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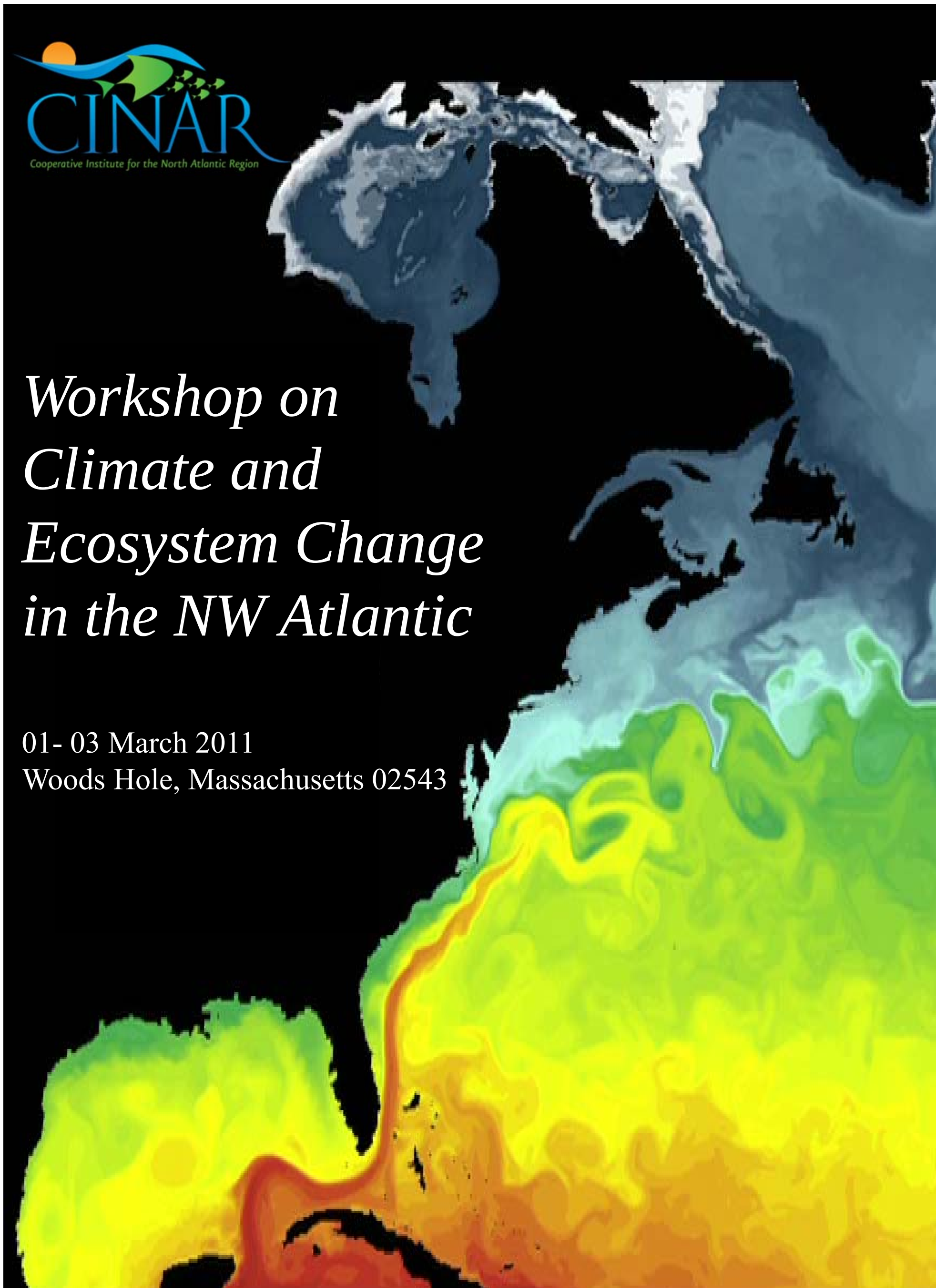
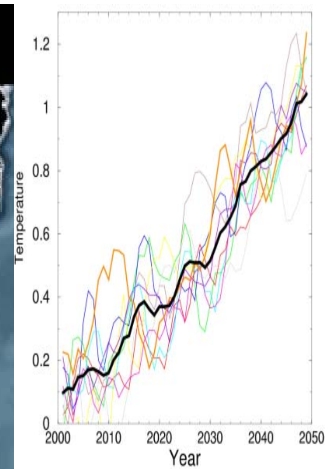
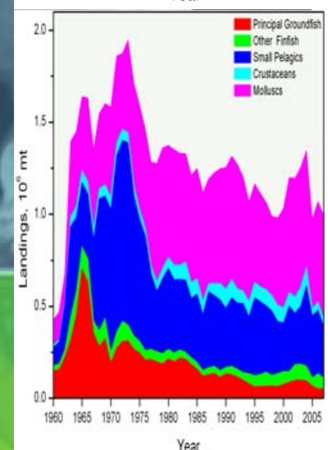
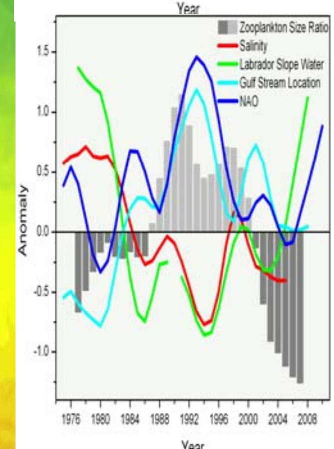


Workshop on Climate and Ecosystem Change in the NW Atlantic

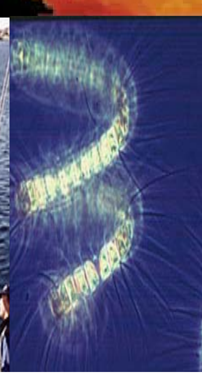
01- 03 March 2011
Woods Hole, Massachusetts 02543













