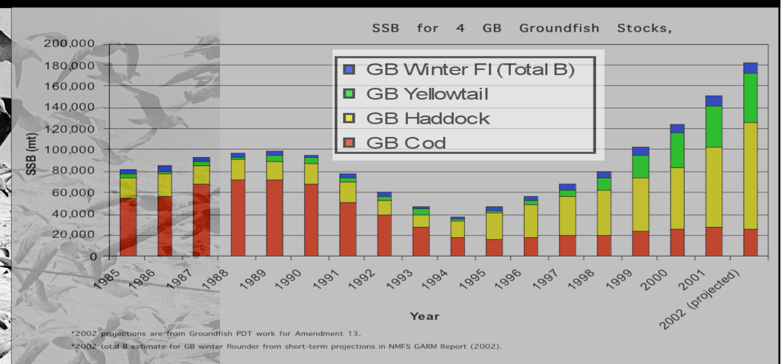
A Report From:

A Workshop on Planning Coordinated Research On Ecosystems, Climate, and Policy in the Northeast

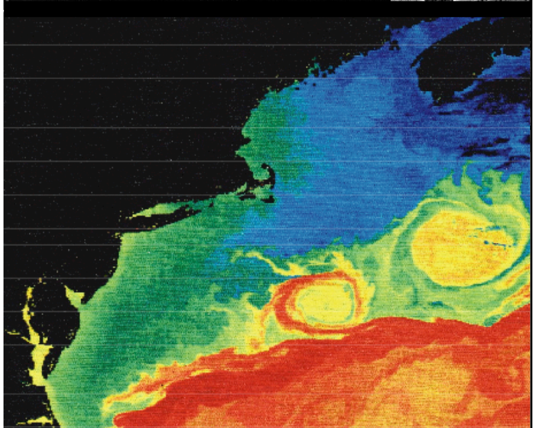


Hosted by

The Cooperative Institute for Climate and Ocean Research at the Woods Hole Oceanographic Institution

&

The Northeast Fisheries Science Center of the National Marine Fisheries Service



January 11-13, 2005
J. Eric Jonsson Center of the National Academy of Sciences
Woods Hole, Massachusetts

Report on a

Workshop on Planning Coordinated Research

on

Ecosystems, Climate, and Policy

in the Northeast

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Cover Photo Credit: www.earldotter.com
Entitled: “Wrecked Bottom and the Hat”
Fishermen Gutting Ground Fish Catch with Seagulls Overhead, 100 Miles Due East of Portland, Maine in Fishing Grounds.

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I. Executive Summary

On January 11 to 13, 2005, a diverse group of researchers, program managers, and ecosystem and marine resource managers were brought together to determine the coordinated research needed to support better understanding of marine ecosystems in the Northeast region of the United States and of the impacts of climate variability and the human population on these ecosystems. The long-term goal of such a coordinated research effort is to improve ecosystem-based approaches to marine resources management in the Northeast.

Climate variability that changes water properties and transports is apparent at time scales of several years and longer. Marine animals at higher trophic levels live several years or longer. Variability in the catch of finfishes and shellfishes has been seen at the several year and longer time scales. The challenge is to distinguish marine resource changes due to human impacts from those resulting from natural forcing, especially climate variability and change.

To initiate discussion, four focus areas were identified prior to the workshop: harmful algal blooms, nutrients and contaminants, fisheries, and biodiversity conservation. Dialog among the participants on the key issues and challenges in these four areas, both from scientific and management perspectives, was used to draw out the common and pressing needs for efforts in the areas of research, observations, modeling, education, and outreach. The workshop concluded by prioritizing the needs and laying out a recommended time line for coordinated research over the next decade.

Discussed in greater detail in section IV the key recommendations are to:

- **Assess the horizons of predictability and management, using research to find the limitations on the deterministic and probabilistic models required for forward-looking management strategies.**

- **Establish a baseline for identifying ecosystem change and thus for managing and conducting research in the Northeast by using field surveys, retrospective analyses, facilitated data exchange, and facilities for sample archiving.**

- **Develop improved predictive capabilities for the Northeast, built around an integrated ecosystem model approach, which considers multiple abiotic and biotic factors and assesses the role of climate change in comparison with other sources of natural and human induced change. Drive model improvement with strong links between sustained observations and comprehensive studies of processes.**

- **Build the Northeast observing system, establishing sustained observations at key sites and broad surveys in the domain and of the estuarine, atmospheric, alongshore, and offshore exchanges within the region in order to provide the data required to initialize, test, and improve climate and ecosystem models and management tools.**

- **Conduct comprehensive research studies characterized by high temporal and spatial sampling to address key uncertainties, determine and resolve critical processes, and build improved understanding, parameterizations, and models.**

- **Develop a system for an adaptive approach to management of the Northeast ecosystem resources, with research embedded in the cycle of evaluation and improvement of the management tools and methods and with facilitated flow of data, analyses, and results to managers as well as of management feedback to the researchers.**

- **Foster ongoing dialog among climate, ecosystems, biodiversity, and fisheries researchers, ecosystem and fisheries managers, marine resource stakeholders, the general public, and the NOAA goal teams and program managers to support the adaptive management system, to integrate observations and research results, to effectively disseminate research results, and to guide future observations and research.**

Based on considerations of readiness, impact, and sequential progress the following phasing is recommended:

Phase 1 (near-term, 0 – 3 years):

- **Initiate development of a baseline assessment (collect and assemble existing data, carry out retrospective analyses, integrate results from current field surveys). As part of this development, facilitate the exchange across the community of the diverse data types (e.g., physical oceanographic, fisheries, atmospheric forcing, catch, biodiversity, population variability across a range of trophic levels).**

- **Identify the priority elements of the Northeast observing system (agree on key sites as sentinel and reference sites, agree on indicator species, develop enhancements to present repeat broad scale sampling, integrate and coordinate all possible sampling elements including those for the critical estuarine, atmospheric, open ocean and adjacent coastal exchanges, and identify the need for new sensors and sampling methods) and the sequence of more intense sampling studies needed.**

- **Assess the coverage of climate and ecosystem issues provided by present models and observations and develop strategies for moving toward integration of all trophic levels and multiple forcing functions.**

- **Initiate the program to assess the horizons of predictability, probing the reasons for limitations on skillful prediction. As part of this identify key data (initialization, validation), parameterization, and understanding (realistic incorporation of all key physical and biological processes, realistic models of elements of the system) needs.**

- **Initiate a working group of researchers (observationalists, modelers, and analysts; climate, ecosystems, fisheries, policy), managers, marine resource stakeholders, and NOAA climate and ecosystems goal team staff to continue interaction, and to embed the research process in a plan for adaptive management of the ecosystems of the Northeast; repeat the Workshop every two years to review progress and improve research plans.**

Phase 2 (3-7 years):

- **Complete the baseline assessment (including comprehensive field surveys of bathymetry, substrate, biodiversity, and retrospective analyses).**

- **Establish sustained observations at key sentinel and reference sites; begin the high intensity process studies addressing the shortfalls in predictive skill and understanding.**

- **Produce and validate improved surface forcing fields; integrate improved surface meteorological and air-sea flux observations (buoys, towers, ships) with improved regional atmospheric and climate models.**

- **Establish partnerships, agreements and cooperative efforts to obtain data from the boundaries of the region: the coast, the open ocean, the coastal ocean to the north, and the coastal ocean to the south.**

- **Begin building the integrated ecosystems model system, drawing upon the models used as building blocks by the research community and supporting a consortium to do the integration; provide operational and research model results to the community, placing an emphasis on having a good regional climate model, accurate surface forcing to drive ocean models, biological models that span the trophic levels, integration of the component models, and assessment of uncertainties in predictions.**

- **Institute model validation experiments, keying on the intense sampling studies, time series at key sites, and broad scale sampling to examine different models and using the historical data collected for the baseline assessment to test hindcast results.**

Phase 3 (7-15 years):

- **Build the integrated ecosystem model system into a Northeast region adaptive ecosystem-based approach to marine resource management, developing the products sought by managers; target prediction of decadal scale variability and longer term change as the goal of this phase.**

- **Operate and improve the Northeast observing system to support and improve the model system; embed it in and link it to the ocean, atmosphere, and land observing systems that provide key knowledge of fluxes at the boundaries. Where possible, develop and include automated observing systems for key biological elements such as plankton, intertidal organisms, and benthos.**

- **Carry out comprehensive studies to resolve processes, build parameterizations, and test and improve models.**

- **Institute a 4-year cycle to document change in the physical and biological systems of the Northeast, the success of models (predictive and hindcast) describing variability and**

change in these systems, the effectiveness of the observing system, and the success and continuing challenges of an ecosystem-based approach to management in the Northeast. Discuss the findings at the workshops.

