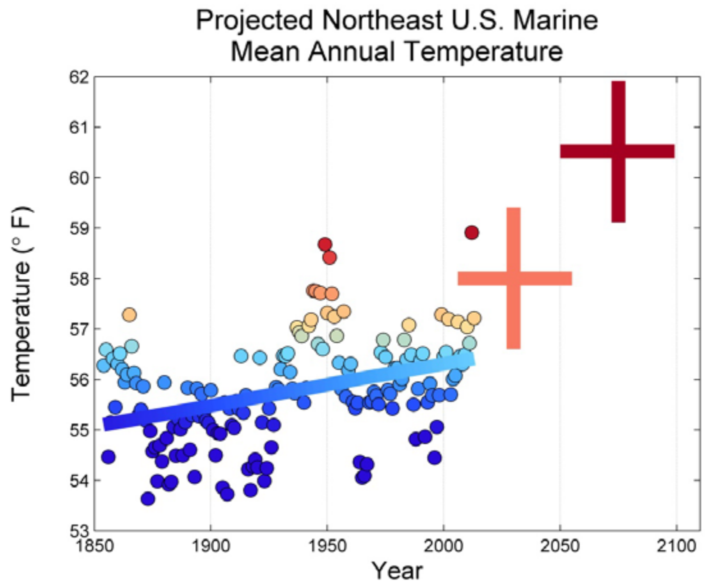
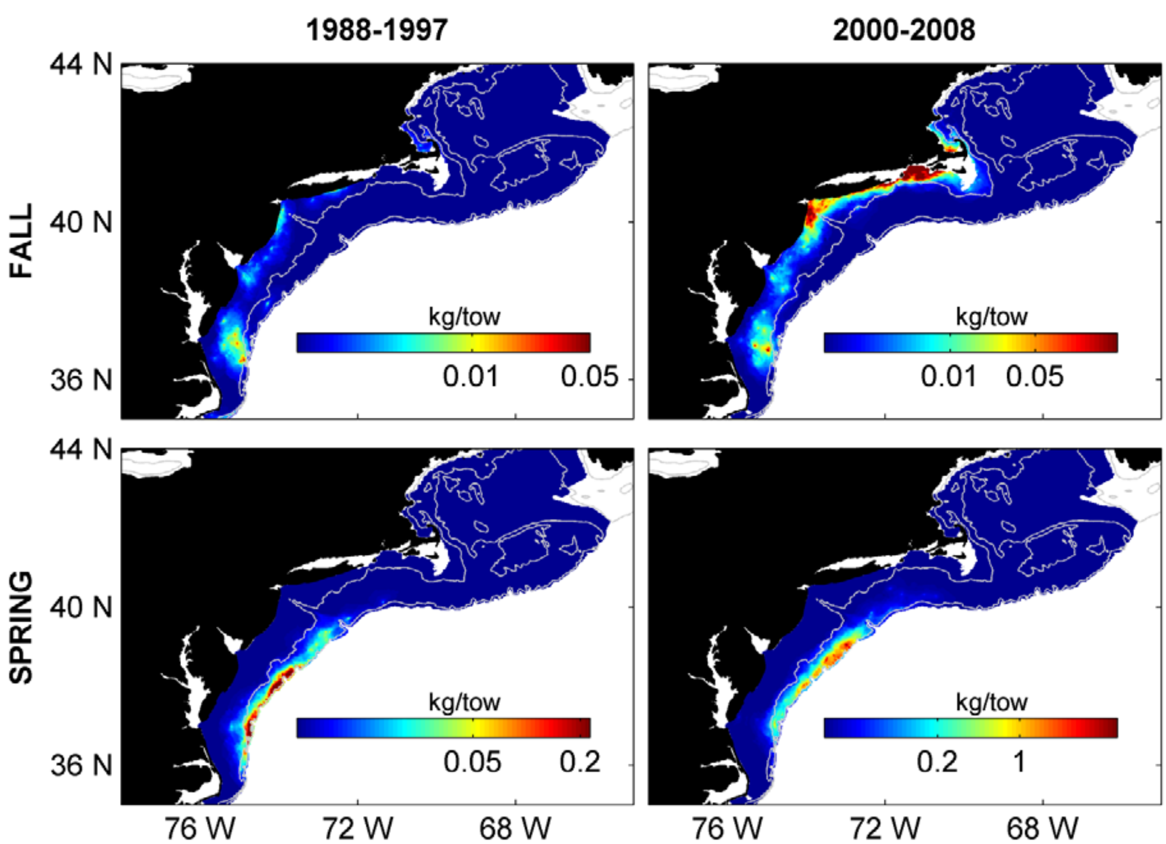
Climate challenges: Sea surface temperature history and climate projections for the NE US shelf

The year 2012 was the warmest year on record in this ecosystem since the 1850s. Crosses show projected temperature ranges from the IPCC AR5.