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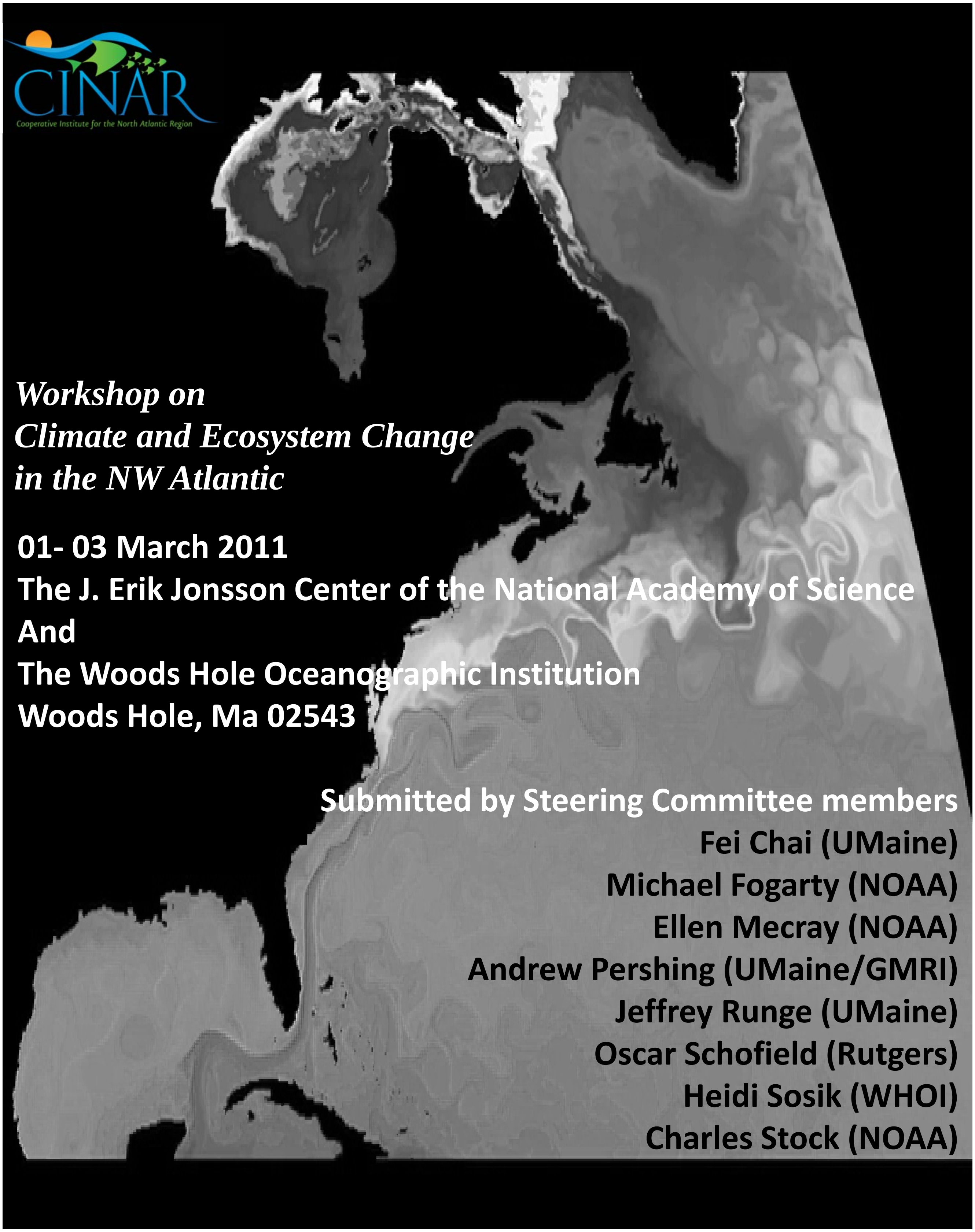

Workshop on
Climate and Ecosystem Change
in the NW Atlantic

01- 03 March 2011
The J. Erik Jonsson Center of the National Academy of Science
And
The Woods Hole Oceanographic Institution
Woods Hole, Ma 02543

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CINAR Workshop on Climate and Ecosystem Change in the NW Atlantic

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Executive Summary

The Northeast Shelf Large Marine Ecosystem is physically and biologically complex and supports valuable fisheries resources. The physical processes and biological dynamics in the region have been characterized by NOAA's long-term monitoring programs and by intensive research programs such as GLOBEC and EcoHAB. These studies have revealed important mechanisms that determine interannual and interdecadal variability in this regional system. Knowledge of mechanisms contributes to identification of processes and indicator variables that must be monitored and modeled in order to understand how the region will respond to future climate variability and change. To advance collaborative research and understanding of regional climate and ecosystem change, the Cooperative Institute for the North Atlantic Region (CINAR) hosted a two-day workshop at the J. Erik Jonsson Center of the National Academy of Science in Woods Hole, MA. Workshop participants were divided into two working groups, one focused on climate variability and change and the other focused on CINAR's contribution to Integrated Ecosystem Assessments (IEAs).

The working group on climate variability and change outlined a strategy for advancing the ability to forecast impact of climate change on key ecosystem processes in the NW Atlantic. Because of the long history of physical and biological measurements, this region provides an ideal test-bed for understanding climate-ecosystem interactions and for developing forecasts of future ecosystem change. The forecasting task is complicated, however, by the region's complex oceanography, with strong influences from the warm Gulf Stream and cold Labrador Current. Nevertheless, workshop participants were optimistic about the potential for relating projections from global climate models to regional processes, and recommended a strategy for developing these much needed forecasts. The strategy has three core components:

- Concerted development of a range of climate model downscaling approaches (statistical and dynamical) and high-resolution climate simulations in order to relate global and basin-scale climate dynamics to responses within the CINAR region.
- The development of robust physical-biological modeling frameworks for regional climate-ecosystem hindcasts and forecasts.
- Synthesis of past observations and targeted augmentation of observing systems to capture climate-driven ecosystem changes and assess the reliability of regional climate-ecosystem models.

The working group on Integrated Ecosystem Assessment (IEA) addressed ways that the CINAR academic partners and NOAA partners could work in concert to advance relevant indicators and model development. The discussion topics included the current status and future development

of IEAs, identification of current observational gaps and how CINAR partnerships might be developed to fill them, potential applications of new technologies for observing and modeling, challenges that must be met to exploit untapped datasets, and needs for new partnerships to advance collaborative research. A roadmap for CINAR-sponsored progress emerged, with discussions highlighting particular topics that should receive attention within future working groups, as well as some other areas where CINAR should place high priority:

- Promotion of CINAR as a vehicle to facilitate partnership development
- Enhancement of CINAR-sponsored graduate student and post doctoral training opportunities
- Establishment of a forum for discussion/exploration of candidate indicators (or refined indicators)
- Creation of a process to identify new indicators, with corresponding reference points for application in the IEA
- Identification of IEA indicators that relate drivers to states, and need for new research to understand the processes involved
- Identification, prioritization, quality control, and accessibility of existing data sets in support of Integrated Ecological Assessment
- Need for new research to constrain important model parameters (e.g., species specific fish consumption rates) and their uncertainties
- Need for socioeconomic information to understand anthropogenic drivers that impact resources
- Need to understand ecosystem impacts of non living resource exploitation
- Need to understand and properly measure “reference points” (values at which major ecosystem or component species shifts are predicted)
- Need for time series observations of nutrients, pH, oxygen and zooplankton
- Need for information on undersampled species (e.g., euphausiids, gelatinous zooplankton)
- Development of new observing technologies, new modeling techniques, and approaches for linking stationary sentinel station time series with mobile observing systems

The workshop concluded with a crosscutting discussion that led to the recommendation for the formation of seven on-going working groups to advance research on climate and ecosystems:

- NW Atlantic Climate Impacts Assessment Expert Group
- Connecting Regional Climate Projections to Living Marine Resource Assessments
- Retrospective Analysis for Forcing and Reference Data Sets
- Regional Physical-Biological Modeling
- Application of Acoustic Data to Ecosystem Monitoring
- Application of Optical and Imaging Data to Ecosystem Monitoring
- Recruitment Processes and Dynamics

The need to understand and predict the impacts of climate change cuts across NOAA's mission. At present, NOAA's climate modeling work provides the capability to make predictions about changes across broad spatial scales. Developing the capacity to predict changes at a regional scale and to extend the predictions of physical change to estimates of ecosystem response is a major challenge. It will require high resolution models of both physics and biology, sustained observations of processes in the region, and additional targeted studies on specific processes as well as evaluation of new modeling and observing technology. NOAA is charged as well with leadership in the development of Integrated Ecosystem Assessments (IEAs), an ongoing process that provides multidisciplinary ecosystem analysis, including identification and interpretation of climate-forced impacts, for incorporation into management decision-making. The effectiveness of the IEA depends on the development and interpretation of a set of crucial indicators that capture the ecosystem state and its responses to change. To be successful, both regional climate modeling and assessment of ecosystem impacts will require pooling of resources both within and outside of NOAA. The CINAR institutions have world-class capabilities in these areas as well as a strong track-record of collaboration, both among the institutions and with NOAA scientists. This workshop takes concrete steps toward development of cooperative partnerships to achieve effective regional management responses to the challenges imposed by global environmental change.

Working Group A Report: Forecasting the Impact of Climate Change on Primary and Secondary Production in the CINAR Region

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NOAA's Cooperative Institute concept is to connect the agency's critical management questions and gaps to the talents of our academic research partners. The Cooperative Institute for North Atlantic Research (CINAR) was awarded to a consortium of institutions allowing NOAA the opportunity to partner with lead researchers to fill critical gaps in the understanding of regional-scale climate and ecosystem issues. CINAR workshops were held in FY11 to identify specific projects that address the critical gap in the link between climate and ecosystem management.

