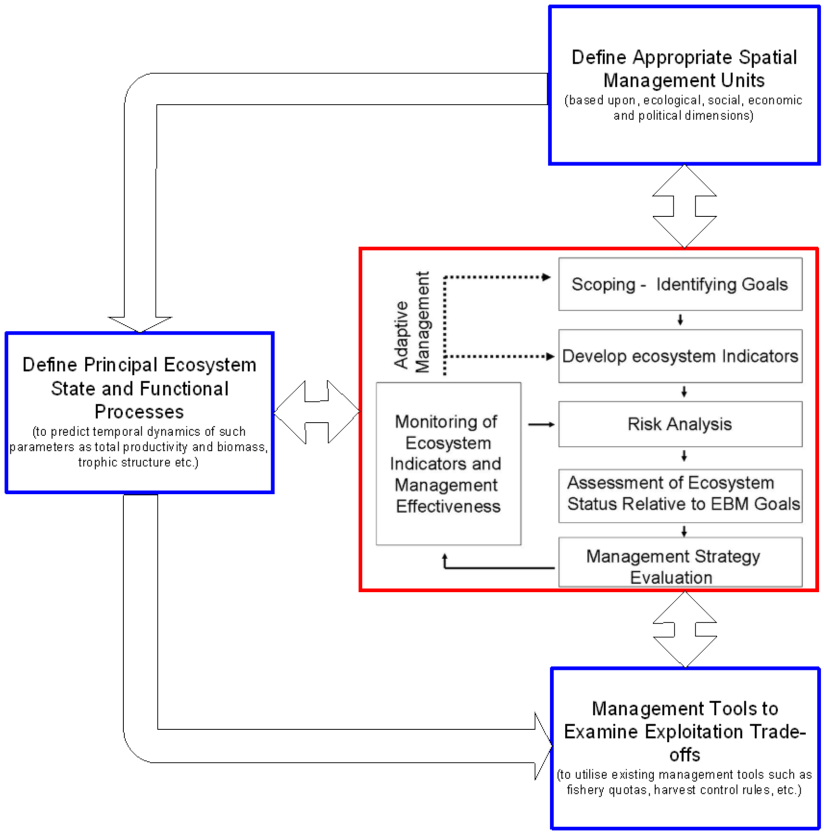

Figure 3.3.1. Relationship between the 3 practical steps in moving towards the implementation of an ecosystem approach to fisheries management (blue boxes) and the steps required to deliver effective holistic integrated ecosystem assessments (IEA) shown in the red box (from NAFO. 2010. Report of the NAFO Scientific Council Working Group on Ecosystem Approaches to Fisheries Management (WGEAFM). NAFO SCS Doc. 10/19).

Specifically on ecosystem state and function, it is considered that overall ecosystem productivity is limited and bounded by large scale forcers; therefore, ecosystem fishery production potential is dependent on ecosystem state. Achieving ecosystem sustainability would require state-dependent ecosystem fishery production to be allocated among target species considering species interactions both in terms of ecosystem goods (e.g. fisheries yields) and ecosystem services (e.g. the role of biodiversity as a "mechanism" for maintaining ecosystem resilience), noting that multispecies maximum sustainable yields are typically less than the summation of the corresponding single-species ones. This implies that trade-offs among fisheries need to be identified, as well as, clear objectives defined. Because all the above considerations may not fully capture species-specific biological and life-history features, stock sustainability needs to be evaluated on the basis of single-species assessments. A three Tier hierarchical process was developed based on these premises, going from overall to single-species yields.

During its third meeting (Dartmouth, 1–10 December 2010) WGEAFM delineated ecoregions and ecosystem units in the NW Atlantic, focusing particularly on the Newfoundland and Labrador Shelf, the Flemish Cap and the Scotian Shelf and their associated slope regions. Seamounts, being geophysical features on the abyssal plains, also received special attention at this meeting. In future meetings, and assuming that personnel and data are available, it is hoped to extend the coverage to include shelf seas around western Greenland and also additional features such as canyons. It is recognized that work on the eastern seaboard of the USA, and especially on Georges Bank, has shown significant advances in over the last 5 or so years. Though not directly comparable to the NAFO area, expertise available at the meeting elaborated on these advances and allowed for a cross fertilization of ideas and concepts. WGEAFM also provided scientific information and guidance that the SC required to address three ecosystem-related requests from Fisheries Commission made in September 2010.

The next WGEAFM meeting is tentatively scheduled to take place on November 1 – December 9, 2011 at the NAFO Headquarters in Dartmouth, Canada. It is expected that the WG will continue addressing its long term Themes and ToRs to continue developing the "Roadmap to EAF", as well as addressing specific requests. With reference to the "Roadmap to EAF", emphasis is expected to be given to the exploration of methods to estimate fisheries production potential at the scale of the ecosystem-level units identified during the third WGEAFM meeting.

Both WGNARS and NAFO WGEAFM have similar general goals (e.g. development of IEAs as a key element of ecosystem approaches), but also differ in terms of the background and expertise of their memberships, as well as their needs to provide tailored advice for specific requests. WGNARS work does not target any specific management organization, while, as expected; WGEAFM work is more tightly linked to NAFO specific needs and timelines. Some other differences between the two working groups worth noting include:

a) WGNARS work covers a wider spectrum of human impacts on marine ecosystems, while WGEAFM is, due to the fisheries-specific mandate of NAFO, restricted to fisheries impacts and management;

b) WGNARS work is mainly concerned with shelf systems, sometimes including coastal ones, while WGEAFM emphasis is on shelf and deep-sea systems;

c) WGNARS membership includes social scientists, and is already dealing with the socio-economic aspects of ecosystem approaches; WGEAFM lacks this expertise and, while it recognizes the importance of socio-economics, it is not yet actively working on these issues; and

d) WGNARS membership is mainly composed by North American scientists (USA and Canada), while WGEAFM membership reflects NAFO contracting parties (i.e. USA, and Canada, but also Spain, Portugal, Russia, and UK); hence, operational and functional issues may pose different sets of constraints for each working group.

3.4 State of the Environment Reporting for Ocean Management in the Maritimes Region, Canada – Jay Walmsley and Melanie Maclean

Canada's Oceans Act recognizes the importance of information for managing the country's coastal and ocean areas. Section 33 of the Act states that the Minister of Fisheries and Oceans is required to "gather, compile, analyse, coordinate and disseminate information". Fisheries and Oceans Canada (DFO) has identified state of the environment (SOE) reporting as a tool to assist in fulfilling this obligation under the Act.

The two main purposes of SOERs are to foster the use of science in policy- and decision-making and to report to the public on the condition of the environment (Environment Canada 2009). A SOER report should: provide a comprehensive analysis of environmental conditions and trends; measure progress towards sustainability; contribute to informed and open decision-making; contribute to public awareness about environmental health and what can be done about it; and serve the public's right to know by providing scientific information about the environment in an easily understandable form (BC Government 2009).

DFO's Maritimes Region is currently undertaking State of the Environment Reporting in two geographic areas: the Gulf of Maine and the Scotian Shelf. The framework recommended for use in SOE reporting for the Maritimes Region is the driving forces-pressures-state-impacts-response (DPSIR) framework. The DPSIR framework is viewed as providing a systems-analysis view of the relation between the environmental system and the human system (Smeets and Weterings, 1999). According to this framework, social and economic developments and natural conditions (driving forces) exert pressure on the environment and, as a consequence, the state of the environment changes. This leads to impacts on human health, ecosystems and materials, which may elicit a societal response that feeds back on all the other elements.

The formal SOER is envisaged as a modular document. It will include an upfront section or "context document" that provides the background and an introduction to the area (Gulf of Maine or Scotian Shelf), and a series of fact sheets or theme papers that focus on priorities for each area. The context document will be a relatively static document. The information provided in this document will be the type of information that rarely changes. The theme papers will provide an evaluation of priority issues that are of interest. The intention is that the theme papers can be regularly updated at a time interval appropriate for each issue, without having to update the rest of the report. The development of SOERs generally assists in identification of indicators that can be used on an ongoing basis for an area. The compilation of the theme papers may require the use of indicators that do not have compatible data Region-wide, but are still valuable for reporting on status and trends. Core indicators, which will be used for monitoring issues into the future, will be identified once the theme papers have been completed. For each SOER a web portal will be developed as a mechanism to deliver the report. The objective is for the site to provide access to all SOE-related documents, links and eventually maps and data. At this time the State of the Gulf of Maine website has been developed and is available at: www.gulfofmaine.org/stateofthegulf.

3.5 Northeast Fisheries Science Center's Ecosystem Status Report and Efforts for Determining Ecosystem-level Thresholds – Jason Link

There are several efforts underway to help address issues associated with Integrated Ecosystem Assessments (IEA; Figure 3.2.1). In fact, it was recommended that future presentations at WGNARS relate to this or a related diagrammatic so that it is clear how the work being discussed fits into the IEA framework. Often these efforts rightly centre on the development, vetting and use of indicators in their various forms. This brief report focuses upon information that can address WGNARS 2011 ToRs b), d) and e).

The NEFSC's Ecosystem Status Report (ESR) was produced to cover the range of topics associated with IEAs (EcoAP, 2009), particularly as they were focusing upon issues associated with the fishing sector. The main elements of the ESR are: Climate Forcing, Physical Pressures, Primary and Secondary Production, Benthos, Upper Trophic Levels, Anthropogenic Factors, and Integrative Ecosystem Measures. The listing of indicators represents, given caveats of terminology, the typical set of candidates that usually emerge after suitable selection criteria have been applied (e.g. Rochet and Trenkel, 2003; Rice and Rochet, 2005; Link, 2005; Jennings, 2005; Shin *et al.*, 2010). An update to the ESR is planned for 2011.

In subsequent discussions, it has become apparent that an examination of the linkages among a triad of drivers, namely human factors, internal factors, and external factors, that affect the core ecosystem goods and services (Figure 3.5.1) is warranted. The drivers aim to capture all the major features and processes that can influence the state and productivity of an ecosystem. Determining what the key thresholds will be among response/state indicators as influenced by driver/pressure indicators is apt to be empirical for some time. These need to be expressed as partial functions for any given indicator X conditioned upon all human (H, e.g. fishing, eutrophication, etc.), internal (I, e.g. trophodynamic, resilience, etc.) and external (E, e.g. climate, environmental signals, etc.) factors over time T such that:

$$\frac{\partial X}{\partial T \delta H \delta I \delta E} \rightarrow \infty \ or\ \mathbf{0}$$

or, where the first derivative (tangent or slope) would be:

$$\delta' X \rightarrow \max \square$$

that all seek to capture points of inflection or similar non-linearities among the relationships of the response indicators and driver indicators. As these non-linear responses become increasingly verified, mechanistic linkages and theoretical tenets can be brought to bear on the observed relationships, such that threshold functions can be established. Clearly there is ample room for work on this topic.

There have been a few nascent attempts to establish such thresholds, particularly with respect to fishing as a driver. There are several proposed protocols for establishing delineations of ecosystem overfishing, including the empirical and multivariate statistical approaches identified by Link *et al.* (2002), Link (2005), Methratta and Link (2006), Shackell *et al.* (in review), Samhouri *et al.* (2010, 2011), Shin *et al.* (2010), and Link *et al.* (2010), among others. Further, more mechanistic approaches have been developed to delineate ecosystem overfishing as seen in those posited by Tudela *et al.* (2005), Libralto *et al.* (2006, 2008; F. Pranovi pers. comm.), Coll *et al.* (2009), and Fulton and Fogarty (B. Fulton, pers. comm.; M. Fogarty, pers. comm.; as seen in Worm *et al.*, 2009, their Figure 2). Even aggregated and system-level applications to derive commonly used fishery biological reference points (e.g. Mueter and Megrey, 2006; Overholtz *et al.*, 2008a, 2008b) have begun to be estimated. There remains much fruitful research to explore this topic, but the discipline is rapidly converging on, if not specific indicators and thresholds, at least procedural benchmarks to establish such thresholds. Of note, and as seen by the related works presented at WGNARS 2011, the institutional (governance and stakeholder) structures to uptake and utilize such indicators and thresholds also warrants further exploration (e.g. Samhouri *et al.*, 2011).

As indicator development continues to evolve in the NW Atlantic, how those indicators become translated into ecosystem management advice will be a key feature of their use in the coming years.

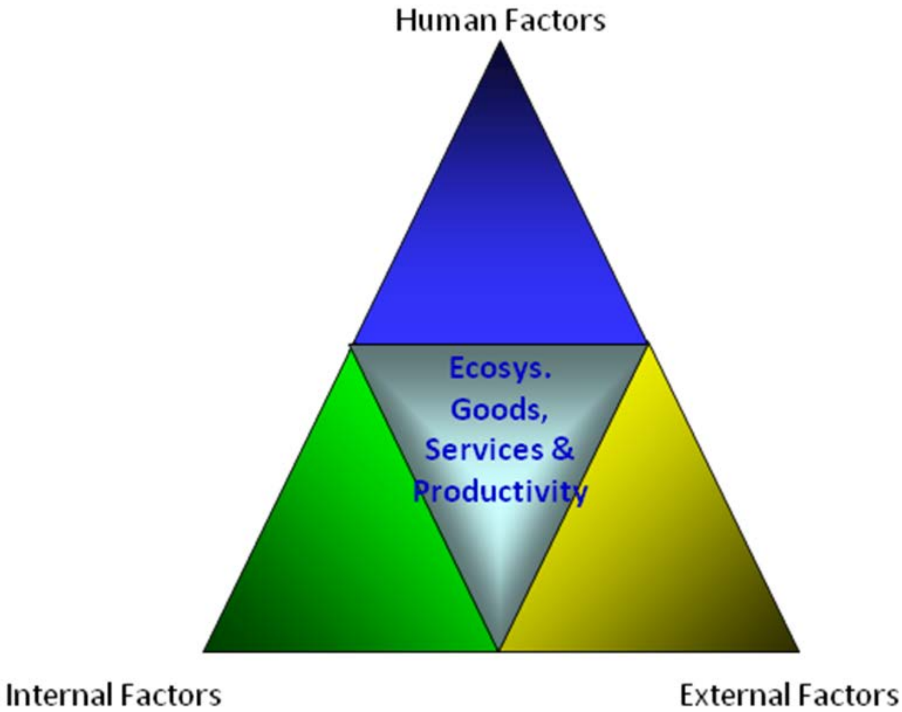

Figure 3.5.1. The triad of drivers that influence core ecosystem properties of interest.

4 Determine socio-economic components of an integrated ecosystem assessment of the Northwest Atlantic (ToR f)

Humans are considered to be an integral part of the ecosystem under Ecosystem Based Management (Levin *et al.*, 2009). The scope of IEA development planned by WGNARS in 2010 includes socio-economic factors, to enable the IEA to better define ecosystem objectives and trade-offs. Following the recommendation made in WGNARS 2010, socio-economic experts were invited to the WGNARS meeting in 2011, and discussion of how to incorporate socio-economic factors into the IEA was initiated.

Jörn Schmidt presented an overview of a new ICES Study Group on Integrating Economics, Stock Assessment and Fisheries Management (SGIMM). This study group is part of the SSGRSP and will examine the use of integrated ecological-economic models to develop long-term strategic planning and short- to medium-term management evaluation and advice.

Tony Charles gave an overview of entry points to Ecosystem-Based Management (e.g. driving forces, costs and benefits, and social, economic, and institutional instruments), human dimensions of EBM, and methodologies and information management tools, as well as ecosystem valuation, approaches to social, economic, and cultural assessment for management, and commonly used socio-economic variables.

Larry Hildebrand asked the WGNARS group to consider the political relevance of its work to national and regional policies and priorities on short to long time-scales, and he presented key questions that the working group should consider in order to maximize the policy and political relevance of its work.

Patricia Clay discussed Ecosystem-Based Fisheries Management from the perspective of governance systems, spatial and temporal scales related to resource use, local ecological knowledge (LEK), and the role of culture, and she recommended incorporating sociocultural and economic information from the outset of development of IEAs.

Several themes recurred throughout the talks and discussion. Decisions about including socio-economic information in an IEA must consider the relevance of this information to policy decisions and governance frameworks and tools. Outcomes should address a range of time-scales ranging from short term goals such as setting up enabling conditions and changing behaviour to longer term objectives such as achieving program and strategic goals. Multiple spatial scales, related to political jurisdictions, spatial scales of resource use patterns, and spatial scales of ecological processes, must also be considered. It is critical to consider who needs the socio-economic information in an assessment and how it will be used, as well as how it will contribute to local, regional, and national policy objectives. Socio-economic information should be included from the start of IEA development, rather than incorporated late in the process, and the success of the assessment and indicators in achieving objectives should be evaluated continually throughout the assessment process. Socio-economic indicators commonly include economic information based on use value (e.g. GDP, production rates, and economic value) and social information such as population density, urbanization rates, and quality of life, but non-use ecosystem values and qualitative socio-cultural information also provide valuable context for decision-making.

As a first step toward incorporating socio-economic information into an IEA, a preliminary set of socio-economic indicators was assembled, based on information from the presentations and discussion (Table 7.1.2, below). These indicators were loosely mapped onto a set of "storylines" representative of strategic objectives related to ecosystem and resource use processes. Further work will be required to develop the linkages between these or alternative indicators and both short- and longer-term policy, political, economic, social, and cultural objectives across a range of spatial scales. This work would be facilitated by adding members with socio-economic expertise to the steering committee, by finding and examining relevant case studies in which socio-economic information has been effectively included in IEAs and management, by coordinating with SGIMM to identify models that are available to incorporate socio-economic information, and by coordinating with relevant groups at DFO and NOAA to identify socio-economic indicators that are available and/or relevant to policy decisions.

4.1 Overview of the ICES Study Group on Integration of Economics, Stock Assessment and Fisheries Management (SGIMM) – Jörn Schmidt and Rasmus Nielsen

The Study Group emerged from a workshop meeting in 2010 in Kiel, Germany, which brought together economic and ecological researchers to explore possibilities of ecological-economic modelling in fisheries science (ICES, 2010a). Fisheries are economic activities, which depend on and interact with the ecosystem in which they take place, and management decisions are driven not only by changes in the environment but by the economic activity itself. The rationale of establishing such an activity within ICES was the perceived need to enhance the understanding of the effect of possible management options on the ecology and the economy and the feedback between these two. Thus the focus was on looking at examples of integrated ecological-economic models, with different level of complexity of the ecosystem and the fishery.

Within the workshop two main approaches were identified, a long-term strategic planning and advice approach, with Ecopath with Ecosim (EwE) or Atlantis as possible model frameworks, and a short to medium term management evaluation and advice approach, with FLR as one possible modelling framework.

It was realized that conceptual work is still needed to establish a model inventory, identify common modelling environments (frameworks) and to build-up capacity to use these models, also within other groups or workshops. Agreement prevailed that the best way to tackle the challenge would be the use of existing models on concrete case studies. Possible case studies identified and suggested for the work of SGIMM are the North Sea mixed round fish fisheries, Central Baltic multispecies (cod, herring and sprat) and Chesapeake Bay as data rich systems and the Northern European Hake long term Management Plan as a data poor example.

