VII. Synthesis

A. Heurism, Relationships, and Generated Hypotheses

Even though we know a lot about many aspects of this ecosystem, we do not fully understand all of the processes and mechanisms that have generated the range of conditions we have observed in this ecosystem. The challenge remains for us as scientists to understand ecosystem function and structure.

The working group listed some of the more important questions related to our understanding of this ecosystem. We list this set of questions and either answer them based on the data presented in this document or recommend research to address them. In many respects, these questions represent some of the key hypotheses of how this ecosystem is structured and functions.

B. Principal Question

What are the natural and anthropogenic factors underlying change (or variability) in the northeast U.S. continental shelf ecosystem and its subsystems?

We may never be able to quantify all of the processes in this ecosystem. Even partially addressing this question will be helpful to our understanding of this ecosystem.

C. Major Questions

1. System

What are the important changes in biota, oceanography, and fisheries through our time period *of observation, by subsystem or finer scale as needed (subsystem-see below)?*

We have documented changes in the ecosystem over our period of observation; see the previous chapter for a more detailed description of these changes. Many of these represent an order of magnitude (or more) of change. That we can ascertain the status of an ecosystem such as this one is not trivial.

Has there been a change in relative energy flux through pelagic and demersal fish populations through time - a trophic regime shift (by subsystem)?

Yes. The system is now “horizontal” (dominated by pelagic species that migrate) rather than “vertical” (demersal species with higher site affinity) and the biomass, energy fluxes, and community structures reflect this (see Figure 3 in Link 1999).

What are the sources of temporal and spatial variation in fish and marine mammals in the system due to climate change, bottom-up forcing (temperature, habitat loss/degradation inshore, impacts of toxic chemicals inshore, and nutrients), trophic cascades (impacts of selective predation by fish/marine mammals, prey refugia, and fisheries harvesting), etc.?

Certainly these are all important potential forcing functions. At this time it is difficult to clearly determine the relative contribution of each source of variability to the overall variability of the biotic community. Future multivariate analyses will need to partition this variance.

What are the potential consequences of a regime-shift between a demersal fish/benthos-dominated ecosystem to a pelagic fish/plankton-dominated system?

We're not sure anyone knows the full ramifications of this type of shift. Certainly there are a few hypothesized outcomes (e.g., slower recovery of groundfish, predation on demersal fish larvae by pelagic planktivores, removal of energy off the shelf or to different parts of the shelf, increased competition among different components of the system, increased ctenophore predation, etc.), but those remain to be tested.

What are the relative strengths of couplings within and between benthic and pelagic systems? How would this vary by oceanographic region (Gulf of Maine, Georges Bank, Mid Atlantic Bight, etc.)? How strongly are regions linked? (What would we be leaving out when we go to smaller/higher resolution models?)

We do not know the relative strength of pelagic versus benthic subsystem couplings, but in general, the system appears to be loosely coupled.

Is there a characteristic predictability/stochasticity of dynamics for each region/component? (How reasonable is "deterministic" management?)

It is difficult to say because of the multiple and simultaneous processes occurring in this ecosystem. We think a standard signal (i.e., pattern) may be generally detectable for key processes. Yet being able to predict specific components of this ecosystem, and evaluating their associated stochasticity, remains difficult.

What are the relative effects of environment vs. fishery on ecosystem/community/population structure and dynamics? (How should we modify current population dynamics models used in *assessments to reflect this?)*

It is fairly clear that in general, the dominant factor influencing fish populations is fishing. The environment is then a key second forcing function that can determine the recovery trajectory. The environment also can strongly dictate the level of productivity of the system or community or a population.

2. Abiotic

Is there evidence of an oceanographic regime shift on a system-wide scale, or by subsystem?

The evidence is unclear. Some metrics show an increased warming in recent times and a change in the NAO, yet the high amount variability and closer examination suggest that the major physical processes acting in the Northeast U.S. Continental Shelf ecosystem are generally the same ones (albeit at slightly different times or magnitudes).

Are there trends in offshore, nearshore, and estuarine habitat quality? What indicators of quality exist for the last few decades, and is there any way to extrapolate back a few more decades?