NOAA has relationships with key regional stakeholders who are demanding climate predictions and projections at relevant temporal and spatial scales. At the same time, NOAA's fisheries management responsibilities require an understanding of the coupled physical and biological system to make predictions of the health of regional ecosystems. These articulated needs have highlighted critical gaps in our regional-scale understanding of the physical climate system and its links to biological indicators for ecosystem change. CINAR investigators are well-positioned to address this gap. Researchers at the University of Maine (UMaine), the Gulf of Maine Research Institute (GMRI), the Woods Hole Oceanographic Institution (WHOI), Rutgers University (Rutgers), and the University of Maryland-Center for Environmental Studies (UMCES) are leaders in coastal ocean modeling, moored climate observations, and observational oceanographic measurements of key indicators needed to link existing data to a regional-scale climate model. Research on climate-ecosystem connections in the NW Atlantic, which presents special challenges due to its complex oceanography and productive ecosystems, would also provide valuable feedback to the global modeling community and would develop techniques and concepts applicable to other regions.

The physical processes and biological dynamics in the Northeast Shelf Large Marine Ecosystem have been characterized by NOAA's long-term monitoring programs and by intensive research programs such as GLOBEC and EcoHAB. These studies have revealed several important mechanisms that determine interannual and interdecadal variability in this regional ecosystem. Understanding these mechanisms contributes to identification of processes and indicator variables that must be monitored and modeled in order to understand how the region will respond to future climate variability and change.

The region is under the influence of multiple environmental forcing functions that will change and interact under future climate change scenarios. Temperature strongly influences both the physical conditions in the region by setting up the large scale circulation and species distribution and abundance through the influence of temperature on biological rates. Changes in salinity have also been linked to ecosystem changes in this region. Both temperature and salinity are strongly influenced by large scale circulation. Notably, the Gulf Stream brings warm, salty water into the region while the southward flowing shelf current brings colder and fresher water from the Canadian Shelf. Heat flux and freshwater input from within the shelf-region is as also important. Local heating and cooling controls the annual cycle of mixing and contributes to the recent warming trend. Freshwater input from rivers is an important driver of the coastal current and estuarine dynamics. Mixing from winds and the strong tides in the region also determines both the vertical distribution of physical and chemical properties and contributes to the general circulation.

Both local and remote forcing has been linked to ecosystem change within the region. During the 1990s, the water flowing down the shelf increased. This lowered the salinity throughout the region and led to increased vertical stratification (Mountain 2003, 2004) and changes in nutrient concentrations and ratios (Townsend et al. 2010). The changes in stratification have been led to changes in spring bloom timing (e.g., Ji et al., 2008), increased fall phytoplankton abundance(Greene & Pershing 2007), a shift towards a plankton community dominated by smaller phytoplankton and zooplankton (Pershing et al. 2005, Kane 2007, Ecosystem Assessment Program 2009), and changes in the recruitment of larval cod and haddock (Mountain & Kane 2010). The recent warming in the region has led to a general northward shift of fish species (Nye et al. 2010).

From global climate dynamics to change in the NW Atlantic

Climate model simulations contributed to the assessment reports of the IPCC are a primary means of analyzing climate dynamics and making projections of future century-scale climate change, while inter-annual to decadal projections are under development. The utility of these models for studying climate impacts on regional ecosystems, however, is hampered by coarse resolution, regional-scale model biases, and limited ability to include region-specific physical and ecological detail in global-scale runs (Stock et al., 2011). While continued climate model development should ameliorate some of these limitations over time, there is a need to translate large-scale physical and biogeochemical changes projected by climate models to the CINAR region.

A variety of techniques are available for accomplishing this "downscaling". These fall into two major categories: statistical and dynamical. Both have distinct advantages and both should be enlisted to produce ensemble regional-scale projections of climate impacts on ecosystems in the CINAR region. Statistical downscaling entails the development of empirical relationships between large-scale dynamics resolved by climate models and regional manifestations of these broad-scale patterns. The main advantage of these approaches is the relatively low computational cost. Disadvantages include the necessity of assuming stationarity in the empirical relationships and difficulty in selecting effective large-scale predictors. Dynamical downscaling, which involves nesting regional high-resolution models within a global simulation, has the advantage of relying on fundamental physical and ecological principles. Disadvantages include higher computational costs and devising strategies to translate coarse resolution information into suitable modifications of the regional model boundary conditions. Developing these downscaling approaches is both a scientific and technical challenge that will require collaborative global- and regional-scale expertise with NOAA and CINAR partners. A synthetic, mechanistic understanding of major climate-driven changes over the North Atlantic basin is an essential starting point for devising robust statistical and dynamical downscaling strategies for climate projections. Global models biases at regional-scales may prevent routine extraction of boundary conditions from global climate models for this purpose and make more sophisticated (e.g., feature-based) approaches necessary. It may also be necessary to connect these model investigations with observational process studies aimed at elucidating linkages between basin- and coastal-scales. Both one-way and two-way dynamical downscaling should be considered. One-way downscaling entails passing information only from the global-scale to the regional-scale. This has the advantage of decoupling regional simulations from the global. The global simulation does not have to be re-run to carry out the regional simulation and one can rely on archived IPCC output. This offers substantial computational and scientific efficiencies for regional climate impacts problems. Two-way nesting, where information passes in both directions, offers the potential of fully-integrated regional/global simulations and may ameliorate inconsistencies between regional and global simulations. However, it introduces significant computational and scientific costs. Climate projections emerging from two-way downscaling will be different than those archived in the IPCC. The relative advantages and disadvantages of this approach for regional climate impacts on ecosystems require further study.

An ensemble of downscaled projections is essential for assessing uncertainty and feeding into management frameworks. This ensemble should consider different downscaling techniques, differences in global climate models, and differences in regional models. While ensemble approaches are critical for many potential applications in the CINAR, detailed diagnosis of individual models is also essential for elucidating mechanisms.

Requirements for a climate-ecosystem modeling framework for the CINAR region

The CINAR region covers the Gulf of Maine (GM) and Middle Atlantic Bight (MAB). The regional oceanography is affected by a diverse array of oceanographic features and processes including the Gulf Stream, winds/air-sea heat exchanges, river runoff, tides, and northern boundary inflow of the Labrador Coastal Current. The Gulf Stream, a western boundary current along the east coast of the United States, separates from the shelf at Cape Hatteras, flowing offshore into the North Atlantic Ocean. The region between the Gulf Stream and the MAB shelf is the "Slope Sea" with a permanent shelf/slope front separating the two regions. The strength and location of the Gulf Steam and attending mesoscale eddies vary interannually and directly affect biological productivity in the CINAR region. While the Gulf Stream forms the offshore boundary, the equatorward Labrador Coastal Current flows into the region and extends to Cape Hatteras. Variation in the volume transported by the Labrador Coastal Current has been linked to changes in hydrographic properties in GM/MAB and to changes in plankton community structure.

Models have been developed for the U.S East Coast, including subregional models for the Gulf of Maine, Chesapeake Bay etc. and regional-scale models such as the NENA (Northeast North Atlantic) model. However, none of these models were specifically designed to address the impacts of climate change/variability on the marine ecosystem productivity in the MAB and GM region. The CINAR work group recommends the development of CINAR regional climate-planktonic ecosystem models. To resolve the interactions between climate and the physical/ecosystem dynamics of the CINAR region, it is important that these models can capture/resolve changes in the following key quantities and processes over seasonal to multi-decadal time-scales: stratification, temperature, fresh water supply (both local river inputs and remote source from Labrador Coastal Current), shelf-scale circulation and transport, nutrient, oxygen and plankton dynamics, carbon cycling and ocean acidification, and trophic interactions. Water-column stratification is a key factor in determining the ocean's primary productivity and has been shown to vary with changing climatic conditions. Temperature increase due to warming affects the thermal habitat for many fish species while nutrient inputs from land drainage and oceanic sources affect primary productivity. Ocean acidification will also affect the community structure of the regional marine ecosystems and needs to be considered in future research and modeling.