One case study was developed at the meeting of the workshop on Including Socio-Economic considerations into the Climate-recruitment framework developed for clupeids in the Baltic Sea (WKSECRET, ICES, 2010b). The existing modelling framework for predicting the population development of different Baltic herring stocks under climate change was extended with an economic optimization, including age specific price and stock dependent harvest costs. The aim was to optimize profit and to investigate which F, especially in the transition of rebuilding the stock, and which SSB would be obtained in the long term using environmental sensitive stock–recruit functions. Interestingly, the optimal long term F is in a range suggested by ICES (2009). One important prerequisite for recruitment functions used in economic optimization models is a density-dependence of the stock. Thus models using just environmental variables as predictors will not necessarily work, but they have to include spawning-stock biomass as a predictor as well.

SGIMM will meet from 14 to 18 June 2011 at ICES headquarters in Copenhagen.

4.2 Socio-economic dimensions of Ecosystem-Based Management – Tony Charles

Over the past decade, there has been remarkable growth in attention paid to human dimensions of ecosystem-based management in fisheries and marine systems (De Young *et al.,* 2008; FAO, 2009) – including a wide range of considerations from socio-cultural to economic to political and institutional. Accompanying a broad acceptance of the need to adopt ecosystem approaches in understanding, assessing and managing marine systems has been a recognition that ecosystem-based management cannot succeed without taking into account those human dimensions.

The move to ensure that human dimensions are taken into account in fisheries and ocean management reflects a broadening of perspective over time (Charles, 2001; Garcia and Charles, 2007). The shift from a single-species focus to one that considers multispecies, ecosystem and fish habitat impacts of fishing is one move in the direction of ecosystem-based management, but in addition, the interaction of humans with ecosystems – through societies, technologies, economies, needs and values – is fundamental. As the FAO (2003) notes, an ecosystem approach "strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties of biotic, abiotic and human components of eco-systems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries."

De Young *et al.* (2008) have discussed the following ten human dimensions relevant to an ecosystem approach to fisheries (EAF): (1) boundaries, scope and scale; (2) human values of ecosystem services; (3) employment, livelihood, regional aspects; (4) policy, institutional and legal frameworks; (5) incentive mechanisms; (6) management benefits and costs; (7) distributional aspects; (8) indigenous people, traditional knowledge; (9) decision-making tools for assessment; (10) information needs for decision-making. For further details on many of these, see Charles and De Young (2009) and De Young and Charles (2009).

These considerations, and more broadly the move toward incorporating human dimensions in ecosystem-based management, are also relevant in considering integrated ecosystem assessments – notably of marine areas such as the Northwest Atlantic. Here too, it is crucial that socio-economic components form an inherent part of such assessments. There are many mutually reinforcing pathways through which this can be achieved – with three of these outlined here.

First, there are various cases globally of initiatives on 'Social, Economic and Cultural Overview and Assessment for Ocean Management' (Charles *et al.*, 2007). These typically involve assessing a specific set of human dimensions that contribute in some way to management decision-making, on scales from large (government) to small (community, NGO). Examples include large ocean management areas (LOMAs) in Canada, OSPAR in Europe, Large Marine Ecosystems (LMEs) worldwide, and on a smaller scale, coral reefs (e.g. the Socio-economic Manual for Coral Reef Management). They identify key roles played by local conditions, capacity, budgets, time and goals, and the importance of having an evaluation phase carried out early in the process. From the cases analysed, it appears that socio-economic assessments have been mostly economic, cultural assessments have been mostly at a local scale, and governance aspects are especially crucial to success.

A second illustration of incorporating human dimensions is an approach based on understanding and assessing the social and economic values of ecosystem services (De Young *et al.*, 2008). This may be especially relevant to integrated ecosystem assessment, which tends to arise initially from an ecological point of view. Also known as 'ecosystem valuation', this involves examining each of the 'use values', 'non-use values' and 'existence values' in an ecosystem. Use values may include the standard net economic benefits of extractive ocean uses (including values from income and employment, from social interaction and livelihoods, and from food provision and food security) and non-extractive use values from marine ecosystems (e.g. tourism). Non-use and existence values might include cultural benefits of marine ecosystems (e.g. art, ceremonies), aesthetic and existence benefits, and the 'option value' in terms of possible (but not necessarily proven) future benefits.

Finally, a third avenue for incorporating human dimensions into integrated assessments is that of indicator frameworks. For example, Charles *et al.* (2009) presents a set of biophysical, ecological, environmental, social and economic indicators relating to fisheries and the marine environment for the province of Nova Scotia, Canada. By integrating indicators relating to 'human dimensions' fully within an indicator framework, this ensures that the human side of the social-ecological system receives equal attention to the ecological side.

Overall, there may be two key factors required to incorporate socio-economic and other human-side elements into ecosystem-based approaches and integrated ecosystem assessment. It is important to avoid human dimensions being (or seen to be) after-the-fact 'add-ons', so a seamless approach is crucial. For example, an indicator framework approach, as noted above, achieves this by having human as well as ecological aspects built fully into the process from the start. Also important is the idea of finding a suitable 'entry point' so human considerations arise naturally in discussions of marine ecosystems. The idea of assessing values of ecosystem services would be an example of an entry point that may link well to other interests in integrated ecosystem assessment.

4.3 Incorporating socio-economic factors into an integrated ecosystem assessment of the Northwest Atlantic regional seas: The policy and political perspective – Larry Hildebrand

ICES Working Groups are well familiar with and comprise a high level of expertise in the biological, physical and ecological dimensions of ecosystem assessments. These natural science skills, while central, do not include all of the necessary perspectives in looking at an ecosystem in a comprehensive way. The 'human dimensions' – that is, the economic, social, cultural, legal, institutional, policy and political – are equally important and must be considered as complementary perspectives in understanding a complex regional sea such as the Northwest Atlantic.

Focusing on the policy and political dimensions, two important questions must be addressed: First, is the question of 'political relevance'. How will the work of the WGNARS contribute to the achievement of national and regional policies and priorities? Do you know what these priorities are and are you focusing your work to address them? Secondly, how will ICES/ WGNARS demonstrate and report progress toward meaningful, time-bound targets? That is, what are the 'orders of outcomes' that you will articulate, work toward and use as the basis for reporting progress?

ICES Working Groups understand well and employ indicators to measure and report on changes and trends in ecosystem health and sustainability. In considering the human dimensions of ecosystem assessment, specifically those of a policy and political nature, we need to consider and focus our attention on answering questions that occupy the time and imagination of senior bureaucrats and political leaders. These 'non-scientists' will want and need straightforward answers to, or at least the best scientific advice on, questions such as: Will this work contribute to the reduction of conflict among ocean and coastal users and lead to a fair and equitable distribution of costs and benefits? Will it provide for greater regulatory certainty for investment among major ocean industries? Will it contribute to meeting our international commitments, such as biodiversity targets? Will a better understood NW Atlantic ecosystem provide a basis for increased investment and support livelihood sustainability in coastal communities? Are we demonstrating due diligence on our sovereignty claims and in an era of fiscal restraint?

Understanding an ecosystem as large and complex as the Northwest Atlantic, putting into effect significant changes in ocean governance and realizing improved ecosystem health, will take significant effort and many years to accomplish. Going from the state-of-the-art today, to a 'better' future, some time off, is a long-term venture that requires reporting milestones along the way. Too many large ecosystem efforts set ambitious goals and objectives (e.g. 'healthy and sustainable ecosystems' and 'increased wealth from the oceans') without building in short-, medium- and long-term outcomes that the public and our political leaders can point to and understand along the way.

Olsen (2003) provides a framework for four orders of outcomes in ecosystem-based governance that have proven effective in setting time-specific targets and increasing our understanding of what we can shoot for and expect in time frames of one-to-two, three-to-five, five-to-ten and ten-to-twenty-five years. Figure 4.3.1 has been modified to include 'suggested' outcomes in the Northwest Atlantic, proceeding through achieving 'enabling' conditions (1st Order), Behavioural changes (2nd Order), Attainment of some program goals (3rd Order), to 4th Order outcomes of sustainable ecosystem conditions and uses. Careful consideration of the actual conditions and goals in this ecosystem is necessary to produce meaningful and relevant milestones.

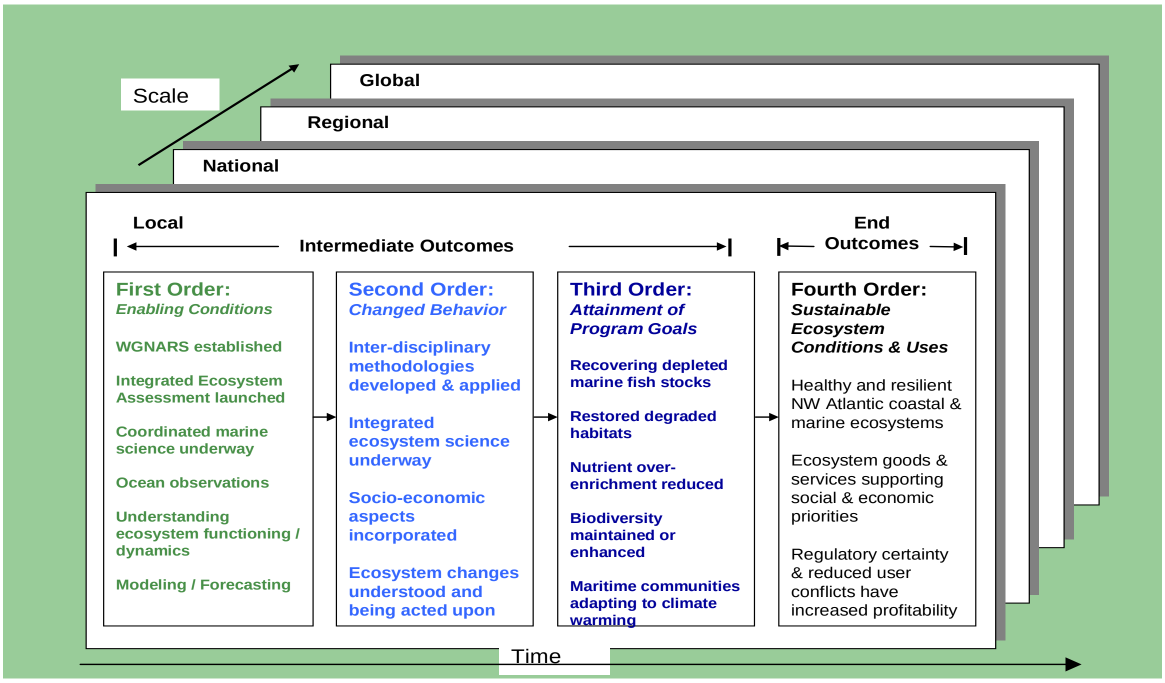

Figure 4.3.1. Hypothetical order of outcomes for WGNARS, adapted from Olsen (2003).

In order to effectively integrate the natural-science and social-science dimensions of ecosystem assessments, the steps described above should be given serious consideration. To guide this integration, four key questions should be addressed: (1) who needs this integrated ecosystem information and advice?; (2) In what form and time frame will you deliver it?; (3) How does this information contribute to achieving national policy objectives?; and (4) What do you want the decision-makers to do with the information you provide?

4.4 Social Science in Ecosystem-based Fisheries Management: a Focus on Sociocultural Aspects – Patricia Clay and Julia Olson

The social sciences have a long history of studying how people use and relate to ecosystems, including the ways people use and value natural resources, the institutions they have developed to manage and respond to environmental change, and patterns of human adaptation to the environment. For ecosystem-based fisheries management (EBFM), key areas of sociocultural focus include 1) governance systems, 2) spatial and chronological scales related to variations in resource use practices and valuation systems, 3) local ecological knowledge (LEK), and 4) the role of culture.

First, the study of governance systems is important because EBFM requires a more adaptive, flexible and holistic connection between management and fishing activities (Clay and Olson, 2008). It requires making difficult trade-offs between competing uses of fisheries and other natural resources. More participatory governance helps ensure that different opinions and values held by stakeholders are used in making these decisions, and forms more effective partnerships between stakeholders and governments (Ostrom, 1990, Wiber *et al.*, 2004). Finally, the ecoregions created under EBFM can support new governance approaches, including forms of area-based management that have been little utilized in US and European fisheries (re. NOAA's Catch Share policy on Territorial Use Rights Fisheries (TURFs) at http://www.nmfs.noaa.gov/sfa/domes_fish/catchshare/).

Second, social scientists study the spatial and chronological scales at which different social processes and activities occur. EBFM ecoregions may cross political jurisdictions such as existing management regions, states or countries. Even fishing grounds may function at a geographical scale that is smaller or larger than ecoregions, which are defined according to criteria such as productivity or habitat. There can also be tremendous variation in how fishers use ecosystem resources, including intensity of fishing in time and space and the level of dependence on particular fishing grounds (Olson, 2011). Furthermore, human activities such as fishing may display seasonal variations that differ, e.g. from fishery to fishery and on a daily, monthly or annual basis. Studies that document these variations provide information that contributes to a better understanding of ecosystem stressors, supports analysis of trade-offs in ecosystem uses, and helps to unify management objectives and authority over EBFM regions.

Third, studying LEK is important because direct resources users can be a key source of information regarding the characteristics of the environment with which they interact. For example, fishers can become intimately aware of seasonal changes and interannual patterns in the areas of the marine environment that they fish. Such local or niche-level knowledge can both supplement the more macroscale studies of ecologists, as well as provide stakeholders one possible point of entry to the management process (Neis *et al.*, 1999).

Fourth and finally, social scientists both develop quantitative social and economic indicators to allow evaluation of trends (e.g. Clay *et al.*, 2010) and also conduct ethnographic studies to provide detailed descriptions of social life and culture that supply a context for interpretation of these quantitative data. As Lees and Bates (1990:248) explain, just as important as knowing *what* relationships people have with the environment is knowing "*why* these relationships [are] organized as they [are], or *how* people respond when these relationships change." For example, explaining a trend of declining household and community dependence on fishing requires understanding the sociocultural and economic forces leading to decreasing participation in particular locations at particular times. Similarly, increases in fishing effort may reflect improved biomass, ecologically unsustainable fishing practices or unrelated political economic changes. Moreover, both the profitability of fishing businesses and different ideas about what constitutes an adequate income can impact changes in the level of fishing intensity. Acquiring this contextual or situational knowledge requires the kind of in-depth study that social scientists conduct in communities and on vessels using such methods as interviews and participant-observation.

To conclude, Integrated Ecosystem Assessments (IEAs) should be holistic, and integrate sociocultural and economic information from the beginning, alongside ecological, biological and physical information (Endter-Wada *et al.*, 1998). This does not mean that all must be decided on together by an interdisciplinary team. Rather, development of supporting information should begin at the same time, by the appropriate research groups, with frequent communication and cross-checking. With the longer lead time, more contextual, often qualitative, research can also be appropriately integrated into the process. In this way a consensus on ecoregions can be achieved that takes into account both human and ecological factors, and the relationships between them.

5 Spatial planning (ToR d)

ToR d): Initiate integrated analyses of the relationships between physical and biological aspects of the Northwest Atlantic ecosystem (e.g. predictable state changes, climate impacts, biodiversity, community analyses)

The goal of this group was to gather expertise and information required for habitat assessments supporting space based management in the Northwest Atlantic Regional Sea. Specifically the group presented and discussed broad scale environmentally explicit analyses designed to identify habitats of species or community properties that support ecosystem resilience and productivity. "Space" based assessment and management is particularly difficult in this region where the properties and processes in water column which regulate many important biological processes are spatially dynamic at short to long time-scales and where those spatial dynamics appear to be changing rapidly with anthropogenic climate change. In the first talk Ellen Kensington reviewed the activities of the ICES NAMPAN study group tasked with developing marine protected area network design strategies that anticipate the effects of climate change. The study group stressed the importance of focusing on species, population, and community properties "crucial" for maintaining the ecological resilience of central and North American marine ecosystems (Table 5.1). John Manderson then reported on the development of a simple ecological niche model for a threatened species that can be coupled to forecasts of ocean properties downscaled from global climate models to forecast "habitat" availability at a regional sea scale. Preliminary simulations show that warming causes a poleward shift in "suitable habitat" that also fragments near geographic range limits because of differences in the spatial dynamics of relatively slow stable habitat features like bottom characteristics and more dynamic water column properties that are driven by higher frequency atmospheric and climate forcing (Figure 5.1). Nancy Shackell and Jon Fisher analysed single species and community properties on the Scotian Shelf using the Kostylev and Hannah (2007; Figure 5.2; KH) habitat template that integrates water column and bottom properties with mechanistic effects on biological processes into synthetic dimensions of natural disturbance and scope for growth. Nancy Shackell showed that sea cucumber was particularly abundant in habitats with high levels of natural disturbance based on the KH template model. She also showed spatial autocorrelation analysis designed to integrate important considerations of metapopulation structure and population connectivity into her KH-based habitat analysis of sea cucumbers (Figure 5.3). Jon Fisher analysed relationships of life-history traits of dominant species and community level properties to the dimensions of the KH model. Habitats with high scopes for growth also had high community evenness and those with intermediate levels of natural disturbance had high species richness, consistent with the intermediate disturbance hypothesis (Figure 5.4; Dial and Roughgarden, 1988). The discussion following the talks focused the framing of near term, medium term and long term goals. The near term goal set was to attempt to bring together information required to apply the KH model throughout the Northwest Atlantic. In the medium term this KH template would be used for 1) a regional sea scale analysis of habitat associations of species and community properties identified as "crucial" or "foundational" for the resilience of ecosystems in the Northwest Atlantic and 2) an evaluation of the applicability of the KH model for important pelagic species and the possible development of a pelagic analogue if required. The long term goal was to continue to develop environmentally explicit approaches to environmentally explicit modelling of rates for foundational species and community processes that integrate considerations of connectivity and mass effects which are crucial determinants of metapopulation/metacommunity dynamics and therefore fundamental to the design of effective MPA networks.

Table 5.1. Ecosystem properties that increase resilience to climate change.