II. Goals and Intent of the Workshop

The Workshop on Planning Coordinated Research on Ecosystems, Climate, and Policy in the Northeast was hosted by the Cooperative Institute for Climate and Ocean Research (CICOR) at the Woods Hole Oceanographic Institution (WHOI) and the Northeast Fisheries Science Center (NEFSC). CICOR is a Cooperative Institute of NOAA's Office of Oceanic and Atmospheric Research (OAR) located at WHOI, an oceanographic research institution with investigators whose interests and expertise include studies of the ocean role in climate, the physical, chemical and biological variability of the ocean's on a broad range of space and time scales, marine policy, and the development and use of ocean observing systems. The NEFSC is the Northeast region's research center for NOAA's National Marine Fisheries Service (NMFS) and conducts ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources, and to generate social and economic opportunities and benefits from their use.

Why did CICOR and NEFSC come together to host this Workshop?

Two of NOAA's four mission goals through 2010 are to "protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management " and to "understand climate variability and change to enhance society's ability to plan and respond." OAR's mission, as stated in its 2005-2010 Strategic Plan, is "to conduct environmental research, provide scientific information and research leadership, and transfer research into products and services to meet the evolving economic, social, and environmental needs of NOAA." The NMFS Strategic Plan for 2005-2010 states that their mission is "stewardship of living marine resources through science-based conservation and management, and the promotion of healthy ecosystem."

Within NOAA and in the external research community great resources can be drawn on to meet these goals. Multi-agency funded, multi-investigator research programs such as the GLOBEC Georges Bank Program contributed much to our understanding and can provide guidance on the subsequent research that needs to be done to address the knowledge gaps that remain. At the same time, many workers in Federal, State and local agencies are now working to protect, manage, restore, and educate students and the public about marine resources in the Northeast. These agencies should be asked what shortcomings they find in observations, models, and understanding that limit their ability to carry out their responsibilities.

CICOR and NEFSC planned this Workshop to engage these resources in planning future research and to develop specific recommendations for the work that needs to be done to meet NOAA's mission goals for marine ecosystems in the Northeast. Natural variability as well as human impacts must be considered, and participants were selected for the Workshop to bring expertise on ecosystem, climate, and societal issues as well as on ecosystem-based approaches to marine resource management. The Workshop on Planning Coordinated Research on Ecosystems, Climate, and Policy in the Northeast is seen by NOAA OAR to be the first in a series of regional workshops on marine ecosystems, each to be organized by the OAR Cooperative Institute in each region and to provide the means to integrate the input of the external community into the development of NOAA's research plans.

The goal of the workshop was to lay the foundations for and initiate the development of a multi-year plan (looking out a decade from the focus of present planning, which is FY 2008) for research activities that bring together interests and expertise in climate variability, in the interrelation between climate and marine ecosystems, and in the human and policy impacts of climate and marine ecosystem variability. The explicit focus for the workshop was on the Northeast, from Hudson's Canyon northward to the Gulf of Maine; however, the context set by the waters off eastern Canada and by the waters as far south as Cape Hatteras was recognized in the discussions and presentations.

The continental shelf region of the Northeast (Figure 1), especially the Gulf of Maine and Georges Bank, is highly productive. It supports commercial fisheries of finfish, lobster, shrimp, and other species with a combined annual ex-vessel value of over $1 billion. The region also contains critical habitat for endangered right whales and other protected species. The productivity of these ecosystems is influenced by environmental forcing – from severe storms to interannual changes in physical forcing to climate variability and climate change. The Northeast region is influenced by inflow of cool, fresh water from the Scotian Shelf to the northeast and warm salty Slope and Gulf Stream water from the south.

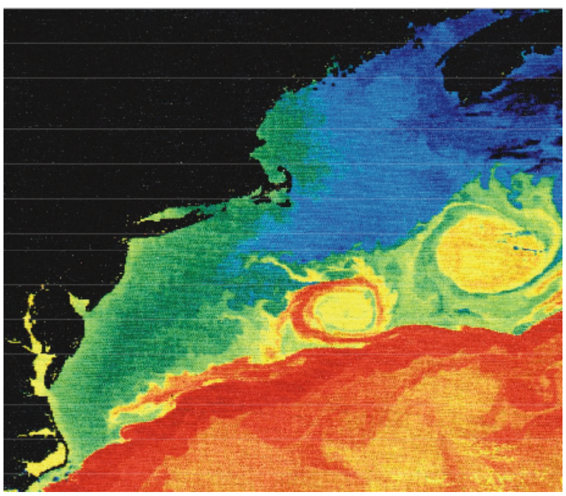

Figure 1. An infrared image from a satellite, showing sea surface temperature in the Northeast. The warm Gulf Stream flows in from the southwest, while cool water is found in the Gulf of Maine flowing to the southwest inshore of the Gulf Stream.

In addition, due to continued increases in human population along the coast, near shore waters are subject to more severe impacts, including inputs of nutrients and pollutants from estuaries, and increasing outbreaks of introduced species and harmful or nuisance organisms – all of which also affect the coastal ecosystems. Thus, there is the need to better understand the physical and biological processes to make possible the forecasting of the physical and biological conditions within the region as a tool for effective ecosystem-based approaches to resource management. In doing so, the understanding of climate variability must be integrated if the causality of variability and change is to be correctly attributed and understood. Climate can govern sea surface temperature, which in turn can influence the ecosystem (Figure 2).

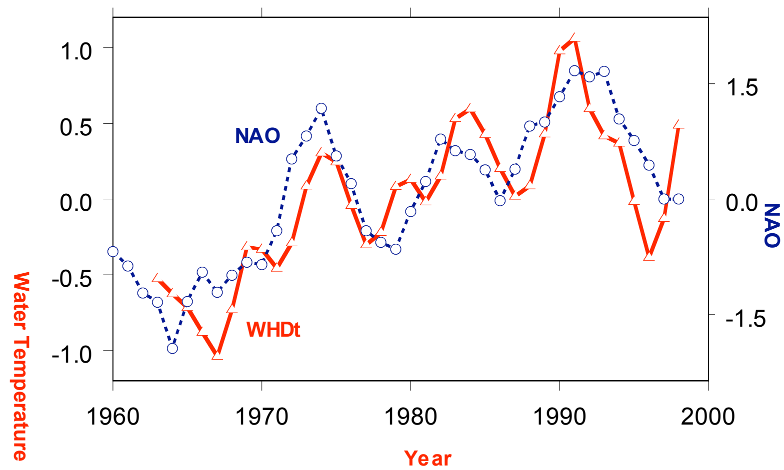

Figure 2. Overplot of annual average surface water temperature anomaly in Woods Hole harbor and the NAO Index. Both time series are smoothed with a 3-year filter.

A convergence of time scales presents a great challenge. Climate variability that changes water properties and transports is apparent at several year time scales and longer. Marine animals at the higher trophic levels have lives of several years and longer. Variability in fish catch has been seen at the several year and longer time scales (Figure 3). The challenge is to distinguish marine resource changes due to human impacts from those resulting from natural forcing, especially climate variability and change.