Several hydrodynamic models are available for use in the CINAR region, including POM, ROMS, FVCOM, GFDL-CM2.5 (high-resolution), CCSM- ROMS two-way coupling for the NWA, and ROFS-NOAA HYCOM at 1/12° resolution. Additional high-resolution global climate models are also under development and should be available following IPCC-AR5. We recommend the development of multiple hydrodynamic models for the CINAR region since the ensemble model simulations can help quantify uncertainties, elucidate the mechanisms underlying inter-model differences, and the ensemble mean may provide a better estimate of past and future climate states (though this must be evaluated on a case-by-case basis). Moreover, the CINAR investigators have extensive expertise in using these different models and are experts in simulating a wide array of physical processes in the MAB/GM subregions.

There are a few key physical processes which are critical in biological production and will be affected by climate change/variability. In many coarse resolution global circulation models used for climate projections, the Gulf Stream separates from the U.S. East Coast at latitudes higher than the observations, leading to temperature overprediction on the northwest of the Atlantic Ocean. The CINAR models must produce more accurate predictions of Gulf Stream separation. Cross-shelf exchange occurs along the entire shelf edge through the meandering of the shelf-break front, and is at times modulated by warm-core-ring interactions and intrusions of slopewater along the seasonal thermocline. Nutrient fluxes across the shelf break front are an important process to resolve in the numerical models. Rivers and Laborador Coastal Current are important sources of freshwater and nutrients. The CINAR models need to accurately simulate the impact freshwater inputs including the mean discharge as well as the timing of peak discharges. Tidal mixing and rectification are important processes affecting productivity in George's Bank. Fine resolution (~2-5 km) will be needed to resolve the tidal processes. Wind mixing is a key determinant of the seasonal cycle of the ocean mixed layer and primary productivity while wind-driven circulation is an important component of the circulation dynamics in MAB/GM. Several wind products are available to force the CINAR models, including satellite measurements, reanalyses (e.g. NARR), and operational models (e.g. NAM). As we focus on fine-scale processes and model resolution is refined, high resolution bathymetry data and information on bottom roughness will be needed. In general, the model l would optimally resolve the Rossby radius of deformation (~5 km). Different resolutions will be needed for different questions, for example, regionally specific questions in estuaries and embayments will require higher resolutions. Unstructured-grid models such as FVCOM are well suited for

adapting resolutions to different regions while structured-grid models such as ROMS are developing new capability such as multiple-domain decomposition or conformal mapping techniques.
For the biogeochemical model, we recommend a size-structured model consisting of multiple nutrient pools (NO3, NH4, Si, P and Fe), 3 groups of phytoplankton classes (diatom, dinoflagellates and pico-size phytoplankton), and 2-3 groups of zooplankton (micro-zooplankton, small and large mesozooplankton). The main reason for having two size groups for mesozooplankton is that there is significant decadal variability in zooplankton species composition in our system. The biogeochemical model should also simulate benthic-pelagic coupling, especially denitrification on the shelf and estuaries. We also suggest simulating carbon cycling and examining the impacts of ocean acidification. Furthermore, this model would need to simulate oxygen dynamics in order to study the impacts of hypoxia. We suggest a "nesting" approach wherein a "general" biological model configuration on the shelf scale will be combined with higher biological resolution (question dependent) for specific systems and species. For example, adding population dynamics for individual species along with the "general" model. We also suggest a Rhomboid approach, that is, focus on targeted trophic level and biological components. We recognize the need to distinguish chlorophyll from biomass (carbon) and account for light and nutrient dependent chl-a/C ratio (e.g. Geider model). When constructing the biogeochemical model, we must balance the considerations of complexity versus uncertainty: increasing complexity will decrease bias but may also increase uncertainty and variance in the model. Data for some of the model components are missing, although some parameterization can (and needs to) be done by using information from other systems (e.g., microzooplankton).

Climate observations

Observations are critical to developing physical and biological climate projections. First and foremost, data are used to develop climatologies of past climate (e.g., temperature, precipitation, sea level, primary productivity, population abundance and distribution, etc.). These climatologies are used for validating, parameterizing and initializing climate-ecosystem models. Ongoing observations are also crucial for the iterative evaluation of climate-ecosystem models into the future. Finally, process-oriented observations are necessary to understand the mechanisms and test hypotheses of the linkages between climate, ecosystem, and living marine resources.

Maintaining current levels of observation is crucial to developing regional climate projections as is obtaining new observations that fill important gaps be they specific parameters or specific scales of variability. Ongoing observations include global (e.g., GOOS, satellites), regional (e.g., IOOS, NMFS), and local (e.g., CBOS, MVCO) observations, as well as physical (e.g., T, S), chemical (e.g. N, C) and biological (e.g. P, Z, LMR) elements of the system. Current observations are made by an array of platforms, programs, organizations, and investigators and a crucial ongoing need is to develop cyberinfrastructure to enhance data interoperability across these observational resources.

Important observational gaps include processes operating at smaller spatial and temporal scales (e.g., timing of the initiation and breakdown of stratification), boundary fluxes (e.g., heat flux, Gulf Stream dynamics, Labrador Current inflow), more detailed information on nutrients (N, P, Si, Fe), oxygen (O) and carbonate chemistry (CO_2, DIC, pH, TAlk), more information on lower (e.g., bacteria, microzooplanton, phytoplankton, zooplankton) and intermediate (e.g., macrozooplankton, mesopelagic fishes, gelatinous zooplankton) trophic levels, and a broader understanding and parameterization of vital rates especially for higher trophic levels. Filling these gaps will in part contribute to different needs (i.e., climate models, integrated ecosystem assessments, single species stock assessments), but will also contribute to a more holistic program supporting climate-ecosystem assessments.

The NOAA-CINAR cooperation can make four important contributions to the observational needs in support of climate-ecosystem assessments. First, observational resources must be identified, prioritized and optimized. The current workshop identified important observational needs (both current and future); a formal catalog of current observing resources must be developed and then current and future observations must be prioritized relative to the specific models that will be used to support regional climate and ecosystem assessments. Once the needs have been prioritized, an optimal plan for collecting the required observations can be designed using a formal process (e.g., Observing Systems Simulation Experiments). Second, from the priority list of observational needs, the requirements for new sensors and technologies will be clear. Focused efforts on the new technologies can then begin in earnest in cooperation with other efforts (e.g., OOI, ASTWG), with workgroups forming around each sensor type and or observational need. Third, a formal hindcast/reanalysis needs to be developed that integrates models and observations similar to atmospheric reanalyses. This reanalysis would include an ensemble of physical models working over the CINAR region using a common set of boundary forcing. Additionally, this reanalysis will provide a community resource for examining climate-ecosystem linkages and form the basis for ecosystem level climatologies. Evaluation of climate-ecosystem models against extensive data will also be essential to establishing the credibility of model forecasts and projections. Fourth, a specific plan needs to be developed for process-oriented research to support the climate-ecosystem modeling and assessments. This plan will allow specific process-oriented research conducted into the region to be integrated into a larger regional effort in support of ecosystem-climate assessments.

Moving forward in climate-ecosystem research

Above, we presented a community vision for how to advance research on climate-ecosystem interactions within the CINAR region. This vision consists of a series of high priority projects and observations as well as model requirements. In the near term, we propose to build momentum on specific areas through a series of working group activities (see Section 3).