Ecosystems	Habitats	Populations
Connectivity (spatial fluxes, trophic connections, mobile link species)	Heterogeneity	Connectivity
Abundance and size structure of upper trophic levels	Spatial arrangement and composition	Dependence on critical habitats
Response diversity	Foundation species	Sensitivity to environmental conditions
Phenological matches	Ecosystem engineers	Flexibility in migration routes
Species richness	Disturbance	Population size and age structure
Functional redundancy (taxonomic diversity)	Distance to ecotones	Phenology

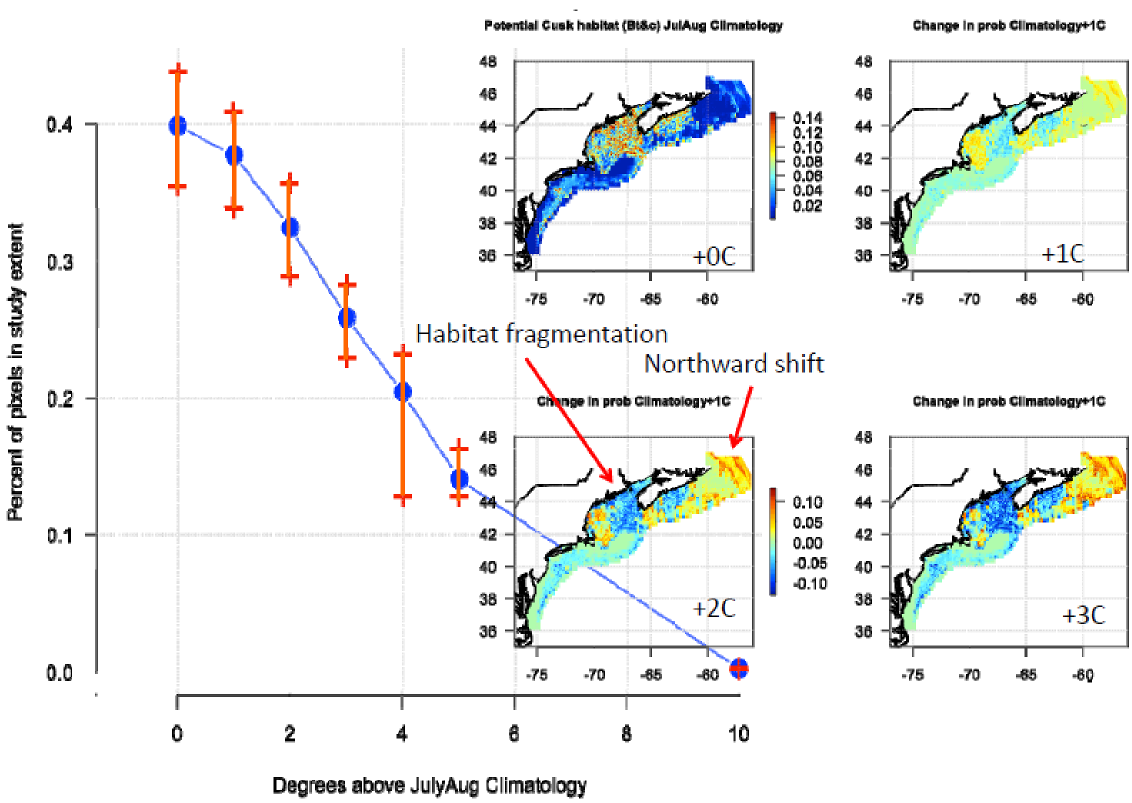

Figure 5.1. Predicted habitat based on GAM threshold p=0.03762.

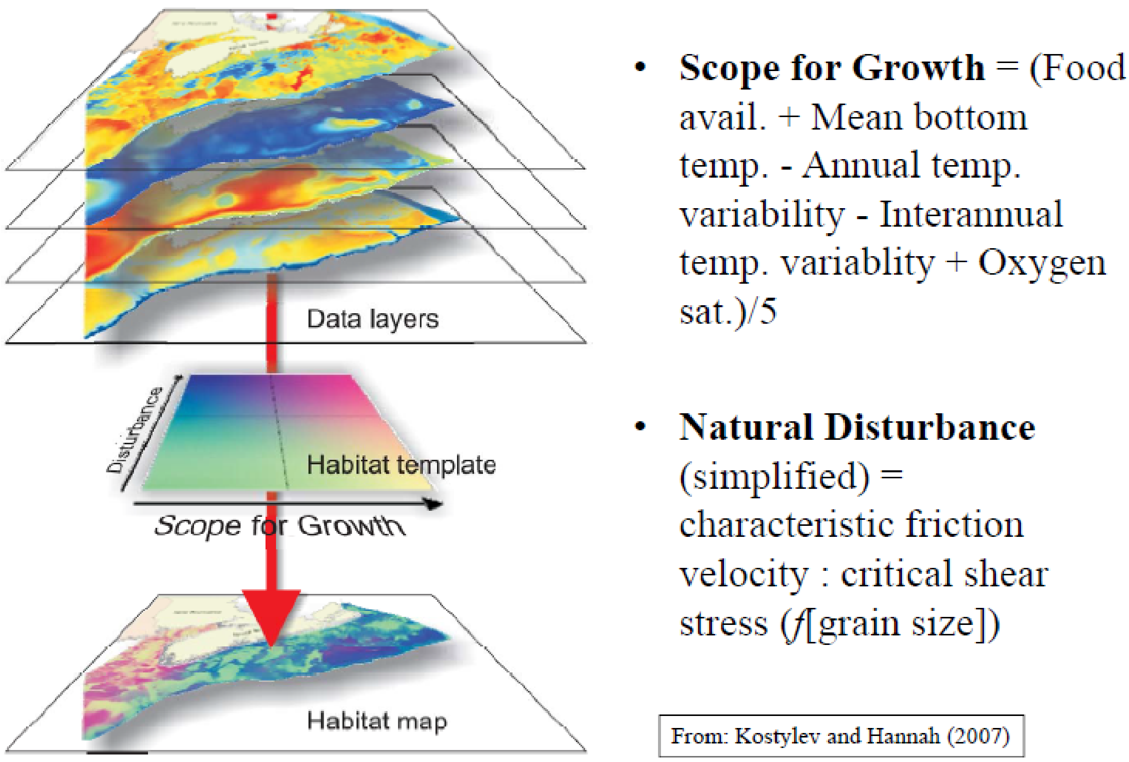

Figure 5.2. Data layers integrated to reduce template dimensions.

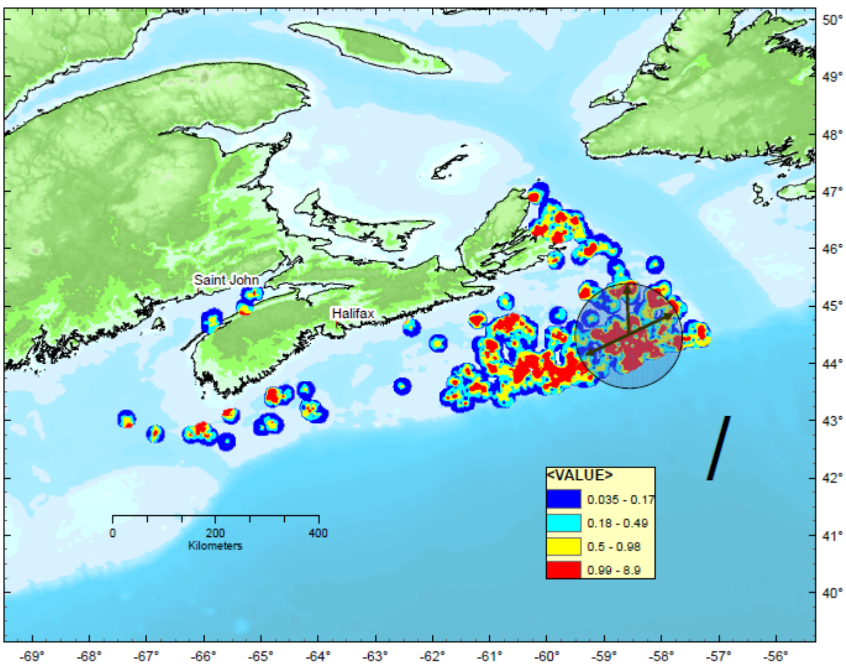

Figure 5.3. Habitat value of sea cucumbers.

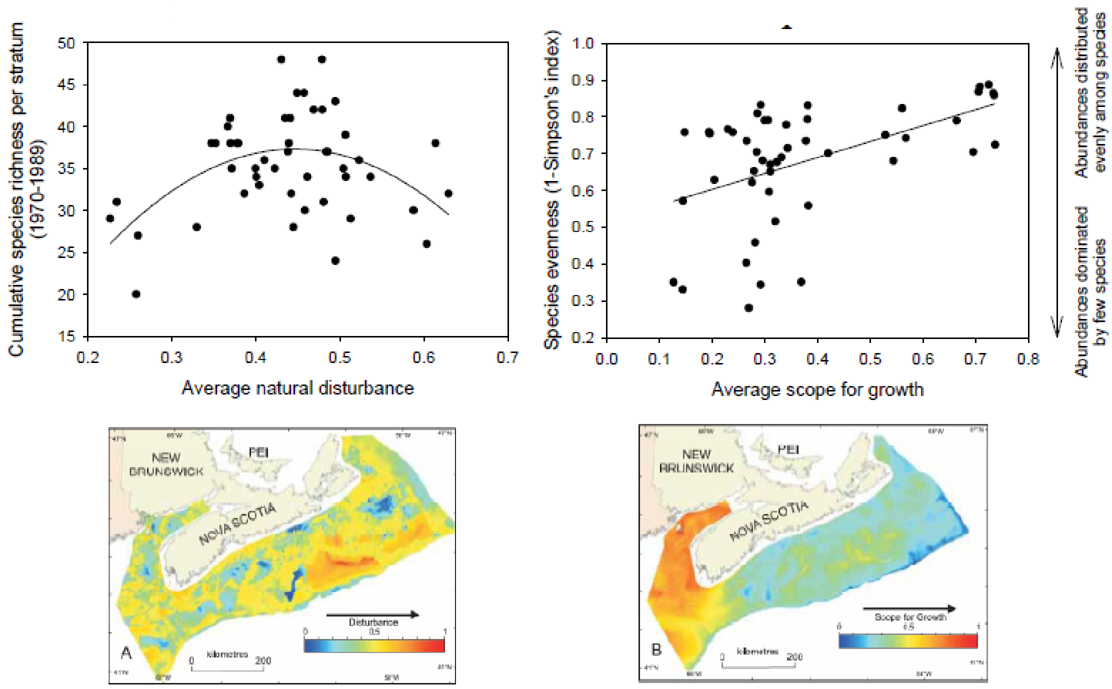

Figure 5.4. Among survey strata, two biodiversity components related to two different habitat template axes.

5.1 ICES-NAMPAN Study Group on designing marine protected area (MPA) networks in a changing climate (SGMPAN) – Ellen Kenchington

The overall aim of this Study Group Report was to develop general guidelines for the MPA network design processes that anticipate the effects of climate change on marine ecosystems. As a joint Study Group between ICES and the North American Marine Protected Areas Network (NAMPAN), a subcommittee of the Commission for Environmental Cooperation (CEC), the area of interest extended from the Western Tropical Atlantic, including the Caribbean Sea and the Gulf of Mexico, to the Canadian Arctic.

An overview, extracted from the scientific literature, of the traits which increase the ability of populations, habitats and ecosystems to adapt to a changing environment was provided. Those elements were examined in the context of aspects of MPA networks that have potential for influence those traits. A high level overview of the nature and timelines of the possible changes in conditions of the study area that biologists can consider when trying to foresee the potential impact of such changes to specific populations, habitats and ecosystems was provided in detail. A literature-based overview of expected biological responses to the physical forecasts provided an overview of existing data for reflecting trends in environmental parameters that may be related to species' distributions and abundances and could serve as covariates in future analyses. A list of species and habitats that deliver important ecosystem services, and a summary of data available to ensure that they are not overlooked in any marine spatial planning exercise were also provided. An analytical framework for assessing biological responses to physical climate change and for evaluating management options includes MPA networks as part or all of the management response to the climate impacts.

The ocean climate off eastern North America naturally varies strongly with latitude and season, with the strength of the seasonality also varying with latitude. It is strongly influenced by atmospheric forcing, continental run-off, Arctic outflows and tropical inflows, the North Atlantic's major gyral circulations, and the complex geometry of the coastline and continental margin. The region's climate is also strongly influenced by several large-scale natural modes of atmosphere and/or ocean variability on time-scales of months to multiple decades. These include the North Atlantic Oscillation (NAO), the Tropical Atlantic Variability (TAV), and the Atlantic Multidecadal Oscillation (AMO). Some of these, or modified versions of them, are expected to remain very important to regional ocean climate for at least the next few decades.

Anthropogenically influenced changes in many ocean variables off eastern North America are already occurring and are expected to become of increasing relative importance, and predominant in many cases, as the century proceeds. The direction of the changes in some of these, such as increasing ocean temperature, stratification, acidity, coastal sea level and coastal erosion, is expected to continue to be widespread following the global trend, although there will be important regional variations in magnitude.

The transports of cold freshwater southward by the Labrador Current in the subpolar Northwest Atlantic, and of warm saline water northward by the Gulf Stream in the subtropical Western North Atlantic, result in a pronounced mid-latitude ocean climate "transition zone" between the Grand Bank and Cape Hatteras. Enhanced climate changes are expected in this zone associated with a northward shift of the Gulf Stream's position.

While available climate change projections provide a good indication of the probable changes for many variables on large-scales, the models used do not adequately resolve many important regional oceanographic features in the western North Atlantic. Thus, there remains substantial uncertainty in the magnitude of future ocean climate change on the space and time-scales of importance to many coastal and marine ecosystem issues. Present and projected greenhouse gas emission rates, and recent climate change assessments, indicate that the rates of future anthropogenic climate change may be near the high end of those outlined in the Fourth Assessment of the Intergovernmental Panel on Climate Change. This means that some so-called "dangerous" climate change may occur earlier than previously projected, and potentially within decades in some cases.

There is also uncertainty in how ecosystems will respond to climate change although some generalized effects are anticipated. Changes in species' distribution across all trophic levels are expected and these are unlikely to be synchronous, causing changes in trophic interactions and ecosystem function. Energy cycling is predicted to change as a result of decreases in primary productivity in low latitude ecosystems and increases in primary productivity in high latitude systems. The generalized effects of climate-driven oceanographic change in relation to key components of the ecosystem are summarized.

MPA networks can be designed to be integrated, mutually supportive and focused on sustaining key ecological functions, services and resources. As such, they can provide a mechanism to mitigate climate change effects on ecosystems. MPA networks are especially suited to address spatial issues of connectivity, habitat heterogeneity, and the spatial arrangement and composition of constituent habitats, all of which can contribute to ecosystem resilience. Single MPAs within a network can further protect critical places for life stages of key species. A suite of properties of ecosystems, habitats and populations have been described which confer increased resilience to marine systems. Some of these can be supported through the size and placement of protected areas (abundance and size structure of upper trophic levels, species richness), while others are not amenable to management and are properties of marine systems which can be used to predict their vulnerability to climate change (e.g. phenological matches, flexibility of migration routes, dependence on critical habitats, functional redundancy, response diversity, community evenness, distance to ecotones). We identify species and habitats which are crucial to ecological functioning and may merit special conservation consideration.

The sections of the Study Group's report collectively adapt existing MPA network design principles for conservation of biodiversity to take better account of enhancing ecosystem robustness to climate change. Other ICES expert groups and similar bodies will assess the various ecosystem components in this region following the framework.

The work to try and figure out how to define a network of MPA that will be useful under climate change winds up being related to many concerns confronted by WGNARS (e.g. how are processes at different scales coupled and how are different levels of ecosystem organization coupled?).

WGNARS recognized that this network research can have applications beyond MPAs. What makes the work worthwhile is that it can be applied to many questions such as climate change, ecosystems, and exploring the factors of resilience. A network analysis of the Bering Sea marine ecosystem revealed a few species that were key nodes in a network diagram. One promising application might be using resilience parameters to marine transportation and fisheries.

The identification of foundation species was viewed as a critical aspect. Foundation species can be identified several ways, such as structural engineering species especially in benthic environments, forage species that have a large impact, or using foodweb models to identify keystone species. If a biomass index is used, then lower trophic levels may dominate.

5.2 Modelling the potential effects of climate change on cusk habitat: work in progress – John Manderson, with J. Nye, J. Hare, E. Huepel, C. Stock, M. Alexander, P. Auster, D. Borggaard, A. Capatondi, K. Damon-Randall, J. Hare, J., I. Mateo, L. O'Brien, D. Richardson, S. Thompson

There is growing concern about the effects of global climate change on marine ecosystems and the ecologically and/or economically important organisms that constitute them. Poleward shifts in the geographic ranges of marine species apparently related to changes in climate are an order of magnitude faster than those reported for terrestrial organisms (Sorte *et al.*, 2010; Cheung, 2009). In an effort to assess the potential impacts of climate change of marine ecosystems, the Protected Species Division of the National Oceanic and Atmospheric Administration in the US has assembled teams of researchers to develop ecological models for sensitive marine species that can be coupled to downscaled forecasts of important ocean variables from global climate models. An interdisciplinary team of government and academic scientists working in the Northwest Atlantic has been assembled to develop a coupled climate-species niche model for the deep water boreal Gadid, Cusk (*Brosme brosme*). This species is in the final stages of a status review under the Endangered Species Act in the United States and has been listed as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; 2003, 2006). Here we report on the ongoing development of a coupled climate-species niche model for cusk.

Cusk inhabit deep rocky reefs, ledges and cold water coral outcrops from the Gulf of Maine to the east coast of Greenland in the Western Atlantic, and in the Eastern Atlantic from Iceland into North Sea along Scandinavian coast to Murmansk, and to Spitsbergen. They occur at depths ranging from ~50m–1000 m. Abundance and frequency of occurrence of cusk in Canada and US fisheries-independent surveys declined dramatically in the late 1980s and have remained at very low levels (Figure 5.2.1). Body sizes of cusk collected in Canadian and US waters have also declined. In US surveys the mean body length was 61 cm from 1964–1993 but declined to 38 cm from 1994 to 1996. Reductions in the abundance and size of cusk are believed to be the result of bycatch mortality in lobster and longline fisheries, but regional changes in climate may also have contributed to the decline (Nye *et al*., 2009; Davies and Jonson, 2011).

Cusk Distribution Data

We used annual fishery-independent bottom-trawl survey data from the US and Canada to develop a simple species niche model for cusk that could be coupled to predictions of ocean conditions from global climate models. The Canadian and US surveys were depth-stratified and intensities of random sampling within strata are proportional to surface areas of strata. In both surveys, stations were sampled throughout the 24 hour day and nets are towed at ~1.8 m/s for 30 minutes. US surveys were conducted by the Northeast Fisheries Science Center (NMFS-NEFSC) using a #36 Yankee trawl with a 10.4 m wide x 3.2 m high opening and rollers (12.7 cm stretched mesh [SM] opening, 11.4 cm SM codend, 1.25 cm SM lining in the codend and upper belly; Azarovitz, 1981). Area of bottom swept by each US tow was ~0.02 km^2. The US surveys have been conducted from a latitude of 35 North to 44 North consistently during spring (March to early May) and autumn (September and October) since 1970. Canadian surveys of the Scotian Shelf (42–47 °N) have been conducted by the Department of Fisheries and Oceans (DFO), Maritimes Region, Canada (Doubleday, 1981; Shackell and Frank, 2003). Canadian surveys used a Western II-A bottom trawl with a 19-mm codend liner. The area swept by nets in the Canadian surveys was approximately 0.04 km^2. The Scotian Shelf has been consistently sampled during summer (July and August) since 1970. Additional surveys of the Scotian Shelf and Georges Bank have been performed in spring beginning in the late 1970s. We did not correct for differences in vessels or gears because inter-calibration of the two surveys has not been performed. Instead we used a presence/absence transformation of cusk abundances to minimize the effects of biases associated with surveys, including habitat specific gear biases.