Range shifts illustrated

Black sea bass range has already shifted, as illustrated by bottom trawl survey data.



Relevant document summaries and links:

Stock assessments integrating ecosystem and climate factors:

Herring and SNE Yellowtail flounder 2012
http://www.nefsc.noaa.gov/publications/crd/crd1214/crd1214.pdf

Butterfish 2014 http://nefsc.noaa.gov/publications/crd/crd1403/

The following summaries are reprinted for reviewer convenience from the full Prospectus document.

Atlantic herring assessment: Atlantic herring were last assessed in a benchmark assessment in 2012 during SARC 54. The 2012 assessment reconsidered nearly all data inputs and model settings from previous assessments. Some major model features are summarized here. Natural mortality rates varied among years with a 50% increase during 1996-2011 that resolved a retrospective pattern and ensured that the implied levels of consumption were consistent with observed increases in estimated consumption of herring. Consumption estimates were based on food habits data primarily for groundfish, but also informed by consumption estimates from marine mammals, highly migratory species, and seabirds. Catches and selectivity for two aggregate gear types, fixed and mobile gears, were modeled separately. This assessment also estimated selectivity for any survey with age composition data. Finally, maturity at age varied through time. The conclusion of the assessment was that the Atlantic herring stock was not overfished and overfishing was not occurring. Time varying natural mortality was considered a major uncertainty in this assessment. This feature of the assessment had significant implications for estimates of stock productivity and reference points. More research should be conducted on the topic of reference point calculation in the presence of time varying life history parameters. Current stock status was also largely driven by the 2008 cohort, which was estimated to be the largest on record. The strength of large cohorts, however, is often overestimated in the short-term, and so this was considered a major uncertainty. Steepness of the stock-recruitment relationship, which directly affects reference point calculations, was not well estimated and this parameter should be carefully reconsidered in future assessments. Atlantic herring also have a complex sub-stock structure that was ignored in the stock assessment, but accounting for this feature may reduce retrospective patterns and address some stakeholder concerns.

Yellowtail flounder assessments: The three stocks of yellowtail flounder, CCGOM, GB, and SNEMA, are currently not producing significant catches relative to their historic amounts. The CCGOM and GB assessments currently suffer from strong retrospective patterns. A wide range of possible “fixes” have been examined, but none have been embraced by reviewers or the fishing industry. Both of these stocks will require either a strong field program to demonstrate there are not many yellowtail flounder in the sea or else an extensive forensic accounting to determine the cause of the missing old fish. Simply running more models does not appear to be a fruitful approach for these stocks. The SNEMA yellowtail flounder is a “success” story because it no longer exhibits a retrospective pattern and was recently reclassified as not overfished and not overfishing. However, this reclassification was due to a major lowering of the bar due to extended poor recruitment in this stock. Without an increase in recruitment, catches will remain low despite its “success” status.

Butterfish: Butterfish are relatively short-lived and have a high natural mortality rate (M = 1.22) which results in the spawning stock biomass (SSB) being strongly dependent on recruitment. Overfishing is not occurring and the stock is not overfished and is rebuilt. The most recent assessment benefited from a broad interaction with ecologists, oceanographers and fishermen. Together, their work improved understanding of thermal habitat and overall catchability. Research on estimation of catchability provided an improved basis for understanding the stock history and allowed estimation of BRP. There were three improvements to the basic ASAP model: 1)catchability was reparameterized as the product of availability and efficiency with the former specified using the availability estimates based on bottom water temperature; 2) length-based calibration of bottom trawl survey data in 2009-2012 was performed internal to the model; and 3) estimation of natural mortality. For the NEFSC fall offshore survey, an average measure of availability based on a bottom temperature was used and the efficiency was based on relative efficiency of the FRV Albatross IV to the FSV Henry B. Bigelow and an assumption that the Bigelow was 100% efficient for daytime tows. An important conclusion of the habitat modeling was there were was NOT significant inter-annual variation in availability. Ability to estimate parameters within the new model framework was confirmed through simulation. Validity of ASAP model estimates of biomass and fishing mortality was supported by the application of a simple envelope analysis method that established a feasible range for biomass. Estimates of consumption by the top six finfish predators appear to be very low and similar in magnitude to historic fishing mortality but well below the estimated natural mortality rate.