Working Group B Report: Models and Ecosystem Indicators for Integrated Ecosystem Assessment

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The status and future development of IEAs and ecological indicators for the NE region

The Integrated Ecosystem Assessment (IEA) is a formal structure for incorporating multidisciplinary ecosystem analysis into the management process (Murawski et al. 2008; Levin et al. 2009). IEAs integrate across taxa, processes, sectors, and scientific disciplines within an ecosystem, which for purposes of the assessment is end-to end in scope, including physical forcing, all trophic levels and human activity. The information about the cumulative impacts of human activities and environmental forcing on marine ecosystems is evaluated with respect to particular reference points that inform what management actions need to be taken. With respect to fisheries objectives, these management actions are typically directed to controlling fishing effort. However, the IEA is a product, a process, and a tool providing ecosystem information not only for fisheries management, but also for decisions across ocean use sectors to best manage among tradeoffs. The consequences of management actions are then monitored in the ecosystem to provide feedback for further management actions.

Regional IEAs are mandated by the National Ocean Policy, and implemented through the recently formed National Ocean Council. It is uncertain how pre-existing regional ocean councils (for example the Northeast and Mid Atlantic Regional Ocean Councils) will be involved with IEAs. NOAA is charged with the lead in IEA development, but will have to consult with many other government agencies. While the IEA will not be conducted at the level of the Fisheries Management Councils, the Councils want to make sure that fisheries' interests are represented in IEA, and are they are now requesting ecosystem information through the IEA.

The present status of IEA development in the Northeast region is represented by the NEFSC EcoAP Ecosystem Status Report (ESR: http://www.nefsc.noaa.gov/ecosys). The current time frame for development of a comprehensive IEA in the Northeast Region is 3-5 years, pending budget constraints. Ecosystem based fisheries management (EBFM) is being developed to ensure that fisheries are represented in the IEA and in Coastal and Marine Spatial Planning (CMSP).

The effectiveness of the IEA depends on the development of a set of critical indicators that capture the ecosystem state and its responses to change. From a suite of over 80 variables, NEFSC determined a set of indicators representing climate and human drivers, pressures on the physical system (e.g., temperature change) resulting from climate drivers, pressures resulting from human activities (e.g., fishing effort and catch), ecosystem state (e.g., phytoplankton and zooplankton biomass indices, and a suite of indicators of living marine resources) and impacts (e.g., amount and value of catch). Currently, most indicators can be directly measured, with some developed as model derived (e.g., primary production required to sustain specified levels of fishing).

Indicators will be different for each region but similar in nature. The present ESR comprises the Northeast Large Marine Ecosystem region, but needs to be stepped down to spatial production units. Work at NOAA has identified 7 eco-regions, but some will be merged and used as special areas of consideration (e.g., shelf break), leaving 4 regions. Indicators need to be flexible enough to provide relevant information for each area.

While many of the indicators in the IEA integrate across species, it is recognized that species, especially at the zooplankton and higher trophic level, may be keystone components of the ecosystem or may not have functional redundancy, and are therefore important to monitor. The IEA is not intended to ignore this kind of relevant detail, but rather consolidate functional redundancy in the system. Therefore, selected keystone species are still identified and reviewed. Other "canary" or ecologically important species could be included, with the caveat that too many will render the indicator list unwieldy.

NOAA has a working list of indicators for the Northeast IEA. The current focus is on developing quantitative relationships among indicators and state variables to establish indicator-based reference points. Management Strategy Evaluations would assess ecosystem state on the basis of indicators, similar to a formal stock assessment. It would be conducted every 3-5 years and if pre-determined levels are breached there would be appropriate management actions in place.

There are many other possible indicators that could be derived from climate/physical, biogeochemical/ecological, fisheries/higher trophic level, larval transport, and human impacts models. However, there are large differences in the "skill" and usefulness of these models, and this needs to be assessed. "Useful" models need to be identified. Operating models have to have their outputs vetted and reviewed in the context of living marine resource management. There are also large differences in the complexity of these models. More complex models are most useful in scenario testing (i.e., what happens to indicators when climate changes? What is the effect on indicators of various management strategies?). The types of models currently applied in NOAA (NEFSC/NMFS) to support indicator and IEA development include primary production, multi-species models, aggregate models, MSVPA, Ecopath with Ecosim, Econetwork, and ATLANTIS (sunlight to fisheries market). There are also indicators and IEA measures that are difficult or impossible to observe, but which can be predicted by models. For example, a particle-tracking circulation model can be used to determine 'advective mortality' as separate from other types of mortality on larval fish/eggs. Through data assimilation, models can also be used to estimate indicators, for example vital rates, that cannot be directly measured.

Models can potentially hindcast, nowcast, and forecast indicators and IEA measures. Operating models can be used within a "Management Strategy Evaluation Framework" for decision support to forecast, for example, climate change, fishing scenarios, etc., and associated effects on indicators and to evaluate which management tools are robust. Hindcasts can be used to go back and answer 'what went wrong?' when a forecast fails. And models can be used to determine 'tipping points' from indicators, i.e., identification of non-linear relationships and/or step-functions. Empirical models can be used to identify thresholds; operating models can inform whether some combination of management or climate change will result in crossing a threshold.

Ensemble modeling approaches can be useful for testing which models work better and why. They can also be used to combine/average model outputs and determine uncertainty of projections, as in the IPCC assessments. Ensemble modeling approaches need to be developed for IEAs. Another similar approach is to assume that there is no one 'right' model and use a range of models along a spectrum of complexity to see if they produce similar trends. Reanalysis products can be used to provide retrospective context for atmospheric and physical conditions that may have contributed to past observed changes in indicators and IEA measures.

At present, there is no formal way to examine and vett new indicators. Ecosystem advisories would be a good starting place, rather than directly instituting reference points. A proposed indicator could be evaluated to determine whether it captured significant information, at which point it could be recommended for use as a reference point. However, there would need to be stakeholder involvement and public hearings for transparency.

Recommendations for CINAR activities on indicator development

Indicators should be made available to the scientific community to facilitate research on indicator development, mechanistic understanding, and application of indicators in predictive models. A link to the Ecology of the Northeast website (http://www.nefsc.noaa.gov/ecosys/ecology/index.html) has been added to the CINAR website.

Several potential projects for development within CINAR include 1) creation of a forum for NOAA/CINAR for discussion/exploration of candidate indicators (or refined indicators), 2) creation of a process to identify new indicators with corresponding reference points for application in the IEA, and 3) identification of IEA indicators that relate drivers to states and conducting research to understand the processes involved.

What are the current observational gaps? How can CINAR partners help fill them?

A number of observational gaps were identified that should be addressed in the context of CINAR-led contributions to the development of IEAs. Discussion of these gaps can provide guidance and motivation for cooperative projects with NOAA and CINAR partner institutions.

- ***Process-oriented studies*** -The development of mechanistic ecosystem models relies heavily on the understanding of the vital rates of organisms that drive biological and ecological processes. Empirical relationships among biological vital rates and environmental forcing are not well described for many species. Specific gaps include species-specific fish consumption, production, and trophic transfer efficiencies, and the variability in those rates across species ranges and through time.

- ***Uncertainty estimates in the available data -*** Quantification of uncertainty in the observations used to validate and parameterize models and IEAs is crucial to understand the impact of drivers of ecosystem processes and thus for the development of robust indicators for IEAs. Further, describing uncertainty at appropriate scales for each data type is fundamental.

- ***Socio-Economic Data*** - Understanding the anthropogenic effects on ecosystems requires a comprehensive look at the socio-economic drivers that impact resources. These data, including census data on the number of fishermen in the CINAR region and their satisfaction, is not widely available, except in certain spatially and temporally restricted cases, and must be addressed.