Habitat data

Since the goal of the project was to develop a niche model for cusk using ocean habitat variables that could be downscaled from global climate models, we were limited in the habitat covariates we could consider. To describe topographic complexity of the bottom habitat we used a 15 arc second (~350 meter) bathymetric grid made by merging data Canadian and US data. This coverage was used to extract depths and to compute a terrain ruggedness index (TRI; Riley *et al.*, 1999) for the centre of each tow (Figure 5.2.2). Moving window analysis was applied to the bathymetric grid to calculate topographic complexity (TRI) as the sum of absolute values of differences in elevation between the centre grid cell and its 8 neighbouring cells. We assumed that the resulting bottom complexity estimates for the Northwest Atlantic were stable at over the time-scale of our forecasting (<100 years). We therefore also used this bottom complexity coverage to project the niche model. Conductivity, temperature, and depth (CTD) profiles collected with bottom trawls in the Canadian and US surveys were used for bottom water temperatures and salinities in our analysis. Because changes in the behaviour of animals during the 24 hour day can affect the capture efficiency of trawls, we also considered solar elevation at the locations and times of tows in our model development.

Species Niche Modelling

We selected generalized additive modelling (GAM) using the mgcv package in R software (Wood, 2006) as our niche modelling technique. We used a conservative iterative approach with the goal of developing a general model of cusk niche dimensions that could be practically downscaled from Global Climate Models or otherwise forecast. We first analysed the Canadian and US survey data separately but in parallel to identify important environmental covariates and assess similarities in cusk responses between the surveys. We then determined whether responses to covariates were density-dependent within each survey using data collected since 1990 to define the low density period (Figure 5.2.1). We merged the Canadian and US surveys to construct general species niche model for cusk for the Northwest Atlantic after we determined that density-dependent responses of cusk were similar between surveys.

Results

Species Niche model

Probabilities of cusk occurrence were related to temperature and the structural complexity of the bottom (TRI). Bottom depth was also significant in a preliminary GAM. However some marine organisms, including cusk, migrate into deeper water to avoid suboptimal temperatures at shallower depths (Nye, 2009). We therefore did not include depth in the final model so as not to constrain the forecast response to a specific depth range. Cusk occurrence was not related to solar elevation, salinity, or residual salinity derived from a non-linear regression that used depth as the independent variable.

In analyses of the US and Canadian surveys, the response of cusk to temperature appeared to be density-dependent while the response to bottom complexity was not. The temperature range for cusk was broader during the high density period (1970–1990) and fish were more likely to occur in warmer temperatures than during the low density (1991–2008) period. An examination of changes in the depth response with density indicated that the broader temperature range for cusk during the high density period was not related to an association of the species with shallower habitats. On the basis of this analysis we argue that the low density GAM model probably resembles the fundamental niche for cusk with respect to bottom temperature and bottom complexity more closely. In contrast the high density model may reflect a realized niche shaped to some degree by competition for structurally complex bottom habitats. Based on this argument we developed a final low density niche model to project in space and time using downscaled ocean forecast from the climate models.

The low density model built using Canadian and US data collected from 1991 to 2009 indicated that cusk "prefer" temperatures between 5 and 10.4° C with an apparent optima at approximately 8° C (Figure 5.2.3). Probabilities of cusk occurrence also increased with increasing bottom complexity (TRI) which had positive effects at values greater than 2.3 (Figure 5.2.4). Probabilities of occurrence declined and became variable at values greater than 9. This is probably the result of habitat specific gear bias since cusk have been observed in very complex habitats (Oster *et al.*). The capture efficiency of bottom trawls is low in structurally complex habitats which the surveys avoid to some degree to prevent gear damage.

Projections of Niche Model

The final projections of the cusk niche model will use downscale bottom water temperatures from 11 global climate models for 3 climate change scenarios (B1, A1B, and A2) in two future time periods (2020–2060 and 2060–2100). However the statistical downscaling of bottom water temperatures is not yet complete. For this demonstration exercise we therefore simulated changes in climate using the simple approach of adding degrees Celsius uniformly to bottom temperature climatology. The resulting raster grids of bottom temperature as well as bottom topographic complexity (TRI) were then used to project the niche model described above.

Bottom temperature climatology for the months of July and August was interpolated using CTD profiles collected during Canadian and US surveys of the Northwest Atlantic from 1960 to the present (Figure 5.2.2). The spatial grain of this raster data were 28 km^2. The grid for bottom complexity measured using the Terrain Roughness Index (TRI) had a spatial grain of 0.35 km (Figure 5.2.2). To match the raster we reduced the resolution of the TRI grid using an aggregation size of 4 cells and maximum values. This produced a grid with a grain of 1.5 km. Bottom temperature climatology was then disaggregated by a factor of 18 cells and resampled using bilinear interpolation to “stack” the temperature and complexity rasters. To simulate warming bottom water temperature climatology for July/August was then uniformly adjusted at 1°C increments.

The projections of the niche model indicated that the amount of available cusk habitat in the Northwest Atlantic regional sea represented by preferences for bottom temperature and topographic complexity declined with increasing temperature (Figures 5.2.5 and 5.2.6). A two degree temperature increase bottom temperature, that falls within the range of 100 year forecasts from global climate models, produced an approximately 20% decline in available cusk habitat defined by our niche model. More importantly, our simple model predicted fragmentation of available cusk habitat because of the differences in the spatial dynamics of bottom temperature and bottom complexity in our niche. With warming, cusk habitat became concentrated in the southwestern Gulf of Maine and Eastern Scotia shelf where deep and structurally complex bottom habitats fell within regions where temperatures remained or became optimal with warming. If this type of habitat fragmentation occurs in real marine systems it will be essential to consider population connectivity and source sink dynamics in assessing future impacts of global climate change on marine ecosystems.

We have several tasks to complete.

1) The niche model is to be verified using cross-validation and out of sample prediction.

2) Statistical downscaling of global climate models that will produced a more nuanced ensemble of projections of bottom temperatures under three climate scenarios and two time-series.

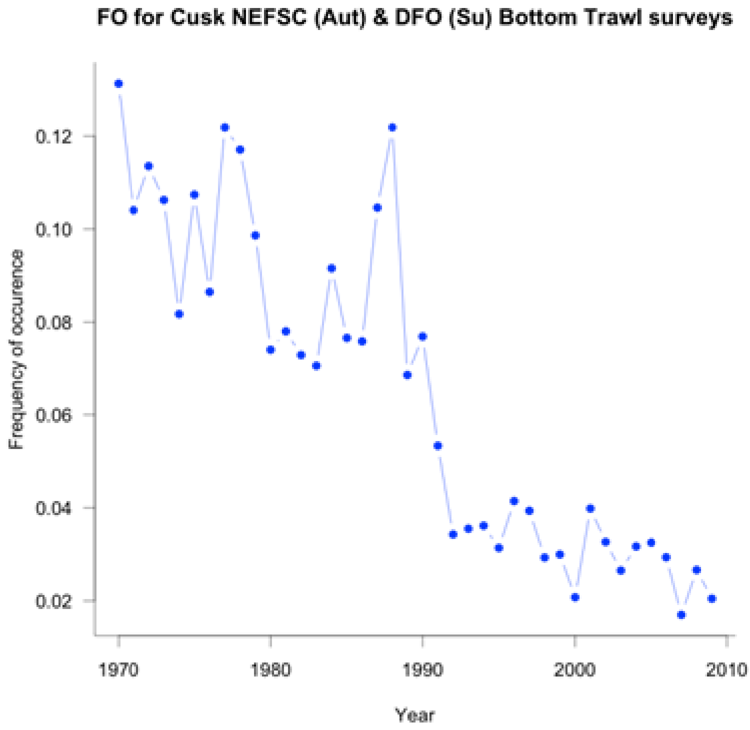

Figure 5.2.1. Frequency of occurrence for Cusk collected in US (Aut=Autumn) and Canadian (Su=Summer) fishery-independent bottom-trawl surveys.

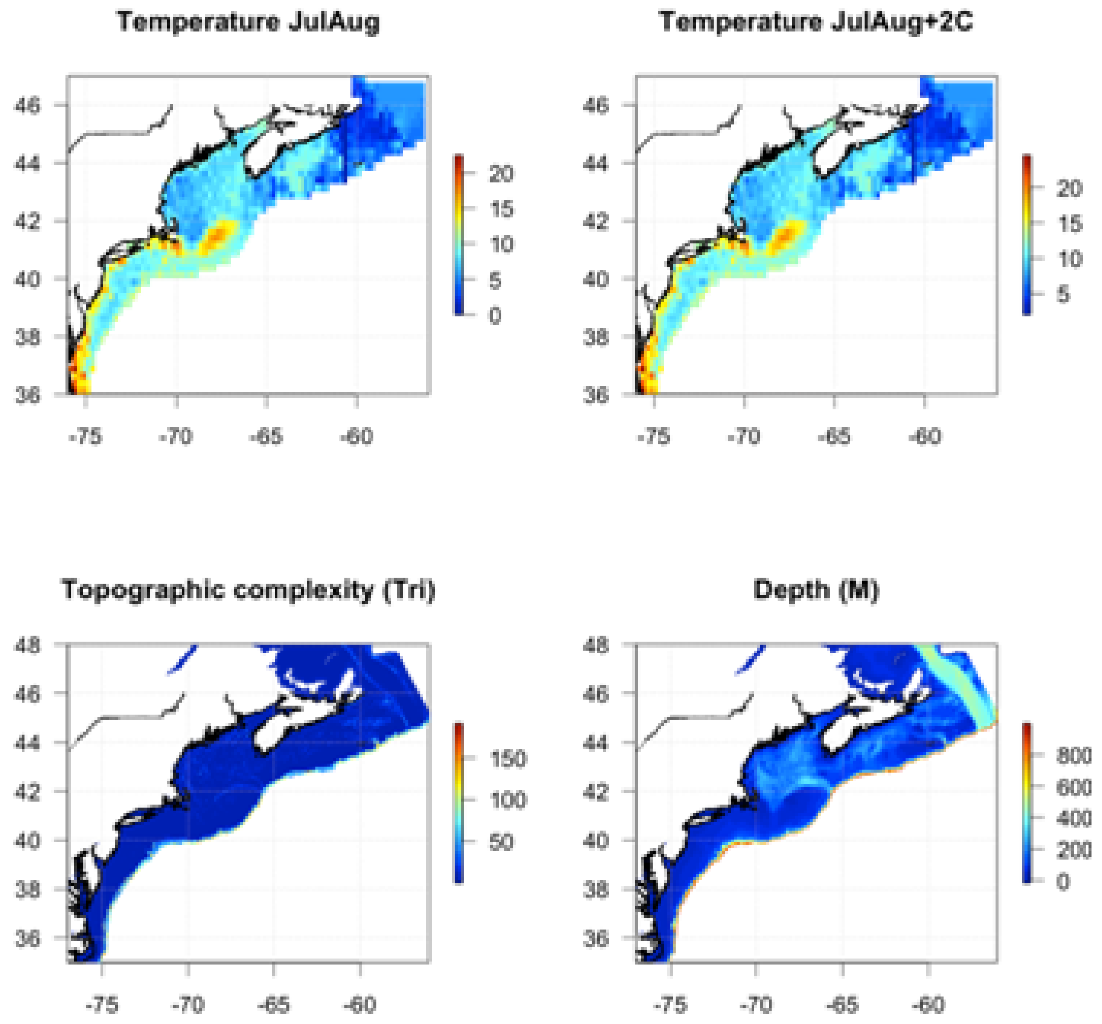

Figure 5.2.2. Variable considered in species niche model for cusk and/or used for the projections. Bottom water temperature climatology for July and August and a +2C anomaly are in the upper panels. Topographic complexity (TRI) was used in the model and was derived from a depth grid that merged Canadian and US bathymetric data (Depth M).

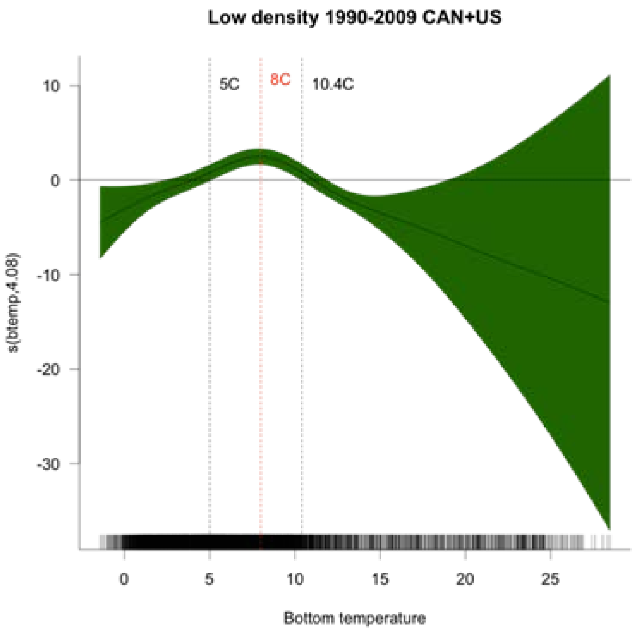

Figure 5.2.3. Temperature effects on cusk occurrence derived from GAM analysis of merged US and Canadian Bottom-trawl data. Numbers and lines indicate thresholds where 2 standard error confidence bands are above 0 in partial deviance plots and therefore within the range of positive effects on cusk occurrence.

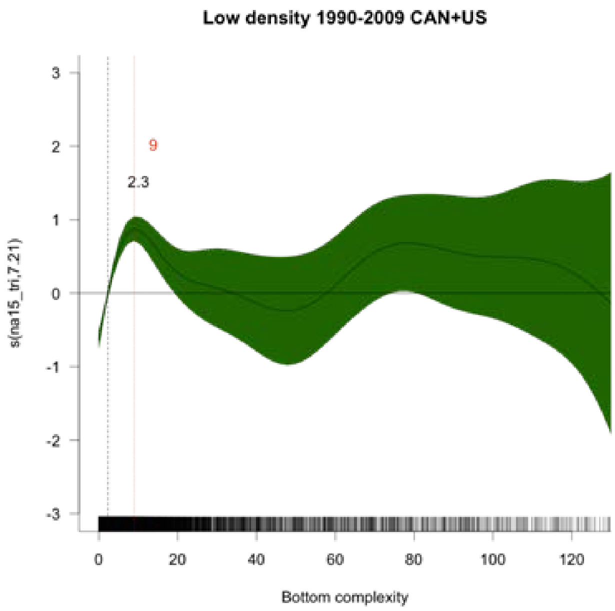

Figure 5.2.4. Effects of Topographic complexity on cusk occurrence derived from GAM analysis of merged US and Canadian Bottom-trawl data. Numbers and lines indicate thresholds where 2 standard error confidence bands are above 0 in partial deviance plots and therefore within the range of positive effects on cusk occurrence. Habitat dependent gear bias probably produced the non monotonic response function evident in values >9.

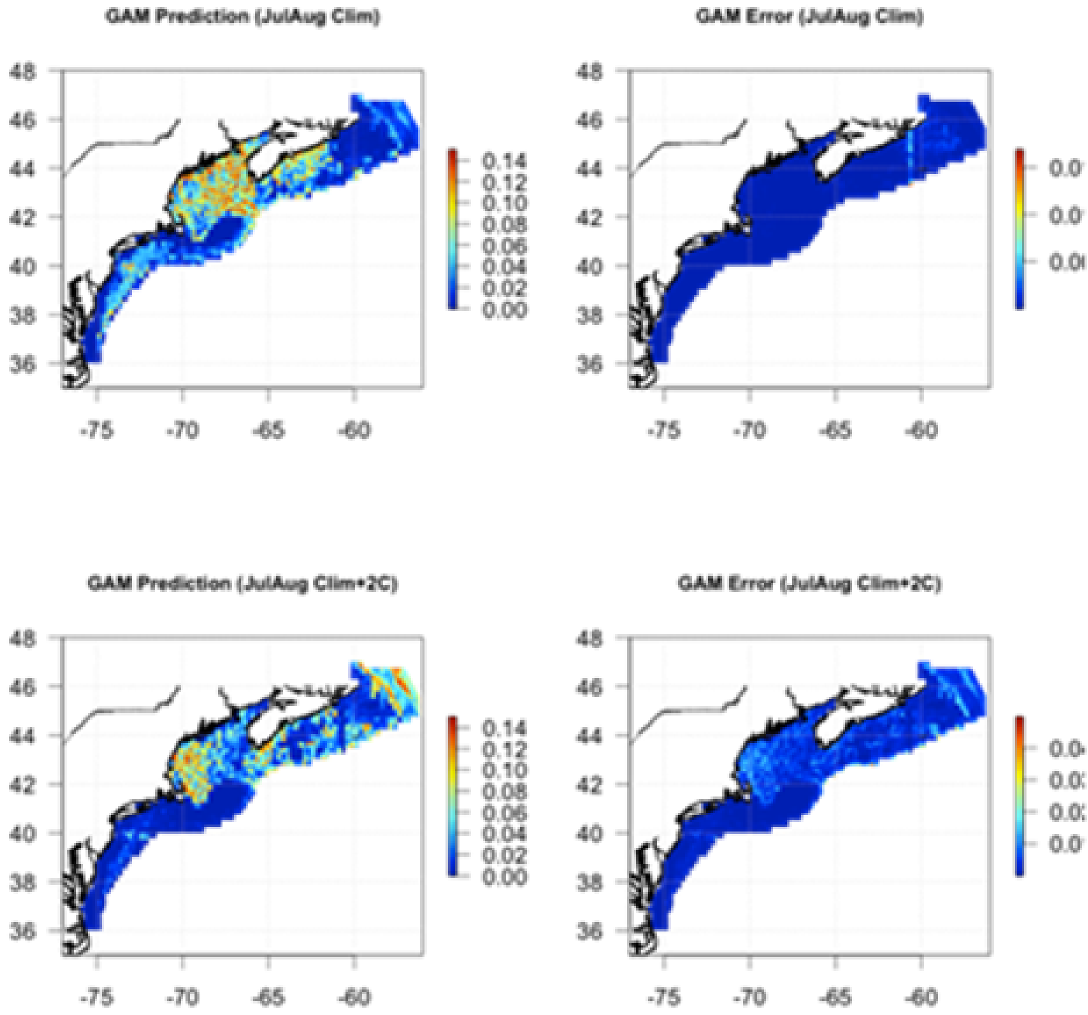

Figure 5.2.5. Projections of the cusk niche model defined by temperature and bottom complexity for climatological bottom temperatures in July/August (top left) and July/August temperatures+2C (bottom left). Panels on the right map 2 standard error estimate projections.