We are unlikely to have the data to answer these questions. Examining sediment cores along transects may be one feasible approach to address this issue.

Is there any spatial/temporal coupling of physical environment and seasonal migrations of biota between estuaries, coastal waters, continental shelf, and continental slope?

We do not know if we have the data to answer the question for couplings and migrations between estuaries and nearshore to the offshore waters. Along the continental shelf and slope, data exists to describe seasonal migrations of various biota. These patterns have been documented elsewhere (e.g., Grosslein and Azarovitz 1982; Bowman et al. 1987; Overholtz et al. 1991).

What are the potential consequences of nitrogen enrichment (from the atmosphere and land use activities in coastal watersheds) of estuaries and coastal waters on the food chains supporting fish/marine mammals and as a source for harmful algal blooms (HABs)?

We do not know the answer to these questions. Satellite imagery and nutrient monitoring would help to better address these issues.

How is fishery performance affected by environmental factors (human behavior, fish behavior/availability)?

In a general sense, the weather greatly influences fish and fisher distribution. In a more specific sense, it is uncertain how the environment influences catch rates.

What is the verdict on environmental change in the Georges Bank ecosystem; is it stable or changing?

It is both stable and changing, depending upon the scale of observation and the particular environmental metric examined. Again, some metrics show an increased warming in recent times and a change in the NAO, yet the high amount variability and closer examination suggest that the major physical processes acting in the northwest Atlantic are generally consistent (albeit at slightly different times or magnitudes).

3. Biotic

What appear to be the dominant top-down and bottom-up effects in the food chain, by subsystem?

Regardless of spatial consideration, fishing is the dominant top-down effect. This effect may or may not propagate through lower trophic levels. Predation is a less dominant top-down effect in this ecosystem. It is unclear to what degree physics, nutrient input, etc., influence lower trophic levels as bottom-up effects. The physical conditions may create local conditions that alter the magnitude of species and fisheries interactions, which may indirectly affect those lower trophic levels.

What appear to be the relative importances of top-down and bottom-up effects on commercial fish and invertebrate recruitment strengths through time?

Fishing is a very strong effect, but environmental conditions are also important. Allocating importance in terms of proportional influence remains to be done. Recruitment remains a particularly difficult issue.

What are the impacts of increasing pinniped populations on fish/endangered species (i.e., Atlantic salmon; sturgeons; etc.) and potential interactions with fixed gear and aquaculture?

We don’t have the data to answer this question at this time.

Are production and net production stable or changing over time in the Georges Bank ecosystem?

The standing biomass of the full ecosystem and sub-components of it (e.g., phytoplankton, zooplankton, various guilds, etc.; c.f., Figures B.7-B13, B.27a-l; O'Reilly and Zetlin (1998)) appear to be roughly constant over time. However, the particular species composition in any one of these groups has changed across time. Thus, the productivity of the different groups and the entire ecosystem is not readily known at this time.

Are zooplankton numbers per m^3 stable or changing over time in the Georges Bank ecosystem?
They appear to be roughly consistent across time, albeit with notable changes in species composition and variation (c.f., Figures B.7-B.13).

4. Human

Do ecosystem-level analogues to single species reference points exist? What about control rules?
There are most likely ecosystem-level analogues. The suite of metrics described in previous chapters are promising possibilities to include in decision criteria models and analyses.

How have anthropogenetic influences other than fishing affected the status of the ecosystem? For example, can changes in the ecosystem be related to pollution? Or, what levels of pollution would be required to have a detectable impact on the ecosystem?
We do not know at this time.

Can ecosystem status be projected? Can current and projected ecosystem status improve management advice from single species stock assessments and forecasts? For example, *recruitment of species X is expected to increase/decrease in future due to changes in temperature, phytoplankton, food web, increase/decrease in species Y, etc. Can the same be done for fishery management reference points as well?*

We think that this certainly can be done, but it remains to be demonstrated in the current management and science institutional context.

Can we offer guidance regarding placement and timing of closed areas that goes beyond a particular commercially important species? That is, how will predictions of ecosystem level impacts of different management measures such as closed areas, mesh size changes, species targeting, etc., influence management strategies?