- ***Non-fishery issues and impacts*** - Marine-spatial planning is an ongoing process, and within the CINAR region, non-living marine resource exploitation, specifically energy development, may have large ecosystem and socio-economic impacts. These impacts may arise rapidly and will have to be included to fully understand ecosystem functioning and develop robust IEAs.

- ***Refining reference points -*** The specific thresholds and "tipping-points" for ecosystem components and processes are not well understood, but are crucial to ecosystem management and prediction. Further, the relationship of tipping points to climate variability is imperative to the development of robust indicators.
- ***Nutrients, Silica, pH and Oxygen*** - Interactions between ecosystem components and climate change may directly affect nutrient inputs, utilization, and source/sink dynamics. Anthropogenic pressures may confound predicted changes, highlighting the need for more measurements of key limiting and driving nutrients.

- ***Undersampled Species -*** Current biological sampling programs are not efficiently sampling certain taxonomic groups that are important either throughout the CINAR region or in specific sub-regions. These include gelatinous zooplankton, euphausiids, seabirds, mesopelagic fish, and epibenthic invertebrates.

Application of new technologies for observation and modeling

A broad spectrum of new and emerging technologies are now available that can address a number of critical data gaps. These systems can also provide complementary measurement systems to existing sampling methods and technologies and serve as a bridge to the future of ocean measurement. Many advances capitalize on integration of new instrument packages with both new and traditional research platforms, including both stationary (e.g., coastal observatories, next-generation moored arrays) and mobile systems (e.g., autonomous underwater vehicles, ships).

Types of operational instrumentation include optical, acoustic, and biochemical packages that can be deployed on both stationary and mobile platforms. Optical systems on towed bodies and moored systems are now used to characterize ecosystem components from plankton to nekton and epibenthos. These should be used to meet identified data gaps for monitoring micronekton, gelatinous zooplankton, and commercially and ecological important benthic organisms. Camera systems on both commercial ships and research vessels have been used to monitor some sea-bird populations and address issues such as incidental catch of protected species on commercial vessels. High frequency radar systems associated with stationary towers can be used to monitor seabird population systems. Passive acoustic systems are now being used to monitoring fish and marine mammal populations.

Acoustic systems can also be deployed on both stationary and mobile platforms and can be used to map distributions of some species of fish and zooplankton for which calibrated target strength estimates are available. Multibeam acoustic systems can also be used to characterize size spectra of planktonic organisms, and acoustic Doppler profiling systems are now routinely used for oceanographic measurements.

Chemical sensors are emerging for characterizing nutrient, oxygen, and pH, concentrations in synoptic sampling programs. Into the future, biochemical and molecular sensing systems also hold considerable promise for measurement such as condition of individual organisms, characterization of genomes, proteomes and other physiological, ecological and evolutionary factors.

A major challenge in adopting new technologies is the requirement for effective approaches to process and interpret large data sets. Optical, acoustic, and molecular datasets are often very large, require careful calibration, and often provide proxies that are only indirectly related (often in complex ways) to the properties of ultimate ecological interest (e.g., fish biomass, plankton diversity). These methods are rapidly advancing within specific academic groups.

Finally, it was noted that important synergies are possible by linking stationary and mobile sampling systems. The detailed characterization of conditions at point locations through observatories or selected 'sentinel sites', in some cases continuously, can be nested within broader-scale synoptic surveys conducted at coarser time scales. These synoptic surveys can potentially provide a broader context for interpretation of the higher resolution observations.

Are there untapped datasets or retrospective analyses that need attention?

There is a need to increase the spatial and temporal coverage of data products in order to 1) test the robustness of current indicators and 2) to examine the temporal and spatial extent of event-scale anomalies. There are numerous underutilized and historical datasets for the CINAR region that could be used to retrospectively analyze events and that can be incorporated into models that improve our understanding of variability within the system. There are, however, questions and concerns about bringing such data together into a common system, in addition to the reliability of the historical data.

There are several estuarine and near coastal datasets and time series (e.g., Chesapeake Bay Program, Narragansett Bay phytoplankton and fish trawl time series, the Massachusetts Bay Program) that could be used to extend the spatial coverage of CINAR into estuaries. These valuable datasets are being used to study impacts of regional scale processes. CINAR could re-use these datasets to examine the connectivity between the nearshore and shelf ecosystems. In addition to the near shore environment, the three open boundaries (Scotian Shelf, Slope Sea and Southern Atlantic Bight) should also be considered to understand better the boundary forcing conditions that influence the CINAR region.

Other untapped datasets range from historical data collected in the Gulf of Maine during the early 1900s to new ocean color satellite data from the European Space Agency sensor MERIS. Use of these datasets are currently limited by lack of resources to catalog, compile and possibly digitize historical data, and enable ready access. It is important to develop an inventory of available data and then to prioritize data needs on the basis of intended uses. It will also be valuable to create higher level data products from the raw data to enable use by a broader base of users.

One highlighted project that requires these additional datasets would be an effort to spatially and temporally extend the Green and Pershing (2007) analysis of regime shift in the Northwest Atlantic. Questions persist about whether this shift was a one-time event or part of the long term cycle in the system. Historical data would make it possible to evaluate which forcing variables lead to changes in biological communities, and whether those relationships have been consistent over time.

There is a strong need for tools that simplify the discovery and ranking of candidate datasets once criteria are established from needs expressed in specific use-cases. Ideally, such tools would help generate a ranked inventory of datasets from sources such as the IOOS, internal NOAA systems, BCO-DMO, and the other NSF funded sources. Work with groups within NOAA that are already creating metadata warehouses to establish improved dataset interoperability will enable simplified discovery, access, and use of NOAA and other data. Additional effort will be required to develop criteria and approaches to quality control data from a range of sources. CINAR can help with the coordination of this and similar data-related efforts to reduce replication of efforts.

Retrospective analyses are important to test the robustness of indicators. If current indicators are not proven valid with historical data, then they may not be effective under climate change scenarios. In addition, these analyzes can be used to identify historical, current, and possible future critical habitats and biodiversity hot spots. Furthermore, as coastal and marine spatial planning efforts continue, it will be important to consider historical patterns of temporal/spatial variability in habitats and indicators.

What new partnerships and projects and partnerships should be encouraged?

Partnerships can and should be developed between other national and regional agencies and organizations and CINAR investigators to leverage strengths, expertise and resources. The CINAR partnership between academic institutions and NOAA provides access to numerous research assets including 1) data/research opportunities on ships, 2) physical, chemical and biological oceanography expertise, 3) instrumentation development and new technologies and innovations, 4) data analysis, storage, interoperability support, 5) social sciences expertise, and 6) ongoing process-oriented research. These assets can both contribute to and leverage the resources and activities of many other national and regional organizations that carry out research and monitoring activities in the CINAR region. The following list identifies several of these organizations, including some within some specific NOAA laboratories, and how they might partner with CINAR.

- OOI and IOOS – Provide observations and models in a more operational context that can be leveraged by CINAR investigators and support both climate research and IEA development.
- NASA – Provide satellite data and products.
- NOAA/GFDL – Integrating climate projections with regional climate-ecosystem modeling frameworks, assist in development of downscaling approaches, improving the representation of coastal and shelf-scale processes in global climate models.
- NOAA/CSDL Chesapeake Bay – Implementation of an operational ROMS-based system (CBOFS2) that can be leveraged for biogeochemical and ecological forecasting.
- USGS Gulf of Maine – Potential to provide regional models.
- EPA/Chesapeake Bay Program – Access to a suite of water quality indicators and large monitoring data and model resources.
- NROC (Northeast Regional Ocean Council) – Coordination for ocean issues with focus on coastal marine planning and wind farms.
- State Agency Indicator Programs – Virtually all states within the CINAR region have Departments of the Environment, Natural Resources, etc., that carry out monitoring and management of natural resources.
- MOP (Massachusetts Ocean Partnership) and COMPASS (Communication Partnership for Science and the Sea) – Development of coastal indicator programs.
- NEARCOOS and MACOORA – The regional coastal observing associations are working toward developing observing systems and data portals.