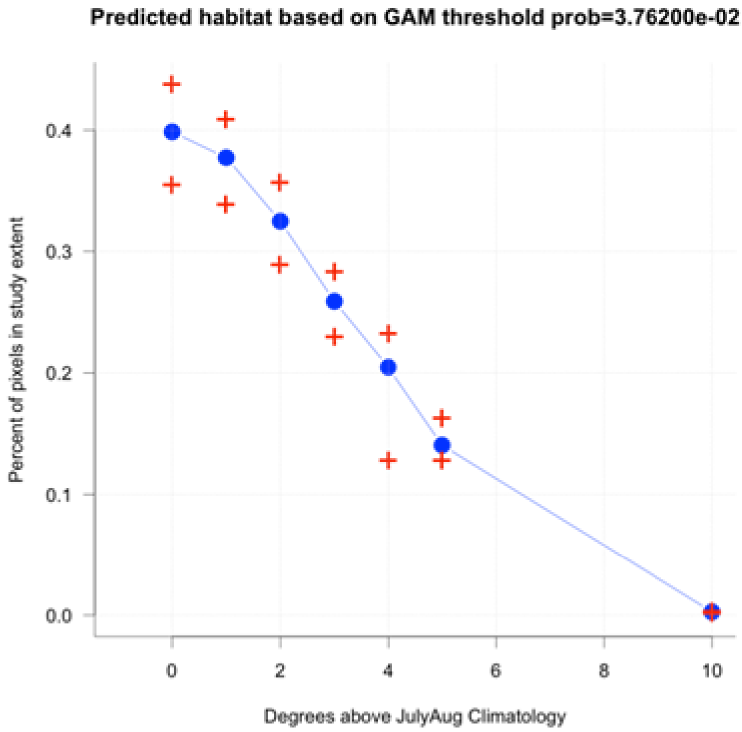

Figure 5.2.6. Estimates of changes in the availability of cusk habitat defined by temperature and bottom complexity in the GAM in the Northwest Atlantic with uniform increases in temperature to the present day bottom temperature climatology for July/August.

5.3 Habitat template model predictions and patterns of marine fish diversity – Jon Fisher

Habitat template models provide a method to integrate physical, chemical and biological data into seabed habitat maps. They also provide predictions of life-history traits within assemblages and the locations most vulnerable to anthropogenic impacts. A previously developed model based on spatial variations in scope for growth (an estimate of local energy available) and natural disturbance (a local characteristic of the sea floor environment) for the Scotian Shelf/Bay of Fundy was tested for its ability to predict demersal fish life-history traits, species diversity and community composition using scientific trawl survey data. Among 30 dominant fish, slow-growing, long lived species tended to occur in naturally stable habitats. Among consistently co-occurring groups of species, functional differentiation, rather than life-history similarity, characterized assemblages whereas species richness peaked at intermediate levels of natural disturbance among survey strata and species evenness increased linearly with average scope for growth. Community composition among samples was significantly correlated with both habitat template values, although geographic distance, depth and bottom temperature were more strongly related to composition. These results revealed compelling matches between template predictions and patterns of marine fish species diversity, but low variation in life-history diversity and high mobility of fish may account for some of the weaknesses in matches to model predictions. Recent extensions of these tests to include temporal dynamics and evaluations at the spatial scale of the WGNARS domain provide further insights into the differential vulnerability of marine species to multiple stressors.

5.4 Assessing the vulnerability of key species to climate change – Nancy Shackell

A general fisheries objective is to protect habitat. Marine reserves have been repeatedly recommended for sustaining fisheries especially of sedentary species that broadcast their gametes into the water and need a minimum density to ensure success of fertilization. Using sea cucumber as an example, we sought to identify essential habitat for means of protection—that is, every new/emerging invertebrate fishery should have a protected core area for the purposes of research as well as a sustainable source of recruitment to marginal areas. We present our initial methodology on the identification of important habitat, patch size and how to determine the proportion of high density areas that should be fully protected.

6 Ecosystem indicators and climate/environmental drivers (ToR b)

6.1 A global comparison of marine ecosystem response to fishing using a suite of ecological indicators – Alida Bundy with Marta Coll (Marie Curie Fellow ICM-CSIC, Spain), Lynne Shannon (UCT, South Africa), Yunne Shin (IRD, France), Julia Blanchard (Imperial College, UK), Didier Jouffre (IRD, France) and Jason Link (NMFS, USA)

Appropriate indicators are required to translate ecosystem impacts and changes into management measures that can be assessed for their effectiveness. The scientific community is challenged to provide a generic set of synthetic indicators to accurately reflect the effects of fisheries on marine ecosystems, to facilitate effective communication of these effects and to promote sound management practices. IndiSeas was established to evaluate fishing impacts on the status of marine ecosystems using indicators. A suite of eight selected ecological indicators were assembled for 19 fished marine ecosystems and results of comparative analyses were synthesized to inform stakeholders of relative states and recent trends in the world's fished marine ecosystems. A web-based "dashboard" was developed, evaluating the exploitation status of marine ecosystems in a comparative framework, guiding fisheries management in each ecosystem www.indiseas.org. Reference levels were explored for the indicator suite, ecosystems were ranked according to exploitation status, a decision tree was developed to classify ecosystems based on trends, and roles were assessed of non-fishery drivers in determining ecosystem changes. Analyses suggest most of the ecosystems are overexploited and the declining trends in ecological indicators led to 79% of the ecosystems being classified as deteriorating. IndiSeas has moved into its second phase; IndiSeas2 aims at "Evaluating the status of marine ecosystems subject to multiple drivers in a changing world" in support of an ecosystem approach to fisheries. Although IndiSeas indicators were selected to reflect impacts of fishing, results need to be considered in the context of human dimensions and environmental drivers. IndiSeas2 will explore the response of a broader suite of ecosystem indicators to ecosystem change across a wider range of ecosystem types and drivers. Combined effects of fishing and climate on indicators trends will be modelled, and means of testing indicator responsiveness and performance will be developed. Further work is planned to identify indicator thresholds and reference points.

6.2 Projecting ocean climate change in the Northwest Atlantic – John Loder

Some issues, challenges and potential ways forward in developing projections of ocean climate change in the NW Atlantic (NWA) were described. The general issue of downscaling the coarse-scale ensemble predictions of global climate models to the key underlying space and time-scales of regional ecosystems is exacerbated in the

NWA by: a) the pronounced influence of ocean circulation on its oceanographic setting, and b) natural temporal variability in the regional climate system associated with the North Atlantic Oscillation (NAO) and the Atlantic Multi-decadal Oscillation (AMO). Changes in Arctic outflows and the strong western boundary currents of the subpolar (Labrador Current) and subtropical (Gulf Stream) gyres can be expected to have strong influences on regional climate changes, but these features have not been well resolved in the coupled models used in IPCC assessments to date. Comparison of model fields with observed temperature and salinity climatologies indicates that the models' orientation of the subtropical-subpolar water boundary is too zonal in the western North Atlantic – too far north off the Gulf of Maine and too far south to the east of the Grand Bank. Also, these models do not reproduce the observed decadal-scale variability in ocean temperature and salinity between the Labrador Sea and Scotia-Maine region that has been associated with the NAO. Thus, outputs from these models should be used with caution in projecting regional ocean climate change in the NWA.

Nevertheless, a combination of empirical, theoretical and modelling information indicates that anthropogenic climate change is occurring in many variables in the NWA, and can be expected to continue. For many variables such as ocean temperature, stratification and acidity, and coastal sea level and erosion, increases are expected to continue following the direction of the global trends in these variables, but with uncertain regional variations in magnitude. Similarly, decreasing sea ice extent is expected in northern areas. On the other hand, ocean salinity is expected to decrease in the subpolar NWA but increase in the subtropical western Atlantic, while there is uncertainty about its change in mid-latitude coastal areas dominated by river discharge. Of particular relevance to the WGNARS is the potential for a northward shift in the subtropical-Subpolar Gyre boundary west of the Grand Bank, associated with large-scale ocean circulation and NAO changes. This may result in amplified warming of the shelf/slope waters between the Mid-Atlantic Bight and the Grand Bank. But it should also be noted that decadal-scale changes in many ocean variables associated with natural modes of regional climate variability (e.g. NAO, AMO) may dominate and confound anthropogenic changes during the next decade or so, with the potential anthropogenic changes noted above not becoming dominant for a couple of decades. It is important that projections of future change and its impacts evaluate observed recent variability and our understanding of its origin and influences, as well as larger-scale climate change scenarios and knowledge of regional ocean and ecosystem dynamics.

The presentation drew on the results of Section 5.1 ("Review of atmospheric and oceanographic information") of the recent report of the NAMPAN-ICES Study Group on Designing Marine Protected Area Networks in a Changing Climate (SGMPAN). This report can be found at http://www.ices.dk/workinggroups/ViewWorkingGroup.aspx?ID=500 .

6.3 The Western North Atlantic shelf break current – Paula Fratantoni

An interconnected coastal boundary current system dominates the shelves and slopes of the Northwest Atlantic, the shelf break front and jet (Figure 6.3.1). This current system extends many thousands of kilometres, from the Subarctic to the subtropical domain, establishing an advective link between fresh arctic sources in the subpolar North Atlantic and the Northeast Continental Shelf Ecosystem, which is the focus of this ICES working group. Through this advective pathway, the boundary current delivers transients of high-latitude climate driven variability (e.g. fresh anomalies) from their source to biologically sensitive regions such as the Scotian Shelf and Gulf of Maine. Recent studies suggest that the dynamics of the boundary current may dictate where mass and freshwater are discharged from the shelf, and that the exchange may be limited to a few specific locations along the path of the current. Coastal ecosystems will undoubtedly be sensitive to where and how much freshwater leaves the boundary as it is advected by the boundary current. For this reason, it is imperative that we understand the behaviour and dynamics of the boundary current both on regional and basin scales. By doing so, this will enhance our ability to predict the impact of climate-driven variability on coastal regimes far from their source, an important step toward effective management of these ecosystems.

Regionally, the shelf break current and its associated thermohaline front play a fundamental role in governing the mass and property budgets on the shelf, influencing fish populations, migrations, and feeding sources to a variety of species. Over the past 50 years, many studies have addressed various aspects of the Northwest Atlantic shelf break current, focusing regionally on one segment of the current. The most intriguing result from the locus of these regional studies is that, despite the large-scale continuity suggested by tracer observations, the basic properties of the current and thermohaline front vary quite a bit from region to region. In order to investigate the "global" vs. "local" nature of the current system, we analysed 12 years of historical temperature and salinity data to quantify the alongstream evolution of its structure, properties, volume transport, and cross-shelf position, following its path from Greenland to Cape Hatteras, NC (Fratantoni and Pickart, 2007). Most notably, the results from this study suggest that the boundary current experiences very abrupt shifts in water mass character, accompanied by large drops in volume transport, near the Grand Banks of Newfoundland, identifying this geographic region as a critical choke point in the coastal boundary current system.

Building on these results, Fratantoni and McCartney (2010) used all publicly available historical temperature and salinity data (110 years) to construct a steady-state description of the freshwater pathways exiting the shelf region, particularly near the Grand Banks of Newfoundland. Our work was motivated by the ultimate desire to use the climatology as a baseline for identifying episodic anomalous freshwater pulses and trace their evolution as they propagate along the boundary away from their source (e.g. the Arctic). The climatology confirms that cold/fresh northern-source waters are advected offshore within the retroflecting Labrador Current along the full length of the boundary between Flemish Cap and the Tail of the Grand Banks. In fact, it is estimated that most of the equatorward baroclinic transport at the boundary must retroflect back toward the north in order to explain the annual mean distribution of salinity in the climatology. While the retroflection of the Labrador Current appears seasonally robust, the freshwater distribution within the retroflection region varies in response to (1) the freshness of the water available for export which is set by the arrival and rapid flushing of the seasonal freshwater pulse at the boundary, (2) seasonal buoyancy forcing at the surface which alters the vertical stratification across the retroflection region, restricting certain isopycnal export pathways, and (3) the density structure along the eastern Grand Banks, which defines the progressive retroflection of the Labrador Current.

While the flow pathways in our climatology appear seasonally robust, we recognize that perturbations in the volume or freshness of water carried by the boundary current may alter the climatological mean dynamics, shifting export pathways or adding new ones. These pathways will determine the impact of such anomalous events on downstream coastal ecosystems, whether they leave the coast or continue equatorward. Indeed, observations and models suggest that basin-scale meteorological forcing (i.e. North Atlantic Oscillation) probably does alter the transport partitioning at the Tail of the Grand Banks of Newfoundland, resulting in changes in the water mass characteristics along the Scotian Shelf and in the Gulf of Maine (Petrie and Drinkwater, 1993; Marsh, 2000; Petrie, 2007.) However, the linkages are far from simple and are complicated by the interplay between remote vs. local forcing and the competing influence of multiple advective sources (e.g. shelf vs. slope).

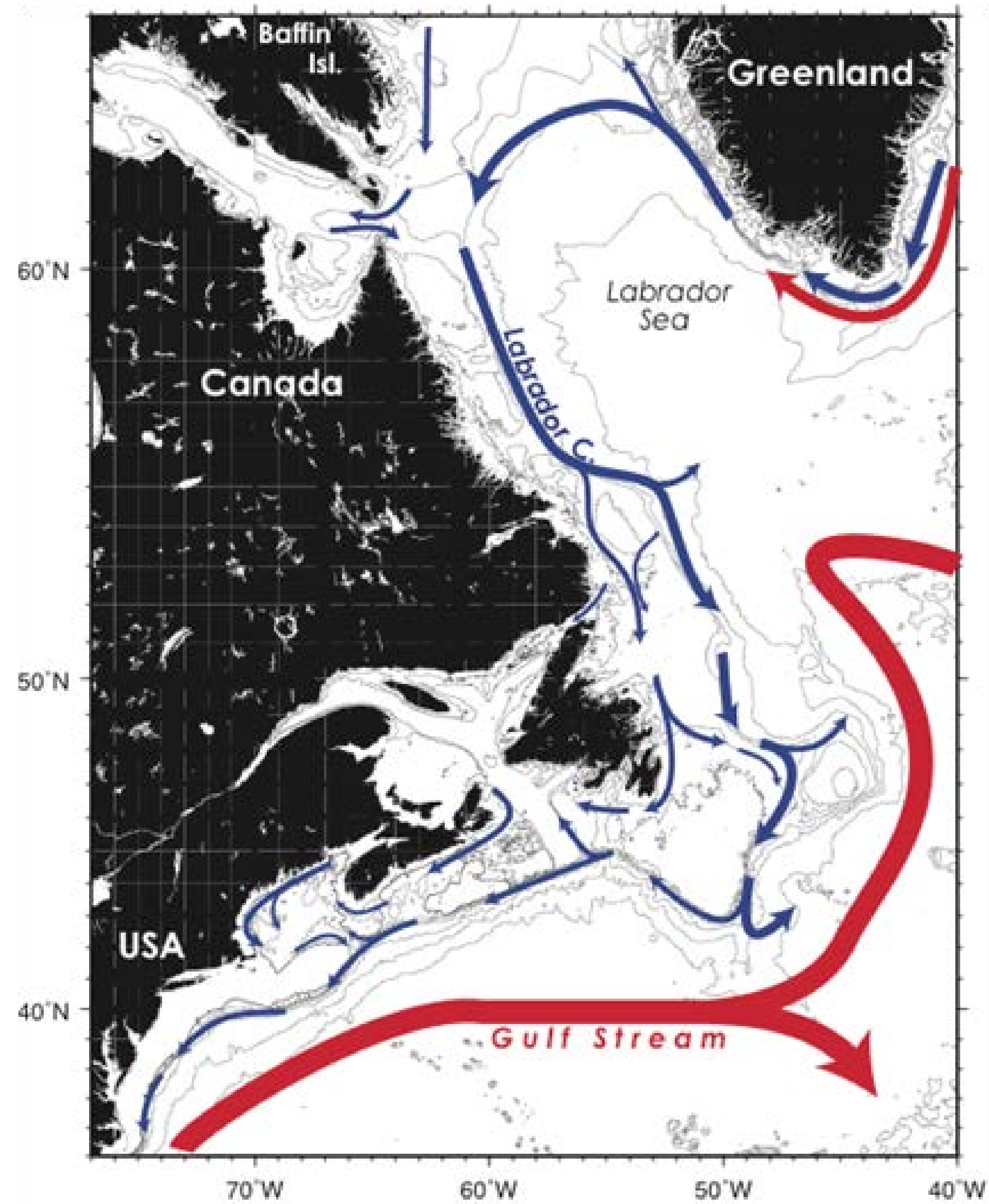

Figure 6.3.1.Major currents of the Northwest Atlantic Ocean.

6.4 An ocean modelling system based on NEMO (for global, basin, an regional applications) – Youyu Lu

Researchers at the Bedford Institute of Oceanography actively participate in a major Canadian effort to develop an ocean modelling system for global, basin and regional applications. The system is based on the Nucleus of European Modelling of the Ocean (NEMO). For applications in the Northwest Atlantic, we have developed a two-way nested model with a horizontal resolution of 1/12° in longitude/latitude focusing on the East Canadian Shelf Seas. The model has 46 unevenly distributed levels in the vertical. With such a high resolution, the model reasonably simulates the separation of Gulf Stream near Cape Hatteras, the characteristics of the Scotian Slope Water, the propagation of cold water from the Labrador Sea to the Slope Water near the Tail of the Grand Banks, and the statistics of mesoscale eddies in this region (Figure 6.4.1).

Focusing on the Scotian Shelf, the model obtains a range of 3–4°C for interannual variations of bottom temperature, consistent with the observed magnitudes. However, without data assimilation the model obtains incorrect timing of the temperature variations. We suspect that this is related to the randomness of the model-simulated mesoscale eddies, in particular those near the Tail of the Grand Banks and in the Slope Water area. We also examined the data assimilative ocean reanalysis product from the Mercator-Ocean of France, based on a 1/4° global NEMO model. The reanalysis obtains interannual variations of bottom temperature that are more consistent with observations on the Scotian Shelf (Figure 6.4.2).

A tentative conclusion is that both high resolution and data assimilation are needed in order to correctly simulate and forecast the important aspects of ocean variability in the Scotian Shelf area. A project is planned to develop seasonal ocean forecasts for the Northwest Atlantic, using the operational seasonal atmospheric forecast of Environment Canada and to apply such forecasts in ecosystem and fishery management.

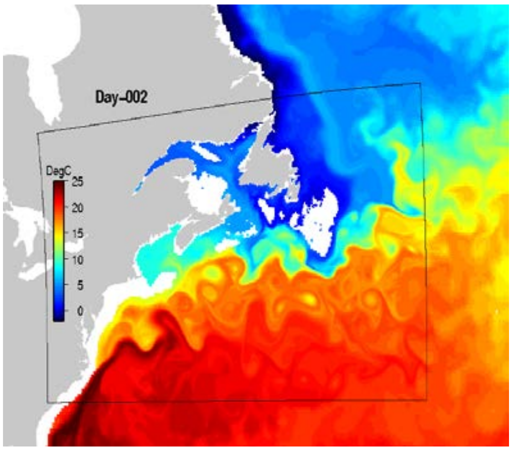

Figure 6.4.1. A snapshot of ocean temperature at 100 m depth, after 9 years of prognostic simulation using a two-way nested ocean model based on NEMO. The horizontal resolutions are 1/4° in longitude/latitude for the outer model covering the whole North Atlantic, and 1/12° for the inner regional model covering the area inside the box.