We think that this certainly can be done, but it remains to be demonstrated beyond generalities.

Is there some utility of closed areas for groundfish as a fishery management tool and as a means for increasing biodiversity/fish productivity, both inside and outside of the closed areas? Similarly, what is the role of Marine Protected Areas (MPAs) as a fishery management tool?

Yes. We do not directly present the type of information to answer these questions in the previous chapters (but see figures H.23, B.1-B.4, B.23, B.24) and refer the reader to Murawski et al. (2000) and Brown et al. (1998).

What are the tradeoffs between optimum fisheries harvesting approaches and maximizing the "net economic return" to the nation from the use of these public resources?

The specifics are uncertain, but in general and based upon first principles we would probably be trading short-term maximization of profit with long-term profit and resource sustainability. Much further work remains to adequately address this issue.

What is the role of socioeconomic forces on the harvesting behavior of commercial and recreational fishers and how do these relate to effective fisheries management strategies?
This is an area in which we have little data. Certainly the broad study of values and valuation would shed some insight into this question, particularly why fishers and fishing communities attempt to persist in an often unprofitable activity.

What is the combined economic value of the commercial stocks (not landed value)? Is it consistent with the long-term notion of sustainability? If not (probably not), what is the magnitude of economic waste each year (these questions/issues involve "green accounting")?
These are difficult questions to address.

What are the implications of systems thinking (e.g., biological and technical interactions) for single-species management and Maximum Sustainable Yield (MSY)? Is there a better systems concept, such as resource portfolios, for fisheries management?
The implications are that some management advice may need to be qualitatively adjusted or modified, probably to be more conservative. Certainly different approaches would be useful to help understand an ecosystem, and we advocate as holistic an examination of the ecosystem as possible, but can not necessarily espouse one approach over any other at this time. Quantitative approaches to alter single species reference points and targets remain a large and fruitful area of

research.

What are the design characteristics and functions of an institutional arrangement that could employ ecosystem-based management of fishery (and other marine) resources? How do these compare to the current Council/NMFS management arrangement?

It is not likely that we will know the answer to this for some time. Changes to the SFA/MSFCMA may force us to reexamine our institutions. Accounting for other laws (e.g., MMPA, ESA, NEPA, etc.) may also contribute to this reexamination. Comparisons to other regions and countries may be an useful first step to address this question.

Have major fishing episodes (i.e., ICNAF, recent USA) permanently altered the ecosystem?

Certainly they have altered parts of the ecosystem. To what extent these changes are "permanent" or irreversible is unknown. A formal stability and steady state analysis would be required to address this question more rigorously.

D. Summary and Conclusions

Although integrating and synthesizing the information from a diverse set of disciplines is a difficult task, there is value in inter-disciplinary working groups. We would encourage the expansion of this approach to include the perspectives from other disciplines working on marine ecosystems.

It takes substantial and multiple time series of metrics and associated monitoring to assess the status of a system. No one metric best described the status of the ecosystem, even though many of the metrics demonstrated similar trends and many of the metrics similarly captured the directionality of key processes and relationships. It is clear that several of these metrics should be examined concurrently. Examining just one or a few may be misleading. This work is distinct from those that focus on a single process in that it integrates all these considerations at once. If one uses the leading indicators of any national economy as an analogy, a similar approach is useful for indexing the status of an ecosystem.

The change observed for many of the metrics during the late 1970s and early 1980s corresponds to the passage of the first Magnuson-Stevens Fisheries Conservation and Management Act in the late 1970s, which resulted in the expansion of the domestic fleet and a subsequent increase in groundfish landings beyond sustainable levels. Changes in the physics of the ecosystem were also occurring during that period. These two considerations, along with their derivatives (e.g., habitat alteration, changes in competitive balance among species, temperature induced migrations, recruitment success, switching targeted species, etc.), were probably the causal (at least initially) events that led to the observed changes (and lags thereof) in the observed ecosystem metrics.

From this work we have developed a unique compilation and understanding of trends, magnitudes, and relationships among key processes. The knowledge from this study is highly heuristic and as such inherently valuable. We recommend regularly assessing the status of ecosystems at appropriate time scales and reference points, analogous to single species fish stock assessments.

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