Prototype Multispecies Bio-Economic Model Overview

Both the New England and Mid-Atlantic Fishery Management Councils have signaled their intent to explore and implement options for EBFM. The form of EBFM as it evolves in New England and the Mid-Atlantic regions will of course depend critically on the goals and objectives ultimately selected by each council. A collaborative NEFSC project involving the Population Dynamics, Oceanography, and Social Sciences Branches, the Food Web Dynamics Program and the Ecosystem Assessment Program has been exploring options for development of a flexible analytical framework for EBFM in the Northeast. Principal elements of the approach include (1) establishment of a transparent connection between single species and ecosystem-based advice using multispecies assessment models as a natural bridge, (2) development of multiple operating models to test assessment models and candidate management procedures, (3) application of formal strategies of multimodel inference in applying results from the multispecies assessment models (4) use of these results to assess uncertainty and risk, and (5) evaluation of tradeoffs in a bioeconomic context. The models under development are designed to accommodate spatial structure and to incorporate consideration of climate variability and change.

As a proof of concept, we are currently developing a prototype multispecies analysis for a 10 species complex for Georges Bank (Figure 1). With colleagues at Renssalaer Polytechnic Institute and Woods Hole Oceanographic Institution we are applying fundamental principles in informatics. Data streams feeding into this process encompass fishery-dependent (both ecological and social-economic) sources, fishery-independent surveys, food habits data to identify and quantify biotic interactions among species, and oceanographic and climate data to track external forcing mechanisms. To further enhance communication with stakeholders we are developing options for data and model visualization to aid in the interpretation of multispecies model outputs.

The core analytical elements of the process involve development and testing of a set of indicators, multispecies assessment models, social-economic modules linked to the assessment models, and forecast models developed outside the assessment model framework to complement predictions made using these assessments. The interplay between the operating models and the other analytical elements of the approach is envisioned as an iterative process (Figure 1). The analysis culminates in a risk analysis accounting for key uncertainties and in the context of multiple candidate management procedures. The process is designed to provide management advice in the form of annual catch limits to match existing requirements under current management approaches on Georges Bank. The results will be provided as an interactive web-based product (Figure 1).

Our overall approach entails the use of four different assessment models encompassing simple multispecies production models applied both to individual species and to defined functional groups, multispecies delay-difference models that implicitly accommodate simple demographic structure (again for individual species and functional groups), and if possible a complex multispecies statistical catch-at-age model applied to individual species (Figure 2). Single species analogues of these models are familiar to resource managers in the region and we have deliberately attempted to frame our approach in a way that trades on this familiarity. Multiple estimation techniques including maximum likelihood, state-space, genetic algorithm and Bayesian methods will be applied to the production models in both aggregated and disaggregated forms to assess aspects of estimation uncertainty.

A key issue in assessment and management of the Georges Bank system is the centrality of the mixed-species nature of the fishery. We define our functional groups as species that are caught together and share basic ecological characteristics (similarity in life history attributes, body size, etc.). Our interest in testing the performance of assessment models based on functional groups defined in this way centers both on their importance as key structural elements of the system and recognition that we cannot fully control the fishing mortality rates on the individual species comprising these mixed-species assemblages. These species, inter alia, share similar histories of exploitation and environmental forcing. Tests will be made to assess the performance of the functional group models against models in which the full species identity of all components is retained to see if they offer any advantage in assessing mixed-species fisheries.

Economic modules link to the assessment models to produce revenue streams and measures of profitability. They are being developed for direct use in tradeoff analysis. For the economic module we are also employing an empirical multispecies portfolio model approach to assess risk. We are developing forecast models using new methods in nonlinear time series analysis to complement the assessment models. We are developing two operating models to serve as a virtual test beds to examine the performance of the assessment models and to evaluate the efficacy of alternative management procedures. These models, Hydra and EcoSim, are currently in different stages of development. Hydra has been developed at NEFSC. It is a length based multispecies model designed to accommodate climate/environment forcing on biological and ecological processes. Work is in progress to allow for spatially structured populations and multiple fleet sectors. This operating model will be used to test the performance characteristics of several simpler assessment models that can be used to provide reference points for management action. EcoSim is a dynamic version of Ecopath developed at the University of British Columbia. We are modifying an open source version developed by Kerim Aydin at the Alaska Fisheries Center.