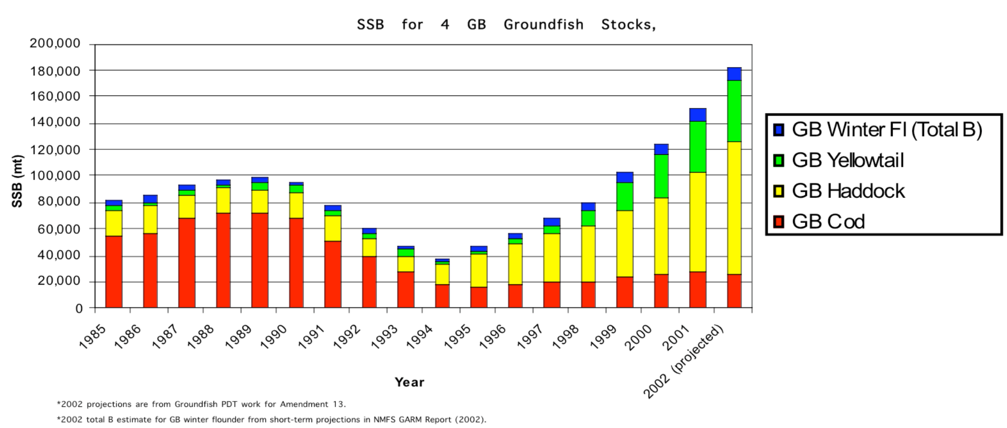

Figure 3. Georges Bank groundfish stocks from 1985 to 2002.

At present there is a national emphasis, not only on the development of ecosystem-based approaches to resource management, but also on the development of the integrated ocean observing system (IOOS) and new ocean observing capabilities, including regional coastal associations supported by a national backbone. There is also a national emphasis on effective data management and efficient use of observations and models to develop products for diverse users. Workshop participants were concerned with how to guide the evolution of observing systems in the Northeast to best serve research, as well as the needs of management, and how to build the foundation for sought-after predictive capabilities and products. This concern served as an underpinning for many of the workshop recommendations.

III. Synthesis Group Reports

Four synthesis groups, research, observations, modeling, and education and outreach, were charged with forming recommendations and plans that integrated across the four topic areas covered by the working groups and, more generally, with taking into account the breadth of climate and ecosystem issues in the Northeast.

The synthesis groups were charged with identifying common scientific research issues, common managerial needs that depend on research, commonalities in the research plans and implementation strategies, with identifying high priority elements that are not common but address pressing needs and with prioritizing research on the basis of management requirements and longer range scientific challenges and needs.

A. Research synthesis group

The highest priorities identified by this group are to:

- Move toward an integrative approach that considers biodiversity and advances past foci on single species, addresses multiple stressors such as climate variability and change, contaminants, and human impacts; and develop this integrative approach to understand the effect of climate change on processes that mediate patterns of biodiversity, including species of economic importance.

- Define the temporal and spatial baseline and variability of the Northeast by retrospective analyses over the broad area, by completion of a survey and characterization of the bathymetry, substrate, and biodiversity of the region, by establishing ongoing monitoring at key time series sites and across the region, and by archiving data and physical samples.

- Advance the realism and completeness of models, building in links between trophic levels and the impact of the biology and nutrients, and validate and improve the models by field studies.

- Conduct field studies that identify, observe, and foster the development of parameterizations of fast and episodic processes and that return sustained, long-term impacts on key variables (i.e., short term forcing functions that produce long-term responses) to identify variability and the impacts of different stressors at different time scales.

A sound understanding is needed of the existing data, including, for example, efforts to contrast the 1920-1930 warm period with the 1980-1990 warm period and to characterize and contrast areas of high diversity and low diversity based on membership in a range of trophic groups in order to compare and contrast species serving in different functional roles. Differences in the roles that component species play in areas of high and low diversity is critical to understanding the population processes that contribute to the maintenance of populations or to dynamics in patterns of diversity in such areas. This understanding will be key to differentiating climate-related variability from responses to other forcing functions, such as fishing and increased estuarine inputs of nutrients and contaminants.

An observing plan and system is needed that addresses the fast time and small scale processes that may have high impact, while at the same time provides effective monitoring over the broad region, including ongoing, sustained observations at key sites; the ability to archive samples for later analysis is essential as new analysis methods will be developed. The boundaries, including the bottom, the estuaries, and the air-sea interface are sites of important exchange and impact and must be observed.

The historic and ongoing observations will be used to improve the completeness and realism of model simulations through hindcast and forecast experiments. One issue to be addressed will be whether or not change in the ecosystem results from the integral effect of a series of episodic events or from response to a slow trend or to an abrupt shift. There are both natural and anthropogenic forcing mechanisms (e.g., climate and weather, eutrophication, trawling, dredging), and the future research, combined with observations and modeling, should be used to establish the basis for credible predictive capabilities. These capabilities need to move beyond empirical relationships to asses how deterministic or chaotic the Northeast ecosystem are, and to determine the skill and limits of predictability. Success in doing this would greatly increase the ability to manage the marine resources of the Northeast.

B. Observations synthesis group

Consideration of the needs identified by the Working Groups on harmful algal blooms, nutrients and contaminants, biodiversity conservation, and fisheries led to the identification of the following high-priority observational needs:

- Regular (~every 5 year) broad scale in-situ surveys of the entire region, sampling the planktonic (including cysts) and microbial communities, the physical structures key to modeling (e.g., stratification, currents), the fish stocks, and the biodiversity of the ecosystem by using ongoing broad-scale monitoring, remote sensing, and in-situ resources (satellite, CODAR, volunteer vessel, moorings and buoys, AUVs, gliders). These surveys continue and expand present efforts.

- Observations of the boundaries, better defining the bathymetry and substrate, quantifying the inputs from streams, rivers, and the atmosphere, and measuring the exchanges with the waters to the north (Scotian Shelf), to the south and offshore. This will improve the physical models and better characterize the habitat.

- Improved integration and availability of observations. Creation of a comprehensive inventory of all available data, including ecological information, habitat information, fisheries information, and physical parameters and facilitation of access to all these data to ensure examination of impacts of multiple forcing functions and of all trophic levels.

- Identification and establishment of long-term observing sites where high-frequency variability would be observed, and where nutrients and contaminants, surface forcing, indicator species, and biodiversity would be measured – some as sentinel sites, indicative of change, and as reference sites, providing a contrast to sites with more active anthropogenic and/or natural forcing at work, and for critical in-situ data needed for model assimilation.

- High spatial and temporal resolution observing programs targeting harmful algal blooms, estuarine inputs, and the determination of the balance of processes at the sentinel and reference sites.

Several activities need to be fostered in conjunction with addressing these observing priorities. First, the community must be brought together to develop consensus on the choice of sentinel and reference sites and of indicator species. Second, the observing efforts, plans, and evolution need to be coordinated with the modeling efforts; in part this is to ensure that the detailed process study observations are done to identify processes that must be included or parameterized in the models and also to ensure that the broad-scale sampling provides the requisite data for initialization as well as for testing and validation. Third, the development of new observing methods must be supported; two examples include, new methods to sustain observations of high-frequency events, and cost effective sampling that provides higher spatial resolution. Finally, the integration of all observing systems across the Northeast must be an ongoing emphasis, include NOAA resources, new resources that the NSF ORION project will develop, NASA and other remote sensing resources, IOOS and regional association platforms, local and state monitoring programs, and volunteer platforms.

C. Modeling synthesis group

Recommended high-priority, recommended activities:

- Development of an integrated ecosystem model system for analysis of impacts of the diverse forcing functions (e.g., climate change, harvesting, nutrient and contaminant concentration) and as a basis for an ecosystem-based approach to management; this system should link observations, model development and validation, and ongoing use of the system to produce products used for management decisions.

Development of the system described above requires that there be: (a) basin/regional/small scale circulation model(s) for general scientific and management use, (b) linked physical/biological models that both enhance understanding and improve simulation of primary and secondary production, (c) better models to manage nutrient inputs to near-shore coastal waters that would predict water quality and biotic resources with changes in nutrient loading, (d) models that can be used to investigate cumulative impacts from multiple stressors, and (e) models to improve understanding of prediction of recruitment.

Modeling would go on in hindcast, nested, and operational (nowcast and predictive) modes. Initialization and validation requires coordination with research and observations; improved surface forcing fields, the physical fields in the ocean, and nesting to include processes with high spatial resolution are needed, as is work on parameterizations and determining data assimilation needs. Nutrient loading models in embayments and coastal water (with incorporation of benthic algae and eelgrass, better simulation of the light field, and links between primary production and critical resources such as shellfish), population genetics and successional models, larval transport models, recruitment models, and fisheries models (including bio-economic and energy flow/trophic level models that include spatial variability) are specific needs.