In addition to direct research activities, these potential partnerships could lead to the development of a model for providing educational opportunities and training. Academic units within CINAR provide a broad range of graduate education opportunities and capacity building for quantitatively trained scientists, some of whom might be recruited into NOAA and other partner agencies. There are also opportunities for postdoctoral research that can develop a cadre of trained researchers (e.g., PACE, run by UCAR but funded by NOAA) experienced with state of the art observing and modeling technologies relevant to NOAA and other partner agencies.

As detailed in previous sections, research conducted by CINAR partners could be the basis for identifying new or improving existing indicators for regional IEAs. Working with NOAA and other partner agencies, CINAR should create a process through which research can be used to identify, define and evaluate new indicators or improve existing indicators for use in IEAs. New sampling technologies could provide information on the distribution and abundance of important components of the ecosystem that are currently difficult to sample adequately. Specific partnerships between NOAA and CINAR scientists should be formed to lead demonstration projects for specific technologies to evaluate their potential for operational use.

Retrospective data analysis and complementary retrospective modeling could provide important insight into the long term robustness of indicators currently used or of new candidate indicators – if an indicator is not be effective in the reconstructed past, it is unlikely to be a reliable indicator of the future. An initial, specific example is the decadal shift (1980s to 1990s) in hydrography, plankton community structure and early life survival of cod and haddock identified through the GLOBEC program, which may contain the basis for indicators relating environmental change to change in important fishery resources. Partnerships should be formed to evaluate existing data sets and investigate apparent relationships in the decades before the GLOBEC studies.

Moving forward in IEA relevant research

The discussions within the working group on models and indicators to support an IEA for the CINAR region were optimistic about the potential for new progress through enhanced interaction between CINAR academic partners and NOAA scientists and managers. The roadmap for progress that is outlined above includes gap filling through data mining and historical analyses, enhanced transfer of new observing and modeling technologies, and a broad range of partnerships with foci spanning from process studies to public outreach.

As a next step along this path, a strong and cross-cutting recommendation emerged for a series of working group activities to initiate partnerships, foster dialog, and jump start progress in specific areas (see Section 3). The discussions highlighted particular topics that should receive attention within these working groups, as well as some other areas where CINAR should place high priority:

- Promotion of CINAR as a vehicle to facilitate partnership development
- Enhancement of CINAR-sponsored graduate student and post doctoral training opportunities

- Establishment of a forum for discussion/exploration of candidate indicators (or refined indicators)
- Creation of a process to identify new indicators, with corresponding reference points for application in the IEA
- Identification of IEA indicators that relate drivers to states, and need for new research to understand the processes involved
- Identification, prioritization, quality control, and accessibility of existing data sets in support of Integrated Ecological Assessment
- Need for research to constrain important model parameters (e.g., species specific fish consumption rates) and their uncertainties
- Need for socioeconomic information to understand anthropogenic drivers that impact resources
- Need to understand ecosystem impacts of non living resource exploitation
- Need to understand and properly measure “reference points” (values at which major ecosystem or component species shifts are predicted)
- Need for time series observations of nutrients, pH, oxygen and zooplankton
- Need for information on undersampled species (e.g., euphausids, gelatinous zooplankton)
- Development of new observing technologies, new modeling techniques, and approaches for linking stationary sentinel station time series with mobile observing systems

Recommended CINAR Working Groups

The CINAR Workshop on Climate and Ecosystem Change in the NW Atlantic concluded with a plenary discussion of cross-cutting recommendations. The current workshop was viewed as an important initial step in outlining a vision for CINAR’s role in science and management in the NW Atlantic, but the need for more substantive progress through focused dialog and activities was also emphasized. As such, there was broad support for the concept that CINAR should sponsor a series of standing working groups in target areas. Several candidate topics and project ideas were actively discussed (see subsections below).

NW Atlantic Climate Impacts Assessment

Updated IPCC-class climate model results will be available in 2011. Multiple groups in the CINAR region (e.g., NERACOOS, NESCAUM, NROC) have called for a regional interpretation of IPCC results. A working group is needed to evaluate the IPCC results and to estimate the response of the NW Atlantic and its embedded ecosystems to projected climate change. In addition, this effort would support NOAA's contribution to the next national climate impacts assessment by providing a perspective for the Northeast region. The working group will evaluate the representation of key regional processes, such as the position of the Gulf Stream, the magnitude of annual cycles of air and water temperature, the strength and direction of winds, in the climate models. The group will then consider how the annual cycles of heating, freshwater input (both local and remote), and mixing are expected to develop over the next century. From understandings of ecosystem responses to past changes, the group will estimate the biological changes in the region. The expert group's evaluation will provide a guide for more quantitative analysis, possibly by a dedicated postdoctoral researcher.

Connecting Regional Climate Projections to Living Marine Resource Assessments

Climate variability strongly impacts ecosystems and living marine resources within the CINAR region. Climate information, however, is often excluded in fisheries, protected species, and ecosystem-based management strategies. A diverse set of scientific and technical challenges contribute to this omission and this working group will identify these issues, devise strategies for more effective and explicit climate incorporation, and demonstrate application in the context of specific case studies.

Retrospective Analysis for Forcing and Reference Data Sets

Within the CINAR region there are a vast array of available data sets in disparate locations that would be useful for model parameterization and validation, specific retrospective analyses of ecosystem functioning, and development of indicators. This working group will be tasked with developing tools for retrospective analysis and data interoperability, to enhance the availability and usability of relevant data for the CINAR community.

Regional Physical-Biological Modeling

A working group is needed to promote interaction and exchange of information and expertise among the different modeling groups within NOAA and the CINAR academic institutions. Although the specific efforts of this working group will be self determined, some potential issues that might be addressed include assessment of regional modeling capabilities and gaps, assessment of the strengths and weaknesses of different modeling approaches, comparison of skill assessment methods, comparison of downscaling methods, and development of retrospective model runs for the CINAR region.

Application of Acoustic Data to Ecosystem Monitoring

In the northeast U.S. continental ecosystem, hydroacoustics are used primarily to monitor Atlantic herring abundance; however, the uses of acoustic data in ecosystem research and monitoring are much broader. This working group will identify potential applications, detail work plans for high priority applications, and develop a long-range vision for the use of acoustics as part of a broader regional ecosystem research and observing system.

Application of Optical and Imaging Data to Ecosystem Monitoring

There is untapped potential for optical technologies to provide observations at scales from individual planktonic organisms to ecosystem level remote sensing. There is increasing recognition that transition of in situ measurement techniques, including those for apparent and inherent optical properties and imaging at habitat and organism scales, to operational status could fill large observational gaps for ecosystem assessment and management in the CINAR region. A working group is needed to identify transition-ready applications, to explore emerging high potential technologies, and to advance methods for automated analysis of optical data to produce relevant products and indicators.

Recruitment Processes and Dynamics

Ecosystem properties have the most direct control on fish and shellfish during early life. Mortality of eggs and larvae integrates the effect of physical conditions (e.g., advective loss) as well as biological properties (e.g., abundance and size of zooplankton prey). Understanding the processes that influence recruitment variability will help derive indicators of ecosystem function for fish, identify the mechanisms by which interannual and climate variability affect recruitment dynamics, and help determine the connection between shelf and estuarine ecosystems for fish whose early life stages span these habitats. A working group is needed to integrate synthetic retrospective analyses and numerical modeling approaches to determine the factors that affect mortality during early life (from egg production to age 0 recruits). This effort will directly support the development of ecological indicators, as well as improved parameterization of individual based models of fish production for use in future climate change scenarios.