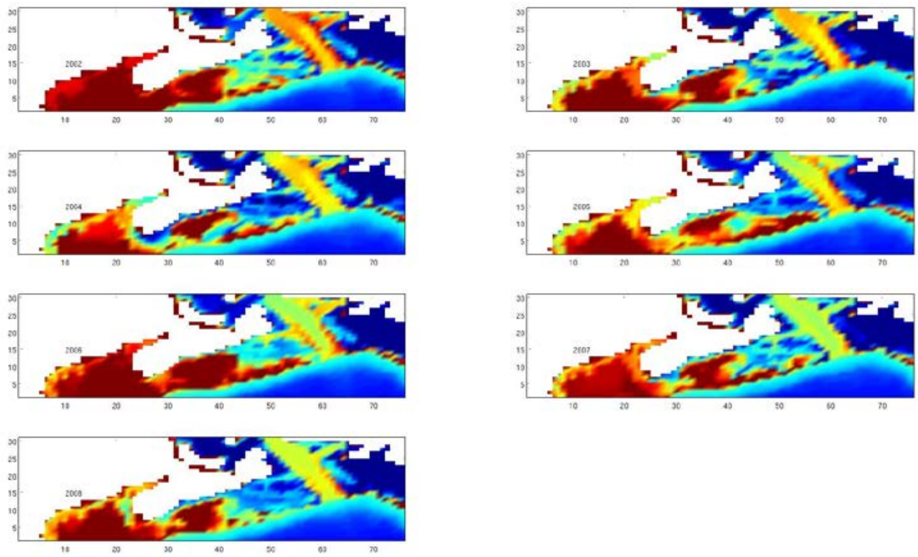

Figure 6.4.2. Bottom temperature in the Scotian Shelf area in July during 2002–2008, obtained from the global data assimilative reanalysis by Mercator-Ocean of France.

6.5 Northwest Atlantic Ocean modelling – Steve Cadrin

One of the 2010 Recommendations from WGNARS was that "multiple oceanographic models should be applied to the entire NW Atlantic to support ensemble analysis of large-scale features", and 2011 terms of reference include: determine candidate indicators of ecosystem status that reflect important patterns in the physical environment, trophic dynamics, and system productivity; initiate integrated analyses of the relationships between physical and biological aspects of the Northwest Atlantic ecosystem (e.g. predictable state changes, climate impacts, biodiversity, community analyses); and propose candidate thresholds for each indicator. Therefore two oceanographic models applied to the Northwest Atlantic were reviewed to evaluate their potential for providing integrated indicators and thresholds.

6.5.1 Regional Ocean Model Simulation (ROMS)

Avijit Gangopadhyay (UMass School for Marine Science & Technology), Dale Haidvogel (Rutgers University) and Fei Chai (University of Maine)

The ROMS Pan-Regional Synthesis includes the Arctic-North Atlantic Model, which involves a pole-shifted grid with varying horizontal resolution (4–5 km in subtropics and Arctic), 50 non-uniform vertical levels, and a grid size of 1258 x 780 x 50km, with retrospective runs for 1985–2007 forced with CORE2 atmospheric fields. Model validation includes comparison with a current schematic derived from hydrographic and drifter data for all major currents in the Arctic - North Atlantic basin. Model circulation was validated from a currents, fronts and features perspective. Comparison with a current schematic derived from hydrographic and drifter data makes evident the model's realism in resolving all major currents such as the Gulf Stream (GS), Azores Current (AzC), North Atlantic Current (NAC), Labrador Current (LC), W. and E. Greenland Currents (WSG and EGC), Irminger Current (IrmC), Baffin Island Current (BIC), North Icelandic Current (NIC), and Slope Current (SF; Figure 6.5.1.1). The model also reproduces other important circulation features such as the well-known Northwest Corner (NWC), closed circulation around the Flemish Cap (FC), a jet south of Iceland, and the Iceland-Faroe Front, as well as recently identified features such as a double-current structure over the Ammassalik Shelf (AmS) and a doublefront structure of the Irminger Current west of the Reykjanes Ridge. Model validation also includes comparison against temperature-salinity profiles, mixed layer depths, Nutrients and Chlorophyll data from World Ocean Atlas.

The CoSINE biogeochemical ecosystem model includes 10 nutrient, phytoplankton, zooplankton and detritus components, and is being used over the North Atlantic basin. The model quantifies the path of N, Si, and CO_2 including uptake as a function of iron availability. The model was run in both low (50 km) and high (5–10 km) resolutions. Observed basin-wide nitrate and silicate distributions were used for model validation.

The Arctic-North Atlantic ROMS model set-up has the potential to provide integrated indicators to monitor and track large-scale oceanographic processes (e.g. great salinity anomalies, GSAs) as an indicator of climate change. A configuration of observational sections across the path of the GSAs can be used to validate model simulations and to characterize the three observed GSAs. The resources needed for ROMS include human resources and hardware. Supercomputers are needed to solve a coupled physical-biogeochemical high-resolution model with at least a (1024 x 1024 x 50) grid for 5–10 years of monitoring (comparable to GSA time-scales).

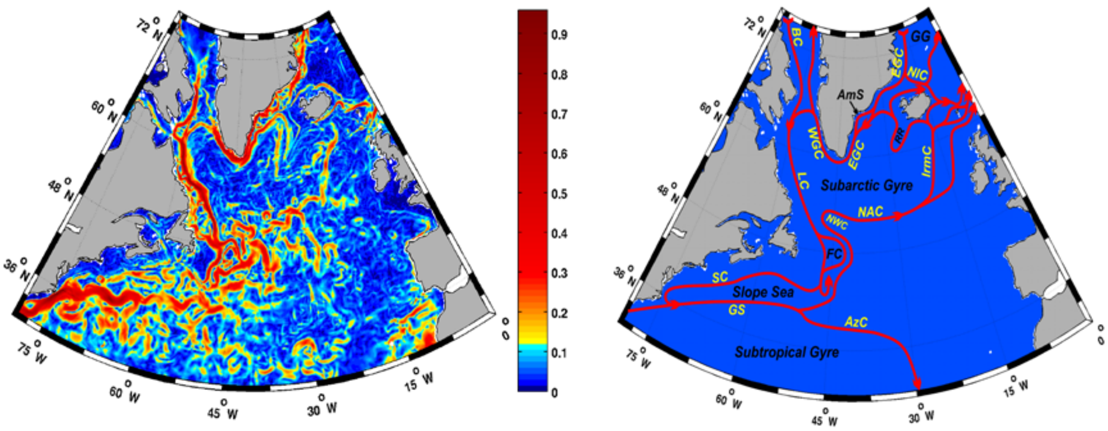

Figure 6.5.1.1. ROMS model validation of major currents (schematic and write-up courtesy Dr Igor Belkin).

6.5.2 An Integrated Global-Arctic-Atlantic-Gulf of Maine-Mass Coastal FVCOM System

Changsheng Chen, Guoping Gao, Zhigang Lai, Brian Rothschild (UMass School for Marine Science and Technology) and Robert C. Beardsley (Department of Physical Oceanography, Woods Hole Oceanographic Institution)

The UMASSD-WHOI joint research team has developed an integrated Global-Arctic-Atlantic-Gulf of Maine-Mass Coastal system (Figure 6.5.2.1) with an aim at studying the responses of multi-scale ocean processes to the climate change. This system was configured by the unstructured grid, Finite Volume Community Ocean Model (FVCOM). This model is being run for 1978 to present, with data assimilation of Sea surface temperature (SST), Sea–Surface Height, and Temperature/Salinity profiles. The global FVCOM includes the ice, tidal, meteorological forcing plus river discharges, etc. Model validation includes comparison of the model-simulated and observed ice coverage at the surface, and model-predicted and observed currents available in the Arctic and North Atlantic Ocean. Ecosystem dynamics (including nutrients, phytoplankton, zooplankton and detritus) have been modelled in the FVCOM framework.

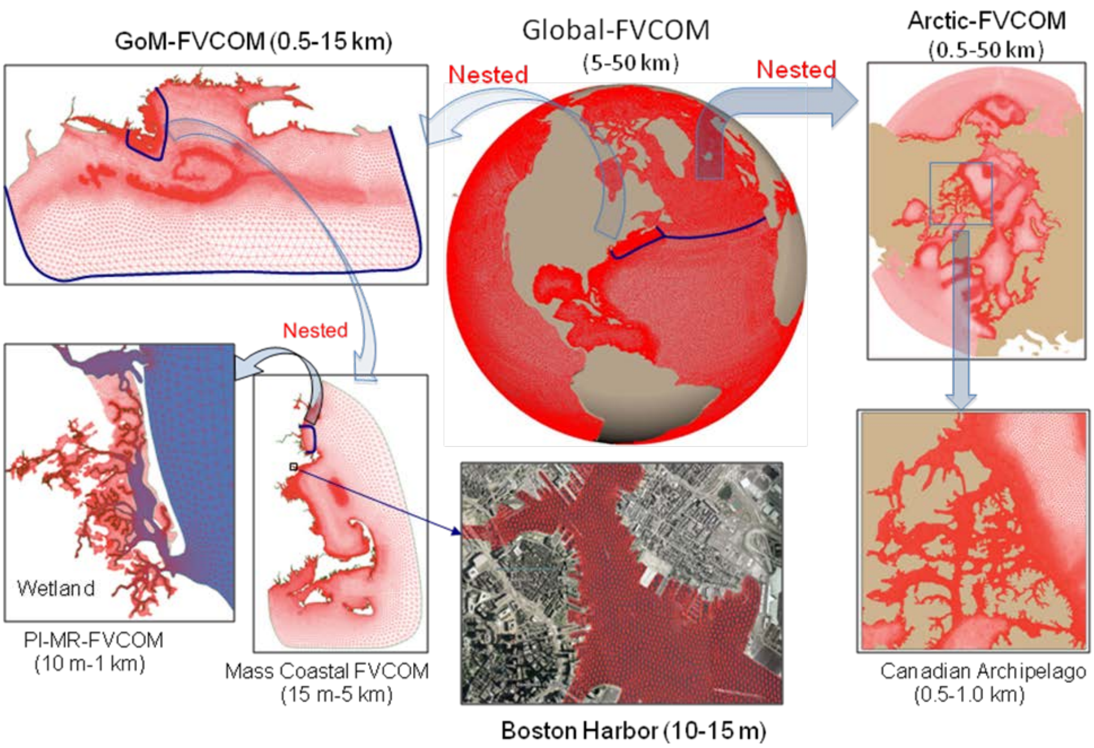

Figure 6.5.2.1. Hierarchical spatial structure of the Finite-Volume Coastal Ocean Model (FVCOM; courtesy of Changsheng Chen).

The FVCOM applications demonstrate the capability of an unstructured grid oceanographic model on simulating the entire Northwest Atlantic. Some validation has been completed (circulation, temperature, salinity, nutrients). Nutrient-Phytoplankton-Zooplankton-Detritus applications, which have been focused on the Gulf of Maine in the past, can be expanded to the entire NW Atlantic.

6.6 Overview of Northwest Atlantic Ocean Tracking Network (OTN) meeting, Dartmouth, NS, 7 February 2011 – Peter Smith

Purpose: Inform participants about what is happening in this region and aid in building collaborations among us.

Attendance: The meeting was co-chaired by Peter Smith (DFO-BIO) and John Kosic (NOAA-NMFS). In all 36 interested persons attended the meeting, including two persons on the phone.

Presentations

VEMCO

Denise King gave a brief overview of the evolution of the technology to its present state, especially the needs for a new global coding scheme, driven by increasing demand for acoustic telemetry projects, and a new global code map. The solution, launched in 2009, provides literally tens of thousands of unique sensor transmitter IDs and millions of pinger IDs. This new scheme also provides improved error correction and strong encryption to protect against cloned duplicate IDs. With regard to receiver technology, there is a new emphasis on enabling upgrades in the field, and all new receivers are compatible with MAP-112 and future maps. Also discussed were improved features of the new VR4 underwater modem, the ability to support a benthic pod sensor suite, Slocum Glider Module and Receiver networking features, and the new V9AP tag which senses both depth and 3D acceleration of the animal as it moves through an array of receivers.

OTN DATA POLICY AND MANAGEMENT

Bob Branton gave an overview on the Data Policy and Management system, and of the safeguards that are in place to restrict access to confidential data. There are four new production servers and a storage server being installed at Dalhousie University. OTN meets OBIS and Global Change Master Directory (GCMD- run by NASA) standards, and GCMD will eventually host a copy of all of the OTN metadata. In the data warehouse, there are presently 500K records from 30 sources, 19 of which are from the NW Atlantic. Eight of the 19 records contain data obtained since August 2010. The current structure integrates both acoustic and satellite datasets, provides consistent views of data, and is very adaptable to new, future requirements. OTN worked with POST and other partners to determine standards for metadata, and a strict policy regarding OTN data submission and access has been implemented for deployment collaborators and trackers.

SOCIAL NETWORK EXAMINATION

Gayle Zydelewski presented the results of a social networking study of trackers her graduate student, Phillip Dionne, conducted as part of his Master's degree at the University of Maine. An illustrative case study looked at shortnose sturgeon from the Penobscot River. This species was thought to spend their lives in their river of origin, but they were found, using acoustic telemetry, to migrate to other rivers, highlighting the need for close cooperation among trackers and deployment collaborators in the region and around the globe for the wider ranging species. To explore this issue, an online survey, using Survey Monkey, was conducted. The survey consisted of 25 multiple choice/short answer questions and was sent to 150 interested parties in Canada, the US East Coast, and the Caribbean, 99 of whom responded. Results may be summarized as follows:

- Obstacles to collaboration identified:
  - Sense of competition (27%);
  - Lack of communication/awareness (22%);
  - Reluctance to make the effort (15%).
- What incentives could improve this?
  - Desire for infrastructure, i.e. fast and easy access point to information about detections (37%);
  - A means to increase communication (24%);
  - Need to develop common rules or expectations (21%).
- What did individuals consider to the most important factor to share data?
  - Potential for reciprocal exchange (37%);
  - Previous interaction with the researcher (35%); and
  - The researcher's reputation for openness to collaboration/data sharing (13%).

OVERVIEW OF EXISTING LINES

Peter Smith provided an overview of the existing NOAA and OTN lines and grids, and some of the data which they have generated, including:

- GoMOOS (now NERACOOS) Network: Receivers deployed on a total of 8 buoys in the Gulf of Maine, maintained by the Physical Oceanography group at the University of Maine.
- Halifax Line: Originally aligned with the historical Halifax Section, the path of the line changed due to the trawl activity of the silver hake fishery and the local pollock fishery. In all 37 stations are currently deployed.
- Cabot Strait Line: Major gateway from North Atlantic to the Gulf of St Lawrence (cod, eel, salmon, grey seal, bluefin tuna). The present deployment runs from Cape Breton to St Paul Island.
- Minas Passage Line: The goal of this curtain is to monitor the passage of migrating species to and from the Minas Basin.

He also provided an overview of the NSERC SNG, recently awarded to Dalhousie U, for which the key objective is to **understand species movements, interaction, and environmental variability across Canada's three oceans.**

Individual SNG projects in the Atlantic Arena include interdisciplinary observing and modelling, as well as work focused on particular species, including Atlantic salmon, American eel, Atlantic sturgeon, grey seals, and leatherback turtles.

He concluded that further progress in the region will require the following:

NEXT STEPS FOR OTN NW Atlantic Region

- Continue to deploy Halifax and Cabot Strait Lines
- Increase number of transmitter tags
- Relate detection patterns to environmental factors including ecosystem indicators
- Increase trans-boundary data analysis and collaboration
- Data analysis on Atlantic Salmon
- Collaboration formalization

Discussion

At the start of the discussion period, John Kosik discussed some key issues regarding the benefits of OTN:

- Provides distant-water observations
- Allows investigations of particular time-space windows
- Archives data on habitat use by multiple species
- Research collaboration – sharing resources and information
- Protected habitats and species

Following this, a wide-ranging open discussion of various issues and questions ensued, including topics such as OTN data policy, concerns /roadblocks to data sharing, importance of ecosystem observations and modelling, means to establish successful management regimes, and the need to establish additional strategic OTN lines.

7 Indicators and thresholds from monitoring data (ToRs c) and e))

7.1 Triad-Story-Indicators-Thresholds, or why Wolf Narratives are important for IEAs – Jason Link

Based upon the WGNARS 2011 presentation by MacLean and Walmsley, the application of indicators to the fairy tale story of little red riding hood delightfully highlighted the need to ensure that a narrative (story) is well developed in any [resource] management context and that any indicators selected for monitoring and/or use as decision support information must clearly support obvious elements of that narrative. The issue that was noted for IEAs is that there are multiple "story lines" facing those attempting to coordinate and manage among the multiple ocean-use sectors.

Upon discussion at WGNARS 2011, it was clear that these storylines map to the previously mentioned triad of drivers that can influence the core ecosystem properties. Table 7.1.1 indicates which "stories", albeit perhaps imperfectly stated, map onto the triad of drivers. From these, it is clear that several external and internal factors need to be monitored but are unlikely able to be directly managed. There are, however, several human factors that can not only be monitored but nominally managed.

The challenge will be to map germane indicators to each of these "story" lines. A first attempt to do so is given in Table 7.1.2. Indicators noted therein are more accurately classes or types of indicators from which more specific indicators could be developed. After suitable indicator examination and culling processes have occurred, further examination of such indicators as they relate to establishing thresholds would then be developed. The point of both these tables is that they could be readily adapted to serve as a scoping tool in exercises determining key priorities among stakeholder and managers and as a culling tool to winnow down from the plethora of indices likely to be proposed in a scientific context. Both steps are necessary early in an IEA context for any given ecosystem. The result would be a robust and wieldy set of indicators from which decision criteria could be established, monitored, modelled and evaluated.

Table 7.1.1. Ecosystem objectives and the associated triad of ecosystem drivers or core properties.

Triad Factor / "Story"	Human	External	Internal	Core (Goods, Services & Productivity)
No spp shall go extinct (PS, ESA, SARA, etc.) or remained **threatened** of doing so	x			
Fisheries prosecuted sustainably	x			
Manage **habitat** for no unacceptable loss (and associated connectivty)	x	x		
No unacceptable loss of **biodiversity**			x	
Nutrients and associated **CZM** issues managed at acceptable levels		x	x	
HABs and related biotic outbreaks			x	
Placement of offshore **energy** systems	x			
Placement of **navigation** routes	x			
No unacceptable **trophic** imbalances (not eroding functional redundancy)			x	
Accounting for **climate** effects		x		
Accounting for **invasive** spp		x	x	
Mitigating **toxic** deposition	x			
Cross-cutting				
Relativity & interactins among drivers	x	x	x	x
Cumulative impacts	x	x	x	x
Systemic resilience	x	x	x	x

Table 7.1.2. Potential ecosystem indicators and the associated ecosystem objectives that they pertain to.