D. Education and outreach synthesis group

Recommended high-priority activities:

- Improved and ongoing dialog among the managers, researchers, and stakeholders in the climate, fisheries, biodiversity, and policy communities.

- Communication of the benefits and results of research to the public, stakeholders, program managers, and Congressional staff.

The workshop brought together diverse participants, ranging from those involved in commercial fishing and fisheries management, to researchers and program managers. While energetic dialogs arose at the workshop, it is clear that insufficient ongoing lines of communication exist across these sectors. In addition to open access to observations and model results, there is a need to share information about stock assessments, harmful algal blooms, the stewardship of marine resources in the Northeast, and the societal value of biodiversity. Engaging those who work at sea as well as citizen volunteers in the research process has the potential of significant dividends in the form of additional observing platforms and information about biodiversity; this can also open the research process to public scrutiny and comment. Follow-on workshops, every 2 years, are recommended to continue to build and reinforce the dialog among participants.

Also, it is important to develop better mechanisms to explain to the public the complexity of fisheries and of ecosystems-based management. Public awareness of the multiple forcing functions, both natural and anthropogenic, on the marine ecosystems in the Northeast needs to be increased so there is better understanding of and support for climate and ecosystem research and management of marine resources. Although the need to do this is clear, the process of going forward is not. There are many existing educational and outreach activities, including those already established by NOAA, and a required first step will be to consider how best the NOAA activities may be integrated into a comprehensive regional approach. Using other regional programs, such as the

Chesapeake Bay Program (http://chesapeakebay.net/) on a large scale or the Integration & Application Network, (http://ian.umces.edu) on a smaller scale as models for regional action- and results-oriented initiatives which link various stakeholders, researchers and the public is strongly recommended.

IV. Recommendations for Coordinated Research

Key recommendations and a timeline for addressing them are presented here. The recommendations are presented in more detail here than in the Executive Summary.

A. The key recommendations are to:

- **Assess the horizons of predictability and management:**
  - Determine how far into the future and over what spatial domain(s) skillful predictions can be made,
  - Assess the extent to which ecosystems are deterministic or are chaotic.
  - Test probabilistic simulations.

- **Develop improved predictive capabilities for the Northeast, built around an integrated ecosystem model system** comprised of:
  - Physical models forced with accurate atmospheric forcing fields,
  - Good regional atmospheric climate models for coupling to ocean models,
  - Coupled physical-biological models,
  - Management task or species-specific models – such as for HAB prediction,
  - Ongoing operational modeling, supporting management and research,
  - Models whose biology includes primary and secondary productivity and links between trophic levels in the ocean biology.

- **Drive model improvement by strong, ongoing links with:**
  - Sustained observations across the region and
  - Comprehensive studies of physical and biological processes and variability.

- **Develop a system using an adaptive management approach to the Northeast ecosystems,** with
  - Research on climate variability and other forcing functions in the region, and
  - Improve the cycle of evaluation and adaptation of the management tools and methods by integrating climate and ecosystem research into both tasks and by facilitating the provision of scientific technical support to the management community.

- **Establish a baseline for managing and conducting research in the Northeast**:
  - Survey the bathymetry, and bottom characteristics (substrate), of the Northeast.
  - Survey the tracking and archiving efforts of biodiversity in the Northeast.
  - Conduct retrospective analyses to assess whether or not there has been change in response to known climatic signals and events and to management actions.
  - Establish a virtual data partnership to provide easy access to past and present data including archives of physical samples.

- **Build the Northeast observing system for climate and ecosystems**:
  - Establish sustained observing sites as foci for studying processes, for identifying change at diverse, key sites, and for initialization, data assimilation, and validating and improving models and management tools.

- Conduct repeat (every ~5 yrs) broad-scale surveys of the physics and biology of the water column and seafloor; build on and expand present surveys to cover the seafloor and more species.
- Quantify atmospheric forcing, interaction with the seafloor, coastal inputs, and exchanges with the open ocean and the regions to the north and south.
- Integrate all potential observations, including those from fishing boats, NDBC buoys, remote sensing, the IOOS, and the NSF ORION project.

- **Foster the ongoing dialog between climate, ecosystems, and fisheries researchers, ecosystems and fisheries managers, marine resource stakeholders, the general public, and the NOAA goal teams and program managers.**
  - Ensure that data and analyses are shared to all, including managers and the general public, in a timely fashion to derive environmental and public health benefits from the research.
  - Improve outreach to the public about the nature, causes, and impacts of nutrients and contaminants in coastal waters.
  - Increase support to and coordinate outreach activities of various entities, including state coastal management programs, National Estuarine Research Reserves, Sea Grant Programs, National Estuary Programs, and Marine Sanctuaries.

B. Based on considerations of readiness, impact, and sequential progress the following phasing is recommended:

Phase 1 (near-term, 0 – 3 years):

- Initiate development of the baseline assessment (collect and assemble existing data, carry out retrospective analyses, integrate results from current field surveys). As part of this, facilitate the exchange across the community of the diverse data types (e.g., physical oceanographic, fisheries, atmospheric forcing, catch, biodiversity, population variability across a range of trophic levels).

- Identify the priority elements of the Northeast observing system (agree on key sites as sentinel and reference sites, agree on indicator species, develop enhancements to current repeat broad-scale sampling, integrate and coordinate all possible elements, identify need for new sensors and sampling methods) and the sequence of more intense sampling studies needed.

- Assess the coverage of climate and ecosystem issues provided by present models and observations and develop strategies for moving forward integration of all trophic levels and multiple forcing functions.

- Initiate program to assess the horizons of predictability, probing limitations on skillful prediction while at the same time identifying key data (initialization, validation), parameterization, and understanding (realistic incorporation of all key physical and biological processes; realistic models of elements of the system) needs, model and parameterization shortcomings, and shortcomings in the foundation of understanding.

- Identify the status of archives of physical samples of biodiversity in the Northeast and survey models in use elsewhere in order to enhance current and coordinate future initiatives.

- Initiate a working group of researchers (observationalists, modelers, and analysts; climate, ecosystems, fisheries, policy), managers, marine resource stakeholders, and NOAA climate and ecosystems goal team staff to continue interaction, and to embed the research process in a plan for adaptive management of the ecosystems of the Northeast; repeat the Workshop every two years.

Phase 2 (3-7 years):

- Complete the baseline assessment (comprehensive field surveys of bathymetry, substrate, biodiversity; retrospective analyses).

- Establish sustained observations at key sentinel and reference sites; begin the intensive process studies addressing the shortfalls in predictive skill and understanding.

- Begin building the integrated ecosystems model system, drawing the models used as building blocks from the research community and supporting a consortium to do the integration; provide operational and research model results to the community, placing an emphasis on having a good regional climate model, accurate surface forcing to drive ocean models, biological models that span the trophic levels, integration of the component models, and assessment of uncertainties in predictions.

- Institute model validation experiments, keying on the intensive surveys and broad scale sampling to examine different models and using the historical data collected for the baseline assessment to test hindcast results.

- Establish a plan for comprehensive archiving of biological samples of the Northeast ecosystems.

Phase 3 (7-15 years):

- Build the integrated ecosystems model system into a Northeast region adaptive ecosystems management system, developing the products sought by managers; target successful prediction of decadal scale variability and longer term change as the goal of this phase.

- Operate and improve the Northeast observing system to support and improve the model system; embed in and link to the ocean, atmosphere, and land observing systems that provide key knowledge of fluxes at the boundaries.

- Carry out comprehensive studies to resolve processes, build parameterizations, and test and improve models.