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Appendix 1: Workshop Agendas and Participant Lists

Workshop A: Forecasting the Impact of Climate Change on Primary and Secondary Production in the CINAR Region

Steering Committee
Andrew Pershing (UMaine/GMRI) Fei Chai (UMaine) Charles Stock (NOAA) Ellen Mecray (NOAA)

Confirmed Participants
NOAA*:* Elizabeth Turner, Roger Griffis, Antonietta Capotondi, Charles Stock, Ryan Rykaczewski, Jon Hare*, and Kenric Osgood
Rutgers*:* Enrique Curchister
UMaine*:* Huijie Xue, and Damian Brady
WHOI: Rubao Ji, Don Anderson*, Andrew Maffei*,
UMCES*:* Ming Li, Raleigh Hood*, and Elizabeth North **invited to both workshops*

Tuesday, March 1 *- The J. Erik Jonsson Center of the National Academy of Science*
9am -12:30pm - Plenary session with both workshops (Carriage House)
12:30pm -1:30pm - Lunch
1:30pm-5:30pm - Breakout meetings (Main House – Room 208)

- *Discussion* 1. What is the local manifestations and local/remote drivers of climate on the Northwest Atlantic Shelf? (lead: Pershing, rapporteur: Stock)
- *Discussion* 2. What observations are necessary to elucidate key climate/ecosystem connections?
(lead: Hare, rapporteur: Mecray)
- *Discussion* 3. What characteristics must models have to capture the mechanisms thought to be responsible for climate impacts on ecosystems on the NW Atlantic shelf? (lead: Chai, rapporteur: Ji)

5:30pm-6:30pm – Poster session / Reception (Main House)
6:30pm-8:00pm – Buffet Dinner

Wednesday, March 2 - *The J. Erik Jonsson Center of the National Academy of Science*
8:30am-9am - Coffee and pastries (Carriage House)
9am-12:30pm - Breakout meetings (Main House – Room 208)

- *Discussion* 4. What techniques can be used to incorporate global-scale information into NW Atlantic projections? (lead: Stock, rapporteur: Rykaczewski)
- *Discussion* 5. Discussion of a research plan for improving long-term forecasts. (lead: Mecray, rapporteur: Pershing)

12:30pm-1:30pm - Lunch
1:30pm-5:30pm - Present workshop summaries in plenary session. Discussion, moving forward.

Thursday, March 3 *- WHOI ~ Smith Conference Room*
8:15am - 8:30am- Coffee and pastries
8:30am -12Noon - Steering committee and volunteers meet to write workshop report

Workshop B: Models and Ecosystem Indicators for Integrated Ecosystem Assessment

Steering Committee

Jeffrey Runge (UMaine) Heidi Sosik (WHOI) Oscar Schofield (Rutgers) Michael Fogarty (NOAA)

Confirmed Participants

NOAA: Chris Chambers, Kevin Friedland, Robert Gamble, Jon Hare*, Kimberly Hyde, Jason Link, Sean Lucy, Stephanie Oakes, David Richardson
Rutgers: Kenneth Able, Olaf Jensen
WHOI: Don Anderson*, Jim Churchill, Andrew Maffei*, Dennis McGillicuddy, David Mountain, Gareth Lawson, Al Plueddemann, Jim Yoder
UMCES: Raleigh Hood*, Elizabeth North*, Jamie Pierson *invited to both workshops

Tuesday, March 1 - The J. Erik Jonsson Center of the National Academy of Science

9am -12:30pm - Plenary session with both workshops (Carriage House)
12:30pm -1:30pm - Lunch
1:30pm-5:30pm - Breakout meetings

- Discussion 1. What are the present state and plans for future development of IEAs and ecological indicators for the NE region? (Lead: Runge, Rapporteur: Link)
- Discussion 2. What are the current observational gaps? How can CINAR partners help fill them? (Lead: Fogarty, Rapporteur: Lawson)
- Discussion 3. What new observing technologies are available? What's ready for operational transition and where should development priorities be placed? (Lead: Sosik, Rapporteur: Schofield)

5:30pm-6:30pm – Poster session / Reception (Main House)
6:30pm-8:00pm – Buffet Dinner

Wednesday, March 2 - The J. Erik Jonsson Center of the National Academy of Science

8:30am-9am - Coffee and pastries (Carriage House)
9am-12:30pm - Breakout meetings

- Discussion 4. How can observations and models be linked in support of indicator and IEA development? (Lead: Hood, Rapporteur: McGillicuddy)
- Discussion 5. Are there untapped datasets or retrospective analyses that need attention (Lead: Pierson, Rapporteur: Hyde)
- Discussion 6. What new partnerships or projects should be encouraged? (Lead: Hare, Rapporteur: Runge)

12:30pm-1:30pm - Lunch
1:30pm-5:30pm - Present workshop summaries in plenary session. Discussion, moving forward.

Thursday, March 3 - WHOI ~ Smith Conference Room

8:15am - 8:30am- Coffee and pastries
8:30am -12Noon - Steering committee and volunteers meet to write workshop report

2011 Participant List ~ Climate and Ecosystem Change in the NW Atlantic

	Facility	First Name	Last Name	Workshop	
1	WHOI	Don	Anderson	both	
2	UMaine	Damian	Brady	A: climate	
3	NOAA ESRL	Antonietta	Capotondi	A: climate	
4	UMaine	Fei	Chai	A: climate	
5	NOAA NEFSC	Chris	Chambers	B: Indicators	
6	WHOI	James	Churchhill	B: Indicators	
7	NOAA NEFSC	Mike	Fogarty	B: Indicators	
8	NOAA NEFSC	Kevin	Friedland	B: Indicators	
9	NOAA NEFSC	Robert	Gamble	B: Indicators	
10	NOAA- NMFS/OST	Roger	Griffis	A: climate	
11	NOAA NEFSC	Jon	Hare	both	
12	UMCES	Raleigh	Hood	both	
13	NOAA NEFSC	Kimberly	Hyde	B: Indicators	
14	WHOI	Rubao	Ji	A: climate	
15	WHOI	Gareth	Lawson	B: Indicators	
16	UMCES	Ming	Li	A: climate	
17	NOAA NEFSC	Jason	Link	B: Indicators	
18	WHOI	Joel	Llopiz	B: Indicators	
19	NOAA NEFSC	Sean	Lucey	B: Indicators	
20	WHOI	Andrew	Maffei	both	
21	NOAA-NESDIS/NCDC	Ellen	Mecray	A: climate	
22	WHOI	David	Mountain	B: Indicators	
23	UMCES	Elizabeth	North	both	
24	NOAA-NMFS/OST	Stephanie	Oakes	A: climate	
25	NOAA-NMFS/OST	Kenric	Osgood	A: climate	
26	UMaine/GMRI	Andrew	Pershing	A: climate	
27	UMCES	Jamie	Pierson	B: Indicators	
28	WHOI	Al	Plueddemann	B: Indicators	
29	NOAA NEFSC	David	Richardson	B: Indicators	
30	Umaine	Jeff	Runge	B: Indicators	
31	NOAA GFDL	Ryan	Rykaczewski	A: climate	
32	Rutgers	Oscar	Schofield	A: climate	
33	WHOI	Heidi	Sosik	B: Indicators	
34	WHOI	Christoph	Stegert	A: climate	
35	NOAA GFDL	Charles	Stock	A: climate	
36	NOAA-NOS/NCCOS	Elizabeth	Turner	A: climate	
37	UMaine	Huijie	Xue	A: climate	
38	WHOI	Jim	Yoder	B: Indicators	