"Stories" / Candidate Indicators	No spp shall go extinct (PS, ESA, SARA, etc.) or remained **threatened** of doing so	**Fisheries** prosecuted sustainably	Manage **habitat** for no unacceptable loss (and associated connectivty)	No unacceptable loss of **biodiversity**	Nutrients and associated **CZM** issues managed at acceptable levels (hypoxia, eutrophication)	**HABs** and related biotic outbreaks	Placement of offshore **energy** systems	Placement of **navigation** routes	No unacceptable **trophic** imbalances (not eroding functional redundancy)	Accounting for **climate** effects	Accounting for **invasive** spp	Mitigating **toxic** deposition
Thermal env.			x		x					x		
H_2O Column stability			x							x		
Divergence zones			x							x		
Frontal Boundaries			x					x		x		
Scope for growth (Habitat)			x									
Disturbance (Habitat)			x									
Broadscale climate forcing										x		
Broadscale hydrodynamic forcing			x				x	x		x		
Ratio of H_2O masses			x							x		
Wind & Current fields							x			x		
Tidal fields							x	x		x		
Biomasses	x	x		x								
Biomass ratios		x		x					x			
Condition factor		x		x					x			
Size/age structure		x		x								
Productive Capacity		x		x					x			
BRPs; e.g. B/B_{msy}		x							x			
Shellfish closures					x	x						
HAB observed						x						
Nutrient Concentration					x							
Ocean Color					x	x						
LTL indices				x	x					x		
Canary Populations	x	x										
Jellyfish abundance		x			x					x		
Diversity indices	x			x								
Resilience indices									x			
PPR									x			
P/B									x			
L Index		x							x			
TL structure									x			
Animal migration patterns	x	x		x						x		
List of Endangered Spp	x											
Fishing Effort Distribution		x	x									
Landings (Catch, Bycatch, etc.)		x										
L/PP		x							x			
L/C		x							x			
see Indiseas indicators		x		x					x	x		
lean Length of the fish community												
Mean life span of fish												
otal biomass of spp in community												
Proportion predatory fish												
TL landings												
der & moderately exploited stocks												
1/CV total biomass												
Human population		x			x							
# Vessel Permits, by TC & Gear		x										
Performance measures	x	x	x	x	x		x	x				x
Compliance	x	x	x	x	x		x	x				x
see Tony Charles list	x	x					x	x				x
Population												
Urbanization rate												
Population density												
Education and Training metrics												
Poverty/Quality of Life												
GDP per capita												
Unemployment rate												
Production rates of Industry												
Value of Industry												
Cultural												
Governance												
Vessel traffic	x							x				
VMS location	x	x						x				
Exploration licences							x					
# Invasive spp & locations											x	
Records of ballast exchenage											x	
Aerosol & H_2O column toxin conc. (organochlorines, heavy metals)												x

8 Signal propagation on the shelf and slope (ToR d)

8.1 Signal propagation on the shelf – Ken Frank

Signal propagation was explored through an analysis of degraded recruitment synchrony in Northwest Atlantic cod stocks (Kelly *et al.*, 2009). Correlated recruitment between North Atlantic cod stocks, separated by hundreds of kilometres, has consistently been interpreted as indicative that a proportion of pre-recruit mortality is forced by large-scaled abiotic conditions. This large-scale pattern was based on analyses that pre-dated the overexploitation-driven stock abundance declines and collapses of the 1990s. We used a sliding window analysis to examine the temporal trajectories of the e-folding decorrelation scales of synchrony of both bottom temperature and de-trended cod recruitment for the Northwest Atlantic from 1950 to 2006. The characteristic scale of temperature synchrony rose from roughly 400 km to 800 km in the 1990s. Rather than mirror changes in temperature as expected, the scale of cod recruitment synchrony declined in the 1990s from roughly 500 km to 250 km, coincident with the severe declines in abundance. Dispersal between populations, another mechanism that generates synchronous population dynamics, may have been an overlooked contributor to recruitment synchrony documented in earlier analyses. Cod are highly mobile, and it has been suggested that they are structured as metapopulations. Overexploitation may have interrupted these dispersal patterns and the associated metapopulation structure, thereby reducing synchrony. If so, dispersal from the most productive of the remaining populations may be an avenue for future recovery.

8.2 Spatial scale of similarity as an indicator of metacommunity stability in exploited marine systems – Nancy Shackell

The spatial scale of similarity among fish communities is characteristically large in temperate marine systems: connectivity is enhanced by high rates of dispersal during the larval/juvenile stages and the increased mobility of large-bodied fish. A larger spatial scale of similarity (low beta-diversity) is advantageous in heavily exploited systems because locally depleted populations are more likely to be “rescued” by neighbouring areas. We explored whether the spatial scale of similarity changed from 1970–2006 due to overfishing of dominant, large-bodied groundfish across a 300 000 km^2 region of the Northwest Atlantic. Annually, similarities among communities decayed slowly with increasing geographic distance in this open system but through time the decorrelation distance (where similarity is ~37% of initial) declined by 33%, concomitant with widespread reductions in biomass, body size and community evenness. There was an erosion of community similarity among local sub-regions separated by distances as small as 100 km. Larger fish of the same species contribute proportionally more viable offspring, so observed body size reductions will have affected maternal output. The cumulative effect of non-linear maternal influences on egg/larval quality may have compromised the spatial scale of effective larval dispersal, which may account for the delayed recovery of certain member species. Our study adds strong support for adopting a regional metacommunity approach to both understand the spatial impacts of exploitation and to incorporate spatial structure into management plans.

8.3 NAO, *Calanus*, and right whales – Charles Hannah

The goal of this short presentation was to provide a concrete of example of how large-scale climate forcing can have important local impacts and to start the discussion on how WGNARS approaches the ToR related to the quest for signals propagating through the NW Atlantic shelf system. The example chosen was the link between the NAO and right whale calving and the likely connection through *Calanus finmarchicus*. Greene and Pershing (2004) proposed a statistical model of right whale calving rates that was a function of the number of female right whales and the abundance of *Calanus* in the Gulf of Maine.

An interesting question for WGNARS is what is the origin of the fluctuations in *Calanus* abundance? Is it:

- a local biological response to NAO atmospheric forcing,
- a local response to a physical signal that propagates along the shelf/edge, or
- a *Calanus* signal that propagates from north to south?

8.4 Large-scale pattern in zooplankton community variability: Atlantic Zone Monitoring Program (AZMP) synthesis – Catherine Johnson, with Alex Curtis, Paula Fratantoni, Peter Galbraith, Jon Hare, Erica Head, Michel Harvey, Dave Hebert, Bill Li, Pierre Pepin, Jeff Runge

Zooplankton communities on the Northwest Atlantic shelf can be influenced by variability in large-scale environmental forcing. For example, the zooplankton communities of the Gulf of Maine and Georges Bank shifted to greater dominance of small copepods in the 1990s, associated with increased advection of low salinity water from the Scotian Shelf (Greene and Pershing, 2007, Kane, 2007). The community shift of the 1990s may have been driven either by increased fall-winter stratification and primary production, related to the lower salinity (Greene and Pershing, 2007), or to direct advection of zooplankton from the Scotian Shelf (Mountain and Kane, 2010). A project is in progress to synthesize Atlantic Zone Monitoring Program (AZMP) data collected in three Fisheries and Oceans Canada (DFO) regions in order to evaluate large-scale patterns in community variability and their drivers across the zone. The objectives of the project are to evaluate (1) spatial and temporal variability in zooplankton community indicators of ecosystem state and their relationship with environmental variability, and (2) regional similarities in the interannual variability of zooplankton and environmental indicators. The approach taken includes (1) development of zooplankton community metrics; (2) use of fixed station data to evaluate the validity of comparing surveys with different seasonal timing; (3) comparison of interannual variability patterns in metrics from survey time-series in different regions, and (4) comparison of indicators with environmental variability at interannual scales. Four categories of zooplankton metrics were used, including core species, groups typical of biogeographic zones, metrics of diversity and community, and functional group metrics. Progress to date on the project includes data compilation and quality checks and development of tools for visualization and analysis of the data. A proposal for an expansion of this approach to synthesis of data from monitoring programs in both Canada and the US was submitted to the DFO International Governance Strategy program in February 2011. This project would develop appropriate and informative indicators of environmental conditions and lower trophic level productivity and diversity on the NW Atlantic continental shelves, from the Labrador Sea to the mid-Atlantic Bight, using ecosystem monitoring data and evaluate the response of these indicators to physical drivers related to climate variability and change and to indicators of fisheries status. Unfortunately this proposal was not successful, and support for expanded synthesis must be sought from other sources.

9 Conclusions

The parallel development of marine ecosystem science, ecosystem-based management, ecosystem approaches to fisheries and integrated ecosystem assessment offers a diversity of scientific advancements and potential policy guidance. However, the rich literature on marine ecosystem science also presents a diversity of jargon, inconsistent terminologies, and potential for miscommunication. Therefore, WGNARS decided to follow the US IEA approach by adopting the terminology developed by Levin *et al.* (2009) and to standardize terminology for future collaborations and development of IEA in the Northwest Atlantic. Furthermore, the wide range of contributions to WGNARS can be confusing, and how they 'fit in' is not always clear. Therefore, WGNARS decided that each presentation to WGNARS should identify which stage of IEA (e.g. scoping, indicators/targets, risk analysis, status assessment, MSE, monitoring; Figure 3.2.1) it contributes to. These practical guidelines are intended to standardize terminology and focus activities on the development of an IEA for the region.

The integration of ocean observation systems, ecosystem surveys and habitat studies was promising. Several national advances in integration can be extended or merged throughout the Northwest Atlantic region. For examples:

- Fogarty *et al.* (2010) defined ecosystem production units off the Northeast US based on patterns of depth, bottom type, basic oceanographic conditions related to temperature, salinity, and stratification (layering) of the water column, and conditions at the base of the foodweb that control the production potential for a region. Ecoregions can be similarly defined on the Scotian Shelf, Newfoundland Shelf and Flemish Cap to support IEA of the regional sea.
- The habitat mapping developed in New England for mitigating fishing impacts could be extended to the north and expanded to include the 'scope for growth' conferred by each habitat type. Incorporating the methods of Kostylev and Hannah (2007) in the New England habitat model would improve its performance for evaluating habitat impact, and applying the spatial analysis developed in New England to other areas in the Northwest Atlantic would help to support IEA. Extending the definition of habitat to include more aspects of the water column would also help to integrate oceanographic and climactic processes.

Many sets of indicators for IEA are available (e.g. the global analysis offered by www.indiseas.org), but their selection for IEA should be based on expected performance for monitoring the triad of drivers (human, internal and external; Figure 3.5.1) or core ecosystem services as demonstrated in Table 7.1.2. Simply monitoring the status of natural resources without evaluating their utilities in the context of human use may lead to unintended outcomes. For example, fishing will effectively degrade all of the indicators developed by www.indiseas.org, and unless the utilities of fishing (e.g. economic yield, employment, fishing communities) are included in the IEA, all indicators would be optimized in a no-fishing scenario. WGNARS recognized that social scientists and people who have not been traditionally involved in marine ecosystem science will need to be included in the development of objectives, indicators and thresholds. From an organizational perspective, WGNARS decided to expand the scientific steering committee to include social scientists.

The evaluation of potential indicators in the Northwest Atlantic indicated a wide range of possibilities, but also identified some gaps in the capabilities of ocean observation, ecosystem surveys and habitat mapping. For example, trends in microzooplankton and macrozooplankton are not well monitored. Similarly, forage fish (small pelagic) are not well monitored by the programmatic trawl surveys in the region, and increased investments in hydroacoustic surveys in the Northwest Atlantic would help to support IEA. The ensemble approach to ocean modelling for integrating across disparate ocean observation systems requires substantial investment in human resources and computing facilities.

The selection of indicators and thresholds go hand-in hand. Indicators should be selected with a focus on determining if they cross a meaningful threshold which would warrant management actions to mitigate human uses. Ideally, thresholds should be based on theoretically based optima to avoid arbitrary thresholds. For example, maximum sustainable yield is an optimum used to manage fisheries. Similarly, perturbed systems have different cumulative production and cumulative biomass relationships that may reflect 'overfishing' and 'overfished' thresholds. Average trophic level and primary production can be used to determine ecosystem overfishing. However, the use of average trophic level as an indicator has come under increased scrutiny in the last year (Branch *et al.*, 2010).

These strategic decisions would benefit from guidance from the ICES Regional Seas Programme, through a dedicated workshop or the benchmark IEA process.

Scenario analyses may help to demonstrate IEA. The Canadian ocean observation systems described in the 2010 WGNARS meeting were developed after recognizing that the basic monitoring data were not available to have foreseen the collapse of northern cod. Now that we have more extensive ocean monitoring, can we prevent such ecosystem failures through IEA? Prior to the collapse of cod, other species started to decline in the early 1980s, when cod was relatively stable, so monitoring a diversity of species and incorporating those signals in management would have helped. The size structure, condition and spatial distribution of cod were truncating, so considering fish size and spatial monitoring in management would have helped. Condition factors appear to have been associated with NAO, so understanding environmental forcing would have helped.

In terms of coordination between ICES WGNARS and NAFO WGEAFM, both working groups can complement each other in several aspects, while there is ample room for collaboration in others. Both working groups are fairly young and are just beginning to develop internal working dynamics, as well as consolidating their research pathways. In order to maintain close communications, avoid duplicating efforts, and fostering collaborations and positive feedbacks between the two groups, it was agreed that, as an initial step for developing these collaborations, efforts should be made to ensure that the chairs and/or co-chairs of both working groups can attend to each other's meetings, as well as to include them in each other's mailing lists. As both working groups mature and develop, more formal linkages between them may need to be explored in future.

10 References

BC Government. 2009. State of the Environment Reporting. http://www.env.gov.bc.ca/soe/about_soe.html (accessed January 2009).

Branch, T.A., Watson, R., Fulton, E.A., Jennings, S., McGilliard, C. R., Pablico, G.T., Ricard, D., and Tracey, S.R. 2010. The trophic fingerprint of marine fisheries. Nature, 468 431–435.

Charles, A. 2001. "Sustainable Fishery Systems", Blackwell Science, Oxford (2001).

Charles, A., Burbidge, C., Boyd, H., and Lavers, A. 2009. Fisheries and the Marine Environment in Nova Scotia: Searching for Sustainability and Resilience. GPI Atlantic, Nova Scotia, Canada [Available on-line at www.gpiatlantic.org/pdf/fisheries/fisheries_2008.pdf].

Charles, A., and De Young, C. 2009. Benefits and Costs of Implementing the Ecosystem Approach to Fisheries. *In:* The Ecosystem Approach to Fisheries. Ed. by G. Bianchi and H.R. Skjoldal. CAB International (2009).

Charles, A., Winterbottom, M., Wilson, L., and Mills, S. 2007. Social, Economic and Cultural Overview and Assessment for Ocean Management". Report prepared for Department of Fisheries and Oceans, Government of Canada (2007).

Cheung, W. W. L., Lam, V. W. Y., Sarmiento, J. L., Kearney, K., Watson, R., and Pauly, D. 2009. Projecting global marine biodiversity impacts under climate change, scenarios. Fish and Fisheries, 10: 235–251.

Clay, P. M., and Olson, J. 2008. Defining "Fishing Communities": Vulnerability and the Magnuson-Stevens Fishery Conservation and Management Act. Human Ecology Review, 15(2), 143–160.

Clay, P. M., Pinto da Silva, P., and Kitts, A. 2010. Defining Social and Economic Performance Measures for Catch Share Systems in the Northeast US IIFET Proceedings, Montpellier, France.

Coll, M., Libralato, S., Tudela, S., Palomera, I., and Pranovi, F. 2008. Ecosystem overfishing in the ocean. Public Library of Science (PLOS) ONE 3(12): e3881. doi:10.1371/journal.pone.0003881.

De Young, C., and Charles, A. 2009. Creating Incentives for the Ecosystem Approach to Fisheries Management: A Portfolio of Approaches. *In:* The Ecosystem Approach to Fisheries. Ed. by G. Bianchi and H.R. Skjoldal. CAB International.

De Young, C., Charles, A., and Hjort, A. 2008. Human Dimensions of the Ecosystem Approach to Fisheries: An Overview of Context, Concepts, Tools and Methods. Fisheries Tech. Paper 489. FAO, Rome.

Dial, R., and Roughgarden, J. 1988. Theory of marine communities: the intermediate disturbance hypothesis. Ecology, 79: 1412–1424.

Ecosystem Assessment Program (EcoAP) 2009. Ecosystem Status Report for the Northeast US Continental Shelf Large Marine Ecosystem. Northeast Fisheries Science Center Reference Document, 09–11. 34 p.

Endter-Wada, J., Blahna, D., Krannich, R., and Brunson, M. 1998. A Framework for Understanding Social Science Contributions to Ecosystem Management. Ecological Application, 8(3):891–904.

Environment Canada. 2009. Federal State of the Environment Reports, a Vision for Federal State of the Environment (SOE) Reporting in Canada. http://www.ec.gc.ca/soer-ree/English/SOER/default.cfm (accessed January 2009).

FAO. "Fisheries management. 2. The Ecosystem Approach to Fisheries. 2.2 Human Dimensions of the Ecosystem Approach to Fisheries". FAO Technical Guidelines for Responsible Fisheries, No. 4, Supplement 2, Add. 2. Food and Agriculture Organisation of the United Nations, Rome (2009).

Fogarty, M. J. 2010. Ecosystem-Based Fishery Management for the Northeast US Continental Shelf: Options for Implementation. Ecosystems 2010: Global Progress on Ecosystem-based Fisheries Management, 26th Lowell Wakefield Fisheries Symposium, Anchorage, Alaska, November 8–11, 2010.

Fratantoni, P. S., and McCartney, M. S. 2010. Freshwater Export from the Labrador Current to the North Atlantic Current at the Tail of the Grand Banks of Newfoundland. Deep Sea Research Part I: Oceanographic Research Papers, 57: 258–283.2.

Fratantoni, P. S., and Pickart, R. S. 2007. The western North Atlantic Shelfbreak Current System in Summer. Journal of Physical Oceanography, 37:2509–2533.

Garcia, S. M., and Charles, A. 20007. Fishery Systems and Linkages: From Clockwork to Soft Watches. ICES J. Marine Sci., 64:580–587.

Greene, C. H., and Pershing, A. J. 2004. Climate and the conservation biology of North Atlantic right whales: the right whale at the wrong time? Front Ecol Environ, 2004; 2: 29–34.

Greene, C. H., and Pershing, A. J. 2007. Climate drives sea change. Science, 315:1084–1085.

ICES. 2009. Report of the Workshop on Multi-annual management of Pelegic Fish Stocks in the Baltic (WKMAMPEL). ICES CM 2009/ACOM:38, 78–105.