Appendix 1:

Agenda

Workshop on Planning Coordinated Research on Ecosystems, Climate, and Policy in the Northeast

<u>Tuesday, January 11, 2005</u>

08:30-09:00	Registration, coffee
09:00-09:30	Welcome and introduction, local logistics (Brief remarks by WHOI, NE NMFS, NOAA OAR)
09:30-09:45	Workshop Overview: Goals and Structure
09:45-10:30	Ecosystems based management - what does it mean - Dr. Michael Sinclair, Regional Director Fisheries and Oceans Canada
10:30-11:00	Coffee
11:00-11:45	Briefing: Harmful Algal Blooms - Paul Anderson, David Townsend
11:45-12:30	Briefing: Nutrients and Contaminants - Anne Giblin, Steve Bliven
12:30-13:30	Lunch
13:30-14:15	Briefing: Fisheries - Chad Demarest, Steve Murawski
14:15-15:00	Briefing: Biodiversity Conservation - Ben Haskell, Willy Bemis
15:00-15:30	Charge to working groups
15:30-15:45	Coffee
15:45-17:45	Working groups meet
17:45-19:15	Reception and Working Dinner

<u>Wednesday, January 12, 2005</u>

08:30-10:15	Working groups: Problem-oriented groups produce draft reports on research needs
10:15-10:30	Coffee
10:30-11:30	Harmful algal bloom report and discussion
11:30-12:30	Nutrient and contaminant report and discussion
12:30-13:30	Lunch
13:30-14:30	Fisheries report and discussion
14:30-15:30	Biodiversity report and discussion
15:30-16:00	Coffee
16:00-17:30	Working groups finalize reports, identify research, modeling, observing, and education and outreach needs

Thursday, January 13, 2005

08:30-10:30	Synthesis groups meet to compile and synthesize summaries for coordinated modeling, research, observations, and education and outreach efforts
10:30-11:00	Coffee
11:00-12:30	Synthesis group reports and discussion in plenary
12:30-13:30	Lunch
13:30-15:00	Commentary from NOAA, with discussion of the NOAA process for planning research, of the role of planning workshops, and of the format of the workshop report
15:00-15:30	Coffee
15:30-17:00	Steering Committee meets to begin work on workshop report

Appendix 2:

Workshop Steering Committee

Bob Beardsley, Woods Hole Oceanographic Institution

John Boreman, National Marine Fisheries Service

Mike Fogarty, National Marine Fisheries Service

Dennis McGuillicuddy, Woods Hole Oceanographic Institution

David Mountain, National Marine Fisheries Service

Andy Solow, Woods Hole Oceanographic Institution

Heide Sosik, Woods Hole Oceanographic Institution

Peter Wiebe, Woods Hole Oceanographic Institution

Robert A. Weller, Woods Hole Oceanographic Institution

Appendix 3:

Workshop Participants

*stearing committee member; **group leader

**Paul Anderson (M)	Maine Sea Grant, University of Maine Orono
*Bob Beardsley	Woods Hole Oceanographic Institution
**William E. Bemis (S)	Shoals Marine Laboratory, Cornell University
Dave Bergeron	Massachusetts Fishermen's Partnership, Inc.
**Steve Bliven	Urban Harbors Institute, UMASS Boston
*John Boreman	National Marine Fisheries Service, NOAA
Mike Bothner - USGS	USGS, Quissett Laboratories
Maureen Conte	Marine Biological Laboratory, Woods Hole
Joe Costa	Buzzards Bay Project National Estuary Program
**Benjamin Cowie-Haskell (M)	Stellwagen Bank National Marine Sanctuary
Ned Cyr	Office of Science & Technology, NOAA
**Chad Demarest	New England Fishery Management Council
Ron Etter	University of Massachusetts Boston
*Mike Fogarty	National Marine Fisheries Service, NOAA
Scott Gallager	Woods Hole Oceanographic Institution
**Anne Giblin (S)	Ecosystems Center, Marine Biological Laboratory
Margarita Gregg	Office of Oceanic and Atmospheric Research, NOAA
Michael Hickey	Massachusetts Division of Marine Fisheries
Lew Incze	Bioscience Research Institute, University of Southern Maine
Les Kaufman	Boston University Marine Program
Bruce Keafer	Woods Hole Oceanographic Institution
Scott Libby -	Battelle, Inc.
Matt Liebman - EPA	Environmental Protection Agency
Daniel Lynch	Dartmouth College, Thayer School of Engineering
Jennifer Martin	Fisheries and Oceans Canada
*Dennis McGuillicuddy	Woods Hole Oceanographic Institution
Linda Mercer	Maine Department of Marine Resources
Michael Mickelson	Mass Water Resources Association
*Dave Mountain	National Marine Fisheries Service, NOAA
**Steve Murawski (S)	National Marine Fisheries Service, NOAA
Kenric Osgood	National Marine Fisheries Service, NOAA
Candace Oviatt - URI	Graduate School of Oceanography, URI
Juliette Rooney-Varga	Biological Sciences Department, UMASS Lowell
Andy Rosenberg	University of New Hampshire
Brian Rothschild	UMASS Dartmouth
Jeffrey Runge	Ocean Process Analysis Laboratory, UNH
Tim Shank	Woods Hole Oceanographic Institution
**Michael Sinclair	Fisheries and Oceans Canada
Peter Smith	Bedford Institute of Oceanography
Paul Snelgrove	St. John's N.F. Memorial University

*Andy Solow	Woods Hole Oceanographic Institution
*Heidi Sosik	Woods Hole Oceanographic Institution
Andrew Thomas	School of Marine Sciences
**David Townsend (S)	School of Marine Sciences, U. Maine
Beth Turner	NOAA Coastal Ocean Program
Jefferson Turner	UMASS Dartmouth
*Bob Weller	Woods Hole Oceanographic Institution
*Peter Wiebe	Woods Hole Oceanographic Institution
John Williamson	Stellwagen Bank National Marine Sanctuary Advisory Council

Appendix 4:

Working Group Reports

Workshop participants were divided into four working groups, each co-chaired by a manager and a scientist who are leaders in their respective fields. During the first phase of the workshop, these groups worked to converge on the issues and goals for future research in each area. It was recognized going into the workshop that the potential scope of the dialog about research on ecosystems, climate, and policy was broad, too broad to cover in a 3-day workshop. Thus, four subtopic areas were chosen to focus the discussion. These were: harmful algal blooms, nutrients and contaminants, fisheries, and biodiversity conservation. Prior to the workshop, the co-chairs were asked to contribute background papers (these are reproduced in Appendix 4).

On the first day of the workshop, the co-chairs shared the task of briefing the entire group. (These presentations are available on the workshop website: http://www.whoi.edu/science/cicor/workshop05/workshop_home.html). After the briefings the participants divided into the four working groups. The groups were charged with developing plans, aiming at the decade starting with FY08, that would address the key issues and challenges in their area while also, more generally, bringing together interests and expertise in climate variability, in the interrelation between climate and fisheries research, and in the human and policy impacts of climate and fisheries variability. The domain was allowed to be from the Scotian Shelf to Cape Hatteras in order to include the boundary regions that influence the Northeast.

The working groups were charged with:

- Summarizing the key science and management issues relating to each specific topic;
- Identifying key outstanding research issues in relation to climate;
- Identifying where research could address management needs;
- Outlining a strategy for conducting that research and
- Developing priorities for implementing that strategy.

In addition, the working groups were asked to look toward the work on the synthesis groups later in the workshop and to appoint members from each working group to be sent to the four synthesis groups: research, observations, modeling, and education and outreach. The synthesis groups would be tasked with looking for common elements and plans and for developing coordination across the working groups.

A. Harmful Algal Blooms

David Townsend, Linda Mercer, Jennifer Martin, Andrew Thomas, Heidi Sosik, Dan Lynch, Juliette Rooney-Varga, Dennis McGillicuddy, Paul Anderson, Bruce Kaefer

1. Key science and management issues:
    a. Public Health related to shellfish consumption and other means of exposure.
    b. Harmful effects on finfish aquaculture operations, other populations including but not limited to: wild fisheries, marine mammals, sea birds.
    c. Potential for HABs to serve as reservoirs for pathogenic bacteria such as Vibrio species.
    d. The effect of climate change on water masses and circulation in the Gulf of Maine with respect to present and future HAB species.
    e. Predictability of phytoplankton community composition and dynamics.

2. Outstanding scientific research issues relating to climate:
    a. Understanding of the in situ interactions between Alexandrium and other organisms, nutrients and light.
    b. The distribution, ecology and life history of other toxigenic species: Pseudo-nitzschia, Dinophysis, Prorocentrum, Gyrodinium and nuisance species: Phaeocystis, Mesodinium, Dictyocha, Chaetoceros, Eucampia.
    c. Understand the genetic variability of HAB species and how they are linked to biogeography, population dynamics and toxicity.