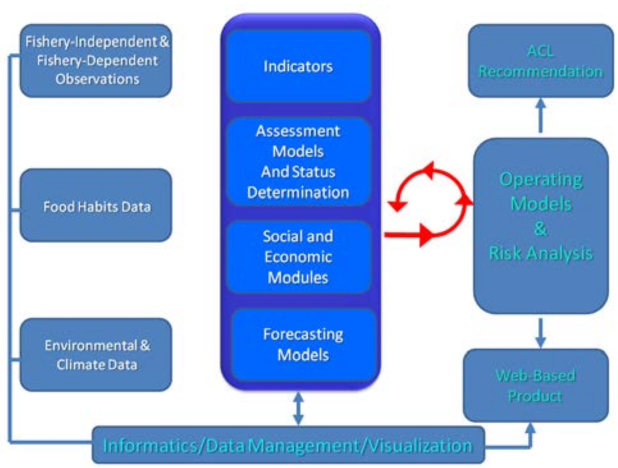


Figure 1. Key structural elements of the NEFSC prototype multispecies analysis of Georges Bank.

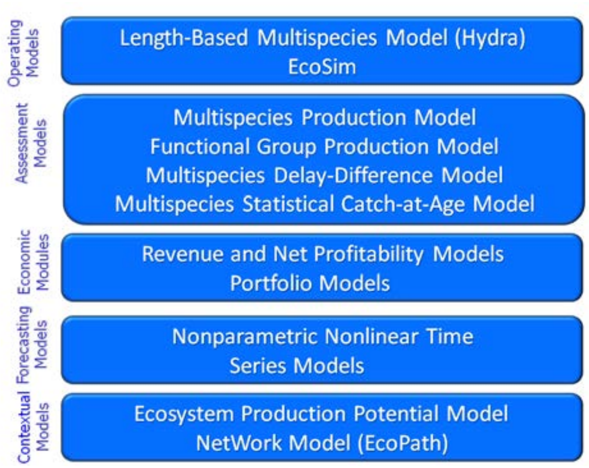


Figure 2. Modeling elements to be employed in the prototype multispecies bio-economic model for Georges Bank.

NEFSC Ecosystem Advisory: published semi-annually on the web. The latest ecosystem advisory is available at http://nefsc.noaa.gov/ecosys/advisory/current/ and the archives are available at http://nefsc.noaa.gov/ecosys/advisory/archives.html .

The Ecosystem Advisory webpage includes a summary section (see below for an example) and links with further explanation, figures, data and sources for each summarized ecosystem condition. The NEFSC ecosystem advisory has been referenced in congressional working papers and in local and regional news outlets, in particular when 2012 sea temperature conditions were at record highs.

Summary of Conditions for the Northeast Shelf Ecosystem (Fall 2013)

- Sea surface temperature (SST) in the Northeast Shelf Large Marine Ecosystem during the first half of 2013 moderated compared to the record high temperatures that occurred in 2012; however, temperatures remain above the long-term mean based on both contemporary satellites remote sensing data and ship-board measurements.
- This moderating effect was not uniform over the ecosystem. The northern ecoregions of the Gulf of Maine and Georges Bank remained relatively warm whereas the Middle Atlantic Bight cooled to a greater extent.
- Spring survey hydrocast data shows that surface and bottom temperatures have moderated since 2012, but remain above average with bottom temperatures being influenced by water entering the ecosystem.
- In contrast to the 2012 Gulf of Maine spring bloom which was a long duration, intense bloom that started at the earliest recorded start date, the 2013 was the latest recorded bloom that was so poorly developed its extent was below detection limits. The bloom on Georges Bank was also relatively late and though it could be detected, it was a small bloom in terms of duration and intensity.
- Though not a regular feature in the Middle Atlantic Bight, a distinct spring bloom could be measured in 2013.
- An analysis of spring transition temperatures shows that there has been an abrupt shift in spring thermal phenology.
- 2013 spring zooplankton biomass on the Northeast Shelf was the lowest on record for the monitoring time series; the biomasses were lowest for the northern segments of the ecosystem and would appear to be related to the poorly developed spring bloom in the Gulf of Maine area
- The Northeast Shelf ecosystem continues to experience wide swings in physical conditions and biological responses that would appear to reflect great variation in the climate system impacting the ecosystem.