ICES. 2010a. Report of the Workshop on Introducing Coupled Ecological-Economic Modelling and Risk Assessment into Management Tools (WKIMM), 16–18 June 2010, Kiel, Germany. ICES CM 2010/SSGRSP:05. 44 pp.

ICES. 2010b. Report of the Workshop on Including Socio-Economic considerations into the Climate-recruitment framework developed for clupeids in the Baltic Sea (WKSECRET), 5–8 October 2010, Ponza, Italy. ICES CM 2010/SSGRSP:09. 55 pp.

ICES. 2010c. Report of the Working Group on the Northwest Atlantic Regional Sea (WGNARS), 20–22 April 2010, Woods Hole, USA. ICES CM 2010/SSGRSP:03. 63 pp.

Jennings, S. 2005. Indicators to support an ecosystem approach to fisheries. Fish and Fisheries, 6:212–232.

Kane, J. 2007. Zooplankton abundance trends of Georges Bank, 1977–2004. ICES Journal of Marine Science, 64:909–919.

Kelly, J. E., Frank, K. T., and Leggett, W. C. 2009. Degraded recruitment synchrony in Northwest Atlantic cod stocks. Mar. Ecol. Prog. Ser., 393: 131–146.

Kostylev, V. E., and Hannah, C. G. 2007. Process-Driven Characterization and Mapping of Seabed Habitats. *In*: Mapping the Seafloor for Habitat Characterization. Ed. by Todd, B. J., and Greene, H. G. Geological Association of Canada, Special Paper, 47, p. 171–184.

Lees, S. H., and Bates, D. G. 1990. The Ecology of Cumulative Change. *In*: The Ecosystem Approach in Anthropology: From Concept to Practice. Ed. by E. F. Moran. Ann Arbor: The University of Michigan Press.

Levin, P. S., Fogarty, M. J., Murawski, S. A., and Fluharty, D. 2009. Integrated ecosystem assessments: developing the scientific basis for ecosystem-based management of the ocean. Public Library of Science (PLOS) Biology 7(1): e1000014 (0023–0028).

Libralato, S., Christensen, V., and Pauly, D. 2006. A method for identifying keystone species in food web models. Ecological Modelling, 195:153–171.

Libralato, S., Coll, M., Tudela, S., Palomera, I., and Pranovi, F. 2008. Novel index for quantification of ecosystem effects of fishing as removal of secondary production. Marine Ecology Progress Series, 355:107–129.

Link, J. S. 2005. Translation of ecosystem indicators into decision criteria. ICES Journal of Marine Science, 62:569–576.

Link, J. S., Brodziak, J. K. T., Edwards, S. F., *et al.* 2002a. Marine ecosystem assessment in a fisheries management context. Canadian Journal of Fisheries and Aquatic Sciences, 59:1429–1440.

Link, J. S., Yemane, D., Shannon, L. J., Coll, M., Shin, Y-J., Hill, L., Borges, M. F., Bundy, A., and Aydin, K. 2010. Relating Marine Ecosystem Indicators to Fishing and Environmental Drivers: An Elucidation of Contrasting Responses. ICES Journal of Marine Science, 67: 787–795.

Marsh, R. 2000. Modelling changes in the North Atlantic circulation under the NAO-minimum wind forcing of 1877–81, Atmosphere-Ocean, 38(2):367–393.

Methratta, E. T., and Link, J. S. 2006. Evaluation of quantitative indicators for marine fish communities. Ecological Indicators, 6:575–588.

Mountain, D. G., and Kane, J. 2010. Major changes in the Georges Bank ecosystem, 1980s to the 1990s. Marine Ecology Progress Series, 398:81–91.

Mueter, F. J., and Megrey, B. A. 2006. Using multi-species surplus production models to estimate ecosystem-level maximum sustainable yields. Fisheries Research, 81:189–201.

Neis, B., Schneider, D. C., Felt, L., Haedrich, R. L., Fischer, J., Hutchings, J. A. 1999. Fisheries Assessment: What can be Learned from Interviewing Resource Users? Canadian Journal of Fisheries and Aquatic Sciences, 56: 1949–1963.

Olson, J. 2011. Producing Nature and Enacting Difference in Ecosystem-based Fisheries Management. Marine Policy, 35(4): 528–535.

Olsen, S. 2003. Frameworks and Indicators for Assessing Progress in Integrated Coastal Management Initiatives. Ocean and Coastal Management, 46:347–361.

Ostrom, E. 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press, New York.

Overholtz, W. J., Fogarty, M.F., Link, J. S., Legault, C., and Col, L. 2008a. Estimates of aggregate surplus production for the GARM and other stock groups for the US Northeast Shelf LME. GARM WP 3.3 GARM-III-BRP Meeting.

Overholtz, W.J., Link, J.S., Fogarty, M., Col, L., and Legault, C. 2008b. Target Biological Reference Points, Worldwide Cross System Comparisons, and Aggregate Production Model Results for GARM Stocks. GARM WP 2.1 GARM-III-Final Meeting.

Petrie, B., and Drinkwater, K. 1993. Temperature and Salinity variability on the Scotian Shelf and in the Gulf of Maine 1945–1990. Journal of Geophysical Research, 98:20079–20089.

Petrie, B. 2007. Does the North Atlantic Oscillation affect hydrographic properties on the Canadian Atlantic continental shelf? Atmosphere-Ocean, 3:141–151.

Rice, J. C., and Rochet, M.-J. 2005. A framework for selecting a suite of indictors for fisheries management. ICES Journal of Marine Science, 53:1214–1225.

Rochet, M.-J., and Trenkel, V. M. 2003. Which community indicators can measure the impact of fishing? Canadian Journal of Fisheries and Aquatic Sciences, 60:86–99.

Samhouri, J. F., Levin, P. S., and Ainsworth, C. H. 2010. Identifying thresholds for ecosystem-based management. Public Library of Science (PLOS) ONE 2010;5:e8907.

Samhouri, J. F., Levin, P. S., James, C. A., Kershner, J., and Williams, G. 2011. Using existing scientific capacity to set targets for ecosystem-based management: A Puget Sound case study. Marine Policy, 35:508–518.

Shackell, N. L., Bundy, A., Nye, J. A., and Link, J. S. (In review). Common Large-scale Responses to Climate and Fishing across Northwest Atlantic Ecosystems.

Shin, Y.-J., Bundy, A., Shannon, L. J., Simier, M., Coll, M., Fulton, E. A., Link, J. S., Jouffre, D., Ojaveer, H., Mackinson, S., Heymans, J. J., Raid, T. 2010. Can simple be useful and reliable? Using ecological indicators for representing and comparing the states of marine ecosystems. ICES Journal of Marine Science, 67: 717–731.

Smeets, E., and Weterings, R. 1999. Environmental Indicators: Typology and Overview. Technical Report No. 25. European Environment Agency, Copenhagen. 19 pp.

Tudela, S., Coll, M., and Palomera, I. 2005. Developing an operational reference framework for fisheries management on the basis of a two-dimensional index of ecosystem impact. ICES Journal of Marine Science, 62:585–591.

Wiber, M., Berkes, F., Charles, A., and Kearney, J. 2004. Participatory research supporting community-based fishery management. Marine Policy, 28(6): 459–468.

Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C., Fogarty, M. J., Fulton, E. A., Hutchings, J. A., Jennings, S., Jensen, O. P., Lotze, H. K., Mace, P. M., McClanahan, T. R., Minto, C., Palumbi, S. R., Parma, A. M., Ricard, D., Rosenberg, A. A., Watson, R., and Zeller, D. 2009. Rebuilding global fisheries. Science, 325:578–585.

Annex 1: List of participants

Participant	E-mail contact	Attending
Laura Bianucci	laura.bianucci@dal.ca	
David Brickman	David.Brickman@dfo-mpo.gc.ca	
Alida Bundy	Alida.Bundy@dfo-mpo.gc.ca	
Steven Cadrin	scadrin@umassd.edu	
Tony Charles	tony.charles@SMU.CA	
Trish Clay	Patricia.M.Clay@noaa.gov	by phone
Katja Fennel	Katja.Fennel@dal.ca	
Jonathan Fisher	jonathan.fisher@dfo-mpo.gc.ca	
Kenneth Frank	Kenneth.Frank@dfo-mpo.gc.ca	
Paula Fratantoni	paula.fratantoni@noaa.gov	
Jacques Gagné	jacques.gagne@dfo-mpo.gc.ca	
Steven Gray	stevenallangray@gmail.com	by phone
Blair Greenan	blair.greenan@dfo-mpo.gc.ca	
Charles Hannah	Charles.Hannah@dfo-mpo.gc.ca	
Glen Harrison	Glen.Harrison@dfo-mpo.gc.ca	
Erica Head	Erica.Head@dfo-mpo.gc.ca	
David Hebert	David.Hebert@dfo-mpo.gc.ca	
Larry Hildebrand	Larry.Hildebrand@EC.GC.CA	
Catherine Johnson	Catherine.Johnson@dfo-mpo.gc.ca	
Ellen Kenchington	Ellen.Kenchington@dfo-mpo.gc.ca	
Mary Kennedy	Mary.Kennedy@dfo-mpo.gc.ca	
Mariano Koen-Alonso	Mariano.Koen-Alonso@dfo-mpo.gc.ca	
Vladimir Kostylev	vkostyle@nrcan.gc.ca	
Bill Li	Bill.Li@dfo-mpo.gc.ca	
Doreen Liew	Doreen.Liew@dfo-mpo.gc.ca	
Jason Link	jason.link@noaa.gov	
John Loder	John.Loder@dfo-mpo.gc.ca	
Youyu Lu	Youyu.Lu@dfo-mpo.gc.ca	
Melanie MacLean	Melanie.MacLean@dfo-mpo.gc.ca	
John Manderson	john.manderson@noaa.gov	
Ian McQuinn	Ian.McQuinn@dfo-mpo.gc.ca	
Hassan Moustahfid	Hassan.Moustahfid@noaa.gov	by phone
Rasmus Nielsen	rn@aqua.dtu.dk	by phone
Janet Nye	nye.janet@epamail.epa.gov	by phone
Joern Schmidt	jschmidt@economics.uni-kiel.de	by phone
Nancy Shackell	Nancy.Shackell@dfo-mpo.gc.ca	
Andrew Sherin	an259184@dal.ca	
Rebecca Shuford	Rebecca.Shuford@noaa.gov	
Mike Sinclair	Michael.Sinclair@dfo-mpo.gc.ca	
Peter Smith	Peter.Smith@dfo-mpo.gc.ca	
Alain Vezina	Alain.Vezina@dfo-mpo.gc.ca	
Jay Walmsley	Jay.Walmsley@dfo-mpo.gc.ca	
Yvonne Walther	yvonne.walther@fiskeriverket.se	by phone

Annex 2: Agenda

WGNARS meeting Agenda

8–10 February 2011, Dartmouth, NS, Canada

Needler II Boardroom, Bedford Institute of Oceanography

Tuesday 8 February

Morning – Opening (08:30–12:30)

Term of Reference a) Continue to develop the scientific support for an integrated assessment of the Northwest Atlantic region to support ecosystem approaches to science and management

08:30	Introductions
09:00	Opening of the meeting – Alain Vezina
09:15	Background of WGNARS and the Regional Seas Program, and IEA Demonstration project – Yvonne Walther and Steve Cadrin
10:00	Health Break
10:15	Update on US IEA – Rebecca Shuford
10:30	Overview of NAFO WGEAFM – Mariano Koen-Alonso
10:45	State of the Environment Reporting for Ocean Management in the Maritimes Region – Melanie MacLean and Jay Walmsley
11:00	Overview of Status reports in US – Jason Link
11:15	Discussion of IEA approach and required science support
	Led by Steve Cadrin
	Discuss coordination between WGNARS and WGEAFM
12:30	Lunch

Afternoon – Socio-economics and habitat / spatial planning (13:30–17:30)

Term of Reference f) Determine socio-economic components of an integrated ecosystem assessment of the Northwest Atlantic.

13:30	Intro – Catherine Johnson
13:35	Overview of ICES WGIMM -- Jörn Schmidt (phone)
13:50	Tony Charles
14:05	Larry Hildebrand
14:20	Patricia Clay (by phone)
14:45	Discussion – What is the most productive way to incorporate socio-economic factors into the IEA approach? Plan next steps.
	Led by Catherine Johnson
15:45	Health Break

Term of Reference d) Initiate integrated analyses of the relationships between physical and biological aspects of the Northwest Atlantic ecosystem (e.g. predictable state changes, climate impacts, biodiversity, community analyses)

16:00	Intro – John Manderson
16:15	Overview of ICES SGMPAN -- Ellen Kenchington
16:30	Cusk and Climate Change – John Manderson
16:45	Recent work on habitat – John Fisher
17:00	Recent work on habitat – Nancy Shackell
17:15	Wrap-up and plan discussion for tomorrow – John Manderson

Wednesday 9 February

Morning – Spatial planning discussion and Indicators talks (08:30-12:30)

Term of Reference b) Determine candidate indicators of ecosystem status that reflect important patterns in the physical environment, trophic dynamics, and system productivity

08:30	Spatial planning discussion – Scale issues; interaction between environmental variability/change and benthic habitat; incorporating spatial planning into IEA Led by John Manderson
10:30	Health Break

Ecosystem indicators and climate/environmental drivers

10:45	Overview of Indicators across ecosystems – Alida Bundy
11:00	Overview of Climate Effects on the NW Atlantic – John Loder
11:15	NW Atlantic shelf break current variability – Paula Fratantoni
11:30	NW Atlantic modelling – Youyu Lu
11:45	NW Atlantic modelling –Gangopadhyay and Chen/Cowles, pres by Steve Cadrin
12:15	Update on Ocean Tracking Network – Peter Smith
12:30	Lunch

Afternoon – Indicators discussion (13:30–17:30)

Term of Reference c) Coordinate ocean observation systems, ecosystem survey data and information on habitats throughout the Northwest Atlantic region; and

Term of Reference e) Propose candidate thresholds for each indicator;

13:30	Input on discussion of indicators
14:00	Discussion Indicators from monitoring data? Coordination of monitoring efforts required for indicators?
15:30	Health break

15:45 Discussion
Led Jason Link and Charles Hannah

Thursday 10 February

Morning – Signal propagation on the shelf and slope (08:30-11:30)

Term of Reference d) Initiate integrated analyses of the relationships between physical and biological aspects of the Northwest Atlantic ecosystem (e.g. predictable state changes, climate impacts, biodiversity, community analyses)

Propagation of signals through the NW Atlantic shelf ecosystem

08:30 Signal propagation on the Shelf – Ken Frank

08:45 Spatial Scale of similarity as an indicator of metacommmunity stability in exploited marine systems – Nancy Shackell

09:00 NAO, *Calanus*, and right whales – Charles Hannah

09:15 AZMP Synthesis and IGS work in progress/proposed – Catherine Johnson

09:30 Discussion – Led by Ken Frank and Paula Fratantoni

10:00 Health Break

10:15 Continued discussion and topic wrap-up

12:30 Wrap-up Discussion

Summary, conclusions, recommendations

Plans to pursue work on major hypotheses

Plan for reporting

Led by Steve Cadrin

13:30 End

Annex 3: WGNARS draft terms of reference for the next meeting

The **Working Group on the Northwest Atlantic Regional Sea** (WGNARS), chaired by Steve Cadrin, USA, and Catherine Johnson, Canada, will meet in Woods Hole, USA, DATE (to be announced) 2012 to:

a) Continue to develop the scientific support for an integrated assessment of the Northwest Atlantic region to support ecosystem approaches to science and management;

b) Review previous scoping exercises in integrated ecosystem assessment for management objectives and socio-economic utilities, for an integrated ecosystem assessment of the Northwest Atlantic;

c) Refine candidate indicators of ecosystem status that reflect important patterns in the physical environment, trophic dynamics, socio-economics and system productivity;

d) Propose candidate thresholds for each indicator;

e) Continue integrated analyses of the relationships between physical and biological aspects of the Northwest Atlantic ecosystem;

f) Develop and test environmentally explicit seascape models to support space and time based ecosystem management;

g) Review the work of other integrated assessment activities in ICES, NAFO and elsewhere.

WGNARS will report by DATE (via SSGRSP) for the attention of SCICOM.

Supporting Information

Priority:	A regional approach to marine science is essential to address high priority research topics in the ICES Science Plan associated with understanding ecosystem functioning, particularly climate change processes, biodiversity and the role of coastal-zone habitat in ecosystem dynamics.
Scientific justification	The continuation of a regional seas programme would address priority scientific issues in the Northwest Atlantic with wider implications over the ICES community. An integrated approach to marine science and management requires coordinated observations, modelling and assessments over the scale of the ecosystem. Ecosystem structure is hierarchical with connections between larger and smaller spatial scales. At the scale of the Northwest Atlantic Ocean, fisheries management is already coordinated between the USA and Canada in the Gulf of Maine as some fishery stocks are trans-boundary. In addition, the North Atlantic Fisheries Organization (NAFO) provides management advice for fisheries outside the jurisdiction of North American countries. Integrated approaches will require greater coordination and cooperation over the scale of connected ecosystems, and there are several rationales for coordination at the scale of the Northwest Atlantic Ocean. The Northwest Atlantic is a relatively data-rich region, and the approaches taken by WGNARS will help to develop programmes in other regional seas in the ICES area.
Resource requirements	Components of the integrated approach, such as ocean observation systems and ecosystem surveys, are being maintained by member countries, and the programme will coordinate and synthesize existing programmes.
Participants	The Group will be attended by 20–25 members and guests.
Secretariat facilities	Report preparation and dissemination
Financial	No financial implications.

Linkages to advisory committees	During the development stage, there will be no direct linkages with advisory committees, but the integrated approach is expected to eventually support advice on Northwest Atlantic resources (e.g. NWWG).
Linkages to other committees or groups	There is a close working relationship with a number of the working groups under the Steering Group on Regional Seas and others within ICES. There is also a linkage to the ICES-GOOS Steering Group and Transition Group for the the development of ecosystem surveys in the Steering Group on Ecosystem Surveys and Sampling Technology.
Linkages to other organizations	The NAFO Ecosystem Based Management Working Group has made progress toward similar objectives and will be a resource for collaboration. The USA CAMEO program will fund projects in the region aimed at improving tools for ecosystem-based management and an international framework for implementation.

Annex 4: Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
1. Contined investments in ocean observation, ecosystem surveys and habitat studies should be supplemented with expanded sampling of zooplankton and small pelagic fish.	WGNARS
2. Substantial investments in human resoruces and computing facilities are needed to support the ensemble approach to integrating informaiton from disparate ocean observation systems through ocean modelling.	WGNARS
3. The WGNARS steering committee should include social scientists.	WGNARS
4. The ecoregions developed for the Northeast US should be expanded to the rest of the Northwest Atlantic continental shelf, and the habitat mapping methods in US and Canada should be integrated and expanded to include more aspects of the water column.	WGNARS
5. Guidance should be developed on selection of thresholds for Integrated Ecosystem Assessment.	SSGRSP
6. WGNARS should meet in spring 2012.	SSGRSP