3. Where research could address management needs:
    a. Develop an observational network to provide evidence of climate change and the information needed to drive present and future models.
    b. Develop sensor technologies for multiple species of plankton that can be deployed on buoy systems (automated in situ imaging system, molecular-based technologies, chemical sensors [e.g., toxin-specific]).
    c. Develop a system for collection and archiving of phytoplankton samples for future analyses such as: determining the distribution and population dynamics of future HABs; determining the genetic variability of current HAB species; and, bringing new technologies to bear on the analysis of the whole community.
    d. Develop and/or assess affordable detection methods for PSP, DSP and Domoic Acid.
    e. Understand the toxicology of HABs including: the physiological function of toxins in the alga, factors that drive toxin production, relationship of toxin production to biogeographic distribution and environmental conditions.
    f. In the case of PSP in the Gulf of Maine, refine predictive models in order to provide timely and useful information for agencies to effectively monitor for shellfish toxicity.

g. Also with respect to PSP in the Gulf of Maine, develop predictive models that can provide long range forecasts of potential high-toxin years that can allow the fishing industry to plan for market supply needs.
h. With respect to other HAB species, begin to explore the need for, and requirements of similar predictive models in e and f above.
i. Identify indices/proxies of both physical and ecosystem changes

4. Science strategy:
    a. OBSERVATIONS: An observational network is needed to provide evidence of climate change and the information needed to drive the models, for example:
        - An observational network for *A. fundyense* and PSP in the Gulf of Maine
            1. Ongoing shellfish and phytoplankton monitoring programs
            2. Mooring lines – "continuous" April-October
                a. BOF, Pen Bay, Cape Ann
                b. ESP: Alexandrium (+ phytoplankton species composition)
                c. Nitrate
                d. T,S,V
                e. Other sensors as needed and available (e,g., fluorometers)
            3. Other sampling platforms (e.g., AUVs)
            4. GoMOOS CODAR surface currents – continuous
            5. GoMOOS moorings (T,S,V)
            6. Cyst surveys – every 5 years
            7. Meteorological forcing – ongoing
            8. NOAA coastal tide gauges – ongoing
            9. Satellite observations – ongoing and new products and new data types
        - Concurrent with the development and deployment of an observational network, we need to continue to develop and improve sensor technologies and detection methods for organisms and toxins as described in section 3 above.

    b. MODELING: Form a regional modeling team for HABs in the region, and charge it with the development of a set of regional model products of sufficient geographic scope, time scale, that are inclusive of physical and biological factors that serve multiple sector needs.
        - Improve existing models
        - Identify new modeling needs

    c. RESEARCH:
        - Implement research program to address currently identified research needs.

1. Life history studies including quantification of vital rates, autecology,
    a. For example, process studies that include investigations of:
        i. Growth regulation: Nutrient limitation; Light limitation; Allelopathy
        ii. Loss mechanisms: Grazing, particularly offshore; Algicidal bacteria?; Virus interactions?
        iii. Encystment / excystment: Inter-annual cyst dynamics in the sediments

- Retrospective meta-analyses and synthesis of recent research programs to identify biological and environmental factors that significantly affect HAB events, etc.

5. Priorities for implementation:
    a. Priorities for years 1-2:
        - Conduct data mining and retrospective analyses of existing research and monitoring results.
        - Design / deploy / expand an observing system that meets the needs detailed above.
        - Use the existing models to the fullest extent to interpret the available data.
        - Establish sample repository /archive

    b. Priorities for years 1-4:
        - Sensor development / detection tools
        - Process studies
        - Collect baseline data on plankton community composition
        - Continued model development: ecosystem models, data assimilation schemes, extend forecasting skill

    c. Priorities for years 1-10
        - Expand foci to other HAB species
        - Genetic variability of HAB species
        - Document climate change and impacts on plankton community structure
        - Continue to develop models to achieve goals detailed above, exploit technological advances, and integrate new data
        - Hypothesis-driven research that flows from the priority research programs from years 1-4

6. The current mechanisms used to input scientific information into the management process and how these mechanisms need to be enhanced or modified to accomplish the move into ecosystem based approaches to management practices.

a. Current Mechanisms:
    - State shellfish control authorities are currently responsible for monitoring biotoxin and managing public health risk.
    - Collaborative approaches to research such as ECOHAB
    - There is informal exchange of information between managers and scientists in the region about the incidence of HAB events.
    - In recent years there has been a biannual workshop in the region to bring scientists and managers together.
    - There is an intention to develop an international data repository for HAB-related data, e.g., Gulf of Maine data partnership

b. Improvements:
    - Ensure that research results from these HAB studies are integrated into ecosystem-based approaches to management efforts, e.g., risks to marine vertebrates.
    - Include managers, government scientists, and industry in research programs.
    - NOAA and other federal-funding programs need to ensure sustainability of observation, monitoring, and modeling activities.

B. Nutrients and Contaminants

Bob Beardsley, Steve Bliven, Mike Bothner, Joe Costa, Anne Giblin (chair), Matt Liebman, Scott Libby (secretary), Mike Mickelson, Candace Oviatt, Jeff Turner

1. Key science and management issues:
   a. Inputs: A better understanding of present day conditions and a better characterization of inputs is needed.
      - Currently most input monitoring is done on surface waters. If the TMDL process goes into implementation there may be a need to make improvements in estimates of loading.
      - More information on atmospheric inputs, especially over water remote from shore, as well as bioavailability of DON is needed.

   b. Monitoring
      - Current observations inshore are largely focused on assessing problems once they occur. Nearshore monitoring of physical parameters (temperature, salinity and oxygen), water column pigments, and contaminant levels in sediments and fish allow scientists and managers to identify water bodies that have been adversely impacted. Most do not adequately address the status of shallow eelgrass systems. Areal coverage is still an issue, as a significant portion of our coastal waters is not monitored on any routine basis. Currently monitoring is being carried out by a host of local, state, and federal agencies. This raises issues of data comparability and availability.
      - In many cases existing monitoring programs are not of sufficient duration to indicate developing problems early on or to detect temporal trends. This, combined with issues of data comparability and accessibility, will severely hamper the ability of scientists and managers to assess how issues such as climate change, may be impacting the region as a whole over the long term.
      - Overall, the current monitoring activities are not sufficient to address issues such as the impacts of multiple stressors on living resources, or climate change. They also are not able to support the development and testing of better models. There are notable exceptions. One is the highly successful MWRA monitoring program. This program has provided high resolution time series data of both physical and biological measurements that are being used to develop an ecosystem level understanding of the ecosystem. This data has already proving useful to examine impacts of climate variability on primary and secondary production. This program is ongoing but will likely be scaled back. Other exceptions are long term time series being measured by individual investigators, or teams of investigators, such as those on fish and phytoplankton in Narragansett Bay or zooplankton in Buzzards Bay. None of these

monitoring activities receive consistent Federal support and hence all are in jeopardy. Driven by one individual

c. Contaminants
    - Working on better sediment transport models and models which incorporate the release of pollutants during resuspension (speciation and bioavailability). These are critical to understanding transport and bioavailability of contaminants.
    - A better way to predict and understand cumulative impacts is needed.

d. Models
    - Physical models are progressing rapidly.
    - Regional and basin models are expected to be available in the next 5-10 years.
    - Progress is being made on biological models but it has been slow.
    - Most models still at the primary production level or there are other models dealing with single species of higher trophic levels. These groups do not seem to get together.
    - NOAA is funding an eelgrass model.
    - There is a need to be able to evaluate models to determine if they are good enough to support a particular decision.