NEFSC Ecosystem Status Report (ESR): published approximately biennially with both web and pdf formats. 2009 and 2011 (http://www.nefsc.noaa.gov/publications/crd/crd1207/crd1207.pdf) editions are available, and the draft web-only 2013 product will be demonstrated during the meeting.

The Ecosystem Status Report tracks ecosystem indicators related to climate forcing, physical pressures, primary and secondary production, benthic invertebrates, fish communities, protected species, human dimensions, and integrative metrics. These indicators are tracked for each of the four identified ecoregions (Scotian Shelf, Gulf of Maine, Georges Bank, Mid Atlantic; Figure 3) where possible. In the 2011 report, there were 16 climate/physical indices, 19 biotic indices, and 18 human dimensions indices; a majority of these indices were reported by ecoregion. Despite the large number of indices, the report is intended to be relatively short and readable, at <50 pages.

Main Findings (reprinted from 2011 ESR)

- The Northeast Shelf Large Marine Ecosystem (NES LME) can be divided into four Ecological Production Units, which can in turn provide spatial domains for Ecosystem Based Fisheries Management.
- Atlantic basin scale climate indices, the North Atlantic Oscillation and the Atlantic Multidecadal Oscillation, are at extreme levels, which is reflected in local scale changes in temperature and precipitation, among other parameters.
- The physical nature of the NES LME continues to change, notably there has been a decline in Labrador origin water, which influences salinity and food web processes in the ecosystem, and, there has been an increase in water column stratification, which affects the vertical transport of nutrients.
- Recent increases in primary phytoplankton production are not matched by increases in secondary zooplankton production raising the concern that the phytoplankton community structure is shifting to species that fail to effectively enter the food web.
- Many benthic resources have increased in recent years, which can be attributed to both fishery management strategies and environmental effects. The total biomass of fish species remains high reflecting the response of interacting species groups to fully utilize the available energy in the ecosystem.
- Though revenues have remained at high levels in the commercial fishing industry, employment in marine-related employment sectors has declined in recent years.

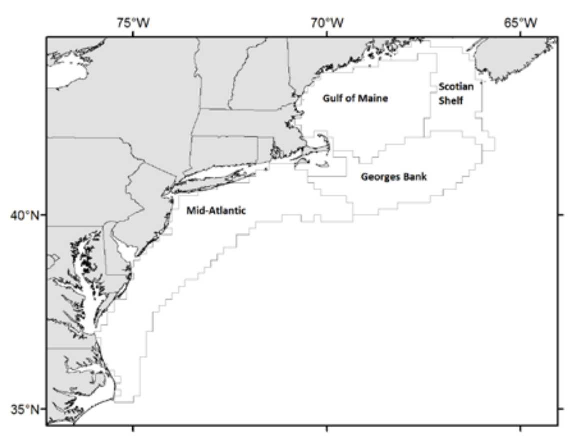


Figure 3. NE Shelf ecoregions

The NEFSC Climate website http://nefsc.noaa.gov/ecosys/climate_change/index.html was launched in 2013. It summarizes climate information relevant to the Northeast shelf ecosystem.

Excerpt: Implications of Climate Change on the Fishing Communities of the U.S. NES LME
In assessing impacts of climate change to oceans and coasts, one key component is impacts to coastal communities, especially communities that depend specifically on the ocean for meeting economic, social and cultural needs. Fishing (commercial, recreational, and subsistence), coastal tourism and recreation, and spiritual or cultural practices centered on marine locations or species are three examples. Existing levels of social vulnerability affect the level of impact that a community experiences from stressors, including climate change. Factors affecting vulnerability include levels of access to resources and power (political, cultural, economic and social) and of susceptibility to harm or loss. Today these communities are experiencing impacts of multiple stressors: economic, social and ecological. Therefore, identification and monitoring of socially vulnerable populations in the coastal zone is a critical aspect of understanding the impacts of climate change and other stressors. Similarly, levels of dependence on and use of ocean-related resources and conditions create greater or lesser likelihood of specific kinds of impacts. Further, coastal gentrification may be an indication of community vulnerability to development that may transform coastlines thus increasing their vulnerability to the impacts of extreme weather conditions that can result from climate change.