2. Outstanding scientific research issues related to climate:
    a. Nearshore water quality may be greatly altered by climate change.
        - Currently it is not clear if climate change will increase or decrease freshwater flows.
        - It is also important to consider that the consequences of human water usage may exceed those due hydrologic changes related to climate change.
        - Increased freshwater inflow may increase nutrient inputs, decrease water residence time, and alter stratification strength (and thereby affect hypoxia and anoxia).

    b. Changes in sea level may lead to losses of wetland areas.
        - Wetlands may serve as important nutrient sinks and their loss could aggravate eutrophication.
        - Rising sea level may also cause coastal erosion, invasion of freshwater resources and local septic system flooding.

    c. Increased temperature appears to reduce the ability of eelgrass to withstand increased nutrient loading.
        - Increased temperature increase benthic respiration thereby exacerbating hypoxia and anoxia.
        - Increased temperature may also alter disease patterns in marine organisms.

d. There are already data suggesting that increases in temperature shifts trophic dynamics by changing the intensity and timing of blooms. We need much more information to know the magnitude and extent of these changes.

e. We need to understand how shifts in coastal currents alter nearshore production and species distributions.

f. Finally, there is a need for more information on possible temperature-nutrient – disease interactions.

3. Research that can address management needs:
   a. Managers need long term data sets to assess the success of management actions and to monitor for long term climate change. Current programs focus on a few simple parameters and long term continuity is not always assured.

   b. Managers need better information to develop estuary specific TMDLs.
      - The first step is to develop a sensitivity index – this was an NRC recommendation.
      - New and improved (and adaptive) models are being developed to link inputs with ecosystem effects and what is desired (clarity, eelgrass, etc.). These efforts need to continue but what is ultimately needed is a validated model that links what is measured to resources (shellfish, finfish, wildlife and recreation).
      - Models need to incorporate new knowledge of climate related changes and help refine TMDL goals in this context.

   c. Managers need a mechanism to assess the cumulative effects of contaminants at the organism, population and ecosystem level.

4. Science Strategy
   a. OBSERVATIONS:
      - Monitoring programs have to be strengthened and continued over the long term. A tiered approach, with some sites providing a more comprehensive time series of physical and biological parameters (MWRA is a model) is needed.
        1. These sites should be sited at some key locations, including the boundary between biogeographic provinces.
        2. Maintenance of long-term measurements is critical.
        3. Continuous monitoring on fixed sites for temperature, Chl a, and oxygen will help improve assessments of coastal areas.
        4. Supplement with phyto- and zooplankton data to characterize community.
        5. Zooplankton needs to include jellies.

- Enhance existing monitoring programs, esp. buoys and sensors, for temporal coverage and biological parameters and more information on atmospheric inputs of N (DON) and pollutants (esp. Hg) especially over water.
    1. Better use could be made of satellite data.
    2. NOAA's buoys could be augmented with sensors (flourometers, VPR (plankton recorders), nutrients) to provide additional information.

b. MODELING:

- Improve large-scale modeling – both hydrodynamic and linked hydro-biological models. These models need to incorporate more trophic dynamics if they are to be useful in understanding potential climate change impacts.
- Experimental systems such as mesocoms can be used to support modeling activities by defining parameter interactions and for model testing. Contaminant exposure effects and trophic transfers can also be effectively studied in model systems. Mesocosms have been used to examine pelagic changes and effect on coupling between benthos and water column.

c. RESEARCH:

- For contaminants we need research into long term monitoring tools that do not depend on organisms with all their inherent variability, (gels, resins, etc.).
    1. Biochemical indicators of exposure and stress can serve as early warning indicators.
    2. For metals, stable isotopes can be used to assess sources, and in some cases transformations.
    3. An additional goal would be to archive samples so that it will be possible to go back to look when "new" pollutants are identified in the environment.
- To facilitate planning in the face of climate change, estuaries could be classified as to their sensitivity to changes in freshwater flows, temperature changes and sea-level-rise in a manner similar to the coastal vulnerability index (CVI) used by the USGS to assess storm damage.
- Existing NOAA buoys in coastal zone have to be maintained and kept operating. More data will be needed to help validate new physical models. The loss of USGS stream gauges is also of concern.
- NOAA should consider continuing to make SeaWiFS data available to the coastal community at no or low cost for research and monitoring.

5. Implementation Plan:
    a. A commitment to long-term observations already underway. Augmenting existing observations with new sites and expanded scope using new technologies is considered the top priority.

    b. Development and application of indices of susceptibility to eutrophication and also to climate change for both management and to identify potential sentinel sites.

    c. Move existing linked hydrodynamic/biological models beyond nutrient and primary production to capture trophic transfers and compartments.

    d. Move ahead on contaminate models dealing with fates, effects and transport.

6. The current mechanisms used to input scientific information into the management process and how these mechanisms need to be enhanced or modified to accomplish the move into ecosystem based approaches to management practices.
    a. Leverage monitoring programs through partnerships with existing programs.

    b. Enhance the capability of NERRS and Marine Sanctuaries to carry out observations and maintain long term data bases

    c. Insure continuity between old and new observations systems (such as SeaWiFS to MODIS).

    d. Engage the academic community

    e. Data collection, interpretation and modeling needs to be much better coordinated between agencies and with academic institutions. A regional group may be the most effective way to make progress. It may be appropriate for some group like CICOR to take the lead on this.

    f. Both inshore and Offshore
        - Cumulative impacts of contaminants – key management need, links with disease, direct impacts.
        - Improved data access
        - More buoys and enhanced capabilities of existing buoys
        - Experiments – such as MERL

C. Fisheries

Dave Bergeron, John Boreman, Ned Cyr, Chad Demarest, Mike Fogarty, Scott Gallager, Les Kaufman, Dave Mountain, Steve Murawksi, Kenric Osgood, Andy Rosenberg, Brian Rothschild, Peter Smith, Bob Weller

We want to emphasize that research in the various disciplines should be integrated to allow evaluations of multiple simultaneous stressors, which is a more realistic way to view ecosystem issues than the one-issue-at-a-time approach. What follows is a set of research questions that are important to fisheries management and that try to set the issues in the context of cumulative effects. A strategy to enhance input from managers and the public is needed to have them involved in defining key research issues. Together, management and stakeholder communities should define the objectives and potential outcomes for management. (This is relevant for the wider set of ecosystem-related governance systems)

1. Key science and management issues:
   a. What ecosystem properties (e.g., energy flow among trophic levels) are useful for informing the management of given resources:
      - Stock rebuilding/maintenance for sustainability is an important policy driver
      - Regime shifts and alternate stable states are possible
      - Spatial heterogeneity occurs across the region (Labrador to Cape Hatteras)?

2. Outstanding scientific research issues related to climate:
   a. What are the effects of climate change, in the context of other cumulative human impacts, on primary fishery targets and incidentally impacted species? Cumulative impacts are those resulting from:
      - Contaminants and nutrient enrichment
      - Physical habitat change (shore-side to deep sea)
      - Biodiversity change at community, species and genetic levels
      - Harvesting effects

3. Research that can address management needs:
   a. Develop objective methods for informing tradeoffs in resource management and improving management tools for:
      - Evaluating the bioeconomic aspects of trade-offs that will result from increasing fishery interactions (e.g. technological, predator-prey, fishery-protected species)
      - Considering alternative ecosystem-based metrics for managing fisheries and monitoring success (balance among trophic levels)
      - Evaluating the appropriateness of various ecosystem-based management "tools" (e.g. gear regulation effects on genetics and trophic balance; placement of MPAs)
      - Communicating ecosystem knowledge to stakeholder groups to inform business and community planning

- Using spatially-explicit management measures for fisheries,
- Evaluating the implications of climate variation, changes in water quality, and coastal modifications for resource management programs

4. Science Strategy:

   a. Synthesize empirical information for evidence* of ecosystem change:
      - Begin with retrospective analysis = synthesis of time series of existing data series and studies,
      - Integrate the information from the length of the coast from Labrador-Cape Hatteras, since climate effects will represent a cline over broad geographic scales,
      - Catalog data from holdings that occur over limited geographic scales into a broader synthesis,

      (Special note: Places GLOBEC in a larger ecosystem context, is a more intensive look at broader species interactions, broader geographic scales than GLOBEC)

   b. Query the observation systems currently in place and synthesize information from it:
      - develop routine methods for serving climate and related data to the research community.
      - Compile regional data holdings and integrate with regional IOOS implementation. (data management/archival/serving step)

   c. Develop hypotheses to explain observed changes and theory-models to integrate data and hypotheses:
      - Based on identified changes in system state, develop coupled dynamical models (dn/dt) to synthesize variables of interest (above) and cumulative stressors (e.g., fine-scale coupled physical/biological models; fluid dynamics models, trophic dynamic models).
      - Link basin-scale models to regional problems.
      - Conduct research on new variables that will come from linking historic information with dynamic models.
      - Identify key ecological observations as components of the observing system.
      - Conduct critical field studies necessary to develop coupled biological and physical models to resolve ambiguities from the synthesis of historical information and improve forecasts.

   d. Products of the Research:
      - Provide a synthesis of ecosystem change in the context of historical observations and models used to explain them.
      - Develop forecasting capability and the ongoing information requirements feeding into predictive models to inform management on issues of interest.

- Identify gaps in observations and priorities for enhancing the observation system (e.g., to improve the resolution of the system relative to processes of interest).

5. Implementation Plan:
   a. An important issue in establishing the program is the necessity of conducting an initial evaluation of candidate theoretical models for interpreting ecosystem change simultaneously with the identification of historical data series that would inform them. This is necessary both to pursue model frameworks that can credibly be parameterized, and to avoid unnecessary data mining.

   b. OBSERVATIONS:
      - Conduct a comprehensive inventory of available (historical) information (EcoINFO)
      - Compile ecosystem and physical variables currently being observed (EcoIOOS)
      - Develop observation requirements to support forecasts of ecosystem state (next generation EcoIOOS)
      - Assemble observations of variables of interest including:
        1. *ecological*: e.g., recruitment, community structure, abundance/biomass, primary, secondary production, biodiversity, distribution patterns, fishery productivity/revenue, catchability, growth rates, natural mortality, demographic structure, predator-prey dynamics
        2. *Physical*: e.g., patterns of change in water temperature, circulation, stratification, water chemistry
        3. *Habitat*: e.g., physical characteristics, benthic structure, coastal nutrients and estuarine connections

   c. RESEARCH:
      - Synthesize historical observations to provide information on ecosystem change over time
      - Identify key field research necessary for coupling physical and biological models
      - Use system of closed areas as pseudo-replicates/controls to interpret dynamic relationships among ecosystem components
      - Develop forecasting tools for integrating models and data

   d. MODELING
      - Develop suites of theoretical models relating ecosystem processes to forcing functions that must be considered as control hypotheses in evaluating key questions (biomass spectrum, N-P-Z, etc.)
      - Contrast single-species models with ecosystem models r.e. their implications for management
      - Define the data requirements necessary to parameterize candidate models

- Match models with historical data synthesis
- Develop approaches for explaining ecosystem change in the context of candidate models and multiple simultaneous drivers

D. Biodiversity Conservation

William Bemis, Benjamin Cowie-Haskell, Ron Etter, Lew Incze, Jeffrey Runge, Tim Shank, Paul Snelgrove, Mike Sinclair, John Williamson

1. Key science and management issues:
    a. Biodiversity: Why is it important to ecosystem-based approaches to management?
        - Without considering biodiversity, species composition, an ecosystem-based approach to management cannot be accomplished.
        - Understanding interactions between species, and changes in trophic structure are basic to effective management.
        - Awareness of and preservation of species is a fundamental and growing human value.
        - Mechanisms that control biodiversity cannot be understood without knowledge of the interaction between species (e.g., trophic cascades, parasitism, symbiosis).
        - Ecosystems provide services that are important to maintaining human health (e.g., nutrient cycling) and without understanding how systems work, we need to adopt a precautionary approach. The link to biodiversity is just emerging.
        - May lose opportunities for improving human condition (e.g., medical insights) or knowledge (e.g., novel ecologies).
        - Biodiversity studies provide baseline data for tracking ecosystem changes (i.e., climate change or invasive species).

2. Outstanding scientific research issues relating to climate:
   What are the effects of climate change, in the context of other cumulative human impacts, on biodiversity?
    - What is the link between biodiversity and ecosystem functioning, including fisheries, HAB, nutrients and contaminants, etc.?
    - Physical habitat change (shore-side to deep sea).
    - Biodiversity change at community, species and genetic levels.
    - Harvesting and lifecycle effects.
    - Coordinate the location of current and future climate observational systems with biodiversity hot and coldspots.

3. Where research could address management needs:
    a. Comprehensive, dynamic species lists
    b. Map biodiversity (annual and seasonal) at all taxonomic levels
    c. High resolution bathymetry
    d. Distribution of physical features
    e. Temporal/spatial patterns of connectivity
    f. Discovery of new species, habitats, interactions, novel ecology

4. Science Strategy
    a. OBSERVATIONS:
        - Continue surveys and monitoring

- Strengthen observing partnerships (e.g., Gulf of Maine Ocean Data Partnership, Census of Marine Life, Gulf of Maine Biogeographic information System, Canadian Corridor, museums, aquaria, agencies, educational institutions)
- Train new taxonomists
- Foster partnerships with fishing industry to conduct sampling and monitoring

b. RESEARCH:

- Understand causes of biodiversity hotspots/coldspots
    1. Workshop to identify geographic areas to study intensively
    2. Spatial and temporal scales need to be considered carefully
- Understand genetic diversity
    1. In order to understand resilience, connectivity among populations, changes to genetic diversity due to environmental and human perturbations, and how to manage long-term conservation;
    2. What are the threats to genetic diversity?
- The theoretical underpinning of biodiversity needs to be articulated.
- Choose surrogate/indicator species representative of a larger group because too many species to deal with (e.g., taxonomic, functional, larval group)
- Understand rare species
    1. Why are they rare - natural, human-induced, migratory?
    2. At what scale are they rare - local, regional, global?
    3. What is the role of rare species in biodiversity?
- Investigate terrestrial/marine species such as seabirds and turtles-these have special requirements that need to be considered
- Understand extirpations, extinctions, and range shifts: how and why do they happen?
- What are the causes and impacts of rapidly changing species assemblages including nuisance species and invasions? What role does biodiversity play in controlling invasions?
- What controls biodiversity (top down, bottom up, intermediate)?
- Protection of benthic habitats; complex habitat mediates diversity.
- Facilitate communication between practioners and support existing initiatives: e.g., COML, OBIS, GMBIS

c. MODELING

- Biological response to environmental and human pressures (can we predict successional stages in particular areas?)
- Effects of climate change
- Resilience of species
- Biogeographic distributions based on other data (environmental past and present)

- Joint (US/CA) effort to link basin and shelf seas models to predict changes in circulation and mixing leading to effects on biogeographic shifts in distribution of species
- Trophic interactions

d. EDUCATION AND OUTREACH
   - Critical for delivering the message that biodiversity is essential to human well-being, fostering stewardship, and training new systematists
   - Support for research students (fellowships)
   - Need systematics workshop/intensive summer study (Shoals Marine Lab/Huntsman as possible locations)
   - Support existing initiatives (e.g., New England Aquarium Center for Ocean Sciences Education Excellence)
   - Foster partnerships with fishing industry

5. Implementation Plan:
   - Engage and train fishers in transitioning from making anecdotal observations to providing data (e.g., oceanographic conditions, species and interactions, habitats).
   - Develop and deploy a comprehensive observing system including in-situ and automated instrumentation, vessels of opportunity, etc.
   - Support intensive study areas (e.g., COML/ Biodiversity Corridor)
   - Implement comparative studies (e.g., MPAs with varying levels of protection including reference areas)
   - Habitat mapping with groundtruthing and focused studies

Appendix 5:

Links to Related Material

CICOR's home page (http://www.whoi.edu/science/cicor/) includes a link to a workshop website (click on "Coordinate Research Webiste" or navigate directly to the following address: http://www.whoi.edu/science/cicor/workshop05/workshop_home.html).

Background white papers were written in preparation for the workshop by the co-chairs of the working groups. The biodiversity conservation paper by William Bemis and Benjamin Cowie-Haskell, the harmful algal blooms paper by Paul Anderson and David Townsend, and the nutrients and contaminants paper by Steve Bliven and Anne Giblin are available on the workshop website at http://www.whoi.edu/science/cicor/workshop05/links.html. The fisheries paper by Steve Murawski and Chad Demarest is not yet available.

Each of the working group co-chairs presented a Powerpoint talk. Pdf files of those presentations are also available at http://www.whoi.edu/science/cicor/workshop05/links.html.