The NMFS Community Social Vulnerability Indicators (CSVIs; Jepson and Colburn 2013) are statistical measures of the vulnerability of communities to climate change and other events such natural hazards, disasters, and regulatory changes to fisheries. The CSVIs currently serve as indicators of social vulnerability, gentrification pressure vulnerability, and commercial and recreational fishing dependence. The CSVIs are constructed annually, using demographic data from the U.S. Census' American Community Survey (ACS) five-year rolling estimates, NOAA Fisheries annual commercial fisheries and Marine Recreational Information Program (MRIP) data, as well as a small number of publically available but non-government online databases. Ongoing data collection will allow the CSVIs to be continually updated to show long term trends[1]. The baseline ACS data covers the years 2005 to 2009 and will be compared to 2010 to 2014 estimates once they are available. The 2006 to 2010 ACS data were used to construct the social and gentrification pressure vulnerability indicators (please see http://nefsc.noaa.gov/ecosys/climate_change/implications.html for figures). NOAA Fisheries and MRIP data from 2010 were used to construct the commercial and recreational dependence indicators. Communities in the Northeastern U.S. are ranked as high, moderate, or low relative to the respective indicator. A high concentration of socially vulnerable communities was observed in the Mid-Atlantic while a high to moderate concentration of communities that are vulnerable to gentrification pressure were observed in Massachusetts, New York and New Jersey. Community dependence on fishing is mixed with significantly more communities dependent on recreational than commercial fishing.

[1] At present, they are not sensitive to single short term events though with enough data this may be calculable in the future.

NEFSC ecosystem models were peer-reviewed in 2011 by the Center for Independent Experts. An overview of NEFSC ecosystem models up to 2011 is provided in an extensive reference document (Link, Gamble and Fogarty 2011: http://www.nefsc.noaa.gov/publications/crd/crd1123/). We include the reference document summary below. In general, the modeling enterprise received positive reviews, in particular for the effort to construct multiple model types, rather than to rely on a single model structure to serve all needs. CIE reviewer summary reports are available at http://nefsc.noaa.gov/ecosys/CIE%20EBFM%20model%20review%20summary%20report.pdf and the full report is available at http://www.nefsc.noaa.gov/ecosys/CIE%20EBFM%20model%20review%20reports.pdf .

NEFSC ecosystem modeling enterprise summary: As we move towards Ecosystem-based Fisheries Management (EBFM) in the Northeast [US] Shelf Large Marine Ecosystem (NES LME), ecosystem modeling will be a critical element of doing so. As such, it is valuable to describe current and ongoing ecosystem modeling efforts in the NES LME, with a particular emphasis on how they are being used in a living marine resource (LMR) management context. We provide a description of the major ecosystem models and salient information associated with their use in the NES LME. We discuss how such models could be used to advance EBFM in the near term with a focus on the appropriate application of classes of models for addressing specific types of high priority research and management questions. We also note those areas of improvement that could be considered to enhance ecosystem modeling efforts for the NES LME. We finally highlight some of the major lessons learned from our modeling endeavors in an LMR context in the NES LME, so that we and other regions around the world can continue to move towards the implementation of EBFM.

NEFSC ecosystem models also have individual, detailed documentation published in Center reference documents, peer-reviewed literature, or both. Below we include selected references.

Fogarty M, Overholtz W, Link J (2012) Aggregate surplus production models for demersal fishery resources of the Gulf of Maine. Mar Ecol Prog Ser 459:247-258

Gamble, R.J. and J.S. Link. 2009. Analyzing the tradeoffs among ecological and fishing effects on an example fish community: A multispecies (fisheries) production model. Ecol. Mod. 220: 2570-2582.

Link JS, Gamble RJ, Fulton EA. 2011. NEUS – Atlantis: Construction, Calibration, and Application of an Ecosystem Model with Ecological Interactions, Physiographic Conditions, and Fleet Behavior. NOAA Tech Memo NMFS NE-218 247 p. Available at http://www.nefsc.noaa.gov/nefsc/publications/ .

Link J, Overholtz W, O'Reilly J, Green J, Dow D, Palka D, Legault C, Vitaliano J, Guida V, Fogarty M, Brodziak J, Methratta L, Stockhausen W, Col L, Griswold C (2008) The Northeast U.S. continental shelf Energy Modeling and Analysis exercise (EMAX): Ecological network model development and basic ecosystem metrics. Journal of Marine Systems 74:453-474